THE

PRACTICAL MECHANIC

COMPRISING

A CLEAR EXPOSITION

OF THE

PRINCIPLES AND PRACTICE OF MECHANISM,

WITH THEIR APPLICATION TO

THE INDUSTRIAL ARTS.

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PREFACE.

MANY mechanical books are obscured by theoretical problems and complicated mathematical formulæ, a defect which, it is believed, has been obviated in this volume. I trust my efforts will be duly appreciated by every "Practical Mechanic."

THE AUTHOR.

Definition of Arithmetical Signs used in the Work.

= When we wish to state that one quantity or number is equal to another quantity or number, the sign of *equality* = is employed. Thus 3 added to $2 = 5$, or 3 added to 2 is equal to 5.

+ When the sum of two quantities or numbers is to be taken, the sign *plus* + is placed between them. Thus $3 + 2 = 5$; that is, the sum of 3 and 2 is 5. This is the sign of Addition.

— When the difference of two numbers or quantities is to be taken, the sign *minus* — is used, and shows that the latter number or quantity is to be taken from the former. Thus $5 - 2 = 3$. This is the sign of Subtraction.

× When the product of any two numbers or quantities is to be taken, the sign *into* × is placed between them. Thus $3 \times 2 = 6$. This is the sign of Multiplication.

÷ When we are to take the quotient of two quantities, the sign *by* ÷ is placed between them, and shows that the former is to be divided by the latter. Thus $6 \div 2 = 3$. This is the sign of Division. But in some cases in this work, the mode of division has been to place the dividend above a horizontal line, and the divisor below it, in the form of a vulgar fraction, thus:

$$\frac{\text{Dividend}}{\text{Divisor}} = \text{Quotient.} \qquad \frac{6}{2} = 3.$$

When the square of any number or quantity is to be taken, this is denoted by placing a small figure 2 above it to the right. Thus 6^2 shows that the square of 6 is to be taken, and therefore $6^2 = 6 \times 6 = 36$.

When we wish to show that the square root of any number or quantity is to be taken, this is denoted by placing the *radical sign* $\sqrt{}$ before it. Thus $\sqrt{36}$ shows that the square root of 36 ought to be taken, hence $\sqrt{36} = 6$.

The common marks of proportion are also used, viz., : : : : as 3 : 6 : : 4 : 8, being read 3 is to 6 as 4 is to 8

The application of these signs to the expression of rules is exceedingly simple. Thus, connected with the circle we have the following rules:

1st. The circumference of a circle will be found by multiplying the diameter by 3.1416.

2d. The diameter of a circle may be found by dividing the circumference by 3.1416.

3d The area of a circle may be found by multiplying the half of the diameter by the half of the circumference, or by multiplying together the diameter and circumference, and dividing the product by 4, or by squaring the diameter and multiplying by .7854.

Now all these rules may be thus expressed:

1st. $\text{diameter} \times 3.1416 = \text{circumference}$

2d. $$\frac{\text{circumference}}{3.1416} = \text{diameter.}$$

3d. $$\frac{\text{diameter}}{2} \times \frac{\text{circumference}}{2} = \text{area.}$$

or, $$\frac{\text{diameter} \times \text{circumference}}{4} = \text{area.}$$

or, $\text{diameter}^2 \times .7851 = \text{area.}$

THE PRACTICAL MECHANIC.

A TABLE

CONTAINING THE

DIAMETERS, CIRCUMFERENCES, AND AREAS OF CIRCLES,

AND THE

CONTENTS OF EACH IN GALLONS AT 1 FOOT IN DEPTH.

UTILITY OF THE TABLE.

EXAMPLES.

1. Required the circumference of a circle, the diameter being *five* inches?

In the column of circumferences, opposite the given diameter, stands 15.708 inches, the circumference required.

2. Required the capacity, in gallons, of a can, the diameter being 6 feet and depth 10 feet?

In the fourth column from the given diameter stands 211.4472, being the contents of a can 6 feet in diameter and 1 foot in depth, which being multiplied by ten gives the required contents, two thousand one hundred fourteen and a half gallons.

3. Any of the areas in feet multiplied by .03704, the product equals the number of cubic yards at 1 foot in depth.

4. The area of a circle in inches multiplied by the length or thickness in inches, and by .263, the product equals the weight in pounds of cast iron.

Diameters and Circumferences of Circles, and the Contents in Gallons at 1 Foot in Depth.

Area in Inches.

Diam.	Circ. in.	Area in.	Gallons.	Diam.	Circ. in.	Area in.	Gallons.
1 in.	3.1416	.7854	.04081	6 1/2	20.420	33.183	1.72552
1/8	3.5343	.9940	.05169	5/8	20.813	34.471	1.79219
1/4	3.9270	1.2271	.06380	3/4	21.205	35.784	1.86077
3/8	4.3197	1.4848	.07717	7/8	21.598	37.122	1.93034
1/2	4.7124	1.7671	.09188	7 in.	21.991	38.484	2.00117
5/8	5.1051	2.0739	.10784	1/8	22.383	39.871	2.07329
3/4	5.4978	2.4052	.12506	1/4	22.776	41.282	2.14666
7/8	5.8905	2.7611	.14357	3/8	23.169	42.718	2.22134
2 in.	6.2832	3.1416	.16333	1/2	23.562	44.178	2.29726
1/8	6.6759	3.5465	.18439	5/8	23.954	45.663	2.37448
1/4	7.0686	3.9760	.20675	3/4	24.347	47.173	2.45299
3/8	7.4613	4.4302	.23036	7/8	24.740	48.707	2.53276
1/2	7.8540	4.9087	.25522	8 in.	25.132	50.265	2.61378
5/8	8.2467	5.4119	.28142	1/8	25.515	51.848	2.69609
3/4	8.6394	5.9395	.30883	1/4	25.918	53.456	2.77971
7/8	9.0321	6.4918	.33753	3/8	26.310	55.088	2.86458
3 in.	9.4248	7.0686	.36751	1/2	26.703	56.745	2.95074
1/8	9.8175	7.6699	.39879	5/8	27.096	58.426	3.03815
1/4	10.210	8.2957	.43134	3/4	27.489	60.132	3.12686
3/8	10.602	8.9462	.46519	7/8	27.881	61.862	3.21682
1/2	10.995	9.6211	.50029	9 in.	28.274	63.617	3.30808
5/8	11.388	10.320	.53664	1/8	28.667	65.396	3.40059
3/4	11.781	11.044	.57429	1/4	29.059	67.200	3.49440
7/8	12.173	11.793	.61324	3/8	29.452	69.029	3.58951
4 in.	12.566	12.566	.65343	1/2	29.845	70.882	3.68586
1/8	12.959	13.364	.69493	5/8	30.237	72.759	3.78347
1/4	13.351	14.186	.73767	3/4	30.630	74.662	3.88242
3/8	13.744	15.033	.78172	7/8	31.023	76.588	3.98258
1/2	14.137	15.904	.82701	10 in.	31.416	78.540	4.08408
5/8	14.529	16.800	.87360	1/8	31.808	80.515	4.18678
3/4	14.922	17.729	.92144	1/4	32.201	82.516	4.29083
7/8	15.315	18.665	.97058	3/8	32.594	84.540	4.39608
5 in.	15.708	19.635	1.02102	1/2	32.986	86.590	4.50268
1/8	16.100	20.629	1.07271	5/8	33.379	88.664	4.61053
1/4	16.493	21.647	1.12564	3/4	33.772	90.762	4.71962
3/8	16.886	22.690	1.17988	7/8	34.164	92.885	4.82846
1/2	17.278	23.758	1.23542	11 in.	34.557	95.033	4.94172
5/8	17.671	24.850	1.29220	1/8	34.950	97.205	5.05466
3/4	18.064	25.967	1.35028	1/4	35.343	99.402	5.16890
7/8	18.457	27.108	1.40962	3/8	35.735	101.623	5.28439
6 in.	18.849	28.274	1.47025	1/2	36.128	103.869	5.40119
1/8	19.242	29.464	1.53213	5/8	36.521	106.139	5.51923
1/4	19.635	30.679	1.59531	3/4	36.913	108.434	5.63857
3/8	20.027	31.919	1.65979	7/8	37.306	110.753	5.75916

[*Area in Feet.*]

Diam. Ft.	Diam. In.	Circ. Ft.	Circ. In.	Area in ft.	Gallons. 1 ft. depth.
1		3	1⅝	.7854	5.8735
1	1	3	4⅜	.9217	6.8928
1	2	3	8	1.0690	7.9944
1	3	3	11	1.2271	9.1766
1	4	4	2⅛	1.3962	10.4413
1	5	4	5⅜	1.5761	11.7866
1	6	4	8½	1.7671	13.2150
1	7	4	11⅝	1.9689	14.7241
1	8	5	2¾	2.1816	16.3148
1	9	5	5⅞	2.4052	17.9870
1	10	5	9	2.6398	19.7414
1	11	6	2¼	2.8852	21.4830
2		6	3⅜	3.1416	23.4940
2	1	6	6½	3.4087	25.4916
2	2	6	9⅝	3.6869	27.5720
2	3	7	0¾	3.9760	29.7340
2	4	7	3⅞	4.2760	32.6976
2	5	7	7	4.5869	34.3027
2	6	7	10¼	4.9087	36.7092
2	7	8	1⅜	5.2413	39.1964
2	8	8	4½	5.5850	41.7668
2	9	8	7⅝	5.9395	44.4179
2	10	8	10¾	6.3049	47.1505
2	11	9	1⅞	6.6813	49.9654
3		9	5	7.0686	52.8618
3	1	9	8¼	7.4666	55.8382
3	2	9	11⅜	7.8757	58·8976
3	3	10	2½	8.2957	62.0386
3	4	10	5⅝	8.7265	65.2602
3	5	10	8¾	9.1683	68.5193
3	6	10	11⅞	9.6211	73.1504
3	7	11	3	10.0846	75.4166
3	8	11	6⅛	10.5591	78.9652
3	9	11	9⅜	11.0446	82.5959
3	10	12	5½	11.5409	86.3074
3	11	12	3⅝	12.0481	90.1054
4		12	6¾	12.5664	93.9754
4	1	12	9⅞	13.0952	97.9310
4	2	13	1	13.6353	101.9701
4	3	13	4⅛	14.1862	103.0300
4	4	13	7¼	14 7479	110.2907
4	5	13	10½	15.3206	114.5735
4	6	14	1⅝	15.9043	118.9386
4	7	14	4⅝	16.4986	123.3830
4	8	14	7⅞	17.1041	127.9112
4	9	14	11	17.7205	132.5209

Diam. Ft.	Diam. In.	Circ. Ft.	Circ. In.	Area in ft.	Gallons. 1 ft. depth.
4	10	15	2⅛	18.3476	137.2105
4	11	15	5¼	18.9858	142.0582
5		15	8½	19.6350	146.8384
5	1	15	11⅝	20.2947	151.7718
5	2	16	2¾	20.9656	156.7891
5	3	16	5¾	21.6475	161.8886
5	4	16	9	22.34'0	167·0674
5	5	17	0⅛	23.0437	172.3300
5	6	17	3¼	23.7583	177.6740
5	7	17	6⅜	24.4835	183 0973
5	8	17	9⅝	25.2199	188.6045
5	9	18	0¾	25.9672	194.1930
5	10	18	3⅞	26.7251	199.8610
5	11	18	7⅛	27.4943	205 6133
6		18	10⅛	28.2744	211.4472
6	3	19	7½	30.6796	229.4342
6	6	20	4⅞	33.1831	248.1564
6	9	21	2⅜	35.7847	267.6122
7		21	11⅞	38.4846	287.8032
7	3	22	9¼	41.2825	308.7270
7	6	23	6¾	44.1787	330.3859
7	9	24	4⅛	47.1730	352.7665
8		25	1¼	50.2656	375.9062
8	3	25	11	53.4562	399.7668
8	6	26	8⅜	56.7451	424.3625
8	9	27	5¾	60.1321	449.2118
9		28	3¼	63.6174	475.7563
9	3	29	0⅝	67.2007	502.5536
9	6	29	10⅛	70.8823	530.0861
9	9	30	7½	74.6620	558.3522
10		31	5	78 5400	587.3534
10	3	32	2⅜	82.5160	617.0876
10	6	32	11¾	86.5903	647.5568
10	9	33	9¼	90.7627	678.2797
11		34	6⅝	95.0334	710.6977
11	3	35	4⅛	99.4021	743.3686
11	6	36	1½	103.8691	776.7746
11	9	36	10⅞	108.4342	810.9143
12		37	8⅜	113.0976	848.1890
12	3	38	5¾	117.8590	881.3966
12	6	39	3¼	122.7187	917.7395
12	9	10	0⅝	127.6765	954 8159

Diameters and Circumferences of Circles, and the Contents in Gallons at 1 Foot in Depth.—(*Cont'd.*)

[*Area in Feet.*]

Diam.		Circ.		Area in ft	Gallons.	Diam.		Circ.		Area in ft.	Gallons.
Ft.	In.	Ft.	In.		1 ft. depth.	Ft.	In	Ft.	In.		1 ft. depth.
13		40	10	132.7326	992.6274	22		69	$1\frac{3}{8}$	380.1336	2812.7910
13	3	41	$7\frac{1}{2}$	137.8867	1031.1719	22	3	69	$10\frac{3}{4}$	388.8220	2907.7664
13	6	42	$4\frac{7}{8}$	143.1391	1070.4514	22	6	70	$8\frac{1}{4}$	397.6087	2973.4889
13	9	43	$2\frac{1}{4}$	148.4896	1108.0645	22	9	71	$5\frac{5}{8}$	406.4935	3039.9209
14		43	$11\frac{3}{4}$	153.9384	1151.2129	23		72	3	415.4766	3107.1001
14	3	44	$9\frac{1}{8}$	159.4852	1192.6940	23	3	73	$0\frac{5}{8}$	424.5577	3175.0122
14	6	45	$6\frac{5}{8}$	165.1303	1234.9104	23	6	73	$9\frac{7}{8}$	433.7371	3243.6595
14	9	46	4	170.8735	1277.8615	23	9	74	$7\frac{1}{4}$	443.0146	3313.0403
15		47	$1\frac{1}{2}$	176.7150	1321.5454	24		75	$4\frac{3}{4}$	452.3904	3383.1563
15	3	47	$10\frac{7}{8}$	182.6545	1365.9631	24	3	76	$2\frac{1}{8}$	461.8642	3454.0051
15	6	48	$8\frac{1}{4}$	188.6923	1497.5165	24	6	76	$11\frac{5}{8}$	471.4363	3525.5929
15	9	49	$5\frac{3}{4}$	194.8282	1457.0032	24	9	77	9	481.1065	3597.9068
16		50	$3\frac{1}{8}$	201.0624	1503.6250	25		78	$6\frac{3}{8}$	490.8750	3670.9596
16	3	51	$0\frac{1}{2}$	207.3946	1550.9797	25	3	79	$3\frac{7}{8}$	590.7415	3744.7452
16	6	51	10	213.8251	1599.0696	25	6	80	$1\frac{1}{4}$	510.7063	3819.2657
16	9	52	$7\frac{5}{8}$	220.3537	1617,8930	25	9	80	$10\frac{3}{4}$	520.7692	3894.5203
17		53	$4\frac{7}{8}$	226.9806	1697.4516	26		81	$8\frac{1}{8}$	530.9304	3970.5098
17	3	54	$2\frac{1}{4}$	233.7055	1747.7431	26	3	82	$5\frac{1}{4}$	541.1896	4047.2322
17	6	54	$11\frac{5}{8}$	240.5287	1798.7698	26	6	83	3	551.5471	4124.6898
17	9	55	$9\frac{1}{8}$	247.1500	1850.5301	26	9	84	$0\frac{3}{8}$	562.0027	4202.9610
18		56	$6\frac{1}{2}$	254.4696	1903.0254	27		84	$9\frac{5}{8}$	572.5566	4281.8072
18	3	57	4	261.5872	1956.2537	27	3	85	$8\frac{1}{8}$	583.2085	4361.4664
18	6	58	$1\frac{3}{8}$	268.8031	2010.2171	27	6	86	$4\frac{5}{8}$	593.9587	4441.8607
18	9	58	$10\frac{3}{4}$	276.1171	2064.9140	27	9	87	$2\frac{1}{8}$	604.8070	4522.9886
19		59	$8\frac{1}{4}$	283.5291	2120.3462	28		87	$11\frac{1}{2}$	615.7536	4604.8517
19	3	60	$5\frac{5}{8}$	291.0397	2176.5113	28	3	88	9	626.7982	4686.4876
19	6	61	$3\frac{1}{8}$	298.6483	2233.2914	28	6	89	$6\frac{3}{8}$	637.9411	4770.7787
19	9	62	$0\frac{1}{2}$	306.3550	2291.0452	28	9	90	$3\frac{3}{4}$	649.1821	4854.8434
20		62	$9\frac{7}{8}$	314.1600	2349.4141	29		91	$1\frac{1}{4}$	660.5214	4939.6432
20	3	63	$\frac{3}{8}$	322.0630	2408.5159	29	3	91	$10\frac{5}{8}$	671.9587	5025.4759
20	6	64	$4\frac{3}{4}$	330.0643	2468.3528	29	6	92	$8\frac{1}{8}$	683.4943	5111.4487
20	9	65	$2\frac{1}{4}$	338.1637	2528.9233	29	9	93	$5\frac{1}{2}$	695.1280	5198.4451
21		65	$11\frac{5}{8}$	346.3614	2590.2290	30		94	$2\frac{1}{4}$	706.8600	5286.1818
21	3	66	9	354.6571	2652.2532	30	3	95	$0\frac{3}{8}$	718.6900	5374.6512
21	6	67	$6\frac{1}{2}$	363.0511	2715.0113	30	6	95	$9\frac{1}{4}$	730.6183	5463.8558
21	9	68	$3\frac{3}{4}$	371.5432	2778.5486	30	9	96	$7\frac{1}{4}$	742.6447	5553.7940

Contents in Gallons of the Frustum of a Cone.

To find the Contents in Gallons of a Vessel whose diameter is larger at one end than the other, such as a Bowl, Pail, Firkin, Tub, Coffee-pot, &c.

RULE.—Multiply the larger diameter by the smaller, and to the product add one-third of the square of their difference, multiply by the height, and multiply that product by .0034 for Wine Gallons and by .002785 for Beer.

EXAMPLE.—Required the contents of a Coffee-pot 6 inches diameter at the top, 9 inches at the bottom, and 18 inches high.

Large diameter	9	Brought up	1026
Small do.	6		.0034
	54		4104
$\frac{1}{3}$ of the square	3		3078
	57		3.4884 Wine Gallons,
height	18		or nearly $3\frac{1}{2}$ gallons.
	456		
	57		
Carried up	1026		

1026 multiplied by .002785 equal 2.8574 *Beer Gallons.*

Rule to find the Contents in Gallons of any Square Vessel.

RULE.—Take the dimensions in inches and decimal parts of an inch, multiply the length, breadth, and height together, and then multiply the product by .004329 for Wine Gallons, and by .003546 for Ale Gallons.

EXAMPLE.—How many Wine Gallons will a box contain that is 10 feet long, 5 feet wide, and 4 feet deep?

Length in inches,	120	Brought up	345600
Breadth in do.	60		.004329
	7200		3110400
Height in inches,	48		691200
	57600		1036800
	28800		1382400
Carried up,	345600		1496.102400 gallons,
			or 1496 galls. and $3\frac{1}{4}$ gills.

Contents in Gallons of Cylindrical Vessels.

RULE.—Take the dimensions in inches and decimal parts of an inch. Square the diameter, multiply it by the length in inches, and then multiply the product by .0034 for Wine Gallons, or by .002785 for Ale Gallons.

EXAMPLE.—How many U. S. Gallons will a Cylindrical Vessel contain, whose diameter is 9 inches and length 9½ inches?

Diameter,	9	Brought up	769.5
	9		.0034
Square Diam.	81		30780
Length,	9.5		23085
	405		2.61630
	729		or 2 gallons and 5 pints.
Carried up	769.5		

To ascertain the Weights of Pipes of Various Metals, and any Diameter required.

Thickness in parts of an inch.	Wrought Iron.	Copper.			Lead.		
1-32	.326	11⅔ lbs. plate		.38	2 lbs. lead		.483
1-16	.653	23⅓	"	.76	4	"	.967
3-32	.976	35	"	1.14	5½	"	1.45
1-8	1.3	46⅔	"	1.52	8	"	1.933
5-32	1.627	58	"	1.9	9¾	"	2.417
3-16	1.95	70	"	2.28	11	"	2.9
7-32	2.277	80⅓	"	2.66	13	"	3.383
1-4	2.6	93	"	3.04	15	"	3.867

RULE.—To the interior diameter of the pipe, in inches, add the thickness of the metal; multiply the sum by the decimal numbers opposite the required thickness and under the metal's name; also by the length of the pipe in feet, and the product is the weight of the pipe in lbs.

1. Required the weight of a copper pipe whose interior diameter is 7½ inches, its length 6¼ feet, and the metal ⅛ of an inch in thickness.

$$7.5 + .125 = 7.625 \times 1.52 \times 6.25 = 72.4 \text{ lbs.}$$

2. What is the weight of a leaden pipe 18½ feet in length, 3 inches interior diameter, and the metal ¼ of an inch in thickness?

$$3 + .25 = 3.25 \times 3.867 \times 18.5 = 232.5 \text{ lbs.}$$

Weight of Water.

1	Cubic inch............	equal to	.03617	pound.
12	Cubic inches..........	equal to	.434	pound.
1	Cubic foot.	equal to	62.5	pounds.
1	Cubic foot.	equal to	7.50	U. S. gallons.
1.8	Cubic feet.	equal to	112.00	pounds.
35.84	Cubic feet.	equal to	2240.00	pounds.
1	Cylindrical inch.......	equal to	.02842	pound.
12	Cylindrical inches.....	equal to	.341	pound.
1	Cylindrical foot.......	equal to	49.10	pounds.
1	Cylindrical foot.......	equal to	6.00	U. S. gallons.
2.282	Cylindrical feet.......	equal to	112.00	pounds.
45.64	Cylindrical feet.......	equal to	2240.00	pounds.
11.2	Imperial gallons	equal to	112.00	pounds.
224	Imperial gallons	equal to	2240.00	pounds.
13.44	United States galls....	equal to	112.00	pounds.
268.8	United States galls....	equal to	2240.00	pounds.

Centre of pressure is at two-thirds depth from surface.

Decimal Equivalents to the Fractional Parts of a Gallon, or an Inch.

[*The Inch, or Gallon, being divided into 32 parts.*]

[In multiplying decimals it is usual to drop all but the first two or three figures]

Decimals.	Gallon. or Inch	Gills.	Pints.	Qts.	Decimals.	Gallon, or Inch.	Gills	Pints	Qts.	Decimals.	Gallon or Inch.	Gills.	Pints.	Qts.
.03125	1-32	1	¼	⅛	.375	3-8	12	3	1½	.71875	23-32	23	5¾	2⅞
.0625	1-16	2	½	¼	.40625	13-32	13	3¼	1⅝	.75	3-4	24	6	3
.09375	3-32	3	¾	⅜	4375	7-16	14	3½	1¾	.78125	25-32	25	6¼	3⅛
.125	1-8	4	1	½	46875	15-32	15	3¾	1⅞	.8125	13-16	26	6½	3¼
.15625	5-32	5	1¼	⅝	.5	1-2	16	4	2	.84375	27-32	27	6¾	3⅜
.1875	3-16	6	1½	¾	.53125	17-32	17	4¼	2⅛	.875	7-8	28	7	3½
.21875	7-32	7	1¾	⅞	.5625	9-16	18	4½	2¼	.90625	29-32	29	7¼	3⅝
.25	1-4	8	2	1	.59375	19-32	19	4¾	2⅜	.9375	15-16	30	7½	3¾
.28125	9-32	9	2¼	1⅛	.625	5-8	20	5	2½	96875	31-32	31	7¾	3⅞
.3125	5-16	10	2½	1¼	.65625	21-32	21	5¼	2⅝	1.000	1	32	8	4
.34375	11-32	11	2¾	1⅜	.6875	11-16	22	5½	2¾					

APPLICATION.—Required the *gallons* in any Cylindrical Vessel. Suppose a vessel 9½ inches deep, 9 inches diameter, and contents 2.6163, that is, 2 gallons and 61 hundredth parts of a gallon; now to ascertain this decimal of a gallon, refer to the above Table for the decimal that is nearest, which is .625, opposite to which is 5-8ths of a gallon, or 20 gills, or 5 pints, or 2½ quarts, consequently the vessel contains 2 gallons and 5 pints.

INCHES.—To find what part of an inch the decimal .708 is. Refer to the above Table for the decimal that is nearest, which is .71875, opposite to which is 23-32, or nearly 3-4ths of an inch.

Tin Plates.

Size, Length, Breadth, and Weight.

Brand Marks.	No. of Sheets in Box.	Length and Breadth. Inches.	Weight per Box. Cwt.	qr.	lbs.	
1 C	225	14 by 10	1	0	0	Each 1 x advances $1.75 to $2.00.
1 x	225	14 by 10	1	1	0	
1 xx	225	14 by 10	1	1	21	
1 xxx	225	14 by 10	1	2	14	
1 xxxx	225	14 by 10	1	3	7	
1 xxxxx	225	14 by 10	2	0	0	
1 xxxxxx	225	14 by 10	2	0	21	
D C	100	17 by 12½	0	3	14	In addition a great variety of sizes is imported for special purposes, usually costing a little more in proportion than those which are esteemed regular sizes.
D x	100	17 by 12½	1	0	14	
D xx	100	17 by 12½	1	1	7	
D xxx	100	17 by 12½	1	2	0	
D xxxx	100	17 by 12½	1	2	21	
D xxxxx	100	17 by 12½	1	3	14	
D xxxxxx	100	17 by 12½	2	0	7	
S D C	200	15 by 11	1	1	27	
S D x	200	15 by 11	1	2	20	
S D xx	200	15 by 11	1	3	13	
S D xxx	200	15 by 11	2	0	6	
S D xxxx	200	15 by 11	2	0	27	
S D xxxxx	200	15 by 11	2	1	20	
S D xxxxxx	200	15 by 11	2	2	13	
TTT Taggers,	225	14 by 10	about 1	0	0	
1 C	225	12 by 12				About the same weight per Box as the plates above of similar brand, 14 by 10.
1 x	225	12 by 12				
1 xx	225	12 by 12				
1 xxx	225	12 by 12				
1 xxxx	225	12 by 12				
1 C	112	14 by 20				
1 x	112	14 by 20				
1 xx	112	14 by 20				
1 xxx	112	14 by 20				
1 xxxx	112	14 by 20				
Leaded or Ternes 1 C	112	14 by 20	1	0	0	*For Roofing.*
Leaded or Ternes 1 x	112	14 by 20	1	1	0	

Oil Canisters (*from 2½ to 125 galls.*), **with the Quantity and Quality of Tin required for Custom Work.**

Galls.	Quantity and Quality.	Galls.	Quantity and Quality.
2½	2 Plates, I X in body.	33	13½ Plates, IX in body, 3 breadths high.
3½	2 " S DX "		
5½	2 " DX "	45	13½ Plates, S D X in body.
8	4 " IX "	60	13½ " D X "
10	3½ " DX "	90	15¼ " D X " *
15	4 " DX "	125	20 " D X "

* The bottom tier of plates to be placed lengthwise.

MENSURATION.

Of the Circle, Cylinder, Sphere, &c.

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

2. The areas of circles are to each other as the squares of their diameters.

3. The diameter of a circle being 1, its circumference equals 3.1416.

4 The diameter of a circle is equal to .31831 of its circumference.

5. The square of the diameter of a circle being 1, its area equals .7854.

6. The square root of the area of a circle, multiplied by 1.12837, equals its diameter.

7. The diameter of a circle multiplied by .8862, or the circumference multiplied by .2821, equals the side of a square of equal area.

8. The sum of the squares of half the chord and versed sine divided by the versed sine, the quotient equals the diameter of corresponding circle.

9. The chord of the whole arc of a circle taken from eight times the chord of half the arc, one-third of the remainder equals the length of the arc; or,

10. The number of degrees contained in the arc of a circle, multiplied by the diameter of the circle and by .008727, the product equals the length of the arc in equal terms of unity.

11. The length of the arc of a sector of a circle multiplied by its radius, equals twice the area of the sector.

12. The area of the segment of a circle equals the area of the sector, minus the area of a triangle whose vertex is the centre, and whose base equals the chord of the segment; or,

13. The area of a segment may be obtained by dividing the height of the segment by the diameter of the circle, and multiplying the corresponding tabular area by the square of the diameter.

14. The sum of the diameters of two concentric circles, multiplied by their difference and by .7854, equals the area of the ring or space contained between them.

15. The sum of the thickness and internal diameter of a cylindric ring, multiplied by the square of its thickness and by 2.4674, equals its solidity.

16. The circumference of a cylinder, multiplied by its length or height, equals its convex surface.

17. The area of the end of a cylinder, multiplied by its length, equals its solid contents.

18. The area of the internal diameter of a cylinder, multiplied by its depth, equals its cubical capacity.

19. The square of the diameter of a cylinder, multiplied by its length and divided by any other required length, the square root of the quotient equals the diameter of the other cylinder of equal contents or capacity.

20. The square of the diameter of a sphere, multiplied by 3.1416, equals its convex surface.

21. The cube of the diameter of a sphere, multiplied by .5236, equals its solid contents.

22. The height of any spherical segment or zone, multiplied by the diameter of the sphere of which it is a part, and by 3.1416, equals the area or convex surface of the segment; or,

23. The height of the segment, multiplied by the circumference of the sphere of which it is a part, equals the area.

24. The solidity of any spherical segment is equal to three times the square of the radius of its base, plus the square of its height, and multiplied by its height and by .5236.

25. The solidity of a spherical zone equals the sum of the squares of the radii of its two ends, and one-third the square of its height, multiplied by the height, and by 1.5708.

26. The capacity of a cylinder, 1 foot in diameter and 1 foot in length, equals 5.875 of a United States gallon.

27. The capacity of a cylinder, 1 inch in diameter and 1 foot in length, equals .0408 of a United States gallon.

28. The capacity of a cylinder, 1 inch in diameter and 1 inch in length, equals .0034 of a United States gallon.

29. The capacity of a sphere, 1 foot in diameter, equals 3.9156 United States gallons.

30. The capacity of a sphere, 1 inch in diameter, equals .002165 of a United States gallon; hence,

31. The capacity of any other cylinder in United States gallons is obtained by multiplying the square of its diameter by its length, or the capacity of any other sphere by the cube of its diameter, and by the number of United States gallons contained as above in the unity of its measurement.

Of the Square, Rectangle, Cube, &c.

1. The side of a square equals the square root of its area.
2. The area of a square equals the square of one of its sides.
3. The diagonal of a square equals the square root of twice the square of its side.
4. The side of a square is equal to the square root of half the square of its diagonal.
5. The side of a square equal to the diagonal of a given square contains double the area of the given square.
6. The area of a rectangle equals its length multiplied by its breadth.
7. The length of a rectangle equals the area divided by the breadth; or, the breadth equals the area divided by the length.
8. The side or end of a rectangle equals the square root of the sum of the diagonal and opposite side to that required, multiplied by their difference.
9. The diagonal in a rectangle equals the square root of the sum of the squares of the base and perpendicular.
10. The solidity of a cube equals the area of one of its sides multiplied by the length or breadth of one of its sides.
11. The length or breadth of a side of a cube equals the cube root of its solidity.
12. The capacity of a 12-inch cube equals 7.4784 United States gallons.

Surfaces and Solidities of the Regular Bodies, each of whose Boundary Lines is 1.

No. of Sides.	Names.	Surfaces.	Solids.
4	Tetrahedron.	1.7321	0.1179
6	Hexahedron.	6.	1.
8	Octahedron.	3.4641	0.4714
12	Dodecahedron.	20.6458	7.6631
20	Icosahedron.	8.6603	2.1817

The tabular surface, multiplied by the square of one of the boundary lines, equals the surface required; or,

The tabular solidity, multiplied by the cube of one of the boundary lines, equals the solidity required.

Of Triangles, Polygons, &c.

1. The complement of an angle is its defect from a right angle.
2. The supplement of an angle is its defect from two right angles.

3. The sine, tangent, and secant of an angle are the cosine, co-tangent, and cosecant of the complement of that angle.

4. The hypotenuse of a right-angled triangle being made radii, its sides become the sines of the opposite angles, or the cosines of the adjacent angles.

5. The three angles of every triangle are equal to two right angles; hence the oblique angles of a right-angled triangle are each other's complements.

6. The sum of the squares of the two given sides of a right-angled triangle is equal to the square of the hypotenuse.

7. The difference between the squares of the hypotenuse and given side of a right-angled triangle is equal to the square of the required side.

8. The area of a triangle equals half the product of the base multiplied by the perpendicular height; or,

9. The area of a triangle equals half the product of the two sides and the natural sine of the contained angle.

10 The side of any regular polygon, mnitiplied by its apothegm or perpendicular, and by the number of its sides, equals twice the area.

Table of the Areas of Regular Polygons, each of whose sides is Unity.

Name of Polygon.	No. of Sides.	Apothegm or Perpend'lar.	Area when Side is Unity.	Interior Angle.	Central Angle.
Triangle....	3	0.2887	0.4330	60° 0′	120° 0′
Square. ...	4	0.5	1	90 9	90 0
Pentagon...	5	0 6882	1.7205	108 0	72 0
Hexagon ...	6	0.8660	2.5981	120 0	60 0
Heptagon..	7	1 0386	3.6339	128 $34\frac{2}{7}$	51 $25\frac{5}{7}$
Octagon....	8	1.2071	4 8281	135 0	45 0
Nonagon .	9	1.3737	6.1818	140 0	40 0
Decagon...	10	1.5388	7.6942	144 0	36 0
Undecagon	11	1.7028	9.3656	147 $16\frac{4}{11}$	35 $43\frac{7}{11}$
Dodecagon .	12	1 8660	11.1962	150 0	30 0

The tabular area of the corresponding polygon, multiplied by the square of the side of the given polygon, equals the area of the given polygon.

Of Ellipses, Cones, Frustums, &c.

1. The square root of half the sum of the squares of the two diameters of an ellipse, multiplied by 3.1416, equals its circumference.

2. The product of the two axes of an ellipse, multiplied by .7854, equals its area.

3. The curve surface of a cone is equal to half the product of the circumference of its base multiplied by its slant side, to which, if the area of the base be added, the sum is the whole surface.

4. The solidity of a cone equals one-third of the product of its base multiplied by its altitude or height.

5. The squares of the diameters of the two ends of the frustum of a cone added to the product of the two diameters, and that sum multiplied by its height and by .2618, equals its solidity.

INSTRUMENTAL ARITHMETIC,

Or Utility of the Slide Rule.

The slide rule is an instrument by which the greater portion of operations in arithmetic and mensuration may be advantageously performed, provided the lines of division and gauge points be made properly correct, and their several values familiarly understood.

The lines of division are distinguished by the letters A B C D; A B and C being each divided alike, and containing what is termed a double radius, or double series of logarithmic numbers, each series being supposed to be divided into 1,000 equal parts, and distributed along the radius in the following manner:

From 1 to	2	contains	301	of those parts,	being	the log. of	2.
"	3	"	477	"		"	3.
"	4	"	602	"		"	4.
"	5	"	699	"		"	5.
"	6	"	778	"		"	6.
"	7	"	845	"		"	7.
"	8	"	903	"		"	8.
"	9	"	954	"		"	9.

1,000 being the whole number.

The line D on the improved rules consists of only a single radius; and although of larger radius, the logarithmic series is the same, and disposed of along the line in a similar proportion, forming exactly a line of square roots to the numbers on the lines B C.

Numeration.

Numeration teaches us to estimate or properly value the numbers and divisions on the rule in an arithmetical form.

Their values are all entirely governed by the value set upon the first figure, and, being decimally reckoned, advance tenfold from the commencement to the termination of each radius: thus, suppose 1 at the joint be one, the 1 in the middle of the rule is ten, and 1 at the end, one hundred; again, suppose 1 at the joint ten, 1 in the middle is 100, and 1 or ten at the end is 1,000, &c., the intermediate divisions on which completes the whole system of its notation.

To Multiply Numbers by the Rule.

Set 1 on B opposite to the multiplier on A; and against the number to be multiplied on B is the product on A.

Multiply 6 by 4.

Set 1 on B to 4 on A; and against 6 on B is 24 on A.

The slide thus set, against 7 on B is 28 on A.

8	"	32	"	
9	"	36	"	
10	"	40	"	
12	"	48	"	
15	"	60	"	
25	"	100	"	&c.

To Divide Numbers upon the Rule.

Set the divisor on B to 1 on A; and against the number to be divided on B is the quotient on A.

Divide 63 by 3.

Set 3 on B to 1 on A; and against 63 on B is 21 on A.

Proportion, or Rule of Three Direct.

RULE.—Set the first term on B to the second on A; and against the third upon B is the fourth upon A.

1. If 4 yards of cloth cost 38 cents, what will 30 yards cost at the same rate?

Set 4 on B to 38 on A; and against 30 on B is 285 cents on A.

2. Suppose I pay 31 dollars 50 cents for 3 cwt. of copper, at what rate is that per ton? 1 *ton* = 20 *cwt.*

Set 3 upon B to 31.5 upon A; and against 20 upon B is 210 upon A.

Rule of Three Inverse.

RULE. Invert the slide, and the operation is the same as direct proportion.

1. I know that six men are capable of performing a certain given portion of work in eight days, but I want the same performed in three; how many men must there be employed?

Set 6 upon C to 8 upon A; and against 3 upon C is 16 upon A.

2. The lever of a safety-valve is 20 inches in length, and 5 inches between the fixed end and centre of the valve; what weight must there be placed on the lower end of the lever to equipoise a force or pressure of 40 lbs., tending to raise the valve?

Set 5 upon C to 40 upon A; and against 20 upon C is 10 upon A.

3. If $8\frac{3}{4}$ yards of cloth, $1\frac{1}{2}$ yards in width, be a sufficient quantity, how much will be required of that which is only 7-8ths in width, to effect the same purpose?

Set 1.5 upon C to 8.75 upon A; and against 8.75 upon C is 15 yards upon A.

Square and Cube Roots of Numbers.

On the engineer's rule, when the lines C and D are equal at both ends, C is a table of squares, and D a table of roots, as

Squares	1	4	9	16	25	36	49	64	81	on C.
Roots	1	2	3	4	5	6	7	8	9	on D.

To find the Geometrical Mean Proportion between two Numbers.

Set one of the numbers upon C to the same number upon D; and against the other number upon C is the mean number or side of an equal square upon D.

Required the mean proportion between 20 and 45.

Set 20 upon C to 20 upon D; and against 45 upon C is 30 upon D.

To cube any number, set the number upon C to 1 or 10 upon D; and against the same number upon D is the cube number upon C.

Required the cube of 4.

Set 4 upon C to 1 or 10 upon D; and against 4 upon D is 64 upon C.

To extract the cube root of any number, invert the slide and set the number upon B to 1 or 10 upon D; and where two numbers of equal value coincide on the lines B D is the root of the given number.

Required the cube root of 64.

Set 64 upon B to 1 or 10 upon D; and against 4 upon B is 4 upon D, or root of the given number.

On the common rule, when 1 in the middle of the line C is set opposite to 10 on D, then C is a table of squares, and D a table of roots.

To cube any number by this rule, set the number upon C to 10 upon D; and against the same number upon D is the cube upon C.

Mensuration of Surface.

1. Squares, Rectangles, &c.

RULE.—When the length is given in feet and the breadth in inches, set the breadth on B to 12 on A; and against the length on A are the contents in square feet on B.

If the dimensions are all inches, set the breadth on B to 144 upon A; and against the length upon A is the number of square feet on B.

Required the contents of a board 15 inches broad and 14 feet long.

Set 15 upon B to 12 upon A; and against 14 upon A is 17.5 square feet on B.

2. *Circles, Polygons, &c.*

RULE.—Set .7854 upon C to 1 or 10 upon D; then will the lines C and D be a table of areas and diameters.

Areas	3.14	7.06	12.56	19.63	28.27	38.48	50.26	63.61	upon C.
Diam.	2	3	4	5	6	7	8	9	upon D.

In the common rule, set .7854 on C to 10 on D; then C is a line or table of areas, and D of diameters, as before.

Set 7 upon B to 22 upon A; then B and A form or become a table of diameters and circumferences of circles.

Cir.	3.14	6.28	9.42	12.56	15.7	18.85	22	25.13	28.27 upon A.
Dia.	1	2	3	4	5	6	7	8	9 upon B.

Polygons from 3 to 12 Sides. Set the gauge-point upon C to 1 or 10 upon D; and against the length of one side upon D is the area upon C.

Sides	3	5	6	7	8	9	10	11	12
Gauge-points	.433	1.7	2.6	3.63	4.82	6.18	7.69	9.37	11.17

Required the area of an equilateral triangle, each side 12 inches in length.

Set .433 upon C to 1 upon D; and against 12 upon D are 62.5 square inches upon C.

Table of Gauge-Points for the Engineer's Rule.

NAMES.	F, F, F.	F, I, I.	I, I, I.	F. I.	I, I.	F.	I.
Cubic inches..	578	83	1728	166	1273	105	121
Cubic feet....	1	144	1	1833	22	121	33
Imp. gallons..	163	231	277	294	353	306	529
Water in lbs..	16	23	276	293	352	305	528
Gold "	814	1175	141	119	178	155	269
Silver "	15	216	261	276	331	286	5
Mercury "	118	169	203	216	258	225	389
Brass "	193	177	333	354	424	369	637
Copper "	18	26	319	331	397	315	596
Lead "	111	203	213	258	31	27	465
Wro't iron "	207	297	357	338	453	394	682
Cast iron "	222	32	384	107	489	424	733
Tin "	219	315	378	101	481	419	728
Steel "	202	292	352	372	448	385	671
Coal "	127	183	22	33	28	242	42
Marble "	591	85	102	116	13	113	195
Freestone "	632	915	11	1162	14	141	21

For the Common Slide Rule.

NAMES.	F, F, F.	F, I, I.	I, I, I.	F, I.	I, I.	F.	I.
Cubic inches.	36	518	624	660	799	625	113
Cubic feet....	625	9	108	114	138	119	206
Water in lbs..	10	144	174	184	22	191	329
Gold "	507	735	88	96	118	939	180
Silver "	938	136	157	173	208	173	354
Mercury "	738	122	127	132	162	141	242
Brass "	12	174	207	221	265	23	397
Copper "	112	163	196	207	247	214	371
Lead "	880	126	152	162	194	169	289
Wro't iron "	129	186	222	235	283	247	423
Cast iron "	139	2	241	254	304	265	458
Tin "	137	135	235	25	300	261	454
Steel "	136	183	22	233	278	239	418
Coal "	795	114	138	146	176	151	262
Marble "	370	53	637	725	81	72	121
Freestone "	394	57	69	728	873	755	132

Mensuration of Solidity and Capacity.

GENERAL RULE.—Set the length upon B to the gauge-point upon A; and against the side of the square, or diameter on D, are the cubic contents, or weight in lbs. on C.

1. Required the cubic contents of a tree, 30 feet in length and 10 inches quarter girt.

Set 30 upon B to 144 (the gauge-point) upon A; and against 10 upon D is 20.75 feet upon C.

2. In a cylinder, 9 inches in length and 7 inches diameter, how many cubic inches?

Set 9 upon B to 1273 (the gauge-point) upon A; and against 7 on D is 346 inches on C.

3. What is the weight of a bar of cast iron, 3 inches square and 6 feet long?

Set 6 upon B to 32 (the gauge-point) upon A; and against 3 upon D is 168 pounds upon C.

BY THE COMMON RULE.

4. Required the weight of a cylinder of wrought iron, 10 inches long and 5½ diameter.

Set 10 upon B to 283 (the gauge-point) upon A; and against 5½ upon D is 66.65 pounds on C.

5. What is the weight of a dry rope, 25 yards long and 4 inches circumference?

Set 25 upon B to 47 (the gauge-point) upon A; and against 4 on D is 53.16 pounds on C.

6. What is the weight of a short-linked chain, 30 yards in length and 6-16ths of an inch in diameter?

Set 30 upon B to 52 (the gauge-point) upon A; and against 6 on D is 129.5 pounds on C.

Power of Steam-Engines.

Condensing Engines. RULE – Set 3.5 on C to 10 on D; then D is a line of diameters for cylinders, and C the corresponding number of horses' power; thus,

H. Pr.	$3\frac{1}{2}$	4	5	6	8	10	12	16	20	25	30	40	50 on C.
C. D.	10 in.	$10\frac{3}{4}$	12	$13\frac{1}{4}$	$15\frac{1}{2}$	17	$18\frac{3}{4}$	$21\frac{1}{2}$	24	$26\frac{3}{4}$	$29\frac{1}{2}$	$33\frac{3}{4}$	$37\frac{3}{4}$ on D.

The same is effected on the common rule by setting 5 on C to 12 on D.

Non-Condensing Engines. RULE.—Set the pressure of steam in pounds per square inch on B to 4 upon A; and against the cylinder's diameter on D is the number of horses' power on C.

Required the power of an engine when the cylinder is 20 inches diameter and steam 30 pounds per square inch.

Set 30 on B to 4 on A; and against 20 on D is 30 horses' power on C.

The same is effected on the common rule by setting the force of the steam on B to 250 on A.

Of Engine Boilers.

How many superficial feet are contained in a boiler, 23 feet in length and $5\frac{1}{2}$ feet in depth?

Set 1 on B to 23 on A; and against 5.5 upon B is 126.5 square feet upon A.

If 5 square feet of boiler surface be sufficient for each horse-power, how many horses' power of engine is the boiler equal to?

Set 5 upon B to 126.5 upon A; and against 1 upon B is 25.5 upon A.

MANUFACTURE OF TIN PLATE.

The different processes in the manufacture of tin plate may be described most properly in seven distinct stages. The first begins with the bars of iron which form the plate: the last terminates with an account of the process of tinning their surface. The description is somewhat technical; but a glance at the following heads will enable the reader to comprehend the whole process:

1. Rolling is the first and most important point requisite to the production of the *latten*, or plates of iron, previous to the operation of tinning them. For this purpose the finest quality of charcoal iron is invariably employed, which, in its commercial state, generally consists of long flat bars. These are cut into small squares averaging one-half an inch in thickness, which are heated repeatedly in a furnace, and are repeatedly passing through iron rollers. A convenient degree of thinness having been obtained, the now extended plates are "doubled up," heated, rolled, opened-out, heated and rolled again, until, at length, the standard thickness of the plate has been reached.

2. Shearing.—A pair of massive shears worked by machinery, is now applied to the ragged edges of this lamellar formation of iron-plate. It is cut into oblong squares, 14 inches by 10, and presents the appearance of a single plate of iron, beautifully smooth on its surface. A juvenile with a knife soon destroys the appearance, however, and eight plates are produced from the slightly coherent mass.

3. Scaling.—This process consists in freeing the iron surface from its oxide and scoriæ. After an application of sulphuric acid, a number of plates, to the extent, we shall say, of 600 or 800, are packed in a cast-iron box, which is exposed for some hours to the heat of a furnace. On being opened the plates are found to have acquired a bright blue steel tint, and to be free from surface impurities.

4. Cold Rolling.—It is impossible that the plates could pass through the last fiery ordeal without becoming disfigured. The cold rolling process corrects this. Each plate is separately passed through a pair of hard polished rollers, screwed tightly together. Not only do the plates acquire from this operation a high degree of smoothness and regularity, but they likewise acquire the peculiar elasticity of hammered metal. One man will cold roll 225,000 plates in a week, and each of them is, on an average, three times passed through the rollers.

5. Annealing.—This process is also a modern improvement on the manufacture: 600 plates are again packed into cast-iron boxes and exposed to the furnace. There is this difference in the present process from that of scaling—that the boxes must be preserved air-tight, otherwise the contained plates would inevitably weld together and produce a solid mass. The infinitessimal portion of confined air prevents this.

6. Pickling.—The plates are again confined in a bath of diluted acid, till the surface becomes uniformly bright and clean. Some nice manipulation belongs to this process. Each plate is, on its removal from the acid, subjected to a rigid scrutiny by women, whose vocation it is to detect any remaining impurity, and scour it from the surface. The multifarious operations, it will be seen, are all preliminary to the last, and the most important of all—that of tinning. Theoretically simple, this process is practically difficult, and to do it full justice would carry us beyond our limits. We shall, however, mention the principal features.

7. Tinning.—A rectangular cast-iron bath, heated from below, and calculated to contain 200 or 300 sheets, and about a ton of pure block tin, is now put in request. A stratum of pyreumatic fat floats upon its surface. Close to the side of this tin pot stands another receptacle, which is filled with melted grease, and contains the prepared plates. On the other side is an empty pot, with a grating; and last of all there is yet another pot, containing a small stratum of melted tin. Let us follow the progress of a single plate. A functionary known as the "washerman," armed with tongs and a hempen brush, withdraws the plate from the bath of tin wherein it has been soaking; and, with a dexterity only to be acquired by long practice, sweeps one side of the plate clean, and then reversing it, repeats the operation. In an instant it is again submerged in the liquid tin, and is then as quickly transferred to the liquid grease. The peculiar use of the hot grease consists in the property it possesses of equalizing the distribution of the tin, of retaining the superfluous metal, and of spreading the remainder equally on the surface of the iron. Still there is left on the plate what we may term a salvage; and this is finally removed by means of the last tin pot, which just contains the necessary quantity of fluid metal to melt it off—a smart blow being given at the same moment to assist the disengagement. The "list-mark" may be observed upon every tin plate without exception. We may add here, that an expert wash-erman will finish 6,000 metallic plates in twelve hours, notwithstanding that each plate is twice washed on both sides, and twice dipped into the melted tin. After some intermediate operations—for we need not continue the consecutive description—the plates are sent to the final operation of cleaning. For this purpose they are rubbed with bran, and dusted upon tables; after which they present the beautiful silvery appearance so characteristic of the best English tin plate. Last of all they reach an individual called the "sorter," who subjects every plate to a strict examination, rejects those which are found to be defective, and sends those which are approved to be packed, 300 at a time, in the rough wooden boxes, with the cabalistic signs with which most of us have been familiar since the days of our adventures in the back-shop of the tinsmith.

Quality of Tin Plate.

The tests for tin plates are ductility, strength, and color; and to possess these, the iron used must be of the best quality, and all the process be conducted with care and skill. The following conditions are inserted in some specifications, and will serve to indicate the strength and ductility of first-class tin plates:

1st. They must bear cutting into strips of a width equal to ten times the thickness of the plate, both with and across the fibre, without splitting; the strips must bear, while hot, being bent upon a mould, to a sweep equal to four times the width of the strip.

2d. While cold, the plates must bear bending in a heading machine, in such a manner as to form a cylinder, the diameter of which shall at most be equal to sixty times the thickness of the plate. In these tests, the plate must show neither flaw nor crack of any kind.

Crytallized Tin-Plate.

Crystallized tin-plate is a variegated primrose appearance, produced upon the surface of tin plate by applying to it in a heated state some dilute nitro-muriatic acid for a few seconds, then washing it with water, drying, and coating it with lacquer. The figures are more or less beautiful and diversified, according to the degree of heat and relative dilution of the acid. Place the tin plate, slightly heated, over a tub of water, and rub its surface with a sponge dipped in a liquor composed of four parts of aquafortis, and two of distilled water, holding one part of common salt or sal ammoniac in solution. Whenever the crystalline spangles seem to be thoroughly brought out, the plate must be immersed in water, washed either with a feather or a little cotton (taking care not to rub off the film of tin that forms the feathering), forthwith dried with a low heat, and coated with a lacquer varnish, otherwise it loses its lustre in the air. If the whole surface is not plunged at once in cold water, but if it be partially cooled by sprinkling water on it, the crystallization will be finely variegated with large and small figures. Similar results will be obtained by blowing cold air through a pipe on the tinned surface, while it is just passing from the fused to the solid state.

Tinning.

1. Plates or vessels of brass or copper, boiled with a solution of stannate of potassa, mixed with turnings of tin, become, in the course of a few minutes, covered with a firmly attached layer of pure tin. 2. A similar effect is produced by boiling the articles with tin filings and caustic alkali, or cream of tartar. In the above way, chemical vessels made of copper or brass may be easily and perfectly tinned.

New Tinning Process.

The articles to be tinned are first covered with dilute sulphuric acid, and when quite clean are placed in warm water, then dipped in a solution of muriatic acid, copper, and zinc, and then plunged into a tin bath to which a small quantity of zinc has been added. When the tinning is finished, the articles are taken out and plunged into boiling water. The operation is completed by placing them in a very warm sand bath. This last process softens the iron.

Kustitien's Metal for Tinning.

Malleable iron 1 pound, heat to whiteness; add 5 ounces regulus of antimony, and Molucca tin 24 pounds.

Capacity of Cans One Inch Deep.

UTILITY OF THE TABLE.

Required the contents of a vessel, diameter 6 7-10ths inches, depth 10 inches.

By the table a vessel one inch deep, and 6 and 7-10ths inches diameter contains .15 (hundredths) of a gallon, then $.15 \times 10 = 1.50$ or 1 gallon and 2 quarts.

Required the contents of a can, diameter 19 8-10ths inches, depth 30 inches.

By the table a vessel 1 inch deep and 19 and 8-10ths inches diameter contains one gallon and .33 (hundredths), then 1.33 × 30 = 39.90 or nearly 40 gallons.

Required the depth of a can whose diameter is 12 and 2-10ths inches, to contain 16 gallons.

By the table a vessel 1 inch deep and 12 and 2-10ths inches diameter contains .50 (hundredths of a gallon), then 16 ÷ .50 = 32 inches, the depth required, viz.:

.50) 16 (32 × .50 = 16 gallons.

Diameter.		$\frac{1}{10}$	$\frac{2}{10}$	$\frac{3}{10}$	$\frac{4}{10}$	$\frac{5}{10}$	$\frac{6}{10}$	$\frac{7}{10}$	$\frac{8}{10}$	$\frac{9}{10}$
3	.03	.03	.03	.03	.03	.04	.04	.04	.04	.05
4	.05	.05	.05	.05	.06	.06	.07	.07	.07	.08
5	.08	.08	.08	.09	.09	.10	.10	.11	.11	.11
6	.12	.12	.12	.13	.13	.14	.14	.15	.15	.16
7	.16	.17	.17	.18	.18	.19	.19	.20	.20	.21
8	.21	.22	.22	.23	.23	.24	.25	.25	.26	.26
9	.27	.28	.28	.29	.30	.30	.31	.31	.32	.33
10	.34	.34	.35	.36	.36	.37	.38	.38	.39	.40
11	.41	.41	.42	.43	.44	.44	.45	.46	.47	.48
12	.48	.49	.50	.51	.52	.53	.53	.54	55	.56
13	.57	.58	.59	.60	.60	.61	.62	.63	.64	.65
14	.66	.67	.68	.69	.70	.71	.72	.73	.74	.75
15	.76	.77	.78	.79	.80	.81	.82	.83	.84	.85
16	.87	88	.89	.90	.91	.92	.93	.94	.95	.97
17	.98	.99	1.005	1.017	1.028	1.040	1.051	1.063	1.075	1.086
18	1.101	1.113	1.125	1.138	1.150	1.162	1.170	1.187	1.200	1.211
19	1.227	1.240	1.253	1.266	1.279	1.292	1.304	1.317	1.330	1.343
20	1.360	1.373	1.385	1.400	1.414	1.428	1.441	1.455	1.478	1.482
21	1.499	1.513	1.527	1.542	1.556	1.570	1.585	1.600	1.612	1.630
22	1.645	1.660	1.675	1.696	1.705	1.720	1.735	1.750	1.770	1.780
23	1.798	1.814	1.830	1.845	1.861	1.876	1.892	1.908	1.923	1.940
24	1.958	1.974	1.991	2.007	2.023	2.040	2.056	2.072	2.096	2.105
25	2.125	2.142	2.159	2.176	2.193	2.210	2.227	2.244	2.261	2 280
26	2.298	2.316	2.333	2.351	2.369	2.386	2.404	2.422	2.440	2.460
27	2.478	2.496	2.515	2.533	2.552	2.570	2.588	2.607	2.625	2.643
28	2.665	2.684	2.703	2.722	2.741	2.764	2.780	2.800	2.820	2.836
29	2.859	2.879	2.898	2.918	2.938	2.958	2.977	2.997	3.017	3.036
30	3.060	3.080	3.100	3.121	3.141	3.162	3.182	3.202	3.223	3.245
31	3.267	3.288	3.309	3.330	3.351	3.372	3.393	3.414	3.436	3.457
32	3.481	3.503	3.524	3.543	3.568	3.590	3.612	3.633	3 655	3.689
33	3 702	3.725	3.747	3.773	3.795	3.814	3.837	3.860	3.882	3.901
34	3.930	3.953	3.976	4.003	4.022	4.016	4.076	4.092	4.115	4.140
35	4.165	4.188	4.212	4.236	4.260	4.284	4.307	4 331	4.355	4.380
36	4 406	4.430	4.455	4.483	4.503	4.528	4.553	4.577	4.602	4.626
37	4.654	4.679	4 701	4.730	4.755	4.780	4.805	1.834	4.855	4.880
38	4.909	4.935	1.961	4.987	5.012	5.038	5.064	5.090	5.120	5.142
39	5.171	5.197	5.221	5.250	5.277	5.304	5.330	5.357	5.383	5.410
40	5.440	5.467	5.491	5.521	5.548	5.576	5.603	5.630	5.657	5.684

RULES AND TABLES

FOR COMPUTING THE WORK OF BRICKLAYERS, WELL-DIGGERS, MASONS, CARPENTERS AND JOINERS, SLATERS, PLASTERERS, PAINTERS, GLAZIERS, PAVERS, AND PLUMBERS.

Measurement of Bricklayers' Work.

Brick-work is estimated at the rate of a number of bricks in thickness, estimating a brick at 4 inches thick. The dimensions of a building are usually taken by measuring half round on the outside, and half round on the inside; the sum of these two gives the compass of the wall,—to be multiplied by the height, for the contents of the materials. Chimneys are by some measured as if they were solid, deducting only the vacuity from the hearth to the mantel, on account of the trouble of them. And by others they are girt or measured round for their breadth, and the height of the story is their height, taking the depth of the jambs for their thickness. And in this case, no deduction is made for the vacuity from the floor to the mantel-tree, because of the gathering of the breast and wings, to made room for the hearth in the next story. To measure the chimney shafts, which appear above the building, gird them about with a line for the breadth, to multiply by their height. And account their thickness half a brick more than it really is, in consideration of the plastering and scaffolding. All windows, doors, &c., are to be deducted out of the contents of the walls in which they are placed. But this deduction is made only with regard to materials; for the whole measure is taken for workmanship, and that all outside measure too, namely, measuring quite round the outside of the building, being in consideration of the trouble of the returns or angles. There are also some other allowances, such as double measure for feathered gable ends, &c.

EXAMPLE.—The end wall of a house is 28 feet long, and 37 feet high to the eaves; 15 feet high is four bricks or 16 inches thick, other 12 feet is three bricks or 12 inches thick, and the remaining 10 feet is two bricks or 8 inches thick; above which is a triangular gable 12 feet high and one brick or 4 inches in thickness. What number of bricks are there in the said wall? *Ans.* 25,620.

Thickness.

$28 \times 15 = 420 \times 4 = 1680$ contents of 1st story.
$28 \times 12 = 336 \times 3 = 1008$ " " 2d "
$28 \times 10 = 280 \times 2 = 560$ " " 3d "
$\frac{12}{2} = 6 \times 28 = 168 \times 1 = 168$ " " gable.

3416 square feet area of whole wall.
7½ bricks to square foot.

23,912
1,708

Answer, 25,620 bricks.

By the table.

3000	sup.	ft.	=	22,500 bk's
400	"	"	=	3,000 "
10	"	"	=	75 "
6	"	"	=	45 "
3416	"	"	=	25,620 bk's

A Table by which to ascertain the number of Bricks necessary to construct any Piece of Building from a four-inch Wall to twenty-four inches in Thickness.

The utility of the Table below can be seen by the following Example. Required the number of bricks to build a wall of 12 inches thickness, and containing an area of 6,437 square feet.

Square feet 1000	22,500 bricks—See table.	
× 6	6	
6000 =	135,000	NOTE.—7½ bricks equal one superficial foot.
400 =	9,000	
30 =	675	
7 =	158	
6,437 =	144,833 bricks.	

Superficial feet of Wall.	Number of Bricks to Thickness of					
	4-inch.	8-inch.	12-inch.	16-inch	20-inch.	24-inch.
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	1125	1350
40	300	600	900	1200	1500	1800
50	375	750	1125	1500	1875	2250
60	450	900	1350	1800	2250	2700
70	525	1050	1575	2100	2625	3150
80	600	1200	1800	2400	3000	3600
90	675	1350	2025	2700	3375	4050
100	750	1500	2250	3000	3750	4500
200	1500	3000	4500	6000	7500	9000
300	2250	4500	6750	9000	11250	13500
400	3000	6000	9000	12000	15000	18000
500	3750	7500	11250	15000	18750	22500
600	4500	9000	13500	18000	22500	27000
700	5250	10500	15750	21000	26250	31500
800	6000	12000	18000	24000	30000	36000
900	6750	13500	20250	27000	33750	40500
1000	7500	15000	22500	30000	37500	45000

Measurement of Wells and Cisterns.

There are two methods of estimating the value of excavating. It may be done by allowing so much a day for every man's work, or so much per cubic foot, or yard, for all that is excavated.

Well Digging.—Suppose a well is 40 feet deep, and 5 feet in diameter, required the number of cubic feet, or yards.

$$5 \times 5 = 25 \times .7854 = 19.635 \times 40 = 785.4 \text{ cubic feet.}$$

Suppose a well to be 4 feet 9 inches diameter, and $16\frac{1}{2}$ feet from the bottom to the surface of the water; how many gallons are therein contained?

$$4.75^2 \times 16.5 \times 5.875 = 2187.152 \text{ gallons.}$$

Again, suppose the well's diameter the same, and its entire depth 35 feet; required the quantity in cubic yards of material excavated in its formation.

$$4.75^2 \times 35 \times .02909 = 22.972 \text{ cubic yards.}$$

A cylindrical piece of lead is required $7\frac{1}{2}$ inches diameter, and 168 lbs. in weight; what must be its length in inches?

$$7.5^2. \times .3223 = 18, \text{ and } 168 \div 18 = 9.3 \text{ inches.}$$

Digging for Foundations, &c.—To find the cubical quantity in a trench, or an excavated area, the length, width, and depth must be multiplied together. These are usually given in feet, and therefore, to reduce the amount into cubic yards it must be divided by 27.

Suppose a trench is 40 feet long, 3 feet wide, and 3 feet deep, required the number of cubic feet, or yards.

$$40 \times 3 = 120 \times 3 = 360 \text{ feet} \div 27 = 13\tfrac{1}{3} \text{ yards.}$$

24 cubic feet of sand, 17 ditto clay, 18 ditto earth, equal one ton.

1 cubic yard of earth or gravel, before digging, will occupy about $1\frac{1}{2}$ cubic yards when dug.

Measurement of Masons' Work.

To masonry belong all sorts of stone-work; and the measure made use of is a foot, either superficial or solid.

Walls, columns, blocks of stone or marble, &c., are measured by the cubic foot; and pavements, slabs, chimney-pieces, &c., by the superficial or square foot. Cubic or solid measure is used for the materials, and square measure for the workmanship. In the solid measure, the true length, breadth, and thickness are taken, and multiplied continually together. In the superficial, there must be taken the length and breadth of every part of the projection, which is seen without the general upright face of the building.

EXAMPLE.—In a chimney-piece, suppose the length of the mantel and slab each 4 feet 6 inches; breadth of both together 3 feet 2 inches; length of each jamb 4 feet 4 inches; breadth of both together 1 foot 9 inches. Required the superficial contents. *Ans.* 21 feet 10 inches.

4 ft. 6 in. × 3 ft. 2 in. = 14 ft. 3 in. }
4 " 4 " × 1 " 9 " = 7 " 7 " } 21 feet 10 inches.

Rubble Walls (unhewn stone) are commonly measured by the perch, which is $16\frac{1}{2}$ feet long, 1 foot deep, and $1\frac{1}{2}$ foot thick, equivalent to $24\frac{3}{4}$ cubic feet. 25 cubic feet is sometimes allowed to the perch, in measuring stone before it is laid, and 22 after it is laid in the wall. This species of work is of two kinds, coursed and uncoursed; in the former the stones are ganged and dressed by the hammer, and the masonry laid in horizontal courses, but not necessarily confined to the same height. The uncoursed rubble wall is formed by laying the stones in the wall as they come to hand, without any previous gauging or working.

27 cubic feet of mortar require for its preparation, 9 bushels of lime and 1 cubic foot of sand.

Lime and sand lessen about one-third in bulk when made into mortar; likewise cement and sand.

Lime, or cement and sand, to make mortar, require as much water as is equal to one-third of their bulk.

All sandstones ought to be placed on their natural beds; from inattention to this circumstance, the stones often split off at the joints, and the position of the lamina much sooner admits of the destructive action of air and water.

The heaviest stones are most suited for docks and harbors, breakwaters to bridges, &c.

Granite is the most durable species of stone yet known for the purposes of building. It varies in weight according to quality; the heaviest is the most durable.

Measurement of Carpenters' and Joiners' Work.

To this branch belongs all the wood-work of a house, such as flooring, partitioning, roofing, &c. Large and plain articles are usually measured by the square foot or yard, &c., but enriched mouldings, and some other articles, are often estimated by running or lineal measures, and some things are rated by the piece.

Joints, Girders, and in fact all the parts of naked flooring, are measured by the cube, and their quantities are found by multiplying the length by the breadth, and the product by the depth. The same rule applies to the measurement of all the timbers of a roof, and also the framed timbers used in the construction of partitions.

Flooring, that is to say, the boards which cover the naked flooring, is measured by the square. The dimensions are taken from wall to wall, and the product is divided by 100, which gives the number of squares; but deductions must be made for staircases and chimneys.

In measuring of joists, it is to be observed, that only one of their dimensions is the same with that of the floor; for the other exceeds the length of the room by the thickness of the wall, and one-third of the same, because each end is let into the wall about two-thirds of its thickness.

No deductions are made for hearths, on account of the additional trouble and waste of materials.

Partitions are measured from wall to wall for one dimension, and from floor to floor, as far as they extend, for the other.

No deduction is made for door-ways, on account of the trouble of framing them.

In measuring of joiners' work, the string is made to ply close to every part of the work over which it passes.

The measuring for centring for CELLARS is found by making a string pass over the surface of the arch for the breadth, and taking the length of the cellar for the length ; but in groin centring, it is usual to allow double measure, on account of their extraordinary trouble.

Roofing.—The length of the house in the inside, together with two-thirds of the thickness of one gable, is to be considered as the length; and the breadth is equal to double the length of a string which is stretched from the ridge down the rafter, and along the eaves-board, till it meets with the top of the wall.

Staircases.—Take the breadth of all the steps, by making a line ply close over them, from the top to the bottom, and multiply the length of this line by the length of a step for the whole area. By the length of a step is meant the length of the front and the returns at the two ends; and by the breadth is to be understood the girth of its two outer surfaces, or the tread and riser.

Balustrade.—Take the whole length of the upper part of the handrail, and girt over its end till it meets the top of the newel post, for the length; and twice the length of the baluster upon the landing, with the girth of the handrail, for the breadth.

Wainscoting.—Take the compass of the room for the length; and the height from the floor to the ceiling, making the string ply close into all the mouldings, for the breadth. Out of this must be made deductions for windows, doors, chimneys, &c., but workmanship is counted for the whole, on account of the extraordinary trouble.

Doors.—It is usual to allow for their thickness, by adding it to both dimensions of length and breadth, and then to multiply them together for the area. If the door be panelled on both sides, take double its measure for the workmanship; but if the one side only be panelled, take the area and its half for the workmanship. For the ***surrounding architrave,*** gird it about the outermost parts for its length; and measure over it, as far as it can be seen when the door is open, for the breadth.

Window-Shutters, Bases, &c., are measured in the same manner.

In the measuring of roofing for workmanship alone, holes for chimney-shafts and skylights are generally deducted. But in measuring for work and materials, they commonly measure in all skylights, lutheran-lights, and holes for the chimney-shafts, on account of their trouble and waste of materials.

The doors and shutters, being worked on both sides, are reckoned work and half work.

Hemlock and ***Pine*** Shingles are generally 18 inches long and of the average width of 4 inches. When nailed to the roof, 6 inches are generally left out to the weather, and 6 shingles are therefore required to a square foot. ***Cedar*** and ***Cypress*** Shingles are generally 20 inches long and 6 inches wide, and therefore a less number are required for a "square." On account of waste and defects, 1,000 shingles should be allowed to a square.

Two 4-penny nails are allowed to each shingle, equal to 1,200 to a square.

The weight of a square of partitioning may be estimated at from 1,500 to 2,000 lbs.; a square of single-joisted flooring, at from 1,200 to 2,000 lbs.; a square of framed flooring, at from 2,700 to 4,500 lbs.; a square of deafening, at about 1,500 lbs. 100 superficial feet make one square of boarding, flooring, &c.

In selecting Timber, avoid spongy heart, porous grain, and dead knots; choose the brightest in color, and where the strong red grain appears to rise on the surface.

Number of American Iron Machine-Cut Nails in a Pound (by count).

Size.	Number	Size.	Number	Size.	Number.
3-penny,	408	6-penny,	156	12-penny,	52
4 "	275	8 "	100	20 "	32
5 "	227	10 "	66	30 "	25

Measurement of Slaters' Work.

In these articles, the contents of a roof are found by multiplying the length of the ridge by the girth over from eaves to eaves; making allowance in this girth for the double row of slates at the bottom, or for how much one row of slates is laid over another. When the roof is of a true pitch, that is, forming a right angle at top, then the breadth of the building, with its half added, is the girth over both sides. In angles formed in a roof, running from the ridge to the eaves, when the angle bends inward, it is called a valley; but when outward, it is called a hip. It is not usual to make deductions for chimney-shafts, skylights, or other openings.

Slates.

[*From the Quarries of Rutland County, Vermont.*]

3 inch Cover.		2 inch Cover.	3 inch Cover.		2 inch Cover.
Sizes.	No of Slates to the square or 100 feet.	No. of Slates to the square or 100 feet.	Sizes.	No. of Slates to the square or 100 feet.	No. of Slates to the square or 100 feet.
24 by 16	86	84	18 by 11	174¼	163½
24 by 14	98	93½	18 by 10	192	180
24 by 12	114	109	18 by 9	213	200
22 by 14	108	102¼	16 by 12	184	171⅓
22 by 12	126	120	16 by 10	221½	205¾
22 by 10	152	144	16 by 9	246	228½
20 by 14	129	114¼	16 by 8	277	257
20 by 12	143	133⅓	14 by 10	262	240
20 by 11	146	145½	14 by 9	293	266½
20 by 10	169¼	160	14 by 8	327	300
18 by 12	160	150	14 by 7	374	343

Each Slate is 3 inches BOND OR COVER. The rule for measuring Slating is, to add one foot for all hips and valleys. No deduction is made for lutheran-lights, skylights, or chimneys, except they are of unusual size; then one-half is deducted.

Imported Slates.

Names of Slates.	Sizes.			No. of Superficial Feet each M of 1200 will cover.	Weight of each M of 1200 Slates.	
	Inches.		Inches.			
Duchesses........ ..	24	by	12	1100	60	cwt.
Marchionesses	22	"	12	1000	55	"
Countesses	20	"	10	750	40	"
Viscountesses.......	18	"	10	666 2-3	36	"
Ladies	16	"	10	583 1-3	31	"
do.	16	"	8	466 2-3	25	"
do.	14	"	8	400	22	"
do.	12	"	8	333 1-3	18 1-2	"
Plantations.........	14	"	12	600	33	"
do.	13	"	10	458 1 3	25	"
do.	12	"	10	416 2-3	23	"
Doubles............	13	"	7	320 5-6	17 1-2	"
do. small... ...	11	"	7	262 1-2	14 1-2	"
School Slates for Blackboards......	5 ft. by 2 1-2 ft. 5 feet by 3 feet					

Measurement of Plasterers' Work.

Plasterers' work is of two kinds, namely, ceiling, which is plastering upon laths; and rendering, which is plastering upon walls, which are measured separately.

The contents are estimated either by the foot or yard, or square of 100 feet. Enriched mouldings, &c., are rated by running or lineal measure. One foot extra is allowed for each mitre.

One half of the openings, windows, doors, &c., allowed to compensate for trouble of finishing returns at top and sides.

Cornices and mouldings, if 12 inches or more in girt, are sometimes estimated by the square foot; if less than 12 inches, they are usually measured by the lineal foot.

1 bushel of cement will cover 1 1-7 sq. yds. at 1 in. in thickness.
1 " " " $1\frac{1}{2}$ " $\frac{3}{4}$ "
1 " " " $2\frac{1}{4}$ " $\frac{1}{2}$ "
1 bushel of cement and 1 of sand will cover $2\frac{1}{4}$ sq. yds, at 1 inch in thickness.
1 bushel of cement and 1 of sand will cover 3 sq. yds. at $\frac{3}{4}$ inch in thickness.
1 bushel of cement and 1 of sand will cover $4\frac{1}{2}$ sq. yds. at $\frac{1}{2}$ inch in thickness.
1 bushel of cement and 2 of sand will cover $3\frac{1}{3}$ sq. yds. at 1 inch in thickness.
1 bushel of cement and 2 of sand will cover $4\frac{1}{2}$ sq. yds. at $\frac{3}{4}$ inch in thickness.
1 bushel of cement and 2 of sand will cover $6\frac{3}{4}$ sq. yds. at $\frac{1}{2}$ inch in thickness.
1 cwt. of mastic and 1 gallon of oil will cover $1\frac{1}{2}$ yards at $\frac{3}{4}$, or $2\frac{1}{2}$ at $\frac{1}{2}$ inch.

1 cubic yard of lime, 2 yards of road or drift sand, and 3 bushels of hair will cover 75 yards of render and set on brick, and 70 yards on lath, or 65 yards plaster, or render, 2 coats and set on brick, and 60 yards on lath; floated work will require about the same as 2 coats and set.

Laths are $1\frac{1}{4}$ to $1\frac{1}{2}$ inches by 4 feet in length, and are usually set $\frac{1}{4}$ of an inch apart. A bundle contains 100. 1 bundle of laths and 500 nails will cover about $4\frac{1}{2}$ yards.

Measurement of Pavers' Work.

Pavers' work is done by the square yard. And the contents are found by multiplying the length by the breadth. Grading for paving is charged by the day.

Measurement of Painters' Work.

Painters' work is computed in square yards. Every part is measured where the color lies; the measuring line is forced into all the mouldings and corners.

Cornices, mouldings, narrow skirtings, reveals to doors and windows, and generally all work not more than nine inches wide, are valued by their length. Sash-frames are charged so much each according to their size, and the squares so much a dozen. Mouldings, cut in, are charged by the foot run, and the workman always receives an extra price for party-colors. Writing is charged by the inch, and the price given is regulated by the skill and manner in which the work is executed; the same is true of imitations and marbling. The price of painting varies exceedingly, some colors being more expensive and requiring much more labor than others. In measuring open railing, it is customary to take it as flat work, which pays for the extra labor; and as the rails are painted on all sides, the two surfaces are taken. It is customary to allow all edges and sinkings.

Measurement of Glaziers' Work.

Glaziers' work is sometimes measured by the square foot, sometimes by the piece, or at so much per light; except where the glass is set in metallic frames, when the charge is by the foot. In estimating by the square foot it is customary to include the whole sash. Circular or oval windows are measured as if they were square.

Table Showing the Size and Number of Lights to the 100 Square Feet.

Size.	Lights	Size.	Lights	Size.	Lights	Size.	Lights
6 by 8	300	12 by 14	86	14 by 22	47	20 by 20	36
7 by 9	229	12 by 15	80	14 by 24	43	20 by 22	33
8 by 10	180	12 by 16	75	15 by 15	64	20 by 24	30
8 by 11	164	12 by 17	71	15 by 16	60	20 by 25	29
8 by 12	150	12 by 18	67	15 by 18	53	20 by 26	28
9 by 10	160	12 by 19	63	15 by 20	48	20 by 28	26
9 by 11	146	12 by 20	60	15 by 21	46	21 by 27	25
9 by 12	133	12 by 21	57	15 by 22	44	22 by 24	27
9 by 13	123	12 by 22	55	15 by 24	40	22 by 26	25
9 by 14	114	12 by 23	52	16 by 16	56	22 by 28	23
9 by 16	100	12 by 24	50	16 by 17	53	24 by 28	21
10 by 10	144	13 by 14	79	16 by 18	50	24 by 30	20
10 by 12	120	13 by 15	74	16 by 20	45	24 by 32	19
10 by 13	111	13 by 16	69	16 by 21	43	25 by 30	19
10 by 14	103	13 by 17	65	16 by 22	41	26 by 36	15
10 by 15	96	13 by 18	61	16 by 24	38	28 by 34	15
10 by 16	90	13 by 19	58	17 by 17	50	30 by 40	12
10 by 17	85	13 by 20	55	17 by 18	47	31 by 36	13
10 by 18	80	13 by 21	53	17 by 20	42	31 by 40	12
11 by 11	119	13 by 22	50	17 by 22	38	31 by 42	12
11 by 12	109	13 by 24	46	17 by 24	35	32 by 42	10
11 by 13	101	14 by 14	73	18 by 18	44	32 by 44	10
11 by 14	94	14 by 15	68	18 by 20	40	33 by 45	10
11 by 15	87	14 by 16	64	18 by 22	36	34 by 46	9
11 by 16	82	14 by 17	60	18 by 24	33	30 by 52	9
11 by 17	77	14 by 18	57	19 by 19	40	32 by 56	8
11 by 18	73	14 by 19	54	19 by 20	38	33 by 56	8
12 by 12	100	14 by 20	51	19 by 22	34	36 by 58	7
12 by 13	92	14 by 21	49	19 by 24	32	38 by 58	7

Measurement of Plumbers' Work.

Plumbers' work is rated at so much a pound, or else by the hundred-weight of 112 pounds. Sheet lead, used in roofing, guttering, &c., is from 7 to 12 lbs. to the square foot; and a pipe of an inch bore is commonly from 6 to 13 lbs. to the yard in length. [See Table, "Weight of Lead Pipe per Foot."]

GAUGING OF CASKS.

In taking the dimensions of a Cask, it must be carefully observed: 1st, That the bung-hole be in the middle of the cask; 2d, That the bung-stave, and the stave opposite to the bung-hole, are both regular and even within; 3d, That the heads of the Cask are equal, and truly circular; if so, the distance between the inside of the chime to the outside of the opposite stave will be the head-diameter within the cask, very near.

Rule.—Take, in inches, the *inside* diameters of a Cask at the head and the bung, and also the length; subtract the head-diameter from the bung-diameter, and note the difference.

If the measure of the Cask is taken outside, with calipers, from head to head, then a deduction must be made of from 1 to 2 inches for the thickness of the heads, according to the size of the Cask.

1. *If the staves of the Cask, between the bung and the head, are* ***considerably curved*** (the shape of a pipe), multiply the difference between the bung and head, by .7.

2. *If the staves be of a* ***medium curve*** (the shape of a molasses hogshead), multiply the difference by .65.

3. *If the staves* ***curve very little*** (less than a molasses hogshead), multiply the difference by .6.

4. *If the staves are* ***nearly straight*** (almost a cylinder), multiply the difference by .55.

5. Add the product, in each case, to the head-diameter; the sum will be a mean diameter, and thus the Cask is reduced to a cylinder.

6. Multiply the *mean* diameter by itself, and then by the length, and multiply, if for wine-gallons, by .0034. The difference of dividing by 294 (the usual method), and multiplying by .0034 (the most expeditious method), is less than 500ths of a gallon in 100 gallons.

Example. Supposing the head-diameter of a Cask to be 24 inches, the bung-diameter 32 inches, and the length of Cask 40 inches, what are the contents in wine gallons?

First variety.

Bung-Diameter,	32	Brought up,	876.16
Head-Diameter,	24	Length,	40
Difference,	8		35046.40
Multiplier,	.7		.0034
	5.6		14018560
Head-Diam.,	24		10513920
multiply	29.6		119.157760
by	29.6		
Square,	876.16	*Ans.* 119 galls. 1 pint.	

