LOCOMOTIVE
.....DATA.....

Alba B. Johnson, Jr.

The Baldwin Locomotive Works

Locomotive Data

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LOCOMOTIVE TYPES

The motive power requirements of railways are so varied, that every system must employ a number of different types of locomotives with which to handle its traffic. It is not possible here to describe all the types in common use, but attention may be called to a few characteristic features of locomotives designed for different classes of service.

Excluding such work as switching, logging and industrial, the majority of locomotives are used in road service, and this may be divided into two general classes, freight and passenger. In heavy freight work, a locomotive is required to exert a high tractive force at comparatively slow speed, while in fast passenger work the tractive force, when running, is comparatively low, while the speed is high. Horse-power is measured by the product of tractive force and speed, hence it is frequently necessary for a passenger locomotive to develop as much horse-power as a freight, even though the tractive forces exerted by the two may be widely different. As the boiler capacity limits the horse-power, it follows that in proportion to the tractive force exerted, a passenger locomotive needs a larger boiler than one intended for freight service. The requirements of fast freight and heavy, medium-speed passenger service are more nearly alike, and the same type of locomotive can frequently be used for both these classes of work.

PASSENGER LOCOMOTIVES

The first requirement of a fast passenger locomotive is sufficient boiler capacity. The principal features necessary to secure this are a large firebox with ample grate area, a liberal amount of well disposed heating surface, and proper provision for circulation. If large driving wheels are required, and bituminous coal is used as fuel, the firebox is usually placed back of the driving wheels, and the resulting overhang is carried on a pair of trailing wheels. This allows the necessary room for a wide and deep furnace. The front end of the engine is preferably carried on a four-wheeled truck, and either two or three pairs of driving wheels are used. In this way the Atlantic (4-4-2) and Pacific (4-6-2) types have been developed. If the weight necessary for adhesion can be carried on two pairs of wheels, without overloading the rails, the Atlantic type should be used, as it is the simpler of the two. During recent years, however, the weights of passenger trains have been increased to such an extent that it is frequently necessary to use the Pacific type. The various conditions under which the engine is to work must determine the preferable wheel arrangement.

The American (4-4-0) and Ten-wheeled (4-6-0) types are used to a considerable extent in passenger service, but their capacity is limited owing chiefly to the difficulty of placing a wide and deep firebox above the driving wheels. The Ten-wheeled type, however, with moderate sized driving wheels, is frequently employed in heavy passenger, and fast freight service. These wheel arrangements are also extensively used abroad, where requirements, as a rule, are not as severe as in the United States. The Ten-wheeled type is especially suitable for

passenger service in South America and Colonial countries, and large numbers of these engines have been built by The Baldwin Locomotive Works for export.

When anthracite is used as fuel, a comparatively shallow furnace will suffice, and the grate can often be placed above the driving wheels. In this way trailing wheels can sometimes be omitted where, in a soft coal burning locomotive of similar capacity, they would be necessary on account of the boiler requirements.

FREIGHT LOCOMOTIVES

It is important in a freight locomotive for heavy service, to have the maximum proportion of the total weight available for adhesion consistent with the conditions of service. As a rule, therefore, truck wheels are used only for guiding purposes, and not because the design of the boiler requires their installation, as is the case with the trailing wheels of Atlantic and Pacific type locomotives. The great bulk of the freight traffic in this country is handled by locomotives having three or four pairs of coupled wheels, while in some cases five pairs have been employed.

If service conditions require the engine to run backward frequently, radial trucks at each end of the locomotive are often used. Such trucks aid in preventing derailments, and reduce flange wear on the driving wheels. They are also used at times in locomotives designed to burn low grade fuel, such as lignite, where an exceptionally deep furnace is required, and the grate cannot be placed above the driving-wheels without raising the boiler to an excessive height. In this way the Prairie (2-6-2) and Mikado (2-8-2) types have been developed. The Prairie type has proved specially successful in fast freight service, while the Mikado type is being used, to an increasing extent, in heavy slow speed service, because both wheel arrangements make possible the use of a larger boiler than could be provided in a similar locomotive with the same weight per driving axle, but without trailing wheels.

ARTICULATED LOCOMOTIVES

In cases where a locomotive of great tractive force is required, and the number of driving wheels necessary is so great that it is not practicable to couple them all in one group, an articulated locomotive may be used. An engine of this type has two sets of frames, which are connected by a hinge, or joint. The driving wheels are divided into two groups, and the wheels of each group are rotated by a separate pair of cylinders. In this way a large number of driving wheels can be used, and a correspondingly high tractive force developed; while the rigid wheel base is that of one group of driving wheels only, and the engine can therefore traverse curves without difficulty.

The type of articulated locomotive most commonly used in America is known, from the name of its inventor, as the "Mallet." This engine operates on the compound principle, and has two high-pressure cylinders, which drive the rear group of wheels, and two low-pressure, which drive the forward group. The hinge pin connecting the front and rear frames is placed on the center line of the engine between the high-pressure cylinders. The boiler is held in alinement with the rear frames, and is supported on the front frames by sliding bearings. When the engine enters a curve the front wheels and frames act like a truck, and swing about the hinge pin as a center. A controlling spring, mounted on the front boiler bearing, is thrown into compression, thus guiding the rear group of wheels into the curve, and aiding in restoring the alinement after the curve has been passed.

In a locomotive of this type, steam is conveyed from the throttle valve to the high-pressure cylinders through rigid pipes, which may be either inside or outside the boiler according to circumstances. The pipes leading from the high-pressure to the low-pressure cylinders, and from the latter to the smoke-box, are necessarily provided with flexible joints. These pipes carry steam at moderate pressures only, a fact which greatly lessens the difficulty of keeping the joints tight.

In the Baldwin Mallet Locomotives, steam at reduced pressure can be admitted direct from the boiler to the low-pressure cylinders by opening a starting valve which is placed in the cab. This enables the locomotive to develop full tractive force in starting a train. As soon, however, as the wheels have made a few revolutions and the low-pressure cylinders are receiving their steam supply from the high pressure, the starting valve should be closed.

Mallet locomotives are built with from two to five pairs of driving wheels in each group, and are frequently fitted with front and rear trucks for the purpose of improving the curving qualities, reducing flange wear on the driving tires and securing a large proportion of heating surface to adhesion. These engines are used to best advantage in heavy freight or pushing service on long grades, where high tractive forces must be exerted for sustained periods of time. A locomotive of this type can be built to develop twice the tractive force of a Consolidation engine having the same load per pair of driving wheels. By using such locomotives, it is often possible to materially reduce the number of engines and of train movements necessary to handle a given tonnage over a division.

SUPERHEATING

The temperature to which it is necessary to raise water before it can be evaporated into steam, depends upon the pressure. For every given pressure there is, therefore, a corresponding minimum temperature at which steam can exist. Steam existing at this temperature is said to be saturated, and any reduction in temperature will cause some of the steam to be condensed as water. If the temperature is above that of saturation the steam is said to be superheated. A device employed for the purpose of raising the temperature of steam above that of saturation, is called a superheater.

The temperature of the cylinder walls of a locomotive is constantly changing, owing to the variation in the steam temperature due to expansion. As a result there is considerable condensation of steam, causing a loss in efficiency. The object in using superheated steam is to reduce this loss, by raising the steam temperature to such a point that condensation is, to a large extent, avoided. Furthermore since the volume per pound of superheated steam is greater than that of saturated steam at the same pressure, there is a gain in efficiency, because each pound of water evaporated forms a larger volume of steam, and therefore fewer pounds of steam are required to fill the cylinders.

Two principal types of superheaters are used in locomotive work—those in which only the waste gases are used for superheating purposes, and those in which the superheater pipes are placed in the fire tubes, so that the steam absorbs heat which would otherwise be imparted to the water. A well known type of waste gas superheater is the Vauclain, which consists of an arrangement of tubes and drums located in the smoke-box. The steam circulates

through the tubes and absorbs, from the smoke-box gases, heat which would otherwise escape up the stack. With this arrangement a sufficient degree of superheat is secured to assure substantial economies; while the device is simple in construction, and no difficulty is experienced in lubricating valves and pistons on account of high temperatures. Furthermore, no reduction in the boiler heating surface is necessary, because of the use of the superheater.

The fire-tube type of superheater is usually designed to give from 150 degrees to 200 degrees of superheat. The superheater pipes are placed in a number of large tubes, which are about five and one-half inches in diameter. These tubes, like the small boiler tubes, convey the products of combustion from the firebox to the smoke-box. A double loop of superheater pipes is usually placed in each large tube, and the pipes extend from the headers in the smoke-box, to within a short distance of the firebox. The hot gases passing through the large tubes, both heat the water and superheat the steam. In some forms of fire-tube superheaters, a damper is placed in the smoke-box to cut off the draft through the large tubes when the throttle is closed. This prevents the burning out of the superheater pipes when no steam is passing through them. With this type of superheater, some reduction in the boiler evaporating surface is necessary in order to accommodate the superheating surface.

Superheaters are of value principally on passenger locomotives, which are required to work at high power for sustained periods of time. If the locomotive exerts power only intermittently, as for example in switching service, the temperature of the superheater is comparatively low, and the advantages which should result from its application are not realized.

Superheaters have been applied to Mallet locomotives, sometimes between the throttle valve and high-pressure cylinders, and sometimes between the high and low-pressure cylinders, in which case they are used as reheaters. In some instances, both a superheater and a reheater are used on the same engine.

COMPOUNDING

The object in using compound cylinders in a locomotive, is to expand the steam through a greater range than is possible in a single cylinder, and thus secure increased economy. Further economies due to compounding are a reduction in the amount of temperature change (and consequently condensation) in each cylinder, and less waste of fuel at the stack, as the exhaust is not as violent, when working at long cut-offs, as in a single-expansion locomotive.

Five principal types of compound locomotives are in service in the United States, as follows:

1. The two-cylinder, or cross compound, having a high-pressure cylinder on one side and a low-pressure on the other.

2. The Vauclain, or four-cylinder type, in which one high and one low-pressure cylinder are placed on each side, one cylinder being above the other. The two pistons on each side are connected to a common crosshead.

3. The balanced compound, in which the two high-pressure cylinders are placed between the frames and drive a crank axle, while the two low-pressure are outside and are connected in the usual manner. The two crank pins on the same side of the engine are placed 180 degrees apart, so that the reciprocating parts act against each other, and the disturbing effects of these parts are largely neutralized. This arrangement is specially suitable for high-speed locomotives.

4. The tandem compound, having one high and one low-pressure cylinder on each side. The high-pressure cylinder is set in advance of the low-pressure, and both pistons are mounted on a common piston rod.

5. The Mallet articulated compound, which has two high-pressure and two low-pressure cylinders. The high-pressure cylinders drive one group of wheels, and the low-pressure a separate group. The principal features of this type have been previously discussed.

The economies resulting from the use of compound cylinders are best realized in locomotives which are worked at high power for sustained periods of time. In any case, when considering the advisability of using such devices as compound cylinders or superheaters, all the conditions under which the engine is to work must be given careful attention.

LOCOMOTIVE CLASSIFICATION

Systems of classifying locomotives have been proposed from time to time, the principles of these being shown on the following pages. The diagram shows graphically in the first column, the arrangement of wheels, and in the second column the generally applied name as used in the United States. The third column shows the Baldwin Locomotive Works' designation, and the fourth that proposed by Mr. F. M. Whyte. The names are largely those applied by the first local users of the respective types of locomotives.

The Baldwin Locomotive Works' notation employs figures and letters to indicate the number of wheels of different kinds and the size of cylinders. A locomotive having one pair of driving wheels is classed as "B," that with two pairs, "C," with three pairs, "D," with four pairs, "E," and with five pairs, "F." The letter "A" is used for a special class of high-speed locomotive with a single pair of driving wheels, and for a smaller type used for rack rail service. In articulated locomotives a letter, as above, is used to designate the number of driving wheels in each group. A figure is used as an initial to indicate the total number of wheels under the locomotive, and the letter, as stated above, indicates the number of driving wheels. The size of the cylinder is, of course, not shown in the third column, but is represented by a number, which is found by subtracting 3 from the diameter of the cylinder in inches and multiplying the remainder by 2; thus, a 19″ cylinder would be represented by the number 32 so that a Mogul locomotive with 19″ cylinders would be termed an 8-32-D. Conversely, the size of cylinder may be obtained by dividing the class designation for cylinder by 2 and adding 3.

When there are trucks at both ends of the locomotive the fraction ¼ is placed after the cylinder number, and when there is a truck at the rear end and none at the front, the fraction is ⅓. Thus, a Mikado type locomotive with 19″ cylinders would be a 12-32¼ E, and one of the Forney type would be 8-32⅓ C.

The same rule is carried out in the classification of compound locomotives. In this case, however, a number is given to indicate the diameter of each cylinder, that indicating the high pressure being written over the low pressure. Thus, $10\frac{22}{42}$ D 100 indicates a compound locomotive with ten wheels in all, having high-pressure cylinders 14″ in diameter and low-pressure cylinders 24″ in diameter, with three pairs of driving wheels and the one-hundredth locomotive of its class.

This final figure indicating the class number of the locomotive is used in connection with all engines regardless of the types to which they belong.

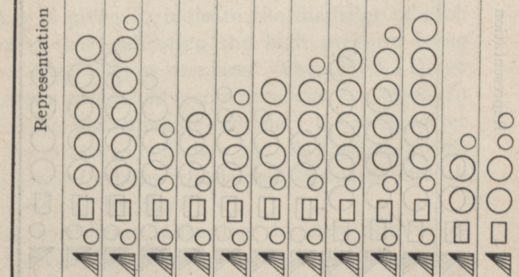
ENGINE CLASSIFICATION

Whyte Symbol	Baldwin Symbol	Type
0-4-0	4 -C	4-Wheeled Switcher
0-6-0	6 -D	6-Wheeled Switcher
0-8-0	8 -E	8-Wheeled Switcher
0-10-0	10 -F	10-Wheeled Switcher
2-4-0	6 -C	
2-4-2	8¼-C	
2-4-4	10¼-C	
2-6-0	8 -D	Mogul
2-6-2	10¼-D	Prairie
2-6-4	12¼-D	
2-8-0	10 -E	Consolidation
2-8-2	12¼-E	Mikado

Representation

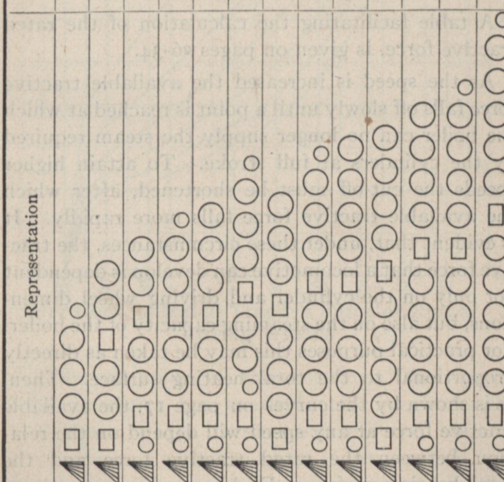
ENGINE CLASSIFICATION

Representation	Type	Baldwin Symbol	Whyte Symbol
	Decapod	12 -F	2-10-0
	Santa Fe	14¼-F	2-10-2
		8¼-A	4-2-2
	American	8 -C	4-4-0
	Atlantic	10¼-C	4-4-2
	10-Wheeled	10-D	4-6-0
	Pacific	12¼-D	4-6-2
	12-Wheeled	12 -E	4-8-0
	Sierra	14¼-E	4-8-2
	Mastodon	14 -F	4-10-0
		6⅓-C	0-4-2
	Forney	8⅓-C	0-4-4



ENGINE CLASSIFICATION

Representation	Type	Baldwin Symbol	Whyte Symbol
		8⅓-D	0-6-2
	Mallet Articulated	8 -CC	0-4-4-0
	"	10 -CC	2-4-4-0
	"	12¼-CC	2-4-4-2
	"	12 -CD	2-4-6-0
	"	16¼-CD	4-4-6-2
	"	12 -DD	0-6-6-0
	"	16¼-DD	2-6-6-2
	"	16 -DE	2-6-8-0
	"	16 -EE	0-8-8-0
	"	18 -EE	2-8-8-0
	"	20¼-EE	2-8-8-2
	"	24¼-FF	2-10-10-2



TRACTIVE FORCE AND HAULING CAPACITY

The hauling capacity of a locomotive is determined by the relation between the tractive force developed and the resistance of the train, and both of these factors are dependent on the speed.

At starting speeds a locomotive will usually develop, at the rim of the driving wheels, the rated tractive force, which is calculated from the dimensions of the engine by the formula:

$$T = \frac{0.85\ P \times C^2 \times S}{D}$$

where T = the rated tractive force at rim of driving wheels in pounds.

P = the boiler pressure in pounds per square inch.

C = diameter of cylinders in inches.

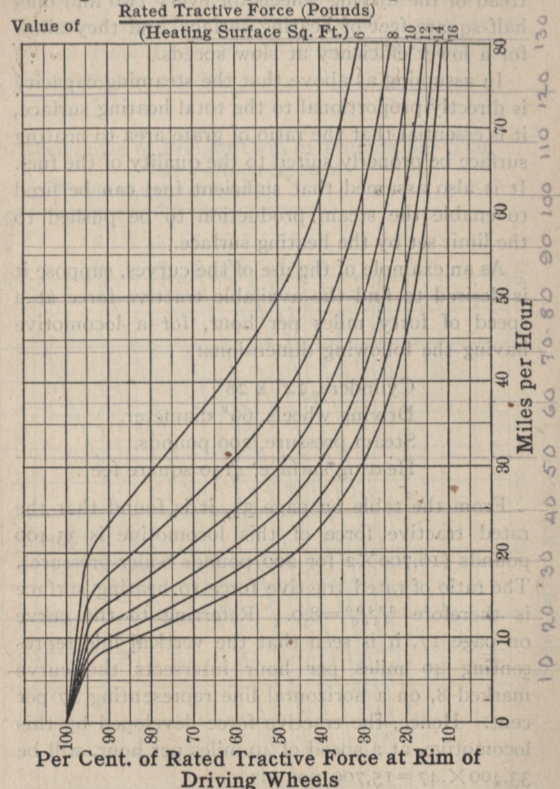
S = stroke in inches.

D = driving wheel diameter in inches.

A table facilitating the calculation of the rated tractive force, is given on pages 26-34.

As the speed is increased the available tractive force falls off slowly until a point is reached at which the boiler can no longer supply the steam required by the cylinders at full stroke. To attain higher speeds the cut-off must be shortened, after which the available tractive force falls more rapidly. It is evident that, under these circumstances, the tractive force that a locomotive can develop is dependent not only on the cylinder and driving wheel dimensions, but also on the steaming capacity of the boiler. For practical purposes this may be taken as directly proportional to the total heating surface. Then, as is shown by the curves on page 17, the available tractive force at any speed will depend on the relation between the rated tractive force and the total heating surface. Each curve corresponds to

Relation between Tractive Force at Rim of Driving Wheels, and Speed in Miles per Hour



a different value of this relation. The vertical scale measures the available tractive force as a percentage of the rated tractive force, while on the horizontal scale the speed is measured in miles per hour. The curves assume that at the high speeds one horse-power can be developed at the tread of the driving wheels for every two and one-half square feet of heating surface, and they allow for a lower efficiency at slow speeds.

In assuming as above that the steaming capacity is directly proportional to the total heating surface, it is essential that the ratio of grate area to heating surface be properly suited to the quality of the fuel. It is also assumed that sufficient fuel can be fired to enable the steam production to be pushed to the limit set by the heating surface.

As an example of the use of the curves, suppose it is desired to find the available tractive force at a speed of forty miles per hour, for a locomotive having the following dimensions:

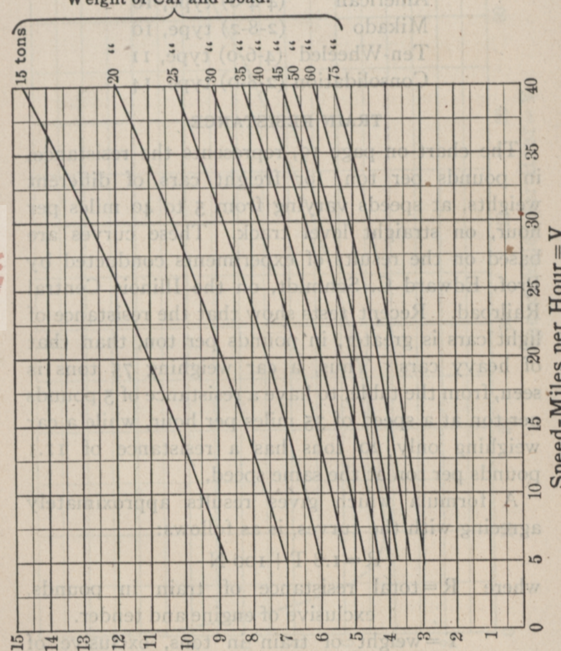
Cylinders, 22″ x 28″
Driving wheels, 69″ diameter.
Steam pressure, 200 pounds.
Heating surface, 4150 square feet.

From the table on page 31, it is found that the rated tractive force of this locomotive is 33,400 pounds (16,700×2 for 200 pounds boiler pressure). The ratio of rated tractive force to heating surface is therefore $\frac{33400}{4150} = 8.0$. Referring to the curve on page 17, it is seen that the vertical line representing 40 miles per hour intersects the curve marked 8, on a horizontal line representing 47 per cent. Hence, the tractive force developed by this locomotive, at a speed of 40 miles per hour, will be 33,400×.47 = 15,700 pounds.

In order that a locomotive may employ all of its rated tractive force in hauling a train, it is desirable that the weight on driving wheels be at least 4 times the rated force; or, in other words, not more than 25 per cent. of the adhesive weight can be utilized as tractive force.

In the case of locomotives equipped with compound cylinders or superheaters, the proportion of the rated tractive force developed at any speed will be from 10 to 20 per cent. higher than that shown by the curves.

Resistance of Freight Cars in Pounds per Ton at Various Speeds



Resistance-Pounds per Ton = R

Formula $R = 1.5 + \frac{106 + 2V}{W + 1} + 0.001\,V^2$

W = Wt. of Car in Tons
V = Speed in Miles per hour

RELATION OF RATED TRACTIVE FORCE TO HEATING SURFACE

Average values of the quotient obtained by dividing the rated tractive force in pounds by the total heating surface in square feet, for different classes of engines, are given below:

Atlantic	(4-4-2) type,	8
Pacific	(4-6-2) type,	9
American	(4-4-0) type,	10
Mikado	(2-8-2) type,	10
Ten-Wheeled	(4-6-0) type,	11
Consolidation	(2-8-0) type,	14

TRAIN RESISTANCE

The chart on page 19, represents the resistance, in pounds per ton, for freight cars of different weights, at speeds varying from 5 to 40 miles per hour, on straight level track. These curves are based on the results of experiments conducted by Prof. Edward C. Schmidt, on the Illinois Central Railroad. Recent tests show that the resistance of light cars is greater, in pounds per ton, than that of heavy cars. Thus, a car weighing 75 tons is seen, from the table, to have a resistance of 5 pounds per ton at a speed of 35 miles per hour, while a car weighing only 20 tons has a resistance of 11.1 pounds per ton at the same speed.

A formula which gives results approximately agreeing with the curves, is as follows:

$$R = 1.8\,T + 100\,N$$

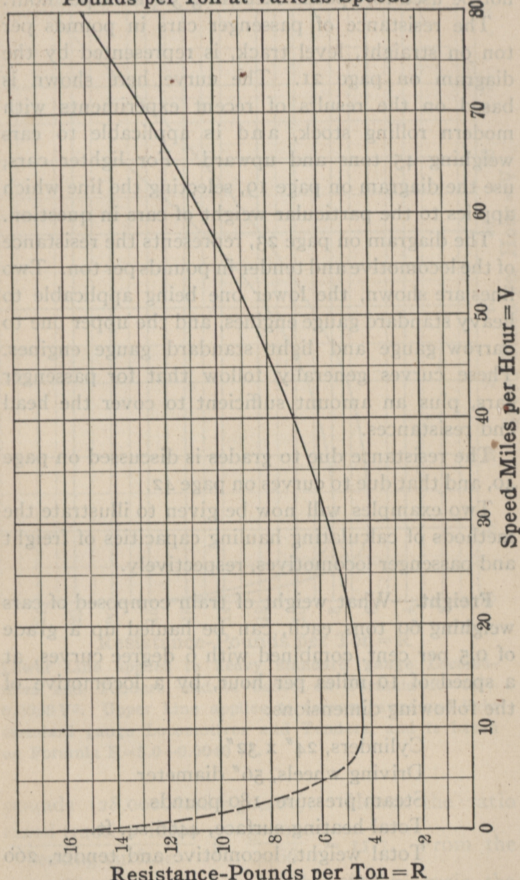
where R = total resistance of train in pounds, exclusive of engine and tender.

T = weight of train in tons, exclusive of engine and tender.

N = number of cars in train.

This formula is worked out for a speed of 5 miles per hour. For higher speeds, add 2 per cent. for

Resistance of Passenger Cars in Pounds per Ton at Various Speeds



This Curve is based on the Formula $R = 4.3 + 0.0017\,V^2$, and should be used for Cars weighing 45 Tons and upwards. For lighter Cars, use Curves for Freight Cars of Corresponding Weights.

each mile per hour above 5. The formula should not be used for speeds exceeding 30 miles per hour.

The resistance of passenger cars in pounds per ton on straight, level track, is represented by the diagram on page 21. The curve here shown is based on the results of recent experiments with modern rolling stock, and is applicable to cars weighing 45 tons and upward. For lighter cars, use the diagram on page 19, selecting the line which applies to the particular weight of cars in question.

The diagram on page 23, represents the resistance of the locomotive and tender in pounds per ton. Two lines are shown, the lower one being applicable to heavy standard gauge engines, and the upper one to narrow gauge and light standard gauge engines. These curves generally follow that for passenger cars, plus an amount sufficient to cover the head end resistances.

The resistance due to grades is discussed on page 40, and that due to curves on page 42.

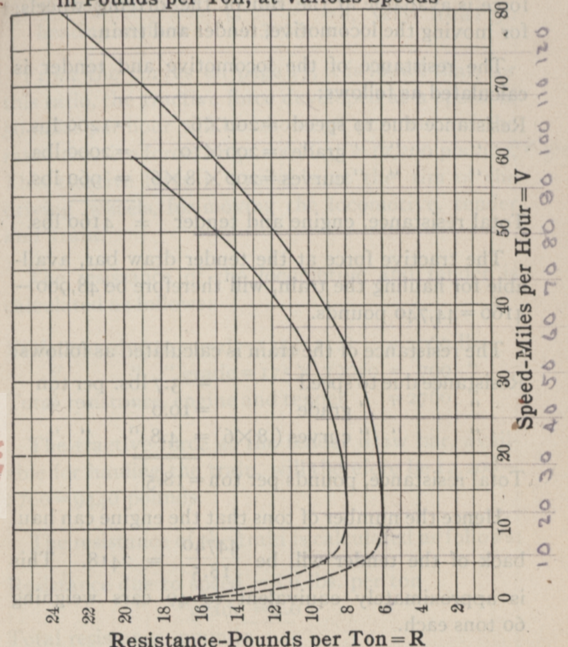
Two examples will now be given to illustrate the methods of calculating hauling capacities of freight and passenger locomotives, respectively.

