LUKENS IRON & STEEL CO.

G. H. Danforth.

June 16-1900

THE FIRST TO MAKE BOILER PLATES IN AMERICA

LUKENS

IRON AND STEEL COMPANY

Main Office and Works, Coatesville, Pa.

ESTABLISHED 1810 INCORPORATED 1890

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C. L. HUSTON, . . . VICE-PRESIDENT
JOS. HUMPTON, . . . SEC'Y AND TREAS.

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TO OUR FRIENDS

THE first edition of our handbook, published in 1893, has been so well received, that we have concluded to issue this second edition.

Our 1893 book was very useful and was well up to date at the time, but changes and improvements have been made at the mill, new machinery added, etc., and other valuable information compiled and collected, so that we are now enabled to present a more complete and useful book than the first.

We have followed a careful system in arranging the data :

FIRST.—Matter referring to our product : Plates, Flanged and Dished Heads, Manholes, Braces, etc.

SECOND.—Rules and Tables, useful in making estimates and specifications.

THIRD.—Miscellaneous Tables, etc., many of the data contained in them being original, and very carefully gotten up, at much expense.

FOURTH.—A Code for Ordering Goods by Telegraph. This many of our customers are already familiar with, and appreciate its value.

We solicit your continued favors, remaining,

Sincerely yours,

LUKENS IRON AND STEEL COMPANY

THE FIRST TO MAKE BOILER PLATES IN AMERICA

In presenting this brief history of our origin and development, we wish to inform our friends, who have been interested in our historical as well as long and successful business career, that whilst we have been advertised, and are widely known as having been established in 1810, the actual and original establishment of our works dates back to the year 1790, when Isaac Pennock, the great-grandfather of the present management, built a mill and began the manufacture of Iron at a place now called Rokeby, situated on Buck Run, Chester Co., Pa., about four miles south of Coatesville. He was signally successful in this pioneer industry, notwithstanding he had been raised as a farmer; his parents strongly objected to his venturing into a business with which he was entirely unfamiliar, as they felt he would be squandering his money in a hopeless undertaking. The mill he first built was called the "Federal Slitting Mill," charcoal slabs being heated in an open charcoal fire, rolled out into Plates, and then slit up into rods for general blacksmith use. In 1810 he bought a saw-mill property on the Brandywine at Coatesville, which he converted into an Iron Mill. The mill at that time was called "Brandywine." It was, therefore, in the year 1810 that the Old Mill was located on the site, which has since developed into the large plant at present in operation, covering many acres of ground, and giving steady employment to a large number of men.

In 1816, Dr. Charles Lukens, a son-in-law of Isaac Pennock, and maternal grandfather of the present management, came into possession of the property, and carried on the business of Iron making until his death in 1825. It was between these dates that Steam Boilers first came into use, and it was during this time, consequently, that the first Boiler Plates produced in this country were made in this mill by Dr. Lukens.

Dr. Lukens died at an early age, and in accordance with his special request, was succeeded by his widow, Rebecca W. Lukens, who continued to successfully carry on the business, although severely handicapped by the fact that in those days there were no railroads. The finished material had to be teamed to Philadelphia, a distance of 38 miles, or to Wilmington, 26 miles, while the coal used was hauled from Columbia, some 35 miles away. However, in spite of these difficulties, she carried on the Iron making business with the assistance of a superintendent to look after the works and employees, while she herself assumed full control and management of the commercial part. Mrs. Lukens was considered an extraordinary business woman, and she built up a business which has remained in the family for four generations, having been continuously successful up to the present time. It was in her honor that the name of the works was changed from "Brandywine" to "Lukens."

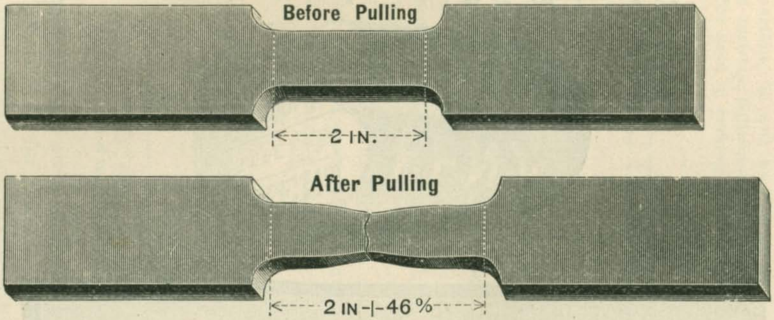
After Mrs. Lukens' death the business was conducted by her sons-in-law, Abram Gibbons and Dr. Charles Huston. Mr. Gibbons retired in 1855, after an honorable and prosperous, although short, business career, leaving the works in Dr. Huston's hands, who, with his partner, Mr. Charles Penrose, carried on the manufacture of Iron up to the time of Mr. Penrose's death in 1881,—they having been joined by Dr. Huston's two sons, A. F. and C. L. Huston, upon their graduation from college in 1872 and 1875, respectively. Dr. Huston remained the head of the concern until his death in January, 1897. A history of the business would not be complete without a fuller reference to Dr. Huston's life, and the close connection he had with the development of the Iron and Steel industry of the country. He was born in Philadelphia in 1822, graduated at the University of Pennsylvania in 1840, finished a three years' course in medicine at the Jefferson Medical College in 1843, which was supplemented by eighteen months of special study in Europe. He began the practice of his profession in Philadelphia, married Miss Isabella Lukens of Coatesville, and settled down to the life of a doctor. In 1848 they moved to the country. He entered the Iron business in 1849, and for nearly fifty years was actively engaged in it. In 1875, when the United States Government began requiring that Plates used in the construction of Steamboat Boilers should be stamped with their Tensile Strength, Dr. Huston promptly purchased a testing-machine, and began investigating the properties of Iron and Steel. In 1877, when the manufacturers of Boiler Plate were requested by the Treasury Department to send a committee to Washington to advise with the Board of Supervising Steamboat Inspectors in framing a proper standard of tests, Dr. Huston was chosen Chairman of that Committee, and with his practical knowledge of the character of metal, and his experience in testing, his recommendations were adopted by the Board of Inspectors, and in addition his counsel has been frequently sought by the Government. His recommendations were sought and followed by the leading Steam Boiler Inspection and Insurance Companies of this country, also by the Committee appointed by the City Councils of Philadelphia, in establishing their standard of test requirements for high-grade Boiler Plates. In 1878–79 he published Revised Articles in the *Journal* of the Franklin Institute, upon the behavior of Iron and Steel under varying conditions of heat and stress. These articles attracted the notice of engineers abroad years afterward, they having just taken up that class of investigation. Later, in 1895, Dr. Huston was selected by the Hon. Chauncey M. Depew as the man best fitted by ability and experience to write the article on the Iron and Steel industry, in his able and comprehensive history of "One Hundred Years of American Commerce." Dr. Huston's scientific education, natural ability, and high personal character have permeated all departments of the Lukens Works.

Originally the Plates were made from single charcoal blooms; the blooms being made in the old-fashioned forge fire, then reheated over an ordinary grate fire, and rolled into Plates, or sheets. The Plates were shipped without being sheared; the shearings in those days were cut into nails. Afterward a reverberatory heating furnace was introduced, enabling the scrap to be worked up. The Plate rolls of that time, as near as known, were about 16 to 18 inches in diameter, and from 3 to 4 feet long between the housings, being driven by an overshot water wheel. It is said that many a time when it looked as if the mill would stall, the workmen would rush for the water wheel, climb up on its rim, and by their united weight help the pass through the rolls, thus preventing a "sticker," which invariably meant fire-cracked rolls and, later on, broken ones. Owing to the constant increase of business, which necessitated more power, the overshot water wheel was afterward supplemented by a breast wheel, so geared that it would convey more power to the rolls, and, in addition, a heavy fly wheel was introduced, geared to a high speed for storage of power. This permitted the use of larger rolls, which were then changed to 21 inches in diameter and 66 inches long. The mill was operated in this shape until 1870, when a modern steam Plate Mill was erected near by, with chilled rolls 25 inches by 84 inches,—the old mill being afterward used as a Puddling Mill, to prepare stock for the new modern mill. After several more changes, each time the rolls being made larger to meet the increased demand for wider and longer Plates, there was finally placed in position a Three-high Mill, with solid chilled rolls, 34 inches in diameter by 120 inches long, weighing 18 tons each. This was then the largest mill of its kind ever erected in the United States. This large mill is equipped with automatic hydraulic lifting tables, and all the mechanical appliances necessary for a first-class mill,—a large Corliss Engine being used to drive it, and modern cooling tables with mechanical transferring apparatus for conducting the Plates to the hydraulic and steam shears. A set of straightening-rolls is placed so as to take the Plates just as they come from the Mill while still red hot, and transform a wavy and irregular surface into a level true one.

CONTENTS

BRANDS

	Tensile Strength
Extra Soft Steel,	45000 to 55000
Extra Locomotive Fire Box Steel,	50000 to 60000
Fire Box Steel,	52000 to 62000
Marine Steel,	50000 to 65000
Flange Steel,	52000 to 62000



Our Rolls are 120 inches long by 34 inches in diameter and three high. The accompanying cuts show the Reduction and Elongation after Pulling a Test-piece

The accompanying cuts show the Drift Test and also the Bending Test. THIS WITHOUT BEING HEATED

MANUFACTURERS' STANDARD SPECIFICATIONS governing the properties of Open Hearth Steel, as adopted by the Association of American Steel Manufacturers, October 23, 1896.

We trust wherever possible our friends will conform to these specifications. It fills a long-felt want to have uniformity in this direction. It will be noticed that Shell Steel has been dropped entirely, believing that no lower grade than "Flange" should be used in making Boilers.

STRUCTURAL STEEL

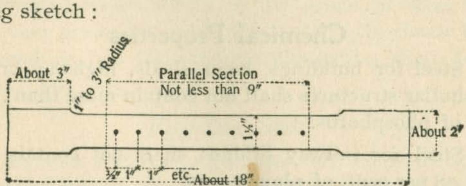
Process of Manufacture

1. Steel may be made by either the Open Hearth or Bessemer process.

Test Pieces

2. All tests and inspections shall be made at the place of manufacture prior to shipment.

3. The tensile strength, limit of elasticity and ductility shall be determined from a standard test piece cut from the finished material. The standard shape of the test piece for sheared plates shall be as shown by the following sketch :



Piece to be of same thickness as the plate

On tests cut from other material the test piece may be either the same as for plates, or it may be planed or turned parallel throughout its entire length. The elongation shall be measured on an original length of 8 inches, except when the thickness of the finished material is $\frac{5}{16}$ inch or less, in which case the elongation shall be measured in a length equal to sixteen times the thickness; and except in rounds of ⅝ inch or less in diameter, in which case the elongation shall be measured in a length equal to eight times the diameter of section tested. Two test pieces shall be taken from each melt or blow of finished material, one for tension and one for bending.

3*a*. Material which is to be used without annealing or further treatment is to be tested in the condition in which it comes from the rolls. When material is to be annealed or otherwise treated before use, the specimen representing such material is to be similarly treated before testing.

4. Every finished piece of steel shall be stamped with the blow or melt number, and steel for pins shall have the blow or melt numbers stamped on the ends. Rivet and lacing steel, and small pieces for pin plates and stiffeners, may be shipped in bundles, securely wired together, with the blow or melt number on a metal tag attached.

Finish

5. Finished bars must be free from injurious seams, flaws, or cracks, and have a workmanlike finish.

Chemical Properties

6. Steel for buildings, train sheds, highway bridges, and similar structures shall not contain more than .10 per cent. of phosphorus.

7. Steel for railway bridges shall not contain more than .08 per cent. of phosphorus.

Physical Properties

8. Structural steel shall be of three grades: **Rivet, Soft** and **Medium.**

Rivet Steel

9. Ultimate strength, 48,000 to 58,000 pounds per square inch. Elastic limit, not less than one-half the

ultimate strength. Elongation, 26 per cent. Bending test, 180 degrees flat on itself, without fracture on outside of bent portion.

Soft Steel

10. Ultimate strength, 52,000 to 62,000 pounds per square inch. Elastic limit, not less than one-half the ultimate strength. Elongation, 25 per cent. Bending test, 180 degrees flat on itself, without fracture on outside of bent portion.

Medium Steel

11. Ultimate strength, 60,000 to 70,000 pounds per square inch. Elastic limit, not less than one-half the ultimate strength. Elongation, 22 per cent. Bending test, 180 degrees to a diameter equal to thickness of piece tested, without fracture on outside of bent portion.

Pin Steel

12. Pins made from either of the above-mentioned grades of steel shall, on a specimen test piece cut at a depth of 1 inch from surface of finished material, fill the physical requirements of the grade of steel from which they are rolled, for ultimate strength, elastic limit, and bending, but the required elongation shall be decreased 5 per cent.

Eye-Bar Steel

13. Eye-bar material, 1½ inches and less in thickness, made of either of the above-mentioned grades of steel, shall, on test pieces cut from finished material, fill the requirements of the grade of steel from which it is rolled. For thicknesses greater than 1½ inches, there will be allowed a reduction in percentage of elongation of 1 per cent. for each ⅛ of an inch increase of thickness, to a minimum of 20 per cent. for medium steel, and 22 per cent. for soft steel.

Full Size Test of Steel Eye-Bars

14. Full size tests of steel eye-bars shall be required to show not less than 10 per cent. elongation in the body of the bar, and tensile strength not more than 5000 pounds below the minimum tensile strength required in specimen tests of the grade of steel from which they are rolled. The bars will be required to break in the body, but should a bar break in the head, but develop 10 per cent. elongation and the ultimate strength specified, it shall not be cause for rejection, provided not more than one-third of the total number of bars tested break in the head; otherwise the entire lot will be rejected.

Variation in Weight

15. The variation in cross-section or weight of more than 2½ per cent. from that specified will be sufficient cause for rejection, except in the case of sheared plates, which will be covered by the following permissible variations:

15*a*. Plates 12½ pounds per square foot or heavier, when ordered to weight shall not average more than 2½ per cent. variation above or 2½ per cent. below the theoretical weight.

15*b*. Plates under 12½ pounds per square foot, when ordered to weight shall not average a greater variation than the following:

Up to 75 inches wide, 2½ per cent. above or 2½ per cent. below the theoretical weight.

75 inches and over, 5 per cent. above or 5 per cent. below the theoretical weight.

15*c*. For all plates ordered to gauge there will be permitted an average excess of weight over that corresponding to the dimensions on the order equal in amount to that specified in the following table:

Table of Allowances for Overweight for Rectangular Plates when Ordered to Gauge

The weight of 1 cubic inch of rolled steel is assumed to be .2833 lb.

PLATES 1-4 INCH AND OVER IN THICKNESS

THICKNESS OF PLATE	WIDTH OF PLATE		
	Up to 75 in.	75 in. to 100 in.	Over 100 in.
$\frac{1}{4}$ inch	10 per cent.	14 per cent.	18 per cent.
$\frac{5}{16}$ "	8 "	12 "	16 "
$\frac{3}{8}$ "	7 "	10 "	13 "
$\frac{7}{16}$ "	6 "	8 "	10 "
$\frac{1}{2}$ "	5 "	7 "	9 "
$\frac{9}{16}$ "	$4\frac{1}{2}$ "	$6\frac{1}{2}$ "	$8\frac{1}{2}$ "
$\frac{5}{8}$ "	4 "	6 "	8 "
Over $\frac{5}{8}$ "	$3\frac{1}{2}$ "	5 "	$6\frac{1}{2}$ "

PLATES UNDER 1-4 INCH IN THICKNESS

THICKNESS OF PLATE	WIDTH OF PLATE	
	Up to 50 in.	50 in. and above
$\frac{1}{8}$ in. up to $\frac{5}{32}$ in.	10 per cent.	15 per cent.
$\frac{5}{32}$ " $\frac{3}{16}$ "	$8\frac{1}{2}$ "	$12\frac{1}{2}$ "
$\frac{3}{16}$ " $\frac{1}{4}$ "	7 "	10 "

STRUCTURAL CAST IRON

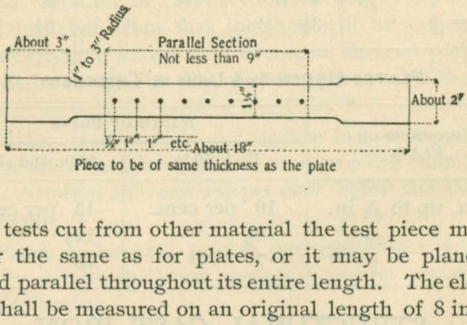
Except when chilled iron is specified, all castings shall be tough gray iron, free from injurious cold-shuts or blow-holes, true to pattern, and of a workmanlike finish. Sample pieces 1 inch square, cast from the same heat of metal in sand moulds, shall be capable of sustaining, on a clear span of 4 feet 8 inches, a central load of 500 pounds when tested in the rough bar.

SPECIAL OPEN-HEARTH PLATE AND RIVET STEEL

Test Pieces

1. All tests and inspections shall be made at the place of manufacture prior to shipment.

2. The tensile strength, limit of elasticity and ductility shall be determined from a standard test piece cut from the finished material. The standard shape of the test piece for sheared plates shall be as shown by the following sketch:



Piece to be of same thickness as the plate

On tests cut from other material the test piece may be either the same as for plates, or it may be planed or turned parallel throughout its entire length. The elongation shall be measured on an original length of 8 inches, except when the thickness of the finished material is $\frac{5}{16}$ inch or less, in which case the elongation shall be measured in a length equal to sixteen times the thickness; and except in rounds of $\frac{5}{8}$ inch or less in diameter, in which case the elongation shall be measured in a length equal to eight times the diameter of section tested. Four test pieces shall be taken from each melt of finished material, two for tension and two for bending.

3. Material which is to be used without annealing or further treatment is to be tested in the condition in which it comes from the rolls. When material is to be annealed or otherwise treated before use, the specimen representing such material is to be similarly treated before testing.

4. Every finished piece of steel shall be stamped with the melt number. Rivet steel may be shipped in bundles, securely wired together, with the melt number on a metal tag attached.

5. All plates shall be free from surface defects and have a workmanlike finish.

Chemical Properties

6. The maximum allowable limits of phosphorus and sulphur shall be as follows:

6a. On Flange or Boiler Steels, .06 per cent. of phosphorus and .04 per cent. of sulphur.

6b. On Fire Box and Extra Soft Steels, .04 per cent. of phosphorus and .04 per cent. of sulphur.

6c. On Boiler Rivet Steel, .04 per cent. of phosphorus, and .04 per cent. of sulphur.

Physical Properties

7. Steel shall be of four grades: **Extra Soft, Fire Box, Flange** or **Boiler,** and **Boiler Rivet Steel.**

Extra Soft Steel

8. Ultimate strength, 45,000 to 55,000 pounds per square inch. Elastic limit, not less than one-half the ultimate strength. Elongation, 28 per cent. Cold and Quench Bends, 180 degrees flat on itself without fracture on outside of bent portion.

Fire Box Steel

9. Ultimate strength, 52,000 to 62,000 pounds per square inch. Elastic limit, not less than one-half the ultimate strength. Elongation, 26 per cent. Cold and Quench Bends, 180 degrees flat on itself without fracture on outside of bent portion.

Flange or Boiler Steel

10. Ultimate strength, 52,000 to 62,000 pounds per square inch. Elastic limit, not less than one-half the ultimate strength. Elongation, 25 per cent. Cold and Quench Bends, 180 degrees flat on itself without fracture on outside of bent portion.

Boiler Rivet Steel

11. Steel for boiler rivets shall be made of the extra soft quality specified in paragraph No. 8.

Variation in Weight

12. Plates 12½ pounds per square foot or heavier, when ordered to weight shall not average more than 2½ per cent. variation above or 2½ per cent. below the theoretical weight.

12*a*. Plates under 12½ pounds per square foot, when ordered to weight shall not average a greater variation than the following:

Up to 75 inches wide, 2½ per cent. above or 2½ per cent. below the theoretical weight.

75 inches and over, 5 per cent. above or 5 per cent. below the theoretical weight.

12*b*. For all plates ordered to gauge, there will be permitted an average excess of weight over that corresponding to the dimensions on the order equal in amount to that specified in the following table, provided no plate shall be rejected for light gauge measuring $\frac{1}{100}$ inch or less, below the ordered thickness:

Table of Allowances for Overweight for Rectangular Plates when Ordered to Gauge

The weight of 1 cubic inch of rolled steel is assumed to be .2833 lb.

PLATES 1-4 INCH AND OVER IN THICKNESS

Thickness of Plate	Width of Plate		
	Up to 75 in.	75 in. to 100 in.	Over 100 in.
$\frac{1}{4}$ inch	10 per cent.	14 per cent.	18 per cent.
$\frac{5}{16}$ "	8 "	12 "	16 "
$\frac{3}{8}$ "	7 "	10 "	13 "
$\frac{7}{16}$ "	6 "	8 "	10 "
$\frac{1}{2}$ "	5 "	7 "	9 "
$\frac{9}{16}$ "	$4\frac{1}{2}$ "	$6\frac{1}{2}$ "	$8\frac{1}{2}$ "
$\frac{5}{8}$ "	4 "	6 "	8 "
Over $\frac{5}{8}$ "	$3\frac{1}{2}$ "	5 "	$6\frac{1}{2}$ "

PLATES UNDER 1-4 INCH IN THICKNESS

Thickness of Plate	Width of Plate	
	Up to 50 in.	50 in. and above
$\frac{1}{8}$ in. up to $\frac{5}{32}$ in.	10 per cent.	15 per cent.
$\frac{5}{32}$ " $\frac{3}{16}$ "	$8\frac{1}{2}$ "	$12\frac{1}{2}$ "
$\frac{3}{16}$ " $\frac{1}{4}$ "	7 "	10 "

EXPLANATION

The term **"Tensile Strength"** or **"Ultimate Strength,"** as usually applied, means the maximum number of pounds per square inch of section required to pull apart a specimen.

"Elastic Limit," of recent time much more accurately termed **"yield point,"** means the point where the applied strain begins to produce a permanent elongation; up to that point the metal will yield slightly, but when the load is removed, will return to its original length like India rubber. It is never safe to strain any structure beyond this point, in actual use, and many prominent engineers rate the strength of metals according to elastic limit instead of tensile strength, not specifying the latter at all.

"Elongation" means the percentage of stretch or elongation in a given length, which is now almost universally taken in 8 inches, except for special tests.

"Reduction of Area" means the percentage of reduction from the original section area of sample, where it is drawn down in the action of pulling apart. Both "Elongation" and "Reduction of Area" are indications of ductility, or "molasses candy" nature of the steel. Some steel will show a high elongation, but not a high reduction of area. Some, again, will show a high reduction of area at point of fracture, but a poor elongation. The best steel is that which shows both high elongation and high reduction of area. Tests taken transversely of the same plate will usually show about as high percentage of elongation, but decidedly less reduction of area, than tests taken in the direction in which the plate was rolled.

STRAIGHTENING ROLLS

We have just put in a straightening machine, so placed to take plates as they leave the mill rolls, still red hot, and by passing them through and back, change a wavy or buckled surface into a flat one. All boiler, bridge, and shipbuilders will recognize the immense benefit of this, as straightening the plates while still red hot will not produce any injurious strains; it will save them labor and enable them to turn out a handsome job. This is a recent improvement in boiler plate manufacture, and being made from our own design, the tool is the most complete and efficient of its kind that we know of. The machine consists of seven rolls, grouped together and adjustable, so that both thick and thin plates can be treated. The rolls were made from fluid compressed steel forgings especially for us, under very rigid specifications as to quality. We are now having made, also, a machine with 11 rolls to straighten the thinner gauges, No. 10 to ¼ inch, such as we roll on our 84-inch mill.

SIZES OF PLATES AND HEADS

ROLLED BY

LUKENS IRON AND STEEL COMPANY

Thickness of Plates	112 wide	108 wide	102 wide	96 wide	90 wide	84 wide	78 wide	72 wide	66 wide	60 wide	48 wide	36 wide	24 wide	Diameter of Heads
No. 10	. .	. .	. .	. .	. .	. .	. .	120	144	180	200	200	200	75
$\frac{3}{16}$ inch	. .	. .	. .	. .	. .	. .	. .	144	180	200	250	300	300	85
$\frac{1}{4}$ "	. .	. .	180	198	216	240	270	300	330	360	360	360	360	110
$\frac{5}{16}$ "	. .	180	198	240	276	300	300	330	360	420	420	384	360	112
$\frac{3}{8}$ "	150	196	240	300	330	360	360	360	390	420	420	384	360	114
$\frac{7}{16}$ "	162	204	240	300	330	360	360	372	396	420	420	384	360	114
$\frac{1}{2}$ "	168	216	240	300	330	360	372	384	402	420	420	384	360	114
$\frac{9}{16}$ "	168	216	240	300	324	360	372	384	402	420	420	384	360	114
$\frac{5}{8}$ "	168	216	240	300	324	360	372	384	402	420	420	384	360	114
$\frac{11}{16}$ "	168	204	240	300	324	360	372	384	402	420	420	384	360	113
$\frac{3}{4}$ "	156	192	240	300	324	348	372	384	402	420	420	384	360	113
$\frac{13}{16}$ "	150	192	240	300	294	342	366	384	402	420	420	384	360	113
$\frac{7}{8}$ "	144	192	240	276	294	312	336	360	390	420	420	384	360	112
1 "	144	192	216	240	258	276	300	324	354	390	420	384	360	112
$1\frac{1}{8}$ "	144	192	210	228	246	258	288	306	336	366	420	384	360	110
$1\frac{1}{4}$ "	144	168	192	216	228	246	270	288	318	348	360	360	360	110

WEIGHTS OF STEEL PLATES

PER SQUARE FOOT

U. S. Standard July 1, 1893	American Brown & Sharpe	English Stubbs or Birmingham	Decimals	Inches	Steel
		17	.058		2.368
16			$.062^{5}$	1-16	2.551
	14		$.064^{084}$		2.616
		16	.065		2.654
15			.07		
	13		$.071^{961}$		2.938
		15	.072		2.939
14			$.078^{125}$	5-64	3.189
	12		$.080^{808}$		3.299
		14	.083		3.388
	11		$.090^{742}$		3.705
			$.093^{75}$	3-32	3.827
13			.094		
		13	.095		3.878
	10		$.101^{89}$		4.160
12		12	.109		4.450
			$.109^{375}$	7-64	4.465
	9		$.114^{43}$		4.672
		11	.12		4.899
11			.125	1-8	5.103
	8		$.128^{49}$		5.246
		10	.134		5.471
			$.140^{625}$	9-64	5.741
10			.141		
	7		$.144^{28}$		5.891
		9	.148		6.042
9			.156		
			$.156^{25}$	5-32	6.379
	6		$.162^{02}$		6.615
		8	.165		6.737
			$.171^{875}$	11-64	7.017
8			.172		
		7	.18		7.349
	5		$.181^{94}$		7.428
			$.187^{5}$	3-16	7.655
7			.188		
6		6	.203		8.288

WEIGHTS OF STEEL PLATES—Continued

PER SQUARE FOOT

U. S. Standard July 1, 1893	American: Brown & Sharpe	English: Stubbs or Birmingham	Decimals	Inches	Steel
			$.203^{125}$	13-64	8.293
	4		$.204^{31}$		8.342
			$.218^{75}$	7-32	8.931
5			.219		
		5	.22		8.982
	3		$.229^{42}$		9.367
4			.234		
			$.234^{375}$	15-64	9.569
		4	.238		9.717
			$.244^{918}$		10.000
3			.250	1-4	10.207
	2		$.257^{63}$		10.519
		3	.259		10.575
			$.265^{625}$	17-64	10.845
2			.266		
1			.281		
			$.281^{25}$	9-32	11.483
		2	.284		11.595
	1		$.289^{3}$		11.812
			$.296^{875}$	19-64	12.121
		1	.300		12.249
			$.312^{5}$	5-16	12.759
0			.313		
	0		$.324^{86}$		13.264
			$.328^{125}$	21-64	13.397
		0	.34		13.882
			$.343^{75}$	11-32	14.035
00			.344		
			$.359^{375}$	23-64	14.673
	00		$.364^{8}$		14.894
			$.367^{3}$		14.996
000			.375	3-8	15.311
		00	.38		15.515
			$.390^{625}$	25-64	15.949
0000			.406		
			$.406^{25}$	13-32	16.587
	000		$.409^{64}$		16.725

WEIGHTS OF STEEL PLATES—Continued

PER SQUARE FOOT

U. S. Standard July 1, 1893	American: Brown & Sharpe	English: Stubbs or Birmingham	Decimals	Inches	Steel
			$.421^{875}$	27-64	17.225
		000	.425		17.352
			$.437^{5}$	7-16	17.863
00000			.438		
			$.453^{125}$	29-64	18.501
		0000	.454		18.536
	0000		.46		18.781
			$.468^{75}$	15-32	19.139
000000			.469		
			$.484^{375}$	31-64	19.777
0000000		00000	.500	1-2	20.415
			$.515^{625}$	33-64	21.053
			$.531^{25}$	17-32	21.691
			$.546^{875}$	35-64	22.329
			$.562^{5}$	9-16	22.966
			$.578^{125}$	37-64	23.604
			$.593^{75}$	19-32	24.242
			$.609^{375}$	39-64	24.880
			.625	5-8	25.518
			$.640^{625}$	41-64	26.156
			$.656^{25}$	21-32	26.794
			$.671^{875}$	43-64	27.432
			$.687^{5}$	11-16	28.070
			$.703^{125}$	45-64	28.708
			$.718^{75}$	23-32	29.346
			$.734^{375}$	47-64	29.984
			.750	3-4	30.622
			$.765^{625}$	49-64	31.260
			$.781^{25}$	25-32	31.898
			$.796^{875}$	51-64	32.536
			$.812^{5}$	13-16	33.174
			$.828^{125}$	53-64	33.812
			$.843^{75}$	27-32	34.450
			$.859^{375}$	55-64	35.088
			.875	7-8	35.726
			$.890^{625}$	57-64	36.364
			$.906^{25}$	29-32	37.002

WEIGHTS OF STEEL PLATES—*Continued*

PER SQUARE FOOT

DECIMALS	INCHES	STEEL	DECIMALS	INCHES	STEEL
.921875	59-64	37.640	1.21875	1.7-32	49.761
.9375	15-16	38.278	1.23437	1.15-64	50.399
.953125	61-64	38.916	1.25	1.1-4	51.037
.96875	31-32	39.554	1.28125	1.9-32	52.313
.984375	63-64	40.192	1.3125	1.5-16	53.589
1.	1.	40.83	1.34375	1.11-32	54.865
1.01562	1.1-64	41.467	1.375	1.3-8	56.141
1.03125	1.1-32	42.106	1.40625	1.13-32	57.417
1.04687	1.3-64	42.744	1.4375	1.7-16	58.693
1.0625	1.1-16	43.381	1.46875	1.15-32	59.969
1.07812	1.5-64	44.019	1.5	1.1-2	61.245
1.09375	1.3-32	44.657	1.53125	1.17-32	62.521
1.10937	1.7-64	45.295	1.5625	1.9-16	63.796
1.125	1.1-8	45.933	1.59375	1.19-32	65.072
1.14062	1.9-64	46.571	1.625	1.5-8	66.348
1.15625	1.5-32	47.209	1.65625	1.21-32	67.624
1.17187	1.11-64	47.847	1.6875	1.11-16	68.900
1.1875	1.3-16	48.485	1.71875	1.23-32	70.176
1.20312	1.13-64	49.123	1.75	1.3-4	71.452

NOTE.—This table is based upon the average weight of 1 cubic foot of Steel and Iron as given by—

	Steel	Iron
Haswell, ...	490.45	485.87
Nystrom, ...	489.80	486.60

In calculating total weights of Plates, a percentage must be added to the weight given in this table to allow for spring of Rolls, according to width and gauge of Plates. See pages 18 and 22.

See Standard Specifications, page 19.

WEIGHT OF CIRCULAR PLATES OF STEEL

DIAMETER IN INCHES

Thickness	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
1/8	7	8	9	10	11	12	14	15	16	18	19	21	23	24	25	27	29	31	33	35
3/16	11	12	14	15	17	19	20	22	24	26	29	31	33	36	38	41	43	46	49	52
1/4	14	16	18	20	23	25	27	30	32	35	38	41	44	47	51	54	58	61	65	69
5/16	18	20	23	25	28	31	34	37	41	44	47	51	55	59	63	68	72	76	81	86
3/8	22	24	27	30	34	37	41	45	49	53	57	62	66	71	76	81	86	92	98	103
7/16	25	28	32	36	39	43	48	52	57	62	67	72	77	83	89	95	101	108	114	121
1/2	29	33	36	42	45	50	55	60	65	70	76	82	88	95	101	108	115	122	130	138

DIAMETER IN INCHES

Thickness	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55
1/8	37	39	41	43	45	47	50	52	55	57	60	62	65	68	. .	. .	. .	. .	. .	. .
3/16	55	58	61	64	68	71	75	78	82	86	89	93	97	101	106	110	114	119	123	128
1/4	73	77	81	86	90	95	99	104	109	114	119	124	130	135	141	147	152	158	164	170
5/16	91	96	102	107	113	118	124	130	136	143	149	156	162	169	176	183	190	198	205	213
3/8	109	116	123	128	135	142	149	156	164	171	179	187	195	203	211	220	228	237	246	255
7/16	128	136	142	150	158	166	174	182	191	200	209	218	227	237	246	256	266	277	287	298
1/2	146	154	163	171	180	189	199	208	218	228	239	249	259	270	281	293	304	316	328	341
9/16	162	172	182	193	203	213	223	234	245	257	268	280	292	304	317	330	343	356	369	383
5/8	178	190	201	213	225	237	248	260	273	285	299	311	324	338	352	366	381	395	410	426
11/16	194	207	220	233	247	259	272	286	301	315	328	342	357	372	387	403	419	435	451	468
3/4	210	225	239	254	269	283	297	313	329	344	358	374	390	406	422	439	457	474	492	511

Extra weights to be added for wide plates. See page 19.

WEIGHT OF CIRCULAR PLATES OF STEEL—Continued

DIAMETER IN INCHES

Thickness	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
3/16	132	137	142	147	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1/4	177	183	189	196	204	212	219	226	233	240	248	255	263	271	279	287	295	303	311	320
5/16	221	229	237	245	254	264	273	282	291	300	310	319	329	338	348	358	368	379	389	400
3/8	265	274	284	294	305	317	328	338	349	360	371	383	394	406	418	430	442	454	467	480
7/16	309	320	331	343	356	370	382	395	407	420	433	447	460	474	487	502	516	530	545	560
1/2	353	366	379	392	408	423	437	451	466	480	495	510	526	541	557	573	589	606	623	640
9/16	397	412	426	441	457	476	492	508	524	540	557	574	591	609	627	645	663	682	700	719
5/8	441	457	473	490	510	529	546	564	582	600	619	638	657	677	696	717	737	757	778	799
11/16	485	503	521	539	561	582	601	620	640	661	681	702	723	744	766	788	810	833	856	879
3/4	530	549	568	588	612	635	656	677	699	721	743	766	789	812	836	860	884	909	934	959

DIAMETER IN INCHES

Thickness	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
1/4	328	337	346	355	367	378	388	397	407	417	427	437	447	457	467	..	..	..	..	..
5/16	410	421	432	443	458	473	485	497	509	521	533	546	558	571	584	597	610	623	637	651
3/8	492	506	519	532	550	568	582	596	610	625	640	655	670	685	701	716	732	748	764	781
7/16	575	590	605	621	641	662	679	695	712	729	746	764	782	799	817	836	854	873	892	911
1/2	657	674	692	710	733	757	776	795	814	833	853	873	893	914	934	955	976	998	1019	1041
9/16	739	758	778	798	830	851	872	894	916	937	960	982	1005	1028	1051	1075	1098	1122	1146	1171
5/8	821	843	865	887	917	946	969	993	1017	1042	1066	1091	1117	1142	1168	1194	1220	1247	1274	1301
11/16	903	927	951	976	1008	1041	1066	1093	1119	1146	1173	1200	1228	1256	1285	1313	1342	1372	1401	1431
3/4	985	1011	1038	1064	1100	1135	1163	1192	1221	1250	1280	1309	1340	1370	1401	1433	1463	1496	1529	1561
13/16	1067	1095	1124	1153	1192	1230	1260	1291	1322	1354	1386	1419	1452	1485	1518	1552	1586	1621	1656	1692
7/8	1149	1180	1210	1242	1283	1324	1357	1390	1424	1458	1493	1528	1563	1599	1635	1671	1708	1746	1783	1822
15/16	1231	1264	1297	1330	1384	1419	1454	1490	1526	1562	1599	1637	1675	1712	1752	1791	1830	1870	1911	1952
1	1313	1348	1383	1419	1476	1514	1551	1589	1628	1667	1706	1746	1787	1827	1869	1910	1953	1995	2038	2082

Extra weights to be added for wide plates. See page 19.

WEIGHT OF CIRCULAR PLATES OF STEEL—Continued

DIAMETER IN INCHES

Thickness	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115
5/16	664	678	692	707	721	735	750	764	779	794	808	822	836	850	865	879	894	909	923	938
3/8	797	814	831	848	865	882	899	916	933	950	967	984	1001	1018	1035	1052	1069	1086	1103	1120
7/16	930	950	969	989	1009	1029	1048	1068	1087	1107	1127	1147	1166	1186	1205	1225	1245	1264	1284	1303
1/2	1063	1085	1108	1130	1153	1175	1197	1219	1241	1263	1286	1309	1331	1354	1376	1398	1420	1442	1464	1486
9/16	1196	1221	1246	1272	1297	1322	1347	1372	1395	1420	1445	1470	1496	1522	1547	1572	1596	1620	1645	1670
5/8	1329	1357	1384	1413	1442	1470	1498	1525	1551	1577	1605	1632	1660	1689	1717	1745	1773	1800	1827	1855
11/16	1462	1492	1523	1554	1585	1616	1647	1678	1706	1735	1765	1796	1827	1858	1888	1919	1950	1980	2010	2040
3/4	1594	1628	1662	1696	1730	1764	1798	1832	1862	1894	1926	1960	1994	2027	2060	2094	2128	2162	2194	2226
13/16	1727	1764	1800	1837	1874	1910	1947	1984	2023	2056	2090	2126	2162	2197	2232	2268	2306	2341	2377	2412
7/8	1860	1899	1939	1978	2018	2058	2098	2138	2178	2215	2254	2293	2331	2369	2405	2443	2484	2522	2560	2598
15/16	1993	2035	2077	2120	2163	2205	2248	2291	2333	2374	2416	2459	2499	2539	2580	2620	2663	2704	2745	2785
1	2126	2171	2215	2261	2307	2352	2398	2444	2488	2533	2578	2624	2666	2710	2753	2795	2842	2886	2930	2973

Extra weights to be added for wide plates. See page 19.

NOTE

We are often asked to perform impossibilities in the way of rolling Plates, namely, to roll to a given gauge, and yet not to exceed table weight for same. This cannot be done on account of the spring in the rolls, especially with extra wide Plates. When gauge is specified, it is always understood that the edge of Plate measures the given thickness, and naturally there will be some overweight in the middle. We can come very close to schedule, if ordered to WEIGHT, but the thickness on edge cannot be regarded in this case, and a lee-way over or under schedule weight is required, according to the usual business practice. See pages 18 and 22.

Table of Allowances for Overweight for Rectangular Plates when Ordered to Gauge

The weight of 1 cubic inch of rolled steel is assumed to be .2833 lb.

Plates 1-4 Inch and Over in Thickness

Thickness of Plate	Width of Plate		
	Up to 75 in.	75 in. to 100 in.	Over 100 in.
$\frac{1}{4}$ inch	10 per cent.	14 per cent.	18 per cent.
$\frac{5}{16}$ "	8 "	12 "	16 "
$\frac{3}{8}$ "	7 "	10 "	13 "
$\frac{7}{16}$ "	6 "	8 "	10 "
$\frac{1}{2}$ "	5 "	7 "	9 "
$\frac{9}{16}$ "	$4\frac{1}{2}$ "	$6\frac{1}{2}$ "	$8\frac{1}{2}$ "
$\frac{5}{8}$ "	4 "	6 "	8 "
Over $\frac{5}{8}$ "	$3\frac{1}{2}$ "	5 "	$6\frac{1}{2}$ "

Plates Under 1-4 Inch in Thickness

Thickness of Plate	Width of Plate	
	Up to 50 in.	50 in. and above
$\frac{1}{8}$ in. up to $\frac{5}{32}$ in.	10 per cent.	15 per cent.
$\frac{5}{32}$ " $\frac{3}{16}$ "	$8\frac{1}{2}$ "	$12\frac{1}{2}$ "
$\frac{3}{16}$ " $\frac{1}{4}$ "	7 "	10 "

[Schedule according to Manufacturers' Standard Specifications, pages 8, 9, per revision of October 23, 1896.]

Machine-Flanged Boiler Heads and Flue Holes

Having for many years been in the business of Flanging by Machinery, Round Boiler Heads and Flue Holes, we feel that our experience and skill, obtained during that time, enables us now to turn out the best character of such work, and far ahead of the majority of such work upon the market to-day. We are prepared to furnish

STEEL BOILER HEADS

ready flanged, of any diameter, 12 inches to 120 inches, outside measurement. We are prepared also to flange **Flue Holes,** from 6 inches to 60 inches or more.

We keep standard sizes of Heads, ready to flange, in stock at our works, thus enabling boiler-makers who have time contracts to get their work out quickly.

Machine-Flanged Heads, when properly done, are better than hand flanged. They are perfectly round and without hammer marks; but, which is the most important, they are heated all over in a furnace and **Flanged at one Heat,** thus relieving them of local strains.

We claim advantages over other Flanging Machines, as follows:

1. **Smooth, Round Flanges.**

2. **Edges Thickened Up,** not drawn out, as is the case in hydraulic flanging.

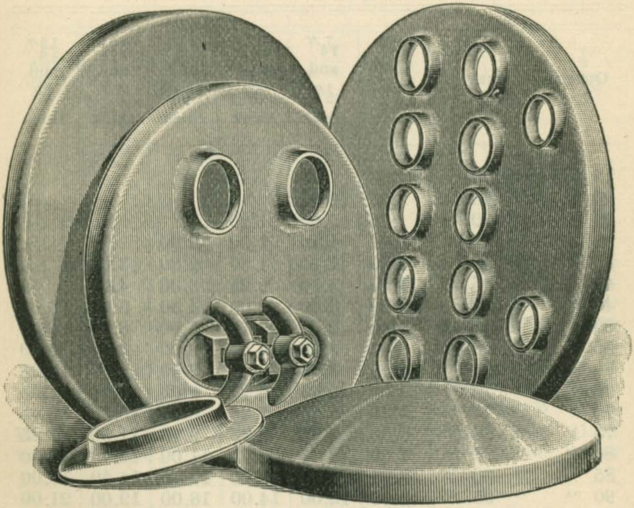
3. **Radius of Flange Varied** to suit customer and work.

4. **We don't have a hole punched in the centre of heads,** as many machines require, to cause trouble to the boiler-makers.

5. Our machines will flange any **Odd** or **Even** sizes wanted, from 12 inches to 120 inches.

6. Our machine-dished Boiler Heads, 12 inches to 108 inches, are the finest and best to be had. We have recently greatly improved our facilities for this work with patented improvements, so that we can turn out especially fine work of any diameter and thickness within the limits of Plate rolling.

DIRECTIONS FOR ORDERING FLANGED WORK



Send a sketch of heads showing the following directions:

Outside diameter of head when finished.

Depth of flange over all.

Radius of flange turn.

Number of flue holes, if any.

Distance between centres of flue holes.

Distance between centre line of upper row of flue holes and centre line of head.

State whether the flue holes are to be flanged the same way as outside flange, or in the opposite direction.

Give quality of material and thickness.

PRICES FOR FLANGING HEADS

Outside Diameter	$\frac{5}{16}''$ and $\frac{3}{8}''$ thick	$\frac{7}{16}''$ and $\frac{1}{2}''$ thick	$\frac{9}{16}''$ and $\frac{5}{8}''$ thick	$\frac{11}{16}''$ and $\frac{3}{4}''$ thick	$\frac{13}{16}''$ and $\frac{7}{8}''$ thick	$\frac{15}{16}''$ and 1″ thick
12 and up to 20 ins.	$0.50	. . .	. . .	. . .	. . .	. . .
20 " " 25 "	.65	$0.80	. . .	. . .	. . .	. . .
25 " " 30 "	.80	.95	$1.25	. . .	. . .	. . .
30 " " 35 "	1.00	1.10	1.50	$2.00	. . .	. . .
35 " " 40 "	1.20	1.40	1.80	2.30	$3.00	. . .
40 " " 45 "	1.50	1.70	2.25	3.00	4.00	. . .
45 " " 50 "	2.00	2.20	3.00	4.00	5.00	$6.00
50 " " 55 "	2.50	2.75	3.75	5.00	6.00	7.50
55 " " 60 "	3.00	3.50	4.50	6.00	7.50	9.00
60 " " 65 "	3.50	4.25	5.25	7.00	8.50	10.25
65 " " 70 "	4.50	5.25	6.25	8.00	9.50	11.25
70 " " 75 "	5.25	6.25	7.25	8.75	10.50	12.25
75 " " 80 "	6.00	7.25	8.25	9.75	11.50	13.25
80 " " 85 "	7.00	8.25	9.25	11.00	12.50	14.50
85 " " 90 "	8.25	10.00	11.00	12.50	14.50	17.00
90 " " 95 "	10.00	12.00	14.00	16.00	19.00	21.00
95 " " 100 "	12.00	15.00	18.00	20.00	23.00	25.00
100 " " 110 "	15.00	19.00	22.00	25.00	29.00	30.00
110 " " 120 "	18.00	23.00	27.00	30.00	34.00	36.00

Flanged without punching hole in centre

Where the total depth of flange exceeds 4½ inches, there is an extra charge of 5 per cent. for each ½ inch additional depth of flange.

PRICES FOR DISHING HEADS OF STANDARD SIZES

Outside Diameter of Head	Depth of Dish	$\frac{3}{16}''$	$\frac{1}{4}''$	$\frac{5}{16}''$ to $\frac{7}{16}''$	$\frac{1}{2}''$ to $\frac{5}{8}''$	$\frac{11}{16}''$ to $\frac{13}{16}''$	$\frac{7}{8}''$ to $1''$
24 inches,	3¼ in.	$1.25	$1.00	$1.00	$1.40	. . .	. . .
30 "	4½ "	2.00	1.75	1.50	1.90	. . .	. . .
36 "	4¾ "	3.25	2.25	1.90	2.35	$3.00	. . .
42 "	5½ "	4.50	2.80	2.35	2.80	3.75	. . .
48 "	6½ "	. . .	3.25	2.90	3.50	5.00	$7.00
54 "	7 "	. . .	4.50	3.50	5.00	7.50	10.00
60 "	8 "	. . .	6.75	4.50	7.00	10.50	14.00
66 "	9 "	. . .	8.75	6.00	8.50	12.50	16.00
72 "	9½ "	. . .	11.00	7.50	10.50	14.50	18.00
78 "	10½ "	. . .	13.75	9.50	12.50	16.50	21.00
84 "	10½ "	. . .	17.00	12.00	15.50	20.00	24.00
90 "	11½ "	. . .	. . .	16.00	20.00	24.50	30.00
96 "	12½ "	. . .	. . .	20.00	24.00	29.00	37.00
102 "	13 "	. . .	. . .	24.00	28.00	33.00	41.00
108 "	14 "	. . .	. . .	. . .	32.00	38.00	45.00

The radius of dish is = the diameter of head when finished.

These prices are for up to 2½ inch flange on flat part; deeper flanges will be at special rates.

NOTE.—Can vary say 1 inch either way, more or less, than sizes above given, and these prices will cover 1 inch more and 1 inch less than sizes given. We can arrange for dishing intermediate sizes also, but prices will be special, to be given on application.