To obtain the contents of a similar Cask in ale gallons, multiply 35046.40 by .002785, and we get 97.6042 (or 97 gallons 5 pints).

Gauging of Casks in Imperial (British) gallons, and also in United States gallons.

Having ascertained the *variety* of the Cask, and its *interior* dimensions, the following Table will facilitate the calculation of its capacity.

Table of the Capacities of Casks, whose Bung-Diameters and Lengths are 1 or Unity.

H.	1st Var.	2d Var	3d Var.	4th Var.	H.	1st Var.	2d Var.	3d Var.	4th Var
.50	.0021244	.0020300	.0017704	.0016523	.76	.0024337	.0021120	.0022343	.0022071
.51	.0021340	.0020433	.0017847	.0016713	.77	.0024482	.0024282	.0022560	.0022310
.52	.0021437	.0020567	.0017993	.0016905	.78	.0024628	.0024445	.0022780	.0022551
.53	.0021536	.0020702	.0018141	.0017098	.79	.0024777	.0024610	.0023002	.0022794
.54	.0021637	.0020838	.0018293	.0017294	.80	.0024927	.0024776	.0023227	.0023038
.55	.0021740	.0020975	.0018447	.0017491	.81	.0025079	.0024942	.0023455	.0023285
.56	.0021845	.0021114	.0018604	.0017690	.82	.0025233	.0025110	.0023686	.0023533
.57	.0021951	.0021253	.0018764	.0017891	.83	.0025388	.0025279	.0023920	.0023783
.58	.0022060	.0021394	.0018927	.0018094	.84	.0025546	.0025449	.0024156	.0024035
.59	.0022170	.0021536	.0019093	.0018299	.85	.0025706	.0025621	.0024396	.0024289
.60	.0022283	.0021679	.0019261	.0018506	.86	.0025867	.0025793	.0024638	.0024545
.61	.0022397	.0021823	.0019433	.0018715	.87	.0026030	.0025967	.0024883	.0024803
.62	.0022513	.0021968	.0019607	.0018925	.88	.0026195	.0026141	.0025131	.0025063
.63	.0022631	.0022114	.0019784	.0019138	.89	.0026363	.0026317	.0025381	.0025324
.64	.0022751	.0022262	.0019964	.0019352	.90	.0026532	.0026494	.0025635	.0025588
.65	.0022873	.0022410	.0020147	.0019568	.91	.0026703	.0026672	.0025891	.0025853
.66	.0022997	.0022560	.0020332	.0019786	.92	.0026875	.0026851	.0026150	.0026120
.67	.0023122	.0022711	.0020521	.0020006	.93	.0027050	.0027032	.0026412	.0026389
.68	.0023250	.0022863	.0020712	.0020228	.94	.0027227	.0027213	.0026677	.0026660
.69	.0023379	.0023016	.0020906	.0020452	.95	.0027405	.0027396	.0026945	.0026933
.70	.0023510	.0023170	.0021103	.0020678	.96	.0027585	.0027579	.0027215	.0027208
.71	.0023643	.0023326	.0021302	.0020905	.97	.0027768	.0027764	.0027489	.0027484
.72	.0023778	.0023482	.0021505	.0021135	.98	.0027952	.0027950	.0027765	.0027763
.73	.0023915	.0023640	.0021710	.0021366	.99	.0028138	.0028137	.0028044	.0028043
.74	.0024054	.0023799	.0021918	.0021599	1.00	.0028326	.0028326	.0028326	.0028326
.75	.0024195	.0023959	.0022129	.0021834					

Divide the head by the bung-diameter, and opposite the quotient in the column H, and under its proper variety, is the tabular number for unity. Multiply the tabular number by the square of the bung-diameter of the given Cask, and by its length, the product equals its capacity in Imperial gallons.

Required the number of gallons in a Cask (1*st variety*), 24 inches head-diameter, 32 bung-diameter, and 4) [sic] inches in length.

32) 24.0 (.75 see Table for tabular No.
.0024195 tabular No. for unity.
32 × 32 is 1024 square of bung-diam.

96780
48390
24195

2.4775680
40 inches long.

99.1027200 Imperial gallons.
1.2

1982054400
991027200

118.92326400 United States gallons.

NOTE.—Multiplying Imperial gallons by one and two-tenths (1.2) will convert them into U. S. gallons; and U. S. gallons, multiplied by .833, equal Imperial gallons.

To Ullage, or find the Contents in Gallons of a Cask partly filled.

To find the contents of the occupied part of a lying cask in gallons.

RULE.—Divide the depth of the liquid, or wet inches, by the bung-diameter, and if the quotient is under .5, deduct from the quotient *one-fourth* of what it is less than .5, and multiply the remainder by the whole capacity of the cask; this product will be the number of gallons in the cask. But if the quotient exceeds .5, add *one-fourth* of that excess to the quotient, and multiply the sum by the whole capacity of the cask; this product will be the number of gallons.

EXAMPLE 1. Suppose the bung-diameter of a cask, on its bilge, is 32 inches, and the whole contents of the cask 118.80 U. S. standard gallons; required the ullage of 15 wet inches.

32) 15.00 (.46875   .5   .46875   .03125 — 4   .0078125   .46875 − .0078125   .4609375 × 118.80   54.759375 U. S. gallons.

EXAMPLE 2.—Required the ullage of 17 wet inches in a cask of the above capacity.

32) 17.00 (.53125 — .5 = .03125 ÷ 4 = .0078125 + .53125 = .5390625 × 118.80 = 64.040625 U. S. gallons.

PROOF.—64.040625 + 51.759375 = 118.80 gallons.

To find the ullage of a filled part of a standing cask in gallons.

RULE.—Divide the depth of the liquid, or wet inches, by the length of the cask; then, if the quotient is less than 5, deduct from the quotient *one-tenth* of what it is less than .5, and multiply the remainder by the whole capacity of the cask; this product will be the number of gallons. But if the quotient exceeds .5, add *one-tenth* of that excess to the quotient, and multiply the sum by the whole capacity of the cask; this product will be the ullage, or contents in U. S. standard gallons.

EXAMPLE.—Suppose a cask, 40 inches in length, and the capacity 118.80 gallons, as above; required the ullage of 21 wet inches.

40) 21.000 (525 — .5 = .025 ÷ 10 = .0025 + .525 = .5275 × 118.80 = 62.667 U. S. gallons.

NOTE.—Formerly the British wine and ale gallon measures were similar to those now used in the United States and British Colonies.

The following Tables exhibit the comparative value between the United States and the present British measures:

U. S. measure for wine, spirits, &c.			British (Im.) measure. galls.	qts.	pts.	gills.
42 gallons	= 1 tierce	=	34	3	1	3
63	= 1 hogshead	=	52	1	1	3
126	= 1 pipe	=	104	3	1	3
252	= 1 tun	=	209	3	1	2

U. S. measure for ale and beer.			British (Im.) measure. galls	qts.	pts.	gills.
9 gallons	= 1 firkin	=	9	0	1	1
36	= 1 barrel	=	36	2	0	3
54	= 1 hogshead	=	54	3	1	1
108	= 1 butt	=	109	3	0	3

To convert Imperial gallons into United States wine gallons, multiply the Imperial by 1.2. To convert U. S. gallons into Imperial, multiply the U. S. wine gallons by .833.

Sixty U. S. ale gallons equal 61 Imperial gallons, therefore to convert one into the other add or deduct 1-60th.

Ploughing.

Table showing the distance travelled by a horse in ploughing an acre of land; also the quantity of land worked in a day, at the rate of 16 and 18 miles per day of 9 hours.

B'dth of furrow slice.	Space travel-ed in plough-ing an acre	Extent plough'd per day.		B'dth of furrow slice.	Space travel-ed in plough-ing an acre.	Extent plough'd per day.	
Inches.	Miles.	18 miles	16 miles	Inches.	Miles.	18 miles	16 miles
7	14 1-2	1 1-4	1 1-8	14	7	2 1-2	2 1-4
8	12 1-2	1 1-2	1 1-4	15	6 1-2	2 3-4	2 2-5
9	11	1 3-5	1 1-2	16	6 1-6	2 9-10	2 3-5
10	9 9-10	1 4-5	1 3-5	17	5 3-4	3 1-10	2 3-4
11	9	2	1 3-4	18	5 1-2	3 1-4	2 9-10
12	8 1-4	2 1-5	1 9-10	19	5 1-4	3 1-2	3 1-10
13	7 1-2	2 1-3	2 1-10	20	4 9-10	3 3-5	3 1-4

Planting.

Table showing the number of plants required for one acre of land, from one foot to twenty-one feet distance from plant to plant.

Feet distance.	No of hills.	Feet distance.	No. of hills.	Feet distance.	No. of hills.	Feet distance.	No of hills	Feet distance.	No. of hills.
1	43,560	4	2,722	7	889	10	436	17	151
1½	19,360	4½	2,151	7½	775	10½	361	18	135
2	10,890	5	1,712	8	680	12	302	20	108
2½	6,969	5½	1,410	8½	602	14	223	21	99
3	4,840	6	1,210	9	538	15	193	25	69
3½	3,556	6½	1,031	9½	482	16	174	30	48

Weight of a Cord of Wood.

Table of the weight of a cord of different kinds of dry wood, and the comparative value per cord.

A Cord of	Hickory	4469	pounds	Carbon	100
"	Maple	2863	"	"	54
"	White Birch	2369	"	"	48
"	" Beech	3236	"	"	65
"	" Ash	3450	"	"	77
"	Pitch Pine	1904	"	"	43
"	White Pine	1868	"	"	42
"	Lombardy Poplar	1771	"	"	40
"	White Oak	3821	"	"	81
"	Yellow Oak	2919	"	"	60
"	Red Oak	3254	"	"	69

NOTE.—Nearly one-half of the weight of a growing oak-tree consists of sap. Ordinary dry wood contains about one-fourth of its weight in water.

Charcoal.

Oak, maple, beech, and chestnut make the best quality. Between 15 and 17 per cent. of coal can be obtained when the wood is properly burned. A bushel of coal from hard wood weighs between 29 and 31 lbs , and from pine between 28 and 30 lbs.

Wonders of the American Continent.

The greatest cataract in the world is the Falls of Niagara, where the water from the great upper lakes forms a river three-fourths of a mile in width, and then, being suddenly contracted, plunges over rocks in two columns to the depth of 175 feet. The greatest cave in the world is the Mammoth Cave of Kentucky, where anyone can make a voyage on the waters of a subterranean river, and catch fish without eyes. The greatest river in the world is the Mississippi, 4,000 miles long. The largest valley in the world is the valley of the Mississippi. It contains 5,000,000 square miles, and is one of the most fertile regions of the globe. The greatest city park in the world is in Philadelphia. It contains 2,700 acres. The greatest grain port in the world is Chicago. The largest lake in the world is Lake Superior, which is truly an inland sea, being 430 miles long and 1,000 feet deep. The longest railroad at present is the Pacific Railroad, over 3,000 miles in length. The greatest mass of solid iron in the world is the Pilot Knob of Missouri. It is 250 feet high and two miles in circuit. The best specimen of Grecian architecture in the world is the Girard College for Orphans, Philadelphia. The largest aqueduct in the world is the Croton Aqueduct, New York. Its length is 40½ miles, and it cost $12,500,000. The largest deposits of anthracite coal in the world are in Pennsylvania, the mines of which supply the market with millions of tons annually, and appear to be inexhaustible.

Excellent Interest Rules.

For finding the interest on any principal for any number of days. The answer in each case being in cents, separate the two right-hand figures of the answer to express it in dollars and cents.

Five per cent.—Multiply by the number of days, and divide by 72.

Six per cent.—Multiply by the number of days, separate the right-hand figure, and divide by six.

Eight per cent.—Multiply by the number of days, and divide by 45.

Nine per cent.—Multiply by the number of days, separate the right-hand figure, and divide by 4.

Ten per cent.—Multiply by the number of days, and divide by 35.

Twelve per cent.—Multiply by the number of days, separate the right-hand figure, and divide by 3.

Fifteen per cent.—Multiply by the number of days, and divide by 24.

Eighteen per cent.—Multiply by the number of days, separate the right-hand figure, and divide by 2.

Twenty per cent.—Multiply by the number of days, and divide by 18.

BELTING.

While the use of belts for the transmission of power is not an American invention, the numerous improvements made in this country have caused it to be known in Europe as the American system. In Europe the greater part of the power is transmitted by cog-wheels, but in this country 99 per cent. is transmitted by belting. The latter is used everywhere, from the sewing-machine to the 500 horse-power engine.

Belts can be run in any way, at any angle, of any length, and at any speed, and can be put up by any one of ordinary skill. They can be made of any flexible material—leather, rubber, gutta-percha, or cloth; yet while so handy and so popular, they have one fault, they are not positive. If the motor makes a certain number of revolutions, a portion of them are lost with every belt used. This is the only fault of the system. It is noiseless, yielding, and regular, but, unlike cog-wheels, it is not positive. The number of revolutions that are lost may, and do, vary continually by changes of the load, or the atmosphere.

Belts derive their power to transmit motion from the friction between the surface of the belt and the pulley, and from nothing else, and are governed by the same laws as in friction between flat surfaces. The friction increases regularly with the pressure. The great difference often observed in the friction of belts is due simply to their elasticity of surface; that is, the more elastic the surface, the greater the friction.

In taking power from any source of motion there are two points which control us; all the others we can control and modify to a certain extent. Ordinary belts will sustain safely a working tension of 45 pounds per inch in width. The rule to determine the width of belt and size of pulley required to transmit a given horse-power is easily found; since a horse-power is 33,000 pounds, raised one foot high per minute, we must adjust the width and velocity of belts so as to effect the required result. Thus, if the belt moves with the velocity of 733 feet per minute, a belt five inches wide will transmit five horse-power, provided the effective tension is 45 pounds per inch. If the velocity be increased to 1,466 feet per minute, the same belt, with the same tension, will transmit ten horse-power. So that a five-inch belt applied to a five-foot pulley, making 120 revolutions per minute, would transmit ten horse-power, when the effective tension is 225 pounds.

By taking the actual effective tension of the belt, and multiplying it by the actual velocity, we get what may be called the indicated horse-power of the belt, which corresponds to the indicated horse-power of the engine. And, finally, by measuring the actual power transmitted, which may be done by means of a dynamometer, we can get the actual power transmitted. Rules based upon the amount of belt surface in contact with the pulley, and on similar data, cannot be made to give reliable results. For practical purposes, velocity and power to resist tension are the only available elements of the calculation. Actual tension, adhesion, friction, etc., can all be varied at will, and consequently form no certain dependence for the calculations of the machinist and engineer.

On the scientific principle that the adhesion, and consequently the capability, of leather belts to transmit power from motors to machines, is in proportion to the pressure of the actual weight of the leather on the surface of the pulley, it is manifest that, as longer belts have more weight than shorter ones, and that broader belts of the same length have more weight than narrower ones, it may be adopted as a rule that the adhesion and capabilty of belts to transmit power is in the ratio of their relative lengths and breadths. A belt of double the length or breadth of another, under the same circumstances, will transmit more than double the power. For this reason it is desirable to use long belts. By doubling the velocity of the same belt its effectual capability for transmitting power is also doubled.

Good stock is the first requirement of a belt, which, if spongy, will not meet that demand. It must be firm, but pliable; the grain or hair side should be free from wrinkles; the stock should show no inequalities in dressing, but be of an even thickness throughout; the splices should be mathematically true, and if rivets are employed they should be inserted on the hair side, and the burrs sent home before riveting; the edges should be parallel and perfectly straight. In handling a belt examine it carefully, double it up the hair side out, and press it together. If it crack under this treatment it should be rejected, as rational use of a belt consists in utilizing the whole amount of power it will transmit.

Belts are sometimes used having a transmitting power of double the capacity necessary where they are employed, while quite as often they are much too narrow for the work required of them The first instance shows a useless waste of material, the latter poor economy, for, in order that it may perform the work required, it is necessary frequently to take it up, as a result of which the weak points succumb to the strain and it is torn asunder, or, if not, the shaft is likely to be drawn out of line, or the bearing overheated.

In using a new Belt a few days, if it present a mottled appearance on the side next to the pulleys, it may be set down that it is not furnishing the full capacity of its power. The spots referred to indicate that certain portions of the belt do not touch the pulley, and that its entire transmitting power is not utilized.

If the face of the pulley is true, and the belt as nearly perfect as possible, the defect may be remedied by the judicious application of rendered tallow and fish oil, two parts of tallow to one of oil, melted, and allowed to cool. A new belt should be used a day or two before it is oiled, and frequent applications of small quantities are better than too liberal oiling at long intervals.

If a belt of the proper size for the work it has to do, slip on the pulley, it is caused by the centrifugal force, which tends to throw it outward; a corresponding degree of tension will check the defect.

Belts should be put on by a person acquainted with their use, as the wear of the belt depends considerably on the manner in which it was put on. Therefore the following suggestions, if practised, will be of much service to persons employed in this capacity. The ends to be joined should be cut perfectly square, in order that one side may not be drawn tighter than the other. Good lace leather, if properly used, will give better satisfaction than any patent fastening.

Where Belts run vertically they should always be drawn moderately tight, or the weight of the belt will not allow it to adhere closely to the lower pulley, but in all other cases they should be slack. In many instances the tearing out of the lace holes is unjustly attributed to poor belting, when in reality the fault lies in having a belt too short, and trying to force it together by lacing; and the more the leather is stretched while being manufactured, the more liable it is to be complained of.

To obtain the greatest amount of power from belts, the pulleys should be covered with leather; this will allow the belts to be run very slack, and give 25 per cent. more wear.

More power can be obtained from using the grain side of a belt to the pulley than from the flesh side, as the belt adheres more closely to the pulley; but it should be remembered that the belts will not last quite so long, for when the grain, which is very thin, is worn off, the substance of the belt is gone.

Double Leather Belts are frequently used, but it is clearly a mistake, as a single leather one will transmit more of the power than a double one. Double leather belts run straighter than single ones, as the flank side of one part can be put against the back of the other. A double leather belt will stand a greater tension than a single one, but a single belt will stand all that should be put upon any belt.

In cases where a belt is incapable of transmitting the required amount of power, and circumstances preclude the possibility of substituting a wider one, the difficulty may be overcome by using two belts of the same width, one on the top of the other. Two belts run in this way will transmit nearly as much power as one belt the width of the two.

How to test the quality of Leather for Belting. Cut a small strip of the leather about one-sixteenth of an inch in thickness, and place it in strong vinegar. If the leather has been thoroughly tanned and is of good quality, it will remain for months even, immersed, without alteration, simply becoming a little darker in color. But, on the contrary, if not thoroughly tanned, the fibres will quickly swell, and after a short period become transformed into a gelatinous mass.

How to make Belts run on the centre of pulleys.—It is a common occurrence for belts to run on one side of the pulleys. This arises from one or two causes. 1. One or both of the pulleys may be conical, and of course the belt will run on the higher side. The most effectual remedy for this would be to straighten the face of the pulleys. 2. The shafts may not be parallel, or exactly in line. In this case the belt would incline off to the side where the ends of the shafts come the nearest together. The remedy in this case would be to slacken up on the hanger bolts, and drive the hangers out or in, as the case may be, until both ends of the shafts become parallel. This can be determined by getting the centres of the shafts at both ends by means of a long lath or a light strip of board.

Tighteners.—The tighteners should be placed as close to the large or driving pulley as circumstances will permit, as the loss of power incurred by the use of the tightener is equal to that required to bend the belt and carry the tightening pulley. Consequently there is a greater loss of power by placing it near the small pulley, as the belt is required to be bent more than when it is placed near the large one.

The reason why belts run to the highest side of a pulley is due in part to a centrifugal force, and also to the fact that the part of a belt nearest to the highest part of a rounded pulley is more rapidly drawn because the circumference of the pulley is greater at that point.

Rubber and Leather Belts.—Rubber belts will transmit nearly as much power as leather belts with the same tension; and they have this advantage, that they may be made of any length, width, or thickness, and yet always run straight, providing the pulleys are in line. Besides, their first cost is much less than those of leather, but they will not last over half as long. They cannot be run in situations where the belt rubs, nor as cross-belts, or through forks, as shifting belts, and when they give out it is almost impossible to repair them.

If a Rubber Belt runs off and becomes entangled in the machinery, ten chances to one that it will be completely ruined, whereas a leather belt, under like circumstances, will sustain very little injury. When saturated with oil they soon rot, and when situated in cold damp places they are liable to freeze, which has a tendency to separate the different thicknesses and ruin the belt; besides, they often freeze to the face of pulleys when standing still, and when started up the gum facing is torn off, which ruins the belt.

A Leather Belt, if made of good stock, not overstrained and properly treated, will last for twenty years. When partly worn out it may be cut and used over again for a narrower or shorter belt; and when entirely unfit for the transmission of power it may be used for different purposes around a factory, but when rubber belts are worn out they are of no value whatever.

To prevent Accidents by shafts revolving within reach of operatives' garments in mills and factories.—Cover the shaft with a loose sleeve of sheet tin or zinc, and insert a rim of thick gum or leather at each end to prevent rattling. Should it become entangled with the garments of any of the operatives the resistance will cause the sleeve to stand still while the shaft is rotating within it, by which means the person may be extricated and accident averted.

Rule for finding the Length of Belt wanted.—Add the diameters of the pulleys together, divide the sum by 2, and multiply the quotient by 3¼. Add the product to twice the distance between the centres of the shafts, and the sum will be the length required.

Rule for finding the Width of Belt to transmit a given Horse-Power.—Multiply 36,000 by the number of horse-power. Multiply the speed of the belt in feet per minute by one-half the length in inches of belt in contact with smaller pulley. Divide the first product by the second; the quotient will be the required width in inches.

Rule for calculating the Number of Horse-Power a Belt will transmit, its velocity, and the number of square inches in contact with the smaller pulley being given.—Divide the number of square inches in contact with the pulley by 2; multiply this quotient by the velocity of the belt in feet per minute, and divide by 36,000. The quotient is the number of horse-power the belt will transmit.

Another Rule.—Divide the number of square inches of belt in contact with the pulley by 2; multiply this quotient by the velocity of the belt in feet per minute; divide this amount by 32,000, and the quotient will be the number of horse-power.

Rule for finding the change required in the length of a belt when one of the pulleys on which it runs is changed for one of a different size.—Take three times the difference between the diameters of the pulleys and divide by 2. The result will be the length of belt to cut out or put in.

How to measure a Coil of Belting.—Add the diameter of the hole in inches to the outside diameter of the roll; multiply by the number of coils in the roll; then multiply this by the decimal .1309, and the product will be the number of feet in the roll. To have the exact length, the average diameter must be used, if the roll is not perfectly round, and fractional parts of an inch must not be omitted in the calculation.

How to put on a Belt.—Never place a belt on the pulley in motion; always place it first on the loose pulley, or the pulley at rest; then run it on the pulley in motion. If the belt is very heavy, and the pulleys run at a very high speed, it is advisable to slack on the speed of the engine; but when this is impracticable or inconvenient, care must be taken to mount the belt on the exact face. The person engaged in so doing must have a firm footing, and prevent his clothes from getting in contact either with the belt or pulley. Where the belt is heavy, and the location such that it is impossible to get a solid footing and exert strength in running on the belt, it is best to stop the engine and mount the belt on the pulley as far as possible. Then take a small rope, double it, slip one end through the arms and around the belt and rim of the pulley, and the other end through the loop formed by the double of the rope; then stand on the floor on the opposite side and draw on the rope, when the belt will be hugged to the periphery of the pulley. When motion is communicated it may be slipped on without any trouble, while, by letting go the end of the rope when the belt is on the pulley, the noose will be undone and the rope thrown off.

MOULDING AND FOUNDING.

The crude iron of the blast-furnace is variously disposed of: the larger portion is applied to the manufacture of malleable iron, while the remainder is converted direct into innumerable articles formed of cast iron. Occasionally, the smelter carries on the founding business also; in which case, castings are frequently made by running the molten iron direct from the blast-furnace into moulds. At other times, the crude iron is run into pigs or bars of convenient size, allowed to cool, and then charged into other furnaces for remelting. This plan affords facilities for examining the quality of each piece charged, and is followed whenever great soundness is required in the castings,—as in the case of heavy girders, beams, and frame-work of engines; for hydraulic rams, and similar works requiring undoubted strength.

The remelting furnaces are of two descriptions; technically, they are distinguished as "air-furnaces" and "cupolas." The former are large reverbatory furnaces, built of fire-brick, having a fire-grate at one end, from whence the products of combustion pass over the charge on to the flue. The floor of the central part is made sloping to the divisional bridge. At its highest part, the charge of pigs is laid, and subjected to the intense heat reflected from the fire-place and roof, until fused; when it flows over the refractory sand bottom to the hearth. The draught is maintained by a lofty chimney, bound with iron hoops, and furnished with a regulating damper at top.

The dimensions of the furnaces are proportioned to the magnitude of the work generally performed in them, namely—from 3 to 10 tons at a casting; which is the common range of their capacity. Doors are provided on one side for charging the pig-iron and supplying the fuel; and on the opposite side is a similar opening for tapping the molten iron into the foundry. In consequence of the intense heat to which the brick-work of the furnace is subjected, a system of strong plate and bolt binding is adopted to retain the erection in position.

The cupola is a blast-furnace of small size, in which the intense heat necessary for fusion is maintained by a fan or other blast. The interior dimensions measure from 18 inches to 3 or 4 feet in diameter, and 6 to 10 or 12 feet in height. It is commonly made of iron plates, bolted together, and lined inside with the best fire-brick, to a thickness of 9 or 10 inches. The blast (cold) is supplied through one or two tuyeres, which, for facility of operating on variable quantities of iron, are so made that they can be inserted at different heights of the furnace. At the bottom, on the side adjoining the foundry, an opening is left for tapping the metal and removing any cinder or other matter adhering to the sides.

Each of these remelting furnaces possesses certain advantages of its own. The air-furnace is preferred where toughness and a homogeneous structure are required; the slight decarbonating influence of the reverberating column of carbonic acid and other products of combustion from the fire-place, appears favorable to a retention of strength. The iron so treated can be filed and chipped, and otherwise cut to shape, with great facility. It contracts less, and with greater regularity, than iron otherwise treated.

Cupolas are less expensive to erect where a supply of blast can be obtained cheaply; and for many operations are extremely useful. Small quantities of iron may be advantageously fused and by means of ladles conveyed simultaneously to several parts of the foundry. Castings from cupolas, however, are weaker, and less to be depended on, than those from air-furnaces In consequence, also, of the carbonizing action of the blast on the metal in the furnace, the castings produced are generally very hard, difficult to cut, and disposed to fly (break spontaneously, through unequal contraction) whilst cooling; and even afterward, danger is to be apprehended from sudden changes of temperature. The tensile strength is inferior, and probably arises from partial disruption of the cohesion, through unequal contraction in cooling.

By the founder, iron castings are distinguished as open sand, green sand, dry sand, loam, or chilled castings, according to the mode of moulding. Occasionally a complex piece embraces two, or even all five methods. The *open sand* method is adapted for rough articles, such as flooring-plates, and other castings in which one side is permitted to be uneven. *Green sand moulding* is largely practised in the production of stove fronts, pans, small pipes, and the innumerable small articles of commerce, plain and ornamented, of cast-iron. *Dry sand* is applied to large pipes, engine and mill work, to girders, and other large castings requiring great strength. *Loam* is a modification of the dry sand method, and is principally applied to large circular castings, such as cylinders and wheels. *Chilled castings* are those cast in thick iron moulds instead of sand: the surface of the metal in contact with the cold iron is rendered extremely hard, in consequence of the sudden manner in which it is cooled. It is much used for axle-boxes, rollers for coffee and sugar-mills, and all purposes requiring great hardness, and capacity for resisting abrasion.

Open sand moulding.—Moulding in open sand is the simplest mode, and requires comparatively little skill. An exact model of the intended casting is made in white deal wood, and placed in an excavation in the damp sand floor of the moulding-bed, the top level with the floor line. Having carefully levelled the model with a T level, the moulder proceeds to ram the sand tightly round it in small quantities at a time, with the large end of a tamping-bar. The sand, placed in contact with the model, is selected with care, and sifted to separate any particles of iron. On attaining the level of the model, the tamping is discontinued, and the sand at the top carefully smoothed with a small trowel; to strengthen the edges in contact with the model, a few drops of water are sprinkled over the sand. With a large iron wire, curved so as to pass under the model without touching it, the moulder pierces the sand all around several times; the model is now taken out, for which purpose an iron spike is screwed into the top, and repeatedly struck lightly, to loosen it from the sand, when the moulder carefully draws it up. To facilitate its removal, it is made rather larger above than beneath, and the adhesion of sand partially prevented by singeing the surface of the wood. In the event of any portion of the sand having been detached in the act of removing the model, the damage is repaired with a little fine sand, worked with the trowel. The interior is then dusted over with some burnt sand from previous castings, or charcoal dust sifted through a horse-hair sieve. If very deep for an open sand casting, the edges of the mould are prevented from rising by a series of heavy weights, disposed wherever there is space. Shallow castings have the edges of the mould protected by thin plates: in all cases care is taken, by weights or sprigs, that the pressure of the molten metal shall not lift up the sand wall. From the top of the mould, previous to withdrawing the model, a small canal is made in the sand-bed leading to the smelting-furnace or to a small pit, into which the metal is poured from a ladle. The communication with the mould is closed by a small iron gate-plate, loamed over to prevent the adhesion of the iron until casting time. If the casting be deep, the canal is continued to the bottom of the model by a small bore-hole, at a few inches distance from the body of the intended casting. Large castings require two or more branches to the canal, to convey the iron to different parts of the mould simultaneously.

The filling of the mould demands great attention, and requires to be done as rapidly as may be practicable. If the metal is run direct from a furnace, it is brought simultaneously to the several gates, and allowed to flow into the different parts of the mould in nearly the same volume. The sprinkling of a few drops of metal around the air-holes left by the wire produces a slight explosion, through ignition of the inflammable gases arising from them. These continue to burn so long as the outside of the metal possesses the property of decomposing water.

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The molten iron is carefully skimmed from time to time, and any oxidized matter removed from the surface. If, at the termination of the running, the mould appears to be filling unequally, the defect is remedied by the adjacent stop-gates being opened or shut, as the circumstances may require. The molten iron is never poured direct from a vessel into the mould; but in a mould partly filled, it is sometimes allowed to flow direct from the ladle. The running finished, the surface of the metal is usually sprinkled with a little dry sand, and the casting left in its bed until sufficiently cold for removal.

If soundness is required, no casting of any kind should be removed until cooled down throughout to within a few degrees of the atmosphere; and in the case of open-run castings, a thick covering of sand should be applied to retain the heat. If removed too soon after casting, the piece is irreparably weakened, if not fractured and lost. Want of room in a confined foundry is commonly adduced as a reason for turning out the work as soon as it has solidified; but a desire to turn out more work than the foundry is capable of producing, is perhaps nearer the mark. From whatever cause it may arise, it is too evident that many disastrous accidents have arisen from the breakage of girders and mill machinery, resulting solely from inattention to this point, thus occasioning great mistrust in cast iron as a material of construction, and lowering its commercial value.

Green sand castings differ from open sand, in being covered with the half of a box during the process of casting.

The green sand of the founder is an argillaceous sand, in the state in which it is raised from the gravel-pit, having been first sifted through a fine wire sieve, carefully mixed with about one-twelfth of its volume of finely powdered coal, and slightly moistened with water; in this state it retains the exact form of any object impressed on it. This mixture can only be used once for the formation of moulds, being afterward employed for filling up. In order to obtain the form of the pattern, the moulder takes a cast-iron frame, which is filled with sand and closely rammed. Taking the pattern from which the casting is to be made, the workman scratches on the smooth surface of the sand, and in the centre of the iron frame, a rough resemblance of the model, which is imbedded into the sand to one-half of its thickness; it is then sprinkled over with charcoal dust.

A counterpart of the cast-iron frame is now filled in a similar manner with sand closely packed, dusted over, also with charcoal dust, and placed upon the model; by this process a mould of the other half is impressed upon it, the charcoal dust preventing any adhesion between the two parts of the frame. The upper frame is now carefully raised, and the model removed from the lower frame, any slight imperfection in the mould being repaired by the use of a little moistened sand and a small trowel shaped for the purpose. The two parts of the frame are now joined together by means of corresponding pins and holes, and a cavity remains of the form of the required casting.

Small articles also have a bottom box, and, if of a complex form, may require several boxes for their complete formation. Pulleys, for instance, require a three-part box—a top, middle, and bottom. The moulding boxes, whether for green or dry sand, are made of cast iron, with cross ribs, wherever the nature of the model permits, for holding the damped sand. The separate parts are made to fit each other accurately by taper pins, through which keys are driven to bind the several parts firmly together during the operations of moulding and casting. If the several parts of the box are large, requiring the assistance of a crane for handling, each part is furnished with trunnions, on which it is turned over, and its under side dressed up by the moulder. The filling of the mould is conducted in much the same manner as with open castings, a suitable jet being left for the escape of confined air.

The moulding of pulleys, as requiring a three-part box, very well exemplifies the principles of the art. The model of the pulley is made in two halves, fitting each other with suitable drilling pins. If several are to be cast from the same model, a cast-iron one is commonly made from a wood pattern, and subsequently fitted to remove any asperities on the surface. In the bottom part of the box the lower side of one-half of the model is moulded, all superfluous sand removed, the exposed portions carefully smoothed over, and fine charcoal dusted over it. The upper half of the model is fitted on, and the middle part of the box clamped down. In this portion of the box the hollow edge of the pulley is moulded. The sand is again smoothed down, and the surface dusted preparatory to re-covering the top part of the box. This is placed on the middle part, and the upper side of the pulley moulded in it. Having left an orifice for the entrance of the metal, and another for the escape of the air, the top part is lifted off, with the upper half of the model adhering to it. The middle part is next lifted off; this is a mere ring of sand, filling up the hollow periphery of the pulley. After removing the halves of the model, the parts of the box are replaced, preparatory to casting. The charcoal dust prevents the sand in one part from adhering to that in the others.

Dry sand castings are usually prepared in boxes similar to those used by green sand moulders. This is more especially needful where a great weight of metal is to be cast in moulds made of this material. Dry sand is generally used without any admixture of coal dust. Castings made in this material are less liable to imperfections and air-holes than those prepared in ordinary green sand moulds, its porous nature permitting of a freer escape of the gases, while there is less chance of its chilling in the mould from the baking process which it undergoes before introducing the metal.

In all casting processes, much of the success of the operation depends on the skilful manipulation of the moulder; on him must depend the adjustment of the mould, and the weight of the metal with which it is charged, the due admixture of the materials, with that degree of porousness necessary for the escape of the gases as they are generated by the fluid metal.

When complete, the several parts of the box are taken separately to a large oven, or drying-stove, and thoroughly dried, to expel all moisture from the sand. Afterward the interior of the mould is blackened with thick washes of ground charcoal or coke, worked up with water to a proper consistence. It is again dried, and the several parts adjusted to each other. If the box seems to require strengthening before the performance of casting, it is sunk in the sand, level with the floor of the foundry, and on the upper part are laid several heavy weights, supplemental to the side keys, in keeping the structure rigidly together under the pressure of the liquid iron.

Several peculiar configurations of cast iron, also such holes as as may be required in the castings, whether large or small, are formed with cores, or loose pieces of sand, strengthened wherever necessary by internal iron bars and frames. These cores are made by tightly ramming the best sand in iron or wooden boxes of the required shape, and then placing them in the stove to dry; subsequently they are blackened, and treated as the other parts of the mould. By means of a system of hollow and solid cores, all castings, whatever be their configuration, may be made with comparative facility; and not unfrequently pieces, the construction of which would seem to involve difficulties, are made with only a few core-boxes and a plain model.

Loam moulding differs from the other methods, inasmuch as no models, or core-boxes, are used; but the moulds are made directly from drawings of the objects to be produced. The mould is made of a mixture of clay, water, sand, and cow-hair, which is first reduced to a paste, and thoroughly kneaded in a pug-mill. This mass is made to assume the required form by the use of various instruments; the proportions of the various ingredients being changed to suit different purposes. The preparation of the loam mould is frequently a difficult process, requiring a skilful moulder, as he is sometimes required to shape and mould very complicated forms with only his eye to regulate his tools. The profile of the circumference of the required casting is cut on a stout board, and attached at the requisite radius to a rigid iron spindle, which freely turns, vertically, on suitable bearings. The mould for a large cylinder, for instance, is commenced at the bottom of a dry pit in the foundry, by laying a course of brick-ends on the loamed bottom to the reach of the sweep-board, and covering their upper surface and face with a layer of loam (sand worked up to the consistence of thin mortar, strengthened by some weak fibrous substance). The board is now swept around, removing any superfluous loam, and a second course of bricks laid on the first; loam is added; and in this manner a rough wall of the required height is built. The inside is well plastered with loam, which is wrought to the precise form by sweeping around the board, and finished with a coat of fine material. When the outside of the mould is complete, the board is taken out, and a grate with lighted fire suspended in it, to effect a thorough drying; subsequently it is blackened and again dried. The core is built in a similar manner, on a circular platform of the required size, which revolves while being built against a fixed loam-board.

Cores for pipes and smaller cylinders are built around a hollow cylindrical core-bar, pierced with numerous holes and open at the ends, with the exception of the space occupied by the trunnions. Around this cylindrical bar is laid a covering of hay or straw rope, and then the usual coating of loam, drying, and blackening. The gases generated in the casing of the core-bar escape through the small holes into the hollow cavity of the core-bar, and out at the ends, where they are ignited. The hay-bands freely allow of the pipe contracting in cooling, which it could not do around a solid substance, and permit of the ready withdrawal of the bar.

The moulding of a large gear-wheel may be taken as an illustration of the manner in which castings, partly in loam and partly in dry sand, are worked up. The moulding of a wheel with four arms is accomplished by loaming a level surface in the wheel-pit, and arranging, by means of a trammel working from the centre, a number of tooth-cores made in the core-box. The model teeth in this box are usually loose, and kept in their place by passing through mortises in each side; the two sides are kept together while tamping by clamps. Four arms are formed by the same number of moulds, while a third box forms the centre core. Great accuracy is required in the setting of the cores; and allowance has to be made for contraction of metal in cooling.

An inspection of the process will convey a correct idea of the way in which many moulds are built up at comparatively trifling expense; and it is to be borne in mind that the binding together of the several parts of the boxes and frames, by means of the taper-pins and cross-keys, previous to pouring in the molten metal, is an operation requiring great care on the part of the operator.

Liquid cast iron presses with a force exceeding one pound the square inch when the column is four inches high. Castings are frequently made and cast, with a column of liquid iron ten feet high; in which case, every inch of the mould exposed to this column has to resist a bursting pressure of more than thirty pounds, or about one-half the pressure to which high-pressure steam-boilers are subjected. Under such circumstances the boxes require to be of great strength, perfectly rigid, and bound together at short intervals with heavy iron bands, in addition to the pins and keys. In green-sand moulding, the column of metal is usually much less; but the surface extended horizontally demands nearly the same precautionary measures.

THE STRENGTH AND OTHER PROPERTIES OF CAST IRON.

The properties of iron of greatest importance in construction and mechanical engineering are—1, tenacity; 2, transverse strength; 3, power to resist impact; 4, power to resist fatigue; and 5, power to resist compressing or crushing forces: to these must be added, in the case of the founder and turner—5, fluidity; 6, hardness; and 7, texture. For special purposes, other qualities are sometimes sought after, but the foregoing comprise the essentials required in a good cast iron.

It is well known to founders and mechanical engineers, that the several qualities for which a given cast iron may be distinguished, are susceptible of considerable modification, improvement, and more marked development, by special treatment in the hands of the founder; and to smelters, that the general qualities of the original crude pig-iron are dependent, in great measure, on the chemical composition of the ores, fuels, and fluxes, and in the smelting-furnace: but with similar materials, the method of working the furnace, the temperature of the blast, the construction of the furnace itself, and various other causes, are found to exercise important influences. The crude iron of the blast-furnace, however, is rarely used for the formation of valuable castings, until it has undergone one or more remeltings; and the following remarks will apply only to iron which has been reworked in this manner.

The importance to the engineering profession, and to science generally, of an elaborate series of experiments on the qualities of cast iron, has been very generally felt for the last quarter of a century; but the time required for their prosecution, and the expense necessarily involved, have been too great for any private individual. Several engineering firms have made a few experiments on the metal as preliminary trials, previous to the execution of particular works; and the British Association for the Advancement of Science allotted a small sum of money for some limited experiments on form and application. More recently a commission was issued by Government to inquire into the application of iron to railway structures; but its labors were confined to testing the stability of a few railway bridges, and collecting the verbal opinions of engineers as to the merits of particular brands of pig-iron: the results of the inquiry were of little or no value to practical workers in the metal.

In the United States, the great difference observed in the strength and durability of cast-iron ordnance, apparently composed of equally good metal, led to the adoption of measures for ascertaining the cause of such difference. These measures were first applied about thirteen years since, and conducted out of the public revenue of the States by competent and highly painstaking officers of engineers: the results as published form the most complete and reliable record of experimental researches on the metal yet issued in any country; and contrasts most favorably with the manner in which similar researches are undertaken and conducted in England. From this work, and from private researches, will be collected, in a condensed form, a few of the principal known facts relating to the qualities of cast iron.

Tensile Strength of Cast Iron.

In all purposes to which cast iron is applied, tenacity is a quality of the first, if not of paramount, importance. Transverse strength, the next in the order of importance, is directly dependent on the tenacity of the metal. Hence, in all well-conducted researches into the qualities of pig-iron, tenacity takes precedence of the others. It is influenced by several causes, separately and combined; the chief of these, so far as yet ascertained, is—

Temperature of the Blast used in the Reduction of Cast Iron.

With the invention and application of the hot-blast, there arose a very general belief that the new process tended to largely deteriorate the tensile strength of the pig-iron produced. With the existing furnaces, however, the invention in one district effected such a considerable saving of coal in the furnace, that the generally inferior character of the iron prepared with it was controverted by the manufacturers. And at the present day the inferiority is very frequently ascribed by writers to the facilities which this invention affords of working up materials of a quality inferior to those capable of being reduced by a cold blast. Recent researches, however, have demonstrated that, with similar ores, fuel, and flux, the quality of hot-blast iron is greatly inferior to that of iron smelted with a cold-blast.

The experiments made for the British Association, with a view of settling this point, were the first of their kind publicly undertaken; and the results are subjoined:

		Tenacity in lbs. per sq. in.
Carron No. 2 quality pig-iron.	hot-blast,	13,505
" " "	cold "	16,683
" No. 3 quality pig-iron..........	hot "	17,755
" " "	cold "	14,200
Coed Talon No. 2 quality pig-iron	hot "	16,676
" " "	cold "	18,855
Bufferey No. 1 quality pig-iron	hot "	13,434
" " "	cold "	17,466

The number of pig-irons tested was sixteen; and it will be observed that, with one exception, the cold-blast irons are greatly superior to the hot. The single exceptional case led the experimenters to the conclusion that the lower qualities of iron were improved by the use of hot air to nearly the same extent as the higher qualities were deteriorated. This conclusion, however, was founded on a single experiment; and to have been of any value, a fresh portion of iron should have been taken and experimented on for corroboration of such a striking anomaly.

Previous to these experiments, the Low Moor Company —whose works in the Bradford district, well known for the superior quality of the iron produced in it, had been wrought entirely with cold-blast – adopted the new mode of smelting; but the reduction in quality was such that the cold-blast was resumed after a very brief trial. These and the other works in this district have since continued to use a cold-blast only. Experiments were made on the Low Moor irons as prepared by the two processes, and the following results obtained, the strength of cold-blast iron being taken as unity:

Mean breaking weight of cold-blast pig-iron	1.000
" " hot " "	.831

Subsequently experiments were made at the Dowlais Works on irons remelted in an air-furnace, also on others remelted in the cupola, with results nearly the same as those occurring at Low Moor, the relative strengths being:

Mean breaking weight of five bars of cold-blast iron,	1.000
" " " six bars of hot-blast iron,	.835

The discovery that a cold-blast of sufficient density could be successfully used in forcing furnaces using anthracite fuel, resulted in some comparative trials being made at the Ystalyfera works on irons prepared by the two processes. The result of a large number of experiments tended to establish the fact of a large deterioration occurring with the hot-blast irons, the relative strengths of the two irons being:

Anthracite iron, cold-blast	1.000
" " hot-blast	.802

These experiments, made on irons reduced from similar ores and under circumstances precisely equal, temperature of of blast excepted, must be held conclusive as far as regards the irons of that country. The experiments in the United States were made principally on charcoal irons; nevertheless, the results are even more unfavorable to the hot-blast irons. The diminution of tenacity which follows on the heating of the blast, is shown in the following statement of the effects produced on the American furnace iron:

	Tensile strength in lbs. per sq. in.
Blast cold	11,140
" heated to 150	12,243
" " 200°	12,970
" " 250°	11,420

This pig-iron was of No. 1 quality, and cast, for the purpose of experiment, into bars in the open-sand furnace-bed. The difference in the tensile strength of hot and cold blast iron from the same furnace was so great in several instances, that the officers engaged in the inquiry sought and obtained the most ample proof, that in every case the inferior metal had been produced from hot-blast iron. In the case of seventeen guns cast from hot-blast, eight failed to stand the proof. Experiments on the metal in three guns gave a density of 7.09 and a tenacity of 20,732 lbs. to the square inch. Similar experiments on guns cast at the same works several years previously, but from cold-blast iron gave a density of 7.185 and a tenacity of 25,246 lbs. to the square inch.

It is worthy of remark, also, as bearing out the opinion that the quality of English pig-iron has deteriorated within the last half century, that in an English gun imported into America in 1845 the cast iron was of a density of 7.04, and tensile strength of 18,145 lbs. to the square inch; while other English guns imported about thirty years previously contained metal of a density of 7.202, and tensile strength corresponding to 28,067 lbs. to the square inch.

The analyses made in the laboratory attached to the Pikesville Arsenal are singularly confirmatory of the unfavorable opinion respecting the hot-blast current, soon after its introduction. The results of numerous analyses, on irons prepared by the two processes, gave—

	Cold-blast.	Hot-blast.
Specific gravity	7 194	7.074
Tensile strength	26,859	18,993
Combined carbon	.0836	.0687
Graphite	.0476	.0600
Silicium	.0386	.0593
Slag	.0189	.0375
Phosphorus	.0228	.0185
Sulphur	.0014	.0010
Manganese	.1141	.0960
Earths	.0117	.0146
Silicium and carbon	.1219	.1281
Silicium and slag	.0575	.0938
Graphite and slag	.0665	.0975
Graphite, slag, and silicium	.1051	.1568
Graphite, slag, silicium, and phosphorus	.1280	.1753
Total carbon	.1312	.1287
Graphite, slag, silicium, phosphorus, sulphur, and earths	.1411	.1909

The result of the numerous experiments made in the United States on cast irons has been the entire rejection of hot-blast smelted iron as a material for constructing ordnance. It must not, however, be supposed that hot-blast iron is inapplicable, or inferior to cold-blast irons, for all purposes. Where great tensile strength is desired it should be carefully avoided; but under other circumstances, it may frequently be substituted for cold-blast iron with considerable advantage.

Remelting the crude iron has an important influence on its tensile properties. An improvement in quality is very generally observed on remelting the crude pig-iron of the blast-furnace in reverberatory furnaces. With founders this improvement is ascribed to the more homogeneous character of the iron so treated, over that of the original pig; but the author, in his large work, combated this opinion, and placed it to the credit of the refining of the iron which necessarily takes place at each remelting. The publication of the American experiments confirms this view of a mere remelting resulting in the production of a purer metal.

Crude pig-iron of the blast-furnace was taken and thrice remelted to observe the change of quality and increase of density produced; the results were:

	Density.	Tensile strength in lbs. per sq. in.
Crude pig iron	6,974	14,000
" " remelted once	7.090	20,900
" " " twice	7.229	30,229
" " " three times.	7.301	35,786

In a second series of experiments the improvement in quality, by remelting, was equally marked. The metal operated on was cold-blast charcoal pig-iron, cast in similar moulds and under similar conditions, the number of fusions alone excepted:

	Tensile strength in lbs. per sq. in.	Density.
Crude pig-iron	11,020	6.949
" " remelted	15,942	7.069
" " " twice.	35,846	7 327

In another case, the iron of third fusion attained a density of 7.304, and tensile strength of 45,970 pounds per square inch—the highest ever sustained by cast iron.

Experiments on a limited scale were made for the British Association by Mr. Fairbairn; and the results, though less marked than the American experiments, demonstrate the great advantages which may, in many instances, be derived from a mere remelting of the cast iron.

One ton of Eglinton hot-blast iron was operated on, and the proportion of flux and coke at each fusion accurately measured, so as to be alike at each. The iron was run into bars one inch square, and the trials were made on lengths of about four feet, supported at each end, and the weight applied in the centre gradually, until the bar broke: one bar was reserved at each trial, and the rest of the iron again remelted. This succession of remeltings and trials was repeated seventeen times, when the quantity of iron was too much reduced for a continuance of the experiments. The results obtained prove that cast iron increases in strength up to the twelfth melting, and that it then rapidly deteriorates. The commencing breaking-weight was 403 lbs., and this went on increasing until at the twelfth melting the breaking-weight was 725 lbs. At the thirteenth it was 671 lbs.;

at the fifteenth, 391 lbs.; at the sixteenth, 353 lbs.; and at the seventeenth melting the ultimate strength was 330 lbs.; or less than one-half of its maximum strength. After the fourteenth melting, the molecules of the metal, when fractured, appeared to have undergone a decided change. There was a bright band, like silver, on the edge of the bar, whilst the middle retained the ordinary crystalline fracture; and in the succeeding meltings, the metal was bright all over, resembling the fracture of cast steel.

Maintaining the iron in fusion for shorter or longer periods, is attended, in many instances, with a corresponding improvement in the textile strength of the product. By keeping it in fusion a longer period, the number of remeltings necessary to develop its maximum strength may be reduced. In the case of the Manchester experiments referred to, the iron was in comparatively small quantity, reduction to a molten state took place with great rapidity, and the process was completed in a very short period, the American experiments, on the other hand, were made on several tons of iron, in reverberatory furnaces; reduction to the liquid state took place more slowly, and the entire process lasted several hours. The gradual reduction, also, of the iron and its flowing to the hearth, exposed it to a prolonged decarbonization, and resulted in a corresponding greater purity, with fewer remeltings.

The improvement in quality obtained by keeping the iron in fusion for periods after deduction, is very well shown by the results obtained with the Stockbridge iron:

	Tensile strength in lbs. per sq. in.	Density
Iron twice remelted and cast on reduction to liquidity.	15,861	7.196
" maintained in fusion 1 hour	20,420	7.234
" " " 2 "	24,383	7.270
" " " 3 "	25,773	7.283

In other experiments the increase of density and tensile strength is equally great, and shows the wide field for improvement which the mere difference in mode of reduction and time of casting offers to the consideration of the practical founder.

	Tenacity.	Density.
Iron in fusion ½ hour	17,843	7.187
" " 1 "	20,127	7.217
" " 1½ "	24,387	7.250
" " 2 "	34,496	7.279

The several trials were made with the same charge of iron, but the metal for testing was withdrawn at the periods named. The composition of the original gray pig-iron doubtless influences, in a very great measure, the amount of improvement obtained with different periods of fusion. A refining of the iron takes place; and the quantity of alloyed matters oxidized and removed, will vary with the character of the pig-iron. Carbon is a principal ingredient in cast iron; and a long exposure, equally with repeated meltings, offers a ready method of burning it away. The reverberating column of gases in the remelting furnace, contains a portion of free oxygen, which combines with the carbon to form carbonic acid; but since the oxygen is in contact only with the surface of the metal, its removal requires numerous fusions, or the maintenance in fusion for a long period. Repeated fusions of the iron are attended with a heavy waste of material, which goes far to compensate for the increase of strength. In the experiments at Manchester, the maximum strength was attained only at the twelfth fusion, and then exceeded the original strength in the ratio of 725 to 403. This increase, however, was obtained by a waste in remelting of more than one-half of the iron originally charged; so that, in a commercial point of view, a casting of given strength prepared from iron remelted this number of times, will cost nearly twice as much as a similar casting prepared from the original crude iron.

By exposing the molten iron to the white-hot current of gases for a longer period, the improvement in strength is obtained with a comparatively small waste of material. Apparently, the forcing of air under the surface of the iron, so as to pervade the entire contents of the hearth, and react with great rapidity on the alloyed matters, would accomplish the refining and development of strength most completely; but in practice the reverse is found to follow this treatment. Combustion of a portion of the iron takes place; and the newly-formed oxide, remaining to a certain extent amongst the particles of iron, reduces its tenacity below that of the original crude iron. On the other hand, the exposure of the reduced iron to a current containing free oxygen results in the rapid deprivation of carbon, silicon, phosphorus, sulphur, &c.; the first in a gaseous combination, the rest in the slag produced in the process. The temperature of the molten mass in the hearth is unequal, and subject to slight variations; the result is the production of numerous slow currents, which successively bring the entire charge of metal under the refining influence of the passing current of gases.

Irons containing a large proportion of carbon, relatively to the other impurities, are most susceptible of improvement by treating in this manner. With other irons, prepared with a heavy burden of materials on the blast-furnace, the improvement is less striking, and is attended with a larger waste of metal through oxidation.

The rapidity and manner of cooling the casting directly influences the tensile strength of the metal. It is found that small castings, moulded in vertical dry-sand flasks, have a less tensile strength than large castings similarly moulded, and cast from the same charge of iron. The diminution of strength in the case of the small bars amounted to nearly five per cent. Tested transversely, however, the strength of the metal in the small casting was to that of the metal in the large as 1,145 to 1,000. This difference between the comparative tensile and transverse strengths of the iron from the two castings is easily explained. The rapid cooling of the small bar resulted in the skin attaining great hardness, and the metal to be in a state of tension. This, while it increased the transverse strength, reduced the ability of the iron to bear a direct tensile force. The large casting cooled slowly, in consequence of its great bulk; and the heat in the interior mass having to pass through the skin, produced a partial annealing of this portion. Softened in this manner, it was less able to bear a transverse strain; but the equal rate of contraction of the mass was favorable to the resistance of tensile force.

The tensile strength, as influenced by the size of the masses and rapidity of cooling, varies with the condition of the iron previous to casting. If the refining process, by lengthened fusion or numerous remeltings, be carried too far, the resulting product will be of a hard, brittle quality; and when cast into small articles, be chilled to that extent as to be incapable of working with steel cutting-tools. Cast into larger articles, however, and cooled more slowly, a maximum tenacity may be developed, and the texture of the iron be found of a character to bear cutting-tools on its surface.

Continuing the operation too long, also produces a thickening of the molten iron, until it is of too great a consistency for the proper filling of the mould, and the prevention of air cavities in the body of the casting. The burning away of the carbon is attended with a loss of fluidity; and this defect occurring, there is no remedy short of introducing further portions of the original crude iron, to restore by mixing a certain degree of fluidity. Thin castings, and others requiring great sharpness in the angles, can be successfully made only when the iron contains a large portion of the carbon contracted in the blast-furnace. Freedom from air cavities demands the employment of a similar metal.

Casting under a head, or considerable pressure of the fluid metal, is resorted to in very many instances, in order to obtain great solidity. The density of the metal is increased, attended with a corresponding augmentation of tensile strength. An experiment on the comparative density and tenacity of rough pigs cast horizontally, and a moulded bar cast vertically, gave the following results:

	Tenacity.	Density.
Rough pigs, cast horizontally	14,481	7.004
Bar, cast vertically	16,424	7.085

In all close-flask castings, the head of metal is required to be several inches above the highest point of the mould, or the perfect filling may not be insured. Rollers for mill machinery, and numerous other articles, are frequently cast with a vertical pressure of two or three feet of liquid metal above the most elevated part of the mould. The effects of atmospheric pressure on the surface of the liquid iron, while cooling, has been tried, and apparently produced a small improvement in the metal. Further experiments, however, are required to show the amount of each improvement under varying pressures of blast.

By the rapid cooling of castings through the intervention of water, the tensile strength of the metal may be nearly destroyed. The unequal rates of contraction which ensue, bring into play forces greater than the cohesive power of the metal is able to withstand. A similar result is frequently observed in the case of iron cylinders, cast in thick iron moulds, with the view of hardening the surface of the casting, especially if the metal is of a high quality. Fissures running nearly parallel with the axis of the cylinder are produced on its surface, and penetrate a short distance toward the centre. Their production is a result of the rapid cooling of the skin of the casting, through the absorption of caloric by the mass of cold iron composing the mould. With a slow and gradual cooling of the entire mass, the skin contracts equally with the rest; but in chilled castings it diminishes in diameter more rapidly than the interior of the incandescent iron, which is forced out of the mould through the head while yet effectively liquid; but immediately solidification commences in the interior, the skin is in a state of tension, and, at its then temperature, a direct severance in one or more places is inevitable. This fracturing of the skin occurs only with irons possessing more than ordinary hardness previous to fusion; but it is only with such that an extremely hard surface to the cylinder can be obtained. Hence, the greater the degree of hardness imparted to the iron, the greater the liability to rupture in cooling.

These considerations point to the important bearing which the manner of cooling has on the tensile strength of cast iron. The circumstance, that a very rapid cooling is frequently attended with a direct fracture of the metal before the casting has left the foundry, shows the very great attention which should be paid to this feature of the process. Unless great care be taken, the best pig-irons may be so weakened during cooling as to possess, in the finished casting, a tensile strength greatly below that of very inferior irons in other castings cooled on correct principles. Probably in a majority of castings the quality of of the original pig-iron has less to do with the ultimate strength of the piece than the mode in which the iron is treated during and after fusion.

When cast into large masses and slowly cooled, some time elapses before the molecules of the metal arrange themselves into the position offering the greatest resistance to tensile strain. The experiments made were confined to the testing, by repeated firing, of heavy ordnance, with various intervals of time between their manufacture and use. Pieces cast some years before testing stood several times the quantity of firing of other pieces cast but a few months previously. The tensile properties of the metal did not explain the difference; and the form, dimensions, weight, method of casting and cooling, and the manner of proving were the same in all the pieces tried. Further experiments on this remarkable property are required to show the several circumstances under which it is developed.

The tensile strength of many cast irons may be improved by adding to them, after fusion, but previous to flowing out of the remelting furnace, a quantity of wrought iron in a divided state. By this proceeding the strength of the iron may be increased to nearly fifty per cent. over that of the original pig. Since, however, the numerous experiments made in America have conclusively shown that remelting alone will produce a much greater improvement of quality, we must infer that the increase of quality placed to the use of malleable scrap really occurred from the remelting; and that by treating the iron to a prolonged fusion, greater strength would have been produced without the use of the scrap-iron.

Resistance of Cast Iron to Compression.

The force required to crush cylinders two and a half times their length, increases with the hardness of the iron, when the cooling has not permanently injured the structure of the iron.

No. 1 foundry iron	required a	force of	119,650	lbs. the sq. in.
Nos. 1 and 3 mixed	"	"	168,589	" "
Nos. 1 and 2 "	"	"	152,560	" "
Nos. 1, 2, and 3 mixed	"	"	160,803	" "

In building and construction, the direct crushing force is seldom brought into action to that extent that the metal is crushed to pieces. Accidents invariably occur from the lateral flexure of castings, produced through a deficiency of stiffness in the deflective part.

In order that the various qualities of different metals may be readily compared, and that the variations which occur in each may be seen at one view, results—collected from the preceding tables, and from all the forms in which the several metals were tested—are given in the following table:

Various Qualities of Different Metals.

		Density.	Tenacity.	Ultimate torsion.	Compres'd strength	Hardness.
Cast Iron	Least....	6 900	9,000	5,605	84,529	4.57
	Greatest.	7.400	45,970	10,467	174,120	33.51
Wrought Iron	Least....	7.704	38,027	....	40,000	10.45
	Greatest.	7.858	74,592	7,700	127,720	12.14
Bronze	Least ...	7.978	17.698	5,511	....	4.57
	Greatest.	8.953	56,786	....	....	5 94
Cast Steel	Least ...	7.729	....	....	198,944	....
	Greatest.	7.862	128,000	....	391,985	....

This table shows the great range in quality of the cast iron, wrought iron, bronze, and steel operated on. By judicious treatment the tensile strength of the cast iron is increased so as to be in excess of much of the wrought iron manufactured, and nearly two-thirds of the strength of the best merchant bar-iron. With cast metal of this quality, the manufacture of malleable iron ordnance will no longer be a desideratum.

MANUFACTURE OF WROUGHT IRON.

The conversion of the crude cast iron of the high-blast furnace into the malleable iron of commerce, is essentially a succession of refining operations for the separation of the extraneous matters combined with the metal. The manner in which this is accomplished varies in different districts, and is, in part, influenced by the nature of the alloyed matter. The old, and hitherto preferable process, consists in exposing the molten metal to currents of blast for two or three hours, in a low open blast-furnace, technically termed a "refinery." In many works, reverberatory furnaces are employed, and the crude metal is exposed on the central bed to the action of a highly-heated column of gas from the fire-place, for about an hour and a half. Several of the French and American manufacturers employ the open charcoal forge, similar in construction to the Catalan hearth already described. It may be remarked, however, that whatever construction of furnace be employed for the purpose, atmospheric air is the principal agent employed in purifying the crude iron.

The Blast Refining Furnace

Is built near the blast-furnace, from whence the liquid iron flows direct into the hearth of the fire. It consists of a cast iron framework, surmounted by a brick chimney; at the bottom is a shallow, quadrangular hearth, into which dip the tuyeres of two or more blast-pipes. The sides of the hearth are formed of hollow cast iron blocks, through which water circulates to keep them from fusing with the high temperature, while the bottom is of refractory sandstone. In front is a cast iron dam-plate, furnished with a tapping hole for withdrawing the refined metal; the inner side being protected with brick or clay lining. A shallow mould, formed of thick cast iron blocks, partially suspended in a cistern of running water, is placed in front of a dam plate, to receive the charge from the hearth; water also circulates in the tuyeres, to prevent their lower extremities from burning. The blast is admitted by a large pipe to the valve-box, from which its escape to the blast-nozzle is regulated by a closely-fitting stop-valve. A single refinery, or one blowing from one side only, will have a hearth about three feet square in the inside by eighteen inches deep; a double refinery, or one blown from two sides, has a hearth about four feet square and twenty-one inches deep, with pipes about an inch and a half bore at the point.

The refining of the crude iron is conducted somewhat in the following manner:—The hearth is filled with coke, and the blast partially applied, until the interior has attained a high temperature. If working on cold iron, a quantity of pigs, weighing from twenty to thirty per cent. are thrown in on the incandescent fuel, and covered with additional coke. The full blast is now applied, and the fire urged so as to attain an intense heat; additional fuel being added as required until the pigs of iron soften, and gradually fusing, fall through the interstices formed by the coke to the bottom. By means of iron bars, the attendant keeps the infused portions of metal under the influence of the heat around the tuyeres; and, finally, stirs up the contents of the hearth, to insure the perfect reduction of the entire charge. When the entire charge has been collected on the bottom of the hearth, the refining process may be said to commence. The union of the oxygen of the blast with the solid carbon combined with the metal, results in such a rapid evolution of gaseous carbon, that the mass spontaneously boils up, rising several inches: the superincumbent stratum of fuel rises also, and vibrates with the movement of the boiling metal, while innumerable minute globules of oxidized iron are thrown out of the chimney. Considerable skill is required in managing the blast to a successful issue. The angle at which the pipe dips into the hearth appears to be of importance to the process; each refiner, however, works his blast according to his own judgment. The several portions of the charge are successfully brought under the oxidizing influence of the blast, so as to be equally acted upon, until the major portion of the carbon being disengaged, indicates the approaching completion of the process. The fire-clay "stopping" of the dam-plate is now removed, and the metal and cinder allowed to flow into the shallow mould in front. When collected in the mould, the water is thrown rapidly over it, cooling the surface portions, and, at the same time, oxidizing a portion of the iron. The cinder, by its inferior specific gravity, separates itself from the metal, rising to the top, in which it is partially assisted by the attendant beating the molten mass with an iron bar. On the first application of water, the steam produced lodging in the viscid cinder, swells it up several inches; this is broken down by the beating as fast as it rises, in order that the water may the more readily reach the lower portions.

When cold, the plate of refined iron, which may be about three inches thick by three feet wide, is removed by a carriage to the bank, where it is broken into pieces of a size convenient for the succeeding operation of puddling. The fracture of good metal exhibits a silvery whiteness, while that of inferior kinds is perceptibly duller. On the surface it is rough, and covered with irregular cavities, to which the name of *honeycomb* has been given from some fancied resemblance to that substance. The depth of this cellular structure varies with the quality of the metal and length of blowing, being least in the best irons with a limited blowing.

The chemical effects of the blowing are not well understood, researches into the several reactions which take place in the hearth having been almost wholly neglected. By carefully analyzing the resulting fine metal and its accompanying cinder, and comparing the results with the analyses of crude iron and cinder, some light was thrown on the subject, which, pending the completion of extensive experimental researches now in progress, the author would sum up as follows:—The metal and cinder together represent the crude iron, with oxygen derived from the blast, and solid matters derived from the fuel: the quantity of matter derived from the material on the hearth is too inconsiderable for remark here. Refinery cinder contains a large percentage of silica, which must have been derived principally from the iron; it also contains protoxide of iron to a large amount, from the same source; phosphoric acid is a constituent to the extent of three or four per cent. in some specimens; sulphur is a common ingredient, but may have been derived in part from the fuel. Manganese, magnesia, and lime exist in small quantities; alumina to the extent of five or six per cent. After deducting the ash of the fuel and the protoxide of the iron, there remains a considerable quantity of earthy matters, the presence of which can only be accounted for on the supposition that they have been derived from the crude iron, and that to this extent the cast iron has been purified of alloys.

Puddling the refined metal.—The further refinement of the iron from the blast refining-furnace is conducted in reverberatory furnaces, technically termed "puddling-furnaces," in which, by skilful manipulation, it is deprived of most of the remaining alloy. The puddling-furnace consists of a rectangular erection of iron plates, nearly six feet high, the same distance between the two sides, and twelve feet long, lined throughout with fire-brick. At one end is a fire-place about three feet square; divided from the fire by a brick bridge is the body of the furnace, six or seven feet long, and three and a half feet wide at its widest part, resting on a cast iron bottom-plate, on a level nearly with the bars of the fire-place; the farthest end of the furnace is contracted to eighteen inches in width, where it joins a brick chimney thirty-five to forty feet high, furnished with a damper at top. The furnace is arched over with fire-brick; and to prevent the sides from being thrust out by the expansion of the heated bricks, a number of stout wrought-iron bolts connect the two side-plates, which receive the thrust of the arch. At one side of the body a working-door is placed, in a stout cast-iron frame; the bottom eight or ten inches above the iron bottom of the furnace. The door is moved vertically by a balanced lever, the inner side fitted with a brick protecting lining, and is furnished at bottom with a small notch, for the insertion of the iron bars used during the operation. The fire-place has a small lateral opening for charging fuel, which is afterward stopped by a large piece of coal. The cinder produced during the puddling process flows over a small bridge in the flue, and through an opening in the bottom of the stack to the outside. To maintain the stream of cinder sufficiently liquid for running, a small coal-fire is maintained at the foot of the chimney, from whence the cinder flows into a receptacle provided for the purpose.

The cast iron bottom-plate is supported at short intervals by cross-bearing bars and pedestals; air is allowed free access to it from below. Indeed, without this precaution, the bottom would be immediately fused. Occasionally a portion of the brick-work of the side of the furnace next the body or working part is removed, and cast iron blocks, cooled by a current of air or water, substituted.

Assuming that a charge has been withdrawn from the hot furnace, the process is recommenced by charging through the furnace door a quantity of refined metal, broken into small pieces: from four to five cwts. constitute a charge. The pieces of metal are evenly distributed over the bottom as far as practicable in an inclined position, the door shut, and a little dust thrown around its edges to exclude the cold air. Attention is now directed to the fire, which should be cleaned, fresh fuel added, and the damper fully opened, to allow of an intense heat being generated in a few minutes. The edges of the pieces of metal soon attain a white heat, and begin gradually to soften; the portion of the charge against the fire-place attaining a melting temperature. The "puddler," as the attendant workman is called with a stout iron bar inserted through the notch in the door, lifts up the coldest pieces and pushes them forward into the hottest parts of the furnace, until the whole is nearly dissolved into a liquid mass. When a portion of the iron has been melted, the hooked bar is inserted and the entire mass raked up and exposed to the reverberating action of the hot gases from the fire. At this stage, the inside of the furnace presents a scene of intense brightness, and an inexperienced eye is unable to distinguish the metal through the dazzling whiteness of the whole of the interior. Through the small notch in the door, the puddler conducts the operation by constantly raking up the fluid iron, in order that the gases of the reverberatory current may play on the whole, thus lifting from the bottom any portions that may have set through lowness of temperature. Since the current has no power to penetrate the liquid iron, and thus combine with the carbon and other alloyed matters, as in the blast-refinery, the puddler's principal duty is to mechanically agitate the particles, so that every portion may be successively brought in contact with the free oxygen in the current. The assistant puddler attends to the fire, which he maintains in full activity; at other times he relieves his partner, or works in conjunction with him. After some time thus occupied, the puddler will have separated the larger portion of the alloyed matters from the iron, and brought it to that point technically known as "coming to nature." When this is the case, the metal is seen to attain consistence, and a curdy-like matter is collected by the hooked bar; this rapidly augments, until a sufficiency has been collected together to form a ball or bloom. A second, third, fourth, and fifth collection is successively made and placed aside in the furnace. The charge of refined metal will thus have been converted into five portions, but some workmen divide it into seven or eight. While collecting the metal into balls, a somewhat lower temperature prevails; but immediately they are formed, the damper is again opened, and the heat of the furnace forced, so as to rapidly agglutinate the particles of metal in the balls. During the raking and stirring of the fluid iron, the door is wedged fast in the frame, for which purpose the latter requires to be made very strong. The securing of the door is especially requisite in forming the blooms, since with the heavy hooked bar it affords the puddler an excellent fulcrum for compressing and hugging the ball, to expel as much as possible of the cinder, and at the same time give it a favorable form for yield. The formation of the balls completed, the damper is lowered and the door opened; they are now withdrawn and conveyed to the squeezer or hammer, for compression into oblong blooms. The yield or produce of blooms will amount to nearly ninety-five per cent. of the metal charged—the consumption of coal-fuel averaging in weight one-half as much as that of the blooms produced.

A superior economy of fuel is obtained by lengthening the body of the furnace, so as to admit of the succeeding charge being placed on the part of the bottom adjoining the stack some time before the charge under operation is withdrawn. In this way the new charge is heated to redness without serious detriment to the charge in course of being balled up, and a considerable saving of time and fuel is effected. The furnace produces nearly one-fourth more blooms, with the same daily consumption of fuel, by this process. Economy of time and fuel is still further increased by drawing the supply of refined metal direct from the fining hearth in a fluid state—the fuel and time expended in melting the iron being thereby saved. This mode of working, however, has not been extensively adopted, difficulties having been met with in effectually separating the refined iron from its accompanying cinder.

The refining of crude iron in the reverberatory furnace, embraces in one furnace the separate operations of refining and puddling. In dimensions and general arrangements, the furnaces employed, known in the trade as "boiling furnaces," are very similar to puddling-furnaces. The charging and first part of melting are similarly conducted in both processes; but after the fusion of the crude iron on the bottom of the furnace, the appearances presented are very dissimilar to those with refined metal. At first the liquid iron forms a level sheet, which gradually swells up with the rapid manipulation of the workman, until it has risen six or seven inches above its former level. The entire mass appears to heave and boil; innumerable eruptions arise on its surface and, bursting, discharge their pent-up gases. The puddler must be incessant in his manipulations; every portion is to be raked up and exposed to the oxidizing influence of the current of the gases, until the diminished action shows the near completion of the refining part of the process. At this stage a careful manipulation, with a judicious regulation of the temperature, results in the segregation of the iron into particles of a pasty consistence, which eventually agglutinate by pressure into masses of the required size for blooms. The conclusion of the process, the drawing-out of the blooms and recharging, differs from this part of the puddling process only in the tapping off the larger portion of the cinder produced previous to recharging.

The rising of the molten mass appears to result from the expansive action of the recently-formed gases against the viscid cinder. By attention to the temperature and consistence of this cinder, the rising may be partly controlled; but the nature and quantity of the alloyed matters greatly influence the process. Since the carbon combined with the metal has to be eliminated, by first converting it into carbonic acid, a greater or less amount of carbon will result in a corresponding rising, and lengthened manipulation, for its exposure to the oxygen of the reverberating column from the fire-place. Iron containing a maximum percentage of carbon, with a deficiency of earthy matters in alloy, is refined with difficulty; and requires an addition of cinder from the mill-rollers, to protect the metal from a too rapid oxidation. Crude iron of this character also works hot in the furnace, and great difficulty is met with in bringing it to the agglutinative point for balling up. This probably arises from the heat evolved by the combustion of the excessive percentage of carbon in the crude iron. Where the quantity of carbon is large, as in Scotch irons smelted from carbonaceous ores, the heat thus evolved, with an ample supply of air, is sufficient to raise the temperature to a degree injurious to the successful manipulation of the iron, and dangerous to the metal bottom. Throughout the process, also, the temperature, from the same cause, is less under the control of the workman.

Various inventions have been tried as auxiliaries for the more perfect separation of the matters in alloy, but very few have stood the test of experience. The application of steam, at one time promised to be an essential improvement. High-pressure steam was conveyed in pipes to the bottom of the molten iron in the blast or reverberatory refining-furnace, and in its escape upward agitated the iron, thereby increasing the surface exposed to the action of the air in the gaseous current from the fire-place. The white-hot iron decomposed the steam into its elements of oxygen and hydrogen; a portion of the former reacted on the carbon in the mass, producing carbonic acid, while the latter was free to combine with any sulphur present. With some irons, the increase of temperature on the combustion of the carbon was considerable, and greatly expedited the operation. Theoretically, it seemed that the use of perfectly dry steam should leave little to be effected in the way of refining crude iron; and the fact of the invention having been repatented five or six times within the last few years, shows that much attention is directed to it. Nevertheless, the use of steam has been abandoned in the works where first tried, and the realization of the theoretical advantages is still a desideratum, Mr. Nasmyth, who last tried the experiment, having come to the conclusion, after many experiments, that the steam-condenser had the effect of reducing the temperature of the metal in the furnace.

The separation of the alloyed matters has also been attempted, by adding in the refining process various substances, singly or in mixture. One of these mixtures consists principally of oxide of manganese with charcoal, plumbago, and nitrate of potash In a second mixture, the ingredients were tap cinder, hematite ore, coke dust, fire-clay, and chalk; a third was composed of sulphur, nitrate of potash, potash, borate of soda, and sulphate of alumina; a fourth consists of peroxide of manganese, common salt, and potter's clay. These and other patented compositions, however, have not answered in practice. Ground hematite, nearly free from silicious matter, added in small quantities at a time, facilitates the puddling operation, as also do rich oxides generally; but it is essential that they be free from deleterious substances.

The refining of the iron by the decomposition of water, has also been several times attempted. This is done by pouring the liquid iron into a quantity of water sufficiently large to prevent the iron heating it above the boiling point. The white-hot iron, falling in finely divided streams, decomposes a portion of the water, liberating oxygen, which reacts on the carbon; the hydrogen, similarly set free, acts on the sulphur. thus forming sulphureted hydrogen. Cold iron, immersed in water, appears to slowly undergo a similar alteration of composition; but in this case a portion of the metal is oxidized. The invention is a very old one, having been used more than half a century ago. It was recently made the subject of a patent, which a professor of metallurgy, in his inaugural address, adduced as a striking instance of the ignorance prevailing among manufacturers. Chemically, however, the discharging the iron into water is a valuable invention; while, practically, the odor of sulphureted hydrogen, evolved during the pouring of sulphury irons, is too apparent to doubt the good effect produced on the quality, when the operation is properly conducted.

The refining of iron in reverberatory furnaces, is sometimes practised on the liquid metal run direct from the blast-furnace. A saving of fuel results from this procedure, and the quality appears to be slightly improved when skilfully conducted. It necessitates the erection of the reverberatory furnace and forge close to the blast-furnace, which is a disadvantage in the majority of works, and leads to a temperature in the forge almost unendurable.

Shingling Puddle-Balls.

The white hot balls of the puddling-furnace are removed to the hammer, to be further shaped before passing through the rollers. The forge-hammer or helve, is usually of a T form on the plan, resting at each wing on cast-iron pillars, fixed in ponderous standards, and lifted at the narrow end by projecting cams fixed in a cast-iron ring piece, which receives a revolving motion from a steam-engine, or other motive power. The anvil is fixed in a massive iron block, weighing several tons, situate between the cam-ring and helve standards. The hammer is a loose piece of iron fixed in a socket in the helve. When not in operation, it is propped up at a distance above the anvil, and beyond the reach of the cams in their revolution. The entire apparatus rests on a stout iron bed-plate, which is firmly spiked down to a ponderous wooden bedding, employed for the purpose of reducing, as much as practicable, the injury which results from the vibration of the blows.

The hammer-man takes hold of the hot puddle-ball, and lifting it on the anvil, allows the hammer to fall on it a few times, giving it a turn between each blow to approximate it to the square or cylindrical form, as may be desired. He then skilfully raises it on end; and allowing the hammer to give it a couple of blows in this direction, completes the "upsetting," as it is technically termed, and again proceeds to the reduction of the bloom to a short bar five or six inches in diameter. The effect of the severe hammering is to expel a large quantity of the cinder wrapped up with the iron in the porous puddle-ball, and by condensing the particles, otherwise improve the quality of the product. Hammering each ball lasts twenty-five or thirty seconds, in which time it may receive thirty or forty blows. To keep the anvil cool, and prevent the adhesion of cinder, a small stream of water is occasionally directed on it. The still red-hot bloom is taken direct to the roughing rollers of the puddling train, and rapidly rolled down to a bar.

The forge-hammer has been nearly supplanted by the squeezer, a modern contrivance of some merit. It consists essentially of a ponderous cast-iron lever, vibrating on centre gudgeons, and wrought by a connecting-rod attached to the crank, placed on a level with the puddling-rollers. The under surface of one end carries a hammer face; underneath this is fixed to the massive frame-work of the apparatus a long and somewhat broad anvil-block: both hammer and anvil are kept from burning out by a stream of water circulating through them.

The reduction of the ball to a cylindrical bloom in the squeezer, is performed by a series of squeezings; but as the stroke given to the lever by the crank is invariable, the space between the hammer and anvil regularly diminishes toward the fulcrum. In the process of squeezing, the bloom is rolled over, at each stroke of the lever, by a movement of the tongs, to the narrow part, until the required diminution of size has been effected. The upsetting is performed at the extremity of the lever, where the stroke and space together afford ample height for the bloom endwise. Care is required on the part of the shingler, that the ball, if hard, is not rolled toward the fulcrum too rapidly; for if this should occur, the apparatus must give way in some part.

Lever squeezers, in their turn, have to compete with numerous inventions professing to perform the blooming of the ball better and at a cheaper rate. Few of them, however, have been able to stand a preliminary trial; and even those invented by practical iron-masters have had to succumb to the common squeezer and hammer. The cost of blooming by either of these apparatus, in a well-arranged forge, working to its full power, amounts to only ten cents per ton, including interest on capital and repairs. In devising a substitute for either, it is necessary to bear this item in mind; for it is very evident that an apparatus which works at a higher rate cannot successfully, in a commercial point, compete with its cheaper rival.

The steam-hammer has likewise been pressed into the service of the iron manufacturer. This apparatus answers admirably the varying work of the engine-maker and millwright; but for iron-making purposes it possesses no superiority over the common forge-hammer, though several times more costly. The balls of porous iron from the puddler are so nearly alike in size and hardness, that little variation is required in the blows, which the common hammer gives with great rapidity.

Rolling the Bloom.

