LOCOMOTIVE HAND-BOOK

COMPILED BY

AMERICAN LOCOMOTIVE COMPANY

30 CHURCH STREET

NEW YORK, U. S. A.

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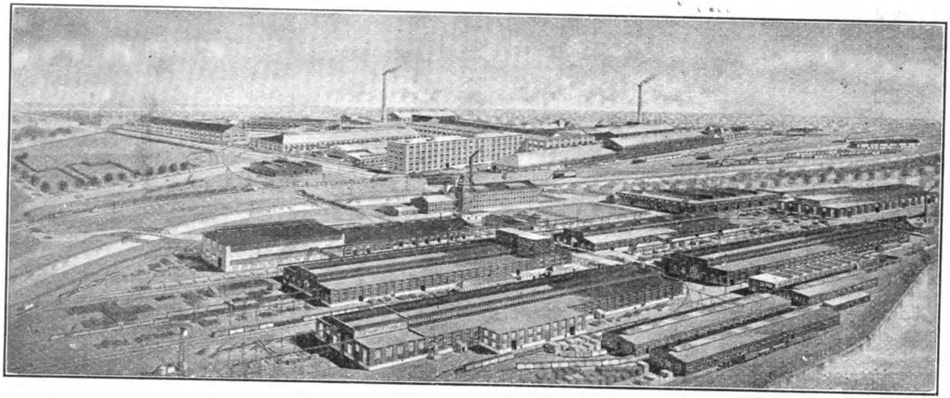
1917



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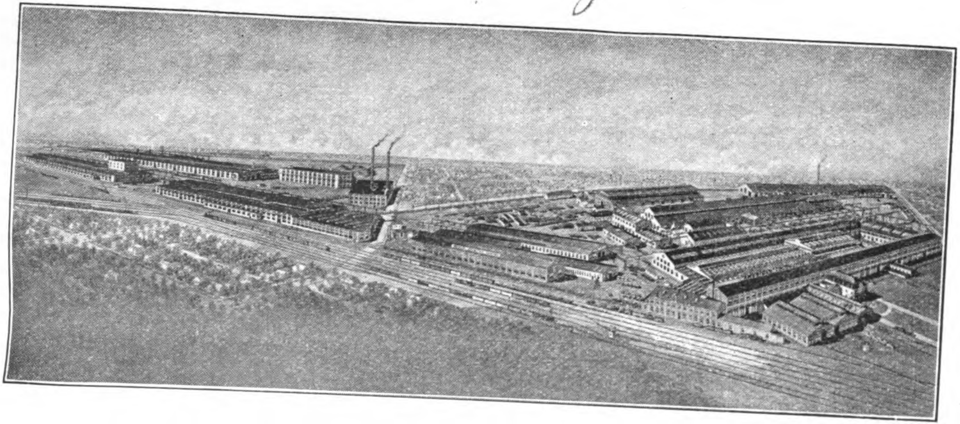


BROOKS WORKS, DUNKIRK, N. Y.

LOCOMOTIVE HAND-BOOK

The American Locomotive Company, the largest builder of steam locomotives in the world, was incorporated under the laws of the State of New York, June 10, 1901. It has an authorized and outstanding capital stock of $50,000,000.

The following properties were acquired:

NAME OF COMPANY	LOCATION	ORGANIZED
Schenectady Locomotive Works	Schenectady, N. Y.	1848
Brooks Locomotive Works	Dunkirk, N. Y.	1869
Pittsburgh Locomotive and Car Works	Pittsburgh, Pa.	1865
Richmond Locomotive Works	Richmond, Va.	1886
Rhode Island Locomotive Works	Providence, R. I.	1866
Dickson Locomotive Mfg. Co.	Scranton, Pa.	1856
Manchester Locomotive Works	Manchester, N. H.	1853
Cooke Locomotive and Machine Co.	Paterson, N. J.	1852
Rogers Locomotive Works	Paterson, N. J.	1835
The Locomotive & Machine Co. of Montreal, Ltd.	Montreal, Canada	1902

It gradually developed that several of the smaller plants could be discontinued and other plants enlarged to the direct benefit of both the company and the locomotive purchasers. With this in view, four of the plants have been closed and other plants enlarged, rearranged and brought up-to-date to facilitate the rapid handling of work pertaining to the construction of modern locomotives. All these plants are kept thoroughly equipped with the latest and most improved machinery of all kinds.

A modern steel foundry at Chester, Pa., has been recently acquired.

The plants now operated have an acreage and floor area as follows:

PLANT	ACREAGE	FLOOR AREA SQ. FT.
Schenectady	74.75	1,301,754
Brooks	117.69	1,063,025
Richmond	53.00	499,450
Montreal	64.75	455,881
Pittsburgh	10.25	314,810
Cooke	24.75	266,486
Chester—Steel Foundry	11.59	136,820
Total	356.78	4,038,226

These plants, when working full capacity, have a combined annual output of 3,000 locomotives and employ 20,000 men.

All types and sizes of locomotives are manufactured. These locomotives range in size from the four-wheel tank engine (0-4-0 T type), having a total weight of 14,500 lb., and a tractive effort of 2,630 lb., to the 2-10-10-2 type Mallet engine, having a total weight, engine and tender, of 875,000 lb., a tractive power of 147,200 lb. working compound, and of 176,600 lb. working simple. This company also manufactures all kinds of spare and repair parts for locomotives and tenders.

In the construction of locomotives, the American Locomotive Company co-operates with the railroads and the different railway associations to obtain the very best results. Careful specifications are prepared for methods of construction and for the manufacture and testing of materials. Rigid inspection is maintained to discover any defects that may occur either in the workmanship or material. Back of each design of the American Locomotive Company is the experience of continuous locomotive building since 1835 and the construction of over 55,000 locomotives.

The following pages give information which the American Locomotive Company has found to be useful in the designing of locomotives.

TRACTIVE POWER OF LOCOMOTIVES WITH BOILER PRESSURE OF 100 LB.

These tables are calculated from formula

$$T = \frac{d^2 S .85 P}{W}$$

in which

T = tractive power;
d = diameter of cylinders in inches;
S = length of stroke in inches;
P = boiler pressure in pounds per sq. inch;
W = diameter of driving wheels in inches.

All the combinations of cylinder diameters, strokes and wheel diameters used in ordinary practice are included. These figures can be used for any boiler pressure by simply dividing the required tractive power by the ratio of the boiler pressure it is desired to use to 100 pounds pressure; as, for instance, 2 for 200 lb., 1.75 for 175 lb., and 1.6 for 160 lb. pressure. Then the proper size cylinders and driving wheels can be found directly from the table, or by multiplying the figures in the table by the proper ratio the desired tractive power can be obtained.

In Europe as low as 60 per cent of the boiler pressure is used instead of 85 per cent; the formula being

$$T = \frac{d^2 S .60 P}{W}$$

TABLE No. 1—TRACTIVE POWER OF LOCOMOTIVES WITH BOILER PRESSURE OF 100 LB.

Cylinders		Diameter of Driving Wheels													
Diam.	Stroke	30″	32″	34″	36″	38″	40″	42″	44″	46″	48″	49″	50″	51″	52″
9″	14″	3200	3000	2800	2700	2500	2400	2300	2200	2100	2000	2000	1900	....	...
10″	14″	4000	3700	3500	3300	3100	3000	2800	2700	2600	2500	2400	2400	....	...
11″	14″	4800	4500	4200	4000	3800	3600	3400	3300	3100	3000	2900	2900	....	...
9″	16″	3700	3400	3200	3100	2900	2800	2600	2500	2400	2300	2300	2200	2200	2100
10″	16″	4500	4300	4000	3800	3600	3400	3200	3100	3000	2800	2800	2700	2700	2600
11″	16″	5500	5100	4800	4600	4300	4000	3900	3700	3600	3400	3400	3300	3200	3200
12″	16″	6500	6100	5800	5500	5200	4900	4700	4500	4300	4200	4000	3900	3800	3800
13″	16″	7700	7200	6800	6400	6000	5700	5500	5200	5000	4800	4700	4600	4500	4400
10″	18″	...	4800	4500	4300	4000	3800	3700	3500	3300	3200	3100	3100	3000	2900
11″	18″	...	5800	5400	5200	4900	4600	4400	4200	4000	3900	3800	3700	3600	3600
12″	18″	...	6900	6500	6100	5800	5500	5200	5000	4800	4600	4500	4400	4300	4200
13″	18″	...	8100	7600	7200	6800	6500	6200	5900	5600	5400	5300	5200	5100	5000
14″	18″	...	9400	8800	8300	7900	7500	7100	6800	6500	6200	6100	6000	5900	5800
15″	18″	...	10800	10100	9600	9100	8600	8200	7800	7500	7200	7100	6900	6800	6600
16″	18″	...	12200	11500	10900	10300	9800	9300	8900	8500	8200	8000	7800	7700	7500
12″	20″	...	...	7200	6800	6400	6100	5800	5600	5300	5100	5000	4900	4800	4700
13″	20″	...	...	8500	8000	7600	7200	6800	6500	6200	6000	5900	5800	5600	5500
14″	20″	...	...	9800	9300	8800	8300	7900	7600	7200	6900	6800	6700	6500	6400
15″	20″	...	...	11300	10600	10100	9600	9100	8700	8000	8000	7800	7700	7500	7400
16″	20″	...	...	12800	12100	11500	10900	10400	9900	9500	9100	8900	8700	8500	8400
17″	20″	...	...	14500	13600	13000	12300	11700	11200	10700	10200	10000	9800	9600	9400
18″	20″	...	...	16200	15300	14500	13800	13100	12500	12000	11500	11200	11000	10800	10600

TABLE No. 2—TRACTIVE POWER OF LOCOMOTIVES WITH BOILER PRESSURE OF 100 LB.

Cylinders		Diameter of Driving Wheels													
Diam.	Stroke	53″	54″	55″	56″	57″	58″	59″	60″	61″	62″	63″	64″	65″	66″
9″	16″	2100	2000	2000	2000	1900	1900	....	....	....	....	....	....	....	...
10″	16″	2600	2500	2500	2400	2400	2300	....	....	....	....	....	....	....	...
11″	16″	3100	3000	3000	2900	2900	2800	....	....	....	....	....	....	....	...
12″	16″	3700	3600	3600	3500	3400	3400	....	....	....	....	....	....	....	...
13″	16″	4300	4300	4200	4100	4000	4000	....	....	....	....	....	....	....	...
10″	18″	2900	2800	2800	2700	2700	2600	....	....	....	....	....	....	....	...
11″	18″	3500	3400	3400	3300	3200	3200	....	....	....	....	....	....	....	...
12″	18″	4100	4100	4000	3900	3900	3800	....	....	....	....	....	....	....	...
13″	18″	4900	4800	4700	4600	4500	4500	....	....	....	....	....	....	....	...
14″	18″	5700	5600	5500	5400	5300	5200	....	....	....	....	....	....	....	...
15″	18″	6500	6400	6300	6100	6000	5900	....	....	....	....	....	....	....	...
16″	18″	7400	7300	7100	7000	6900	6800	....	....	....	....	....	....	....	...
12″	20″	4600	4500	4500	4300	4300	4200	4100	4100	4000	4000	3900	3800	3800	3700
13″	20″	5400	5300	5200	5100	5000	5000	4900	4800	4700	4600	4600	4500	4400	4400
14″	20″	6300	6200	6100	6000	5800	5700	5600	5600	5500	5400	5300	5200	5100	5100
15″	20″	7300	7100	7000	6800	6600	6600	6500	6400	6300	6200	6100	6000	5900	5800
16″	20″	8200	8100	7900	7800	7600	7600	7400	7300	7100	7000	6900	6800	6700	6600
17″	20″	9300	9100	9000	8800	8600	8500	8300	8200	8100	7900	7800	7700	7600	7400
18″	20″	10400	10200	10000	9800	9700	9500	9300	9200	9000	8900	8700	8600	8500	8400

TABLE No. 3—TRACTIVE POWER OF LOCOMOTIVES WITH BOILER PRESSURE OF 100 LB.

Cylinders		Diameter of Driving Wheels														
Diam.	Stroke	40"	42"	44"	46"	48"	49"	50"	51"	52"	53"	54"	55"	56"	57"	58"
14"	22"	9200	8700	8300	8000	7600	7500	7300	7200	7000	6900	6800	6700	6600	6400	6300
15"	22"	10500	10000	9600	9100	8800	8600	8400	8300	8100	7900	7800	7700	7500	7400	7300
16"	22"	12000	11400	10900	10400	10000	9800	9600	9400	9200	9000	8900	8700	8500	8400	8300
17"	22"	13500	12900	12300	11700	11300	11000	10800	10600	10300	10200	10000	9800	9700	9500	9300
18"	22"	15100	14400	13800	13200	12600	12400	12100	11900	11700	11400	11200	11000	10800	10600	10400
19"	22"	16900	16100	15300	14700	14100	13800	13500	13200	13000	12700	12500	12300	12100	11800	11600
20"	22"	18700	17800	17000	16300	15600	15300	15000	14700	14400	14100	13900	13600	13400	13200	12900
14"	24"	...	9500	9100	8700	8300	8200	8000	7800	7700	7500	7400	7300	7100	7000	6900
15"	24"	...	10900	10400	10000	9600	9400	9200	9000	8800	8700	8500	8300	8200	8100	7900
16"	24"	...	12400	11900	11400	10900	10700	10400	10200	10000	9800	9700	9500	9300	9200	9000
17"	24"	...	14000	13400	12800	12300	12000	11800	11600	11300	11100	10900	10700	10500	10300	10200
18"	24"	...	15800	15000	14400	13800	13500	13200	13000	12700	12500	12200	12000	11800	11600	11400
19"	24"	...	17500	16700	16100	15300	15100	14800	14500	14200	13900	13700	13400	13200	12900	12700
20"	24"	...	19400	18500	17700	17000	16700	16300	16000	15700	15400	15100	14800	14600	14300	14100
21"	24"	...	21400	20400	19600	18700	18400	18000	17700	17300	17000	16700	16400	16100	15800	15500
22"	24"	...	23600	22400	21500	20600	20200	19800	19400	19000	18600	18300	18000	17600	17300	17000
23"	24"	...	25800	24500	23500	22500	22000	21600	21200	20800	20400	20000	19600	19300	18900	18600
17"	26"	...	...	14500	13900	13300	13000	12800	12500	12300	12100	11800	11600	11400	11200	11000
18"	26"	...	...	16300	15600	14900	14600	14300	14000	13800	13500	13300	13000	12800	12600	12300
19"	26"	...	...	18100	17300	16600	16300	16000	15600	15300	15100	14800	14500	14300	14000	13800
20"	26"	...	...	20100	19200	18400	18100	17700	17300	17000	16700	16400	16100	15800	15500	15300
21"	26"	...	...	22200	21200	20300	19900	19500	19100	18800	18400	18000	17700	17400	17100	16800
22"	26"	...	...	24300	23300	22300	21900	21400	21000	20600	20200	19800	19500	19100	18800	18400
23"	26"	...	...	26600	25400	24400	23900	23400	22900	22500	22100	21700	21300	20900	20500	20200
24"	26"	...	...	...	...	...	...	25500	25000	24500	24000	23600	23100	22700	22300	21900
25"	26"	...	...	...	...	...	...	27600	27100	26600	26100	25600	25100	24700	24200	23800
26"	26"	...	...	...	...	...	...	29900	29300	28700	28200	27700	27200	26700	26200	25800

TABLE No. 4—TRACTIVE POWER OF LOCOMOTIVES WITH BOILER PRESSURE OF 100 LB.

Cylinders		Diameter of Driving Wheels													
Diam.	Stroke	59″	60″	61″	62″	63″	64″	65″	66″	67″	68″	69″	70″	71″	72″
14″	22″	6200	6100	6000	5900	5800	5700	5600	5600	5500	5400	5300	5200	5200	5100
15″	22″	7100	7000	6900	6800	6700	6600	6500	6400	6300	6200	6100	6000	5900	5900
16″	22″	8100	8000	7800	7700	7600	7500	7400	7300	7100	7000	6900	6800	6700	6700
17″	22″	9200	9000	8900	8700	8600	8400	8300	8200	8100	8000	7800	7700	7600	7500
18″	22″	10300	10100	9900	9800	9600	9500	9300	9200	9000	8900	8800	8700	8500	8400
19″	22″	11400	11300	11100	10900	10700	10500	10400	10200	10100	9900	9800	9600	9500	9400
20″	22″	12700	12500	12300	12100	11900	11700	11500	11300	11200	11000	10900	10700	10500	10400
14″	24″	6800	6700	6600	6500	6400	6300	6200	6100	6000	5900	5800	5700	5600	5600
15″	24″	7800	7700	7500	7400	7300	7200	7100	7000	6900	6800	6700	6600	6500	6400
16″	24″	8900	8700	8600	8400	8300	8200	8000	7900	7800	7700	7600	7500	7400	7300
17″	24″	10000	9800	9700	9500	9400	9200	9100	8900	8800	8700	8600	8400	8300	8200
18″	24″	11200	11000	10900	10700	10500	10300	10200	10000	9900	9700	9600	9400	9300	9200
19″	24″	12500	12300	12100	11900	11700	11500	11300	11200	11000	10800	10700	10500	10400	10200
20″	24″	13800	13600	13400	13200	13000	12800	12600	12400	12200	12000	11800	11700	11500	11300
21″	24″	15200	15000	14800	14500	14300	14100	13800	13600	13400	13200	13000	12900	12700	12500
22″	24″	16700	16500	16200	15900	15700	15400	15200	15000	14700	14500	14300	14100	13900	13700
23″	24″	18300	18000	17700	17400	17100	16900	16600	16400	16100	15900	15600	15400	15200	15000
17″	26″	10800	10600	10500	10300	10100	10000	9800	9700	9500	9400	9300	9100	9000	8900
18″	26″	12100	11900	11700	11500	11400	11200	11000	10900	10700	10500	10400	10200	10100	10000
19″	26″	13500	13300	13100	12900	12700	12500	12300	12100	11900	11700	11600	11400	11200	11100
20″	26″	15000	14700	14500	14300	14100	13800	13600	13400	13200	13000	12800	12600	12500	12300
21″	26″	16500	16200	16000	15700	15500	15200	15000	14800	14500	14300	14100	13900	13700	13500
22″	26″	18100	17900	17500	17300	17000	16700	16500	16200	16000	15700	15500	15300	15100	14900
23″	26″	19800	19500	19200	18900	18600	18300	18000	17700	17500	17200	17000	16700	16500	16300
24″	26″	21600	21200	20900	20500	20200	19900	19600	19300	19000	18700	18400	18200	17900	17700
25″	26″	23400	23000	22600	22300	21900	21600	21300	20900	20600	20300	20000	19700	19500	19200
26″	26″	25300	24900	24500	24100	23700	23300	23000	22600	22300	22000	21600	21300	21000	20700

TABLE No. 5—TRACTIVE POWER OF LOCOMOTIVES WITH BOILER PRESSURE OF 100 LB.

Cylinders		Diameter of Driving Wheels													
Diam.	Stroke	73″	74″	75″	76″	77″	78″	79″	80″	81″	82″	83″	84″	85″	86″
14″	24″	5500	5400	5300	5300	5200	5100	5100	....	....	....	....	....	....	...
15″	24″	6300	6200	6100	6000	6000	5900	5800	....	....	....	....	....	....	...
16″	24″	7200	7100	7000	6900	6800	6700	6600	....	....	....	....	....	....	...
17″	24″	8100	8000	7900	7800	7700	7600	7500	....	....	....	....	....	....	...
18″	24″	9100	8900	8800	8700	8600	8500	8400	....	....	....	....	....	....	...
19″	24″	10100	10000	9800	9700	9600	9500	9300	....	....	....	....	....	....	...
20″	24″	11200	11000	10900	10700	10600	10500	10300	....	....	....	....	....	....	...
21″	24″	12300	12200	12000	11800	11700	11500	11400	....	....	....	....	....	....	...
22″	24″	13500	13300	13200	13000	12800	12700	12500	....	....	....	....	....	....	...
23″	24″	14800	14600	14400	14200	14000	13800	13700	....	....	....	....	....	....	...
17″	26″	8800	8600	8500	8400	8300	8200	8100	8000	7900	7800	7700	7600	7500	7400
18″	26″	9800	9700	9600	9400	9300	9200	9100	9000	8800	8700	8600	8500	8400	8300
19″	26″	10900	10800	10600	10500	10400	10200	10100	10000	9900	9700	9600	9500	9400	9300
20″	26″	12100	12000	11800	11600	11500	11300	11200	11100	10900	10800	10700	10500	10400	10300
21″	26″	13400	13200	13000	12800	12700	12500	12300	12200	12000	11900	11700	11600	11500	11300
22″	26″	14700	14500	14300	14100	13900	13700	13500	13400	13200	13100	12900	12700	12600	12400
23″	26″	16000	15800	15600	15400	15200	15000	14800	14600	14400	14300	14100	13900	13800	13600
24″	26″	17400	17200	17000	16700	16500	16300	16100	15900	15700	15500	15300	15100	15000	14800
25″	26″	18900	18700	18400	18200	17900	17700	17500	17300	17100	16900	16600	16400	16200	16100
26″	26″	20400	20200	19900	19700	19400	19200	18900	18700	18400	18200	18000	17800	17600	17400

TABLE No. 6—TRACTIVE POWER OF LOCOMOTIVES WITH BOILER PRESSURE OF 100 LB.

Cylinders		Diameter of Driving Wheels																
Diam.	Stroke	53″	54″	55″	56″	57″	58″	59″	60″	61″	62″	63″	64″	65″	66″	67″	68″	69″
17″	28″	13000	12700	12500	12300	12100	11900	11700	11500	11300	11100	10900	10700	10600	10400	10300	10100	10000
18″	28″	14500	14300	14000	13800	13500	13300	13100	12900	12600	12400	12300	12100	11900	11700	11500	11300	11200
19″	28″	16200	15900	15600	15300	15000	14800	14600	14300	14100	13900	13600	13400	13200	13000	12800	12600	12500
20″	28″	18000	17700	17300	17000	16700	16400	16100	15900	15600	15400	15100	14900	14700	14400	14200	14000	13800
21″	28″	19800	19400	19100	18700	18400	18100	17800	17500	17200	16900	16700	16400	16200	15900	15700	15500	15200
22″	28″	21700	21300	20900	20600	20200	19900	19500	19200	18900	18600	18300	18000	17700	17500	17200	17000	16700
23″	28″	23800	23300	22900	22500	22100	21700	21300	21000	20600	20300	20000	19700	19400	19100	18800	18500	18300
24″	28″	25900	25400	24900	24500	24100	23600	23200	22800	22500	22100	21800	21400	21100	20800	20500	20200	19900
25″	28″	28100	27500	27000	26600	26100	25600	25200	24800	24400	24000	23600	23200	22900	22500	22200	21900	21600
26″	28″	30400	29800	29300	28700	28200	27700	27300	26800	26400	26000	25500	25100	24800	24400	24000	23700	23300
27″	28″	32700	32100	31500	31000	30400	29900	29400	28900	28400	28000	27500	27100	26700	26300	25900	25500	25200
28″	28″	35200	34600	33900	33300	32700	32200	31600	31100	30600	30100	29600	29200	28700	28300	27800	27400	27000
29″	28″	37800	37100	36400	35800	35100	34500	33900	33400	32800	32300	31800	31300	30800	30300	29800	29400	29000
19″	30″	17400	17000	16700	16400	16200	15900	15600	15400	15100	14900	14600	14400	14200	14000	13800	13600	13400
20″	30″	19300	18900	18600	18200	17900	17600	17300	17000	16700	16500	16200	16000	15700	15500	15300	15000	14800
21″	30″	21200	20900	20500	20100	19800	19400	19100	18800	18500	18200	17900	17600	17300	17100	16800	16600	16300
22″	30″	23300	22900	22500	22100	21700	21300	20900	20600	20200	19900	19600	19300	19000	18700	18400	18200	17900
23″	30″	25500	25000	24600	24100	23700	23300	22900	22500	22100	21800	21400	21100	20800	20500	20200	19900	19600
24″	30″	27700	27200	26700	26300	25800	25300	24900	24500	24100	23700	23300	23000	22700	22300	22000	21600	21300
25″	30″	30100	29500	29000	28500	28000	27500	27000	26600	26100	25700	25300	25000	24600	24200	23800	23400	23100
26″	30″	32500	31900	31300	30800	30200	29700	29200	28700	28200	27800	27400	26900	26500	26100	25700	25400	25000
27″	30″	35100	34400	33800	33200	32600	32100	31500	31000	30500	30000	29500	29000	28600	28200	27700	27300	26900
28″	30″	37800	37100	36400	35800	35100	34500	33900	33400	32800	32300	31700	31200	30700	30300	29800	29400	29000
29″	30″	40500	39700	39000	38300	37600	37000	36300	35700	35200	34600	34000	33500	33000	32500	32000	31600	31100
30″	30″	43300	42500	41700	41000	40300	39600	38900	38300	37600	37000	36400	35900	35300	34800	34300	33800	33300
31″	30″	46200	45300	44500	43700	43000	42200	41500	40800	40200	39500	38900	38300	37700	37100	36600	36000	35500

TABLE No. 7—TRACTIVE POWER OF LOCOMOTIVES WITH BOILER PRESSURE OF 100 LB.

Cylinders		Diameter of Driving Wheels																
Diam.	Stroke	70″	71″	72″	73″	74″	75″	76″	77″	78″	79″	80″	81″	82″	83″	84″	85″	86″
17″	28″	9800	9700	9600	9400	9300	9200	9100	8900	8800	8700	8600	8500	8400	8300	8200	8100	8000
18″	28″	11000	10900	10700	10600	10400	10300	10100	10000	9900	9800	9700	9500	9400	9300	9200	9100	9000
19″	28″	12300	12100	11900	11800	11600	11500	11300	11200	11000	10900	10700	10600	10500	10400	10200	10100	10000
20″	28″	13600	13400	13200	13000	12900	12700	12500	12400	12200	12100	11900	11800	11600	11500	11300	11200	11100
21″	28″	15000	14800	14600	14400	14200	14000	13800	13600	13500	13300	13100	13000	12800	12700	12500	12400	12200
22″	28″	16500	16200	16000	15800	15600	15400	15200	15000	14800	14600	14400	14200	14100	13900	13700	13600	13400
23″	28″	18000	17800	17500	17300	17000	16800	16600	16400	16200	16000	15800	15600	15400	15200	15000	14800	14700
24″	28″	19600	19300	19000	18800	18500	18300	18100	17800	17600	17400	17200	16900	16700	16500	16300	16100	16000
25″	28″	21200	20900	20600	20400	20100	19800	19600	19300	19100	18800	18600	18400	18100	17900	17700	17500	17300
26″	28″	23000	22600	22300	22000	21700	21400	21200	20900	20600	20400	20100	19900	19600	19400	19200	18900	18700
27″	28″	24800	24500	24100	23800	23400	23100	22800	22500	22200	22000	21700	21400	21200	20900	20700	20400	20200
28″	28″	26600	26300	25900	25600	25200	24900	24600	24200	23900	23600	23300	23000	22800	22500	22200	22000	21700
29″	28″	28600	28200	27800	27400	27000	26700	26400	26000	25700	25400	25000	24700	24400	24100	23800	23600	23300
19″	30″	13200	13000	12800	12600	12500	12300	12100	11900	11800	11700	11500	11400	11200	11100	11000	10900	10700
20″	30″	14600	14400	14200	14000	13800	13600	13400	13300	13100	12900	12800	12600	12500	12300	12200	12000	11900
21″	30″	16100	15900	15600	15400	15200	15000	14800	14600	14400	14300	14100	13900	13700	13600	13400	13300	13100
22″	30″	17700	17400	17200	16900	16700	16500	16300	16100	15900	15700	15500	15300	15100	14900	14700	14500	14400
23″	30″	19300	19000	18800	18500	18300	18000	17800	17500	17300	17100	16900	16700	16500	16300	16000	15900	15700
24″	30″	21000	20700	20400	20200	19900	19600	19400	19100	18900	18600	18400	18200	18000	17700	17500	17300	17100
25″	30″	22800	22400	22200	21800	21500	21200	21000	20700	20400	20200	19900	19700	19400	19200	19000	18800	18500
26″	30″	24600	24300	24000	23600	23300	23000	22700	22400	22100	21800	21600	21300	21000	20800	20500	20300	20100
27″	30″	26600	26200	25800	25500	25100	24800	24500	24100	23800	23500	23200	22900	22600	22400	22100	21900	21600
28″	30″	28600	28200	27800	27400	27000	26600	26300	26000	25600	25300	25000	24700	24400	24100	23800	23500	23200
29″	30″	30700	30200	29800	29400	29000	28600	28200	28000	27500	27200	26800	26500	26200	25800	25500	25200	25000
30″	30″	32800	32300	31900	31400	31000	30600	30200	29800	29400	29100	28700	28300	28000	27700	27300	27000	26700
31″	30″	35000	34500	34000	33600	33100	32700	32200	31800	31400	31000	30600	30200	29900	29500	29200	28800	28500

TABLE No. 8—TRACTIVE POWER OF LOCOMOTIVES WITH BOILER PRESSURE OF 100 LB.

Cylinders		Diameter of Driving Wheels																
Diam.	Stroke	56″	57″	58″	59″	60″	61″	62″	63″	64″	65″	66″	67″	68″	69″	70″	71″	72″
19″	32″	17600	17300	17000	16700	16400	16100	15900	15600	15400	15100	14900	14700	14500	14300	14100	13900	13700
20″	32″	19500	19100	18800	18500	18200	17900	17600	17300	17000	16800	16500	16300	16000	15800	15600	15400	15100
21″	32″	21400	21100	20700	20400	20000	19700	19400	19100	18800	18500	18200	17900	17700	17400	17200	16900	16700
22″	32″	23500	23100	22700	22300	21900	21600	21200	20900	20600	20300	20000	19700	19400	19100	18800	18600	18300
23″	32″	25700	25200	24800	24400	24000	23600	23200	22900	22500	22200	21800	21500	21200	20900	20600	20300	20000
24″	32″	28000	27500	27000	26500	26100	25700	25300	24900	24500	24100	23800	23400	23000	22700	22400	22100	21800
25″	32″	30400	29800	29300	28800	28300	27900	27400	27000	26600	26200	25800	25400	25000	24600	24300	23900	23600
26″	32″	32800	32300	31700	31200	30700	30200	29700	29200	28700	28300	27900	27400	27000	26600	26300	25900	25500
27″	32″	35400	34800	34200	33600	33100	32500	32000	31500	31000	30500	30000	29600	29200	28700	28300	27900	27500
28″	32″	38100	37400	36800	36100	35600	35000	34400	33800	33300	32800	32300	31800	31400	30900	30500	30000	29600
29″	32″	40800	40100	39400	38800	38100	37500	36900	36300	35700	35200	34700	34100	33600	33100	32700	32200	31800
30″	32″	43700	42900	42200	41500	40800	40100	39500	38900	38300	37700	37100	36600	36000	35500	35000	34500	34000
31″	32″	46700	45800	45100	44300	43600	42900	42200	41500	40800	40200	39600	39000	38400	37900	37400	36800	36300
32″	32″	49700	48800	48000	47200	46400	45700	44900	44200	43500	42800	42200	41600	41000	40400	39800	39200	38700
21″	34″	22800	22400	22000	21600	21300	25900	20600	20300	19900	19600	19300	19000	18800	18500	18200	18000	17700
22″	34″	25000	24600	24100	23700	23300	23000	22600	22200	21900	21500	21200	20900	20600	20300	20000	19700	19500
23″	34″	27300	26900	26400	25900	25500	25100	24700	24300	23900	23500	23200	22800	22500	22200	21900	21600	21300
24″	34″	29700	29200	28700	28200	27700	27300	26900	26400	26000	25600	25200	24800	24500	24100	23800	23500	23100
25″	34″	32300	31700	31100	30600	30100	29600	29100	28700	28200	27800	27400	27000	26600	26200	25800	25500	25100
26″	34″	34900	34300	33700	33100	32600	32000	31500	31000	30500	30000	29600	29200	28800	28300	27900	27500	27100
27″	34″	37600	37000	36300	35700	35100	34500	34000	33400	32900	32400	31900	31400	31000	30500	30100	29700	29300
28″	34″	40500	39800	39100	38400	37800	37200	36600	36000	35400	34800	34300	33800	33300	32800	32400	31900	31500
29″	34″	43400	42600	41900	41200	40500	39900	39200	38600	38000	37400	36800	36300	35700	35200	34700	34200	33800
30″	34″	46400	45600	44800	44100	43400	42600	42000	41300	40700	40000	39400	38800	38200	37700	37100	36600	36100
31″	34″	49600	48700	47900	47100	46300	45500	44800	44100	43400	42800	42200	41500	40800	40200	39700	39200	38600
32″	34″	52800	51900	51000	50200	49300	48500	47700	47000	46200	45500	44800	44200	43500	42900	42300	41700	41100

TABLE No. 9—TRACTIVE POWER OF LOCOMOTIVES WITH BOILER PRESSURE OF 100 LB.

Cylinders		Diameter of Driving Wheels													
Diam.	Stroke	73"	74"	75"	76"	77"	78"	79"	80"	81"	82"	83"	84"	85"	86"
19"	32"	13500	13300	13100	12900	12800	12600	12500	12300	12100	12000	11900	11700	11600	11400
20"	32"	14900	14700	14600	14400	14200	14000	13800	13600	13500	13300	13100	13000	12800	12700
21"	32"	16500	16200	16000	15800	15600	15400	15200	15000	14800	14700	14500	14300	14100	14000
22"	32"	18100	17800	17500	17300	17100	16900	16700	16500	16300	16100	15900	15700	15500	15300
23"	32"	19700	19500	19200	19000	18700	18500	18200	18000	17800	17600	17400	17200	17000	16800
24"	32"	21500	21200	20900	20600	20400	20100	19800	19600	19400	19200	18900	18700	18500	18200
25"	32"	23300	23000	22700	22400	22100	21800	21500	21200	21000	20800	20500	20200	20000	19800
26"	32"	25200	24900	24500	24200	23900	23600	23300	23000	22700	22400	22100	21900	21600	21400
27"	32"	27200	26800	26500	26100	25800	25500	25200	24800	24500	24200	23900	23600	23300	23000
28"	32"	29200	28800	28500	28100	27700	27400	27000	26700	26300	26000	25700	25400	25100	24800
29"	32"	31300	30800	30400	30000	29700	29300	28900	28500	28200	27800	27500	27200	26800	26500
30"	32"	33500	33100	32600	32200	31800	31400	31000	30600	30200	29800	29500	29200	28800	28500
31"	32"	35800	35400	34900	34400	34000	33500	33100	32700	32300	31900	31500	31100	30700	30400
32"	32"	38200	37700	37200	36700	36200	35700	35300	34800	34400	34000	33600	33200	32800	32400
21"	34"	17500	17300	17000	16800	16600	16400	16100	15900	15700	15500	15300	15200	15000	14800
22"	34"	19200	18900	18700	18500	18200	18000	17700	17500	17300	17000	16800	16600	16400	16300
23"	34"	21000	20700	20400	20100	19900	19600	19300	19100	18900	18600	18400	18200	17900	17700
24"	34"	22800	22500	22000	21900	21600	21300	21100	20800	20600	20300	20100	19800	19600	19400
25"	34"	24800	24500	24100	23800	23500	23200	22900	22600	22300	22000	21800	21600	21300	21000
26"	34"	26800	26400	26100	25800	25400	25100	24800	24400	24100	23800	23600	23300	23000	22700
27"	34"	28900	28500	28200	27800	27400	27000	26700	26300	26000	25700	25400	25100	24800	24600
28"	34"	31000	30500	30100	29700	29400	29000	28600	28300	27900	27600	27200	26900	26600	26300
29"	34"	33300	32800	32400	32000	31600	31200	30800	30400	30000	29600	29300	28900	28600	28200
30"	34"	35600	35100	34600	34200	33800	33300	32900	32500	32100	31700	31400	31000	30600	30200
31"	34"	38000	37500	37000	36500	36000	35600	35200	34700	34300	33900	33500	33100	32700	32300
32"	34"	40500	40000	39500	39000	38500	38000	37500	37000	36600	36100	35600	35200	34800	34400

TRACTIVE POWER—COMPOUND ENGINES

T = Tractive power (maximum).
d = Diameter of H. P. cylinder.
D = Diameter of L. P. cylinder.
S = Stroke of piston.
P = Boiler pressure.
C = Constant (taken from Table No. 10).
W = Diameter of driving wheels.
R = Ratio of L. P. to H. P. cylinder volume.

$$T_1 \quad \text{(Two-cylinder compound)} = \frac{D^2\,S\,P\,C}{2\,W}$$

$$T_2 \quad \text{(Four-cylinder compound)} = \frac{D^2\,S\,P\,C}{W}$$

When C = .52 and R = 2.5

T_3 (Two-cylinder compound working simple)

$$= \frac{.85\ d^2SP}{W} = T_1 \times \frac{1.7}{CR} = 1.3T_1$$

T_4 (Four-cylinder compound working simple)

$$= \frac{(2 \times .85)d^2SP}{W} = T_2 \times \frac{1.7}{CR} = 1.3T_2$$

T_3 and T_4 give T when just moving. At slow speeds T working simple will exceed the power working compound by approximately 20 per cent.

For cylinder ratio of approximately 2.5 to 1, as ordinarily used, a constant of 0.52 may be considered as sufficiently accurate for estimates.

On superheater compound engines, in order to properly divide the work between the high and low pressure cylinders, the cut-off in the low-pressure cylinder should be approximately 5 per cent later than the cut-off in the high-pressure cylinder for a cylinder ratio of 2.5 to 1. This difference in cut-off should be reduced for higher cylinder ratios to 0 for a ratio of 2.75 to 1, and increased for lower cylinder ratios to approximately 10 per cent for a ratio of 2.2 to 1.

TABLE No. 10—CONSTANTS ("C")

Per Cent Cut-off H. P. Cylinder	Ratio of L. P. to H. P. Cylinder Volume						
	2.2	2.3	2.4	2.5	2.6	2.7	2.8
90	....	....	.571	.557	.542	.528	.513
89	....	....	.565	.550	.536	.521	.507
88	....	.573	.559	.543	.529	.515	.500
87	....	.567	.552	.537	.523	.509	.494
86	.575	.560	.546	.531	.517	.502	.489
85	.570	.555	.540	.526	.511	.497	.483
84	.564	.550	.534	.520	.506	.491	....
83	.559	.544	.529	.515	.500	.486	....
82	.553	.541	.524	.510	.496	....	....
81	.548	.534	.520	.505	.490	....	....
80	.543	.531	.515	.500	.486	....	....

TRAIN RESISTANCE

By F. J. COLE, Chief Consulting Engineer

How many tons will a locomotive of known proportions pull, or what is its tonnage rating? Many important considerations in railroad transportation, such as size of locomotives, most economical grade, curvature, etc., depend upon the answer to this question.

Figures for freight and passenger car resistance are based on data obtained from Pennsylvania Railroad dynamometer records, Bulletin 26. Figures are also based on well-ballasted, properly maintained first-class track, laid with heavy rails. Greater allowance must be made when track conditions are not so favorable.

The resistance of a car to movement on a straight, level track may be divided into the following components:

(a) Journal friction.

(b) Rolling of the wheel on the rail; track resistance due to compression of the track, concussions; miscellaneous losses due to oscillations and vibrations that absorb energy from which no return can be obtained.

(c) Flange friction due to the pressure of the wheel flange against the rail.

(d) Atmospheric resistance; still air and wind.

In the above component parts it is probable that (a) is fairly constant within certain limitations of speed; that (b) and (c) increase with the speed, also vary materially with the condition of track and stiffness of rail; and that (d) increases as the square of the speed. With heavy rails well supported, good surface and alignment, absence of kinks, properly maintained and gaged, the losses of energy due to (b) and (c) are reduced to a minimum.

Train resistance is usually expressed in pounds per ton (2000 lb.) Under the most favorable conditions it may be as low as 2½ lb. per ton for 80 ton loaded cars; 7 or 8 lb. for empty cars at uniformly slow speeds and 14 to 24 lb. or even more from the moment of start or rest, depending upon the time, temperature, and length of stop. These figures refer only to resistance of cars behind the tender, and for straight and level track. When in combination with grades or uncompensated curves additional amounts must be added.

For grades, the energy required is capable of exact calculation, amounting to 20 lb. per ton (2000 lb.) for each 1 per cent. When expressed in feet per mile, resistance per ton equals rise X 0.37878.

For uncompensated curves, the resistance per degree of curvature is usually taken at 0.8 lb. or equivalent grade of 0.04 per cent.

For the sake of simplicity and greater accuracy the resistance of the engine and tender are considered separately.

ENGINE AND TENDER RESISTANCE

Engine and tender resistance is made up of the following components:

(a) Engine or machine friction is the energy required to overcome the internal machine friction of such parts as driving wheels, pistons, valves, crossheads, etc. This may be taken at 25 lb. per ton of weight on driving wheels for all speeds, track resistance included.

(b) Weight on drivers in tons of 2000 lb. X grade resistance only.

(c) Resistance of engine trucks, both leading and trailing, and tender trucks, assumed to be the same as the cars in the train. The figures may be taken directly from the tables for car resistance.

(d) Head air resistance of engine assumed to be 120 sq. ft. X 0.002 V^2. (See Table No. 12.)

(e) Uncompensated curve resistance may be taken at 1½ pounds per degree per ton of engine.

The sum of the above makes up the total engine and tender resistance which must be deducted from the available tractive power or added to the car resistance.

Example: What drawbar pull back of tender can be exerted by a Mikado superheater freight locomotive 282 S 261 type, 25″ x 30″ cylinders, 64″ driving wheels, and 200 lb. boiler pressure, at 20 miles per hour on a 0.5 per cent grade and compensated curves?

Tractive power (85% boiler pressure) = 49,800 lb.

Weight on drivers.......	101.5 tons
Weight on trucks........	29.0 tons
	130.5 tons
Weight of tender (⅔ load)	63.0 tons
	193.5 tons

TABLE No. 11—RESISTANCE OF FREIGHT CARS AT 5 TO 25 MILES PER HOUR IN POUNDS PER TON ON LEVEL, STRAIGHT TRACK, AND IN COMBINATION WITH VARIOUS GRADES

Per Cent Grade	Resistance due to Grade Only	Total Weight of Cars in Tons of 2000 lb.							
		20	25	30	40	50	60	70	80
Level	0	7.00	5.89	5.13	4.20	3.64	3.27	3.00	2.80
.05	1	8.00	6.89	6.13	5.20	4.64	4.27	4.00	3.80
.10	2	9.00	7.89	7.13	6.20	5.64	5.27	5.00	4.80
.15	3	10.00	8.89	8.13	7.20	6.64	6.27	6.00	5.80
.20	4	11.00	9.89	9.13	8.20	7.64	7.27	7.00	6.80
.25	5	12.00	10.89	10.13	9.20	8.64	8.27	8.00	7.80
.30	6	13.00	11.89	11.13	10.20	9.64	9.27	9.00	8.80
.35	7	14.00	12.89	12.13	11.20	10.64	10.27	10.00	9.80
.40	8	15.00	13.89	13.13	12.20	11.64	11.27	11.00	10.80
.45	9	16.00	14.89	14.13	13.20	12.64	12.27	12.00	11.80
.50	10	17.00	15.89	15.13	14.20	13.64	13.27	13.00	12.80
.55	11	18.00	16.89	16.13	15.20	14.64	14.27	14.00	13.80
.60	12	19.00	17.89	17.13	16.20	15.64	15.27	15.00	14.80
.65	13	20.00	18.89	18.13	17.20	16.64	16.27	16.00	15.80
.70	14	21.00	19.89	19.13	18.20	17.64	17.27	17.00	16.80
.75	15	22.00	20.89	20.13	19.20	18.64	18.27	18.00	17.80
.80	16	23.00	21.89	21.13	20.20	19.64	19.27	19.00	18.80
.85	17	24.00	22.89	22.13	21.20	20.64	20.27	20.00	19.80
.90	18	25.00	23.89	23.13	22.20	21.64	21.27	21.00	20.80
.95	19	26.00	24.89	24.13	23.20	22.64	22.27	22.00	21.80
1.00	20	27.00	25.89	25.13	24.20	23.64	23.27	23.00	22.80
2.00	40	47.00	45.89	45.13	44.20	43.64	43.27	43.00	42.80
3.00	60	67.00	65.89	65.13	64.20	63.64	63.27	63.00	62.80
4.00	80	87.00	85.89	85.13	84.20	83.64	83.27	83.00	82.80
5.00	100	107.00	105.89	105.13	104.20	103.64	103.27	103.00	102.80
6.00	120	127.00	125.89	125.13	124.20	123.64	123.27	123.00	122.80

TABLE No. 12—ENGINE FRICTION AND HEAD AIR RESISTANCE

Tests show that engine friction approximates 25 pounds per ton of weight on drivers and that it is constant at all speeds. Head air resistance $= .002V^2A$, taken at 120 sq. ft.

V = velocity in miles per hour. A = sectional area in square feet (assumed to be 120).

