USEFUL INFORMATION

:: :: :: FOR :: :: ::

PRACTICAL MEN

Compiled for

E. I. DU PONT DE NEMOURS POWDER CO.
WILMINGTON, DELAWARE

PRICE, ONE DOLLAR

E. I. DU PONT DE NEMOURS POWDER CO.

1802 1908

Dando Printing and Publishing Co.
Philadelphia, Pa.

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Useful Information for Practical Men.

GENERAL TABLES.

TROY WEIGHT.

24 grains = 1 pennyweight (dwt.).
20 pennyweights = 1 ounce = 480 grains.
12 ounces = 1 pound = 240 dwt. = 5760 grains.

Troy weight is used for gold and silver.

A carat of the jewelers, for precious stones, is, in the United States = 3.2 grs.; in London, 3.17 grs.; in Paris, 3.18 grs., divided into 4 jewelers' grs. In troy, apothecaries' and avoirdupois the grain is the same.

APOTHECARIES' WEIGHT.

20 grains (gr.) = 1 scruple (℈).
3 scruples = 1 dram (ʒ) = 60 grains.
8 drams = 1 ounce (oz.) = 24 scruples = 480 grains.
12 ounces = 1 pound (lb.) = 96 drams = 288 scruples = 5760 grains.

In troy and apothecary weights, the grain, ounce and pound are the same.

AVOIRDUPOIS OR COMMERCIAL WEIGHT.

16 drams = 1 ounce (oz.) = 437½ grains.
16 ounces = 1 pound (lb.) = 7000 grains.
100 pounds = 1 hundredweight (cwt.).
20 hundredweight = 1 ton = 2000 pounds.

In collecting duties upon foreign goods at the United States custom houses, and also in freighting coal and selling it by wholesale:

28 pounds	= quarter.
4 quarters or 112 pounds	= 1 hundredweight.
20 hundredweight	= 1 ton (long) = 2240 pounds.
A stone	= 14 pounds.
A quintal	= 100 pounds.
A ton (2000 lbs.)	= 29,166.666 ounces troy.

The following measures are sanctioned by custom or law:

WEIGHT PER BUSHEL OF DIFFERENT GRAINS, ETC.

Barley	48 lbs.	Flax seed	56 lbs.
Beans	63 "	Hemp seed	48 "
Buckwheat	46 "	Oats	32 "
Blue grass seed	14 "	Peas	64 "
Corn	56 "	Rye	56 "
Corn meal	50 "	Salt	80 "
Clover seed	60 "	Timothy seed	45 "
Dried apples	22 "	Wheat	60 "
Dried peaches	33 "	Potatoes (heaped)	60 "

WEIGHT PER BARREL OF DIFFERENT ARTICLES.

Flour	196 lbs.	Fish	200 lbs.
Salt	280 "	Soap	256 "
Beef	200 "	Cement	300 "
Pork	200 "		

56 pounds of butter = 1 firkin.
100 pounds of meal or flour = 1 sack.
100 pounds of grain or flour = 1 central.
100 pounds of dry fish = 1 quintal.
100 pounds of nails = 1 cask.

MISCELLANEOUS ARTICLES.

1 ton (2240 lbs.) cured hay	= 425 cubic feet.
1 ton of hay in mow	= 414.37 cubic feet, or a cube of 7½ feet.
Hay as usually delivered	= 5 pounds per cubic foot.
Hay, well pressed	= 8 pounds per cubic foot.
Straw, loose	= 3½ pounds per cubic foot.
Straw, well pressed	= 5⅛ pounds per cubic foot.
1 gallon of water (U. S.)	= 8.33 pounds.
1 gallon of oil	= 7¾ pounds.
1 gallon of molasses	= 11⅔ pounds.
1 gallon of alcohol	= 6.9 pounds.
1 gallon of spirits of turpentine	= 7.31 pounds.
1 keg of powder	= 25 pounds.

WEIGHTS, IN POUNDS, OF VARIOUS ARTICLES.

(*As rated by Railway Companies, when their weights cannot otherwise be ascertained.*)

			LBS.
Ashes, pot or pearl		barrel	450
Apples and barreled fruits		barrel	200
Apples		bushel	50
Barley		bushel	45
Beef, pork, bacon	per	hhd.	1000
Butter, tallow, lard	per	bbl.	333
Salt fish and meat	per	firkin	100

		LBS.
Bran, feed, shipstuffs, oats	bushel	35
Buckwheat	bushel	48
Bricks, common	each	5
Bark	cord	2000
Charcoal	bushel	22
Coke and cake meal	bushel	40
Clover seed	bushel	62
Eggs	barrel	200
Fish and salt meat	per firkin	100
Flour and meal	per bushel, 56 pounds, barrel	216
Grain and seeds, not stated	bushel	60
Hides (green)	each	85
Hides (dry). salted or spanish	each	33
Ice, coal, lime	bushel	80
Liquors, malt and distilled	barrel	350
Liquors	per gallon	10
Lumber—pine, poplar, hemlock	foot B. M.	4
Lumber—oak, walnut, cherry, ash	foot B. M.	5
Nails and spikes	keg	106
Onions, wheat, potatoes	bushel	60
Oysters	per bushel, 100 pounds, per 1000	350
Plastering lath	per 1000	600
Rosin, tar, turpentine	barrel	300
Sand, gravel, etc.	per cubic foot	150
Shingles	per 1000, short 900 pounds, long	1400
Salt	per bushel	70
Stone, undressed	perch	4000
Stone, dressed	cubic foot	180
Timothy and light grass seed	bushel	40
Wood—hickory	cord	4500
Wood—oak	cord	3500

WEIGHT OF ONE CUBIC FOOT OF PURE WATER.

At 32° F. (freezing point) . . . . 62.418 lbs.
At 39.1° F. (maximum density) . . . . 62.425 "
At 62° F. (standard temperature) . . . . 62.355 "
At 212° F. (boiling point, under 1 atmosphere) . . . . . . 59.76 "
American gallon = 231 cubic inches of water at 62° F. = 8.3356 lbs.
British gallon = 277.274 cubic inches of water at 62° F. = 10 lbs.

MEASURES OF LENGTH

12 inches = 1 foot.
3 feet = 1 yard = 36 inches.
5½ yards = 1 rod = 198 inches = 16½ feet.
40 rods = 1 furlong = 7920 inches = 660 feet = 220 yards.
8 furlongs = 1 mile = 63,360 inches = 5280 feet = 1760 yards = 320 rods.

GUNTER'S CHAIN.

(*Sometimes used in Land Surveying.*)

7.92 inches = 1 link.
100 links = 1 chain = 4 rods = 66 feet.
80 chains = 1 mile.

ROPES AND CABLES.

6 feet = 1 fathom ; 120 fathoms = 1 cable's length.

The United States standard yard is the same as the imperial yard of Great Britain. It is determined as follows: The rod of a pendulum vibrating seconds of mean time in the latitude of London in a vacuum at the level of the sea is divided into 391,393 equal parts, and 360,000 of these parts are 36 inches, or 1 standard yard.

An inch is one 500,500,000th part of the earth's polar axis.

Artificers sometimes divide the inch into lines or twelfths, but more commonly into binary divisions—half, quarter, eighth, sixteenth and thirty-second.

Mechanical engineers divide the inch decimally—10ths, 100ths, 1000ths, etc.

Civil engineers divide the foot decimally.

A nautical mile, geographical mile, sea mile, or knot, as adopted by United States Coast and Geodetic Survey, is equal to 6080.27 feet.

British Admiralty knot = 6080 feet.

A geographical or nautical mile may be taken = 1.15 statute miles.

The league = 3 nautical miles.

The geographical degree = 60 geographical or nautical miles.

The length of a degree of latitude varies, being 68.72 miles at the equator, 69.05 miles in middle latitudes, and 69.34 miles in the polar regions. A degree of longitude is greatest at the equator, where it is 69.16 miles, and it gradually decreases toward the poles, where it is 0.

1 hand = 4 inches.

1 pace = 3 feet.

The hand is used for heights of horses and girths of spars.

CIRCULAR AND ANGULAR MEASURE.

60 seconds (″) = 1 minute (′).
60 minutes = 1 degree (°).
360 degrees = 1 circumferance (C).

SQUARE OR LAND MEASURE.

144 square inches = 1 square foot.
9 square feet = 1 square yard = 1296 square inches.
30¼ square yards = 1 square rod = 272¼ square feet.
40 square rods = 1 rood = 1210 square yards
= 10,890 square feet.
4 roods = 1 acre = 160 rods.
= 4840 square yards = 43,560 square feet.
A section of land = 640 acres = 1 square mile.

208.71 feet square = 43,560 square feet = 10 square Gunter's chains = 1 acre, or 220 × 198 feet = 1 acre.

A square ½ acre is 147.58 feet at each side; or 110×198 feet.

A square ¼ acre is 104.355 feet at each side; or 55×198 feet.

A circular acre is 235.504 feet in diameter.

A circular ½ acre is 166.527 feet in diameter.

A circular ¼ acre is 117.752 feet in diameter.

A circular inch is a circle of 1 inch diameter; a square foot = 183.346 circular inches.

1 square inch = 1.27324 circular inches; and one circular inch = 0.7854 of a square inch.

CUBIC MEASURE.

1728 cubic inches = 1 cubic, or solid foot.
27 cubic feet = 1 cubic, or solid yard.

A pile of wood cut 4 feet long, piled 4 feet high, 8 feet long = 128 cubic feet = 1 cord.

A perch of stone = 16½ feet long, by 1 foot high, by 1½ feet thick = 24¾ cubic feet.

A perch of stone = 22 cubic feet in Philadelphia.

A perch of stone = 16½ cubic feet in some New England States.

The perch is so variable in different localities that it should never be used in making a contract unless the contents in cubic feet be specified.

A ton (2240 pounds) of Pennsylvania anthracite, when broken for domestic use, occupies from 41 to 43 cubic feet of space; the mean of which is equal to 1.556 cubic yards, or a cube of 3.476 feet on each edge.

A ton (2240 pounds) of bituminous coal equals 44 to 48 cubic feet, mean equal to 1.704 cubic yards; or a cube of 3.583 feet on each edge.

A ton (2240 pounds) coke = 80 cubic feet.

A cubic foot is equal to

1728	cubic inches.	29.92208	U. S. liquid quarts.
0.037037	cubic yards.	25.71405	U. S. dry quarts.
0.803564	U. S. struck bushel of 2150.42 cubic inches.	59.84416	U. S. liquid pints.
3.21426	U. S. pecks.	51.42809	U. S. dry pints.
7.48052	U. S. liquid gallons of 231 cubic inches.	239.37662	U. S. gills.
6.42851	U. S. dry gallons of 268.8025 cubic inches.	0.26667	flour barrel of 3 struck bushels.
		0.23748	U. S. liquid barrel of 31½ gallons.

A cubic yard is equal to 7.2 flour barrels of 3 struck bushels each.

A ton in computing the tonnage of a ship or other vessel is 100 cubic feet of their internal space.

A ton in computing freight on ships is taken at 40 cubic feet or 2240 lbs., at the ship's option.

MEASURES OF VOLUME.

LIQUID MEASURE.

4 gills = 1 pint.
2 pints = 1 quart = 8 gills.
4 quarts = 1 gallon = 32 gills = 8 pints.

1 gallon liquid = 231 cubic inches and contains 8.339 avoirdupois pounds of distilled water at 39.8° F. (equal old British wine gallon).

63 gallons = 1 hogshead.
2 hogsheads = 1 pipe or butt.
2 pipes = 1 tun.

In the United States and Great Britain, 1 barrel of wine or brandy = 31½ gallons = 4.211 cubic feet.

A hogshead is 63 gallons, but this term is often applied to casks of various capacities.

Butt of sherry	= 108 gallons.
Pipe of port	= 115 gallons.
Butt of malaga	= 105 gallons.
Puncheon of brandy	110 to 120 gallons.
Puncheon of rum	100 to 110 gallons.
Hogshead of brandy	55 to 60 gallons.
Hogshead of claret	46 gallons.
Puncheon of Scotch whisky	110 to 130 gallons.

The following cylinders give measures of liquid volumes in common use:

	Dia. in.	Height in.		Dia. in.	Height in.
1 gill (7.2 cu. in.)	1¾	3	1 gallon	7	6
½ pint	2¼	3⅝	2 gallon	7	12
1 pint	3½	3	8 gallon	14	12
1 quart	3½	6	10 gallon	14	15

DRY MEASURE.

	Edge of a cube of equal capacity.
2 pints = 1 quart	4.066 inches.
4 quarts = 1 gallon = 8 pints	6.454 inches.
2 gallons = 1 peck = 16 pints = 8 gallons	8.131 inches.
4 pecks = 1 bushel (struck) = 64 pints = 32 quarts = 8 gallons	12.908 inches.

A gallon dry measure = 268.8 cubic inches.

A bushel dry measure (same as British Winchester struck bushel) = 2150.42 cubic inches, or 77.63 pounds avoirdupois of pure water at its maximum density.

The dimensions of a bushel by law are 18½ inches inner diameter, 19½ inches outer diameter, and 8 inches deep; and when heaped, the cone is not to be less than 6 inches high, which makes a heaped bushel equal to 1¼ struck bushels, or to 1.56 cubic feet.

A struck bushel = 1.24 cubic feet.

The dry flour barrel = 3.75 cubic feet = 3 struck bushels. The dry barrel is not, however, a legalized measure.

36 heaped bushels = 1 chaldron.

SHORT METRIC TABLES.

The common units in the metric tables of measurements can be classed as follows for simplicity :

LENTH.

10 millimeters	= 1 centimeter.
100 centimeters	= 1 meter = 39.36982 inches.
1000 meters	= 1 kilometer.

VOLUME.

1000 cubic centimeters	= 1 liter = 1.05671 quarts U. S.
1000 liters	= 1 cubic meter.

1 centimeter of water at 4° centigrade weighs 1 gram.

1 liter of water at 4° centigrade weighs 1 kilogram.

WEIGHT.

1000 milligrams	= 1 gram.
1000 grams	= 1 kilogram.
1000 kilograms	= 1 metric ton = 2204.6 lbs. avoirdupois.

AREA.

10,000 square centimeters	= 1 square meter.
100 square meters	= 1 are.
100 ares	= 1 hectare.
100 hectares	= 1 square kilometer.

METRIC CONVERSION TABLE OF WEIGHTS.

1 grain	=	0.0647989	grams.
1 ounce, avoirdupois	=	28.3496	grams
1 ounce, troy	=	31.10348	grams.
1 pound, avoirdupois	=	453.593	grams.
1 ton, 2000 pounds	=	907.186	kilograms.
1 ton, 2240 pounds	=	1.016	metric tons.
1 gram	=	15.432	grains.
1 kilogram	=	2.2046	pounds avoirdupois.
1 tonne or metric ton	=	2204.6	pounds avoirdupois.

METRIC CONVERSION TABLE OF LENGTHS.

1 inch	=	2.54	centimeters.
1 foot	=	0.3048	meter.
1 yard	=	0.914402	meter.
1 mile	=	1.60935	kilometers.
1 millimeter	=	0.03937	inch.
1 centimeter	=	0.3937	inch.
1 meter	=	39.37	inches.
1 kilometer	=	3280.83	feet = 0.62137 mile.

METRIC CONVERSION TABLE OF VOLUME.

1 cubic inch	=	16.387	cubic centimeters.
1 cubic foot	=	0.02832	cubic meter = 28.317 liters.
1 cubic yard	=	0.7645	cubic meter.
1 U. S. gallon	=	3.78543	liters.
1 bushel	=	0.35242	hectoliter.
1 perch	=	0.700846	cubic meter.
1 cubic centimeter	=	0.0610234	cubic inch.
1 cubic meter	=	35.314	cubic feet = 1.308 cubic yards.
1 liter	=	0.26417	U. S. gallon = 61.023 cubic inches.
1 hectoliter	=	2.8375	bushels.

METRIC CONVERSION TABLE OF SURFACE.

1 square inch	=	6.45163	square centimeters.
1 square foot	=	0.0929034	square meter.
1 square yard	=	0.836131	square meter.
1 acre	=	4046.87	square meters.
1 square mile	=	2.59000	square kilometers.
1 square centimeter	=	0.15500	square inch.
1 square meter	=	10.764	square feet.
1 hectare	=	2.47104	acres = 107641 square feet.
1 square kilometer	=	0.386101	square mile.

MENSURATION.

PROPERTIES OF THE CIRCLE.

Diameter $\times$ 3.14159 = circumference.
Diameter $\times$ .8862 = side of an equal square.
Diameter $\times$ .7071 = side of an inscribed square.
Diameter^2 $\times$ .7854 = area of a circle.
Radius $\times$ 6.28318 = circumference.
Circumference $\div$ 3.14159 = diameter.

1st. The circle contains a greater area than any plane figure, bounded by an equal perimeter or outline.

2d. The areas of circles are to each other as the squares of their diameters. Any circle whose diameter is double that of another contains four times the area of the other.

3d. Area of a circle is equal to the area of a triangle whose base equals the circumference, and perpendicular equals the radius.

AREA OF CIRCLES AND THEIR CIRCUMFERENCE.

DIA.	AREA.	CIR.	DIA.	AREA.	CIR.	DIA.	AREA.	CIR.	DIA.	AREA.	CIR.
1/8	0.0123	.3926	10	78.54	31.41	30	706.86	94.24	65	3318.3	204.2
1/4	0.0491	.7854	1/2	86.59	32.98	31	754.76	97.38	66	3421.2	207.3
3/8	0.1104	1.178	11	95.03	34.55	32	804.24	100.5	67	3525.6	210.4
1/2	0.1963	1.570	1/2	103.86	36.12	33	855.30	103.6	68	3631.6	213.6
5/8	0.3067	1.963	12	113.09	37.69	34	907.92	106.8	69	3739.2	216.7
3/4	0.4417	2.356	1/2	122.71	39.27	35	962.11	109.9	70	3848.4	219.9
7/8	0.6013	2.748	13	132.73	40.84	36	1017.8	113.0	71	3959.2	223.0
1	0.7854	3.141	1/2	143.13	42.41	37	1075.2	116.2	72	4071.5	226.1
1/8	0.9940	3.534	14	153.93	43.98	38	1134.1	119.3	73	4185.3	229.3
1/4	1.227	3.927	1/2	165.13	45.55	39	1194.5	122.5	74	4300.8	232.4
3/8	1.484	4.319	15	176.71	47.12	40	1256.6	125.6	75	4417.8	235.6
1/2	1.767	4.712	1/2	188.69	48.69	41	1320.2	128.8	76	4536.4	238.7
5/8	2.073	5.105	16	201.06	50.26	42	1385.4	131.9	77	4656.0	241.9
3/4	2.405	5.497	1/2	213.82	51.83	43	1452.2	135.0	78	4778.3	245.0
7/8	2.761	5.890	17	226.98	53.40	44	1520.5	138.2	79	4901.6	248.1
2	3.141	6.283	1/2	240.52	54.97	45	1590.4	141.3	80	5026.5	251.3
1/4	3.976	7.068	18	254.46	56.54	46	1661.9	144.5	81	5153.0	254.4
1/2	4.908	7.854	1/2	268.80	58.11	47	1734.9	147.6	82	5281.0	257.6
3/4	5.939	8.639	19	283 52	59.69	48	1809.5	150.7	83	5410.6	260.7
3	7.068	9.424	1/2	298.64	61.26	49	1885.7	153.9	84	5541.7	263.8
1/4	8.295	10.21	20	314.16	62.83	50	1963.5	157.0	85	5674.5	267.0
1/2	9.621	10.99	1/2	330.06	64.40	51	2042.8	160.2	86	5808.8	270.1
3/4	11.044	11.78	21	346.36	65.97	52	2123.7	163.3	87	5944.6	273.3
4	12.566	12.56	1/2	363.05	67.54	53	2206.1	166.5	88	6082.1	276.4
1/2	15.904	14.13	22	380.13	69.11	54	2290.2	169.6	89	6221.1	279.6
5	19 635	15.70	1/2	397.60	70.68	55	2375.8	172.7	90	6361.7	282.7
1/2	23.758	17.27	23	415.47	72.25	56	2463.0	175.9	91	6503.8	285.8
6	28.274	18.84	1/2	433.73	73.82	57	2551.7	179.0	92	6647.6	289.0
1/2	33.183	20.42	24	452.39	75.39	58	2642.0	182.2	93	6792.9	292.1
7	38.484	21.99	1/2	471.43	76.96	59	2733.9	185.3	94	6939.7	295.3
1/2	44.178	23.56	25	490.87	78.54	60	2827.4	188.4	95	7088.2	298.4
8	50.265	25.13	26	530.93	81.68	61	2922.4	191.6	96	7238.2	301.5
1/2	56.745	26.70	27	572.55	84.82	62	3019.0	194.7	97	7389.8	304.7
9	63.617	28.27	28	615.75	87.96	63	3117.2	197.9	98	7542.9	307.8
1/2	70.882	29.84	29	660.52	91.10	64	3216.9	201.0	99	7697.7	311.0

CYLINDRICAL VESSELS, TANKS, CISTERNS, ETC. (KENT).

Diameter in feet and inches, area in square feet and United States gallons capacity for one foot in depth.

$$1 \text{ gallon} = 231 \text{ cubic inches} = \frac{1 \text{ cubic foot}}{7.4805} = 0.13368 \text{ cubic feet.}$$

Dia. Ft.	Dia. In.	Area. Sq. ft.	Gals. 1 foot depth.	Dia. Ft.	Dia. In.	Area. Sq. ft.	Gals. 1 foot depth.	Dia. Ft.	Dia. In.	Area. Sq. ft.	Gals. 1 foot depth.
1		0.785	5.87	3	4	8.727	65.28	5	8	25.22	188.66
1	1	0.922	6.89	3	5	9.168	68.58	5	9	25.97	194.25
1	2	1.069	8.00	3	6	9.621	71.97	5	10	26.73	199.92
1	3	1.227	9.18	3	7	10.085	75.44	5	11	27.49	205.67
1	4	1.396	10.44	3	8	10.559	78.99	6		28.27	211.51
1	5	1.576	11.79	3	9	11.045	82.62	6	3	30.68	229.50
1	6	1.767	13.22	3	10	11.541	86.33	6	6	33.18	248.23
1	7	1.969	14.73	3	11	12.048	90.13	6	9	35.78	267.69
1	8	2.182	16.32	4		12.566	94.00	7		38.48	287.88
1	9	2.405	17.99	4	1	13.095	97.96	7	3	41.28	308.81
1	10	2.640	19.75	4	2	13.635	102.00	7	6	44.18	330.48
1	11	2.885	21.58	4	3	14.186	106.12	7	9	47.17	352.88
2		3.142	23.50	4	4	14.748	110.32	8		50.27	376.01
2	1	3.409	25.50	4	5	15.321	114.61	8	3	53.46	399.88
2	2	3.687	27.58	4	6	15.90	118.97	8	6	56.75	424.48
2	3	3.976	29.74	4	7	16.50	123.42	8	9	60.13	449.82
2	4	4.276	31.99	4	8	17.10	127.95	9		63.62	475.89
2	5	4.587	34.31	4	9	17.72	132.56	9	3	67.20	502.70
2	6	4.909	36.72	4	10	18.35	137.25	9	6	70.88	530.24
2	7	5.241	39.21	4	11	18.99	142.02	9	9	74.66	558.51
2	8	5.585	41.78	5		19.63	146.88	10		78.54	587.52
2	9	5.940	44.43	5	1	20.29	151.82	10	3	82.52	617.26
2	10	6.305	47.16	5	2	20.97	156.83	10	6	86.59	647.74
2	11	6.681	49.98	5	3	21.65	161.93	10	9	90.76	678.95
3		7.069	52.88	5	4	22.34	167.12	11		95.03	710.90
3	1	7.467	55.86	5	5	23.04	172.38	11	3	99.40	743.58
3	2	7.876	58.92	5	6	23.76	177.72	11	6	103.87	776.99
3	3	8.296	62.06	5	7	24.48	183.15	11	9	108.43	811.14

The circumference of a circle multiplied by 0.282 equals the side of a square of the same area. Useful in turning round tanks into square.

CYLINDRICAL VESSELS, TANKS, CISTERNS, ETC. (KENT)—continued.

Diameter in feet and inches, area in square feet and United States gallons capacity for one foot in depth.

$$1 \text{ gallon} = 231 \text{ cubic inches} = \frac{1 \text{ cubic foot}}{7.4805} = 0.13368 \text{ cubic feet.}$$

DIA. Ft.	DIA. In.	AREA. Sq. ft.	GALS. 1 foot depth.	DIA. Ft.	DIA. In.	AREA. Sq. ft.	GALS. 1 foot depth.	DIA. Ft.	DIA. In.	AREA. Sq. ft.	GALS. 1 foot depth.
12		113.10	846.03	19		283.53	2120.9	26		530.93	3971.6
12	3	117.86	881.65	19	3	291.04	2177.1	26	3	541.19	4048.4
12	6	122.72	918.00	19	6	298.65	2234.0	26	6	551.55	4125.9
12	9	127.68	955.09	19	9	306.35	2291.7	26	9	562.00	4204.1
13		132.73	992.91	20		314.16	2350.1	27		572.56	4283.0
13	3	137.89	1031.5	20	3	322.06	2409 2	27	3	583.21	4362.7
13	6	143.14	1070.8	20	6	330.06	2469.1	27	6	593.96	4443.1
13	9	148.49	1110.8	20	9	338.16	2529.6	27	9	604.81	4524.3
14		153.94	1151.5	21		346.36	2591.0	28		615.75	4606.2
14	3	159.48	1193.0	21	3	354.66	2653.0	28	3	626.80	4688.8
14	6	165.13	1235.3	21	6	363.05	2715.8	28	6	637.94	4772.1
14	9	170.87	1278.2	21	9	371.54	2779.3	28	9	649.18	4856.2
15		176.71	1321.9	22		380.13	2843.6	29		660.52	4941.0
15	3	182.65	1366.4	22	3	388.82	2908.6	29	3	671.96	5026.6
15	6	188.69	1411.5	22	6	397.61	2974.3	29	6	683.49	5112.9
15	9	194.83	1457.4	22	9	406.49	3040.8	29	9	695.13	5199.9
16		201.06	1504.1	23		415.48	3108.0	30		706.86	5287.7
16	3	207.39	1551.4	23	3	424.56	3175.9	30	3	718.69	5376.2
16	6	213.82	1599.5	23	6	433.74	3244 6	30	6	730.62	5465.4
16	9	220.35	1648.4	23	9	443.01	3314.0	30	9	742.64	5555.4
17		226.98	1697.9	24		452.39	3384.1	31		754.77	5646.1
17	3	233.71	1748.2	24	3	461.86	3455.0	31	3	766.99	5737.5
17	6	240.53	1799.3	24	6	471.44	3526.6	31	6	779.31	5829.7
17	9	247.45	1851.1	24	9	481.11	3598.9	31	9	791 73	5922.6
18		254.47	1903.6	25		490.87	3672.0	32		804.25	6016.2
18	3	261.59	1956.8	25	3	500.74	3745.8	32	3	816.86	6110.6
18	6	268.80	2010.8	25	6	510.71	3820.3	32	6	829.58	6205.7
18	9	276.12	2065.5	25	9	520.77	3895.6	32	9	842.39	6301.5

The circumference of a circle multiplied by 0.282 equals the side of a square of the same area. Useful in turning round tanks into square.

TABLE OF AREAS OF CIRCULAR SEGMENTS (TRAUTWINE).

(For use in the calculation of Contents of Cylindrical Tanks lying on their sides.)

If the segment exceeds a semicircle, its area = area of circle — area of a segment whose rise is = (diameter of circle — rise of given segment). Diameter of circle = (square of half chord ÷ rise) + rise, whether the segments exceeds a semicircle or not.

Rise div. by diam. of circle	AREA = (sq. of diam.) mult. by	Rise div. by diam. of circle	AREA = (sq. of diam.) mult. by	Rise div. by diam. of circle	AREA = (sq. of diam.) mult. by	Rise div. by diam. of circle	AREA = (sq. of diam.) mult. by	Rise div. by diam. of circle	AREA = (sq. of diam.) mult. by
.001	.000042	.046	.012971	.091	.035586	.136	.064074	.181	.096904
.002	.000119	.047	.013393	.092	.036162	.137	.064761	.182	.097675
.003	.000219	.048	.013818	.093	.036742	.138	.065449	.183	.098447
.004	.000337	.049	.014248	.094	.037324	.139	.066140	.184	.099221
.005	.000471	.050	.014681	095	.037909	.140	.066833	.185	.099997
.006	.000619	.051	.015119	.096	.038497	.141	.067528	.186	.100774
.007	.000779	.052	.015561	.097	.039087	.142	.068225	.187	.101553
.008	.000952	.053	.016008	.098	.039681	.143	.068924	.188	.102334
.009	.001135	.054	.016458	.099	.040277	.144	069626	.189	.103116
.010	.001329	.055	.016912	.100	.040875	.145	.070329	.190	.103900
.011	.001533	.056	.017369	.101	.041477	.146	.071034	.191	.104686
.012	.001746	.057	.017831	.102	.042081	.147	.071741	.192	.105472
.013	.001969	.058	.018297	.103	.042687	.148	.072450	.193	.106261
.014	.002199	.059	.018766	.104	.043296	.149	.073162	.194	.107051
.015	.002438	.060	.019239	.105	.043908	.150	.073875	.195	.107843
.016	.002685	.061	.019716	.106	.044523	.151	.074590	.196	.108636
.017	.002940	.062	.020197	.107	.045140	.152	.075307	.197	.109431
.018	.003202	.063	.020681	.108	.045759	.153	.076026	.198	.110227
.019	.003472	.064	.021168	.109	.046381	.154	.076747	.199	.111025
.020	.003749	.065	.021660	.110	.047006	.155	.077470	.200	.111824
.021	.004032	.066	.022155	.111	.047633	.156	.078194	.201	.112625
.022	.004322	.067	.022653	.112	.048262	.157	.078921	.202	.113427
.023	.004619	.068	.023155	.113	.048894	.158	.079650	.203	.114231
.024	.004922	.069	.023660	.114	.049529	.159	.080380	.204	.115036
.025	.005231	.070	.024168	.115	.050165	.160	081112	.205	.115842
.026	.005546	.071	.024680	.116	.050805	.161	.081847	.206	.116651
.027	.005867	.072	.025196	.117	.051446	.162	.082582	.207	.117460
.028	.006194	.073	.025714	.118	.052090	.163	.083320	.208	.118271
.029	.006527	.074	.026236	.119	.052737	.164	.084060	.209	.119084
.030	.006866	.075	.026761	.120	.053385	.165	.084801	.210	.119898
.031	.007209	.076	.027290	.121	.054037	.166	.085545	.211	.120713
.032	.007559	.077	.027821	.122	.054690	.167	.086290	.212	.121530
.033	.007913	.078	.028356	.123	.055346	.168	087037	.213	.122348
.034	.008273	.079	.028894	.124	.056004	.169	.087785	.214	.123167
.035	.008638	.080	.029435	.125	.056664	.170	.088536	.215	.123988
.036	.009008	.081	.029979	.126	.057327	.171	.089288	.216	.124811
.037	.009383	.082	.030526	.127	.057991	.172	.090042	.217	.125634
.038	.009764	.083	.031077	.128	.058658	.173	.090797	.218	126459
.039	.010148	.084	.031630	.129	.059328	.174	.091555	.219	.127286
.040	.010538	.085	.032186	.130	.059999	.175	.092314	.220	.128114
.041	.010932	.086	.032746	.131	.060673	.176	.093074	.221	.128943
.042	.011331	.087	.033308	.132	.061349	.177	.093837	.222	.129773
.043	.011734	.088	.033873	.133	.062027	.178	.094601	.223	.130605
.044	.012142	.089	.034441	.134	.062707	.179	.095367	.224	.131438
.045	.012555	.090	.035012	.135	.063389	.180	.096135	.225	.132273

TABLE OF AREAS OF CIRCULAR SEGMENTS (TRAUTWINE)—continued.

Rise div. by diam. of circle	AREA = (sq. of diam.) mult. by	Rise div. by diam. of circle	AREA = (sq. of diam.) mult. by	Rise div. by diam. of circle	AREA = (sq. of diam.) mult. by	Rise div. by diam. of circle	AREA = (sq. of diam.) mult. by	Rise div. by diam. of circle	AREA = (sq. of diam.) mult. by
.226	.133109	.281	.180918	.336	.231689	.391	.284569	.446	.338804
.227	.133946	.282	.181818	.337	.232634	.392	.285545	.447	.339799
.228	.134784	.283	.182718	.338	.233580	.393	.286521	.448	.340793
.229	.135624	.284	.183619	.339	.234526	.394	.287499	.449	.341788
.230	.136465	.285	.184522	.340	.235473	.395	.288476	.450	.342783
.231	.137307	.286	.185425	.341	.236421	.396	.289454	.451	.343778
.232	.138151	.287	.186329	.342	.237369	.397	.290432	.452	.344773
.233	.138996	.288	.187235	.343	.238319	.398	.291411	.453	.345768
.234	.139842	.289	.188141	.344	.239268	.399	.292390	.454	.346764
.235	.140689	.290	.189048	.345	.240219	.400	.293370	.455	.347760
.236	.141538	.291	.189956	.346	.241170	.401	.294350	.456	.348756
.237	.142388	.292	.190865	.347	.242122	.402	.295330	.457	.349752
.238	.143239	.293	.191774	.348	.243074	.403	.296311	.458	.350749
.239	.144091	.294	.192685	.349	.244027	.404	.297292	.459	.351745
.240	.144945	.295	.193597	.350	.244980	.405	.298274	.460	.352742
.241	.145800	.296	.194509	.351	.245935	.406	.299256	.461	.353739
.242	.146656	.297	.195423	.352	.246890	.407	300238	.462	.354736
.243	.147513	.298	.196837	.353	.247845	.408	.301221	.463	.355733
.244	.148371	.299	.197252	.354	.248801	.409	.302204	.464	.356730
.245	.149231	.300	.198168	.355	.249758	.410	.303187	.465	.357728
.246	.150091	.301	.199085	.356	250715	.411	.304171	.466	.358725
.247	.150953	.302	.200003	.357	.251673	.412	.305156	.467	.359723
.248	.151816	.303	.200922	.358	.252632	.413	.306140	.468	.360721
.249	.152681	.304	.201841	.359	.253591	.414	.307125	.469	.361719
.250	.153546	.305	.202762	.360	.254551	.415	.308110	.470	.362717
.251	.154413	.306	.203683	.361	.255511	.416	.309096	.471	.363715
.252	.155281	.307	.204605	.362	.256472	.417	.310082	.472	.364714
.253	.156149	.308	.205528	.363	.257433	.418	.311068	.473	.365712
.254	.157019	.309	.206452	.364	.258395	.419	.312055	.474	.366711
.255	.157891	.310	.207376	.365	.259358	.420	.313042	.475	.367710
.256	.158763	.311	.208302	.366	.260321	.421	.314029	.476	.368708
.257	.159636	.312	.209228	.367	.261285	.422	.315017	.477	.369707
.258	.160511	.313	.210155	.368	.262249	.423	.316005	.478	.370706
.259	.161386	.314	.211083	.369	.263214	.424	.316993	.479	.371705
.260	.162263	.315	.212011	.370	.264179	.425	.317981	.480	.372704
.261	.163141	.316	.212941	.371	.265145	.426	.318970	.481	.373704
.262	.164020	.317	.213871	.372	.266111	.427	.319959	.482	.374703
.263	.164900	.318	.214802	.373	.267078	.428	.320949	.483	.375702
.264	.165781	.319	.215734	.374	.268046	.429	.321938	.484	.376702
.265	.166663	.320	.216666	.375	.269014	.430	.322928	.485	.377701
.266	.167546	.321	.217600	.376	.269982	.431	.323919	.486	.378701
.267	.168481	.322	.218534	.377	.270951	.432	.324909	.487	.379701
.268	.169316	.323	.219469	.378	.271921	.433	.325900	.488	.380700
.269	.170202	.324	.220404	.379	.272891	.434	.326891	.489	.381700
.270	.171090	.325	.221341	.380	.273861	.435	.327883	.490	.382700
.271	.171978	.326	.222278	.381	.274832	.436	.328874	.491	.383700
.272	.172868	.327	.223216	.382	.275804	.437	.329866	.492	.384699
.273	.173758	.328	.224154	.383	.276776	.438	.330858	.493	.385699
.274	.174650	.329	.225094	.384	.277748	.439	.331851	.494	.386699
275	.175542	.330	.226034	.385	.278721	.440	.332843	.495	.387699
.276	.176436	.331	.226974	.386	.279695	.441	.333836	.496	.388699
.277	.177830	.332	.227916	.387	.280669	.442	.334829	.497	.389699
.278	.178226	.333	.228858	.388	.281643	.443	.335823	.498	.390699
.279	.179122	.334	.229801	.389	.282618	.444	.336816	.499	.391699
.280	.180020	.335	.230745	.390	.283593	.445	.337810	.500	.392699

Example.—What are the contents in gallons of a cylindrical tank 12 feet long and 8 feet in diameter when the gauge shows depths first of 3 feet 10 inches and second of 5 feet 3 inches?

Case 1.—Where the depth is less than half the diameter.

3 feet 10 inches = 3.833 feet,
3.833 ÷ 8 = 0.479.

On looking up in the table, we find in the column "Area = the square of the diameter multiplied by" opposite the figures 0.479 in the column "Rise divided by diameter of circle" the figures 0.371705.

Therefore, the area of a vertical section through the liquid is:

$$8 \times 8 \times 0.371705 = 23.78912 \text{ square feet.}$$

The contents of the tank are:

$$23.78912 \times 12 = 285.46944 \text{ cubic feet, or}$$
$$285.46944 \div 0.133681 = 2135.5 \text{ gallons.}$$

Case 2.—Where the depth is greater than half the diameter.

The depth of empty space above the liquid is:

8 — 5 feet 3 inches = 2 feet 9 inches.

Following the same calculation as given in Case 1, we find the area of a vertical section through the empty space above the liquid to be 15.313152 square feet.

The area of a circle is equal to the square of the radius × 3.1416.

The area of a vertical section through the tank is:

$$4 \times 4 \times 3.1416 = 50.2656 \text{ square feet.}$$

The area of a vertical section through the liquid is:

$$50.2656 - 15.313152 = 34.952448 \text{ square feet.}$$

The contents of the tank are:

$$34.952448 \times 12 = 419.429376 \text{ cubic feet, or}$$
$$419.429376 \div 0.133681 = 3137.5 \text{ gallons.}$$

Where several of this class of tanks are in use, it is a fairly simple task to compute a table of contents to correspond with the gauge readings of each tank.

MENSURATION OF SURFACES.

Area of any parallelogram . = base × perpendicular height.
Area of any triangle . . . . = base × ½ perpendicular height.

Area of any circle	= diameter squared × .7854.
Area of sector of circle . . .	= arc × ½ radius.
Area of segment of circle . .	= area of sector of equal radius, less area of triangle.
Area of parabola	= base × ⅔ height.
Area of ellipse	= longest diameter × shortest diameter × .7854.
Area of cycloid	= area of generating circle × 3.
Area of any regular polygon	= sum of its sides × perpendicular from its center to one of its sides ÷ 2.
Surface of cylinder	= area of both ends + length × circumference.
Surface of cone	= area of base + circumference of base × ½ slant height.
Surface of sphere	= diameter^2 × 3.14159 = diameter × circumference.
Surface of frustum	= sum of girt at both ends × ½ slant height + area of both ends.
Surface of cylindrical ring .	= thickness of ring added to the inner diameter × the thickness × 9.8698.
Surface of segment	= height of segment × whole circumference of sphere of which it is a part.

MENSURATION OF SOLIDS.

Cylinder	= area of one end × length.
Sphere	= cube of diameter × .5236.
Segment of sphere	= square root of the height added to three times the square of radius of base × by height and by .5236.
Cone or pyramid	= area of base × ⅓ perpendicular height.
Frustum of a cone	= product of diameter of both ends + sum of their squares × perpendicular height × .2618.
Frustum of a pyramid . . .	= sum of the areas of the two ends + square root of their product × by ⅓ of the perpendicular height.
Solidity of a wedge	= area of base × ½ perpendicular height.
Frustum of a wedge	= ½ perpendicular height × sum of the areas of the two ends.
Solidity of a ring	= thickness + inner diameter × square of the thickness × 2.4674.

WEIGHT AND SPECIFIC GRAVITY OF LIQUIDS.

LIQUIDS AT 32° F.	Weight of one cubic foot.	Weight of one gallon (imperial)	Specific gravity.
	Pounds.	Pounds.	Water = 1
Mercury	848.7	136.0	13.596
Bromine	185.1	29.7	2.966
Sulphuric acid	114.9	18.4	1.84
Nitrous acid	96.8	15.5	1.55
Chloroform	95.5	15.3	1.53
Water of the Dead Sea	77.4	12.4	1.24
Nitric acid	76.2	12.2	1.22
Acetic acid	67.4	10.8	1.08
Milk	64.3	10.3	1.03
Sea water	64.05	10.3	1.026
Pure water (distilled) at 39° F.	62.425	10.0	1.0
Wine of Bordeaux	62.9	9.9	0.994
Wine of Burgundy	61.9	9.9	0.991
Oil, linseed	58.7	9.4	0.94
Oil, poppy	58.1	9.3	0.93
Oil, rape seed	57.4	9.2	0.92
Oil, whale	57.4	9.2	0.92
Oil, olive	57.1	9.15	0.915
Oil, turpentine	54.3	8.7	0.87
Oil, potato	51.2	8.2	0.82
Petroleum	54.9	8.8	0.88
Naphtha	53.1	8.5	0.85
Ether, nitric	69.3	11.1	1.11
Ether, sulphurous	67.4	10.8	1.08
Ether, nitrous	55.6	8.9	0.89
Ether, acetic	55.6	8.9	0.89
Ether, hydrochloric	54.3	8.7	0.87
Ether, sulphuric	44.9	7.2	0.72
Alcohol, proof spirit	57.4	9.2	0.92
Alcohol, pure	49.3	7.9	0.79
Benzine	53.1	8.5	0.85
Wood spirit	49.9	8.0	0.80

The specific gravity, or specific weight, of a body is the ratio which the weight of the body bears to the weight of another body of equal volume.

WEIGHT AND SPECIFIC GRAVITY OF METALS (KENT).

	Specific gravity. Range according to several authorities.	Specific gravity. Approximate mean value used in calculation of weight.	Weight per cubic foot, lbs.	Weight per cubic inch, lbs.
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 23.0		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	7.0 to 8.0	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	8.8	548.7	.3175
Platinum	20.33 to 22.07	21.5	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	17.0 to 17.6			
Zinc	6.86 to 7.20	7.00	436.5	.2526

* Hard and burned. † Very pure and soft. The specific gravity decreases as the carbon is increased.

In the first column of figures, the lowest are usually those of cast metals, which are more or less porous; the highest are of metals finely rolled or drawn into wire.

TABLE OF POLYHEDRONS.

NAME.	No. of sides.	$R = S \times$	$r = S \times$	$A = S^2 \times$	$C = S^3 \times$
Texahedron	4	0.6123	0.2041	1.7320	0.1178
Hexahedron	6	0.8660	0.5000	6.0000	1.0000
Octahedron	8	0.7071	0.4082	3.4641	0 4714
Dodecahedron	12	1.4012	1.1135	20.6457	7.6631
Icosahedron	20	0.9510	0.7558	8.6602	2.1817

S = Length of linear edge of a side.
R = Radius of circumscribed circle.
r = Radius of inscribed circle.
A = Area of polyhedron.
C = Cube contents of polyhedron.

TABLE OF POLYGONS.

S = Side of polygon.
R = Radius of circumscribed circle.
r = Radius of inscribed circle.
A = Angle formed by the intersection of the sides.

NAME.	No. of sides.	A	$A = S^2 \times$	$S = R \times$	$S = r \times$
Trigon	3	60°	0.4330	1.732	3.4641
Pentagon	5	108°	1.7205	1.1755	1.4536
Hexagon	6	120°	2.5980	1.0000	1.1547
Octagon	8	135°	4.8284	0.7653	0.8284
Decagon	10	144°	7.6942	0.6180	0.6498

Area of polygon = radius of inscribed circle × ½ number of sides × length of one side.

THE EFFECT OF HEAT ON VARIOUS SUBSTANCES.

COMPARISON OF TEMPERATURE SCALES.

F. = Fahrenheit temperature.
C. = Centigrade or Celsius temperature.
R. = Réaumur temperature.
32° F. = 0° C. = 0° R.
212° F. = 100° C. = 80° R.
Temperature Fahrenheit = $\frac{9}{5}$ C. + 32 = $\frac{9}{4}$ R. + 32.
Temperature Centigrade = $\frac{5}{9}$ (F. — 32) = $\frac{5}{4}$ R.
Temperature Réaumur = $\frac{4}{9}$ (F. — 32) = $\frac{4}{5}$ C.

MELTING POINTS (KENT).

METALS.	C.	F.
Aluminum	625.0	1157.0
Antimony	435.0	835.0
Bismuth	268.1	514.6
Cadmium	318.0	604.4
Chromium	above	platinum
Cobalt	1650.0	3002.0
Copper	1100.0	2012.0
Gold	1080.0	1976.0
Iridium	2225.0	4037.0
Iron, pure	1635.0	2975.0
Iron, white pig	1075.0	1967.0
Iron, gray pig	1200.0	2192.0
Steel	1360.0	2480.0
Steel, cast	1375.0	2507.0
Lead	326.0	618.8
Magnesium	775.0	1427.0
Manganese	1900.0	3452 0
Mercury	—39.04	—38.27
Nickel	1500.0	2732.0
Osmium	2500.0	4532.0
Palladium	1600 0	2912.0
Platinum	1775.0	3227.0
Rhodium	2000 0	3632.0
Silver	950.0	1742.0
Sulphur	115.1	241.2
Tin	230.0	446.0
Zinc	415.0	779.0

MELTING POINTS (KENT)—Continued.

ALLOYS.	C.	F.
Bronze	924.4	1692.0
Brass	1037.8	1900.0
Lead 1, tin 1, bismuth 1, cadmium 1	68.3	155.0
Lead 3, tin 5, bismuth 8	97.8	208.0
Lead 1, tin 3, bismuth 5	100.0	212.0
Lead 1, tin 4, bismuth 5	115.5	240.0
Lead 1, bismuth 1	141.1	286.0
Lead 2, tin 3	167.8	334.0
Tin 2, bismuth 1	168.9	336.0
Lead 1, tin 2	182.2	360.0
Tin 1, lead 1	187.8 to 241.1	370.0 to 466.0
Tin 8, bismuth 1	200.1	392.0
Lead 2, tin 1	235.0	475.0

OTHER SUBSTANCES.	C.	F.
Sulphurous acid	— 94.4	— 148.0
Carbonic acid	— 77.8	— 108.0
Bromine	— 12.6	+ 9.5
Turpentine	— 10.0	14.0
Ice	0.0	32.0
Nitroglycerin	+ 7.2	45 0
Tallow	33.3	92.0
Acetic acid	45.0	113.0
Stearine	42.8 to 48.9	109 to 120
Spermaceti	48.9	120.0
Wax	61.1 to 67.8	142 to 154
Stearic acid	70.0	158.0
Potassium sulphate	1015.0	1859.0

BOILING POINTS AT ATMOSPHERIC PRESSURE (KENT).

14.7 lbs. per square inch.

	C.	F.		C.	F.
Ether sulphuric	37.8	100.0	Average sea water	100.7	213.2
Carbon bisulphide	47.8	118.0	Saturated brine	107.9	226.0
Ammonia	60.0	140.0	Nitric acid	120.0	248.0
Chloroform	60.0	140.0	Oil of turpentine	157.2	315.0
Bromine	62.8	145.0	Phosphorus	290.0	554.0
Wood spirit	65.6	150.0	Sulphur	298.9	570.0
Alcohol	78.3	173.0	Sulphuric acid	310.0	590.0
Benzine	80.0	176.0	Linseed oil	313.9	597.0
Water	100.0	212.0	Mercury	357.8	676.0

The boiling points of liquids increase as the pressure increases and decrease as the pressure decreases. The boiling point of water at any given pressure is the same as the temperature of saturated steam of the same pressure.

PROPORTIONS OF VARIOUS COMPOSITIONS IN COMMON USE.

(In one hundred parts.)

Babbit's metal . . . . Tin 89, copper 3.7, antimony 7.3.
Fine yellow brass . . . . . . Copper 66, zinc 34.
Gun metal, valves, etc. . . . . Copper 90, tin 10.
White brass . . . . Copper 10, zinc 80, tin 10.
German silver . . . . Copper 33.3, zinc 33.4, nickel 33.3.
Church bells . . . . Copper 80, zinc 5.6, tin 10.1, lead 4.3.
Gongs . . . . Copper 81.6, tin 18.4.
Lathe bushes . . . . Copper 80, tin 20.
Machinery bearings . . . . . Copper 87.5, tin 12.5.
Muntz metal . . . . Copper 60, zinc 40.
Sheathing metal . . . . Copper 56, zinc 44.

SHORT METHOD FOR CALCULATING INTEREST.

Multiply the principal by as many hundredths as there are days, and

For 4 per cent . . . . Divide by 90
For 5 per cent . . . . Divide by 72
For 6 per cent . . . . Divide by 60
For 7 per cent . . . . Divide by 52
For 8 per cent . . . . Divide by 45
For 9 per cent . . . . Divide by 40
For 10 per cent . . . . Divide by 36
For 12 per cent . . . . Divide by 30

EXAMPLE.—Interest on $50 for 30 days at 4 per cent. $50 \times .30 = 15.00$, which divided by 90 = 16⅔ cents—the required result.

INTEREST TABLE.

FOUR PER CENT.

TIME.	$1	$2	$3	$4	$5	$6	$7	$8	$9	$10	$100	$1000
1 day . .	0	0	0	0	0	0	0	0	0	0	1	11
3 days . .	0	0	0	0	0	0	0	0	0	½	3½	33
5 days . .	0	0	0	0	0	0	0	½	½	½	5½	56
10 days . .	0	0	0	½	½	½	1	1	1	1	11	1.11
1 month .	0	½	1	1½	1½	2	2½	2½	3	3½	33	3.33
2 months	½	1½	2	2½	3½	4	4½	5½	6	6½	67	6.67
3 months	1	2	3	4	5	6	7	8	9	10	1.00	10.00
4 months	1½	2½	4	5½	6½	8	9½	10½	12	13½	1.33	13.33
6 months	2	4	6	8	10	12	14	16	18	20	2.00	20.00
9 months	3	6	9	12	15	18	21	24	27	30	3.00	30.00
1 year . .	4	8	12	16	20	24	28	32	36	40	4.00	40.00

FIVE PER CENT.

TIME.	$1	$2	$3	$4	$5	$6	$7	$8	$9	$10	$100	$1000
1 day . .	0	0	0	0	0	0	0	0	0	0	1	14
3 days . .	0	0	0	0	0	0	0	0	0	0	4	42
5 days . .	0	0	0	0	0	0	0	1	1	1	7	69
10 days . .	0	0	0	0	1	1	1	1	1	1½	14	1.39
1 month .	½	1	1	2	2	3	3	3	4	4	42	4.17
2 months	1	1½	3	3	4	5	6	7	8	8	83	8.33
3 months	1	2½	4	5	6	8	9	10	11	13	1.25	12.50
4 months	1½	3	5	7	8	10	12	13	15	17	1.67	16.67
6 months	2½	5	8	10	13	15	18	20	23	25	2.50	25.00
9 months	3¾	7½	11	15	19	23	26	30	34	38	3.75	37.50
1 year .	5	10	15	20	25	30	35	40	45	50	5.00	50.00

SIX PER CENT.

TIME.	$1	$2	$3	$4	$5	$6	$7	$8	$9	$10	$100	$1000
1 day . .	0	0	0	0	0	0	0	0	0	0	2	17
3 days . .	0	0	0	0	0	0	0	0	0	1	5	50
5 days . .	0	0	0	0	0	1	1	1	1	1	8	83
10 days . .	0	0	1	1	1	1	1	1	2	2	17	1.67
1 month .	½	1	2	2	3	3	4	4	5	5	50	5.00
2 months	1	2	3	4	5	6	7	8	9	10	1.00	10.00
3 months	1½	3	5	6	8	9	11	12	14	15	1.50	15.00
4 months	2	4	6	8	10	12	14	16	18	20	2.00	20.00
6 months	3	6	9	12	15	18	21	24	27	30	3.00	30.00
9 months	4½	9	14	18	23	27	32	36	41	45	4.50	45.00
1 year . .	6	12	18	24	30	36	42	48	54	60	6.00	60.00

ALGEBRAIC SIGNS.

$=$ The sign of equal.
$+$ Addition, as $4 + 8 = 12$.
$\times$ Multiplication, as $4 \times 8 = 32$.
$-$ Subtraction, as $8 - 4 = 4$.
$\div$ Division, as $8 \div 4 = 2$.
$\therefore$ Therefore.
() Parenthesis, $(8 \times 4 \times 3) \div 6 = 16$.
$\surd$ Square root, $\sqrt{9} = 3$.
$\sqrt[3]{}$ Cube root, $\sqrt[3]{27} = 3$.
9^2 Square of, as $9^2 = 81$.
9^3 Cube of, as $9^3 = 729$.
7.5 Decimal point, $7.5 = 7\frac{1}{2}$, $.75 = \frac{75}{100} = \frac{3}{4}$.
$\pm$ plus or minus.
$\Leftrightarrow$ is equivalent to.
$>$ greater than.
$<$ less than.

When letters are used they represent the initials of the word, as T for time, V for velocity.

SOUND.

Velocity in	Ft. per second.	Velocity in	Ft. per second.
Air	1,142	Copper	10,378
Water	4,900	Wood	12,000 to 16,000
Iron	17,500		

Distance sounds may be heard on a still day—

Human voice	150 yds.	Military band	5,200 yds.
Rifle	5,300 yds.	Cannon	35,000 yds.

TO MEASURE DISTANCES BY SOUND.

RULE.—Multiply the time the sound takes in seconds by 1142; the product will be the distance in feet.

NOTE.—Sound in common air moves uniformly at the rate of about 1142 feet in a second. Cold and uneven surfaces retard its motion a little, and heat accelerates it in a small degree.

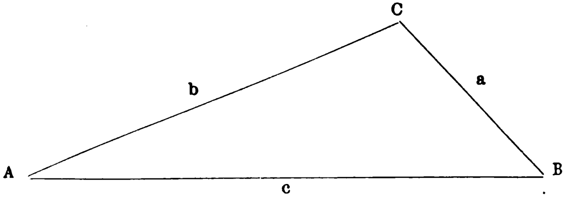
INTERNATIONAL ATOMIC WEIGHTS FOR 1906.

Alumnum	Al	27.1	Copper	Cu	63.6
Antimony	Sb	120.2	Didymium	D	147.0
Argon	A	39.9	Erbium	Er	166.0
Arsenic	As	75.0	Fluorine	F	19.0
Barium	Ba	137.4	Gadolinium	Gd	156.0
Beryllium	Be	9.1	Gallium	Ga	70.0
Bismuth	Bi	208.5	Germanium	Ge	72.5
Boron	B	11.0	Glucinum	Gl	9.1
Bromine	Br	79.96	Gold	Au	197.2
Cadmium	Cd	112.4	Helium	He	4.0
Caesium	Cs	132.9	Hydrogen	H	1.008
Calcium	Ca	40.1	Indium	In	115.0
Carbon	C	12.00	Iodine	I	126.97
Cerium	Ce	140.25	Iridium	Ir	193.0
Chlorine	Cl	35.45	Iron	Fe	55.9
Chromium	Cr	52.1	Krypton	Kr	81.8
Cobalt	Co	59.0	Lanthanum . . .	La	138.9
Columbium	Cb	94.0	Lead	Pb	206.9

INTERNATIONAL ATOMIC WEIGHTS FOR 1906—CONTINUED.

Lithium	Li	7.03
Magnesium	Mg	24.36
Manganese	Mn	55.0
Mercury	Hg	200.0
Molybdenum	Mo	96.0
Neodymium	Nd	143.6
Neon	Ne	20.0
Nickel	Ni	58.7
Niobium	Nb	94.0
Nitrogen	N	14.04
Osmium	Os	191.0
Oxygen	O	16.00
Palladium	Pd	106.5
Phosphorus	P	31.0
Platinum	Pt	194.8
Potassium	K	39.15
Praseodymium	Pr	140.5
Radium	Rd	225.0
Rhodium	Rh	103.0
Rubidium	Rb	85.5
Ruthenium	Ru	101.7
Samarium	Sa	150.3
Scandium	Sc	44.1
Selenium	Se	79.2
Silicon	Si	28.4
Silver	Ag	107.93
Sodium	Na	23.05
Strontium	Sr	87.6
Sulphur	S	32.06
Tantalum	Ta	183.0
Tellurium	Te	127.6
Terbium	Tb	160.0
Thallium	Tl	204.1
Thorium	Th	232.5
Thulium	Tm	171.0
Tin	Sn	119.0
Titanium	Ti	48.1
Tungsten	W	184.0
Uranium	U	238.5
Vanadium	V	51.2
Xenon	Xe	128.0
Ytterbium	Yb	173.0
Yttrium	Yt	89.0
Zinc	Zn	65.4
Zirconium	Zr	90.6

FORMULÆ FOR THE SOLUTION OF TRIANGLES.



A, B, C = angles opposite sides designated by corresponding small letters.
a, b, c = sides opposite angles designated by corresponding capital letters.
S = ½ sum of sides.
K = area.

Given a side and any two angles or two sides and an angle opposite one of them. A, B and c or A, b and a.

$$\frac{a}{b} = \frac{\sin A}{\sin B}$$

Given two sides and their included angle, a, c, B,

$$\frac{a + c}{a - c} = \frac{\tan \frac{1}{2}(A + C)}{\tan \frac{1}{2}(A - C)}$$

Given three sides, a, b and c,

$$\tan \tfrac{1}{2} A = \sqrt{\frac{(s - b)\ (s - c)}{s\,(s - a)}}$$

To find area,

$$2\,K = \frac{a^2 \sin B \sin C}{\sin A}$$

$$K = \tfrac{1}{2}\ \text{base} \times \text{altitude}$$

$$K = \frac{a\,b \sin C}{2}$$

$$K = \sqrt{\frac{a + b + c}{2} \times \left(\frac{a + b + c}{2} - a\right) \times \left(\frac{a + b + c}{2} - b\right) \left(\frac{a + b + c}{2} - c\right)}$$

NATURAL TRIGONOMETRICAL FUNCTIONS.

°	′	Sine.	Tangent.	Cotangent.	Cosine.	°	′
0	0	.00000	.00000	Infinite.	1.00000	90	0
0	15	.00436	.00436	229.1816	.99999	89	45
0	30	.00873	.00873	114.5886	.99996	89	30
0	45	.01309	.01309	76.3900	.99991	89	15
1	0	.01745	.01746	57.28996	.99985	89	0
1	15	.02181	.02182	45.82935	.99976	88	45
1	30	.02618	.02619	38.18845	.99966	88	30
1	45	.03054	.03055	32.73026	.99953	88	15
2	0	.03490	.03492	28.63625	.99939	88	0
2	15	.03926	.03929	25.45170	.99923	87	45
2	30	.04362	.04366	22.90376	.99905	87	30
2	45	.04798	.04803	20.81882	.99885	87	15
3	0	.05234	.05241	19.08113	.99863	87	0
3	15	.05669	.05678	17.61055	.99839	86	45
3	30	.06105	.06116	16.34985	.99813	86	30
3	45	.06540	.06554	15.25705	.99786	86	15
4	0	.06976	.06993	14.30066	.99756	86	0
4	15	.07411	.07431	13.45662	.99725	85	45
4	30	.07846	.07870	12.70620	.99692	85	30
4	45	.08281	.08309	12.03462	.99657	85	15
5	0	.08716	.08749	11.43005	.99619	85	0
5	15	.09150	.09189	10.88292	.99580	84	45
5	30	.09585	.09629	10.38539	.99540	84	30
5	45	.10019	.10069	9.93101	.99497	84	15
6	0	.10453	.10510	9.51436	.99452	84	0
6	15	.10887	.10952	9.13093	.99406	83	45
6	30	.11320	.11394	8.77689	.99357	83	30
6	45	.11754	.11836	8.44896	.99307	83	15
7	0	.12187	.12278	8.14435	.99255	83	0
7	15	.12620	.12722	7.86064	.99200	82	45
7	30	.13053	.13165	7.59575	.99144	82	30
7	45	.13485	.13609	7.34786	.99087	82	15
8	0	.13917	.14054	7.11537	.99027	82	0
8	15	.14349	.14499	6.89688	.98965	81	45
8	30	.14781	.14945	6.69116	.98902	81	30
8	45	.15212	.15391	6.49710	.98836	81	15
9	0	.15643	.15838	6.31375	.98769	81	0
9	15	.16074	.16286	6.14023	.98700	80	45
9	30	.16505	.16734	5.97576	.98629	80	30
9	45	.16935	.17183	5.81966	.98556	80	15
10	0	.17365	.17633	5.67128	.98481	80	0
10	15	.17794	.18083	5.53007	.98404	79	45
10	30	.18224	.18534	5.39552	.98325	79	30
10	45	.18652	.18986	5.26715	.98245	79	15
11	0	.19081	.19438	5.14455	.98163	79	0
11	15	.19509	.19891	5.02734	.98079	78	45
11	30	.19937	.20345	4.91516	.97992	78	30
11	45	.20364	.20800	4.80769	.97905	78	15
12	0	.20791	.21256	4.70463	.97815	78	0
12	15	.21218	.21712	4.60572	.97723	77	45
12	30	.21644	.22169	4.51071	.97630	77	30
12	45	.22070	.22628	4.41936	.97534	77	15
13	0	.22495	.23087	4.33148	.97437	77	0
13	15	.22920	.23547	4.24685	.97338	76	45
13	30	.23345	.24008	4.16530	.97237	76	30
13	45	.23769	.24470	4 08666	.97134	76	15
14	0	.24192	.24933	4.01078	.97030	76	0
14	15	.24615	.25397	3.93751	.96923	75	45
14	30	.25038	.25862	3.86671	.96815	75	30
14	45	.25460	.26328	3.79827	.96705	75	15
15	0	.25882	.26795	3.73205	.96593	75	0
		Cosine.	Cotangent.	Tangent.	Sine.		