Freight.—What weight of train composed of cars weighing 60 tons each, can be hauled up a grade of 0.5 per cent. combined with 6 degree curves, at a speed of 10 miles per hour, by a locomotive of the following dimensions:

Cylinders, 24″ x 32″
Driving wheels, 56″ diameter
Steam pressure, 180 pounds
Total heating surface, 4466 sq. ft.
Total weight, locomotive and tender, 200 tons.

From the table on page 33, it is found that the rated tractive force of this locomotive is 50,400

Resistance of Locomotives and Tenders, in Pounds per Ton, at Various Speeds



Lower Line applies to heavy standard gauge Locomotives and Tenders, and is based on Formula $R = 4.3 + 0.0030 V^2$. Upper Line applies to narrow gauge and light standard gauge Locomotives and Tenders, and is based on Formula $R = 5.0 + 0.0040 V^2$.

pounds $(28{,}000 \times 1.8 = 50{,}400)$. Hence the ratio $\frac{\text{rated tractive force}}{\text{heating surface}}$ is $\frac{50400}{4466} = 11.3$. From the curves on page 17 it is found that, for this ratio, the tractive force developed at a speed of 10 miles per hour will be about 97 per cent. of the rated tractive force, or 50,400 × .97 = 48,900 pounds. This tractive force is available at the rim of the driving wheels, for moving the locomotive, tender and train.

The resistance of the locomotive and tender is calculated as follows:

Resistance due to speed	= 200 × 6	= 1200 lbs.
" " " grade	= 200 × 10	= 2000 lbs.
" " " curves	= 200 × .8 × 6	= 960 lbs.
Total resistance, engine and tender		= 4160 lbs.

The tractive force at the tender draw bar, available for hauling the train, will therefore be 48,900 − 4160 = 44,740 pounds.

The resistance of the train is calculated as follows:

Resistance due to speed	= 3.7 lbs. per ton	
" " " grade	= 10.0 " " "	
" " " curves (.8 × 6)	= 4.8 " " "	
Total resistance, pounds per ton	= 18.5	

Hence the number of tons that the engine can haul back of the tender will be $\frac{44740}{18.5} = 2418$. This is approximately equivalent to 40 cars weighing 60 tons each.

Passenger.—What weight of train can be hauled up a straight grade of 0.2 per cent., at a speed of 50 miles per hour, by a locomotive of the following dimensions:

Cylinders, 22″ × 28″
Driving wheels, 72″ diameter
Steam pressure, 200 pounds
Total heating surface, 3935 sq. ft.
Total weight, locomotive and tender, 175 tons.

From the table on page 32, it is found that the rated tractive force of this locomotive is 32,200

pounds. (16,100 × 2 = 32,200). Hence the ratio $\frac{\text{rated tractive force}}{\text{heating surface}}$ is $\frac{32200}{3935} = 8$, very nearly.

From the curves on page 17, it is found that, for this ratio, the tractive force developed at a speed of 50 miles per hour will be about 38 per cent. of the rated tractive force, or 32,200 × .38 = 12,200 pounds. This tractive force is available at the rim of the driving wheels, for moving the locomotive, tender and train.

The resistance of the locomotive and tender is calculated as follows:

Resistance due to speed	= 175 × 11.8	= 2060 lbs.
" " " grade	= 175 × .2 × 20	= 700 "
Total resistance, engine and tender		= 2760 "

The tractive force at the tender draw bar, available for hauling the train, will therefore be 12,200 − 2760 = 9440 pounds.

The resistance of the train is calculated as follows:

Resistance due to speed	= 8.6 lbs. per ton
" " " grade	= 4.0 " " "
Total resistance, pounds per ton	= 12.6

Hence the number of tons that the engine can haul back of the tender will be $\frac{9440}{12.6} = 750$.

RATED TRACTIVE FORCE OF LOCOMOTIVES

The following tables contain the rated tractive forces of locomotives having various sizes of cylinders and driving wheels. The calculations are based on the formula given on page 16. The boiler pressure is assumed to be 100 pounds per square

RATED TRACTIVE FORCE OF LOCOMOTIVES
Boiler Pressure 100 Lbs. Per Square Inch

Cylinders		DIAMETER OF DRIVING WHEELS—INCHES													
Dia. Ins.	Stroke Ins.	30	32	34	36	38	40	42	44	46	48	50	51	52	53
9	14	3200	3000	2800	2700	2500	2400	2300	2200	2100	2000	1900			
10	14	3900	3700	3500	3300	3100	3000	2800	2700	2600	2500	2400			
11	14	4800	4500	4200	4000	3800	3600	3400	3250	3100	3000	2900			
9	16	3700	3450	3200	3050	2900	2750	2600	2500	2400	2300	2200	2150	2100	2070
10	16	4500	4250	4000	3800	3600	3400	3200	3150	2950	2800	2700	2650	2600	2550
11	16	5500	5100	4800	4550	4300	4100	3900	3700	3550	3400	3300	3200	3150	3100
12	16	6500	6100	5700	5400	5100	4900	4600	4400	4250	4100	3900	3850	3750	3650
13	16	7700	7200	6800	6400	6100	5800	5500	5250	5000	4800	4600	4550	4450	4350
10	18	......	4800	4500	4250	4050	3800	3600	3500	3300	3200	3050	3000	2950	2900
11	18	......	5800	5400	5150	4850	4650	4400	4200	4050	3850	3700	3650	3550	3500
12	18	......	6900	6500	6100	5800	5500	5250	5000	4800	4600	4400	4300	4250	4150
13	18	......	8100	7600	7200	6800	6450	6150	5900	5600	5400	5200	5100	5000	4900
14	18	......	9400	8800	8350	7900	7500	7150	6800	6500	6250	6000	5900	5750	5650
15	18	......	10800	10100	9550	9050	8600	8200	7850	7500	7150	6900	6750	6600	6500
16	18	......	12200	11500	10900	10300	9800	9350	8900	8500	8150	7850	7700	7550	7400
12	20	......	......	7200	6800	6450	6150	5850	5550	5300	5100	4900	4800	4700	4600
13	20	......	......	8450	8000	7550	7200	6850	6550	6250	6000	5750	5650	5500	5400
14	20	......	......	9800	9300	8800	8350	7950	7600	7250	6950	6700	6550	6400	6300
15	20	......	......	11300	10700	10100	9600	9150	8700	8350	8000	7700	7550	7400	7250
16	20	......	......	12800	12100	11450	10900	10350	9900	9450	9050	8700	8550	8400	8250
17	20	......	......	14400	13650	12950	12300	11700	11150	10700	10250	9850	9650	9450	9250
18	20	......	......	16200	15300	14500	13750	13100	12500	12000	11500	11000	10800	10600	10400

RATED TRACTIVE FORCE OF LOCOMOTIVES
Boiler Pressure 100 Lbs. Per Square Inch

Cylinders		DIAMETER OF DRIVING WHEELS—INCHES												
Dia. Ins.	Stroke Ins.	54	55	56	57	58	59	60	61	62	63	64	65	66
9	16	2030	2000	1960	1930	1900								
10	16	2500	2460	2420	2380	2340								
11	16	3050	3000	2940	2880	2830								
12	16	3600	3550	3500	3440	3380								
13	16	4250	4180	4110	4040	3970								
10	18	2850	2800	2750	2700	2650								
11	18	3450	3350	3300	3250	3200								
12	18	4100	4000	3950	3850	3800								
13	18	4800	4700	4600	4550	4450								
14	18	5550	5450	5350	5250	5150								
15	18	6400	6250	6150	6050	5950								
16	18	7250	7100	7000	6850	6750								
12	20	4550	4450	4350	4300	4200	4150	4080	4020	3950	3880	3830	3770	3720
13	20	5300	5200	5150	5050	4950	4850	4780	4710	4630	4560	4500	4420	4360
14	20	6200	6100	5950	5850	5750	5650	5580	5470	5390	5300	5210	5130	5060
15	20	7100	6950	6850	6700	6600	6500	6390	6280	6180	6080	5990	5900	5810
16	20	8100	7900	7750	7650	7500	7400	7250	7120	7010	6900	6800	6700	6600
17	20	9100	8950	8800	8600	8450	8350	8200	8050	7900	7800	7700	7550	7450
18	20	10200	10000	9850	9650	9500	9350	9200	9050	8900	8750	8600	8450	8350

RATED TRACTIVE FORCE OF LOCOMOTIVES
Boiler Pressure 100 Lbs. Per Square Inch

Cylinders		Diameter of Driving Wheels—Inches													
Dia. Ins.	Stroke Ins.	42	44	46	48	50	51	52	53	54	55	56	57	58	59
14	22	8750	8350	7950	7650	7350	7200	7050	6900	6800	6650	6550	6450	6300	6200
15	22	10000	9550	9150	8750	8400	8250	8100	7950	7800	7650	7500	7350	7250	7150
16	22	11400	10900	10400	10000	9600	9400	9200	9050	8850	8700	8550	8400	8250	8100
17	22	12850	12300	11750	11250	10800	10600	10400	10200	10000	9800	9650	9450	9300	9150
18	22	14450	13750	13200	12600	12100	11900	11650	11450	11200	11000	10800	10650	10450	10250
19	22	16100	15350	14700	14100	13600	13300	13000	12750	12500	12300	12050	11850	11650	11450
14	24	......	9100	8700	8350	8000	7850	7700	7550	7400	7250	7150	7000	6900	6800
15	24	......	10450	10000	9600	9200	9000	8850	8650	8500	8350	8200	8050	7900	7800
16	24	......	11850	11350	10900	10450	10250	10050	9850	9650	9500	9350	9200	9000	8850
17	24	......	13400	12800	12300	11800	11550	11350	11150	10900	10700	10550	10350	10150	10000
18	24	......	15000	14400	13800	13200	12950	12700	12450	12250	12000	11800	11600	11400	11200
19	24	......	16700	16000	15350	14700	14400	14150	13850	13600	13350	13200	12950	12700	12500
20	24	......	18500	17700	16950	16250	16000	15700	15400	15100	14800	14550	14300	14050	13850
21	24	......	20500	19600	18750	18000	17650	17300	17000	16700	16400	16100	15800	15500	15250
22	24	......	22300	21400	20500	19650	19300	18900	18550	18200	17900	17600	17300	16950	16700
23	24	......	24500	23500	22500	21500	21100	20700	20300	19900	19600	19200	18900	18600	18300
17	26	......	......	......	......	12800	12500	12300	12050	11800	11600	11400	11200	11000	10850
18	26	......	......	......	......	14350	14100	13800	13550	13300	13050	12800	12550	12350	12100
19	26	......	......	......	......	16000	15700	15400	15100	14850	14550	14250	14000	13750	13500
20	26	......	......	......	......	17700	17400	17100	16700	16400	16100	15800	15500	15300	15000
21	26	......	......	......	......	19500	19100	18800	18400	18100	17750	17400	17100	16800	16500
22	26	......	......	......	......	21300	21000	20600	20200	19800	19500	19100	18700	18400	18100
23	26	......	......	......	......	23300	23000	22600	22200	21700	21300	20800	20500	20100	19800
24	26	......	......	......	......	25500	25100	24600	24100	23700	23300	22800	22300	21900	21600
25	26	......	......	......	......	27600	27100	26600	26100	25600	25100	24700	24300	23800	23400

RATED TRACTIVE FORCE OF LOCOMOTIVES
Boiler Pressure 100 Lbs. Per Square Inch

Cylinders		Diameter of Driving Wheels—Inches													
Dia. Ins.	Stroke Ins.	60	61	62	63	64	65	66	67	68	69	70	71	72	73
14	22	6100	6000	5900	5800	5750	5650	5550	5450	5400	5300	5250	5150	5100	5050
15	22	7000	6900	6800	6700	6550	6450	6400	6300	6200	6100	6000	5900	5850	5750
16	22	8000	7850	7700	7600	7500	7350	7250	7150	7050	6950	6850	6750	6650	6550
17	22	9000	8850	8700	8600	8450	8300	8200	8050	7950	7850	7700	7600	7500	7400
18	22	10100	9900	9750	9600	9450	9300	9200	9050	8900	8800	8650	8550	8400	8300
19	22	11250	11050	10950	10750	10550	10400	10250	10100	9950	9800	9700	9550	9400	9250
14	24	6650	6550	6450	6350	6250	6150	6050	5950	5900	5800	5700	5650	5550	5500
15	24	7650	7550	7400	7300	7200	7100	6950	6850	6750	6650	6550	6450	6400	6300
16	24	8700	8550	8400	8300	8150	8050	7900	7800	7700	7550	7450	7350	7250	7150
17	24	9850	9650	9500	9350	9200	9050	8950	8800	8650	8550	8400	8300	8200	8100
18	24	11000	10850	10650	10500	10350	10200	10000	9900	9750	9650	9500	9350	9200	9100
19	24	12300	12100	11900	11700	11500	11350	11200	11000	10850	10700	10500	10400	10250	10100
20	24	13600	13400	13150	12950	12750	12550	12400	12200	12000	11850	11650	11500	11350	11200
21	24	15000	14750	14500	14300	14100	13900	13650	13450	13250	13050	12850	12650	12500	12350
22	24	16400	16100	15900	15700	15400	15200	14950	14700	14500	14300	14100	13900	13700	13500
23	24	18000	17700	17400	17100	16800	16600	16350	16100	15850	15600	15400	15200	15000	14800
17	26	10650	10450	10300	10150	10000	9850	9750	9550	9450	9300	9150	9000	8900	8800
18	26	11900	11700	11550	11350	11200	11000	10850	10650	10500	10400	10250	10100	9950	9800
19	26	13300	13100	12850	12700	12500	12300	12100	11900	11700	11550	11400	11250	11100	10950
20	26	14750	14500	14250	14050	13800	13600	13400	13200	13000	12800	12650	12450	12300	12100
21	26	16250	16000	15700	15450	15250	15000	14750	14550	14350	14100	13900	13750	13550	13350
22	26	17800	17500	17250	17000	16700	16500	16200	16000	15800	15500	15300	15100	14900	14700
23	26	19500	19200	18900	18500	18250	18000	17700	17400	17200	16950	16700	16450	16200	16000
24	26	21200	20900	20600	20200	19900	19600	19300	19000	18700	18450	18200	17950	17700	17450
25	26	23000	22700	22300	22000	21700	21300	21000	20600	20300	20100	19800	19500	19250	19000

RATED TRACTIVE FORCE OF LOCOMOTIVES
Boiler Pressure 100 Pounds Per Square Inch

Diameter of Driving Wheels—Inches

Cylinders Dia. Ins.	Stroke Ins.	74	75	76	77	78	79	80	81	82	83	84	85	86
14	24	5400	5350	5250	5200	5150	5050							
15	24	6200	6100	6050	5950	5900	5800							
16	24	7050	6950	6850	6800	6700	6600							
17	24	7950	7850	7750	7650	7550	7450							
18	24	8950	8850	8750	8650	8500	8400							
19	24	10000	9800	9700	9600	9500	9300							
20	24	11050	10900	10750	10600	10500	10350							
21	24	12200	12000	11850	11700	11550	11400							
22	24	13350	13150	13000	12800	12650	12500							
23	24	14600	14400	14200	14000	13800	13650							
17	26	8650	8550	8450	8350	8200	8100	8000	7900	7800	7750	7650	7550	7450
18	26	9700	9550	9450	9350	9200	9100	8950	8850	8750	8650	8550	8450	8350
19	26	10800	10650	10500	10350	10250	10100	10000	9850	9750	9650	9550	9400	9250
20	26	11950	11800	11650	11500	11350	11200	11050	10900	10800	10650	10500	10400	10300
21	26	13150	13000	12850	12650	12500	12350	12200	12050	11900	11750	11600	11450	11350
22	26	14500	14300	14100	13900	13700	13550	13400	13250	13100	12900	12750	12600	12450
23	26	15800	15600	15400	15200	15000	14800	14600	14450	14250	14100	13900	13750	13600
24	26	17200	17000	16750	16550	16300	16100	15900	15700	15500	15350	15200	15000	14800
25	26	18700	18450	18200	18000	17800	17550	17300	17100	16900	16700	16500	16300	16100

RATED TRACTIVE FORCE OF LOCOMOTIVES
Boiler Pressure 100 Lbs. Per Square Inch

Diameter of Driving Wheels—Inches

Cylin. D. In.	S. In.	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
17	28	12300	12050	11850	11650	11450	11300	11100	10900	10750	10600	10400	10250	10100	9950	9850	9700
18	28	13750	13550	13300	13100	12900	12700	12500	12300	12100	11900	11700	11500	11350	11200	11000	10850
19	28	15400	15100	14850	14600	14300	14100	13900	13700	13450	13200	13000	12850	12700	12500	12300	12100
20	28	17000	16700	16400	16100	15900	15600	15350	15100	14900	14650	14450	14200	14000	13800	13600	13400
21	28	18750	18400	18100	17800	17500	17200	17000	16700	16400	16150	15900	15700	15500	15200	15000	14800
22	28	20500	20200	19800	19500	19100	18800	18500	18300	18100	17800	17500	17250	17000	16700	16500	16300
23	28	22500	22100	21700	21300	21000	20600	20300	20000	19700	19400	19100	18800	18500	18250	18000	17750
24	28	24500	24100	23600	23300	22900	22500	22100	21800	21400	21100	20800	20500	20200	19900	19600	19300
25	28	26600	26100	25700	25300	24900	24500	24000	23600	23300	22900	22600	22200	21900	21600	21300	21000
26	28	28800	28300	27800	27300	26800	26400	26000	25600	25200	24800	24400	24100	23700	23300	23000	22700
27	28	31000	30400	29900	29400	28900	28500	28000	27500	27100	26700	26300	25900	25500	25100	24800	24400
28	28	33400	32800	32200	31700	31200	30700	30200	29700	29200	28800	28300	27900	27500	27100	26700	26300
18	30	14750	14500	14250	14000	13800	13550	13350	13100	12900	12700	12500	12300	12150	12000	11800	11650
19	30	16450	16150	15850	15600	15350	15100	14850	14600	14400	14150	13950	13750	13550	13350	13150	13000
20	30	18250	17900	17600	17300	17050	16800	16500	16200	15950	15750	15500	15300	15050	14850	14600	14400
21	30	20100	19750	19400	19050	18750	18450	18150	17850	17550	17300	17050	16800	16550	16300	16050	15850
22	30	22000	21600	21300	20900	20600	20200	19900	19600	19300	19000	18700	18400	18150	17900	17650	17400
23	30	24100	23700	23300	22900	22500	22200	21800	21400	21100	20800	20500	20200	19900	19600	19300	19000
24	30	26200	25800	25300	24900	24500	24100	23700	23300	23000	22600	22200	21900	21600	21300	21000	20700
25	30	28500	28000	27500	27000	26600	26200	25700	25300	24900	24500	24200	23800	23500	23100	22700	22400
26	30	30700	30200	29600	29200	28700	28200	27700	27400	27000	26600	26100	25700	25300	25000	24600	24200
27	30	33200	32600	32000	31500	31000	30500	30000	29500	29000	28600	28200	27700	27300	26900	26600	26200
28	30	35700	35100	34500	33900	33400	32800	32300	31800	31200	30800	30300	29800	29400	29000	28600	28200

RATED TRACTIVE FORCE OF LOCOMOTIVES

Boiler Pressure 100 Lbs. Per Square Inch

Cylinders		DIAMETER OF DRIVING WHEELS—INCHES														
Dia. Ins.	Stroke Ins.	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
17	28	9550	9400	9300	9200	9050	8900	8800	8700	8600	8500	8400	8300	8200	8100	8000
18	28	10700	10550	10400	10300	10150	10000	9900	9800	9700	9600	9450	9350	9200	9100	9000
19	28	11950	11800	11650	11500	11300	11150	11000	10900	10750	10600	10500	10350	10250	10100	10000
20	28	13200	13050	12850	12700	12550	12350	12200	12050	11900	11750	11600	11450	11350	11200	11050
21	28	14600	14400	14200	14000	13800	13650	13450	13300	13100	12950	12800	12650	12500	12350	12200
22	28	16100	15850	15600	15400	15200	15000	14800	14650	14500	14300	14100	13900	13750	13600	13500
23	28	17500	17250	17000	16800	16600	16350	16100	15900	15800	15600	15350	15200	15000	14850	14700
24	28	19100	18800	18500	18300	18000	17800	17600	17400	17100	16900	16700	16550	16350	16150	16000
25	28	20700	20400	20100	19900	19650	19350	19100	18900	18650	18400	18150	17950	17750	17500	17300
26	28	22400	22100	21800	21500	21200	20900	20700	20400	20100	19900	19700	19400	19200	19000	18700
27	28	24100	23800	23500	23100	22800	22500	22200	22000	21700	21400	21100	20900	20700	20500	20200
28	28	26000	25600	25300	24900	24600	24300	24000	23700	23400	23100	22800	22500	22200	22000	21800
18	30	11500	11350	11200	11050	10900	10750	10600	10500	10350	10200	10100	10000	9900	9750	9650
19	30	12800	12600	12450	12300	12150	11950	11800	11650	11500	11350	11250	11100	11000	10850	10700
20	30	14200	14000	13850	13700	13500	13300	13100	12950	12800	12650	12500	12300	12200	12050	11900
21	30	15600	15400	15200	15000	14800	14600	14400	14250	14050	13900	13700	13550	13400	13250	13100
22	30	17200	16900	16700	16450	16250	16050	15850	15600	15400	15250	15050	14850	14700	14500	14350
23	30	18750	18500	18250	18000	17750	17500	17300	17100	16850	16650	16450	16250	16100	15900	15700
24	30	20400	20100	19850	19600	19350	19100	18800	18600	18350	18150	17900	17700	17500	17300	17100
25	30	22100	21800	21500	21200	21000	20700	20500	20200	19950	19700	19450	19200	19000	18750	18500
26	30	23900	23600	23300	23000	22700	22400	22100	21800	21500	21300	21000	20700	20500	20300	20050
27	30	25800	25400	25100	24800	24500	24100	23800	23500	23200	22900	22600	22400	22100	21800	21600
28	30	27800	27400	27100	26700	26300	26000	25600	25300	25000	24700	24400	24100	23800	23500	23200

RATED TRACTIVE FORCE OF LOCOMOTIVES

Boiler Pressure 100 Lbs. Per Square Inch

Cylin.		DIAMETER OF DRIVING WHEELS—INCHES															
D. In.	S. In.	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
19	32	17550	17250	16950	16650	16350	16100	15850	15600	15350	15100	14900	14650	14450	14200	14000	13850
20	32	19400	19100	18750	18450	18150	17850	17550	17300	17000	16700	16500	16250	16000	15800	15600	15350
21	32	21400	21000	20700	20300	20000	19700	19400	19050	18750	18450	18200	17900	17650	17400	17150	16900
22	32	23500	23100	22700	22300	22000	21600	21200	20900	20600	20200	19950	19650	19350	19100	18800	18550
23	32	25700	25300	24800	24400	24000	23600	23200	22900	22500	22100	21800	21500	21200	20800	20500	20300
24	32	28000	27500	27000	26500	26100	25700	25300	24900	24500	24100	23700	23400	23100	22700	22400	22100
25	32	30300	29800	29300	28800	28300	27900	27500	27000	26600	26200	25800	25400	25000	24600	24300	24000
26	32	32900	32300	31700	31200	30700	30200	29700	29200	28700	28300	27900	27500	27100	26700	26300	25900
27	32	35400	34800	34200	33600	33000	32500	32000	31500	31000	30500	30000	29600	29200	28700	28300	27900
28	32	38100	37400	36800	36200	35600	35000	34400	33900	33400	32800	32300	31800	31400	30900	30500	30100
29	32	40800	40100	39300	38700	38000	37400	36800	36200	35600	35100	34500	34000	33500	33000	32600	32100
30	32	43600	42900	42200	41400	40700	40000	39400	38800	38200	37600	37000	36500	35900	35400	34900	34400
20	34	20700	20300	19950	19600	19300	18950	18700	18400	18100	17800	17500	17250	17000	16750	16500	16300
21	34	22800	22400	22000	21600	21200	20900	20600	20300	19900	19600	19300	19000	18750	18500	18200	17950
22	34	25000	24600	24200	23700	23300	23000	22600	22200	21900	21500	21200	20900	20600	20300	20000	19700
23	34	27300	26900	26400	25900	25500	25100	24700	24300	23900	23500	23200	22800	22500	22200	21800	21500
24	34	29800	29200	28700	28200	27800	27400	26800	26400	26000	25700	25300	24800	24500	24200	23800	23500
25	34	32300	31800	31200	30700	30200	29700	29200	28700	28200	27800	27400	27000	26600	26200	25800	25500
26	34	34900	34300	33700	33200	32600	32100	31600	31100	30600	30100	29700	29200	28700	28300	27900	27500
27	34	37700	37000	36300	35800	35200	34600	34000	33400	32900	32400	32000	31500	31000	30600	30200	29800
28	34	40400	39700	39100	38400	37800	37200	36500	36000	35400	34800	34400	33800	33300	32800	32400	31900
29	34	43400	42600	41900	41200	40500	39800	39200	38500	37900	37400	36800	36200	35700	35200	34700	34200
30	34	46500	45600	44900	44200	43400	42700	42000	41300	40700	40000	39400	38800	38300	37700	37200	36700

RATED TRACTIVE FORCE OF LOCOMOTIVES

Boiler Pressure 100 Lbs. Per Square Inch

Cylinders		DIAMETER OF DRIVING WHEELS—INCHES														
Dia. Ins.	Stroke Ins.	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
19	32	13650	13450	13300	13100	12900	12750	12600	12450	12300	12100	12000	11850	11700	11550	11400
20	32	15150	14900	14700	14550	14350	14150	13950	13750	13600	13450	13250	13100	12950	12800	12650
21	32	16650	16450	16200	16000	15800	15600	15400	15200	15000	14800	14650	14450	14300	14100	13950
22	32	18300	18050	17800	17500	17300	17100	16900	16700	16500	16300	16050	15850	15650	15500	15300
23	32	20000	19700	19450	19200	18950	18700	18450	18200	18000	17800	17550	17350	17150	16950	16750
24	32	21800	21500	21200	20900	20600	20400	20100	19800	19600	19400	19150	18900	18700	18450	18200
25	32	23600	23300	23000	22700	22400	22100	21800	21500	21200	21000	20800	20500	20200	20000	19750
26	32	25600	25200	24900	24500	24200	23900	23600	23300	23000	22700	22400	22100	21900	21600	21400
27	32	27600	27200	26800	26500	26100	25800	25500	25200	24800	24500	24200	23900	23600	23300	23000
28	32	29700	29200	28800	28500	28100	27700	27400	27000	26700	26300	26000	25700	25400	25100	24800
29	32	31800	31300	30800	30400	30000	29700	29300	28900	28500	28200	27800	27500	27200	26800	26500
30	32	34000	33500	33100	32600	32200	31800	31400	31000	30600	30200	29800	29500	29200	28800	28500
20	34	16050	15850	15650	15450	15250	15000	14800	14600	14400	14250	14100	13900	13750	13550	13400
21	34	17750	17500	17250	17000	16800	16550	16350	16100	15900	15700	15500	15300	15150	15000	14800
22	34	19450	19200	18900	18650	18450	18200	17950	17700	17450	17250	17000	16800	16600	16400	16250
23	34	21200	21000	20700	20400	20100	19850	19600	19300	19100	18850	18600	18400	18150	17900	17700
24	34	23200	22800	22500	22000	21900	21600	21300	21100	20800	20600	20300	20100	19800	19600	19400
25	34	25100	24800	24500	24100	23800	23500	23200	22900	22600	22300	22000	21800	21600	21300	21000
26	34	27200	26800	26400	26100	25800	25400	25100	24800	24400	24100	23800	23600	23300	23000	22700
27	34	29300	28900	28500	28200	27800	27400	27000	26700	26300	26000	25700	25400	25100	24800	24600
28	34	31500	31000	30500	30100	29700	29400	29000	28600	28300	27900	27600	27200	26900	26600	26300
29	34	33800	33300	32800	32400	32000	31600	31200	30800	30400	30000	29600	29300	28900	28600	28200
30	34	36100	35600	35100	34600	34200	33800	33300	32900	32500	32100	31700	31400	31000	30600	30200

inch, and the mean effective pressure on the pistons is therefore 85 pounds. Using this pressure, it is a simple matter to calculate the rated tractive force for a locomotive carrying any other pressure, as the two following examples will show.