These prices do not include flanging—simply dishing

PRICES FOR FLANGING FLUE HOLES

Inside Diameter	5/16" and 3/8" thick	7/16" and 1/2" thick	9/16" and 5/8" thick	11/16" and 3/4" thick	13/16" and 7/8" thick	15/16" and 1" thick
6 and up to 9 ins.	$1.20	$1.40	$1.80	$2.25	$2.75	$3.50
9 " " 12 "	1.35	1.60	2.00	2.75	3.50	4.50
12 " " 16 "	1.55	1.80	2.30	3.00	4.00	5.00
16 " " 20 "	1.75	2.00	2.60	3.60	4.70	5.75
20 " " 24 "	2.00	2.40	3.00	4.20	5.60	7.00
24 " " 28 "	2.30	2.90	3.60	5.00	6.70	8.75
28 " " 32 "	2.60	3.40	4.30	6.00	8.00	10.50
32 " " 36 "	3.00	3.90	5.10	7.00	9.50	13.00
36 " " 40 "	3.60	4.70	6.00	8.25	11.70	14.50
40 " " 44 "	4.25	5.75	7.30	9.75	13.50	16.25
44 " " 48 "	5.00	7.00	9.00	12.00	15.00	18.00
48 " " 52 "	6.00	8.50	10.50	14.00	16.75	20.00
52 " " 56 "	7.75	10.00	12.00	15.75	19.75	23.00
56 " " 61 "	10.00	11.50	13.50	17.00	21.50	27.00

Regular sizes are every ½ inch from 6 inches up to 20 inches; then every 2 inches up to 60 inches inclusive. Sizes between these can be made at special rates.

Material punched out of centres to be kept as part payment.

An extra charge may have to be made in case holes are to be flanged in very heavy plates, which would entail extra expense for handling.

PRICES FOR CUTTING TUBE HOLES

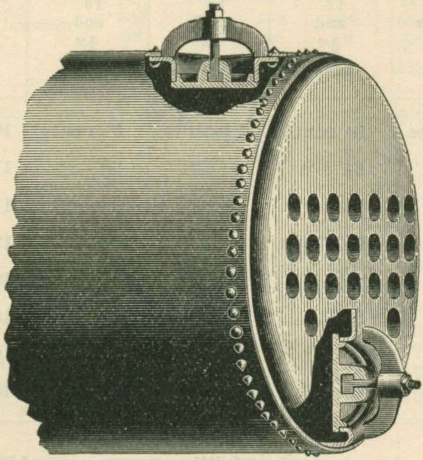
Diameter of Hole	$\frac{5}{16}''$ and $\frac{3}{8}''$ thick	$\frac{7}{16}''$ and $\frac{1}{2}''$ thick	$\frac{9}{16}''$ and $\frac{5}{8}''$ thick	$\frac{11}{16}''$ and $\frac{3}{4}''$ thick
2 inches	6 cents	7½ cents	9 cents	10½ cents
2½ "	6½ "	8 "	9½ "	11 "
3 "	7 "	8½ "	10 "	11½ "
3½ "	7½ "	9 "	10½ "	12 "
4 "	8 "	9½ "	11 "	12½ "
4½ "	9 "	10½ "	12 "	13½ "
5 "	10 "	12 "	14 "	16 "
6 "	12 "	14 "	16 "	18 "

Above prices are for **drilling.** For **punching** and **reaming** can offer a large discount from figures given. The latter makes a strictly first-class job. The strain that may be caused by the operation of punching is relieved by putting the head in a large furnace and annealing it after the operation of punching is completed. This plan is pursued by some of our largest locomotive works.

THE LUKENS MANHOLE

is made in the following sizes:

No. 1.	**9 x 14 inches,**	. . . .	**$10.00**
No. 2.	**10½ x 16 inches,**	. . . .	**10.00**
No. 3.	**11 x 15 inches,**	. . . .	**10.00**
No. 4.	**11 x 13 inches,**	. . . .	**10.00**



The above prices include Flanging the Opening, Facing it Off, Furnishing the Manhole Plate, two Arch Pieces, two Wrought-Iron Bolts and Nuts, also Gasket.

We use heavier castings and larger bolts than are usually furnished, and, therefore, give more for the money.

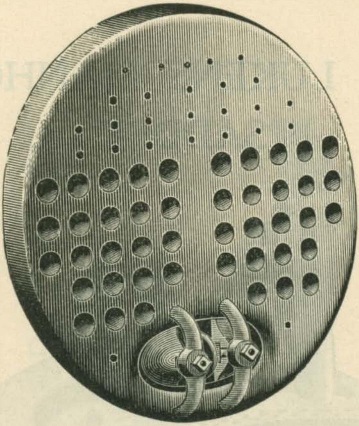
We fit Man Heads to Dished Heads as well as Flat ones.

HAND-HOLES

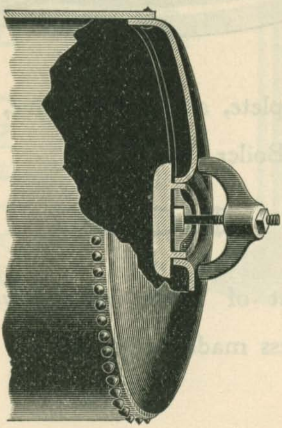
6 x 10 inches,	. . . .	**$7.00**
4 x 6 inches,	. . . .	**6.00**

These prices include all fittings, complete.

THE LUKENS MANHOLE

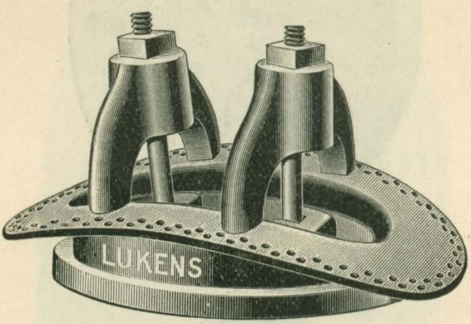


As Applied to Boiler Head



Showing Dished Head with Lukens Manhole

THE LUKENS MANHOLE SADDLE

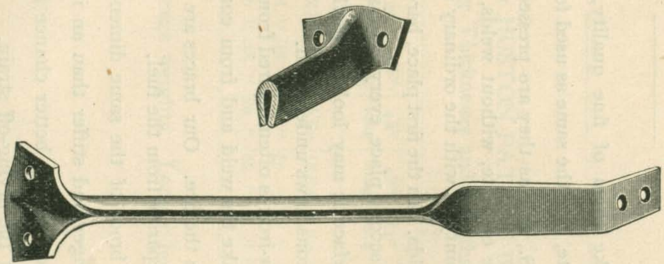


Price, complete, as shown above, set to any diameter of Boiler,

$10.00

plus the cost of Plate, which weighs about 100 lbs., unless made extra thick.

HUSTON PATENT BOILER BRACE



Patented November 14th, 1893. All Rights Reserved

HUSTON PATENT BOILER BRACE

We make them of fine quality, Open Hearth Steel Boiler Plate, just the same as used for boilers of 55,000 to 60,000 T. S., and as they are pressed at one heat from a solid piece of plate, without welds, there is no element of uncertainty as with the ordinary iron brace made with several welds. In the first place, bar-iron is much weaker, and in the second place, every weld is uncertain ; although on the surface it may look perfectly sound, there often are dangerous flaws underneath.

Then bar-iron is often injured from the high heat necessary to make the weld and from coming in contact with sulphur in the fire. Our braces are heated in a furnace, entirely separate from the fuel.

A steel brace of the same dimensions is fully 25 per cent. stronger and stiffer than an iron one, so that the rivets have a much better chance for resistance, being relieved of the prying-off strain.

Observe that in our brace the width of metal, at base of rib in foot, along the fillet, where straightening out strain comes, is about 4 inches, while almost all other braces have only 1½ inches to 2 inches width.

We make these braces of varying lengths and thicknesses to suit the trade, but ½ inch and $\frac{7}{16}$ inch are usually found amply strong for any use, while ⅜ inch will do in case of smaller boilers on lower pressures.

Write us for price.

Average Weights for HUSTON PATENT BRACES,
for Varying Thicknesses and Lengths

THICKNESS	24″ long	30″ long	36″ long	42″ long	48″ long	54″ long	60″ long	72″ long
⅜ inch	10 lbs.	12 lbs.	13 lbs.	15 lbs.	18 lbs.	20 lbs.	23 lbs.	26 lbs.
$\frac{7}{16}$ "	12 "	14 "	16 "	19 "	20 "	23 "	26 "	30 "
½ "	14 "	16 "	18 "	20 "	23 "	26 "	28 "	34 "

The above are average weights. Longer lengths furnished when wanted.

STEEL FOR BOILERS AND FIRE BOXES

The quality and properties of Structural Steel are always carefully studied by engineers in bridge and ship-building; parts subject to compression, tension, torsion, flexure, etc., being made from material especially made or selected for their particular requirements, and a boiler should be made from still more carefully selected material.

It will be noticed that we do not recommend any lower grade of steel for boiler purposes than that known as Flange Steel. We can make an excellent Shell grade of Steel, but recommend boiler makers to always use the best grade. We use exclusively the Siemens-Martin (open hearth) process for making all our grades of boiler plates, and with our finely equipped Steel Plant, mixing and refining the metal, under the most careful and intelligent management, added to our long years of experience, we are able to carry out our constant aim of being second to none in the superiority of our product.

The Tensile Strength by itself is by no means a safe guide to indicate the value or quality of the steel, and even tensile strength and ductility combined are not conclusive proof of good steel, as so many other elements enter in, to affect the quality. The Tensile Strength may be varied at will by the maker, from very soft to hard, in any of the grades, and without much difference in the expense, simply by the amount of the carbon allowed to remain in the steel. The difference in the expense comes in, in the character of the stock used, and the care and time taken in melting down and refining the metal, so as to give it density, homogeneity, and body,—those points which show up in a long life of hard service of the boilers.

Flange Steel.—Flange grade is made from carefully selected stock, low in chemical impurities and especially adapted to stand, without injury, the heating and forming necessary for the flanged portions of the boilers, and to undergo, without injury to its toughness and strength, the strains of punching, bending, and riveting of the cylinder plates, and will make a high-class, safe boiler. Its tensile strength can be made anywhere from 50,000 to 62,000 pounds, or even higher, but we recommend that in the ordinary gauges of 3/8 inch to 1/2 inch it should be not less than 50,000, nor more than 60,000 pounds tensile strength, with a minimum elongation of 25 per cent. in a length of 8 inches.

Marine Steel.—Marine Steel, so called because of being made especially to meet the requirements of the U. S. Steamboat Inspection Service, is a grade between Flange and Fire Box, or may be made of Fire Box quality. It is made in each case to suit the specification, and can be made as soft as 50,000 pounds tensile strength, or as hard as 65,000 pounds tensile strength per square inch in usual thicknesses, although we recommend 55,000 to 60,000 as about the best degree of strength. Elongation, as prescribed by U. S. Rules.

Fire Box Steel.—Fire Box Steel is made from especially selected stock, prepared with especial care, so as to secure, first, freedom from chemical impurities, and, second, density and fineness of texture, with freedom from sponginess or what is called "piping," being fitted especially to stand the unequal strain caused by the local action of the fire, and to readily transmit the heat from the fire to the water, requirements which steel without life in its nature, or a spongy steel, will not fulfil successfully. Tensile strength recommended is 50,000 to 62,000 pounds, with 26 per cent. elongation in 8 inches, in usual thicknesses.

Extra Locomotive Fire Box Steel.—This is the grade most difficult to make successfully, owing to the varying conditions of fuel, water, and service the boilers will have to meet, so that the metal has to be specially adapted in each case to meet the requirements of service, as well as to comply with the rigid specifications adopted by the different Railroads or Associations. (See table on following page,—51.) This grade must have the conditions of regular Fire Box Steel mentioned above even more rigidly carried out. In our judgment, a medium or moderately stiff grade of steel, say about 60,000 pounds T. S., gives the best service under average conditions, but some conditions require very soft and others quite hard steel to give the best service, as the following list of specifications of leading Railroads and Associations will show; these, of course, being based on the result of large experience in each case.

FIRE BOX STEEL SPECIFICATIONS OF LEADING RAILROADS, ASSOCIATIONS, AND LOCOMOTIVE WORKS

Name	Minimum Tensile Strength	Maximum Tensile Strength	Minimum Elongation	Maximum Carbon	Minimum Carbon	Maximum Phosphorus	Maximum Sulphur	Maximum Manganese	Maximum Silicon	Maximum Copper
Pennsylvania R. R. Co., ...	55000	65000	25% in 8″	.25	.15	.035	.045	.45	.03	.05
Philadelphia & Reading R. R., .	52000	60000	30% in 2″	. .	. .	.035	.04	. .	. .	. .
Baltimore & Ohio R. R., ...	55000	65000	. . . . .	.25	.15	.035	.035	.45	.03	.05
Seaboard Air Line, ...	55000	60000	22% in 8″	.25	.15	.035	.035	.45	.03	. .
South Carolina & Georgia R. R., .	55000	65000	22% in 8″	.25	.15	.035	.045	.45	.03	. .
Canada Pacific R. R., ...	50000	58000	25% in 8″	. .	. .	. .	. .	. .	. .	. .
Chicago & Northwestern R. R., .	50000	65000	25% in 8″	. .	. .	. .	. .	. .	. .	. .
Chicago, Milw. & St. Paul R. R.,	50000	60000	25% in 5″	. .	. .	. .	. .	. .	. .	. .
Chicago, Burl'g'n & Quincy R. R.,	50000	60000	25% in 4″	. .	. .	. .	. .	. .	. .	. .
Great Northern R'y, ...	52000	60000	25% in 8″	.20	.13	.03	.03	.40	.02	.03
Northern Pacific R'y, ...	54000	62000	25%	.20	.12	.03	.02	.40	.02	. .
Union Pacific R'y, ...	50000	56000	28% in 4″	.20	. .	.04	.04	.50	.04	.04
Missouri Pacific R'y, ...	48000	55000	28% in 8″	. .	. .	. .	. .	. .	. .	. .
Southern Pacific R'y, ...	50000	65000	25% in 4″	. .	. .	. .	. .	. .	. .	. .
Baldwin Locomotive Works, . . .	55000	65000	25% in 8″	.25	.15	.03	.035	.45	.03	. .
Cooke Locomotive Works, ...	52000	62000	26%	. .	. .	.04	.04	. .	. .	. .
Railway Master Mechanics' Ass'n,	55000	65000	25% in 8″	.25	.15	.035	.035	.45	.03	. .

In addition to above tests, the Railway Master Mechanics' Association and some of the principal railroads require a test for homogeneity by nicking a test piece on alternate sides in three places and breaking where nicked; a cavity more than ¼ inch long in any of the three fractures being sufficient cause for rejection of the plate.

STEAM BOILERS

Generally speaking, a steam boiler is a closed metallic vessel, of suitable form to generate steam from heat, either from a fire inside or under the boiler, or from the waste gases of a puddling or other furnace, where the temperature for melting or heating purposes is necessarily very high and the heat of the outgoing flames would otherwise be wasted. It must be both tight and strong, and suitable to receive and transmit the necessary heat to the water without injury to itself, and may be of any suitable shape to fulfil these conditions.

Boilers for various purposes are known to have been used as far back as the time of the Romans, about 100 A. D., and have been constructed of many kinds of materials, mostly Cast Iron, Copper, Wrought Iron, and Steel, the last two mentioned being the best suited for hard service.

Cast Iron is too brittle, Copper is too soft as well as too expensive for general use, and in these days the advantages of Soft Steel over Wrought Iron, in the various desirable qualifications, and in the facility with which it can be cheaply manufactured and made into a boiler, make good steel the best material for general use at the present time.

Generally speaking, boilers may be divided into two classes: *internally* fired and *externally* fired. Internally fired boilers are so constructed that the fire is in a box or casing inside the boiler, and consequently surrounded by water, much of the heat passing to the water by radiation and direct transmission through the fire-box plates, the gases being carried away by tubes or flues passing through the water, and no brick setting being needed. Of this type are Locomotive boilers, Marine boilers, Cornish, Scotch, or Lancashire boilers, and most of the Upright tubular boilers.

Externally fired boilers have the fire usually under the outside of the boiler, so that a brick casing or setting is required, the construction in most cases being such that the flames afterward pass through tubes or flues surrounded by water in the body of the boiler, or, as in the water-tube and sectional types, the flames circulate between tubes or small sections connected with each other and filled with water. Externally fired boilers include plain cylinder boilers, ordinary flue boilers, horizontal tubular boilers, and most water-tube or sectional boilers.

HORSE POWER OF BOILERS

A Committee of the American Society of Mechanical Engineers recommended 30 pounds evaporation as the unit of boiler power, and this has been generally accepted. They advised that the commercial horse power should be taken as an evaporation of 30 pounds of water from a feed-water temperature of 100° Fahr. into steam at 70 pounds gauge pressure, which may be considered to be equal to 34½ pounds of water evaporated from a feed-water temperature of 212° Fahr. into steam at the same temperature.

It was the opinion of this Committee that a boiler rated at any stated power should be capable of developing that power with easy firing, moderate draught, and ordinary fuel.—*R. H. Thurston.*

The standard, adopted by the judges at the Centennial Exhibition, of 30 pounds water per hour evaporated from 212°, for each horse power, is a fair one for both boilers and engines, and has been favorably received by engineers and steam men; but as the same boiler may be made to do more or less work, with less or greater economy, the rating of a boiler should be based on the amount of water it will evaporate at an economical rate.

Each nominal horse power of boilers requires 1 cubic foot of water per hour.

The rate of combustion should not exceed 0.3 pound of coal per hour for each square foot of heating surface, except where the quantity of steam is of greater importance than economy of fuel.

Where a blast is used, the grate surface should be proportionately reduced to secure the best economy.

The accumulation of scale on the interior, and of soot on the exterior, will seriously affect the efficiency and economy of the boilers. Only 1/8 of an inch deposit of soot renders the heating surface practically useless. 1/16 of an inch of scale or sediment will cause a loss of 13 per cent. in fuel. The result of a bad setting for a boiler has been known to be a loss of 21 per cent. in economy.

In common practice, and when an approximate rating is desired, it has become customary to allow a certain number of square feet of heating surface per horse power.

The following table gives the approximate square feet of heating surface per horse power in various styles of boilers :

Plain Cylinder, ...	6 to 10 sq. ft.
Flue Boiler, ...	8 " 12 "
Water Tube or Sectional, ...	10 " 12 "
Locomotive Boiler, ...	12 " 16 "
Horizontal Tubular Boiler, ...	12 " 15 "
Upright Tubular Boiler, ...	15 " 20 "

TABLE SHOWING RATIO OF HEATING SURFACE TO GRATE SURFACE

Plain Cylinder Boilers, .	12 to 15 sq. ft. to 1 sq. ft. of grate.
Cylindrical Flue Boilers,	20 " 25 " " 1 " "
Cylindrical Tubular, . .	20 " 35 " " 1 " "
Marine Fire Tubular, .	30 " 35 " " 1 " "
Marine Water Tube, . .	35 " 40 " " 1 " "
Locomotive Tubular, .	50 " 75 " " 1 " "

As a rule, there should be 1 square foot of clean, efficient heating surface for each 3 pounds of water to be evaporated, and so arranged as to suit the character of the fuel.

Heating surface immediately over or near the fire is of course more valuable, particularly in slow firing; the crown sheet of fire box in a locomotive boiler, for instance, being most efficient and the last end of tubes the least efficient. Grates should have from 30 per cent. to 50 per cent. of air space.

For 1 foot of grate surface area over bridge wall should be 7 feet.

For 1 foot of grate surface area of flue opening, anthracite coal, should be 8 to 10 feet.

For 1 foot of grate surface area of flue opening, bituminous coal, should be 6 to 7 feet.

For 1 foot of grate surface area of chimney should be 8 to 10 feet.—"*Barrus.*"

Table showing the composition and calorific power of various combustibles,—the quantity of oxygen and air necessary for combustion,—and the volume of the products of combustion of 1 pound of combustible. (From Morin and Tresca.)

Name of Combustible	Composition				Calorific Power	Weight of Oxygen Necessary for Combustion	Weight of Air Necessary for Combustion	Volume of Air Corresponding in Cubic Feet	Volume of Products in Cubic Feet
	C	H	Volatile Matter	Ashes					
Carbon,	1.00	. . .	. . .	. . .	14400	2.66	11.29	137.6	137.6
Anthracite Coal,	0.90	0.03	0.03	0.04	13500	2.64	11.21	138.9	136.2
Bituminous Coal,	0.85	0.05	0.06	0.06	14400	2.66	11.29	139.6	140.1
Lignite,	0.70	0.05	0.20	0.05	11700	2.26	9.69	120.2	116.3
Peat,	0.55	0.05	0.30	0.10	9000	1.86	7.90	97.9	102.1
Peat 0.20 Water,	0.39	0.04	0.50	0.07	7200	1.49	6.32	78.3	81.5
Coke,	0.85	0.05	. . .	0.10	12500	2.26	9.69	120.2	116.9
Peat-charcoal,	0.82	. . .	. . .	0.18	9000	2.18	9.25	114.5	112.7
Dry Wood,	0.48	0.06	0.05	0.01	7200	1.75	7.43	91.9	89.2
Wood 0.20 Water,	0.40	0.05	0.25	0.01	5400	1.40	5.94	73.5	71.8
Wood-charcoal,	0.80	. . .	0.04	0.07	10800	1.86	7.90	97.9	96.3
Hydrogen,	. . .	1.00	. . .	. . .	62000	8.00	33.97	420.6	475.4
Carbonic Oxide,	0.43	. . .	0.57	. . .	4320	0.57	2.42	29.9	35.6
Illuminating Gas,	0.62	0.21	0.17	. . .	18000	2.64	11.22	136.3	176.7
Gas from Blast Furnace,	0.06	0.02	0.92	. . .	1620	0.23	0.99	12.2	30.3

The water evaporated per pound of coal varies all the way from 7 pounds to 15 pounds, but 10 to 12 pounds is considered at present a very excellent result.

The proportion required of grate surface to heating surface for best results, will vary according to the conditions from 1.10 to 1.75, according to rapidity of combustion and character of fuel used.

A strong draft, and free burning fuel, as wood or bituminous coal, will need a large proportion of heating surface to take up the heat from the large volume of rapidly moving heated gases, while a mild draft or a slow burning fuel, such as anthracite coal, particularly the smaller sizes, need a larger proportion of grate surface; and the heating surface, so arranged that a large proportion of it will be exposed to the direct effect of the fire, because the slow movement, and comparatively small volume of the after-gases can easily be taken care of by a small amount of tube or flue surface.

RATES OF COMBUSTION

	Pounds per sq. ft. per hour
With Chimney Draught:	
Slowest Rate, Cornish Boilers,	4 to 6
Ordinary Rate, Cornish Boilers,	10 to 15
Ordinary Rate, Factory Boilers,	12 to 18
Ordinary Rate, Marine Boilers,	15 to 25
Quickest Rate for Anthracite Coal,	15 to 20
Quickest Rate for Bituminous Coal,	20 to 25
With Forced Draught:	
Locomotives,	40 to 100
Torpedo Boats,	60 to 125

The following table, prepared from careful collation of French experience by Morin and Tresca, and first published by the late W. P. Trowbridge, indicates the rapidity of combustion which is to be expected with chimneys of the height.

Heights of Chimneys in Feet	Pounds of Coal per Square Foot of Section of Chimney, per Hour	Pounds of Coal per Square Foot of Grate, per Hour
20	60	7.5
25	68	8.5
30	76	9.5
35	84	10.5
40	93	11.6
50	105	13.1
60	116	14.5
70	126	15.8
80	135	16.9
90	144	18.0
100	152	19.0
110	160	20.0

PRESSURE

Rule for calculating pressure allowed on boilers according to *United States Government Rules*. (See circular of Treasury Department, Office of Supervising Inspector General of Steamboats, 3-22-81.) "Multiply one-sixth of tensile strength of iron by thickness expressed in inches, or parts, and divide by half the diameter of shell, expressed in inches. The result will be pressure allowed per square inch of surface for *single riveting*, to which add 20 per cent. for *double riveting*, where all the rivet holes have been fairly drilled."

Philadelphia City Rules for Rating Maximum Working Pressure on Cylindrical Boiler Shells

In estimating the strength of the longitudinal seams, two formulæ shall be applied.

Formula (A): (Pitch of rivets) — (diameter of the holes punched to receive the rivets) ÷ (pitch of rivets) = (percentage of the strength of the solid part of the same sheet).

Formula (B): (Area of the hole filled by the rivet) × (number of rows of rivets in the seam) ÷ (pitch of rivets) × (thickness of the sheet). This product × (shearing strength of the rivet) ÷ (tensile strength of the sheet) = (percentage of the strength of the rivets in the seam as compared to the strength of the solid part of the sheet).

$$\left(\frac{A\ N}{p\ t}\right) \times \frac{S}{T} = \text{Percentage.}$$

The shearing strength of a rivet, in a composite joint made of iron rivets and steel plates, shall not be considered in excess of forty thousand (40,000) pounds.

Take the lowest of the percentages as found by formulæ (A) and (B) and apply that percentage as the value of the seam in the following formula (C), which determines the strength of the longitudinal seams.

Formula (C): (Thickness of the boiler plate, expressed in parts of an inch) × (value of the seam as obtained by formula A or B) × (ultimate strength of the iron in the plates) ÷ (internal radius of the boiler in inches) × (factor of safety) = (pressure per square inch at which the safety-valve may be set).

Boiler Heads.—If the radius of the curvature of the convex head of the boiler be equal to the diameter of the shell of the boiler to which it is attached, then the metal in the head sheet must be of the same thickness as the plates used in the shell or cylindrical part, and no bracing is necessary.

Hartford Steam Boiler Inspection and Insurance Company's Rule for Ascertaining the Safe Working Pressure of a Cylindrical Boiler

Multiply the tensile strength of the iron or steel by the thickness of the plate. Then multiply this product by the efficiency of the joint, and divide the result by the radius or half diameter of the boiler. This gives the bursting pressure, and this result divided by the factor of safety gives the safe working pressure. The factor of safety generally adopted is 5.

The strength of a properly proportioned *single* riveted joint is 56 to 60 per cent. to the total strength of the plate. A properly proportioned *double* riveted joint, 71 to 75 per cent.

A properly proportioned *triple* riveted joint with inside and outside welt strips, 85 per cent. to 87½ per cent. In this last joint, the outside welt strip takes simply two rows of rivets, the inside strip being wide enough to take three rows; the pitch of the third row, however, is double that of the other rows.

This rule may be expressed as follows:

$$\text{Safe working pressure} = \frac{\text{tensile strength} \times \text{thickness} \times \text{efficiency of joint}}{\text{radius} \times \text{factor of safety.}}$$

EXAMPLE

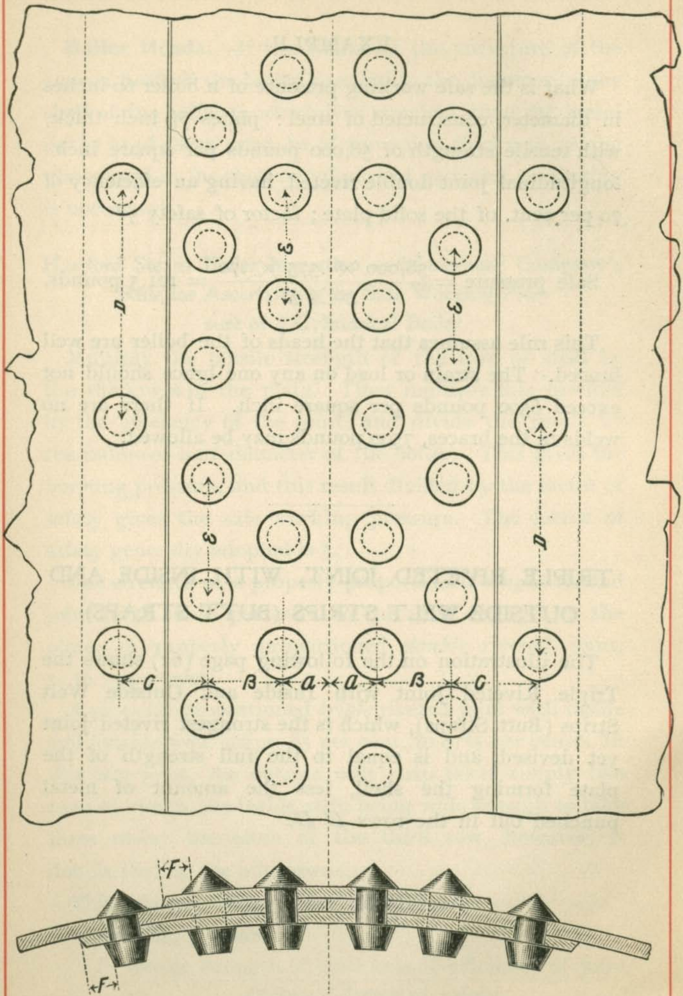
What is the safe working pressure of a boiler 60 inches in diameter, constructed of steel; plates ⅜ inch thick, with tensile strength of 58,000 pounds per square inch; longitudinal joint double riveted, having an efficiency of 70 per cent. of the solid plate; factor of safety 5?

$$\text{Safe pressure} = \frac{58{,}000 \times .375 \times .70}{30 \times 5} = 101.5 \text{ pounds.}$$

This rule assumes that the heads of the boiler are well braced. The strain or load on any one brace should not exceed 6500 pounds per square inch. If there are no welds in the braces, 7500 pounds may be allowed.

TRIPLE RIVETED JOINT, WITH INSIDE AND OUTSIDE WELT STRIPS (BUTT STRAPS)

The illustration on the following page (62) shows the Triple Riveted Joint with Inside and Outside Welt Strips (Butt Straps), which is the strongest riveted joint yet devised, and is equal to the full strength of the plate forming the shell, less the amount of metal punched out in the rows *D D*.



Triple Riveted Joint, with Inside and Outside Welt Strips (Butt Straps)

The strength of a properly proportioned **single** riveted joint is 56 per cent. to 60 per cent. of the strength of the plate.

A properly proportioned **double** riveted joint 71 per cent. to 75 per cent.

A properly proportioned **triple** riveted joint, with inside and outside welt strips, 85 per cent. to 87½ per cent.

MR. WILLIAM G. PIKE, Consulting Engineer of Hartford Insurance Company, Philadelphia, furnishes the following figures for boilers of different dimensions, showing the pressures they will carry:

	Diameter of Boiler, 60 Inches Steam Pressure Allowed, 120 Pounds	Diameter of Boiler, 60 Inches Steam Pressure Allowed, 127 Pounds	Diameter of Boiler, 66 Inches Steam Pressure Allowed, 120 Pounds	Diameter of Boiler, 66 Inches Steam Pressure Allowed, 138 Pounds	Diameter of Boiler, 72 Inches Steam Pressure Allowed, 120 Pounds
Distance A, ...	$1\frac{3}{8}$	$1\frac{3}{8}$	$1\frac{3}{8}$	$1\frac{13}{32}$	$1\frac{13}{32}$
Distance B, ...	$2\frac{3}{16}$	$2\frac{3}{16}$	$2\frac{3}{16}$	$2\frac{1}{4}$	$2\frac{1}{4}$
Distance C, ...	$2\frac{11}{16}$	$2\frac{11}{16}$	$2\frac{11}{16}$	$2\frac{3}{4}$	$2\frac{3}{4}$
Distance D, ...	7	7	7	7	$7\frac{1}{4}$
Distance E, ...	$3\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{5}{8}$
Distance F, ...	$\frac{7}{8}$	$\frac{7}{8}$	$\frac{7}{8}$	$\frac{15}{16}$	$\frac{15}{16}$
Diameter Rivets, ...	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{7}{8}$
Diameter Rivet Holes, .	$\frac{13}{16}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	$\frac{15}{16}$
Thickness Shell Plates, .	$\frac{3}{8}$	$\frac{4}{10}$	$\frac{7}{16}$	$\frac{45}{100}$	$\frac{45}{100}$
Thickness Welt Strips, .	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$

Factor of safety is 5 in all the above. Tensile strength is figured at 55,000 pounds, according to the uniform custom of the Hartford Insurance Company.

Hartford Steam Boiler Inspection and Insurance Company's Rules—Continued

BOILER FLUES AND FURNACES OF CYLINDRICAL FORM

Boiler flues and furnaces of cylindrical form submitted to external pressure, tending to cause the cylinder to collapse, when formed of wrought-iron plates united by rivets and all the seams made with lap joints, shall be rated by the following rule:

Eighty-nine thousand six hundred (89,600) multiplied by the square of the thickness, and this amount divided by the length in feet multiplied by the diameter in inches of the flue, equals the safe load.

N. B.—This rule is based on the assumption that the circumferential seams act as braces, and reduce the unsupported length of the flue or furnace to the length of the sections joined by the circumferential seams.

STAY-BOLTS AND STAYS

The area of stay-bolts and stays submitted to strain shall be measured at their least section, and one-fifth of the breaking strength of the iron shall be assumed as the safe-working load, if the ductility test of the iron does not exceed 15 per cent.; but may be taken at one-fourth, when the ductility test shows 20 per cent. or over. The allowable strain on stay-bolts or stays of unknown quality of iron shall never be considered higher than 7500 pounds per square inch of section, measured at the point of least section.

ATTACHMENTS AND INDICATORS

There shall be for each boiler, or series of connected boilers, at least one efficient feeding apparatus, and in case there is but one such apparatus, and it be worked by an engine employed for other purposes, this feeding apparatus shall be of such character and construction that it can be examined and repaired in all its parts while the engine is in motion.

Each boiler shall have upon it three gauge-cocks, and one glass water-gauge, or in place of the gauge-cocks a second glass water-gauge. Each should have an independent connection with the boiler itself. If one connecting pipe is used for both apparatus, it must be at least 9 square inches area, "and all the connections to which shall be made with not less than one and one-quarter (1¼) inch pipe." Gauge-cocks, when used, must be so placed that the middle gauge must be at least 4 inches above the top of the flues, tubes, or crown of the fire-box. The lowest point of vision of the water in glass gauge must be above the top of flues, tubes, or crown of the fire-box.

Every boiler, when fired separately, and every set or series of boilers when placed over one fire, shall have attached thereto, without the interposition of any other valve, two or more safety-valves, the aggregate area of which shall have such relations to the area of the grate and the pressure within the boiler as is expressed below; and every safety-valve shall have an arm or bearer distinctly notched and marked with 5 pounds or 10 pounds divisions, and shall have but one "P" or ball for a weight. The weight of said "P" or ball is to be determined by the Inspector, the pounds and ounces of which shall be stamped or plainly marked on the weight and on the lever, and a record of the same is to be kept in the office of the Inspector; and the arm shall not have greater length than will allow the "P" to be placed so as to produce on the boiler the maximum pressure which the certificate authorizes to be carried.

The Inspector shall have authority to grant to any user or users of steam boilers to place thereon any spring safety-valve which has been, or may hereafter be, approved by the United States Board of Supervising Inspectors of Steam Vessels.

There shall be for each boiler, or series of boilers connected in one range, at least one good and reliable steam-pressure gauge attached, without the intervention of any valve except its own.

Every range of boilers over one fire shall be so connected by steam and feed pipes that a uniform level of water may be maintained therein.

The least aggregate area of safety-valve (being the least sectional area for the discharge of steam) to be placed upon all stationary boilers with natural chimney draft may be expressed by the following formula:

$$A = \frac{22.5 \times G}{P + 8.62}$$

in which A is area of combined safety-valves in square inches. G is area of grate in square feet. P is pressure of steam in pounds per square inch to be carried in the boiler above the atmosphere, or as indicated by gauge.

NOTE "*a*." Where boilers have a forced or artificial draft, the Inspector must estimate the area of grate at the rate of 1 square foot of grate surface for each 16 pounds of fuel burned on the average per hour.

NOTE "*b*." When boilers are heated by waste heat of furnaces, or otherwise than by fire on grates, the proper grate area is to be estimated by the Inspector.

The following table gives the results of the formula for 1 square foot of grate surface as applied to boilers used at different pressures.

10	20	30	40	50	60	70	80	90	100	110	120
1.21	0.79	0.58	0.46	0.38	0.33	0.29	0.25	0.23	0.21	0.19	0.17

(The figures in the upper row indicate pressures—those in the lower indicate the area of valve corresponding to 1 square foot of grate surface.)

Example: Boiler 25 square feet of grate area and 60 pounds of pressure.

For 1 square foot (from table) 0.33
25 square feet.
8.25 square inches.

This would call for two safety-valves, each with 4.13 square inches area or 2.3 diameter.

Table Showing Thickness of Shell and Safe Working Pressure for Horizontal Tubular Steel Boilers, Without Domes

ACCORDING TO RULES OF CITY OF PHILADELPHIA.—(ORIGINAL—BAIR)

Diameter of Shell Inches	Thickness of Shell Inches	Longitudinal Seams Single Riveted			Longitudinal Seams Double Staggered Riveted			Longitudinal Seams Double Triple Riveted Butt Joint		
		Tensile Strength of Steel			Tensile Strength of Steel			Tensile Strength of Steel		
		50000 Pounds	55000 Pounds	60000 Pounds	50000 Pounds	55000 Pounds	60000 Pounds	50000 Pounds	55000 Pounds	60000 Pounds
		Pressure Pounds	Pressure Pounds	Pressure Pounds	Pressure Pounds	Pressure Pounds	Pressure Pounds	Pressure Pounds	Pressure Pounds	Pressure Pounds
24	$\frac{1}{4}$	118	130	142	150	165	180	. . . .	. . . .	. . . .
	$\frac{5}{16}$	148	163	178	187	206	225	. . . .	. . . .	. . . .
28	$\frac{1}{4}$	101	112	122	128	141	154	. . . .	. . . .	. . . .
	$\frac{5}{16}$	127	139	152	156	171	187	. . . .	. . . .	. . . .
30	$\frac{1}{4}$	95	104	114	116	128	140	. . . .	. . . .	. . . .
	$\frac{5}{16}$	118	130	142	145	160	175	. . . .	. . . .	. . . .
34	$\frac{1}{4}$	83	92	100	102	113	123	. . . .	. . . .	. . . .
	$\frac{5}{16}$	104	115	125	128	141	154	. . . .	. . . .	. . . .
36	$\frac{1}{4}$	79	87	95	97	106	116	. . . .	. . . .	. . . .
	$\frac{5}{16}$	98	108	118	121	133	145	. . . .	. . . .	. . . .
38	$\frac{1}{4}$	75	82	90	92	101	110	. . . .	. . . .	. . . .
	$\frac{5}{16}$	93	103	112	115	126	138	. . . .	. . . .	. . . .
40	$\frac{9}{32}$	80	88	96	98	108	118	. . . .	. . . .	. . . .
	$\frac{5}{16}$	89	97	106	109	120	131	. . . .	. . . .	. . . .

Table Showing Thickness of Shell and Safe Working Pressure, Etc.—Continued

Diameter of Shell Inches	Thickness of Shell Inches	Longitudinal Seams Single Riveted			Longitudinal Seams Double Staggered Riveted			Longitudinal Seams Double Triple Riveted Butt Joint		
		Tensile Strength of Steel			Tensile Strength of Steel			Tensile Strength of Steel		
		50000 Pounds	55000 Pounds	60000 Pounds	50000 Pounds	55000 Pounds	60000 Pounds	50000 Pounds	55000 Pounds	60000 Pounds
		Pressure Pounds	Pressure Pounds	Pressure Pounds	Pressure Pounds	Pressure Pounds	Pressure Pounds	Pressure Pounds	Pressure Pounds	Pressure Pounds
42	$\frac{9}{32}$	76	84	91	93	103	112	. . . .	. . . .	. . . .
	$\frac{5}{16}$	85	92	101	104	114	125	. . . .	. . . .	. . . .
44	$\frac{3}{10}$	77	85	93	95	105	114	. . . .	. . . .	. . . .
	$\frac{32}{100}$	82	91	98	101	112	122	. . . .	. . . .	. . . .
46	$\frac{5}{16}$	77	85	92	95	104	114	. . . .	. . . .	. . . .
	$\frac{34}{100}$	84	92	101	103	113	124	. . . .	. . . .	. . . .
48	$\frac{32}{100}$	76	83	91	93	102	112	114	126	137
	$\frac{36}{100}$	85	94	102	105	115	126	129	141	154
50	$\frac{33}{100}$	75	82	90	92	101	110	113	124	136
	$\frac{36}{100}$	82	90	98	100	110	120	123	136	148
52	$\frac{34}{100}$	74	81	89	91	100	109	112	123	134
	$\frac{36}{100}$	78	86	94	96	106	116	119	130	142
54	$\frac{36}{100}$	76	83	91	93	102	112	114	126	137
	$\frac{3}{8}$	79	87	95	97	106	116	119	131	143
56	$\frac{3}{8}$	76	83	91	93	103	112	115	126	138
	$\frac{4}{10}$	81	89	97	100	110	120	122	135	147

Table Showing Thickness of Shell and Safe Working Pressure, Etc.—Continued

Diameter of Shell Inches	Thickness of Shell Inches	Longitudinal Seams Single Riveted — Tensile Strength of Steel 50000 Pounds (Pressure Pounds)	55000 Pounds (Pressure Pounds)	60000 Pounds (Pressure Pounds)	Longitudinal Seams Double Staggered Riveted — Tensile Strength of Steel 50000 Pounds (Pressure Pounds)	55000 Pounds (Pressure Pounds)	60000 Pounds (Pressure Pounds)	Longitudinal Seams Double Triple Riveted Butt Joint — Tensile Strength of Steel 50000 Pounds (Pressure Pounds)	55000 Pounds (Pressure Pounds)	60000 Pounds (Pressure Pounds)
60	$\frac{4}{10}$	76	83	91	93	102	112	114	126	137
	$\frac{42}{100}$	79	87	95	98	107	117	120	132	144
66	$\frac{43}{100}$	74	81	89	91	100	109	112	123	134
	$\frac{45}{100}$	77	85	93	95	105	114	117	129	140
72	$\frac{45}{100}$	71	78	85	84	96	105	107	118	129
	$\frac{48}{100}$	76	83	91	93	102	112	114	122	137
78	$\frac{45}{100}$	65	72	78	80	88	96	99	109	119
	$\frac{1}{2}$	73	80	87	89	98	107	110	121	132
84	$\frac{45}{100}$	61	67	73	75	82	90	92	101	109
	$\frac{1}{2}$	67	77	81	83	91	100	102	112	122

In the above table a factor of safety of 5 was used and strength of seams as follows:

57 per cent. for single riveting,
70 per cent. for double staggered,
86 per cent. for butt joint.

RIVETS AND RIVETING. Number of Rivets in 100 Pounds

Lengths	3/8 Inch	7/16 Inch	1/2 Inch	9/16 Inch	5/8 Inch	11/16 Inch	3/4 Inch	7/8 Inch
3/4	1965	1429	1092	944	665	. . .	. . .	. . .
7/8	1848	1335	1027	846	597	. . .	. . .	. . .
1	1692	1222	940	763	538	450	. . .	. . .
1 1/8	1512	1092	840	726	512	415	. . .	. . .
1 1/4	1437	1036	797	691	487	389	356	228
1 3/8	1368	998	760	653	460	370	329	211
1 1/2	1300	949	730	624	440	357	280	180
1 5/8	1260	924	711	596	420	340	271	174
1 3/4	1200	900	693	553	390	325	262	169
1 7/8	1156	840	648	532	375	312	257	165
2	1100	789	608	511	360	297	243	156
2 1/8	1031	744	573	502	354	289	237	152
2 1/4	999	721	555	491	347	280	232	149
2 1/2	945	682	525	475	335	260	220	141
2 3/4	900	650	500	443	312	242	208	133
3	828	598	460	411	290	224	197	127
3 1/4	779	562	433	379	267	212	180	115
3 1/2	743	536	413	352	248	201	169	108
3 3/4	715	513	395	341	241	192	160	102
4	. . .	. . .	. . .	326	230	184	158	99
4 1/4	. . .	. . .	. . .	312	220	177	150	96
4 1/2	. . .	. . .	. . .	298	210	171	146	94
4 3/4	. . .	. . .	. . .	284	200	166	138	89
5	. . .	. . .	. . .	270	190	161	135	87
5 1/4	. . .	. . .	. . .	256	180	156	130	84
5 1/2	. . .	. . .	. . .	244	172	151	124	80
5 3/4	. . .	. . .	. . .	233	164	145	120	77
6	. . .	. . .	. . .	223	157	140	115	74
6 1/4	. . .	. . .	. . .	213	150	138	111	71
6 1/2	. . .	. . .	. . .	207	146	134	107	69
6 3/4	. . .	. . .	. . .	203	143	129	104	67
7	. . .	. . .	. . .	198	140	125	100	64

The length of rivets is the measure under the head

STRENGTH OF RIVETS

(TRAUTWINE)

The diameter of a rivet in inches to resist safely a given single shearing force is found by using the formula—

Diameter in inches =

$$\sqrt{\frac{\text{shearing force} \times \text{coef. of safety}}{\text{ultimate shearing strength per sq. in.} \times .7854}}$$

If the rivet is to be double sheared, first multiply only half the shearing force by the coefficient of safety and proceed as before; or, near enough for practice, multiply the diameter in single shear by the decimal .7.

Table of Ultimate Single Shearing Strength of Rivets

(ORIGINAL)

Diameter in Fractions	Diameter in Decimals	40000 Pounds Per Square Inch	45000 Pounds Per Square Inch
$\frac{1}{8}$	.125	490	552
$\frac{3}{16}$	.187	1104	1242
$\frac{1}{4}$	.250	1963	2209
$\frac{5}{16}$	.312	3068	3452
$\frac{3}{8}$	.375	4418	4970
$\frac{7}{16}$	.437	6013	6765
$\frac{1}{2}$	.500	7854	8836
$\frac{9}{16}$	.562	9940	11183
$\frac{5}{8}$	.625	12272	13806
$\frac{11}{16}$	.687	14848	16705
$\frac{3}{4}$	.750	17671	19880
$\frac{13}{16}$	.812	20739	23332
$\frac{7}{8}$	.875	24052	27060
$\frac{15}{16}$	.937	27611	31064
1	1.000	31416	35343
$1\frac{1}{16}$	1.062	35465	39899
$1\frac{1}{8}$	1.125	39760	44731
$1\frac{3}{16}$	1.187	44300	49838
$1\frac{1}{4}$	1.250	49088	55224
$1\frac{5}{16}$	1.312	54120	60885
$1\frac{3}{8}$	1.375	59396	66820
$1\frac{7}{16}$	1.437	64920	73035
$1\frac{1}{2}$	1.500	70684	79519

RIVETING

(THURSTON)

The following table gives the proportions of rivets adopted in some of the best establishments in the United States:

Thickness of Plate, ...	$\frac{1}{4}''$	$\frac{5}{16}''$	$\frac{3}{8}''$	$\frac{7}{16}''$	$\frac{1}{2}''$
Diameter of Rivet, ...	$\frac{5}{8}''$	$\frac{11}{16}''$	$\frac{3}{4}''$	$\frac{13}{16}''$	$\frac{7}{8}''$
Diameter of Rivet-hole, . .	$\frac{11}{16}''$	$\frac{3}{4}''$	$\frac{13}{16}''$	$\frac{7}{8}''$	$\frac{15}{16}''$
Pitch-single Riveting, . . .	$2''$	$2\frac{1}{16}''$	$2\frac{1}{8}''$	$2\frac{3}{16}''$	$2\frac{1}{4}''$
Pitch-double Riveting, . .	$3''$	$3\frac{1}{8}''$	$3\frac{1}{4}''$	$3\frac{3}{8}''$	$3\frac{1}{2}''$

Plates more than ½ inch in thickness should never be joined with lap joints. When it is necessary to use them a butt joint with a double fish-plate should always be used. In recommending the above proportions we assume that the workmanship is fair.

