FRANK SOULE

National Tube Company

BOOK OF STANDARDS

AND

USEFUL INFORMATION

CONTAINING

TABLES OF SIZES AND
OTHER USEFUL INFORMATION PERTAINING
TO TUBULAR GOODS

THE ENGINEERING DATA FOR THIS BOOK
EDITED BY
PROF. REID T. STEWART

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National Tube Company

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PREFACE

In the following tables of Standard dimensions of Tubular Goods, it has been our aim to group together in one book all of the dimensions and data pertaining to standards as manufactured by National Tube Co. at this date, with the object of making this book a practical and valuable aid to all users of Pipes, Tubes, etc. The use of Tubular Goods has become so extensive that a great variety of articles necessary for different purposes has to be manufactured, and a large amount of data has accumulated on the subject, and we trust that our effort to put this before the public in a compact form will prove of value.

We have also taken up certain subjects closely related to the use of pipes, tubes, etc., and furnished such general information and engineering data pertaining to same, as, we think, will be useful and appropriate in a book of this kind, with the idea of popularizing such information that would lead to the intelligent application of tubular goods for purposes where engineering skill and judgment should be exercised. This data was prepared for publication by Prof. Reid T. Stewart and is largely compiled from modern well-known engineering authorities on the subjects.

Tables

of

Standard Dimensions

of

Tubular Goods

as manufactured
by the

National Tube Co.

NATIONAL TUBE CO.—Black or Galvanized Standard Weight Pipe.

Diameter.			Thick-ness.	Circumference.		Transverse Areas.			Nom. Wgt. per ft. lbs.	Threads per In.
Nom.	External.	Internal.		External.	Internal.	External.	Internal.	Metal.		
⅛	.405	.269	.068	1.272	.845	.1288	.0568	.0720	.241	27
¼	.540	.364	.088	1.696	1.144	.2290	.1041	.1249	.42	18
⅜	.675	.493	.091	2.121	1.549	.3578	.1909	.1669	.559	18
½	.840	.622	.109	2.639	1.954	.5542	.3039	.2503	.837	14
¾	1.050	.824	.113	3.299	2.589	.8659	.5333	.3326	1.115	14
1	1.315	1.047	.134	4.131	3.289	1.3581	.8609	.4972	1.668	11½
1¼	1.660	1.380	.140	5.215	4.335	2.1642	1.4957	.6685	2.244	11½
1½	1.900	1.610	.145	5.969	5.058	2.8353	2.0358	.7995	2.678	11½
2	2.375	2.067	.154	7.461	6.494	4.4301	3.3556	1.074	3.609	11½
2½	2.875	2.467	.204	9.032	7.750	6.4918	4.7800	1.712	5.739	8
3	3.500	3.066	.217	10.996	9.632	9.6211	7.3827	2.238	7.536	"
3½	4.000	3.548	.226	12.566	11.146	12.566	9.886	2.680	9.001	"
4	4.500	4.026	.237	14.137	12.648	15.904	12.730	3.174	10.665	"
4½	5.000	4.508	.246	15.708	14.162	19.635	15.960	3.675	12.34	"
5	5.563	5.045	.259	17.477	15.849	24.306	19.985	4.321	14.502	"
6	6.625	6.065	.280	20.813	19.054	34.472	28.886	5.586	18.762	"
7	7.625	7.023	.301	23.955	22.063	45.664	38.743	6.921	23.271	"
8	8.625	7.981	.322	27.096	25.073	58.426	50.021	8.405	28.177	"
9	9.625	8.937	.344	30.238	28.076	72.760	62.722	10.04	33.701	"
10	10.750	10.018	.366	33.772	31.472	90.763	78.822	11.94	40.065	"
11	11.750	11.000	.375	36.913	34.558	108.43	95.034	13.40	45.95	"
12	12.750	12.000	.375	40.055	37.699	127.68	113.09	14.59	48.985	"

Allow variation in weight per foot of 5 per cent. above and 5 per cent. below. Cannot cut closer to length than $\frac{1}{16}$ inch. Shipped threads and couplings unless otherwise ordered.

NATIONAL TUBE CO.—Standard Extra Strong Pipe.

Diameter.			Thick-ness.	Circumference.		Transverse Areas.			Nom. Wgt. per ft. lbs.	Threads per In.
Nom.	External.	Internal.		External.	Internal.	External.	Internal.	Metal.		
1/8	.405	.205	.100	1.272	.644	.129	.033	.096	.29	27
1/4	.540	.294	.123	1.696	.924	.229	.068	.161	.54	18
3/8	.675	.421	.127	2.121	1.323	.358	.139	.219	.74	18
1/2	.840	.542	.149	2.639	1.703	.554	.231	.323	1.09	14
3/4	1.050	.736	.157	3.299	2.312	.866	.425	.441	1.39	14
1	1.315	.951	.182	4.131	2.988	1.358	.710	.648	2.17	11 1/2
1 1/4	1.660	1.272	.194	5.215	3.996	2.164	1.271	.893	3.00	11 1/2
1 1/2	1.900	1.494	.203	5.969	4.694	2.835	1.753	1.082	3.63	11 1/2
2	2.375	1.933	.221	7.461	6.073	4.430	2.935	1.495	5.02	11 1/2
2 1/2	2.875	2.315	.280	9.032	7.273	6.492	4.209	2.283	7.67	8
3	3.500	2.892	.304	10.996	9.086	9.621	6.569	3.052	10.25	"
3 1/2	4.000	3.358	.321	12.566	10.549	12.566	8.856	3.710	12.47	"
4	4.500	3.818	.341	14.137	11.995	15.904	11.449	4.455	14.97	"
4 1/2	5.000	4.280	.360	15.708	13.446	19.635	14.387	5.248	18.22	"
5	5.563	4.813	.375	17.477	15.120	24.306	18.193	6.113	20.54	"
6	6.625	5.751	.437	20.813	18.067	34.472	25.976	8.496	28.58	"
7	7.625	6.625	.500	23.955	20.813	45.664	34.472	11.192	37.67	"
8	8.625	7.625	.500	27.096	23.955	58.426	45.664	12.762	43.00	"
9	9.625	8.625	.500	30.238	27.096	72.760	58.426	14.334	48.25	"
10	10.750	9.750	.500	33.772	30.631	90.763	74.662	16.101	54.25	"
12	12.750	11.750	.500	40.055	36.914	127.68	108.43	19.25	65.00	"

Allow variation in weight per foot of 5 per cent. above and 5 per cent. below standard. Cannot cut to length closer than 1/16 inch. Shipped plain ends unless otherwise ordered. Where Extra Strong Pipe is ordered with threads and couplings, our regular line pipe couplings will be furnished, unless otherwise specified.

NATIONAL TUBE CO.—Standard Double Extra Strong Pipe.

Diameter.			Thickness.	Circumference.		Transverse Areas.			Nom. Wgt. per ft. lbs.	Threads per In.
Nom.	External.	Internal.		External.	Internal.	External.	Internal.	Metal Area.		
½	.840	.244	.298	2.639	.767	.554	.047	.507	1.7	14
¾	1.050	.422	.314	3.299	1.326	.866	.140	.726	2.44	14
1	1.315	.587	.364	4.131	1.844	1.358	.271	1.087	3.65	11½
1¼	1.660	.885	.388	5.215	2.780	2.164	.615	1.549	5.2	11½
1½	1.900	1.088	.406	5.969	3.418	2.835	.930	1.905	6.4	11½
2	2.375	1.491	.442	7.461	4.684	4.430	1.744	2.686	9.02	11½
2½	2.875	1.755	.560	9.032	5.514	6.492	2.419	4.073	13.68	8
3	3.500	2.284	.608	10.996	7.176	9.621	4.097	5.524	18.56	"
3½	4.000	2.716	.642	12.566	8.533	12.566	5.794	6.772	22.75	"
4	4.500	3.136	.682	14.137	9.852	15.904	7.724	8.180	27.48	"
4½	5.000	3.564	.718	15.708	11.197	19.635	9.976	9.659	32.53	"
5	5.563	4.063	.750	17.477	12.764	24.306	12.965	11.341	38.12	"
6	6.625	4.875	.875	20.813	15.315	34.472	18.665	15.807	53.11	"
7	7.625	5.875	.875	23.955	18.457	45.664	27.109	18.555	62.38	"
8	8.625	6.875	.875	27.096	21.598	58.426	37.122	21.304	71.62	"

Allow variation of 5 per cent. above and 5 per cent. below standard in weight per foot.

Cannot cut to length closer than $\frac{1}{16}$ inch. Shipped plain ends unless otherwise ordered.

HEATING SURFACE.

STANDARD WEIGHT PIPE.			EXTRA STRONG PIPE.			DBLE. EX. STRONG PIPE.		
	Length of Pipe in Ft. per Sq. Ft. of			Length of Pipe in Ft. per Sq. Ft. of			Length of Pipe in Ft. per Sq. Ft. of	
SIZE.	EXTERNAL SURFACE.	INTERNAL SURFACE.	SIZE.	EXTERNAL SURFACE.	INTERNAL SURFACE.	SIZE.	EXTERNAL SURFACE.	INTERNAL SURFACE.
1/8	9.44	14.2	1/8	9.44	18.63	1/2	4.55	15.67
1/4	7.07	10.5	1/4	7.07	12.99	3/4	3.64	9.05
3/8	5.66	7.76	3/8	5.66	9.07	1	2.90	6.51
1/2	4.55	6.15	1/2	4.55	7.05	1 1/4	2.30	4.32
3/4	3.64	4.64	3/4	3.64	5.11	1 1/2	2.01	3.51
1	2.90	3.66	1	2.90	4.02	2	1.61	2.56
1 1/4	2.30	2.77	1 1/4	2.30	3.00	2 1/2	1.33	2.18
1 1/2	2.01	2.38	1 1/2	2.01	2.56	3	1.09	1.67
2	1.61	1.85	2	1.61	1.97	3 1/2	.955	1.41
2 1/2	1.33	1.55	2 1/2	1.33	1.65	4	.849	1.22
3	1.09	1.25	3	1.09	1.33	4 1/2	.764	1.07
3 1/2	.955	1.08	3 1/2	.955	1.14	5	.687	.94
4	.849	.949	4	.849	1.00	6	.577	.78
4 1/2	.764	.848	4 1/2	.764	.893	7	.501	.65
5	.687	.757	5	.687	.793	8	.443	.55
6	.577	.630	6	.577	.664	....	....	....
7	.501	.544	7	.501	.598	....	....	....
8	.443	.478	8	.443	.502	....	....	....
9	.397	.427	9	.397	.443	....	....	....
10	.355	.381	10	.355	.399	....	....	....
11	.325	.348	....	....	....	....	....	....
12	.299	.319	12	.299	.325	....	....	....

NATIONAL TUBE CO.—Lap-Welded Casing.

Lap-Welded Casing is ordinarily furnished with screw and sockets for the joint. It may, however, be joined with what is known as an inserted joint. This consists of a male and female thread; the female thread being cut on the inside of casing, the other having been expanded slightly so that the male thread or outside of other joint can be secured therein. The weights are practically the same.

Diameter.			Thickness.		Circumference.		Transverse Areas.			Nom. Wgt. per ft. lbs.	Threads per inch.	Nom. Diam.
Nom.	Exter'l	Inter'l.	Ins.	B.W.G.	Exter'l	Inter'l.	Exter'l.	Inter'l.	Metal.			
2	2.25	2.06	.095	13	7.069	6.4717	3.976	3.33	.643	2.22	14	2
2¼	2.50	2.282	.109	12	7.854	7.1691	4.909	4.090	.819	2.82	14	2¼
2½	2.75	2.532	.109	12	8.639	7.9545	5.939	5.035	.904	3.13	14	2½
2¾	3.	2.782	.109	12	9.425	8.7399	7.069	6.078	.991	3.45	14	2¾
3	3.25	3.01	.120	11	10.210	9.4562	8.296	7.116	1.180	4.10	14	3
3¼	3.50	3.26	.120	11	10.996	10.2416	9.621	8.347	1.274	4.45	14	3¼
3½	3.75	3.51	.120	11	11.781	11.0270	11.045	9.676	1.369	4.78	14	3½
3¾	4.	3.732	.134	10	12.566	11.7244	12.566	10.940	1.626	5.56	14	3¾
4	4.25	3.982	.134	10	13.352	12.5098	14.186	12.454	1.732	6.00	14	4
4¼	4.50	4.218	.141	..	14.137	13.2513	15.904	13.973	1.931	6.36	14	4¼
4¼	4.50	4.094	.203	6	14.137	12.8617	15.904	13.163	2.741	9.38	14	4¼
4½	4.75	4.468	.141	..	14.923	14.0367	17.728	15.676	2.052	6.73	14	4½
4½	4.75	4.344	.203	6	14.923	13.6471	17.728	14.820	2.908	9.39	14	4½
4¾	5.	4.704	.148	9	15.708	14.7781	19.635	17.380	2.255	7.80	14	4¾
5	5.25	4.954	.148	9	16.493	15.5634	21.648	19.275	2.373	8.20	14	5
5	5.25	4.867	.191	..	16.493	15.2902	21.648	18.604	3.044	9.86	14	5
5	5.25	4.753	.248	3½	16.493	14.9320	21.648	17.743	3.905	12.80	11½	5
5	5.25	4.65	.300	1	16.493	14.6084	21.648	16.982	4.666	15.88	11½	5
5 3/16	5.50	5 187	.156	..	17.279	16.2955	23.758	21.131	2.627	8.62	14	5 3/16
5 3/16	5.50	5.042	.229	4½	17.279	15.8399	23.758	19.965	3.793	12.49	11½	5 3/16
5⅝	6.	5.688	.156	..	18.850	17.8694	28.274	25.407	2.867	10.46	14	5⅝

Allow variation of 5 per cent. above and 5 per cent. below standard in weight per foot. Cannot cut to length closer than 1-16 inch.

NATIONAL TUBE CO.—Lap-Welded Casing. *Continued.*

Diameter.			Thickness.		Circumference.		Transverse Areas.			Nom. Wgt. per ft. lbs.	Threads per inch.	Nom. Diam.
Nom.	Exter'l	Inter'l.	Ins.	B.W.G.	Exter'l.	Inter'l.	Exter'l.	Inter'l.	Metal.			
5⅝	6.	5.594	.203	6	18.850	17.5741	28.274	24.575	3.699	12.04	11½	5⅝
5⅝	6.	5.560	.220	5	18.850	17.4673	28.274	24.279	3.995	14.20	11½	5⅝
5⅝	6.	5.457	.271	..	18.850	17.1437	28.274	23.388	4.886	16.70	11½	5⅝
6¼	6.625	6.280	.172	..	20.813	19.7292	34.472	30.975	3.497	11.58	14	6¼
6¼	6.625	6.219	.203	6	20.813	19.5376	34.472	30.379	4.093	13.32	14–11½	6¼
6¼	6.625	6.149	.238	..	20.813	19.3177	34.472	29.696	4.776	17.02	11½	6¼
6⅝	7.	6.640	.180	7	21.991	20.8602	38.485	34.628	3.857	12.34	14	6⅝
6⅝	7.	6.503	.248	..	21.991	20.4298	38.485	33.214	5.271	17.51	11½–10	6⅝
7¼	7.625	7.265	.180	7	23.955	22.8237	45.664	41.454	4.210	13.55	14	7¼
7⅝	8.	7.617	.191	..	25.133	23.9295	50.265	45.569	4.696	15.41	11½	7⅝
7⅝	8.	7.482	.259	..	25.133	23.5054	50.265	43.968	6.297	20.17	11½	7⅝
8¼	8.625	8.265	.180	7	27.096	25.9653	58.426	53.651	4.775	16.07	11½	8¼
8¼	8.625	8.167	.229	4½	27.096	25.6574	58.426	52.386	6.040	20.10	11½	8¼
8¼	8.625	8.082	.271	..	27.096	25.3904	58.426	51.301	7.125	24.38	11½–8	8¼
8⅝	9.	8.640	.180	7	28.274	27.1434	63.617	58.630	4.987	17.60	11½	8⅝
9⅝	10.	9.577	.211	..	31.416	30.0871	78.540	72.036	6.504	21.90	11½	9⅝
10⅝	11.	10.594	.203	6	34.558	33.2821	95.033	88.147	6.886	26.72	11½	10⅝
11⅝	12.	11.594	.203	6	37.699	36.4237	113.10	105.574	7.526	30.35	11½	11⅝
12½	13.	12.457	.271	..	40.841	39.1349	132.73	121.878	10.852	33.78	11½	12½
13½	14.	13.432	.284	..	43.982	42.1980	153.94	141.701	12.24	42.02	11½	13½
14½	15.	14.416	.292	..	47.124	45.2893	176.71	163.223	13.49	47.66	11½	14½
15½	16.	15.416	.292	..	50.265	48.4309	201.06	186.650	14.41	51.47	11½	15½

Allow variation of 5% above and 5% below standard in weight per foot. Cannot cut to length closer than $\frac{1}{16}$ inch.

National Tube Co. Standard Line Pipe.

Nominal Inside Diameter.	Actual Outside Diameter.	Nominal Thickness.	Nom'l Weight per foot in Pounds.	Number of Threads per inch of Screw.	Nominal Inside Diameter.	Actual Outside Diameter.	Nominal Thickness.	Nom'l Weight per foot in Pounds.	Number of Threads per inch of Screw.
2	2.375	.154	3.609	11½	8	8.625	.281	25.00	8
2½	2.875	.204	5.739	8	8	8.625	.322	28.177	8
3	3.5	.217	7.536	8	9	9.625	.344	33.701	8
3½	4.	.226	9.001	8	10	10.75	.2865	32.00	8
4	4.5	.237	10.665	8	10	10.75	.3145	35.00	8
4½	5.	.246	12.49	8	10	10.75	.366	40.065	8
5	5.563	.259	14.502	8	12	12.75	.340	45.00	8
6	6.625	.28	18.762	8	12	12.75	.375	48.985	8
7	7.625	.301	23.271	8					

National Tube Co. Standard Oil Well Tubing.

Nominal Inside Diameter.	Actual Outside Diameter.	Nominal Thickness.	Nom'l Weight per foot in Pounds.	Number of Threads per inch of Screw.	Nominal Inside Diameter.	Actual Outside Diameter.	Nominal Thicknes.	Nom'l Weight per foot in Pounds.	Number of Threads per inch of Screw.
2	2.375	.1725	4.	11½	4½	5.	.246	12.49	8
2	2.375	.1935	4.50	11½	5	5.563	.259	14.502	8
2½	2.875	.204	5.739	11½	6	6.625	.28	18.76	8
2½	2.875	.221	6.25	11½	7	7.625	.301	23.271	8
3	3.5	.217	7.536	11½	8	8.625	.322	28.177	8
3	3.5	.2445	8.50	11½	8	8.625	.363	32.00	8
3	3.5	.2925	10.00	11½	9	9.625	.344	33.701	8
3½	4.	.226	9.001	8	10	10.75	.366	40.065	8
4	4.5	.237	10.665	8	12	12.75	.375	49.98	8
4	4.5	.2595	11.75	8					

National Tube Co. Standard Drive Pipe.

Nominal Inside Diameter.	Actual Outside Diameter.	Nominal Thickness.	Nom'l Weight per foot in Pounds.	Number of Threads per inch of Screw.	Nominal Inside Diameter.	Actual Outside Diameter.	Nominal Thickness.	Nom'l Weight per foot in Pounds.	Number of Threads per inch of Screw.
2	2.375	.154	3.609	11½	6	6.625	.28	18.76	8
2½	2.875	.204	5.739	8	7	7.625	.301	23.271	8
3	3.5	.217	7.536	8	8	8.625	.322	28.177	8
3½	4.	.226	9.001	8	9	9.625	.344	33.701	8
4	4.5	.237	10.665	8	10	10.75	.366	40.065	8
4½	5.	.246	12.49	8	12	12.75	.375	49.98	8
5	5.563	.259	14.502	8					

Thickness of Metal Required for Flush Joint Pipe and Tubing.

SIZE.	5 Inch Pipe.	5 Inch Extern'l Diameter.	6 Inch Pipe.	6 Inch Extern'l Diameter.	7 Inch Pipe.	7 Inch Extern'l Diameter.	8 Inch Pipe.	8 Inch Extern'l Diameter.	9 Inch Pipe.	9 Inch Extern'l Diameter.
Thickness of Metal, inches	¼	¼	9/32	9/32	5/16	5/16	11/32	11/32	11/32	11/32

SIZE.	10 Inch Pipe.	10 Inch Extern'l Diameter.	11 Inch Pipe.	11 Inch Extern'l Diameter.	12 Inch Pipe.	12 Inch Extern'l Diameter.	13 Inch Extern'l Diameter.	14 Inch Extern'l Diameter.	15 Inch Extern'l Diameter.
Thickness of Metal, inches	⅜	⅜.	⅜	⅜	⅜	⅜	13/32	13/32	13/32

Nominal Weight in Pounds per Foot of Standard Thicknesses of Large Sizes O. D. Pipe.

O. D.	¼ in. thick	5/16 in. thick	⅜ in. thick	7/16 in. thick	½ in. thick	9/16 in. thick	⅝ in. thick	11/16 in. thick	¾ in. thick
14 inches	36.75	45.72	54.61	63.42	72.16	80.80	89.36	97.84	106.2
15 "	39.42	49.06	58.62	68.10	77.50	86.81	96.03	105.2	114.2
16 "	42.09	52.40	62.63	72.78	82.85	92.83	102.7	112.5	122.2
17 "	44.76	55.74	66.64	77.46	88.19	98.84	109.4	119.9	130.3
18 "	47.44	59.08	70.65	82.14	93.54	104.8	116.1	127.2	138.3
20 "	52.78	65.76	78.67	91.49	104.2	116.9	129.4	141.9	154.3
21 "	55.45	69.10	82.68	96.17	109.6	122.9	136.1	149.3	162.3
22 "	......	72 44	86.68	100.8	114.9	128.9	142.8	156.6	170.3
24 "	......	79.13	94.70	110.2	125.6	140.9	156.2	171.3	186.3
26 "	......	......	102.7	119.5	136.3	152.9	169.5	186.0	202.4
28 "	......	......	110.7	128.9	147.0	165.0	182.9	200.7	218.4
30 "	......	......	......	138.2	157.7	177.0	196.3	215.4	234.4

This pipe will be shipped in random lengths, plain ends, unless otherwise ordered.

NATIONAL TUBE CO.—Standard Boiler Tubes.

Diameter.		Thickness.		Circumference.		Transverse Areas.			Length of Tube per Square Ft.		Nom. Wgt. per ft. lbs.
O. D.	I. D.	Ins.	Nearest B.W.G.	External.	Internal.	External.	Internal.	Metal.	Ex. Surf.	In. Surf.	
1	.810	.095	13	3.142	2.545	.7854	.5153	.2701	3.819	4.715	.90
1¼	1.060	.095	13	3.927	3.330	1.2272	.8825	.3447	3.056	3.603	1.15
1½	1.310	.095	13	4.712	4.115	1.7671	1.3478	.4193	2.547	2.916	1.40
1¾	1.560	.095	13	5.498	4.901	2.4053	1.9113	.4940	2.183	2.448	1.66
2	1.810	.095	13	6.283	5.686	3.1416	2.5730	.5686	1.909	2.110	1.91
2¼	2.060	.095	13	7.069	6.472	3.9761	3.3329	.6432	1.698	1.854	2.16
2½	2.282	.109	12	7.854	7.169	4.9087	4.0899	.8188	1.528	1.674	2.75
2¾	2.532	.109	12	8.639	7.954	5.9396	5.0349	.9047	1.389	1.508	3.04
3	2.782	.109	12	9.425	8.740	7.0686	6.0787	.9899	1.273	1.373	3.33
3¼	3.010	.120	11	10.210	9.456	8.2958	7.1157	1.1801	1.175	1.269	3.96
3½	3.260	.120	11	10.996	10.242	9.6211	8.3469	1.274	1.091	1.171	4.28
3¾	3.510	.120	11	11.781	11.027	11.045	9.6762	1.369	1.018	1.088	4.6
4	3.732	.134	10	12.566	11.724	12.566	10.939	1.627	.955	1.024	5.47
4½	4.232	.134	10	14.137	13.295	15.904	14.066	1.838	.849	.902	6.17
5	4.704	.148	9	15.708	14.778	19.635	17.379	2.256	.764	.812	7.58
6	5.670	.165	8	18.850	17.813	28.274	25.249	3.025	.637	673	10.16
7	6.670	.165	8	21.991	20.954	38.485	34.941	3.544	.546	.573	11.9

Allow variation of 5 per cent. above and 5 per cent. below standard in weight per foot.
Cannot cut to length closer than $\frac{1}{16}$ inch.

NATIONAL TUBE CO.—Standard Boiler Tubes.

Diameter.		Thickness.		Circumference.		Transverse Areas.			Length of Tube per Square Ft.		Nom. Wgt. per ft. lbs.
O. D.	I. D.	Ins.	Nearest B.W.G.	External.	Internal.	External.	Internal.	Metal.	Ex. Surf.	In. Surf.	
8	7.670	.165	8	25.133	24.096	50.265	46.204	4.061	.477	.498	13.65
9	8.640	.180	7	28.274	27.143	63.617	58.629	4.988	.424	.442	16.76
10	9.594	.203	6	31.416	30.140	78.540	72.291	6.249	.382	.398	21.00
11	10.560	.220	5	34.558	33.175	95.033	87.582	7.451	.347	.362	25.00
12	11.542	.229	4½	37.699	36.260	113.10	104.63	8.47	.319	.330	28.50
13	12.524	.238	4	40.841	39.345	132.73	123.19	9.54	.294	.305	32.06
14	13.594	.248	3½	43.982	42.424	153.94	143.22	10.72	.273	.283	36.00
15	14.482	.259	3	47.124	45.496	176.71	164.72	11.99	.254	.264	40.60
16	15.460	.270	2½	50.265	48.569	201.06	187.71	13.35	.239	.247	45.20
18	17.432	.284	2	56.549	54.764	254.47	238.66	15.81	.212	.219	53.00
20	19.376	.312	1	62.832	60.872	314.16	294.86	19.30	.190	.197	65.00
22	21.314	.343	0	69.115	66.960	380.13	356.80	23.33	.173	.179	78.00
24	23.25	.375	00	75.398	73.042	452.39	424.56	27.83	.159	.164	93.00
26	25.25	.375	00	81.681	79.325	530.93	500.74	30.19	.147	.151	101.00
28	27.25	.375	00	87.965	85.608	615.75	583.21	32.54	.136	.140	109.00
30	29.25	.375	00	94.248	91.892	706.86	671.96	34.90	.127	.130	117.00

Allow variation of 5 per cent. above and 5 per cent. below standard in weight per foot.
Cannot cut to length closer than $\frac{1}{16}$ inch.

NATIONAL TUBE CO.—Special Brands Locomotive Boiler Tubes.

LOCOMOTIVE. SALAMANDER. FRANKLINITE.

Diameter.		Thickness.		Circumference.		Transverse Areas.			Length of Tube per Square Ft.		Nom. Wgt. per ft. lbs.
Ext.	Internal	Dec.	B. W. G.	External.	Internal.	External.	Internal.	Metal.	Ex. Surf.	In. Surf.	
1	.810	.095	13	3.142	2.545	.7854	.5153	.2701	3.819	4.715	.90
1¼	1.060	.095	13	3.927	3.330	1.2272	.8825	.3447	3.056	3.603	1.15
1½	1.310	.095	13	4.712	4.115	1.7671	1.3478	.4193	2.547	2.916	1.40
1¾	1.532	.109	12	5.498	4.813	2.4053	1.8433	.5620	2.183	2.493	1.87
2	1.782	.109	12	6.283	5.598	3.1416	2.4941	.6475	1.909	2.144	2.17
2	1.760	.120	11	6.283	5.529	3.1416	2.4329	.7087	1.909	2.171	2.38
2	1.732	.134	10	6.283	5.441	3.1416	2.3560	.7856	1.909	2.205	2.64
2¼	2.032	.109	12	7.069	6.384	3.9761	3.2429	.7332	1.698	1.880	2.45
2¼	2.010	.120	11	7.069	6.315	3.9761	3.1731	.8030	1.698	1.900	2.70
2¼	1.982	.134	10	7.069	6.227	3.9761	3.0853	.8908	1.698	1.927	2.99
2½	2.260	.120	11	7.854	7.100	4.9087	4.0115	.8972	1.528	1.69	3.00
2½	2.232	.134	10	7.854	7.012	4.9087	3.9127	.9960	1.528	1.711	3.35
2½	2.204	.148	9	7.854	6.924	4.9087	3.8152	1.0935	1.528	1.733	3.67
2¾	2.510	.120	11	8.639	7.885	5.9396	4.9481	.9915	1.389	1.522	3.31
3	2.760	.120	11	9.425	8.671	7.0686	5.9828	1.086	1.273	1.384	3.63
3	2.732	.134	10	9.425	8.583	7.0686	5.8621	1.2065	1.273	1.398	4.05
3	2.704	.148	9	9.425	8.495	7.0686	5.7425	1.3261	1.273	1.413	4.46
3¼	2.982	.134	10	10.210	9.368	8.2958	6.9840	1.312	1.175	1.281	4.39
3½	3.232	.134	10	10.996	10.154	9.6211	8.2041	1.417	1.091	1.182	4.74
3¾	3.482	.134	10	11.781	10.939	11.045	9.522	1.523	1.018	1.097	5.09
4	3.704	.148	9	12.566	11.636	12.566	10.775	1.791	.955	1.031	6.00

Allow variation of 5% above and 5% below standard weight per foot. Cannot cut to length closer than $\frac{1}{16}$ in.

NATIONAL TUBE CO.

SPECIAL SIZES OF BOILER TUBES NOT ELSEWHERE LISTED.

Diameter.		Thickness.		Circumference.		Transverse Areas.			Length of Tube per Square Ft.		Nom. Wgt. per ft. lbs.
Ext.	Internal	Dec.	B.W.G.	External.	Internal.	External.	Internal.	Metal.	Ex. Surf.	In. Surf.	
1 1/8	.935	.095	13	3.534	2.937	.9940	.6866	.3074	3.395	4.085	1.04
1 5/16	1.122	.095	13	4.123	3.526	1.3530	.9896	.3634	2.910	3.403	1.22
1 3/8	1.185	.095	13	4.320	3.723	1.4849	1.1029	.3820	2.778	3.223	1.29
1 5/8	1.435	.095	13	5.105	4.508	2.0739	1.6173	.4566	2.351	2.662	1.53
1 7/8	1.685	.095	13	5.890	5.294	2.7612	2.2299	.5313	2.037	2.266	1.78
2 1/8	1.935	.095	13	6.676	6.079	3.5466	2.9407	.6059	1.797	1.974	2.04
2 3/8	2.185	.095	13	7.461	6.864	4.4301	3.7497	.6804	1.608	1.748	2.30
2 7/8	2.657	.109	12	9.032	8.347	6.4918	5.5446	.9472	1.328	1.439	3.18
4 1/4	3.982	.134	10	13.352	12.51	14.186	12.453	1.733	.899	.959	5.82
4 3/4	4.482	.134	10	14.923	14.081	17.728	15.777	1.951	.804	.852	6.53
5 1/4	4.954	.148	9	16.493	15.563	21.648	19.275	2.373	.728	.771	7.97
5 1/2	5.204	.148	9	17.279	16.349	23.758	21.270	2.488	.694	.734	8.36

Allow variation of 5% above and 5% below standard in weight per foot.

Cannot cut to length closer than $\frac{1}{16}$ inch.

NATIONAL TUBE CO.—Bedstead Tubing.

Diameter.		Thickness.	Circumference.		Transverse Areas.			Nominal Weight per Foot. Pounds.
External.	Internal.		External.	Internal.	External.	Internal.	Metal.	
.375	.231	.072	1.178	.7257	.1104	.0419	.0685	.2333
.500	.356	.072	1.571	1.118	.1963	.0995	.0968	.3293
.625	.471	.077	1.963	1.480	.3068	.1742	.1326	.4511
.750	.584	.083	2.356	1.835	.4418	.2679	.1739	.5916
.840	.674	.083	2.639	2.117	.5542	.3568	.1974	.6715
.875	.709	.083	2.749	2.227	.6013	.3948	.2065	.7025
1.000	.834	.083	3.142	2.620	.7854	.5463	.2391	.8134
1.05	.884	.083	3.299	2.777	.8659	.6137	.2522	.8580
1.25	1.072	.089	3.927	3.361	1.227	.8992	.3278	1.115
1.31	1.132	.089	4.115	3.550	1.348	1.003	.345	1.174
1.50	1.31	.095	4.712	4.115	1.767	1.348	.419	1.425
2.00	1.76	.120	6.283	5.529	3.142	2.433	.709	2.412

Lap-Welded Tuyere Pipe.

Diameter.			Thickness.	Circumference.		Transverse Areas.			Nominal Weight per Foot. Pounds.	Threads per Inch.
Nominal.	External.	Internal.		External.	Internal.	External.	Internal.	Metal.		
1	1.315	.940	.1875	4.131	2.9531	1.358	.69398	.66402	2.21	11½
1¼	1.66	1.2225	.21875	5.215	3.8406	2.164	1.17378	.99022	3.30	11½

STANDARD DIMENSIONS OF COUPLINGS

FOR

STEAM, GAS AND WATER PIPE,

BLACK AND GALVANIZED.

Size of Pipe. Nominal Inside Diameter	Inside Diameter of Coupling	Outside Diameter of Coupling	Length of Coupling	Thread per Inch of Screw.	Average Weight of Coupling in Pounds.
Inches.	Inches.	Inches.	Inches.		
1/8	11/32	19/32	13/16	27	.031
1/4	15/32	23/32	15/16	18	.046
3/8	37/64	27/32	1 1/16	18	.078
1/2	23/32	1	1 5/16	14	.124
3/4	63/64	1 21/64	1 9/16	14	.250
1	1 11/64	1 9/16	1 13/16	11 1/2	.455
1 1/4	1 1/2	1 61/64	2 1/8	11 1/2	.562
1 1/2	1 3/4	2 7/32	2 3/8	11 1/2	.800
2	2 7/32	2 3/4	2 5/8	11 1/2	1.250
2 1/2	2 21/32	3 9/32	2 7/8	8	1.757
3	3 1/4	3 15/16	3 1/8	8	2.625
3 1/2	3 25/32	4 7/16	3 5/8	8	4.000
4	4 17/64	5	3 5/8	8	4.125
4 1/2	4 3/4	5 1/2	3 5/8	8	4.875
5	5 9/32	6 7/32	4 1/8	8	8.437
6	6 11/32	7 5/16	4 1/8	8	10.625
7	7 3/8	8 5/16	4 1/8	8	11.270
8	8 3/8	9 5/16	4 5/8	8	15.150
9	9 7/16	10 3/8	5 1/8	8	17.820
10	10 7/16	11 21/32	6 1/8	8	27.700
11	11 15/32	12 21/32	6 1/8	8	33.250
12	12 7/16	13 7/8	6 1/8	8	43.187
13	13 11/16	15 1/16	6 1/8	8	49.280
14	14 23/32	16 3/8	6 1/8	8	63.270
15	15 11/16	17 3/8	6 1/8	8	66.000

STANDARD DIMENSIONS OF COUPLINGS

FOR

REGULAR CASING.

Size of Casing. Nominal Inside Diameter	Inside Diameter of Coupling	Outside Diameter of Coupling	Length of Coupling	Thread per Inch of Screw.	Average Weight of Coupling in Lbs.
Inches.	Inches.	Inches.	Inches.		
$1\frac{3}{4}$	$1\frac{7}{8}$	$2\frac{5}{16}$	$2\frac{3}{8}$	14	.90
2	$2\frac{7}{64}$	$2\frac{23}{32}$	$2\frac{5}{8}$	14	1.31
$2\frac{1}{4}$	$2\frac{11}{32}$	$2\frac{29}{32}$	$2\frac{5}{8}$	14	1.50
$2\frac{1}{2}$	$2\frac{19}{32}$	$3\frac{5}{32}$	$2\frac{5}{8}$	14	1.62
$2\frac{3}{4}$	$2\frac{27}{32}$	$3\frac{15}{32}$	$2\frac{5}{8}$	14	1.75
3	$3\frac{3}{32}$	$3\frac{3}{4}$	$3\frac{1}{8}$	14	2.62
$3\frac{1}{4}$	$3\frac{11}{32}$	4	$3\frac{1}{8}$	14	2.87
$3\frac{1}{2}$	$3\frac{19}{32}$	$4\frac{1}{4}$	$3\frac{1}{8}$	14	3.06
$3\frac{3}{4}$	$3\frac{27}{32}$	$4\frac{1}{2}$	$3\frac{1}{8}$	14	2.25
4	$4\frac{1}{16}$	$4\frac{23}{32}$	$3\frac{5}{8}$	14	3.62
$4\frac{1}{4}$	$4\frac{3}{8}$	5	$3\frac{5}{8}$	14	3.93
$4\frac{1}{2}$	$4\frac{19}{32}$	$5\frac{7}{32}$	$3\frac{5}{8}$	14	4.06
$4\frac{3}{4}$	$4\frac{13}{16}$	$5\frac{15}{32}$	$3\frac{5}{8}$	14	4.93
5	$5\frac{5}{64}$	$5\frac{13}{16}$	$4\frac{1}{8}$	14 & $11\frac{1}{2}$	5.68
$5\frac{3}{16}$	$5\frac{5}{16}$	$6\frac{1}{32}$	$4\frac{1}{8}$	14 & $11\frac{1}{2}$	5.93
$5\frac{5}{8}$	$5\frac{55}{64}$	$6\frac{5}{8}$	$4\frac{1}{8}$	14 & $11\frac{1}{2}$	6.37
$6\frac{1}{4}$	$6\frac{13}{32}$	$7\frac{5}{32}$	$4\frac{1}{8}$	14 & $11\frac{1}{2}$	7.93
$6\frac{5}{8}$	$6\frac{51}{64}$	$7\frac{5}{8}$	$4\frac{5}{8}$	14 & $11\frac{1}{2}$	9.68
$7\frac{1}{4}$	$7\frac{15}{32}$	$8\frac{1}{4}$	$4\frac{5}{8}$	14 & $11\frac{1}{2}$	9.93
$7\frac{5}{8}$	$7\frac{25}{32}$	$8\frac{23}{32}$	$5\frac{1}{8}$	$11\frac{1}{2}$	14.00
$8\frac{1}{4}$	$8\frac{13}{32}$	$9\frac{3}{8}$	$5\frac{1}{8}$	$11\frac{1}{2}$	15.37
$8\frac{5}{8}$	$8\frac{25}{32}$	$9\frac{3}{4}$	$5\frac{1}{8}$	$11\frac{1}{2}$	15.93
$9\frac{5}{8}$	$9\frac{3}{4}$	$10\frac{25}{32}$	$6\frac{1}{8}$	$11\frac{1}{2}$	24.60
$10\frac{1}{4}$	$10\frac{1}{2}$	$11\frac{1}{2}$	$6\frac{1}{8}$	$11\frac{1}{2}$	26.00
$10\frac{5}{8}$	$10\frac{25}{32}$	$11\frac{7}{8}$	$6\frac{1}{8}$	$11\frac{1}{2}$	27.83
$11\frac{5}{8}$	$11\frac{25}{32}$	$12\frac{7}{8}$	$6\frac{1}{8}$	$11\frac{1}{2}$	29.75
$12\frac{1}{2}$	$12\frac{25}{32}$	14	$6\frac{1}{8}$	$11\frac{1}{2}$	35.00
$13\frac{1}{2}$	$13\frac{25}{32}$	15	$6\frac{1}{8}$	$11\frac{1}{2}$	42.50
$14\frac{1}{2}$	$14\frac{3}{4}$	$16\frac{1}{8}$	$6\frac{1}{8}$	$11\frac{1}{2}$	50.00
$15\frac{1}{2}$	$15\frac{3}{4}$	$17\frac{1}{8}$	$6\frac{1}{8}$	$11\frac{1}{2}$	52.50

STANDARD DIMENSIONS OF COUPLINGS

FOR

LINE PIPE.

Size of Pipe, Nominal Inside Diameter	Inside Diameter of Coupling	Outside Diameter of Coupling	Length of Coupling	Thread per Inch of Screw.	Average Weight of Coupling in Pounds.
Inches.	Inches.	Inches.	Inches.		
¼	15/32	51/64	1 5/16	18	.06
⅜	37/64	31/32	1⅝	18	.17
½	23/32	1 5/32	1 13/16	14	.29
¾	15/16	1⅜	2 1/16	14	.41
1	1 11/64	1⅝	2 5/16	11½	.64
1¼	1½	2⅛	2 13/16	11½	1.10
1½	1 23/32	2 9/32	2 13/16	11½	1.18
2	2 5/32	2⅞	3¾	11½	2.50
2½	2 19/32	3 7/16	3¾	8	3.12
3	3 7/32	4 1/16	3¾	8	3.85
3½	3¾	4 23/32	4 3/16	8	5.00
4	4 7/32	5 3/16	4 3/16	8	6.50
4½	4 23/32	5⅝	4 3/16	8	7.70
5	5¼	6 5/16	5⅛	8	11.21
6	6 5/16	7 13/32	5⅛	8	12.00
7	7 11/32	8 15/32	6⅛	8	14.75
8	8 11/32	9 9/16	5⅛	8	23.25
9	9 11/32	10 9/16	6⅛	8	26.48
10	10⅜	11 11/16	6⅛	8	29.50
11	11⅜	12 11/16	6⅛	8	34.75
12	12 7/16	13⅞	6⅛	8	39.50
13	13 11/16	15 1/16	6⅛	8	46.00
14	14 23/32	16 5/16	6⅛	8	59.75
15	15 11/16	17¼	6⅛	8	62.25

STANDARD DIMENSIONS OF COUPLINGS FOR

DRIVE PIPE.

Size of Pipe Nominal Inside Diameter	Inside Diameter of Coupling	Outside Diameter of Coupling	Length of Coupling	Thread per Inch of Screw.	Average Weight of Coupling in Pounds.
Inches.	Inches	Inches.	Inches.		
1 1/4	1 1/2	2 1/8	2 13/16	11 1/2	1.10
1 1/2	1 3/4	2 9/32	2 13/16	11 1/2	1.18
2	1 3/16	2 7/8	3 3/4	11 1/2	2.50
2 1/2	2 5/8	3 15/32	3 3/4	8	3.12
3	3 1/4	4 1/16	3 3/4	8	3.85
3 1/2	3 25/32	4 23/32	4 3/16	8	5.00
4	4 1/4	5 3/16	4 3/16	8	6.50
4 1/2	4 3/4	5 5/8	4 3/16	8	7.70
5	5 17/64	6 11/32	5 1/8	8	11.21
6	6 5/16	7 13/32	5 1/8	8	12.00
7	7 11/32	8 13/32	5 1/8	8	14.75
8	8 11/32	9 9/16	6 1/8	8	23.25
9	9 11/32	10 9/16	6 1/8	8	26 48
10	10 3/8	11 11/16	6 1/8	8	29.50
11	11 3/8	12 11/16	6 1/8	8	34.75
12	12 7/16	13 7/8	6 1/8	8	39.50
13	13 11/16	15 1/16	6 1/8	8	46.00
14	14 23/32	16 5/16	6 1/8	8	59.75
15	15 11/16	17 1/4	6 1/8	8	62.25

STANDARD DIMENSIONS OF COUPLINGS FOR

TUBING.

Size of Tube Nominal Inside Diameter	Inside Diameter of Coupling	Outside Diameter of Coupling	Length of Coupling	Thread per Inch of Screw.	Average Weight of Coupling in Pounds.
Inches.	Inches.	Inches.	Inches.		
1 1/4	1 1/2	2 1/8	2 13/16	11 1/2	1.10
1 1/2	1 23/32	2 9/32	2 13/16	11 1/2	1.18
2	2 5/32	2 7/8	3 3/4	11 1/2	2.50
2 1/2	2 19/32	3 7/16	3 3/4	11 1/2	3.12
3	3 7/32	4 1/16	3 3/4	11 1/2	3.85
3 1/2	3 3/4	4 23/32	4 3/16	8	5.00
4	4 7/32	5 3/16	4 3/16	8	6.50
4 1/2	4 23/32	5 5/8	4 3/16	8	7.70
5	5 1/4	6 5/16	5 1/8	8	11 21
6	6 5/16	7 13/32	5 1/8	8	12.00

SPECIAL LIGHT LAP-WELDED PIPE

FITTED WITH

CAST IRON LUGGED FLANGES.

Shrunk on, Beaded and Expanded, and Finished with Bolts, Nuts and Gaskets, Complete.

Exact O. D. of Pipe.	Thickness of Pipe.	Mill Test of Pipe.	Safe Pressure.	Weight per Foot of Pipe, Pl. Ends.	O. D. of Flange.	Thickness of Hub of Flange.	Number of Bolt Holes in Flange.	Centre of Bolt Holes.	Length of Bolts.	Size of Bolts.	Weight of Pair of Flanges.	Size of Gasket.	Nom. Wgt. per foot of Light Pipe with Fl'g's, Bolts, etc.	Exact O. D. of Pipe.
Ins.	W.G.	Lbs.	Lbs.	Lbs.	Ins.	Ins.		Ins.	Ins.	Ins.	Lbs.	Ins.	Lbs.	Ins.
3	12	500	80	3.31	6½	1¾	4	5⅛	4¼	½	12	⅛ x 2⅞ x 4⅜	4.06	3
4	11	500	80	4.89	7¾	1¾	4	6⅜	4¼	½	15	⅛ x 3⅞ x 5¾	5.83	4
5	10	500	80	6.85	9	1¾	4	7⅝	4¼	½	19	⅛ x 4⅞ x 6⅞	8.04	5
6	10	500	80	8.26	10⅛	2	4	8⅝	5	⅝	26	⅛ x 5⅞ x 7¾	9.88	6
7	9	500	80	10.65	11¼	2¼	6	9⅝	5½	⅝	36	⅛ x 6⅞ x 8¾	12.90	7
8	9	500	80	12.21	12½	2¼	6	10½	5½	⅝	40	⅛ x 7⅞ x 9⅝	14.71	8
10	8½	500	80	16.18	15⅞	2½	6	13⅞	6	¾	86	⅛ x 9⅞ x12⅞	21.55	10
12	7	500	80	22.35	17¼	3⅛	8	15	7½	⅞	113	⅛ x11⅞ x13⅞	29.41	12

All quotations based on random lengths, 16 to 18 feet. Suitable for water at pressure not exceeding 80 lbs. per square inch. For compressed air. For gas, and for exhaust steam. (See illustration, page 25.)

LAP-WELDED PUMP COLUMNS FITTED WITH CAST IRON LUGGED PUMP COLUMN FLANGES.

Shrunk on, Beaded and Expanded, and Finished with Bolts, Nuts and Gaskets, Complete.

Finished Weights are Based on 16 Foot Lengths. All Quotations Based on Random Lengths.

Exact O. D. of Pipe.	Thickness of Pipe.	Mill Test of Pipe.	Safe Pressure.	Weight per Foot of Pipe. Pl. Ends.	O. D. of Flange.	Thickness of Hub of Flange.	Number of Bolt Holes in Flange.	Centre of Bolt Holes in Flange.	Length of Bolts.	Size of Bolts.	Weight of Pair of Flanges.	Size of Gasket.	Weight per Foot of Pump Column with Flanges, Bolts, etc.	Exact O. D. of Pipe.
Ins.		Lbs.	Lbs.	Lbs.	Ins.	Ins.		Ins.	Ins.	Ins.	Lbs.	Ins.	Lbs.	Ins.
3	10 W.G.	500	350	4.05	6½	1¾	4	5¼	4½	⅝	14	⅛ x 2⅞ x 4⅜	4.85	3
4	9 "	500	350	6.00	8	2	4	6½	5	⅝	20	⅛ x 3⅞ x 5⅝	7.25	4
5	8 "	500	350	8.38	10	2½	6	8	6	⅝	46	⅛ x 4⅞ x 7⅛	11.30	5
6	7 "	500	350	11.00	11¼	2⅞	6	9⅛	7	¾	64	⅛ x 5⅞ x 8⅛	15.00	6
7	7 "	500	350	12.90	12	2⅞	6	9⅝	7	¾	72	⅛ x 6⅞ x 8⅝	17.50	7
8	3/16 in.	500	350	15.48	13	3¼	6	10⅝	7¾	¾	84	⅛ x 7¾ x 9⅝	21.00	8
9	¼ "	500	350	23.10	15	3½	6	13	8¼	⅞	134	⅛ x 8¾ x 11⅞	31.50	9
10	¼ "	500	350	25.75	16	3⅞	6	14	9	⅞	148	⅛ x 9¾ x 12⅞	35.00	10
12	¼ "	500	350	31.05	18	3⅞	8	16	9	⅞	184	⅛ x 11¾ x 14⅞	42.00	12
13	¼ "	500	350	33.71	19	3⅞	8	17	9	⅞	170	⅛ x 12¾ x 15⅞	44.25	13
14	¼ "	500	350	36.32	20	3⅞	8	17½	9	⅞	194	⅛ x 13¾ x 16⅞	48.40	14
15	¼ "	500	350	39.00	20¾	3⅞	8	18⅝	9	⅞	200	3/16 x 14¾ x 17½	51.50	15
16	¼ "	500	350	41.60	22	4	10	19¾	9¼	⅞	231	3/16 x 15¾ x 18½	56.40	16
18	5/16 "	500	350	58.25	25½	4¼	12	23	9¾	⅞	422	3/16 x 17¾ x 21¾	85.00	18
20	5/16 "	500	250	64.84	27½	4¼	12	25	9¾	⅞	454	3/16 x 19¾ x 23¾	94.00	20
22	⅜ "	500	250	85.49	29½	4¼	16	27	9¾	⅞	512	3/16 x 21¾ x 26¾	117.00	22
24	⅜ "	500	250	93.37	31½	4¼	16	29	9¾	⅞	556	3/16 x 23¾ x 27¾	128.00	24

(See illustration, page 25.)

LAP-WELDED PIPE FITTED WITH CAST IRON COLLAR FLANGES.

Shrunk on, Beaded and Expanded, and Finished with Bolts, Nuts and Gaskets, Complete.

Finished Weights are Based on 16 Foot Lengths. All Quotations Based on Random Lengths.

Exact O.D. of Pipe.	Thickness of Pipe.	Mill Test of Pipe.	Safe Pressure.	Weight per Foot of Pipe Pl. Ends.	O. D. of Flange.	Thickness of Flange.	Number of Bolt Holes in Flange.	Centre of Bolt Holes in Flange.	Length of Bolts.	Size of Bolts.	Weight of Pair of Flanges.	Size of Gasket.	Weight per Foot of Pipe, with Flanges, Bolts, Etc.	Exact O.D. of Pipe.
Ins.		Lbs.	Lbs.	Lbs.	Ins.	Ins.		Ins.	Ins.	Ins.	Lbs.	Ins.	Lbs.	Ins.
4½	9 W.G.	500	100	6.77	9¼	¾	4	7¾	2½	⅝	25	⅛ x 4 3/16 x 7	8.33	4½
5	8 "	500	100	8.38	10	¾	6	8	2½	⅝	26	⅛ x 4⅞ x 7¼	10.00	5
5 9/16	8 "	500	100	9.35	10	¾	6	8½	2½	⅝	28	⅛ x 5 3/16 x 7¾	11.10	5 9/16
6	7 "	500	100	11.00	11	⅞	6	9¼	2⅞	¾	37	⅛ x 5⅞ x 8¼	13.31	6
6⅝	7 "	500	100	12.26	11	⅞	6	9½	2⅞	¾	36	⅛ x 6¼ x 8⅝	14.51	6⅝
7	7 "	500	100	12.90	12½	⅞	6	10½	2⅞	¾	47	⅛ x 6⅞ x 9⅝	15.84	7
7⅝	7 "	500	100	14.16	12½	⅞	6	10¾	2⅞	¾	50	⅛ x 7¼ x 9⅞	17.28	7⅝
8	3/16 "	500	100	15.48	13½	⅞	8	11¾	2⅞	¾	57	⅛ x 7¾ x 10⅞	19.04	8
8⅝	3/16 inch	500	100	16.72	13½	⅞	8	11¾	2⅞	¾	60	⅛ x 8¼ x 10⅞	20.47	8⅝
9	¼ "	500	100	23.10	15	1	8	13¼	3⅛	¾	76	⅛ x 8¾ x 12⅜	27.85	9
9⅝	¼ "	500	100	24.76	15	1	8	13¼	3⅛	¾	73	⅛ x 9⅛ x 12⅜	29.32	9⅝
10	¼ "	500	100	25.75	16	1	8	14¼	3⅛	¾	83	⅛ x 9¾ x 13⅜	30.93	10
10¾	¼ "	500	100	27.73	18	1⅛	8	16	3½	⅞	116	⅛ x 10¼ x 15	34.98	10¾
12	¼ "	500	100	31.05	20	1¼	8	18	3¾	⅞	154	⅛ x 11¾ x 17	40.67	12
12¾	¼ "	500	100	33.01	20¾	1¼	12	18½	3¾	⅞	162	⅛ x 12¼ x 17½	43.13	12¾
14	¼ "	500	100	36.32	21	1⅜	12	19	4	⅞	172	⅛ x 13¾ x 18	47.07	14
15	¼ "	500	100	39.00	22	1½	12	20	4¼	⅞	200	3/16 x 14¾ x 19	51.50	15
16	¼ "	500	100	41.60	23	1⅝	16	21	4½	⅞	228	3/16 x 15¾ x 20	55.85	16
18	5/16 "	500	100	58.25	25½	1⅝	16	23½	4½	⅞	276	3/16 x 17¾ x 22½	75 50	18
20	5/16 "	500	100	64.84	27	1¾	16	24¾	4¾	⅞	304	3/16 x 19¾ x 23¾	83.84	20
22	⅜ "	500	100	85.49	29½	1¾	16	27¼	4⅞	1	360	3/16 x 21¾ x 26⅛	107.99	22
24	⅜ "	500	100	93.37	32	1¾	20	29½	4¾	⅞	440	3/16 x 23¾ x 28½	120.87	24
26	⅜ "	500	100	101.30	33¾	1¾	20	31½	4¾	⅞	486	3/16 x 25¼ x 30½	131.67	26
28	7/16 "	500	100	127.36	36	2	20	33½	5⅜	1	618	3/16 x 27⅛ x 32⅜	165.98	28
30	7/16 "	500	100	136.60	40	2¼	24	38	5⅞	1	874	3/16 x 29⅛ x 36⅞	191.22	30

Suitable for Water at Pressures not exceeding 100 pounds per square inch, for Compressed Air, for Gas and for Low Pressure Steam. (See illustration, page 25.)

LAP-WELDED PIPE FITTED WITH CAST IRON SINGLE RIVETED FLANGES.

BOLTS, NUTS AND GASKETS INCLUDED.

Finished Weights Based on 16 Foot Lengths. All Quotations Based on Random Lengths.

Exact O. D. of Pipe.	Thickness of Pipe.	Mill Test of Pipe.	Safe Pressure, Steam.	Weight per Foot of Pipe, Pl. Ends.	O. D. of Flange.	Thickness of Flange.	Number of Bolt Holes in Flange.	Centre of Bolt Holes in Flange.	Length of Bolts.	Size of Bolts.	Weight of Pair of Flanges.	Size of Gasket.	Weight per Foot of Pipe, with Flanges, Bolts, etc.	Exact O. D. of Pipe.
Ins.	Ins.	Lbs.	Lbs.	Lbs.	Ins.	Ins.		Ins.	Ins.	Ins.	Lbs.	Ins.	Lbs.	Ins.
8⅝	5/16	1000	120	27.37	15	1⅛	8	13	3⅜	¾	104	⅛ x 8⅝ x 12⅛	33.87	8⅝
9⅝	5/16	1000	120	30.67	16	1½	8	14¼	4⅛	¾	146	⅛ x 9⅝ x 13⅜	39.79	9⅝
10	⅜	1000	120	38.05	17	1½	12	15	4⅛	¾	162	⅛ x 10 x 14⅛	48.17	10
10¾	⅜	1000	120	41.01	18	1½	12	16	4⅛	¾	177	⅛ x 10¾ x 15⅛	52.07	10¾
12	⅜	1000	120	45.95	20	1¾	12	17½	4¾	⅞	237	⅛ x 12 x 16½	60.76	12
12¾	⅜	1000	120	48.92	21	1¾	12	18½	4¾	⅞	256	⅛ x 12¾ x 17⅛	64.92	12¾
14	⅜	750	120	53.89	21	1¾	12	19	4¾	⅞	244	⅛ x 14 x 18	69.14	14
15	⅜	750	120	57.81	22	1¾	12	20	4¾	⅞	269	3/16 x 15 x 19	74.62	15
16	⅜	750	120	61.77	23½	1¾	12	21¼	4¾	⅞	300	3/16 x 16 x 20¼	80.52	16
18	⅜	750	120	69.66	25½	1¾	16	23½	4¾	⅞	338	3/16 x 18 x 22½	90.78	18
20	⅜	500	100	77.57	28	1¾	16	26	4¾	⅞	395	3/16 x 20 x 25	102.25	20
22	⅜	500	100	85.49	31	1¾	20	28	4¾	⅞	472	3/16 x 22 x 27	114.99	22
24	7/16	500	100	108.86	33	2	20	30½	5⅜	1	562	3/16 x 24 x 29⅜	143.98	24
26	7/16	500	80	118.12	35	2	24	32	5⅜	1	634	3/16 x 26 x 30⅞	157.74	26
28	½	500	80	145.43	37½	2⅛	28	35	5¾	1⅛	740	3/16 x 28 x 33¾	191.68	28
30	½	500	80	156.00	40¼	2¼	28	37	6	1⅛	876	3/16 x 30 x 35¾	210.75	30

(See illustration, page 25.)

LAP-WELDED PIPE FITTED WITH CAST IRON DOUBLE RIVETED FLANGES.

BOLTS, NUTS AND GASKETS INCLUDED.

Finished Weights Based on 16 Foot Lengths. All Quotations Based on Random Lengths.