NATURAL TRIGONOMETRICAL FUNCTIONS—CONTINUED

°	′	Sine	Tangent	Cotangent	Cosine	°	′
15	0	.25882	.26795	3.73205	.96593	75	0
15	15	.26303	.27263	3.66796	.96479	74	45
15	30	.26724	.27732	3.60588	.96363	74	30
15	45	.27144	.28203	3.54573	.96246	74	15
16	0	.27564	.28675	3.48741	.96126	74	0
16	15	.27983	.29147	3.43084	.96005	73	45
16	30	.28402	.29621	3.37594	.95882	73	30
16	45	.28820	.30097	3.32264	.95757	73	15
17	0	.29237	.30573	3.27085	.95630	73	0
17	15	.29654	.31051	3.22053	.95502	72	45
17	30	.30071	.31530	3.17159	.95372	72	30
17	45	.30486	.32010	3 12400	.95240	72	15
18	0	.30902	.32492	3.07768	.95106	72	0
18	15	.31316	.32975	3.03260	.94970	71	45
18	30	.31730	.33460	2.98869	.94832	71	30
18	45	.32144	.33945	2.94591	.94693	71	15
19	0	.32557	.34433	2.90421	.94552	71	0
19	15	.32969	.34922	2.86356	.94409	70	45
19	30	.33381	.35412	2.82391	.94264	70	30
19	45	.33792	.35904	2.78523	.94118	70	15
20	0	.34202	.36397	2.74748	.93969	70	0
20	15	.34612	.36892	2.71062	.93819	69	45
20	30	.35021	.37388	2.67462	.93667	69	30
20	45	.35429	.37887	2.63945	.93514	69	15
21	0	.35837	.38386	2.60509	.93358	69	0
21	15	.36244	.38888	2.57150	.93201	68	45
21	30	36650	.39391	2.53865	.93042	68	30
21	45	.37056	.39896	2.50652	.92881	68	15
22	0	.37461	.40403	2.47509	.92718	68	0
22	15	.37865	.40911	2.44433	.92554	67	45
22	30	.38268	.41421	2.41421	.92388	67	30
22	45	.38671	.41933	2.38473	.92220	67	15
23	0	.39073	.42447	2.35585	.92050	67	0
23	15	.39474	.42963	2.32756	.91879	66	45
23	30	.39875	.43481	2.29984	.91706	66	30
23	45	.40275	.44001	2.27267	.91531	66	15
24	0	.40674	.44523	2.24604	.91355	66	0
24	15	.41072	.45047	2.21992	.91176	65	45
24	30	.41469	.45573	2.19430	.90996	65	30
24	45	.41866	.46101	2 16917	.90814	65	15
25	0	.42262	.46631	2.14451	.90631	65	0
25	15	.42657	.47163	2.12030	.90446	64	45
25	30	.43051	.47698	2.09654	.90259	64	30
25	45	.43445	.48234	2.07321	.90070	64	15
26	0	.43837	.48773	2.05030	.89879	64	0
26	15	.44229	.49315	2.02780	.89687	63	45
26	30	.44620	.49858	2.00569	.89493	63	30
26	45	.45010	.50404	1.98396	.89298	63	15
27	0	.45399	.50953	1.96261	.89101	63	0
27	15	.45787	.51503	1 94162	.88902	62	45
27	30	.46175	.52057	1.92098	.88701	62	30
27	45	.46561	.52613	1 90069	.88499	62	15
28	0	.46947	.53171	1.88073	.88295	62	0
28	15	.47332	.53732	1 86109	.88089	61	45
28	30	.47716	.54296	1.84177	.87882	61	30
28	45	.48099	.54862	1.82276	.87673	61	15
29	0	.48481	.55431	1.80405	.87462	61	0
29	15	.48862	.56003	1.78563	.87250	60	45
29	30	49242	.56577	1.76749	.87036	60	30
29	45	.49622	.57155	1.74964	.86820	60	15
30	0	.50000	.57735	1.73205	.86603	60	0
		Cosine	Cotangent	Tangent	Sine		

NATURAL TRIGONOMETRICAL FUNCTIONS—CONTINUED.

°	′	Sine.	Tangent.	Cotangent.	Cosine.	°	′
30	0	.50000	.57735	1.73205	.86603	60	0
30	15	.50377	.58318	1.71473	.86384	59	45
30	30	.50754	.58905	1.69766	.86163	59	30
30	45	.51129	.59494	1.68085	.85941	59	15
31	0	.51504	.60086	1.66428	.85717	59	0
31	15	.51877	.60681	1.64795	.85491	58	45
31	30	.52250	.61280	1.63185	.85264	58	30
31	45	.52621	.61882	1.61598	.85035	58	15
32	0	.52992	.62487	1.60033	.84805	58	0
32	15	.53361	.63095	1.58490	.84573	57	45
32	30	.53730	.63707	1.56969	.84339	57	30
32	45	.54097	.64322	1.55467	.84104	57	15
33	0	.54464	.64941	1.53987	.83867	57	0
33	15	.54829	.65563	1.52525	.83629	56	45
33	30	.55194	.66189	1.51084	.83389	56	30
33	45	.55557	.66818	1.49661	.83147	56	15
34	0	.55919	.67451	1.48256	.82904	56	0
34	15	.56280	.68088	1.46870	.82659	55	45
34	30	.56641	.68728	1.45501	.82413	55	30
34	45	.57000	.69372	1.44149	.82165	55	15
35	0	.57358	.70021	1.42815	.81915	55	0
35	15	.57715	.70673	1.41497	.81664	54	45
35	30	.58070	.71329	1.40195	.81412	54	30
35	45	.58425	.71990	1.38909	.81157	54	15
36	0	.58779	.72654	1.37638	.80902	54	0
36	15	.59131	.73323	1.36383	.80644	53	45
36	30	.59482	.73996	1.35142	.80386	53	30
36	45	.59832	.74674	1.33916	.80125	53	15
37	0	.60182	.75355	1.32704	.79864	53	0
37	15	.60529	.76042	1.31507	.79600	52	45
37	30	.60876	.76733	1.30323	.79335	52	30
37	45	.61222	.77428	1.29152	.79069	52	15
38	0	.61566	.78129	1.27994	.78801	52	0
38	15	.61909	.78834	1.26849	.78532	51	45
38	30	.62251	.79544	1.25717	.78261	51	30
38	45	.62592	.80258	1.24597	.77988	51	15
39	0	.62932	.80978	1.23490	.77715	51	0
39	15	.63271	.81703	1.22394	.77439	50	45
39	30	.63608	.82434	1.21310	.77162	50	30
39	45	.63944	.83169	1.20237	.76884	50	15
40	0	.64279	.83910	1.19175	.76604	50	0
40	15	.64612	.84656	1.18125	.76323	49	45
40	30	.64945	.85408	1.17085	.76041	49	30
40	45	.65276	.86166	1.16056	.75757	49	15
41	0	.65606	.86929	1.15037	.75471	49	0
41	15	.65935	.87698	1.14028	.75184	48	45
41	30	.66262	.88473	1.13029	.74896	48	30
41	45	.66588	.89253	1.12041	.74606	48	15
42	0	.66913	.90040	1.11061	.74314	48	0
42	15	.67237	.90834	1.10091	.74022	47	45
42	30	.67559	.91633	1.09131	.73728	47	30
42	45	.67880	.92439	1.08179	.73432	47	15
43	0	.68200	.93252	1.07237	.73135	47	0
43	15	.68518	.94071	1.06303	.72837	46	45
43	30	.68835	.94896	1.05378	.72537	46	30
43	45	.69151	.95729	1.04461	.72236	46	15
44	0	.69466	.96569	1.03553	.71934	46	0
44	15	.69779	.97416	1.02653	.71630	45	45
44	30	.70091	.98270	1.01761	.71325	45	30
44	45	.70401	.99131	1.00876	.71019	45	15
45	0	.70711	1.00000	1.00000	.70711	45	0
		Cosine.	Cotangent.	Tangent.	Sine.		

ROCK DRILLING.

Revised and Condensed from "Trautwine's Pocket-Book."

HAND DRILLS.

Holes for blasting drilled by hand are generally from 2½ to 4 feet deep and from 1½ to 2 inches in diameter.

The drilling of rock by hand is divided naturally into three classes, single hand, double hand and churn drilling, according to the depth of hole to be drilled.

For shallow holes in rock, of not exceeding hardness, where an extra hard blow is not required, single hand drilling is cheapest. In mine work the economical limit of a hole by this method is from 4 to 5 feet. The limit is reached where the drill is nearly double the weight of the hammer used. The standard single hand hammer weighs 4 pounds. The limit can be defined as such a depth of hole that the ratio of the weight of the hammer to the weight of the drill is so small that the greater part of the blow is taken up by the inertia of the drill.

Thus when holes deeper than 4 to 5 feet have to be drilled, the double hand drilling, with the heavier hammers (8 to 12 pounds) and consequent heavier blows, has to be resorted to. In turn, double hand drilling reaches a limit at about 10 to 12 feet, where the greater part of the hammer blows are taken up by the inertia of the drill. With 16-pound hammers down holes can be drilled up to 16 feet by the double hand method.

At this point, where holes of greater depth are needed, churn drills should be used. With these drills their weight is such that the simple dropping of them is sufficient to do all the rock cutting. Experience has shown that in hard rock a perfectly square cutting edge with a small taper and strong corners does the best work.

THE CHURN DRILL is a round bar of iron, usually about 1¼ inches in diameter and 6 to 8 feet long, with a steel cutting edge or bit (weighing about a pound, and a little wider than the diameter of the bar), welded to its lower end. A man lifts it a few inches, or rather catches it as it rebounds, turns it partially around and lets it fall again.

A man can drill from 5 to 15 feet of a hole nearly 2 inches in diameter in a day of 10 hours, progress depending on character of the rock. From 7 to 8 feet of holes, 1¾ inches diameter, is about a fair day's work in hard gneiss, granite or compact silicious limestone; 5 to 7 feet in tough compact hornblende; 3 to 5 feet in solid quartz; 8 to 9 feet in ordinary marble or limestone; 9 to 10 feet in sandstone, which, however, may vary within all these limits. When the hole is more than about 4 feet deep two men are put to the drill. Artesian and oil wells in rock are bored on the principle of the churn drill.

THE JUMPER, as now used, is much shorter than the churn drill. One man (the holder) sitting down, lifts it slightly, and turns it partly round, during the intervals between the blows from about 8 to 12 pound hammers, wielded by two other men (the strikers). It can be used for holes of smaller diameters than can be made by the churn drill, because the holder can more readily keep the cutting edge at the exact spot required to be drilled. It is also better in conglomerate rock, the hard silicious pebbles of which deflect the churn drill from its vertical direction, so that the hole becomes crooked, and the drill becomes bound in it. Either tool requires resharpening at about each 6 to 18 inches depth of hole; and the wear of the steel edge requires a new one to be put on every 2 to 4 days.

With iron jumpers, the top becomes battered away rapidly. As the hole becomes deeper, longer drills are frequently used than at the beginning. *The smaller the diameter of the hole the greater depth can be drilled in a given time;* and the depth will be greater in proportion than the decrease of diameter. Where "DUPONT HIGH EXPLOSIVES" are used in blasting, this decrease in the diameter of holes is a source of great economy, as drilling, not the cost of powder, is the great expense in blasting.

MACHINE DRILLS.

Machine rock drills bore much more rapidly and economically than hand drills. They drill in any direction, and can often be used in boring holes so located that they cannot be bored by hand. They work either by steam or air. The air is best for tunnels and shafts, because, after leaving the drills, it aids ventilation. Machine drills are of two kinds, *ratating drills* and *percussion drills.*

IN ROTATING DRILLS the drill rod is a long tube, revolving about its axis. The end ot this tube, hardened so as to form an annular cutting edge, is kept in contact with the rock, and, by its rotation, cuts in it a cylindrical hole, generally with a solid core in the center. The drill rod is fed forward, or into the hole, as the drilling proceeds. The debris is removed from the hole by a constant stream of water, which is led to the bottom of the hole through the hollow drill rod, and which carries the debris up through the narrow space between the outside of the drill rod and the sides of the hole.

THE DIAMOND DRILL is the only form of rotary drill used extensively in America. In it the boring rod consists of a number of tubes jointed rigidly together at their ends by hollow interior sleeves. The boring is done either by a "*core bit*" or a "*boring head.*" In the "*core bit*" the cutting edge has imbedded in it a number of diamonds. These are so arranged as to project slightly from both its inner and outer edges. Annular spaces are thus left between core and core barrel, and between the latter and the walls of the hole. These spaces permit the ingress and egress of the water used in removing the debris from the hole, and at the same time prevent the core from binding in the barrel, or the latter in the hole. Just above the "core bit" the "*core lifter*" is screwed to the barrel. The core lifter has the same outer diameter as the barrel. Inside it is slightly coned, with base of cone upward. The core lifter by its arrangement, when the core barrel is raised, breaks off the core at the bottom, and it can be brought up; these sections of core are very useful at times, showing the exact character and position of each stratum drilled through.

Where it is not desired to preserve the core intact, the "*boring head*" may be used instead of the "core bit." This is a solid bit (except that it is perforated with holes, which allow the water to pass out from the drill rod), and is armed with diamonds, some of which project beyond its circumference.

Advantages and Uses.—The diamond drill bores perfectly circular holes, in straight lines, and in any direction, to great depths; from 300 to 1500 feet being not uncommon. It brings up unbroken cores, from 8 to 16 feet long, showing precise nature and stratification of the rock penetrated, rendering it very valuable in test borings, prospecting of mines, sinking artesian wells, etc. The roundness of the holes bored enables the use of casing of nearly as great diameter as that of the hole; and their straightness is an advantage in case a pump is to be used.

In soft rock, a bit may drill through 200 feet or more without resetting. In very hard rocks, similar drills will wear out in 10 feet or less.

PERCUSSION MACHINE DRILLS.

This class of machine drills is the one in most universal use in quarries and general construction work. The leading manufacturers are the Rand Drill Co., 23 Park Place, New York, and the Ingersoll Rock Drill Co., 10 Park Place, New York.

In percussion drilling machines, the drill bar is driven forcibly against the rock by the pressure of steam or of compressed air, acting upon a piston, moving in a cylinder, and making about 300 strokes per minute. The rotation of the drill bar is accomplished automatically. The *cylinder* is free to slide longitudinally in a fixed frame or shell, to which it is attached, and which in turn is fixed to a tripod or other stand upon which the machine is supported. The *drill rod*, corresponding to a churn drill, is fastened by a chuck to the end of the piston rod. The drilling is begun with a short drill rod, and with the cylinder as far from the hole as the length of the shell will permit. As the bit penetrates the rock the cylinder is fed forward (toward the hole), either automatically or by hand, as far as the length of the shell permits. The drilling is then stopped by shutting off the steam, and the cylinder is run back, by reversing the motion of the feeding apparatus. The short drill bar is then removed, and, if the drilling is to be continued, a longer one substituted in its place, and the process repeated. As the act of drilling wears the edge of the bit, thus reducing its diameter somewhat, *the hole will of course be tapering*, or of a slightly less diameter at bottom than at top. The second bit must therefore be of slightly less diameter than the first—say from $\frac{1}{16}$ to $\frac{1}{8}$ inch less; the third must be less than the second, and so on. On the other hand, in long holes, the drill bar will seldom be in a perfectly straight line, so that the bit, instead of striking always in the same spot, will describe a circle, and thus enlarge the hole. The closer the drill is set up to the working face the less danger there is of bending the drill shanks and breaking the bits.

The *shell*, in which the cylinder slides, is provided with an arrangement by which it may be clamped either to a *tripod* or to a long *bar* or *column*, along which it may slide. The column, if horizontal, may rest upon two pairs of legs; or it may be braced in any position against the opposite sides of a narrow cut, or against the floor and ceiling of a tunnel heading, etc., in which case one of its ends is provided with a screw, which is run out so as to cause the two ends of the column to press firmly against the opposite rock walls, or rather against wooden blocks which are always placed between each end of the column and the rock. In any case, the supports of the drill are so jointed that it can bore in any direction.

Frequently the drill is *clamped to a short arm*, which in turn is clamped to the column and projects at right angles from it. The arm may be slid lengthwise of the column and may be revolved around it, and thus may be placed in any desired position and there clamped. This gives the drill a greater range of motion, and enables it to bore holes over a greater space than would otherwise be possible without moving the column.

In tunnels, one or more drills may be mounted upon a *drill carriage*, traveling upon a railroad track running longitudinally of the tunnel. Upon this track the carriage is moved up to the work or run back from it when a blast is to be fired. The gauge of the track may be made wide enough to admit of a second track of narrower gauge, running underneath the drill carriage. Upon said narrower track the cars are run which carry away the debris.

"*The pressure used* in the cylinders of percussion drills should never be below from 60 to 70 pounds per square inch." *In an hour one will drill* a hole from 1 to 2 inches in diameter, and from 3 to 10 feet deep, depending on the character of the rock and the size of the machine. *A bit requires sharpening* at about every 2 to 4 feet depth of hole.

One blacksmith and helper can sharpen drills for five or six machines.

The bits are of many different shapes, varying with the nature of the work to be done. For uniform hard rock the bit has two cutting edges, forming a cross with equal arms at right angles to each other. For seamy rock, the arms of the cross are equal, but form two acute and two obtuse angles with each other, as in letter X. For soft rock, the cutting edge sometimes has the shape of the letter Z.

Each drill requires one man to operate it. Two or three men are required for removing the heavier sizes from place to place. One man can attend to a small air compressor and its boiler.

Running Percussion Drills.—In setting tripod, spot a place for each leg. If the surface of the rock is slanting or uneven, point off level where the hole is to be drilled so as to avoid a glancing blow. Put oil in the nozzle of the throttle valve and in the back head through the hole provided. Blow out the hose before connecting to the drill. In starting a new machine with steam, slack back the nuts on the cylinder side rods, so as to leave the heads quite loose. Open the throttle valve and the water will blow out through the heads, and then steam will appear and heat the machine. Work the piston up and down two or three times by hand and it will go off all right. Where open diagonal seams or cavities are encountered, the dropping of a few handfuls of pebbles, to fill the cavity, will prevent the bit from jamming.

ROCK CRUSHING MACHINERY.

In general, coarse crushers can be divided into two classes—the jaw and the spindle or gyratory crushers. The jaw crushers in turn are divided into three classes—those with the jaw pivot at the top, those with the jaw pivot at the bottom and the roll jaw crushers.

The Blake crusher is the standard type of jaw crushers with the jaw pivot at the top. This is the type best adapted for heavy work, as the greatest leverage comes at the point where the greatest force is required, that is, at the feed opening, where the largest pieces of material are crushed. As this crusher has its greatest movement at the point of discharge, the product is very unevenly sized, but the free discharge of this type of crusher makes it most suitable for use where wet, clayey ores are encountered.

The Dodge crusher is the standard type of jaw crusher where the pivot is placed at the bottom. This style of crusher is not suitable for heavy work, but it gives a very evenly sized product on account of the smallest amount of motion being at the point of discharge. The discharge of this crusher not being as free as that of the Blake makes it unsuitable for wet, clayey ores, but it does good work as a secondary crusher to reduce the material from Blake crushers to a smaller and more even size.

The Sturtevant crusher is a standard type of the roll jaw crusher. In this type of crusher the material is subjected to a rubbing as well as a squeezing action. This crusher delivers the most evenly sized product of any of the different types of crushers. For coarse work this crusher has a very free discharge. The smaller sizes have met with wonderful success in laboratory work. The Sturtevant 2 inch by 3 inch will crush material easily through a 60 mesh screen.

The two standard spindle or gyratory crushers in use today are the Gates and McCully. These crushers have their smallest motion and greatest leverage at the feed opening, which is the point where the greatest force is required. They have a large capacity and do good and rapid work. The large feed opening and crushing surfaces make this type of crusher a wonderfully efficient machine. This type of crusher is best adapted for crushing rock for railroad ballast, macadam, etc., because the pieces delivered by the crusher are all practically cubical in shape. There are no flat pieces or flakes that are commonly found in the product of jaw crushers. The fact that the shoe is conical and the die annular overcomes in a large measure difficulty of having the greatest motion at the point of discharge and gives a fairly even sized product. This style of crusher has a large discharge opening. Very wet, clayey and talcose ores cannot be treated in this crusher, as they pack against the die and often completely choke the crusher. The absence of fly wheels on the gyratory crushers, such as are absolutely necessary with the jaw crushers, entirely avoids the heavy vibrations of the building caused by the use of jaw crushers. For small capacities the spindle crusher is more expensive than the jaw type. Both the Gates and McCully have a part designed to break in case of undue strain. Thus, if a hammer head falls into the hopper the machine will not be wrecked.

TABLE OF BLAKE CRUSHERS.

(*Coal and Metal Miners' Pocket-Book.*)

Size of receiving capacity.	Approximate product per hours, cubic yards to two inches.	Weight of heaviest piece.	Total weight.	Extreme dimensions.						Proper speed.	Horse power required.
				Length.		Breadth		Height.			
Inches.		Lbs.	Lbs.	Ft.	In.	Ft.	In.	Ft.	In.		
3 x 1½	Laboratory	40	100	1	1	0	6	0	10	250	½
6 x 2	One	560	1,200	2	10	2	1	2	3	250	4
10 x 4	Three	1,800	4,900	4	0	3	3	3	9	250	6
10 x 7	Five	3,800	8,000	5	1	3	9	4	5	250	8
15 x 9	Eight	7,400	15,500	6	6	5	0	5	11	250	15
15 x 10	Nine	7,800	16,000	6	6	5	5	5	11	250	15
20 x 6	Ten	5,300	11,200	5	3	2	11	4	6	250	15
20 x 10	Ten	8,100	18,300	6	10	5	9	5	11	250	20
12 x 30	Sixteen	14,200	33,000	7	10	8	4	6	4	250	30
15 x 30	Twenty	14,200	35,000	7	10	8	4	6	4	250	30

THE DODGE CRUSHER.

(*Coal and Metal Miners' Pocket-Book.*)

Number	Size of jaw opening.	Diameter of pulleys.	Width of belt used.	Horse power required.	Number of tons per hour, nut size.	Revolutions per minute.	Weight complete.
	Inches.	Inches.	Inches.				
1	4 x 6	20	4	2 to 4	½ to 1	275	1,200
2	7 x 9	24	5	4 to 8	1 to 3	235	4,300
3	8 x 12	30	6	8 to 12	2 to 5	220	5,600
4	10 x 16	36	8	12 to 18	5 to 8	200	12,000

DIMENSIONS, WEIGHTS, CAPACITIES AND REQUIRED POWER OF THE GATES ROTARY CRUSHER. (*Coal and Metal Miners' Pocket-Book.*)

Size.	Dimensions of each receiving opening, about.	Dimensions of three receiving openings combined, about.	Weight of breaker	Capacity per hour, in tons of 2000 lbs., passing $2\frac{1}{2}$ in. ring, according to rock or ore.	Dimensions of driving pulley.		Revolutions of driving pulley.	Space occupied by breaker.			Diameter of hopper.	Size of engine recommended to drive breaker, elevator and screen.	
					Inches.			Inches.				Indicated horse power.	
	Inches.	Inches.	Pounds.		Diam.	Face.		Height from bottom frame to top hopper.	Width of frame.	Length of frame.	Inches.	Limestone.	Granite, ore.
00	2 x 4	2 x 12	500	. . . .	8	$2\frac{5}{8}$	700	24	17	26	13	1	1
0	4 x 10	4 x 30	3,300	2 to 4	16	6	500	50	30	73	28	4	4
1	5 x 12	5 x 36	5,600	4 to 8	20	7	475	55	31	76	$42\frac{1}{4}$	8	8
2	6 x 14	6 x 42	7,800	6 to 12	24	8	450	61	39	90	$46\frac{1}{4}$	12	15
3	7 x 15	7 x 45	13,800	10 to 20	28	10	425	75	48	103	$54\frac{1}{2}$	20	30
4	8 x 18	8 x 54	21,500	15 to 30	32	12	400	91	54	114	$79\frac{3}{4}$	30	40
5	10 x 20	10 x 60	30,000	25 to 40	36	14	375	101	63	123	88	40	50
6	11 x 24	11 x 72	40,500	30 to 60	40	16	350	114	73	139	103	50	60
$7\frac{1}{2}$	14 x 30	14 x 90	65,800	50 to 125	44	18	350	144	84	145	120	80	125
8	18 x 42	18 x 126	89,000	100 to 150	48	20	350	156	90	164	182	125	150

For still finer crushing, rolls and stamps are the most common machines in use. For special kinds of work and on favorable materials, the Chili and Huntington mills are used. For cracking coal, toothed rolls are used to give an even product without an undue amount of fines. In rock crushing, where fines are to be avoided, rolls are the best to use. The larger the diameter the rolls have the larger the material that can be crushed, and there is much less liability of choking.

RADIAL ROLLER MILLS.—The Chili mill is derived from the old arrastra. This can be classed as a radial roller mill. In this type of mill the crushing is performed on a ring or die by a series of heavy rolls pressing upon it by gravity. In some cases the rolls travel around the die and in others the die travels in relation to the rolls.

The peculiarity of the grinding action of the radial rolling mills is that it is not a pure crushing action, but a triturating or grinding action as well, owing to the fact that while different portions of the face of the roll are all traveling at the same speed, the outer portions have to travel over a greater portion of ring than the inner portions, so that there is only one line along which true crushing action occurs. Some manufacturers have made the crushing ring and rollers both with coning faces, the vertices of the cones meeting at a common point. This has resulted in a true crushing action, but for some classes of work the triturating action is to be preferred, as, for instance, in the grinding of silver ores for the patio process of amalgamation, the amalgamating of gold ores, etc.

CENTRIFUGAL ROLLER MILLS.—In centrifugal roller mills the crushing is accomplished between rapidly moving rolls and the inside of a stationary die or ring. The Huntington mill is the principal representative of this class of machinery. This type has given its best results in the crushing of clayey or soft ores and the regrinding of middlings for further concentration.

STAMPS.

Gravity stamps are well suited for material, the valuable portion of which does not have a tendency to slime. The fact that these stamps are very simple in construction, easy to transport and erect, as well as operate, gives them a decided advantage over other forms of crushers.

Modern practice tends towards the use of rather heavy stamps (about 1000 lbs.), quick drop (about 100 per minute) and low discharge (4 to 6 inches). The advantages are that the capacity of the battery is very great and the sliming reduced to a minimum. A special practice, known as the Colorado system, is used in the district around Central City, Col. Here a light stamp is used (600 lbs.), with a slow speed (55 to 60 drops per minute) and a high discharge (16 to 20 inches). Of course, the duty per stamp is much less than when the other method, known as the California system, is used. This method gives the best results in the amalgamation of the gold ores of that district. The two methods can be contrasted by the following statement: The California stamp is a crushing device used for amalgamation and the Colorado stamp is an amalgamating device used for crushing.

The steam stamp is very successful for crushing very hard rock, the valuable contents of which will not slime. This stamp has been most successfully used for crushing the native copper ores that occur in northern Michigan. With very few exceptions this stamp has not proved as successful for amalgamation as the gravity stamp, owing to the violence of its action.

For pulverization the ball and tube mills have been used with the best results. In this class of machine balls or tubes, as the case may be, are introduced into a large barrel or chamber, where they roll over one another, the ore being crushed between the different balls or tubes, or between them, and the lining of the chamber. Where material approaching 100 mesh and finer in size is required, these machines have been found the most economical for the final crushing.

For a complete discussion of crushing, see "Ore Dressing," by Robert H. Richards, and "The Stamp Milling of Gold Ores," by T. A. Richards. Published by the Engineering Mining Journal Company New York.

CRUSHING ROLLS.

(*Coal and Metal Miners' Pocket-Book.*)

Name.	Size, inches.	Peripheral speed in feet per minute.	Spring pressure in lb. per inch of face width.	Character of rolls.
Frazer & Chalmers . .	24 x 8 36 x 16	600–1500	4000 for hard quartz	Cornish.
Frazer & Chalmers . .	44 x 5 56 x 8	2200–2300		Narrow face, high speed.
Earle C. Bacon		1000		Cornish.
Sturtevant Mill Co. . .	16 x 3 27 x 5	3000		Special centrifugal.
E. P. Allis & Co.	20 x 12 26 x 14 30 x 14 36 x 14	800		Cornish.
E. P. Allis & Co.		1885		Narrow face, high speed.
Colorado Iron Works .	20 x 12 27 x 14 36 x 16 40 x 16	600	4000 for hard rock 4800 for very hard rock	Cornish.
Colorado Iron Works .	36 x 6 42 x 6 54 x 8	2100–2800		Narrow face, high speed.
Denver Engineering Works Co.	20 x 12 to 36 x 16	350–100	3500–4500	Cornish.
Gates Iron Works . . .	9 x 4 26 x 15 36 x 15	470–850	2266–3333	Cornish.

EARTHWORK, ETC.

EARTHWORK—ANGLES OF SLOPES.

Slopes ½ to 1	=63° 30′	Slopes 1¾ to 1	=29° 44′
Slopes ¾ to 1	=53° 00′	Slopes 2 to 1	=26° 35′
Slopes 1 to 1	=45° 00′	Slopes 3 to 1	=18° 25′
Slopes 1¼ to 1	=38° 40′	Slopes 4 to 1	=14° 12′
Slopes 1½ to 1	=33° 42′		

NATURAL SLOPES OF EARTHS WITH HORIZONTAL LINE.

Gravel	average 40°	Shingle	average 39°
Dry sand	average 38°	Rubble	average 45°
Sand	average 22°	Clay, well drained	average 45°
Vegetable earth	average 28°	Clay, wet	average 16°
Compact earth	average 50°		

WEIGHT OF EARTHS, ROCKS, ETC.

Weight of cubic yard of sand	about 30 cwt.
Weight of cubic yard of gravel	about 30 cwt.
Weight of cubic yard of mud	about 25 cwt.
Weight of cubic yard of marl	about 26 cwt.
Weight of cubic yard of clay	about 31 cwt.
Weight of cubic yard of chalk	about 36 cwt.
Weight of cubic yard of sandstone	about 39 cwt.
Weight of cubic yard of shale	about 40 cwt.
Weight of cubic yard of quartz	about 41 cwt.
Weight of cubic yard of granite	about 42 cwt.
Weight of cubic yard of trap	about 42 cwt.
Weight of cubic yard of slate	about 43 cwt.

QUANTITY OF EARTHS EQUAL TO A TON.

Sand, river, as filled into carts	21 cubic feet.
Sand, pit, as filled into carts	22 cubic feet.
Gravel, coarse, as filled into carts	23 cubic feet.
Marl, as filled into carts	28 cubic feet.
Clay, stiff, as filled into carts	28 cubic feet.
Chalk in lumps, as filled into carts	29 cubic feet.
Earth, mould, as filled into carts	33 cubic feet.

Earth and clay increase in bulk ¼ when dug, but subside ⅛ in height and decrease ⅛ in bulk when formed into embankments.

Sand and gravel increase in bulk $\frac{1}{12}$ when dug; sand subsides in embankment ¼ in height; gravel from $\frac{1}{10}$ to $\frac{1}{12}$, according to coarseness.

Rock increases ½ of its original bulk when excavated.

COST OF LABOR ON EMBANKMENTS.

(*Elwood Morris.*)

SINGLE HORSE AND CART. — Loaded cart in excavation and embankment can go 100 lineal feet and return in one minute, while moving. Time lost in loading, waiting, etc.=4 minutes per load.

A medium laborer will load in a cart, in 10 hours, cubic yards of earth measured in the bank as follows: *Gravelly earth*, 10; *loam*, 13; *sandy earth*, 14.

Carts are loaded from banks: *Descending hauling*, $\frac{1}{3}$ of a cubic yard, in bank; *level hauling*, $\frac{2}{7}$ of a cubic yard, in bank; *ascending hauling*, $\frac{1}{4}$ of a cubic yard, in bank.

LOOSENING.—In Loam.—A 3-horse plow will loosened 250 to 800 cubic yards in 10 hours; cost of same, from 1 to 8 cents per cubic yard, when wages=105 cents per day.

TRIMMING AND BOSSING=2 cents per cubic yard.

SCOOPING.—A scoop load=$\frac{1}{10}$ of a cubic yard, in bank. The time lost in loading, unloading and turning per load=$1\frac{1}{3}$ minutes. Time lost for every 70 feet of distance from excavation to bank and returning=1 minute.

HAULING STONE.—A cart, with horse, over an ordinary road, will travel 1.1 miles per hour. A 4-horse team will haul 25 to 36 cubic feet of limestone per load.

Time of unloading, loading etc., averages 35 minutes per trip; cost of same, with horse crane at quarry and unloading by hand, when labor = $1.25 per day and horse = 75, is 25 cents per perch = 24.75 cubic feet.

The work done by an animal is greatest when the velocity with which he moves is $\frac{1}{8}$ of the greatest velocity he can move when unloaded, and the force then exerted is equal to .45 of the force the animal can exert at a dead pull.

ORDINARY RULE FOR CALCULATING QUANTITIES IN EARTHWORK.

RULE 1, END AREAS.—Take the two side cuttings as marked on slope stakes, add them together, divide by 2, and multiply by one-half the roadbed. This gives *first product*. Take the two distances out from the center line to the two slope stakes, add them together, divide by 2 and multiply by the center cutting as marked on the center stake. This gives *second product*.

Add first and second products together and you get the *end area* in *square feet*.

RULE 2.—To get the quantity in *cubic yards* between *two adjacent end areas*.

Add the two end areas as computed by the above rule, divide this product by 2 and you get *average area* in *square feet*.

Multiply average area by the distance (in feet) between the two end areas and divide product by 27 and the final result thus obtained is the required volume in *cubic yards*.

This rule applies to *fills* as well as *cuts* and to *any roadway or slope*. Take all measurements in feet and tenths of feet (not inches).

EXAMPLE.—Roadbed = 18 feet. Side slopes 1 to 1. Center cutting 6.2 feet. Left cutting 7.0 feet. Right cutting 10.0 feet.

Then to get the distance that the left slope stake is from the center line, we have one-half the roadbed plus the projection of the slope, in the present case 9 feet (one-half the roadbed) + 7 feet (projection of slope) = 16 feet out from center line. For the distance out of right slope stake from center line we have 9 + 10 = 19 feet out from center line. In general practice these distances out are marked on the slope stakes or they can be measured in the field.

By Rule 1.—7 + 10 = 17, 17 ÷ 2 = 8.5.

8.5 × 9 = 76.5 (first product).

16 + 19 = 35, 35 ÷ 2 = 17.5, 17.5 × 6.2 = 108.5 (second product).

76.5 + 108.5 = 185.0 = *end area.*

Now to further illustrate: Take first end area = 185 square feet as gotten above, and take the next end area = 200 square feet, and take the distance between these end areas as 100 feet (usual distance between stations on railroad work).

Now by Rule 2:

185 + 200 = 385, 385 ÷ 2 = 192.5 (average area).

192.5 × 100 = 19,250, 19,250 ÷ 27 = 712.96 *cubic yards.*

The prismoidal formula is sometimes used.

By this rule to get volume: Take first end area, plus four times the *mean* (not average) area plus second end area, divide product by 6; then multiply by the distance between the first and second end areas and divide by 27. In *perfectly level* earthwork or in *masonry* work this rule gives more precise results than the regular rule first given. But owing to irregularities of surface, etc., in average railroad or canal work it is extremely doubtful whether the results are more accurate than the above; in fact, the writer is inclined to think that the rule of *average areas* is the more accurate on general public works.

CEMENT, LIME MORTAR, CONCRETE AND PLASTER.

CEMENT MORTAR.

A barrel of American Hydraulic Cement weighs on an average 300 pounds net, and contains 3.6 cubic feet. Trautwine gives the following: "A barrel of cement, 300 pounds, and 2 barrels of sand mixed with about half a barrel of water will make 8 cubic feet of mortar, sufficient for

192 square feet of mortar joint ½ inch thick = 21⅓ square yards,
288 square feet of mortar joint ⅜ inch thick = 32 square yards,
384 square feet of mortar joint ¼ inch thick = 42⅔ square yards,
768 square feet of mortar joint ⅛ inch thick = 85⅓ square yards,

or to lay one cubic yard, or 522 bricks 8¼ by 4 by 2 inches with joints ⅜ inch thick; or a cubic yard of roughly scabbled rubble stone work. The quantity of sand may be increased, however, to 3 or 4 measures for ordinary work."

In all mortar use clean sharp sand, *the finer the sand the less the strength.*

The finer cements are ground the better. As a general rule cements set and harden better in water than in air, especially in warm weather. Cement takes anywhere from three minutes to eight hours to set, according to grade and quality; slow setting is not a sign of inferiority. "*Setting*" does not imply any great hardening, but merely that the mortar has changed its plastic condition to one of brittleness.

LIME MORTAR.

(*Trautwine.*)

One measure of quicklime to five of sand, when properly mixed with clean water, equal a quantity of mortar about one-eighth in excess of the dry loose sand alone, used in the mortar.

Quantity required, 20 cubic feet or 16 struck bushels of sand, and 4 cubic feet or 3.2 struck bushels of quicklime, the measures slightly shaken in both cases, will make about 22½ cubic feet of mortar; sufficient to lay 1000 bricks of the ordinary average size of 8¼ by 4 by 2 inches with the coarse mortar joints usual in interior house walls, varying, say, from ⅜ to ½ inch. With such joints 1000 such bricks make 2 cubic yards of massive work.

For face walls, finer work and whiter joints, mix in proportions 1 to 4 or 1 to 3.

Lime is usually sold in lump by the barrel, of about 230 pounds net, or 250 pounds gross.

A heaped bushel of lump lime averages about 75 pounds. Ground quicklime, loose, averages about 70 pounds per struck bushel, and 3 bushels loose just fill a common flour barrel.

Brickdust or burnt clay improves common mortar and makes it hydraulic.

In localities where sand cannot be obtained, burnt clay, ground, may be substituted with good results.

The average weight of common hardened mortar is about 105 to 115 pounds per cubic foot.

CONCRETE.

A strong concrete can be made in following proportions (by measure):

1. Cement (any standard American brand).
2. Sand.
4. Broken stone (of size to pass through a 3-inch ring).

Directions for mixing.—Mix sand and cement thoroughly dry, then barely wet, making a stiff mortar. Wet the broken stone before putting it in the mortar, a bucket or two of water to a barrel of stone; do not get the stone "dripping" wet. Mix broken stone into the mortar, and turn at least *three* times thoroughly over with shovel and hoe.

Lay concrete in six-inch layers, and ram each layer until water appears on top surface.

Concrete cannot be rammed under water, but should be raked level on top.

To deposit concrete under water, a V-shaped box is used, which may be made large enough to hold a cubic yard if necessary, although a smaller box is more easily handled. One side is made movable and swings out discharging load when the box is lowered to the bottom of the water, and a trigger is released by a string attached for the purpose. This box can be handled with a derrick. In depositing concrete under water, the area to be covered by concrete must be surrounded by a cofferdam, or some similar contrivance, to keep concrete from spreading. This surrounding fence or barrier must be firmly strengthened on the outside to prevent bulging as concrete is being laid.

The concrete *sub-foundation* in masonry structures should extend 2 to 5 feet beyond regular foundation on all sides, thus distributing load over a greater area and increasing stability of the structure.

Bags filled with concrete may be used to advantage under water in some cases.

Concrete is very useful for leveling irregular foundations, and for foundations on a soft bottom, as the entire mass, when set, acts as a monolith. The proportion of stone to cement is sometimes made 6 to 1, and gravel is also sometimes added to concrete to fill in interstices between stones. Slow-setting cements are best for concrete. Weight of good concrete, 130 to 160 pounds per cubic foot, dry.

We add some few extracts from "LIMES, HYDRAULIC CEMENTS AND MORTARS," by Gen. Q. A. Gillmore, our most reliable authority.

Mortar used at Forts Richmond and Tomkins, N. Y. H., for masonry and concrete:

1 cask cement (308 pounds, net) = 3.70 to 3.75 cubic feet stiff paste.

3 casks loose sand = 12 cubic feet, which gave 11.75 cubic feet mortar (rather thin).

At Fort Warren, Mass.:

MORTAR FOR STONE MASONRY.

1 cask cement (325 pounds, net) = 3.85 cubic feet paste.
½ cask lime = 4 cubic feet.
14.67 cubic feet sand, which gave 18½ cubic feet of mortar.

MORTAR FOR BRICK MASONRY.

1 cask cement.
½ cask lime.
12 cubic feet sand, which gave 16 cubic feet of mortar.

Most American cements will sustain, without any great loss of strength, a dose of lime paste equal to that of the cement paste, while a dose equal to ½ to ¾ the volume of cement paste may be safely added to any energetic Rosendale cement.

The advantages gained by addition of lime to cement mortar are slowness in setting and cheapness.

POINTING MORTAR.

1 cement.
2½ to 2¾ sand, by measure.

Mix the mortar very stiff and not over two or three pints at a time. Clean out and enlarge joint if necessary. Before pointing, wall should be thoroughly saturated with water and kept in such a condition that it will neither take nor give water. Walls should not be allowed to dry too soon after pointing, but kept moist for several days. Caulk well into joint with caulking iron; when joint is full it should be rubbed and polished.

TABLE

Showing Volume of Mortar per Cubic Yard Required.

Kind of masonry.	Volume of mortar in cubic feet.	Quantity of lime required if no cement is used, in barrels.	Quantity of cement required if no lime is used, in barrels.
Rough masonry in rubble stone, from ⅛ to $\frac{1}{10}$ cubic feet in volume	10.8	.565	1.22
Ordinary masonry in blocks, large and small not in courses, joints rough hammer dressed	8.1	.423	.92
Masonry in large masses, headers and stretchers dovetailed, as ordinarily used for facing sea walls, good hammer dressed beds and joints kept full	1.0	.05	.11
Ordinary masonry in courses of 20 in. to 30 in. rise	1.5	.08	.17
Ordinary masonry in courses of 12 in. to 20 in. rise	2.0	.105	.22
Brick masonry	8.0	.42	.90
Concrete (the volume of voids in coarse fragments being about .30)			
Of good quality	11.0	.54	1.75
Of medium quality	9.0	.41	1.06
Of inferior quality	8.0	.37	.97

MEMORANDA FOR PLASTERERS.

(*Kidder.*)

One hundred yards of plastering will require fourteen hundred laths, four bushels and a half of lime, four-fifths of a cubic yard of sand, nine pounds of hair, and five pounds of nails for two-coat work.

Three men and one helper will put on four hundred and fifty yards in a day's work of two-coat work, and will put on a hard finish for three hundred yards.

A load of mortar measures one cubic yard, requires one cubic yard of sand and nine bushels of lime, and will fill thirty hods. A bushel of hair weighs, when dry, about fifteen pounds.

John Roebling's Sons Co., of Trenton, N. J., manufacture a wire lathing for which following advantages are claimed:

(*a.*) The cost of insurance lowered.

(*b.*) The liability of destruction by fire lessened.

(*c.*) The beauty of a ceiling free from unsightly cracks.

LATHS.—A plain lath is 1¼ inches wide by ¼ inch thick.

100 laths 5 feet long equal 1 bundle.

1 bundle of laths }
500 3-penny nails } will cover 5 superficial yards.

MASONRY.

FOUNDATIONS.

Kidder gives the following as permissible loads upon various kinds of foundation beds, per square foot:

Rock foundations 4,000 to 40,000 lbs., average 20,000 pounds.
Coarse gravel and sand . . . . 2,500 to 3,500 pounds.
Clay . . . . 4,000 pounds.
Concrete . . . . 8,000 pounds.
Piles in artificial soil, for each pile . . . . . . 4,000 pounds.
Piles in firm soil, for each pile . . . 30,000 to 140,000 pounds.

FOOTING COURSES.

Footing courses are the bottom courses in masonry; they are generally built to extend beyond the face of the wall and to cover a greater area than the base of the regular wall.

Footing courses distribute the weight of a structure over a great area, thus diminishing liability of settlement and increasing stability.

Always use the largest stones in the footing courses; they should be laid upon their natural beds and well bonded into the wall so as to avoid the possibility of shearing off that portion of the footing course which projects beyond the face of the wall; also care should be observed to keep all joints in this projecting portion of the footing courses, especially in brickwork, as far as possible back of face of wall.

Stones used in footing courses should be at least eight inches thick and two or three feet on other dimensions.

Footing courses should extend, at the bottom, at least twelve inches beyond the face of the wall.

After carefully looking over the subject, we have come to the conclusion that the following table, taken from "Architects' and Builders' Pocket-Book," Kidder, gives most reliable results on the important subject of "Strength of Masonry," *i. e.*, Ultimate Crushing Load, which we reprint below.

AVERAGE ULTIMATE CRUSHING LOAD IN POUNDS PER SQUARE INCH, FOR STONES, MORTARS AND CEMENTS.

Stones, etc.	Crushing weight in pounds per square inch.
Brick, common (Eastern)	10,000
Brick, best pressed	12,000
Brick (Trautwine)	770 to 4,660
Brickwork, ordinary	300 to 500
Brickwork, good in cement	450 to 1,000
Brickwork, first-class in cement	930
Concrete (1 part lime, 3 parts gravel, 3 weeks old)	620
Lime mortar, common	770
Portland cement, best English:	
Pure, three months old	3,760
Pure, nine months old	5,960

AVERAGE ULTIMATE CRUSHING LOAD IN POUNDS PER SQUARE INCH, FOR STONES, MORTARS AND CEMENTS—CONTINUED.

Stones, etc.	Crushing weight in pounds per square inch.
1 part sand, 1 part cement:	
Three months old	2,480
Nine months old	4,520
Granites, 7,750 to 22,750	12,000
Blue granite, Fox Island, Me.	14,875
Blue granite, Staten Island, N. Y.	22,250
Gray granite, Stony Creek, Conn.	15,750
North River (N. Y.) flagging	13,425
Limestones, 11,000 to 25,000	12,000
Limestones, from Glen Falls, N. Y.	11,475
Lake limestone, Lake Champlain, N. Y.	25,000
White limestone, Marblehead, Ohio	11,225
White limestone, from Joliet, Ill.	12,775
Marbles:	
From East Chester, N. Y.	12,950
Common Italian	11,250
Vermont (Sutherland Falls Co.)	10,750
Vermont, Dorset, Vt.	7,612
Drab, North Bay Quarry, Wis.	20,025
Sandstones	6,000
Brown, Little Falls, N. Y.	9,850
Brown, Middletown, Conn.	6,950
Red, Haverstraw, N. Y.	4,350
Red-brown Seneca freestone, Ohio [Md.(?)]	9,687
Freestone, Dorchester, N. B.	9,150
Longmeadow sandstone, from Springfield, Mass.	8,000 to 14,000

The stones in table are supposed to be *on bed*, and the height to be not more than four times the least side.

Rankine gives "the resistance of *good coursed rubble* masonry to crushing is about four-tenths of that of single blocks of the stone it is built with. The resistance of *common rubble* to crushing is not much greater than that of the mortar which it contains."

Stones generally begin to crack or split under about one-half their ultimate crushing load.

TABLE OF WEIGHTS OF STONES AND ALLIED BUILDING MATERIALS.

Description.	Average weight of a cubic foot in lbs.
Alabaster, falsely so called, but really marbles	168
Alabaster, real; a compact white plaster of Paris	144
Asphaltum	87.3
Basalt	181
Bath stone, oolite	131
Cement, Rosendale, ground loose	56
Cement, Louisville, ground loose	49.6
Cement, Copley, ground loose	53.6

TABLE OF WEIGHTS OF STONES AND ALLIED BUILDING MATERIALS—CONTINUED.

Description.	Average weight of a cubic foot in lbs.
Cement, Portland, ground loose	90
Glass, thick flooring	158
Granite	170
Gneiss, common	168
Gneiss, in loose piles	96
Gypsum, plaster of Paris	141.6
Gypsum, in irregular lumps	82
Gypsum, ground loose	56
Greenstone, trap	187
Greenstone, trap, quarried in loose piles	107
Hornblende, *black*	203
Limestones and marbles, ordinary, about	168
Limestones and marbles, quarried in irregular fragments, 1 cubic yard solid, makes about 1.9 cubic yards perfectly loose, or about $1\frac{3}{4}$ cubic yards piled. In this last case .571 of the pile is solid, and the remaining .429 part of it is voids	96
Lime, quick, of ordinary limestones and marbles	95
Lime, quick, in small irregular lumps, or ground loose	53
Lime, quick, ground, well shaken	64
Lime, quick, thoroughly shaken	75
Masonry, of granite or limestones, well-dressed throughout	165
Masonry, of granite, well scabbled mortar rubble; about $\frac{1}{5}$ the mass will be mortar	154
Masonry, of granite, well scabbled dry rubble	138
Masonry, of granite, roughly scabbled mortar rubble; about $\frac{1}{4}$ to $\frac{1}{3}$ part will be mortar	150
Masonry, of granite, roughly scabbled dry rubble	125
Masonry, of sandstone, about $\frac{1}{8}$ part less than the foregoing.	
Masonry, of brickwork, pressed, fine joints	140
Masonry, of brickwork, medium quality	125
Masonry, of brickwork, coarse, inferior soft brick	100
Mortar, hardened	103
Quartz, common pure	165
Sandstones, fit for building, dry	151
Serpentines, good	162
Shales, red or black	162
Slate	175
Trap, compact	187
Trap, quarried in piles	107
Water, pure rain or distilled, at 62° Fahrenheit	62.36

WORKING STRENGTH OF MASONRY.

The working strength of masonry is generally taken at from *one-sixth* to *one-tenth* of the crushing load for piers, columns, etc., and in the case of arches a factor of safety of twenty is often recommended for computing the resistance of the voussoirs (ringstones) to crushing.

Trautwine states that even first-class pressed brickwork in *cement* should not be exposed to more than thirteen or sixteen tons pressure per square foot, or good hand-moulded brick to more than two-thirds as much.

RULES FOR PROPORTIONING MASONRY.

RETAINING WALLS AND ABUTMENTS.—The only practical rules are gained from experience and practice. The following table by John C. Trautwine, C. E., is a fair average of first-class practice, sand or earth backing:

PROPORTIONS OF RETAINING WALLS.

Total height of earth compared with the height of the wall above ground.	Wall of cut stone in mortar.	Good mortar rubble or brick.	Wall of good dry rubble.
	Thickness at base, in part of the height.		
1	.35	.40	.50
1.1	.42	.47	.57
1.2	.46	.51	.61
1.3	.49	.54	.64
1.4	.51	.56	.66
1.5	.52	.57	.67
1.6	.54	.59	.69
1.7	.55	.60	.70
1.8	.56	.61	.71
2	.58	.63	.73
2.5	.60	.65	.75
3	.62	.67	.77
4	.63	.68	.78
6	.64	.69	.79

In above table, the first case, where height of earth (embankment) equal height of wall, corresponds to the case of an abutment.

In railway abutments, where the wall has to resist a thrust induced by the approaching train, it is well to slightly increase the above to

.40 height for width at base of cut stone in mortar.

.45 height for width at base of good rubble in mortar.

.55 height for width at base of good rubble laid dry.

The above table is for vertical walls, but they may be battered to any extent not exceeding 1½ inches to a foot, or 1 in 8, without sensibly affecting their stability without increasing the base.

The above table answers very well for any ordinary filling material when deposited from cars and carts as in railroad construction.

When fill is composed of a mixture of sand or earth, with a *large proportion of round boulders*, it weighs considerably more than material ordinarily used for backing, and will exert a greater pressure against the wall; the thickness of which should be increased, say about one-eighth to one-sixth part over table when such backing is used. The wall is stronger when courses of masonry are laid with an inclination inward.

All backing should be well consolidated against back of wall, as any movement of backing material, however slight, exerts an enormous overturning force.

When backing material is saturated with water, small holes or drains should be left through wall to allow such water to drain off.

After calculating a vertical wall as per above table, a more stable wall may be gotten by making offsets on the back of wall by increasing the thickness of the wall at the base and decreasing thickness at the top; in this change in design the same area of section of wall should be kept as that gotten by use of table. The change being that instead of a rectangular section we have one with the top of the wall thinner than the base.

In practice it is not well to make a wall of this class less than two feet thick at the top.

Another method of designing a wall is to assume a top thickness, say two feet, and then as you descend keep the thickness a certain proportion of the height of the wall, say .40 for cut stonework (second-class masonry).

When a wall is built, before any pressure is brought against it, care should be taken to fill all the space left between foundation masonry and sides of foundation pit—otherwise the wall acts as one of a height equal to *the distance from top of wall to bottom of foundation pit* instead of *from top of wall to natural surface of the ground*, as designed.

PIERS.—In practice all that is necessary in pier work is to design the top of the pier of a size to receive bridge, and then let the sides have a proper batter, say one-half inch to the foot for cut stonework.

ARCHES.—Depth of ring—Ellet's Rule. Very satisfactory. Depth of ring in feet equal three-eighths of the square root of the span of the arch in feet.

Trautwine's Rule.

$$\text{Depth of key in feet} = \sqrt{\frac{\text{radius} + \text{half span}}{4}} + .2 \text{ foot.}$$

This rule gives depth for *first-class* cut stone arches, whether circular or elliptic.

For *second-class* work this depth may be increased one-eighth part.

For *brick or fair rubble*, increase one-third part.

TABLE.—Depth of keystones (ring) for arches of *first-class* cut stone by above rule (*Trautwine*).

Span. Feet.	Rise, in parts of the span						
	$\frac{1}{2}$	$\frac{1}{3}$	$\frac{1}{4}$	$\frac{1}{5}$	$\frac{1}{6}$	$\frac{1}{8}$	$\frac{1}{10}$
	Key ft.	Key ft.	Key ft.	Key ft.	Key ft.	Key ft.	Key ft.
4	.70	.72	.74	.76	.79	.83	.88
6	.81	.83	.86	.89	.92	.97	1.03
8	.91	.93	.96	1.00	1.03	1.09	1.16
10	.99	1.01	1.04	1.07	1.11	1.18	1.26
15	1.17	1.19	1.22	1.26	1.30	1.40	1.50
20	1.32	1.35	1.38	1.43	1.48	1.59	1.70
25	1.45	1.48	1.53	1.58	1.64	1.76	1.88
30	1.57	1.60	1.65	1.71	1.78	1.91	2.04
35	1.68	1.70	1.76	1.83	1.90	2.04	2.19
40	1.78	1.81	1.88	1.95	2.03	2.18	2.33
50	1.97	2.00	2.08	2.16	2.25	2.41	2.58

RULE.—For thickness of arch abutment at springing line (*Trautwine*).

Thickness of abutment at springing line when the height does not exceed 1½ times the base. $= \frac{\textit{Radius in ft.}}{5} + \frac{\textit{rise in ft.}}{10} + 2 \text{ ft.}$

If of rough rubble, add six inches to insure full thickness in every part. This wall can be built with face plumb, and back with batter 3 inches to one foot.

Flat arches cheaper than semicircular for equal waterway, as waterway can only be calculated as extending to the springing line. And *the abutments, not the sheathing* (ring) takes larger percentage of the masonry.

CENTERS FOR ARCHES.—The question of removing centers is a much mooted one.

Trautwine advises that centers be allowed to remain three or four months after the arch is finished, to *allow mortar to harden* to prevent undue compression and consequent settlement. As this opinion is based on his long professional career and careful observation, the writer with diffidence advances a diametrically opposite theory as the results of his observation, very limited when compared with Mr. Trautwine's. Centers should be slowly slacked, say one-half inch about three days after arch is keyed, so as to *allow settlement before mortar entirely hardens, otherwise unequal settlement will cause cracks.*

After, say a week longer, if the arch ring has settled upon the wooden sheeting over centers, ease another half inch, and a half inch thereafter for each week until settlement stops.

Fifty foot arches have been known to settle three inches without in any way impairing their stability, but great care should be taken to so proportion foundation that very little settlement will occur; it is nearly impossible to avoid some small settlement of masonry in an arch, especially when not built of first-class cut stone.

Build all masonry to last for an unlimited time ; *the best is the cheapest.*

FOUNDATIONS FOR MACHINERY.

All machinery works better and has a much longer life by having suitable and solid foundations. Foundations for machinery are best of stone, brick or concrete.

If these are not at hand, a fair foundation can be built of squared timbers framed together, forming cribs and filled with gravel, clay or sand firmly tamped. Bolt bedplates to the timbers.

In fact, bedplates should be well bolted into *any foundation.*

STRENGTH OF MATERIALS.

WORKING UNIT STRESSES FOR BUILDINGS IN LBS. PER SQ. IN.

(*From the Building Code of the City of New York.*)

Material.	Tension.	Compression.	Shear.	Flexure.
Brick	. . .	300	. . .	50
Brick work:				
In Portland cement	. . .	250	. . .	30
In natural cement	. . .	208	. . .	30
In lime mortar	. . .	111		
Cast iron	3,000	16,000	3,000	3,000T 16,000C
Concrete:				
Portland cement—1, 2, 4	. . .	230	. . .	30
Natural cement—1, 2, 4	. . .	125	. . .	16
Rubble stonework:				
In Portland cement	. . .	140		
In natural cement	. . .	111		
In lime mortar	. . .	70		
Steel:				
Cast	16,000	16,000		
Rolled	16,000	16,000	9,000	16,000
Shop rivets	. . .	. . .	10,000	
Field rivets	. . .	. . .	8,000	
Stone:				
Granite	. . .	1,700	. . .	180
Limestone	. . .	1,500	. . .	150
Marble	. . .	900	. . .	120
Sandstone	. . .	1,000	. . .	100
Slate	. . .	1,000	. . .	400
Timber:				
Hemlock	600	500	275	600
Oak	1,000	900	600	1,000
Spruce	800	800	320	800
White pine	800	800	250	800
Yellow pine	1,200	1,000	500	1,200
Wrought iron	12,000	12,000	6,000	12,000
Shop rivets	. . .	. . .	7,500	
Field rivets	. . .	. . .	6,000	

FOUNDATIONS.

SUSTAINING POWER OF VARIOUS SOILS.

(*From the Building Code of New York City.*)

	Tons per sq. ft.
Soft clay	1
Ordinary clay and sand together in layers, wet and springy	2
Loam, clay or fine sand, firm and dry	3
Very fine coarse sand, stiff gravel or hard clay	4

Solid rock will sustain load which can be put upon it.

BRICKS.

Brickwork is generally measured by the thousand bricks laid in wall, and sometimes by the cubic feet.

In measuring brickwork it is customary to deduct large openings, such as spaces for doors, windows and arches, but not for small openings, such as flues, etc., as the extra work necessary to finish these openings takes as much time as it would to build a solid wall.

In engineering works of magnitude brickwork is measured by the cubic yard, solid measurement.

There are different methods of computing measurement of bricks in a given wall. One is to find the number of bricks in a cubic foot of finished work and multiply this by the number of cubic feet in the given work. This is a very good method, but the more common method among masons is to compute the superficial area of wall and multiply by the number of bricks in a square foot for walls of a given thickness.

In the Middle and Western States, with average mortar joints, the following gives number of bricks per square foot for different thicknesses of wall:

4½-inch wall or ½ brick in thickness, 7 bricks per superficial foot.

9-inch wall or 1 brick in thickness, 14 bricks per superficial foot..

13-inch wall or 1½ bricks in thickness, 21 bricks per superficial foot.

18-inch wall or 2 bricks in thickness, 28 bricks per superficial foot.

22-inch wall or 2½ bricks in thickness, 35 bricks per superficial foot.

In Eastern States bricks are smaller, therefore:

4-inch wall or ½ brick in thickness, 7½ bricks per superficial foot.

8-inch wall or 1 brick in thickness, 15 bricks per superficial foot.

12-inch wall or 1½ bricks in thickness, 22½ bricks per superficial foot.

16-inch wall or 2 bricks in thickness, 30 bricks per superficial foot.

20-inch wall or 2½ bricks in thickness, 37½ bricks per superficial foot.

24-inch wall or 3 bricks in thickness, 45 bricks per superficial foot.

HOW TO FIND NUMBER OF BRICKS IN A WALL.

(*Kidder.*)

Applicable to Eastern States; for Western States, reduce by one-fifteenth.

Superficial feet of wall.	Number of bricks to thickness of 4 in.	8 in.	12 in.	16 in.	20 in.	24 in.
1	8	15	23	30	38	45
2	15	30	45	60	75	90
3	23	45	68	90	113	135
4	30	60	90	120	150	180
5	38	75	113	150	188	225
6	45	90	135	180	225	270
7	53	105	158	210	263	315
8	60	120	180	240	300	360
9	68	135	203	270	338	405
10	75	150	225	300	375	450
20	150	300	450	600	750	900
30	225	450	675	900	1,125	1,350
40	300	600	900	1,200	1,500	1,800
50	375	750	1,125	1,500	1,875	2,250
60	450	900	1,350	1,800	2,250	2,700
70	525	1,050	1,575	2,100	2,625	3,150
80	600	1,200	1,800	2,400	3,000	3,600
90	675	1,350	2,025	2,700	3,375	4,050
100	750	1,500	2,250	3,000	3,750	4,500
200	1,500	3,000	4,500	6,000	7,500	9,000
300	2,250	4,500	6,750	9,000	11,250	13,500
400	3,000	6,000	9,000	12,000	15,000	18,000
500	3,750	7,500	11,250	15,000	18,750	22,500
600	4,500	9,000	13,500	18,000	22,500	27,000
700	5,250	10,500	15,750	21,000	26,250	31,500
800	6,000	12,000	18,000	24,000	30,000	36,000
900	6,750	13,500	20,250	27,000	33,750	40,500
1,000	7,500	15,000	22,500	30,000	37,500	45,000
2,000	15,000	30,000	45,000	60,000	75,000	90,000
3,000	22,500	45,000	67,500	90,000	112,500	135,000
4,000	30,000	60,000	90,000	120,000	150,000	180,000
5,000	37,500	75,000	112,500	150,000	187,500	225,000
6,000	45,000	90,000	135,000	180,000	225,000	270,000
7,000	52,500	105,000	157,500	210,000	262,500	315,000
8,000	60,000	120,000	180,000	240,000	300,000	360,000
9,000	67,500	135,000	202,500	270,000	337,500	405,000
10,000	75,000	150,000	225,000	300,000	375,000	450,000

APPLICATION OF TABLE.—How many bricks will there be in 9846 superficial feet of wall 16 inches thick?

ANSWER.—In 9,000 square feet there are 270,000 bricks.
In 800 square feet there are 24,000 bricks.
In 40 square feet there are 1,200 bricks.
In 6 square feet there are 180 bricks.

In 9,846 square feet there are 295,380 bricks.

SIZE OF CHIMNEYS FOR STEAM BOILERS (KENT).

Formula, H. P. = $3.33 (A - 0.6\sqrt{A})\sqrt{H}$. (Assuming 1 H. P. = 5 lbs. of coal burned per hour.)