LAP-WELDED CHARCOAL IRON BOILER TUBES

TABLE OF STANDARD DIMENSIONS

Diameter		Thickness	Wire Gauge	Circumference		Transverse Areas			Length of Tube per Sq. Foot of		Nominal Weight per Foot
Ext'nal	Int'nal			External	Internal	External	Internal	Metal	Ex. Surf.	Int. Surf.	
Inches	Inches	Inches	No.	Inches	Inches	Sq. Ins.	Sq. Ins.	Sq. Ins.	Feet	Feet	Pounds
1	.856	.072	15	3.142	2.689	.785	.575	.21	3.819	4.462	.71
1⅛	.981	.072	15	3.534	3.082	.994	.756	.238	3.395	3.894	.8
1¼	1.106	.072	15	3.927	3.475	1.227	.961	.266	3.056	3.453	.89
1 5/16	1.146	.083	14	4.123	3.6	1.353	1.031	.322	2.91	3.333	1.08
1⅜	1.209	.083	14	4.32	3.798	1.485	1.148	.337	2.778	3.159	1.13
1½	1.334	.083	14	4.712	4.191	1.767	1.398	.369	2.547	2.863	1 24
1⅝	1.435	.095	13	5.105	4.508	2.074	1.618	.456	2.352	2.662	1.53
1¾	1.56	.095	13	5.498	4.901	2.405	1.911	.494	2.183	2.448	1.66
1⅞	1.685	.095	13	5.89	5.294	2.761	2.23	.531	2.037	2.267	1.78
2	1.81	.095	13	6 283	5.686	3.142	2.573	.569	1.909	2.11	1.91
2⅛	1.935	.095	13	6.676	6.079	3.547	2.94	.607	1.797	1.974	2.04
2¼	2.06	.095	13	7.069	6.472	3.976	3.333	.643	1.698	1.854	2.16
2⅜	2.157	.109	12	7.461	6.776	4.43	3.654	.776	1.608	1.771	2.61
2½	2.282	.109	12	7.854	7.169	4.909	4.09	.819	1.528	1.674	2.75
2¾	2.532	.109	12	8.639	7 954	5.94	5.035	.905	1.389	1.509	3.04
2⅞	2.657	.109	12	9.032	8.347	6.492	5.545	.947	1.328	1.438	3.18
3	2.782	.109	12	9.425	8.74	7.069	6.079	.99	1.273	1.373	3.33
3¼	3.01	.12	11	10.21	9.456	8.296	7.116	1.18	1.175	1.26	3.96
3½	3 26	.12	11	10.996	10.241	9.621	8.347	1.274	1.091	1.172	4.28
3¾	3.51	.21	11	11.781	11.027	11.045	9.676	1.369	1.018	1.088	4.6
4	3.732	.134	10	12.566	11.724	12.566	10.939	1.627	.955	1.024	5.47

LAP-WELDED CHARCOAL IRON BOILER TUBES—Continued

TABLE OF STANDARD DIMENSIONS

Diameter		Thickness	Wire Gauge	Circumference		Transverse Areas			Length of Tube per Sq. Foot of		Nominal Weight per Foot
Ext'nal	Int'nal			External	Internal	External	Internal	Metal	Ex. Surf.	Int. Surf.	
Inches	Inches	Inches	No.	Inches	Inches	Sq. Ins.	Sq. Ins.	Sq. Ins.	Feet	Feet	Pounds
4¼	3.982	.134	10	13.352	12.51	14.186	12.453	1.733	.899	.959	5.82
4½	4.232	.134	10	14.137	13.295	15.904	14.066	1.838	.849	.902	6.17
4¾	4.482	.134	10	14.923	14.081	17.721	15.777	1.944	.804	.852	6.53
5	4.704	.148	9	15.708	14.778	19.635	17.379	2.256	.764	.812	7.58
5¼	4.954	.148	9	16.493	15.563	21.648	19.275	2.373	.728	.771	7.97
5½	5.204	.148	9	17.279	16.349	23.758	21.27	2.488	.694	.734	8.36
6	5.67	.165	8	18.85	17.813	28.274	25.249	3.025	.637	.673	10.16
7	6.67	.165	8	21.991	20.954	38.485	34.942	3.543	.546	.573	11.9
8	7.67	.165	8	25.133	24.096	50.266	46.204	4.062	.477	.498	13.65
9	8.64	.18	7	28.274	27.143	63.617	58.629	4.988	.424	.442	16.76
10	9.594	.203	6	31.416	30.14	78.54	72.292	6.248	.382	.398	20.99
11	10.56	.22	5	34.558	33.175	95.033	87.583	7.45	.347	.362	25.03
12	11.542	.229	4½	37.699	36.26	113.098	104.629	8.469	.319	.33	28.46
13	12.524	.238	4	40.841	39.345	132.733	123.19	9.543	.294	.305	32.06
14	13.504	.248	3½	43.982	42.424	153.938	143.224	10.714	.273	.283	36.
15	14.482	.259	3	47.124	45.497	176.715	164.72	11.995	.254	.264	40.3
16	15.432	.284	2	50.26	48.48	201.06	187.04	14.02	.239	.248	46.92
18	17.40	.3	1	56.548	54.663	254.47	237.78	16.69	.212	.219	56.
20	19.376	.312	5/16	62.832	60.863	314.16	294.83	19.33	.190	.197	65.
22	21.312	.344	11/32	69.115	66.953	380.13	356.73	23.40	.173	.179	78.50
24	23.25	.375	3/8	75.398	73.042	452.39	424.56	27.83	.159	.163	93.

LAP-WELDED LOCOMOTIVE BOILER TUBES

TABLE OF STANDARD DIMENSIONS

Diameter		Thickness	Wire Gauge	Circumference		Transverse Areas			Length of Tube per Sq. Foot of		Nominal Weight per Foot
Ext'nal	Int'nal			External	Internal	External	Internal	Metal	External Surface	Internal Surface	
Inches	Inches	Inches	No.	Inches	Inches	Sq. Ins.	Sq. Ins.	Sq. Ins.	Feet	Feet	Pounds
1	.834	.083	14	3.1416	2.62	.7854	.5463	.2391	3.82	4.53	.81
1¼	1.084	.083	14	3.927	3.405	1.227	.9229	.3041	3.056	3.524	1.02
1½	1.31	.095	13	4.712	4.115	1.767	1.3478	.4192	2.546	2.916	1.40
1¾	1.532	.109	12	5.498	4.813	2.405	1.8433	.5617	2.183	2.493	1.87
2	1.782	.109	12	6.283	5.598	3.1416	2.494	.6476	1.91	2.144	2.17
2¼	2.032	.109	12	7.069	6.384	3.976	3.2429	.7331	1.698	1.88	2.45
2½	2.26	.12	11	7.854	7.1	4.9087	4.011	.8977	1.528	1.69	3.00
2¾	2.51	.12	11	8.639	7.885	5.94	4.948	.992	1.389	1.522	3.31
3	2.76	.12	11	9.425	8.67	7.069	5.983	1.086	1.273	1.384	3.63
3¼	2.982	.134	10	10.21	9.366	8.295	6.984	1.311	1.175	1.275	4.39
3½	3.232	.134	10	10.99	10.151	9.621	8.214	1.407	1.091	1.181	4.74
3¾	3.482	.134	10	11.78	10.936	11.044	9.522	1.52	1.018	1.096	5.09
4	3.704	.148	9	12.56	11.634	12.566	10.75	1.81	.955	1.031	6.00

NOTE.—These special Tubes are manufactured expressly for locomotive work.

Bursting and Collapsing Pressures of Wrought Iron Tubes

(D. K. CLARK)

External Diameter	Thickness	Bursting — Per Sq. In. of Internal Surface	Collapsing — Per Sq. In. of External Surface	External Diameter	Thickness	Bursting — Per Sq. In. of Internal Surface	Collapsing — Per Sq. In. of External Surface
Ins.	In.	Lbs.	Lbs.	Ins.	In.	Lbs.	Lbs.
1.25	.083	7700	6500	3.25	.12	4000	2700
1.375	.083	6900	5800	3.5	.134	4200	2700
1.5	.083	6200	5200	3.75	.134	3900	2400
1.625	.083	5700	4700	4.	.134	3600	2100
1.75	.083	5300	4300	4.25	.134	3400	1900
1.875	.083	4900	4000	4.5	.134	3200	1700
2.	.083	4500	3700	4.75	.134	3000	1600
2.125	.095	4900	3800	5.	.134	2800	1400
2.25	.095	4600	3600	5.25	.148	3000	1400
2.5	.109	4800	3600	5.5	.148	2800	1200
2.75	.109	4300	3100	5.75	.148	2700	1100
3.	.12	4400	3000	6.	.148	2600	1000

It has been ascertained by experiment that resistance of thin metal plates to a force tending to crush or to crumple them varies directly as a certain power (x) of their thickness.

Hence, *Value* of a tube, etc., to resist collapse is as $\frac{P}{tx}$, *t representing thickness of metal in inches, and* P *total pressure in pounds per square inch.*

To Compute Collapsing Pressure Upon a Flue or Tube (Wrought Iron)

Mean of product of P′ *l d* in several experiments where metal was of a uniform thickness of .043 inch is 850, for a thickness of .125 inch 9140, etc.; and mean of value of *x* for all thicknesses is $^{2.19}$.

P′ *representing pressure to which tube is subjected in pounds per square inch, l length of tube in feet, and d diameter in inches.*

By taking $^{2.19}$ for index of *t*, this formula becomes $\frac{t^{2.19}}{l\,d}\,V = P'$, *collapsing pressure*, which is general formula for computing strength of wrought iron short flues and tubes subjected to external pressure—that is, provided their length is not less than 1.5 feet, and not greater than 10 feet.

V varies somewhat with length of flues and tubes, and is taken by Fairbairn at 806 300.

Hence,

$$\frac{t^{2.19}}{l\,d} \times 806\,300 = P', \text{ and } \sqrt[2.19]{\frac{l\,d\,P'}{806\,300}} = t, \text{ or } \frac{l\,d\,P'}{806\,300} = t^{2.19}.$$

Flues or tubes subjected to internal pressure or bursting have much greater resistance than when subjected to external pressure or collapsing; in some cases, where lengths of collapsed tubes were 25 feet, difference was about 6.2 times.

Difference, however, between these strains cannot be determined as a rule, for reason that resistance to internal pressure is inversely as diameter of flue or tube alone, without regard to its length; whereas, with resistance to collapse, stress is inversely as product of diameter and length.

FUEL

The most important fuel in use for boiler purposes at the present time is coal. Wood is used, as a rule, only where it is very abundant, or where coal cannot be readily obtained. In some locations where gas and oil can be favorably procured, these can be used for fuel. Frequently the waste gases from furnaces of various kinds is made use of.

Some degree of success has been reached by first converting coal into gas, and then burning the gas under the boilers, but as yet the advantages do not seem to be sufficient to induce extended use of this method, so that, generally speaking, either bituminous or anthracite coal is used for boilers. In the United States a long ton of coal is 2240 pounds, and a short one 2000 pounds.

From 70 to 80 pounds of bituminous coal makes a bushel, depending upon the location. According to measurements made with Wilkes-Barre Anthracite coal from the Wyoming Valley, 28.8 cubic feet of lump, 30.3 cubic feet of broken, 30.8 cubic feet of egg, 31.1 cubic feet of stove, 31.9 cubic feet of chestnut, or 32.8 cubic feet of pea, make one net ton of 2000 pounds.—*Kent.*

6 cubic feet of bituminous coal to ton of 2000 pounds. The practical effect of exposing coal to the weather, whilst sometimes increasing its absolute weight, is to diminish the quantity of carbon and to reduce its calorific value. —*Kent.*

PETROLEUM COMPOUND WITH COAL AS FUEL

Comparison of petroleum with coal as a heating agent, according to comparative tests reported to the Engineers' Club of Philadelphia, showed—

	Pounds Water from and at 212° Fahr.
1 pound Anthracite Coal Evaporated, . . .	9.70
1 pound Bituminous Coal Evaporated, . .	10.14
1 pound Free Oil, 36 degrees gravity, . . .	16.48
1 cubic foot Gas, 20 c. p., ...	1.28

showing that while petroleum has theoretically only about 45 per cent. more heat units (21,000) than bituminous coal (14,500), the practical evaporative efficiency is about 60 per cent. greater.—*Kent.*

HEATING EFFICIENCY OF DIFFERENT KINDS OF WOOD

One cord dry hickory or hard maple, 4500 pounds, equals 1800 to 2000 pounds of coal.

One cord white oak, 3850 pounds, equals 1500 to 1715 pounds of coal.

One cord beech, red and black oak, 3250 pounds, equals 1300 to 1450 pounds of coal.

One cord poplar, chestnut, and elm, 2350 pounds, equals 940 to 1050 pounds of coal.

One cord of average soft pine, 2000 pounds, equals 800 to 925 pounds of coal; *i. e.*, on an average 2¼ pounds of dry wood equals 1 pound of dry coal for heat efficiency.—*Kent.*

CLASSIFICATION OF COALS, AS ANTHRACITE, BITUMINOUS, ETC.

(KENT)

Carbon ratio meaning ratio of fixed carbon to volatile or hydrocarbon.

	Carbon Ratio	Fixed Carbon, Per cent.	Volatile Hydrocarbon, Per cent.
1. Hard, dry anthracite,	100 to 12	100 to 92.31	0 to 7.69
2. Semi-anthracite, . .	12 to 7	92.31 to 87.5	7.69 to 12.5
3. Semi-bituminous, .	7 to 3	87.5 to 75	12.5 to 25
4. Bituminous, ...	3 to 0	75 to 0	25 to 100

COAL

Coal, as a fuel, is rated according to the quantities and calorific value of the combustible elements it contains. The most important of these are carbon and hydrogen; the combustion of 1 pound of hydrogen producing 62,000 B. T. U., and of 1 pound of carbon, 14,500 B. T. U. Hence, although several coals may have the same percentage of combustible and ash, it does not follow that their calorific value will be identical, for this depends upon the amount of hydrogen and carbon they contain.

The value of fuel may be determined by chemical analysis, by which the proportion of the elements that it contains is found, and by calorimetric test, although the latter is considered the more reliable method of the two.

In practice, no fuel gives its full theoretical evaporation value, owing, first, to the losses that result from radiation and conduction of heat from the boiler setting, which in some cases have been found as high as 24 per cent.; second, to the carelessness or ignorance of the fireman in improperly firing; third, to the frequent admission of cold air into the furnace, either through the firing doors or through cracks in the setting; fourth, to errors in the design and construction of the boiler itself. An efficiency of 80 per cent. is seldom obtained, and only in the best boilers, whilst the average is about 65 per cent.,—the better the boiler, the higher the efficiency.

The following table, giving the chemical analyses and calculated calorific values of coals, has been prepared from the reports of the "Mineralogical Resources of the United States," and from similar publications by coal-producing States:

TABLE OF AMERICAN COALS

COAL	Constituents in Per Cent. of Total Weight					Fuel Value Per Pound of Coal		
NAME OR LOCALITY	Moisture	Volatile Matter	Fixed Carbon	Ash	Sulphur	B. T. U. Calculated	B. T. U. by Calorimeter	Theoretical Evaporation in lbs., from and at 212°
ARKANSAS								
Coal Hill, Johnson Co.,	1.70	14.60	74.91	8.79	3.04	. . .	11812	12.22
Lignite,	. . .	. . .	. . .	5.00	. . .	9215	. . .	9.54
ALABAMA								
Coalburg, Jefferson Co.,	0.935	30.745	65.075	3.014	1.203	14513	. . .	15.02
Brierfield, Bibb Co.,	. . .	41.04	55.76	3.20	1.01	14620	. . .	15.13
Patton Junction, Walker Co.,	1.66	22.12	68.34	6.00	1.85	13410	. . .	13.88
COLORADO								
Lignite,	. . .	. . .	. . .	9.25	. . .	13560	. . .	14.04
Lignite, Slack,	14.80	32.00	42.86	10.34	0.76	8500	. . .	8.80
Fremont Co.,	3.93	42.43	47.16	6.48	. . .	13555	. . .	14.03
ILLINOIS								
Big Muddy, Jackson Co.,	6.12	30.95	53.74	9.19	1.22	. . .	11529	11.93
Bureau Co.,	. . .	. . .	. . .	5.20	. . .	13025	. . .	13.48
Colchester,	11.60	25.02	44.76	18.62	. . .	. . .	9848	10.19
Duquoin Jupiter, Perry Co.,	11.30	30.31	49.91	8.48	0 91	. . .	10710	11.08

TABLE OF AMERICAN COALS—Continued

COAL Name or Locality	Constituents in Per Cent. of Total Weight: Moisture	Volatile Matter	Fixed Carbon	Ash	Sulphur	Fuel Value Per Pound of Coal: B. T. U. Calculated	B. T. U. by Calorimeter	Theoretical Evaporation in lbs., from and at 212°
ILLINOIS								
Girard, Macoupin Co.,	9.70	34.39	45.76	10.15	3.49	. . .	9954	10.30
Heitz Bluff, St. Clair Co.,	8.95	37.81	48.24	5.00	3.27	. . .	10332	10.69
Mercer Co.,	. . .	. . .	. . .	5.60	. . .	13123	. . .	13.58
Montauk Co.,	. . .	. . .	. . .	5.50	. . .	12659	. . .	13.10
Oakland, St. Clair Co.,	8.30	34.40	43.12	14.18	4.42	. . .	10395	10.76
INDIANA								
Block,	3.50	32.50	63.00	1.00	0.98	14020	. . .	14.5
Caking,	. . .	. . .	. . .	5.66	. . .	14146	. . .	14.64
Cannel,	. . .	. . .	. . .	6.00	. . .	13097	. . .	13.56
Parke Co.,	4.0	46.0	46.5	3.5	. . .	14062	. . .	14.56
Clay Co.,	3.5	32.5	61.5	2.5	. . .	13898	. . .	14.39
Greene Co.,	7.0	29.5	63.0	0.05	. . .	13861	. . .	14.35
KENTUCKY								
Caking,	. . .	. . .	. . .	2.75	. . .	14391	. . .	14.89
Cannel,	. . .	. . .	. . .	2.00	. . .	15198	. . .	16.76
Cannel,	. . .	. . .	. . .	14.80	. . .	13360	. . .	13.84

TABLE OF AMERICAN COALS—Continued

COAL	Constituents in Per Cent. of Total Weight					Fuel Value Per Pound of Coal		
NAME OR LOCALITY	Moisture	Volatile Matter	Fixed Carbon	Ash	Sulphur	B. T. U. Calculated	B. T. U. by Calorimeter	Theoretical Evaporation in lbs., from and at 212°
KENTUCKY								
Lignite, ...	. . .	. . .	. . .	7.00	. . .	9326	. . .	9.65
Hawesville, Hancock Co., . .	3.30	39.00	50.50	7.20	3.373	12490	. . .	12.93
MARYLAND								
Cumberland, ...	1.23	15.47	73.51	9.09	0.70	13067	. . .	13.53
Cumberland, ...	. . .	. . .	. . .	13.88	. . .	12226	. . .	12.65
OHIO								
Briar Hill, Mahoning Co., . .	2.47	31.83	64.25	1.45	0.56	13714	. . .	14.20
Brookfield, Trumbull Co., . .	3.27	40.23	42.72	11.78	5.90	12800	. . .	13.25
Hocking Valley, ...	8.25	35.88	53.15	2.72	0.43	13414	. .	13.9
Bellaire, Belmont Co., ...	1.53	42.29	47.57	8.61	4.47	13575	. . .	14.05
Buchtel, Athens Co., ...	5.10	36.97	49.68	8.25	2.41	13037	. . .	13.50
Brilliant, Jefferson Co., ...	1.85	37.82	55.62	4.71	1.32	14072	. . .	14.57
Morgan, Morgan Co., ...	4.20	38.65	43.83	13.32	5.37	12403	. . .	12.84
PENNSYLVANIA								
Centre, Butler Co., ...	2.11	37.57	51.248	7.178	1.894	13372	. . .	13.84
Gillesville, McKean Co., . . .	0.67	36.065	48.417	13.79	1.058	12653	. . .	13.09
Bernice, Sullivan Co., ...	1.295	8.10	83.344	6.23	1.031	13350	. . .	13.82

TABLE OF AMERICAN COALS—Continued

COAL NAME OR LOCALITY	Constituents in Per Cent. of Total Weight					Fuel Value Per Pound of Coal		
	Moisture	Volatile Matter	Fixed Carbon	Ash	Sulphur	B. T. U. Calculated	B. T. U. by Calorimeter	Theoretical Evaporation in lbs., from and at 212°
PENNSYLVANIA								
Monongahela, Washington Co.,	1.18	35.83	58.154	4.075	0.761	14130	. . .	14.63
Summer Hill, Cambria Co., . .	0.820	19.155	70.175	9.405	0.445	13164	. . .	13.62
Keystone, Somerset Co., . . .	1.29	20.865	67.201	8.805	1.839	13012	. . .	13.47
Latrobe, Westmoreland Co., .	1.59	30.945	63.489	3.18	0.796	14135	. . .	14.63
Anthracite, ...	. . .	. . .	. . .	. . .	. . .	14221	. . .	14.72
Anthracite, Pea, ...	2.04	6.36	8.41	13.19	. . .	12300	. . .	12.73
Anthracite, Buckwheat, . . .	3.88	3.84	81.32	10.96	0.67	12200	. . .	12.63
Cannel, ...	. . .	. . .	. . .	15.02	. . .	13143	. . .	13.60
Connellsville, ...	. . .	. . .	. . .	6.50	. . .	13368	. . .	13.84
Pittsburgh Coking, ...	1.43	30.22	61.87	6.48	1.35	14415	. . .	14.90
Youghiogheny, ...	1.96	34.06	58.98	5.00	. . .	. . .	12936	13.39
Franklin, Greene Co., ...	1.265	34.685	49.59	13.19	1.27	12309	. . .	12.74
Osceola, Clearfield Co., ...	1.24	24.45	67.045	5.945	1.32	13589	. . .	14.07
Carbon, Huntingdon Co., . . .	0.45	16.21	70.601	8.569	4.17	13770	. . .	14.25
Schuylkill Co., ...	2.98	3.38	87.127	5.856	0.657	13153	. . .	13.61
Cameron, Northumberland Co.,	1.815	6.180	86.748	4.502	0.755	13557	. . .	14.04

TABLE OF AMERICAN COALS—Continued

COAL NAME OR LOCALITY	Constituents in Per Cent. of Total Weight					Fuel Value Per Pound of Coal		
	Moisture	Volatile Matter	Fixed Carbon	Ash	Sulphur	B. T. U. Calculated	B. T. U. by Calorimeter	Theoretical Evaporation in lbs., from and at 212°
TENNESSEE								
Coal Creek, Anderson Co., . .	. . .	34.20	58.80	6.93	0.79	13936	. . .	14.43
TEXAS								
Fort Worth, ...	4.60	34.72	49.27	11.41	1.56	. . .	11403	11.80
Lignite, ...	. . .	. . .	. . .	. . .	4.50	12962	. . .	13.41
VIRGINIA								
Pocahontas, Wise Co., ...	6.940	18.832	74.066	5.647	0.761	13718	. . .	14.20
Clover Hill, ...	1.339	30.984	56.831	10.132	0.514	13103	. . .	13.56
WEST VIRGINIA								
Elmo, Fayette Co., ...	1.05	23.62	72.67	2.20	0.76	14314	. . .	14.81
Cedar Grove, Kanawha Co., .	2.10	34.08	60.67	2.50	0.65	12233	. . .	12.66
New River, ...	. . .	. . .	. . .	. . .	. . .	13400	. . .	13.87

The following is a table that has been calculated by D. S. JACOBUS, M. E., from data obtained by experiment, which shows the relative saving of fuel of the various methods for supplying feed water to boilers:

METHOD OF SUPPLYING FEED WATER TO BOILER Temperature of feed water as delivered to the pump or to the injector, 60° Fahr. Rate of evaporation of boiler, 10 pounds of water per pound of coal from and at 212° Fahr.	Relative amount of coal required per unit of time, the amount for a direct acting pump, feeding water at 60°, without a heater, being taken as unity	Saving of fuel over the amount required when the boiler is fed by a direct acting pump without heater
Direct acting pump, feeding water at 60°, without a heater, ...	1.000	.0
Injector feeding water at 150°, without a heater, .	.985	1.5 per cent.
Injector feeding through a heater in which the water is heated from 150° to 200°, ...	.938	6.2 "
Direct acting pump feeding water through a heater, in which it is heated from 60° to 200°,	.879	12.1 "
Geared pump, run from the engine, feeding water through a heater, in which it is heated from 60° to 200°, ...	.868	13.2 "

Table showing the saving of fuel in per cent. by heating the feed water, steam being taken at 60 pounds.

Initial Temp. of Water	Final Temperature of Feed Water						
	120	140	160	180	200	250	300
32°	7.50	9.20	10.90	12.36	14.30	18.03	22.90
35	7.25	8.96	10.66	12.09	14.09	19.34	22.60
40	6.85	8.57	10.28	12.00	13.71	17.99	22.27
45	6.45	8.17	9.90	11.61	13.34	17.64	21.94
50	6.05	7.71	9.50	11.23	13.00	17.28	21.61
55	5.64	7.37	9.06	10.85	12.60	16.93	21.27
60	5.23	6.97	8.72	10.46	12.20	16.58	20.92
65	4.82	6.56	8.32	10.07	11.82	16.20	20.58
70	4.40	6.15	7.91	9.28	11.43	15.83	20.23
75	3.98	5.74	7.50	9.08	11.04	15.46	19.88
80	3.55	5.32	7.09	8.87	10.65	15.08	19.52
85	3.12	4.60	6.63	8.46	10.25	14.70	19.17
90	2.68	4.47	6.26	8.06	9.85	14.32	18.81
95	2.24	4.04	5.84	7.65	9.44	13.94	18.44
100	1.80	3.61	5.42	7.23	9.03	13.55	18.07
110	.90	2.73	4.55	6.38	8.20	12.76	17.28
120	.00	1.84	3.67	5.52	7.36	11.95	16.49
130	. . .	.92	2.77	4.64	6.99	11.14	15.24
140	. . .	.00	1.87	3.75	5.62	10.31	14.99
150	. . .	. . .	.94	2.83	4.72	9.46	14.18
160	. . .	. . .	.00	1.91	3.82	8.59	13.37
170	. . .	. . .	. . .	.96	2.89	7.71	12.54
180	. . .	. . .	. . .	.00	1.96	6.81	11.70
190	. . .	. . .	. . .	. . .	.90	5.90	10.82
200	. . .	. . .	. . .	. . .	.00	4.85	9.93

The most economical means of heating feed water above 212 degrees is to utilize the furnace gases after they have passed the boiler.

CHIMNEYS

Chimneys are required for two purposes, (1) to carry off noxious gases; (2) to produce a draught, and so facilitate combustion. The first requires size, the second, height.

Each pound of coal burned yields from 13 to 30 pounds of gas, the volume of which varies with the temperature.

The weight of gas to be carried off by a chimney in a given time depends upon three things: size of chimney, velocity of flow, and density of gas. But as the density decreases directly as the absolute temperature, while the velocity increases, with a given height, nearly as the square root of the temperature, it follows that there is a temperature at which the weight of gas delivered is a maximum. This is about 550 degrees above the surrounding air. Temperature, however, makes so little difference that at 550 degrees above, the quantity is only four per cent. greater than at 300 degrees. Therefore, height and area are the only elements necessary to consider in an ordinary chimney.

A round chimney is better than square, and a straight flue better than a tapering, though it may be either larger or smaller at top without detriment.

The effective area of a chimney for a given power varies inversely as the square root of the height. The actual area, in practice, should be greater because of retardation of velocity due to friction against the walls. On the basis that this is equal to a layer of air 2 inches thick over the whole interior surface, and that a commercial horse power requires the consumption on an average of 5 pounds of coal per hour, we have the following formulæ :

$$E = \frac{0.3\,H}{\sqrt{h}} = A - 0.6\sqrt{A} \quad \ldots\ldots\ldots\ 1$$

$$H = 3.33\,E\sqrt{h} \quad \ldots\ldots\ldots\ 2$$

$$S = 12\sqrt{E} + 4 \quad \ldots\ldots\ldots\ 3$$

$$D = 13.54\sqrt{E} + 4 \quad \ldots\ldots\ldots\ 4$$

$$h = \left(\frac{0.3\,H}{E}\right)^2 \quad \ldots\ldots\ldots\ 5$$

in which

H equals horse power.
h " height of chimney in feet.
E " effective area.
A " actual area in square feet.
S " side of square chimney.
D " diameter of round chimney, in inches.

The table on page 93 is calculated by means of these formulæ.

The external diameter of a brick chimney at the base should be one-tenth the height, unless it be supported by some other structure.

The "batter" or taper of a chimney should be from $\frac{1}{16}$ to $\frac{1}{4}$ inch to the foot on each side.

Thickness of brick work: One brick (8 or 9 inches) for 25 feet from the top, increasing half a brick (4 or $4\frac{1}{2}$ inches) for each 25 feet from top downward.

If the inside diameter exceed 5 feet, the top length should be one and a half bricks, and if under 3 feet, it may be half a brick for 10 feet.

In many places, iron stacks are preferred to brick chimneys. Their efficiency for the same dimensions is somewhat higher, because there is no infiltration of air as through brickwork.

These chimney stacks, when properly constructed, are stronger than brick chimneys of the same size. There are in general use three characters of steel plate chimneys, the first being the ordinary smoke stack, which is guyed with outstanding guys; the second has a bell-shaped bottom and is erected upon heavy foundations with the metal of such thickness as not to require any guying; the third is made similar in construction to the second, excepting that it is lined clear to the top with brick. A so-called self-supporting smoke stack, lined clear to the top with brick, will cost somewhat less than a brick chimney of the same dimensions. Iron stacks of the self-supporting character should be well secured to the foundation with heavy bolts, extending either through a heavy cast-iron base plate covering the foundation or through special holding-down lugs placed upon the stack. For this character of stack, it is also recommended that the flue from the boilers enter the stack under the base-plate, so that there will be no opening cut through the steel shell. They should also be well painted to prevent rusting, for which purpose a ladder extending from the base to the top is usually placed upon it. When iron stacks are braced with outstanding guys to surrounding objects, these guys are generally attached at about two-thirds the height of the stack, spreading laterally, at least an equal distance, and are composed of heavy wire, galvanized wire rope, or rods. Each brace should have an area in square inches equal to one one-thousandth of the exposed area of the stack (diameter times the height) in feet.

Stability, or power to withstand the overturning force of the highest winds, requires a proportionate relation between the weight, height, breadth of base, and exposed area of the chimney. This relation is expressed in the equation—

$$C \frac{d h^2}{b} = W$$

in which

d equals the average breadth of the shaft, in feet.
h " its height, in feet.
b " the breadth of base, in feet.
W " the weight of chimney, in pounds.
C, a coefficient of wind pressure per square foot of area.

This varies with the cross-section of the chimney, and equals 56 for a square, 35 for an octagon, and 28 for a round chimney. Thus a square chimney of average breadth of 8 feet, 10 feet wide at base and 100 feet high, would require to weigh 56 x 8 x 100 x 10, or 448,000 pounds to withstand any gale likely to be experienced. Brickwork weighs from 100 to 130 pounds per cubic foot, hence such a chimney must average 13 inches thick to be safe. A round stack would weigh half as much or have less base.

Height of Chimneys and Commercial Horse Power of Boilers

Diameter in Inches	50 Ft.	60 Ft.	70 Ft.	80 Ft.	90 Ft.	100 Ft.	110 Ft.	125 Ft.	150 Ft.	175 Ft.	200 Ft.	Side of Square Inches	Effective Area, Sq. Ft.	Actual Area, Sq. Ft.
	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.			
18	23	25	27	...	...	...	...	...	...	...	...	16	0.97	1.77
21	35	38	41	...	...	...	...	...	...	...	...	19	1.47	2.41
24	49	54	58	62	...	...	...	...	...	...	...	22	2.08	3.14
27	65	72	78	83	87	...	...	...	...	...	...	24	2.78	3.98
30	84	92	100	107	113	119	...	...	...	...	...	27	3.58	4.91
33	105	115	125	133	141	149	...	...	...	...	...	30	4.48	5.94
36	128	141	152	163	173	182	191	...	...	...	...	32	5.47	7.07
39	154	168	183	196	208	219	229	...	...	...	...	35	6.57	8.30
42	182	200	216	231	245	258	271	288	...	...	...	38	7.76	9.62
48	...	269	290	311	330	348	365	389	...	...	...	43	10.44	12.57
54	...	348	376	402	427	449	472	503	551	...	...	48	13.51	15.90
60	...	436	471	503	536	565	593	632	692	748	...	54	16.98	19.64
66	...	...	579	620	658	694	728	776	849	918	981	59	20.83	23.76
72	...	...	698	746	792	835	876	934	1023	1105	1181	64	25.08	28.27
78	...	...	...	885	949	990	1038	1107	1212	1310	1400	70	29.73	33.18
84	...	...	...	1035	1098	1157	1214	1294	1418	1531	1637	75	34.76	38.48
90	...	...	...	...	1269	1338	1403	1496	1639	1770	1893	80	40.19	44.18
96	...	...	...	...	...	1532	1606	1712	1876	2027	2167	86	46.01	50.27
100	...	...	...	...	...	...	1760	1865	2043	2197	2359	89	50.11	54.54
104	...	...	...	...	...	...	1899	2024	2218	2395	2560	93	54.39	59.00
108	...	...	...	...	...	...	2051	2190	2399	2591	2770	96	58.83	63.62
112	...	...	...	...	...	...	...	2323	2588	2795	2988	100	63.46	68.42
118	...	...	...	...	...	...	...	2632	2883	3114	3339	105	70.71	75.94
120	...	...	...	...	...	...	...	2725	2986	3225	3447	107	73.22	78.54
124	...	...	...	...	...	...	...	2915	3193	3449	3687	110	78.31	83.86
130	...	...	...	...	...	...	...	3165	3467	3745	4004	116	85.04	90.76
136	...	...	...	...	...	...	...	...	3868	4178	4466	121	94.85	100.88
142	...	...	...	...	...	...	...	...	4305	4567	4886	126	103.69	109.98
150	...	...	...	...	...	...	...	...	4719	5097	5448	133	115.72	122.72

Table of the Force and Velocity of Wind According to Hutton's Experiments

Pressure	Velocity		Character of the Wind According to Rouse & Lind
In Inches of Water	In Feet Per Second	In Miles Per Hour	
.01926	2.87	5.37	Gentle Wind.
.0481	12.90	8.79	Pleasant Wind.
.0963	16.18	11.03	Fresh Breeze.
.193	24.33	16.60	Brisk Gale.
.385	34.17	23.30	Very Brisk Gale.
.578	41.69	27.77	
.770	48.00	32.73	
.963	53.55	36.51	High Wind.
1.155	58.55	39.92	
1.348	63.15	43.06	
1.541	67.43	45.97	
1.733	71.43	48.70	Very High Wind.
1.926	75.22	51.28	
2.118	78.82	53.74	
2.311	82 20	56.07	
2.504	85.54	58.32	
2.696	88.70	60.48	Storm or Tempest.
2.889	91.76	62.56	
3.081	94.70	64.57	
3.274	97.56	66.52	
3.467	100.30	68.41	
3.659	103.00	70.25	
3.852	105.70	72.03	Great Storm.
4.815	117.80	80.36	
5.778	128.9	87.97	Hurricane.
6.741	139.0	94.97	
7.704	148.7	101.4	Very Great Hurricane.
8.667	157.2	107.2	
9.630	165.6	112.9	Most Violent Hurricane.
10.593	177.5	118.3	
11.556	181.0	123.4	

HEAT, STEAM, WATER

HEAT—(Thurston)

Heat is the form in which we receive most of the sun-energy. In the various fuels it exists in a potential form, requiring combustion, *i. e.*, combustion of the active elements of the fuel with the oxygen of the air, to reappear in its active form.

Heat, as a form of energy, is subject to the general laws which govern every form of energy, and control all matter in motion, whether that motion be molecular or the movement of masses.

Quantities of heat are measured in English units, by what is termed the British thermal unit, or for brevity, B. T. U. The B. T. U. is the quantity of heat required to raise 1 pound of pure water from a temperature of 62° Fahr. to 63° Fahr., and has an equivalent in mechanical units of power. This is simply called a heat unit or designated by h. u. The mechanical unit of power is the foot-pound, or the power required to raise 1 pound 1 foot high. Joule's experiments, and those of later investigations, show 772 foot-pounds to be equivalent to one B. T. U. This number, 772, is known as Joule's equivalent, or symbolically J. 33,000 foot-pounds per minute was called a horse power by Watt, and is used as such to-day, it being the unit for large power.

The electrical unit of power is the Watt, which is the product of 1 Ampère by 1 volt; 746 Watts are equivalent to 1 horse power or 33,000 foot-pounds. Hence the Watt is an equivalent in heat units also.

Equivalents of Power and Heat

B. T. U.	FT. LBS.	WATTS.
1 =	772 =	17.45
43.78 =	33000 =	746 = 1 h. p.

A French "calorie" is the heat required to raise one kilogramme of water 1° C., and is equal to 3.96832 B. T. U.

The elements necessary to generate steam are fuel, heat, atmosphere, and water. The chief constituents of fuel are carbon and hydrogen, and the union of oxygen with these elements is termed combustion. Heat is a peculiar motion of the particles of matter which prevents their contact. Heat and mechanical power are convertible forces. The force of the heat that raises 1 pound of water 1° Fahr. will lift a weight of 772 pounds 1 foot high. The power of a weight of 772 pounds descending 1 foot, if applied to a small paddle-wheel turning 1 pound of water, will, by friction, raise the temperature of the water 1° Fahr.

A heat-unit is the amount of heat that raises a pound of water 1° Fahr., or that lifts a weight of 772 pounds 1 foot high. The mechanical equivalent of a heat-unit is the power of a weight of 772 pounds descending 1 foot, or of a 1-pound weight descending 772 feet. Hence,

$$772 \text{ foot-pounds} = 1 \text{ heat-unit.}$$
$$1 \text{ heat-unit} = 772 \text{ foot-pounds.}$$

Sensible heat is that which is sensible to the touch or measurable by a thermometer. The mechanical equivalent of heat is the amount of work performed by the conversion of 1 unit of heat into work, and the *mechanical theory* of heat is based on the assumption that heat and work are mutually convertible.

Latent heat is that which is insensible to the touch of our bodies, and is incapable of being detected by a thermometer. That is, a quantity of heat which has disappeared, having been employed in producing some change other than elevation of temperature, and by exactly reversing that change, the quantity of heat which has disappeared, is reproduced. For instance, while 1 heat-unit applied to a pound of water will elevate its temperature 1° Fahr., it will require $142\frac{65}{100}$ heat-units to change 1 pound of ice at 320° Fahr. into water at 32° Fahr., or $965\frac{7}{10}$ heat-units to change 1 pound of water at 212° Fahr. into steam at 212° Fahr. Or, if that 1 pound of steam were reduced to the liquid state, simply by compression, without the removal of any of its heat, the temperature of the pound of water would be found to be approximately 212° plus $965\frac{7}{10}$° equals $1177\frac{7}{10}$°, the $965\frac{7}{10}$° of latent heat becoming sensible heat again.

Specific Heat.—The ratio of the heat required to raise the temperature of a given substance to that required to raise the temperature of water, is commonly called the "Specific Heat" of the substance.—*Kent.*

WATER

Water with a barometer at 30° boils in the open air at sea level at 212° Fahr., and in vacuum at 88° Fahr. The less the pressure of the atmosphere, the lower is the temperature at which water will boil. The pressure of the atmosphere at sea level is 14.7 pounds per square inch, pressing equally and in all directions. This has been ascertained from the following illustration: Because the height of a column of air of one square inch area exactly balances a column of mercury of the same area 30 inches in height, and also a column of water 33.86 feet in height, it follows that a column of air, 30 inches of mercury, and 33.86 feet of water weigh the same; and since the last two weigh the same, respectively 14.7 pounds, per square inch, a full column of air must weigh the same. A cubic foot of water, evaporated under a pressure of one atmosphere, or 15 pounds per square inch, occupies a space of 1700 cubic feet.

Salt water boils at a higher temperature than fresh, owing to its greater density, and because the boiling point of water is increased by any substance that enters into chemical combination with it. The density of water decreases as the temperature increases, since heat destroys cohesion and expands the particles, causing them to occupy greater space. The power of water to hold chemical substances, such as salts of lime, in solution decreases as the temperature increases; from this follows that boilers carrying high pressure of steam form more scale than those working at low temperatures.

The law of expansion by heat and contraction by cold is true as relating to water, with this exception: that, as hot water cools down from the boiling point, it contracts until 45° Fahr. is reached; but if it cools down from this point it expands again. In other words, from 32° to 45° Fahr. the density of water increases; above the latter temperature the density diminishes, because water is expanded into a greater space by an increase of temperature. Water has the greatest specific heat of all known liquids, except hydrogen, and is, therefore, taken as the standard for all solids and fluids.

WATER AT DIFFERENT TEMPERATURES

There are four notable temperatures for pure water, viz.:

1. Freezing point at sea level, . . . 32° F.
2. Point of maximum density, . . . 39.1° F.
3. British standard for spec. gravity, 62° F.
4. Boiling point at sea level, ... 212° F.

32° F.	Weight per cu. ft.,	62.418 lb;	per	cu.	in.,	.03612 lb
39.1° F.	" " "	62.425 "	"		"	.036125 "
62° F.	" " "	62.355 "	"		"	.03608 "
212° F.	" " "	59.760 "	"		"	.03458 "

A United States standard gallon holds 231 cubic inches and 8⅓ pounds water at 62° F.

A British Imperial gallon holds 277.274 cubic inches and 10 pounds water at 62° F.

Sea water (average) has a specific gravity of 1.028, boils at 213.2° F., and weighs 64 pounds per cubic foot at 62° F.

A pressure of 1 pound per square inch is exerted by a column of water 2.3093 feet, or 27.71 inches high, at 62° F.

In solvent power water has a greater range than any other liquid. For common salt this is nearly constant at all temperatures, while it increases with increase of temperature for others,—magnesium and sodium sulphates, for instance.

Where water contains carbonic acid it dissolves some minerals quite readily, but a boiling temperature causes the disengagement of the carbonic acid in gaseous form and the deposition of a large part of the minerals thus held in solution.

Lime salts are more soluble in cold than in hot water, and most of them are deposited at 320°, or less. When frozen into ice, or evaporated into steam, water parts with nearly all substances held in solution.

TABLE OF SOLUBILITIES OF SCALE-MAKING MINERALS

SUBSTANCE	Soluble in Parts of Pure Water at 32° F.	Soluble in Parts of Carbonic Acid Water, Cold	Soluble in Parts of Pure Water at 212° F.	Insoluble in Water at—
Carbonate of Lime, .	62500	150	62500	302° F.
Sulphate of Lime, . .	500	. . .	460	302° F.
Carbonate of Magnesia,	5500	150	9600	. . .
Phosphate of Lime, .	. . .	1333	. . .	212° F.
Oxide of Iron, ...	. . .	. . .	. . .	212° F.
Silica, ...	. . .	Und't'd	. . .	212° F.

Water has a greater specific heat, or heat-absorbing capacity, than any other known substance (bromine and hydrogen excepted), and is the unit of comparison employed for all measurements of the capacities for heat of all substances whatever. The specific heat of water is not constant, but rises in an increasing ratio with the temperature, so that it requires slightly more heat, the higher the temperature, to raise a given quantity of water from one temperature to another. The specific heat of ice and steam are, respectively, .504 and .475, or practically about half that of water.

The table on opposite page (101) gives the number of British thermal units in a pound of water at different temperatures. They are reckoned above 32° F., for, strictly speaking, *water* does not exist below 32°, and ice follows another law.

WATER BETWEEN 32 DEGREES AND 212 DEGREES FAHR.