1. What is the rated tractive force of a locomotive having 10×16 inch cylinders and driving wheels 36 inches in diameter, with a boiler pressure of 175 pounds?

Referring to the table on page 26, the cylinder dimensions, 10×16, are found in the first two columns on the left hand side.

Following the horizontal line to the intersection of the vertical line headed 36, it is found that the rated tractive force of a locomotive having the given dimensions and carrying a boiler pressure of 100 pounds, is 3800 pounds. Hence the rated tractive force of the locomotive under consideration will be $3800 \times 1.75 = 6650$ pounds.

2. What is the rated tractive force of a locomotive with 24×32 inch cylinders, driving wheels 63 inches in diameter, and a boiler pressure of 200 pounds?

Referring to the table on page 33, it is found that a locomotive of the dimensions given, and carrying a boiler pressure of 100 pounds, exerts a rated tractive force of 24,900 pounds. The rated tractive force of the engine under consideration will therefore be $24{,}900 \times 2 = 49{,}800$ pounds.

RATED TRACTIVE FORCE OF COMPOUND LOCOMOTIVES

The rated tractive forces of the various types of compound locomotives built by The Baldwin Locomotive Works, may be calculated by the following formulas:

Vauclain, Balanced, and Tandem Compound Locomotives

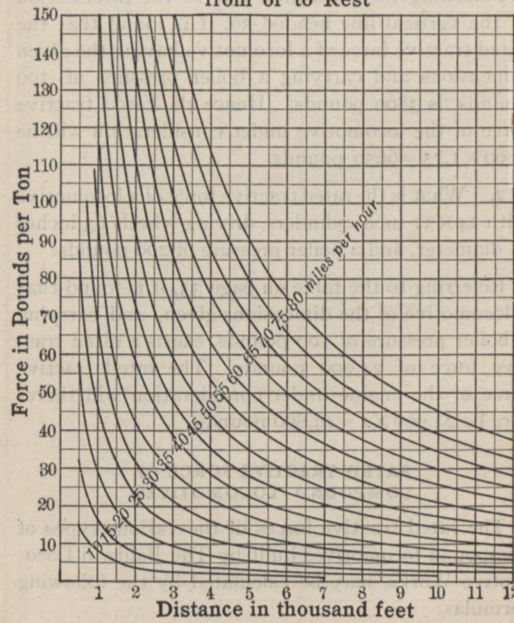
The formula is

$$T = \frac{S \times P}{D}\left(\tfrac{2}{3}\,C^2 + \tfrac{1}{4}\,c^2\right)$$

in which

T = rated tractive force in pounds.
C = diameter of high-pressure cylinders in inches.
c = diameter of low-pressure cylinders in inches.
S = stroke of piston in inches.
P = boiler pressure in pounds.
D = diameter of driving wheels in inches.

Force of Acceleration and Retardation from or to Rest



Two Cylinder or Cross Compound Locomotives

The formula is

$$T = \frac{C^2 \times S \times 0.6\,P}{D}$$

in which

T = rated tractive force in pounds.
C = diameter of high-pressure cylinder in inches.
S = stroke of piston in inches.
P = boiler pressure in pounds.
D = diameter of driving wheels in inches.

Mallet Compound Locomotives

The formula given above, for cross compound locomotives, is also applicable to Mallet type locomotives, the result being multiplied by two as the Mallet type has four cylinders. The formula thus modified is as follows:

$$T = \frac{C^2 \times S \times 1.2\,P}{D}$$

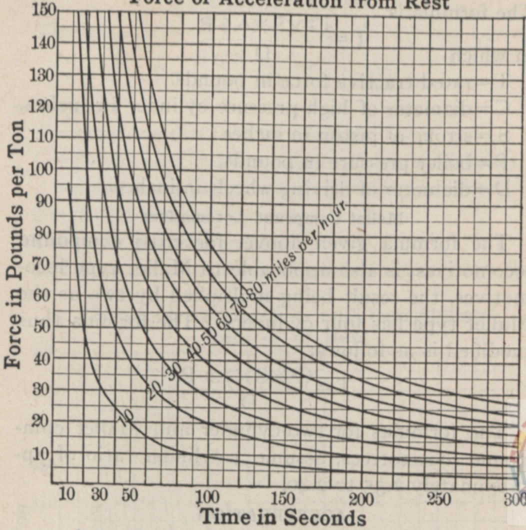
The formulas for two-cylinder and Mallet compound locomotives, assume a cylinder ratio of approximately 2.35 to 2.40.

ACCELERATION

The charts on pages 36 and 38 give the resistance in pounds per ton, due to acceleration of speed up to 80 miles per hour. The chart on page 36 gives the resistance due to the acceleration within a given distance, while the chart on page 38 gives the resistance due to the acceleration within a given time.

The principal elements to be considered in determining the resistance due to acceleration are the longitudinal inertia of the engine and train and the rotative inertia of the wheels. The charts above referred to are approximate only, in that the rotative inertia of the wheels is assumed to be equal in amount to five per cent. of the total longitudinal inertia for all cases. In actual cases this approximation has been found to be very close in every instance.

Force of Acceleration from Rest



The formulas on which the charts are based are as follows:

$A = 70\dfrac{V_2^2 - V_1^2}{S}$ and $A = 95.6\dfrac{V_2 - V_1}{t}$ in which

A = force producing acceleration or retardation in pounds per ton.

S = distance in feet through which the force A acts.

t = time in seconds during which the force A acts.

V_2 = greater velocity in miles per hour.

V_1 = smaller velocity in miles per hour.

(In the charts $V_1 = 0$; that is, the train is supposed to start from rest).

HORSE-POWER

While the term horse-power is not generally used with great significance in connection with the work done by locomotives, yet there are times when it may be of interest to make comparisons in this unit. The horse-power is represented by the exertion of a force of 33,000 lbs. through one foot in a minute. If we represent the speed of a locomotive in miles per hour by V and the tractive force exerted by T, the horse power is $\dfrac{T \times V}{375}$

If the distance run under these conditions in miles is M the time would be $\dfrac{M}{V}$ in hours, and the total horse-power hours would be $\dfrac{T \times V}{375} \times \dfrac{M}{V} = \dfrac{TM}{375}$. A locomotive will ordinarily consume in the neighborhood of 4 pounds of coal and 28 pounds of water per horse-power hour. Hence, on a run under the conditions noted by the symbols above given the quantity of coal in pounds would be represented approximately by $\dfrac{T \times M}{100}$, and as one gallon of water is approximately the evaporation of one pound of coal, the same equation will represent the gallons of water used on the run.

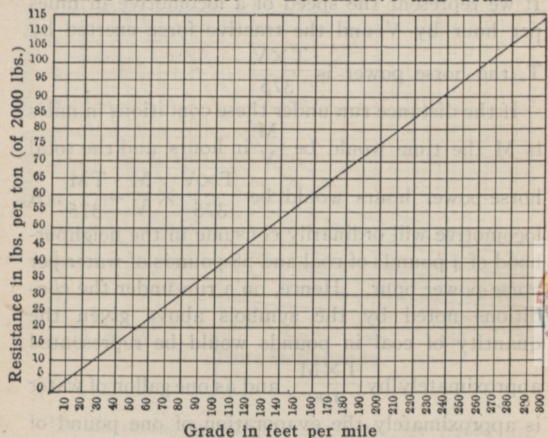
The actual evaporation for any fuel of course depends upon the heat units contained in the fuel. Good coal will liberate about 14,000 heat units per pound while poor coal will run at times below 10,000. Fuel oil will give off about 19,000 heat units per pound, so that oil may be from 1½ to 2 times as valuable a heat agent as coal for the same weight burned in a given time. Wood fuel will average about 5500 heat units per pound, under ordinary conditions, or about .4 the heating value of coal.

Under the conditions in which locomotives are

Allow 2.5 □' heating surface per H.P. required.

ordinarily designed it is roughly assumed that one horse-power will be produced for every 3 square feet of heating surface under unfavorable conditions, and a horse-power for 2 square feet of heating surface with compound engines, or with single expansion engines using oil fuel.

Grade Resistance. Locomotive and Train



GRADES

When a train is hauled up a grade, the resistance due to friction is increased by that due to lifting the train against gravity. The amount of this increased resistance is determined as follows:—One mile equals 5280 feet, and if the grade be one foot per mile, the pull necessary to lift a ton of 2000 pounds will be $2000/5280 = .3788$ pounds. Similarly the pull necessary to lift a ton of 2240 pounds will be $2240/5280 =$ .4242 pounds. Therefore to find the total resistance due to grade in pounds per ton of 2000 pounds, the rise in feet per mile must be multiplied by .3788; while to find the resistance in pounds per ton of

2240 pounds, the rise in feet per mile must be multiplied by .4242.

If the grade is expressed in feet per hundred or per cent., the resistance in pounds per ton of 2000 pounds will be $2000/100 = 20$ pounds for each per cent. of grade; while for a ton of 2240 pounds the resistance will be $2240/100 = 22.4$ pounds for each per cent. of grade.

Assuming a resistance of .3788 pounds per ton for a straight grade of one foot per mile, the chart gives the resistance for grades from level to 300 feet per mile. To the resistance so obtained, must be added that due to speed and internal friction in order to find the total resistance in pounds per ton.

CURVES

In the United States it is customary to express curvature in degrees noted by the deflection from the tangent measured at stations 100 feet apart. In other words the number of degrees of central angle subtended by a chord of 100 feet represents the "degree curve." One degree of curvature is equal to a radius of 5730 feet. Therefore, the number of degrees divided into 5730 gives the radius in feet, or, per contra, the number of feet radius divided into 5730 gives the number of degrees. This assumes that the 100 feet are measured on the arc instead of the chord, but the error is so slight on curves commonly used that it may be ignored for ordinary calculation.

In Great Britain it is common to define a curve as so many chains (66 ft.) radius. Thus the radius of a one degree curve expressed in chains would be $5730/66$ equals 86.81, therefore 86.81 divided by the degrees equals the radius in chains, or 86.81 divided by the radius in chains equals the degrees.

In the metric system instead of the stations being 100 feet apart they are taken at 20 metres (65.61 ft.). The central angle remaining the same the radius must necessarily be less. This is represented by $^{65.61}/_{100}$ for a one degree curve or approximately $\frac{5}{8}$ English measurement, which can be used as a factor for converting the English to the French system.

CURVE RESISTANCE

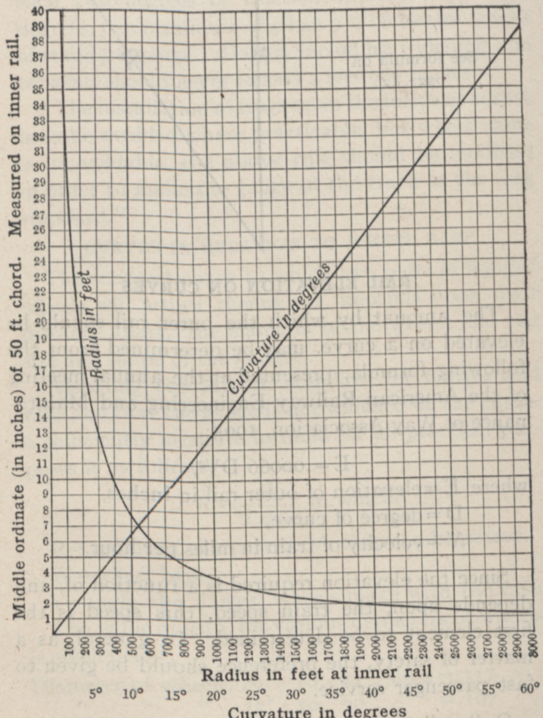
The construction of the road bed, speed, length of train, weight of cars, and various other conditions make it impossible to give an exact rule for computing the resistance due to curves of any given radius. It is generally considered, however, that the resistance amounts to from .7 of a pound to 1.0 pound per ton per degree of curvature, the lower figure being used for large capacity cars and the higher figure for smaller capacity cars, as in the latter case there are more wheels and axles per ton of weight than in the former. Many roads are compensated to an allowance of .035 per cent. in grade for each degree of curve.

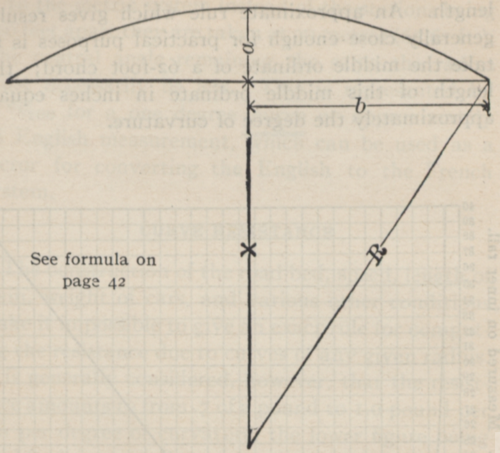
RADIUS OF CURVES

To determine the radius of any existing curve, lay off on the inside rail by any convenient means a chord of any desired length as shown on the accompanying diagram on page 44. Note the center height or middle ordinate of the chord in feet, represented by "a" in the diagram, and the radius of curvature may be obtained by the formula $R = \frac{a^2 + b^2}{2a}$, in which all the dimensions are in feet.

The following diagram gives the radius in feet, and the curvature in degrees, for ordinates from one to forty inches measured on a chord of fifty feet in

length. An approximate rule which gives results generally close enough for practical purposes is to take the middle ordinate of a 62-foot chord; the length of this middle ordinate in inches equals approximately the degree of curvature.





See formula on
page 42

RAIL ELEVATION ON CURVES

The amount by which the outer rail should be elevated on a curve, may be determined from the following formula, presented at the annual meeting of the American Railway Engineering and Maintenance of Way Association, 1905:

$$E = .00066\,DV^2,$$

where E = elevation of outer rail in inches,
D = degree of curve,
V = velocity of train in miles per hour.

Since the elevation required is a function of, and depends upon, the train speed, this speed is the first element to be determined. In general, as a matter of safety, the preference should be given to fast passenger service.

Ordinarily an elevation of eight inches is not exceeded, and speed of trains should be regulated to conform to that elevation.

SPREAD OF RAILS ON CURVES

At the convention of the American Railway Master Mechanics Association, 1910, the committee on widening the gauge of tracks at curves recommended as follows:

"Curves eight degrees and under should be standard gauge. Gauge should be widened 1/8 inch for each two degrees or fraction thereof over eight degrees, to a maximum of 4 feet 9 1/4 inches for tracks of standard gauge. Gauge, including widening due to wear, should never exceed 4 feet 9 1/2 inches.

"The installation of frogs upon the inside of curves is to be avoided where practicable, but where same is unavoidable, the above rule should be modified in order to make the gauge of the track at the frog standard."

CURVES IN RELATION TO WHEEL BASE

The sharpest curve to which two pairs of flanged wheels will adjust themselves, depends upon their distance apart, the diameter of the wheels and the size and shape of the flanges.

Assuming the M.C.B. standard for flanges and rails and that the gauge is not widened on the curve, a sufficiently accurate formula for all practical purposes is as follows:

$$R = \frac{W}{2 \sin a} \text{ in which}$$

R = radius of sharpest curve that can be passed.
W = wheel base.
a = angle the flanged wheels make with the rails.

The value of sin a, for various diameters of wheels, is given below.

Diameter of wheels,	20″	to	24″,	sin a = .117
" " "	25″	to	30″,	" = .107
" " "	31″	to	40″,	" = .09
" " "	41″	to	50″,	" = .08
" " "	51″	to	60″,	" = .075

If intermediate wheels are introduced between the two pairs of flanged wheels their relation with the rail requires a separate consideration. If these wheels are plain, the tires must be of sufficient width to prevent them from dropping between the rails, or an additional rail must be introduced at the curve. If single rails be used, then the approximate radius of the sharpest curve is found by the formula on page 42, by taking $a = \frac{1}{2}$ width of plain tire $- \frac{1}{2}$ the play $- \frac{1}{2}$ width of rail. If the intermediate wheels are flanged the sharpest curve is dependent upon the play allowed between the flanges and the rails, and its radius is also found by the formula on page 42 by taking $a = \frac{1}{2}$ the total play. In each case b is made equal to $\frac{1}{2}$ the rigid wheel base.

When a truck is used the swing must be sufficient to allow the locomotive to pass the curve. The relationship between the truck swing, wheel base and radius of curve, is given by the following formula, which is only approximate, but for all practical purposes sufficiently accurate;

$$\frac{W\,T}{2\,S} = R \text{ in which}$$

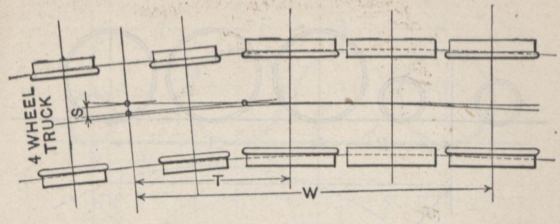
W = distance from center pin of truck to rear of of rigid wheel base.

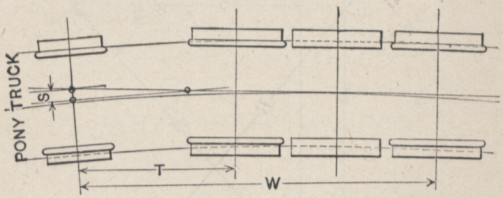
T = Distance from center pin of truck to front of rigid wheel base.

S = one-half of the total swing of the truck.

R = radius of sharpest curve which can be passed.

All dimensions must be in the same unit. The sketches below show how these dimensions are taken for two-wheeled and four-wheeled trucks.





Where the curves are very sharp, as in logging camps, quarries, etc. (where radii less than 50 feet are often found), or where extreme accuracy is required, the following methods may be used:

Swing of Four-wheeled Truck

Let:

A = length of rigid wheel base.

B = distance from center of front driving wheel to center-pin of truck when engine is on a straight track.

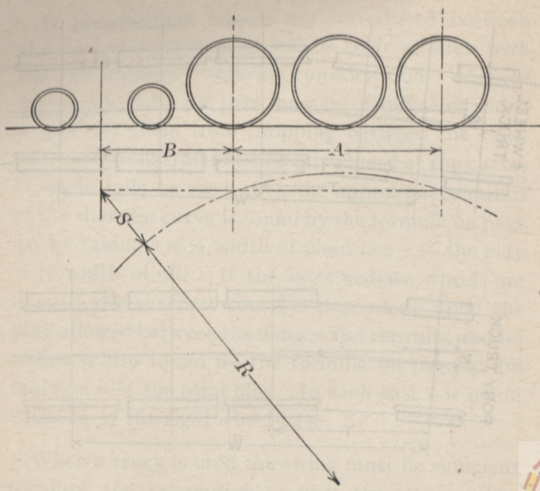
S = one-half the total swing of the truck.

R = radius of curve of track,

all dimensions to be expressed in the same unit.

The formula is as follows:

$$S = \sqrt{R^2 + B\,(A + B)} - R$$



Swing of Pony Truck

Let:

A = length of rigid wheel base.

B = distance from center of front driving wheel to center-pin of truck when engine is on straight track.

a = distance from center of front driving wheel to radius-bar pin.

b = length of radius bar.

S = one-half the total swing of truck.

R = radius of curve of track,

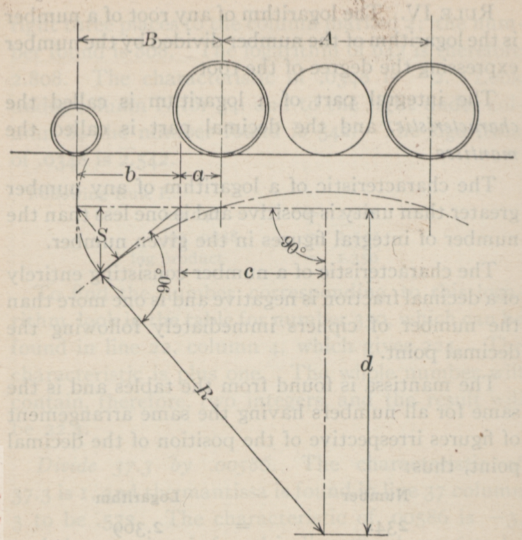
all dimensions to be expressed in the same unit.

The formula for truck swing is based on the following equations:

$$d = \tfrac{1}{2}\sqrt{4\,R^2 - A^2},\quad c = \frac{A}{2} + a \text{ and } b = \frac{(A+B)\,B}{A+2B}$$

The formula is as follows:

$$S = \frac{d\,b^2 + b\,c\,R}{b^2 + R^2}$$



S may be taken either as the lateral displacement of the center of the truck with reference to the center line of engine, or as the displacement of the center pin with reference to the center line of truck, as indicated by the two arrows in the above diagram.

LOGARITHMS

A common logarithm is the power to which the base ten must be raised to produce a given number.

RULE I. The sum of the logarithms of two numbers is the logarithm of their product.

RULE II. The logarithm of the quotient of two numbers is the logarithm of the dividend minus the logarithm of the divisor.

RULE III. The logarithm of the power of a number is the logarithm of the number multiplied by the index of the power.

RULE IV. The logarithm of any root of a number is the logarithm of the number divided by the number expressing the degree of the root.

The integral part of a logarithm is called the *characteristic*, and the decimal part is called the *mantissa*.

The characteristic of a logarithm of any number greater than unity is positive and is one less than the number of integral figures in the given number.

The characteristic of a number consisting entirely of a decimal fraction is negative and is one more than the number of ciphers immediately following the decimal point.

The mantissa is found from the tables and is the same for all numbers having the same arrangement of figures irrespective of the position of the decimal point, thus:

Number		Logarithm
234.	=	2.369
23.4	=	1.369
2.34	=	0.369
.234	=	$\bar{1}$.369
.0234	=	$\bar{2}$.369

It must be borne in mind that the negative sign applies only to the characteristics, the mantissæ being positive.

The tables on pages 52–53 contain the decimal parts to three places of the logarithms of numbers from 1 to 100, and although necessarily condensed, will be found useful for approximate calculations for larger values.

To illustrate the use of the tables take the following example:

Multiply 642 by .0348. The characteristic of 642 = 2. Look under column N for 64, and to the right three places to the column marked 2; the number found is 808. The logarithm of 642 is therefore 2.808. The characteristic of .0348 is −2. Look under column N for 34, and to the right under column 8; the number found is 542. The logarithm of .0348 is $\bar{2}$.542.

Following Rule I,

log 642	=	2.808
log .0348	=	$\bar{2}$.542
log product	=	1.350

To find the number corresponding to this logarithm, look in the table for number 350, which can be found in line 22, column 4, which gives 224. The characteristic is plus one. The whole number will contain, therefore, two integers, and the result will be 22.4.

Divide 37.3 by .00586. The characteristic of 37.3 is 1, and the mantissa is found in line 37 column 3 to be .572. The characteristic of .00586 is −3, and the mantissa is found in line 58 column 6 to be .768.

Following Rule II,

log 37.3	=	1.572
log .00586	=	$\bar{3}$.768
log quotient	=	3.804

In subtracting the mantissa, one is borrowed from the characteristic of the number leaving zero, and the characteristic −3 from zero equals +3. Consequently the answer will have four figures to the left of the decimal point. The mantissa 804 is found in line 63 column 7 and the quotient therefore is 6370.

Find the fourth power of .38, or .38^4.