Diam., inches.	Area A, sq. ft.	Effective area, $E = A - 0.6\sqrt{A}$ sq. ft.	Height of chimney. Commercial horse power of boiler. 50 ft.	60 ft.	70 ft.	80 ft.	90 ft.	100 ft.	110 ft.	125 ft.	150 ft.	175 ft.	200 ft.	225 ft.	250 ft.	300 ft.		Equivalent sq. chimney. Side of square $\sqrt{E}+4$ inches.
18	1.77	.97	23	25	27	29	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	16
21	2.41	1.47	35	38	41	44	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	19
24	3.14	2.08	49	54	58	62	66	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	22
27	3.98	2.78	65	72	78	83	88	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	24
30	4.91	3.58	84	92	100	107	113	119	. .	. .	. .	. .	. .	. .	. .	. .	. .	27
33	5.94	4.48	. .	115	125	133	141	149	156	. .	. .	. .	. .	. .	. .	. .	. .	30
36	7.07	5.47	. .	141	152	163	173	182	191	204	. .	. .	. .	. .	. .	. .	. .	32
39	8.30	6.57	. .	. .	183	196	208	219	229	245	268	. .	. .	. .	. .	. .	. .	35
42	9.62	7.76	. .	. .	216	231	245	258	271	289	316	342	. .	. .	. .	. .	. .	38
48	12.57	10.44	. .	. .	. .	311	330	348	365	389	426	460	492	. .	. .	. .	. .	43
54	15.90	13.51	. .	. .	. .	. .	427	449	472	503	551	595	636	675	. .	. .	. .	48
60	19.64	16.98	. .	. .	. .	. .	536	565	593	632	692	748	800	848	894	. .	. .	54
66	23.76	20.83	. .	. .	. .	. .	. .	694	728	776	849	918	981	1040	1097	1201	. .	59
72	28.27	25.08	. .	. .	. .	. .	. .	835	876	934	1023	1105	1181	1253	1320	1447	. .	64
78	33.18	29.73	. .	. .	. .	. .	. .	. .	1038	1107	1212	1310	1400	1485	1565	1715	. .	70
84	38.48	34.76	. .	. .	. .	. .	. .	. .	1214	1294	1418	1531	1637	1736	1830	2005	. .	75
90	44.18	40.19	. .	. .	. .	. .	. .	. .	. .	1496	1639	1770	1893	2008	2116	2318	. .	80
96	50.27	46.01	. .	. .	. .	. .	. .	. .	. .	1712	1876	2027	2167	2298	2423	2654	. .	86
102	56.75	52.23	. .	. .	. .	. .	. .	. .	. .	1944	2130	2300	2459	2609	2750	3012	. .	91
108	63.62	58.83	. .	. .	. .	. .	. .	. .	. .	2090	2399	2592	2771	2939	3098	3393	. .	96
114	70.88	65.83	. .	. .	. .	. .	. .	. .	. .	. .	2685	2900	3100	3288	3466	3797	. .	101
120	78.54	73.22	. .	. .	. .	. .	. .	. .	. .	. .	2986	3226	3448	3657	3855	4223	. .	107
132	95.03	89.18	. .		. .	. .	. .	. .	. .	. .	3637	3929	4200	4455	4696	5144	. .	117
144	113.10	106.72	. .	. .	. .	. .	. .	. .	. .	.	4352	4701	5026	5331	5618	6155	. .	128

For pounds of coal burned per hour for any given size of chimney, multiply the figures in the table by 5.

MEMORANDA FOR BRICKLAYERS.

(*Kidder.*)

To make one cubic yard of mortar requires one cubic yard of sand and nine bushels of lime, and will fill thirty hods.

A bricklayer's hod, measuring 1 foot 4 inches by 9 inches by 9 inches, equals 1296 cubic inches in capacity, and contains twenty bricks.

A single load of sand and other material equal one cubic yard, or twenty-seven cubic feet; and a double load equals twice that quantity. Quantity in *a load* should be specified when buying.

A measure of lime is one cubic yard.

One thousand brick closely stacked occupy about fifty-six cubic feet.

One thousand old bricks, cleaned and loosely stacked, occupy about seventy-two cubic feet.

One superficial foot of gauged arches requires ten bricks.

One superficial foot of facing requires seven bricks.

One yard of paving requires thirty-six *stock bricks* laid flat, or fifty-two on edge, and thirty-six *paving bricks* laid flat or eighty-two on edge. The bricks of different makers vary in dimensions, and those of the same maker vary also, owing to the different degrees of heat to which they are subjected in burning. The memoranda given above for brickwork are therefore only approximate.

The following table gives the usual dimensions of the bricks in various parts of the country:

Description.	Inches.	Description.	Inches.
Baltimore front	$8\frac{1}{4}$x$4\frac{1}{8}$x$2\frac{3}{8}$	Maine	$7\frac{1}{2}$x$3\frac{3}{8}$x$2\frac{3}{8}$
Philadelphia front		Milwaukee . .	$8\frac{1}{2}$x$4\frac{1}{8}$x$2\frac{3}{8}$
Wilmington front		North River . .	8 x$3\frac{1}{2}$x$2\frac{1}{4}$
Trenton front		Trenton	8 x4 x$2\frac{1}{4}$
Croton	$8\frac{1}{2}$x4 x$2\frac{1}{4}$	Ordinary . . .	$7\frac{3}{4}$x$3\frac{5}{8}$x$2\frac{1}{4}$
Colabaugh	$8\frac{1}{4}$x$3\frac{5}{8}$x$2\frac{3}{8}$		$8\frac{3}{4}$x$4\frac{1}{4}$x$2\frac{3}{4}$

Fire-brick { Valentine's (Woodbridge, N. J.), $8\frac{7}{8}$ x $4\frac{3}{8}$ x $2\frac{1}{2}$ inches.
Downing's (Allentown, Pa.), 9 x $4\frac{1}{2}$ x $2\frac{1}{2}$ inches.

The weight of the small sized bricks is about four pounds on the average, and of the larger about six pounds.

Dry bricks will absorb about one-fifteenth of their weight in water.

All bricks should be wet before laying, especially in dry weather, as otherwise they take water from the mortar and thus reduce its strength—do not have bricks "dripping wet," but allow them to take all the water they will; this is especially necessary where cement mortar is used.

LAYING PER DAY.—Trautwine gives, one bricklayer and one helper will lay in common house walls on an average about 1500 bricks per day of ten working hours. In neater face work of back buildings from 1000 to 1200; in good ordinary street fronts, 800 to 1,000; finest lower story faces, 150 to 300. In plain massive engineering work, he should average about 2000 per day, or 4 cubic yards; and in large arches about 1500, or 3 cubic yards.

In Philadelphia a barrel of lump lime (230 pounds net) is allowed for 1000 bricks. Trautwine gives 20 cubic feet, or 16 struck bushels of sand and 4 cubic feet, or 3.2 struck bushels of quicklime, the measures slightly shaken in both cases, will make about 22½ cubic feet of mortar, sufficient to lay 1000 bricks.

WEIGHTS.

Description.	Average weight in lbs. per cubic foot.
Brick, best pressed	150
Brick, common hard	125
Brick, soft	100
Brick, fire	137
Brickwork, common	112
Brickwork, pressed	140
Mortar, hardened	103

For ultimate crushing strength, see "Masonry."

GENERAL RULES FOR BRICK CHIMNEYS.

(*From Molesworth's "Pocket-Book."*)

The diameter at the base should be not less than one-tenth of the height.

Batter of chimneys, 0.3 inch to the foot.

Thickness of brickwork, a brick from top to twenty-five feet from ditto. A brick and a half from twenty-five to fifty feet from the top, increasing by half a brick for each twenty-five feet from the top.

If the inside diameter at the top exceeds four feet six inches, the top length should be a brick and a half thick.

BOILERS.

The boilers in ordinary use are divided into two broad general classes—water tubular, in which the water circulates on the interior of the tubes and the gas on the exterior, and fire tubular, in which the gases pass through the tubes while the water is on the exterior.

WATER TUBULAR.—These boilers are made in various types by different manufacturers. Fig. A shows an ordinary type, that manufactured by the Babcock & Wilcox Company. One or more horizontal combined steam and water drums are connected to several front and rear headers which are serpentine in form and into which the tubes are expanded, a handhole plate being provided in front of each tube for inspection, cleaning and tube removal. The fuel is burned on a grate in the front of the boiler, the gases passing between the tubes vertically until past a firebrick baffle attached to the tubes, whence they turn, passing downward and are finally for a third time passed between the tubes and out to the stack or flue in the rear. Water is taken into the front of the drum and steam taken from the top. A mud drum is connected to all the rear headers and the blow-off valve attached to same. The boiler is hung on an independent steel framework and is enclosed by a brick setting.

FIRE TUBULAR BOILERS.—A boiler of this type may be either internally or externally fired. In the former division may be mentioned the vertical, suspension furnace and locomotive types. In the latter divisions the type most frequently met with is ordinary return tubular boiler.

VERTICAL BOILERS.—A vertical boiler consists of an external shell for its full length and an internal shell of the height of the firebox some 8 inches or more smaller in diameter than the external shell and to which it is attached at the bottom of the boiler. The top of the internal shell is fastened to the lower tube sheet and the upper tube sheet is fastened to the top of the external shell. Between and expanded into these tube sheets are the tubes through which pass the gases from the combustion of fuel on the grate, placed inside of the internal shell near the base of the boiler. The stack is attached to the top of the boiler. Water enters near the base and steam is taken from near the top. The firebox is entirely surrounded by water to prevent the high heat weakening the internal steel shell. As in the firebox the pressure is on the outside of the internal shell, it is necessary to tie this shell in the external shell by suitable stay bolts. This type of boiler is entirely self-contained, requires no brick setting and is easily portable. Fig. B shows a usual design and table on page 56 gives the standard sizes.

SUSPENSION FURNACE BOILERS.—This type of boiler is largely used for marine and semi-portable work, as well as for stationary purposes. It requires no brick setting and is entirely self-contained. The boiler consists of an external shell, which, being entirely removed from the fire, can be made as thick as desired without danger of localized heating.

The grate is placed in an internal suspension furnace extending the length of the boiler and which is ordinarily corrugated to provide

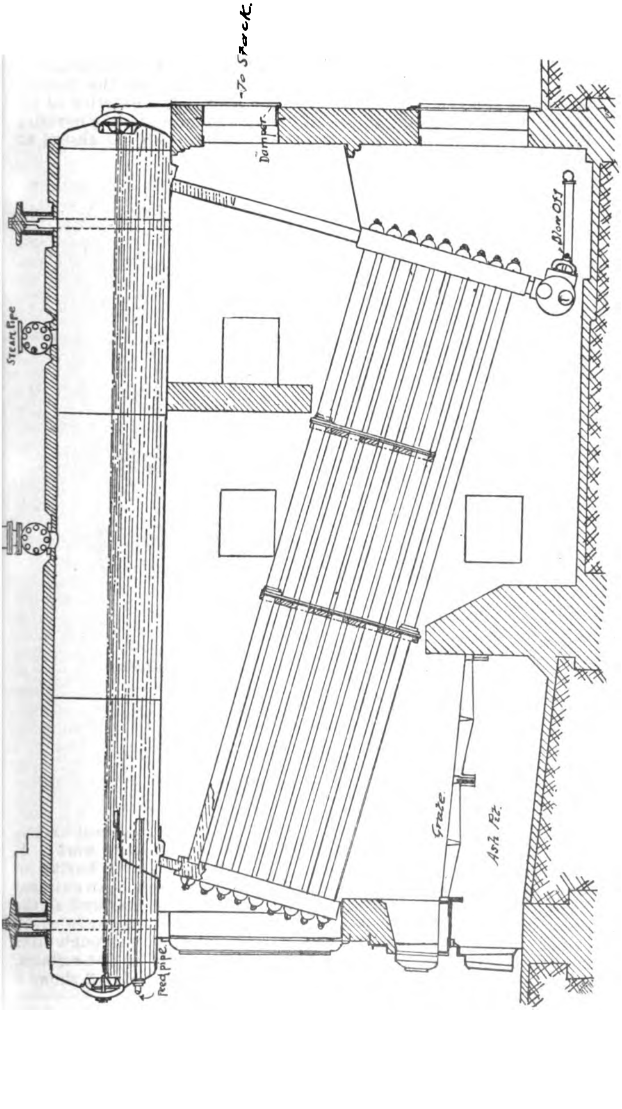


FIG. A.

for expansion with changes in temperature and to provide necessary strength to resist collapsing from the pressure of the boiler. Attached to the external shell and suspension furnace are the front and rear heads between which extend the tubes through which the gases from the suspension furnace pass to reach the stack or flue placed over the front of the boiler. Water is introduced over the furnace and steam is taken in from the top of the shell. The exterior of the boiler should be covered thoroughly with a non-conducting covering to permit radiation of heat from the boiler. Fig. D shows an ordinary type.

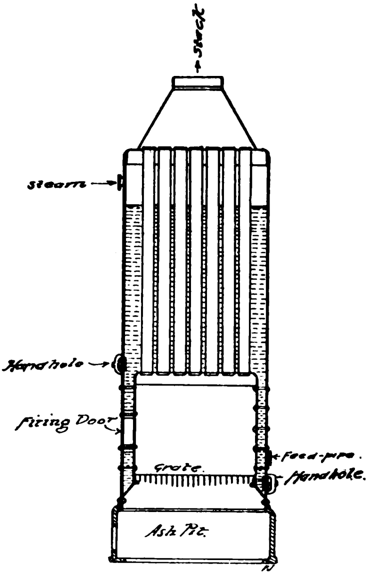


FIG. B.

LOCOMOTIVE BOILERS.—This type of boiler is used almost exclusively on locomotives and to some extent for stationary work. It combines the advantages of simplicity, portability and, having no brick setting, is easily installed. The boiler consists of an external shell to which is attached at the rear the stack or flue and at the front the firebox, which is arranged to be entirely surrounded by water. The gases of combustion pass from the firebox through tubes into the stack at the rear. The firebox is composed of flat surfaces, which it is necessary to stiffen with stay bolts. Fig. E shows a usual design of locomotive boiler.

RETURN TUBULAR BOILERS.—This boiler is used perhaps more than any other type. It consists of an external shell at the ends of

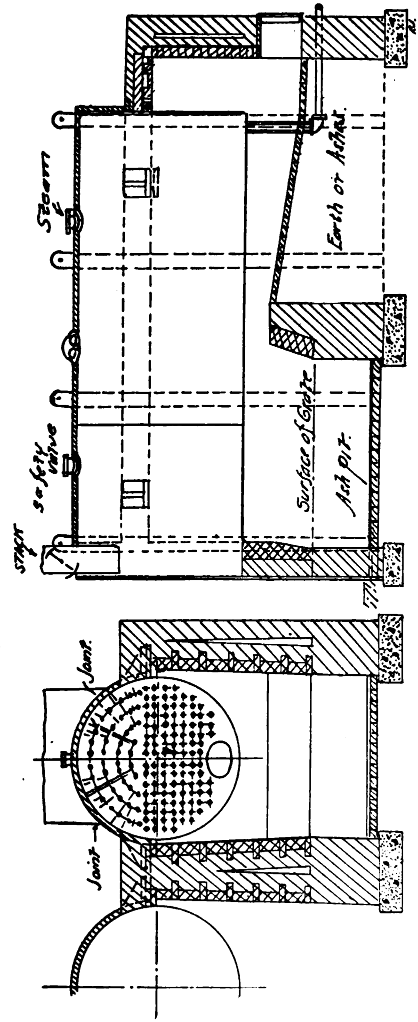

Steam
Safety valve
Stack
Earth or Ashes
Surface of Grate
Ash pit
Joint
Joint

FIG. C.

which are attached the tube sheets between which are the tubes. The boiler is surrounded by a brick setting, the fuel being burned in the front of the boiler under the shell, thence passing backwards under the shell, turning and passing through the tubes into the stack

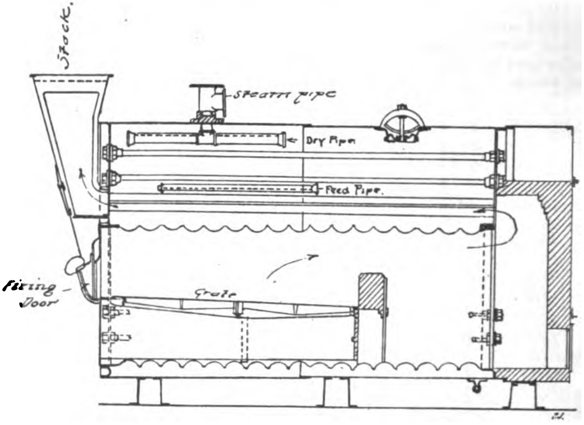


FIG. D.

or flue at the front. The flat tube sheets are stayed to each other or to the shell. Water enters at the front, usually passing through a pipe to the rear and bottom of the boiler. Steam is taken either from a dome or the top of the shell. Fig. C shows a usual design of shell and setting.

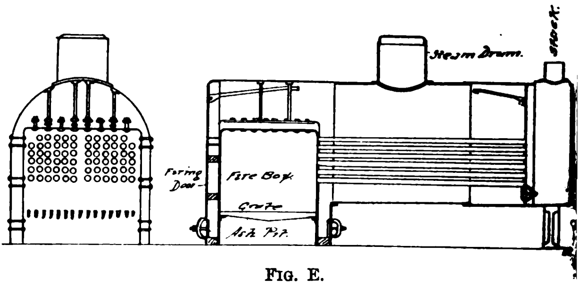


FIG. E.

The usual sizes of return tubular boilers are given in the table, page 62.

HORSE POWER OF BOILERS.—The horse power of a boiler bears no distinct relation to a mechanical horse power, which is equal to the power required to raise 33,000 lbs. to the height of one foot in one minute. It is rather the evaporating power of the boiler, and a boiler horse power is defined as the evaporation of 34.5 lbs. of water from a temperature of 212° F. into steam at atmospheric pressure, or 34.5 lbs. of water from and at 212° F. as it is called. It is customary to rate boilers by the square feet of heating surface they contain, measuring in the case of tubes or shell always the outside surface, inasmuch as the steel is taken as a good conductor of heat. All surfaces in contact with hot gases on the one side and water on the other should be considered as heating surface.

The square feet of heating surface in a horizontal return tubular boiler is expressed by the following formula:

$$\text{Heating surface} = \frac{(2L+D)\frac{D}{3} + dn\left(L-\frac{d}{2}\right)}{46}$$

L = Length of shell, inches.
D = Diameter of shell, inches.
d = Diameter of tubes, inches.
n = Number of tubes.

Boilers should be rated as follows:

All fire tubular boilers—12 sq. ft. heating surface per H. P.

All water tubular boilers—10 sq. ft. heating surface per H. P.

These figures represent the best practice and boilers should be purchased only on the above rating.

THICKNESS OF SHELL.—The pressure which can be safely carried by a boiler or indeed any riveted shell subjected to internal pressure is as follows:

$$P = \frac{2t\,Se}{Fd}$$

P = Allowable pressure in lbs. per square inch.
t = Thickness of plate composing shell, inches.
S = Tensile strength of plate, which may be taken at 55,000 for steel and 45,000 for wrought iron.
e = Efficiency of joint or ratio of strength of joint to full strength of plate. The following are approximate figures of joint efficiencies:

Single-riveted lap joint	.55
Double-riveted lap joint	.70
Triple-riveted lap joint	.75
Triple-riveted butt joint double covering strips,	.86

F = Factor of safety or ratio of allowable stress in plate to breaking stress (usually taken at 5).
d = Diameter of shell, inches.

SAFETY VALVE.—A safety valve is a device to limit the pressure to which a boiler may be subjected. According to the rules of the U. S. Supervising Inspectors of Steam Vessels, it should have an effective area of discharge equal to 1 square inch for each 2 square feet grate for lever safety valves; 1 square inch for each 3 square feet grate area spring safety valves attached to boilers carrying a pressure less than 175 lbs. per square inch and 1 square inch for each 6 square feet of grate area for spring safety valves attached to water tubular boilers carrying a pressure of 175 lbs. per square inch or more.

The old style of safety valve with a weight may be calculated as follows, neglecting the weight of valve and needle:

$$P = \frac{WL}{Al}$$

P = Pressure in pounds per square inch at which valve will open.
L = Distance from center of weight to center of lever fulcrum.

W = Weight on lever arm, pounds.

A = Area of surface of safety valve to which boiler pressure is applied.

l = Distance from center of pin connecting to valve seat to center of lever fulcrum.

Spring safety valves are marked by the manufacturers with the pressure at which they are set to open.

STACKS.—The sizes of stacks for boiler installations are given in table, page 49.

PRINCIPAL DIMENSIONS OF VERTICAL BOILERS WITH FULL-LENGTH TUBES AS FURNISHED BY THE TRADE.

Commercial rating.	Shell.			Furnace.			Flanged heads.	Tubes 2 ins. in diameter.		Heating surface.	Diameter of stack.
	Diameter.	Height.	Thickness.	Diameter.	Height.	Thickness.	Thickness.	Length.	Number.		
H.P.	Ins.	Ft.	In.	Ins.	Ins.	In.	In.	Ins.		Sq. ft.	Ins.
4	24	4	1/4	20	24	1/4	3/8	24	31	44	12
5	24	5	1/4	20	24	1/4	3/8	36	31	60	12
6	24	6	1/4	20	24	1/4	3/8	48	31	75	12
8	30	5	1/4	25	27	1/4	3/8	33	55	92	14
10	30	6	1/4	25	27	1/4	3/8	45	55	121	14
12	30	7	1/4	25	27	1/4	3/8	57	55	150	14
15	36	6 1/2	1/4	31	27	1/4	3/8	51	77	189	15
18	36	7	1/4	31	27	1/4	3/8	57	77	210	15
20	36	8	1/4	31	27	1/4	3/8	69	77	250	15
25	42	7 1/4	9/32	37	27	1/4	3/8	60	109	307	18
30	42	8 1/4	9/32	37	27	1/4	3/8	72	109	364	18
35	42	9 1/4	9/32	37	27	1/4	3/8	84	109	422	18
40	48	8 1/2	5/16	43	30	1/4	3/8	72	149	496	20
45	48	9	5/16	43	30	1/4	3/8	78	149	535	20
50	48	10	5/16	43	30	1/4	3/8	90	149	613	20
60	54	9	5/16	48	30	1/4	3/8	78	201	716	24

STANDARD STEAM BOILER MEASUREMENTS.

Based on 12 square feet of heating surface to a horse power.

Size: Diameter.	Size: Length.	Thickness: Shell.	Thickness: Heads.	Size of dome.	Boiler with handholes. Tubes. No.	Tubes. Dia.	Heat. surf. Sq. ft.	Horse power.	Boiler with handholes. Tubes. No.	Tubes. Dia.	Heat. surf. Sq. ft.	Horse power.
30	6	¼	⅜	16 x 20	19	2½	106	9				
30	8	¼	⅜	16 x 20	19	2½	141	12				
36	8	¼	⅜	18 x 20	38	2½	256	21				
					28	3	226	19				
					25	3½	234	20				
36	10	¼	⅜	18 x 20	38	2½	311	26				
					28	3	283	24				
					25	3½	292	24				
42	10	¼	⅜	20 x 24	38	3	372	31				
					34	3½	385	32				
42	12	¼	⅜	20 x 24	38	3	446	37				
					34	3½	462	39				
42	14	¼	⅜	20 x 24	38	3	520	43				
					34	3½	539	45				
42	16	¼	⅜	20 x 24	38	3	595	50				
					34	3½	616	51				
44	12	¼	⅜	24 x 24	48	3	544	45				
					38	3½	510	43				
44	14	¼	⅜	24 x 24	48	3	635	53				
					38	3½	491	41				
48	12	5/16	7/16	24 x 24	58	3	647	54	50	3	572	48
					50	3½	651	54	34	3½	475	40
48	14	5/16	7/16	24 x 24	58	3	755	63	50	3	667	55
					50	3½	759	63	34	3½	547	46
48	16	5/16	7/16	24 x 24	58	3	862	72	50	3	762	64
					50	3½	867	72	34	3½	633	53
48	18	5/16	7/16	24 x 24	58	3	970	81	50	3	857	71
					50	3½	976	81	34	3½	712	59
54	14	5/16	½	30 x 30	71	3	912	76	59	3	780	65
					56	3½	851	71	48	3½	748	62
					43	4	763	64	40	4	719	60
54	16	5/16	½	30 x 30	71	3	1042	87	59	3	891	74
					56	3½	972	81	48	3½	855	71
					43	4	802	67	40	4	821	68
54	18	5/16	½	30 x 30	71	3	1173	98	59	3	1003	84
					56	3½	1094	91	48	3½	962	80
					43	4	980	82	40	4	924	77
60	12	5/16	½	36 x 36	71	3½	907	75	56	3½	742	62
					54	4	804	67	46	4	704	59
					43	4½	733	61	36	4½	634	53
60	14	5/16	½	36 x 36	71	3½	1058	88	56	3½	865	72
					54	4	938	78	46	4	821	68
					43	4½	855	71	36	4½	740	62
60	16	5/16	½	36 x 36	71	3½	1209	101	56	3½	989	82
					54	4	1073	89	46	4	939	78
					43	4½	978	82	36	4½	846	71
60	18	5/16	½	36 x 36	71	3½	1360	113	56	3½	1113	93
					54	4	1207	101	46	4	1056	88
					43	4½	1100	92	36	4½	952	79
66	16	⅜	½	40 x 40	90	3½	1504	125	84	3½	1416	118
					68	4	1324	110	56	4	1122	94
					56	4½	1239	103	46	4½	1051	88
66	18	⅜	½	40 x 40	90	3½	1692	141	84	3½	1593	133
					68	4	1489	124	56	4	1263	105
					56	4½	1394	116	46	4½	1113	93
72	16	⅜	½	42 x 42	108	3½	1785	149	98	3½	1638	137
					82	4	1575	131	72	4	1407	117
					64	4½	1407	117	60	4½	1331	111
72	18	⅜	½	42 x 42	108	3½	2008	167	98	3½	1843	154
					82	4	1772	148	72	4	1584	132
					64	4½	1583	132	60	4½	1498	125

RULES

FOR THE MANAGEMENT AND CARE OF

STEAM BOILERS

UNDER THE SUPERVISION OF THE

HARTFORD STEAM BOILER INSPECTION AND INSURANCE COMPANY.

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1. CONDITION OF WATER.—The first duty of an engineer, when he enters his boiler room in the morning, is to ascertain how many gauges of water there are in his boilers. *Never unbank nor replenish the fires until this is done.* Accidents have occurred, and many boilers have been entirely ruined, from neglect of this precaution.

2. LOW WATER.—In case of low water, immediately cover the fires with ashes, or, if no ashes are at hand, use *fresh coal*, and close ash pit doors. Don't turn on the feed under any circumstances, nor tamper with or open the safety valve. Let the steam outlets remain as they are.

3. IN CASE OF FOAMING.—Close throttle, and keep closed long enough to show true level of water. If that level is sufficiently high, feeding and blowing will usually suffice to correct the evil. In case of violent foaming, caused by dirty water, or change from salt to fresh, or *vice versa*, in addition to the action above stated, check draft and cover fires with fresh coal.

4. LEAKS.—When leaks are discovered, they should be repaired as soon as possible.

5. BLOWING OFF.—Clean furnace and bridge wall of all coal and ashes. Allow brickwork to cool down for two hours at least before opening blow. A pressure exceeding 20 pounds should not be allowed when boilers are blown out. Blow out at least once in two weeks. In case the feed becomes muddy, blow out six or eight inches every day. When surface blow cocks are used, they should be often opened for a few moments at a time.

6. FILLING UP THE BOILER.—After blowing down *allow the boiler to become cool* before filling again. Cold water pumped into hot boilers is very injurious from sudden contraction.

7. EXTERIOR OF BOILER.—Care should be taken that no water comes in contact with the exterior of the boiler, either from leaky joints or other causes.

8. REMOVING DEPOSIT AND SEDIMENT.—In tubular boilers the handholes should be often opened and all collections removed and fire plates carefully cleaned. Also, when boilers are fed in front and blown off through the same pipe, the collection of mud or sediment in the rear end should be often removed.

9. SAFETY VALVES.—Raise the safety valves cautiously and frequently, as they are liable to become fast in their seats and useless for the purpose intended.

10. SAFETY VALVE AND PRESSURE GAUGE.—Should the gauge at any time indicate the limit of pressure allowed by this company, see that the safety valves are blowing off. In case of difference, notify the company's inspector.

11. GAUGE COCKS, GLASS GAUGE.—Keep gauge cocks clear and in constant use. Glass gauges should not be relied on altogether.

12. BLISTERS.—When a blister appears, there must be no delay in having it carefully examined and *trimmed* or *patched*, as the case may require.

13. CLEAN SHEETS.—Particular care should be taken to keep sheets and parts of boilers exposed to the fire perfectly clean, also all tubes, flues and connections well swept. This is particularly necessary where wood or soft coal is used for fuel.

14. GENERAL CARE OF BOILERS AND CONNECTIONS.—Under all circumstances, keep the gauge cocks, etc., clean and in good order, and things generally in and about the engine and boiler room in a neat condition.

15. GETTING UP STEAM.—In preparing to get up steam after boilers have been open or out of service, great care should be exercised in making the man and hand hole joints. Safety valve should then be opened and blocked open and the necessary supply of water run in or pumped into the boilers until it shows at second gauge in tubular and locomotive boilers; a higher level is advisable in vertical tubulars as a protection to the top ends of tubes. After this is done, fuel may be placed upon the grate, dampers opened and fire started. If chimney or stack is cold and does not draw properly, burn some oily waste or light kindlings at the base. Start fires in ample time so it will not be necessary to urge them unduly. When steam issues from the safety valve, lower it carefully to its seat and note pressure and behavior of steam gauge.

If there are other boilers in operation and stop valves are to be opened to place boilers in connection with others on a steam pipe line, watch those recently fired up until pressure is up to that of the other boilers to which they are to be connected and, when that pressure is attained, open the stop valves *very slowly and carefully.*

PUMPS.

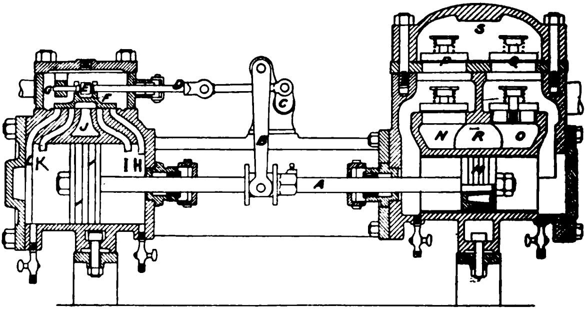
Two general types of steam-driven, direct-acting, reciprocating pumps are in ordinary use, simplex and duplex.

SIMPLEX PUMPS.

A simplex pump is one in which a single steam cylinder acts directly on a single water cylinder. The valve motions in different makes of simplex pumps are so different that it is not possible here to give a description of this type of pump. In general, a cross head attached to the piston rod moves an auxiliary valve which opens a small port, allowing steam to enter the main valve chamber and force the main valve to one end, allowing the proper side of the cylinder to receive high pressure steam while the other side is opened to the exhaust.

DUPLEX PUMPS.

This type of pump, the invention of the late Henry R. Worthington, is in more general use than any other type. It consists of two simplex pumps of equal dimensions built side by side on the same frame. The valve motion is so arranged that the movement of one piston operates the valve motion for the other piston, the effect of which is to allow one piston to proceed to the end of its stroke and gradually come to a state of rest. During the latter part of this movement the opposite piston then moves forward in its stroke and also comes to rest, but in its movement forward and before reaching the end of its stroke the slide valve controlling the first piston is reversed, and in consequence the first piston returns to its original position, and in nearing the end of its stroke it in a similar manner reverses the slide valve controlling the second piston. These movements are both uniform and continuous as long as steam is supplied to the pistons.



Thus referring to the figure, which shows a sectional elevation through one water cylinder, steam cylinder and its valve chest. Piston rod "A" transmits motion through arm "B" to the rocker shaft and valve arm moving steam valve of the other side of the pump not shown in the figure. Similarly the other piston rod actuates through a similar connection, valve arm "C," which through valve rod "D" moves the main steam valve "F." This valve is of the ordinary slide valve pattern, but covers five ports, "H" and "L" steam ports, "I" and "K" exhaust ports, and "J," the exhaust passage. The valve, moreover, has no lap on either steam or exhaust edges; that is, in its central position, the outside and inside edges of the valve are coincident with the edges of the steam and exhaust ports. The steam valve is not rigidly attached to the valve rod, but by means of the inside nut shown in the figure or in other patterns, two inside or two outside nuts, a certain amount of lost motion, either definite or adjustable, is allowed between the valve and the mechanism driving it.

In operation, as the piston (not shown) moves to the right, the valve "E," by means of valve arm "C" and rod "D," is forced to the left, uncovering port "H" to allow steam to enter the front end of the steam cylinder and connecting the back end by means of port "K" to the exhaust passage "J." Steam entering the front end causes the piston to move to the left, but before it reaches the end of its stroke it covers exhaust port "K," confining a small amount of exhaust steam in the end of the cylinder, which, compressing, forms a cushion to bring the piston easily to rest. In the latter part of its stroke, the piston also reverses the valve on the other side of the pump, which causes its piston to move to the left, moving valve "F" to the right, when the reverse operation as described is gone through with. Thus the two sides of the pump work alternately back and forth delivering an almost continuous stream of water.

TO SET THE STEAM VALVE.

Provided steam is supplied under sufficient pressure to the pump and the valve is properly set, the pump will certainly run. To set the valve properly, place both pistons in the middle of their strokes, when the cross head arms and valve arms should be vertical. Place both valves in the position shown in the figure; that is, with edges coinciding with edges of ports. Then adjust nuts "E" or sets of nuts, answering the same purpose, to divide equally the distances between nut and striking points on valves. Then will the valves be properly adjusted for operation.

THE WATER END.

Referring again to the figure, the piston "M," in moving to the left, creates a pressure less than that existing in suction chamber "O," which causes suction valve "O" to be raised on its seat, allowing water to pass into the cylinder. On the return stroke the spring on valve "O" causes it to seat as soon as this difference in pressure does not obtain, while discharge valve "Q" is raised against its spring on account of a greater pressure existing in the cylinder than in discharge chamber "S." At the end of the stroke the pressure in discharge chamber and cylinder being equalized, the spring seats the discharge valve. The alternating movement of the piston from one side to the other alternately raises suction and discharge valves and allows passage of water from suction chamber "R" to discharge chamber "S," which chambers are respectively connected to suction and discharge pipes.

OPERATION.

For cold water, a medium hard rubber valve is provided for ordinary pressures and metal valves for high pressures. A hard rubber valve is used almost exclusively for hot water. The springs on both suction and discharge valves should be as light as is consistent with their operation, and are usually wound larger at their lower end so that they raise easily at first, but with increasing difficulty at the end of their stroke. The valve should raise sufficiently to admit of the free passage of the water, but no more.

VELOCITIES.

Good practice admits of the following velocities:

Feet traveled per minute by each piston in small pumps . . . 50
Varying to 100 feet in larger sizes.

Water in suction pipe, linear feet per minute 200

Water in discharge, feet . . . . 300 to 500

Water in suction and discharge valve passages, linear feet per minute 200

The following table shows the piston speed and sizes of water cylinders of duplex pumps recommended by the Standard Plunger Elevator Company, Worcester Mass., and conforms to the best practice of today. The pump sizes given are standard with almost all manufacturers.

(TABLE A.)

PUMPS.

Size duplex pump recommended by Standard Plunger Elevator Company.

10″ Stroke—50 F. P. M.					12″ Stroke—60 F. P. M.				
Gals. per min.	Pump size. Plgr. stro.	Theo. stro.	Theo. gals. per min.	Area of plgr.	Gals. per min.	Pump size. Plgr. str.	Theo. stro.	Theo. gals. per min.	Area of plunger
50	3¾x10	.48	57	11.0	50	3¾x12	.57	68	11.0
75	4½x10	.68	82	15.9	75	4½x12	.82	98	15.9
100	5¼x10	.94	112	21.6	100	5¼x12	1.12	134	21.6
125	6 x10	1.22	146	28.3	125	6 x12	1.46	175	28.3
150	7 x10	1.67	200	38.5	150	6 x12	1.46	175	28.3
175	7 x10	1.67	200	38.5	175	7 x12	2.00	240	38.5
200	7½x10	1.91	229	44.2	200	7 x12	2.00	240	38.5
225	8 x10	2.17	261	50.2	225	7½x12	2.29	275	44.2
250	8 x10	2.17	261	50.2	250	7½x12	2.29	275	44.2
275	8½x10	2.46	294	56.7	275	8 x12	2.61	313	50.2
300	9 x10	2.75	330	63.7	300	8 x12	2.61	313	50.2
325	9 x10	2.75	330	63.7	325	8½x12	2.95	354	56.7
350	9½x10	3.07	368	70.8	350	9 x12	3.30	396	63.6
375	10 x10	3.40	408	78.5	375	9 x12	3.30	396	63.6
400	10¼x10	3.57	428	82.5	400	9½x12	3.68	441	70.8
425	10½x10	3.74	449	86.6	425	10 x12	4.08	489	78.5
					450	10 x12	4.08	489	78.5
					475	10¼x12	4.29	515	82.5
					500	10¼x12	4.29	515	82.5
					525	10½x12	4.50	540	86.6

(TABLE A—continued.)

15″ Stroke—62½ F. M. P.					18″ Stroke—75 F. P.M.				
Gals. per min.	Pump size. Plgr. stro.	Theo. stro.	Theo. gals. per min.	Area of plgr.	Gals. per min.	Pump size. Plgr. stro.	Theo. stro.	Theo. gals. per min.	Area of plunger.
350	8½x15	3.67	367	56.7	550	10 x18	6.14	614	78.5
400	9 x15	4.12	412	63.3	600	10¼x18	6.42	642	82.5
450	9½x15	4.60	460	70.9	650	10½x18	6.75	675	86.6
500	10 x15	5.10	510	78.5	700	11 x18	7.39	739	95.0
525	10¼x15	5.35	535	82.5	750	11½x18	8.08	808	103.8
550	10½x15	5.60	560	86.6	800	12 x18	8.81	881	113.1
600	11 x15	6.20	620	95.0	850	12 x18	8.81	881	113.1
650	11½x15	6.73	673	103.8	900	12½x18	9.55	955	122.7
700	12 x15	7.34	734	113.1	950	13 x18	10.34	1034	132.7
750	12½x15	7.96	796	122.7	1000	13 x18	10.34	1034	132.7
800	13 x15	8.61	861	132.7	1050	13½x18	11.15	1115	143.1
850	13½x15	9.28	928	143.1	1100	14 x18	12.00	1200	153.9
900	13½x15	9.28	928	143.1	1150	14 x18	12.00	1200	153.9
950	14 x15	10.00	1000	153.9	1200	14½x18	12.86	1286	165.1
1000	14 x15	10.00	1000	153.9	1250	14½x18	12.86	1286	165.1
					1300	15 x18	13.77	1377	176.7
					1350	15 x18	13.77	1377	176.7
					1400	16 x18	15.67	1567	201.0
					1450	16 x18	15.67	1567	201.0
					1500	16 x18	15.67	1567	201 0

24″ Stroke—100 P. F. M.

Gals. per min.	Pump size. Plgr. stro.	Theo. stro.	Theo. gals. per min.	Area of plunger.	Gals. per min.	Pump size. Plgr. stre.	Theo. stro.	Theo. gals. per min.	Area of plunger.
800	10¼x24	8.56	856	82.5	1300	13 x24	13.78	1378	132.7
850	10½x24	8.98	898	86.6	1400	13½x24	14.86	1486	143.1
900	11 x24	9.86	986	95.0	1500	14 x24	15.98	1598	153.9
950	11½x24	10.78	1078	103.8	1600	14½x24	17.16	1716	165.1
1000	11½x24	10.78	1078	103.8	1700	15 x24	18.36	1836	176.7
1050	12 x24	11.74	1174	113.1	1800	15½x24	19.60	1960	188.7
1100	12 x24	11.74	1174	113.1	1900	16 x24	20.88	2088	201.0
1200	12½x24	12.74	1274	122.7	2000	16½x24	22.20	2229	213.8

CAPACITY.

The amount of water displaced by pumps is shown by the following formula. About 10 per cent. should be deducted in ordinary pumps to account for leakage past piston and through valves. In pumps in poor condition this leakage may amount to as much as 50 per cent.

$$Q = \frac{d^2 l \times .7854}{231}$$

Q = gallons displaced per stroke.
d = diameter of water cylinder, inches.
l = stroke of water cylinder, inches.

To obtain the discharge per minute, after deducting the leakage, multiply the displacement per stroke as given above by the number of *working strokes* per minute, taking care in a duplex pump to treat each side as a separate pump.

The following table shows the displacement in gallons per *working strokes* of a single pump of all sizes of cylinders from 1 x 3 to 20 x 36. The discharge per minute should be obtained as above.

(TABLE B.)

CALCULATED* CAPACITY OF PUMPS IN GALLONS PER STROKE.

Diameter of piston or plunger in inches.	Length of stroke in inches.											
	3	4	5	6	7	8	9	10	11	12	13	1
1	.010	.014	.017	.020	.024	.027	.031	.034	.038	.041	.045	.0
1½	.023	.031	.038	.046	.053	.061	.067	.077	.082	.092	.099	.1
2	.041	.054	.068	.082	.095	.109	.121	.136	.148	.163	.176	.1
2¼	.052	.069	.086	.103	.120	.138	.153	.172	.187	.206	.223	.2
2½	.064	.085	.106	.128	.148	.170	.189	.213	.231	.255	.276	.2
2¾	.077	.103	.129	.154	.179	.206	.225	.257	.275	.309	.334	.3
3	.092	.122	.153	.184	.214	.245	.270	.306	.330	.367	.397	.4
3¼	.108	.144	.180	.215	.251	.287	.324	.369	.396	.431	.466	.5
3½	.125	.167	.208	.260	.291	.333	.369	.417	.451	.500	.541	.5
3¾	.143	.191	.239	.287	.334	.382	.423	.478	.517	.574	.621	.6
4	.163	.218	.272	.326	.380	.435	.486	.544	.594	.653	.707	.7
4¼	.184	.246	.307	.368	.429	.491	.549	.614	.671	.737	.798	.8
4½	.207	.275	.344	.413	.481	.551	.621	.689	.759	.826	.895	.9
4¾	.230	.307	.384	.460	.536	.614	.684	.767	.836	.920	.997	1.0
5	.255	.340	.425	.510	.595	.680	.792	.850	.968	1.020	1.105	1.1
5¼	.281	.375	.469	.562	.656	.750	.837	.937	1.023	1.124	1.208	1.3
5½	.309	.411	.514	.617	.719	.823	.927	1.029	1.133	1.234	1.337	1.4
5¾	.337	.450	.562	.674	.786	.899	1.008	1.124	1.232	1.348	1.451	1.5
6	.367	.490	.612	.734	.856	.979	1.098	1.224	1.342	1.469	1.588	1.7
6¼	.398	.531	.664	.797	.929	1.062	1.197	1.328	1.463	1.593	1.696	1.8
6½	.431	.574	.718	.861	1.005	1.149	1.287	1.436	1.573	1.796	1.866	2.0
6¾	.465	.620	.775	.929	1.084	1.239	1.386	1.549	1.694	1.858	2.013	2.1
7	.500	.666	.833	1.000	1.166	1.333	1.494	1.666	1.826	1.999	2.165	2.3
7½	.574	.765	.956	1.148	1.337	1.530	1.719	1.913	2.101	2.295	2.483	2.6
8	.653	.870	1.088	1.306	1.523	1.741	1.953	2 176	2.387	2.611	2.838	3.0
8½	.735	.980	1.225	1.470	1.680	1.960	2.160	2.450	2.640	2.940	3.120	3.4
9	.826	1.101	1.377	1.652	1.927	2.203	2.475	2.754	3.025	3.305	3.580	3.8
9½	.918	1.224	1.530	1.830	2.142	2.448	2.754	3.060	3.366	3.672	3.978	4.2
10	1.020	1.360	1.700	2.040	2.380	2.720	3.060	3.400	3.740	4.080	4.420	4.7
10½	1.125	1.500	1.870	2.250	2.625	3.000	3.375	3.750	4.125	4.500	4.875	5.2
11	1.234	1.645	2.057	2.464	2.879	3.291	3.699	4.114	4.521	4.937	5.343	5.7
11½	1.351	1.800	2.252	2.701	3.150	3 600	4.050	4.505	4.950	5.406	5.850	6.3
12	1.468	1.958	2.448	2.938	3.422	3.917	4.392	4.896	5.368	5.875	6.359	6.8
13	1.723	2.297	2.872	3.445	4.022	4.596	5.166	5.745	6.314	6.894	7.467	8.0
14	1.998	2.665	3.331	3.997	4.664	5.330	5.994	6.663	7.326	7.994	8.661	9.3
15	2.294	3.959	3.824	4.589	5.354	6.119	6.876	7.649	8.404	9.178	9.943	10.7
16	2.610	3.480	4.350	5.220	6.090	6.960	7.830	8.703	9.570	10.440	11.310	12.1
18	3.303	4.404	5.505	6.606	7.707	8.808	9.909	11.010	12.111	13.210	14.613	15.4
20	4.080	5.440	6.800	8.160	9.520	10.880	12.240	13.600	14.960	16.320	17.680	19.0

*The actual capacity is found by subtracting the loss by leakage a slip from the values in the table.

(TABLE B—continued.)

CALCULATED* CAPACITY OF PUMPS IN GALLONS PER STROKE.

piston or plunger in inches.	Length of stroke in inches.											
	15	16	17	18	19	20	22	24	26	28	30	36
	.051	.054	.059	.061	.066	.068	.076	.082	.090	.096	.102	.122
½	.115	.122	.127	.138	.145	.153	.164	.184	.198	.214	.231	.276
	.204	.218	.229	.245	.256	.272	.296	.326	.352	.380	.408	.490
¼	.258	.275	.289	.310	.323	.344	.374	.413	.446	.482	.516	.620
½	.319	.340	.357	.383	.399	.425	.462	.510	.556	.596	.639	.766
¾	.386	.411	.425	.463	.475	.514	.550	.617	.668	.720	.771	.926
	.459	.490	.510	.551	.570	.612	.660	.734	.794	.856	.918	1.102
¼	.539	.575	.612	.647	.684	.718	.792	.862	.932	1.006	1.077	1.294
½	.525	.666	.697	.750	.779	.833	.902	1.000	1.082	1.166	1.251	1.500
¾	.717	.765	.799	.861	.893	.956	1.034	1.147	1.242	1.338	1.434	1.722
	.816	.870	.918	.979	1.026	1.088	1.188	1.306	1.414	1.524	1.632	1.958
¼	.921	.982	1.037	1.105	1.239	1.228	1.342	1.473	1.596	1.720	1.842	2.210
½	1.033	1.102	1.173	1.239	1.311	1.377	1.518	1.652	1.790	1.928	2.067	2.478
¾	1.151	1.227	1.292	1.380	1.444	1.534	1.672	1.840	1.994	2.146	2 301	2.760
	1.275	1.360	1.496	1.530	1.672	1.700	1.936	2.040	2.210	2.380	2.550	3.060
¼	1.405	1.499	1 581	1.686	1.767	1.874	2.046	2.248	2.416	2.622	2.811	3.372
½	1.543	1.646	1.751	1.851	1.957	2.057	2.266	2.468	2.674	2.880	3.087	3.702
¾	1.686	1.798	1.904	2.022	2.128	2.248	2.464	2.696	2.902	3.146	3.372	4.044
	1.836	1.958	2.074	2.203	2.318	2.448	2.684	2.938	3.176	3.428	3.672	4.406
¼	1.992	2.124	2.261	2.390	2.527	2.656	2.926	3.186	3.392	3.718	3.984	4.780
½	2.155	2.298	2.431	2.589	2.717	2.873	3.146	3.447	3.732	4.022	4.308	5.178
¾	2.323	2.479	2.612	2.788	2.926	3.098	3.388	3.716	4.026	4.336	4.647	5.576
	2.499	2.666	2.822	2.999	3.154	3.332	3.652	3.998	4.330	4.664	4.998	5.998
7½	2.869	3.060	3.247	3.443	3.629	3.825	4.202	4.590	4.966	5.356	5.739	6.886
	3.264	3.482	3.689	3.917	4.123	4.352	4.774	5.222	5.676	6.092	6.528	7.834
½	3.675	3.920	4.080	4.410	4.560	4.900	5.280	5.880	6.240	6.860	7.350	8.820
	4.131	4.406	4.675	5.057	5.225	5.508	6.050	6.610	7.160	7.712	8.262	10.114
½	4.590	4.896	5.202	5.510	5.814	6.120	6.732	7.344	7.956	8.568	9.180	11.020
	5.100	5.440	5.780	6.120	6.460	6.800	7.480	8.160	8.840	9.520	10.200	12.240
½	5.625	6.000	6.375	6.750	7.125	7.500	8.250	9.000	9.750	10.500	11.250	13.500
	6.171	6.582	6.987	7.405	7.809	8.228	9.042	9.874	10.686	11.520	12.342	14.810
½	6.750	7.200	7.650	8.100	8.550	9.000	9.900	10.800	11.700	12.600	13.515	16.200
	7.344	7.833	8.296	8.813	9.277	9.792	10.736	11.750	12.718	13.608	14.688	17.626
	8.616	9.192	9.758	10.340	10.906	11.490	12.628	13.780	14.934	16.084	17.235	20.680
	9.993	10.660	11.322	11.990	12.661	13.320	14.652	15.980	17.322	18.656	19.989	23.980
	11.470	12.230	13.988	13.760	14.516	15.290	16.808	18.350	19.886	20.140	22.947	27.520
	13.050	13.920	14.790	15.660	16.530	17.400	19.140	20.880	22.620	24.360	26.109	31.320
	16.510	17.610	18.717	19.810	20.919	22.020	24.222	26.420	29.226	30.820	33.030	39.720
	20.400	21.760	23.120	24.480	25.840	27 200	29.920	32.640	35.360	38.080	40.800	48.060

* The actual capacity is found by subtracting the loss by leakage and p from the values in the table.

SIZE OF STEAM CYLINDER.

By making the steam cylinder of larger diameter than the water cylinder, the discharge water pressure may be greater than the steam pressure. The following formula gives the water pressure against which a pump will discharge when when supplied with steam inside the steam chest of a given pressure:

$$P = \frac{eP' d^2}{d'^2}$$

P = water pressure in lbs. per square inch in discharge chamber.
e = efficiency of pump, which may be taken at .8
P′ = steam pressure in lbs. per square inch in discharge chamber.
d = diameter of water cylinder.
d′ = diameter of steam cylinder.

In designing pumps for a given duty, it is customary to design a steam cylinder about twice as large as would be actually required, to allow for greater water pressure and smaller steam pressure than originally figured on.

HORSE POWER TO RAISE WATER.

The theoretical horse power required to raise water or theoretical horse power due to a fall of water is expressed approximately by the following formula:

$$HP = \frac{h\,Q}{4000}$$

h = head of water in feet.
Q = quantity of water in gallons per minute.

HEIGHT OF SUCTION.

The pump cylinders may be located some distance above the level of water to be pumped, when the pump piston, by moving away from either head, will create a partial vacuum, causing the external atmospheric pressure to force water up into the pump cylinders. The maximum height through which a pump could possibly raise cold water would be 34 feet at sea level, decreasing 1.15 feet for every 1000 feet in altitude. In practice it should not be attempted to raise water more than 5 feet less than this amount, and as a matter of principle the suction lift should be kept as small as is compatible with the existing conditions on account of the danger of air leaks in the suction pipe at high lifts. For hot water the lift should be decreased, as it is impossible for a pump to raise boiling water. In case it is desired to handle boiling water, it should be furnished to the pump under at least a slight pressure.

USEFUL INFORMATION.

STEAM.

A cubic inch of water evaporated under ordinary atmospheric pressure is converted into 1 cubic *foot* of steam (approximately).

The specific gravity of steam (at atmospheric pressure) is .411 that of air at 34° Fahrenheit, and .0006 that of water at same temperature.

27.222 cubic feet of steam weigh 1 pound; 13.817 cubic feet of air weigh 1 pound.

Locomotives average a consumption of 3000 gallons of water per 100 miles run.

The best designed boilers, well set, with good draft, and skillful firing, will evaporate from 7 to 10 pounds of water per pound of first-class coal.

In calculating horse power of tubular or flue boilers, consider 15 square feet of heating surface equivalent to one *nominal* horse power.

On one square foot of grate can be burned on an average from 10 to 12 pounds of hard coal or 18 to 20 pounds soft coal per hour, with natural draft. With forced draft nearly double these amounts can be burned.

Steam engines, in economy, vary from 40 to 60 pounds of feed water and from 1½ to 7 pounds of coal per hour per indicated H. P. See table below for duty of high-grade engines.

Condensing engines require from 20 to 30 gallons of water, at an average low temperature, to condense the steam represented by every gallon of water evaporated in the boilers supplying engines—approximately for most engines, we say, from 1 to 1½ gallons condensing water per minute per indicated horse power.

Surface condensers should have about 2 square feet of tube [cooling] surface per horse power for a compound steam engine. Ordinary engines will require more surface according to their economy in the use of steam. It is absolutely necessary to place air pumps below condensers to get satisfactory results.

RATIO OF VACUUM TO TEMPERATURE (FAHRENHEIT) OF FEED WATER.

00 inches, Vacuum . .	212°	27½ inches, Vacuum . .	112°
11 inches, Vacuum .	190°	28½ inches, Vacuum . .	92°
18 inches, Vacuum . .	170°	29 inches, Vacuum . .	72°
22½ inches, Vacuum .	150°	29½ inches, Vacuum . .	52°
*25 inches, Vacuum . .	135°		

*Usually considered the standard point of efficiency—condenser and air pump being well proportioned.

WEIGHT AND COMPARATIVE FUEL VALUE OF WOOD.

One cord air-dried hickory or hard maple weighs about 4500 pounds and is equal to about 2000 pounds coal.

One cord air-dried white oak weighs about 3850 pounds and is equal to about 1715 pounds coal.

One cord air-dried beech, red oak and black oak weighs about 3250 pounds and is equal to about 1450 pounds coal.

One cord air-dried poplar (white wood), chestnut and elm weighs about 2350 pounds and is equal to about 1050 pounds coal.

One cord air-dried average pine weighs about 2000 pounds and is equal to about 925 pounds coal.

From the above it is safe to assume that 2¼ pounds of dry wood is equal to 1 pound average quality of soft coal, and that the fuel value of the same *weight* of different woods is very nearly the same; that is, a pound of hickory is worth no more for fuel than a pound of pine, assuming both to be dry. It is important that the wood be dry, as each 10 per cent. of water or moisture in wood will detract about 12 per cent. from its value as fuel.

DUTY OF STEAM ENGINES.

A well-known engineer of high authority gives the following comparative figures showing the economy of high-grade steam engines in actual practice:

Type of engine.	Temperature of feed water.	Pounds of water evaporated per pound of Cumberland coal.	Pounds of steam per I. H. P. used per hour.	Pounds of Cumberland coal used per I. H. P. per hour.	Cost per I. H. P. per hour, supposing coal at [illegible]
Non-condensing . . .	210°	10.5	29.0	2.75	$0.0073
Condensing	100°	9.4	20.0	2.12	.0056
Compound jacketed . .	100°	9.4	17.0	1.81	.0045
Triple expansion jacketed	100°	9.4	13.6	1.44	.0036

The effect of a good condenser and air pump should be to make available about 10 pounds more mean effective pressure, with the same terminal pressure, or to give the same mean effective pressure with a correspondingly less terminal pressure. When the load on the engine requires 20 pounds M. E. P., the condenser does half the work; at 30 pounds, one-third of the work; at 40 pounds, one-fourth, and so on. It is safe to assume that practically the condenser will save from one-fourth to one-third of the fuel, and it can be applied to any engine, cut-off, or throttling where a sufficient supply of water is available.

…RESSURES, TEMPERATURE AND VOLUME OF STEAM FROM ATMOSPHERIC PRESSURE TO 140 LBS. PER SQUARE INCH.

Lbs. per sq. in.	Temperature.	Volume.	Lbs. per sq. in.	Temperature.	Volume.	Lbs. per sq. in.	Temperature.	Volume.	Lbs. per sq. in.	Temperature.	Volume.
Atmos. pres.	212.8	1669	12	245.5	973	34	281.9	564	90	335.8	282
* 1	216.2	1573	14	249.6	911	40	289.3	508	95	339.2	271
2	219.6	1488	16	253.6	857	45	295.5	470	100	342.7	259
3	222.7	1411	18	257.3	810	50	301.3	437	105	345.8	251
4	225.6	1343	20	260.9	767	55	306.4	408	110	349.1	240
5	228.5	1281	22	264.3	729	60	311.2	383	115	352.1	233
6	231.2	1225	24	267.5	695	65	315.8	362	120	355.0	224
7	233.8	1174	26	270.6	664	70	320.1	342	125	357.9	218
8	236.3	1127	28	273.6	635	75	324.3	325	130	360.6	210
9	238.7	1084	30	276.4	610	80	328.2	310	135	363.4	205
10	241.0	1044	32	279.2	586	85	332.0	295	140	366.0	198

* These are boiler pressures (above atmospheric), as shown by the …team gauge. The temperatures are Fahrenheit scale. The volumes …iven represent cubic inches of steam for every cubic inch of water …vaporated.

PERCENTAGE OF SAVING OF FUEL BY HEATING FEED WATER.

(Steam at 60 lbs.)

…perature.	Initial temperature of water.											
	32°	40°	50°	60°	70°	80°	90°	100°	120°	140°	160°	180°
60°	2.39	1.71	0.86									
80	4.09	3.43	2.59	1.74	0.88							
00	5.79	5.14	4.32	3.49	2.64	1.77	0.90					
20	7.50	6.85	6.05	5.23	4.40	3.55	2.68	1.80				
40	9.20	8.57	7.77	6.97	6.15	5.32	4.47	3.61	1.84			
60	10.90	10.28	9.50	8.72	7.91	7.09	6.26	5.42	3.67	1.87		
80	12.60	12.00	11.23	10.46	9.68	8.87	8.06	7.23	5.52	3.75	1.91	
00	14.30	13.71	13.00	12.20	11.43	10.65	9.85	9.03	7.36	5.62	3.82	1.96
20	16.00	15.42	14.70	14.00	13.19	12.33	11.64	10.84	9.20	7.50	5.73	3.93
40	17.79	17.13	16.42	15.69	14.96	14.20	13.43	12.65	11.05	9.37	7.64	5.90
60	19.40	18.85	18.15	17.44	16.71	15.97	15.22	14.45	11.88	11.24	9.56	7.86

MEAN EFFECTIVE AND TERMINAL PRESSURES.

Initial pressures.	Points of cut-off.												Initial pressures.
	1/5		1/4		3/10		35/100		4/10		1/2		
	M. E. P.	Ter.	M. E. P.	Ter.	M. E. P.	Ter.	M. E. P.	Ter.	M. E. P.	Ter.	M. E. P.	Ter.	
40	13.46	11.79	17.34	14.49	20.75	17.11	23.70	19.80	26.22	22.44	30 50	27.78	40
45	16.15	12.87	20.39	15 81	24.13	18.67	27.32	21.61	30.08	24.49	34.75	30.33	45
50	18.85	13.94	23.45	17.13	27.50	20.24	30.94	23.42	33.95	26.55	39.00	32.88	50
55	21.54	15.00	26.50	18.45	30.87	21.80	34.56	25.23	37.81	28.60	43.25	35.43	55
60	24.24	16.08	29.56	19.77	34.24	23.37	38.18	27.04	41.68	30.66	47.50	37.98	60
65	26.93	17.15	32.61	21.09	37.61	24.94	41.80	28.85	45.54	32.71	51.75	40.52	65
70	29.63	18.23	35.67	22.41	40.98	26.51	45.42	30.66	49.41	34.77	56.00	43.07	70
75	32.32	19 31	38.72	23.73	44.35	28.07	49.05	32.47	53.27	36.82	60.25	45.61	75
80	35.02	20.39	41.78	25.05	47.72	29.64	52.68	34.28	57.14	38.88	64.50	48.16	80
85	37.71	21.46	44.83	26.37	51.09	31.20	56.31	36.09	61.00	40.93	68.75	50.70	85
90	40.41	22.54	47.89	27.67	54.46	32.77	59.94	37.90	64.87	42.99	73.00	53.25	90
95	43.10	23.62	50.94	29.01	57.83	34.33	63.57	39.71	68.73	45.04	77.25	55.79	95
100	45.80	24.70	54.04	30.33	61.20	35.96	67.20	41.52	72.60	47.10	81.50	58.34	100

The Initial and M. E. P. in above table are pressures above atmosphere and for non-condensing engines; the terminal

WATER.

Doubling the diameter of a pipe increases its capacity four times. iction of liquids in pipes increases as the square of the velocity. e table of "friction of water in pipes."

The mean pressure of the atmosphere is usually estimated at 14.7 unds per square inch, so that with a perfect vacuum it will sustain olumn of mercury 29.9 inches, or a column of water 33.9 feet high sea level.

To find the pressure in pounds per square inch of a column water. Multiply the height of the column in feet by .434. Approxi-itely, we say that every foot elevation is equal to ½ pound pressure r square inch; this allows for ordinary friction.

To find the diameter of a pump cylinder to move a given antity of water per minute (100 feet of piston being the standard of ed). Divide the number of gallons by 4, then extract the square ot, and the product will be the diameter in inches of the pump linder.

To find quantity of water elevated in one minute running at) feet of piston speed per minute. Square the diameter of the ter cylinder in inches and multiply by 4.

EXAMPLE.—Capacity of a 5-inch cylinder is desired. The square the diameter (5 inches) in 25, which, multiplied by 4, gives 100, e number of gallons per minute (approximately).

To find the horse power necessary to elevate water to a given ight. Multiply the weight of the water elevated per minute in unds by the height in feet, and divide the product by 33,000. (An owance should be added for water friction, and a further allow-ce for loss in steam cylinder, say, 20 to 30 per cent.)

The area of the steam piston, multiplied by the steam pressure, ves the total amount of pressure that can be exerted. *The area the water piston*, multiplied by the pressure of water per square ch, gives the resistance. *A margin* must be made between the wer and the *resistance* to *move* the pistons at the required speed, y from 20 to 40 per cent., according to speed and other conditions.

To find the capacity of a cylinder in gallons. Multiply the ea in inches by the length of stroke in inches will give the total mber of cubic inches; divide this amount by 231 (which is the bical contents of a United States gallon in inches), and product is e capacity in gallons.

The carrying power of a stream of water varies as the sixth power its velocity (*Le Conte*).

WEIGHT AND CAPACITY OF DIFFERENT STANDARD GALLONS OF WATER

	Cubic inches in a gallon.	Weight of a gallon in lbs.	Gallons in a cubic foot.	Weight of a cubic foot of water, English standard,
Imperial or English . . .	277.274	10.	6.232102	equal 62.321
United States	231.	8.33111	7.480519	lbs. avoirdupois

Weight of crude petroleum, 6½ pounds per U. S. gallon.
Weight of refined petroleum, 6½ pounds per U. S. gallon.
} 42 gallons to th barrel.

A "miner's inch" of water is approximately equal to a supply o 12 U. S. gallons per minute.

Water presses equally in every direction, and finds its level.

CAPACITY OF FANS AND BLOWERS.

(*Kent.*)

The following tables show the guaranteed air supply and air removal of leading forms of blowers and exhaust fans. The figures given are often exceeded in practice, especially when the blowers and fans are driven at higher speeds than stated. The ratings, particularly of the blowers, are below those generally given in catalogues, but it was the desire to present only conservative and assured practice. (A. R. Wolff on "Ventilation.")

QUANTITY OF AIR SUPPLIED TO BUILDERS BY BLOWERS OF VARIOUS SIZES.

Diameter of wheel in feet.	Ordinary number of revolutions per minute.	Horse power to drive blower.	Capacity cubic feet per minute against a pressure of 1 ounce per square inch.	Diameter of wheel in feet.	Ordinary number of revolutions per minute.	Horse power to drive blower.	Capacity cubic feet per minute against a pressure of 1 ounce per square inch.
4	350	6	10,635	9	175	29	56,800
5	325	9.4	17,000	10	160	35.5	70,340
6	275	13.5	29,618	12	130	49.5	102,000
7	230	18.4	42,700	14	110	66	139,000
8	200	24	46,000	15	100	77	160,000

If the resistance exceeds the pressure of one ounce per square inch of above table, the capacity of the blower will be correspondingly decreased, or power increased, and allowance for this must be made when the distributing ducts are small, of excessive length and contain many contractions and bends.