The bloom from the hammer or squeezer is passed first between a pair of roughing-rollers (in Staffordshire they are called "bolting-rollers"), and then between a pair of finishing-rollers, to convert it into a flat bar. The two pairs of rollers, and their connecting spindles, pinions, frames, and appendages, are technically called a "train." Commonly, the rollers are sixteen or eighteen inches diameter, and three or four feet long, with end bearings nine or ten inches diameter, and square or fluted projecting ends, by which they are driven. They are cast of tolerably hard iron, and turned in a lathe to the required longitudinal section. Very strong pinions couple together top and bottom rollers, so as to deliver the iron simultaneously in the same direction. The cast iron frames require to be exceedingly massive, and substantially fitted with adjusting screws and nuts. At one end, the train of rollers is connected to a prime-mover (generally steam), by which they are driven at the rate of sixty or eighty revolutions per minute. The inequalities of motion, which otherwise would be very great, are met by a ponderous fly-wheel, revolving with the same, or even greater rapidity than the rollers.

The bloom is first passed through the largest groove; it is then lifted back over the top roller, turned one quarter around, and passed through the next smaller; repeating the process until it is reduced to a square bar, sufficiently small for entering the flat grooves of the finishing-rollers. In the finishing pair of rollers, a repetition of the rolling and returning reduces it to the required thickness, when it is delivered as a puddle-bar. From first to last, the bloom passes through nine or ten grooves, and is reduced from five inches diameter and fifteen inches long, to a flat bar three inches wide, three-quarters of an inch thick, and eleven feet long. The rolling and returning over the rolls occupies a minute and a quarter; the shingling, half a minute;

and from the charging of the refined metal to the delivery of the finished puddle-bar nearly one hour and a half will have elapsed.

A considerable difference is observed in the quality of puddle-iron, from the two methods of refining. The blast-refined iron possesses greater fibre, and altogether produces a better malleable iron than the product of the reverberatory furnace. Chemical analysis shows the latter to contain an excess of phosphorus and sulphur, and also a larger quantity of silicon. Their presence in greater quantity seems to point to the incompleteness of the reverberatory process for refining. The irons made by this process are very generally hot-short (that is, brittle when hot), and incapable of being rolled into some intricate forms of finished bar-iron. When cold, however, the purest specimens possess considerable tenacity.

It is a question whether the cleansing the iron of the alloyed matters can be efficiently performed in a single operation, without the employment of a blast. Chemically, the constituents of refined iron from the blast-refinery accord very nearly with the composition of puddle-bar from the reverberatory refinery. Hence the bars from the former are more pure, by the quantity of alloy removed in the puddling process. This defect of boiled bars deserves the serious consideration of manufacturers in more than one district, which recently has lost its character for making superior qualities of merchant iron.

The matters in alloy are principally derived from the ore; the sulphur partly from the fuel. In the preparation, then, of the best irons, especial attention must be paid to the constituents of the ore used in the smelting-furnace. If these are unfavorable as to quality, it is hopeless to attempt the complete separation of the injurious ingredients in subsequent processes, other than with a ruinous waste of metal and labor. The blast-refinery removes a portion, the puddling process a second portion, and the reheating furnace a further quantity; but the resulting malleable iron is still contaminated by the presence of minute quantities of the alloy, which it is nearly impossible to wholly eradicate. Phosphorus and sulphur are commonly considered the substances which exercise the greatest deteriorating influence on quality; it is, however, highly probable that silicon, calcium, magnesium, and a few other substances, impair the quality to nearly an equal extent.

The cinders produced in the puddling process appear to be of a different composition to those from the boiling furnace. The latter display a larger amount of lime, phosphoric acid, sulphur, and silica; in fact, are not widely different from some varieties of the blast-refinery cinder. By adding together the constituents of the refinery and puddling cinders, it is seen that the proportion of injurious matter removed, relatively to the quantity of iron, is very much larger than in the boiling process.

A difference of quality is observed between the iron worked with a forge-hammer, and such as is worked with a squeezer. The former is found to be more tenacious and freer from cinder than the latter. This difference, it is generally believed, arises from the motion of the squeezer, which is gradual and pressing, while the hammer violently expels the impurities by heavy blows given in quick succession. A preference is very generally given to the hammer, where the quality is considered of paramount importance.

The balling-up of the iron in the puddling process is a highly interesting point in the manufacture, insomuch that it forms the connecting link between cast and malleable iron. Up to this point in the operation the iron is brittle, devoid of malleability, and melts readily at a temperature between 2,000 and 3,000 Fahrenheit's thermometer. After the balling-up and the manipulation of the shingle, the iron is malleable, tenacious, and fuses only at a very high temperature.

Chemical analysis hitherto has failed to inform us of the cause of malleability in iron, since no appreciable difference can be detected between bar-irons and some crude cast irons. The latter may be deprived of its alloy so as to produce an iron similar in composition to bars, yet the malleable principle is wanting. Crude cast irons made from the rich hematites of Lancashire and Cumberland, appear to be less brittle than others, and possess a limited amount of elasticity; in other respects, however, they show the characteristics of cast iron. Exposing thin castings from these ores to heat along with ground hematite in close vessels for a long period, results in the abstraction of most of the carbon, and the consequent production of limited malleability. Attempts have been made, and are now being made, to convert the crude cast iron into wrought iron, by a system of blast-refining without fuel, and subsequent application of the hammer or squeezer—a process which we shall describe in detail, although it has not as yet attained such certainty as to justify a decided opinion of its merits. Mere refining, however, even with the addition of fluxes, fails to produce malleable iron. Manipulation to a certain extent is essential to the development of the malleable principle, which then progresses proportionately with the working. Various oxides and sulphurets, however, possess the property of retarding and sometimes entirely destroying the agglutinous character of the iron at the critical point. Their presence is shown by the inability of the puddler to ball up his iron, which persists in retaining the consistency of a dry pebbly mass.

The welding principle of wrought iron, also developed at this critical point in the operation, is equally characteristic of the singular properties of the metal. Here, also, analysis fails to point out the acting cause why some irons are capable of welding and others not; nor does it explain the reason of iron being so pre-eminently distinguished for this property over all other metals. Various theories have been propounded, but the most feasible explanation of the welding appears to be the accession of a quantity of heat, sufficient for softening and uniting the two pieces by pressure, considerably before the temperature of fusion is attained. Metals apparently devoid of this principle retain their hardness up to the moment of liquefaction; consequently no opportunity is offered for union in the malleable state.

Cutting Puddle-Bars to Length.

This is performed by powerful lever shears, containing steel knife-edges, driven by the same power as the rollers, and at nearly similar velocities. The proportions of the shears intended for cutting bars cold, are considerably heavier than for bars direct from the finishing rollers. Knives, four inches deep, one and a half inch wide, and sixteen inches long, bolted to the fixed and movable arm of the apparatus, are a common proportion. Great care is required that the knives pass each other with a certain degree of tightness, or the wedge-like action of the flat bar at the point may break off the movable arm. This is more especially the case with shears for cutting cold iron, which, in addition to being kept in contact, require the knives at all times to be clean with a sharp V-cutting angle. The knives of shears cutting hot bars are kept from softening by a small current of water directed against them; but the same degree of sharpness is not required here as in cold shearing.

Piling the Cut Puddle-Bars.

To convert the puddle-bars into the various forms of the finished malleable iron met with in commerce, the short pieces from the cutting-shears are piled one on the other to form a mass of a weight suited to the weight of the bar to be operated on. The piles vary greatly in size and arrangement, according to the magnitude and purpose of the finished bar. If common bar-iron of average size be the order of the day, they will measure some two feet long and four inches square; with larger sizes they measure five or six feet long by ten or twelve inches square. A nearly uniform size in the pieces composing the pile, whatever be its dimensions, is essential to successful results. The piles are constructed to the number of six or seven, or more, on an iron frame standing about two feet above the floor, from whence they are taken as required by the workmen engaged in bringing them to a welding-heat preparatory to rolling.

Heating Furnace.

A reverberatory furnace of nearly the same dimensions as the puddling-furnace, but having a refractory silicious sand-bottom, is employed in heating the piles. The bottom is rendered even, and declines from the charging door to the back and flue, for the flow of the liquid cinder. Cast iron framing, with tension bolts to restrain the pressure of the arched roof, and the same powerful chimney, are required as in the puddling-furnace. The piles are inserted into the furnace on a "peeler," and disposed on the bottom in such manner that the workman can readily turn them over, or grasp them for withdrawal. The number charged at one time is inversely as the size; but for small piles of the dimensions given above, they may be taken at eight or ten. When properly disposed on the bottom, the charging-door is shut and all entrance of air around it prevented by a thick dusting of small-coal or ashes. The grate is now cleaned of adhering matters, coals added to the fire, the stoke-hole closed with the fuel so as to prevent the admission of air, and the damper opened to its widest. An intense heat is generated, and communicated by deflecting from the roof to the charge in the body of the furnace. The piles receive the heat unequally, those nearest the fire-place being heated first; it is the duty of the attendant to inspect from time to time the condition of the charge, and by exposing them alternately to the strongest action of the fire, to heat them to the same temperature, occasionally turning them over to expose the under side equally with the others. When the piles are large, turning over to heat the under side is the only operation to which they are subjected in the furnace. At a white heat the softening of the iron is followed by the flowing of a quantity of cinder from the interstices, which runs down the flue to the exterior of the chimney. Considerable dexterity is required in managing the fire; for though in theory the mere heating of a few masses of iron may seem a very simple operation, in practice it is difficult of attainment economically. The flow of cinder over the mass, when at a white heat, protects them to a considerable extent from oxidation; but great care must be taken that no air gains access to the iron during the process. If this precaution be neglected, and air enters the furnace, either through the fire being too open or the door imperfectly sealed, the metal is rapidly oxidized, and great loss results. The particles of oxide of iron formed, eventually cool into brittle scales, which cut into the malleable iron, and destroy its continuity in the subsequent processes. If allowed to proceed, the oxidized surfaces of metal cannot be brought to a welding condition; and whatever pressure be applied, the pieces of puddle-bar composing the pile cannot be forced into union.

It may be here remarked, that by bringing gaseous and solid carbon in contact with the oxide in the blast-furnace, the oxygen forms new combinations, liberating the iron in the metallic state. The superior affinity at high temperatures of carbon over iron for oxygen, has been taken advantage of from time immemorial for the ready separation of oxygen in oxides of iron. But in its progress from the blast-furnace to the state of a finished bar of malleable iron, in the absence of carbon, the iron has a constant tendency to return to the condition of an oxide. In the blast-refinery, one-half of the metal would be oxidized, were it not for the stratum of carbon fuel covering the molten iron, and which decomposes the oxide nearly as fast as it is formed. In the puddling-furnace the metal is unprotected by carbon, and the greatest care and skill is demanded from the puddler that a large portion is not lost through wasteful oxidation. The heating process is similarly situated; access of air to the iron causing a portion to revert to its original state in the ore. So much of the iron as is thus oxidized in the several processes passes back to the blast-furnace, to be again reduced by presenting to the oxide the carbon necessary for liberating the metal.

The heating the charge to the requisite temperature is accomplished in forty-five or fifty minutes, when the bars are withdrawn singly by grasping them with a pair of heavy tongs, and conveying them on a light carriage to the rollers. A frequent practice is to drag the white-hot pile on the metal floor of the mill to the rollers; but such a proceeding scarcely ever fails to soil the iron, and injure the quality to a slight extent. Where the quality is sought to be superior, too much care cannot be taken to keep the iron from contact with deleterious substances.

The cinder flowing from the iron is contaminated by the addition of a portion of the fused sand of the furnace-bottom, as also by the small quantity of brick-work of the interior fused by the intensely high temperature. The composition of the cinder varies with the iron and treatment; generally it contains sixty or sixty-five per cent. of protoxide of iron, twenty-nine or thirty of silica, with smaller quantities of protoxide of manganese, alumina, phosphoric acid, lime, magnesia, and sulphur.

The Rolling-Mill.

The rollers used in this process vary in size with the iron to be reduced: heavy bars are rolled between rollers of eighteen or twenty inches diameter; lighter bars between rollers twelve and fourteen inches; and the smallest sizes in mills have rollers six to eight inches diameter. A heavy rolling-mill consists of two pairs, distinguished as "roughing" and "finishing" rollers, with shears, saws, and other appendages for completing the operations on the bar, in addition to the eight or nine heating-furnaces. The roughing-rollers are commonly about six feet long, the finishing about half as much; the two pairs are coupled as in the puddling train, and driven at speeds varying from sixty to a hundred and twenty revolutions per minute. The frames, sole-plates, connecting-spindles, and pinions, are required to be heavier than in the puddling process, and greater accuracy and finish are required throughout. When a steam-engine is employed to drive the trains, the size ought to afford 100 horse-power to each; but smaller rollers are driven with proportionately less power. The tooth-wheels to bring up the speed of the rollers, the fly-wheel to equalize the speed, and the shafts, framework of the mill, and substructure, require to be proportionately heavy and strong. All the parts subject to strain are made many times stronger than a casual spectator would consider necessary; this is done to avoid the loss of iron and labor, and the ruinous delay necessarily attendant on every breakage of the machinery employed.

Turning the Rollers.

The rollers employed are made of cast iron, of as hard texture as can well be worked; soft iron is inadmissible. They are allowed to cool in the mould, having been cast on end with a high pressure of metal to insure solidity in every part, without which they are useless; they are afterward taken to the lathes, and placed in a centring-lathe for turning the axles. This is done by the projecting end of a wide chisel, firmly held horizontally by wedging in a cast iron frame, and pressed against the metal of the roller by other wedges in the rear. Motion is communicated to the roller through the intervention of powerful spur-gearing, from a steam-engine or water-wheel. Though rude, this process is more expeditious than with the highly-finished lathe of the engine-manufacturer, which would speedily be rendered unserviceable if forced to cut off, at each revolution, a thick ring of cast iron from a cylinder weighing several tons. From the centring-lathe the roller is taken to a second lathe and placed in brasses on its recently turned axles; motion is here communicated to it through the intervention of strong tooth-wheels and spindles to the amount of two or three revolutions per minute, depending on the hardness of the iron and the size of the roller. With hard iron the velocity is reduced, to prevent softening of the steel cutting-tools by heating. The hardest rollers cannot be advantageously turned at greater velocities than one revolution in three minutes, but the majority of grooved rollers bear turning at the higher velocity.

The lathe in which the working part of the roller is turned, requires to be exceedingly strong; a minimum section of 100 square inches of iron in the weakest place is not too much.

The first operation performed on the body of the roller is to reduce it to a smooth cylinder of the same diameter throughout. This is done with chisels three or four inches wide, resting on iron blocks and secured in the desired position by wedging as in turning the axle. The best cast-steel, carefully tempered, is demanded for the cutting-tools. When reduced to a perfect cylinder, the motion is discontinued and the design inscribed on its periphery; the design varies with the section of the bar which it is intended to roll. If intended for a cylindrical bar, grooves nearly of a semi-circular shape are cut out by similarly shaped tools, during the revolution of the roller; square bars have the grooves of a triangular shape. On placing two of these together, it is obvious that they form either a square or circular orifice; and if made to revolve so that the peripheries of the rollers when in contact move in the same direction and with the same velocity, a soft substance interposed is forced to the figure produced by their junction. On the other hand, the substitution of a plain cylindrical roller on one part would result in the production of a bar having a section corresponding to the semi-circular or triangular form of the single groove used. Flat bars are produced on similar principles: a groove of the required width is sunk in the roller much deeper than the intended thickness of the bar; the excess being filled up by a projecting tongue on the top roller. By merely altering the distances of the two rollers, bars of various thicknesses may be rolled by the same pair of rollers. When the depth of the groove is considerable, allowance has to be made for delivering the bar freely, by widening the top of the groove so as to give it a slightly tapering form. This tapering, however, interferes with the parallelism of the sides of the bar, which has to be reversed and rolled in the finishing groove twice, by which the deviation from the parallel is reduced one-half; except in very thick bars, the remainder is not readily perceptible to an inexperienced eye. A distorted figure of the section of a thick bar shows the effect on the sides more clearly. By careful attention to the form of the groove and projecting tongue, very many apparently difficult sections may be rolled.

The reduction of the white-hot pile of puddle-bars to the finished merchant-bars, is accomplished by a succession of rollings, probably twelve or fifteen in number, each time through a groove smaller in section than the preceding one. This produces successive elongations, corresponding to the reduction of metal in section. It is, however, necessary to observe, that the groove through which the bar passes, while of a reduced section and smaller in one direction than the previous groove, in the other direction it is required to be longer. The rollers in their revolution are capable of pressing the iron in one direction only, viz., vertically: the degree of pressure exerted in this direction may be varied at pleasure, by allowing the rollers to recede from each other to diminish it, or the reverse by screwing them into closer contact with the ponderous set-screws in the frames. But the rollers are incapable of exerting any action horizontally on the iron in the direction of their length. If the bar is of a section that admits of turning on edge, and passing between the rollers in this way alternately, the width of each groove is gradually diminished, but it is in excess of the height of the preceding one. Flat bars are rolled in grooves increasing in width to the last or finishing; but the thickness in each is diminished very rapidly. With very thick masses of iron of a flat-bottom section, it is not unusual to work half in each roll, and afterward remove the angular piece at the side by repassing it through the last groove.

To insure the delivery of the iron freely in a straight line without contortions, great attention has to be paid to the diameter of the rollers at the points where they press on the iron. If one be larger than the other, the periphery of the larger roller, by moving at a greater velocity, deflects the iron from it. A groove or tongue of one roller of greater diameter on one side than the other, unless counteracted by a corresponding enlargement in the other roller, throws the iron out in a spiral direction, from which it is almost impossible to straighten it. This defect in the turning seldom occurs with bars of common section, but unusual sections entail a mass of unseen labor in guarding against its occurrence.

The interior of the grooves and the working part of the tongue, if any, it is preferable to keep smooth. This is absolutely essential in the case of the last grooves through which the bar passes. In the grooves of the roughing-rollers, it is common to cut notches, or otherwise dent the working surface, to insure a sufficient adhesion to force the bar through. This is met more effectively by increasing the diameter of the rollers to the largest practicable point. The use of notches, in any shape, injures the fibre of the iron, besides affecting the surface appearance of the bar.

Allowance has also to be made for the reduction of size which the bar undergoes in cooling from a red heat down to that of the atmosphere. The measure allowed for contraction is affected by the character of the iron, and temperature at time of delivery from the groove; but one-fifth of an inch may be considered a fair allowance for bars one foot wide.

Rolling Bar-Iron.

The white-hot pile from the heating furnace is passed through a large groove in the roughing-rollers, by pushing it forward on the fore-plate until caught and drawn through by the rollers. If the pile is well proportioned to the groove, it passes through easily; but if too large, it may require blows from the iron carriage to make it enter the groove: should this occur, and the roughing-rollers be a small distance apart at the largest diameter, the immense vertical pressure on the iron in the small groove, forces out a portion each side in the form of a thin flange. This has to be carefully guarded against, as from its thinness this strip of iron cools rapidly, and may become too cold for turning down and welding in the succeeding groove. The pile is now seized by a second workman, with a heavy pair of tongs; and two hooked levers, suspended by chains from the roof of the mill, are inserted underneath, lifting it up over the top roller and delivering it on the other side. In its descent the first workman turns it over at a right angle from its former direction, and pushes it toward the next smaller groove until it is drawn in. The lifting back and rolling operations in the roughing-rollers are repeated till a suitable reduction has been made for the finishing rollers, to which it is eventually transferred, resting on the hooked levers. In these it is rolled five or six times, through as many diminishing grooves, to the required section, each time turned partly around, or the position in regard to the jointing of the rollers otherwise altered. With a heavy strain and soft iron, constant attention is paid to the action of the rollers, that no side flange be formed on the bar.

The top roller is made a fraction larger than the bottom, in order to throw the bar down on the guides as it is delivered by the rollers The guides are two tiers of heavy wedges, the points of the top tier resting on the top of the bottom roller, while the lower tier is kept in reserve immediately below. In its delivery the bar is conducted in a straight line by these wedges, instead of turning down underneath the roller, as it otherwise would. If, from accident, the guides opposite any one groove are displaced, the end of the bar is likely to return under the roll, and be united with the other part into a solid ring. This untoward accident may also occur through defect in the iron, the more so if partially oxidized by long exposure in the heating furnace. In this case a portion of the pile separates from the rest, and following the course of the top roll, is welded into a massive iron ring Considerable delay occurs under such circumstances, for operations must be suspended while the iron ring is being cut through ; and this requires some time when the metal is five or six inches wide and half as much in thickness.

With some sections great exactness is required, and a deviation of the thickness of a hair either way renders the bar unsalable. If obliged to work to a very exact section, the rollers are adjusted with the greatest care, the tightening and set-screws without play, and frequent examinations made of the bars produced. With the greatest care, however, a few days at most results in so much abrasion in the rollers, that they have to be sent to the turner for repairs. Where they rub on each other, the surfaces are frequently lubricated with black-lead and grease, or carbonaceous matter and palm oil.

The overheating of the rollers, by contact with the hot iron, is prevented by small streams of water directed on the parts of the finishing-rollers liable to heating. With bars of a concave section on the upper surface in rolling, the water which falls on the red-hot charcoal affords an instructive example of the spheroidal condition of water in contact with substances at high temperatures. While the bar remains at a bright red-heat, no steam is formed, the drops of water merely rolling over the surface ; but the surface of the rollers, though scarcely heated above the boiling point of water, is enveloped in clouds of steam. These phenomena of water were known to operatives in rail-rolling mills many years before the publication of M. Boutigny's experiments.

During the successive rollings, the great pressure exerted on the bar expels with violence a portion of the remaining cinder, and leaves the iron comparatively pure. This cinder is composed, to the extent of about ninety per cent., of magnetic oxide of iron; the remaining ten per cent. of silica, phosphoric acid, lime, sulphur, and other bases, depending on the local constitution of the crude iron.

Cutting Bar-Iron to Length.

The finished bar is taken from the rollers and cut to the required length whilst hot. This is done either by lever shears, as in the case of puddle-bars, or circular saws revolving at great rapidity. The latter, a modern invention, performs the work in an exceedingly neat and expeditious manner, and is applicable to iron bars of all sizes irrespective of section—an advantage not possessed by any shears. Thin merchant-bars are frequently cut cold, in order to show off the texture of the iron; but large bars of every description are cut whilst hot. The sawing apparatus consists of a pair of steel disks, four feet diameter and one-eighth of an inch thick, with coarse teeth on the edges, mounted on a spindle about four feet long. By a small pulley-wheel on the centre of this spindle, motion is communicated by bands from larger wheels driven by the engine. Against the outside of each saw, but near its front edge, is placed a narrow sliding-frame of cast iron, equal in length to the longest bar rolled, on which the red-hot bar is placed and retained in its position by stops. The ragged end of the bar is made to project sufficiently in front of, and finally pressed against, the saw, by which it is cut from the body in a few seconds. If gradually performed in fifteen or sixteen seconds, with good saws, the ends of the bar have a smooth, polished appearance; performed in three or four seconds, the ends are less smooth. The second end of the bar is cut in a similar manner by the other saw; the projecting ends cut off being placed aside for remanufacture. Great care is commonly required in cutting the second end, as the amount then cut off regulates the length of the bar. To insure the requisite accuracy in this respect, the second movable platform is furnished with a sliding-gauge, the distance of which from the face of the saw regulates the length of the finished bar. Allowance, however, has to be made for contraction of the bar from its red-hot state; and some attention requires to be given to the difference of temperature at which some are cut, in order to obtain bars of nearly uniform length.

The saws revolve 1,000 to 1,500 revolutions per minute, equal to a velocity at the cutting-edge of 142 to 213 miles per hour. Their edges are kept from overheating by dipping into narrow cast-iron cisterns containing water. When cutting, the shower of sparks created is partially confined to the vicinity of the saws by sheet-iron casings, supported over the upper edges of the saw. The entire apparatus requires to be fitted up very correctly, the revolving parts evenly balanced, and working in good brasses rigidly fixed to pedestals and a heavy substructure. Every twenty-four hours the saws require sharpening, and are then replaced by others.

The cutting into lengths completed, the bar is straightened by wooden mallets on a massive cast-iron plane placed level with the floor; the asperities of the edge, from the action of the saw, removed with a coarse file, and the trade-mark of the maker stamped upon it, when the operations attending the manufacture of a merchant-bar terminate. The iron so produced is known amongst manufacturers as No. 2, from having been twice rolled. In commerce it is known as common bar-iron.

Recapitulation of the Process.

In tracing the progress of the metal from the state of an oxide in the ore through the several transformations, finally ending in the production of a bar of malleable iron, it is seen that recourse is had to heating in close or open furnaces five times, viz., calcining, smelting, refining, puddling and heating. But frequently the bar is produced with four heatings; and by a modification of the refining process, at one time largely adopted in

Staffordshire, and to a less extent in South Wales, only three heatings were required from the ore to the finished bar. In the first process—the calcining of the ore—it is heated to a high temperature, and allowed to cool down for filling into the blast-furnace: the author is of opinion that this is a process properly belonging to the blast-furnace, where the calcination could be effected without loss of heat as at present. In the smelting process, the ore is again heated, fused along with fluxes, and descends to the lower hearth as crude iron, whence, in many works, it flows, without cooling, into the refinery furnace. The product of this furnace may either be malleable blooms, or refined metal, according to the kind of furnace used.

Assuming that the crude iron is refined by the boiling process, the heat imparted the metal in the blast-furnace will last through the whole process of refining, balling-up, conveyance to hammer or squeezers, shingling, removal to the rollers, rolling in two pairs of rollers, removal to the shears, cutting into short lengths. It is now allowed to cool, is piled, and the mass heated in the heating furnace, from whence it is taken to the roughing-rollers, where it is roughed to a thick massive bar; removed to the finishing-rollers, and rolled to a square, round, or flat bar, as may be required. It is now drawn out, the ends cut with a circular saw, straightened, filed clean at the ends, and, finally, stamped with a trade-mark and placed aside as a finished bar, with one single heating.

The several mechanical operations performed in the forge and mill on masses of iron weighing several cwts. are executed with admirable precision and dexterity. Frequently, the same bar is passed fifteen or sixteen times between the rollers, and has to be grasped and released twice this number of times with a pair of heavy tongs, when moving at the rate of nearly six miles per hour. In its progress, also, in the rollers it has to be adjusted in a different direction each time it is passed between them. When it is considered that the substance thus handled is a white-hot piece of iron, exposing a surface of from twelve to thirty-five feet to the operatives, and in a temperature compared with which the torrid zone is cold, the great skill of the men, and the severe bodily labor, will be seen to surpass everything having the least analogy in the industrial arts of any country.

From the period when the bloom leaves the puddling-furnace to the delivery of the puddle-bars from the shearing apparatus, five or six minutes will have elapsed; the time occupied in conveying the pile from the heating furnace, and submitting it to the several finishing operations, seven to eight minutes.

It may be remarked, that in both pairs of rollers in puddling, and also in the rolling-mill, the violent compression of the iron is attended with the evolution of large quantities of caloric; so much so, indeed, that it compensates to a great degree, for the loss by radiation and from the currents of water thrown on the finishing-rollers. The quantity of caloric thus evolved, appears to vary with the character of the iron. The South Wales irons require to be rolled quickly, or the bar becomes too cold and hard for compression. South Staffordshire iron, on the other hand, may be rolled slowly, and is compressible between rollers at greatly lower temperatures.

The expenditure of power in forcing the iron into shape in the larger mills is very great. Fly-wheels, eighteen feet in diameter, having fifteen tons of metal in the rim alone and propelled by powerful engines at the rate of 120 revolutions per minute, are brought down to half this speed in four or five seconds, simply from the resistance of the iron to compression, when from any cause the temperature is slightly reduced. The expenditure of force in reducing a pile to a flat bar six inches by one inch, and fifteen feet long, is equal to the lifting of 4,500 tons one foot high.

Manufacture of Railway Bars.

Rolling railway iron is conducted in a nearly similar manner to that pursued with other large bars. The piles are larger; and if a superior quality is desired, great care is taken in the arrangement of the several pieces of puddle-bar. In the finishing-rollers, the reduction of the ultimate section is performed by a succession of intricately-shaped grooves. The turner's skill is severely taxed to adapt the grooves in these rollers to each other, and at the same time to deliver a clean bar of the precise section. This frequently requires a careful selection of the ores used in the production of the crude iron of part or the whole of the puddle-iron in the pile, according to the strain exerted on different parts of it in rolling to a bar. The bar first enters the groove on the left-hand side, and is successively passed on to the right-hand groove, from whence it emerges exhibiting the required section. This form of bar is one of the most difficult to roll; a considerable portion of it is thin, consequently liable to cool quickly. A still greater difficulty is met with in the difference in diameter of the working portions of the grooves; the smallest diameter occurs at the edges of the thin flanges. In consequence of this difference of diameter, the several portions of the bar are not propelled with the same velocity; the greatest movement occurring with the largest diameter, and *vice versa.* With wide flange rails the difference is very considerable; for instance, the part of the roller bearing on the body of the bar will move at the rate of six miles, while the bottom of the groove, which presses on the flanges, will move only five miles per hour. The distention of the parts of the bar is in direct ratio to the diameter of the roller of that part; hence, a direct tendency to drag the thick portion of the bar away from the flange. To counteract it, the thin part is spread out to a great width in the second groove; in the succeeding grooves the additional work thrown on this amply compensates for the lesser distention. Without a provision of this kind, the thin edges would crack; and not unfrequently long strips peel off, especially with iron of the red-short class.

Rail bars are cut into lengths with circular saws. In consequence of the hollowness at the sides or bottom they cannot be shorn hot with any degree of neatness ; and the adaptation of cold shears to the purpose frequently leaves a hollow cavity in the end, and is altogether a tedious operation. The first bars manufactured were secured in heavy cast-iron blocks, fitted with counterparts, and closely fitting the rail all round. The end of the bar was made red-hot before insertion in the cavity of the block, and then cut with common blacksmiths' chisels, any inequalities being removed by filing. The substitution of revolving saws, however, has enabled the manufacturer to square and finish the ends at less than one twelfth the expense incurred with hand-blocks.

After the ends are cleaned by filing with heavy double-handled rasps, the railway bar is subjected to the hot straightening process. This is performed on a massive iron block, placed over its surface the length of the rail, and cast of such thickness as will prevent flexure by heat. Any deviations from a right line are taken out of the hot bar by long-handled wooden mallets, having heads nine or ten inches diameter, and eighteen or twenty long: iron hammers would leave an impression on the soft iron, and are therefore inadmissible in all hot-straightening operations. If the section permit, it is now stocked on a level grated floor, formed of bars on edge, till quite cold.

With the majority of bars, however, it is subjected to a further hot-straightening, or, more correctly, hot-bending, to counteract the unequal contraction of the several parts of the bar during cooling. In the two sections, the larger portion of the metal is thrown in the head or wearing part of the railway bar. If a bar of either of those sections be made perfectly straight when at a bright red heat, and allowed to cool, the thinner portions part with their heat and contract more rapidly. The head containing the great mass of metal cools very slowly; and several hours after the flanges have contracted nearly to the amount due to the reduction of temperature, this part continues to cool and contract.

In practice, this inequality of construction is obviated by curving the bar, in a reverse direction, to the amount of curvature which it would have taken if allowed to cool from a straight bar. The curve taken by a bar in cooling forms the profile of a massive cast-iron block, over which the bars are successively bent with heavy wooden mallets. In doing this, attention is paid to the temperature so that no serious deviation occurs from that at which the trial rail-bar took its curve. Great care, indeed, ought to be taken to insure the bar taking a straight line with its loss of heat, or permanent injury is caused to the iron.

If the hot straightening and bending have been well-conducted, the cold bar will not deviate greatly from the right line; but as absolute correctness is demanded by the purchaser, the bars subsequently undergo a series of cold straightenings by hammers or pressure. Formerly the heavy sledge-hammer (94 lbs. weight) was the only instrument used; but of late years the increased weight and stiffness of the bars, and the general desire to reduce the cost of manufacturing, have resulted in the very general adoption of machinery for this purpose.

The rail-straightening press consists of a massive cast-iron frame, with a projecting stand on each side to receive the railway bar; on the top revolves a large shaft, carrying an eccentric cam, which acts on a slider moving vertically in grooves in the large frame immediately over the projecting stand. The bottom of the slider is slightly bevelled, and at the down stroke reaches to within four or five inches of the rail. When straightening, the bar rests on two shallow supports, about eighteen inches apart, on the stand, the convex side up; a wedge-shaped key is carefully inserted under the slider, so that at the lowest movement the slider presses on the rail through the intervention of the key, and removes, at one pressure, part or whole of the convexity. The operation is repeated until all irregularities are taken out. If the bends in the bar are very short, a less distance between the supports is demanded. Considerable delicacy is required in using the taper key; if projected too far, the rail may be bent in the reverse direction, or completely broken if made of cold-short iron. Commonly the slider moves up and down about thirty times in a minute, thereby enabling skilful workmen to straighten 100 bars daily in a single press. The strain thrown on the approaches is very great, and renders it necessary to make the whole of massive proportions.

Frequently the bar, after leaving the straightener, possesses a degree of "winding" or twist, which is detected by placing the ends on two planed blocks accurately levelled on the upper surface. It is removed by grasping the ends with long levers, and applying a light torsional strain until the desired effect is produced.

Boiler-Plate Iron.

This is made from selected No. 2 bar-iron, when a superior quality is sought; but the larger portion of the present manufacture is rolled direct from puddle-blooms. The pile for best plate is built short and wide, with an equal quantity of pieces running along and across it. They are brought to a welding heat in a reverberatory furnace of the ordinary description, and taken to the plate-iron rollers. These consist of two pairs, a slabbing and a finishing, both of a plain cylindrical form, chilled to extreme hardness on the surface. The frames in which the rollers revolve are furnished with large tightening screws (six or eight inches in diameter), by means of which the top rollers are screwed down or permitted to rise at pleasure. Commonly, a system of levers, carrying balance-weights, is appended to one or both top rollers, to diminish the weight on the other rollers. The coupling pinions connecting the top to the bottom rollers are frequently dispensed with in rolling thin plates.

The short flat pile is passed several times between the slabbing-rollers, end or sidewise, according as it may appear to require distention, until sufficiently reduced in thickness for the finishing-rollers, to which it is transferred for further distention. If the iron requires it, the slab is reheated and passed between the slabbing-rollers a second time, in its reduction to a suitable thinness for the finishing-rollers. These are made of the hardest iron, and turned to glassy smoothness on the surface. At first its direction between the finishing-rollers is regu'ated to supply any omission in the slabbing : the object being to assimilate its horizontal proportions to those of the intended plate. When this is accomplished, it is passed successively in the same direction until the desired thinness has been attained. Metal gauges of the length, breadth, and thickness of the plate, indicate when the rolling is to be discontinued. The shearing to the exact size is performed on the cold iron by powerful lever-shears, with steel knives five or six feet long.

The manufacture of common boiler-plates, ship-building plates, and much of the inferior descriptions of sheet-iron, is conducted in a different manner.

The puddle-ball of the boiling furnace is hammered into a flat bloom, two of which are placed together to constitute the plate ; when cold, they are charged into a furnace, heated to melting, slabbed, and rolled in the foregoing manner to the desired thinness. Plates made in this manner, however, ought never to be used in any description of boiler building. A very general recourse to this mode of manufacturing has unquestionably lowered the character of boiler-plate iron, and led to many fatal explosions. Good boiler-plates should not break with a less strain than twenty-five tons to the square inch of metal ; but much of what is manufactured for the purpose will not bear more than two-thirds of this strain.

Nail Rod Iron.

Nail rods are manufactured in two ways : by rolling a bar down to the desired section ; and by cutting a thin strip of iron into a number of parallel rods, by means of revolving shears. The first method is pursued with iron for horse-shoe nails, and the superior kind of rods, forming about two per cent. of the manufacture ; and the shearing with the remaining ninety-eight per cent.

The manufacture by shearing strips, is known in the trade as slitting nail rods. A slitting-mill consists of two or three heating furnaces, a pair of grooved rollers for roughing the pile, a pair of smooth chilled-iron rollers for flattening it, and a pair of revolving shears, with the requisite lever-cropping shears. Rollers and shears are commonly placed in parallel lines, seventeen or eighteen feet apart and driven at nearly the same number of revolutions per minute by strong spur-gearing. The shears are formed of two parts, each consisting of a number of disks of wrought iron, sixteen or seventeen inches diameter, edged with steel, kept the requisite distance apart by other disks of iron of lesser diameter ; the whole firmly bolted together, and mounted on a cast or wrought iron spindle. When revolving, the upper series of steeled disks project into the spaces of the lower series, thus forming a number of continuous shearing edges. The depth when they project is regulated by screw bolts attached to the cast-frames; while the entrance of the iron to be shorn is regulated by guides and plates, similarly adjusted by screw-bolts. Through the bottom of a cistern at top, a shower of water falls on the steel, to keep it from softening with the heat of the bars. In front of the apparatus a wrought iron grated frame is constructed of iron bars, to receive the rods delivered by the shears.

The mode of rolling may be described thus: Two or three pieces of puddle-bar, or other flat iron, are placed to form a low pile, which is brought to a welding-heat in a reverberatory furnace, and transferred to the grooved rollers. In these it is distended to a bar ten or twelve feet long, by three and a half or four inches wide, and of a thickness proportionate to the size of the intended rod. It is now passed between the smooth rollers, so as to reduce it to the precise thickness, and at the same time remove any roughness on the face of the iron. It is now of a width somewhat less than the breadth of the upper series of steeled disks; and on inserting one end of the strip between the guides, it is drawn on by the revolving shears, and cut into as many rods as there are steeled disks in its width. The divided rods are secured on light hooks, and transferred to the grating. The strips vary slightly in width; and when such is the case, or the iron is of a weak red-short character, a number of imperfect rods are shorn off at the sides, and passing aside the guides, require constant cleaning from the apparatus.

The finished rods are cut to length, weighed into bundles, and tied up by twisting around them three or four small bands of hot iron. If placed in stock, or in carriages for conveyance to purchasers, great care should be taken that they do not get wet and rusted on the surface. Rods prepared by shearing may readily be distinguished from rolled rods by the concavity of the one and convexity of the opposite side; the other two sides also show the cutting action of the shears, and two edges project slightly with minute serrations.

The rapidity with which nail-rods are produced by this process is perfectly marvellous to the uninitiated. Working on the smaller sizes of rods, a mill rolling three lengths at once, as is now generally done in the larger mills, delivers ninety to a hundred rods at each operation, equal to the continuous delivery of a single rod through the week at a velocity of ten miles per hour.

Hoop-Iron is manufactured from small piles or billets, rolled first between small rollers having grooves on their circumference, and lastly between a short pair of hard cylindrical rollers, in which it is pressed to the width and thickness desired. The great length of the bars and their tendency to cool quickly, renders it necessary to propel the grooved rollers at very high velocities; but the smooth pair is driven at the more usual speed of ninety or a hundred revolutions per minute. This pair requires to be exceedingly strong, in order that the iron may be finished comparatively cold and thereby carry a blue face.

Small flats, squares, bolts, and fine irons generally are rolled with trains having three rollers in height. The addition of a third roller to each set expedites the rolling one-half; inasmuch as the operation is continued in both directions, instead of returning the bar over the top roller, as in large mills. The rollers are commonly eight or nine inches in diameter; the roughing set thirty inches long; the second twenty-four, and the finishing nine inches long: three rollers in height, instead of the two in other mills. A speed of 230 revolutions per minute is common and preferable to slower working; at this velocity the periphery of the roller moves over six miles per hour; and calculating the several movements of the operatives in following the bar through the day, it is seen that several of them walk more than twenty miles daily at this quick rate.

The rolling of small flats and squares in such trains is conducted on principles similar to those pursued in larger mills; but the round iron is rolled with the assistance of double guides. Small piles, or solid pieces of iron termed "billets," are roughed between the first pair of rollers; in the second, the iron is first converted to a square and then into a bar of an oval section, precisely equal in area to that of the intended round bar. The grooves in the short finishing-rollers (of which there are only two in rolling rounds) are of an exact semicircular shape, and together form a complete circle. The oval bar is presented to these rollers, guided in a vertical direction by closely-fitting iron blocks, where it is violently compressed to a perfectly cylindrical form. To insure this being done, there must be a rigid correspondence between the oval and circle. If the oval is too small, the deficiency of metal to fill the circle is seen in the flattened sides of the latter; if too large, the excess of metal is frequently forced out at the sides, forming thin flanges. If the guides fail to hold the bar sufficiently tight to prevent its turning around, the bar is similarly spoiled. As may be imagined, it is only very good iron that will stand the violent alteration of structure when comparatively cold.

Weight of Square Rolled Iron.

From 1-16th Inch to 9½ Inches.

ONE FOOT IN LENGTH.

Side.	Weight.	Side.	Weight.	Side.	Weight.	Side.	Weight.
Ins.	Lbs.	Ins.	Lbs.	Ins.	Lbs.	Ins.	Lbs.
$\frac{1}{16}$	.013	$\frac{7}{8}$	11.883	$\frac{7}{8}$	50.756	$\frac{7}{8}$	116.671
$\frac{1}{8}$	.053	2	13.52	4	54.084	6	121.664
$\frac{3}{16}$	.118	$\frac{1}{8}$	15.263	$\frac{1}{8}$	57.517	$\frac{1}{4}$	132.04
$\frac{1}{4}$	.211	$\frac{1}{4}$	17.112	$\frac{1}{4}$	61.055	$\frac{1}{2}$	142 816
$\frac{3}{8}$	.475	$\frac{3}{8}$	19.066	$\frac{3}{8}$	64.7	$\frac{3}{4}$	154.012
$\frac{1}{2}$	.845	$\frac{1}{2}$	21.12	$\frac{1}{2}$	68.448	7	165.632
$\frac{5}{8}$	1.32	$\frac{5}{8}$	23.292	$\frac{5}{8}$	72.305	$\frac{1}{4}$	177.672
$\frac{3}{4}$	1.901	$\frac{3}{4}$	25.56	$\frac{3}{4}$	76.264	$\frac{1}{2}$	190.136
$\frac{7}{8}$	2.588	$\frac{7}{8}$	27.939	$\frac{7}{8}$	80 333	$\frac{3}{4}$	203.024
1	3.38	3	30.416	5	84.48	8	216.336
$\frac{1}{8}$	4.278	$\frac{1}{8}$	33.01	$\frac{1}{8}$	88.784	$\frac{1}{4}$	230.068
$\frac{1}{4}$	5.28	$\frac{1}{4}$	35.704	$\frac{1}{4}$	93.168	$\frac{1}{2}$	244.22
$\frac{3}{8}$	6.39	$\frac{3}{8}$	38.503	$\frac{3}{8}$	97.657	$\frac{3}{4}$	258.8
$\frac{1}{2}$	7.604	$\frac{1}{2}$	41.408	$\frac{1}{2}$	102.24	9	273.792
$\frac{5}{8}$	8.926	$\frac{5}{8}$	44.418	$\frac{5}{8}$	106.953	$\frac{1}{4}$	289.22
$\frac{3}{4}$	10.352	$\frac{3}{4}$	47.534	$\frac{3}{4}$	111.756	$\frac{1}{2}$	305.056

ILLUSTRATION.—What is the weight of a bar 1½ ins. by 12 inches in length?

In column 1st, find 1½; opposite to it is 7.604 lbs., which is 7 lbs., and .604 of a lb. If the lesser denomination of ounces is required, the result is obtained as follows:

Multiply the remainder by 16, point off the decimals, and the figures remaining on the left of the point give the number of ounces.

Thus, .604 of a lb. = .604 × 16 = 9.664 = 7 *lbs.* 9.664 *ounces.*

TO ASCERTAIN THE WEIGHT FOR LESS THAN A FOOT IN LENGTH.

OPERATION. What is the weight of a bar 6¼ inches square and 9¼ inches long?

In column 4th, opposite to 6¼, is 132.04, which is the weight for a foot in length.

6.25 × 12 inches			=	132.04
6.	"	is .5	=	66.02
3.	"	is .5 of 6	=	33.01
.25	"	is $\frac{1}{12}$ of 3	=	2.7508
9.25			=	101.7808 *pounds.*

Weight of Round Rolled Iron.

From 1-16th Inch to 12 Inches in Diameter.

ONE FOOT IN LENGTH.

Diam.	Weight.	Diam.	Weight.	Diam.	Weight.	Diam.	Weight
Ins.	Lbs.	Ins.	Lbs.	Ins.	Lbs.	Ins.	Lbs.
1/16	.01	1/4	13 44	5/8	56.788	1/2	149.328
1/8	.041	3/8	14.975	3/4	59.9	3/4	159.456
3/16	.093	1/2	16.588	7/8	63 094	8	169.856
1/4	.165	5/8	18.293	5	66 35	1/4	180.696
3/8	.373	3/4	20.076	1/8	69.731	1/2	191.808
1/2	.663	7/8	21 944	1/4	73.172	3/4	203.26
5/8	1.043	3	23.888	3/8	76.7	9	215.04
3/4	1.493	1/8	25.926	1/2	80.304	1/4	227.152
7/8	2.032	1/4	28.04	5/8	84.001	1/2	239.6
1	2.654	3/8	30.24	3/4	87.776	3/4	252.376
1/8	3.359	1/2	32.512	7/8	91.634	10	265.4
1/4	4.147	5/8	34.886	6	95.552	1/4	278.924
3/8	5 019	3/4	37.332	1/4	103.704	1/2	292.688
1/2	5.972	7/8	38.864	3/8	107.86	3/4	306.8
5/8	7 01	4	42.464	1/2	112.16	11	321.216
3/4	8.128	1/8	45.174	5/8	116 484	1/4	336.004
7/8	9.333	1/4	47 952	3/4	120.96	1/2	351.104
2	10.616	3/8	50.815	7	130.048	3/4	366.536
1/8	11.988	1/2	53.76	1/4	139.544	12	382.208

Weight of Cast Iron Pipes of different Thicknesses.

From 1 Inch to 24 Inches in Diameter.

ONE FOOT IN LENGTH.

Diam.	Thkn.	Weight.	Diam.	Thkn.	Weight.	Diam.	Thkn.	Weight.
Ins.	Ins.	Lbs.	Ins.	Ins.	Lbs.	Ins.	Ins.	Lbs.
1	1/4	3 06	2 3/4	5/8	20.59	4 1/4	1/2	23.35
	3/8	5 05	3	3/8	12.28		5/8	29.85
1 1/4	1/4	3.67		1/2	17.15		3/4	36.73
	3/8	6.		5/8	22.15	4 1/2	1/2	24.49
1 1/2	3/8	6.89		3/4	27.56		5/8	31.4
	1/2	9.8	3 1/4	1/2	18.4		3/4	38.58
1 3/4	3/8	7.8		5/8	23.72	4 3/4	1/2	25.7
	1/2	11.04		3/4	29.64		5/8	32.91
2	3/8	8.74	3 1/2	1/2	19.66		3/4	40.43
	1/2	12.23		5/8	25.27	5	1/2	26.94
2 1/4	3/8	9.65		3/4	31 2		5/8	34.34
	1/2	13.48	3 3/4	1/2	20.9		3/4	42.28
2 1/2	3/8	10.57		5/8	26.83	5 1/2	1/2	29.4
	1/2	14.66		3/4	33.07		5/8	37.44
	5/8	19.05	4	1/2	22.05		3/4	45.94
2 3/4	3/8	11.54		5/8	28 28	6	1/2	31.82
	1/2	15.91		3/4	34.94		5/8	40.56

Weight of Cast Iron Pipes.—*Continued.*

Diam.	Thkn.	Weight.	Diam.	Thkn.	Weight.	Diam.	Thkn.	Weight.
Ins.	Ins.	Lbs.	Ins.	Ins.	Lbs.	Ins.	Ins.	Lbs.
6	3/4	49.6	11	3/4	86.4	16	1/2	80.87
	7/8	58.96		7/8	101.83		5/8	101.82
6½	1/2	34.32		1	117.6		3/4	123.14
	5/8	43.68	11½	1/2	58.82		7/8	144.76
	3/4	53.3		5/8	74.28		1	166.6
	7/8	63.18		3/4	90.06	16½	1/2	83.3
7	1/2	36.66		7/8	106.14		5/8	104.82
	5/8	46.8		1	122.62		3/4	126.79
	3/4	56.96	12	1/2	61.26		7/8	149.02
	7/8	67.6		5/8	77.36		1	171 6
	1	78.39		3/4	93.7	17	1/2	85.73
7½	1/2	39.22		7/8	110.48		5/8	107.96
	5/8	49.92		1	127.42		3/4	130.48
	3/4	60.48	12½	1/2	63.7		7/8	153.3
	7/8	71.76		5/8	80.4		1	176.58
	1	83.28		3/4	97.4	17½	1/2	88.23
8	1/2	41.64		7/8	114.72		5/8	111.06
	5/8	52.68		1	132.35		3/4	134.16
	3/4	64.27	13	1/2	66.14		7/8	157.59
	7/8	76.12		5/8	83.46		1	181 33
	1	88.2		3/4	101 08	18	5/8	114.1
8½	1/2	44.11		7/8	118.97		3/4	137.84
	5/8	56.16		1	137.28		7/8	161.9
	3/4	68.	13½	1/2	68.64		1	186.24
	7/8	80.5		5/8	86.55	19	5/8	120.24
	1	93.28		3/4	104.76		3/4	145.2
9	1/2	46.5		7/8	123.3		7/8	170.47
	5/8	58.92		1	142.16		1	195.92
	3/4	71.7	14	1/2	71.07	20	5/8	126.33
	7/8	84.7		5/8	89.61		3/4	152.53
	1	97.98		3/4	108.46		7/8	179.02
9½	1/2	48.98		7/8	127.6		1	205.8
	5/8	62.02		1	147 03	21	5/8	132.5
	3/4	75.32	14½	1/2	73.72		3/4	159.84
	7/8	88.98		5/8	92.66		7/8	187.6
	1	102.9		3/4	112.1		1	215.52
10	1/2	51.46		7/8	131.86	22	5/8	138.6
	5/8	65.08		1	151.92		3/4	167.24
	3/4	78.99	15	1/2	75.96		7/8	196.46
	7/8	93.24		5/8	95.72		1	225.38
	1	108.84		3/4	115.78	23	5/8	144.77
10½	1/2	53.88		7/8	136.15		3/4	174.62
	5/8	68.14		1	156.82		7/8	204.78
	3/4	82.68	15½	1/2	78.4		1	235.28
	7/8	97.44		5/8	98.78	24	5/8	150.85
	1	112.68		3/4	119.48		3/4	181.92
11	1/2	56.31		7/8	140.4		7/8	213.28
	5/8	71.19		1	161.82		1	245.03

NOTE.—These weights do not include any allowance for spigot and faucet ends.

CAST IRON.

To Compute the Weight of a Cast Iron Bar or Rod.

Find the weight of a wrought iron bar or rod of the same dimensions in the preceding tables or by computation, and from the weight deduct the 2-27th part ; or,

As 1000 : .9257 : : the weight of a wrought bar or rod : to the weight required. Thus, what is the weight of a piece of cast iron $4 \times 3\frac{3}{4} \times 12$ inches.

In table, page 108, the weight of wrought iron of these dimensions is 50.692 lbs.

Then 1000 : .9257 : : 50.692 : 46 93 lbs.

To Compute the Weight of a piece of Cast or Wrought Iron of any Dimension or Form.

By the rules given in Mensuration of Solids, ascertain the number of cubic inches in the piece, then multiply by the weight of a cubic inch, and the product will give the weight in pounds.

EXAMPLE.—What is the weight of a cube of wrought iron 10 inches square by 15 inches in length ?

$10 \times 10 \times 15 = 1500$ cubic inches.
.2816 weight of a cubic inch.*
422.4 pounds.

2. What is the weight of a cast iron ball 15 inches in diameter ?

Ball, 15 ins. = 176.7149 cubic inches.
.2607 weight of a cubic inch.*
460.6957 pounds.

COPPER.

To Compute the Weight of Copper.

RULE.—Ascertain the number of cubic inches in the piece ; multiply them by .32418,* and the product will give you the weight in pounds.

EXAMPLE.—What is the weight of a copper plate $\frac{1}{2}$ an inch thick by 16 inches square ?

$16^2 = 256$
.5 for $\frac{1}{2}$ an inch
$128 \times .32418 = 41.495$ pounds.

BRAZIER'S SHEETS are 30×60 inches, and from 12 to 100 lbs. per square foot.

SHEATHING COPPER is 14×48 inches, and from 14 to 34 oz. per square foot.

* The weights of a cubic inch as here given are for the ordinary metals ; when, however, the specific gravity of the metal under consideration is accurately known, the weight of a cubic inch of it should be substituted for the units here given.

LEAD.

To Compute the Weight of Lead.

RULE.—Ascertain the number of cubic inches in the piece; multiply the sum by .41015, and the product will give the weight in pounds.

EXAMPLE.—What is the weight of a leaden pipe 12 feet long, 3.75 inches in diameter, and 1 inch thick?

BY RULE IN MENSURATION OF SURFACES, TO ASCERTAIN THE AREA OF CYLINDRICAL RINGS.

Area of $(3.75 + 1 + 1) = 25.967$
" " $3.75 = 11.044$

Difference, 14.923, or area of ring.
$144 = 12$ feet.

$2148.912 \times .41015 = 881.376$ pounds.

BRASS.

To Compute the Weight of Ordinary Brass Castings.

RULE.—Ascertain the number of cubic inches in the piece; multiply them by .3112, and the product will give the weight in pounds.

SHIP AND RAILROAD SPIKES.

Number of Iron Spikes per 100 lbs.—P. C. Page.

Ship Spikes or Hatch Nails 1-4 in. sq're.		Ship Spikes or Hatch Nails 5-16 in. sq.		Ship Spikes or Deck Nails 3-8 in. sq're.		Ship Spikes 7-16 inch square.		Ship Spikes 1-2 inch square.		Ship Spikes 9-16 inch square.		Ship Spikes 5-8 inch square.	
Size in inc.	No. 100 lbs.	Size in inc.	No. 100 lbs.	Size in inc	No. 100 lbs.	Size in inc.	No. 100 lbs.	Size in inc.	No. 100 lbs.	Size in inc.	No. 100 lbs.	Size in inc	No. 100 lbs.
3	1900	3	1000	4	540	5	340	6	220	8	140	10	80
3½	1580	3½	960	4½	500	5½	310	6½	200	9	120	15	60
4	1320	4	800	5	460	6	300	7	190	10	110		
4½	1220	4½	600	5½	420	6½	280	7½	180	11	100		
5	1020	5	580	6	400	7	260	8	170				
		6	520	6½	320	7½	210	8½	160				
						8	220	9	150				
								10	140				

Railroad Spikes 9-16ths square 5¼ inches 160 per 100 pounds.
Railroad Spikes 1-2 inch " 5½ " 200 per 100 pounds.

Burden's Patent Spikes and Horseshoes.

MANUFACTURED AT THE TROY IRON AND NAIL FACTORY, TROY, NEW YORK.

Boat Spikes.		Ship Spikes.		Hook Head.		Horseshoes.	
Size in inches.	No. in 100 lbs.	Size in inches.	No. in 100 lbs.	Size in inches.	No. in 100 lbs.	Size in inches.	No. in 100 lbs.
3	1,750	4	800	4 × ⅜	555	1	84
3½	1,468	4½	650	4½ × 7-16	414	2	75
4	1,257	5	437	5 × ½	252	3	65
4½	920	5½	430	5½ × ½	241	4	56
5	720	6	420	5½ × 9-16	187	5	39
5½	630	6½	377	6 × 9-16	172	—	—
6	497	7	275	6 × ⅝	138	—	—
6½	478	7½	250	7 × 9-16	140	—	—
7	362	8	174	8 × ⅝	110	—	—
7½	337	8½	163	— —	—	—	—
8	295	9	155	— —	—	—	—
8½	290	10	115	— —	—	—	—
9	210	—	—	— —	—	—	—
10	198	—	—	— —	—	—	—

Coppers.

Dimensions and Weight from 1 to 208 Gallons.

Inches lag to brim.	Gallons	Weight in pounds	Inches lag to brim.	Gallons	Weight in pounds	Inches lag to brim	Gallons	Weight in pounds
9¾	1	1½	24	15	22½	29½	29	43½
12¼	2	3	24½	16	24	30	30	45
14	3	4½	25	17	25½	32	36	54
15½	4	6	25½	18	27	34	43	64½
16½	5	7½	26	19	28½	35	48	72
17½	6	9	26½	20	30	36	53	79½
18½	7	10½	26¾	21	31½	37	58	87
19½	8	12	27	22	33	38	63	94½
20¼	9	13½	27¼	23	34½	39	67	100½
21	10	15	27½	24	36	40	71	106½
21½	11	16½	27¾	25	37½	45	104	156
22	12	18	28	26	39	50	146	219
22½	13	19½	28½	27	40½	55	208	312
23¼	14	21	29	28	42			

Copper Tubing.

Weight of the usual thickness.

When the inside diameter is ¼ of an inch, 3 ozs.; ⅜ do., 5 ozs.; ½ do., 6 ozs.; ⅝ do., 8 ozs.; ¾ do., 10 ozs. per foot.

Brass, Copper, Steel, and Lead.

Weight of a Foot.

	BRASS.		COPPER.		STEEL.		LEAD.	
Diamt'r and Side of Sq're.	Weight of Round.	Weight of Square.	Weight of Round.	Weight of Square.	Weight of Round.	Weight of Square.	Weight of Round.	Weight of Square.
Inches.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1/4	.17	.22	.19	.24	.17	.21		
3/8	.39	.50	.42	.54	.38	.48		
1/2	.70	.90	.75	.96	.67	.85		
5/8	1.10	1.40	1.17	1.50	1.04	1.33		
3/4	1.59	2.02	1.69	2.16	1.50	1.91		
7/8	2.16	2.75	2.31	2.94	2.05	2.61		
1	2.83	3.60	3.02	3.84	2.67	3.40	3.87	4.93
1 1/8	3.58	4.56	3.82	4.86	3.38	4.34	4.90	6.25
1 1/4	4.42	5.63	4.71	6.	4.18	5.32	6.06	7.71
1 3/8	5.35	6.81	5.71	7.27	5.06	6.44	7.33	9.33
1 1/2	6.36	8.10	6.79	8.65	6.02	7.67	8.72	11.11
1 5/8	7.47	9.51	7.94	10.15	7.07	9.	10.24	13.04
1 3/4	8.66	11.03	9.21	11.77	8.20	10.14	11.87	15.12
1 7/8	9.95	12.66	10.61	13.52	9.41	11.98	13.63	17.36
2	11.32	14.41	12.08	15.38	10.71	13.63	15.51	19.75
2 1/8	12.78	16.27	13.64	17.36	12.05	15.80	17.51	22.29
2 1/4	14.32	18.24	15.29	19.47	13.51	17.20	19.63	25.
2 3/8	15.96	20.32	17.03	21.69	15.05	19.17	21.80	27.80
2 1/2	17.68	22.53	18.87	24.03	16.68	21.21	24.24	30.86
2 5/8	19.50	24.83	20.81	26.50	18.39	23.41	26.72	34.02
2 3/4	21.40	27.25	22.84	29.08	20.18	25.70	29.33	37.34
2 7/8	23.39	29.78	24.92	31.79	22.06	28.10	32.05	40.81
3	25.47	32.43	27.18	34.61	24.23	30.60	34.90	44.44

Steel.

Weight of a Foot in Length of Flat.

Size.	Thick, 1-4 in.	Thick, 3-8ths	Thick, 1-2 in.	Thick, 5-8ths.	Size.	Thick, 1-4 in.	Thick, 3-8ths.	Thick, 1-2 in.	Thick, 5-8ths.
in.	lbs.	lbs.	lbs.	lbs.	in.	lbs.	lbs.	lbs.	lbs.
1	.852	1.27	1.70	2.13	2 1/2	2.13	3.20	4.26	5.32
1 1/8	.958	1.43	1.91	2.39	2 3/4	2.34	3.51	4.68	5.85
1 1/4	1.06	1.59	2.13	2.66	3	2.55	3.83	5.11	6.39
1 3/8	1.17	1.75	2.34	2.92	3 1/4	2.77	4.15	5.53	6.92
1 1/2	1.27	1.91	2.55	3.19	3 1/2	2.98	4.47	5.98	7.45
1 3/4	1.49	2.23	2.98	3.72	3 3/4	3.19	4.79	6.38	7.98
2	1.70	2.55	3.40	4.26	4	3.40	5.10	6.80	8.52
2 1/4	1.91	2.87	3.83	4.79					

Cast Iron.

Weight of a Foot in Length of Flat Cast Iron.

Width of Iron	Thick, 1-4th in.	Thick, 3-8ths in.	Thick, 1-2 inch.	Thick, 5-8ths in.	Thick, 3-4ths in.	Thick, 7-8ths in.	Thick, 1 inch.
Inc's.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.
2	1.56	2.34	3 12	3.90	4.68	5.46	6.25
2¼	1.75	2.63	3.51	4 39	5.27	6.15	7.03
2½	1.95	2.92	3.90	4.88	5.85	6.83	7.81
2¾	2.14	3.22	4.29	5.37	6 44	7.51	8 59
3	2 34	3.51	4.68	5.85	7.03	8.20	9.37
3¼	2.53	3.80	5.07	6.34	7.61	8.88	10.15
3½	2 73	4.10	5 46	6.83	8.20	9.57	10.93
3¾	2 93	4.39	5.85	7.32	8.78	10.25	11.71
4	3.12	4.68	6 25	7.81	9.37	10.93	12.50
4¼	3.32	4.97	6.64	8.30	9.96	11.62	13.28
4½	3.51	5.27	7.03	8.78	10.54	12.30	14 06
4¾	3.71	5.56	7 42	9.27	11.13	12.98	14.84
5	3.90	5.86	7.81	9.76	11.71	13 67	15 62
5¼	4 10	6.15	8.20	10.25	12 30	14.35	16.40
5½	4.29	6 44	8.59	10 74	12 89	15.03	17.18
5¾	4 49	6.73	8 98	11.23	13 46	15 72	17 96
6	4.68	7.03	9.37	11.71	14.06	16 40	18.75

Cast Iron, Copper, Brass, and Lead Balls.

Weight of Cast Iron, Copper, Brass, and Lead Balls, from 1 *inch to* 11 *inches in diameter.*

Dia.	C. Iron.	Copper.	Brass.	Lead.	Dia.	C. Iron.	Copper.	Brass	Lead.
In.	Pounds	Pounds	Pounds	Pounds	In.	Pounds	Pounds	Pounds	Pounds
1	.136	.166	.158	.214	7	46.76	57.1	54.5	73 7
1½	.46	.562	.537	.727	7½	57.52	70.0	67.11	90.0
2	1.09	1.3	1.25	1.7	8	69.81	85.2	81.4	110.1
2½	2.13	2.60	2.50	3.35	8½	83.73	102.3	100.0	132.3
3	3.68	4.5	4.3	5.8	9	99.4	121.3	115.9	156.7
3½	5.84	7.14	6.82	9.23	9½	116 9	143 0	136.4	184 7
4	8.72	10.7	10.2	13.8	10	136.35	166.4	159.0	215.0
4½	12 42	15.25	14.5	19.6	10½	157.84	193.0	184.0	250.0
5	17.04	20.8	19 9	26.9	11	181.48	221.8	211.8	286.7
5½	22.68	27.74	26.47	36.0	11½	207.37	253.5	242.0	327.7
6	29.45	35.9	34.3	46.4	12	235.62	288.1	275.0	372.3
6½	37.44	45.76	43.67	59.13					

Cast Iron.—*Weight of a Foot in Length of Square and Round.*

SQUARE.				ROUND.			
Size.	Weight.	Size.	Weight.	Size.	Weight.	Size.	Weight.
Inch sq.	Pounds.	Inch. sq.	Pounds.	Inch. sq.	Pounds.	Inch sq.	Pounds.
1/2	.78	4 7/8	74.26	1/2	.61	4 7/8	58.32
5/8	1.22	5	78.12	5/8	.95	5	61.35
3/4	1.75	5 1/8	82.08	3/4	1.38	5 1/8	64.46
7/8	2.39	5 1/4	86.13	7/8	1.87	5 1/4	67.64
1	3.12	5 3/8	90.28	1	2.45	5 3/8	70.09
1 1/8	3.95	5 1/2	94.53	1 1/8	3.10	5 1/2	74.24
1 1/4	4.88	5 5/8	98.87	1 1/4	3.83	5 5/8	77.65
1 3/8	5.90	5 3/4	103.32	1 3/8	4.64	5 3/4	81.14
1 1/2	7.03	5 7/8	107.86	1 1/2	5.52	5 7/8	84.71
1 5/8	8.25	6	112.50	1 5/8	6.48	6	88.35
1 3/4	9.57	6 1/4	122.08	1 3/4	7.51	6 1/4	95.87
1 7/8	10.98	6 1/2	132.03	1 7/8	8.62	6 1/2	103.69
2	12.50	6 3/4	142.38	2	9.81	6 3/4	111.82
2 1/8	14.11	7	153.12	2 1/8	11.08	7	120.26
2 1/4	15.81	7 1/4	164.25	2 1/4	12.42	7 1/4	129.
2 3/8	17.62	7 1/2	175.78	2 3/8	13.84	7 1/2	138.05
2 1/2	19.53	7 3/4	187.68	2 1/2	15.33	7 3/4	147.41
2 5/8	21.53	8	200.	2 5/8	16.91	8	157.08
2 3/4	23.63	8 1/4	212.56	2 3/4	18.56	8 1/4	167.05
2 7/8	25.83	8 1/2	225.78	2 7/8	20.28	8 1/2	177.10
3	28.12	8 3/4	239.25	3	22.08	8 3/4	187.91
3 1/8	30.51	9	253.12	3 1/8	23.96	9	198.79
3 1/4	33.	9 1/4	267.38	3 1/4	25.92	9 1/4	210.
3 3/8	35.59	9 1/2	282.	3 3/8	27.95	9 1/2	221.50
3 1/2	38.28	9 3/4	297.07	3 1/2	30.06	9 3/4	233 31
3 5/8	41.06	10	312.50	3 5/8	32.25	10	245.43
3 3/4	43.94	10 1/4	328.32	3 3/4	34.51	10 1/4	257 86
3 7/8	46.92	10 1/2	344.53	3 7/8	36.85	10 1/2	270.59
4	50.	10 3/4	361.13	4	39.27	10 3/4	283.63
4 1/8	53.14	11	378.12	4 1/8	41.76	11	296.97
4 1/4	56.44	11 1/4	395.50	4 1/4	44.27	11 1/4	310.63
4 3/8	59.81	11 1/2	413.28	4 3/8	46.97	11 1/2	324.59
4 1/2	63.28	11 3/4	431.44	4 1/2	49.70	11 3/4	338 85
4 5/8	66.81	12	450.	4 5/8	52.50	12	353.43
4 3/4	70.50			4 3/4	55.37		

Cast Iron. *Weight of a Superficial Foot from 1/4 to 2 inches thick.*

Size	Weight	Size	Weight	Size.	Weight	Size.	Weight.	Size.	Weight.
Ins.	Pounds	Ins.	Pounds	Ins.	Pounds	Ins.	Pounds	Ins.	Pounds
1/4	9.37	5/8	23.43	1	37.50	1 3/8	51.56	1 3/4	65.62
3/8	14.06	3/4	28.12	1 1/8	42.18	1 1/2	56.25	1 7/8	70.31
1/2	18.75	7/8	32.81	1 1/4	46.87	1 5/8	60.93	2	75.

To Ascertain the Weight of Wrought Iron, Copper, or Brass Tubes and Pipes per Lineal Foot.

From ½ an Inch in Internal Diameter to 6 Inches.

Diam.	Area of Plate.	Diam.	Area of Plate.	Diam.	Area of Plate.	Diam.	Area of Plate.
Ins.	Sq. Feet.	Ins.	Sq. Feet.	Ins.	Sq. Feet.	Ins.	Sq. Feet.
½	.1309	1 5-16	.3436	2¾	.7199	4½	1.1781
9-16	.1473	1⅜	.36	2⅞	.7526	4⅝	1.2108
⅝	.1636	1 7-16	.3764	3	.7854	4¾	1.2435
11-16	.18	1½	.3927	3⅛	.8181	4⅞	1.2763
3-4	.1964	1⅝	.4254	3¼	.8508	5	1.309
13-16	.2127	1¾	.4581	3⅜	.8836	5⅛	1.3417
⅞	.2291	1⅞	.4909	3½	.9163	5¼	1.3744
15-16	.2454	2	.5236	3⅝	.949	5⅜	1 4072
1	.2618	2⅛	.5543	3¾	.9818	5½	1.4399
1 1-16	.2782	2¼	.587	4	1.0472	5⅝	1.4726
1 ⅛	.2945	2⅜	.6198	4⅛	1.0799	5¾	1.5053
1 3-16	.3105	2½	.6545	4¼	1.1126	5⅞	1.5381
1 ¼	.3272	2⅝	.6872	4⅜	1.1454	6	1.5708

Application of the Table.

WHEN THE THICKNESS OF THE METAL IS GIVEN IN THE DIVISIONS OF AN INCH.

To the internal diameter of the tube or pipe add the thickness of the metal; take the area of a plate in square feet, from the table, for a diameter equal to the sum of the diameter and thickness of the tube or pipe, and multiply it by the weight of a square foot of the metal for the given thickness, and again by its length in feet.

ILLUSTRATION.—Required the weight of 10 feet of copper tube 1 inch in circumference and ⅛ of an inch in thickness.

$1 + \frac{1}{8} = 1\frac{1}{8} = .2945$ square feet for 1 foot of length.

Weight of 1 square foot of copper ⅛ of an inch in thickness $= 5.781$ lbs.; then, $.2945 \times 5.781 = 1.7025$ lbs.

WHEN THE THICKNESS OF THE METAL IS GIVEN IN NUMBERS OF A WIRE GAUGE.

To the internal diameter of the tube or pipe add the thickness, multiply the sum by 3.1416, divide the product by 12, and the quotient will give you the area of the plate in square feet. Then proceed as before given.

ILLUSTRATION.—Required the weight of 10 feet of copper pipe 2 inches in diameter, and No. 2 American wire gauge in thickness.

$2 + .25763 \times 3.1416 \div 12 = 2.25763 \times 3.1416 \div 12 = .591$ square feet; then, $.591 \times 11.6706 = 6.897$ lbs

Table showing the Thickness and Weight of Galvanized Sheet Iron.

DIMENSIONS OF SHEET, 2 FEET IN WIDTH BY FROM 6 TO 9 FEET IN LENGTH.

Wire Gauge.	Weight per Sq. Foot.	Wire Gauge.	Weight per Sq. Foot.	Wire Gauge.	Weight per Sq. Foot.	Wire Gauge.	Weight per Sq. Foot.
No.	Oz.	No.	Oz.	No.	Oz.	No.	Oz.
30	10	26	15	22	21	18	37
29	11	25	16	21	24	17	43
28	12	24	17	20	28	16	48
27	14	23	19	19	33	14	60

Patent Improved Lead Pipe, Sizes and Weight per Foot.

Calibre.	Weight Per Foot	Calibre.	Weight Per Foot	Calibre.	Weight Per Foot.	Calibre.	Weight Per Foot.	Calibre.		Weight Per Foot.
In.	lbs. oz.	In	lbs. oz.	In.	lbs. oz.	In.	lbs. oz.	In.		lbs. oz.
3/8	6	1/2	1 4	3/4	1 4	1	4 0	1½		5 0
"	8	"	1 8	"	2 0	"	6 0	1¾		4 0
"	10	"	2 0	"	2 4	1¼	2 8	2		5 0
"	12	"	3 0	"	2 8	"	3 0	"		6 0
"	1 0	5/8	13	"	3 0	"	3 8	"		7 0
"	1 8	"	1 0	"	4 0	"	4 0	2½	1-4 in. thick.	11 0
1/2	8	"	1 8	1	1 8	"	5 0	3		13 0
"	10	"	2 0	"	1 12	1½	3 0	3½		15 0
"	12	"	2 12	"	2 0	"	3 8	4		18 0
"	14	3/4	12	"	2 8	"	4 0	4½		20 0
"	1 0	"	14	"	3 0	"	4 8	5		22 0

Boston Lead Pipe, Sizes and Weight per Foot.

½ in.		⅝ in.		¾ in.		1 in.		1¼ in.		1½ in.		1¾ in.		2 in.	
lbs.	oz.	lbs.	oz	lbs.	oz.	lbs.	oz.	lbs	oz.	lbs.	oz.	lbs.	oz	lbs	oz.
	10	2	12	1	1	1	8	2	1	3	5	3	10	4	12
	12	3		1	6	1	12	2	8	3	12	4	3	5	8
	15			1	12	2		2	13	4	4	5	2	7	12
1	4			2	4	2	6	3	3	4	10				
1	8			3	2	2	11	3	15	6					
1	11			3	14	3	13								
1	14					5									
2	4					6	4								

Sheet Lead.—Weight of a Square Foot, 2½, 3, 3½, 4, 4½, 5, 6, 7, 8½, 9, 10 lbs. and upward.

Comparative Strength and Weight of Ropes and Chains.

Circum. of Rope in inches.	Weight per Fathom in lbs.	Diameter of Chain in inches.	Weight per Fathom in lbs.	Proof Strength in tons and cwt.	Circum. of Rope in inches.	Weight per Fathom in lbs.	Diameter of Chain in inches.	Weight per Fathom in lbs.	Proof Strength in tons and cwt.
3½	2¾	5/16	5½	1 5½	10	23	7/8	43	10 0
4¼	4¾	3/8	8	1 16¾	10¾	28	15/16	49	11 11
5	5¾	7/16	10½	2 10	11½	30½	1	56	13 8
5¾	7	½	14	3 5½	12¼	36	1 1/16	63	14 18
6½	9¾	9/16	18	4 3½	13	39	1⅛	71	16 14
7	11¼	5/8	22	5 2	13¾	45	1 3/16	79	18 11
8	15	11/16	27	6 4½	14½	48½	1¼	87	20 8
8¾	19	¾	32	7 7	15¼	56	1 5/16	96	22 13
9½	21	13/16	37	8 13½	16	60	1⅜	106	24 18

NOTE.—It must be understood and also borne in mind, that, in estimating the amount of tensile strain to which a body is subjected, the weight of the body itself must also be taken into account; for according to its position so may it approximate to its whole weight in tending to produce extension within itself; as in the almost constant application of ropes and chains to great depths, considerable heights, &c.

STRENGTH OF MATERIALS OF CONSTRUCTION.

Materials of construction are liable to four different kinds of strain; viz., stretching, crushing, transverse action, and torsion or twisting; the first of which depends upon the body's tenacity alone; the second, on its resistance to compression; the third, on its tenacity and compression combined; and the fourth, on that property by which it opposes any acting force tending to change from a straight line, to that of a spiral direction, the fibres of which the body is composed.

In bodies, the power of tenacity and resistance to compression, in the direction of their length, is as the cross-section of their area multiplied by the results of experiments on similar bodies, as exhibited in the following tables.

Table showing the Tenacities, Resistances to Compression, and other Properties of the common Materials of Construction.

Names of Bodies.	Absolute		Compared with Cast Iron		
	Tenacity in lbs. per sq. inch.	Resistance to compression in lbs per sq. inch	Its strength is	Its extensibility is	Its stiffness is
Ash,	14,130		0.23	2.6	0.089
Beech,	12,225	8,548	0.15	2.1	0.073
Brass,	17,968	10,304	0.435	0.9	0.49
Brick,	275	562			
Cast Iron,	13,434	86,397	1.0	1.0	1.0
Copper (wrought),	33,000				
Elm,	9,720	1,033	0.21	2.9	0.073
Fir, or Pine, White,	12,346	2,028	0.23	2.4	0.1
" " Red,	11,800	5,375	0.3	2.4	0.1
" " Yellow,	11,835	5,445	0.25	2.9	0.087
Granite (Aberdeen),		10,910			
Gun-metal (copper 8, and tin 1),	35,838		0.65	1.25	0.535
Malleable Iron,	56,000		1.12	0.86	1.3
Larch,	12,240	5,568	0.136	2.3	0.0585
Lead,	1,824		0.096	2.5	0.038
Mahogany, Honduras	11,475	8,000	0.24	2.9	0.487
Marble,	551	6,060			
Oak,	11,880	9,504	0.25	2.8	0.093
Rope (1 in. in circum.)	200				
Steel,	128,000				
Stone, Bath,	478				
" Craigleith,	772	5,490			
" Dundee,	2,661	6,630			
" Portland,	857	3,729			
Tin (cast),	4,736		0.182	0.75	0.25
Zinc (sheet),	9,120		0.365	0.5	0.76

Resistance to Lateral Pressure, or Transverse Action.

The strength of a square or retangular beam to resist lateral pressure, acting in a perpendicular direction to its length, is as the breadth and square of the depth, and inversely as the length; thus, a beam twice the breadth of another, all other circumstances being alike, equals twice the strength of the other; or twice the depth equals four times the strength, and twice the length equals only half the strength, &c., according to the rule.

Table of Data, containing the Results of Experiments on the Elasticity and Strength of various Species of Timber, by Mr. Barlow.

Species of Timber.	Value of E.	Value of S.	Species of Timber.	Value of E.	Value of S.
Teak..........	174.7	2,462	Elm...........	50.64	1,013
Poona...... ...	122.26	2,221	Pitch Pine	88.68	1,632
English Oak...	105.	1,672	Red Pine.. ...	133.	1,341
Canadian " ...	155.5	1,766	New Engl'd Fir	158.5	1,102
Dantzic " ...	86.2	1,457	Riga Fir.......	90.	1,100
Adriatic " ..	70.5	1,383	Mar Forest Fir.	63.	1,200
Ash...........	119.	2,026	Larch..... .	76.	900
Beech..	98.	1,556	Norway Spruce	105.47	1,474

To find the dimensions of a beam capable of sustaining a given weight, with a given degree of deflection, when supported at both ends.

Rule.—Multiply the weight to be supported in lbs. by the cube of the length in feet; divide the product by 32 times the tabular value of E, multiplied into the given deflection in inches; and the quotient is the breadth multiplied by the cube of the depth in inches.

Note 1.—When the beam is intended to be square, then the fourth root of the quotient is the breadth and depth required.

Note 2.—If the beam is to be cylindrical, multiply the quotient by 1.7, and the fourth root of the product is the diameter.

Ex.—The distance between the supports of a beam of Riga fir is 16 feet, and the weight it must be capable of sustaining in the middle of its length is 8,000 lbs., with a deflection of not more than $\frac{3}{4}$ of an inch; what must be the depth of the beam, supposing the breadth 8 inches?

$$\frac{16 \times 8000}{90 \times 32 \times .75} = 15175 \div 8 = \sqrt[3]{1897} = 12.35 \text{ in., the depth.}$$

To determine the absolute strength of a rectangular beam of timber, when supported at both ends, and loaded in the middle of its length, as beams in general ought to be calculated to, so that they may be rendered capable of withstanding all accidental cases of emergency.

Rule.—Multiply the tabular value of S by 4 times the depth of the beam in inches, and by the area of the cross-section in inches; divide the product by the distance between the supports in inches, and the quotient will be the absolute strength of the beam in lbs.

Note 1.—If the beam be not laid horizontally, the distance between the supports, for calculation, must be the horizontal distance.

NOTE 2.—One-fourth of the weight obtained by the rule is the greatest weight that ought to be applied in practice as permanent load.

NOTE 3.—If the load is to be applied at any other point than the middle, then the strength will be as the product of the two distances is to the square of half the length of the beam between the supports; or, twice the distance from one end, multiplied by twice from the other and divided by the whole length, equals the effective length of the beam.

EX.—In a building 18 feet in width, an engine boiler of $5\frac{1}{2}$ tons (2,240 lbs. to a ton) is to be fixed, the centre of which is to be 7 feet from the wall, and having two pieces of red pine, 10 inches by 6, which I can lay across the two walls for the purpose of slinging it at each end,—may I, with sufficient confidence, apply them so as to effect this object?

$$2240 \times 5.5 \div 2 = 6160 \text{ lbs. to carry at each end.}$$

And 18 feet $- 7 = 11$, double each, or 14 and 22, then $14 \times 22 \div 18 = 17$ feet, or 204 inches, effective length of beam.

Tabular value of S, red pine, $= 1341 \times 4 \times 10 \times 60 \div 204 =$ 15,776 lbs., the absolute strength of each piece of timber at that point.

To determine the dimensions of a rectangular beam capable of supporting a required weight, with a given degree of deflection, when fixed at one end.

RULE.—Divide the weight to be supported, in lbs., by the tabular value of E, multiplied by the breadth and deflection, both in inches, and the cube root of the quotient, multiplied by the length in feet, equals the depth required in inches.

EX.—A beam of ash is intended to bear a load of 700 lbs. at its extremity, its length being 5 feet, breadth 4 inches, and the deflection not to exceed $\frac{1}{2}$ an inch.