Following Rule III,

log .38	=	$\bar{1}$.580
		4
log power	=	$\bar{2}$.320

LOGARITHMS

N	0	1	2	3	4	5	6	7	8	9
10	000	004	009	013	017	021	025	029	033	037
11	041	045	049	053	057	061	064	068	072	076
12	079	083	086	090	093	097	100	104	107	111
13	114	117	121	124	127	130	134	137	140	143
14	146	149	152	155	158	161	164	167	170	173
15	176	179	182	185	188	190	193	196	199	201
16	204	207	210	212	215	217	220	223	225	228
17	230	233	236	238	241	243	246	248	250	253
18	255	258	260	262	265	267	270	272	274	276
19	279	281	283	286	288	290	292	294	297	299
20	301	303	305	307	310	312	314	316	318	320
21	322	324	326	328	330	332	334	336	338	340
22	342	344	346	348	350	352	354	356	358	360
23	362	364	365	367	369	371	373	375	377	378
24	380	382	384	386	387	389	391	393	394	396
25	398	400	401	403	405	407	408	410	412	413
26	415	417	418	420	422	423	425	427	428	430
27	431	433	435	436	438	439	441	442	444	446
28	447	449	450	452	453	455	456	458	459	461
29	462	464	465	467	468	470	471	473	474	476
30	477	479	480	481	483	484	486	487	489	490
31	491	493	494	496	497	498	500	501	502	504
32	505	507	508	509	511	512	513	515	516	517
33	519	520	521	522	524	525	526	528	529	530
34	531	533	534	535	537	538	539	540	542	543
35	544	545	547	548	549	550	551	553	554	555
36	556	558	559	560	561	562	563	565	566	567
37	568	569	571	572	573	574	575	576	577	579
38	580	581	582	583	584	585	587	588	589	590
39	591	592	593	594	595	597	598	599	600	601
40	602	603	604	605	606	607	609	610	611	612
41	613	614	615	616	617	618	619	620	621	622
42	623	624	625	626	627	628	629	630	631	632
43	633	634	635	636	637	638	639	640	641	642
44	643	644	645	646	647	648	649	650	651	652
45	653	654	655	656	657	658	659	660	661	662
46	663	664	665	666	667	667	668	669	670	671
47	672	673	674	675	676	677	678	679	679	680
48	681	682	683	684	685	686	687	688	688	689
49	690	691	692	693	694	695	695	696	697	698
50	699	700	701	702	702	703	704	705	706	707
51	708	708	709	710	711	712	713	713	714	715
52	716	717	718	719	719	720	721	722	723	723
53	724	725	726	727	728	728	729	730	731	732
54	732	733	734	735	736	736	737	738	739	740

LOGARITHMS

N	0	1	2	3	4	5	6	7	8	9
55	740	741	742	743	744	744	745	746	747	747
56	748	749	750	751	751	752	753	754	754	755
57	756	757	757	758	759	760	760	761	762	763
58	763	764	765	766	766	767	768	769	769	770
59	771	772	772	773	774	775	775	776	777	777
60	778	779	780	780	781	782	782	783	784	785
61	785	786	787	787	788	789	790	790	791	792
62	792	793	794	794	795	796	797	797	798	799
63	799	800	801	801	802	803	803	804	805	806
64	806	807	808	808	809	810	810	811	812	812
65	813	814	814	815	816	816	817	818	818	819
66	820	820	821	822	822	823	823	824	825	825
67	826	827	827	828	829	829	830	831	831	832
68	833	833	834	834	835	836	836	837	838	838
69	839	839	840	841	841	842	843	843	844	844
70	845	846	846	847	848	848	849	849	850	851
71	851	852	852	853	854	854	855	856	856	857
72	857	858	859	859	860	860	861	862	862	863
73	863	864	865	865	866	866	867	867	868	869
74	869	870	870	871	872	872	873	873	874	874
75	875	876	876	877	877	878	879	879	880	880
76	881	881	882	883	883	884	884	885	885	886
77	886	887	888	888	889	889	890	890	891	892
78	892	893	893	894	894	895	895	896	897	897
79	898	898	899	899	900	900	901	901	902	903
80	903	904	904	905	905	906	906	907	907	908
81	908	909	910	910	911	911	912	912	913	913
82	914	914	915	915	916	916	917	918	918	919
83	919	920	920	921	921	922	922	923	923	924
84	924	925	925	926	926	927	927	928	928	929
85	929	930	930	931	931	932	932	933	933	934
86	934	935	936	936	937	937	938	938	939	939
87	940	940	941	941	942	942	943	943	943	944
88	944	945	945	946	946	947	947	948	948	949
89	949	950	950	951	951	952	952	953	953	954
90	954	955	955	956	956	957	957	958	958	959
91	959	960	960	960	961	961	962	962	963	963
92	964	964	965	965	966	966	967	967	968	968
93	968	969	969	970	970	971	971	972	972	973
94	973	974	974	975	975	975	976	976	977	977
95	978	978	979	979	980	980	980	981	981	982
96	982	983	983	984	984	985	985	985	986	986
97	987	987	988	988	989	989	989	990	990	991
98	991	992	992	993	993	993	994	994	995	995
99	996	996	997	997	997	998	998	999	999	000

In the above example four times the mantissa (.580) equals +2.320, and four times the characteristic (−1) equals −4; hence the product equals −4+2.320 or $\bar{2}.320$. The number corresponding to this logarithm is found to be .0209.

Find the cube root of 765 or $\sqrt[3]{765}$

Following Rule IV,

$$\log 765 = 2.884$$
$$2.884 \div 3 = .961 = \text{log of root.}$$

The number corresponding to this logarithm is found to be 9.14.

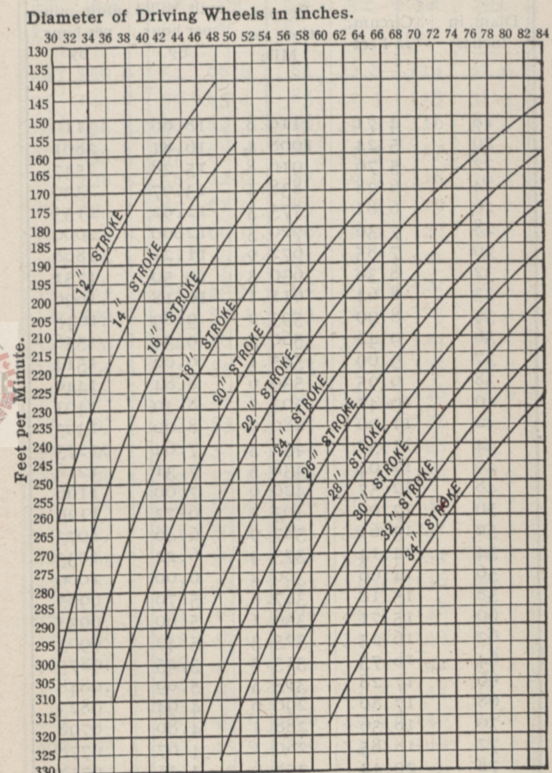
PISTON SPEED

The figures at the top of the chart on page 55 represent the diameter of the driving wheels in inches, and those at the left hand side indicate the piston speed in feet per minute. The several curves in the body of the chart represent different strokes of piston.

Follow the perpendicular line from the number representing the diameter of wheel selected until it intersects the curve representing the desired stroke; then follow the horizontal line from the point of intersection to the left hand margin, and the figures here given will denote the piston speed.

It will be noted that the calculations are based on an engine speed of ten miles per hour. Greater speed will be determined by multiplying the results by the proper factor indicated by the speed required. In locomotive practice the maximum piston speed should not exceed 1600 feet per minute. The economical speed may be placed at about 1100 feet per minute.

Piston Speeds in Feet per Minute at Engine Speed of Ten Miles per Hour.



REVOLUTIONS OF WHEELS PER MINUTE AND PER SECOND AT VARIOUS SPEEDS

WHEELS			For Rev. per minute, mult. miles per hour by	For Rev. per second, mult. miles per hour by
Diam. in Inches	Circum. in Feet	Revolutions per Mile		
18	4.71	1119.8	18.66	.3110
20	5.24	1008.4	16.81	.2801
22	5.76	916.8	15.28	.2547
24	6.28	838.4	13.97	.2329
26	6.81	775.3	12.92	.2153
28	7.36	720.3	12.00	.2000
30	7.85	672.6	11.21	.1868
32	8.38	630.3	10.50	.1751
33	8.64	611.1	10.18	.1696
34	8.90	593.2	9.89	.1648
36	9.42	560.5	9.34	.1556
37	9.69	545.1	9.09	.1514
38	9.95	530.6	8.84	.1440
40	10.47	504.2	8.40	.1401
42	11.00	480.0	8.00	.1363
44	11.52	458.3	7.64	.1273
46	12.04	438.5	7.31	.1218
48	12.57	420.0	7.00	.1166
50	13.00	403.4	6.72	.1120
52	13.61	387.9	6.46	.1073
54	14.14	373.4	6.22	.1033
56	14.66	360.2	6.00	.1000
58	15.18	347.8	5.79	.0965
60	15.71	336.1	5.60	.0933
62	16.23	325.3	5.42	.0903
64	16.75	315.2	5.25	.0875
66	17.28	305.5	5.09	.0848
68	17.80	296.6	4.94	.0823
70	18.36	288.1	4.80	.0798
72	18.85	280.1	4.67	.0778
78	20.42	258.6	4.31	.0718
84	21.99	240.1	4.00	.0666
90	23.56	224.1	3.73	.0622
96	25.16	210.1	3.50	.0586

SPEED, SECONDS PER MILE IN MILES PER HOUR

Seconds per Mile	Miles per Hour	Seconds per Mile	Miles per Hour	Seconds per Mile	Miles per Hour	Seconds per Mile	Miles per Hour
24	150.0	54	66.6	84	42.8	114	31.6
25	144.0	55	65.4	85	42.3	115	31.3
26	138.5	56	64.3	86	41.8	116	31.0
27	133.3	57	63.1	87	41.3	117	30.7
28	128.5	58	62.0	88	40.9	118	30.5
29	124.1	59	61.0	89	40.4	119	30.2
30	120.0	60	60.0	90	40.0	120	30.0
31	116.1	61	59.0	91	39.5	121	29.7
32	112.5	62	58.0	92	39.1	122	29.5
33	109.0	63	57.1	93	38.7	123	29.2
34	105.8	64	56.2	94	38.3	124	29.0
35	102.8	65	55.3	95	37.9	125	28.8
36	100.0	66	54.5	96	37.5	126	28.6
37	97.3	67	53.7	97	37.1	127	28.3
38	94.7	68	52.9	98	36.7	128	28.1
39	92.3	69	52.1	99	36.4	129	27.9
40	90.0	70	51.4	100	36.0	130	27.7
41	87.8	71	50.7	101	35.6	132	27.2
42	85.7	72	50.0	102	35.3	134	26.8
43	83.7	73	49.3	103	34.9	136	26.4
44	81.8	74	48.6	104	34.6	138	26.0
45	80.0	75	48.0	105	34.3	140	25.7
46	78.2	76	47.3	106	34.0	142	25.3
47	76.6	77	46.7	107	33.7	144	25.0
48	75.0	78	46.1	108	33.4	146	24.6
49	73.4	79	45.5	109	33.0	148	24.3
50	72.0	80	45.0	110	32.7	150	24.0
51	70.5	81	44.4	111	32.4	152	23.6
52	69.2	82	43.9	112	32.1	154	23.3
53	67.9	83	43.3	113	31.8	156	23.1

SPEED, TIME PER MILE, FEET PER SECONDS

Miles per Hour		Time per Mile Min.	Sec.		Feet per Second	Miles per Hour		Time per Mile Min.	Sec.		Feet per Second
8	=	7	30.0	=	11¾	58	=	1	2.1	=	85
15	=	4	0.0	=	22	59	=	1	1.0	=	86½
16	=	3	45.0	=	23½	60	=	1	0.0	=	88
17	=	3	31.8	=	25	61	=		59.0	=	89½
18	=	3	20.0	=	26½	62	=		58.0	=	91
19	=	3	9.5	=	28	63	=		57.1	=	92½
20	=	3	0.0	=	29¼	64	=		56.2	=	94
21	=	2	51.4	=	30¾	65	=		55.4	=	95¼
22	=	2	43.6	=	32¼	66	=		54.5	=	96¾
23	=	2	36.5	=	33¾	67	=		53.7	=	98¼
24	=	2	30.0	=	35¼	68	=		52.9	=	99¾
25	=	2	24.0	=	36¾	69	=		52.1	=	101¼
26	=	2	18.5	=	38¼	70	=		51.4	=	102¾
27	=	2	13.2	=	39½	71	=		50.7	=	104¼
28	=	2	8.6	=	41	72	=		50.0	=	105½
29	=	2	4.1	=	42½	73	=		49.3	=	107
30	=	2	0.0	=	44	74	=		48.6	=	108½
31	=	1	56.2	=	45½	75	=		48.0	=	110
32	=	1	52.5	=	47	76	=		47.3	=	111½
33	=	1	49.1	=	48½	77	=		46.7	=	112¾
34	=	1	45.8	=	50	78	=		46.1	=	114¼
35	=	1	42.7	=	51¼	79	=		45.5	=	115½
36	=	1	40.0	=	52¾	80	=		45.0	=	117
37	=	1	37.3	=	54¼	81	=		44.4	=	118¾
38	=	1	34.8	=	55¾	82	=		43.9	=	120¼
39	=	1	32.3	=	57¼	83	=		43.4	=	121¾
40	=	1	30.0	=	58¾	84	=		42.8	=	123¼
41	=	1	27.8	=	60¼	85	=		42.3	=	124¾
42	=	1	25.7	=	61½	86	=		41.8	=	126¼
43	=	1	23.7	=	63	87	=		41.3	=	127¾
44	=	1	21.8	=	64½	88	=		40.8	=	129
45	=	1	20.0	=	66	89	=		40.4	=	130½
46	=	1	18.2	=	67½	90	=		40.0	=	132
47	=	1	16.6	=	69	91	=		39.5	=	133½
48	=	1	15.0	=	70½	92	=		39.1	=	135
49	=	1	13.5	=	71¾	93	=		38.7	=	136½
50	=	1	12.0	=	73¼	94	=		38.2	=	137¾
51	=	1	10.6	=	74¾	95	=		37.8	=	139¼
52	=	1	9.2	=	76¼	96	=		37.5	=	140¾
53	=	1	7.9	=	77¾	97	=		37.1	=	142¼
54	=	1	6.7	=	79¼	98	=		36.7	=	143¾
55	=	1	5.5	=	80¾	99	=		36.4	=	145¼
56	=	1	4.3	=	82¼	100	=		36.0	=	146½
57	=	1	3.2	=	83½	101	=		35.6	=	148¼

MISCELLANEOUS

Weight of Various Materials

Water—One cubic inch weighs .036 pounds.

One cubic foot at 32″F. weighs 62.4 pounds and contains 7.48 United States gallons.

One gallon, United States standard, contains 231 cubic inches and weighs 8⅓ pounds.

One gallon, Imperial, contains 277¼ cubic inches and weighs 10 pounds.

Gravel—One cubic foot weighs 125 pounds.

One cubic yard weighs 3350 pounds.

Wood—A cord of wood measures 8 feet in length, 4 feet in width and 4 feet in height, and contains 128 cubic feet, or 3.625 cubic metres.

Logs—1000 feet of green logs weigh 8,000 to 10,000 pounds.

Lumber—Weight of one cubic inch:

Seasoned oak,	.025 pounds
Seasoned pine,	.018 pounds

Coal—Average weight of one cubic foot:

Bituminous, large size,	52 pounds
Bituminous, run of mine,	54 pounds
Anthracite, large size,	54 pounds
Anthracite, buckwheat,	52 pounds

Average weight of one bushel containing 2500 cubic inches:

Bituminous,	75 pounds
Anthracite,	78 pounds

Specific gravity:

Bituminous,	1.40
Anthracite,	1.60

Average bulk of one ton,	(2240 pounds)
Bituminous,	43.0 cubic feet
Anthracite,	41.5 cubic feet

Coal—Grade Divisions

In designing a locomotive for a particular quality of coal, the question is likely to arise as to what is anthracite or what is bituminous. The division between the different grades is largely empirical. That given by Kent has been adopted by The Baldwin Locomotive Works as generally satisfactory, and is as follows:

Anthracite, all coal with less than 7.5 per cent. volatile matter in combustible.

Semi-anthracite, all coal with 7.5 per cent. to 12.5 per cent. volatile matter in combustible.

Semi-bituminous, all coal with 12.5 per cent. to 25 per cent. volatile matter in combustible.

Bituminous, all coal with 25 per cent. to 50 per cent. volatile matter in combustible.

Lignite, all coal with more than 50 per cent. volatile matter in combustible.

Relative Heating Value of Fuels—One pound of average soft coal possesses as much heating value as fuel, as 2¼ pounds of average dry wood.

One pound of oil possesses nearly as much heating value as two pounds of average coal.

Weight and Volume of Crude Petroleum

Pound	U. S. Liquid Gal.	Barrel	Gross Ton
1.	.13158	.0031328	.0004464
7.6	1.	.02381	.003393
319.2	42.	1.	.1425
2240.	294.72	7.017	1.

Rails, Safe Load—Each ten pounds weight per yard of ordinary steel rail, properly supported by cross-ties (not less than 14 for 30-foot rail), is capable of sustaining a safe load per wheel of 3000 pounds.

Rails, Tons per Mile—The following formula gives the weight of rails required to lay one mile of single track:

$$\frac{\text{Weight per yard of rail,} \times 11}{7} = \text{Tons of 2240 lbs.}$$

Driving Wheels, Minimum Diameter—For proper clearances, the minimum outside diameter of driving wheels should ordinarily be not less than twice the length of the stroke.

Rules for Driving Wheel Speed—Revolutions per mile—Divide 1680 by the diameter of the driving wheel in feet. Revolutions per minute—Multiply the speed in miles per hour by 28 and divide the product by the diameter of the driving wheel in feet.

Piston Speeds—Piston speed in feet per minute—Multiply revolutions per minute by twice the stroke of piston in feet.

TUBE INFORMATION

Diameter	Heating Surface		Area of Section	Weight of Water Displaced Per Foot	Thickness Wire Gauge	Area of Metal	Weight Per Foot					
							Iron		Brass		Copper	
	Per Ft.	Per In.					Tube	Excess	Tube	Excess	Tube	Excess
In.	Sq. Ft.	Sq. Ft.	Sq. In.	Lbs.	No.	Sq. In.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1¼	.327	.027	1.227	.533	13	.347	1.21	.677	1.27	.737	1.33	.797
					12	.397	1.37	.837	1.44	.907	1.51	.977
					11	.427	1.50	.967	1.56	1.03	1.64	1.11
1½	.393	.033	1.767	.767	13	.419	1.47	.703	1.54	.773	1.62	.853
					12	.480	1.67	.903	1.75	.983	1.84	1.073
					11	.520	1.83	1.06	1.91	1.143	2.01	1.243
1¾	.458	.038	2.405	1.039	13	.495	1.74	.701	1.82	.781	1.91	.871
					12	.565	1.98	.941	2.06	1.02	2.16	1.12
					11	.615	2.16	1.12	2.26	1.22	2.37	1.33
2	.524	.044	3.142	1.361	13	.572	2.00	.639	2.09	.729	2.19	.829
					12	.652	2.28	.919	2.38	1.02	2.50	1.14
					11	.712	2.49	1.23	2.60	1.24	2.73	1.37

TUBE INFORMATION

Diameter	Heating Surface		Area of Section	Weight of Water Displaced Per Foot	Thickness Wire Gauge or Inches	Area of Metal	Weight Per Foot					
							Iron		Brass		Copper	
	Per Ft.	Per In.					Tube	Excess	Tube	Excess	Tube	Excess
In.	Sq. Ft.	Sq. Ft.	Sq. In.	Lbs.	No.	Sq. In.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
2¼	.589	.049	3.976	1.718	13	.643	2.16	.442	2.38	.662	2.50	.782
					12	.739	2.58	.862	2.69	.972	2.82	1.10
					11	.803	2.82	1.10	2.95	1.23	3.10	1.38
2½	.654	.055	4.908	2.13	11	.90	3.16	1.03	3.30	1.17	3.46	1.33
					10	.99	3.50	1.37	3.66	1.53	3.84	1.71
					9	1.09	3.83	1.70	4.02	1.89	4.22	2.09
5	1.309	.109	19.64	8.50	3/16"	2.84	9.94	1.44	10.22	1.72	10.91	2.41
5¼	1.374	.114	21.64	9.37	3/16"	2.98	10.35	.98	10.60	1.23	11.15	1.78
5⅜	1.407	.117	22.69	9.82	3/16"	3.05	10.68	.86	10.98	1.16	11.71	1.89
5½	1.439	.120	23.76	10.28	3/16"	3.13	10.96	.68	11.27	.99	12.02	1.74

Weight of water (cubic foot), 62⅓ pounds at atmospheric pressure (62°); 54.4 pounds at 200 pounds gauge pressure (388°).
Columns headed "Excess" give excess of weight of tube over weight of water displaced.

HEATING SURFACE OF BOILER TUBES

Length in Inches	Heating Surface in Square Feet — Outside Diameter 1½"	1¾"	2"	2¼"	2½"	5"	5¼"	5⅜"	5½"
¼	.008	.009	.011	.012	.014	.0273	.0286	.0293	.0300
½	.016	.019	.022	.025	.027	.0545	.0573	.0586	.0600
¾	.025	.029	.033	.037	.041	.0818	.0859	.0879	.0900
1	.033	.038	.044	.049	.055	.1091	.1145	.1173	.1200
2	.066	.076	.087	.098	.109	.2182	.2291	.2345	.2400
3	.098	.115	.131	.147	.164	.3272	.3436	.3518	.3600
4	.131	.153	.175	.196	.218	.4363	.4582	.4691	.4800
5	.164	.191	.218	.245	.272	.5454	.5727	.5863	.6000
6	.196	.229	.262	.294	.327	.6545	.6872	.7036	.7200
7	.229	.267	.305	.344	.382	.7636	.8018	.8209	.8400
8	.262	.305	.349	.393	.436	.8727	.9163	.9381	.9600
9	.295	.344	.393	.442	.491	.9817	1.0308	1.0554	1.0800
10	.327	.382	.436	.491	.545	1.0908	1.1454	1.1726	1.2000
11	.360	.420	.480	.540	.600	1.1999	1.2599	1.2899	1.3200
12	.393	.458	.524	.589	.654	1.3090	1.3745	1.4072	1.4390

HEATING SURFACE OF BOILER TUBES (Continued)

Length in Feet	Heating Surface in Square Feet — Outside Diameter 1½"	1¾"	2"	2¼"	2½"	5"	5¼"	5⅜"	5½"
5	1.964	2.291							
6	2.356	2.749	3.142						
7	2.749	3.207	3.665	4.123	4.581	9.163	9.621	9.850	10.079
8	3.142	3.665	4.189	4.712	5.236	10.472	10.995	11.257	11.519
9	3.534	4.123	4.712	5.301	5.890	11.781	12.369	12.665	12.959
10	3.927	4.582	5.236	5.891	6.545	13.090	13.744	14.072	14.399
11	4.320	5.040	5.760	6.480	7.199	14.399	15.118	15.479	15.839
12	4.712	5.498	6.283	7.069	7.854	15.708	16.493	16.886	17.279
13	5.105	5.956	6.807	7.658	8.508	17.017	17.867	18.293	18.719
14	5.498	6.414	7.330	8.247	9.163	18.326	19.242	19.700	20.159
15	5.891	6.872	7.854	8.836	9.817	19.635	20.616	21.108	21.599
16	....	7.320	8.378	9.425	10.472	20.944	21.990	22.515	23.038
17	....	7.788	8.901	10.014	11.127	22.253	23.365	23.922	24.478
18	....	8.246	9.425	10.603	11.781	23.562	24.739	25.329	25.918
19	....	8.705	9.948	11.192	12.435	24.871	26.114	26.736	27.358
20	....	9.164	10.472	11.781	13.090	26.180	27.488	28.143	28.798
21	....	....	10.995	12.360	13.744	27.489	28.862	29.551	30.238
22	....	....	11.519	12.959	14.398	28.798	30.236	30.958	31.678
23	....	....	12.043	13.549	15.053	30.107	31.610	32.365	33.118
24	....	....	12.566	14.138	15.708	31.416	32.984	33.772	34.558
25	....	....	....	14.727	16.363	32.725	34.358	35.179	35.998

HEATING SURFACE OF TUBES PER FOOT AND PER INCH OF LENGTH

DIAMETER	PER FOOT	PER INCH
1¼ Inches	.3272 Sq. Feet	.0272 Sq. Inches
1⅜ "	.3599 " "	.0299 " "
1½ "	.3927 " "	.0327 " "
1⅝ "	.4254 " "	.0354 " "
1¾ "	.4580 " "	.0381 " "
1⅞ "	.4908 " "	.0409 " "
2 "	.5236 " "	.0436 " "
2⅛ "	.5562 " "	.0463 " "
2¼ "	.5890 " "	.0490 " "
2⅜ "	.6218 " "	.0518 " "
2½ "	.6545 " "	.0545 " "
2⅝ "	.6872 " "	.0572 " "
2¾ "	.7199 " "	.0599 " "
3 "	.7854 " "	.0655 " "
3¼ "	.8508 " "	.0709 " "
3½ "	.9163 " "	.0763 " "
3¾ "	.9817 " "	.0818 " "
4 "	1.0472 " "	.0872 " "
4¼ "	1.1126 " "	.0927 " "
4½ "	1.1781 " "	.0981 " "
4¾ "	1.2435 " "	.1036 " "
5 "	1.3090 " "	.1090 " "
5¼ "	1.3745 " "	.1140 " "
5⅜ "	1.4072 " "	.1173 " "
5½ "	1.4390 " "	.1200 " "
5¾ "	1.5053 " "	.1250 " "
6 "	1.5708 " "	.1309 " "

STANDARD SIZES OF WROUGHT IRON PIPE

Size of Pipe	Actual Outside Diameter (Inches)	Actual Inside Diameter (Inches)	External Circumference (Inches)	Length of Pipe per Square Foot of Outside Surface (Feet)	Weight per Foot of Length (Pounds)	Number of Threads per Inch of Screw	Diameter of Drill (Inches)
⅛"	0.405	0.270	1.272	9.434	0.243	27	11/32
¼"	0.540	0.364	1.696	7.075	0.422	18	29/64
⅜"	0.675	0.494	2.120	5.660	0.561	18	37/64
½"	0.840	0.623	2.639	4.547	0.845	14	47/64
¾"	1.050	0.824	3.299	3.637	1.126	14	61/64
1"	1.315	1.048	4.131	2.904	1.670	11½	1 13/64
1¼"	1.660	1.380	5.215	2.301	2.258	11½	1½
1½"	1.900	1.611	5.969	2.010	2.694	11½	1 49/64
2"	2.375	2.067	7.461	1.608	3.667	11½	2 7/32
2½"	2.875	2.468	9.032	1.328	5.773	8	2 11/16
3"	3.500	3.067	10.996	1.091	7.547	8	3 9/32
3½"	4.000	3.548	12.566	0.955	9.055	8	3¾
4"	4.500	4.026	14.137	0.849	10.728	8	4¼
4½"	5.000	4.508	15.708	0.764	12.492	8	4¾
5"	5.563	5.045	17.477	0.686	14.564	8	5 5/16
6"	6.625	6.065	20.813	0.576	18.767	8	6 5/16
7"	7.625	7.023	23.954	0.501	23.410	8	7⅜
8"	8.625	7.982	27.096	0.443	28.347	8	8⅜