QUANTITY OF AIR MOVED BY AN IMPROVED FORM OF EXHAUST FAN.

(The fan discharging directly from room into the atmosphere.)

Diameter of wheel in feet.	Ordinary number of revolutions per minute.	Horse power to drive fan.	Capacity in cubic feet per minute.	Diameter of wheel in feet.	Ordinary number of revolutions per minute.	Horse power to drive fan.	Capacity in cubic feet per minute.
2	600	.50	5,000	4	475	3.5	28,000
2.5	550	.75	8,000	5	350	4.5	35,000
3	500	1	12,000	6	300	7	50,000
3.5	500	2.5	20,000	7	250	9	80,000

The capacity of exhaust fans here stated, and the horse power to drive them, are for free exhaust from room into atmosphere. The capacity decreases and the horse power increases materially as the resistance, resulting from lengths, smallness and bends of ducts, enters as a factor. The difference in pressures in the two tables is the main cause of variation in the respective records. The fan referred to in the second table could not be used with as high a resistance as one ounce per square inch, the rated resistance of the blowers.

CAUTION IN REGARD TO USE OF FAN AND BLOWER TABLES.—Many engineers report that manufacturers' tables overrate the capacity of their fans and underestimate the horse power required to drive them. In some cases the complaints may be due to restricted air outlets, long and crooked pipes, slipping of belts, too small engines, etc.

TABLE OF VOLUMES THROUGH AIR-WAYS—CUBIC FEET PER MINUTE.

(*C. H. Ruderer, Engineering and Mining Journal, July 13, 1907.*)

Size of air-way, feet.	Length of air-way, feet.	Rubbing surface, square feet.	Section of air-way, square feet.	Vol. at 1/10″ W. G.	Vol. at 2/10″ W. G.	Vol. at 3/10″ W. G.	Vol. at 4/10″ W. G.	Vol. at 5/10″ W. G.	Vol. at 6/10″ W. G.	Vol. at 7/10″ W. G.	Vol. at 8/10″ W. G.	Vol. at 9/10″ W. G.	Vol. at 1″ W. G	Vol. at 1 1/10″ W. G.	Vol. at 1 2/10″ W. G.	Vol. at 1 3/10″ W. G.	Vol. at 1 4/10″ W. G.
1′ x 1′	1000	4,000	1	80	114	140	152	175	198	213	225	240	250	258	268	272	283
1′ 6″ x 1′ 6″	1000	6,000	2¼	242	344	380	476	544	596	648	688	729	775	810	831	860	909
2′ x 2′	1000	8,000	4	400	576	650	816	920	1,000	1,120	1,195	1,224	1,295	1,348	1,412	1,485	1,531
2′ 6″ x 2′ 6″	1000	10,000	6¼	812	1,125	1,730	1,755	1,781	1,956	2,106	2,250	2,306	2,500	2,637	2,756	2,900	2,981
3′ x 3′	1000	12,000	9	1,125	1,593	2,070	2,250	2,450	2,754	2,970	3,177	3,366	3,537	3,610	3,750	3,880	3,900
3′ 6″ x 3′ 6″	1000	14,000	12¼	1,788	2,523	2,817	3,564	3,981	4,373	4,716	5,047	5,304	5,635	5,900	6,173	6,350	6,651
4′ x 4′	1000	16,000	16	2,656	3,760	3,680	5,328	5,936	6,528	7,056	7,536	7,984	7,904	8,800	9,150	9,600	9,968
4′ 6″ x 4′ 6″	1000	18,000	20¼	2,280	4,171	4,550	6,561	7,320	8,039	8,687	8,748	9,618	10,388	10,700	11,259	11,800	12,291
5′ x 5′	1000	20,000	25	4,500	6,375	8,000	9,000	10,000	11,100	11,915	12,750	13,550	14,250	14,900	15,600	16,275	16,725
5′ 6″ x 5′ 6″	1000	22,000	30¼	5,360	7,562	9,000	10,708	13,300	13,600	14,217	15,155	16,090	16,970	17,840	18,573	19,000	20,055
6′ x 6′	1000	24,000	36	6,912	9,900	12,060	13,968	15,550	17,028	18,396	19,440	20,880	22,030	23,140	24,192	25,128	26,064
6′ 6″ x 6′ 6″	1000	26,000	42¼	8,027	12,421	13,984	16,139	18,040	19,173	21,378	22,941	24,293	25,814	26,820	28,000	29,152	30,420
7′ x 7′	1000	28,000	49	10,000	14,210	17,542	20,188	22,540	24,696	26,705	28,567	29,841	31,997	33,320	34,937	36,946	37,800
7′ 6″ x 7′ 6″	1000	30,000	56¼	12,375	17,660	21,487	24,806	27,840	29,418	33,187	35,210	37,237	39,093	44,620	43,031	44,437	46,462
8′ x 8′	1000	32,000	64	13,952	19,840	23,296	27,906	31,168	33,920	37,120	39,424	41,856	44,160	46,272	48,256	50,304	52,160
8′ 6″ x 8′ 6″	1000	34,000	72¼	16,689	23,698	28,972	32,606	37,425	41,172	44,289	47,213	50,213	52,742	55,632	57,914	60,328	62,718
9′ x 9′	1000	36,000	81	18,630	26,244	32,035	87,179	41,553	44,522	49,167	52,488	59,940	63,018	64,000	65,600	66,987	69,660
9′ 6″ x 9′ 6″	1000	38,000	90¼	21,840	31,865	37,814	43,682	48,737	52,706	58,030	62,137	65,521	67,687	72,470	75,719	78,968	81,766
10′ x 10′	1000	40,000	100	24,000	34,000	40,600	48,400	53,700	59,000	63,840	68,000	72,900	78,000	79,000	83,300	86,700	89,500

For length of air-ways not given in table, multiply volume in table opposite size of air-way and under the pressure W. G. by constant No. opposite length.

TABLE OF VOLUMES THROUGH AIR-WAYS—CUBIC FEET PER MINUTE—CONTINUED.

(*C. H. Ruderer, Engineering and Mining Journal, July 13, 1907.*)

Size of air-way, feet.	Length of air-way, feet.	Rubbing surface, square feet.	Section of air-way, square feet.	Vol. at $1\frac{5}{10}''$ W. G.	Vol. at $1\frac{6}{10}''$ W. G.	Vol. at $1\frac{7}{10}''$ W. G.	Vol. at $1\frac{8}{10}''$ W. G.	Vol. at $1\frac{9}{10}''$ W. G.	Vol. at 2″ W. G.	Vol. at $2\frac{1}{10}''$ W. G.	Vol. at $2\frac{2}{10}''$ W. G.	Vol. at $2\frac{3}{10}''$ W. G.	Vol. at $2\frac{4}{10}''$ W. G.	Vol. at $2\frac{5}{10}''$ W. G.	Vol. at $2\frac{6}{10}''$ W. G.
1′ x 1′	1000	4,000	1	290	300	310	320	330	340	345	353	360	365	372	380
1′ 6″ x 1′ 6″	1000	6,000	2¼	940	974	1,000	1,032	1,068	1,090	1,113	1,140	1,175	1,192	1,233	1,246
2′ x 2′	1000	8,000	4	1,580	1,628	1,680	1,732	1,776	1,800	1,860	1,910	1,950	2,000	2,040	2,080
2′ 6″ x 2′ 6″	1000	10,000	6¼	3,060	3,187	3,281	3,400	3,456	3,462	3,675	3,737	3,843	3,900	4,000	4,062
3′ x 3′	1000	12,000	9	4,050	4,160	4,400	4,600	4,870	5,040	5,130	5,361	5,670	5,517	5,660	5,715
3′ 6″ x 3′ 6″	1000	14,000	12¼	6,909	7,127	7,435	7,570	7,650	7,999	8,200	8,360	8,500	8,722	8,935	9.114
4′ x 4′	1000	16,000	16	10,300	10,640	10,990	11,296	11,500	11,800	12,240	12,544	12,900	13,040	13,328	13,584
4′ 6″ x 4′ 6″	1000	18,000	20¼	12,750	13,122	13,567	13,932	14,316	14,701	15,000	15,450	15,850	16,198	16,422	16,727
5′ x 5′	1000	20,000	25	17,450	18,015	18,570	19,200	19,600	20,150	20,700	21,125	21,700	22,075	22,525	22,875
5′ 6″ x 5′ 6″	1000	22,000	30¼	20,600	21,447	21,930	22,778	23,474	23,980	24,714	25,168	25,800	26,105	26,800	27,431
6′ x 6′	1000	24,000	36	27,000	27,504	28,584	29,592	30,348	31,140	31,932	32,652	33,403	34,128	35,000	35,496
6′ 6″ x 6′ 6″	1000	26,000	42¼	31,307	32,321	33,370	34,240	35,236	37,180	37,530	37,813	38,827	39,588	40,381	41,236
7′ x 7′	1000	28,000	49	38,955	40,817	41,650	42,875	43,855	45,217	46,256	47,334	48,412	49,000	50,400	51,597
7′ 6″ x 7′ 6″	1000	30,000	56¼	48,000	49,781	51,356	52,706	54,281	55,631	56,810	58,217	59,625	60,975	62,040	63,168
8′ x 8′	1000	32,000	64	54,000	55,800	57,216	59,200	61,056	62,400	63,360	65,344	66,880	68,480	69,696	71,168
8′ 6″ x 8′ 6″	1000	34,000	72¼	64,808	66,614	69,360	71,094	72,250	74,700	76,585	78,782	80,269	81,859	83,810	85,471
9′ x 9′	1000	36,000	81	71,928	74,458	76,226	84,240	86,670	87,000	87,500	88,100	89,100	90,963	92,907	94,470
9′ 6″ x 9′ 6″	1000	38,000	90¼	84,654	86,793	89,790	92,500	93,000	98,740	100,000	102,253	105,051	106,946	109,290	111,278
10′ x 10′	1000	40,000	100	93,000	96 300	98,700	102,000	104,200	104,500	110,000	113,000	115,000	117,500	120,000	123,300

For length of air-ways not given in table, multiply volume in table opposite size of air-way and under the pressure W. G. by constant No. opposite length.

TABLE OF VOLUMES THROUGH AIR-WAYS—CUBIC FEET PER MINUTE—CONTINUED.

(*C. H. Ruderer, Engineering and Mining Journal, July 13, 1907.*)

Size of air-way, feet.	Length of air-way, feet.	Rubbing surface, square feet.	Section of air-way, square feet.	Vol. at 2 7/10" W. G.	Vol. at 2 8/10" W. G.	Vol. at 2 9/10" W. G.	Vol. at 3" W. G.	Vol. at 3 1/10" W. G.	Vol. at 3 2/10" W. G.	Vol. at 3 3/10" W. G.	Vol. at 3 4/10" W. G.	Vol. at 3 5/10" W. G.	Vol. at 3 6/10" W. G.	Vol. at 3 7/10" W. G.	Vol. at 3 8/10" W. G.
1' x 1'	1000	4,000	1	385	395	410	415	420	425	432	440	446	452	460	465
1' 6" x 1' 6"	1000	6,000	2¼	1,265	1,282	1,300	1,330	1,354	1,377	1,390	1,417	1,440	1,451	1,482	1,496
2' x 2'	1000	8,000	4	2,120	2,160	2,200	2,240	2,280	2,320	2,360	2,380	2,412	2,440	2,480	2,516
2' 6" x 2' 6"	1000	10,000	6¼	4,143	4,218	4,290	4,306	4,437	4,550	4,600	4,637	4,715	4,800	4,850	4,890
3' x 3'	1000	12,000	9	5,850	5,967	6,066	6,192	6,255	6,363	6,450	6,550	6,600	6,696	6,840	6,957
3' 6" x 3' 6"	1000	14,000	12¼	9,273	9,493	9,777	9,726	9,900	10,094	10,125	10,412	10,633	10,718	10,878	10,939
4' x 4'	1000	16,000	16	13,840	14,160	14,304	14,600	14,800	15,088	15,360	15,520	15,800	15,920	16,256	16,400
4' 6" x 4' 6"	1000	18,000	20¼	17,020	17,115	17,579	17,982	18,200	18,589	18,850	19,176	19,440	19,743	20,027	20,250
5' x 5'	1000	20,000	25	23,425	23,900	24,325	24,575	25,000	25,825	26,000	26,475	26,600	27,100	27,400	27,700
5' 6" x 5' 6"	1000	22,000	30¼	27,981	28,283	28,979	29,400	29,735	30,340	30,800	31,271	31,762	32,116	32,670	33,123
6' x 6'	1000	24,000	36	36,000	36,792	37,512	38,160	38,880	39,384	40,356	40,680	41,200	41,760	42,120	43,000
6' 6" x 6' 6"	1000	26,000	42¼	41,827	42,799	43,517	45,840	44,990	45,714	46,432	47,151	47,827	48,400	49,179	49,850
7' x 7'	1000	28,000	49	52,430	53,410	54,390	54,880	55,252	52,085	58,165	58,800	59,380	60,417	61,446	62,475
7' 6" x 7' 6"	1000	30,000	56¼	64,687	65,000	67,210	68,000	69.187	70,200	71,437	72,225	73,460	74,418	75,543	76,550
8' x 8'	1000	32,000	64	72,512	73,856	75,264	76,800	77,000	73,912	80,320	82,000	82,560	83,712	84,200	86,016
8' 6" x 8' 6"	1000	34,000	72¼	86,700	88,361	90,095	91,757	93,202	94,647	96,670	97,754	98,127	100,280	101,872	102,810
9' x 9'	1000	36,000	81	97,200	98,253	102,300	103,000	104,000	105,300	106,272	108,540	110,160	111,780	112,185	115,000
9' 6" x 9' 6"	1000	38,000	90¼	113,715	115,790	117,686	120,212	121,657	122,400	124,990	127,700	129,418	131,180	132,667	134,000
10' x 10'	1000	40,000	100	123,500	127,500	129,400	133,500	134,000	136,000	138,000	140,000	142,300	144,400	146,500	147,500

For length of air-ways not given in table, multiply volume in table opposite size of air-way and under the pressure W. G. by constant No. opposite length.

TABLE OF VOLUMES THROUGH AIR-WAYS—CUBIC FEET PER MINUTE—CONTINUED.

(C. H. Ruderer, Engineering and Mining Journal, July 13, 1907.)

Size of air-way, feet.	Length of air-way, feet.	Rubbing surface, square feet.	Section of air-way, square feet.	Vol. at $3\frac{9}{10}''$ W. G.	Vol. at 4″ W. G.	Vol. at $4\frac{1}{10}''$ W. G.	Vol. at $4\frac{2}{10}''$ W. G.	Vol. at $4\frac{3}{10}''$ W. G.	Vol. at $4\frac{4}{10}''$ W. G.	Vol. at $4\frac{5}{10}''$ W. G.	Vol. at $4\frac{6}{10}''$ W. G.	Vol. at $4\frac{7}{10}''$ W. G.	Vol. at $4\frac{8}{10}''$ W. G.	Vol. at $4\frac{9}{10}''$ W. G.	Vol. at 5″ W. G.
1′ x 1′	1000	4,000	1	470	478	482	487	492	497	505	514	520	525	530	535
1′ 6″ x 1′ 6″	1000	6,000	2¼	1,500	1,525	1,552	1,577	1,600	1,617	1,633	1,647	1,671	1,687	1,700	1,720
2′ x 2′	1000	8,000	4	2,552	2,590	2,676	2,652	2,680	2,708	2,732	2,768	2,800	2,824	2,852	2,900
2′ 6″ x 2′ 6″	1000	10,000	6¼	4,900	5,000	5,106	5,162	5,200	5,281	5,343	5,406	5,000	5,531	5,581	5,625
3′ x 3′	1000	12,000	9	7,020	7,110	7,155	7,270	7,330	7,400	7,450	7,500	7,600	7,785	7,875	7,965
3′ 6″ x 3′ 6″	1000	14,000	12¼	11,200	11,306	11,500	11,540	11,570	11,845	11,968	12,041	12,237	12,360	12,490	12,607
4′ x 4′	1000	16,000	16	16,848	17,000	17,200	17,280	17,500	17,660	17,872	18,080	18,256	18,480	18,600	18,832
4′ 6″ x 4′ 6″	1000	18,000	20¼	20,513	20,776	20,800	21,323	21,500	21,768	22,000	22,173	22,578	22,720	23,000	23,240
5′ x 5′	1000	20,000	25	27,800	28,625	28,700	28,900	29,300	29,850	30,200	30,600	30,975	31,250	31,525	32,150
5′ 6″ x 5′ 6″	1000	22,000	30¼	33,486	33,910	34,300	34,784	35,000	35,543	35,997	36,301	36,784	37,207	37,631	37,900
6′ x 6′	1000	24,000	36	43,488	43,990	44,300	45,144	45,540	46,296	46,540	47,340	47,772	48,240	48,780	49,320
6′ 6″ x 6′ 6″	1000	26,000	42¼	50,277	52,939	51,670	52,390	53,360	53,657	54,375	54,671	55,389	55,895	56,615	59,150
7′ x 7′	1000	28,000	49	63,210	64,000	64,680	65,415	66,640	67,150	67,875	68,110	69,188	69,825	70,756	71,540
7′ 6″ x 7′ 6″	1000	30,000	56¼	77,906	78,761	79,593	80,437	81,562	82,350	83,360	83,700	85,106	85,950	86,281	89,268
8′ x 8′	1000	32,000	64	87,360	88,320	89,300	90,432	92,032	94,500	95,000	95,500	96,000	96,640	97,536	98,752
8′ 6″ x 8′ 6″	1000	34,000	72¼	104,545	105,485	108,000	108,375	109,675	111,980	112,276	113,793	114,395	115,961	117,117	118,490
9′ x 9′	1000	36,000	81	116,000	117,600	118,600	120,285	121,500	123,120	124,659	125,790	127,494	129,400	130,000	131,500
9′ 6″ x 9′ 6″	1000	38,000	90¼	135,826	138,263	139,850	141,692	143,226	144,309	146,380	148,190	149,818	151,250	152,242	155,108
10′ x 10′	1000	40,000	100	150,000	153,500	154,000	155,000	157,500	158,000	161,200	163,000	164,500	165,200	168,200	170,000

For length of air-ways not given in table, multiply volume in table opposite size of air-way and under the pressure W. G. by constant No. opposite length.

TABLE OF VOLUMES THROUGH AIR-WAYS—CUBIC FEET PER MINUTE—CONTINUED

(*C. H. Ruderer, Engineering and Mining Journal, July 13, 1907.*)

Length of air-way . . . feet, 2,000 . . . Constant = .72

Length of air-way . . . feet, 3,000 . . . Constant = .62

Length of air-way . . . feet, 4,000 . . . Constant = .47

Length of air-way . . . feet, 5,000 . . . Constant = .45

Length of air-way . . . feet, 6,000 . . . Constant = .43

Length of air-way . . . feet, 7,000 . . . Constant = .40

Length of air-way . . . feet, 8,000 . . . Constant = .37

Length of air-way . . . feet, 9,000 . . . Constant = .34

Length of air-way . . . feet, 10,000 . . . Constant = .31

Length of air-way . . . feet, 11,000 . . . Constant = .29

EXAMPLE:

How much air C. F. can be passed through 8′ x 8′ air-way under 3″ W. G. air-way 5000 feet long?

Looking in table, we find under 3″ and opposite 8′ x 8′ volume, 76,800 C. F.

For air-way 5000′ long, volume = Constant × 76,800 = 76,800 × .45 = 34,500 C. F.

NOTE.—Table is calculated from Atkinson's formulæ:

$Q = \frac{P \times A}{K \times S} \times A \quad K = .0000000217.$

THE PULSOMETER STEAM PUMP.

As made by the Pulsometer Steam Pump Co., 16 Battery Place, New York.

THE NEW PULSOMETER

The pulsometer is a simple piece of casting, formed in one piece, consisting of a pair of chambers called working chambers, side by side, joined at their top ends by tapering necks with a third chamber situated between them. These three chambers are connected at or near their bottom ends with certain passages, which are covered with suitable valves, and are also provided with an inlet and outlet opening for water, and at their top ends with means for connecting with a steam pipe leading to boiler.

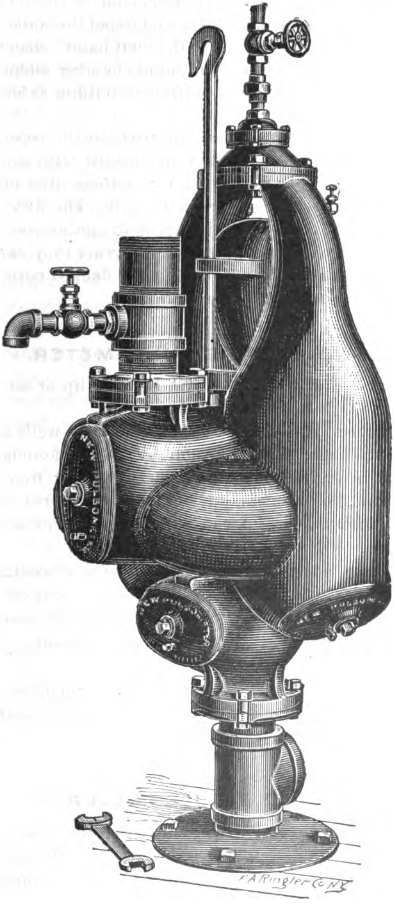
OPERATION.

It is only necessary to place the pulsometer in the desired position, and connect it with the proper suction and delivery pipes and with a steam supply, when it will, by simply opening the steam valve as per directions, perform within its scope all that the most complicated steam piston pump can do.

Its two working chambers fill and discharge alternately just the same as a steam pump, but it has no piston. The level surface of the water within the chamber serves as a most perfect piston in the action of the pulsometer.

EXPLANATION.

The steam enters at the top, or neck, of pump and passes into whichever chamber the position of the steam ball valve permits, and pressing upon the surface of the water therein forces it down and out past the discharge valves and through the discharge pipe. So soon as the water line has been forced downward to the discharge outlet, the steam above it instantly condenses, owing to the peculiar construction of the pulsometer, and a nearly perfect vacuum is formed and the chamber in consequence suddenly fills again.



PERSPECTIVE VIEW.

Now, while the steam is entering this chamber, which we will designate as the "left-hand" one, the steam ball valve is seated over the entrance to the "right hand" chamber preventing the entrance of steam thereto, but so soon as the sudden collapse of steam occurs it is instantly drawn over to its seat at the entrance to the "left hand" chamber, thus cuts off the admission of steam thereto and allows it to enter the other chamber and expel the water therefrom in the same manner as described for the "left hand" chamber.

The steam and water occupy the same chamber alternately, and will thus alternate, keeping up a continuous outflow as long as steam and water are supplied.

There being absolutely no working parts in the construction of the pulsometer, it is obvious that water loaded with *sand*, *grit* or *thick mud* may be pulsated through it with as little injury to its interior as to the pipes leading to and from it. The disks of rubber which serve as valves in the lower part of the pulsometer are of the simplest form, and while they will last for years they can be interchanged for new in a few minutes. Suitable flanged covers are provided for this purpose, as is shown in the cut.

USES FOR THE PULSOMETER.

Requiring no foundation, it may be hung up or set down in a convenient place.

In a suspended position, it is used for sinking wells and shafts, and in positions where it is impossible to make a foundation for a pump, it may be hung from a projecting beam or from a pole or tripod, and arranged with suitable tackle to be lowered or raised at will. Suitable flexible steam and water connections are provided for the purpose.

Also in quarrying and rock excavations, where blasting is necessary, the pulsometer may be in a moment lifted out of danger by means of the derrick, and be immediately placed in position again when blasting operations are over. It has no breakable parts to be injured by rough usage.

In its capability of suspension in operation, and of being lowered and raised and swung about without interrupting its work, the pulsometer stands without a rival.

THE NEW PULSOMETER.

The illustration, page 90, represents in section the form of the pulsometer, which in design and construction and universal scope of usefulness, will be found to combine maximum durability, efficiency, simplicity and strength with minimum weight, size and operative expenditure.

Its operation is sustained by steam pressure brought to bear directly upon the liquid as the forcing element, while the subsequent condensation of the same furnishes the lifting force to supply the pump, which action is maintained by the purely functional conditions of alternate pressure and vacuum.

DESCRIPTION.

The main body of the pulsometer, as shown in the perspective cut on page 87, and the sectional cut on page 90, is a casting made in one piece and consisting of two bottle-shaped chambers A, A, placed side by side. These are called working chambers. They taper toward each other at their upper halves and meet at their upper ends at a point at which is situated the steam valve ball C. This oscillates with a slight rolling motion between seats (with which it makes a steam tight joint) formed at the upper entrance to each of the already mentioned working chambers A, A.

The portion B of the pump, containing the steam valve ball C, is called the neck piece, and is a separate casting bolted to the main body of the pump, so that it can be readily removed for renewal when necessary. To the upper part of this neck piece B is bolted the neck cap, into which the steam supply pipe is screwed.

The openings communicating between the chambers A, A, and the induction, or foot valve, chamber D, are covered by suitable valves E, E, called suction valves, their valve seats F, F, and valve guards I, I, which latter prevent the valves from opening too far.

A third chamber J, called the vacuum chamber, situated behind the chambers A, A, at their lower halves, and between them at their upper, or tapering halves, communicates with them through the round opening in the induction or foot valve chamber D.

A fourth chamber, called the discharge chamber, situated on the lower side of the working chambers A, A, opposite to the vacuum chamber J, and represented by the dotted lines in the sectional view on page 90, communicates with each of the working chambers A, A, by passages at the lower half of its intersection with these chambers. This discharge chamber contains the discharge valves E, E, their valve seats G, G, and the valve guards I, I, which cover the passages leading from the chambers A, A.

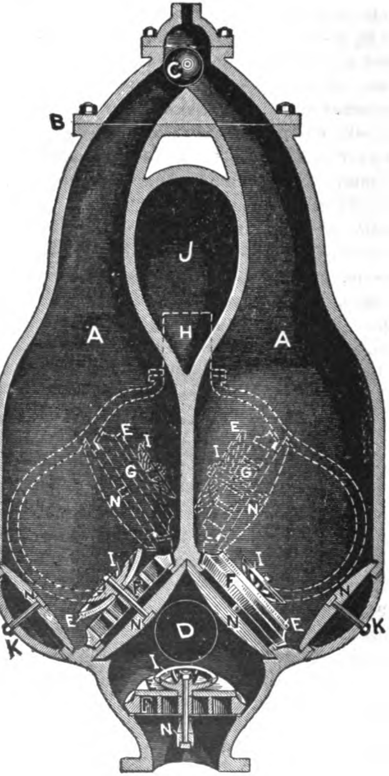
The delivery pipe H connects with the discharge opening in the top of the discharge chamber by means of a flanged joint.

The induction, or foot valve chamber D, contains the valve E, its valve seat F, and the guard I, which serve the purpose of holding the charge of water in the pump. The lower end of this chamber is connected to the suction pipe by a flanged joint.

K, K are oval plates covering the openings through which the seat, valve and guard are inserted to the respective chambers, and are fastened in position by means of strong clamps and bolts N, N. The ends of these clamps fit loosely into suitable recesses and are thus held in position while the cover plates are being applied.

Another set of similar clamps and bolts serve, in a like manner, to fasten the seats, valves and guards in place.

The object in employing four openings to the pump, instead of two, is to make it possible and convenient to get at every square inch of



SECTIONAL VIEW.

the interior for thorough examination, chipping and cleaning of the new casting, and ease of removing any deposit that certain classes of work might help to form on the walls of the chambers, and which could not be reached otherwise.

Vent plugs are inserted in the cover plates for the purpose of draining off the water in the pump to prevent its freezing.

Near the top of each of the working chambers A, A and of the vacuum chamber J is a small tapped hole, into which is screwed a brass air check valve, so that its check hangs downward. The air check valves in the chambers A, A allow a small quantity of air to be automatically admitted above the water and ahead of the steam, separating the steam and the water upon their first entrance, thus preventing condensation and forming an air piston, ever new and always tight. The air check valve in the chamber J likewise admits air automatically, which serves to cushion the ram action of the water consequent upon the alternate filling of each of the chambers A, A.

It will be seen from the foregoing that the pulsometer combines, in its design and construction, maximum durability, simplicity and strength with minimum size and weight.

Our improved pattern, while not differing in any essential from the old pattern, has been considerably simplified in construction, making it more compact, with fewer parts, and its interior much easier of access for inspection and cleaning or renewal of valves when necessary.

ADVANTAGES.—Its capability of suspension in operation, and of being lowered and raised and swung about without interrupting its work.

Requires no foundation.

Cheapness in first cost and operation.

The following examples of work done by a pulsometer were kindly given to the writer by Major S. Canby, Park Engineer, Wilmington, Del.:

Actual work done.—EXAMPLE 1.—Steam conveyed 400 feet from boiler to pulsometer. Pressure at boiler, 60 to 80 pounds; pressure at pulsometer, 40 pounds. With these conditions, the pulsometer pumped a semi-fluid material largely composed of clay up 20 feet, and the material was so solid that it required to be shoveled away from the discharge pipe.

EXAMPLE 2.—In this case the pulsometer was in a hole and covered with 5 feet of water and inaccessible. When steam was turned on the pulsometer pumped the hole dry in a comparatively short time.

In comparing "The Pulsometer" with the regular direct-acting steam pump of *the best makers*, it will not exert as great power, and therefore is not capable of as great a lift and cannot force water so high as the direct-acting steam pump.

But for moderate lifts its cheapness and simplicity of construction and operation recommend it.

PRICES AND SPECIFICATIONS OF THE NEW PULSOMETER.

Size of pipes, inches.				Capacity in gallons per minute at different elevations with boiler power and steam pressure usually provided. (Approximate.)				List prices.			Dimensions and weights.			
Number.	Steam.	Suction.	Discharge.	25 feet.	50 feet.	75 feet.	Horse power required.	Flat valve. (Standard.)	Ball valve. (Special.)	Composition metal.	Number.	Height, inches.	Floor space, inches.	Weight, pounds.
2	1/4	1 1/2	1 1/2	20	17	13	4	$75	$79	On application.	2	25	14 x 13	95
3	3/8	2	2	60	50	38	5	100	106		3	27	17 x 14	140
4	1/2	2 1/2	2 1/2	100	80	65	6	150	158		4	33	19 x 19	295
5	1/2	3	3	180	160	115	9	175	187		5	38	21 x 22	430
6	3/4	3 1/2	3 1/2	300	265	200	12	225	241		6	43	23 x 24	570
7	3/4	4	4	425	375	275	15	275	300		7	49	25 x 26	745
8	1	5	5	700	625	450	25	400	440		8	61	32 x 33	1,375
9	1 1/2	7	6	1,000	900	650	35	500	550		9	72	38 x 36	2,100
10	2	8	8	2,000	1,800	1,400	70	1,000	. .		10	88	52 x 45	3,800

The price includes suitable strainer, either basket or mushroom, steam-controlling globe valve with nipple and union, and relief valve. The capacities given are estimated from results obtained in actual practice and are rather underrated, better results being obtained in most cases, especially so where conditions are favorable as to short suction, high steam pressure, etc. Flat valve pumps are used for all general purposes. Ball valve pumps are used only for pumping liquids containing foreign matter, as waste of breweries, slaughter houses, pulp in paper mills, tan liquors, etc. Gun metal pumps are used only for handling chemicals, liquids liable to crystallize, acids, etc., that are destructive to cast iron.

SPECIFICATIONS OF UPRIGHT TUBULAR STEEL BOILERS.

Adapted to each size pulsometers.

No. of pump.	Gallons per minute.	Horse power.	No. of boiler.	Diameter of boiler.	Height of boiler.	Diameter of furnace.	Height of furnace.	No. of 2 in. tubes.	Length of tubes.	Heating surface.	Approx. weight complete.
				In.	Ft.	In.	In.		In.	Sq. ft.	Lbs.
2	20	4	1	24	4	20	24	31	24	45	1180
3	60	5	2	24	5	20	24	31	36	60	1280
4	110	6	3	24	6	20	24	31	48	75	1380
5	175	9	5	30	6	25	27	50	45	118	1960
6	300	12	6	30	7	25	27	50	57	148	2160
7	425	15	8	36	7	31	27	68	57	186	2980
8	750	23	10	42	8	37	33	88	63	280	4000
9	1100	31	12	42	10	37	33	88	87	383	4600
10	2200	41	14	48	10	43	33	124	87	500	6025

These boilers are made for a working pressure of 100 lbs. and are tested at 150 lbs. hydrostatic pressure per square inch.

HOISTING ENGINES.

Hoisting engines are in such universal use on all public works, quarries, mines, etc., that a few remarks on this subject, together with tables, are here given, as compiled from catalogue of the Lidgerwood Manufacturing Company of New York, the well-known manufacturers of hoisting engines, boilers and suspension cableways.

SINGLE CYLINDER FRICTION DRUM PORTABLE HOISTING ENGINE, with boiler and fixtures complete on bed plate. Specially adapted for pile-driving, railroads, contractors, bridge builders, coal yards, docks, ships, quarries and general hoisting. This engine made with or without foot brake.

Foot brakes are recommended, as they save wear on the drum friction, although they are not actually required, as improved friction drum answers for all ordinary lowering purposes. When it is desired to lower heavy weights, or long distances, or to use engine for other purposes, while the weight hoisted hangs suspended, then foot brakes should be used. They can be applied to any engine without them at any time.

Dock wheels are of cast iron, and their axle is clamped to bed plate. They are suitable for moving engine on docks or on a smooth surface.

DOUBLE CYLINDER FRICTION DRUM PORTABLE HOISTING ENGINE, WITH BOILER AND FIXTURES COMPLETE.

Specially adapted for Pile-Driving, Railroads, Contractors, Bridge Builders, Quarries, Docks, Coal Yards, Ships and General Hoisting Duty.

The double cylinder engines are similar in all respects to the single cylinder engines described above, except that they have the special feature of having no centers—the engines being connected at an angle of 90°—thus being much easier to start, handle, etc. This is of special importance for many kinds of hoisting, particularly for quarry and other heavy work, as they are always ready to start the load easily and steadily, while a single cylinder engine will occasionally get caught on the center. We therefore recommend the double cylinder engines for all general hoisting purposes where these advantages more than outweigh the difference in the first cost of the engine. Injectors are supplied for feeding the boilers, instead of pumps, as on the single cylinder engines. Foot brakes are recommended, although not actually required for ordinary hoisting purposes, except where it is desired to lower heavy weights, or long distances, etc.

HOISTING ENGINES WITHOUT BOILERS ATTACHED are adapted where there is danger from fire, as on docks, in certain mines, etc.

They are also adapted for all purposes where a compact and simple engine is required. They are very portable and convenient for use in tunnels and all places where it would be impossible to erect a boiler.

A boiler can be set at a distance to run one or more of these engines.

They can be handled either at engine or at a distance.

If desired, compressed air can be used with these engines.

These engines are lower in price than those with boiler attached, for equal power.

HOISTING ENGINES WITH DOUBLE FRICTION DRUMS.

Hoisting engines of both of the above types are also made with double friction drum, operated with either single or double cylinder.

These engines adapted where two *independent* drums are required.

For quarrying or heavy hoisting and general work, the *double cylinder* is recommended.

For pile-driving, the *single cylinder* does excellent work. A band fly wheel is attached to the crank shaft, and is properly turned off to receive belting for running a saw for cutting off piles or furnishing power for other purposes. Each drum has ratchets and pawls for holding a weight suspended on one drum while the other is used, or while winch head on the same drum is being operated. Or the boom of a derrick can be held while the other drum hoists the load.

Foot brakes recommended for each drum, although not absolutely necessary for pile-driving work. There is a winch head on the outer end of each drum shaft.

A single acting plunger pump, driven by an eccentric, is attached to the engine for feeding the boilers.

SINGLE CYLINDER FRICTION DRUM PORTABLE HOISTING ENGINE

TABLE OF SIZES.

Size number of engine.	Horse power, usually rated.	Dimensions of cylinder.		Weight hoisted, single rope, usual speed, lbs.	Suitable weight of pile-driving hammer for quick work, lbs.	Dimensions of hoisting drum.			Dimensions of bed plate.		Dimensions of boiler.			Estimated shipping weight complete, lbs.
		Diameter, inches.	Stroke, inches.			Diameter body between flanges, inches.	Length body between flanges, inches.	Diameter flanges, inches.	Width, inches.	Length, inches.	Diameter shell, inches.	Height shell, inches.	Number of 2 inch tubes.	
1	4	5	8	1200	1000	10	20	22	38	60	28	63	40	3550
2	6	6¼	8	1500	1250	10	20	22	38	60	28	69	40	3950
2½	8	6¼	10	1750	1500	12	20	24	41	73	30	72	44	4850
3	10	7	10	2500	1800	12	20	24	41	73	32	75	48	5050
3½	11	7	10	2500	2000	14	22	26	45	73	34	78	52	5350
4	12½	8¼	10	4000	2500	14	23	29	47	73	36	75	57	6550
4½	15	8¼	10	4000	2800	14	23	29	47	73	36	81	57	6750
5	20	8½	12	6000	4000	16	26	33	54	84	40	84	80	8500
6	25	10	12	8000	5000	16	26	33	54	84	42	90	88	9500

DOUBLE CYLINDER SINGLE FRICTION DRUM HOISTING ENGINE WITH BOILER FOR PILE-DRIVING, RAILROADS, CONTRACTORS, QUARRIES, DOCKS, COAL YARDS AND GENERAL HOISTING.

TABLE OF SIZES.

Size number of engine.	Horse power usually rated.	Dimensions of cylinder.		Weight hoisted, single rope, usual speed, lbs.	Suitable weight of pile-driving hammer for quick work, lbs.	Dimensions of hoisting drum.			Dimensions of bed plate.		Dimensions of boiler.			Estimated shipping weight complete, lbs.
		Diameter, inches.	Stroke, inches.			Diameter body between flanges, inches.	Length body between flanges, inches.	Diameter flanges, inches.	Width, inches.	Length, inches.	Diameter shell, inches.	Height shell, inches.	Number of 2 inch tubes.	
6½	6	5	6	1,500	1,000	10	20	22	40	57	30	72	44	3,765
7	8	5	8	2,000	1,500	12	22	24	47	67	32	75	48	5,150
8	12	6¼	8	3,000	2,000	14	22	26	50	71	36	75	57	6,275
8½	16	6¼	10	4,000	2,800	14	26	26	54	75	38	81	57	7,350
9	20	7	10	5,000	4,000	14	26	26	54	75	40	84	80	7,950
10	30	8¼	10	8,000	6,000	14	27	29	57	79	42	90	88	9,275
11	40	8½	12	10,000	8,000	16	32	36	70	97	50	102	115	15,000
12	50	10	12	12,000	9,000	16	32	36	70	97	53	102	124	18,000

NOTE.—Reversible link motion and friction drum engines combined made to order. The drums are thereby shortened about three inches.

TRAMWAYS AND NARROW GAUGE RAILWAYS.

This form of track is much in use among contractors and others interested in our public works, therefore we give some few practical rules and data with the hope that they may be of use and interest.

WEIGHT OF RAILS, ETC.

The most common weights used are 16, 20, 25, 30 and 35 lbs. per yard.

TABLE (Original).

Weight of rail, in pounds per yard.	Size of spike used, in inches.	Number of spikes to keg of 200 pounds.	Weight of spikes in pounds per mile. Cross ties 2 feet apart, c. to c.
16	$3\frac{1}{2}$ x $\frac{3}{8}$	1190	1780
20	4 x $\frac{7}{16}$	720	2940
25	4 x $\frac{1}{2}$	600	3520
30	$4\frac{1}{2}$ x $\frac{1}{2}$	530	3960
35	$4\frac{1}{2}$ x $\frac{1}{2}$	530	3960

To get weight per mile of *any rail* needed for one mile of single track in tons of 2240 lbs. Multiply the weight per yard by 11 and divide product by 7.

EXAMPLE.—What weight in tons of 2240 lbs. of 16 lb. rail will lay one mile of track? $16 \times 11 = 176$. $176 \div 7 = 25$ tons 320 lbs.

Rails are regularly sold by the ton of 2240 lbs. The length of rails as usually sold is 90 per cent. 30 feet long, and 10 per cent. 24 and 28 feet long, requiring 357 splice joints per mile.

SPLICE JOINTS PER MILE.

(2 bars and 4 bolts and nuts to each joint.)

Rails 20 feet long = 528 joints.
Rails 24 feet long = 440 joints.
Rails 26 feet long = 406 joints.
Rails 28 feet long = 378 joints.
Rails 30 feet long = 352 joints.

Weights of splice joints vary according to their length, and also size of bolts. The general shape of rails, as well as their weight per yard, also controls the weight of splice joints. Splice joints are sold both by the piece and by weight. The average weight of splice joints (complete with 2 bars and 4 bolts and nuts) is:

For rails of 16 to 20 lbs. per yard, each joint weighs 5 to 6 lbs.
For rails of 24 to 28 lbs. per yard, each joint weighs 6 to 8 lbs.
For rails of 30 to 35 lbs. per yard, each joint weighs 10 to 12 lbs.

To find the size of rail needed for a locomotive: [H. K. Porter & Co.] multiply the number of tons (of 2000 lbs.) on *one* driving wheel by 10, and the result is the number of lbs. per yard of the lightest rail advisable. Where there is greater weight on one set of driving wheels than the other, the heavier must be taken. This rule only approximate.

CROSS TIES NEEDED FOR ONE MILE OF SINGLE TRACK.

Center to center, in feet.	Ties.
1½	3520
1¾	3017
2	2640
2¼	2348
2½	2113

AVERAGE WEIGHTS AND CAPACITIES OF CARS (NARROW GAUGE).

Description.	Weight of car.	Capacity.
Contractor's four wheel dump car	4000 pounds	3 cubic yards
	2500 pounds	2 cubic yards
Contractor's rotary dump car	3775 pounds	3 cubic yards

A cubic yard of loose earth weighs 2200 to 2600 pounds.

A cubic yard of wet sand weighs 3000 to 3500 pounds.

A cubic yard of broken rock weighs 2600 to 3000 pounds.

GRADES.—It may be economy to retain easy grade as long as possible, and then introduce steep grade, which may be overcome by momentum of train or by extra locomotive used as pusher.

REDUCE GRADES ON CURVES.

GAUGE must be widened on curves.

SHARP CURVES should be avoided as much as possible.

VERY LIGHT RAILS NOT ECONOMICAL.

WOODEN RAILS.—The best wood is maple, laid with heart up; heart pine used in the South.

The simplest form of wooden rails is a stringer in 16 to 20 feet lengths; 5 inches square good average size. When worn, wooden rails may be turned over. Where best wood, such as maple, is scarce, a strip of maple of the width of stringer, and say 1 inch thick, may be nailed upon some cheaper wood, as white oak; strip can be replaced when worn. Ties for wooden rails spaced 2 to 4 feet apart, and are say 6 inches square, and at least 3 feet longer than width of track. Ties cut out accurately to receive rails. The recess should be about 3 inches deep, and be at top of face of the tie 1 inch, and at the bottom of the recess 1½ inch wider than the rail. The inner faces of the recesses are perpendicular, and the distance between them is the gauge of the track. The bottom of recess should be level, and ties laid well to afford proper bearing for the stringer.

Wedges, which are best made from the ends of stuff left from rails, are driven on the outside of the rails. They are made of right shape to fit the space left; the reason for making this space wider at the bottom than at the top is to keep the wedges from working up.

Disadvantages of wooden rails. Wooden rails waste power, are very slippery in wet or freezing weather, require constant repairs and necessitate very slow speed.

The disadvantages of this form of track are greatly reduced by nailing light strap iron (not steel) upon the stringers. This gives better wear, greater tractile force and the iron is worth something as scrap when worn out.

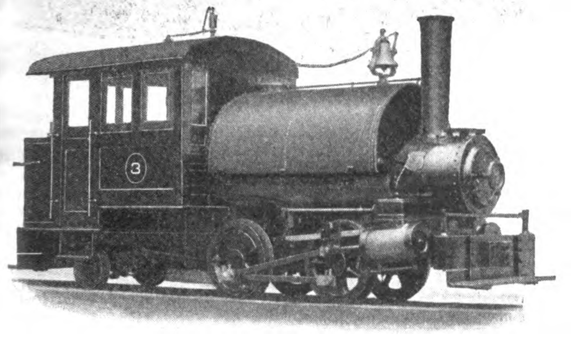
LIGHT LOCOMOTIVES.

The subject of locomotives and motors is so exhaustive that we are only able to give a few hints as to power, work, etc., and would refer those interested in the subject to the manufacturers, the works of H. K. Porter & Co., of Pittsburgh, Pa., being one of the largest and best, the company gladly giving any information required. The following matter is compiled from their catalogue:

LIGHT "BACK-TRUCK" LOCOMOTIVES.

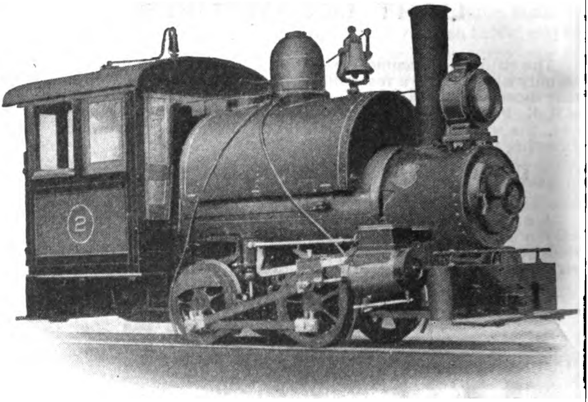
For Logging Railroads and Similar Service.

Are adapted to logging and plantation railroads, where track is uneven and the speed slow; for switching and shifting, where heavy loads are to be stopped and started promptly; and for local passenger traffic, where the speed is fast and frequent stops are made.



Cylinders { diameter, inches	6	7	8	9	10
Cylinders { stroke, inches	10	12	14	14	14
Diameter of driving wheels, inches	24	28	30	33	33
Diameter of truck wheels, inches	16	16	18	20	20
Rigid wheel base, feet and inches	3-6	4-0	4-0	4-6	4-6
Total wheel base, feet and inches	9-7	10-7	11-8	12-2½	12-2½
Length over bumpers, feet and inches	16-0	17-0	18-3	19-6	21-0
Extreme height above rail, feet and inches	9-6	9-8	9-10	10-0	10-3
Weight in working order, pounds	15,000	21,000	26,000	30,500	35,500
Weight on driving wheels, pounds	11,000	15,500	20,000	23,500	28,000
Weight on two-wheel truck, pounds	4,000	6,000	6,000	7,000	7,500
Water capacity of tank, gallons	150	200	300	350	400
Fuel capacity { coal, pounds	300	400	600	700	800
Fuel capacity { wood, cubic feet	20	25	30	35	40
Weight per yard of lightest rail advised, pounds	14	16	20	25	25
Radius of sharpest curve advised, feet	60	70	80	90	90
Radius of sharpest curve practicable, feet	45	50	55	60	60
Boiler pressure per square inch, pounds	150	150	150	150	150
Tractive force, pounds	1910	2680	3810	4375	5415

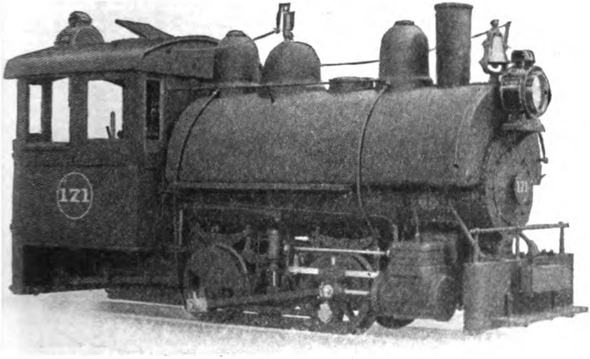
NEW DESIGN CLASS B-S LIGHT LOCOMOTIVES.



These engines are designed for special service, contractor's work and other work where the run is not long, on wide or narrow gauge, where a simple design with power is needed without special capacity for speed. The 8 x 14 and 9 x 14 are useful for light work on wide gauge; smaller than 7 x 12 is rarely advisable on wide gauge. The 5 x 10 is adapted for very narrow gauges, and is only advisable for easy work. These engines are well balanced and easy in their motion, being equalized across at front drivers. They are adapted to sharp curves and heavy grades. The proper speed with load is 6 to 10 miles per hour.

Cylinders { diameter, inches	5	6	7	8	9	10
Cylinders { stroke, inches	10	10	12	14	14	14
Diameter of driving wheels, ins.	20	20	24	28	28	30
Wheel base, feet and inches	4-0	4-0	4-8	5-0	5-3	4-6
Length over bumpers, ft. and ins.	11-0	11-6	12-9	14-0	15-4	16-9
Extreme height above rail, feet and inches	9-4	9-6	9-8	9-10	10-0	10-3
Weight in working order, all on driving wheels, pounds	11,500	14,000	17,500	23,000	27,000	32,000
Water capacity of tank, gallons	125	150	200	250	325	400
Fuel capacity { coal, pounds	200	200	250	300	350	450
Fuel capacity { wood, cubic feet	15	18	20	20	25	25
Weight per yard of lightest rail advised, pounds	14	16	16	20	25	30
Radius of sharpest curve advised, feet	30	30	35	35	40	35
Radius of sharpest curve practicable, feet	15	15	16	18	20	18
Boiler pressure per sq. in., lbs.	150	150	150	150	150	150
Tractive force, pounds	1,590	2,290	3,125	4,075	5,160	5,960

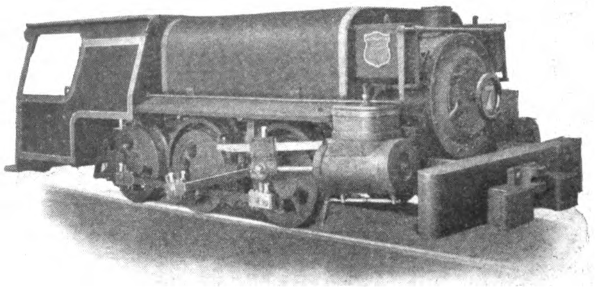
NEW DESIGN EXTRA POWERFUL CONTRACTOR'S LOCOMOTIVE.



The above illustration shows our new design narrow gauge "stopped-off frame" locomotive. For narrow gauges the main frames are stopped in front of the firebox with a heavy steel cross brace and tie plate connection to the rear frames; this construction secures a full width straight side large firebox and large free steaming boiler in combination with a perfectly balanced engine very easy on the track, and extremely strong and rigid frame construction, avoiding any strains from pulling or pushing trains affecting the boiler. For wide gauges, continuous frames are used. These locomotives are built with best forged iron frames, case-hardened forged steel skeleton links, steel crossheads, and all details to give the longest wear. They are built to duplicate system and duplicate parts kept on hand in stock. The 10 x 16 size is most generally used by contractors and is kept on hand completed in stock, both 36 inch and 56½ inch gauge.

Cylinders { diameter, ins	10	10	11	11	12	12	13
Cylinders { stroke, inches	14	16	14	16	16	18	18
Diam. of driving wheels, inches	30	30	30	33	36	36	36
Wheel base, feet and ins.	4-6	5-3	4-6	5-3	5-0	5-9	6-3
Length over bumpers, feet and inches	16-9	18-2	18-0	18-6	19-0	20-0	21-6
Extreme height above rail, feet and inches	10-3	10-3	10-3	10-9	11-3	11-6	12-0
Weight in working order on driving wheels, lbs.	32,000	36,000	39,000	42,000	47,000	51,000	58,000
Water capacity of tank, gallons	400	500	500	600	700	750	800
Fuel capacity { coal, lbs.	450	800	800	1,000	1,100	1,200	1,300
Fuel capacity { wood, cu. feet	25	30	30	30	35	35	40
Weight per yard of lightest rail advised, pounds	30	35	35	40	40	45	50
Radius of sharpest curve advised, feet	35	35	40	45	45	50	60
Radius of sharpest curve practicable, feet	18	25	25	25	25	30	35
Boiler pressure per square inch, pounds	160	160	160	160	160	160	160
Tractive force, pounds	6,350	7,250	7,680	7,970	8,710	9,800	11,500

SIX WHEEL CONNECTED STEAM MINE LOCOMOTIVE.



It is possible for these six wheel connected mine locomotives to pass around curves of 30 to 50 feet radius, but we advise 75 feet as shortest radius desirable.

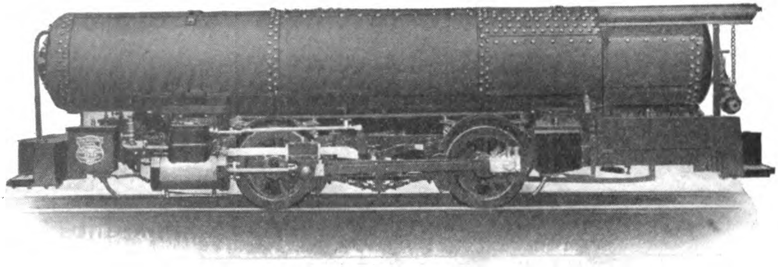
SIX WHEEL CONNECTED STEAM MINE LOCOMOTIVE.

Cylinders { diameter, inches	6	7	8	9	10	11	12	13	14
Cylinders { stroke, inches	10	12	14	14	14	14	16	16	18
Diameter of driving wheels, inches	18	22	24	26	28	28	33	33	36
Wheel base, feet and inches	4-8	4-8	5-0	5-0	5-6	6-3	7-0	7-6	8-6
Length over bumpers, feet and inches	12-6	13-1	14-7	17-0	18-0	19-0	21-0	21-10	24-0
Excess of width at cylinders over gauge of track, feet and inches	2-1½	2-3⅜	2-5¼	2-7⅜	2-9⅞	3-3/8	3-1⅞	3-6¼	3-8⅛
Height above rail least desirable, feet and inches	5-0	5-4	5-9	6-0	6-3	6-7	6-8	7-0	8-0
Height above rail least practicable, feet and inches	4-6	5-0	5-4	5-7	5-9	5-11	6-0	6-3	6-10
Weight in working order, pounds	15,000	19,000	24,000	29,000	34,000	40,000	48,000	56,000	68,000
Capacity of tank, gallons	175	200	275	325	400	500	600	750	900
Weight per yard of lightest rail advised, pounds	12	16	16	20	25	25	30	35	45
Radius of sharpest curve advised, feet	30	30	45	45	50	55	65	75	100
Radius of sharpest curve practicable, feet	20	20	25	30	35	40	50	55	75
Boiler pressure per square inch, pounds	150	150	150	150	150	150	160	160	165
Tractive force, pounds	2,550	3,420	4,760	5,560	6,375	7,720	9,495	11,150	13,740

FOUR WHEEL CONNECTED STEAM MINE LOCOMOTIVE.

Cylinders { diameter, inches	5	5	6	7	8	9	10	10	11	11	12	13	14
Cylinders { stroke, inches	8	10	10	12	14	14	14	16	14	16	16	16	18
Diameter of driving wheels, inches	20	20	20	23	26	28	30	30	30	33	33	33	36
Wheel base, feet and inches	3-0	3-6	4-0	4-0	4-0	4-6	4-6	5-3	4-6	5-3	5-9	6-3	6-3
Length over bumpers, feet and inches	10-0	10-10	11-7	14-4	14-9	16-6	16-9	18-0	17-9	18-4	19-6	21-6	22-0
Excess of width at cylinders over gauge of track, feet and inches	1-11¼	2-1½	2-1½	2-3⅜	2-5¼	2-7⅜	2-9⅞	2-11¼	3-0	3-3/8	3-1⅞	3-6¼	3-8⅛
Height above rail least desirable, ft. and ins.	4-10	5-0	5-2	5-4	5-7	5-9	5-11	6-1	6-3	6-4	6-6	7-0	8-6
Height above rail least practicable, ft. and ins.	4-4	4-6	4-7	4-9	5-0	5-2	5-5	5-6	5-8½	5-9	6-0	6-6	7-9
Weight in working order, pounds	9,000	11,000	14,000	17,000	23,000	27,000	31,000	36,000	38,000	40,000	47,000	55,000	66,000
Capacity of tank, gallons	80	100	125	200	250	300	400	500	500	500	600	700	800
Weight per yard of lightest rail advised, lbs.	12	14	16	20	20	25	30	35	35	40	45	50	60
Radius of sharpest curve advised, feet	20	22	25	25	25	30	30	35	30	35	45	50	60
Radius of sharpest curve practicable, feet	12	12	15	15	15	16	16	20	16	20	25	30	50
Boiler pressure per square inch, pounds	150	150	150	150	150	150	150	150	150	160	160	160	160
Tractive force, pounds	1,275	1,590	2,290	3,265	4,390	5,160	5.960	6,800	7,200	7,970	9,495	11,150	13,830

COMPRESSED AIR MINE LOCOMOTIVE, TWO TANKS, FOUR DRIVING WHEELS.



We give below some notes on this form of locomotive, of which, to the best of our knowledge, H. K. Porter & Co., Pittsburgh, Pa., and the Baldwin Locomotive Co. are the principal manufacturers.

Compressed air locomotives are recommended where no risk of fire, however slight, can be permitted, or where steam locomotives would interfere with ventilation, as in some mines, or where fire damp is present.

They are therefore recommended for use in badly ventilated mines, powder mills, arsenals, oil refineries, cotton mills, rope walks, lumber yards, etc.

Advantages.—Air locomotives are easier to run and less expensive to keep in order than steam locomotives since there is no fire to keep up. They are wholly free from steam, smoke or gas, and improve instead of vitiating the air; being absolutely fireless, they are perfectly safe even where fire damp is present. (See table, p. 97.)

COMPRESSED AIR MINE LOCOMOTIVE, TWO TANKS, FOUR DRIVING WHEELS.

Cylinders { diameter, inches	5	6	7	8	9	10
Cylinders { stroke, inches	10	10	12	14	14	14
Diameter of driving wheels, inches	20	23	24	24	26	26
Wheel base usually desirable, ft. and ins.	4-0	4-0	4-8	5-3	5-3	5-9
Usual length over bumpers, feet	10 to 12	12 to 14	14 to 16	16 to 19	17 to 19	17 to 20
Usual length of tanks, feet	8 to 10	10 to 12	12 to 14	14 to 17	15 to 17	15 to 18
Usual diameter of tanks, inches	24 to 26	24 to 26	26 to 28½	28½ to 31¾	31¾ to 34½	31¾ to 34½
Extreme width of tanks, inches	52½ to 57	52½ to 57	57 to 62	62 to 69	69 to 77	69 to 77
Excess of width at cylinders over gauge of track, inches	24½	24½	26	28	30	32
Extreme height least desirable, ft. and ins.	4-4	4-6	4-9	5-3	5-3½	5-5
Approximate cubic feet capacity of tanks	50 to 60	60 to 80	100 to 120	140 to 170	160 to 190	180 to 220
Maximum tank pressure usually advisable, pounds	600	600	600 to 700	600 to 700	600 to 700	600 to 700
Approximate weight in working order, lbs.	10,000	12,000	16,000	22,000	28,000	32,000
Weight per yd. of lightest rail advised, lbs.	14	14	16	25	25	30
Radius of sharpest curve advised, feet	25	25	30	35		5
Radius of sharpest curve practicable, feet	15	15	16	20	20	25
Maximum pressure per square in. usually desirable for auxiliary reservoir, lbs.	140	140	140	140	140	140
Tractive force, pounds	1,490	1,860	2,915	4,440	5,190	6,410

HAULING CAPACITY EXPLAINED.

The number of tons given as hauling capacity of each locomotive is the *total weight of the heaviest train, including the weight of the cars and of their loads*, which the locomotives are guaranteed to haul in addition to locomotive itself on straight track in good condition.

The *regular* work of a locomotive should not exceed one-half to two-thirds of its full capacity. This allowance to provide a surplus power for special occasions, and to cover imperfections of track and rolling stock, as found in average practice.

TABLE FOR COMPUTING HAULING CAPACITY ON GRADES.

Applicable to preceding tables on light locomotives, which are all of the class "saddle tank locomotives." In this table 100 per cent. stands for hauling capacity on a *level*. Opposite each grade is given the proper percentage to denote the hauling capacity on that grade.

TABLE FOR SADDLE TANK LOCOMOTIVES.

Grades.	Per cent.
On a level the hauling capacity is	100
1 foot per mile	94
2 feet per mile	90
3 feet per mile	86
5 feet per mile	78
8 feet per mile	69
10 feet per mile	64
15 feet per mile	54
20 feet per mile	47
25 feet per mile	42
$26\frac{4}{10}$ feet per mile	40
30 feet per mile	37
35 feet per mile	33
40 feet per mile	30
45 feet per mile	28
50 feet per mile	26
$52\frac{8}{10}$ feet per mile	25
55 feet per mile	24
60 feet per mile	22
65 feet per mile	21
70 feet per mile	20
75 feet per mile	19
80 feet per mile	18
85 feet per mile	17
90 feet per mile	16
95 feet per mile	15
100 feet per mile	14
$105\frac{6}{10}$ feet per mile	$13\frac{1}{2}$
110 feet per mile	13
120 feet per mile	12
130 feet per mile	11
132 feet per mile	$10\frac{3}{4}$
140 feet per mile	10
150 feet per mile	$9\frac{1}{2}$
$158\frac{4}{10}$ feet per mile	$9\frac{1}{4}$
160 feet per mile	9
170 feet per mile	$8\frac{1}{2}$
180 feet per mile	8
$184\frac{8}{10}$ feet per mile	$7\frac{3}{4}$
190 feet per mile	$7\frac{1}{2}$
200 feet per mile	7
$211\frac{2}{10}$ feet per mile	$6\frac{1}{2}$
225 feet per mile	6
250 feet per mile	$5\frac{1}{2}$
264 feet per mile	$5\frac{1}{4}$
275 feet per mile	5
300 feet per mile	$4\frac{1}{2}$
$316\frac{8}{10}$ feet per mile	$4\frac{1}{4}$
325 feet per mile	4
350 feet per mile	$3\frac{1}{2}$
375 feet per mile	3
400 feet per mile	$2\frac{3}{4}$
450 feet per mile	$2\frac{1}{4}$
500 feet per mile	2

DIRECTIONS FOR USING THE PRECEDING TABLES.

To compute how many tons (of 2000 lbs.) a locomotive can haul up a grade.

EXAMPLE.—What is the hauling capacity up a grade of 300 feet per mile of the "light four wheel connected tank locomotive" cylinders 9 x 14? Table under this head gives the hauling capacity on a level for this locomotive 550 tons. The table for "computing hauling capacity on grades" gives 4½ as the percentage for a 300 feet grade.

Four and one-half per cent. of 550 gives (disregarding fractions) 25 tons as the hauling capacity.

To select a locomotive of suitable power for any required work.

EXAMPLE.—Add 50 to 100 per cent. to the regular work to be done, according to the margin of surplus power desired, and for allowance for imperfections of track, cars, etc. Refer to table for the percentage for the given grade. The regular work to be done, as above increased, will then be the percentage of the locomotive's hauling capacity on a level, and the capacity on a level is found by multiplying by 100 and dividing by the rate of percentage. When locomotive can be selected according to the nature of service, and the hauling capacity on a level as given in tables. [Many other sizes and forms of locomotives are made in addition to those given in tables above, but those selected represent class most used on public works.]