Tons on Drivers	Miles per Hour											
	10	15	20	25	30	35	40	45	50	60	70	80
0	24	54	96	150	216	294	384	486	600	864	1176	1536
10	275	305	345	400	465	545	635	735	850	1115	1425	1785
15	400	430	470	525	590	670	760	860	975	1240	1550	1910
20	525	555	595	650	715	795	885	985	1100	1365	1675	2035
25	650	680	720	775	840	920	1010	1110	1225	1490	1800	2160
30	775	805	845	900	965	1045	1135	1235	1350	1615	1925	2285
35	900	930	970	1025	1090	1170	1260	1360	1475	1740	2050	2410
40	1025	1055	1095	1150	1215	1295	1385	1485	1600	1865	2175	2535
45	1150	1180	1220	1275	1340	1420	1510	1610	1725	1990	2300	2660
50	1275	1305	1345	1400	1465	1545	1635	1735	1850	2115	2425	2785
55	1400	1430	1470	1525	1590	1670	1760	1860	1975	2240	2550	2910
60	1525	1555	1595	1650	1715	1795	1885	1985	2100	2365	2675	3035
65	1650	1680	1720	1775	1840	1920	2010	2110	2225	2490	2800	3160
70	1775	1805	1845	1900	1965	2045	2135	2235	2350	2615	2925	3285
75	1900	1930	1970	2025	2090	2170	2260	2360	2475	2740	3050	3410
80	2025	2055	2095	2150	2215	2295	2385	2485	2600	2865	3175	3535
85	2150	2180	2220	2275	2340	2420	2510	2610	2725	2990	3300	3660
90	2275	2305	2345	2400	2465	2545	2635	2735	2850	3115	3425	3785
100	2525	2555	2595	2650	2715	2795	2885	2985	3100	3365	3675	4035
110	2775	2805	2845	2900	2965	3045	3135	3235	3350	3615	3925	4285
120	3025	3055	3095	3150	3215	3295	3385	3485	3600	3865	4175	4535
130	3275	3305	3345	3400	3465	3545	3635	3735	3850	4115	4425	4785
140	3525	3555	3595	3650	3715	3795	3885	3985	4100	4365	4675	5035
150	3775	3805	3845	3900	3965	4045	4135	4235	4350	4615	4925	5285
160	4025	4055	4095	4150	4215	4295	4385	4485	4600	4865	5175	5535
170	4275	4305	4345	4400	4465	4545	4635	4735	4850	5115	5425	5785
180	4525	4555	4595	4650	4715	4795	4885	4985	5100	5365	5675	6035
190	4775	4805	4845	4900	4965	5045	5135	5235	5350	5615	5925	6285
200	5025	5055	5095	5150	5215	5295	5385	5485	5600	5865	6175	6535

Grade 0.5 per cent = 10 lb. per ton.	
Piston speed = 525 feet per minute.	
Speed factor (Table No. 14) = 0.75.	
Tractive power at 20 M. P. H. = 49,800 × 0.75	= 37,350 lb.
Internal friction = 101.5 × 25.0 = 2,537 lb.	
Grade resistance, drivers 101.5 × 10 . = 1,015 lb.	
Grade resistance, tender and engine trucks = 92 × 10 = 920 lb.	
Rolling friction, tender and engine trucks = 92 × 3.27 = 301 lb. . .	4,773 lb.
	32,577 lb.

Head air resistance when running through still air at 20 M. P. H. is not included in these figures because it amounts to less than 100 lb. Head air resistance for high speeds is a considerable factor; since the amount, varies directly as the square of the velocity, in combination with the small amount of tractive power available back of tender after deducting the energy required for moving the engine and tender.

What tonnage with cars of different weights can be hauled at 20 M. P. H. by the engine described, conditions as in the foregoing example?

Except in the first case, the weight includes the load and the light weight of cars.

20 ton cars empty $\frac{32,577}{7.0+10} = 1,915$ tons

30 ton cars $\frac{32,577}{5.13+10} = 2,150$ tons

40 ton cars	$\frac{32{,}577}{4.20+10}$	= 2,290 tons
50 ton cars	$\frac{32{,}577}{3.64+10}$	= 2,390 tons
60 ton cars	$\frac{32{,}577}{3.27+10}$	= 2,450 tons
70 ton cars	$\frac{32{,}577}{3.0+10}$	= 2,505 tons
80 ton cars	$\frac{32{,}577}{2.8+10}$	= 2,545 tons

In the above, no allowance is made for variations in steam pressure.

PASSENGER CAR RESISTANCE

Passenger car resistance is shown in Table No. 13 for cars varying in weight from 45 to 65 tons. Table No. 13 is derived from formula:

$$R = .85 \left\{ \frac{100}{W} + 1.5 + \frac{V(V+16)}{100\sqrt{W}} \right\}$$

W = weight of car in tons.
V = miles per hour.

The H. P. required per ton for cars at various speeds is given in Tables Nos. 21 and 22, to which must be added the resistance per ton due to curves and for grades.

TABLE No. 13—RESISTANCE OF PASSENGER CARS IN POUNDS PER TON ON LEVEL, STRAIGHT TRACK

Note that the resistance per ton varies with the weight of car. The resistance due to grade can be taken from second column Table No. 11.

Tons per Car	Miles per Hour										
	30	35	40	45	50	55	60	65	70	75	80
45	4.93	5.42	6.00	6.64	7.34	8.11	8.94	9.82	10.79	11.81	12.88
50	4.64	5.12	5.66	6.28	6.94	7.67	8.45	9.30	10.22	11.18	12.22
55	4.40	4.87	5.39	5.97	6.60	7.29	8.05	8.82	9.72	10.64	11.62
60	4.21	4.66	5.15	5.70	6.32	6.96	7.69	8.47	9.30	10.17	11.12
65	4.04	4.46	4.95	5.48	6.07	6.71	7.39	8.13	8.93	9.76	10.67

SPEED FACTORS

Table No. 14 gives the speed factors and horse power in connection with the piston speed for superheated and saturated steam. For superheated steam the average maximum H. P. is reached at 1,000 feet piston speed per minute and is constant at higher speeds. For saturated steam the average maximum H. P. is reached at about 700 feet piston speed per minute, constant H. P. at 700 to 1,000 feet, and then slightly decreasing at higher velocities.

TABLE No. 14—SPEED FACTORS

Figures in tractive power tables are calculated for a piston speed of 250 feet per minute. For other speeds multiply by factors below.

Piston Speed Feet per Minute	Saturated Steam		Superheated Steam	
	Speed Factor	Per Cent of Maximum Horse power	Speed Factor	Per Cent of Maximum Horse power
250	1.000	60.4	1.000	55.6
275	.976	65.1	.976	60.3
300	.954	69.1	.954	64.3
325	.932	73.5	.932	68.0
350	.908	77.2	.908	71.3
375	.886	80.7	.886	74.5
400	.863	83.7	.863	77.6
425	.840	86.4	.840	79.8
450	.817	89.0	.817	82.3
475	.795	91.4	.795	84.4
500	.772	93.5	.772	86.8
525	.750	95.3	.750	88.0
550	.727	96.8	.727	89.5
575	.704	98.0	.704	90.8
600	.680	98.7	.682	92.0
625	.660	99.3	.664	92.8
650	.636	99.7	.643	93.6
675	.614	99.9	.624	94.4
700	.590	100.0	.605	95.2
725	.570	100.0	.588	95.8
750	.550	100.0	.572	96.3
775	.530	100.0	.558	96.9
800	.517	100.0	.542	97.5
850	.487	100.0	.515	98.3
900	.460	100.0	.490	99.3
950	.435	100.0	.467	99.7
1000	.412	100.0	.445	100.0
1100	.372	99.0	.405	100.0
1200	.337	97.8	.371	100.0
1300	.307	96.8	.342	100.0
1400	.283	95.7	.318	100.0
1500	.261	94.7	.297	100.0
1600	.241	93.5	.278	100.0

TABLE No. 15—DATA OBTAINED FROM TRAINS HAULED ON VARIOUS RAILROADS COMPARED WITH FIGURES FROM TABLES

Road, Date, Kind of Train, Location	Tons behind Tender. Per Car	Miles per Hour.. Per Cent of Grade. Curvature	Tractive Power. Maximum. Available	Resistances: Lb. per Ton due to Speed. Grade. Curvature	Resistances: Locomotive: Driving	Resistances: Locomotive: Truck and Tender	Resistances: Cars	Resistances: Total of All	Margin of Power over all Resistance: Lb.	Margin of Power over all Resistance: Per Cent
P. R. R., June 14, 1909. Freight. Altoona to Enola	5953 70	17 0.2% —	45300 45300	3 4 —	2630 420	279 372	17859 23812	45372	—72	—0.16
Virginian Railway, Spring, 1909, Frt., 90 cars, Roanoke to Sewall's Pt.	6858 —	Slow 0.2% —	50350 50350	2.87 4 —	2605 416	333 440	19680 27424	50898	—548	—1.09
Same as above, except 85 cars.	6000 70.5	Slow 0.2% —	50350 50350	3 4 —	2605 416	330 440	18000 24000	45791	4459	8.9
P. R. R., July, 1909, 6 cars. 18-hour train, between Ft. Wayne and Crestline.	360 60	69 — —	23800 7660	9.12 — —	2530 —	970 —	3275 —	6775	885	11.5

TABLE No. 15—DATA OBTAINED FROM TRAINS HAULED ON VARIOUS RAILROADS COMPARED WITH FIGURES FROM TABLES—Continued

Road, Date, Kind of Train, Location	Tons behind Tender. Per Car	Miles per Hour. Per Cent of Grade. Curvature	Tractive Power. Maximum. Available	Resistances: Lb. per Ton due to Speed. Grade. Curvature	Resistances: Locomotive: Driving	Resistances: Locomotive: Truck and Tender	Resistances: Cars	Resistances: Total of All	Margin of Power over all Resistance: Lb.	Margin of Power over all Resistance: Per Cent
N. Y. C., July 24, 1909, 5 cars, 20th Century, Elkhart and Toledo.	314.6 62.9	70.2 — —	29200 8322	9.15 — —	3300 —	1182 —	2876 —	7358	964	11.5
Same as above, except May 23, 1909. 9 cars.	564.2 61.7	60 — —	29200 9870	7.62 — —	2990 —	965 —	4300 —	8255	1615	16.4
Same as above, except 8 cars. Spring, 1909.	505 63.1	62 — —	29200 9630	8.0 — —	3045 —	1025 —	4040 —	8110	1520	15.8
N. Y. C., Aug. 9, 1899. 16 cars. So. West. Ltd., N. Y. to Albany	785 49	50 — 2.0°	27200 10130	7.06 — —	2169 102 2271	505 114 619	5540 1255 6795	9685	445	4.4

TABLE No. 16—PISTON SPEED IN FEET PER MINUTE AT TEN MILES PER HOUR

Wheel Diam.	Revolutions per Mile	Stroke												
		12	14	16	18	20	22	24	26	28	30	32	34	36
30	672.2	224.0	261.1	298.8	336.1	373.4	....	....	....	....	....	....	....	....
31	650.5	216.8	252.9	289.1	325.2	361.3	....	....	....	....	....	....	....	....
32	630.2	210.1	245.0	280.1	315.1	350.1	....	....	....	....	....	....	....	....
33	611.0	203.7	237.6	271.8	305.5	339.3	....	....	....	....	....	....	....	....
34	593.2	197.7	230.6	263.7	296.6	329.5	....	....	....	....	....	....	....	....
35	576.5	192.2	224.1	256.3	288.2	320.2	....	....	....	....	....	....	....	....
36	560.2	186.7	217.8	249.1	280.1	311.1	....	....	....	....	....	....	....	....
37	545.0	181.6	211.4	242.3	272.5	302.7	....	....	....	....	....	....	....	....
38	530.6	176.9	206.3	236.0	265.3	294.6	....	....	....	....	....	....	....	....
39	517.2	172.4	201.1	229.9	258.6	287.3	....	....	....	....	....	....	....	....
40	504.4	168.1	196.2	224.3	252.2	280.1	....	....	....	....	....	....	....	....
41	491.9	163.9	191.2	218.6	245.9	273.3	....	....	....	....	....	....	....	....
42	480.3	160.1	186.7	213.5	240.1	266.8	....	....	....	....	....	....	....	....
43	469.3	156.4	182.5	208.6	234.6	260.7	286.8	312.9	338.9	365.0	391.0	....	....	....
44	458.4	152.8	178.2	203.8	229.2	254.6	280.2	305.6	331.0	356.4	382.0	....	....	....
45	448.2	149.4	174.0	199.2	224.1	249.0	273.9	298.8	323.7	348.6	373.5	....	....	....
46	438.4	146.1	170.4	194.9	219.2	243.5	268.0	292.3	316.6	341.0	365.3	....	....	....
47	429.1	143.0	168.8	190.8	214.5	238.3	262.3	286.1	309.7	333.6	357.5	....	....	....
48	420.1	140.0	163.4	186.8	210.0	233.3	256.7	280.1	303.5	326.8	350.0	....	....	....
49	411.6	137.2	160.1	183.0	205.8	228.6	251.5	274.4	297.2	320.1	343.0	....	....	....
50	403.3	134.4	156.8	179.3	201.6	224.0	246.5	268.9	291.2	313.7	336.0	358.5	380.8	....

TABLE No. 16—PISTON SPEED IN FEET PER MINUTE AT TEN MILES PER HOUR—Continued

Wheel Diam.	Revolutions per Mile	Stroke												
		12	14	16	18	20	22	24	26	28	30	32	34	36
51	395.4	131.8	153.7	175.8	197.7	219.6	241.7	263.6	285.6	307.5	329.5	351.4	373.4	....
52	387.8	129.3	150.8	172.4	193.9	215.4	237.0	258.5	280.1	301.6	323.1	344.7	366.2	....
53	380.5	126.8	147.9	169.2	190.2	211.3	232.6	253.7	274.8	295.9	317.0	338.2	359.3	380.5
54	373.4	124.4	145.6	155.9	186.7	207.5	227.8	249.0	270.4	291.2	311.1	332.8	353.6	373.4
55	366.7	122.4	142.6	163.0	183.3	203.7	224.5	244.5	264.8	285.1	305.5	325.9	346.3	366.7
56	360.1	120.0	140.0	160.0	180.0	200.1	220.1	240.1	260.1	280.1	300.1	320.1	340.1	360.1
57	353.8	117.9	137.5	157.3	176.9	196.5	216.3	235.9	255.5	275.1	294.8	314.5	334.1	353.8
58	347.7	115.9	135.2	154.6	173.8	193.1	212.5	231.8	251.2	270.5	289.8	309.1	328.4	347.7
59	341.8	113.9	132.9	152.0	170.9	189.8	208.9	227.9	246.8	265.8	284.7	303.7	322.7	341.8
60	336.1	112.0	130.7	149.4	168.0	186.7	205.4	224.1	242.7	261.4	280.0	298.7	317.4	336.1
61	330.6	....	....	....	....	....	202.0	220.4	238.7	257.1	275.5	293.8	312.2	330.6
62	325.3	....	....	....	....	....	199.0	217.0	235.0	253.0	271.0	289.2	307.3	325.3
63	320.1	....	....	....	....	....	195.6	213.4	231.1	248.9	266.7	284.5	302.3	320.1
64	315.1	....	....	....	....	....	192.6	210.1	227.6	245.0	262.5	280.0	297.6	315.1
65	310.2	....	....	....	....	....	189.6	206.8	224.0	241.2	258.5	275.7	292.5	310.2
66	305.5	....	....	....	....	....	186.6	203.6	220.6	237.6	254.5	271.5	288.5	305.5
67	301.0	....	....	....	....	....	183.9	200.6	217.3	234.0	250.8	267.5	284.3	301.0
68	296.6	....	....	....	....	....	181.4	197.7	214.2	230.7	247.1	263.6	280.0	296.6
69	292.2	....	....	....	....	....	178.6	194.8	211.0	227.2	243.5	259.7	275.9	292.2
70	288.1	....	....	....	....	....	176.1	192.1	208.1	224.1	240.1	256.1	272.1	288.1
71	284.0	....	....	....	....	....	173.6	189.3	205.1	220.9	236.6	252.4	268.2	284.0

TABLE No. 16—PISTON SPEED IN FEET PER MINUTE AT TEN MILES PER HOUR—Continued

Wheel Diam.	Revolutions per Mile	Stroke												
		12	14	16	18	20	22	24	26	28	30	32	34	36
72	280.1	....	....	....	....	....	171.2	186.7	202.3	217.8	233.4	249.0	264.5	280.1
73	276.2	....	....	....	....	....	168.8	184.1	199.5	214.8	230.2	245.5	260.8	276.2
74	272.5	....	....	....	....	....	166.5	181.7	196.8	211.9	227.1	242.2	257.3	272.5
75	268.9	....	....	....	....	....	164.3	179.3	194.2	209.1	224.1	239.0	253.9	268.9
76	265.3	....	....	....	....	....	162.1	176.9	191.6	206.2	221.0	235.8	250.5	265.3
77	261.9	....	....	....	....	....	160.0	174.6	189.1	203.7	218.0	232.8	247.3	261.9
78	258.5	....	....	....	....	....	158.0	172.3	186.6	201.0	215.4	229.7	243.9	258.5
79	255.3	....	....	....	....	....	156.0	170.2	184.4	198.6	212.7	226.9	241.1	255.3
80	252.1	....	....	....	....	....	154.1	168.1	182.1	196.1	210.1	224.1	238.1	252.1
81	249.0	....	....	....	....	....	152.2	166.0	179.8	193.7	207.5	221.3	235.1	249.0
82	245.9	....	....	....	....	....	150.3	163.9	177.6	191.3	204.9	218.6	232.2	245.9
83	243.0	....	....	....	....	....	148.5	162.0	175.5	189.0	202.5	216.0	229.5	243.0
84	240.1	....	....	....	....	....	146.7	160.1	173.3	186.7	200.0	213.3	226.7	240.1
85	237.3	....	....	....	....	....	145.0	158.2	171.4	184.6	197.7	210.9	224.1	237.3
86	234.5	....	....	....	....	....	143.3	156.3	169.4	182.4	195.4	208.4	221.4	234.5
87	231.8	....	....	....	....	....	141.7	154.5	167.4	180.3	193.2	206.0	218.9	231.8
88	229.2	....	....	....	....	....	140.1	152.8	165.5	178.3	191.0	203.7	216.4	229.2
89	226.6	....	....	....	....	....	138.5	151.1	163.6	176.2	188.8	201.4	214.0	226.6
90	224.1	....	....	....	....	....	136.9	149.4	161.8	174.3	186.7	199.2	211.6	224.1

FOUR AND SIX-WHEEL FREIGHT TRUCKS COMPARED

(Cars fully loaded)

Maximum, minimum and average resistances in pounds per ton for the various classes of gondola cars when fully loaded and operating on level tangent track at a speed of from 10 to 15 miles per hour, are as follows:

Class of Car	Trucks	Size of Journals	Average Weight: Per Car and Lading Tons	Average Weight: Per Axle Lb.	Resistance Pounds per Ton: Maximum	Resistance Pounds per Ton: Minimum	Resistance Pounds per Ton: Average
P.R R.H21...	Four-wheel...	5½x10	81.11	40555	3.55	2.76	3.13
P.R.R.H21a..	Four-wheel...	6 x11	98.47	49235	3.34	2.77	3.05
N. & W. Gka	Six-wheel....	5½x10	121.12	40373	3.36	2.90	3.17

EMPTY FREIGHT CARS

(Four and Six-Wheel Trucks Compared)

Resistances of empty cars having six-wheel trucks of the Gka class, and four-wheel trucks of the H21a class on level tangent track, are as follows:

Class of Car	Light Weight Tons	Resistance Pounds per Ton: Maximum	Resistance Pounds per Ton: Minimum	Resistance Pounds per Ton: Average
N. & W. Ry. Gka........	30.15	7.85	6.75	7.27
P.R.R.H21a.............	25.40	6.01	4.11	5.04

The resistance of the class H21a cars (5.04 lb. per ton) is somewhat lower than for the other cars of about the same weight. These cars were known to be in good running condition.

The resistance of the cars with the six-wheel trucks is higher than for cars of equal weight having four-wheel trucks. This may be due to the greater number of axles per truck.

EFFECT OF A STOP IN INCREASING RESISTANCE

The following figures show the increase in resistance due to the cooling of the car journals at a stop. The average weight of the cars was 72 tons.

Speed Miles per Hour		Air Temperature Degrees F	Resistance Pounds per Ton		Increase in Resistance Per Cent	Time Standing Minutes	Temperature of Dynamometer Car Journal while in Motion Degrees F	
Approaching Tower	Beyond Tower		Before Stop	After Stop			Before Stop	After Stop
13.5	8.2	12	4.05	4.75	18	8	86	70
12.8	7.1	20	3.26	4.05	21	14	101	74
14.0	10.0	29	2.99	3.27	10	14	105	83
10.0	10.0	70	2.99	3.05	2	10 to 15	...	...

The following table shows the resistance in pounds per ton for cars of 72 tons weight over the same stretch of track and at different air temperatures. The speed on these tests was from 10 to 12 miles per hour taken on a 0.3 per cent grade; however, the figures given are based on level tangent track.

Resistance Pounds per Ton	Air Temperature Degrees F	Increase over Summer Resistance Per Cent	Time Standing at Tower Minutes
3.05	70	....	10 to 15
3.27	29	7.2	14
4.05	12	32.0	14

RESISTANCE OF CARS AT STARTING

It is well known that the power required to start a car from rest is very much greater than that required to keep it in motion. This is principally due to the increase in journal friction at starting, and to the acceleration required. Experiments made on machines for testing journal friction indicate that the resistance varies from 14 to 25 and 28, and in one instance to 31 pounds per ton.

In starting freight or passenger trains on the level or where they can be bunched, the high figures indicated do not present a serious problem since the starting of the cars is assisted by the drawbar springs and by the slack in the couplers and drawgear of the cars. For trains on a grade, or for passenger trains where they cannot be bunched, the whole train has to be started at the same time; therefore this question must receive due consideration.

The weight of the car, whether full or partially loaded or empty, temperature of journal and bearing, kind of lubricant used, and duration of stop, are factors which greatly influence the starting resistance of cars per ton.

CURVES

In the United States, railroad curves are usually expressed in degrees and minutes of central angle subtended by a chord of 100 ft.

One degree of curvature is equal to a radius of 5,730 ft., since $5{,}730 \times 2 \times 3.1416 = 360 \times 100$. Usually, the slight error produced by measuring the distance as a straight line instead of an arc may be ignored, except in very sharp curves.

To obtain approximately the radius of a curve in feet, divide 5,730 by the number of degrees.

To obtain degrees, divide 5,730 by the radius in feet.

The slight inaccuracies by this method increase with the sharpness of the curve. Thus, at 10° the actual radius is 0.7 ft. longer; at 20°, 1.4 ft. longer; at 30°, 2.2 ft. longer; and at 40°, 2.95 ft. longer than by the formula.

In the metric system, the radius is less per degree because the chord is 20 meters (65.62 ft.); therefore, in converting to English measurements multiply by 0.6562.

In Great Britain, the radius of a curve is generally taken in chains (66 ft.); therefore, a one degree curve equals 86.818 chains, or 5,730 divided by 66. To obtain radius in chains, divide 86.818 by degrees; or to obtain degrees, divide 86.818 by the radius in chains.

It is sometimes necessary to find the radius of an existing curve on a railroad. To do this, measure a chord of any suitable length in feet and its rise in feet or fractions thereof, see Fig. No. 1. The square of half the chord added to square of the rise divided by twice the rise will equal the radius in feet, thus:

$$R = \frac{\left(\frac{A}{2}\right)^2 + B^2}{2\,B}$$

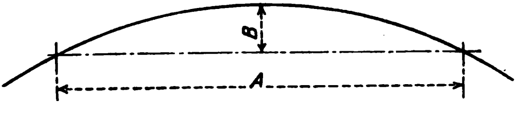


Figure No. 1

One of the most convenient methods of measuring an existing curve is to use a string of say 30 ft. in length, hold it on the inside of the outer rail at the lower edge of the head, and measure at the center the middle ordinate or distance from string to rail head. To insure a fair degree of accuracy, several measurements should be taken at different places. For convenience Table No. 17 is given.

The resistance of curves is usually expressed in pounds per ton per degree of curvature, and is variously estimated by different authorities from 0.50 to 1.72 pounds. More generally, it is taken at 0.80 pounds, equivalent to a grade of 0.04 per cent, and this figure has been taken in these calculations.

TABLE No. 17—MIDDLE ORDINATE (IN FEET) OF CHORD 30 FEET IN LENGTH

Degree of Curvature	Radius in Feet	Middle Ordinate		Degree of Curvature	Radius in Feet	Middle Ordinate	
		Feet	Inches			Feet	Inches
0.5	11460.0	.010	.12	11.0	521.7	.216	2.59
1.0	5730.0	.020	.24	12.0	478.3	.236	2.83
1.5	3820.0	.029	.35	13.0	441.7	.254	3.05
2.0	2865.0	.038	.46	14.0	410.3	.275	3.30
2.5	2292.0	.049	.59	15.0	383.1	.295	3.54
3.0	1910.0	.058	.70	16.0	359.3	.313	3.76
3.5	1637.0	.070	.84	17.0	338.3	.333	4.00
4.0	1433.0	.079	.95	18.0	319.6	.351	4.21
4.5	1274.0	.088	1.06	19.0	302.9	.371	4.45
5.0	1146.0	.099	1.19	20.0	287.9	.392	4.70
5.5	1042.0	.108	1.30	21.0	274.4	.410	4.92
6.0	955.4	.117	1.40	22.0	262.0	.430	5.16
6.5	882.0	.128	1.54	23.0	250.8	.450	5.40
7.0	819.0	.137	1.64	24.0	240.5	.469	5.63
7.5	764.5	.146	1.75	25.0	231.0	.486	5.83
8.0	716.8	.158	1.90	26.0	222.3	.506	6.07
8.5	674.7	.166	1.99	27.0	214.2	.524	6.29
9.0	637.3	.175	2.10	28.0	206.7	.545	6.54
9.5	603.8	.187	2.24	29.0	199.7	.564	6.77
10.0	573.7	.196	2.35	30.0	193.2	.583	7.00

In Table No. 18 the curve resistance and equivalent grades from 1° to 26° are given.

TABLE No. 18—CURVE RESISTANCE
FREIGHT AND PASSENGER CARS

Curve resistance = 0.8 lb. per ton per degree.

Equivalent grade per degree of curvature = 2.11 feet per mile or 0.04 per cent grade.

Degree of Curve	Radius of Curve in Feet	Resistance Lb. Per Ton	Equivalent Grade	
			Per Cent	Feet Per Mile
1	5730	0.80	.04	2.1
2	2865	1.60	.08	4.2
3	1910	2.40	.12	6.3
4	1433	3.20	.16	8.4
5	1146	4.00	.20	10.6
6	955	4.80	.24	12.7
7	819	5.60	.28	14.8
8	717	6.40	.32	16.9
9	637	7.20	.36	19.0
10	574	8.00	.40	21.1
11	522	8.80	.44	23.2
12	478	9.60	.48	25.3
13	442	10.40	.52	27.5
14	410	11.20	.56	29.6
15	383	12.00	.60	31.7
16	359	12.80	.64	33.8
17	338	13.60	.68	35.9
18	320	14.40	.72	38.0
19	303	15.20	.76	40.1
20	288	16.00	.80	42.2
21	274	16.80	.84	44.3
22	262	17.60	.88	46.4
23	251	18.40	.92	48.6
24	240	19.20	.96	50.7
25	231	20.00	1.00	52.8
26	222	20.80	1.04	54.9

From tests shown in P. R. R. Bulletin No. 26, the following conclusions were drawn:

(a) For a freight car weighing 72 tons, inclusive of lading, the resistance per ton per degree of level curve may be as low as 0.10 pounds or as high as 1.75 pounds.

(b) A fair average for curve resistance at low speeds may be taken as 0.8 pounds per ton per degree of level curve.

(c) Thus a curve of one degree offers the same resistance as a grade of 0.04 per cent, a curve of two degrees the same as a grade of 0.08 per cent, etc.

The report of the Committee on Train Resistance and Tonnage Rating of the American Railway Master Mechanics' Association, 1914, states as follows:

> "The resistance of cars due to curvature of track depends on various track and speed conditions, 0.8 lb. per ton per degree being much used. For ordinary track, however, 0.9 lb. per ton per degree will be found correct in a great many cases."

LOCOMOTIVE CURVE RESISTANCE

Resistance of locomotives in passing curves is evidently higher than for cars because of the long driving wheel base, and for the reason that the portion of the weight carried upon the drivers follows other laws than are applicable to freight cars with their short wheel base trucks. It would therefore seem that the curve resistance of locomotives increases materially with the length of rigid wheel base. The data on this subject, however, is very incomplete.

TABLE No. 19—RESISTANCE, POUNDS PER TON PER DEGREE, LEVEL CURVE

Train Passing Completely Over Curve				Train on Curve Only			
Curvature in Degrees	Resistance			Curvature in Degrees	Resistance		
	Maximum	Minimum	Average		Maximum	Minimum	Average
2° 0′	1.54	0.76	1.01	2° 0′	1.16	0.12	0.58
1° 0′	0.98	0.20	0.51	1° 0′	1.22	0.42	0.74
1° 0′	1.68	0.47	0.89	1° 0′	1.74	0.69	1.13
.....	....	....	....	0° 15′	1.32	0.08	0.87
Average			0.80	Average			0.83

The report of the American Railway Master Mechanics' Association Committee on Train Resistance and Tonnage Rating, 1916, states the following:

> "The curve resistance of locomotive (including tender) is also found to vary. For Consolidation locomotives 1.5 lb. per ton per degree will be found nearly correct for average conditions; for locomotives of longer wheel base or having more wheels, the resistance will be greater."

HORSE POWER

It is sometimes convenient to express train resistance in terms of horse power, because in recent locomotive designing the boiler and cylinder H. P. forms the basis for determining the heating surface and the dimensions of the grate required. Therefore, the total H. P. output for engine, tender and train on any grade and at any speed can be compared with the H. P. the

TABLE No. 20—HORSE POWER PER TON (2000 LB.) DUE TO GRADE AND SPEED ONLY

Grade		Miles Per Hour													
Per Cent	Ft. Per Mile	0	5	10	15	20	25	30	35	40	45	50	60	70	80
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
.05	2.6	0	.01	.03	.04	.05	.07	.08	.09	.11	.12	.13	.16	.19	.21
.1	5.3	0	.03	.05	.08	.11	.13	.16	.19	.21	.24	.27	.32	.37	.43
.15	7.9	0	.04	.08	.12	.16	.20	.24	.28	.32	.36	.40	.48	.56	.64
.2	10.6	0	.05	.11	.16	.21	.27	.32	.37	.43	.48	.53	.64	.75	.85
.25	13.2	0	.07	.13	.20	.27	.33	.40	.47	.53	.60	.67	.80	.93	1.07
.3	15.8	0	.08	.16	.24	.32	.40	.48	.56	.64	.72	.80	.96	1.12	1.28
.35	18.4	0	.09	.19	.28	.37	.47	.56	.65	.75	.84	.93	1.12	1.31	1.49
.4	21.1	0	.11	.21	.32	.43	.53	.64	.75	.86	.96	1.07	1.28	1.50	1.71
.45	23.7	0	.12	.24	.36	.48	.60	.72	.84	.96	1.08	1.20	1.44	1.68	1.92
.5	26.4	0	.13	.27	.40	.53	.67	.80	.93	1.07	1.20	1.33	1.60	1.87	2.13
.55	29.1	0	.15	.29	.44	.59	.73	.88	1.03	1.18	1.32	1.47	1.76	2.05	2.35
.6	31.7	0	.16	.32	.48	.64	.80	.96	1.12	1.28	1.44	1.60	1.92	2.24	2.56
.65	34.3	0	.17	.35	.52	.69	.87	1.04	1.21	1.39	1.56	1.73	2.08	2.43	2.78
.7	36.9	0	.18	.37	.56	.75	.93	1.12	1.31	1.49	1.68	1.87	2.24	2.61	2.99
.75	39.6	0	.20	.40	.60	.80	1.00	1.20	1.40	1.60	1.80	2.00	2.40	2.80	3.20
.8	42.2	0	.21	.43	.64	.85	1.07	1.28	1.49	1.71	1.92	2.13	2.56	2.99	3.41
.85	44.9	0	.23	.45	.68	.91	1.13	1.36	1.58	1.82	2.04	2.27	2.72	3.17	3.62
.9	47.5	0	.24	.48	.72	.96	1.20	1.44	1.68	1.92	2.16	2.40	2.88	3.36	3.84
.95	50.2	0	.26	.51	.76	1.01	1.27	1.52	1.77	2.03	2.28	2.54	3.04	3.47	4.05
1	52.8	0	.27	.53	.80	1.07	1.33	1.60	1.87	2.13	2.40	2.67	3.20	3.73	4.27
2	105.6	0	.53	1.07	1.60	2.13	2.66	3.20	3.73	4.26	4.80	5.33	6.40	7.47	8.53
3	158.4	0	.80	1.60	2.40	3.20	4.00	4.80	5.60	6.40	7.20	8.00	9.60	11.20	12.80
4	211.2	0	1.07	2.13	3.20	4.27	5.33	6.40	7.47	8.52	9.60	10.66	12.80	14.93	17.06
5	264.0	0	1.33	2.66	4.00	5.33	6.67	8.00	9.33	10.67	12.00	13.33	16.00	18.67	21.33
6	316.8	0	1.60	3.20	4.80	6.40	8.00	9.60	11.20	12.80	14.40	16.00	19.20	22.40	25.60

The horse power resistance required for movement of cars on level, straight track, must be added to the above figures. Use Table No. 21 for freight cars and Table No. 22 for passenger cars.

cylinders, and what is more important, the boiler, are capable of developing. When the speed and tractive effort are known, the equivalent H. P. will be:

$$\frac{V \times T}{375}$$

where

V = speed in miles per hour.

T = tractive power in pounds at given speed.

The H. P. required per ton for cars at various speeds and grades is given in Tables Nos. 20, 21 and 22.

The available H. P. back of tender is decreased from that obtained from the mean effective pressure because of the energy absorbed by the internal friction of engine and the rolling, grade, and curve friction for engine and tender.

TABLE No. 21—HORSE POWER IN POUNDS PER TON (2000 LB.)—FREIGHT CARS

Tons Per Car	Miles Per Hour				
	5	10	15	20	25
20	.093	.187	.280	.373	.466
25	.079	.157	.235	.314	.393
30	.069	.137	.205	.273	.342
40	.056	.112	.168	.224	.280
50	.049	.097	.145	.194	.242
60	.044	.087	.131	.174	.218
70	.040	.080	.120	.160	.200
80	.037	.075	.112	.150	.187

This table shows the H. P. required per ton for weights from 20 to 80 tons total on level, straight track, and for speeds between 5 to 25 miles per hour. This table does not include resistance due to curves and grades.

TABLE No. 22—HORSE POWER PER TON (2000 LB.) PASSENGER CARS

Tons Per Car	Miles Per Hour							
	30	35	40	45	50	60	70	80
45	.394	.505	.640	.797	.978	1.43	2.03	2.75
50	.371	.477	.604	.754	.925	1.35	1.91	2.61
55	.352	.454	.575	.717	.880	1.29	1.81	2.48
60	.337	.434	.549	.648	.843	1.23	1.74	2.37
65	.324	.416	.528	.658	.810	1.18	1.67	2.28

This table shows the H. P. per ton of passenger cars of 45 to 65 tons in weight on level, straight track at 30 to 80 miles per hour. The table does not include resistance due to curves and grades.

VELOCITY GRADES

A short ruling grade can often be approached at a higher velocity than the average speed. Where 25 to 45 miles per hour can be depended on at critical points, it is possible to haul heavier trains than if the grade is run at a constant speed or dead pull. Suppose a train has a velocity of 35 miles per hour at the bottom of a grade and gradually decreases the velocity until the summit is reached at slow speeds of say 5 to 10 miles per hour. The energy or momentum represented by the difference between the speeds is therefore gradually given out to assist the tractive power of the engine. Under these conditions of relatively high speeds and short up-grades, trains of much heavier weight than would otherwise be possible can be hauled.

The effect of velocity to assist the tractive power of a locomotive in surmounting velocity grades is generally considered from two points of view:

(a) The determination of grades on a new road or the reduction of grades on an old road.
(b) The hauling power or tonnage rating of a locomotive on existing railroads.

The velocity grade reduction in percentage of grade which may be subtracted from the total percentage is:

$$G_1 = 3.5 \frac{V^2 - v^2}{L}$$

Expressed in the number of feet which may be subtracted from the total rise in feet per mile is:

$$F = 184.8 \frac{V^2 - v^2}{L}$$

The decrease in resistance in pounds per ton which may be subtracted from the total resistance is:

$$R = 70 \frac{V^2 - v^2}{L}$$

where

R = number of pounds per ton to be deducted from total resistance.
F = number of feet to be deducted from actual grade.
G_1 = per cent of grade to be deducted from actual grade.
V = initial speed at foot of grade in miles per hour.
v = speed at top of grade in miles per hour.
L = length of grade in feet.

The equivalent grade can be found by deducting G_1 from the actual grade and the tonnage rating calculated accordingly; but the decreased tractive power of the locomotive at higher speeds must be considered, b cause the mean effective pressure in the locomotive cylinders decreases as the piston speed increases.

The length of grade and conditions, such as location of stations, towers, sidings and block signals must be considered, because, if located on the grade or near its foot, they will interfere with its operation as a velocity or momentum grade.

Example: A locomotive hauling a train of nine 60-ton passenger cars, approaches the foot of a 2 per cent grade one mile long at 60 miles per hour and passes the summit at 30 m.p.h. The virtual grade reduction is:

$$G_1 = 3.5 \frac{60^2 - 30^2}{5280} = 1.79 \text{ or } 0.21 \text{ per cent virtual}$$

grade, which is equivalent to 4.2 pounds resistance per ton.

If considered as reduction in feet per mile:

$$F = 184.8 \frac{60^2 - 30^2}{5280} = 94.4 \text{ feet.}$$

Since a 2 per cent grade equals 105.6 feet per mile, the virtual grade is 105.6 — 94.4 = 11.2 feet grade. Resistance = 11.2 × 0.3787 = 4.2 pounds.

For reduction in resistance in pounds per ton:

$$R = 70 \frac{60^2 - 30^2}{5280} = 35.77 \text{ pounds.}$$

The resistance per ton for 2 per cent grade is 40 pounds. Therefore, the virtual resistance will be 40 — 35.77 = 4. 2 pounds.

Force in pounds to accelerate one ton from rest to any speed in a certain number of seconds (including 5 per cent for revolving weights) is:

$$A = 95.6 \frac{V - v}{t}$$

Force in pounds to accelerate one ton from rest to any speed in a certain distance (including 5 per cent for revolving weights) is:

$$A = 70\,\frac{V^2 - v^2}{L}$$

where

A = force of acceleration or deceleration in pounds per ton (2000 lb.)

L = distance in feet through which the force "A" acts.

t = time in seconds.

V = maximum velocity in miles per hour.

v = minimum velocity in miles per hour.

Including 5 per cent for the inertia of revolving weights, 95.6 pounds total force will accelerate or decelerate one ton (2000 lb.) at the rate of 1 m. p. h. in each second. To this must be added or deducted the train resistance per ton for straight, level track, uncompensated curves, grades, etc.

TABLE No. 23—SECONDS REQUIRED TO ACCELERATE FROM REST TO VARIOUS VELOCITIES WITH FORCES VARYING FROM 15 TO 95.6 POUNDS PER TON

Accelerating Force in Lb. Per Ton	Miles Per Hour											
	5	10	15	20	25	30	35	40	50	60	70	80
15	32	64	96	128	159	191	223	255	319	382	446	510
20	24	48	72	96	120	143	167	191	239	286	335	382
25	19	38	57	77	96	115	134	153	191	229	267	306
30	16	32	48	64	80	96	111	127	159	191	223	255
40	12	24	36	48	60	72	84	96	120	143	167	191
50	10	19	29	38	48	57	67	76	96	115	134	153
60	8	16	24	32	40	48	56	64	80	96	112	127
70	7	14	21	27	34	41	48	55	68	82	96	109
80	6	12	18	24	30	36	42	48	60	72	84	96
90	5	11	16	21	27	32	37	43	53	64	75	85
95.6	5	10	15	20	25	30	35	40	50	60	70	80

WEATHER CONDITIONS

Tables of train resistance give the maximum amounts for fair weather conditions, temperature 45° F. and above, with no wind or light winds not exceeding 20 m. p. h. For heavy winds, quartering winds, or decrease in temperature below 45°, allowances must be made.

Cold weather increases journal friction but does not alter materially the other elements of train resistance such as rolling and flange friction, track resistance, and air resistance.

High winds increase head air resistance on exposed parts and in most cases flange friction also, especially when winds are quartering, because the wind pressure forces the wheel flanges hard against the opposite rails.

Obviously the element of grade resistance remains unaffected by either cold weather or high winds.

In cold weather, locomotive efficiency is lower, because with congealed lubricants and cold rubbing surfaces journal friction is higher. Heat losses from the boiler, firebox, cylinders, etc., are much increased but vary with the temperature.

At slow speeds in zero weather, a reduction in tonnage of more than a small percentage may not be necessary because the full horse power of the boiler is seldom used. At high speeds the effect of cold is much more noticeable on account of greater radiation losses and greater demands upon the boiler.

Experiments made on the Illinois Central Railroad by Prof. E. C. Schmidt for the University of Illinois, published in 1912, show a large increase in journal friction in cold weather, and explanations are made owing how the temperature of the journal and aring is related to the resistance on straight and level track. These tests show that journal friction in a temperature of 0° F. of freight cars moving at 10 to 12 m. p. h. is 50 per cent greater than at 70° F. At 20 m. p. h. the resistance was increased by 68 per cent.

Because cold weather adds largely to the train resistance on a straight level track, it does not necessarily follow that a corresponding reduction need be made in tonnage, since the resistance required for grades remains unaffected.

The necessary reduction in tonnage rating will depend upon the physical characteristics of the road. If the road is comparatively level, with or without momentum grades, the reduction necessary for cold weather will be a considerable percentage of the maximum rating. If, on the contrary, the run includes long, heavy grades on which momentum is of little assistance, the percentage of reduction for cold weather will be small, because the resistance on straight and level track (of which journal friction constitutes so large a proportion) is quite small in comparison with resistance due to grade. For general conditions the following is suggested:

Temperature 45° F. and above—light or no winds	100%
Temperature 45° to 25° F. or heavy winds.	92%
Temperature 25° to 0° F.	84%
Temperature 0° F. and below	75%

The effect of head winds is to increase the air pressure. It may be approximated by adding to the velocity of the train the velocity of the wind, and using this figure instead of the speed of the train in the expression $0.002\ V^2\ A$.

For example: If a train is running at 60 m. p. h. with a head wind of 30 m. p. h., it is evident that the air pressure will be 90 m. p. h. In Table No. 12 for Engine Friction and Head Air Resistance, the result may be read directly from the table under the appropriate speeds, as the machine friction does not increase materially with the speed. For an engine having 100 tons on the drivers, the figures would be 3085 pounds for 60 m. p. h.; but if running into a head wind 30 m. p. h., the increased resistance would be 1080, or a total of 4165 pounds.

"A" has been assumed as equal to 120 sq. ft. If the increased pressure due to the velocity of the wind, in addition to the speed of the train, is taken as in the foregoing example, the suggested percentages of reduction may be omitted in good weather. In case of stormy weather and heavy quartering winds a reduction of 8 to 25 per cent from maximum may be required.

TONNAGE RATING

From the foregoing it will be seen that the resistance of a car, either passenger or freight, varies with its weight. For freight cars the resistance per ton may be twice as much when empty as when fully loaded. Before the number of tons which a locomotive will haul can be accurately determined, it is necessary to know the make up of the train as to the number and average weight of the cars. The two principal conditions which affect tonnage rating are (a) weight of cars (loaded, partially loaded or empty), (b) temperature or weather conditions.

From the preceding tables, the loaded resistance per ton may be taken and divided into the drawbar pull available at the limiting points, whether due to grade, ɜed or other service conditions. If the conditions and the average make up of trains were constant, the problem would be simple and need but little more consideration than the data which has been given in the preceding pages; but on account of the variations in the size and weight of cars, whether loaded, partially loaded or empty, it has been found desirable on many of the leading railroads to adopt a method of train loading which consists of assigning a definite number of adjustable tons to a given class of locomotive on a certain division or portion of division. This adjusted tonnage is so arranged that the total resistance of the train is equal for all make up of trains, whether loaded, partially loaded, or empty.

Space in this hand-book is insufficient to discuss this matter in detail. Information on this subject is given in the report of the American Railway Master Mechanics' Association Committee for 1915-1916 on Train Resistance and Tonnage Rating which is largely based on information obtained in the Pennsylvania Railroad Bulletin.

FOREIGN FREIGHT CAR RESISTANCE

(4-Wheeled)

An average resistance of 6 pounds per ton of 2240 lb. (equivalent to 5.36 lb. per ton of 2000 lb.) was obtained from test run on the London & Northwestern Railway. An automatic record was taken of the drawbar pull by means of a dynamometer car behind the engine. The average speed, exclusive of stops, was 16.5 m. p. h. The train consisted of 57 ten-ton capacity coal wagons. The average tare of each wagon was 5.4 tons (6.048 tons of 2000 lbs.) Load 7.44 tons (8.33 tons per 2000 lb.) Journals 4¼ inches and wheels 33 inches diameter. Wheel base 9 feet. Two axles, no trucks.

TABLE No. 24—FOREIGN PASSENGER CARS RESISTANCE IN POUNDS PER TON OF 2000 LB.

(Aspinall's Experiments)

Average weight of cars, 23.5 tons (2000 lb.) 4-wheeled trucks. Oil lubrication. Bodies 49 feet long. Air friction may account for the resistance at high speeds being greater than the latest American tests of passenger cars two or three times their weight.