Tabular value of $E = 119 \times 4 \times .5 = 238$ the divisor;
then $700 \div 238 = \sqrt[3]{2.94} \times 5 = 7.25$ inches, depth of the beam.

To find the absolute strength of a rectangular beam, when fixed at one end and loaded at the other.

RULE.—Multiply the value of S by the depth of the beam and by the area of its section, both in inches; divide the product by the leverage in inches, and the quotient equals the absolute strength of the beam in lbs.

EX. A beam of Riga fir, 12 inches by $4\frac{1}{2}$, and projecting $6\frac{1}{2}$ feet from the wall; what is the greatest weight it will support at the extremity of its length?

Tabular value of S $= 1100$. $12 \times 4.5 = 54$ sectional area.
Then $1100 \times 12 \times 54 \div 78 = 9138.4$ lbs.

When fracture of a beam is produced by vertical pressure, the fibres of the lower section of fracture are separated by extension, whilst at the same time those of the upper portion are destroyed by compression; hence exists a point in section where neither the one nor the other takes place, and which is distinguished as the point of neutral axis. Therefore, by the law of fracture thus established, and proper data of tenacity and compression given, as in the preceding table, we are enabled to form metal beams of strongest section with the least possible material. Thus, in cast iron, the resistance to compression is nearly as $6\frac{1}{2}$ to 1 of tenacity, consequently a beam of cast iron, to be of strongest section, must be a parabola in the direction of its length, the quantity of material in the bottom flange being about $6\frac{1}{2}$ times that of the upper. But such is not the case with beams of timber; for although the tenacity of timber be on an average twice that of its resistance to compression, its flexibility is so great that any considerable length of beam, where columns cannot be situated to its support, requires to be strengthened or trussed by iron rods.

And these applications of principle not only tend to diminish deflection, but the required purpose is more effectively attained, and that by lighter pieces of timber.

To ascertain the absolute strength of a cast iron beam of the preceding form, or that of strongest section.

Rule.—Multiply the sectional area of the bottom flange, in inches, by the depth of the beam in inches, and divide the product by the distance between the supports, also in inches; and 514 times the quotient equal the absolute strength of the beam in cwts.

The strongest form in which any given quantity of matter can be disposed is that of a hollow cylinder; and it has been demonstrated that the maximum of strength is obtained in cast iron, when the thickness of the annulus or ring amounts to one-fifth of the cylinder's external diameter; the relative strength of a solid to that of a hollow cylinder being as the diameters of their sections. (*See Tables.*)

Resistance of Bodies to Flexure by Vertical Pressure.

When a piece of timber is employed as a column or support, its tendency to yielding by compression is different according to the proportion between its length and area of its cross-section; and supposing the form that of a cylinder whose length is less than seven or eight times its diameter, it is impossible to bend it by any force applied longitudinally, as it will be destroyed by splitting before bending can take place; but when the length exceeds this, the column will bend under a certain load, and be ultimately destroyed by a similar kind of action to that which has place in the transverse strain. Columns of cast iron and of other bodies are also similarly circumstanced.

When the length of a cast iron column with flat ends equals about thirty times its diameter, fracture will be produced wholly by bending of the material. When of less length, fracture takes place partly by crushing and partly by bending. But when the column is enlarged in the middle of its length from one and a half to twice its diameter at the ends, by being cast hollow, the strength is greater by one-seventh than in a solid column containing the same quantity of material.

Table,

SHOWING THE WEIGHT OR PRESSURE A BEAM OF CAST IRON, 1 INCH IN BREADTH, WILL SUSTAIN, WITHOUT DESTROYING ITS ELASTIC FORCE, WHEN IT IS SUPPORTED AT EACH END AND LOADED IN THE MIDDLE OF ITS LENGTH, AND ALSO THE DEFLECTION IN THE MIDDLE WHICH THAT WEIGHT WILL PRODUCE. BY MR. HODGKINSON, MANCHESTER.

L'gth.	6 feet.		7 feet.		8 feet		9 feet.		10 feet.	
Depth in in.	Weight in lbs.	Defl. in in	Weight in lbs.	Defl. in in.	Weight in lbs.	Defl. in in.	Weight in lbs.	Defl in in.	Weight in lbs.	Defl. in in.
3	1,278	.24	1 089	.33	954	.426	855	.54	765	.66
$3\frac{1}{2}$	1,739	.205	1,482	28	1,298	.365	1,164	.46	1,041	.57
4	2,272	.18	1,936	.245	1,700	.32	1,520	.405	1,360	.5
$4\frac{1}{2}$	2,875	.16	2,450	.217	2,146	.284	1,924	.36	1,721	.443
5	3,560	.144	3,050	.196	2,650	.256	2,375	.32	2,125	.4
6	5,112	.12	4 356	.163	3,816	.213	3,420	.27	3,060	.33
7	6,958	.103	5 929	.14	5,194	.183	4,655	.23	4,165	.29
8	9,088	.09	7,744	.123	6,784	16	6,080	.203	5,440	.25
9			9,801	.109	8,586	.142	7,695	.18	6,885	.22
10			12,100	.098	10,600	.128	9,500	.162	8,500	.2
11					12,826	.117	11,495	.15	10,285	.182
12					15,264	.107	13,680	.135	12,240	.17
13							16,100	.125	14,400	.154
14							18,600	.115	16,700	.143
	12 feet.		14 feet.		16 feet.		18 feet.		20 feet	
6	2,548	.48	2,184	.65	1,912	.85	1,699	1.08	1,530	1.34
7	3,471	.41	2,975	.58	2,603	.73	2,314	.93	2,082	1.14
8	4,532	.36	3,881	.49	3.396	.64	3,020	.81	2,720	1.00
9	5,733	.32	4,914	.44	4,302	.57	3,825	.72	3.438	.89
10	7,083	.28	6,071	.39	5,312	.51	4,722	.64	4,250	.8
11	8,570	.26	7,346	.36	6,428	.47	5,714	.59	5,142	.73
12	10,192	.24	8,736	.33	7,648	.43	6,796	.54	6,120	.67
13	11,971	.22	10,260	.31	8,978	.39	7,980	.49	7,182	.61
14	13,883	.21	11,905	.28	10,412	.36	9,255	.46	8,330	.57
15	15,937	.19	13,660	.26	11,952	.34	10,624	.43	9,562	.53
16	18,128	.18	15,536	.24	13,584	.32	12,080	40	10,880	.5
17	20,500	.17	17,500	.23	15,353	.30	13,647	.38	12,282	·47
18	22,932	.16	19,656	.21	17,208	.28	15.700	.36	13,752	.44

NOTE. This table shows the greatest weight that ever ought to be laid upon a beam for permanent load; and if there be any liability to jerks, etc., ample allowance must be made; also the weight of the beam itself must be included. (*See Tables of Cast Iron.*)

To find the weight of a cast iron beam of given dimensions.

Rule.—Multiply the sectional area in inches by the length in feet, and by 3.2; the product equals the weight in lbs.

Ex.—Required the weight of a uniform rectangular beam of cast iron, 16 feet in length, 11 inches in breadth, and $1\frac{1}{2}$ inches in thickness.

$$11 \times 1.5 \times 16 \times 3.2 = 844.8 \text{ lbs.}$$

To determine the dimensions of a support or column to bear, without sensible curvature, a given pressure in the direction of its axis.

Rule.—Multiply the pressure to be supported in pounds by the square of the column's length in feet, and divide the product by twenty times the tabular value of E; and the quotient will be equal to the breadth multiplied by the cube of the least thickness, both being expressed in inches.

Note 1.—When the pillar or support is a square, its side will be the fourth root of the quotient.

Note 2.—If the pillar or column be a cylinder, multiply the tabular value of E by 12, and the fourth root of the quotient equals the diameter.

Ex. 1.—What should be the least dimensions of an oak support, to bear a weight of 2,240 lbs., without sensible flexure, its breadth being 3 inches and its length 5 feet?

Tabular value of E = 105,

$$\text{and } \frac{2240 \times 5^2}{20 \times 105 \times 3} = \sqrt[3]{8.888} = 2.05 \text{ inches.}$$

Ex. 2.—Required the side of a square piece of Riga fir, 9 feet in length, to bear a permanent weight of 6,000 lbs.

Tabular value of E = 96,

$$\text{and } \frac{6000 \times 9^2}{20 \times 96} = \sqrt[4]{253} = 4 \text{ inches nearly.}$$

Elasticity of Torsion, or Resistance of Bodies to Twisting.

The angle of flexure by torsion is as the length and extensibility of the body directly, and inversely as the diameter; hence, the length of a bar or shaft being given, the power and the leverage the power acts with being known, and also the number of degrees of torsion that will not affect the action of the machine, to determine the diameter in cast iron with a given angle of flexure.

Rule.—Multiply the power in pounds by the length of the shaft in feet, and by the leverage in feet; divide the product by fifty-five times the number of degrees in the angle of torsion; and the fourth root of the quotient equals the shaft's diameter in inches.

Ex.—Required the diameters for a series of shafts 35 feet in length, and to transmit a power equal to 1,245 lbs., acting at the circumference of a wheel $2\frac{1}{2}$ feet radius, so that the twist of the shafts on the application of the power may not exceed one degree.

$$\frac{1245 \times 35 \times 2.5}{55 \times 1} = \sqrt[4]{1981} = 6.67 \text{ inches in diameter.}$$

To determine the side of a square shaft to resist torsion with a given flexure.

RULE.—Multiply the power in pounds by the leverage it acts with in feet, and also by the length of the shaft in feet; divide this product by 92.5 times the angle of flexure in degrees, and the square root of the quotient equals the area of the shaft in inches.

Ex.—Suppose the length of a shaft to be 12 feet, and to be driven by a power equal to 700 lbs., acting at one foot from the centre of the shaft—required the area of cross-section, so that it may not exceed 1 degree of flexure.

$$\frac{700 \times 1 \times 12}{92.5 \times 1} = \sqrt[2]{90.8} = 9.53 \text{ inches.}$$

Relative Strength of Bodies to resist Torsion, Lead being 1.

Tin	1.4	Gun-Metal	5.0	English Iron	10.1
Copper	4.3	Cast Iron	9.0	Blistered Steel	16.6
Yellow Brass	4.6	Swedish Iron	9.5	Shear Steel	17.0

Bar of Iron.—The average breaking weight of a bar of wrought iron, 1 inch square, is 25 tons; its elasticity is destroyed, however, by about two-fifths of that weight, or 10 tons. It is extended, within the limits of its elasticity, .000096, or one ten-thousandth part of an inch for every ton of strain per square inch of sectional area. Hence, the greatest constant load should never exceed one-fifth of its breaking weight, or 5 tons for every square inch of sectional area.

The lateral strength of wrought iron, as compared with cast iron, is as 14 to 9. Mr. Barlow finds that wrought iron bars, 3 inches deep, $1\frac{1}{2}$ inches thick, and 33 inches between the supports, will carry $4\frac{1}{2}$ tons.

Bridges.—The greatest extraneous load on a square foot is about 120 pounds.

Floors.—The least load on a square foot is about 160 pounds.

Roofs.—Covered with slate, on a square foot, $51\frac{1}{2}$ pounds.

Beams.—When a beam is supported in the middle and loaded at each end, it will bear the same weight as when supported at both ends and loaded in the middle; that is, each end will bear half the weight.

Cast iron beams should not be loaded to more than one-fifth of their ultimate strength.

The strength of similar beams varies inversely as their lengths; that is, if a beam 10 feet long will support 1,000 pounds, a similar beam 20 feet long would support only 500 pounds.

A beam supported at one end will sustain only one-fourth part the weight which it would if supported at both ends.

When a beam is fixed at both ends and loaded in the middle it will bear one-half more than it will when loose at both ends. When the beam is loaded uniformly throughout it will bear double. When the beam is fixed at both ends and loaded uniformly throughout it will bear triple the weight.

In any beam standing obliquely, or in a sloping direction, its strength or strain will be equal to that of a beam of the same breadth, thickness, and material, but only of the length of the horizontal distance between the points of support.

In the construction of beams it is necessary that their form should be such that they will be equally strong throughout. If a beam be fixed at one end and loaded at the other, and the breadth uniform throughout its length, then, that the beam may be equally strong throughout, its form must be that of a parabola. This form is generally used in the beams of steam-engines.

When a beam is regularly diminished toward the points that are least strained, so that all the sections are similar figures, whether it be supported at each end and loaded in the middle, or supported in the middle and loaded at each end, the outline should be a cubic parabola.

When a beam is supported at both ends and is of the same breadth throughout, then, if the load should be uniformly distributed throughout the length of the beam, the line bounding the compressed side should be a semi-ellipse.

The same form should be made use of for the rails of a wagon-way, where they have to resist the pressure of a load rolling over them.

Similar plates of the same thickness, either supported at the ends or all round, will carry the same weight either uniformly distributed or laid on similar points, whatever be their extent.

The lateral strength of any beam or bar of wood, stone, metal, &c., is in proportion to its breadth multiplied by the square of its depth. In square beams the lateral strengths are in proportion to the cubes of the sides, and in general of like-sided beams as the cubes of the similar sides of the section.

The lateral strength of any beam or bar, one end being fixed in the wall and the other projecting, is inversely as the distance of the weight from the section acted upon; and the strain upon any section is directly as the distance of the weight from that section.

The absolute strength of ropes or bars pulled lengthwise, is in proportion to the squares of their diameters. All cylindrical or prismatic rods are equally strong in every part, if they are equally thick, but if not they will break where the thickness is least.

The strength of a tube or hollow cylinder is to the strength of a solid one, as the difference between the fourth powers of the exterior and interior diameters of the tube, divided by the exterior diameter, is to the cube of the diameter of a solid cylinder—the quantity of matter in each being the same. Hence, from this it will be found that a hollow cylinder is one-half stronger than a solid one having the same weight of material.

The strength of a column to resist being crushed is directly as the square of the diameter, provided it is not so long as to have a chance of bending. This is true in metals or stone, but in timber the proportion is rather greater than the square.

Models proportioned to Machines.

The relation of models to machines as to strength, deserves the particular attention of the mechanic. A model may be perfectly proportioned in all its parts as a model, yet the machine, if constructed in the same proportion, will not be sufficiently strong in every part; hence, particular attention should be paid to the kind of strain the different parts are exposed to; and from the statements which follow, the proper dimensions of the structure may be determined.

If the strain to draw asunder in the model be 1, and if the structure is 8 times larger than the model, then the stress in the structure will be 8^3 equals 512. If the structure is 6 times as large as the model, then the stress on the structure will be 6^3 equals 216, and so on; therefore the structure will be much less firm than the model; and this the more, as the structure is cube times greater than the model. If we wish to determine the greatest size we can make a machine of which we have a model, we have,

The greatest weight which the beam of the model can bear, divided by the weight which it actually sustains, equals a quotient which, when multiplied by the size of the beam in the model, will give the greatest possible size of the same beam in the structure.

Example.—If a beam in the model be 7 inches long, and bear a weight of 4 lbs., but is capable of bearing a weight of 26 lbs., what is the greatest length which we can make the corresponding beam in the structure? Here

$$26 \div 4 = 6.5; \qquad \text{therefore, } 6.5 \times 7 = 45.5 \text{ inches.}$$

The strength to resist crushing increases from a model to a structure in proportion to their size, but, as above, the strain increases as the cubes; wherefore, in this case, also, the model will be stronger than the machine, and the greatest size of the structure will be found by employing the square root of the quotient in the last rule, instead of the quotient itself; thus,

If the greatest weight which the column in a model can bear is 3 cwt., and if it actually bears 28 lbs., then, if the column be 18 inches high, we have

$$\sqrt{\left(\frac{336}{28}\right)} = 3.464; \qquad \text{wherefore } 3.464 \times 18 = 62.352$$

inches, the length of the column in the structure.

LIST OF METALS, ARRANGED ACCORDING TO THEIR STRENGTH.—Steel, wrought iron, cast iron, platinum, silver, copper, brass, gold, tin, bismuth, zinc, antimony, lead.

According to Tredgold's and Duleau's experiments, a piece of the best bar-iron 1 square inch across the end would bear a weight of about 77,373 lbs. while a similar piece of cast iron would be torn asunder by a weight of from 16,243 to 19,464 lbs. Thin iron wires, arranged parallel to each other, and presenting a surface at their extremity of 1 square inch, will carry a mean weight of 126,340 lbs.

LIST OF WOODS, ARRANGED ACCORDING TO THEIR STRENGTH.—Oak, alder, lime, box, pine (*sylv.*), ash, elm, yellow pine, fir

A piece of well-dried pine wood, presenting a section of 1 square inch, is able, according to Eytelwein, to support a weight of from 15,646 lbs. to 20,408 lbs., whilst a similar piece of oak will carry as much as 25,850 lbs

Hempen cords, twisted, will support the following weights to the *square inch* of their section.

$\frac{1}{4}$ inch to 1 inch thick, 8,746 lbs.; 1 to 3 inches thick, 6,800 lbs.; 3 to 5 inches thick, 5,345 lbs.; 5 to 7 inches thick, 4,860 lbs.

Tredgold gives the following rule for finding the weight in pounds which a hempen rope will be capable of supporting: Multiply the square of the circumference in inches by 200, and the product will be the quantity sought.

In the practical application of these measures of absolute strength, that of metals should be reckoned at one-half, and that of woods and cords at one-third of their estimated value.

In a parallelopipedon of uniform thickness, supported on two points and loaded in the middle, *the lateral strength is directly as the product of the breadth into the square of the depth, and inversely as the length.* Let W represent the lateral strength of any material, estimated by the weight, b the breadth, and d the depth of its end, and l the distance between the points of support; then $W = fd^2b \div l$.

If the parallelopipedon be fastened only at one end in a horizontal position, and the load be applied at the opposite end, $W = fd^2b \div 4l$.

It is to be observed that the three dimensions, b, d, and l, are to be taken in the same measure, and that b be so great that no lateral curvature arise from the weight; f in each formula represents the lateral strength, which varies in different materials, and which must be learnt experimentally.

A beam having a rectangular end, whose breadth is two or three times greater than the breadth of another beam, has a power of suspension respectively two or three times greater than it; if the end be two or three times deeper than the end of the other, the suspension power of that which has the greater depth exceeds the suspension power of the other four or nine times; if its length be two or three times greater than the length of another beam, its power of suspension will be $\frac{1}{2}$ or $\frac{1}{3}$ respectively that of the other; provided that in each case the mode of suspension, the position of the weight, and other circumstances be similar.

Hence it follows that a beam, one of whose sides tapers, has a greater power of suspension if placed on a slant than on the broad side, and that the powers of suspension in both cases are in the ratio of their sides; so, for instance, a beam, one of whose sides is double the width of the other, will carry twice as much if placed on the narrow side, as it would if laid on the wide one.

In a piece of round timber (a cylinder) the power of suspension is in proportion to the diameters cubed, and inversely as the length; thus a beam with a diameter two or three times longer than that of another, will carry a weight 8 or 27 times heavier respectively than that whose diameter is unity, the mode of fastening and loading it being similar in both cases.

The lateral strength of square timber is to that of a tree whence it is hewn as 10 : 17 nearly.

A considerable advantage is frequently secured by using hollow cylinders instead of solid ones, which, with an equal expenditure of materials, have far greater strength, provided only that the solid part of the cylinder be of a sufficient thickness, and that the workmanship be good; especially that in cast metal beams the thickness be uniform and the metal free from flaws. According to Eytelwein, such hollow cylinders are to solid ones of equal weight of metal as 1.212 : 1, when the inner semi-diameter is to the outer as 1 : 2; according to Tredgold as 17 : 10, when the two semi-diameters are to each other as 15 : 25; and as 2 : 1, when they are to each other as 7 : 10.

A method of increasing the suspensive power of timber supported at both ends, is, to saw down from $\frac{1}{3}$ to $\frac{1}{2}$ of its depth, and forcibly drive in a wedge of metal or hard wood. until the timber is slightly raised at the middle out of the horizontal line. By experiment it was found that the suspensive power of a beam thus cut $\frac{1}{3}$ of its depth was increased 1-19th, when cut $\frac{1}{2}$ it was increased 1-29th, and when cut $\frac{3}{4}$ through it was increased 1-87th.

The force required to crush a body increases as the section of the body increases; and this quantity being constant, the resistance of the body diminishes as the height increases.

According to Eytelwein's experiments, the strength of columns or timbers of rectangular form in resisting compression is, as

1. The cube of their thickness (the lesser dimension of their section). 2. As the breadth (the greater dimension of their section). 3. Inversely as the square of their length.

Cohesive Power of Bars of Metal one inch square, in Tons.

Iron Swedish bar,	29.20	Copper, wrought,	15.08
" Russian bar,	26.70	Gun-metal,	16.23
" English bar,	25.00	Copper, cast,	8.51
Steel cast,	59.93	Brass, cast, yellow,	8.01
" blistered,	59.43	Iron, cast,	7.87
" sheer,	56.97	Tin, cast,	2.11

Relative Strength of Cast and Malleable Iron.

It has been found, in the course of the experiments made by Mr. Hodgkinson and Mr. Fairbairn, that the average strain that cast iron will bear in the way of tension, before breaking, is about seven tons and a half per square inch; the weakest, in the course of 16 trials on various descriptions, bearing 6 tons, and the strongest 9¾ tons. The experiments of Telford and Brown show that malleable iron will bear on an average 27 tons; the weakest bearing 24, and the strongest 29 tons. On approaching the breaking point, cast iron may snap in an instant, without any previous symptom, while wrought iron begins to stretch with half its breaking weight, and so continues to stretch till it breaks. The experiments of Hodgkinson and Fairbairn show also that cast iron is capable of sustaining compression to the extent of nearly 50 tons on the square inch; the weakest bearing 36⅓ tons, and the strongest 60 tons. In this respect, malleable iron is much inferior to cast iron. With 12 tons on the square inch it yields, contracts in length, and expands laterally; though it will bear 27 tons, or more, without actual fracture.

Rennie states that cast iron may be crushed with a weight of 93,000 lbs., and brick with one of 562 lbs., on the square inch.

Strength of Beams.

SOLID, RECTANGULAR, AND ROUND: TO FIND THEIR STRENGTH.

Square and Rectangular.

$$\frac{(\text{Depth ins.})^2 \times \text{Thickness ins.}}{\text{Length, ft.}} \times \text{Tab'r No.} = \text{Breaking wt., tons.}$$

Round.

$$\frac{(\text{Diameter ins.})^3}{\text{Length in ft.}} \times \text{Tabular No.} = \text{Breaking weight, tons.}$$

Hollow.

$$\frac{(\text{Outside dia. ins.})^3 - (\text{Inside dia. ins.})}{\text{Length, ft.}} \times \text{Tabular No.} = \text{Breaking weight, tons.}$$

Thickness not exceeding	1 in. for iron 3 in. for wood	2 in. for iron 6 in. for wood	3 in. for iron 12 in., wood
Round.			
Cast and wrought iron......	.8	.68	.56
Teak and greenheart.	.28	.25	.2
Fir and English oak........	.14	.125	.1

Square and Rectangular.

Cast and wrought iron......	.1	.85	.7
Teak and greenheart.......	.36	.32	.26
Pitch pine and Canadian oak........	.25	.22	.18
Fir, red pine, and English oak......	.18	.16	.13

To find the Breaking Weight in Pounds use the Tabular Number below.

Thickness not exceeding	1 in. for iron 3 in. for wood	2 in. for iron 6 in. for wood	3 in. for iron 12 in., wood

Square and Rectangular.

Iron..........	2,240	1,900	1,570
Teak....	800	710	570
Fir and oak................	400	355	285

Round.

Iron...........	1,800	1,570	1,260
Teak	640	570	460
Fir and oak................	320	285	230

Though wrought and cast iron are represented in these rules as of equal strength, it should be observed that while a cast iron bar 1 inch × 1 inch × 1 foot 0 inch long, of average quality, will break with one ton, a similar bar of wrought iron only loses its elasticity, and deflects 1-16th of an inch, yet as it can only carry a further weight by destroying its shape and increasing the deflection, it is best to calculate on the above basis:

	Deflects
A wrought iron bar 1 in. × 1 in × 1 ft. 0 in. long	1-16 with 1 ton.
	1-8 " $1\frac{1}{4}$ "
	2 1-2 " $2\frac{1}{4}$ "

The above rule gives the weight that will break the beam if put on the middle. If the weight is laid equally all over, it would require double the weight to break it.

A beam should not be loaded with more than 1-3 of the breaking weight in any case, and as a general rule not with more than 1-4, for the purposes of machinery not with more than 1-6 to 1-10, depending on circumstances.

To find the Proper Size for any given purpose.

Rectangular.

$$\frac{\text{Weight} \times \text{Length, ft.}}{\text{Tabular No.}} \times 3 \text{ or } 4 \text{ or } 6, \&c\text{, according to circumstances} = \text{B D}^2 \text{ ins.}$$

Round.

$$\sqrt[3]{\frac{\text{Weight} \times \text{Length, ft.}}{\text{Tabular No.}}} \times 3 \text{ or } 4 \text{ or } 6, \&c.\text{, according to circumstances} = \text{diam. ins.}$$

Solid Columns.

Fail by crushing with length under................5 diameters
Principally by crushing from...... .... 5 to 15 "
Partly by crushing, partly by bending, from.15 to 25 "
Altogether by bending above ....25 "

Cast iron of average quality is crushed with ..49 tons per sq. in.
Wr'ght iron of average quality is crushed with..16 " "
Wrought iron is permanently injured with...12 " "
Oak wrought is crushed with................ 4 " "
Deal wrought is crushed with................ 2 " "

The comparative strength of different columns, of different lengths, will be seen very clearly from the following table derived from experiments by Mr. Hodgkinson :

Wrought Iron Bars.		Proportion of Length to Thickness.	Gave way with
Square.	Length.		
ins.	ft. ins.		
1 × 1	7½	7½ to 1	21.7 tons per sq. inch.
"	1 3	15 to 1	15.4 "
"	2 6	30 to 1	11.3 "
"	5 0	60 to 1	7.5 "
"	7 6	90 to 1	4.3 "
½ × ½	5 0	120 to 1	2.5 "
"	7 6	180 to 1	1. "

To find the Strength of any Wrought Iron Column with Square Ends.

Area of column sq. inches × tons per inch corresponding to proportion of length, as per table above = Breaking weight, tons.

If the ends are rounded, divide the final result by 3 to find the breaking weight.

In columns of oblong section, the narrowest side must always be taken in calculating the proportion of height to width.

To find the Strength of Round Columns exceeding 25 diameters in length—Mr. Hodgkinson's Rule.

$$\frac{(\text{Diameter, ins.})^{3.6}}{(\text{Length, ft.})^{1.7}} \times \text{Tabular No.} = \text{Breaking weight, tons.}$$

	Square Ends.	Rounded or Movable Ends.
Wrought iron	77	26
Cast iron.......	44	15
Dantzic oak.................	4.5	1.7
Red deal....................	3.3	1.2

A column should not be loaded with more than 1-3 of the breaking weight in any case, and as a general rule, not with more than 1-4; for purposes of machinery not with more than 1-6 to 1-10, according to circumstances.

Tables of Powers for the Diameters and Lengths of Columns.

Diameter.	3.6 Power.	Diameter.	3.6 Power.	Length.	1-7 Power.
1 in.	1.	7 in.	1,102.4	1	1.
¼	2 23	¼	1,251.	2	3.25
½	4.3	½	1,413.3	3	6.47
¾	7.5	¾	1,590.3	4	10.556
2	12.1	8	1,782.9	5	15.426
¼	18.5	¼	1,991.7	6	21.031
½	27.	½	2,217.7	7	27.332
¾	38.16	¾	2,461.7	8	34.297
3	52.2	9	2,721.4	9	41.9
¼	69.63	¼	3,006.85	10	50.119
½	90.9	½	3,309.8	11	58.934
¾	116.55	¾	3,634.3	12	68.329
4	147.	10	3,981.07	13	78.289
¼	182 9	¼	4,351.2	14	88.8
½	224.68	½	4,745.5	15	99.85
¾	272.96	¾	5,165.	16	111.43
5	328.3	11	5,610.7	17	123.53
¼	391.36	¼	6,083.4	18	136.13
½	462.71	½	6,584.3	19	149.24
¾	543.01	¾	7,114.4	20	162.84
6	632.91	12	7,674.5	21	176.92
¼	733.11			22	191.48
½	844.28			23	206.51
¾	967.15			24	222.

Hollow Columns.

Hollow columns fail principally by crushing, provided the length does not exceed 25 diameters; indeed the length does not appear to affect the strength much till it exceeds 50 diameters.

The comparative strength of different forms and of different thicknesses will appear so distinctly from the experiments below, made by Mr. Hodgkinson, that no difficulty will be found in ascertaining the strength due to any size or form of column that may be required.

Square Columns of Plate Iron riveted.

Columns 10 feet 0 inches long.

Size.	Thickness.	Proportion of Thickness to Width.	Proportion of Length to Width.	Break'g w'ght Tons per sq. in. of section.
4 in. × 4 in.	.03	$\frac{1}{133}$	30 to 1	4.9
"	.06	$\frac{1}{66}$	"	8.6
"	.1	$\frac{1}{40}$	"	10.
"	.2	$\frac{1}{20}$	"	12.
8 in. × 8 in.	.06	$\frac{1}{133}$	15 to 1	6.
"	.14	$\frac{1}{60}$	"	9.
"	.22	$\frac{1}{36}$	"	11.5
"	.25	$\frac{1}{32}$	"	12.

Column 8 feet 0 inches long.

18 × 18	.5	$\frac{1}{30}$ practically.	5.4 to 1	13.6

Column 10 feet 0 inches long, with cells.

8 in. × 8 in.	.06	$\frac{1}{66}$ of width of cells.	15 to 1	8.6

To find the Strength of any Hollow Wrought Iron Column.

$$\text{Sec. area, sq. ins.} \times \left(\begin{array}{l}\text{tons per inch, corresponding to the pro-}\\ \text{portions of length and thickness to width}\end{array}\right)$$
$$= \text{Breaking weight, tons.}$$

Columns of Oblong Section.

The strength of these may be ascertained by the same rule as that of square columns. The smallest width being taken in calculating the proportion of height to width, while the longest side must be taken into consideration in calculating the proportion of thickness to width.

Column 10 feet 0 inches long.

Size.	Thick-ness.	Proportion of Thickness to greatest Width.	Proportion of Length to least Width.	Breaking wt. tons per sq. in. of sec.
8 in × 4 in.	.06	$\frac{1}{333}$	30 to 1	6.78

Round Columns of Plate Iron Riveted.

Columns 10 feet 0 inches in length.					Same Columns Reduced in Length.	
					Breaking Weights. Tons per square inch.	
Diameter.	Thickness.	Proportion of thickness to Diameter.	Proportion of length to Diameter.	Breaking Weight Tons per sq. inch	5 ft. 0 in. long	2 ft. 6 in. long
$1\frac{1}{2}$	.1	$\frac{1}{15}$	80 to 1	6.5	3.9	5.8
2	.1	$\frac{1}{20}$	60 to 1	10.35	4.8	16.5
$2\frac{1}{2}$	.1	$\frac{1}{25}$	48 to 1	13.3	15.6	16.3
$2\frac{1}{2}$	.24	$\frac{1}{11}$	48 to 1	9.6	15.6	16.
$2\frac{1}{2}$	.21	$\frac{1}{12}$	48 to 1	9.9	13.	17.
3	.15	$\frac{1}{26}$	40 to 1	12.36	13.	16.5
4	.15	$\frac{1}{26}$	30 to 1	12.34	13.	
6	.1	$\frac{1}{60}$	20 to 1	15.	17.	18.6
6	.13	$\frac{1}{46}$	20 to 1	18.6		

It would seem from this that a thickness of 1-48, or ¼ inch in thickness for every foot in diameter, is a good proportion for this kind of column.

It will be seen from these experiments, that it is the proportion of thickness to the width of cell which regulates the strength within certain limits of height.

And that a thickness of 1-30 or ⅛ inch for every 4 inches in width will give the highest result practicable for square columns.

Crane.

The strains on the principal parts can be ascertained with great ease in the following manner—the strength being proportioned accordingly.

To find the Strain on the Post.

$$\frac{\text{Weight suspended, tons} \times \text{Projection, feet}}{\text{Height of post above ground, feet}} = \text{Strain on top of post, tons.}$$

The post can then be calculated as a beam, twice as long as this height from ground, with twice the weight on the middle.

Cold Water Pump.

Usually $\frac{1}{4}$ of cylinder diameter when the stroke is $\frac{1}{2}$ that of piston.
" $\frac{1}{3}$ " " $\frac{1}{4}$ "

TO FIND THE PROPER SIZE, UNDER ANY CIRCUMSTANCES, CAPABLE OF SUPPLYING TWICE THE QUANTITY ORDINARILY USED FOR INJECTION.

$$\frac{\text{Cub ft. water per hour used in form of steam}}{\text{Stroke of pump, ft.} \times \text{strokes per minute}} = \left\{ \begin{array}{l}\text{Area of pump} \\ \text{in square ft.}\end{array} \right.$$

Tensile Strength.

Tensile Strength is the resistance of the fibres or particles of a body to separation. It is therefore proportional to their number, or to the area of its transverse section.

The fibres of wood are strongest near the centre of the trunk or limb of a tree.

Cast Iron.—Experiments on cast iron bars give a tensile strength of from 4,000 lbs. to 5,000 lbs. per square inch of its section, as just sufficient to balance the elasticity of the metal; and as a bar of it is extended the 5,500th part of its length for every ton of direct strain per square inch of its section, it is deduced that its elasticity is fully excited when it is extended less than the 3,000th part of its length, and the extension of it at its limit of elasticity is estimated at the 1,200th part of its length.

The mean tensile strength, then, of cast iron being from 16,000 to 20,000 lbs., the value of it, when subjected to a tensile strain, may be safely estimated at from $\frac{1}{4}$ to $\frac{1}{3}$ of this, or of its breaking strain.

A bar of cast iron will contract or expand .000006173, or the 162,000th of its length for each degree of heat; and assuming the extreme range of the temperature in this country 140° (—20° + 120°), it will contract or expand with this change .0008642, or the 1,157th part of its length. It shrinks in cooling from .0104 to .0118th of its length.

It follows, then, that as 2,240 lbs. will extend a bar the 5,500th part of its length, the contraction or extension for the 1,157th part will be equivalent to a force of 10,648 lbs. ($4\frac{3}{4}$ tons) per square inch of section.

Cast iron (Greenwood) at three successive meltings gave tenacities of 21,300, 30,100, and 35,700 lbs.

Cast iron at 2.5 tons per square inch will extend the same as wrought iron at 5.6 tons.

The mean tensile strength of four kinds of English cast iron, as determined by the Commissioners on the Application of Iron to Railway Structures, was 15,711 lbs. per square inch (7.014 tons); and the mean ultimate extension was, for lengths of 10 feet,

.1997 inch, being the 600th part of its length; and this weight would compress a bar the 775th part of its length.

Tensile strength of the strongest piece of cast iron ever tested —45,970 lbs. This was a mixture of grades 1, 2, and 3 of Greenwood iron, and at the third fusion.

Wrought Iron.—Experiments on wrought iron bars give a tensile strength of from 18,000 lbs. to 22,400 lbs. per square inch of its section, as just sufficient to balance the elasticity of the metal; and as a bar of it is extended the 10,000 part of its length for every ton of direct strain per square inch of its section, it is deduced that its elasticity is fully excited when it is extended the 1,000th part of its length, and the extension of it at its limit of elasticity is estimated at the 1,520th part of its length.

The mean tensile strength of wrought iron being from 55,0 0 to 65,000 lbs., the value of it, when subjected to a tensile strain, may be safely estimated at from $\frac{1}{4}$ to $\frac{1}{3}$ of this, or of its breaking strain.

A bar of wrought iron will expand or contract .000006614, or the 151,200th part of its length for each degree of heat; and assuming, as before stated for cast iron, that the extreme range of temperat: re in the air in this country is 140°, it will contract or expand with this change .000926, or the 1,080th of its length, which is equivalent to a force of 20,740 lbs. ($9\frac{1}{4}$ tons) per square inch of section.

Experiments upon wrought iron, to determine the results from repeated heating and laminating, furnished the following:

From one to six reheatings and rollings, the tensile stress increased from 43,904 lbs. to 61,824 lbs., and from six to twelve it was reduced to 43,904 again.

The tensile force of metals varies with their temperature, generally decreasing as the temperature is increased. In silver the tenacity decreases more rapidly than the temperature; in copper, gold, and platinum it decreases less rapidly than the temperature.

In iron the tensile strength at different temperatures is as follows: 60°, 1; 114°, 1.14; 212°, 1.2; 250°, 1.32; 270°, 1.35; 325°, 1.41; 435°, 1.4.

Stirling's Mixed or Toughened Iron.—By the mixture of a portion of malleable iron with cast iron, carefully fused in a crucible, a tensile strain of 25,764 lbs. has been attained. This mixture, when judiciously managed and duly proportioned, increases the resistance of cast iron about one-third—the greatest effect being obtained with a proportion of about 30 per cent. of malleable iron.

Bronze (gun-metal) varies in tenacity from 23,000 to 54,500 lbs.

Elements connected with the Tensile Resistance of various Substances.

Substances.	Tensile strain per sq. inch for limit of elasticity.	Ratio of strain to that causing rupture.
	Lbs.	
Beech	3,355	.3
Cast iron, English	4,000	.22
" American	5,000	.2
Oak	2,856	.23
Steel plates, blue tempered	53,720	.62
" wire	55,700	.5
Yellow pine	3,332	.23
Wrought iron, ordinary	17,600	.3
" " Swedish	24,400	.34
" " English	18,850	.35
	22,400	.35
" " American	15,000	.26
" " wire, No. 9, unannealed	47,532	.46
" " " " annealed	36,300	.45

Tensile Strength of Materials—Weight or Power required to tear asunder one Square Inch.

MISCELLANEOUS SUBSTANCES.

	Lbs.		Lbs.
Brick, well burned	750	Limestone	670
" fire	65		2800
" inferior	290	Marble, Italian	5200
	100	" white	9000
Cement, blue stone	77	Mortar, 12 years old	60
" hydraulic	234	Plaster of Paris	72
" Harwich	30	Rope, Manila	9000
" Portland, 6 mo.	414	" hemp, tarred	15000
" Sheppy	24	" wire	37000
" Port'd 1, sand 3	380	Sandstone, fine grain	200
Chalk	118	Slate	12000
Glass, crown	2346	Stone, Bath	352
Gutta-percha	3500	" Craigleth	400
Hydraulic lime	140	" Hailes	360
" " mortar	140	" Portland	857
Ivory	16000		1000
Leather belts	330	Whalebone	7600

METALS.

	Lbs.		Lbs.
Copper, wrought.......	34000	Iron, plates, mean, Eng.	51000
" rolled.........	36000	" " lengthwise.	53800
" cast, American.	24250	" " crosswise..	48800
" wire	61200	" inferior bar......	30000
" bolt	36800	" wire, Am'n	73600
Iron, cast, Low Moor, No. 2..	14076	" " " 16 dia.	80000
" Clyde, No. 1......	16125	" scrap.	53400
" " No. 3.....	23468	Lead, cast	1800
" Calder, No. 1	13735	" milled..........	3320
" Stirling, mean....	25764	" wire............	2580
" mean of American.	31829	Platinum, wire..	53000
" mean* of English.	19484	Silver, cast	40000
" Greenwood, Am'n.	45970	Steel, cast, maximum..	142000
" gun-metal, mean.	37232	" " mean..	88657
" wrought wire.....	103000	" blistered, soft..	133000
" best Swedish bar.	72000		104000
" Russian bar......	59500	" shear.	124000
" English bar	56000	" chrome, mean ..	170980
" rivets, American..	53300	" puddled, extreme	173817
" bolts.	52250	" Am. Tool Co ...	179980
" hammered.	53913	" plates, lengthwise	96300
" mean of English..	53900	" " crosswise .	93700
" rivets, English. .	65000	" razor	150000
" crank shaft.......	44750	Tin, cast, block	5000
" turnings.	55800	" Banca.	2122
" plates, boiler,	48000	Zinc..................	3500
American	62000	" sheet	16000

* By Commissioners, on application of iron to Railway Structures.

Lake Superior and Iron Mountain charcoal bloom iron has resisted 90,000 lbs. per square inch.

COMPOSITIONS.

	Lbs.		Lbs.
Gold 5, Copper 1.......	50000	Copper 10, Tin 1........	32000
Brass	42000	" 8, " 1, gun metal	30000
" yellow.	18000	" 8, " 1, small bars	50000
Bronze, least	17698	Tin 10, Antimony 1 ..	11000
" greatest........	56788	Yellow metal	48700

WOODS.

	Lbs.		Lbs.
Ash	14000	Maple	10500
Beech	11500	Oak, American white	11500
Box	20000	" English	10000
Bay	14000	" seasoned	13600
Cedar	11400	" African	14500
Chestnut, sweet	10500	Pear	9800
Cypress	6000	Pine, pitch	12000
Deal, Christiana	12400	" larch	9500
Elm	13400	" American white	11800
Lance	23000	Poplar	7000
Lignum-vitæ	11800	Spruce, white	10290
Locust	20500	Sycamore	13000
Mahogany	21000	Teak	14000
" Spanish	12000	Walnut	7800
" "	8000	Willow	13000

Results of Experiments on the Tensile Strength of Wrought-Iron Tie-Rods.

Common English Iron, 1 3-16 *inches in Diameter.*

Description of Connection.	Breaking Wght
	Lbs.
Semicircular hook fitted to a circular and welded eye	14,000
Two semicircular hooks hooked together	16,220
Right-angled hook or goose-neck fitted into a cylindrical eye	29,120
Two links or welded eyes connected together	48,160
Straight rods without any connection articulation.	56,000

Iron bars when cold rolled are materially stronger than when only hot rolled, the difference being in some cases as great as 3 to 2.

Wire Ropes—Result of Experiments on the Tensile Strength of Iron and Steel Wire Ropes.

Charcoal Iron Wire Rope Circum.	Weight per Foot.	Breaking Weight.	Steel Wire Rope Circum.	Stretch in 6 Feet.	Weight per Foot.	Breaking Weight.
Ins.	Lbs.	Lbs.	Ins.	Ins.	Lbs.	Lbs.
$1\frac{7}{8}$	$\frac{1}{3}$	13,440	1 15-16	$1\frac{3}{8}$	$\frac{1}{2}$	23,600
$3\frac{3}{8}$	$1\frac{1}{2}$	44,800	$2\frac{3}{8}$	$\frac{5}{8}$	$\frac{7}{8}$	36,000

Tensile Strength of Copper at different Temperatures.

Temp.	Strength in lbs.	Temp.	Strength in lbs.	Temp.	Strength in lbs.
122°	33,079	482°	26,981	801°	18,854
212°	32,187	545°	25,420	912°	14,789
302°	30,872	602°	22,302	1,016°	11,054

Extension of Cast-iron Bars, when suspended Vertically.

1 *inch Square and* 10 *feet in Length.* *Weight applied at one End.*

Weight applied.	Extension.	Set.	Weight applied.	Extension.	Set.
Lbs.	Ins.	Ins.	Lbs.	Ins.	Ins.
529	.0044	—	4,234	.0397	.00265
1,058	.0092	.000015	8,468	.0871	.00855
2,117	.0190	.000059	14,820	.1829	.02555

Steel.

The tensile strength of steel increases by reheating and rolling up to the second operation, but decreases after that.

Ratio of the Ductility and Malleability of Metals.

In the order of Wire-drawing Ductility.	In the order of Laminable Ductility.	In the order of Wire-drawing Ductility.	In the order of Laminable Ductility.	In the order of Wire-drawing Ductility.	In the order of Laminable Ductility.
Gold.	Iron.	Tin.	Gold.	Tin.	Zinc.
Silver.	Copper.	Lead.	Silver.	Platinum	Iron.
Platinum.	Zinc.	Nickel.	Copper.	Lead.	Nickel.

The relative resistance of Wrought Iron and Copper to tension and compression is as 100 to 54.5.

Transverse Strength.

The Transverse or Lateral Strength of any Bar, Beam, Rod, etc., is in proportion to the product of its breadth and the square of its depth; in like-sided beams, bars, etc., it is as the cube of the side, and in cylinders as the cube of the diameter of the section.

When one End is fixed and the other projecting, the strength is inversely as the distance of the weight from the section acted upon; and the strain upon any section is directly as the distance of the weight from that section.

When both Ends are supported only, the strength is 4 times greater for an equal length, when the weight is applied in the middle between the supports, than if one end only is fixed.

When both Ends are fixed, the strength is 6 times greater for an equal length, when the weight is applied in the middle, than if one end only is fixed.

The strength of any beam, bar, etc., to support a weight in the centre of it, when the ends rest merely upon two supports, compared to one when the ends are fixed, is as 2 to 3.

When the Weight or Strain is uniformly distributed, the weight or strain that can be supported, compared with that when the weight or strain is applied at one end or in the middle between the supports, is as 2 to 1.

In metals, the less the dimensions of the side of a beam, etc., or the diameter of a cylinder, the greater its proportionate transverse strength: this is in consequence of their having a greater proportion of chilled or hammered surface compared to their elements of strength, resulting from dimensions alone.

The strength of a cylinder, compared to a square of like diameter or sides, is as 6.25 to 8. The strength of a hollow cylinder to that of a solid cylinder, of the same length and volume, is as the greater diameter of the former is to the diameter of the latter.

The strength of an equilateral triangle, fixed at one end and loaded at the other, having an edge up, compared to a square of the same area, is as 22 to 27; and the strength of an equilateral triangle, having an edge down, compared to one with an edge up, is as 10 to 7.

NOTE.—In these comparisons, the beam, bar, etc., is considered as one end being fixed, the weight suspended from the other. In Barlow and other authors the comparison is made when the beam, etc , rested on supports. Hence the stress is contrariwise.

Detrusion is the resistance that the particles or fibres of materials oppose to their sliding upon each other. Punching and shearing are detrusive strains.

Deflection.—When a bar, beam, etc., is deflected by a cross-strain, the side of the beam, etc., which is bounded by the concave surface, is compressed, and the opposite side is extended.

In stones and cast metals, the resistance to compression is greater than the resistance to extension.

In woods, the resistance to extension is greater than the resistance to compression.

The general law regarding deflection is, that it increases, *cæteris paribus*, directly as the cube of the length of the beam, bar, etc., and inversely as the breadth and cube of the depth.

The resistance of flexure of a body at its cross-section is very nearly 9-10 of its tensile resistance.

The stiffest bar or beam that can be cut out of a cylinder is that of which the depth is to the breadth as the square root of 3 to 1; the strongest, as the square root of 2 to 1; and the most resilient, that which has the breadth and depth equal.

Relative Stiffness of Materials to Resist a Transverse Strain.

Ash	.089	Elm	.073	Wrought iron	1.3
Beech	.073	Oak	.095	Yellow pine	.087
Cast iron	1.	White pine	.1		

The strength of a rectangular beam in an inclined position, to resist a vertical stress, is to its strength in a horizontal position as the square of radius to the square of the cosine of elevation; that is, as the square of the length of the beam to the square of the distance between its points of support, measured upon a horizontal plane.

Experiments upon bars of cast iron, 1, 2, and 3 inches square, give a result of transverse strength of 447, 348, and 338 lbs. respectively; being in the ratio of 1, .78, and .756.

The strongest rectangular bar or beam that can be cut out of a cylinder is one of which the squares of the breadth and depth of it, and the diameter of the cylinder, are as 1, 2, and 3 respectively.

The ratio of the crushing to the transverse strength is nearly the same in glass, stone, and marble, including the hardest and softest kinds.

Green sand iron castings are 6 per cent. stronger than dry, and 30 per cent. stronger than chilled; but when the castings are chilled and annealed, a gain of 115 per cent. is attained over those made in green sand.

Chilling the under side of cast iron very materially increases its strength.

Woods.—Beams of wood, when laid with their annual or annular layers vertical, are stronger than when they are laid horizontal, in the proportion of 8 to 7.

Woods are denser at the roots and at the centre of their trunks. Their strength decreases with the decrease of their density.

Oak loses strength in drying.

Concretes, Cements, &c.

Materials.	Breaking Weight.
CONCRETES (English).	
Fire-brick beam, Portland cement	3.1
" sand 3 parts, lime 1 part	.7
CEMENTS (English).	
Blue clay and chalk	5.4
Portland	37.5 10.2
Sheppy	5.
BRICKS (English).	
Best stock	11.8
Fire-brick	14.
New brick	10.7
Old brick	9.1
Stock-brick, well burned	5.8
" inferior, burned	2.5

Transverse Strength of Cast Iron Bars and Oak Beams of various Figures.

Reduced to the uniform measure of one inch square of sectional area, and one foot in length. Fixed at one end; weight suspended from the other.

Form of Bar or Beam.	Breaking Weight.
CAST IRON.	Lbs.
 Square	873
 Square, diagonal vertical	568
 Column	573
 Hollow column; greater diameter twice that of lesser	794
 Rectangular prism, 2 in. deep × $\frac{1}{2}$ in. depth	1,456
" " 3 in. deep × $\frac{1}{3}$ in. depth	2,392
" " 4 in. deep × $\frac{1}{4}$ in. depth	2,652
 Equilateral triangle, an edge up	560
 Equilateral triangle, an edge down	958
 2 in. deep × 2 in. wide × .268 in. depth	2,068
 2 in. deep × 2 in. wide × .268 in. depth	565
OAK.	
 Equilateral triangle, an edge up	114
 Equilateral triangle, an edge down	130

To Compute the Transverse Strength of a Rectangular Beam or Bar.

When a Beam or Bar is fixed at one end and loaded at the other.

Rule.—Multiply the value of the material in the preceding tables, or, as may be ascertained, by the breadth and square of the depth in inches, and divide the product by the length in feet.

Note.—When the beam is loaded uniformly throughout its length, the result must be doubled.

Example.—What are the weights each that a cast and wrought iron bar, 2 inches square and projecting 30 inches in length, will bear without permanent injury?

The values for cast and wrought iron in this and the following calculations are assumed to be 225 and 180.

Hence $225 \times 2 \times 2^2 = 1800$, which, $\div 2.5 = 720$ lbs., and
$180 \times 2 \times 2^2 = 1440$, which, $\div 2.5 = 576$ lbs.

If the Dimensions of a Beam or Bar are required to support a given weight at its end.

RULE.—Divide the product of the weight and the length in feet by the value of the material and the quotient will give the product of the breadth and the square of the depth.

EXAMPLE.—What is the depth of a wrought iron beam, 2 inches broad, necessary to support 576 lbs. suspended at 30 inches from the fixed end?

$$\frac{576 \times 2.5}{180} = 8, \text{ which, } \div 2 \text{ ins. for the breadth} = 4, \text{ and } \sqrt{4} = 2 \text{ ins., the depth.}$$

When a Beam or Bar is fixed at both ends, and loaded in the middle.

RULE.—Multiply the value of the material by 6 times the breadth and the square of the depth in inches, and divide the product by the length in feet.

NOTE.—When the beam is loaded uniformly throughout its length, the result must be doubled.

EXAMPLE.—What weight will a bar of cast iron, 2 inches square and 5 feet in length, support in the middle, without permanent injury?

$$225 \times 2 \times 6 \times 2^2 = 10800, \text{ which, } \div 5 = 2160 \text{ lbs.}$$

Or, *If the Dimensions of a Beam or Bar are required to support a given weight in the middle between the fixed ends.*

RULE.—Divide the product of the weight and the length in feet by 6 times the value of the material, and the quotient will give the product of the breadth and the square of the depth.

EXAMPLE.—What dimensions will a cast iron square bar, 5 feet in length, require to support without permanent injury a stress of 2,160 lbs.?

$$\frac{2160 \times 5}{225 \times 6} = \frac{10800}{1350} = 8, \text{ which, } \div 2 \text{ ins. for the assumed breadth, } = 4, \text{ and } \sqrt{4} = 2 \text{ inches, the depth.}$$

When the Breadth or Depth is required.

RULE.—Divide the product obtained by the preceding rules by the square of the depth, and the quotient is the breadth; or by the breadth, and the square root of the quotient is the depth.

ILLUSTRATION.—If 128 is the product and the depth is 8; then $128 \div 8^2 = 2$, the breadth. Also, $128 \div 2 = 64$, and $\sqrt{64} = 8$, the depth.

When the weight is not in the middle between the ends.

RULE.—Multiply the value of the material by 3 times the length in feet, and the breadth and square of the depth in inches, and divide the product by twice the product of the distances of the weight or stress from either end.

EXAMPLE.—What is the weight a cast iron bar, fixed at both ends, 2 inches square and 5 feet in length, will bear without permanent injury, 2 feet from one end?

$$\frac{225 \times 3 \times 5 \times 2 \times 2^2}{2 \times 2 \times 3} = \frac{27000}{12} = 2{,}250 \text{ lbs.}$$

Transverse Strength of Solid and Hollow Cylinders of various Materials.

One foot in length. Fixed at one end; weight suspended from the other.

Materials.	Solid External Diameter	Hollow Internal Diameter	Breaking Weight.	Breaking Weight for 1 in. external diam , and proportionate internal diameter.
WOODS.	Ins.	Ins.	Lbs.	Lbs.
Ash..................	2.	—	685	86
"	2.	1.	604	75
Fir*..................	2.	—	772	97
White pine.............	1.	—	75	75
"	2.	—	610	76
METAL.				
Cast iron, cold blast.	3	—	12,000	444
STONE-WARE.				
Rolled pipe of fine clay .	2.87	1.928	190	8

* An inch-square batten, from the same plank as this specimen, broke at 139 lbs.

Brick-Work.

A brick arch, having a rise of 2 feet, a span of 15 feet 9 inches, and 2 feet in width, with a depth at its crown of 4 inches, bore 358,400 lbs. laid along its centre.

Girders, Beams, Lintels, etc.

The Tranverse or Lateral Strength of any Girder, Beam, Brest-summer, Lintel, etc., is in proportion to the product of its breadth and the square of its depth, and also to the area of its cross-section.

The best form of section for cast iron girders or beams, etc., is deduced from the experiments of Mr. E. Hodgkinson, and such as have this form of section ⌶ are known as Hodgkinson's.

The rule deduced from his experiments directs that the area of the bottom flange should be 6 times that of the top flange—flanges connected by a thin vertical web, sufficiently rigid, however, to give the requisite lateral stiffness, and tapering both upward and downward from the neutral axis; and in order to set aside the risk of an imperfect casting, by any great disproportion between the web and the flanges, it should be tapered so as to connect with them, with a thickness corresponding to that of the flange.

As both cast and wrought iron resist crushing or compression with a greater force than extension, it follows that the flange of a girder or beam of either of these metals, which is subjected to a crushing strain, according as the girder or beam is supported at both ends, or fixed at one end, should be of less area than the other flange, which is subjected to extension or a tensile strain.

When girders are subjected to impulses, and are used to sustain vibrating loads, as in bridges, etc., the best proportion between the top and bottom flange is as 1 to 4; as a general rule, they should be as narrow and deep as practicable, and should never be deflected to more than one five-hundredth of their length.

In public halls, churches, and buildings where the weight of people alone is to be provided for, an estimate of 175 pounds per square foot of floor surface is sufficient to provide for the weight of the flooring and the load upon it.

In churches, buildings, etc., the weight to be provided for should be estimated at that which may at any time be placed thereon, or which at any time may bear upon any portion of their floors; the usual allowance, however, is for a weight of 280 lbs. per square foot of floor surface for stores and factories, and 175 lbs. per square foot when the weight of people alone is to be provided for.

In all uses, such as in buildings and bridges, where the structure is exposed to sudden impulses, the load or stress to be sustained should not exceed from 1-5 to 1-6 of the breaking weight of the material employed; but when the load is uniform or the stress quiescent, it may be increased to 1-3 or 1-4 of the breaking weight.

An open-web girder or beam, etc., is to be estimated in its resistance on the same principle as if it had a solid web. In cast metals, allowance is to be made for the loss of strength due to the unequal contraction in cooling of the web and flanges.

In cast iron, the mean resistance to crushing or extension is as 3.6 to 1, and in wrought iron as 1 to 1.3; hence the mass of metal below the neutral axis will be greatest in these proportions when the stress is intermediate between the ends or supports of the girders, etc.

Wooden Girders or Beams, when sawed in two or more pieces, and have slips set between them, and the whole bolted together, are made stiffer by the operation, and are rendered less liable to decay.

Girders cast with a face up are stronger than when cast on a side, in the proportion of 1 to .96, and they are strongest also when cast with the bottom flange up.

The following results of the resistances of metals will show how the material should be distributed in order to obtain the maximum of strength with the minimum of material:

	To Tension.	To Crushing.
Cast Iron....................	21,000 32,000	90,300 140,500
Copper......................	24,250	117,000
Wrought iron...............	45,000 72,000	40,000 83,000

The best iron has the greatest tensile strength, and the least compressive or crushing.

The most economical construction of a girder or beam, with reference to attaining the greatest strength with the least material, is as follows: The outline of the top, bottom, and sides should be a curve of various forms, according as the breadth or the depth throughout is equal, and as the girder or beam is loaded only at one end, or in the middle, or uniformly throughout.

To Compute the Dimensions and Form of a Girder or Beam.

When a Girder or Beam is Fixed at one End and Loaded at the other.

1. *When the Depth is uniform throughout the entire Length,* The section at every point must be in proportion to the product of the length, breadth, and square of the depth, and as the square of the depth is in every point the same, the breadth must vary directly as the length; consequently, each side of the beam must be a vertical plane, tapering gradually to the end

2. *When the Breadth is uniform throughout the entire Length,* The depth must vary as the square root of the length; hence the upper or lower sides, or both, must be determined by a parabolic curve.

3. *When the Section at every point is similar—that is, a Circle, an Ellipse, a Square, a Rectangle, the sides of which bear a fixed proportion to each other,* The section at every point being a regular figure, for a circle, the diameter at every point must be as the cube root of the length; and for an ellipse, or a rectangle, the breadth and depth must vary as the cube root of the length.

When a Girder or Beam is Fixed at one End, and Loaded uniformly throughout its Length.

1. *When the Depth is uniform throughout its entire Length,* The breadth must increase as the square of the length.

2. *When the Breadth is uniform throughout its entire Length,* The depth will vary directly as the length.

3. *When the Section at every point is similar, as a Circle, Ellipse, Square, and Rectangle,* The section at every point being a regular figure, the cube of the depth must be in the ratio of the square of the length.

When a Girder or Beam is Supported at both Ends.

1. *When Loaded in the Middle,* The constant of the beam, or the

product of the breadth and the square of the depth, must be in proportion to the distance from the nearest support; consequently, whether the lines forming the beam are straight or curved, they meet in the centre, and of course the two halves are alike; the beam, therefore, may be considered as one of half the length, the supported end corresponding with the free end in the case of beams, one end being fixed, and the middle of the beams similarly corresponding with the fixed end.

2. *When the Depth is uniform throughout,* The breadth must be in the ratio of the length.

3. *When the Breadth is uniform throughout,* The depth will vary as the square root of the length.

4. *When the Section at every point is similar, as a Circle, Ellipse, Square, and Rectangle,* The section at every point being a regular figure, the cube of the deptlr will be as the square of the distance from the supported end.

When a Girder or Beam is Supported at both Ends, and Loaded uniformly throughout its Length.

1. *When the Depth is uniform,* The breadth will be as the product of the length of the beam and the length of it on one side of the given point, less the square of the length on one side of the given point.

2. *When the Breadth is uniform,* The depth will be as the square root of the product of the length of the beam and the length of it on one side of the given point, less the square of the length on one side of the given point.

3. *When the Secton at every point is similar, as a Circle, Ellipse, Square, and Rectangle,* The section at every point being a regular figure, the cube of the depth will be as the product of the length of the beam and the length of it on one side of the given point, less the square of the length on one side of the given point.

General Deductions from the Experiments of Stephenson, Fairbairn, Cubitt, Hughes, etc.

Fairbairn shows in his experiments that with a stress of abont 12,320 lbs. per square inch on cast iron, and 28,000 lbs on wrought iron, the sets and elongations are nearly equal to each other.

A cast iron beam will be bent to one-third of its breaking weight if the load is laid on gradually; and one-sixth of it, if laid on at once, will produce the same effect, if the weight of the beam is small compared with the weight laid on. Hence beams of cast iron should be made capable of bearing more than 6 times the greatest weight which will be laid upon them.

In beams of cast or wrought iron the flanges should be proportionate to the relative crushing and tensile resistances of the material.

The breaking weights in similar beams are to each other as the squares of their like linear dimensions; that is, the breaking weights of beams are computed by multiplying together the area of their section, their depth, and a constant, determined from experiments on beams of the particular form under investigation, and dividing the product by the distance between the supports.

Cast and wrought iron beams, having similar resistances, have weights nearly as 2.44 to 1.

The range of the comparative strength of girders of the same depth, having a top and bottom flange, and those having bottom flange alone, is from having but a little area of bottom flange to a large proportion of it, from 1-2 to 1-4 greater strength.

A box beam or girder, constructed of plates of wrought iron, compared to a single rib and flanged beam ⌶, of equal weights, has a resistance as 100 to 93.

The resistance of beams or girders, where the depth is greater than their breadth, when supported at top, is much increased. In some cases the difference is fully one-third.

When a beam is of equal thickness throughout its depth, the curve should be an ellipse to enable it to support a uniform load with equal resistance in every part; and if the beam is an open one, the curve of equilibrium for a uniform load should be that of a parabola. Hence, when the middle portion is not wholly removed, the curve should be a compound of an ellipse and a parabola, approaching nearer to the latter as the middle part is decreased.

Girders of cast iron, up to a span of 40 feet, involve a less cost than of wrought iron.

Cast iron beams and girders should not be loaded to exceed one-fifth of their breaking weight; and when the strain is attended with concussion and vibration, this proportion must be increased.

Simple cast-iron girders may be made 50 feet in length, and the best form is that of Hodgkinson; when subjected to a fixed load, the flange should be as 1 to 6, and when to a concussion, etc., as 1 to 4.

The forms of girders for spaces exceeding the limit of those of simple cast iron are various; the principal ones adopted are those of the straight or arched cast-iron girders in separate pieces, and bolted together—the Trussed, the Bow-string, and the wrought iron Box and Tubular.

A *Straight* or *Arched Girder* is formed of separate castings, and is entirely dependent upon the bolts of connection for its strength.

A *Trussed* or *Bow-string Girder* is made of one or more castings to a single piece, and its strength depends, other than upon the depth or area of it, upon the proper adjustment of the tension, or the initial strain, upon the wrought iron truss.

A *Box* or *Tubular Girder* is made of wrought iron, and is best constructed with cast iron tops, in order to resist compression; this form of girder is best adapted to afford lateral stiffness.

Floor Beams, Girders, etc.

The condition of the stress borne by a floor beam is that of a beam supported at both ends and uniformly loaded; and from the irregularity in its loading and unloading, and from the necessity of its possessing great rigidity, it is impracticable to estimate its capacity other than as a beam having the weight borne upon the middle of its length.

To Compute the Depth of a Floor Beam.

When the Length and Breadth are given, and the Distance between the Centres of the Beam is One Foot.

Rule.—Divide the product of the square of the length in feet and the weight to be borne in pounds per square foot of floor, by the product of 4 times the breadth and the value of the material, and the square root of the quotient will give the depth of the beam in inches.

Example.—A white pine beam is two inches wide, and 12 feet in length between the supports; what should be the depth of it to support a weight of 175 lbs. per square foot?

$$\frac{12^2 \times 175}{2 \times 4 \times 30} = 105, \text{ and } \sqrt{105} = 10.25 \text{ ins.}$$

When the Distance between the Centres of the Beam is greater or less than One Foot.

Rule.—Divide the product of the square of the depth for a beam, when the distance between the centres is one foot, by the distance given in inches by 12, and the square root of the quotient will give the depth of the beam in inches.

Example.—Assume the beam in the preceding case to be set 15 ins. from the centres of its adjoining beams, what should be its depth?

$$\frac{10.25^2 \times 15}{12} = 131.25, \text{ and } \sqrt{131.25} = 11.45 \text{ ins.}$$

Header and Trimmer Beams.

The conditions of the stress borne or to be provided for by them are as follows:

Header or *Trimmer* beams support half of the weight of and upon the tail beams inserted into or attached to them.

Trimmer Beams support, in addition to that borne by them directly as a floor beam, each half the weight on the headers.

The stress, therefore, upon a header is due directly to its length, or the number of tail beams it supports; and the stress upon the trimmer beams is that of their own stress as a floor beam, and half of the weight upon the header supported by them.

Note.—The distance between the support of the trimmer beams and the point of connection with the header does not in anywise affect the stress upon the trimmer beams; for in just proportion as this distance is increased, and the stress upon them consequently increased, by the suspension of the header from them nearer to the middle of their length, so is the area of the surface supported by the header reduced, and, consequently, the load to be borne by it.

Transverse Strength of Cast Iron Girders and Beams, deduced from the Experiments of Barlow, Hodgkinson, Hughes, Tredgold, Taylor, etc.

Reduced to a uniform measure of one inch in depth, one foot in length, supported at both ends; the stress or weight applied in the middle.

Section of Girder or Beam.		Flanges. Top.	Flanges. Bottom.	Width of Vertical Web.	Depth of Girder.	Breadth of Girder	Area of Section in Centre.	Breaking Weight at length of one foot.	Strength per sq. inch of section.	Value for Breaking Weight.
		Sq. Ins.	Sq. Ins.	In.	In.	In.	Sq. I.	Lbs.	Lbs	Lbs
	Eq. area of flange at top and bottom,	1.75x 42 =.735	1.77x.39 =.69	.29	5.125	1.77	2.82	301[illegible]0	10768	6100
	do.	2.02 x.515 =1.040	2 02 x 515 =1.040	.51*	2 02	2.02	2 59	10276	3952	1900
	Area of sec. of top and bot. 1 to 6,	2.23x.31 =.72	6.67x 66 =4.4	.266	5.125	6.67	6.23	117450	18852	3650
		......	5 x.3=1.5	.365	1.56	5.	1.96	7280	3714	2350
		5 x.3=1.5	....	.365	1.56	5.	1.96	2366	[illegible]213	760
		....	23.9x 3.12 =74.56	3.3	36.1	23.9	183.5	806624[illegible]	43958	1200
		5x.5=.25	1.5x.5= .75	.5	4.†	1.5	1.	19980	19980	5000
		1.5x 5= .75	.5x 5= .25	.5	4.†	1.5	1.	7252	7252	1800
		4x2=8	....	2.	4.	4	12.	3[illegible]600	2800	700
		5.1x2.33 =11.68	12.1x2 07 =25 04	2.08	30.5	11.1	90.8	4793800	52795	1700
	Rectangular Prism,	....	....	.994	2.012	.994	2.025	9440	4662	2350
	Open Beam,	1 005 x.98	1 005 x.99	1.005	2.51	1.005	1 98	12340	6232	2450
		.995 x1.01	.995 x.1	.995	3.01	.995	2.	15420	7710	2550
		1 005 x.98	1.005 x.99	1.005	4	1 005	1.98	21765	10992	2700
		.771 x1.51	.771 x1.5	.771	4 04	.771	2.[illegible]22	25705	11070	2750
		1.507 x 74	1.507 x.74	1 507	4.04	1.507	2 23	25735	11540	2850
		1.525 x.78	1.525 x.78	1 525	4.07	1.525	2.35	30000	12689	3100
	Square Prism,	....	....	1.02	1.02	1 02	1.03	2635	2552	2500
	Column,	....	....	1.122	1.122	1.122	.989	2370	2396	2150
	Square Prism, angle up.	....	......	1.443	1.443	1.443	1.041	2269	2182	1500

* Horizontal web. † Depth of opening, 3 inches.

General Deductions.

In cast iron, the permanent deflection is from one-third to one-quarter of its breaking weight, and the deflection should never exceed one-third of the ultimate deflection.

All rectangular bars of wrought iron, having the same bearing length, and loaded in their centre to the full extent of their elastic power, will be so deflected, that their deflection, being multiplied by their depth, the product will be a constant quantity, whatever may be their breadth or other dimensions, provided their lengths are the same.

The heaviest running weight that a bridge is subjected to is that of a locomotive and tender, which is equal to 1.5 tons per lineal foot.

Girders should not be deflected to exceed the one fortieth of an inch to a foot in length.

In cast iron, the one-twentieth to one-thirtieth of the breaking weight will give a visible set.

When a load on a girder is supported by the bottom flange of it alone, it produces a torsional strain.

A continuous weight, equal to that a beam, etc., is suited to sustain, will not cause the deflection of it to increase unless it is subjected to considerable changes of temperature.

The heaviest load on a railway girder should not exceed one-sixth of that of the breaking weight of the girder when laid on at rest.

Deflection consequent upon Velocity of the Load.—Deflection is very much increased by instantaneous loading; by some authorities it is estimated to be doubled.

The momentum of a railway train in deflecting girders, etc., is greater than the effect from the dead weight of it, and the deflection increases with the velocity.

Experiments made by the Commissioners of Railway Structures of 1849, showed that a passing load produced a greater effect on a beam than a load at rest.

A carriage was moved at a velocity of 10 miles per hour; the deflection was .8 inch, and when at a velocity of 30 miles the deflection was $1\frac{1}{2}$ inches.

In this case, 4 150 lbs. would have been the breaking weight of the bars if applied in their middle, but 1,778 lbs. would have broken them if passed over them with a velocity of 30 miles per hour.

Cast iron will bend to one-third of its ultimate deflection with less than one-third of its breaking weight if it is laid on gradually, and but one-sixth if laid on rapidly.

When motion is given to the load on a beam, etc., the point of greatest deflection does not remain in the centre of the beam, etc., as beams broken by a travelling load are always fractured at points beyond their centres, and often into several pieces.

Chilled bars of cast iron deflect more readily than unchilled.

Results of Experiments on the Subjection of Iron Bars to Continual Strains.

Cast iron bars subjected to a regular depression, equal to the deflection due to a load of one-third of their statical breaking weight, bore 10,000 successive depressions, and when broken by statical weight gave as great a resistance as like bars subjected to a like deflection by statical weight.

Of two bars subjected to a deflection equal to that carried by half of their statical breaking weight, one broke with 28,602 depressions, and the other bore 30,000, and did not appear weakened to resist statical pressure.

Hence cast iron bars will not bear the continual applications of one-third of their breaking weight.

A bar of wrought iron, 2 inches square and 9 feet in length between its supports, was subjected to 100,000 vibratory depressions, each equal to the deflection due to a load of five-ninths of that which permanently injured a similar bar, and their depressions only produced a permanent set of .015 inch.

The greatest deflection which did not produce any permanent set was due to rather more than one-half the statical weight, which permanently injured it.

A wrought-iron box girder 6 × 6 inches and 9 feet in length, was subjected to vibratory depressions, and a strain corresponding to 3,762 lbs., repeated 43,370 times, did not produce any appreciable effect on the rivets.

Mr. Tredgold, in his experiments upon cast iron, has shown that a load of 300 lbs., suspended from the middle of a bar 1 inch square and 34 inches between its supports, gave a deflection of .16 of an inch, while the elasticity of the metal remained unimpaired. Hence a bar 1 inch square and 1 foot in length will sustain 650 lbs., and retain its elasticity

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Torsional Strength.

The *Torsional Strength* of any square bar or beam is as the cube of its side, and of a cylinder as the cube of its diameter. Hollow cylinders or shafts have greater torsional strength than solid ones containing the same volume of material.

The *Torsional Angle* of a bar, etc., under equal pressures will vary as the length of the bar, etc. Hence the torsional strength of bars of like diameters is inversely as their lengths.

The strength of a cylindrical prism compared to a square is as 1 to .85.

When a bar, beam, etc., having a length greater than its diameter, is subjected to a torsional strain, the direction of the greatest strain is in the line of the diagonal of a square, and if a square be drawn on the surface of the bar, etc., in its primitive form, it will become a rhombus by the action of the strain.

To Compute the Diameter of a Square or Round Shaft, etc., to resist Torsion.

RULE.—Multiply the extreme of pressure upon the crank-pin, or at the pitch-line of the pinion, or at the centre of effect upon the blades of the wheel, etc., that the shaft may at any time be subjected to, by the length of the crank or radius of the wheel, etc., in feet; divide their product by the value, and the cube root of the quotient will give the diameter of the shaft or its journal in inches.

EXAMPLE.—What should be the diameter for the journal of a wrought-iron water-wheel shaft, the extreme pressure upon the crank-pin being 59,400 lbs., and the crank 5 feet in length?

$$\frac{59{,}400 \times 5}{125} = 2{,}376, \text{ and } \sqrt[3]{2{,}276} = 13.34 \text{ inches.}$$

When two Shafts are used, as in Steam-vessels with one Engine, etc.

RULE.—Divide three times the cube of the diameter for one shaft by four, and the cube root of the quotient will give the diameter of the shaft in inches.

EXAMPLE.—The area of the journal of a shaft is 113 inches; what should be the diameter, two shafts being used?

Diameter for area of 113 = 12.

$$\text{Then } \frac{3 \times 12^3}{4} = 1{,}296, \text{ and } \sqrt[3]{1{,}296} = 10.9 \text{ inches.}$$

NOTE.—The examples here given are deduced from instances of successful practice; where the diameter has been less, fracture has almost universally taken place, the strain being increased beyond the ordinary limit.

When the work to be performed is of a regular character, and the stress is consequently uniform, the proportion of $\frac{3}{4}$ may be reduced to $\frac{5}{8}$.

Relative Values of Diameters.

When shafts of less diameter than 12 inches are required, the values here given may be slightly reduced or increased, according to the quality of the iron and the diameter of the shaft to be used, but when they exceed this diameter, the values may not be increased, as the strength of a cast or wrought iron shaft decreases very materially as its diameter increases.

To Compute the Torsional Strength of Hollow Shafts and Cylinders.

RULE.—From the fourth power of the exterior diameter subtract the fourth power of the interior diameter, and multiply the remainder by the value of the material; divide this product by the product of the exterior diameter and the length or distance from the axis at which the stress is applied in feet; the quotient will give the resistance in pounds.

EXAMPLE.—What torsional stress may be borne by a cast-iron hollow shaft, having diameters of 3 and 2 inches, the power being applied at 1 foot from its axis?

$$3^4 - 2^4 \times 105 = 81 - 16 \times 105 = 6{,}825, \text{ which} \div 3 \times 1 = \frac{6{,}825}{3} = 2{,}275 \text{ lbs.}$$

The order of shafts, with reference to the degree of torsional stress to which they are subjected, is as follows:

1. Fly-wheel.
2. Water-wheel.
3. Secondary.
4. Tertiary, etc.

Hence the diameters of their journals may be reduced in this order.

Results of Experiments upon the Detrusive Strength of Metals with Shears.

MADE BY PARALLEL CUTTERS.

Wrought Iron.—Thickness from .5 to 1 inch, 50,000 lbs., per square inch.

MADE BY INCLINED CUTTERS, ANGLE 1 IN 8 = 7°.

Sheet Metals.	Thickness.	Power.	Bolts.	Diameter.	Power.
	Ins.	Lbs.		Ins.	Lbs.
Brass..........	.05	540	Brass..	1.11	29,700
Copper........	.297	11,196	Copper..	.775	11,310
Steel....	.24	14,930	Steel...........	.775	28,720
Wrought iron.	.51	39,150	Wrought iron.	1.142	35,410
	1.	44,800		.32	3,093

The resistance of wrought iron to shearing is about 75 per cent. of its resistance to tensile stress.

The resistance to shearing of plates and bolts is not in a direct ratio. It approximates to that of the square of the depth of the former, and to the square of the diameter of the latter.

Character of Strains to which Connecting Rods, Straps, Gibs, and Keys are subjected.

Heads of Rods.—At sides of keyholes, tensile and crushing; at front of keyholes, detrusive.

Straps.—At crown and at the sides of keyhole, tensile; at back of keyholes, detrusive.

Gib.—Transverse, uniformly loaded along its length, fixed at both ends.

Key.—With single gib, transverse, uniformly loaded along its length, fixed at both ends.

Key.—With double gib, transverse, uniformly loaded along its length, fixed at both ends.

Woods.

When a beam or any piece of wood is let in (not mortised) at an inclination to another piece, so that the thrust will bear in the direction of the fibres of the beam that is cut, the depth of the cut at right angles to the fibres should not be more than .2 of the piece, the fibres of which, by their cohesion, resist the thrust.

Shafts and Gudgeons.

Shafts are divided into shafts and spindles, according to their magnitude.

A Gudgeon is the metal journal or arbor upon which a wooden shaft revolves.

Shafts are subjected to torsion and lateral stress combined, or to lateral stress alone.

Lateral Stiffness and Strength.—Shafts of equal length have lateral stiffness as their breadth and the cube of their depth, and have lateral strength as their breadth and the square of their depths. Hence, in shafts of equal lengths, their stiffness by any increase of depth increases in a greater proportion than their strength.

Shafts of different lengths have lateral stiffness, directly as their breadth and the cube of their depth, and inversely as the cube of their length; and have lateral strength directly as their breadth and as the square of their depth, and inversely as their length. Hence, in shafts of different lengths, their stiffness by any increase of their length decreases in a greater proportion than their strength.

Hollow shafts having equal lengths and equal quantities of material, have lateral stiffness as the square of their diameter, and have lateral strength as their diameters. Hence, in hollow shafts, one having twice the diameter of another will have four times the stiffness, and but double the strength; and when having equal lengths, by an increase in diameter they increase in stiffness in a greater proportion than in strength.

The stress upon a shaft from a weight upon it is proportional to the product of the parts of the shaft multiplied into each other. Thus, if a shaft is 10 feet in length, and a weight upon the centre of gravity of the stress is at a point 2 feet from one end, the parts 2 and 8, multiplied together, are equal to 16; but if the weight or stress were applied in the middle of the shaft, the parts 5 and 5, multiplied together, would produce 25.

The ends of a shaft having to support the whole weight, the end which is nearest the weight has to support the greatest proportion of it, in the inverse proportion of the distance of the weight from the end. Hence, when a shaft is loaded in the middle, each of the journals or gudgeons has half the weight or stress to support.

When the load upon a shaft is uniformly distributed over any part of it, it is considered as united in the middle of that part;

and if the load is not uniformly distributed, it is considered as united at its centre of gravity.

When the transverse section of a shaft is a regular figure, as a square, circle, etc., and the load is applied in one point, in order to give it equal resistance throughout its length, the curve of the sides becomes a cubic parabola; but when the load is uniformly distributed over the shaft, the curve of the sides becomes a semi-cubical parabola.

The deflection of a shaft produced by a load which is uniformly distributed over its length is the same as when five-eighths of the load is applied at the middle of its length.

The resistance of the body of a shaft to lateral stress is as its breadth and the square of its depth; hence the diameter will be as the product of the length of it and the length of it on one side of a given point, less the square of that length.

WOOD, TIMBER, ETC.

Selection of Standing Trees.—Wood grown in a moist soil is lighter and decays sooner than that grown in dry, sandy soil.

The best timber is that grown in a dark soil intermixed with gravel. Poplar, cypress, willow, and all others which grow best in a wet soil, are exceptions.

The hardest and densest woods, and the least subject to decay, grow in warm climates, but they are more liable to split and warp in seasoning.

Trees grown upon plains or in the centre of forests are less dense than those from the edge of a forest, from the side of a hill, or from open ground.

Trees (in the U. S.) should be selected in the latter part of July or first part of August; for at this season the leaves of the sound, healthy trees are fresh and green, while those of the unsound are beginning to turn yellow. A sound, healthy tree is recognized by its top branches being well leaved, the bark even and of a uniform color. A rounded top, few leaves, some of them turned yellow, a rougher bark than common, covered with parasitic plants and with streaks or spots upon it, indicate a tree upon the decline. The decay of branches and the separation of bark from the wood are infallible indications that the wood is impaired.

Felling Timber.—The most suitable time for felling timber is in midwinter and in midsummer. Recent experiments indicate the latter season and in the month of July.

A tree should be allowed to attain full maturity before being felled. Oak matures at 75 to 100 years and upward, according to circumstances. The age and rate of growth of a tree are indicated by the number and width of the rings of annual increase which are exhibited in a cross-section.

A tree should be cut as near to the ground as practicable, as the lower part furnishes the best timber.

Dressing Timber.—As soon as a tree is felled, it should be stripped of its bark, raised from the ground, the sap-wood taken off, and the timber reduced to its required dimensions.