AREAS AND CIRCUMFERENCES OF CIRCLES

Diam. Ins.	Circum. Ins.	Area Sq. Ins.	Diam. Ins.	Circum. Ins.	Area Sq. Ins.	Diam. Ins.	Circum. Ins.	Area Sq. Ins.
¼	.785398	.04990						
5/16	.981748	.07670						
⅜	1.17810	.11045						
7/16	1.37445	.15033						
½	1.57080	.19635	3	9.42478	7.0686	5½	17.2788	23.758
9/16	1.76715	.24850	1/16	9.62113	7.3662	9/16	17.4751	24.301
⅝	1.96350	.30680	⅛	9.81748	7.6699	⅝	17.6715	24.850
11/16	2.15984	.37122	3/16	10.0138	7.9798	11/16	17.8678	25.406
¾	2.35619	.44179	¼	10.2102	8.2958	¾	18.0642	25.967
13/16	2.55254	.51849	5/16	10.4065	8.6179	13/16	18.2605	26.535
⅞	2.74889	.60132	⅜	10.6029	8.9462	⅞	18.4569	27.109
15/16	2.94524	.69029	7/16	10.7992	9.2806	15/16	18.6532	27.688
1	3.14159	.78540	3½	10.9956	9.6211	6	18.8496	28.274
1/16	3.33794	.88664	9/16	11.1919	9.9678	⅛	19.2423	29.465
⅛	3.53429	.99402	⅝	11.3883	10.321	¼	19.6350	30.680
3/16	3.73064	1.1075	11/16	11.5846	10.680	⅜	20.0277	31.919
¼	3.92699	1.2272	¾	11.7810	11.045	½	20.4204	33.183
5/16	4.12334	1.3530	13/16	11.9773	11.416	⅝	20.8131	34.472
⅜	4.31969	1.4849	⅞	12.1737	11.793	¾	21.2058	35.785
7/16	4.51604	1.6230	15/16	12.3700	12.177	⅞	21.5984	37.122
1½	4.71239	1.7671	4	12.5664	12.566	7	21.9911	38.485
9/16	4.90874	1.9175	1/16	12.7627	12.962	⅛	22.3838	39.871
⅝	5.10509	2.0739	⅛	12.9591	13.364	¼	22.7765	41.282
11/16	5.30144	2.2365	3/16	13.1554	13.772	⅜	23.1692	42.718
¾	5.49779	2.4053	¼	13.3518	14.186	½	23.5619	44.179
13/16	5.69414	2.5802	5/16	13.5481	14.607	⅝	23.9546	45.664
⅞	5.89049	2.7612	⅜	13.7445	15.033	¾	24.3473	47.173
15/16	6.08684	2.9483	7/16	13.9408	15.466	⅞	24.7400	48.707
2	6.28319	3.1416	4½	14.1372	15.904	8	25.1327	50.265
1/16	6.47953	3.3410	9/16	14.3335	16.349	⅛	25.5224	51.849
⅛	6.67588	3.5466	⅝	14.5299	16.800	¼	25.9181	53.456
3/16	6.87223	3.7583	11/16	14.7262	17.257	⅜	26.3108	55.088
¼	7.06858	3.9761	¾	14.9226	17.721	½	26.7035	56.745
5/16	7.26493	4.2000	13/16	15.1189	18.190	⅝	27.0962	58.426
⅜	7.46128	4.4301	⅞	15.3153	18.665	¾	27.4889	60.132
7/16	7.65763	4.6664	15/16	15.5116	19.147	⅞	27.8816	61.862
2½	7.85398	4.9087	5	15.7080	19.635	9	28.2743	63.617
9/16	8.05033	5.1572	1/16	15.9043	20.129	⅛	28.6670	65.397
⅝	8.24668	5.4119	⅛	16.1007	20.629	¼	29.0597	67.201
11/16	8.44303	5.6727	3/16	16.2970	21.135	⅜	29.4524	69.029
¾	8.63938	5.9396	¼	16.4934	21.648	½	29.8451	70.882
13/16	8.83573	6.2126	5/16	16.6897	22.166	⅝	30.2378	72.760
⅞	9.03208	6.4918	⅜	16.8861	22.691	¾	30.6305	74.662
15/16	9.22843	6.7771	7/16	17.0824	23.221	⅞	31.0232	76.589

π × r² = area.   π × D = Circ

AREAS AND CIRCUMFERENCES OF CIRCLES

Diam. Ins.	Circum. Ins.	Area Sq. Ins.	Diam. Ins.	Circum. Ins.	Area Sq. Ins.	Diam. Ins.	Circum. Ins.	Area Sq. Ins.
10	31.4159	78.540	15	47.1239	176.71	20	62.8319	314.16
⅛	31.8086	80.516	⅛	47.5166	179.67	⅛	63.2246	318.10
¼	32.2013	82.516	¼	47.9093	182.65	¼	63.6173	322.06
⅜	32.5940	84.541	⅜	48.3020	185.66	⅜	64.0100	326.05
½	32.9867	86.590	½	48.6947	188.69	½	64.4026	330.06
⅝	33.3794	88.664	⅝	49.0874	191.75	⅝	64.7953	334.10
¾	33.7721	90.763	¾	49.4801	194.83	¾	66.1880	338.16
⅞	34.1648	92.886	⅞	49.8728	197.93	⅞	65.5807	342.25
11	34.5575	95.033	16	50.2655	201.06	21	65.9734	346.36
⅛	34.9502	97.205	⅛	50.6582	204.22	⅛	66.3661	350.50
¼	35.3429	99.402	¼	51.0509	207.39	¼	66.7588	354.66
⅜	35.7356	101.62	⅜	51.4436	210.60	⅜	67.1515	358.84
½	36.1283	103.87	½	51.8363	213.82	½	67.5442	363.05
⅝	36.5210	106.14	⅝	52.2290	217.08	⅝	67.9369	367.28
¾	36.9137	108.43	¾	52.6217	220.35	¾	68.3296	371.54
⅞	37.3064	110.75	⅞	53.0144	223.65	⅞	68.7223	375.83
12	37.6991	113.10	17	53.4071	226.98	22	69.1150	380.13
⅛	38.0918	115.47	⅛	53.7998	230.33	⅛	69.5077	384.46
¼	38.4845	117.86	¼	54.1925	233.71	¼	69.9004	388.82
⅜	38.8772	120.28	⅜	54.5852	237.10	⅜	70.2931	393.20
½	39.2699	122.72	½	54.9779	240.53	½	70.6858	397.61
⅝	39.6626	125.19	⅝	55.3706	243.98	⅝	71.0785	402.04
¾	40.0553	127.68	¾	55.7633	247.45	¾	71.4712	406.49
⅞	40.4480	130.19	⅞	56.1560	250.95	⅞	71.8639	410.97
13	40.8407	132.73	18	56.5487	254.47	23	72.2566	415.48
⅛	41.2334	135.30	⅛	56.9414	258.02	⅛	72.6493	420.00
¼	41.6261	137.89	¼	57.3341	261.59	¼	73.0420	424.56
⅜	42.0188	140.50	⅜	57.7268	265.18	⅜	73.4347	429.13
½	42.4115	143.14	½	58.1195	268.80	½	73.8274	433.74
⅝	42.8042	145.80	⅝	58.5122	272.45	⅝	74.2201	438.36
¾	43.1969	148.49	¾	58.9049	276.12	¾	74.6128	443.01
⅞	43.5896	151.20	⅞	59.2976	279.81	⅞	75.0055	447.69
14	43.9823	153.94	19	59.6903	283.53	24	75.3982	452.39
⅛	44.3750	156.70	⅛	60.0830	287.27	⅛	75.7909	457.11
¼	44.7677	159.48	¼	60.4757	291.04	¼	76.1836	461.86
⅜	45.1604	162.30	⅜	60.8684	294.83	⅜	76.5763	466.64
½	45.5531	165.13	½	61.2611	298.65	½	76.9690	471.44
⅝	45.9458	167.99	⅝	61.6538	302.49	⅝	77.3617	476.26
¾	46.3385	170.87	¾	62.0465	306.35	¾	77.7544	481.11
⅞	46.7312	173.78	⅞	62.4392	310.24	⅞	78.1471	485.98

AREAS AND CIRCUMFERENCES OF CIRCLES

Diam. Ins.	Circum. Ins.	Area Sq. Ins.	Diam. Ins.	Circum. Ins.	Area Sq. Ins.	Diam. Ins.	Circum. Ins.	Area Sq. Ins.
25	78.5398	490.87	**30**	94.2478	706.86	**35**	109.956	962.11
⅛	78.9325	495.79	⅛	94.6405	712.76	⅛	110.348	969.00
¼	79.3252	500.74	¼	95.0332	718.69	¼	110.741	975.91
⅜	79.7179	505.71	⅜	95.4259	724.64	⅜	111.134	982.84
½	80.1106	510.71	½	95.8186	730.62	½	111.527	989.80
⅝	80.5033	515.72	⅝	96.2113	736.62	⅝	111.919	996.78
¾	80.8960	520.77	¾	96.6040	742.64	¾	112.312	1003.8
⅞	81.2887	525.84	⅞	96.9967	748.69	⅞	112.705	1010.8
26	81.6814	530.93	**31**	97.3894	754.77	**36**	113.097	1017.9
⅛	82.0741	536.05	⅛	97.7821	760.87	⅛	113.490	1025.0
¼	82.4668	541.19	¼	98.1748	766.99	¼	113.883	1032.1
⅜	82.8595	546.35	⅜	98.5675	773.14	⅜	114.275	1039.2
½	83.2522	551.55	½	98.9602	779.31	½	114.668	1046.3
⅝	83.6449	556.76	⅝	99.3529	785.51	⅝	115.061	1053.5
¾	84.0376	562.00	¾	99.7456	791.73	¾	115.454	1060.7
⅞	84.4303	567.27	⅞	100.138	797.98	⅞	115.846	1068.0
27	84.8230	572.56	**32**	100.531	804.25	**37**	116.239	1075.2
⅛	85.2157	577.87	⅛	100.924	810.54	⅛	116.632	1082.5
¼	85.6084	583.21	¼	101.316	816.86	¼	117.024	1089.8
⅜	86.0011	588.57	⅜	101.709	823.21	⅜	117.417	1097.1
½	86.3938	593.96	½	102.102	829.58	½	117.810	1104.5
⅝	86.7865	599.37	⅝	102.494	835.97	⅝	118.202	1111.8
¾	87.1792	604.81	¾	102.887	842.39	¾	118.596	1119.2
⅞	87.5719	610.27	⅞	103.280	848.83	⅞	118.988	1126.7
28	87.9646	615.75	**33**	103.673	855.30	**38**	119.381	1134.1
⅛	88.3573	621.26	⅛	104.065	861.79	⅛	119.773	1141.6
¼	88.7500	626.80	¼	104.458	868.31	¼	120.166	1149.1
⅜	89.1427	632.36	⅜	104.851	874.85	⅜	120.559	1156.6
½	89.5354	637.94	½	105.243	881.41	½	120.951	1164.2
⅝	89.9281	643.55	⅝	105.636	888.00	⅝	121.344	1171.7
¾	90.3208	649.18	¾	106.029	894.62	¾	121.737	1179.3
⅞	90.7135	654.84	⅞	106.421	901.26	⅞	122.129	1186.9
29	91.1062	660.52	**34**	106.814	907.92	**39**	122.522	1194.6
⅛	91.4989	666.23	⅛	107.207	914.61	⅛	122.915	1202.3
¼	91.8916	671.96	¼	107.600	921.32	¼	123.308	1210.0
⅜	92.2843	677.71	⅜	107.992	928.06	⅜	123.700	1217.7
½	92.6770	683.49	½	108.385	934.82	½	124.093	1225.4
⅝	93.0697	689.30	⅝	108.788	941.61	⅝	124.486	1233.2
¾	93.4624	695.13	¾	109.170	948.42	¾	124.878	1241.0
⅞	93.8551	700.98	⅞	109.563	955.25	⅞	125.271	1248.8

AREAS AND CIRCUMFERENCES OF CIRCLES

Diam. Ins.	Circum. Ins.	Area Sq. Ins.	Diam. Ins.	Circum. Ins.	Area Sq. Ins.	Diam. Ins.	Circum. Ins.	Area Sq. Ins.
40	125.664	1256.6	**45**	141.372	1590.4	**50**	157.080	1963.5
⅛	126.056	1264.5	⅛	141.764	1599.3	⅛	157.472	1973.3
¼	126.449	1272.4	¼	142.157	1608.2	¼	157.865	1983.2
⅜	126.842	1280.3	⅜	142.550	1617.0	⅜	158.258	1993.1
½	127.235	1288.2	½	142.942	1626.0	½	158.650	2003.0
⅝	127.627	1296.2	⅝	143.335	1684.9	⅝	159.043	2012.9
¾	128.020	1304.2	¾	143.728	1643.9	¾	159.436	2022.8
⅞	128.413	1312.2	⅞	144.121	1652.9	⅞	159.829	2032.8
41	128.805	1320.3	**46**	144.513	1661.9	**51**	160.221	2042.8
⅛	129.198	1328.3	⅛	144.906	1670.9	⅛	160.614	2052.8
¼	129.591	1336.4	¼	145.299	1680.0	¼	161.007	2062.9
⅜	129.993	1344.5	⅜	145.691	1689.1	⅜	161.399	2073.0
½	130.376	1352.7	½	146.084	1698.2	½	161.792	2083.1
⅝	130.769	1360.8	⅝	146.477	1707.4	⅝	162.185	2093.2
¾	131.161	1369.0	¾	146.869	1716.5	¾	162.577	2103.3
⅞	131.554	1377.2	⅞	147.262	1725.7	⅞	162.970	2113.5
42	131.947	1385.4	**47**	147.655	1734.9	**52**	163.363	2123.7
⅛	132.340	1393.7	⅛	148.048	1744.2	⅛	163.756	2133.9
¼	132.732	1402.0	¼	148.440	1753.5	¼	164.148	2144.2
⅜	133.125	1410.3	⅜	148.833	1762.7	⅜	164.541	2154.5
½	133.518	1418.6	½	149.226	1772.1	½	164.934	2164.8
⅝	133.910	1427.0	⅝	149.618	1781.4	⅝	165.326	2175.1
¾	134.303	1435.4	¾	150.011	1790.8	¾	165.719	2185.4
⅞	134.696	1443.8	⅞	150.404	1800.1	⅞	166.112	2195.8
43	135.088	1452.2	**48**	150.796	1809.6	**53**	166.504	2206.2
⅛	135.481	1460.7	⅛	151.189	1819.0	⅛	166.897	2216.6
¼	135.874	1469.1	¼	151.582	1828.5	¼	167.290	2227.0
⅜	136.267	1477.6	⅜	151.975	1837.9	⅜	167.683	2237.5
½	136.659	1486.2	½	152.367	1847.5	½	168.075	2248.0
⅝	137.052	1494.7	⅝	152.760	1857.0	⅝	168.468	2258.5
¾	137.445	1503.3	¾	153.153	1866.5	¾	168.861	2269.1
⅞	137.837	1511.9	⅞	153.545	1876.1	⅞	169.253	2279.6
44	138.230	1520.5	**49**	153.938	1885.7	**54**	169.646	2290.2
⅛	138.623	1529.2	⅛	154.331	1895.4	⅛	170.039	2300.8
¼	139.015	1537.9	¼	154.723	1905.0	¼	170.431	2311.5
⅜	139.408	1546.6	⅜	155.116	1914.7	⅜	170.824	2322.1
½	139.801	1555.3	½	155.509	1924.4	½	171.217	2332.8
⅝	140.194	1564.0	⅝	155.902	1934.2	⅝	171.609	2343.5
¾	140.586	1572.8	¾	156.294	1943.9	¾	172.002	2354.3
⅞	140.979	1581.6	⅞	156.687	1953.7	⅞	172.395	2365.0

AREAS AND CIRCUMFERENCES OF CIRCLES

Diam. Ins.	Circum. Ins.	Area Sq. Ins.	Diam. Ins.	Circum. Ins.	Area Sq. Ins.	Diam. Ins.	Circum. Ins.	Area Sq. Ins.
55	172.788	2375.8	**60**	188.496	2827.4	**65**	204.204	3318.3
⅛	173.180	2386.6	⅛	188.888	2839.2	⅛	204.596	3331.1
¼	173.573	2397.5	¼	189.281	2851.0	¼	204.989	3343.9
⅜	173.966	2408.3	⅜	189.674	2862.9	⅜	205.382	3356.7
½	174.358	2419.2	½	190.066	2874.8	½	205.774	3369.6
⅝	174.751	2430.1	⅝	190.459	2886.6	⅝	206.167	3382.4
¾	175.144	2441.1	¾	190.852	2898.6	¾	206.560	3395.3
⅞	175.536	2452.0	⅞	191.244	2910.5	⅞	206.952	3408.2
56	175.929	2463.0	**61**	191.637	2922.5	**66**	207.345	3421.2
⅛	176.322	2474.0	⅛	192.030	2934.5	⅛	207.738	3434.3
¼	176.715	2485.0	¼	192.423	2946.5	¼	208.131	3447.2
⅜	177.107	2496.1	⅜	192.815	2958.5	⅜	208.523	3460.2
½	177.500	2507.2	½	193.208	2970.6	½	208.916	3473.2
⅝	177.893	2518.3	⅝	193.601	2982.7	⅝	209.309	3486.3
¾	178.285	2529.4	¾	193.993	2994.8	¾	209.701	3499.4
⅞	178.678	2540.6	⅞	194.386	3006.9	⅞	210.094	3512.5
57	179.071	2551.8	**62**	194.779	3019.1	**67**	210.487	3525.7
⅛	179.463	2563.0	⅛	195.171	3031.3	⅛	210.879	3538.8
¼	179.856	2574.2	¼	195.564	3043.5	¼	211.272	3552.0
⅜	180.249	2585.4	⅜	195.957	3055.7	⅜	211.665	3565.2
½	180.642	2596.7	½	196.350	3068.0	½	212.058	3578.5
⅝	181.034	2608.0	⅝	196.742	3080.3	⅝	212.450	3591.7
¾	181.427	2619.4	¾	197.135	3092.6	¾	212.843	3605.0
⅞	181.820	2630.7	⅞	197.528	3104.9	⅞	213.236	3618.3
58	182.212	2642.1	**63**	197.920	3117.2	**68**	213.628	3631.7
⅛	182.605	2653.5	⅛	198.313	3129.6	⅛	214.021	3645.0
¼	182.998	2664.9	¼	198.706	3142.0	¼	214.414	3658.4
⅜	183.390	2676.4	⅜	199.098	3154.5	⅜	214.806	3671.8
½	183.783	2687.8	½	199.491	3166.9	½	215.199	3685.3
⅝	184.176	2699.3	⅝	199.884	3179.4	⅝	215.592	3698.7
¾	184.569	2710.9	¾	200.277	3191.9	¾	215.984	3712.2
⅞	184.961	2722.4	⅞	200.669	3204.4	⅞	216.377	3725.7
59	185.354	2734.0	**64**	201.062	3217.0	**69**	216.770	3739.3
⅛	185.747	2745.6	⅛	201.455	3229.6	⅛	217.163	3752.8
¼	186.139	2757.2	¼	201.847	3242.2	¼	217.555	3766.4
⅜	186.532	2768.8	⅜	202.240	3254.8	⅜	217.948	3780.0
½	186.925	2780.5	½	202.633	3267.5	½	218.341	3793.7
⅝	187.317	2792.2	⅝	203.025	3280.1	⅝	218.733	3807.3
¾	187.710	2803.9	¾	203.418	3292.8	¾	219.126	3821.0
⅞	188.103	2815.7	⅞	203.811	3305.6	⅞	219.519	3834.7

AREAS AND CIRCUMFERENCES OF CIRCLES

Diam. Ins.	Circum. Ins.	Area Sq. Ins.	Diam. Ins.	Circum. Ins.	Area Sq. Ins.	Diam. Ins.	Circum. Ins.	Area Sq. Ins.
70	219.911	3848.5	**75**	235.619	4417.9	**80**	251.327	5026.5
⅛	220.304	3862.2	⅛	236.012	4432.6	⅛	251.720	5042.3
¼	220.697	3876.0	¼	236.405	4447.4	¼	252.113	5058.0
⅜	221.090	3889.8	⅜	236.798	4462.2	⅜	252.506	5073.8
½	221.482	3903.6	½	237.190	4477.0	½	252.898	5089.6
⅝	221.875	3917.5	⅝	237.583	4491.8	⅝	253.291	5105.4
¾	222.268	3931.4	¾	237.976	4506.7	¾	253.684	5121.2
⅞	222.660	3945.3	⅞	238.368	4521.5	⅞	254.076	5137.1
71	223.053	3959.2	**76**	238.761	4536.5	**81**	254.469	5153.0
⅛	223.446	3973.1	⅛	239.154	4551.4	⅛	254.862	5168.9
¼	223.838	3987.1	¼	239.546	4566.4	¼	255.254	5184.9
⅜	224.231	4001.1	⅜	239.939	4581.3	⅜	255.647	5200.8
½	224.624	4015.2	½	240.332	4596.3	½	256.040	5216.8
⅝	225.017	4029.2	⅝	240.725	4611.4	⅝	256.433	5232.8
¾	225.409	4043.3	¾	241.117	4626.4	¾	256.825	5248.9
⅞	225.802	4057.4	⅞	241.510	4641.5	⅞	257.218	5264.9
72	226.195	4071.5	**77**	241.903	4656.6	**82**	257.611	5281.0
⅛	226.587	4085.7	⅛	242.295	4671.8	⅛	258.003	5297.1
¼	226.980	4099.8	¼	242.688	4686.9	¼	258.396	5313.3
⅜	227.373	4114.0	⅜	243.081	4702.1	⅜	258.789	5329.4
½	227.765	4128.2	½	243.473	4717.3	½	259.181	5345.6
⅝	228.158	4142.5	⅝	243.866	4732.5	⅝	259.574	5361.8
¾	228.551	4156.8	¾	244.259	4747.8	¾	259.967	5378.1
⅞	228.944	4171.1	⅞	244.652	4763.1	⅞	260.359	5394.3
73	229.336	4185.4	**78**	245.044	4778.4	**83**	260.752	5410.6
⅛	229.729	4199.7	⅛	245.437	4793.7	⅛	261.145	5426.9
¼	230.122	4214.1	¼	245.830	4809.0	¼	261.538	5443.3
⅜	230.514	4228.5	⅜	246.222	4824.4	⅜	261.930	5459.6
½	230.907	4242.9	½	246.615	4839.8	½	262.323	5476.0
⅝	231.300	4257.4	⅝	247.008	4855.2	⅝	262.716	5492.4
¾	231.692	4271.8	¾	247.400	4870.7	¾	263.108	5508.8
⅞	232.085	4286.3	⅞	247.793	4886.2	⅞	263.501	5525.3
74	232.478	4300.8	**79**	248.186	4901.7	**84**	263.894	5541.8
⅛	232.871	4315.4	⅛	248.579	4917.2	⅛	264.286	5558.3
¼	233.263	4329.9	¼	248.971	4932.7	¼	264.679	5574.8
⅜	233.656	4344.5	⅜	249.364	4948.3	⅜	265.072	5591.4
½	234.049	4359.2	½	249.757	4963.9	½	265.465	5607.9
⅝	234.441	4373.8	⅝	250.149	4979.5	⅝	265.857	5624.5
¾	234.834	4388.5	¾	250.542	4995.2	¾	266.250	5641.2
⅞	235.227	4403.1	⅞	250.935	5010.9	⅞	266.643	5657.8

AREAS AND CIRCUMFERENCES OF CIRCLES

Diam. Ins.	Circum. Ins.	Area Sq. Ins.	Diam. Ins.	Circum. Ins.	Area Sq. Ins.	Diam. Ins.	Circum. Ins.	Area Sq. Ins.
85	267.035	5674.5	90	282.743	6361.7	95	298.451	7088.2
1/8	267.428	5691.2	1/8	283.136	6379.4	1/8	298.844	7106.9
1/4	267.821	5707.9	1/4	283.529	6397.1	1/4	299.237	7125.6
3/8	268.213	5724.7	3/8	283.921	6414.9	3/8	299.629	7144.3
1/2	268.606	5741.5	1/2	284.314	6432.6	1/2	300.022	7163.0
5/8	268.999	5758.3	5/8	284.707	6450.4	5/8	300.415	7181.8
3/4	269.392	5775.1	3/4	285.100	6468.2	3/4	300.807	7200.6
7/8	269.784	5791.9	7/8	285.492	6486.0	7/8	301.200	7219.4
86	270.177	5808.8	91	285.885	6503.9	96	301.593	7238.2
1/8	270.570	5825.7	1/8	286.278	6521.8	1/8	301.986	7257.1
1/4	270.962	5842.6	1/4	286.670	6539.7	1/4	302.378	7276.0
3/8	271.355	5859.6	3/8	287.063	6557.6	3/8	302.771	7294.9
1/2	271.748	5876.5	1/2	287.456	6575.5	1/2	303.164	7313.8
5/8	272.140	5893.5	5/8	287.848	6593.5	5/8	303.556	7332.8
3/4	272.533	5910.6	3/4	288.241	6611.5	3/4	303.949	7351.8
7/8	272.926	5927.6	7/8	288.634	6629.6	7/8	304.342	7370.8
87	273.319	5944.7	92	289.027	6647.6	97	304.734	7389.8
1/8	273.711	5961.8	1/8	289.419	6665.7	1/8	305.127	7408.9
1/4	274.104	5978.9	1/4	289.812	6683.8	1/4	305.520	7428.0
3/8	274.497	5996.0	3/8	290.205	6701.9	3/8	305.913	7447.1
1/2	274.889	6013.2	1/2	290.597	6720.1	1/2	306.305	7466.2
5/8	275.282	6030.4	5/8	290.990	6738.2	5/8	306.698	7485.3
3/4	275.675	6047.6	3/4	291.383	6756.4	3/4	307.091	7504.5
7/8	276.067	6064.9	7/8	291.775	6774.7	7/8	307.483	7523.7
88	276.460	6082.1	93	292.168	6792.9	98	307.876	7543.0
1/8	276.853	6099.4	1/8	292.561	6811.2	1/8	308.269	7562.2
1/4	277.246	6116.7	1/4	292.954	6829.5	1/4	308.661	7581.5
3/8	277.638	6134.1	3/8	293.346	6847.8	3/8	309.054	7600.8
1/2	278.031	6151.4	1/2	293.739	6866.1	1/2	309.447	7620.1
5/8	278.424	6168.8	5/8	294.132	6884.5	5/8	309.840	7639.5
3/4	278.816	6186.2	3/4	294.524	6902.9	3/4	310.232	7658.9
7/8	279.209	6203.7	7/8	294.917	6921.3	7/8	310.625	7678.3
89	279.602	6221.1	94	295.310	6939.8	99	311.018	7697.7
1/8	279.994	6238.6	1/8	295.702	6958.2	1/8	311.410	7717.1
1/4	280.387	6256.1	1/4	296.095	6976.7	1/4	311.803	7736.6
3/8	280.780	6273.7	3/8	295.488	6995.3	3/8	312.196	7756.1
1/2	281.173	6291.2	1/2	296.881	7013.8	1/2	312.588	7775.6
5/8	281.565	6308.8	5/8	297.273	7032.4	5/8	312.981	7795.2
3/4	281.958	6326.4	3/4	297.666	7051.0	3/4	313.374	7814.8
7/8	282.351	6344.1	7/8	298.059	7069.6	7/8	313.767	7834.4
						100	314.159	7854.0

DECIMAL EQUIVALENTS

1/64	.015625	33/64	.515625
1/32	.03125	17/32	.53125
3/64	.046875	35/64	.546875
1/16	.0625	9/16	.5625
5/64	.078125	37/64	.578125
3/32	.09375	19/32	.59375
7/64	.109375	39/64	.609375
1/8	.125	5/8	.625
9/64	.140625	41/64	.640625
5/32	.15625	21/32	.65625
11/64	.171875	43/64	.671875
3/16	.1875	11/16	.6875
13/64	.203125	45/64	.703125
7/32	.21875	23/32	.71875
15/64	.234375	47/64	.734375
1/4	.25	3/4	.75
17/64	.265625	49/64	.765625
9/32	.28125	25/32	.78125
19/64	.296875	51/64	.796875
5/16	.3125	13/16	.8125
21/64	.328125	53/64	.828125
11/32	.34375	27/32	.84375
23/64	.359375	55/64	.859375
3/8	.375	7/8	.875
25/64	.390625	57/64	.890625
13/32	.40625	29/32	.90625
27/64	.421875	59/64	.921875
7/16	.4375	15/16	.9375
29/64	.453125	61/64	.953125
15/32	.46875	31/32	.96875
31/64	.484375	63/64	.984375
1/2	.5	1	1.