Number of Coaches	Miles Per Hour						Formulae
	20	30	40	50	60	70	
5	4.48	6.64	9.35	12.55	16.18	20.30	$R=2.5-\frac{V^{\frac{5}{3}} \times 2000}{58.7 \times 2240}$
10	4.24	6.17	8.57	11.43	14.68	18.34	$R=2.5-\frac{V^{\frac{5}{3}} \times 2000}{65.82 \times 2240}$
15	4.04	5.77	7.95	10.52	13.45	16.75	$R=2.5-\frac{V^{\frac{5}{3}} \times 2000}{73.05 \times 2240}$
20	3.88	5.46	7.45	9.81	12.48	15.48	$R=2.5-\frac{V^{\frac{5}{3}} \times 2000}{80.00 \times 2240}$

TABLE No. 25—FOREIGN PASSENGER CARS RESISTANCE IN POUNDS PER TON OF 2000 LB.

(Barbier's Experiments)

Average weight of cars, 11.75 tons of 2000 lb. Two axles, no trucks.

Miles Per Hour						Barbier's Formula for 4-Wheeled Cars
20	30	40	50	60	70	
5.62	7.57	9.95	12.82	16.20	20.10	$\left[3.58+1.658V\left(\frac{1.609V+50}{1000}\right)\right] \times \frac{2000}{2240}$

TRACK RESISTANCE

Upon the correct surfacing, alignment and stiffness of the track depends to a very great degree the elimination of useless oscillations and concussions that absorb energy and from which no return can be made. "Lateral oscillation, especially the kind dampened by friction, is an absorption which forms part of the general resistance." Under this heading may be grouped low joints and irregular surface of the rails, either by kinking or lack of support. Therefore, the items chargeable broadly to track resistance are two, namely:

(a) Deflection of track, requiring the wheels to run always on a grade.

(b) Those which produce concussion and oscillation.

The track which would give apparently the lowest resistance values per ton consists of rails which are true on the surface, which deflect little under the moving load, and are in correct alignment horizontally and vertically.

Regarding the stiffness of the track, Dr. Dudley, in his pamphlet "Condensed Diagrams of the Inspection of the N. Y. C. & H. R. R. R.," 1899, says:

> "On the light 4½-inch, 65 lb. rails, the freight train resistance was 7 to 8 lb. per ton, and is now reduced to 3½ lb. on a 5⅛-inch, 80 lb. rail for the 60,000 lb. capacity cars and long trains. For 80,000 to 100,000 lb. capacity loaded cars it would be still less."

Two or three years later he adds:

> "The great reduction in train resistance in America in the past few years has been due to putting stiffer rails in the track, quite as much as to improvements in rolling stock. In fact the former had permitted the latter."

RESISTANCE OF MALLET LOCOMOTIVES

On a straight track, whether level or on grades, the resistance of Mallet locomotives may be estimated in a similar manner to the figures previously given, but on curves the superiority of the Mallet locomotive will be apparent, since the flexibility due to the articulation of the front engine lessens materially the resistance in passing curves. This difference is most marked when the Mallet engines are compared with other types of large locomotives, such as four and five coupled, having long, rigid wheel bases. Therefore, in estimating the curve resistance of Mallet engines, they should be considered in regard to the length of rigid wheel bases of engines used in similar service.

Mallet engines frequently take the place of two or three ordinary types of locomotives, because the number of driving axles in one unit can be increased without exceeding the limit of axle load. Therefore, the weight available for adhesion is greater, and there is less flange and rolling friction. The total supply of coal and water can be carried in one tender instead of two or three. For these reasons the live tonnage ratings of the Mallets may be increased proportionately.

INFLUENCE OF GAGE

Other things being equal, there is no reason why the resistance of trains on straight track is affected by the difference in the distance apart the rails may be placed; therefore, whether narrow, standard or broad gage is used, the resistance per ton under the stated conditions remains the same.

It is only when we consider curvature that a slight difference in favor of the narrower gages appears, because the closer the rails are placed together the less difference there is in the length of the inner and outer rails for curves of the same radius, and consequently there is less slipping of the wheels. For the same reason sharper curves may be used on narrow gages; also the rolling stock is better adapted for sharp curvature on account of the shorter wheel bases generally used. The data available on curve resistance for narrow gages is far from complete, but in a general way the figures most commonly used indicate that 0.6 pounds per ton per degree, equivalent to a grade of 0.03 per cent, is fairly satisfactory in practice.

TRAIN RESISTANCE OVER FROGS AND SWITCHES

Ordinary rules for train resistance on straight, level track will not apply in connection with ladder tracks in yards or similar purposes, because the switches and frogs offer much greater resistance to the rolling of a car. The recognition of this increased resistance is especially necessary in connection with gravity yards.

From tests in "Rolling Resistance of Cars over Switches and Frogs," by C. L. Eddy, Bulletin, American Railway Engineering Association, March, 1915, it has been ascertained that in a general way the resistance of such ladder tracks varies from 13¾ lb. for a 60-ton gross weight car to 24½ lb. for a 15-ton car. These figures were plotted out from a large number of tests and therefore represent average results. The resistance was found to vary with the weight of the car in a similar manner to the resistance on straight, level track. Also, the temperature has an important bearing on this question, since the resistance is influenced very materially by the journal friction and condition of lubricant. In the report it was suggested that in order to prevent lagging of cars on a gravity track it was desirable to provide for a resistance of 33 pounds per ton, which corresponds to a grade of 1.65 per cent. This provides for adverse winds, low temperature, etc.

SUMMARY

Some general conclusions upon train resistance are as follows:

1. The resistance per ton of freight cars decreases greatly with the increase of weight and capacity: therefore it is economical to use fully loaded large capacity cars. An empty or partially loaded car has a much greater resistance per ton than one fully loaded.

2. The condition of track, alignment—both in vertical and horizontal planes—stiffness of rails, etc., materially affect train resistance because much energy is expended in hauling cars on poor track on account of dampened oscillations causing absorption of energy, and concussions which principally increase flange friction.

3. The decrease in resistance on level, straight track of cars of 50 tons capacity (total about 72 tons) or greater, is of great significance in estimating tonnage ratings on low grade roads. This decrease in resistance becomes of relatively less importance with increase of grade.

4. It has been observed frequently that the resistance of American freight cars is practically the same between the limits of 5 and 25 miles per hour.

5. Journal friction is greatest at starting, then rapidly decreasing and gradually reaching its minimum somewhere around 15 to 20 miles per hour, and afterwards remaining constant or slowly increasing. This condition is influenced materially by weather conditions.

6. Journal friction with good lubrication within the

limits of railroad pressures probably varies inversely as the square root of the pressure.

7. With large capacity loaded cars at freight car speed on good stiff track, journal friction forms a large percentage of freight car resistance.

8. Decrease in temperature causes journal friction to increase. Allowance from full tonnage must be made for cold weather and high winds.

9. Grade resistance is equal to 20 pounds per ton (2000 lb.) for each one per cent. It is unaffected by weather conditions, but the length of grade, if operated by reducing velocity, must be considered.

10. Resistance per degree of curvature in pounds per ton should not be taken at less than 0.08 for standard gage, and 0.06 for narrow gages. For locomotives it varies materially with the length of rigid wheel base.

11. Engine friction should be considered apart from the resistance of cars and estimated from the weight on drivers. The tender and part of the engine supported on trucks or trailing wheels may be taken at the same resistance per ton as cars of approximate weight.

12. Engine friction may be approximated by multiplying the weight on drivers in tons by 25 pounds.

13. The maximum horse power of a saturated steam locomotive is usually reached at about 700 feet piston speed per minute; constant horse power at 700 to 1000 feet piston speed, decreasing slightly at higher speeds with the decrease in the efficiency of the engine. For superheated steam locomotives the maximum horse power is usually reached at 1000 feet piston speed per minute, then constant horse power up to its limitations.

14. The resistance of passenger cars has usually been over-estimated; but the decrease in available power of a locomotive at high speeds, due to the decrease in

mean effective pressure in combination with the energy absorbed in moving the engine and tender generally has been under-estimated.

LOCOMOTIVE RATIOS

By F. J. Cole, Chief Consulting Engineer

The following rules are based on cylinder and boiler horse power and on proper evaporating values being assigned to firebox, tube and flue, arch tube and combustion chamber heating surfaces.

Because the horse power is based on piston speeds, the stroke and diameter of wheels are omitted in the figures. This also eliminates any further regard to the specific service of the locomotive, making this method of proportioning apply equally both to passenger and freight service.

For saturated steam the horse power calculation becomes by cancellation:

$$\frac{.85\,P \times .412 \times 1000 \times 2\,A}{33{,}000} = \frac{1.7\,P \times .412 \times A}{33}$$

$$= .0212 \times P \times A$$

$$H.\,P. = .0212 \times P \times A$$

A = area of one cylinder in square inches.
P = boiler pressure.
.412 = speed factor, Table No. 14.

In a similar manner the horse power calculation for superheated steam becomes:

$$H.\,P. = .0229 \times P \times A$$

Using 0.445 as the speed factor, Table No. 14.

For a given diameter of cylinder and boiler pressure, the horse power may be read directly from the Tables No. 26 and No. 27.

TABLE No. 26—CYLINDER HORSE POWER OF SATURATED LOCOMOTIVES FOR VARYING PRESSURES AND DIAMETERS OF CYLINDERS

Piston speed 700-1000 feet per minute.

H. P. = .0212 x P x A. A = Area of 1 cyl. sq. inches. P = Boiler Pressure.

Diam. of Cylin.	Area	Boiler Pressure													
		150	160	165	170	175	180	185	190	195	200	205	210	215	220
16 ″	201.0	638	680	701	723	744	765	787	808	829	850	871	893	914	935
16½″	213.8	681	726	748	771	794	816	839	861	884	907	929	952	975	998
17 ″	227.0	722	769	794	818	842	866	890	914	938	962	986	1010	1035	1059
17½″	240.5	764	815	840	866	891	917	941	967	993	1018	1043	1069	1095	1121
18 ″	254.5	809	863	889	917	944	971	998	1024	1052	1078	1106	1131	1159	1186
18½″	268.8	855	912	940	969	997	1026	1055	1083	1112	1140	1168	1197	1225	1255
19 ″	283.5	902	962	992	1022	1052	1082	1112	1142	1172	1202	1232	1262	1292	1322
19½″	298.6	948	1010	1043	1074	1106	1138	1170	1201	1233	1264	1296	1327	1359	1391
20 ″	314.0	999	1067	1099	1132	1165	1199	1232	1265	1299	1332	1365	1398	1432	1465
20½″	330.0	1050	1120	1155	1190	1225	1260	1295	1330	1365	1400	1435	1470	1505	1540
21 ″	346.3	1103	1176	1213	1250	1286	1323	1360	1397	1434	1470	1506	1543	1580	1617
21½″	363.0	1157	1236	1273	1311	1350	1388	1427	1465	1504	1542	1581	1620	1650	1695
22 ″	380.0	1211	1291	1332	1371	1412	1452	1493	1533	1574	1614	1655	1695	1735	1766
22½″	397.6	1264	1348	1390	1433	1475	1517	1560	1601	1645	1686	1727	1770	1812	1856
23 ″	415.5	1323	1410	1455	1500	1543	1587	1631	1675	1720	1764	1807	1853	1896	1940
23½″	433.7	1380	1472	1518	1564	1610	1656	1703	1748	1795	1840	1886	1932	1978	2025
24 ″	452.4	1440	1536	1584	1632	1680	1728	1776	1824	1872	1920	1967	2015	2063	2110
24½″	471.4	1500	1600	1650	1700	1750	1800	1850	1900	1950	2000	2050	2100	2150	2200
25 ″	490.9	1562	1665	1718	1770	1822	1874	1926	1978	2030	2082	2134	2187	2238	2290
25½″	510.7	1627	1734	1788	1842	1896	1950	2005	2059	2112	2168	2222	2275	2330	2386
26 ″	530.9	1689	1803	1858	1915	1971	2027	2084	2140	2197	2252	2310	2365	2421	2478
26½″	551.5	1754	1870	1928	1986	2045	2104	2151	2220	2280	2338	2397	2455	2512	2572
27 ″	572.5	1821	1942	2002	2063	2125	2185	2247	2308	2368	2428	2489	2550	2610	2671
27½″	594.0	1888	2012	2075	2139	2201	2265	2327	2390	2453	2516	2580	2642	2703	2766
28 ″	615.8	1957	2088	2152	2218	2283	2348	2415	2480	2545	2610	2674	2740	2805	2871
28½″	637.9	2025	2160	2228	2295	2362	2430	2498	2565	2632	2700	2768	2836	2901	2970
29 ″	660.5	2100	2240	2310	2380	2450	2520	2590	2660	2730	2800	2870	2940	3010	3080
29½″	683.5	2172	2318	2390	2462	2535	2608	2680	2752	2825	2898	2970	3040	3115	3185
30 ″	706.9	2250	2400	2475	2550	2625	2700	2775	2850	2925	3000	3075	3150	3225	3300

TABLE No. 27—CYLINDER HORSE POWER OF SUPERHEATED LOCOMOTIVES FOR VARYING PRESSURES AND DIAMETERS OF CYLINDERS

Piston speed 1000 feet per minute.

H. P. = .0229 x P x A. A = Area of 1 cyl. sq. inches. P = Boiler Pressure.

Diam. of Cylin.	Area	Boiler Pressure													
		150	160	165	170	175	180	185	190	195	200	205	210	215	220
16 "	201.0	691	737	760	783	806	830	853	876	900	922	945	968	991	1014
16½ "	213.8	735	784	808	833	857	882	906	931	955	980	1004	1029	1053	1078
17 "	227.0	780	832	858	884	910	936	962	988	1014	1040	1066	1092	1118	1144
17½ "	240.5	826	881	909	936	964	991	1018	1047	1074	1102	1129	1157	1184	1212
18 "	254.5	875	933	962	991	1020	1049	1078	1107	1136	1166	1195	1224	1253	1283
18½ "	268.8	924	986	1016	1047	1078	1109	1139	1170	1201	1232	1263	1294	1325	1355
19 "	283.5	975	1040	1073	1105	1138	1170	1202	1235	1267	1300	1332	1365	1397	1430
19½ "	298.6	1025	1093	1128	1162	1196	1230	1264	1297	1332	1368	1402	1436	1470	1505
20 "	314.2	1081	1153	1189	1225	1261	1297	1333	1369	1406	1442	1478	1514	1550	1586
20½ "	330.0	1136	1212	1248	1287	1325	1363	1400	1438	1476	1514	1552	1590	1628	1666
21 "	346.3	1191	1270	1310	1350	1390	1429	1469	1509	1549	1588	1628	1667	1707	1747
21½ "	363.0	1248	1331	1372	1414	1456	1497	1538	1580	1622	1664	1705	1747	1788	1830
22 "	380.0	1306	1394	1436	1481	1524	1568	1612	1655	1698	1742	1786	1829	1872	1916
22½ "	397.6	1367	1458	1503	1549	1594	1640	1685	1731	1776	1822	1867	1913	1958	2004
23 "	415.5	1428	1523	1570	1618	1666	1714	1761	1809	1856	1904	1951	1999	2046	2094
23½ "	433.7	1492	1592	1642	1692	1741	1791	1841	1891	1940	1990	2040	2099	2139	2189
24 "	452.4	1557	1661	1713	1765	1817	1868	1920	1972	2024	2076	2128	2180	2232	2284
24½ "	471.4	1623	1731	1785	1839	1893	1948	2002	2056	2110	2164	2218	2272	2326	2380
25 "	490.9	1689	1802	1858	1914	1970	2027	2083	2139	2195	2252	2308	2365	2421	2477
25½ "	510.7	1757	1874	1932	1991	2050	2108	2166	2225	2283	2342	2400	2459	2517	2576
26 "	530.9	1825	1947	2009	2069	2130	2190	2251	2312	2372	2434	2494	2556	2616	2677
26½ "	551.5	1896	2022	2086	2149	2212	2275	2339	2402	2465	2528	2591	2654	2717	2780
27 "	572.5	1968	2099	2165	2230	2296	2362	2427	2493	2558	2624	2690	2755	2820	2886
27½ "	594.0	2043	2179	2247	2315	2383	2452	2520	2588	2656	2724	2792	2860	2928	2996
28 "	615.8	2118	2259	2330	2400	2471	2542	2613	2683	2754	2824	2895	2965	3036	3106
28½ "	637.9	2195	2341	2414	2487	2560	2633	2706	2780	2853	2926	3000	3072	3145	3219
29 "	660.6	2273	2424	2500	2576	2651	2727	2802	2878	2954	3030	3102	3182	3257	3333
29½ "	683.5	2352	2509	2587	2666	2744	2822	2900	2979	3059	3136	3215	3293	3375	3450
30 "	706.9	2433	2595	2676	2757	2838	2920	3000	3082	3163	3244	3325	3406	3487	3568

When the locomotive is operated under the most favorable conditions the maximum horse power can sometimes be increased to a greater amount than given. It is considered safer and better practice to take figures which represent average conditions rather than the abnormal and unusual figures obtained when all conditions are most favorable.

The horse power basis affords many additional advantages in designing locomotives. For instance, in determining the maximum amount of water and coal required per hour, the size of the grate naturally follows along after the amount of coal is determined, to be varied according to the quality that can be burned to the best advantage. Knowing the amount of coal required to be supplied to the firebox per hour, directs attention to the question of hand firing or the use of a mechanical stoker. Knowing the amount of water evaporated per hour determines the location of water stations, size of tender and tank, and also forms the basis for other features of the boiler such as stack, size of injectors, safety valve capacity, and the size of steam pipes.

From the reports of Pennsylvania Railroad testing plant at St. Louis and Altoona, various road tests made under different conditions, and reports of Dr. Goss, the conclusion is reached that a horse power can be obtained from 25 to 29 lb. of saturated steam in simple cylinders with piston speeds of 700 to 1000 feet per minute. A fair average value has been taken as 27 lb., and in a corresponding way 20.8 lb. for steam superheated 200° and over. These figures provide steam for auxiliaries. The evaporation of combined firebox and tube heating surface in a locomotive boiler having 2¼-inch tubes, 18 feet long, spaced ⅝ inch, is taken at 13⅜ pounds of water per square foot per hour. While careful tests show that the evaporation can be increased under the most advantageous conditions to 14¾ or 15 lb., or more per hour with high degrees of smokebox vacuum, it is considered better practice to take the lower figure in order to provide a margin for average conditions.

Short tubes have much greater evaporative value per square foot of heating surface than long tubes, but they discharge the gases into the smokebox at much higher temperatures. Therefore, while the heat absorbed per foot of length is much greater for short than long tubes, it is not so economical, and the short tube boiler, other things being equal, requires more coal for a given evaporation. Where tube lengths of 12 or 14 feet were common fourteen or fifteen years ago, lengths of 20, 22 and even 24 feet are used in the modern engine of to-day. The result is that the smokebox temperatures have decreased from about 750 to 800 degrees, to 550 to 600 degrees, the only increase of energy required being the slightly greater draft in the smokebox to pull the gases through the long tubes. This is not intended as a defense of the long tubes in modern engines, especially of the 462, 482, and other types, because in most cases their construction requires long boilers. Nevertheless it can be shown by tests that economy results from the better utilization of coal in the modern engine than in older types, as the range of temperatures at which the engine works, that is, the difference between the temperature of the furnace and that of the stack with the long tube locomotive is greater.

EVAPORATIVE VALUES—TUBES, FLUES AND FIREBOX

Equated evaporative values in pounds per square foot of outside heating surface are given in Table

TABLE No. 28—EVAPORATION FROM TUBES AND FLUES IN LB. OR STEAM PER HR. PER SQ. FT. OUTSIDE SERVICE

Length in Feet	2″ Tubes							
	Spacing							
	9/16″	5/8″	11/16″	3/4″	13/16″	7/8″	15/16″	1″
10	11.10	11.45	11.78	12.08	12.37	12.63	12.90	13.12
10½	10.87	11.22	11.55	11.85	12.13	12.38	12.65	12.87
11	10.65	11.00	11.32	11.62	11.90	12.13	12.41	12.61
11½	10.45	10.78	11.10	11.40	11.67	11.90	12.17	12.37
12	10.25	10.57	10.89	11.18	11.45	11.68	11.94	12.13
12½	10.05	10.37	10.68	10.97	11.23	11.46	11.71	11.90
13	9.86	10.17	10.47	10.76	11.02	11.24	11.49	11.68
13½	9.68	9.98	10.27	10.56	10.81	11.03	11.27	11.46
14	9.50	9.80	10.08	10.36	10.60	10.82	11.06	11.24
14½	9.33	9.62	9.89	10.16	10.40	10.62	10.85	11.03
15	9.16	9.44	9.70	9.97	10.21	10.42	10.65	10.82
15½	9.00	9.27	9.53	9.78	10.02	10.23	10.45	10.63
16	8.85	9.10	9.36	9.60	9.83	10.05	10.26	10.44
16½	8.69	8.94	9.19	9.42	9.65	9.87	10.07	10.25
17	8.54	8.78	9.03	9.27	9.48	9.69	9.89	10.07
17½	8.38	8.62	8.87	9.11	9.31	9.52	9.71	9.89
18	8.23	8.47	8.71	8.95	9.15	9.35	9.54	9.72
18½	8.07	8.32	8.55	8.79	8.99	9.13	9.37	9.55
19	7.92	8.18	8.40	8.63	8.83	9.02	9.20	9.38
19½	7.77	8.04	8.25	8.47	8.67	8.83	9.04	9.21
20	7.65	7.90	8.10	8.32	8.51	8.70	8.88	9.05
21	7.36	7.63	7.82	8.02	8.20	8.40	8.56	8.73
22	....	....	....	....	....	....	....	....
23	....	....	....	....	....	....	....	....
24	....	....	....	....	....	....	....	....
25	....	....	....	....	....	....	....	....

Length in Feet	2¼″ Tubes						
	Spacing						
	5/8″	11/16″	3/4″	13/16″	7/8″	15/16″	1″
10	12.06	12.36	12.62	12.88	13.12	13.35	13.55
10½	11.81	12.13	12.38	12.64	12.86	13.19	13.30
11	11.57	11.90	12.15	12.40	12.61	12.84	13.05
11½	11.36	11.67	11.92	12.17	12.38	12.60	12.81
12	11.16	11.45	11.70	11.95	12.16	12.37	12.57
12½	11.96	11.25	11.49	11.73	11.94	12.15	12.34
13	10.77	11.05	11.28	11.52	11.72	11.93	12.12
13½	10.58	10.85	11.08	11.31	11.51	11.71	11.90
14	10.39	10.66	10.88	11.10	11.30	11.50	11.69
14½	10.20	10.47	10.70	10.90	11.11	11.30	11.49
15	10.02	10.29	10.51	10.70	10.92	11.10	11.29
15½	9.83	10.11	10.33	10.51	10.73	10.91	11.09
16	9.67	9.93	10.15	10.33	10.55	10.72	10.90
16½	9.50	9.76	9.97	10.15	10.37	10.53	10.71
17	9.34	9.59	9.80	9.98	10.19	10.34	10.53
17½	9.18	9.43	9.63	9.82	10.02	10.17	10.35
18	9.03	9.27	9.46	9.66	9.85	10.00	10.18
18½	8.88	9.11	9.29	9.48	9.68	9.83	10.01
19	8.73	8.96	9.12	9.30	9.51	9.66	9.84
19½	8.58	8.80	8.97	9.15	9.34	9.50	9.68
20	8.44	8.66	8.83	9.00	9.18	9.34	9.51
21	8.15	8.38	8.55	8.73	8.89	9.03	9.19
22	7.90	8.11	8.28	8.45	8.61	8.76	8.90
23	7.66	7.86	8.03	8.20	8.35	8.49	8.62
24	7.42	7.61	7.78	7.95	8.08	8.22	8.35
25	7.20	7.40	7.55	7.70	7.85	7.98	8.10

Length in Feet	5½ and 5⅜″ Flues						
	Spacing						
	5/8″	11/16″	3/4″	13/16″	7/8″	15/16″	1″
10	13.62	13.70	13.78	13.85	13.93	14.00	14.08
10½	13.39	13.47	13.54	13.61	13.69	13.76	13.84
11	13.16	13.24	13.31	13.38	13.45	13.53	13.60
11½	12.94	13.02	13.09	13.16	13.22	13.30	13.37
12	12.72	12.80	12.87	12.94	13.00	13.07	13.15
12½	12.51	12.59	12.65	12.72	12.78	12.85	12.92
13	12.30	12.38	12.44	12.50	12.57	12.63	12.70
13½	12.10	12.17	12.24	12.30	12.37	12.43	12.50
14	11.90	11.97	12.04	12.10	12.17	12.23	12.30
14½	11.71	11.78	11.84	11.91	11.97	12.03	12.10
15	11.53	11.59	11.65	11.72	11.78	11.84	11.90
15½	11.35	11.51	11.46	11.53	11.59	11.65	11.71
16	11.17	11.23	11.28	11.35	11.40	11.46	11.52
16½	10.99	11.05	11.11	11.17	11.23	11.28	11.34
17	10.82	10.88	10.94	11.00	11.06	11.11	11.16
17½	10.65	10.71	10.77	10.83	10.89	10.94	10.99
18	10.49	10.55	10.60	10.66	10.72	10.77	10.82
18½	10.33	10.39	10.44	10.50	10.56	10.61	10.66
19	10.17	10.23	10.29	10.35	10.40	10.45	10.51
19½	10.02	10.08	10.14	10.20	10.25	10.30	10.36
20	9.88	9.94	10.00	10.05	10.10	10.16	10.22
21	9.60	9.66	9.72	9.77	9.83	9.87	9.94
22	9.33	9.39	9.44	9.50	9.55	9.58	9.66
23	9.08	9.13	9.18	9.24	9.29	9.32	9.38
24	8.83	8.89	8.94	8.99	9.04	9.08	9.12
25	8.60	8.65	8.70	8.75	8.80	8.85	8.90

No. 28 for tubes 2 and 2¼ inches in diameter and superheater flues 5⅜ and 5½ inches in diameter. The range of length is 10 to 25 feet, and spacing ⅝ inch to 1 inch. By extending the Coatesville evaporation tests beyond the figures obtained when the firebox and tube evaporation were taken separately, 9.97 lb. of water evaporated per hour per square foot of outside tube heating surface, and 54.8 lb. per hour per square foot of firebox heating surface were obtained. These, for the sake of eliminating unimportant fractions, were taken at 10 lb. for tube heating surface and 55 lb. for firebox heating surface. Values for heating surfaces for different outside diameters of tubes and flues are given in Table No. 29.

Best available data shows that the evaporative value of tubes or flues varies with differences in length, diameter and spacing. The rate of evaporation on this basis will vary directly as the difference of temperature of the gases passing through the tubes and flues and that of the steam contained in the boiler. The base figure taken is 10 lb. of water per hour per square foot of outside heating surface of 2¼-inch tubes 18 feet long.

Equated values for 2-inch tubes from 10 to 21 feet in length and spaced ⅝ inch to 1 inch apart, are based on the theory that the degree of evaporative efficiency due to difference in diameter, because of their smaller cross-sectional area, may be taken proportionately to the difference in heating surface; or expressed differently, no loss or gain occurs within the range of locomotive practice between 2 inch and 2¼ inch O. D. tubes, and the figured gain for heating surface of 2-inch tubes is decreased in porportion to their cross-sectional area.

In equating the tube spacing, half the difference in the loss or gain of heating surface on a given tube

TABLE No. 29—HEATING SURFACE OF TUBES, OUTSIDE (IN SQUARE FEET)

Outside Diameter of Tubes	Circum. in Ins.	Feet (in Length) 7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1½"	4.712	2.749	3.142	3.534	3.927	4.319	4.712	5.105	5.497	5.890	6.283	6 676	7.068	7.461	7.854	8.247	8.640
1¾"	5.497	3.207	3.665	4.123	4.582	5.040	5.498	5.956	6.414	6.872	7.330	7.789	8.247	8.705	9.163	9.621	10.079
2	6.283	3.665	4.189	4.712	5.236	5.760	6.283	6.807	7.330	7.854	8.378	8 901	9.425	9.948	10.472	10.995	11.519
2¼"	7.068	4.123	4.712	5.301	5.890	6.480	7.069	7.658	8.247	8.836	9.425	10.014	10.603	11.192	11.781	12.370	12.959
2½"	7.854	4.581	5.236	5.890	6.545	7.199	7.854	8.508	9.163	9.817	10.472	11.127	11.781	12.435	13.090	13.744	14.399
5	15.708	9.163	10.472	11.781	13.090	14.399	15.708	17.017	18.326	19.635	20.944	22.253	23.562	24.871	26.180	27.489	28.798
5¼"	16.493	9.621	10.995	12.370	13.744	15.119	16.493	17.868	19.242	20.617	21.991	23.366	24.740	26.114	27.489	28.863	30.238
5⅜"	16.886	9.850	11.257	12.665	14.072	15.479	16.886	18.293	19.700	21.108	22.515	23.922	25.329	26.736	28.143	29.550	30.958
5½"	17.279	10.079	11.519	12.959	14.399	15.839	17.279	18.719	20.159	21.599	23.038	24.478	25.918	27.358	28.798	30.238	31.678

Outside Diameter of Tubes	Feet (in Length) 23	24	25	Inches (in Length) ¼	½	¾	1	2	3	4	5	6	7	8	9	10	11	12
1½"	9.033	9.424	9.818	.008	.016	.024	.033	.065	.098	.131	.164	.196	.229	.262	.295	.327	.360	.393
1¾"	10.537	10.996	11.454	.009	.019	.029	.038	.076	.115	.153	.191	.229	.267	.305	.344	.382	.420	.458
2 "	12.042	12.565	13.090	.011	.022	.033	.044	.087	.131	.175	.218	.262	.305	.349	.393	.436	.480	.524
2¼"	13.548	14.139	14.726	.012	.024	.037	.049	.098	.147	.196	.245	.295	.344	.393	.442	.491	.540	.589
2½"	15.053	15.708	16.364	.014	.027	.041	.055	.109	.164	.218	.273	.327	.382	.436	.491	.545	.600	.655
5 "	30.107	31.416	32.725	.027	.054	.082	.109	.218	.327	.436	.545	.654	.763	.873	.982	1.091	1.200	1.309
5¼"	31.612	32.986	34.361	.029	.057	.086	.114	.229	.344	.458	.573	.687	.802	.916	1.031	1.145	1.260	1.370
5⅜"	32.365	33.772	35.179	.029	.058	.088	.117	.235	.352	.469	.586	.704	.821	.938	1.055	1.173	1.290	1.407
5½"	33.118	34.558	35.998	.030	.060	.090	.120	.240	.360	.480	.600	.720	.840	.960	1.080	1.200	1.320	1.440

sheet area has been taken as affecting the value of the tube for evaporation. For instance: The percentage of loss of heating surface in spacing 2-inch tubes 1 inch, in comparison with ¾ inch, is 16 per cent. See Table No. 30, ratios of heating surface to diameter and spacing of tubes. Because of the better circulation of water and freer discharge of steam, the actual heating surface is not in proportion to the actual amount lost. Half the difference, or 8 per cent, has therefore been taken as the amount of equated heating surface lost, and this amount has been used in preparing Table No. 28.

TABLE No. 30—RATIOS OF OUTSIDE HEATING SURFACE TO DIAMETER AND SPACING OF TUBES

This table shows the effect of changes in tube diameter and spacing in relation to heating surface. Unity is expressed by 2-inch O. D. tubes spaced ¾ inches apart. For comparison, if 2¼-inch tubes were spaced 1-inch, 80.6 per cent heating surface would be obtained.

Space between Tubes	Diameter of Tubes				
	1½"	1¾"	2"	2¼"	2½"
⅜"	1.611	1.466	1.341	1.238	1.144
7/16"	1.509	1.379	1.271	1.177	1.096
½"	1.418	1.307	1.210	1.125	1.050
9/16"	1.332	1.238	1.150	1.077	1.010
⅝"	1.256	1.173	1.097	1.029	.968
11/16"	1.184	1.111	1.047	.986	.930
¾"	1.120	1.059	1.000	.945	.895
13/16"	1.061	1.006	.957	.909	.860
⅞"	1.005	.963	.915	.871	.830
15/16"	.953	.916	.877	.837	.799
1"	.907	.875	.840	.806	.772
1 1/16"	.863	.837	.808	.774	.742
1⅛"	.825	.801	.774	.747	.719
1 3/16"	.785	.767	.744	.719	.696
1¼"	.750	.735	.716	.694	.672
1 5/16"	.718	.707	.688	.670	.652
1⅜"	.686	.678	.664	.647	.630
1 7/16"	.658	.651	.639	.626	.613
1½"	.630	.627	.617	.605	.591

"Tube spacing," as referred to, means the space between the tubes or flues proper. This should not be confused with the tube and flue bridges on the tube sheet, which may differ from the spacing because of swedging.

Tube spacing depends principally upon the quality of feed water. A spacing of 19/32 inch for 2-inch tubes 21 feet long has been successfully used in good water districts, but can hardly be recommended for bad water. The tube spacing most generally used and representing average conditions is 3/4 inch, increasing to 7/8 inch, 15/16 inch, 1 inch or more in bad water districts, and decreasing to 11/16 inch or even 5/8 inch in good water districts and for short flues.

GRATE AREA

Grate area required for bituminous coal is based on the assumption that 120 lb. of coal per square foot of grate per hour is a maximum figure for economical evaporation. While 200 and 225 pounds have at times been burnt in small, deep fireboxes and the engines made to produce sufficient steam, it is wasteful of fuel and it has been found, after numerous and careful tests, that the evaporation per pound of coal under these conditions is very low. If, on the other hand, the rate of combustion is too slow, economical results will not be produced owing to the fact that at least 20 per cent of the coal burned produces no useful work in hauling trains, but is consumed in firing up, waiting at round houses or terminals, on side tracks, or to the fact that the greater portion of the time locomotives are used at considerably less than their maximum power.

An evaporation per hour of 6 3/4 lb. of water per pound of bituminous coal has been assumed as a fair average value. It has already been shown that a horse power can be obtained from 27 lb. of saturated steam. Therefore, 27 divided by 6¾ equals 4 lb. of coal per horse power hour for saturated steam locomotives.

Maximum rate of combustion is taken at 120 lb. per square foot of grate per hour with coal of good quality, containing say 14,000 B. T. U. The grate surface required will equal H. P. times 4 divided by 120, or by cancellation dividing the H. P. directly by 30.00 for saturated steam.

For hard coal, the grates should be proportioned for a range of from 55 to 70 lb. of coal per square foot per hour according to the grade of the fuel.

SUPERHEATED STEAM

When steam is superheated 200 degrees or more, the volume is largely increased and the cylinder condensation decreased. For temperatures and pressures ordinarily used for superheater locomotives, the saving in weight of steam due to these two causes may be conservatively taken at 23 per cent. Therefore, the boiler may be proportioned with 23 per cent less evaporating heating surface than for saturated steam. With saturated steam a horse power can be obtained from 27 pounds of steam. The steam consumption for superheated steam then becomes 27 lb. less 23 per cent or 20.8 lb. per H. P. hour. This figure, 20.8 lb. per H. P. hour, is consistent with results obtained in actual tests of superheater locomotives. As some heat is absorbed in superheating the steam, the fuel saving has been assumed to be equal to 18.75 per cent. With saturated steam a horse power hour requires 4 lb. of coal. With superheated steam, 4 lb. less 18.75 per cent equals 3.25 lb. of coal per H. P. hour.

$$\text{Grate area} = \frac{\text{H. P.} \times 3.25}{120} = \frac{\text{H. P.}}{36.9}$$

$$\text{Total steam used per hour} = \text{H. P.} \times 20.8 \text{ lb.}$$
$$\text{Total coal burned per hour} = \text{H. P.} \times 3.25 \text{ lb.}$$

BOILER CAPACITY

The most desirable proportion of boiler capacity to aim for is 100 per cent, making the boiler and cylinder horse power equal, but on account of the difficulty of obtaining the full amount of heating surface in locomotives of light and moderate weight, it may be necessary to accept something below these figures. For heavy engines, the 100 per cent figures may be readily obtained. If there is a surplus of heating surface; for instance, if the calculated figures are 105 per cent; it would be optional whether the cylinder proportions should not be increased and the factor of adhesion reduced, provided there is sufficient weight on drivers. This would seem desirable in case the factor of adhesion was very high, say 4.75 and over, with good quality coal and favorable conditions generally.

It must be remembered, however, that the boiler capacity for a locomotive cannot generally be made too large within the permissible limits of weight, and it can be shown by numerous tests, especially by Dr. Goss' investigations, that such increase in boiler capacity makes for considerable economy in the use of fuel and steam. For passenger service, the boilers may often be made with advantage over 100 per cent.

In a general way, a boiler will have ample steam making capacity if proportioned by the tables for 100 per cent, provided the grate is sufficiently large and deep so that the rate of combustion at maximum horse power does not exceed 120 lb. per square foot of grate per hour of bituminous coal of average quality. For gas coal a smaller grate may be used, but it is better practice to use the larger grate and brick off a portion at the front end in order to obtain sufficient volume of firebox for proper combustion, because nearly all large modern locomotives are deficient in firebox volume.

The method of proportioning described has been used by the American Locomotive Company for the last six years in all their locomotive designing. Numerous road tests, laboratory tests, and records of engines in service have been investigated and carefully checked with the ratios. These six years of service have so thoroughly proven the consistency of the method that it has been adopted as this company's standard.

OIL BURNERS

Locomotives for burning oil should be designed with the same proportions of heating surfaces, grate, etc., as for bituminous coal. Many locomotives in service designed for coal have demonstrated themselves to be perfectly satisfactory for oil, the oil is burnt under good conditions and the evaporation is high as oil has a greater heating value than coal. Advantage is also gained in the possible conversion of the engines into coal burners without sacrificing any of their steaming qualities. Conversion may sometime be required as the supply of oil may be exhausted in certain localities, or the engines may be transferred to other divisions.

SWITCHING ENGINES

For switching engines, which are not used in road or transfer service, the maximum H. P. is rarely developed, because a piston speed of 700 feet per minute is seldom reached. Therefore, the percentage of heating surface may be decreased. It is economical to use large boilers to obtain the necessary weight, spacing the flues relatively further apart.

RECAPITULATION

HORSE POWER

May be read directly from Tables No. 26 and No. 27.
Saturated Steam Table No. 26.
Superheated Steam Table No. 27
or calculated from

H. P. = .02120 × P × A—saturated steam.
H. P. = .02290 × P × A—superheated steam.
P = boiler pressure, pounds per sq. inch.
A = area of one cylinder diameter.

Maximum H. P. assumed to be reached at the following piston speeds:

Saturated steam—700 feet per minute.
Superheated steam—1000 feet per minute.

STEAM

Amount per hour
H. P. × 27.0 lb.—saturated steam.
H. P. × 20.8 lb.—superheated steam.

EVAPORATION

Pounds per sq. ft. of heating surface per hour:

Firebox—55 lb. per sq. ft.
Combustion chamber—55 lb. per sq. ft.
Firebox water tubes—55 lb. per sq. ft.

2-inch tubes, 18 ft. long, 15/16-inch spaces, 9.54 lb.—base figure.

2¼-inch tubes, 18 ft. long, 15/16-inch spaces, 10.00 lb.—base figure.

(Equated for spacing and length.)
For tabulated values, see Table No. 28.

COAL

Quantity burned per hour:
H. P. × 4.00 lb.—saturated steam.
H. P. × 3.25 lb.—superheated steam.

GRATE AREA

Grate area required:
H. P. divided by 30.00—saturated steam.
H. P. divided by 36.90—superheated steam.
or calculated from
Total coal divided by 120.

CONDENSED METHOD OF USING LOCOMOTIVE RATIOS

(a) From weight limitation on drivers, and from service, type, etc., obtain the required tractive power.

(b) From tractive power, boiler pressure, stroke, and size of driving wheels, obtain diameter of cylinder. Ascertain horse power from diameter of cylinder and boiler pressure. See Tables No. 26 and No. 27.

(c) Estimate total steam per hour from:
H. P. × 27.0 lb.—saturated steam.
H. P. × 20.8 lb.—superheated steam.

(d) Estimate total coal per hour from:
H. P. × 4.00 lb.—saturated steam.
H. P. × 3.25 lb.—superheated steam.

(e) Ascertain size of grate from total coal divided by 120 or H. P. divided by
30.00 for saturated steam.
36.90 for superheated steam.

(f) The evaporation of the firebox equals firebox heating surface × 55 lb. per square foot per hour. If combustion chamber or arch tubes are used, add their heating surface to the firebox.

(g) Subtract (f) from (c) to obtain tube and flue evaporation required.

(h) Obtain evaporative value of each tube or flue for length, diameter and spacing. Subtract total flue evaporation from (g) if boiler has superheater, and divide remainder by value for each tube to obtain number required. See Table No. 28.

(i) To obtain percentage of boiler divide total pounds of steam proposed boiler will evaporate by pounds of steam required.

(j) When the proportions of existing boilers are desired for comparison with their engine cylinder horse power, or with other boilers, the evaporative value of the tubes can be obtained by multiplying their outside heating surface in square feet by the value in Table No. 28 for length, diameter and spacing.

EXAMPLE

A Pacific (462 type) with 150,000 lb. on driving wheels, 200 lb. boiler pressure, SATURATED STEAM, 75-inch drivers, 28-inch stroke, simple cylinders.

Assuming 33,600 lb. tractive power, factor of adhesion equals 150,000 divided by 33,600 or 4.46.

$$\text{Diameter of cylinder} = \sqrt[2]{\frac{33{,}600 \times 75}{.85 \times 200 \times 28}} = 23$$

or direct from tables of tractive power.

Horse power from Table No. 26 = 1764

Total steam per hour = 1764 × 27 = 47,630 lb.

Total coal per hour = 1764 × 4 = 7056 lb.

Grate area in sq. ft. = 1764 ÷ 30 = 58.8 sq. ft.

Firebox, assumed 212 sq. ft., evaporation at 55 lb. 11,660 lb.

Leaving to be evaporated by tubes 35,970 l

Surface of one 2-inch tube, 20 ft. long, after deducting for tube sheets = 10.423 sq. ft.

Tubes 2 inches diameter, 20 feet long, spaced ¾ inch—rate of evaporation = 8.32.

Evaporation for each tube = 10.423 × 8.32 = 86.7.

Number of tubes required = 35,970 ÷ 86.7 = 415.

EXAMPLE

A Pacific (462 type) with 150,000 lb. on drivers, 200 lb. boiler pressure, SUPERHEATED STEAM, 75-inch drivers, 28-inch stroke, simple cylinders.

Assuming 33,600 lb. tractive power, factor of adhesion equals 150,000 divided by 33,600 or 4.46.

$$\text{Diameter of cylinder} = \sqrt[2]{\frac{33{,}600 \times 75}{.85 \times 200 \times 28}} = 23$$

or direct from tables of tractive power.

Horse power from Table No. 27 = 1904

Total steam per hour = 1904 × 20.8 = 39,600 lb.

Total coal per hour = 1904 × 3.25 = 6188 lb.

Grate area in sq. ft. = 1904 ÷ 36.90 = 51.6 sq. ft.

Firebox, assumed 212 sq. ft., evaporation at 55 lb.	11,660 lb.
Leaving to be evaporated by tubes and flues	27,940 lb.

Tubes 2 inches diam., 20 feet long, spaced ¾ inch—rate of evaporation = 8.32.

Flues 5⅜ inch diam., 20 feet long, spaced ¾ inch—rate of evaporation = 10.00.

Surface of one 2-inch tube, after deducting for tube sheets = 10.423 sq. ft.

Surface of one 5⅜-inch flue, after deducting for tube sheets = 28.011 sq. ft.

Assuming 30, 5⅜-inch flues, the evaporation is 30 × 28.011 × 10.00 = 8403 lb.

27,940 — 8,403 = 19,537 lb. for tubes to evaporate.
Number of tubes = 19,537 ÷ (10.423 × 8.32) = 225.

INFLUENCE OF WEIGHT

Satisfactory proportions of heating surface are obtained easier in heavy than in light engines of the same class. This is owing to the fact that a large number of details, as cabs, couplers, boiler fittings, brakes, and a number of other items do not vary in direct proportion to the total weight of the engine. The greater portion of any increase in weight being due to increased boiler capacity.

TABLE No. 31—BOILER TUBES
RELATION OF DIAMETER TO LENGTH

For bituminous coal burning engines the preferred ratio of tube length to the sectional area of tube outside, is from 70 to 73.

Outside Diameter of Tube	Length corresponding to Ratio of: 70	Length corresponding to Ratio of: 73
2"	18′ — 4″	19′ — 1″
2¼″	23′ — 2″	24′ — 2″
2½″	28′ — 7″	29′ — 10″

TABLE No. 32—WEIGHT OF TUBES

Weight for tubes is calculated on the basis of one cubic inch of steel weighing 0.2833 lb., one cubic inch of brass weighing 0.303 lb., and one cubic inch of copper weighing 0.320 lb.

Weight of water (cubic feet) — 62.33 lb. at atmospheric pressure, 62°; 54.4 lb. at 200 lb. gage pressure, 388°.