Exact O. D. of Pipe.	Thickness of Pipe.	Mill Test of Pipe.	Safe Pressure. Steam.	Weight per Foot of Pipe. Pl. Ends.	O. D. of Flange.	Thickness of Flange.	Number of Bolt Holes in Flange.	Centre of Bolt Holes in Flange.	Length of Bolts.	Size of Bolts.	Weight of Pair of Flanges.	Size of Gasket.	Weight per Foot of Pipe with Flanges, Bolts, etc	Exact O. D. of Pipe.
Ins.	Ins.	Lbs.	Lbs.	Lbs.	Ins.	Ins.		Ins.	Ins.	Ins.	Lbs.	Ins.	Lbs.	Ins.
8⅝	5/16	1000	175	27.37	15	1⅛	8	13	3⅜	¾	116	⅛ x 8⅝ x 12⅛	34.62	8⅝
9⅝	5/16	1000	175	30.67	16	1½	8	14¼	4⅛	¾	160	⅛ x 9⅝ x 13⅜	40.67	9⅝
10	⅜	1000	175	38.05	17	1½	12	15	4⅛	¾	177	⅛ x 10 x 14⅛	49.11	10
10¾	⅜	1000	175	41.01	18	1½	12	16	4⅛	¾	193	⅛ x 10¾ x 15⅛	53.07	10¾
12	⅜	1000	175	45.95	20	1¾	12	17½	4¾	⅞	255	⅛ x 12 x 16½	61.88	12
12¾	⅜	1000	150	48.92	21	1¾	12	18½	4¾	⅞	276	⅛ x 12¾ x 17½	66.17	12¾
14	⅜	750	150	53.89	21	1¾	12	19	4¾	⅞	264	⅛ x 14 x 18	70.39	14
15	⅜	750	150	57.81	22	1¾	12	20	4¾	⅞	294	3/16 x 15 x 19	76.18	15
16	⅜	750	150	61.77	23½	1¾	16	21¼	4¾	⅞	338	3/16 x 16 x 20¼	82.89	16
18	⅜	750	150	69.66	25½	1¾	16	23½	4¾	⅞	369	3/16 x 18 x 22½	92.72	18
20	⅜	500	125	77.57	28	1¾	16	26	4¾	⅞	430	3/16 x 20 x 25	104.44	20
22	⅜	500	125	85.49	31	1¾	20	28	4¾	⅞	512	3/16 x 22 x 27	117.49	22
24	7/16	500	125	108.86	33	2	20	30½	5⅜	1	605	3/16 x 24 x 29⅜	146.67	24
26	7/16	500	100	118.12	35	2	24	32	5⅜	1	684	3/16 x 26 x 30⅞	160.87	26
28	½	500	100	145.43	37½	2⅛	28	35	5¾	1⅛	795	3/16 x 28 x 33¾	195.11	28
30	½	500	100	156.00	40¼	2¼	28	37	6	1⅛	934	3/16 x 30 x 35¾	214.37	30

(See illustration, page 25.)

LAP-WELDED PIPE FITTED WITH SOLID WELDED FLANGES.

BOLTS, NUTS AND GASKETS INCLUDED.

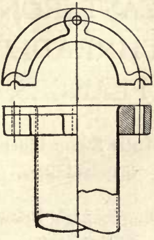
Finished Weights Based on 16 Foot Lengths. All Quotations are Based on Random Lengths.

Exact O. D. of Pipe.	Thickness of Pipe.	Mill Test of Pipe.	Safe Pressure. Steam.	Weight per Foot of Pipe. Pl. Ends.	O. D. of Flange.	Thickness of Flange.	Number of Bolt Holes in Flange.	Centre of Bolt Holes in Flange.	Length of Bolts.	Size of Bolts.	Weight of Pair of Flanges.	Size of Gasket.	Weight per Foot of Pipe with Flanges, Bolts, etc.	Exact O. D. of Pipe.
Ins.	Ins.	Lbs.	Lbs.	Lbs.	Ins.	Ins.		Ins.	Ins.	Ins.	Lbs.	Ins.	Lbs.	Ins.
4½	¼	1000	200	11.22	9	1	6	7½	3	⅝	26	⅛ x 4 x 6¾	12.84	4½
5 9/16	¼	1000	200	14.05	10	1	8	8½	3	⅝	32	⅛ x 5 1/16 x 7¾	16.05	5 9/16
6⅝	¼	1000	200	16.82	11	1⅛	8	9½	3¼	⅝	45	⅛ x 6⅛ x 8¾	19.63	6⅝
7⅝	5/16	1000	200	24.08	12½	1 3/16	8	10¾	3½	⅝	56	⅛ x 7 x 10	27.58	7⅝
8⅝	5/16	1000	200	27.37	13½	1 3/16	8	11¾	3½	¾	60	⅛ x 8 x 10⅞	31.12	8⅝
9⅝	5/16	1000	200	30.67	15	1 3/16	12	13¼	3½	¾	73	⅛ x 9 x 12⅜	35.23	9⅝
10¾	⅜	1000	200	41.01	16	1¼	12	14¼	3¾	¾	85	⅛ x 10 x 13⅜	46.32	10¾
12	⅜	1000	200	45.95	18	1¼	12	15⅛	3¾	⅞	98	⅛ x 11¼ x 14½	52.07	12
12¾	⅜	1000	200	48.92	19	1¼	12	17	3¾	⅞	108	⅛ x 12 x 16	55.67	12¾
14	⅜	750	200	53.89	21	1⅜	12	18¾	4	⅞	148	⅛ x 13¼ x 17¾	63.14	14
15	⅜	750	200	57.81	22¼	1⅜	16	20	4	⅞	162	3/16 x 14¼ x 19	67.93	15
16	⅜	750	200	61.77	23½	1 7/16	16	21¼	4¼	⅞	195	3/16 x 15¼ x 20¼	73.97	16
18	⅜	750	200	69.66	25	1 9/16	16	22¾	4½	1	207	3/16 x 17¼ x 21⅝	82.60	18
20	⅜	500	200	77.57	27½	1 11/16	20	25	4¾	1	275	3/16 x 19¼ x 23⅞	94.76	20
22	⅜	500	200	85.49	29½	1⅞	20	27¼	5¼	1	320	3/16 x 21¼ x 26⅛	105.49	22
24	7/16	500	200	108.86	32	2	20	29½	5½	1⅛	400	3/16 x 23⅛ x 28¼	133.86	24
26	7/16	500	200	118.12	34¼	2	24	31¾	5½	1⅛	440	3/16 x 25⅛ x 30½	145.62	26
28	½	500	200	145.43	36½	2⅛	28	34	5¾	1⅛	510	3/16 x 27 x 32¾	177.31	28
30	½	500	200	156.00	38¾	2⅛	28	36	5¾	1⅛	560	3/16 x 29 x 34¾	191.00	30

In long lines it is desirable to use Flanges of smaller diameters, thereby decreasing the cost. (Illustration, page 25.)

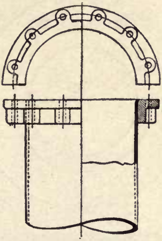
SPECIAL LIGHT LAP-WELDED PIPE

Fitted with Cast Iron Lugged Flanges.



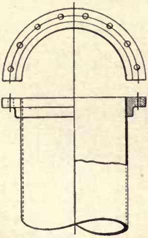
LAP-WELDED PUMP COLUMNS

Fitted with Cast Iron Lugged Pump Column Flange.



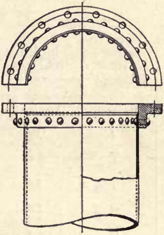
LAP-WELDED PIPE

Fitted with Cast Iron Collar Flanges.



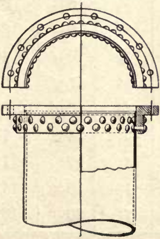
LAP-WELDED PIPE

Fitted with Cast Iron Single Riveted Flanges.



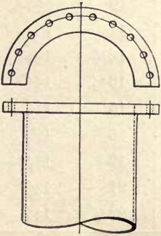
LAP-WELDED PIPE

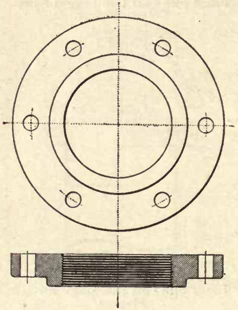
Fitted with Cast Iron Double Riveted Flanges.



LAP-WELDED PIPE

Fitted with Solid Welded Flanges.





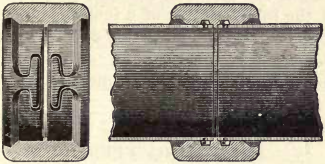
CAST IRON THREADED FLANGES.

Master Steam Fitters' Standard Sizes.

Bolting for Light Pressures Not Exceeding Seventy-Five Pounds.

Pipe Size.	Outside Diameter of Flange.	Thickness of Face.	Number of Bolts.	Size of Bolts.	Bolt Hole Circle.	Weight per Pair in Lbs.
Inches.	Inches.	Inches.		Inches.	Inches.	
2	6	⅝	4	½	4¾	8
2½	7	11/16	4	½	5½	12
3	7½	¾	4	½	6	14
3½	8½	13/16	4	½	7	20
4	9	15/16	4	⅝	7½	24
4½	9¼	15/16	8	⅝	7¾	25
5	10	15/16	8	⅝	8½	30
6	11	1	8	⅝	9½	34
7	12½	1 1/16	8	⅝	10¾	46
8	13½	1⅛	8	⅝	11¾	54
9	15	1⅛	12	⅝	13¼	66
10	16	1 3/16	12	¾	14¼	74
12	19	1¼	12	¾	17	112
14 O.D.	21	1⅜	12	⅞	18¾	147
15 "	22¼	1⅜	16	⅞	20	162

SPECIAL
Steel Lap-Welded Pipe,
FITTED WITH
CONVERSE PATENT LOCK JOINT.
(Cast Iron Hub.)



SILVERTIN.

Size.		Approximate Weight.			
O. D. Inches.	Nearest B'g'm Wire Gauge.	Plain Ends, per foot. lbs.	Hub. lbs.	Lead, one side. lbs.	Complete, per foot. lbs.
2	13	1.91	5	1	2.00
3	12	3.33	9	2	3.94
4	11	4.89	14	2½	5.81
5	10	6.85	19	3	8.02
6	10	8.26	21	4	9.65
7	9	10.65	32	5½	12.74
8	9	12.21	35	7	14.54
9	8½	14.58	37½	7½	17.08
10	8½	16.18	41	8	18.90
12	7	22.35	58	10	26.13
14	7	25.25	73	12	30.00
15	6½	30.00	85	15	36.40
16	5	39.60	132	17½	46.25
18	¼"	47.00	149	30	56.25
20	5/16"	65.15	217	38	78.50
22	11/32"	78.50	280	50	96.00
24	⅜"	93.50	342	58½	114.50
26	⅜"	102.00	380	70	138.00
28	⅜"	110.00	430	85	151.00
30	7/16"	136.60	475	100	168.60

WEIGHTS OF FITTINGS.

Converse Joint.

As a matter of convenience and to give an idea of the average weight of Converse Patent Lock Joint Fittings, we submit the following list of a few standard patterns.

All ends are Converse Lock Bells, except where otherwise stated. Bell connections for cast iron pipe are indicated by an asterisk (*); bell connections for threaded pipe, by a single dagger (†).

REDUCING TEES.

Size.	Weight lbs.	Size.	Weight lbs.	Size.	Weight lbs.
3x2x2	34	6x5x5	81	14x14x10	...
3x2x3	30	6x6x5	97	14x14x12	...
3x3x2	36	7x4x7	...	16x16x 4	330
3x4x3	35	7x7x4	81	16x16x 6	355
4x2x4	43	7x5x7	...	16x16x 8	...
4x3x2	39	7x7x5	...	16x16x10	...
4x4x2	35	7x6x7	...	16x16x12	...
4x3x4	36	7x7x6	...	16x16x14	...
4x4x3	37	7x6x6	...	18x18x 6	...
4x3x3	40	8x4x8	107	18x18x10	...
4x4x6	55	8x8x4	91	18x18x12	...
5x3x5	..	8x5x8	117	18x18x16	...
5x5x3	57	8x8x5	118	20x20x 6	...
5x4x5	..	8x6x5	100	20x20x 8	640
5x5x4	60	8x6x8	103	20x20x10	...
5x5x6	70	8x8x6	97	20x20x12	...
6x3x3	60	8x6x6	87	20x20x14	...
6x3x6	60	10x10x4	118	20x20x16	...
6x4x5	76	10x10x5	...	24x24x 6	...
6x4x6	68	10x6x10	...	24x24x 8	...
6x6x3	59	10x10x6	141	24x24x10	...
6x6x4	70	10x10x8	136	24x24x12	...
6x5x4	79	12x12x4	161	24x24x14	...
6x4x4	58	12x12x6	156	24x24x16	...
6x5x6	..	12x12x8	160	....	...

CONVERSE JOINT FITTINGS.

CROSSES.

SIZE.	Weight lbs.	SIZE.	Weight lbs.	SIZE.	Weight lbs.
2x2x2x2	21	8x 8x 8x 8	156	18x18x18x18	...
3x3x3x3	39	10x10x10x10	205	20x20x20x20	...
4x4x4x4	57	12x12x12x12	306	22x22x22x22	...
5x5x5x5	71	14x14x14x14	...	24x24x24x24	...
6x6x6x6	104	16x16x16x16	...	....	...

REDUCING CROSSES.

SIZE.	Weight lbs.	SIZE.	Weight lbs.	SIZE.	Weight lbs.
3x3x2x2	...	6x 4x 6x 4	78	10x 8x10x 8	218
3x2x3x2	...	6x 6x 6x 3	103	12x12x 6x 6	166
4x4x2x2	39	8x 8x 4x 4	98	12x 6x12x 6	...
4x4x3x3	46	8x 4x 8x 8	131	12x12x 8x 8	...
4x3x4x3	60	8x 6x 8x 6	129	12x 8x12x 8	...
5x5x3x3	50	8x 6x 4x 4	132	12x10x12x10	261
5x3x5x3	...	8x 8x 6x 6	118	14x14x12x12	...
5x5x4x4	71	8x 8x 5x 5	127	16x16x10x10	...
5x4x5x4	...	10x10x 4x 4	125	16x16x12x12	...
5x5x5x4	71	10x 4x10x 4	123	18x18x 6x 6	...
6x6x4x4	77	10x10x 5x 5	162	18x18x10x10	...
6x6x3x3	67	10x 5x10x 5	...	18x18x12x12	646
6x3x6x3	...	10x10x 6x 6	166	20x20x 6x 6	...
6x6x5x5	120	10x 6x10x 6	...	20x20x10x10	...
6x5x6x5	102	10x10x 8x 8	198	20x20x16x16	...

MISCELLANEOUS CROSSES.

SIZE.	Weight lbs.	SIZE.	Weight lbs.	SIZE.	Weight lbs.
4x4x6x4	92	6x6x6x4	105	8x6x8x4	...
6x5x6x4	110	6x6x6x3	103	8x4x6x6	136
6x4x4x4	90	8x6x8x5	126	....	...
6x4x6x3	93	8x4x8x8	131	....	...

Some of the weights in these tables of Converse Joint Fittings are not given; the reason being that there are not Standard patterns for the sizes where weights are omitted, and the patterns of some other sizes are made adaptable for same. This would cause a variation in weights, and for this reason it is thought best to give no fixed weights for fittings so manufactured.

TEES.

Size.	Weight, lbs.	Size.	Weight, lbs.	Size.	Weight, lbs.
2x2x2	17	8x 8x 8	127	15x15x15	...
3x3x3	29	9x 9x 9	...	16x16x16	...
4x4x4	45	10x10x10	178	18x18x18	...
5x5x5	56	12x12x12	192	20x20x20	957
6x6x6	70	13x13x13	...	22x22x22	...
7x7x7	84	14x14x14	359	24x24x24	...

MISCELLANEOUS TEES.

Size.	Weight, lbs.	Size.	Weight, lbs.	Size.	Weight, lbs.
6x 5x 4	79	10x 8x10	135	12x 8x12	282
10x 4x10	...	10x10x12	182	12x 8x 8	...
10x 5x10	...	10x 8x 8	...	14x12x14	...
10x 6x 6	110	12x 6x12	...	16x 8x16	600

REDUCERS.

Size.	Weight, lbs.	Size.	Weight, lbs.	Size.	Weight, lbs.
3 to 2	27	8 to 5	70	16 to 6	295
4 to 2	22	8 to 6	63	16 to 8	...
4 to 3	27	10 to 4	90	16 to 10	256
5 to 3	39	10 to 5	94	16 to 12	256
5 to 4	36	10 to 6	94	18 to 16	442
6 to 2	55	10 to 8	107	20 to 12	395
6 to 3	36	12 to 5	154	20 to 18	505
6 to 4	40	12 to 6	154	20 to 16	608
6 to 5	46	12 to 8	138	24 to 12	...
7 to 5	52	12 to 10	...	24 to 18	...
8 to 3	60	13 to 12	90	24 to 20	...
8 to 4	53	14 to 13	88	....	...

ELLS.

SIZE.	Wt. lbs.	SIZE.	Wt. lbs.	SIZE.	Wt. lbs.
2x2x90°	12	7x 7x45°	..	14x14x22½°	...
2x2x60°	..	7x 7x30°	..	14x14x10°	...
2x2x45°	9	7x 7x22½°	39	15x15x90°	...
2x2x30°	8	7x 7x10°	..	15x15x60°	...
2x2x22½°	..	8x 8x90°	95	15x15x45°	...
2x2x10°	..	8x 8x60°	71	15x15x30°	...
3x3x90°	25	8x 8x45°	69	15x15x22½°	...
3x3x60°	..	8x 8x30°	..	15x15x10°	...
3x3x45°	12	8x 8x22½°	64	16x16x90°	420
3x3x30°	..	8x 8x10°	50	16x16x60°	...
3x3x22½°	13	10x10x90°	148	16x16x45°	265
3x3x10°	..	10x10x60°	..	16x16x30°	...
4x4x90°	32	10x10x45°	93	16x16x22½°	...
4x4x60°	25	10x10x30°	..	16x16x10°	...
4x4x45°	23	10x10x22½°	..	18x18x90°	...
4x4x30°	17	10x10x10°	..	18x18x60°	...
4x4x22½°	..	12x12x90°	205	18x18x45°	...
4x4x10°	..	12x12x60°	..	18x18x30°	...
5x5x90°	41	12x12x45°	132	18x18x22½°	...
5x5x60°	..	12x12x30°	108	18x18x10°	...
5x5x45°	32	12x12x22½°	112	20x20x90°	840
5x5x30°	..	12x12x10°	95	20x20x60°	...
5x5x22½°	..	13x13x90°	230	20x20x45°	...
5x5x10°	..	13x13x60°	..	20x20x30°	620
6x6x90°	57	13x13x45°	..	20x20x22½°	365
6x6x60°	48	13x13x30°	..	20x20x10°	...
6x6x45°	41	13x13x22½°	..	24x24x90°	1143
6x6x30°	39	13x13x10°	..	24x24x60°	...
6x6x22½°	30	14x14x90°	247	24x24x45°	...
6x6x10°	30	14x14x60°	...	24x24x30°	...
7x7x90°	72	14x14x45°	163	24x24x22½°	550
7x7x60°	..	14x14x30°	...	24x24x10°	...

Y'S.

SIZE.	Wt. lbs.	SIZE.	Wt. lbs.	SIZE.	Wt. lbs.
3x3x3	33	6x6x6	123	12x12x12	350
4x4x4	70	8x8x8	180	18x18x18	1145
5x5x5	95	10x10x10	262	20x20x20	2400

PLUGS.

SIZE.	Wt. lbs.	SIZE.	Wt. lbs.	SIZE.	Wt. lbs.
2	1	6	10	10	25
3	3	7	14	12	30
4	5	8	19	14	40
5	9	9	22	16	54

MISCELLANEOUS.

CROSSES.

SIZE.	Wt. lbs.
3x3x1†x1†	22
4x4x2†x2†	56
4x4x6*x6*	124
4x4x4 x2†	75
6x6x8*x8*	184
6x6x4x2†	83

TEES.

SIZE.	Wt. lbs.
2x 2 x ¾†	11
2x 2 x1½†	11
3x 3 x1 †	22
3x 2†x3	43
4x 4 x2 †	44
5x 3 x2 †	40
6x 6 x2 †	97
10x10 x4½†	163
10x10 x7 †	165
4x 4 x4 †	49
2x 2 x2 †	16
6x 6 x6 *	115

ELLS.

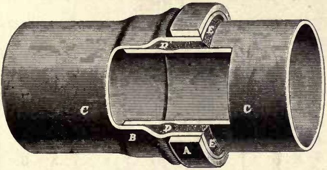
SIZE.	Wt. lbs.
6x 4†x90°	70
6x 5†x90°	65
12x12†x60°	180

REDUCERS.

SIZE.	Wt. lbs
4 to 2†	17
12 to 12*	247
16 to 16*	450
8 to 8 *	61
8* to 6	62
6* to 6	46

Fittings on the above Miscellaneous List may vary in weight 15 per cent. All combinations of Converse and threaded pipe, and Converse and cast-iron pipe connections will be uncertain weights, as patterns are changed for each requirement.

SPECIAL
Steel Lap-Welded Pipe
FITTED WITH
MATHESON PATENT JOINT.



O. D.	Thickness Nearest B. W. G.	Approximate Weights. Per Foot Complete.	Approximate Weights. Pounds of Lead in Joint.	Lead Space.	Size of Rings.
2	13	1.91	3/4	1/8	3/16 x 3/4
3	12	3.40	1	1/8	3/16 x 3/4
4	10 1/2	5.25	1 3/4	5/32	1/4 x 3/4
5	9 1/2	7.30	2	5/32	1/4 x 3/4
6	9 1/2	8.75	3 5/8	3/16	5/16 x 1
7	9	10.75	4	3/16	5/16 x 1
8	8 1/2	13.00	5	7/32	3/8 x 1
9	8 1/2	14.65	6 1/4	7/32	3/8 x 1
10	8	17.08	7 3/8	7/32	7/16 x 1
12	6	25.12	11 3/4	1/4	1/2 x 1 1/4
14	5 1/2	31.00	13 3/4	1/4	5/8 x 1 1/4
15	4 1/2	35.42	15	1/4	5/8 x 1 1/4
16	3 1/2	42.00	16	1/4	5/8 x 1 1/4
18	1 1/2	56.00	26 1/2	3/8	5/8 x 1 1/4
20	0 1/2	67.00	30	3/8	3/4 x 1 1/4

WEIGHT OF FITTINGS.

Matheson Joint.

Heavy-faced figures indicate openings tapped for Standard Pipe.

TEES.

SIZE.	Wgt. lbs.	SIZE.	Wgt. lbs.
2 x 2 x 2	11	6 x 6 x 4	96
3 x 3 x 3	19	6 x 6 x 3	93
3 x 3 x 4	35	6 x 4 x 4	100
4 x 4 x 4	35	6 x 3 x 6	90
4 x 4 x **4**	39	7 x 7 x 7	..
4 x 4 x **3**	35	7 x 7 x 6	115
4 x 4 x 3	35	8 x 8 x 8	159
4 x 4 x 2	37	8 x 8 x 6	173
4 x 4 x **2**	36	8 x 8 x 4	172
4 x 4 x **1**	34	8 x 6 x 8	176
4 x 4 x 6	98	9 x 9 x 9	..
4 x 3 x 4	35	10 x 10 x 10	256
5 x 5 x 5	41	10 x 10 x 8	270
5 x 5 x 4	58	10 x 10 x 6	268
5 x 5 x **4**	58	10 x 10 x 4	285
5 x 3 x **5**	56	11 x 11 x 11	353
6 x 6 x 6	91	12 x 12 x 12	..

ELBOWS.

SIZE.	Degree.	Wgt lbs.	SIZE.	Degree.	Wgt. lbs.
2 x 2	90	9	8 x 8	30	60
3 x 3	45	11	8 x 8	45	77
3 x 3	90	18	8 x 8	90	137
4 x 4	45	22	9 x 9	45	..
4 x 4	90	33	9 x 9	90	..
4 x 3	90	32	10 x 10	13	66
5 x 5	45	36	10 x 10	16	78
5 x 5	90	45	10 x 10	18	79
6 x 6	30	29	10 x 10	25	90
6 x 6	45	45	10 x 10	28	98
6 x **6**	45	45	10 x 10	30	98
6 x 6	90	79	10 x 10	36	110
7 x 7	45	57	10 x 10	45	126
7 x 7	90	100	10 x 10	90	235

ELBOWS.

SIZE.	Degree.	Weight lbs.	SIZE.	Degree.	Weight lbs.
11 x 11	45	160	12 x 12	45	...
11 x 11	60	192	12 x 12	90	372
11 x 11	90	255			

CROSSES.

SIZE.	Weight. lbs.	SIZE.	Weight. lbs.
2 x 2 x 2 x 2	13	6 x 4 x 3 x 3	125
3 x 3 x 3 x 3	28	7 x 7 x 7 x 7	135
4 x 4 x 4 x 4	42	7 x 7 x 6 x 6	153
4 x 4 x 4 x 3	43	8 x 8 x 8 x 8	200
4 x 4 x 3 x 3	46	8 x 8 x 8 x 4	229
4 x 4 x 2 x 2	45	8 x 8 x 8 x 6	230
4 x 4 x **2** x **2**	43	8 x 8 x 4 x 4	209
4 x 3 x 3 x 3	45	8 x 8 x 14 x 16	1190
5 x 5 x 5 x 5	66	8 x 6 x 8 x 6	220
5 x 5 x 5 x 4	69	8 x 6 x 8 x 4	235
5 x 5 x **4** x **4**	74	8 x 6 x 3 x 3	238
5 x 4 x 5 x 5	72	8 x 4 x 4 x 4	218
6 x 6 x 6 x 6	108	9 x 9 x 9 x 9	...
6 x 6 x 4 x 4	117	10 x 10 x 10 x 10	337
6 x **6** x **4** x **3**	120	10 x 10 x 10 x 8	339
6 x 4 x 4 x 4	127	12 x 12 x 12 x 12	...

Heavy faced figures indicate openings tapped for Standard Pipe.

REDUCERS.

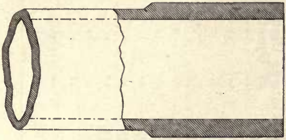
SIZE.	Weight Lbs.	SIZE.	Weight Lbs.	SIZE.	Weight Lbs.
3 x 2	..	6 x 4	21	9 x 8	..
4 x 3	11	6 x 3	..	9 x 7	..
4 x 3	14	6 x 3	25	9 x 6	..
4 x 2	12	7 x 6	..	10 x 9	..
5 x 5	19	7 x 5	..	10 x 8	50
5 x 4	17	8 x 7	..	10 x 6	46
5 x 3	..	8 x 6	39	10 x 4	52
6 x 5	..	8 x 4	43	12 x10	75
6 x 4	22				

PLUGS.

SIZE.	Weight Lbs.	SIZE.	Weight Lbs.	SIZE.	Weight Lbs.
2	1	6	7	10	23
3	2	7	13	12	..
4	3	8	15	14	58
5	5	9	..	16	88

Heavy-faced figures indicate openings tapped for Standard Pipe.

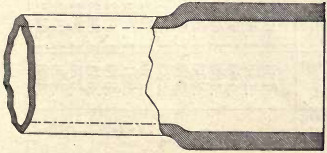
Some of the weights in these tables of Matheson Joint Fittings are not given; the reason being that there are not Standard patterns for sizes where weights are omitted and the patterns of some other size are made adaptable for same. This would cause a variation in weights, and for this reason it is thought best to give no fixed weights for fittings so manufactured.



PLAIN UPSET.

UPSET TUBES are becoming very generally used for Marine Boiler work ; in many cases the ordinary, as well as the Stay Tubes, are thickened or upset on ends, greater durability and strength being claimed for same.

The difficulties encountered in upsetting ends of tubes are not generally appreciated, and upsets are often asked for that are either very difficult or practically impossible to make. As a guide for ordering such tubes a set of tables has been prepared showing the practicable limits that should be observed in tubes of this kind. If a greater diameter is required for upset end than that shown on table giving maximum upset—this can be accomplished by expanding the end after upsetting as is shown in the cut below. The tables are all based on an upset 2½ inches long which is the usual length for Boiler Stay Tubes. If shorter length will answer a heavier upset than those shown on maximum table can be secured.



UPSET AND SWELLED.

NATIONAL TUBE COMPANY.

TABLE SHOWING ORDINARY UPSET FOR TUBES.

Thickness of Tubes in B. W. G. and Fraction of Inch.	Thickness of Tubes in Decimal of Inch.	OUTSIDE DIAMETER IN INCHES.															
		1½	1¾	2	2¼	2½	2¾	3	3¼	3½	3¾	4	4¼	4½	4¾	5	
10	.134	1.63	1.88	2.13	2.38	2.63	2.88	3.13	3.38	3.63	3.88	4.13	4.38	4.63	4.88	5.13	Outside Diameter of Upset.
9	.148	1.65	1.90	2.15	2.40	2.65	2.90	3.15	3.40	3.65	3.90	4.15	4.40	4.65	4.90	5.15	" "
8	.165	1.67	1.92	2.17	2.42	2.67	2.92	3.17	3.42	3.67	3.92	4.17	4.42	4.67	4.92	5.17	" "
7	.188	1.69	1.94	2.19	2.44	2.69	2.94	3.19	3.44	3.69	3.94	4.19	4.44	4.69	4.94	5.19	" "
6	.203	1.70	1.95	2.20	2.45	2.70	2.95	3.20	3.45	3.70	3.95	4.20	4.45	4.70	4.95	5.20	" "
5	.219	1.72	1.97	2.22	2.47	2.72	2.97	3.22	3.47	3.72	3.97	4.22	4.47	4.72	4.97	5.22	" "
4	.238	1.74	1.98	2.24	2.49	2.74	2.98	3.24	3.49	3.74	3 98	4.24	4.49	4.74	4.98	5.24	" "
¼	.250	1.75	2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	" "
9/32	.281	1.78	2.03	2.28	2.53	2.78	3.03	3.28	3.53	3.78	4.03	4.28	4.53	4.78	5.03	5.28	" "
5/16	.313	1.81	2.06	2.31	2.56	2.81	3.06	3.31	3.56	3.81	4.06	4.31	4.56	4.81	5.06	5.31	" "
11/32	.344	1 84	2.09	2.34	2.59	2.84	3.09	3.34	3.59	3.84	4.09	4.34	4.59	4.84	5.09		" "
⅜	.375	1.88	2.13	2.38	2.63	2.88	3.13	3.38	3.63	3.88	4.13	4.38	4.63	4.88			" "
13/32	.406	1.91	2.16	2.41	2.66	2.91	3.16	3.41	3.66	3.91	4.16	4.41	4.66				" "
7/16	.438	1.94	2.19	2.44	2:69	2.94	3.19	3.44	3.69	3.94	4.19	4.44					" "

Length of Upset 2½ inches.

NATIONAL TUBE COMPANY.

TABLE SHOWING ADVISABLE LIMITS OF UPSETS FOR TUBES.

Thickness of Tubes in B. W. G and Fraction of Inch	Thickness of Tubes in Decimal of Inch	Outside Diameter in Inches.															
		1½	1¾	2	2¼	2½	2¾	3	3¼	3½	3¾	4	4¼	4½	4¾	5	
10	.134	1.70	1.95	2.20	2.45	2.70	2.95	3.20	3.45	3.70	3.95	4.20	4.45	4.70	4.95	5.20	Outside Diameter of Upset.
9	.148	1.72	1.97	2.22	2.47	2.72	2.97	3.22	3.47	3.72	3.97	4.22	4.47	4.72	4.97	5.22	" "
8	.165	1.75	2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	" "
7	.188	1.78	2.03	2.28	2.53	2.78	3.03	3.28	3.53	3.78	4.03	4.28	4.53	4.78	5.03	5.28	" "
6	.203	1.80	2.05	2.30	2.55	2.80	3.05	3.30	3.55	3.80	4.05	4.30	4.55	4.80	5.05	5.30	" "
5	.219	1.83	2.08	2.33	2.58	2.83	3.08	3.33	3.58	3.83	4.08	4.33	4.58	4.83	5.08	5.33	" "
4	.238	1.86	2.11	2.36	2.61	2.86	3.11	3.36	3.61	3.86	4.11	4.36	4.61	4.86	5.11	5.36	" "
1/4	.250	1.88	2.13	2.38	2.63	2.88	3.13	3.38	3.63	3.88	4.13	4.38	4.63	4.88	5.13	5.38	" "
9/32	.281	1.92	2.17	2.42	2.67	2.92	3.17	3.42	3.67	3.92	4.17	4.42	4.67	4.92	5.17	5.42	" "
5/16	.313	1.97	2.22	2.47	2.72	2.97	3.22	3.47	3.72	3.97	4.22	4.47	4.72	4.97	5.22	5.47	" "
11/32	.344	2.02	2.27	2.52	2.77	3.02	3.27	3.52	3.77	4.02	4.27	4.52	4.77	5.02	5.27		" "
3/8	.375	2.06	2.31	2.56	2.81	3.06	3.31	3.56	3.81	4.06	4.31	4.56	4.81	5.06			" "
13/32	.406	2.11	2.36	2.61	2.86	3.11	3.36	3.61	3.86	4.11	4.36	4.61	4.86				" "
7/16	.438	2.16	2.41	2.66	2.91	3.16	3.41	3.66	3.91	4.16	4.41	4.66					" "

Length of Upset 2½ inches.

NATIONAL TUBE COMPANY.

TABLE SHOWING POSSIBLE UPSETS (BUT DIFFICULT) FOR TUBES.

Thickness of Tubes in B. W. G. and Fraction of Inch	Thickness of Tubes in Decimal of Inch	Outside Diameter in Inches.															
		1½	1¾	2	2¼	2½	2¾	3	3¼	3½	3¾	4	4¼	4½	4¾	5	
10	.134	1.77	2.02	2.27	2.52	2.77	3.02	3.27	3.52	3.77							Outside Diameter of Upset.
9	.148	1.80	2.05	2.30	2.55	2.80	3.05	3.30	3.55	3.80	4.05	4.30					" "
8	.165	1.83	2.08	2.33	2.58	2.83	3.08	3.33	3.58	3.83	4.08	4.33	4.58	4.83			" "
7	.188	1.88	2.13	2.38	2.63	2.88	3.13	3.38	3.63	3.88	4.13	4.38	4.63	4.88	5.13	5.38	" "
6	.203	1.91	2.16	2.41	2.66	2.91	3.16	3.41	3.66	3.91	4.16	4.41	4.66	4.91	5.16	5.41	" "
5	.219	1.94	2.19	2.44	2.69	2.94	3.19	3.44	3.69	3.94	4.19	4.44	4.69	4.94	5.19	5.44	" "
4	.238	1.98	2.23	2.48	2.73	2.98	3.23	3.48	3.73	3.98	4.23	4.48	4.73	4.98	5.23	5.48	" "
1/4	.250	2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	" "
9/32	.281	2.06	2.31	2.56	2.81	3.06	3.31	3.56	3.81	4.06	4.31	4.56	4.81	5.06	5.31	5.56	" "
5/16	.313	2.13	2.38	2.63	2.88	3.13	3.38	3.63	3.88	4.13	4.38	4.63	4.88	5.13	5.38	5.63	" "
11/32	.344	2.19	2.44	2.69	2.94	3.19	3.44	3.69	3.94	4.19	4.44	4.69	4.94	5.19	5.44		" "
3/8	.375	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25			" "
13/32	.406	2.31	2.56	2.81	3.06	3.31	3.56	3.81	4.06	4.31	4.56	4.81	5.06				" "
7/16	.438	2.38	2.63	2.88	3.13	3.38	3.63	3.88	4.13	4.38	4.63	4.88					" "

Length of Upset 2½ inches.

PIPE BENDS.

The attached table gives the advisable radius and the greatest and least radii to which standard thickness pipe may be bent.

If the radius must be reduced from the minimum given in the table, the thickness of the pipe must be increased. For such bends it is best to submit sketch.

When the radius is greater than the maximum given in the list, the bend is apt to look like a series of kinks, owing to the Bender having to take short heats, unless the radius is so great that the pipe may be bent cold.

With offset bends try to make according to Drawing F.–261, rather than Drawings F.–257 or 262. The straight length between the bends is of advantage to the pipe Bender.

With the welded flanges there must be a short straight length of pipe adjacent to each flange. On sizes under 4 inches this should equal, at least, one and a half diameters. On sizes over 4 inches it should equal, at least, one diameter of the pipe. In all cases it is better if equal to two diameters of straight pipe.

BENT TUBES.

These are more difficult to bend than standard weight pipe. Try not to vary from the advisable radius given in the table. With tubes it is frequently necessary to increase the thickness over that of standard boiler tubes in order to bend them.

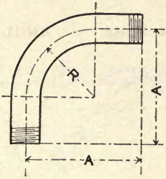
TABLE OF RADII FOR PIPE BENDS.

Pipe Size.	Minimum Radius.	Maximum Radius.	Advisable Radius.
Inches.	Inches.	Inches.	Inches.
2½	10	25	15
3	12	30	18
3½	14	35	21
4	16	40	24
4½	18	45	27
5	20	50	30
6	24	60	36
7	28	70	42
8	32	80	48
9	36	90	54
10	40	100	60
11	44	110	66
12	48	120	72
14 o. d.	60	140	84
15 "	68	145	90
16 "	76	150	100
18 "	90	165	125
20 "	120	180	150
22 "	132	198	165
24 "	144	216	180

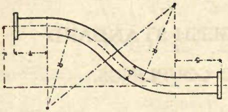
STOCK PIPE BENDS

AMERICAN OR ENGLISH STANDARD

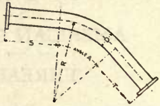
THREADS AND COUPLINGS.



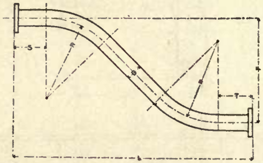
Pipe Size.	Radius "R."	Centre To Face "A."
Inches.	Inches.	Inches.
1/8	1 1/4	2
1/4	1 5/16	2 1/4
3/8	1 7/16	2 9/16
1/2	1 3/4	3 1/8
3/4	2 3/16	3 15/16
1	2 9/16	4 9/16
1 1/4	3	5 1/8
1 1/2	3 5/16	5 11/16
2	4 7/16	6 15/16
2 1/2	6 11/16	9 7/16
3	8	10
3 1/2	9 9/16	13 1/16
4	10 1/8	14 1/8
5	14 5/8	18 5/8



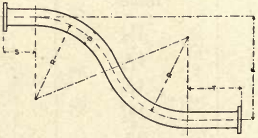
OFFSET BEND, No. F. 257.



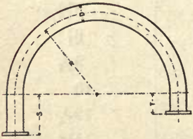
ANGLE BEND, No. F. 260.



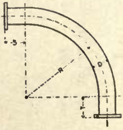
OFFSET BEND, No. F. 261.



OFFSET BEND, No. F. 262.



180° BEND, No. F. 258.



90° BEND, No. F. 259.

DIMENSIONS

OF

National Trolley Poles

AND

DEFLECTIONS
UNDER STATED LOADS

Length of Pole, 34 feet. End of Pole 6 feet in ground.

Number.	Weight.	BUTT. 17′–8″ O D.	BUTT. THICK.	MIDDLE. 10′–10″ O. D.	MIDDLE. THICK.	END. 8′–6″ O. D.	END. THICK.	TABLE OF DEFLECTIONS MEASURED AT FREE END. TOP LINE GIVES LOADS IN POUNDS APPLIED 18″ FROM END. 200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400
1	1637	9.625	0.625	8.00	0.437	7.00	0.312	0.706	1.41	2.12	2.82	3.53	4.24	4.94	5.64	6.35	7.06	7.77	8.47
2	1493	"	0.562	"	0.406	"	0.281	0.764	1.53	2.29	3.06	3.82	4.59	5.35	6.11	6.89	7.64	8.41	9.17
3	1392	"	0.500	"	0.406	"	0.281	0.814	1.63	2.44	3.26	4.07	4.87	5.70	6.51	7.32	8.14	8.95	
4	1207	"	0.437	8.625	0.312	7.625	0.220	0.876	1.75	2.62	3.50	4.38	5.26	6.15	7.01	7.89	8.76		2600
5	1127	"	0.406	"	0.281	"	0.220	0.940	1.88	2.82	3.76	4.70	5.64	6.58	7.52	8.46			9.18
6	1069	"	0.375	8.00	0.312	7.00	0.218	1.04	2.08	3.11	4.15	5.19	6.24	7.28	8.32				
7	969	"	0.312	8.625	0.281	7.625	0.220	1.11	2.22	3.32	4.43	5.54	6.64	7.64					
8	1025	9.00	0.375	8.00	0.300	7.00	0.220	1.20	2.41	3.61	4.82	6.02	7.23	8.43					
9	895	"	0.312	"	0.281	"	0.220	1.37	2.74	4.12	5.49	6.86	8.23	9.60					

Length of Pole, 34 feet. End of Pole 6 feet in ground.

Number.	Weight.	BUTT. 17′–8″ O. D.	BUTT. 17′–8″ THICK.	MIDDLE. 10′–10″ O. D.	MIDDLE. 10′–10″ THICK.	END. 8′–6″ O. D	END. 8′–6″ THICK.	100	200	300	400	500	600	700	800	900	1000	1200
								TABLE OF DEFLECTIONS MEASURED AT FREE END. TOP LINE GIVES LOADS IN POUNDS APPLIED 18″ FROM END.										
10	997	8.625	0.406	7.625	0.281	6.625	0.220	....	....	2.01	2.68	3.36	4.03	4.60	5.37	6.04	6.71	8.05
11	905	"	0.343	"	"	"	"	....	....	2.23	2.97	3.72	4.46	5.20	5.94	6.69	7.43	8.91
12	810	"	0.281	"	"	"	"	....	..	2.54	3.38	4.23	5.07	5.92	6.76	7.60	8.45	
13	889	8.00	0.375	6.625	0.343	5.562	0.203	....	1.82	2.73	3.64	4.56	5.47	6.38	7.29	8.20		
14	810	"	0.343	"	0.281	"	"	....	2.02	3.03	4.04	5.05	6.06	7.07	8.08			
15	746	"	0.281	7.00	"	6.00	0.220	....	2.16	3.24	4.32	5.40	6.48	7.56	8.64			1400
16	751	7.625	0.343	6.625	0.259	5.00	0.203	....	2.32	3.48	4.64	5.80	6.96	8.12	9.28			
17	676	"	0.281	"	"	5.562	"	....	2.58	3.87	5.16	6.45	7.74	9.03	10.3			9.39
18	650	"	0.281	6.00	"	5.00	"	1.41	2.81	4.22	5.62	7.03	8.43	9.84				
19	701	7.00	0.343	5.562	0.312	4.50	"	1.57	3.14	4.71	6.28	7.85	9.42	11.0				
20	619	"	0.281	6.00	0.259	5.00	"	1.71	3.42	5.13	6.84	8.55	10.3	12.0				
21	594	"	0.281	5.562	"	4.50	"	1.86	3.72	5.58	7.44	9.30	11.2					
22	580	6.625	0.300	"	0.238	"	"	2.06	4.12	6.18	8.24	10.3	12.4					
23	536	"	0.259	"	"	"	"	2.22	4.44	6.66	8.88	11.1	13.3					
24	592	6.00	0.343	5.00	0.281	4.00	"	2.50	5.00	7.50	10.0	12.5						
25	537	"	0.312	"	0.238	"	"	2.75	5.50	8.25	11.0	13.8						
26	481	"	0.259	"	"	"	"	3.05	6.10	9.15	12.2	15.3						

Length of Pole, 33 feet. End of Pole 6 feet in ground.

Number.	Weight.	BUTT. 17′–3″ O. D.	BUTT. 17′–3″ THICK.	MIDDLE. 10′–6″ O. D.	MIDDLE. 10′–6″ THICK.	END. 8′–3″ O. D.	END. 8′–3″ THICK.	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400
								TABLE OF DEFLECTIONS MEASURED AT FREE END. TOP LINE GIVES LOADS IN POUNDS APPLIED 18″ FROM END.											
27	1594	9.625	0.625	8.00	0.437	7.00	0.312	0.632	1.26	1.90	2.53	3.16	3.80	4.41	5.06	5.69	6.32	6.95	7.60
28	1455	"	0.562	"	0.406	"	0.281	0.688	1.38	2.06	2.76	3.44	4.12	4.82	5.52	6.19	6.88	7.57	8.24
29	1356	"	0.500	"	"	"	"	0.732	1.46	2.20	2.93	3.66	4.40	5.12	5.86	6.59	7.32	8.05	
30	1176	"	0.437	8.625	0.312	7.625	0.220	0.792	1.58	2.37	3.17	3.96	4.74	5.53	6.34	7.13	7.92		2600
31	1097	"	0.406	"	0.281	"	"	0.844	1.69	2.53	3.38	4.22	5.06	5.91	6.76	7.60			8.22
32	1041	"	0.375	8.00	0.312	7.000	0.218	0.932	1.86	2.80	3.73	4.66	5.60	6.52	7.46				
33	944	"	0.312	8.625	0.281	7.625	0.220	0.994	1.99	2.98	3.98	4.97	5.96	6.96					
34	988	9.00	0.375	8.00	0.300	7.00	"	1.13	2.26	3.40	4.53	5.45	6.80	7.92					
35	871	"	0.312	"	0.281	"	"	1.23	2.46	3.70	4.93	6.16	7.40	8.62					

Length of Pole, 33 feet. End of Pole 6 feet in ground.

Number.	Weight.	BUTT. 17′–3″ O. D.	BUTT. 17′–3″ THICK.	MIDDLE. 10′–6″ O. D.	MIDDLE. 10′–6″ THICK.	END. 8′–3″ O. D.	END. 8′–3″ THICK.	100	200	300	400	500	600	700	800	900	1000	1200
								TABLE OF DEFLECTIONS MEASURED AT FREE END. TOP LINE GIVES LOADS IN POUNDS APPLIED 18″ FROM END.										
36	971	8.625	0.406	7.625	0.281	6.625	0.220	0.603	1.21	1.81	2.41	3.02	3.62	4.22	4.83	5.43	6.03	7.24
37	881	"	0.343	"	"	"	"	0.672	1.34	2.02	2.69	3.36	4.04	4.72	5.38	6.05	6.72	8.08
38	789	"	0.281	"	"	"	"	0.759	1.52	2.28	3.04	3.80	4.56	5.31	6.08	6.83	7.59	
39	865	8.00	0.375	6.625	0.343	5.563	0.203	0.816	1.63	2.45	3.26	4.08	4.90	5.71	6.53	7.34	8.16	
40	789	"	0.343	"	0.281	"	"	0.906	1.81	2.72	3.62	4.53	5.44	6.34	7.25			
41	726	"	0.281	7.00	"	6.00	0.220	0.969	1.94	2.91	3.88	4.85	5.82	6.78	7.76			1400
42	731	7.625	0.343	6.625	0.259	5.00	0.203	1.04	2.07	3.11	4.15	5.19	6.23	7.27	8.30			
43	658	"	0.281	"	"	5.563	"	1.16	2.32	3.48	4.64	5.80	6.95	8.11				8.44
44	633	"	"	6.00	"	5.00	"	1.27	2.54	3.81	5.08	6.35	7.62	8.88				
45	683	7.00	0.343	5.563	0.312	4.50	"	1.40	2.80	4.20	5.60	7.00	8.40					
46	603	"	0.281	6.00	0.259	5.00	"	1.53	3.06	4.59	6.12	7.68	9.18					
47	578	"	"	5.563	"	4.50	"	1.66	3.32	4.98	6.64	8.30						
48	565	6.625	0.300	"	0.238	4.50	"	1.82	3.64	5.46	7.28	9.10						
49	522	"	0.259	"	"	"	"	1.97	3.94	5.91	7.88	9.85						
50	576	6.00	0.343	5.00	0.281	4.00	"	2.24	4.48	6.72	8.96							
51	523	"	0.312	"	0.238	"	"	2.44	4.88	7.32	9.76							
52	469	"	0.259	"	"	"	"	2.75	5.50	8.25	11.00							

Length of Pole, 32 feet. End of Pole 6 feet in ground.

Number.	Weight.	BUTT. 16′–10″ O. D	BUTT. 16′–10″ THICK.	MIDDLE. 10′–2″ O. D.	MIDDLE. 10′–2″ THICK	END. 8′–0″ O. D.	END. 8′–0″ THICK.	TABLE OF DEFLECTIONS MEASURED AT FREE END. TOP LINE GIVES LOADS IN POUNDS APPLIED 18″ FROM END. 400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600
53	1552	9.625	0.625	8.00	0.437	7.00	0.312	1.14	1.71	2.29	2.86	3.42	4.00	4.58	5.15	5.72	6.29	6.84	7.44
54	1416	"	0.562	"	0.406	"	0.281	1.22	1.83	2.43	3.04	3.65	4.26	4.86	5.47	6.08	6.69	7.30	7.90
55	1319	"	0.500	"	"	"	"	1.29	1.94	2.59	3.24	3.88	4.54	5.18	5.83	6.48	7.13	7.76	
56	1144	"	0.437	8.625	0.312	7.625	0.220	1.39	2.09	2.80	3.49	4.19	4.89	5.60	6.28	6.98			2800
57	1068	"	0.406	"	0.281	"	"	1.50	2.26	3.00	3.76	4.52	5.26	6.00	6.77				8.00
58	1013	"	0.375	8.00	0.312	7.00	0.218	1.65	2.47	3.30	4.12	4.94	5.77	6.60					
59	918	"	0.312	8.625	0.281	7.625	0.220	1.77	2.65	3.53	4.42	5.30	6.19						
60	971	9.00	0.375	8.00	0.300	7.00	0.220	1.92	2.89	3.85	4.81	5.77	6.73						
61	848	"	0.312	"	0.281	"	0.220	2.20	3.29	4.39	5.49	6.58	7.69						

Length of Pole, 32 feet. End of Pole 6 feet in ground.

Number.	Weight.	BUTT. 16′–10″ O. D.	BUTT. 16′–10″ THICK.	MIDDLE. 10′–2″ O. D	MIDDLE. 10′–2″ THICK.	END. 8′–0″ O D.	END. 8′–0″ THICK.	100	200	300	400	500	600	700	800	900	1000	1200	1400
								TABLE OF DEFLECTIONS MEASURED AT FREE END. Top Line Gives Loads in Pounds Applied 18″ From End.											
62	945	8.625	0.406	7.625	0.281	6.625	0.220	0.534	1.07	1.60	2.13	2.67	3.20	3.74	4.27	4.81	5.34	6.41	7.48
63	857	“	0.343	“	“	“	“	0.591	1.18	1.77	2.36	2.96	3.55	4.14	4.70	5.32	5.91	7.09	
64	767	“	0.281	“	“	“	“	0.676	1.35	2.03	2.70	3.38	4.06	4.73	5.40	6.08	6.76		
65	842	8.00	0.375	6.625	0.343	5.562	0.203	0.762	1.45	2.17	2 90	3.63	4.34	5.08	5.80	6.53			
66	768	“	0.343	“	0.281	“	“	0.802	1.60	2.40	3.21	4.01	4.81	5.61	6.42				1500
67	707	“	0.281	7.00	“	6.00	0.220	0.863	1.73	2.59	3.46	4.31	5.18	6.04	6.92				
68	712	7.625	0.343	6.625	0.259	5.00	0.203	0.916	1.83	2.75	3.66	4.58	5.50	6.41	7.33				8.01
69	640	“	0.281	“	“	5.562	“	1.03	2.06	3.09	4.12	5.15	6.18	7.21	8.24				
70	616	“	“	6.00	“	5.00	“	1.13	2.26	3.39	4.52	5.65	6.78	7.91	9.04				
71	664	7.00	0.343	5.562	0.312	4.50	“	1.24	2.48	3.72	4.96	6.20	7.44	8.68					
72	586	“	0.281	6.00	0.259	5.00	“	1.36	2.72	4.08	5.44	6.80	8.16	9.52					
73	563	“	“	5.562	“	4.50	“	1.46	2.92	4.38	5.84	7.30	8.76						
74	550	6.625	0.300	“	0.238	“	“	1.62	3.24	4.86	6.48	8.10	9.72						
75	508	“	0.259	“	0.238	“	“	1.77	3.54	5.31	7.08	8.85	10.6						
76	561	6.00	0.343	5.00	0.281	4.00	“	1.98	3.96	5.94	7.92	9.90							
77	509	“	0.312	“	0.238	“	“	2.19	4.38	6.57	8.76	11.0							
78	456	“	0.259	“	“	“	“	2.43	4.86	7.29	9.72	12.2							

Length of Pole, 31 feet. End of Pole 6 feet in ground.

Number.	Weight.	BUTT. 16′–5″ O. D.	BUTT. 16′–5″ THICK.	MIDDLE. 9′–10″ O. D.	MIDDLE. 9′–10″ THICK.	END. 7′–9″ O. D.	END. 7′–9″ THICK.	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600
								TABLE OF DEFLECTIONS MEASURED AT FREE END. TOP LINE GIVES LOADS IN POUNDS APPLIED 18″ FROM END.											
79	1509	9.623	0.625	8.00	0.437	7.00	0.312	0.988	1.48	1.98	2.47	2.96	3.46	3.96	4.45	4.94	5.43	5.92	6.42
80	1377	"	0.562	"	0.406	"	0.281	1.09	1.63	2.18	2.72	3.26	3.81	4.36	4.90	5.44	5.98	6.52	7.08
81	1283	"	0.500	"	"	"	"	1.14	1.70	2.28	2.84	3.40	3.98	4.56	5.11	5.68	6.25	6.82	
82	1112	"	0.437	8.625	0.312	7.625	0.220	1.22	1.84	2.45	3.06	3.68	4.24	4.90	5.51	6.12			2800
83	1038	"	0.406	"	0.281	"	"	1.32	1.99	2.65	3.31	3.98	4.63	5.30	5.96				6.92
84	985	"	0.375	8.00	0.312	7.00	0.218	1.45	2.18	2.90	3.63	4.36	5.03	5.80					
85	892	"	0.312	8.625	0.281	7.625	0.220	1.56	2.35	3.12	3.91	4.70	5.47						
86	944	9.00	0.375	8.00	0.300	7.00	"	1.70	2.55	3.40	4.25	5.10	5.95						
87	824	"	0.312	"	0.281	"	"	1.94	2.90	3.88	4.84	5.80	6.78						

Length of Pole, 31 feet. End of Pole 6 feet in ground.

Number.	Weight.	BUTT. 16′–5″ O. D.	BUTT. 16′–5″ THICK.	MIDDLE. 9′–10″ O. D.	MIDDLE. 9′–10″ THICK.	END. 7′–9″ O. D.	END. 7′–9″ THICK.	TABLE OF DEFLECTIONS MEASURED AT FREE END. TOP LINE GIVES LOADS IN POUNDS APPLIED 18″ FROM END. 100	200	300	400	500	600	700	800	900	1000	1200	1400
88	919	8.625	0.406	7.625	0.281	6.625	0.220	0.472	0.944	1.42	1.89	2.36	2.84	3.30	3.78	4.25	4.72	5.68	6.60
89	834	"	0.343	"	"	"	"	0.522	1.04	1.57	2.08	2.61	3.14	3.65	4.16	4.70	5.22	6.28	
90	746	"	0.281	"	"	"	"	0.597	1.19	1.79	2.38	2.90	3.58	4.18	4.76	5.37	5.97		
91	819	8.00	0.375	7.625	0.343	5.562	0.203	0.641	1.28	1.92	2.56	3.21	3.85	4.49	5.13	5.77			
92	737	"	0.343	"	0.281	"	"	0.731	1.46	2.19	2.92	3.66	4.38	5.12	5.84				1500
93	687	"	0.281	7.00	"	6.00	0.220	0.756	1.51	2.27	3.02	3.78	4.54	5.29	6.04				
94	692	7.625	0.343	6.625	0.259	5.00	0.203	0.809	1.62	2.43	3.24	4.05	4.85	5.66	6.47				7.08
95	622	"	0.281	"	"	5.562	"	0.906	1.81	2.72	3.62	4.53	5.44	6.34	7.24				
96	599	"	"	6.00	"	5.00	"	0.987	1.97	2.96	3.95	4.94	5.92	6.91	7.90				
97	646	7.00	0.343	5.562	0.312	4.50	"	1.11	2.21	3.32	4.42	5.53	6.64	7.74					
98	570	"	0.281	6.00	0.259	5.00	"	1.19	2.38	3.57	4.76	5.95	7.14	8.33					
99	547	"	"	5.562	"	4.50	"	1.29	2.59	3.88	5.18	6.47	7.76						
100	535	6.625	0.30	"	0.238	"	"	1.43	2.86	4.29	5.72	7.15	8.58						
101	494	"	0.259	"	"	"	"	1.57	3.14	4.71	6.28	7.85	9.42						
102	529	6.00	0.343	5.00	0.281	4.00	"	1.76	3.52	5.28	7.04	8.80							
103	495	"	0.312	"	0.238	"	"	1.92	3.84	5.76	7.68	9.60							
104	443	"	0.259	"	"	"	"	2.16	4.32	6.48	8.64	10.8							

Length of Pole, 30 feet. End of Pole 6 feet in ground.