METRIC CONVERSION TABLE

Millimetres × .03937 = inches.
Millimetres ÷ 25.4 = inches.
Centimetres × .3937 = inches.
Centimetres ÷ 2.54 = inches.
Metres × 39.37 = inches. (Act of Congress.)
Metres × 3.281 = feet.
Metres × 1.094 = yards.
Kilometres × .621 = miles.
Kilometres ÷ 1.6093 = miles.
Kilometres × 3280.7 = feet.
Square millimetres × .00155 = square inches.
Square millimetres ÷ 645.1 = square inches.
Square centimetres × .155 = square inches.
Square centimetres ÷ 6.451 = square inches.
Square metres × 10.764 = square feet.
Square kilometres × 247.1 = acres.
Hectares × 2.471 = acres.
Cubic centimetres ÷ 16.383 = cubic inches.
Cubic centimetres ÷ 3.69 = fluid drachms (U.S.P.)
Cubic centimetres ÷ 29.57 = fluid ounces (U.S.P.)
Cubic metres × 35.315 = cubic feet.
Cubic metres × 1.308 = cubic yards.
Cubic metres × 264.2 = gallons (231 cubic inches.)
Litres × 61.022 = cubic inches (Act of Congress.)
Litres × 33.84 = fluid ounces (U.S.P.)
Litres × .2642 = gallons (231 cubic inches.)
Litres ÷ 3.78 = gallons (231 cubic inches.)
Litres ÷ 28.316 = cubic feet.
Hectolitres × 3.531 = cubic feet.
Hectolitres × 2.84 = bushels (2150.42 cubic inches.)
Hectolitres × .131 = cubic yards.
Hectolitres × 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 cent. ÷ 27.7 = pounds per cubic inch.
Joules × .7373 = foot pounds.
Kilogrammes × 2.2046 = pounds.
Kilogrammes × 35.3 = ounces avoirdupois.
Kilogrammes ÷ 907.2 = tons (2,000 pounds.)
Kilogrammes per square cent. × 14.223 = pounds per sq. inch.
Kilogrammes per square metre ÷ 4.89 = pounds per square foot.
Kilogrammetres × 7.233 = foot pounds.
Kilogrammes per metre × .672 = pounds per foot.
Kilogrammes per cu. metre × .062 = pounds per cubic foot.
Kilogrammes per cheval × 2.235 = pounds per horse-power.
Kilowatts × 1.34 = horse-power.
Watts ÷ 746 = horse-power.
Watts × .7373 = foot pounds per second.
Calories × 3.968 = British thermal units.
Cheval vapeur × .9863 = horse-power.
Cheval vapeur per square metre of heating surface ÷ 10.9 = horse-power per square foot of heating surface.
(Centigrade × 1.8) + 32 = degrees Fahrenheit.
Francs × .193 = dollars approximate.
Gravity Paris = 980.94 centimetres per second.

U S gal : Imp Gal = 6 : 5

1" = 0.02540 m

ENGLISH MEASURES WITH METRIC EQUIVALENTS

INCHES IN METRES

Inches	Metres	Inches	Metres	Inches	Metres
1/64	.000397	13/32	.01032	51/64	.02024
1/32	.000794	27/64	.01072	13/16	.02064
3/64	.00119	7/16	.01111	53/64	.02103
1/16	.00159	29/64	.01151	27/32	.02143
5/64	.00198	15/32	.01191	55/64	.02183
3/32	.00238	31/64	.01230	7/8	.02223
7/64	.00278	1/2	.01270	57/64	.02262
1/8	.00318	33/64	.01310	29/32	.02302
9/64	.00357	17/32	.01349	59/64	.02342
5/32	.00397	35/64	.01389	15/16	.02381
11/64	.00437	9/16	.01429	61/64	.02421
3/16	.00476	37/64	.01468	31/32	.02461
13/64	.00516	19/32	.01508	63/64	.02500
7/32	.00556	39/64	.01548	1	.02540
15/64	.00595	5/8	.01588	2	.05080
1/4	.00635	41/64	.01627	3	.07620
17/64	.00675	21/32	.01667	4	.1016
9/32	.00714	43/64	.01707	5	.1270
19/64	.00754	11/16	.01746	6	.1524
5/16	.00794	45/64	.01786	7	.1778
21/64	.00833	23/32	.01826	8	.2032
11/32	.00873	47/64	.01865	9	.2286
23/64	.00913	3/4	.01905	10	.2540
3/8	.00953	49/64	.01945	11	.2794
25/64	.00992	25/32	.01984	12	.3048

ENGLISH MEASURES WITH METRIC EQUIVALENTS

INCHES IN METRES

Inches	Metres	Inches	Metres	Inches	Metres	Inches	Metres
1	.0254	26	.6604	51	1.2954	76	1.9304
2	.0508	27	.6858	52	1.3208	77	1.9558
3	.0762	28	.7112	53	1.3462	78	1.9812
4	.1016	29	.7366	54	1.3716	79	2.0066
5	.1270	30	.7620	55	1.3970	80	2.0320
6	.1524	31	.7874	56	1.4224	81	2.0574
7	.1778	32	.8128	57	1.4478	82	2.0828
8	.2032	33	.8382	58	1.4732	83	2.1082
9	.2286	34	.8636	59	1.4986	84	2.1336
10	.2540	35	.8890	60	1.5240	85	2.1590
11	.2794	36	.9144	61	1.5494	86	2.1844
12	.3048	37	.9398	62	1.5748	87	2.2098
13	.3302	38	.9652	63	1.6002	88	2.2352
14	.3556	39	.9906	64	1.6256	89	2.2606
15	.3810	40	1.0160	65	1.6510	90	2.2860
16	.4064	41	1.0414	66	1.6764	91	2.3114
17	.4318	42	1.0668	67	1.7018	92	2.3368
18	.4572	43	1.0922	68	1.7272	93	2.3622
19	.4826	44	1.1176	69	1.7526	94	2.3876
20	.5080	45	1.1430	70	1.7780	95	2.4130
21	.5334	46	1.1684	71	1.8034	96	2.4384
22	.5588	47	1.1938	72	1.8288	97	2.4638
23	.5842	48	1.2192	73	1.8542	98	2.4892
24	.6096	49	1.2446	74	1.8796	99	2.5146
25	.6350	50	1.2700	75	1.9050	100	2.5400

4'8½" = 1,4342

ENGLISH MEASURES WITH METRIC EQUIVALENTS

FEET IN METRES

Feet	Metres	Feet	Metres	Feet	Metres	Feet	Metres
1	.3048	26	7.9248	51	15.5448	76	23.1648
2	.6096	27	8.2296	52	15.8496	77	23.4696
3	.9144	28	8.5344	53	16.1544	78	23.7744
4	1.2192	29	8.8392	54	16.4592	79	24.0792
5	1.5240	30	9.1440	55	16.7640	80	24.3840
6	1.8288	31	9.4488	56	17.0688	81	24.6888
7	2.1336	32	9.7536	57	17.3736	82	24.9936
8	2.4384	33	10.0584	58	17.6784	83	25.2984
9	2.7432	34	10.3632	59	17.9832	84	25.6032
10	3.0480	35	10.6680	60	18.2880	85	25.9080
11	3.3528	36	10.9728	61	18.5928	86	26.2128
12	3.6576	37	11.2776	62	18.8976	87	26.5176
13	3.9624	38	11.5824	63	19.2024	88	26.8224
14	4.2672	39	11.8872	64	19.5072	89	27.1272
15	4.5720	40	12.1920	65	19.8120	90	27.4320
16	4.8768	41	12.4968	66	20.1168	91	27.7368
17	5.1816	42	12.8016	67	20.4216	92	28.0416
18	5.4864	43	13.1064	68	20.7264	93	28.3464
19	5.7912	44	13.4112	69	21.0312	94	28.6512
20	6.0960	45	13.7160	70	21.3360	95	28.9560
21	6.4008	46	14.0208	71	21.6408	96	29.2608
22	6.7056	47	14.3256	72	21.9456	97	29.5656
23	7.0104	48	14.6304	73	22.2504	98	29.8704
24	7.3152	49	14.9352	74	22.5552	99	30.1752
25	7.6200	50	15.2400	75	22.8600	100	30.4800

ENGLISH MEASURES WITH METRIC EQUIVALENTS

MILES IN KILOMETRES

Miles	Kilometres	Miles	Kilometres	Miles	Kilometres	Miles	Kilometres
1	1.6093	26	41.8423	51	82.0754	76	122.3084
2	3.2186	27	43.4517	52	83.6847	77	123.9177
3	4.8280	28	45.0610	53	85.2940	78	125.5270
4	6.4373	29	46.6703	54	86.9033	79	127.1364
5	8.0466	30	48.2796	55	88.5127	80	128.7457
6	9.6559	31	49.8890	56	90.1220	81	130.3550
7	11.2652	32	51.4983	57	91.7313	82	131.9643
8	12.8746	33	53.1076	58	93.3406	83	133.5736
9	14.4839	34	54.7169	59	94.9499	84	135.1830
10	16.0932	35	56.3262	60	96.5593	85	136.7923
11	17.7025	36	57.9356	61	98.1686	86	138.4016
12	19.3119	37	59.5449	62	99.7779	87	140.0109
13	20.9212	38	61.1542	63	101.3872	88	141.6202
14	22.5305	39	62.7635	64	102.9965	89	143.2296
15	24.1392	40	64.3728	65	104.6059	90	144.8389
16	25.7491	41	65.9822	66	106.2152	91	146.4482
17	27.3585	42	67.5915	67	107.8245	92	148.0575
18	28.9678	43	69.2008	68	109.4338	93	149.6669
19	30.5771	44	70.8101	69	111.0431	94	151.2762
20	32.1864	45	72.4194	70	112.6525	95	152.8855
21	33.7957	46	74.0288	71	114.2618	96	154.4948
22	35.4051	47	75.6381	72	115.8711	97	156.1041
23	37.0144	48	77.2474	73	117.4804	98	157.7135
24	38.6237	49	78.8567	74	119.0898	99	159.3228
25	40.2330	50	80.4661	75	120.6991	100	160.9321

ENGLISH MEASURES WITH METRIC EQUIVALENTS

SQUARE FEET IN SQUARE METRES

Sq. Feet	Sq. Metres	Sq. Feet	Sq. Metres	Sq. Feet	Sq. Metres	Sq. Feet	Sq. Metres
1	.0929	26	2.4154	51	4.7379	76	7.0604
2	.1858	27	2.5083	52	4.8308	77	7.1533
3	.2787	28	2.6012	53	4.9237	78	7.2462
4	.3716	29	2.6941	54	5.0166	79	7.3391
5	.4645	30	2.7870	55	5.1095	80	7.4320
6	.5574	31	2.8799	56	5.2024	81	7.5249
7	.6503	32	2.9728	57	5.2953	82	7.6178
8	.7432	33	3.0657	58	5.3882	83	7.7107
9	.8361	34	3.1586	59	5.4811	84	7.8036
10	.9290	35	3.2515	60	5.5740	85	7.8965
11	1.0219	36	3.3444	61	5.6669	86	7.9894
12	1.1148	37	3.4373	62	5.7598	87	8.0823
13	1.2077	38	3.5302	63	5.8527	88	8.1752
14	1.3006	39	3.6231	64	5.9456	89	8.2681
15	1.3935	40	3.7160	65	6.0385	90	8.3610
16	1.4864	41	3.8089	66	6.1314	91	8.4539
17	1.5793	42	3.9018	67	6.2243	92	8.5468
18	1.6722	43	3.9947	68	6.3172	93	8.6397
19	1.7651	44	4.0876	69	6.4101	94	8.7326
20	1.8580	45	4.1805	70	6.5030	95	8.8255
21	1.9509	46	4.2734	71	6.5959	96	8.9184
22	2.0438	47	4.3663	72	6.6888	97	9.0113
23	2.1367	48	4.4592	73	6.7817	98	9.1042
24	2.2296	49	4.5521	74	6.8746	99	9.1971
25	2.3225	50	4.6450	75	6.9675	100	9.2900

1□" = 0.000645 □m

1 Acre = 4840 sq yds = 0.4047 Hectare

ENGLISH MEASURES WITH METRIC EQUIVALENTS

POUNDS IN KILOGRAMMES

Lbs.	Kilo-grammes	Lbs.	Kilo-grammes	Lbs.	Kilo-grammes	Lbs.	Kilo-grammes
1	.4536	26	11.7934	51	23.1332	76	34.4731
2	.9072	27	12.2470	52	23.5868	77	34.9267
3	1.3608	28	12.7006	53	24.0404	78	35.3803
4	1.8144	29	13.1542	54	24.4940	79	35.8338
5	2.2680	30	13.6078	55	24.9476	80	36.2874
6	2.7216	31	14.0614	56	25.4012	81	36.7410
7	3.1752	32	14.5150	57	25.8548	82	37.1946
8	3.6287	33	14.9686	58	26.3084	83	37.6482
9	4.0823	34	15.4222	59	26.7620	84	38.1018
10	4.5359	35	15.8758	60	27.2156	85	38.5554
11	4.9895	36	16.3293	61	27.6692	86	39.0090
12	5.4431	37	16.7829	62	28.1228	87	39.4626
13	5.8967	38	17.2365	63	28.5764	88	39.9162
14	6.3503	39	17.6901	64	29.0300	89	40.3698
15	6.8039	40	18.1437	65	29.4835	90	40.8234
16	7.2575	41	18.5973	66	29.9371	91	41.2770
17	7.7111	42	19.0509	67	30.3907	92	41.7306
18	8.1647	43	19.5045	68	30.8443	93	42.1841
19	8.6183	44	19.9581	69	31.2979	94	42.6377
20	9.0719	45	20.4117	70	31.7515	95	43.0913
21	9.5255	46	20.8653	71	32.2051	96	43.5449
22	9.9790	47	21.3189	72	32.6587	97	43.9985
23	10.4326	48	21.7725	73	33.1123	98	44.4521
24	10.8862	49	22.2261	74	33.5659	99	44.9057
25	11.3398	50	22.6797	75	34.0195	100	45.3593

(16 oz)

1 metric ton = 1000 kilog. = 2204 lbs

1 stone = 14 lbs = 6.3503 Kilogrammes
1 hwt. = 8 stone = 50.8024 " = 112 lbs
1 Ton = 20 hwt = 1,016.0475 " = 2240 lbs

ENGLISH MEASURES WITH METRIC EQUIVALENTS

GALLONS (of 231 CUBIC INCHES) IN LITRES

Gal.	Litres	Gal.	Litres	Gal.	Litres	Gal.	Litres
1	3.79	26	98.41	51	193.04	76	287.66
2	7.57	27	102.20	52	196.82	77	291.45
3	11.36	28	105.98	53	200.61	78	295.23
4	15.14	29	109.77	54	204.39	79	299.02
5	18.93	30	113.55	55	208.18	80	302.80
6	22.71	31	117.34	56	211.96	81	306.59
7	26.50	32	121.12	57	215.75	82	310.37
8	30.28	33	124.91	58	219.53	83	314.16
9	34.07	34	128.69	59	223.32	84	317.94
10	37.85	35	132.48	60	227.10	85	321.73
11	41.64	36	136.26	61	230.89	86	325.51
12	45.42	37	140.05	62	234.67	87	329.30
13	49.21	38	143.83	63	238.46	88	333.08
14	52.99	39	147.62	64	242.24	89	336.87
15	56.78	40	151.40	65	246.03	90	340.65
16	60.56	41	155.19	66	249.81	91	344.44
17	64.35	42	158.97	67	253.60	92	348.22
18	68.13	43	162.76	68	257.38	93	352.01
19	71.92	44	166.54	69	261.17	94	355.79
20	75.70	45	170.32	70	264.95	95	359.58
21	79.49	46	174.11	71	268.74	96	363.36
22	83.27	47	177.90	72	272.52	97	367.15
23	87.06	48	181.68	73	276.31	98	370.93
24	90.84	49	185.47	74	280.09	99	374.72
25	94.63	50	189.25	75	283.88	100	378.50

U.S. gal : Imp. gal = 6 : 5

ENGLISH MEASURES WITH METRIC EQUIVALENTS

POUNDS PER SQUARE INCH IN KILOGRAMMES PER SQUARE CENTIMETRE

Lbs. per Sq. In.	Kgs. per Sq. Centim.	Lbs. per Sq. In.	Kgs. per Sq. Centim.	Lbs. per Sq. In.	Kgs. per Sq. Centim.	Lbs. per Sq. In.	Kgs. per Sq. Centim.
1	.0703	26	1.8280	51	3.5857	76	5.3434
2	.1406	27	1.8983	52	3.6560	77	5.4138
3	.2109	28	1.9686	53	3.7263	78	5.4841
4	.2812	29	2.0389	54	3.7966	79	5.5544
5	.3515	30	2.1092	55	3.8669	80	5.6247
6	.4218	31	2.1795	56	3.9373	81	5.6950
7	.4921	32	2.2498	57	4.0076	82	5.7653
8	.5624	33	2.3202	58	4.0779	83	5.8356
9	.6327	34	2.3905	59	4.1482	84	5.9059
10	.7031	35	2.4608	60	4.2185	85	5.9762
11	.7734	36	2.5311	61	4.2888	86	6.0465
12	.8437	37	2.6014	62	4.3591	87	6.1168
13	.9140	38	2.6717	63	4.4294	88	6.1872
14	.9843	39	2.7420	64	4.4997	89	6.2575
15	1.0546	40	2.8123	65	4.5700	90	6.3278
16	1.1249	41	2.8826	66	4.6404	91	6.3981
17	1.1952	42	2.9529	67	4.7107	92	6.4684
18	1.2655	43	3.0232	68	4.7810	93	6.5387
19	1.3358	44	3.0936	69	4.8513	94	6.6090
20	1.4062	45	3.1639	70	4.9216	95	6.6793
21	1.4765	46	3.2342	71	4.9919	96	6.7496
22	1.5468	47	3.3045	72	5.0622	97	6.8199
23	1.6171	48	3.3748	73	5.1325	98	6.8902
24	1.6874	49	3.4451	74	5.2028	99	6.9606
25	1.7577	50	3.5154	75	5.2731	100	7.0309

175=12,3
185= 13
195=
165=11,6
205= 14,4

METRIC MEASURES WITH ENGLISH EQUIVALENTS

MILLIMETRES IN INCHES

Mm.	Inches	Mm.	Inches	Mm.	Inches	Mm.	Inches
1	0.039	26	1.024	51	2.008	76	2.992
2	0.079	27	1.063	52	2.047	77	3.031
3	0.118	28	1.102	53	2.087	78	3.071
4	0.158	29	1.141	54	2.126	79	3.110
5	0.197	30	1.181	55	2.165	80	3.150
6	0.236	31	1.220	56	2.205	81	3.189
7	0.276	32	1.260	57	2.244	82	3.228
8	0.315	33	1.300	58	2.283	83	3.268
9	0.354	34	1.338	59	2.323	84	3.307
10	0.394	35	1.378	60	2.362	85	3.346
11	0.433	36	1.417	61	2.401	86	3.386
12	0.472	37	1.457	62	2.441	87	3.425
13	0.512	38	1.496	63	2.480	88	3.465
14	0.551	39	1.535	64	2.520	89	3.504
15	0.590	40	1.575	65	2.559	90	3.543
16	0.630	41	1.614	66	2.598	91	3.583
17	0.669	42	1.653	67	2.638	92	3.622
18	0.709	43	1.693	68	2.677	93	3.661
19	0.748	44	1.732	69	2.717	94	3.701
20	0.787	45	1.772	70	2.756	95	3.740
21	0.827	46	1.811	71	2.795	96	3.779
22	0.866	47	1.850	72	2.835	97	3.819
23	0.906	48	1.890	73	2.874	98	3.858
24	0.945	49	1.929	74	2.913	99	3.898
25	0.984	50	1.968	75	2.953	100	3.937

METRIC MEASURES WITH ENGLISH EQUIVALENTS

METRES IN FEET

Metres	Feet	Metres	Feet	Metres	Feet	Metres	Feet
1	3.2809	26	85.3034	51	167.3258	76	249.3483
2	6.5618	27	88.5843	52	170.6067	77	252.6292
3	9.8427	28	91.8652	53	173.8876	78	255.9101
4	13.1236	29	95.1461	54	177.1685	79	259.1910
5	16.4045	30	98.4270	55	180.4494	80	262.4719
6	19.6854	31	101.7079	56	183.7303	81	265.7528
7	22.9663	32	104.9888	57	187.0112	82	269.0337
8	26.2472	33	108.2697	58	190.2921	83	272.3146
9	29.5281	34	111.5506	59	193.5730	84	275.5955
10	32.8090	35	114.8315	60	196.8539	85	278.8764
11	36.0899	36	118.1124	61	200.1348	86	282.1573
12	39.3708	37	121.3933	62	203.4157	87	285.4362
13	42.6517	38	124.6742	63	206.6966	88	288.7191
14	45.9326	39	127.9551	64	209.9775	89	292,0000
15	49.2135	40	131.2360	65	213.2584	90	295.2809
16	52.4944	41	134.5169	66	216.5393	91	298.5618
17	55.7753	42	137.7978	67	219.8202	92	301.8427
18	59.0562	43	141.0787	68	223.1011	93	305.1236
19	62.3371	44	144.3596	69	226.3820	94	308.4045
20	65.6180	45	147.6405	70	229.6629	95	311.6854
21	68.8989	46	150.9214	71	232.9438	96	314.9663
22	72.1798	47	154.2023	72	236.2247	97	318.2472
23	75.4607	48	157.4832	73	239.5056	98	321.5281
24	78.7416	49	160.7641	74	242.7865	99	324.8090
25	82.0225	50	164.0450	75	246.0674	100	328.0899

METRIC MEASURES WITH ENGLISH EQUIVALENTS

KILOMETRES IN MILES

Km.	Miles	Km.	Miles	Km.	Miles	Km.	Miles
1	0.621	26	16.156	51	31.690	76	47.225
2	1.243	27	16.777	52	32.312	77	47.846
3	1.864	28	17.398	53	32.933	78	48.468
4	2.485	29	18.020	54	33.554	79	49.089
5	3.107	30	18.641	55	34.176	80	49.710
6	3.728	31	19.263	56	34.797	81	50.332
7	4.350	32	19.884	57	35.419	82	50.953
8	4.971	33	20.505	58	36.040	83	51.574
9	5.592	34	21.127	59	36.661	84	52.196
10	6.214	35	21.748	60	37.283	85	52.817
11	6.835	36	22.370	61	37.904	86	53.439
12	7.456	37	22.991	62	38.525	87	54.060
13	8.078	38	23.612	63	39.147	88	54.681
14	8.699	39	24.234	64	39.768	89	55.303
15	9.321	40	24.855	65	40.390	90	55.924
16	9.942	41	25.476	66	41.011	91	56.545
17	10.563	42	26.098	67	41.632	92	57.167
18	11.185	43	26.719	68	42.254	93	57.788
19	11.806	44	27.341	69	42.875	94	58.410
20	12.427	45	27.962	70	43.496	95	59.031
21	13.049	46	28.583	71	44.118	96	59.652
22	13.670	47	29.205	72	44.739	97	60.274
23	14.292	48	29.826	73	45.361	98	60.895
24	14.913	49	30.448	74	45.982	99	61.517
25	15.534	50	31.069	75	46.603	100	62.138

METRIC MEASURES WITH ENGLISH EQUIVALENTS

SQUARE METRES IN SQUARE FEET							
Sq. M.	Sq. Ft.	Sq. M.	Sq. Ft.	Sq. M.	Sq. Ft.	Sq. M.	Sq. Ft.
1	10.764	26	279.872	51	548.979	76	818.087
2	21.528	27	290.636	52	559.744	77	828.851
3	32.293	28	301.400	53	570.508	78	839.615
4	43.057	29	312.165	54	581.272	79	850.380
5	53.821	30	322.929	55	592.036	80	861.144
6	64.586	31	333.693	56	602.800	81	871.908
7	75.350	32	344.458	57	613.565	82	882.673
8	86.114	33	355.222	58	624.329	83	893.437
9	96.879	34	365.986	59	635.094	84	904.207
10	107.643	35	376.750	60	645.858	85	914.965
11	118.407	36	387.545	61	656.622	86	925.730
12	129.172	37	398.279	62	667.387	87	936.494
13	139.936	38	409.043	63	678.151	88	947.258
14	150.700	39	419.808	64	688.915	89	958.023
15	161.464	40	430.572	65	699.679	90	968.787
16	172.229	41	441.336	66	710.444	91	979.551
17	182.993	42	452.100	67	721.208	92	990.316
18	193.757	43	462.865	68	731.971	93	1001.080
19	204.522	44	473.629	69	742.736	94	1011.844
20	215.286	45	484.393	70	753.501	95	1022.608
21	226.050	46	495.158	71	764.265	96	1033.373
22	236.815	47	505.922	72	775.030	97	1044.137
23	247.579	48	516.686	73	785.794	98	1054.901
24	258.343	49	527.450	74	796.558	99	1065.666
25	269.107	50	538.215	75	807.322	100	1076.430