O D	Thickness		Area Sq. In.		Weight lb. per Foot of Water Displaced		Weight Per Foot		
	B. W G.	Inch	Ext.	Int.	Atmos. Press. 62°	200 lb. Press. 388°	Seamless Steel	Brass	Copper
1¼"	15	.072	1.23	.96	.533	.465	.91	.98	1.03
	14	.083		.92			1.03	1.11	1.17
	13	.095		.88			1.17	1.25	1.32
	12	.109		.83			1.33	1.43	1.51
	11	.12		.80			1.45	1.55	1.64
1⅜"	13	.095	1.49	1.10	.646	.563	1.30	1.39	1.47
	12	.109		1.05			1.47	1.58	1.66
	11	.12		1.01			1.61	1.73	1.82
	10	.134		.96			1.78	1.91	2.02
	9	.148		.91			1.94	2.08	2.20
1 7/16"	13	.095	1.62	1.22	.703	.612	1.36	1.46	1.54
	12	.109		1.17			1.55	1.66	1.76
	11	.12		1.13			1.69	1.81	1.91
	10	.134		1.07			1.87	2.00	2.12
	9	.148		1.02			2.04	2.19	2.31
1½"	13	.095	1.77	1.35	.767	.669	1.43	1.53	1.62
	12	.109		1.29			1.62	1.74	1.84
	11	.12		1.25			1.77	1.90	2.01
	10	.134		1.19			1.96	2.10	2.22
1¾"	13	.095	2.41	1.91	1.041	.908	1.68	1.80	1.91
	12	.109		1.84			1.91	2.05	2.16
	11	.12		1.79			2.09	2.24	2.37
	10	.134		1.73			2.31	2.48	2.62
2"	13	.095	3.14	2.57	1.361	1.187	1.93	2.07	2.19
	12	.109		2.49			2.20	2.36	2.50
	11	.12		2.43			2.41	2.58	2.73
	10	.134		2.36			2.67	2.86	3.03
2¼"	12	.109	3.98	3.24	1.727	1.507	2.49	2.67	2.82
	11	.12		3.17			2.73	2.93	3.10
	10	.134		3.09			3.03	3.25	3.43
2½"	11	.12	4.9	4.00	2.13	1.857	3.05	3.27	3.46
	10	.134		3.91			3.39	3.63	3.84
	9	.148		3.81			3.72	3.98	4.22
5"	9	.148	19.64	17.38	8.50	7.42	7.67	8.22	8.68
		5/32		17.26			8.08	8.66	9.15
		3/16		16.80			9.64	10.33	10.90
5¼"	9	.148	21.64	19.28	9.37	8.17	8.07	8.65	9.14
		5/32		19.15			8.50	9.10	9.62
		3/16		18.67			10.14	10.86	11.47
5⅜"	9	.148	22.69	20.26	9.82	8.57	8.26	8.85	9.35
		5/32		20.13			8.71	9.33	9.85
		3/16		19.64			10.39	11.12	11.73
5½"	9	.148	23.76	21.27	10.28	8.98	8.46	9.07	9.57
		5/32		21.14			8.92	9.56	10.10
		3/16		20.63			10.64	11.40	12.05

CALCULATIONS FOR BOILER AS ADOPTED BY THE AMERICAN LOCOMOTIVE COMPANY

EFFICIENCY OF LONGITUDINAL SEAMS

As the ordinary longitudinal seam is divided into a certain number of equal rivet pitches, for convenience in figuring only one pitch or section is considered. Therefore when the pitches are uniform throughout the length of the sheet the efficiency of the seam will be the same as the efficiency of one pitch.

As a basis for calculation, assume an ultimate tensile strength of 55,000 lb. per sq. inch in the shell plates and welt strips, and an ultimate shearing strength of 40,000 lb. per sq. inch in the plate or rivets.

As it is difficult to give a formula that will govern all conditions that may come up in different seams, the figures and method given are for obtaining the efficiency of seam as shown by the following sketch, and by using this method the efficiency of seams of any pitch, thickness of sheet, or size of rivets can be determined.

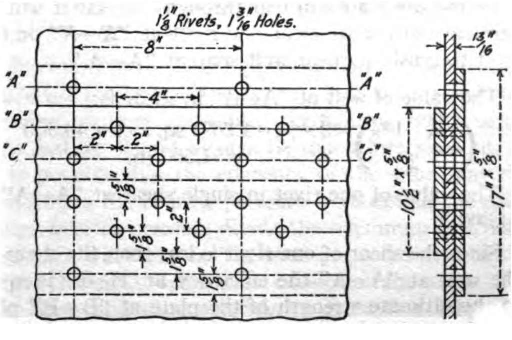


Figure No. 2

The value of rivet in single shear is:

$$1.1075 \times 40{,}000 = 44{,}300 \text{ lb.}$$

With a pitch of 8" and a thickness of shell sheet of 13/16" the ultimate strength of solid plate is:

$$8 \times 13/16'' \times 55{,}000 = 357{,}500 \text{ lb.}$$

Let the point "A—A" marked on the sketch be the outer row of rivets.

At "A—A" we have an area to resist tearing equal to 8" minus the diameter of one riveted hole multiplied by the thickness of the plate or $(8 - 1\frac{3}{16}) \times 13/16 = 5.535$ sq. inches.

$5.535 \times 55{,}000 = 304{,}400$ lb. the ultimate strength at "A—A."

Let "B—B" be the middle row of rivets.

At "B—B" we have an area to resist tearing equal to 8" minus the diameter of two rivet holes multiplied by the thickness of plate or $(8 - 2\frac{3}{8}) \times 13/16 = 4.5703$ sq. inches.

$4.5703 \times 55{,}000 = 251{,}400$ lb. the ultimate strength of plate at "B—B."

Before the plate can tear through "B—B" it will be necessary either to shear one rivet at "A—A" or the rivet to crush or shear welt strip at "A—A."

The value of welt at "A—A" in shear is:

$$\left(\frac{1\frac{5}{8} - 1\frac{3}{16}}{2}\right) \times 2 \times \frac{5}{8} = 1.2891 \text{ sq. inch} \times 40{,}000 = 51{,}560 \text{ lb.}$$

The value of one rivet in single shear at "A—A" is 44,300 lb.

Since the shear of one rivet is less than the shear of the welt at "A—A" the efficiency at "B—B" is equal to the ultimate strength of the plate at "B—B" plus the shear of one rivet or 251,400 lb. plus 44,300 lb. = 295,700 lb.

The strength of plate through "C—C" is the same as the strength of plate through "B—B" and in addition it is necessary to shear out both the inside and outside welts or five rivets in single shear. The seam therefore is evidently stronger at "C—C" than at "B—B."

The efficiency at "A—A" is equal to the strength at "A—A" divided by the strength of solid plate or 304,400 divided by 357,500 = 85.2%.

The efficiency at "B—B" is equal to the maximum strength at "B—B" divided by the strength of solid plate or 295,700 divided by 357,500 = 82.6%.

The seam may also fail by shearing all the rivets. We have four (4) rivets in double shear and one (1) in single shear. Four (4) rivets in double shear = 354,400 lb. One (1) rivet in single shear = 44,300 lb.

Total value of rivets in shear = 398,700 lb.

Therefore the efficiency of the rivets will be:
398,700 divided by 357,500 = 111.4%.

The minimum efficiency of the seam therefore would be at "B—B" or 82.6%.

In regard to the bearing pressure on rivets; on A. L. Co.'s std. seams 14,000 lb. per sq. inch is the maximum bearing pressure allowable. In figuring boiler seams this feature should always be taken into account, as it is possible that the efficiency of the seam may depend upon the bearing pressure. To obtain the maximum bearing pressure divide the maximum load that the seam will carry by the total projected area of the rivets through the shell plate of one-half the seam. For the seam above considered, we have five (5) rivets through the 13/16" plate on which the bearing for the total load of one rivet pitch must come. Thus for a factor of safety of 4.5 in the above seam the maximum load is 295,700 divided by 4.5=65,700 lb.

$$\frac{65700}{5\times13/16\times1\frac{3}{16}}=13600 \text{ lb. maximum bearing pressure on rivets.}$$

STRESSES IN STAYBOLTS AND CROWN STAYS

To obtain the fiber stress in staybolts and radial stays the following method is used:

The area supported by one staybolt or radial stay is obtained by multiplying the pitch in one direction by the pitch in the other direction measured on the firebox sheet. The cross sectional area of staybolt is not deducted from the supported surface, it being assumed that the reduction of strength due to the tell-tale hole is approximately offset by the reduction of net area due to the area of the staybolt itself. This area multiplied by the boiler pressure gives the load on one staybolt or radial stay.

The fibre stress in that stay is equal to the load as obtained above divided by the least net area. This least net area is in the body or at the root of the thread as the case may be.

COMBUSTION CHAMBER

Area to be braced on throat and for the portion below the tube sheet follow the rules for backhead.

BACKHEAD BRACING

For backhead bracing the area to be stayed by the backhead longitudinal braces is obtained as follows:

A line is taken one inch below the point from which the radius of the back head flange is struck, and also to two inches from the center of the nearest row of staybolts. The area thus inclosed is considered as being supported by the backhead longitudinal braces. The load on the total number of braces is equal to this area multiplied by the boiler pressure. The braces should be as evenly distributed as possible and the load on each brace is considered as equal to the total load divided by the total number of braces.

The feet for braces to back head and front tube sheet should be distributed so as not to concentrate the stress on any one section. Preferably a portion of the brace feet on the second course from the back head or front tube sheet. Usually the diagonal should be within 10 or 12 degrees. The increased stress due to the diagonal of bracing need not be considered when the angle does not exceed 15 degrees.

In figuring the longitudinal braces, the fiber stress of all parts in tension, the pins in shear and the rivets in sheer or tension are considered; also the bearing value of the pins and brace eyes and rivets. While the tee iron riveted to the back head adds something to the bracing, this is not considered. This method is based on supporting the total load by the longitudinal braces.

When gusset braces are used, divide the area of the backhead braced into sections supported by each gusset. The fiber stress in each gusset is obtained by dividing the load on each separate section by the least area of that gusset.

FRONT TUBE SHEET BRACING

Braced area for front tube sheet to extend three and one-half inches from outside of flange, and two inches from outside of nearest tubes. Compute area to vertical center line of boiler (that is, each side separately) and deduct one-eighth area of outside diameter of dry pipe ring when there is sufficient space for crowfoot below the tube sheet ring. Deduct one-sixth area of outside diameter of dry pipe ring when there is not sufficient space for crowfoot.

Concentrate braces as much as possible at lower ends of tees and around dry pipe ring.

SHEARING STRESS ON RIVETS

The shearing stress on rivets in pounds per sq. inch can be calculated by using the following formula:

$$S = \frac{D \times P \times K}{2 \times N \times A}$$

S = Shearing stress on rivets in pounds per sq. inch.
D = Inside diameter of boiler.
P = Working pressure.
K = Pitch of rivets in inches.
N = Number of rivets to be sheared per pitch length of seam.
A = Area of rivet.

For example we will consider the lap riveted joint as shown by the following sketch and assuming a working pressure of 185 lb. per sq. inch and the inside diameter of boiler to be 65½".

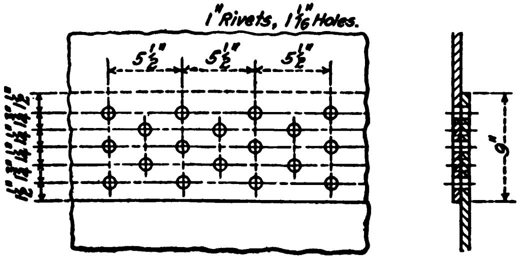


Figure No. 3

For this seam we have the following values to substitute in the formula:

D = 65.5
P = 185
K = 5½
N = 5 (All rivets being in single shear.)
A = .8866. (Area of 1 1/16 hole.)

Substituting in the formula we have:

$$S = \frac{65.5 \times 185 \times 5.5}{2 \times 5 \times .8866} = 7520 \text{ lb. per sq. inch.}$$

For another example we will consider the butt riveted joint as shown by the following sketch:

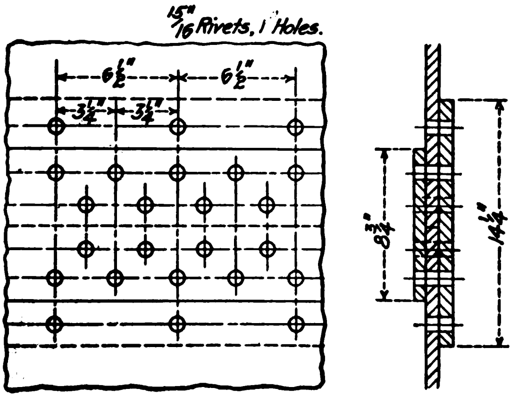


Figure No. 4

For this seam we have the following values to substitute in the formula:

D = 65.5
P = 185
K = $6\frac{1}{2}$
N = 9 (One rivet in single shear and 4 in double shear.)
A = .7854 (Area of 1" hole.)

Then substituting in formula we have:

$$S = \frac{65.5 \times 185 \times 6.5}{2 \times 9 \times .7854} = 5570 \text{ lb. per sq. inch.}$$

TENSION ON NET SECTION OF PLATE

The tension on net section of plate in pounds per sq. inch may be calculated by the following formula:

$$T = \frac{P \times D.}{2 \times E \times A.}$$

T = Tension on net section in pounds per sq. inch.
P = Working pressure.
E = Efficiency of seam.
A = Area of solid plate per lineal inch.
D = Maximum inside diameter of any course of the boiler shell.

COUNTERBALANCING

FROM REPORT OF THE PROCEEDINGS OF THE AMERICAN RAILWAY MASTER MECHANICS' ASSOCIATION, 1915.

GENERALLY ACCEPTED RULES AND PRINCIPLES

The reciprocating parts to be considered in counterbalancing are: piston head, rod and nut; cross-head, cross-head key, pin and nuts; approximately one-half the total weight of the main rod; arm and link fastened to cross-head for outside valve gear.

Each driving wheel should have sufficient weight added to counterbalance exactly the weight of its revolving parts, which are: crank pin, crank pin hub, and the proportion of the weight of the side rods attached to the pin. The main driving wheel should have added approximately one-half the total weight of the main rod, plus two-thirds the weight of the eccentric arm, considered acting at crank pin distance, for outside valve gear.

Cross-counterbalancing, to correct the disturbances caused by the parts revolving in different planes, is thought to be unnecessary with outside cylinders, on account of the disturbing forces being slight when compared to the principal reciprocating and centrifugal forces.

The overbalance which is used to counteract the desired portion of the weight of the reciprocating parts should be distributed as nearly equally as possible among all driving wheels, adding to it the weight of the revolving parts for each wheel. This sum for each wheel, if placed at a distance from the driving wheel center equal to the length of the crank, or a proportionally less weight if at a greater distance, will be the counterbalance required.

Centrifugal and reciprocating forces are usually figured at a speed in miles per hour equal to the diameter of the driving wheel in inches, which may be considered as a maximum for good practice. This is ordinarily referred to as "diameter-speed." At this speed the reciprocating parts, due to the laws of inertia, tend to continue their motion at the end of each stroke with a force about equal to 40 times their weight. *The overbalance exerts a centrifugal force

*The dynamic augment varies with the stroke.

equal to about 40 times its weight, and is at a maximum at the top and bottom position of the crank. This force is added to the static weight in the lower position of the overbalance, and is opposed to this weight in the upper position. Approximately one-fortieth of the static weight on a wheel will therefore give the weight of the reciprocating parts which could be balanced without causing the wheel to rise from the track at diameter-speed. This amount of balance would also double the load on the rail when the balance is down.

If W = overbalance or excess weight at one-half stroke distance, then the dynamic augment at different strokes is as follows:

Stroke Inches	Dynamic Augment
18	29.1 x W at diameter speed
20	32.3 x W at diameter speed
22	35.5 x W at diameter speed
24	38.5 x W at diameter speed
26	41.7 x W at diameter speed
28	44.9 x W at diameter speed
30	48.4 x W at diameter speed
32	51.7 x W at diameter speed
34	54.9 x W at diameter speed

A simple counterbalancing rule, expressed in general terms, which should give good average results when applied to any class of locomotives in any service, might be stated as follows:

Keep the total weight of the reciprocating parts on each side of the locomotive below 1-160 part of the total weight of the locomotive in working order, and then balance one-half the weight of the reciprocating parts.

The above general rule is based upon diameter-speed, and should keep the dynamic augment well within the limits of good practice. Where the normal speed is regularly considerably below the diameter-speed, it may be desirable to increase the proportion of the reciprocating weights to be balanced to as much as 60 per cent or 65 per cent.

Another counterbalancing rule is, to set an arbitrary percentage which the dynamic force of the overbalance will be allowed to increase the static weight; for example:

If it is desired that the dynamic force of the overbalance at a speed in miles per hour equal to the diameter of the driving wheel in inches, should not increase the static weight on a wheel more than 50 per cent, calculations should be made as follows:

442 type locomotive with 26 in. stroke.

Given: Static weight on one wheel = 30,000 lb.

To find: Maximum permissible weight of reciprocating parts to be balanced in one wheel = W.

$$W = \frac{\text{50 per cent static weight on one wheel} \times .312.}{\text{Crank radius in inches.}}$$

$$W = \frac{15000 \times .312}{13} = 360 \text{ lb.}$$

Therefore: The total reciprocating weight to be balanced on one side of this locomotive would be 720 lb. With 50 per cent of the total reciprocating parts balanced on one side, the total weight of these parts must be designed to weigh 1440 lb.

The converse of this is:

Given: Weight of reciprocating parts balanced in one wheel, W = 360 lb.

To find: Dynamic augment = A.

$A = W \times 3.2 \times \text{crank radius in inches.}$

$A = 360 \times 3.2 \times 13 = 15000$ lb.

Therefore: 15000 lb. dynamic weight is added to the 30000 lb. static weight, giving a total of 45000 lb. on the rail.

The dynamic augment may be expressed in percentage of the static weight on one driving wheel.

Your committee believes that 50 per cent increase in the static weight on the driver at diameter-speed would represent good average practice, while much less than this percentage is greatly to be desired.

Your committee concludes, therefore, that the secret of proper counterbalancing for any class of locomotive in any service is to reduce the weight of the reciprocating parts as far as possible.

Great benefit will be obtained if the railroads will determine the maximum load that they can carry on the rails, bridges, etc., and then reduce the weight of the reciprocating parts to a point where the dynamic augment of the parts balanced will be only a small proportion of this maximum allowed load.

Special designs of piston heads, cross-heads, hollow piston rods, and the use of high grade materials, including heat-treated carbon and alloy steel, aluminum, etc., make it possible to construct very light parts, the expense of which will be many times justified by the consequent saving in repairs to equipment and track, as well as the saving due to the increase in tractive power of the locomotive. With a refinement of design along these lines, it is altogether possible to construct reciprocating parts approaching in lightness 1/240 part of the total weight of the locomotive in working order, instead of 1/160 part as expressed in the previously mentioned general rule representing a fair average. With an increased tendency toward these very light parts, the percentage of parts balanced or unbalanced becomes less and less a factor. Greater efficiency is thus given to the locomotive, in that more and more of the weight allowable on the rail will be used in starting and pulling the train.

FUEL OIL

There are two kinds of oil or petroleum, one having parafine base and the other asphaltum base. Either may be used as fuel in its crude state, but both are largely distilled in order to obtain the more volatile oils, such as gasoline, benzine, kerosene, etc. The residue is called Fuel Oil and is used in every class of service where coal, coke, wood or gas can be used.

The analysis of Fuel Oil is as follows:

Carbon	84.35%
Hydrogen	11.33%
Oxygen	2.82%
Nitrogen	.60%
Sulphur	.90%

Gravity, from 26 to 28 Baume.
Weight per gallon, 7.3 lb.
Vaporizing point, 130 deg. Fahr.
Calorific Value varies from 18,350 to 19,348 B. T. U. per lb.

Analysis of Beaumont (Texas) Crude Oil:

Carbon	84.60%
Hydrogen	10.90%
Sulphur	1.63%
Oxygen	2.87%

Gravity, 21 Baume.
Weight per gallon, 7.5 lb.
Calorific value, 19,060 B. T. U. per lb.
Vaporizing point, 142 deg. Fahr.

Analysis of California Crude Oil (heavy oils):

Carbon	81.52%
Hydrogen	11.01%
Sulphur	.55%
Nitrogen, Oxygen	6.92%

Gravity varies from 12 to 36 Baume.
Weight per gallon, 7.6 lb.
Calorific value varies from 18,462 to 20,680 B. T. U. per lb.
Vaporizing point, 230 deg. Fahr.

Analysis of Mexican Crude Oil (Tampico Fields).

Carbon	82.83%
Hydrogen	12.19%
Oxygen	.43%
Nitrogen	1.72%
Sulphur	2.83%

Gravity varies from 12 to 23.8 Baume.
Weight per gallon, 7.82 lb.
Calorific value, 18,493 B. T. U. per lb.
Vaporizing point, 175 deg. Fahr.

The crude oil of Russia, Roumania and Borneo has approximately the same calorific value as that of the Beaumont fields in Texas, while the oil thus far discovered in Argentine Republic, Chile and Peru, is of approximately the same calorific value and gravity as the California petroleum.

Oil tar is a by-product of the water gas system used in numerous gas works. Coal tar is a by-product from coke oven benches. When either of these tars is heated sufficiently to reduce their viscosity, they are a most excellent fuel. Per pound their calorific value less than that of oil but as they weigh from 9.5 to

10 lb. per gallon, while fuel oil only weighs 7.3 lb. per gallon, their calorific value per gallon is greater than that of fuel oil. Oil tar has a calorific value of 16,970 B. T. U. per lb. or 161,200 B. T. U. per gallon, while that of coal tar is 16,260 B. T. U. per lb. or 162,600 B. T. U. per gallon.

Analysis of London Tar and Tar from Dominion Coal:

	London	Dominion
Carbon	77.53	81.50
Hydrogen	6.33	5.68
Nitrogen	1.03	....
Oxygen	14.50	12.45
Sulphur	.61	.37

NOTE—The British unit of heat, or British thermal unit (B. T. U.) herein referred to, is that quantity of heat which is required to raise the temperature of 1 lb. of pure water 1 deg. Fahr. at 39 deg. Fahr., the temperature of maximum density of water.

The above from "The Science of Burning Liquid Fuel," by W. N. Best.

In the tests made by the Southern Pacific and Kansas City Southern, together with other information received from the Chicago, Milwaukee & St. Paul; Great Northern; Atchison, Topeka & Santa Fe; Kansas City Southern; Southern Pacific; and Western Pacific, some advantages are shown in the use of oil for fuel. However, with but few exceptions, the deciding factor is the comparative cost of oil and coal.

From the data received, 150 to 168 gallons of oil, approximately 4 barrels, are equivalent to a ton of coal on a ton mile basis. It does not seem possible to establish a definite relation that can be used as absolute basis, as the quality of coal and oil with regard to heat units varies in proportion to the chemical characteristics of the fuel.

The cost of fuel based on the ratio given above would cover only the equivalent values of the fuel. To the base price of coal per ton and oil per barrel must be added the cost of handling, transportation and terminal facilities.

In regard to terminal charges, the advantage favors oil in that hostler service is reduced and ash pit service practically done away with.

Other advantages in the use of fuel oil are:

1. There is practically no limit to the fireman's ability to force the boiler which means the elimination of the mechanical stoker on large power.

2. With careful handling the steam can be kept closer to the limiting boiler pressure without frequent or prolonged opening of the pops.

3. Less waste of fuel through grates and stack.

4. Less smoke.

5. No cinders.

6. Less danger of starting fires along right of way.

There seems to be little difference in the cost of repairs provided the fireboxes are properly arranged for the fuel used.

From a general review of the data available, it seems that only experiments and tests on the same type of engine and service, and on the same division would settle definitely for that division the economies to be derived from the use of fuel oil over coal.

INTERSTATE COMMERCE COMMISSION RULES FOR INSPECTION AND TESTING

PORTIONS OF ORDER OF COMMISSION DATED OCTOBER 11, 1915, AS APPLY TO THE DESIGN AND MANUFACTURE OF LOCOMOTIVES

ASH PANS

Locomotives built after Jan. 1, 1916, shall have ash pans supported from mudrings or frames. Locomotives built prior to Jan. 1, 1916, which do not have ash pans supported from mudrings or frames, shall be changed when the locomotive receives new firebox. No part of ash pan shall be less than 2½" above the rail.

COMPRESSORS

The compressor or compressors shall be tested for capacity by orifice test as often as conditions may require, but not less frequently than once each three months.

The diameter of orifice, speed of compressor, and the air pressure to be maintained for compressors in common use are given in the following table:

Make	Size Compressor	Single Stroke Per Minute	Diameter of Orifice	Air Pressure Maintained
			Inches	Pounds
Westinghouse..	9½	120	11/64	60
Westinghouse..	11	100	3/16	60
Westinghouse..	8½ c.c	100	9/32	60
New York.....	2a	120	5/32	60
New York.....	6a	100	13/64	60
New York.....	5b	100	15/64	60

This table shall be used for altitudes to and including 1000 feet. For altitudes over 1000 feet the speed of compressor may be increased 5 single strokes per minute for each 1000 feet increase in altitude.

TESTING MAIN RESERVOIRS

Every main reservoir before being put into service and at least once each 12 months thereafter, shall be subjected to hydrostatic pressure not less than 25 per cent above the maximum allowed air pressure.

The entire surface of the reservoir shall be hammer tested each time the locomotive is shopped for general repairs, but not less frequently than once each 18 months.

AIR GAGES

Air gages shall be so located that they may be conveniently read by the engineer from his usual position in the cab.

PISTON TRAVEL

The minimum piston travel shall be sufficient to provide proper brake shoe clearance when the brakes are released.

The maximum piston travel when locomotive is standing shall be as follows:

	Inches
Cam type of driving wheel brake...	3½
Other forms of driving wheel brake .	6
Engine truck brake...............	8
Tender brake.....................	9

FOUNDATION BRAKE GEAR

No part of the foundation brake gear of the locomotive or tender shall be less than 2½" above the rail.

CABS

Cab windows shall be so located and maintained that the enginemen may have a clear view of track and signals from their usual and proper positions in the cab. Road locomotives used in regions where snow storms are generally encountered shall be provided with what is known as a "clear vision" window, which is a window hinged at the top and placed in the glass in each front cab door or window. These windows shall be not less than 5 inches high, located as nearly as possible in line of the enginemen's vision, and so constructed that they may be easily opened or closed.

CAB APRONS

Cab aprons shall be of the proper length and width to insure safety. Aprons must be securely hinged, maintained in a safe and suitable condition for service, and roughened, or other provision made to afford secure footing.

DRAW-GEAR BETWEEN LOCOMOTIVE AND TENDER

Inverted draw-bar pins shall be held in place by plate or stirrup. Safety chains or safety bars shall be of the minimum length consistent with the curvature of the railroad on which the locomotive is operated. When spring buffers are used between locomotive and tender the springs shall be applied with not less than ¾" compression, and shall at all times be under sufficient compression to keep the chafing faces in contact.

CAB LIGHTS

Each locomotive used between sunset and sunrise shall have cab lamps which will provide sufficient illumination for the steam, air, and water gages to enable the enginemen to make necessary and accurate readings from their usual and proper positions in the cab. These lights shall be so located and constructed that the light will shine only on those parts requiring illumination. Locomotives used in road service shall have an additional lamp conveniently located to enable the person operating the locomotive to easily and accurately read train orders and time-tables, and so constructed that it may be readily darkened or extinguished.

PILOT

The minimum clearance of pilot above the rail shall be 3", and the maximum clearance 6".

WHEELS

Wheels shall be securely pressed on axles. Prick punching or shimming the wheel fit will not be permitted. The diameter of wheels on the same axle shall not vary more than three thirty-seconds inch.

Wheels used on standard gage track will be out of gage if the inside gage of flanges, measured on base line, is less than 53 inches or more than 53⅜ inches.

The distance back to back of flanges of wheels mounted on the same axle shall not vary more than one-fourth inch.

DRIVING AND TRAILING WHEEL TIRES

The minimum height of flange for driving and trailing wheel tires, measured from tread, shall be 1 inch for locomotives used in road service, except for locomotives originally constructed for plain tires, when the minimum height of flange on one pair of wheels may be seven-eighths inch.

The minimum height of flange for driving wheel tires, measured from tread, shall be seven-eighths inch for locomotives used in switching service.

The maximum taper for tread of tires from throat of flange to outside of tire, for driving and trailing wheels for locomotives used in road service, shall be one-fourth inch, and for locomotives used in switching service five-sixteenths inch.

The minimum number of tires for driving and trailing wheels of standard gage locomotives shall be 5½ inches for flanged tires, and 6 inches for plain tires.

The minimum width of tires for driving and trailing wheels of narrow gage locomotives shall be 5 inches for flanged tires, and 5½ inches for plain tires.

When all tires are turned or new tires applied to driving and trailing wheels, the diameter of the wheels on the same axle, or in the same driving wheel base, shall not vary more than three thirty-seconds inch. When a single tire is applied the diameter must not vary more than three thirty-seconds inch from that of the opposite wheel on the same axle. When a single pair of tires is applied the diameter must be within three thirty-seconds inch of the average diameter of the wheels in the driving wheel base to which they are applied.

When retaining rings are used, measurements of tires to be taken from the outside circumference of the ring, and the minimum thickness of tires may be as much below the limits specified above as the tires extend between the retaining rings, provided it does not reduce the thickness of the tire to less than 1⅛ inches from the throat of flange to the counterbore for the retaining ring.

The minimum thickness for driving wheel tires shall be 1 inch for locomotives operated on track of 2-foot gage.

TENDER FRAMES

The difference in height between the deck on the tender and the cab floor or deck on the locomotive shall not exceed 1½ inches. The minimum width of the gangway between locomotive and tender, while standing on straight track, shall be 16 inches.

OIL TANKS

An automatic safety cutout valve, which may be operated by hand from inside and outside of cab, shall be provided for the oil supply pipe.

TABLE No. 33—MINIMUM THICKNESS FOR DRIVING WHEEL AND TRAILER TIRES ON STANDARD AND NARROW GAGE LOCOMOTIVES

Weight Per Axle (Weight on Drivers divided by Number of Pairs of Driving Wheels)	Diameter of Wheel Center	Minimum Thickness, Service Limits	
		Road Service	Switching Service
	Inches	Inches	Inches
30000 lb. and under . . .	44 and under. . . .	1¼	1⅛
	Over 44 to 50 . . .	1 5/16	1 3/16
	Over 50 to 56 . . .	1⅜	1¼
	Over 56 to 62 . . .	1 7/16	1 5/16
	Over 62 to 68 . . .	1½	. . .
	Over 68 to 74 . . .	1 9/16	. . .
	Over 74	1⅝	. . .
Over 30000 to 35000 lb	44 and under. . . .	1 5/16	1 3/16
	Over 44 to 50 . . .	1⅜	1¼
	Over 50 to 56 . . .	1 7/16	1 5/16
	Over 56 to 62 . . .	1½	1⅜
	Over 62 to 68 . . .	1 9/16	. . .
	Over 68 to 74 . . .	1⅝	. . .
	Over 74	1 11/16	. . .
Over 35000 to 40000 lb.	44 and under. . . .	1⅜	1¼
	Over 44 to 50 . . .	1 7/16	1 5/16
	Over 50 to 56 . . .	1½	1⅜
	Over 56 to 62 . . .	1 9/16	1 7/16
	Over 62 to 68 . . .	1⅝	. . .
	Over 68 to 74 . . .	1 11/16	. . .
	Over 74	1¾	. . .
Over 40000 to 45000 lb.	44 and under. . . .	1 7/16	1 5/16
	Over 44 to 50 . . .	1½	1⅜
	Over 50 to 56 . . .	1 9/16	1 7/16
	Over 56 to 62 . . .	1⅝	1½
	Over 62 to 68 . . .	1 11/16	. . .
	Over 68 to 74 . . .	1¾	. . .
	Over 74	1 13/16	. . .
Over 45000 to 50000 lb.	44 and under. . . .	1½	1⅜
	Over 44 to 50 . . .	1 9/16	1 7/16
	Over 50 to 56 . . .	1⅝	1½
	Over 56 to 62 . . .	1 11/16	1 9/16
	Over 62 to 68 . . .	1¾	. . .
	Over 68 to 74 . . .	1 13/16	. . .
	Over 74	1⅞	. . .
Over 50000 to 55000 lb.	44 and under. . . .	1 9/16	1 7/16
	Over 44 to 50 . . .	1⅝	1½
	Over 50 to 56 . . .	1 11/16	1 9/16
	Over 56 to 62 . . .	1¾	1⅝
	Over 62 to 68 . . .	1 13/16	. . .
	Over 68 to 74 . . .	1⅞	. . .
	Over 74	1 15/16	. . .
Over 55000 lb	44 and under. . . .	1⅝	1½
	Over 44 to 50 . . .	1 11/16	1 9/16
	Over 50 to 56 . . .	1¾	1⅝
	Over 56 to 62 . . .	1 13/16	1 11/16
	Over 62 to 68 . . .	1⅞	. . .
	Over 68 to 74 . . .	1 15/16	. . .
	Over 74	2	. . .

TENDER TRUCKS

The maximum clearance of side bearings on rear truck shall be 3/8", and if used on front truck 3/4", when the spread of side bearings is 50". When the spread of the side bearings is increased, the maximum clearance may be increased in proportion.

STAMPING AXLES, PISTON RODS AND CRANK PINS

The date applied, the original diameter of the journal, and the kind of material shall be legibly stamped on one end of each Driving Axle, Trailing Truck Axle and Engine Truck Axle applied after January 1, 1916. All Piston Rods applied after January 1, 1916, shall have the date of application, original diameter, and kind of material legibly stamped on or near the end of the rod. All Crank Pins applied after January 1, 1916, shall have date applied and kind of material used legibly stamped on end of pin.

Note. Use the following abbreviations in stamping axles, etc.:

I	=Iron.
S	=Steel.
H T S	=Heat-treated Steel.
CHR	=Chrome.
VAN	=Vanadium.
NKL	=Nickel.
NIK	=Nikrome.
COF PROC	=Coffin Process.
CAM SPEC	=Cambria Special.
TAY I	=Taylor Iron.

PIPING

Steam pipes shall not be fastened to the cab. On new construction or when renewals are made of iron or steel pipe subject to boiler pressure in cabs, it shall be what is commercially known as double-strength pipe, with extra-heavy valves and fittings.

BOILER

Portions of order of Commission dated June 2, 1911, and orders amending same dated September 12, 1912, and June 9, 1914, as apply to the design and manufacture of locomotives.

FACTOR OF SAFETY

The lowest factor of safety to be used for all locomotive boilers which are constructed after January 1, 1912, shall be 4″. (A. L. Co. Standard is 4½.)

MAXIMUM ALLOWABLE STRESS ON STAYS AND BRACES

For locomotives constructed after January 1, 1915, the maximum allowable stress per square inch of net cross-sectional area on firebox and combustion chamber stays shall be 7,500 pounds. The maximum allowable stress per square inch of net cross-sectional area on round, rectangular, or gusset braces shall be 9,000 pounds.

STAYBOLTS

Telltale Holes—All staybolts shorter than 8 inches applied after July 1, 1911, except flexible bolts, shall have telltale holes three-sixteenths inch in diameter and not less than 1¼ inches deep in the outer end. These holes must be kept open at all times.

STEAM GAGES

Location of Gages—Every boiler shall have at least one steam gage which will correctly indicate the working pressure. Care must be taken to locate the gage so that it will be kept reasonably cool, and can be conveniently read by the enginemen.

Siphon—Every gage shall have a siphon of ample capacity to prevent steam entering the gage. The pipe connection shall enter the boiler direct, and shall be maintained steam tight between boiler and gage.

Method of Testing—Steam gages shall be compared with an accurate test gage or dead weight tester and gages found inaccurate shall be corrected before being put into service.

BADGE PLATES

A metal badge plate showing the allowed steam pressure shall be attached to the boiler head in the cab. If boiler head is lagged, the lagging and jacket shall be cut away so the plate can be seen.

BOILER NUMBER

The builder's number of the boiler shall be stamped on the dome.

SAFETY VALVES

Number and Capacity—Every boiler shall be equipped with at least two safety valves, the capacity of which shall be sufficient to prevent, under any conditions of service, an accumulation of pressure more than 5 per cent. above the allowed steam pressure.

Setting of Safety Valves—Safety valves shall be set to pop at pressures not exceeding 6 pounds above the working steam pressure. When setting safety valves two steam gages shall be used, one of which must be so located that it will be in full view of the person engaged in setting such valves; and if the pressure indicated by the gages varies more than 3 pounds they shall be removed from the boiler, tested, and corrected before the safety valves are set. Gages shall in all cases be tested immediately before the safety valves are set or any change made in the setting. When setting safety valves the water level in the boiler shall not be above the highest gage cock.

WATER GLASS, GAGE COCKS AND LUBRICATOR GLASSES

Number and Location—Every boiler shall be equipped with at least one water glass and three gage cocks. The lowest gage cock and the lowest reading of the water glass shall be not less than 3 inches above the highest part of the crown sheet.

Water Glass Valves—All water glasses shall be supplied with two valves or shut-off cocks, one at the upper and one at the lower connection to the boiler, and also a drain cock, so constructed and located that they can be easily opened and closed by hand.

Water and Lubricator Glass Shields—All tubular water glasses and lubricator glasses must be equipped with a safe and suitable shield which will prevent the glass from flying in case of breakage.

Water Glass Lamps—All water glasses must be supplied with a suitable lamp properly located to enable the engineer to easily see the water in the glass.

Portion of Order of Commission Dated December 26, 1916.

LIGHTS

Locomotives Used in Road Service—Each locomotive used in road service between sunset and sunrise shall have a headlight which shall afford sufficient illumination to enable a person in the cab of such locomotive who possesses the usual visual capacity required of locomotive enginemen, to see in a clear atmosphere, a dark object as large as a man of average size standing erect at a distance of at least 800 feet ahead and in front of such headlight; and such headlight must be maintained in good condition.

Each locomotive used in road service, which is regularly required to run backward for any portion of its trip, except to pick up a detached portion of its train, or in making terminal movements, shall have on its rear a headlight which shall meet the foregoing requirements.

Such headlights shall be provided with a device whereby the light from same may be diminished in yards and at stations or when meeting trains.

When two or more locomotives are used in the same train, the leading locomotive only will be required to display a headlight.

Locomotives Used in Yard Service—Each locomotive used in yard service between sunset and sunrise shall have two lights, one located on the front of the locomotive and one on the rear, each of which shall enable a person in the cab of the locomotive under the conditions, including visual capacity, set forth in Rule 29, to see a dark object such as there described for a distance of at least 300 feet ahead and in front of such headlight; and such headlights must be maintained in good condition.

It is Further Ordered, That the said rules pertaining to Lights shall apply to all locomotives constructed after July 1, 1917, and for locomotives constructed prior to that date the changes required by the above rules shall be made the first time locomotives are shopped for general or heavy repairs after July 1, 1917, and all locomotives must be so equipped before July 1, 1920.

AXLES, DRIVING, MAIN

METHOD OF CALCULATION

(All dimensions in inches)

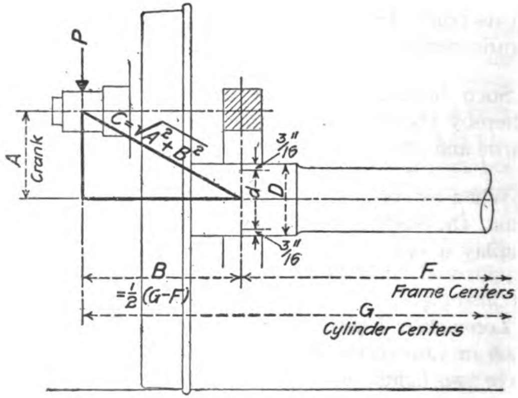


Figure No. 5

P = Piston thrust with full boiler pressure. (See Table No. 54.)

M = Combined bending and twisting moment

$$= \frac{P\ (B + C)}{2}$$

S = Fibre stress $= \frac{M}{R}$ = 23000 lb. per sq. in. max. for steel axles.

R = Modulus of circular section with diameter equal to "d" $= .0982\ d^3 = \frac{M}{S}$ (See Table No. 64.)

D = Nominal diameter of journal.

d = D — ⅜″ allowance for wear $= \sqrt[3]{\frac{M}{.0982\ S}}$

TABLE No. 34—MOUNTING PRESSURES

AXLES AND CRANK PINS

Use the following pressures for forcing AXLES into driving and truck wheels and CRANK PINS into driving wheels.

Diameter of Fit in Ins.	MOUNTING PRESSURES, IN TONS							
	Driving, Engine and Trailing Truck Wheels						Engine and Trailing Truck Wheels	
	Steel-Tired, Cast Steel or Wrought Steel Centers, Solid Wrought Steel			Steel-Tired, Cast Iron Center			Cast Iron, Chilled Tread Pressures Based on M. M. Standard of 1916	
	Minimum	Preferred	Maximum	Minimum	Preferred	Maximum	Minimum	Maximum
4	58	64	80	36	40	48	25	35
4½	65	72	90	40	45	54	30	45
5	72	80	100	45	50	60	30	45
5½	79	88	110	49	55	66	35	50
6	86	96	120	54	60	72	35	50
6½	94	104	130	58	65	78	40	60
7	101	112	140	63	70	84	45	65
7½	108	120	150	67	75	90	50	70
8	115	128	160	72	80	96	50	70
8½	122	136	170	76	85	102	55	75
9	130	144	180	81	90	108	..	..
9½	137	152	190	85	95	114	..	..
10	144	160	200	90	100	120	..	..
10½	151	168	210	94	105	126	..	..
11	158	176	220	99	110	132	..	..
11½	166	184	230	..	..	..	..	..
12	173	192	240	..	..	..	..	..
12½	180	200	250	..	..	..	..	..
13	187	208	260	..	..	..	..	..
13½	194	216	270	..	..	..	..	..

TABLE No. 34—MOUNTING PRESSURES—Continued

TENDER TRUCK WHEELS

Wheel Seat Diameter	M. C. B. Standard Axle Size	Mounting Pressures, in Tons. M. M. Standard of 1916 — Tender Truck Wheels — Steel-Tired, Cast Steel or Wrought Steel Centers. Solid Wrought Steel — Minimum	Maximum	Steel-Tired, Cast Iron Center. Cast Iron, Chilled Tread — Minimum	Maximum
Ins.	Ins.				
5⅛	3¾x 7	45	60	30	45
5¾	4¼x 8	50	70	35	50
6½	5 x 9	60	80	40	60
7	5½x10	65	85	45	65
7⅝	6 x11	70	95	50	70

TABLE No. 35—RECOMMENDED BEARING PRESSURE ON JOURNALS

Net loads (exclusive of wheels, axles, etc., not carried by journals) per square inch of projected area of journals.

Axles	Pounds Per Sq. Inch — Passenger	Freight	Switcher
Driving	175	200	200
Trailing	175	185	...
Eng. Truck	160	180	...

TABLE No. 36—RECOMMENDED BEARING PRESSURE ON JOURNALS

M. C. B. STANDARD TENDER AXLES

Size of Axle	Load Limited by Bearing Pressure — Total Per Axle — Passenger 300 lb. Per Sq. In.	Load Limited by Bearing Pressure — Total Per Axle — Freight 325 lb. Per Sq. In.	Load Limited by Fibre Stress — Passenger and Freight — Total Per Axle	Load Limited by Fibre Stress — Passenger and Freight — Per Sq. in. Projected Area of Journal	Weight of One Axle
3¾"x 7"	.....	.....	15000	285	390
4¼"x 8"	20400	22000	22000	325	493
5 "x 9"	27000	29250	31000	345	655
5½"x10"	33000	35800	38000	345	780
6 "x11"	39600	42900	50000	379	950

Preferred limitations are by bearing pressure but fibre stress limitation should not be exceeded for M. C. B. Axles.

TABLE No. 37—CYLINDER CLEARANCE

	% of Cylinder Clearance $= \frac{\text{Clearance}}{\text{Area x Stroke}}$ — Desired	Minimum	Maximum
Simple cylinders, saturated steam...	8	7	9
Simple cylinders, superheated steam.	9	8	10
Mallet compounds, pushing service.			
Saturated steam, H. P. Cylinders..	11	10	12
Saturated steam, L. P. Cylinders..	7	6	8
Superheated steam, H. P. Cylinders	11	10	12
Superheated steam, L. P. Cylinders	7	6	8
Mallet compounds, road service.			
Saturated steam, H. P. Cylinders..	13	12	14
Saturated steam, L. P. Cylinders..	8	7	9
Superheated steam, H. P. Cylinders	14	13	15
Superheated steam, L. P. Cylinders	9	8	10

CRANK PINS, MAIN
METHOD OF CALCULATION

(All dimensions in inches.)

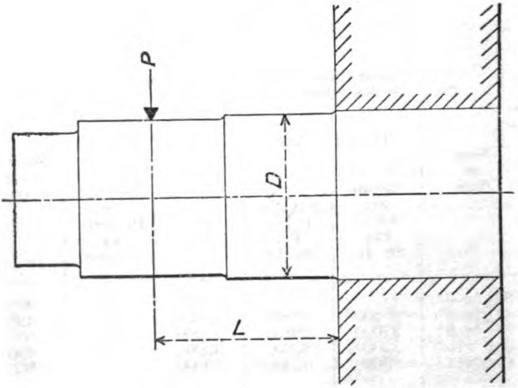


Figure No. 6

P = Piston thrust with full boiler pressure. (See Table No. 54.)
M = Bending moment = P L

S = Fibre stress = $\frac{M}{R}$ 17000 lb. per sq. in. max. for steel crank pins.

R = Modulus of circular section with diameter equal to

"D" = $.0982\,D^3 = \frac{M}{S}$ (See Table No. 64.)

$$D = \sqrt[3]{\frac{M}{.0982\,S}}$$

A = Projected area of journal = diameter × length.

Maximum allowable bearing pressure on journals $(\frac{P}{A})$.