Number.	Weight.	BUTT. 16′–0″ O. D	BUTT. 16′–0″ THICK.	MIDDLE. 9′–6″ O. D.	MIDDLE. 9′–6″ THICK.	END. 7′–6″ O. D.	END. 7′–6″ THICK.	TABLE OF DEFLECTIONS MEASURED AT FREE END. TOP LINE GIVES LOADS IN POUNDS APPLIED 18″ FROM END. 600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800
105	1466	9.625	0.625	8.00	0.437	7.00	0.312	1.31	1.74	2.18	2.62	3.05	3.49	3.92	4.36	4.80	5.24	5.67	6.10
106	1339	"	0·562	"	0.406	"	0.281	1.42	1.89	2.36	2.84	3.30	3.78	4.25	4.72	5.23	5.68	6.14	6.60
107	1246	"	0.500	"	"	"	"	1.51	2.01	2.51	3.01	3.51	4.02	4.52	5.02	5.52	6.02	6.53	
108	1080	"	0.437	8.625	0.312	7.625	0.220	1.62	2.16	2.70	3.24	3.78	4.32	4.86	5.40	5.94			3000
109	1008	"	0.406	"	0.281	"	"	1.75	2.33	2.91	3.50	4.07	4.66	5.24	5.82				6.54
110	957	"	0.375	8.00	0.312	7.00	0.218	1.91	2.55	3.19	3.82	4.47	5.10	5.74					
111	866	"	0.312	8.625	0.281	7.625	0.220	2.05	2.74	3.42	4.10	4.79	5.48						
112	916	9.00	0.375	8.00	0.300	7.000	"	2.24	2.98	3.73	4.48	5.22	5.96						
113	800	"	0.312	"	0.281	"	"	2.54	3.39	4 24	5.08	5.95	6.78						

Length of Pole, 30 feet. End of Pole 6 feet in ground.

Number.	Weight.	BUTT. 16′–0″ O. D.	BUTT. 16′–0″ THICK.	MIDDLE. 9′–6″ O. D.	MIDDLE. 9′–6″ THICK.	END. 7′–6″ O. D.	END. 7′–6″ THICK.	100	200	300	400	500	600	700	800	900	1000	1200	1400
								TABLE OF DEFLECTIONS MEASURED AT FREE END. Top Line Gives Loads in Pounds Applied 18" from End.											
114	893	8.625	0.406	7.625	0.281	6.625	0.220	0.415	0.830	1.24	1.66	2.08	2.48	2.91	3.32	3.74	4.15	4.96	5.82
115	810	"	0.343	"	"	"	"	0.459	0.918	1.38	1.84	2.29	2.76	3.21	3.68	4.13	4.59	5.52	6.42
116	724	"	0.281	"	"	"	"	0.523	1.05	1.57	2.10	2.62	3.14	3.66	4.20	4.71	5.23	6.28	
117	793	8.00	0.375	6.625	0.343	5.562	0.203	0.564	1.13	1.69	2.26	2.82	3.38	3.95	4.52	5.08	5.64		
118	716	"	0.343	"	0.281	"	"	0.627	1.25	1.88	2.50	3.14	3.70	4.39	5.10	5.64			
119	665	"	0.281	7.00	"	6.00	0.220	0.667	1.33	2.00	2.66	3.34	4.00	4.67	5.32	6.00			1600
120	672	7.625	0.343	6.625	0.259	5.00	0.203	0.713	1.43	2.14	2.86	3.57	4.28	4.99	5.72	6.42			
121	605	"	0.281	"	"	5.562	"	0.793	1.59	2.38	3.18	3.97	4.76	5.55	6.36	7.14			6.64
122	581	"	"	6.00	"	5.00	"	0.868	1.73	2.60	3.46	4.34	5.20	6.08	6.92	7.81			
123	628	7.00	0.343	5.562	0.312	4.50	"	0.970	1.94	2.91	3.88	4.85	5.82	6.79	7.76				
124	553	"	0.281	6.00	0.259	5.00	"	1.05	2.10	3.15	4.20	5.25	6.30	7.35	8.40				
125	532	"	"	5.562	"	4.50	"	1.14	2.28	3.42	4.56	5.70	6.84	7.98	9.12				
126	520	6.625	0.30	"	0.238	"	"	1.26	2.52	3.78	5.04	6.30	7.56	8.82					
127	480	"	0.259	"	"	"	"	1.37	2.74	4.11	5.48	6.85	8.22	9.59					
128	529	6.00	0.343	5.00	0.281	4.00	"	1.54	3.08	4.62	6.16	7.70	9.24						
129	481	"	0.312	"	0.238	"	"	1.70	3.40	5.10	6.80	8.50	10.2						
130	431	"	0.259	"	"	"	"	1.88	3.76	5.64	7.52	9.40	11.3						

Length of Pole, 29 feet. End of Pole 6 feet in ground.

Number.	Weight.	BUTT. 15′–7″		MIDDLE. 9′–2″		END. 7′–3″		TABLE OF DEFLECTIONS MEASURED AT FREE END. TOP LINE GIVES LOADS IN POUNDS APPLIED 18″ FROM END.											
		O. D.	THICK.	O. D.	THICK.	O. D.	THICK.	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000
131	1425	9.625	0.625	8.00	0.437	7.00	0.312	1.55	1.94	2.33	2.72	3.10	3.49	3.88	4.27	4.66	5.04	5.44	5.82
132	1299	"	0.562	"	0.406	"	0.281	1.67	2.09	2.51	2.92	3.34	3.76	4.18	4.60	5.02	5.43	5.84	6.27
133	1210	"	0.500	"	"	"	"	1.75	2.19	2.63	3.07	3.50	3.94	4.38	4.82	5.26	5.69	6.14	
134	1049	"	0.437	8.625	0.312	7.625	0.220	1.87	2.34	2.81	3.28	3.74	4.21	4.68	5.15	5.62			3200
135	980	"	0.406	"	0.281	"	"	2.02	2.53	3.04	3.54	4.04	4.55	5.06	5.57				6.20
136	929	"	0.375	8.00	0.312	7.00	0.218	2.22	2.78	3.34	3.89	4.44	5.00	5.56					
137	841	"	0.312	8.625	0.281	7.625	0.220	2.38	2.97	3.56	4.16	4.76	5.35						
138	891	9.00	0.375	8.00	0.300	7.00	"	2.60	3.25	3.90	4.55	5.20							
139	777	"	0.312	"	0.281	"	"	2.97	3.72	4.46	5.21	5.94							

Length of Pole, 29 feet. End of Pole 6 feet in ground.

Number.	Weight.	BUTT. 15′–7″ O. D.	BUTT. 15′–7″ THICK.	MIDDLE. 9′–2″ O. D.	MIDDLE. 9′–2″ THICK.	END. 7′–3″ O. D.	END. 7′–3″ THICK.	100	200	300	400	500	600	700	800	900	1000	1200	1400
								TABLE OF DEFLECTIONS MEASURED AT FREE END. TOP LINE GIVES LOADS IN POUNDS APPLIED 18″ FROM END.											
140	867	8.625	0.406	7.625	0.281	6.625	0.220	0.366	0.732	1.10	1.46	1.83	2.20	2.56	2.92	3.29	3.66	4.40	5.12
141	786	"	0.343	"	"	"	"	0.400	0.800	1.20	1.60	2.00	2.40	2.80	3.20	3.60	4.00	4.80	5.60
142	702	"	0.281	"	"	"	"	0.459	0.918	1.38	1.84	2.30	2.76	3.21	3.68	4.13	4.59	5.52	
143	772	8.00	0.375	6.625	0.343	5.562	0.203	0.494	0.988	1.48	1.98	2.47	2.96	3.46	3.96	4.45	4.94		
144	695	"	0.343	"	0.281	"	"	0.547	1.09	1.64	2.18	2.74	3.28	3.83	4.36	4.92			
145	646	"	0.281	7.00	"	6.00	0.220	0.582	1.16	1.74	2.33	2.91	3.49	4.07	4.66	5.24			1600
146	653	7.625	0.343	6.625	0.259	5.00	0.203	0.622	1.24	1.87	2.49	3.11	3.73	4.35	4.98	5.60			
147	587	"	0.281	"	"	5.562	"	0.694	1.39	2.08	2.78	3.47	4.16	4.86	5.56	6.25			5.84
148	564	"	"	6.00	"	5.00	"	0.763	1.53	2.29	3.05	3.82	4.58	5.34	6.10	6.87			6.40
149	609	7.00	0.343	5.562	0.312	4.50	"	0.856	1.71	2.57	3.42	4.28	5.14	5.99	6.84	7.70			
150	537	"	0.281	6.00	0.259	5.00	"	0.919	1.84	2.76	3.68	4.60	5.51	6.43	7.36	8.27			
151	516	"	"	5.562	"	4.50	"	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00				
152	503	6.625	0.30	"	0.238	"	"	1.10	2.20	3.30	4.40	5.50	6.60	7.70					
153	464	"	0.259	"	"	"	"	1.20	2.40	3.60	4.80	6.00	7.20	8.40					
154	514	6.00	0.343	5.00	0.281	4.00	"	1.36	2.72	4.08	5.44	6.80	8.16						
155	467	"	0.312	"	0.238	"	"	1.49	2.98	4.47	5.96	7.45	8.94						
156	418	"	0.259	"	"	"	"	1.65	3.30	4.95	6.60	8.25	9.90						

Length of Pole, 28 feet. End of Pole 6 feet in ground.

Number.	Weight.	BUTT. 15′–2″ O. D.	BUTT. 15′–2″ THICK.	MIDDLE. 8′–10″ O. D.	MIDDLE. 8′–10″ THICK.	END. 7′–0″ O. D.	END. 7′–0″ THICK	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200
								TABLE OF DEFLECTIONS MEASURED AT FREE END. TOP LINE GIVES LOADS IN POUNDS APPLIED 18″ FROM END.											
157	1382	9.625	0.625	8.00	0.437	7.00	0.312	1.66	1.99	2.32	2.65	2.99	3.32	3.65	3.98	4.32	4.64	4.98	5.30
158	1261	"	0.562	"	0.406	"	0.281	1.80	2.16	2.52	2.88	3.24	3.60	3.96	4.32	4.68	5.04	5.40	5.76
159	1174	"	0.500	"	"	"	"	1.91	2.29	2.67	3.06	3.44	3.82	4.20	4.58	4.97	5.34		
160	1018	"	0.437	8.625	0.312	7.625	0.220	2.06	2.47	2.88	3.30	3.71	4.12	4.53	4.94	5.36			3400
161	950	"	0.406	"	0.281	"	"	2.22	2.66	3.11	3.55	4.00	4.44	4.88					5.64
162	901	"	0.375	8.00	0.312	7.00	0.218	2.43	2.92	3.40	3.89	4.37	4.86	5.35					
163	815	"	0.312	8.625	0.281	7.625	0.220	2.60	3.12	3.64	4.16	4.68							
164	864	9.00	0.375	8.00	0.300	7.00	"	2.84	3.41	4.00	4 54	5.11							
165	753	"	0.312	"	0.281	"	"	3.20	3.84	4.48	5.12	5.76							

Length of Pole, 28 feet. End of Pole 6 feet in ground.

Number.	Weight.	BUTT. 15′–2″ O. D.	BUTT. 15′–2″ THICK.	MIDDLE. 8′–10″ O. D.	MIDDLE. 8′–10″ THICK.	END. 7′–0″ O. D.	END. 7′–0″ THICK	100	200	300	400	500	600	700	800	1000	1200	1400	1600
								TABLE OF DEFLECTIONS MEASURED AT FREE END. TOP LINE GIVES LOADS IN POUNDS APPLIED 18″ FROM END.											
166	841	8.625	0.406	7.625	0.281	6.625	0.220	0.316	0.632	0.948	1.26	1.58	1.90	2.21	2.52	3.16	3.79	4.42	5.04
167	762	“	0.343	“	“	“	“	0.349	0.698	1.05	1.40	1.75	2.09	2.44	2.79	3.49	4.18	4.88	5.58
168	681	“	0.281	“	“	“	“	0.398	0.796	1.19	1.59	1.99	2.38	2.79	3.18	3.98	4.76	5.58	
169	749	8.00	0.375	6.625	0.343	5.562	0.203	0.429	0.858	1.28	1.72	2.15	2.56	3.00	3.44	4.29	5.12		
170	674	“	0.343	“	0.281	“	“	0.475	0.950	1.43	1.80	2.38	2.86	3.32	3.60	4.75			
171	626	“	0.281	7.00	“	6.00	0.220	0.506	1.01	1.52	2.02	2.53	3.04	3.54	4.04	5.06			1800
172	673	7.625	0.343	6.625	0.259	5.00	0.203	0.542	1.08	1.63	2.17	2.71	3.26	3.79	4.35	5.42			
173	633	“	0.281	“	“	5.562	“	0.606	1.21	1.82	2.42	3.03	3.67	4.24	4.85	6.06			5.69
174	569	“	“	6.00	“	5.00	“	0.661	1.32	1.98	2.64	3.31	3.96	4.63	5.28				
175	591	7.00	0.343	5.562	0.312	4.50	“	0.737	1.47	2.21	2.94	3.69	4.42	5.16	5.88				
176	520	“	0.281	6.00	0.259	5.00	“	0.802	1.60	2.41	3.21	4.01	4.81	5.61	6.42				
177	500	“	“	5.562	“	4.50	“	0.868	1.73	2.60	3.46	4.34	5.20	6.07					
178	588	6.625	0.300	“	0.238	“	“	0.953	1.91	2.86	3.82	4.77	5.71	6.67					
179	450	“	0.259	“	“	“	“	1.04	2.08	3.12	4.16	5.20	6.24	7.28					
180	499	6.00	0.343	5.00	0.281	4.00	“	1.18	2.36	3.54	4.72	5.90	7.08						
181	453	“	0.312	“	0.238	“	“	1.29	2.58	3.87	5.16	6.45	7.74						
182	405	“	0.259	“	“	“	“	1.43	2.86	4.29	5.72	7.15	8.58						

Length of Pole, 27 feet. End of Pole 6 feet in ground.

Number.	Weight.	BUTT. 14′-9″ O. D.	BUTT. 14′-9″ THICK.	MIDDLE. 8′-6″ O. D.	MIDDLE. 8′-6″ THICK.	END. 6′-9″ O. D.	END. 6′-9″ THICK.	TABLE OF DEFLECTIONS MEASURED AT FREE END. TOP LINE GIVES LOADS IN POUNDS APPLIED 18" FROM END. 1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200
183	1345	9.625	0.625	8.00	0.437	7.00	0.312	1.44	1.73	2.02	2.30	2.59	2.88	3.18	3.46	3.74	4.04	4.32	4.60
184	1223	"	0.562	"	0.406	"	0.281	1.55	1.86	2.17	2.48	2.79	3.10	3.41	3.72	4.03	4.34	4.65	4.96
185	1136	"	0.500	"	"	"	"	1.66	1.99	2.32	2.66	2.99	3.32	3.65	3.98	4.32	4.64		
186	986	"	0.437	8.625	0.312	7.625	0.220	1.80	2.16	2.52	2.88	3.24	3.60	3.96	4.32	4.68			3400
187	921	"	0.406	"	0.281	"	"	1.92	2.30	2.69	3.07	3.44	3.84	4.22					4.90
188	873	"	0.375	8.00	0.312	7.00	0.218	2.09	2.51	2.93	3.34	3.76	4.18	4.60					
189	790	"	0.312	8.625	0.381	7.625	0.220	2.33	2.88	3.26	3.73	4.19							
190	837	9.00	0.375	8.00	0.300	7.00	"	2.44	2.93	3.42	3.90	4.39							
191	729	"	0.312	"	0.281	"	"	2.78	3.34	3.89	4.45								

Length of Pole, 27 feet. End of Pole 6 feet in ground.

Number.	Weight.	BUTT. 14′–9″ O. D.	BUTT. 14′–9″ THICK.	MIDDLE. 8′–6″ O. D.	MIDDLE. 8′–6″ THICK.	END. 6′–9″ O. D.	END. 6′–9″ THICK.	TABLE OF DEFLECTIONS MEASURED AT FREE END. TOP LINE GIVES LOADS IN POUNDS APPLIED 18″ FROM END. 100	200	300	400	500	600	700	800	1000	1200	1400	1600
192	815	8.625	0.406	7.625	0.281	6.625	0.220	0.272	0.544	0.816	1.09	1.36	1.63	1.90	2.18	2.72	3.26	3.80	4.36
193	738	"	0.343	"	"	"	"	0.300	0.600	0.900	1.20	1.50	1.80	2.10	2.40	3.00	3.60	4.20	4.80
194	659	"	0.281	"	"	"	"	0.344	0.688	1.03	1.38	1.72	2.06	2.41	2.76	3.44	4.12	4.82	
195	725	8.00	0.375	6.625	0.343	5.62	0.203	0.369	0.738	1.11	1.48	1.85	2.21	2.58	2.96	3.69			
196	654	"	0.343	"	0.281	"	"	0.409	0.818	1.23	1.64	2.05	2.45	2.86	3.27	4.09			
197	607	"	0.281	7.00	"	6.00	0.220	0.441	0.882	1.32	1.76	2.21	2.65	3.09	3.53	4.41			1800
198	614	7.625	0.343	6.625	0.259	5.00	0.203	0.469	0.938	1.41	1.88	2.35	2.82	3.28	3.76	4.69			
199	551	"	0.281	"	"	5.562	"	0.522	1.04	1.57	2.09	2.61	3.14	3.65	4.18	5.22			4.89
200	530	"	"	6.00	"	5.00	"	0.588	1.18	1.76	2.35	2.94	3.53	4.12	4.70				
201	573	7.00	0.343	5.562	0.312	4.50	"	0.638	1.28	1.91	2.56	3.19	3.82	4.47	5.16				
202	504	"	0.281	6.00	0.259	5.00	"	0.688	1.38	2.06	2.75	3.44	4.12	4.82	5.50				
203	485	"	"	5.562	"	4.50	"	0.750	1.50	2.25	3.00	3.75	4.50	5.25					
204	474	6.625	0.300	"	0.238	"	"	0.825	1.65	2.48	3.30	4.13	4.95	5.78					
205	436	"	0.259	"	"	"	"	0.900	1.80	2.70	3.60	4.50	5.40	6.30					
206	483	6.00	0.343	5.00	0.281	4.00	"	1.01	2.02	3.04	4.05	5.06	6.08						
207	489	"	0.312	"	0.238	"	"	1.11	2.22	3.34	4.45	5.56	6.67						
208	393	"	0.259	"	"	"	"	1.25	2.50	3.75	5.00	6.25	7.50						

Length of Pole, 26 feet. End of Pole 6 feet in ground.

Number.	Weight.	BUTT. 14′–4″ O. D.	BUTT. 14′–4″ THICK.	MIDDLE. 8′–2″ O. D.	MIDDLE. 8′–2″ THICK.	END. 6′–6″ O. D.	END. 6′–6″ THICK.	TABLE OF DEFLECTIONS MEASURED AT FREE END. TOP LINE GIVES LOADS IN POUNDS APPLIED 18″ FROM END. 1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3300
209	1297	9.625	0.625	8.00	0.437	7.00	0.312	1.23	1.48	1.72	1.97	2.21	2.46	2.71	2.96	3.20	3.44	3.69	4.06
210	1183	"	0.562	"	0.406	"	0.281	1 33	1.60	1.86	2.13	2.39	2.66	2.93	3.20	3.46	3.72	3.99	4.39
211	1100	"	0.500	"	"	"	"	1.42	1.70	1.99	2.27	2.56	2.84	3.12	3.40	3.69	3.98	4.26	
212	954	"	0.437	8.625	0.312	7.625	0.220	1.53	1.84	2.14	2.45	2.75	3.06	3.37	3.68	3.98			3600
213	891	"	0.406	"	0.281	"	"	1.64	1.97	2.30	2.62	2.95	3.28	3.61	3.94				4.44
214	845	"	0.375	8.00	0.312	7.00	0.218	1.80	2.16	2.52	2.88	3.24	3.60	3.96					
215	764	"	0.312	8.625	0.281	7.625	0.220	1.94	2.23	2.72	3.10	3.49	3.88						
216	810	9.00	0.375	8.00	0.300	7.00	"	2.10	2.52	2.94	3.36	3.78	4.20						
217	705	"	0.312	"	0.281	"	"	2.39	2.87	3.35	3.82	4.30	4.78						

Length of Pole, 26 feet. End of Pole 6 feet in ground.

Number.	Weight.	BUTT. 14′–4′ O. D.	BUTT. 14′–4′ THICK.	MIDDLE. 8′–2″ O D.	MIDDLE. 8′–2″ THICK.	END. 6′–6″ O. D.	END. 6′–6″ THICK.	TABLE OF DEFLECTIONS MEASURED AT FREE END. TOP LINE GIVES LOADS IN POUNDS APPLIED 18″ FROM END. 100	200	300	400	500	600	800	1000	1200	1400	1600	1800
218	789	8.625	0.406	7.625	0.281	6.625	0.220	0.234	0.468	0.702	0.936	1.17	1.40	1.87	2.34	2.80	3.28	3.74	4.21
219	715	"	0.343	"	"	"	"	0.259	0.518	0.777	1.03	1.29	1.54	2.06	2.59	3.10	3.63	4.12	4.66
220	638	"	0.281	"	"	"	"	0.295	0.590	0.885	1.18	1.48	1.77	2.36	2.95	3.54	4.13	4.72	
221	702	8.00	0.375	6.625	0.343	5.562	0.203	0.318	0.636	0.954	1.27	1.59	1.91	2.54	3.18	3.82	4.45		
222	633	"	0.343	"	0.281	"	"	0.351	0.702	1.05	1.40	1.76	2.10	2.80	3.51	4.20			
223	587	"	0.281	7.00	"	6.00	0.220	0.376	0.752	1.13	1.50	1.88	2.26	3.00	3.76	4.52			2000
224	594	7.625	0.343	6.625	0.259	5.00	0.203	0.401	0.802	1.20	1.60	2.00	2.40	3.20	4.01	4.81			
225	533	"	0.281	"	"	5.562	"	0.448	0.896	1.34	1.79	2.24	2.68	3.58	4.48				4.68
226	513	"	"	6.00	"	5.00	"	0.490	0.980	1.47	1.96	2.45	2.94	3.92	4.90				
227	554	7.00	0.343	5.562	0.312	4.50	"	0.546	1.09	1.64	2.18	2.73	3.28	4.36	5.46				
228	487	"	0.281	6.00	0.259	5.00	"	0.593	1.19	1.78	2.38	2.97	3.56	4.76	5.93				
229	469	"	"	5.562	"	4.50	"	0.641	1.28	1.92	2.56	3.21	3.84	5.12					
230	458	6.625	0.300	"	0.238	"	"	0.709	1.42	2.13	2.84	3.55	4.26	5.68					
231	422	"	0.259	"	"	"	"	0.772	1.54	2.32	3.09	3.86	4.64	6.18					
232	468	6.00	0.343	5.00	0.281	4.00	"	0.869	1.74	2.61	3.48	4.55	5.22						
233	425	"	0.312	"	0.238	"	"	0.952	1.90	2.86	3.80	4.76	5.72						
234	380	"	0.259	"	"	"	"	1.06	2.12	3.18	4.24	5.30	6.36						

Length of Pole, 25 feet. End of Pole 6 feet in ground.

Number.	Weight.	BUTT. 13′-11″ O. D.	BUTT. 13′-11″ THICK.	MIDDLE. 7′-10″ O. D.	MIDDLE. 7′-10″ THICK.	END. 6′-3″ O. D.	END. 6′-3″ THICK.	TABLE OF DEFLECTIONS MEASURED AT FREE END. TOP LINE GIVES LOADS IN POUNDS APPLIED 18″ FROM END. 1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3400
235	1255	9.625	0.625	8.00	0.437	7.00	0.312	1.05	1.26	1.47	1.68	1.89	2.10	2.31	2.52	2.73	2.94	3.15	3.67
236	1144	"	0.562	"	0.406	"	0.281	1.13	1.36	1.58	1.81	2.03	2.26	2.49	2.72	2.94	3.16	3.39	3.84
237	1063	"	0.500	"	"	"	"	1.18	1.42	1.67	1.90	2.14	2.38	2.62	2.84	3.09	3.34	3.57	
238	923	"	0.437	8.625	0.312	7.625	0.220	1.30	1.56	1.82	2.08	2.34	2.60	2.86	3.12	3.38	3.64		3800
239	862	"	0.406	"	0.281	"	"	1.41	1.69	1.97	2.26	2.54	2.82	3.10	3.38	3.67			3.99
240	817	"	0.375	8.00	0.312	7.00	0.218	1.53	1.84	2.14	2.45	2.75	3.06	3.37	3.68				
241	738	"	0.312	8.625	0.281	7.625	0.220	1.63	1.95	2.28	2.61	2.93	3.26	3.59					
242	783	9.00	0.375	8.00	0.300	7.00	"	1.78	2.14	2.49	2.85	3.20	3.56	3.92					
243	682	"	0.312	"	0.281	"	"	2.02	2.42	2.83	3.23	3.64	4.04						

Length of Pole, 25 feet. End of Pole 6 feet in ground.

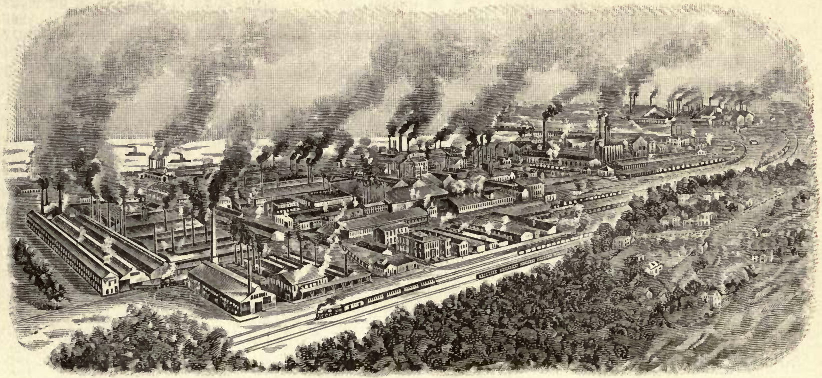
Number.	Weight.	BUTT. 13′–11″ O. D.	BUTT. Thick.	MIDDLE. 7′–10″ O. D.	MIDDLE. Thick.	END. 6′–3″ O. D.	END. Thick.	Table of Deflections Measured at Free End. Top Line Gives Loads in Pounds Applied 18″ from End. 100	200	300	400	500	600	800	1000	1200	1400	1600	1800
244	763	8.625	0.406	7.625	0.281	6.625	0.220	0.197	0.394	0.591	0.788	0.985	1.18	1.58	1.97	2.36	2.76	3.16	3.55
245	691	"	0.343	"	"	"	"	0 222	0.444	0.666	0.888	1.11	1.33	1.77	2.22	2.66	3.11	3.54	4.00
246	616	"	0.281	"	"	"	"	0 253	0.506	0.759	1.01	1.27	1.52	2.02	2.53	3.04	3.54	4.04	
247	678	8.00	0.375	6.625	0.343	5.562	0.203	0.272	0.544	0.816	1.09	1.36	1.63	2.18	2.72	3.26	3.81		
248	618	"	0.343	"	0.281	"	"	0.300	0.600	0.900	1.20	1.50	1.80	2.40	3.00	3.60			
249	567	"	0.281	7.00	"	6.00	0.220	0.322	0.644	0.966	1.29	1.61	1.93	2.57	3.22	3.86			2000
250	574	7.625	0.343	6.625	0.259	5.00	0.203	0.344	0.688	1.03	1.37	1.72	2.06	2 74	3.44	4.12			
251	515	"	0.281	"	"	5.562	"	0.384	0.768	1.15	1.54	1.92	2.30	3.06	3.84	4.60			3.94
252	493	"	"	6.00	"	5.00	"	0.419	0.838	1.26	1.68	2 10	2.52	3.36	4.19				
253	536	7.00	0.343	5.562	0.312	4.50	"	0.469	0.938	1.41	1.87	2.35	2.82	3.74	4.69				
254	471	"	0.281	6.00	0.259	5.00	"	0.506	1.01	1.52	2.02	2.53	3.04	4.05	5.06				
255	453	"	"	5.562	"	4.50	"	0.544	1.09	1.63	2.18	2.72	3.26	4.36	5.44				
256	443	6.625	0.300	"	0.238	"	"	0.600	1 20	1.80	2 40	3.00	3.60	4.80					
257	408	"	0.259	"	"	"	"	0.656	1.31	1.97	2.62	3.28	3.94	5 24					
258	452	6.00	0.343	5.00	0.281	4.00	"	0.744	1.49	2.23	2.97	3.72	4.46	5.94					
259	411	"	0.312	"	0.238	"	"	0.806	1.61	2.42	3.22	4.03	4.84	6.44					
260	367	"	0.259	"	"	"	"	0.906	1.81	2.72	3.62	4.53	5.44	7.25					

Length of Pole, 24 feet. End of Pole 6 feet in ground.

Number.	Weight.	BUTT. 13′–6″ O. D.	BUTT. 13′–6″ Thick.	MIDDLE. 7′–6″ O. D.	MIDDLE. 7′–6″ Thick.	END. 6′–0″ O. D.	END. 6′–0″ Thick.	Table of Deflections Measured at Free End. Top Line Gives Loads in Pounds Applied 18″ From End. 1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3200	3600
261	1243	9.625	0.625	8.00	0.437	7.00	0.312	0.878	1.05	1.29	1.40	1.58	1.75	1.93	2.10	2.28	2.58	2.80	3.15
262	1105	"	0.562	"	0.406	"	0.281	0.949	1.14	1.32	1.52	1.71	1.90	2.09	2.28	2.47	2.64	3.04	3.42
263	1027	"	0.500	"	"	"	"	1.02	1.22	1.43	1.63	1.84	2.04	2.24	2.45	2.65	2.86	3.26	3.68
264	891	"	0.437	8.625	0.312	7.625	0.220	1.09	1.31	1.53	1.74	1.96	2.18	2.40	2.62	2.83	3.06	3.48	
265	833	"	0.406	"	0.281	"	"	1.18	1.41	1.66	1.89	2.12	2.36	2.60	2.82	3.07	3.30		4000
266	789	"	0.375	8.00	0.312	7.00	0.218	1.29	1.55	1.81	2.06	2.32	2.58	2.84	3.10	3.35			3.51
267	712	"	0.312	8.625	0.281	7.625	0.220	1.39	1.67	1.95	2.22	2.50	2.78	3.06	3.34				3.80
268	756	9.00	0.375	8.00	0.300	7.00	"	1.51	1.81	2.11	2.42	2.79	3.02	3.32	3.62				
269	658	"	0.312	"	0.281	"	"	1.72	2.06	2.41	2.75	3.10	3.44	3.78					

Length of Pole, 24 feet. End of Pole 6 feet in ground.

Number.	Weight.	BUTT. 13′–6″ O. D.	BUTT. 13′–6″ Thick.	MIDDLE. 7′–6″ O. D.	MIDDLE. 7′–6″ Thick.	END. 6′–0″ O. D.	END. 6′–0″ Thick.	100	200	300	400	600	800	1000	1200	1400	1600	1800	2000
								Table of Deflections Measured at Free End. Top Line Gives Loads in Pounds Applied 18″ From End.											
270	737	8.625	0.406	7.625	0.281	6.625	0.220	0 168	0.336	0.504	0 672	1.01	1,34	1.68	2.02	2.35	2.69	3.02	3 36
271	677	"	0.343	"	"	"	"	0.185	0.370	0.555	0.740	1.11	1 48	1.85	2.22	2.59	2.96	3.33	3.70
272	594	"	0.281	"	"	"	"	0 212	0.424	0.636	0.848	1.27	1.70	2.12	2.54	2.97	3.39	3.82	
273	655	8.00	0.375	6.625	0.343	5.563	0.203	0·227	0.454	0.681	0.908	1.36	1 82	2.27	2.72	3.18			
274	591	"	0.343	"	0.281	"	"	0.252	0.514	0.756	1.01	1.51	2.02	2.52	3.02				
275	546	"	0.281	7.00	"	6.00	0.220	0.271	0.542	0.813	1.08	1 63	2.16	2.71	3.26				2400
276	555	7.625	0.342	6.625	0.259	5.00	0.203	0.288	0.576	0.864	1.15	1.73	2.30	2.88	3.46				
277	497	"	0.281	"	"	5.563	"	0.322	0 644	0.966	1.29	1.93	2.58	3 22	3.86				4.04
278	479	"	"	6.00	"	5.00	"	0.358	0.716	1.07	1.43	2.14	2.86	3.58					
279	517	7.00	0.343	5.562	0.312	4.50	"	0.391	0.782	1.17	1.56	2.34	3.12	3.91					
280	454	"	0.281	6.00	0.259	5.00	"	0.426	0 852	1.28	1.70	2.56	3.40	4.26					
281	438	"	"	5.562	"	4.50	"	0.460	0.920	1.38	1.84	2.76	3.68						
282	428	6.625	0.300	"	0.238	"	"	0.508	1.02	1.52	2.03	3.04	4.06						
283	395	"	0.259	"	"	"	"	0 553	1.11	1.66	2,22	3.32	4.44						
284	437	6.00	0.343	5.00	0.281	4.00	"	0.622	1.24	1.87	2.48	3.74	4 96						
285	397	"	0.312	"	0.238	"	"	0.682	1.36	2.05	2.72	4.10	5.44						
286	355	"	0.259	"	"	"	"	0.759	1.51	2.28	3 02	4.53	6.04						



NATIONAL DEPARTMENT, McKEESPORT, PENNA.

SEAMLESS
TUBULAR GOODS

SEAMLESS DRAWN TUBING.

In submitting the following information on the subject of Seamless Tubing, together with the accompanying tables, etc., we call attention to the rapid strides made in the demand and in process of manufacture of this grade of Tubes in the last few years. These Tubes are becoming generally used for high grade Boiler work, where high steam pressures are required, especially for Marine Boilers, the Navy Department of all first-class Naval powers having extensively adopted the same. In both Locomotive and Stationary Boilers the use of this Tubing is becoming recognized as a high grade quality. The extending use of compressed air and other gases under high pressures has developed a good demand for these tubes for storage tanks, high pressure bottles, transmission lines, etc. The absence of all laps or seams, together with uniformity of size, gauge and quality, recommends this grade of material as very superior where unquestioned uniformity and strength are required, in connection with the lightest weight available for the purpose.

Seamless Tubes with varying thicknesses of walls are also being used quite extensively for Mechanical and Engineering purposes; for bushings, collars, hollow shafts, spindles, axles, etc., in the construction of different classes of machinery.

Different grades of steel can be used, giving a wide range of ductility and tensile strength, which allows a selection of material suited and adaptable to the requirements demanded. The methcd of manufacture of Seamless Tubes is such that the possibilities of physical defects in material are reduced to a minimum.

Extract from Proceedings of Niagara Falls Society of American Mechanical Engineers. December, 1898.

What Constitutes a Seamless Tube?

"Henry Souther said, in the discussion of this question, that the scientific and technical designation of a tube, whether seamed or seamless, depended solely upon the tube itself, and not upon the process followed in its manufacture. Referring to the dictionary you will find that the word "seamless" means without seam, which conveys no light upon the subject. Turning to the word "seam" it is found that it is defined as a joint, suture, or line of union, and here in the last term we find the key. A tube jointed in any way cannot be seamless. If, in the primary stages of its manufacture, it be lap, butt or lock-jointed, it cannot by any subsequent operation be deprived of the seam, and therefore cannot be considered, when completed, as being seamless A strictly seamless tube may be made by any one of three operations. First, a billet may be, by successive steps, punched into the form of a tube with extremely thick sides; and these may then, by the ordinary drawing processes, be reduced to a tube with thin walls. Next, the billet may be bored, or the blank may be cast with a hole in it, and in either case then drawn to the required dimensions. Thirdly, the tube may be made by the cupping process, which consists in taking a disk of the metal, forming it into a cup shape, gradually elongating the cup and reducing it in diameter, and finally by this means producing a tube. Each and all of these processes yield a tube which is absolutely seamless and about which there is and can be no dispute. In all tubes formed with a seam the edges have first been separated, then united, either by lap or butt weld, or by some lock-joint system, and in these the joint cannot be eliminated by any after processes. The Custom House of the United States recognizes the difference between a seam and a seamless tube. *A seamless tube is one in which the walls have never been separated from the time the metal was in a molten condition to the time of the completion of the tube.*"

COLD DRAWN TUBES.

The Weight Sheet for Seamless Cold Drawn Tubes, as given on following page, is applicable for Tubes intended for many different purposes. The sizes from 3/8 inch to 1½ inch diameter and from 16 to 23 gauge inclusive are generally classified as Bicycle Tubing, on account of their very general use in Bicycle construction. They are used, however, for many other different purposes. These Tubes are manufactured from Open Hearth Steel of analysis best suited for the purpose. They have a fine finish and are drawn accurate to size and gauge. These tubes are admirably adapted for all construction requiring a maximum strength and minimum weight. They have great rigidity and are suited for high transverse strains.

Tubes for boiler purposes, from 1 inch to 4 inches, and and from 13 to 6 gauge inclusive, are made of mild Open Hearth Steel, of analysis best suited to give toughness and ductility. The process of manufacture is such that only material free from laps, seams, cracks and all physical imperfections can be used. This insures a high uniformity of quality and reduces the possibility of accident, due to imperfections of material, laps and welds, to a minimum.

Tubes of thicknesses other than those given above are generally termed "Mechanical Tubes," and are used in the construction of many classes of machinery for bushings, hollow shafts and spindles, axles, collars, rings, ferrules, pump barrels, etc., etc. Often a considerable saving in machine work is effected by the use of these tubes in place of parts heretofore made by boring and turning round bars, the tubes admitting of a lighter and stronger construction than by using the former material.

Weight Table in Pounds per Foot of Seamless Cold Drawn Tubing for Locomotive, Marine and Stationary Boilers and for Mechanical and Engineering Purposes.

B'g'm Wire Gauge (Stubbs)	Equivalent in Fraction of Inch.	Outside Diameter in Inches.																			
		3/8	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	1 3/4	2	2 1/4	2 1/2	2 3/4	3	3 1/4	3 1/2	3 3/4	4
23	.025	.0926	.1260	.1587	.1921	.2248	.2581	.2908	.3242												
22	.028	.1029	.1402	.1769	.2140	.2511	.2881	.3252	.3623	.3993	.4364										
21	.032	.1162	.1587	.2009	.2423	.2854	.3279	.3703	.4128	.4550	.4971										
20	.035	.1260	.1725	.2187	.2649	.3111	.3575	.4041	.4502	.4964	.5426	.574	.675	.740							
19	.042	.1481	.2039	.2591	.3148	.3703	.4260	.4816	.5372	.5928	.6481	.688	.788	.888							
18	.049	.1691	.2342	.2989	.3636	.4283	.4934	.5581	.6231	.6878	.7660	.852	.977	1.102	1.227						
17	.058	.1946	.2716	.3481	.4250	.5014	.5783	.6604	.7320	.8098	.8853	1.009	1.156	1.304	1.452						
16	.065	.2134	.2996	.3855	.4715	.5574	.6433	.7293	.8218	.9008	.9874	1.18	1.32	1.53	1.71						
15	.072	.2310	.3265	.4216	.5170	.6120	.7074	.8061	.8981	.9932	1.0882	1.31	1.47	1.66	1.84						
14	.083	.....	.....	.....	.5860	.6959	.8059	.9156	.9918	1.135	1.245	1.49	1.70	1.91	2.12						
13	.095	.....	.....	.....	.6588	.7846	.9102	1.039	1.162	1.290	1.413	1.690	1.920	2.170	2.420	2.70	2.94	3.19	3.42		
12	.109	.....	.....	.....	.7397	.884	1.028	1.172	1.317	1.461	1.605	1.92	2.19	2.52	2.73	3.08	3.35	3.68	3.91		
11	.120	.....	.....	.....	.8004	.9591	1.118	1.277	1.436	1.594	1.753	2.10	2.41	2.72	3.04	3.38	3.70	4.03	4.32	4.63	
10	.134	.....	.....	.....	.8739	1.051	1.229	1.406	1.583	1.797	1.938	2.29	2.69	3.05	3.41	3.74	4.14	4.44	4.83	5.20	5.62
9	.148	.....	.....	.....	.9570	1.156	1.35	1.55	1.75	1.95	2.16	2.55	2.95	3.34	3.72	4.14	4.52	4.92	5.28	5.69	6.09
8	.165	.....	.....	.....	1.036	1.258	1.48	1.70	1.92	2.14	2.34	2.81	3.25	3.70	4.11	4.56	5.01	5.43	5.86	6.31	6.78
7	.180	.....	.....	.....	1.102	1.344	1.58	1.83	2.07	2.31	2.55	3.04	3.52	4.00	4.48	4.97	5.44	5.91	6.38	6.85	7.39
6	.203	.....	.....	.....	.....	.....	1.74	2.01	2.28	2.56	2.82	3.37	3.92	4.46	5.02	5.52	6.09	6.59	7.19	7.63	8.33
	1/4"	.....	.....	.....	.....	.....	2.002	2.336	2.670	3.004	3.338	4.005	4.67	5.34	6.00	6.67	7.34	8.00	8.67	9.35	10.02
	5/16"	.....	.....	.....	.....	.....	.....	.....	3.129	3.546	3.963	4.798	5.63	6.46	7.29	8.13	8.96	9.79	10.64	11.47	12.30
	3/8"	.....	.....	.....	.....	.....	.....	.....	.....	4.005	4.597	5.507	6.51	7.51	8.51	9.51	10.52	11.52	12.52	13.52	14.53
	7/16"	.....	.....	.....	.....	.....	.....	.....	.....	.....	4.965	6.133	7.30	8.47	9.64	10.81	11.98	13.15	14.32	15.49	16.65
	1/2"	.....	.....	.....	.....	.....	.....	.....	.....	.....	5.340	6.675	8.01	9.35	10.68	12.02	13.36	14.69	16.03	17.36	18.70

Table showing Weight per Foot in Pounds of Various Diameters and Thicknesses of

HOT FINISHED TUBES.

Outside Diameter.	THICKNESS OF WALL.									
	¼	5/16	⅜	7/16	½	9/16	⅝	¾	⅞	1
2	4.60	5.54	6.40	7.18	7.88					
⅛	4.93	5.96	6.90	7.76	8.54					
¼	5.26	6.37	7.40	8.34	9.20					
⅜	5.59	6.78	7.89	8.92	9.86					
½	5.92	7.19	8.38	9.49	10.52					
⅝	6.25	7.61	8.88	10.07	11.18					
¾	6.58	8.02	9.38	10.65	11.84					
⅞	6.91	8.43	9.87	11.23	12.50					
3	7.24	8.84	10.36	11.80	13.16	14.43	15.62			
⅛	7.57	9.26	10.86	12.38	13.82	15.18	16.45			
¼	7.90	9.67	11.36	12.96	14.48	15.92	17.28			
⅜	8.23	10.08	11.85	13.54	15.14	16.66	18.10			
½	8.56	10.49	12 36	14.11	15.80	17.40	18.92			
⅝	8.89	10.91	12.84	14.69	16.46	18.15	19.75			
¾	9.22	11.32	13.34	15.27	17.12	18.89	20.58			
⅞	9.55	11.73	13.83	15.85	17.78	19.63	21.40			
4	9.88	12.14	14.32	16.42	18.44	20.37	22.22	25.68	28.80	
⅛	10.21	12.56	14.82	17.00	19.10	21.12	23.05	26.67	29.96	
¼	10.54	12.97	15.32	17.58	19.76	21.86	23.88	27.66	31.12	
⅜	10.87	13.38	15.81	18.16	20.42	22.60	24.70	28.65	32.27	
½	11.20	13.79	16.30	18.73	21.08	23.34	25.52	29.64	33.42	
⅝	11.53	14.21	16.80	19.31	21.74	24.09	26.35	30.63	34.58	
¾	11.86	14.62	17.30	19.89	22.40	24.83	27.18	31.62	35.74	
⅞	12.19	15.03	17.79	20.47	23.06	25.57	28.00	32.61	36.89	
5	12.52	15.44	18.28	21.04	23.74	26.31	28.82	33.60	38.04	42.16
⅛	12.85	15.86	18.78	21.62	24.40	27.06	29.65	34.59	39.20	43.48
¼	13.18	16.27	19.28	22.20	25.06	27.80	30.48	35.58	40.36	44.80
⅜	13.51	16.68	19.77	22.78	25.72	28.54	31.30	36.57	41 51	46.12
½	13.85	17.10	20.27	23.36	26.39	29.29	32.13	37.57	42.67	47.45
⅝	14.18	17.52	20.77	23.94	27.05	30.04	32.96	38.56	43.83	48.77
¾	14.51	17.93	21.27	24.52	27.71	30.78	33.79	39.55	44.99	50.09
⅞	14.85	18.35	21.77	25.11	28.38	31.53	34.62	40.55	46.15	51.42
6	15.18	18.77	22.27	25.69	29.05	32.28	35.45	41.55	47.31	52.75
⅛	15.51	19.18	22.77	26.27	29.71	33.03	36.28	42.54	48.47	54.07
¼	15.84	19.59	23.26	26.85	30.37	33.77	37.11	43.53	49.63	55.39
⅜	16.17	20.01	23.76	27.43	31 04	34.52	37.94	44.53	50.79	56.72
½	16.50	20.42	24.26	28.01	31.70	35.27	38.77	45.53	51.95	58.05
⅝	16.83	20.83	24.75	28.59	32.36	36.01	39.60	46.52	53.11	59.37
¾	17.17	21.25	25.25	29.17	33.01	36.76	40.43	47.52	54.28	60.70
⅞	17.50	21.67	25.75	29.75	33.67	37.51	41.26	48.52	55.44	62.03

Table showing Weight per Foot in Pounds of Various Diameters and Thicknesses of

HOT FINISHED TUBES.

(CONTINUED.)

Outside Diameter.	THICKNESS OF WALL.									
	¼	5/16	⅜	7/16	½	9/16	⅝	¾	⅞	1
7	17.83	22.08	26.25	30.33	34.33	38.25	42.09	49.51	56.60	63.36
⅛	18.17	22.50	26.75	30.92	35.00	38 99	42.92	50.51	57.79	64.69
¼	18.50	22.92	27.25	31.49	35.67	39.74	43.75	51.51	58.95	66.02
⅜	18.83	23.33	27.75	32.07	36.33	40.49	44.58	52.50	60.11	67.35
½	19.16	23.74	28.24	32.66	36.99	41.23	45.41	53.49	61.27	68.67
⅝	19.49	24.16	28.74	33.24	37.66	41.98	46.24	54.49	62.43	70.00
¾	19.82	24.57	29.24	33.82	38.32	42.73	47.07	55.49	63.57	71.33
⅞	20.15	24.98	29.73	34.40	38.98	43.47	47.90	56.48	64.73	72.65
8	20.48	25.39	30.22	34.97	39.64	44.21	48.72	57.47	65.89	73.97
⅛	20.80	25.80	30.71	35.54	40.29	44.95	49.54	58.46	67.04	75.29
¼	21.12	26.20	31.20	36.11	40.94	45.68	50.36	59.44	68.19	76.61
⅜	21.44	26.61	31.68	36.68	41.59	46.41	51.17	60.42	69.34	77.92
½	21.77	27.02	32.17	37.25	42.25	47.15	51.99	61.41	70.49	79.24
⅝	22.10	27.44	32.66	37.82	42.90	47.89	52.81	62.39	71.64	80.56
¾	22.43	27.85	33.15	38.39	43.55	48.62	53.63	63.37	72.79	81.87
⅞	22.76	28.26	33.64	38.96	44.20	49.36	54.44	64.35	73.93	83.18
9	23.08	28.67	34.13	39.53	44.85	50.09	55.25	65.33	75.07	84.49
⅛	23.41	29.08	34.63	40.11	45.51	50.83	56.07	66.31	76 22	85.80
¼	23.74	29.48	35.12	40.69	46.17	51.57	56.89	67.29	77.37	87.11
⅜	24.07	29.88	35.61	41.26	46.83	52.31	57.71	68.27	78.51	88.42
½	24.40	30.29	36.10	41.83	47.48	53.05	58.53	69.25	79.65	89.73
⅝	24·73	30.71	36.60	42.41	48.14	53.79	59.36	70.24	80.80	91.04
¾	25.06	31.12	37.10	42.99	48.80	54.53	60.18	71.23	81.95	92.35
⅞	25.39	31.53	37.59	43.57	49.46	55.27	61.00	72.22	83.10	93.66
10	25.72	31.94	38.08	44.14	50.12	56.01	61.82	73.20	84.25	94.97
⅛	26.04	32.35	38.57	44.71	50.77	56.75	62.64	74.18	85.40	96.28
¼	26.36	32.75	39.06	45.28	51.42	57.48	63.46	75.16	86.54	97.59
⅜	26.68	33.15	39.54	45.85	52 07	58.21	64.27	76.14	87.68	98 90
½	27.01	33.56	40.03	46.42	52.73	58.95	65.09	77.13	88.83	100.21
⅝	27.34	33.97	40.52	46.99	53.37	59.69	65.91	78.11	89.98	101.52
¾	27.67	34.38	41.01	47.56	54.02	60.42	66.73	79.09	91.13	102.83
⅞	28.00	34.79	41.50	48.13	54.68	61.15	67.54	80.07	92.27	104.14
11	28.32	35.20	41.99	48.70	55.33	61.88	68.35	81.05	93.41	105.45
⅛	28.65	35.61	42.49	49.28	55.99	62.62	69.17	82 03	94.56	106.76
¼	28.98	36.02	42.98	49.87	56.65	63.36	69.99	83.01	95.71	108.07
⅜	29.31	36.43	43.47	50.44	57.31	64.10	70.81	83.99	96.85	109.38
½	29.64	36.84	43.96	51.01	57.96	64.84	71.63	84.97	97.99	110.69
⅝	29.97	37.26	44.46	51.59	58.60	65.58	72.46	85.96	99.14	112.00
¾	30.30	37.67	44.96	52.17	59.26	66.32	73.28	86.95	100.29	113.31
⅞	30.63	38.08	45.45	52.74	59.92	67.06	74.10	87.94	101.44	114.62

Table showing Weight per Foot in Pounds of Various Diameters and Thicknesses of

HOT FINISHED TUBES.

(CONTINUED.)

Outside Diameter.	Thickness of Wall.									
	¼	5/16	⅜	7/16	½	9/16	⅝	¾	⅞	1
12	30.96	38.49	45.94	53.31	60.58	67.80	74.92	88.92	102.59	115.93
⅛	31.28	38.90	46.43	53.88	61.23	68.54	75.74	89.90	103.73	117.24
¼	31.60	39.30	46.92	54.45	61.88	69.27	76.56	90.88	104.87	118.55
⅜	31.92	39.70	47.40	55.02	62.53	70.00	77.37	91.86	106.01	119.86
½	32.25	40.11	47.89	55.59	63.19	70.74	78.19	92.85	107.16	121.17
⅝	32.58	40.52	48 38	56 16	63.84	71.48	79.01	93.83	108.31	122.48
¾	32.92	40.94	48.88	56.74	64.50	72.22	79.84	94.82	109.47	123.80
⅞	33.26	41.36	49.38	57.32	65.16	72.96	80.66	95.81	110.62	125.12
13	33.60	41.79	49.89	57.91	65.83	73.71	81.49	96.81	111.78	126.45
⅛	33.94	42.21	50.40	58.50	66.50	74.46	82.32	97.80	112.94	127.77
¼	34.28	42.64	50.91	59.10	67.18	75.22	83.16	98.80	114.11	129.10
⅜	34.62	43.06	51.42	59.69	67.86	75.98	84.00	99.80	115.28	130.43
½	34.96	43.49	51.93	60.29	68.54	76.75	84.85	100.81	116.45	131.77
⅝	35.28	43.89	52.42	60.86	69.20	77.49	85.68	101.80	117.60	133.08
¾	35.59	44.29	52.90	61.43	69.85	78.23	86.50	102.79	118.75	134.39
⅞	35.90	44.68	53.38	61.99	70.50	78.96	87.32	103.78	119.90	135.70
14	36.20	45.07	53.85	62.55	71.14	79.69	88.13	104.76	121.05	137.01
⅛	36.52	45.45	54.32	63.10	71.78	80.41	88.94	105.74	122.20	138.32
¼	36.85	45.86	54.79	63.66	72.42	81.14	89.75	106.72	123.35	139.64
⅜	37.19	46.28	55.29	64.22	73.07	81.87	90.57	107.71	124.51	140.97
½	37.54	46.71	55.80	64.81	73.72	82.61	91.39	108.70	125.67	142.30
⅝	37.90	47.15	56.32	65.41	74.40	83.35	92.22	109.70	126.84	143.64
¾	38.25	47.59	56.84	66.01	75.08	84.11	93.04	110.69	128.00	144.97
⅞	38.60	48.03	57.37	66.62	75.77	84.88	93.89	111.69	129.17	146.31
15	38.94	48.46	57.89	67.23	76.46	85.65	94.74	112.68	130.33	147.64
⅛	39 27	48.88	58.40	67.83	77.15	86.42	95.59	113.69	131.49	148.97
¼	39.60	49.29	58.90	68.42	77.83	87.19	96.44	114.70	132.64	150.29
⅜	39.92	49.70	59.39	69.00	78.50	87.95	97.29	115.71	133.81	151.61
½	40.24	50.10	59.88	69.57	79.16	88.70	98.13	116.72	134.98	152.92
⅝	40.56	50.50	60.36	70.14	79.81	89.44	98.96	117.73	136.15	154.25
¾	40.88	50.90	60.84	70.70	80.46	90 17	99.78	118.73	137.32	155.58
⅞	41.20	51.30	61.32	71.26	81.12	90.90	100.59	119.72	138.49	156.91
16	41.52	51.70	61.80	71.82	81.76	91.62	101.40	120.70	139.65	158.24
⅛	41.84	52.10	62.28	72.38	82.40	92.34	102.20	121.67	140.80	159.57
¼	42.14	52.48	62.74	72.92	83.02	93.04	102.98	122.62	141.92	160.87
⅜	42.45	52.87	63.21	73.47	83.65	93.75	103.77	123.57	143.04	162.17
½	42 76	53.26	63.68	74.02	84.28	94.45	104.56	124.52	144.16	163.46
⅝	43.13	53.71	64.21	74.63	84.97	95.23	105.41	125.53	145.33	164.80
¾	43.47	54.11	64.69	75.19	85.61	95.95	106.21	126.49	146.45	166.09
⅞	43.82	54.55	65.19	75.77	86.27	96.69	107.03	127.47	147.59	167.39
17	44.19	55.00	65.73	76.37	86.95	97.45	107.87	128.47	148.75	168.71

Table Showing Weight Per Foot in Lbs. of Various Diameters and Gauges of

COLD-DRAWN TUBES.

B. W. G.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Decimal of 1 Inch.	.34	.3	.284	.259	.238	.220	.203	.180	.165	.148	.134	.120	.109	.095	.083	.072	.065	.058	.049
Nearest Fraction of 1 Inch.	11/32	19/64	9/32	17/64	15/64	7/32	13/64	3/16	11/64	9/64	17/128	1/8	7/64	3/32	11/128	5/64	1/16	7/128	3/64
Outside Diam.																			
1	2.38	2.22	2.14	2.00	1.91	1.81	1.70	1.55	1.44	1.33	1.23	1.12	1.03	0.90	0.80	0.71	0.64	0.57	0.49
1/8	2.82	2.61	2.51	2.34	2.23	2.10	1.97	1.79	1.66	1.53	1.41	1.27	1.17	1.03	0.91	0.80	0.72	0.64	0.55
1/4	3.27	3.01	2.88	2.68	2.54	2.38	2.23	2.02	1.87	1.72	1.58	1.42	1.31	1.15	1.02	0.90	0.81	0.72	0.61
3/8	3.72	3.40	3.26	3.02	2.85	2.66	2.49	2.25	2.08	1.91	1.75	1.57	1.45	1.27	1.13	0.99	0.89	0.79	0.68
1/2	4.17	3.80	3.63	3.36	3.16	2.96	2.76	2.49	2.30	2.10	1.93	1.73	1.59	1.40	1.24	1.09	0.98	0.87	0.74
5/8	4.62	4.19	4.00	3.70	3.48	3.25	3.03	2.72	2.51	2.30	2.10	1.89	1.73	1.52	1.35	1.18	1.06	0.95	0.81
3/4	5.07	4.59	4.38	4.04	3.79	3.54	3.29	2.96	2.73	2.49	2.28	2.05	1.88	1.65	1.46	1.28	1.15	1.02	0.87
7/8	5.52	4.98	4.75	4.38	4.11	3.84	3.56	3.20	2.95	2.69	2.46	2.21	2.02	1.77	1.57	1.37	1.24	1.10	0.94
2	5.97	5.38	5.12	4.72	4.42	3.13	3.83	3.43	3.16	2.88	2.63	2.36	2.16	1.90	1.68	1.47	1.32	1.18	1.00
1/8	6.42	5.77	5.50	5.06	4.74	4.41	4.09	3.67	3.38	3.08	2.81	2.52	2.31	2.02	1.79	1.56	1.41	1.25	1.07
1/4	6.87	6.17	5.87	5.40	5.05	4.70	4.36	3.91	3.60	3.27	2.98	2.68	2.45	2.15	1.90	1.66	1.49	1.33	1.13
3/8	7.31	6.56	6.24	5.74	5.36	4.99	4.63	4.14	3.81	3.46	3.16	2.84	2.59	2.27	2.01	1.75	1.58	1.40	1.20
1/2	7.76	6.96	6.62	6.08	5.69	5.28	4.89	4.38	4.03	3.66	3.34	3.00	2.74	2.40	2.12	1.85	1.66	1.48	1.26
5/8	8.21	7.35	6.99	6.42	6.00	5.57	5.16	4.62	4.25	3.85	3.51	3.15	2.88	2.52	2.23	1.94	1.75	1.56	1.33
3/4	8.66	7.74	7.36	6.76	6.32	5.86	5.43	4.85	4.46	4.05	3.69	3.31	3.02	2.65	2.34	2.04	1.84	1.63	1.39
7/8	9.11	8.23	7.74	7.10	6.63	6.14	5.69	5.09	4.68	4.24	3.86	3.47	3.16	2.77	2.45	2.13	1.92	1.71	1.46
3	9.56	8.63	8.11	7.44	6.95	6.43	5.96	5.32	4.90	4.44	4.04	3.63	3.31	2.90	2.56	2.23	2.01	1.79	1.52
1/8	10.03	9.02	8.48	7.78	7.26	6.72	6.23	5.56	5.11	4.63	4.22	3.79	3.45	3.02	2.67	2.32	2.09	1.86	1.58

Table Showing Weight Per Foot in Lbs. of Various Diameters and Gauges of COLD-DRAWN TUBES.