EXAMPLE.—It is desired to haul a load of 80 tons of cars and lading regularly up a grade of 75 feet per mile. What is the smallest saddle tank locomotive advisable?

Adding 50 to 100 per cent. as an average, say 75 per cent. = 60 tons to 80 tons gives 140 tons.

Table gives 19 as percentage for a 75 feet grade.

$(140 \times 100) \div 19 = 733$ tons (disregarding fractions).

A locomotive of 733 tons capacity on a level is thus indicated; and by examination of tables it will be seen that "back truck" locomotive, 10 x 16 inch cylinders, hauling capacity on level 750 tons, is best suited to this case.

LOCOMOTIVES FOR CONTRACTORS' WORK.

10 x 16 cylinders is usually smallest size of locomotive desirable.

Owing to constant shifting of track, narrow gauge most desirable, say 24 to 30 inches.

One locomotive, or two if haul long and grades steep, will keep a steam shovel busy.

GENERAL DIRECTIONS FOR ORDERING.

In ordering locomotives state following:

1. The gauge of track (exact space in clear between rails).

2. The kind of fuel.

3. The height of the center of car couplings above rail.

4. The length of road, weight of rail and radius of sharpest curve.

5. The steepest grade, with its length, for loaded cars to go up (also the same for empty cars if they return empty).

6. The number of cars to be hauled in each train, and the weight of each car and of its load.

7. The total amount of freight to be carried one way daily.

IRON AND STEEL.

Cast iron weighs on an average 450 lbs. per cubic foot.
Wrought iron weighs on an average 480 lbs. per cubic foot.
Steel weighs on an average 489.6 lbs. per cubic foot.
From above we see that
One cubic foot of wrought iron weighs 480 lbs.
One square foot, one inch thick, weighs $\frac{480}{12}$ or 40 lbs.
One square inch, one foot long, weighs $\frac{40}{12}$ or $3\frac{1}{3}$ lbs.
One square inch, one yard long, weighs $3\frac{1}{3} \times 3$ or 10 lbs.

Therefore, in *any section* of wrought iron, the weight in pounds *per yard* is *precisely* equal to ten times its sectional area in square inches.

EXAMPLE.—What is the weight of a bar of wrought iron 2″ x 4″ x 9′—0″?

Answer: $2 \times 4 \times 3$ (yards) $\times 10 = 240$ lbs.

For round wrought iron, the weight *per foot* may be found by taking the diameter in quarter inches, squaring it and dividing by 6. This rule is not absolutely exact, but will do for all practical purposes.

EXAMPLE.—What is the weight per foot of ¾ inch round iron?

¾ inch = 3 quarter inches. $3^2 = 9$.
$\frac{9}{6} = 1\frac{1}{2}$ lbs.

WEIGHTS AND AREAS OF SQUARE AND ROUND BARS AND CIRCUMFERENCES OF ROUND BARS.

(Phœnix Iron Co.)

One cubic foot of steel weighing 489.6 pounds.

Thickness or diameter in inches.	Weight of □ bar one foot long.	Weight of ○ bar one foot long.	Area of □ bar in square inches.	Area of ○ bar in square inches.	Circumference of ○ bar in inches.
1/16	.013	.010	.0039	.0031	.1963
1/4	.053	.042	.0156	.0123	.3927
3/16	.119	.094	.0352	.0276	.5890
1/4	.212	.167	.0625	.0491	.7854
5/16	.333	.261	.0977	.0767	.9817
3/8	.478	.375	.1406	.1104	1.1781
7/16	.651	.511	.1914	.1503	1.3744
1/2	.850	.667	.2500	.1963	1.5708
9/16	1.076	.845	.3164	.2485	1.7671
5/8	1.328	1.043	.3906	.3068	1 9635
11/16	1.608	1.262	.4727	.3712	2.1598
3/4	1.913	1.502	.5625	.4418	2.3562
13/16	2.245	1.763	.6602	.5185	2.5525
7/8	2.603	2.044	.7656	.6013	2.7489
15/16	2.989	2.347	.8789	.6903	2.9452

WEIGHTS AND AREAS SQUARE AND ROUND BARS—CONT'D.

One cubic foot of steel weighing 489.6 pounds.

Thickness of diameter in inches.	Weight of □ bar one foot long.	Weight of ○ bar one foot long.	Area of □ bar in square inches.	Area of ○ bar in square inches.	Circumference of ○ bar in inches.
1	3.400	2.670	1.0000	.7854	3.1416
1 1/16	3.838	3.014	1.1289	.8866	3 3379
1 1/8	4.303	3.379	1.2656	.9940	3.5343
1 3/16	4.795	3.766	1.4102	1.1075	3.7306
1 1/4	5.312	4 173	1.5625	1.2272	3.9270
1 5/16	5.857	4.600	1.7227	1.3530	4.1233
1 3/8	6.428	5.049	1.8906	1.4849	4.3197
1 7/16	7.026	5.518	2.0664	1.6230	4.5160
1 1/2	7.650	6 008	2.2500	1.7671	4.7124
1 9/16	8.301	6.520	2.4414	1.9175	4.9087
1 5/8	8.978	7.051	2.6406	2.0739	5.1051
1 11/16	9.682	7.604	2.8477	2.2365	5.3014
1 3/4	10.41	8.178	3.0625	2.4053	5.4978
1 13/16	11.17	8.773	3.2852	2.5802	5.6941
1 7/8	11.95	9.388	3.5156	2.7612	5.8905
1 15/16	12.76	10.02	3.7539	2.9483	6.0868
2	13.60	10.68	4.0000	3.1416	6.2832
2 1/16	14.46	11.36	4.2539	3.3410	6.4795
2 1/8	15.35	12.06	4.5156	3.5466	6.6759
2 3/16	16.27	12.78	4.7852	3.7583	6.8722
2 1/4	17.22	13.52	5.0625	3.9761	7.0686
2 5/16	18.19	14.28	5.3477	4.2000	7.2649
2 3/8	19.18	15.07	5.6406	4.4301	7.4613
2 7/16	20.20	15.86	5.9414	4.6664	7.6576
2 1/2	21.25	16.69	6.2500	4.9087	7.8540
2 9/16	22.33	17.53	6.5664	5.1572	8.0503
2 5/8	23.43	18.40	6.8906	5.4119	8.2467
2 11/16	24.56	19.29	7.2227	5.6727	8.4430
2 3/4	25.00	20.20	7.5625	5.9396	8.6394
2 13/16	26.90	21.12	7.9102	6.2126	8.8357
2 7/8	28.10	22.07	8.2656	6.4918	9.0321
2 15/16	29.34	23.04	8.6289	6.7771	9.2284
3	30.60	24.03	9.0000	7.0686	9.4248
3 1/16	31.89	25.04	9.3789	7.3662	9.6211
3 1/8	33.20	26.08	9.7656	7.6699	9.8175
3 3/16	34.55	27.13	10.160	7.9798	10.014
3 1/4	35.92	28.20	10.563	8.2958	10.210
3 5/16	37.31	29.30	10.973	8.6179	10.407
3 3/8	38.73	30.42	11.391	8.9462	10.603
3 7/16	40.18	31.56	11.816	9.2806	10.799
3 1/2	41.65	32.71	12.250	9.6211	10.996
3 9/16	43.14	33.90	12.691	9.9678	11.192
3 5/8	44.68	35.09	13.141	10.321	11.388
3 11/16	46.24	36.31	13.598	10.680	11.585

WEIGHTS AND AREAS SQUARE AND ROUND BARS—CONT'D.
One cubic foot of steel weighing 489.6 pounds.

Thickness or diameter in inches.	Weight of □ bar one foot long.	Weight of ○ bar one foot long.	Area of □ bar in square inches.	Area of ○ bar in square inches.	Circumference of ○ bar in inches.
3¾	47.82	37.56	14.063	11.045	11.781
3 13/16	49.42	38.81	14.535	11.416	11.977
3⅞	51.05	40.10	15.016	11.793	12.174
3 15/16	52.71	41.40	15.504	12.177	12.370
4	54.40	42.73	16.000	12.566	12.566
4 1/16	56.11	44.07	16.504	12 962	12.763
4⅛	57.85	45.44	17.016	13.364	12.959
4 3/16	59.62	46.83	17.535	13.772	13.155
4¼	61.41	48.24	18.063	14.186	13.352
4 5/16	63.23	49.66	18.598	14.607	13.548
4⅜	65.08	51.11	19.141	15.033	13.744
4 7/16	66.95	52.58	19.691	15.466	13.941
4½	68.85	54.07	20.250	15.904	14.137
4 9/16	70.78	55.59	20.816	16.349	14.334
4⅝	72.73	57.12	21.391	16.800	14.530
4 11/16	74.70	58.67	21.973	17.257	14.726
4¾	76.71	60.25	22.563	17.721	14.923
4 13/16	78.74	61.84	23.160	18.190	15.119
4⅞	80.81	63.46	23.766	18.665	15 315
4 15/16	82.89	65.10	24.379	19.147	15.512
5	85.00	66.76	25.000	19.635	15.708
5 1/16	87.14	68 44	25.629	20.129	15.904
5⅛	89.30	70.14	26.266	20.629	16.101
5 3/16	91.49	71.86	26.910	21.135	16.297
5¼	93.72	73.60	27.563	21.648	16.493
5 5/16	95.96	75.37	28.223	22.166	16.690
5⅜	98.23	77 15	28.891	22.691	16.886
5 7/16	100.5	78.95	29.566	23.221	17.082
5½	102.8	80.77	30.250	23.758	17.279
5 9/16	105.2	82.62	30.941	24.301	17.475
5⅝	107.6	84.49	31.641	24.850	17.671
5 11/16	110.0	86.38	32.348	25.406	17.868
5¾	112.4	88.29	33.063	25.967	18.064
5 13/16	114.9	90.22	33.785	26.535	18.261
5⅞	117.4	92.17	34.516	27.109	18.457
5 15/16	119.9	94.14	35.254	27.688	18.653
6	122.4	96.14	36.000	28.274	18.850
6 1/16	125.0	98.14	36.754	28.866	19.046
6⅛	127.6	100.2	37.516	29.465	19.242
6 3/16	130.2	102.2	38.285	30.069	19.439
6¼	132.8	104.3	39.063	30.680	19.635
6 5/16	135.5	106.4	39.848	31.296	19.831
6⅜	138.2	108.5	40.641	31.919	20.028
6 7/16	140.9	110.7	41.441	32.548	20.224

WEIGHTS AND AREAS SQUARE AND ROUND BARS—CONT'D.

One cubic foot of steel weighing 489.6 pounds.

Thickness or diameter in inches.	Weight of □ bar one foot long.	Weight of ○ bar one foot long.	Area of □ bar in square inches.	Area of ○ bar n square inches.	Circumference of ○ bar in inches.
6½	143.6	112.8	42.250	33.183	20.420
6 9/16	146.5	114.9	43.066	33.824	20.617
6⅝	149.2	117.2	43.891	34.472	20.813
6 11/16	152.1	119.4	44.723	35.125	21.009
6¾	154.9	121.7	45.563	35.785	21.206
6 13/16	157.8	123.9	46.410	36.450	21.402
6⅞	160 8	126.2	47.266	37.122	21.598
6 15/16	163.6	128.5	48.129	37.800	21.795
7	166.6	130.9	49.000	38.485	21.991
7 1/16	169.6	133.2	49.879	39.175	22.187
7⅛	172.6	135.6	50.766	39.871	22.384
7 3/16	175.6	137.9	51.660	40.574	22.580
7¼	178.7	140.4	52.563	41.282	22.777
7 5/16	181.8	142.8	53.473	41.997	22.973
7⅜	184.9	145.3	54.391	42.718	23.169
7 7/16	188.1	147.7	55.316	43.445	23.366
7½	191.3	150.2	56.250	44.179	23.562
7 9/16	194.4	152.7	57.191	44.918	23.758
7⅝	197.7	155.2	58.141	45.664	23.955
7 11/16	200.9	157.8	59.098	46.415	24.151
7¾	204.2	160.3	60.063	47.173	24.347
7 13/16	207.6	163.0	61.035	47.937	24.544
7⅞	210.8	165.6	62.016	48.707	24.740
7 15/16	214.2	168.2	63.004	49.483	24.936
8	217.6	171.0	64.000	50.265	25.133
8 1/16	221.0	173.6	65.004	51.054	25.329
8⅛	224.5	176.3	66.016	51.849	25.525
8 3/16	228.0	179.0	67.035	52.649	25.722
8¼	231.4	181.8	68.063	53.456	25.918
8 5/16	234.9	184.5	69.098	54.269	26.114
8⅜	238.5	187.3	70.141	55.088	26.811
8 7/16	242.0	190.1	71.191	55.914	26.507
8½	245.6	193.0	72.250	56.745	26.704
8 9/16	249.3	195.7	73.316	57.583	26.900
8⅝	252.9	198.7	74.391	58.426	27.096
8 11/16	256.6	201.6	75.473	59.276	27.293
8¾	260.3	204.4	76.563	60.132	27.489
8 13/16	264.1	207.4	77.660	60.994	27.685
8⅞	267.9	210.3	78.766	61.862	27.882
8 15/16	271.6	213.3	79.879	62.737	28.078
9	275.4	216.3	81.000	63.617	28.274
9 1/16	279.3	219.3	82.129	64.504	28.471
9⅛	283.2	222.4	83.266	65.397	28.667
9 3/16	287.0	225.4	84.410	66.296	28.863

WEIGHTS AND AREAS SQUARE AND ROUND BARS—CONT'D.

One cubic foot of steel weighing 489.6 pounds.

Thickness or diameter in inches.	Weight of □ bar one foot long.	Weight of ○ bar one foot long.	Area of □ bar in square inches.	Area of ○ bar in square inches.	Circumference of ○ bar in inches.
9¼	290.9	228.5	85.563	67 201	29.060
9 5/16	294.9	231.5	86.723	68.112	29.256
9⅜	298.9	234.7	87.891	69.029	29.452
9 7/16	302.8	237.9	89.066	69.953	29.649
9½	306.8	241.0	90.250	70.882	29.845
9 9/16	310.9	244.2	91.441	71.818	30.041
9⅝	315.0	217.4	92.641	72.760	30.238
9 11/16	319.1	250.6	93.848	73.708	30.434
9¾	323.2	253 9	95.063	74.662	30.631
9 13/16	327.4	287.1	96.285	75.622	30.827
9⅞	331.6	260.4	97.516	76.589	31.023
9 15/16	335.8	263.7	98.754	77.561	31.220
10	340.0	267.0	100.00	78.540	31.416
10 1/16	344.3	270.4	101.25	79.525	31.612
10⅛	348.5	273.8	102.52	80.516	31.809
10 3/16	352.9	277.1	103.79	81.513	32 005
10¼	357.2	280.6	105.06	82.516	32.201
10 5/16	361.6	284.0	106.35	83.525	32.398
10⅜	366.0	287.4	107 64	84.541	32.594
10 7/16	370.4	290.9	108.94	85.562	32.790
10½	374.9	294.4	110.25	86.590	32.987
10 9/16	379.4	297.9	111.57	87.624	33.183
10⅝	383.8	301.4	112.89	88.664	33.379
10 11/16	388.3	305.0	114.22	89.710	33.576
10¾	392.9	308.6	115.56	90.763	33.772
10 13/16	397.5	312.2	116.91	91.821	33.968
10⅞	402.1	315.8	118.27	92.886	34.165
10 15/16	406.8	319.5	119.63	93.956	34.361
11	411.4	323.1	121.00	95.033	34.558
11 1/16	416.1	326.8	122.38	96.116	34.754
11⅛	420.9	330.5	123.77	97.205	34.950
11 3/16	425.5	334.3	125.16	98.301	35 147
11¼	430.3	337.9	126.56	99.402	35.343
11 5/16	435.1	341.7	127.97	100.51	35.539
11⅜	439.9	345.5	129.39	101.62	35.736
11 7/16	444.8	349.4	130.82	102.74	35.932
11½	449.6	353.1	132.25	103.87	36.128
11 9/16	454.5	357.0	133.69	105.00	36.325
11⅝	459.5	360.9	135.14	106.14	36.521
11 11/16	464.4	364.8	136.60	107.28	36.717
11¾	469.4	368.6	138.06	108.43	36.914
11 13/16	474.4	372.6	139.54	109 59	37.110
11⅞	479.5	376.6	141.02	110.75	37.306
11 15/16	481.5	380.6	142.50	111.92	37.503

The preceding table can also be used approximately; for copper add ⅛ part; lead, multiply by 1.47; brass, multiply by 1.06; zinc, multiply by 0.9; tin, multiply by 0.95.

SIZES AND WEIGHTS OF SQUARE AND HEXAGONAL NUTS (KENT).

United States standard sizes. Chamfered and trimmed. Punched to suit United States standard taps. Number of each size in 100 pounds.

Diam. of bolt.	Width.	Thickness.	Diam. of hole.	Long diam. sq. nuts	Long diam. hex. nuts.	Square.		Hexagon.	
						No. in 100 lbs.	Wt. each in lbs.	No. in 100 lbs.	Wt. each in lbs.
1/4	1/2	1/4	13/64	11/16	9/16	7270	.0138	7615	.0131
5/16	19/32	5/16	1/4	13/16	11/16	4700	.0231	5200	.0192
3/8	11/16	3/8	19/64	1	13/16	2350	.0426	3000	.0333
7/16	25/32	7/16	11/32	1 1/8	7/8	1630	.0613	2000	.050
1/2	7/8	1/2	25/64	1 1/4	1	1120	.0893	1430	.070
9/16	31/32	9/16	29/64	1 3/8	1 1/8	890	.1124	1100	.091
5/8	1 1/16	5/8	33/64	1 1/2	1 1/4	640	.156	740	.135
3/4	1 1/4	3/4	39/64	1 3/4	1 7/16	380	.263	450	.222
7/8	1 7/16	7/8	47/64	2 1/16	1 11/16	280	.357	309	.324
1	1 5/8	1	53/64	2 5/16	1 7/8	170	.588	216	.463
1 1/8	1 13/16	1 1/8	59/64	2 9/16	2 1/16	130	.769	148	.676
1 1/4	2	1 1/4	1 1/16	2 13/16	2 5/16	96	1.04	111	.901
1 3/8	2 3/16	1 3/8	1 5/32	3 1/8	2 1/2	70	1.43	85	1.18
1 1/2	2 3/8	1 1/2	1 9/32	3 3/8	2 3/4	58	1.72	68	1.47
1 5/8	2 9/16	1 5/8	1 13/32	3 5/8	2 15/16	44	2.27	56	1.79
1 3/4	2 3/4	1 3/4	1 1/2	3 7/8	3 3/16	34	2.94	40	2.50
1 7/8	2 15/16	1 7/8	1 5/8	4 1/8	3 3/8	30	3.33	37	2.70
2	3 1/8	2	1 23/32	4 7/16	3 5/8	23	4 35	29	3.45
2 1/4	3 1/2	2 1/4	1 15/16	4 15/16	4 1/16	19	5.26	21	4.76
2 1/2	3 7/8	2 1/2	2 3/16	5 1/2	4 1/2	12	8.33	15	6.67
2 3/4	4 1/4	2 3/4	2 7/16	6	4 15/16	9	11.11	11	9.09
3	4 5/8	3	2 5/8	6 1/2	5 5/16	7 1/3	13.64	8 1/2	11.76

STANDARD SIZES OF WASHERS.

Number in 100 pounds.

Diameter.	Size of hole.	Thickness wire gauge.	Size of bolt.	Number in 100 pounds.
Inch.	Inch.	No.	Inch.	
5/8	5/16	16	1/4	29,300
3/4	3/8	16	5/16	18,000
1	7/16	14	3/8	7,600
1 1/2	9/16	11	1/2	3,300
1 1/2	5/8	11	9/16	2,180
1 1/2	11/16	11	5/8	2,350
1 3/4	13/16	11	3/4	1,680
2	31/32	10	7/8	1,140
2 1/2	1 1/8	8	1	580
2 3/4	1 1/4	8	1 1/8	470
3	1 3/8	7	1 1/4	360
3	1 1/2	6	1 3/8	360

SQUARE HEADS.

Diameter.	¼	5/16	⅜	7/16	½	9/16	⅝	¾	⅞	1	1⅛	1¼	1⅜	1½	1¾	2
Length.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
¾ inch.	2.4	4.4	6.9	10.4												
⅞ inch.	2.6	4.7	7.3	10.9												
1 inch.	2.8	4.9	7.6	11.5	16.3											
1¼ inch.	3.1	5.5	8.4	12.5	17.7											
1½ inch.	3.4	6.0	9.2	13.6	19.1	26.0	33.8	55.3	83.4	118.0	170.5	230.3				
2 inch.	4.1	7.1	10.8	15.7	21.8	29.5	38.1	61.5	91.8	129.0	184.5	247.5				
2½ inch.	4.8	8.2	12.3	17.8	24.6	33.0	42.4	67.7	99.7	140.1	198.4	264.8				
3 inch.	5.5	9.2	13.8	19.9	27.4	36.5	46.7	73.9	108.1	151.1	212.4	282.0	350	480		
3½ inch.	6.2	10.3	15.3	21.8	29.8	40.0	51.0	80.1	116.6	162.2	226.4	299.3	370	500		
4 inch.	6.9	11.4	16.9	24.0	32.6	43.5	55.4	86.3	125.0	173.2	240.4	316.6	390	520	800	
4½ inch.	7.5	12.4	18.4	26.1	35.4	46.7	59.3	92.1	132.9	182.7	253.3	332.6	410	545	833	
5 inch.	8.2	13.5	19.9	28.2	38.1	50.2	63.6	98.3	141.3	193.7	267.3	349.9	430	570	866	1370
5½ inch.	8.9	14.6	21.5	30.3	40.9	53.7	67.9	104.5	149.8	204.8	281.2	367.1	450	595	900	1414
6 inch.	9.6	15.6	23.0	32.4	43.7	57.2	72.3	110.7	158.2	215.8	295.2	384.4	470	620	934	1458
6½ inch.	10.3	16.7	24.6	34.5	46.4	60.7	76.6	116.9	166.7	226.9	309.2	401.6	490	645	968	1502
7 inch.	11.0	17.8	26.1	36.6	49.2	64.2	80.9	123.1	175.1	237.9	323.2	418.9	510	670	1002	1546
7½ inch.	11.7	18.9	27.7	38.8	51.9	67.6	85.2	129.4	183.6	248.9	337.2	436.2	530	695	1036	1590
8 inch.	12.4	20.0	29.2	40.9	54.7	71.1	89.5	135.6	192.0	260.0	351.1	453.4	550	725	1070	1634
9 inch.	13.7	22.1	32.4	44.9	60.0	77.8	97.8	147.5	208.3	281.3	377.0	486.7	590	775	1138	1722
10 inch.	15.1	24.3	35.5	49.1	65.5	84.8	106.4	160.0	225.2	303.3	404.9	521.2	630	825	1206	1810
11 inch.	16.5	26.4	38.6	53.4	71.0	91.8	115.1	172.4	242.2	325.5	432.9	555.8	670	875	1274	1898
12 inch.	17.9	28.6	41.7	57.6	76.5	98.8	123.7	184.8	259.1	347.6	460.8	590.3	710	925	1342	1986
13 inch.	19.3	30.7	44.8	61.8	82.0	105.5	132.0	197.2	276.0	369.6	488.8	624.8	751	975	1410	2074
14 inch.	20.6	32.9	47.9	66.0	87.6	112.5	140.6	209.7	292.9	391.7	516.7	659.3	793	1025	1478	2162
15 inch.	22.0	35.1	51.0	70.3	93.1	119.5	149.2	222.1	309.8	413.8	544.7	693.8	835	1075	1548	2250
16 inch.	23.4	37.2	54.1	74.5	98.6	126.4	157.9	234.5	326.7	435.9	572.7	728.3	877	1125	1616	2338
17 inch.	24.8	39.4	57.2	78.7	104.1	133.4	166.5	246.9	343.6	458.0	600.6	762.8	919	1175	1684	2426
18 inch.	26.2	41.5	60.3	82.9	109.7	140.4	175.1	259.4	360.5	480.1	628.6	797.4	961	1225	1752	2514
19 inch.	27.5	43.7	63.4	87.2	115.2	147.4	183.7	271.8	377.5	502.2	656.5	831.9	1003	1275	1820	2602
20 inch.	28.9	45.8	66.5	91.4	120.7	154.4	192.4	284.2	394.4	524.3	684.5	866.4	1045	1325	1888	2690
21 inch.	30.3	48.0	69.6	95.6	126.2	161.4	201.0	296.6	411.3	546.4	712.4	900.9	1087	1375	1956	2778
22 inch.	31.7	50.2	72.7	99.9	131.7	168.4	209.6	309.1	428.2	568.4	740.4	935.4	1129	1425	2024	2866
23 inch.	33.1	52.3	75.8	104.1	137.3	175.4	218.3	321.5	445.1	590.5	768.3	969.9	1171	1475	2092	2954
24 inch.	34.4	54.5	78.9	108.3	142.8	182.4	226.9	333.9	462.0	612.6	796.3	1004.5	1213	1525	2160	3042
25 inch.	35.8	56.6	82.1	112.5	148.3	189.3	235.5	346.3	478.9	634.7	824.3	1039.0	1255	1575	2228	3130
26 inch.	37.2	58.8	85.2	116.8	153.8	196.3	244.1	358.8	495.8	656.8	852.2	1073.5	1297	1625	2296	3218
27 inch.	38.6	60.9	88.3	121.0	159.4	203.3	252.8	371.2	512.7	678.9	880.2	1108.0	1339	1675	2364	3306
28 inch.	40.0	63.1	91.4	125.2	164.9	210.3	261.4	383.6	529.7	701.0	908.1	1142.5	1381	1725	2432	3394
29 inch.	41.3	65.3	94.5	129.5	170.4	217.3	270.0	396.0	546.6	723.1	936.1	1177.0	1423	1775	2500	3482
30 inch.	42.7	67.4	97.6	133.7	175.9	224.3	278.7	408.5	563.5	745.2	964.0	1211.5	1465	1825	2568	3570

STANDARD MACHINE SCREWS (KENT).

No.	Threads per inch.	Diam. of body.	Diam. of flat head.	Diam. of round head.	Diam. of fillister head.	Lengths. From	Lengths. To
2	56	.0842	.1631	.1544	.1332	3/16	1/2
3	48	.0973	.1894	.1786	.1545	3/16	5/8
4	32, 36, 40	.1105	.2158	.2028	.1747	3/16	3/4
5	32, 36, 40	.1236	.2421	.2270	.1985	3/16	7/8
6	30, 32	.1368	.2684	.2512	.2175	3/16	1
7	30, 32	.1500	.2947	.2754	.2392	1/4	1 1/8
8	30, 32	.1631	.3210	.2936	.2610	1/4	1 1/4
9	24, 30, 32	.1763	.3474	.3238	.2805	1/4	1 3/8
10	24, 30, 32	.1894	.3737	.3480	.3035	1/4	1 1/2
12	20, 24	.2158	.4263	.3922	.3445	3/8	1 3/4
14	20, 24	.2421	.4790	.4364	.3885	3/8	2
16	16, 18, 20	.2684	.5316	.4866	.4300	3/8	2 1/4
18	16, 18	.2947	.5842	.5248	.4710	1/2	2 1/2
20	16, 18	.3210	.6368	.5690	.5200	1/2	2 3/4
22	16, 18	.3474	.6894	.6106	.5557	1/2	3
24	14, 16	.3737	.7420	.6522	.6005	1/2	3
26	14, 16	.4000	.7420	.6938	.6425	3/4	3
28	14, 16	.4263	.7946	.7354	.6920	7/8	3
30	14, 16	.4520	.8473	.7770	.7240	1	3

Lengths vary by 16ths from 3/16 to 1/2, by 8ths from 1/2 to 1 1/2, by 4ths from 1 1/2 to 3.

WORKING PROPORTIONS FOR CONTINUOUS SHAFTING.

(Pencoyd Iron Works.)

WROUGHT IRON AND STEEL.

Transmitting power, but subject to no bending action except its own weight.

Diameter of shaft in inches.	Maximum safe torsional moment in inch-pounds.	Revolutions per minute. 100 H. P.	150 H. P.	200 H. P.	Maximum distance in feet between bearings.
1 1/2	5,940	6	10	14	11.7
1 5/8	7,552	9	13	17	12.4
1 3/4	9,432	11	16	21	13 0
1 7/8	11,602	13	20	26	13.6
2	14,080	16	24	32	14.2
2 1/8	16,892	19	29	38	14.8
2 1/4	20,048	23	34	46	15.4
2 3/8	23,580	27	40	54	16.0
2 1/2	27,500	31	47	63	16.5
2 3/4	36,603	42	62	83	17.6
3	47,520	54	81	108	18.6
3 1/4	60,417	69	103	137	19.7
3 1/2	75,460	86	129	172	20.7
3 3/4	92,812	105	158	211	21.6
4	112,640	128	192	256	22.6

Transmitting power, and subject to bending action of pulleys, belting, etc.

Diameter of shaft in inches.	Maximum safe tortional moment in inch-pounds.	Revolutions per minute.			Maximum distance in feet between bearings.
		100	150	200	
		H. P.	H. P.	H. P.	
1½	5,940	5	7	10	6.8
1⅝	7,552	6	9	12	7.2
1¾	9,432	8	11	15	7.5
1⅞	11,602	9	14	19	7.9
2	14,080	11	17	23	8.2
2⅛	16,892	14	21	27	8.6
2¼	20,048	16	24	33	8.9
2⅜	23,580	19	29	38	9.2
2½	27,500	22	33	45	9.6
2¾	36,603	24	36	48	10.2
3	47,520	39	58	77	10.8
3¼	60,417	49	74	98	11.4
3½	75,460	61	92	123	12.0
3¾	92,812	75	113	151	12.5
4	112,640	91	137	183	13.1

IRON AND STEEL BEAMS.

The manufacture of iron and steel beams and structural iron has reached such a high degree of development that for thorough information we would refer those interested in this subject to the following leading manufacturers: Phœnix Iron Co., American Bridge Co., Jones & Laughlin Steel Co., Bethlehem Steel Co.

The following remarks are important:

The *deepest beam* which it is possible to use is always most economical, as a lighter beam will carry same weight, and the deeper the beam the greater the stiffness.

Girders formed of wooden beams with iron beams, or plates fastened between them, will not support a load equal to the *sum* of the safe loads of the wooden and iron beams separately, because the wooden beams under their safe load deflect rather more than double the amount of the iron beams or plates of the same depth under *their* safe load; hence, when bolted together so that the deflection of both is equal to the deflection of the iron, only half the strength of the wooden beams comes into play.

PROPERTIES OF JONES & LAUGHLIN STEEL CO.'S STEEL BEAMS.

2	3	4	5	6	7	8	9	10	11	12	13
Depth of beam.	Weight per foot.	Area of section.	Thickness of web.	Width of flange.	Moment of inertia, neutral axis, perpendicular to web at center.	Section factor, neutral axis as before.	Radius of gyration, neutral axis as before.	Coefficient of strength for fiber strain of 16,000 lbs. per sq. in. used for bldgs.	Coefficient of strength for fiber strain of 12,500 lbs. per sq. in. used for bridges.	Moment of inertia, neutral axis, coincident with center line of web.	Radius of gyration, neutral axis as before.
In.	Lbs.	Sq. in.	Ins.	Ins.	I	R	r	C	C′	I′	r′
24	100	29.2	.745	7.245	2369.6	197.5	9.01	2,106,300	1,645,600	48.35	1.29
24	80	23.32	.5	7.	2087.2	173.9	9.46	1,855,300	1,449,500	42.86	1.36
20	100	29.62	.894	7.294	1662.3	166.2	7.49	1,773,200	1,385,800	52.92	1.34
20	80	23.73	.6	7.	1466.3	146.6	7.86	1,564,200	1,222,000	45.81	1.39
20	80	23.79	.735	6.485	1326.4	132.6	7.46	1,414,800	1,105,300	31.74	1.15
20	65	19.08	.5	6.25	1169.5	116.95	7.83	1,247,500	974,800	27.86	1.21
18	70	20.59	.719	6.259	920.0	102.2	6.68	1,090,344	851,832	24.63	1.09
18	55	15.93	.460	6.	794.2	88.2	7.06	941,224	735,336	21.19	1.15
15	100	29.46	1.192	6.792	899.4	119.92	5.53	1,279,200	999,300	50.92	1.31
15	80	23.57	.8	6.4	789.1	105.2	5.79	1,122,800	876,800	41.31	1.32
15	80	23.56	.982	6.392	719.3	95.9	5.53	1,023,000	799,200	32.50	1.18
15	60	17.67	.59	6.	609.0	81.2	5.87	866,100	676,700	25.96	1.22
15	55	16.18	.664	5.754	511.0	68.1	5.23	726,800	567,800	17.06	1.00
15	42	12.48	.41	5.5	441.8	58.9	5.95	628,300	490,800	14.62	1.08
12	60	17.64	.948	5.738	339.46	56.6	4.39	603,733	471,700	18.86	1.03
12	55	16.25	.828	5.618	321.89	53.6	4.45	572,300	447,100	17.54	1.04
12	40	11.84	.46	5.25	268.95	44.8	4.77	478,100	373,600	13.81	1.08
12	35	10.29	.436	5 085	228.30	38.0	4.71	405,800	317,000	10.07	.99
12	31.5	9.3	.35	5.	215.81	36.0	4.82	383,700	299,800	9.5	1.01
10	40	11.69	.75	5.1	158.85	31.8	3.68	338,900	264,800	9.51	.9
10	25	7.35	.31	4.66	122.1	24.4	4.07	260,500	203,500	6.89	.97
9	35	10.29	.747	4.787	112.68	25.0	3.31	267,000	208,600	7.4	.84
9	21	6.31	.29	4.33	84.92	18.9	3.7	201,300	157,200	5.16	.9
8	25.25	7.43	.546	4.276	68.64	17.2	3.04	183,100	143,000	4.76	.8
8	17.75	5.22	.27	4.	56.87	14.2	3.31	151,700	118,500	3.78	.84
7	20	5.88	.46	3.87	42.23	12.1	2.68	128,700	100,600	3.24	.74
7	15	4.42	.25	3.66	36.23	10.4	2.87	110,400	86,200	2.67	.78
6	17.25	5.07	.475	3.575	26.2	8.7	2.27	93,100	72,800	2.36	.68
6	12.25	3.61	.23	3.33	21.79	7.3	2.46	77,400	60,600	1.85	.72
5	14.75	4.34	.504	3.294	15.15	6.1	1.87	61,700	50,500	1.71	.63
5	9.75	2.87	.21	3.	12.09	4.8	2.05	51,600	40,800	1.23	.65
4	10.5	3.09	.41	2.88	7.14	3.6	1.52	38,100	29,800	1.01	.57
4	7.5	2.21	.19	2.66	5.97	3.0	1.65	31,800	24,900	.77	.59
3	7.5	2.21	.366	2.526	2.92	1.9	1.15	20,800	16,200	.61	.52
3	5.5	1.63	.17	2.33	2.48	1.7	1.23	17,600	13,800	.46	.53

L=safe load in pounds uniformly distributed. l=span in feet
M=moment of forces in foot-pounds. C and C′ = coefficient
given above

$$L = \frac{C \text{ or } C'}{l}; \quad M = \frac{C \text{ or } C'}{8}; \quad C \text{ or } C' = L\,l; \; = 8\,M.$$

Rolled Beams.—The tables for steel beams specify the maximum safe loads uniformly distributed, assuming fiber strains of 16,000 pounds per square inch for steel. For vibratory loading, as in bridge floors, take three-fourths of loading as given by tables. If load concentrated at center of beam, take one-half of loading as given by tables.

SAFE LOADS, UNIFORMLY DISTRIBUTED, FOR JONES & LAUGHLIN STEEL CO.'S STEEL BEAMS.

In tons of 2000 pounds.

Size of beam.	Distance between supports.			
	12 feet.	16 feet.	20 feet.	24 feet.
24 inch standard:				
100 pounds	87.76	65.82	52.66	43.88
95 pounds	85.15	63.86	51.09	42.57
90 pounds	82.53	61.90	49.52	41.27
85 pounds	79.92	59.90	47.95	39.96
80 pounds	77.30	57.97	46.38	38.65
Def. in inches	.10	.18	.29	.41
20 inch heavy section:				
100 pounds	73.88	55.41	44.33	36.94
95 pounds	71.70	53.78	43.02	35.85
90 pounds	69.53	52.15	41.72	34.76
85 pounds	67.35	50.51	40.41	33.68
80 pounds	65.17	48.88	39.10	32.59
Def. in inches	.12	.22	.34	.49
20 inch standard:				
75 pounds	56.82	42.58	34.06	28.41
70 pounds	54.59	40.94	32.76	27.29
65 pounds	52.41	39.31	31.45	26.21
Def. in inches	.12	.22	.34	.49
18 inch standard:				
70 pounds	45.43	34.07	27.26	22.71
65 pounds	43.47	32.60	26.08	21.73
60 pounds	41.50	31.12	24.90	20.75
55 pounds	39.22	29.42	23.53	19.61
Def. in inches	.14	.24	.38	.55
15 inch heavy section:				
100 pounds	53.30	39.97	31.98	26.65
95 pounds	51.66	38.75	31.00	25.83
90 pounds	50.03	37.52	30.02	25.01
85 pounds	48.40	36.30	29.04	24.20
80 pounds	46.76	35.07	28 06	23.38
Def. in inches	.16	.29	.46	.66
15 inch light section:				
80 pounds	42.62	31.97	25.57	21.31
75 pounds	40.99	30.74	24.59	20.50
70 pounds	39.36	29.52	23.61	19.68
65 pounds	37.72	28.29	22.63	18.86
60 pounds	36.09	27.07	21.65	18.04
Def. in inches	.16	.29	.46	.66

SAFE LOADS, UNIFORMLY DISTRIBUTED, FOR JONES & LAUGHLIN STEEL CO.'S STEEL BEAMS—CONTINUED.

In tons of 2000 pounds.

Size of beam.	Distance between supports.			
	12 feet.	16 feet.	20 feet.	24 feet.
15 inch standard:				
55 pounds	30.42	22.82	18.26	15.21
50 pounds	28.79	21.59	17.26	14.40
45 pounds	27.16	20.37	16.29	13.58
42 pounds	26.18	19.63	15.71	13.09
Def. in inches	.16	.29	.46	.66
12 inch special section:				
60 pounds	25.14	18.86	15.10	12.57
55 pounds	23.84	17.88	14.31	11.92
50 pounds	22.54	16.90	13.52	11.27
45 pounds	21.23	15.92	12.74	10.61
40 pounds	19.92	14.94	11.95	9.96
35 pounds	16 90	12 68	10.14	8.45
31½ pounds	15.99	11.99	9 59	7.99
Def. in inches	.21	.37	.57	.82
10 inch standard:				
40 pounds	14.12	10.59	8.47	7.06
35 pounds	13.03	9.77	7 82	6.52
30 pounds	11.94	8.96	7.16	5.97
25 pounds	10.85	8.14	6.51	5.43
Def. in inches	.25	.45	.69	.99
9 inch standard:				
35 pounds	11.12	8.34	6.67	5.56
30 pounds	10.15	7.61	6.09	5.07
25 pounds	9 17	6.88	5.50	4.58
21 pounds	8.39	6.29	5.03	4.19
Def. in inches	.27	.49	.76	1.10
8 inch standard:	8 feet.	12 feet.	16 feet.	20 feet.
25¼ pounds	11.44	7.63	5.72	4.58
22¾ pounds	10.79	7.19	5.39	4.32
20¼ pounds	10.13	6.76	5.07	4.05
17¾ pounds	9.48	6.32	4.74	3.79
Def. in inches	.14	.31	.55	.86
7 inch beam standard:				
20 pounds	8.04	5.36	4.02	3.22
17½ pounds	7.47	4.98	3.74	2.99
15 pounds	6.90	4.60	3.45	2 76
Def. in inches	.16	.35	.63	.98

SAFE LOADS, UNIFORMLY DISTRIBUTED, FOR JONES & LAUGHLIN STEEL CO.'S STEEL BEAMS—CONTINUED.

In tons of 2000 pounds.

Size of beam.	Distance between supports.			
	12 feet.	16 feet.	20 feet.	24 feet.
6 inch standard:				
17¼ pounds	5.82	3.88	2.91	2.33
14¾ pounds	5.33	3.55	2.66	2.13
12¼ pounds	4.84	3.23	.42	1.93
Def. in inches	.18	.41	.73	1.14
5 inch standard:				
14¾ pounds	4.04	2.69	2.02	1.62
12¼ pounds	3.63	2.42	1.82	1.45
9¾ pounds	3.22	2.15	1.61	1.29
Def. in inches	.22	.49	.88	1.37
4 inch standard:				
10½ pounds	2.38	1.59	1.19	.95
9½ pounds	2.25	1.50	1.12	.90
8½ pounds	2.12	1.41	1.06	.85
7½ pounds	1.99	1.33	.99	.79
Def. in inches	.27	.62		
3 inch standard:				
7½ pounds	1.30	.87	.65	.52
6½ pounds	1.20	.80	.60	.48
5½ pounds	1.10	.73	.55	.44
Def. in inches	.37	.82		

PIPE.

CAST IRON PIPE.

All pipe should be cast vertically in dry sand, bell end down, 3 to 12 inch pipe lengths of 12 feet, all larger sizes in lengths of 12 feet 4 inches, including bell—which lay 12 feet.

Pipe castings include the cross, ⅛ bend, ¼ bend and curves of other radii, also sleeve, ½ sleeve, reducers, tee, seat bend and other forms in all sizes of pipe.

Cast iron culvert pipe makes one of the cheapest and most desirable drains. Gas and water pipes having some slight flaws which unfit them for pressure pipes are largely used for culvert purposes on railroads, for road culverts, and also for sewers and drains.

The best practice is to dig a ditch in which a bed of broken stones or concrete is laid to receive the pipe. In laying pipe the broken stone or concrete should be brought up around the pipe, say halfway up the sides. The bed of broken stone or concrete should be well rammed both under and around the pipe—by thus making a solid foundation, settlement, breaking and leakage are avoided.

At the exposed ends of pipe culvert, small rubble head walls should be built, say one foot above the top of the pipe, and of such length as the size of pipe demands to keep the bank from running around the ends and stopping up openings of culvert. Thickness of wall 9 to 18 inches varying with size of pipe. These end walls act as aprons to cut off water from passing around outside the pipe, and should extend at least 3 feet below the bottom of pipe, unless founded on solid rock. A grade of 1 inch in 10 feet clears pipe of all detritus.

The following table of size, weights, etc., of water pipe from Kent is a standard of good practice :

WEIGHT OF CAST IRON PIPES OR COLUMNS (KENT).

In pounds per lineal foot. Cast iron = 450 pounds per cubic foot.

Bore.	Thick. of meta .	Weight per foot.	Bore.	Thick. of metal.	Wei ht per foot.	Bore.	Thick. of metal.	Weight per foot.
Ins.	Ins.	Lbs.	Ins.	Ins.	Lbs.	Ins.	Ins.	Lbs.
3	⅜	12.4	4	⅜	16.1	5	⅜	19.8
3	½	17.2	4	½	22.1	5	½	27.0
3	⅝	22.2	4	⅝	28.4	5	⅝	34.4
3½	⅜	14.3	4½	⅜	17.9	5½	⅜	21.6
3½	½	19.6	4½	½	24.5	5½	½	29 4
3½	⅝	25.3	4½	⅝	31.5	5½	⅝	37.6

WEIGHT OF CAST IRON PIPES OR COLUMNS—CONTINUED.

In pounds per lineal foot. Cast iron = 450 pounds per cubic foot.

Bore.	Thick. of metal.	Weight per foot.	Bore.	Thick. of metal.	Weight per foot.	Bore.	Thick. of metal.	Weight per foot.
Ins.	Ins.	Lbs.	Ins.	Ins.	Lbs.	Ins.	Ins.	Lbs
6	⅜	23.5	12	¾	93.9	24	⅞	213.7
6	½	31.8	12½	½	63.8	24	1	245.4
6	⅝	40.7	12½	⅝	80.5	25	¾	189.6
6½	⅜	25.3	12½	¾	97.6	25	⅞	222.3
6½	½	34.4	13	½	66.3	25	1	255.3
6½	⅝	43.7	13	⅝	83.6	26	¾	197.0
7	⅜	27.1	13	¾	101.2	26	⅞	230.9
7	½	36.8	14	½	71.2	26	1	265.1
7	⅝	46.8	14	⅝	89.7	27	¾	204.3
7½	⅜	29.0	14	¾	108.6	27	⅞	239.4
7½	½	39.3	15	⅝	95.9	27	1	274.9
7½	⅝	49.9	15	¾	116.0	28	¾	211.7
8	⅜	30.8	15	⅞	136.4	28	⅞	248.1
8	½	41.7	16	⅝	102.0	28	1	284.7
8	⅝	52.9	16	¾	123.3	29	¾	219.1
8½	½	44.2	16	⅞	145.0	29	⅞	256.6
8½	⅝	56.0	17	⅝	108.2	29	1	294.5
8½	¾	68.1	17	¾	130.7	30	⅞	265.2
9	½	46.6	17	⅞	153.6	30	1	304.3
9	⅝	59.1	18	⅝	114.3	30	1⅛	343.7
9	¾	71.8	18	¾	138.1	31	⅞	273.8
9½	½	49.1	18	⅞	162.1	31	1	314.2
9½	⅝	62.1	19	⅝	120.4	31	1⅛	354.8
9½	¾	75.5	19	¾	145.4	32	⅞	282.4
10	½	51.5	19	⅞	170.7	32	1	324.0
10	⅝	65.2	20	⅝	126.6	32	1⅛	365.8
10	¾	79.2	20	¾	152.8	33	⅞	291.0
10½	½	54.0	20	⅞	179.3	33	1	333.8
10½	⅝	68.2	21	⅝	132.7	33	1⅛	376.9
10½	¾	82.8	21	¾	160.1	34	⅞	299.6
11	½	56.5	21	⅞	187.9	34	1	343.7
11	⅝	71.3	22	⅝	138.8	34	1⅛	388.0
11	¾	86.5	22	¾	167.5	35	⅞	308.1
11½	½	58.9	22	⅞	196.5	35	1	353.4
11½	⅝	74.4	23	¾	174.9	35	1⅛	399.0
11½	¾	90.2	23	⅞	205.1	36	⅞	316.6
12	½	61.3	23	1	235.6	36	1	363.1
12	⅝	77.5	24	¾	182.2	36	1⅛	410.0

The weight of the two flanges may be reckoned = weight of 1 ft.

CAST IRON PIPE.

SAFE THICKNESS OF METAL AND WEIGHT PER LENGTH, INCLUDING BELLS, FOR DIFFERENT SIZES AND UNDER VARIOUS HEADS OF WATER.

Size. Inside diameter.	25 ft. head or 10.82 lbs. pressure.		50 ft. head or 21.65 lbs. pressure.		100 ft. head or 43.30 lbs. pressure.		150 ft. head pr 64.85 lbs. pressure.		200 ft. head or 86.60 lbs. pressure.		250 ft. head or 108.25 lbs. pressure.		300 ft. head or 129.90 lbs. pressure.		Contents in gallo for 1 ft. in length.
	Thickness of metal.	Weight per length.	Thickness of metal.	Weight per length.	Thickness of metal.	Weight per length.	Thickness of metal.	Weight per length.	Thickness of metal.	Weight per length.	Thickness of metal.	Weight per length.	Thickness of metal.	Weight per length.	
2	.255	54	.294	63	.312	67½	.330	72	.348	76½	.366	81	.384	86	.163
3	.320	132	.344	144	.353	149	.362	153	.371	157	.380	161	.390	166	.367
4	.335	180	.361	197	.373	204	.385	211	.397	218	.409	226	.421	235	.652
6	.375	300	.393	815	.411	330	.429	345	.447	361	.465	377	.483	393	1.469
8	.433	456	.422	445	.450	475	.474	502	.498	529	.522	557	.546	584	2.611
10	.442	576	.459	600	.489	641	.519	682	.549	723	.579	766	.609	808	4.081
12	.446	720	.491	768	.527	826	.563	885	.599	944	.635	1,004	.671	1,064	5.876
14	....	...	.524	952	.566	1,031	.608	1,111	.650	1,191	.692	1,272	.734	1,352	7.997
16	....	...	.580	1,215	.604	1,253	.652	1,360	.700	1,463	.748	1,568	.796	1,673	10.44
18	....	...	.589	1,370	.643	1,500	.697	1,630	.751	1,761	.805	1,894	.859	2,026	13.22
20	....	...	.622	1,603	.682	1,763	.742	1,924	.802	2,086	.862	2,248	.922	2,412	16.32
24	....	...	.687	2,120	.759	2,349	.831	2,580	.903	2,811	.975	3,045	1.047	3,279	23.50
30	....	...	.785	3,020	.875	3,376	.965	3,735	1.055	4,095	1.145	4,458	1.235	4,822	36.72
36	....	...	.882	4,070	.990	4,581	1.098	5,096	1.206	5,613	1.314	6,133	1.422	6,656	52.88
48	....	...	1.078	6,616	1.222	7,521	1.366	8,431	1.510	9,840	1.654	10,269	1.798	11,195	94.02

All pipe cast in lengths of 12 feet, except the 2 inch, which are cast 9 feet long.
Pipes with flanges weigh about 15 per cent. more than above.
Packing of rubber for flanged pipe is usually ⅛ inch thick, and weighs about 10 lbs. to the square yard.

Nominal inside diam.	Actual outside diam.	Actual inside diam.	Thickness of metal.	Internal circumference.	External circumference.	Lgth. of pipe per sq. ft. inside surf.	Lgth. of pipe per sq. ft. outside surf.	Internal area.	Internal area.	External area.	External area.	Length of pipe contg. 1 cubic foot.	U. S. gallons per ft. of pipe.	Weight of pipe per lin. foot.	Weight of water per lin. ft. of pipe.	No. of threads per inch.	Length of perf. thread.
Ins.	In.	Ins.	Ins.	Ins.	Ins.	Feet.	Feet.	Sq. ins.	Sq. ft.	Sq. ins.	Sq. ft.	Feet.	Gallons.	Lbs.	Lbs.	No.	Ins.
1/8	.405	.270	.068	.848	1.272	14.151	9.434	.057	.0004	.1288	.0009	2500.0	.0029	.24	.024	27	.19
1/4	.540	.364	.088	1.144	1.696	10.500	7.075	.104	.0007	.2290	.0016	1383.280	.0054	.42	.045	18	.29
3/8	.675	.493	.091	1.552	2.121	7.732	5.658	.191	.0018	.3578	.0025	754.322	.0099	.56	.083	18	.30
1/2	.840	.622	.109	1.957	2.639	6.132	4.547	.304	.0021	.554	.0038	473.840	.0158	.84	.132	14	.39
3/4	1.050	.824	.113	2.589	3.299	4.635	3.638	.533	.0037	.866	.0060	270.016	.0277	1.12	.231	14	.40
1	1.315	1.048	.134	3.292	4.131	3.645	2.904	.861	.0060	1.358	.0094	167.246	.0447	1.67	.373	11½	.51
1¼	1.660	1.380	.140	4.335	5.215	2.768	2.301	1.496	.0104	2.164	.0150	96.257	.0777	2.24	.648	11½	.54
1½	1.900	1.610	.145	5.058	5.969	2.372	2.010	2.036	.0141	2.835	.0197	70.727	.1058	2.68	.882	11½	.55
2	2.375	2.067	.154	6.434	7.461	1.848	1.608	3.356	.0233	4.430	.0308	42.908	.1743	3.61	1.453	11½	.58
2½	2.875	2.468	.204	7.753	9.032	1.548	1.329	4.780	.0332	6.492	.0451	30.337	.2483	5.74	2.070	8	.89
3	3.500	3.067	.217	9.635	10.996	1.245	1.091	7.383	.0513	9.621	.0668	19.504	.3835	7.54	3.197	8	.95
3½	4.000	3.548	.226	11.146	12.566	1.077	.955	9.887	.0687	12.566	.0875	14.567	.5136	9.00	4.291	8	1.00
4	4.500	4.026	.237	12.648	14.137	.949	.849	12.730	.0884	15.904	.1104	11.312	.6613	10.66	5.512	8	1.05
4½	5.000	4.508	.246	14.162	15.708	.847	.764	15.961	.1108	19.635	.1364	9.022	.829	12.34	6.910	8	1.10
5	5.563	5.045	.259	15.849	17.475	.757	.687	19.986	.1388	24.301	.1688	7.205	1.038	14.50	8.652	8	1.16
6	6.625	6.065	.280	19.054	20.813	.630	.577	28.890	.2006	34.472	.2394	4.984	1.500	18.76	12.503	8	1.26
7	7.625	7.023	.301	22.063	23.955	.543	.501	38.738	.2690	45.664	.3171	3.717	2.012	23.27	16.771	8	1.36
8	8.625	7.981	.322	25.076	27.096	.479	.443	50.027	.3474	58.426	.4057	2.876	2.599	28.18	21.664	8	1.46
9	9.625	8.937	.344	28.076	30.238	.427	.397	62.730	.4356	72.760	.5053	2.290	3.259	33.70	27.166	8	1.57
10	10.75	10.018	.366	31.476	33.772	.381	.355	78.823	.5474	90.763	.6303	1.827	4.095	40.06	34.134	8	1.68
11	11.75	11.000	.375	34.558	36.914	.347	.325	95.033	.6600	108.434	.7530	1.515	4.937	45.02	41.153	8	1.78
12	12.75	12.000	.375	37.699	40.055	.318	.300	113.098	.7854	127.677	.8867	1.273	5.875	49.00	48.972	8	1.88
13	14	13.25	.375	41.626	43.982	.288	.273	137.887	.9577	153.938	1.0690	1.044	7.163	54.00	59.708	8	2.09
14	15	14.25	.375	44.768	47.124	.268	.255	159.485	1.1075	176.715	1.2272	.900	8.285	58.00	69.060	8	2.10
15	16	15.25	.375	47.909	50.266	.250	.239	182.665	1.2685	201.062	1.3963	.793	9.489	62.00	79.097	8	2.20
	18	17.25	.375	54.193	56.549	.221	.212	239.706	1.6229	254.470	1.7671	.616	12.141	70.00	101.203		
	20	19.25	.375	60.476	62.832	.198	.191	291.040	2.0211	314.159	2.1817	.495	15.119	78.00	126 026		
	22	21.25	.375	66.759	69.115	.180	.174	354.657	2.4629	380.134	2.6398	.406	18.424	85.00	153.575		
	24	23.25	.375	73.042	75.398	.164	.159	424.558	2.9483	452.390	3.1416	.339	22.055	93.00	183.842		

Pipe from ⅛ inch to 1 inch inclusive is butt-welded and proved to 300 pounds per square inch. Pipe 1¼ inches and larger is lap-welded and proved to 500 pounds per square inch.

FRICTION OF WATER IN PIPES.

Friction loss in pounds pressure per square inch, for each 100 feet of length in different size clean iron pipes, discharging given quantities of water per minute.

Gallons per minute.	Sizes of pipes—Inside diameter.								
	3/4 inch.	1 inch.	1¼ inches.	1½ inches.	2 inches.	2½ inches.	3 inches.	4 inches.	6 inches.
5	3.3	.84	.31	.12					
10	13.0	3.16	1.05	.47	.12				
15	28.7	6.98	2.38	.97					
20	50.4	12.03	4.07	1.66	.42				
25	78.0	19.00	6.40	2.62	....	.21	.10		
30	...	27.05	9.15	3.75	.91				
35	...	37.00	12.04	5.05					
40	...	48.00	16.01	6.52	1.60				
45	...	....	20.02	8.15					
50	...	....	24.09	10.00	2.44	.81	.35	.09	
75	...	....	50.01	22.04	5.32	1.80	.74		
100	...	....	....	39.00	9.46	3.20	1.31	.33	.05
125	...	....	....	....	14.09	4.89	1.99		
150	...	....	....	....	21.02	7.00	2.85	.69	.10
175	...	....	....	....	28.01	9.46	3.85		
200	...	....	....	....	37.05	12.47	5.02	1.22	.17

Gallons per minute.	Sizes of pipes—Inside diameter.									
	2½ inches.	3 inches.	4 inches.	6 inches.	8 inches.	10 inches.	12 inches.	14 inches.	16 inches.	18 inches.
250	19.66	7.76	1.89	.26	.07	.03	.01			
300	28.66	11.02	2.66	.37	.09	.04				
350	...	15.02	3.65	.50	.12	.05	.02			
400	...	19.05	4.73	.65	.16	.06				
450	...	25.00	6.01	.81	.20	.07	.03			
500	...	30.08	7.43	.96	.25	.09	.04	.017	.009	.005
750	...	...	...	2.21	.53	.18	.08			
1,000	...	...	...	3.88	.94	.32	.13	.062	.036	.020
1,250	...	...	...	...	1.46	.49	.20			
1,500	...	...	...	...	2.09	.70	.29	.135	.071	.040
1,750	...	...	...	...	...	.95	.38			
2,000	...	...	...	...	...	1.23	.49	.234	.123	.071
2,250	...	...	...	...	...	...	.63			
2,500	...	...	...	...	...	...	.77	.362	.188	.107
3,000	...	...	...	...	...	...	1.11	.515	.267	.150
3,500	...	...	...	...	...	...	...	.697	.365	.204
4,000	...	...	...	...	...	...	...	.910	.472	.263
4,500	...	...	...	...	...	...	...	...	.593	.333
5,000	...	...	...	...	...	...	...	...	.730	.408

TERRA COTTA PIPE.

"Blackmer and Post Pipe Co.," of St. Louis, Mo., make an excellent vitrified and salt-glazed double thickness culvert pipe in 2½ feet sections (net) with extra long socket and running from 12 to 30 inches inner diameter. This pipe is cheaper than cast iron, and when laid as directed above for cast iron pipe makes a thoroughly durable drain.

All culvert pipe should be laid with the top of pipe at least 3 feet below subgrade on railroads and 2 feet below grade on highways.

The firm above noted issue an excellent catalogue which it would well repay those interested in this subject to read.

CAPACITY OF DRAIN PIPE. (Salt-glazed.)

Size of pipe in inches.	Gallons per minute.							
	1½-inch fall per 100 feet.	3-inch fall per 100 feet.	6-inch fall per 100 feet.	9-inch fall per 100 feet.	12-inch fall per 100 feet.	18-inch fall per 100 feet.	2-feet fall per 100 feet.	3-feet fall per 100 feet.
3	21	30	42	52	60	74	85	104
4	36	52	76	92	108	132	148	184
6	84	120	169	206	240	294	338	414
9	232	330	470	570	660	810	930	1140
12	470	680	960	1160	1360	1670	1920	2350
15	830	1180	1680	2040	2370	2920	3340	4100
18	1300	1850	2630	3200	3740	4600	5270	6470
20	1760	2450	3450	4180	4860	5980	6850	8410

The maximum rainfall, as shown by statistics, is about an inch per hour (except during very heavy storms), equal to 22,633 gallons per hour for each acre, or 377 gallons per minute per acre.

Owing to various obstructions, not more than fifty to seventy-five per cent. of the rainfall will reach the drain within the same hour. An allowance should be made for this fact in determining size of pipe required.

TABLE SHOWING APPROXIMATE WEIGHT OF LEAD AND PACKING REQUIRED FOR LAYING CAST IRON PIPE.

Diameter pipe in inches.	Weight of pipe, lbs.	Weight of lead in lbs.	Weight of packing in ounces.
4	20	5.5	3.5
4	22	5.0	3.0
6	30	7.0	5.0
6	33	6.5	4.5
8	42	10.0	7 0
8	45	9.0	6.5
10	60	12.5	9 5
10	65	11.5	8.5
12	75	17.0	12.0
12	80	15.5	10.5
14	117	19.5	14.0
14	120	18.0	13.0
16	125	20.5	20.0
16	130	19.5	18.0
18	170	24.0	23.5
18	175	22.5	22.0
20	180	29.0	26.0
20	190	27.0	24.0

WIRE.

COMPARISON OF WIRE GAUGES.

No. of wire gauge.	American or Brown & Sharpe.	Birmingham or Stub's wire.	Washburn & Moen Manufacturing Co., Worcester, Mass.	Imperial wire gauge.	Stub's steel wire.	U. S. Standard for plate.
000000	. . . . .	. . . . .	. . . . .	.464	. . . . .	.46875
00000	. . . . .	. . . . .	. . . . .	.432	. . . . .	.4375
0000	.46	.454	.3938	.400	. . . . .	.40625
000	.40964	.425	.3625	.372	. . . . .	.375
00	.3648	.38	.3310	.348	. . . . .	.34375
0	.32486	.34	.3065	.324	. . . . .	.3125
1	.2893	.3	.2830	.300	.227	.28125
2	.25763	.284	.2625	.276	.219	.265625
3	.22942	.259	.2437	.252	.212	.25
4	.20431	.238	.2253	.232	.207	.234375
5	.18194	.22	.2070	.212	.204	.21875
6	.16202	.203	.1920	.192	.201	.203125
7	.14428	.18	.1770	.176	.199	.1875
8	.12849	.165	.1620	.160	.197	.171875
9	.11443	.148	.1483	.144	.194	.15625
10	.10189	.134	.1350	.128	.191	.140625
11	.090742	.12	.1205	.116	.188	.125
12	.080808	.109	.1055	.104	.185	.109375
13	.071961	.095	.0915	.092	.182	.09375
14	.064084	.083	.0800	.080	.180	.078125
15	.057068	.072	.0720	.072	.178	.0703125
16	.05082	.065	.0625	.064	.175	.0625
17	.045257	.058	.0540	.056	.172	.05625
18	.040303	.049	.0475	.048	.168	.05
19	.03589	.042	.0410	.040	.164	.04375
20	.031961	.035	.0348	.036	.161	.0375
21	.028462	.032	.03175	.032	.157	.034375
22	.025347	.028	.0286	.028	.155	.03125
23	.022571	.025	.0258	.024	.153	.028125
24	.0201	.022	.0230	.022	.151	.025
25	.0179	.02	.0204	.020	.148	.021875
26	.01594	.018	.0181	.018	.146	.01875
27	.014195	.016	.0173	.0164	.143	.0171875
28	.012641	.014	.0162	.0149	.139	.015625
29	.011257	.013	.0150	.0136	.134	.0140625
30	.010025	.012	.0140	.0124	.127	.0125
31	.008928	.01	.0132	.0116	.120	.0109375
32	.00795	.009	.0128	.0108	.115	.01015625
33	.00708	.008	.0118	.0100	.112	.009375
34	.006304	.007	.0104	.0092	.110	.00859375
35	.005614	.005	.0095	.0084	.108	.0078125
36	.005	.004	.0090	.0076	.106	.00703125
37	.004453	. . . . .	. . . . .	.0068	.103	.006640625
38	.003965	. . . . .	. . . . .	.0060	.101	.00625
39	.003531	. . . . .	. . . . .	.0052	.099	
40	.003144	. . . . .	. . . . .	.0048	.097	

WEIGHT AND LENGTH OF STEEL WIRE.

(John A. Roebling's Sons Co.)