Saturated locomotives: 1700 lb. per sq. in.
Superheater locomotives: 1600 lb. per sq. in.

MAIN JOURNAL

Product pressure by velocity (feet per minute) not over 1,100,000.

(The velocity to be based on the speed of the locomotive in miles per hour equal to the diameter of the drivers in inches.)

Diameter of pin not to exceed the length: preferably less.

TABLE No. 38—FRAMES

Approximate Rules for Proportioning Wrought Iron or Cast Steel Frames

$S = \frac{T}{C}$ Where S = sectional area of frame.
T = piston thrust (= area of piston multiplied by the boiler pressure).
C = constant (see table below).

Sectional Area of Frame in Square Inches (S)		C	
		From Cylinders to Main Pedestal (including Top Rail over Main Pedestal)	Back of Main Pedestal
A	Top of Pedestals	2500–2700	2900–3200
B	Top Rail Between Pedestals	3000–3200	3500–3800
C	Lower Rail Between Pedestals	4300–4500	5100–5300
D	Integral Single Rail at back of Cyl. Keying Lug	1600–1800	....

This method gives sectional areas back of main pedestal approximately 15 per cent less than similar areas at or ahead of main pedestal.

Depth of top rail ahead of front pedestals must not be less than that of top rail over front pedestals.

TABLE No. 39—PRESSURES FOR FORCING PISTON RODS INTO PISTON HEADS

Diameter of Rod	Pressure in Tons	Diameter of Rod	Pressure in Tons	Diameter of Rod	Pressure in Tons
2½"	30–40	3¼"	40–50	4¼"	55–65
2¾"	30–40	3½"	45–55	4½"	55–65
3"	35–45	3¾"	45–55	4¾"	60–70
		4"	50–60	5"	65–75

Pressures within the above limits must be obtained just before collar reaches its seat, and collar must in all cases seat solidly on piston head.

TABLE No. 40—PISTON RODS

For simple engines use Piston Rods having diameter of body given below.

Cylinder Diameter	Boiler Pressures									
	160	165	170	175	180	185	190	200	210	220
16"	....	....	....	....	2¾"	2¾"	2¾"	3"	....	....
16½" and 17"	....	....	....	....	2¾"	3"	3"	3"	....	....
17½" and 18"	....	....	....	....	3¼"	3¼"	3¼"	3¼"	3¼"	....
18½" and 19"	....	....	....	....	3¼"	3¼"	3¼"	3½"	3½"	....
19½" and 20"	....	....	....	....	3½"	3½"	3½"	3½"	3½"	....
20½" and 21"	....	....	....	....	3¾"	3¾"	3¾"	3¾"	3¾"	3¾"
21½" and 22"	....	....	....	....	3¾"	3¾"	3¾"	4"	4"	4"
22½"	....	....	....	....	4"	4"	4"	4"	4"	4"
23"	3¾"	3¾"	3¾"	3¾"	4"	4"	4"	4"	....	....
23½"	3¾"	3¾"	4"	4"	4"	4"	4"	4¼"	....	....
24"	3¾"	4"	4"	4"	4"	4"	4¼"	4¼"	....	....
24½"	4"	4"	4"	4"	4¼"	4¼"	4¼"	4¼"	....	....
25"	4"	4"	4"	4¼"	4¼"	4¼"	4¼"	4½"	....	....
25½"	4"	4¼"	4¼"	4¼"	4¼"	4¼"	4½"	4½"	....	....
26"	4¼"	4¼"	4¼"	4¼"	4¼"	4½"	4½"	4½"	....	....
26½"	4¼"	4¼"	4¼"	4½"	4½"	4½"	4½"	4¾"	....	....
27"	4¼"	4¼"	4½"	4½"	4½"	4½"	4¾"	4¾"	....	....
27½"	4¼"	4½"	4½"	4½"	4¾"	4¾"	4¾"	4¾"	....	....
28"	4½"	4½"	4½"	4¾"	4¾"	4¾"	4¾"	5"	....	....
28½"	4½"	4½"	4¾"	4¾"	4¾"	4¾"	5"	5"	....	....
29"	4½"	4¾"	4¾"	4¾"	4¾"	5"	5"	5"	....	....
29½"	4¾"	4¾"	4¾"	5"	5"	5"	5"	5"	....	....
30"	4¾"	4¾"	5"	5"	5"	5"	5"	5"	....	....

Note—Sizes are based on 9500 lb. fibre stress in tension at least area through keyway with nominal diameter of cylinder and full boiler pressure.

Piston Rods to have enlarged fit in Piston and in Crosshead with taper ¾" in 12".

Increase length of Piston Rod whenever the design will permit, so that the clearance between piston rod packing gland and crosshead is sufficient to let out the piston at front end of cylinder for examination of piston packing. Piston should clear front grinding of cylinder about 1".

TABLE No. 41—STAYBOLTS—WHITWORTH THREAD, 12 PER INCH

Diameter Outside	Diameter at Root	Area at Root Sq. Ins.	Load, Maximum at 5500 lb.	Maximum Area Sq. Ins. Supported by One Stay at 200 lb. Pressure	Maximum Pressure Per Sq. Inch for Spacing, in Inches				
					4″x4″	3.9″x3.9″	3.8″x3.8″	3.7″x3.7″	3.6″x3.6″
¾″	.6434″	.3251	1788	9.26	114	120	127	134	141
13/16″	.7059″	.3914	2153	11.16	138	145	153	162	171
⅞″	.7684″	.4637	2550	13.21	164	173	183	194	204
15/16″	.8309″	.5423	2983	15.48	194	204	215	227	241
1″	.8934″	.6269	3448	17.87	224	236	250	265	280
1 1/16″	.9559″	.7177	3947	20.45	258	272	288	304	322
1⅛″	1.0180″	.8139	4476	23.19	295	311	328	348	368

TABLE No. 42—STAYBOLTS—"V" THREAD, 12 PER INCH

Diameter Outside	Diameter at Root	Area at Root Sq. Ins.	Load, Maximum at 5500 lb.	Maximum Area Sq. Ins. Supported by One Stay at 200 lb. Pressure	Maximum Pressure Per Sq. Inch for Spacing, in Inches				
					4″x4″	3.9″x3.9″	3.8″x3.8″	3.7″x3.7″	3.6″x3.6″
¾″	.6057″	.2881	1585	8.21	101	106	112	118	125
13/16″	.6682″	.3507	1929	9.99	123	130	137	145	153
⅞″	.7307″	.4193	2306	11.95	148	156	164	174	184
15/16″	.7932″	.4941	2718	14.08	175	185	195	206	218
1″	.8557″	.5751	3163	16.39	205	216	228	241	255
1 1/16″	.9182″	.6622	3642	18.87	237	250	264	280	296
1⅛″	.9807″	.7554	4155	21.53	273	287	304	321	340

TABLE No. 43—SPRINGS, HELICAL METHOD OF CALCULATING

Calculations: In obtaining the net static load, the actual weights of the parts constituting dead load, such as wheels, axles, boxes, etc., should be deducted instead of taking a certain arbitrary percentage.

Maximum fibre stress allowable 80000 pounds, when springs are solid. The figures given in table in "Load" column are the calculated loads which will bring springs solid at 80000 pounds fibre stress.

It is advisable usually to make the capacity of springs slightly more than the net actual load, as given below.

The static load for helical springs must not exceed one-half the load required to bring the springs solid.

Required Capacity:

- **Driving and Engine Truck Springs:** Use calculated static load plus 500 to 1000 pounds, or about 5 per cent.
- **Trailing Springs:** Use calculated static load plus 15 per cent.
- **Tender Springs:** Use calculated static load taken with three-quarters of maximum load of coal and water.

Spring Tables for helical springs give the capacity or load, for all heights, when spring is solid; the height free is per one inch of solid height.

Out-side Diam. of Coil	3/8″ Steel		7/16″ Steel		1/2″ Steel		9/16″ Steel		5/8″ Steel	
	Load Solid	Hg't Free	Load Solid	Hg't Free	Load Solid	Hg't Free	Load Solid	Hg't Free	Load Solid	Hg't Free
2	1,020	1.38	1,680	1.26	2,600	1.18				
2¼	880	1.50	1,450	1.35	2,250	1.25	3,300	1.18		
2½	780	1.64	1,270	1.44	1,970	1.32	2,900	1.24	4,100	1.18
2¾	700	1.80	1,140	1.56	1,750	1.41	2,550	1.30	3,600	1.23
3	630	1.98	1,030	1.68	1,580	1.50	2,300	1.37	3,200	1.29
3¼	.....	....	940	1.83	1,430	1.61	2,100	1.46	2,900	1.36
3½	.....	....	860	1.98	1,310	1.72	1,910	1.54	2,650	1.42
3¾	.....	....	.....	....	1,210	1.85	1,760	1.64	2,450	1.50
4	.....	....	.....	....	1,130	1.98	1,630	1.75	2,300	1.58
4¼	.....	....	.....	....	.....	....	1,520	1.86	2,100	1.67
4½	.....	....	.....	....	.....	....	1,420	1.98	1,980	1.77
4¾	.....	....						....	1,860	1.87
5	.....	....						....	1,760	1.98
5¼	.....	....								
5½	.....	....								
5¾	.....	....								
6	.....	....								
6½	.....	....								
7	.....	....								
7½	.....	....								

Formula Used in Computing Table

$$P = \frac{S \pi d^3}{16r} \qquad \triangle = \frac{0.08 r^2 h}{d^2}$$

P = load at solid height
S = fibre stress = 80000 lb.
d = diameter of steel
r = radius of center of coil
△ = deflection. h = solid height

TABLE No. 43—SPRINGS, HELICAL METHOD OF CALCULATING—Continued

Outside Diam. of Coil	11/16" Steel		3/4" Steel		13/16" Steel		7/8" Steel		15/16" Steel	
	Load Solid	Hg't Free	Load Solid	Hg't Free	Load Solid	Hg't Free	Load Solid	Hg't Free	Load Solid	Hg't Free
2										
2¼										
2½										
2¾	4,900	1.18								
3	4,400	1.23	5,900	1.18						
3¼	4,000	1.28	5,300	1.22	6,900	1.18				
3½	3,600	1.33	4,800	1.27	6,300	1.22	8,000	1.18		
3¾	3,300	1.40	4,400	1.32	5,800	1.26	7,300	1.22	9,200	1.18
4	3,100	1.46	4,100	1.38	5,300	1.31	6,700	1.25	8,500	1.21
4¼	2,850	1.54	3,800	1.44	4,900	1.36	6,200	1.30	7,800	1.25
4½	2,650	1.61	3,500	1.50	4,600	1.41	5,800	1.34	7,300	1.29
4¾	2,500	1.70	3,300	1.57	4,300	1.47	5,400	1.39	6,800	1.33
5	2,350	1.79	3,100	1.64	4,000	1.53	5,100	1.44	6,400	1.38
5¼	2,250	1.88	2,950	1.72	3,800	1.59	4,800	1.50	6,000	1.42
5½	2,100	1.98	2,800	1.80	3,600	1.67	4,600	1.55	5,700	1.47
5¾	.....	....	2,700	1.89	3,400	1.74	4,300	1.62	5,400	1.53
6	.....	....	2,550	1.98	3,300	1.81	4,100	1.69	5,100	1.58
6½	.....	....	.....	....	3,000	1.98	3,800	1.83	4,700	1.71
7	.....	....	.....	....	.....	....	3,400	1.98	4,300	1.84
7½	.....	....	.....	....	.....	....	.....	....	3,900	1.98

TABLE No. 43—SPRINGS, HELICAL METHOD OF CALCULATING—Continued

Outside Diam. of Coil	1" Steel		1 1/16" Steel		1 1/8" Steel		1 3/16" Steel		1¼" Steel	
	Load Solid	Hg't Free	Load Solid	Hg't Free	Load Solid	Hg't Free	Load Solid	Hg't Free	Load Solid	Hg't Free
4	10,500	1.18								
4¼	9,700	1.21	11,800	1.18						
4½	9,000	1.25	10,900	1.21	13,300	1.18				
4¾	8,400	1.28	10,200	1.24	12,400	1.21	14,800	1.18		
5	7,900	1.32	9,500	1.28	11,600	1.24	13,800	1.21	16,400	1.18
5¼	7,400	1.36	8,900	1.31	10,900	1.27	13,000	1.23	15,300	1.21
5½	7,000	1.41	8,400	1.35	10,300	1.30	12,200	1.26	14,500	1.23
5¾	6,600	1.45	8,000	1.39	9,700	1.34	11,500	1.30	13,700	1.26
6	6,300	1.50	7,600	1.43	9,200	1.37	10,900	1.33	12,900	1.29
6½	5,700	1.61	6,900	1.52	8,300	1.46	9,900	1.40	11,700	1.36
7	5,200	1.72	6,300	1.63	7,600	1.54	9,000	1.48	10,700	1.42
7½	4,800	1.85	5,800	1.73	7,000	1.64	8,300	1.56	9,800	1.50
8	4,500	1.98	5,400	1.85	6,500	1.75	7,700	1.66	9,100	1.58
8½	.....	....	5,000	1.98	6,100	1.86	7,200	1.76	8,500	1.67
9	.....	....	.....	....	5,700	1.98	6,700	1.87	7,900	1.77
9½	.....	....	.....	....	.....	....	6,300	1.98	7,400	1.87
10	.....	....	.....	....	.....	....	.....	....	7,000	1.98

TABLE No. 43—SPRINGS, HELICAL
METHOD OF CALCULATING—Continued

Outside Diam. of Coil	1 5/16" Steel		1 3/8" Steel		1 7/16" Steel		1 1/2" Steel	
	Load Solid	Height Free	Load Solid	Height Free	Load Solid	Height Free	Load Solid	Hg't Free
4								
4¼								
4½								
4¾								
5								
5¼	18,000	1.18						
5½	16,900	1.20	19,800	1.18				
5¾	16,000	1.23	18,700	1.20	21,700	1.18		
6	15,100	1.26	17,600	1.23	20,400	1.20	23,600	1.18
6½	13,700	1.31	16,000	1.28	18,500	1.25	21,200	1.22
7	12,500	1.38	14,600	1.33	16,800	1.30	19,300	1.27
7½	11,500	1.45	13,400	1.40	15,400	1.36	17,700	1.32
8	10,600	1.52	12,400	1.46	14,200	1.42	16,300	1.38
8½	9,900	1.60	11,500	1.54	13,200	1.48	15,200	1.44
9	9,200	1.69	10,700	1.61	12,300	1.55	14,200	1.50
9½	8,600	1.78	10,100	1.70	11,600	1.63	13,300	1.57
10	8,200	1.88	9,500	1.79	10,900	1.71	12,500	1.64

TABLE No. 43—SPRINGS, HELICAL
METHOD OF CALCULATING—Continued

Outside Diam. of Coil	1 9/16" Steel		1 5/8" Steel		1 11/16" Steel		1 3/4" Steel	
	Load Solid	Height Free	Load Solid	Height Free	Load Solid	Height Free	Load Solid	Hg't Free
6½	24,300	1.20	27,600	1.18				
7	22,000	1.24	25,000	1.22	28,400	1.19	32,100	1.18
7½	20,200	1.29	23,000	1.26	26,000	1.24	29,300	1.22
8	18,600	1.34	21,100	1.31	23,900	1.28	26,900	1.26
8½	17,300	1.39	19,600	1.36	22,200	1.33	25,000	1.30
9	16,100	1.45	18,300	1.41	20,600	1.38	23,200	1.34
9½	15,100	1.51	17,100	1.47	19,300	1.43	21,700	1.39
10	14,200	1.58	16,100	1.53	18,200	1.49	20,400	1.44

NOTE: Broken horizontal line shows limit of preferred minimum ratio (5:1) between outside diameter of coil and diameter of steel.

SPRINGS—ELLIPTIC

METHOD OF CALCULATING

CALCULATIONS—In obtaining the net static load, the actual weights of the parts constituting dead load, such as wheels, axles, boxes, etc., should be deducted instead of taking a certain arbitrary percentage.

Maximum fibre stresses allowable 80,000 pounds. The figures given in Table in "Load" column are the calculated loads which springs will carry at 80,000 pounds fibre stress and are the maximum loads for which springs should be used.

It is advisable usually to make the capacity of springs slightly more than the actual net load, as follows:

REQUIRED CAPACITY

DRIVING AND ENGINE TRUCK SPRINGS—Use calculated static load plus 500 to 1000 pounds, or about 5 per cent.

UNDERHUNG DRIVING SPRINGS—For passenger engines use calculated static load plus 20 per cent.

TRAILING SPRINGS—Use calculated static load plus 10 to 15 per cent and order the springs so that they will come to the right height for the calculated weight to be carried.

TENDER SPRINGS—Use calculated static load taken with maximum load of coal and water.

SPRING TABLES for semi-elliptic springs give the capacity of one plate one inch wide and different thicknesses. To obtain the required number of plates multiply the figure given in "Load" column by the width of spring in inches and divide the required capacity by the result. The quotient gives the number of plates required.

NOTE—Where quotient gives decimal more than 3 add one plate to the whole number.

The number of full length plates must be 25 per cent of the whole number required. The last full length plate must be tapered at ends and the remaining plates must be regularly shortened and tapered. The length of the shortest plate must not be less than twice the length of the spring band.

The deflection given in table is the difference between free and loaded height, irrespective of width or number of plates; for full elliptics the number of plates and deflections given is for each half of spring.

TABLE No. 44—SEMI-ELLIPTIC SPRINGS

ONE PLATE 1" WIDE

Length Between Centers	1/4" Plate Load	1/4" Plate Defl.	5/16" Plate Load	5/16" Plate Defl.	3/8" Plate Load	3/8" Plate Defl.	7/16" Plate Load	7/16" Plate Defl.	1/2" Plate Load	1/2" Plate Defl.	9/16" Plate Load	9/16" Plate Defl.	5/8" Plate Load	5/8" Plate Defl.
20	167	.98	260	.78	...	....	...	....	...	....	...	....	...	....
22	152	1.19	235	.95	341	.79	464	.67	...	....	...	....	...	....
24	139	1.41	217	1.13	312	.94	425	.80	...	....	...	....	...	....
26	128	1.66	200	1.32	288	1.10	393	.95	...	....	...	....	...	....
28	119	1.92	186	1.53	268	1.28	365	1.10	...	....	...	....	...	....
30	111	2.20	173	1.76	250	1.47	341	1.26	444	1.10	...	....	...	....
32	...	....	163	2.00	234	1.67	319	1.43	416	1.25	...	....	...	....
34	...	....	153	2.26	220	1.88	301	1.62	392	1.41	...	....	...	....
36	...	....	144	2.53	208	2.12	284	1.81	372	1.58	...	....	...	....
38	...	....	...	....	197	2.35	269	2.03	350	1.76	...	....	...	....
40					187	2.60	255	2.24	333	1.95	...	....	...	....
42					178	2.87	243	2.47	317	2.16	421	1.73	...	....
44					170	3.15	232	2.71	303	2.37	401	1.91	...	....
46					163	3.45	222	2.96	290	2.58	383	2.10	...	....
48					156	3.75	213	3.22	277	2.82	366	2.29	...	....
50					...	....	204	3.49	266	3.06	351	2.50	416	2.44
52					...	....	197	3.78	256	3.30	337	2.71	400	2.64
54					...	....	189	4.08	247	3.57	324	2.93	385	2.85
56					...	....	...	....	238	3.83	312	3.16	372	3.06
58					...	....	...	....	230	4.12	301	3.40	359	3.28
60					...	....	...	....	...	....	291	3.65	347	3.52
62					...	....	...	....	...	....	281	3.91	336	3.75
64					...	....	...	....	...	....	...	....	325	4.00
66					...	....	...	....	...	....	...	....	315	4.25
68					...	....	...	....	...	....	...	....	306	4.52

FORMULA USED IN COMPUTING TABLE

$$P = \frac{53333\ H^2}{L}$$

$$F = .000611 \frac{L^2}{H}$$

P = net static load
F = deflection
H = thickness of plate
L = length between centers

TABLE No. 45—WHEELS, TIRES, SHRINKAGE OF

M. M. Standard, 1908. Shrinkage 1/80" per ft. for 38" centers, 1/60" per ft. for 90" centers; increasing uniformly between these limits. M. M. Standard center diameters are shown in heavy type.

CENTER	TIRE		CENTER	TIRE		CENTER	TIRE	
Exact Dia.	Shrinkage	Exact Bore	Exact Dia.	Shrinkage	Exact Bore	Exact Dia.	Shrinkage	Exact Bore
20"	.021"	19.979"	40"	.042"	39.958"	60"	.071"	59.929"
21"	.022"	20.978"	41"	.044"	40.956"	61"	.073"	60.927"
22"	.023"	21.977"	42"	.045"	41.955"	**62"**	.075"	61.925"
23"	.024"	22.976"	43"	.046"	42.954"	63"	.076"	62.924"
24"	.025"	23.975"	**44"**	.048"	43.952"	64"	.078"	63.922"
25"	.026"	24.974"	45"	.049"	44.951"	65"	.079"	64.921"
26"	.027"	25.973"	46"	.050"	45.950"	**66"**	.081"	65.919"
27"	.028"	26.972"	47"	.052"	46.948"	67"	.083"	66.917"
28"	.029"	27.971"	48"	.053"	47.947"	68"	.084"	67.916"
29"	.030"	28.970"	49"	.055"	48.945"	69"	.086'	68.914"
30"	.031"	29.969"	**50"**	.056"	49.944"	**70"**	.088"	69.912"
31"	.032"	30.968"	51"	.058"	50.942"	71"	.090"	70.910"
32"	.033"	31.967"	52"	.059"	51.941"	**72"**	.091"	71.909"
33"	.034"	32.966"	53"	.060"	52.940"	73"	.093"	72.907"
34"	.035"	33.965"	54"	.062"	53.938"	**74"**	.095"	73.905"
35"	.036"	34.964"	55"	.064"	54.936"	75"	.097"	74.903"
36"	.038"	35.962"	**56"**	.065"	55.935"	76"	.098"	75.902"
37"	.039"	36.961"	57"	.067"	56.933"	77"	.100"	76.900"
38"	.040"	37.960"	58"	.068"	57.932"	**78"**	.102"	77.898"
39"	.041"	38.959"	59"	.070"	58.930"	79"	.104"	78.896"

TABLE No. 46—WHEELS—TIRE SETTING

Make distance between backs of flanged tires for Leading, Driving, Trailing and Tender Wheels as follows:

	Truck and Tender	Driving (Pair Nos.)				
		Back 5	4	3	2	Front 1
Leading Truck (Steel Tired)	53⅜"	....	....	....	....	....
Leading Truck (C.I. Chilled)	53⅛"	....	....	....	....	....
Driving, 4-coupled	....	....	....	....	53⅜"	53⅜"
Driving, 6-coupled	....	....	....	53¼"	53⅜"	53¼"
Driving, 8-coupled	....	....	53¼"	53⅜"	53⅜"	53¼"
Driving, 10-coupled	....	53⅛"	53⅜"	53⅛"	53⅜"	53⅛"
Driving, Mallet, 6-coupled F. Engine	....	....	....	53¼"	53⅜"	53¼"
Driving, Mallet, 6-coupled B. Engine	....	....	....	53¼"	53⅜"	53⅛"
Driving, Mallet, 8-coupled F. Engine	....	....	53⅛"	53⅜"	53⅜"	53⅛"
Driving, Mallet, 8-coupled B. Engine	....	....	53⅛"	53⅜"	53⅛"	53⅛"
Trailing (Rigid)	53¼"	....	....	....	....	....
Trailing (Truck)	53⅜"	....	....	....	....	....
Tender Wheels (Steel Tired)	53⅜"	....	....	....	....	....
Tender Wheels (C.I. Chilled)	53⅛"	....	....	....	....	....

TABLE No. 47—BOILERS—HEIGHT OF CROWN

Outside Diameter Largest Course	Over Crown to Roof	Outside Diameter Largest Course	Over Crown to Roof
Inches	Inches	Inches	Inches
40	15.0	81	22.6
41	15.1	82	22.8
42	15.3	83	22.9
43	15.4	84	23.1
44	15.6	85	23.3
45	15.8	86	23.4
46	15.9	87	23.6
47	16.1	88	23.7
48	16.2	89	23.9
49	16.4		
50	16.5	90	24.5
51	16.7	91	24.7
52	16.8	92	24.8
53	16.9	93	24.9
		94	25.1
54	17.6	95	25.3
55	17.8	96	25.4
56	17.9	97	25.6
57	18.1	98	25.7
58	18.2	99	25.9
59	18.4	100	26.0
60	18.5	101	26.1
61	18.6	102	26.3
62	18.8	103	26.4
63	18.9	104	26.6
64	19.1	105	26.8
65	19.3	106	26.9
		107	27.1
66	19.9	108	27.2
67	20.1	109	27.4
68	20.2	110	27.5
69	20.4	111	27.7
70	20.5		
71	20.7	112	28.3
72	20.8	113	28.4
73	20.9	114	28.6
74	21.1	115	28.8
75	21.3	116	28.9
76	21.4	117	29.1
77	21.6	118	29.2
		119	29.4
78	22.2	120	29.5
79	22.4		
80	22.5		

TABLE No. 48—LOCATION OF GAGE COCKS

L	D—Up to 53″								D—54″ to 65″							
	H in Inches—For Grades of:								H in Inches—For Grades of:							
Ins.	Up to 1½%	2%	2½%	3%	3½%	4%	4½%	5%	Up to 1½%	2%	2½%	3%	3½%	4%	4½%	5%
48	3	3	3	3½	3½	4	4	4½								
54	3	3	3	3½	4	4	4½	4½								
60	3	3	3½	3½	4	4½	4½	5	3½	3½	3½	4	4	4½	5	5
66	3	3	3½	4	4	4½	5	5	3½	3½	4	4	4½	4½	5	5½
72	3	3½	3½	4	4½	5	5	5½	3½	3½	4	4½	4½	5	5½	5½
78	3	3½	4	4	4½	5	5½	6	3½	3½	4	4½	5	5	5½	6
84	3	3½	4	4½	5	5½	5½	6	3½	4	4	4½	5	5½	6	6½
90	3	3½	4	4½	5	5½	6	6½	3½	4	4½	5	5½	5½	6	6½
96	3½	4	4½	5	5½	5½	6	6½	3½	4	4½	5	5½	6	6½	7
102	3½	4	4½	5	5½	6	6½	7	3½	4	4½	5	5½	6	6½	7
108	3½	4	4½	5	5½	6	6½	7½	3½	4½	5	5½	6	6½	7	7½
114	..	...	...	...	...	...	...	...	4	4½	5	5½	6	6½	7	8
120	...	...	...	...	...	...	...	...	4	4½	5	5½	6½	7	7½	8
126	...	...	...	...	...	...	...	...	4	4½	5½	6	6½	7	8	8½
132	...	...	...	...	...	...	...	...	4	5	5½	6	6½	7½	8	8½
138																
144																
150																
156																
162																
168																
174																
180																
186																

TABLE No. 48—LOCATION OF GAGE COCKS—Continued

L Ins.	D—66″ to 77″								D—78″ to 89″							
	H in Inches—For Grades of:								H in Inches—For Grades of:							
	Upto1½%	2%	2½%	3%	3½%	4%	4½%	5%	Upto1½%	2%	2½%	3%	3½%	4%	4½%	5%
48																
54																
60																
66																
72																
78	4	4	4½	5	5	5½	6	6½								
84	4	4	4½	5	5½	6	6	6½								
90	4	4	4½	5	5½	6	6½	7	4½	4½	5	5½	6	6½	7	7½
96	4	4½	5	5½	6	6½	7	7	4½	5	5½	6	6½	7	7	7½
102	4	4½	5	5½	6	6½	7	7½	4½	5	5½	6	6½	7	7½	8
108	4	4½	5	5½	6½	6½	7½	8	4½	5	5½	6	6½	7	8	8½
114	4	4½	5½	6	6½	7	7½	8	4½	5	6	6½	7	7½	8	8½
120	4	5	5½	6	6½	7	8	8½	4½	5½	6	6½	7	7½	8½	9
126	4½	5	5½	6	7	7½	8	8½	5	5½	6	6½	7½	8	8½	9
132	4½	5	5½	6½	7	7½	8½	9	5	5½	6	7	7½	8	9	9½
138	4½	5	6	6½	7½	8	8½	9½	5	5½	6½	7	8	8½	9	10
144	4½	5½	6	6½	7½	8	8½	9½	5	6	6½	7½	8	8½	9½	10
150	4½	5½	6	7	7½	8½	9	10	5	6	6½	7½	8	9	9½	10½
156	5	5½	6½	7	8	8½	9½	10½	5½	6	7	7½	8½	9	10	11
162	...	...	...	...	...	...	...	...	5½	6	7	8	8½	9½	10½	11
168	...	...	...	...	...	...	...	...	5½	6½	7	8	9	9½	10½	11½
174	...	...	...	...	...	...	...	...	5½	6½	7½	8	9	10	11	11½
180	...	...	...	...	...	...	...	...	5½	6½	7½	8½	9½	10	11	12
186																

TABLE No. 48—LOCATION OF GAGE COCKS—Continued

L	D—90″ to 111″								D—112″ and Over							
	H in Inches—For Grades of:								H in Inches—For Grades of:							
Ins.	Up to 1½%	2%	2½%	3%	3½%	4%	4½%	5%	Up to 1½%	2%	2½%	3%	3½%	4%	4½%	5%
90																
96																
102																
108	5	5½	6	6½	7	7½	8	8½								
114	5	5½	6	6½	7½	8	8½	9								
120	5	5½	6½	7	7½	8	8½	9½	5½	6	7	7½	8	8½	9	10
126	5	6	6½	7	7½	8½	9	9½	5½	6½	7	7½	8	9	9½	10
132	5	6	6½	7	8	8½	9	10	5½	6½	7	7½	8½	9	9½	10½
138	5½	6	6½	7½	8	9	9½	10	6	6½	7	8	8½	9½	10	10½
144	5½	6	7	7½	8½	9	9½	10½	6	6½	7½	8	9	9½	10	11
150	5½	6½	7	8	8½	9½	10	11	6	7	7½	8½	9	10	10½	11½
156	5½	6½	7	8	8½	9½	10½	11	6	7	7½	8½	9	10	11	11½
162	5½	6½	7½	8	9	9½	10½	11½	6	7	8	8½	9½	10	11	12
168	6	6½	7½	8½	9	10	11	11½	6½	7	8	9	9½	10½	11½	12
174	6	6½	7½	8½	9½	10	11	12	6½	7	8	9	10	10½	11½	12½
180	6	7	8	8½	9½	10½	11½	12½	6½	7½	8½	9	10	11	12	13
186	6	7	8	9	10	10½	11½	12½	6½	7½	8½	9½	10½	11	12	13
192	6	7	8	9	10	11	12	13	6½	7½	8½	9½	10½	11½	12½	13½
198	6	7	8	9	10	11	12	13	6½	7½	8½	9½	10½	11½	12½	13½
204	6½	7½	8½	9½	10½	11½	12½	13½	7	8	9	10	11	12	13	14
210	...	...	...	...	...	...	...	...	7	8	9	10	11	12	13	14½
216	...	...	...	...	...	...	...	...	7	8	9	10	11½	12½	13½	14½
222	...	...	...	...	...	...	...	...	7	8	9½	10½	11½	12½	14	15
228	...	...	...	...	...	...	...	...	7	8½	9½	10½	11½	13	14	15

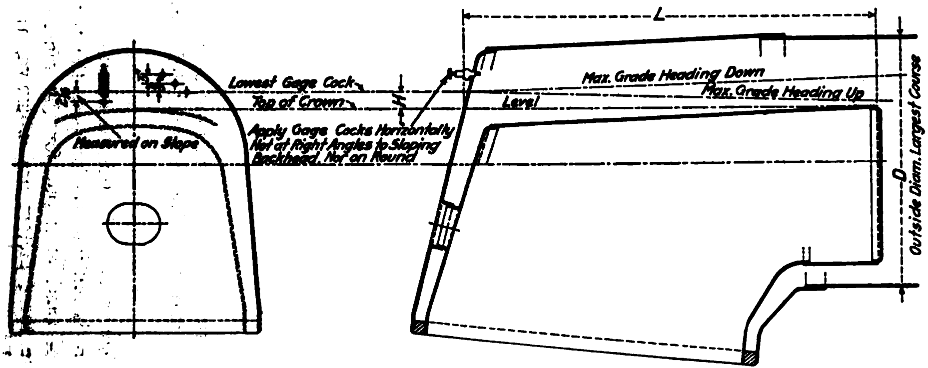


Figure No. 7

On wide firebox boilers with engineer's cab ahead of firebox, locate gage cocks and water glass on backhead and in engineer's cab as provided for above except that "L" must be measured ahead from front of crown to center of lowest gage cocks when cocks are located in engineer's cab. When gage cocks are tapped directly into boiler, special care should be taken to measure height to lowest point of cock. If cocks are applied to separate column use reading ½ inch higher than given in table.

TABLE No. 49—MAXIMUM RIGID WHEEL BASE (ALL TIRES FLANGED) BASED ON 1" TOTAL CLEARANCE

CURVE	MAX. RIGID WHEEL BASE	
	6-coupled	8-coupled
16°	15′ 6″	16′ 6″
17°	15′ 0″	16′ 0″
18°	14′ 6″	15′ 6″
19°	14′ 0″	15′ 0″
20°	14′ 0″	14′ 6″
21°	13′ 6″	14′ 0″
22°	13′ 0″	14′ 0″
23°	13′ 0″	13′ 6″
24°	12′ 6″	13′ 6″
25°	12′ 6″	13′ 0″

The 1" total clearance includes widening of gage, flange play, hub play, and other conditions not definitely known.

The maximum figures given in this table may be exceeded when there is full information as to the tire setting, widening of gage, etc.; but for the general run of work where these factors are unknown, the table will be useful.

TABLE No. 50—VALVE SETTING
STEPHENSON GEAR

	Valve				Per Cent Cut Off	Running Cut Off	Exhaust Clearance		Cylinder	
			Lead							
	Travel	Lap	Run. Cut Off	Full Gear	Full Str'ke	Per Cent Str'ke	Piston Valves	Slide Valves	Diam.	Area
	Ins.	Ins.	Ins.				Ins.	Ins.	Ins.	Sq. Ins.
	5	15/16	1/4		85.0				17 –18	227–254
Fast Passenger	5½	1 1/16	1/4		84.2		1/8	1/16	18½–20	269–314
	6	1 1/8	1/4	0	85.0	25			20½–24	330–452
	6½	1 1/4	5/16		84.0				24½ up	471 up
	5	7/8			85.6				17 –18	227–254
Passenger	5½	1	1/4	0	86.0	25	1/8	1/16	18½–20	269–314
	6	1 1/16			85.0				20½–24	330–452
	6½	1 3/16			85.7				24½ up	471 up
	5	7/8			86.6				17 –18	227–254
Fast Freight	5½	15/16		0	87.5	33	0	0	18½–20	269–314
	6	1 1/16			86.5				20½–24	330–452
	6½	1 1/8			87.0				24½ up	471 up
	5	13/16			88.3				17 –18	227–254
Freight	5½	7/8		0	90.0	50	0	0	18½–20	269–314
	6	15/16			89.3				20½–24	330–452
	6½	1			89.5				24½ up	471 up
	5	13/16			88.3				17 –20	227–314
Switcher	5½	7/8		0	90.0	66	0	0	20½–22	330–380
	6	15/16			89.3				22½ up	398 up
	2½	13/32			88.3				5 – 6	20– 26
Light Locomotives	3	1/2			87.9				6¼– 8	31– 50
	3½	9/16		0	88.7	50	0	0	8¼–10	53– 79
	4	11/16			87.0				10½–13	87–133
	4½	3/4			87.5				13½–16	143–201
	5	13/16			88.3				16½ up	214 up

TABLE No. 51—VALVE SETTING WALSCHAERT GEAR

	Valve			Per Cent Cut Off Full Gear	Running Cut Off		Exhaust Clearance		Cylinder	
	Travel	Lap	Lead		Per Cent Stroke	Port Opening	Piston Valve	Slide Valve	Diam.	Area
	Ins.	Ins.	Ins.			Ins.	Ins.	Ins.	Ins.	Sq. Ins.
Fast Passenger	5	7/8		83.0		19/64			17 –18	227–254
	5½	15/16		84.2		5/16			18½–20	269–314
	6	1 1/16	¼	83.3	25	21/64	¼	⅛	20½–22	330–380
	6	1 1/16		83.3		21/64			22½–24	398–452
	6½	1⅛		84.0		11/32			24½–26	471–531
	7	1¼		83.6		23/64			26½ up	552 up
Passenger	5	7/8		84.0		¼			17 –18	227–254
	5½	15/16		85.0		17/64			18½–20	269–314
	6	1 1/16	3/16	84.0	25	9/32	3/16	⅛	20½–22	330–380
	6	1 1/16		84.0		9/32			22½–24	398–452
	6½	1⅛		85.0		19/64			24½–26	471–531
	7	1¼		84.4		5/16			26½ up	552 up
Fast Freight	5	7/8		84.0		5/16			17 –18	227–254
	5½	15/16		85.0		21/64			18½–20	269–314
	6	1 1/16	3/16	84.0		23/64	⅛	1/16	20½–22	330–380
	6	1 1/16		84.0	33	23/64			22½–24	398–452
	6½	1⅛		85.0		⅜			24½–26	471–531
	7	1¼		84.4		25/64			26½ up	552 up
Freight	5	13/16		86.9		27/64			17 –18	227–254
	5½	7/8		87.5		29/64			18½–20	269–314
	6	1	⅛	86.5	50	½	0	0	20½–22	330–380
	6	1		86.5		½			22½–24	398–452
	6½	1 1/16		87.1		17/32			24½–26	471–532
	7	1 3/16		86.5		37/64			26½ up	552 up
Switching	5	13/16		87.7		41/64			17 –20	227–314
	5½	7/8	1/16	88.2	66	11/16	0	0	20½–22	330–380
	6	1		87.2		25/32			22½ up	398 up
Light Locomotives	2½	13/32		86.9		7/32			5 – 6	20– 28
	3	½		86.5		¼			6¼– 8	31– 50
	3½	19/32	1/16	86.5	50	9/32	0	0	8¼–10	53– 79
	4	⅝		87.0		5/16			10½–13	87–133
	4½	¾		86.8		23/64			13½–16	143–201
	5	13/16		87.7		⅜			16½ up	214 up

TABLE No. 52—VALVE SETTING—ARTICULATED ENGINES

Ratio of full cylinder volumes 1:2.5 for both saturated and superheated steam. Setting given in table below makes ratio of cut-off volumes approximately 1:2.5 for saturated and 1:2.35 for superheated steam. When ratio of full cylinder volumes differs from 1:2.5 relation between cut-offs in H. P. and L. P. cylinders should be varied to maintain cut-off volume ratios given above. Preferred sizes in heavy-faced type.

Cyl. Diam.		H. P. Valve Diameter	L. P. Port Length	Lead		Superheated Steam								Saturated Steam							
						H. P.				L. P.				H. P.				L. P.			
H. P.	L. P.			H. P.	L. P.	Travel	Lap	Exh. Clearance	% Cut Off Full Gear	Travel	Lap	Exh. Clearance	% Cut Off Full Gear	Travel	Lap	Exh. Clearance	% Cut Off Full Gear	Travel	Lap	Exh. Clearance	% Cut Off Full Gear
16″ **16½″** **17″** **17½″**	25″ **26″** 27″ **28″**	10″	20″	⅛″	3/16″	5½″	13/16″	⅛″	89.5	5″	⅞″	¼″	84.0	5½″	⅞″	¼″	87.5	5½″	⅞″	¼″	87.0
18½″ **19″** 19½″ 20½″	29″ **30″** 31″ **32″**	11″	23″	⅛″	3/16″	6″	⅞″	3/16″	89.6	5½″	1″	5/16″	83.0	6″	15/16″	¼″	88.2	6″	15/16″	5/16″	87.5

TABLE No. 52—VALVE SETTING—ARTICULATED ENGINES—Continued

Cyl. Diam.				Lead		Superheated Steam								Saturated Steam							
						H. P.				L. P.				H. P.				L. P.			
H. P.	L. P.	H. P. Valve Diameter	L. P. Port Length	H. P.	L. P.	Travel	Lap	Exh. Clearance	% Cut Off Full Gear	Travel	Lap	Exh. Clearance	% Cut Off Full Gear	Travel	Lap	Exh. Clearance	% Cut Off Full Gear	Travel	Lap	Exh. Clearance	% Cut Off Full Gear
21" 21½" **22"** 23"	33" 34" **35"** 36"	12"	26"	⅛"	3/16"	6½"	1"	¼"	89.0	6"	1⅛"	⅜"	82.4	6"	15/16"	¼"	88.2	6"	15/16"	⅜"	87.5
23½" 24" **24½"** 25½" **26"**	**37"** 38" **39"** 40" **41"**	14"	29"	⅛"	3/16"	6½"	1"	¼"	89.0	6"	1⅛"	7/16"	82.4	6"	15/16"	¼"	88.2	6"	15/16"	7/16"	87.5
26½" **27"** 28" **28½"** 29"	**42"** **43"** 44" **45"** 46"	16"	32"	⅛"	3/16"	6½"	1"	¼"	89.0	6"	1⅛"	7/16"	82.4	6"	15/16"	¼"	88.2	6"	15/16"	7/16"	87.5

SETTING VALVES—WALSCHAERT VALVE GEAR

The following method of setting the Walschaert Valve gear is equally applicable to designs having constant lead and those having variable lead.

First—Check the lengths of the eccentric crank, the lap and lead lever, and the lap and lead lever connector.

These dimensions should conform to the drawings and should not be altered.

Second—Raise the main wheels so that the distance from the center of the wheel to the top of the frame conforms to the amount specified. Then find the dead centers and port marks in the usual manner.

Third—Assemble the gear complete, temporarily tightening the eccentric crank in a position which will give the specified throw.

Fourth—Place the radius bar in the center of the link. Mark the mid-gear position. Then get the lead at each end of the cylinder. When the lead is constant, the *average* lead, or the sum of the lead on opposite ends divided by two, should be equal to the specified lead in full gear. When the lead is variable, the *average* lead in mid-gear position should be equal to one-half of the sum of the specified leads in full forward and full back gear. In other words, it should be the lead due to the lap and lead lever, unaffected by the position of the eccentric crank. Any error in the average lead when the radius bar is in central position is due to an error in the length of the upper or lower arms of the lap and lead lever.

Having thus checked the lengths of the lap and lead lever, equalize the lead by means of the adjusting nuts on the valve stem or by changing the length of the radius bar.

Fifth—Drop the lever into forward gear until the specified travel is obtained. Then, if the average lead is equal to the specified lead in full gear, the eccentric crank is correctly set. If this is not the case, the eccentric crank should be driven one way or the other until the error is corrected. If the average lead is less than the specified lead, the eccentric crank should be driven *inward*, if it *leads* the main pin; and driven *outward*, if it *follows* the main pin. If the average lead is more than the specified lead, the eccentric crank should be driven *outward*, if it *leads* the main pin; and driven *inward* if it *follows* the main pin.

After eccentric crank is correctly set, check valve travel; and relocate full forward position of the reverse lever.

Sixth—If the average lead is correct but unequally divided on the front and back centers, lengthen or shorten the eccentric rod, according to the rules given on this page until it is equalized. It must be borne in mind that to change the lead a given amount the eccentric rod must be changed to a greater amount, or about in proportion as the eccentric throw is greater than the valve travel.

Place the reverse lever in a position that will give full travel to back gear, marking this position on the quadrant; and check the lead in the same manner. With variable lead, the full back gear lead should be as much greater than the lead at mid gear as the lead at mid gear is greater than that at full forward gear.

Seventh—Run over the cut-offs and obtain other events for as many positions as required. In running over the cut-offs of locomotives of the articulated type, obtain the cut-offs for each position of the lever for *both engines* before moving the lever to a new position. This is necessary in order that the relative cut-offs in high and low pressure cylinders may be compared.

Note—Do not attempt to square cut-off at the expense of lead and port opening.

VARIABLE LEAD

When this setting is resorted to, it is advisable to adjust the gear according to the general rule, using a temporarily fixed eccentric crank to obtain the proper length of the eccentric rod and valve location, afterwards, readjust the eccentric crank to suit the desired lead in full gear.

WIDENING GAGE OF TRACKS AT CURVES

From Report of the Proceedings of the American Railway Master Mechanics' Association, 1910

Curves eight degrees and under should be standard gage. Gage 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 gage. Gage, 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 wherever practicable, but where same is unavoidable the above rule should be modified in order to make the gage of the track at the frog standard.

WEIGHT THAT RAIL WILL CARRY

It may be assumed that light steel rails weighing less than 40 pounds per yard, with crossties properly spaced, will carry from 200 to 250 pounds on a wheel for each pound weight of rail. For heavy rails it is safe to use from 275 to 350 pounds on a wheel for each pound weight of rail.