(CONTINUED.)

B. W. G.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Decimal of 1 Inch.	.34	.3	.284	.259	.238	.220	.203	.180	.165	.148	.134	.120	.109	.095	.083	.072	.065	.058	.049
Nearest Fraction of 1 Inch.	11/32	19/64	9/32	17/64	15/64	7/32	13/64	3/16	11/64	9/64	17/128	1/8	7/64	3/32	11/128	5/64	1/16	7/128	3/64
Outside Diam.																			
3¼	10.46	9.42	8.86	8.12	7.58	7.01	6.49	5.80	5.33	4.82	4.39	3.94	3.59	3.15	2.78	2.42	2.18	1.95	1.65
⅜	10.91	9.81	9.23	8.46	7.89	7.29	6.76	6.03	5.55	5.02	4.57	4.10	3.74	3.27	2.89	2.51	2.27	2.02	1.71
½	11.36	10.12	9.61	8.80	8.20	7.58	7.03	6.27	5.76	5.21	4.74	4.26	3.88	3.40	3.00	2.61	2.35	2.09	1.78
⅝	11.80	10.51	9.98	9.14	8.52	7.86	7.29	6.51	5.98	5.41	4.92	4.42	4.02	3.52	3.11	2.70	2.44	2.17	1.84
¾	12.25	10.91	10.35	9.48	8.83	8.16	7.56	6.74	6.20	5.60	5.10	4.58	4.17	3.65	3.22	2.80	2.52	2.24	1.91
⅞	12.70	11.30	10.73	9.82	9.15	8.45	7.83	6.98	6.41	5.80	5.27	4.73	4.31	3.77	3.33	2.89	2.61	2.32	1.97
4	13.15	11.70	11.10	10.16	9.46	8.74	8.09	7.22	6.63	5.99	5.45	4.89	4.45	3.90	3.44	2.99	2.69	2.40	2.04
⅛	13.60	12.10	11.47	10.50	9.78	9.03	8.36	7.45	6.85	6.18	5.62	5.05	4.59	4.02	3.55	3.08	2.78	2.47	2.10
¼	14.05	12.49	11.85	10.84	10.09	9.32	8.63	7.69	7.06	6.38	5.80	5.21	4.74	4.15	3.66	3.18	2.87	2.55	2.17
⅜	14.50	12.88	12.24	11.18	10.41	9.61	8.89	7.93	7.28	6.57	5.98	5.37	4.88	4.27	3.77	3.27	2.95	2.63	2.23
½	14.95	13.28	12.59	11.52	10.72	9.89	9.16	8.16	7.50	6.77	6.15	5.52	5.02	4.40	3.88	3.37	3.04	2.70	2.30
⅝	15.40	13.67	12.97	11.86	11.03	10.18	9.43	8.40	7.71	6.96	6.33	5.68	5.17	4.52	3.99	3.46	3.12	2.78	2.36
¾	15.85	14.07	13.34	12.20	11.35	10.47	9.69	8.63	7.93	7.16	6.50	5.84	5.31	4.65	4.10	3.56	3.21	2.85	2.43
⅞	16.30	14.46	13.71	12.54	11.66	10.75	9.96	8.87	8.15	7.35	6.68	6.00	5.45	4.77	4.21	3.65	3.29	2.93	2.49
5	16.75	14.86	14.09	12.88	11.99	11.05	10.23	9.11	8.36	7.54	6.86	6.16	5.60	4.90	4.32	3.75	3.38	3.01	2.56
⅛	17.20	15.25	14.46	13.22	12.30	11.35	10.49	9.34	8.58	7.74	7.03	6.31	5.74	5.02	4.43	3.84	3.47	3.08	2.62
¼	17.65	15.65	14.83	13.56	12.62	11.63	10.76	9.58	8.80	7.93	7.21	6.47	5.88	5.15	4.54	3.94	3.55	3.16	2.68
⅜	18.10	16.04	15.21	13.90	12.93	11.91	11.03	9.82	9.01	8.13	7.38	6.63	6.02	5.27	4.65	4.03	3.64	3.24	2.75

Table Showing Weight Per Foot in Lbs. of Various Diameters and Gauges of
COLD-DRAWN TUBES.
(CONTINUED.)

B. W. G.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Decimal of 1 Inch.	.34	.3	.284	.259	.238	.220	.203	.180	.165	.148	.134	.120	.109	.095	.083	.072	.065	.058	.049
Nearest Fraction of 1 Inch.	11/32	19/64	9/32	17/64	15/64	7/32	13/64	3/16	11/64	9/64	17/128	1/8	7/64	3/32	11/128	5/64	1/16	7/128	3/64
Outside Diam.																			
5 1/2	18.55	16.44	15.58	14.24	13.24	12 19	11.29	10.05	9.23	8 32	7.56	6.79	6.17	5.40	4.76	4.13	3.72	3.31	2.81
5/8	19 00	16.83	15.95	14.58	13.56	12.47	11.56	10.29	9.45	8.52	7.74	6.95	6.31	5.52	4.87	4.22	3.81	3.39	2.88
3/4	19.45	17.23	16.33	14.92	13.87	12.76	11.83	10.53	9.66	8.71	7.91	7.10	6.45	5.65	4.98	4.32	3.90	3.46	2.94
7/8	19.90	17.62	16.70	15.26	14.19	13.08	12.09	10.76	9.88	8.90	8.09	7.26	6.60	5.77	5.09	4.41	3.98	3.54	3.01
6	20.34	18.02	17.08	15.60	14.50	13.36	12.36	11.00	10.10	9.10	8.26	7.42	6.74	5.90	5.20	4.51	4.07	3.62	3.07
1/8	20.78	18.41	17.45	15.94	14.82	13.65	12.63	11.23	10.31	9.29	8.44	7.58	6.88	6.02	5.31	4.60	4.15	3.69	3.14
1/4	21.23	18.81	17 82	16.28	15.13	13.94	12.89	11.47	10.53	9.49	8.62	7 74	7.03	6.15	5.42	4.70	4.24	3.77	3.20
3/8	21 68	19.20	18.20	16.62	15.45	14.23	13.16	11.71	10.75	9.68	8.79	7.89	7.17	6.27	5.53	4 79	4.32	3.85	3.27
1/2	22.13	19 60	18.57	16.96	15.76	14.52	13.43	11.94	10.96	9.88	8.97	8.05	7.31	6.40	5.64	4.89	4.41	3.92	3.33
5/8	22.58	19.99	18.94	17.30	16.07	14.81	13.69	12.18	11.18	10.07	9.14	8.21	7.45	6.52	5.75	4.98	4.50	4.00	3.40
3/4	23.03	20.39	19.32	17.64	16.39	15.09	13.96	12.42	11.40	10.26	9.32	8.37	7.60	6.65	5.86	5.08	4.58	4.07	3.46
7/8	23.48	20.78	19.69	17.98	16.70	15.38	14.23	12.65	11.61	10.46	9.50	8.53	7.74	6.77	5.97	5.17	4.67	4 15	3.53
7	23 93	21.18	20.06	18.32	17.02	15 67	14.49	12.89	11.83	10.65	9.67	8.68	7 88	6.90	6.08	5.27	4.75	4.23	3.59
1/8	24.38	21.57	20.44	18.66	17.33	15.96	14.76	13.13	12.05	10.85	9.85	8.84	8.03	7.02	6.19	5.36	4.84	4.30	3.66
1/4	24.83	21.97	20.81	19.00	17.65	16.25	15.03	13.36	12.26	11.04	10.02	9.00	8.17	7.15	6.30	5.46	4.93	4.38	3.72
3/8	25.27	22.36	21.18	19.34	17.96	16.54	15.29	13.60	12.48	11.24	10.20	9.16	8.31	7.27	6 41	5.55	5.01	4.46	3.78
1/2	25.72	22.76	21.56	19.68	18.28	16.83	15.56	13.84	12.70	11.43	10.38	9 32	8.46	7.40	6.52	5.65	5.10	4.53	3.85
5/8	26.27	23.15	21.93	20.02	18.59	17.11	15.83	14.07	12.91	11.62	10.55	9.47	8.60	7.52	6.63	5.74	5.18	4.61	3.91

Table Showing Weight Per Foot in Lbs. of Various Diameters and Gauges of
COLD-DRAWN TUBES.
(CONTINUED.)

B. W. G.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Decimal of 1 Inch.	.34	.3	.284	.259	.238	.220	.203	.180	.165	.148	.134	.120	.109	.095	.083	.072	.065	.058	.049
Nearest Fraction of 1 Inch.	11/32	19/64	9/32	17/64	15/64	7/32	13/64	3/16	11/64	9/64	17/128	1/8	7/64	3/32	11/128	5/64	1/16	7/128	3/64
Outside Diam.																			
7¾	26.72	23.55	22.30	20.36	18.90	17.40	16.09	14.31	13.13	11.82	10.73	9.63	8.74	7.65	6.74	5.84	5.27	4.69	3.98
⅞	27.17	23.94	22.68	20.70	19.22	17.69	16.36	14.54	13.34	12.01	10.90	9.79	8.88	7.77	6.85	5.93	5.35	4.76	4.09
8	27.62	24.33	23.05	21.04	19.53	17.98	16.63	14.78	13.56	12.21	11.08	9.95	9.03	7.90	6.96	6.03	5.44	4.84	4.11
⅛	28.07	24.72	23.42	21.38	19.85	18.27	16.89	15.02	13.78	12.40	11.26	10.11	9.17	8.02	7.07	6.12	5.53	4.91	4.17
¼	28.52	25.12	23.80	21.72	20.16	18.56	17.16	15.25	13.99	12.60	11.43	10.26	9.31	8.15	7.18	6.22	5.61	4.99	4.24
⅜	28.97	25.51	24.17	22.06	20.48	18.84	17.43	15.49	14.21	12.79	11.61	10.42	9.46	8.27	7.29	6.31	5.70	5.07	4.30
½	29.32	25.91	24.55	22.40	20.79	19.14	17.69	15.73	14.43	12.98	11.78	10.58	9.60	8.40	7.40	6.41	5.78	5.14	4.37
⅝	29.76	26.31	24.92	22.74	21.10	19.43	17.96	15.96	14.64	13.18	11.96	10.74	9.74	8.52	7.51	6.50	5.87	5.22	4.43
¾	30.21	26.71	25.29	23.08	21.42	19.72	18.23	16.20	14.86	13.37	12 14	10.90	9.89	8.65	7.62	6.60	5.95	5.30	4.50
⅞	30.66	27.10	25.67	23.42	21.73	20.01	18.49	16.44	15.08	13.57	12.31	11.05	10.03	8.77	7.73	6.69	6.04	5.37	4.56
9	31.11	27.50	26.04	23.76	22.05	20 30	18.76	16.67	15 29	13.76	12.49	11.21	10.17	8.90	7.84	6.79	6.13	5.45	4.63
⅛	31.56	27.89	26.41	24.10	22.36	20.58	19.03	16.91	15.51	13.96	12.66	11.37	10.31	9.02	7.95	6.88	6.21	5.52	4.69
¼	32.01	28.29	26.79	24.44	22.68	20.87	19.29	17.14	15.73	14.15	12.84	11.53	10.46	9.15	8.06	6.98	6.30	5.60	4.76
⅜	32.46	28.68	27.16	24.78	22.99	21 16	19.56	17.38	15.94	14.34	13.02	11.69	10.60	9.26	8.17	7.07	6.38	5.68	4.82
½	32.91	29.08	27.53	25.12	23.31	21.45	19.83	17.62	16.16	14.54	13.19	11.84	10.74	9.39	8.28	7.17	6.47	5.75	4.88
⅝	33.36	29.47	27.91	25.46	23.62	21.74	20.09	17.85	16.38	14.73	13.37	12.00	10.89	9.51	8.39	7.26	6.56	5.83	4.95
¾	33.81	29.87	28.28	25.80	23 93	22.03	20.36	18.09	16.59	14.93	13.54	12.16	11.03	9.64	8.50	7.36	6.64	5.91	5.01
⅞	34.25	30.26	28.65	26.14	24.25	22.31	20.63	18.33	16.81	15.12	13.72	12.32	11.17	9.76	8.61	7.45	6.73	5.98	5.08

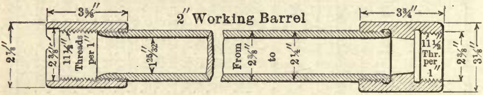
Table Showing Weight Per Foot in Lbs. of Various Diameters and Gauges of
COLD-DRAWN TUBES.
(CONTINUED.)

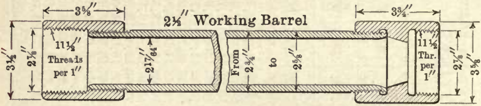
B. W. G.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Decimal of 1 Inch.	.34	.3	.284	.259	.238	.220	.203	.180	.165	.148	.134	.120	.109	.095	.083	.072	.065	.058	.049
Nearest Fraction of 1 Inch.	11/32	19/64	9/32	17/64	15/64	7/32	13/64	3/16	11/64	9/64	17/128	1/8	7/64	3/32	11/128	5/64	1/16	7/128	3/64
Outside Diam. 10	34.70	30.66	29.03	26.48	24.57	22.60	20.89	18.56	17.03	15.32	13.90	12.48	11.32	9.89	8.72	7.55	6.81	6.06	5.14
1/8	35.15	31.05	29.40	26.82	24.89	22.89	21.16	18.80	17.24	15.51	14.07	12.63	11.46	10.01	8.83	7.64	6.90	6.13	5.21
1/4	35.60	31.45	29.77	27.16	25.20	23.18	21.43	19.03	17.46	15.70	14.25	12.79	11.60	10.14	8.94	7.74	6.98	6.21	5.27
3/8	36.05	31.84	30.15	27.50	25.52	23.47	21.69	19.27	17.68	15.90	14.42	12.95	11.74	10.25	9.05	7.83	7.07	6.29	5.34
1/2	36.50	32.24	30.52	27.84	25.83	23.76	21.96	19.51	17.89	16.09	14.60	13.11	11.89	10.38	9.16	7.93	7.16	6.36	5.40
5/8	36.95	32.63	30.89	28.18	26.15	24.05	22.23	19.74	18.11	16.29	14.78	13.27	12.03	10.50	9.27	8.02	7.24	6.44	5.47
3/4	37.40	33.03	31.27	28.52	26.46	24.33	22.50	19.98	18.33	16.48	14.95	13.42	12.17	10.63	9.38	8.12	7.33	6.52	5.53
7/8	37.85	34.42	31.64	28.86	26.77	24.62	22.77	20.22	18.54	16.68	15.13	13.58	12.32	10.75	9.49	8.21	7.41	6.59	5.60
11	38.30	33.82	32.02	29.20	27.10	24.91	23.04	20.45	18.76	16.87	15.30	13.74	12.46	10.88	9.60	8.31	7.50	6.67	5.66
1/8	38.74	34.21	32.39	29.54	27.41	25.20	23.30	20.69	18.98	17.06	15.48	13.90	12.60	11.00	9.71	8.40	7.58	6.75	5.73
1/4	39.19	34.61	32.76	29.88	27.73	25.49	23.56	20.93	19.19	17.26	15.66	14.06	12.75	11.13	9.82	8.50	7.67	6.82	5.79
3/8	39.64	35.00	33.14	30.22	28.04	25.78	23.83	21.16	19.41	17.45	15.83	14.21	12.89	11.25	9.93	8.59	7.76	6.90	5.86
1/2	40.09	35.40	33.51	30.56	28.37	26.06	24.09	21.40	19.63	17.65	16.01	14.37	13.03	11.38	10.04	8.69	7.84	6.97	5.92
5/8	40.54	35.79	33.88	30.90	28.68	26.35	24.36	21.64	19.84	17.84	16.18	14.53	13.17	11.50	10.15	8.78	7.93	7.05	5.98
3/4	40.99	36.19	34.26	31.24	28.99	26.64	24.63	21.87	20.06	18.04	16.36	14.69	13.32	11.63	10.26	8.88	8.01	7.13	6.05
7/8	41.44	36.58	34.63	31.58	29.30	26.93	24.89	22.11	20.28	18.23	16.54	14.85	13.46	11.75	10.37	8.97	8.10	7.20	6.11
12	41.89	36.98	35.00	31.92	29.62	27.22	25.16	22.35	20.50	18.43	16.71	15.00	13.60	11.88	10.48	9.07	8.19	7.28	6.18

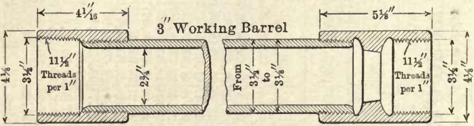
TABLE OF LENGTHS AND WEIGHTS

OF

WORKING BARRELS.







Length in Feet.	2 Inch Barrel Weight in lbs.	2½ Inch Barrel Weight in lbs.	3 Inch Barrel Weight in lbs.
5	32 to 37	37 to 43	47 to 55
6	35 " 40	43 " 49	54 " 62
7	38 " 43	49 " 55	61 " 69
8	41 " 46	55 " 61	68 " 76
9	44 " 49	61 " 67	75 " 83

ILLUSTRATIONS

OF

Standard and Special Seamless Cylinders.

5 inch Standard Seamless Cylinder.

(See Table, page 84.)

8 inch Standard Seamless Cylinder.

(See Table, page 85.)

8 inch Special Seamless Cylinder.

(See Table, page 86.)

Table of Weights and Capacities of 5 inch Standard Seamless Cylinders.

Outside Diameter, 5 9/16 inches. Thickness of Wall, 13/64 inch.

(See illustration, page 83.)

Tested to 3700 lbs. per square inch Hydrostatic Pressure.

Length over all in inches.	Average Weight in lbs.	Capacity in Cubic inches.	Capacity in Cubic feet.	Capacity in U. S. Gallons.	Capacity in lbs. Liquid Carbonic Acid Gas.
36	39.00	653	0.3779	2.83	15.
36½	39.47	663	0.3839	2.87	15.2
37	39.94	673	0.3900	2.92	15.4
37½	40.41	683	0.3961	2.96	15.6
38	40.88	694	0.4022	3.01	15.8
38½	41.35	704	0.4083	3.05	16.
39	41.82	714	0.4143	3.10	16.2
39½	42.29	725	0.4204	3.14	16.4
40	42.76	735	0.4265	3.19	16.6
40½	43.23	745	0.4326	3.23	16.8
41	43.71	756	0.4387	3.28	17.
41½	44.18	766	0.4447	3.32	17.2
42	44.65	776	0.4508	3.37	17.4
42½	45.12	786	0.4569	3.41	17.6
43	45.59	797	0.4630	3.46	17.8
43½	46.06	807	0.4691	3.50	18.
44	46.53	817	0.4751	3.55	18.2
44½	47.00	828	0.4812	3.59	18.4
45	47.47	838	0.4873	3.64	18.6
45½	47.94	848	0.4934	3.68	18.8
46	48.42	859	0.4995	3.73	19.
46½	48.89	869	0.5055	3.77	19.2
47	49.36	879	0.5116	3.81	19.4
47½	49.83	889	0.5177	3.85	19.6
48	50.30	900	0.5238	3.90	19.8
48½	50.77	910	0.5299	3.94	20.
49	51.24	920	0.5359	3.99	20.2
49½	51.71	931	0.5420	4.03	20.4
50	52.18	941	0.5481	4.08	20.6
50½	52.65	951	0.5542	4.12	20.8
51	53.13	962	0.5603	4.17	21.
51½	53.60	972	0.5663	4.21	21.2
52	54.07	982	0.5724	4.26	21.4
52½	54.54	992	0.5785	4.30	21.6
53	55.01	1003	0.5846	4.35	21.8
53½	55.48	1013	0.5907	4.39	22.
54	55.95	1023	0.5967	4.44	22.2
54½	56.42	1034	0.6028	4.48	22.4
55	56.89	1044	0.6089	4.53	22.6
55½	57.36	1054	0.6150	4.57	22.8
56	57.84	1065	0.6211	4.62	23.
56½	58.31	1075	0.6271	4.66	23.2
57	58.78	1085	0.6332	4.71	23.4
57½	59.25	1095	0.6393	4 75	23.6
58	59.72	1106	0.6454	4.80	23.8
58½	60.19	1116	0.6515	4.84	24.
59	60.66	1126	0.6575	4.89	24.2
59½	61.13	1137	0.6636	4.93	24.4
60	61.60	1147	0.6697	4.97	24.6

Table of Weights and Capacities of 8 inch Standard Seamless Cylinders.

Outside Diameter, 8 9/16 inches. Thickness of Wall, 7/32 inch.

(See illustration, page 83.)

Tested to 3700 lbs. per square inch Hydrostatic Pressure.

Length over all in inches.	Average Weight in lbs.	Capacity in Cubic inches.	Capacity in Cubic feet.	Capacity in U. S. Gallons.	Capacity in lbs. Liquid Carbonic Acid Gas.
36	69.4	1781	1.0307	7.71	37.
36½	70.25	1806	1.0454	7.82	37.5
37	71.1	1832	1.0601	7.94	38.
37½	71.95	1857	1.0783	8.05	38.5
38	72.8	1883	1.0895	8.16	39.
38½	73.65	1908	1.1042	8.27	39.5
39	74.5	1934	1.1189	8.38	40.
39½	75.35	1952	1.1336	8.49	40.5
40	76.2	1985	1.1483	8.60	41.
40½	77.05	2010	1.1630	8.71	41.5
41	77.9	2036	1.1778	8.82	42.
41½	78.75	2061	1.1925	8.93	42.5
42	79.7	2087	1.2072	9.04	43.
42½	80.55	2112	1.2219	9.15	43.5
43	81.4	2138	1.2368	9.26	44.
43½	82.25	2163	1.2515	9.37	44.5
44	83.1	2189	1.2662	9.48	45.
44½	83.95	2214	1.2809	9.59	45.5
45	84.8	2240	1.2956	9.70	46.
45½	85.65	2265	1.3103	9.81	46.5
46	86.5	2291	1.3251	9.92	47.
46½	87.35	2316	1.3398	10.03	47.5
47	88.2	2342	1.3545	10.14	48.
47½	89.05	2367	1 3692	10.25	48.5
48	89.9	2393	1.3839	10.36	49.
48½	90.75	2418	1.3966	10.47	49.5
49	91.6	2444	1.4113	10.58	50.
49½	92.45	2469	1.4260	10.69	50.5
50	93.3	2495	1.4407	10.80	51.
50½	94.1	2520	1.4554	10.91	51.5
51	95.	2546	1.4702	11.02	52.
51½	95.85	2571	1.4849	11.13	52.5
52	96.7	2597	1.4996	11.24	53.
52½	97.55	2622	1.5143	11.35	53.5
53	98.4	2648	1.5290	11.46	54.
53½	99.25	2673	1.5437	11.57	54.5
54	100.1	2699	1.5585	11.68	55.
54½	100.95	2724	1.5732	11.79	55.5
55	101.8	2750	1.5879	11.90	56.
55½	102.65	2775	1.6026	12.01	56.5
56	103.5	2801	1.6174	12.12	57.
56½	104.35	2826	1.6321	12.23	57.5
57	105.2	2852	1.6468	12.34	58.
57½	106.05	2877	1.6615	12.45	58.5
58	106.9	2903	1.6762	12.56	59.
58½	107.75	2928	1.6909	12.67	59.5
59	108.6	2954	1.7056	12.78	60.
59½	109.45	2979	1.7203	12.89	60.5
60	110.5	3005	1.7303	13.00	61.

Table of Weights and Capacities of 8 inch Special Seamless Cylinders for Holding Carbonic Gas.

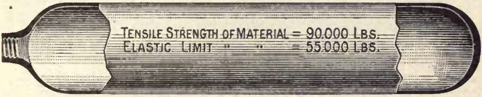
Outside Diameter, 8 inches. Thickness of Wall, 7/32 inch.

(See illustration, page 83.)

Tested to 3000 lbs. per square inch Hydrostatic Pressure.

Length over all in inches.	Average Weight in lbs.	Capacity in Cubic inches.	Capacity in Cubic feet.	Capacity in U. S. Gallons.	Capacity in lbs. Liquid Carbonic Acid Gas.
36	74.2	1459	.8443	6.31	30.
36½	75.0	1482	.8573	6.41	30.4
37	75.8	1504	.8703	6.51	30.9
37½	76.6	1526	.8833	6.60	31.3
38	77.4	1549	.8963	6.70	31.8
38½	78.2	1571	.9093	6.80	32.2
39	79.0	1594	.9223	6.89	32.7
39½	79.8	1616	.9353	6.99	33.1
40	80.6	1639	.9483	7.09	33.6
40½	81.4	1661	.9613	7.19	34.
41	82.2	1684	.9744	7.28	34.5
41½	83.0	1706	.9874	7.38	34.9
42	83.8	1729	1.0004	7.48	35.4
42½	84.6	1751	1.0134	7.58	35.8
43	85.4	1773	1.0264	7.68	36.3
43½	86.2	1796	1.0394	7.77	36.7
44	87.0	1818	1.0524	7.87	37.2
44½	87.8	1841	1.0654	7.96	37.6
45	88.6	1863	1.0784	8.06	38.1
45½	89.4	1886	1.0914	8.16	38.5
46	90.2	1908	1.1045	8.26	39.
46½	91.0	1931	1.1175	8.35	39.4
47	91.8	1953	1.1305	8.45	39.9
47½	92.6	1976	1.1435	8.55	40.3
48	93.4	1998	1.1565	8.65	40.8
48½	94.2	2020	1.1695	8.74	41.2
49	95.0	2043	1.1825	8.84	41.7
49½	95.8	2067	1.1955	8.94	42.1
50	96.6	2090	1.2085	9.04	42.6
50½	97.4	2112	1.2215	9.13	43.0
51	98.2	2135	1.2346	9.23	43.5
51½	99.0	2157	1.2476	9.33	43.9
52	99.8	2180	1.2606	9.42	44.3
52½	100.6	2202	1.2736	9.52	44.8
53	101.4	2225	1.2866	9.62	45.2
53½	102.2	2247	1.2996	9.72	45.7
54	103.0	2269	1.3126	9.81	46.1
54½	103.8	2292	1.3256	9.91	46.6
55	104.6	2314	1.3386	10.01	47.0
55½	105.4	2337	1.3516	10.11	47.5
56	106.2	2359	1.3647	10.20	47 9
56½	107.0	2381	1.3777	10.30	48.4
57	107.8	2403	1.3907	10.40	48.8
57½	108.6	2426	1.4037	10.49	49.3
58	109.4	2449	1.4167	10.59	49.7
58½	110.2	2471	1.4297	10.69	50 2
59	111.0	2493	1.4427	10.79	50.6
59½	111.8	2516	1.4558	10.88	51.1
60	112.6	2538	1.4687	10.98	51.5

Table of Weights and Capacities of Seamless Cylinders of various diameters.



Tested 3700 lbs. per square inch Hydrostatic Pressure.

Inside Diameter.	Outside Diameter.	Thickness of Wall.	Weight in lbs. of a Cylinder 2 feet long.	Weight of each additional foot in length.	Weight of each additional inch in length.	Capacity in Cubic inches of a Cylinder 2 feet long.	Capacity of each additional foot in length.	Capacity of each additional inch in length.
3	3 3/8	3/16	14	6.	.5	161	84.8	7.
3 1/4	3 5/8	3/16	15	6.8	.57	189	99.5	8.29
3 1/2	3 7/8	3/16	16	7.2	.6	219	115.4	9.62
3 3/4	4 1/8	3/16	17	7.8	.67	251	132.5	11.04
4	4 3/8	3/16	19	8.2	.7	285	150.7	12.56
4 1/4	4 5/8	3/16	20	8.7	.76	323	169.9	14.18
4 1/2	4 7/8	3/16	21	9.2	.78	358	190.8	15.90
4 3/4	5 1/8	3/16	22	9.6	.8	397	212.6	17.72
5	5 3/8	3/16	24	10.	.83	438	235.5	19.63
5 1/4	5 5/8	3/16	25	10.6	.88	471	259.7	21.64
5 1/2	5 7/8	3/16	27	11.	.91	526	285.	23.75
5 3/4	6 1/8	3/16	28	11.8	.98	573	311.5	25.96
6	6 3/8	3/16	30	12.	1.	622	339.2	28.27
6 1/4	6 5/8	3/16	33	12.6	1.05	673	368.	30.68
6 1/2	6 15/16	7/32	36	15.	1.3	724	398.	33.18
6 3/4	7 3/16	7/32	39	16.	1.4	778	429.3	35.78
7	7 7/16	7/32	43	17.	1.43	834	461.7	38.48
7 1/4	7 11/16	7/32	46	18.	1.5	891	495.4	41.28
7 1/2	8	1/4	50	20.5	1.7	950	530.	44.17
7 3/4	8 1/4	1/4	53	21.2	1.8	1010	566.	47.17
8	8 1/2	1/4	56	21.7	1.82	1072	603.	50.26
8 1/4	8 3/4	1/4	59	22.4	1.88	1136	641.4	53.45
8 1/2	9 1/16	9/32	62	26.	2.1	1200	680.9	56.74
8 3/4	9 5/16	9/32	66	26.7	2.22	1267	721.5	60.13
9	9 9/16	9/32	70	27.5	2.3	1336	763.3	63.61
9 1/4	9 13/16	9/32	74	28.1	2.4	1406	806.4	67.20
9 1/2	10 1/8	5/16	79	32.5	2.7	1477	850.5	70.88
9 3/4	10 3/8	5/16	85	33.	2.8	1550	895.9	74.66
10	10 5/8	5/16	90	34.	2.9	1623	942.5	78.54
10 1/4	10 7/8	5/16	94	35.2	3.	1699	990.	82.51
10 1/2	11 3/16	11/32	98	39.4	3.3	1775	1039.	86.59
10 3/4	11 7/16	11/32	103	40.5	3.4	1854	1089.	90.76

Table of Weights and Capacities of Seamless Cylinders of various diameters.

(CONTINUED.)

Inside Diameter.	Outside Diameter.	Thickness of Wall.	Weight in lbs. of a Cylinder 2 feet long.	Weight of each additional foot in length.	Weight of each additional inch in length.	Capacity in Cubic inches of a Cylinder 2 feet long.	Capacity of each additional foot in length.	Capacity of each additional inch in length.
11	11 11/16	11/32	109	41.2	3.47	1932	1140.3	95.03
11¼	11 15/16	11/32	114	42.7	3.62	2012	1192.8	99.40
11½	12¼	⅜	119	47.	3.9	2093	1245.6	103.87
11¾	12½	⅜	125	48.	4.	2176	1290.8	108.43
12	12¾	⅜	132	49.	4.05	2261	1356.	113.10
12¼	13	⅜	137	50.	4.1	2347	1414.3	117.86
12½	13 5/16	13/32	143	55.	4.5	2433	1472.4	122.72
12¾	13 9/16	13/32	150	56.4	4.7	2521	1532.	127.68
13	13 13/16	13/32	162	57.4	4.8	2610	1592.	132.73
13¼	14 1/16	13/32	168	58.5	4.9	2700	1654.7	137.89
13½	14⅜	7/16	174	64.5	5.4	2790	1717.2	143.14
13¾	14⅝	7/16	180	65.5	5.5	2883	1781.9	148.49
14	14⅞	7/16	187	66.2	5.55	2976	1846.8	153.94
14¼	15⅛	7/16	193	67.2	5.6	3074	1913.7	159.48
14½	15 7/16	15/32	200	74.	6.1	3173	1981.2	165.13
14¾	15 11/16	15/32	209	75.6	6.2	3265	2050.4	170.87
15	15 15/16	15/32	220	76.6	6.3	3357	2120.4	176.71
15¼	16 3/16	15/32	227	77.6	6.45	3452	2191.8	182.65
15½	16½	½	235	84.3	7.	3548	2263.2	188.69
15¾	16¾	½	244	85.7	7.1	3650	2337.9	194 83
16	17	½	255	87.	7.2	3753	2412.	201.06
16¼	17¼	½	263	88.7	7.4	3855	2487.6	207.39
16½	17 9/16	17/32	272	95.5	8.	3957	2565.6	213.82
16¾	17 13/16	17/32	282	96.7	8.1	4058	2646.6	220.35
17	18 1/16	17/32	291	98.3	8.2	4160	2722.8	226.98
17¼	18 5/16	17/32	299	99.7	8.3	4274	2804.4	233.71
17½	18⅝	9/16	309	107.	8.6	4389	2886.	240.53
17¾	18⅞	9/16	320	108.7	9.06	4484	2968.8	247.45
18	19⅛	9/16	331	110.2	9.2	4580	3052.8	254.47
18¼	19⅜	9/16	340	111.5	9.3	4686	3139.	261.59
18½	19 11/16	19/32	350	119.6	9.9	4793	3225.6	268.80
18¾	19 15/16	19/32	361	121.3	10.1	4900	3313.4	276.12
19	20 3/16	19/32	373	122.6	10.2	5008	3402.	283.53
19¼	20 7/16	19/32	382	126.5	10.5	5117	3492.	291.04
19½	20¾	⅝	392	132.7	11.	5226	3583.2	298.65
19¾	21	⅝	403	134.4	11.2	5336	3676.2	306.35
20	21¼	⅝	415	136.4	11.4	5446	3769.2	314.16

Table of Weights and Capacities of 5 inch Standard Lap-Welded Cylinders (Class B).

Outside Diameter, 5 9/16 inches. Thickness of Wall, ¼ inch.

Tested to 3700 lbs. per square inch Hydrostatic Pressure.

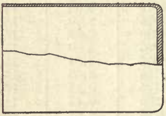
Length over all in inches.	Average Weight in lbs.	Capacity in Cubic inches.	Capacity in Cubic feet.	Capacity in U. S. Gallons.	Capacity in lbs. Liquid Carbonic Acid Gas.
36	49.14	618.	0.3576	2.68	14.
36½	49.67	628.	0.3636	2.72	14.2
37	50.20	638.	0.3696	2.77	14.4
37½	50.73	648.	0.3756	2.81	14.6
38	51.26	658.	0.3816	2.86	14.8
38½	51.79	668.	0.3876	2.90	15.
39	52.32	679.	0.3930	2.95	15.2
39½	52.85	689.	0.3996	2.99	15.4
40	53.38	699.	0.4056	3.04	15.6
40½	53.91	709.	0.4116	3.08	15.8
41	54.44	719.	0.4176	3.13	16.
41½	54.97	730.	0.4236	3.17	16.2
42	55.50	740.	0.4296	3.22	16.4
42½	56.03	750.	0.4356	3.26	16.6
43	56.56	760.	0.4416	3.31	16.8
43½	57.09	770.	0.4476	3.35	17.
44	57.62	781.	0.4536	3.40	17.2
44½	58.15	791.	0.4596	3.44	17.4
45	58.68	801.	0.4656	3.49	17.6
45½	59.21	811.	0.4716	3.53	17.8
46	59.74	821.	0.4776	3.58	18.
46½	60.27	831.	0.4836	3.62	18.2
47	60.80	842.	0 4896	3.67	18.4
47½	61.33	852.	0.4956	3.71	18.6
48	61.86	862.	0.5016	3.76	18.8
48½	62.39	872.	0.5076	3.80	19.
49	62.92	882.	0.5136	3.85	19.2
49½	63.45	892.	0.5196	3.89	19.4
50	63.98	903.	0.5256	3.94	19.6
50½	64.51	913.	0.5316	3.98	19.8
51	65 04	923.	0.5376	4.03	20.
51½	65.57	933.	0.5436	4.07	20.2
52	66.10	943.	0.5496	4.12	20.4
52½	66.63	954.	0.5556	4.16	20.6
53	67.16	964.	0.5616	4.21	20.8
53½	67.69	974.	0.5676	4.26	21.
54	68.22	984.	0.5736	4.31	21.2
54½	68.75	994.	0.5796	4.35	21.4
55	69.28	1005.	0.5856	4.40	21.6
55½	69.81	1015.	0.5916	4.44	21.8
56	70.34	1025.	0.5976	4.48	22.
56½	70.87	1035.	0.6036	4.52	22.2
57	71.40	1045.	0.6096	4 57	22.4
57½	71.93	1055.	0.6156	4.61	22.6
58	72.46	1066.	0.6216	4.66	22.8
58½	72.99	1076.	0.6276	4.70	23.
59	73.52	1086.	0.6336	4.73	23.2
59½	74.05	1096.	0.6396	4.76	23.4
60	74.58	1106.	0.6456	4.80	23.6

Illustrations of Various Hydraulic Forgings.

Various Styles of Valve Protecting Caps used on Carbonic Acid Gas Cylinders.

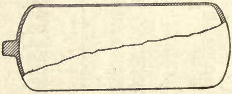
These Caps are made of light material in various sizes, suitable for the Valves of Cylinders.

Boiler Shells.



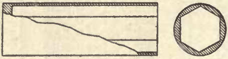
These Shells are made in various sizes from 6" Diameter, by 1 foot long, to 24" Diameter, x 3 feet long. They are made from Steel of 55,000 to 60,000 Tensile Strength.

Seamless Floats For Feed Water Regulators.



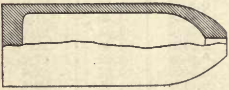
These Floats are made from Steel of High Tensile Strength, so as to make them as light as possible. They are subjected to a Hydrostatic Collapsing Test of 500 lbs. per square inch.

Shrapnel Forging.



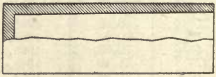
These Shrapnels are made of a Special Grade of Steel, and Forged from a Solid Billet.

Shrapnel Forging.



These Shrapnels are made of a Special Grade of Steel, and Forged from a Solid Billet.

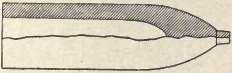
Shrapnel Forging.



These Shrapnels are made of a Special Grade of Steel, and Forged from a Solid Billet.

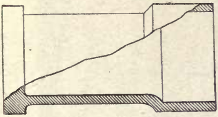
Illustrations of Various Hydraulic Forgings.

Projectile Forging.



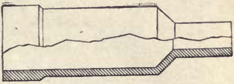
Made from Special Grade of Steel, and Forged from a Solid Billet.

Bushing Forging for Axle Bearings.



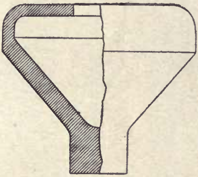
These are made from High Grade Steel, and forged from a Solid Billet.

Separator Tubular Forging.



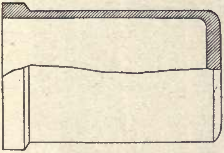
These Tubulars are made from High Grade Steel of 85,000 to 90,000 Tensile Strength.

Separator Bowl Forging.



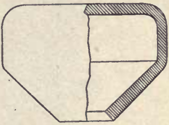
These Bowls are made from High Grade Steel of 85,000 to 90,000 Tensile Strength.

Separator Bowl Forging.

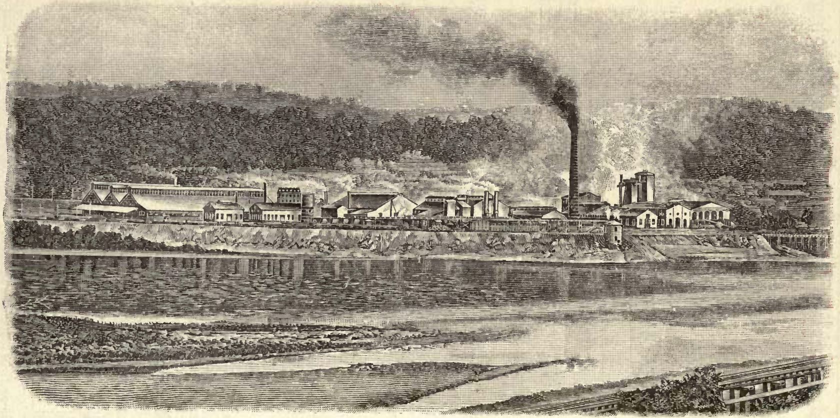


These Bowls are made from High Grade Steel of 85,000 to 90,000 Tensile Strength.

Separator Bowl Forging.



These Bowls are made from High Grade Steel of 85,000 to 90,000 Tensile Strength.



RIVERSIDE DEPARTMENT, WHEELING, W. VA.

USEFUL INFORMATION

RELATING CHIEFLY TO

TUBULAR CONSTRUCTION

COMPILED BY

NATIONAL TUBE CO.

WATER.

Water is composed of two gases, hydrogen and oxygen, in the ratio of two volumes of former to one of the latter. It is never found pure in nature, owing to the readiness with which it absorbs impurities from the air and soil. Water boils under atmospheric pressure (14.7 lb.) at 212°, passing off as steam. Its greatest density is at 39.1°F., when it weighs 62.425 lbs. per cubic ft.

Weight of Water per Cubic Foot at Different Temperatures.

Temperature Fahrenheit.	Weight, lbs. per Cubic Foot.	Temperature Fahrenheit.	Weight, lbs. per Cubic Foot.	Temperature Fahrenheit.	Weight, lbs. per Cubic Foot.	Temperature Fahrenheit.	Weight, lbs. per Cubic Foot.	Temperature Fahrenheit.	Weight. lbs. per Cubic Foot.
32°	62.42	140°	61.37	240°	59.10	350°	55.52	460°	51.26
40	62.42	150	61.18	250	58.81	360	55.16	470	50.85
50	62.41	160	60.98	260	58.52	370	54.79	480	50.44
60	62.37	170	60.77	270	58.21	380	54.41	490	50.05
70	62.31	180	60.55	280	57.90	390	54.03	500	49.61
80	62.23	190	60.32	290	57.59	400	53.64	510	49.20
90	62.13	200	60.07	300	57.26	410	53.26	520	48 78
100	62 02	210	59.82	310	56.93	420	52.86	530	48.36
110	61.89	212	59.71	320	56.58	430	52.47	540	47.94
120	61.74	220	59.64	330	56.24	440	52.07	550	47.52
130	61.56	230	59.37	340	55.88	450	51.66	560	47.10

One ft. of water column at 39°.1F = 62.425 lbs. on the square ft.
" " " " " " = 0.4335 " " " " in.
" " " " " " = 0.0295 atmospheric pressure
" " " " " " = 0.8826 in. mercury column at 32°.F.
" " " " " " = 773.3 ft. of air column at 32°.F. and atmospheric pressure.

One lb. pressure on sq. ft. = 0.01602 ft. water column at 39.1°F.
" " " " " in. = 2.307 " " " " 39.1°F.

One atmospheric pressure = 29.92 in. mercury column = 33.9 ft. water column.

One inch of mercury column at 32°F. = 1.133 ft water column.

One foot of air column at 32°F. and 1 atmospheric pressure = 0.001293 ft. water column.

BOILER INCRUSTATION AND CORROSION.

Water, from natural sources, as a rule contains more or less carbon dioxide, which holds in solution carbonates of lime and magnesia. On boiling the water, the carbon dioxide is driven out and the lime and magnesium in solution are thrown down in the form of a white or grayish mud, that may be easily removed from the boiler by thorough washing. The presence of other impurities, such as organic matter or sulphate of lime, is likely to make the deposit hard and adhering.

Sulphate of lime is more soluble in cold than in hot water, and is entirely thrown down at a temperature of 280° Fahrenheit. It forms a hard and adhering scale and has a bad effect upon scales and deposits, composed chiefly of carbonates.

The evident treatment of water containing sulphate of lime is to heat the feed water, before entering the boiler, to a temperature of at least 280° Fahrenheit. This should be done in such a manner as to give time for the deposition of the sulphate of lime when thrown out of solution.

A deposition may arise from the settling of clay and other matter held in suspension in the water. In water otherwise free from impurities this matter commonly deposits in the form of a soft mud that may be easily removed from the boiler. In conjunction, however, with other impurities, as, for example, sulphate of lime, it may form an adhesive scale, in which case it is usually best to free the feed water from suspended matter by filtration.

In some cases chemical treatment, either internally or externally, should be resorted to. This is especially the case with feed waters containing much free acid, in which case the free acid should be neutralized by chemical treatment, preferably before entering the boiler.

If more than 100 parts per 100,000 of total solid residue be present in the water, it will ordinarily cause trouble from scale, and should be condemned for use in the boiler unless a better supply be unattainable. Scale reduces the efficiency of the heating surface by detracting from the conducting quality of the metal and is apt to cause overheating or burning of the metal, or even bulging of the plates that are subjected to the intense heat of the furnace. Grease, owing to its adhesive nature, may, by collecting impurities contained in the water, become sufficiently heavy to sink. In this condition it is apt to attach itself to a plate or pipe near the furnace and may, owing to its non-conducting qualities, cause serious overheating, resulting in burning, bulging or even blowing out.

If water contains more than 5 parts per 100,000 of free sulphuric or nitric acid, serious corrosion will ensue not only in boiler plates, but also in tubes, pipes, cylinders and other parts with which the steam comes in contact.

Animal and vegetable oils and greases decompose into fatty acids when subjected to the temperature of high pressure steam. Because of this their presence in a high pressure steam engine or boiler will cause serious corrosion.

Experiments have shown that pure water, into which air has been forced, on boiling causes corrosion.

Highly heated surfaces in contact with water containing common salt corrode and pit rapidly. The sides of the furnace, the tube plates and the hottest tubes suffer most.

It is clear then that feed-water, free from solids, combined or in suspension, organic matter, acids of all kinds, and air, would be best for the life of boilers.

TABULAR VIEW.

Troublesome Substance.	Trouble.	Remedy or Palliation.
Sediment, mud, clay, etc.	Incrustation.	Filtration ; blowing off.
Readily soluble salts.	"	Blowing off.
Bicarbonates of lime, magnesia, iron.	"	Heating feed. Addition of caustic soda, lime, or magnesia, etc.
Sulphate of lime.	"	Addition of carbonate soda, barium chloride, etc.
Chloride and sulphate of magnesium.	Corrosion.	Addition of carbonate of soda, etc.
Carbonate of soda in large amounts.	Priming.	Addition of barium chloride, etc.
Acid (in mine waters).	Corrosion.	Alkali.
Dissolved carbonic acid and oxygen.	"	Heating feed. Addition of caustic soda, slacked lime, etc.
Grease (from condensed water).	"	Slacked lime and filtering. Carbonate of soda. Substitute mineral oil.
Organic matter (sewage).	"	Precipitate with alum or ferric chloride and filter.
Organic matter.	Corrosion.	Ditto.

Analyses in Parts per 100,000 of Water giving Bad Results in Steam-boilers. (A. E. Hunt.)

	Bicarbonate of Lime deposited on Boiling.	Bicarbonate of Magnesia depos'd on Boil'g	Total Lime.	Total Magnesia.	Sulphuric Acid.	Chlorine	Iron.	Organic Matter.	Alumina.	Chloride of Sodium.
Coal-mine water.....	110	25	119	39	890	590	780	30	640	
Salt-well............	151	38	1.90	48	360	990	38	21	30	13.10
Spring.....	75	89	95	120	310	21	75	10	80	36
Monongahela River..	130	21	161	33	210	38	70			
" "	80	70	94	81	219	210	90			
" "	32	82	61	1.04	28	1.90	38			
Allegheny River near Oil-works......	30	50	41	68	890	42	23			

In cases where water containing large amounts of total solid residue is necessarily used, a heavy petroleum oil, free from tar or wax, which is not acted upon by acids or alkalies, not having sufficient wax in it to cause saponification, and which has a vaporizing-point at nearly 600° F., will give the best results in preventing boiler-scale. Its action is to form a thin greasy film over the boiler linings, protecting them largely from the action of acids in the water and greasing the sediment which is formed, thus preventing the formation of scale and keeping the solid residue from the evaporation of the water in such a plastic suspended condition that it can be easily ejected from the boiler by the process of "blowing off." If the water is not blown off sufficiently often, this sediment forms into a "putty" that will necessitate cleaning the boilers.

Oxidation of pipes may be prevented by coating the pipe with some protecting material. Galvanizing is coating the pipe with zinc, which, being practically unacted upon by water from most natural sources, preserves it. A coating of hot coal tar is very effective as a preventive of corrosion by fresh or salt water.

WATER PRESSURE.

The pressure of still water in pounds per square inch against the sides of any pipe or vessel of any shape whatever, is due alone to the *head*, or height of the surface of the water above the point considered pressed upon, and is equal to 0.434 pounds per square inch for every foot of head. The fluid pressure per square inch is equal in all directions.

To find the total pressure of quiet water against and perpendicular to any surface, whether vertical, horizontal or inclined at any angle, whether it be flat or curved; multiply together the area in square feet of the surface pressed, the vertical depth of its center of gravity below the surface of the water, and the constant 62.5. The product will be the required pressure in pounds. This may be expressed by formula as follows:

$$P = 62.5\ A\ D,$$

In which P = the pressure in pounds of quiescent water on the surface considered.

A = the area pressed upon in square feet, and

D = the vertical depth in feet of center of gravity of surface considered.

Pressures in Pounds per Square Inch in Pipes, Etc., under different Heads of Water.

Feet Head.	Pressure per square inch.	Feet Head.	Pressure per square inch.	Feet Head.	Pressure per square inch.	Feet Head.	Pressure per square inch.	Feet Head.	Pressure per square inch.
1	0.43	15	6.49	29	12.55	43	18.62	57	24.69
2	0.86	16	6.93	30	12.99	44	19.05	58	25.12
3	1.30	17	7.36	31	13.42	45	19.49	59	25.55
4	1.73	18	7.79	32	13.86	46	19.92	60	25.99
5	2.16	19	8.22	33	14.29	47	20.35	61	26.42
6	2.59	20	8.66	34	14.72	48	20.79	62	26.85
7	3.03	21	9.09	35	15.16	49	21.22	63	27.29
8	3.46	22	9.53	36	15.59	50	21.65	64	27.72
9	3.89	23	9.96	37	16.02	51	22.09	65	28.15
10	4.33	24	10.39	38	16.45	52	22.52	66	28.58
11	4.76	25	10.82	39	16.89	53	22.95	67	29.02
12	5.20	26	11.26	40	17.32	54	23.39	68	29.45
13	5.63	27	11.69	41	17.75	55	23.82	69	29.88
14	6.06	28	12.12	42	18.19	56	24.26	70	30.32

Pressures in Pounds per Square Inch in Pipes, Etc., under different Heads of Water.

(CONTINUED.)

Feet Head.	Pressure per square inch.	Feet Head.	Pressure per square inch.	Feet Head.	Pressure per square inch.	Feet Head.	Pressure per square inch.	Feet Head.	Pressure per square inch.
71	30.75	121	52.41	171	74.07	221	95.73	271	117.39
72	31.18	122	52.84	172	74.50	222	96.16	272	117.82
73	31.62	123	53.28	173	74.94	223	96.60	273	118.26
74	32.05	124	53.71	174	75.37	224	97.03	274	118.69
75	32.48	125	54.15	175	75.80	225	97.46	275	119.12
76	32.92	126	54.58	176	76.23	226	97.90	276	119.56
77	33.35	127	55.01	177	76.67	227	98.33	277	119.99
78	33.78	128	55.44	178	77.10	228	98.76	278	120.42
79	34.21	129	55.88	179	77.53	229	99.20	279	120.85
80	34.65	130	56.31	180	77.97	230	99.63	280	121.29
81	35.08	131	56.74	181	78.40	231	100.06	281	121.72
82	35.52	132	57.18	182	78.84	232	100.49	282	122.15
83	35.95	133	57.61	183	79.27	233	100.93	283	122.59
84	36.39	134	58.04	184	79.70	234	101.36	284	123.02
85	36.82	135	58.48	185	80.14	235	101.79	285	123.45
86	37.25	136	58.91	186	80.57	236	102.23	286	123.89
87	37.68	137	59.34	187	81.00	237	102.66	287	124.32
88	38.12	138	59.77	188	81.43	238	103.09	288	124.75
89	38.55	139	60.21	189	81.87	239	103.53	289	125.18
90	38.98	140	60.64	190	82 30	240	103.96	290	125.62
91	39.42	141	61.07	191	82.73	241	104.39	291	126.05
92	39.85	142	61.51	192	83.17	242	104.83	292	126.48
93	40.28	143	61.94	193	83.60	243	105.26	293	126.92
94	40.72	144	62.37	194	84.03	244	105.69	294	127.35
95	41.15	145	62.81	195	84.47	245	106.13	295	127.78
96	41.58	146	63.24	196	84.90	246	106.56	296	128.22
97	42.01	147	63.67	197	85.33	247	106.99	297	128.65
98	42.45	148	64.10	198	85.76	248	107.43	298	129.08
99	42.88	149	64.54	199	86.20	249	107.86	299	129.51
100	43.31	150	64.97	200	86.63	250	108.29	300	129.95
101	43.75	151	65.40	201	87.07	251	108.73	310	134.28
102	44.18	152	65.84	202	87.50	252	109.16	320	138.62
103	44.61	153	66.27	203	87.93	253	109.59	330	142.95
104	45.05	154	66.70	204	88.36	254	110.03	340	147.28
105	45.48	155	67.14	205	88.80	255	110.46	350	151.61
106	45.91	156	67.57	206	89.23	256	110.89	360	155.94
107	46.34	157	68.00	207	89.66	257	111.32	370	160.27
108	46.78	158	68.43	208	90.10	258	111.76	380	164.61
109	47.21	159	68.87	209	90.53	259	112.19	390	168.94
110	47.64	160	69.31	210	90.96	260	112.62	400	173.27
111	48.08	161	69.74	211	91.39	261	113.06	500	216.58
112	48.51	162	70.17	212	91.83	262	113.49	600	259.90
113	48.94	163	70.61	213	92.26	263	113.92	700	303.22
114	49.38	164	71.04	214	92.69	264	114.36	800	346.54
115	49.81	165	71.47	215	93.13	265	114.79	900	389.86
116	50.24	166	71.91	216	93 56	266	115.22	1000	433.18
117	50.68	167	72.34	217	93.99	267	115.66		
118	51.11	168	72.77	218	94.43	268	116.09		
119	51.54	169	73.20	219	94.86	269	116.52		
120	51.98	170	73.64	220	95.30	270	116.96		

FLOW OF WATER IN PIPES.

The vertical height of the source of water above the outlet is called the *head*. The greater the head the greater will be the *velocity of efflux* if the length and diameter of the pipe remain constant.

To find the velocity of water discharged from a pipe line longer than 4 times its diameter, knowing the head, length and inside diameter, use the following formula:

$$v = m\sqrt{\frac{hd}{L+54d}},$$

In which v = approximate mean velocity in feet per second,
m = coefficient from table below,
d = diameter of pipe in feet,
h = total head in feet,
L = total length of line in feet.

VALUES OF COEFFICIENT M.

$\frac{hd}{L+54d}$	Diameter of Pipe in Feet.							
	0.05	0.10	0.50	1	1.5	2	3	4
	M	M	M	M	M	M	M	M
0.005	29	31	33	35	37	40	44	47
0.01	34	35	37	39	42	45	49	53
0.02	39	40	42	45	49	52	56	59
0.03	41	43	47	50	54	57	60	63
0.05	44	47	52	54	56	60	64	67
0.10	47	50	54	56	58	62	66	70
0.20	48	51	55	58	60	64	67	70

The above coefficients are averages deduced from a large number of experiments. In most cases of pipes carefully laid and in fair condition, they should give results within 5 to 10 per cent. of the truth.

Example.—Given the head, $h = 50$ ft.; the length, $L = 5280$ ft.; and the diameter, $d = 2$ ft.; to find the velocity and quantity of discharge.

Substituting these values in above formula, we get:

$$\sqrt{\frac{d \times h}{L+54d}} = \sqrt{\frac{2 \times 50}{2580+108}} = \sqrt{\frac{100}{5388}} = 0.136.$$

In column headed $\sqrt{\frac{hd}{L+54d}}$ find 0.10, which is the value nearest to 0.136, and look along this line until column headed "2" is reached, then read 62 as the value of coefficient *m*.

Then $v = 62 \times 0.136 = 8.432$ ft. per sec., the required velocity.

To find the discharge in cu. ft. per sec., multiply this velocity by area of cross section of pipe in sq. ft.

Thus, $3.1416 \times (1)^2 \times 8.432 = 26.49$ cu. ft. per sec.

Since there are 7.48 gal. in a cu. ft., the discharge in gal. per sec. $= 26.49 \times 7.48 = 198.2$.

The above formula is only an approximation, since the flow is modified by bends, joints, incrustations, etc. Wrought Iron and Steel Pipes are smoother than cast iron ones, thereby presenting less friction and less encouragement for deposits; and, being in longer lengths, the number of joints is reduced, thus lessening the undesirable effects of eddy currents.

To find the head in feet necessary to give a stated discharge in cu. ft., use the formula.*

$$h = \frac{0.000704\ Q^2\ (L+54\ d)}{d^5},$$

In which h = total head in feet,
L = total length of line in feet,
d = diameter of pipe in feet,
Q = quantity of water in cu. ft. per second.

Example.—Given the diameter of pipe, $d = 0.5$ ft.; the length of pipe, $L = 20$ ft.; and the quantity of water to be discharged, $q = 3.07$ cu. ft. per sec.; to find the necessary head.

Substituting these values in the above formula,* we get:

$$h = \frac{0.000704 \times 9.4 \times (20+27)}{(0.5)^5}$$

$$= \frac{0.000704 \times 9.4 \times 47}{0.03125} = 9.95 \text{ ft., the required head.}$$

The following formula* is simpler and can be used when 54 *d* in relation to *L* is so small as to be negligible.

$$h = \frac{0.000704 \, Q^2 \times L}{d^5}.$$

If the pipe, instead of being straight, has easy curves (say with radius not less than 5 diameters of the pipe) either horizontal or vertical, the discharge will not be materially diminished, so long as the total heads, and total actual lengths of pipe remain the same, but it is advisable to make the radius as much more than 5 diameters as can conveniently be done.

To find the diameter of a pipe of given length to deliver a given quantity of water under a given head, use the following:

$$d = 0.234 \sqrt[5]{\frac{Q^2 L}{h}},$$

In which d = diameter of pipe in feet,
Q = cu. ft. per second delivered,
L = length of line in feet,
h = head in feet.