Number Roebling gauge.	Diameter in inches.	Area in square inches.	Weight in pounds.		Number of feet in 2000 pounds.
			Per 1000 feet.	Per mile.	
000000	.460	.166191	558.4	2,948	3,582
00000	.430	.145221	487.9	2,576	4,099
0000	.393	.121304	407.6	2,152	4,907
000	.362	.102922	345.8	1,826	5,783
00	.331	.086049	289.1	1,527	6,917
0	.307	.074023	248.7	1,313	8,041
1	.283	.062902	211.4	1,116	9,463
2	.263	.054325	182.5	964	10,957
3	.244	.046760	157.1	830	12,730
4	.225	.039761	133.6	705	14,970
5	.207	.033654	113.1	597	17,687
6	.192	.028953	97.3	514	20,559
7	.177	.024606	82.7	437	24,191
8	.162	.020612	69.3	366	28,878
9	.148	.017203	57.8	305	34,600
10	.135	.014314	48.1	254	41,584
11	.120	.011310	38.0	201	52,631
12	.105	.008659	29.1	154	68,752
13	.092	.006648	22.3	118	89,525
14	.080	.005027	16.9	89.2	118,413
15	.072	.004071	13.7	72.2	146,198
16	.063	.003117	10.5	55.3	191,022
17	.054	.002290	7.7	40.6	259,909
18	.047	.001735	5.83	30.8	343,112
19	.041	.001320	4.44	23.4	450,856
20	.035	.000962	3.23	17.1	618,620
21	.032	.000804	2.70	14.3	740,193
22	.028	.000616	2.07	10.9	966,651
23	.025	.000491	1.65	8.71	
24	.023	.000415	1.40	7.37	
25	.020	.000314	1.06	5.58	
26	.018	.000254	.855	4.51	
27	.017	.000227	.763	4.03	
28	.016	.000201	.676	3.57	
29	.015	.000177	.594	3.14	
30	.014	.000154	.517	2.73	
31	.0135	.000143	.481	2.54	
32	.013	.000133	.446	2.36	
33	.011	.000095	.319	1.69	
34	.010	.000079	.264	1.39	
35	.0095	.000071	.238	1.26	
36	.009	.000064	.214	1.13	

Steel wire can be manufactured at present with such variable tensile strengths that the manufacturers, as a rule, publish no tables giving information on this subject. These strengths vary from 75,000 to 300,000 pounds per square inch. What is sold at the present time as bright wire is low carbon steel, bessemer or open hearth.

The Roebling Co. estimates the average tensile strength of steel wire at 100,000 pounds per square inch. The Trenton Iron Co. estimates it at 90,000 pounds per square inch.

WEIGHT OF COPPER WIRE (ROEBLING).

English system per 1000 feet and per mile, in pounds.

Number.	New British standard.			Birmingham.			Brown & Sharpe.		
	Diameter in decimals of an inch.	Weight. 1000 feet.	Weight. Mile.	Diameter in decimals of an inch.	Weight. 1000 feet.	Weight. Mile.	Diameter in decimals of an inch.	Weight. 1000 feet.	Weight. Mile.
000000	.464	652	3441						
00000	.432	565	2983						
0000	.400	484	2557	.454	624	3294	.460	641	3382
000	.372	419	2212	.425	547	2887	.410	509	2687
00	.348	367	1935	.380	437	2308	.365	403	2129
0	.324	318	1678	.340	350	1847	.325	320	1688
1	.300	272	1438	.300	272	1438	.289	253	1335
2	.276	231	1217	.284	244	1289	.258	202	1064
3	.252	192	1015	.259	203	1072	.229	159	838
4	.232	163	860	.238	171	905	.204	126	665
5	.212	136	718	.220	146	773	.182	100	529
6	.192	112	589	.203	125	659	.162	79	419
7	.176	94	495	.180	98	518	.144	63	331
8	.160	77	409	.165	82	435	.128	50	262
9	.144	63	331	.148	66	350	.114	39	208
10	.128	50	262	.134	54	287	.102	32	166
11	.116	41	215	.120	44	230	.091	25	132
12	.104	33	173	.109	36	190	.081	20	105
13	.092	25.6	135	.095	27.3	144	.072	15.7	83
14	.080	19.4	102	.083	20.8	110	.064	12.4	65
15	.072	15.7	83	.072	15.7	83	.057	9.8	52
16	.064	12.4	65	.065	12.8	68	.051	7.9	42
17	.056	9.5	50	.058	10.2	54	.045	6.1	32
18	.048	7.0	36.8	.049	7.3	38.4	.040	4.8	25.6
19	.040	4.8	25.6	.042	5.3	28.2	.036	3.9	20.7
20	.036	3.9	20.7	.035	3.7	19.6	.032	3.1	16.4
21	.032	3.1	16.4	.032	3.1	16.4	.0285	2.5	13.0
22	.028	2.4	12.5	.028	2.4	12.5	.0253	1.9	10.2
23	.024	1.7	9.2	.025	1.9	10.0	.0226	1.5	8.2
24	.022	1.5	7.7	.022	1.5	7.7	.0201	1.2	6.5
25	.020	1.2	6.4	.020	1.2	6.4	.0179	.97	5.1
26	.018	.98	5.2	.018	.98	5.2	.0159	.77	4.0
27	.0164	.81	4.3	.016	.77	4.1	.0142	.61	3.2
28	.0148	.66	3.5	.014	.59	3.1	.0126	.48	2.5
29	·0136	.56	3.0	.013	.51	2.7	.0113	.39	2.0
30	.0124	.47	2.5	.012	.44	2.3	.0100	.30	1.6
31	.0116	.41	2.15	.010	.30	1.6	.0089	.24	1.27
32	.0108	.35	1.86	.009	.25	1.3	.0080	.19	1.02
33	.010	.30	1.60	.008	.19	1.02	.0071	.15	.81
34	.0092	.26	1.35	.007	.15	.78	.0063	.12	.63
35	.0084	.21	1.13	.005	.075	.40	.0056	.095	.50
36	.0076	.17	.92	.004	.048	.256	.0050	.076	.40

NOTE.—The diameters given for the various sizes are those to which the wire is actually drawn.

ROPES, CABLES AND HAWSERS.

WIRE ROPES.

We give tables and general information on iron and cast steel ropes, as made by John A. Roebling's Sons Co., Trenton, N. J.

The wire ropes of John A. Roebling's Sons Co. have been made the standard by the United States Navy Department.

STANDARD HOISTING ROPE.

Composed of 6 strands and a hemp center, 19 wires to the strand.

Trade number.	Diameter in inches.	Approximate circumference in inches.	Weight per foot in pounds.	Swedish iron. Approximate breaking strain in tons of 2000 pounds.	Swedish iron. Allowable working strain in tons of 2000 pounds.	Swedish iron. Minimum size of drum or sheave in feet.	Cast steel. Approximate breaking strain in tons of 2000 pounds.	Cast steel. Allowable working strain in tons of 2000 pounds.	Cast steel. Minimum size of drum or sheave in feet.
	2¾	8⅝	11.95	114	22.80	16	228	45.6	10
	2½	7⅞	9.85	95	18.90	15	190	37.9	9½
1	2¼	7⅛	8.00	78	15.60	13	156	31.2	8½
2	2	6¼	6.30	62	12.40	12	124	24.8	8
3	1¾	5½	4.85	48	9.60	10	96	19.2	7¼
4	1⅝	5	4.15	42	8.40	8½	84	16.8	6¼
5	1½	4¾	3.55	36	7.20	7½	72	14.4	5¾
5½	1⅜	4¼	3.00	31	6.20	7	62	12.4	5½
6	1¼	4	2.45	25	5.00	6½	50	10.0	5
7	1⅛	3½	2.00	21	4.20	6	42	8.4	4½
8	1	3	1.58	17	3.40	5¼	34	6.8	4
9	⅞	2¾	1.20	13	2.60	4½	26	5.2	3½
10	¾	2¼	.89	9.7	1.94	4	19.4	3.88	3
10¼	⅝	2	.62	6.8	1.36	3½	13.6	2.72	2¼
10½	$\frac{9}{16}$	1¾	.50	5.5	1.10	2¾	11.0	2.20	1¾
10¾	½	1½	.39	4.4	.88	2¼	8.8	1.76	1½
10a	$\frac{7}{16}$	1¼	.30	3.4	.68	2	6.8	1.36	1¼
10b	⅜	1⅛	.22	2.5	.50	1½	5.0	1.00	1
10c	$\frac{5}{16}$	1	.15	1.7	.34	1	3.4	.68	⅔
10d	¼	¾	.10	1.2	.24	¾	2.4	.48	½

The preceding table shows the kind of rope in common use. It is made of six strands of nineteen wires each, laid around a hemp heart.

In substituting steel ropes for iron rope the object should be to gain an increase wear from the rope, rather than to reduce the size.

Tiller ropes are used for steering ropes on river steamers, hand ropes on elevators and in any place where a smooth and flexible rope is required.

TRANSMISSION OR HAULAGE ROPE.

Composed of 6 strands and a hemp center, 7 wires to the strand.

				Swedish iron.			Cast steel.		
Trade No.	Diameter in inches.	Approximate circumference in ins.	Weight per foot in pounds.	Approximate breaking strain in tons of 2000 lbs.	Allowable working strain in tons of 2000 lbs.	Minimum size of drum or sheave in ft.	Approximate breaking strain in tons of 2000 lbs.	Allowable working strain in tons of 2000 lbs.	Minimum size of drum or sheave in ft.
11	1½	4¾	3.55	34	6.80	13	68	13.6	8½
12	1⅜	4¼	3.00	29	5.80	12	58	11.6	8
13	1¼	4	2.45	24	4.80	10¾	48	9.6	7¼
14	1⅛	3½	2.00	20	4.00	9½	40	8.0	6¼
15	1	3	1.58	16	3.20	8½	32	6.4	5¾
16	⅞	2¾	1.20	12	2.40	7½	24	4.8	5
17	¾	2¼	.89	9.3	1.86	6¾	18.6	3.72	4½
18	11/16	2⅛	.75	7.9	1 58	6	15.8	3.16	4
19	⅝	2	.62	6.6	1.32	5¼	13.2	2.64	3½
20	9/16	1¾	.50	5.3	1.06	4½	10.6	2.12	3
21	½	1½	.39	4.2	.84	4	8 4	1.68	2½
22	7/16	1¼	.30	3.3	.66	3¼	6.6	1.32	2¼
23	⅜	1⅛	.22	2.4	.48	2¾	4.8	.96	2
24	5/16	1	.15	1.7	.34	2½	3.4	.68	1¾
25	9/32	⅞	.125	1.4	.28	2¼	2.8	.56	1½

In the preceding table the rope is composed of six strands of seven wires each, laid around hemp heart. This rope is much stiffer than "standard hoisting rope," and is more suitable for standing rope, guys and rigging.

The wires being fewer in the strand are coarser and better adapted to resist the rough work of a mine than the fine wire of the more pliable rope.

CAST STEEL FLAT ROPE.

½ inch thick.					⅜ inch thick.				
Width and thickness in inches.	Weight in pounds per foot.	Approximate breaking strain in tons of 2000 lbs.	Allowable working strain in tons of 2000 lbs.	Approximate diam. in ins. of round cast steel rope of equal strength.	Width and thickness in inches.	Weight in pounds per foot.	Approximate breaking strain in tons of 2000 lbs.	Allowable working strain in tons of 2000 lbs.	Approximate diam. in ins. of round cast steel rope of equal strength.
½ x 7	5.90	89	17.8	1⅝	⅜ x 5½	3.90	55	11	1 5/16
½ x 6	5.10	77	15.4	1 9/16	⅜ x 5	3.40	50	10	1¼
½ x 5½	4.82	72	14.4	1½	⅜ x 4½	3.12	47	9.4	1 3/16
½ x 5	4.27	64	12.8	1⅜	⅜ x 4	2.86	43	8.6	1⅛
1/9 x 4½	4.00	60	12.0	1 5/16	⅜ x 3½	2.50	38	7.6	1
½ x 4	3.30	50	10.0	1¼	⅜ x 3	2.00	30	6.0	15/16
½ x 3½	2.97	45	9.0	1⅛	⅜ x 2½	1.86	28	5.6	⅞
½ x 3	2.38	36	7.2	1	⅜ x 2	1.19	18	3.6	¾

Steel wire flat ropes are composed of a number of strands, alternately twisted to right and left, laid alongside of each other and sewed together with soft iron wires. These ropes are used at times in place of round ropes in shafts of mines. They wind up themselves on a nar-

row winding drum, which takes up less room than one necessary for round rope.

The soft iron sewing wears out sooner than the steel strands, and then it becomes necessary to sew the rope with new iron wires.

GALVANIZED IRON WIRE ROPE.

FOR SHIPS' RIGGING AND DERRICK GUYS.

Composed of 6 strands and a hemp center, 7 or 12 wires to the strand.

Approximate diameter in inches.	Circumference in inches.	Weight per foot in pounds.	Approximate breaking strain in tons of 2000 pounds.	Circumference in inches of new manilla rope of equal strength.
1¾	5½	4.85	44	11
1 11/16	5¼	4.40	40	10½
1⅝	5	4.00	36	10
1½	4¾	3.60	32	9½
1 7/16	4½	3.25	29	9
1⅜	4¼	2.90	26	8½
1¼	4	2.55	23	8
1 3/16	3¾	2.25	20	7½
1⅛	3½	1.95	18	6½
1 1/16	3¼	1.70	15	6
1	3	1.44	13	5¾
⅞	2¾	1.21	11	5¼
13/16	2½	1.00	9	5
¾	2¼	.81	7.3	4¾
⅝	2	.64	5.8	4½
9/16	1¾	.49	4.4	3¾
½	1½	.36	3.2	3
7/16	1¼	.25	2.3	2½
⅜	1⅛	.20	1.8	2¼
5/16	1	.16	1.4	2
9/32	⅞	.123	1.1	1¾
¼	¾	.090	.81	1½
7/32	⅝	.063	.56	1¼
3/16	½	.040	.36	1⅛

The preceding table gives a rope which has the following advantages over a manilla rope: Durability; will not stretch or give, under a strain to anything like the extent of manilla rope; reduction of size and weight, the bulk of wire rigging being one-sixth, and the weight one-half that of a manilla rigging of equal strength.

NOTES ON THE USE OF WIRE ROPE.

Two kinds of wire rope are manufactured. The most pliable variety contains nineteen wires in the strand, and is generally used for hoisting and running rope. The ropes with twelve wires and seven wires in the strand are stiffer, and are better adapted for standing rope, guys and rigging.

For safe working load, allow one-fifth to one-seventh of the ultimate strength, according to the speed, so as to get good wear from the rope. When substituting wire rope for hemp rope, it is good economy to allow for the former the same weight per foot which experience has approved for the latter.

The greater the diameter of the sheaves, pulleys or drums the longer wire rope will last. In the construction of machinery for wire rope, it will be found good economy to make the drums and sheaves as large as possible. The minimum size of drum is given in a column in the table.

Experience has demonstrated that the wear increases with the speed. It is, therefore, better to increase the load than the speed.

Wire rope is manufactured either with a wire or a hemp center. The latter is more pliable than the former, and will wear better where there is short bending.

Wire rope must not be coiled or uncoiled like hemp rope. When mounted on a reel, the latter should be mounted on a spindle or flat turn table to pay off the rope. When forwarded in a small coil without reel, roll it over the ground like a wheel and run off the rope in that way. All untwisting or kinking must be avoided.

To preserve wire rope, apply raw linseed oil with a piece of sheep skin, wool inside, or mix the oil with equal parts of Spanish brown or lampblack.

To preserve wire rope under water or under ground, take mineral or vegetable tar and add one bushel of fresh slacked lime to one barrel of tar, which will neutralize the acid. Boil it well and saturate the rope with the hot tar. To give the mixture body, add some sawdust.

In no case should *galvanized rope* be used for running rope. One day's use scrapes off the coating of zinc, and rusting proceeds with twice the rapidity.

The grooves of cast iron pulleys and sheaves should be filled with well-seasoned blocks of hard wood, set on end, to be renewed when worn out. This end wood will save wear and increase adhesion. The smaller pulleys or rollers which support the ropes on inclined planes should be constructed on the same plan. When large sheaves run with very great velocity, the grooves should be lined with leather, set on end, or with india rubber. This is done in the case of all sheaves used in the *transmission of power* between distant points by means of rope which frequently run at the rate of 4000 feet per minute.

Steel ropes are, to a certain extent, taking the place of iron ropes where it is a special object to combine lightness with strength.

But in substituting a steel rope for an iron running rope, the object in view should be to gain an increased wear from the rope rather than to reduce the size.

To be serviceable, a steel rope should be of the best obtainable quality, as ropes made from low grades of steel are inferior to good iron ropes.

TRANSMISSION OF POWER BY WIRE ROPE.

The use of a round endless wire rope running at a great velocity in a grooved sheave, in place of a flat belt running on a flat-faced pulley, constitutes the transmission of power by wire ropes. The distance to which this can be applied ranges from fifty feet up to about three miles. It commences at the point where a belt becomes too long to be used profitably, and can then be extended almost indefinitely.

A table of horse powers is here presented. It embraces every case that will ordinarily arise in practice, and one can readily select that combination which will suit his own case, especially if the driving machinery already exists. Where there is a choice between a small wheel and fast speed, or a larger wheel with slower speed, it is recommended to take the larger wheel. The range in the size of wire ropes used is small; it varies only from ⅜-inch diameter to 1⅛-inch diameter in a range of 3 to 250 horse power. The ropes are the cheapest part of a transmission, and the cost of renewal is very small.

When placing wheels, special care must be taken to set the wheel shafts at right angles to the line of transmission, and also to set the wheels true on the shafts, otherwise the wheels will wabble and cause the rope to jerk. When possible, the use of guide wheels or supporting wheels should be avoided, as each one adds to the wear on the rope and also diminishes the power slightly.

For speeds below 80 revolutions, use rope one size larger than given in table in order to get same horse power as given in table for 80 revolutions. For short transmissions less than 100 feet span, use rope two sizes larger.

By using pliable wire rope, having 19 wires to strand, an increase of 5 to 10 per cent. in horse power is obtained, less power being consumed in bending the wires. For spans 250 feet and upwards, steel rope may be used to advantage, because it stretches less and splices require to be taken up less frequently.

By use of tightening pulleys, working the under rope under a high tension, double the power can be obtained in short spans. In such cases a pliable rope should be used, 19 wires to strand, of double the weight of rope named in table.

Avoid the use of taper keys.

TABLE OF TRANSMISSION OF POWER BY WIRE ROPES.

Showing necessary size and speed of wheels and rope to obtain any desired amount of power (Roebling).

Diameter of wheel in feet.	Number of revolutions.	Diameter of rope.	Horse power.	Diameter of wheel in feet.	Number of revolutions.	Diameter of rope.	Horse power.
4	80	3/8	3.3	10	80	11/16	58.4
4	100	3/8	4.1	10	100	11/16	73.0
4	120	3/8	5.0	10	120	11/16	87.6
4	140	3/8	5.8	10	140	11/16	102.2
5	80	7/16	6.9	11	80	11/16	75.5
5	100	7/16	8.6	11	100	11/16	94.4
5	120	7/16	10.3	11	120	11/16	113.3
5	140	7/16	12.1	11	140	11/16	132.1
6	80	1/2	10.7	12	80	3/4	99.3
6	100	1/2	13.4	12	100	3/4	124.1
6	120	1/2	16.1	12	120	3/4	148.9
6	140	1/2	18.7	12	140	3/4	173.7
7	80	9/16	16.9	13	80	3/4	122.6
7	100	9/16	21.1	13	100	3/4	153.2
7	120	9/16	25.3	13	120	3/4	183.9
8	80	5/8	22.0	14	80	7/8	148
8	100	5/8	27.5	14	100	7/8	185
8	120	5/8	33.0	14	120	7/8	222
9	80	5/8	41.5	15	80	7/8	217
9	100	5/8	51.9	15	100	7/8	259
9	120	5/8	62.2	15	120	7/8	300

The above table gives the power produced by patent rubber-lined wheels and wire belt ropes at various speeds.

INCLINED PLANES.

For the benefit of those desiring to use wire rope on slopes, inclined planes, etc., we subjoin a table by which the strain produced by any load can easily be calculated.

The table gives the strain on a rope due to a load of 1 ton of 2000 pounds, allowing for rolling friction. An additional allowance for the weight of the rope will have to be made.

EXAMPLE.—For an inclination of 25 feet in 100 feet, corresponding to an angle of $14\frac{1}{12}°$, a load of 2000 pounds will produce a strain on the rope of 497 pounds, and for a load of 8000 pounds the strain on the rope will be $\frac{497 \times 8000}{2000} = 1988$ pounds.

Elevation in 100 feet.	Corresponding angle of inclination.	Strain in pounds on rope from a load of 2000 pounds.	Elevation in 100 feet.	Corresponding angle of inclination.	Strain in pounds on rope from a load of 2000 pounds.
5	$2\frac{7}{8}°$	112	95	$43\frac{1}{2}°$	1385
10	$5\frac{1}{2}°$	211	100	$45°$	1419
15	$8\frac{1}{3}°$	308	105	$46\frac{1}{2}°$	1457
20	$11\frac{1}{3}°$	404	110	$47\frac{3}{4}°$	1487
25	$14\frac{1}{12}°$	497	115	$49°$	1516
30	$16\frac{3}{4}°$	586	120	$50\frac{1}{4}°$	1544
35	$19\frac{1}{3}°$	673	125	$51\frac{1}{2}°$	1570
40	$21\frac{4}{5}°$	754	130	$52\frac{1}{2}°$	1592
45	$24\frac{1}{4}°$	832	135	$53\frac{1}{2}°$	1614
50	$26\frac{1}{8}°$	905	140	$54\frac{1}{2}°$	1633
55	$28\frac{4}{5}°$	975	145	$55\frac{1}{2}°$	1653
60	$31°$	1040	150	$56\frac{1}{4}°$	1671
65	$33\frac{1}{12}°$	1100	155	$57\frac{1}{4}°$	1689
70	$35°$	1156	160	$58°$	1703
75	$37°$	1210	165	$58\frac{4}{5}°$	1717
80	$38\frac{2}{3}°$	1260	170	$59\frac{1}{2}°$	1729
85	$40\frac{1}{2}°$	1304	175	$60\frac{1}{4}°$	1742
90	$42°$	1347			

In selecting a rope a factor of safety from 5 to 7 should be taken, that is, the working load on the rope should only be one-fifth to one-seventh of its breaking strength. As a rule, ropes for shafts should have a factor of safety of 5, and for inclined planes, where the wear is much greater, the factor of safety should be 7. Usually the transmission rope, composed of 6 strands of 7 wires, with a hemp center, is used on inclined planes because it resists the wear better than a rope with smaller wires.

The Roebling Company issues a publication on the subject of "Rope Splicing" which they will send to anyone interested on application.

MANILLA AND HEMP ROPES, HAWSERS AND CABLES.

Ropes of hemp fibers are laid with three or four strands of twisted fibers, and run up to a circumference of 12 inches.

Hawsers are laid with three strands of rope, or with four rope strands.

Cables are laid with three strands of rope only. Ropes of four strands, up to eight inches, are fully 16 per cent. stronger than those having but three strands.

Hawsers and cables of three strands, up to 12 inches, are fully 10 per cent. stronger than those having four strands.

Tarring ropes lessens their strength; this is in consequence of the injury the fibers receive from the high temperature of the tar (290° F.).

The use of tarred ropes in standing rigging is partially to diminish contraction and expansion by alternately wet and dry weather. Tarred hemp and manilla ropes are of about equal strength.

The greater the degree of twisting given to the fibers of a rope, etc., the less the strength, as the exterior alone resists the greater portion of the strain.

TABLE OF MANILLA ROPE.

Diam., inches.	Circ., inches.	Weight per foot, pounds.	Breaking load, pounds.	Diam., inches.	Circ., inches.	Weight per foot, pounds.	Breaking load, pounds.
.239	¾	.019	560	1.91	6	1.19	25,536
.318	1	.033	784	2.07	6½	1.39	29,120
.477	1½	.074	1,568	2.23	7	1.62	32,704
.636	2	.132	2,733	2.39	7½	1.86	36,288
.795	2½	.206	4,278	2.55	8	2.11	39,872
.955	3	.297	6,115	2.86	9	2.67	47,040
1.11	3½	.404	8,534	3.18	10	3.30	54,208
1.27	4	.528	11,558	3.50	11	3.99	61,376
1.43	4½	.668	14,784	3.82	12	4.75	68,544
1.59	5	.825	18,368	4.14	13	5.58	75,712
1.75	5½	.998	21,952	4.45	14	6.47	82,880

The strength of manilla rope is very variable. The strength of pieces from same coil may vary 25 per cent.

A few months of exposed work weakens ropes 20 to 50 per cent.

TABLE OF HORSE POWERS OF MANILLA ROPES AT VARIOUS SPEEDS.

(Stephens-Adamson Manufacturing Company.)

Driving and driven sheaves should not be less than thirty diameters of the rope. Ropes give the best service by using sheaves of large diameter.

Diameter of rope, inches.	Weight per foot, pounds.	Breaking strain, pounds.	Working strain, pounds.	1000 feet per minute.		1500 feet per minute.		2000 feet per minute.		2500 feet per minute.		3000 feet per minute.		3500 feet per minute.		4000 feet per minute.		4500 feet per minute.		5000 feet per minute.	
				Horse power.	Tension weights, pounds.	Horse power.	Tension weights, pounds.	Horse power.	Tension weights, pounds.	Horse power.	Tension weights, pounds.	Horse power.	Tension weights, pounds.	Horse power.	Tension weights, pounds.	Horse power.	Tension weights, pounds.	Horse power.	Tension weights, pounds.	Horse power.	Tension weights, pounds.
5/8	.15	4,000	121	2.25	100	3.37	100	4.50	100	5.37	100	6.25	75	6.87	75	7.50	75	8.00	75	8.50	75
3/4	.20	5,000	151	2.75	100	4.12	100	5.50	100	6.62	100	7.75	100	8.75	100	9.75	100	10.25	100	10.75	100
7/8	.27	7,500	227	4.25	175	6.25	175	8.25	175	10.00	175	11.75	150	13.12	150	14.50	150	15.25	150	16.00	125
1	.33	9,000	272	5.00	200	7.50	200	10.00	200	12.00	200	14.00	175	15.62	175	17.25	175	18.12	175	19.00	150
1 1/8	.45	12,250	371	7.00	275	10.25	275	13.50	275	16.25	250	19.00	250	21.25	250	23.50	225	24.75	225	26.00	200
1 1/4	.50	16,000	424	8.00	375	11.75	325	15.50	300	18.75	300	22.00	300	24.50	275	27.00	275	28.25	250	29.50	250
1 3/8	.65	18,060	547	10.25	400	15.12	400	20.00	400	24.12	375	28.25	375	31.50	350	34.75	350	36.62	325	33.50	300
1 1/2	.75	22,500	613	11.50	450	16.75	450	22.00	450	26.75	425	31.50	425	35.25	400	39.00	400	41.25	375	43.50	350
1 5/8	.90	26,000	758	14.25	575	21.00	550	27.75	550	33.62	525	39.50	525	44.25	500	49.00	500	52.25	475	55.50	450
1 3/4	1.10	30,250	916	17.00	675	25.25	675	33.50	650	40.37	650	47.25	625	52.75	600	58.25	575	61.50	550	64.75	525
2	1.40	39,000	1090	20.50	800	30.25	800	40.00	800	48.25	775	56.50	750	62.87	700	69.25	675	73.37	650	77.50	625

Our tension weights are twenty-five and fifty pounds each. In the above table working strains are approximately 3 per cent. of breaking strains.

All computations made on the highest quality of long fiber transmission rope, "S-A" brand. Splicing—lengths of rope splices should be from sixty to eighty times the diameter of rope.

To avoid reducing the lugs of the sprockets in wheel chains, we recommend that the lengths of the links be increased 1/16 inch to include 5/8 inch and 1/8 inch above that size.

STANDARD CHAIN COMPANY.

TABLE OF PITCH, BREAKING, PROOF AND WORKING STRAINS.

Size of chain.	Dist. from cent. of one link to cent. of next.	Weight per foot in lbs. approximately.	Outside width.	Best special dredge.			B. B. B. crane.		
				Proof test, pounds.	Average breaking strain, lbs.	Ordinary safe load, general use, pounds.	Proof test, pounds.	Average breaking strain, lbs.	Ordinary safe load, general use, pounds.
1/4	25/32	3/4	15/16	2,500	5,000	1,665	2,000	4,000	1,335
5/16	27/32	1	1 1/8	3,500	7,000	2,340	3,000	6,000	2,000
3/8	31/32	1 1/2	1 5/16	5,000	10,000	3,335	4,500	9,000	3,000
7/16	1 5/32	2	1 1/2	7,000	14,000	4,670	6,500	13,000	4,335
1/2	1 11/32	2 1/2	1 13/16	9,000	18,000	6,000	8,000	17,000	5,335
9/16	1 15/32	3 1/6	2	11,000	22,000	7,335	10,000	20,000	6,665
5/8	1 23/32	4 1/3	2 3/16	14,000	27,000	9,333	12,000	26,000	8,000
11/16	1 13/16	5 1/3	2 3/8	17,000	32,500	11,335	14,500	30,000	9,665
3/4	1 15/32	6 1/6	2 9/16	20,000	40,000	13,333	17,500	36,000	11,665
13/16	2 1/16	7	2 3/4	23,000	42,000	15,335	19,000	40,000	12,665
7/8	2 3/16	8	2 15/16	26,000	48,000	17,333	22,000	44,000	14,666
15/16	2 7/16	9 1/6	3 3/16	29,000	54,000	19,335	25,000	50,000	16,666
1	2 1/2	10 1/2	3 3/8	32,000	61,000	21,333	28,000	57,000	18,666
1 1/16	2 5/8	12	3 9/16	35,000	69,000	23,335	32,000	65,000	21,335
1 1/8	2 3/4	13 1/6	3 13/16	40,000	78,000	26,665	36,000	72,000	24,000
1 3/16	3 1/16	14 2/3	4	46,000	88,000	30,666	40,000	80,000	26,666
1 1/4	3 1/8	16 2/3	4 3/16	51,000	95,000	34,000	44,000	88,000	29,333
1 5/16	3 3/8	17 1/2	4 3/8	54,000	104,000	36,000	48,000	96,000	32 000
1 3/8	3 9/16	19 2/3	4 9/16	58,000	114,000	38,665	53,000	104,000	35,335
1 7/16	3 11/16	21 1/6	4 3/4	62,000	122,000	41,335	58,000	116,000	38,665
1 1/2	3 7/8	23	5 1/8	67,000	134,000	44,465	62,000	124,000	41,335
1 9/16	4	25 1/6	5 5/16	70,500	142,000	47,000	66.000	132,000	44,000
1 5/8	4 1/4	28	5 1/2	77,000	154,000	51,335	72,000	144,000	48,000
1 11/16	4 1/2	30	5 11/16	79,000	158,000	52,666			
1 3/4	4 3/4	32	5 7/8	83,000	166,000	55,333			
1 13/16	5	33	6 1/16	89,000	178,000	59,335			
1 7/8	5 1/4	35	6 3/8	95,000	190,000	63,333			
1 15/16	5 1/2	38	6 9/16	101,000	202,000	67,333			
2	5 3/4	40	6 3/4	108,000	216,000	72,000			
2 1/16	6	43	6 15/16	115,000	230,000	76,666			
2 1/8	6 1/4	47	7 1/8	122,000	244,000	81,333			
2 3/16	6 1/2	50	7 5/16	129,000	258,000	86,000			
2 1/4	6 3/4	53	7 5/8	136,500	273,000	91,000			
2 3/8	6 7/8	58 1/2	8	152,000	304,000	101,333			
2 1/2	7	65	8 3/8	168,500	337,000	112,333			
2 5/8	7 1/8	70	8 3/4	181,000	362,000	120,666			
2 3/4	7 1/4	73	9 1/8	193,500	387,000	129,000			
2 7/8	7 1/2	76	9 1/2	206,000	412,000	137,333			
3	7 3/4	86	9 7/8	218,000	436,000	145,333			

BELTING AND VELOCITY OF PULLEYS.

(*The Coal and Metal Miners' Pocket-Book.*)

Belts should not be made tighter than necessary. Over half the trouble from broken pulleys, hot boxes, etc., can be traced to the fault of tight belts, while the machinery wears much more rapidly than when loose belts are employed.

The speed of belts should not be more than 3000 feet per minute.

The motion of driving should run with the stronger or flesh side on the outside and the grain (hair) side on the inside, nearest the pulley, so that the stronger part of the belt may be subject to the least wear. It will also drive 30 per cent more than if run with the flesh side nearest the pulley. The grain side adheres better because it is smooth. Do not expose leather belts to the weather.

When the length of a belt cannot be conveniently ascertained by measuring around the pulleys with a tape line, the following rule will be serviceable:

Add the diameters of the two pulleys together and divide by 2; multiply this quotient by 3¼, and to the product add twice the distance between the centers of the shafts; the sum will be the length required.

PULLEYS.

APPROXIMATE WEIGHTS OF CAST IRON PULLEYS—SINGLE BELT.

(Stephens-Adamson Mfg. Co., Aurora, Ill., U. S. A.)

Diameter, inches.	Face in inches.							
	3	4	5	6	7	8	9	10
6	10	15	18	21	25	27	30	40
8	14	16	20	23	27	30	32	45
10	16	20	23	28	30	31	40	50
12	20	22	24	28	33	42	49	56
14	22	28	32	36	40	45	50	60
16	27	30	40	45	58	60	63	66
18	30	35	42	50	54	62	80	95
20	40	52	58	63	70	75	80	102
22	45	58	63	70	75	80	93	106
24	50	60	65	70	75	85	95	110
26	55	62	83	100	115	125	130	135
28	62	65	90	105	120	130	140	145
30	66	75	88	110	120	125	145	165
32	71	80	95	130	148	165	190	220
34	75	90	110	135	150	170	195	230
36	77	100	125	140	160	180	198	240

Split pulleys weigh about 10 per cent. more than the above.

NOTE.—In the manufacture of cast iron pulleys the size of arms and hub depends on the bore, diameter and face of pulley, so naturally there is considerable variation in the weights. Weights given in

the above table are made from records taken during several years and are given for the purpose of enabling our customers to estimate freight costs and also to assist engineers in work where weight is to be taken into consideration. While we do not guarantee these weights, we believe the table is as near correct as it is possible to make a table of this kind.

APPROXIMATE WEIGHTS OF CAST IRON PULLEYS—DOUBLE BELT.

(Stephens-Adamson Mfg. Co., Aurora, Ill., U. S. A.)

Diameter, inches.	Face in inches.											
	8	10	12	14	16	18	20	22	24	26	28	30
18 . . .	93	102	115	135	145	160	195	225	245			
20 . . .	104	119	130	160	190	200	225	250				
22 . . .	118	145	165	185	218	238	265	280				
24 . . .	134	170	185	200	225	245	290	325	360	390	430	500
26 . . .	145	180	195	245	275	300	350	375	435	485	520	575
28 . . .	165	200	211	271	310	345	390	440	510	565	610	675
30 . . .	190	215	240	300	320	360	430	470	600	650	700	750
32 . . .	198	225	270	326	374	423	471	500	560	665	767	824
34 . . .	217	250	280	350	407	450	531	590	660	700	800	875
36 . . .	230	280	305	385	440	495	600	620	670	725	825	900
38 . . .	259	308	355	416	470	500	610	660	710	760	875	940
40 . . .	275	320	375	440	490	550	625	700	760	810	900	980
42 . . .	290	340	400	450	540	600	675	743	820	890	950	1000
44 . . .	325	360	425	490	560	650	720	795	864	992	1100	1200
46 . . .	340	380	440	530	582	700	774	840	940	1050	1170	1275
48 . . .	350	400	450	550	600	750	850	950	1050	1150	1250	1350
50 . . .	376	440	531	612	710	800	847	980	1061	1170	1300	1425
52 . . .	400	480	560	664	740	838	925	1012	1121	1194	1378	1500
54 . . .	425	536	610	700	750	900	950	1050	1150	1250	1400	1600
56 . . .	490	540	640	720	831	925	1002	1121	1231	1330	1600	1700
58 . . .	515	600	652	741	875	981	1071	1190	1292	1400	1690	1800
60 . . .	550	645	720	750	890	1000	1100	1250	1350	1462	1800	1900
62 . . .	570	663	760	860	970	1092	1202	1301	1432	1550	1850	2000
64 . . .	600	700	780	915	1027	1200	1262	1375	1500	1625	1900	2100
66 . . .	621	735	842	900	1069	1211	1321	1450	1576	1703	1950	2200
68 . . .	662	765	910	1002	1121	1250	1400	1500	1651	1780	2000	2300
70 . . .	690	785	950	1050	1179	1300	1450	1600	1729	1861	2100	2350
72 . . .	721	840	1000	1095	1230	1350	1500	1650	1799	1950	2200	2400
74 . . .	760	900	1021	1150	1350	1420	1600	1725	1900	2050	2300	2600
76 . . .	802	935	1056	1200	1375	1500	1750	1900	2200	2250	2500	2800
78 . . .	825	960	1100	1250	1400	1600	1792	1924	2250	2300	2600	3100
80 . . .	870	1000	1150	1300	1460	1800	1900	1981	2340	2600	2800	3300
82 . . .	900	1050	1200	1350	1520	1842	1921	2100	2382	2741	3000	3400
84 . . .	940	1080	1232	1400	1600	1850	1950	2250	2400	2750	3200	3500

Split pulleys weigh about 10 per cent. more than the above.

NOTE.—In the manufacture of cast iron pulleys the size of arms and hub depends on the bore, diameter and face of pulley, so naturally there is considerable variation in the weights. Weights given in the above table are made from records taken during several years and are given for the purpose of enabling our customers to estimate freight costs and also to assist engineers in work where weight is to be taken into consideration. While we do not guarantee these weights, we believe the table is as near correct as it is possible to make a table of this kind.

WOOD.

BOARD AND TIMBER MEASURE.

One foot board measure (B. M.) is equal to one foot square and one inch thick.

One inch board measure is equal to one foot long, one inch wide and one inch thick.

Twelve inches board measure = one foot board measure.

One cubic foot = 12 feet (B. M.)

One thousand (M) feet board measure = $83\frac{1}{3}$ cubic feet.

Lumber is usually measured and sold by the thousand (M) feet board measure (B. M.)

TO COMPUTE THE MEASURE OF SURFACE IN SQUARE FEET.

When all the dimensions are in feet: Multiply the length by the breadth = product required.

When either of the dimensions are in inches: Multiply as above, and divide by 12 = product required.

When all the dimensions are in inches: Multiply as before, and divide by 144 = product required.

TO COMPUTE THE VOLUME OF SQUARE TIMBER.

When all the dimensions are in feet: Multiply the breadth, by the depth, by the length, and the product will give the volume in cubic feet.

When either of the dimensions are given in inches: Multiply as above, and divide the product by 12.

When any two of the dimensions are given in inches: Multiply as before, and divide by 144.

TO COMPUTE THE VOLUME OF ROUND TIMBER.

When all the dimensions are in feet: Multiply the length by the square of one quarter of the mean girth, and the product will give the volume in cubic feet.

When the length is given in feet, and the girth in inches: Multiply as above, and divide by 144.

When all the dimensions are in inches: Multiply as before, and divide by 1728.

TABLE OF BOARD MEASURE.

Length in feet.	Width in inches.								
	6	7	8	9	10	11	12	13	14
	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Feet.	Ft. In.	Ft. In.
1	0 6	0 7	0 8	0 9	0 10	0 11	1	1 1	1 2
2	1 0	1 2	1 4	1 6	1 8	1 10	2	2 2	2 4
3	1 6	1 9	2 0	2 3	2 6	2 9	3	3 3	3 6
4	2 0	2 4	2 8	3 0	3 4	3 8	4	4 4	4 8
5	2 6	2 11	3 4	3 9	4 2	4 7	5	5 5	5 10
6	3 0	3 6	4 0	4 6	5 0	5 6	6	6 6	7 0
7	3 6	4 1	4 8	5 3	5 10	6 5	7	7 7	8 2
8	4 0	4 8	5 4	6 0	6 8	7 4	8	8 8	9 4
9	4 6	5 3	6 0	6 9	7 6	8 3	9	9 9	10 6

TABLE OF BOARD MEASURE—continued.

Length in feet.	Width in inches.								
	6	7		9	10	11	12	13	14
	Ft. In.	Ft In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Feet.	Ft. In.	Ft. In.
10	5 0	5 10	6 8	7 6	8 4	9 2	10	10 10	11 8
11	5 6	6 5	7 4	8 3	9 2	10 1	11	11 11	12 10
12	6 0	7 0	8 0	9 0	10 0	11 0	12	13 0	14 0
13	6 6	7 7	8 8	9 9	10 10	11 11	13	14 1	15 2
14	7 0	8 2	9 4	10 6	11 8	12 10	14	15 2	16 4
15	7 6	8 9	10 0	11 3	12 6	13 9	15	16 3	17 6
16	8 0	9 4	10 8	12 0	13 4	14 8	16	17 4	18 8
17	8 6	9 11	11 4	12 9	14 2	15 7	17	18 5	19 10
18	9 0	10 6	12 0	13 6	15 0	16 6	18	19 6	21 0
19	9 6	11 1	12 8	14 3	15 10	17 5	19	20 7	22 2
20	10 0	11 8	13 4	15 0	16 8	18 4	20	21 8	23 4
21	10 6	12 3	14 0	15 9	17 6	19 3	21	22 9	24 6
22	11 0	12 10	14 8	16 6	18 4	20 2	22	23 10	25 8
23	11 6	13 5	15 4	17 3	19 2	21 1	23	24 11	26 10
24	12 0	14 0	16 0	18 0	20 0	22 0	24	26 0	28 0
25	12 6	14 7	16 8	18 9	20 10	22 11	25	27 1	29 2
26	13 0	15 2	17 4	19 6	21 8	23 10	26	28 2	30 4
27	13 6	15 9	18 0	20 3	22 6	24 9	27	29 3	31 6
28	14 0	16 4	18 8	21 0	23 4	25 8	28	30 4	32 8
29	14 6	16 11	19 4	21 9	24 2	26 7	29	31 5	33 10
30	15 0	17 6	20 0	22 6	25 0	27 6	30	32 6	35 0
31	15 6	18 1	20 8	23 3	25 10	28 5	31	33 7	36 2

In the above table length of board is given in feet in left hand column; the width in inches in the upper row of figures. Boards taken in table at one inch thick.

To use table for boards of greater thickness: for 1¼ inch boards add one-fourth to quantity given in table, and follow same method with any other thickness of board.

For greater widths take sum of quantities given in two columns, the sum of the widths of which equal width desired.

EXAMPLE 1.—How many feet board measure in a plank 24 feet long, 16 inches wide and 2½ inches thick?

For one inch boards we see by table:

24 ft. × 6 inches = 12 ft. 0 in. B. M.
24 ft. × 10 inches = 20 ft. 0 in. B. M.
Therefore 24 ft. × 16 in. × 1 in. = 32 ft. B. M.
and 24 ft. × 16 in. × 2½ in. = 80 ft. B. M.

SCANTLINGS REDUCED TO BOARD MEASURE.

Length in feet.	2 x 4 inches.	2 x 6 inches.	2 x 8 inches	2 x 10 inches.	3 x 4 inches.	3 x 6 inches.	3 x 8 inches.	3 x 10 inches.
	Ft. In.	Feet.	Ft. In.	Ft. In.	Feet.	Feet.	Feet.	Feet.
10	6 8	10	13 4	16 8	10	15	20	25
12	8 0	12	16 0	20 0	12	18	24	30
14	9 4	14	18 8	23 4	14	21	28	35
16	10 8	16	21 4	26 8	16	24	32	40
18	12 0	18	24 0	30 0	18	27	36	45
20	13 4	20	26 8	33 4	20	30	40	50
22	14 8	22	29 4	36 8	22	33	44	55
24	16 0	24	32 0	40 0	24	36	48	60
26	17 4	26	34 8	43 4	26	39	52	65
28	18 8	28	37 4	46 8	28	42	56	70
30	20 0	30	40 0	50 0	30	45	60	75
32	21 4	32	42 8	53 4	32	48	64	80

SCANTLINGS REDUCED TO BOARD MEASURE—continued.

Length in feet.	4 x 5 inches.	4 x 7 inches.	5 x 6 inches.	5 x 8 inches.	5 x 10 inches.	6 x 7 inches.	7 x 8 inches.
	Ft. In.	Ft. In.	Feet.	Ft. In.	Ft. In.	Feet.	Ft. In.
10	16 8	23 4	25	33 4	41 8	35	46 8
12	20 0	28 0	30	40 0	50 0	42	56 0
14	23 4	32 8	35	46 8	58 4	49	65 4
16	26 8	37 4	40	53 4	66 8	56	74 8
18	30 0	42 0	45	60 0	75 0	63	84 0
20	33 4	46 8	50	66 8	83 4	70	93 4
22	36 8	51 4	55	73 4	91 8	77	102 8
24	40 0	56 0	60	80 0	100 0	84	112 0
26	43 4	60 8	65	86 8	108 4	91	121 4
28	46 8	65 4	70	93 4	116 8	98	130 8
30	50 0	70 0	75	100 0	125 0	105	140 0
32	53 4	74 8	80	106 8	133 4	112	149 4

By the above tables the feet B. M. in any common size of scantling can be gotten directly from the tables or by a simple use of same.

EXAMPLE.—How many feet B. M. in a scantling 6 x 6 x 18 feet long?

From table we see:

$3 \times 6 \times 18$ ft. long = 27 ft. B. M.

Therefore $6 \times 6 \times 18$ ft. long = 54 ft. B. M.

Bear in mind that 12 *inches board measure* = 1 *foot board measure.*

WEIGHT OF LUMBER PER 1000 (M) FEET B. M.

	Dry.	Partly seasoned.	Green.
Pine and hemlock	2500 lbs.	2700 lbs.	3000 lbs.
Norway and yellow pine	3000 lbs.	4000 lbs.	5000 lbs.
Oak and walnut	4000 lbs.	5000 lbs.	
Ash and maple	3500 lbs.	4000 lbs.	

WEIGHT OF GREEN LOGS TO SCALE 1000 (M) FEET B. M

Yellow pine (Southern), 8000 to 10,000 pounds.

Norway pine (Michigan), 7000 to 8000 pounds.

White pine (Michigan) { off of stump, 6000 to 7000 pounds.
out of water, 7000 to 8000 pounds.

White pine (Pennsylvania), bark off, 5000 to 6000 pounds.

Hemlock (Pennsylvania), bark off, 6000 to 7000 pounds.

Four acres of water are required to store 1,000,000 feet of logs.

The strongest beam which can be cut out of round log is one in which the breadth is to the depth as 5 to 7 very nearly.

PROPERTIES OF TIMBER.

Description.	Lumber, weight per cubic foot in lbs.	Cord wood, weight per cord, seasoned = 128 cubic feet.	Tenacity in lbs. per square inch.	Crushing weight in lbs. per square inch.
Ash, Am., white, dry .	38	3,450	20,000	
Beech	48	3,250	11,500	9,300
Cherry, dry	42			
Chestnut, dry	41			
Elm, dry	35	. . . . .	13,000	
Hemlock, dry.	25	. . . . .	8,740	5,400
Hickory, dry	53	4,500	15,000	
Locust, dry	44	. . . . .	. . . . .	11,720
Maple, dry	49	. . . . .	10,000	
Oak, white, dry	48	3,850	16,000	3,150 to 7,000
Oak, live, dry	59			
Oak, other kinds . .	32 to 45	3,250		
Pine, white dry	25	2,000	7,000	2,800 to 4,500
Pine, yellow, Northern	34	. . . . .	. . . . .	} 4,400 to 6,000
Pine, yellow, Southern	45	. . . . .	. . . . .	
Spruce, dry	25	. . . . .	14,000	2,800 to 4,500
Walnut, black, dry . .	38	. . . . .	. . . . .	5,690

Green timbers usually weigh from one-fifth to one-half more than dry; ordinary building materials when tolerably well seasoned about one-sixth more than perfectly dry.

Tenacity.—For working timbers take one-fifth to one-sixth tenacity as shown by table; the table gives breaking weight.

Crushing.—The same remarks apply to crushing as to tenacity.

STRENGTH OF WOODEN POSTS AND COLUMNS (KIDDER).

SAFE LOAD IN POUNDS FOR YELLOW PINE AND OREGON PINE POSTS (ROUND AND SQUARE). *

Size of post in inches.	Length of post in feet.								
	8	10	12	14	15	16	18	20	24
4 x 6	18,200	16,800	15,360						
5½ round	19,590	18,760	17,550	16,500					
6 x 6	30,200	28,800	27,400	25,900	25,200	24,500			
6 x 8	40,300	38,400	36,500	34,600	33,600	32,600			
6 x 10	50,400	48,000	45,600	43,200	42,000	40,800			
7½ round	38,540	37,130	35,710	34,300	33,590	32,890			
8 x 8	64,000	54,400	52,500	50,600	49,600	48,600	46,700		
8 x 10	80,000	68,000	65,600	63,200	62,000	60,800	53,400		
8 x 12	96,000	81,600	78,700	76,800	74,400	73,000	70.100		
9½ round	70,900	61,970	60,190	58,350	57,429	56,580	54,800		
10 x 10	100,000	100,000	85,600	83,200	82,000	80,800	78,400	76,000	
10 x 12	120,000	120,000	102,700	99,800	98,400	97,000	94,100	91,200	
10 x 14	140,000	140,000	119,800	116,500	114,800	113,100	109,800	106,400	
11½ round	103,900	103,900	90,912	88,730	87,690	86,550	84,160	82,290	
12 x 12	144,000	144,000	144,000	123,800	122,400	121,000	118,100	115,200	109,440
12 x 14	168,000	168,000	168,000	144,500	142,800	141,100	137,800	134,400	127,680
12 x 16	192,000	192,000	192,000	165,100	163,200	161,300	157,400	153,600	145,920
14 x 14	196,000	196,000	196,000	196,000	170,900	169 100	165,800	162,400	155,800
16 x 16	256,000	256,000	256,000	256,000	229,100	225,300	221,400	217,600	209,900
18 x 18	324,000	324,000	324,000	324,000	324,000	289,400	285,100	280,800	272,160
20 x 20	400,000	400,000	400,000	400,000	400,000	400,000	356,800	352,000	342,400

*These two woods appear to be of about equal strength for posts exeeding 12 diameters in height.

SAFE LOAD FOR TEXAS (YELLOW) PINE POSTS (ROUND AND SQUARE).

Size of post in inches.	Length of post in feet.								
	8	10	12	14	15	16	18	20	24
4 x 6	15,500	14,280	13,050						
5½ round	16,650	15,790	14,900	14,030					
6 x 6	25,704	24,480	23,256	22,032	21,420	20,808			
6 x 8	34,272	32,640	31,008	29,376	28,560	27,744			
6 x 10	42,840	40,800	37,760	36,720	35,700	34,680			
7½ round	32,740	31,540	30,340	29,140	28,540	27,940	26,740		
8 x 8	47,870	46,240	44,600	42,970	42,160	41,340	39,710		
8 x 10	59,840	57,800	55,760	53,720	52,700	51,680	49,640		
8 x 12	71,808	69,360	66,910	64,460	63,240	62,000	59,560		
9½ round	54,150	52,650	51,150	49,580	48,820	48,070	46,570		
10 x 10	85,000	78,800	72,760	70,720	69,700	68,680	66,640	64,600	
10 x 12	102,000	89,760	87,300	84,860	83,640	82,400	80,000	77,500	
10 x 14	119,000	104,700	101,860	99,000	97,580	96,150	93,300	90,400	
11½ round	88,290	79,100	77,250	75,400	74,470	73,550	71,700	69,850	66,160
12 x 12	122,400	110,160	107,700	105,260	104,040	102,800	100,360	97,920	93,000
12 x 14	142,800	128,520	125,660	122,800	121,380	119,950	117,100	114,240	108,520
12 x 16	163,200	146,880	143,600	140,350	138,720	137,080	133,800	130,560	124,030
14 x 14	166,600	166,600	149,450	146,600	145,180	143,760	140,900	138,080	132,400
14 x 16	190,400	190,400	170,800	167,500	165,900	164,300	161,000	157,800	151,300
16 x 16	217,600	217,600	217,600	194,700	193,000	191,400	188,200	184,900	178,400

SAFE LOAD IN POUNDS FOR OAK AND NORWAY PINE POSTS (ROUND AND SQUARE).

Size of post in inches.	Length of post in feet.								
	8	10	12	14	15	16	18	20	24
4 x 6	13,680	12,600	11,520						
5½ round	14,700	13,900	13,160	12,370					
6 x 6	22,680	21,600	20,520	19,440	18,900	18,360			
6 x 8	30,240	28,800	27,360	25,920	25,200	24,480			
6 x 10	37,800	36,000	34,200	32,400	31,500	30,600			
7½ round	28,900	27,850	26,780	25,720	25,190	24,660			
8 x 8	42,240	40,768	39,360	37,880	37,120	36,480	35,000		
8 x 10	52,800	50,960	49,200	47,360	46,400	44,600	43,760		
8 x 12	63,360	61,152	59,040	56,830	55,680	54,720	52,500		
9½ round	47,960	46,440	45,160	43,740	43,100	42,400	41,120		
10 x 10	75,000	66,000	64,200	62,400	61,500	60,600	58,800	57,000	
10 x 12	90,000	79,200	77,040	74,880	73,800	72,720	70,560	68,400	
10 x 14	105,000	92,400	89,880	87,360	86,100	84,840	82,320	79,800	
11½ round	77,925	69,820	68,160	66,490	65,770	64,833	63,170	61,600	
12 x 12	108,000	108,000	95,040	92,880	91,700	90,700	88,560	86,400	82,080
12 x 14	126,000	126,000	110,800	108,300	107 000	105,840	103,300	100,802	95,760
12 x 16	144,000	144,000	126,700	123,800	122,300	120,900	118,000	115,200	109,400
14 x 14	147,000	147,000	147,000	129,300	128,100	127,000	124,400	121,900	116,800
16 x 16	192,000	192,000	192,000	192.000	170,500	168,900	166,100	163,000	157,400
18 x 18	243,000	243,000	243,000	243,000	243,000	217,000	213,800	210,600	204,100
20 x 20	300,000	300,000	300,000	300,000	300,000	300,000	267,600	264,000	256,000

SAFE LOAD IN POUNDS FOR WHITE PINE AND SPRUCE POSTS (ROUND AND SQUARE).

Size of post in inches.	Length of post in feet.								
	8	10	12	14	15	16	18	20	24
4 x 6	11,520	10,550	9,800	8,700					
5½ round	12,350	11,730	11,180	10,490					
6 x 6	19,080	18,216	17,352	16,490	16,050	15,620			
6 x 8	25,440	24,290	23,140	21,980	21,400	20,830			
6 x 10	31,800	30,360	28,920	27,480	26,760	26,040			
7½ round	24,220	23,380	22,540	21,660	21,260	20,820			
8 x 8	35,450	34,300	33,150	32,000	31,420	30,850	29,700		
8 x 10	44,320	42,480	41,440	40,000	39,280	38,560	37,120		
8 x 12	53,180	51,450	49,730	48,000	47,140	46,270	44,544		
9½ round	40,000	39,000	37,860	36,800	36,230	35,730	34,670		
10 x 10	62,500	55,400	53,960	52,520	51,800	51,080	49,640	48,200	
10 x 12	75,000	66,480	64,800	63,000	62,160	61,300	59,570	57,840	
10 x 14	87,500	77,560	75,600	73,500	72,520	71,510	69,500	67,480	
11½ round	64,930	58,390	57,140	55,800	55,170	54,550	53,100	51,950	
12 x 12	90,000	90,000	79,780	78,000	77,180	76,320	74,590	72,860	69,400
12 x 14	105,000	105,000	93,170	91,050	90,050	89,000	87,020	85,000	80,900
12 x 16	120,000	120,000	106,300	104,000	102,900	101,700	99,400	97,150	92,500
14 x 14	122,500	122,500	110,350	108,350	107,400	106,400	104,460	102,300	98,400
16 x 16	160,000	160,000	160,000	143,870	142,590	141,570	139,260	136,960	132,360
18 x 18	202,500	202,500	202,500	202,500	183,060	181,760	179,170	176,580	171,400
20 x 20	250,000	250,000	250,000	250,000	250,000	250,000	224,500	221,200	215,200

For *safe load* take one-fifth or one-sixth of the *breaking load* as given in table.

MINIMUM SAFE SUPERIMPOSED LOADS FOR FLOORS REQUIRED BY VARIOUS BUILDING LAWS.

Class of buildings.	Minimum live load per square foot of floor.					
	Buffalo, 1906.	Boston, 1895.	Chicago, 1895.	Denver, 1898.	New York, 1899.	St. Louis, 1897.
Dwellings	40	50	70	40	60	70
Hotels, tenements and lodging houses	70	50	70	50†	60	70
Offices	70	100	70	70	75*	70*
Bldgs. for public assem.,	100	150	70	80‡	90	120†
Stores, warehouses and manufacturing bldgs.,	120	250	150§	150§	120§	150§

*First floor, 150 lbs. ‡With fixed desks.
†Also schoolhouses. §And upwards.

It is the opinion of Kidder that the following allowances for floor loads, taken in connection with the values given for the safe strength of beams, will provide absolute safety with proper allowance for economy:

For dwellings, sleeping and lodging rooms . . . . 40 pounds.
For school rooms . . . . 50 pounds.
For offices (upper stories) . . . . 60 pounds.
For offices (first story) . . . . 80 pounds.
For stables and carriage houses . . . . 65 pounds.
For banking rooms, churches and theaters . . . . 80 pounds.
For assembly halls, dancing halls and the corridors of all public buildings, including hotels . . . . 120 pounds.
For drill rooms . . . . 150 pounds.

Iron caps for timber pillars are useful in important structures to distribute thrust evenly through the pillar, and also for supporting the ends of girders where a second post rests on top of the first.

Floors.—Kidder gives following assumed weights per square foot *in addition* to dead weight of the floor itself in designing floors:

For street bridges for general public traffic, 80 pounds per square foot.

WHITE OAK BEAMS (KIDDER).

Table of safe quiescent loads for horizontal rectangular beams, one inch broad, supported at both ends, load *uniformly distributed.* For *concentrated* load at center *divide by two.* For *permanent* loads (such as masonry) reduce by 10 per cent.

Depth of beam.	Span in feet.												
	6	8	10	12	14	15	16	17	18	20	22	24	25
Ins.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
6	900	675	540	450	386	360							
7	1225	919	735	612	525	490	459						
8	1600	1200	960	800	685	640	600	565					
9	2025	1519	1215	1012	868	801	759	715	675				
10	2500	1875	1500	1250	1071	1000	937	882	833	750			
12	3600	2700	2160	1800	1544	1440	1350	1270	1200	1080			
14	4900	3675	2940	2450	2100	1960	1837	1729	1633	1470	1336		
15	5625	4218	3375	2812	2410	2250	2109	1985	1875	1687	1534	1406	1350
16	6400	4800	3840	3200	2742	2560	2400	2260	2133	1920	1745	1600	1536

Loads above and to the right of heavy line will crack plastered ceilings.

SPRUCE BEAMS.

Table of safe quiescent loads for horizontal rectangular beams, one inch broad, supported at both ends, load *uniformly distributed.* For *concentrated* load at center *divide by two.* For *permanent* loads (such as masonry) reduce by 10 per cent.

Depth of beam.	Span in feet.												
	6	8	10	12	14	15	16	17	18	20	22	24	25
Ins.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
6	840	630	504	420	360	336							
7	1143	857	686	572	490	457	428						
8	1493	1120	896	746	640	597	560	527					
9	1890	1417	1134	945	810	756	708	667	630				
10	2333	1750	1400	1166	1000	933	875	824	777	700			
12	3360	2520	2016	1680	1440	1344	1260	1086	1120	1018			
14	4573	3430	2744	2286	1960	1828	1715	1614	1524	1372	1247	1143	1097
15	5250	3937	3150	2625	1875	2100	1968	1853	1750	1575	1431	1312	1260
16	5973	4480	3584	2986	2540	2388	2240	2108	1991	1792	1629	1493	1433

Loads above and to the right of heavy line will crack plastered ceilings.

HARD PINE BEAMS (KIDDER).

Table of safe quiescent loads for horizontal rectangular beams of Georgia yellow pine, one inch broad, supported at both ends, load *uniformly distributed.* For *concentrated* load at center *divide by two.* For *permanent* loads (such as masonry) reduce by 10 per cent.

Depth of beam.	Span in feet.												
	6	8	10	12	14	15	16	18	20	22	24	25	27
Ins.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
6	1200	900	720	600	514	480							
7	1633	1225	980	816	700	653	612						
8	2133	1600	1280	1066	914	853	800						
9	2700	2025	1620	1350	1157	1080	1012	900					
10	3333	2500	2000	1666	1428	1333	1250	1111	1000				
12	4800	3600	2880	2400	2056	1920	1800	1600	1440				
14	6533	4900	3920	3266	2800	2613	2450	2177	1960	1782	1633	1568	1450
15	7500	5633	4500	3750	3214	3000	2816	2500	2250	2045	1875	1800	1666
16	8533	6400	5120	4266	3656	3412	3200	2844	2560	2327	2133	2048	1896

Loads above and to the right of heavy line will crack plastered ceilings.

OREGON PINE (DOUGLAS FIR) BEAMS.

Table of safe quiescent loads for horizontal rectangular beams of Oregon pine (Douglas fir), one inch broad, supported at both ends, load *uniformly distributed.* For *concentrated* load at center *divide by two.* For *permanent* loads (such as masonry) reduce by 10 per cent.

Depth of beam.	Span in feet.												
	6	8	10	12	14	15	16	18	20	22	24	25	27
Ins.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
6	1080	810	648	540									
7	1470	1102	882	735									
8	1920	1440	1152	960	823	768	720						
9	2430	1822	1458	1215	1041	972	911	810					
10	3000	2250	1800	1500	1286	1200	1125	1000	900				
12	4320	3240	2592	2160	1851	1728	1620	1440	1296	1178	1080	1036	
14	5880	4410	3528	2940	2520	2352	2205	1960	1764	1604	1470	1411	1306
15	6750	5062	4050	3375	2892	2700	2531	2250	2025	1841	1687	1620	1500
16	7680	5760	4608	3840	3291	3072	2880	2560	2304	2094	1920	1843	1707

Loads above and to the right of heavy line will crack plastered ceilings.

WHITE PINE (OR COMMON SOFT PINE) BEAMS (KIDDER).

Table of safe quiescent loads for horizontal rectangular beams, one inch broad, supported at both ends, load *uniformly distributed.* For *concentrated* load at center *divide by two.* For *permanent* loads (such as masonry) reduce by 10 per cent.