TABLE No. 53—ELEVATION OF OUTER RAIL ON CURVES IN INCHES

Curve		Velocity in Miles Per Hour													Curve
Deg.	Feet	10	15	20	25	30	35	40	45	50	55	60	65	70	Deg.
1	5730	0	⅛	¼	⅜	⅝	⅞	1⅛	1⅜	1¾	2⅛	2½	3	3⅜	1
2	2865	⅛	⅜	½	⅞	1¼	1⅝	2¼	2¾	3⅜	4⅛	5	6⅛	6¾	2
3	1910	¼	½	⅞	1¼	1⅞	2½	3¼	4⅛	5⅛	6¼	7⅜	9⅛	10	3
4	1432	¼	⅝	1⅛	1¾	2½	3⅜	4⅜	5½	6⅞	8⅜	9⅞	...	...	4
5	1146	⅜	¾	1⅜	2⅛	3⅛	4¼	5½	7	8½	...	...	...	...	5
6	955	⅜	⅞	1⅝	2⅝	3¾	5	6⅝	8⅜	...	...	...	...	...	6
7	818	½	1⅛	1⅞	3	4⅜	5⅞	7⅝	...	...	...	...	...	...	7
8	716	½	1¼	2¼	3⅜	5	6¾	8¾	...	...	...	...	...	...	8
9	636	⅝	1⅜	2½	3⅞	5½	7⅝	...	...	...	...	...	...	...	9
10	573	⅝	1½	2¾	4¼	6⅛	8⅜	...	...	...	...	...	...	...	10
11	521	¾	1¾	3	4¾	6¾	9¼	...	...	...	...	...	...	...	11
12	477	⅞	1⅞	3¼	5⅛	7⅜	...	...	...	...	...	...	...	...	12
13	441	⅞	2	3½	5⅝	8	...	...	...	...	...	...	...	...	13
14	409	1	2⅛	3⅞	6	8⅝	...	...	...	...	...	...	...	...	14
15	382	1	2⅜	4⅛	6⅜	9¼	...	...	...	...	...	...	...	...	15
16	358	1⅛	2½	4⅜	6⅞	...	...	...	...	...	...	...	...	...	16
17	337	1⅛	2⅝	4⅝	7¼	...	...	...	...	...	...	...	...	...	17
18	318	1¼	2¾	4⅞	7¾	...	...	...	...	...	...	...	...	...	18
19	301	1¼	3	5¼	8⅛	...	...	...	...	...	...	...	...	...	19
20	286	1⅜	3⅛	5½	8⅝	...	...	...	...	...	...	...	...	...	20

Formula $e = 0.000685\ S^2D$ taken from "The Elements of Railroad Engineering," by Dr. Wm. G. Raymond.
e = elevation of outer rail in inches.
S = speed in miles per hour.
D = degree of curve.

TABLE No. 54—PISTON THRUST

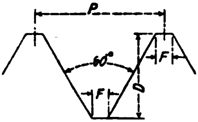
Cylinder		Boiler Pressure—Pounds							
Diameter	Area	150	160	170	180	190	200	210	220
17 "	226.98	34045	36315	38585	40855	43125	45395	47665	49935
17½"	240.53	36080	38485	40890	43295	45700	48105	50510	52915
18 "	254.47	38170	40715	43260	45805	48350	50895	53440	55985
18½"	268.80	40320	43010	45695	48385	51070	53760	56450	59135
19 "	283.53	42530	45365	48200	51035	53870	56705	59540	62375
19½"	298.65	44800	47785	50770	53755	56745	59730	62715	65705
20 "	314.16	47125	50265	53405	56550	59690	62830	65975	69115
20½"	330.06	49510	52810	56110	59410	62710	66010	69310	72615
21 "	346.36	51955	55420	58880	62345	65810	69270	72735	76200
21½"	363.05	54460	58090	61720	65350	68980	72610	76240	79870
22 "	380.13	57020	60820	64620	68425	72225	76025	79825	83630
22½"	397.61	59640	63615	67595	71570	75545	79520	83500	87475
23 "	415.48	62320	66475	70630	74785	78940	83095	87250	91405
23½"	433.74	65060	69400	73735	78075	82410	86750	91085	95425
24 "	452.39	67860	72380	76905	81430	85955	90480	95000	99525
24½"	471.44	70715	75430	80145	84860	89575	94290	99000	103715
25 "	490.87	73630	78540	83450	88355	93265	98175	103085	107990
25½"	510.71	76605	81715	86820	91930	97035	102140	107250	112355
26 "	530.93	79640	84950	90255	95565	100875	106185	111495	116805
26½"	551.55	82730	88250	93760	99280	104795	110310	115825	121340
27 "	572.56	85885	91610	97335	103060	108785	114510	120235	125960
27½"	593.96	89095	95035	100975	106910	112850	118790	124730	130670
28 "	615.75	92365	98520	104680	110835	116995	123150	129310	135465
28½"	637.94	95690	102070	108450	114830	121210	127590	133965	140345
29 "	660.52	99080	105685	112290	118895	125500	132105	138710	145315
29½"	683.49	102525	109360	116195	123030	129865	136700	143535	150370
30 "	706.86	106030	113100	120165	127235	134305	141370	148440	155510
30½"	730.62	109595	116900	124205	131510	138815	146125	153430	160735
31 "	754.77	113215	120765	128310	135860	143405	150955	158500	166050
31½"	779.31	116895	124690	132485	140275	148070	155860	163655	171450
32 "	804.25	120640	128680	136720	144765	152810	160850	168890	176935
32½"	829.58	124440	132735	141030	149325	157620	165915	174210	182510
33 "	855.30	128295	136850	145400	153955	162510	171060	179615	188165
33½"	881.41	132210	141025	149840	158655	167470	176280	185095	193910
34 "	907.92	136190	145265	154345	163425	172505	181585	190660	199740
34½"	934.82	140225	149570	158920	168265	177615	186965	196310	205660
35 "	962.11	144315	153940	163560	173180	182800	192420	202045	211665

TABLE No. 55—PRESSURES—ATMOSPHERES

Atmospheres	Pounds Per Square Inch	Kilograms Per Sq. CM.
1	14.70	1.033
2	29.39	2.067
3	44.09	3.100
4	58.79	4.133
5	73.48	5.166
6	88.18	6.200
7	102.88	7.233
8	117.57	8.266
9	132.27	9.300
10	146.97	10.333
11	161.66	11.366
12	176.36	12.400
13	191.06	13.433
14	205.76	14.466
15	220.45	15.499
16	235.15	16.533
17	249.85	17.566
18	264.54	18.599
19	279.24	19.633
20	293.94	20.666

NOTE—On all gages, zero reading is at atmospheric pressure.

TABLE No. 56—U. S. STANDARD SCREW THREADS



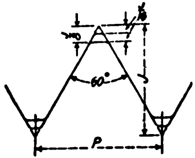
$$P = \frac{1}{\text{No. of threads per inch}}$$

$$D = P \times 0.6495.$$

$$F = \frac{P}{8}$$

Bolts and Threads						Rough Nuts and Heads				
Diameter	Threads per Inch	Width of Flats of Threads	Diameter at Root of Threads	Area at Root of Threads	Area of Body	Short Diameter of Square and Hexagon	Long Diameter of Square	Long Diameter of Hexagon	Thickness of Nuts	Thickness of Heads
Ins.		Ins.	Ins.	Sq. Ins	Sq. Ins	Ins.	Ins.	Ins.	Ins.	Ins.
1/4	20	.0062	.185	.027	.049	1/2	.707	.578	1/4	1/4
5/16	18	.0074	.240	.045	.077	19/32	.840	.686	5/16	19/64
3/8	16	.0078	.294	.068	.110	11/16	.972	.794	3/8	11/32
7/16	14	.0089	.344	.093	.150	25/32	1.105	.902	7/16	25/64
1/2	13	.0096	.400	.126	.196	7/8	1.237	1.011	1/2	7/16
9/16	12	.0104	.454	162	.249	31/32	1.370	1.119	9/16	31/64
5/8	11	.0113	.507	.202	.307	1 1/16	1.502	1.227	5/8	17/32
3/4	10	.0125	.620	.302	.442	1 1/4	1.768	1.444	3/4	5/8
7/8	9	.0138	.731	.420	.601	1 7/16	2.033	1.660	7/8	23/32
1	8	.0156	.837	.550	.785	1 5/8	2.298	1.877	1	13/16
1 1/8	7	.0178	.940	.694	.994	1 13/16	2.563	2.093	1 1/8	29/32
1 1/4	7	.0178	1.065	.893	1.227	2	2.828	2.310	1 1/4	1
1 3/8	6	.0218	1.160	1.057	1.485	2 3/16	3.093	2.527	1 3/8	1 3/32
1 1/2	6	.0218	1.284	1.295	1.767	2 3/8	3.358	2.743	1 1/2	1 3/16
1 5/8	5 1/2	.0227	1.389	1.515	2.074	2 9/16	3.623	2.960	1 5/8	1 9/32
1 3/4	5	.0250	1.491	1.746	2.405	2 3/4	3.889	3.176	1 3/4	1 3/8
1 7/8	5	.0250	1.616	2.051	2.761	2 15/16	4.154	3.393	1 7/8	1 15/32
2	4 1/2	.0277	1.712	2.302	3.142	3 1/8	4.419	3.609	2	1 9/16
2 1/4	4 1/2	.0277	1.962	3.023	3.976	3 1/2	4.949	4.043	2 1/4	1 3/4
2 1/2	4	.0312	2.176	3.719	4.909	3 7/8	5.479	4.476	2 1/2	1 15/16
2 3/4	4	.0312	2.426	4.620	5.940	4 1/4	6.010	4.909	2 3/4	2 1/8
3	3 1/2	.0357	2.629	5.428	7.069	4 5/8	6.540	5.342	3	2 5/16
3 1/4	3 1/2	.0357	2.879	6.510	8.296	5	7.070	5.775	3 1/4	2 1/2
3 1/2	3 1/4	.0384	3.100	7.548	9.621	5 3/8	7.600	6.208	3 1/2	2 11/16
3 3/4	3	.0413	3.317	8.641	11.045	5 3/4	8.131	6.641	3 3/4	2 7/8
4	3	.0413	3.567	9.993	12.566	6 1/8	8.661	7.074	4	3 1/16
4 1/4	2 7/8	.0435	3.798	11.329	14.186	6 1/2	9.191	7.508	4 1/4	3 1/4
4 1/2	2 3/4	.0454	4.028	12.743	15.904	6 7/8	9.721	7.941	4 1/2	3 7/16
4 3/4	2 5/8	.0476	4.256	14.226	17.721	7 1/4	10.252	8.374	4 3/4	3 5/8
5	2 1/2	.0500	4.480	15.763	19.635	7 5/8	10.782	8.807	5	3 13/16
5 1/4	2 1/2	.0500	4.730	17.572	21.648	8	11.312	9.240	5 1/4	4
5 1/2	2 3/8	.0526	4.953	19.267	23.758	8 3/8	11.842	9.673	5 1/2	4 3/16
5 3/4	2 3/8	.0526	5.203	21.262	25.967	8 3/4	12.373	10.106	5 3/4	4 3/8
6	2 1/4	.0555	5.423	23.098	28.274	9 1/8	12.903	10.539	6	4 9/16

TABLE No. 57—INTERNATIONAL STANDARD THREAD



The inset due to the play between the screw and the nut at the angle of the profile must not exceed J/16.

The thickness of nut should equal the diameter of the screw, and the thickness of the bolt head should equal 7/10 the diameter of the screw.

Diameter		Pitch.	Root Diameter		Short Diam. of Nut.	Diameter		Pitch.	Root Diameter		Short Diam. of Nut.
Mm.	Inches	Mm.	Mm.	Inches	Mm.	Mm.	Inches	Mm.	Mm.	Inches	Mm.
6	0.2362	1.0	4.70	0.1851	12	33	1.2992	3.5	28.45	1.1201	50
7	0.2756	1.0	5.70	0.2245	13	36	1.4173	4.0	30.80	1.2126	54
8	0.3150	1.25	6.38	0.2511	15	39	1.5354	4.0	33.80	1.3307	58
9	0.3543	1.25	7.38	0.2904	16	42	1.6535	4.5	36.15	1.4232	63
10	0.3937	1.5	8.05	0.3170	18	45	1.7716	4.5	39.15	1.5413	67
11	0.4331	1.5	9.05	0.3564	19	48	1.8898	5.0	41.51	1.6343	71
12	0.4724	1.75	9.73	0.3830	21	52	2.0472	5.0	45.51	1.7918	77
14	0.5512	2.0	11.40	0.4489	23	56	2.2047	5.5	48.86	1.9235	82
16	0.6299	2.0	13.40	0.5276	26	60	2.3622	5.5	52.86	2.0810	88
18	0.7087	2.5	14.75	0.5808	29	64	2.5197	6.0	56.21	2.2130	94
20	0.7874	2.5	16.75	0.6595	32	68	2.6772	6.0	60.21	2.3705	100
22	0.8661	2.5	18.75	0.7382	35	72	2.8346	6.5	63.56	2.5023	105
24	0.9449	3.0	20.10	0.7915	38	76	2.9921	6.5	67.56	2.6598	110
27	1.0630	3.0	23.10	0.9095	42	80	3.1497	7.0	70.91	2.7918	116
30	1.1811	3.5	25.45	1.0020	46						

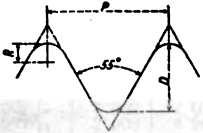


TABLE No. 58—WHITWORTH THREAD—BRITISH STANDARD

Taper of threaded pipe ends, 3/4" diameter per foot.
The drill sizes given imply that in each case a taper reamer is to follow the drill before the tap is used.
Whitworth Screw Threads—Formula:

$$P = \text{Pitch} = \frac{1}{\text{No. of threads per inch}}$$

$$D = \text{Depth} = P \times .64033. \qquad R = \text{Radius} = P \times .1373.$$

Diameters				Thickness	Transverse Area (Inside)	Th'ds per Inch	Tap Drill Diameter	Thread at End of Pipe		Couplings	
Inside		Outside									
Nominal	Actual	Approx.	Actual					O. D.	I. D.	Approx. O. D.	Length
1/8"	.196	13/32"	.406	.105	.0276	28	5/16"	.373	.327	5/8"	1"
1/4"	.345	17/32"	.531	.093	.0768	19	27/64"	.506	.439	3/4"	1"
3/8"	.465	11/16"	.687	.111	.151	19	9/16"	.640	.573	15/16"	1 1/4"
1/2"	.604	27/32"	.844	.120	.2493	14	11/16"	.809	.718	1 1/8"	1 1/2"
3/4"	.760	1 1/16"	1.062	.151	.4417	14	29/32"	1.018	.927	1 3/8"	1 3/4"
1"	1.024	1 11/32"	1.344	.160	.7856	11	1 1/8"	1.286	1.170	1 11/16"	2"
1 1/4"	1.325	1 11/16"	1.687	.181	1.356	11	1 15/32"	1.619	1.503	2 1/16"	2 1/4"
1 1/2"	1.522	1 29/32"	1.906	.192	1.767	11	1 23/32"	1.851	1.735	2 11/32"	2 1/2"
1 3/4"	1.748	2 5/32"	2.156	.204	2.405	11	1 15/16"	2.077	1.961	2 37/64"	2 1/2"
2"	1.961	2 3/8"	2.375	.207	2.952	11	2 5/32"	2.308	2.192	2 55/64"	2 3/4"
2 1/4"	2.181	2 5/8"	2.625	.222	3.758	11	2 13/32"	2.801	2.544	3 3/32"	2 3/4"
2 1/2"	2.582	3"	3.000	.209	5.185	11	2 25/32"	3.043	2.917	3 33/64"	3"
2 3/4"	2.832	3 1/4"	3.250	.209	6.215	11	3"	3.293	3.159	3 49/64"	3"
3"	3.084	3 1/2"	3.500	.208	7.366	11	3 1/16"	3.409	3.293	4 1/8"	3 1/2"
3 1/2"	3.586	4"	4.000	.207	9.967	11	3 3/4"	3.895	3.779	4 39/64"	3 1/2"
4"	4.086	4 1/2"	4.500	.207	12.962	11	4 1/4"	4.387	4.271	5 5/32"	3 1/2"
4 1/2"	4.500	5"	5.000	.250	15.904	11	4 3/4"	4.887	4.771	5 21/32"	3 1/2"
5"	5.000	5 1/2"	5.500	.250	19.635	11	5 3/16"	5.380	5.264	6 13/64"	4 1/4"
6"	6.000	6 1/2"	6.500	.250	28.274	11	6 3/16"	6.364	6.248	7 11/32"	4 3/4"

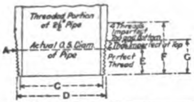


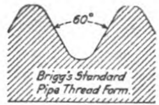
TABLE No. 59—BRIGGS STANDARD PIPE THREADS STANDARD IN THE UNITED STATES

Standard taper of thread ¾" diameter per foot

Briggs Formula:

E = Perfect thread = (4.8 + 0.8A) P P = Pitch of thread = $\frac{1}{N}$

N = Number of threads per inch. Height of thread = 0.8P



Diameters				Transverse Area				Threaded Portion				
Nominal	Actual Outside	Actual Inside Standard Weight	Actual Inside Extra Strong	Inside Standard Weight	Inside Extra Strong	Thread per Inch	Tap Drill	C	D	E	F	G
⅛"	.405	.269	.205	.0568	.033	27	23/64"	.334	.393	.19	.41	.264
¼"	.540	.364	.294	.1041	.068	18	29/64"	.433	.522	.29	.62	.402
⅜"	.675	.493	.421	.1909	.139	18	19/32"	.568	.658	.30	.63	.408
½"	.840	.622	.542	.3039	.231	14	23/32"	.701	.815	.39	.82	.534
¾"	1.050	.824	.736	.5333	.425	14	15/16"	.911	1.025	.40	.83	.546
1"	1.315	1.047	.951	.8609	.710	11½	1 3/16"	1.144	1.283	.51	1.03	.683
1¼"	1.660	1.380	1.272	1.4957	1.271	11½	1½"	1.488	1.627	.54	1.06	.707
1½"	1.900	1.610	1.494	2.0358	1.753	11½	1¾"	1.727	1.866	.55	1.07	.724
2"	2.375	2.067	1.933	3.3556	2.935	11½	2¼"	2.223	2.339	.58	1.10	.757
2½"	2.875	2.467	2.315	4.7800	4.209	8	2 21/32"	2.620	2.820	.89	1.64	1.138
3"	3.500	3.066	2.892	7.3827	6.569	8	3 9/32"	3.241	3.441	.95	1.70	1.200
3½"	4.000	3.548	3.358	9.886	8.856	8	3 49/64"	3.738	3.938	1.00	1.75	1.250
4"	4.500	4.026	3.818	12.730	11.449	8	4¼"	4.234	4.434	1.05	1.80	1.300
4½"	5.000	4.508	4.280	15.960	14.387	8	4¾"	4.731	4.931	1.10	1.85	1.350
5"	5.563	5.045	4.813	19.985	18.193	8	5 5/16"	5.291	5.491	1.16	1.91	1.406
6"	6.625	6.065	5.751	28.886	25.976	8	6⅜"	6.347	6.547	1.26	2.01	1.513
7"	7.625	7.023	6.625	38.743	34.472	8	7⅜"	7.340	7.540	1.36	2.11	1.612
8"	8.625	7.981	7.625	50.021	45.664	8	8⅜"	8.334	8.534	1.46	2.21	1.712
9"	9.625	8.937	8.625	62.722	58.426	8	9⅜"	9.327	9.527	1.57	2.31	1.812
10"	10.750	10.018	9.750	78.822	74.662	8	10½"	10.445	10.645	1.68	2.425	1.925

TABLE No. 60—PROPERTIES OF SATURATED AND SUPERHEATED STEAM

Saturated: Temperature Degrees F.	Saturated: Spec. Vol. cu. ft. per lb.	Saturated: Total Heat B.T.U.	Boiler Pressure, lb. per sq. in.	Superheated: Superheat Degrees F.	Superheated: Temperature Degrees F.	Superheated: Spec. Vol. cu. ft. per lb.	Superheated: Total Heat B.T.U.	Superheated: Increased Volume over Sat. Per Cent.
				50	416.0	2.99	1225.2	8.7
				100	466.0	3.21	1252.0	16.7
				150	516.0	3.43	1277.6	24.7
366.0	2.75	1195.0	150	200	566.0	3.64	1302.5	32.4
				250	616.0	3.84	1327.1	39.7
				300	666.0	4.04	1351.5	47.0
				350	716.0	4.24	1375.8	54.2
				400	766.0	4.44	1400.1	61.5
				50	420.8	2.83	1226.6	8.9
				100	470.8	3.04	1253.6	16.9
				150	520.8	3.24	1279.1	24.6
370.8	2.60	1195.9	160	200	570.8	3.44	1304.1	32.2
				250	620.8	3.63	1328.7	39.6
				300	670.8	3.82	1353.2	47.0
				350	720.8	4.01	1377.5	54.3
				400	770.8	4.20	1401.9	61.6
				50	425.4	2.68	1227.9	8.5
				100	475.4	2.89	1255.0	17.0
				150	525.4	3.08	1280.6	24.7
375.4	2.47	1196.8	170	200	575.4	3.27	1305.6	32.4
				250	625.4	3.45	1330.2	39.6
				300	675.4	3.63	1354.7	47.0
				350	725.4	3.81	1379.1	54.3
				400	775.4	3.98	1403.5	61.2
				50	427.6	2.62	1228.6	8.7
				100	477.6	2.81	1255.7	16.6
				150	527.6	3.00	1281.3	24.4
377.6	2.41	1197.3	175	200	577.6	3.19	1306.3	32.3
				250	627.6	3.37	1330.9	39.8
				300	677.6	3.55	1355.5	47.4
				350	727.6	3.72	1379.9	54.4
				400	777.6	3.89	1404.3	61.4

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TABLE No. 60—PROPERTIES OF SATURATED AND SUPERHEATED STEAM—Continued

Saturated			Boiler Pressure, lb. per sq. in.	Superheated				
Temperature Degrees F.	Spec. Vol. cu. ft. per lb.	Total Heat B.T.U.		Superheat Degrees F.	Temperature Degrees F	Spec. Vol. cu. ft. per lb.	Total Heat B.T.U.	Increased Volume over Sat. Per Cent.
				50	429.8	2.55	1229.2	8.5
				100	479.8	2.75	1256.4	17.0
				150	529.8	2.93	1282.0	24.6
379.8	2.35	1197.7	180	200	579.8	3.11	1307.0	32.3
				250	629.8	3.29	1331.6	40.0
				300	679.8	3.46	1356.2	47.2
				350	729.8	3.63	1380.6	54.5
				400	779.8	3.80	1415.1	61.7
				50	431.9	2.49	1229.8	8.7
				100	481.9	2.68	1257.1	17.0
				150	531.9	2.86	1282.6	24.8
381.9	2.29	1198.1	185	200	581.9	3.04	1307.7	32.7
				250	631.9	3.21	1332.4	40.1
				300	681.9	3.38	1357.0	47.6
				350	731.9	3.54	1381.4	54.6
				400	781.9	3.71	1405.9	62.0
				50	434.0	2.44	1230.4	8.9
				100	484.0	2.62	1257.7	17.0
				150	534.0	2.80	1283.3	25.0
384.0	2.24	1198.5	190	200	584.0	2.97	1308.3	32.6
				250	634.0	3.14	1333.0	40.2
				300	684.0	3.30	1357.7	47.4
				350	734.0	3.46	1382.1	54.5
				400	784.0	3.62	1406.6	61.6
				50	438.0	2.33	1231.6	8.9
				100	488.0	2.51	1259.0	17.3
				150	538.0	2.68	1284.6	25.2
388.0	2.14	1199.2	200	200	588.0	2.84	1309.7	32.7
				250	638.0	3.00	1334.4	40.2
				300	688.0	3.16	1359.1	49.6
				350	738.0	3.31	1383.6	54.7
				400	788.0	3.47	1408.0	62.2

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TABLE No. 60—PROPERTIES OF SATURATED AND SUPERHEATED STEAM—Continued

Saturated			Boiler Pressure, lb. per sq. in.	Superheated				
Temperature Degrees F.	Spec. Vol. cu. ft. per lb.	Total Heat B.T.U.		Superheat Degrees F.	Temperature Degrees F.	Spec. Vol. cu. ft. per lb.	Total Heat B.T.U.	Increased Volume over Sat. Per Cent.
				50	439.9	2.28	1232.2	9.1
				100	489.9	2.45	1259.6	17.2
				150	539.9	2.62	1285.2	25.3
389.9	2.09	1199.6	205	200	589.9	2.78	1310.3	33.0
				250	639.9	2.94	1335.1	40.6
				300	689.9	3.10	1359.8	48.3
				350	739.9	3.25	1384.3	55.5
				400	789.9	3.40	1408.8	62.7
				50	441.9	2.23	1232.7	8.8
				100	491.9	2.40	1260.2	17.1
				150	541.9	2.57	1285.9	25.3
391.9	2.05	1199.9	210	200	591.9	2.72	1310.9	32.6
				250	641.9	2.88	1335.7	40.4
				300	691.9	3 03	1360.3	47.8
				350	741.9	3.18	1384.9	55.2
				400	791.9	3.33	1409.9	62.5
				50	443.8	2.18	1233.2	9.0
				100	493.8	2.35	1260.7	17.5
				150	543.8	2.51	1286.5	25.5
393.8	2.00	1200.2	215	200	593.8	2.67	1311.6	33.5
				250	643.8	2.82	1336.3	41.0
				300	693.8	2.97	1361.0	48.5
				350	743.8	3.12	1385.6	56.0
				400	793.8	3.26	1410.1	63.0
				50	445.6	2.14	1233.8	9.2
				100	495.6	2.30	1261.4	17.3
				150	545.6	2.46	1287.1	25.5
395.6	1.96	1200.6	220	200	595.6	2.62	1312.2	33.6
				250	645.6	2.77	1337.0	41.3
				300	695.6	2.91	1361.7	48.5
				350	745.6	3.06	1386.2	56.2
				400	795.6	3.20	1410.8	63.3

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TABLE No. 61—WIRE AND SHEET METAL GAGES

Gage Numbers	United States	American or Brown & Sharpe	Washburn & Moen, Amer. Steel & Wire Co., Roebling.	Trenton Iron Co.	Birmingham or Stubs' Iron Wire	Stubs' Steel Wire	British Imperial	Gage Numbers
	Inches	Inches	Inches	Inches	Inches	Inches	Inches	
7–0	.500	....	....	....	....	....	.500	7–0
6–0	.469	....	.460	....	....	....	.464	6–0
5–0	.438	....	.430	.450	....	....	.432	5–0
4–0	.406	.460	.394	.400	.454	....	.400	4–0
000	.375	.410	.363	.360	.425	....	.372	000
00	.344	.365	.331	.330	.380	....	.348	00
0	.313	.325	.307	.305	.340	....	.324	0
1	.281	.289	.283	.285	.300	.227	.300	1
2	.266	.258	.263	.265	.284	.219	.276	2
3	.250	.229	.244	.245	.259	.212	.252	3
4	.234	.204	.225	.225	.238	.207	.232	4
5	.219	.182	.207	.205	.220	.204	.212	5
6	.203	.162	.192	.190	.203	.201	.192	6
7	.188	.144	.177	.175	.180	.199	.176	7
8	.172	.128	.162	.160	.165	.197	.160	8
9	.156	.114	.148	.145	.148	.194	.144	9
10	.141	.102	.135	.130	.134	.191	.128	10
11	.125	.0907	.121	.118	.120	.188	.116	11
12	.109	.0808	.106	.105	.109	.185	.104	12
13	.0938	.072	.0915	.0925	.095	.182	.092	13
14	.0781	.0641	.080	.0806	.083	.180	.080	14
15	.0703	.0571	.072	.070	.072	.178	.072	15
16	.0625	.0508	.0625	.061	.065	.175	.064	16
17	.0563	.0453	.054	.0525	.058	.172	.056	17
18	.050	.0403	.0475	.045	.049	.168	.048	18
19	.0438	.0359	.041	.040	.042	.164	.040	19
20	.0375	.032	.0348	.035	.035	.161	.036	20
21	.0344	.0285	.0318	.031	.032	.157	.032	21
22	.0313	.0253	.0286	.028	.028	.155	.028	22
23	.0281	.0226	.0258	.025	.025	.153	.024	23
24	.025	.0201	.023	.0225	.022	.151	.022	24
25	.0219	.0179	.0204	.020	.020	.148	.020	25
26	.0188	.0159	.0181	.018	.018	.146	.018	26
27	.0172	.0142	.0173	.017	.016	.143	.0164	27
28	.0156	.0126	.0162	.016	.014	.139	.0149	28
29	.0141	.0113	.015	.015	.013	.134	.0136	29
30	.0125	.010	.014	.014	.012	.127	.0124	30
31	.0109	.0089	.0132	.013	.010	.120	.0116	31
32	.0102	.008	.0128	.012	.009	.115	.0108	32
33	.0094	.0071	.0118	.011	.008	.112	.010	33
34	.0086	.0063	.014	.010	.007	.110	.0092	34
35	.0078	.0056	.0095	.0095	.005	.108	.0084	35
36	.007	.005	.009	.009	.004	.106	.0076	36
37	.0066	.0045	.0085	.0085	....	.103	.0068	37
38	.0063	.004	.008	.008	....	.101	.006	38
39	....	.0035	.0075	.0075	....	.099	.0052	39
40	....	.0031	.007	.007	....	.097	.0048	40

TABLE No. 62—MOMENTS OF RESISTANCE (MAXIMUM SAFE)—FOR RECTANGULAR BEAMS (INCH, LB.) WROUGHT IRON

Fibre Stress	Thick	Depth of Beam (Inches) 2″	2½″	3″	3½″	4″	4½″	5″	5½″	6″	6½″	7″	7½″	8″
12000 Lb.	½″	4000	6250	7500	12250	16000	20200	25000	30200	36000	42200	49000	56200	63800
	⅝″	5000	7800	11200	15200	20000	25400	31200	37700	45000	52800	61200	70200	80000
	¾″	6000	9400	13500	18400	24000	30400	37500	45400	54000	63300	73500	84600	96000
	⅞″	7000	10900	15700	21400	28000	35400	43800	52900	63000	73800	85600	98300	112000
	1″	8000	12500	18000	24500	32000	40500	50000	60500	72000	84500	98000	112500	128000
	1⅛″	9000	14100	20200	27500	36000	45600	56300	68000	81000	95000	110200	126500	144000
	1¼″	10000	15600	22500	30600	40000	50600	62500	75500	90000	105500	122500	140500	160000
	1⅜″	11000	17200	24700	33600	44000	55600	68700	83200	99000	116100	135000	154500	176000
	1½″	12000	18800	27000	36700	48000	60700	75000	90700	108000	127000	147000	168700	192000
	1¾″	14000	21900	29700	42800	56000	70800	87500	105700	126000	147800	171200	196800	224000
16000 Lb.	½″	5300	8300	12000	16400	21300	27000	33300	40400	48000	56300	65300	74800	85300
	⅝″	6700	10400	15000	20400	26700	33700	41600	50400	60000	70400	81600	93700	106600
	¾″	8000	12500	18000	24500	32000	40500	50000	60500	72000	84500	98000	112500	128000
	⅞″	9300	14600	21200	28600	37300	47200	58300	70400	84000	98600	114200	131200	149200
	1″	10700	16700	24000	32700	42700	54000	66600	80600	96000	112600	130700	150000	170400
	1⅛″	12000	18800	27000	36500	48000	60800	75000	90800	108000	126700	147000	168800	192000
	1¼″	13300	20800	30000	40800	53300	67500	83300	100600	120000	140800	163300	187500	213300
	1⅜″	14700	22900	33000	44900	58700	74200	91700	110900	132000	154900	180000	207000	234700
	1½″	16000	25000	36000	49000	64000	81000	100000	121000	144000	169000	196300	225000	256000
	1¾″	18600	29200	39600	57100	74500	94400	116600	141100	168000	197200	228500	262500	298200

TABLE No. 63—MODULI OF RECTANGULAR SECTIONS $\frac{bd^2}{6}$

Depth	Thickness in Inches										
	½	⅝	¾	⅞	1	1⅛	1¼	1⅜	1½	1¾	2
2	.3333	.4167	.5000	.5833	.6667	.7500	.8333	.9167	1.0000	1.1667	1.3333
2½	.5208	.6510	.7813	.9115	1.0417	1.1714	1.3021	1.4323	1.5625	1.8229	2.0833
3	.7500	.9375	1.1250	1.3125	1.5000	1.6875	1.8750	2.0625	2.2500	2.4750	3.0000
3½	1.0284	1.2760	1.5312	1.7865	2.0417	2.2877	2.5521	2.8073	3.0625	3.5729	4.0833
4	1.3333	1.6667	2.0000	2.3333	2.6667	3.0000	3.3333	3.6667	4.0000	4.6667	5.3333
4½	1.6875	2.1094	2.5313	2.9495	3.3750	3.7969	4.2188	4.6406	5.0625	5.9063	6.7500
5	2.0833	2.6042	3.1250	3.6458	4.1667	4.6875	5.2083	5.7292	6.2500	7.2917	8.3333
5½	2.5208	3.1510	3.7813	4.4115	5.0417	5.6719	6.2921	6.9322	7.5625	8.8229	10.083
6	3.0000	3.7500	4.5000	5.2500	6.0000	6.7500	7.5000	8.2500	9.0000	10.500	12.000
6½	3.5208	4.4010	5.2813	6.1615	7.0417	7.9219	8.8031	9.6823	10.563	12.323	14.083
7	4.0833	5.1042	6.1250	7.1458	8.1667	9.1875	10.208	11.229	12.250	14.292	16.333
7½	4.6875	5.8594	7.0313	8.2031	9.3750	10.547	11.719	12.891	14.063	16.406	18.750
8	5.3333	6.6667	8.0000	9.3333	10.667	12.000	13.333	14.667	16.000	18.667	21.333

R = Modulus of Resistance: Sf = Fibre Stress (lb. per sq. in.): Mb = Bending Moment (ins. lb.)

$$R = \frac{Mb}{Sf} \quad RSf = Mb: \quad Sf = \frac{Mb}{R}$$

TABLE No. 64—MODULI OF CIRCULAR SECTIONS—SOLID DIAMETER IN 8TH INCHES

Inches		⅛	¼	⅜	½	⅝	¾	⅞
1	.098	.139	.191	.255	.331	.421	.526	.647
2	.785	.942	1.12	1.31	1.53	1.77	2.04	2.33
3	2.65	2.99	3.37	3.77	4.20	4.67	5.18	5.71
4	6.28	6.89	7.53	8.22	8.94	9.71	10.53	11.37
5	12.27	13.27	14.21	15.25	16.33	17.47	18.66	19.90
6	21.21	22.56	23.96	25.43	26.96	28.55	30.00	31.91
7	33.68	35.52	37.31	39.38	41.34	43.53	45.71	47.95
8	50.27	52.70	55.14	57.68	60.30	63.00	65.78	68.64
9	71.58	74.52	77.71	80.90	84.18	87.55	90.91	94.55
10	98.2	101.9	105.7	109.6	113.6	117.8	122.0	126.3
11	130.7	135.2	139.8	144.5	149.3	154.3	159.3	164.4
12	169.7	175.0	180.5	186.1	191.8	197.6	203.5	209.6

R = Modulus of Resistance: Sf = Fibre Stress (lb. per sq. in.):
Mb = Bending Moment (in.—lb.)

$$R = \frac{3.1416\ d^3}{32} = 0.0982\ d^3 \quad R = \frac{Mb}{Sf} \quad RSf = Mb \quad Sf = \frac{Mb}{R}$$

TABLE No. 65—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.

TABLE No. 66—COMPARISON OF THERMOMETER SCALES

CENTIGRADE AND FAHRENHEIT

C	F	C	F	C	F	C	F	C	F	C	F
—30	-22	42	107.6	114	237.2	186	366.8	490	914	850	1562
—28	-18.4	44	111.2	116	240.8	188	370.4	500	932	860	1580
—26	-14.8	46	114.8	118	244.4	190	374.0	510	950	870	1598
—24	-11.2	48	118.4	120	248.0	192	377.6	520	968	880	1616
—22	—7.6	50	122.0	122	251.6	194	381.2	530	986	890	1634
—20	—4.0	52	125.6	124	255.2	196	384.8	540	1004	900	1652
—18	—0.4	54	129.2	126	258.8	198	388.4	550	1022	910	1670
—16	3.2	56	132.8	128	262.4	200	392.0	560	1040	920	1688
—14	6.8	58	136.4	130	266.0	210	410	570	1058	930	1706
—12	10.4	60	140.0	132	269.6	220	428	580	1076	940	1724
—10	14.0	62	143.6	134	273.2	230	446	590	1094	950	1742
— 8	17.6	64	147.2	136	276.8	240	464	600	1112	960	1760
— 6	21.2	66	150.8	138	280.4	250	482	610	1130	970	1778
— 4	24.8	68	154.4	140	284.0	260	500	620	1148	980	1796
— 2	28.4	70	158.0	142	287.6	270	518	630	1166	990	1814
— 0	32.0	72	161.6	144	291.2	280	536	640	1184	1000	1832
2	35.6	74	165.2	146	294.8	290	554	650	1202	1050	1922
4	39.2	76	168.8	148	298.4	300	572	660	1220	1100	2012
6	42.8	78	172.4	150	302.0	310	590	670	1238	1150	2102
8	46.4	80	176.0	152	305.6	320	608	680	1256	1200	2192
10	50.0	82	179.6	154	309.2	330	626	690	1274	1250	2282
12	53.6	84	183.2	156	312.8	340	644	700	1292	1300	2372
14	57.2	86	186.8	158	316.4	350	662	710	1310	1350	2462
16	60.8	88	190.4	160	320.0	360	680	720	1328	1400	2552
18	64.4	90	194.0	162	323.6	370	698	730	1346	1450	2642
20	68.0	92	197.6	164	327.2	380	716	740	1364	1500	2732
22	71.6	94	201.2	166	330.8	390	734	750	1382	1550	2822
24	75.2	96	204.8	168	334.4	400	752	760	1400	1600	2912
26	78.8	98	208.4	170	338.0	410	770	770	1418	1650	3002
28	82.4	100	212.0	172	341.6	420	788	780	1436	1700	3092
30	86.0	102	215.6	174	345.2	430	806	790	1454	1750	3182
32	89.6	104	219.2	176	348.8	440	824	800	1472	1800	3272
34	93.2	106	222.8	178	352.4	450	842	810	1490	1850	3362
36	96.8	108	226.4	180	356.0	460	860	820	1508	1900	3452
38	100.4	110	230.0	182	359.6	470	878	830	1526	1950	3542
40	104.0	112	233.6	184	363.2	480	896	840	1544	2000	3632

In the Fahrenheit thermometer the freezing point of water is taken at 32°. and the boiling point of water at mean atmospheric pressure at the sea level is taken at 212°. The distance between these points is divided into 180°.

In the Centigrade thermometer the freezing point is taken at 0°, and the boiling point at 100°.

1 Fahrenheit degree = 5/9 degree Centigrade.
1 Centigrade degree = 9/5 degree Fahrenheit.

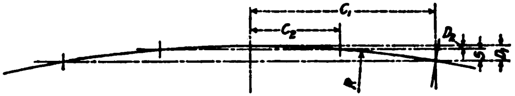
Temperature Fahrenheit = (9/5 × temperature Centigrade) + 32°.

Temperature Centigrade = 5/9 × (temperature Fahrenheit — 32°.)

TABLE No. 67—SPEED—SECONDS PER MILE IN MILES PER HOUR

Secs. per Mile	Miles per Hour	Secs. per Mile	Miles per Hour	Secs. per Mile	Miles per Hour	Secs. per Mile	Miles per Hour
24	150.0	48	75.0	72	50.0	96	37.5
25	144.0	49	73.5	73	49.3	97	37.1
26	138.4	50	72.0	74	48.6	98	36.7
27	133.3	51	70.6	75	48.0	99	36.3
28	126.6	52	69.2	76	47.4	100	36.0
29	124.1	53	67.9	77	46.7	101	35.6
30	120.0	54	66.6	78	46.1	102	35.3
31	116.1	55	65.4	79	45.5	103	34.9
32	112.5	56	64.3	80	45.0	104	34.6
33	109.0	57	63.1	81	44.4	105	34.3
34	105.9	58	62.0	82	43.9	106	33.9
35	102.8	59	61.0	83	43.4	107	33.6
36	100.0	60	60.0	84	42.8	108	33.3
37	97.3	61	59.0	85	42.3	109	33.0
38	94.7	62	58.0	86	41.9	110	32.7
39	92.3	63	57.1	87	41.4	111	32.5
40	90.0	64	56.2	88	40.9	112	32.2
41	87.8	65	55.4	89	40.4	113	31.9
42	85.7	66	54.5	90	40.0	114	31.5
43	83.7	67	53.7	91	39.6	115	31.3
44	81.8	68	52.9	92	39.1	116	31.0
45	80.0	69	52.2	93	38.7	117	30.8
46	78.3	70	51.4	94	38.3	118	30.5
47	76.6	71	50.7	95	37.9	119	30.2
..	....	..	....	..	....	120	30.0

TABLE No. 68—TANGENT DEFLECTIONS



C_1 = Distance from center of rigid wheelbase to center of truck.
C_2 = Half-rigid wheelbase.
D_1 = Tangent deflection for half-chord C_1.
D_2 = Tangent deflection for half-chord C_2.
S = Truck swing = $D_1 - D_2$.

Table gives tangent deflections in inches, calculated by the following approximate formula:

$$D = \frac{6\,C^2}{R}$$

Where D = Tangent deflection in inches.
C = Half chord in feet.
R = Radius of curve in feet.