Example.—Given the head, h = 700 feet; the length of pipe, L = 3000 feet; the quantity to be delivered, Q = 4 cu. ft. per. sec.; required the diameter of pipe necesssary.

Substituting these values in the above formula,* we get:

$$d = 0.234 \sqrt[5]{\frac{16 \times 3000}{700}} = 0.234 \sqrt[5]{68.57} = 0.545 \text{ ft.} = 6.54 \text{ in.}$$

The diameter of a pipe may also be found by using the following formula: *

$$D = 1.25 \sqrt[5]{\frac{q^2 \times L}{h}},$$

In which D = diameter of pipe in inches,
q = gallons per second,
L = length of line in feet,
h = head in feet.

If, in formula $v = m\sqrt{\frac{d \times h}{L + 54d}}$ we substitute 48 as an average value for *m*, we get:

$$v = 48\sqrt{\frac{d \times h}{L + 54d}}.$$

The following table, calculated by the above formula shows the velocities and discharges through a pipe one mile long and one foot in diameter, under different heads. But they will be *very* nearly the same for any greater lengths; and also quite approximate for shorter ones not less than 1000 or even 500 diameters long, *provided that in all cases they have the same* RATE OF HEAD; that is, if the given pipe of one foot diameter is 2 or 3 miles long, it must have 2 or 3 times as much head as the pipe in the table in order to have very nearly the same velocity and discharge.

* When solving examples by the use of these formulas use the table of *Fifth Powers and Fifth Roots*. Solutions may also be easily effected by the use of logarithms.

The velocities and discharges through a straight, smooth pipe one foot in diameter, and one mile or 5280 diameters in length.

Head in feet per 100 feet.	Head in feet per mile.	Velocity in feet per second.	Discharge in cubic feet per second.	Discharge in cubic feet per 24 hours.
.0019	.1	.208	.1633	14,114
.0038	.2	.293	.2301	19,880
.0057	.3	.359	.2819	24,360
.0076	.4	.415	.3267	28,229
.0095	.5	.464	.3638	31,435
.0114	.6	.508	.3989	34,464
.0132	.7	.549	.4311	37,247
.0151	.8	.585	.4602	39,760
.0170	.9	.623	.4901	42,343
.0189	1.	.656	.5144	44,431
.0237	.25	.735	.5753	49,701
.0284	.5	.805	.6322	54,604
.0331	.75	.871	.6832	59,011
.0379	2.	.928	.7276	62,870
.0426	.25	.984	.7696	66,484
.0473	.5	1.04	.8168	70,572
.0521	.75	1.08	.8482	73,284
.0568	3.	1 13	.8914	76,982
.0758	4.	1.31	1.028	88,862
.0947	5.	1.47	1.150	99,403
.1136	6.	1.61	1.264	109,209
.1325	7.	1.74	1.366	118,022
.1514	8.	1.86	1.455	125,740
.1703	9.	1.96	1.539	132,969
.1894	10.	2.08	1.633	141,145
.2273	12.	2.27	1.782	153,964
.2652	14.	2.45	1.924	166,233
.3030	16.	2.62	2.057	177,724
.3409	18.	2.78	2.183	188,611
.3788	20.	2.93	2.301	198,806
.4735	25.	3.28	2.572	222,156
.5682	30.	3.59	2.819	243,604
.6629	35.	3.88	3.047	263,260
.7576	40.	4.15	3.267	282,288
.8523	45.	4.40	3.451	298,209
.9470	50.	4.64	3.638	314,352
1.136	60.	5.08	3.989	344,649
1.326	70.	5.49	4.311	372,470
1.515	80.	5.85	4.602	397,613

The velocities and discharges through a straight, smooth pipe one foot in diameter, and one mile or 5280 diameters in length.

Head in feet per 100 feet.	Head in feet per mile.	Velocity in feet per second.	Discharge in cubic feet per second.	Discharge in cubic feet per 24 hours.
1.704	90.	6.23	4.900	423,435
1.894	100.	6.56	5.144	444,312
2.083	110.	6.87	5.395	466,128
2.272	120.	7.18	5.639	487,209
2.462	130.	7.47	5.866	506,822
2.652	140.	7.76	6.094	526,521
2.841	150.	8.05	6.322	546,048
3.030	160.	8.30	6.534	564,576
3.219	170.	8.55	6.715	580,176
3.408	180.	8.80	6.903	596,418
3.596	190.	9.04	7.100	613,440
3.788	200.	9.28	7.276	628,704
4.261	225.	9.84	7.696	664,848
4.735	250.	10.4	8.168	705,728
5.208	275.	10.8	8.482	732,844
5.682	300.	11.3	8.914	769,824
6.629	350.	12.3	9.621	831,168
7.576	400.	13.1	10.28	888,624
8.532	450.	13.9	10.91	943,056
9.47	500.	14.7	11.50	994,032
10.41	550.	15.4	12.09	1,044,576
11.36	600.	16.1	12.64	1,092,096
12.30	650.	16.7	13.11	1,132,704
13.25	700.	17.4	13.66	1,180,224
14.20	750.	18.0	14.13	1,220,832
15.15	800.	18.6	14.55	1,257,408
16.09	850.	19.1	15.00	1,296,000
17.04	900.	19.6	15.39	1,329,696
17.99	950.	20.3	15.94	1,377,216
18.94	1000.	20.8	16.33	1,411,456
22.73	1200.	22.7	17.82	1,539,648
26.52	1400.	24.5	19.24	1,662,336
30.30	1600.	26.2	20.57	1,777,248
34.08	1800.	27.8	21.83	1,886,112
37.87	2000.	29.3	23.01	1,988,064
47.35	2500.	32.8	25.72	2,221,560
56.81	3000.	35.9	28.19	2,436,040

Head is the vertical distance from the surface of the water in the reservoir to the center of gravity of the lower end of the pipe when the discharge is into the air; or to the level surface of the lower reservoir when the discharge is under water.

To reduce cubic feet to U. S. Gallons, multiply by 7.48.

To find either the area of pipe, the mean velocity, or the quantity discharged, when the other two are given, use the following:

$$\text{Area in square feet} = \frac{\text{Discharge in cubic feet per second,}}{\text{Mean velocity in feet per second.}}$$

$$\begin{array}{c}\text{Mean velocity in}\\ \text{feet per second.}\end{array} = \frac{\text{Discharge in cubic feet per second,}}{\text{Area in square feet.}}$$

$$\begin{array}{c}\text{Discharge in cubic feet}\\ \text{per second.}\end{array} = \begin{array}{c}\text{Area in}\\ \text{square feet}\end{array} \times \begin{array}{c}\text{Mean velocity in}\\ \text{feet per second.}\end{array}$$

[The terms may be in inches instead of feet; and in minutes or hours instead of seconds.]

For the diameter of a long pipe required to deliver either more or less water than that of a 1 foot diameter, and under the same rate of inclination, or of head in feet per mile, see table on next page.

The use of this table is not sufficiently correct for pipes less than about 1,000 (or at furthest 500) diameters long.

Diameter of pipe in inches.	Diameter of pipe in feet.	Ratio of discharge to that through a 1 foot pipe, with the same head per mile.	Diameter of pipe in inches.	Diameter of pipe in feet.	Ratio of discharge to that through a 1 foot pipe, with the same head per mile.
1	.0833	.0020	12½	1.042	1.106
1½	.1250	.0055	13	1.083	1.221
2	.1667	.0113	14	1.167	1.470
2½	.2083	.0198	15	1.250	1.746
3	.2500	.0310	16	1.333	2.053
3½	.2917	.0458	17	1.417	2.388
4	.3333	.0643	18	1.5	2.754
4½	.3750	.0857	19	1.583	3.153
5	.4167	.1119	20	1.667	3.585
5½	.4583	.1422	21	1.75	4.051
6	.5	.1767	22	1.833	4.551
6½	.5417	.2159	23	1.917	5.084
7	.5833	.2600	24	2.	5.649
7½	.6250	.3090	24⅝	2.052	6.000
8	.6667	.3631	26	2.167	6.912
8½	.7083	.4220	28	2.333	8.319
9	.75	.4871	30	2.5	9.822
9½	.7917	.5575	30¼	2.521	10.
10	.8333	.6337	32	2.667	11.6
10½	.8750	.7157	34	2.833	13.5
11	.9167	.8044	36	3.	15.5
11½	.9583	.8987	38	3.167	17.8
12	1.	1.	40	3.333	20.2

To find the discharge from a pipe (not less than 1,000, or at least 500 times its own diameter in length) when the head is given, take from the first table the discharge through a pipe one ft. in diameter for the given head, and divide the required discharge by this tabular one; then look for the quotient in the column of the second table, headed "Ratio of Discharge," and opposite it, in columns 1 and 2, will be found the required diameter.

From this table we see that a 14 inch pipe will deliver nearly 1½ times as much as a 12 inch pipe, and a 16 inch one fully twice as much as a 12 inch, all having the same length and head.

EXAMPLE.—Having given the head from a reservoir to a certain point of delivery, as 20 ft. in a distance of 1,860 ft., what must be the diameter of a pipe to deliver 6 cubic feet of water per second?

We find that a fall of 20 ft. in 1,860, is equal to a fall of 1.075 ft. in 100; or 1,860: 20 = 100: 1.075. Then we see by the first table that with a fall of 1.075 ft. in 100, a long pipe of 1 ft. diameter discharges about 3.8 cubic feet per second. But we want $\frac{6}{3.8} = 1.58$ times as much as the 1 ft. pipe can deliver; then by the second table, we see that the pipe to do this, under the same rate of head, must be about 14½ in. in diameter. In practice we should adopt at least 15 in.

Frictional Heads at Given Rates of Discharge in Clean Cast Iron Pipes for Each 1000 Feet of Length.

Condensed from Tables by Ellis and Howland.

U. S. gallons discharged per minute.	U. S. gallons discharged per twenty-four hours.	4-Inch Pipe.			6-Inch Pipe.			8-Inch Pipe.			10-Inch Pipe.			12-Inch Pipe			14-Inch Pipe.		
		Velocity in feet per second.	Friction Head. Feet.	Friction Head. Lbs.	Velocity in feet per second.	Friction Head. Feet.	Friction Head. Lbs.	Velocity in feet per second.	Friction Head. Feet.	Friction Head. Lbs.	Velocity in feet per second.	Friction Head. Feet.	Friction Head. Lbs.	Velocity in feet per second.	Friction Head. Feet.	Friction Head. Lbs.	Velocity in feet per second.	Friction Head. Feet.	Friction Head. Lbs.
25	36000	.64	.59	.26	.28	.11	.05	.16	.04	.02	.10	.02	.01	.07	.01	.....	.....	.....	.....
50	72000	1.28	2.01	.87	.57	.32	.14	.32	.10	.04	.20	.04	.02	.14	.02	.01	.10	.01	.....
100	144000	2.55	7.36	3.19	1.13	1.08	.47	.64	.29	.13	.41	.11	.05	.28	.04	.02	.21	.03	.01
150	216000	3.83	16.05	6.95	1.70	2.28	.99	.96	.60	.26	61	.22	.10	.43	.10	.04	.31	.04	.02
200	288000	5.11	28.09	12.17	2.27	3.92	1.70	1.28	1.01	.44	.82	.36	.16	.57	.16	.07	.42	.08	.04
250	360000	6.37	43.47	18.83	2.84	6.00	2.60	1.60	1.52	.66	1.02	.54	.23	.71	.24	.10	.52	.12	.05
300	432000	7.66	62.20	26.94	3.40	8.52	3.69	1.91	2.13	.92	1.23	.75	.32	.85	.32	.14	.63	.16	.07
350	504000	8.94	84.26	36.50	3.97	11.48	4.97	2.23	2.85	1.24	1.43	.99	.43	.99	.43	.18	.73	.21	.09
400	576000	10.21	109.68	47.50	4.54	14.89	6.45	2.55	3.68	1.59	1.63	1.27	.55	1.13	.54	.23	.83	.27	.12
450	648000	11.49	138.43	59.96	5.11	18.73	8.11	2.87	4.61	2.00	1.83	1.58	.69	1.28	.67	.29	.94	.33	.14
500	720000	12.77	170.53	73.87	5.67	23.01	9.97	3.19	5.64	2.44	2.04	1 93	.84	1.42	.81	.35	1.04	.40	.17
600	864000	15.32	244.76	106.02	6.81	32.89	14.25	3.83	8.03	3.48	2.45	2.72	1.18	1.70	1.14	.49	1.25	.55	.24
700	1008000	17.87	332.36	143.98	7.94	44.54	19.08	4.47	10.83	4.69	2.86	3.66	1.58	1.98	1.52	.66	1.46	.73	.32
800	1152000	.....	.....	.....	9.08	57.95	25.10	5.09	14.05	6.08	3.27	4.73	2.05	2.27	1.96	.85	1.67	.94	.41
900	1290000	.....	.....	.....	10.21	73.12	31.67	5.74	17.68	7.69	3.68	5.93	2.57	2.55	2.45	1.06	1.88	1.17	.51
1000	1440000	.....	.....	.....	11.35	90.05	38.99	6.38	21.74	9.41	4.08	7.28	3.15	2.84	3.00	1.30	2.08	1.43	.62
1200	1728000	.....	.....	.....	13.61	129.20	55.96	7.66	31.10	13.47	4.90	10.38	4.50	3.40	4.26	1.85	2.50	2.02	.88
1400	2016000	.....	.....	.....	15.88	175.38	75.97	8.94	42.13	18.25	5.72	14.02	6.07	3.97	5.74	2.49	2.91	2.72	1.18
1600	2304000	.....	.....	.....	18.15	228.62	99.03	10.21	54 84	23.75	6.53	18.22	7.89	4.54	7.44	3.22	3.33	3.51	1.52
1800	2592000	.....	.....	.....	20.42	288.90	125.14	11.47	69.22	29.98	7.35	22.96	9.95	5.11	9.36	4.06	3.75	4.41	1.91
2000	2880000	.....	.....	.....	22.69	356.22	154.30	12.77	85.27	36.93	8.17	28.25	12.34	5.67	11.50	5.00	4.17	5.41	2.34
2500	3600000	.....	.....	.....	.....	.....	.....	15.96	132.70	57.49	10.21	43.87	19.00	7.09	17.82	7.72	5.21	8.35	3.62
3000	4320000	.....	.....	.....	.....	.....	.....	.....	.....	.....	12.25	62.92	27.25	8.51	25.51	11.05	6.25	11.93	5.17
3500	5040000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	9.93	34.58	14.98	7.29	16.14	6.99
4000	5760000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	8.34	21.00	9.10
4500	6480000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	9.38	26.49	11.47

Frictional Heads at Given Rates of Discharge in Clean Cast Iron Pipe for Each 1000 Feet of Length.

(CONTINUED.)

U. S. gallons discharged per minute.	U. S. gallons discharged per twenty-four hours.	16-Inch Pipe.			18-Inch Pipe.			20-Inch Pipe.			24-Inch Pipe.			30-Inch Pipe.			36-Inch Pipe.		
		Velocity in feet per second.	Friction Head.		Velocity in feet per second.	Friction Head.		Velocity in feet per second.	Friction Head.		Velocity in feet per second.	Friction Head.		Velocity in feet per second.	Friction Head.		Velocity in feet per second.	Friction Head.	
			Feet.	Lbs.		Feet.	Lbs.		Feet.	Lbs.		Feet.	Lbs.		Feet.	Lbs.		Feet.	Lbs.
500	720000	.80	.22	.09	.63	.13	.06	.51	.08	.04	.35	.04	.02	.23	.01	.00	.16	.01	.00
1000	1440000	1.60	.76	.34	1.26	.44	.19	1.02	.27	.12	.71	.12	.05	.45	.04	.02	.32	.02	.01
1500	2160000	2.39	1.63	.71	1.89	.93	.40	1.53	.56	.24	1.06	.24	.10	.68	.09	.04	.47	.04	.02
2000	2880000	3.19	2.82	1.22	2.52	1.60	.69	2.04	.96	.42	1.42	.41	.18	.91	.15	.06	.63	.06	.03
2500	3600000	3.99	4.34	1.88	3.15	2.45	1.06	2.55	1.47	.64	1.77	.62	.27	1.13	.22	.09	.79	.09	.04
3000	4320000	4.79	6.19	2.68	3.78	3.48	1.51	3.06	2.09	.90	2.13	.87	.38	1.36	.30	.13	.95	.13	.06
3500	5040000	5.59	8.37	3.63	4.41	4.70	2.03	3.57	2.81	1.22	2.48	1.16	.50	1.59	.40	.17	1.10	.17	.07
4000	5760000	6.38	10.87	4.71	5.04	6.09	2.64	4.08	3.64	1.58	2.84	1.50	.65	1.82	.52	.22	1.26	.22	.09
4500	6480000	7.18	13.70	5.93	5.67	7.67	3.32	4.59	4.58	1.98	3.19	1.88	.82	2.04	.64	.28	1.42	.27	.12
5000	7200000	7.98	16.85	7.30	6.30	9.43	4.08	5.11	5.62	2.43	3.55	2.31	1.00	2.27	.78	.34	1.58	.33	.14
5500	7920000	8.78	20.33	8.71	6.93	11.38	4.92	5.62	6.77	2.93	3.90	2.77	1.20	2.50	.94	.41	1.73	.39	.17
6000	8640000	....	....	....	7.57	13.49	5.84	6.13	8.03	3.48	4.26	3.28	1.42	2.72	1.11	.48	1.89	.46	.20
7000	10080000	....	....	....	....	....	....	7.15	10.86	4.71	4.96	4.43	1.92	3.18	1.49	.65	2.21	.62	.27
8000	11520000	....	....	....	....	....	....	....	....	....	5.67	5.75	2.49	3.63	1.93	.84	2.52	.80	.35
9000	12960000	....	....	....	....	....	....	....	....	....	6.38	7.25	3.14	4.08	2.43	1.05	2.84	1.00	.43
10000	14400000	....	....	....	....	....	....	....	....	....	....	....	....	4.54	2.98	1.29	3.15	1.23	.53
11000	15840000	....	....	....	....	....	....	....	....	....	....	....	....	5.00	3.59	1.55	3.46	1.47	.64
12000	17280000	....	....	....	....	....	....	....	....	....	....	....	....	5.44	4.25	1.84	3.78	1.74	.75
13000	18720000	....	....	....	....	....	....	....	....	....	....	....	....	5.90	4.97	2.15	4.09	2.03	.88
14000	20160000	....	....	....	....	....	....	....	....	....	....	....	....	6.36	5.75	2.49	4.41	2.35	1.02
15000	21600000	....	....	....	....	....	....	....	....	....	....	....	....	6.80	6.58	2.85	4.73	2.69	1.17
16000	23040000	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5.05	3.46	1.32
17000	24480000	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5.36	3.43	1.49
18000	25920000	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5.68	3.83	1.66
20000	28800000	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	6.30	4.71	2.04

EXAMPLE.—Given 120 feet head and 600 feet length of 18 inch pipe, discharging 3500 gallons per minute : To find *effective head:* Look in column headed "18 inch Pipe," and opposite 3500 in. first column read "4.7 ft." (which is the loss of head by friction for an 18 in. pipe 1000 ft. long), and multiplying this by 600/1000, or 0.6, we get 2.82 ft., the loss of head. The *effective head* required then equals 120 ft. less 2.8 ft. or 117.2 ft.

Flow of Water in Pipes for a Velocity of 100 Ft. per Minute.

Diameter in Inches.	Area in Square Feet.	Flow in Cubic Feet per Minute.	Flow in U. S. Gallons per Minute.	Flow in U.S. Gallons per Hour.
3/8	.00077	0.077	.57	34
1/2	.00136	0.136	1.02	61
3/4	.00307	0.307	2.30	138
1	.00545	0.545	4.08	245
1 1/4	.00852	0.852	6.38	383
1 1/2	.01227	1.227	9.18	551
1 3/4	.01670	1.670	12.50	750
2	.02182	2.182	16.32	979
2 1/2	.0341	3.41	25.50	1,530
3	.0491	4.91	36.72	2,203
4	.0873	8.73	65.28	3,917
5	.136	13.6	102.00	6,120
6	.196	19.6	146.88	8,813
7	.267	26.7	199.92	11,995
8	.349	34.9	261.12	15,667
9	.442	44.2	330.48	19,829
10	.545	54.5	408.00	24,480
11	.660	66.0	493.68	29,621
12	.785	78.5	587.52	35,251

To find the quantity in gallons a pipe will deliver, the velocity of flow being 100 ft. per minute : Square the diameter in inches and multiply by 4.08.

Flow of Water in House-service Pipes.

(Thomson Meter Co.)

Condition of Discharge.	Pressure in Main, lbs. per sq. inch.	Discharge in Cubic Feet per Minute from the Pipe. Nominal Diameters of Iron or Lead Service-pipe in Inches.								
		½	⅝	¾	1	1½	2	3	4	6
Through 35 feet of service-pipe, no back pressure.	30	1.10	1.92	3.01	6.13	16.58	33.34	88.16	173.85	444.63
	40	1.27	2.22	3.48	7.08	19.14	38.50	101.80	200.75	513.42
	50	1.42	2.48	3 89	7.92	21.40	43.04	113.82	224.44	574.02
	60	1.56	2.71	4.26	8.67	23.44	47.15	124.68	245.87	628.81
	75	1.74	3.03	4.77	9.70	26.21	52.71	139.39	274.89	703.03
	100	2.01	3.50	5.50	11.20	30.27	60.87	160.96	317.41	811.79
	130	2.29	3.99	6.28	12.77	34.51	69.40	183.52	361.91	925.58
Through 100 feet of service-pipe, no back pressure.	30	0.66	1.16	1.84	3.78	10.40	21.30	58.19	118.13	317.23
	40	0.77	1.34	2.12	4.36	12.01	24.59	67.19	136.41	366.30
	50	0.86	1.50	2.37	4.88	13.43	27.50	75.13	152.51	409.54
	60	0.94	1.65	2.60	5.34	14.71	30.12	82.30	167.06	448.63
	75	1.05	1.84	2.91	5.97	16.45	33.68	92.01	186.78	501.58
	100	1.22	2.13	3.36	6.90	18.99	38.89	106.24	215.68	579.18
	130	1.39	2.42	3.83	7.86	21.66	44.34	121.14	245.91	660.36
Through 100 feet of service-pipe, and 15 feet vertical rise.	30	0.55	0.96	1.52	3.11	8.57	17.55	47.90	97.17	260.56
	40	0.66	1.15	1.81	3.72	10.24	20.95	57.20	116.01	311.09
	50	0.75	1.31	2.06	4.24	11.67	23.87	65.18	132.20	354.49
	60	0.83	1.45	2.29	4.70	12.94	26.48	72.28	146.61	393.13
	75	0.94	1.64	2.59	5.32	14.64	29.96	81.79	165.90	444.85
	100	1.10	1.92	3.02	6.21	17.10	35.00	95.55	193.82	519.72
	130	1.26	2.20	3.48	7.14	19.66	40.23	109.82	222.75	597.31
Through 100 feet of service-pipe, and 30 feet vertical rise.	30	0.44	0.77	1.22	2.50	6.80	14.11	38.63	78.54	211.54
	40	0.55	0.97	1.53	3.15	8.68	17.79	48.68	98.98	266.59
	50	0.65	1.14	1.79	3.69	10.16	20.82	56.98	115.87	312.08
	60	0.73	1.28	2.02	4.15	11.45	23.47	64.22	130.59	351.73
	75	0.84	1.47	2 32	4.77	13.15	26.95	73.76	149.99	403.98
	100	1.00	1.74	2.75	5.65	15.58	31.93	87.38	177.67	478.55
	130	1.15	2.02	3.19	6.55	18.07	37.02	101.33	206.04	554.96

RELATIVE DISCHARGING CAPACITIES OF FULL SMOOTH PIPES.

(From Fanning's Water Supply Engineering).

3	4	6	8	10	12	14	16	18	20	22	24	27	30	33	36	40	44	48	Diameter in inches.
......	......	......	......	......	......	......	15.59	11.61	8.92	7.03	5.65	4.21	3.24	2.55	1.65	1.58	1.24	1.	48
......	......	......	......	......	......	17.50	12.54	9.34	7.17	5.66	4.55	3.39	2.61	2.00	1.65	1.27	1.	....	44
......	......	......	......	......	20.23	13.47	9.85	7.34	5.64	4.44	3.57	2.66	2.05	1.65	1.26	1.	....	....	40
......	......	......	......	......	15.58	8.41	7.59	5.65	4.34	3.42	2.74	2.05	1.58	1.24	1.	......	....	....	36
......	......	......	34.55	19.78	12.54	8.52	6.11	4.55	3.49	2.75	2.21	1.65	1.27	1.	......	......	....	....	33
......	......	......	27.09	15.54	9.85	6.54	4.80	3.57	2.74	2.16	1.74	1.29	1.	......	......	......	....	....	30
......	......	42.95	16.61	9.96	7.59	5.16	3.70	2.75	2.11	1.67	1.34	1.	......	......	......	......	....	....	27
......	......	32.00	15.58	8.92	5.65	3.84	2.75	2.05	1.57	1.24	1.	......	......	......	......	......	....	....	24
......	70.96	25.73	12.53	7.17	4.55	3.09	2.16	1.65	1.26	1.	......	......	......	......	......	......	....	....	22
......	55.96	20.29	9.88	5.66	3.58	2.43	1.74	1.30	1.	......	......	......	......	......	......	......	....	....	20
......	42.01	15.58	7.25	4.34	2.75	1.87	1.34	1.	......	......	......	......	......	......	......	......	....	....	18
65.77	32.01	11.60	5.65	3.23	2.05	1.39	1.	......	......	......	......	......	......	......	......	......	....	....	16
47.14	22.94	8.32	4.05	2.32	1.47	1.	......	......	......	......	......	......	......	......	......	......	....	....	14
32.05	15.60	5.65	2.75	1.57	1.	......	......	......	......	......	......	......	......	......	......	......	....	....	12
20.31	9.88	3.58	1.74	1.	......	......	......	......	......	......	......	......	......	......	......	......	....	....	10
11.63	5.66	2.05	1.	......	......	......	......	......	......	......	......	......	......	......	......	......	....	....	8
5.66	2.75	1.	......	......	......	......	......	......	......	......	......	......	......	......	......	......	....	....	6
2.05	1.	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	....	....	4
1.	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	....	....	3

EXAMPLE.—To find how many 4 inch pipes will discharge as much as one 12 inch pipe, look in column headed "4" and opposite to "12" in the last column: Read 15.6; therefore 16 is the number required.

SAFE PRESSURES AND EQUIVALENT HEADS OF WATER FOR CAST IRON PIPE OF DIFFERENT SIZES AND THICKNESSES.

(Calculated by F. H. Lewis, from Fanning's Formula.)

Thickness.	SIZE OF PIPE. 4"		6"		8"		10"		12"		14"		16"		18"		20"	
	Pressure in Pounds.	Head in Feet.	Pressure in Pounds	Head in Feet.	Pressure in Pounds.	Head in Feet.	Pressure in Pounds.	Head in Feet.	Pressure in Pounds.	Head in Feet.	Pressure in Pounds.	Head in Feet.	Pressure in Pounds.	Head in Feet.	Pressure in Pounds.	Head in Feet.	Pressure in Pounds.	Head in Feet.
7/16	112	258	49	112	18	42												
1/2	224	516	124	280	74	171	44	101	24	55								
9/16	336	774	199	458	130	300	89	205	62	143	42	97						
5/8	.....	......	274	631	186	429	132	304	99	228	74	170	56	129	41	95		
11/16	.....	......	......	......	......	......	177	408	137	316	106	244	84	194	66	152	51	118
3/4	.....	......	......	......	......	......	224	516	174	401	138	316	112	258	91	210	74	170
13/16	.....	......	......	......	......	......	......	......	212	488	170	392	140	323	116	267	96	221
7/8	.....	......	......	......	......	......	......	......	249	574	202	465	168	387	141	325	119	274
15/16	.....	......	......	......	......	......	......	......	......	......	234	538	196	452	166	382	141	325
1	.....	......	......	......	......	......	......	......	......	......	266	612	224	516	191	440	164	378
1 1/8	.....	.....	......	......	......	......	......	......	......	......	......	......	......	......	216	497	209	481
1 1/4	.....	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	256	589

Safe Pressures and Equivalent Heads of Water for Cast Iron Pipe of Different Sizes and Thicknesses. (Cont'd)

SIZE OF PIPE.

Thickness.	22"		24"		27"		30"		33"		36"		42"		48"		60"	
	Pressure in Pounds.	Head in Feet.	Pressure in Pounds.	Head in Feet.	Pressure in Pounds.	Head in Feet.	Pressure in Pounds.	Head in Feet.	Pressure in Pounds.	Head in Feet.	Pressure in Pounds.	Head in Feet.	Pressure in Pounds.	Head in Feet.	Pressure in Pounds.	Head in Feet.	Pressure in Pounds.	Head in Feet.
11/16	40	92	30	69	19	64												
3/4	60	138	49	113	36	83	24	55										
13/16	80	184	68	157	52	120	39	90										
7/8	101	233	86	198	69	159	54	124	42	97	32	74						
15/16	121	279	105	242	85	196	69	159	55	127	44	101						
1	142	327	124	286	102	235	84	194	69	159	57	131	38	88	24	55		
1 1/8	182	419	161	371	135	311	114	263	96	221	82	189	59	136	43	99		
1 1/4	224	516	199	458	169	389	144	332	124	286	107	247	81	187	62	143	34	78
1 3/8	......	......	237	546	202	465	174	401	151	348	132	304	103	237	81	187	49	113
1 1/2	......	......	......	......	236	544	204	470	178	410	157	362	124	286	99	228	64	147
1 5/8	......	......	......	......	......	......	234	538	205	472	182	419	145	334	118	272	79	182
1 3/4	......	......	......	......	......	......	......	......	233	537	207	477	167	385	136	313	94	217
1 7/8	......	......	......	......	......	......	......	......	......	......	......	......	188	433	155	357	109	251
2	......	......	......	......	......	......	......	......	......	......	......	......	210	484	174	401	124	286
2 1/8	......	......	......	......	......	......	......	......	......	......	......	......	......	......	193	445	139	320
2 1/4	......	......	......	......	......	......	......	......	......	......	......	......	......	......	212	488	154	355
2 1/2	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	184	424
2 3/4	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	214	482

FORMULA FOR THICKNESS OF CAST IRON WATER PIPE.

$t = .00008hd + .01d + .36$ .... Shedd,

$t = .00006hd + .0133d + .296$ .... Warren Foundry,

$t = .000058hd + .0152 + .312$ .... Francis,

$t = .000048hd + .013d + .32$ .... Dupuit,

$t = .00004hd + .1\sqrt{d} + .15$ .... Box,

$t = .000135hd + .4 - .0011d$ .... Whitman,

$t = .00006(h + 230d) + .333 - .0033d$ .... Fanning,

$t = 00015hd + .25 - .0052d$ .... Meggs,

In which t = thickness in inches, h = head in feet, d = diameter.

WEIGHTS OF CAST IRON PIPE TO LAY 12 FEET LENGTHS.

Weights are in Pounds and include Hub.

(Calculated by F. H. Lewis.)

Thickness.		Inside Diameter.								
Inches.	Equiv. Decimals.	4"	6"	8"	10"	12"	14"	16"	18"	20"
3/8	.375	209	304	400						
13/32	.40625	228	331	435						
7/16	.4375	247	358	470	581					
15/32	.4687	266	386	505	624	692	804			
1/2	.5	286	414	541	668	744	863			
17/32	.53125	306	442	577	712	795	922	1050	1177	
9/16	.5625	327	470	613	756	846	983	1118	1253	
19/32	.59375	....	498	649	801	899	1043	1186	1329	
5/8	.625	....	....	686	845	951	1103	1254	1405	
11/16	.6875	....	....	....	935	1003	1163	1322	1481	1640
3/4	.75	....	....	....	1026	1110	1285	1460	1635	1810
13/16	.8125	....	....	....	....	1216	1408	1598	1789	1980
7/8	.875	....	....	....	....	1324	1531	1738	1945	2152
15/16	.9375	....	....	....	....	1432	1656	1879	2101	2324
1	1.	....	....	....	....	....	1783	2021	2259	2498
1 1/8	1.125	....	....	....	....	....	1909	2163	2418	2672
1 1/4	1.25	....	....	....	....	...	....	......	2738	3024
1 3/8	1.375	...	....	....	....	....	....	......	3062	3380

Thickness.		Inside Diameter.								
Inches.	Equiv. Decimals.	22"	24"	27"	30"	33"	36"	42"	48"	60"
5/8	.625	1799								
11/16	.6875	1985	2160	2422						
3/4	.75	2171	2362	2648	2934	3221	3507			
13/16	.8125	2359	2565	2875	3186	3496	3806	4426		
7/8	.875	2547	2769	3103	3437	3771	4105	4773	5442	
15/16	.9375	2737	2975	3332	3690	4048	4406	5122	5839	
1	1.	2927	3180	3562	3942	4325	4708	5472	6236	
1 1/8	1.125	3310	3598	4027	4456	4886	5316	6176	7034	
1 1/4	1.25	3698	4016	4492	4970	5447	5924	6880	7833	9742
1 3/8	1.375	....	4439	4964	5491	6015	6540	7591	8640	10740
1 1/2	1.5	....	....	5439	6012	6584	7158	8303	9447	11738
1 5/8	1.625	....	....	....	6539	7159	7782	9022	10260	12744
1 3/4	1.75	....	....	....	....	7737	8405	9742	11076	13750
1 7/8	1.875	....	....	....	....	.	....	10468	11898	14763
2	2.	....	....	....	....	....	....	11197	12725	15776
2 1/4	2.25	....	....	....	....	. .	....	......	14385	17821
2 1/2	2.5	....	....	....	....	....	....	......	......	19880
2 3/4	2.75	....	....	....	....	....	....	......	......	21956

Contents in Cubic Feet and U. S. Gallons of Pipes and Cylinders of Various Diameters and One Foot in Length.

1 gallon=231 cubic inches. 1 cubic foot=7.4805 gallons.

Diameter in Inches.	For 1 Foot in Length.		Diameter in Inches.	For 1 Foot in Length.		Diameter in Inches.	For 1 Foot in Length.	
	Cubic ft. also Area in Sq. ft	U. S. Gals. 231 Cu. In.		Cubic Ft. also Area in Sq. Ft.	U. S. Gals. 231 Cu. In.		Cubic Ft. also Area in Sq. Ft.	U. S. Gals. 231 Cu. In.
¼	.0003	.0025	6¾	.2485	1.859	19	1.969	14.73
5/16	.0005	.004	7	.2673	1.999	19½	2.074	15.51
⅜	.0008	.0057	7¼	.2867	2.145	20	2.182	16.32
7/16	.001	.0078	7½	.3068	2.295	20½	2.292	17 15
½	.0014	.0102	7¾	.3276	2.45	21	2.405	17.99
9/16	.0017	.0129	8	.3491	2.611	21½	2.521	18.86
⅝	.0021	.0159	8¼	.3712	2.777	22	2.640	19.75
11/16	.0026	.0193	8½	.3941	2.948	22½	2.761	20.66
¾	.0031	.0230	8¾	.4176	3.125	23	2.885	21.58
13/16	.0036	.0269	9	.4418	3.305	23½	3.012	22.53
⅞	.0042	.0312	9¼	.4667	3.491	24	3.142	23.50
15/16	.0048	.0359	9½	.4922	3.682	25	3.409	25.50
1	.0055	.0408	9¾	.5185	3.879	26	3.687	27.58
1¼	.0085	.0638	10	.5454	4.08	27	3.976	29.74
1½	.0123	.0918	10¼	.5730	4.286	28	4.276	31.99
1¾	.0167	.1249	10½	.6013	4.498	29	4.587	34.31
2	.0218	.1632	10¾	.6303	4.715	30	4.909	36.72
2¼	.0276	.2066	11	.66	4.937	31	5.241	39.21
2½	.0341	.2550	11¼	.6903	5.164	32	5.585	41.78
2¾	.0412	.3085	11½	.7213	5.396	33	5.940	44.43
3	.0491	.3672	11¾	.7530	5.633	34	6.305	47.16
3¼	.0576	.4309	12	.7854	5.875	35	6.681	49.98
3½	.0668	.4998	12½	.8522	6.375	36	7.069	52.88
3¾	.0767	.5738	13	.9218	6.895	37	7.467	55.86
4	.0873	.6528	13½	.994	7.436	38	7.876	58.92
4¼	.0985	.7369	14	1.069	7.997	39	8.296	62.06
4½	.1134	.8263	14½	1.147	8.578	40	8.727	65.28
4¾	.1231	.9206	15	1.227	9.180	41	9.168	68.58
5	.1364	1.020	15½	1.310	9.801	42	9.621	71.97
5¼	.1503	1.125	16	1.396	10.44	43	10.085	75.44
5½	.1650	1.234	16½	1.485	11.11	44	10.559	78.99
5¾	.1803	1.349	17	1.576	11.79	45	11.045	82.62
6	.1963	1.469	17½	1.670	12.49	46	11.541	86.33
6¼	.2131	1.594	18	1.768	13.22	47	12.048	90.13
6½	.2304	1.724	18½	1.867	13.96	48	12.566	94.00

To find the capacity of pipes greater than those given, look in the table for a pipe of one half the given size, and multiply its capacity by 4; or one of one third its size, and multiply its capacity by 9, etc.

To find the *weight* of water in any of the given sizes multiply the capacity in cubic feet by the weight of a cubic foot of water at the temperature of the water in the pipe.

To find the capacity of a cylinder in U. S. gallons, multiply the length by the square of the diameter and by 0.0034.

CYLINDRICAL VESSELS, TANKS, CISTERNS, ETC.

Diameter in Feet and Inches, Area in Square Feet, and U. S. Gallons Capacity for One Foot in Depth.

1 gallon = 231 cubic inches = 0.1337 cubic foot.

Diam.		Area.	Gals.	Diam.		Area.	Gals.	Diam.		Area.	Gals.
Ft.	In.	Sq. ft.	One foot depth.	Ft.	In.	Sq. ft.	One foot depth.	Ft.	In.	Sq. ft.	One foot depth.
1		.785	5.87	3	4	8.727	65.28	5	8	25.22	188.66
1	1	.922	6.89	3	5	9.168	68.58	5	9	25.97	194.25
1	2	1.069	8.00	3	6	9.621	71.97	5	10	26.73	199.92
1	3	1.227	9.18	3	7	10.085	75.44	5	11	27.49	205.67
1	4	1.396	10.44	3	8	10.559	78 99	6		28.27	211.51
1	5	1.576	11.79	3	9	11.045	82.62	6	3	30.68	229.50
1	6	1.767	13.22	3	10	11.541	86.33	6	6	33.18	248.23
1	7	1.969	14.73	3	11	12.048	90.13	6	9	35.78	267.69
1	8	2.182	13.32	4		12.566	94.00	7		38.48	287.88
1	9	2.405	17.99	4	1	13.095	97.96	7	3	41.28	308.81
1	10	2.640	19.75	4	2	13.635	102.00	7	6	44.18	330.48
1	11	2.885	21.58	4	3	14.186	106.12	7	9	47.17	352.88
2		3.142	23.50	4	4	14.748	110.32	8		50.27	376.01
2	1	3.409	25.50	4	5	15.321	114.61	8	3	53.46	399.88
2	2	3.687	27.58	4	6	15.90	118.97	8	6	56.75	424.48
2	3	3.976	29.74	4	7	16.50	123.42	8	9	60.13	449.82
2	4	4.276	31.99	4	8	17.10	127.95	9		63.62	475.89
2	5	4.587	34.31	4	9	17.72	132.56	9	3	67.20	502.70
2	6	4.909	36.72	4	10	18.35	137.25	9	6	70.88	530.24
2	7	5.241	39.21	4	11	18.99	142.02	9	9	74.66	558.51
2	8	5.585	41.78	5		19.63	146.88	10		78.54	587.52
2	9	5.940	44.43	5	1	20.29	151.82	10	3	82.52	617.26
2	10	6.305	47.16	5	2	20.97	156.83	10	6	86.59	647.74
2	11	6.681	49.98	5	3	21.65	161.93	10	9	90.76	678.95
3		7.069	52.88	5	4	22.34	167.12	11		95.03	710.90
3	1	7.467	55.86	5	5	23.04	172.38	11	3	99.40	743.58
3	2	7.876	58.92	5	6	23.76	177.72	11	6	103.87	776.99
3	3	8.296	62.06	5	7	24.48	183.15	11	9	108.43	811.14

CYLINDRICAL VESSELS, TANKS, CISTERNS, ETC.

Diameter in Feet and Inches, Area in Square Feet, and U. S. Gallons Capacity for One Foot in Depth.

1 gallon = 231 cubic inches = 0.1337 cubic foot.

(CONTINUED.)

Diam. Ft.	Diam. In.	Area. Sq. ft.	Gals. One foot depth.	Diam. Ft.	Diam. In.	Area. Sq. ft.	Gals. One foot depth.	Diam. Ft.	Diam. In.	Area. Sq. ft.	Gals. One foot depth.
12		113.10	846.03	19		283.53	2120.9	26		530.93	3971.6
12	3	117.86	881.65	19	3	291.04	2177.1	26	3	541.19	4048.4
12	6	122.72	918.00	19	6	298.65	2234.0	26	6	551.55	4125.9
12	9	127.68	955.09	19	9	306.35	2291.7	26	9	562.00	4204.1
13		132.73	992.91	20		314.16	2350.1	27		572.56	4283.0
13	3	137.89	1031.5	20	3	322.06	2409.2	27	3	583.21	4362.7
13	6	143.14	1070.8	20	6	330.06	2469.1	27	6	593.96	4443.1
13	9	148.49	1110.8	20	9	338.16	2529.6	27	9	604.81	4524.3
14		153.94	1151.5	21		346.36	2591.0	28		615.75	4606.2
14	3	159.48	1193.0	21	3	354.66	2653.0	28	3	626.80	4688.8
14	6	165.13	1235.3	21	6	363.05	2715.8	28	6	637.94	4772.1
14	9	170.87	1278.2	21	9	371.54	2779.3	28	9	649.18	4856.2
15		176.71	1321.9	22		380.13	2843.6	29		660.52	4941.0
15	3	182.65	1366.4	22	3	388.82	2908.6	29	3	671.96	5026.6
15	6	188.69	1411.5	22	6	397.61	2974.3	29	6	683.49	5112.9
15	9	194.83	1457.4	22	9	406.49	3040.8	29	9	695.13	5199.9
16		201.06	1504.1	23		415.48	3108.0	30		706.86	5287.7
16	3	207.39	1551.4	23	3	424.56	3175.9	30	3	718.69	5376.2
16	6	213.82	1599.5	23	6	433.74	3244.6	30	6	730.62	5465.4
16	9	220.35	1648.4	23	9	443.01	3314.0	30	9	742.64	5555.4
17		226.98	1697.9	24		452.39	3384.1	31		754.77	5646.1
17	3	233.71	1748.2	24	3	461.86	3455.0	31	3	766.99	5737.5
17	6	240.53	1799.3	24	6	471.44	3526.6	31	6	779.31	5829.7
17	9	247.45	1851.1	24	9	481.11	3598.9	31	9	791.73	5922.6
18		254.47	1903.6	25		490.87	3672.0	32		804.25	6016.2
18	3	261.59	1956.8	25	3	500.74	3745.8	32	3	816.86	6110.6
18	6	268.80	2010.8	25	6	510.71	3820.3	32	6	829.58	6205.7
18	9	276.12	2065.5	25	9	520.77	3895.6	32	9	842.39	6301.5

Weight of Water in Foot Lengths of Pipe of Different Bores.

(62.425 Lbs. Per Cubic Foot.)

Bore In.	Water Lbs.	Bore In.	Water Lbs.	Bore In.	Water Lbs.	Bore In.	Water Lbs.
1/8	0.0053	3	3.0643	7 3/4	20.450	17	98.397
1/4	0.0213	3 1/8	3.3250	8	21.790	17 1/2	104.27
3/8	0.0479	3 1/4	3.5963	8 1/4	23.174	18	110.31
1/2	0.0851	3 3/8	3.8782	8 1/2	24.599	18 1/2	116.53
5/8	0.1330	3 1/2	4.1708	8 3/4	26.068	19	122.91
3/4	0.1915	3 5/8	4.4741	9	27.579	19 1/2	129.47
7/8	0.2607	3 3/4	4.7879	9 1/4	29.132	20	136.19
1	0.3405	3 7/8	5.1125	9 1/2	30.728	21	150.15
1 1/8	0.4309	4	5.4476	9 3/4	32.366	22	164.79
1 1/4	0.5320	4 1/4	6.1498	10	34.048	23	180.11
1 3/8	0.6437	4 1/2	6.8946	10 1/2	37.537	24	196.11
1 1/2	0.7661	4 3/4	7.6820	11	41.198	25	212.80
1 5/8	0.8997	5	8.5119	11 1/2	45.028	26	230.16
1 3/4	1.0427	5 1/4	9.3844	12	49.028	27	248.21
1 7/8	1.1970	5 1/2	10.299	12 1/2	53.199	28	266.93
2	1.3619	5 3/4	11.257	13	57.540	29	286.34
2 1/8	1.5375	6	12.257	13 1/2	62.052	30	306.43
2 1/4	1.7237	6 1/4	13.300	14	66.733	31	327.20
2 3/8	1.9205	6 1/2	14.385	14 1/2	71.585	32	348.65
2 1/2	2.1280	6 3/4	15.513	15	76.607	33	370.78
2 5/8	2.3461	7	16.683	15 1/2	81.799	34	393.59
2 3/4	2.5748	7 1/4	17.896	16	87.162	35	417.08
2 7/8	2.8142	7 1/2	19.152	16 1/2	92.694	36	441.26

Weights of water in cylinders of the same length are proportional to the squares of the diameters. Therefore, to get weight of cylinder of water one foot long and 60 inches diameter, take from above table weight of water of 30 inch pipe and multiply it by the square of 60 ÷ 30, or the square of two; thus, 306.43 × 4 = 1225.72 = the weight of water in one foot length of a 60 inch pipe.

NUMBER OF BARRELS (31½ GALLONS) CONTAINED IN CISTERNS AND TANKS.

Diam. in Ft.	Depth in Feet. 5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
5	23.3	28.0	32.7	37.3	42.0	46.7	51.3	56.0	60.7	65.3	70.0	74.7	79.3	84.0	88.7	99.3
6	33.6	40.3	47.0	53.7	60.4	67.1	73.9	80.6	87.3	94.0	100.7	107.4	114.1	120.9	127.6	134.3
7	45.7	54.8	64.0	73.1	82.2	91.4	100.5	109.7	118.8	127.9	137.1	146.2	155.4	164.5	173.6	182.8
8	59.7	71.7	83.6	95.5	107.4	119.4	131.3	143.2	155.2	167.1	179.0	191.0	202.9	214.8	226.8	238.7
9	75.5	90.6	105.7	120.9	136.	151.1	166.2	181.3	196.4	211.5	226.6	241.7	256.8	272.0	287.0	302.1
10	93.2	111.9	130.6	149.2	167.9	186.5	205.1	223.8	242.4	261.1	289.8	298.4	317.0	335.7	354.3	373.0
11	112.8	135.4	158.0	180.5	203.1	225.7	248.2	270.8	293.4	315.9	338.5	361.1	383.6	406.2	428.8	451.3
12	134.3	161.1	188.0	214.8	241.7	268.6	295.4	322.3	349.1	376.0	402.8	429.7	456.6	483.4	510.3	537.1
13	157.6	189.1	220.6	252.1	283.7	315.2	346.7	378.2	409.7	441.3	472.8	504.3	535.8	567.3	593.	630.4
14	182.8	219.3	255.9	292.4	329.0	365.5	402.1	438.6	475.2	511.8	548.3	584.9	621.4	658.0	694.5	731.1
15	209.8	251.8	293.7	335.7	377.7	419.6	461.6	503.5	545.5	587.5	629.4	671.4	713.4	755.3	797.3	839.3
16	238.7	286.5	334.2	382.0	429.7	477.4	525.2	572.9	620.7	668.2	716.2	773.9	811.6	859.4	907.1	954.9
17	269.5	323.4	377.3	431.2	485.1	539.	592.9	646.8	700.7	754.6	808.5	862.4	916.3	970.2	1024.1	1078.
18	302.1	362.6	423.	483.4	543.8	604.3	667.7	725.1	785.5	846.0	906.4	966.8	1027.2	1087.7	1148.1	1208.5
19	336.6	404.	471.3	538.6	605.9	673.3	740.6	807.9	875.2	942.6	1009.9	1077.2	1144.6	1211.9	1279.2	1346.5
20	373.	447.6	522.2	596.8	671.4	746.0	820.6	895.2	969.8	1044.4	1119.0	1193.6	1268.2	1342.8	1417.4	1492.0
21	411.2	493.5	575.7	658.0	740.2	822.5	904.7	987.0	1069.2	1151.5	1233.7	1315.9	1398.2	1480.4	1562.7	1644.9
22	451.3	541.6	631.9	722.1	812.4	902.7	992.9	1083.2	1173.5	1263.7	1354.0	1444.3	1534.5	1624.8	1715.1	1805.3
23	493.3	592.0	690.6	789.3	887.9	986.6	1085.2	1183.9	1282.6	1381.2	1479.9	1578.5	1677.2	1775.9	1874.5	1973.2
24	537.1	644.5	752.0	859.4	966.8	1074.2	1181.7	1289.1	1396.5	1503.9	1611.4	1718.8	1826.2	1933.6	2041.1	2148.5
25	582.8	699.4	815.9	932.5	1049.1	1165.6	1282.2	1398.7	1515.3	1631.9	1748.4	1865.0	1981.6	2098.1	2214.7	2321.2
26	630.4	756.5	882.5	1008.6	1134.7	1260.8	1386.8	1512.9	1639.	1765.1	1891.1	2017.2	2143.3	2269.4	2395.4	2521.5
27	679.8	815.8	951.7	1087.7	1223.6	1359.6	1495.6	1631.5	1767.5	1903.4	2039.4	2175.4	2311.3	2447.3	2583.2	2719.2
28	731.1	877.3	1023.5	1169.7	1316.0	1462.2	1608.7	1754.6	1900.8	2047.1	2193.3	2339.5	2485.7	2631.9	2778.1	2924.4
29	784.2	941.1	1097.9	1254.8	1411.6	1568.5	1725.3	1882.2	2039.0	2195.9	2352.7	2509.6	2668.4	2823.3	2980.1	3137.0
30	839.3	1007.1	1175.0	1342.8	1510.7	1678.5	1846.4	2014.2	2182.0	2343.9	2517.8	2685.6	2853.5	3021.3	3189.2	3357.0

Number of U. S. Gallons in Rectangular Tanks.

For One Foot in Depth.

Width in Feet.	Length of Tank in Feet.										
	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7
2	29.92	37.40	44.88	52.36	59.84	67.32	74.81	82.29	89.77	97.25	104.73
2.5	.....	46.75	56.10	65.45	74.80	84 16	93.51	102.86	112.21	121.56	130.91
3	.....	.....	67.32	78.54	89.77	100.99	112.21	123.43	134.65	145.87	157.09
3.5	.....	.....	.....	91.64	104.73	117.82	130.91	144.00	157.09	170.18	183.27
4	.....	.....	.....	.....	119.69	134.65	149.61	164.57	179.53	194.49	209.45
4.5	.....	.....	.....	.....	.....	151.48	168.31	185.14	201.97	218.80	235.63
5	.....	.....	.....	.....	.....	.....	187.01	205.71	224.41	243.11	261.82
5.5	.....	.....	.....	.....	.....	.....	.....	226.28	246.86	267.43	288.00
6	.....	.....	.....	.....	.....	.....	.....	.....	269.30	291.74	314.18
6.5	.....	.....	.....	.....	.....	.....	.....	.....	.....	316.05	340.36
7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	366.54

Width in Feet.	Length of Tank in Feet.									
	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12
2	112.21	119.69	127.17	134.65	142.13	149.61	157.09	164.57	172.05	179.53
2.5	140.26	149.61	158.96	168.31	177.66	187.01	196.36	205.71	215.06	224.41
3	168.31	179.53	190.75	202.97	213.19	224.41	235.63	246.86	258.07	269.30
3.5	196.36	209.45	222.54	235.63	248.73	261.82	274.90	288.00	301.09	314.18
4	224.41	239.37	254.34	269.30	284.26	299.22	314.18	329.14	344.10	359.06
4.5	252.47	269.30	286.13	302.96	319.79	336.62	353.45	370.28	387.11	403.94
5	280.52	299.22	317.92	336.62	355.32	374.03	392.72	411.43	430.13	448.83
5.5	308.57	329.14	349.71	370.28	390.85	411.43	432.00	452.57	473.14	493.71
6	336.62	359.06	381.50	403.94	426.39	448.83	471.27	493.71	516.15	538.59
6.5	364.67	388.98	413.30	437.60	461.92	486.23	510.54	534.85	559.16	583.47
7	392.72	418.91	445.09	471.27	497.45	523.64	549.81	575.99	602.18	628.36
7.5	420.78	448.83	476.88	504.93	532.98	561.04	589.08	617.14	645.19	673.24
8	.....	478.75	508 67	538.59	568.51	598.44	628.36	658.28	688.20	718.12
8.5	.....	.....	540.46	572.25	604.05	635.84	667.63	699.42	731.21	763.00
9	.....	.....	.....	605.92	639.58	673.25	706.90	740.56	774.23	807.89
9.5	.....	.....	.....	.....	675.11	710.65	746.17	781.71	817.24	852.77
10	.....	.....	.....	.....	.....	748.05	785.45	822.86	860.26	897.66
10.5	.....	.....	.....	.....	.....	.....	824.73	864.00	903.26	942.56
11	.....	.....	.....	.....	.....	.....	.....	905.14	946.27	987.43
11.5	.....	.....	.....	.....	.....	.....	.....	.....	989.29	1032.3
12	.....	.....	.....	.....	.....	.....	.....	.....	.....	1077.2

EXAMPLE.—To find number of gallons in a rectangular tank that is 7.5 ft. by 10 ft., the water being 4 ft. deep: Look in extreme left hand column for *7.5* and opposite to this in column headed "*10*" read 561.04, which being multiplied by 4, the depth of water in the tank, gives 2244.2 the number of gallons required.

Theoretical Discharge of Circular Orifices or Nozzles.—Diameters in Inches. (Ellis.)

NOTE.—The actual discharge will be less than the theoretical one given below, varying with the form of nozzle or tube through which the water flows. For a ring nozzle 64 per cent., and for a good form of tapering smooth nozzle about 82 per cent., can be assumed as the actual discharge.

HEAD.		Velocity of discharge in feet per second.	NUMBER OF UNITED STATES GALLONS OF 231 CUBIC INCHES DISCHARGED PER MINUTE.													
Lbs.	Feet.		1/16	1/8	3/16	1/4	3/8	1/2	5/8	3/4	7/8	1	1¼	1½	2	2½
10	23.1	38.58	0.37	1.48	3.30	5.90	13.2	23.6	36.8	53.2	72.2	94.4	148	212	378	590
15	34.7	47.25	0.45	1.81	4.02	7.23	16.2	28.7	45.0	65.1	88.4	116	181	260	463	723
20	46.2	54.55	0.52	2.09	4.66	8.35	18.7	33.4	52.0	75.3	102	134	209	300	534	835
25	57.8	60.99	0.58	2.33	5.23	9.33	20.9	37.2	58.2	84.1	114	149	233	336	597	933
30	69.3	66.82	0.64	2.56	5.71	10.2	22.8	40.9	63.7	92.2	125	164	256	368	654	1022
35	80.9	72.16	0.69	2.76	6.16	11.0	24.7	44.2	68.8	99.6	135	177	276	397	707	1104
40	92.4	77.14	0.74	2.95	6.60	11.8	26.4	47.2	73.6	106	144	189	295	425	755	1180
45	104.0	81.83	0.78	3.13	6.99	12.5	28.0	50.2	78.1	113	153	200	313	450	801	1252
50	115.5	86.26	0.82	3.30	7.37	13.2	29.5	52.8	82.3	119	161	211	330	475	845	1320
55	127.1	90.46	0.86	3.46	7.73	13.8	30.9	55.4	86.3	125	169	221	346	498	886	1385
60	138.6	94.49	0.90	3.62	8.08	14.5	32.3	57.8	90.1	130	177	231	362	520	925	1446
65	150.2	98.35	0.94	3.77	8.40	15.1	33.6	60.2	93.8	136	184	241	377	542	963	1506
70	161.7	102.06	0.97	3.91	8.73	15.6	34.9	62.5	97.4	141	191	250	391	562	999	1561
75	173.3	105.65	1.01	4.04	9.03	16.2	36.1	64.6	101	146	198	259	404	582	1034	1616
80	184.8	109.11	1.04	4.18	9.33	16.7	37.8	66.6	104	150	204	267	418	601	1068	1669
85	196.4	112.46	1.07	4.31	9.62	17.2	38.5	68.8	107	155	210	275	431	620	1101	1720
90	207.9	115.72	1.10	4.43	9.89	17.7	39.6	70.8	110	160	217	283	443	637	1133	1770
95	219.5	118.89	1.13	4.55	10.2	18.2	40.7	72.8	113	164	223	291	455	655	1164	1820
100	231.1	121.98	1.16	4.67	10.4	18.7	41.7	74.6	116	168	228	299	467	672	1194	1866
105	242.6	125.00	1.19	4.78	10.7	19.1	42.8	76.5	119	172	234	306	478	688	1224	1912
110	254.2	127.94	1.22	4.90	10.9	19.6	43.8	78.3	122	177	239	313	490	705	1253	1957
115	265.7	130.82	1.25	5.01	11.2	20.0	44.8	80.1	125	181	245	320	501	720	1281	2002
120	277.3	133.63	1.27	5.12	11.4	20.4	45.7	81.8	127	184	250	327	512	736	1308	2044
125	288.8	136.38	1.30	5.22	11.7	20.9	46.7	83.5	130	188	255	334	522	751	1335	2086
130	300.4	139.08	1.33	5.32	11.9	21.3	47.6	85.1	133	192	260	341	532	766	1362	2128

WATER-POWER.