Temperature Fahr.	Heat Units per Pound	Weight, Pounds per Cubic Foot	Temperature Fahr.	Heat Units per Pound	Weight, Pounds per Cubic Foot	Temperature Fahr.	Heat Units per Pound	Weight, Pounds per Cubic Foot	Temperature Fahr.	Heat Units per Pound	Weight, Pounds per Cubic Foot
32°	0.00	62.42	110°	78.00	61.89	145°	113.26	61.28	179°	147.54	60.57
35	3.02	62.42	112	80.00	61.86	146	114.27	61.26	180	148.54	60.55
40	8.06	62.42	113	81.01	61.84	147	115.28	61.24	181	149.55	60.53
45	13.08	62.42	114	82.02	61.83	148	116.29	61.22	182	150.56	60.50
50	18.10	62.41	115	83.02	61.82	149	117.30	61.20	183	151.57	60.48
52	20.11	62 40	116	84.03	61.80	150	118.30	61.18	184	152.58	60.46
54	22.11	62.40	117	85.04	61.78	151	119.31	61.16	185	153.58	60.44
56	24.11	62.39	118	86.05	61.77	152	120.32	61.14	186	154.59	60.41
58	26.12	62.38	119	87.06	61.75	153	121.33	61.12	187	155.60	60.39
60	28.12	62.37	120	88.06	61.74	154	122.34	61.10	188	156.61	60.37
62	30.12	62.36	121	89.07	61.72	155	123.34	61.08	189	157.62	60.34
64	32.12	62.35	122	90.08	61.70	156	124.35	61.06	190	158.62	60.32
66	34.12	62.34	123	91.09	61.68	157	125.36	61.04	191	159.63	60.29
68	36.12	62.33	124	92.10	61.67	158	126.37	61.02	192	160.63	60.27
70	38.11	62.31	125	93.10	61.65	159	127.38	61.00	193	161.64	60.25
72	40.11	62.30	126	94.11	61.63	160	128.38	60.98	194	162.65	60.22
74	42.11	62.28	127	95.12	61.61	161	129.39	60.96	195	163.66	60.20
76	44.11	62.27	128	96.13	61.60	162	130.40	60.94	196	164.66	60.17
78	46.10	62.25	129	97.14	61.58	163	131.41	60.92	197	165.67	60.15
80	48.09	62.23	130	98.14	61.56	164	132.42	60.90	198	166.68	60.12
82	50.08	62.21	131	99.15	61.54	165	133.42	60.87	199	167.69	60.10
84	52.07	62.19	132	100.16	61.52	166	134.43	60.85	200	168.70	60.07
86	54.06	62.17	133	101.17	61.51	167	135.44	60.83	201	169.70	60.05
88	56.05	62.15	134	102.18	61.49	168	136.45	60.81	202	170.71	60.02
90	58.04	62.13	135	103.18	61.47	169	137.46	60.79	203	171.72	60.00
92	60.03	62.11	136	104.19	61.45	170	138.46	60.77	204	172.73	59.97
94	62.02	62.09	137	105.20	61.43	171	139.47	60.75	205	173.74	59.95
96	64.01	62.07	138	106.21	61.41	172	140.48	60.73	206	174.74	59.92
98	66.01	62.05	139	107.22	61.39	173	141.49	60.70	207	175.75	59.89
100	68.01	62.02	140	108.22	61.37	174	142.50	60.68	208	176.76	59.87
102	70.00	62.00	141	109.23	61.36	175	143.50	60.66	209	177.77	59.84
104	72.00	61.97	142	110.24	61.34	176	144.51	60.64	210	178.78	59.82
106	74.00	61.95	143	111.25	61.32	177	145.52	60.62	211	179.78	59.79
108	76.00	61.92	144	112.26	61.30	178	146.53	60.59	212	180.79	59.76

TABLE OF WATER ANALYSES

Grains per U. S. Gallon, 231 Cubic Inches

Where From	Lime and Magnesia Carbonates	Lime and Magnesia Sulphates	Sodium Chloride (Salt)	Iron Oxide, Carb. Sulph., etc.	Volatile and Organic Matter	Total Solids in Grains
Buffalo, N. Y., Lake Erie,	5.66	3.32	0.58	. . .	0.18	9.74
Pittsburgh, Allegheny River,	0.37	3.78	0.58	0.37	1.50	6.60
Pittsburgh, Monongahela River,	1.06	5.12	0.64	0.78	3.20	10.80
Milwaukee, Wisconsin River,	6.23	4.67	1.76	20.14	6.50	39.30
Galveston, Texas, 1,	13.68	13.52	326.64	Trace	Trace	353.84
Columbus, Ohio,	20.76	11.74	7.02	0.58	6.50	46.60
Washington, D. C., city supply,	2.87	3.27	Trace	0.36	2.10	8.60
Baltimore, Md., city supply,	2.77	0.65	Trace	0.10	3.80	7.30
Sioux City, Ia., city supply,	19.76	1.24	1.17	1.03	4.40	27.60
Los Angeles, Cal., 1,	10.12	5.84	3.51	2.63	4.10	26.20
Bay City, Michigan, Bay,	8.47	10.36	20.48	1.15	8.74	49.20
Bay City, Michigan, River,	4.84	33.66	126.78	3.00	10.92	179.20
Cincinnati, Ohio River,	3.88	0.78	1.79	. . .	Trace	6.73
Watertown, Conn.,	1.47	4.51	1.76	Trace	1.78	9.52
Ft. Wayne, Ind.,	8.78	6.22	3.51	1.59	10.98	31.08
Wilmington, Del.,	10.04	6.02	4.29	8.48	6.17	35.00
Galveston, Texas, 2,	21.79	29.149	398.99	. . .	4.00	433.93
Wichita, Kansas,	14.14	25.91	24.34	. . .	2.00	66.39
Los Angeles, Cal., 2,	3.72	12.59	. . .	0.76	6.00	23.07
St. Louis, Mo., well water,	27.04	23.73	15.57	3.49	0.46	70.29
Pittsburgh, Pa., artesian well,	23.45	5.71	18.41	1.04	0.82	49.43
Springfield, Ill., 1,	12.99	7.40	1.97	2.19	8.62	33.17
Springfield, Ill., 2,	5.47	4.31	1.56	4.28	5.83	21.45
Hillsboro, Ill.,	14.56	2.97	2.39	1.63	Trace	21.55
Pueblo, Colo.,	4.32	16.15	1.20	1.97	5.12	28.76
Long Island City, L. I.,	4.0	28.0	16.0	. . .	1.0	39.0
Mississippi River, above Missouri River,	8.24	1.02	0.50	. . .	5.25	15.01
Mississippi River, below mouth of Missouri River,	10.64	7.41	1.36	1.22	15.86	36.49
Mississippi River at St. Louis W.W.,	9.64	6.94	1.54	1.57	9.85	29.54
Missouri River, above mouth,	10.07	8.92	1.87	3.26	11.37	35.49

NUMBER OF GALLONS IN CISTERNS AND TANKS

ACTUAL CONTENTS—(ORIGINAL)

DIAM. IN FEET	DEPTH IN FEET															
	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1½	66	79	...	...	...	...	...	...	...	...	...	...	...	...	...	...
2	117	141	164	188	212	235	...	...	...	...	...	...	...	...	...	...
2½	184	221	258	294	335	372	419	455	...	...	...	...	...	...	...	...
3	265	318	371	424	477	530	583	636	689	742	...	...	...	...	...	...
3½	360	432	504	572	644	716	788	860	932	1004	1076	1148	...	...	...	...
4	471	565	659	754	848	942	1036	1131	1225	1319	1414	1508	1602	1696	...	...
5	736	883	1031	1178	1326	1473	1610	1757	1905	2052	2199	2347	2494	2641	2789	2936
6	1060	1272	1284	1696	1908	2120	2332	2544	2754	2966	3178	3390	3602	3814	4026	4238
7	1444	1732	2021	2309	2598	2887	3175	3463	3752	4041	4330	4618	4907	5195	5494	5772
8	1885	2262	2639	3016	3393	3770	4147	4524	4901	5278	5655	6032	6409	6786	7163	7540
9	2386	2863	3340	3817	4294	4772	5249	5726	6203	6680	7157	7634	8112	8589	9066	9543
10	2945	3534	4123	4712	5301	5890	6479	7068	7657	8246	8835	9424	10013	10602	11191	11780
11	3565	4278	4991	5704	6417	7130	7843	8556	9267	9980	10693	11406	12119	12832	13545	14258
12	4240	5088	5936	6784	7632	8480	9328	10176	11024	11872	12720	13568	14416	15264	16112	16960
13	4977	5973	6968	7964	8959	9955	10950	11946	12941	13937	14932	15928	16923	17919	18914	19910
14	5773	6927	8082	9236	10390	11545	12709	13865	15019	16174	17328	18483	19637	20792	21946	23101
15	6625	7950	9275	10600	11925	13250	14575	15900	17225	18550	19875	21200	22525	23850	25175	26500
16	7540	9048	10556	11064	12572	14080	15588	17096	18604	20112	21620	23128	24636	26144	27652	30160
18	9545	11454	13363	15272	17181	19090	20999	22908	24817	26726	28635	30544	32453	34362	36271	38180
20	11780	14136	16492	18848	21204	23560	25916	28272	30628	32984	35340	37696	40052	42408	44764	47120
22	14255	17106	19957	22808	25659	28510	31361	34212	37063	39914	42765	45616	48467	51318	54169	57020
24	16965	20358	23741	27134	30537	33930	37323	40716	44109	48502	51895	55288	58681	62074	65467	68860
25	18410	22092	25774	29456	33138	36820	40502	44182	47864	51546	55228	58910	62592	66274	69856	73538
26	19910	23892	27874	31856	35838	39820	43802	47784	51766	55748	59730	63712	67694	71676	75658	79640
27	21465	25758	30051	34344	38637	42930	47223	51516	55809	60102	64395	68688	72981	77274	81567	85860
28	23925	28710	33495	38280	43065	47850	52635	57420	62205	66990	71775	76560	81345	86130	91915	96700
29	24770	29724	34678	39632	44586	49540	54494	59448	64402	69356	74310	79264	84218	89172	94126	99080
30	26505	31806	37107	42408	47709	53010	58311	63612	68913	74214	79515	84816	90117	95418	100719	106020

NUMBER OF GALLONS IN CISTERNS AND TANKS—Continued

ACTUAL CONTENTS—(ORIGINAL)

DIAM. IN FEET	DEPTH IN FEET 21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
1½	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
2½	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
3½	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
5	3083	3232	3379	3526	3673	3821	3968	4115	4263	4419	4566	4713	4860	5008	5156
6	4460	4672	4884	5096	5308	5520	5732	5944	6156	6368	6580	6792	7004	7216	7428
7	6061	6349	6638	6926	7215	7504	7792	8081	8369	8658	8947	9235	9524	9812	10101
8	7917	8294	8671	9048	9425	9802	10179	10556	10933	11310	11687	12064	12441	12818	13195
9	10020	10497	10974	11452	11929	12406	12883	13360	13837	14314	14792	15269	15746	16223	16700
10	12369	12958	13547	14136	14725	15314	15903	16492	17081	17670	18259	18848	19437	20026	20615
11	14971	15684	16397	17110	17823	18536	19249	19962	20675	21388	22101	22814	23527	24240	24953
12	17808	18656	19504	20352	21200	22048	22896	23744	24592	25440	26288	27136	27984	28832	29680
13	20905	21901	22896	23892	24887	25883	26878	27874	28869	29865	30860	31856	32841	33837	34832
14	24255	25410	26564	27719	28873	30028	31182	32337	33491	34646	35800	36955	38110	39265	40419
15	27825	29150	30475	31800	33125	34450	35775	37100	38425	39850	41175	42500	43825	45150	46475
16	31668	33176	34684	36192	37700	39208	40716	42224	43732	45240	46748	48256	49764	51272	52780
18	40089	41998	43907	45816	47725	49634	51543	53452	55361	57270	59179	61088	62997	64906	66815
20	49476	51832	54188	56444	58800	61156	63512	65868	68224	70580	72936	74292	76648	79004	81360
22	59871	62722	65573	68424	71275	74126	76977	79828	82679	85530	88381	91232	94083	96934	98785
24	72253	75646	79039	82432	85825	89218	92611	96004	99395	102788	106181	109574	112967	116360	119753
25	77220	80902	84584	88266	91948	95630	99312	102994	106676	110358	114040	117722	121404	125086	128768
26	83622	87604	91586	95568	99550	103532	107514	111496	115478	119460	123442	127424	131406	135388	139370
27	90153	94446	98739	103032	107325	112618	116911	121204	125497	129790	134083	138376	142669	146962	151255
28	101485	106250	111035	115820	120605	125390	130175	134960	139745	144530	149315	154100	158885	163670	168455
29	104034	108988	113942	118896	123850	128804	133758	138712	143666	148620	153574	158528	163482	168436	173396
30	111321	116622	121923	127224	132525	137826	143127	148428	153729	159030	164331	169632	174933	180234	185535

STEAM

Steam is an elastic fluid resulting from the combination of heat with water, and, when the steam is not in contact with the water from which it is formed, it follows the same general law as all other gases. This law is as follows: All gases expand by heat $\frac{1}{459}$ part of their volume for every degree Fahr., while their elastic pressure remains unaltered; and so long as the temperature of a gas remains unaltered, its elastic pressure will vary inversely to the volume. Steam is of several kinds. *Superheated steam* is steam removed from contact with water and heated to a temperature higher than is due to its pressure; called also *surcharged steam*. *Saturated steam* is steam which, in contact with the fluid from which it is formed, has brought with it a proportion of moisture. *Supersaturated steam* is steam in which there is more water mingled in the form of minute spray than is generally contained in saturated steam, which is called the water of supersaturation.

The temperature of the steam is always equal to that of water from which it is formed, and the elastic force of steam formed is equal to the pressure under which it is formed. The elastic force of steam, barometer at 30°, at 212° Fahr., is one atmosphere, or 14.7 lbs. per square inch; while at 250° Fahr. its elastic force is two atmospheres, or 29.4 lbs. per square inch. This includes the pressure of the atmosphere.

FLOW OF STEAM THROUGH PIPES

The approximate weight of any fluid which will flow in one minute through any given pipe with a given head or pressure may be found by the following formula:

$$W = 87 \sqrt{\frac{D(p_1 - p_2)d^5}{L\left(1 + \frac{3.6}{d}\right)}}$$

in which W = weight in pounds avoirdupois, d = diameter in inches, D = density or weight per cubic foot; p_1 the initial pressure, p_2 pressure at end of pipe, and L = the length in feet.

The table on opposite page (107) gives, approximately, the weight of steam per minute which will flow from various initial pressures, with one pound loss of pressure through straight, smooth pipes, each having a length of 240 times its own diameter.

For sizes of pipe below 6-inch, the flow is calculated from the *actual* areas of "standard" pipe of such nominal diameters.

For horse power, multiply the figures in the table by 2. For any other loss of pressure, multiply by the square root of the given loss. For any other length of pipe, *divide 240 by the given length expressed in diameters, and multiply the figures in the table by the square root of this quotient*, which will give the flow for 1 pound loss of pressure. Conversely, dividing the given length by 240 will give the loss of pressure for the flow given in the table.

The loss of head due to getting up the velocity, to the friction of the steam entering the pipe, and passing elbows and valves, will reduce the flow given in the tables. The resistance at the opening, and that at a globe valve, are each about the same as that for a length of pipe equal to 114 diameters divided by a number represented by 1 + (3.6 ÷ diameter). For the sizes of pipes given in the table, these corresponding lengths are:

¾	1	1½	2	2½	3	4	5	6	8	10	12	15	18
20	25	34	41	47	52	60	66	71	79	84	88	92	95

The resistance at an elbow is equal to two-thirds that of a globe valve. These equivalents,—for opening, for

TABLE OF FLOW OF STEAM THROUGH PIPES

Initial Pressure by Gauge Lbs. Per Sq. Inch	Diameter of Pipe in Inches. Length of Each = 240 Diameters													
	3/4	1	1 1/2	2	2 1/2	3	4	5	6	8	10	12	15	18
	Weight of Steam Per Minute in Pounds, with One Pound Loss of Pressure													
1	1.16	2.07	5.7	10.27	15.45	25.38	46.85	77.3	115.9	211.4	341.1	502.4	804	1177
10	1.44	2.57	7.1	12.72	19.15	31.45	58.05	95.8	143.6	262.0	422.7	622.5	996	1458
20	1.70	3.02	8.3	14.94	22.49	36.94	68.20	112.6	168.7	307.8	496.5	731.3	1170	1713
30	1.91	3.40	9.4	16.84	25.35	41.63	76.84	126.9	190.1	346.8	559.5	824.1	1318	1930
40	2.10	3.74	10.3	18.51	27.87	45.77	84.49	139.5	209.0	381.3	615.3	906.0	1450	2122
50	2.27	4.04	11.2	20.01	30.13	49.48	91.34	150.8	226.0	412.2	665.0	979.5	1567	2294
60	2.43	4.32	11.9	21.38	32.19	52.87	97.60	161.1	241.5	440.5	710.6	1046.7	1675	2451
70	2.57	4.58	12.6	22.65	34.10	56.00	103.37	170.7	255.8	466.5	752.7	1108.5	1774	2596
80	2.71	4.82	13.3	23.82	35.87	58.91	108.74	179.5	269.0	490.7	791.7	1166.1	1866	2731
90	2.83	5.04	13.9	24.92	37.52	61.62	113.74	187.8	281.4	513.3	828.1	1219.8	1951	2856
100	2.95	5.25	14.5	25.96	39.07	64.18	118.47	195.6	293.1	534.6	862.6	1270.1	2032	2975
120	3.16	5.63	15.5	27.85	41.93	68.87	127.12	209.9	314.5	573.7	925.6	1363.3	2181	3193
150	3.45	6.14	17.0	30.37	45.72	75.09	138.61	228.8	343.0	625.5	1009.2	1486.5	2378	3481

elbows, and for valves,—must be added in each instance to the actual length of pipe. Thus a 4-inch pipe, 120 diameters (40 feet) long, with a globe valve and three elbows, would be equivalent to $120 + 60 + 60 + (3 \times 40) = 360$ diameters long; and $360 \div 240 = 1\frac{1}{2}$. It would therefore have $1\frac{1}{2}$ pounds loss of pressure at the flow given in the table, or deliver $(1 \div \sqrt{1\frac{1}{2}} = .816)$, 81.6 per cent. of the steam with the same (1 pound) loss of pressure.

COVERING FOR BOILERS, STEAM PIPES, ETC.

The losses by radiation from unclothed pipes and vessels containing steam is considerable, and in the case of pipes leading to steam engines, is magnified by the action of the condensed water in the cylinder. It therefore is important that such pipes should be well protected.

There is a wide difference in the value of different substances for protection from radiation, their value varying nearly in the inverse ratio of their conducting power for heat, up to their ability to transmit as much heat as the surface of the pipe will radiate, after which they become detrimental, rather than useful, as covering. This point is reached nearly at baked clay or brick.

The table on opposite page (109) of the relative value of various substances for protection against radiation has been compiled from a variety of sources, mainly the experiments of the Massachusetts Institute of Technology, and of C. E. Emery, M.E., LL.D.

Where two values are given in the table for the same substance, the lower one is for the denser condition.

A smooth or polished surface is of itself a good protection, polished tin or Russia iron having a ratio, for radiation, of 53 to 100 for cast iron. Mere color makes but little difference.

TABLE OF RELATIVE VALUE OF NON-CONDUCTING MATERIALS

SUBSTANCE	Value	SUBSTANCE	Value
* Loose Wool,	3.35	* Wood, across grain,	.40 to .55
* Loose Lampblack,	1.12	Loam, dry and open,	.55
* Geese Feathers,	1.08	Chalk, ground, Spanish white,	.51
* Felt, Hair or Wool,	1.	Coal Ashes,	.35 to .49
* Carded Cotton,	1.	Gas-house Carbon,	.47
* Charcoal from Cork,	.87	Asbestos Paper,	.47
Mineral Wool,	.68 to .83	Paste of Fossil Meal and Asbestos,	.47
Fossil Meal,	.66 to .79	Asbestos, fibrous,	.36
* Straw Rope, wound spirally,	.77	Plaster of Paris, dry,	.34
* Rice Chaff, loose,	.76	Clay, with vegetable fibre,	.34
Carbonate Magnesia,	.67 to .76	Anthracite Coal, powdered,	.29
* Charcoal from Wood,	.63 to .75	Coke, in lumps,	.27
* Paper,	.50 to .74	Air Space, undivided,	.14 to .22
* Cork,	.71	Sand,	.17
* Sawdust,	.61 to .68	Baked Clay, Brick,	.07
Paste of Fossil Meal and Hair,	.63	Glass,	.05
Wood Ashes,	.61	Stone,	.02

* Combustible and sometimes dangerous.

Hair or wool felt, and most of the better non-conductors, have the disadvantage of becoming soon charred from the heat of steam at high pressure, and sometimes of taking fire therefrom.

"Mineral wool," a fibrous material made from blast furnace slag, is the best non-combustible covering, but is quite brittle, and liable to fall to powder where much jarring exists.

Air space alone is one of the poorest of non-conductors, though the best owe their efficiency to the numerous minute air-cells in their structure. This is best seen in the value of different forms of carbon, from cork charcoal to anthracite dust, the former being three times as valuable for this purpose, though in chemical constitution they are practically identical.

Any suitable substance used to prevent the escape of steam heat should not be less than one inch thick.

The table on opposite page (111) gives the loss of heat from steam pipes, naked and clothed with wool or hair felt, of different thicknesses, the steam pressure being assumed at 75 lbs. and the external air at 60°.

TABLE OF LOSS OF HEAT FROM STEAM PIPES

Thickness of Covering in Inches	Outside Diameter of Pipe, without Felt														
	2 In. Diameter			4 In. Diameter			6 In. Diameter			8 In. Diameter			12 In. Diameter		
	Loss in Units per Foot Run per Hour	Ratio of Loss	Feet in Length per H. P. Lost	Loss in Units per Foot Run per Hour	Ratio of Loss	Feet in Length per H. P. Lost	Loss in Units per Foot Run per Hour	Ratio of Loss	Feet in Length per H. P. Lost	Loss in Units per Foot Run per Hour	Ratio of Loss	Feet in Length per H. P. Lost	Loss in Units per Foot Run per Hour	Ratio of Loss	Feet in Length per H. P. Lost
0	219.0	1.00	152	390.8	1.00	86	624.1	1.000	53	729.8	1.000	46	1077.4	1.000	31
¼	100.7	.46	331	180.9	.46	182	. .	. .	. .	. .	. .	. .	. .	. .	. .
½	65.7	.30	507	117.2	.30	284	187.2	.300	177	219.6	.301	151	301.7	.280	114
1	43.8	.20	761	73.9	.18	451	111.0	.178	300	128.3	.176	259	185.3	.172	179
2	28.4	.13	1173	44.7	.11	745	66.2	.106	504	75.2	.103	443	98.0	.091	340
4	19.8	.09	1683	28.1	.07	1186	41.2	.066	808	46.0	.063	724	60.3	.056	553
6	. .	. .	. .	23.4	.06	1424	33.7	.054	989	34.3	.047	972	45.2	.042	735

TABLE OF PROPERTIES OF SATURATED STEAM

(PARTLY FROM C. H. PEABODY'S TABLES)

Pressure in Pounds per Square Inch above Vacuum	Temperature in Degrees Fahrenheit	Total Heat in Heat Units from Water at 32°	Heat in Liquid from 32° in Units	Heat of Vaporization, or Latent Heat in Heat Units	Density or Weight of Cubic Feet in Pounds	Volume of One Pound in Cubic Feet	Factor of Equivalent Evaporation at 212°	Total Pressure above Vacuum
1	101.99	1113.1	70.0	1043.0	0.00299	334.5	.9661	1
2	126.27	1120.5	94.4	1026.1	0.00576	173.6	.9738	2
3	141.62	1125.1	109.8	1015.3	0.00844	118.5	.9786	3
4	153.09	1128.6	121.4	1007.2	0.01107	90.33	.9822	4
5	162.34	1131.5	130.7	1000.8	0.01366	73.21	.9852	5
6	170.14	1133.8	138.6	995.2	0.01622	61.65	.9876	6
7	176.90	1135.9	145.4	990.5	0.01874	53.39	.9897	7
8	182.92	1137.7	151.5	986.2	0.02125	47.06	.9916	8
9	188.33	1139.4	156.9	982.5	0.02374	42.12	.9934	9
10	193.25	1140.9	161.9	979.0	0.02621	38.15	.9949	10
15	213.03	1146.9	181.8	965.1	0.03826	26.14	1.0003	15
20	227.95	1151.5	196.9	954.6	0.05023	19.91	1.0051	20
25	240.04	1155.1	209.1	946.0	0.06199	16.13	1.0099	25
30	250.27	1158.3	219.4	938.9	0.07360	13.59	1.0129	30
35	259.19	1161.0	228.4	932.6	0.08508	11.75	1.0157	35
40	267.13	1163.4	236.4	927.0	0.09644	10.37	1.0182	40
45	274.29	1165.6	243.6	922.0	0.1077	9.285	1.0205	45
50	280.85	1167.6	250.2	917.4	0.1188	8.418	1.0225	50
55	286.89	1169.4	256.3	913.1	0.1299	7.698	1.0245	55
60	292.51	1171.2	261.9	909.3	0.1409	7.097	1.0263	60
65	297.77	1172.7	267.2	905.5	0.1519	6.583	1.0280	65
70	302.71	1174.3	272.2	902.1	0.1628	6.143	1.0295	70
75	307.38	1175.7	276.9	898.8	0.1736	5.760	1.0309	75
80	311.80	1177.0	281.4	895.6	0.1843	5.426	1.0323	80
85	316.02	1178.3	285.8	892.5	0.1951	5.126	1.0337	85
90	320.04	1179.6	290.0	889.6	0.2058	4.859	1.0350	90
95	323.89	1180.7	294.0	886.7	0.2165	4.619	1.0362	95
100	327.58	1181.9	297.9	884.0	0.2271	4.403	1.0374	100
105	331.13	1182.9	301.6	881.3	0.2378	4.205	1.0385	105
110	334.56	1184.0	305.2	878.8	0.2484	4.026	1.0396	110
115	337.86	1185.0	308.7	876.3	0.2589	3.862	1.0406	115
120	341.05	1186.0	312.0	874.0	0.2695	3.711	1.0416	120
125	344.13	1186.9	315.2	871.7	0.2800	3.571	1.0426	125
130	347.12	1187.8	318.4	869.4	0.2904	3.444	1.0435	130
140	352.85	1189.5	324.4	865.1	0.3113	3.212	1.0453	140
150	358.26	1191.2	330.0	861.2	0.3321	3.011	1.0470	150
160	363.40	1192.8	335.4	857.4	0.3530	2.883	1.0486	160
170	368.29	1194.3	340.5	853.8	0.3737	2.676	1.0502	170
180	372.97	1195.7	345.4	850.3	0.3945	2.535	1.0517	180
190	377.44	1197.1	350.1	847.0	0.4153	2.408	1.0531	190
200	381.73	1198.4	354.6	843.8	0.4359	2.294	1.0545	200
225	391.79	1201.4	365.1	836.3	0.4876	2.051	1.0576	225
250	400.99	1204.2	374.7	829.5	0.5393	1.854	1.0605	250
275	409.50	1206.8	383.6	823.2	0.5913	1.691	1.0632	275
300	417.42	1209.3	391.9	817.4	0.644	1.553	1.0657	300
325	424.82	1211.5	399.6	811.9	0.696	1.437	1.0680	325
350	431.90	1213.7	406.9	806.8	0.748	1.337	1.0703	350
375	438.40	1215.7	414.2	801.5	0.800	1.250	1.0724	375
400	445.15	1217.7	421.4	796.3	0.853	1.172	1.0745	400
500	466.57	1224.2	444.3	779.9	1.065	.939	1.0812	500

The gauge pressure is about 15 pounds (14.7) less than the total pressure, so that in using the table on opposite page (112), 15 must be added to the pressure as given by the steam gauge. The column of Temperatures gives the thermometric temperature of steam and the boiling point at each pressure. The "factor of equivalent evaporation" shows the proportionate cost in heat or fuel of producing steam at the given pressure as compared with atmospheric pressure.

To ascertain the equivalent evaporation at any pressure, multiply the given evaporation by the factor of its pressure, and divide the product by the factor of the desired pressure.

Each degree of difference in temperature of feed-water makes a difference of .00104 in the amount of evaporation. Hence, to ascertain the equivalent evaporation from any other temperature of feed than 212°, add to the factor given as many times .00104 as the temperature of feed-water is degrees below 212°. For other pressures than those given in the table, it will be practically correct to take the proportion of the difference between the nearest pressures given in the table.

WROUGHT-IRON WELDED STEAM, GAS, AND WATER PIPE

TABLE OF STANDARD DIMENSIONS

Diameter			Thickness	Circumference		Transverse Areas			Length of Pipe per Sq. Foot of		Length of Pipe contain'g One Cubic Foot	Nominal Weight per Foot	Number of Threads per Inch of Screw
Nominal Int'l	Actual Ext'l	Actual Int'l		Ext'l	Int'l	Ext'l	Int'l	Metal	Ext'l Surface	Int'l Surface			
Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Sq. Ins.	Sq. Ins.	Sq. Ins.	Feet	Feet	Feet	Lbs.	. . .
1/8	.405	.27	.068	1.272	.848	.129	.0573	.0717	9.44	14.15	2513.	.241	27
1/4	.54	.364	.088	1.696	1.144	.229	.1041	.1249	7.075	10.49	1383.3	.42	18
3/8	.675	.494	.091	2.121	1.552	.358	.1917	.1663	5.657	7.73	751.2	.559	18
1/2	.84	.623	.109	2.639	1.957	.554	.3048	.2492	4.547	6.13	472.4	.837	14
3/4	1.05	.824	.113	3.299	2.589	.866	.5333	.3327	3.637	4.635	270.	1.115	14
1	1.315	1.048	.134	4.131	3.292	1.358	.8626	.4954	2.904	3.645	166.9	1.668	11½
1¼	1.66	1.38	.14	5.215	4.335	2.164	1.496	.668	2.301	2.768	96.25	2.244	11½
1½	1.9	1.611	.145	5.969	5.061	2.835	2.038	.797	2.01	2.371	70.66	2.678	11½
2	2.375	2.067	.154	7.461	6.494	4.43	3.356	1.074	1.608	1.848	42.91	3.609	11½
2½	2.875	2.468	.204	9.032	7.753	6.492	4.784	1.708	1.328	1.547	30.1	5.739	8
3	3.5	3.067	.217	10.996	9.636	9.621	7.388	2.243	1.091	1.245	19.5	7.536	8
3½	4.	3.548	.226	12.566	11.146	12.566	9.887	2.679	.955	1.077	14.57	9.001	8
4	4.5	4.026	.237	14.137	12.648	15.904	12.73	3.174	.849	.949	11.31	10.665	8
4½	5.	4.508	.246	15.708	14.162	19.635	15.961	3.674	.764	.848	9.02	12.34	8
5	5.563	5.045	.259	17.477	15.849	24.306	19.99	4.316	.687	.757	7.2	14.502	8
6	6.625	6.065	.28	20.813	19.054	34.472	28.888	5.584	.577	.63	4.98	18.762	8

WROUGHT-IRON WELDED STEAM, GAS, AND WATER PIPE—Continued

TABLE OF STANDARD DIMENSIONS

Diameter			Thickness	Circumference		Transverse Areas			Length of Pipe per Sq. Foot of		Length of Pipe contain'g One Cubic Foot	Nominal Weight per Foot	Number of Threads per Inch of Screw
Nominal Int'l	Actual Ext'l	Actual Int'l		Ext'l	Int'l	Ext'l	Int'l	Metal	Ext'l Surface	Int'l Surface			
Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Sq. Ins.	Sq. Ins.	Sq. Ins.	Feet	Feet	Feet	Lbs.	. .
7	7.625	7.023	.301	23.955	22.063	45.664	38.738	6.926	.501	.544	3.72	23.271	8
8	8.625	7.982	.322	27.096	25.076	58.426	50.04	8.386	.443	.478	2.88	28.177	8
9	9.625	8.937	.344	30.238	28.076	72.76	62.73	10.03	.397	.427	2.29	33.701	8
10	10.75	10.019	.366	33.772	31.477	90.763	78.839	11.924	.355	.382	1.82	40.065	8
11	12.	11.25	.375	37.699	35.343	113.098	99.402	13.696	.318	.339	1.456	45.95	8
12	12.75	12.	.375	40.055	37.7	127.677	113.098	14.579	.299	.319	1.27	48.985	8
13	14.	13.25	.375	43.982	41.626	153.938	137.887	16.051	.273	.288	1.04	53.921	8
14	15.	14.25	.375	47.124	44.768	176.715	159.485	17.23	.255	.268	.903	57.893	8
15	16.	15.25	.375	50.265	47.909	201.062	182.655	18.407	.239	.250	.788	61.77	8
. .	18.	17.25	.375	56.549	54.192	254.47	233.706	20.764	.212	.221	.616	69.66	. .
. .	20.	19.25	.375	62.832	60.476	314.16	291.04	23.12	.191	.198	.495	77.57	. .
. .	22.	21.25	.375	69.115	66.759	380.134	354.657	25.477	.174	.179	.406	85.47	. .
. .	24.	23.25	.375	75.398	73.042	452.39	424.558	27.832	.159	.164	.339	93.37	. .

WROUGHT-IRON WELDED EXTRA STRONG PIPE

TABLE OF STANDARD DIMENSIONS

Diameter			Thickness	Nearest Wire Gauge	Circumference		Transverse Areas			Length of Pipe per Sq. Foot of		Nominal Weight per Foot
Nominal Int'l	Actual Ext'l	Actual Int'l			External	Internal	Ext'l	Int'l	Metal	Ext'l Surface	Int'l Surface	
Ins.	Ins.	Ins.	Ins.	No.	Ins.	Ins.	Sq. Ins.	Sq. Ins.	Sq. Ins.	Feet	Feet	Lbs.
⅛	.405	.205	.1	12½	1.272	.644	.129	.033	.086	9.433	18.632	.29
¼	.54	.294	.123	11	1.696	.924	.229	.068	.161	7.075	12.986	.54
⅜	.675	.421	.127	10½	2.121	1.323	.358	.139	.219	5.657	9.07	.74
½	.84	.542	.149	9	2.639	1.703	.554	.231	.323	4.547	7.046	1.09
¾	1.05	.736	.157	8½	3.299	2.312	.866	.452	.414	3.637	5.109	1.39
1	1.315	.951	.182	7	4.131	2.988	1.358	.71	.648	2.904	4.016	2.17
1¼	1.66	1.272	.194	6½	5.215	3.996	2.164	1.271	.893	2.301	3.003	3.
1½	1.9	1.494	.203	6	5.969	4.694	2.835	1.753	1.082	2.01	2.556	3.63
2	2.375	1.933	.221	5	7.461	6.073	4.43	2.935	1.495	1.608	1.975	5.02
2½	2.875	2.315	.28	2	9.032	7.273	6.492	4.209	2.283	1.328	1.649	7.67
3	3.5	2.892	.304	1	10.996	9.085	9.621	6.569	3.052	1.091	1.328	10.25
3½	4.	3.358	.321	0	12.566	10.549	12.566	8.856	3.71	.955	1.137	12.47
4	4.5	3.818	.341	0	14.137	11.995	15.904	11.449	4.455	.849	1.	14.97
5	5.563	4.813	.375	00	17.477	15.120	24.306	18.193	6.12	.687	.793	20.54
6	6.625	5.75	.437	000	20.813	18.064	34.472	25.967	8.505	.577	.664	28.58

TABLE OF EQUATION OF PIPES

The table below gives the number of pipes of one size required to equal in delivery other larger pipes of same length and under same conditions. The upper portion above the diagonal line of blanks pertains to "standard" steam and gas pipes, while the lower portion is for pipes of the ACTUAL internal diameters given. The figures given in the table opposite the intersection of any two sizes is the number of the smaller-sized pipes required to equal one of the larger. Thus, it requires 29 standard 2-inch pipes to equal one standard 7-inch pipe.

STANDARD STEAM AND GAS PIPES

Dia.	½	¾	1	1½	2	2½	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Dia.
½		2.27	4.88	15.8	31.7	52.9	96.9	205	377	620	918	1292	1767	2488	3014	3786	4904	5927	7321	8535	9717	½
¾	2.60		2.05	6.97	14.0	23.3	42.5	90.4	166	273	405	569	779	1096	1328	1668	2161	2615	3226	3761	4282	¾
1	7.55	2.90		3.45	6.82	11.4	20.9	44.1	81.1	133	198	278	380	536	649	815	1070	1263	1576	1837	2092	1
1½	24.2	9.30	3.20		1.26	3.34	6.13	13.0	23.8	39.2	58.1	81.7	112	157	190	239	310	375	463	539	614	1½
2	54.8	21.0	7.25	2.26		1.67	3.06	6.47	11.9	19.6	29.0	40.8	55.8	78.5	95.1	119	155	187	231	269	307	2
2½	102	39.4	13.6	4.23	1.87		1.83	3.87	7.12	11.7	17.4	24.4	33.4	47.0	56.9	71.5	92.6	112	138	161	184	2½
3	170	65.4	22.6	7.03	3.11	1.66		2.12	3.89	6.39	9.48	13.3	20.9	23.7	31.2	39.1	50.6	61.1	75.5	88.0	100	3
4	376	144	49.8	15.5	6.87	3.67	2.21		1.84	3.02	4.48	6.30	8.61	12.1	14.7	18.5	23.9	28.9	35.7	41.6	47.4	4
5	686	263	90.9	28.3	12.5	6.70	4.03	1.83		1.65	2.44	3.43	4.69	6.60	8.00	10.0	13.0	15.7	19.4	22.6	25.8	5
6	1116	429	148	46.0	20.4	10.9	6.56	2.97	1.63		1.48	2.09	2.85	4.02	4.86	6.11	7.91	9.56	11.8	13.8	15.6	6
7	1707	656	226	70.5	31.2	16.6	10.0	4.54	2.49	1.51		1.41	1.93	2.71	3.28	4.12	5.34	6.45	7.97	9.31	10.6	7
8	2435	936	322	101	44.5	23.8	14.3	6.48	3.54	2.18	1.43		1.35	1.93	2.33	2.92	3.79	4.57	5.67	6.60	7.52	8
9	3335	1281	440	137	60.8	32.5	19.5	8.85	4.85	2.98	1.95	1.37		1.41	1.71	2.14	2.77	3.35	4.14	4.83	5.50	9
10	4393	1688	582	181	80.4	42.9	25.8	11.7	6.40	3.93	2.57	1.80	1.32		1.21	1.52	1.97	2.38	2.94	3.43	3.91	10
11	5642	2168	747	233	103	55.1	33.1	15.0	8.22	5.05	3.31	2.32	1.70	1.28		1.26	1.63	1.88	2.43	2.83	3.22	11
12	7087	2723	938	293	129	69.2	41.6	18.8	10.3	6.34	4.15	2.91	2.13	1.61	1.26		1.30	1.57	1.93	2.26	2.58	12
13	8657	3326	1146	358	158	84.5	50.7	23.0	12.6	7.75	5.07	3.56	2.60	1.98	1.53	1.22		1.21	1.49	1.74	1.98	13
14	10600	4070	1403	438	193	103	62.2	28.2	15.4	9.48	6.21	4.35	3.18	2.41	1.88	1.50	1.22		1.24	1.44	1.64	14
15	12824	4927	1698	530	234	125	75.3	34.1	18.7	11.5	7.52	5.27	3.85	2.92	2.27	1.81	1.48	1.21		1.17	1.35	15
16	14978	5758	1984	619	274	146	88.0	39.9	21.8	13.4	8.78	6.15	4.51	3.41	2.66	2.12	1.73	1.42	1.18		1.14	16
17	17537	6738	2322	724	320	171	103	46.6	25.6	15.7	10.3	7.20	5.27	3.99	3.11	2.47	2.03	1.66	1.37	1.17		
18	20327	7810	2691	840	371	198	119	54.1	29.6	18.2	11.9	8.35	6.11	4.63	3.60	2.87	2.35	1.92	1.59	1.36	1.16	
20	26676	10249	3532	1102	487	260	157	70.9	38.9	23.9	15.6	10.9	8.02	6.07	4.73	3.76	3.08	2.52	2.08	1.78	1.52	
24	42624	16376	5644	1761	778	416	250	113	62.1	38.2	25.0	17.5	12.8	9.70	7.55	6.01	4.92	4.02	3.32	2.84	2.43	
30	75453	28990	9990	3117	1378	736	443	201	110	67.6	44.2	31.0	22.7	17.2	13.4	10.7	8.72	7.14	5.88	5.03	4.30	
36	120100	46143	15902	4961	2193	1172	705	319	175	108	70.4	49.3	36.1	27.3	21.3	16.9	13.9	11.3	9.37	8.01	6.85	
42	177724	68282	23531	7341	3245	1734	1044	473	259	159	104	73.0	53.4	40.5	31.5	25.1	20.5	16.8	13.9	11.9	10.1	
48	249351	95818	33020	10301	4554	2434	1465	663	363	223	146	102	75.0	56.8	44.2	35.2	28.8	23.5	19.4	16.6	14.2	
Dia.	½	¾	1	1½	2	2½	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	

ACTUAL INTERNAL DIAMETERS

VENTILATION; STEAM AND HOT WATER HEATING

In ventilating apartments, from 3.5 to 5 cubic feet of air is required per minute in winter, and 5 to 10 feet in summer, for each occupant. In hospitals, this rate must be materially increased.

In heating buildings by steam, the amount of boiler and heating pipe depends largely on the kind of building, its location, and the following conditions: Whether building is protected or isolated; whether stone or wood; amount of glass and outside wall surface to space to be heated, and also largely upon the exposure of rooms. Without this information it is impossible to correctly estimate the amount of radiator surface. We give below results obtained by averaging the different existing conditions.

	One Sq. Ft. of Radiating Surface Heats	
	Low Pressure Steam	Hot Water
	Cubic Feet	Cubic Feet
Living rooms with three exposures and large amount of glass, . . .	40	20 to 25
Living rooms with two exposures and ordinary amount of glass, .	50	25 to 30
Living rooms with one exposure and ordinary windows, ...	60	30 to 35
Halls located on corner, ...	55	30 to 33
Halls located in centre of house, .	70	35 to 40
Bath and small exposed rooms, .	40	20 to 25
Sleeping-rooms, ...	60 to 70	25 to 35
School rooms, ...	60 to 80	30 to 50
Churches and auditoriums, . . .	75 to 125	80 to 100
Offices, ...	60 to 80	30 to 50
Stores, ...	70 to 100	40 to 70
Theatres, ...	200 to 300	

The foregoing figures are based on zero weather. If extreme is above zero, less can be used, and if below, the radiators should be increased.

For *indirect* radiators add at least 50 per cent. to the above ratings. For *direct-indirect*, add 25 per cent.

The best results are attained by using indirect radiation to supply the necessary ventilation, and direct radiation for the balance of the heat. The best place for a radiator in a room is beneath a window. Heated air cannot be made to enter a room unless means are provided for permitting an equal amount to escape. The best place for such exit openings is near the floor.

Small pipes are more effective than large. When the diameter is doubled, 20 per cent. additional surface should be allowed, and for three times the diameter, 30 per cent. additional is required. For indirect radiation that surface is most efficient which secures the most intimate contact of the current of air with the heated surface. Rooms on windward side of house require more radiating surface than those on sheltered side.

Where the condensed water is returned to the boiler, or where low pressure of steam is used, the diameter of mains leading from the boiler to the radiating surface should be equal, in inches, to *one-tenth the square root of the radiating surface,—mains included*, in square feet. Thus, a 1-inch pipe will supply 100 square feet of surface, itself included. Return pipes should be at least ¾ of an inch in diameter, and never less than *one-half* the diameter of the main—longer returns requiring larger pipe. A thorough drainage of steam pipes will effectually prevent all cracking and pounding noises therein.

One square foot of boiler surface will supply from 7 to 10 square feet of radiating surface, depending upon the size of boiler and the efficiency of its surface, as well as that of the radiating surface. Small boilers for house use should be much larger proportionately than large plants. Each horse power of boiler will supply from 240 to 360 feet of 1-inch steam pipe, or 80 to 120 square feet of radiating surface.

Cubic feet of space has little to do with amount of steam or surface required, but is a convenient factor for rough calculations. Under ordinary conditions 1 horse power will heat, approximately, in

	Cubic feet.
Brick dwellings, in blocks, as in cities, . .	15000 to 20000
" stores, in blocks, ...	10000 to 15000
" dwellings, exposed all round, . . .	10000 to 15000
" mills, shops, factories, etc., ...	7000 to 10000
Wooden dwellings, exposed, ...	7000 to 10000
Foundries and wooden shops, ...	6000 to 10000
Exhibition buildings, largely glass, etc., .	4000 to 15000

The system of heating mills and manufactories by means of pipes placed overhead, is being largely adopted in preference to radiators near the floor, particularly for rooms in which there are shafting and belting to circulate the air.

In heating buildings, care should be taken to supply the necessary moisture to keep the air from being "dry" and uncomfortable. The capacity of air for moisture rises rapidly as it is heated, it being four times as great at 72° as at 32°. For comfort, air should be kept at about "50 per cent. saturated." This would require one pound of vapor to be added to each 2500 cubic feet heated from 32° to 70°.

A much-needed attachment has recently been introduced, which acts automatically upon the steam valves of the radiators, or upon the hot-air registers and ventilators, and maintains the temperature in a room to within ½ a degree of any standard desire.

A "separator" acting by centrifugal force has been recently tested, and is very efficient in trapping out all the water entrained in steam. It will be found valuable, particularly where the steam has to be carried a long distance from the boiler, and for the purpose of preventing "hammering" of water in the pipes.

SIZES OF EXPANSION TANKS

Square Feet Radiation	Size Tanks	Capacity Gallons
150 to 300	12 x 20	10
325 to 500	12 x 30	15
525 to 700	14 x 30	20
725 to 900	16 x 30	26
925 to 1300	16 x 36	32
1325 to 2200	16 x 48	48
2225 to 3800	18 x 60	66
3900 to 5100	20 x 60	82

MISCELLANEOUS INFORMATION

B. T. U. (British Thermal Unit) = heat required to raise 1 pound of water 1 degree Fahrenheit (from 39.1 degree to 40.1 degree).—*Kent.*

1 horse power = 43.78 B. T. U. = 746 Watts.

Millimeters × 0.03937 = inches.

Millimeters ÷ 25.4 = inches.

Centimeters × 0.3937 = inches.

Centimeters ÷ 2.54 = inches.

Meters × 39.37 = inches. (Act of Congress.)

Meters × 3.281 = feet.

Meters × 1.094 = yards.

Kilometers × 0.621 = miles.

Kilometers ÷ 1.6093 = miles.

Kilometers × 3280.7 = feet.

Square millimeters × 0.0155 = square inches.

Square millimeters ÷ 645.1 = square inches.

Square centimeters × 0.155 = square inches.

Square centimeters ÷ 6.451 = square inches.

Square meters × 10.764 = square feet.

Square kilometers × 247.1 = acres.

Hectares × 2.471 = acres.

Cubic centimeters ÷ 16.383 = cubic inches.

Cubic centimeters ÷ 3.69 = fluid drachms. (U. S. P.)

Cubic centimeters ÷ 29.57 = fluid ounces. (U. S. P.)

Cubic meters × 35.315 = cubic feet.

Cubic meters × 1.308 = cubic yards.

Cubic meters × 264.2 = gallons (231 cubic inches).

Liters × 61.022 = cubic inches. (Act of Congress.)

Liters × 33.84 = fluid ounces. (U. S. P.)
Liters × 0.2642 = gallons (231 cubic inches).
Liters ÷ 3.78 = gallons (231 cubic inches).
Liters ÷ 28.316 = cubic feet.
Hectoliters × 3.531 = cubic feet.
Hectoliters × 2.84 = bushels (2150.42 cubic inches).
Hectoliters × 0.131 = cubic yards.
Hectoliters ÷ 26.42 = gallons (231 cubic inches).
Grammes × 15.432 = grains. (Act of Congress.)
Grammes × 981 = dynes.
Grammes (water) ÷ 29.57 = fluid ounces.
Grammes ÷ 28.35 = ounces avoirdupois.
Grammes per cubic centimeter ÷ 27.7 = pounds per cubic inch.
Joule × 0.7373 = foot pounds.
Kilogrammes × 2.2046 = pounds.
Kilogrammes × 35.3 = ounces avoirdupois.
Kilogrammes ÷ 1102.3 = tons (2000 pounds).
Kilogrammes per square centimeter × 14.223 = pounds per square inch.
Kilogrammeters × 7.233 = foot pounds.
Kilogrammes per meter × 0.672 = pounds per square foot.
Kilogrammes per cubic meter × 0.062 = pounds per cubic foot.
Kilogrammes per cheval vapeur × 2.235 = pounds per horse power.
Kilowatts × 1.34 = horse power.
Watts ÷ 0.7373 = foot pounds per second.
Calorie × 3.968 = B. T. U.
Cheval vapeur × 0.9863 = horse power.
(Centigrade × 1.8) + 32 = degrees Fahrenheit.
Francs × 0.193 = dollars.
Gravity, Paris = 980.94 centimeters per second.

MENSURATION

LENGTH

Circumference of circle = diameter × 3.1416.
Diameter of circle = circumference × 0.3183.
Side of square of equal periphery as circle = diameter × 0.7854.
Diameter of circle of equal periphery as square = side × 1.2732.
Side of an inscribed square = diameter of circle × 0.7071.
Length of arc = No. of degrees × diameter × 0.008727.
Circumference of circle whose diameter is 1 =

$$\pi = 3.14159265.$$

(Ratio of circumference to diameter of circle.)

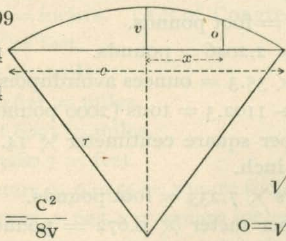
$\log. \pi = 0.4971499$

$\sqrt{\pi} = 1.772454$

$\pi^2 = 9.869604$

$$r = \frac{v^2 + \frac{c^2}{4}}{2v}$$

or, very nearly, $= \frac{c^2}{8v}$



$\frac{1}{\pi} = 0.318310$

$\frac{1}{\pi^2} = 0.101321$

$\sqrt{\frac{1}{\pi}} = 0.564190$

$o = \sqrt{r^2 - x^2} - (r - v)$

$$v = r - \sqrt{r^2 - \frac{c^2}{4}}\text{; or, very nearly, } = \frac{c^2}{8r}$$

AREA

Triangle = base × half perpendicular height.
Parallelogram = base × perpendicular height.
Trapezoid = half the sum of the parallel sides × perpendicular height.
Trapezium, found by dividing into two triangles.
Circle = diameter squared × 0.7854; or,
= circumference squared × 0.07958.
Sector of circle = length of arc × half radius.

Segment of circle = area of sector less triangle; also, for flat segments very nearly $= \frac{4\,v}{3}\sqrt{0.388\,v^2 + \frac{c^2}{4}}$.

Side of square of equal area as circle = diameter $\times$ 0.8862; also, = circumference $\times$ 0.2821.

Diameter of circle of equal area as square = side $\times$ 1.1284.

Parabola = base $\times$ ⅔ height.

Ellipse = long diameter $\times$ short diameter $\times$ 0.7854.

Regular polygon = sum of sides $\times$ half perpendicular distance from center to sides.

Surface of cylinder = circumference $\times$ height + area of both ends.

Surface of sphere = diameter squared $\times$ 3.1416; also, = circumference $\times$ diameter.

Surface of a right pyramid or cone = periphery or circumference of base $\times$ half slant height.

Surface of a frustrum of a regular right pyramid or cone = sum of peripheries or circumferences of the two ends $\times$ half slant height + area of both ends.

SOLID CONTENTS

Prism, right or oblique, = area of base $\times$ perpendicular height.

Cylinder, right or oblique, = area of section at right angles to sides $\times$ length of side.

Sphere = diameter cubed $\times$ 0.5236; also, = surface $\times$ ⅙ diameter.

Pyramid or cone, right or oblique, regular or irregular, = area of base $\times$ ⅓ perpendicular height.

WEIGHTS AND MEASURES

AVOIRDUPOIS OR ORDINARY COMMERCIAL WEIGHT

UNITED STATES AND BRITISH

Gross Ton	Cwts.	Pounds	Ounces
1.	20.	2240.	35840.
0.050	1.	112.	1792.
	0.0089	1.	16.
		0.0625	1.

1 pound = 27.7 cubic inches of distilled water at its maximum density (39° Fahrenheit).

LONG MEASURE

UNITED STATES AND BRITISH

Miles	Rods	Yards	Feet	Inches
1.	320.	1760.	5280.	63360.
0.003125	1.	5.5	16.5	198.
0.000568	0.1818	1.	3.	36.
0.0001894	0.0606	0.3333	1.	12.
0.0000158	0.005051	0.02778	0.08333	1.

The British measures are shorter than those of the United States by about 1 part in 17,230, or 3.677 inches in a mile.

A fathom = 6 feet. A Gunter's surveying chain = 66 feet, or 4 rods, 80 chains making a mile.

SQUARE OR LAND MEASURE

UNITED STATES AND BRITISH

Sq. Miles	Acres	Sq. Rods	Sq. Yards	Sq. Feet	Sq. Inches
1.	640.	102400.	3097600.	27878400.	. . .
	1.	160.	4840.	43560.	6272640.
		1.	30.25	272.25	39204.
		0.0331	1.	9.0	1296.
			0.111	1.	144.
				0.00694	1.