Half Chord in Feet	Degrees and Radius of Curve									
	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°
	5730′	2865′	1910′	1433′	1146′	955′	819′	717′	637′	574′
2	....	.01	.01	.02	.02	.03	.03	.03	.04	.04
2½	.01	.01	.02	.03	.04	.05	.05	.05	.06	07
3	.01	.02	.03	.04	.05	.06	.07	.07	.08	.09
3½	.01	.03	.04	.06	.07	.08	.10	.10	.12	.13
4	.02	.03	.05	.07	.08	.10	.12	.13	.15	.17
4½	.02	.04	.07	.08	.11	.13	.15	.17	.20	.22
5	.03	.05	.08	.10	.13	.16	.18	.21	.24	.26
5½	.03	.06	.10	.13	.16	.20	.22	.26	.29	.32
6	.04	.07	.11	.15	.19	.23	.26	.30	.34	.38
6½	.04	.09	.13	.18	.23	.27	.31	.36	.40	.45
7	.05	.10	.15	.21	.26	.31	.36	.41	.46	.51
7½	.06	.12	.18	.24	.30	.36	.42	.48	.53	.59
8	.07	.13	.20	.27	.34	.40	.47	.54	.60	.67
8½	.08	.15	.23	.31	.38	.46	.53	.61	.68	.76
9	.08	.17	.25	.34	.42	.51	.59	.68	.76	.85
9½	.09	.19	.28	.38	.47	.57	.66	.76	.85	.95
10	.10	.21	.31	.42	.52	.63	.73	.84	.94	1.05
10½	.12	.23	.35	.46	.59	.69	.81	.92	1.04	1.15
11	.13	.25	.38	.51	.63	.76	.89	1.01	1.14	1.26
11½	.14	.28	.42	.55	.69	.83	.97	1.10	1.25	1.38
12	.15	.30	.45	.60	.75	.90	1.05	1.20	1.36	1.51
12½	.16	.33	.49	.66	.82	.99	1.15	1.31	1.47	1.64
13	.18	.35	.53	.71	.88	1.06	1.24	1.41	1.59	1.77
13½	.19	.38	.57	.76	.96	1.15	1.34	1.53	1.72	1.91
14	.20	.41	.62	.82	1.03	1.23	1.44	1.64	1.85	2.05
14½	.22	.44	.66	.88	1.10	1.32	1.54	1.76	1.98	2.20
15	.24	.47	.71	.94	1.18	1.41	1.65	1.88	2.12	2.35
15½	.25	.50	.76	1.01	1.26	1.51	1.76	2.02	2.27	2.52
16	.27	.54	.80	1.07	1.34	1.61	1.88	2.14	2.41	2.68
16½	.29	.57	.86	1.14	1.43	1.71	2.00	2.28	2.57	2.85
17	.30	.60	.91	1.21	1.51	1.82	2.12	2.42	2.72	3.02
17½	.32	.64	.97	1.29	1.60	1.92	2.24	2.56	2.88	3.20

TABLE No. 68—TANGENT DEFLECTIONS—Continued

Half Chord in Feet	Degree and Radius of Curve									
	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°
	5730 ′	2865 ′	1910 ′	1433 ′	1146 ′	955 ′	819 ′	717 ′	637 ′	574 ′
18	.34	.68	1.02	1.36	1.70	2.04	2.37	2.71	3.05	3.39
18½	.35	.71	1.07	1.43	1.79	2.15	2.50	2.86	3.22	3.57
19	.38	.76	1.13	1.51	1.89	2.27	2.64	3.02	3.40	3.77
19½	.39	.79	1.19	1.59	1.99	2.38	2.78	3.18	3.58	3.97
20	.42	.84	1.26	1.67	2.09	2.51	2.93	3.35	3.77	4.18
20½	.44	.88	1.32	1.75	2.20	2.64	3.07	3.51	3.95	4.39
21	.46	.92	1.39	1.85	2.31	2.77	3.23	3.69	4.16	4.61
21½	.48	.96	1.45	1.94	2.42	2.90	3.38	3.87	4.36	4.83
22	.51	1.01	1.52	2.03	2.53	3.03	3.55	4.05	4.56	5.06
22½	.53	1.06	1.58	2.13	2.65	3.17	3.71	4.23	4.77	5.29
23	.55	1.11	1.66	2.21	2.77	3.32	3.88	4.43	4.98	5.53
23½	.57	1.16	1.73	2.31	2.89	3.47	4.05	4.62	5.20	5.77
24	.60	1.21	1.81	2.41	3.02	3.62	4.22	4.82	5.43	6.02
24½	.63	1.26	1.88	2.50	3.14	3.77	4.40	5.02	5.66	6.27
25	.65	1.31	1.96	2.61	3.27	3.92	4.58	5.23	5.89	6.53
25½	.68	1.36	2.04	2.72	3.40	4.08	4.76	5.44	6.13	6.80
26	.71	1.41	2.12	2.83	3.54	4.25	4.95	5.66	6.37	7.07
26½	.73	1.47	2.20	2.94	3.67	4.40	5.14	5.87	6.61	7.34
27	.76	1.53	2.29	3.05	3.82	4.59	5.34	6.10	6.87	7.62
27½	.79	1.58	2.37	3.15	3.95	4.76	5.53	6.32	7.12	7.91
28	.82	1.64	2.46	3.28	4.11	4.93	5.74	6.56	7.38	8.20
28½	.85	1.70	2.55	3.40	4.25	5.10	5.95	6.80	7.65	8.48
29	.88	1.76	2.64	3.52	4.40	5.27	6.16	7.04	7.92	8.79
29½	.91	1.82	2.73	3.64	4.55	5.47	6.37	7.28	8.19	9.10
30	.94	1.88	2.83	3.77	4.71	5.65	6.59	7.53	8.47	9.41
30½	.97	1.94	2.92	3.89	4.87	5.84	6.81	7.78	8.76	9.73
31	1.01	2.01	3.02	4.02	5.03	6.04	7.04	8.04	9.05	10.05
31½	1.04	2.07	3.12	4.15	5.18	6.24	7.27	8.30	9.34	10.37
32	1.07	2.14	3.22	4.29	5.36	6.43	7.50	8.57	9.65	10.70
32½	1.10	2.21	3.31	4.42	5.53	6.63	7.74	8.84	9.95	11.05
33	1.14	2.28	3.42	4.56	5.70	6.84	7.98	9.11	10.26	11.40
33½	1.17	2.35	3.51	4.70	5.87	7.05	8.21	9.39	10.58	11.75
34	1.21	2.42	3.63	4.84	6.05	7.26	8.47	9.67	10.90	12.10
34½	1.24	2.49	3.74	4.98	6.23	7.48	8.72	9.96	11.22	12.44
35	1.28	2.56	3.85	5.13	6.41	7.70	8.97	10.25	11.54	12.80
35½	1.32	2.63	3.96	5.28	6.60	7.92	9.23	10.55	11.87	13.16
36	1.36	2.71	4.07	5.43	6.79	8.14	9.50	10.85	12.21	13.55
36½	1.39	2.78	4.18	5.58	6.98	8.36	9.76	11.15	12.55	13.93
37	1.43	2.86	4.30	5.73	7.17	8.60	10.03	11.46	12.90	14.31
37½	1.47	2.93	4.41	5.89	7.35	8.83	10.30	11.76	13.25	14.70
38	1.51	3.02	4.54	6.05	7.56	9.07	10.58	12.08	13.60	15.10
38½	1.55	3.10	4.56	6.20	7.75	9.31	10.85	12.40	13.95	15.49
39	1.59	3.18	4.78	6.36	7.96	9.56	11.13	12.73	14.33	15.90
39½	1.63	3.26	4.90	6.51	8.16	9.79	11.41	13.06	14.70	16.31
40	1.68	3.35	5.03	6.69	8.38	10.05	11.72	13.39	15.07	16.72
40½	1.71	3.43	5.15	6.86	8.58	10.30	11.98	13.72	15.45	17.14
41	1.76	3.52	5.28	7.04	8.80	10.56	12.32	14.07	15.83	17.57
41½	1.80	3.61	5.41	7.20	9.02	10.82	12.62	14.40	16.22	18.00
42	1.85	3.70	5.54	7.39	9.24	11.08	12.92	14.76	16.62	18.44
42½	1.89	3.78	5.67	7.56	9.46	11.34	13.22	15.11	17.02	18.87
43	1.94	3.87	5.81	7.74	9.68	11.62	13.55	15.48	17.42	19.33
43½	1.98	3.95	5.94	7.92	9.91	11.88	13.86	15.85	17.82	19.78

TABLE No. 68—TANGENT DEFLECTIONS—Continued

Half Chord in Feet	Degree and Radius of Curve									
	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°
	5730′	2865′	1910′	1433′	1146′	955′	819′	717′	637′	574′
44	2.03	4.06	6.08	8.11	10.14	12.16	14.20	16.20	18.24	20.24
44½	2.07	4.15	6.22	8.29	10.36	12.44	14.51	16.56	18.65	20.70
45	2.12	4.24	6.36	8.48	10.60	12.72	14.83	16.94	19.07	21.17
45½	2.17	4.33	6.50	8.67	10.84	13.00	15.21	17.30	19.50	21.64
46	2.22	4.44	6.65	8.86	11.08	13.29	15.50	17.71	19.93	22.12
46½	2.26	4.53	6.79	9.05	11.31	13.58	15.82	18.10	20.36	22.60
47	2.31	4.62	6.94	9.25	11.57	13.87	16.18	18.49	20.81	23.09
47½	2.36	4.72	7.08	9.44	11.81	14.17	16.52	18.88	21.25	23.58
48	2.41	4.82	7.24	9.65	12.06	14.48	16.90	19.28	21.70	24.08
48½	2.46	4.92	7.39	9.85	12.31	14.77	17.25	19.69	22.16	24.58
49	2.51	5.03	7.55	10.05	12.57	15.08	17.60	20.10	22.62	25.10
49½	2.56	5.14	7.70	10.26	12.83	15.40	17.98	20.52	23.20	25.64
50	2.62	5.23	7.85	10.47	13.09	15.71	18.36	20.95	23.58	26.18

Half Chord in Feet	Degree and Radius of Curve									
	11°	12°	13°	14°	15°	16°	17°	18°	19°	20°
	522′	478′	442′	410′	383′	359′	338′	320′	303′	288′
2	.05	.05	.05	.06	.06	.07	.07	.08	.08	.08
2½	.08	.08	.09	.10	.10	.12	.12	.12	.13	.13
3	.10	.11	.12	.13	.14	.15	.16	.17	.18	.19
3½	.14	.16	.17	.18	.20	.21	.22	.23	.25	.26
4	.18	.20	.22	.23	.25	.27	.28	.30	.32	.33
4½	.24	.26	.28	.30	.32	.34	.36	.38	.40	.42
5	.29	.31	.34	.37	.39	.42	.44	.47	.50	.52
5½	.35	.38	.42	.45	.48	.51	.54	.58	.61	.63
6	.41	.45	.49	.53	.56	.60	.64	.68	.71	.75
6½	.49	.53	.58	.63	.67	.71	.76	.80	.84	.88
7	.56	.61	.67	.72	.77	.82	.87	.92	.97	1.02
7½	.65	.71	.77	.83	.89	.95	1.01	1.06	1.12	1.17
8	.74	.80	.87	.94	1.00	1.07	1.14	1.20	1.27	1.33
8½	.84	.91	.99	1.07	1.14	1.21	1.29	1.36	1.44	1.51
9	.93	1.02	1.10	1.19	1.27	1.35	1.44	1.52	1.60	1.69
9½	1.04	1.14	1.23	1.33	1.42	1.51	1.61	1.70	1.79	1.88
10	1.15	1.26	1.36	1.46	1.57	1.67	1.78	1.88	1.98	2.08
10½	1.27	1.39	1.50	1.61	1.73	1.84	1.96	2.07	2.18	2.29
11	1.39	1.52	1.64	1.77	1.90	2.02	2.15	2.27	2.40	2.52
11½	1.52	1.66	1.80	1.93	2.07	2.21	2.34	2.48	2.62	2.76
12	1.66	1.81	1.95	2.11	2.26	2.41	2.56	2.70	2.85	3.00
12½	1.80	1.96	2.12	2.29	2.45	2.61	2.78	2.93	3.10	3.26
13	1.94	2.12	2.29	2.47	2.65	2.82	3.00	3.17	3.35	3.52
13½	2.10	2.29	2.48	2.67	2.85	3.04	3.24	3.42	3.60	3.80
14	2.25	2.46	2.66	2.87	3.07	3.28	3.48	3.68	3.88	4.08
14½	2.42	2.64	2.86	3.08	3.30	3.52	3.74	3.95	4.17	4.38
15	2.59	2.82	3.05	3.29	3.53	3.76	3.99	4.22	4.46	4.69
15½	2.77	3.02	3.26	3.52	3.78	4 02	4.27	4.52	4.76	5.02
16	2.94	3.21	3.47	3.75	4.01	4.28	4.58	4.80	5.07	5.33
16½	3.13	3.42	3.70	3.98	4.27	4.56	4.83	5.10	5.40	5.67
17	3.32	3.63	3.92	4.23	4.53	4.83	5.13	5.42	5.72	6.02
17½	3.52	3.84	4.15	4.50	4.80	5.12	5.44	5.76	6.06	6.38

TABLE No. 68—TANGENT DEFLECTIONS—Continued

Half Chord in Feet	Degree and Radius of Curve									
	11°	12°	13°	14°	15°	16°	17°	18°	19°	20°
	522′	478′	442′	410′	383′	359′	338′	320′	303′	288′
18	3.72	4.07	4.40	4.74	5.08	5.41	5.75	6.08	6.42	6.75
18½	3.93	4.29	4.64	5.00	5.36	5.72	6.07	6.41	6.77	7.13
19	4.15	4.53	4.90	5.28	5.66	6.03	6.41	6.77	7.15	7.52
19½	4.37	4.77	5.16	5.56	5.95	6.35	6.75	7.12	7.52	7.92
20	4.60	5.02	5.43	5.85	6.27	6.69	7.10	7.50	7.92	8.33
20½	4.83	5.27	5.70	6.15	6.59	7.02	7.46	7.88	8.32	8.76
21	5.07	5.54	5.99	6.45	6.91	7.37	7.83	8.27	8.73	9.19
21½	5.32	5.81	6.28	6.76	7.25	7.73	8.21	8.69	9.15	9.64
22	5.56	6.08	6.57	7.08	7.58	8.09	8.59	9.08	9.58	10.08
22½	5.82	6.35	6.87	7.41	7.92	8.46	8.98	9.50	10.03	10.55
23	6.08	6.64	7.18	7.74	8.29	8.84	9.39	9.92	10.48	11.02
23½	6.35	6.93	7.49	8.08	8.65	9.23	9.80	10.35	10.94	11.51
24	6.62	7.23	7.82	8.43	9.02	9.63	10.22	10.80	11.41	12.00
24½	6.89	7.54	8.15	8.79	9.39	10.04	10.65	11.26	11.88	12.51
25	7.18	7.85	8.48	9.15	9.79	10.45	11.09	11.72	12.38	13.02
25½	7.48	8.17	8.83	9.52	10.20	10.87	11.54	12.20	12.89	13.55
26	7.77	8.49	9.18	9.89	10.59	11.30	12.00	12.68	13.39	14.08
26½	8.07	8.81	9.53	10.27	11.00	11.73	12.47	13.17	13.90	14.63
27	8.38	9.15	9.90	10.67	11.42	12.18	12.94	13.67	14.44	15.19
27½	8.68	9.48	10.26	11.06	11.85	12.64	13.42	14.18	14.97	15.76
28	9.01	9.84	10.64	11.47	12.28	13.10	13.92	14.70	15.52	16.33
28½	9.34	10.20	11.03	11.89	12 73	13.57	14.43	15.23	16.08	16.91
29	9.67	10.57	11.42	12.31	13.18	14.06	14.93	15.77	16.65	17.52
29½	10.00	10.93	11.81	12.73	13.63	14.54	15.44	16.32	17.23	18.12
30	10.34	11.30	12.22	13.17	14.10	15.04	15.98	16.88	17.82	18.75
30½	10.68	11.67	12.62	13.61	14.58	15.54	16.51	17.45	18.41	19.37
31	11.05	12.06	13.04	14.06	15.06	16.06	17.06	18.02	19.03	20.02
31½	11.40	12.44	13.46	14.51	15.54	16.57	17.61	18.60	19.64	20.66
32	11.77	12.85	13.90	14.98	16.04	17.11	18.18	19.20	20.28	21.33
32½	12.14	13.26	14.32	15.46	16.54	17.65	18.74	19.80	20.91	22.00
33	12.52	13.67	14.77	15.94	17.06	18.20	19.33	20.42	21.56	22.69
33½	12.90	14.09	15.23	16.43	17.57	18.75	19.92	21.05	22.23	23.37
34	13.29	14.51	15.69	16.92	18.11	19.32	20.52	21.68	22.90	24.08
34½	13.68	14.94	16.16	17.41	18.65	19.89	21.12	22.31	23.58	24.83
35	14.08	15.38	16.63	17.93	19.20	20.47	21.74	22.97	24.26	25.52
35½	14.49	15.82	17.11	18.45	19.75	21.06	22.37	23.63	24.95	26.25
36	14.90	16.27	17.59	18.97	20.30	21.66	23.01	24.30	25.66	27.00
36½	15.32	16.71	18.08	19.50	20.86	22.26	23.64	24.98	26.38	27.76
37	15.74	17.18	18.57	20.03	21.45	22.88	24.30	25.67	27.11	28.52
37½	16.16	17.65	19.08	20.58	22.03	23.50	24.95	26.36	27.85	29.30
38	16.60	18.13	19.60	21.13	22.62	24.13	25.63	27.08	28.59	30.08
38½	17.03	18.60	20.11	21.69	23.21	24.76	26.31	27.80	29.34	30.88
39	17.47	19.09	20.65	22.26	23.83	25.42	27.00	28.52	30.12	31.69
39½	17.93	19.58	21.18	22.83	24.45	26.07	27.69	29.25	30.90	32.51
40	18.39	20.08	21.72	23.41	25.07	26.74	28.40	30.00	31.68	33.33
40½	18.85	20.59	22.26	24.00	25.69	27.41	29.12	30.75	32.48	34.18
41	19.32	21.10	22.82	24.60	26.33	28.09	29.84	31.52	33.29	35.02
41½	19.80	21.62	23.37	25.19	26.98	28.77	30.56	32.30	34.11	35.88
42	20.28	22.14	23.94	25.81	27.63	29.48	31.31	33.08	34.93	36.75
42½	20.75	22.67	24.51	26.42	28.30	30.18	32.06	33.87	35.76	37.62
43	21.25	23.21	25.10	27.06	28.97	30.90	32.82	34.67	36.61	38.52
43½	21.74	23.73	25.70	27.68	29.65	31.62	33.58	35.48	37.46	39.42

TABLE No. 68—TANGENT DEFLECTIONS—Continued

Half Chord in Feet	Degree and Radius of Curve									
	11°	12°	13°	14°	15°	16°	17°	18°	19°	20°
	522′	478′	442′	410′	383′	359′	338′	320′	303′	288′
44	22.25	24.30	26.28	28.33	30.33	32.36	34.37	36.30	38.34	40.33
44½	22.75	24.84	26.88	28.98	31.02	33.10	35.16	37.13	39.21	41.25
45	23.28	25.42	27.49	29.63	31.72	33.84	35.95	37.97	40.10	42.19
45½	23.80	25.98	28.15	30.28	32.42	34.59	36.75	38.80	41.00	43.13
46	24.32	26.56	28.72	30.96	33.15	35.36	37.56	39.67	41.90	44.08
46½	24.85	27.13	29.35	31.64	33.88	36.13	38.36	40.53	42.81	45.04
47	25.39	27.73	29.98	32.33	34.62	36.92	39.21	41.42	43.74	46.02
47½	25.92	28.32	30.63	33.02	35.33	37.71	40.10	42.31	44.68	47.01
48	26.48	28.92	31.27	33.72	36.15	38.51	40.90	43.20	45.62	48.00
48½	27.03	29.53	31.93	34.42	36.85	39.31	41.26	44.10	46.58	49.00
49	27.60	30.14	32.59	35.14	37.61	40.13	42.62	45.02	47.54	50.02
49½	28.20	30.75	33.31	35.92	38.43	41.03	43.60	46.10	48.70	51.23
50	28.80	31.44	34.08	36.72	39.30	41.94	44.58	47.22	49.86	52.08

Half Chord in Feet	Degree and Radius of Curve									
	21°	22°	23°	24°	25°	26°	27°	28°	29°	30°
	274′	262′	251′	240′	231′	222′	214′	207′	200′	193′
2	.09	.09	.10	.10	.10	.11	.11	.12	.12	.12
2½	.13	.14	.14	.15	.16	.16	.17	.18	.18	.19
3	.20	.21	.22	.23	.23	.24	.25	.26	.27	.28
3½	.26	.28	.29	.30	.31	.33	.34	.35	.36	.38
4	.35	.37	.38	.40	.42	.43	.45	.46	.48	.50
4½	.44	.46	.48	.50	.52	.54	.56	.58	.60	.62
5	.55	.57	.60	.62	.65	.68	.70	.72	.75	.78
5½	.66	.69	.72	.75	.78	.81	.84	.87	.90	.94
6	.79	.82	.86	.90	.94	.97	1.01	1.04	1.08	1.12
6½	.92	.96	1.00	1.05	1.09	1.14	1.18	1.22	1.26	1.31
7	1.07	1.12	1.17	1.22	1.27	1.32	1.37	1.42	1.47	1.52
7½	1.23	1.28	1.34	1.40	1.46	1.52	1.57	1.63	1.68	1.74
8	1.40	1.47	1.53	1.59	1.66	1.73	1.80	1.86	1.92	1.99
8½	1.58	1.65	1.72	1.80	1.87	1.95	2.02	2.09	2.16	2.24
9	1.77	1.86	1.94	2.02	2.10	2.19	2.27	2.35	2.43	2.52
9½	1.97	2.06	2.15	2.25	2.34	2.43	2.53	2.61	2.70	2.80
10	2.19	2.29	2.39	2.49	2.60	2.70	2.80	2.90	3.00	3.11
10½	2.41	2.52	2.63	2.75	2.86	2.97	3.08	3.19	3.30	3.42
11	2.65	2.77	2.90	3.01	3.14	3.27	3.39	3.51	3.63	3.76
11½	2.89	3.02	3.16	3.30	3.43	3.57	3.70	3.83	3.97	4.11
12	3.15	3.30	3.44	3.59	3.74	3.90	4.04	4.17	4.32	4.48
12½	3.42	3.57	3.73	3.90	4.05	4.22	4.38	4.52	4.68	4.85
13	3.70	3.87	4.04	4.21	4.39	4.57	4.74	4.90	5.07	5.24
13½	3.99	4.17	4.35	4.55	4.73	4.92	5.10	5.28	5.46	5.66
14	4.30	4.50	4.68	4.90	5.10	5.30	5.50	5.69	5.88	6.10
14½	4.61	4.82	5.03	5.26	5.46	5.68	5.89	6.09	6.31	6.53
15	4.93	5.15	5.38	5.62	5.85	6.09	6.30	6.52	6.75	7.00
15½	5.26	5.50	5.74	6.01	6.25	6.50	6.75	6.96	7.21	7.48
16	5.60	5.86	6.11	6.40	6.65	6.91	7.17	7.42	7.68	7.95
16½	5.96	6.24	6.51	6.81	7.07	7.35	7.64	7.90	8.17	8.46

TABLE No. 68—TANGENT DEFLECTIONS—Continued

Half Chord in Feet	Degree and Radius of Curve									
	21°	22°	23°	24°	25°	26°	27°	28°	29°	30°
	274′	262′	251′	240′	231′	222′	214′	207′	200′	193′
17	6.33	6.62	6.90	7.22	7.51	7.81	8.10	8.36	8.67	8.98
17½	6.70	7.01	7.32	7.66	7.95	8.28	8.59	8.88	9.19	9.50
18	7.10	7.42	7.75	8.08	8.40	8.75	9.08	9.40	9.72	10.07
18½	7.49	7.83	8.18	8.55	8.88	9.25	9.59	9.92	10.26	10.63
19	7.90	8.27	8.63	9.03	9.38	9.76	10.12	10.46	10.83	11.22
19½	8.32	8.70	9.08	9.50	9.87	10.27	10.66	11.02	11.40	11.82
20	8.76	9.16	9.56	10.00	10.39	10.81	11.21	11.60	12.00	12.43
20½	9.20	9.62	10.04	10.50	10.91	11.35	11.78	12.18	12.60	13.06
21	9.67	10.10	10.53	10.98	11.46	11.92	12.37	12.79	13.24	13.72
21½	10.15	10.59	11.05	11.51	12.02	12.50	12.96	13.40	13.89	14.38
22	10.60	11.08	11.58	12.05	12.58	13.09	13.58	14.03	14.52	15.04
22½	11.08	11.59	12.10	12.59	13.15	13.69	14.20	14.67	15.18	15.73
23	11.58	12.10	12.63	13.16	13.72	14.29	14.82	15.32	15.86	16.42
23½	12.09	12.64	13.19	13.74	14.32	14.93	15.47	16.00	16.57	17.16
24	12.61	13.19	13.76	14.32	14.95	15.56	16.14	16.69	17.28	17.90
24½	13.15	13.75	14.34	14.93	15.59	16.22	16.82	17.39	18.01	18.65
25	13.69	14.31	14.93	15.55	16.22	16.89	17.51	18.11	18.74	19.41
25½	14.24	14.89	15.54	16.18	16.89	17.58	18.23	18.85	19.50	20.21
26	14.80	15.49	16.16	16.82	17.56	18.28	18.96	19.60	20.28	21.01
26½	15.37	16.08	16.78	17.56	18.24	18.98	19.68	20.35	21.06	21.83
27	15.96	16.69	17.43	18.23	18.94	19.70	20.44	21.13	21.87	22.66
27½	16.56	17.31	18.07	18.91	19.64	20.43	21.20	21.93	22.68	23.50
28	17.18	17.96	18.74	19.60	20.36	21.19	21.98	22.73	23.52	24.37
28½	17.80	18.61	19.41	20.31	21.15	21.95	22.78	23.59	24.41	25.26
29	18.42	19.26	20.10	21.03	21.86	22.73	23.60	24.38	25.23	26.15
29½	19.05	19.92	20.80	21.75	22.61	23.51	24.40	25.23	26.12	27.05
30	19.71	20.61	21.51	22.50	23.41	24.32	25.23	26.09	27.00	27.98
30½	20.36	21.30	22.24	23.25	24.19	25.14	26.07	26.97	27.90	28.92
31	21.04	22.00	22.97	24.03	24.96	25.97	26.94	27.86	28.83	29.88
31½	21.72	22.71	23.72	24.80	25.79	26.82	27.81	28.77	29.76	30.84
32	22.42	23.45	24.48	25.60	26.60	27.68	28.71	29.68	30.72	31.83
32½	23.12	24.17	25.24	26.41	27.43	28.54	29.61	30.62	31.68	32.83
33	23.85	24.94	26.03	27.23	28.29	29.43	30.53	31.57	32.67	33.85
33½	24.58	25.70	26.83	28.11	29.15	30.33	31.47	32.53	33.66	34.88
34	25.31	26.47	27.63	28.90	30.03	31.24	32.41	33.51	34.68	35.94
34½	26.07	27.26	28.45	29.75	30.91	32.17	33.37	34.50	35.71	37.01
35	26.83	28.05	29.28	30.63	31.82	33.11	34.35	35.51	36.75	38.08
35½	27.60	28.86	30.13	31.48	32.73	34.07	35.33	36.53	37.81	39.17
36	28.38	29.68	30.98	32.40	33.66	35.03	36.34	37.57	38.88	40.29
36½	29.18	30.51	31.85	33.30	34.61	36.01	37.36	38.62	39.97	41.42
37	29.98	31.35	32.72	34.23	35.56	37.00	38.38	39.68	41.07	42.56
37½	30.80	32.21	33.62	35.16	36.53	38.01	39.43	40.76	42.19	43.72
38	31.62	33.07	34.52	36.10	37.51	39.03	40.49	41.86	43.32	44.89
38½	32.45	33.94	35.43	37.06	38.49	40.06	41.55	42.97	44.46	46.08
39	33.30	34.83	36.36	38.03	39.51	41.11	42.64	44.09	45.63	47.28
39½	34.17	35.72	37.30	39.01	40.53	42.16	43.75	45.23	46.80	48.51
40	35.04	36.64	38.25	40.00	41.56	43.24	44.86	46.38	48.00	49.74

TABLE No 69—CONVERSION TABLE

METRIC UNIT	U. S. EQUIVALENT
1 Centimeter	0.3937006 inch.
1 Meter	3.280838 feet.
1 Meter	1.093613 yards.
1 Kilometer	0.6213709 miles.
1 Square centimeter	0.1550002 square inch.
1 Square meter	10.7639 square feet.
1 Square meter	1.195989 square yards.
1 Square kilometer	0.3861018 square mile.
1 Hectare	2.471052 acres.
1 Cubic centimeter	0.0610236 cubic inch.
1 Cubic meter	35.31463 cubic feet.
1 Cubic meter	1.307949 cubic yards.
1 Cubic kilometer	0.2399124 cubic mile.
1 Cubic centimeter	0.0338022 U. S. fluid ounce.
1 Liter	1.056304 U. S. fluid quarts.
1 Liter	0.264076 U. S. gallon.
1 Liter	0.88086 British liquid quart.
1 Liter	0.220215 British gallon.
1 Liter	0.908082 U. S. dry quart.
1 Stere (cubic meter)	28.3776 U. S. bushels.
1 Gramme	15.4323487 grains.
1 Gramme	0.0352739 avoirdupois ounce.
1 Kilogram	2.2046212 avoirdupois pounds.
1 Millier (tonneau)	1.1023107 short tons (2000 lb.)
1 Gramme	0.0321507 Troy (apoth.) ounce.
1 Kilogram	2.679228 Troy (apoth.) pound.
1 Kilogram per sq. m.	0.2048161 pounds per sq. ft.
1 Kilogram per sq. cm.	14.22335 pounds per sq. in.
1 Kilogram-meter	7.233007 foot pounds.
1 Calorie	3.968318 British heat units.
1 Calorie	3091.36 foot pounds.
1 Force de cheval	0.9863193 horse power.
1 Gramme in a cu. cm.	0.5780371 ounces in a cubic inch.
1 Kilogram in a cu. m.	0.0624279 pound in a cubic foot.
1 Millier in a cu. m.	0.842778 short ton in a cubic yard.
1 Milligram in a liter	0.058439 grain in a U. S. gallon.

TABLE No. 69—CONVERSION TABLE—Continued

U. S. Unit	Metric Equivalent
1 Inch	2.540001 centimeters.
1 Foot	0.3048001 meter.
1 Yard	0.9144 meter.
1 Mile	1.609344 kilometer.
1 Square inch	6.451606 square centimeters.
1 Square foot	0.0929031 square meter.
1 Square yard	0.8361281 square meter.
1 Square mile	2.589989 square kilometers.
1 Acre	0.4046858 hectare.
1 Cubic inch	16.387083 cubic centimeters.
1 Cubic foot	0.0283169 cubic meter.
1 Cubic yard	0.7645558 cubic meter.
1 Cubic mile	4.168186 cubic kilometers.
1 U. S. fluid ounce	29.5839 cubic centimeters.
1 U. S. liquid quart	0.946698 liter.
1 U. S. gallon	3.78679 liters.
1 British liquid quart	1.135254 liters.
1 British gallon	4.54102 liters.
1 U. S. dry quart	1.101222 liters.
1 U. S. bushel	0.035239 stere (cubic meter).
1 Grain	0.0647989 gramme.
1 Avoirdupois ounce	28.34954 grammes.
1 Avoirdupois pound	0.4535926 kilogram.
1 Short ton (2000 pounds)	0.9071852 millier (tonneau).
1 Troy (apoth.) ounce	31.1035 grammes.
1 Troy (apoth.) pound	0.3732419 kilogram.
1 Pound per square foot	4.882427 kilograms per sq. m.
1 Pound per square inch	0.0703069 kilogram per sq. cm.
1 Foot-pound	0.1382551 kilogram—meter.
1 British heat unit	0.2519959 calorie.
1 Foot-pound	0.0003234 calorie.
1 Horse power	1.013871 forces de chevaux.
1 Ounce in a cubic inch	1.729993 grammes in a cu. cm.
1 Pound in a cubic foot	16.01846 kilograms in a cu. m.
1 Short ton in a cubic yard	1.186552 milliers in a cu. m.
1 Grain in a U. S. gallon	17.11184 milligrams in a liter.

TABLE No. 70—CONVERSION TABLE—INCHES IN MILLIMETERS

In.	0	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16	In
0	0.000	1.587	3.175	4.762	6.350	7.937	9.525	11.112	12.700	14.287	15.875	17.462	19.050	20.637	22.225	23.812	0
1	25.400	26.957	28.574	30.162	31.749	33.337	34.924	36.512	38.099	39.687	41.274	42.862	44.449	46.037	47.624	49.212	1
2	50.799	52.387	53.974	55.561	57.149	58.736	60.324	61.911	63.499	65.086	66.674	68.261	69.859	71.436	73.024	74.611	2
3	76.199	77.786	79.374	80.961	82.549	84.136	85.723	87.311	88.898	90.486	92.073	93.661	95.248	96.836	98.423	100.01	3
4	101.60	103.19	104.77	106.36	107.95	109.54	111.12	112.71	114.30	115.89	117.47	119.06	120.65	122.24	123.82	125.41	4
5	127.00	128.59	130.17	131.76	133.35	134.94	136.52	138.11	139.70	141.28	142.87	144.46	146.05	147.64	149.22	150.81	5
6	152.40	153.98	155.57	157.16	158.75	160.33	161.92	163.51	165.10	166.68	168.27	169.86	171.45	173.03	174.62	176.21	6
7	177.80	179.38	180.97	182.56	184.15	185.73	187.32	188.91	190.50	192.08	193.67	195.26	196.85	198.43	200.02	201.61	7
8	203.20	204.78	206.37	207.96	209.55	211.13	212.72	214.31	215.90	217.48	219.07	220.66	222.25	223.83	225.42	227.01	8
9	228.60	230.18	231.77	233.36	234.95	236.53	238.12	239.71	241.30	242.88	244.47	246.06	247.65	249.23	250.82	252.41	9
10	254.00	255.58	257.17	258.76	260.35	261.93	263.52	265.11	266.70	268.28	269.87	271.46	273.05	274.64	276.22	277.81	10
11	279.39	280.98	282.57	285.16	285.74	287.33	288.92	290.51	292.09	293.68	295.27	296.86	298.44	300.03	301.62	303.21	11
12	304.79	306.38	307.97	309.56	311.14	312.73	314.32	315.91	317.49	319.08	320.67	322.26	323.84	325.43	327.02	328.61	12
13	330.19	331.78	333.37	334.96	336.54	338.13	339.72	341.31	342.89	344.48	346.07	347.66	349.24	350.83	352.42	354.01	13
14	355.59	357.18	358.77	360.36	361.94	363.53	365.11	366.71	368.29	369.88	371.47	373.06	374.64	376.23	377.82	379.41	14
15	380.99	382.58	384.17	385.76	387.34	388.93	390.52	392.11	393.69	395.28	396.87	398.46	400.04	401.63	403.22	404.81	15
16	406.39	407.98	409.57	411.16	412.74	414.33	415.92	417.50	419.09	420.68	422.27	423.85	425.44	427.03	428.62	430.20	16
17	431.79	433.38	434.97	436.55	438.14	439.73	441.32	442.90	444.49	446.08	447.67	449.25	450.84	452.43	454.02	455.60	17
18	457.19	458.78	460.37	461.95	463.54	465.13	466.72	468.30	469.89	471.48	473.07	474.65	476.24	477.83	479.42	481.00	18
19	482.59	484.18	485.77	487.35	488.94	490.53	492.12	493.70	495.29	496.88	498.47	500.05	501.64	503.23	504.82	506.40	19
20	507.99	509.58	511.17	512.75	514.34	515.93	517.52	519.10	520.69	522.28	523.87	525.45	527.04	528.63	530.22	531.80	20
21	533.39	534.98	536.57	538.15	539.74	541.33	542.92	544.50	546.09	547.68	549 27	550.85	552.44	554.03	555.61	557.20	21
22	558.79	560.38	561.96	563.55	565.14	566.73	568.31	569.90	571.49	573.08	574.66	576.25	577.84	579.43	581.01	582.60	22
23	584.19	585.78	587.36	588.95	590.54	592.13	593.71	595.30	596.89	598.48	600.06	601.65	603.24	604.83	606.41	608.00	23
24	609.59	611.18	612.76	614.35	615.94	617.53	619.11	620.70	622.29	523.88	625.46	627.05	628.64	630.23	631.81	633.40	24

TABLE No. 70—CONVERSION TABLE—INCHES IN MILLIMETERS—Continued

In.	0	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16	In
25	634.99	636.58	638.16	639.75	641.34	642.93	644.51	646.10	647.69	649.28	650.86	652.45	654.04	655.63	657.21	658.80	25
26	660.39	661.98	663.56	665.15	666.74	668.33	669.91	671.50	673.09	674.68	676.26	677.85	679.44	681.03	682.61	684.20	26
27	685.79	687.38	688.96	690.55	692.14	693.73	695.31	696.90	698.49	700.07	701.66	703.25	704.84	706.42	708.01	709.60	27
28	711.19	712.77	714.36	715.95	717.54	719.12	720.71	722.30	723.89	725.47	727.06	728.65	730.24	731.82	733.41	735.00	28
29	736.59	738.17	739.76	741.35	742.94	744.52	746.11	747.70	749.29	750.87	752.46	754.05	755.64	757.22	758.81	760.40	29
30	761.99	763.57	765.16	766.75	768.34	769.92	771.51	773.10	774.69	776.27	777.86	779.45	781.04	782.62	784.21	785.80	30
31	787.39	788.97	790.56	792.15	793.74	795.32	796.91	798.50	800.09	801.67	803.26	804.85	806.44	808.02	809.61	811.20	31
32	812.79	814.37	815.96	817.55	819.14	820.72	822.31	823.90	825.49	827.07	828.66	830.25	831.83	833.42	835.01	836.60	32
33	838.18	839.77	841.36	842.95	844.53	846.12	847.71	849.30	850.88	852.47	854.06	855.65	857.23	858.82	860.41	862.00	33
34	863.58	865.17	866.76	868.35	869.93	871.52	873.11	874.70	876.28	877.87	879.46	881.05	882.63	884.22	885.81	887.40	34
35	888.98	890.57	892.16	893.75	895.33	896.92	898.51	900.10	901.68	903.27	904.86	906.45	908.03	909.62	911.21	912.80	35
36	914.38	915.97	917.56	919.15	920.73	922.32	923.91	925.50	927.08	928.67	930.26	931.85	933.43	935.02	936.61	938.20	36
37	939.78	941.37	942.96	944.55	946.13	947.72	949.31	950.99	952.48	954.07	955.66	957.25	958.83	960.42	962.01	963.60	37
38	965.18	966.77	968.36	969.94	971.53	973.12	974.71	976.29	977.88	979.47	981.06	982.64	984.23	985.82	987.41	988.99	38
39	990.58	992.17	993.76	995.34	996.93	998.52	1000.1	1001.7	1003.3	1004.9	1006.5	1008.0	1009.6	1011.2	1012.8	1014.4	39
40	1016.0	1017.6	1019.2	1020.7	1022.3	1023.9	1025.5	1027.1	1028.7	1030.3	1031.9	1033.4	1035.0	1036.6	1038.2	1039.8	40
41	1041.4	1043.0	1044.6	1046.1	1047.7	1049.3	1050.9	1052.5	1054.1	1055.7	1057.3	1058.8	1060.4	1062.0	1063.6	1065.2	41
42	1066.8	1068.4	1070.0	1071.5	1073.1	1074.7	1076.3	1077.9	1079.5	1081.1	1082.7	1084.2	1085.8	1087.4	1089.0	1090.6	42
43	1092.2	1093.8	1095.4	1096.9	1098.5	1100.1	1101.7	1103.3	1104.9	1106.5	1108.1	1109.6	1111.2	1112.8	1114.4	1116.0	43
44	1117.6	1119.2	1120.8	1122.3	1123.9	1125.5	1127.1	1128.7	1130.3	1131.9	1133.5	1135.0	1136.6	1138.2	1139.8	1141.4	44
45	1143.0	1144.6	1146.2	1147.7	1149.3	1150.9	1152.5	1154.1	1155.7	1157.3	1158.9	1160.4	1162.0	1163.6	1165.2	1166.8	45
46	1168.4	1170.0	1171.6	1173.1	1174.7	1176.3	1177.9	1179.5	1181.1	1182.7	1184.3	1185.8	1187.4	1189.0	1190.6	1192.2	46
47	1193.8	1195.4	1197.0	1198.5	1200.1	1201.7	1203.3	1204.9	1206.5	1208.1	1209.7	1211.2	1212.8	1214.4	1216.0	1217.6	47
48	1219.2	1220.8	1222.4	1223.9	1225.5	1227.1	1228.7	1230.3	1231.9	1233.5	1235.1	1236.6	1238.2	1239.8	1241.4	1243.0	48
49	1244.6	1246.2	1247.8	1249.3	1250.9	1252.5	1254.1	1255.7	1257.3	1258.9	1260.5	1262.0	1263.6	1265.2	1266.8	1268.4	49
50	1270.0	1271.6	1273.2	1274.7	1276.3	1277.9	1279.5	1281.1	1282.7	1284.3	1285.9	1287.4	1289.0	1290.6	1292.2	1293.8	50

TABLE No. 71—CONVERSION TABLE
MILLIMETERS 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	1.142	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	1.339	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	2.402	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	0.591	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	1.654	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	3.780
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	1.969	75	2.953	100	3.937

TABLE No. 72—CONVERSION TABLE
FEET IN METERS

Feet	Meters	Feet	Meters	Feet	Meters	Feet	Meters
1	0.3048	26	7.9248	51	15.5448	76	23.1648
2	0.6096	27	8.2296	52	15.8496	77	23.4696
3	0.9144	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

TABLE No. 73—CONVERSION TABLE
METERS IN FEET

Meters	Feet	Meters	Feet	Meters	Feet	Meters	Feet
1	3.281	26	85.302	51	167.323	76	249.344
2	6.562	27	88.583	52	170.604	77	252.625
3	9.843	28	91.863	53	173.884	78	255.905
4	13.123	29	95.144	54	177.165	79	259.186
5	16.404	30	98.425	55	180.446	80	262.467
6	19.685	31	101.706	56	183.727	81	265.748
7	22.966	32	104.987	57	187.008	82	269.029
8	26.247	33	108.268	58	190.289	83	272.310
9	29.528	34	111.548	59	193.569	84	275.590
10	32.808	35	114.829	60	196.850	85	278.871
11	36.089	36	118.110	61	200.131	86	282.152
12	39.370	37	121.391	62	203.412	87	285.433
13	42.651	38	124.672	63	206.693	88	288.714
14	45.932	39	127.953	64	209.974	89	292.995
15	49.213	40	131.234	65	213.254	90	295.275
16	52.493	41	134.514	66	216.535	91	298.556
17	55.774	42	137.795	67	219.816	92	301.837
18	59.055	43	141.076	68	223.097	93	305.118
19	62.336	44	144.357	69	226.378	94	308.399
20	65.617	45	147.638	70	229.659	95	311.680
21	68.898	46	150.919	71	232.939	96	314.960
22	72.178	47	154.199	72	236.220	97	318.241
23	75.459	48	157.480	73	239.501	98	321.522
24	78.740	49	160.761	74	242.782	99	324.803
25	82.021	50	164.042	75	246.063	100	328.084

TABLE No. 74—CONVERSION TABLE KILOMETERS IN MILES

Km.	Miles	Km.	Miles	Km.	Miles	Km.	Miles
1	0.621	26	16.156	51	31.690	76	47.224
2	1.243	27	16.777	52	32.311	77	47.846
3	1.864	28	17.398	53	32.933	78	48.467
4	2.485	29	18.020	54	33.554	79	49.088
5	3.107	30	18.641	55	34.175	80	49.710
6	3.728	31	19.262	56	34.797	81	50.331
7	4.350	32	19.884	57	35.418	82	50.952
8	4.971	33	20.505	58	36.040	83	51.574
9	5.592	34	21.127	59	36.661	84	52.195
10	6.214	35	21.748	60	37.282	85	52.817
11	6.835	36	22.369	61	37.904	86	53.438
12	7.456	37	22.991	62	38.525	87	54.059
13	8.078	38	23.612	63	39.146	88	54.681
14	8.699	39	24.233	64	39.768	89	55.302
15	9.321	40	24.855	65	40.389	90	55.923
16	9.942	41	25.476	66	41.010	91	56.545
17	10.563	42	26.098	67	41.632	92	57.166
18	11.185	43	26.719	68	42.253	93	57.787
19	11.806	44	27.340	69	42.875	94	58.409
20	12.427	45	27.962	70	43.496	95	59.030
21	13.049	46	28.583	71	44.117	96	59.652
22	13.670	47	29.204	72	44.739	97	60.273
23	14.292	48	29.826	73	45.360	98	60.894
24	14.913	49	30.447	74	45.981	99	61.516
25	15.534	50	31.069	75	46.603	100	62.137

TABLE No. 75—CONVERSION TABLE
MILES IN KILOMETERS

Miles	Kilo-meters	Miles	Kilo-meters	Miles	Kilo-meters	Miles	Kilo-meter
1	1.609	26	41.843	51	82.077	76	122.310
2	3.219	27	43.452	52	83.686	77	123.919
3	4.828	28	45.062	53	85.295	78	125.529
4	6.437	29	46.671	54	86.905	79	127.138
5	8.047	30	48.280	55	88.514	80	128.748
6	9.656	31	49.890	56	90.123	81	130.357
7	11.265	32	51.499	57	91.733	82	131.966
8	12.875	33	53.108	58	93.342	83	133.576
9	14.484	34	54.718	59	94.951	84	135.185
10	16.093	35	56.327	60	96.561	85	136.794
11	17.703	36	57.936	61	98.170	86	138.404
12	19.312	37	59.546	62	99.779	87	140.013
13	20.921	38	61.155	63	101.389	88	141.622
14	22.531	39	62.764	64	102.998	89	143.232
15	24.140	40	64.374	65	104.607	90	144.841
16	25.750	41	65.983	66	106.217	91	146.450
17	27.359	42	67.592	67	107.826	92	148.060
18	28.968	43	69.202	68	109.435	93	149.669
19	30.578	44	70.811	69	111.045	94	151.278
20	32.187	45	72.420	70	112.654	95	152.888
21	33.796	46	74.030	71	114.263	96	154.497
22	35.406	47	75.639	72	115.873	97	156.106
23	37.015	48	77.249	73	117.482	98	157.716
24	38.624	49	78.858	74	119.091	99	159.325
25	40.234	50	80.468	75	120.702	100	160.934

TABLE No. 76—CONVERSION TABLE KILOGRAMS IN AVOIRDUPOIS POUNDS

Kilo-grams	Pounds	Kilo-grams	Pounds	Kilo grams	Pounds	Kilo-grams	Pounds
1	2.205	26	57.320	51	112.436	76	167.551
2	4.409	27	59.525	52	114.640	77	169.756
3	6.614	28	61.729	53	116.845	78	171.960
4	8.818	29	63.934	54	119.050	79	174.165
5	11.023	30	66.139	55	121.254	80	176.370
6	13.228	31	68.343	56	123.459	81	178.574
7	15.432	32	70.548	57	125.663	82	180.779
8	17.637	33	72.752	58	127.868	83	182.984
9	19.842	34	74.957	59	130.073	84	185.188
10	22.046	35	77.162	60	132.277	85	187.393
11	24.251	36	79.366	61	134.482	86	189.597
12	26.455	37	81.571	62	136.687	87	191.802
13	28.660	38	83.776	63	138.891	88	194.007
14	30.865	39	85.980	64	141.096	89	196.211
15	33.069	40	88.185	65	143.300	90	198.416
16	35.274	41	90.389	66	145.505	91	200.621
17	37.479	42	92.594	67	147.710	92	202.825
18	39.683	43	94.799	68	149.914	93	205.030
19	41.888	44	97.003	69	152.119	94	207.234
20	44.092	45	99.208	70	154.323	95	209.439
21	46.297	46	101.413	71	156.528	96	211.644
22	48.502	47	103.617	72	158.733	97	213.848
23	50.706	48	105.822	73	160.937	98	216.053
24	52.911	49	108.026	74	163.142	99	218.257
25	55.116	50	110.231	75	165.347	100	220.462

TABLE No. 77—CONVERSION TABLE
AVOIRDUPOIS POUNDS IN KILOGRAMS

Lb.	Kilo-grams	Lb.	Kilo-grams	Lb.	Kilo-grams	Lb.	Kilo-grams
1	0.4536	26	11.7934	51	23.1332	76	34.4731
2	0.9072	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

TABLE No. 78—CONVERSION TABLE
U. S. GALLONS IN LITERS

U. S. Gallons	Liters	U. S. Gallons	Liters	U. S. Gallons	Liters	U. S. Gallons	Liters
1	3.79	26	98.46	51	193.13	76	287.80
2	7.57	27	102.24	52	196.91	77	291.58
3	11.36	28	106.03	53	200.70	78	295.37
4	15.15	29	109.82	54	204.49	79	299.16
5	18.93	30	113.60	55	208.27	80	302.94
6	22.72	31	117.39	56	212.06	81	306.73
7	26.51	32	121.18	57	215.85	82	310.52
8	30.29	33	124.96	58	219.63	83	314.30
9	34.08	34	128.75	59	223.42	84	318.09
10	37.87	35	132.54	60	227.21	85	321.88
11	41.65	36	136.32	61	230.99	86	325.66
12	45.44	37	140.11	62	234.78	87	329.45
13	49.23	38	143.90	63	238.57	88	333.24
14	53.02	39	147.68	64	242.35	89	337.02
15	56.80	40	151.47	65	246.14	90	340.81
16	60.59	41	155.26	66	249.93	91	344.60
17	64.38	42	159.05	67	253.71	92	348.38
18	68.16	43	162.83	68	257.50	93	352.17
19	71.95	44	166.62	69	261.29	94	355.96
20	75.74	45	170.41	70	265.08	95	359.75
21	79.52	46	174.19	71	268.86	96	363.53
22	83.31	47	177.98	72	272.65	97	367.32
23	87.10	48	181.77	73	276.44	98	371.11
24	90.88	49	185.55	74	280.22	99	374.89
25	94.67	50	189.34	75	284.01	100	378.68