(Kent's Pocket Book.)

Power of a Fall of Water—Efficiency.—The gross power of a fall of water is the product of the weight of water discharged in a unit of time into the total head, i. e., the difference of vertical elevation of the upper surface of the water at the points where the fall in question begins and ends. The term "head" used in connection with water-wheels is the difference in height from the surface of the water in the wheel-pit to the surface in the pen-stock when the wheel is running.

If Q = cubic feet of water discharged per second, D = weight of a cubic foot of water = 62.36 lbs. at 60° F., H = total head in feet; then

DQH = gross power in foot-pounds per second,

and $DQH \div 550 = 0.1134\ QH$ = gross horse power.

If Q' is taken in cubic feet per minute,

$$\text{H. P.} = \frac{Q'H \times 62.36}{33{,}000} = 0.00189Q'H.$$

A water-wheel or motor of any kind cannot utilize the whole of the head H, since there are losses of head at both the entrance to and the exit from the wheel. There are also losses of energy due to friction of the water in its passage through the wheel. The ratio of the power developed by the wheel to the gross power of the fall is the efficiency of the wheel. For 75% efficiency, net horse-power $= 0.00142Q'H = \frac{Q'H}{706}$

Horse-power of Water Flowing in a Tube.—The head due to the velocity is $\frac{v^2}{2g}$; the head due to the pressure is $\frac{f}{w}$; the head due to actual height above the datum plane is h feet. The total head is the sum of these $= \frac{v^2}{2g} + h + \frac{f}{w}$ in feet, in which $v =$ velocity in feet per second, $f =$ pressure in lbs. per sq. ft., $w =$ weight of 1 cu. ft. of water $= 62.4$ lbs. If $p =$ pressure in lbs. per sq. in., $\frac{f}{w} = 2.309p$. In hydraulic transmission the velocity and the height above datum are usually small compared with the pressure-head. The work or energy of a given quantity of water under pressure = its volume in cubic feet × its pressure in lbs. per sq. ft.; or if $Q =$ quantity in cubic feet per second, and $p =$ pressure in lbs. per square inch, $W = 144pQ$, and the H. P. $= \frac{144pQ}{550} = 0.2618pQ$.

Formula for Computing Power of Jet Water-Wheels of the Pelton Type. (F. K. Blue).

Let $HP =$ horse-power delivered by the water-wheel; $d =$ diameter of nozzle; $w =$ weight of one cu. ft. of water, or 62.5 lbs.; $E =$ efficiency of the water-wheel; $q =$ quantity of water in cubic feet per minute; $c =$ coefficient of discharge from the nozzle, which may be ordinarily taken as 0.9; $h =$ effective head (actual head less friction head) in feet; then

$$\mathrm{HP} = \frac{\mathrm{w\,E\,q\,h}}{33{,}000} = 0.00189\ \mathrm{E\,q\,h} = 0.00436\ \mathrm{E\,q\,p.} =$$

$$0.00496\ \mathrm{E\,c\,d^2}\sqrt{\mathrm{h}^3} = 0.0174\ \mathrm{E\,c\,d^2}\sqrt{\mathrm{p}^3}.$$

$$\mathrm{q} = 529\,\frac{\mathrm{HP}}{\mathrm{E\,h}} = 2.62\ \mathrm{c\,d^2}\sqrt{\mathrm{h}} = 4\ \mathrm{c\,d^2}\sqrt{\mathrm{p}^3}.$$

$$\mathrm{d} = 14.2\sqrt{\frac{\mathrm{HP}}{\mathrm{E\,c}\sqrt{\mathrm{h}^3}}} = 7.58\sqrt{\frac{\mathrm{HP}}{\mathrm{E\,c}\sqrt{\mathrm{p}^3}}} =$$

$$0.62\sqrt{\frac{\mathrm{q}}{\mathrm{c}\sqrt{\mathrm{h}}}} = \tfrac{1}{2}\sqrt{\frac{\mathrm{q}}{\mathrm{c}\sqrt{\mathrm{p}}}}.$$

The Pelton Water-wheel.—Mr. Ross E. Browne (*Eng'g News*, Feb. 20, 1892) thus outlines the principles upon which this water-wheel is constructed:

The function of a water-wheel, operated by a jet of water escaping from a nozzle, is to convert the energy of the jet, due to its velocity, into useful work. In order to utilize this energy fully the wheel-bucket, after catching the jet, must bring it to rest before discharging it, without inducing turbulence or agitation of the particles.

This cannot be fully effected, and unavoidable difficulties necessitate the loss of a portion of the energy. The principal losses occur as follows: First, in sharp or angular diversion of the jet in entering, or in its course through the bucket, causing impact, or the conversion of a portion of the energy into heat instead of useful work. Second, in the so-called frictional resistance offered to the motion of the water by the wetted surfaces of the buckets, causing also the conversion of a portion of the energy into heat instead of useful work. Third, in the velocity of the water, as it leaves the bucket, representing energy which has not been converted into work

Hence, in seeking a high efficiency: 1. The bucket-surface at the entrance should be approximately parallel to the relative course of the jet, and the bucket should be curved in such a manner as to avoid sharp angular deflection of the stream. If, for example, a jet strikes a surface at an angle and is sharply deflected, a portion of the water is backed, the smoothness of the stream is disturbed, and there results considerable loss by impact and otherwise. The entrance and deflection in the Pelton bucket are such as to avoid these losses in the main.

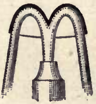


FIG. 134.

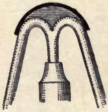


FIG. 135.

2. The number of buckets should be small, and the path of the jet in the bucket short; in other words, the total wetted surface should be small, as the loss by friction will be proportional to this.

3. The discharge end of the bucket should be as nearly tangential to the wheel periphery as compatible with the clearance of the bucket which follows; and great differences of velocity in the parts of the escaping water should be avoided. In order to bring the water to rest at the discharge end of the bucket, it is shown, mathematically, that the velocity of the bucket should be one half the velocity of the jet.

A bucket, such as shown in Fig. 135, will cause the heaping of more or less dead or turbulent water at the point indicated by dark shading. This dead water is subsequently thrown from the wheel with considerable velocity, and represents a large loss of energy. The introduction of the wedge in the Pelton bucket (see Fig. 134) is an efficient means of avoiding this loss.

A wheel of the form of the Pelton conforms closely in construction to each of these requirements.

In a test made by the proprietors of the Idaho mine, near Grass Valley, Cal., the dimensions and results were as follows: Main supply-pipe, 22 in. diameter, 6900 ft. long, with the head of 386½ feet above centre of nozzle. The loss by friction in the pipe was 1.8 ft., reducing the effective head to 384.7 ft. The Pelton wheel used in the test was 6 ft. in diameter and the nozzle was 1.89 in. diameter. The work done was measured by a Prony brake, and the mean of 13 tests showed a useful effect of 87.3%.

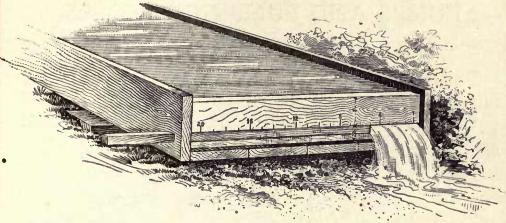


FIG. 136.

Miners' Inch Measurements. (Pelton Water Wheel Co.)

The cut, Fig. 136, shows the form of measuring-box ordinarily used, and the following table gives the discharge in cubic feet per minute of a miner's inch of water, as measured under the various heads and different lengths and heights of apertures used in California.

Length of Opening in inches.	Openings 2 Inches High.			Openings 4 Inches High.		
	Head to Centre 5 inches.	Head to Centre 6 inches.	Head to Centre 7 inches.	Head to Centre, 5 inches.	Head to Centre, 6 inches.	Head to Centre, 7 inches.
	Cu ft.	Cu ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.
4	1.348	1.473	1.589	1.320	1.450	1.570
6	1.355	1.480	1.596	1.336	1.470	1.595
8	1.359	1.484	1.600	1.344	1.481	1.608
10	1.361	1.485	1.602	1.349	1.487	1.615
12	1.363	1.487	1.604	1.352	1.491	1.620
14	1.364	1.488	1.604	1.354	1.494	1.623
16	1.365	1.489	1.605	1.356	1.496	1.626
18	1.365	1.489	1.606	1.357	1.498	1.628
20	1.365	1.490	1·606	1.359	1.499	1.630
22	1.366	1.490	1.607	1.359	1.500	1.631
24	1.366	1.490	1.607	1.360	1.501	1.632
26	1.366	1.490	1.607	1.361	1.502	1.633
28	1.367	1.491	1.607	1.361	1.503	1.634
30	1.367	1.491	1.608	1.362	1.503	1.635
40	1.367	1.492	1.608	1.363	1.505	1.637
50	1.368	1.493	1.609	1.364	1.507	1.639
60	1.368	1.493	1.609	1.365	1.508	1.640
70	1.368	1.493	1.609	1.365	1.508	1.641
80	1.368	1.493	1.609	1.366	1.509	1.641
90	1.369	1.493	1.610	1.366	1.509	1.641
100	1.369	1.494	1.610	1.366	1.509	1.642

PUMPS AND PUMPING ENGINES.

(Kent's Pocket Book.)

Theoretical Capacity of a Pump.—Let $Q' =$ cu. ft. per min.; $G' =$ Amer. gals. per min. $= 7.4805Q'$; $d =$ diam. of pump in inches; $l =$ stroke in inches; $N =$ number of single strokes per min.

Capacity in cu. ft. per min.

$$Q' = \frac{\pi}{4} \cdot \frac{d^2}{144} \cdot \frac{lN}{12} = 0.0004545Nd^2l;$$

Capacity in gals. per min.

$$G' = \frac{\pi}{4} \cdot \frac{Nd^2l}{231} = 0.0034Nd^2l;$$

Diameter required for a given capacity per min.

$$d = 46.9\sqrt{\frac{Q'}{Nl}} = 17.15\sqrt{\frac{G'}{Nl}}.$$

If $v =$ piston speed in feet per min.,

$$d = 13.54\sqrt{\frac{Q'}{v}} = 4.95\sqrt{\frac{G'}{v}}$$

If the piston speed is 100 feet per min.:

$$Nl = 1200, \text{ and } d = 1.354\sqrt{Q'} = 0.495\sqrt{G'};$$

$$G' = 4.08d^2 \text{ per min.}$$

The actual capacity will be from 60% to 95% of the theoretical, according to the tightness of the piston, valves, suction-pipe, etc.

Theoretical Horse-power required to raise Water to a given Height.

Let $Q' =$ cu. ft. per min.; $G' =$ gals. per min.; $W =$ wt. in lbs.; $P =$ pressure in lbs. per sq. ft.; $p =$ pressure in lbs. per sq. in.; $H =$ height of lift in ft.; $W = 62.36Q'$, $P = 144p$, $p = 0.433\,H$, $H = 2.309p$, $G' = 7.4805Q'$.

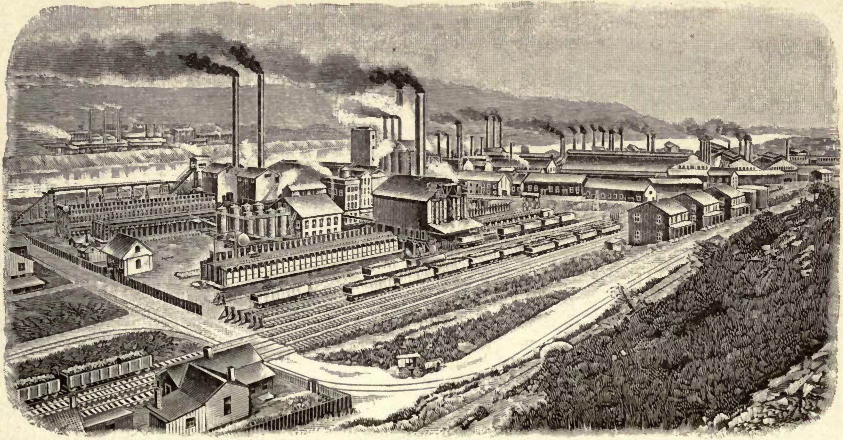
$$HP = \frac{Q'P}{33{,}000} = \frac{Q'H \times 144 \times .433}{33{,}000} = \frac{Q'H}{529.2} = \frac{G'H}{3958.7};$$

$$HP = \frac{WH}{33{,}000} = \frac{Q' \times 62.36 \times 2.309p}{33{,}000} = \frac{Q'p}{229.2} = \frac{G'p}{1714.5}.$$

For the actual horse-power required an allowance must be made for the friction, slips, etc., of engine, pump, valves, and passages.

Depth of Suction.—Theoretically a perfect pump will lift water from a depth of nearly 34 feet, corresponding to a perfect vacuum (14.7 lbs. $\times$ 2.309 $=$ 33.95 feet); but since a perfect vacuum cannot be obtained, on account of valve-leakage, air contained in the water, and the vapor of the water itself, the actual height is generally less than 30 feet. In pumping hot water, the water must flow into the pump by gravity. The following table shows the theoretical maximum depth of suction for different temperatures, leakage not considered :

Temp. F.	Absolute Pressure of Vapor, lbs. per. sq. in.	Vacuum in Inches of Mercury.	Max. Depth of Suction, feet.	Temp. F.	Absolute Pressure of Vapor, lbs per sq. in.	Vacuum in Inches of Mercury.	Max. Depth of Suction, feet.
101.4	1	27.88	31.6	183.0	8	13.63	15.5
126.2	2	25.85	29.3	188.4	9	11.59	13.2
144.7	3	23.81	27.0	193.2	10	9.55	10.9
153.3	4	21.77	24.7	197.6	11	7.51	8.5
162.5	5	19.74	22.4	201.9	12	5.48	6.2
170.3	6	17.70	20.1	205.8	13	3.44	3.9
177.0	7	15.66	17.8	209.6	14	1.40	1.6



RIVERSIDE DEPARTMENT, WHEELING, W. VA.

STEAM

AND

STEAM APPARATUS.

STEAM.

Under the ordinary atmospheric pressure of 14.7 pounds per square inch, water boils at 212° Fahr., passing off as steam, the temperature at which it boils varying with a variation in the pressure.

Dry steam is steam not containing any free moisture. It may be either saturated or superheated.

Wet steam is steam containing free moisture in the form of spray or mist, and has the same temperature as dry saturated steam of the same pressure.

Saturated steam is steam in its normal state, that is, steam whose temperature is that due its pressure; by which is meant steam at the same temperature as that of the water from which it was generated and upon which it rests.

Superheated steam is steam at a temperature above that due to its pressure.

A British thermal unit is the quantity of heat required to raise one pound of water at 39°.1 Fahr. through one degree of temperature.

The total heat of the water is the number of British thermal units needed to raise one pound of water from 32°F. to the boiling point, under the given pressure.

The latent heat of steam is the number of British thermal units required to convert one pound of water, at the boiling point, into steam of the same temperature.

The total heat of saturated steam is the number of heat units required to raise a pound of water from 32°F. to the boiling point, at the given pressure, plus the number required to evaporate the water at that temperature.

The specific heat of steam is the quantity of heat required to raise the temperature of one pound of steam through one degree of temperature. In British units and near the saturation temperature it equals, at constant pressure, 0.48.

The specific gravity of steam at any temperature and pressure, as compared with air of same temperature and pressure, is approximately 0.622. One cubic inch of water evaporated into steam at 212°F. becomes 1646 cubic in., that is, nearly one cu. ft.

Water in contact with saturated steam has the same temperature as the steam itself. Water introduced into superheated steam will be vaporized until the steam becomes saturated, and its temperature becomes that due its pressure. Cold water, or water at a lower temperature than that of the steam, introduced into saturated steam, will condense some of it, thus lowering both the temperature and pressure of the rest until the temperature again equals that due its pressure.

PROPERTIES OF SATURATED STEAM.

Pressure lbs. per sq. in. absolute.	Temperature in degrees Fahr.	Heat in liquid from 32°, B. T. U.	Latent Heat, B. T. U.	Total Heat from water at 32°. B. T. U.	Weight of one cubic ft. in lbs.	Volume of one lb. in cubic feet
1	101.99	70.0	1043.0	1113.1	0.00299	334.5
2	126.27	94.4	1026.1	1120.5	0.00576	173.6
3	141.62	109.8	1015.3	1125.1	0.00844	118.5
4	153.09	121.4	1007.2	1128.6	0.01107	90.33
5	162.34	130.7	1000.8	1131.5	0.01366	73.21
6	170.14	138.6	995.2	1133 8	0.01622	61.65
7	176.90	145.4	990.5	1135.9	0.01874	53.39
8	182.92	151.5	986.2	1137.7	0.02125	47.06
9	188.33	156.9	982.5	1139.4	0.02374	42.12
10	193.25	161.9	979.0	1140.9	0.02621	38.15
15	213.03	181.8	965.1	1146.9	0.03826	26.14
20	227.95	196.9	954.6	1151.5	0.05023	19.91
25	240.04	209.1	946.0	1155.1	0.06199	16.13
30	250.27	219.4	938.9	1158.3	0.07360	13.59
35	259.19	228.4	932.6	1161.0	0.08508	11.75
40	267.13	236.4	927.0	1163.4	0.09644	10.37
45	274.29	243.6	922.0	1165.6	0.1077	9.285
50	280.85	250.2	917.4	1167.6	0.1188	8.418
55	286.89	256.3	913.1	1169.4	0.1299	7.698
60	292.51	261.9	909.3	1171.2	0.1409	7.097
65	297.77	267.2	905.5	1172.7	0.1519	6.583
70	302.71	272.2	902.1	1174.3	0.1628	6.143
75	307.38	276.9	898.8	1175.7	0.1736	5.760
80	311.80	281.4	895.6	1177.0	0.1843	5.426
85	316.02	285.8	892.5	1178.3	0.1951	5.126
90	320.04	290.0	889.6	1179.6	0.2058	4.859
95	323.89	294.0	886.7	1180.7	0.2165	4.619
100	327.58	297.9	884.0	1181.9	0.2271	4.403
105	331.13	301.6	881.3	1182.9	0.2378	4.205
110	334.56	305.2	878.8	1184.0	0.2484	4.026
115	337.86	308.7	876.3	1185.0	0.2589	3.862
120	341.05	312.0	874.0	1186.0	0.2695	3.711
125	344.13	315.2	871.7	1186.9	0.2800	3.571
130	347.12	318.4	869.4	1187.8	0.2904	3.444
140	352.85	324.4	865.1	1189.5	0.3113	3.212
150	358.26	330.0	861.2	1191.2	0.3321	3.011
160	363.40	335.4	857.4	1192.8	0.3530	2.833
170	368.29	340.5	853.8	1194.3	0.3737	2.676
180	372.97	345.4	850.3	1195.7	0.3945	2.535
190	377.44	350.1	847.0	1197.1	0.4153	2.408
200	381.73	354.6	843.8	1198.4	0.4359	2.294
225	391.79	365.1	836.3	1201.4	0.4876	2.051
250	400.99	374.7	829.5	1204.2	0.5393	1.854
275	409.50	383.6	823.2	1206.8	0.5913	1 691
300	417.42	391.9	817.4	1209.3	0.644	1.553
325	424.82	399.6	811.9	1211.5	0.696	1.437
350	431.90	406.9	806.8	1213.7	0.748	1.337
375	438.40	414.2	801.5	1215.7	0.800	1.250
400	445.15	421.4	796.3	1217.7	0.853	1.172
500	466.57	444.3	779.9	1224.2	1.065	0.939

The absolute pressures given in column one may be converted into gauge pressures by subtracting the constant 14.7: Thus, 115 lbs., absolute = 115 — 14.7 = 100.3 lbs. gauge.

FACTORS OF EVAPORATION.

Temperature Feed-Water, Fahrenheit.	STEAM PRESSURE IN POUNDS PER SQUARE INCH, GAUGE.									
	0.	5.	15.	25.	35.	45.	55.	65.	75.	85.
Dgrs.										
32	1.187	1.192	1.199	1.204	1.209	1.212	1.216	1.218	1.221	1.223
35	1.184	1.189	1.196	1.201	1.206	1.209	1.213	1.215	1.218	1.220
40	1.179	1.184	1.191	1.196	1.201	1.204	1.208	1.219	1.213	1.215
45	1.173	1.178	1.185	1.190	1.195	1.198	1.202	1.204	1.207	1.209
50	1.168	1.173	1.180	1.185	1.190	1.193	1.197	1.199	1.202	1.204
55	1.163	1.168	1.175	1.180	1.185	1.188	1.192	1.194	1.197	1.199
60	1.158	1.163	1.170	1.175	1.180	1.183	1.187	1.189	1.192	1.194
65	1.153	1.158	1.165	1.170	1.175	1.178	1.182	1.184	1.187	1.189
70	1.148	1.153	1.160	1.165	1.170	1.173	1.177	1.179	1.182	1.184
75	1.143	1.148	1.155	1.160	1.165	1.168	1.172	1.174	1.177	1.179
80	1.137	1.142	1.149	1.154	1.159	1.162	1.166	1.168	1.171	1.173
85	1.132	1.137	1.144	1.149	1.154	1.157	1.161	1.163	1.166	1.168
90	1.127	1.132	1.139	1.144	1.149	1.152	1.156	1.158	1.161	1.163
95	1.122	1.127	1.134	1.139	1.144	1.147	1.151	1.153	1.156	1.158
100	1.117	1.122	1.129	1.134	1.139	1.142	1.146	1.148	1.151	1.153
105	1.111	1.116	1.123	1.128	1.133	1.136	1.140	1.142	1.145	1.147
110	1.106	1.111	1.118	1.123	1.128	1.131	1.135	1.137	1.140	1.142
115	1.101	1.106	1.113	1.118	1.123	1.126	1.130	1.132	1.135	1.137
120	1.096	1.101	1.108	1.113	1.118	1.121	1.125	1.127	1.130	1.132
125	1.091	1.096	1.103	1.108	1.113	1.116	1.120	1.122	1.125	1.127
130	1.085	1.090	1.097	1.102	1.107	1.110	1.114	1.116	1.119	1.121
135	1.080	1.085	1.092	1.097	1.102	1.105	1.109	1.111	1.114	1.116
140	1.075	1.080	1.087	1.092	1.097	1.100	1.104	1.106	1.109	1.111
145	1.070	1.075	1.082	1.087	1.092	1.095	1.099	1.101	1.104	1.106
150	1.065	1.070	1.077	1.082	1.087	1.090	1.094	1.096	1.099	1.101
155	1.059	1.064	1.071	1.076	1.081	1.084	1.088	1.090	1.094	1.095
160	1.054	1.059	1.066	1.071	1.076	1.079	1.083	1.085	1.088	1.090
165	1.049	1.054	1.061	1.066	1.071	1.074	1.078	1.080	1.083	1.085
170	1.044	1.049	1.056	1.061	1.066	1.069	1.073	1.075	1.078	1.080
175	1.039	1.044	1.051	1.056	1.061	1.064	1.068	1.070	1.073	1.075
180	1.033	1.038	1.045	1.050	1.055	1.058	1.062	1.064	1.067	1.069
185	1.028	1.033	1.040	1.045	1.050	1.053	1.057	1.059	1.062	1.064
190	1.023	1.028	1.035	1.040	1.045	1.048	1.052	1.054	1.057	1.059
195	1.018	1.023	1.030	1.035	1.040	1.043	1.047	1.049	1.052	1.054
200	1.013	1.018	1.025	1.030	1.035	1.038	1.042	1.044	1.047	1.049
205	1.007	1.012	1.019	1.024	1.029	1.032	1.036	1.038	1.041	1.043
210	1.002	1.007	1.014	1.019	1.024	1.027	1.031	1.033	1.036	1.038
212	1.000	1.005	1.012	1.017	1.022	1.025	1.029	1.031	1.034	1.036

FACTORS OF EVAPORATION.

Temperature Feed-Water, Fahrenheit.	STEAM PRESSURE IN POUNDS PER SQUARE INCH, GAUGE.									
	95.	105.	115.	125.	135.	145.	155.	165.	175.	185.
Dgrs.										
32	1.226	1.228	1.230	1.231	1.233	1.235	1.236	1.238	1.239	1.240
35	1.223	1.225	1.227	1.228	1.230	1.232	1.233	1.235	1.236	1.237
40	1.218	1.220	1.222	1.223	1.225	1.227	1.228	1.230	1.231	1.232
45	1.212	1.214	1.216	1.217	1.219	1.221	1.222	1.224	1.225	1 226
50	1.207	1.209	1.211	1.212	1.214	1.216	1.217	1.219	1.220	1.221
55	1.202	1.204	1.206	1.207	1.209	1.211	1.212	1.214	1.215	1.216
60	1.197	1.199	1.201	1.202	1.204	1.206	1.207	1.209	1.210	1.211
65	1.192	1.194	1.196	1.197	1.199	1.201	1.202	1.204	1.205	1.206
70	1.187	1.189	1.191	1.192	1.194	1.196	1.197	1.199	1.200	1.201
75	1.182	1.184	1.186	1.187	1.189	1.191	1.192	1.194	1.195	1.196
80	1.176	1.178	1.180	1.181	1.183	1.185	1.186	1.188	1.189	1.190
85	1.171	1.173	1.175	1.176	1.178	1.180	1.181	1.183	1.184	1.185
90	1.166	1.168	1.170	1.171	1.173	1.175	1.176	1.178	1.179	1.180
95	1.161	1.163	1.165	1.166	1.168	1.170	1.171	1.173	1.174	1.175
100	1.156	1.158	1.160	1.161	1.163	1.165	1.166	1.168	1.169	1.170
105	1.150	1.152	1.154	1.155	1.157	1.159	1.160	1.162	1.163	1.164
110	1.145	1.147	1.149	1.150	1.152	1.154	1.155	1.157	1.158	1.159
115	1.140	1.142	1.144	1.145	1.147	1.149	1.150	1.152	1.153	1.154
120	1.135	1.137	1.139	1.140	1.142	1.144	1.145	1.147	1.148	1.149
125	1.130	1.132	1.134	1.135	1.137	1.139	1.140	1.142	1.143	1.144
130	1.124	1.126	1.128	1.129	1.131	1.133	1.134	1.136	1.137	1.138
135	1.119	1.121	1.123	1.124	1.126	1.128	1.129	1.131	1.132	1.133
140	1.114	1.116	1.118	1.119	1.121	1.123	1.124	1.126	1.127	1.128
145	1.109	1.111	1.113	1.114	1.116	1.118	1.119	1.121	1.122	1.123
150	1.104	1.106	1.108	1.109	1.111	1.113	1.114	1.116	1.117	1.118
155	1.098	1.100	1.102	1.103	1.105	1.107	1.108	1.110	1.111	1.112
160	1.093	1.095	1.097	1.098	1.100	1.102	1.103	1.105	1.106	1.107
165	1.088	1.090	1.092	1.093	1.095	1.097	1.098	1.100	1.101	1.102
170	1.083	1.085	1.087	1.088	1.090	1.092	1.093	1.095	1.096	1.097
175	1.078	1.080	1.082	1.083	1.085	1.087	1.088	1.090	1.091	1.092
180	1.072	1.074	1.076	1.077	1.079	1.081	1.082	1.084	1.085	1.086
185	1.067	1.069	1.071	1.073	1.074	1.076	1.077	1.079	1.080	1.081
190	1.062	1.064	1.066	1.067	1.069	1.071	1.072	1.074	1.075	1.076
195	1.057	1.059	1.061	1.062	1.064	1.066	1.066	1.069	1.070	1.071
200	1.052	1.054	1.056	1.057	1.059	1.061	1.062	1.064	1.065	1.066
205	1.046	1.048	1.050	1.051	1.053	1.055	1.056	1.058	1.059	1.060
210	1.041	1.043	1.045	1.046	1.048	1.050	1.051	1.053	1.054	1.055
212	1.039	1.041	1.043	1.044	1.046	1.048	1.049	1.051	1.052	1.053

Explanation of Table of Properties of Saturated Steam: The first column shows the absolute pressure of steam as it rises freely from water of the same temperature, and is equal to 14.7 lbs. + the pressure shown by the steam gauge.

The second column shows the temperatures in degrees Fahrenheit at which water vaporizes under the pressures opposite in column one.

The third column shows the number of British thermal units required to raise one pound of water from 32°F. to the boiling temperatures opposite in column two.

The fourth column shows the number of heat units that are absorbed, or changed from sensible to latent heat, when one pound of water at the boiling point changes to steam of the same temperature.

The fifth column shows the number of heat units absorbed when one pound of water at 32°F. has its temperature raised to the boiling point and is then changed to steam at constant pressure and temperature. This column gives the total heat of formation of steam from water at 32°F.

The sixth column shows the weights in pounds per cubic ft. of saturated steam at the corresponding pressures and temperatures given in columns one and two.

The seventh column shows volumes in cubic ft. of one pound of steam.

Explanation of Table of Factors of Evaporation: The factors in this table were obtained, for the various feed-water temperatures and steam pressures given, by subtracting the heat above 32°F. in one pound of feed-water from the total heat above 32° in one pound of steam, and then dividing the remainder thus obtained by 965.7, the latent heat of steam at atmospheric pressure.

Example:—Given the boiler pressure = 105 lbs. per square in. guage, and the feed-water temperature = 55°F.; to find the factor of evaporation. Look in the column or steam pressures headed 105 and opposite to 55 degrees in the first column, read 1.204, the factor required. It will therefore require 1.204 times as many heat units to evaporate a certain weight of water from a feed-water temperature of 55°F. into steam under 105 pounds guage as would be required to evaporate the same weight of water from a temperature of 212°F. into steam under one atmospheric pressure. that is, **from and at 212°F.**

This table is useful in rating boilers and in preparing reports of tests.

FLOW OF STEAM FROM ORIFICES.

The flow of steam from a vessel of one pressure into that of another pressure becomes greater the greater the difference in pressure between the two vessels, until the lower is 0.58 the absolute pressure of the higher. Any further reduction of the pressure in the second vessel, even down to a vacuum, fails to enhance the flow of the steam between the two. In flowing through the best shaped nozzle the steam expands to the external pressure and also to the volume corresponding to this pressure, so long as it is not less than 58 per cent. of the internal pressure. For an external pressure of 58 per cent. or less, the ratio of expansion becomes constant and is 1.624.

OUTFLOW OF STEAM INTO THE ATMOSPHERE.

(D. K. CLARK.)

Initial Pressure.	External Pressure.	Expansion in nozzle.	Velocity of outflow at constant density.	Actual velocity of outflow expanded.	Discharge
Lbs. per sq. in. absolute.	Lbs. per sq. in. absolute.	Ratio.	Ft. per sec.	Ft. per sec.	Lbs. per sq. in. per minute.
25.37	14.7	1.624	863	1401	22.81
30	14.7	1.624	867	1408	26.84
40	14.7	1.624	874	1419	35.18
45	14.7	1.624	877	1424	39.78
50	14.7	1.624	880	1429	44.06
60	14.7	1.624	885	1437	52.59
70	14.7	1.624	889	1444	61.07
75	14.7	1.624	891	1447	65.30
90	14.7	1.624	895	1454	77.94
100	14.7	1.624	898	1459	86.34
115	14.7	1.624	902	1466	98.76
135	14.7	1.624	906	1472	115.61
155	14.7	1.624	910	1478	132.21
165	14.7	1.624	912	1481	140.46
215	14.7	1.624	919	1493	181.58

The weight of steam discharged from a cylindrical nozzle or a short pipe may be approximately found, when the pressure of the atmosphere receiving the steam is less than 58 per cent. of the initial pressure, by the following formula (Napier's Rule): $W = a\ p \div 70$; in which W = flow in pounds per second, a = area of orifice in square inches; and p = absolute initial pressure per square inch of the steam.

For a circular opening in a thin plate multiply the discharge as obtained from the above formula by 0.65.

FLOW OF STEAM IN PIPES.

(KENT'S POCKET BOOK).

A formula commonly used for velocity of flow of steam in pipes is the same as Downing's for the flow of water in smooth cast iron pipes, viz.:

$$V = 50\sqrt{\frac{H}{L} D},$$

in which V = velocity in feet per second, L = length, and D = diameter of pipe in feet, H = height in feet of a column of steam, of the pressure of the steam at the entrance, which would produce a pressure equal to the difference of pressures at the two ends of the pipe. (For derivation of the coefficient 50, see Briggs on "Warming Buildings by Steam," Proc. Inst. C. E., 1882.)

If Q = quantity in cubic ft. per minute, d = diameter in inches, L and H being in feet, the formula reduces to

$$Q = 4.723 \sqrt{\frac{H}{L} d^5}, \quad H = 0.448 \frac{Q^2 L}{d^5}, \quad d = 0.537 \sqrt[5]{\frac{Q^2 L}{H}}.$$

If p_1 = pressure in pounds per sq. in. of the steam at the entrance to the pipe, p^2 = the pressure at the exit, then $144\,(p_1 - p_2)$ = difference in pressure per sq. ft. Let w = density or weight per cu. ft. of steam at the pressure p_1, then the height of column equivalent to the difference in pressures is

$$H = \frac{144\,(p_1 - p_2)}{w} \text{ and } Q = 60 \times 0.7854 \times 50 D^2 \sqrt{\frac{144\,(p_1 - p_2) D}{w L}}.$$

If W = weight of steam flowing in pounds per minute $= Qw$ and d is taken in inches, L being in feet:

$$W = 56.68 \sqrt{\frac{w\,(p_1 - p_2)\,d^5}{L}}\,; \quad Q = 56.68 \sqrt{\frac{(p_1 - p_2)\,d^5}{L\,w}}\,;$$

$$d = 0.199 \sqrt[5]{\frac{W^2 L}{w\,(p_1 - p_2)}} = 0.199 \sqrt[5]{\frac{Q^2\,w\,L}{p_1 - p_2}}.$$

Velocity in feet per minute $= V = Q \div 0.7854 \frac{d^2}{144}$ $= 10390 \sqrt{\frac{(p_1 - p_2)\,d.}{w\,L}}$

For a velocity of 6000 feet per minute, $d = \frac{w\ L}{3(p_1 - p_2)}$; $p_1 - p_2 = \frac{w\ L}{3\ d}$.

For a velocity of 6000 feet per minute, a steam pressure of 100 pounds gauge, or W=0.264, and a length of 100 feet.

$$d = \frac{8.8}{p_1 - p_2};\quad p_1 - p_2 = \frac{8.8}{d}.$$

That is, a pipe 1 inch diameter, 100 feet long, carrying steam of 100 pounds gauge pressure at 6000 feet velocity per minute, would have a loss of pressure of 8.8 pounds per sq. inch, while steam traveling at the same velocity in a pipe 8.8 inches diameter would lose only 1 pound pressure.

G. H. Babcock in "Steam," gives the formula

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

One of the most widely accepted formulae for flow of water is D'Arcy's, which is

$$V = c\sqrt{\frac{H\ D}{L\ 4}}.$$

Using D'Arcy's coefficients, and modifying his formula to make it apply to steam, to the form

$$Q = c\sqrt{\frac{(p_1 - p_2)\ d^5}{w\ L}};\quad \text{or}\quad W = c\sqrt{\frac{w\,(p_1 - p_2)\,d^5}{L}},$$

we obtain for,

Diam. in.	1	2	3	4	5	6	7	8
Value of c,	45.3	52.7	56.1	57.8	58.4	59.5	60.1	60.7
Diam. in.	9	10	12	14	16	18	20	24
Value of c,	61.2	61.8	62.1	62.3	62.6	62.7	62.9	63.2

In the absence of direct experiments these coefficients are probably as accurate as any that may be derived from formulae for flow of water.

Loss of pressure in lbs. per sq. in. $= p_1 - p_2 = \frac{Q^2\ w\ L}{c^2\ d^5}$.

RESISTANCE TO FLOW BY BENDS, VALVES, ETC.

Mr. Briggs states that in "Warming Buildings by Steam," that the resistance at the entrance to a pipe consists of two parts, namely: the head $\frac{v^2}{2g}$, which is necessary to create the velocity of flow, and the head $0.505\frac{v^2}{2g}$, which overcomes the resistance to entrance offered by the mouth of the pipe. The total loss of head at entrance then equals the sum of these, or $1.505\frac{v^2}{2g}$, in which V = velocity of flow of steam in the pipe, in feet per second, and g = acceleration due to gravity, or 32.2.

The Babcock & Wilcox Co. state in "Steam" that the resistance at the opening, and that at a globe valve, are each about the same as that caused by an additional length of straight pipe, as computed by the formula,

$$\text{Additional length of pipe} = \frac{114 \times \text{diameter of pipe}}{1 + (3.6 \div \text{diameter})},$$

from which has been computed the following table:

Diameter in inches	2	2½	3	3½	4	5	6	7
Additional length, feet	7	10	13	16	20	28	36	44
Diameter in inches	8	10	12	15	18	20	22	24
Additional length, feet	53	70	88	115	143	162	181	200

The resistance to flow at a right-angled elbow is about equal to ⅔ that of a globe valve.

The above values are to be considered as being only approximations to the truth.

Example.—Find the discharge from a steam pipe when the given length = 120 feet and the diameter = 8 inches; the pipe containing 6 right-angled elbows and two globe valves, the pressure at the two ends being respectively 105 and 103 lbs. per sq. in. gauge.

The resistance to entrance, from the above table, for 8 inch pipe = 53 feet; the resistance of 6 elbows = $6 \times 53 \times \frac{2}{3}$ = 212 feet; the resistance of two globe valves = 2×53 = 106 feet; making a total resistance = 53 + 212 + 106 = 371 feet of additional length of pipe. Therefore, the steam would encounter the same resistance flowing through a straight 8-inch pipe, whose length equals 120 + 371, or 491 feet, as it would in flowing through the given pipe with its various resistances.

Then in the formula $W = c\sqrt{\frac{w\,(p_1 - p_2)\,d^5}{L}}$,

$L = 491$ feet; $p_1 = 105$ lbs. per sq. in.; $p_2 = 103$ lbs. per sq. in.; $d = 8$ inches; c, for an 8-inch pipe = 60.7; and w, from table of Properties of Saturated Steam, = 0.27

Substituting in formula we get

$$W = 60.7\sqrt{\frac{0.27\,(105-103)\,8^5}{491}} = 364.$$

The pipe, then, under the stated conditions, would discharge approximately 364 pounds of steam per minute, or 21,800 lbs. per hour; which, on the basis of 30 lbs. per horse-power hour, would have a capacity of 728 boiler horse-power. Since one pound of steam at 104 lbs. gauge has a volume of 3.7 cu. ft., the pipe would discharge 1,350 cu.ft. per minute, or 81,000 cu. ft. per hour.

TABLE OF EQUATION OF PIPES.—Standard Steam and Gas Pipes.—(BABCOX & WILCOX).

Dia.	½	¾	1	1½	2	2½	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Dia.
½		2.27	4.88	15.8	31.7	52.9	96.9	205	377	620	918	1,292	1,767	2,488	3,014	3,786	4,904	5,927	7,321	8,535	9,717	½
¾	2.60		2.05	6.97	14.0	23.3	42.5	90.4	166	273	405	569	779	1,096	1,328	1,668	2,161	2,615	3,226	3,761	4,282	¾
1	7.55	2.90		3.45	6.82	11.4	20.9	44.1	81.1	133	198	278	380	536	649	815	1,070	1,263	1,576	1,837	2,092	1
1½	24.2	9.30	3.20		1.26	3.34	6.13	13.0	23.8	39.2	58.1	81.7	112	157	190	239	310	375	463	539	614	1½
2	54.8	21.0	7.25	2.26		1.67	3.06	6.47	11.9	19.6	29.0	40.8	55.8	78.5	95.1	119	155	187	231	269	307	2
2½	102	39.4	13.6	4.23	1.87		1.83	3.87	7.12	11.7	17.4	24.4	33 4	47.0	56.9	71.5	92.6	112	138	161	184	2½
3	170	65.4	22.6	7.03	3.11	1.66		2.12	3.89	6.39	9.48	13.3	20.9	23.7	31.2	39.1	50.6	61.1	75.5	88.0	100	3
4	376	144	49.8	15.5	6.87	3.67	2.21		1.84	3.02	4.48	6.30	8.61	12.1	14.7	18.5	23.9	28.9	35.7	41.6	47.4	4
5	686	263	90.9	28.3	12.5	6.70	4.03	1.83		1.65	2.44	3.43	4.69	6 60	8.00	10.0	13.0	15.7	19.4	22.6	25.8	5
6	1,116	429	148	46.0	20.4	10.9	6.56	2.97	1.63		1.48	2.09	2.85	4 02	4.86	6.11	7.91	9.56	11.8	13.8	15.6	6
7	1,707	656	226	70.5	31.2	16.6	10.0	4.54	2.49	1.51		1.41	1.93	2.71	3.28	4.12	5.34	6.45	7.97	9.31	10.6	7
8	2,435	936	322	101	44.5	23.8	14.3	6.48	3.54	2.18	1.43		1.35	1.93	2.33	2.92	3.79	4.57	5.67	6.60	7.52	8
9	3,335	1,281	440	137	60.8	32.5	19.5	8.85	4.85	2.98	1.95	1.37		1.41	1.71	2.14	2.77	3.35	4.14	4.83	5.50	9
10	4,393	1,688	582	181	80.4	42.9	25.8	11.7	6.40	3.93	2.57	1.80	1.32		1.21	1.52	1.97	2.38	2.94	3.43	3.91	10
11	5,642	2,168	747	233	103	55.1	33.1	15.0	8.22	5.05	3.31	2.32	1.70	1.28		1.26	1.63	1.88	2.43	2.83	3.22	11
12	7,087	2,723	938	293	129	69.2	41.6	18.8	10.3	6.34	4.15	2.91	2 13	1.61	1.26		1.30	1.57	1.93	2.26	2.58	12
13	8,657	3,326	1,146	358	158	84.5	50.7	23.0	12.6	7.75	5.07	3.56	2.60	1.98	1.53	1.22		1.21	1.49	1.74	1.98	13
14	10,600	4,070	1,403	438	193	103	62.2	28.2	15.4	9.48	6.21	4 35	3.18	2.41	1.88	1.50	1.22		1.24	1.44	1.64	14
15	12,824	4,927	1,698	530	234	125	75.3	34.1	18.7	11.5	7.52	5.27	3.85	2.92	2.27	1.81	1.48	1.21		1.17	1.35	15
16	14,978	5,758	1,984	619	274	146	88.0	39.9	21.8	13.4	8.78	6.15	4.51	3 41	2.66	2.12	1.73	1.42	1.18		1.14	16
17	17,537	6,738	2,322	724	320	171	103	46.6	25.6	15.7	10.3	7.20	5.27	3.99	3.11	2.47	2.03	1.66	1.37	1.17		
18	20,327	7,810	2,691	840	371	198	119	54.1	29.6	18.2	11.9	8.35	6.11	4.63	3.60	2.87	2.35	1.92	1.59	1.36	1.16	
20	26,676	10,249	3,532	1,102	487	260	157	70.9	38.9	23.9	15.6	10.9	8.02	6.07	4.73	3.76	3.08	2.52	2.08	1.78	1.52	
24	42,624	16,376	5,644	1,761	778	416	250	113	62.1	38.2	25.0	17.5	12 8	9.70	7.55	6.01	4.92	4.02	3.32	2.84	2.43	
30	75,453	28,990	9,990	3,117	1,378	736	443	201	110	67.6	44.2	31.0	22.7	17.2	13.4	10.7	8.72	7.14	5.88	5.03	4.30	
36	120,100	46,143	15,902	4,961	2,193	1,172	705	319	175	108	70.4	49.3	36 1	27.3	21.3	16.9	13 9	11.3	9.37	8.01	6.85	
42	177,724	68,282	23,531	7,341	3,245	1,734	1,044	473	259	159	104	73.0	53.4	40.5	31.5	25.1	20.5	16.8	13.9	11.9	10.1	
48	249,351	95,818	33,020	10,301	4,554	2,434	1,465	663	363	223	146	102	75.0	56 8	44.2	35.2	28.8	23.5	19.4	16.6	14.2	

ACTUAL INTERNAL DIAMETERS.

The above table was calculated by the formula $W \propto$ (varies as) $\frac{d^3}{d + 3.6}$, in which $W =$ weight of fluid delivered in a given time, and $d =$ diameter (internal) in inches. In the upper right hand triangle of the table the figures refer to nominal diameters, while in the lower triangle they refer to actual diameters.

Example.—To find number of standard 2 inch pipes to deliver as much fluid as one standard 7 inch pipe: In the upper triangle look in column headed **7** and opposite **2** in the extreme right hand column, read 29. Twenty-nine 2-inch pipes will then deliver as much as one 7-inch pipe.

NON-CONDUCTING COVERINGS FOR STEAM PIPES.

A bare pipe carrying steam, and made of iron, steel or other conducting material, loses heat by convection to the surrounding air and by radiation to the surrounding objects, both of which cause a loss of steam by condensation.

This loss is lessened in practice by covering the outer surface of the steam pipe with a material that will offer a greater resistance to the flow of heat than that offered by the material of the pipe.

A good material for this purpose should not suffer serious deterioration from the heat or vibration to which it would be subjected in practice; and in all cases where damage from fire might result, it should never consist of combustible matter. Under the conditions of practice, especially in places where it may become damp, a good pipe covering should consist of materials that will not rapidly deteriorate, and should contain nothing that will seriously corrode the pipe.

Since air does not take up heat by radiation, but receives heat by contact with a hot body only, it would appear that the greater the porosity of a material, that is, the greater the percentage of volume of finely divided air it contains, the greater will be its non-conducting qualities. This is noticeably the case in the commercial pipe coverings that consist substantially of the same materials, when these materials contain different percentages of still air. In every case the more porous the material, other things being equal, the greater will be its non-conducting properties.

The following table contains averages made up from results obtained by a number of carefully conducted tests, and represent approximately what may be expected when these materials are properly applied as steam-pipe coverings in practice. The table gives the quantity of heat transmitted through covered steam-pipes, when that transmitted through a naked pipe is taken as 100, the covering, except where otherwise indicated, being **one inch thick.**

Kind of Covering.	Relative Amount of Heat Transmitted.
Naked pipe	100
Hair felt, asbestos lined and canvas covered	16 to 18
Wool felt, " " " " "	20 to 22
Two layers of asbestos paper	70 to 80
Four " " " "	45 to 55
Asbestos mixed with some plaster of paris	28 to 34
Magnesia mixed with a little asbestos fiber, canvas covered	18 to 20
Best mineral wool, lined and canvas covered	18 to 20
Pipe painted with black asphaltum	about 105
Pipe painted with white glossy paint	" 95

For coverings having values less than 25 in the above table, the values for thicknesses of covering of 1½ and 2 inches (those in the table being for one inch, as noted) may be approximately obtained by multiplying respectively by 0.78 and 0.58. Thus, a pipe covered with magnesia and canvas covered would transmit an amount, if 1½ inches thick $= (18 \text{ to } 20) \times 0.78 = 14 \text{ to } 15.5$; and if 2 inches thick an amount $= (18 \text{ to } 20) \times 0.58 = 10.5$ to 11.5, that transmitted by a similar bare pipe being 100 in the same length of time.

LOSS OF HEAT FROM BARE IRON STEAM PIPES.

Steam pressure=100 lbs. gauge, surrounding air at 62° F.

Steam temperature = 338° Fahr.

Nominal Diameter of Pipe in Inches.	B. T. U. Lost per Hour per Foot Length.	Nominal Diameter of Pipe in Inches.	B. T. U. Lost per Hour per Foot Length.	Nominal Diameter of Pipe in Inches.	B. T. U. Lost per Hour per Foot Length.	Nominal Diameter of Pipe in Inches.	B. T. U. Lost per Hour per Foot Length.
1½	423	6	1221	12	2290	22	3949
2	494	7	1420	14	2645	24	4264
3	692	8	1580	16	2961	26	4617
4	869	9	1738	18	3315	28	4932
5	1067	10	1935	20	3632	30	5288

CONDENSATION OF STEAM IN BARE IRON PIPES.

Steam pressure=100 lbs. gauge, surrounding air at 62° F.

Steam temperature = 338° Fahr.

Nominal Diameter of Pipe in Inches.	Steam Condensed in Lbs. per Hour per Foot Length.	Nominal Diameter of Pipe in Inches.	Steam Condensed in Lbs. per Hour per Foot Length.	Nominal Diameter of Pipe in Inches.	Steam Condensed in Lbs. per Hour per Foot Length.	Nominal Diameter of Pipe in Inches.	Steam Condensed in Lbs. per Hour per Foot Length.
1½	0.48	6	1.39	12	2.61	22	4.51
2	0.56	7	1.62	14	3.02	24	4.87
3	0.79	8	1.80	16	3.38	26	5.27
4	0.99	9	1.98	18	3.78	28	5.63
5	1.22	10	2.21	20	4.15	30	6.04

CONDENSATION OF STEAM IN COVERED IRON PIPES.

Corresponding to a percentage of that in a bare pipe varying from 15 per cent. for a 30-inch pipe to 19 for a 1½ inch pipe, which approximates to what may be expected in practice from the application of the best commercial pipe coverings.

Steam pressure=100 lbs. gauge, surrounding air at 62° F.

Steam temperature = 338° Fahr.

Nominal Diameter of Pipe in Inches.	Steam Condensed in Lbs. per Hour per Foot Length.	Nominal Diameter of Pipe in Inches.	Steam Condensed in Lbs. per Hour per Foot Length.	Nominal Diameter of Pipe in Inches.	Steam Condensed in Lbs. per Hour per Foot Length.	Nominal Diameter of Pipe in Inches.	Steam Condensed in Lbs. per Hour per Foot Length.
1½	0.09	6	0.22	12	0.40	22	0.68
2	0.10	7	0.25	14	0.46	24	0.73
3	0.13	8	0.28	16	0.51	26	0.79
4	0.16	9	0.30	18	0.57	28	0.84
5	0.19	10	0.34	20	0.63	30	0.90

Example.—Find the saving resulting from covering an 8-inch steam pipe that is 120 feet long.

Condensation in bare pipe = 1.80×120 = 216.0 lbs. per hr.
" "covered" = 0.28×120 = 33.6 " " "

Saving of steam effected by covering = 182.4 " " "

Which on a 10-hour basis would amount to an annual saving of about 550,000 pounds of steam. Assuming that one lb. of coal evaporates, under actual conditions, 9 lbs. of water, the saving of fuel in this case resulting from the application of a good commercial pipe covering, would amount to about 60,000 lbs. of coal, or 30 short tons per annum. At two, three and four dollars per ton for fuel this would amount to an annual saving of $60.00, $90.00 and $120.00 respectively.

Since the steam carrying capacity of a pipe of this size, as ordinarily installed for power purposes, would be about 24,000 lbs. of steam per hour, the above saving would represent about ½ of one per cent. of its carrying capacity.

Where fuel is inexpensive and the steam pipes are short, the net saving due to covering the pipes is, of course, insignificant; but even in this case, especially in confined situations, the pipes should be ordinarily covered in order to make the temperature of the space near them less unendurable to workmen and others, in warm weather.

POWER OF ENGINES AND BOILERS.

Work, in the mechanical sense, is the overcoming of resistance through space, and is measured by the amount of the resistance multiplied by the distance through which it is overcome.

The unit of work, in Great Britain and the United States, is the foot-pound, which is an amount of energy equivalent to the lifting of one pound through a height of one foot.

The unit of rate of doing work is a quantity of work equivalent to the doing of 33,000 foot-pounds in one minute, and is called a **horse-power**. This is a mechanical horse-power, and should not be confused with the boiler horse-power, which is based upon the evaporation of a stated quantity of water under certain stated conditions.

The indicated horse-power of a steam engine is the horse-power developed by the steam in the cylinder and delivered to the piston. In a double acting single cylinder engine, the indicated horse-power $= \frac{plan}{33,000}$, in which p = the mean effective pressure in lbs. per sq. in., as obtained from the indicator card, l = length of stroke in feet, a = area of piston in sq. inches and n = number of working strokes per minute. If the engine has more than one cylinder compute the power of each and take the sum. If great accuracy is desired the area of cross-section of piston rod should be deducted from the piston area for the crank end, and the powers of the two ends computed separately, since the mean effective pressures of the two ends will not ordinarily be found to be exactly the same. For single acting engines substitute for n the number of working strokes only.

Net or brake horse-power of an engine is the horse-power delivered by the engine from its shaft, by belt or otherwise. It may be obtained from the indicated horse-power by multiplying by the mechanical efficiency: For example, an engine indicating 300 H.P., with a mechanical efficiency of 88 per cent., would have a net or brake horse-power $= 300 \times 0.88 = 264$.

The unit of evaporation is the number of B.T.U. necessary to convert one pound of water at 212°F. into steam of the same temperature, and is therefore equal to 965.7 B.T.U., the latent heat of one pound of steam at atmospheric pressure.

Boiler Horse-power. A Committee of the American Society of Mechanical Engineers recommended the unit of boiler power known as the "Centennial Standard," and this is now generally accepted. They advised that the **commercial horse-power** be taken as an evaporation of 30 pounds of water per hour from a feed water temperature of 100°Fahr. into steam at 70 pounds per square inch gauge pressure. This is equivalent to 34½ units of evaporation, that is, to 34½ pounds of water evaporated from a feed water temperature of 212° Fahr. into steam at the same temperature. This "Centennial Standard" unit is equivalent to 33,305 British thermal units per hour.

It was the opinion of this Committee that a boiler rated at any stated power should be capable of developing that power with easy firing, moderate draught, and ordinary fuel, while exhibiting good economy; and, at times, when maximum economy is not the most important object to be attained, at least one-third more than its rated power to meet emergencies.

Example.—A battery of boilers evaporate 20,000 lbs. of feed-water per hour, the temperature of feed-water being 40°F., and the gauge pressure 100 lbs. per sq. in. Find the **equivalent evaporation from and at 212°F.;** also the **commercial horse-power.**

The factor of evaporation, from 40°F. and at 100 lbs. gauge, is (see table of factors of evaporation) 1.219. Therefore the **equivalent evaporation from and at 212°** = 20,000 × 1.219 = 24,380 lbs. per hr.

Since one commercial horse-power is equivalent to the evaporation of 34.5 lbs. of water per hour, from and at 212°, the **commercial horse-power** = 24,380 ÷ 34.5 = 707.

In the above example the steam is assumed to be dry and saturated. In case it is not a correction must be made.

1. Assume that the steam contains 2 per cent. of moisture. Of the 20,000 lbs. of feed-water, then, 98 per cent. or 19,600 lbs. will be evaporated and the remaining 400 lbs. will pass from the boiler as water at the temperature of the steam. Each pound of this water will carry away from the boiler an amount of heat necessary to raise its temperature from 40°F., the temperature of the feed-water, to 337°, the temperature of the steam, or 296 B.T.U. per lb. of entrained water. Had the entrained water been evaporated each pound would have carried away an additional amount equal to its latent heat at boiler pressure, or 876 B.T.U. per lb., or 876 × 400 = 350,400 B.T.U. per hour, for the total amount of entrained water. Under the assumed conditions, then, the boiler imparts 350,400 heat units less to the feed-water per hour than would have been the case had there been no entrained water; that is, its capacity is less by 350,400 ÷ 33,305 (the heat equivalent of a boiler H.P.) = 10.5 horse-power. The actual commercial horse-power of the boiler then = 707 — 10.5 = 696.5.

2. Assume that the steam is superheated 20 degrees; that is, to a temperature of 337° + 20° = 357° F. Then the additional heat imparted to each pound of feed-water over that necessary to generate dry saturated steam is 20° × 0.48 (the specific heat of steam) = 9.6 heat units per lb., or 9.6 × 20,000 = 192,000 per hr., or 192.000 ÷ 33,305 = 5.8 horse-power. The actual horse-power of boiler then = 707 + 5.8 = 712.8.