Depth of beam.	Span in feet.												
	6	8	10	12	14	15	16	17	18	20	22	24	25
Ins.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
6	720	540	432	360	308								
7	980	735	588	490	420	392							
8	1280	960	768	640	548	512	480						
9	1620	1215	972	810	694	648	607	572					
10	2000	1500	1200	1000	857	800	750	705	666				
12	2880	2160	1728	1440	1234	1152	1080	1016	960	864			
14	3920	2940	2352	1960	1680	1568	1470	1383	1306	1176	1069	980	940
15	4500	3375	2700	2250	1928	1800	1687	1588	1500	1350	1227	1125	1080
16	5120	3840	3072	2560	2192	2048	1920	1807	1706	1536	1396	1280	1230

Loads above and to the right of heavy line will crack plastered ceilings.

These tables give safe loads uniformly distributed. If the load is concentrated at center of beam, take one-half of the load given in the table.

WEIGHT OF FLOOR JOISTS PER SQUARE FOOT OF FLOOR (KIDDER).

Size of joists in inches.	Spruce, hemlock, white pine. Spacing in inches, center to center.		Hard pine or oak. Spacing in inches, center to center.	
	12 pounds.	16 pounds.	12 pounds.	16 pounds.
2 x 6	3	2¼	4	3
2 x 8	4	3	5⅓	4
3 x 8	6	4½	8	6
2 x 10	5	3¾	6⅔	5
3 x 10	7½	5½	10	7½
2 x 12	6	4½	8	6
3 x 12	9	6¾	12	9
2 x 14	7	5¼	9⅓	7
3 x 14	10½	8½	14	10½

NAILS.

NAILS AND SPIKES.

Size, length and number to the pound.
(Cumberland Nail and Iron Co.)

ORDINARY.

Size.	Length.	No. to lb.
	Ins.	
2d.	7/8	716
3 fine	1 1/16	588
3	1 1/16	448
4	1 3/8	336
5	1 3/4	216
6	2	166
7	2 1/4	118
8	2 1/2	94
10	2 3/4	72
12	3 1/8	50
20	3 3/4	32
30	4 1/4	20
40	4 3/4	17
50	5	14
60	5 1/2	10

LIGHT.

Size.	Length.	No. to lb.
	Ins.	
4d.	1 3/8	373
5	1 3/4	272
6	2	196

BRADS.

Size.	Length.	No. to lb.
	Ins.	
6d.	2	163
8	2 1/2	96
10	2 3/4	74
12	3 1/8	50

CLINCH.

Length.	No. to lb.
Ins.	
2	152
2 1/4	133
2 1/2	92
2 3/4	72
3	60
3 1/4	43

FENCE.

Length.	No. to lb.
Ins.	
2	96
2 1/4	66
2 1/2	56
2 3/4	50
3	40

SPIKES.

Length.	No. to lb.
Ins.	
3 1/2	19
4	15
4 1/2	13
5	10
5 1/2	9
6	7

BOAT.

Length.	No. to lb.
Ins.	
1 1/2	206

FINISHING.

Size.	Length.	No. to lb.
	Ins.	
4d.	1 3/4	384
5	1 3/8	256
6	2	204
8	2 1/2	102
10	3	80
12	3 5/8	65
20	3 7/8	46

CORE.

Size.	Length.	No. to lb.
	Ins.	
6d.	2	143
8	2 1/2	68
10	2 1/8	60
12	3 1/8	42
20	3 3/8	25
30	4 1/4	18
40	4 3/4	14
W H	2 1/2	69
W H L	2 1/4	72

SLATE.

Size.	Length.	No. to lb.
	Ins.	
3d.	1 5/16	288
4	1 7/16	244
5	1 3/4	187
6	2	146

TACKS.

Size.	Length.	Number to lb.	Size.	Length.	Number to lb.	Size.	Length.	Number to lb.
Ounce.			Ounce.			Ounce.		
1	1/8	16,000	4	7/16	4,000	14	13/16	1,143
1 1/2	3/16	10,066	6	9/16	2,666	16	7/8	1,000
2	1/4	8,000	8	5/8	2,000	18	15/16	888
2 1/2	5/16	6,400	10	11/16	1,600	20	1	800
3	3/8	5,333	12	3/4	1,333	22	1 1/16	727

NAILING MEMORANDA.

For 1000 shingles allow $3\frac{1}{2}$ to 5 pounds 4d. nails or 3 to $3\frac{1}{2}$ pounds 3d. nails.

1000 laths about 6 pounds 3d. fine.

1000 feet clapboard about 18 pounds 6d. box.

1000 feet covering boards about 20 pounds 8d. common.

1000 feet covering boards about 25 pounds 10d. common.

1000 feet upper floors, square edged, about 38 pounds 10d. floor.

1000 feet upper floors, square edged, about 41 pounds 12d. floor.

1000 feet upper floors, matched and blind nailed, about 35 pounds 10d. floor.

1000 feet upper floors, matched and blind nailed, about 42 pounds 12d. floor.

10 feet partitions, studs or studding, about 1 pound 10d. common.

1000 feet furring, 1 by 3, about 45 pounds 10d. common.

1000 feet furring, 1 by 2, about 65 pounds 10d.

1000 feet pine finish about 30 pounds 8d. finish.

ROOFING.

SLATING.

Slating is estimated by the "square," which is the quantity required to cover 100 square feet. Slates are usually laid so that the third slate laps the first three inches. Therefore to compute the number of slates of a given size required per square: Subtract 3 inches from the length of the slate, multiply the remainder by the width, and divide by 2. This will give the number of square inches covered per plate.

TABLE SHOWING NUMBER OF SLATES PER SQUARE LAID AS ABOVE.

Size in inches.	Pieces per square.	Size in inches.	Pieces per square.	Size in inches.	Pieces per square.
6 x 12	533	8 x 16	277	12 x 20	141
7 x 12	457	9 x 16	246	14 x 20	121
8 x 12	400	10 x 16	221	11 x 22	137
x 12	355	9 x 18	213	12 x 22	126
x 14	374	10 x 18	192	14 x 22	108
x 14	327	12 x 18	160	12 x 24	114
9 x 14	291	10 x 20	169	14 x 24	98
10 x 14	261	11 x 20	154	16 x 24	86

Slate weighs per cubic foot about 174 pounds; per square foot various thickness as follows:

Thickness in inches	⅛	$\frac{3}{16}$	¼	⅜	½
Weight in pounds per square foot . .	1.81	2.71	3.62	5.43	7.25

The weight of slating laid per square foot of *surface covered* will of course depend on the size of the slate used. Each slate fastened by two 3d. slate nails, either of galvanized iron, copper or zinc. On roofs of gashouses the nails should be of copper or yellow metal.

ESTIMATED WEIGHTS OF GALVANIZED SHEETS. (Joseph T. Ryerson & Sons.)

U. S. standard gauge.	10	12	14	16	18	20	22	24	25	26	27	28	29	30
Weight per sq. ft., lbs.	5.781	4.531	3.281	2.656	2.156	1.656	1.406	1.156	1.031	.9062	.8437	.7812	.7187	.6562
Size of sheet.	Weight of Sheet—Pounds.													
24 x 72	69	54	39	32	26	20	17	14	12	11	10	9	9	8
24 x 84	81	63	46	37	30	23	20	16	14	13	12	11	10	9
24 x 96	93	73	53	43	35	27	23	19	17	15	14	13	12	11
24 x 120	116	91	66	53	43	33	28	23	21	18	17	16	14	13
26 x 72	75	59	43	35	28	22	18	15	13	12	11	10	9	9
26 x 84	88	69	50	40	33	25	21	18	16	14	13	12	11	10
26 x 96	100	79	57	46	37	29	24	20	18	16	15	14	12	11
26 x 120	125	98	71	58	47	36	30	25	22	20	18	17	16	14
28 x 72	81	63	46	37	30	23	20	16	14	13	12	11	10	9
28 x 84	94	74	54	43	35	27	23	19	17	15	14	13	12	11
28 x 96	108	85	61	50	40	31	26	22	19	17	16	15	13	12
28 x 120	135	106	77	62	50	39	33	27	24	21	20	18	17	15
30 x 72	87	68	49	40	32	25	21	17	15	14	13	12	11	10
30 x 84	101	79	57	46	38	29	25	20	18	16	15	14	13	11
30 x 96	116	91	66	53	43	33	28	25	21	18	17	16	14	13
30 x 120	145	113	82	66	54	41	35	29	26	23	21	20	18	16
36 x 72	104	82	59	48	39	30	25	21	19	16	15	14	13	12
36 x 84	121	95	69	55	45	35	30	24	22	19	18	16	15	14
36 x 96	139	109	79	64	52	40	34	28	25	22	20	19	17	16
36 x 120	173	136	98	80	65	50	42	35	31	27	25	23	22	20
42 x 72	121	95	71	56	45	34	29	24	22	19	18	16	15	14
42 x 84	142	111	80	65	53	41	34	28	25	22	21	19	18	16
42 x 96	162	127	92	74	60	46	39	32	29	25	24	22	20	18
42 x 120	202	159	115	93	75	58	49	41	36	33	29	27	25	23
48 x 72	139	109	79	64	52	40	34	28	25	22	20	19	17	16
48 x 84	162	125	92	74	60	46	39	82	29	25	24	22	20	18
48 x 96	185	145	105	85	69	55	45	87	33	29	27	25	23	21
48 x 120	231	181	131	106	86	66	56	46	41	36	34	31	29	

WEIGHT OF CORRUGATED SHEETS.

Per square.

Gauge No.	Black. 2, 2½ and 3-in. corrugation.	Black. 1¼-in. corrugation.	Galvanized. 2, 2½ and 3-in. corrugation.	Galvanized. 1¼-in. corrugation.
	Lbs.	Lbs.	Lbs.	Lbs.
16	271	....	286	
18	217	....	232	
20	163	170	178	185
21	150	156	165	
22	136	142	151	157
23	123	128	133	
24	110	114	124	129
25	96	100	111	
26	83	86	98	101
27	76	79	91	94
28	68	72	85	87

Sheets 25 and 26 inches wide after corrugating cover 24 inches (approximately). 2-inch corrugations furnished in No. 18 and lighter. ⅝-inch corrugations furnished in No. 24 and lighter. $\frac{3}{16}$-inch corrugations furnished in No. 26 and lighter.

NUMBER OF SHEETS IN ONE SQUARE.

100 square feet.

Corrugation, inches.	Width flat, inches.	Width after corrugation, inches.	Length of sheet. 72 inches.	84 inches.	96 inches.	108 inches.	120 inches.
2, 2½, 3	28	26	7.692	6.593	5.769	5.128	4.616
1¼	28	25	8.000	6.857	6.000	5.333	4.800

ESTIMATED WEIGHTS OF BLACK SHEETS. (Joseph T. Ryerson & Sons.)

U. S. standard gauge. Weight per sheet in pounds.

U. S. gauge.	10	12	14	15	16	18	20	22	24	26	27	28	29	30
Lbs. per sq. ft.	5.625	4.375	3.125	2.8125	2.50	2.00	1.50	1.25	1.00	.75	.6875	.625	.5625	.50
Thickness (inches).	$\frac{9}{64}$	$\frac{7}{64}$	$\frac{5}{64}$	$\frac{9}{128}$	$\frac{1}{16}$	$\frac{1}{20}$	$\frac{3}{80}$	$\frac{1}{32}$	$\frac{1}{40}$	$\frac{3}{160}$	$\frac{11}{640}$	$\frac{1}{64}$	$\frac{9}{640}$	$\frac{1}{80}$
24 x 96	90.00	70.00	50.00	45.00	40.00	32.00	24.00	20.00	16.00	12.00	11.00	10.00	9.00	8.00
24 x 101	94.69	73.65	52.60	47.34	42.08	33.67	25.25	21.04	16.84	12.63	11.57	10.52	9.47	8.42
24 x 108	101.25	78.75	56.25	50.63	45.00	36.00	27.00	22.50	18.00	13.50	12.38	11.25	10.13	9.00
24 x 120	112.50	87.50	62.50	56.25	50.00	40.00	30.00	25.00	20.00	15.00	13.75	12.50	11.25	10.00
24 x 138	129.38	100.63	71.88	64.69	57.50	46.00	34.50	28.75	23.00	17.25	15.81	14.38		
24 x 144	135.00	105.00	75.00	67.50	60.00	48.00	36.00	30.00	24.00	18.00	16.50	15.00		
26 x 96	97.50	75.83	54.17	48.75	43.33	34.67	26.00	21.67	17.34	13.00	11.92	10.83	9.75	8.67
26 x 101	102.58	79.78	57.00	51.29	45.59	36.47	27.35	22.79	18.24	13.68	12.54	11.40	10.26	9.12
26 x 108	109.69	85.31	60.94	54.84	48.75	39.00	29.25	24.37	19.50	14.63	13.41	12.19	10.97	9.75
26 x 120	121.88	94.79	67.71	60.94	54.17	43.33	32.50	27.08	21.67	16.25	14.90	13.54	12.19	10.83
26 x 138	140.16	109.01	77.87	70.08	62.29	49.83	37.38	31.15	24.92	18.69	17.13	15.57		
26 x 144	146.25	113.75	81.25	73.13	65.00	52.00	39.00	32.50	26.00	19.50	17.88	16.25		
28 x 96	105.00	81.67	58.33	52.50	46.67	37.33	28.00	23.33	18.67	14.00	12.83	11.67	10.50	9.33
28 x 101	110.47	85.92	61.37	55.23	49.09	39.28	29.46	24.55	19.64	14.73	13.50	12.27	11.05	9.82
28 x 108	118.13	91.88	65.63	59.06	52.50	42.00	31.50	26.25	21.00	15.75	14.44	13.13	11.81	10.50
28 x 120	131.25	102.08	72.92	65.63	58.33	46.67	35.00	29.17	23.33	17.50	16.04	14.58	13.13	11.67
30 x 96	112.50	87.50	62.50	56.25	50.00	40.00	30.00	25.00	20.00	15.00	13.75	12.50	11.25	
30 x 101	118.36	92.06	65.76	59.18	52.60	42.08	31.56	26.30	21.04	15.78	14.47	13.15		
30 x 108	126.56	98.44	70.31	62.69	56.25	45.00	33.75	28.12	22.50	16.88	15.47	14.06		
30 x 120	140.63	109.38	78.13	70.31	62.50	50.00	37.50	31.25	25.00	18.75	17.19	15.63		
30 x 138	161.72	125.78	89.84	80.86	71.88	57.50	43.13	35.94	28.75	21.56	19.77	17.97		
30 x 144	168.75	131.25	93.75	84.38	75.00	60.00	45.00	37.50	30.00	22.50	20.63	18.75		

36 x 77	108.28	84.22	60.17	54.14	48.13	38.50	28.88	24.06	19.25	14.44	13.28	12.08
36 x 96	135.00	105.00	75.00	67.50	60.00	48.00	36.00	30.00	24.00	18.00	16.50	15.00
36 x 108	151.88	118.13	84.38	75.94	67.50	54.00	40.50	33.75	27.00	20.25	18.56	16.88
36 x 120	168.75	131.25	93.75	84.38	75.00	60.00	45.00	37.50	30.00	22.50	20.63	18.75
36 x 138	194.06	145.47	107.81	97.03	86.25	69.00	51.75	43.13	34.50	25.88	23.72	21.56
36 x 144	202.50	157.50	112.50	101.25	90.00	72.00	54.00	45.00	36.00	27.00	24.75	22.50
42 x 77	126.33	98.26	70.18	63.16	56.14	44.92	33.69	28.07	22.46	16.84	15.44	14.04
42 x 96	157.50	122.50	87.50	78.75	70.00	56.00	42.00	35.00	28.00	21.00	19.25	17.50
42 x 108	177.19	137.81	98.44	88.59	78.75	63.00	47.25	39.37	31.50	23.63	21.66	19.69
42 x 120	196.88	153.13	109.38	98.44	87.50	70.00	52.51	43.75	35.00	26.25	24.06	21.88
42 x 138	226.41	176.09	125.78	113.20	100.63	80.50	60.38	50.31	40.25	30.19	27.67	25.16
42 x 144	236.25	183.75	131.25	118.13	105.00	84.00	63.00	52.50	42.00	31.50	28.88	26.24
48 x 77	144.38	112.29	80.21	72.19	64.17	51.33	38.50	32.08	25.67	19.25	17.65	16.04
48 x 96	180.00	140.00	100.00	90.00	80.00	64.00	48.00	40.00	32.00	24.00	22.00	20.00
48 x 108	202.50	157.50	112.50	101.25	90.00	72.00	54.00	45.00	36.00	27.00	24.75	22.50
48 x 120	225.00	175.00	125.00	112.50	100.00	80.00	60.00	50.00	40.00	30.00	27.50	25.00
48 x 138	258.75	201.25	143.75	129.38	115.00	92.00	69.00	57.50	46.00	34.50	31.63	28.75
48 x 144	270.00	210.00	150.00	135.00	120.00	96.00	72.00	60.00	48.00	36.00	33.00	30.00
54 x 77	162.42	126.33	90.26									
54 x 96	201.50	157.50	112.50									
54 x 108	227.82	177.20	126.57									
54 x 120	253.13	196.88	140.63									
54 x 138	291.09	218.21	161.71									
54 x 144	303.75	236.25	168.75									
60 x 77	180.48	140.36										
60 x 96	225.00	175.00										
60 x 108	253.12	196.88										
60 x 120	281.26	219.36										
60 x 138	328.44	251.56										
60 x 144	337.50	262.50										

NOTE.—Above estimated weights are based on U. S. standard gauge of iron. For steel, add 2 per cent. These figures are given for convenience in estimating only, and may vary somewhat in actual practice. The sizes below the heavy black line will probably considerably exceed the weights given, and it is safe, therefore, to allow for an overweight of at least 10 per cent.

TIN ROOFS,

Improperly so called, are made of iron plates covered with lead or tin, or a mixture of both. The most common form of these plates are coated with a mixture of lead and tin, and are called *terns*.

Felt paper should be placed under plates upon the roof to deaden sound of rain and act as a cushion. Roof should be allowed to be thoroughly washed by the rain, and then all rosin, if any used in soldering, should be scraped off before roof is painted on outside.

Paint for tin roof: 10 pounds venetian red, 1 pound red lead, 1 gallon pure linseed oil.

Common sizes, 14 x 20 and 20 x 28.

Smaller sizes are best, as making more joints and therefore making better allowance for expansion.

Tin should be laid with smaller dimensions for width.

In soldering, rosin is flux generally used.

Tin roofs should be locked and soldered at all joints, and secured by tin cleats, not by driving nails through the tin itself.

Two good workmen can put on, and paint outside, from 250 to 300 square feet of tin roof per day of eight hours.

Tin roofs of good material when properly painted and put on should last thirty to forty years.

Tin plates before being laid should be painted on under side. Tin roofs are often laid on old shingle roofs.

SHINGLES.

The best shingles are of white cedar or cypress, and last in Northern states forty to fifty years; in warm, damp climates will only last six to twelve years. All shingles wear thin by rain.

With an average width of six inches:

If laid 4 inches to the weather 600 wil cover a square.
If laid 4½ inches to the weather 535 will cover a square.
If laid 5 inches to the weather 480 will cover a square.
If laid 5½ inches to the weather 440 will cover a square.
If laid 6 inches to the weather 400 will cover a square.

This applies to common gable roofs. In hip roofs add 5 per cent. to above allowance.

For 1000 shingles allow 3½ to 5 pounds 4d. nails or 3 to 3½ 3d. nails.

ROOFING TILES.

Roofing tiles are coming largely into use in this country—their use for a long time having been very common in Europe.

Plain tiles, usually made ⅝ inch thick, 6¼ inches wide and 10½ inches long. They weigh from 2 to 2½ pounds each. Exposed one-half to the weather, 720 tiles cover one square (100 square feet). Tiles are hung to the roof by oak pins inserted in two holes made in the tile by the manufacturer. Semi-cylindrical tiles made for ridge, crown, hip, valley and gutter.

GENERAL RULES FOR ROOFING.

A "square" = 100 square feet or 10 feet square.

Roofs covered with metal should have a slope of at least 1 inch per foot.

Trautwine allows "12 pounds per square foot for average snow load in the United States and 20 pounds for combined loading of snow and wind." This is, of course, a variable factor depending on the locality.

"In first-class work, top course of slate on ridge, and the slate for 2 to 4 feet from all gutters, and 1 foot each way from all valleys and hips should be bedded in elastic cement."—(*Kidder*).

Flashings are pieces of tin, copper or zinc, laid over slate or other roofing material, and up against walls, chimneys, copings, etc.

PRESERVATIVE COATINGS.

(*Kent.*)

The following notes have been furnished to the author by Prof. A. H. Sabin:

Cement.—Ironwork is sometimes protected by bedding in concrete, in which case it is first cleaned and then washed with neat cement before being imbedded.

Asphaltum.—This is applied hot, either by dipping (as water-pipe) or by pouring it on (as bridge floors). The asphalt should be slightly elastic when cold, with a high melting point, not softening much at 100° F., applied at 300 to 400°; surface must be dry and should be hot; coating should be of considerable thickness.

Paint.—Composed of a vehicle or binder, usually linseed oil or some inferior substitute, or varnish (enamel paints); and a pigment, which is a more or less inert solid in the form of powder, either mixed or ground together. The principal pigments are white lead (carbonate) and white zinc (oxide), red lead (peroxide), oxides of iron, hydrated and dehydrated, graphite, lampblack, chrome yellow, ultramarine and prussian blue and various tinting colors. White lead has the greatest body or opacity of white pigments; three coats of it equal five of white zinc; zinc is more brilliant and permanent, but it is liable to peel, and it is customary to mix the two. These are the standard white paints for all uses and the basis of all light-colored paints. Anhydrous iron oxides are brown and purplish brown; hydrated iron oxides are yellowish red to reddish yellow, with more or less brown; most iron oxides are mixtures of both sorts. They also contain frequently manganese and clay. They are cheap, and are serviceable paints for wood, and are often used on iron, but for the latter use are falling into disrepute. Graphite used for painting iron contains from 10 to 90 per cent. foreign matter, usually silicates and iron oxides. It is very opaque, hence has great covering power, and may be applied in a very thin coat, which should be avoided. It retards the drying of oil, hence the necessity of using dryers; these are lead and manganese compounds dissolved in oil and turpentine or benzine, and act as carriers of oxygen; they are necessary in most paints, but should be used as little as possible. There are many grades of lampblack; as a rule the cheaper sorts contain oily matter and are especially hard to dry; all lampblack is slow to dry in oil. It is the principal black on wood, and is used sometimes on iron, usually in combination with varnish or varnish-like compounds. It is very permanent on wood. A gallon of oil takes only a pound of lampblack to make a paint, while the same amount of oil requires about 40 pounds of red lead. On this account red lead paint, which weighs about 30 pounds per gallon, is the most expensive of all common paints. It does not dry slowly like other oil paints, but combines with the oil to make a sort of cement; on this account it is used on the joints of steam pipes, etc. To prevent the mixture of red lead and oil setting into a cake, and also to cheapen it, it is often adulterated with whiting or sometimes with white zinc, the proportion of the adulterant being sometimes double the lead. Red lead has long had a high reputation as a paint for iron and steel, and is still used very extensively; but of late years some of the new paints and varnish-like preparations have displaced it to some extent, even on the most important work.

VARNISHES.—These are made by melting fossil resin, to which is then added from half its weight to three times its weight of refined linseed oil, and the compound is thinned with turpentine; they usually contain a little dryer. They are chiefly used on wood, being more durable and more brilliant than oil, and are often used over paint to preserve it. Asphaltum is sometimes substituted in part or in whole for the fossil resin, and in this way are made varnishes which have been applied to iron and steel with good results. Asphaltum and animal and vegetable tar and pitch have also been simply dissolved in solvents, as benzine or carbon disulphide, and used for the same purpose.

All these preservative coatings are supposed to form impervious films, keeping out air and moisture, but in fact all are somewhat porous. On this account it is necessary to have a film of appreciable thickness, best formed by successive coats, so that the pores of one will be closed by the next. The pigment is used to give an agreeable color, to help fill the pores of the oil film, to make the paint harder so that it will resist abrasion and to make a thicker film. In varnishes these results are sought to be obtained by the resin, which is dissolved in the oil. There is no sort of agreement among practical men as to which is the best coating for any particular case; this is probably because so much depends on the preparation of the surface and the care with which the coating is applied, and also because the conditions of exposure vary so greatly.

METHODS OF APPLICATION.—Too much care cannot be given to the preparation of the surface. If it is wood, it should be dry, and the surface of knots should be coated with some preparation which will keep the tarry matter in the wood from the coating. All old paint or varnish should be removed by burning and scraping. Metallic surfaces should be cleaned by wire brushes and scrapers, and if the permanence of the work is of much importance the scale and oxide should be completely removed by acid pickling or with the sand blast or some equally efficient means. Pickling is usually done by a 10 per cent. solution of sulphuric acid; as the solution becomes exhausted it may be made more active by heating. All traces of acid must be removed by washing, and the metals must be rapidly dried and painted before it becomes in the slightest degree oxidized. The sand blast, which has been applied to large work recently and for many years to small work, with good results, leaves the surface perfectly clean and dry; the paint must be applied immediately. Plenty of time should always be allowed, usually about a week, for each coat of paint to dry before the next coat is applied; less than two coats should never be used. Two will last three times as long as one coat. Benzine should not be an ingredient in coating for ironwork, because formation of due on the surface adjacent to paint which is immediately to be painted.

Cast iron water pipes are usually coated by dipping in a hot mixture of coal tar and coal tar pitch; riveted steel pipes by dipping in hot asphalt or by japan enamel which is baked on at about 400° F. Ships' bottoms are usually coated with some sort of paint to prevent rusting, over which is spread, hot, a poisonous soluble compound, usually a copper soap, to prevent adhesion of marine growths.

Galvanized iron and tin surfaces should be thoroughly cleaned with benzine and scrubbed before painting. When new they are covered with grease and chemicals used in coating the plates, and these must be removed or the paint will be destroyed.

QUANTITY OF PAINT FOR A GIVEN SURFACE.—One gallon of paint will cover 250 to 350 square feet as a first coat, depending on the character of the surface, and from 350 to 450 square feet as a second coat.

RECIPES.

TO CLEAN BRASS, ETC.

Powdered rottenstone, ½ pound; soft soap, ½ pound; oil of vitriol, 4 drops; sweet oil, 1 teaspoonful; turpentine, 1 tablespoonful. Mix in a basin with a wooden spoon or stick, and keep in a jar. Put on with a piece of flannel, and while damp rub off with a piece of soft linen. Polish with leather dipped in fine dry whiting.

Oxalic acid dissolved in soft water, say ½ an ounce to a pint, is one of the best known means for cleaning and brightening brass work.

IRON OR STEEL immersed warm in a solution of carbonate of soda (washing soda) for a few minutes will not rust.

WHITEWASH.

For indoor work.—2 pounds paris whiting, 1 ounce white glue; dissolve the glue in warm water Mix whiting with warm water, stir in glue, thin with warm water.

For outside work.—Slack 1 peck of lime with water. While hot, add ½ pound of tallow or other grease, stir thoroughly. Will stand rain.

QUANTITIES.—1½ cubic feet of lime will cover 100 yards superficed—1 coat. 2 cubic feet of lime will cover 100 yards superficed—2 coats.

A PERMANENT WHITEWASH.

Slack ½ bushel unslacked lime with boiling water, keeping it covered during process; strain it, and add a peck of salt dissolved in warm water, 3 pounds ground rice, boiled in hot water to a thin paste, ½ pound ground spanish whiting, and a pound of clear glue, dissolved in warm water; mix these well together and let stand for a few days. When used, put it on as hot as possible.

AIR AND STEAM TIGHT RUBBER PACKING.

Brush the packing over with a solution of powdered resin in ten times its weight of strong water of ammonia. This mixture is at first a sticky mass, but becomes fit for use in about three or four weeks. It easily adheres to rubber, as well as to wood or metal, and becomes perfectly impervious to liquids.

TO SOFTEN PUTTY IN SASHES.

Run a red hot iron over it, it will then peel off easily.

CEMENT FOR JOINTS.

Paris white, ground, 4 pounds; litharge, ground, 10 pounds; yellow ocher, fine, ½ pound; ½ ounce of hemp, cut short. Mix well together with linseed oil to a stiff putty.

This cement is good for joints on steam or water pipes; it will set under water.

MIXTURE FOR WELDING STEEL.

1 sal ammoniac, 10 borax; pounded together and fused until clear, when it is poured out, and when cool reduced to powder.

RUST JOINT CEMENT (*quickly setting*).

1 sal ammoniac in powder (by weight); 2 flower of sulphur; 80 iron borings made to a paste with water.

RUST JOINT CEMENT (*slowly setting*).

2 sal ammoniac; 1 flower of sulphur; 200 iron borings.

The latter cement is the best if the joint is not required for immediate use.

RED LEAD CEMENT FOR FACE JOINTS.

1 of white lead; 1 of red lead, mixed with linseed oil to the proper consistency.

GLUE TO RESIST MOISTURE.

1 pound of glue melted in 2 quarts of skimmed milk.

When strong glue is required, add powdered chalk to common glue.

MARINE GLUE.

1 of india rubber; 12 of mineral naphtha or coal tar; heat gently; mix, and add 20 of powdered shellac. Pour out on a slab to cool; when used, to be heated to about 250 degrees.

GLUE CEMENT TO RESIST MOISTURE.

1 glue; 1 black resin; ¼ red ocher, mixed with the least possible quantity of water; or 4 of glue; 1 of boiled oil by weight; 1 oxide of iron.

GLUE LEATHER TO IRON.

Paint iron with white lead and lampblack; when dry cover with cement made as follows: Soak best glue in cold water till soft, then dissolve in vinegar with moderate heat; add one-third of its bulk of white pine turpentine; mix thoroughly, and reduce with vinegar to a proper consistency to spread with brush. Apply while hot. Draw leather on quickly and press tightly to place.

CEMENT FOR CLOTH OR LEATHER.

16 gutta percha, cut small; 4 india rubber, cut small; 2 pitch, cut small; 1 shellac, cut small; 2 linseed oil, melted together and well mixed.

ANTI-FRICTION GREASE.

Boil together 1¾ cwt. of tallow with 1¼ cwt. of palm oil. When boiling point is reached, allow it to cool to blood heat, stirring it meanwhile, then strain through a sieve into a solution of ½ cwt. of soda in 3 gallons of water, mixing it well.

The above is for summer.

For winter, 1½ cwt. of tallow to 1¾ cwt. palm oil.

Spring and autumn, 1½ cwt. of tallow to 1½ cwt. palm oil.

MIXTURE TO COOL HOT JOURNALS.

11 pounds black lead; 23 pounds epsom salts; 9 pounds sulphur; 2 pounds lampblack; 5 pounds oxalic acid.

The ingredients to be pulverized, mixed and ground together.

MISCELLANEOUS INFORMATION.

DERRICK MEMORANDA.

(From catalogue American Hoist & Derrick Co., St. Paul, Minn.)

Desirable length of guys on level ground should be three times the height of the mast. Four guys are the usual number, although six or eight guys are sometimes used to give extra strength and stiffness.

In the "Sectional Derrick," made by above company, no part exceeds 20 feet in length; boom, 75 feet; capacity, 5 and 15 tons.

Long sticks used for masts and booms of derricks are often difficult to ship, and in many localities long sticks are difficult to get. The mast and boom of this derrick are each made of four pieces of timber butted together at the cross trees and held straight by the truss rods. The only tool required to put this derrick together is a wrench.

The "Crane Derrick" (steam or hand power). The special feature of this derrick is an inclined boom, in general practice 25 to 39 feet from the ground.

The boom is made of two pieces held at the right distance apart by iron yokes. On the top side of the boom timbers are tracks made of light railroad irons.

On these tracks rolls the trolley which guides the hoisting line. The trolley is moved toward the boom end by a trolley line. Releasing the pull on the trolley line allows the load to move down the incline boom toward the mast. These derricks are especially adapted to buildings, where all materials for two stories can be handled and set in place without moving derrick; also useful in stone yards, as it takes up little room, and can handle stone from end of boom to point near mast.

TABLE SHOWING PRACTICAL PROPORTIONS.

Estimated capacity.	Length of mast.	Length of boom.	Ground to boom.	Price of all iron and blocks complete, with necessary drawings for making woodwork (wire rope not included).
5 tons	72 ft.	55 ft.	39 ft.	$480.00
5 "	65 "	50 "	35 "	475.00
5 "	58 "	45 "	31 "	470.00
5 "	52 "	40 "	28 "	465.00
5 "	46 "	35 "	25 "	460.00

"*Wrought iron tubular derricks*" similar to the "sectional derrick" are also made by American Hoist & Derrick Co., with capacities 5, 10 and 20 tons.

LEAD MEMORANDA (KIDDER).

For roofs and gutters, use 7 pound lead.

For hips and ridges, use 6 pound lead.

For flashings, use 4 pound lead.

Gutters should have a fall of at least 1 inch in 10 feet.

No sheet of lead should be laid in greater length than 10 or 12 feet without a drip to allow of expansion.

Joints of lead pipes require a pound of solder for every inch in diameter.

A pig of lead is about 3 feet long and weighs from a hundredweight and a fourth to a hundredweight and a half.

Spanish pigs are about a hundredweight.

THE FEEDING PROPERTIES OF DIFFERENT VEGETABLES IN COMPARISON WITH TEN POUNDS OF HAY.

Hay	10	Carrots	35
Clover hay	8	Cabbage	30 to 40
Vetch hay	4	Peas and beans	2 to 3
Wheat straw	52	Wheat	5
Barley straw	52	Barley	6
Oat straw	55	Oats	5
Pea straw	6	Rye	5
Potatoes	28	Indian corn	6
Old potatoes	40	Bran	5
Turnips	60	Oil cake	2

Thus 2 pounds of oil cake is worth as much as 55 pounds of oat straw.

Dimensions of drawings for patents (U. S.).—8½ by 12 inches.

Dimensions of a barrel.—Diameter at head, 17 inches; bung, 19 inches; length, 28 inches; volume, 7680 cubic inches.

A gallon of fresh water weighs 8½ pounds, and contains 231 cubic inches.

A cubic foot of water weighs 62½ pounds, and contains 1728 cubic inches, or 7½ gallons.

Doubling the diameter of a pipe increases its capacity four times. Friction of liquids in pipes increases as the square of the velocity.

Melted snow produces from one-fourth to one-eighth of its bulk in water.

In Kentucky, 80 pounds of bituminous or cannel coal make a bushel.

In Illinois, 80 pounds of bituminous coal make a bushel.

In Missouri, 80 pounds of bituminous coal make a bushel.

In Indiana, 70 pounds of bituminous coal make a bushel.

In Pennsylvania, 76 pounds of bituminous coal make a bushel.

Coal, corn in the ear, fruit and roots are sold by heaped measure, that is, the bushel is heaped in the form of a cone, which cone must be 19½ inches in diameter (equal to the outside diameter of the standard bushel measure) and at least 6 inches in height.

Grain and some other commodities are sold by stricken measure, that is, the measure is to be stricken with a round stick or roller, straight and of the same diameter from end to end.

Glazing and stonecutting are estimated by the square foot.

Painting, plastering, paving, ceiling and paperhanging are estimated by the square yard.

Pitch of tin, copper or tar and gravel roof.—One inch to the foot and upward.

FACTS ABOUT GOLD.

Gold, 1000 fine, U. S. mint value,	$20.6718	per ounce,	troy.
Gold, 900 fine, U. S. mint value,	18.60	per ounce,	troy.
Gold, 800 fine, U. S. mint value,	16.33	per ounce,	troy.
Gold, 700 fine, U. S. mint value,	14.47	per ounce,	troy.
Gold, 600 fine, U. S. mint value,	12.40	per ounce,	troy.
Gold, 500 fine, U. S. mint value,	10.335	per ounce,	troy.

United States mints and assay offices will not buy gold less than 500 fine.

$1.00 U. S. gold coin weighs	25.8 troy grains.
2.50 U. S. gold coin weighs	64.5 troy grains.
5.00 U. S. gold coin weighs	129.0 troy grains.
10.00 U. S. gold coin weighs	258.0 troy grains.
20.00 U. S. gold coin weighs	516.0 troy grains.

One ton (2000 lbs.) pure gold is worth $602,791.21.

24 karat gold is worth	$20.6718	per troy ounce.
22 karat gold is worth	18.94	per troy ounce.
20 karat gold is worth	17.22	per troy ounce.
18 karat gold is worth	15.50	per troy ounce.
16 karat gold is worth	13.78	per troy ounce.
14 karat gold is worth	12.05	per troy ounce.
12 karat gold is worth	10.335	per troy ounce.
10 karat gold is worth	8.61	per troy ounce.

43 ounces troy of standard gold (900 fine) are worth $800.

All gold coins in the civilized world are 900 fine (21.6 karat), with the exception of the English, which are 916⅔ fine (22 karat).

The United States mint charges on a shipment of gold bullion can be generally classed as follows:

1. *Assaying and Stamping Charge.*—One-eighth of 1 per cent. on the gross value of the gold and silver contained in the ingot.

2. *Melting Charge.*—$1 for each melt.

3. *Parting and Refining Charge.*—4 cents per ounce on the weight of the ingot after melting.

4. *Toughening and Alloying Charge.*—2 cents per ounce on the equivalent weight of standard gold contained in the ingot.

$$\text{Equivalent weight of standard gold} = \frac{\text{weight of ingot x gold fineness}}{900}$$

5 *Loss of Silver in Recovery after Parting.*—One ninety-ninth of the equivalent weight of standard gold is deducted from the gross equivalent standard weight of the silver contained in the ingot and the remainder is paid for at the current rate.

$$\text{Equivalent weight of standard silver} = \frac{\text{wgt. of ingot x silver fineness}}{900}$$

These rates are varied slightly in different parts of the United States. The gold fineness is always reported as the next half part below the assay: *i. e.*, 837.8 fine is reported 837.5 fine, 837.5 is reported 837.5 fine, 837.2 fine is reported 837.0 fine.

FIRST AID TO THE INJURED.

IN ANY CASE OF SERIOUS INJURY, POISONING, DROWNING, SUNSTROKE, ETC.,

SEND FOR A PHYSICIAN AT ONCE.

RULES FOR THE COURSE TO BE FOLLOWED BY THE BYSTANDERS IN CASE OF INJURY BY MACHINERY WHEN SURGICAL ASSISTANCE CANNOT BE AT ONCE OBTAINED.

The dangers to be feared in these cases are: Shock or collapse, loss of blood and unnecessary suffering in the moving of the patient.

In shock the injured person lies pale, faint, cold, sometimes insensible, with labored pulse and breathing.

Place the patient in a horizontal position, the head slightly lowered; if the patient has not been drinking, give two teaspoonfuls of whisky or other alcoholic liquor in a tablespoonful of hot water every ten minutes until five or six doses have been taken. Place hot water bottles, hot bricks or anything hot along both sides of the body and legs, inside the thighs and under the armpits and cover the patient warmly. In using hot water bottles or hot bricks, care must be taken not to burn the patient. This danger may be obviated by wrapping the bottle thickly in cloth before applying it, or by inserting it in a thick stocking. To warm and stimulate the patient in every way is the object of treatment.

A hot (110° F.) rectal injection of one-half pint of water and whisky (equal parts), or of water alone, is sometimes very efficacious.

Loss of Blood.—If the patient is *not* bleeding *do not* apply any constriction to the limb, but cover the wounded part lightly with the softest rags to be had (linen is the best).

Fig. 1—*Arm.*

In order to stop bleeding, first apply something over the opening to prevent the escape, either the fingers or thumb or a piece of folded gauze, called a compress, bound tightly on. If these measures do not stop the flow, the stream must be interrupted on its way from the source of supply, which is the heart. This is done by a pressure on the artery somewhere between the heart and the point where the injury is situated.

Unless the wound is in either the leg or arm, the bleeding must be arrested by placing the fingers or a pad and bandage directly over the bleeding point. In fact, any hemorrhage whatsoever may be stopped by the direct application of pressure to the bleeding point.

FIG. 2—*Leg.*

To stop bleeding from wounds in the extremities, everyone can learn to compress the arteries between the wound and the heart.

In the upper arm the artery lies on the inner side of the bone on a line with the inner seam of the coat and under the biceps muscle. By pressing the thumb deep under the muscle and towards the bone, the artery may be compressed. (Fig. 1.)

In the upper part of the thigh, the artery lies in front and just below the center of the groin. By deep pressure with the two thumbs at this point the blood supply of the whole leg may be cut off. (Fig. 2.)

To stop a violent hemorrhage temporarily, thrust the fingers or thumb into the wound, so as to close tightly the openings in the bleeding vessels. If the wound is in the limb, and these means have not been sufficient, then compress the artery above the bleeding point. In the case of venous hemorrhage in an extremity, cessation of the bleeding is favored by the elevation of the extremity.

FIG. 3.

FIG. 4.

Instead of the thumbs and fingers, a compress may be used to arrest the flow of blood. This is done by placing a round, flat stone, or anything hard and not much larger than an egg, upon the artery in question. Then tie a piece of cloth about the compress, place a stick through the cloth and twist it until the compress is pressed deeply in against the artery and bleeding stops. This is called a tourniquet.

FIG. 5.

TO TRANSPORT A WOUNDED PERSON COMFORTABLY.—Make a soft and even bed for the injured part of straw, folded blankets, quilts or pillows laid on a board with sides—pieces of board nailed on, where this can be done. If possible, let the patient be laid on a door, shutter or some firm support, properly covered. Have sufficient force to lift him steadily, and let those who bear him *not* keep step.

WORK IN AIR PRESSURE.

When a person has remained in compressed air, such as in submarine tunnel work, for any length of time, his blood is caused to absorb a much greater quantity of air than it could hold in solution at ordinary atmospheric pressure. Now, if a workman, after having his blood supercharged with air, suddenly comes out of the air pressure, this extra amount of air is incapable of remaining in solution and suddenly breaks free in the form of bubbles, just as gas does in a bottle of soda when the cork is removed. The blood froths, and as the blood vessels are not adapted for the circulation of air, little bubbles plug up the smaller arteries and capillaries like foreign bodies, and the heart churns the mixture of blood and air up into a thick foam entirely unsuited to circulation.

This state of affairs causes the disease known as the "bends." The first symptoms are a feeling of dullness with more or less headache. These are followed by excruciating pains in the abdomen and joints and then symptoms of paralysis appear, sometimes preceded by convulsions.

Persons seldom become afflicted with the "bends" when certain precautions are observed. The most important is to avoid a rapid reduction of the air pressure in coming out. At least one minute should elapse for every 2 pounds pressure to which one has been exposed. The length of time one has remained under pressure has a great influence. Do not stay over one hour on the first trip, and not that long if it can be helped, if the pressure is over 30 pounds, until one finds out if his constitution will stand it. Under 30 pounds there is not so much danger.

On coming out drink a cup of hot coffee, and be particular to abstain from cold drinks, particularly beer and carbonated beverages. If possible, put on fresh dry underclothing.

In going in pains in the ears can be obviated by closing the mouth and nostrils and blowing so as to open the eustachian tubes, thus equalizing the pressure on the inside of the ear drums. If one cannot obviate this trouble immediately, the air valve should be closed until the trouble is overcome. If this cannot be remedied, then do not go in, as one's hearing is liable to be seriously injured.

One should not leave the scene of operations for an hour because if there is going to be trouble from the "bends" it will be evident in that time, in which case the "medical" lock can be used.

Beware of the air lock unprovided with a gauge, and under no circumstances rush through the locks in either direction. Be extremely careful where pressures are in excess of 30 pounds.

FOR BURNS OR SCALDS.

In the early stage, soon after the accident, if there is no separation of the skin, do not cut the bladder, but allow the *bladder* of *water*, of whatever size, to remain untouched; merely dress it with a piece of linen or muslin lightly coated with vaseline.

If the parts are denuded of the skin, dress the parts with cotton, the object being to exclude the air and prevent suppuration. If cotton cannot be procured, apply any covering until you can have an ointment made of beeswax and sweet oil, equal parts, or lime water and linseed oil, or lay on scraped potatoes or carrots, or sprinkle flour on the injured surface when the above cannot be procured. Flour is troublesome in its removal. If the scald is extensive and on the body, COLD APPLICATIONS are NOT PROPER; then use warm fomentation, or, in the case of a child, the WARM BATH. Keep the air from the wound as much as possible; do not remove the dressing often. When a cold lotion is used, pour it upon the rags, letting them remain undisturbed.

BRUISES.

Use tepid applications at first. After inflammation has subsided, use stimulating applications, as vinegar and water, alcohol, camphorated liniment.

SPRAINS.

Elevate the limb; keep the joint perfectly quiet; apply hot lotions or fomentation. When inflammation has ceased, apply stimulating liniments and bandages; shower the part with cold water, alternating with warm water.

CONTUSIONS AND SPRAINS.

(*Dr. Bradford.*)

Tinc. opii (laudanum), 6 fluid drams; Liq. plumbi subacet. (strong solution subacetate lead), 3 fluid drams; Aquæ, q. s. ad (water sufficient to measure), 6 fluid ounces. Use externally. This is the well-known "lead and opium wash."

TO RESTORE PERSONS AFFECTED BY COLD.

FOR FROSTBITE OR NUMBNESS.—Restore warmth *gradually* in proportion as circulation in the parts of the body increases.

FOR A FROZEN LIMB.—Rub with snow and place in cold water for a short time. When sensation returns, place again in cold water; add heat *very gradually* by adding warm water.

IF APPARENTLY DEAD OR INSENSIBLE.—Strip entirely of clothes, and cover body, with exception of mouth and nostrils, with SNOW OR ICE COLD WATER. When body is thawed, dry it, place it in a cold bed; rub with warm hands under the cover; continue this for hours. If life appears, give small injections of camphor and water; put a drop of spirits of camphor on tongue; than rub body with spirits and water, finally with spirits; then give tea, coffee or brandy and water.

Send for a physician in all cases.

APPARENT DEATH FROM BREATHING NOXIOUS VAPOR, AS IN WELLS, ETC.

If insensible, expose person to the open air; sprinkle cold water on the face and head; rub strong vinegar about nostrils; give drink of vinegar and water. If suffocated by breathing fumes of charcoal, proceed as above, and excite breathing as in remedy given in cases of drowning. Artificial respiration is generally the most efficient treatment.

Send for a physician in all cases.

To purify wells, etc., shower water down them until a candle will burn at the bottom with a clear flame.

RULES FOR ACCIDENTS ON WATER.

When upset in a boat, or thrown into the water and unable to swim, draw the breath in well; keep the mouth tightly shut; do not struggle and throw the arms up, but yield quietly to the water; hold the head well up, and stretch out the hands only *below* the water; to throw the hands or feet *up* will pitch the head *down* and cause the whole person to go immediately under water. Keep the head *above* and everything else under water.

METHOD TO BE USED IN CASES OF DROWNING.

Send for a physician in all cases.

Treat the patient *instantly on the spot*, in the *open air*, freely exposing the face, neck and chest to the breeze, except in severe weather.

In order to *clear the throat*, place the patient gently on the face, with one wrist under the forehead, that all fluid, and the tongue itself, may fall forward, and leave the entrance into the windpipe free.

If the patient does not start breathing after this, it is best not to temporize, but to proceed at once to ARTIFICIAL RESPIRATION. Sylvester's method is the best. After clearing the mouth of all water, mucus and other obstructions, seize the tongue with the fingers and draw it well out. Placing a piece of cloth over the fingers will enable you to hold on to the tongue without its slipping. Then turn this part of the work over to an assistant and have him hold it out.

Then, the patient being upon his back, kneel behind his head, grasp his wrists or forearms and draw both arms well above his head until his hands touch the ground behind his head. Hold them there for two or three seconds. This motion expands the chest and draws in air. Now reverse the movement, that is, carry the arms back until they rest against the sides and front of the chest. Press the forearms downward and inward against the sides of the chest for one or two seconds, thus squeezing the air out. Repeat these two motions, taking about four or five seconds for each, until the patient shows signs of being able to breathe for himself. Then proceed to the following auxiliary measures:

Rub the limbs *upward* with *firm pressure* and with *energy.* (The object being to aid the return of venous blood to the heart.)

Substitute for the patient's wet clothing, if possible, such other clothing as can be instantly procured, each bystander supplying a coat or cloak, etc. Meantime, and from time to time, *to excite inspiration*, let the surface of the body be *slapped* briskly with the hand.

Rub the body briskly till it is dry and warm, then dash cold water upon it and repeat the rubbing.

Avoid the immediate removal of the patient, as it involves a *dangerous loss of time;* also the use of bellows or any *forcing* instrument; also the *warm bath*, and *all rough treatment. Don't give up!* People have been saved after *hours* of patient, vigorous work.

SUNSTROKE.

Take patient immediately into the shade, place in a half recumbent position, head raised; loosen the clothes about the neck and chest; apply immediately ice in an ice bag, if one can be obtained, or cold wet cloths to the head and nape of the neck, changing them frequently.

Send for a physician as soon as possible.

POISONS AND ANTIDOTES.

First, send for a physician immediately, letting him know that it is a case of poisoning, so he may come prepared.

In all cases of poisoning the first step is to evacuate the stomach. This should be effected by an emetic which is quickly obtained, and most powerful and speedy in its operation; such are powered mustard (a large teaspoonful in a tumblerful of water), or salt, or half-teaspoonful powdered ipecac every ten to fifteen minutes.

When vomiting has already taken place, copious draughts of warm water or warm mucilaginous drinks should be given to keep up the effect till the poisoning substance has been thoroughly evacuated. If vomiting cannot be produced, the stomach pump must be used. This instrument will be particularly useful when narcotics, in liquid form, have been taken. In cases of corrosive poisoning, it is liable to lacerate the stomach.

POISONS.	ANTIDOTES.
Acids.	The alkalies; common soap (soft or hard), in solution, is a good remedy. It should be followed by copious draughts of tepid water or flaxseed tea. For nitric or oxalic acids, chalk and water are the best antidotes. When sulphuric acid has been taken, the use of much water is improper.

POISONS.	ANTIDOTES.
Alkalies and their Salts.	The vegetable acids; common vinegar is most frequently used. Oils, as castor, flaxseed, almond and olive, form soaps with the alkalies and destroy their caustic effect; should be given in large quantities.
Prussic Acid.	Chlorine water, solution of chlorinated soda, aqua ammonia; cold effusion.

F. S. Tuttle, of McCabe, Ariz., recommends a warm bath containing sodium bicarbonate and sodium chloride for external cyanide poisoning. For internal poisoning, he recommends two drops of ammonia on a lump of sugar to be eaten immediately. Rinsing the mouth with weak ammonia is good.

Another method very highly recommended for internal poisoning is freshly precipitated ferrous hydroxide. This is made by mixing ferrous sulphate and bicarbonate of soda. These two ingredients should be in proportion sufficient to just neutralize each other. Solutions of these two compounds may be placed in sealed bottles and kept in a small covered tin box. To take them, break both bottles into the box and use it as a drinking cup. Boxes containing the two bottles can be placed at convenient points in cyanide mills, laboratories or wherever required. Follow this treatment with an emetic.

POISONS.	ANTIDOTES.
Iodine—Iodide of Potassium.	Starch, wheat flour or arrowroot, in large quantities, well mixed with water; drink freely of them; afterward, strong mixture of vinegar and water. When this is done, life will be saved.
Antimony and its Salts.	Tartar emetic; astringent infusions, as of galls, oak bark, *strong* green tea.
Arsenic and its Compounds.	Any oil or fat (sweet oil, buttermilk); magnesia in large quantities. The freshly precipitated ferrous hydroxide recommended under prussic acid is the best antidote of all.
Bismuth.	Albumen; copious draughts of milk, with sweet mucilaginous drinks.
Copper and its Compounds. Verdigris.	Albumen, as milk or white of eggs in solution, freely used, ferrocyanuret of potassium. Vinegar must be avoided. Follow with an emetic.
Gold, Salts of.	Sulphate of iron and mucilaginous drinks.
Iron, Salts of.	Carbonate of soda, mucilaginous drinks.
Lead, Salts of.	Albumen, Epsom salts, Glaubers salts, lemonade.

POISONS.	ANTIDOTES.
Mercury, Salts of. Corrosive Sublimate.	Albumen, as white of eggs, milk or wheat flour beaten up with water; followed by an emetic.
Silver, Salts of.	Common salt, freely, in solution.
Tin, Salts of.	Albumen, white of eggs, milk or flour.
Zinc, Salts of.	Albumen or carbonate of soda, with copious draughts of warm water, and especially milk.
Phosphorus.	Magnesia with water, and copious draughts of mucilaginous drinks.
Gases.	Ammonia, cautiously inhaled, is recommended for chlorine. Asphyxia from noxious gases must be treated by cold effusions to the head, blood letting, artificial respiration and stimulants carefully administered.
Creosote.	White of eggs, milk, wheat flour.
Alcohol.	A powerful emetic to be given, followed by copious draughts of warm water.
Opium—Morphine, Laudanum, Strychnine.	Use most active emetics — mustard, alum, stomach pump; 2 drops tincture belladonna every hour for 3 or 4 hours. Patient must be kept in motion, slapped or flagellated, cold water dashed on head and shoulders.
Ivy.	Wash affected part with solution of sugar of lead, 20 grains to a pint of water.
Snake Bites.	Suck the wound immediately; give stimulants even to intoxication if there is prostration. *Send for a physician in all cases.*

DIARRHŒA.

Tincture of capsicum, 1 ounce; laudanum, ¼ ounce. Mix. Dose for an adult, 40 drops (or half a teaspoonful) after each evacuation, in a little water. If there is much pain, apply a mustard plaster to the stomach and bowels, or lay a cloth saturated with above mixture on parts if mustard plaster is not readily procured.

FEVER AND AGUE.

Fever and ague, malaria or "chills and fever," occurs in attacks or paroxysms, and each paroxysm has three stages: 1. The cold, when teeth chatter; 2. The hot, with high fever; 3. The sweating, when moisture appears and feeling of health returns. *Consult a* *physician*. If one cannot be obtained, in cold stage give *hot* drinks, hot foot bath, hot bottles to sides and limbs.

In hot stage give cooling drinks, ½ teaspoonful of sweet spirits of niter in water every two hours.

During sweating stage rub patient with a dry towel.

In intermission between chills, regulate the bowels and give quinine in 2-grain doses every three hours; when ten doses are taken, then give 10 drops of the tincture of iron three times a day for a week. Avoid the hot sun and damp evening and morning air. Where fever prevails, high hills and upper floors of dwellings are the healthiest.

SUBSTANCES IN THE THROAT.

A piece of food or some other substance often gets back into the mouth and cannot be swallowed. In such cases the finger will often be able to thrust it downward, should that be thought best. A *hair-pin*, straightened and bent at the extremity will often drag it out. If the body is firm in character a pair of scissors, separated at the rivet, and one blade held by the point will furnish a *loop*, which often can be made to extract it.

See that everything put in the throat is perfectly clean. In case of a fish bone stuck in throat, pieces of dry bread calmly swallowed will generally carry it downward, which is best, as it will be dissolved in stomach.

LIGHTNING.

Dash cold water over a person struck until conscious. Do artificial respiration if breathing has stopped.

MAD DOG OR SNAKE BITE.

Tie cord tight about the wound. Suck the wound, and cauterize with caustic or white-hot iron at once or cut out adjoining parts with a sharp knife.

VENOMOUS INSECTS, STINGS, ETC.

Apply weak ammonia, oil, salt water or iodine.

FAINTING.

Place flat on back, allow fresh air and sprinkle with water. Loosen anything tight around the neck.

TESTS OF DEATH.

Hold a cold mirror to mouth; if living, moisture will gather. Push pin into flesh; if dead, the hole will remain; if alive, it will close up. Cut an artery; if living, blood will flow, while if dead it will be empty.

CINDERS IN THE EYE.

Roll soft paper up like a lamp lighter and wet the tip to remove, or use a medicine dropper to draw it out. Rub the *other* eye.

FIRE IN ONE'S CLOTHING.

Don't run—especially not down stairs or out of doors. Roll on carpet or wrap in woolen rug or blanket. Keep the head down so as not to inhale flame. Get under a shower bath or into water if either is handy.

FIRE IN A BUILDING.

Crawl on the floor; the clearest air is the lowest in the room. Cover head with a woolen wrap, wet, if possible. Cut holes for the eyes. Don't get excited.

FIRE IN KEROSENE.

Don't use water; it will spread the flames. Dirt, salt, sand or flour is the best extinguisher; or smother with woolen rug, table-cloth or carpet.

SUFFOCATION FROM INHALING BURNING GAS.

Get into the fresh air as soon as possible and lie down. Keep warm. Take ammonia, 20 drops to a tumbler of water, at frequent intervals.

FOR DIARRHŒA.

(*Dr. Bradford.*)

Ext. hematoxyli (ext. logwood), 2 drams.

Acid sulph. aromat. (aromatic sulphuric acid), 3 fluid drams.

Tinc. opii camph. (paregoric), 1½ fluid ounces.

Syr. zingiberis q. s. ad (ginger syrup sufficient to make the whole measure), 6 fluid ounces.

M. sig. (directions): One table spoonful in water every four hours until relieved.

It is best to take several small doses ($\frac{1}{10}$ to ¼ grain) of calomel before starting with the diarrhœa mixture.

PILES.

Ointment of stramonium.

CHAFING.

Oxide of zinc mixed with vaseline to a white ointment, or borated talcum powder, or stearate of zinc powder.

MEASURES BY SPOONFULS.

One teaspoonful = 1 fluid dram = 45 to 60 drops pure water.

One dessert spoonful = 2 fluid drams = 2 teaspoonfuls.

One table spoonful = 4 fluid drams = 4 teaspoonfuls, or 2 dessert spoonfuls, and is also equal to ½ fluid ounce.

Two table spoonfuls, of course, make 1 fluid ounce.

POSTAL INFORMATION.

FIRST-CLASS MATTER.

Rates of letter postage to any part of the United States, Hawaii, Porto Rico, the Philippine Archipelago, Gaum, Tutuila (including all adjacent islands of the Samoan Group, which are possessions of the United States) and the Canal Zone are included. The Canal Zone includes all the territory purchased of Panama, comprising the Canal Zone proper and the islands in the Bay of Panama, named Perico, Naos, Culebra and Flamenco. Order of P M. G. No. 1440, Article 529, 2 cents per ounce or fraction thereof.

DROP LETTERS.

Two cents an ounce or fraction thereof when mailed at letter carrier post offices, or when mailed at post offices which are not letter carrier offices if rural free delivery has been established and the persons addressed can be served by rural carrier; and 1 cent for each ounce or fraction thereof at offices where neither letter carrier nor rural delivery service has been established and at offices where rural delivery service has been established, and if the person addressed cannot be served by rural carrier because they reside beyond the limits of the rural delivery service.

At a letter carrier office a drop letter bearing 2 cents in postage may be forwarded to another office without additional charge for forwarding. At other offices a drop letter bearing a 1 cent stamp may be forwarded on payment of 1 cent additional postage.

Letters, prepaid at the drop rate, inclosed in a package on which the bulk postage is paid at the letter rate, cannot be sent by mail from one office to the postmaster at another for distribution. Each letter must be prepaid at the regular first-class rate.

MONEY ORDERS.

DOMESTIC RATES.

For orders for sums not exceeding	$2.50	3 cents.
Over $2.50 and not exceeding	5.00	5 cents.
Over 5.00 and not exceeding	10.00	8 cents.
Over 10.00 and not exceeding	20.00	10 cents.
Over 20.00 and not exceeding	30.00	12 cents.
Over 30.00 and not exceeding	40.00	15 cents.
Over 40.00 and not exceeding	50.00	18 cents.
Over 50.00 and not exceeding	60.00	20 cents.
Over 60.00 and not exceeding	75.00	25 cents.
Over 75.00 and not exceeding	100.00	30 cents.

Domestic rates charged for orders to Canada, Cuba, the Philippines and Hawaii.

WHEN PAYABLE IN MEXICO.

For orders for sums not exceeding	$10.00	8 cents.
Over $10.00 and not exceeding	20.00	10 cents.
Over 20.00 and not exceeding	30.00	15 cents.
Over 30.00 and not exceeding	40.00	20 cents.
Over 40.00 and not exceeding	50 00	25 cents.
Over 50.00 and not exceeding	60.00	30 cents.
Over 60.00 and not exceeding	70.00	35 cents.
Over 70.00 and not exceeding	80.00	40 cents.
Over 80.00 and not exceeding	90.00	45 cents.
Over 90.00 and not exceeding	100.00	50 cents.

FOREIGN RATES.

To all parts of the Universal Postal Union (embracing nearly every civilized country), letters, 5c. per half ounce, prepayment optional; if not prepaid, a fine is collected on delivery.

International postal card, 2 cents; newspapers, books, pamphlets, photographs, engravings, etc., 1 cent for each 2 ounces or fraction thereof.

The fees for money orders on Great Britain and other foreign countries are: Not over $10.00, 10 cents; $20.00, 20 cents; $30.00, 30 cents; $40.00, 40 cents; $50.00, 50 cents; $60.00, 60 cents; $70.00, 70 cents; $80.00, 80 cents; $90.00, 90 cents; $100.00, $1.00.

Mailing to the Dominion of Canada, New Brunswick and Nova Scotia, same as United States rates.

REGISTRY.

Registration insures greater security in the delivery of mail matter, by placing it in special custody and under a complete system of checks attained through receipts given and records made by every person handling it.

The cost of registering is 8 cents for each piece, in addition to the regular postage, both of which must be fully prepaid with ordinary postage stamps affixed to the envelope or wrapper of the article registered.

Matter to be registered must be enclosed in a wrapper or envelope sufficiently strong to bear transportation, and in case of other than first-class matter must not be sealed, but admit of *easy inspection*, and be correctly and legibly addressed; have the name and address of the sender endorsed upon it; have the necessary stamps affixed to pay both the postage and registry fee, and be presented at the registry window of any post office to secure the proper receipt from the postmaster.

SPECIAL DELIVERY.

Special delivery to house or place of business by special messenger of any class of mail matter may be secured by affixing 10 cents in stamps in addition to the regular postage and writing on envelope "for special delivery."

The special delivery stamp is not required; any denomination of stamps to the amount of 10 cents can be used.

EXPLOSIVES.

Explosives used for blasting are naturally divided into two classes or groups, viz.:

*Class I. High explosives: Indirect exploding materials.

Class II. Low explosives: Direct exploding materials.

Class I is made up of those explosives which require an intermediate agent, such as fulminate detonator, to cause them to explode properly.

Class II includes all of those explosives that can be made to develop their full force by direct means, such as ignition.

HIGH EXPLOSIVES.

Few persons realize how large are the quantities of explosives which are absolutely required daily, directly or indirectly, by nearly all the larger industries of the present day. The recognition of the uses to which explosives can be put has become more general, and the greatly increased safety in the handling of the best brands of explosives, has been the result of persistent effort and study on the part of the DU PONT COMPANY to fully meet all the requirements.

The value of an explosive depends on three things:

STRENGTH or disruptive power.

SAFETY in handling.

And last, but by no means least, STABILITY OF KEEPING qualities.

Generally speaking, all explosives which cannot, like gunpowder, be exploded by simple ignition, but which require the use of an exploder or detonator to produce complete detonation, are called High Explosives.

The DU PONT COMPANY, the oldest and largest manufacturer in the business in the United States, manufactures the following standard brands of "HIGH EXPLOSIVES."