Inspection of Timber.—The quality of wood is in some degree indicated by its color, which should be nearly uniform in the heart, a little deeper toward the centre, and free from sudden transitions of color. White spots indicate decay. The sap-wood is known by its white color; it is next to the bark, and very soon rots.

Defects of Timber.—Wind-shakes are circular cracks separating the concentric layers of wood from each other. It is a serious defect.

Splits, checks, and cracks, extending toward the centre, if deep and strongly marked, render the timber unfit for use, unless the purpose for which it is intended will admit of its being split through them.

Brash-wood is generally consequent upon the decline of the tree from age. The wood is porous, of a reddish color, and breaks short, without splinters.

Bolted timber is that which has been killed before being felled, or which has died from other causes. It is objectionable.

Knotty timber is that containing many knots, though sound; usually of stunted growth.

Twisted wood is when the grain of it winds spirally; it is unfit for long pieces.

Dry-rot.—This is indicated by yellow stains. Elm and beech are soon affected if left with the bark on.

Large or decayed knots injuriously affect the strength of timber.

Seasoning and Preserving Timber.

Timber freshly cut contains about 37 to 45 per cent. of liquids. By exposure to the air in seasoning one year, it loses from 17 to 25 per cent., and when seasoned it yet retains from 10 to 15 per cent.

Timber of large dimensions is improved and rendered less liable to warp and crack in being seasoned by immersion in water for some weeks.

For the purpose of seasoning, timber should be piled under shelter and kept dry; it should have a free circulation of air about it, without being exposed to strong currents. The bottom piece should be placed upon skids, which should be free from decay, raised not less than two feet from the ground; a space of an inch should intervene between the pieces of the same horizontal layers, and slats or piling-strips placed between each layer, one near each end of the pile and others at short distances, in order to keep the timber from winding. These strips should be one over the other, and in large piles should not be less than one inch thick. Light timber may be piled in the upper portion of the shelter, heavy timber upon the ground floor. Each pile should contain but one description of timber. The piles should be at least 2½ feet apart.

Timber should be repiled at intervals, and all pieces indicating decay should be removed, to prevent their affecting those which are still sound.

Timber houses are best provided with blinds, which keep out rain and snow, but which can be turned to admit air in fine weather, and they should be kept entirely free from any pieces of decayed wood.

The gradual mode of seasoning is the most favorable to the strength and durability of timber, but various methods have been proposed for hastening the process. For this purpose, steaming timber has been applied with success; and the results of experiments of various processes of saturating timber with a solution of corrosive sublimate and antiseptic fluids are very satisfactory. This process hardens and seasons wood, at the same time that it secures it from dry-rot and the attacks of worms. Kiln-drying is serviceable only for boards and pieces of small dimensions, and is apt to cause cracks and to impair the strength of wood, unless performed very slowly. Charring or painting is highly injurious to any but seasoned timber, as it effectually prevents the drying of the inner part of the wood, in consequence of which fermentation and decay soon take place.

Timber piled in badly-ventilated sheds is apt to be attacked with the common-rot. The first outward indications are yellow spots upon the ends of the pieces, and a yellowish dust in the checks and cracks, particularly where the pieces rest upon the piling-strips.

Timber requires from two to eight years to be seasoned thoroughly, according to its dimensions. It should be worked as soon as it is thoroughly dry, for it deteriorates after that time.

Oak timber loses one-fifth of its weight in seasoning, and about one-third of its weight in becoming perfectly dry. Seasoning is the extraction or dissipation of the vegetable juices and moisture, or the solidification of the albumen. When wood is exposed to currents of air at a high temperature, the moisture evaporates too rapidly and the wood cracks; and when the temperature is high and sap remains, it ferments, and dry-rot ensues.

Timber is subject to common-rot or dry-rot, the former occasioned by alternate exposure to moisture or dryness. The progress of this decay is from the exterior; hence the covering of the surface with paint, tar, etc., is a preservative.

Painting and charring green timber hastens its decay.

Dry or Sap rot is inherent in timber, and it is occasioned by the putrefaction of the vegetable albumen. Sap wood contains a large proportion of fermentable elements. Insects attack wood for the sugar or gum contained in it, and fungi subsist upon the albumen of wood; hence, to arrest dry-rot, the albumen must be either extracted or solidified.

In the seasoning of timber naturally there is required a period of from 2 to 4 years. Immersion in water facilitates seasoning by solving the sap.

The most effective method of preserving timber is that of expelling or exhausting its fluids, solidifying its albumen, and introducing an antiseptic liquid.

The strength of impregnated timber is not reduced, and its resilience is improved.

In desiccating timber by expelling its fluids by heat and air, its strength is increased fully 15 per cent.

In coating unseasoned timber with creosote, tar, etc., the fluids are retained, and decay facilitated thereby.

When timber is saturated with creosote, tar, antiseptics, etc., it is also preserved from the attack of worms. Jarrow wood, from Australia, is not subjected to their attack.

The condition of timber, as to its soundness or decay, is readily recognized when struck a quick blow.

Timber that has been for a long time immersed in water, when brought into the air and dried, becomes brashy and useless.

When trees are barked in the spring, they should not be felled until the foliage is dead.

Timber cannot be seasoned by either smoking or charring; but when it is to be used in locations where it is exposed to worms or to produce fungi, it is proper to smoke or char it.

Timber may be partially seasoned by being boiled or steamed.

Impregnation of Wood.

The several processes are as follows:

Kyan, 1832. Saturated with corrosive sublimate. Solution 1 lb. of chloride of mercury to 4 gallons of water.

Burnett, 1838. Impregnation with chloride of zinc by submitting the wood endwise to a pressure of 150 lbs. per square inch. Solution 1 lb. of the chloride to 10 gallons of water.

Boucheri. Impregnation by submitting the wood endwise to a pressure of about 15 lbs. per square inch. Solution 1 lb. of sulphate of copper to 12½ gallons of water.

Bethel. Impregnation by submitting the wood endwise to a pressure of 150 to 200 lbs. per square inch, with oil of creosote mixed with bituminous matter.

Louis S. Robbins, 1865. Aqueous vapor dissipated by the wood being heated in a chamber, the albumen solidified, then submitted to the vapor of coal tar, resin, or bituminous oils, which, being at a temperature not less than 325°, readily takes the place of the vapor expelled by a temperature of 212°.

Fluids will pass with the grain of wood with great facility, but will not enter it except to a very limited extent when applied externally.

Absorption of Preserving Solution by different Woods for a Period of Seven Days.

Average Pounds per Cubic Foot.

Black Oak.......3 6	Hemlock.. .....2.6	Rock Oak.......3.9
Chestnut.... ...3.	Red Oak.......3.9	White Oak......3.1

Proportion of Water in various Woods.

Alder (*Betula alnus*).......41.6	Pine (*Pinus Sylvestris L.*)..39.7
Ash (*Fraxinus excelsior*)....28.7	Red Beech (*Fagus sylvatica*).39.7
Birch (*Betula alba*).... ...30.8	Red Pine (*Pinus picea dur*).45.2
Elm (*Ulmus campestris*) ...44.5	Sycamore (*Acer pseudo platanus*) .... 27.
Horse-chestnut (*Æsculus hippocast*).... ....38.2	White Oak (*Quercus alba*)..36 2
Larch (*Pinus larix*)....... 48.6	White Pine (*Pinus abies dur*)...... ... .37.1
Mountain Ash (*Sorbus aucuparia*) 28.3	White Poplar (*Populus alba*).50.6
Oak (*Quercus robur*). 34.7	Willow (*Salix caprea*)......26.

Comparative Resilience of Timber.

Ash......1.	Chestnut . .73	Larch ... .84	Spruce ... .64
Beech ... .86	Elm...... .54	Oak...... .63	Teak ... .59
Cedar .. .66	Fir....... .4	Pitch Pine .57	Yel. Pine. .64

Weight and Strength of Oak and Yellow Pine.

	White Oak, Va.		Yellow Pine, Va.		Live Oak.
Age.	Round.	Square.	Round.	Square.	
Green	64.7	67.7	47.8	39.2	78.7
1 Year..........	53.6	53 5	39.8	34.2	
2 Years.........	46.	49.9	34.3	33.5	66.7

In England, timber sawed into boards is classed as follows: 6½ to 7 ins in width, Battens; 8½ to 10 ins., Deals; and 11 to 12 ins., Planks.

In a perfectly dry atmosphere the durability of woods is almost unlimited. Rafters of roofs are known to have existed 1,000 years, and piles submerged in fresh water have been found perfectly sound 800 years from the period of their being driven.

Distillation.—From a single cord of pitch pine distilled by chemical apparatus, the following substances and in the quantities stated have been obtained:

Charcoal..........50 bushels.	Pyroligenous Acid..100 galls.
Illum'ng Gas .ab't 1000 cu. ft.	Sp'ts of Turpentine 20 "
Illum'ng Oil and Tar.50 galls.	Tar ....1 barrel.
Pitch or Resin.....1½ barrels.	Wood Spirit........5 gallons.

Decrease in Dimensions of Timber by Seasoning.

Woods.	Ins.		Ins.
Cedar, Canada	14	to	$13\frac{1}{4}$
Elm	11	to	$10\frac{3}{4}$
Oak, English	12	to	$11\frac{5}{8}$
Pitch Pine, North	10×10	to	$9\frac{3}{4} \times 9\frac{3}{4}$
Pitch Pine, South	$18\frac{3}{8}$	to	$18\frac{1}{4}$
Spruce	$8\frac{1}{2}$	to	$8\frac{3}{8}$
White Pine, American	12	to	$11\frac{5}{8}$
Yellow Pine, North	18	to	$17\frac{7}{8}$

The weight of a beam of English oak, when wet, was reduced by seasoning from 972.25 to 630.5 pounds.

REVOLVING DISK.

To compute the Power.

RULE.—Multiply one half-the weight of the disk by the height due to the velocity of its circumference in feet per second.

EXAMPLE.—A grindstone $3\frac{3}{8}$ feet in diameter, weighing 2,000 lbs., is required to make $362\frac{1}{4}$ revolutions per minute; what power must be communicated to it?

Circum. of $3\frac{3}{8} = 10.6$ feet, which $\times 362.25 \div 60 = 64$ feet per second. Then $2{,}000 \div 2 \times 64 = 64{,}000$ lbs. raised 1 foot.

NOTE.—If the revolving disk is not an entire or solid wheel, being a ring or annulus, it must first be computed as if an entire disk, and then the portion wanting must be computed and deducted.

Power concentrated in Moving Bodies.

Simple power is force multiplied by its velocity Power concentrated in a moving body is the weight of the body multiplied by the square of its velocity; and the product divided by the accelleratrix, or the power concentrated in a moving body, is equal to the power expended in generating the motion.

SHRINKAGE OF CASTINGS.

Iron, small cylinders	= 1-16 inch per foot.
" Pipes	= 1-8 inch per foot.
" Girders, beams, etc.	= 1-8 in 15 inches.
" Large cylinders, the contraction of diameter at top.	= 1-16 per foot.
" " bottom	= 1-12 per foot.
" " contraction in length	= 1-8 in 16 inches.
Brass, thin	= 1-8 in 9 inches.
Brass, thick	= 1-8 in 10 inches.
Zinc	= 5-16 in a foot.
Lead	= 5-16 in a foot.
Copper	= 3-16 in a foot.
Bismuth	= 5-32 in a foot.

WHEEL GEARING.

The pitch line of a wheel, is the circle upon which the pitch is measured, and it is the circumference by which the diameter, or the velocity of the wheel, is measured.

The pitch, is the arc of the circle of the pitch line, and is determined by the number of the teeth in the wheel.

The true pitch (chordial), or that by which the dimensions of the tooth of a wheel are alone determined, is a straight line drawn from the centres of two contiguous teeth upon the pitch line.

The line of centres, is the line between the centres of two wheels.

The radius of a wheel, is the semi-diameter running to the periphery of a tooth. The pitch radius, is the semi-diameter running to the pitch line.

The length of a tooth, is the distance from its base to its extremity.

The breadth of a tooth, is the length of the face of wheel.

The teeth of wheels should be as small and numerous as is consistent with strength.

When a pinion is driven by a wheel, the number of teeth in the pinion should not be less than eight.

When a wheel is driven by a pinion, the number of teeth in the pinion should not be less than ten.

The number of teeth in a wheel should always be prime to the number of the pinion; that is, the number of teeth in the wheel should not be divisible by the number of teeth in the pinion without a remainder. This is in order to prevent the same teeth coming together so often as to cause an irregular wear of their faces. An odd tooth introduced into a wheel is termed a hunting tooth or cog.

To compute the Pitch of a Wheel.

Rule.—Divide circumference at the pitch-line by the number of teeth.

Example.—A wheel 40 ins. in diameter requires 75 teeth; what is its pitch?

$$\frac{3.1416 \times 40}{75} = 1.6755 \text{ ins.}$$

To compute the Chordial Pitch.

Rule.—Divide 180° by the number of teeth, ascertain the sine of the quotient, and multiply it by the diameter of the wheel.

Example.—The number of teeth is 75, and the diameter 40 inches; what is the true pitch?

$$\frac{180}{75} = 2^\circ\ 24' \text{ and sin. of } 2^\circ\ 24' = .04188, \text{ which} \times 40 = 1.6752 \text{ ins.}$$

To compute the Diameter of a Wheel.

RULE.—Multiply the number of teeth by the pitch, and divide the product by 3.1416.

EXAMPLE.—The number of teeth in a wheel is 75, and the pitch 1.675 ins.; what is the diameter of it?

$$\frac{75 \times 1.675}{3.1416} = 40 \text{ ins.}$$

To compute the Number of Teeth in a Wheel.

RULE.—Divide the circumference by the pitch.

To compute the Diameter when the True Pitch is given.

RULE.—Multiply the number of teeth in the wheel by the true pitch, and again by .3184.

EXAMPLE.—Take the elements of the preceding case.

$$75 \times 1.6752 \times .3184 = 40 \text{ ins.}$$

To compute the Number of Teeth in a Pinion or Follower to have a given Velocity.

RULE.—Multiply the velocity of the driver by its number of teeth, and divide the product by the velocity of the driven.

EXAMPLE.—The velocity of a driver is 16 revolutions, the number of its teeth 54, and the velocity of the pinion is 48; what is the number of its teeth?

$$\frac{16 \times 54}{48} = 18 \text{ teeth.}$$

2. A wheel having 75 teeth is making 16 revolutions per minute; what is the number of teeth required in the pinion to make 24 revolutions in the same time?

$$\frac{16 \times 75}{24} = 50 \text{ teeth.}$$

To compute the Proportional Radius of a Wheel or Pinion.

RULE.—Multiply the length of the line of centres by the number of teeth in the wheel for the wheel, and in the pinion for the pinion, and divide by the number of teeth in both the wheel and pinion.

To compute the Diameter of a Pinion, when the Diameter of the Wheel and Number of Teeth in the Wheel and Pinion are given.

RULE.—Multiply the diameter of the wheel by the number of teeth in the pinion, and divide the product by the number of teeth in the wheel.

EXAMPLE.—The diameter of a wheel is 25 inches, the number of its teeth 210, and the number of teeth in the pinion 30; what is the diameter of the pinion?

$$\frac{25 \times 30}{210} = 3.57 \text{ ins.}$$

To compute the Circumference of a Wheel.

RULE.—Multiply the number of teeth by their pitch.

To compute the Revolutions of a Wheel or Pinion.

RULE.—Multiply the diameter or circumference of the wheel or the number of its teeth, as the case may be, by the number of its revolutions, and divide the product by the diameter, circumference, or number of teeth in the pinion.

EXAMPLE.—A pinion 10 inches in diameter is driven by a wheel 2 feet in diameter, making 46 revolutions per minute; what is the number of revolutions of the pinion?

$$\frac{2 \times 12 \times 46}{10} = 110.4 \text{ revolutions.}$$

To compute the Velocity of a Pinion.

RULE.—Divide the diameter, circumference, or number of teeth in the driver, as the case may be, by the diameter, etc., of the pinion.

When there is a Series or Train of Wheels and Pinions.

RULE.—Divide the continued product of the diameter, circumference, or number of teeth in the wheels by the continued product of the diameter, etc., of the pinions.

EXAMPLE.—If a wheel of 32 teeth drive a pinion of 10, upon the axis of which there is one of 30 teeth, driving a pinion of 8, what are the revolutions of the last?

$$\frac{32}{10} \times \frac{30}{8} = \frac{960}{80} = 12 \text{ revolutions.}$$

Ex. 2.—The diameters of a train of wheels are 6, 9, 9, 10, and 12 inches; of the pinions, 6, 6, 6, 6, and 6 inches; and the number of revolutions of the driving shaft or prime mover is 10; what are the revolutions of the last pinion?

$$\frac{6 \times 9 \times 9 \times 10 \times 12 \times 10}{6 \times 6 \times 6 \times 6 \times 6} = \frac{583200}{7776} = 75 \text{ revolutions.}$$

To compute the Proportion that the Velocities of the Wheels in a Train should bear to one another.

RULE.—Subtract the less velocity from the greater, and divide the remainder by one less than the number of wheels in the train; the quotient is the number, rising in arithmetical progression from the less to the greater velocity.

EXAMPLE.—What should be the velocities of 3 wheels to produce 18 revolutions, the driver making 3?

$$\frac{18-3=15}{3-1=2} = 7.5 = \text{number to be added to velocity of the driver}$$

$= 7.5 + 3 = 10.5$, and $10.5 + 7.5 = 18$ revolutions.

Hence 3, 10.5, and 18 are the velocities of the three wheels.

General Illustrations.

1. A wheel 96 inches in diameter, having 42 revolutions per minute, is to drive a shaft 75 revolutions per minute; what should be the diameter of the pinion?

$$\frac{96 \times 42}{75} = 53.76 \text{ ins.}$$

2. If a pinion is to make 20 revolutions per minute, required the diameter of another to make 58 revolutions in the same time.

$58 \div 20 = 2.9 =$ the ratio of their diameters. Hence, if one to make 20 revolutions is given a diameter of 30 inches, the other will be $30 \div 2.9 = 10.345$ ins.

3. Required the diameter of a pinion to make 12½ revolutions in the same time as one of 32 ins. diameter making 26.

$$\frac{32 \times 26}{12.5} = 66.56 \text{ ins.}$$

4. A shaft, having 22 revolutions per minute, is to drive another shaft at the rate of 15, the distance between the two shafts upon the line of centres is 45 inches; what should be the diameter of the wheels?

Then, 1st, $22 + 15 : 22 : : 45 : 26.75 =$ inches in the radius of the pinion.

2d. $22 + 15 : 15 : : 45 : 18.24 =$ inches in the radius of the spur.

5. A driving shaft, having 16 revolutions per minute, is to drive a shaft 81 revolutions per minute, the motion to be communicated by two geared wheels and two pulleys, with an intermediate shaft; the driving wheel is to contain 54 teeth, and the driving pulley upon the driven shaft is to be 25 inches in diameter; required the number of teeth in the driven wheel, and the diameter of the driven pulley.

Let the driven wheel have a velocity of $\sqrt{16 \times 81} = 36$, a mean proportional between the extreme velocities 16 and 81.

Then, 1st $36 : 16 :: 54 : 24$ = teeth in the driven wheel.

2d. $81 : 36 :: 25 : 11.11$ = inches diameter of the driven pulley.

6. If, as in the preceding case, the whole number of revolutions of the driving shaft, the number of teeth in its wheel, and the diameters of the pulleys are given, what are the revolutions of the shafts? Then,

1st. $18 : 16 :: 54 : 48$ = revolutions of the intermediate shaft.

2d. $15 : 48 :: 25 : 80$ = revolutions of the driven shaft.

To compute the Diameter of a Wheel for a given Pitch and Number of Teeth.

RULE.—Multiply the diameter in the following table for the number of teeth by the pitch, and the product will give the diameter at the pitch circle.

EXAMPLE.—What is the diameter of a wheel to contain 48 teeth of 2.5 ins. pitch?

$$15.29 \times 2.5 = 38.225 \text{ ins.}$$

To compute the Pitch of a Wheel for a given Diameter and Number of Teeth.

RULE.—Divide the diameter of the wheel by the diameter in the table for the number of teeth, and the quotient will give the pitch.

EXAMPLE.—What is the pitch of a wheel when the diameter of it is 50 94 inches, and the number of its teeth 80?

$$\frac{50\ 94}{25.47} = 2 \text{ ins.}$$

To compute the Stress that may be borne by a Tooth.

RULE.—Multiply the value of the material of the tooth to resist a transverse strain, as estimated for this character of stress, by the breadth and square of its depth, and divide the product by the extreme length of it in the decimal of a foot.

To compute the Number of Teeth of a Wheel for a given Diameter and Pitch.

RULE.—Divide the diameter by the pitch, and opposite to the quotient in the following table is given the number of teeth.

Pitch of Wheels.

A Table whereby to Compute the Diameter of a Wheel for a given Pitch, or the Pitch for a given Diameter.

From 8 to 192 teeth.

No. of Teeth	Diameter.	No. of Teeth.	Diameter.	No. of Teeth.	Diameter.	No. of Teeth.	Diameter.	No. of Teeth.	Diameter.
8	2.61	45	14.33	82	26.11	119	37.88	156	49.66
9	2 93	46	14.65	83	26.43	120	38.2	157	49.98
10	3.24	47	14.97	84	26.74	121	38.52	158	50.3
11	3.55	48	15.29	85	27.06	122	38.84	159	50.61
12	3.86	49	15.61	86	27.38	123	39.16	160	50.93
13	4.18	50	15.93	87	27.7	124	39.47	161	51.25
14	4.49	51	16.24	88	28.02	125	39.79	162	51.57
15	4.81	52	16.56	89	28.33	126	40.11	163	51.89
16	5.12	53	16.88	90	28.65	127	40.43	164	52.21
17	5.44	54	17.2	91	28.97	128	40.75	165	52.52
18	5.76	55	17 52	92	29.29	129	41.07	166	52.84
19	6.07	56	17.8	93	29.61	130	41.38	167	53.16
20	6.39	57	18.15	94	29.93	131	41.7	168	53.48
21	6.71	58	18.47	95	30.24	132	42.02	169	53.8
22	7 03	59	18.79	96	30.56	133	42.34	170	54.12
23	7.34	60	19.11	97	30 88	134	42,66	171	54.43
24	7.66	61	19.42	98	31.2	135	42.98	172	54.75
25	7.98	62	19.74	99	31.52	136	43.29	173	55.07
26	8.3	63	20.06	100	31.84	137	43.61	174	55.39
27	8 61	64	20.38	101	32.15	138	43.93	175	55.71
28	8.93	65	20.7	102	32.47	139	44.25	176	56.02
29	9.25	66	21.02	103	32.79	140	44.57	177	56.34
30	9.57	67	21.33	104	33.11	141	44.88	178	56.66
31	9.88	68	21.65	105	33.43	142	45.2	179	56.98
32	10.2	69	21.97	106	33.74	143	45.52	180	57.23
33	10.52	70	22.29	107	34.06	144	45.84	181	57.62
34	10.84	71	22.61	108	34 38	145	46.16	182	57.93
35	11.16	72	22.92	109	34.7	146	46.48	183	58.25
36	11.47	73	23.24	110	35.02	147	46.79	184	58.57
37	11.79	74	23.56	111	35.34	148	47.11	185	58.89
38	12.11	75	23.88	112	35.65	149	47.43	186	59.21
39	12.43	76	24 2	113	35 97	150	47.75	187	59.53
40	12.74	77	24.52	114	36.29	151	48.07	188	59.84
41	13.06	78	24.83	115	36.61	152	48 39	189	60.16
42	13.38	79	25.15	116	36.93	153	48.7	190	60.48
43	13 7	80	25.47	117	37.25	154	49.02	191	60.81
44	14.02	81	25.79	118	37.56	155	49.34	192	61.13

Teeth of Wheels.

Epicycloidal.

In order that the teeth of the wheels and pinions should work evenly and without unnecessary rubbing friction, the face (from pitch line to top) of the outline should be determined by an epicycloidal curve, and the flank (from pitch line to base) by an hypocycloidal.

When the generating circle is equal to half the diameter of the pitch circle, the hypocycloid described by it is a straight diametrical line, and, consequently, the outline of a flank is a right line and radial to the centre of the wheel.

If a like generating circle is used to describe face of a tooth of other wheel or pinion respectively, the wheel and pinion will operate evenly.

Involute.

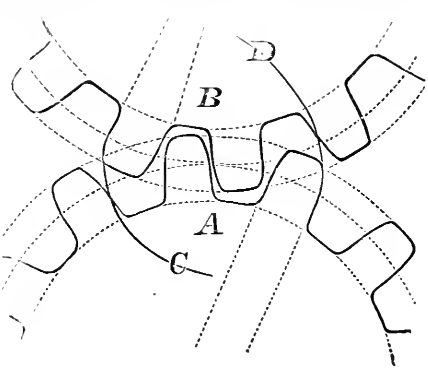
Teeth of two wheels will work truly together when surfaces of their face is an involute ; and that two such wheels should work truly, the circles from which the involute lines for each wheel are generated must be concentric with the wheels, with diameters in the same ratio as those of the wheels.

Curves of Teeth.—In the pattern shop, the curves of epicycloidal or involute teeth are defined by rolling a template of the generating circle on a template corresponding to the pitch line. A scriber on the periphery of the template being used to define the curve.

Least number of teeth that can be employed in pinions having teeth of following classes are : involute, 25 ; epicycloidal, 12 ; staves or pins, 6.

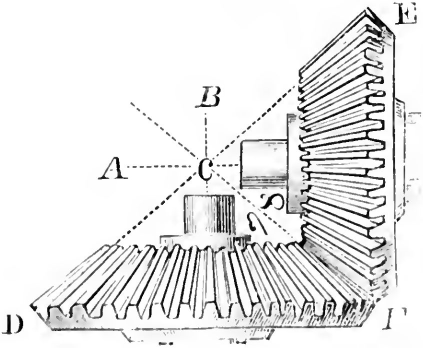
Construction of Gearing.

If the dimensions of two wheels are determined, as well as the size of the teeth and spaces, the wheel is drawn as is shown in figure. The starting-point for the division of the wheels is where the two pitch-circles meet in A. It is advisable to determine the exact diameters of the wheels by calculation, if the difference between them is remarkable; for any division upon two circles of unequal size,



by means of a divider, is incorrect, because the latter measures the chord instead of the arc. From the point A we construct the epicycloid C, by rolling the circle A upon B, as its base line. That short piece of the epicycloid, from the pitch-line to the face of the tooth, is the curvature for that part of the tooth and the wheel B. This curvature obtained for one side of the tooth, serves for both sides of it, and also for all the teeth in the wheel. The lower part of the tooth, or that inside the pitch-line, is immaterial to the working of the wheel; this may be a straight line, as shown by the dotted lines which are in the direction of the diameters, or may be a curved line, as is seen in the wheel A. This line must be so formed as not to touch the upper or curved part of the tooth. The root of the tooth, or that part of it which is connected with the rim of the wheel, is the weakest part of the tooth, and may be strengthened by filling the angles at the corners. The curvature for the teeth in the wheel A is found in a similar manner to that for B. The pitch-circle A serves now as a base-line, and the circle B is rolled upon it, to obtain the circle D. This line forms the curvature for the teeth of A, and serves for all the teeth in A also for both sides of the teeth. In most practical cases the curvature of the teeth is described as a part of a circle, drawn from the centre of the next tooth, or from a point more or less above or below that centre, or the radius greater or less in length than the pitch of the wheel. Such circles are never correct curves, and no rule can be established by which their size and centre meets the form of the epicycloid.

Bevel Wheels.



If the lines C A and B C represent the prolonged axes, which are to revolve with different or similar velocities, the position and sizes of the wheels for driving these axes are determined by the distance of the wheels from the point C. The di-

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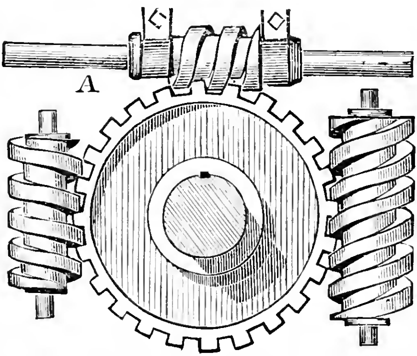
ameters of the wheels are as the angles α and β, and inversely as the number of revolutions. These angles are therefore to be determined before the wheels can be drawn. By measuring the distances from C to the line E, or from C to F, the sizes of the wheels are determined. These lines, E F and D F, are the diameters for the pitch-lines; from them the form of the tooth is described on the bevelled face of the wheel. If the form of the tooth is described on the largest circle of the wheel, all the lines from this face run to the point C, so that when the wheel revolves around its axis, all the lines from the teeth concentrate in the point C, and form a perfect cone. Curvature, thickness, length, and spaces are here calculated as on face wheels; the thickness is measured in the middle of the width of the wheel.

Worm-Screw.



If a single screw, A, works in a toothed wheel, each revolution of the screw will turn the wheel one cog; if the screw is formed of more than one thread, a corresponding number of teeth will be moved by each revolution. With the increase of the number of threads, the side motion of the wheel and screw is accelerated; and when the threads and number of teeth are equal, an angle of 45° is required for teeth and thread, provided their diameters also are equal. This motion causes a great deal of friction, and it is only resorted to where no other means can be employed to produce the required motion. In small machinery, the worm is frequently made use of to produce a uniform, uninterrupted motion; the screw in such cases is made of hardened steel, and the teeth of the wheel are cut by the screw which is to work in the wheel. If the form of the teeth in the wheel is not curved, and its face is concave so as to fit the thread in all points, the screw will touch the teeth but in one point, and cause them to be liable to breakage.

Proportions of Teeth of Wheels.

Tooth.—In computing the dimensions of a tooth, it is to be considered as a beam fixed at one end, the weight suspended from the other, or face of the beam; and it is essential to consider the element of velocity, as its stress in operation, at high velocity with irregular action, is increased thereby.

The dimensions of a tooth should be much greater than is necessary to resist the direct stress upon it, as but one tooth is proportioned to bear the whole stress upon the wheel, although two or more are actually in contact at all times; but this requirement is in consequence of the great wear to which a tooth is subjected, the shocks it is liable to from lost motion, when so worn as to reduce its depth and uniformity of bearing, and the risk of the breaking of a tooth from a defect.

A tooth running at a low velocity may be materially reduced in its dimensions compared with one running at a high velocity and with a like stress.

The result of operations with toothed wheels, for a long period of time, has determined that a tooth with a pitch of 3 inches and a breadth 7.5 inches will transmit, at a velocity of 6.66 feet per second, the power of 59.16 horses.

To compute the Depth of a Cast Iron Tooth.

1. When the Stress is given.

Rule.—Extract the square root of the stress, and multiply it by .02.

Example.—The stress to be borne by a tooth is 4,886 lbs.; what should be its depth?

$$\sqrt{4886} \times .02 = 1.4 \text{ ins.}$$

2. When the Horse-Power is given.

Rule.—Extract the square root of the quotient of the horse-power divided by the velocity in feet per second, and multiply it by .466.

Example.—The horse-power to be transmitted by a tooth is 60, and the velocity of it at its pitch-line is 6.66 feet per second: what should be the depth of the tooth?

$$\sqrt{\frac{60}{6.66}} \times .466 = 1.398 \text{ ins.}$$

To compute the Horse-Power of a Tooth.

Rule.—Multiply the pressure at the pitch-line, by its velocity in feet per minute, and divide the product by 33,000.

CALCULATING SPEED.

When Time is not taken into Account.

RULE.—Divide the greater diameter, or number of teeth, by the lesser diameter or number of teeth, and the quotient is the number of revolutions the lesser will make, for one of the greater.

EXAMPLE.—How many revolutions will a pinion of 20 teeth make, for 1 of a wheel with 125?

$$125 \div 20 = 6.25 \text{ or } 6\tfrac{1}{4} \text{ revolutions.}$$

To find the Number of Revolutions of the last, to one of the first, in a Train of Wheels and Pinions.

RULE.—Divide the product of all the teeth in the driving by the product of all the teeth in the driven; and the quotient equals the ratio of velocity required.

EXAMPLE 1.—Required the ratio of velocity of the last, to 1 of the first, in the following train of wheels and pinions, viz.: pinions driving—the first of which contains 10 teeth, the second 15, and third 18. Wheels driven, first, 15 teeth, second, 25, and third, 32.

$$\frac{10 \times 15 \times 18}{15 \times 25 \times 32} = .225 \text{ of a revolution the wheel will make to one of the pinion.}$$

EXAMPLE 2.—A wheel of 42 teeth giving motion to one of 12, on which shaft is a pulley of 21 inches diameter driving one of 6; required the number of revolutions of the last pulley to one of the first wheel.

$$\frac{42 \times 21}{12 \times 6} = 12.25 \text{ or } 12\tfrac{1}{4} \text{ revolutions.}$$

NOTE.—Where increase or decrease of velocity is required to be communicated by wheel-work, it has been demonstrated that the number of teeth on each pinion should not be less than 1 to 6 of its wheel, unless there be some other important reason for a higher ratio.

When Time must be regarded.

RULE.—Multiply the diameter or number of teeth in the driver, by its velocity in any given time, and divide the product by the required velocity of the driven; the quotient equals the number of teeth or diameter of the driven, to produce the velocity required.

EXAMPLE 1.—If a wheel containing 84 teeth makes 20 revolutions per minute, how many must another contain, to work in contact, and make 60 revolutions in the same time?

$$84 \times 20 \div 60 = 28 \text{ teeth.}$$

EXAMPLE 2.—From a shaft making 45 revolutions per minute, and with a pinion 9 inches diameter at the pitch line, I wish to transmit motion at 15 revolutions per minute; what, at the pitch line, must be the diameter of the wheel?

$$45 \times 9 \div 15 = 27 \text{ inches.}$$

EXAMPLE 3.—Required the diameter of a pulley to make 16 revolutions in the same time as one of 24 inches making 36.

$$24 \times 36 \div 16 = 54 \text{ inches.}$$

The Distance between the Centres and Velocities of Two Wheels being given, to find their Proper Diameters.

RULE.—Divide the greatest velocity by the least; the quotient is the ratio of diameter the wheels must bear to each other.

Hence, divide the distance between the centres by the ratio + 1; the quotient equals the radius of the smaller wheel; and subtract the radius thus obtained from the distance between the centres; the remainder equals the radius of the other.

EXAMPLE.—The distance of two shafts from centre to centre is 50 inches, and the velocity of the one 25 revolutions per minute, the other is to make 80 in the same time; the proper diameters of the wheels at the pitch lines are required.

$80 \div 25 = 3.2$, ratio of velocity, and $50 \div 3.2 + 1 = 11.9$ the radius of the smaller wheel; then $50 - 11.9 = 38.1$, radius of larger; their diameters are $11.9 \times 2 = 23.8$ and $38.1 \times 2 = 76.2$ inches.

To obtain or diminish an accumulated velocity by means of wheels and pinions, or wheels, pinions, and pulleys, it is necessary that a proportional ratio of velocity should exist, and which is thus attained; multiply the given and required velocities together; and the square root of the product is the mean or proportionate velocity.

EXAMPLE.—Let the given velocity of a wheel containing 54 teeth equal 16 revolutions per minute, and the given diameter of an intermediate pulley equal 25 inches, to obtain a velocity of 81 revolutions in a machine; required the number of teeth in the intermediate wheel and diameter of the last pulley.

$\sqrt{81 \times 16} = 36$ mean velocity;
$54 \times 16 \div 36 = 24$ teeth, and
$25 \times 36 \div 81 = 11.1$ inches, diameter of pulley.

Table of the Weight of a Square Foot of Sheet Iron in Pounds Avoirdupois.

No. 1 is $\frac{5}{16}$ of an inch; No. 4, $\frac{1}{4}$; No. 11, $\frac{1}{8}$, &c.

No. on wire-gauge,	1	2	3	4	5	6	7	8	9	10	11
Pounds avoir.,	12.5	12	11	10	9	8	7.5	7	6	5.68	5

No. on wire-gauge,	12	13	14	15	16	17	18	19	20	21	22
Pounds avoir.,	4.62	4.31	4	3.95	3	2.5	2.18	1.93	1.62	1.5	1.37

SCREW CUTTING.

In a lathe properly adapted, screws to any degree of pitch, or number of threads in a given length, may be cut by means of a leading screw of any given pitch, accompanied with change wheels and pinions; coarse pitches being effected generally by means of one wheel and one pinion with a carrier, or intermediate wheel, which cause no variation or change of motion to take place. Hence the following

RULE.—Divide the number of threads in a given length of the screw which is to be cut, by the number of threads in the same length of the leading screw attached to the lathe; and the quotient is the ratio that the wheel on the end of the screw must bear to that on the end of the lathe spindle.

EXAMPLE.—Let it be required to cut a screw with 5 threads in an inch, the leading screw being of ½ inch pitch, or containing 2 threads in an inch; what must be the ratio of wheels applied?

$5 \div 2 = 2.5$, the ratio they must bear to each other.

Then suppose a pinion of 40 teeth be fixed upon for the spindle:

$40 \times 2.5 = 100$ teeth for the wheel on the end of the screw.

But screws of a greater degree of fineness than about 8 threads in an inch are more conveniently cut by an additional wheel and pinion, because of the proper degree of velocity being more effectively attained; and these, on account of revolving upon a stud, are commonly designated the stud-wheels, or stud-wheel and pinion; but the mode of calculation and ratio of screw are the same as in the preceding rule. Hence, all that is further necessary is to fix upon any 3 wheels at pleasure, as those for the spindle and stud-wheels; then multiply the number of teeth in the spindle-wheel by the ratio of the screw, and by the number of teeth in that wheel or pinion which is in contact with the wheel on the end of the screw; divide the product by the stud-wheel in contact with the spindle-wheel; and the quotient is the number of teeth required in the wheel on the end of the leading screw.

EXAMPLE.—Suppose a screw is required to be cut containing 25 threads in an inch, and the leading screw, as before, having two threads in an inch, and that a wheel of 60 teeth is fixed upon for the end of the spindle, 20 for the pinion in contact with the screw-wheel, and 100 for that in contact with the wheel on the end of the spindle; required the number of teeth in the wheel for the end of the leading screw.

$$25 \div 2 = 12.5, \text{ and } \frac{60 \times 12.5 \times 20}{100} = 150 \text{ teeth.}$$

Or suppose the spindle and screw-wheels to be those fixed upon, also any one of the stud-wheels, to find the number of teeth in the other.

$$\frac{60 \times 12.5}{150 \times 100} = 20 \text{ teeth, or } \frac{60 \times 12.5 \times 20}{150} = 100 \text{ teeth.}$$

WATER-WHEELS.

The properties of water, as a motive power, are gravity and impulsive force, each being rendered peculiarly available for the production of uniform circular motion through the medium of the water-wheel.

Water-wheels are necessarily and designedly of various modifications, so as to obtain the greatest amount of mechanical effect from a known quantity of water flowing at a certain velocity, or from a given height, and generally ranked, by estimation of effect, into first, second, and third class wheels.

1st class includes overshot-wheels, pitchback-wheels, and turbines.

2d class consists of breast-wheels, or those which receive the water below the level of the axis.

And 3d class is composed of undershot-wheels, tub-wheels, and flutter-wheels.

The most modern and best-conducted experiments on each description, as known to the public at present, are those by Poncelot of America, and of Morin in France, the results of which are as follows:

Overshot-wheels, &c.; ratio of power to effect,	varies from			.60 to .80
Breast-wheels,	"	"	"	.45 to .50
Undershot-wheels, &c.	"	"	"	.27 to .30

The greatest effect is obtained by an overshot-wheel when the diameter of the wheel is so proportioned to the height of the fall, that the water shall flow upon the wheel at a point about $52\frac{3}{4}$ degrees distant from the top of the wheel.

If the portion of the total descent passed through by the water be given, then the velocity of the circumference should be one-half of that, due to this height. Therefore, multiply the portion of fall, in feet, by 64.38, and the square root of the product equals the water's velocity, in feet, per second. Also,

If the area of cross-section of the overflow be multiplied by the velocity at the end of the fall, the product equals the quantity, in cubic feet, per second.

Experiments on Overshot-Wheels.

1. When the depth of water in the reservoir is invariable, the diameter of the wheel should never exceed the entire height of the fall, less so much as is requisite to generate a proper velocity on entering the buckets.

2. Where the depth of water in the reservoir varies considerably and unavoidably, an advantage may be obtained by applying a larger wheel, dependent upon the extent of fluctuation, and ratio in time, that the water is at its highest or lowest levels during a given prolonged period. If this be a ratio of equality, in time there will be no advantage; and hence, in practice, the cases

will be rare when any advantage will be obtained by the use of an overshot-wheel greater in diameter than the height of fall, minus the head due to the required velocity of the water reaching the wheel.

3. If the level of the water in the reservoir never falls below the mean depth of the reservoir, when at the highest and lowest, and the average depth be between an eighth and a tenth of the height of the fall, then the average mechanical force of the large wheel will be greater than that of the small one: and it will of course retain its increased advantage at periods of increased depths of the reservoir.

4. That a positive advantage is gained by a wheel revolving in a conduit, varying with the conditions of the wheel and fall of nearly 11 per cent. of the total power.

To ascertain the Power of a Water-Wheel.

Rule.—Multiply the velocity of the wheel, in feet, per minute, by the weight of the water, in pounds, expended on the wheel in the same time; divide the product by the co-efficient of power to effect, and the quotient equals the mechanical effect of the wheel, expressed in horse-power.

Co-efficients	1st class wheels,	47,190
	2d class "	69,300
	3d class "	115,500

Or multiply the product of the quantity of water expended, in cubic feet, per minute, and the velocity of the wheel, in feet, in the same time, by the following decimal equivalents; the product will be the number of horse-power that the wheel is equal to in useful effect.

Decimal equivalents	1st class wheels,	.001325
	2d class "	.000902
	3d class "	.000541

Example.—Suppose a stream of water flowing on an overshot-wheel at the rate of 95 cubic feet per minute, and the velocity of the wheel's periphery equals 6 feet per second, or 360 feet per minute; required the effect of the wheel in horse-power.

$$\frac{360 \times 95 \times 62.5}{47190} = 45.29 \text{ horse-power.}$$

Or, $360 \times 95 \times .001325 = 45.29$ " "

Note.—When the fall of water does not exceed 4 feet, an undershot-wheel ought to be applied; from 4 to 10 feet, a breast-wheel; and from 10 feet upward, an overshot or pitchback wheel.

To ascertain the Power of a Stream.

Rule.—Multiply the weight of the water, in pounds, discharged in one minute by the height of the fall in feet; divide by 33,000, and the quotient is the answer.

Example.—What power is a stream of water equal to of the following dimensions, viz.: 1 foot deep by 22 inches broad, velocity 350 feet per minute, and fall 60 feet; and what should be the size of the wheel applied to it?

$12 \times 22 \times 350 \times 12 \div 1728 \times 62\frac{1}{2} \times 60$ feet $\div 33000 = 72.9$. Ans.

Height of fall 60 feet, from which deduct, for admission of water and clearance below, 15 inches, which gives 58.9 feet for the diameter of the wheel.

Clearance above 3 } 15 inches.
" below 12 }

The power of a stream, applied to an overshot-wheel, produces effect as 10 to 6.6.

Then, as 10 : 6.6 : : 72.9 : 48 horse-power equal that of an overshot-wheel of 60 feet applied to this stream.

When the fall exceeds 10 feet the overshot-wheel should be applied.

The higher the wheel is in proportion to the whole descent, the greater will be the effect.

The effect is as the quantity of water and its perpendicular height multiplied together.

The weight of the arch of loaded buckets, in pounds, is found by multiplying 4-9 of their number, × the number of cubic feet in each, and that product by 40.

To ascertain the Power of an Undershot-Wheel when the Stream is confined to the Wheel.

RULE.—Ascertain the weight of the water discharged against the floats of the wheel in one minute by the preceding rules, and divide it by 100,000; the quotient is the number of horse-power.

NOTE.—The 100,000 is obtained thus: The power of a stream, applied to an undershot-wheel, produces effect as 10 to 3.3; then 3.3 : 10 : : 33,000 : 100,000.

When the opening is above the centre of the floats, multiply weight of the water by the height, as in the rule for an overshot wheel.

EXAMPLE.—What is the power of an undershot-wheel, applied to a stream 2 by 80 inches, from a head of 25 feet?

$\sqrt{25} \times 6.5 \times 60 = 1950$ feet velocity of water per minute, and $2 \times 80 = 160$ inches $\times 1950 \times 12 \times 1728 = 2166.6$ cubic feet $\times 62.5 =$ *135412 lbs. of water discharged in one minute; then $135412 \div 100000 = 1.35$ horse-power.

To find the Power of a Breast-Wheel.

RULE.—Find the effect of an undershot-wheel, the head of water of which is the difference of level between the surface and where it

* Equal $160 \times 12 \div 1728 \times 62.5 \times 1950 =$ momentum of water and its velocity.

strikes the wheel (breast), and add to it the effect of that of an overshot-wheel, the height of the head of which is equal to the difference between where the water strikes the wheel, and the tail water; the sum is the effective power.

Example.—What would be the power of a breast-wheel applied to a stream 2 × 80 inches, 14 feet from the surface, the rest of the fall being 11 feet?

$\sqrt{14 \times 6.5} \times 60 = 1458.6$ feet velocity of water per minute.

And $2 \times 80 \times 1458 \times 12 \div 1728 = 1620$ cubic feet $\times 62.5 =$ 101250 lbs. of water discharged in one minute.

Then $101250 \div 100000 = 1.012$ horse-power as an undershot.

$\sqrt{11 \times 6.5} \times 60 = 1290$ feet velocity of water per minute.

And $2 \times 80 \times 1290 \times 12 \div 1728 = 1433$ cubic feet $\times 62.5 =$ 89562 lbs. of water discharged in one minute, which

$\times$ 11 height of fall $\div$ 50000 = 19.703 horse-power, which, added to the above, = 20.715. Ans.

Note.—When the fall exceeds 10 feet, it may be divided into two, and two breast-wheels applied to it.

When the fall is between 4 and 10 feet, a breast-wheel should be applied.

The power of a water-wheel ought to be taken off opposite to the point where the water is producing its greatest action upon the wheel.

Remarks on Reaction Water-Wheels.

Reaction water-wheels are a very numerous family, of which the well-known hydraulic motor, called Barker's mill, is the parent; those used in various parts of the United States have usually vertical axes of rotation, and curved buckets, or vanes, against which the impulsive force of the water (spouting from within the wheel by adjutages, of which the curved vanes form the sides) acts indirectly, or rather reacts, thus producing (in reference to the affluent water) a backward rotary motion, similar, in character and effect, to the forward rotary motion produced by direct impulse in the case of undershot-wheels.

In the American Philosophical Transactions for 1793, it is stated that the principles of reaction wheels had been fully investigated analytically in examining the merits of Rumsey's improvements on Barker's mill; and the conclusion come to, after a train of reasoning based upon scientific principles, was, that "action and reaction are equal;" that the undershot-wheel is propelled by the action; and Barker's mill by the reaction of the same agent, or momentum; therefore their mechanical effects must be equal.

This conclusion no doubt tended to retard any effort at improvement of wheels on that principle for a considerable length of time; for it is only, comparatively speaking, quite recently that reaction water-wheels, of the form at present in use, have occupied a prominent position before the public.

In 1830, Calvin Wing, of the United States, took out a patent for a reaction water-wheel with curved vanes or buckets, the vanes of which lapped over, or rather on to each other, in the ratio of $1\frac{1}{2}$ inches for each inch of the width of the adjutage, or shortest horizontal distance between any two adjacent vanes.

In this wheel the water has free entrance to a circular space within, and, spouting out by the openings between the curved vanes, impels the wheel around in a backward direction, by its reaction against the vanes, in issuing with velocity from within the wheel.

But this species of wheel, so far, seems not to realize the amount of effect as anticipated; for, according to recent experiments, it appe rs that, with 788 cubic feet of water, at the rate of one foot per minute, applied on an overshot-wheel, will grind and dress one bushel of wheat per hour; whereas to do the same by means of the reaction wheel required 1,600.

Some of later date, as the turbine of France, by M. Fourneyron, and the recently patented water-mill, by Whitelaw and Stirrat, Scotland, seem much improved hydraulic motors; for, according to the experiments of M. Morin, and others of high authority, they rank, in effect to power, equal to first-class wheels.

The chief objection to the common overshot-wheel, is its great size an l formidable cost, to which might be added, the loss of power consequent on the friction of the gearing requisite for bringing up the speed of the prime mover to the velocity indispensable to most ordinary mechanical operations. These objections do not apply to this species of water-power, as the machine occupies but a very small space in comparison with a water-wheel of the same power; its speed is high, and the expense of its construction greatly inferior to that of any other effectual mechanism we are at present acquainted with for deriving a rotary motion from a head of water.

The arms of the machine by Whitelaw and Stirrat are bent in the form of an Archimedes spiral, so as to obviate the communication of a centrifugal force to the water, which, if the arms were straight, it would necessarily acquire to the diminution of the useful effect. Any number of arms may be used, but two is the common number. The machine revolves horizontally, and the affluence of the water at the orifices of the arms is regulated by means of valves of a peculiar description, governed by the centrifugal force of the machine, or, in other words, by its velocity.

Turbines.

In high-pressure turbines the reservoir (of the wheel) is inclosed at top, and the water is admitted through a pipe at its side. In low-pressure, the water flows into the reservoir, which is open.

In turbines working under water, the height is measured from the surface of the water in the supply to the surface of the discharged water or race; and when they work in air, the height is measured from the surface in the supply to the centre of the wheel.

In order to obtain the maximum effect from the water, the velocity of it, when leaving a turbine, should be the least practicable.

The efficiency is greater when the sluice or supply is wide open, and it is less affected by head than by variations in the supply of water. It varies but little with the velocity, as it was ascertained by experiment that when 35 revolutions gave an effect of .64, 55 gave but .66.

When turbines operate under water, the flow is always full through them; hence they become reaction-wheels, which are the most efficient.

The experiments of Morin gave results of the efficiency of turbines as high as .75 of the power expended.

The angle of the plane of the water entering a turbine with the inner periphery of it should be greater than 90°, and the angle which the plane of the water leaving the reservoir makes with the inner circumference of the turbine should be less than 90°.

When turbines are constructed without a guide curve,* the angle of plane of flowing water and inner circumference of wheel = 90°.

Great curvature involves greater resistance to the efflux of the water; and hence it is advisable to make the angle of the plane of the entering water rather obtuse than acute, say 100°; the angle of the plane of the water leaving, then, should be 50°, if the internal pressure is to balance the external; and if the wheel operates free of water, it may be reduced to 25° and 30°.

The angle made by the plane of the discharged water with the water periphery should never exceed 20°.

Fourneyron's work either in or out of water, are applicable to high and low falls, and are either high or low pressure turbines. They are best adapted for very low falls, and those of moderate height, say up to 30 feet, with large supplies of water. The pressure upon their step is confined to the weight of the wheel alone.

Fourneyron makes the angle of the plane of the water entering a turbine = 90°, and the angle of the plane of the water leaving = 30°.

Jonval's.—This wheel is essentially alike in its principal proportions to Fontaine's, and in the principle of operation it is the same. The water in the race must be at a certain depth below the wheel.

The efficiency of this wheel decreases as the volume of water is diminished, or as the sluice is contracted.

Fontaine's.—In the operation of this wheel the water in the race is in immediate contact with the wheel, and its efficiency is greatest when the sluice is fully opened. Its efficiency, also, is

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* Guide curves are plates upon the centre body of a turbine, which give direction to the flowing water, or to the blades of the wheel which surround them.

less affected by variations of the head of the flow than in the volume of the water supplied; hence they are adapted for tide-mills.

The pressure upon the step, in addition to the weight of the wheel, includes that of the contained water.

Whitelaw's.—This wheel is best adapted for high falls and small volumes of water.

Poncelet's.—This wheel is alike to one of his undershot-wheels set horizontally, and it is the most simple of all the horizontal wheels.

THE RATIO OF EFFECT TO POWER OF THE SEVERAL TURBINES IS AS FOLLOWS:

Poncelet........	.65 to .75 to 1	Jonval.......	.6 to .7 to 1
Fourneyron.....	.6 to .75 to 1	Fontaine	.6 to .7 to 1
Whitelaw.	.6 to .75 to 1		

A Tremont turbine, as observed by Mr. Francis, in his experiments at Lowell, Mass., gave a ratio of effect to power as .79375 to 1.

WATER.

TO FIND THE QUANTITY OF WATER THAT WILL BE DISCHARGED THROUGH AN ORIFICE OR PIPE IN THE SIDE OR BOTTOM OF A VESSEL.

Area of orifice, sq. in × { No. corresponding to height of surface above orifice, as per table } = cubic feet discharged per minute.

Height of Surface above Orifice	Multiplier	Height of Surface above Orifice	Multiplier.	Height of Surface above Orifice	Multiplier.
Ft.		Ft.		Ft.	
1	2.25	18	9.5	40	14.2
2	3.2	20	10.	45	15.1
4	4.5	22	10.5	50	16.
6	5.11	24	11.	60	17.4
8	6.1	26	11.5	70	18.8
10	7.1	28	12.	80	20.1
12	7.8	30	12.3	90	21.3
14	8.1	32	12.7	100	22.5
16	9.	35	13.3		

To find the size of Hole necessary to discharge a given Quantity of Water under a given Head.

$$\frac{\text{Cubic ft. water discharged}}{\text{No. corresponding to height, as per table}} = \text{area of orifice, sq. in.}$$

To find the Height necessary to discharge a given Quantity through a given Orifice.

$$\frac{\text{Cubic ft. water discharged}}{\text{Area orifice, sq. inches}} = \text{No. corresp. to height, as per table.}$$

The Velocity of Water issuing from an Orifice in the Side or Bottom of a Vessel being ascertained to be as follows:

$$\sqrt{\text{Height ft. surface above orifice}} \times 5.4 = \text{Velocity of water, ft. per second.}$$

$$\sqrt{\text{Height ft.}} \times \text{area orifice, ft.} \times 324 = \text{Cubic feet discharged per minute.}$$

$$\sqrt{\text{Height ft.}} \times \text{area orifice, ins.} \times 2.2 = \text{Do. do.}$$

It may be observed, that the above rules represent the actual quantities that will be delivered through a hole cut in the plate; if a short pipe be attached, the quantity will be increased, the greatest delivery with a straight pipe being attained with a length equal to 4 diameters, and being 1-3 more than the delivery through the plain hole; the quantity gradually decreasing as the length of pipe is increased, till, with a length equal to 60 diameters, the discharge again equals the discharge through the plain orifice. If a taper pipe be attached, the delivery will be still greater, being $1\frac{1}{2}$ times the delivery through the plain orifice; and it is probable, that if a pipe with curved decreasing taper were to be tried, the delivery through it would be equal to the theoretical discharge, which is about 1.65 the actual discharge through a plain hole.

To find the Quantity of Water that will run through any Orifice, the Top of which is level with the Surface of Water, as over a Sluice or Dam

$$\sqrt{\text{Height ft. from water-surface to bottom of orifice or top of dam}} \times \text{Area of water-passage, sq. ft.} \times 216$$
$$= \text{cubic ft. discharged per minute.}$$

Or,

Two-thirds area of water-passage, sq. ins. × No. corresponding to height, as per table = cubic feet discharged per minute.

To find the time in which a Vessel will empty itself through a given Orifice.

$$\frac{\sqrt{\text{Height ft. surface above orifice}} \times \text{area water-surface, sq ins.}}{\text{Area orifice, sq. in.} \times 3.7}$$
$$= \text{Time required, seconds.}$$

The above rules are founded on Bank's experiments.

TABLE OF SPECIFIC GRAVITIES.

Liquids.

Divide the Specific Gravity by 16, and the quotient is the weight of a cubic foot in lbs.	Specific Gravity.
Acid, acetic	1.062
" nitric	1.217
" sulphuric	1.841
" muriatic	1.200
Alcohol, pure	.792
" of commerce	.835
Oil, essential, turpentine	.870
" olive	.915
" whale	.923
" linseed	.932
Proof spirit	.925
Vinegar	1.080
Water, distilled	1.000
Ether, sulphuric	.715
Honey	1.450
Human blood	1.054
Milk	1.032
Water, sea	1.026
" Dead Sea	1.240
Wine	.992
" port	.997
" champagne	.997

Elastic Fluids.

Divide the Specific Gravity by 16, and the quotient is the weight of a cubic foot in lbs.	Specific Gravity
1 cubic ft. of atmospheric air weighs 527.04 troy grains.	
Its assumed gravity of 1 is the unit of elastic fluids	1.000
Ammoniacal gas	.597
Azote	.976
Carbonic acid	1.524
Carbureted hydrogen	.555
Chlorine	2.470
Chloro-carbonic	3.389
Hydrogen	.070
Oxygen	1.104
Sulphureted hydrogen	1.777
Steam, 212°	.490
Nitrogen	.972
Vapor of alcohol	1.613
" turpentine spts	5.013
" water	.623
Smoke of bituminous coal	.102
" wood	.900

Metals.

Divide the Specific Gravity by 16, and the quotient is the weight of a cubic foot in lbs.	Specific Gravity.
Antimony	6.712
Arsenic	5.763
Bismuth	9.823
Brass, common	7.820
Bronze, gun-metal	8.700
Copper, cast	8.788
" wire drawn	8.878
Gold, pure, cast	19.258
" hammered	19.361
" 22 carats fine	17.486
" 20 carats fine	15.709
Iron, cast	7.207
Iron bars	7.788
Lead, cast	11.352
Mercury, 32	13.598
" 60	13,580
Platinum, rolled	22.069
" hammered	20.337
Silver, pure, cast	10.474
" hammered	10.511
Steel, soft	7.833
" temp'd and hard'd	7.818
Tin, Cornish	7.291
Zinc, cast	6.861

HYDRAULICS.

The science of hydrodynamics embraces hydrostatics and hydraulics, the former of which treats of the properties and equilibrium of liquids in a state of rest, and the latter of liquids in motion, as conducting water in pipes, raising liquids by pumps, &c.

1. The peculiar distinguishing properties of liquids or fluids in general are, capability of flowing, and constant tendency to press outward in every direction.

2. Fluids are of two kinds, aeriform and liquid, or elastic and non-elastic; that is, bodies of which are easily compressed into a smaller bulk, and bodies which are scarcely susceptible of compression. Atmospheric air, steam, or vapor of water, and all other gaseous bodies, are of the first kind; and water, alcohol, mercury, &c., are of the second.

Compression of Liquids, in Millionth Parts per Atmosphere.

Mercury,	2.65	of their original bulk.
Alcohol,	21.60	
Water,	46.63	
Ether,	61.58	

3. The weight of water or other fluid is as the quantity, but the pressure exerted is as the vertical height.

4 Fluids press equally in all directions; hence, any vessel containing a fluid sustains a pressure equal to as many times the weight of the column of greatest height of that fluid, as the area of the vessel is to the sectional area of the column.

5. The hydraulic press is of this principle. A jet of water is thrown into a cavity by means of a force pump; the action and non-compressible property of the liquid repels a piston or ram, the force of which equals the product of the effective power or pressure exerted on the fluid in the pump, multiplied by the number of times the area of the base of the ram exceeds the sectional area of the pump.

EXAMPLE.—Required the repulsive force of a six-inch ram, when a power of 50 lbs. is applied to the end of the lever, which is as 12 to 1, and the diameter of the pump or plunger 7-8 of an inch.

$$\frac{\text{Area of ram} = 28.2744}{\text{Area of pump} = .6013} = 47\ ;$$

and $50 \times 12 \times 47 = 28,200$ lbs., or 12 tons, nearly.

6. The lateral pressure of a fluid on the sides of any vessel in which it is contained is equal to the product of the length multiplied by half the square of the depth, and by the weight of the fluid in cubic unity of dimensions.

Example.—A cistern 12 feet square and 8 feet deep is filled with water; required the whole amount of lateral pressure.

(Weight of a cubic foot of water, 62.5 lbs.)

$$12 \times 4 = 48 \text{ feet, the whole length of sides,}$$

$$\text{and } \frac{8^2}{2} = 32; \quad \text{then } \frac{48 \times 32 \times 62.5}{2000} = 48 \text{ tons net.}$$

7 Fluids always tend to a natural level, or curve similar to the earth's convexity, every point of which is equally distant from the centre of the earth, the apparent level, or level taken by any instrument for that purpose, being only a tangent to the earth's circumference; hence, in levelling for canals, &c., the difference caused by the earth's curvature must be deducted from apparent level to obtain the true level.

To find the Difference between True and Apparent Level.

When the distance is	Feet,	the square of that distance multiplied by	.000000287	equal the difference in inches when refraction is not taken into account.
	Yards,		.000002583	
	Chains		.00125	

If the distance is considerable, and refraction must be attended to, diminish the distance in respect to calculation by 1-12.

Example. What is the difference between true and apparent level at a distance of 18 chains, when refraction is taken into account?

$$\frac{18}{12} = 1.5, \text{ and } 18 - 1.5 = 16.5^2 \times .00125 = .3403 \text{ inch.}$$

8. When a body is partly or wholly immersed in a fluid, the vertical pressure of the fluid tends to raise the body with a force equal to the weight of the fluid displaced; hence, the weight of any displaced quantity of a fluid by a buoyant body equals the weight of that body.

9. The centre of pressure, and also the centre of percussion in a fluid, is two-thirds the depth from the surface.

10. The resistance by which a moving body is opposed in passing through a liquid is as the square of its velocity: hence, if a body be propelled at a certain velocity by a known power, to double that velocity will require four times the power; to triple it, nine times the power, &c.

Of Liquids in Motion.

The flowing of water through pipes, or in natural channels, is liable to be materially affected by friction. Water flows smoothly and with least retardation when the course is perfectly smooth and straight. Every little inequality which is presented to the liquid tends to retard its motion, and so likewise does every bend or angle in its path.

1. When water issues out of a circular aperture in a thin plate on the bottom or side of a reservoir, the issuing stream tends to converge to a point at the distance of about half its diameter outside the orifice, and this contraction of the stream reduces the area of its section from 1 to .666, according to Bossut ; to .631, according to Venturi ; and to .64, according to Eytelwein. But, from more accurate experiments, it is found that the quantity discharged is not sufficient to fill this section with the velocity due or corresponding to the height, and that the orifice must be diminished to .619, or nearly $\frac{5}{8}$.

1. When water issues through a short tube, the vein of the stream is less contracted than in the former case, in the proportion of 16 to 13 ; and if it issues through an aperture which is the frustum of a cone, whose greater base is the aperture, the height of the frustum, half the diameter of the aperture, and the area of the small end to the area of the large end as 10 to 16, there will be no contraction of the vein. Hence, when the greatest possible supply of water is required, this form of orifice ought to be employed.

Table,

SHOWING THE QUANTITY OF WATER DISCHARGED PER MINUTE BY EXPERIMENTS WITH ORIFICES DIFFERING IN FORM AND POSITION.

Constant Weight of the fluid above the centre of the Orifice. FT. IN. LINES.	Form.	Position.	Diameter of the Orifice.	Number of Cubic Inches discharged per minute.
11 8 10	Circular.	Horizontal.	6 lines.	2.311
	"	"	12 "	9.281
	"	"	24 "	37.203
	Rectangular.	"	12 by 3.	2.933
	Square.	"	12 side.	11.817
	"	"	24 "	47.361
9 0 0	Circular.	Vertical.	6 lines.	2.018
	"	"	12 "	8.135
4 0 0	"	"	6 "	1.353
	"	"	12 "	5.436
5 0 7	"	"	12 "	.628

Deductions from the Preceding Experiments.

1. That the quantities of water discharged in equal times by the same orifice, from the same head of water, are nearly as the areas of the orifices.

2. That the quantities of water discharged in equal times by the same orifices, under different heads, are nearly as the square roots of the corresponding heights of the water in the reservoir, above the surface of the orifices.

3. That the quantities of water discharged during the same time by different apertures, under different heights of water in the reservoir, are to one another in the compound ratio of the areas of the apertures, and of the square roots of the heights in the reservoir.

4. That, on account of the friction, small orifices discharge proportionally less fluid than those which are larger and of similar figure, under the same altitude of fluid in the reservoir.

5. That, in consequence of a slight augmentation which the contraction of the fluid vein undergoes, in proportion as the height of the fluid in the reservoir increases, the expenditure ought to be a little diminished.

6. That circular apertures are most advantageous, as they have less rubbing surface under the same area.

7. That the discharge of a fluid through a cylindrical horizontal tube, the diameter and length of which are equal to one another, is the same as through a simple orifice.

8. That if the cylindrical horizontal tube be of greater length than the extent of the diameter, the discharge of water is much increased, and may be increased with advantage to four times the diameter of the orifice.

Weight of Water at its Common Temperature.

1	cubic inch		=	.03617 lbs.
12	"	inches	=	.434 "
1	"	foot	=	62.5 "
1	"	"	=	7.81 gallons.
1.6	"	feet	=	1 lb.
32	"	"	=	1 ton.
1	cylindrical inch		=	.02842 lbs.
12	"	inches	=	.341 "
1	"	foot	=	49.1 "
1	"	"	=	6.136 gallons.
2.036	"	feet	=	1 cwt.
40.73	"	"	=	1 ton.
12.5 gallons			=	1 cwt.
250	"		=	1 ton.

On the Discharge of Water by Horizontal Conduit, or Conducting Pipes.

1. The less the diameter of the pipe, the less, proportionally, is the discharge of fluid.

2. The greater the length of conduit pipe, the greater the diminution of discharge.

3. The discharges made in equal times, by horizontal pipes of different lengths, but of the same diameter, and under the same altitude of water, are to one another in the inverse ratio of the square roots of the lengths.

4. That in order to have a perceptible and continuous dis-

charge of fluid, the altitude of the water in the reservoir, above the axis of the conduit pipe, must not be less than 148 inches for every 180 feet of the length of the pipe.

5. That in the construction of hydraulic machines, it is not enough that elbows and contractions be avoided, but also any intermediate enlargements. the bad effects of which are proportionate, as in the following:

Head of Water, in Cubic Inches.	Number of Enlarged Parts.	Seconds in which 4 Cubic Feet were discharged.
32.5	0	109
32.5	1	147
32.5	3	192
32.5	5	240

Practical Rules and Examples for ascertaining the Diameters of Pipes, and Quantity of Water discharged in any given time.

RULE.—Multiply 2,500 times the diameter of the pipe, in feet, by the height in feet, and divide the product by the length in feet, added to 50 times the diameter, and the square root of the quotient will be the velocity of discharge in feet per second.

EXAMPLE.—Suppose the diameter of a pipe to be .375 foot; the height of the water in the reservoir, above the point of discharge, 51.5 feet, and the length of pipe 14,637 feet. Required the velocity of the water, and the quantity discharged in cubic feet per second?

$$\frac{2500 \times .375 \times 51.5}{14637 + (50 \times .375)} = \frac{48281.25}{14655.75} = \sqrt{3.3} = 1.816 \text{ feet per second,}$$

velocity;

And $.375^2 \times .7854 \times 1.816 = .20057$ cubic foot per second.

Or, multiply 1,542, 133 times the fifth power of the diameter of the pipe in feet, by the height in feet, and divide the product by the length in feet, added to 50 times the diameter in feet, and the square root of the quotient equals the discharge in cubic feet per second.

These rules apply only to the case where the pipe is straight. If there be bends in it, the velocity (found by the rule as above) must be diminished, by taking the product of its square, multiplied by the sum of the sines of the several angles of inflection, and by .0038, which will give the degree of pressure required to overcome the resistance occasioned by the bends, and deducting this height from the height corresponding to the velocity, the corrected velocity is obtained.

If power is to be obtained by the issuing stream of water through a pipe, the whole of the power due to the height which is necessary to send the water through the pipe, at the required velocity, is not lost, for the power due to this velocity is still in the water. Thus, suppose five-tenths or half a foot of head of water be given to maintain a required velocity of water through a pipe, and this velocity be found, as per rule, to be 2.988 feet per second: then $\left(\frac{2.988}{8}\right)^2 = .1395$ or the height that would give that water a velocity of 2.988 per second. Hence, $.5 - .1395 = .3605$ of a foot, the positive height lost by the resistance in passing through the pipe.

A pressure of .75 of a foot in height, will give a velocity of discharge equal to 3.5355 feet per second, at the lower end of a straight pipe of 2 feet diameter and 200 feet in length; but if there be a bend, or number of bends, in the pipe, the velocity of the water will not be so great. Say that there are three bends, one of 90°, and the other two of 150° each, the sum of the sines of those angles equal 2. Hence, $3.5355^2 \times 2 \times .0038 = .095$, and $.75 - .095 = .655$, that must be used or taken instead of .75 in the rule for obtaining the velocity of discharge at the lower end of the pipe.

As an approximate rule for determining the diameters of pipes capable of conducting any required quantity of water in cubic feet per minute:

Multiply the square of the quantity in cubic feet per minute by .96, and the product equals the diameter of the pipe in inches.

Example.—Required the diameter of a pipe large enough to conduct 625 cubic feet of water per minute.

$\sqrt{625} = 25$, and $25 \times .96 = 24$ inches diameter.

Diameter of Pipes sufficient in size to discharge a required Quantity of Water per Minute.

Cub. ft	Diam. in inches.	Cub. ft.	Diam. in inches	Cub. ft.	Diam. in inches.
1	.96	18	4.07	130	10.94
2	1.36	20	4.29	140	11.35
3	1.66	25	4.80	150	11.75
4	1.92	30	5.25	160	12.14
5	2.15	35	5.67	170	12.51
6	2.35	40	6.07	180	12.67
7	2.60	45	6.53	190	13.23
8	2.72	50	6.80	200	13.57
9	2.88	55	7.12	225	14.40
10	3.01	60	7.43	250	15.1
11	3.18	70	8.03	275	15.91
12	3.33	80	8.60	300	16.62
13	3.46	90	9.10	350	17.95
14	3.60	100	9.60	400	19.20
15	3.72	110	10.06	500	20.46
16	3.84	120	10.51	600	23.51

Of the Discharge of Water by Rectangular Orifices in the Side of a Reservoir extending to the Surface.

The velocity of the water varies nearly as the square root of the height, and the quantity discharged per second two-thirds of the velocity due to the mean height, allowing for the contraction of the fluid, according to the form of the opening, which renders the co-efficient in this case equal to 5.1. Hence,

Suppose, in the side of a lake or in the side of a reservoir, a rectangular opening is made, without any oblique lateral walls, 3 feet wide, and extending 2 feet below the surface of the water. Required the quantity that will be discharged in cubic feet per second.

The area of the opening $= 3 \times 2 = 6$ ft.; and $\frac{2}{3}$ of $\sqrt{2 \times 5.1 \times 6}$ $= 28.85$ cubic feet.

The same co-efficient is applicable to the finding of the dimensions of a weir in the side of a lake or in the side of a still river.

For example:

In the side of a lake is a weir of 3 feet in breadth, and the surface of the water stands 5 feet above it. How much must the weir be widened in order that the water may be a foot lower, and an equal quantity discharged?

Here, the velocity is $\frac{2}{3}$ the $\sqrt{5 \times 5.1}$, and the quantity of water $\frac{2}{3}\sqrt{5 \times 5.1} \times 3 \times 5$;

but the velocity must be reduced to $\frac{2}{3}$ of $\sqrt{4 \times 5.1}$,

then the section will be $\dfrac{\frac{2}{3}\sqrt{5 \times 5.1} \times 3 \times 5}{\frac{2}{3}\sqrt{4 \times 5.1}} = \dfrac{\sqrt{5} \times 3 \times 5}{\sqrt{4}} = 7.5$;

and $\dfrac{7.5}{4} \times \sqrt{5} = 4.19$ feet in breadth.

Of the Motion of Water in Rivers.

The velocity of the water in a river decreases from or near the surface downward; so that the mean velocity under any point of the surface will, on this account, be less than that obtained by a float or light body swimming on the surface of the fluid. But after having, by means of a float, determined the velocity at the surface, at any particular point of the width of the stream, the mean velocity of the water, passing under that point, and also the velocity at the bottom, will be obtained by the following rules:

1. Take 1.03 from the square root of the velocity at the surface, and the square of the remainder will be the velocity at the bottom.

2. Add the surface and bottom velocities together, and half the sum is the mean velocity.

Table,

CONTAINING THE QUANTITIES OF WATER, IN CUBIC FEET, THAT WILL BE DISCHARGED OVER A WEIR PER MINUTE, FOR EVERY INCH IN ITS BREADTH, WHEN THE DEPTH OF THE WATER FROM THE SURFACE TO THE TOP EDGE OF THE WASTEBOARD DOES NOT EXCEED 18 INCHES.

Depth of the Water, in Inches.	Cubic Feet per Minute, according to Du Buat's Formula.	Cubic Feet per Minute, according to Experiments made in Scotland.	Depth of the Water in Inches.	Cubic Feet per Minute, according to Du Buat's Formula.	Cubic Feet per Minute, according to Experiments made in Scotland.
1	0.403	0.428	10	12.748	13.535
2	1.140	1.211	11	14.707	15.632
3	2.095	2.226	12	16.758	17.805
4	3.225	3.427	13	18.895	20.076
5	4.507	4.789	14	21.117	22.437
6	5.925	6.295	15	23.419	24.883
7	7.466	7.933	16	25.800	27.413
8	9.122	9 692	17	28.258	30.024
9	10.884	11.564	18	30.786	33 710

To find the Velocity of Water issuing through a Circular Orifice at any given Depth from the Surface.

RULE.—Multiply the square root of the height or depth to the centre of the orifice by 8.1, and the product is the velocity of the issuing fluid in feet per second.

EXAMPLE.—Required the velocity of water issuing through an orifice under a head of 11 feet from the surface.

$\sqrt{11} = 3.3166 \times 8.1 = 26.864$ feet velocity per second.

In the discharge of water by a rectangular aperture in the side of a reservoir, and extending to the surface, the velocity varies nearly as the square root of the height, and the quantity discharged per second equal 2-3 of the velocity due to the mean height, allowing for the contraction of the fluid according to the form of the opening, which renders the co-efficient in this case equal to 5.1; whence the following general rules:

1. *When the Aperture extends to the Surface of the Fluid.*—Multiply the area of the opening in feet by the square root of its depth also in feet, and that product by 5.1; then 2-3 of the last product equal the quantity discharged in cubic feet per second.

2. *When the Aperture is under a Given Head.*—Multiply the area of the aperture in feet by the square root of the depth also in feet, and by 5.1; the product is the quantity discharged in cubic feet per second.

EXAMPLE 1.—Required the quantity of water in cubic feet per second discharged through an opening in the side of a dam or weir, the width or length of the opening being $6\frac{1}{2}$ feet, and the depth 9 inches, or .75 of a foot.

Square root of $.75 = .866$.

$$\text{Then } \frac{6.5 \times .75 \times .866 \times 5.1 \times 2}{3} = 14.3839 \text{ cubic feet.}$$

EXAMPLE 2.—What would be the quantity discharged through the above opening if under a head of water 4 feet in height?

Square root of $4 = 2$; and

$2 \times 5.1 = 10.2$ feet, velocity of the water per second; and

$6.5 \times .75 \times 2 \times 5.1 = 49.725$ cu. ft. discharged in the same time.

THE CENTRE OF GYRATION.

The centre of gyration is that point in any revolving body, or system of bodies, that if the whole quantity of matter were collected in it, the angular velocity would be the same; *i. e.*, the momentum of the body, or system of bodies, is centred at this point.

To Find the Centre of Gyration.

RULE 1.—Multiply the weight of the several particles by the squares of their distances in feet from the centre of motion, and divide the sum of the products by the weight of the whole mass; the square root of the quotient will be the distance of the centre of gyration from the centre of motion

EXAMPLE.—Suppose 3 weights of 3 lbs., 4 lbs., and 5 lbs. respectively, be fixed on a lever, which is assumed to be without weight, at the respective distances of 1, 2, and 3 feet: required the distance of the centre of gyration from the centre of motion.

3 lbs. $\times 1^2 = 3$; 4 lbs. $\times 2^2 = 16$; and 5 lbs. $\times 3^2 = 45$.

Hence, $\frac{3 + 16 + 45}{3 + 4 + 5} = 5.33$; and $\sqrt{5.33} = 2.3$ feet distance from the centre of motion.

Therefore, a single weight of 12 lbs., placed at 2.3 feet from the centre of motion, and revolving in the same time, would have the same impetus as the 3 weights in their respective places.

RULE 2.—Multiply the distance of the centre of oscillation from the centre of the system, or point of suspension, by the distance of the centre of gravity from the same point; the square root of the product will be the centre of gyration.

EXAMPLE.—The centre of gravity being 4 feet from the point of suspension, and that of oscillation 9 feet: required at what distance the centre of gyration is from the point of suspension.

$4 \times 9 = 36$; and $\sqrt{36} = 6$ feet. Ans.

Mr. Farey has given the following as the distances of the centres of gyration from the centre of motion, in different revolving bodies.

In a straight uniform rod, revolving about 1 end, the length of the rod × by .5773.

In a circular plate, revolving on its centre, the radius of the circle × 7071.

In a circular plate, revolving about 1 of its diameters as an axis, the radius × .5.

In a thin circular ring, revolving about 1 of its diameters as an axis, the radius × .7071.

In a solid sphere, revolving about 1 of its diameters as an axis, the radius × .6325.

In a thin hollow sphere, revolving about 1 of its diameters as an axis, the radius × .8164

In a cone, revolving about its axis, the radius of the circular base × .5477.

In a right-angled cone, revolving about its vertex, the height of the cone × .866.

In a paraboloid, revolving about its axis, the radius of the circular base × .5773.

Note.—The weight of the revolving body, multiplied into the height due to the velocity with which the centre of gyration moves in its circle, is the energy of the body, or the mechanical power which must be communicated to it to give it that motion.

CENTRIFUGAL FORCE.

All bodies moving round a central point, have a tendency to fly off in a straight line: this tendency is called the centrifugal force: it is opposed to the centripetal force, or that power which maintains the body in its curvilinear path.

The centrifugal force of a body, moving with different velocities, in the same circle, is proportional to the square of the velocity, or to the square of the number of revolutions performed in a given time. Thus, the centrifugal force of a body making 40 revolutions per minute, is 4 times as great as the centrifugal force of the same body when making 20 revolutions per minute.

To find the Centrifugal Force of any Body.

Rules.—1. Divide the velocity in feet, per second, by 4.01, and the square of the quotient by the diameter of the circle; the quotient is the centrifugal force when the weight of the body is 1. Hence, the quotient multiplied by the weight of the body, is the centrifugal force.

Example. Required the centrifugal force of the rim of a fly-wheel, 20 feet in diameter, moving with the velocity 32 1-6 feet in a second.

$$32\ 1\text{-}6 \div 4.01 = 8.02;$$

$$8.02^2 \div 20 = 3.216 \text{ times the weight of the rim.}$$

2 Multiply the square of the number of revolutions in a minute by the diameter of the circle in feet, and divide the

product by the constant number 5870; the quotient is the centrifugal force when the weight of the body is 1. Hence, as in the 1st rule, the quotient multiplied by the weight of the body, is the centrifugal force.

Example.—Required the centrifugal force of a stone, weighing 2 lbs., revolving in a circle 4 feet in diameter, at the rate of 120 revolutions in a minute.

$$120^2 \times 4 = 57600 : \text{ and } \frac{57600}{5870} = 9.81.$$

Hence, $9.81 \times 2 = 19.62$ centrifugal force.

Dr. Brewster has summed up the whole doctrine of centrifugal forces in the following propositions:

1. The centrifugal forces of two unequal bodies, moving with the same velocity, and at the same distance from the central body, are to one another as the respective quantities of matter in the two bodies.
2. The centrifugal forces of two equal bodies, which perform their revolutions round the central body in the same time, but at different distances from it, are to one another as their respective distances from the central body.
3. The centrifugal forces of two bodies which perform their revolutions in the same time, and whose quantities of matter are inversely as their distances from the centre, are equal to one another.
4. The centrifugal forces of two equal bodies, moving at equal distances from the central body, but with different velocities, are to one another as the squares of their velocities.
5. The centrifugal forces of two unequal bodies, moving at equal distances from the centre, with different velocities, are to one another in the compound ratio of their quantities of matter, and the squares of their velocities.
6. The centrifugal forces of two equal bodies, moving with equal velocities at different distances from the centre, are inversely as their distances from the centre.
7. The centrifugal forces of two unequal bodies, moving with equal velocities at different distances from the centre, are to one another as their quantities of matter multiplied by their respective distances from the centre.
8. The centrifugal forces of two unequal bodies, moving with unequal velocities at different distances from the central body, are in the compound ratio of their quantities of matter, the squares of their velocities, and their distances from the centre.