Horse-power per Pound Mean Effective Pressure.

$$\text{Formula, } \frac{\text{Area in sq. in.} \times \text{piston-speed}}{33{,}000}.$$

Diameter of Cylinder, inches.	SPEED OF PISTON IN FEET PER MINUTE.								
	100	200	300	400	500	600	700	800	900
4	.0381	.0762	.1142	.1523	.1904	.2285	.2666	.3046	.3427
4½	.0482	.0964	.1446	.1928	.2410	.2892	.3374	.3856	.4338
5	.0595	.1190	.1785	.2380	.2975	.3570	.4165	.4760	.5355
5½	.0720	.1440	.2160	.2880	.3600	.4320	.5040	.5760	.6480
6	.0857	.1714	.2570	.3427	.4284	.5141	.5998	.6854	.7711
6½	.1006	.2011	.3017	.4022	.5028	.6033	.7039	.8044	.9050
7	.1166	.2332	.3499	.4665	.5831	.6997	.8163	.9330	1.0496
7½	.1339	.2678	.4016	.5355	.6694	.8033	.9371	1.0710	1.2049
8	.1523	.3046	.4570	.6093	.7616	.9139	1.0662	1.2186	1.3709
8½	.1720	.3439	.5159	.6878	.8598	1.0317	1.2037	1.3756	1.5476
9	.1928	.3856	.5783	.7711	.9639	1.1567	1.3495	1.5422	1.7350
9½	.2148	.4296	.6444	.8592	1.0740	1.2888	1.5036	1.7184	1.9532
10	.2380	.4760	.7140	.9520	1.1900	1.4280	1.6660	1.9040	2.1420
11	.2880	.5760	.8639	1.1519	1.4399	1.7279	2.0159	2.3038	2.5818
12	.3427	.6854	1.0282	1.3709	1.7136	2.0563	2.3990	2.7418	3.0845
13	.4022	.8044	1.2067	1.6089	2.0111	2.4133	2.8155	3.2178	3.6200
14	.4665	.9330	1.3994	1.8659	2.3324	2.7989	3.2654	3.7318	4.1983
15	.5355	1.0710	1.6065	2.1420	2.6775	3.2130	3.7485	4.2840	4.8195
16	.6093	1.2186	1.8278	2.4371	3.0464	3.6557	4.2650	4.8742	5.4835
17	.6878	1.2756	1.9635	2.6513	3.3391	4.0269	4.6147	5.4026	6.1904
18	.7711	1.5422	2.3134	3.0845	3.8556	4.6267	5.3978	6.1690	6.9401
19	.8592	1.7184	2.5775	3.4367	4.2959	5.1551	6.0143	6.8734	7.7326
20	.9520	1.9040	2.8560	3.8080	4.7600	5.7120	6.6640	7.6160	8.5680
21	1.0496	2.0992	3.1488	4.1983	5.2479	6.2975	7.3471	8.3966	9.4462
22	1.1519	2.3038	3.4558	4.6077	5.7596	6.9115	8.0634	9.2154	10.367
23	1.2590	2.5180	3.7771	5.0361	6.2951	7.5541	8.8131	10.072	11.331
24	1.3709	2.7418	4.1126	5.4835	6.8544	8.2253	9.5962	10.967	12.338
25	1.4875	2.9750	4.4625	5.9500	7.4375	8.9250	10.413	11.900	13.388
26	1.6089	3.2178	4.8266	6.4355	8.0444	9.6534	11.262	12.871	14.480
27	1.7350	3.4700	5.2051	6.9401	8.6751	10.410	12.145	13.880	15.615
28	1.8659	3.7318	5.5978	7.4637	9.3296	11.196	13.061	14.927	16.793
29	2.0016	4.0032	6.0047	8.0063	10.008	12.009	14.011	16.013	18.014
30	2.1420	4.2840	6.4260	8.5680	10.710	12.852	14.994	17.136	19.278
32	2.4371	4.8742	7.3114	9.7485	12.186	14.623	17.060	14.497	21.934
34	2.7513	5.5026	8.2538	11.005	13.756	16.508	19.259	22.010	24.762
36	3.0845	6.1690	9.2534	12.338	15.422	18.507	21.591	24.676	27.760
38	3.4367	6.8734	10.310	13.747	17.184	20.620	24.057	27.494	30.930
40	3.8080	7.6160	11.424	15.232	19.040	22.848	26.656	30.464	34.272
42	4.1983	8.3866	12.585	16.783	20.982	25.180	29.378	33.577	37.775
44	4.6077	9.2154	13.823	18.431	23.038	27.646	32.254	36.861	41.469
46	5.0361	10.072	15.108	20.144	25.180	30.216	35.253	40.289	45.325
48	5.4835	10.967	16.451	21.934	27.418	32.901	38.385	43.868	49.352
50	5.9500	11.900	17.850	23.800	29.750	35.700	41.650	47.600	53.550
52	6.4355	12.871	19.307	25.742	32.178	38.613	45.049	51.484	57.920
54	6.9401	13.880	20.820	27.760	34.700	41.640	48.581	55.521	62.461
56	7.4637	14.927	22.391	29.855	37.318	44.782	52.246	59.709	67.173
58	8.0063	16.013	24.019	32.025	40.032	48.038	56.044	64.051	72.057
60	8.5680	17.136	25.704	34.272	42.840	51.408	59.976	68.544	77.112

The indicated horse-power of an engine equals $\frac{plan}{33,000} = \frac{a \times l\,n \times p}{33,000} = \frac{\text{area of piston} \times \text{piston speed}}{33,000} \times p$, in which $p =$ mean effective pressure in lbs. per sq. in.; $l =$ length of stroke in ft.; $a =$ effective area of piston in sq. in.; and $n =$ number of impulse strokes per minute.

The piston speed for a single acting, double acting or a multiple cylinder engine = the length of stroke in ft. × number of impulse strokes per minute.

FEED-WATER HEATERS.—(KENT).

Percentage of Saving for Each Degree of Increase in Temperature of Feed-water Heated by Waste Steam.

Initial Temp. of Feed.	Pressure of Steam in Boiler, lbs. per sq. in. above Atmosphere.										
	0	20	40	60	80	100	120	140	160	180	200
32°	.0872	.0861	.0855	.0851	.0847	.0844	.0841	.0839	.0837	.0835	.0833
40	.0878	.0867	.0861	.0856	.0853	.0850	.0847	.0845	.0843	.0841	.0839
50	.0886	.0875	.0868	.0864	.0860	.0857	.0854	.0852	.0850	.0848	.0846
60	.0894	.0883	.0876	.0872	.0867	.0864	.0862	.0859	.0856	.0855	.0853
70	.0902	.0890	.0884	.0879	.0875	.0872	.0869	.0867	.0864	.0862	.0860
80	.0910	.0898	.0891	.0887	.0883	.0879	.0877	.0874	.0872	.0870	.0868
90	.0919	.0907	.0900	.0895	.0888	.0887	.0884	.0883	.0879	.0877	.0875
100	.0927	.0915	.0908	.0903	.0899	.0895	.0892	.0890	.0887	.0885	.0883
110	.0936	.0923	.0916	.0911	.0907	.0903	.0900	.0898	.0895	.0893	.0891
120	.0945	.0932	.0925	.0919	.0915	.0911	.0908	.0906	.0903	.0901	.0899
130	.0954	.0941	.0934	.0928	.0924	.0920	.0917	.0914	.0912	.0909	.0907
140	.0963	.0950	.0943	.0937	.0932	.0929	.0925	.0923	.0920	.0918	.0916
150	.0973	.0959	.0951	.0946	.0941	.0937	.0934	.0931	.0929	.0926	.0924
160	.0982	.0968	.0961	.0955	.0950	.0946	.0943	.0940	.0937	.0935	.0933
170	.0992	.0978	.0970	.0964	.0959	.0955	.0952	.0949	.0946	.0944	.0941
180	.1002	.0988	.0981	.0973	.0969	.0965	.0961	.0958	.0955	.0953	.0951
190	.1012	.0998	.0989	.0983	.0978	.0974	.0971	.0968	.0964	.0962	.0960
200	.1022	.1008	.0999	.0993	.0988	.0984	.0980	.0977	.0974	.0972	.0969
210	.1033	.1018	.1009	.1003	.0998	.0994	.0990	.0987	.0984	.0981	.0979
220	.....	.1029	.1019	.1013	.1008	.1004	.1000	.0997	.0994	.0991	.0989
230	.....	.1039	.1031	.1024	.1018	.1012	.1010	.1007	.1003	.1001	.0999
240	.....	.1050	.1041	.1034	.1029	.1024	.1020	.1017	.1014	.1011	.1009
250	.....	.1062	.1052	.1045	.1040	.1035	.1031	.1027	.1025	.1022	.1019

An approximate rule for the conditions of ordinary practice is: A saving of 1% is made by each increase of 11° in the temperature of the feed-water. This corresponds to 0.0909 per cent. for each degree.

The calculation of saving is made as follows: Let total heat of 1 lb. of steam at the boiler-pressure $= H$; total heat of 1 lb. of feed-water before entering the heater $= h_1$, and after passing through the heater $= h_2$; then the saving made by the heater is $\frac{h_2 - h_1}{H - h_1}$.

Example.—Given boiler pressure = 100 lbs. gauge; feed water temperature, original = 60°F. and final = 209°F.; to find the percentage of saving resulting from heating the feed-water. From the table of properties of saturated steam we find $H = 1185$ B.T.U.; $h_1 = 60 - 32 = 28$ B.T.U.; $h_2 = 209 - 32 = 177$ B.T.U.

Then the saving by heater $= \frac{h_2 - h_1}{H - h.} = \frac{177 - 28}{1185 - 28} = 12.9$ per cent.

To solve by table look in column of steam pressures headed "100" and opposite to 60° in first column read 0.0864, which multiplied by (209—60 = 149) the increase of temperature of feed-water, gives 12.9 per cent., as before.

Safe Working Pressures in Cylindrical Shells of Boilers, Tanks, Pipes, etc., in Pounds per Square Inch.

(KENTS POCKET BOOK).

Longitudinal seams double-riveted.

(Calculated from formula $P = 14{,}000 \times \text{thickness} \div \text{diameter.}$)

Thickness in 16ths of an Inch.	DIAMETER IN INCHES.										
	24	30	36	38	40	42	44	46	48	50	52
1	36.5	29.2	24.3	23.0	21.9	20.8	19.9	19.0	18.2	17.5	16.8
2	72.9	58.3	48.6	46.1	43.8	41.7	39.8	38.0	36.5	35.0	33.7
3	109.4	87.5	72.9	69.1	65.6	62.5	59.7	57.1	54.7	52.5	50.5
4	145.8	116.7	97.2	92.1	87.5	83.3	79.5	76.1	72.9	70.0	67.3
5	182.3	145.8	121.5	115.1	109.4	104.2	99.4	95.1	91.1	87.5	84.1
6	218.7	175.0	145.8	138.2	131.3	125.0	119.3	114.1	109.4	105.0	101.0
7	255.2	204.1	170.1	161.2	153.1	145.9	139.2	133.2	127.6	122.5	117.8
8	291.7	233.3	194.4	184.2	175.0	166.7	159.1	152.2	145.8	140.0	134.6
9	328.1	262.5	218.8	207.2	196.9	187.5	179.0	171.2	164.1	157.5	151.4
10	364.6	291.7	243.1	230.3	218.8	208.3	198.9	190.2	182.3	175.0	168.3
11	401.0	320.8	267.4	253.3	240.6	229.2	218.7	209.2	200.5	192.5	185.1
12	437.5	350.0	291.7	276.3	262.5	250.0	238.6	228.3	218.7	210.0	201.9
13	473.9	379.2	316.0	299.3	284.4	270.9	258.5	247.3	237.0	227.5	218.8
14	410.4	408.3	340.3	322.4	306.3	291.7	278.4	266.3	255.2	245.0	235.6
15	546.9	437.5	364.6	345.4	328.1	312.5	298.3	285.3	273.4	266.5	252.4
16	583.3	466.7	388.9	368.4	350.0	333.3	318.2	304.4	291.7	280.0	269.2

Thickness in 16ths of an Inch.	DIAMETER IN INCHES.										
	54	60	66	72	78	84	90	96	102	108	120
1	16.2	14.6	13.3	12.2	11.2	10.4	9.7	9.1	8.6	8.1	7.3
2	32.4	29.2	26.5	24.3	22.4	20.8	19.4	18.2	17.2	16.2	14.6
3	48.6	43.7	39.8	36.5	33.7	31.3	29.2	27.3	25.7	24.3	21.9
4	64.8	58.3	53.0	48.6	44.9	41.7	38.9	36.5	34.3	32.4	29.2
5	81.0	72.9	66.3	60.8	56.1	52.1	48.6	45.6	42.9	40.5	36.5
6	97.2	87.5	79.5	72.9	67.3	62.5	58.3	54.7	51.5	48.6	43.8
7	113.4	102.1	92.8	85.1	78.5	72.9	68.1	63.8	60.0	56.7	51.0
8	129.6	116.7	106.1	97.2	89.7	83.3	77.8	72.9	68.6	64.8	58.3
9	145.8	131.2	119.3	109.4	101.0	93.8	87.5	82.0	77.2	72.9	65.6
10	162.0	145.8	132.6	121.5	112.2	104.2	97.2	91.1	85.8	81.0	72.9
11	178.2	160.4	145.8	133.7	123.4	114.6	106.9	100.3	94.4	89.1	80.2
12	194.4	175.0	159.1	145.8	134.6	125.0	116.7	109.4	102.9	97.2	87.5
13	210.7	189.6	172.4	158.0	145.8	135.4	126.4	118.5	111.5	105.3	94.8
14	226.9	204.2	185.6	170.1	157.1	145.8	136.1	127.6	120.1	113.4	102.1
15	243.1	218.7	198.9	182.3	168.3	156.3	145.8	136.7	128.7	121.5	109.4
16	259.3	233.3	212.1	194.4	179.5	166.7	155.6	145.8	137.3	129.6	116.7

The preceding table has been computed for externally-fired boilers, with longitudinal seams double-riveted and having an efficiency of 0.7. A factor of safety of 5.5 has been assumed for steel of 55,000 lbs. tensile strength.

SIZES OF CHIMNEYS FOR STEAM BOILERS.

BY WILLIAM KENT, M. E.

The accompanying tabe of sizes of chimneys for various horse powers of boilers is based on the following data:

1. The draught power of the chimney varies as the square root of the height.

2. The retarding of the ascending gases by friction may be considered as equivalent to a diminution of the area of the chimney, or to a lining of the chimney by a layer of gas which has no velocity. The thickness of this lining is assumed to be two inches for all chimneys, or the diminution of area equal to the perimeter × two inches (neglecting the overlapping of the corners of the lining). Expressed algebraically, let D = diameter, A = area, E = effective area.

For square chimneys, $E = D^2 - \frac{8D}{12} = A - \frac{2\sqrt{A}}{3}$.

For round chimneys, $E = \pi\left(D^2 - \frac{8D}{12}\right) = A - 0.592\sqrt{A}$.

For simplifying calculations, the coefficient of $\sqrt{A}$ may be taken as 0.6 for both square and round chimneys, and the formula becomes

$$E = A - 0.6\sqrt{A}.$$

3. The power varies directly as this effective area E.

4. A chimney 80 feet high, 42 inches diameter, has been found to be sufficient to cause a rate of combustion

of 120 pounds of coal per hour per square foot of area of chimney, or if the grate area is to the chimney area as 8 to 1, a combustion of 15 pounds of coal per square foot of grate per hour. This is fair practice for a boiler of modern type, in which flues, or tubes are of moderate diameter, gas passages circuitous, and heating surface extensive in proportion to rate of combustion, so as to cool the chimney gases to 400° or 500° Fahr. and produce high economy.

5. A chimney should be proportioned so as to be capable of giving sufficient draught to cause the boiler to develop much more than its rated power, in case of emergencies, or to cause the combustion of 5 pounds of fuel per rated horse-power of boiler per hour.

Conditions 4 and 5 being assumed, the 80 feet × 42 inches chimney, 9.62 square feet area, will cause the combustion of $9.62 \times 120 = 1154.4$ pounds of coal per hour, or at 5 pounds of coal per horse-power per hour, is rightly proportioned for 231 horse-power of boilers.

The power of the chimney varying directly as the effective area, E, and as the square root of the height, h, the formula for horse-power of boiler for a given size of chimney will take the form,—

$$\text{HP.} = CE\sqrt{h}, \text{ in which } C \text{ is a constant.}$$

For the 80′ × 42″ chimney,—

$$E = A - 0.6\sqrt{A} = 7.76 \text{ square feet.}$$

$$\sqrt{h} = 8.944 \text{ feet.}$$

Substituting these values in the formula it becomes —

$$231 = C \times 7.76 \times 8.944,$$

$$\text{whence } C = 3.33,$$

and the formula for horse-power is

$$HP. = 3.33\,E\,\sqrt{h}, \text{ or, } HP. = 3.33\left(A - 0.6\sqrt{A}\right)\sqrt{h}.$$

If the horse-power of boiler is given, to find the size of chimney, the height being assumed,

$$E = \frac{0.3\ HP.}{\sqrt{h}}.$$

For round chimneys, diameter of chimney = Diam. of $E + 4''$.

For square chimneys, side of chimney $= \sqrt{E} + 4''$.

In the formulae and table no account has been taken of the difference which is believed by some authorities to exist in the efficiencies of round and square chimneys of equal area, nor of the differences of friction and of rate of cooling of the gases in iron and in brick chimneys. Should experimental data of these differences, or of the effect of infiltration of air into brick chimneys, be obtained in future, the formulae and table may be corrected accordingly.

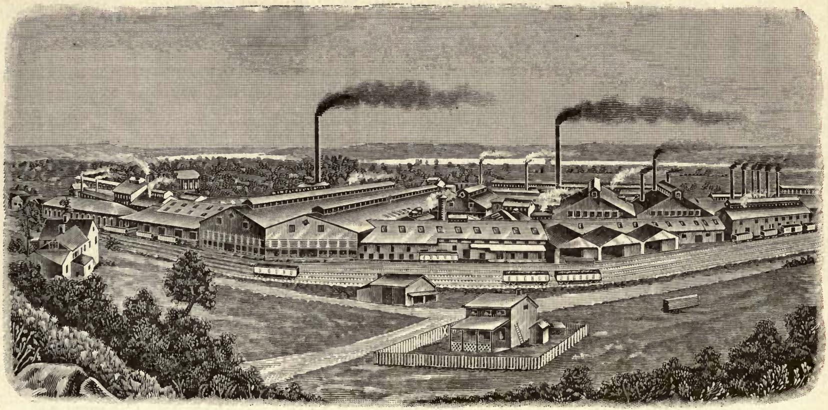
SIZE OF CHIMNEYS FOR STEAM-BOILERS.

(KENT.)

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

Diameter Inches.	Area A. sq. ft.	Effective Area, $E = A - 0.6 \sqrt{A}$ sq. ft.	HEIGHT OF CHIMNEY IN FEET.													Equivalent Square Chimney. Side of Square $\sqrt{E}+4$ inches
			50	60	70	80	90	100	110	125	150	175	200	225	250	
			COMMERCIAL HORSE-POWER OF BOILER.													
18	1.77	.97	23	25	27	29	......	......	......	......	......	......	......	......	......	16
21	2.41	1.47	35	38	41	44	......	......	......	......	......	......	......	......	......	19
24	3.14	2.08	49	54	58	62	66	......	......	......	......	......	......	......	......	22
27	3.98	2.78	65	72	78	83	88	......	......	......	......	......	......	......	......	24
30	4.91	3.58	84	92	100	107	113	119	......	......	......	......	......	......	......	27
33	5.94	4.48	......	115	125	133	141	149	156	......	......	......	......	......	......	30
36	7.07	5.47	......	141	152	163	173	182	191	204	......	......	......	......	......	32
39	8.30	6.57	......	......	183	196	208	219	229	245	......	......	......	......	......	35
42	9.62	7.76	......	......	216	231	245	258	271	289	316	......	......	......	......	38
48	12.57	10.44	......	......	......	311	330	348	365	389	426	......	......	......	......	43
54	15.90	13.51	......	......	......	......	427	449	472	503	551	595	......	......	......	48
60	19.64	16.98	......	......	......	......	536	565	593	632	692	748	......	......	......	54
66	23.76	20.83	......	......	......	......	......	694	728	776	849	918	981	......	......	59
72	28.27	25.08	......	......	......	......	......	835	876	934	1023	1105	1181	1253	......	64
78	33.18	29.73	......	......	......	......	......	......	1038	1107	1212	1310	1400	1485	1565	70
84	38.48	34.76	......	......	......	......	......	......	1214	1294	1418	1531	1637	1736	1830	75
90	44.18	40.19	......	......	......	......	......	......	......	1496	1639	1770	1893	2008	2116	80
96	50.27	46.01	......	......	......	......	......	......	......	1712	1876	2027	2167	2298	2423	86
102	56.75	52.23	......	......	......	......	......	......	......	1944	2130	2300	2459	2609	2750	91
108	63.62	58.83	......	......	......	......	......	......	......	2090	2399	2592	2771	2939	3098	96
114	70.88	65.83	......	......	......	......	......	......	......	......	2685	2900	3100	3288	3466	101
120	78.54	73.22	......	......	......	......	......	......	......	......	2986	3226	3448	3657	3855	107

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



AMERICAN DEPARTMENT, MIDDLETOWN, PA.

AIR.

AIR.

Air consists of a mechanical mixture of the two gases oxygen and nitrogen in the ratio of 20.7 parts of the former to 79.3 of the latter by volume, and 23 of the former to 77 of the latter by weight. In its natural state it contains small quantities of various substances, such as moisture, carbon dioxide, CO_2, the lately discovered element argon, etc.

The weight of dry air at 32°F. and atmospheric pressure (14.7 lbs. per sq. in.) is 0.0807 lbs. per cu. ft.; from which the volume of one pound=12.4 cu. ft. At other temperatures and pressures its weight in lbs. per cu. ft. is $W=\frac{1.325xB}{459.2+t}$, in which B=reading of barometer in inches and t=temperature F.

The absolute zero of temperature, on the Fahr. scale is 492° below 32°, or—460°F.

The absolute temperature then is obtained by adding 460° to the temperature as read from the Fahr. scale. Thus 60°F. = 60° + 460° = 520° absolute; and—20°F. = —20°+460°=440° absolute.

Mechanical equivalent of heat.—Heat energy and mechanical energy are mutually convertible, that is, a unit of heat requires for its production, and produces by its disappearance, a definite amount of mechanical energy, namely, 778 foot-pounds of work for each British thermal unit.

Boyle's law states that the product of the pressure and volume of a portion of gas is constant so long as the temperature is constant, that is, $pv=c$, in which p=pressure in lbs. per sq. ft. and v=volume in cu. ft. For air at 32°F,, this constant quantity is 26,200 foot-pounds, or pv=26,200 ft. lbs.

Charles' and Gay Lussac's law states that when the pressure is constant all gases expand alike for the same increase of temperature. The amount of this expansion between 32° and 212°F, is 0.365 of the original volume: and for each degree it equals 0.365÷180=0.00203. Similiarly, when the volume remains constant the pressure varies in the above ratio.

Combining Boyle's and Charles' laws we see that the product of the pressure and volume of a portion of gas is proportional to the absolute temperature. Thus, $\frac{pv}{p_1v_1}=\frac{T}{T_1}$, in which p and p_1=absolute pressures (that is pressures above a vacuum) in lbs. per sq. ft.; v and v_1=volumes in cu. ft.; T and T_1=absolute temperatures.

Transforming the above equation and substituting 32 for T_1 and 26,200 for p_1v_1, we get

$$pv=\frac{p_1v_1}{T_1}T=53.2\ T.$$

The specific heat of a gas is the quantity of heat, in heat units, necessary to raise the temperature of one pound of the gas through one degree of temperature.

The specific heat of air at constant pressure is $c_p=0.238$ and at constant volume is $c_v=0.169$ British thermal unit.

Adiabatic expansion or compression of a gas means that the gas is expanded or compressed without transmission of heat to or from the gas. This would be the case were the expansion or compression to take place in an absolutely non-conducting cylinder, in which case the temperature, pressure and volume would vary as indicated by the following formulae.

$$\frac{v_2}{v_1}=\left(\frac{p_1}{p_2}\right)^{0.71}. \qquad \frac{p_2}{p_1}=\left(\frac{v_1}{v_2}\right)^{1.41}. \qquad \frac{T_2}{T_1}=\left(\frac{v_1}{v_2}\right)^{0.41}.$$

$$\frac{v_2}{v_1}=\left(\frac{T_1}{T_2}\right)^{2.46}. \qquad \frac{p_2}{p_1}=\left(\frac{T_2}{T_1}\right)^{3.46}. \qquad \frac{T_2}{T_1}=\left(\frac{p_2}{p_1}\right)^{0.29}.$$

in which p_1, v_1 and T_1=initial absolute pressure, volume and absolute temperature and p_2, v_2 and T_2=final absolute pressure, volume and absolute temperature of the gas.

Table for Adiabitic Compression or Expansion of Air.

(Proc., Inst. M. E., Jan. 1881, p. 123.)

Absolute Pressure.		Absolute Temperature.		Volume.	
$\frac{P_2}{P_1}$	$\frac{P_1}{P_2}$	$\frac{T_2}{T_1}$	$\frac{T_1}{T_2}$	$\frac{V_1}{V_2}$	$\frac{V_2}{V_1}$
1.2	8.33	1.054	.948	1.138	8.79
1.4	7.14	1.102	.907	1.270	.788
1.6	.625	1.146	.873	1.396	.716
1.8	.556	1.186	.843	1.518	.659
2.0	.500	1.222	.818	1.636	.611
2.2	.454	1.257	.796	1.750	.571
2.4	.417	1.289	.776	1.862	.537
2.6	.385	1.319	.758	1.971	.507
2.8	.357	1.348	.742	2.077	.481
3.0	.333	1.375	.727	2.182	.458
3.2	.312	1.401	.714	2.284	.438
3.4	.294	1.426	.701	2.384	.419
3.6	.278	1.450	.690	2.483	.403
3.8	.263	1.473	.679	2.580	.388
4.0	.250	1.495	.669	2.676	.374
4.2	.238	1.516	.660	2.770	.361
4.4	.227	1.537	.651	2.863	.349
4.6	.217	1.557	.642	2.955	.338
4.8	.208	1.576	.635	3.046	.328
5.0	.200	1.595	.627	3.135	.319
6.0	.167	1.681	.595	3.569	.280
7.0	.143	1.758	.569	3.981	.251
8.0	.125	1.828	.547	4.377	.228
9.0	.111	1.891	.529	4.759	.210
10.0	.100	1.950	.513	5.129	.195

Work of adiabatic compression of air.—If air is compressed from a volume v_1 and pressure p_1 to a volume v_2 and pressure p_2, in a non-conducting cylinder without clearance, the work involved in delivering one pound is as follows:

Work of compression $= 2.46\, p_1 v_1 \left[\left(\frac{v_1}{v_2}\right)^{0.41} - 1\right] = 2.46\, p_1 v_1 \left[\left(\frac{p_2}{p_1}\right)^{0.29} - 1\right]$.

Work of expulsion $= p_2v_2 = p_1v_1 \left(\frac{p_2}{p_1}\right)^{0.29}$.

Total work is the sum of the work of compression and expulsion less the work, p_1v_1, of the atmosphere done on the piston during admission, or

Total work $= 3.46\ p_1v_1 \left[\left(\frac{p_2}{p_1}\right)^{0.29} - 1\right]$.

The mean effective pressure equals the total work ÷ the initial volume, v_1, or

$$3.46\ p_1 \left[\left(\frac{p_2}{p_1}\right)^{0.29} - 1\right].$$

Isothermal expansion or compression of a gas means that the gas is expanded or compressed with the addition or rejection of sufficient heat to maintain the temperature constant. In this case, the temperature being constant, the pressure and volume will vary according to Boyle's law, namely

$$p\ v = C,$$

in which p=absolute pressure in lbs. per sq. ft., v=volume in cu. ft., and C=a constant depending upon the temperature. For a temperature of 32°F. this constant is 26,200 ft. lbs., and for isothermals corresponding to other temperatures it may be found from the formula $C = 53.2\ T$, in which T=the absolute temperature of the isothermal.

Work of isothermal compression of air.—If air is compressed from a volume v_1 and pressure p_1 to a volume v_2 and pressure p_2, in a cylinder without clearance, in such manner as to keep the temperature constant, the work involved in delivering one pound is as follows:

Work of compression $= p_1v_1 \log_e \frac{v_1}{v_2}$.

Work of expulsion $= p_2v_2 = p_1v_1$.

The total work then is the sum of the work of compression and expulsion less the work, p_1v_1, of the atmosphere done on the piston during admission, or

Total work $= p_1\ v_1 \log_e \frac{v_1}{v_2} + p_1v_1 - p_1v_1 = p_1v_1 \log_e \frac{v_1}{v_2}$.

In this formula Naperian, or hyperbolic, logarithms must be used. These may be obtained from the common logarithms by multiplying by the constant 2.303.

The mean effective pressure equals the total work ÷ the initial volume, v_1, or $p_1 \log_e \frac{v_1}{v_2}$.

Volumes Mean Pressures per Stroke, Temperatures, etc., in the Operation of Air-compression from from 1 Atmosphere and 60° Fahr. (F. RICHARDS, *Am. Mach.*, March 30, 1893.)

Gauge-pressure.	Atmospheres.	Volume with Air at Constant Temp.	Volume with Air not cooled.	Mean Pressure per Stroke; Air Constant Temperature.	Mean Pressure per Stroke; Air not cooled	Temperature of Air; not cooled.
1	2	3	4	5	6	7
0	1	1	1	0	0	60°
1	1.068	.9363	.950	.96	.97	71
2	1.136	.8803	.910	1.87	1.91	80
3	1.204	.8305	.876	2.72	2.80	89
4	1.272	.7861	.840	3.53	3.67	98
5	1.340	.7462	.810	4.30	4.50	106
10	1.680	.5952	.690	7.62	8.27	145
15	2.020	.4950	.606	10.33	11.51	178
20	2.360	.4237	.543	12.62	14.40	207
25	2.700	.3703	.494	14.59	17.01	234
30	3.040	.3289	.453	16.34	19.40	252
35	3.381	.2957	.420	17.92	21.60	281
40	3.721	.2687	.393	19.32	23.66	302
45	4.061	.2462	.370	20.57	25.59	321
50	4.401	.2272	.350	21.69	27.39	339
55	4.741	.2109	.331	22.76	29.11	357
60	5.081	.1968	.314	23.78	30.75	375
65	5.423	.1844	.301	24.75	32.32	389
70	5.762	.1735	.288	25.67	33.83	405
75	6.102	.1639	.276	26.55	35.27	420

Volumes, Mean Pressures per Stroke, Temperatures, etc.
(CONTINUED.)

Gauge-pressure.	Atmospheres.	Volume with Air at Constant Temp.	Volume with Air not cooled.	Mean Pressure per Stroke; Air Constant Temperature.	Mean Pressure per Stroke; Air not cooled	Temperature of Air; not cooled.
1	2	3	4	5	6	7
80	6.442	.1552	.2670	27.38	36.64	432°
85	6.782	.1474	.2566	28.16	37.94	447
90	7.122	.1404	.2480	28.89	39.18	459
95	7.462	.1340	.2400	29.57	40.40	472
100	7.802	.1281	.2324	30.21	41.60	485
105	8.142	.1228	.2254	30.81	42.78	496
110	8.483	.1178	.2189	31.39	43.91	507
115	8.823	.1133	.2129	31.98	44.98	518
120	9.163	.1091	.2073	32.54	46.04	529
125	9.503	.1052	.2020	33.07	47.06	540
130	9.843	.1015	.1969	33.57	48.10	550
135	10.183	.0981	.1922	34.05	49.10	560
140	10.523	.0950	.1878	34.57	50.02	570
145	10.864	.0921	.1837	35.09	51.00	580
150	11.204	.0892	.1796	35.48	51.89	589
160	11.880	.0841	.1722	36.29	53.65	607
170	12.560	.0796	.1657	37.20	55.39	624
180	13.240	.0755	.1595	37.96	57.01	640
190	13.920	.0718	.1540	38.68	58.57	657
200	14.600	.0685	.1490	39.42	60.14	672

Combined compression of air, is compression under conditions that permit of some withdrawal of heat during compression, but not sufficient to keep the temperature of the air constant. In this case the compression curve lies between the isothermal and adiabatic curves, and the relation of pressure to volume may be expressed by the formula

$$p\ v^n = C,$$

in which p = absolute pressure in lbs, per sq. ft.; v = volume in cu. ft.; C = a constant; and n = an exponent whose value may vary from 1, that for isothermal, to 1.41, that for adiabatic compression or expansion.

Work of combined compression.—If air is compressed from a volume v_1 and pressure p_1 to a volume v_2 and pressure p_2, in a cylinder without clearance, the work involved in delivering one pound is as follows:

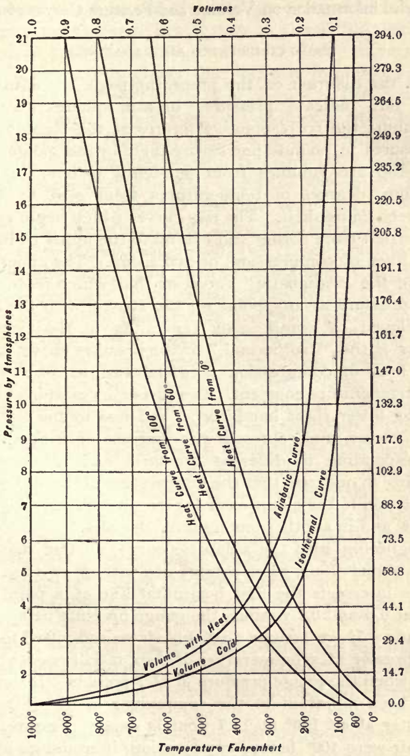
$$\text{Work of compression} = (p_2v_2 - p_1v_1)\frac{v_2}{v_1 - v_2} = 53.2\,(T_2 - T_1)\frac{v_2}{v_1 - v_2}.$$

Work of expulsion $= p_2v_2$.

The total work is the sum of the work of compression and expulsion less the work, p_1v_1, done by the atmosphere on the piston during admission, or

$$\text{Total work} = (p_2v_2 - p_1v_1)\frac{v_2}{v_1 - v_2} + p_2v_2 - p_1v_1$$

$$= (p_2v_2 - p_1v_1)\frac{v_1}{v_1 - v_2}.$$



The results of air compression and expansion are shown by the above diagram.

Useful information on Volume and Pressure Curves of Air.

(FROM COMPRESSED AIR MAGAZINE.)

In the diagram on the preceding page, the figures at the left indicate pressures in atmospheres above a vacuum; the corresponding figures at the right denote pressures in pounds per square inch, by the gauge. At the top are volumes from one-tenth to one. At the bottom, degrees of temperatures from zero to 1,000 degrees Fahrenheit. The two curves which begin at the lower left hand corner and extend to the upper right are the lines of compression, or expansion. The upper one being the "Adiabatic" curve, or that which represents the pressure at any point on the stroke, with the heat developed by compression remaining in the air; the lower is the "Isothermal," or the pressure curve, when the heat of compression is withdrawn so as to keep the temperature constant. The three curves which begin at the lower right hand corner and rise to the left are heat curves, and represent the increase of temperature corresponding to different pressures and volumes, assuming in one case that the temperature of the air before admission to the compressor is zero, in another sixty degrees, and in another one hundred degrees.

Beginning with the adiabatic curve, we find that for one volume of air, when compressed without cooling, the curve intersects the first horizontal line at a point between 0.6 and 0.7 volume, the gauge pressure being 14.7 pounds. If we assume that this air was admitted to the compressor at a temperature of zero, it will reach about 100° when the gauge pressure is 14.7 pounds. If the air had been admitted to the compressor at 60°, it would register about 176° at 14.7 pounds gauge pressure. If the air were 100° before compression, it would go up to about 230° at this pressure. Following this adiabatic curve until it intersects line No. 5, representing a pressure of five atmospheres above a vacuum (58.8 pounds gauge pressure), we see that the total increase of temperature on the zero heat curve is about 270°; for the 60° curve it is about 370°, and for the 100° curve it is 435°. The diagram shows that when a volume of air is compressed adiabatically to 21 atmospheres (294 pounds gauge pressure), it will occupy a volume a little more than one-tenth; the total increase of temperature with an initial temperature of zero, is about 650°; with 60° initial temperature it is 800° and with 100° initial it is 900°. It will be observed that the zero heat curve is flatter than the others, indicating that when free air is admitted to a compressor cold, the relative increase of temperature is less than when the air is hot. This points to the importance of low initial temperature. It is plain that a high initial temperature means a higher temperature throughout the stroke of a compressor. The diagram gives the loss of temperature during compression from initial temperatures of 0°, 60°, 100°. If we compare the compression line from zero with the compression line from 100°, we observe that in compressing the air from, say 1 atmosphere to 10 atmospheres, the original difference, which at the start was only 100°, has now been about doubled; that is, it has reached 200°, and in carrying the compression to 20 atmospheres, the difference now becomes about 250°. Each horizontal division represented by the figures at the bottom is equal to 100°, and the space between any two adjacent horizontal lines may be sub-divided into 100 equal parts representing 1° each.

Where there is a system of cooling the air during compression, the lines on the indicator cards can be traced between the adiabatic and isothermal curves on the diagram.

For all practical purposes in using this diagram, it is best to follow the adiabatic curve in all determinations, except where the exact pressure line is known. This diagram will be found convenient to those who are called upon to figure the pressure at different points in the stroke of an air compressor, and it points out the common error of neglecting to take into consideration in one's figures the fact that, at the beginning of the stroke, one atmosphere in volume already exists. Beginning at the lower left hand corner, the adiabatic pressure curve intersects the first horizontal line at that point in the stroke when the pressure on the gauge will register 14.7 pounds.

The next horizontal line shows where the gauge reaches 29.4 pounds, and it is evident here that the piston of an air compressor travels much farther in reaching 14.7 pounds than in doubling that pressure or in reaching 29.4 pounds; thus an air compressor is an engine of unevenly distributed resistance. During the early stages of the stroke it has a slowly accumulating load to carry, while later on this load is multiplied very rapidly. This is one of the reasons for heavy flywheels in air compressors.

Compressed Air.

EFFECT OF COMPOUNDING, COOLING, INTER-COOLING, AFTER-COOLING AND REHEATING.

(From *Compressed Air* Magazine.)

Builders of air compressors and those who use compressed air will agree that the problem of heating or cooling air is a difficult one. Hot air in the cylinder of an air compressor means a reduction in the efficiency of the machine. The trouble is, that there is not sufficient time during the stroke to cool thoroughly by any available means. Water-jacketing is the generally accepted practice, but it does not by any means effect through cooling. The air in the cylinder is so large in volume that but a fraction of its surface is brought in contact with the jacketed parts. Air is a bad conductor of heat and takes time to change its temperature. The piston while pushing the air towards the head rapidly drives it away from the jacketed surfaces; so that little or no cooling takes place. This is especially true of large cylinders where the economy effected by water-jackets is considerably less than in small cylinders. Engineers who are shown indicator cards from large air compressors with pressure lines running away from the adiabatic, naturally regard them with suspicion and look for leaks past the piston or through the valves. Such leaks will explain many isothermal cards, and until something better than a water-jacket is devised, it is well to seek economy in air compression through compounding.

The great advantage of compounding is in the fact that the inter-cooler, which should always be used with compound machines, effects a larger saving by cooling and thereby causing the air to shrink in volume between the stages. A properly designed inter-cooler should reduce the temperature of the air back to the orginal point, that is, to the temperature of the intake air. It can even do more than this, especially in winter, when the water used in the inter-color is of low temperature. A simple coil of pipe submerged in water is not an effective inter-cooler, because the air passes through the coil too rapidly to be cooled to the core, and such inter-coolers do not sufficiently split up the air to enable it to be cooled rapidly. This splitting up of air is an important point. A nest of tubes carrying water and arranged so that the air is forced between and around the tubes is an efficient form of inter-cooler.

Receiver inter-coolers are more efficient than those of the common type because the air is given more time to pass through the cooling stages and because of the freedom from wire drawing which may take place in inter-coolers of small volumetric capacity.

After-coolers are in some installations as important as inter-coolers. An after-cooler serves to reduce the temperature of the air after the final compression. In doing this it serves as a drier, reducing the temperature of air to the dew point, thus abstracting moisture before the air is started on its journey. In cold weather with air pipes laid over the ground an after-cooler may prevent accumulation of frost in the interior walls of the pipes, for where the hot compressed air is allowed to cool gradually the walls of the pipe in cold weather act like a surface condenser and moisture may be deposited on the inside, for the same reason that we have frost on the inner side of a window pane. Another advantage of the after-cooler is that it keeps the temperature of the line pipe uniform, otherwise this pipe will be hottest near the compressor, gradually cooling down and being thus subject to irregularities of expansion and contraction.

The following table will serve to illustrate the large saving that it is possible to effect by compounding. This table gives the percentage of work lost by the heat of compression, taking isothermal compression, or compression without heat, as a base.

Gauge Pressures.	One Stage.		Two Stage.		Four Stage.	
	% of work lost in terms of Isothermal Compression.	% of work lost in terms of Adiabatic Compression.	% of work lost in terms of Isothermal Compression.	% of work lost in terms of Adiabatic Compression.	% of work lost in terms of Isothermal Compression.	% of work lost in terms of Adiabatic Compression.
60	30. %	23. %	13.38%	11.8 %	4.65%	4.45%
80	34.	25.26	15.12	13.12	5.04	4.80
100	38.	27.58	17.10	14.62	8.00	7.41
200	52.35	34.40	23.20	18.88	9.01	8.27
400	68.60	40.75	29.70	22.90	12.40	11.04
600	83.75	44.60	32.65	24.60	15.06	13.10
800	90.	47.40	35.80	26.33	16.74	14.32
1000	96.80	49.20	39.00	28.10	16.90	14.45
1200	106.15	51.60	40.00	28.60	17.45	14.85
1400	108.	52.	41.60	29.4	17.70	15.00
1600	110.	53.3	42.90	30.0	18.40	15.54
1800	116.80	54.	44.40	30.6	19.12	16.05
2000	121.70	54.8	44.60	30.8	20.00	16.65

In the above table no account is taken of jacket cooling, it being a well known fact among pneumatic engineers that water jackets, especially cylinder jackets, though useful and perhaps indispensable, are not efficient in cooling, especially so in large compressors. The volume of air is so great in proportion to the surface exposed and at the time of compression so short, that little or no cooling takes place. Jacketed heads are useful auxiliaries in cooling, but it has become an accepted theory among engineers that compounding or stage compression is more fertile as a means of economy than any other system that has yet been devised. The two and four stage figures in this table (columns 3 and 4), are based on reduction to atmospheric temperature, or 60° Fahrenheit, between stages. A rule which might be observed to advantage among engineers is to specify that the manufacturers should supply a compressor with coolers provided with one square foot of tube cooling surface for every ten cubic feet of free air furnished by the compressor when running at its normal speed.

Referring again to the table, we learn that when air is compressed to 100 pounds pressure per square inch in a single stage compressor without cooling, the heat loss may be thirty-eight (38) per cent. This condition, of course, does not exist in practice, except perhaps, at exceedingly high speeds, as there will be some absorption of heat by the exposed parts of the machine. It is safe, however, to say that in large air compressors that compress in a single stage up to 100 pounds gauge pressure, the heat loss reaches thirty (30) per cent. This, as shown by the table, may be cut down more than one-half by compressing in two-stages, and with three-stages this loss is brought down to eight (8) per cent. theoretically, and perhaps to three or five (3 or 5) per cent. in practice. As higher pressures are used, the gain by compounding is greater.

Efficiency of Air Compressors at Different Altitudes.

The altitude, where the compressor is to operate, is an important factor because it affects its capacity to a greater or lesser extent, according to the elevation. As the density of the atmosphere decreases with the altitude, a compressor located at a high altitude takes in less weight of air at each revolution, that is to say, the air being taken in at a lower pressure, the early part of each stroke is occupied in compressing the air up to the normal pressure of 14.7 pounds, and the capacity of the air cylinder is correspondingly diminished. The power required to drive the same compressor is also less than at sea level, but the decrease in power required is not in as great a ratio as the reduction in capacity. Therefore, compressors to be used at high altitudes should have the steam and air cylinders properly proportioned to meet the varying conditions at different places.

The following table shows the efficiency and loss in capacity of compressors working at different altitudes, also the approximate decrease in power required as compared with the same compressor working at sea level, and delivering air at 70 pounds pressure per square inch.

TABLE OF EFFICIENCIES AT DIFFERENT ALTITUDES.

THE EFFICIENCY AT SEA LEVEL BEING 100 PER CENT.

Altitude, feet.	Barometric Pressure.		Volumetric Efficiency of Compressor, Per Cent.	Loss of Capacity, Per Cent.	Decreased Power Required, Per Cent.
	Inches, Mercury.	Pounds per Square Inch.			
1000	28.88	14.20	97.	3.	1.8
2000	27.80	13.67	93.	7.	3.5
3000	26.76	13.16	90.	10.	5.2
4000	25.76	12.67	87.	13.	6.9
5000	24.79	12.20	84.	16.	8.5
6000	23.86	11.73	81.	19.	10.1
7000	22.97	11.30	78.	22.	11.6
8000	22 11	10.87	76.	24.	13.1
9000	21.29	10.46	73.	27	14.6
10000	20.49	10.07	70.	30.	16.1
11000	19.72	9.70	68.	32.	17.6
12000	18.98	9.34	65.	35.	19.1
13000	18.27	8.98	63.	37.	20.6
14000	17.59	8.65	60.	40.	22.1
15000	16.93	8.32	58.	42.	23.5

Horse-power Required to Compress 100 Cubic Feet Free Air, from Atmospheric to Various Pressures.

Gauge Pressure, Pounds.	One-Stage Compression, D. H. P.	Gauge Pressure, Pounds.	Two-Stage Compression, D. H. P.	Four-Stage Compression, D H. P.
10	3.60	60	11.70	10.80
15	5.03	80	13.70	12.50
20	6.28	100	15.40	14.20
25	7.42	200	21.20	18.75
30	8.47	300	24.50	21.80
35	9.42	400	27.70	24.00
40	10.30	500	29.75	25.90
45	11.14	600	31.70	27.50
50	11.90	700	33.50	28.90
55	12.67	800	34.90	30.00
60	13.41	900	36.30	31.00
70	14.72	1000	37.80	31.80
80	15.94	1200	39.70	33.30
90	17.06	1600	43.00	35.65
100	18.15	2000	45.50	37.80
		2500		39.06
		3000		40.15

D. H. P., delivered horse-power at compressor cylinder.

Capacity of Air Compressors.

To ascertain the capacity of an air compressor in cubic feet of free air per minute, the common practice is to multiply the area of the intake cylinder by the feet of piston travel per minute. The free air capacity of the compressor divided by the number of atmospheres will give the volume of compressed air per minute. To ascertain the number of atmospheres at any given pressure, add 14.7 lbs. to the gauge pressure, divide this sum by 14.7 and the result will be the number of atmospheres.

The above method of calculation, however, is only theoretical and these results are never obtained in actual practice even with compressors of the very best design.

Allowances should be made for losses of various kinds, the principal loss being due to clearance spaces, but in machines of poor design and construction other considerable losses occur through imperfect cooling, leakages past the piston and through the discharge valves, insufficient area and improper working of inlet valves, etc. We have seen compressors where the total loss was fully 25 to 30 per cent., whereas, 3 to 10 per cent. should be the maximum—according to the size—in compressors of proper design and construction.

Weights of Air, Vapor of Water, and Saturated Mixtures of Air and Vapor at Different Temperatures, under the Ordinary Atmospheric Pressure of 29.92 inches of Mercury.

Temperature, Fahrenheit, Degrees.	Weight of a Cubic ft. of Dry Air at Different Temperatures, lbs.	Elastic Force of Vapor, Inches of Mercury.	Mixtures of Air Saturated with Vapor				
			Elastic Force of the Air in mixture of Air and Vapor, Inches of Mercury.	Weight of Cubic Foot of the Mixture of Air and Vapor.			Weight of Vapor mixed with 1 lb. of Air, lbs.
				Weight of the Air, lbs.	Weight of the Vapor, lbs.	Total W'ght of Mixture, lbs.	
0	.0864	.044	29.877	.0863	.000079	.086379	.00092
12	.0842	.074	29.849	.0840	.000130	.084130	.00155
22	.0824	.118	29.803	.0821	.000202	.082302	.00245
32	.0807	.181	29.740	.0802	.000304	.080504	.00379
42	.0791	.267	29.654	.0784	.000440	.078840	.00561
52	.0776	.388	29.533	.0766	.000627	.077227	.00819
62	.0761	.556	29.365	.0747	.000881	.075581	.01179
72	.0747	.785	29.136	.0727	.001221	.073921	.01680
82	.0733	1.092	28.829	.0706	.001667	.072267	.02361
92	.0720	1.501	28.420	.0684	.002250	.070717	.03289
102	.0707	2.036	27.885	.0659	.002997	.068897	.04547
112	.0694	2.731	27.190	.0631	.003946	.067046	.06253
122	.0682	3.621	26.300	.0599	.005142	.065042	.08584
132	.0671	4.752	25.169	.0564	.006639	.063039	.11771
142	.0660	6.165	23.756	.0524	.008473	.060873	.16170
152	.0649	7.930	21.991	.0477	.010716	.058416	.22465
162	.0638	10.099	19.822	.0423	.013415	.055715	.31713
172	.0628	12.758	17.163	.0360	.016682	.052682	.46338
182	.0618	15.960	13.961	.0288	.020536	.049336	.71300
192	.0609	19.828	10.093	.0205	.025142	.045642	1.22643
202	.0600	24.450	5.471	.0109	.030545	.041445	2.80230
212	.0591	29.921	0.000	.0000	.036820	.036820	Infinite.

FLOW OF AIR THROUGH AN ORIFICE FROM A RESERVOIR INTO THE ATMOSPHERE,

In Cubic Feet of Free Air per Minute for Varying Diameters of Orifice and Gauge Pressures.

Diam. of Orifice, Inches.	Receiver Gauge Pressure.								
	2 lbs.	5 lbs.	10 lbs.	15 lbs.	20 lbs.	25 lbs.	30 lbs.	35 lbs.	40 lbs.
1/64	0.038	0.060	0.084	0.103	0.119	0.133	0.156	0.173	0.19
1/32	0.153	0.242	0.342	0.418	0.485	0.54	0.632	0.71	0.77
1/16	0.647	0.965	1.36	1.67	1.93	2.16	2.52	2.80	3.07
1/8	2.435	3.86	5.45	6.65	7.7	8.6	10.	11.2	12.3
1/4	9.74	15.4	21.8	26.7	30.8	34.5	40.	44.7	49.
3/8	21.95	34.6	49.	60.	69.	77.	90.	100.	110.
1/2	39.	61.6	87.	107.	123.	138.	161.	179.	196.
5/8	61.	96.5	136.	167.	193.	216.	252.	280.	307.
3/4	87.6	133.	196.	240.	277.	310.	362.	400.	442.
7/8	119.5	189.	267.	326.	378.	422.	493.	550.	601.
1	156.	247.	350.	427.	494.	550.	645.	715.	785.
1¼	242.	384.	543.	665.	770.	860.	1000.		
1½	350.	550.	780.	960.					
2	625.	985.							

Diam. of Orifice, Inches.	45 lbs.	50 lbs.	60 lbs.	70 lbs.	80 lbs.	90 lbs.	100 lbs.	125 lbs.	150 lbs.
1/64	0.208	0.225	0.26	0.295	0.33	0.364	0.40	0.486	0.57
1/32	0.843	0.914	1.05	1.19	1.33	1.47	1.61	1.97	2.33
1/16	3.36	3.64	4.2	4.76	5.32	5.87	6.45	7.85	9.25
1/8	13.4	14.50	16.8	19.0	21.2	23.50	25.8	31.4	37.2
1/4	53.8	58.2	67.	76.	85.	94.	103.	125.	148.
3/8	121.	130.	151.	171.	191.	211.	231.	282.	334.
1/2	215.	232.	268.	304.	340.	376.	412.	502.	596.
5/8	336.	364.	420.	476.	532.	587.	645.	785.	925.
3/4	482.	522.	604.	685.	765.	843.	925.		
7/8	658.	710.	622.	930.	1004.				
1	860.	930.							

The above table was computed with the aid of Fliegner's equations and have given results that approximate very closely to the conditions of actual practice. These equations are :

$$\text{For } p_1 > 2pa, \quad G = 0.530\, F \frac{p_1}{\sqrt{T_1}};$$

$$p_1 > 2pa, \quad G = 1.060\, F \sqrt{\frac{pa\,(p_1 - pa)}{T_1}}; \text{ in which}$$

G = flow of air through the orifice in lbs. per sec., F = area of orifice in square inches, p_1 = pressure in reservoir in lbs. per sq. in., pa = pressure of atmosphere, T_1 = absolute temperature, Fahrenheit, of air in reservoir.

FLOW OF AIR THROUGH PIPES.*

The following new and original tables are based upon D'Arcy's formula adapted to the flow of elastic fluids, namely:

$$\text{Discharge in cubic feet per minute} = c\sqrt{\frac{d^5 \times (p_1 - p_2)}{l \times w_1}}.$$

As it is most convenient in the case of compressed air installations to deal with its equivalent volume of free air, *i. e.*, air at atmospheric pressure, these tables have been specially calculated with this end in view.

Table I. Gives the theoretical volume of equivalent free air in cubic feet that will flow per minute at various pressures through straight pipes of various diameters, each 100 feet long, *no reduction of the final pressure* being allowed for.

The formula by which it is calculated is:

$$\text{Theoretical discharge of free air} = F_t = \frac{c\sqrt{d^5}}{10} \times \frac{f_1}{\sqrt{w_1}}.$$

Table II. Is a table of multipliers to be used in connection with F_t, as found by Table I., by which may be obtained the theoretical discharge of equivalent free air from pipes of various lengths up to 60,000 feet. It is calculated from

$$\text{Multiplier for length of pipe} = M_l = \sqrt{\frac{100}{l}}.$$

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Table III. Is a table of Multipliers to be used in connection with F_t and M_l as found by Tables I. and II., to obtain the *real volume* of discharge of equivalent free air, for reductions of the terminal pressure varying from 1 to 50 pounds. It is calculated from

$$\left.\begin{array}{l}\text{Multiplier for}\\ \text{real discharge}\end{array}\right\} = M_r = \frac{f_2}{f_1} \times \sqrt{p_1 - p_2}.$$

The notation used in above formulas is

d=*actual* diameter of pipe in inches.

l=length of pipe in feet.

c=a co-efficient, (D'Arcy's) varying with the diameter of the pipe.

w_1=density of the air at initial gauge pressure.

p_1 and p_2=initial and terminal gauge pressures.

f_1 and f_2=factors to reduce compressed air at initial and terminal pressures p_1 and p_2 to their corresponding volumes of free air.

Tables are also added showing the increase in the length of pipe to be allowed for on account of the friction caused by globe valves, elbows and tees.

Several examples are worked out to show the method of using the tables for the solution of problems likely to be met with by the Engineer.

TABLE I. Giving the Theoretical Volume of Equivalent Free Air, in Cubic Feet, that will flow per minute at various pressures through straight pipes of different diameters, each 100 feet long, not allowing for reduction of pressure.

Initial and Terminal Gauge Pressure.	NOMINAL DIAMETERS OF PIPES IN INCHES.																	
	1	1½	2	2½	3	3½	4	5	6	7	8	10	12	15	18	20	22	24
10 lbs.	24.05	75.67	153.0	244.7	433.3	636.4	883.8	1585	2542	3701	5134	9212	14530	22530	36280	48180	61870	77880
20 "	28.48	89.54	177.9	288.8	512.9	753.0	1045	1871	3006	4381	6076	10900	17210	26640	42940	57000	73220	92150
30 "	32.35	101.6	202.0	329.1	582.5	855.0	1187	2124	3415	4975	6900	12380	19540	30270	48750	64760	83160	104630
40 "	35.82	112.5	223.5	364.2	644.7	946.4	1314	2352	3779	5507	7635	13700	21620	33500	53960	71640	92010	115800
50 "	38.96	122.4	243.4	396.3	701.5	1030	1430	2558	4114	5993	8312	14910	23520	36450	58730	74300	100150	126030
60 "	41.83	131.4	261.1	425.4	752.9	1105	1535	2747	4416	6433	8920	16000	25260	39120	63040	83660	107470	135240
70 "	44.53	139.9	278.0	452.9	801.8	1176	1634	2925	4701	6848	9499	17030	26900	41660	67110	89100	114420	144000
80 "	47.08	147.9	294.0	478.8	847.6	1244	1728	3091	4971	7240	10040	18000	28430	44050	70960	94180	120970	152230
90 "	49.54	155.6	309.3	503 8	891.8	1307	1817	3253	5230	7619	10560	18940	29920	46340	74660	99100	127300	160190
100 "	51.88	163.0	324.0	527.5	933.8	1370	1904	3407	5477	7979	11050	19850	31330	48530	78190	103770	133300	167720
110 "	54.10	169.9	337.8	550.1	973.9	1429	1985	3552	5712	8320	11530	20690	32670	50610	81540	108220	139000	174920
125 "	57.15	179.5	356.8	581.3	1028	1510	2097	3754	6034	8789	12180	21860	34520	53470	86140	114430	146850	184800
150 "	62.10	195.1	387.8	631.7	1117	1641	2280	4080	6558	9553	13240	23760	37520	58120	93610	124280	159600	
175 "	66.71	209.6	416.5	678.4	1201	1762	2448	4382	7044	10250	14220	25520	40300	62420	100520	133460		
200 "	70.93	222.9	443.0	721.4	1277	1874	2603	4659	7489	10900	15120	27140	42850	66370	106900	141910		
250 "	78.70	247.3	491.4	800.4	1416	2079	2889	5170	8309	12100	16780	30110	47550	73640	118620			
300 "	85.85	269.9	536.3	873.4	1546	2269	3152	5642	9063	13210	18320	32870	51890	80380				
400 "	98.55	309.9	615.7	1002	1775	2606	3619	6477	10400	15160	21020	37730	59580	92270				
500 "	109.7	345.1	685.3	1116	1976	2902	4031	7215	11590	16890	23420	42020	66340	102750				
600 "	119.9	377.3	749.5	1220	2160	3172	4405	7882	12670	18460	25600	45940	72520					
700 "	129.3	406.6	807.6	1315	2328	3419	4748	8496	13650	19890	27590	49500	78150					
800 "	138.1	434.1	862.0	1404	2486	3650	5070	9072	14580	21240	29450	52840						
900 "	146.3	460.0	914.4	1489	2636	3871	5373	9618	15460	22520	31230	56040						
1000 "	154.3	485.1	963.5	1569	2778	4079	5664	10130	16290	23730	32920	59060						
1100 "	161.3	507.1	1008	1641	2906	4264	5924	10590	17040	24820	34430							
1200 "	168.6	530.3	1053	1716	3037	4457	6193	11080	17810	25940	35980							
1300 "	175.7	552.2	1097	1787	3163	4643	6448	11540	18550	27030								
1400 "	182.2	572.4	1137	1853	3280	4814	6686	11970	19230	28020								
1500 "	188.2	591.5	1175	1914	3389	4973	6908	12360	19870									

TABLE II. MULTIPLIERS FOR LENGTH OF PIPE.

Length, feet.	Multipler M_1.	Length, feet.	Multipler M_1.
100	1.0	6000	0.129
200	0.707	7000	0.119
300	0.577	8000	0.112
400	0.500	9000	0.105
500	0.447	10000	0.100
600	0.408	12000	0.0912
750	0.365	15000	0.0817
1000	0.316	20000	0.0707
1250	0.283	25000	0.0632
1500	0.258	30000	0.0577
2000	0.224	35000	0.0534
2500	0.200	40000	0.0500
3000	0.183	45000	0.0471
3500	0.169	50000	0.0447
4000	0.158	55000	0.0426
5000	0.141	60000	0.0408

Table III. Multipliers for the Real Volume of Discharge.