METRIC MEASURES WITH ENGLISH EQUIVALENTS

KILOGRAMMES IN POUNDS							
Kg.	Pounds	Kg.	Pounds	Kg.	Pounds	Kg.	Pounds
1	2.205	26	57.320	51	112.435	76	167.550
2	4.409	27	59.524	52	114.639	77	169.754
3	6.614	28	61.729	53	116.844	78	171.959
4	8.818	29	63.933	54	119.048	79	174.163
5	11.023	30	66.138	55	121.253	80	176.368
6	13.228	31	68.343	56	123.458	81	178.573
7	15.432	32	70.547	57	125.662	82	180.777
8	17.637	33	72.752	58	127.867	83	182.982
9	19.841	34	74.956	59	130.071	84	185.186
10	22.046	35	77.161	60	132.276	85	187.391
11	24.251	36	79.366	61	134.481	86	189.596
12	26.455	37	81.570	62	136.685	87	191.800
13	28.660	38	83.775	63	138.890	88	194.005
14	30.864	39	85.979	64	141.094	89	196.209
15	33.069	40	88.184	65	143.299	90	198.414
16	35.274	41	90.389	66	145.504	91	200.619
17	37.478	42	92.593	67	147.708	92	202.823
18	39.683	43	94.798	68	149.913	93	205.028
19	41.887	44	97.002	69	152.117	94	207.232
20	44.092	45	99.207	70	154.322	95	209.437
21	46.297	46	101.412	71	156.527	96	211.642
22	48.501	47	103.616	72	158.731	97	213.846
23	50.706	48	105.821	73	160.936	98	216.051
24	52.910	49	108.025	74	163.140	99	218.255
25	55.115	50	110.230	75	165.345	100	220.460

METRIC MEASURES WITH ENGLISH EQUIVALENTS

LITRES IN GALLONS (of 231 CUBIC INCHES)

Litres	Gallons	Litres	Gallons	Litres	Gallons	Litres	Gallons
1	.2642	26	6.8683	51	13.4724	76	20.0765
2	.5283	27	7.1324	52	13.7366	77	20.3407
3	.7925	28	7.3966	53	14.0007	78	20.6048
4	1.0567	29	7.6608	54	14.2649	79	20.8690
5	1.3208	30	7.9249	55	14.5290	80	21.1332
6	1.5850	31	8.1891	56	14.7932	81	21.3973
7	1.8491	32	8.4533	57	15.0574	82	21.6615
8	2.1133	33	8.7174	58	15.3215	83	21.9256
9	2.3775	34	8.9816	59	15.5857	84	22.1898
10	2.6416	35	9.2458	60	15.8499	85	22.4540
11	2.9058	36	9.5099	61	16.1140	86	22.7181
12	3.1700	37	9.7741	62	16.3782	87	22.9823
13	3.4341	38	10.0382	63	16.6424	88	23.2465
14	3.6983	39	10.3024	64	16.9065	89	23.5106
15	3.9625	40	10.5666	65	17.1707	90	23.7748
16	4.2266	41	10.8307	66	17.4349	91	24.0390
17	4.4908	42	11.0949	67	17.6990	92	24.3031
18	4.7550	43	11.3591	68	17.9632	93	24.5673
19	5.0191	44	11.6232	69	18.2273	94	24.8315
20	5.2833	45	11.8874	70	18.4915	95	25.0956
21	5.5475	46	12.1516	71	18.7557	96	25.3598
22	5.8116	47	12.4157	72	19.0198	97	25.6240
23	6.0758	48	12.6799	73	19.2840	98	25.8881
24	6.3399	49	12.9441	74	19.5482	99	26.1523
25	6.6041	50	13.2082	75	19.8123	100	26.4164

METRIC MEASURES WITH ENGLISH EQUIVALENTS

KILOGRAMMES PER SQUARE CENTIMETRE IN POUNDS PER SQUARE INCH

Kgs. per Sq. Centim.	Lbs. per Sq. In.	Kgs. per Sq. Centim.	Lbs. per Sq. In.	Kgs. per Sq. Centim.	Lbs. per Sq. In.	Kgs. per Sq. Centim.	Lbs. per Sq. In.
1.0	14.223	3.6	51.203	6.2	88.183	8.8	125.162
1.1	15.645	3.7	52.625	6.3	89.605	8.9	126.585
1.2	17.068	3.8	54.047	6.4	91.027	9.0	128.007
1.3	18.490	3.9	55.470	6.5	92.450	9.1	129.429
1.4	19.912	4.0	56.892	6.6	93.872	9.2	130.852
1.5	21.335	4.1	58.314	6.7	95.294	9.3	132.274
1.6	22.757	4.2	59.737	6.8	96.716	9.4	133.696
1.7	24.179	4.3	61.159	6.9	98.139	9.5	135.119
1.8	25.601	4.4	62.581	7.0	99.561	9.6	136.541
1.9	27.024	4.5	64.004	7.1	100.983	9.7	137.963
2.0	28.446	4.6	65.426	7.2	102.406	9.8	139.385
2.1	29.868	4.7	67.848	7.3	103.828	9.9	140.808
2.2	31.291	4.8	68.270	7.4	105.250	10.0	142.230
2.3	32.713	4.9	69.693	7.5	106.673	10.1	143.652
2.4	34.135	5.0	71.115	7.6	108.095	10.2	145.074
2.5	35.558	5.1	72.537	7.7	109.517	10.3	146.497
2.6	36.980	5.2	73.960	7.8	110.939	10.4	147.919
2.7	38.402	5.3	75.382	7.9	112.362	10.5	149.341
2.8	39.824	5.4	76.804	8.0	113.784	10.6	150.764
2.9	41.247	5.5	78.227	8.1	115.206	10.7	152.186
3.0	42.669	5.6	79.649	8.2	116.629	10.8	153.608
3.1	44.091	5.7	81.071	8.3	118.051	10.9	155.030
3.2	45.514	5.8	82.493	8.4	119.473	11.0	156.453
3.3	46.936	5.9	83.916	8.5	120.896	11.1	157.875
3.4	48.358	6.0	85.338	8.6	122.318	11.2	159.297
3.5	49.781	6.1	86.760	8.7	123.740	11.3	160.720

PROPERTIES OF SATURATED STEAM

Complied from Peabody's Steam Tables

Pressure above the Atmosphere (Boiler Pressure)	Number of Atmospheres	Temperature of Steam Degrees Fahr.	Total Heat in B. T. U. From Water at 32° Frhr.	Density Weight of one cu. ft. of Steam	Volume of one lb. of Steam in cu. ft.
0	1.	212.0	1146.57	.037489	26.67
5	1.34	227.1	1151.26	.049396	20.25
15	2.02	249.7	1158.12	.072780	13.74
25	2.70	266.6	1163.25	.095639	10.46
35	3.38	280.4	1167.48	.117940	8.48
45	4.06	292.2	1171.08	.140040	7.14
55	4.74	302.4	1174.18	.161940	6.18
65	5.42	311.5	1176.94	.18347	5.45
75	6.10	319.8	1179.51	.20487	4.88
85	6.78	327.4	1181.81	.22617	4.42
100	7.80	337.7	1184.94	.25787	3.88
105	8.14	341.0	1185.94	.26847	3.73
110	8.48	343.9	1186.84	.27887	3.59
115	8.82	346.9	1187.74	.28927	3.46
120	9.16	349.9	1188.64	.29967	3.34
125	9.50	352.7	1189.47	.31007	3.23
130	9.84	355.5	1190.34	.32057	3.12
135	10.18	358.1	1191.14	.33087	3.02
140	10.52	360.7	1191.94	.34137	2.93
145	10.86	363.3	1192.77	.35177	2.84
150	11.20	365.8	1193.54	.36227	2.76
155	11.54	368.2	1194.27	.37237	2.69
160	11.88	370.6	1194.94	.38277	2.61
165	12.22	372.9	1195.67	.39320	2.54
170	12.56	375.1	1196.34	.40350	2.48
175	12.90	377.3	1197.04	.41387	2.42
180	13.24	379.5	1197.67	.42417	2.36
185	13.58	381.6	1198.34	.43430	2.30
190	13.92	383.7	1198.97	.44450	2.25
195	14.26	385.8	1199.57	.45487	2.20
200	14.60	387.8	1200.17	.46527	2.15
205	14.94	389.7	1200.77	.47557	2.10
210	15.28	391.7	1201.37	.48597	2.06
215	15.62	393.6	1201.97	.49630	2.02
220	15.96	395.5	1202,57	.50650	1.98
225	16.30	397.3	1203.10	.51687	1.94

PROPERTIES OF SUPERHEATED STEAM

From Tables by Marks and Davis

Boiler Pressure lbs. per Sq. Inch	Superheat, Degrees F	Temp. of Steam Degrees F	Total Heat B. T. U.'s per Pound	Specific Volume, Cubic Feet per Pound	Increase in Volume over Sat. Steam per cent.
150	25	390.9	1210.6	2.87	4.4
	50	415.9	1225.2	2.99	8.7
	75	440.9	1238.8	3.10	12.7
	100	465.9	1252.0	3.21	16.7
	150	515.9	1277.6	3.43	24.7
	200	565.9	1302.5	3.64	32.4
160	25	395.8	1211.8	2.72	4.5
	50	420.7	1226.6	2.83	8.9
	75	445.7	1240 3	2.93	12.6
	100	470.7	1253.6	3.04	16.9
	150	520.7	1279.1	3.24	24.6
	200	570.7	1304.1	3.44	32.3
170	25	400.3	1213.0	2.58	4.4
	50	425.3	1227.9	2.68	8.5
	75	450.3	1241.7	2.78	12.5
	100	475.3	1255.0	2.89	17.0
	150	525.3	1280.6	3.08	24.8
	200	575.3	1305.6	3.27	32.4
180	25	404.6	1214.2	2.45	4.3
	50	429.6	1229.2	2.55	8.5
	75	454.6	1243.1	2.65	12.8
	100	479.6	1256.4	2.75	17.0
	150	529.6	1282.0	2.93	24.7
	200	579.6	1307.0	3.11	32.3
190	25	408.8	1215.2	2.34	4.4
	50	433.8	1230.4	2.44	8.9
	75	458.8	1244.4	2.53	13.0
	100	483.8	1257.7	2.62	17.0
	150	533.8	1283.3	2.80	25.0
	200	583.8	1308.3	2.97	32.7
200	25	412.9	1216.3	2.23	4.3
	50	437.9	1231.6	2.33	8.9
	75	462.9	1245.6	2.42	13.1
	100	487.9	1259.0	2.51	17.3
	150	537.9	1284.6	2.68	25.2
	200	587.9	1309.7	2.84	32.7

CYLINDER VOLUMES IN CUBIC FEET
(For One Cylinder Only)

Diam. Inches	Stroke in Inches												
	12	14	16	18	20	22	24	26	28	30	32	34	36
10	.550	.64	.72	.81	.90								
10½	.601	.70	.80	.90	1.00								
11	.660	.77	.88	.99	1.10	1.21							
11½	.721	.84	.96	1.08	1.20	1.32							
12	.780	.91	1.04	1.17	1.30	1.43	1.56						
12½	.849	.99	1.13	1.27	1.41	1.55	1.69						
13		1.07	1.23	1.39	1.54	1.69	1.85						
13½		1.16	1.33	1.49	1.66	1.82	1.99						
14		1.24	1.42	1.60	1.78	1.95	2.13						
14½			1.53	1.72	1.91	2.10	2.29						
15			1.63	1.84	2.04	2.24	2.45	2.65					
15½			1.74	1.96	2.18	2.40	2.62	2.84					
16			1.85	2.08	2.32	2.55	2.78	3.02					
16½				2.23	2.47	2.72	2.97	3.23					
17				2.38	2.64	2.90	3.17	3.43	3.69				
17½				2.50	2.78	3.06	3.34	3.72	3.98				
18				2.65	2.94	3.23	3.53	3.82	4.12				
18½					3.11	3.42	3.73	4.04	4.35				
19					3.28	3.61	3.94	4.26	4.59	4.92			
19½					3.46	3.80	4.15	4.50	4.84	5.19			
20					3.64	4.00	4.37	4.73	5.10	5.46			
20½						4.20	4.58	4.96	5.34	5.73			
21						4.40	4.80	5.20	5.60	6.00	6.42		
21½						4.62	5.04	5.46	5.88	6.30	6.72		
22						4.84	5.28	5.72	6.16	6.60	7.05		
22½							5.52	5.98	6.44	6.90	7.36		
23							5.76	6.24	6.72	7.20	7.68	8.18	
23½							6.02	6.52	7.02	7.52	8.02	8.52	
24							6.27	6.79	7.31	7.83	8.38	8.90	
24½								7.10	7.65	8.20	8.75	9.30	
25								7.38	7.95	8.52	9.08	9.65	10.21
25½								7.68	8.27	8.86	9.45	10.04	10.63
26								7.98	8.60	9.21	9.83	10.44	11.08
27								8.61	9.27	9.93	10.59	11.26	11.92
28								9.26	9.97	10.68	11.39	12.10	12.82
29								9.93	10.70	11.46	12.22	13.00	13.76
30								10.63	11.45	12.27	13.09	13.90	14.72
31									12.23	13.10	13.97	14.84	15.71
32									13.03	13.96	14.90	15.84	16.76
33									13.85	14.84	15.82	16.82	17.81
34									14.71	15.76	16.82	17.87	18.92
35									15.59	16.70	17.81	18.92	20.10
36									16.49	17.67	18.85	20.03	21.21
37									17.42	18.67	19.91	21.15	22.40
38									18.38	19.69	21.00	22.31	23.63
39										20.74	22.12	23.50	24.89
40										21.82	23.27	24.72	26.18
41										22.92	24.45	25.98	27.51
42										24.05	25.66	27.26	28.86
43										25.21	26.89	28.57	30.25
44										26.40	28.16	29.92	31.68
45										27.61	29.45	31.29	33.13

COMPARATIVE THICKNESS OF WIRE GAUGES IN DECIMALS OF ONE INCH

B.L.W. std. Birmingham Stubb		American B. & S.		American Screw Gauge	
No.	Thickness	No.	Thickness	No.	Thickness
0000	.454	0000	.46		
000	.425	000	.40964		
00	.38	00	.3648		
0	.34	0	.321186	0	.0578
1	.30	1	.2893	1	.0710
2	.284	2	.25763	2	.0842
3	.259	3	.22942	3	.0973
4	.238	4	.20431	4	.1105
5	.22	5	.18194	5	.1236
6	.203	6	.16202	6	.1368
7	.18	7	.14428	7	.150
8	.165	8	.12849	8	.1631
9	.148	9	.11443	9	.1763
10	.134	10	.10189	10	.1894
11	.12	11	.090742	11	.2026
12	.109	12	.080808	12	.2158
13	.095	13	.071961	13	.2289
14	.083	14	.064084	14	.2421
15	.072	15	.057068	15	.2552
16	.065	16	.05082	16	.2684
17	.058	17	.045257	17	.2816
18	.049	18	.040303	18	.2947
19	.042	19	.03589		
20	.035	20	.031961	20	.3210
21	.032	21	.028462		
22	.028	22	.025347	22	.3474
23	.025	23	.022571		
24	.022	24	.0201	24	.3737
25	.02	25	.0179		
26	.018	26	.01594	26	.40
27	.016	27	.014195		
28	.014	28	.012641	28	.4263
29	.013	29	.011257		
30	.012	30	.010025	30	.4520
31	.01	31	.008928		
32	.009	32	.00795		
33	.008	33	.00708		
34	.007	34	.006304		
35	.005	35	.005614		
36	.004	36	.005		

VALUES OF MOMENT OF INTERTIA (I) AND MODULUS OF SECTION (Z) FOR VARIOUS SECTIONS

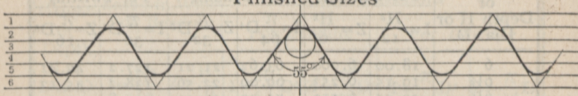
Height or Depth H or Dia. D	Bars 1 in. Wide For Bending		Circular Sections For Bending		Circular Sections For Twisting	
	$I=\frac{H^3}{12}$	$Z=\frac{H^2}{6}$	$I=\frac{\pi}{64}D^4$	$Z=\frac{\pi}{32}D^3$	$I=\frac{\pi}{32}D^4$	$Z=\frac{\pi}{16}D^3$
⅛	0.00016	0.0026	0.000012	0.00019	0.000024	0.00038
¼	0.00130	0.0104	0.000192	0.00153	0.000384	0.00307
⅜	0.00439	0.0234	0.000971	0.00518	0.001941	0.01035
½	0.01042	0.0417	0.003068	0.01227	0.006136	0.02454
⅝	0.02034	0.0651	0.007490	0.02397	0.01498	0.04794
¾	0.03516	0.0937	0.01553	0.04142	0.03106	0.08284
⅞	0.05583	0.1276	0.02877	0.06577	0.05755	0.1315
1	0.08333	0.1667	0.04909	0.09817	0.09817	0.1963
1⅛	0.1187	0.2109	0.07863	0.1398	0.1573	0.2796
1¼	0.1628	0.2604	0.1198	0.1917	0.2397	0.3835
1⅜	0.2166	0.3151	0.1755	0.2552	0.3509	0.5104
1½	0.2812	0.3750	0.2485	0.3313	0.4970	0.6627
1⅝	0.3576	0.4401	0.3431	0.4213	0.6862	0.8425
1¾	0.4466	0.5104	0.4604	0.5261	0.9208	1.052
1⅞	0.5493	0.5859	0.6067	0.6471	1.213	1.294
2	0.6667	0.6667	0.7854	0.7854	1.571	1.571
2⅛	0.7996	0.7526	1.001	0.9421	2.002	1.884
2¼	0.9492	0.8437	1.258	1.118	2.516	2.236
2⅜	1.116	0.9401	1.562	1.315	3.124	2.630
2½	1.302	1.042	1.917	1.534	3.835	3.068
2⅝	1.507	1.148	2.331	1.776	4.661	3.551
2¾	1.733	1.260	2.807	2.042	5.615	4.083
2⅞	1.979	1.378	3.354	2.332	6.707	4.664
3	2.250	1.500	3.976	2.651	7.952	5.301
3⅛	2.543	1.628	4.681	2.996	9.363	5.992
3¼	2.861	1.760	5.476	3.370	10.95	6.740
3⅜	3.204	1.898	6.369	3.774	12.74	7.548
3½	3.573	2.042	7.366	4.209	14.73	8.418
3⅝	3.969	2.190	8.476	4.676	16.95	9.353
3¾	4.394	2.344	9.707	5.177	19.41	10.35
3⅞	4.849	2.503	11.07	5.712	22.14	11.42
4	5.333	2.667	12.57	6.283	25.13	12.57
4⅛	5.849	2.836	14.21	6.891	28.42	13.78
4¼	6.397	3.010	16.01	7.536	32.03	15.07
4⅜	6.978	3.190	17.98	8.221	35.97	16.44
4½	7.594	3.375	20.13	8.946	40.26	17.89
4⅝	8.244	3.565	22.46	9.713	44.92	19.43
4¾	8.931	3.760	24.99	10.52	49.98	21.04
4⅞	9.655	3.961	27.72	11.37	55.45	22.75
5	10.42	4.167	30.68	12.27	61.36	24.54
5⅛	11.22	4.378	33.86	13.22	67.73	26.43
5¼	12.06	4.594	37.29	14.21	74.58	28.41
5⅜	12.94	4.815	40.97	15.25	81.94	30.49
5½	13.86	5.042	44.92	16.33	89.84	32.67
5⅝	14.83	5.273	49.14	17.47	98.29	34.95
5¾	15.84	5.510	53.66	18.66	107.3	37.33
5⅞	16.90	5.753	58.48	19.91	117.0	39.82

VALUES OF MOMENT OF INERTIA (I) AND MODULUS OF SECTIONS (Z) FOR VARIOUS SECTIONS

Height or Depth H or Dia. D	Bars 1 in. Wide For Bending		Circular Sections For Bending		Circular Sections For Twisting	
	$I=\frac{H^3}{12}$	$Z=\frac{H^2}{6}$	$I=\frac{\pi}{64}D^4$	$Z=\frac{\pi}{32}D^3$	$I=\frac{\pi}{32}D^4$	$Z=\frac{\pi}{16}D^3$
6	18.00	6.000	63.62	21.21	127.2	42.41
6⅛	19.15	6.253	69.09	22.56	138.2	45.12
6¼	20.35	6.510	74.90	23.97	149.8	47.94
6⅜	21.59	6.773	81.08	25.44	162.2	50.87
6½	22.89	7.042	87.62	26.96	175.2	53.92
6⅝	24.23	7.315	94.56	28.55	189.1	57.09
6¾	25.63	7.594	101.9	30.19	203.8	60.39
6⅞	27.08	7.878	109.7	31.90	219.3	63.80
7	28.58	8.167	117.9	33.67	235.7	67.35
7⅛	30.14	8.461	126.5	35.51	253.0	71.02
7¼	31.76	8.760	135.6	37.41	271.2	74.82
7⅜	33.43	9.065	145.2	39.38	290.4	78.76
7½	35.16	9.375	155.3	41.42	310.6	82.84
7⅝	36.94	9.690	165.9	43.52	331.9	87.05
7¾	38.79	10.01	177.1	45.70	354.2	91.40
7⅞	40.70	10.34	188.8	47.95	377.6	95.89
8	42.67	10.67	201.1	50.27	402.1	100.5
8⅛	44.70	11.00	213.9	52.66	427.9	105.3
8¼	46.79	11.34	227.4	55.13	454.8	110.3
8⅜	48.95	11.69	241.5	57.67	483.0	115.3
8½	51.18	12.04	256.2	60.29	512.5	120.6
8⅝	53.47	12.40	271.6	62.99	543.3	126.0
8¾	55.83	12.76	287.7	65.77	575.5	131.5
8⅞	58.25	13.13	304.5	68.63	609.1	137.3
9	60.75	13.50	322.1	71.57	644.1	143.1
9⅛	63.32	13.88	340.3	74.59	680.7	149.2
9¼	65.95	14.26	359.4	77.70	718.7	155.4
9⅜	68.66	14.65	379.2	80.89	758.4	161.8
9½	71.45	15.04	399.8	84.17	799.6	168.3
9⅝	74.31	15.44	421.3	87.54	842.6	175.1
9¾	77.24	15.84	443.6	90.99	887.2	182.0
9⅞	80.25	16.25	466.8	94.54	933.6	189.1
10	83.33	16.67	490.9	98.17	981.7	196.3
10⅛	86.50	17.09	515.8	101.9	1032	203.8
10¼	89.74	17.51	541.8	105.7	1084	211.4
10⅜	93.06	17.94	568.8	109.6	1138	219.3
10½	96.47	18.38	596.7	113.6	1193	227.3
10⅝	99.96	18.82	625.6	117.8	1251	235.5
10¾	103.5	19.26	655.6	122.0	1311	243.9
10⅞	107.2	19.71	686.6	126.3	1373	252.5
11	110.9	20.17	718.7	130.7	1437	261.3
11⅛	114.7	20.63	751.9	135.2	1504	270.4
11¼	118.7	21.09	786.3	139.8	1573	279.6
11⅜	122.7	21.57	821.8	144.5	1644	289.0
11½	126.7	22.04	858.5	149.3	1717	298.6
11⅝	130.9	22.52	896.5	154.2	1793	308.5
11¾	135.2	23.01	935.7	159.3	1871	318.5
11⅞	139.5	23.50	976.1	164.4	1952	328.8
12	144.0	24.00	1018	169.6	2036	339.3
12¼	153.2	25.01	1105	180.5	2211	360.9
12½	162.8	26.04	1198	191.7	2397	383.5
12¾	172.7	27.09	1297	203.5	2594	407.0
13	183.1	28.17	1402	215.7	2804	431.