THE FLY-WHEEL.

It is an object of great importance in machines to have means of accumulating power when the moving force is in excess, and of expending it when the moving force operates more feebly or the resistance increases. This equalization of motion is obtained by what is called the fly-wheel, which is generally made in the form of a heavy wheel. The fly-wheel being made to revolve about its axis, keeps up its force by its own inertia, and distributes it in all parts of its revolution. Fly-wheels are capable of accumulating power to a great extent, and, when thus accumulated, they assist in bringing the crank past its centres, but much of their efficacy depends on the position assigned them in the machinery. If the fly is used as a regulator of force, it should be placed near the prime mover; but if, on the other hand, it be used as a magazine of power, it should be near the working point. No general rules can be given for its exact position.

To find the Weight of the Rim or Ring of a Fly-Wheel proper for a Steam-Engine.

RULE.—Multiply the constant number 1368 by the number of horse-power that the engine is equal to; divide the product by the diameter of the wheel in feet, multiplied by the number of revolutions per minute, and the quotient is the weight of the ring in 100 pounds nearly.

EXAMPLE.—Required the weight of the rim of a fly-wheel proper for an engine of 30 horse-power, the wheel to be 14 feet in diameter, and making 40 revolutions per minute.

$$\frac{1368 \times 30}{14 \times 40} = \frac{41040}{560} = 64.1 \text{ cwt.}$$

NOTE.—The fly-wheel of an engine for a flour-mill ought to be of such a diameter that the velocity of the periphery of the wheel may exceed the velocity of the periphery of the stones, to prevent, as much as possible, any tendency to back lash, as it is termed.

The necessary weight and diameter of the wheel being found, suppose a breadth of a rim. Then,

To find the Thickness necessary to make the Weight in Cast Iron.

RULE.—Divide the required weight in pounds by the area of the ring in inches multiplied by .261, and the quotient is the thickness of the ring in inches.

EXAMPLE.—What thickness must a ring of a fly-wheel be to equal 64.1 cwt., when the outer diameter is 14 feet and the inner diameter 12 feet?

64.1 cwt. = 6410 lbs.

Diam. 14 feet = 168 in. and 12 ft = 144 in., and the area of the ring = 5881 sq. in.

$$\text{Then, } \frac{6410}{5881 \times .261} = \frac{6410}{153.50} = 4.17 \text{ in., nearly.}$$

NOTE.—If the ring is to be of a cylindrical form, its diameter may be easily found by the following approximate

RULE.—Multiply the required weight in pounds by 1.62; divide the product by the diameter of the wheel in inches and the square root of the quotient will be the diameter of the cross-section of the ring in inches, nearly.

$$\text{Thus, } \sqrt{\frac{6410 \times 162}{14 + 12}} = 7.7 \text{ inches.}$$

NOTE.—The centre of percussion in a fly-wheel, or wheels in general, is $\frac{3}{4}$ distant from the centre of suspension, nearly.

The centrifugal force is that power or tendency which all revolving bodies have to burst or fly asunder in a direct line.

And the centre of percussion in a revolving body is that point where the whole force or motion is collected, or that point which would strike any obstacle with the greatest effect.

MELTING POINT OF SOLIDS.

	DEGREES.		DEGREES.
Cast Iron melts	3,477	Platinum melts	3,077
Wr't " "	3,981	Lead "	600
Gold "	2,587	Zinc "	741
Silver "	1,250	Cadmium "	602
Steel "	2,501	Saltpetre "	600
Brass "	1,897	Tin "	420
Copper "	2,550	Sulphur "	225
Glass "	2,377	Potassium "	135

Table of Hollow Cylindrical Columns, for Large Mills, with Cores.

Diameter of Column at small end.	Diameter of a Cross-Section in the mid'le	Diameter of the Core at small end.	Diameter of the Core at the middle.	Length of the Column in Feet.	No. of Cubic Inches in the Column.	Total Weight of Column in Pounds.
Inches.	Inches.	Inches.	Inches.			
7	11	2	$3\frac{3}{4}$	12	8,944	2,236
8	12	2	4	12	10,400	2,600
9	14	3	$7\frac{1}{2}$	14	13,849	3,462
10	16	4	10	16	33,744	8,438

It has been fully tested that cast iron columns of a large dimension with a core are much stronger than without it. This, no doubt, arises from the fact that the case affords a sensible spring in case of a sudden strain, and therefore less liable to fracture.

STEAM AND THE STEAM-ENGINE.

Nominal Power of Steam-Engines.

The usual estimate of the dynamical effect per minute of a horse, called by engineers a horse-power, is 33,000 lbs. at a velocity of 1 foot per minute; or the effect of a load of 200 lbs. raised by a horse for 8 hours a day at the rate of 2½ miles per hour; or 150 lbs. at the rate of 220 feet per minute.

To determine the Diameter of a Cylinder for an Engine of a required Nominal Power.

Divide 5,500 by the velocity of the piston in feet per minute, and the quotient equals the number of square inches to a horse-power, which multiply by the required number of horse-power, and the product is the cylinder's area, against which, in the Table of Areas, is the diameter required.

EXAMPLE.—Required the diameter of the cylinder for a 25-horse engine, with a velocity of 230 feet per minute.

$\frac{5500}{230} = 23.913 \times 25 = 597.825$ inches area; or $27\frac{5}{8}$ inches diameter, nearly.

Proportionate Velocities for the Pistons of Stationary Condensing Engines.

Length of Stroke, in feet.	Velocity in Feet per Minute.	Number of Revolutions per Minute.
8	256	16
7	245	17½
6	240	20
5½	236½	21½
5	230	23
4½	220½	24½
4	214	26¾
3½	203	29
3	192	32
2½	177½	35½
2	160	40

To estimate the Amount of Effective Power of an Engine by an Indicator.

Multiply the area of the piston in square inches by the average force of the steam in lbs., and by the velocity of the piston in feet per minute; divide the product by 33,000, and 7-10 of the quotient equal the effective power.

EXAMPLE.—Suppose an engine, with a cylinder of $37\frac{1}{2}$ inches diameter, a stroke of 7 feet, and making 17 revolutions per minute, or 238 velocity, and the average indicated pressure of the steam 16.73 lbs. per square inch: required the effective power.

$$\text{Area} = \frac{1104.4687 \text{ inches} \times 16.73 \text{ lbs.} \times 238 \text{ feet}}{33000} = \frac{133.26 \times 7}{10}$$
$$= 93.282 \text{ horse-power.}$$

To find the Greatest Quantity of Water required for Steam.

Multiply the area of the cylinder in feet by the piston's velocity in feet per minute, add 1-10 for cooling and waste, divide the sum by the volume of steam compared to the volume of water (as per Table of Pressures), and the quotient equals the quantity in cubic feet per minute.

NOTE.—For single-acting engines only about half the quantity is required.

EXAMPLE —Required the quantity of water for steam to supply an engine, whose cylinder is 2 feet diameter, the piston's velocity 214 feet per minute, and the pressure of steam 18 lbs. per square inch, including the pressure of the atmosphere.

Area $= 3.1416 \times 214 = 672.3 + 67.23 = 739.53 \div 1411 = .523$ cubic feet per minute.

To find the Quantity of Water required for Injection.

From 1212 subtract the temperature of the condensed water; divide the result by the temperature of the condensed water minus the temperature of the cold water; multiply the quotient by the quantity of steam in cubic feet in a given time, and the product equals the quantity of water in cubic inches.

EXAMPLE.—Required the quantity of water at 60°, to condense 500 cubic feet of steam to water at 95° Fahrenheit.

$$\frac{1212 - 95}{95 - 60} = 31.9 \times 500 = 15950 \text{ cubic inches.}$$
$$\text{or, } 15950 \times .00058 = 9.251 \text{ cubic feet.}$$

Proportions of Cylinder, Condenser, and Air-Pump.

The length of the cylinder, and consequently the stroke of the piston, ought not to be less than twice the cylinder's diameter; as then the least surface is exposed in proportion to the capacity; and the longer the stroke, the greater the effect, from the principle of expansive force.

The capacities of the condenser and air-pump are each $\frac{1}{8}$ the capacity of the cylinder.

Advantages derived from the Expansive Properties of Steam.

If steam of a uniform elastic force be employed throughout the whole ascent or descent of the piston of a steam-engine, the amount of effect is as the quantity expended. But suppose the steam to be shut off at any portion of the stroke, say, for instance, at one-half, it expands by degrees until the termination of the stroke, and then exerts half its original force; hence an accumulation of effect in proportion to the quantity of steam.

To obtain or calculate the Amount of Effect.

Divide the length of the stroke by the length of the space into which the dense steam is admitted, and find the hyperbolic logarithm of the quotient, to which add 1, and the sum is the ratio of the gain.

EXAMPLE.—Suppose an engine with a stroke of 6 feet, and the steam cut off when the piston has moved through 2: required the ratio of uniform elastic force.

$6 \div 2 = 3$; hyperbolic logarithm of $3 = 1.0986 + 1 = 2.0986$, ratio of effect; that is, supposing the whole effect of the steam to be 3, the effect by the steam being cut off at $\frac{1}{3} = 2.0986$.

Table of Hyperbolic Logarithms.

No.	Logarithm.	No.	Logarithm.	No.	Logarithm.	No.	Logar'm.
1¼	.22314	3½	1.25276	5¾	1.74919	8	2.07944
1½	.40546	3¾	1.32175	6	1.79175	8½	2.14006
1¾	.55961	4	1.38629	6¼	1.83258	9	2.19722
2	.69314	4¼	1.44691	6½	1.87180	9½	2.25129
2¼	.81093	4½	1.50507	6¾	1.90954	10	2.30258
2½	.91629	4¾	1.55814	7	1.94591	12	2.48490
2¾	1.01160	5	1.60943	7¼	1.98100	14	2.63905
3	1.09861	5¼	1.65822	7½	2.01490	16	2.77258
3¼	1.17865	5½	1.70474	7¾	2.04769	18	2.89037

LOCOMOTIVE ENGINES.

Table showing the Circumferences of different Driving Wheels.

Diam. of Wheel. ft.	in.	Length of Circum. feet.	Diam. of Wheel. ft.	in.	Length of Circum. feet.
4	0	12.566	6	6	20.419
4	6	13.927	7	0	21.990
5	0	15.707	7	6	23.561
5	6	17.278	8	0	25.132
6	0	18.849			

Table containing the Velocity of the Pistons, that of the Circumference of the Driving Wheels being taken as 1.

Stroke of the Pistons.	Diameters of Driving Wheels.								
in.	4ft. 0in.	4ft. 6in.	5ft. 0in.	5ft. 6 in.	6ft. 0in.	6ft. 6in.	7ft. 0in	7ft. 6in.	8ft. 0in.
20	0.2652	0.2393	0.2122	0.1929	0.1768	0.1632	0.1516	0.1414	0.1326
19	0.2519	0.2273	0.2016	0.1832	0.1679	0.1550	0.1440	0.1343	0.1259
18	0.2386	0.2153	0.1910	0.1736	0.1591	0.1468	0.1364	0.1272	0.1194
17	0.2254	0.2034	0.1803	0.1640	0.1503	0.1387	0.1288	0.1202	0.1127
16	0.2121	0.1914	0.1697	0.1543	0.1415	0.1305	0.1213	0.1131	0.1061
15	0.1989	0.1795	0.1591	0.1447	0.1326	0·1224	0.1137	0.1060	0.0994
14	0.1856	0.1675	0.1485	0.1350	0.1237	0.1141	0.1061	0.0990	0.0928
13	0.1724	0.1555	0.1379	0.1254	0.1149	0.1061	0.0985	0.0919	0.0862
12	0.1591	0.1436	0.1273	0.1157	0.1061	0.0979	0.0909	0.0848	0.0796

Application of this Table for finding the Tractive Power of Locomotive Engines.

Multiply the sum of the areas of the two pistons by the *effective pressure* of the steam in pounds, and further, that product by the co-efficient in the table (belonging to its driving wheels and stroke of the pistons), and this new product will be the traction of the engine in pounds.

Example.—A locomotive engine to have 5 feet 6 inch driving wheels, cylinders of 13 inches diameter by 18 inches stroke, and the effective pressure of the steam to be 40 lbs. on the square inch: what is its traction?

$$\frac{(2 \times 132.66)40 \times 0.1736}{1842.39 \text{ lbs. of traction.}}$$

If it be required to know the number of tons the engine is able to draw on a level, divide its traction by the friction in pounds.

If the engine is to go up inclines, then add to that friction the gravity in pounds due to a ton on that incline, and use this sum as a divisor for the traction, the quotient will be the number of tons the engine is capable to rise up that incline with. In both cases is the weight of the engine and its tender in the quotient included.

Explanations.—By effective pressure is understood the pressure of the steam above the pressure of the atmosphere, less the number of pounds necessary to keep the engine by itself just in motion.

Friction, the power necessary to move a mass along, which is generally taken to be on railroads equal to 10 lbs. for every ton.

Gravity, the power to overcome the tendency of a mass or load to descend an incline, being always equal to the quotient of the product of the load and height of the incline, divided by the length of the incline.

Therefore the above engine would draw

$$\frac{1842.39}{10} = 184 \text{ tons on a level;}$$

and on an inclined plane, say as 1 in 300.

$$\text{Friction} = 10 \text{ lbs.}$$

$$\text{Gravity} = \frac{1 \times 2240}{300} = 7.466 \text{ lbs.}$$

$$17.466 \text{ lbs.}$$

$$\text{Consequently } \frac{1842.39}{17.466} = 105.5 \text{ tons up an incline of 1 in 300.}$$

If the weight of the engine with its tender be taken at 18 tons it will draw a net gross load of

166 tons on a level, and
87.5 tons up an incline of 1 in 300.

To calculate for the Travel of the Valves, Throw of Eccentrics, &c.

Example.—Suppose, in a locomotive engine, the valves require a travel of $3\frac{3}{4}$ inches; the top lever, or lever immediately connected with the valve spindle, being $9\frac{1}{4}$ inches, and the bottom lever 8 inches: what must be the throw of eccentrics?

$$\frac{3.75 \times 8}{9.25} = 3.243 \text{ inches, or } 3\tfrac{1}{4}, \text{ nearly.}$$

Note.—The travel of a valve equals the width of the two steam openings, plus the lap of the valve over each opening; and the whole length of its movement or face upon the cylinder equals twice the travel of the valve, plus the distance between the two steam openings.

To ascertain the Amount of Weight or Pressure on the Safety-Valve of a Locomotive Engine.

Divide the length of the lever by the distance from its centre of motion to centre of valve, and multiply the indicated pressure on the spring balance by the quotient, to which add the action or pressure of the lever and spring balance; divide the sum by the area of the valve, and the quotient equals the pressure on each inch of the boiler.

Example.—Suppose an engine with valve levers of $22\frac{1}{2}$ inches in length, and the distance from the pin to centre of valve $2\frac{1}{2}$ inches; the action of the lever and spring balance 5 lbs.; the indicated pressure 50 lbs., and the area of the valve 7 inches: required the pressure on each square inch.

$$22.5 \div 2.5 = 9\text{ ; and } \frac{9 \times 50 + 5}{7} = 65 \text{ lbs. per square inch.}$$

To determine the Pressure of Steam equal to the resistance of a given load by a Locomotive Engine.

It is ascertained, by experiment, that 6 lbs. per ton of the engine's weight is expended in overcoming the friction of its parts when unloaded; 9 lbs. per ton of gross load for horizontal traction and additional friction caused by the load; and 14.7 lbs. per square inch, the pressure of the atmosphere. Hence, to 9 times the gross load of the train in tons, add the friction of the engine; multiply the sum by the diameter of the driving wheels in inches; divide the product by the cylinder's capacity in inches, and the quotient, plus 14.7, equals the pressure of the steam in lbs. per square inch on the piston.

Example.—Required the pressure per square inch on the piston's area, to overcome a load of 120 tons gross on a level line, the engine being 13 tons, driving wheels $5\frac{1}{2}$ feet, cylinders 13 inches diameter, and length 18.

$120 - 13 = 107 \times 9 = 1080$; and $13 \times 6 = 78$, the force of traction;

$$13^2 \times 18 = 3042.$$

$$\text{Then } \frac{1080 + 78 \times 66}{3042} = 25.12 + 14.7 = 39.82 \text{ lbs. per sq. inch.}$$

Table of the Areas of Cylinders from 9 to 15 Inches Diameter.

Diam. of Cylinder.	Area of Cylinder.	Diam. of Cylinder.	Area of Cylinder.
Inches.	Square Inches.	Inches.	Square Inches.
9	63.58	$12\frac{1}{2}$	122.65
10	78.5	13	132.66
$10\frac{1}{2}$	86.56	$13\frac{1}{2}$	143.02
11	95.01	14	153.96
$11\frac{1}{2}$	103.84	$14\frac{1}{2}$	165.04
12	113.07	15	176.62

Note.—The areas of cylinders are as the squares of their diameters.

Various modifications have lately been added to the list of improvements in locomotive engines, and among the most efficient is that of using steam more or less expansively, as required. The arrangement is such, that the quantity of steam, of uniform density, is immediately changed to suit either the load or inclinations of the line.

Another essential improvement is that of insuring a uniform equilibrium of the engine, in case of fracture in the front axle; such an occurrence being the only real cause of fear in running a six-wheeled engine.

Table of Dimensions of the Principal Parts of Locomotive Engines.

PORTIONS OF THE ENGINES.	GAUGE OF RAILWAY.					
	4 Ft. 8½ In.		5 Feet.		7 Feet.	
	ft.	ins.	ft.	ins.	ft.	ins.
Cylinders and steam passages.						
Diameters of cylinders...... ...	1	1	1	2	1	3
Distance from cen. to cen. of do.	2	5	2	5	3	0
Length of stroke	1	6	1	6	1	8
" steam and eduction ports	0	11	0	11	0	11½
Width of steam ports..........	0	1¼	0	1¼	0	1¼
" eduction ports.......	0	2½	0	2½	0	2⅝
Breadth of bridges betw. ports	0	0⅝	0	0⅝	0	0⅜
Cylindrical part of the boiler and tubes.						
Diameter of the boiler.........	3	4	3	7	4	0
Length " "	8	0	8	6	8	6
" " tubes.	8	5	8	11	9	0
Diameter " "	0	2	0	2	0	2
Thickness of tubes by wire gauge	No. 14		No. 14		No. 14	
Number of the tubes	121		131		137	
Inside and outside fire boxes.						
Length of inside fire box	3	0	3	4	3	8½
Breadth " "	3	7	3	5	3	11
Height above the fire bars......	3	10	3	10	3	11
Area of fire grate.............	10	9	11	4	14	8
Length of outside fire box......	3	6	3	10	4	3
Breadth " "	4	1	4	0	4	6
Thickness of plates.....	0	0⅜	0	0⅜	0	0⅜
Ex. thick. where tubes inserted.	0	0⅜	0	0⅜	0	0⅜
Smoke box, chimney, and blast pipe.						
Length of smoke box, inside. ..	2	1	2	1	2	2½
Breadth " " ...	4	2	4	2¾	5	2½
Thickness of plates.	0	0¼	0	0¼	0	0¼
Diameter of chimney..........	1	1½	1	2¼	1	4
Height to top of do. from rails.	13	4	13	6	14	10
Diameter of blast pipe.........	0	3¼	0	3¼	0	3⅝
Wheels, springs, &c.						
Diameter of driving wheels	5	6	6	0	7	0
" leading " ...	4	0	4	0	4	0
" trailing "	3	6	4	0	4	0
Breadth of tires..............	0	5½	0	5½	0	5½
Thickness, average............	0	1¾	0	1¾	0	1¾
Diameter of axle bearings......	0	3½	0	3¾	0	4
Length " " ...	0	6¾	0	6¾	0	7
" driving-wheel springs.	2	9	2	9	2	6
Breadth of " " .	0	3½	0	3½	0	3½

PORTIONS OF THE ENGINES.	GAUGE OF RAILWAY.					
	4 Ft. 8½ In.		5 Feet.		7 Feet.	
	ft.	ins.	ft.	ins.	ft.	ins.
Wheels, springs, &c.						
Number of plates	1 at $\frac{3}{8}$ and 12 at 5-16		1 at $\frac{3}{8}$ and 14 at 5-16		2 at $\frac{3}{8}$ and 10 at 5-16	
Length of leading wheel-springs	2	5	2	5	2	3
Breadth of " "	0	3½	0	3½	0	3½
Number of plates	1 at $\frac{3}{8}$ and 14 at 5-16		1 at $\frac{3}{8}$ and 14 at 5-16		2 at $\frac{3}{8}$ and 10 at 5-16	
Trailing-wheel springs	2	2	2	2	2	3
Breadth of do.	0	3¼	0	3¼	0	3¼
Number of plates	1 at $\frac{3}{8}$ and 6 at 5-16		1 at $\frac{3}{8}$ and 6 at 5-16		2 at $\frac{3}{8}$ and 8 at 5-16	
Diameter of safety valves	0	3½	0	3½	0	4
" piston rods	0	2	0	2 1-16	0	2¼
" valve spindles	0	1⅛	0	1⅛	0	1¼
" crank pins	0	5½	0	5¾	0	6½
" pump rams	0	2	0	2	0	2¼
Extreme breadth of outside frame	6	5	6	8½	8	9¼
" length " "	18	2½	18	2½	20	4

Table showing the Approximate of Useful Effect of an Ordinary Locomotive Engine at different Velocities.

Load in Tons.	Miles per hour.	Miles per hour.	Load in Tons.
25	30.90	10	250
50	25.15	12½	184
75	22.54	15	138
100	18.18	17½	106
125	15.98	20	83
150	14.29	22½	65
175	13.28	25	50
200	11.20	27½	38
225	10.77	30	28

The increased resistance to traction on ascending inclined planes is as the increased gravity of the load, caused by the inclination of the plane; or as the length of the plane to the perpendicular height. Hence, divide 2,240 (or the number of lbs. in a ton) by the inclination of the plane to 1 or unity, to the quotient of which add 9, and the sum equals the total resistance, in lbs., per ton upon the plane.

EXAMPLE.—Required the resistance to traction, per ton, on an inclined railway rising 1 in 300.

$$\frac{2240}{300} = 7.47 + 9 = 16.47 \text{ lbs. per ton.}$$

Useful effect of a single-acting pumping engine, with a consumption of 1 bushel of coals:

Diameter of cylinder, 5 feet, 3 inches.
Length of stroke, 7 " 9 "
Stroke of pump, 6 " 9 "
Number of strokes per minute, 6.1.
Effective pressure, per square inch, of piston, 13.4 lbs.
Water lifted 1 foot high, per minute, 38,063,288 lbs.

Table

SHOWING THE NUMBER OF REVOLUTIONS OF THE DRIVING WHEELS, OR STROKES OF THE PISTON, PER MINUTE, WHILE THE ENGINE IS PERFORMING A KNOWN NUMBER OF MILES PER HOUR.

Diam. of Wheel 4 ft.	Diam of Wheel 4 ft. 6 in.	Diam. of Wheel 5 ft.	Diam. of Wheel 5 ft. 6 in.	Diam. of Wheel 6 ft.	Diam. of Wheel 6 ft. 6 in.	Diam. of Wheel 7 ft.	Diam. of Wheel 7 ft. 6 in.	Diam. of Wheel 8 ft.	Number of Miles performed per Hour.
No. of revol. or strokes per min.	No. of revol. or strokes per min.	No. of revol. or strokes per min.	No. of revol. or strokes per min.	No. of revol. or strokes per min.	No. of revol. or strokes per min.	No. of revol. or strokes per min.	No. of revol. or strokes per min.	No. of revol. or strokes per min.	
35.03	31.59	28.03	25.47	23.34	21.55	20	18.67	17.5	5
70.06	63.17	56.06	50.95	46.68	43.10	40	37.34	35.0	10
105.09	94.76	84 09	76.42	70 02	64.65	60	56.01	52.5	15
140.12	126.36	112.12	101.70	93.36	86.20	80	74.68	75.0	20
175.15	157.95	140.20	127.37	116 70	107.75	100	93 35	87.5	25
210.18	189.54	168.18	152.85	140.04	129.30	120	112.02	105.0	30
245.21	221.13	196.21	177.29	163.38	150.85	140	130.69	122.5	35
280.24	252.72	224.24	203.76	186.72	172.40	160	149.36	140.0	40
315.27	284.30	252.27	229.23	210 06	193.95	180	168.03	157.5	45
350.30	315.90	280 30	254.75	233.40	215.50	200	186.70	175.0	50
385.33	347.49	308.33	280.17	256.74	237.05	220	205.37	192.5	55
420.36	379.08	336.36	305.61	280.08	258.60	210	224.04	210.0	60
455.39	416.67	364 39	331.11	303.42	280 15	260	242.71	227.5	65
490.42	412.19	392.42	356.58	326.76	301.70	280	261.38	245.0	70
525.45	473.85	420.50	372 05	350.10	323.25	300	280.05	262 5	75
560.48	505.50	448.48	407.60	373.44	344 80	320	298.72	280.0	80
595.51	536.89	477.01	432.99	396.78	366.35	340	317.39	297.5	85
630.54	568.60	504.51	458.55	420.12	387.90	360	336.06	315.0	90
665 57	600.19	532.57	483.93	443.46	409.45	380	354.73	332.5	95
700.60	631.78	560.63	509.50	466.80	431.00	400	373 40	350.0	100

NOTE.—To find the velocity the piston is travelling at in feet per minute, multiply the number of revolutions of its driving wheels, in the table, by twice the length of its stroke in feet.

EXAMPLE.—What is the speed of the piston of an engine with 6 feet driving wheels and 15-inch stroke, when going at the rate of 50 miles an hour?

By means of the table:

$$233.4 \text{ revolutions} \times \left(\frac{2 \times 5}{4}\right) = 583.5 \text{ feet per minute.}$$

The number of revolutions of driving wheels are inversely as their diameters, and in direct proportion to the number of miles performed.

EXAMPLE.—How many revolutions have the driving wheels of an engine to make when it is going at 95 miles an hour, their diameter being 9 feet 6 inches?

According to the table, a 4-foot wheel would have to make 665.57 revolutions, therefore

$$9.5 : 4 :: 665.57 : \frac{4 \times 665.57}{9.5} = 280 \text{ revolutions.}$$

The driving wheels of an engine make 35.03 revolutions when going at the rate of 5 miles an hour, how many will they make when going at 9 miles?

$$5 : 9 :: 35.03 : \frac{9 \times 35.03}{5} = 63.05 \text{ revolutions.}$$

To compute the Pressure of Steam.

When the Height of the Column of Mercury it will Support is given.

RULE.—Divide the height of the column of mercury in inches by 2.0376, and the quotient will give the pressure per square inch in pounds.

EXAMPLE.—The height of a column of mercury is 203.76 inches; what pressure per square inch will it contain?

$$203.76 \div 2.0376 = 100 \text{ lbs.}$$

To compute the Temperature of Steam.

RULE.—Multiply the 6th root of its force in inches of mercury by 177, and subtract 100 from the product, the remainder will give the temperature in degrees.

EXAMPLE.—When the elastic force of steam is equal to a pressure of 49 inches of mercury, what is its temperature?

NOTE.—To extract the 6th root of a number, ascertain the cube root of its square root.

$$\sqrt{\ } \text{ of } 49 = 7, \text{ and } \sqrt[3]{\ } \text{ of } 7 = 1.9129.$$

$$\text{Hence } 1.9129 \times 177 - 100 = 238^\circ.58.$$

To compute the Pressure of Steam in Inches of Mercury.

When the Temperature is given.

RULE.—Add 100 to the temperature, divide the sum by 177, and the 6th power of the quotient will give the pressure in inches of mercury.

EXAMPLE.—The temperature of steam is 312°; what is its pressure?

$$\frac{100+312}{177}=2.3277, \text{ and } 2.3277^6=159 \text{ ins.}$$

NOTE.—To involve the 6th power of a number, square its cube.

To compute the Specific Gravity of Steam compared with Air.

RULE.—Divide the constant number 830.11 (1700 × .4883) by the volume of the steam at the temperature of pressure at which the gravity is required.

EXAMPLE.—The pressure of steam is 60 lbs., and the volume of it is 470; what is its specific gravity?

$$830.11 \div 470 = 1.766.$$

NOTE.—The specific gravity of steam compared with water = .00058823.

SLIDE VALVES.

All Dimensions in Inches.

To compute how much Lap must be given on the Steam Side of a Slide Valve, to cut off the Steam at any given Part of the Stroke of the Piston.

RULE.—From the length of stroke of piston subtract the length of the stroke that is to be made before the steam is cut off; divide the remainder by the stroke of the piston, and extract the square root of the quotient. Multiply this root by half the throw of the valve, from the product subtract half the lead, and the remainder will give the lap required.

EXAMPLE.—Having stroke of piston 60 ins., stroke of valve 16 ins., lap upon exhaust side ½ in. = 1-32 of valve stroke, lap upon steam side 3¼ ins., lead 2 ins., steam to be cut off at 5-6 the stroke; what is the lap?

$$60 - \frac{5}{6} \text{ of } 60 = 10. \quad \frac{10}{60} = .166. \quad \sqrt{.166} = .408. \quad .408\times\frac{16}{2} = 3.264,$$

$$\text{and } 3.264 - \frac{2}{2} = 2.264 \text{ ins. or the lap} \quad \text{half the lead.}$$

To compute the Lap required on the Steam Side of a Valve, to cut the Steam off at various Portions of the Stroke of the Piston.

Value without Lead.

	Distance of the piston from the end of its stroke when the steam is cut off, in parts of the length of its stroke.									
	$\frac{1}{2}$	$\frac{5}{12}$	$\frac{1}{3}$	$\frac{7}{24}$	$\frac{1}{4}$	$\frac{5}{24}$	$\frac{1}{6}$	$\frac{1}{8}$	$\frac{1}{12}$	$\frac{1}{24}$
Lap in parts of the stroke	.354	.323	.286	.27	.25	.228	.204	.177	144	.102

Illustration.—Take the elements of the preceding case.

Under 1-6 is .204, and $.204 \times 16 = 3.264$ ins. lap.

When the Valve is to have Lead.—Subtract half the proposed lead from the lap ascertained by the table, and the remainder will be the proper lap to give to the valve.

If, therefore, as in the last case, the valve was to have 2 ins. lead, then $3.264 - 2 \div 2 = 2.264$ ins.

To compute at what Part of the Stroke of the Piston any given Lap on the Steam Side will cut off the Steam.

Rule.—To the lap on the steam side add the lead; divide the sum by half the length of throw of the valve. From a table of natural sines find the arc, the sine of which is equal to the quotient; to this arc add 90°, and from their sum subtract the arc, the cosine of which is equal to the lap on the steam side, divided by half the throw of the valve. Find the cosine of the remaining arc, add 1 to it, and multiply the sum by half the stroke of the piston, and the product will give the length of that part of the stroke that will be made by the piston before the steam is cut off.

Example.—Take the elements of the preceding case.

$$\frac{2.25 + 2}{16 \div 2} = .53125;\ \text{sin. } .53125 = 32^\circ\ 5';\ 32^\circ\ 5 + 90^\circ = 122^\circ\ 5';$$

$$2.25 \div 8 = .28125 = \text{cos. of } 73^\circ\ 40';\ \text{then } 122^\circ\ 5' - 73^\circ\ 40' = 48^\circ\ 25;$$

$$\text{cos.} + 1 = 1.66371,\ \text{which} \times \frac{60}{2} = 50 \text{ ins., or 5-6 stroke.}$$

To compute the Distance of a Piston from the End of its Stroke, when the Lead produces its Effect.

Rule.—Divide the lead by the width of the steam port, both in inches, and term the quotient sine; multiply its corresponding versed sine by half the stroke, and the product will give the distance of the piston from the end of its stroke, when steam is admitted for the return stroke and exhaustion ceases.

EXAMPLE. The stroke of a piston is 48 ins., width of port $2\frac{1}{2}$ ins., and the lead $\frac{1}{2}$ in.; what will be the distance of the piston from the end of its stroke when exhaustion commences?

$$.5 \div 2.5 = .2 = \text{sine, and versed sine of } .2 = .0202.$$

$$\text{Then } .0202 \times \frac{48}{2} = .4848 \text{ ins.}$$

To compute the Lead, when the Distance of a Piston from the End of its Stroke is given.

RULE.—Divide the distance in inches by half the stroke in inches, and term the quotient versed sine; multiply the corresponding sine by the width of the steam port, and the product will give the lead.

EXAMPLE.—Take the elements of the preceding case.

$$.4848 \div 24 = .0202 = \text{versed sine,}$$

and sine of versed sine $.0202 = .2$. Then $.2 \times 2.5 = .5$ inches.

To compute the Distance of a Piston from the End of its Stroke, when Steam is admitted for its return Stroke.

RULE.—Divide the width of the steam port, and also that width less the lead, by half the stroke of the slide, and term the quotient versed sines first and second. Ascertain their corresponding arcs, and multiply the versed sine of the difference between the first and second by half the stroke, and the product will give the distance required.

Portion of the Stroke of a Piston at which the Exhausting Port is closed and opened.

Lap on the Exhaust Side of the Valve in Parts of its Throw.

Lap.	Portion of Stroke at which the Steam is cut off.							
	$\frac{1}{3}$	$\frac{7}{24}$	$\frac{1}{4}$	$\frac{5}{24}$	$\frac{1}{6}$	$\frac{1}{8}$	$\frac{1}{12}$	$\frac{1}{24}$
A								
$\frac{1}{8}$	.178	.161	.143	.126	.109	.093	.074	.053
$\frac{1}{16}$	.13	.118	.1	.085	.071	.058	.043	.027
$\frac{1}{32}$	.113	.101	.085	.069	.053	.043	.033	.024
0	.092	.082	.067	.055	.041	.033	.022	.011
B								
$\frac{1}{8}$	.033	.026	.019	.012	.008	.004	.001	.001
$\frac{1}{16}$	.06	.052	.04	.03	.022	.015	.008	.002
$\frac{1}{32}$	.073	.066	.051	.042	.033	.023	.013	.004
0	.092	.082	.067	.055	.041	.033	.022	.011

The units in the columns of the table marked A express the distance of the piston, in parts of its stroke, from the end of the stroke when the exhaust port in advance of it is closed; and those in the columns of the table marked B express the distance of the piston, in parts of its stroke, from the end of its stroke when the exhaust port behind it is opened.

Illustration.—A slide valve is to cut off at 1-6 from the end of the stroke of the piston, the lap on the exhaust side is 1-32 of the stroke of the valve (16 ins.), and the stroke of the piston is 60 inches. At what point of the stroke of the piston will the exhaust port in advance of it be closed, and the one behind it opened?

Under 1-6 in table A, opposite to 1-32, is .053, which $\times$ 60, the length of the stroke, = 3.18 ins.; and under 1-6 in table B, opposite to 1-32, is .033, which $\times$ 60 = 1.98 inches.

If the lap on the exhaust side of this valve was increased, the effect would be to cause the port in advance of the valve to be closed sooner, and the port behind it opened later. And if the lap on the exhaust side was removed entirely, the port in advance of the piston would be shut and the one behind it open at the same time.

The lap on the steam side should always be greater than that on the exhaust side, and the difference greater the higher the velocity of the piston.

In fast-running engines, alike to locomotives, it is necessary to open the exhaust valve before the end of the stroke of the piston, in order to give more time for the escape of the steam.

To ascertain the Breadth of the Ports.

Half the throw of the valve should be at least equal to the lap on the steam side, added to the breadth of the port. If this breadth does not give the required area of port, the throw of the valve must be increased until the required area is attained.

To compute the Stroke of a Slide Valve.

Rule.—To twice the lap add twice the width of a steam port in inches, and the sum will give the stroke required.

Expansion by lap, with a slide valve operated by an eccentric alone, cannot be extended beyond $\frac{1}{3}$ of the stroke of a piston without interfering with the efficient operation of the valve; with a link motion, however, this distortion of the valve is somewhat compensated. When the lap is increased, the throw of the eccentric should also be increased.

When low expansion is required, a cut-off valve should be resorted to in addition to the main valve.

POWER OF STEAM.

Mr. Tredgold gives the following table, which will show how the power of the steam as it issues from the boiler is distributed.

In a Non-Condensing Engine.

Let the pressure on the boiler be		10.000
Force required to produce motion of the steam in the cylinder will be	0.069	
Loss by cooling in the cylinder and pipes	0.160	
Loss by friction of the piston and waste	2.000	
Force required to expel the steam into the atmosphere	0.069	
Force expended in opening the valves, and friction of the various parts	0.622	
Loss by the steam being cut off before the end of the stroke	1.000	
Amount of deductions		3.920
Effective pressure		6.080

In a Condensing Engine.

Let the pressure on the boiler be		10.000
Force required to produce motion of the steam in the cylinder	0.070	
Loss by cooling in the cylinder and pipes	0.160	
Loss by friction of the piston and waste	1.250	
Force required to expel steam through the passages	0.070	
Force required to open and close the valves, raise the injection water, and overcome the friction of the axes	0.630	
Loss by the steam being cut off before the end of the stroke	1.000	
Power required to work the air pump	0.500	
Amount of deductions		3.680
Effective pressure		6.320

If we now suppose a cylinder whose diameter is 24 inches, the area of this cylinder, and consequently the area of the piston, in square inches will be

$$24^2 \times .7854 = 452.39.$$

Let us also make the supposition that steam is admitted into the cylinder of such power as exerts an effective pressure on the piston of 12 lbs. to the square inch; therefore $452.39 \times 12 = 5128.68$ lbs., the whole force with which the piston is pressed. If we now suppose that the length of the stroke is five feet, and the engine makes 44 single or 22 double strokes in a minute, then the piston will move through a space of $22 \times 5 \times 2 = 220$ feet in a minute; the power of the engine being equivalent to a weight of 5,428 lbs raised through 220 feet in a minute.

This is the most certain measure of the power of a steam-engine. It is usual, however, to estimate the effect as equivalent to the power of so many horses. This method, however simple and natural it may appear, is yet, from differences of opinion as to the power of a horse, not very accurate; and its employment in calculation can only be accounted for on the ground, that when steam-engines were first employed to drive machinery, they were substituted instead of horses; and it became thus necessary to estimate what size of a steam-engine would give a power equal to so many horses.

There are various opinions as to the power of a horse. According to Smeaton, a horse will raise 22,916 lbs. one foot high in a minute. Desaguliers makes the number 27,500; and Watt makes it larger still, that is, 33,000. There is reason to believe that even this number is too small, and that we may add at least 11,000 to it, which gives 44,000 lbs. raised one foot high per minute.

BOILERS.

Natural Draught.

Boilers (Land) should be set at an inclination of .5 inch in 10 feet.

Grates (Coal).—They should have a superficial area of 1 square foot for every 15 lbs. of coal required to be consumed per hour, at a rapid rate of combustion, and they should be set at an inclination toward the bridge wall of 1 inch in every foot of length. When, however, the rate of combustion is not high, in consequence of the low velocity of the draught of the furnace, or the fuel being insufficient, this proportion must be increased to 1 square foot for every 12 lbs. of fuel.

With wood as the fuel, their area should be 1.25 to 1.4 that for coal.

The width of the bars should be the least practicable, and the spaces between them from .5 to .75 of an inch, according to the fuel used.

Ash-pit.—The transverse area of it, for a like combustion of 15 lbs. of coal per hour, should be .25 the area of the grate surface for bituminous coal, and .33 for anthracite.

The velocity of the current of air entering an ash-pit may be estimated at 12 feet per second.

Furnace or Chamber (Coal).—The volume of it should be from 2.75 to 3 cubic feet for every square foot of its grate surface. ***(Wood.)*** The volume should be 4.6 to 5 cubic feet.

Combustion is the most complete with firings or charges at intervals of from 15 to 20 minutes.

The volume of air and smoke for each cubic foot of water converted into steam is from coal 1,780 to 1,950 cubic feet, and for wood 3,900.

Bridge Wall (Flue boilers).—The cross-section of the flues or tubes should have an area of 1.7 to 2 square inches for each lb. of coal consumed per hour, or from 22.5 to 26 square inches for each square foot of grate, for a combustion of 13 lbs. of coal per hour; the difference in the area depending upon the character of the conformation of the section of and the length of the passage of the gases; the area being inversely with the diameter, and directly as the length of the flues, tubes, or spaces between them. Thus, in horizontal tubular boilers, the area should be increased to 27.5 and 31 square inches; in vertical tubular, to 32.5 and 36 square inches; and when a blast is used, the area may be decreased to 15.5 and 20.5 square inches.

The temperature of a furnace is about 1000°, and the volume of air required for the combustion of 1 lb. of bituminous coal, together with the products of combustion, is 154.81 cubic feet, which, when exposed to the above temperature, makes the volume of heated air at the bridge wall from 450 to 470 cubic feet for each lb. of coal consumed upon the grates.

Hence, at a velocity of the draught of about 36 feet per second, the area over a bridge wall, required to admit of this volume being passed off in an hour, would be .5 of a square inch, but in practice it should be 2 square inches.

When 13 lbs. of coal per hour are consumed upon a square foot of grate, $13 \times 2 = 26$ square inches are required, and in this proportion for other quantities.

The temperature of the heated air at the end of the flues should be about 500°, and their area and that of the base of the chimney should be .75 of that over the bridge wall, or 1.5 square inches for each lb. of coal consumed per hour.

When the area of the flues is determined upon, and the area over the bridge wall is required, it should be taken at from .7 to .8 the area of the lower flues for a natural draught, and from .5 to .6 for a blast.

Flues.—Their area should decrease with their length, but not in proportion with the reduction of the temperature of the heated air, their area at their termination being from .7 to .8 that of their calorimeter or area immediately at the bridge wall.

Large flues absorb more heat than small, as both the volume and intensity of the heat is greater with equal surfaces.

The temperature of the base of the chimney, or the termination of the flues or tubes, is estimated at 500°; and the base of the chimney, or the calorimeter, should have an area of 1.33 square inches for every pound of coal consumed per hour. With tubes of small diameter, compared to their length, this proportion may be reduced to 1 inch.

The admission of air behind a bridge wall increases the temperature of the gases, but it must be at a point where their temperature is not below 800°.

Evaporation. 1 square foot of grate surface, at a combustion of 13 lbs. coal per hour, will evaporate 2 cubic feet of salt water per hour.

A square foot of heating surface, at the above combustion of fuel, will evaporate from 4.33 to 5.33 lbs. of salt water per hour; and at a combustion of 40 lbs. coal per hour (as upon the Western rivers of the U. S.), from 10 to 11 lbs. fresh water, exclusive of that lost by blowing out from the boilers.

12 to 15 square feet of surface will evaporate 1 cubic foot of

salt water per hour at a combustion of 13 lbs. coal per hour per square foot of grate.

NOTE.—The boilers of the steamer Arctic, of N. Y., vertical tubular, having a surface of $33\frac{1}{4}$ to 1 of grate, consuming 13 lbs. of coal per square foot of grate per hour, evaporated 8.56 lbs. of salt water per lb. of coal, including that lost by blowing out of saturated water.

The relative evaporating powers of iron, brass, and copper are as 1, 1.25, and 1.56.

Water Surface.—At low evaporations, 3 square feet are required for each square foot of grate surface, and at high evaporation 4 to 5 square feet.

Heating Surfaces.

Heating Surfaces (Sea-Water).—The grate and heating surfaces should be increased about .07 over that for fresh water.

RELATIVE VALUE OF HEATING SURFACES.

Horizontal surface above the flame	= 1.
Vertical	= .5
Horizontal beneath the flame....	= .1
Tubes and flues..................	= .56

A scale one sixteenth of an inch in thickness will effect a loss of 14.7 per cent. of fuel.

One square foot of fire surface is computed to be as effective as three of heating surface.

When the combustion in a furnace is complete, the tubes may be shorter than when it is incomplete.

Tubes should always be set in vertical rows, and the spaces between them should be increased with their number.

Boilers with Internal Furnaces.

FOR COAL, 13 LBS. PER HOUR PER SQUARE FOOT OF GRATE. (NATURAL DRAUGHT.)

Pressure of Steam 20 lbs. (Mercurial Gauge), and 20 Revolutions of the Engine per Minute.

Fire and Flue Surface.* (*Arches or Flues and Return Flues.*)—For every cubic foot of steam to be expended in the steam cylinder, for a single stroke of the piston (computed only to the point of cutting off), the length of the flues and steam chimney not exceeding 45 or 50 feet, there should be from 48 to 54 square feet.

(*Arches or Flues, and Tubes or Return Tubes.*) *Horizontal Return.*—The length of the tubes and steam chimney not exceeding 30 or 35 feet, there should be from 58 to 64 square feet.

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* Estimated from above the grate bars, including steam chimney, and for sea-water.

Vertical Water Tubes.—From 64 to 70 square feet.

Grates.—For every cubic foot of steam as above, there should be from 1.75 to 2.1 square feet.

FOR COAL, 30 LBS. PER HOUR PER SQUARE FOOT OF GRATE. (BLAST OR EXHAUST.)

Pressure of Steam 30 lbs. (Mercurial Gauge), and 20 Revolutions of the Engine per Minute.

Fire and Flue Surface.*** (*Arches or Flues and Return Flues.*)—For every cubic foot of steam to be expended in the steam cylinder, for a single stroke of the piston (computed only to the point of cutting off), the length of the flues and steam chimney not exceeding 55 or 60 feet, there should be from 24 to 28 square feet.

(*Arches or Flues and Tubes.*) *Horizontal Return.*—The length of the tubes and steam chimney not exceeding 30 or 35 feet, there should be from 29 to 32 square feet.

Vertical Water Tubes.—From 32 to 35 square feet.

Grates.—For every cubic foot of steam as above, there should be from 1.15 to 1.35 square feet.

Boilers with External Furnace and Internal Flues. (Cylindrical Flue.)

FOR COAL, 20 LBS. PER HOUR PER SQUARE FOOT OF GRATE, OR FOR WOOD AT 40 LBS. (NATURAL DRAUGHT.)

Pressure of Steam 100 lbs. (Mercurial Gauge), and 20 Revolutions of the Engine per Minute.

Fire and Flue Surface.†—For every cubic foot of steam to be expended in the steam cylinder for a single stroke of the piston (computed only to the point of cutting off), the length of the flues and steam chimney not exceeding 55 to 60 feet, there should be from 100 to 108 square feet.

Grates.—For every cubic foot of steam as above, there should be from 3.8 to 4 square feet.

Western Boilers.—In the boilers upon the Western lakes and rivers of the United States, where the coal consumed is of the very best quality, and the smoke pipes are carried to a great height, the combustion of coal per square foot of grate per hour readily reaches 40 lbs.

$1\frac{1}{8}$ cords of Western wood have been burned per hour upon 48 square feet of grate.

In this case the units above given may be reduced to 50 and 54 for heating surface, and the grate surface decreased to 1.85 and 2.

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* Estimated from above the grate bars, including steam chimney, and for sea water

† Estimated from above the grate bars including steam chimney, where one exists, and for fresh water.

Boilers with External Furnace and Flue. (Plain Cylindrical.)

FOR COAL, 20 LBS. PER HOUR PER SQUARE FOOT OF GRATE, OR FOR WOOD AT 40 LBS. (NATURAL DRAUGHT.)

Pressure of Steam 100 *lbs.* (*Mercurial Gauge*), *and* 20 *Revolutions of the Engine per Minute.*

Fire and Flue Surface.*—For every cubic foot of steam to be expended in the steam cylinder, for a single stroke of the piston (computed only to the point of cutting off), the length of the flues and steam chimney not exceeding 30 feet, there should be from 85 to 92 square feet.

Grates.—For every cubic foot of steam as above, there should be from 3.8 to 4 square feet.

All of these units are based upon the volume of furnace, area of bridge wall, or cross-section of flues or tubes, etc., as given in the preceding rules.

The ranges given, of from 48 to 54, 24 to 48, etc., are for the purpose of meeting the ordinary differences of construction, thickness of metal, etc.

When a heater is used, and the temperature of the feed-water is raised above that obtained in a condensing engine, the proportions of surfaces may be correspondingly reduced.

Steam Room.—There should be from 2.5 to 3.5 times the volume of steam room that there are cubic feet of steam expended in the cylinder for each single stroke of the piston for 25 revolutions; or the volume of it should be from 5 to 7 times the volume of the cylinder, increasing in proportion with the number of revolutions.

When there are two engines, or an increased number of revolutions, these proportions of steam room must be increased.

Felt covering to a boiler and steam pipes effects a very material saving in fuel.

NOTES —Four copper boilers, with a natural draught and bituminous coal, flues 40 feet in length, including steam chimney, with 14 square feet of fire and flue surface, and .6 of a square foot of grate surface for every cubic foot in the cylinders, furnished steam at 20 lbs. pressure, cut off at ½ of the stroke of the piston, for 18.5 revolutions.

The mean of four cases, with iron boilers and anthracite coal, with a blast, flues 50 feet in length, gave, with 12.5 square feet of fire and flue surface, and .5 of a square foot of grate surface for every cubic foot in the cylinders, steam at 35 lbs. pressure, cut off at ½ of the stroke of the piston, for 22 revolutions.

The space in the steam room of the boilers and chimney was about 5 times that of the cylinders in the preceding cases.

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* These proportions are for the evaporation of fresh water; if sea-water is used, the surface must be increased .066.

To compute the Heating and Grate Surface required for a given Evaporation, or Volume of Cylinder and Revolutions.

OPERATION.—Reduce the evaporation to the required volume of cylinder, number of revolutions of engine, pressure of steam, and point of cutting off; then reduce these results to the range of consumption of fuel per square foot of grate, pressure of steam, and number of revolutions given for the several cases at pp. 199 to 201, and multiply them by the units given for the surfaces required.

ILLUSTRATION.—There is required an evaporation of 492.24 cubic feet of salt water per hour, under a pressure of steam of 17.3 lbs. per square inch, stroke of engine 10 feet, cutting off at ½ stroke, revolutions 15 per minute, and consumption of fuel (coal) 13 lbs. per square foot of grate per hour, in a marine boiler having internal furnaces and vertical tubes.

Volume of steam at this pressure compared with water, 833.

$492.24 \times 833 \div 60 = 6833.93$ cubic feet of cylinder per minute.

$6833.93 \div \overline{15 \times 2} = 227.79$ cubic feet of cylinder at half stroke.

Then $\frac{227.79 \times 17.3}{20} = 197.04$ cubic feet at 17.3 lbs. pressure,

and $\frac{197.04 \times 15}{20} = 147.78$, which $\times$ 66, the unit for heating surface for a vertical tubular boiler at 20 lbs. pressure and 20 revolutions, $=$ 9753.48 square feet.

And $147.78 \times 2 =$ the unit for grate under like condition $=$ 295.56 square feet.

NOTE.—The steamer Baltic has developed all the elements here given, and the surface of her boilers and grates (for one engine) were 9,742 and 293.9 square feet.

To compute the Consumption of Fuel in the Furnace of a Boiler.

The Dimensions of the Cylinder, the Pressure of the Steam, the Point of Cutting Off, the Revolutions, and the Evaporation of the Boilers per Pound of Fuel per Minute being given.

RULE. Ascertain the volume of water expended in steam, and multiply it by the weight of a cubic foot of the water used; divide the product by the evaporating power of the fuel in the boiler under computation in pounds of water, and add thereto the loss per cent. by blowing off.

Boiler Plates and Bolts.

Boiler Plates and Bolts.—The tensile strength of wrought iron plates and bolts ranges from 45,500 to 62,500 lbs.

for plates. and to 65,000 for bolts, being increased when subjected to a moderate temperature.

The mean tensile strength of copper plates and bolts is 33,000 lbs., being reduced when subjected to a temperature exceeding 120°: at 212° being 32,000 lbs., and at 555° but 25,000 lbs.

Bursting and Collapsing Pressures.

The computation for plates and bolts should be based, so far as may be practicable, upon their exact tensile strength. Whenever, then, the strength of plates is ascertained, there should be deducted therefrom one-half for single riveting and three-tenths for double riveting, and the remainder divided by a factor of safety of three. When the exact strength cannot be ascertained, a factor of six should be used both for plates and bolts.

The resistance to collapse of a flue or tube is much less than the resistance to bursting; the ratio cannot well be determined, as the resistance of a flue decreases with its length, or that of its courses.

With an ordinary cylindrical boiler, 4 feet in diameter, single riveted, 20 feet in length, with flues $15\frac{1}{2}$ inches in diameter, shell 5-16 thick, flues $\frac{1}{4}$ in., the relative strengths are: Bursting, 350 lbs.; Collapsing, 152 lbs.

To compute the Thickness, Maximum Working Pressure, and Diameter of a Wrought Iron Boiler or Flue.

For Service in Salt Water.—Add one-sixth to the thickness of the plate or diameter of the bolt.

Thickness. RULE.—Multiply the diameter in inches by half the maximum working pressure in lbs. per square inch, and divide the product by 9,000 (one-sixth of 54,000) for single riveting, and 12,500 for double, and the result will give the thickness in decimals of an inch.

Pressure. RULE.—Multiply the thickness by 9,000 or 12,500, as before given; divide the product by the diameter, and twice the quotient will give the maximum pressure in pounds.

Diameter. RULE—Multiply the thickness by 9,000 or 12,500, as before; divide the product by half the maximum pressure, and the quotient will give the diameter in inches.

EXAMPLE.—The diameter of a single riveted wrought-iron boiler is 42 inches, and the plates $\frac{1}{4}$ of an inch in thickness; what is its maximum working pressure?

$$\frac{.25 \times 9000}{42} \times 2 = 110 \text{ lbs.};$$

and what its thickness at this pressure?

$$\frac{42 \times \overline{110 \div 2}}{9000} = .257 \text{ in.}$$

To compute the Diameter of Stay Bolts.

RULE.—Multiply the distance between their centres in inches by the square root of the quotient of the maximum working pressure, divided by 5,500 for wrought iron, and 4,100 for copper, and the result will give the diameter of the body of the bolt in inches.

EXAMPLE.—The maximum working pressure of a wrought iron boiler is 110 lbs., and the distance apart of the bolts is 6 inches; what should be their diameter?

$$6 \times \sqrt{\frac{110}{5500}} = 6 \times \sqrt{.02} = 6 \times .1414 = .85 \text{ in.}$$

To compute the Distance apart of Stay Bolts.

RULE.—Multiply the square root of the quotient of 5,500 for wrought iron, and of 4,100 for copper, divided by the maximum working pressure, by the diameter of the bolt, and the product will give the distance in inches.

EXAMPLE.—The maximum working pressure of a wrought iron boiler is 110 lbs., and the diameter of the stay bolts is .85 inch; what should be their distance apart?

$$\sqrt{\frac{5500}{110}} \times .85 = \sqrt{50} \times .85 = 6 \text{ ins.}$$

NOTE.—Where stays are secured by keys, their ends should be $1\frac{1}{4}$ times the diameter of the stay, the depth of the slot 1.6 of the diameter of stay, and the width .3.

To compute the Thickness of Flat Surfaces in a Wrought Iron Boiler.

RULE.—Multiply the maximum working pressure by the square of the distance, or the area of the surface, between the centres of the stays in inches; divide the product by 15,500, and the quotient will give the thickness in inches.

EXAMPLE.—Take the elements of the preceding case.

$$\frac{110 \times 6^2}{15500} = .255 \text{ in.}$$

Stay Bolts.—Iron stay bolts, $\frac{3}{4}$ ins. in diameter, screwed into a copper plate $\frac{3}{8}$ thick, drew at a strain of 18,260 lbs.

A like stay bolt, screwed and riveted into an iron plate, drew at a strain of 28,760 lbs.

A like stay bolt of copper, screwed and riveted into a copper plate, drew at a strain of 16,265 lbs.

Hence, stay bolts when screwed and riveted are $\frac{1}{3}$ stronger than when screwed alone.

METRIC SYSTEM OF MEASURES AND WEIGHTS.

ACCORDING TO ACT OF 1866.

Equivalents of Old and New U. S. Measures.

LENGTH.

		Metres.
1 Inch	=	.02540005
1 Foot	=	.3048006
1 Yard	=	.9144018
1 Chain	=	20.1168396
1 Furlong	=	201.168396
1 Mile	=	1609.347168

SURFACE.

		Square Metres.
1 Inch	=	.000645161
1 Foot	=	.092903184
1 Yard	=	.836128656
1 Rod	=	25.292891844
1 Rood	=	1011.71567376
1 Acre	=	4046.86269504

VOLUME.

		Litres.*
1 Fluid Dram	=	.0036967
1 Fluid Ounce	=	.0295739
1 Fluid Pound	=	.35488656
1 Gill	=	.1182955
1 Wine Pint	=	.4731821
1 Dry Quart	=	1.1012344
1 Wine Quart	=	.9463642
1 Wine Gallon	=	3.7854579

WEIGHT.

		Grammes.
1 Grain	=	.0648004
1 Scruple	=	1.296008
1 Pennyweight	=	1.5552096
1 Dram	=	3.888024
1 Ounce (Troy)	=	31.104192
1 Ounce †	=	28.350175
1 Pound	=	453.6028
1 Ton	=	1016070.272

NOTE.—A square metre is 1549.9969 square inches, but by Act of Congress it is declared to be 1550 square inches; hence the litre (cubic decimetre) = 61.023377953 cubic inches. In the Act of Congress, a litre is declared to be 61.022 cubic inches, which is erroneous, as here shown, by the .001 + of an inch.

Measures of Length.

Denominations and Values.			Equivalents in use.
Myriametre.	10,000 metres.		6.2137 miles.
Kilometre. .	1,000	"	.62137 " or 3280 ft. & 10 ins.
Hectometre	100	"	328 ft. and 1 inch.
Decametre. .	10	"	393.7 inches.
Metre	1	"	39.37 "
Decimetre . .	$\frac{1}{10}$ of a	"	3.937 "
Centimetre. .	$\frac{1}{100}$ "	"	.3937 "
Millimetre. .	$\frac{1}{1000}$ "	"	.0394 "

* 61.023 cubic inches.

† Avoirdupois.

Measures of Surface,

Denominations and Values.		Equivalents in use.
Hectare....	10,000 sq. metres.	2.471 acres.
Are.........	100 " "	119.6 square yards.
Centare.....	1 " "	1550 square inches.

Measures of Volume.

Denominations and Values.			Equivalents in use.	
Names.	No. of Litres.	Cubic Measure.	Dry Measure.	Liq. or Wine Measure.
Kilolitre or Stere	1,000	1 cubic metre	1.308 cub. yds.	264.17 gals
Hectolitre	100	$\frac{1}{10}$ " "	2 bh., 3.35 pks.	26.417 "
Decalitre ..	10	10 " decimetres	9.08 quarts.	2.6417 "
Litre	1	1 " "	.908 "	1.0567 qts.
Decilitre ..	$\frac{1}{10}$	$\frac{1}{10}$ " "	6.1022 cub. ins.	.845 gill.
Centilitre ..	$\frac{1}{100}$	10 " centimetres	.6102 " "	.338 fld. oz
Millilitre...	$\frac{1}{1000}$	1 " "	.061 " "	.27 " drm

Weights.

Denominations and Values.			Equiv. in use.
Names.	Number of Grammes.	Weight of Volume of Water at its Maximum Density.	Avoirdupois Weight.
Millier or Tonneau	1,000,000	1 cubic metre.	2204.6 lbs.
Quintal.....	100,000	1 hectolitre.	220.46 "
Myriagramme	10,000	10 litres.	22.046 "
Kilogram. or Kilo.	1,000	1 "	2.2046 "
Hectogramme....	100	1 decilitre.	3.5274 oz.
Decagramme	10	10 cubic centimetres.	.3527 "
Gramme..........	1	1 " "	15.432 grs.
Decigramme	$\frac{1}{10}$	$\frac{1}{10}$ " "	1.5432 "
Centigramme......	$\frac{1}{100}$	10 cubic millimetres.	.1543 "
Milligramme......	$\frac{1}{1000}$	1 " "	.0154 "

For measuring surfaces, the square Decametre is used under the term of Are; the Hectare, or 100 Ares, is equal to about 2 acres.

The Unit of Capacity is the cubic Decimetre or Litre, and the series of measures is formed in the same way as in the case of the table of lengths.

The cubic Metre is the unit of measure for solid bodies, and is termed Stere.

The Unit of Weight is the Gramme, which is the weight of one cubic centimetre of pure water weighed in a vacuum of 4° Centigrade, or 39°.2 Fahrenheit, which is about its temperature of maximum density.

In practice, the term cubic Centimetre, abbreviated C. C., is used instead of Millilitre, and cubic Metre instead of Kilolitre.

ALLOYS AND COMPOSITIONS.

Composition for Welding Cast Steel.

Borax, 10 parts; sal-ammoniac, 1 part. Grind or pound them roughly together; fuse them in a metal pot over a clear fire, continuing the heat until all spume has disappeared from the surface. When the liquid is clear, pour the composition out to cool and concrete, and grind to a fine powder; then it is ready for use.

To use this composition, the steel to be welded should be raised to a bright yellow heat; then dip it in the welding powder, and again raise it to a like heat as before; it is then ready to be submitted to the hammer.

Fusible Compounds.

Compounds.	Zinc.	Tin.	Lead.	Bism'h.	Cadm.
Rose's, fusing at 200°	—	25	25	50	—
Fusing at less than 200°	33.3	—	33.3	33.4	—
Newton's, fusing at less than 212°	—	19	31	50	—
Fusing at 150° to 160°	—	12	25	50	13

Soldering Fluid for Use with soft Solder.

To 2 fluid oz. of muriatic acid add small pieces of zinc until bubbles cease to rise. Add half a teaspoonful of sal-ammoniac and 2 fluid oz. of water.

By the application of this to iron or steel, they may be soldered without their surfaces being previously tinned.

Babbitt's Anti-Attrition Metal.

Melt 4 lbs. copper; add, by degrees, 12 lbs. best Banca tin, 8 lbs. regulus of antimony, and 12 lbs. more of tin. After 4 or 5 lbs. tin have been added, reduce the heat to a dull red, then add the remainder of the metal as above.

This composition is termed hardening; for lining, take 1 lb. of this hardening, melt with it 2 lbs. Banca tin, which produces the lining metal for use. Hence, the proportions for lining metal are 4 lbs. of copper, 8 of regulus of antimony, and 96 of tin.

TEMPERING.

The article after being completed is hardened by being heated gradually to a bright red, and then plunged into cold water; it is then tempered by being warmed gradually and equably, either over a fire, or on a piece of heated metal till of the color corresponding to the purpose for which it is required, as per table below, when it is again plunged into water.

	Corresponding Temperature.	
A very pale straw	430°	Lancets
Straw	450°	Razors
Darker straw	470°	Penknives } All kinds of wood tools.
Yellow	490°	Scissors } Screw taps.
Brown yellow	500°	Hatchets, Chipping Chisels,
Slightly tinged purple	520°	Saws
Purple	530°	All kinds of percussive tools.
Dark purple	550°	Springs.
Blue	570°	Springs.
Dark blue	600°	Soft for saws.

To Temper by the Thermometer.

Put the articles to be tempered into a vessel containing a sufficient quantity to cover them of oil or tallow; sand; or a mixture of 8 parts bismuth, 5 of lead, and 3 of tin, the whole to be brought up to, and kept up at the heat corresponding to the hardness required, by means of a suitable thermometer, till heated equally throughout; the articles are then withdrawn and plunged into cold water. If no thermometer is available, it may be observed that oil or tallow begins to smoke at 430° or straw color, and that it takes fire on a light being presented, and goes out when the light is withdrawn, at 570° or blue.

Case Hardening.

Put the articles requiring to be hardened, after being finished but not polished, into an iron box in layers with animal carbon, that is, horns, hoofs, skins, or leather, partly burned so as to be capable of being reduced to powder, taking care that every part of the iron is completely surrounded; make the box tight with a lute of sand and clay in equal parts, put the whole into the fire, and keep it at a light red heat for half an hour to two hours, according to the depth of hardened surface required, then empty the contents of the box into water, care being taken that any articles liable to buckle be put in separately and carefully, end in first.

Cast iron may be case hardened as follows:

Bring to a red heat, and roll it in a mixture of powdered prussiate of potash, saltpetre, and sal-ammoniac in equal parts, then plunge it into a bath containing 2 oz. prussiate of potash, and 4 oz. sal ammoniac per gallon of water.

To find the Weight of any Casting.

Width in $\frac{1}{4}$ in. × thickness in $\frac{1}{8}$ in., or, vice versa, ÷ 10 × length, ft. = wt. lbs., cast iron.

For instance: To find the weight of a casting $3\frac{1}{4}$ in. × $1\frac{1}{8}$ in. × 2 ft. 6 in. long.

$$13 \times 9 \div 10 = 11.7 \times 2.5 = 29.25 \text{ lbs.}$$

This rule is very useful, and can easily be remembered in the following form:

Width in $\frac{1}{4}$ in. × thickness in $\frac{1}{8}$ in.; or, vice versa, cut off 1 figure for decimal, the result is lbs. per foot of length.

For wrought iron add 1-20 to the result; for lead add $\frac{1}{2}$; for brass add 1-7; for copper add 1-5.

To find the Weight from the Areas.

Area, sq. ins. × length, ft. × 3 1-7 = wt. lbs. cast iron.

Multiplier for cast iron .... 3.156, or 3 1-7
" " wrought iron.... .....3.312, " $3\frac{1}{3}$
" " lead 4.854
" " brass 3.641
" " copper 3.87

or, area sq. ins. × 10 = lbs. per yard for wrought iron.

To find the Weight in Cwts.

Area, sq. ins × length, ft. ÷ 31.9 = wt. cwts. cast iron.

For wrought iron ÷ 33.6.

To compute the Weight of Cast Metal by the Weight of the Pattern, when the Pattern is of White Pine.

Rule.—Multiply the weight of the pattern in lbs. by the following multiplier, and the product will give the weight of the casting. Iron, 14; brass, 15; lead, 22; tin, 14; zinc, 13.5.

Table of Alloys.

Alloys having a density greater than the Mean of their Constituents.		Alloys having a density less than the Mean of their Constituents.	
Gold and zinc.	Silver & antimony.	Gold and silver.	Iron and bismuth.
Gold and tin.	Copper and zinc.	Gold and iron.	Iron and antimony
Gold and bismuth.	Copper and tin.	Gold and lead.	Iron and lead.
Gold and antimony	Copper & palladium	Gold and copper.	Tin and lead.
Gold and cobalt.	Copper & bismuth.	Gold and iridium.	Tin and palladium.
Silver and zinc.	Lead and antimony	Gold and nickel.	Tin and antimony.
Silver and lead.	Platinum & molybdenum.	Silver and copper.	Nickel and arsenic.
Silver and tin.	Palladium and bismuth.	Silver and lead.	Zinc and antimony
Silver and bismuth			

Alloys of Copper and Zinc, and Copper and Tin.

Composition by Weight per cent	Specific Gravity.	Color.	Ultimate Cohesive Strength of an In. sq. Bar, in Tons.	Characteristic Properties, &c.
Copper	8667	Tile red.	24.6	Malleable.
100.00 Zinc	6895	Bluish gray.	15.2	Brittle.
83.02+16.98	8415	Yellowish red.	13.7	Bath metal.
79.65+20.35	8448	" "	14.7	Dutch brass.
74.58+25.42	8397	Pale yellow.	13.1	Rolled sheet brass.
66.18+33.82	8299	Full yellow.	12.5	British brass.
49.47+50.53	8230	" "	9.2	German brass.
32.85+67.15	8283	Deep yellow.	19.3	Watchmakers' brass.
30.30+69.70	7836	Silver white.	2.2	Very brittle.
24.50+75.50	7449	Ash gray.	3.1	Brittle.
19.65+80.35	7371	" "	1.9	White button metal.
Tin	7291	White.	2.7	
84.29+15.71	8561	Reddish yellow	16.1	Gun-metal.
81.10+18.90	8459	Yellowish red.	17.7	Gun-metal and bronze.
78.97+21.03	8728	" "	13.6	Hard, mill brasses.
34.92+65.08	8065	White.	1.4	Small bells.
15.17+84.83	7447	Very white.	3.1	Speculum metal.
11.82+88.18	7472	" "	3.1	Files, tough.

NOTE.—No simple binary alloy of copper and zinc, or of copper and tin, works as pleasantly in turning, planing, or filing, as if combined with a small proportion of a third fusible metal; generally lead is added to copper and zinc, and zinc to copper and tin.

Alloys for Bronze.

Professor Hoffman, of the Prussian artillery, has made experiments with the view of obtaining a good statuary bronze, and recommends the alloys ranging between the two following admixtures:

1st. To produce the reddest bronze.

88.75 copper zinc (7 atoms copper, 1 atom zinc).
11.25 copper tin (3 atoms copper, 1 atom tin).

100.00

2d. To produce a cheap bronze, with a bright yellow color, almost golden.

93.5 copper zinc (2 atoms copper, 1 atom zinc).
6.5 copper tin (3 atoms copper, 1 atom tin).

100.00

Glue. Powdered chalk added to common glue strengthens it. A glue which will resist the action of water is made by boiling 1 pound of glue in 2 quarts of skimmed milk

To joint Lead Pipes.—Widen out the end of one pipe with a taper wood drift, and scrape it clean inside; scrape the end of the other pipe outside a little tapered, and insert it in the former; then solder it with common lead solder as before described; or if required to be strong, rub a little tallow over, and cover the joint with a ball of melted lead, holding a cloth (2 or 3 plies of greased bed-tick) on the under side; and smoothing over with it and the plumber's iron.

To polish Brass.—When the brass is made smooth by turning or filing with a very fine file, it may be rubbed with a smooth fine grained stone, or with charcoal and water. When it is made quite smooth and free from scratches, it may be polished with rotten stone and oil, alcohol, or spirits of turpentine.

To clean Brass.—If there is any oily substance on the brass, boil it in a solution of potash or strong lye. Mix equal quantities of nitric and sulphuric acids in a stone or earthen vessel, let it stand a few hours, stirring it occasionally with a stick, then dip the brass in the solution, but take it out immediately and rinse it in soft water, and wipe it in sawdust till it is dry.

To fill Holes in Castings.—Lead, 9 parts; antimony, 2; and bismuth, 1: to be melted and poured in.

Babbitt Metal—Copper, 4 lbs.; regulus of antimony, 8 lbs.; Banca tin, 88 lbs.

To soften Iron or Steel.—Anoint it all over with tallow; heat it in a charcoal fire; then let it cool.

To restore Burnt Steel.—Borax, 3 oz.; sal-ammoniac, 8 oz.; prussiate of potash, 3 oz.; blue clay, 2 oz.; resin, 1½ lbs.; water, 1 gill; alcohol, 1 gill. Put all on a fire, and simmer until it dries to a powder; then heat the steel and dip it into this powder and hammer it.

Babbitt Metal.—Block tin, 8 lbs.; antimony, 2 lbs.; copper, 1½ lbs. If the metal is too hard add a little lead.

Composition to toughen Steel.—Resin, 2½ lbs.; tallow, 2½ lbs.; pitch, 1½ lbs. Melt together, and apply the steel while hot.

Substitute for Borax.—Copperas, 2 oz.; common salt, 5 oz.; saltpetre, 1 oz.; black oxide of manganese, 1 oz.; prussiate of potash, 1½ oz. Pulverize and mix with 3½ lbs. of welding sand: use same as borax.

Tempering Liquids.—Salt, 4 oz.; saltpetre, ½ oz.; pulverized alum, 1 oz.; soft water, 1 gallon. Heat to a cherry red, but do not draw the temper.

Another.—Saltpetre and alum, each 2 oz.; sal-ammoniac, ½ oz.; salt, 1½ lbs.; soft water, two gallons. Heat to a cherry red and plunge in.

Case-Hardening for Iron.—Heat the iron to a bright cherry red, then roll it in a composition composed of equal parts of sal-ammoniac, saltpetre, and prussiate of potash; cover the iron thoroughly with this composition, and plunge it while hot into a bath composed of 2½ oz. prussiate of potash, 4½ oz. sal-ammoniac, and 1 gallon of water.

To restore Burnt Steel.—Borax, 3 lbs.; sal-ammoniac, 1 lb.; prussiate potash, ½ lb.; resin, ½ lb.; alcohol, 1 gill; soft water, 1 pint. Put into an iron pan and hold over a slow fire until it comes to a slow boil and until the liquid matter evaporates; be careful to stir it well from the bottom and let it boil slow. This receipt is very valuable, no matter how bad the steel is burned, it will restore and make it as durable as ever.

To blue Gun Barrels.—Apply nitric acid and let it eat into the iron a little; then the latter will be covered with a thin film of oxide. Clean the barrel, oil, and burnish.

Lining Boxes with Babbitt Metal.—Heat the box hot enough to melt the metal; then smoke the shaft where the metal is to be poured in; this insures its coming out of the box readily after it is cold. After smoking the shaft put it into the box and put putty around the ends, taking care not to press too hard, or the putty will be forced into the box; then heat your metal and pour in, letting it stand until cold; then drive out the shaft and it is complete.

To estimate the Percentage of Iron in Ores.—Prepare a crucible of refractory clay by pressing into it successive layers of moistened powdered charcoal until full and solid; clear out a cavity by removing the central portion. Take 200 grains of the powdered ore, and mix it with the same weight of dry slacked lime, and 50 grains charcoal; if necessary a little carbonate of soda may be used with very refractory ores; introduce this mixture into the crucible and lute it up. Expose the crucible to a moderate heat until the contents of the crucible are dry, then apply and maintain for half an hour the full heat of a blast furnace. Then remove the crucible, tap it steadily on the edge of the furnace, so as to bring the metallic portion of its contents together at the bottom; and, when cool, break the crucible open. The iron will be found in a clean button at the bottom of the slag. Clean the iron with a scratch brush, and weigh it. Its weight, divided by 2, will give the percentage of richness of the ore under examination.

To distinguish Wrought and Cast Iron from Steel. Elsner produces a bright surface by polishing or filing, and applies a drop of nitric acid, which is allowed to remain there for one or two minutes, and is then washed off with water. The spot will then look a pale ashy gray on wrought iron, a brownish black on steel, a deep black on cast iron. It is the carbon present in various proportions which produces the difference in appearance.

Very deep Case-Hardening for Iron.—Put the iron into a crucible with cyanide of potash. Cover over and heat together, then plunge into water. This process will harden to the depth of three inches.

To impart to Cast Iron the Appearance of Bronze.—The article to be so treated is first cleaned with great care, and then coated with a uniform film of some vegetable oil; this done, it is exposed in a furnace to the action of a high temperature, which, however, must not be strong enough to carbonize the oil. In this way the cast iron absorbs oxygen at the moment the oil is decomposed, and there is formed at the surface a thin coat of brown oxide, which adheres very strongly to the metal, and will admit of a high polish, giving it quite the appearance of the finest bronze.

Brown Tint for Iron and Steel.—Dissolve in 4 parts of water, 2 parts crystallized chloride of iron, 2 parts chloride of antimony, and 1 part gallic acid, and apply the solution with a sponge or cloth to the article, and dry it in the air. Repeat this any number of times according to the depth of color which it is desired to produce. Wash with water, and dry, and finally rub the articles over with boiled linseed oil. The metal thus receives a brown tint and resists moisture. The chloride of antimony should be as little acid as possible.

To ornament Gun Barrels.—A very pretty appearance is given to gun barrels by treating them with dilute nitric acid and vinegar, to which has been added sulphate of copper. The metallic copper is deposited irregularly over the iron surface. Wash, oil, and rub well with a hard brush.

To remove Rust from Iron.—We have never seen any iron so badly scaled or incrusted with oxide, that it could not be cleaned with a solution of 1 part sulphuric acid in 10 parts water. Paradoxical as it may seem, strong sulphuric acid will not attack iron with anything like the energy of a solution of the same. On withdrawing the articles from the acid solution they should be dipped in a bath of hot lime-water, and held there till they become so heated that they will dry immediately when taken out. Then, if they are rubbed with dry bran or sawdust, there will be an almost chemically clean surface left, to which zinc will adhere readily.

To protect Iron from Oxidization.—Among the many processes and preparations for preserving iron from the action of the atmosphere, the following will be found the most efficient in all cases where galvanization is impracticable; and, being unaffected by sea-water, it is especially applicable to the bottom of iron ships, and marine work generally: Sulphur, 17 pounds; caustic potash lye of 35° Baumé, 5 pounds; and copper filings, 1 pound. To be heated until the copper and sulphur dissolve. Heat, in another vessel, tallow, 750 pounds, and turpentine, 150 pounds, until the tallow is liquefied. The compositions are to be mixed and used same as paint.

To scour Cast Iron, Zinc, or Brass.—Cast iron, zinc, and brass surfaces can be scoured with great economy of labor, time, and material, by using either glycerine, stearine, napthaline, or creosote, mixed with dilute sulphuric acid.

Wood Chips, Bark, &c., as a Preventive of Incrustation in Boilers.—Catechu, nut-galls, oak bark, shavings and sawdust, tan bark, tormentilla root, mahogany, logwood, etc. These substances all contain more or less tannic acid, associated with soluble extractive and coloring matters. When they are introduced into the boiler, the soluble constituents are dissolved by the water, and basic tannate of lime is formed, which separates as a loose deposit, and does not adhere to the sides of the boiler. It is preferable to use the aqueous extract, as sawdust, chips, etc., are liable to find their way into the cocks and tubes, although they act mechanically, receiving incrustations which would otherwise fasten themselves on the sides of the boiler. In selecting one of these substances, the principal object is to secure the largest quantity of tannic acid and soluble extractive matter for the lowest price. Some of these substances are said to be very effective, ½ pound of catechu being sufficient for 100 cubic feet of water. From 4 to 6 pounds of oak chips have been recommended per horse-power, or ½ bushel mahogany chips for every 10 horse-power.

Mucilaginous Substances as Preventives.—Potatoes, starch, bran, linseed meal, gum, dextrine, Irish moss, slippery elm, marshmallow root, glue, etc. These substances form, sooner or latter, a slimy liquid in the boiler, which prevents more or less completely the settling and hardening of the deposits. Some of them may even hold the lime and magnesia in solution. Potatoes have been used for many years, wherever steam-engines are employed; half a peck or a peck are thrown into the boiler weekly. Linseed meal mixed with chopped straw was employed on a German railway, a peck at a time being introduced into each boiler. Some writers object to these organic substances, on the ground that they are liable to cause frothing.

Saccharine Matter as Preventives.—Sugar, molasses, corn or potato sirup. Both cane and grape sugar form soluble compounds with lime salts, and consequently prevent their separation as incrustations. One engineer found that 10 pounds of brown sugar protected his boiler for two months; another, that 6 pounds of corn starch sirup had a similar effect. Another used molasses with success, introducing a gallon at a time.

Fatty Substances as Preventives. One writer used whale oil to prevent incrustations, 2 or 3 gallons at a time. Others smear the inside of the boiler with various mixtures of a fatty character. Stearine, mixed with wood ashes, charcoal, and tar, has been recommended; or tallow, with soap and charcoal diluted with oil or tar, or tallow and graphite. This plan could not well be applied to a locomotive boiler with its numerous tubes, even though it should prove effective in cylinder boilers.

To protect Iron from Rust.—A mastic or covering for this purpose, proposed by M. Zeni, is as follows: Mix 80 parts pounded brick, passed through a silk sieve, with 20 parts litharge; the whole is then rubbed up by the muller with linseed oil, so as to form a thick paint, which may be diluted with spirits of turpentine. Before it is applied the iron should be well cleaned. From an experience of two years upon locks exposed to the air, and watered daily with salt water, after being covered with two coats of this mastic, the good effects of it have been thoroughly proved.

To prevent the Decay of Iron Railings.—Every one must have noticed the destructive combination of lead and iron, from railings being fixed in stone with the former metal. The reason for this is, that the oxygen of the atmosphere keeps up a galvanic action between the two metals. This waste may be prevented by substituting zinc for lead, in which case the galvanic influence would be inverted; the whole of its action would fall on the zinc; the one remaining uninjured, the other nearly so. Paint formed of the oxide of zinc, for the same reason preserves iron exposed to the atmosphere infinitely better than the ordinary paint composed of the oxide of lead.

To clean Steel and Iron.—Make 1 ounce soft soap and 2 ounces emery into a paste; rub it on the article with wash-leather and it will have a brilliant polish. Kerosene oil will also clean steel.