CUBIC OR SOLID MEASURE

UNITED STATES AND BRITISH

1728 cubic inches = 1 cubic foot.
27 cubic feet = 1 cubic yard.
A cord of wood = 4′ × 4′ × 8′ = 128 cubic feet.
A perch of masonry = 16.5′ × 1.5′ × 1′ = 24.75 cubic feet, but is generally assumed at 25 cubic feet.

DRY MEASURE

UNITED STATES ONLY

Struck Bush.	Pecks	Quarts	Pints	Gallons	Cubic Inch
1	4	32.	64	8.	2150.
	1	8.	16	2.	537.6
		1.	2	0.25	67.2
		0.5	1	0.125	33.6
		4.	8	1.	268.8

A gallon of liquid measure = 231 cubic inches.
A heaped bushel = 1¼ struck bushels. The cone in a heaped bushel must be not less than 6 inches high.
A barrel of U. S. hydraulic cement = 300 to 310 pounds, usually, and of genuine Portland cement = 425 pounds.

To reduce U. S. dry measures to British imperial of the same name, divide by 1.032.

NAUTICAL MEASURE

A nautical or sea mile is the length of a minute of longitude of the earth at the equator at the level of the sea. It is assumed at 6086.07 feet = 1.152664 statute or land miles by the United States Coast Survey.

3 nautical miles = 1 league.

WEIGHT OF ROUND AND SQUARE IRON

PER LINEAL FOOT

Size in Inches	● Weight in Pounds	■ Weight in Pounds	Size in Inches	● Weight in Pounds	■ Weight in Pounds
$\frac{3}{16}$	.0930	.1184	$1\frac{3}{4}$	8.101	10.31
$\frac{7}{32}$	.1266	.1612	$1\frac{7}{8}$	9.300	11.84
$\frac{1}{4}$	.1653	.2105	2	10.58	13.47
$\frac{9}{32}$	.2093	.2665	$2\frac{1}{8}$	11.95	15.21
$\frac{5}{16}$	.2583	.3290	$2\frac{1}{4}$	13.39	17.05
$\frac{11}{32}$	.3126	.3980	$2\frac{3}{8}$	14.92	19.00
$\frac{3}{8}$	.3720	.4736	$2\frac{1}{2}$	16.53	21.05
$\frac{13}{32}$	.4365	.5558	$2\frac{5}{8}$	18.23	23.21
$\frac{7}{16}$	.5063	.6446	$2\frac{3}{4}$	20.01	25.47
$\frac{1}{2}$	.6613	.8420	$2\frac{7}{8}$	21.87	27.84
$\frac{9}{16}$	.8370	1.066	3	23.81	30.31
$\frac{5}{8}$	1.033	1.316	$3\frac{1}{4}$	27.94	35.57
$\frac{11}{16}$	1.250	1.592	$3\frac{1}{2}$	32.41	41.26
$\frac{3}{4}$	1.488	1.895	$3\frac{3}{4}$	37.20	47.37
$\frac{13}{16}$	1.746	2.223	4	42.33	53.89
$\frac{7}{8}$	2.025	2.579	$4\frac{1}{4}$	47.78	60.84
$\frac{15}{16}$	2.325	2.960	$4\frac{1}{2}$	53.57	68.20
1	2.645	3.368	$4\frac{3}{4}$	59.69	75.99
$1\frac{1}{16}$	2.986	3.803	5	66.13	84.20
$1\frac{1}{8}$	3.348	4.263	$5\frac{1}{4}$	72.91	92.83
$1\frac{3}{16}$	3.730	4.750	$5\frac{1}{2}$	80.02	101.9
$1\frac{1}{4}$	4.133	5.263	$5\frac{3}{4}$	87.46	111.4
$1\frac{5}{16}$	4.557	5.802	6	95.23	121.3
$1\frac{3}{8}$	5.001	6.368	$6\frac{1}{2}$	111.8	142.3
$1\frac{7}{16}$	5.466	6.960	7	129.6	165.0
$1\frac{1}{2}$	5.952	7.578	$7\frac{1}{2}$	148.8	189.5
$1\frac{9}{16}$	6.458	8.223	8	169.3	215.6
$1\frac{5}{8}$	6.985	8.893	$8\frac{1}{2}$	191.1	243.4

WEIGHT OF FLAT IRON

PER LINEAL FOOT

Width, Inches	Thickness in Inches									
	1/8	3/16	1/4	5/16	3/8	1/2	5/8	3/4	7/8	1
1/2	.211	.361	.422	.491	.634	. . .	. . .	. . .	. . .	. . .
5/8	.260	.420	.510	.640	.784	.90	. . .	. . .	. . .	. . .
3/4	.316	.471	.633	.790	.950	1.26	1.58	. . .	. . .	. . .
7/8	.370	.551	.730	.915	1.09	1.46	1.82	2.19	. . .	. . .
1	.421	.623	.832	1.04	1.25	1.67	2.08	2.50	2.9[illegible]	. . .
1 1/8	.475	.700	.940	1.17	1.41	1.88	2.34	2.81	3.28	3.75
1 1/4	.524	.782	1.04	1.30	1.56	2.08	2.60	3.12	3.64	4.17
1 3/8	.574	.860	1.15	1.43	1.72	2.29	2.86	3.44	4.01	4.5[illegible]
1 1/2	.631	.940	1.25	1.56	1.88	2.50	3.13	3.75	4.38	5.00
1 5/8	.682	1.02	1.35	1.69	2.03	2.71	3.38	4.01	4.74	5.42
1 3/4	.730	1.09	1.46	1.82	2.19	2.92	3.65	4.37	5.10	5.83
2	.831	1.24	1.67	2.08	2.50	3.33	4.17	5.00	5.83	6.67
2 1/4	.945	1.41	1.88	2.34	2.81	3.75	4.69	5.63	6.51	7.50
2 1/2	1.04	1.56	2.08	2.60	3.12	4.17	5.21	6.2	7.29	8.33
2 3/4	1.14	1.72	2.29	2.86	3.44	4.59	5.73	6.8	8.02	9.17
3	1.25	1.87	2.50	3.12	3.75	5.00	6.25	7.0	8.75	10.00
3 1/4	1.35	2.03	2.71	3.38	4.07	5.42	6.77	8.12	9.48	10.83
3 1/2	1.46	2.19	2.92	3.65	4.38	5.83	7.29	8.75	10.21	11.61
3 3/4	1.56	2.34	3.12	3.90	4.69	6.25	7.81	9.37	10.94	12.50
4	1.67	2.50	3.33	4.17	5.00	6.67	8.33	10.00	11.67	13.33
4 1/2	1.87	2.81	3.75	4.69	5.63	7.50	9.38	11.25	13.13	15.60
5	2.08	3.13	4.17	5.21	6.25	8.34	10.42	12.50	14.59	16.67
6	2.50	3.75	5.00	6.25	7.50	10.00	12.50	15.00	17.50	20.00

WEIGHT OF BOLTS PER HUNDRED

SQUARE HEADS

DIAMETER	1/4	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
LENGTH	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1 1/2 inches	3.9	6.2	9.7	14.7	20.4	26.	37.	58.	...	...	...	...	...	...
1 3/4 "	4.2	6.7	10.5	15.5	21.3	27.4	37.9	60.5	...	...	...	...	...	...
2 "	4.6	7.2	11.3	16.5	22.4	29.	39.9	63.2	97.7	145	...	...	...	...
2 1/4 "	5.	7.7	12.1	17.5	23.6	30.6	42.	66.	101 6	149	...	...	...	...
2 1/2 "	5.4	8.2	12.9	18.5	25.	32.2	44.1	69.	105.6	153	...	...	...	...
2 3/4 "	5.8	8.7	13.7	19.5	26.4	33.8	46.2	72.1	109.7	158	...	...	...	...
3 "	6.2	9.3	14.5	20.5	27.8	35.4	48.3	75.2	113.8	163	200	289	350	480
3 1/2 "	6.9	10.4	16.1	22.6	30.6	38.7	52.5	81.4	122.	174	213	305	370	500
4 "	7.6	11.5	17.7	24.7	33.4	42.	56.7	87.6	130.2	185	226	322	390	520
4 1/2 "	8.3	12.6	19.2	26.8	36.2	45.3	60.9	93.8	138.4	196	240	339	410	545
5 "	9.	13.7	20.7	28.9	39.	48.6	65.1	100.	146.6	207	255	356	430	570
5 1/2 "	9.7	14.8	22.2	31.	41.8	51.9	69.2	106.1	154.9	218	270	373	450	595
6 "	10.4	15.9	23.7	33.1	44.6	55.2	73.4	112.2	163.2	229	285	390	470	620
6 1/2 "	11.1	17.	25.2	35.2	47:4	58.5	77.6	118.3	171.5	240	300	407	490	645
7 "	11.8	18.1	26.7	37.3	50.2	61.8	81.8	124.4	179.8	251	315	434	510	670
7 1/2 "	12.5	19.2	28.2	39.4	53.1	65.1	86.	130.5	187.1	262	330	451	530	695
8 "	13.2	20.3	29.7	41.5	56.	68.5	90.	136.6	195.4	273	345	468	550	725
9 "	...	...	33.1	45.7	61.5	75.2	98.	148.8	212.	295	375	505	590	775
10 "	...	...	36.5	49.9	67.	81.9	106.3	161.	229.	317	405	540	630	825
11 "	...	...	40.	54.1	72.5	88.7	114.6	173.2	246.	339	435	575	670	875
12 "	...	...	43.5	58.3	78.	95.5	122.9	184.4	263.	361	465	610	710	925
13 "	...	...	...	...	83.5	102.3	131.2	196.6	280.	383	495	645	751	975
14 "	...	...	...	...	89.	109.1	139.5	208.8	297.	405	525	680	793	1025
15 "	...	...	...	...	94.5	116.	148.	221.	314.	427	555	715	835	1075
16 "	...	...	...	...	100.	123.	156.5	233.2	331.	449	585	750	877	1125
17 "	...	...	...	...	105.5	130.	165.	245.4	348.	471	615	785	919	1175
18 "	...	...	...	...	111.	137.	173.5	257.6	365.	493	645	810	961	1225
19 "	...	...	...	...	116.5	144.	182.	269.8	382.	515	675	845	1003	1275
20 "	...	...	...	...	122.	151.	191.	282.	399.	537	705	880	1045	1325

WEIGHT OF BOLTS PER HUNDRED

Hexagon Heads and Nuts

DIMENSIONS IN INCHES

DIAM.	¼	⅜	½	⅝	¾	⅞	1	1⅛	1¼	1⅜	1½
Length	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1½	3.4	8.5	17.7	32.5	49.0	..	..	..	..	..	..
1¾	3.7	9.3	18.6	33.4	51.5	..	..	..	..	..	..
2	4.1	10.1	19.7	35.4	54.2	86.6	128	..	..	..	..
2¼	4.5	10.9	20.9	37.5	57.0	90.6	132	..	..	.	..
2½	4.9	11.7	22.3	39.9	60.0	94.6	136	..	..	..	..
2¾	5.3	12.5	23.7	41.7	63.1	98.7	141	..	..	..	..
3	5.7	13.3	25.1	43.8	66.2	102.8	144	174	255	310	430
3½	6.1	14.1	26.6	45.7	69.4	107.0	151	187	271	330	450
4	6.8	15.7	29.4	49.9	75.6	115.2	162	200	288	350	470
4½	7.5	17.0	32.2	56.1	81.8	123.4	173	214	305	370	495
5	8.2	18.7	35.0	58.3	88.0	131.6	184	229	322	390	520
5½	8.9	20.2	37.8	62.4	94.1	139.9	195	244	339	410	545
6	9.6	21.7	40.6	66.6	100.2	148.2	206	259	356	430	570
6½	10.3	23.2	43.4	70.8	106.3	156.5	217	274	373	450	595
7	11.0	24.7	46.2	75.0	112.4	164.8	228	289	400	470	620
7½	11.7	26.2	49.1	79.2	118.5	172.1	239	304	417	490	645
8	12.4	27.7	52.0	83.2	124.6	180.3	250	319	424	510	670
9	..	29.7	54.8	87.0	130.8	189.0	262	336	465	530	700
10	..	33.1	60.3	95.0	143.0	206.0	284	366	500	570	750
11	..	36.6	65.8	103.6	155.2	223.0	306	396	535	610	800
12	..	40.1	71.3	111.9	166.4	240.0	328	426	570	650	850
13	..	..	76.8	120.2	178.6	257.0	350	456	605	691	900
14	..	..	82.3	128.5	190.8	274.0	372	486	640	733	950
15	..	..	87.8	137.0	203.0	291.0	384	516	675	775	1000
16	..	..	93.3	145.5	215.2	308.0	416	546	710	817	1050
17	..	..	98.8	154.0	227.4	325.0	438	576	745	859	1100
18	..	..	104.3	162.5	239.6	342.0	460	606	780	901	1150

WEIGHT AND STRENGTH OF IRON BOLTS (TRAUTWINE)

Ends Enlarged or Upset				Equiv. of Ends Not Enlarged		Ends Enlarged or Upset				Equiv. of Ends Not Enlarged	
Diam. of Shank	Weight Per Foot Run	Breaking Strain	Breaking Strain	Diam. of Shank	Weight Per Foot Run	Diam. of Shank	Weight Per Foot Run	Breaking Strain	Breaking Strain	Diam. of Shank	Weight Per Foot Run
Inches	Pounds	Tons	Pounds	Inches	Pounds	Inches	Pounds	Tons	Pounds	Inches	Pounds
1/8	.0414	.245	549	. . .	. . .	1 3/4	8.10	45.7	102368	2.14	12.0
3/16	.093	.553	1239	. .	. . .	1 13/16	8.69	49.0	109760	2.22	12.9
1/4	.165	.983	2202	.35	.321	1 7/8	9.30	52.5	117600	2.30	13.8
5/16	.258	1.53	3427	.43	.452	1 15/16	9.93	56.0	125440	2.38	14.7
3/8	.372	2.21	4950	.50	.654	2	10.6	59.7	133728	2.45	15.7
7/16	.506	3.00	6720	.58	.897	2 1/8	12.0	63.8	142912	2.59	17.5
1/2	.661	3.93	8803	.66	1.14	2 1/4	13.4	71.6	160384	2.73	19.5
9/16	.837	4.97	11133	.73	1.41	2 3/8	14.9	79.7	178528	2.88	21.6
5/8	1.03	6.14	13754	.80	1.67	2 1/2	16.5	88.4	198016	3.02	23.9
11/16	1.25	7.42	16621	.88	2.03	2 5/8	18.2	97.4	218176	3.16	26.1
3/4	1 49	8.83	19779	.96	2.41	2 3/4	20.0	106.9	239456	3.30	28.5
13/16	1.75	10.4	23296	1.04	2.81	2 7/8	21.9	116.8	261632	3.45	31.1
7/8	2.03	12.0	26880	1.12	3.26	3	23.8	127.2	284928	3.60	33.9
15/16	2.33	13.8	30912	1.20	3.77	3 1/4	27.9	141.0	315840	3.86	39.1
1	2.65	15.7	35168	1.27	4.27	3 1/2	32.4	163.6	366464	4.12	44.4
1 1/16	2.99	16.8	37632	1.35	4.77	3 3/4	37.2	187.7	420448	4.41	51.0
1 1/8	3.35	18.9	42336	1.42	5.28	4	42.3	213.6	478464	4.70	57.8
1 3/16	3.73	21.1	47264	1.49	5.81	4 1/4	47.8	227.0	508480	4.98	65.2
1 1/4	4.13	23.3	52192	1.55	6.39	4 1/2	53.6	254.5	570080	5.25	72.9
1 5/16	4.56	25.7	57568	1.64	7.04	4 3/4	59.7	283.5	635040	5.53	80.5
1 3/8	5.00	28.2	63168	1.72	7.74	5	66.1	314.2	703808	5.80	88.1
1 7/16	5.47	30.8	68992	1.80	8.48	5 1/4	72.9	324.7	727328	6.08	97.0
1 1/2	5 95	33.6	75264	1.87	9.20	5 1/2	80.0	356.4	798336	6.36	106.
1 9/16	6.46	36.4	81536	1.94	9.88	5 3/4	87.5	389.5	872480	6.63	116.
1 5/8	6.99	39.4	88256	2.00	10.6	6	95.2	424.1	949984	6.90	126.
1 11/16	7.53	42.5	95200	2.07	11.3						

Proportions for U. S. Standard

SCREW THREADS AND NUTS

Diameter of Screw	Threads per Inch	Diameter at Root of Thread	Short Diameter of Nuts	Long Diameter, Hexagon Nuts	Long Diameter, Square Nuts	Thickness of Nuts
1/4	20	.185	1/2	37/64	7/10	1/4
5/16	18	.240	19/32	11/16	10/12	5/16
3/8	16	.294	11/16	51/64	63/64	3/8
7/16	14	.344	25/32	9/10	1 7/64	7/16
1/2	13	.400	7/8	1	1 15/64	1/2
9/16	12	.454	31/32	1 1/8	1 23/64	9/16
5/8	11	.507	1 1/16	1 7/32	1 1/2	5/8
3/4	10	.620	1 1/4	1 7/16	1 49/64	3/4
7/8	9	.731	1 7/16	1 21/32	2 1/32	7/8
1	8	.837	1 5/8	1 7/8	2 19/64	1
1 1/8	7	.940	1 13/16	2 3/32	2 9/16	1 1/8
1 1/4	7	1.065	2	2 5/16	2 53/64	1 1/4
1 3/8	6	1.160	2 3/16	2 17/32	3 3/32	1 3/8
1 1/2	6	1.284	2 3/8	2 3/4	3 23/64	1 1/2
1 5/8	5 1/2	1.389	2 9/16	2 31/32	3 5/8	1 5/8
1 3/4	5	1.491	2 3/4	3 3/16	3 57/64	1 3/4
1 7/8	5	1.616	2 15/16	3 13/32	4 5/32	1 7/8
2	4 1/2	1.712	3 1/8	3 5/8	4 27/64	2
2 1/4	4 1/2	1.962	3 1/2	4 1/16	4 61/64	2 1/4
2 1/2	4	2.176	3 7/8	4 1/2	5 31/64	2 1/2
2 3/4	4	2.426	4 1/4	4 29/32	6	2 3/4
3	3 1/2	2.629	4 5/8	5 3/8	6 17/32	3
3 1/4	3 1/2	2.879	5	5 13/16	7 1/16	3 1/4
3 1/2	3 1/4	3.100	5 3/8	6 7/64	7 39/64	3 1/2
3 3/4	3	3.317	5 3/4	6 21/32	8 1/8	3 3/4
4	3	3.567	6 1/8	7 3/32	8 41/64	4

WEIGHT AND STRENGTH OF IRON CHAINS

Assuming 20 tons per square inch as the average breaking strain of a single straight bar of ordinary rolled iron, 1 inch in diameter, or 1 inch square; 19 tons, from 1 to 2 inches; and 18 tons, from 2 to 3 inches. Chains of superior iron will require $\frac{1}{4}$ to $\frac{1}{3}$ more to break them.

Diameter of Rod of which Links are made	Weight of Chain per Foot Run	Breaking Strain of the Chain		Diameter of Rod of which Links are made	Weight of Chain per Foot Run	Breaking Strain of the Chain	
Inches	Pounds	Pounds	Tons	Inches	Pounds	Pounds	Tons
$\frac{3}{16}$	.325	1731	.773	1	9.26	49280	22.00
$\frac{1}{4}$	.579	3069	1.37	$1\frac{1}{8}$	11.7	59226	26.44
$\frac{5}{16}$	.904	4794	2.14	$1\frac{1}{4}$	14.5	73114	32.64
$\frac{3}{8}$	1.30	6922	3.09	$1\frac{3}{8}$	17.5	88301	39.42
$\frac{7}{16}$	1.78	9408	4.20	$1\frac{1}{2}$	20.8	105280	47.00
$\frac{1}{2}$	2.31	12320	5.50	$1\frac{5}{8}$	24.4	123514	55.14
$\frac{9}{16}$	2.93	15590	6.96	$1\frac{3}{4}$	28 4	143293	63.97
$\frac{5}{8}$	3.62	19219	8.58	$1\frac{7}{8}$	32.6	164505	73.44
$\frac{11}{16}$	4.38	23274	10.39	2	37.0	187152	83.55
$\frac{3}{4}$	5.21	27687	12.36	$2\frac{1}{4}$	46.9	224448.	100.2
$\frac{13}{16}$	6.11	32301	14.42	$2\frac{1}{2}$	57.9	277088	123.7
$\frac{7}{8}$	7.10	37632	16.80	$2\frac{3}{4}$	70.0	335328	149.7
$\frac{15}{16}$	8.14	43277	19.32	3	83.3	398944	178.1

WEIGHT AND SPECIFIC GRAVITY OF VARIOUS MATERIALS

Name	Weight in Pounds Per Cu. Ft.	Per Cu. In.	Specific Gravity	Name	Weight in Pounds Per Cu. Ft.	Per Cu. In.	Specific Gravity
Water, Pure, 60° F.	62.3	.036	1.00	Glass, Crown, .	156	.090	2.52
" Sea, . . .	64.3	.037	1.03	" Plate, . .	172	.099	2.76
METALS				" Flint, . .	192	.111	3.07
Iron, Cast, . . .	450	.260	7.20	Granite, ...	164	.095	2.63
" Wrought, .	480	.277	7.69	Gypsum, ...	143	.082	2.28
" Steel, . . .	490	.283	7.84	Lime, Quick, . .	53	.030	0.84
Aluminum, . . .	166	.096	2.67	Limestone, . . .	168	.097	2.70
Brass, ...	524	.302	8.40	Marl, ...	119	.069	1.90
Bronze, ...	534	.308	8.56	Masonry, from,	120	.068	1.90
Copper, ...	548	.317	8.80	" to, . .	144	.083	2.30
Gold, ...	1208	.697	19.36	Mortar, Average,	109	.063	1.75
Lead, ...	710	.410	11.40	Mud, ...	102	.059	1.63
Platinum, ...	1344	.775	21.53	Petroleum, . . .	55	.032	0.88
Silver, ...	654	.377	10.47	Plumbago, . . .	140	.081	2.27
Tin, ...	455	.262	7.29	Sand, Average, .	100	.058	1.61
Zinc, ...	437	.252	7.00	Sandstone, . . .	144	.083	2.30
MINERALS				Shale, ...	162	.094	2.60
Asphalt, ...	87	.050	1.40	Slate, ...	175	.101	2.80
Brick, Soft, . . .	100	.058	1.60	Trap, ...	170	.098	2.72
" Hard, . .	125	.071	2.00	WOODS			
" Pressed, .	135	.077	2.16	Apple, ...	49	.028	0.79
Brickwork, Ord'y,	112	.064	1.80	Ash, ...	47	.027	0.75
" Fine,	120	.068	2.10	Cedar, ...	35	.020	0.55
Clay, ...	119	.068	1.92	Cherry, ...	42	.024	0.67
Coal, Anthracite,	96	.056	1.57	Chestnut, . . .	41	.023	0.66
" Bituminous,	84	.048	1.35	Hemlock, . . .	25	.015	0.40
Coke, ...	63	.036	1.01	Maple, ...	49	.028	0.78
Concrete Cement,	130	.075	2.20	Oak, White, . .	50	.030	0.80
Earth, from, . .	90	.052	1.63	" Red, . . .	45	.026	0.73
" to, . . .	135	.068	1.92	Pine, White, . .	30	.017	0.48
Felspar, ...	162	.094	2.60	" Yellow, .	35	.019	0.56
Flint, ...	164	.095	2.63	Walnut, ...	41	.023	0.65

CAST-IRON PIPE

WEIGHT OF A LINEAL FOOT

Bore in Inches	Thickness of Metal in Inches								
	¼	⅜	½	⅝	¾	⅞	1	1⅛	1¼
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
2	5.5	8.7	12.3	16.1	20.3	24.7	29.5	34.5	39.9
2½	6.8	10.6	14.7	19.2	24.0	29.0	34.4	40.0	46.0
3	7.9	12.4	17.2	22.2	27.6	32.3	39.3	45.6	52.2
3½	9.2	14.3	19.6	25.3	31.3	37.6	44.2	51.0	58.3
4	10.4	16.1	22.1	28.4	35.0	41.9	49.1	56.6	64.4
4½	11.7	18.0	24.5	31.5	38.7	46.2	54.0	62.1	70.6
5	12.9	19.8	27.0	34.5	42.3	50.5	59.9	67.7	76.7
5½	14.1	21.6	29.5	37.6	46.0	54.8	63.8	73.2	82.9
6	15.3	23.5	31.9	40.7	49.7	59.1	68.7	78.7	89.0
7	17.8	27.2	36.9	46.8	57.1	67.7	78.5	89.8	101.
8	20.3	30.8	41.7	52.9	64.4	76.2	88.4	101.	114.
9	22.7	34.5	46.6	59.1	71.8	84.8	98.2	112.	126.
10	25.2	38.2	51.5	65.2	79.2	93.4	108.	123.	138.
11	27.6	41.9	56.5	71.3	86.5	102.	118.	134.	150.
12	30.1	45.6	61.4	77.5	93.9	111.	128.	145.	163.
13	32.5	49.2	66.3	83.6	101.	119.	138.	156.	175.
14	35.0	52.9	71.2	89.7	109.	128.	147.	167.	187.
15	37.4	56.6	76.1	95.9	116.	136.	157.	178.	199.
16	39.1	60.3	81.0	102.	123.	145.	167.	189.	212.
18	44.8	67.7	90.9	114.	138.	162.	187.	211.	236.
20	49.7	75.2	101.	127.	153.	179.	206.	233.	261.
22	54.6	82.6	111.	139.	168.	197.	226.	255.	285.
24	59.6	89.9	120.	151.	182.	214.	245.	278.	310.
26	64.5	97.3	131.	164.	198.	231.	266.	300.	335.
28	69.4	105.	140.	176.	212.	249.	286.	323.	360.
30	74.2	112.	150.	188.	227.	266.	305.	345.	384.

NOTE.—For each joint, add a foot to length of pipe.

Minimum and Maximum Weights and Dimensions of Standard Angles

EQUAL LEGS

Thickness of Metal	Size	Weight per Foot
7/8	6 x 6	33.1
13/16	6 x 6	30.9
3/4	6 x 6	28.7
11/16	6 x 6	26.5
5/8	6 x 6	24.2
9/16	6 x 6	21.9
1/2	6 x 6	19.6
7/16	6 x 6	17.2
13/16	4 x 4	19.9
3/4	4 x 4	18.5
11/16	4 x 4	17.1
5/8	4 x 4	15.7
9/16	4 x 4	14.3
1/2	4 x 4	12.8
7/16	4 x 4	11.3
3/8	4 x 4	9.8
5/16	4 x 4	8.2
13/16	3 1/2 x 3 1/2	17.1
3/4	3 1/2 x 3 1/2	16.0
11/16	3 1/2 x 3 1/2	14.8
5/8	3 1/2 x 3 1/2	13.6
9/16	3 1/2 x 3 1/2	12.3
1/2	3 1/2 x 3 1/2	11.1
7/16	3 1/2 x 3 1/2	9.8
3/8	3 1/2 x 3 1/2	8.5
5/8	3 x 3	11.4
9/16	3 x 3	10.4
1/2	3 x 3	9.4
7/16	3 x 3	8.3
3/8	3 x 3	7.2

Thickness of Metal	Size	Weight per Foot
5/16	3 x 3	6.1
1/4	3 x 3	4.9
1/2	2 1/2 x 2 1/2	7.7
7/16	2 1/2 x 2 1/2	6.8
3/8	2 1/2 x 2 1/2	5.9
5/16	2 1/2 x 2 1/2	5.0
1/4	2 1/2 x 2 1/2	4.1
7/16	2 x 2	5.3
3/8	2 x 2	4.7
5/16	2 x 2	4.0
1/4	2 x 2	3.2
3/16	2 x 2	2.5
7/16	1 3/4 x 1 3/4	4.6
3/8	1 3/4 x 1 3/4	4.0
5/16	1 3/4 x 1 3/4	3.4
1/4	1 3/4 x 1 3/4	2.8
3/16	1 3/4 x 1 3/4	2.1
3/8	1 1/2 x 1 1/2	3.4
5/16	1 1/2 x 1 1/2	2.9
1/4	1 1/2 x 1 1/2	2.4
3/16	1 1/2 x 1 1/2	1.8
5/16	1 1/4 x 1 1/4	2.4
1/4	1 1/4 x 1 1/4	1.9
3/16	1 1/4 x 1 1/4	1.5
1/8	1 1/4 x 1 1/4	1.0
1/4	1 x 1	1.5
3/16	1 x 1	1.2
1/8	1 x 1	0.8
3/16	3/4 x 3/4	0.8
1/8	3/4 x 3/4	0.6

Angles vary only by 1/16 inch.

Minimum and Maximum Weights and Dimensions of Standard Angles

UNEQUAL LEGS

Thickness of Metal	Size	Weight per Foot
$\frac{7}{8}$	6 x 4	27.2
$\frac{13}{16}$	6 x 4	25.4
$\frac{3}{4}$	6 x 4	23.6
$\frac{11}{16}$	6 x 4	21.8
$\frac{5}{8}$	6 x 4	20.0
$\frac{9}{16}$	6 x 4	18.1
$\frac{1}{2}$	6 x 4	16.2
$\frac{7}{16}$	6 x 4	14.3
$\frac{3}{8}$	6 x 4	12.3
$\frac{7}{8}$	6 x 3½	25.7
$\frac{13}{16}$	6 x 3½	24.0
$\frac{3}{4}$	6 x 3½	22.3
$\frac{11}{16}$	6 x 3½	20.6
$\frac{5}{8}$	6 x 3½	18.9
$\frac{9}{16}$	6 x 3½	17.1
$\frac{1}{2}$	6 x 3½	15.3
$\frac{7}{16}$	6 x 3½	13.5
$\frac{3}{8}$	6 x 3½	11.7
$\frac{7}{8}$	5 x 3½	22.7
$\frac{13}{16}$	5 x 3½	21.3
$\frac{3}{4}$	5 x 3½	19.8
$\frac{11}{16}$	5 x 3½	18.3
$\frac{5}{8}$	5 x 3½	16.8
$\frac{9}{16}$	5 x 3½	15.2
$\frac{1}{2}$	5 x 3½	13.6
$\frac{7}{16}$	5 x 3½	12.0
$\frac{3}{8}$	5 x 3½	10.4
$\frac{13}{16}$	5 x 3	19.9
$\frac{3}{4}$	5 x 3	18.5
$\frac{11}{16}$	5 x 3	17.1
$\frac{5}{8}$	5 x 3	15.7
$\frac{9}{16}$	5 x 3	14.2
$\frac{1}{2}$	5 x 3	12.8
$\frac{7}{16}$	5 x 3	11.3
$\frac{3}{8}$	5 x 3	9.8
$\frac{5}{16}$	5 x 3	8.2

Thickness of Metal	Size	Weight per Foot
$\frac{13}{16}$	4 x 3	17.1
$\frac{3}{4}$	4 x 3	16.0
$\frac{11}{16}$	4 x 3	14.8
$\frac{5}{8}$	4 x 3	13.6
$\frac{9}{16}$	4 x 3	12.3
$\frac{1}{2}$	4 x 3	11.1
$\frac{7}{16}$	4 x 3	9.8
$\frac{3}{8}$	4 x 3	8.5
$\frac{5}{16}$	4 x 3	7.1
$\frac{13}{16}$	3½ x 3	15.7
$\frac{3}{4}$	3½ x 3	14.7
$\frac{11}{16}$	3½ x 3	13.6
$\frac{5}{8}$	3½ x 3	12.5
$\frac{9}{16}$	3½ x 3	11.4
$\frac{1}{2}$	3½ x 3	10.2
$\frac{7}{16}$	3½ x 3	9.1
$\frac{3}{8}$	3½ x 3	7.8
$\frac{5}{16}$	3½ x 3	6.6
$\frac{11}{16}$	3½ x 2½	12.4
$\frac{5}{8}$	3½ x 2½	11.4
$\frac{9}{16}$	3½ x 2½	10.4
$\frac{1}{2}$	3½ x 2½	9.4
$\frac{7}{16}$	3½ x 2½	8.3
$\frac{3}{8}$	3½ x 2½	7.2
$\frac{5}{16}$	3½ x 2½	6.1
$\frac{1}{4}$	3½ x 2½	4.9
$\frac{9}{16}$	3 x 2½	9.5
$\frac{1}{2}$	3 x 2½	8.5
$\frac{7}{16}$	3 x 2½	7.6
$\frac{3}{8}$	3 x 2½	6.6
$\frac{5}{16}$	3 x 2½	5.5
$\frac{1}{4}$	3 x 2½	4.5
$\frac{1}{2}$	2½ x 2	6.8
$\frac{7}{16}$	2½ x 2	6.1
$\frac{3}{8}$	2½ x 2	5.3
$\frac{5}{16}$	2½ x 2	4.5
$\frac{1}{4}$	2½ x 2	3.7
$\frac{3}{16}$	2½ x 2	2.8

Angles vary only by $\frac{1}{16}$ inch.

Minimum and Maximum Weights and Dimensions of Standard I Beams

Depth of Beam in Inches	Weight per Foot: Min.	Coefficient of Strength for Minimum Weights	For every lb. Incr. in Weight of Beam add to Coefficient for Min. Wts.	Intermediate	Max.	Flange Width: Min.	Flange Width: Max.	Web Thickness: Min.	Web Thickness: Max.	Increase of Web and Flanges for each lb. Increase of Weight
24	80.00	1855900	12600	Vary by 5 lbs., ...	100.00	7.00	7.25	.50	.75	.0123
20	64.00	1237150	10450	65 lbs. then vary by 5 lbs.	75.00	6.25	6.40	.50	.65	.015
15	42.00	628300	7800	45 " " " " 5 "	55.00	5.50	5.75	.41	.66	.020
12	31.50	383700	6300	. . . .	35.00	5.00	5.09	.35	.44	.025
10	25.00	260500	5200	Vary by 5 lbs., ...	40.00	4.66	5.10	.31	.75	.029
9	21.00	201300	4700	25 lbs. then vary by 5 lbs.	35.00	4.33	4.77	.29	.73	.033
8	18.00	151700	4200	Vary by 2½ lbs., ...	25.50	4.00	4.27	.27	.54	.037
7	15.00	110400	3600	" " 2½ "	20.00	3.66	3.87	.25	.46	.042
6	12.25	77500	3100	" " 2½ "	17.25	3.33	3.57	.23	.47	.049
5	9.75	51600	2600	" " 2½ "	14.75	3.00	3.29	.21	.50	.059
4	7.50	31800	2100	Vary by 1 lb., ...	10.50	2.66	2.88	.19	.41	.074
3	5.50	17600	1560	" " 1 "	7.50	2.33	2.52	.17	.36	.098

The above coefficients are based upon a fibre stress of 16,000 pounds per square inch, used for buildings.

For bridges coefficients should be taken at three-quarters of above amount. To find the distributed safe load in pounds a beam will carry in a given span, divide the coefficients given for size and weight beam by the length of span in feet. To find the coefficient of strength for a given equally distributed load and span, multiply the load in pounds by the span in feet between centres of supports. Beams having the load concentrated in middle of span will safely carry one-half the amount the same beam would carry if the load was equally distributed.

Minimum and Maximum Weights and Dimensions of Standard Channels

Depth of Channel in Inches	Weight per Foot: Min.	Weight per Foot: Coefficient of Strength for Minimum Weights	Weight per Foot: For every lb. Incr. in Weight of Channel add to Coefficient for Min. Wts.	Weight per Foot: Intermediate	Weight per Foot: Max.	Flange Width: Min.	Flange Width: Max.	Web Thickness: Min.	Web Thickness: Max.	Increase of Web and Flanges for each lb. Increase of Weight
15	33.00	444500	7800	35 lbs. then vary by 5 lbs.	55.00	3.40	3.82	.40	.82	.020
12	20.50	227800	6300	25 " " " " 5 "	40.00	2.94	3.42	.28	.76	.025
10	15.00	142700	5200	Vary by 5 lbs., ...	35.00	2.60	3.18	.24	.82	.029
9	13.25	112200	4700	15 lbs. then vary by 5 lbs.	25.00	2.43	2.82	.23	.62	.033
8	11.25	86100	4200	Vary by 2½ lbs., ...	21.25	2.26	2.62	.22	.58	.037
7	9.75	66800	3600	" " 2½ "	19.75	2.09	2.51	.21	.63	.042
6	8.00	46200	3100	" " 2½ "	15.50	1.92	2.28	.20	.56	.049
5	6.50	31600	2600	" " 2½ "	11.50	1.75	2.04	.19	.48	.059
4	5.25	20200	2100	Vary by 1 lb., ...	7.25	1.58	1.73	.18	.33	.074
3	4.00	11600	1560	" " 1 "	6.00	1.41	1.60	.17	.36	.098

The above coefficients are based upon a fibre stress of 16,000 pounds per square inch, used for buildings.

For bridges coefficients should be taken at three-quarters of above amount. To find the distributed safe load in pounds a beam will carry in a given span, divide the coefficients given for size and weight beam by the length of span in feet. To find the coefficient of strength for a given equally distributed load and span, multiply the load in pounds by the span in feet between centres of supports. Beams having the load concentrated in middle of span will safely carry one-half the amount the same beam would carry if the load was equally distributed.

ALLOYS AND COMPOSITIONS

There does not appear to be any standard rule among founders for alloys and compositions. The mixtures vary in proportion to the price and the purpose of the metal required. The following table of alloys may be taken as a fair standard. In all cases where the metal is to be turned, use a small portion of lead, say one ounce to the pound.

	Copper	Zinc	Tin	Lead	Nickel	Antimony
Babbitt's Metal,	3.7	...	89	...	...	7.3
Brass, common,	84.3	5.2	10.5	...	...	...
" hard,	79.3	6.4	14.3	...	...	...
" locomotive bearings,	90	1	9	...	...	...
" rolled,	74.3	22.3	3.4	...	...	...
" very tenacious,	88.9	2.8	8.3	...	...	...
Britannia Metal,	...	...	25	.	...	25
Bronze, red,	87	13	...	...	...	...
" yellow,	67.2	31.2	1.6	...	...	...
" gun metal, large,	90	...	10	...	...	...
" " " small,	93	...	7	...	...	..
" " " soft,	95	...	5	...	...	...
" cymbals,	80	...	20	...	...	...
" medals,	93	...	7	...	...	...
" statuary,	91.4	5.5	1.4	1.7	...	...
Church Bells,	80	5.6	10.1	4.3	...	..
Clocks, musical bells,	87.5	...	12.5	...	...	...
Clock Bells,	72	...	26.5	...	...	1.5
German Silver,	33.3	33.4	...	...	33.3	2.6
" " fine,	49.5	24	...	...	24	2.5
Gongs,	81.6	...	18.4	...	...	...
House Bells,	77	...	23	...	...	...
Lathe Bushes,	80	...	20	...	...	...
Machinery Bearings,	87.5	...	12.5	...	...	...
" " hard,	77.4	7	15.6	...	Bism'h	...
Metal that expands in cooling,	...	...	...	75	8.3	16.7
Muntz Metal, 10 oz. lead,	60	40	...	...	...	...
White Metal,	7.4	7.4	28.4	...	...	56.8
SOLDERS						
Tin,	...	...	25	75	...	...
Spelter, soft,	50	50	...	...	...	...
" hard,	65	35	...	...	...	...
Lead,	...	...	33	67	Silver	Gold
Steel,	13	5	...	...	82	89
Gold,	4		...	...		...
" hard,	66	34	...	...	71	...
" soft,	...	...	66	34	...	...
Silver, hard,	20	...	...	C'dm	80	...
" soft,	12	...	...	21	67	...
					Bism'h	
Pewter,	...	...	40	20	40	...

Approximate Expansion of Solids by Heat, and Their Melting Points by Fahrenheit's Thermometer

	For 1 Degree		For 180 Degrees		Melting Point in Degrees
	1 part in	⅛ inch in Feet	1 part in	⅛ inch in Feet	
Fire-brick, . . .	365220	3804	2029	21.14	. . .
Granite, . from	187560	1954	1042	10.85	. . .
Granite, . to	228060	2375	1267	13.20	. . .
Glass Rod, . . .	221400	2306	1230	12.81	. . .
Platina, ...	208800	2175	1160	12.08	4593
Marble, ...	173000	1802	961	10.00	. . .
Antimony, . . .	166500	1722	925	9.63	955
Cast Iron, ...	162000	1688	900	9.38	1920 to
Slate, ...	173000	1802	961	10.00	2800
Steel, ...	151200	1575	840	8.75	2370
Iron, rolled, . . .	149940	1562	833	8.68	3000 to
Iron, soft, forged,	147420	1536	819	8.53	3500
Bismuth, ...	129600	1350	720	7.50	506
Copper, . average	104400	1088	580	6.04	2000
Sandstone, . . .	103320	1076	574	5.98	. . .
Brass, . . average	97740	1018	543	5.66	1873
Silver, ...	95040	990	528	5.50	1861
Tin, . . . average	87840	915	488	5.08	444
Lead, . . average	63180	658	351	3.66	612
Pewter, ...	78840	821	438	4.56	. . .
Zinc, ...	61920	645	344	3.58	680 to 772

Heat of a common wood fire variously estimated from 800° to 1140°. That of a charcoal one about 2200°; coal about 2400°.

Each 12° to 15° of expansion of wrought iron is equivalent to about 1 ton tension per square inch of section; varying with quality of iron.

A 10-inch iron steam pipe, 105 feet long, expanded 2½ inches after steam was turned into it at 125 lbs. pressure. An 18-inch steam pipe, 210 feet long, expanded 4¾ inches after steam was turned on.

SHAFTING

POWER OF SHAFTS

The strength of a cylindrical shaft to resist torsion varies as d^3 (d = diameter) and is independent of the length, but torsional stiffness varies as $\frac{d^4}{L}$ (L = length) and it is necessary to consider both the strength and the stiffness in fixing the proper size for a shaft.

It is necessary to make a distinction between engine crank shafts and ordinary ones, and in that case the following formula may be used :

$P = \frac{d^3 \times R}{M}$ and $\frac{M \times P}{R} = d^3$, in which P = nominal horse power, R = number of revolutions, M = constant. The value of M for cast iron crank shafts for large engines, say 30 horse power, is 400, and for wrought iron 260. For ordinary shafts the value of M is 254 for cast iron, and 160 for wrought iron. Where there is a liability to sudden strain, extra strong shafting should be used. For shafts, say 4½ inches diameter and under, owing to their greater elasticity, a different rule from the above becomes necessary, and we have for ordinary wrought iron shafts the rules :

$P = d^4 \times R \times .00135$ and $\frac{P}{R \times .00135} = d^4$.

PRESSURE PER SQUARE INCH ON BEARINGS

Bearings should be proportioned according to the pressure ; otherwise the lubricant is squeezed out. This pressure may be as high as 700 lbs. to the square inch with proper lubrication, but in ordinary practice should never exceed 500 lbs. per square inch. The power consumed by friction is not increased by lengthening the bearings, and a wide bearing will wear longer and is easier to keep cool. In cases where the shaft has only its own weight to carry, the distance between bearings may be expressed by the formula: $L = \sqrt[3]{(D \times 16)^2}$, in which D = diameter in inches, and L = length between bearings in feet.

PROPORTIONS OF KEYS FOR WHEELS AND PULLEYS

D = Diameter of shaft in inches.
B = Breadth of key in inches.
T = Thickness of key in inches.
d = Depth sunk in shaft, measured at side of key.
d′ = Depth sunk in boss of wheel, measured at side of key.

$$\frac{D}{4} + .125 = B. \quad \frac{D}{11} + .16 = T. \quad \frac{D}{40} + .075 = d. \quad T - d = d'.$$

The key should be of equal breadth the whole length, but should taper in thickness about ⅛ inch to the foot in length. The same taper should be given to the key seat in the boss of the wheel, but not to the key bed in shaft.

RULE FOR CALCULATING SIZE AND SPEED OF PULLEYS

In calculating the speed and size of pulleys, it should be remembered that the diameter of the driving pulley, multiplied by its number of revolutions, is equal to the diameter of the receiving pulley multiplied by its number of revolutions. Therefore, the following rules may be easily remembered:

$$\frac{\text{Diam. driving pulley} \times \text{rev. per min.}}{\text{diam. receiving pulley}} = \left\{\begin{array}{l}\text{rev. per min.}\\ \text{receiv'g pulley.}\end{array}\right.$$

$$\frac{\text{Diam. driving pulley} \times \text{rev. per min.}}{\text{rev. per min. receiving pulley}} = \left\{\begin{array}{l}\text{diam. receiving}\\ \text{pulley.}\end{array}\right.$$

$$\frac{\text{Diam. receiv'g pulley} \times \text{rev. per min.}}{\text{diameter driving pulley}} = \left\{\begin{array}{l}\text{rev. per min.}\\ \text{driving pulley.}\end{array}\right.$$

$$\frac{\text{Diam. receiv'g pulley} \times \text{rev. per min.}}{\text{rev. per min. driving pulley}} = \left\{\begin{array}{l}\text{diam. driving}\\ \text{pulley.}\end{array}\right.$$

HORSE POWER OF BELTING

A simple rule for ascertaining transmitting power of belting, without first computing speed per minute that it travels, is as follows: Multiply diameter of pulley in inches by its number of revolutions per minute, and this product by width of the belt in inches; divide this product by 3300 for single belting, or by 2100 for double belting, and the quotient will be the amount of horse power that can be safely transmitted.

Table for Single Leather, Four-ply Rubber and Four-ply Cotton Belting, Belts not Overloaded

One inch wide, 800 feet per minute = One Horse Power.

Speed in Feet per Minute	Width of Belts in Inches											
	2	3	4	5	6	8	10	12	14	16	18	20
	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.
400	1	1½	2	2½	3	4	5	6	7	8	9	10
600	1½	2¼	3	3¾	4½	6	7½	9	10½	12	13½	15
800	2	3	4	5	6	8	10	12	14	16	18	20
1000	2½	3¾	5	6¼	7½	10	12½	15	17½	20	22½	25
1200	3	4½	6	7½	9	12	15	18	21	24	27	30
1500	3¾	5¾	7½	9½	11½	15	18¾	22½	26½	30	33¾	37½
1800	4½	6¾	9	11¼	13½	18	22½	27	31½	36	40½	45
2000	5	7½	10	12½	15	20	25	30	35	40	45	50
2400	6	9	12	15	18	24	30	36	42	48	54	60
2800	7	10½	14	17½	21	28	35	42	49	56	63	70
3000	7½	11¼	15	18¾	22½	30	37½	45	52½	60	67½	75
3500	8¾	13	17½	22	26	35	44	52½	61	70	79	88
4000	10	15	20	25	30	40	50	60	70	80	90	100
4500	11¼	17	22½	28	34	45	57	69	78	90	102	114
5000	12½	19	25	31	37½	50	62½	75	87½	100	112	125

Double leather, six-ply rubber, or six-ply cotton belting will transmit 50 to 75 per cent. more power than is shown in this table. (One inch wide, 550 feet per minute = one horse power.)