WHITWORTH STANDARD THREADS AND NUTS

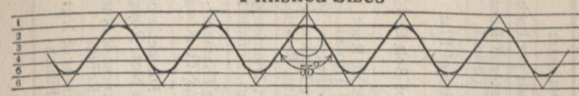
Finished Sizes



SCREW THREADS			HEADS AND NUTS			
Diam. of Bolt Inches	No. of Thr'ads	Diam. at Root	Thickness of Head Inches	Thickness of Nut Inches	Across Flats Inches	Across Corners Inches
1/8	40	.093	7/64	1/8	11/32	
3/16	24	.134	5/32	3/16	7/16	33/64
1/4	20	.186	7/32	1/4	17/32	39/64
5/16	18	.241	17/64	5/16	39/64	11/16
3/8	16	.295	21/64	3/8	45/64	13/16
7/16	14	.346	3/8	7/16	53/64	61/64
1/2	12	.393	7/16	1/2	59/64	1 1/16
9/16	12	.456	31/64	9/16	1 1/64	1 5/32
5/8	11	.508	35/64	5/8	1 3/32	1 17/64
11/16	11	.571	39/64	11/16	1 13/64	1 25/64
3/4	10	.622	21/32	3/4	1 19/64	1 1/2
13/16	10	.684	23/32	13/16	1 25/64	1 19/32
7/8	9	.733	49/64	7/8	1 31/64	1 45/64
15/16	9	.795	53/64	15/16	1 37/64	1 53/64
1	8	.840	7/8	1	1 43/64	1 61/64
1 1/8	7	.942	63/64	1 1/8	1 55/64	2 5/32
1 1/4	7	1.067	1 3/32	1 1/4	2 3/64	2 23/64
1 3/8	6	1.161	1 13/64	1 3/8	2 7/32	2 35/64
1 1/2	6	1.286	1 5/16	1 1/2	2 13/32	2 25/32
1 5/8	5	1.369	1 27/64	1 5/8	2 37/64	2 31/32
1 3/4	5	1.494	1 17/32	1 3/4	2 3/4	3 3/16
1 7/8	4 1/2	1.590	1 41/64	1 7/8	3 1/64	3 31/64
2	4 1/2	1.715	1 3/4	2	3 5/32	3 5/8
2 1/8	4 1/2	1.840	1 55/64	2 1/8	3 11/32	3 7/8
2 1/4	4	1.930	1 31/32	2 1/4	3 35/64	4 3/32
2 3/8	4	2.055	2 5/64	2 3/8	3 3/4	4 11/32
2 1/2	4	2.180	2 3/16	2 1/2	3 57/64	4 31/64
2 5/8	4	2.305	2 19/64	2 5/8	4 3/64	4 45/64
2 3/4	3 1/2	2.384	2 13/32	2 3/4	4 3/16	4 53/64
2 7/8	3 1/2	2.509	2 33/64	2 7/8	4 11/32	5 3/64
3	3 1/2	2.634	2 5/8	3	4 17/32	5 15/64

WHITWORTH STANDARD THREADS

Finished Sizes



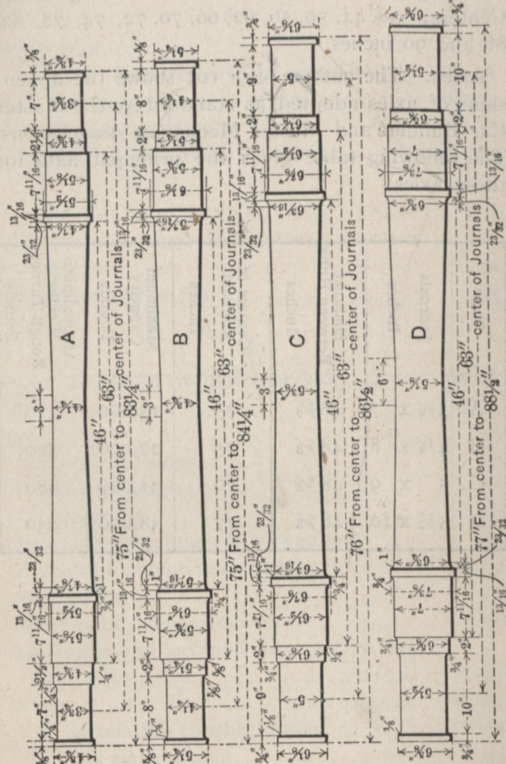
PIPE THREADS					
Nominal Diam. of Pipe Inches	No. of Threads	Diam. at Root Inches	Diam. at Top Inches	Actual Pipe Diam. Inches: Inside	Actual Pipe Diam. Inches: Outside
1/8	28	.3367	.3825	.27	.40
1/4	19	.4506	.518	.36	.54
3/8	19	.5889	.6563	.49	.67
1/2	14	.7342	.8257	.62	.84
5/8	14	.8107	.9022		
3/4	14	.9495	1.041	.82	1.05
7/8	14	1.0975	1.189		
1	11	1.1925	1.309	1.05	1.31
1 1/8	11	1.3755	1.492		
1 1/4	11	1.5335	1.65	1.38	1.66
1 3/8	11	1.6285	1.745		
1 1/2	11	1.765	1.8825	1.61	1.90
1 5/8	11	1.905	2.021		
1 3/4	11	1.9305	2.047		
1 7/8	11	2.1285	2.245		
2	11	2.2305	2.347	2.07	2.37
2 1/4	11	2.471	2.5875		
2 1/2	11	2.8848	3.0013	2.47	2.87
2 3/4	11	3.1305	3.247		
3	11	3.3685	3.485	3.07	3.5
3 1/4	11	3.582	3.6985		
3 1/2	11	3.7955	3.912	3.55	4.0
3 3/4	11	4.009	4.1255		
4	11	4.223	4.339	4.03	4.5

U.S. STANDARD SCREW THREADS

Diameter	Threads per Inch	Diameter of Root of Thread	Width of Flat	Area of Bolt Body	Area at Root of Thread	Short Diameter of Nut, Rough	Short Diameter of Nut, Finished	Long Diameter of Hex. Nut, Rough	Long Diameter of Square Nut, Rough	Thickness of Nut, Rough	Thickness of Nut, Finish
Ins.		Ins.	Ins.	Sq. Ins.	Sq. Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
1/4	20	.185	.0062	.049	.027	1/2	7/16	37/64	7/10	1/4	3/16
5/16	18	.240	.0074	.077	.045	19/32	17/32	11/16	10/12	5/16	1/4
3/8	16	.294	.0078	.110	.068	11/16	5/8	51/64	63/64	3/8	5/16
7/16	14	.344	.0089	.150	.093	25/32	23/32	9/10	1 7/64	7/16	3/8
1/2	13	.400	.0096	.196	.126	7/8	13/16	1	1 15/64	1/2	7/16
9/16	12	.454	.0104	.249	.162	31/32	29/32	1 1/8	1 23/64	9/16	1/2
5/8	11	.507	.0113	.307	.202	1 1/16	1	1 7/32	1 1/2	5/8	9/16
3/4	10	.620	.0125	.442	.302	1 1/4	1 3/16	1 7/16	1 49/64	3/4	11/16
7/8	9	.731	.0138	.601	.420	1 7/16	1 3/8	1 21/32	2 1/32	7/8	13/16
1	8	.837	.0156	.785	.550	1 5/8	1 9/16	1 7/8	2 19/64	1	15/16
1 1/8	7	.940	.0178	.994	.694	1 13/16	1 3/4	2 3/32	2 9/16	1 1/8	1 1/16
1 1/4	7	1.065	.0178	1.227	.893	2	1 15/16	2 5/16	2 53/64	1 1/4	1 3/16
1 3/8	6	1.160	.0208	1.485	1.057	2 3/16	2 1/8	2 17/32	3 3/32	1 3/8	1 5/16
1 1/2	6	1.284	.0208	1.767	1.295	2 3/8	2 5/16	2 3/4	3 23/64	1 1/2	1 7/16
1 5/8	5 1/2	1.389	.0227	2.074	1.515	2 9/16	2 1/2	2 31/32	3 5/8	1 5/8	1 9/16
1 3/4	5	1.491	.0250	2.405	1.746	2 3/4	2 11/16	3 3/16	3 57/64	1 3/4	1 11/16
1 7/8	5	1.616	.0250	2.761	2.051	2 15/16	2 7/8	3 13/32	4 5/32	1 7/8	1 13/16
2	4 1/2	1.712	.0277	3.142	2.302	3 1/8	3 1/16	3 5/8	4 27/64	2	1 15/16
2 1/4	4 1/2	1.962	.0277	3.976	3.023	3 1/2	3 7/16	4 1/16	4 61/64	2 1/4	2 3/16
2 1/2	4	2.176	.0312	4.909	3.719	3 7/8	3 13/16	4 1/2	5 31/64	2 1/2	2 7/16
2 3/4	4	2.426	.0312	5.940	4.620	4 1/4	4 3/16	4 29/32	6	2 3/4	2 11/16
3	3 1/2	2.629	.0357	7.069	5.428	4 5/8	4 9/16	5 3/8	6 17/32	3	2 15/16
3 1/4	3 1/2	2.879	.0357	8.296	6.510	5	4 15/16	5 13/16	7 1/16	3 1/4	3 3/16
3 1/2	3 1/4	3.100	.0384	9.621	7.548	5 3/8	5 5/16	6 7/64	7 39/64	3 1/2	3 7/16
3 3/4	3	3.317	.0413	11.045	8.641	5 3/4	5 11/16	6 21/32	8 1/8	3 3/4	3 11/16
4	3	3.567	.0413	12.566	9.963	6 1/8	6 1/16	7 3/32	8 41/64	4	3 15/16
4 1/4	2 7/8	3.798	.0435	14.186	11.329	6 1/2	6 7/16	7 9/16	9 3/16	4 1/4	4 3/16
4 1/2	2 3/4	4.028	.0454	15.904	12.753	6 7/8	6 13/16	7 31/32	9 3/4	4 1/2	4 7/16
4 3/4	2 5/8	4.256	.0476	17.721	14.226	7 1/4	7 3/16	8 13/32	10 1/4	4 3/4	4 11/16
5	2 1/2	4.480	.0500	19.635	15.763	7 5/8	7 9/16	8 27/32	10 49/64	5	4 15/16
5 1/4	2 1/2	4.730	.0500	21.648	17.572	8	7 15/16	9 9/32	11 23/64	5 1/4	5 3/16
5 1/2	2 3/8	4.953	.0526	23.758	19.267	8 3/8	8 5/16	9 23/32	11 7/8	5 1/2	5 7/16
5 3/4	2 3/8	5.203	.0526	25.967	21.262	8 3/4	8 11/16	10 5/32	12 3/8	5 3/4	5 11/16
6	2 1/4	5.423	.0555	28.274	23.098	9 1/8	9 1/16	10 19/32	12 15/16	6	5 15/16

Standard Axles

Adopted by The Master Car Builders and Master Mechanics Associations



Driving Wheel Centers.—At the Conventions of 1886, 1893 and 1907, the American Railway Master Mechanics Association adopted as standard the following diameters of Locomotive Driving Wheel Centers:—38, 44, 50, 56, 62, 66, 70, 72, 74, 78, 82, 86 and 90 inches.

Axles.—The cut on page 101 shows the dimensions of axles adopted as standard by the Master Car Builders and Master Mechanics Associations. The following table gives the principal data for these axles.

Type	Journals Inches	Distance Between Hubs Inches	Centers of Journals Inches	Maximum Capacity Pounds	Approximate Weight Rough Turned Pounds
A	3¾ x 7	48⅝	75	15,000	420
B	4¼ x 8	48⅝	75	22,000	520
C	5 x 9	48⅝	76	31,000	680
D	5½ x 10	48⅝	77	38,000	830

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W

Analysis of Various B.L.W. Metals

	Bearing Metal.	Valve Metal.	Bells	Yellow Brass
Copper	81.50	88.0	82.7	82.3
Lead	9.50	4.5	.8	3.6
Tin	*(9-11) 8.10	*(5-7) 6.2	16.0	1.0
Zinc	.50	1.3	.60	13.5
			Iron	.28

*Limits.

NO4
Wheel Centers Heat 7323. 10 36D598-599 N.E.
C. .34 Mn. .65 Ph. .036 Sul .045 Si .250

Shrinkage allowed per foot in BLW Pattern Shop.
3/16" for C.S. 1/10" for C.I. 1/8" for Brass.

Size of hub on C.S. wheel centers.
Back 2 Dia+1", Front 2 Dia−1"
Old Law. Average size − 1 3/4 × Dia.
C.I. Front 2 Dia. Back − to suit.
Cylinder Iron, Eddystone.
33 1/3 % pig iron.
33 1/3 % car wheels.
33 1/3 % scrap.

C.I. Driving Wheel Centers. Eddystone.
75% soft floor pig. Letter to C. Phillips 1-17-12
25% selected scrap

Silicon	2.75 to 3.25 %
Manganese	.40 %
Sulphur	.07 %
Phosphorous	.80 %
Graphite Carbon	3. to 3 1/2 %
Combined Carbon	.10 %

Coef exp. steel .000006 per inch.

Oil for superheated engines, BLW

(O.F. Zurn.) Test.	# 622 oil.
Gravity, ° Beaumé	22.9
Flash, °F.	635.0
Fire, °F	676.0
Viscosity, sec. @ 212°F	377.0
Tarry deposit.	None.
Saponifiable matter, %	None.

B.L.W. Specification for Brass Mixtures.

Valve metal		Bell Metal
Copper	87 – 89 %	– not over 84 %
Lead	3 – 5 %	– (none.)
Tin	5 – 7 %	– not below 16 %
Zinc	1 – 3 %	– (none.)

Bearing metal.	Mixture	Average Analysis.
Copper.	80.	80.
Lead.	10.	12.
Tin.	10.	8.

Special Babbitt for P.R.R. Engines. Formula B-659
Tin - 63.00 Zinc 28.91 Copper - 4.36 Lead 4.35

Elvin Grease Lubricators - Instructions of Franklin Rwy Supply Co. 10-18-11.
"Bore brass 1/64" larger than journal on all but main box. Easy fit (1/100") on main box."

Shrinkage allowance - driving Tires - A.T. & S.F.
1/64" per each 12" dia. of wheel center.

Valveringiron - Properties - solid, dense, fairly hard

Silicon	about	2.00 to 2.40
Manganese	about	.30 – .45
Sulphur	under	.10
Combined Car.	about	.40 – .70
Phosphorous	about	.60 – .90

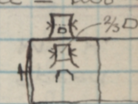
Copper Ferrules (from "Amer. Eng'r" Aug. 1912).
B.L.W. .065" B&O .09", P.R.R. .075" thick.

Average life of tubes.
Superheater Engines - 40,000 miles
Non- " " 55,000 - 60,000 miles.

$$\frac{\text{Firebox heating surface}}{\text{Tube heating surface}} = \frac{1}{18}$$

Steel rivets B.L.W. standard June 1903

Diameter smoke box cleaning pipe = two-thirds diameter of stack



Piston fit in crosshead - So. Ry.
Letters Jan 25 & 26., 1912, File 246

Eddystone. Loco Scales - Riehle.

No. of Loco.	No. of Cars	Average Indicated Horse Power	Average Dynamomet'r Horse Power	Average Speed M.P.H.	Average D. B. P. in Pounds	Av. Coal per I.H.P. per Hour, in lbs.	Av. Coal per D.H.P. per Hour, in lbs	Av. Water p. I. H. P. per Hour, in lbs	Av. Water per D. H. P. per Hour in lbs	Degrees (F) of Superheat above Boiler Steam
675	8	1360	857.0	57.40	5414	4.50	7.13	28.0	44.36	51
3 Cyl 10 Whlr	8	1293	816.7	54.93	5513	4.48	7.10	27.9	44.22	--
Superht	8	1261	820.4	54.91	5536	4.36	6.57	27.8	42.58	60
300	8	1343	870.0	56.00	5730	4.70	7.28	24.2	37.48	65
	8	1162	850.0	56.70	5550	5.52	7.54	28.8	39.60	65
3 Cyl Atlantic	8	1377	943.3	56.81	6120	4.52	6.66	25.0	36.46	61
Superht	8	1312	909.6	55.10	6180	5.22	7.86	24.6	34.74	71
	8	1386	945.5	56.60	6120	5.42	7.96	23.7	34.79	66
301	8	1319	889.4	57.14	5700	4.52	6.71	24.3	36.54	41
2 Cyl Atlantic	8	1211	869.4	54.30	5910	4.98	6.96	27.7	38.89	51
Superht	8	1155	870.0	53.38	5970	5.35	7.10	29.1	40.61	46
302	8	1414	857.6	56.20	5640	4.51	7.21	24.8	39.85	0
2 Cyl Atlantic	8	1264	868.8	53.74	6000	4.75	6.91	26.0	38.99	0
Saturated	8	1133	892.5	57.32	5760	4.81	6.06	33.4	42.12	0

P. & R. Philadelphia to New York, 90 miles.

P.R.R. Fort Wayne to Valparaiso and Return - 210 miles.

P.R.R. Fort Wayne to Valparaiso and Return - 210 miles.

No. of Loco.	No. of Cars	Average Indicated Horse Power	Average Dynamomet'r Horse Power	Average Speed M.P.H.	Average D.B.P. in Pounds	Av. Coal per I.H.P. per Hour, in lbs.	Av. Coal per D.H.P. per Hour, in lbs	Av. Water p. I.H.P. per Hour, in lbs	Av. Water per D.H.P. per Hour in lbs	Degrees (F) of Superheat above Boiler Steam
5075 2 Cyl. Atlantic Saturated	9	1645	1000	67.46	5454	5.31	8.74	27.17	44.66	0
	10	1662	995	68.00	5442	4.47	7.47	27.39	45.75	0
	11	1511	1075	63.55	6254	4.70	6.61	29.49	41.46	0
	12	1539	1108	60.33	6767	4.56	6.34	28.95	40.26	0
	13	1665	1150	62.43	6830	4.60	6.67	27.66	40.05	0
	14	1782	1200	58.80	7535	4.34	6.45	26.15	38.83	0
	15	1686	1205	56.70	7863	5.91	7.01	27.09	37.90	0
7514 2 Cyl. Pacific Superht	9	1843	1633	69.09	5933	3.00	4.89	20.17	32.80	235.3
	10	1882	1112	69.61	5875	2.92	4.95	18.84	31.88	----
	11	1768	1165	65.60	6532	2.79	4.24	20.00	30.35	190.3
	12	1745	1171	66.98	6446	2.99	4.45	19.53	29.11	209.8
	13	1717	1162	62.51	6816	2.91	4.30	20.03	29.59	214.7
	15	1953	1334	62.78	7853	2.84	4.16	19.45	28.48	220.6
9996 2 Cyl. Pacific Saturated Stoker	9	1459	846	60.42	5178	3.74	6.46	26.63	45.92	0
	10	1307	780	57.78	4983	3.68	6.34	28.80	48.24	0
	11	1401	838	57.06	5420	3.94	6.60	28.12	47.02	0
	12	1548	992	57.43	6366	4.31	6.72	27.97	43.64	0
	13	1683	1100	57.59	7063	4.82	7.37	26.08	39.88	0
	14	1694	1139	56.80	7440	4.85	7.23	26.84	39.94	0
	15	1723	1179	55.54	7884	4.84	7.09	26.77	39.00	0
9999 2 Cyl. Pacific Saturated	9	1419	795	61.23	4787	3.53	6.82	30.06	53.69	0
	10	1447	850	60.33	5201	3.73	6.36	29.33	49.92	0
	11	1571	905	60.18	5855	4.37	7.19	27.77	45.68	0
	12	1687	1021	50.59	6263	4.00	6.18	28.46	47.02	0
	13	1785	1099	54.63	7379	3.66	5.94	26.51	43.03	0
	15	1697	1165	54.46	7907	4.37	6.37	27.63	40.25	0

1 Heat of Casting Steel 5-7-12

Charge.

8000# Pig Iron @ 20.50	73.21
6000# plate Scrap @ 18.00	48.21
8000# Couplers @ 14.25	50.89
14000# Standard Scrap 16.25	101.56

Additions

100# Titanium @ 8¢	8.00
160# 50% Ferro Silicon @ 66.00	4.29
575# Manganese @ 41.02	10.53
	296.69
Less Pit & Ladle Scrap @ 16.00	7.14
	289.55

Operating Expenses:

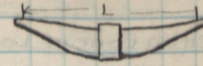
Prod. Labor	19.80	
Maintenance	16.13	
Errors & Defects	3.02	
Fuel	16.11	
Foremen & Clerks, Expenses on Property, Watchmen, etc.	7.38	62.44

Fluid Steel Poured, 33,560# $351.99

Average cost per pound, .01049

" " " Gross Ton, $23.50

Spring formula



W = Load in lbs, per 1 plate
b = width of plate
h = thickness " "
L = Length of spring
δ = deflection of spring
f = fibre stress
n = number of plates

$$W = \frac{50{,}000 bh^2}{L}$$

$$\delta = \frac{L^2}{1920 h}$$

$$W = \frac{2f bh^2 n}{3L}$$

$$f = \frac{3LW}{2bh^2 n}$$

H.V.W's experience on breakage of axles of 75000# tensile. Stresses up to 22,000# are safe. 22000#-26000# are very apt to break. Above 26000# failure is an even bet.

Coefficients of expansion (Degrees Cent)

	Car.	Phos	Mang	Sul.	a
Charcoal Iron	Trace	.049	Trace	.020	.00001235
Bessemer Steel	.07	.132	.40	.052	.00001258
Seamless O.H. Steel (hot finished)	.12	.0145	.51	.035	.00001239

The length of a tube at t degrees Centigrade is

$$L_t = L_0(1+at)$$

Possible error – 1.3% either way.

B.L.W. Standard Mounting Pressures.
Cast Iron Chilled – 6-8 Tons per Inch Bore
Rolled Steel – 10-13 Tons " " "

Test Dept 11-9-12

Melting Point of Lead & some Lead Alloys
Determined with a Brown Pyrometer

U.S. Metallic Packing Co.
80 Lead
20 Antimony } Melts at 500°F.

B.L.W. Brass Fdy. Mixture.
80 Pb
20 Ant'y } 530°F

B.L.W. Brass Fdy. Mixture.
87 Pb
13 Ant'my } 480°F

B.L.W. Brass Fdy Mixture.
65 Pb
15 Ant'my
20 Tin } 525°F

Lead used in B.L.W. Brass Fdy.
99.5 % Pb. Melts at 625°F.

Melting Point of Tin
Checked 438°F
Kent gives 492°F
54°F

	Melting Point of other Metals, etc.		Wt per cu ft pounds	Wt. per cu. in pounds	Specific Gravity
625°C	Aluminum	1157°F	163	.094	2.583
621	Antimony	1170	Cast:-419	.242	6.72
891	Barium Cloride	1635			
267	Bismuth	513	611	.353	9.882
1021	Brass	1870	524	.300	8.40
-7	Bromine	19.4			
322	Cadmium	611	Bronze 534	.300	8.561
790	Calcium	1436			
1515	Chromium	2759			
1528	Cobalt	2782	Cast 537	.310	8.607
1085	Copper	1985	Wire 555	.320	8.9
30	Gallium	86			

°C.		°F	Wt. per cu ft. lbs	Wt. per cu in. lbs.	Specific Gravity
1309	Glass	2377			
1038	Gold	1900	24K:-1208	.697	19.361
	Gold		Standard:-1106	.638	17.724
	Gun Metal		528	.304	8.459
103	Iodine	237			
1950	Iridium	3542			
1600	Iron, Pure	2912			
1221	" Cast. Grey	2230	} 450	.260	7.21
1075	" " White	1967			
1500	" Wrought	2732	485	.280	7.78
326	Lead	619	Cast 708	.410	11.36
			Rolled 711	.411	11.41
1245	Manganese	2273			
861	Magnesium	1382			
-40	Mercury	-40	849	.492	13.596
1450	Nickel	2642			
1500	Palladium	2732			
44	Phosphorus	111			
1832	Platinum	3327	1344	.778	21.531
			Sheet 1436	.832	23.000
58	Potassium	136			
718	" Cloride	1325			
125	Selenium	257			
1430	Silicon	2606			
962	Silver	1764	Pure 654	.379	10.474
			Standard 644	.372	10.312
96	Sodium	206			
800	Sodium Cloride	1472			
1371	Steel	2500	490	.284	7.85
114	Sulphur	237			
2275	Tantalium	4127			
444	Tellurium	851			
290	Thallium	554			
229	Tin	445	Cast 455	.263	7.291
420	Zinc	788	437	.252	7.1

1° Gauge of track.
2° Height of Center of coupler above top of rail. (Kind)
3° Weight of rail.
4° Sharpest curve to be traversed.
5° Heaviest grade on which the load must be handled and is the grade straight or on a curve. If on a curve, please state degree of curvature and whether it is compensated for grade or not.
6° Load to be handled on the grade. Please state this in number of cars and give total tonnage of cars and lading
7° Kind of fuel to be burned.
8° Service
9° Clearances
10° Lettering + numbering.
11° Distance water stations
12° Turntable Limits.

Weight of Tenders

Tenders weigh approx. 20 lbs for each galon of water capacity.
or. 3000 gal + less x 23 = weight
3000 to 7000 x 20 = weight
7000 gal & over x 18 = " or 19

E.B.H.

Weight on Engine Truck Relative to Drivers

American Type	1/2 or	.5
Mogul	1/5 "	.2
10 Wheeler	1/3 "	.33
Consolidation	1/6 "	.16, 1/7 or 1/8 sometimes

E.B.H.

Rigid Wheel Base suited to traversing curves
9' 2" = 35°
11' 0" = 30°
14' 0" = 16°-20°
16' & 17' = 16°
15' 0" = 20° } maximum and
16' 0" = 16° } undesirable.

E.B.H.

Grate Area should be 1/60 of Heating Surface, where H.S. is 2½ sq ft per HP, or 1/70 of H.S. where H.S. is 3 sq ft per HP. (about 5 for 4-4 C.)

Ry Age G. 8-22-13

When operating above 1/4 stroke, keep throttle wide open, below that point regulate speed by throttle.

Russian Duty [illegible]
3.65 R per pood = 1.55 $ per 36.1 lbs
+ 20% on value plus above duty

North British Loco. Co. Number of Employes
1909 - 7037   1910 - 6216   1911 - 7346
1912 - 6912   1913 - 8031

BLW Heating Surface is Water Side H.S.

B.L.W standard wire gauge:-
Birmingham Wire Gauge
To transpose into metric, see table p. 95, (decimals of 1 inch)

Geared Truck Locomotives

$$T.P. = \frac{C^2 \times S \times P \times .75 \times R.}{D}$$

C = Dia. of Cyls.
S = Stroke " "
P = Working Pressure of boiler.
.75 = Arbitrary % of boiler presure assumed effective in cyls.
R = Ratio of gearing 2.17 (8-21 GT
3.48 (12-24 GT
D = Dia. of Truck wheels.

Russian [illegible]armation

1 Bérkovetz = 10 pud = 361.12 lbs
1 Pud = 40 lbs (Russian) = 36.11 lbs
1 lb. (Russian) = 32 lot = 14.44 oz. av.
62 Pud = 1 Ton.

1 Verst = 500 sazhen = 1.067 km = 0.663 M. (7 V. = ca. 1 geogr. M.)
1 Sazhen = 3 arshin (28") = 48 vershóh (1¾") = 7 Ft (1 ft = 0.305 m. = 0.143 sazhen)

1 Desyatina = 2400 sq. sazhen = 2.7 acres.

1 Botchka = 40 vedro = 108.28 gallons

А	а	a
Б	б	b
В	в	v
Г	г	g, h
Д	д	d
Е	е	e, ye
	ё	o, yo
Ж	ж	zh
З	з	z
И	и	i
	й	i or mute
І	і	i
К	к	k
Л	л	l
М	м	m
Н	н	n
О	о	o
П	п	p
Р	р	r
С	с	s
Т	т	t
У	у	u
Ф	ф	f
Х	х	kh
Ц	ц	tz
Ч	ч	tch
Ш	ш	sh
Щ	щ	shtch
Ъ		mute
Ы		ui, i
Ь		mute
Ѣ	ѣ	ye
Э	э	e
Ю	ю	yu
Я	я	ya

Θ θ f

	Carbon. n. %	%Ph. Not over	% Mn.	% Si. Not over	% S Not over	Tensile Strength	Elongation, %	
Boiler & F.B. Steel	.15 - .25	.05	not over 0.45	.03	.05	55-65000	20-25%+, 8"	
F.B. Copper.	99.75% pure Lake Superior Copper.					29,500-30000	35.% 2"	
Stay Bolt Iron	Double refined iron.					Min. 48000	Min. 25% 8"	
Copper Stay Bolts	99.75% pure L.S. copper.					29,500-30000	35% 2"	
Bar Iron	Granular fracture not permitted.					48-50,000	15-20% 2"	
Steel Forgings	0.40%	.05%	not over .60%		.05%	75-90,000	15-20%+ 2"	
Steel Castings						60-70000	Min 15% 2"	annealed.
Spring Steel	.90-1.10%	.08-.05%	.25-.50%	.15-.25%	.02-.05%	Permanent set & Deflection tests on 24" bar.		O.H. or Crucible
S. Steel Tubes	.18-24%	.04	.40-.65		.05			

Industrial Locomotives

British Practice (Ry. Gaz. 20-11-14)

$$T.E = \frac{.85\ (d^2 \times S \times m.p)}{D}$$

m.p = M.E.P. in cylinders, usually 75% cut off.

$$\frac{\text{Total H.S.}}{\text{G.A}} = 60$$

$$\frac{\text{Firebox H.S}}{\text{G.A.}} = 5\tfrac{1}{4}$$

$$\frac{\text{Total H.S}}{\text{Firebox H.S}} = 11\tfrac{1}{2}$$

Ratio adhesion to Tractive Power.

0-4-0	full	5 to 1
	empty	4.25 to 1
0-6-0	full	5.2 to 1
	empty	4.5 to 1

$$\text{Horse Power} = \frac{H.S \times 13}{28} = .46\ H.S.$$

13 = evap. power per sq ft. H.S. per hour
28 = weight of steam per H.P. hour.

$$\text{Max axle load (long tons)} = \frac{\text{wt. rail}}{5}$$

Sanbeat

Sanbean