To convert Iron into Steel.—This is usually done by the process of cementation, producing what is termed blistered steel. At the bottom of a trough about 2 feet square and 14 feet long, usually formed of fire-clay, is placed a layer, about 2 inches thick, of a cement composed of 10 parts charcoal and 1 part ashes and common salt; upon this is laid a tier of thin iron bars about ½ inch apart; between and over them, a layer of cement is spread, then a second row of bars, and so on, alternately, until the trough is nearly full; lastly a layer of cement covered with moist sand and a close cover of fire-tiles, so as to exclude the air. The trough is exposed to the heat of a coal fire, until a full red heat, about 2000° Fahr., is obtained and kept up steadily for about 7 days. A hole is left in the end of the trough, to allow of a bar being drawn out for examination. When a bar, on being withdrawn and broken, has acquired a crystalline texture, the metal is allowed to cool down gradually, some days being allowed for this, and the charge, when cool, withdrawn from the trough. The bars will be found covered with large blisters, hence the name of the process, and increased about $\frac{1}{150}$ in weight. The steel is now sufficiently good for files and coarser tools, but for finer instruments several varieties of finer steel are required.

Steel made from Iron Scraps.—Take iron scraps in small pieces, put 40 pounds in a crucible, with 8 ounces charcoal, and 4 ounces black oxide of manganese; expose the whole 1½ hours to a high heat and run into moulds.

To make Shear Steel.—This is produced by cutting up bars of blistered steel, into lengths of 30 inches, and binding them in bundles of 8 or 9 by a ring of steel, a rod being fixed for a handle. These are brought to a welding heat, and welded together under a tilt hammer. The binding ring is then removed; and, after reheating, the mass is forged solid, and extended into a bar. In cases where this operation is repeated, the steel is called double-shear steel.

To make Cast Steel.—Cast steel is the best variety for all fine cutting tools. This is a mixture of scraps of different varieties of blistered steel, collected together in a good refractory clay crucible; upon this a cover is luted, and it is exposed to an intense heat in a blast furnace for 3 or 4 hours. The contents are then run into moulds. After being subjected to the blows of a tilt-hammer, the cast steel is ready for use.

To keep Polished Iron Work bright.—Common resin melted with a little gallipoli oil and spirits of turpentine has been found to answer very well for preserving polished iron work bright. The proportions should be such as to form a coating which will adhere firmly, not chip off, and yet admit of being easily detached by cautious scraping.

To take Proof-Impressions of Seals and Stamps.—For this purpose the very best sealing-wax is melted as usual by a flame, and carefully worked on the surface to which it is applied, until perfectly even; the stamp is then firmly and evenly pressed into it. The flame of a spirit lamp is preferable, having no tendency to blacken the wax. A beautiful dead appearance is given to the impression by dusting the stamp before using it with a finely-powdered pigment of the same color as the wax; thus, for vermilion sealing-wax, powdered vermilion, &c.

To blue Steel.—The mode employed in blueing steel is merely to subject it to heat. The dark blue is produced at a temperature of 600°, the full blue at 560°, and the blue at 550°. The steel must be finely polished on its surface, and then exposed to a uniform degree of heat. Accordingly, there are three ways of coloring: first, by a flame producing no soot, as spirit of wine; secondly, by a hot plate of iron; and thirdly, by wood ashes. As a very regular degree of heat is necessary, wood ashes for fine work bear the preference. The work must be covered over with them, and carefully watched; when the color is sufficiently heightened, the work is perfect. This color is occasionally taken off with a very dilute muriatic acid.

To remove Scale from Steel.—Scale may be removed from steel articles by pickling in water with a little sulphuric acid in it, and when the scale is loosened, brushing with sand and a stiff brush.

To temper Spiral Springs.—Heat to a cherry red in a charcoal fire, and harden in oil. To temper, blaze off the oil three times, the same as for flat springs.

Cautions on the use of Lead for Cisterns, &c.—Ordinary water, which abounds in mineral salts, may be safely kept in leaden cisterns; but distilled and rain water, and water that contains scarcely any saline matter, speedily corrode, and dissolve a portion of lead, when kept in vessels of that metal. When, however, leaden cisterns have iron or zinc fastenings or braces, a galvanic action is set up, the preservative power of saline matter ceases, and the water speedily becomes contaminated with lead. Water containing free carbonic acid also acts on lead; and this is the reason why the water of some springs, kept in leaden cisterns, or raised by leaden pumps, possesses unwholesome properties. Free carbonic acid is evolved during the fermentation or decay of vegetable matter, and hence the propriety of preventing the leaves of trees falling into water-cisterns formed of lead.

To test the Richness of Lead Ores.—Lead ores, or galena, may be tested in different ways. The wet way is as follows: Digest 100 grains of the ore in sufficient nitric acid diluted with a little water, apply heat to expel any excess of acid, and largely dilute the remainder with distilled water. Next add dilute hydrochloric acid, by drops, as long as it occasions a precipitate, and filter the whole, after being moderately heated, upon a small paper filter. Treat the filtered liquid with a stream of sulphureted hydrogen; collect the black precipitate, wash it, and digest it in strong nitric acid; when entirely dissolved, precipitate the lead with sulphuric acid dropped in it, evaporate the precipitate to dryness, the excess of sulphuric acid being expelled by a rather strong heat applied toward the end. The dry mass should be washed, dried, and exposed to slight ignition in a porcelain crucible. The resulting dry sulphate is equal to .68 per cent. of its weight in lead.

To anneal Steel.—For a small quantity. Heat the steel to a cherry red in a charcoal fire, then bury it in sawdust, in an iron box, covering the sawdust with ashes. Let it stay until cold. For a larger quantity, and when it is required to be very soft, pack the steel with cast iron (lathe or planer) chips in an iron box, as follows: Having at least ½ or ¾ inch in depth of chips in the bottom of the box, put in a layer of steel, then more chips to fill spaces between the steel, and also the ½ or ¾ inch space between the sides of box and steel, then more steel; and lastly, at least 1 inch in depth of chips, well rammed down on top of the steel. Heat to and keep at a red heat for from 2 to 4 hours. Do not disturb the box until cold.

To straighten Hardened Steel.—To straighten a piece of steel already hardened and tempered, heat it lightly, not enough to draw the temper, and you may straighten it on an anvil with a hammer, if really not dead cold. It is best, however, to straighten it between the centres of a lathe, if a turned article, or on a block of wood with a mallet. Warm, it yields readily to the blows of the mallet, but cold, it would break like glass.

To prevent the Corrosion of Copper and other Metals.—The best means of preventing corrosion of metals is to dip the articles first into a very dilute nitric acid, immerse them afterward in linseed oil, and allow the excess of oil to drain off. By this process metals are effectually prevented from rust or oxidation.

To clean Coppers and Tins.—These are cleaned with a mixture of rotten stone, soft soap, and oil of turpentine, mixed to the consistency of stiff putty. The stone should be powdered very fine and sifted; and a quantity of the mixture may be made sufficient to last for a long while. The articles should first be washed with hot water, to remove grease. Then a little of the above mixture, mixed with water, should be rubbed over the metal; then rub off briskly, with dry clean rag or leather, and a beautiful polish will be obtained. When tins are much blackened by the fire they should be scoured with soap, water, and fine sand.

To find the percentage of Lead in Lead Ores.—This can be done by applying the test in the wet way and multiplying the weight of the product obtained in grains by .68. It may also be found in the dry way, as follows: Plunge a conical wrought-iron crucible into a blast furnace, raised to as high a heat as possible; when the crucible has become of a dull red heat, introduce into it 1,000 grains galena (lead ore) reduced to powder, and stir it gently with a piece of stiff iron wire flattened at the end. This wire must never be suffered to get red hot. To prevent the ore from adhering, after 3 or 4 minutes, cover up the crucible; and when at a full cherry-red heat, add 2 or 3 spoonfuls of reducing flux, and bring to a full white heat; in 12 to 15 minutes, after having scraped down the scoria, etc., from the sides of the crucible, into the melted mass, the crucible should be removed from the fire, and the contents tilted into a small brass mould, observing to run out the metal free from scoria, by raking the latter back with a piece of green wood. The scoria is then reheated in the crucible with ½ spoonful of flux, and this second reduction added to the first. The weight in grains of the metal obtained, divided by 10, gives the percentage of metallic lead in the sample of ore.

To temper Picks.—After working the steel carefully, prepare a bath of lead heated to the boiling point, which will be indicated by a slight agitation of the surface. In it place the end of the pick to the depth of 1½ inches, until heated to the temperature of the lead, then plunge immediately in clear cold water. The temper will be just right, if the bath is at the temperature required. The principal requisities in making mill picks are: First, get good steel. Second, work it at a low heat; most blacksmiths injure steel by overheating. Third, heat for tempering without direct exposure to the fire. The lead bath acts merely as protection against the heat, which is almost always too great to temper well.

To blue small Steel Articles.—Make a box of sheet iron, fill it with sand, and subject it to a great heat. The articles to be blued must be finished and well polished. Immerse the articles in the sand, keeping watch of them until they are of the right color, when they should be taken out and immersed in oil.

To restore burnt Cast Steel.—Take $1\frac{1}{2}$ lbs. borax, $\frac{1}{2}$ lb. sal-ammoniac, $\frac{1}{4}$ lb. prussiate of potash, 1 oz. resin. Pound the above fine, add a gill each of water and alcohol. Put in an iron kettle, and boil until it becomes a paste. Do not boil too long, or it will become hard on cooling.

To temper Drills.—Heat the best steel to a cherry red, and hammer until nearly cold, forming the end into the requisite flattened shape, then heat it again to a cherry red and plunge it into a lump of resin or into quicksilver. A solution of cyanide of potassium in rain-water is sometimes used for the tempering plunge-bath, but it is not as good as quicksilver or resin.

To temper Gravers.—These may be tempered in the same way as drills; or the red-hot instrument may be pressed into a piece of lead, in which a hole about $\frac{1}{3}$ an inch deep has been cut to receive the graver; the lead melting around and inclosing it will give it an excellent temper.

To temper Old Files.—Grind out the cuttings on one side, until a bright surface is obtained; then damp the surface with a little oil, and lay the file on a piece of red-hot iron, bright side upward. In about a minute the bright surface will begin to turn yellow; and when the yellow has deepened to about the color of straw, plunge in cold water.

To make Polished Steel Straw Color or Blue.—The surface of polished steel acquires a pale straw color at 460° Fahr., and a uniform deep blue at 580° Fahr.

Bath for hardening Picks.—Take 2 gallons rain-water, 1 ounce corrosive sublimate, 1 of sal-ammoniac, 1 of saltpetre, $1\frac{1}{2}$ pints rock salt. The picks should be heated to a cherry red, and cooled in the bath. The salt gives hardness, and the other ingredients toughness to the steel; and they will not break, if they are left without drawing the temper.

Composition for tempering Cast-Steel Mill Picks. To 3 gallons of water, add 3 ounces each nitric acid, spirits of hartshorn, sulphate of zinc, sal-ammoniac, and alum; 6 ounces salt, with a double handful of hoof-parings; the steel to be heated a dark cherry red. It must be kept corked tight to prevent evaporation.

Tempering Steel.—Mr. N. P. Ames, late of Chicopee, Mass., after expending much time and money in experiments, found that the most successful means of tempering swords and cutlasses that would stand the United States Government test, was by heating in a charcoal fire, hardening in pure spring water, and drawing the temper in charcoal flame.

Engraving Mixture for Writing on Steel.—Sulphate of copper, 1 ounce; sal-ammoniac, ½ ounce; pulverize separately, adding a little vermilion to color it, and mix with 1½ ounces vinegar. Rub the steel with soft soap and write with a clean hard pen, without a slit, dipped in the mixture.

To make Edge-Tools from Cast Steel and Iron.—This method consists in fixing a clean piece of wrought iron, brought to a welding heat, in the centre of a mould, and then pouring in melted steel, so as entirely to envelop the iron; and then forging the mass into the shape required.

Cement for fixing Metal to Leather.—Wash the metal in hot gelatine, steep the leather in hot gall-nut infusion, and unite while hot.

Cement for Gas Retorts.—A new cement, especially adapted to the retorts of gas-works, is very warmly recommended in a German gas-light journal. It consists of finely-powdered barytes and a soluble water-glass; or the barytes and a solution of borax. The joints are to be coated several times with this cement, by means of a brush. The addition of two-thirds of a part of clay improves the cement, and the retorts will then stand a red heat very well. Instead of the water-glass, a solution of borax may be used, or even finely powdered white glass.

Cement for Cloth, Leather, or Belting.—Take ale, 1 pint; best Russia isinglass, 2 ounces; put them into a common glue kettle and boil until the isinglass is dissolved; then add 4 ounces best glue, and dissolve it with the other; then slowly add 1½ ounces boiled linseed oil, stirring all the time while adding and until well mixed. When cold it will resemble india-rubber. To use this, dissolve what is needed in a suitable quantity of ale to the consistence of thick glue. It is applicable for leather, for harness, bands for machinery, cloth belts for cracker machines for bakers, &c., &c. If for leather, shave off as if for sewing, apply the cement with a brush while hot, laying a weight to keep each joint firmly for 6 to 10 hours, or over night.

Cement for Leather Belting.—Take of common glue and American isinglass, equal parts; place them in a glue-pot and add water sufficient to just cover the whole. Let it soak 10 hours, then bring the whole to a boiling heat, and add pure tannin until the whole becomes ropy or appears like the white of eggs. Apply it warm. Buff the grain off the leather where it is to be cemented; rub the joint surfaces solidly together, let it dry a few hours, and it is ready for use; and, if properly put together, it will not need riveting, as the cement is nearly of the same nature as the leather itself. We know of no cement better either for emery wheels or emery belts than the best glue. In an experience of fifteen years we never found anything superior.

Cement for fixing Metal to Marble, Stone, or Wood.—Mix together 4 parts carpenters' glue and 1 part Venice turpentine.

Cement to stop Flaws or Cracks in Wood of any Color.—Put any quantity of fine sawdust, of the same wood the work is made with, into an earthen pan, and pour boiling water on it, stir it well, and let it remain for a week or ten days, occasionally stirring it; then boil it for some time, and it will be of the consistence of pulp or paste; put it into a coarse cloth, and squeeze all the moisture from it. Keep for use, and, when wanted, mix a sufficient quantity of thin glue to make it into a paste; rub it well into the cracks, or fill up the holes in the work with it. When quite hard and dry, clean the work off, and, if carefully done, the imperfection will be scarcely discernible.

To cement Cloth to Polished Metal.—Cloth can be cemented to polished iron shafts, by first giving them a coat of best white lead paint; this being dried hard, coat with best Russian glue, dissolved in water containing a little vinegar or acetic acid.

Gutta-Percha Cement.—This highly recommended cement is made by melting together, in an iron pan, 2 parts common pitch and 1 part gutta-percha, stirring them well together until thoroughly incorporated, and then pouring the liquid into cold water. When cold it is black, solid, and elastic; but it softens with heat, and at 100° Fahr is a thin fluid. It may be used as a soft paste, or in the liquid state, and answers an excellent purpose in cementing metal, glass, porcelain, ivory, &c. It may be used instead of putty for glazing windows.

To dissolve India-Rubber for Cement, &c.—India-rubber dissolves readily in rectified sulphuric ether, which has been washed with water to remove alcohol and acidity; also in chloroform. These make odorless solutions, but are too expensive for general use. The gum dissolves easily in bisulphuret of carbon; or a mixture of 94 parts bisulphuret of carbon and 6 parts absolute alcohol; also in caoutchoucine. These dissolve the gum rapidly in the cold, and leave it unaltered on evaporation; they have a disagreeable odor, but they leave the india-rubber in better condition than most other solvents. Oil of turpentine, rendered pyrogenous by absorbing it with bricks of porous ware, and distilling it without water, and treating the product in the same way, is also used for this purpose. It is stated that the solution on evaporation does not leave the caoutchouc in a sticky state. Another method is to agitate oil of turpentine repeatedly with a mixture of equal weights of sulphuric acid and water, and afterward expose it to the sun for some time. Benzole, rectified mineral or coal tar naphtha, and oil of turpentine reduce the gum slowly by long digestion and trituration, with heat, forming a glutinous jelly which dries slowly, and leaves the gum when dry, very much reduced in hardness and elasticity. The fats and fixed oils combine readily with india-rubber by boiling, forming a permanently glutinous paste. India-rubber is rendered more readily soluble by first digesting it with a solution of carbonate of soda, or water of ammonia.

Cement for coating Acid Troughs.—Melt together 1 part pitch, 1 part resin, and 1 part plaster of Paris (perfectly dry).

Cement for Uniting Sheet Gutta-Percha to Leather.—For uniting sheet gutta-percha to leather, as soles of shoes, etc.: Gutta-percha, 50 pounds; Venice turpentine, 40 pounds; shellac, 4 pounds; caoutchouc, 1 pound; liquid storax, 5 pounds. In making the cement, the Venice turpentine should be first heated; then the gutta-percha and the shellac should be added; the order in which the other materials are added is not important. Care should be taken to incorporate them thoroughly, and the heat should be regulated, so as not to burn the mixture.

Case-Hardening is the operation of giving a surface of steel to pieces of iron, by which they are rendered capable of receiving great external hardness, while the interior portion retains all the toughness of good wrought iron. This is accomplished by heating the iron in contact with animal carbon, in close vessels. The articles intended to be case-hardened are put into the box with animal carbon, and the box made air-tight by luting it with clay. They are then placed in the fire and kept at a light-red heat for any length of time, according to the depth required. In half an hour after the box and its contents have been heated quite through, the hardness will scarcely be the thickness of a half dime; in an hour, double; and so forth, until the desired depth is acquired. The box is then taken from the fire, and the contents emptied into pure cold water. They can then be taken out of the water and dried (to keep them from rusting), by riddling them in a sieve with some dry sawdust; and they are then ready for polishing. Case-hardening is a superficial conversion of iron into steel. It is not always merely for economy that iron is case-hardened, but for a multitude of things it is preferable to steel, and answers the purpose better. Delicate articles, to keep from blistering while heating, may be dipped into a powder of burnt leather, or bones, or other coaly animal matter.

To case-harden.—Make a paste with a concentrated solution of prussiate of potash and loam, and coat the iron therewith; then expose it to a strong red heat, and when it has fallen to a dull red, plunge the whole into cold water.

To case-harden Polished Iron.—The iron, previously polished and finished, is to be heated to a bright red and rubbed or sprinkled over with prussiate of potash. As soon as the prussiate appears to be decomposed and dissipated, plunge the article into cold water. When the process of case-hardening has been well conducted, the surface of the metal proves sufficiently hard to resist a file. The last two plans are a great improvement upon the common method. By the application of the prussiate, as in the last receipt, any part of a piece of iron may be case-hardened, without interfering with the rest.

To case-harden with Charcoal.—The goods, finished in every respect but polishing, are put into an iron box, and covered with animal or vegetable charcoal, and cemented at a red heat for a period varying with the size and description of the articles operated on.

Moxon's Method of Case-Hardening.—Cow's horn or hoof is to be baked or thoroughly dried and pulverized, in order that more may be got into the box with the articles. Or bones reduced to dust answer the same purpose. To this add an equal quantity of bay salt; mix them with stale chamber-lye, or white wine vinegar; cover the iron with this mixture, and bed it in the same in loam, or inclose it in an iron box; lay it on the hearth of the forge to dry and harden; then put it into the fire, and blow till the lump has a blood-red heat, and no higher, lest the mixture be burnt too much. Take the iron out, and immerse it in water.

Improved Process of Hardening Steel.—Articles manufactured of steel for the purposes of cutting, are, almost without an exception, taken from the forger to the hardener without undergoing any intermediate process; and such is the accustomed routine, that the mischief arising has escaped observation. The act of forging produces a strong scale or coating, which is spread over the whole of the blade; this scale or coating is unequal in substance, varying in proportion to the degree of heat communicated to the steel in forging; it is almost impenetrable to the action of water when immersed for the purpose of hardening. Hence it is that different degrees of hardness prevail in nearly every razor manufactured; this is evidently a positive defect; and so long as it continues to exist, great difference of temper must exist likewise. Instead, therefore, of hardening the blade from the anvil, let it be passed immediately from the hands of the forger to the grinder; a slight application of the stone will remove the whole of the scale or coating, and the razor will then be properly prepared to undergo the operation of hardening with advantage. It is plain that steel in this state heats in the fire with greater regularity, and that, when immersed, becomes equally hard from one extremity to the other. To this may be added, that, as the lowest possible heat at which steel becomes hard is indubitably the best, the mode here recommended will be found the only one by which the process of hardening can be effected with a less portion of fire than is, or can be, required in any other way. These observations are decisive, and will, in all probability, tend to establish in general use what cannot but be regarded as a very important improvement in the manufacturing of edge steel instruments.

To case-harden Small Articles of Iron.—Fuse together, in an iron vessel or crucible, 1 part prussiate of potash and 10 parts common salt, and allow the article to remain in the liquid 30 minutes, then put them in cold water and they will be case-hardened.

To clean a Shot Gun.—Wrap clean tow around the cleaning rod; then take a bucket of tepid water—soap-suds if procurable—and run the rod up and down the barrel briskly until the water is quite black. Change the water until it runs quite clear through the nipple; pour clean tepid water down the barrel, and rub dry with fresh clean tow; run a little sweet oil on tow down the barrel for use. To clean the stock, rub it with linseed oil. If boiling hot water is used the barrel will dry sooner, and no fear need be apprehended of its injuring the temper of a fine gun. Some sportsmen use boiling vinegar, but we cannot recommend this method. The reason hot water does not injure the gun, is that boiling water is only 212° Fahr., and the gun was heated to 450° to give it its proper temper.

Grease for anointing Gun-Barrels on the Sea-Shore.—It is said that an ointment made of corrosive sublimate and lard will prove an effectual protection against the rusting of gun-barrels on the sea-shore.

To protect Polished Metal from Rust.—Take 10 pounds gutta-percha, 20 pounds mutton suet, 30 pounds beef suet, 20 gallons neats' foot oil, and 1 gallon rape oil. Melt together until thoroughly dissolved and mixed, and color with a small portion of rose pink: oil of thyme or other perfuming matter may be added. When cold the composition is to be rubbed on the surface of bright steel, iron, brass, or other metal, requiring protection from rust.

New Mode of removing Rust.—Plunge the article in a bath of 1 pint hydrochloric (muriatic) acid diluted with 1 quart water. Leave it there 24 hours; then take it out and rub well with a scrubbing-brush. The oxide will come off like dirt under the action of soap. Should any still remain, as is likely, in the corroded parts, return the metal to the bath for a few hours more, and repeat the scrubbing. The metal will present the appearance of dull lead. It must then be well washed in plain water several times, and thoroughly dried before a fire. Lastly, a little rubbing with oil and fine emery powder will restore the polish. Should oil or grease have mingled with the rust, it will be necessary to remove it by a hot solution of soda before submitting the metal to the acid. This last attacks the rust alone, without injuring the steel; but the washing in plain water is all-important, as, after the process, the metal will absorb oxygen from the atmosphere freely if any trace of the acid be allowed to remain.

Purification of Zinc.—Granulate zinc by melting, and pouring it, while very hot, into a deep vessel filled with water. Place the granulated zinc in a Hessian crucible, in alternate layers, with one-fourth its weight of nitre, with an excess of nitre at the top. Cover the crucible, and secure the lid; then apply heat. When deflagration takes place, remove from the fire, separate the dross, and run the zinc into an ingot mould. It is quite free from arsenic.

To remove Rust from Steel.—Rust may be removed from steel by immersing the article in kerosene oil for a few days. The rust will become so much loosened that it may easily be rubbed off. By this simple method badly rusted knives and forks may be made to present a tolerable appearance, but for new goods there is no way to remove rust from metal but by getting below it, or renewing the surface. Where it is not deep-seated, emery paper will do, but if long standing the goods must be refinished.

To protect Polished Steel from Rust.—Nothing is equal to pure paraffine for preserving the polished surface of iron and steel from oxidation. The paraffine should be warmed, rubbed on, and then wiped off with a woolen rag. It will not change the color, whether bright or blue, and will protect the surface better than any varnish.

Fine Light Yellow Brass.—Melt together 2 parts copper and 1 part zinc.

Bright Yellow Malleable Brass.—Melt together 7 parts copper and 3 parts zinc.

Deep Yellow Malleable Brass.—Melt together 4 parts copper and 1 part zinc.

Brass malleable whilst hot.—Melt together 3 parts copper and 2 parts zinc.

Red Brass.—Melt together 5 parts copper and 1 part zinc. As much as 10 parts of copper to 1 part of zinc may be used, the color being a deeper red for every additional part of copper employed.

Brass for Buttons.—Copper 8 parts and zinc 5 parts. This is the Birmingham platin.

Pale Brass for Buttons, &c.—Melt together 16 parts fine light yellow brass, 2 parts zinc, and 1 part tin.

Common Pale Brass.—Melt together 25 parts copper, 20 parts zinc, 3 parts lead, and 2 parts tin.

Fine Pale Brass for Castings.—Melt together 15 parts copper, 9 parts zinc, and 4 parts tin. This is rather brittle.

Dark Brass for Castings.—Melt together 90 parts copper, 7 parts zinc, 2 parts tin, and 1 part lead. The color will be still deeper by using 2 parts less of zinc and 1 part more each of copper and tin.

Pale Brass for Gilding.—Melt together 64 parts copper, 32 parts zinc, 3 parts lead, and 1 part tin.

Red Brass for Gilding.—Melt together 82 parts copper, 18 parts zinc, 3 parts tin, and 1 part lead.

Brass for Solder.—Melt together 12 parts fine yellow brass, 6 parts zinc, and 1 part tin. Used for ordinary brazing.

Pale Brass for Turning.—Melt together 98 parts fine brass and 2 parts lead.

Red Brass for Turning.—Melt together 65 parts copper, 33 parts zinc, and 2 parts lead.

Red Brass for Wire.—Melt together 72 parts copper and 28 parts zinc, properly annealed.

Pale Brass for Wire.—Melt together 64 parts copper, 34 parts zinc, and 2 parts lead.

To make Brass which expands by Heat equally with Iron.—It is difficult to make a permanent joint between brass and iron, on account of their unequal expansion by heat. In a recent issue of the journal of "Applied Chemistry," a new alloy is given, for which the inventor claims an expansion by heat so nearly similar to that of iron as to allow of a union between them, which, for all practical purposes, is permanent. This consists of a mixture of 79 parts copper, 15 parts zinc, and 6 parts tin.

To harden Brass.—Brass is tempered or hardened by rolling or hammering: consequently, if any object is to be made of tempered brass, the hardening must be done before working it into the required shape.

To soften Brass.—Heat it to a cherry red, and plunge it into water.

To cover Brass with beautiful Lustre Colors.—Dissolve 1 ounce cream of tartar in 1 quart of boiling water; then add ½ ounce protochloride of tin dissolved in 4 ounces cold water. Next heat the whole to boiling, and decant the clear solution from a trifling precipitate, and pour, under continual stirring, into a solution of 3 ounces hyposulphate of soda in ½ pint water, then heat again to boiling and filter from the separated sulphur. This solution produces on brass the various lustre colors, depending on the length of time during which the articles are allowed to remain in it. The colors at first will be light to dark gold yellow, passing through all the tints of red to an iridescent brown. A similar series of colors is produced by sulphide of copper and lead, which, however, are not remarkable for their stability, whether this defect will be obviated by the use of the tin solution, experience and time alone can show.

Alloys of Platinum and Copper.—A compound of 1 part platinum and 4 parts copper is of a yellow-pink color, hard, ductile, and susceptible of a fine polish.

An alloy of 3 parts platinum and 2 parts copper is nearly white, very hard, and brittle.

Red Tombac.—Put into a crucible 5½ pounds copper; when fused add ½ pound zinc; these metals will combine, forming an alloy of a reddish color, but possessing more lustre than copper, and also greater durability.

White Tombac.—When copper is combined with arsenic, by melting them together in a close crucible, and covering the surface with common salt to prevent oxidation, a white brittle alloy is formed.

French Bell-Metal.—The metal used in France for hand-bells, clock-bells, etc , is made of 55 to 60 parts copper, 30 to 40 parts tin, and 10 to 15 parts zinc.

Alloy of Nickel and Copper.—A mixture of 1 part nickel and 2 parts copper produces a grayish-white metal, tenacious, ductile, and moderately fusible.

To put a Black Finish on Brass Instruments.—Make a strong solution of nitrate of silver in one dish, and of nitrate of copper in another. Mix the two together, and plunge the brass in it. Now heat the brass evenly till the required degree of dead blackness is obtained. This is the method of producing the beautiful dead black so much admired in optical instruments, and which was so long kept a secret by the French.

Speculum Metal for Telescopes.—Melt 7 pounds of copper, and when fused add 3 pounds zinc and 4 pounds tin. These metals will combine to form a beautiful alloy of great lustre, and of a light yellow color, fitted to be made into specula for telescopes. Mr. Mudge used only copper and grain tin, in the proportion of 2 pounds of the former to 14½ ounces of the latter.

Phosphor Bronzes.—A great advance has lately been made in the construction of bronzes, by the addition of a small percentage of phosphorus, although the precise function of this substance has not been hitherto well understood. According to Levi and Kunzel, however, one cause of the inferiority in bronze consists in the constant presence of traces of tin in the state of an oxide, which acts mechanically by separating the molecules of the alloy, thus interposing a substance which in itself has no tenacity. The addition of phosphorus reduces this oxide, and renders the alloy much more perfect, improving its color, its tenacity, and all its physical properties. The grain of its fracture resembles more that of steel, its elasticity is much augmented, and its resistance to pressure sometimes more than doubled. Its durability is greater, and when melted it is of greater fluidity, and fills the mould in its finest details.

To clean Bronze.—It was observed in Berlin that those parts of a bronze statue which were much handled by the public retained a good surface, and this led to the conclusion that fat had something to do with it. An experiment was therefore tried for some years with four bronzes. One, says our authority—Chambers' Journal—was coated every day with oil, and wiped with a cloth; another was washed every day with water; the third was similarly washed, but was oiled twice a year; and the fourth was left untouched. The first looked beautifully; the third, which had been oiled twice a year, was passable; the second looked dead; and the fourth was dull and black.

Gongs and Cymbals.—The secret method employed by the Chinese for working the hard brittle bronze used for making gongs and cymbals, seems to be solved by the fact that the bronze of which these instruments are made, consisting of copper alloyed with about 20 per cent. of tin, and almost as brittle as glass at ordinary temperatures, becomes as malleable as soft iron, if worked at a dull red heat. This discovery was recently made in Paris by MM. Julien and Champion, the result of experiments at the Paris Mint.

Fontainemoreau's Bronzes.—This is a kind of bronze known as Fontainemoreau's bronze, in which zinc predominates. It is said to answer well for chill moulding, that is, for pouring in metal moulds, by which method it is rendered very homogeneous. The crystalline nature of the zinc is entirely changed by the addition of a small proportion of copper, iron, etc. The alloy is hard, close-grained, and resembles steel. Moreover, it is easier to file than either zinc or copper. The following table presents the proportions in use:

Zinc.	Copper.	Cast Iron.	Lead.
90	8	1	1
91	8	0	1
92	8	0	0
92	7	1	0
97	2½	½	0
97	3	0	0
99½	0	½	0
99	1	0	0

Use of Petroleum in turning Metals.—A bronze composed of seven parts of copper, 4 of zinc, and 1 of tin, has been found to be so hard as to be difficult to work, and yet of considerable value in certain ways when worked. Various methods have been attempted, aiming at effecting a ready working of this alloy, and M. Bechstein has recently, by soaking the alloy in petroleum, attained this desirable end.

Expansion Metal.—Melt together 9 parts of lead, 2 parts of antimony, and 1 part bismuth.

Tutenag.—Melt together 8 parts of copper, 5 parts of zinc, and 3 parts of nickel.

Wood's Patent Fusible Metal melts between 150° and 160° Fahr. It consists of 3 parts cadmium, 4 tin, 8 lead, and 15 bismuth. It has a brilliant metallic lustre, and does not tarnish readily.

Fluid Alloy of Sodium and Potassium.—If 4 parts sodium are mixed with 2½ potassium, the alloy will have exactly the appearance and consistency of mercury, remaining liquid at the ordinary temperature of the air.

Fusible Alloys.—Bismuth, 8 parts; lead, 5 parts; tin, 3 parts; melt together. Melts below 212° Fahr. Or: Bismuth, 2 parts; lead, 5 parts; tin, 3 parts. Melts in boiling water. Or: Lead, 3 parts; tin, 2 parts; bismuth, 5 parts; mix. Melts at 197° Fahr. The above are used to make toy-spoons, to surprise children by their melting in hot tea or coffee; and to form pencils for writing on asses' skin, or paper prepared by rubbing burnt hartshorn into it. The last may be employed as an anatomical injection, by adding (after removing it from the fire) 1 part quicksilver (warm). Liquid at 172°, solid at 140° Fahr.

Engestroom Tutania.—Melt together 4 parts copper, 8 parts regulus of antimony, and 1 part bismuth. When added to 100 parts of tin, this compound will be ready for use.

The most Fusible Alloy.—There is an alloy of bismuth, tin, and lead, which, from its very low melting point, is called fusible metal. Dr. Von Hauer has found, however, that the addition of cadmium to the alloys of the above-mentioned metals reduces their melting point still lower. An alloy of 4 volumes cadmium, with 5 volumes each tin, lead, and bismuth, is quite liquid at 150° Fahr. In parts by weight, the above would be 224 parts cadmium, 517½ lead, 295 tin, and 1050 bismuth. An alloy of 3 volumes of cadmium, with 1 each of tin, lead, and bismuth, fuses at 153½° Fahr., and an alloy of 1 equivalent of cadmium with 2 equivalents each of these three other metals, at 155½°, which is also the fusing point of an alloy of 1 part each of all the four metals. Dr. Von Hauer made these alloys by fusing their ingredients in a covered porcelain crucible at the lowest practicable temperature. They all become pasty at lower temperatures than those given above; the temperatures quoted are those at which the alloys are perfectly fluid. It should be added that, unfortunately, all these alloys very rapidly oxidize when placed in water.

Brass Solder for brazing Iron or Steel.—Thin plates of brass are to be melted between the pieces that are to be joined. If the work be very fine—as when two leaves of a broken saw are to be brazed together—cover it with pulverized borax, dissolved in water, that it may incorporate with some brass powder which is added to it; the piece must be then exposed to the fire without touching the coals, and heated till the brass is seen to run.

To tin Iron for Soldering, &c.—Drop zinc shavings into muriatic (hydrochloric) acid, until it will dissolve no more; then add ¼ its bulk of soft water. Iron, however rusty, will be cleansed by this solution, and receive from it a sufficient coating of zinc for solder to adhere to.

To solder gray Cast Iron.—First dip the castings in alcohol, after which, sprinkle muriate of ammonia (sal-ammoniac) over the surface to be soldered. Then hold the casting over a charcoal fire till the sal-ammoniac begins to smoke, then dip it into melted tin (not solder). This prepares the metal for soldering, which can then be done in the ordinary way.

To solder Ferrules for Tool Handles.—Take the ferrule, lap round the jointing a small piece of brass wire, then just wet the ferrule, scatter ground borax on the joining, put it on the end of a wire, and hold it in the fire till the brass fuses. It will fill up the joining, and form a perfect solder. It may afterward be turned in the lathe.

Solder for Iron.—Fuse together 67 parts copper and 33 parts zinc. Or: 60 parts copper and 40 parts zinc.

Hard Solder for Copper or Brass.—Take 13 parts copper and 1 part zinc. Or: 7 copper, 3 zinc, and 2 tin.

Solder for Brass in General.—Take 4 parts of scraps of the metal to be soldered, and 1 part zinc.

To make Solder-Drops.—Melt the solder and pour it in a steady stream of about ⅛ inch in diameter, from a height of 2 or 3 inches, into cold water; taking care that the solder, at the time of pouring, is no hotter than is just necessary for fluidity.

Aluminum Solder.—Mouray employs five different solders, being different proportions of zinc, copper, and aluminum. The copper is melted first, the aluminum is then added in 3 or 4 portions; when the whole is melted, it is stirred with an iron rod. The crucible is then withdrawn from the fire, the zinc gradually stirred into the mass, and the whole poured into ingot-shaped moulds, previously wiped out with benzine. The parts given in the following proportions are by weight.

1.—80	parts	zinc,	8	parts	copper,	12	parts	aluminum.
2.—85	"	"	6	"	"	9	"	"
3.—88	"	"	5	"	"	7	"	"
4.—90	"	"	4	"	"	6	"	"
5.—94	"	"	2	"	"	4	"	"

To solder Aluminum.—The selection of either of the above solders depends upon the nature of the object. In order to quicken its fusion on the metal, a mixture of 3 parts balsam of copaiba and 1 part Venice turpentine is made use of; otherwise the operation is performed in exactly the same manner as in the brazing of other metals. The aluminum solder is spread without delay on the previously heated surfaces to be fastened together. In heating, the blue gas flame or the turpentine blast lamp is employed. The more and oftener the solder is spread over the surface, the better it is.

Aluminum Solder.—If soft solder is fused with one-half, one-fourth, or one-eighth of its weight of zinc amalgam (to be made by dissolving zinc in mercury), a more or less hard and easily fusible solder is obtained, which may be used to solder aluminum to itself or to other metals.

Welding Composition.—Fuse borax with 1-16 its weight of sal-ammoniac; cool, pulverize, and mix with an equal weight of quicklime, when it is to be sprinkled on the red-hot iron and the latter replaced in the fire.

Welding Powder for Iron and Steel.—For welding iron and steel a composition has lately been patented in Belgium, consisting of iron filings, 40 parts; borax, 20 parts; balsam of copaiba, or some other resinous oil, 2, and sal-ammoniac, 3 parts. They are mixed, heated, and pulverized. The process of welding is much the same as usual. The surfaces to be welded are powdered with the composition, and then brought to a cherry-red heat, at which the powder melts, when the portions to be united are taken from the fire and joined. If the pieces to be welded are too large to be both introduced at the same time into the forge, one can be first heated with the welding powder to a cherry-red heat, and the others afterward to a white heat, after which the welding may be effected.

Welding Composition for Cast Steel.—Take borax, 10 parts; sal-ammoniac, 1 part; grind or pound them roughly together, then fuse them in a metal pot over a clear fire, taking care to continue the heat until all spume has disappeared from the surface. When the liquid appears clear, the composition is ready to be poured out to cool and concrete; afterward, being ground to a fine powder, it is ready for use. To use this composition, the steel to be welded is first raised to a bright yellow heat, it is then dipped among the welding powder, and again placed in the fire until it attains the same degree of heat as before; it is then ready to be placed under the hammer.

Welding Powder.—For iron or steel, or both together, calcine and pulverize together 100 parts iron or steel filings, 10 sal-ammoniac, 6 borax, 5 balsam of copaiba. One of the pieces is to be heated red, carefully cleaned of scale, the composition is to be spread upon it, and the other piece applied at a white heat and welded with the hammer.

Welding Composition.—Take 15 parts borax, 2 of sal-ammoniac, and 2 of prussiate of potash. Being dissolved in water, the water should be gradually evaporated at a low temperature.

Welding Composition.—Mix 10 parts borax with 1 part sal-ammoniac; fuse the mixture, and pour it on an iron plate. When cold, pulverize it, and mix it with an equal weight of quicklime, sprinkle it on iron heated to redness, and replace it in the fire. It may be welded below the usual heat.

Compound for welding Steel.—The following composition is said to be superior to borax for welding steel. Mix coarsely powdered borax with a thin paste of Prussian blue; then let it dry.

Amalgam of Gold for gilding Brass, Copper, &c.—Place one part grain or leaf gold in a small iron saucepan or ladle, perfectly clean, then add 8 parts mercury, and apply a gentle heat, when the gold will dissolve; agitate the mixture for one minute with a smooth iron stirrer, and pour it out on a clean plate or stone slab. When cold it is ready for use.

Fluxes for Soldering and Welding.—

For Iron or steel.	Borax or sal-ammoniac.
" Tinned iron	Resin or chloride of zinc.
" Copper and brass	Sal-ammoniac or chloride of zinc.
" Zinc	Chloride of zinc.
" Lead	Tallow or resin.
" Lead and tin pipes	Resin and sweet oil.

To gild with Gold Amalgam.—For gilding brass, copper, &c. The metal to be gilded is first rubbed over with a solution of nitrate of mercury, and then covered with a very thin film of the amalgam. On heat being applied, the mercury volatilizes, leaving the gold behind. A much less proportion of gold is often employed than the above, where a very thin and cheap gilding is required, as, by increasing the quantity of the mercury, the precious metal may be extended over a much larger surface.

How to fasten Rubber to Wood and Metal.—As rubber plates and rings are now-a-days almost exclusively used for making connections between steam and other pipes and apparatus, much annoyance is often experienced by the impossibility or imperfectness of an air-tight connection. This is obviated entirely by employing a cement which fastens equally well to the rubber and to the metal or wood. Such cement is prepared by a solution of shellac in ammonia. This is best made by soaking pulverized gum-shellac in ten times its weight of strong ammonia, when a slimy mass is obtained, which, in three to four weeks, will become liquid without the use of hot water. This softens the rubber, and becomes, after volatilization of the ammonia, hard and impermeable to gases and fluids.

Marine Cement for uniting Leather to Gutta-Percha.—This will unite leather to gutta-percha, and is impervious to damp. It is made by dissolving by the aid of heat, 1 part india-rubber in naphtha, and when melted adding 2 parts shellac, and melting until mixed. Pour it while hot on metal plates to cool. When required for use, melt, and apply with a brush. This cement does not adhere very well to vulcanized rubber, and the joint is always weak.

Cement to unite India-Rubber.—Take 16 parts gutta-percha, 4 parts india-rubber, 2 parts common calker's pitch, 1 part linseed oil. The ingredients are melted together, and used hot. It will unite leather or rubber that has not been vulcanized.

Gutta-Percha Cement for Leather Belts.—Dissolve a quantity of gutta-percha in chloroform in quantity to make a fluid of honey-like consistence. When spread it will dry in a few moments. Heat the surfaces at a fire or gas flame until softened, and apply them together. Small patches of leather can be thus cemented on boots, etc., so as almost to defy detection, and some shoemakers employ it with great success for this purpose. It is waterproof, and will answer almost anywhere unless exposed to heat, which softens it.

Antimonoid.—A welding powder, named antimonoid, has been in use for some time past in Germany, and found to be of great efficiency. The formula for its preparation has, until lately, been kept a secret; it consists of 4 parts iron turnings, 3 parts borax, 2 parts borate of iron, and 1 of water.

Caoutchouc Cement is made as follows:—Gutta-percha, 3 parts; virgin india-rubber (caoutchouc), 1 part (both cut small); pyrogenous oil of turpentine, or bisulphuret of carbon, 8 parts; mix in a close vessel, and dissolve by the heat of hot water. This cement should be gently heated before being used.

Cement for attaching Metal Letters to Plate Glass.—Copal varnish, 16 parts; drying oil, 6 parts; turpentine and oil of turpentine, of each 3 parts; liquefied glue (made with the least possible quantity of water), 5 parts. Melt together in a water-bath, and add fresh slacked lime (perfectly dry and in very fine powder), 10 parts.

Cement for Metal and Glass.—Mix 2 ounces of a thick solution of glue with 1 ounce of linseed oil varnish, or ¾ ounce Venice turpentine; boil them together, stirring them until they mix as thoroughly as possible. The pieces cemented should be tied together for 2 or 3 days. This cement will firmly attach any metallic substance to glass or porcelain.

To guard against Incrustation in Boilers.—Prof. Chandler recommends the following precautions: The use of the purest waters that can be obtained, rain-water wherever possible. Frequent use of the blow-off cock. That the boilers never be emptied while there is fire enough to harden the deposit. Frequent washing out. Experiments on the efficacy of zinc, lime-water, carbonate of soda, carbonate of baryta, chloride of ammonium, some substance containing tannic acid, linseed meal, and the electro-magnetic inductor.

Management of the Water to prevent Boiler Incrustation.—Blowing off. The frequent blowing off of small quantities of water, say a few gallons at a time, is undoubtedly one of the most effective and simple methods for removing sediments and preventing their hardening on the sides of the boiler. The water entering the boiler should be directed in such a way as to sweep the loose particles toward the blow-off cocks, that when these are open they may be carried out with the water. This blowing off should take place at least two or three times daily, perhaps much oftener.

To preserve Timber from Decay and Dry-Rot.—The best way to preserve timber exposed to the action of the weather is to force into the pores of well-seasoned wood as much carbolic acid or creosote as possible. This soon resinifies, and most effectually preserves the timber from dry-rot and decay. On a large scale, as for railway sleepers, expensive appliances are needed; but for barns or outbuildings it may be applied to considerable advantage by the use of a paint brush.

To fasten Chamois and other Leather to Iron and Steel.—Dr. Carl W. Heinischen, of Dresden, gives the following receipt for the above purpose: Spread over the metal a thin, hot solution of good glue; soak the leather with a warm solution of gall-nuts before placing on the metal, and leave to dry under an even pressure. If fastened in this manner it is impossible to separate the leather from the metal without tearing it.

Incrustation in Boilers.—The only effectual remedy is to blow out frequently. Blow out once a week at least 10 per cent. of the water in the boilers. It should be done while the water is at rest, that is, before starting in the feed water. A practical engineer says: Our boilers were badly incrusted. We loosened the scale with chisels and kerosene oil, and after running them a year as above, they came out as clean and bright as could be.

Scale in Boilers.—A practical engineer recommends the following: Get some cow or ox feet, just as they are cut off in the slaughter-house, put them in a wire net fine enough to detain the small bones from getting from the boiler into the blow-off pipe. Use 5 of the feet to a 6 horse-power boiler, and no further trouble with scale in the boilers will be experienced. They must be replaced every two or three months, according to the quality of the water. They do not make the water foam.

Solution to preserve Wood.—With every 25 gallons of water required, mix 5 pounds chloride of zinc. Wood steeped in this solution will effectually resist dry-rot.

To kyanize Wood or Cordage.—Immerse the wood or cordage in a solution of 50 or 60 parts water and 1 part corrosive sublimate. This preserves it from decay, and renders wood tough and more difficult to split.

To preserve and harden Wood. Wood steeped in a solution of copperas becomes harder and more indestructible.

German Receipt for coating Wood with a Substance as hard as Stone.—Melt together 40 parts chalk, 50 resin, and 4 linseed oil; to this should be added 1 part oxide of copper, and afterward 1 part sulphuric acid. This last ingredient must be added carefully. The mixture, while hot, is applied with a brush, and forms, when dry, a varnish as hard as stone. This is an excellent application to protect posts, tubs, or other wooden articles which are set in the earth.

To prevent the Splitting of Logs and Planks.—Logs and planks split at the ends because the exposed surface dries faster than the inside. Saturate muriatic acid with lime, and apply like whitewash to the ends. The chloride of calcium formed attracts moisture from the air and prevents the splitting. Tobacconists' signs, and other wooden images, have usually a hole bored through their centre, from top to bottom; this in a great measure prevents the outer surface from cracking, by allowing the wood to dry and shrink more uniformly.

To petrify Wooden Objects.—Take equal quantities of gem-salt, rock-alum, white vinegar, chalk, and pebbles, powdered. Mix all these ingredients; ebullition will ensue. After it has ceased, throw some wooden objects into this liquid, and let them soak for 4 or 5 days, at the end of which time they will be transformed into petrifactions.

To preserve Wood under Water.—Wood impregnated with creosote oil has been found to resist effectually the ravages of the teredo worm; this worm being the cause of decay by honeycombing the entire substance of the wood. In Germany chloride of zinc is used for this purpose, the timber being placed in boilers, partly exhausted of air, and the vapor of chlorine thus driven into it. These remedies are recommended by a committee of practical experts, appointed by the Academy of Sciences in Holland, to ascertain the best means for preserving timber under water.

Preservation of Wood.—Armand Muller has instituted some interesting experiments on this subject, and arrives at the conclusion that the phosphate of baryta, formed by the mutual decomposition of phosphate of soda and chloride of barium, in the pores of the wood, is one of the best preservative agents available to chemists. Soak the wood 5 days in a 7 per cent. solution of phosphate of soda, and, after drying, suspend in a 13 per cent. solution of chloride of barium for 7 days. It is believed that wood thus prepared will withstand the action of moisture better than with any other preparation. The chief obstacle to the use of such chemicals is in their cost.

To coat Copper Plates with Brass.—Expose the plates, heated sufficiently, to the fumes of zinc. Zinc boils and is vaporized by heating it to a white heat.

To coat the Inside of Copper Vessels with Brass.—Dissolve 1 part zinc amalgam in 2 parts muriatic acid; add 1 part argol (crude tartar), and add sufficient water to fill the vessel; then boil it in the vessel.

Graeger's Process for covering Iron and Steel with Copper without a Battery.—The objects are first well cleaned, and then painted over with a solution of protochloride of tin, and immediately afterward with an ammoniacal solution of sulphate of copper. The layer of copper thus produced adheres so firmly to the iron or steel, that the different objects can be rubbed and polished with fine chalk without injuring the deposit. The tin solution is prepared with 1 part crystallized chloride of tin, 2 parts water, and 2 parts hydrochloric acid. The copper solution, with 1 part sulphate of copper, 16 parts water, adding ammonia sufficient to redissolve the precipitate first thrown down by it. Zinc and galvanized iron can be treated, according to Boettger, directly by the copper solution, without using the tin salt. The above process may be found useful by gilders, and for various ornamental purposes.

To deposit Copper upon Cast Iron.—The pieces of cast iron are first placed in a bath made of 50 parts hydrochloric acid, specific gravity 1.105, and 1 part nitric acid; next, in a second bath, composed of 10 parts nitric acid, 10 parts of chloride of copper, dissolved in 80 parts of the same hydrochloric acid as just alluded to. The objects are rubbed with a woolen rag and a soft brush, next washed with water, and again immersed until the desired thickness of copper is deposited. When it is desired to give the appearance of bronze, the copper surface is rubbed with a mixture of 4 parts sal-ammoniac and 1 part each oxalic and acetic acids dissolved in 30 parts water.

Weil's Process for coating Iron with Copper.—This process yields a coating of copper of great brightness and strong cohesion. The object, whether of cast or wrought iron is freed from rust by immersion for from 5 to 10 minutes in water containing 2 per cent. of muriatic acid, and subsequent scrubbing for ¼ hour with a wire brush and sand, then washing in water until all traces of acid are removed. It is then covered with zinc wire in spiral turns of about 6 inches from each other, which also serves as a means of suspension. The bath consists of a solution of 8 parts caustic soda in 100 parts water, of which 11 quarts are mixed with 50 ounces Rochelle salts and 12½ ounces sulphate of copper, making a liquid of a density equal to 19° Baumé. It retains its activity as long as the copper is kept replaced, and deposition from it proceeds with great regularity. The material of the vessel is best when made of wood, lined with gutta-percha, and covered with a wooden lid. When the coating is of sufficient thickness, the object is removed from the bath, first washed with water slightly acidified with sulphuric acid, and then with pure water until the disappearance of all traces of acid; after this it passes into a drying-room heated to 132° Fahr. The bronzing, when required, is obtained by a bath of sulphide of sodium, or by means of the same bath as above, somewhat modified, that is, by increasing the proportion of copper to a threefold, in which case the bath no longer deposits copper, but, to all appearances, bronze. By reducing the points of contact between the iron and wire, though retaining the spiral turns at uniform distances, the deposit gradually assumes a number of colors in the following series, viz.: orange, silver-white, pale yellow, golden yellow, carmine, green, brown, and dark bronze. As soon as the desired color is attained, the object is washed in warm water, and again dried at 132°. Between each subsequent change of color is an interval of about 5 minutes. The reaction is more decided when the alkaline reaction of the bath is stronger. For indoor work or ornaments the time of immersion may vary from 3 to 72 hours; for outdoor objects a much longer time would be necessary.

To tin a Copper Vessel.—Boil the copper vessel with a solution of stannate of potassa mixed with tin borings, or boil with tin filings and caustic alkali or cream of tartar. In a few minutes a layer of pure tin will be firmly attached.

To tin Iron Pots and other Domestic Articles.—The articles are cleaned with sand, and, if necessary, with acid, and put then in a bath, prepared with 1 ounce cream of tartar, 1 ounce tin salt (protochloride of tin), 10 quarts water. This bath must be kept at a temperature of 190° Fahr., in a stoneware or wooden tank. Bits of metallic zinc are put into and between the different pieces. When the coat of tin is considered thick enough, the articles are taken out of the fluid, washed with water, and dried.

To tin by the Moist Way.—Make a solution of 1 part protochloride of tin in 10 parts water, to which add a solution of 2 parts of caustic soda in 20 parts water; the mixture becomes turbid, but this does not affect the tinning operation, which is effected by heating the objects to be tinned in this fluid, care being taken, at the same time, to place in the liquid a piece of perforated block tin plate, and to stir up the fluid during the tinning with a rod of zinc.

To tin Iron without the Aid of Heat.—To 105 quarts water are added 6½ pounds rye meal; this mixture is boiled for 30 minutes, and next filtered through cloth; to the clear but thickish liquid are added 2.3 pounds pyrophosphate of soda, 37½ pounds protochloride of tin in crystals (so-called tin salt), 147½ pounds neutral protochloride of tin, 3½ to 4 ounces sulphuric acid; this liquid is placed in well-made wooden troughs, and serves more especially for the tinning of iron and steel wire (previously polished) for the use of carding machines. When, instead of the two salts of tin just named, cyanide of silver and cyanide of potassium are taken, the iron is perfectly silvered.

To cleanse Iron for Tinning.—The metal must be cleansed by immersion in an acid solution; for new metal, this solution should be sulphuric acid and water, but for old metal, muriatic acid and water; next scour with sand, and cleanse well with water.

To tin Iron.—First cleanse as above, then heat the article just hot enough to melt the tin, rub the surface over with a piece of sal-ammoniac, and sprinkle some of the sal-ammoniac in powder over it; then apply the tin and wipe it over evenly with a piece of tow.

Cold Tinning.—Rub pure tinfoil and quicksilver together until the amalgam becomes soft and fusible, clean the surface to be tinned with spirits of salt (hydrochloric acid), and, while moist, rub the amalgam on, and then evaporate the quicksilver by heat.

To tin Cast Copper or Brass.—Make a saturated solution of oxide of tin (tin putty), in potash lye; add to the solution some tin filings or shavings; make it as hot as possible; then introduce the brass or copper and it will be tinned in a few seconds.

Stolba's method of tinning Copper, Brass, and Iron in the Cold, and without Apparatus. The object to be coated with tin must be entirely free from oxide or rust. It must be carefully cleaned, and care be taken that no grease spots are left; it makes no difference whether the object be cleaned mechanically or chemically. Two preparations are requisite for the purpose of tinning Zinc powder—the best is that prepared artificially by melting zinc and pouring it into an iron mortar. It can be easily pulverized immediately after solidification; it should be about as fine as writing sand. A solution of protochloride of tin, containing 5 to 10 per cent., to which as much pulverized cream of tartar must be added as will go on the point of a knife.

The object to be tinned is moistened with the tin solution, after which it is rubbed hard with the zinc powder. The tinning appears at once. The tin salt is decomposed by the zinc, metallic tin being deposited. When the object tinned is polished brass or copper, it appears as beautiful as if silvered, and retains its lustre for a long time. This method may be used in a laboratory to preserve iron, steel, and copper apparatus from rust; and would become of great importance if the tinning could be made as thick as in the dry way, but this has not as yet been accomplished.

To tin Copper Tubes.—W. Wollweber recommends for still-worms copper tubes tinned inside in the following manner: To a solution of Rochelle salts a solution of salts of tin is added; a precipitate of stannous tartrate is formed, which is washed and then dissolved in caustic lye. The copper tube, which has first been rinsed with sulphuric acid and then washed, is then filled with the alkaline solution, warmed a little, and touched with a tin rod, which causes the deposition of a coat of metallic tin.

To tin a worn Copper Kettle.—A thick coating may be obtained by preparing a tinning solution of zinc dissolved in muriatic acid, making the solution as thick or heavily charged with zinc as possible, adding a little sal-ammoniac. Clean the inside of the kettle, place it in a charcoal fire until a piece of block tin placed inside melts, then rub the melted tin, with some of the tinning solution, quickly on the copper surface, by means of a ball of oakum and a little powdered resin; the tin will readily adhere. Wrought iron and steel may be tinned in the same manner.

Fine Green Bronze.—Dissolve 2 ounces verdigris and 1 ounce sal-ammoniac in 1 pint vinegar, and dilute the mixture with water until it tastes but slightly metallic, when it must be boiled for a few minutes, and filtered for use. Copper medals, &c., previously thoroughly cleaned from grease and dirt, are to be steeped in the liquor at the boiling point, until the desired effect is produced. Care must be taken not to keep them in the solution too long. When taken out, they should be carefully washed in hot water, and well dried. Gives an antique appearance.

To galvanize Iron.—The difference between galvanized plates, so-called, and "sheet-tin," is, that the latter is sheet-iron covered with a thin coating of block-tin, while the former is sheet-iron covered with a thin coating of zinc. To effect the latter result, the iron plates are first immersed in a cleansing bath of equal parts of sulphuric or muriatic acid and water, used warm. They are then scrubbed with emery or sand, to clean them thoroughly and detach all scales, if any are left; after which they are immersed in a preparing bath of equal parts of saturated solutions of chloride of zinc and chloride of ammonium, from which bath they are directly transferred to the fluid metallic bath, consisting of 20 chemical equivalents of zinc to 1 of mercury; or, by weight, 640 pounds of zinc to 166 of mercury, to which are added from 5 to 6 pounds of sodium. As soon as the iron has attained the temperature of this hot fluid bath, which is only 680° Fahr., it may be removed, and will then be found thoroughly coated with zinc. Care must be taken not to leave the plates too long immersed in this bath, as its affinity for iron is such that they may become dissolved. This is the case with thin plates of wrought-iron, which, even when $\frac{1}{8}$ inch thick, may be dissolved in a few seconds. It is safe, therefore, to let the bath previously act on some wrought iron, so that it dissolves a portion of it, in order to satisfy its inconveniently great affinity for this metal.

Green Bronzes for Figures and Busts.—Green bronzes require a little more time than those already described. They depend upon the formation of an acetate, carbonate, or other green salt of copper upon the surface of the metal. Steeping for some days in a strong solution of common salt will give a partial bronzing which is very beautiful, and, if washed in water and allowed to dry slowly, is very permanent. Sal-ammoniac may be substituted for common salt. Even a strong solution of sugar alone, or with a little acetic or oxalic acid, will produce a green bronze; so also will exposure to the fumes of dilute acetic acid, to weak fumes of hydrochloric acid, and to several other vapors. A dilute solution of ammonia allowed to dry upon the copper surface will leave a green tint, but not very permanent.

To bronze Brass Orange, Greenish Gray, and Violet Tint.—An orange tint, inclining to gold, is produced by first polishing the brass, and then plunging it for a few seconds into a neutral solution of crystallized acetate of copper, care being taken that the solution is completely destitute of all free acid, and possesses a warm temperature. Dipped into a bath of copper, the resulting tint is a grayish green, while a beautiful violet is obtained by immersing it for a single instant in a solution of chloride of antimony, and rubbing it with a stick covered with cotton. The temperature of the brass at the time the operation is in progress has a great influence upon the beauty and delicacy of the tint; in the last instance it should be heated to a degree so as just to be tolerable to the touch.

Bronzing with Bleaching Powder.—Electrotypes may be bronzed green, having the appearance of ancient bronze, by a very simple process. Take a small portion of bleaching powder (chloride of lime), place it in the bottom of a dry vessel, and suspend the medal over it, and cover the vessel; in a short time the medal will acquire a green coating, the depth of which may be regulated by the quantity of bleaching powder used, or the time that the medal is suspended in its fumes; of course, any sort of vessel, or any means by which the electrotype may be exposed to the fumes of the powder, will answer the purpose; a few grains of the powder is all that is required. According as the medal is clean or tarnished, dry or wet, when suspended, different tints, with different degrees of adhesion, will be obtained.

Moire Bronze.—A moire appearance, vastly superior to that usually seen, is produced by boiling the object in a solution of sulphate of copper. According to the proportions observed between the zinc and the copper in the composition of the brass article, so will the tints obtained vary. In many instances it requires the employment of a slight degree of friction with a resinous or waxy varnish, to bring out the wavy appearance characteristic of moire, which is also singularly enhanced by dropping a few iron nails into the bath.

French Bronze.—An eminent Parisian sculptor makes use of a mixture of ½ ounce sal-ammoniac, ½ ounce common salt, 1 ounce spirits of hartshorn, and 1 imperial quart of vinegar. A good result will also be obtained by substituting an additional ½ ounce sal-ammoniac, instead of the spirits of hartshorn. The piece of metal, being well cleaned, is to be rubbed with one of these solutions and then dried by friction with a clean brush. If the hue be found too pale at the end of 2 or 3 days, the operation may be repeated. It is found to be more advantageons to operate in the sunshine than in the shade.

To bronze Copper with Sulphur. When objects made of copper are immersed in melted sulphur mixed with lampblack, the objects so treated obtain the appearance of bronze, and can be polished without losing that aspect.

Antique Bronze. Dissolve 1 ounce sal-ammoniac, 3 ounces cream of tartar, and 6 ounces common salt, in 1 pint hot water; then add 2 ounces nitrate of copper, dissolved in ½ pint water; mix well, and apply it repeatedly to the article, placed in a damp situation, by means of a brush moistened therewith. This produces a very antique effect.

Bronzing Liquids for Tin Castings.—Wash them over, after being well cleaned and wiped, with a solution of 1 part sulphate of iron, and 1 part sulphate of copper, in 24 parts water; afterward with a solution of 4 parts verdigris in 11 of distilled vinegar; leave for an hour to dry, and then polish with a soft brush and crocus.

To bronze Iron Castings.—Iron castings may be bronzed by thorough cleaning and subsequent immersion in a solution of sulphate of copper, when they acquire a coat of the latter metal. They must be then washed in water.

Surface Bronzing.—This term is applied to the process of imparting to the surfaces of figures of wood, plaster of Paris, &c., a metallic appearance. This is done by first giving them a coat of oil or size varnish, and when this is nearly dry, applying with a dabber of cotton or a camel-hair pencil, any of the metallic bronze powders; or the powder may be placed in a little bag of muslin, and dusted over the surface, and afterward finished off with a wad of linen. The surface must be afterward varnished.

Beautiful Red Bronze Powder.—Mix together sulphate of copper, 100 parts; carbonate of soda, 60 parts; apply heat until they unite into a mass, then cool, powder, and add copper filings, 15 parts; well mix, and keep them at a white heat for 20 minutes, then cool, powder, wash thoroughly with water, and dry.

Gold-Colored Bronze Powder.—Verdigris, 8 ounces; tutty powder, 4 ounces; borax and nitre, each 2 ounces; bichloride of mercury, ¼ ounce; make them into a paste with oil, and fuse them together. Used in japanning as a gold color. Or: grind Dutch foil or pure gold leaf to an impalpable powder.

Bright Yellow Dye for Wood.—To every gallon of water necessary to cover the veneers, add 1 pound French berries; boil the veneers till the color has penetrated through; add some brightening liquid (see next receipt) to the infusion of the French berries, and let the veneers remain for 2 or 3 hours, and the color will be very bright.

Liquid for brightening and setting Colors.—To every pint of strong aquafortis, add 1 ounce grain tin, and a piece of sal-ammoniac the size of a walnut; set it by to dissolve, shake the bottle round with the cork out, from time to time: in the course of 2 or 3 days it will be fit for use. This will be found an admirable liquid to add to any color, as it not only brightens it, but renders it less likely to fade from exposure to the air.

Fine Blue Dye for Wood.—Into a clean glass bottle put 1 pound oil of vitriol, and 4 ounces best indigo pounded in a mortar (take care to set the bottle in a basin or earthen glazed pan, as it will effervesce), put the veneers into a copper or stone trough; fill it rather more than ⅓ with water, and add as much of the vitriol and indigo (stirring it about) as will make a fine blue, which you may know by trying it with a piece of white paper or wood; let the veneers remain till the dye has struck through. The color will be much improved if the solution of indigo in vitriol be kept a few weeks before using it. The color will also strike better if the veneers be boiled in plain water till completely soaked through, and left for a few hours to dry partially, previous to immersing them in the dye.

Bright Green Dye for Wood.—Proceed as in either of the previous receipts to produce a yellow: but instead of adding aquafortis or the brightening liquid, add as much vitriolated indigo as will produce the desired color.

Bright Red Dye for Wood.—To 2 pounds genuine Brazil dust add 4 gallons water; put in as many veneers as the liquor will cover; boil them for 3 hours, then add 2 ounces alum and 2 ounces aquafortis, and keep it lukewarm until it has struck through.

Red Dye for Wood.—To every pound of logwood chips add 2 gallons of water; put in the veneers, and boil as in the last; then add a sufficient quantity of the brightening liquid, till the color is of a satisfactory tint; keep the whole as warm as you can bear your finger in it, till the color has sufficiently penetrated. The logwood chips should be picked from all foreign substances with which it generally abounds, as bark, dirt, &c.; and it is always best when fresh cut, which may be known by its appearing of a bright red color; for if stale, it will look brown, and not yield so much coloring matter.

Rose-colored Dye for Wood.—Monier produces a fine pink or rose-color on wood of cellulose, especially that of the ivory nut, by immersing it first in a solution of iodide of potassium, $1\frac{1}{4}$ ounces per pint of water, in which it remains for several hours, when it is placed in a bath of corrosive sublimate, 135 grains to the pint. When properly dyed it is washed and varnished over. We should think that less poisonous materials might be found to answer the same purpose.

Bright Purple Dye for Wood.—Boil 2 pounds logwood, either in chips or powder, in 4 gallons water, with the veneers; after boiling till the color is well struck in, add by degrees vitriolated indigo till the purple is of the shade required, which may be known by trying it with a piece of paper; let it then boil for 1 hour, and keep the liquid in a milk-warm state till the color has penetrated the veneer. This method, when properly managed, will produce a brilliant purple.

Yellow Brass, FOR TURNING.—(Common article.)—Copper, 20 lbs.; zinc, 10 lbs.; lead, from 1 to 5 ozs. Put in the lead last before pouring off.

Red Brass, FOR TURNING.—Copper, 24 lbs.; zinc, 5 lbs.; lead, 8 ozs. Put in the lead last before pouring off.

Red Brass, FOR TURNING.—Copper, 160 lbs.; zinc, 50 lbs.; lead, 10 lbs.; antimony, 44 ozs.

Another Brass, FOR TURNING.—Copper, 32 lbs. zinc, 10 lbs; lead, 1 lb.

Best Red Brass, FOR FINE CASTINGS.—Copper, 24 lbs.; zinc, 5 lbs.; bismuth, 1 oz. Put in the bismuth last before pouring off.

Bronze Metal.—Copper, 7 lbs.; zinc, 3 lbs.; tin, 2 lbs.
Or: Copper, 1 lb.; zinc, 12 lbs.; tin, 8 lbs.

Bell Metal, FOR LARGE BELLS.—Copper, 100 lbs.; tin, from 20 to 25 lbs.

Bell Metal, FOR SMALL BELLS.—Copper, 3 lbs; tin, 1 lb.

Cock Metal.—Copper, 20 lbs.; lead, 8 lbs.; litharge, 1 oz.; antimony, 3 ozs.

Hardening for Britannia.—(To be mixed separately from the other ingredients.)—Copper, 2 lbs.; tin, 1 lb.

Britannia Metal, 1ST QUALITY.—Tin, 150 lbs.; copper, 3 lbs.; antimony, 10 lbs.

2D QUALITY.—Tin, 140 lbs.; copper, 3 lbs.; antimony, 9 lbs.

FOR CASTING.—Tin, 210 lbs.; copper, 4 lbs.; antimony, 12 lbs.

FOR SPINNING.—Tin, 100 lbs.; Britannia hardening, 4 lbs.; antimony, 4 lbs.

FOR REGISTERS.—Tin, 100 lbs.; hardening, 8 lbs.; antimony, 8 lbs.

FOR SPOUTS.—Tin, 140 lbs.; copper, 3 lbs.; antimony, 6 lbs.

FOR SPOONS.—Tin, 100 lbs.; hardening, 5 lbs.; antimony, 10 lbs.

FOR HANDLES.—Tin, 140 lbs.; copper, 2 lbs.; antimony, 5 lbs.

FOR LAMPS, PILLARS, AND SPOUTS.—Tin, 300 lbs.; copper, 4 lbs.; antimony, 15 lbs.

Casting.—Tin, 100 lbs.; hardening, 5 lbs.; antimony, 5 lbs.

Lining Metal, FOR BOXES OF RAILROAD CARS.—Mix tin, 24 lbs.; copper, 4 lbs.; antimony, 8 lbs. (for a hardening); then add tin, 72 lbs.

Fine Silver-colored Metal.—Tin, 100 lbs.; antimony, 8 lbs.; copper, 4 lbs.; bismuth, 1 lb.

German Silver, 1ST QUALITY FOR CASTING.—Copper, 50 lbs.; zinc, 25 lbs.; nickel, 25 lbs.

2D QUALITY FOR CASTING.—Copper, 50 lbs.; zinc, 20 lbs.; nickel (best pulverized), 10 lbs.

FOR ROLLING.—Copper, 60 lbs.; zinc, 20 lbs.; nickel, 25 lbs.

FOR BELLS AND OTHER CASTINGS.—Copper, 60 lbs.; zinc, 20 lbs.; nickel, 20 lbs.; lead, 3 lbs.; iron (that of tin-plate being best), 2 lbs.

Imitation of Silver.—Tin, 3 ozs.; copper, 4 lbs.

Hard White Metal.—Sheet brass, 32 ozs.; lead, 2 ozs.; tin, 2 ozs.; zinc, 1 oz.

Tombac.—Copper, 16 lbs.: tin, 1 lb.; zinc, 1 lb.

Red Tombac.—Copper, 10 lbs.; zinc, 1 lb.

Pinchbeck.—Copper, 5 lbs.; zinc, 1 lb.

Metal for taking Impressions.—Lead, 3 lbs.; tin, 2 lbs.; bismuth, 5 lbs.

Spanish Tutania.—Iron or steel, 8 ozs.; antimony, 16 ozs.; nitre, 3 ozs. Melt and harden 8 ozs. tin with 1 oz. of the above compound.

Another Tutania.—Antimony, 4 ozs.; arsenic, 1 oz., tin, 2 lbs.

Gun-Metal.—Bristol brass, 112 lbs.; zinc, 14 lbs.; tin, 7 lbs.

Rivet Metal.—Copper, 32 ozs.; tin, 2 ozs.; zinc, 1 oz.

Rivet Metal, FOR HOSE.—Copper, 64 lbs.; tin, 1 lb.

Fusible Alloy (which melts in boiling water).—Bismuth, 8 ozs.; tin, 3 ozs.; lead, 5 ozs.

Fusible Alloy, FOR SILVERING GLASS.—Tin, 6 ozs.; lead, 10 ozs.; bismuth, 21 ozs.; mercury, a small quantity.

Solder, FOR GOLD.—Gold, 6 pwts.; Silver, 1 pwt.; copper, 2 pwts.

Solder, FOR SILVER.—(For the use of jewellers.)—Fine silver, 19 pwts.; copper, 1 pwt.; sheet brass, 10 pwts.

White Solder, FOR SILVER.—Silver, 1 oz.; tin, 1 oz.

White Solder, FOR RAISED BRITANNIA WARE.—Tin, 100 lbs.; copper, 3 ozs.; to make it free, add lead, 3 ozs.

Best Soft Solder, FOR CAST BRITANNIA WARE.—Tin, 8 lbs.; lead, 5 lbs.

Yellow Solder, FOR BRASS OR COPPER.—Copper, 1 lb.; zinc, 1 lb.

Soft Cement, FOR STEAM-BOILERS, STEAM-PIPES, &c.—Red or white lead, in oil, 4 parts; iron borings, 2 to 3 parts.

Hard Cement.—Iron borings and salt water, and a small quantity of sal-ammoniac with fresh water.

Statuary Bronze.—Darcet has discovered that this is composed of copper, 91.4; zinc, 5.5; lead, 1.7; tin, 1.4.

Bronze for Cannon of large Calibre.—Copper, 90; tin, 7.

Bronze for Cannon of small Calibre.—Copper, 93; tin, 7.

Bronze for Medals.—Copper, 100; tin, 8.

Alloy for Cymbals.—Copper, 80; tin, 20;

Metal for the Mirrors of Reflecting Telescopes.—Copper, 100; tin, 50.

White Argentan.—Copper, 8; nickel, 3; zinc, 35. This beautiful composition is in imitation of silver.

Chinese Silver.—M. Mairer discovered the following proportions: Silver, 2.5; copper, 65.24; zinc, 19.52; nickel, 13; cobalt of iron, 0.12.

Tutenag.—Copper, 8; nickel, 3; zinc, 5.

Printing Characters.—Lead, 4; antimony, 1. For stereotype plates—Lead, 9; antimony, 2; bismuth, 2.

Orange Dye for Wood.—Let the veneers be dyed by either of the methods given for a fine deep yellow, and while they are still wet and saturated with the dye, transfer them to the bright red dye, till the color penetrates equally throughout.

Silver-Gray Dye for Wood.—Expose any quantity of old iron, or, what is better, the borings of gun-barrels, &c., in any convenient vessel, and from time to time sprinkle them with muriatic acid, diluted in 4 times its quantity of water, till they are very thickly covered with rust; then to every 6 pounds add 1 gallon of water in which has been dissolved 2 ounces salt of tartar (carbonate of potassa); lay the veneers in the copper, and cover them with this liquid; let it boil 2 or 3 hours till well soaked, then to every gallon of liquor add ¼ pound of green copperas, and keep the whole at a moderate temperature till the dye has sufficiently penetrated.

To dye Veneers.—Some manufacturers of Germany, who had been supplied from Paris with veneers, colored throughout their mass, were necessitated by the late war to produce them themselves. Mr. Puscher states that experiments in this direction gave in the beginning colors fixed only on the outside, while the inside was untouched, until the veneers were soaked for 24 hours in a solution of caustic soda containing 10 per cent. of soda, and boiled therein for ½ hour; after washing them with sufficient water to remove the alkali, they may be dyed throughout their mass. This treatment with soda effects a general disintegration of the wood, whereby it becomes, in the moist state, elastic and leather-like, and ready to absorb the color; it must then, after dyeing, be dried between sheets of paper and subjected to pressure to retain its shape.

To dye Veneers Black.—Veneers treated as in last receipt and left for 24 hours in a hot decoction of logwood (1 part logwood to 3 water), removing them after the lapse of that time, and, after drying them superficially, putting them into a hot solution of copperas (1 part copperas to 30 water), will, after 24 hours, become beautifully and completely dyed black.

To stain Wood like Ebony.—Take a solution of sulphate of iron (green copperas), and wash the wood over with it 2 or 3 times; let it dry, and apply 2 or 3 coats of a strong hot decoction of logwood; wipe the wood, when dry, with a sponge and water, and polish with linseed oil.

To dye Veneers Yellow.—A solution of 1 part picric acid in 60 water, with the addition of so much ammonia as to become perceptible to the smell, dyes veneers yellow, which color is not in the least affected by subsequent varnishing.

To dye Veneers Rose-Color.—Coralline dissolved in hot water, to which a little caustic soda and one-fifth of its volume of soluble glass has been added, produces rose-colors of different shades, dependent on the amount of coralline taken.

To dye Veneers Silver-Gray.—The only color which veneers will take up, without previous treatment of soda, is silver-gray, produced by soaking them for a day in a solution of 1 part copperas to 100 parts water.

Black Stain for Immediate Use.—Boil ½ pound chip logwood in 2 quarts water, add 1 ounce pearlash, and apply it hot to the work with a brush. Then take ½ pound logwood, boil it as before in 2 quarts water, and add ½ ounce verdigris and ½ ounce green copperas; strain it off, put in ½ pound rusty steel filings; with this, go over the work a second time.

To stain Wood light Mahogany Color.—Brush over the surface with diluted nitrous acid, and when dry apply the following, with a soft brush: dragon's blood, 4 ounces; common soda, 1 ounce; spirits of wine, 3 pints. Let it stand in a warm place, shake it frequently, and then strain. Repeat the application until the proper color is obtained.

To stain Dark Mahogany Color.—Boil ½ pound madder and 2 ounces logwood in 1 gallon water; then brush the wood well over with the hot liquid. When dry, go over the whole with a solution of 2 drams pearlash in 1 quart of water.

Beechwood Mahogany.—Dissolve 2 ounces dragon's blood and 1 ounce aloes in 1 quart rectified spirit of wine, and apply it to the surface of the wood previously well polished. Or: Wash over the surface of the wood with aquafortis, and when thoroughly dry give it a coat of the above varnish. Or: Boil 1 pound logwood chips in 2 quarts water, and add 2 handfuls of walnut peel; boil again, then strain, and add 1 pint good vinegar: apply as above.

Artificial Mahogany.—The following method of giving any species of wood of a close grain the appearance of mahogany in texture, density, and polish, is said to be practised in France with success. The surface is planed smooth, and the wood is then rubbed with a solution of nitrous acid; 1 ounce dragon's blood is dissolved in nearly a pint of spirits of wine; this, and ⅓ ounce carbonate of soda, are then to be mixed together and filtered, and the liquid in this thin state is to be laid on with a soft brush. This process is to be repeated, and in a short interval afterward the wood possesses the external appearance of mahogany. When the polish diminishes in brilliancy, it may be restored by the use of a little cold-drawn linseed oil.

To stain Mahogany Color.—Pure Socotrine aloes, 1 ounce; dragon's blood, ½ ounce; rectified spirit, 1 pint; dissolve, and apply 2 or 3 coats to the surface of the wood; finish off with wax or oil tinged with alkanet. Or: Wash over the wood with strong aquafortis, and when dry, apply a coat of the above varnish; polish as last. Or: Logwood, 2 ounces; madder, 8 ounces; fustic, 1 ounce; water, 1 gallon; boil 2 hours, and apply it several times to the wood boiling hot; when dry, slightly brush it over with a solution of pearlash, 1 ounce, in water, 1 quart; dry and polish as before. Or: Logwood, 1 part; water, 8 parts. Make a decoction and apply it to the wood; when dry, give it 2 or 3 coats of the following varnish: dragon's blood, 1 part; spirits of wine, 20 parts. Mix.

Fine Black Stain.—Boil 1 pound logwood in 4 quarts water, add a double handful of walnut-peel or shells; boil it up again, take out the chips, add 1 pint best vinegar, and it will be fit for use; apply it boiling hot. This will be improved by applying a hot solution of green copperas dissolved in water (an ounce to a quart), over the first stain.

To imitate Rosewood.—Boil ½ pound logwood in 3 pints water till it is of a very dark red; add ½ ounce salt of tartar (carbonate of potassa). While boiling hot, stain the wood with 2 or 3 coats, taking care that it is nearly dry between each; then, with a stiff flat brush, such as is used by the painters for graining, form streaks with the black stain above named (see last receipt), which, if carefully executed, will be very nearly the appearance of dark rosewood; or, the black streaks may be put in with a camel's hair pencil, dipped in a solution of copperas and verdigris in a decoction of logwood. A handy brush for the purpose may be made out of a flat brush, such as is used for varnishing; cut the sharp points off, and make the edges irregular, by cutting out a few hairs here and there, and you will have a tool which will accurately imitate the grain.

To polish Varnish is certainly a tedious process, and considered by many as a matter of difficulty. Put 2 ounces powdered tripoli into an earthen pot or basin, with water sufficient to cover it; then with a piece of fine flannel four times doubled, laid over a piece of cork rubber, proceed to polish the varnish, always wetting it well with the tripoli and water. It will be known when the process is complete by wiping a part of the work with a sponge, and observing whether there is a fair and even gloss. Clean off with a bit of mutton-suet and fine flour. Be careful not to rub the work too hard, or longer than is necessary to make the face perfectly smooth and even.

The French Method of Polishing.—With a piece of fine pumice-stone and water pass regularly over the work with the grain until the rising of the grain is down; then, with powdered tripoli and boiled linseed oil, polish the work to a bright face. This will be a very superior polish, but it requires considerable time.

To polish Brass Ornaments inlaid in Wood.—The brass-work must first be filed very even with a smooth file; then, having mixed some very finely powdered tripoli with linseed oil, polish the work with a rubber made from a piece of old hat or felt, as you would polish varnish, until the desired effect is produced. If the work be ebony, or black rosewood, take some elder-coal, powdered very fine, and apply it dry after you have done with the tripoli. It will increase the beauty of the polish.