Decimals of a Foot for Each 1-64 of an Inch

Ins.	Foot	Ins.	Foot	Ins.	Foot	Ins.	Foot
1/64	.0013	5/16	.0260	39/64	.0508	29/32	.0755
1/32	.0026	21/64	.0273	5/8	.0521	59/64	.0768
3/64	.0039	11/32	.0286	41/64	.0534	15/16	.0781
1/16	.0052	23/64	.0299	21/32	.0547	61/64	.0794
5/64	.0065	3/8	.0313	43/64	.0560	31/32	.0807
3/32	.0078	25/64	.0326	11/16	.0573	63/64	.0820
7/64	.0091	13/32	.0339	45/64	.0586	1	.0833
1/8	.0104	27/64	.0352	23/32	.0599	2	.1667
9/64	.0117	7/16	.0365	47/64	.0612	3	.2500
5/32	.0130	29/64	.0378	3/4	.0625	4	.3333
11/64	.0143	15/32	.0391	49/64	.0638	5	.4167
3/16	.0156	31/64	.0404	25/32	.0651	6	.5000
13/64	.0169	1/2	.0417	51/64	.0664	7	.5833
7/32	.0182	33/64	.0430	13/16	.0677	8	.6667
15/64	.0195	17/32	.0443	53/64	.0690	9	.7500
1/4	.0208	35/64	.0456	27/32	.0703	10	.8333
17/64	.0221	9/16	.0469	55/64	.0716	11	.9167
9/32	.0234	37/64	.0472	7/8	.0729	12	1.
19/64	.0247	19/32	.0495	57/64	.0742		

To obtain the foot decimal for an inch and fraction of an inch, add together the corresponding decimals; thus, for 1 1/32 inches:

1 inch, ...	.0833
1/32 inch, ...	.0026
1 1/32 inch, ...	.0859

Decimals of an Inch for Each 1-64th

1/32DS	1/64THS	DECIMAL	FRACTION	1/32DS	1/64THS	DECIMAL	FRACTION
	1	.015625			33	.515625	
1	2	.03125		17	34	.53125	
	3	.046875			35	.546875	
2	4	.0625	$\frac{1}{16}$	18	36	.5625	$\frac{9}{16}$
	5	.078125			37	.578125	
3	6	.09375		19	38	.59375	
	7	.109375			39	.609375	
4	8	.125	$\frac{1}{8}$	20	40	.625	$\frac{5}{8}$
	9	.140625			41	.640625	
5	10	.15625		21	42	.65625	
	11	.171875			43	.671875	
6	12	.1875	$\frac{3}{16}$	22	44	.6875	$\frac{11}{16}$
	13	.203125			45	.703125	
7	14	.21875		23	46	.71875	
	15	.234375			47	.734375	
8	16	.25	$\frac{1}{4}$	24	48	.75	$\frac{3}{4}$
	17	.265625			49	.765625	
9	18	.28125		25	50	.78125	
	19	.296875			51	.796875	
10	20	.3125	$\frac{5}{16}$	26	52	.8125	$\frac{13}{16}$
	21	.328125			53	.828125	
11	22	.34375		27	54	.84375	
	23	.359375			55	.859375	
12	24	.375	$\frac{3}{8}$	28	56	.875	$\frac{7}{8}$
	25	.390625			57	.890625	
13	26	.40625		29	58	.90625	
	27	.421875			59	.921875	
14	28	.4375	$\frac{7}{16}$	30	60	.9375	$\frac{15}{16}$
	29	.453125			61	.953125	
15	30	.46875		31	62	.96875	
	31	.484375			63	.984375	
16	32	.5	$\frac{1}{2}$	32	64	1.	1

STANDARD GAUGES

No. of Gauge	Thickness in Decimals of an Inch							No. of Gauge
	Birmingham	Browne & Sharpe	Standard United States July 1, 1893	British Imperial	Washburn & Moen Co.	Trenton Iron Co.	Stubs Steel Wire	
7°	. . .	. . . .	.500	.500	. . . .	. . .	. .	7°
6°	. . .	. . . .	.46875	.464	. . . .	. . .	. .	6°
5°	. . .	. . . .	.4375	.432	. . . .	.45	. .	5°
4°	.454	.46	.40625	.400	.3938	.40	. .	4°
3°	.425	.40964	.375	.372	.3625	.36	. .	3°
2°	.380	.3648	.34375	.348	.3310	.33	. .	2°
0	.340	.32486	.3125	.324	.3065	.305	. .	0
1	.300	.2893	.28125	.300	.2830	.285	.227	1
2	.284	.25763	.265625	.276	.2625	.265	.219	2
3	.259	.22942	.25	.252	.2437	.245	.212	3
4	.238	.20431	.234375	.232	.2253	.225	.207	4
5	.220	.18194	.21875	.212	.2070	.205	.204	5
6	.203	.16202	.203125	.192	.1920	.190	.201	6
7	.180	.14428	.1875	.176	.1770	.175	.199	7
8	.165	.12849	.171875	.160	.1620	.160	.197	8
9	.148	.11443	.15625	.144	.1483	.145	.194	9
10	.134	.10189	.140625	.128	.1350	.130	.191	10
11	.120	.090742	.125	.116	.1205	.1175	.188	11
12	.109	.080808	.109375	.104	.1055	.1050	.185	12
13	.095	.071961	.09375	.092	.0915	.0925	.182	13
14	.083	.064084	.078125	.080	.0800	.0800	.180	14
15	.072	.057068	.0703125	.072	.0720	.0700	.178	15
16	.065	.05082	.0625	.064	.0625	.0610	.175	16
17	.058	.045257	.05625	.056	.0540	.0525	.172	17
18	.049	.040303	.05	.048	.0475	.0450	.168	18
19	.042	.03589	.04375	.040	.0410	.0400	.164	19
20	.035	.031961	.0375	.036	.0348	.0350	.161	20
21	.032	.028462	.034375	.032	.03175	.0310	.157	21
22	.028	.025347	.03125	.028	.0286	.0280	.155	22
23	.025	.022571	.028125	.024	.0258	.0250	.153	23
24	.022	.0201	.025	.022	.0230	.0225	.151	24
25	.020	.0179	.021875	.020	.0204	.0200	.148	25
26	.018	.01594	.01875	.018	.0181	.0180	.146	26
27	.016	.014195	.0171875	.0164	.0173	.0170	.143	27
28	.014	.012641	.015625	.0148	.0162	.0160	.139	28
29	.013	.011257	.0140625	.0136	.0150	.0150	.134	29
30	.012	.010025	.0125	.0124	.0140	.0140	.127	30
31	.010	.008928	.0109375	.0116	.0132	.0130	.120	31
32	.009	.00795	.01015625	.0108	.0128	.0120	.115	32
33	.008	.00708	.009375	.0100	.0118	.0110	.112	33
34	.007	.006304	.00859375	.0092	.0104	.0100	.110	34
35	.005	.005614	.0078125	.0084	.0095	.0095	.108	35
36	.004	.005	.00703125	.0076	.0090	.0090	.106	36
37	. . .	.004453	.006640625	.0068	. . . .	.0085	.103	37
38	. . .	.003965	.00625	.0060	. . . .	.0080	.101	38
39	. . .	.003531	. . . . .	. . .	. . . .	.0075	.099	39
40	. . .	.003144	. . . . .	. . .	. . . .	.0070	.097	40

Squares, Cubes, Square Roots, Cube Roots, Logarithms, Reciprocals, Circumferences and Circular Areas of Nos. from 1 to 1000

No.	Square	Cube	Square Root	Cube Root	Log.	1000 x Recip.	No. = Dia.	
							Circum.	Area
1	1	1	1.0000	1.0000	0.00000	1000.000	3.142	0.7854
2	4	8	1.4142	1.2599	0.30103	500.000	6.283	3.1416
3	9	27	1.7321	1.4422	0.47712	333.333	9.425	7.0686
4	16	64	2.0000	1.5874	0.60206	250.000	12.566	12.5664
5	25	125	2.2361	1.7100	0.69897	200.000	15.708	19.6350
6	36	216	2.4495	1.8171	0.77815	166.667	18.850	28.2743
7	49	343	2.6458	1.9129	0.84510	142.857	21.991	38.4845
8	64	512	2.8284	2.0000	0.90309	125.000	25.133	50.2655
9	81	729	3.0000	2.0801	0.95424	111.111	28.274	63.6173
10	100	1000	3.1623	2.1544	1.00000	100.000	31.416	78.5398
11	121	1331	3.3166	2.2240	1.04139	90.9091	34.558	95.0332
12	144	1728	3.4641	2.2894	1.07918	83.3333	37.699	113.097
13	169	2197	3.6056	2.3513	1.11394	76.9231	40.841	132.732
14	196	2744	3.7417	2.4101	1.14613	71.4286	43.982	153.938
15	225	3375	3.8730	2.4662	1.17609	66.6667	47.124	176.715
16	256	4096	4.0000	2.5198	1.20412	62.5000	50.265	201.062
17	289	4913	4.1231	2.5713	1.23045	58.8235	53.407	226.980
18	324	5832	4.2426	2.6207	1.25527	55.5556	56.549	254.469
19	361	6859	4.3589	2.6684	1.27875	52.6316	59.690	283.529
20	400	8000	4.4721	2.7144	1.30103	50.0000	62.832	314.159
21	441	9261	4.5826	2.7589	1.32222	47.6190	65.973	346.361
22	484	10648	4.6904	2.8020	1.34242	45.4545	69.115	380.133
23	529	12167	4.7958	2.8439	1.36173	43.4783	72.257	415.476
24	576	13824	4.8990	2.8845	1.38021	41.6667	75.398	452.389
25	625	15625	5.0000	2.9240	1.39794	40.0000	78.540	490.874
26	676	17576	5.0990	2.9625	1.41497	38.4615	81.681	530.929
27	729	19683	5.1962	3.0000	1.43136	37.0370	84.823	572.555
28	784	21952	5.2915	3.0366	1.44716	35.7143	87.965	615.752
29	841	24389	5.3852	3.0723	1.46240	34.4828	91.106	660.520
30	900	27000	5.4772	3.1072	1.47712	33.3333	94.248	706.858
31	961	29791	5.5678	3.1414	1.49136	32.2581	97.389	754.768
32	1024	32768	5.6569	3.1748	1.50515	31.2500	100.531	804.248
33	1089	35937	5.7446	3.2075	1.51851	30.3030	103.673	855.299
34	1156	39304	5.8310	3.2396	1.53148	29.4118	106.814	907.920
35	1225	42875	5.9161	3.2711	1.54407	28.5714	109.956	962.113
36	1296	46656	6.0000	3.3019	1.55630	27.7778	113.097	1017.88
37	1369	50653	6.0828	3.3322	1.56820	27.0270	116.239	1075.21
38	1444	54872	6.1644	3.3620	1.57978	26.3158	119.381	1134.11
39	1521	59319	6.2450	3.3912	1.59106	25.6410	122.522	1194.59
40	1600	64000	6.3246	3.4200	1.60206	25.0000	125.66	1256.64
41	1681	68921	6.4031	3.4482	1.61278	24.3902	128.81	1320.25
42	1764	74088	6.4807	3.4760	1.62325	23.8095	131.95	1385.44
43	1849	79507	6.5574	3.5034	1.63347	23.2558	135.09	1452.20
44	1936	85184	6.6332	3.5303	1.64345	22.7273	138.23	1520.53
45	2025	91125	6.7082	3.5569	1.65321	22.2222	141.37	1590.43
46	2116	97336	6.7823	3.5830	1.66276	21.7391	144.51	1661.90
47	2209	103823	6.8557	3.6088	1.67210	21.2766	147.65	1734.94
48	2304	110592	6.9282	3.6342	1.68124	20.8333	150.80	1809.56
49	2401	117649	7.0000	3.6593	1.69020	20.4082	153.94	1885.74

Squares, Cubes, Square Roots, Cube Roots, Logarithms, Reciprocals, Circumferences and Circular Areas of Nos. from 1 to 1000

No.	Square	Cube	Square Root	Cube Root	Log.	1000 x Recip.	No. = Dia.	
							Circum.	Area
50	2500	125000	7.0711	3.6840	1.69897	20.0000	157.08	1963.50
51	2601	132651	7.1414	3.7084	1.70757	19.6078	160.22	2042.82
52	2704	140608	7.2111	3.7325	1.71600	19.2308	163.36	2123.72
53	2809	148877	7.2801	3.7563	1.72428	18.8679	166.50	2206.18
54	2916	157464	7.3485	3.7798	1.73239	18.5185	169.65	2290.22
55	3025	166375	7.4162	3.8030	1.74036	18.1818	172.79	2375.83
56	3136	175616	7.4833	3.8259	1.74819	17.8571	175.93	2463.01
57	3249	185193	7.5498	3.8485	1.75587	17.5439	179.07	2551.76
58	3364	195112	7.6158	3.8709	1.76343	17.2414	182.21	2642.08
59	3481	205379	7.6811	3.8930	1.77085	16.9492	185.35	2733.97
60	3600	216000	7.7460	3.9149	1.77815	16.6667	188.50	2827.43
61	3721	226981	7.8102	3.9365	1.78533	16.3934	191.64	2922.47
62	3844	238328	7.8740	3.9579	1.79239	16.1290	194.78	3019.07
63	3969	250047	7.9373	3.9791	1.79934	15.8730	197.92	3117.25
64	4096	262144	8.0000	4.0000	1.80618	15.6250	201.06	3216.99
65	4225	274625	8.0623	4.0207	1.81291	15.3846	204.20	3318.31
66	4356	287496	8.1240	4.0412	1.81954	15.1515	207.35	3421.19
67	4489	300763	8.1854	4.0615	1.82607	14.9254	210.49	3525.65
68	4624	314432	8.2462	4.0817	1.83251	14.7059	213.63	3631.68
69	4761	328509	8.3066	4.1016	1.83885	14.4928	216.77	3739.28
70	4900	343000	8.3666	4.1213	1.84510	14.2857	219.91	3848.45
71	5041	357911	8.4261	4.1408	1.85126	14.0845	223.05	3959.19
72	5184	373248	8.4853	4.1602	1.85733	13.8889	226.19	4071.50
73	5329	389017	8.5440	4.1793	1.86332	13.6986	229.34	4185.39
74	5476	405224	8.6023	4.1983	1.86923	13.5135	232.48	4300.84
75	5625	421875	8.6603	4.2172	1.87506	13.3333	235.62	4417.86
76	5776	438976	8.7178	4.2358	1.88081	13.1579	238.76	4536.46
77	5929	456533	8.7750	4.2543	1.88649	12.9870	241.90	4656.63
78	6084	474552	8.8318	4.2727	1.89209	12.8205	245.04	4778.36
79	6241	493039	8.8882	4.2908	1.89763	12.6582	248.19	4901.67
80	6400	512000	8.9443	4.3089	1.90309	12.5000	251.33	5026.55
81	6561	531441	9.0000	4.3267	1.90849	12.3457	254.47	5153.00
82	6724	551368	9.0554	4.3445	1.91381	12.1951	257.61	5281.02
83	6889	571787	9.1104	4.3621	1.91908	12.0482	260.75	5410.61
84	7056	592704	9.1652	4.3795	1.92428	11.9048	263.89	5541.77
85	7225	614125	9.2195	4.3968	1.92942	11.7647	267.04	5674.50
86	7396	636056	9.2736	4.4140	1.93450	11.6279	270.18	5808.80
87	7569	658503	9.3274	4.4310	1.93952	11.4943	273.32	5944.68
88	7744	681472	9.3808	4.4480	1.94448	11.3636	276.46	6082.12
89	7921	704969	9.4340	4.4647	1.94939	11.2360	279.60	6221.14
90	8100	729000	9.4868	4.4814	1.95424	11.1111	282.74	6361.73
91	8281	753571	9.5394	4.4979	1.95904	10.9890	285.88	6503.88
92	8464	778688	9.5917	4.5144	1.96379	10.8696	289.03	6647.61
93	8649	804357	9.6437	4.5307	1.96848	10.7527	292.17	6792.91
94	8836	830584	9.6954	4.5468	1.97313	10.6383	295.31	6939.78
95	9025	857375	9.7468	4.5629	1.97772	10.5263	298.45	7088.22
96	9216	884736	9.7980	4.5789	1.98227	10.4167	301.59	7238.23
97	9409	912673	9.8489	4.5947	1.98677	10.3093	304.73	7389.81
98	9604	941192	9.8995	4.6104	1.99123	10.2041	307.88	7542.96
99	9801	970299	9.9499	4.6261	1.99564	10.1010	311.02	7697.69

Squares, Cubes, Square Roots, Cube Roots, Logarithms, Reciprocals, Circumferences and Circular Areas of Nos. from 1 to 1000

No.	Square	Cube	Square Root	Cube Root	Log.	1000 x Recip.	No. = Dia. Circum.	No. = Dia. Area
100	10000	1000000	10.0000	4.6416	2.00000	10.0000	314.16	7853.98
101	10201	1030301	10.0499	4.6570	2.00432	9.90099	317.30	8011.85
102	10404	1061208	10.0995	4.6723	2.00860	9.80392	320.44	8171.28
103	10609	1092727	10.1489	4.6875	2.01284	9.70874	323.58	8332.29
104	10816	1124864	10.1980	4.7027	2.01703	9.61538	326.73	8494.87
105	11025	1157625	10.2470	4.7177	2.02119	9.52381	329.87	8659.01
106	11236	1191016	10.2956	4.7326	2.02531	9.43396	333.01	8824.73
107	11449	1225043	10.3441	4.7475	2.02938	9.34579	336.15	8992.02
108	11664	1259712	10.3923	4.7622	2.03342	9.25926	339.29	9160.88
109	11881	1295029	10.4403	4.7769	2.03743	9.17431	342.43	9331.32
110	12100	1331000	10.4881	4.7914	2.04139	9.09091	345.58	9503.32
111	12321	1367631	10.5357	4.8059	2.04532	9.00901	348.72	9676.89
112	12544	1404928	10.5830	4.8203	2.04922	8.92857	351.86	9852.03
113	12769	1442897	10.6301	4.8346	2.05308	8.84956	355.00	10028.7
114	12996	1481544	10.6771	4.8488	2.05690	8.77193	358.14	10207.0
115	13225	1520875	10.7238	4.8629	2.06070	8.69565	361.28	10386.9
116	13456	1560896	10.7703	4.8770	2.06446	8.62069	364.42	10568.3
117	13689	1601613	10.8167	4.8910	2.06819	8.54701	367.57	10751.3
118	13924	1643032	10.8628	4.9049	2.07188	8.47458	370.71	10935.9
119	14161	1685159	10.9087	4.9187	2.07555	8.40336	373.85	11122.0
120	14400	1728000	10.9545	4.9324	2.07918	8.33333	376.99	11309.7
121	14641	1771561	11.0000	4.9461	2.08279	8.26446	380.13	11499.0
122	14884	1815848	11.0454	4.9597	2.08636	8.19672	383.27	11689.9
123	15129	1860867	11.0905	4.9732	2.08991	8.13008	386.42	11882.3
124	15376	1906624	11.1355	4.9866	2.09342	8.06452	389.56	12076.3
125	15625	1953125	11.1803	5.0000	2.09691	8.00000	392.70	12271.8
126	15876	2000376	11.2250	5.0133	2.10037	7.93651	395.84	12469.0
127	16129	2048383	11.2694	5.0265	2.10380	7.87402	398.98	12667.7
128	16384	2097152	11.3137	5.0397	2.10721	7.81250	402.12	12868.0
129	16641	2146689	11.3578	5.0528	2.11059	7.75194	405.27	13069.8
130	16900	2197000	11.4018	5.0658	2.11394	7.69231	408.41	13273.2
131	17161	2248091	11.4455	5.0788	2.11727	7.63359	411.55	13478.2
132	17424	2299968	11.4891	5.0916	2.12057	7.57576	414.69	13684.8
133	17689	2352637	11.5326	5.1045	2.12385	7.51880	417.83	13892.9
134	17956	2406104	11.5758	5.1172	2.12710	7.46269	420.97	14102.6
135	18225	2460375	11.6190	5.1299	2.13033	7.40741	424.12	14313.9
136	18496	2515456	11.6619	5.1426	2.13354	7.35294	427.26	14526.7
137	18769	2571353	11.7047	5.1551	2.13672	7.29927	430.40	14741.1
138	19044	2628072	11.7473	5.1676	2.13988	7.24638	433.54	14957.1
139	19321	2685619	11.7898	5.1801	2.14301	7.19424	436.68	15174.7
140	19600	2744000	11.8322	5.1925	2.14613	7.14286	439.82	15393.8
141	19881	2803221	11.8743	5.2048	2.14922	7.09220	442.96	15614.5
142	20164	2863288	11.9164	5.2171	2.15229	7.04225	446.11	15836.8
143	20449	2924207	11.9583	5.2293	2.15534	6.99301	449.25	16060.6
144	20736	2985984	12.0000	5.2415	2.15836	6.94444	452.39	16286.0
145	21025	3048625	12.0416	5.2536	2.16137	6.89655	455.53	16513.0
146	21316	3112136	12.0830	5.2656	2.16435	6.84932	458.67	16741.5
147	21609	3176523	12.1244	5.2776	2.16732	6.80272	461.81	16971.7
148	21904	3241792	12.1655	5.2896	2.17026	6.75676	464.96	17203.4
149	22201	3307949	12.2066	5.3015	2.17319	6.71141	468.10	17436.6

Squares, Cubes, Square Roots, Cube Roots, Logarithms, Reciprocals, Circumferences and Circular Areas of Nos. from 1 to 1000

No.	Square	Cube	Square Root	Cube Root	Log.	1000 x Recip.	No. = Dia. Circum.	No. = Dia. Area
150	22500	3375000	12.2474	5.3133	2.17609	6.66667	471.24	17671.5
151	22801	3442951	12.2882	5.3251	2.17898	6.62252	474.38	17907.9
152	23104	3511808	12.3288	5.3368	2.18184	6.57895	477.52	18145.8
153	23409	3581577	12.3693	5.3485	2.18469	6.53595	480.66	18385.4
154	23716	3652264	12.4097	5.3601	2.18752	6.49351	483.81	18626.5
155	24025	3723875	12.4499	5.3717	2.19033	6.45161	486.95	18869.2
156	24336	3796416	12.4900	5.3832	2.19312	6.41026	490.09	19113.4
157	24649	3869893	12.5300	5.3947	2.19590	6.36943	493.23	19359.3
158	24964	3944312	12.5698	5.4061	2.19866	6.32911	496.37	19606.7
159	25281	4019679	12.6095	5.4175	2.20140	6.28931	499.51	19855.7
160	25600	4096000	12.6491	5.4288	2.20412	6.25000	502.65	20106.2
161	25921	4173281	12.6886	5.4401	2.20683	6.21118	505.80	20358.3
162	26244	4251528	12.7279	5.4514	2.20952	6.17284	508.94	20612.0
163	26569	4330747	12.7671	5.4626	2.21219	6.13497	512.08	20867.2
164	26896	4410944	12.8062	5.4737	2.21484	6.09756	515.22	21124.1
165	27225	4492125	12.8452	5.4848	2.21748	6.06061	518.36	21382.5
166	27556	4574296	12.8841	5.4959	2.22011	6.02410	521.50	21642.4
167	27889	4657463	12.9228	5.5069	2.22272	5.98802	524.65	21904.0
168	28224	4741632	12.9615	5.5178	2.22531	5.95238	527.79	22167.1
169	28561	4826809	13.0000	5.5288	2.22789	5.91716	530.93	22431.8
170	28900	4913000	13.0384	5.5397	2.23045	5.88235	534.07	22698.0
171	29241	5000211	13.0767	5.5505	2.23300	5.84795	537.21	22965.8
172	29584	5088448	13.1149	5.5613	2.23553	5.81395	540.35	23235.2
173	29929	5177717	13.1529	5.5721	2.23805	5.78035	543.50	23506.2
174	30276	5268024	13.1909	5.5828	2.24055	5.74713	546.64	23778.7
175	30625	5359375	13.2288	5.5934	2.24304	5.71429	549.78	24052.8
176	30976	5451776	13.2665	5.6041	2.24551	5.68182	552.92	24328.5
177	31329	5545233	13.3041	5.6147	2.24797	5.64972	556.06	24605.7
178	31684	5639752	13.3417	5.6252	2.25042	5.61798	559.20	24884.6
179	32041	5735339	13.3791	5.6357	2.25285	5.58659	562.35	25164.9
180	32400	5832000	13.4164	5.6462	2.25527	5.55556	565.49	25446.9
181	32761	5929741	13.4536	5.6567	2.25768	5.52486	568.63	25730.4
182	33124	6028568	13.4907	5.6671	2.26007	5.49451	571.77	26015.5
183	33489	6128487	13.5277	5.6774	2.26245	5.46448	574.91	26302.2
184	33856	6229504	13.5647	5.6877	2.26482	5.43478	578.05	26590.4
185	34225	6331625	13.6015	5.6980	2.26717	5.40541	581.19	26880.3
186	34596	6434856	13.6382	5.7083	2.26951	5.37634	584.34	27171.6
187	34969	6539203	13.6748	5.7185	2.27184	5.34759	587.48	27464.6
188	35344	6644672	13.7113	5.7287	2.27416	5.31915	590.62	27759.1
189	35721	6751269	13.7477	5.7388	2.27646	5.29101	593.76	28055.2
190	36100	6859000	13.7840	5.7489	2.27875	5.26316	596.90	28352.9
191	36481	6967871	13.8203	5.7590	2.28103	5.23560	600.04	28652.1
192	36864	7077888	13.8564	5.7690	2.28330	5.20833	603.19	28952.9
193	37249	7189057	13.8924	5.7790	2.28556	5.18135	606.33	29255.3
194	37636	7301384	13.9284	5.7890	2.28780	5.15464	609.47	29559.2
195	38025	7414875	13.9642	5.7989	2.29003	5.12821	612.61	29864.8
196	38416	7529536	14.0000	5.8088	2.29226	5.10204	615.75	30171.9
197	38809	7645373	14.0357	5.8186	2.29447	5.07614	618.89	30480.5
198	39204	7762392	14.0712	5.8285	2.29667	5.05051	622.04	30790.7
199	39601	7880599	14.1067	5.8383	2.29885	5.02513	625.18	31102.6

Squares, Cubes, Square Roots, Cube Roots, Logarithms, Reciprocals, Circumferences and Circular Areas of Nos. from 1 to 1000

No.	Square	Cube	Square Root	Cube Root	Log.	1000 x Recip.	No. = Dia.	
							Circum.	Area
200	40000	8000000	14.1421	5.8480	2.30103	5.00000	628.32	31415.9
201	40401	8120601	14.1774	5.8578	2.30320	4.97512	631.46	31730.9
202	40804	8242408	14.2127	5.8675	2.30535	4.95050	634.60	32047.4
203	41209	8365427	14.2478	5.8771	2.30750	4.92611	637.74	32365.5
204	41616	8489664	14.2829	5.8868	2.30963	4.90196	640.89	32685.1
205	42025	8615125	14.3178	5.8964	2.31175	4.87805	644.03	33006.4
206	42436	8741816	14.3527	5.9059	2.31387	4.85437	647.17	33329.2
207	42849	8869743	14.3875	5.9155	2.31597	4.83092	650.31	33653.5
208	43264	8998912	14.4222	5.9250	2.31806	4.80769	653.45	33979.5
209	43681	9129329	14.4568	5.9345	2.32015	4.78469	656.59	34307.0
210	44100	9261000	14.4914	5.9439	2.32222	4.76190	659.73	34636.1
211	44521	9393931	14.5258	5.9533	2.32428	4.73934	662.88	34966.7
212	44944	9528128	14.5602	5.9627	2.32634	4.71698	666.02	35298.9
213	45369	9663597	14.5945	5.9721	2.32838	4.69484	669.16	35632.7
214	45796	9800344	14.6287	5.9814	2.33041	4.67290	672.30	35968.1
215	46225	9938375	14.6629	5.9907	2.33244	4.65116	675.44	36305.0
216	46656	10077696	14.6969	6.0000	2.33445	4.62963	678.58	36643.5
217	47089	10218313	14.7309	6.0092	2.33646	4.60829	681.73	36983.6
218	47524	10360232	14.7648	6.0185	2.33846	4.58716	684.87	37325.3
219	47961	10503459	14.7986	6.0277	2.34044	4.56621	688.01	37668.5
220	48400	10648000	14.8324	6.0368	2.34242	4.54545	691.15	38013.3
221	48841	10793861	14.8661	6.0459	2.34439	4.52489	694.29	38359.6
222	49284	10941048	14.8997	6.0550	2.34635	4.50450	697.43	38707.6
223	49729	11089567	14.9332	6.0641	2.34830	4.48431	700.58	39057.1
224	50176	11239424	14.9666	6.0732	2.35025	4.46429	703.72	39408.1
225	50625	11390625	15.0000	6.0822	2.35218	4.44444	706.86	39760.8
226	51076	11543176	15.0333	6.0912	2.35411	4.42478	710.00	40115.0
227	51529	11697083	15.0665	6.1002	2.35603	4.40529	713.14	40470.8
228	51984	11852352	15.0997	6.1091	2.35793	4.38596	716.28	40828.1
229	52441	12008989	15.1327	6.1180	2.35984	4.36681	719.42	41187.1
230	52900	12167000	15.1658	6.1269	2.36173	4.34783	722.57	41547.6
231	53361	12326391	15.1987	6.1358	2.36361	4.32900	725.71	41909.6
232	53824	12487168	15.2315	6.1446	2.36549	4.31034	728.85	42273.3
233	54289	12649337	15.2643	6.1534	2.36736	4.29185	731.99	42638.5
234	54756	12812904	15.2971	6.1622	2.36922	4.27350	735.13	43005.3
235	55225	12977875	15.3297	6.1710	2.37107	4.25532	738.27	43373.6
236	55696	13144256	15.3623	6.1797	2.37291	4.23729	741.42	43743.5
237	56169	13312053	15.3948	6.1885	2.37475	4.21941	744.56	44115.0
238	56644	13481272	15.4272	6.1972	2.37658	4.20168	747.70	44488.1
239	57121	13651919	15.4596	6.2058	2.37840	4.18410	750.84	44862.7
240	57600	13824000	15.4919	6.2145	2.38021	4.16667	753.98	45238.9
241	58081	13997521	15.5242	6.2231	2.38202	4.14938	757.12	45616.7
242	58564	14172488	15.5563	6.2317	2.38382	4.13223	760.27	45996.1
243	59049	14348907	15.5885	6.2403	2.38561	4.11523	763.41	46377.0
244	59536	14526784	15.6205	6.2488	2.38739	4.09836	766.55	46759.5
245	60025	14706125	15.6525	6.2573	2.38917	4.08163	769.69	47143.5
246	60516	14886936	15.6844	6.2658	2.39094	4.06504	772.83	47529.2
247	61009	15069223	15.7162	6.2743	2.39270	4.04858	775.97	47916.4
248	61504	15252992	15.7480	6.2828	2.39445	4.03226	779.12	48305.1
249	62001	15438249	15.7797	6.2912	2.39620	4.01606	782.26	48695.5

Squares, Cubes, Square Roots, Cube Roots, Logarithms, Reciprocals, Circumferences and Circular Areas of Nos. from 1 to 1000

No.	Square	Cube	Square Root	Cube Root	Log.	1000 x Recip.	No. = Dia.	
							Circum.	Area
250	62500	15625000	15.8114	6.2996	2.39794	4.00000	785.40	49087.4
251	63001	15813251	15.8430	6.3080	2.39967	3.98406	788.54	49480.9
252	63504	16003008	15.8745	6.3164	2.40140	3.96825	791.68	49875.9
253	64009	16194277	15.9060	6.3247	2.40312	3.95257	794.82	50272.6
254	64516	16387064	15.9374	6.3330	2.40483	3.93701	797.96	50670.7
255	65025	16581375	15.9687	6.3413	2.40654	3.92157	801.11	51070.5
256	65536	16777216	16.0000	6.3496	2.40824	3.90625	804.25	51471.9
257	66049	16974593	16.0312	6.3579	2.40993	3.89105	807.39	51874.8
258	66564	17173512	16.0624	6.3661	2.41162	3.87597	810.53	52279.2
259	67081	17373979	16.0935	6.3743	2.41330	3.86100	813.67	52685.3
260	67600	17576000	16.1245	6.3825	2.41497	3.84615	816.81	53092.9
261	68121	17779581	16.1555	6.3907	2.41664	3.83142	819.96	53502.1
262	68644	17984728	16.1864	6.3988	2.41830	3.81679	823.10	53912.9
263	69169	18191447	16.2173	6.4070	2.41996	3.80228	826.24	54325.2
264	69696	18399744	16.2481	6.4151	2.42160	3.78788	829.38	54739.1
265	70225	18609625	16.2788	6.4232	2.42325	3.77358	832.52	55154.6
266	70756	18821096	16.3095	6.4312	2.42488	3.75940	835.66	55571.6
267	71289	19034163	16.3401	6.4393	2.42651	3.74532	838.81	55990.3
268	71824	19248832	16.3707	6.4473	2.42813	3.73134	841.95	56410.4
269	72361	19465109	16.4012	6.4553	2.42975	3.71747	845.09	56832.2
270	72900	19683000	16.4317	6.4633	2.43136	3.70370	848.23	57255.5
271	73441	19902511	16.4621	6.4713	2.43297	3.69004	851.37	57680.4
272	73984	20123648	16.4924	6.4792	2.43457	3.67647	854.51	58106.9
273	74529	20346417	16.5227	6.4872	2.43616	3.66300	857.66	58534.9
274	75076	20570824	16.5529	6.4951	2.43775	3.64964	860.80	58964.6
275	75625	20796875	16.5831	6.5030	2.43933	3.63636	863.94	59395.7
276	76176	21024576	16.6132	6.5108	2.44091	3.62319	867.08	59828.5
277	76729	21253933	16.6433	6.5187	2.44248	3.61011	870.22	60262.8
278	77284	21484952	16.6733	6.5265	2.44404	3.59712	873.36	60698.7
279	77841	21717639	16.7033	6.5343	2.44560	3.58423	876.50	61136.2
280	78400	21952000	16.7332	6.5421	2.44716	3.57143	879.65	61575.2
281	78961	22188041	16.7631	6.5499	2.44871	3.55872	882.79	62015.8
282	79524	22425768	16.7929	6.5577	2.45025	3.54610	885.93	62458.0
283	80089	22665187	16.8226	6.5654	2.45179	3.53357	889.07	62901.8
284	80656	22906304	16.8523	6.5731	2.45332	3.52113	892.21	63347.1
285	81225	23149125	16.8819	6.5808	2.45484	3.50877	895.35	63794.0
286	81796	23393656	16.9115	6.5885	2.45637	3.49650	898.50	64242.4
287	82369	23639903	16.9411	6.5962	2.45788	3.48432	901.64	64692.5
288	82944	23887872	16.9706	6.6039	2.45939	3.47222	904.78	65144.1
289	83521	24137569	17.0000	6.6115	2.46090	3.46021	907.92	65597.2
290	84100	24389000	17.0294	6.6191	2.46240	3.44828	911.06	66052.0
291	84681	24642171	17.0587	6.6267	2.46389	3.43643	914.20	66508.3
292	85264	24897088	17.0880	6.6343	2.46538	3.42466	917.35	66966.2
293	85849	25153757	17.1172	6.6419	2.46687	3.41297	920.49	67425.6
294	86436	25412184	17.1464	6.6494	2.46835	3.40136	923.63	67886.7
295	87025	25672375	17.1756	6.6569	2.46982	3.38983	926.77	68349.3
296	87616	25934336	17.2047	6.6644	2.47129	3.37838	929.91	68813.5
297	88209	26198073	17.2337	6.6719	2.47276	3.36700	933.05	69279.2
298	88804	26463592	17.2627	6.6794	2.47422	3.35570	936.19	69746.5
299	89401	26730899	17.2916	6.6869	2.47567	3.34448	939.34	70215.4

Squares, Cubes, Square Roots, Cube Roots, Logarithms, Reciprocals, Circumferences and Circular Areas of Nos. from 1 to 1000

No.	Square	Cube	Square Root	Cube Root	Log.	1000 x Recip.	No. = Dia.	
							Circum.	Area
300	90000	27000000	17.3205	6.6943	2.47712	3.33333	942.48	70685.8
301	90601	27270901	17.3494	6.7018	2.47857	3.32226	945.62	71157.9
302	91204	27543608	17.3781	6.7092	2.48001	3.31126	948.76	71631.5
303	91809	27818127	17.4069	6.7166	2.48144	3.30033	951.90	72106.6
304	92416	28094464	17.4356	6.7240	2.48287	3.28947	955.04	72583.4
305	93025	28372625	17.4642	6.7313	2.48430	3.27869	958.19	73061.7
306	93636	28652616	17.4929	6.7387	2.48572	3.26797	961.33	73541.5
307	94249	28934443	17.5214	6.7460	2.48714	3.25733	964.47	74023.0
308	94864	29218112	17.5499	6.7533	2.48855	3.24675	967.61	74506.0
309	95481	29503629	17.5784	6.7606	2.48996	3.23625	970.75	74990.6
310	96100	29791000	17.6068	6.7679	2.49136	3.22581	973.89	75476.8
311	96721	30080231	17.6352	6.7752	2.49276	3.21543	977.04	75964.5
312	97344	30371328	17.6635	6.7824	2.49415	3.20513	980.18	76453.8
313	97969	30664297	17.6918	6.7897	2.49554	3.19489	983.32	76944.7
314	98596	30959144	17.7200	6.7969	2.49693	3.18471	986.46	77437.1
315	99225	31255875	17.7482	6.8041	2.49831	3.17460	989.60	77931.1
316	99856	31554496	17.7764	6.8113	2.49969	3.16456	992.74	78426.7
317	100489	31855013	17.8045	6.8185	2.50106	3.15457	995.88	78923.9
318	101124	32157432	17.8326	6.8256	2.50243	3.14465	999.03	79422.6
319	101761	32461759	17.8606	6.8328	2.50379	3.13480	1002.2	79922.9
320	102400	32768000	17.8885	6.8399	2.50515	3.12500	1005.3	80424.8
321	103041	33076161	17.9165	6.8470	2.50651	3.11527	1008.5	80928.2
322	103684	33386248	17.9444	6.8541	2.50786	3.10559	1011.6	81433.2
323	104329	33698267	17.9722	6.8612	2.50920	3.09598	1014.7	81939.8
324	104976	34012224	18.0000	6.8683	2.51055	3.08642	1017.9	82448.0
325	105625	34328125	18.0278	6.8753	2.51188	3.07692	1021.0	82957.7
326	106276	34645976	18.0555	6.8824	2.51322	3.06749	1024.2	83469.0
327	106929	34965783	18.0831	6.8894	2.51455	3.05810	1027.3	83981.8
328	107584	35287552	18.1108	6.8964	2.51587	3.04878	1030.4	84496.3
329	108241	35611289	18.1384	6.9034	2.51720	3.03951	1033.6	85012.3
330	108900	35937000	18.1659	6.9104	2.51851	3.03030	1036.7	85529.9
331	109561	36264691	18.1934	6.9174	2.51983	3.02115	1039.9	86049.0
332	110224	36594368	18.2209	6.9244	2.52114	3.01205	1043.0	86569.7
333	110889	36926037	18.2483	6.9313	2.52244	3.00300	1046.2	87092.0
334	111556	37259704	18.2757	6.9382	2.52375	2.99401	1049.3	87615.9
335	112225	37595375	18.3030	6.9451	2.52504	2.98507	1052.4	88141.3
336	112896	37933056	18.3303	6.9521	2.52634	2.97619	1055.6	88668.3
337	113569	38272753	18.3576	6.9589	2.52763	2.96736	1058.7	89196.9
338	114244	38614472	18.3848	6.9658	2.52892	2.95858	1061.9	89727.0
339	114921	38958219	18.4120	6.9727	2.53020	2.94985	1065.0	90258.7
340	115600	39304000	18.4391	6.9795	2.53148	2.94118	1068.1	90792.0
341	116281	39651821	18.4662	6.9864	2.53275	2.93255	1071.3	91326.9
342	116964	40001688	18.4932	6.9932	2.53403	2.92398	1074.4	91863.3
343	117649	40353607	18.5203	7.0000	2.53529	2.91545	1077.6	92401.3
344	118336	40707584	18.5472	7.0068	2.53656	2.90698	1080.7	92940.9
345	119025	41063625	18.5742	7.0136	2.53782	2.89855	1083.8	93482.0
346	119716	41421736	18.6011	7.0203	2.53908	2.89017	1087.0	94024.7
347	120409	41781923	18.6279	7.0271	2.54033	2.88184	1090.1	94569.0
348	121104	42144192	18.6548	7.0338	2.54158	2.87356	1093.3	95114.9
349	121801	42508549	18.6815	7.0406	2.54283	2.86533	1096.4	95662.3

Squares, Cubes, Square Roots, Cube Roots, Logarithms, Reciprocals, Circumferences and Circular Areas of Nos. from 1 to 1000

No.	Square	Cube	Square Root	Cube Root	Log.	1000 x Recip.	No. = Dia. Circum.	No. = Dia. Area
350	122500	42875000	18.7083	7.0473	2.54407	2.85714	1099.6	96211.3
351	123201	43243551	18.7350	7.0540	2.54531	2.84900	1102.7	96761.8
352	123904	43614208	18.7617	7.0607	2.54654	2.84091	1105.8	97314.0
353	124609	43986977	18.7883	7.0674	2.54777	2.83286	1109.0	97867.7
354	125316	44361864	18.8149	7.0740	2.54900	2.82486	1112.1	98423.0
355	126025	44738875	18.8414	7.0807	2.55023	2.81690	1115.3	98979.8
356	126736	45118016	18.8680	7.0873	2.55145	2.80899	1118.4	99538.2
357	127449	45499293	18.8944	7.0940	2.55267	2.80112	1121.5	100098
358	128164	45882712	18.9209	7.1006	2.55388	2.79330	1124.7	100660
359	128881	46268279	18.9473	7.1072	2.55509	2.78552	1127.8	101223
360	129600	46656000	18.9737	7.1138	2.55630	2.77778	1131.0	101788
361	130321	47045881	19.0000	7.1204	2.55751	2.77008	1134.1	102354
362	131044	47437928	19.0263	7.1269	2.55871	2.76243	1137.3	102922
363	131769	47832147	19.0526	7.1335	2.55991	2.75482	1140.4	103491
364	132496	48228544	19.0788	7.1400	2.56110	2.74725	1143.5	104062
365	133225	48627125	19.1050	7.1466	2.56229	2.73973	1146.7	104635
366	133956	49027896	19.1311	7.1531	2.56348	2.73224	1149.8	105209
367	134689	49430863	19.1572	7.1596	2.56467	2.72480	1153.0	105785
368	135424	49836032	19.1833	7.1661	2.56585	2.71739	1156.1	106362
369	136161	50243409	19.2094	7.1726	2.56703	2.71003	1159.2	106941
370	136900	50653000	19.2354	7.1791	2.56820	2.70270	1162.4	107521
371	137641	51064811	19.2614	7.1855	2.56937	2.69542	1165.5	108103
372	138384	51478848	19.2873	7.1920	2.57054	2.68817	1168.7	108687
373	139129	51895117	19.3132	7.1984	2.57171	2.68097	1171.8	109272
374	139876	52313624	19.3391	7.2048	2.57287	2.67380	1175.0	109858
375	140625	52734375	19.3649	7.2112	2.57403	2.66667	1178.1	110447
376	141376	53157376	19.3907	7.2177	2.57519	2.65957	1181.2	111036
377	142129	53582633	19.4165	7.2240	2.57634	2.65252	1184.4	111628
378	142884	54010152	19.4422	7.2304	2.57749	2.64550	1187.5	112221
379	143641	54439939	19.4679	7.2368	2.57864	2.63852	1190.7	112815
380	144400	54872000	19.4936	7.2432	2.57978	2.63158	1193.8	113411
381	145161	55306341	19.5192	7.2495	2.58093	2.62467	1196.9	114009
382	145924	55742968	19.5448	7.2558	2.58206	2.61780	1200.1	114608
383	146689	56181887	19.5704	7.2622	2.58320	2.61097	1203.2	115209
384	147456	56623104	19.5959	7.2685	2.58433	2.60417	1206.4	115812
385	148225	57066625	19.6214	7.2748	2.58546	2.59740	1209.5	116416
386	148996	57512456	19.6469	7.2811	2.58659	2.59067	1212.7	117021
387	149769	57960603	19.6723	7.2874	2.58771	2.58398	1215.8	117628
388	150544	58411072	19.6977	7.2936	2.58883	2.57732	1218.9	118237
389	151321	58863869	19.7231	7.2999	2.58995	2.57069	1222.1	118847
390	152100	59319000	19.7484	7.3061	2.59106	2.56410	1225.2	119459
391	152881	59776471	19.7737	7.3124	2.59218	2.55755	1228.4	120072
392	153664	60236288	19.7990	7.3186	2.59329	2.55102	1231.5	120687
393	154449	60698457	19.8242	7.3248	2.59439	2.54453	1234.6	121304
394	155236	61162984	19.8494	7.3310	2.59550	2.53807	1237.8	121922
395	156025	61629875	19.8746	7.3372	2.59660	2.53165	1240.9	122542
396	156816	62099136	19.8997	7.3434	2.59770	2.52525	1244.1	123163
397	157609	62570773	19.9249	7.3496	2.59879	2.51889	1247.2	123786
398	158404	63044792	19.9499	7.3558	2.59988	2.51256	1250.4	124410
399	159201	63521199	19.9750	7.3619	2.60097	2.50627	1253.5	125036

Squares, Cubes, Square Roots, Cube Roots, Logarithms, Reciprocals, Circumferences and Circular Areas of Nos. from 1 to 1000

No.	Square	Cube	Square Root	Cube Root	Log.	1000 x Recip.	No. = Dia.	
							Circum.	Area
400	160000	64000000	20.0000	7.3681	2.60206	2.50000	1256.6	125664
401	160801	64481201	20.0250	7.3742	2.60314	2.49377	1259.8	126293
402	161604	64964808	20.0499	7.3803	2.60423	2.48756	1262.9	126923
403	162409	65450827	20.0749	7.3864	2.60531	2.48139	1266.1	127556
404	163216	65939264	20.0998	7.3925	2.60638	2.47525	1269.2	128190
405	164025	66430125	20.1246	7.3986	2.60746	2.46914	1272.3	128825
406	164836	66923416	20.1494	7.4047	2.60853	2.46305	1275.5	129462
407	165649	67419143	20.1742	7.4108	2.60959	2.45700	1278.6	130100
408	166464	67917312	20.1990	7.4169	2.61066	2.45098	1281.8	130741
409	167281	68417929	20.2237	7.4229	2.61172	2.44499	1284.9	131382
410	168100	68921000	20.2485	7.4290	2.61278	2.43902	1288.1	132025
411	168921	69426531	20.2731	7.4350	2.61384	2.43309	1291.2	132670
412	169744	69934528	20.2978	7.4410	2.61490	2.42718	1294.3	133317
413	170569	70444997	20.3224	7.4470	2.61595	2.42131	1297.5	133965
414	171396	70957944	20.3470	7.4530	2.61700	2.41546	1300.6	134614
415	172225	71473375	20.3715	7.4590	2.61805	2.40964	1303.8	135265
416	173056	71991296	20.3961	7.4650	2.61909	2.40385	1306.9	135918
417	173889	72511713	20.4206	7.4710	2.62014	2.39808	1310.0	136572
418	174724	73034632	20.4450	7.4770	2.62118	2.39234	1313.2	137228
419	175561	73560059	20.4695	7.4829	2.62221	2.38664	1316.3	137885
420	176400	74088000	20.4939	7.4889	2.62325	2.38095	1319.5	138544
421	177241	74618461	20.5183	7.4948	2.62428	2.37530	1322.6	139205
422	178084	75151448	20.5426	7.5007	2.62531	2.36967	1325.8	139867
423	178929	75686967	20.5670	7.5067	2.62634	2.36407	1328.9	140531
424	179776	76225024	20.5913	7.5126	2.62737	2.35849	1332.0	141196
425	180625	76765625	20.6155	7.5185	2.62839	2.35294	1335.2	141863
426	181476	77308776	20.6398	7.5244	2.62941	2.34742	1338.3	142531
427	182329	77854483	20.6640	7.5302	2.63043	2.34192	1341.5	143201
428	183184	78402752	20.6882	7.5361	2.63144	2.33645	1344.6	143872
429	184041	78953589	20.7123	7.5420	2.63246	2.33100	1347.7	144545
430	184900	79507000	20.7364	7.5478	2.63347	2.32558	1350.9	145220
431	185761	80062991	20.7605	7.5537	2.63448	2.32019	1354.0	145896
432	186624	80621568	20.7846	7.5595	2.63548	2.31482	1357.2	146574
433	187489	81182737	20.8087	7.5654	2.63649	2.30947	1360.3	147254
434	188356	81746504	20.8327	7.5712	2.63749	2.30415	1363.5	147934
435	189225	82312875	20.8567	7.5770	2.63849	2.29885	1366.6	148617
436	190096	82881856	20.8806	7.5828	2.63949	2.29358	1369.7	149301
437	190969	83453453	20.9045	7.5886	2.64048	2.28833	1372.9	149987
438	191844	84027672	20.9284	7.5944	2.64147	2.28311	1376.0	150674
439	192721	84604519	20.9523	7.6001	2.64246	2.27790	1379.2	151363
440	193600	85184000	20.9762	7.6059	2.64345	2.27273	1382.3	152053
441	194481	85766121	21.0000	7.6117	2.64444	2.26757	1385.4	152745
442	195364	86350888	21.0238	7.6174	2.64542	2.26244	1388.6	153439
443	196249	86938307	21.0476	7.6232	2.64640	2.25734	1391.7	154134
444	197136	87528384	21.0713	7.6289	2.64738	2.25225	1394.9	154830
445	198025	88121125	21.0950	7.6346	2.64836	2.24719	1398.0	155528
446	198916	88716536	21.1187	7.6403	2.64933	2.24215	1401.2	156228
447	199809	89314623	21.1424	7.6460	2.65031	2.23714	1404.3	156930
448	200704	89915392	21.1660	7.6517	2.65128	2.23214	1407.4	157633
449	201601	90518849	21.1896	7.6574	2.65225	2.22717	1410.6	158337