Atlas Powder,	Repauno Gelatine,
Hercules Powder,	Hercules Gelatine,
†Giant Powder,	†Giant Gelatine,
Red Cross Dynamite,	Forcite,
Judson R. R. P.,	Nyalite,

*Priming compounds and mixtures, such as fulminate of mercury and the mixtures of which it forms the base, are exceptions to this classification, being high explosives that develop their full explosive force on ignition.

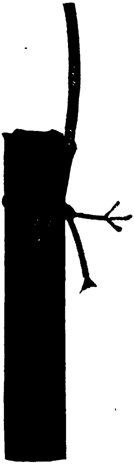
†Rights of manufacture and sale owned by the DU PONT COMPANY in the states east of and including North Dakota, South Dakota, Nebraska, Kansas, Oklahoma and Texas.

which are now very generally used wherever work of any kind needing explosives is in progress. Some of the more important applications are:

For driving tunnels, railroad and other grading; sinking shafts and wells; mining silver, gold, lead, zinc, copper, iron and other ores; breaking salamanders and scrap iron castings, etc.; moving piles of frozen ore in winter, blasting fire clay and coal, submarine blasting, removing wrecks, clearing ice gorges, starting log jams and rollways, breaking boulders, clearing land of stumps and trees, blowing holes for transplanting trees, etc.

GENERAL DIRECTIONS FOR USING HIGH EXPLOSIVES.

First of all it is necessary to be sure that the cartridges are properly *thawed*. See article on "Thawing Dynamite."

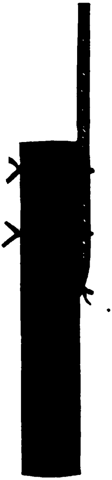


A

Having made the hole ready to receive the charge, the "primer" should be prepared. *When using caps and safety fuse*, the "primer" is made as shown in cuts "A" or "B," as follows:

Two or three inches of the coil of fuse should be cut off and thrown away, as it may have absorbed moisture. Then a piece of fuse of the required length is taken, cutting the end squarely, thus securing a better fit and fresh powder at the end. One end of the piece of fuse is inserted into the open end of the cap, care being taken not to jam or force it against the filling of the cap. The cap is then crimped tightly at the open end around the fuse to hold it in position.

With a wooden pin prepared for the purpose, a hole is punched downward in the side of a cartridge of dynamite, and in this hole the cap with the fuse attached is inserted, the fuse being tied to the cartridge with string, as shown in cuts "A" or "B."



B

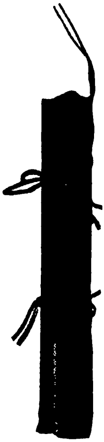
When using electric fuzes, the primer is made as shown in cut "C," as follows:

With a wooden pin prepared for the purpose, a hole is punched in the lower end of a cartridge of dynamite and the electric fuze inserted therein, the wires being bent back and fastened at two points to the cartridge by string, as shown in cut "C."

These methods have been found very satisfactory since:

First.—The fuse or wires come against the side of the hole and are not likely to be kinked or otherwise injured by the tamping bar.

Second.—The exploder cannot be pulled from the primer, thus avoiding a misfire.



C

Third.—The tamping bar cannot reach the cap and cause an explosion.

The method of making primers as shown by cut "D" is a favorite with a great many blasters when using fuse and caps. This is the method recommended as best with nyalite and similar powders.

To make a primer by this method, open one end of the cartridge and by means of a wooden pin punch a hole in the powder just deep enough to receive the cap. Wrap the end of the cartridge closely about the fuse and tie it tightly in place. To avoid the possibility of setting the powder on fire, do not bury the cap in the explosive.

D

After the primer has been prepared, the proper number of cartridges should be placed in the hole. It is important that no air spaces should remain in the hole below the tamping, and to guard against this, the cartridges should be slit and well rammed. However, when water is in the hole and cannot be removed, the cartridges should not be slit.

When the proper number of cartridges have been inserted, then the primer is introduced into the hole and gently pressed into position. The hole is then to be filled with clay, loam or similar material, containing no grit or sharp particles, this being tamped tightly.

The tamping bar used in loading should have no metal parts. It should preferably be made of hardwood, which will be found to do the work very satisfactorily.

It is very essential to use good electric fuzes or caps and fuse. Tape fuse is recommended, as it resists the force of tamping and the influence of moisture. An attempt should never under any circumstances be made to use a weak or cheap cap or electric fuze. It has been found that though an explosion might occur, the full strength of the explosive is not developed by the use of a weak exploder. Single strength electric fuzes and DU PONT triple and quadruple caps may be used with DU PONT ordinary dynamites, although the stronger caps and electric fuzes are recommended for use with all high explosives. Nothing less in strength than double strength electric fuzes and DU PONT quintuple caps should be used with DU PONT "Extra" grades and DU PONT gelatine powders. In deep holes blasting caps (without fuse) should be placed in the charge at a distance of 5 feet apart throughout the charge to secure the best results.

In handling the exploders, great care must be exercised. They should *never* be stored, carried, packed or shipped with dynamite.

There are special classes of work in which high explosives are used to which the above "general directions" do not fully apply. In such cases the DU PONT COMPANY will very gladly furnish advice to any of its customers as to the best methods to be pursued.

ROCK BLASTING.

DRILLING—Adapt the location, size and depth of the holes to the work to be accomplished. Be careful to point the holes in a direction that will give the explosive an opportunity to do its full amount of work.

As a general rule for ordinary rock blasting, the distance between the holes should be about the same as the depth of the holes. Set the holes back from the face twice as far as for common blasting powder, say a distance back from the face equal to the depth of the hole.

CHARGING.—For methods of charging, see "General Directions for Using High Explosives." Where deep submarine blasting is done, the drill hole should first be carefully cleared of borings and a metal tubing inserted to near the bottom, and the cartridges carefully passed down through it.

No definite rule can be given for the charges for bore holes as the amount and strength of explosive used depends not only upon the nature of the material to be blasted, but upon the form in which the excavated material is desired. In all cases the experience and judgment of the blaster must be his guide. One or two blasts will demonstrate if any change is needed.

Do not use a very deep hole of small diameter or a shallow hole of large diameter. A lack of care in this regard will cause a waste of explosive. For making primers, see section on "General Directions for Using High Explosives." When the electric method of firing is used, the primer may be placed at any point in the charge; some blasters prefer to place it in the middle. When the cap and fuse method of firing is used, the primer should be placed at the top of the charge. In deep holes the placing of quintuple force blasting caps without fuse at intervals of 5 feet is recommended.

TAMPING.—The tamping recommended by the DU PONT COMPANY is clay, loam or similar material containing no grit or sharp particles that can be compressed easily into a compact mass.

Fill in for a few inches *carefully*, so as not to displace the cap and primer; then with a hardwood rammer one can pack as solid as they please, ramming by hand alone and not using any form of hammer.

FIRING.—The electric method of firing is most highly recommended by the DU PONT COMPANY. This applies in particular to submarine blasting and other wet work. It is difficult to manufacture fuse that will withstand the pressure of more than 20 feet of water, as the pressure of water is so great on the fuse that it is forced through the covering, dampening the powder train and cap, thus preventing the firing of the blast.

When the cap and fuse method is used for wet work, triple tape or gutta percha water proof fuse should be used. The end of the fuse can be protected by applying yellow bar soap, pitch or tallow around the edge of the cap. Water must not be allowed to reach the powder train in the fuse or the fulminate in the cap.

SEAM BLASTING.—Occasionally when conditions favor it, seam blasting can be done to great advantage. The method is as follows: Remove the powder from the cartridge and push it into the most favorably located seam and fire a cap beside it. This will open the seam so that a larger quantity of powder can be used, and the rock broken without drilling.

In blasting slate, marble, granite, freestone or any other material which it is desirable to obtain in large blocks, black powder should be used; but if none can be obtained, high explosive cartridges of small diameter may be used in wide bore holes, the charge being rolled in several folds of paper to prevent its touching the sides of the bore hole. The intensity of action and crushing effect of the explosives are thus lessened. In the use of high explosives, do not judge the execution done by a blast by first appearances. It frequently happens that a blast which seems to have had little effect proves to have done remarkable execution in cracking and loosening the rock, and preparing the way for subsequent blasts.

SUBMARINE BLASTING.

The methods of using high explosives in submarine blasting depends entirely upon the nature of the work to be performed. As a general rule, for blasting out ledges and other rock in harbors and streams, drill boats with steam or air drills are used, although in some instances divers have been sent down to place a number of cartridges fastened together, and called torpedoes, on or under an abutting point on a ledge or reef, and this, and perhaps 8 or 10 similar charges placed at other points on the same reef, were fired simultaneously. This proceeding can be repeated until enough rock has been broken off to keep the dredges busy for a time. This method is not to be recommended where the current or tide is at all strong, for the reason that it is a hard matter to keep the charges in place. This method can only be recommended for the removal of small masses of rock where the cost of installing a drill boat or stagings would be too large for the amount of work to be accomplished.

The most common method of drilling for submarine excavations is by the use of drill boats or platforms with steam or air drills.

The drilling is done, as a rule, through pipes anywhere from 4 inches to 8 inches in diameter. This is to keep the drill steady and

Fig. 13.

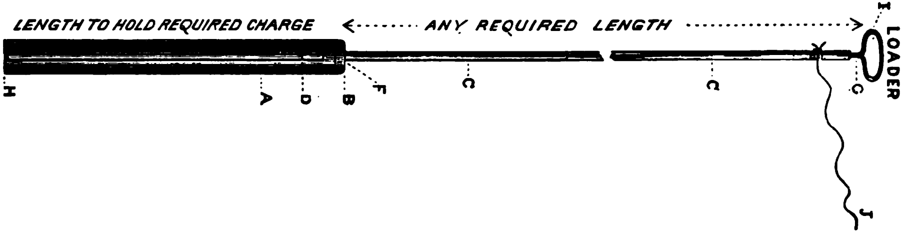


Fig 12.

This illustration shows a good form of submarine loader. It consists of a section of pipe (a) long enough to receive charge required and of suitable diameter to fit drill hole (say 2 ins.) and to have cartridges fit snug inside. A cap (b) is forged on one end of this pipe with a threaded hole in same to receive upper section of loader (c). A slit (d), say ¼ in. wide, is made to allow fuze wires to slip up, as the charge is placed in lower section of pipe. Edges of this slit should be rounded so as to avoid injury to insulated covering of fuze wires. The upper section (c) of loader is a ¾-in. pipe of any required length screwed into the cap of lower section at (f). A ½-in. iron rod (g) slightly longer than the two sections of pipe passes down through them. This rod has a disc (h) on the bottom (size to fit in lowest section) and handle at top (i). A line (j) is attached to the upper casing to withdraw loader when charge is in place.

in the same position at all times. This tubing is removed before blasting. The bits run from $3\frac{1}{2}$ to 5 inches in diameter and the holes vary according to the amount of rock taken out.

As a general rule, bore holes should be drilled closer together and nearer to the face than on land. This is on account of the great weight of water, which makes considerable resistance to the force of the dynamite.

The DU PONT COMPANY recommends the highest available strengths of dynamite and gelatine powders for submarine blasting. They should not be less than 60 per cent. strength. The detonators used should be electric fuzes of not less than DU PONT double strength. Cap and fuse firing is not to be recommended for submarine blasting except in very shallow depths. It is hard to make fuse that will withstand the pressure of over 20 feet of water. Guttapercha fuse is the best for this purpose.

In charging bore holes, several methods are in use. Some contractors prefer to use the services of divers entirely. Probably this is the most satisfactory method, for the reason that one will always know exactly how the hole is loaded. Also proper care can be taken in placing the cartridges which contain the exploders and to see that the wires do not scrape on the rocky sides of the hole, thereby wearing off the insulation, causing misfires.

Loading can also be done by means of the tubing through which the drilling is done, forcing the powder down by means of a wooden tamping rod. In using this method, care must be taken not to break the cartridges or scrape the insulation from the wires at the point where the drill tube touches the upper end of the bore hole.

The method in use on most large contracts is to make use of a charger, swung from the framework on which the drill runs.

The charger consists of an iron pipe sufficiently large to contain the cartridges and at the same time fit the drill hole easily. This charger is slit from the bottom on one side for about 3 feet in order that the exploder wires may be guided into the hole and still remain on the outside of the charge. The average charger is about 25 feet long. Inside is a long iron piston with a disk attachment on the end, which is used to force the cartridges out into the hole. In loading this instrument, it is charged from the bottom up.

As already mentioned, the exploders should always be double strength or stronger. In shallow depths of water the exploders can be protected by means of tar or asphalt paint to insure their being water proof. For great depth, the guttapercha electric fuzes should be used.

When working close to wharves and vessels, the bore holes should be drilled closer together and light charges used. By this means the same results as with the regular blasts are obtained with less concussion. For the removal of wrecks 40 per cent. strength of dynamite can be used with good results. To remove the masts of sunken vessels, a ring of cartridges, primed with an electric fuze, large enough to fit over the lower end of the mast is made. This ring is weighted and dropped down the mast to the point at which it is to be cut off. The blast is then fired by means of a battery. This will generally cut the mast off clean at the point where the charge was placed. This method can also be used to cut off piles, logs and tree trunks under water.

To destroy sunken wrecks, after the masts are removed, the decks, upper works, etc., are first blown off by means of charges placed beneath them. Then the hull is blown up in a similar manner. The success of this work depends entirely on the ingenuity and experience of the man in charge and the diver. For steel vessels, dynamite not less than 60 per cent. strength should be used.

In submarine blasting where the water is cold, be sure to fire the blast as soon as possible after loading, to avoid loss of strength or partial detonation due to chilled powder. See section on "Thawing Dynamite."

BLASTING STUMPS.

In order to remove stumps by means of explosives, the nature of the wood, the size of the stump, the number and size of the roots and the character of the ground in which they are located, must be taken into consideration.

In the Eastern States the most successful method is to place the explosive beneath and as close as possible to the toughest part of the stump, boring into the tap root if necessary.

In the Northwestern States, along the Pacific Coast, very large stumps occur, which, owing to the great annual rainfall, have no tap roots, all of the roots spreading out close to the surface. The general rule given for removing these stumps is as follows:

Place the charge 16 to 24 inches below the center of the stump, so as to bring it out with the greatest possible length of roots. For stumps below 4 feet in diameter, use 1½ pounds of 20 per cent. strength dynamite for each foot in diameter. For sizes over 4 feet in diameter, use 2½ pounds of 20 per cent. strength dynamite for each foot in diameter. If the ground beneath the stump is loose, add one more pound for each foot in diameter.

Judson R. R. P. or low powder appears to do the best work in removing the large redwood stumps occurring in California. For stumps less than 8 feet in diameter, the product of the largest diameter in feet multiplied by 8 indicates the number of pounds of Judson R. R. P. required. For stumps over 8 feet in diameter, square the largest diameter. For the correct method to use in order to detonate Judson R. R. P. properly, see section on "Judson Powder."

To remove cypress stumps, such as occur in the Southern States, place 4 or 5 pounds of 60 per cent. strength dynamite in a hole bored in the tap root, together with a half cartridge under each of the principal spreaders. Fire all simultaneously by means of an electric blasting machine.

FELLING TREES.

Load similarly to stump blasting. When the explosion takes place, the tree above the blast jumps about a foot and then falls generally with the wind; the stump is splintered down into the roots and can be readily removed.

For the detailed methods used for blasting stumps, send for the "Farmer's Catalogue" issued by the DU PONT COMPANY.

BLASTING BOULDERS AND MASSES OF IRON.

Boulder blasting differs but little from stump blasting.

The number of cartridges essential to a charge depends, of course, upon the size and toughness of the rock, but in cases of field boulders a small charge is generally sufficient.

BLOCK HOLE BLASTING.—For large boulders, the best method is to use drill holes one inch or more in diameter as may be needed. A boulder of 10 tons should have a drill hole from 10 to 20 inches deep, as the shape and grain of the rock may demand and sufficient in diameter to allow the proper placing of about a pound or two of dynamite. This should break it in pieces. Smaller boulders in a quarry would require holes of from 4 to 6 inches in depth, and if necessary can be filled full of powder, the cap pushed into the charge and no tamping used.

SURFACE BLASTING.—Boulders may frequently be broken by placing a charge of dynamite on their surface, and exploding it while in that position. For this kind of blasting, one should select the spot which they would naturally pick out to strike with a sledge hammer (if the boulder were going to be broken in that manner). First loosening the dirt around the base of the boulder, place the charge in position and cover it with sand or dirt, and upon that lay a heavy rock. If the boulder to be blasted is cracked or seamy, the best results may be secured by placing the charge in such depression and covering the dynamite with a quantity of earth or sand. This will furnish resistance and make available a greater force from the explosive.

To blast a boulder from below, proceed as in stump blasting, taking care that the hole be made on a flat or hollow side of the rock and not on bulging side of it. Make a hole with a crowbar or dirt auger, close up under the center of the rock; load the dynamite into the hole in the same manner as for stump blasting. Then fire the charge. Care should be taken to be sure that when the charge is placed, no means have been left by which the force of the dynamite may leak out. If it has not been thoroughly tamped, or if it lies too near the surface of the ground and not in the proper position beneath the boulder, the dynamite will blow the dirt out and leave the rock untouched.

FOR BREAKING HARD HEAD BOULDERS, the strongest grade of dynamite is the best and cheapest. As a general rule, it is best to put the powder under the boulder and close up to the rock, tamping the ground well under and around the charge. But if the boulder is flat or slightly concave on top and is not imbedded in the ground, it can be broken by placing the powder on top and covering it as given above; but if much imbedded, the earth should be loosened around and under it.

FOUNDRY PRACTICE.—*No foundry* that works up old castings *should be without* DU PONT DYNAMITE.

A cartridge or two of dynamite laid upon the most stubborn casting and covered with sand will do in a few seconds, and at a trifling cost, the work that two men with sledges would accomplish in a day.

When blasting "chills" or "salamanders" that often occur at blast furnaces, it is best to drill holes of sufficient size and depth; but for castings press the powder close to the place you desire to break, then cover with a few shovelfuls of clay.

LOG JAMS.

DU PONT HIGH EXPLOSIVES are invaluable in breaking log jams. A charge exploded on a log, above or *below water*, will cut it in two as readily as can be done with an ax, with the advantage of the operator being at a safe distance from the starting of the jam when the cutting takes place.

BREAKING UP ROLLWAYS.—DU PONT HIGH EXPLOSIVES are now used to great advantage in breaking up "rollways" of logs. Large quantities of these powerful explosives are each season used for this purpose by the lumbermen.

At a season when time is truly money, the use of a little dynamite will save many times its cost in labor alone, beside avoiding delay and loss of valuable time, due to the slow and laborious methods of prying apart huge piles of logs, frozen and matted together by snow and sleet, with cant hooks and levers. It is safely and easily transported in fifty pound cases, and no logging camp can afford to be without it a single day when engaged in this work.

BLASTING ICE.

Ice in streams often forms jams or gorges 10 to 40 feet high. When water banks up behind such a dam, it may cause a flood, which by carrying away valuable bridges, etc., may do great damage and cause serious losses in the district. This can readily be prevented by the use of DU PONT HIGH EXPLOSIVES.

CHARGES.—Tie together as many cartridges as are wanted for the charge. One cartridge only need be loaded with cap and fuse. Place the primer in the center of the bunch of cartridges. Use water proof fuse and protect the cap as directed under "General Directions for Using High Explosives."

TO OPEN A CHANNEL THROUGH SOLID ICE.—Cut holes and hang charges, of from a ½ pound to 5 pounds each, in the water from 6 inches to 5 feet under the ice. Experience on solid fresh water ice, of 3 feet in thickness, has shown that a charge of 4 pounds, exploded 5 feet under the ice, will break a circle of 60 to 70 feet in diameter, and that a charge of ⅛ pound, exploded 18 inches under 10 inches of rotten salt water ice, will break a circle of 20 feet in diameter.

If the charge is placed too near the ice, the force of the explosion is spent in throwing the ice and water of a small circle high in the air. The same charge, fired at a greater depth, makes a more extended blast with less display.

The rule adopted for loading is: Increase the size of the charge and depth of firing point until the result is the greatest circumference of breakage.

The charges are loaded and fired very rapidly, and the amount of work accomplished in one day is something wonderful.

To BREAK FLOATING ICE.—Fasten the charge to a stone, block of wood, or other object, to prevent its rolling. Use fuse of sufficient length to give time to place the charge in position, and retreat in safety. After lighting the fuse, throw the charge as nearly on to the center of the ice cake as possible. Begin with from one to three cartridges, and be guided by their effect in future operations.

To BREAK OUT ICE WHEN IT IS PILED FROM TEN TO FORTY FEET HIGH.—Find the weakest point and place the charge where it will get, as near as possible, a bearing on all its sides. Charge required from 5 to 25 pounds, according to work performed. If passage from place of firing is too difficult to admit of using fuse, perfect safety can be gained by using a battery.

To BREAK ICE ABOUT WHARVES AND PILING.—Decrease size of charge as you approach wharves and piling. Charges of one-third of a pound have been fired within 2 feet of piling, clearing the ice from it and doing no damage. Where there are crevices in the ice, lay the charge in them. If there are none, it is well to cut a shallow hole in which to lay the charge, giving it all the bearing possible.

To OBTAIN THE GREATEST RESULTS.—In operations on ice, it should be remembered that the charge, to be most effective, must be warm, and should be fired as soon as possible after being thawed. See article on "Thawing."

BLASTING BY ELECTRICITY.

Blasting by electricity is now conceded to be the most effective and economical method, surpassing any other for safety and certainty of action.

The articles necessary for use in blasting in electricity are, first, a blasting machine; second, heavily insulated leading wire; third, connecting wire; and last in order, but most important, the best and strongest electric fuzes on the market. To succeed in blasting by electricity, only the best materials should be used.

By electric firing, the entire strength of the explosive is developed at the same instant, less explosives being thus required than if each hole had been fired separately, with a consequent material reduction in the cost of blasting. This saving applies both to the cost of the explosives and the cost of drilling, as fewer holes are required.

Much time is saved in such places as shafts and tunnels where ventilation is defective and where it is usual to wait half an hour or more after each blast to allow smoke and fumes to clear away. The reason is that by the electric method *and the use of good explosives* the loss of time is reduced to a minimum, as fewer blasts are required.

By electric blasting, all holes are exploded simultaneously, if all connections are properly made, and there is no possibility of a second explosion. If a misfire occurs by reason of improper connections, such missed hole will not hang fire and explode unexpectedly, as sometimes occurs when blasting with safety fuse. Electric blasting consequently eliminates this dangerous feature in connection with blasting operations.

BLASTING MACHINES.

The most popular blasting machine in this country consists of a small series wound dynamo operated through a clutch by either the downward or upward stroke of a rack and pinion. The machine is arranged so that, until the rack bar reaches the end of its stroke, the current is short circuited through the magnets, thus building up current.

When the rack bar reaches the end of its stroke, the short circuit is broken and the current sent through the main leading wires, thus firing the blasts.

In order to prevent the possible misfire of a few holes in the center of a long line, due to leakage of the current, the three-post blasting machine has been placed on the market. With this machine, an extra leading wire from the middle post is connected with the middle of the circuit.

An electric exploder resembles a blasting cap in shape. Imbedded in loose fulminate on the top of the charge is a fine platinum wire, connected with the leading wires and held in place by a water proof sulphur plug. The heating of this wire to redness fires the charge of fulminate in the fuze. Electric fuzes are manufactured with leading wires varying in length from 4 to 30 feet.

For a complete description of blasting machines and electric fuzes, send for the du Pont High Explosives Catalogue.

DIRECTIONS FOR BLASTING BY ELECTRICITY.

Drill the number of holes desired to be fired at one time, the depth and spacing of the holes depending on the character of the rock, size of drill holes, etc., the blaster, of course, using his judgment in this matter. Load the holes in the usual manner.

Avoid taking hitches in electric fuze wires, as by this very common practice the insulation of the wires may be injured, and the current of electricity may pass from one wire to the other, without passing through the cap, hazarding a misfire. The cartridge containing the electric fuze is put in the top of the charge, and in deep holes good blasting caps (without fuse) should be placed in the charge at a distance of 5 feet apart throughout the charge to secure the best results. In tamping the hole, great care must be taken not to cut wires nor injure the cotton covering of fuze wires, and not to pull the electric fuze out of the cartridge. Allow at least 8 inches of fuze wire to project above the hole to make connections.

The above description of loading for electric blasting applies to the use of high explosives. Where black powder is fired by electricity, it is well to get the cap of the electric fuze as near the center of the charge as possible.

When all the holes, to be fired at one time are tamped, when one fuze only is used in each hole, separate the end of the *two* wires in each hole, and by the use of connecting wire, join one wire of the first hole with one of the second, the other or free wire of the second with one of the third, and so on to the last hole, leaving a free wire at each end hole.

When two electric fuzes are used in each hole, connect one wire of each of these two fuzes together and then connect the holes by the remaining wires of the fuzes as would be done when using only one fuze in each hole. In other words, connect the fuzes *in series* throughout.

All connections of wires should be made by *twisting* together the *bare* and *clean* ends; it is best to have the joined parts *bright*. Scrape off the cotton covering at ends of wires to be connected, say for 2 inches, then scrape the wire bright. This makes a clean, fresh connection. Bare joints in wire should never be allowed to touch the ground, particularly if the ground is wet, as the electricity will then be short-circuited into the ground. This can be prevented by putting dry stones under joints. Insulating tape is also furnished for water-proofing bare joints. The charges having all been connected, as directed above, the free wire of the first hole should be joined to one of the leading wires and the free wire of the last hole to the other of the two leading wires. The leading wires should be long enough to reach a point at a safe distance from the blast, say 250 feet at least. All being ready, *and not until the men are at a safe distance*, connect the leading wires, one to each of the projecting screws on the front side or top of the blasting machine, through each of which a hole is bored for the purpose, and bring the nuts down firmly on the wires.

Now, to fire, take hold of the handle for the purpose, lift the rack bar (a square rod, toothed upon one side) to its full length, and press it down quickly with all the force possible, bringing rack bar to the bottom of the box with a solid *thud*, and the blast will be made. Do not churn rack bar up and down. It is unnecessary and harmful to the machine.

Please remember that the directions given in this publication are of necessity only general in their nature. The DU PONT COMPANY will gladly furnish its customers with the benefit of its advice as to the best methods to be followed in connection with any work in which blasting supplies and explosives are used.

CAUTION.

Do not *overload* a blasting machine.

The best blasting machines are the cheapest.

Misfires are usually due to the use of inferior machines or failure to develop the full current of electricity. An inferior blasting machine is always dangerous.

Complaints are sometimes made that all of the electric fuzes connected to a machine do not fire. This fault, in nine cases out of ten, is not with the electric fuzes, but is either with the blasting machine or with its manipulation. Tests have proved absolutely that when some of the holes in a circuit explode and some fail, the reason is an insufficient amount of electricity.

This is caused by the blasting machine being in bad condition or by the blaster giving only a rather light push to the handle. To avoid the latter trouble, observe this rule: "When exploding a blast, *push the rack bar down as fast as possible.*"

When a "pull-up" machine is used, the rule reads: "When exploding a blast, *pull the rack bar up as fast as possible.*"

Blasting machines should not be left carelessly lying around, but should be kept in the office or other dry room when not in use.

SPECIAL METHODS FOR BLASTING BY ELECTRICITY.

These methods involve the use of the regular electric fuzes (exploders or detonators), but the ordinary blasting machine is not always used. An electric current generated by other means than by a blasting machine is often applied and this can be done satisfactorily by anyone having a clear understanding of the principles involved. The DU PONT COMPANY will be glad to furnish advice upon this subject to any of its customers.

GRADES OF POWDER.

There are many different grades of high explosives, appropriate for different kinds of work, such as rock, ore and other blasting. Many persons employed in work entailing the use of explosives have a preference for one or the other of the brands of explosives, all of which have peculiarities which, for one reason or another, have recommended them most favorably to the user.

Recommendations in regard to the proper grades of powder can only be considered in a very general way. The DU PONT COMPANY gives the following advice in regard to the grades of powder to use in different kinds of blasting, more to indicate what grades may give the best results in the kinds of work mentioned than to have these recommendations considered as being correct in all cases. The texture of the material to be blasted and the size and condition of the product desired as well as the toughness and hardness have to be taken into consideration in all cases:

For submarine blasting, very hard rock, boulders. iron, etc., use the 60 to 75 per cent. strength grades of dynamite or gelatine powders.

For tunneling in hard rock, mining copper and magnetic iron ore, lead ore, gold quartz, limestone, etc., use the 40 to 60 per cent. strength grades of high explosives.

For general quarrying, coal, cement, slate, sand or earth blasting, removing growing trees, stumps, etc., use the 20 to 40 per cent. strength grades of high explosives.

However, in all cases the DU PONT COMPANY strongly urges upon its customers the advisability of *applying to their nearest office* (*see list, page x*) to have a representative sent to examine the work and advise what grade of powder should be used and how applied. By this means, the company can give its customer a grade especially adapted to his work, and is enabled to do justice to both the customer and itself.

GELATINE POWDER.

GELATINE POWDER is an explosive especially suited for work in places where there is a limited supply of air, as in underground mining, tunnel work, etc., and also for wet blasting.

The gases generated by the explosion of gelatine powder in close places are not as objectionable as those of other explosives, and for this reason there is a great saving in underground labor, where it is necessary to follow closely one shift by another. In addition to this most important factor, the miners not only reach their work sooner, but on account of the purer air are in better physical condition, which enables them to accomplish much more work.

The mistake should not be made of supposing that gelatine powders produce no smoke ; there is simply an absence of any considerable quantity of objectionable fumes.

They are plastic, as their name indicates, and stick well in uppers. On account of their greater density, as compared with ordinary dynamite, they are more readily loaded in water, which does not affect them. They are, however, less sensitive, and for this reason should never be used with caps less than DU PONT quintuple strength, or electric fuzes of less than double strength.

While nitroglycerin forms an important ingredient in the composition of gelatine powders, yet is not the only explosive agent employed. The use of other high explosive materials in conjunction with nitroglycerin gives to gelatine its distinction over ordinary dynamite. Thus to obtain the same relative explosive strength in gelatines, as in corresponding grades of other dynamites, the nitroglycerin contained in the gelatine must be reduced in proportion to the explosive force generated by the other ingredients.

Therefore, the term "40 per cent. strength gelatine" indicates a grade equal in explosive force to 40 per cent. dynamite, but does not mean, as will be seen from the foregoing, that there is 40 per cent. of nitroglycerin in "40 per cent. strength gelatine."

THE "EXTRA" GRADES OF POWDER.

The "EXTRA" grades of powder are sold according to percentage strength. For the meaning of this term, see the preceding article on "Gelatine Powder."

The "Extra" grades of powder are especially adapted for work in material where a strong heaving or rending action is desired. These grades of powder are made up of ingredients that give explosive strengths equal to the corresponding percentage strengths of the standard grades of dynamite, with an action which is a little slower than either dynamite or gelatine powders. In addition, the "Extra" grades of powder are less inflammable, and cannot be so readily ignited by ordinary means as either dynamite or gelatine powders.

These properties make the "Extra" grades of powder especially adapted for railroad grading and quarry work, and for use in mines, where the values are contained in the softer material or where a minimum of fine ore is desired; for instance, the mining of ores that are to be smelted or concentrated. On account of the difficulty with which this powder ignites, it is rarely, if ever, that charges take fire from defective fuse, etc., and cause the formation of the so-called "stinkers." The "Extra" grades of powder and the gelatine powders are not quite as sensitive as dynamite, and, therefore, no exploder of a strength less than a DU PONT quintuple cap should be used with them.

NYALITE.

NYALITE is a valuable and comparatively new and high explosive patented and introduced to the trade by the DU PONT COMPANY, after extensive experiments and years of research by its corps of chemists and explosive experts in the field, as well as in the laboratories.

Nyalite is especially designed for use in mining coal, and when properly loaded, tamped and fired, may be used in gaseous, dusty and dry mines with less danger than is incurred with any other explosive known. It has been tested under the most severe conditions in some of the most gaseous mines in the Pennsylvania, West Virginia, Alabama, Oklahoma and other coal fields and has never failed to give satisfaction.

Nyalite produces less smoke and fumes than any other explosive in the market. This means a great saving of time on the part of the miner, with increased production. It is as strong as any high explosive required for use in coal mining, and exercises a rending and heaving action on the coal without unduly pulverizing it. It is not affected by ordinary ranges of temperature. It does not freeze.

Nyalite requires no special manipulation. Prime, load, tamp and fire in the same manner as any other high explosive and good results are assured.

Nyalite brand of caps and electric fuzes are manufactured especially for use with nyalite and their use is necessary to insure satisfactory results with this explosive.

JUDSON R. R. P.

Judson R. R. P. is a powder which has properties intermediate between those of dynamite and black blasting powder. It is now largely used where black powder was formerly used, and is very much stronger than the best blasting powder.

It is without an equal for blasting soft and friable rock or rock which is very seamy. It has been found that dynamite is too quick to allow all its strength to be utilized in rock of this nature. Black powder, on the other hand, is too slow, and when fired simply puffs out of the seams and cracks without moving the rock. Judson R. R. P. heaves and breaks such rock into pieces which can be readily handled and is the only powder which will do this satisfactorily.

Judson R. R. P. is used to excellent advantage in blasting stumps. It also shows to great advantage when used in slates, hard pan, tough clay, hard and frozen earths and other materials of a similar nature Most of these materials are met with frequently by contractors, and by the use of this powder large economies can be obtained.

This powder is granular and runs freely into irregular cracks and crevices, and for its special field of work is unequaled.

Judson R. R. P. is used much like common blasting powder. A hole is drilled in the usual manner in the rock or material to be blasted, and then a stick, or part of a stick, of dynamite is exploded in the bottom of the hole without tamping. The explosion forms a chamber or pocket at the bottom of the hole and this operation is known as the "springing the hole." After the pocket is thoroughly cooled, Judson R. R. P. is poured into this pocket, and well rammed down with a wooden tamp. When the powder begins to come up in the hole, that is, when the pocket has been filled, a primer of dynamite is introduced.

Judson R. R. P. can only be exploded properly by using a dynamite primer of the highest available strength. To explode the powder properly, the following amounts of dynamite should be used:

Judson R. R. P. Pounds.	Dynamite. Number of cartridges.	Size.
10	1	1¼ x 8
20	2	1¼ x 8
50	4	1¼ x 8
300	25	1¼ x 8

An exploder equivalent to or stronger than a DU PONT quintuple force cap should be used in all cases. The method of preparing a primer is fully described under "General Directions for Using High Explosives," to which special attention is directed. Where more than one stick of dynamite is used for a primer, the best results are obtained when the cartridges are tied together in a compact bunch, with the stick containing the exploder in the center.

After the primer has been placed in the charge, the hole must be well tamped with earth, clay, or similar material containing no grit or sharp particles. The tamping should never be done with anything but a tamp made entirely of wood.

Judson R. R. P. has also been used extensively in "chamber blasting." In this work very large charges are placed at the end of a small tunnel, driven under a large mass of rock or earth, and at one shot enormous quantities of material are dislodged. By this method even very hard rock in large quantities can be broken to pieces. Judson R. R. P. has also been used largely in shaking up rock in open cuts where it is desired to use a steam shovel for economical handling of the rock into cars.

This powder is packed in bags containing 12½ or 6¼ pounds and four or eight of these bags respectively are packed in each box.

SIZE OF CARTRIDGES, PACKING, ETC.

Du Pont high explosives are put up in cartridges of all commercial sizes, cartridges 8 inches in length and ⅞ inch or 1¼ inches in diameter being the standard sizes. Cartridges are packed in cases containing 25 and 50 pounds *of powder*. The number of cartridges in a case is not counted, but the *full weight of powder* is always packed as marked on the case.

TRANSPORTATION AND STORAGE.

While du Pont high explosives can be handled with a high degree of safety, it is advisable to remember at all times that *they are explosives and, therefore, recklessness in their handling should neither be practiced nor tolerated.*

Explosives and electric fuzes, blasting caps, etc., should never be carried together.

It is best on public works, and at mines, quarries and other important works to store high explosives in a dry, well-ventilated magazine, the keys to which should be in charge of one man, who alone should have the responsibility for the proper disposition of the powder.

Where it is necessary to store any considerable quantity of high explosives, it is advisable to construct in a protected location a substantial bullet proof magazine.

The du Pont Company will, at any time, be glad to give its customers the benefit of its advice as to the location and style of construction to be used in the erection of such magazines.

Electric fuzes, blasting caps, etc., should never be stored in the same magazine with high explosives or black powder.

THAWING DYNAMITE.

Ordinary dynamite freezes at a temperature between 45 and 50° F. and should not be used in a frozen or chilled condition as its full effectiveness cannot when in that condition, be obtained, and also it is generally difficult to detonate satisfactorily when chilled.

In these pages plans are given showing the details of a properly designated thawing house recommended where large quantities of dynamite are to be used daily. A full description of this building, together with a bill of material, etc., will be gladly furnished any DU PONT customer upon application. The advantages of such a building are numerous, and such as are not obvious to the user of dynamite will be gladly pointed out.

The plans show the use of a small hot water heater.

The temperature of the thawing room should not exceed 80° F., and this can be governed by the use of a thermostat, the connections and use of which will be most willingly explained to DU PONT customers upon application.

DYNAMITE THAWING HOUSE WITH DRAWERS AND HOT WATER RADIATOR. CAPACITY, 500 POUNDS OF DYNAMITE.

The object desired by this study is to design a thawing house of such a character that no one would have to or could easily enter it.

Where entrance is essential, it can be made at the back door.

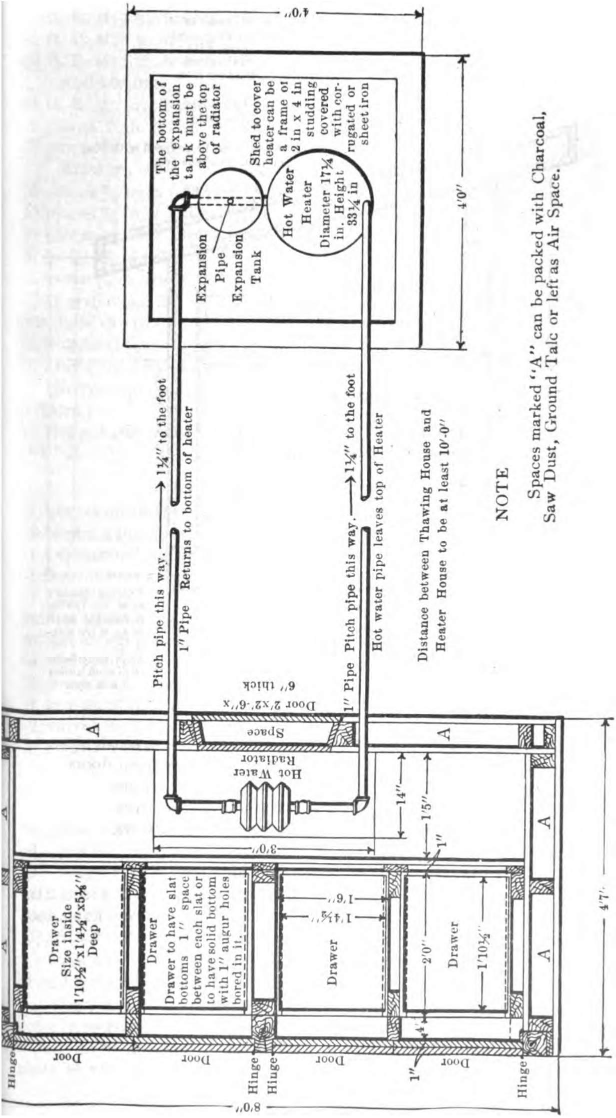
This house can be set on a brick floor, thus doing away with all foundations and floor except the sills.

The THAWING DRAWERS can be carried to the blasting face; they must be run into a sleeve of wood made just large enough to receive them; or the thawed cartridges can be taken from the drawer and placed in a good tight box, the thawed cartridges to be covered with sawdust, a woolen cloth or other good covering to prevent refreezing

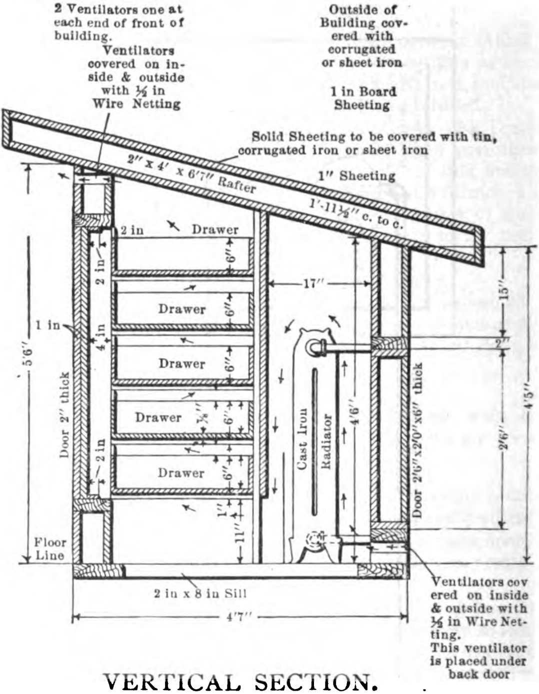
Capacity of thawing house, 500 pounds of dynamite.

BILL OF MATERIAL, THAWING HOUSE.

2 pieces 2 in. x 8 in. x 8 ft. 0 in. sills.
2 pieces 2 in. x 8 in. x 5 ft. 0 in. sills.
30 ft. B. M. 1 in. flooring M. and D. floor (blind nailed).
2 pieces 4 in. x 4 in. x 5 ft. 6 in. door posts.
2 pieces 1 in. x 4 in. x 5 ft. 6 in. corners.
5 pieces 2 in. x 4 in. x 0 ft. 8 in. studding above front doors.
5 pieces 2 in. x 4 in. x 0 ft. 9 in. studding below front doors.
2 pieces 2 in. x 4 in. x 5 ft. 6 in. studding.
2 pieces 2 in. x 4 in. x 5 ft. 0 in. studding.
8 pieces 2 in. x 4 in. x 4 ft. 6 in. studding.
2 pieces 2 in. x 4 in. x 3 ft. 9 in. for doors to close against.
8 pieces 3/4 in. x 2 in. x 1 ft. 9 in. for doors to close against.
2 pieces 3/4 in. x 2 in. x 3 ft. 9 in. for doors to close against.



HORIZONTAL SECTION.



VERTICAL SECTION.

1 piece 4 in. x 6 in. x 3 ft. 9 in. for doors to close against.
4 pieces 2 in. x 6 in. x 3 ft. 6 in. above and below front doors.
5 pieces 2 in. x 4 in. x 5 ft. 6 in. to support the drawers.
5 pieces 2 in. x 4 in. x 5 ft. 0 in. to support the drawers.
5 pieces 1 in. x 4 in. x 5 ft. 0 in. to support the drawers.
40 pieces 1 in. x 2 in. x 2 ft. 0 in. drawer rests.
70 ft. B, M. 1 in. M. and D. stuff for front doors.

(There are four front doors, two of size 1 ft. 9 in. x 3 ft. 9 in. x 2 in. thick, and two of size 1 ft. 7½ in. x 3 ft. 9 in. x 2 in. thick. Each door is made of two 1 in. thicknesses battened on.

12 ft. B. M. 1 in. M. and D. stuff for back door.
2 pieces 1 in. x 6 in. x 2 ft. 6 in. part of back door.
2 pieces 1 in. x 6 in. x 2 ft. 0 in. part of back door.
2 pieces 2 in. x 6 in. x 3 ft. 0 in. above and below back door.
60 ft. B. M. 1 in. boards 5 ft. 0 in. long outside sheeting.
52 ft. B. M. 1 in. boards 8 ft. 0 in. long outside sheeting.

44 ft. B. M. 1 in. boards 4 ft. 0 in. long inside sheeting.
35 ft. B. M. 1 in. boards 7 ft. 0 in. long inside sheeting.
160 ft. B. M. 1 in. boards 10 ft. 0 in. sheeting roof inside and outside and boxing.
28 ft. B. M. 1 in. boards 7 ft. 0 in. baffle.
5 pieces 2 in. x 4 in. x 7 ft. 0 in. rafters.
5 pieces 3/4 in. x 2 in. x 7 ft. 0 in. pieces above front of tops of drawers.
20 pieces 3/4 in. x 6 in. x 1 ft. 6 in. front of drawers.
20 pieces 3/4 in. x 6 in. x 1 ft. 6 in. back of drawers.
40 pieces 3/4 in. x 6 in. x 2 ft. 0 in. sides of drawers.
30 ft. B. M. 7/8 in. stuff 2 ft. 0 in. long bottom of drawers.
1 piece 1/16 in. sheet iron 1 ft. 6 in. x 5 ft. 4 in. baffle.

It will take 2½ squares of corrugated iron to entirely cover the outside of the building, including roof and boxing. Or if roof (including boxing) is covered with tin, it will take for roof 1 2/10 squares tin; for rest of building, 1 3/10 squares corrugated iron.

(NOTE.—Do not let metal rub on metal anywhere, as for example at doors.)

Hinges and nails.

HEATING APPARATUS.

1 hot water heater.
3 sections hot water radiator, 38 inches high.
1 expansion tank with gauge.
1 Detroit valve.
1 union elbow.
32 feet 1 inch pipe.
20 feet asbestos moulded covering for 1 inch pipe.
6 feet 3/4 inch pipe.
1 composition key air valve.
1 key for above.
2 valves for 1 inch pipe.
3 elbows for 1 inch pipe.

SHED TO COVER HEATER.

12 pieces 2 in. x 4 in. x 4 ft. 0 in. studding } frame.
6 pieces 2 in. x 4 in. x 8 ft. 0 in. studding } frame.
3 pieces 2 in. x 4 in. x 4 ft. 8 in. rafters.
2 pieces 2 in. x 4 in. x 2 ft. 0 in. door.
2 pieces 2 in. x 4 in. x 5 ft. 0 in. door.
1½ squares corrugated iron.

Floor of this shed to be of brick, clay or any suitable material to be had without extra expense.

When the foregoing plans and devices are considered too expensive to follow, or unnecessarily large, the DU PONT COMPANY would suggest that a small building, heated by steam or hot water pipes or radiators, be constructed 50 feet or more from any other building. These pipes or radiators should be placed in one end ot the room and should be encased in such a manner that it will not be possible for anyone to put dynamite where it can touch these pipes, or where any drop of nitroglycerin, which might exude from the cartridges, would come in contact with the pipes or radiators, and so possibly cause an explosion.

Manure is frequently used to thaw dynamite and is fairly satisfactory for thawing small quantities, provided always that the manure is fresh. The cartridges should be laid on their sides in a box imbedded in the manure, where they should remain until soft. Under no circumstances should the cartrides be allowed to come in contact with manure, since they may absorb moisture.

For temporary use, when only a small amount of dynamite is required, no improvement has yet been made over the old-fashioned double kettle, which is simply a large kettle containing warm water, in which is placed a smaller kettle containing the dynamite. The water should always be warmed in a separate vessel and poured from that into the larger kettle. Fresh warm water should be used for each thawing. Neither of these kettles should ever be placed over a fire or other source of heat.

There are numerous other arrangements for thawing dynamite which could be suggested and which may doubtless suggest themselves to those interested in this subject, but only those methods known to be entirely safe have been recommended.

BLACK BLASTING POWDER.

The DU PONT COMPANY manufactures high grade black blasting powders for use in coal mines, building stone quarries and for blasting in soft material where all classes of high explosives are too quick in their action to utilize their entire strength. The great advantage that black blasting powder enjoys over high explosives for these classes of work is that it exerts a *strong push* upon the material to be moved, and not a blow similar to that exerted by high explosives. This makes black powder very valuable in quarry work, where it is desired to obtain material in large lumps.

GRADES OF BLACK POWDER.

The DU PONT COMPANY manufactures two kinds of black powder, the "A Blasting," or saltpetre powders, and the "B Blasting," or soda powders. The "A Blasting" Powder is manufactured in the following standard sizes, running from fine to coarse; 7F or Fuse Powder, FFFFFF, FFFFF, FFFF, FFF, FF, F and C hard or soft grain and glazed or unglazed. The "B Blasting" Powder is manufactured in the following sizes, running from fine to coarse, FFFF, FFF, FF, F, C, CC, CCC, hard or soft grain, glazed or unglazed. "B Blasting" Powder is also manufactured in a size known as "B Mixed" Powder, which is composed of a mixture of the F, FF, FFF and FFFF sizes.

In order to obtain a concentrated charge of black powder, many blasters prefer to use a powder made up of a combination of different sized grains called "Railroad Powder," the idea being to fill the space between the larger grains of powder with smaller grains.

Black powder is packed in sheet iron and wood pulp kegs, containing 25 pounds each net weight of powder.

PROPERTIES OF BLACK POWDER.

As black powder is a deflagrating and not a detonating explosive, its quickness depends on its rate of burning. By a deflagrating explosive is meant an explosive that does its work by an extremely quick burning of its ingredients to form a gas, as against those explosives known as high explosives, which are instantaneously converted into gas by means of a blasting cap or electric fuze. The "B Blasting" Powders are slower in their action than the corresponding sizes of "A Blasting," and consequently, in use, do not appear to be as "strong." The DU PONT COMPANY recommends the "B Blasting" Powders wherever a particularly slow powder is required, such as in blasting coal, particularly bituminous coal, earth, soft or rotten rock, etc.

Although both grades of black powder are ruined by contact with water, the "A Blasting" Powders are less susceptible to the moisture of the atmosphere than are the "B Blasting" Powders. If necessarily exposed to damp air or stored in a damp place, the "A Blasting" Powders will retain their quality for a considerably longer time. The "A Blasting" Powders should therefore be used in tropical climates where the air is heavily charged with moisture or wherever the powder in storage or use is to be exposed to unusual climatic conditions.

As already mentioned, black powder is a deflagrating explosive and its quickness can be varied by changing its rate of burning. A certain number of large grains present less surface for ignition than an equal weight of smaller grains, thus the smaller grained black powders burn faster and are quicker in their action than a larger grained powder of the same quality.

For blasting in any soft material, such as the soft coals of the middle western fields of the United States, particularly where the coal is desired in lump form, a coarse grained powder should be used. Where the coal is hard or when it is desired fine as for coking, a fine grain of powder should be used. In either case the same amount of coal will be moved, but in the latter instance the coal will be shattered into finer fragments.

Hard pressed powder and glazed powder burn slower than soft pressed powders of the same grade and unglazed powders. Also hard pressed and glazed powders are not affected by moisture as readily as soft pressed or unglazed powders. Again, on account of the greater density of the hard pressed grades of black powder and on account of the smooth polish on glazed powders, these grades will pack closer in bore holes and cartridges, and consequently give a greater explosive force, bulk for bulk, than the soft pressed powders or the unglazed. Therefore, in the selection of a suitable powder for any particular work, these properties must also be taken into consideration. The DU PONT COMPANY is undeniably in the best position to furnish reliable advice as to the grades of powder to be used in different classes of work. This advice and assistance in choosing a proper powder will be gladly furnished DU PONT customers on application.

The DU PONT COMPANY recommends for railroad and other grading, and any work requiring large blasts of black powder, the "Railroad Powder." As already mentioned, this is a powder made up of a mixture of different sizes of grains. On this account it is possible to get a greater weight of railroad powder than any single size of powder in a given space. This fact makes the railroad powder especially valuable in a large blast where it is desired to shake up a large amount of material for removal by means of a steam shovel, and in giant mine blasts. Occasionally when a piece of work is of sufficient magnitude to warrant the manufacture of a special powder, the DU PONT COMPANY manufactures special powders in which the regular formula of manufacture and sizes are changed to suit the particular undertaking in question. When a piece of work is of sufficient magnitude, the DU PONT COMPANY is always glad and willing to send an experienced man to examine the location and conditions, and recommend the proper explosive to use and instruct the consumer as to the proper method of using it.

USE OF BLACK POWDER.

Black powder has a wide range of use in railroad and other grading work. It can be so used in sprung holes and large chamber blasts to shake up a large amount of material so that it can be removed by a steam shovel, or used so as to "waste" the material, as is often desired.

In some building stone quarries a line of wedges is placed together with a few bore holes at regular intervals along the line where it is desired to split the rock. After the wedges have been driven in solid, a few light blasts with black powder will generally split the rock perfectly along the line desired.

In building stone quarries black powder gives a product of better quality than do high explosives. The DU PONT COMPANY recommends the "A Blasting" Powders for use in blasting granite, slate and any other hard rock when desired in large pieces on account of its superiority, as regards quickness and strength, to the "B Blasting" Powders

For use in mining, as the ordinary black powder is in grains, it is impossible to put it in most drill holes unless it is confined in cartridges, which are usually cylinders of manilla paper. Bore holes underground should never be loaded with loose powder on account of the danger of dust from the powder coming in contact with lights and carrying the flames into the main body of powder and causing an explosion. However, in quarry work, railroad and other grading, etc., it can be poured into dry downward holes. In large chamber blasts, the powder can be placed in the room excavated to receive it in kegs or bags.

The cartridges for use in mines can be made by rolling the paper around a wooden cartridge bar of a slightly smaller diameter than the drill hole. The loose edges of the paper are stuck down by means of miner's soap, one end of the paper is folded over to close the end of the cartridge, and the stick removed, leaving a paper cylinder. When the cylinder is filled with powder, the cartridge is completed by folding down the other end.

A uniform and compact tamping is essential with the use of black powder. For tamping black powder charges, the material used should be free from small pieces of stone or other hard matter that might produce sparks or damage the fuse; hence stone dust, coal dust, etc., are not considered suitable as tamping. The best material is moist clay, which should be rammed home in layers with a wooden tamping rod, a paper wad being placed between the powder charge and the first layer of clay. In holes having anything but a downward slant, the tamping material is best wrapped in short paper cartridges.

In blasting with black powder, the method of ignition most highly recommended by the DU PONT COMPANY for safety and best results is by means of an electric fuze placed in the center of the charge. If the charge is ignited at either the top or bottom, there is always the possibility of enough pressure being generated to cause some rock or coal to fall before the entire charge is burned, thus losing a great deal of the strength of the blast. By igniting the charge in the middle and having the powder burned in both directions from the point of ignition, this chance of loss is almost entirely overcome. When the powder is wrapped in a cartridge for use, the electric fuze should be placed in the center of the charge while the cartridge is being filled. When the cartridge is filled, wrap the end of the paper closely about the fuze wires and tie it firmly in place. (See "General Directions for Using High Explosives," cut D. When powder is poured directly into the holes, care should be taken in tamping the powder near the electric fuze.

For use with black powder, safety fuse and blasting caps are also recommended by the DU PONT COMPANY. Safety fuse without blasting caps can also be used to ignite a charge of black powder. When these methods of firing are used with black powder in cartridges, the fuse should be placed in the same manner as given for electric fuzes. Strong blasting caps are not required for use with black powder.

As above mentioned, the DU PONT COMPANY recommends the electric system as the safest and most efficient method of firing blasts with black powder. Charging with a needle and firing by means of squibs is used in some mines. This operation is rather dangerous and requires careful manipulation. If this method of firing is followed, needles of copper or brass should be used. The needle is placed along the side of the bore hole, the powder placed in position, pressed down, the hole tamped, and the needle carefully withdrawn. When the powder is used in cartridges, the cartridge is first inserted in the bore hole, and the needle placed penetrating the interior of the cartridges a few inches. The withdrawal of the needle leaves a channel down one side of the tamping, into which the squib is inserted.

A squib consists of a small paper tube or straw that is filled with a quick powder and has a slow match attached to one end. The burning of this slow match gives the blaster time to get away after lighting it and before the flames reaches the powder. When this quick powder is fired, it shoots like a rocket through the hole that has been left in the tamping back into the blasting powder.

Tamping rods having metal parts should never be used on account of the danger of striking sparks in tamping. For the same reason in squib firing where a metal needle is required, this needle should be of copper or brass and *not iron or steel.*

In the blasting of "sprung holes" a great many blasters prefer to use a primer consisting of a cartridge of dynamite containing an electric fuze. The advantages claimed for this method are, first, that primer, once placed in the center of the charge, is not easily displaced by the loading of more powder or by tamping the charge, and second, the explosion of the dynamite enables one to obtain a quicker and more violent action from the powder.

Care should always be taken not to select black powder for use where high explosives give better results, as in stump blasting and blasting in hard rock where the shattering of materials is desired instead of large pieces.

TRANSPORTATION AND STORAGE OF BLACK POWDER.

All of the rules given for the transportation of high explosives should be observed in the transportation of black powder.

The site for a magazine for the storage of black powder should be such that the possibility of damage due to an accidental explosion is reduced to a minimum and at the same time have a location as dry as possible. A magazine should never be constructed against rock or earthen banks, and should be well ventilated throughout and beneath the floor. The ground around and beneath should be well drained. The powder kegs should be placed on their ends, *bung down,* in order to prevent the possible entrance of moisture to the powder. The floor of a black powder magazine should be kept scrupulously clean.

PRECAUTIONS TO BE OBSERVED

IN GENERAL WITH REGARD TO EXPLOSIVES.

DON'T forget the nature of explosives. If sensibly handled, they can be very safely handled.

DON'T smoke while you are handling powder and other explosives, and don't handle powder or explosives near an open light.

NEVER fire into dynamite with a rifle or pistol either in or out of a magazine.

NEVER leave dynamite or black powder in a field or any place where stock can get at it. Cattle like the taste of the soda and saltpetre in explosives, but the other ingredients would probably make them sick.

WITH CAPS AND ELECTRIC FUZES.

DON'T carry detonators (caps and electric fuzes) in your pocket, and don't tap or otherwise investigate a detonator.

DON'T attempt to withdraw a wire from an electric fuze.

DON'T tighten a cap around fuse by biting it with your teeth. Use a cap crimper for this purpose, and don't attach the fuse to a blasting cap carelessly.

DON'T attempt to remove blasting caps from boxes by inserting wire, nails or any sharp instruments.

IN THE TRANSPORTATION AND STORAGE OF HIGH EXPLOSIVES.

DON'T handle or store explosives in or near a residence.

DON'T store blasting caps or electric fuzes in the same building with other explosives, and don't carry detonators (caps and electric fuzes) and explosives together.

NEVER leave dynamite in a wet or damp place.

ALL explosives material should be kept in a suitably dry place, under lock and key, and where children or irresponsible persons cannot get at it.

IN THE USE OF HIGH EXPLOSIVES.

DON'T use short fuse to hasten explosion or with the idea that it is economical to do so.

DON'T fire a charge to chamber a hole and then immediately reload it, as the hole will be hot.

DON'T do tamping with iron or steel bars or tools. Use only a wooden rod with no metal parts. Don't force a primer into a hole.

DON'T fire a shot before everyone is well beyond the danger zone and protected from flying debris. Protect your supply of explosives also from danger from this source.

DON'T hurry in seeking for an explanation for a misfire. Take plenty of time before you approach a misfire.

DON'T drill, bore or pick out a misfire shot. Drill and charge another hole at least two feet from the missed hole.

NEVER use two kinds of explosives in the same hole except where one is used as a primer to detonate the other, as where dynamite is used to detonate Judson Powder. The quicker explosive may open cracks in the rock and allow the slower to blow out through these cracks doing little or no work.

DON'T use frozen or chilled dynamite. Dynamite freezes at a temperature between 45 and 50° F.

IN THE THAWING OF DYNAMITE.

DON'T use any arrangement for thawing dynamite other than one of those recommended by the DU PONT COMPANY.

DON'T thaw dynamite on heated stoves, rocks, bricks or metal, or in an oven, and don't thaw dynamite in front of, near or over a steam boiler or fire of any kind.

DON'T take dynamite into or near a blacksmith shop or near a forge on open work.

DON'T put dynamite on shelves or anything else directly over steam or hot water pipes or other heated metal surface.

DON'T cut or break a dynamite stick while it is frozen, and don't rub a stick of dynamite in hands to complete thawing.

DON'T heat a thawing house with pipes containing steam under pressure.

DON'T allow priming (the placing of a cap or electric fuze in dynamite) to be done in a thawing house.

DON'T place a hot water thawer over a fire, and never put dynamite into hot water or allow it to come in contact with steam.

DON'T allow thawed dynamite to remain exposed to low temperature, but use as soon as possible.

DON'T put dynamite in the sun as all nitroglycerin compounds decompose when exposed to the direct rays of the sun for any length of time, no matter what the temperature of the air may be, and hence lose their efficiency.

DON'T keep any blasting caps or electric fuzes in thawing house.

WITH BLACK POWDER.

DON'T permit kegs containing powder to remain open after having taken out the quantity needed for use.

DON'T tamp black powder with a metal tamping rod or one having metal parts; use a wooden rod.

DON'T use a needle of iron or steel when firing by means of squibs; use one of copper or brass.

DON'T leave black powder in a damp place, even if the kegs are closed.

DON'T open kegs by cutting with a coldchisel or by driving a pick through the same. Always open the bung.

DON'T drop or throw about black powder in kegs. In the use of black powder underground, bore holes should never be loaded with powder unless it is made up into cartridges, nor should a naked light be allowed near an open keg of powder, and never on the "lee" side of the keg when loading cartridges, because the dust from the loading may communicate with any naked light near and carry the flame into the main body of the powder and explode it.

DON'T use wet powder. If damp only, it may be dried by spreading it out in the hot sun on a dry day.

MEMORANDA.

A carload of DU PONT HIGH EXPLOSIVES consists of 400 cases of 50 lbs. each, say 20,000 lbs. net.

A carload of DU PONT BLACK POWDER contains from 400 to 800 kegs of 25 lbs. each, say from 10,000 lbs. to 20,000 lbs. net.

The amounts given above are the minimum carload weights at the present writing (spring, 1907). These are liable to be changed at any time by the railroads, and do vary at the present time in different parts of the country.

A box containing 50 lbs. of DU PONT HIGH EXPLOSIVES, of any grade or size, weighs about 58 lbs. gross.

A box containing 25 lbs. of DU PONT HIGH EXPLOSIVES, of any grade or size, weighs about 29 lbs. gross.

A keg containing 25 lbs. of DU PONT BLACK POWDER, of any grade or size, weighs about 27½ lbs. gross.

Electric fuzes, when the leading wires are 18 feet or less in length, are packed in cartons containing 50 exploders each. When the leading wires are over 18 feet in length, 25 exploders are packed in each carton.

A case of electric fuzes contains 10 cartons or 500 or 250 exploders, according to the length of the leading wires.

Blasting caps are packed in tin boxes containing 100 caps each.

These boxes are packed in cartons containing 10 boxes each or 1000 caps.

The cartons are packed in cases containing 25 cartons each or 25,000 caps.

Safety fuze is packed in barrels and cases. The contents of the standard packages vary according to the grades as indicated in the following table:

	Barrels.	Cases.
Triple tape	7,000 ft.	6,000 ft.
Single and double tape	8,000 ft.	1,000 ft. 3,000 ft. 6,000 ft.
Gutta percha and white countered	8,000 ft.	6,000 ft.
Cotton and hemp	12,000 ft.	12,000 ft.

The very first blasts are generally conclusive of the great superiority of DU PONT EXPLOSIVES over their many rivals, but their full economical value can only appear when workmen have gained experience enough not to waste its power by overcharging; not on the other hand attempting impossibilities.

Do not compare powder bills, but take *total cost* per cubic yard or ton, and consider the smaller drill holes needed and the absence of danger in using a *standard powder.*