To clean Soft Mahogany or other Porous Wood.—After scraping and sand-papering in the usual manner, take a sponge and well wet the surface, to raise the grain; then, with a piece of fine pumice-stone, free from stony particles, and cut the way of the fibres, rub the wood in the direction of the grain, keeping it moist with water. Let the work dry; then wet it again, and the grain will be much smoother, and will not raise so much. Repeat the process, and the grain will become perfectly smooth, and the texture of the wood much hardened. If this does not succeed to satisfaction, the surface may be improved by using the pumice-stone with cold-drawn linseed oil, proceeding in the same manner as with water. This will be found to give a most beautiful as well as a durable face to the work, which may then be polished or varnished.

To clean and finish Mahogany Work.—Scrape and sand-paper the work as smooth as possible; go over every part with a brush dipped in furniture oil, and let it remain all night; have ready the powder of the finest red brick, which tie up in a cotton stocking, and sift equally over the work the next morning, and, with a leaden or iron weight in a piece of carpet, rub it well the way of the grain, backward and forward, till it has a good gloss. If not sufficient, or if the grain appears at all rough, repeat the process. Be careful not to put too much of the brick-dust, as it should not be rubbed dry, but rather as a paste upon the cloth. When the surface is perfectly smooth, clean it off with a rubber of carpet and fine mahogany sawdust. This process will give a good gloss, and make a surface that will improve by wear.

To clean and polish Old Furniture.—Take a quart of stale beer or vinegar, put a handful of common salt and a table-spoonful of muriatic acid into it, and boil it for 15 minutes; it may be kept in a bottle, and warmed when wanted for use. Having previously washed the furniture with soft hot water, to get the dirt off, wash it carefully with the above mixture; then polish, according to the directions, with any of the foregoing polishes.

Composition for Soft or Light Mahogany.—Boil together cold-drawn linseed oil, and as much alkanet root as it will cover, and to every pint of oil add one ounce of the best rose pink. When all the color is extracted, strain it off, and to every pint add ½ gill spirits of turpentine. This will be a very superior composition for soft and light mahogany.

Mixture for cleaning Furniture.—Cold-drawn linseed oil, 1 quart; spirits of wine and vinegar, ½ pint each; butter (terchloride) of antimony, 2 ounces; spirits of turpentine, ½ pint. This mixture requires to be well shaken before it is used. A little of it is then to be poured upon a rubber, which must be well applied to the surface of the furniture; several applications will be necessary for new furniture, or for such as had previously been French polished or rubbed with bees' wax.

Furniture Polish.—Dissolve 4 ounces best shellac in 2 pints 95 per cent. alcohol; add to this 2 pints linseed oil, and 1 pint spirits of turpentine; when mixed, add 4 ounces sulphuric ether, and 4 ounces ammonia water; mix thoroughly. Shake when used, and apply with a sponge lightly. This is an excellent article, especially where the varnish has become old and tarnished.

Furniture Polish.—Bees' wax, ½ pound; alkanet root, ¼ ounce; melt together in a pipkin until the former is well colored. Then add linseed oil and spirits of turpentine, of each ½ gill; strain through a piece of coarse muslin.

Furniture Paste.—Turpentine, 1 pint; alkanet root, ½ ounce; digest until sufficiently colored, then add bees' wax, scraped small, 4 ounces; put the vessel into hot water and stir until dissolved. If wanted pale, the alkanet may be omitted.

Best French Polish.—Shellac, 3 parts; gum mastic, 1 part; gum sandarach, 1 part; spirits of wine, 40 parts; the mastic and sandarach must first be dissolved in the spirits of wine, and then the shellac; the process may be performed by putting them into a bottle loosely corked, and placing it in a vessel of water heated to a little below 173° Fahr., or the boiling point of spirits of wine, until the solution be effected; the clear solution may be poured off into another bottle for use. Various receipts for the French polish have been published, in which ingredients are inserted that are insoluble in spirits of wine, and therefore useless; and others contain ingredients that are soluble in water, so as to render the mixture more easily injured.

To wax Furniture.—In waxing it is of great importance to make the coating as thin as possible, in order that the veins of the wood may be distinctly seen. The following preparation is the best for performing this operation: Put 2 ounces white and yellow wax over a moderate fire, in a very clean vessel, and, when it is quite melted, add 4 ounces best spirits of turpentine. Stir the whole until it is entirely cool, and you will have a pomade fit for waxing furniture, which must be rubbed over it according to the usual method. The oil soon penetrates the pores of the wood, brings out the color of it, causes the wax to adhere better, and produces a lustre equal to that of varnish, without being subject to any of its inconveniences. The polish may be renewed at any time by rubbing it with a piece of fine cork.

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To French Polish.—The varnish being prepared (shellac), the article to be polished being finished off as smoothly as possible with glass paper, and the rubber being made as directed below, proceed to the operation as follows: The varnish, in a narrow-necked bottle, is to be applied to the middle of the flat face of the rubber, by laying the rubber on the mouth of the bottle and shaking up the varnish once, as by this means the rubber will imbibe the proper quantity to varnish a considerable extent of surface. The rubber is then to be inclosed in a soft linen cloth, doubled, the rest of the cloth being gathered up at the back of the rubber to form a handle. Moisten the face of the linen with a little raw linseed oil, applied with the finger to the middle of it. Place the work opposite the light, pass the rubber quickly and lightly over its surface uniformly in small circular strokes, until the varnish becomes dry, or nearly so; again charge the rubber as before with varnish (omitting the oil), and repeat the rubbing, until three coats are laid on, when a little oil may be applied to the rubber, and two coats more given to it. Proceed in this way until the varnish has acquired some thickness; then wet the inside of the linen cloth, before applying the varnish, with alcohol, or wood naphtha, and rub quickly, lightly, and uniformly, the whole surface. Lastly, wet the linen cloth with a little oil and alcohol without varnish, and rub as before till dry. Each coat is to be rubbed until the rag appears dry; and too much varnish must not be put on the rag at a time. Be also very particular in letting the rags be very clean and soft, as the polish depends, in a great measure, on the care taken in keeping it clean and free from dust during the operation. If the work be porous, or the grain coarse, it will be necessary to give it a coat of clear size previous to commencing with the polish; and, when dry, gently go over it with very fine glass paper. The size will fill up the pores, and prevent the waste of the polish, by being absorbed into the wood, and be also a saving of considerable time in the operation.

To make a French Polish Rubber.—Roll up a strip of thick woolen cloth which has been torn off, so as to form a soft elastic edge. It should form a coil, from 1 to 3 inches in diameter, according to the size of the work. This rubber is to be securely bound with thread, to prevent it from uncoiling when it is used.

Polishing Paste.—Take 3 ounces white wax, ½ ounce Castile soap, 1 gill turpentine. Shave the wax and soap very fine, and put the wax to the turpentine; let it stand 24 hours; then boil the soap in 1 gill water, and add to the wax and turpentine. This has been highly recommended.

Sandarach French Polish.—Shellac, 2 pounds; mastic and sandarach (both in powder), of each 1 ounce; copal varnish, 12 ounces; alcohol, 1 gallon. All the above are made in the cold by frequently stirring or shaking the ingredients together in a well-closed bottle or other vessel. French polish is used without filtering.

French Polish.—To 1 pint spirits of wine add ½ ounce gum shellac, the same quantity gum lac, and ¼ ounce gum sandarach; put these ingredients into a stone bottle near a fire, frequently shaking it; when the various gums are dissolved it is fit for use.

French Polish.—Take 2 ounces wood naphtha, ½ ounce best shellac, 1 dram gum benzoin; crush the gums, mix them with the naphtha in a bottle; shake them frequently till dissolved; it is then ready for use. This is the clear polish. Take a little cotton wool, apply a little of the polish to it, cover it tightly with a linen rag, to which apply a drop of linseed oil, to prevent it from sticking to the wood; use your rubber gently, polishing from a centre in a circular manner; finish with a drop of spirits of wine on a clean rubber, which will extract the oil.

To stain or color French Polish.—Wood may be stained or grained any color or design, by mixing it with the polish, or dipping the rubber in the color (finely powdered), at the time you apply the polish. To produce a red, dip the cotton into dragon's blood (finely powdered), immediately applying the polish; then cover with the linen, and polish. For yellow, use the best chrome yellow. For blue, ultramarine blue, or indigo. For black, ivory or lamp-black, &c. Graining is produced by touching or streaking the wood with the color, as above, in irregular lines or marks, and in such shapes as the fancy may suggest, then finishing it with a coat of clear polish.

Water-Proof Polish.—Take 1 pint spirits of wine, 2 oz. gum-benzoin, ¼ ounce gum sandarach, and ¼ ounce gum anime; these must be put into a stoppered bottle, and placed either in a sand-bath or in hot water till dissolved; then strain the mixture, and, after adding about ¼ gill best clear poppy oil, shake it well up, and put it by for use.

Bright Polish.—1 pint spirits of wine, 2 ounces gum-benzoin, and ½ ounce gum-sandarach, put in a glass bottle corked, and placed in a sand-bath or hot water until you find all the gum dissolved, will make a beautiful clear polish for Tunbridgeware goods, tea-caddies, &c. It must be shaken from time to time, and, when all dissolved, strained though a fine muslin sieve, and bottled for use.

Prepared Spirits for Finishing Polish.—This preparation is useful for finishing after any of the foregoing receipts, as it adds to the lustre and durability, as well as removing every defect, of the other polishes; and it gives the surface a most brilliant appearance. Take ½ pint best rectified spirits of wine, 2 drams shellac, and 2 drams gum-benzoin. Put these ingredients in a bottle, and keep it in a warm place till the gum is all dissolved, shaking it frequently; when cold, add 2 tea-spoonfuls of the best clear white poppy oil; shake them well together, and it is fit for use. This preparation is used in the same manner as the foregoing polishes; but, in order to remove all dull places, the pressure in rubbing may be increased.

How to give Black Walnut a Dark Dead Smooth Surface.—Take asphaltum, pulverize it, place it in a jar or bottle, pour over it about twice its bulk of turpentine or benzole, put it in a warm place, and shake it from time to time. When dissolved, strain it and apply it to the wood with a cloth or stiff brush. If it should make too dark a stain, thin it with turpentine or benzole. This will dry in a few hours. If it is desired to bring out the grain still more, apply a mixture of boiled oil and turpentine; this is better than oil alone. Put no oil with the asphaltum mixture, as it will dry very slowly. When the oil is dry the wood can be polished with the following: Shellac varnish, of the usual consistency, 2 parts; boiled oil, 1 part. Shake it well before using. Apply it to the wood by putting a few drops on a cloth and rubbing briskly on the wood for a few moments. This polish works well on old varnished furniture.

Polish for Turners' Work.—Dissolve sandarach in spirits of wine in the proportion of 1 oz. sandarach to ½ pint of spirits; next shave bees' wax, 1 oz., and dissolve it in a sufficient quantity of spirits of turpentine to made it into a paste; add the former mixture by degrees to it; then with a woolen cloth apply it to the work while it is in motion in the lathe, and with a soft linen rag polish it. It will appear as if highly varnished.

To prepare the Filling-up Color for enamelling Wood.—The filling-up color, which forms the body of the enamel, is of the greatest importance to the ultimate success of the work. Of this material there are several kinds manufactured—black, brown, and yellow, for coach painters, japanners, and others; but for use in interior decoration it is preferable to use the white lead filling, as, by adding the necessary staining colors (which do not affect the properties of the enamel), a solid body of color is formed, of the same tint, or nearly so, as that with which the work is required to be finished, thus doing away with the objections that may be urged against the black or dark-colored filling. It is evident that if work which has to be finished white, or with very light tints of color, be filled up with dark-colored filling, the number of coats of paint required to obscure or kill the dark color will be so many that there will be danger of the work becoming rough and uneven in parts. The white lead should be ground stiff in turpentine, and about one-fourth part of the ordinary white lead, ground in oil added to it. in order to prevent the enamel cracking, which it has a tendency to do, except there be some little oil mixed with it. A sufficient quantity of polishing copal or best carriage varnish should now be added to bind it so that it will rub down easily, which fact cannot be properly ascertained except by actual trial, inasmuch as the drying properties of varnishes vary, and other causes influence the matter. If there be too much varnish in the stuff the work will be exceedingly difficult to cut down, and if too little, it is apt to break up in rubbing, so that it is always the safest plan to try the enamel color before commencing anything important.

Strong Polish.—To be used in the carved parts of cabinet-work with a brush, as in standards, pillars, claws, &c. Dissolve 2 ounces seed lac and 2 ounces white resin in 1 pint spirits of wine. This varnish or polish must be laid on warm, and if the work can be warmed also, it will be so much the better; at any rate, moisture and dampness must be avoided.

To prepare the Pumice-Stone for enamelling Wood.—The pumice-stone to be used should be of different degrees of fineness, and should be carefully selected, so as to be sure that it is free from any gritty substance. It is sold ready ground, but in situations where it cannot be readily got, it may be prepared from the lump, by grinding or crushing with a stone and muller, and then passed through fine sieves or muslin; by using these of different degrees of texture the ground pumice may be produced of different degrees of fineness. Unless great care be exercised in this matter, it will be found that particles of grit will be mixed with it, which make deep scratches on the work, thus causing endless trouble and annoyance, besides spoiling the work. The greatest care is also required in keeping the felt clean and free from grit. Many workmen are careless in this matter, and, when working, set down the felt on the step-ladder or floor, thus allowing particles of sand or grit to get upon it.

To cut down or prepare the Surface for polishing.—In cutting down, it is best to use a piece of soft lump pumice stone to take off the rough parts. The work should then be wet with a sponge; the felt must first be soaked in water, then dipped into the powdered pumice, and the work rubbed with it, keeping it moderately wet, and rubbing with a circular motion, not straight up and down and across, and with a light touch, using only just as much pressure as will cause the pumice to bite, which will be very clearly felt while the hand is in motion. Care and patience are required to do this properly, for if the pressure be too great it forces the pumice into the body of the filling color, and scratches it instead of cutting or grinding it fairly down. No hurry will avail in doing this work, it must have its time; hurry often defeats the end in view, and often causes much unnecessary labor. A scratch, caused by want of care and too much haste, will often throw the work back for days, and involve the cost and labor of refilling. In practice the purpose is best answered by using the pumice-stone, the coarser kind first, then the medium, and finishing with the finest last. It will be found advantageous to let a day elapse between the rubbing, for when the surface is cut down the filling will in all cases be softer underneath, and if it be allowed to stand for a day, the newly exposed surface gets harder, and of course rubs down better. The pumice-stone should be well washed off the work occasionally, in order to see what progress is being made, and if it require more rubbing or not. If, after the first rubbing, the surface be found not sufficiently filled up, it may have one or more additional coats of filling before much labor has been spent upon it.

To lay the Color on Enamelled Wood.—The color, being properly mixed, should be laid on the work in the ordinary manner, using it rather freely. It may be as well to state here that no filling should be put upon new work without the same having had 2 or 3 coats of ordinary oil paint, nor on old work without its having one coat. This gives a foundation for the filling. Successive coats of the filling should now be laid on the work until there is a sufficient thickness to cut down to a level surface. One day should intervene between each coat, in order to allow it to harden in some degree. When a sufficient number of coats are put on (which number will, of course, depend upon the state of the work to be filled up), it should stand for 2 or 3 weeks, until it is thoroughly hard; it will then be ready for cutting down, which is to be done with a felt rubber, ground pumice-stone, and water.

To prepare the Rubber for enamelling Wood.—The felt used should be such as the sculptors use for polishing marble, which varies in thickness from ⅛ to ½ an inch, and about 3 inches square. This should be fastened with resinous gum to square pieces of wood of the same size, but 1 inch thick, so as to give a good hold for the hand in using. These pieces of wood covered with felt, may be made of any size or shape to fit moulded surfaces or other inequalities.

Tinman's Solder.—Lead, 1 part; tin, 1 part.

Pewterer's Solder.—Tin, 2 parts; lead, 1 part.

Common Pewter.—Tin, 4 parts; lead, 1 part.

Best Pewter.—Tin, 100 parts; antimony, 17 parts.

A Metal that expands in cooling.—Lead, 9 parts; antimony, 2 parts; bismuth, 1 part. This metal is very useful in filling small defects in iron castings, &c.

Silver Coin of the United States.—Pure silver, 9 parts; alloy, 1 part; the alloy of silver is fine copper.

Gold Coin of the United States.—Pure gold, 9 parts; alloy, 1 part; the alloy of gold is ¼ silver and ¾ copper (not to exceed ½ silver).

Silver Coin of Great Britain.—Pure silver, 11.1 parts; copper, 0.9 part.

Gold Coin of Great Britain.—Pure gold, 11 parts; copper, 1 part. Previous to 1826 silver formed part of the alloy of gold coin; hence the different color of English gold money.

Cast Iron Cement.—Clean borings or turnings of cast iron, 16 parts; sal-ammoniac, 2 parts; flour of sulphur, 1 part; mix them well together in a mortar and keep them dry. When required for use, take of the mixture, 1 part; clean borings, 20 parts; mix thoroughly, and add a sufficient quantity of water. A little grindstone-dust added improves the cement.

Queen's Metal.—Tin, 9 parts; antimony, 1 part; bismuth, 1 part; lead, 1 part.

Mock Platinum.—Brass, 8 parts; zinc, 5 parts.

Booth's Patent Grease, FOR RAILWAY AXLES.—Water, 1 gal.; clean tallow, 3 lbs.; palm oil, 6 lbs.; common soda, ½ lb.
Or: Tallow, 8 lbs.; palm oil, 10 lbs. The mixture to be heated to about 210° F., and well stirred till it cools down to about 70°, when it is ready for use.

Cement, FOR STEAM-PIPE JOINTS, &c., WITH FACED FLANGES.—White lead, mixed, 2 parts; red lead, dry, 1 part; grind or otherwise mix them to a consistence of thin putty, apply interposed layers with one or two thicknesses of canvas or gauze wire, as the necessity of the case may be.

Olive Bronze Dip, FOR BRASS.—Nitric acid, 3 ozs.; muriatic acid, 2 ozs.; add titanium or palladium; when the metal is dissolved, add 2 gals pure soft water to each pint of the solution.

Brown Bronze Paint, FOR COPPER VESSELS.—Tincture of steel, 4 ozs.; spirits of nitre, 4 ozs; essence of dendi, 4 ozs.; blue vitriol, 1 oz.; water, ½ pint. Mix in a bottle. Apply it with a fine brush, the vessel being full of boiling water. Varnish after the application of the bronze.

Bronze, FOR ALL KINDS OF METAL.—Muriate of ammonia (sal-ammoniac), 4 drs.; oxalic acid, 1 dr.; vinegar, 1 pint. Dissolve the oxalic acid first. Let the work be clean. Put on the bronze with a brush, repeating the operation as many times as may be necessary.

Bronze Paint, FOR IRON OR BRASS.—Chrome green, 2 lbs.; ivory black, 1 oz.; chrome yellow, 1 oz.; good japan, 1 gill; grind all together and mix with linseed oil.

To bronze Gun-Barrels.—Dilute nitric acid with water and rub the gun-barrels with it; lay them by for a few days, then rub them with oil, and polish them with bees-wax.

For tinning Brass.—Water, 2 pailfuls; cream of tartar, ½ lb.; salt, ½ pint. Shaved or Grained Tin—Boil the work in the mixture, keeping it in motion during the time of boiling.

Silvering by Heat.—Dissolve 1 oz. of silver in nitric acid; add a small quantity of salt; then wash it and add sal-ammoniac or 6 oz. of salt and white vitriol; also ¼ oz. of corrosive sublimate; rub them together till they form a paste, rub the piece which is to be silvered with the paste, heat it till the silver runs, after which dip it in a weak vitriol pickle to clean it.

Mixture for Silvering.—Dissolve 2 ozs. of silver with 3 grains of corrosive sublimate; add tartaric acid, 4 lbs.; salt, 8 qts.

Solvent for Gold.—Mix equal quantities of nitric and muriatic acids.

To separate Silver from Copper.—Mix sulphuric acid, 1 part; nitric acid, 1 part; water, 1 part; boil the metal in the mixture till it is dissolved, and throw in a little salt to cause the silver to subside.

Varnish, FOR SMOOTH MOULDING PATTERNS.—Alcohol, 1 gal.; shellac, 1 lb.; lamp or ivory black, sufficient to color it.

Fine Black Varnish, FOR COACHES.—Melt, in an iron pot, amber, 32 ozs; resin, 6 ozs.; asphaltum, 6 ozs; drying linseed oil, 1 pt; when partly cooled, add oil of turpentine, warmed, 1 pt.

Chinese White Copper.—Copper, 40.4 parts; nickel, 31.6 parts; zinc, 25.4 parts, and iron, 2.6 parts

Manheim Gold.—Copper, 3 parts; zinc, 1 part, and a small quantity of tin.

Alloy of the Standard Measures used by the British Government.—Copper, 576 parts; tin, 59 parts, and brass, 48 parts.

Bath Metal.—Brass, 32 parts, and zinc, 9 parts.

Speculum Metal.—Copper, 6 parts; tin, 2 parts, and arsenic, 1 part. Or: Copper, 7 parts; zinc, 3 parts, and tin 4 parts.

Hard Solder.—Copper, 2 parts; zinc, 1 part.

Blanched Copper.—Copper, 8 parts, and arsenic, ½ part.

Britannia Metal.—Brass, 4 parts; tin, 4 parts; when fused, add bismuth, 4 parts, and antimony, 4 parts. This composition is added at discretion to melted tin.

Yellow Solder, FOR BRASS OR COPPER.—(*Stronger than that on page 241.*) Copper, 32 lbs.; zinc, 29 lbs.; tin, 1 lb.

Solder, FOR COPPER.—Copper, 10 lbs.; zinc, 9 lbs.

Black Solder.—Copper, 2 lbs.; zinc, 3 lbs.; Tin, 2 ozs.

Black Solder.—Sheet brass, 20 lbs.; tin, 6 lbs.; zinc, 1 lb.

Soft Solder.—Tin, 15 lbs.; lead, 15 lbs.

Silver Solder, FOR PLATED METAL.—Fine silver, 1 oz.; brass, 10 pwts.

Yellow Dipping Metal.—Copper, 32 lbs.; zinc, 2 lbs.; soft solder, 2¼ ozs.

Quick Bright Dipping Acid, FOR BRASS WHICH HAS BEEN ORMOLUED.—Sulphuric acid, 1 gal.; nitric acid, 1 gal.

Ormolu Dipping Acid, FOR SHEET BRASS.—Sulphuric acid, 2 gals.; nitric acid, 1 pt.; muriatic acid, 1 pt.; water, 1 pt.; nitre, 12 lbs. Put in the muriatic acid last, a little at a time and stir the mixture with a stick.

Ormolu Dipping Acid, FOR SHEET OR CAST BRASS.—Sulphuric acid, 1 gal.; sal-ammoniac, 1 oz.; sulphur (in flour), 1 oz.; blue vitriol, 1 oz.; saturated solution of zinc in nitric acid, mixed with an equal quantity of sulphuric acid, 1 gal.

Dipping Acid.—Sulphuric acid, 12 lbs.; nitric acid, 1 pint; nitre, 4 lbs.; soot, 2 handfuls, brimstone, 2 ozs. Pulverize the brimstone and soak it in water an hour. Add the nitric acid last.

Good Dipping Acid, FOR CAST BRASS.—Sulphuric acid, 1 qt.; nitre, 1 qt.; water, 1 qt. A little muriatic acid may be added or omitted.

Dipping Acid.—Sulphuric acid, 4 gals.; nitric acid, 2 gals.; saturated solution of sulphate of iron (copperas), 1 pint; solution of sulphate of copper, 1 qt.

To prepare Brass Work for Ormolu Dipping.—If the work is oily, boil it in lye; and if it is finished work, filed or turned, dip it in old acid, and it is then ready to be ormolued; but if it is unfinished, and free from oil, pickle it in strong sulphuric acid, dip in pure nitric acid, and then in the old acid, after which it will be ready for ormoluing.

To repair old Nitric Acid Ormolu Dips.—If the work after dipping appears coarse and spotted, add vitriol till it answers the purpose. If the work after dipping appears too smooth, add muriatic acid and nitre till it gives the right appearance.

The other ormolu dips should be repaired according to the receipts, putting in the proper ingredients to strengthen them. They should not be allowed to settle, but should be stirred often while using.

Tinning Acid, FOR BRASS OR ZINC.—Muriatic acid, 1 qt.; zinc, 6 ozs. To a solution of this add, water, 1 qt.; sal-ammoniac, 2 ozs.

Vinegar Bronze, FOR BRASS.—Vinegar, 10 gals.; blue vitriol, 3 lbs.; muriatic acid, 3 lbs.; corrosive sublimate, 4 grs.; sal-ammoniac, 2 lbs.; alum, 8 ozs.

Directions for making Lacquer.—Mix the ingredients and let the vessel containing them stand in the sun or in a place slightly warmed three or four days, shaking it frequently till the gum is dissolved, after which let it settle from twenty-four to forty-eight hours, when the clear liquor may be poured off for use. Pulverized glass is sometimes used in making lacquer, to carry down the impurities.

Lacquer, FOR DIPPED BRASS.—Alcohol, proof specific gravity not less than 95-100, 2 gals.; seed lac, 1 lb.; gum copal, 1 oz.; English saffron, 1 oz.; annotto, 1 oz.

Good Lacquer, FOR BRASS.—Seed lac, 6 oz.; amber or copal, 2 ozs.; best alcohol, 4 gals.; pulverized glass, 4 ozs.; dragon's blood, 40 grs.; extract of red sandal wood obtained by water, 30 grs.

Lacquer, FOR BRONZED BRASS.—To one pint of the above lacquer, add gamboge, 1 oz.; and after mixing it add an equal quantity of the first lacquer.

Deep Gold Colored Lacquer.—Best alcohol, 40 ozs.; Spanish annotto, 8 grs.; turmeric, 2 drs.; shellac, ½ oz.; red sanders, 12 grs.; when dissolved add spirits of turpentine 30 drops.

Gold Colored Lacquer, FOR BRASS NOT DIPPED.—Alcohol, 4 gals.; tumeric, 3 lbs.; gamboge, 3 ozs.; gum sandarach, 7 lbs.; shellac, 1½ lb.; turpentine varnish, 1 pint.

Gold Colored Lacquer, FOR DIPPED BRASS.—Alcohol, 36 ozs.; seed lac, 6 ozs.; amber, 2 ozs.; gum gutta, 2 ozs.; red sandal wood, 24 grs.; dragon's blood, 60 grs.; oriental saffron, 36 grs.; pulverized glass, 4 ozs.

Lacquer, FOR DIPPED BRASS.—Alcohol, 12 gals.; seed lac, 9 lbs.; tumeric, 1 lb. to a gallon of the above mixture; Spanish saffron, 4 ozs. The saffron is to be added for bronze work.

Whitewash for Out-Door Use.—Take a clean water-tight barrel or other suitable cask, and put into it ½ bushel of lime. Slack it by pouring boiling water over it, and in sufficient quantity to cover 5 inches deep, stirring it briskly till thoroughly slacked. When slacking has been effected, dissolve in water and add 2 pounds sulphate of zinc and 1 of common salt. These will cause the wash to harden and prevent it from cracking, which gives an unseemly appearance to the work. If desirable, a beautiful cream color may be communicated to the above wash, by adding 3 pounds yellow ochre. This wash may be applied with a common whitewash brush, and will be found much superior, both in appearance and durability, to common whitewash,

Treasury Department Whitewash.—This receipt for whitewashing, sent out by the Light-house Board of the Treasury Department, has been found, by experience, to answer on wood, brick, and stone nearly as well as oil paint, and is much cheaper. Slack ½ bushel unslacked lime with boiling water, keeping it covered during the process. Strain it, and add a peck of salt, dissolved in warm water; 3 pounds ground rice, put in boiling water and boiled to a thin paste; ½ pound powdered Spanish whiting, and a pound of clear glue, dissolved in warm water; mix these well together, and let the mixture stand for several days. Keep the wash thus prepared in a kettle or portable furnace, and when used put it on as hot as possible with painters' or whitewash brushes.

Fire-Proof Whitewash.—Make ordinary whitewash and add 1 part silicate of soda (or potash) to every 5 parts of the whitewash.

Whitewash for Fences or Out-Buildings.—Slack the lime in boiling water, and to 3 gallons ordinary whitewash add 1 pint molasses and 1 pint table salt. Stir the mixture frequently while putting it on. Two thin coats are sufficient.

To prepare Kalsomine.—Kalsomine is composed of zinc white mixed with water and glue sizing. The surface to which it is applied must be clean and smooth. For ceilings, mix ½ pound glue with 15 pounds zinc; for walls, 1 pound glue with 15 pounds zinc. The glue, the night before its use, should be soaked in water, and in the morning liquefied on the fire. It is difficult to prepare or apply kalsomine; few painters can do so successfully Paris white is often made use of for it, but it is not the genuine article. (See next receipt.) The kalsomining mixture may be colored to almost any required tint, by mixing appropriate coloring matter with it.

To kalsomine Walls.—In case the wall of a room, say 16 by 20 feet square, is to be kalsomined with two coats, it will require ¼ pound light-colored glue and 5 or 6 pounds Paris white. (See last receipt.) Soak the glue overnight in a tin vessel containing about a quart of warm water. If the kalsomine is to be applied the next day, add a pint more of clean water to the glue, and set the tin vessel containing the glue into a kettle of boiling water over the fire, and continue to stir the glue until it is well dissolved and quite thin. If the glue-pail be placed in a kettle of boiling water, the glue will not be scorched. Then, after putting the Paris white into a large water-pail, pour on hot water, and stir it until the liquid appears like thick milk. Now mingle the glue liquid with the whiting, stir it thoroughly, and apply it to the wall with a whitewash-brush, or with a large paint-brush. It is of little consequence what kind of an instrument is employed in laying on the kalsomine, provided the liquid is spread smoothly. Expensive brushes, made expressly for kalsomining, may be obtained at brush factories and at some drug and hardware stores. But a good whitewash-brush, having long and thick hair, will do very well. In case the liquid is so thick that it will not flow from the brush so as to make smooth work, add a little more hot water. When applying the kalsomine, stir it frequently. Dip the brush often, and only so deep in the liquid as to take as much as the hair will retain without letting large drops fall to the floor. If too much glue be added, the kalsomine cannot be laid on smoothly, and will be liable to crack. The aim should be to apply a thin layer of sizing that cannot be brushed off with a broom or dry cloth. A thin coat will not crack.

A Fine Whitewash for Walls.—Soak ¼ pound of glue overnight in tepid water. The next day put it into a tin vessel with a quart of water, set the vessel in a kettle of water over a fire, keep it there till it boils, and then stir till the glue is dissolved. Next put from 6 to 8 pounds Paris white into another vessel, add hot water, and stir until it has the appearance of milk of lime. Add the sizing, stir well, and apply in the ordinary way, while still warm. Except on very dark and smoky walls and ceilings, a single coat is sufficient. It is nearly equal in brilliancy to zinc-white (a far more expensive article), and is very highly recommended by those who have used it Paris white is sulphate of baryta, and may be found at any drug or paint store.

To color Whitewash.—Coloring matter may be put in and made of any shade. Spanish brown stirred in will make red pink, more or less deep according to the quantity. A delicate tinge of this is very pretty for inside walls. Finely pulverized common clay, well mixed with Spanish brown, makes a reddish stone color. Yellow ochre stirred in makes a yellow wash, but chrome goes further and makes a color generally esteemed prettier. In all these cases the darkness of the shades of course is determined by the quantity of coloring used. It is difficult to make rules, because tastes are different; it would be best to try experiments on a shingle and let it dry. Green must not be mixed with lime. The lime destroys the color, and the color has an effect on the whitewash, which makes it crack and peel. When walls have been badly smoked, and you wish to have them a clean white, it is well to squeeze indigo plentifully through a bag into the water you use, before it is stirred in the whole mixture.

Whitewash for Outside Work.—Take of good quicklime ½ a bushel, slack in the usual manner, and add one pound common salt, ½ pound sulphate of zinc (white vitriol), and 1 gallon sweet milk. The salt and the white vitriol should be dissolved before they are added, when the whole should be thoroughly mixed with sufficient water to give the proper consistency. The sooner the mixture is then applied the better.

To mix Whitewash.—Pour boiling water on unslacked lime, and stir it occasionally while it is slacking, as it will make the paste smoother. To 1 peck of lime add a quart of salt and ½ ounce of indigo dissolved in water, or the same quantity of Prussian blue finely powdered; add water to make it the proper thickness to put on a wall. One pound soap will give gloss.

To keep Whitewash.—Keep the lime covered with water and in a tub which has a cover, to prevent dust or dirt from falling in. If the water evaporates the lime is useless, but if kept covered it will be good as long as any remains.

To whiten Smoked Walls.—A method of cleaning and whitening smoked walls consists, in the first place, of rubbing off all the black, loose dirt upon them, by means of a broom, and then washing them down with a strong soda lye, which is to be afterward removed by means of water to which a little hydrochloric acid has been added. When the walls are dry a thin coating of lime, with the addition of a solution of alum, is to be applied. After this has become perfectly dry the walls are to be kalsomined or coated with a solution of glue and chalk.

To color and prevent Whitewash rubbing off.—Alum is one of the best additions to make whitewash of lime which will not rub off. When powdered chalk is used, glue water is also good, but would not do for outside work exposed to much rain. Nothing is easier than to give it any desired color by small quantities of lamp-black, brown sienna, ochre, or other coloring material.

Zinc Whitewash.—Mix oxide of zinc with common size, and apply it with a whitewash-brush to the ceiling. After this, apply in the same manner a wash of chloride of zinc, which will combine with the oxide to form a smooth cement with a shining surface.

To paper Whitewashed Walls.—The following method is simple, sure, and inexpensive: Make flour starch as you would for starching calico clothes, and with a whitewash-brush wet the wall you wish to paper with the starch; let it dry; then, when you wish to apply the paper, wet the wall and paper both with the starch, and apply the paper. Walls have been papered in this way that have been whitewashed 10 or even 20 years successively, and the paper has never failed to stick. When you wish to re-paper the wall, with the brush wet the paper with clear water, and it will come off readily.

Red Wash for Bricks.—To remove the green that gathers on bricks, pour over the bricks boiling water in which any vegetables (not greasy) have been boiled. Do this for a few days successively, and the green will disappear. For the red wash melt 1 ounce of glue in a gallon of water; while hot put in a piece of alum the size of an egg, ½ pound Venetian red, and 1 pound Spanish brown. Try a little on the bricks, let it dry, and if too light add more red and brown; if too dark, put in more water. This receipt was contributed by a person who has used it for 20 years with perfect success.

Waterproof Mastic Cement.—Mix together 1 part red-lead to 5 parts ground lime, and 5 parts sharp sand, with boiled oil. Or: 1 part red-lead to 5 whiting and 10 sharp sand mixed with boiled oil.

Masons' Cement for coating the Insides of Cisterns.—Take equal parts of quicklime, pulverized baked bricks, and wood ashes. Thoroughly mix the above substances, and dilute with sufficient olive oil to form a manageable paste. This cement immediately hardens in the air, and never cracks beneath the water.

Fine Stuff for Plastering.—This is made by slacking lime with a small portion of water, after which sufficient water is added to give it the consistence of cream. It is then allowed to settle for some time, and the superfluous water is poured off, and the sediment suffered to remain till evaporation reduces it to a proper thickness for use. For some kinds of work it is necessary to add a small portion of hair.

Higgins' Stucco.—To 15 pounds best stone lime add 14 pounds bone ashes, finely powdered, and about 95 pounds clean, washed sand, quite dry, either coarse or fine, according to the nature of the work in hand. These ingredients must be intimately mixed, and kept from the air till wanted. When required for use, it must be mixed up into a proper consistence for working with lime water, and used as speedily as possible.

Marble Workers' Cement.—Flower of sulphur, 1 part; hydrochlorate of ammonia, 2 parts; iron filings, 16 parts. The above substances must be reduced to a powder, and securely preserved in closely stopped vessels. When the cement is to be employed, take 20 parts very fine iron filings, add 1 part of the above powder, mix them together with enough water to form a manageable paste. This paste solidifies in 20 days and becomes as hard as iron.

Portland Cement.—Portland cement is formed of clay and limestone, generally containing some silica, the properties of which may vary without injury to the cement. The proportion of clay may also vary from 19 to 25 per cent. without detriment. The only necessary condition for the formation of a good artificial Portland cement, is an intimate and homogeneous mixture of carbonate of lime and clay, the proportion of clay being as above stated. The materials are raised to a white heat in kilns of the proper form, so that they are almost vitrified. After the calcination all pulverulent and scorified portions are carefully pricked out and thrown away. The remainder is then finely ground and becomes ready for use. The amount of water which enters into combination with it in mixing is about .366 by weight. It sets slowly, from 12 to 18 hours being required. Made into a thin solution like whitewash, this cement gives woodwork all the appearance of having been painted and sanded. Piles of stone may be set together with common mortar, and then the whole washed over with this cement, making it look like one immense rock of gray sandstone. For temporary use a flour-barrel may have the hoops nailed, and the inside washed with a little Portland cement, and it will do for a year or more to hold water. Boards nailed together, and washed with it, make good hot-water tanks. Its water-resisting properties make it useful for a variety of purposes.

Stucco for Inside of Walls.—This stucco consists of 3 parts fine stuff and 1 part fine washed sand. Those parts of interior walls which are intended to be painted are finished with this stucco. In using this material, great care must be taken that the surface be perfectly level, and to secure this it must be well worked with a floating tool or wooden trowel. This is done by sprinkling a little water occasionally on the stucco, and rubbing it in a circular direction with the float, till the surface has attained a high gloss. The durability of the work much depends upon how it is done, for if not thoroughly worked it is apt to crack.

New Plastic Material.—A beautiful plastic substance can be prepared by mixing collodion with phosphate of lime. The phosphate should be pure, or the color of the compound will be unsatisfactory. On setting, the mass is found to be hard and susceptible of a very fine polish. The material can be used extensively, applied in modes that will suggest themselves to any intelligent artist, to high-class decoration

Durable Composition for Ornaments.—This is frequently used, instead of plaster of Paris, for the ornamental parts of buildings, as it is more durable, and becomes in time as hard as stone itself. It is of great use in the execution of the decorative parts of architecture, and also in the finishings of picture-frames, being a cheaper method than carving, by nearly 80 per cent. It is made as follows: 2 pounds best whiting, 1 pound glue, and ½ pound linseed oil are heated together, the composition being continually stirred until the different substances are thoroughly incorporated. Let the compound cool, and then lay it on a stone covered with powdered whiting, and heat it well until it becomes of a tough and firm consistence. It may then be put by for use, covered with wet cloths to keep it fresh. When wanted for use it must be cut into pieces adapted to the size of the mould, into which it is forced by a screw press. The ornament, or cornice, is fixed to the frame or wall with glue, or with white lead.

Coarse Stuff for Plastering.—Coarse stuff, or lime and hair, as it is sometimes called, is prepared in the same way as common mortar, with the addition of hair procured from the tanner, which must be well mixed with the mortar by means of a three-pronged rake, until the hair is equally distributed throughout the composition. The mortar should be first formed, and when the lime and sand have been thoroughly mixed, the hair should be added by degrees, and the whole so thoroughly united that the hair shall appear to be equally distributed throughout.

Concrete.—A compact mass, composed of pebbles, lime, and sand, employed in the foundations of buildings. The best proportions are 60 parts of coarse pebbles, 25 of rough sand, and 15 of lime; others recommend 80 parts pebbles, 40 parts river sand, and only 10 parts lime. The pebbles should not exceed about ½ pound each in weight. Abbé Moigno, in his valuable scientific journal, "Les Mondes," relates his personal experience with a concrete formed of fine wrought and cast iron filings and Portland cement. The Abbé states that a cement made thus is hard enough to resist any attempts to fracture it. As he states that the iron filings are to replace the sand usually put into the mixture, we presume that the relative quantities are to be similar.

Concrete Floors and Walks.—Compost for barn and kitchen floors: After the ground on which the floor is intended to be made is levelled, let it be covered to the thickness of 3 or 4 inches with stones, broken small, and well rammed down; upon which let there be run, about 1½ inches above the stones, 1 part by measure calcined ferruginous marl, and 2 parts coarse sand and fine gravel, mixed to a thin consistence with water. Before this coating has become thoroughly set, lay upon it a coat of calcined marl, mixed with an equal part of fine sand, 1 to 1½ inches thick, levelled to an even surface. The addition of blood will render this compost harder.

Roman Cement.—Calcine 3 parts of any ordinary clay, and mix it with 2 parts lime; grind it to powder, and calcine again. This makes a beautiful cement, improperly called Roman, since the preparation was entirely unknown to the Romans.

Gauge Stuff.—This is chiefly used for mouldings and cornices which are run or formed with a wooden mould. It consists of about 1-5 plaster of Paris, mixed gradually with 4-5 fine stuff. When the work is required to set very expeditiously, the proportion of plaster of Paris is increased. It is often necessary that the plaster to be used should have the property of setting immediately it is laid on, and in all such cases gauge stuff is used, and consequently it is extensively employed for cementing ornaments to walls or ceilings, as well as for casting the ornaments themselves.

To Lacquer Brass-Work.—If the work is old, clean it first, according to the directions hereafter given; but if new, it will merely require to be freed from dust, and rubbed with a piece of wash-leather, to make it as bright as possible. Put the work on a hot iron plate (or upon the top of the stove), till it is moderately heated, but not too hot, or it will blister the lacquer; then, according to the color desired, take of the following preparations, and, making it warm, lay hold of the work with a pair of pincers or pliers, and with a soft brush apply the lacquer, being careful not to rub it on, but stroke the brush gently one way, and place the work on the hot plate again till the varnish is hard; but do not let it remain too long. Experience will best tell you when it should be removed. Some, indeed, do not place it on the stove or plate a second time. If it should not be quite covered, you may repeat it carefully; and, if pains be taken with the lacquer, it will look equal to metal gilt.

To clean old Brass-Work for Lacquering. Make a strong lye of wood ashes, which may be strengthened by soap-lees; put in the brass-work, and the lacquer will soon come off; then have ready a mixture of aquafortis and water, sufficiently strong to take off the dirt; wash it afterward in clean water, and lacquer it with such of the following compositions as may be most suitable to the work.

Gold Lacquer.—Put into a clean four-gallon tin, 1 pound ground turmeric, 1½ ounces powdered gamboge, 3½ ounces powdered gum sandarach, ¾ pound shellac, and 2 gallons spirits of wine. After being agitated, dissolved, and strained, add 1 pint of turpentine varnish, well mixed.

Deep Gold Lacquer. Seed-lac, 3 ounces; turmeric, 1 ounce; dragon's blood, ¼ ounce; alcohol 1 pint. Digest for a week, frequently shaking, decant and filter. Deep gold colored.

Dark Gold-Colored Lacquer. Strongest alcohol, 4 ounces, Spanish annotto, 8 grains, powdered turmeric, 2 drams; red sanders, 12 grains. Infuse and add shellac, etc., and when dissolved add 30 drops of spirits of turpentine.

To make Gold Lacquer for Brass.—Rectified spirits of wine, ½ pint; mix ½ pound of seed-lac, picked clean, and clear of all pieces (as upon that depends the beauty of the lacquer), with the spirits of wine; keep them in a warm place, and shake them repeatedly. When the seed-lac is quite dissolved, it is fit for use.

Gold-Colored Lacquer for Watch-Keys, etc.—Seed-lac, 6 ounces; amber, 2 ounces; gamboge, 2 ounces; extract of red sandal wood in water, 24 grains; dragon's blood, 60 grains; oriental saffron, 36 grains; pounded glass, 4 ounces; pure alcohol, 36 ounces. The seed-lac, amber, gamboge, and dragon's blood must be pounded very fine on porphyry or clean marble, and mixed with the pounded glass. Over this mixture is poured the tincture formed by infusing the saffron and the extract of sandal-wood in the alcohol for 24 hours. Metal articles that are to be covered with this varnish are heated, and, if they are of a kind to admit of it, are immersed in packets. The tint of the varnish may be varied in any degree required, by altering the proportions of the coloring quantities according to circumstances.

Gold Lacquer.—Ground turmeric, 1 pound; gamboge, 1½ ounces; gum sandarach, 3½ pounds; shellac, ¾ pound; all in powder; rectified spirits of wine, 2 gallons. Dissolve, strain, and add turpentine varnish, 1 pint.

Brass Lacquer.—Take 8 ounces shellac, 2 ounces sandarach, 2 ounces annotto, ¼ ounce dragon's blood resin, 1 gallon of spirits of wine. The article to be lacquered should be heated slightly, and the lacquer applied by means of a soft camel's-hair brush.

Lacquer for Bronzed Dipped Work.—A lacquer for bronzed dipped work may be made thus: Alcohol, 12 gallons; seed-lac, 9 pounds; turmeric, 1 pound to the gallon; Spanish saffron, 4 ounces. The saffron may be omitted if the lacquer is to be very light.

Lacquer for Tin Plate.—Best alcohol, 8 ounces; turmeric, 4 drams; hay saffron, 2 scruples; dragon's blood, 4 scruples; red sanders, 1 scruple; shellac, 1 ounce; gum sandarach, 2 drams; gum mastic, 2 drams; Canada balsam, 2 drams; when dissolved, add spirits of turpentine, 80 drops.

Iron Lacquer.—Take 12 parts amber, 12 parts turpentine, 2 parts resin, 2 parts asphaltum, 6 parts drying oil. Or: 3 pounds asphaltum, ½ pound shellac, 1 gallon turpentine.

Red Lacquer.—Take 2 gallons spirits of wine, 1 pound dragon's blood, 3 pounds Spanish annotto, 4½ pounds gum sandarach, 2 pints turpentine. Made as pale brass lacquer.

Red Lacquer.—Spanish annotto, 3 pounds; dragon's blood, 1 pound; gum sandarach, 3¼ pounds; rectified spirit, 2 gallons; turpentine varnish, 1 quart. Dissolve and mix as the last.

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Pale Tin Lacquer.—Strongest alcohol, 4 ounces; powdered turmeric, 2 drams; hay saffron, 1 scruple; dragon's blood in powder, 2 scruples; red sanders, ⅓ scruple. Infuse this mixture in the cold for 48 hours, pour off the clear, and strain the rest; then add powdered shellac, ½ ounce; sandarach, 1 dram; mastic, 1 dram; Canada balsam, 1 dram. Dissolve this in the cold by frequent agitation, laying the bottle on its side, to present a greater surface to the alcohol. When dissolved, add 40 drops of spirits of turpentine.

Pale Brass Lacquer.—Take 2 gallons spirits of wine, 3 ounces cape aloes, cut small, 1 pound fine pale shellac, 1 ounce gamboge, cut small. Digest for a week, shake frequently, decant and filter.

To make Lacquer of various Tints.—Put 4 ounces best gum gamboge into 32 ounces spirits of turpentine; 4 ounces dragon's blood into the same quantity of spirits of turpentine as the gamboge, and 1 ounce annotto into 8 ounces of the same spirits. The 3 mixtures should be made in different vessels. They should then be kept for about two weeks in a warm place, and as much exposed to the sun as possible. At the end of that time they will be fit for use; and any desired tints may be obtained by making a composition from them, with such proportions of each liquor as the nature of the color desired will point out.

Durable and lustrous Black Coating for Metals.—The bottom of a cylindrical iron pot, which should be about 18 inches in height, is covered half an inch with powdered bituminous coal; a grate is then put in and the pot filled with the articles to be varnished. Articles of cast iron, iron wire, brass, zinc, steel, tinned iron, &c., may be subjected to the same treatment. The cover is then put on and the pot heated over a coke fire under a well-drawing chimney. In the beginning the moisture only evaporates, but soon the coking commences, and deep brown vapors escape, which irritate the throat. When the bottom of the pot has been heated for 15 minutes to a dull red heat, the coal has been mostly converted into coke; the pot is then removed from the fire, and after standing 10 minutes opened for evaporation, all the articles will be found covered with the above described coating. This lacquer is not only a protection against oxidation of metals, but will stand also a considerable heat, only disappearing at beginning redness, and therefore its useful application for ovens and furnaces. The coating produced is thin, lustrous, and cannot easily be scratched. Fine iron-ware articles, such as sieves, are in this manner coated with remarkable evenness, which cannot be accomplished in any other way. Articles made of tin, or soldered, cannot be subjected to this process, as they would fuse. Smaller articles, like hooks and eyes, receive this coating by heating them together with small pieces of bituminous coal in a cylindrical sheet iron drum like that used for roasting coffee, until they present the desired lustrous black appearance.

Lacquer for Philosophical Instruments.—Gamboge, $1\frac{1}{2}$ ounces; gum sandarach, 4 ounces; gum elemi, 4 ounces; best dragon's blood, 2 ounces; terra merita, $1\frac{1}{2}$ ounces; oriental saffron, 4 grains; seed-lac, 2 ounces; pounded glass, 6 ounces; pure alcohol, 40 ounces. The dragon's blood, gum elemi, seed-lac, and gamboge, are all pounded and mixed with the glass. Over them is poured the tincture obtained by infusing the saffron and terra merita in the alcohol for 24 hours. This tincture, before being poured over the dragon's blood, etc., should be strained through a piece of clean linen cloth, and strongly squeezed. If the dragon's blood gives too high a color, the quantity may be lessened according to circumstances. The same is the case with the other coloring matters. In choosing the terra merita, select that which is sound and compact. This lacquer has a very good effect when applied to many cast or moulded articles used in ornamenting furniture, the irregularity of surface of which would render it difficult, if not impossible, to polish in the ordinary manner.

To frost Aluminum.—The metal is plunged into a solution of caustic potash. The surface, becoming frosted, does not tarnish on exposure to the air.

Platinum—also called platina—is the heaviest substance but one known, having a specific gravity of fully 21, which may be raised to about 21.5 by hammering. It is whiter than iron, harder than silver, infusible in the hottest furnace, and melts only before the compound blow-pipe at a heat of about 3080° Fahr. On this account it is valuable for making capsules, &c., intended to resist strong heat. Platinum undergoes no change by exposure to air and moisture, or the strongest heat of a smith's forge, and is not attacked by any of the pure acids, but is dissolved by chlorine and nitro-muriatic acid (aqua regia), though with more difficulty than gold. Spongy and powdered platinum possess the remarkable property of causing the union of oxygen and hydrogen gases. It is chiefly imported from South America, but is also found in the Ural Mountains of Russia, in Ceylon, and a few other places. Platinum, when alloyed with silver, is soluble in nitric acid; the pure metal is dissolved by aqua regia, and is more or less attacked by caustic alkali, nitre, phosphorus, &c., with heat. Platinum is precipitated from its solutions by deoxidizing substances under the form of a black powder, which has the power of absorbing oxygen, and again imparting it to combustible substances, and thus causing their oxidation. In this way alcohol and pyroxilic spirit may be converted into acetic and formic acids, &c.

To estimate the Purity of Antimony.—Treat pulverized antimony with nitric acid; this oxidizes the antimony, and leaves it in an insoluble state, whilst it dissolves the other metals. Collect the oxide on a filter, wash, dry, ignite, and weigh it. This weight, multiplied by .843 gives the weight of pure metal in the sample examined. If this has been previously weighed, the percentage of pure metal is easily arrived at.

To purify Platinum.—The native alloy (crude platinum) is acted upon, as far as possible, with nitro-muriatic acid, containing an excess of muriatic acid, and slightly diluted with water. The solution is precipitated by the addition of sal-ammoniac, which throws down nearly the whole of the platinum in the state of an ammonio-chloride, which is washed with a little cold water, dried, and heated to redness; the product is spongy metallic platinum. This is made into a thin uniform paste with water, pressed in a brass mould, to squeeze out the water and render the mass sufficiently solid to bear handling. It is then dried, carefully heated to whiteness, and hammered or pressed in the heated state; after this treatment it may be rolled into plates or worked into any desired shape.

Platinated Asbestos.—Dip asbestos in a solution of chloride of platinum, and heat it to redness. It causes the inflammation of hydrogen in the same manner as spongy platinum.

Platinum-Black. Platina Mohr.—This is platinum in a finely divided state, and is obtained thus: Add to a solution of bichloride of platinum, an excess of carbonate of soda, and a quantity of sugar. Boil until the precipitate which forms becomes, after a little while, perfectly black, and the supernatant liquid colorless; filter the powder, wash, and dry it by a gentle heat. Another method is by melting platina ore with twice its weight of zinc, powdering, digesting first in dilute sulphuric acid, and next in dilute nitric acid, to remove the zinc, assisting the action of the menstruum by heat; it is then digested in potash lye, and lastly in pure water, after which it is carefully dried. Platinum-black possesses the property of condensing gases, more especially oxygen, into its pores, and afterward yielding it to various oxidizable substances. If some of it be mixed with alcohol into a paste, and spread on a watch glass, pure acetic acid is given off, and affords a ready means of diffusing the odor of vinegar in an apartment.

Tests for Antimony.—An acid solution of antimony gives, in combination with sulphureted hydrogen, an orange-red precipitate, sparingly soluble in ammonia, but readily soluble in pure potassa and alkaline sulphurets. Hydrosulphuret of ammonia throws down from the acid solution an orange-red precipitate, readily soluble in excess of the precipitant, if the latter contain sulphur in excess; and the liquor containing the re-dissolved precipitate gives a yellow or orange-yellow precipitate on the addition of an acid. Ammonia, and potassa, and their carbonates (except in solutions of tartar emetic) give a bulky white precipitate; that from ammonia being insoluble in excess of the precipitant; that from potassa readily so; while those from the carbonate are only soluble on the application of heat.

To obtain Commercial Antimony.—Fuse together 100 parts sulphuret of antimony, 40 parts metallic iron, and 10 parts dry crude sulphate of soda. This produces from 60 to 65 parts of antimony, besides the scoriæ or ash, which is also valuable.

Spongy Platinum.—Dissolve separately crude bichloride of platinum, and hydrochlorate of ammonia in proof spirit; add the one solution to the other as long as a precipitate falls; this is collected, and, while still moist, formed into little balls or pieces, which are then dried, and gradually heated to redness.

Spongy Platinum.—Dissolve platinum, by the aid of heat, in a mixture of 3 parts nitric and 5 parts muriatic acid, avoiding great excess of acid. To this solution add a strong solution of muriate of ammonia; collect the resulting precipitate on a filter, and, when nearly dry, form it into a mass of the shape desired for the sponge. Heat this to whiteness on charcoal, with a blow-pipe or otherwise, and the platinum remains in the spongy state. Its characteristic properties may be restored, when lost, by simply heating it to redness.

To purify Bismuth.—Dissolve crude bismuth in nitric acid, and concentrate the solution by evaporation. Then pour the clear solution into a large bulk of distilled water, and a white powder (sub-nitrate of bismuth) will be precipitated. Collect the precipitate and digest it for a time in a little caustic potash, to dissolve away any arsenious acid that may be present; next wash and dry the sub-nitrate; heat it with about one-tenth its weight of charcoal in an earthen crucible, and the pure bismuth will be found at the bottom of the crucible.

To separate Bismuth from Lead.—Dissolve the mixed metal in nitric acid; add caustic potash in excess, and the oxides of bismuth and lead will be precipitated, but the lead oxide will be at once re-dissolved by the alkali. The oxide of bismuth can then be separated by filtration, washed, and ignited.

To obtain Metallic Antimony.—Mix together 16 parts sulphuret of antimony and 6 parts cream of tartar, both in powder; put the mixture, in small quantities at a time, into a vessel heated to redness; when reaction ceases, fuse the mass, and, after 15 minutes, pour it out and separate the metal from the slag. The product is nearly pure.

Or: Equal parts of protoxide of antimony and bitartrate of potassa (cream of tartar); mix and fuse as above, and pour the metal into small conical moulds.

Or: 8 parts sulphuret of antimony, 6 parts cream of tartar, and 3 parts nitre. Treated as above.

Or: 2 parts sulphuret of antimony and 1 part iron filings; calcine at a strong heat in a covered crucible.

Black Bronzes.—A very dark colored bronze may be obtained by using a little sulphureted alkali (sulphuret of ammonia is best). The face of the medal is washed over with the solution, which should be dilute, and the medal dried at a gentle heat, and afterward polished with a hard hair brush. Sulphureted hydrogen gas is sometimes employed to give this black bronze, but the effect of it is not so good, and the gas is very deleterious when breathed. In these bronzes the surface of the copper is converted into a sulphuret.

Nagel's Method of Electroplating with Nickel.—A process devised by Mr. Nagel, of Hamburg, for coating iron, steel, and other oxidizable metals with an electro-deposit of nickel or cobalt, consists in taking 4 parts, by weight, of pure sulphate of the protoxide of nickel by crystallization, and 2 parts, by weight, of pure ammonia, so as to form a double salt, which is then dissolved in 60 parts of distilled water, and 12 parts of ammoniacal solution of the specific gravity of .909 added. The electro-deposit is effected by an ordinary galvanic current, using a platinum positive pole, the solution being heated to about 100° Fahr. The strength of the galvanic current is regulated according to the number of objects to be coated.

Antique Bronze Coloring.—To impart a brass or antique bronze color, either of the three following means may be adopted: A solution of copper, with some acetic acid. Or: The means before described for copper color, with a large proportion of liquid ammonia. Or: Water acidulated with nitric acid, by which beautiful bluish shades may be produced. It must be observed, however, this last process can only be properly employed on the alloys which contain a portion of copper.

To prepare a Brass Solution.—For each gallon of water used to make the solution, take 1 part carbonate of ammonia, 1 pound cyanide of potassium, 2 ounces cyanide of copper, and 1 ounce cyanide of zinc. This constitutes the solution for the decomposing cell. It may be prepared, also from the above proportions of carbonate of ammonia and cyanide of potassium, by immersing in it a large sheet of brass of the desired quality, and making it the anode or positive electrode of a powerful galvanic battery or magneto-electric machine; and making a small piece of metal the cathode or negative electrode, from which hydrogen must be freely evolved. This operation is continued till the solution has taken up a sufficient quantity of the brass to produce a reguline deposit.

To electroplate with Brass. For wrought or fancy work, about 150° Fahr. will give excellent results. The galvanic battery, or magneto-electric machine, must be capable of evolving hydrogen freely from the cathode or negative electrode, or article attached thereto. It is preferred to have a large anode or positive electrode, as this favors the evolution of hydrogen. The article or articles treated as before described will immediately become coated with brass. By continuing the process, any desired thickness may be obtained. Should the copper have a tendency to come down in a greater proportion than is desired, which may be known by the deposit assuming too red an appearance, it is corrected by the addition of carbonate of ammonia, or by a reduction of temperature when the solution is heated. Should the zinc have a tendency to come down in too great a proportion, which may be seen by the deposit being too pale in its appearance, this is corrected by the addition of cyanide of potassium or by an increase of temperature.

To protect Steel from rusting.—It has been found by experiment that an electro-deposited coating of nickel protects the surface of polished steel completely from rust. Swords, knives, and other articles of steel liable to exposure, may be coated with nickel without materially altering the color of the metal.

To electroplate with German Silver.—The alloy, German silver, is deposited by means of a solution consisting of carbonate of ammonia and cyanide of potassium (in the proportions given above for the brass), and cyanides or other compounds of nickel, copper, and zinc, in the requisite proportions to constitute German silver. It is, however, preferred to make the solution by means of the galvanic battery or magneto-electric machine, as above described for brass. Should the copper of the German silver come down in too great a proportion, this is corrected by adding carbonate of ammonia, which brings down the zinc more freely; and should it be necessary to bring down the copper in greater quantity, cyanide of potassium is added—such treatment being similar to that of the brass before described.

Brown Bronzes for Medals, &c.—Take a wine-glass of water, and add to it 4 or 5 drops nitric acid; with this solution wet the medal (which ought to have been previously well cleaned from oil or grease) and then allow it to dry; when dry impart to it a gradual and equable heat, by which the surface will be darkened in proportion to the heat applied.

Chinese Bronze.—Take 2 ounces each verdigris and vermilion; 5 ounces each alum and sal-ammoniac, all in fine powder, and sufficient vinegar to make a paste; then spread it over the surface of the copper, previously well cleaned and brightened; uniformly warm the article by the fire, and afterward well wash and dry it, when, if the tint be not deep enough, the process may be repeated. The addition of a little sulphate of copper inclines the color to a chestnut brown; and a little borax to a yellowish brown. Much employed by the Chinese for copper tea-urns.

German Method of bronzing Brass black.—There are two methods of procuring a black lacquer upon the surface of brass. The one, which is that usually employed for optical and scientific instruments, consists in first polishing the object with tripoli, then washing it with a mixture composed of 1 part nitrate of tin and 2 parts chloride of gold, and, after allowing this wash to remain on for about 12 or 15 minutes, wiping it off with a linen cloth. An excess of acid increases the intensity of the tint. In the other method, copper turnings are dissolved in nitric acid until the acid is saturated; the objects are immersed in the solution, cleaned, and subsequently heated moderately over a charcoal fire. This process must be repeated in order to produce a black color, as the first trial only gives a deep green; when the desired color is attained, the finishing touch is given by polishing with olive oil.

Black Bronzes.—Many metallic solutions, such as weak acid solutions of platinum, gold, palladium, antimony, etc., will impart a dark color to the surface of medals when they are dipped into them. The medal, after being dipped into the metallic solution, is to be well washed and brushed. In such bronzes the metals contained in the solution are precipitated upon the face of the copper medal, which effect is accompanied by a partial solution of the copper.

Nagel's Method of Electroplating Metal with Cobalt.—For coating with cobalt, 138 parts, by weight, of pure sulphate of cobalt, are combined with 69 parts of pure ammonia, to form a double salt, which is then dissolved in 1,000 parts of distilled water, and 120 parts of ammoniacal solution, of the same specific gravity as before, are added. The process of deposition with cobalt is the same as with nickel.

To make Bronze Powder for Plaster Casts, &c.—To a solution of soda-soap in linseed oil, cleared by straining, add a mixture of 4 pints sulphate of copper solution, and 1 pint sulphate of iron solution, which precipitates a metallic soap of a peculiar bronze hue; wash with cold water, strain, and dry to powder.

To bronze Plaster Casts, &c.—The powdered soap of the last receipt is thus applied: Boil 3 pounds pure linseed oil with 12 ounces finely powdered litharge; strain through a coarse canvas cloth, and allow to stand until clear; 15 ounces of this soap varnish, mixed with 12 ounces metallic-soap powder (see last receipt), and 5 ounces fine white wax, are to be melted together at a gentle heat in a porcelain basin, by means of a water-bath, and allowed to remain for a time in a melted state to expel any moisture that it may contain; it is then applied with a brush to the surface of the plaster previously heated to 200° Fahr., being careful to lay it on smoothly, and without filling up any small indentations of the plaster design. Place it for a few days in a cool place; and, as soon as the smell of the soap varnish has gone off, rub the surface over with cotton wool, or fine linen rag, and variegated with a few streaks of metal powder or shell gold. Small objects may be dipped in the melted mixture, and exposed to the heat of a fire till thoroughly penetrated and evenly coated with it.

To make Bronzing for Wood.—Grind separately to a fine powder, Prussian blue, chrome yellow, raw umber, lamp-black, and clay, and mix in such proportions as will produce a desired dark green hue; then mix with moderately strong glue size.

To bronze Wood.—First coat the clean wood with a mixture of size and lamp-black; then apply two coats of the green colored sizing in the last receipt, and lastly with bronze powder, such as powdered Dutch foil, mosaic gold, &c., laid on with a brush. Finish with a thin solution of castile soap; and, when dry, rub with a soft woolen cloth.

Bronzing with Crocus.—Make a thin paste of crocus and water; lay this paste on the face of the medal, which must then be put into an oven, or laid on an iron plate over a slow fire; when the paste is perfectly reduced to powder, brush it off and lay on another coating; at the same time quicken the fire, taking care that the additional heat is uniform; as soon as the second application of paste is thoroughly dried, brush it off. The medal being now effectually secured from grease, which often occasions failures in bronzing, coat it a third time, but add to the strength of the fire, and sustain the heat for a considerable time; a little experience will soon enable the operator to decide when the medal may be withdrawn; the third coating being removed, the surface will present a beautiful brown bronze. If the bronze is deemed too light the process can be repeated.

To bronze Porcelain, Stoneware, and Composition Picture-Frames.—A bronzing process, applicable to porcelain, stoneware, and composition picture and looking-glass frames, is performed as follows: The articles are first done over with a thin solution of water-glass by the aid of a soft brush. Bronze powder is then dusted on, and any excess not adherent is knocked off by a few gentle taps. The article is next heated, to dry the silicate, and the bronze becomes firmly attached. Probably, in the case of porcelain, biscuit, or stoneware, some chemical union of the silicate will take place, but in other cases the water-glass will only tend to make the bronze powder adhere to the surface. After the heating, the bronze may be polished or burnished with agate tools.

Browning for Gun-Barrels.—Mix 1 ounce each aquafortis and sweet spirits of nitre; 4 ounces powdered blue vitriol; 2 ounces tincture of iron, and water, 1½ pints; agitate until dissolved.

Or: Blue vitriol and sweet spirits of nitre, of each 1 ounce; water, 1 pint; dissolve as last.

Or: Mix equal parts of butter of antimony and sweet oil, and apply the mixture to the iron previously warmed.

To brown Gun-Barrels.—The gun-barrel to be browned must be first polished and then rubbed with whiting to remove all oily matter. Its two ends should be stopped with wooden rods, which serve as handles, and the touch-hole filled with wax. Then rub on above solution with a linen rag or sponge till the whole surface is equally moistened. Let it remain till the next day, then rub it off with a stiff brush. The liquid may be again applied until a proper color is produced. When this is the case, wash in pearlash water, and afterward in clean water, and then polish, either with the burnisher or with bees-wax; or apply a coat of shellac varnish.

Belgian Burnishing Powder.—A burnishing powder in use in Belgium is composed of ½ pound fine chalk, 3 ounces pipe clay, 2 ounces white lead, ¾ ounce magnesia (carbonate), and the same quantity of jeweller's rouge.

Drab Bronze for Brass.—Brass obtains a very beautiful drab bronze by being worked in moulders' damp sand for a short time and brushed up.

To protect Silver-Ware from tarnishing.—The loss of silver which results from the impregnation of our atmosphere with sulphur compounds, especially where gas is burned, is very great. Silversmiths may thank one of their confraternity—Mr. Strolberger, of Munich—for a happy thought. He seems to have tried various plans to save his silver, if possible. He covered his goods with a clear white varnish, but found that it soon turned yellow in the window, and spoiled the look of his wares. Then he tried water-glass (solution of silicate of potash), but this did not answer. He tried some other solutions, to no purpose; but at last he hit upon the expedient of coating his goods over with a thin coating of collodion, which he found to answer perfectly. No more loss of silver, and no longer incessant labor in keeping it clean. The plan he adopts is this: He first warms the articles to be coated, and then paints them over carefully with a thinnish collodion diluted with alcohol, using a wide soft brush for the purpose. Generally, he says, it is not advisable to do them over more than once. Silver goods, he tells us, protected in this way, have been exposed in his window more than a year, and are as bright as ever, while others unprotected have become perfectly black in a few months.

To prevent Coins and small Ornaments from tarnishing. All ornaments, whether gold or silver, can be kept from tarnishing if they are carefully covered from the air in box-wood sawdust, which will also dry them after being washed. The tarnish on silver-ware is most often due to sulphur. A gentleman who wears a silver watch finds that it is tarnished from the sulphur fumes of the rubber ring which holds together his ferry tickets. Sulphur fumes enough get into the air to account for all ordinary cases of tarnishing.

To clean Silver. Immerse for half an hour the silver article into a solution made of 1 gallon water, 1 pound hyposulphite of soda, 8 ounces muriate of ammonia, 4 ounces liquid ammonia, and 4 ounces cyanide of potassium; but, as the latter substance is poisonous, it can be dispensed with if necessary. The article, being taken out of the solution, is washed, and rubbed with a wash-leather.

To clean Silver-Plate. Fill a large saucepan with water; put into it 1 ounce carbonate of potash and ¼ pound whiting. Now put in all the spoons, forks, and small plate, and boil them for 20 minutes; after which take the saucepan off the fire and allow the liquor to become cold; then take each piece out and polish with soft leather. A soft brush must be used to clean the embossed and engraved parts.

To separate Tin from Copper. Digest in nitric acid; the copper will be dissolved, but the tin will remain in an insoluble peroxide.

Plate Boiling Powder.—Mix equal parts of cream of tartar, common salt, and alum. A little of this powder, added to the water in which silver-plate is boiled, gives to it a silvery whiteness.

Test for the Quantity of Copper in a Compound.—The quantity of copper present in any compound may be estimated by throwing it down from its solution by pure potassa, after which it must be carefully collected, washed, dried, ignited, and weighed. This will give the quantity of the oxide from which its equivalent of metallic copper may be calculated; every 5 parts of the former being nearly equal to 4 of the latter; or, more accurately, every 39.7 parts are equal to 31.7 of pure metallic copper. Copper may also be precipitated at once in the metallic state, by immersing a piece of polished steel into the solution; but this method will not give very accurate results.

To separate Lead from Copper.—Copper may be separated from lead by adding sulphuric acid to the nitric solution, and evaporating to dryness, when water digested on the residuum will dissolve out the sulphate of copper, but leave the sulphate of lead behind. From this solution the oxide of copper may be thrown down as before.

To separate Zinc from Copper.—Copper may be separated from zinc by sulphuretted hydrogen, which will throw down a sulphuret of copper, which may be dissolved in nitric acid, and treated as in last receipt.

To separate Silver from Copper.—Digest, in a state of filings or powder, in a solution of chloride of zinc, which dissolves the copper and leaves the silver unchanged.

To separate Copper from its Alloys.—Copper may be separated in absolute purity from antimony, arsenic, bismuth, lead, iron, &c., as it exists in bell-metal, brass, bronze, and other commercial alloys, by fusing, for about half an hour, in a crucible. 10 parts of the metal with 1 part each of copper scales (black oxide) and bottle glass. The pure copper is found at the bottom of the crucible, whilst the other metals or impurities are either volatilized or dissolved in the flux.

Reduction of Copper in Fine Powder.—M. Schiff gives the following process for obtaining copper in a state of fine division: A saturated solution of sulphate of copper, together with some crystals of the salt, are introduced into a bottle or flask, and agitated with some granulated zinc. The zinc displaces the copper from its solution, fresh sulphate dissolving as the action goes on, until the whole is exhausted. Heat is disengaged during the operation. The precipitated copper must be washed and dried as rapidly as possible, to prevent oxidation.

Feather-Shot Copper.—Melted copper, poured in a small stream into cold water. It forms small pieces, with a feathered edge, hence the name. It is used to make solution of copper.

Copper in Fine Powder.—A solution of sulphate of copper is heated to the boiling-point, and precipitated with sublimated zinc. The precipitated copper is then separated from the adherent zinc by diluted sulphuric acid, and dried by exposure to a moderate temperature.

Black Enamels.—I. Pure clay, 3 parts; protoxide of iron, 1 part; mix and fuse. A fine black.

II. Calcined iron (protoxide), 12 parts; oxide of cobalt, 1 part; mix, and add an equal weight of white flux.

III. Peroxide of manganese, 3 parts; zaffre, 1 part; mix and add it as required to white flux. Zaffre is crude oxide of cobalt.

Blue Enamels.—I. Either of the white fluxes colored with oxide of cobalt.

II. Sand, red-lead, and nitre, of each 10 parts; flint glass or ground flints, 20 parts; oxide of cobalt, 1 part, more or less, the quantity depending on the depth of color required.

Brown Enamels.—I. Red-lead and calcined iron, of each 1 part; antimony, litharge, and sand, of each, 2 parts; mix and add it in any required proportion to a flux, according to the color desired. A little oxide of cobalt or zaffre is frequently added, and alters the shade of brown.

II. Manganese, 5 parts; red-lead, 16 parts; flint powder, 8 parts; mix.

III. Manganese, 9 parts; red-lead, 34 parts; flint powder, 16 parts.

Green Enamels.—I. Flux, 2 pounds; black oxide of copper, 1 ounce; red oxide of iron, $\frac{1}{2}$ dram; mix.

II. As above, but use the red oxide of copper. Less decisive.

III. Copper dust and litharge, of each 2 ounces; nitre, 1 oz.; sand, 4 oz.; flux, as much as required.

IV. Add oxide of chrome to a sufficient quantity of flux to produce the desired shade; when well managed the color is superb, and will stand a very great heat; but in careless hands, it frequently turns on the dead-leaf tinge.

V. Transparent flux, 5 ounces; black oxide of copper, 2 scruples; oxide of chrome, 2 grains. Resembles the emerald.

VI. Mix blue and yellow enamel in the required proportions.

Orange Enamels.—I. Red-lead, 12 parts; red sulphate of iron and oxide of antimony, of each 1 part; flint powder, 3 parts; calcine, powder, and melt with flux, 50 parts.

II. Red-lead, 12 parts; oxide of antimony, 4 parts; flint powder, 3 parts; red sulphate of iron, 1 part; calcine, then add flux, 5 parts to every 2 parts of this mixture.

Red Enamel.—Paste or flux colored with the red or protoxide of copper. Should the color pass into the green or brown, from the partial peroxidizement of the copper, from the heat being raised too high, the red color may be restored by the addition of any carbonaceous matter, as tallow, or charcoal.

Purple Enamels.—I. Flux colored with oxide of gold, purple precipitate of cassius, or peroxide of manganese.

II. Sulphur, nitre, vitriol, antimony, and oxide of tin, of each 1 pound; red-lead, 60 pounds; mix and fuse, cool and powder; add rose copper 19 ounces; zaffre, 1 ounce; crocus martis, 1½ ounces; borax, 3 ounces; and 1 pound of a compound formed of gold, silver, and mercury; fuse, stirring the melted mass with a copper rod all the time, then place it in crucibles, and submit them to the action of a reverberatory furnace for 24 hours. This is said to be the purple enamel used in the mosaic pictures of St. Peter's at Rome.

Olive Enamels.—Good blue enamel, 2 parts; black and yellow enamels, of each 1 part; mix. (See Brown Enamels.)

Beautiful Red Enamel.—The most beautiful and costly red, inclining to the purple tinge, is produced by tinging glass or flux with the oxide or salts of gold, or with the purple precipitate of cassius, which consists of gold and tin. In the hands of the skilful artist, any of these substances produces shades of red of the most exquisite hue; when most perfect, the enamel comes from the fire quite colorless, and afterward receives its rich hue from the flame of the blow-pipe.

Rose-colored Enamels.—Purple enamel, or its elements, 3 parts; flux, 90 parts; mix, and add silver-leaf or oxide of silver, 1 part or less.

To make Soldering Fluid for Soft Solder.—Into muriatic acid put small pieces of zinc until all bubbling ceases; some add 1 ounce sal-ammoniac to each pound of the liquid.

Neutral Soldering Fluid.—Dissolve zinc in muriatic acid as above, then warm the solution and add sufficient oxide or carbonate of tin in powder to neutralize it. This prevents the fluid from corroding the seams.

Soldering Liquid.—Soldering liquid is made by taking hydrochloric acid, ¼ pint; granulated tin, 1½ ounce; dissolve and add some common solder and hydrochlorate of ammonia.

Flux for Soldering.—For common purposes powered resin is generally used. Stearic acid, obtained from the candle factories, makes a good flux for fine tin work.

Flux for soldering Iron or Steel.—Dissolve chloride of zinc in alcohol.

Flux for soldering Steel.—This answers perfectly when the fracture is an old one. To a saturated solution of zinc in 1 pint muriatic acid, add 4 ounces pulverized sal-ammoniac; boil it for 10 minutes; put it, when cold, in a well-corked bottle. The boiling must be done in a copper vessel.

Flux for soldering Pewter.—Pewter requires a flux of oil, and may, in addition to the soldering-iron process, be soldered by a current of heated air.

Soft Soldering.—The solder is an alloy of 2 parts tin to 1 part lead, fusible at 340° Fahr.; or, for cheapness, the proportion is sometimes 3 to 2, fusible at 334°. This substance is applied with a hot copper tool called a soldering-iron, or by blow-pipe flame. Heat, however, causes the edges of the metal to oxidize; therefore the edges are covered with a substance having a strong attraction for oxygen, and disposing the metal to unite to the solder at a low temperature. Such substances are called fluxes, and are chiefly borax, resin, sal-ammoniac, muriate of zinc, Venice turpentine, tallow, or oil.

Flux for soldering Brass.—For brass or other similar alloy, resin, sal-ammoniac, and muriate of zinc are the proper fluxes. Should the work be heavy and thick, the soldering requires to be done over a charcoal fire in order to keep the tool heated within proper limits. It is well to tin the surfaces before soldering; in some cases simply dipping into a pot of melted solder effects the purpose, but the dip must be done instantly to be effective.

Flux for soldering Zinc.—Zinc is difficult to solder, from the fact that it is apt to withdraw the tin from the soldering bolt, zinc and copper having a stronger affinity for each other than tin and copper. The proper flux is muriate of zinc, made by dissolving small bits of zinc or zinc drops in muriatic acid mixed with an equal bulk of water.

Flux for soldering Tin and Lead.—Tin and lead require resin or oil as the flux.

Flux for soldering Britannia Metal.—Britannia metal should have muriate of zinc for a flux, and be soldered by the blow-pipe.

To soft solder Small Articles.—Join together the parts to be soldered, first moistening them with soldering fluid, lay a small piece of solder over the joint and apply heat, either over a spirit flame, or by means of a blow-pipe, as the case may be. The heat should be withdrawn at the moment of fusion, otherwise the solder may become brittle.

To soft solder Smooth Surfaces.—Where two smooth surfaces are to be joined, moisten the surfaces with soldering fluid, and lay a piece of tin foil between them, press them together closely, and apply heat sufficient to fuse the tin foil.

Hard Soldering or Brazing.—The alloy used in hard soldering is generally made of equal parts of copper and zinc; much of the zinc, however, is lost in the process, so that the real proportion is not equal parts. The alloy is heated over a charcoal fire, and broken to granulations in an iron mortar. A different proportion is used for soldering copper and iron, viz: 3 zinc to 1 copper. The commercial name is "spelter solder."

Solder for Gold.—Take 12 parts pure gold, 2 parts pure silver, and 2 parts copper.

Flux for Spelter Solder.—The flux employed for spelter solder is borax, which can either be used separately, or mixed, by rubbing to a cream, or mixed with the solder in a very little water.

To make Solder.—The mixture of the metals is performed by melting them together in the same manner as for alloys, with the aid of a flux. The metals employed should be pure, especially silver, as silver coin makes the solder too hard.

Solder for Silver.—Take 5 parts pure silver—not silver coin—6 parts brass, and 2 parts zinc. Or, 2 parts silver, 1 part common pins. This is an easy flowing solder. Use a gas jet to solder with.

Hard Solder.—Take 2 parts copper and 1 part zinc. Or, equal parts of copper and zinc.

Solder for Silver.—Take 19 parts fine silver, 1 part copper, and 10 parts brass.

Silver Solder.—Melt together 31 parts, by weight, silver coin, and 5 parts copper; after cooling a little, drop into the mixture 4 parts zinc, then heat again.

Fine Silver Solder.—Melt in a clean crucible, 19 parts pure silver, 10 parts brass, and 1 part copper; add a small piece of borax as a flux.

Solder for Copper.—Same as hard soldering.

Solder for Tin.—Take 4 parts pewter, 1 part tin, and 1 part bismuth. Use powdered resin when soldering.

To give Brass an Orange Tint.—An orange tint, inclining to gold, is produced by first polishing the brass and then plunging it for a few seconds into a neutral solution of crystallized acetate of copper, care being taken that the solution is completely destitute of all free acid, and possesses a warm temperature.

To color Brass Violet.—A beautiful violet is obtained by immersing the polished brass for a single instant in a solution of chloride of antimony, and rubbing it with a stick covered with cotton. The temperature of the brass at the time the operation is in progress has a great influence upon the beauty and delicacy of the tint; in this instance it should be heated to a degree so as just to be tolerable to the touch.

To give Brass a Moire Appearance.—A moiré appearance, vastly superior to that usually seen, is produced by boiling the object in a solution of sulphate of copper. According to the proportions observed between the zinc and the copper in the composition of the brass, so will the tints obtained vary. In many instances it requires the employment of a slight degree of friction, with a resinous or waxy varnish, to bring out the wavy appearance characteristic of moiré, which is also singularly enhanced by dropping a few iron nails into the bath.

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