Squares, Cubes, Square Roots, Cube Roots, Logarithms, Reciprocals, Circumferences and Circular Areas of Nos. from 1 to 1000

No.	Square	Cube	Square Root	Cube Root	Log.	1000 x Recip.	No. = Dia.	
							Circum.	Area
450	202500	91125000	21.2132	7.6631	2.65321	2.22222	1413.7	159043
451	203401	91733851	21.2368	7.6688	2.65418	2.21730	1416.9	159751
452	204304	92345408	21.2603	7.6744	2.65514	2.21239	1420.0	160460
453	205209	92959677	21.2838	7.6801	2.65610	2.20751	1423.1	161171
454	206116	93576664	21.3073	7.6857	2.65706	2.20264	1426.3	161883
455	207025	94196375	21.3307	7.6914	2.65801	2.19780	1429.4	162597
456	207936	94818816	21.3542	7.6970	2.65896	2.19298	1432.6	163313
457	208849	95443993	21.3776	7.7026	2.65992	2.18818	1435.7	164030
458	209764	96071912	21.4009	7.7082	2.66087	2.18341	1438.9	164748
459	210681	96702579	21.4243	7.7138	2.66181	2.17865	1442.0	165468
460	211600	97336000	21.4476	7.7194	2.66276	2.17391	1445.1	166190
461	212521	97972181	21.4709	7.7250	2.66370	2.16920	1448.3	166914
462	213444	98611128	21.4942	7.7306	2.66464	2.16450	1451.4	167639
463	214369	99252847	21.5174	7.7362	2.66558	2.15983	1454.6	168365
464	215296	99897344	21.5407	7.7418	2.66652	2.15517	1457.7	169093
465	216225	100544625	21.5639	7.7473	2.66745	2.15054	1460.8	169823
466	217156	101194696	21.5870	7.7529	2.66839	2.14592	1464.0	170554
467	218089	101847563	21.6102	7.7584	2.66932	2.14133	1467.1	171287
468	219024	102503232	21.6333	7.7639	2.67025	2.13675	1470.3	172021
469	219961	103161709	21.6564	7.7695	2.67117	2.13220	1473.4	172757
470	220900	103823000	21.6795	7.7750	2.67210	2.12766	1476.5	173494
471	221841	104487111	21.7025	7.7805	2.67302	2.12314	1479.7	174234
472	222784	105154048	21.7256	7.7860	2.67394	2.11864	1482.8	174974
473	223729	105823817	21.7486	7.7915	2.67486	2.11417	1486.0	175716
474	224676	106496424	21.7715	7.7970	2.67578	2.10971	1489.1	176460
475	225625	107171875	21.7945	7.8025	2.67669	2.10526	1492.3	177205
476	226576	107850176	21.8174	7.8079	2.67761	2.10084	1495.4	177952
477	227529	108531333	21.8403	7.8134	2.67852	2.09644	1498.5	178701
478	228484	109215352	21.8632	7.8188	2.67943	2.09205	1501.7	179451
479	229441	109902239	21.8861	7.8243	2.68034	2.08768	1504.8	180203
480	230400	110592000	21.9089	7.8297	2.68124	2.08333	1508.0	180956
481	231361	111284641	21.9317	7.8352	2.68215	2.07900	1511.1	181711
482	232324	111980168	21.9545	7.8406	2.68305	2.07469	1514.3	182467
483	233289	112678587	21.9773	7.8460	2.68395	2.07039	1517.4	183225
484	234256	113379904	22.0000	7.8514	2.68485	2.06612	1520.5	183984
485	235225	114084125	22.0227	7.8568	2.68574	2.06186	1523.7	184745
486	236196	114791256	22.0454	7.8622	2.68664	2.05761	1526.8	185508
487	237169	115501303	22.0681	7.8676	2.68753	2.05339	1530.0	186272
488	238144	116214272	22.0907	7.8730	2.68842	2.04918	1533.1	187038
489	239121	116930169	22.1133	7.8784	2.68931	2.04499	1536.2	187805
490	240100	117649000	22.1359	7.8837	2.69020	2.04082	1539.4	188574
491	241081	118370771	22.1585	7.8891	2.69108	2.03666	1542.5	189345
492	242064	119095488	22.1811	7.8944	2.69197	2.03252	1545.7	190117
493	243049	119823157	22.2036	7.8998	2.69285	2.02840	1548.8	190890
494	244036	120553784	22.2261	7.9051	2.69373	2.02429	1551.9	191665
495	245025	121287375	22.2486	7.9105	2.69461	2.02020	1555.1	192442
496	246016	122023936	22.2711	7.9158	2.69548	2.01613	1558.2	193221
497	247009	122763473	22.2935	7.9211	2.69636	2.01207	1561.4	194000
498	248004	123505992	22.3159	7.9264	2.69723	2.00803	1564.5	194782
499	249001	124251499	22.3383	7.9317	2.69810	2.00401	1567.7	195565

Squares, Cubes, Square Roots, Cube Roots, Logarithms, Reciprocals, Circumferences and Circular Areas of Nos. from 1 to 1000

No.	Square	Cube	Square Root	Cube Root	Log.	1000 x Recip.	No. = Dia.	
							Circum.	Area
500	250000	125000000	22.3607	7.9370	2.69897	2.00000	1570.8	196350
501	251001	125751501	22.3830	7.9423	2.69984	1.99601	1573.9	197136
502	252004	126506008	22.4054	7.9476	2.70070	1.99203	1577.1	197923
503	253009	127263527	22.4277	7.9528	2.70157	1.98807	1580.2	198713
504	254016	128024064	22.4499	7.9581	2.70243	1.98413	1583.4	199504
505	255025	128787625	22.4722	7.9634	2.70329	1.98020	1586.5	200296
506	256036	129554216	22.4944	7.9686	2.70415	1.97629	1589.7	201090
507	257049	130323843	22.5167	7.9739	2.70501	1.97239	1592.8	201886
508	258064	131096512	22.5389	7.9791	2.70586	1.96850	1595.9	202683
509	259081	131872229	22.5610	7.9843	2.70672	1.96464	1599.1	203482
510	260100	132651000	22.5832	7.9896	2.70757	1.96078	1602.2	204282
511	261121	133432831	22.6053	7.9948	2.70842	1.95695	1605.4	205084
512	262144	134217728	22.6274	8.0000	2.70927	1.95312	1608.5	205887
513	263169	135005697	22.6495	8.0052	2.71012	1.94932	1611.6	206692
514	264196	135796744	22.6716	8.0104	2.71096	1.94553	1614.8	207499
515	265225	136590875	22.6936	8.0156	2.71181	1.94175	1617.9	208307
516	266256	137388096	22.7156	8.0208	2.71265	1.93798	1621.1	209117
517	267289	138188413	22.7376	8.0260	2.71349	1.93424	1624.2	209928
518	268324	138991832	22.7596	8.0311	2.71433	1.93050	1627.3	210741
519	269361	139798359	22.7816	8.0363	2.71517	1.92678	1630.5	211556
520	270400	140608000	22.8035	8.0415	2.71600	1.92308	1633.6	212372
521	271441	141420761	22.8254	8.0466	2.71684	1.91939	1636.8	213189
522	272484	142236648	22.8473	8.0517	2.71767	1.91571	1639.9	214008
523	273529	143055667	22.8692	8.0569	2.71850	1.91205	1643.1	214829
524	274576	143877824	22.8910	8.0620	2.71933	1.90840	1646.2	215651
525	275625	144703125	22.9129	8.0671	2.72016	1.90476	1649.3	216475
526	276676	145531576	22.9347	8.0723	2.72099	1.90114	1652.5	217301
527	277729	146363183	22.9565	8.0774	2.72181	1.89753	1655.6	218128
528	278784	147197952	22.9783	8.0825	2.72263	1.89394	1658.8	218956
529	279841	148035889	23.0000	8.0876	2.72346	1.89036	1661.9	219787
530	280900	148877000	23.0217	8.0927	2.72428	1.88679	1665.0	220618
531	281961	149721291	23.0434	8.0978	2.72509	1.88324	1668.2	221452
532	283024	150568768	23.0651	8.1028	2.72591	1.87970	1671.3	222287
533	284089	151419437	23.0868	8.1079	2.72673	1.87617	1674.5	223123
534	285156	152273304	23.1084	8.1130	2.72754	1.87266	1677.6	223961
535	286225	153130375	23.1301	8.1180	2.72835	1.86916	1680.8	224801
536	287296	153990656	23.1517	8.1231	2.72916	1.86567	1683.9	225642
537	288369	154854153	23.1733	8.1281	2.72997	1.86220	1687.0	226484
538	289444	155720872	23.1948	8.1332	2.73078	1.85874	1690.2	227329
539	290521	156590819	23.2164	8.1382	2.73159	1.85529	1693.3	228175
540	291600	157464000	23.2379	8.1433	2.73239	1.85185	1696.5	229022
541	292681	158340421	23.2594	8.1483	2.73320	1.84843	1699.6	229871
542	293764	159220088	23.2809	8.1533	2.73400	1.84502	1702.7	230722
543	294849	160103007	23.3024	8.1583	2.73480	1.84162	1705.9	231574
544	295936	160989184	23.3238	8.1633	2.73560	1.83824	1709.0	232428
545	297025	161878625	23.3452	8.1683	2.73640	1.83486	1712.2	233283
546	298116	162771336	23.3666	8.1733	2.73719	1.83150	1715.3	234140
547	299209	163667323	23.3880	8.1783	2.73799	1.82815	1718.5	234998
548	300304	164566592	23.4094	8.1833	2.73878	1.82482	1721.6	235858
549	301401	165469149	23.4307	8.1882	2.73957	1.82149	1724.7	236720

Squares, Cubes, Square Roots, Cube Roots, Logarithms, Reciprocals, Circumferences and Circular Areas of Nos. from 1 to 1000

No.	Square	Cube	Square Root	Cube Root	Log.	1000 x Recip.	No. = Dia. Circum.	Area
550	302500	166375000	23.4521	8.1932	2.74036	1.81818	1727.9	237583
551	303601	167284151	23.4734	8.1982	2.74115	1.81488	1731.0	238448
552	304704	168196608	23.4947	8.2031	2.74194	1.81159	1734.2	239314
553	305809	169112377	23.5160	8.2081	2.74273	1.80832	1737.3	240182
554	306916	170031464	23.5372	8.2130	2.74351	1.80505	1740.4	241051
555	308025	170953875	23.5584	8.2180	2.74429	1.80180	1743.6	241922
556	309136	171879616	23.5797	8.2229	2.74507	1.79856	1746.7	242795
557	310249	172808693	23.6008	8.2278	2.74586	1.79533	1749.9	243669
558	311364	173741112	23.6220	8.2327	2.74663	1.79211	1753.0	244545
559	312481	174676879	23.6432	8.2377	2.74741	1.78891	1756.2	245422
560	313600	175616000	23.6643	8.2426	2.74819	1.78571	1759.3	246301
561	314721	176558481	23.6854	8.2475	2.74896	1.78253	1762.4	247181
562	315844	177504328	23.7065	8.2524	2.74974	1.77936	1765.6	248063
563	316969	178453547	23.7276	8.2573	2.75051	1.77620	1768.7	248947
564	318096	179406144	23.7487	8.2621	2.75128	1.77305	1771.9	249832
565	319225	180362125	23.7697	8.2670	2.75205	1.76991	1775.0	250719
566	320356	181321496	23.7908	8.2719	2.75282	1.76678	1778.1	251607
567	321489	182284263	23.8118	8.2768	2.75358	1.76367	1781.3	252497
568	322624	183250432	23.8328	8.2816	2.75435	1.76056	1784.4	253388
569	323761	184220009	23.8537	8.2865	2.75511	1.75747	1787.6	254281
570	324900	185193000	23.8747	8.2913	2.75587	1.75439	1790.7	255176
571	326041	186169411	23.8956	8.2962	2.75664	1.75131	1793.9	256072
572	327184	187149248	23.9165	8.3010	2.75740	1.74825	1797.0	256970
573	328329	188132517	23.9374	8.3059	2.75815	1.74520	1800.1	257869
574	329476	189119224	23.9583	8.3107	2.75891	1.74216	1803.3	258770
575	330625	190109375	23.9792	8.3155	2.75967	1.73913	1806.4	259672
576	331776	191102976	24.0000	8.3203	2.76042	1.73611	1809.6	260576
577	332929	192100033	24.0208	8.3251	2.76118	1.73310	1812.7	261482
578	334084	193100552	24.0416	8.3300	2.76193	1.73010	1815.8	262389
579	335241	194104539	24.0624	8.3348	2.76268	1.72712	1819.0	263298
580	336400	195112000	24.0832	8.3396	2.76343	1.72414	1822.1	264208
581	337561	196122941	24.1039	8.3443	2.76418	1.72117	1825.3	265120
582	338724	197137368	24.1247	8.3491	2.76492	1.71821	1828.4	266033
583	339889	198155287	24.1454	8.3539	2.76567	1.71527	1831.6	266948
584	341056	199176704	24.1661	8.3587	2.76641	1.71233	1834.7	267865
585	342225	200201625	24.1868	8.3634	2.76716	1.70940	1837.8	268783
586	343396	201230056	24.2074	8.3682	2.76790	1.70649	1841.0	269701
587	344569	202262003	24.2281	8.3730	2.76864	1.70358	1844.1	270624
588	345744	203297472	24.2487	8.3777	2.76938	1.70068	1847.3	271547
589	346921	204336469	24.2693	8.3825	2.77012	1.69779	1850.4	272471
590	348100	205379000	24.2899	8.3872	2.77085	1.69492	1853.5	273397
591	349281	206425071	24.3105	8.3919	2.77159	1.69205	1856.7	274325
592	350464	207474688	24.3311	8.3967	2.77232	1.68919	1859.8	275254
593	351649	208527857	24.3516	8.4014	2.77305	1.68634	1863.0	276184
594	352836	209584584	24.3721	8.4061	2.77379	1.68350	1866.1	277117
595	354025	210644875	24.3926	8.4108	2.77452	1.68067	1869.3	278051
596	355216	211708736	24.4131	8.4155	2.77525	1.67785	1872.4	278986
597	356409	212776173	24.4336	8.4202	2.77597	1.67504	1875.5	279923
598	357604	213847192	24.4540	8.4249	2.77670	1.67224	1878.7	280862
599	358801	214921799	24.4745	8.4296	2.77743	1.66945	1881.8	281802

Squares, Cubes, Square Roots, Cube Roots, Logarithms, Reciprocals, Circumferences and Circular Areas of Nos. from 1 to 1000

No.	Square	Cube	Square Root	Cube Root	Log.	1000 x Recip.	No. = Dia.	
							Circum.	Area
600	360000	216000000	24.4949	8.4343	2.77815	1.66667	1885.0	282743
601	361201	217081801	24.5153	8.4390	2.77887	1.66389	1888.1	283687
602	362404	218167208	24.5357	8.4437	2.77960	1.66113	1891.2	284631
603	363609	219256227	24.5561	8.4484	2.78032	1.65837	1894.4	285578
604	364816	220348864	24.5764	8.4530	2.78104	1.65563	1897.5	286526
605	366025	221445125	24.5967	8.4577	2.78176	1.65289	1900.7	287475
606	367236	222545016	24.6171	8.4623	2.78247	1.65017	1903.8	288426
607	368449	223648543	24.6374	8.4670	2.78319	1.64745	1907.0	289379
608	369664	224755712	24.6577	8.4716	2.78390	1.64474	1910.1	290333
609	370881	225866529	24.6779	8.4763	2.78462	1.64204	1913.2	291289
610	372100	226981000	24.6982	8.4809	2.78533	1.63934	1916.4	292247
611	373321	228099131	24.7184	8.4856	2.78604	1.63666	1919.5	293206
612	374544	229220928	24.7386	8.4902	2.78675	1.63399	1922.7	294166
613	375769	230346397	24.7588	8.4948	2.78746	1.63132	1925.8	295128
614	376996	231475544	24.7790	8.4994	2.78817	1.62866	1928.9	296092
615	378225	232608375	24.7992	8.5040	2.78888	1.62602	1932.1	297057
616	379456	233744896	24.8193	8.5086	2.78958	1.62338	1935.2	298024
617	380689	234885113	24.8395	8.5132	2.79029	1.62075	1938.4	298992
618	381924	236029032	24.8596	8.5178	2.79099	1.61812	1941.5	299962
619	383161	237176659	24.8797	8.5224	2.79169	1.61551	1944.7	300934
620	384400	238328000	24.8998	8.5270	2.79239	1.61290	1947.8	301907
621	385641	239483061	24.9199	8.5316	2.79309	1.61031	1950.9	302882
622	386884	240641848	24.9399	8.5362	2.79379	1.60772	1954.1	303858
623	388129	241804367	24.9600	8.5408	2.79449	1.60514	1957.2	304836
624	389376	242970624	24.9800	8.5453	2.79518	1.60256	1960.4	305815
625	390625	244140625	25.0000	8.5499	2.79588	1.60000	1963.5	306796
626	391876	245314376	25.0200	8.5544	2.79657	1.59744	1966.6	307779
627	393129	246491883	25.0400	8.5590	2.79727	1.59490	1969.8	308763
628	394384	247673152	25.0599	8.5635	2.79796	1.59236	1972.9	309748
629	395641	248858189	25.0799	8.5681	2.79865	1.58983	1976.1	310736
630	396900	250047000	25.0998	8.5726	2.79934	1.58730	1979.2	311725
631	398161	251239591	25.1197	8.5772	2.80003	1.58479	1982.4	312715
632	399424	252435968	25.1396	8.5817	2.80072	1.58228	1985.5	313707
633	400689	253636137	25.1595	8.5862	2.80140	1.57978	1988.6	314700
634	401956	254840104	25.1794	8.5907	2.80209	1.57729	1991.8	315696
635	403225	256047875	25.1992	8.5952	2.80277	1.57480	1994.9	316692
636	404496	257259456	25.2190	8.5997	2.80346	1.57233	1998.1	317690
637	405769	258474853	25.2389	8.6043	2.80414	1.56986	2001.2	318690
638	407044	259694072	25.2587	8.6088	2.80482	1.56740	2004.3	319692
639	408321	260917119	25.2784	8.6132	2.80550	1.56495	2007.5	320695
640	409600	262144000	25.2982	8.6177	2.80618	1.56250	2010.6	321699
641	410881	263374721	25.3180	8.6222	2.80686	1.56006	2013.8	322705
642	412164	264609288	25.3377	8.6267	2.80754	1.55763	2016.9	323713
643	413449	265847707	25.3574	8.6312	2.80821	1.55521	2020.0	324722
644	414736	267089984	25.3772	8.6357	2.80889	1.55280	2023.2	325733
645	416025	268336125	25.3969	8.6401	2.80956	1.55039	2026.3	326745
646	417316	269586136	25.4165	8.6446	2.81023	1.54799	2029.5	327759
647	418609	270840023	25.4362	8.6490	2.81090	1.54560	2032.6	328775
648	419904	272097792	25.4558	8.6535	2.81158	1.54321	2035.8	329792
649	421201	273359449	25.4755	8.6579	2.81224	1.54083	2038.9	330810

Squares, Cubes, Square Roots, Cube Roots, Logarithms, Reciprocals, Circumferences and Circular Areas of Nos. from 1 to 1000

No.	Square	Cube	Square Root	Cube Root	Log.	1000 x Recip.	No. = Dia.	
							Circum.	Area
650	422500	274625000	25.4951	8.6624	2.81291	1.53846	2042.0	331831
651	423801	275894451	25.5147	8.6668	2.81358	1.53610	2045.2	332853
652	425104	277167808	25.5343	8.6713	2.81425	1.53374	2048.3	333876
653	426409	278445077	25.5539	8.6757	2.81491	1.53139	2051.5	334901
654	427716	279726264	25.5734	8.6801	2.81558	1.52905	2054.6	335927
655	429025	281011375	25.5930	8.6845	2.81624	1.52672	2057.7	336955
656	430336	282300416	25.6125	8.6890	2.81690	1.52439	2060.9	337985
657	431649	283593393	25.6320	8.6934	2.81757	1.52207	2064.0	339016
658	432964	284890312	25.6515	8.6978	2.81823	1.51976	2067.2	340049
659	434281	286191179	25.6710	8.7022	2.81889	1.51745	2070.3	341084
660	435600	287496000	25.6905	8.7066	2.81954	1.51515	2073.5	342119
661	436921	288804781	25.7099	8.7110	2.82020	1.51286	2076.6	343157
662	438244	290117528	25.7294	8.7154	2.82086	1.51057	2079.7	344196
663	439569	291434247	25.7488	8.7198	2.82151	1.50830	2082.9	345237
664	440896	292754944	25.7682	8.7241	2.82217	1.50602	2086.0	346279
665	442225	294079625	25.7876	8.7285	2.82282	1.50376	2089.2	347323
666	443556	295408296	25.8070	8.7329	2.82347	1.50150	2092.3	348368
667	444889	296740963	25.8263	8.7373	2.82413	1.49925	2095.4	349415
668	446224	298077632	25.8457	8.7416	2.82478	1.49701	2098.6	350464
669	447561	299418309	25.8650	8.7460	2.82543	1.49477	2101.7	351514
670	448900	300763000	25.8844	8.7503	2.82607	1.49254	2104.9	352565
671	450241	302111711	25.9037	8.7547	2.82672	1.49031	2108.0	353618
672	451584	303464448	25.9230	8.7590	2.82737	1.48810	2111.2	354673
673	452929	304821217	25.9422	8.7634	2.82802	1.48588	2114.3	355730
674	454276	306182024	25.9615	8.7677	2.82866	1.48368	2117.4	356788
675	455625	307546875	25.9808	8.7721	2.82930	1.48148	2120.6	357847
676	456976	308915776	26.0000	8.7764	2.82995	1.47929	2123.7	358908
677	458329	310288733	26.0192	8.7807	2.83059	1.47711	2126.9	359971
678	459684	311665752	26.0384	8.7850	2.83123	1.47493	2130.0	361035
679	461041	313046839	26.0576	8.7893	2.83187	1.47275	2133.1	362101
680	462400	314432000	26.0768	8.7937	2.83251	1.47059	2136.3	363168
681	463761	315821241	26.0960	8.7980	2.83315	1.46843	2139.4	364237
682	465124	317214568	26.1151	8.8023	2.83378	1.46628	2142.6	365308
683	466489	318611987	26.1343	8.8066	2.83442	1.46413	2145.7	366380
684	467856	320013504	26.1534	8.8109	2.83506	1.46199	2148.9	367453
685	469225	321419125	26.1725	8.8152	2.83569	1.45985	2152.0	368528
686	470596	322828856	26.1916	8.8194	2.83632	1.45773	2155.1	369605
687	471969	324242703	26.2107	8.8237	2.83696	1.45560	2158.3	370684
688	473344	325660672	26.2298	8.8280	2.83759	1.45349	2161.4	371764
689	474721	327082769	26.2488	8.8323	2.83822	1.45138	2164.6	372845
690	476100	328509000	26.2679	8.8366	2.83885	1.44928	2167.7	373928
691	477481	329939371	26.2869	8.8408	2.83948	1.44718	2170.8	375013
692	478864	331373888	26.3059	8.8451	2.84011	1.44509	2174.0	376099
693	480249	332812557	26.3249	8.8493	2.84073	1.44300	2177.1	377187
694	481636	334255384	26.3439	8.8536	2.84136	1.44092	2180.3	378276
695	483025	335702375	26.3629	8.8578	2.84198	1.43885	2183.4	379367
696	484416	337153536	26.3818	8.8621	2.84261	1.43678	2186.6	380459
697	485809	338608873	26.4008	8.8663	2.84323	1.43472	2189.7	381554
698	487204	340068392	26.4197	8.8706	2.84386	1.43267	2192.8	382649
699	488601	341532099	26.4386	8.8748	2.84448	1.43062	2196.0	383746

Squares, Cubes, Square Roots, Cube Roots, Logarithms, Reciprocals, Circumferences and Circular Areas of Nos. from 1 to 1000

No.	Square	Cube	Square Root	Cube Root	Log.	1000 x Recip.	No. = Dia.	
							Circum.	Area
700	490000	343000000	26.4575	8.8790	2.84510	1.42857	2199.1	384845
701	491401	344472101	26.4764	8.8833	2.84572	1.42653	2202.3	385945
702	492804	345948408	26.4953	8.8875	2.84634	1.42450	2205.4	387047
703	494209	347428927	26.5141	8.8917	2.84696	1.42248	2208.5	388151
704	495616	348913664	26.5330	8.8959	2.84757	1.42046	2211.7	389256
705	497025	350402625	26.5518	8.9001	2.84819	1.41844	2214.8	390363
706	498436	351895816	26.5707	8.9043	2.84880	1.41643	2218.0	391471
707	499849	353393243	26.5895	8.9085	2.84942	1.41443	2221.1	392580
708	501264	354894912	26.6083	8.9127	2.85003	1.41243	2224.3	393692
709	502681	356400829	26.6271	8.9169	2.85065	1.41044	2227.4	394805
710	504100	357911000	26.6458	8.9211	2.85126	1.40845	2230.5	395919
711	505521	359425431	26.6646	8.9253	2.85187	1.40647	2233.7	397035
712	506944	360944128	26.6833	8.9295	2.85248	1.40449	2236.8	398153
713	508369	362467097	26.7021	8.9337	2.85309	1.40253	2240.0	399272
714	509796	363994344	26.7208	8.9378	2.85370	1.40056	2243.1	400393
715	511225	365525875	26.7395	8.9420	2.85431	1.39860	2246.2	401515
716	512656	367061696	26.7582	8.9462	2.85491	1.39665	2249.4	402639
717	514089	368601813	26.7769	8.9503	2.85552	1.39470	2252.5	403765
718	515524	370146232	26.7955	8.9545	2.85612	1.39276	2255.7	404892
719	516961	371694959	26.8142	8.9587	2.85673	1.39082	2258.8	406020
720	518400	373248000	26.8328	8.9628	2.85733	1.38889	2261.9	407150
721	519841	374805361	26.8514	8.9670	2.85794	1.38696	2265.1	408282
722	521284	376367048	26.8701	8.9711	2.85854	1.38504	2268.2	409416
723	522729	377933067	26.8887	8.9752	2.85914	1.38313	2271.4	410550
724	524176	379503424	26.9072	8.9794	2.85974	1.38122	2274.5	411687
725	525625	381078125	26.9258	8.9835	2.86034	1.37931	2277.7	412825
726	527076	382657176	26.9444	8.9876	2.86094	1.37741	2280.8	413965
727	528529	384240583	26.9629	8.9918	2.86153	1.37552	2283.9	415106
728	529984	385828352	26.9815	8.9959	2.86213	1.37363	2287.1	416248
729	531441	387420489	27.0000	9.0000	2.86273	1.37174	2290.2	417393
730	532900	389017000	27.0185	9.0041	2.86332	1.36986	2293.4	418539
731	534361	390617891	27.0370	9.0082	2.86392	1.36799	2296.5	419686
732	535824	392223168	27.0555	9.0123	2.86451	1.36612	2299.7	420835
733	537289	393832837	27.0740	9.0164	2.86510	1.36426	2302.8	421986
734	538756	395446904	27.0924	9.0205	2.86570	1.36240	2305.9	423138
735	540225	397065375	27.1109	9.0246	2.86629	1.36054	2309.1	424293
736	541696	398688256	27.1293	9.0287	2.86688	1.35870	2312.2	425448
737	543169	400315553	27.1477	9.0328	2.86747	1.35685	2315.4	426604
738	544644	401947272	27.1662	9.0369	2.86806	1.35501	2318.5	427762
739	546121	403583419	27.1846	9.0410	2.86864	1.35318	2321.6	428922
740	547600	405224000	27.2029	9.0450	2.86923	1.35135	2324.8	430084
741	549081	406869021	27.2213	9.0491	2.86982	1.34953	2327.9	431247
742	550564	408518488	27.2397	9.0532	2.87040	1.34771	2331.1	432412
743	552049	410172407	27.2580	9.0572	2.87099	1.34590	2334.2	433578
744	553536	411830784	27.2764	9.0613	2.87157	1.34409	2337.3	434746
745	555025	413493625	27.2947	9.0654	2.87216	1.34228	2340.5	435916
746	556516	415160936	27.3130	9.0694	2.87274	1.34048	2343.6	437087
747	558009	416832723	27.3313	9.0735	2.87332	1.33869	2346.8	438259
748	559504	418508992	27.3496	9.0775	2.87390	1.33690	2349.9	439433
749	561001	420189749	27.3679	9.0816	2.87448	1.33511	2353.1	440609

Squares, Cubes, Square Roots, Cube Roots, Logarithms, Reciprocals, Circumferences and Circular Areas of Nos. from 1 to 1000

No.	Square	Cube	Square Root	Cube Root	Log.	1000 x Recip.	No. = Dia.	
							Circum.	Area
750	562500	421875000	27.3861	9.0856	2.87506	1.33333	2356.2	441786
751	564001	423564751	27.4044	9.0896	2.87564	1.33156	2359.3	442965
752	565504	425259008	27.4226	9.0937	2.87622	1.32979	2362.5	444146
753	567009	426957777	27.4408	9.0977	2.87680	1.32802	2365.6	445328
754	568516	428661064	27.4591	9.1017	2.87737	1.32626	2368.8	446511
755	570025	430368875	27.4773	9.1057	2.87795	1.32450	2371.9	447697
756	571536	432081216	27.4955	9.1098	2.87852	1.32275	2375.0	448883
757	573049	433798093	27.5136	9.1138	2.87910	1.32100	2378.2	450072
758	574564	435519512	27.5318	9.1178	2.87967	1.31926	2381.3	451262
759	576081	437245479	27.5500	9.1218	2.88024	1.31752	2384.5	452453
760	577600	438976000	27.5681	9.1258	2.88081	1.31579	2387.6	453646
761	579121	440711081	27.5862	9.1298	2.88138	1.31406	2390.8	454841
762	580644	442450728	27.6043	9.1338	2.88196	1.31234	2393.9	456037
763	582169	444194947	27.6225	9.1378	2.88252	1.31062	2397.0	457234
764	583696	445943744	27.6405	9.1418	2.88309	1.30890	2400.2	458434
765	585225	447697125	27.6586	9.1458	2.88366	1.30719	2403.3	459635
766	586756	449455096	27.6767	9.1498	2.88423	1.30548	2406.5	460837
767	588289	451217663	27.6948	9.1537	2.88480	1.30378	2409.6	462042
768	589824	452984832	27.7128	9.1577	2.88536	1.30208	2412.7	463247
769	591361	454756609	27.7308	9.1617	2.88593	1.30039	2415.9	464454
770	592900	456533000	27.7489	9.1657	2.88649	1.29870	2419.0	465663
771	594441	458314011	27.7669	9.1696	2.88705	1.29702	2422.2	466873
772	595984	460099648	27.7849	9.1736	2.88762	1.29534	2425.3	468085
773	597529	461889917	27.8029	9.1775	2.88818	1.29366	2428.5	469298
774	599076	463684824	27.8209	9.1815	2.88874	1.29199	2431.6	470513
775	600625	465484375	27.8388	9.1855	2.88930	1.29032	2434.7	471730
776	602176	467288576	27.8568	9.1894	2.88986	1.28866	2437.9	472948
777	603729	469097433	27.8747	9.1933	2.89042	1.28700	2441.0	474168
778	605284	470910952	27.8927	9.1973	2.89098	1.28535	2444.2	475389
779	606841	472729139	27.9106	9.2012	2.89154	1.28370	2447.3	476612
780	608400	474552000	27.9285	9.2052	2.89209	1.28205	2450.4	477836
781	609961	476379541	27.9464	9.2091	2.89265	1.28041	2453.6	479062
782	611524	478211768	27.9643	9.2130	2.89321	1.27877	2456.7	480290
783	613089	480048687	27.9821	9.2170	2.89376	1.27714	2459.9	481519
784	614656	481890304	28.0000	9.2209	2.89432	1.27551	2463.0	482750
785	616225	483736625	28.0179	9.2248	2.89487	1.27389	2466.2	483982
786	617796	485587656	28.0357	9.2287	2.89542	1.27226	2469.3	485216
787	619369	487443403	28.0535	9.2326	2.89597	1.27065	2472.4	486451
788	620944	489303872	28.0713	9.2365	2.89653	1.26904	2475.6	487688
789	622521	491169069	28.0891	9.2404	2.89708	1.26743	2478.7	488927
790	624100	493039000	28.1069	9.2443	2.89763	1.26582	2481.9	490167
791	625681	494913671	28.1247	9.2482	2.89818	1.26422	2485.0	491409
792	627264	496793088	28.1425	9.2521	2.89873	1.26263	2488.1	492652
793	628849	498677257	28.1603	9.2560	2.89927	1.26103	2491.3	493897
794	630436	500566184	28.1780	9.2599	2.89982	1.25945	2494.4	495143
795	632025	502459875	28.1957	9.2638	2.90037	1.25786	2497.6	496391
796	633616	504358336	28.2135	9.2677	2.90091	1.25628	2500.7	497641
797	635209	506261573	28.2312	9.2716	2.90146	1.25471	2503.8	498892
798	636804	508169592	28.2489	9.2754	2.90200	1.25313	2507.0	500145
799	638401	510082399	28.2666	9.2793	2.90255	1.25156	2510.1	501399

Squares, Cubes, Square Roots, Cube Roots, Logarithms, Reciprocals, Circumferences and Circular Areas of Nos. from 1 to 1000

No.	Square	Cube	Square Root	Cube Root	Log.	1000 x Recip.	No. = Dia.	
							Circum.	Area
800	640000	512000000	28.2843	9.2832	2.90309	1.25000	2513.3	502655
801	641601	513922401	28.3019	9.2870	2.90363	1.24844	2516.4	503912
802	643204	515849608	28.3196	9.2909	2.90417	1.24688	2519.6	505171
803	644809	517781627	28.3373	9.2948	2.90472	1.24533	2522.7	506432
804	646416	519718464	28.3549	9.2986	2.90526	1.24378	2525.8	507694
805	648025	521660125	28.3725	9.3025	2.90580	1.24224	2529.0	508958
806	649636	523606616	28.3901	9.3063	2.90634	1.24069	2532.1	510223
807	651249	525557943	28.4077	9.3102	2.90687	1.23916	2535.3	511490
808	652864	527514112	28.4253	9.3140	2.90741	1.23762	2538.4	512758
809	654481	529475129	28.4429	9.3179	2.90795	1.23609	2541.5	514028
810	656100	531441000	28.4605	9.3217	2.90849	1.23457	2544.7	515300
811	657721	533411731	28.4781	9.3255	2.90902	1.23305	2547.8	516573
812	659344	535387328	28.4956	9.3294	2.90956	1.23153	2551.0	517848
813	660969	537367797	28.5132	9.3332	2.91009	1.23001	2554.1	519124
814	662596	539353144	28.5307	9.3370	2.91062	1.22850	2557.3	520402
815	664225	541343375	28.5482	9.3408	2.91116	1.22699	2560.4	521681
816	665856	543338496	28.5657	9.3447	2.91169	1.22549	2563.5	522962
817	667489	545338513	28.5832	9.3485	2.91222	1.22399	2566.7	524245
818	669124	547343432	28.6007	9.3523	2.91275	1.22249	2569.8	525529
819	670761	549353259	28.6182	9.3561	2.91328	1.22100	2573.0	526814
820	672400	551368000	28.6356	9.3599	2.91381	1.21951	2576.1	528102
821	674041	553387661	28.6531	9.3637	2.91434	1.21803	2579.2	529391
822	675684	555412248	28.6705	9.3675	2.91487	1.21655	2582.4	530681
823	677329	557441767	28.6880	9.3713	2.91540	1.21507	2585.5	531973
824	678976	559476224	28.7054	9.3751	2.91593	1.21359	2588.7	533267
825	680625	561515625	28.7228	9.3789	2.91645	1.21212	2591.8	534562
826	682276	563559976	28.7402	9.3827	2.91698	1.21065	2595.0	535858
827	683929	565609283	28.7576	9.3865	2.91751	1.20919	2598.1	537157
828	685584	567663552	28.7750	9.3902	2.91803	1.20773	2601.2	538456
829	687241	569722789	28.7924	9.3940	2.91855	1.20627	2604.4	539758
830	688900	571787000	28.8097	9.3978	2.91908	1.20482	2607.5	541061
831	690561	573856191	28.8271	9.4016	2.91960	1.20337	2610.7	542365
832	692224	575930368	28.8444	9.4053	2.92012	1.20192	2613.8	543671
833	693889	578009537	28.8617	9.4091	2.92065	1.20048	2616.9	544979
834	695556	580093704	28.8791	9.4129	2.92117	1.19904	2620.1	546288
835	697225	582182875	28.8964	9.4166	2.92169	1.19760	2623.2	547599
836	698896	584277056	28.9137	9.4204	2.92221	1.19617	2626.4	548912
837	700569	586376253	28.9310	9.4241	2.92273	1.19474	2629.5	550226
838	702244	588480472	28.9482	9.4279	2.92324	1.19332	2632.7	551541
839	703921	590589719	28.9655	9.4316	2.92376	1.19189	2635.8	552858
840	705600	592704000	28.9828	9.4354	2.92428	1.19048	2638.9	554177
841	707281	594823321	29.0000	9.4391	2.92480	1.18906	2642.1	555497
842	708964	596947688	29.0172	9.4429	2.92531	1.18765	2645.2	556819
843	710649	599077107	29.0345	9.4466	2.92583	1.18624	2648.4	558142
844	712336	601211584	29.0517	9.4503	2.92634	1.18483	2651.5	559467
845	714025	603351125	29.0689	9.4541	2.92686	1.18343	2654.6	560794
846	715716	605495736	29.0861	9.4578	2.92737	1.18203	2657.8	562122
847	717409	607645423	29.1033	9.4615	2.92788	1.18064	2660.9	563452
848	719104	609800192	29.1204	9.4652	2.92840	1.17925	2664.1	564783
849	720801	611960049	29.1376	9.4690	2.92891	1.17786	2667.2	566116

Squares, Cubes, Square Roots, Cube Roots, Logarithms, Reciprocals, Circumferences and Circular Areas of Nos. from 1 to 1000

No.	Square	Cube	Square Root	Cube Root	Log.	1000 x Recip.	No. = Dia. Circum.	No. = Dia. Area
850	722500	614125000	29.1548	9.4727	2.92942	1.17647	2670.4	567450
851	724201	616295051	29.1719	9.4764	2.92993	1.17509	2673.5	568786
852	725904	618470208	29.1890	9.4801	2.93044	1.17371	2676.6	570124
853	727600	620650477	29.2062	9.4838	2.93095	1.17233	2679.8	571463
854	729316	622835864	29.2233	9.4875	2.93146	1.17096	2682.9	572803
855	731025	625026375	29.2404	9.4912	2.93197	1.16959	2686.1	574146
856	732736	627222016	29.2575	9.4949	2.93247	1.16822	2689.2	575490
857	734449	629422793	29.2746	9.4986	2.93298	1.16686	2692.3	576835
858	736164	631628712	29.2916	9.5023	2.93349	1.16550	2695.5	578182
859	737881	633839779	29.3087	9.5060	2.93399	1.16414	2698.6	579530
860	739600	636056000	29.3258	9.5097	2.93450	1.16279	2701.8	580880
861	741321	638277381	29.3428	9.5134	2.93500	1.16144	2704.9	582232
862	743044	640503928	29.3598	9.5171	2.93551	1.16009	2708.1	583585
863	744769	642735647	29.3769	9.5207	2.93601	1.15875	2711.2	584940
864	746496	644972544	29.3939	9.5244	2.93651	1.15741	2714.3	586297
865	748225	647214625	29.4109	9.5281	2.93702	1.15607	2717.5	587655
866	749956	649461896	29.4279	9.5317	2.93752	1.15473	2720.6	589014
867	751689	651714363	29.4449	9.5354	2.93802	1.15340	2723.8	590375
868	753424	653972032	29.4618	9.5391	2.93852	1.15207	2726.9	591738
869	755161	656234909	29.4788	9.5427	2.93902	1.15075	2730.0	593102
870	756900	658503000	29.4958	9.5464	2.93952	1.14943	2733.2	594468
871	758641	660776311	29.5127	9.5501	2.94002	1.14811	2736.3	595835
872	760384	663054848	29.5296	9.5537	2.94052	1.14679	2739.5	597204
873	762129	665338617	29.5466	9.5574	2.94101	1.14548	2742.6	598575
874	763876	667627624	29.5635	9.5610	2.94151	1.14416	2745.8	599947
875	765625	669921875	29.5804	9.5647	2.94201	1.14286	2748.9	601320
876	767376	672221376	29.5973	9.5683	2.94250	1.14155	2752.0	602696
877	769129	674526133	29.6142	9.5719	2.94300	1.14025	2755.2	604073
878	770884	676836152	29.6311	9.5756	2.94349	1.13895	2758.3	605451
879	772641	679151439	29.6479	9.5792	2.94399	1.13766	2761.5	606831
880	774400	681472000	29.6648	9.5828	2.94448	1.13636	2764.6	608212
881	776161	683797841	29.6816	9.5865	2.94498	1.13507	2767.7	609595
882	777924	686128968	29.6985	9.5901	2.94547	1.13379	2770.9	610980
883	779689	688465387	29.7153	9.5937	2.94596	1.13250	2774.0	612366
884	781456	690807104	29.7321	9.5973	2.94645	1.13122	2777.2	613754
885	783225	693154125	29.7489	9.6010	2.94694	1.12994	2780.3	615143
886	784996	695506456	29.7658	9.6046	2.94743	1.12867	2783.5	616534
887	786769	697864103	29.7825	9.6082	2.94792	1.12740	2786.6	617927
888	788544	700227072	29.7993	9.6118	2.94841	1.12613	2789.7	619321
889	790321	702595369	29.8161	9.6154	2.94890	1.12486	2792.9	620717
890	792100	704969000	29.8329	9.6190	2.94939	1.12360	2796.0	622114
891	793881	707347971	29.8496	9.6226	2.94988	1.12233	2799.2	623513
892	795664	709732288	29.8664	9.6262	2.95036	1.12108	2802.3	624913
893	797449	712121957	29.8831	9.6298	2.95085	1.11982	2805.4	626315
894	799236	714516984	29.8998	9.6334	2.95134	1.11857	2808.6	627718
895	801025	716917375	29.9166	9.6370	2.95182	1.11732	2811.7	629124
896	802816	719323136	29.9333	9.6406	2.95231	1.11607	2814.9	630530
897	804609	721734273	29.9500	9.6442	2.95279	1.11483	2818.0	631938
898	806404	724150792	29.9666	9.6477	2.95328	1.11359	2821.2	633348
899	808201	726572699	29.9833	9.6513	2.95376	1.11235	2824.3	634760

Squares, Cubes, Square Roots, Cube Roots, Logarithms, Reciprocals, Circumferences and Circular Areas of Nos. from 1 to 1000

No.	Square	Cube	Square Root	Cube Root	Log.	1000 x Recip.	No. = Dia.	
							Circum.	Area
900	810000	729000000	30.0000	9.6549	2.95424	1.11111	2827.4	636173
901	811801	731432701	30.0167	9.6585	2.95472	1.10988	2830.6	637587
902	813604	733870808	30.0333	9.6620	2.95521	1.10865	2833.7	639003
903	815409	736314327	30.0500	9.6656	2.95569	1.10742	2836.9	640421
904	817216	738763264	30.0666	9.6692	2.95617	1.10619	2840.0	641840
905	819025	741217625	30.0832	9.6727	2.95665	1.10497	2843.1	643261
906	820836	743677416	30.0998	9.6763	2.95713	1.10375	2846.3	644683
907	822649	746142643	30.1164	9.6799	2.95761	1.10254	2849.4	646107
908	824464	748613312	30.1330	9.6834	2.95809	1.10132	2852.6	647533
909	826281	751089429	30.1496	9.6870	2.95856	1.10011	2855.7	648960
910	828100	753571000	30.1662	9.6905	2.95904	1.09890	2858.8	650388
911	829921	756058031	30.1828	9.6941	2.95952	1.09769	2862.0	651818
912	831744	758550528	30.1993	9.6976	2.95999	1.09649	2865.1	653250
913	833569	761048497	30.2159	9.7012	2.96047	1.09529	2868.3	654684
914	835396	763551944	30.2324	9.7047	2.96095	1.09409	2871.4	656118
915	837225	766060875	30.2490	9.7082	2.96142	1.09290	2874.6	657555
916	839056	768575296	30.2655	9.7118	2.96190	1.09170	2877.7	658993
917	840889	771095213	30.2820	9.7153	2.96237	1.09051	2880.8	660433
918	842724	773620632	30.2985	9.7188	2.96284	1.08932	2884.0	661874
919	844561	776151559	30.3150	9.7224	2.96332	1.08814	2887.1	663317
920	846400	778688000	30.3315	9.7259	2.96379	1.08696	2890.3	664761
921	848241	781229961	30.3480	9.7294	2.96426	1.08578	2893.4	666207
922	850084	783777448	30.3645	9.7329	2.96473	1.08460	2896.5	667654
923	851929	786330467	30.3809	9.7364	2.96520	1.08342	2899.7	669103
924	853776	788889024	30.3974	9.7400	2.96567	1.08225	2902.8	670554
925	855625	791453125	30.4138	9.7435	2.96614	1.08108	2906.0	672006
926	857476	794022776	30.4302	9.7470	2.96661	1.07991	2909.1	673460
927	859329	796597983	30.4467	9.7505	2.96708	1.07875	2912.3	674915
928	861184	799178752	30.4631	9.7540	2.96755	1.07759	2915.4	676372
929	863041	801765089	30.4795	9.7575	2.96802	1.07643	2918.5	677831
930	864900	804357000	30.4959	9.7610	2.96848	1.07527	2921.7	679291
931	866761	806954491	30.5123	9.7645	2.96895	1.07411	2924.8	680752
932	868624	809557568	30.5287	9.7680	2.96942	1.07296	2928.0	682216
933	870489	812166237	30.5450	9.7715	2.96988	1.07181	2931.1	683680
934	872356	814780504	30.5614	9.7750	2.97035	1.07066	2934.2	685147
935	874225	817400375	30.5778	9.7785	2.97081	1.06952	2937.4	686615
936	876096	820025856	30.5941	9.7819	2.97128	1.06838	2940.5	688084
937	877969	822656953	30.6105	9.7854	2.97174	1.06724	2943.7	689555
938	879844	825293672	30.6268	9.7889	2.97220	1.06610	2946.8	691028
939	881721	827936019	30.6431	9.7924	2.97267	1.06496	2950.0	692502
940	883600	830584000	30.6594	9.7959	2.97313	1.06383	2953.1	693978
941	885481	833237621	30.6757	9.7993	2.97359	1.06270	2956.2	695455
942	887364	835896888	30.6920	9.8028	2.97405	1.06157	2959.4	696934
943	889249	838561807	30.7083	9.8063	2.97451	1.06045	2962.5	698415
944	891136	841232384	30.7246	9.8097	2.97497	1.05932	2965.7	699897
945	893025	843908625	30.7409	9.8132	2.97543	1.05820	2968.8	701380
946	894916	846590536	30.7571	9.8167	2.97589	1.05708	2971.9	702865
947	896809	849278123	30.7734	9.8201	2.97635	1.05597	2975.1	704352
948	898704	851971392	30.7896	9.8236	2.97681	1.05485	2978.2	705840
949	900601	854670349	30.8058	9.8270	2.97727	1.05374	2981.4	707330

Squares, Cubes, Square Roots, Cube Roots, Logarithms, Reciprocals, Circumferences and Circular Areas of Nos. from 1 to 1000