TABLE No. 79—CONVERSION TABLE LITERS IN U. S. GALLONS

Liters	U. S. Gallons	Liters	U. S. Gallons	Liters	U. S. Gallons	Liters	U. S. Gallons
1	0.264	26	6.866	51	13.468	76	20.070
2	0.528	27	7.130	52	13.732	77	20.334
3	0.792	28	7.394	53	13.996	78	20.598
4	1.056	29	7.658	54	14.260	79	20.862
5	1.320	30	7.922	55	14.524	80	21.126
6	1.584	31	8.186	56	14.788	81	21.390
7	1.849	32	8.451	57	15.053	82	21.655
8	2.113	33	8.715	58	15.317	83	21.919
9	2.377	34	8.979	59	15.581	84	22.183
10	2.641	35	9.243	60	15.845	85	22.447
11	2.905	36	9.507	61	16.109	86	22.711
12	3.169	37	9.771	62	16.373	87	22.975
13	3.433	38	10.035	63	16.637	88	23.239
14	3.697	39	10.299	64	16.901	89	23.503
15	3.961	40	10.563	65	17.165	90	23.767
16	4.225	41	10.827	66	17.429	91	24.031
17	4.489	42	11.091	67	17.693	92	24.295
18	4.753	43	11.355	68	17.957	93	24.559
19	5.018	44	11.620	69	18.222	94	24.824
20	5.282	45	11.884	70	18.486	95	25.088
21	5.546	46	12.148	71	18.750	96	25.352
22	5.810	47	12.412	72	19.014	97	25.616
23	6.074	48	12.676	73	19.278	98	25.880
24	6.338	49	12.940	74	19.542	99	26.144
25	6.602	50	13.204	75	19.806	100	26.408

TABLE No. 80—CONVERSION TABLE
SQUARE METERS IN SQUARE FEET

Square Meters	Square Feet	Square Meters	Square Feet	Square Meters	Square Feet	Square Meters	Square Feet
1	10.764	26	279.861	51	548.959	76	818.056
2	21.528	27	290.625	52	559.723	77	828.820
3	32.292	28	301.389	53	570.487	78	839.584
4	43.056	29	312.153	54	581.251	79	850.348
5	53.820	30	322.917	55	592.015	80	861.112
6	64.583	31	333.681	56	602.778	81	871.876
7	75.347	32	344.445	57	613.542	82	882.640
8	86.111	33	355.209	58	624.306	83	893.404
9	96.875	34	365.973	59	635.070	84	904.168
10	107.639	35	376.737	60	645.834	85	914.932
11	118.403	36	387.500	61	656.598	86	925.695
12	129.167	37	398.264	62	667.362	87	936.459
13	139.931	38	409.028	63	678.126	88	947.223
14	150.695	39	419.792	64	688.890	89	958.987
15	161.459	40	430.556	65	699.654	90	968.751
16	172.222	41	441.320	66	710.417	91	979.515
17	182.986	42	452.084	67	721.181	92	990.279
18	193.750	43	462.848	68	731.945	93	1001.043
19	204.514	44	473.612	69	742.709	94	1011.807
20	215.278	45	484.376	70	753.473	95	1022.571
21	226.042	46	495.139	71	764.237	96	1033.334
22	236.806	47	505.903	72	775.001	97	1044.098
23	247.570	48	516.667	73	785.765	98	1054.862
24	258.334	49	527.431	74	796.529	99	1065.626
25	269.098	50	538.195	75	807.293	100	1076.390

TABLE No. 81—CONVERSION TABLE SQUARE FEET IN SQUARE METERS

Square Feet	Square Meters	Square Feet	Square Meters	Square Feet	Square Meters	Square Feet	Square Meters
1	0.0929	26	2.4155	51	4.7381	76	7.0606
2	0.1858	27	2.5084	52	4.8310	77	7.1535
3	0.2787	28	2.6013	53	4.9239	78	7.2464
4	0.3716	29	2.6942	54	5.0168	79	7.3394
5	0.4645	30	2.7871	55	5.1097	80	7.4323
6	0.5574	31	2.8800	56	5.2026	81	7.5252
7	0.6503	32	2.9729	57	5.2955	82	7.6181
8	0.7432	33	3.0658	58	5.3884	83	7.7110
9	0.8361	34	3.1587	59	5.4813	84	7.8039
10	0.9290	35	3.2516	60	5.5742	85	7.8968
11	1.0219	36	3.3445	61	5.6671	86	7.9897
12	1.1148	37	3.4374	62	5.7600	87	8.0826
13	1.2077	38	3.5303	63	5.8529	88	8.1755
14	1.3006	39	3.6232	64	5.9458	89	8.2684
15	1.3936	40	3.7161	65	6.0387	90	8.3613
16	1.4865	41	3.8090	66	6.1316	91	8.4542
17	1.5794	42	3.9019	67	6.2245	92	8.5471
18	1.6723	43	3.9948	68	6.3174	93	8.6400
19	1.7652	44	4.0877	69	6.4103	94	8.7329
20	1.8581	45	4.1806	70	6.5032	95	8.8258
21	1.9510	46	4.2735	71	6.5961	96	8.9187
22	2.0439	47	4.3665	72	6.6890	97	9.0116
23	2.1368	48	4.4594	73	6.7819	98	9.1045
24	2.2297	49	4.5523	74	6.8748	99	9.1974
25	2.3226	50	4.6452	75	6.9677	100	9.2903

TABLE No. 82—CONVERSION TABLE
CUBIC METERS IN CUBIC FEET

Cubic Meters	Cubic Feet	Cubic Meters	Cubic Feet	Cubic Meters	Cubic Feet	Cubic Meters	Cubic Feet
0.5	17.65	14	494.40	27.5	971.15	41	1447.90
1	35.31	14.5	512.06	28	988.81	41.5	1465.56
1.5	52.97	15	529.72	28.5	1006.47	42	1483.21
2	70.63	15.5	547.38	29	1024.12	42.5	1500.87
2.5	88.29	16	565.03	29.5	1041.78	43	1518.53
3	105.94	16.5	582.69	30	1059.44	43.5	1536.19
3.5	123.60	17	600.35	30.5	1077.10	44	1553.84
4	141.26	17.5	618.01	31	1094.75	44.5	1571.50
4.5	158.92	18	635.66	31.5	1112.41	45	1589.16
5	176.57	18.5	653.32	32	1130.07	45.5	1606.82
5.5	194.23	19	670.98	32.5	1147.73	46	1624.47
6	211.89	19.5	688.64	33	1165.38	46.5	1642.13
6.5	229.55	20	706.29	33.5	1183.04	47	1659.79
7	247.20	20.5	723.95	34	1200.70	47.5	1677.44
7.5	264.86	21	741.61	34.5	1218.35	48	1695.10
8	282.52	21.5	759.26	35	1236.01	48.5	1712.76
8.5	300.17	22	776.92	35.5	1253.67	49	1730.42
9	317.83	22.5	794.58	36	1271.33	49.5	1748.07
9.5	335.49	23	812.24	36.5	1288.98	50	1765.73
10	353.15	23.5	829.89	37	1306.64	50.5	1783.39
10.5	370.80	24	847.55	37.5	1324.30	51	1801.05
11	388.46	24.5	865.21	38	1341.96	51.5	1818.70
11.5	406.12	25	882.87	38.5	1359.61	52	1836.36
12	423.78	25.5	900.52	39	1377.27	52.5	1854.01
12.5	441.43	26	918.18	39.5	1394.93	53	1871.68
13	459.09	26.5	935.84	40	1412.59	53.5	1889.33
5	476.75	27	953.49	40.5	1430.24	54	1906.99

TABLE No. 83—CONVERSION TABLE
CUBIC FEET IN CUBIC METERS

Cubic Feet	Cubic Meters	Cubic Feet	Cubic Meters	Cubic Feet	Cubic Meters	Cubic Feet	Cubic Meters
1	0.0283	14.5	0.4106	28	0.7929	41.5	1.1752
1.5	0.0425	15	0.4247	28.5	0.8071	42	1.1893
2	0.0566	15 5	0.4389	29	0.8212	42.5	1.2035
2.5	0.0708	16	0.4531	29.5	0.8354	43	1.2176
3	0.0849	16.5	0.4673	30	0.8495	43.5	1.2318
3.5	0.0991	17	0.4814	30.5	0.8637	44	1.2459
4	0.1133	17.5	0.4956	31	0.8778	44.5	1.2601
4.5	0.1275	18	0.5097	31.5	0.8920	45	1.2743
5	0.1416	18.5	0.5239	32	0.9061	45.5	1.2885
5.5	0.1558	19	0.5380	32.5	0.9203	46	1.3026
6	0.1699	19.5	0.5522	33	0.9345	46.5	1.3168
6.5	0.1841	20	0.5663	33.5	0.9487	47	1.3309
7	0.1982	20.5	0.5805	34	0.9628	47.5	1.3451
7.5	0.2124	21	0.5946	34.5	0.9770	48	1.3592
8	0.2265	21.5	0.6088	35	0.9911	48.5	1.3734
8.5	0.2407	22	0.6230	35.5	1.0053	49	1.3875
9	0.2548	22.5	0.6372	36	1.0194	49.5	1.4017
9.5	0.2690	23	0.6513	36.5	1.0336	50	1.4158
10	0.2832	23.5	0.6655	37	1.0477	50.5	1.4300
10.5	0.2974	24	0.6796	37.5	1.0619	51	1.4442
11	0.3115	24.5	0.6938	38	1.0760	51.5	1.4584
11.5	0.3257	25	0.7079	38.5	1.0902	52	1.4725
12	0.3398	25.5	0.7221	39	1.1044	52.5	1.4867
12.5	0.3540	26	0.7362	39.5	1.1186	53	1.5008
13	0.3681	26.5	0.7504	40	1.1327	53.5	1.5150
13.5	0.3823	27	0.7646	40.5	1.1469	54	1.5391
14	0.3964	27.5	0.7788	41	1.1610	54.5	1.5533

TABLE No. 84—CONVERSION TABLE—POUNDS PER SQ. IN. IN KILOGRAMS PER SQUARE CENTIMETER

Pounds per Sq. In.	Kg. per Sq.Cm.	Pounds per Sq. In.	Kg. per Sq. Cm.	Pounds per Sq. In.	Kg. per Sq.Cm.	Pounds per Sq. In.	Kg. per Sq.Cm.
100	7.031	154	10.827	208	14.624	262	18.420
102	7.171	156	10.968	210	14.764	264	18.561
104	7.312	158	11.108	212	14.905	266	18.702
106	7.453	160	11.249	214	15.046	268	18.842
108	7.593	162	11.390	216	15.186	270	18.983
110	7.734	164	11.530	218	15.327	272	19.123
112	7.874	166	11.671	220	15.467	274	19.264
114	8.015	168	11.812	222	15.608	276	19.405
116	8.156	170	11.952	224	15.749	278	19.545
118	8.296	172	12.093	226	15.889	280	19.686
120	8.437	174	12.233	228	16.030	282	19.826
122	8.577	176	12.374	230	16.171	284	19.967
124	8.718	178	12.515	232	16.311	286	20.108
126	8.858	180	12.655	234	16.452	288	20.248
128	8.999	182	12.796	236	16.592	290	20.389
130	9.140	184	12.937	238	16.733	292	20.530
132	9.281	186	13.077	240	16.874	294	20.670
134	9.421	188	13.218	242	17.014	296	20.811
136	9.562	190	13.358	244	17.155	298	20.951
138	9.702	192	13.499	246	17.295	300	21.092
140	9.843	194	13.639	248	17.436	302	21.233
142	9.984	196	13.780	250	17.577	304	21.373
144	10.124	198	13.921	252	17.717	306	21.514
146	10.265	200	14.061	254	17.858	308	21.654
148	10.405	202	14.202	256	17.999	310	21.795
150	10.546	204	14.343	258	18.139		
[illegible]2	10.687	206	14.483	260	18.280		

TABLE No. 85—CONVERSION TABLE—KILOGRAMS PER SQUARE CENTIMETER IN POUNDS PER SQUARE INCH

Kg. per Sq.Cm.	Pounds per Sq. In.	Kg. per Sq.Cm.	Pounds per Sq. In.	Kg. per Sq.Cm.	Pounds per Sq. In.	Kg. per Sq.Cm.	Pounds per Sq. In.
1.0	14.223	6.4	91.029	11.8	167.836	17.2	244.642
1.2	17.068	6.6	93.874	12.0	170.680	17.4	247.486
1.4	19.913	6.8	96.719	12.2	173.525	17.6	250.331
1.6	22.757	7.0	99.563	12.4	176.370	17.8	253.176
1.8	25.602	7.2	102.408	12.6	179.214	18.0	256.020
2.0	28.447	7.4	105.253	12.8	182.059	18.2	258.865
2.2	31.291	7.6	108.097	13.0	184.904	18.4	261.710
2.4	34.136	7.8	110.942	13.2	187.748	18.6	264.554
2.6	36.981	8.0	113.787	13.4	190.593	18.8	267.399
2.8	39.825	8.2	116.631	13.6	193.438	19.0	270.244
3.0	42.670	8.4	119.476	13.8	196.282	19.2	273.088
3.2	45.515	8.6	122.321	14.0	199.127	19.4	275.933
3.4	48.359	8.8	125.165	14.2	201.972	19.6	278.778
3.6	51.204	9.0	128.010	14.4	204.816	19.8	281.622
3.8	54.049	9.2	130.855	14.6	207.661	20.0	284.467
4.0	56.893	9.4	133.699	14.8	210.506	20.2	287.312
4.2	59.738	9.6	136.544	15.0	213.350	20.4	290.156
4.4	62.583	9.8	139.389	15.2	216.195	20.6	293.001
4.6	65.427	10.0	142.234	15.4	219.040	20.8	295.846
4.8	68.272	10.2	145.078	15.6	221.884	21.0	298.690
5.0	71.117	10.4	147.923	15.8	224.729	21.2	301.535
5.2	73.961	10.6	150.768	16.0	227.574	21.4	304.380
5.4	76.806	10.8	153.612	16.2	230.418	21.6	307.224
5.6	79.651	11.0	156.457	16.4	233.263	21.8	310.069
5.8	83.495	11.2	159.302	16.6	236.108	22.0	312.914
6.0	85.340	11.4	162.146	16.8	238.952		
6.2	88.185	11.6	164.991	17.0	241.797		

TABLE No. 86—WEIGHT AND SPECIFIC GRAVITY OF METALS

	Specific Gravity Range according to several Authorities	Specific Gravity Approximate Mean Valve used in Calculation of Weight	Weight per cu. ft. pounds	Weight per cu. in. pounds
Aluminum	2.56 to 2.71	2.67	166.5	.0963
Antimony	6.66 to 6.86	6.76	421.6	.2439
Bismuth	9.74 to 9.90	9.82	612.4	.3544
Brass: Copper Zinc				
80 20	7.8 to 8.6	8.60	536.3	.3103
70 30		8.40	523.8	.3031
60 40		8.36	521.3	.3017
50 50		8.20	511.4	.2959
Bronze: Copper 95 to 80, Tin 5 to 20	8.52 to 8.96	8.853	552.0	.3195
Cadmium	8.6 to 8.7	8.65	539.0	.3121
Calcium	1.58			
Chromium	5.0			
Cobalt	8.5 to 8.6			
Gold, pure	19.245 to 19.361	19.258	1200.9	.6949
Copper	8.69 to 8.92	8.853	552.0	.3195
Iridium	22.38 to 23.00		1396.0	.8076
Iron, Cast	6.85 to 7.48	7.218	450.0	.2604
Iron, Wrought	7.4 to 7.9	7.70	480.0	.2779
Lead	11.07 to 11.44	11.38	709.7	.4106
Manganese	7.00 to 8.00	8.00	499.0	.2887
Magnesium	1.69 to 1.75	1.75	109.0	.0641
Mercury 32°	13.60 to 13.62	13.62	849.3	.4915
Mercury 60°	13.58	13.58	846.8	.4900
Mercury 212°	13.37 to 13.38	13.38	834.4	.4828
Nickel	8.279 to 8.93	8.80	548.7	.3175
Platinum	20.33 to 22.07	21.50	1347.0	.7758
Potassium	0.865			
Silver	10.474 to 10.511	10.505	655.1	.3791
Sodium	0.97			
Steel	7.69 to 7.932	7.854	489.6	.2834
Tin	7.291 to 7.409	7.350	458.3	.2652
Titanium	5.3			
Tungsten	17.00 to 17.6			
Zinc	6.86 to 7.20	7.00	436.5	.2526

TABLE No. 87—WEIGHT AND SPECIFIC GRAVITY OF WOOD

	Specific Gravity Average	Weight Per cu. ft. pounds		Specific Gravity Average	Weight per cu. ft. pounds
Alder	.68	42	Hornbeam	.76	47
Apple	.76	47	Juniper	.56	35
Ash	.72	45	Larch	.56	35
Bamboo	.35	22	Lignum vitae	1.00	62
Beech	.73	46	Linden	.60	37
Birch	.65	41	Locust	.73	46
Box	1.12	70	Mahogany	.81	51
Cedar	.62	39	Maple	.68	42
Cherry	.66	41	Mulberry	.73	46
Chestnut	.56	35	Oak, Live	1.11	69
Cork	.24	15	Oak, White	.77	48
Cypress	.53	33	Oak, Red	.74	46
Dogwood	.76	47	Pine, White	.45	28
Ebony	1.23	76	Pine, Yellow	.61	38
Elm	.61	38	Poplar	.48	30
Fir	.59	37	Spruce	.45	28
Gum	.92	57	Sycamore	.60	37
Hackmatack	.59	37	Teak	.82	51
Hemlock	.38	24	Walnut	.58	36
Hickory	.77	48	Willow	.54	34
Holly	.76	47			

TABLE No. 88—SPECIFIC GRAVITY OF LIQUIDS

Liquid	Specific Gravity	Liquid	Specific Gravity
Acetic acid	1.06	Muriatic acid	1.20
Alcohol, pure	0.79	Naphtha	0.76
Alcohol, 95 per cent.	0.82	Nitric acid	1.22
Alcohol, 50 per cent.	0.93	Olive oil	0.92
Ammonia	0.89	Palm oil	0.97
Benzine	0.69	Petroleum oil	0.82
Bromine	2.97	Phosphoric acid	1.78
Carbolic acid	0.96	Rape oil	0.92
Carbon disulphide	1.26	Sulphuric acid	1.84
Cotton-seed oil	0.93	Tar	1.00
Ether, sulphuric	0.72	Turpentine oil	0.87
Fluoric acid	1.50	Vinegar	1.08
Gasoline (Petrol)	0.70	Water	1.00
Kerosene	0.80	Water, sea	1.03
Linseed oil	0.94	Whale oil	0.92
Mineral oil	0.92		

TABLE No. 89—WEIGHT AND SPECIFIC GRAVITY OF MISCELLANEOUS SUBSTANCES

	Specific Gravity	Pounds per cu. ft.
Asphaltum	1.39	87
Brick, Soft	1.6	100
Brick, Common	1.79	112
Brick, Hard	2.0	125
Brick, Pressed	2.16	135
Brick, Fire	2.24 to 2.4	140 to 150
Brickwork in mortar	1.6	100
Brickwork in cement	1.79	112
Cement, Rosendale, loose	.96	60
Cement, Portland, loose	1.25	78
Clay	1.92 to 2.4	120 to 150
Concrete	1.92 to 2.24	120 to 140
Earth, loose	1.15 to 1.28	72 to 80
Earth, rammed	1.44 to 1.76	90 to 110
Emery	4.0	250
Glass	2.5 to 2.75	156 to 172
Glass, flint	2.88 to 3.14	180 to 196
Gneiss, Granite	2.56 to 2.72	160 to 170
Gravel	1.6 to 1.92	100 to 120
Gypsum	2.08 to 2.4	130 to 150
Hornbiende	3.2 to 3.52	200 to 220
Lime, quick, in bulk	.8 to .88	50 to 55
Limestone	2.72 to 3.2	170 to 200
Magnesia, Carbonate	2.4	150
Marble	2.56 to 2.88	160 to 180
Masonry, dry rubble	2.24 to 2.56	140 to 160
Masonry, dressed	2.24 to 2.88	140 to 180
Mortar	1.44 to 1.6	90 to 100
Pitch	1.15	72
Plaster of Paris	1.18 to 1.28	74 to 80
Quartz	2.64	165
Sand	1.44 to 1.76	90 to 110
Sandstone	2.24 to 2.4	140 to 150
Slate	2.72 to 2.88	170 to 180
Stone, various	2.16 to 3.4	135 to 200
Trap	2.72 to 3.4	170 to 200
Tile	1.76 to 1.92	110 to 120
Soapstone	2.65 to 2.8	166 to 175

WEIGHTS OF VARIOUS SUBSTANCES

Fuel

A bushel of bituminous coal weighs 76 lb. and contains 2688 cu. in. or 1.554 cu. ft. 29.47 bushels = 1 gross ton.

A bushel of coke weighs 40 lb. (35 to 42 lb.)

41 to 45 cu. ft. bituminous coal when broken down	1 ton, 2240 lb.
34 to 41 cu. ft. anthracite, prepared for market	1 ton, 2240 lb.
123 cu. ft. charcoal	1 ton, 2240 lb.
70.9 cu. ft. coke	1 ton, 2240 lb.
1 cu. ft. anthracite coal	55 to 66 lb.
1 cu. ft. bituminous coal	50 to 55 lb.
1 cu. ft. Cumberland coal	53 lb.
1 cu. ft. Cannel coal	5.03 lb.
1 cu. ft. charcoal (hardwood)	18.5 lb.
1 cu. ft. charcoal (pine)	18 lb.

Water

1 cu. in.	.036 lb.
1 cu. ft. 32° F.	62.4 lb.
1 cu. ft.	7.48 U. S. Gals.
1 gallon, U. S.	231 cu. in.
1 gallon, U. S.	8⅓ lb.
1 gallon, Imperial	277¼ cu. in.
1 gallon, Imperial	10 lb.
Cold water, per cu. ft.	62.50 lb.
Hot water, 25 lb. press., per cu. ft.	58.28 lb.
Hot water, 50 lb. press., per cu. ft.	57.32 lb.
Hot water, 75 lb. press., per cu. ft.	56.69 lb.
Hot water, 100 lb. press., per cu. ft.	56.18 lb.
Hot water, 125 lb. press., per cu. ft.	55.69 lb.
Hot water, 150 lb. press., per cu. ft.	55.29 lb.
Hot water, 175 lb. press., per cu. ft.	54.93 lb.
Hot water, 200 lb. press., per cu. ft.	54.60 lb.

ORES, EARTHS, ETC.

20 cu. ft. of broken quartz........	1 ton (2000 lb.)
18 cu. ft. of gravel in bank.......	1 ton (2000 lb.)
27 cu. ft. of gravel when dry......	1 ton (2000 lb.)
25 cu. ft. of sand................	1 ton (2000 lb.)
18 cu. ft. of earth in bank........	1 ton (2000 lb.)
27 cu. ft. of earth when dry.......	1 ton (2000 lb.)
17 cu. ft. of clay.................	1 ton (2000 lb.)
Earth, common brown, loose...	72 to 80 lb. per cu. ft.
Earth, common brown, shaken.	82 to 92 lb. per cu. ft.
Earth, common brown, rammed moderately	90 to 100 lb. per cu. ft.
Gravel.....................	90 to 106 lb. per cu. ft.
Sand.......................	90 to 106 lb. per cu. ft.
Soft flowing mud...........	104 to 120 lb. per cu. ft.
Sand, perfectly wet.........	118 to 129 lb. per cu. ft.

GAGES OF PRINCIPAL RAILROADS OF THE WORLD

Abyssinia, meter.
Algiers, 4 ft. 8½ in., 1.05 meters, meter.
Angola (West Africa), 3 ft. 6 in., meter.
Argentine, 5 ft. 6 in., 4 ft. 8½ in., meter, 0.75 meter.
Australia, 5 ft. 3 in., 4 ft. 8½ in., 3 ft. 6 in.
Austria, 4 ft. 8½ in., meter, 2 ft. 6 in.
Barbadoes, 2 ft. 6 in.
Belgium, 4 ft. 8½ in., meter.
Belgian Congo, 3 ft. 6 in., 2 ft. 5½ in.
Bolivia, meter.
Borneo, meter.
Brazil, 5 ft. 3 in., meter.
British Central Africa, 3 ft. 6 in.
British East Africa, meter.
British Guiana, 4 ft. 8½ in., 3 ft. 6 in.
British Honduras, 3 ft.

GAGES OF PRINCIPAL RAILROADS OF THE WORLD
Continued

Bulgaria, 4 ft. 8½ in.
Canada, 4 ft. 8½ in.
Ceylon, 5 ft. 6 in., 2 ft. 6 in.
Chile, 5 ft. 6 in., 4 ft. 8½ in., 4 ft. 2 in., 3 ft. 6 in., meter, 2 ft. 6 in.
China, 5 ft., 4 ft. 8½ in., meter.
Chosen (Korea), 4 ft. 8½ in.
Colombia, 3 ft. 6 in., meter, 3 ft.
Costa Rica, 3 ft. 6 in.
Cuba, 5 ft., 4 ft. 8½ in., 3 ft.
Cyprus, 2 ft. 6 in.
Denmark, 4 ft. 8½ in., meter.
Dutch East Indies, 4 ft. 8½ in., 3 ft. 6 in., 2 ft. 5½ in.
Dutch Guiana, meter.
Ecuador, 3 ft. 6 in.
Egypt, 4 ft. 8½ in., 3 ft. 6 in., 0.75 meter.
England and Wales, 4 ft. 8½ in., 4 ft., 3 ft. 6 in.
Finland, 1.524 meters, 0.75 meter.
France 4 ft. 8½ in., meter, 0.60 meter.
French Soudan, meter.
German East Africa, meter.
German South West Africa, 1.067 meters, 0.60 meter.
Germany, 4 ft. 8½ in., meter, 29½ in.
Greece, 4 ft. 8½ in., meter.
Guatemala, 3 ft.
Hawaii, 4 ft. 8½ in., 3 ft.
Holland, 4 ft. 8½ in.
Hungary, 4 ft. 8½ in., meter, 2 ft. 6 in.
India, 5 ft. 6 in., meter, 2 ft. 6 in., 2 ft.
Ireland, 5 ft. 3 in., 3 ft.
Italy, 4 ft. 8½ in., meter, 0.95 meter.
Jamaica, 4 ft. 8½ in.
Japan, 3 ft. 6 in., 2 ft. 6 in.

GAGES OF PRINCIPAL RAILROADS OF THE WORLD
Continued

Kamerun, meter.
Madagascar, meter.
Malay Peninsula, meter.
Mauritius, 4 ft. 8½ in.
Mexico, 4 ft. 8½ in., 3 ft. 6 in., meter, 3 ft.
Mozambique, 3 ft. 6 in.
New South Wales, 4 ft. 8½ in., 3 ft. 6 in.
New Zealand, 3 ft. 6 in.
Newfoundland, 3 ft. 6 in.
Nicaragua, 3 ft. 6 in.
Nigeria, 3 ft. 6 in., 2 ft. 6 in.
Norway, 4 ft. 8½ in., 1.067 meters, 0.75 meter.
Nova Scotia, 4 ft. 8½ in.
Panama, 5 ft.
Paraguay, 4 ft. 8½ in.
Peru, 4 ft. 8½ in., 3 ft. 6 in., meter, 3 ft.
Philippine Islands, 3 ft. 6 in.
Porto Rico, 4 ft. 8½ in., meter.
Portugal, 1.67 meters, meter.
Queensland, 3 ft. 6 in.
Rhodesia, 3 ft. 6 in.
Roumania, 4 ft. 8½ in.
Russia, 5 ft., 3 ft. 6 in., meter, 0.75 meter.
Salvador, 3 ft.
San Domingo, 3 ft. 6 in., 2 ft. 6 in.
Scotland, 4 ft. 8½ in.
Serbia, 4 ft. 8½ in., 2 ft. 6 in.
Siam, 4 ft. 8½ in., meter.
Siberia, 5 ft.
South Manchuria, 4 ft. 8½ in.
Spain, 1.67 meters, meter.
Sweden, 4 ft. 8½ in., 1.067 meters, 0.891 meter.
Switzerland, 4 ft. 8½ in., meter.

GAGES OF PRINCIPAL RAILROADS OF THE WORLD

Continued

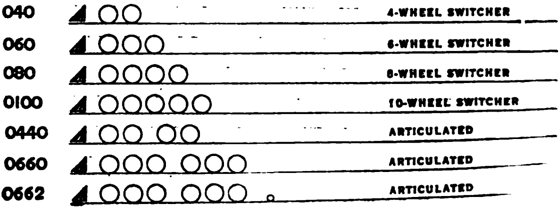
Tasmania, 3 ft. 6 in.
Trinidad, 4 ft. 8½ in.
Tunis, 4 ft. 8½ in., meter.
Turkey, 4 ft. 8½ in., meter.
Union of South Africa, 3 ft. 6 in., 2 ft.
United States, 4 ft. 8½ in., 3 ft.
Uruguay, 4 ft. 8½ in.
Venezuela, 3 ft. 6 in., meter, 3 ft., 2 ft.
Victoria, 5 ft. 3 in., 2 ft. 6 in.

CLASSIFICATION OF LOCOMOTIVES

WHYTE'S SYSTEM

The locomotive classification adopted by the American Locomotive Company is based on the representation by numerals of the number and arrangement of the wheels, commencing at the front. Thus 260 means a Mogul and 460 a Ten Wheel engine, the cypher denoting that no trailing truck is used.

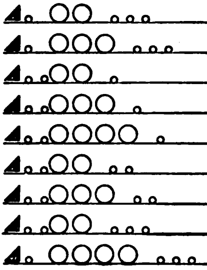
Total weight is expressed in 1000 of pounds. Thus an Atlantic locomotive weighing 176000 lb. would be classified as a 442–176 type. If the engine is Compound the letter C should be substituted for the dash, thus 442 C 176. If equipped with Superheater, the letter S should be used—thus a Mallet locomotive having six pairs of drivers, with Superheater, would be classified: 0660 C S 334 if Compound, or 0660 S 334 if Simple. When tanks are used in place of separate Tender the letter T should be used in place of the dash. Thus a double end suburban locomotive with two wheeled leading truck, six drivers and six wheeled rear truck, weighing 214000 lb. would be a 266 T 214 type.



CLASSIFICATION OF LOCOMOTIVES—Continued

0880	ARTICULATED
010100	ARTICULATED
2440	ARTICULATED
2660	ARTICULATED
2880	ARTICULATED
2442	ARTICULATED
2662	ARTICULATED
2882	ARTICULATED
210102	ARTICULATED
240	4-COUPLED
260	MOGUL
280	CONSOLIDATION
2100	DECAPOD
440	8-WHEEL
460	10-WHEEL
480	12-WHEEL
042	4-COUPLED AND TRAILING
062	6-COUPLED AND TRAILING
082	8-COUPLED AND TRAILING
044	FORNEY 4-COUPLED
064	FORNEY 6-COUPLED
046	FORNEY 4-COUPLED
066	FORNEY 6-COUPLED
242	COLUMBIA
262	PRAIRIE
282	MIKADO
2102	SANTA FE
244	4-COUPLED
264	6-COUPLED
284	8-COUPLED

CLASSIFICATION OF LOCOMOTIVES—Continued



246	4-COUPLED
266	6-COUPLED
442	ATLANTIC
462	PACIFIC
482	MOUNTAIN
444	4-COUPLED DOUBLE ENDER
464	6-COUPLED DOUBLE ENDER
446	4-COUPLED DOUBLE ENDER
286	8-COUPLED DOUBLE ENDER

LOCOMOTIVE REQUIREMENTS

When ordering locomotives the data as below should be supplied with order by cable or letter.

General

Name of Road........................
No. of Engines Desired..................
Type of Engine........................
Wheel Arrangement....................
Class of Service.......................
Fuel—Kind and Grade..................
Boiler Pressure Desired ....
Is Superheater Desired..................
Tender, Type..........................
" Capacity, Water...............Galls......
" " Fuel.........................

Hauling Capacity

State Tonnage to be Hauled (cars and loading) on Ruling Grade, giving Grade and Speed............
Give Capacity of Car and state if Maximum Tonnage on Grades is made up of Loaded or Light Cars......
Maximum Speed in Miles per Hour................
Is Engine to be operated backing in Road Service ....

LOCOMOTIVE REQUIREMENTS—Continued

Give profile of road or state Maximum Grade and Curvature..............................
Are Curves compensated on Grades..................

Track Data and Weight Limitations

Spread of Rails on Maximum Curves.................
Elevation of outer rail on Maximum Curves..........
Track Centers...........................
Weight of Rail per Yard.......................
Limit of Weight per Axle.......................
" " " " foot of Driving Wheel Base......

Clearance Limitations

Tender, Height above Rail to top of Filling Hole.....
" " " " for Coaling..............
Limit of Height..............................
" " Width..............................
Limit of Total Wheel Base of Engine and Tender.. ..
Limit of Total Length........................
Fill in Blank Dimensions on Clearance Diagram, Fig. No. 10, giving in each case maximum figures.......

Foreign Engines and Gages Other Than 4′ 8½″

If Engine is for Foreign Service, or for Domestic Service but not 4′8½″ Gage, give the following additional information:

Gage of Road...........................
Tie Spacing............................
Couplers, Style of..........................
" Height above rail to center...............
Buffers, Style of...........................
" Center to Center............................
" Height above Rail............................

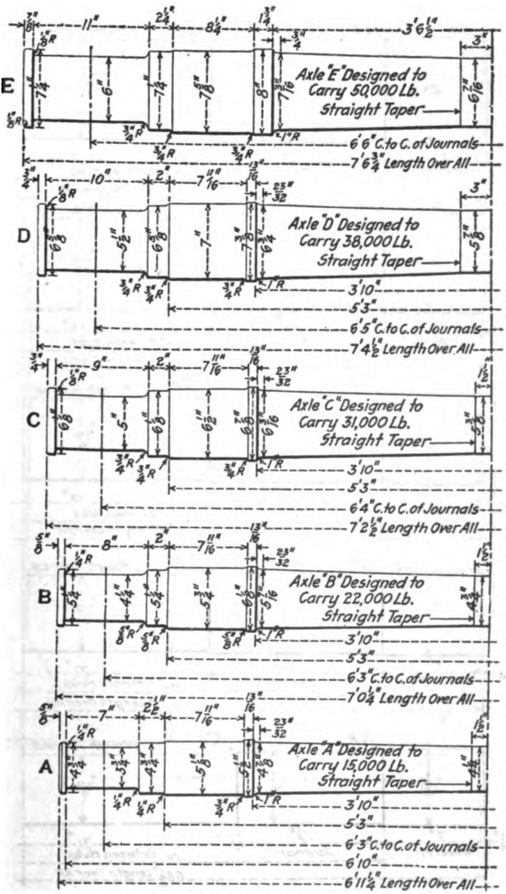


Fig. No. 8—Standard car axles used on tenders. Adopted by the M. C. B. & A. R. M. M. Associations.

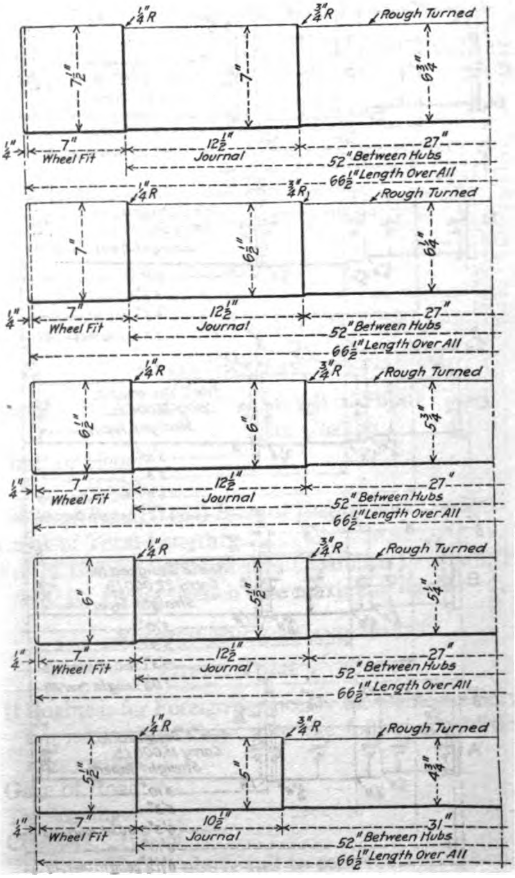


Fig. No. 9—Standard engine truck axles. Adopted by the American Locomotive Company.

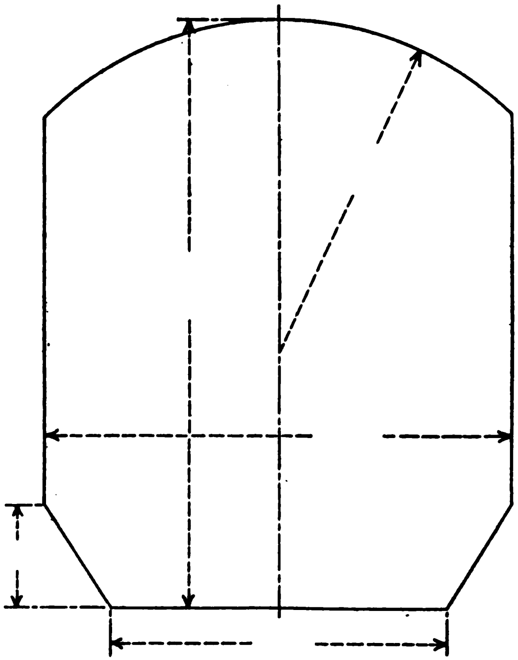


Fig. No. 10—Clearance Diagram

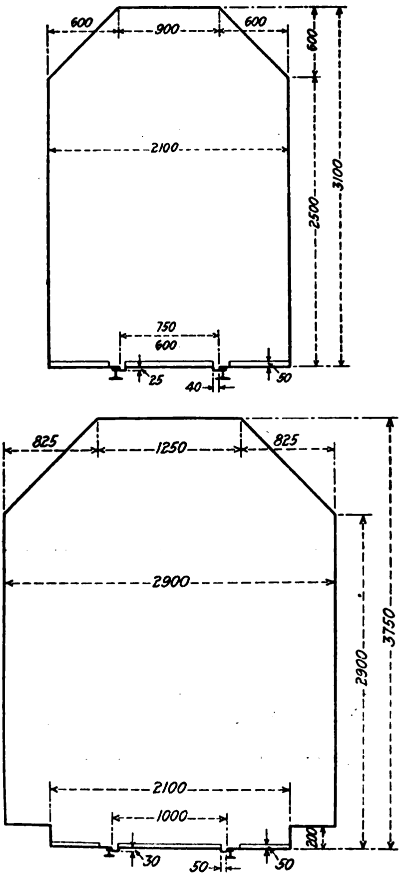


Fig. No. 11—Clearance Diagram—Dimensions in m.m.

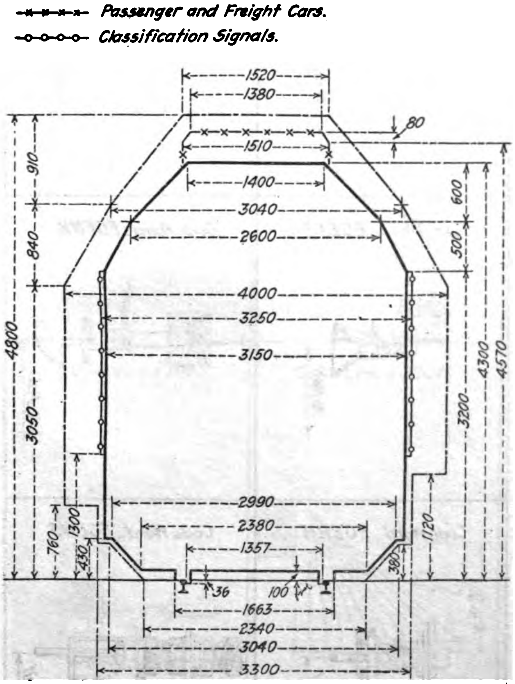


Fig. No. 12—Clearance Diagram—Dimensions in m.

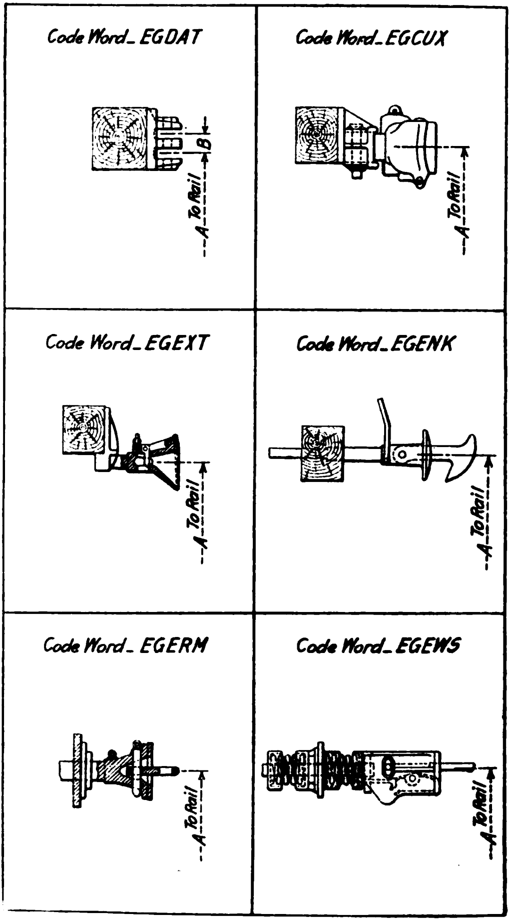


Fig. No. 13—Couplers

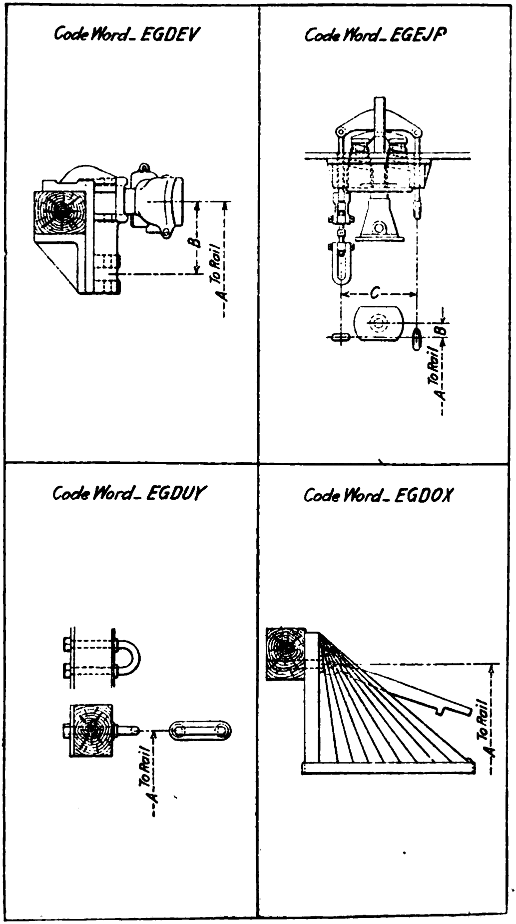


Fig. No. 14—Couplers

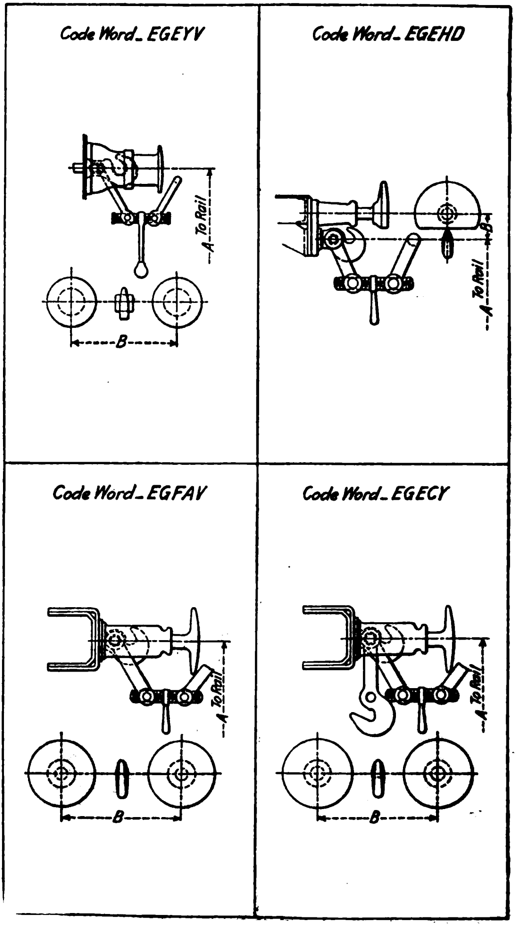


Fig. No. 15—Couplers

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