No.	Square	Cube	Square Root	Cube Root	Log.	1000 x Recip.	No. = Dia.	
							Circum.	Area
950	902500	857375000	30.8221	9.8305	2.97772	1.05263	2984.5	708822
951	904401	860085351	30.8383	9.8339	2.97818	1.05152	2987.7	710315
952	906304	862801408	30.8545	9.8374	2.97864	1.05042	2990.8	711809
953	908209	865523177	30.8707	9.8408	2.97909	1.04932	2993.9	713306
954	910116	868250664	30.8869	9.8443	2.97955	1.04822	2997.1	714803
955	912025	870983875	30.9031	9.8477	2.98000	1.04712	3000.2	716303
956	913936	873722816	30.9192	9.8511	2.98046	1.04603	3003.4	717804
957	915849	876467493	30.9354	9.8546	2.98091	1.04493	3006.5	719306
958	917764	879217912	30.9516	9.8580	2.98137	1.04384	3009.6	720810
959	919681	881974079	30.9677	9.8614	2.98182	1.04275	3012.8	722316
960	921600	884736000	30.9839	9.8648	2.98227	1.04167	3015.9	723823
961	923521	887503681	31.0000	9.8683	2.98272	1.04058	3019.1	725332
962	925444	890277128	31.0161	9.8717	2.98318	1.03950	3022.2	726842
963	927369	893056347	31.0322	9.8751	2.98363	1.03842	3025.4	728354
964	929296	895841344	31.0483	9.8785	2.98408	1.03734	3028.5	729867
965	931225	898632125	31.0644	9.8819	2.98453	1.03627	3031.6	731382
966	933156	901428696	31.0805	9.8854	2.98498	1.03520	3034.8	732899
967	935089	904231063	31.0966	9.8888	2.98543	1.03413	3037.9	734417
968	937024	907039232	31.1127	9.8922	2.98588	1.03306	3041.1	735937
969	938961	909853209	31.1288	9.8956	2.98632	1.03199	3044.2	737458
970	940900	912673000	31.1448	9.8990	2.98677	1.03093	3047.3	738981
971	942841	915498611	31.1609	9.9024	2.98722	1.02987	3050.5	740506
972	944784	918330048	31.1769	9.9058	2.98767	1.02881	3053.6	742032
973	946729	921167317	31.1929	9.9092	2.98811	1.02775	3056.8	743559
974	948676	924010424	31.2090	9.9126	2.98856	1.02669	3059.9	745088
975	950625	926859375	31.2250	9.9160	2.98900	1.02564	3063.1	746619
976	952576	929714176	31.2410	9.9194	2.98945	1.02459	3066.2	748151
977	954529	932574833	31.2570	9.9227	2.98989	1.02354	3069.3	749685
978	956484	935441352	31.2730	9.9261	2.99034	1.02249	3072.5	751221
979	958441	938313739	31.2890	9.9295	2.99078	1.02145	3075.6	752758
980	960400	941192000	31.3050	9.9329	2.99123	1.02041	3078.8	754296
981	962361	944076141	31.3209	9.9363	2.99167	1.01937	3081.9	755837
982	964324	946966168	31.3369	9.9396	2.99211	1.01833	3085.0	757378
983	966289	949862087	31.3528	9.9430	2.99255	1.01729	3088.2	758922
984	968256	952763904	31.3688	9.9464	2.99300	1.01626	3091.3	760466
985	970225	955671625	31.3847	9.9497	2.99344	1.01523	3094.5	762013
986	972196	958585256	31.4006	9.9531	2.99388	1.01420	3097.6	763561
987	974169	961504803	31.4166	9.9565	2.99432	1.01317	3100.8	765111
988	976144	964430272	31.4325	9.9598	2.99476	1.01215	3103.9	766662
989	978121	967361669	31.4484	9.9632	2.99520	1.01112	3107.0	768214
990	980100	970299000	31.4643	9.9666	2.99564	1.01010	3110.2	769769
991	982081	973242271	31.4802	9.9699	2.99607	1.00908	3113.3	771325
992	984064	976191488	31.4960	9.9733	2.99651	1.00806	3116.5	772882
993	986049	979146657	31.5119	9.9766	2.99695	1.00705	3119.6	774441
994	988036	982107784	31.5278	9.9800	2.99739	1.00604	3122.7	776002
995	990025	985074875	31.5436	9.9833	2.99782	1.00503	3125.9	777564
996	992016	988047936	31.5595	9.9866	2.99826	1.00402	3129.0	779128
997	994009	991026973	31.5753	9.9900	2.99870	1.00301	3132.2	780693
998	996004	994011992	31.5911	9.9933	2.99913	1.00200	3135.3	782260
999	998001	997002999	31.6070	9.9967	2.99957	1.00100	3138.5	783828

DISCOUNT TABLE

Discount, Per Cent.	Equivalent	Net	Discount, Per Cent.	Equivalent	Net
25	.25	.75	30	.30	.70
25 and 2½	.26875	.73125	30 and 2½	.3175	.6825
25 2½ and 2½	.2870	.7130	30 2½ and 2½	.3346	.6654
25 2½ 5	.3053	.6947	30 2½ 5	.3516	.6484
25 2½ 7½	.3236	.6764	30 2½ 7½	.3687	.6313
25 2½ 10	.3419	.6581	30 2½ 10	.38575	.61425
25 5	.2875	.7125	30 5	.335	.665
25 5 2½	.3053	.6947	30 5 2½	.3516	.6484
25 5 5	.3231	.6769	30 5 5	.36825	.63175
25 5 7½	.3409	.6591	30 5 7½	.3849	.6151
25 5 10	.35875	.64125	30 5 10	.4015	.5985
25 7½	.30625	.69375	30 7½	.3525	.6475
25 7½ 2½	.3236	.6764	30 7½ 2½	.3687	.6313
25 7½ 5	.3409	.6591	30 7½ 5	.3849	.6151
25 7½ 7½	.3583	.6417	30 7½ 7½	.4009	.5991
25 7½ 10	.3756	.6244	30 7½ 10	.41725	.58275
25 10	.3250	.6750	30 10	.37	.63
25 10 2½	.3419	.6581	30 10 2½	.38575	.61425
25 10 5	.35875	.64125	30 10 5	.4015	.5985
25 10 7½	.3756	.6244	30 10 7½	.41725	.58275
25 10 10	.3925	.6075	30 10 10	.433	.567
27½	.275	.725	32½	.325	.675
27½ 2½	.2931	.7069	32½ 2½	.3419	.6581
27½ 2½ 2½	.3108	.6892	32½ 2½ 2½	.3583	.6417
27½ 2½ 5	.3285	.6715	32½ 2½ 5	.3748	.6252
27½ 2½ 7½	.3461	.6539	32½ 2½ 7½	.3912	.6088
27½ 2½ 10	.3638	.6362	32½ 2½ 10	.4077	.5923
27½ 5	.31125	.68875	32½ 5	.35875	.64125
27½ 5 2½	.3285	.6715	32½ 5 2½	.3748	.6252
27½ 5 5	.3457	.6543	32½ 5 5	.3908	.6092
27½ 5 7½	.3629	.6371	32½ 5 7½	.4068	.5932
27½ 5 10	.3801	.6199	32½ 5 10	.4229	.5771
27½ 7½	.3294	.6706	32½ 7½	.3756	.6244
27½ 7½ 2½	.3461	.6539	32½ 7½ 2½	.3912	.6088
27½ 7½ 5	.3629	.6371	32½ 7½ 5	.4068	.5932
27½ 7½ 7½	.3797	.6203	32½ 7½ 7½	.4225	.5775
27½ 7½ 10	.3964	.6036	32½ 7½ 10	.4381	.5619
27½ 10	.3475	.6525	32½ 10	.3925	.6075
27½ 10 2½	.3638	.6362	32½ 10 2½	.4077	.5923
27½ 10 5	.3801	.6199	32½ 10 5	.4229	.5771
27½ 10 7½	.3965	.6035	32½ 10 7½	.4381	.5619
27½ 10 10	.41275	.58725	32½ 10 10	.45325	.54675

DISCOUNT TABLE—Continued

Discount, Per Cent.	Equivalent	Net	Discount, Per Cent.	Equivalent	Net
35	.35	.65	40	.40	.60
35 and 2½	.36625	.63375	40 and 2½	.415	.585
35 2½ and 2½	.3821	.6179	40 2½ and 2½	.4296	.5704
35 2½ 5	.3979	.6021	40 2½ 5	.44425	.55575
35 2½ 7½	.4138	.5862	40 2½ 7½	.4589	.5411
35 2½ 10	.4296	.5704	40 2½ 10	.4735	.5265
35 5	.3825	.6175	40 5	.43	.57
35 5 2½	.3979	.6021	40 5 2½	.44425	.55575
35 5 5	.4134	.5866	40 5 5	.4585	.5415
35 5 7½	.4288	.5712	40 5 7½	.47275	.52725
35 5 10	.44425	.55575	40 5 10	.487	.513
35 7½	.39875	.60125	40 7½	.445	.555
35 7½ 2½	.4138	.5862	40 7½ 2½	.4589	.5411
35 7½ 5	.4288	.5712	40 7½ 5	.47275	.52725
35 7½ 7½	.4438	.5562	40 7½ 7½	.4866	.5134
35 7½ 10	.4589	.5411	40 7½ 10	.5005	.4995
35 10	.415	.585	40 10	.46	.54
35 10 2½	.4296	.5704	40 10 2½	.4735	.5265
35 10 5	.44425	.55575	40 10 5	.487	.513
35 10 7½	.4589	.5411	40 10 7½	.5005	.4995
35 10 10	.4735	.5265	40 10 10	.524	.486
37½	.375	.625	42½	.425	.575
37½ 2½	.3906	.6094	42½ 2½	.4394	.5606
37½ 2½ 2½	.4059	.5941	42½ 2½ 2½	.4534	.5466
37½ 2½ 5	.4211	.5789	42½ 2½ 5	.4674	.5326
37½ 2½ 7½	.4363	.5637	42½ 2½ 7½	.4814	.5186
37½ 2½ 10	.4516	.5484	42½ 2½ 10	.4954	.5046
37½ 5	.40625	.59375	42½ 5	.45375	.54625
37½ 5 2½	.4211	.5789	42½ 5 2½	.4674	.5326
37½ 5 5	.4359	.5641	42½ 5 5	.4811	.5189
37½ 5 7½	.4508	.5492	42½ 5 7½	.4947	.5053
37½ 5 10	.4656	.5344	42½ 5 10	.5084	.4916
37½ 7½	.4219	.5781	42½ 7½	.4681	.5319
37½ 7½ 2½	.4363	.5637	42½ 7½ 2½	.4814	.5186
37½ 7½ 5	.4508	.5492	42½ 7½ 5	.4947	.5053
37½ 7½ 7½	.4652	.5348	42½ 7½ 7½	.508	.492
37½ 7½ 10	.4797	.5203	42½ 7½ 10	.5213	.4787
37½ 10	.4375	.5625	42½ 10	.4825	.5175
37½ 10 2½	.4516	.5484	42½ 10 2½	.4954	.5046
37½ 10 5	.4656	.5344	42½ 10 5	.5084	.4916
37½ 10 7½	.4797	.5203	42½ 10 7½	.5213	.4787
37½ 10 10	.49375	.50625	42½ 10 10	.53425	.46575

DISCOUNT TABLE—Continued

Discount, Per Cent.	Equivalent	Net	Discount, Per Cent.	Equivalent	Net
45	.45	.55	50	.50	.50
45 and 2½	.46375	.53625	50 and 2½	.5125	.4875
45 2½ and 2½	.4772	.5228	50 2½ and 2½	.5247	.4753
45 2½ 5	.4906	.5094	50 2½ 5	.5369	.4631
45 2½ 7½	.504	.496	50 2½ 7½	.5491	.4509
45 2½ 10	.5174	.4826	50 2½ 10	.56125	.43875
45 5	.4775	.5225	50 5	.525	.475
45 5 2½	.4906	.5094	50 5 2½	.5369	.4631
45 5 5	.5036	.4964	50 5 5	.54875	.45125
45 5 7½	.5167	.4833	50 5 7½	.5606	.4394
45 5 10	.52975	.47025	50 5 10	.5725	.4275
45 7½	.49125	.50875	50 7½	.5375	.4625
45 7½ 2½	.504	.496	50 7½ 2½	.5491	.4509
45 7½ 5	.5167	.4833	50 7½ 5	.5606	.4394
45 7½ 7½	.5294	.4706	50 7½ 7½	.5722	.4278
45 7½ 10	.5421	.4579	50 7½ 10	.58375	.41625
45 10	.505	.495	50 10	.55	.45
45 10 2½	.5174	.4826	50 10 2½	.56125	.43875
45 10 5	.52975	.47025	50 10 5	.5725	.4275
45 10 7½	.5421	.4579	50 10 7½	.58375	.41625
45 10 10	.5545	.4455	50 10 10	.595	.405
47½	.475	.525	52½	.525	.472
47½ 2½	.4881	.5119	52½ 2½	.5369	.4631
47½ 2½ 2½	.5009	.4991	52½ 2½ 2½	.5485	.4515
47½ 2½ 5	.5137	.4863	52½ 2½ 5	.56	.44
47½ 2½ 7½	.5265	.4735	52½ 2½ 7½	.5716	.4284
47½ 2½ 10	.5393	.4607	52½ 2½ 10	.5832	.4168
47½ 5	.50125	.49875	52½ 5	.54875	.45125
47½ 5 2½	.5137	.4863	52½ 5 2½	.56	.44
47½ 5 5	.5262	.4738	52½ 5 5	.5713	.4287
47½ 5 7½	.5386	.4614	52½ 5 7½	.5826	.4174
47½ 5 10	.5511	.4489	52½ 5 10	.5939	.4061
47½ 7½	.5144	.4856	52½ 7½	.5606	.4394
47½ 7½ 2½	.5265	.4735	52½ 7½ 2½	.5716	.4284
47½ 7½ 5	.5387	.4613	52½ 7½ 5	.5826	.4174
47½ 7½ 7½	.5508	.4492	52½ 7½ 7½	.5936	.4064
47½ 7½ 10	.5629	.4371	52½ 7½ 10	.6046	.3954
47½ 10	.5275	.4725	52½ 10	.5725	.4275
47½ 10 2½	.5393	.4607	52½ 10 2½	.5832	.4168
47½ 10 5	.5511	.4489	52½ 10 5	.5939	.4061
47½ 10 7½	.5629	.4371	52½ 10 7½	.6046	.3954
47½ 10 10	.57475	.42525	52½ 10 10	.61525	.38475

DISCOUNT TABLE—Continued

Discount, Per Cent.	Equivalent	Net	Discount, Per Cent.	Equivalent	Net
55	.55	.45	60	.60	.40
55 and 2½	.56125	.43875	60 and 2½	.61	.39
55 2½ and 2½	.5722	.4278	60 2½ and 2½	.61975	.38025
55 2½ 5	.5832	.4168	60 2½ 5	.6295	.3705
55 2½ 7½	.5942	.4058	60 2½ 7½	.63925	.36075
55 2½ 10	.6051	.3949	60 2½ 10	.649	.351
55 5	.5725	.4275	60 5	.62	.38
55 5 2½	.5832	.4168	60 5 2½	.6295	.3705
55 5 5	.5939	.4061	60 5 5	.639	.361
55 5 7½	.6046	.3954	60 5 7½	.6485	.3515
55 5 10	.61525	.38475	60 5 10	.658	.342
55 7½	.58375	.41625	60 7½	.63	.37
55 7½ 2½	.5942	.4058	60 7½ 2½	.63925	.36075
55 7½ 5	.6046	.3954	60 7½ 5	.6485	.3515
55 7½ 7½	.615	.385	60 7½ 7½	.65775	.34225
55 7½ 10	.6254	.3746	60 7½ 10	.667	.333
55 10	.595	.405	60 10	.64	.36
55 10 2½	.6051	.3949	60 10 2½	.649	.351
55 10 5	.61525	.38475	60 10 5	.658	.342
55 10 7½	.6254	.3746	60 10 7½	.667	.333
55 10 10	.6355	.3645	60 10 10	.676	.324
57½	.575	.425	62½	.625	.375
57½ 2½	.5856	.4144	62½ 2½	.6344	.3656
57½ 2½ 2½	.596	.404	62½ 2½ 2½	.6435	.3565
57½ 2½ 5	.6063	.3937	62½ 2½ 5	.6527	.3473
57½ 2½ 7½	.6167	.3833	62½ 2½ 7½	.6618	.3382
57½ 2½ 10	.6271	.3729	62½ 2½ 10	.6709	.3291
57½ 5	.5962	.40375	62½ 5	.64375	.35625
57½ 5 2½	.60635	.3937	62½ 5 2½	.6527	.3473
57½ 5 5	.6164	.3836	62½ 5 5	.6616	.3384
57½ 5 7½	.6265	.3735	62½ 5 7½	.6705	.3295
57½ 5 10	.6366	.3634	62½ 5 10	.6794	.3206
57½ 7½	.6069	.3931	62½ 7½	.6531	.3469
57½ 7½ 2½	.6167	.3833	62½ 7½ 2½	.6618	.3382
57½ 7½ 5	.6265	.3735	62½ 7½ 5	.6705	.3295
57½ 7½ 7½	.6364	.3636	62½ 7½ 7½	.6791	.3209
57½ 7½ 10	.6462	.3538	62½ 7½ 10	.6878	.3122
57½ 10	.6175	.3825	62½ 10	.6625	.3375
57½ 10 2½	.6271	.3729	62½ 10 2½	.6709	.3291
57½ 10 5	.6366	.3634	62½ 10 5	.6794	.3206
57½ 10 7½	.6462	.3538	62½ 10 7½	.6878	.3122
57½ 10 10	.6557	.34425	62½ 10 10	.69625	.30375

DISCOUNT TABLE—Continued

Discount, Per Cent.	Equivalent	Net	Discount, Per Cent.	Equivalent	Net
65	.65	.35	70	.70	.30
65 and 2½	.65875	.34125	70 and 2½	.7075	.2925
65 2½ and 2½	.6673	.3327	70 2½ and 2½	.7148	.2852
65 2½ 5	.6758	.3242	70 2½ 5	.7221	.2779
65 2½ 7½	.6843	.3157	70 2½ 7½	.7294	.2706
65 2½ 10	.6929	.3071	70 2½ 10	.73675	.26325
65 5	.6675	.3325	70 5	.715	.285
65 5 2½	.6758	.3242	70 5 2½	.7221	.2779
65 5 5	.6841	.3159	70 5 5	.72925	.27075
65 5 7½	.6924	.3076	70 5 7½	.7364	.2636
65 5 10	.70075	.29925	70 5 10	.7435	.2565
65 7½	.67625	.32375	70 7½	.7225	.2775
65 7½ 2½	.6843	.3157	70 7½ 2½	.7294	.2706
65 7½ 5	.6924	.3076	70 7½ 5	.7364	.2636
65 7½ 7½	.7005	.2995	70 7½ 7½	.7433	.2567
65 7½ 10	.7086	.2914	70 7½ 10	.75025	.24975
65 10	.685	.315	70 10	.73	.27
65 10 2½	.6929	.3071	70 10 2½	.73675	.26325
65 10 5	.70075	.29925	70 10 5	.7435	.2565
65 10 7½	.7086	.2914	70 10 7½	.75025	.24975
65 10 10	.7165	.2835	70 10 10	.757	.243
67½	.675	.325	72½	.725	.275
67½ 2½	.6831	.3169	72½ 2½	.7319	.2681
67½ 2½ 2½	.691	.309	72½ 2½ 2½	.7386	.2614
67½ 2½ 5	.699	.301	72½ 2½ 5	.7452	.2548
67½ 2½ 7½	.7069	.2931	72½ 2½ 7½	.752	.248
67½ 2½ 10	.7148	.2852	72½ 2½ 10	.7587	.2413
67½ 5	.69125	.30875	72½ 5	.73875	.26125
67½ 5 2½	.699	.301	72½ 5 2½	.7453	.2547
67½ 5 5	.7067	.2933	72½ 5 5	.7518	.2482
67½ 5 7½	.7144	.2856	72½ 5 7½	.7583	.2417
67½ 5 10	.7221	.2779	72½ 5 10	.7649	.2351
67½ 7½	.6994	.3006	72½ 7½	.7456	.2544
67½ 7½ 2½	.7069	.2931	72½ 7½ 2½	.752	.248
67½ 7½ 5	.7144	.2856	72½ 7½ 5	.7583	.2417
67½ 7½ 7½	.7219	.2781	72½ 7½ 7½	.7647	.2353
67½ 7½ 10	.7294	.2706	72½ 7½ 10	.7711	.2289
67½ 10	.7075	.2925	72½ 10	.7525	.2475
67½ 10 2½	.7148	.2852	72½ 10 2½	.7587	.2413
67½ 10 5	.7221	.2779	72½ 10 5	.7649	.2351
67½ 10 7½	.7294	.2706	72½ 10 7½	.7711	.2289
67½ 10 10	.73675	.26325	72½ 10 10	.77725	.22275

DISCOUNT TABLE—Concluded

Discount, Per Cent.	Equivalent	Net
75	.75	.25
75 and 2½	.75625	.24375
75 2½ and 2½	.76234	.23766
75 2½ 5	.7684	.2316
75 2½ 7½	.7745	.2255
75 2½ 10	.7806	.2194
75 5	.7625	.2375
75 5 2½	.7684	.2316
75 5 5	.7744	.2256
75 5 7½	.7803	.2197
75 5 10	.78625	.21375
75 7½	.76875	.23125
75 7½ 2½	.7745	.2255
75 7½ 5	.7803	.2197
75 7½ 7½	.7861	.2139
75 7½ 10	.7919	.2081
75 10	.775	.225
75 10 2½	.7806	.2194
75 10 5	.78625	.21375
75 10 7½	.7919	.2081
75 10 10	.7975	.2025
77½	.775	.225
77½ 2½	.7806	.2194
77½ 2½ 2½	.7861	.2139
77½ 2½ 5	.7916	.2084
77½ 2½ 7½	.7971	.2029
77½ 2½ 10	.8026	.1974
77½ 5	.78625	.21375
77½ 5 2½	.7916	.2084
77½ 5 5	.7969	.2031
77½ 5 7½	.8023	.1977
77½ 5 10	.8076	.1924
77½ 7½	.7919	.2081
77½ 7½ 2½	.7971	.2029
77½ 7½ 5	.8023	.1977
77½ 7½ 7½	.8075	.1925
77½ 7½ 10	.8127	.1873
77½ 10	.7975	.2025
77½ 10 2½	.8026	.1974
77½ 10 5	.8076	.1924
77½ 10 7½	.8127	.1873
77½ 10 10	.81775	.18225
80	.80	.20
80 and 2½	.805	.1950
80 2½ and 2½	.8099	.1901
80 2½ 5	.8147	.1853
80 2½ 7½	.8197	.1803
80 2½ 10	.8245	.1755
80 5	.81	.19
80 5 2½	.8148	.1852
80 5 5	.8195	.1805
80 5 7½	.8243	.1757
80 5 10	.829	.1710
80 7½	.815	.1850
80 7½ 2½	.8196	.1804
80 7½ 5	.8242	.1758
80 7½ 7½	.8289	.1711
80 7½ 10	.8335	.1665
80 10	.82	.18
80 10 2½	.8245	.1755
80 10 5	.829	.1710
80 10 7½	.8335	.1665
80 10 10	.838	.162

A System

for

Economically Transmitting

by

Telegraph

Messages relating to and Specifications for

Steel Plates

Code Questions

Allegheny —At what price will you furnish . . . tons . . . steel for immediate delivery?

Appomattox —At what price will you furnish . . . tons . . . steel for delivery in . . . days?

Big Sandy —How soon can you deliver . . . tons . . steel?

Chemung —At what price and how soon will you deliver . . . tons . . . steel?

Congaree —At what price will you deliver at . . . . , . . . tons . . . steel?

Genesee —What is the lowest contract rate of freight you can obtain by cheapest route to . . . ?

Housatonic —What is the lowest contract rate of freight you can obtain by fast freight to . . . ?

Juniata —What is the lowest rate by express per 100 pounds to . . . ?

Kanawha —When will our (my) order dated . . . be shipped?

Kankakee —What discount from price will you allow for prompt cash on receipt of invoice and bill of lading?

Lehigh —What discount from price will you allow for prompt cash on receipt of goods?

Merrimac —What are your best terms (longest time) you will allow us on our orders?

Moselle —Did you receive our letter of . . . ?

Murray —Did you receive our telegram of . . . ?

Malheur —By what route did you ship?

Marias —When did you ship?

Machias —Has there been any change in price?

Murchison —Is price quoted net, or list, subject to a discount?

Magdalena —Can you substitute?

Meta —Have you sold?

Mamore —Is the order still in force?

Maderia —Have you remitted?

Mezene —How shall we draw?

Marcus —Shall we draw at sight?

Maros —Have you drawn?

Meinam —How have you drawn?

Main —How much did you draw for?

Maravia —Have you anything new to report?

Maroni —Is there anything further in this locality that requires attention?

Commands and Correspondence

Mohawk —Make for us immediately and ship per first steamer.

Monongahela—Make for us immediately and ship per fast freight.

Maumee —Make for us immediately and ship per express.

Miami —Make for us immediately and ship per rail.

Mobile —Make for us immediately and ship per rail and lake.

Niagara —Duplicate our entire order of date . . . instant.

Ocmulgee —Duplicate entire revised order of date . . . . . . instant.

Piscataqua —Have shipment of our order of date . . . . . . instant, wired through to us. We are in pressing need of the stock.

Passaic —Send telegraphic tracer after your shipment to us of date . . . . . . instant. The stock has not arrived.

Potomac —Shipment dated . . . . , partly arrived, have tracer sent after . . . . missing plates.

ADDITIONAL CODE WORDS

Plague	—Ship what you have ready and balance as soon as possible.
Plaint	—Minimum tensile strength to be 60,000 pounds per square inch.
Played	—Minimum tensile strength to be 65,000 pounds per square inch.
Pleader	—Minimum tensile strength to be 50,000 pounds per square inch.
Pledged	—Order is being executed and cannot be cancelled.
Plaintly	—Too late to make any alterations in order now.
Plinth	—The alterations in order have been (or will be) made.
Plodder	—See letter.
Popgun	—If not satisfactory, telegraph at once.
Pontiff	—We have none in stock, but can make and ship.
Powder	—For immediate acceptance.
Pollux	—We will hold offer open until . . . . .
Polite	—We hereby withdraw all quotations.
Poems	—We cannot hold offer open later than . . . .
Poacher	—Your telegram is unintelligible, please repeat.
Plural	—Freight, by rail, in car loads, per 100 pounds is . . . .
Plumes	—Freight, by rail, in less than car loads is . . . .
Plumber	—See our letter of . . . .
Plumage	—See our telegram of . . . .

Raritan —Substitute . . . . plates . . . ., for . . . . plates . . . . , ... in our order of date . . . . . . instant.

Rappahannock—Suspend work on our order of date . . . . . . instant.

Roanoke —Suspend work on our order of date . . . . . until receipt of our revised specification.

Saranac —Suspend work on our order of date . . . . . instant, until receipt of revised specification mailed to you this day.

Saguenay —Wire quickly lowest price and earliest delivery the following plates . . . .

Santee — . . . . are in the market for . . . . Can secure preference at . . . . . Will you authorize us to take the order? Answer.

Saskatchewan —Your telegram received.

Sabine —We can ship at once.

Saluda —Your letter received.

Saco —We can ship to-morrow if ordered at once.

Slave —We can ship in two days after order, if ordered at once.

Skeena —We can ship this week, if ordered at once.

Souris —We can ship in one week after order, if ordered at once.

Shenandoah —We can ship in a week or ten days after order, if ordered at once.

Staunton —We can ship in ten days after order, if ordered at once.

Susquehanna —We can ship in two to three weeks after order, if ordered at once.

Surinam —We can ship in three to four weeks, if ordered at once.

Tallapoosa —Cannot promise definite time delivery. Will do the very best we can.

NOTE.—("If not unexpectedly delayed for reasons beyond our control,")—should be understood as following all the above promises to ship in a specified time.

Tensas —We shipped your order on the . . . .

Thames —We have shipped.

Tombigbee —We cannot ship at present for want of cars.

Tiber —We cannot sell at the price you offer.

Trinity —We cannot shade the price quoted.

Tugaloo —The price quoted is net F. O. B. Coatesville.

Ural —The price quoted is subject to freight allowance to your city.

Uruguay —To meet requirements of latest Standard Specifications of Association of American Steel Manufacturers for Soft Steel.

Vistritza —To meet requirements of latest Standard Specifications of Association of American Steel Manufacturers for Medium Steel.

Vermejo —To meet requirements of latest Standard Specifications of Association of American Steel Manufacturers for Flange or Boiler Steel.

Vilaine —To meet requirements of latest Standard Specifications of Association of American Steel Manufacturers for Fire-box Steel.

Verdigris —The minimum and maximum tensile strength to be 55,000 to 60,000 pounds per square inch.

Ventuari —Elongation to be 25% in 8 inches.

Vistula —Reduction of area 50%.

Volga —Furnish copy of Mill test of at least two plates.

Wabash —Leave coupons on all the Rectangular plates.

Weser —All plates for marine work, and subject to Government inspection.

Zambesi —This boiler work will be subject to Hartford inspection.

Number of Plates Required

1	**Aback**	30	**Affirm**
2	**Abaft**	31	**Afflict**
3	**Abase**	32	**Afford**
4	**Abated**	33	**Affray**
5	**Abbot**	34	**Afresh**
6	**Abide**	35	**Again**
7	**Abject**	36	**Ahead**
8	**Abroad**	37	**Ahoy**
9	**Abound**	38	**Aim**
10	**Abrupt**	39	**Aisle**
11	**Absent**	40	**Akin**
12	**Absorb**	41	**Alarm**
13	**Abused**	42	**Alas**
14	**Accuse**	43	**Albino**
15	**Acorn**	44	**Album**
16	**Acquit**	45	**Alder**
17	**Across**	46	**Alert**
18	**Acted**	47	**Alike**
19	**Actor**	48	**Allow**
20	**Acute**	49	**Allude**
21	**Adapt**	50	**Aloft**
22	**Adhere**	51	**Aloud**
23	**Adjoin**	52	**Alpaca**
24	**Admit**	53	**Alpine**
25	**Adore**	54	**Amber**
26	**Advent**	55	**Amid**
27	**Adverb**	56	**Amity**
28	**Advise**	57	**Amuse**
29	**Affair**	58	**Anchor**

NUMBER OF PLATES REQUIRED—Concluded

59	Anew	84	Arson
60	Angle	85	Artery
61	Angry	86	Ascend
62	Annoy	87	Aslant
63	Anthem	88	Asleep
64	Anthill	89	Assail
65	Anvil	90	Assent
66	Apace	91	Assign
67	Apart	92	Assume
68	Apathy	93	Astray
69	Appetite	94	Asylum
70	Appear	95	Attain
71	Apron	96	Attend
72	Arab	97	Auburn
73	Arch	98	Aurora
74	Arctic	99	Author
75	Ardent	100	Avast
76	Argosy	200	Averse
77	Aright	300	Avidious
78	Armlet	400	Avarice
79	Armory	500	Avenged
80	Armies	600	Avenue
81	Arouse	700	Avouch
82	Arrange	800	Avowal
83	Arrest	900	Awake

1000 Awning

CODE

QUALITY REQUIRED

STEEL PLATES

SORGHUM	Tank
TANSY	Shell
EXOTIC	Flange
EVERGREEN	Fire Box
LICHEN	Marine
EXTRA	Extra Locomotive Fire Box

CODE

THICKNESS

OF

STEEL PLATES

$\frac{1}{8}$	Antelope	$\frac{1}{2}$	Merino
No. 10	Bear	$\frac{9}{16}$	Opossum
No. 9	Buffalo	$\frac{5}{8}$	Otter
No. 8	Deer	$\frac{11}{16}$	Panther
No. 7	Dog	$\frac{3}{4}$	Raccoon
$\frac{3}{16}$	Elk	$\frac{13}{16}$	Rabbit
No. 6	Elephant	$\frac{7}{8}$	Sheep
No. 5	Fox	$\frac{15}{16}$	Tiger
No. 4	Goat	1	Tapir
$\frac{1}{4}$	Horse	$1\frac{1}{8}$	Turtle
No. 3	Hyena	$1\frac{1}{4}$	Whale
No. 2	Jackal	$1\frac{3}{8}$	Walrus
No. 1	Kangaroo	$1\frac{1}{2}$	Wolf
$\frac{5}{16}$	Lion	$1\frac{5}{8}$	Weasel
$\frac{3}{8}$	Lynx	$1\frac{3}{4}$	Wren
$\frac{7}{16}$	Leopard		

Widths of Plates

The following words will answer for transmitting fractions of an inch:

1-4	**Came**
1-2	**Saw**
3-4	**Conquered**

In specifying fractions of an inch, above should be used IN ADDITION to the other word signifying width, length, or diameter wanted, as the case may be.

6	**Babble**
7	**Badly**
8	**Balmy**
9	**Bandit**
10	**Bantam**
11	**Bargains**
12	**Basely**
13	**Bathe**
14	**Bayard**
15	**Beast**
16	**Become**
17	**Beeves**
18	**Begin**
19	**Behind**
20	**Belong**
21	**Bestir**
22	**Beyond**
23	**Birch**
24	**Bleeds**
25	**Bluff**
26	**Bobbin**
27	**Booked**
28	**Bound**
29	**Brains**
30	**Break**
31	**Cabal**
32	**Caddy**
33	**Cake**
34	**Calendar**
35	**Calker**
36	**Calumny**
37	**Camlet**
38	**Canary**
39	**Candor**
40	**Canopy**
41	**Capital**
42	**Carbon**
43	**Caress**
44	**Carry**
45	**Casket**
46	**Caveat**
47	**Cellar**
48	**Chance**
49	**Cheek**
50	**Chisel**
51	**Chorus**

WIDTHS OF PLATES—Concluded

52 **Cinder**
53 **Clamor**
54 **Clarify**
55 **Clergy**
56 **Cloak**
57 **Coaches**
58 **Coffee**
59 **Comet**
60 **Cooler**
61 **Dabble**
62 **Damage**
63 **Dapper**
64 **Dative**
65 **Dandle**
66 **Dazzle**
67 **Debase**
68 **Defile**
69 **Decay**
70 **Deepen**
71 **Delight**
72 **Demon**
73 **Dialect**
74 **Deploy**
75 **Diamond**
76 **Dignity**
77 **Detach**
78 **Device**
79 **Diadem**
80 **Disarm**
81 **Dismay**
82 **Dodge**
83 **Dragoon**
84 **Dowager**
85 **Docible**
86 **Docility**
87 **Dock**
88 **Doctor**
89 **Doctress**
90 **Doctrinal**
91 **Document**
92 **Dodo**
93 **Doer**
94 **Doff**
95 **Dogged**
96 **Doggedness**
97 **Dogma**
98 **Dogmatic**
99 **Dogmatizer**
100 **Doily**
101 **Doings**
102 **Dole**
103 **Doleful**
104 **Dolesome**
105 **Doll**
106 **Dollar**
107 **Dolorous**
108 **Dolt**
109 **Domain**
110 **Dome**
111 **Domestic**
112 **Domicile**
113 **Domineer**
114 **Dominion**
115 **Don**
116 **Donkey**
117 **Donor**
118 **Doom**
119 **Doris**
120 **Dormant**

Lengths of Plates

The following words will answer for transmitting fractions of an inch:

1-4 Came
1-2 Saw
3-4 Conquered

In specifying fractions of an inch, above should be used IN ADDITION to the other word signifying width, length, or diameter wanted, as the case may be.

12	**Eager**	33	**Ember**
13	**Earldom**	34	**Embrace**
14	**Ear-ring**	35	**Emigrant**
15	**Easel**	36	**Empanel**
16	**Easterly**	37	**Empty**
17	**Eaves**	38	**Enamel**
18	**Echelon**	39	**Endear**
19	**Ecstasy**	40	**Endow**
20	**Edging**	41	**Enemy**
21	**Edify**	42	**Engineer**
22	**Educate**	43	**Enigma**
23	**Efface**	44	**Enlist**
24	**Egotism**	45	**Enormity**
25	**Eject**	46	**Ensign**
26	**Elated**	47	**Enter**
27	**Elder**	48	**Entreat**
28	**Elegant**	49	**Enviable**
29	**Elfin**	50	**Epilogue**
30	**Eligible**	51	**Equality**
31	**Eloped**	52	**Equity**
32	**Emanate**	53	**Errand**

LENGTHS OF PLATES—Continued

54	Eschew	89	Flyer
55	Essay	90	Fodder
56	Etching	91	Foliage
57	Ethics	92	Fooled
58	Eunuch	93	Forded
59	Evening	94	Foster
60	Evermore	95	Fraud
61	Exact	96	Frenzy
62	Exceed	97	Frisky
63	Excuse	98	Frozen
64	Exhale	99	Fugue
65	Exhume	100	Furze
66	Fable	101	Gable
67	Faceless	102	Gaiety
68	Factor	103	Galaxy
69	Fagot	104	Gambler
70	Faith	105	Gaoler
71	Falsette	106	Garret
72	Famish	107	Gauged
73	Fangle	108	Gelder
74	Fastened	109	Gentle
75	Faucet	110	Gilder
76	Feline	111	Girths
77	Fence	112	Glance
78	Fetched	113	Gloated
79	Fickle	114	Gloves
80	Figure	115	Gnome
81	Finger	116	Goodly
82	Fiscal	117	Gospel
83	Flabby	118	Gouty
84	Flashy	119	Graded
85	Flaxen	120	Grassy
86	Flighty	121	Habit
87	Float	122	Hamlet
88	Flower	123	Hangeth

LENGTHS OF PLATES—Continued

124	**Harem**	159	**Lawsuit**
125	**Hasty**	160	**Lazily**
126	**Haven**	161	**League**
127	**Heaper**	162	**Legacy**
128	**Heave**	163	**Lenten**
129	**Heeded**	164	**Levant**
130	**Height**	165	**Lexicon**
131	**Herald**	166	**Liberty**
132	**Hereof**	167	**Lifted**
133	**Hewed**	168	**Ligneous**
134	**Hiatus**	169	**Lilies**
135	**Hither**	170	**Linden**
136	**Hobby**	171	**Lingo**
137	**Honest**	172	**Lintel**
138	**Hotbed**	173	**Listen**
139	**Hugged**	174	**Litigant**
140	**Hunter**	175	**Livelong**
141	**Iceberg**	176	**Loadstar**
142	**Idolater**	177	**Lobelia**
143	**Illness**	178	**Lockjaw**
144	**Imitate**	179	**Lofty**
145	**Impart**	180	**Longer**
146	**Impel**	181	**Loudly**
147	**Impugn**	182	**Lowest**
148	**Indian**	183	**Lucent**
149	**Influx**	184	**Limber**
150	**Inmate**	185	**Lunar**
151	**Labial**	186	**Macaw**
152	**Ladder**	187	**Madman**
153	**Lagoon**	188	**Magnet**
154	**Languid**	189	**Majesty**
155	**Larger**	190	**Malady**
156	**Lastly**	191	**Manful**
157	**Lateral**	192	**Mansard**
158	**Lattice**	193	**Manure**

LENGTHS OF PLATES—Continued

194	**Marine**	229	**Nervous**
195	**Martyr**	230	**Nettle**
196	**Master**	231	**Newsboy**
197	**Maugre**	232	**Nickname**
198	**Meadow**	233	**Nipper**
199	**Medal**	234	**Noddle**
200	**Meeky**	235	**Noodle**
201	**Memoir**	236	**Oaken**
202	**Mentor**	237	**Oatcake**
203	**Merged**	238	**Obituary**
204	**Merman**	239	**Oblong**
205	**Method**	240	**Obtain**
206	**Mewler**	241	**Obviate**
207	**Midway**	242	**Ocean**
208	**Milker**	243	**Ocular**
209	**Mince**	244	**Odious**
210	**Minor**	245	**Offence**
211	**Mirth**	246	**Ogled**
212	**Mislay**	247	**Ointment**
213	**Mizzen**	248	**Omega**
214	**Modify**	249	**Oozing**
215	**Moisten**	250	**Oppose**
216	**Moody**	251	**Pacers**
217	**Moral**	252	**Packing**
218	**Mortar**	253	**Pageant**
219	**Mouser**	254	**Paladin**
220	**Muffin**	255	**Palfrey**
221	**Nabob**	256	**Pallor**
222	**Nailer**	257	**Paltry**
223	**Napkin**	258	**Pandora**
224	**Nation**	259	**Panorama**
225	**Nausea**	260	**Pantry**
226	**Nearly**	261	**Parabola**
227	**Necklace**	262	**Paragon**
228	**Negro**	263	**Parish**

LENGTHS OF PLATES—Continued

264	**Parody**	299	**Pomade**
265	**Parrot**	300	**Poplar**
266	**Partly**	301	**Poach**
267	**Passion**	302	**Pock**
268	**Pathos**	303	**Pod**
269	**Pavement**	304	**Poesy**
270	**Peanut**	305	**Poetess**
271	**Pectoral**	306	**Poetic**
272	**Pedantry**	307	**Poetical**
273	**Pedlar**	308	**Poetry**
274	**Pegged**	309	**Pignant**
275	**Pelisse**	310	**Point**
276	**Peltry**	311	**Polemical**
277	**Pendulum**	312	**Pointed**
278	**Penury**	313	**Pointer**
279	**Perch**	314	**Pointless**
280	**Perilous**	315	**Poise**
281	**Perked**	316	**Poke**
282	**Persist**	317	**Poker**
283	**Petals**	318	**Polarity**
284	**Petulant**	319	**Polarize**
285	**Phantom**	320	**Polary**
286	**Phrases**	321	**Polemic**
287	**Picketed**	322	**Police**
288	**Pigeon**	323	**Polish**
289	**Pilfer**	324	**Polite**
290	**Pinnace**	325	**Political**
291	**Pipkin**	326	**Polity**
292	**Pistol**	327	**Polka**
293	**Places**	328	**Poll**
294	**Planet**	329	**Pollard**
295	**Plenty**	330	**Pollen**
296	**Plucky**	331	**Pollock**
297	**Plunged**	332	**Pollute**
298	**Poison**	333	**Pollution**

LENGTHS OF PLATES—Continued

334	Poltroon	369	Port
335	Polyglot	370	Portable
336	Polygon	371	Portage
337	Polygraph	372	Portal
338	Polyp	373	Portico
339	Pomace	374	Portion
340	Pony	375	Portly
341	Pomatum	376	Portrait
342	Pommel	377	Portray
343	Pomp	378	Pose
344	Pond	379	Position
345	Ponder	380	Positive
346	Pongee	381	Possess
347	Poniard	382	Possession
348	Pontiff	383	Posset
349	Pontoon	384	Possible
350	Poodle	385	Post
351	Poor	386	Postage
352	Popery	387	Postal
353	Popish	388	Postboy
354	Poppy	389	Posterity
355	Populace	390	Postery
356	Populate	391	Postman
357	Populousness	392	Posture
358	Porphyry	393	Postulate
359	Porcelain	394	Posy
360	Porch	395	Pot
361	Porcine	396	Potable
362	Pore	397	Potash
363	Poriness	398	Potation
364	Pork	399	Potato
365	Porker	400	Potency
366	Porosity	401	Pother
367	Porridge	402	Potion
368	Porringer	403	Pottage

LENGTHS OF PLATES—Concluded

404	**Potter**	427	**Precedent**
405	**Pouch**	428	**Precept**
406	**Poulterer**	429	**Precious**
407	**Poultice**	430	**Precipice**
408	**Poultry**	431	**Precipitant**
409	**Pounce**	432	**Precise**
410	**Pound**	433	**Precision**
411	**Pounder**	434	**Predial**
412	**Pour**	435	**Predicate**
413	**Pout**	436	**Predict**
414	**Poverty**	437	**Predominate**
415	**Power**	438	**Preen**
416	**Powerful**	439	**Preface**
417	**Practical**	440	**Prefix**
418	**Prairie**	441	**Pregnant**
419	**Praise**	442	**Prehensile**
420	**Prance**	443	**Prejudice**
421	**Prank**	444	**Prelacy**
422	**Prattle**	445	**Prelatism**
423	**Prawn**	446	**Prelatic**
424	**Prayer**	447	**Preliminary**
425	**Prebend**	448	**Premier**
426	**Precede**	449	**Premise**

450 **Premium**

For longer sizes, use two words, thus:

497″ = **Premium, Enter**

Heads—in Diameter

The following words will answer for transmitting fractions of an inch:

1-4 **Came**
1-2 **Saw**
3-4 **Conquered**

In specifying fractions of an inch, above should be used IN ADDITION to the other word signifying width, length, or diameter wanted, as the case may be.

12	**Rabbits**	39	**Remind**
13	**Radishes**	40	**Remove**
14	**Raging**	41	**Renew**
15	**Raisin**	42	**Renown**
16	**Ramify**	43	**Rents**
17	**Rankle**	44	**Repass**
18	**Rapier**	45	**Repeal**
19	**Rarest**	46	**Reporter**
20	**Rasper**	47	**Repute**
21	**Rational**	48	**Rescind**
22	**Ravish**	49	**Reseated**
23	**Readily**	50	**Resident**
24	**Reaped**	51	**Resort**
25	**Rebel**	52	**Retail**
26	**Reckless**	53	**Retina**
27	**Recur**	54	**Retort**
28	**Reflector**	55	**Reveals**
29	**Reflow**	56	**Reviews**
30	**Refund**	57	**Revoke**
31	**Regal**	58	**Reward**
32	**Regent**	59	**Rhyme**
33	**Regret**	60	**Riband**
34	**Reigning**	61	**Richer**
35	**Relax**	62	**Riddle**
36	**Relief**	63	**Riders**
37	**Relying**	64	**Riding**
38	**Remark**	65	**Rifle**

HEADS—IN DIAMETER—Concluded

66	**Rigger**	93	**Rumbled**
67	**Ringlead**	94	**Rupee**
68	**Ripely**	95	**Ruralist**
69	**Ripened**	96	**Rushing**
70	**Risen**	97	**Russian**
71	**Risking**	98	**Rustic**
72	**Rivalry**	99	**Rustle**
73	**Roamer**	100	**Ruthless**
74	**Roasts**	101	**Rub**
75	**Robin**	102	**Rubber**
76	**Rocket**	103	**Rubescent**
77	**Rogue**	104	**Rubied**
78	**Romish**	105	**Ruck**
79	**Roofed**	106	**Ructation**
80	**Roosts**	107	**Ruffian**
81	**Rosary**	108	**Rufous**
82	**Rotation**	109	**Rugged**
83	**Rotten**	110	**Ruggedness**
84	**Rouged**	111	**Rugose**
85	**Rousing**	112	**Rulable**
86	**Royals**	113	**Rule**
87	**Rubric**	114	**Rum**
88	**Ruddiest**	115	**Ruminant**
89	**Rudely**	116	**Rummage**
90	**Rueful**	117	**Rump**
91	**Ruined**	118	**Rumple**
92	**Ruling**	119	**Runagate**

120 **Rundle**

For Heads round at one end

DIAGRAM

For Heads round at both ends

ELLIPSE

CONCERNING FLANGED HEADS

Heads to be flanged to sizes given, which are outside diameters when finished

Depth of flange over all to be $3\frac{1}{2}$ inches, . **Beech**
Depth of flange over all to be 4 inches, . **Oak**
Depth of flange over all to be $4\frac{1}{2}$ inches, . **Maple**
Depth of flange over all to be 5 inches, . **Poplar**
Depth of flange over all to be $5\frac{1}{2}$ inches, . **Buttonwood**
Depth of flange over all to be 6 inches, . **Mahogany**

Usual radii for varying sizes of heads are as follows:

12 inches to 24 inches flanged heads = $\frac{1}{2}$ inch
24 inches to 42 inches flanged heads = 1 inch
42 inches to 66 inches flanged heads = $1\frac{1}{4}$ to $1\frac{1}{2}$ inches
66 inches to 120 inches flanged heads = 2 to $2\frac{1}{2}$ inches

Inside radius of flange (sharp as possible), **Cypress**
Inside radius of flange $\frac{1}{2}$ inch, ... **Spruce**
Inside radius of flange $\frac{3}{4}$ inch, ... **Locust**
Inside radius of flange 1 inch, ... **Larch**
Inside radius of flange $1\frac{1}{4}$ inches, ... **Linden**
Inside radius of flange $1\frac{1}{2}$ inches, ... **Palmetto**
Inside radius of flange 2 inches, ... **Sycamore**
Inside radius of flange $2\frac{1}{2}$ inches, ... **Banyan**
Inside radius of flange 3 inches, ... **Juniper**