Initial Gauge Pressure	REDUCTION OF THE FINAL PRESSURE IN POUNDS, PER SQUARE INCH.																				
	1	2	3	4	5	6	7	8	9	10	12	14	16	18	20	25	30	35	40	45	50
10 lbs.	0.958	1.30	1.52	1.67	1.78																
20 "	0.971	1.34	1.58	1.77	1.91	2.02	2.11	2.17	2.22	2.25											
30 "	0.978	1.35	1.61	1.82	1.98	2.12	2.23	2.32	2.39	2.45											
40 "	0.984	1.36	1.64	1.85	2.03	2.18	2.31	2.41	2.50	2.58											
50 "	0.984	1.37	1.65	1.87	2.06	2.22	2.36	2.48	2.58	2.67											
60 "	0.986	1.37	1.66	1.89	2.08	2.24	2.39	2.52	2.63	2.74											
70 "	0.988	1.38	1.67	1.90	2.10	2.27	2.42	2.56	2.68	2.79	2.97	3.12	3.24								
80 "	0.989	1.38	1.67	1.91	2.11	2.29	2.45	2.59	2.71	2.82	3.02	3.19	3.32	3.43	3.53						
90 "	0.990	1.38	1.68	1.92	2.12	2.31	2.47	2.61	2.74	2.86	3.06	3.24	3.39	3.51	3.61						
100 "	0.991	1.39	1.68	1.93	2.13	2.32	2.48	2.63	2.76	2.88	3.10	3.28	3.44	3.57	3.69	3.91					
110 "	0.992	1.39	1.69	1.93	2.14	2.33	2.49	2.64	2.78	2.90	3.13	3.32	3.48	3.63	3.75	3.99					
125 "	0.993	1.39	1.69	1.94	2.15	2.34	2.51	2.66	2.81	2.93	3.16	3.36	3.54	3.69	3.83	4.10	4.30				
150 "	0.994	1.39	1.70	1.95	2.16	2.36	2.53	2.69	2.83	2.97	3.21	3.42	3.61	3.77	3.92	4.24	4.47				
175 "	0.994	1.40	1.70	1.95	2.17	2.37	2.54	2.71	2.85	2.99	3.24	3.46	3.66	3.84	4.00	4.34	4.61	4.82			
200 "	0.995	1.40	1.70	1.96	2 18	2.38	2.56	2.72	2.87	3.01	3.27	3.49	3.70	3.88	4.05	4.41	4.71	4.95			
250 "	0.996	1.40	1.71	1.97	2.19	2.39	2.57	2.74	2.89	3.04	3.30	2.53	3.75	3.95	4.13	4.52	4.85	5.13	5.37		
300 "	0.997	1.40	1.71	1.97	2.20	2.40	2.58	2.75	2.91	3.06	3.33	3.57	3.79	4.00	4.18	4.60	4.95	5.25	5.52		
400 "	0.997	1.40	1.72	1.98	2.21	2.41	2.60	2.77	2.93	3.08	3.36	3.61	3.84	4.06	4.25	4.70	5.08	5.41	5.71	5.98	
500 "	0 998	1.40	1.72	1.98	2.21	2.42	2.61	2.78	2.94	3.10	3.38	3.64	3.87	4.09	4.29	4.75	5.15	5.51	5.85	6.12	6.38
600 "	0.998	1.41	1.72	1.98	2.21	2.42	2.61	2.79	2.95	3.11	3.40	3.65	3.89	4.12	4.32	4.80	5.21	5.58	5.91	6.21	6.49
700 "	0.998	1.41	1.72	1.99	2.22	2.42	2.62	2.79	2.96	3.11	3.40	3.67	3.91	4.13	4.34	4.82	5.24	5.62	5.97	6.28	6.57
800 "	0.998	1.41	1.72	1.99	2.22	2.43	2.62	2.80	2.96	3.12	2.41	3.67	3.92	4.15	4.36	4.84	5.27	5.66	6.01	6.33	6.63
900 "	0.999	1.41	1.72	1.99	2.22	2.43	2.62	2.80	2.97	3.12	3.41	3.68	3.93	4.16	4.37	4.86	5.29	5.69	6.04	6.37	6.68
1000 "	0.999	1.41	1.72	1.99	2.22	2.43	2.62	2.80	2.97	3.13	3.42	3.69	3.93	4.16	4.38	4.87	5.31	5.71	6.07	6.41	6.72
1100 "	0.999	1.41	1.72	1.99	2.22	2.43	2.63	2.81	2.97	3.13	3.42	3.69	3.94	4.17	4.39	4.88	5.33	5.73	6.09	6.43	6.75
1200 "	0.999	1.41	1.72	1.99	2.22	2.43	2.63	2.81	2.97	3.13	3.43	3.69	3.94	4.18	4.39	4.89	5.34	5.74	6.11	6.46	6.78
1300 "	0.999	1.41	1.72	1.99	2.22	2.43	2.63	2.81	2.98	3.13	3.43	3.70	3.95	4.18	4.40	4.90	5.35	5.76	6.13	6.47	6.80
1400 "	0.999	1.41	1.72	1.99	2.22	2.43	2.63	2.81	2.98	3.14	3.43	3.70	3.95	4.19	4.40	4.91	5.36	5.77	6.14	6.49	6.82
1500 "	0.999	1.41	1.72	1.99	2.22	2.43	2.63	2.81	2.98	3.14	3.43	3.70	3.95	4.19	4.41	4.91	5.36	5.78	6.15	6.50	6.83

The formulas by which these tables have been calculated show that the following factors enter into their composition :

The diameter of the pipe........ $=d$.
The length of the pipe.......... $=l$.
The initial and final pressures, or the reduction of pressure $\} = p_1 - p_2$.
The equivalent free air discharged .... $=F$.

It being often required to find any one of these factors when the others are known, the following examples are given to show the method of procedure in each case.

The simple statement of the formula, adapted to the tables becomes

Free air discharged $= F = F_t \times M_1 \times M_r$
and by this all problems involving any of the above factors may be solved, as shown in the examples.

EXAMPLE 1.—To find the volume of free air discharged.

EXAMPLE 2.—To find the reduction of pressure.
" 3.—To find a suitable diameter of pipe.
" 4.—To find the length of pipe which may be used.

Example I.—Given a 3-inch pipe, 10,000 feet long, initial pressure 1,100 lbs., terminal pressure 1,050 lbs.; to find the volume of equivalent free air discharged.

By Table I.—Under 3″ pipe and opposite 1,100 lbs. we find $F_t = 2{,}906$.
By Table II.—For 10,000 feet of pipe, $M_1 = 0.1$.
" " III.—Under 50 lbs. reduction and opposite 1,100 lbs., $M_r = 6.75$.

Then as shown

$F = F_t \times M_1 \times M_r = 2{,}906 \times 0.1 \times 6.75 = 1{,}961$ cubic feet free air.

Example 2.—Given a 4-inch pipe, 600 feet long, initial pressure 60 lbs., required to discharge 1,200 cubic feet free air. What will be the reduction of pressure and the terminal pressure?

By Table I.—Under 4″ pipe and opposite 60 lbs., we find F_t=1,535.

By Table II.—For 600 feet, M_1=0.408.

Given F=1,200.

By transposing the formula

$$M_r = \frac{F}{F_t \times M_1} = \frac{1,200}{1,535 \times 0.408} = 1.9.$$

Now by Table III., opposite 60 lbs. pressure, and under 4 lbs. reduction, we find M_r=1.89, so that the terminal pressure will be slightly less than 60—4=56 pounds.

Example 3.—It is required to discharge 1000 cubic feet of free air from a pipe 2,500 feet long. The initial pressure is 100 lbs. and the terminal pressure must not be less than 90 lbs. What diameter of pipe should be used?

Here we have given F=1000.

By Table II ....M_1=0.200 for 2,500 feet.

" " III........M_r= 2.88 for p_1=100 lbs., and p_2=90 lbs.

By transposing the formula we get

$$F_t = \frac{F}{M_1 \times M_r} = \frac{1,000}{0.200 \times 2.88} = 1,736.$$

By Table I. looking along the line of 100 lbs. pressure we see that the value of F_t for a 3½-inch pipe is 1,370, and for a 4-inch pipe 1,904, so that this latter size of pipe would have to be used.

Example 4.—It is required to transmit 4,000 cubic feet of free air through a 6-inch pipe, the initial pressure being 200 lbs. How far can it be carried with a reduction of pressure of 10 lbs.?

Here we have given F=4,000.

By Table I.....F_t=7,489 for 200 lbs. pressure and 6″ pipe.

By Table III.....M_r=3.01 for 200 lbs. pressure and 10 lbs. reduction.

Then by transposing the formula:

$$M_l = \frac{F}{F_t \times M_r} = \frac{4,000}{7,489 \times 3.01} = 0.177.$$

Now by Table II. we see that this is an intermediate value of M_l between 3000 and 3500 feet, so that the distance sought is approximately 3250 feet.

GLOBE VALVES, TEES AND ELBOWS.

The reduction of pressure produced by globe valves is the same as that caused by the following additional lengths of straight pipe, as calculated by the formula:

$$\text{Additional length of pipe} = \frac{114 \times \text{diameter of pipe}}{1 + (3.6 \div \text{diameter})}.$$

Diameter of pipe.	1	1½	2	2½	3	3½	4	5	6	inches.
Addition'l length.	2	4	7	10	13	16	20	28	36	feet.
Diameter of pipe.	7	8	10	12	15	18	20	22	24	ins.
Addition'l length.	44	53	70	88	115	143	162	181	200	ft.

The reduction of pressure produced by elbows and tees is equal to $\frac{2}{3}$ of that caused by globe valves.

These additional lengths of pipe for globe valves, elbows and tees must be added in each case to the actual lengths of straight pipe. Thus, a 6-inch pipe, 500 feet long, with one globe valve, 2 elbows and three tees, would be equivalent to a straight pipe 500+36+(2×24)+(3×24)=656 feet long, and this is the length which must be used in the tables as the value of M_l.

GENERAL EXAMPLE.

How much free air will a 6-inch pipe, 8,000 feet long, discharge under the following conditions, namely: Initial pressure 150 lbs., terminal pressure 135 lbs., with 2 globe valves, 3 elbows and 1 tee?

The equivalent length of straight pipe must first be found as follows:

$$8{,}000+(2\times 36)+(3\times 24)+24=8{,}168 \text{ feet.}$$

Now we have

By Table I., F_t=6,558 for 6 inch pipe and 150 lbs. pressure.

By Table II., M_l=0.112 for 8000 feet, making by interpolation say 0.110 for 8,168 feet.

By Table III., M_r=3.42 for150 lbs. pressure and 14 lbs. reduction, and 3.61 for 150 lbs. pressure and 16 lbs. reduction, so that by interpolation M_r would be 3.51 for 15 lbs. reduction of pressure.

Then by the formula:

$$\text{Free air discharged} = F = F_t \times M_l \times M_r.$$
$$= 6{,}558 \times 0.11 \times 3.51.$$
$$= 2{,}532 \text{ cubic feet equivalent free air per minute.}$$

FORMULA FOR FLOW OF AIR IN PIPES.

Mr. Richards, in *Am. Mach.*, Dec. 27, 1894, published a new formula, viz.:

$$p=\frac{V^2L}{10{,}000d^5a};\quad V=\sqrt{\frac{10{,}000d^5ap}{L}};\quad L=\frac{10{,}000d^5ap}{V^2};$$

$$d^5ap=\frac{V^2L}{10{,}000p};$$

in which V= actual volume of compressed air delivered, in cubic feet per minute (not the volume of free air, as in the other formula), L=length of pipe in feet, d= internal diameter of pipe in inches, p = head or additional pressure in pounds per square inch required to maintain the flow, and a is a coefficient varying with the diameter of the pipe. Its value for different nominal diameters of wrought-iron pipe is given by Mr. Richards as follows :

Diam., Inches.	Value of a.	Diam., Inches.	Value of a.	Diam., Inches.	Value of a.
1	.35	3½	.79	12	1.26
1¼	.44	4	.84	16	1.34
1½	.50	5	.93	20	1.4
2	.56	6	1.	24	1.45
2½	.65	8	1.125		
3	.73	10	1.2		

The following values of the fifth power of d and of d^5a are given by Mr. Richards to facilitate calculations :

Fifth Powers of d.		Value of d^5a.	
1"........ 1	5"... 3,125	1"....... .35	5"... 2,918.75
1¼"...... 3.05	6"... 7,776	1¼"..... 1.34	6"... 7,776
1½"...... 7.59	8"... 32,768	1½"..... 3.80	8"... 36,864
2"........ 32	10"... 100,000	2"....... 18.08	10"... 120,000
2½"...... 97.65	12"... 248,832	2½"..... 63.47	12"... 313,528
3"........ 243	16".... 1,048,576	3".......177.4	16"... 1,405,091
3½"...... 525	20".... 3,200,000	3½"... .413.2	20"... 4,480,000
4"........1024	24".... 7,962,624	4".......860.2	24"...11,545,805

GAS.

FLOW OF GAS IN PIPES.

If d = diameter of pipe in inches; Q = quantity of gas delivered in cu. ft. per hour; l = length of pipe in yards; h = pressure in inches of water column; s = specific gravity of the gas, air being one; then

$$Q = 1000 \sqrt{\frac{d^5 h}{s\, l}}, \quad \text{(Molesworth).}$$

$$Q = 1350\, d^2 \sqrt{\frac{d\, h}{s\, l}}, \quad \text{(King's Treatise on Coal Gas.)}$$

$$Q = 1290 \sqrt{\frac{d^5 h}{d\,(s + l)}}, \quad \text{(J. P. Gill, \textit{Am. Gas-light Jour.}, 1894).}$$

Mr. Gill's formula is said to be based on experimental data, and to make allowance for obstructions by tar, etc., that tend to check the flow of gas through the pipe.

An experiment made by Mr. Klegg, in London, on a 4 inch pipe, 6 miles long, gave a discharge that corresponds very closely with that computed by the use of Molesworth's formula.

Maximum Supply of Gas through Pipes in cu. ft. per Hour, Specific Gravity being 0.45. Formula $Q = 1000 \sqrt{d^5 h \div sl}$.

(MOLESWORTH.)

LENGTH OF PIPE = 10 YARDS.

Diameter of Pipe in Inches.	Pressure by the Water-gauge in Inches.									
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
3/8	13	18	22	26	29	31	34	36	38	41
1/2	26	37	46	53	59	64	70	74	79	83
3/4	73	103	126	145	162	187	192	205	218	230
1	149	211	258	298	333	365	394	422	447	471
1 1/4	260	368	451	521	582	638	689	737	781	823
1 1/2	411	581	711	821	918	1006	1082	1162	1232	1299
2	843	1192	1460	1686	1886	2066	2231	2385	2530	2667

Maximum Supply of Gas through Pipes, etc.—(CONTINUED.)

LENGTH OF PIPE = 100 YARDS.

Diameter of Pipe in Inches	Pressure by the Water-gauge in Inches.										
	0.1	0.2	0.3	0.4	0.5	0.75	1.0	1.25	1.5	2.0	2.5
½	8	12	14	17	19	23	26	29	32	36	42
¾	23	32	42	46	51	63	73	81	89	103	115
1	47	67	82	94	105	129	149	167	183	211	236
1¼	82	116	143	165	184	225	260	291	319	368	412
1½	130	184	225	260	290	356	411	459	503	581	649
2	267	377	462	533	596	730	843	943	1033	1193	1333
2½	466	659	807	932	1042	1276	1473	1647	1804	2083	2329
3	735	1039	1270	1470	1643	2012	2323	2598	2846	3286	3674
3½	1080	1528	1871	2161	2416	2958	3416	3820	4184	4831	5402
4	1508	2133	2613	3017	3373	4131	4770	5333	5842	6746	7542

LENGTH OF PIPE = 1000 YARDS.

Diameter of Pipe in Inches.	Pressure by the Water-gauge in Inches.						
	0.5	0.75	1.0	1.5	2.0	2.5	3.0
1	33	41	47	58	67	75	82
1½	92	113	130	159	184	205	226
2	189	231	267	327	377	422	462
2½	329	403	466	571	659	737	807
3	520	636	735	900	1039	1162	1273
4	1067	1306	1508	1847	2133	2385	2613
5	1863	2282	2635	3227	3727	4167	4564
6	2939	3600	4157	5091	5879	6573	7200

LENGTH OF PIPE = 5000 YARDS.

Diameter of Pipe in Inches.	Pressure by the Water-gauge in Inches.				
	1.0	1.5	2.0	2.5	3.0
2	119	146	169	189	207
3	329	402	465	520	569
4	675	826	955	1067	1168
5	1179	1443	1667	1863	2041
6	1859	2277	2629	2939	3220
7	2733	3347	3865	4321	4734
8	3816	4674	5397	6034	6610
9	5123	6274	7245	8100	8873
10	6667	8165	9428	10541	11547
12	10516	12880	14872	16628	18215

Where there is apt to be trouble from frost no pipe less than ¾ inch should be used, and in extremely cold climates the smallest size should not be less than one inch.

To provide for the resistance due to bends, one rule is to allow a pressure of 0.204 inch of water column for each right angled elbow.

Services for Burners.

The following table is the standard of the principal gas works. It governs the size of pipe used by gas fitters for consumers, and will be found of value. Every service should have a T so placed as to permit of easily clearing the service pipe should any obstruction occur in it.

Size of Pipe.	Threads per Inch.	Weight per Foot.	Length allowed.	Number of Burners.
			Feet.	
1/8	27	.243	2	1
1/4	18	.422	6	1
3/8	14	.561	20	3
1/2	14	.845	30	6
3/4	11½	1.126	50	20
1	11½	1.670	70	35
1¼	11½	2.258	100	60
1½	11½	2.694	150	100
2	8	3.367	200	200
2½	8	5.773	300	300
3	8	7.547	450	450
4	8	10.728	600	750

TABLE OF AQUEOUS VAPOR

Contained in 1000 Cubic Feet of Gas at Indicated Temperature.

Temp. Degrees	Volume, Aqueous Vapor.	Temp Degrees	Volume, Aqueous Vapor.	Temp. Degrees	Volume, Aqueous Vapor.
40	9.33	54	15.33	68	24.06
41	9.73	55	15.86	69	24.83
42	10.13	56	16.40	70	25.66
43	10.53	57	16.93	71	26.53
44	10.93	58	17.53	72	27.40
45	11.33	59	18.10	73	28.30
46	11.73	60	18.66	74	29.23
47	12.13	61	19.23	75	30.20
48	12.53	62	19.80	76	31.20
49	12.93	63	20.50	77	32.20
50	13.33	64	21.20	78	33.23
51	13.80	65	21.90	79	34.23
52	14.26	66	22.60	80	35.33
53	14.80	67	23.30	81	36.43

TABLE OF THE WEIGHTS OF GAS-HOLDERS.

In Pounds for every One-tenth of an Inch maximum Pressure, and for Diameter from 20 to 200 Feet.

Diameter of Gas-holder in Feet.	Weight in lbs. for each one-tenth of an inch Pressure.	Diameter of Gas-holder in Feet.	Weight in lbs. for each one-tenth of an inch Pressure.	Diameter of Gas-holder in Feet.	Weight in lbs. for each one-tenth of an inch Pressure.	Diameter of Gas-holder in Feet.	Weight in lbs for each one-tenth of an inch Pressure.
20	164	53	1149	86	3026	119	5793
21	181	54	1193	87	3097	120	5891
22	198	55	1238	88	3168	121	5990
23	217	56	1283	89	3241	122	6089
24	236	57	1329	90	3314	123	6189
25	256	58	1376	91	3388	124	6290
26	277	59	1424	92	3463	125	6392
27	298	60	1473	93	3538	126	6495
28	321	61	1522	94	3615	127	6598
29	344	62	1573	95	3692	128	6703
30	368	63	1624	96	3770	129	6808
31	393	64	1676	97	3849	130	6914
32	419	65	1729	98	3929	131	7021
33	446	66	1782	99	4010	132	7128
34	473	67	1837	100	4091	133	7237
35	501	68	1892	101	4173	134	7346
36	530	69	1948	102	4256	135	7456
37	560	70	2005	103	4340	136	7567
38	591	71	2062	104	4425	137	7678
39	622	72	2121	105	4510	138	7791
40	655	73	2180	106	4597	139	7904
41	688	74	2240	107	4684	140	8018
42	722	75	2301	108	4772	141	8133
43	757	76	2363	109	4861	142	8249
44	792	77	2426	110	4950	143	8366
45	828	78	2489	111	5041.	144	8483
46	866	79	2553	112	5132	145	8601
47	904	80	2618	113	5224	146	8720
48	943	81	2684	114	5317	147	8840
49	982	82	2751	115	5410	148	8961
50	1023	83	2818	116	5505	149	9083
51	1064	84	2887	117	5600	150	9205
52	1106	85	2956	118	5696	200	16364

Example.—Find the weight of a gas-holder 80 feet in diameter, the maximum pressure being 3.2 inches water column, or 32/10ths.

In preceding table, opposite 80 in column of diameters read 2618, the weight for 1/10th inch pressure. Therefore the weight required $= 2618 \times 32 = 83{,}776$ lbs.

IRON AND STEEL.

IRON AND STEEL.

Wrought Iron is the product of the puddling process. It is made in a reverberatory furnace by melting pig iron on a hearth of iron oxide, over which passes a reducing flame which causes the carbon to unite with the oxide during the mixing which the puddler gives it, and further causes a large portion of the impurities to enter the surrounding slag. As the impurities—carbon, manganese, phosphorus, sulphur, silicon—leave the molten iron, the melting point rises so that the iron becomes first viscous, then pasty. When it has been worked into a ball the puddler carries it, still at a welding heat, to the hammer or squeezer where the greater part of the slag which permeated it is expelled from the mass. The roughly shapen slab is then rolled into muck bar, which, when piled, rolled and re-rolled becomes the wrought iron of commerce.

Steel is the malleable product of either the cementation process, the crucible, the converter or the open hearth furnace.

Cementation is the earliest process that we know of for making steel, and was founded upon the fact that wrought iron if packed in charcoal and heated to a high temperature, while excluded from air, absorbs carbon. The process consisted in packing bars of wrought iron, of about ¾ inch thickness, in charcoal, and then sealing up the vessel and keeping it at a yellow heat until the carbon had penetrated to the centres of the bars and converted them into steel. The carbon penetrates the bar at the rate of about ⅛ inch in 24 hours, and while the point of saturation of iron by carbon is about 1.50%, yet the average content of carbon by this process in the finished bars, is about 1% or lower.

The use of steel made by this process was always limited because of the fact that it contained the old seams and slag marks which everywhere crossed and recrossed the iron, causing great trouble in the manufacture of cutting tools. But by melting this steel (called also blister steel, because its surface was covered with blisters) in a covered crucible, the seams and fibres of slag all disappeared, and a homogeneous ingot was the result. But this was a long way to a steel ingot, and the pursuit of cheapness gave rise to the direct method of melting iron in a crucible, made for the purpose, together with the requisite carbon and other ingredients necessary for imparting hardness, toughness, etc. The molten iron absorbs the carbon very quickly and gives a product which approaches closely the merit of that produced by the older method.

Up to the middle of the nineteenth century these two processes were the principal ones, yet they were too expensive for a product of general use, except for tools.

About 1856, Sir Henry Bessemer completed his experiments and gave to the world his famous process. In this process the pig iron is melted and poured into a bottle shaped vessel. Air is then blown into it from the bottom, burning out, first the silicon, then the manganese and carbon, (the first two elements entering the slag, the last one going out of the mouth of the converter as gas) but not reducing either the phosphorus or sulphur. When the carbon is burned out—a fact recognized by the color of the flame—the vessel contains practically pure wrought iron, which becomes steel on the addition of sufficient carbon and manganese to give the requisite hardness and toughness to the cast.

When the iron is melted in a Converter which has a silicon lining the process is called the *Acid Bessemer*, and the principal fuel to keep the bath liquid is silicon. If the iron is high in phosphorus and melted in a vessel lined with dolomite or magnesite the process is called the *Basic Bessemer* and phosphorus is the principal element of fuel.

Following the introduction of Sir Henry Bessemer's process, William Siemans invented the *regenerative* *furnace*, a furnace in which the heat of the waste gases passes through chambers checkered off with fire brick, which so obstruct the passage of the gases to the chimney as to make them give up their heat. The air and fuel gas entering the furnace is then passed through this hot checker work and highly heated, thus returning to the furnace a large part of the heat carried out before by the gases passing to the stack. In a furnace of similar construction *Open Hearth Steel* is made. Pig iron, steel scrap, wrought iron, and iron ore charged together, or separately, (all, one or any two of them) are rendered steel by burning out their impurities with an oxidizing flame. If the metal is melted on a hearth lined with sand, the carbon, manganese and silicon are burned out and the sulphur and phosphorus remain as before. This is the *Acid Open Hearth Process*. But if, on the other hand, the bottom is made of dolomite or magnesite, and lime is added to hold the phosphorus in the slag formed (as in the case of Basic Bessemer) the phosphorus, silicon, carbon and manganese are burned out, and sulphur remains as before. This is the *Basic Open Hearth* process.

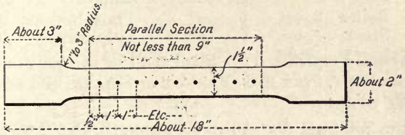
We have, then, steel made by the following processes:

1st. Cementation.
2d. Crucible.
3rd. Bessemer, {Acid / Basic} Converter.
4th. Open Hearth, {Acid / Basic} Furnace.

Standard Specifications for Special Open-Hearth Plate and Rivet Steel, as adopted by the Association of American Steel Manufacturers.

Testing and Inspection (1). All tests and inspections shall be made at place of manufacture prior to shipment.

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



Piece to be of same thickness as the plate.

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

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

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

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

Chemical Properties (6).

Extra soft and Fire Box Steel.	Maximum	Phosphorous,	.04 %
	"	Sulphur.	.04 %
Flange or boiler Steel.	"	Phosphorous,	.06 %
	"	Sulphur,	.04 %
Boiler Rivet Steel.	"	Phosphorous,	.04 %
	"	Sulphur,	.04 %

Physical Properties (7). Steel shall be of four grades—EXTRA SOFT, FIRE BOX, FLANGE or BOILER, and BOILER RIVET STEEL.

Extra Soft Steel (8). Ultimate strength, 45,000 to 55,000 pounds per square inch.

Elastic limit, not less than one-half the ultimate strength. Elongation, 28 per cent.

Cold and Quench bends, 180 degrees flat on itself, without fracture on outside of bent portion.

Fire Box Steel (9). Ultimate strength, 52,000 to 62,000 pounds per square inch.

Elastic limit, not less than one-half the ultimate strength. Elongation 26 per cent.

Cold and Quench bends, 180 degrees, flat on itself, without fracture on outside of bent portion.

Flange or Boiler Steel (10). Ultimate strength, 52,000 to 62,000 pounds per square inch.

Elastic limit, not less than one-half the ultimate strength. Elongation, 25 per cent.

Cold and Quench bends, 180 degrees flat on itself, without fracture on outside of bent portion.

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

Variation When Ordered to Gauge (12). For all plates ordered to gauge, there will be permitted an average excess of weight over that corresponding to the dimensions on the order equal in amount to that specified in the following table, provided no plate shall be rejected for light gauge measuring .01" or less, below the ordered thickness.

Table of Allowances for Overweight for Rectangular Plates 1/4 Inch Thick and Heavier.

NOTE.—The weight of 1 cubic inch of rolled steel is taken at 0.2833 pounds.

THICKNESS OF PLATE.	WIDTH OF PLATE.		
	Up to 75 in.	75 in. to 100 in.	Over 100 in.
$\frac{1}{4}$ in....	10 per cent.	14 per cent.	18 per cent.
$\frac{5}{16}$ "	8 "	12 "	16 "
$\frac{3}{8}$ "	7 "	10 "	13 "
$\frac{7}{16}$ "	6 "	8 "	10 "
$\frac{1}{2}$ "	5 "	7 "	9 "
$\frac{9}{16}$ "	4½ "	6½ "	8½ "
$\frac{5}{8}$ "	4 "	6 "	8 "
Over $\frac{5}{8}$ " ...	3½ "	5 "	6½ "

Table of Allowances for Overweight for Rectangular Plates less than 1/4 Inch in Thickness.

THICKNESS OF PLATE.	WIDTH OF PLATE.	
	Up to 50 in.	50 in. and above.
$\frac{1}{8}$ in. up to $\frac{5}{32}$ in.	10 per cent.	15 per cent.
$\frac{5}{32}$ " $\frac{3}{16}$ "	8½ "	12 "
$\frac{3}{16}$ " $\frac{1}{4}$ "	7 "	10 "

Variation When Ordered to Weight (13). Plates 12½ lbs. or heavier when ordered to weight, shall not average more variation than 2½ per cent., either above or below the theoretical weight.

Plates from 10 to 12½ lbs., when ordered to weight, shall not average a greater variation than the following :

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

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

Plates under 10 lbs. down to 5 lbs. when ordered to weight shall not average more variation than 3 per cent. above or 5 per cent. below the theoretical weight.

Plates under 5 lbs. when ordered to weight shall not average more variation than 5 per cent. either above or below the theoretical weight.

TABLE OF STRENGTH OF MATERIALS IN POUNDS PER SQUARE INCH.

MATERIAL.		Tensile Strength.		Compressive Strength.		Shearing Strength.	Modulus of Elasticity.	
		Elastic Limit.	Ultimate.	Elastic Limit.	Ultimate.	Ultimate.	Tension.	Shear.
Steel, Bessemer and open hearth	Per cent. of Carbon 0.10	36,000	56,000	34,000	....	43,000	30,000,000	9,000,000
	0.15	42,000	63,000	39,000	....	48,000	"	"
	0.20	47,000	68,000	43,000	....	53,000	"	"
	0.50	48,000	80,000	46,000	....	57,000	"	"
	0.70	53,000	89,000	53,000	....	60,000	"	"
	0.80	63,000	103,000	63,000	....	68,000	"	"
Steel, crucible	untempered	80,000	120,000	80,000	....	......	30,000,000	12,000,000
	tempered	190,000	....	......	....	......	36,000,000	14,000,000
Steel, 3 to 5% nickel	from	......	80,000	......	....	......	....	....
	to	......	250,000	......	....	......	....	....
Steel castings	from	......	60,000	......	....	......	....	....
	to	......	80,000	......	....	......	....	....
Wrought iron	high grade	28,000	56,000	......	....	40,000	28,000,000	9,000,000
	common	24,000	45,000	......	....	32,000	....	....
Cast iron	from	......	15,000	......	70,000	13,000	15,000,000	5,000,000
	to	......	25,000	......	110,000	20,000	20,000,000	8,000,000
Malleable cast iron	from	15,000	25,000	......	....	......	....	....
	to	22,000	35,000	......	....	......	....	....
Brass	castings	......	18,000	......	....	......	....	....
	hard drawn	......	48,000	......	....	......	....	....
Delta metal	castings	17,000	36,000	......	....	......	12,000,000	....
	rolled	51,000	74,000	......	....	......	13,000,000	....
Copper	castings	5,500	20,000	4,000	....	......	15,000,000	5,000,000
	rolled plates	......	30,000	......	....	......	16,000,000	....
	hard drawn	......	58 000	......	....	......	17,000,000	....
Phosphor bronze		20,000	58,000	......	....	43,000	14,000,000	5,000,000
Aluminum bronze	0.1 al., 0.9 c	......	82,000	......	....	......	....	....
	0.07 " 0.93 "	......	65,000	......	....	......	....	....
Manganese bronze	castings	30,000	60,000	......	125,000	......	....	....
	rolled	80,000	100.000	......	....	......	....	....

TENACITY OF METALS AT VARIOUS TEMPERATURES.

Tensile Strength of Iron and Steel at High Temperatures.—James E. Howard's tests (*Iron Age*, April 10, 1890), shows that the tensile strength of steel diminishes as the temperature increases from 0° until a minimum is reached between 200° and 300°F., the total decrease being about 4,000 lbs. per square inch in the softer steels and from 6,000 to 8,000 lbs. in steels of over 80,000 lbs. tensile strength. From this minimum point the strength increases up to a temperature of 400° to 650°F., the maximum being reached earlier in the harder steels, the increase amounting to from 10,000 to 20,000 lbs. per square inch above the minimum strength at from 200° to 300°. From this maximum, the strength of all the steels decreases steadily at a rate approximating 10,000 lbs. decrease per 100° increase of temperature. A strength of 20,000 lbs. per square inch is still shown by 0.10 C. steel at about 1000 F., and by 0.60 to 1.00 C. steel at about 1600° F.

The strength of wrought iron increases with temperature from 0° up to a maximum at from 400 to 600° F., the increase being from 8,000 to 10,000 lbs. per square inch, and then decreases steadily till a strength of only 6,000 lbs. per square inch is shown at 1,500°F.

Cast iron appears to maintain its strength, with a tendency to increase, until 900° is reached, beyond which temperature the strength gradually diminishes. Under the highest temperatures, 1,500° to 1,600° F., numerous cracks on the cylindrical surface of the specimen were developed prior to rupture. It is remarkable that cast iron, so much inferior in strength to the steels at atmospheric temperature, under the highest temperatures has nearly the same strength the high-temper steels then have.

Strength of Iron and Steel Boiler-plate at High Temperatures. (Chas. Huston, *Jour. F. I.*, 1877.)

AVERAGE OF THREE TESTS OF EACH.

Temperature F.	68°	575°	925°
Charcoal iron plate, tensile strength, lbs.	55,366	63,080	65,343
" " " contr. of area %.	26	23	21
Soft open-hearth steel, tensile strength, lbs.	54,600	66,083	64,350
" " " contr. %.	47	38	33
" Crucible steel, tensile strength, lbs.	64,000	69,266	68,600
" " " contr. %.	36	30	21

Strength of Wrought Iron and Steel at High Temperatures. —(*Jour. F. I.*, cxii., 1881, p. 241.) Kollmann's experiments at Oberhausen included tests of the tensile strength of iron and steel at temperatures ranging between 70° and 2000° F. Three kinds of metal were tested, viz., fibrous iron having an ultimate tensile strength of 52,464 lbs., an elastic strength of 38,280 lbs., and an elongation of 17.5%; fine-grained iron having for the same elements values of 56,892 lbs., 39,113 lbs., and 20%; and Bessemer steel having values of 84,826 lbs., 55,029 lbs., and 14.5%. The mean ultimate tensile strength of each material expressed in per cent. of that at ordinary atmospheric temperature is given in the following table, the fifth column of which exhibits, for purposes of comparison, the results of experiments carried on by a committee of the Franklin Institute in the years 1832–36.

Temperature Degrees F.	Fibrous Wrought Iron, p. c.	Fine-grained Iron, per cent.	Bessemer Steel, per cent.	Franklin Institute, per cent.
0	100.0	100.0	100.0	96.0
100	100.0	100.0	100.0	102.0
200	100.0	100.0	100.0	105.0
300	97.0	100.0	100.0	106.0
400	95.5	100.0	100.0	106.0
500	92.5	98.5	98.5	104.0
600	88.5	95.5	92.0	99.5
700	81.5	90.0	68.0	92.5
800	67.5	77.5	44.0	75.5
900	44.5	51.5	36.5	53.5
1000	26.0	36.0	31.0	36.0
1100	20.0	30.5	26.5	.....
1200	18.0	28.0	22.0	.....
1300	16.5	23.0	18.0	.....
1400	13.5	19.0	15.0	.....
1500	10.0	15.5	12.0	.....
1600	7.0	12.5	10.0	.....
1700	5.5	10.5	8.5	.....
1800	4.5	8.5	7.5	.....
1900	3.5	7.0	6.5	.....
2000	3.5	5.0	5.0	.....

MECHANICS OF MATERIALS RELATING TO TUBULAR CONSTRUCTION.

STRENGTH OF MATERIALS.

A tensile stress is produced in the walls of a cylindrical vessel, such as a pipe, tank, boiler, etc. when it contains a fluid such as water, steam or air, under pressure.

The ultimate or breaking strength of a material is reached when the tensile stress equals its cohesive force, in which case the material is on the point of being ruptured.

The working strength of a material is that fraction, or portion, of the ultimate or breaking strength that experience has shown it is best to use in practice, in order to guard against failure due to unforeseen causes, such as defects and the possible action of unknown forces.

The unit working strength of a material is the working strength of one square inch of cross section of that material.

The factor of safety is the factor or number by which the ultimate strength is divided in order to obtain the working strength. The proper factor to use in any given case would depend upon the characteristics of the material and the nature of the forces, whether quiescent or impulsive.

In tubular construction, reasonably free from vibration and shock, a factor of safety of from 5 to 6 should be ordinarily used for wrought iron and steel, and from 8 to 10 for cast iron. Where there is uncertainty as to the magnitude and nature of the forces acting, or where there is much vibration or shock, such as water hammer in steam pipes or the sudden stoppage of flow in a water pipe, these factors should be increased to from one and one-half to three or more times the values given, depending upon the severity of the vibration or shock.

It is best, when possible, to compute the straining actions of shocks, as for example the increase in fluid pressure in a long water pipe when the flow is more or less quickly checked, in which case they should be added to the normal straining action. Having provided for these abnormal forces, the ordinary factors of safety should then be used.

Stress and Strain.—Should the fluid pressure in a cylindrical vessel be gradually increased from zero, it will be observed that the walls of the vessel will stretch, thus increasing its volume. The stretch of the material constituting the walls is termed the *strain* due to the force tending to tear the material asunder.

The molecular actions within the material which oppose the external forces, and which resist deformation, are termed *stresses.*

An elastic material when deformed by a straining action recovers its original form when the straining action is removed; as, for example, spring steel, ivory, etc.

A plastic material when deformed does not recover its original form when the straining action is removed; as, for example, lead, putty, etc.

Elastic limit.—Materials such as wrought iron and low carbon steel are elastic under some conditions and plastic under others. At ordinary atmospheric temperatures, these materials may be strained up to a point, termed the *elastic limit*, without suffering any permanent deformation when the straining action is removed.

Should, however, the elastic limit be exceeded, the material will but partially recover its original form when the straining action is removed, in which case it is said to have received a *permanent deformation or set.*

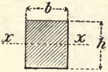
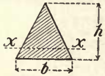
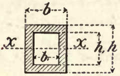
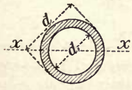
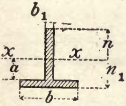
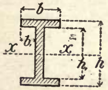
Up to the elastic limit the strain is proportional to the stress, that is, *strain* ÷ *stress* = a constant. Beyond the elastic limit this constant becomes ordinarily an increasing varible.

The modulus of elasticity of a material is obtained by dividing the unit stress by the strain, for unit length.

Shearing strength of a material.—When a cylindrical vessel, made up from plates, connected together in the usual manner by riveted joints, is subjected to a fluid pressure, the adjoining plates will tend to separate by sliding one upon the other, thus subjecting the material of the rivets to a shearing action. The ability of a rivet to resist this action is known as its *shearing strength*, and the stress created by snch action is called the *shearing stress*.

Unit shearing strength of a material is the shearing strength of one square inch of cross-section of that material.

VALUES OF I (Moment of Inertia), AND S. (Section Modulus), FOR USUAL SECTIONS.

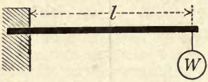
SECTIONS.	I	S
	$I=\frac{bh^3}{12}$	$\frac{bh^3}{6}$
	$I=\frac{bh^3}{36}$	$Min.=\frac{bh^2}{24}$
	$I=\frac{\pi d^4}{64}$ $=0.0491\ d^4$	$\frac{\pi d^3}{32}$ $=0.0982\ d^3$
	$I=\frac{bh^3-b_1h_1{}^3}{12}$	$\frac{I}{0.5h}$
	$I=0.0491\ (d^4-d_1{}^4)$	$0.0982\left(d^3-\frac{d_1{}^4}{d}\right)$
	$I=\frac{b_1n^3+bn_1{}^3-(b-b_1)a^3}{3}$	$Min.=\frac{I}{n}$
	$I=\frac{bh^3-2b_1h_1{}^3}{12}$	$\frac{I}{0.5h.}$

x x Denotes position of neutral axis.

Bending Moments and Deflections of Beams under Various Systems of Loading.

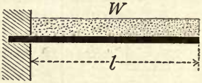
W = total load.
l = length of beam.
I = moment of inertia
E = modulus of elasticity.

(1) Beam fixed at one end and loaded at the other.



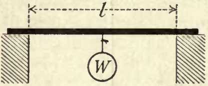
Maximum bending moment at point of support $= Wl$.
Maximum shear at point of support $= W$.
Deflection $= \frac{Wl^3}{3EI}$

(2) Beam fixed at one end, and uniformly loaded.



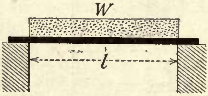
Maximum bending moment at point of support $= \frac{Wl}{2}$
Maximum shear at point of support $= W$.
Deflection $= \frac{Wl^3}{8EI}$

(3) Beam supported at both ends, single load in the middle



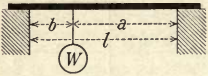
Maximum bending moment at middle of beam $= \frac{Wl}{4}$
Maximum shear at points of support $= \frac{1}{2}W$.
Deflection $= \frac{Wl^3}{48EI}$

(4) Beam supported at both ends and uniformly loaded.



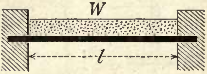
Maximum bending moment at middle of beam $= \frac{Wl}{8}$
Maximum shear at points of support $= \frac{1}{2}W$.
Deflection $= \frac{Wl^3}{76.8EI}$

(5) Beams supported at both ends, single unsymmetrical load.



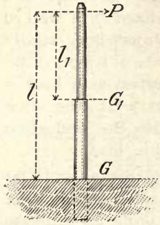
Maximum bending moment under load $= \frac{Wab}{l}$
Maximum shear: at support near $a = \frac{Wb}{l}$; at other support $= \frac{Wa}{l}$
Maximum deflection $= \frac{Wab(2l-a)}{9EIl}\sqrt{\frac{1}{3}a(2l-a)}$

(6) Beam fixed at both ends and uniformly loaded.



Maximum bending moment at point of support $= \frac{Wl}{12}$
Maximum shear at points of support $= \frac{1}{2}W$.
Deflection $= \frac{Wl^3}{384EI}$

DEFLECTION AND STRENGTH OF PIPES TO RESIST BENDING ACTION.



The bending moment of a force is obtained by multiplying the force, *P*, in pounds, by the lever arm, *l*, in inches, with which it acts. Thus in the case of a trolley pole the bending moment at the ground, G, is

$M = P\,l$, and at G_1 is $M_1 = Pl_1$.

The deflection of a pipe or tube when loaded transversely, that is, so as to subject it to a bending moment, is the deformation in inches produced by the given loading, and is due, of course, to the elasticity of the materials constituting it. In case of a trolley pole the greatest deformation will be at the extreme top of the pole.

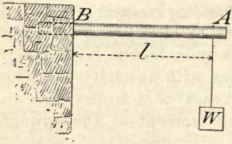
For a horizontal pipe supported at equidistant points the greatest deflection will be midway between supports.

The moment of inertia of a section is the sum of the products of each elementary area of the section by the square of its distance from an assumed axis of rotation. It is a necessary factor in formulæ for the determination of deflection of structures considered as beams.

The moment of resistance of cross-section of a beam is the moment that resists a bending action at that cross-section.

The section modulus is the factor that when multiplied by the unit working strength of the material will give the moment of resistance of cross-section of a structure considered as a beam.

In every case when a beam, as for example a trolley pole or a horizontal pipe supported at points, is subjected to a bending action the following condition must exist at every cross-section, namely: *Bending moment=moment* *of resistance of cross-section=unit working strength of material × section modulus.*



Example 1.—A 4 inch steel pipe has one end firmly fixed in a wall so as to project horizontally a distance of 8 feet. Find the greatest safe load it will carry at the free end, also the deflection with this load.

Solution: From the table of Standard Steam and Gas Pipe, we see that the outside and inside diameters are $d=4.500$ and $d_1 = 4.026$ inch. Assuming an ultimate strength of material = 60,000 lbs. per sq. inch, and a factor of safety of 6, we get as a working unit strength $60{,}000 \div 6 = 10{,}000$ lbs. From the table of Section Moduli we get

$$\text{Section modulus} = 0.098 \left(d^3 - \frac{d_1^4}{d} \right);$$

which multiplied by the unit working strength gives

$$\text{Moment of resistance} = 980 \left(d^3 - \frac{d_1^4}{d} \right).$$

$$d^3 = (4.5)^3 = 91.125 \text{ (see table of cubes).}$$

$$\log. \frac{d_1^4}{d} = \log. \frac{(4.026)^4}{4.5} = 4 \log. 4.026 - \log. 4.5 = 4 \times 0.6049$$

$$-0.6532 = 1.7664, \text{ or } \frac{d_1^4}{d} = 58.4, \text{ the number whose}$$

log. is 1.7664

Then moment of resistance=980 (91.1—58.4)=32,046 inch lbs.

The bending moment at support = WL = W8×12 = 96 W inch lbs. Since the bending moment equals the moment of resistance, then

96 W=32,046, or

W=333 lbs., the required load.

For this style of loading (see table) the

$$\text{Deflection} = \frac{W\,l^3}{3\,E\,I},$$

In which W=333, the safe load as computed;

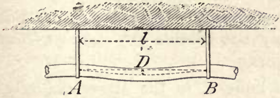
L=96, the length of beam in inches;

E=26,000,000. the modulus of elasticity;

$I = 0.049\ (d^4 - d_1{}^4) = 0.049 \left[(4.5^4 - (4.026)^4 \right] =$ 7.21, the moment of inerta of cross-section.

Substituting these values in above formula we get

$$\text{Deflection} = \frac{333 \times (96)^3}{3 \times 26{,}000{,}000 \times 7.21} = 0.53 \text{ inch.}$$



Example 2.—A 10 inch standard lap welded steel pipe, carrying water, is suspended from the top of a tunnel, as shown in the figure, the points of support being spaced at a distance of 20 feet apart.

Find the deflection, D, due to the weight of the pipe and its contained water, on the supposition that the pipe bears equally on all of its supports.

Solution: From the table of Standard Steel Welded Pipe we get weight of pipe per ft.=40.06 lbs., and weight of contained water per ft.=34.13 lbs., making a gross weight per foot of 74.2 lbs., or for 20 feet a total weight of approximately 1500 pounds.

Since the pipe is assumed to run continuously from one support to another, the deflection will be greatest midway between supports, and will be the same as that for a beam *fixed* at both ends and uniformly loaded. For this style of loading (see page 212) the

$$\text{Deflection} = \frac{W\,l^3}{384\,EI},$$

In which W=1500 pounds;

L=20×12=240 inches;

E=26,000,000, the modulus of elasticity;

$I = 0.049\,(d^4 - d_1{}^4) = 0.049\left[(10.75)^4 - (10.02)^4\right]$

$= 160$, the moment of inertia of cross-section.

Substituting these values in above formula we get

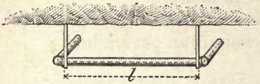
$$\text{Deflection} = \frac{1500 \times (240)^3}{384 \times 26{,}000{,}000 \times 160} = 0.014 \text{ inch.}$$

In practice, where the usual rigid joints are used, it is often the case that a pipe does not bear equally upon all the hangers, and in cases of careless erecting or of shifting of hangers, the pipe may not receive any support from one or more of the hangers.

Should each alternate hanger, in the above example, become inactive, owing to any cause, the maximum deflection then would be that due to an unsupported length of 40 feet of pipe. An inspection of the formula will show that the deflection of a beam increases directly as the *weight* × $(\textit{length})^3$, or, for uniformly loaded beams, since the weight increases directly as the length, as the $(\textit{length})^4$.

Since in this case the length is doubled, the deflection will be increased 16 fold (that is 2^4), or to an amount = 0.014×16=0.22 inch.

In the same manner it can be shown that an unsupported portion of 60 feet in length will deflect or sag an amount = $0.014 \times 3^4 = 1.13$ inch.



Should the pipe be merely supported at the ends, and not straight and continuous from one support to another, then the conditions would be those of a simple beam uniformly loaded and supported at the ends.

By comparing the deflection formulæ for the case just considered and this case, it will appear that the deflection for this case will be *five times* as great; or, for the three cases considered above, 0.07, 1.10 and 5.65 inches respectively.

The maximum deflection, or sag, that should be permitted in practice will depend ordinarily upon the effective thickness of wall of pipe and the unit working strength of the material composing it.

The effective thickness of pipe in any particular case will be the thickness remaining after deducting the depth of screw-thread (for wrought pipe with threaded ends for coupling or flange connections) plus a reasonable amount for the deterioration due to corrosion, or other causes; which amount will depend upon the nature of the service and the expected life of pipe.

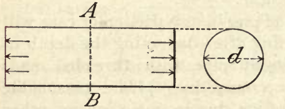
In every practical example the *effective thickness of pipe should be used* in applying all formulæ relating to strength of pipe to resist either bending or bursting.

STRESS DUE TO INTERNAL BURSTING PRESSURE.

Owing to the difference in the nature of the stress occuring in thin and thick walls of cylinders, pipes, etc., when subjected to a fluid pressure, it will be necessary to divide them into two classes, namely, those having *thin walls* and those having *thick walls*. In the following discussion only those having thin walls will be considered.

Let d = internal diameter in inches;
t = thickness of cylinder wall in inches;
p = internal fluid pressure, lbs. per sq. inch;
$\pi = 3.1416$;
f_t = unit working strength in tension;
f_c = " " " " compression;
f_s = " " " " shear;
e = efficiency of joint, or $\frac{\text{strength of joint}}{\text{strength of plate}}$;
c = thickness of metal, in inches, allowed for wasting away due to corrosion, or other causes.

STRENGTH OF THIN CYLINDERS TO RESIST BURSTING.



The force tending to tear the plate along a line lying circumferentially around the cylinder, as, for example, along the section lying in the plane A B, will equal the fluid pressure exerted on one end of the cylinder, which equals the area of a cross-section of cylinder in square inches × internal pressure per square inch, or

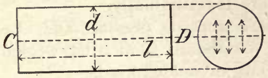
$$\left.\begin{array}{l}\text{Longitudinal bursting pressure}\\ \text{tending to rupture circumferentially}\end{array}\right\} = \frac{\pi d^2}{4} p.$$

This bursting pressure will be resisted by the tenacity of the metal whose cross-section lies in the plane A B, which equals the circumference, or distance around the cylinder, multiplied by the thickness of the metal. Hence

$$\left.\begin{array}{l}\text{Resistance to bursting pressure}\\ \text{tending to rupture circumferentially}\end{array}\right\} = \pi d t f_t.$$

Since the resistance to the bursting pressure must equal the pressure itself, we have

$$\pi d t f_t = \frac{\pi d^2}{4} p, \text{ or } t = \frac{d p}{4 f_t};\ p = \frac{4 f_t t}{d}.$$



The force tending to tear the plate along a line extending longitudinally, as, for example, along the section lying in the plane C D, will equal the sum of the normal components of the fluid pressures on the inner surface of the cylinder, which it can be shown is the same as the fluid pressure on a surface equal to the length of the cylinder multiplied by its diameter, or d l. We then have

$$\left.\begin{array}{l}\text{Transverse bursting pressure}\\ \text{Tending to rupture longitudinally}\end{array}\right\} = d\,l\,p.$$

This bursting pressure will be resisted by the tenacity of the metal whose cross-section lies in the plane C D, which latter equals twice the length of cylinder multiplied by the thickness of the metal. Hence

$$\left.\begin{array}{l}\text{Resistance to bursting pressure}\\ \text{Tending to rupture longitudinally}\end{array}\right\} = 2\,l\,t\,f_t.$$

Since the resistance to the bursting pressure must equal the pressure itself, we have

$$2\,l\,t\,f_t = d\,l\,p, \text{ or } t = \frac{d\,p}{2\,f_t};\; p = \frac{2\,f_t\,t}{d}.$$

From a comparison of the above formulæ, it will be seen that the force due to a fluid pressure within a pipe, boiler, or other cylindrical vessel, that tends to cause rupture longitudinally is twice that which tends to cause rupture transversely, that is circumferentially or around the pipe.

From the above relations, then, it will appear that a pipe, or other cylindrical vessel having walls of uniform thickness, when subjected to a fluid pressure only, will always tend to rupture longitudinally. The strength at the joints, resisting rupture transversely, may be reduced by the cutting of threads or riveting to flanges, or otherwise, to an amount equal to one-half the strength of the metal of pipe in cross-section, without altering the tendency of the pipe to rupture longitudinally.

Example 1.—Find the safe working pressure and also the bursting pressure of a standard 10-inch lap-welded steel pipe, having plain ends, or welded heads.

Solution: Assuming that the pipe is not subjected to shock or vibration, we will assume a unit working strength of material=10,000 lbs., which allows a factor of safety of 6 on the assumption that the ultimate tensile strength is 60,000 lbs. per sq. inch.

Then in the formula for the internal fluid pressure.

$$p = \frac{2 f_t t}{d},$$

f_t =10,000 lbs., the unit working strength of material;
t = 0.366 inch, the thickness of wall of pipe;
d =10.385, the diameter of pipe.
Substituting these values we get

$$p = \frac{2 \times 10{,}000 \times 0.366}{10.385} = 705 \text{ lbs. per sq. in.}$$

The bursting pressure, on the above assumption, would be six times the working pressure, or

Bursting pressure=705×6=4,230 lbs. per sq. in.

Example 2.—Find the working pressure for the pipe given in example 1, when provision is made for wasting away of the metal by corrosion, or otherwise, so as to reduce the thickness of the walls by ⅛ inch.

Then t=0.366—0.125=0.241 inch, the thickness of wall after corrosion of ⅛ inch has occurred, the other values remaining the same as before. Substituting in the formula for pressure we get

$$p = \frac{2 \times 10{,}000 \times 0.241}{10.385} = 465 \text{ lbs. per sq. in.}$$

In practice it is often necessary to provide, especially in steam and water pipes, for stresses due to vibration, shock, temperature changes and various other causes, in which case the factor of safety of six assumed in the above examples should be increased to from 8 to 15 for wrought pipe, depending upon the severity of these actions.

Assuming a factor of safety of 12, the safe working pressure in the above examples would be for Example 1, 350 lbs. per sq. in., and for example 2, 230 lbs. per sq. inch.

Example 3.—Find the thickness of a mild steel seamless cylindrical receiver, 20 inches in diameter, to contain air at 2,000 lbs. per sq. in. gauge pressure.

Solution: Assuming a unit working strength of material of 12,000 lbs. then in the formula for thickness,

$$t = \frac{d\,p}{2\,f_t},$$

d=20, the diameter of receiver in inches;

p=2,000, the internal pressure in lbs. per sq. inch;

f_t=12,000, the working strength per sq. in. of material;

Substituting these values in the formula we get

$$t = \frac{20 \times 2{,}000}{2 \times 12{,}000} = 1.67 \text{ inches.}$$

In tubular construction, having longitudinal riveted joints intended to resist internal fluid pressure, the formulæ for thickness of wall and for safe working pressure will become

$$t = \frac{d\,p}{2e\,f_t}; \qquad p = \frac{2e\,f_t\,t}{d};$$

In which d=diameter of vessel in inches;

t=thickness of wall in inches;

p=internal fluid pressure, lbs. per sq. inch;

f_t=unit working strength of material in tension;

e=efficiency of riveted joint, from 0.6 to 0.8.

To provide in practice for wasting away of the metal, due to corrosion, or other causes, the above formulæ will become

$$t = \frac{d\,p}{2e\,f_t} + c; \qquad p = \frac{2\,ef_t\,(t-c)}{d}.$$

Where c=reduction in the thickness, in inches, of the metal constituting the wall of the vessel, because of the wasting away of the metal in practice due to corrosion and other causes.

Example 4.—Find the thickness of plate for a 60-inch steam boiler, to carry 100 lbs. gauge pressure, the longitudinal riveted joints having an efficiency of 0.7, the ultimate tensile strength of the material being 60,000 lbs. per sq. inch.

Solution: Assuming an actual factor of safety of five and allowing ⅛ inch for wasting away of plates during the life of the boiler, we have in the above formula for thickness of plate:

$d=60$, the diameter of boiler in inches;
$p=100$, the gauge pressure per sq. inch;
$f_t=12{,}000$, the unit working strength of material;
$e=0.7$, the efficiency of longitudinal joint;
$c=0.125$, the allowance for corrosion, etc.

Substituting these values in the formula we get

$$t = \frac{60 \times 100}{2 \times 0.7 \times 12{,}000} + 0.125 = 0.48 \text{ inch.}$$

Example 5.—Find the greatest steam pressure that could be carried by the boiler, in Example 4, when new, that is, before any wasting away of metal has occurred, all other conditions being the same.

Solution: Making $c = 0$ in the above equation, we get

$$t = \frac{d\,p}{2e\,f_t}; \text{ and } p = \frac{2\,e\,f_t\,t}{d};$$

Which are the general equations for the thickness, t, in inches and safe fluid pressure, p, in lbs. per sq. inch, for pipes or other cylindrical vessels having *longitudinal riveted joints*.

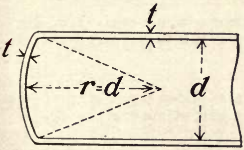
Substituting the values, given in Example 4, in the above formula for pressure, we get

$$p = \frac{2 \times 0.7 \times 12{,}000 \times 0.48}{60} = 135 \text{ lbs. gauge.}$$

In Examples 4 and 5 an *actual factor of safety* at the longitudinal joints is assumed, which makes the *apparent factor of safety*, that is, the factor of safety on the plate itself, for the assumed conditions, $=5\div0.7=7.1$.

In practice an *apparent factor of safety* of 5 is often used, for double riveted longitudinal lap joints, resulting in an *actual factor of safety* of $5\times(0.68 \text{ to } 0.72)=$ from 3.4 to 3.6. Very often no allowance is made for the wasting away of the metal, which fact in conjunction with the use of too small a factor of safety will account for a large number of the boiler explosions that have occurred in practice.

STRENGTH OF CYLINDER ENDS OR HEADS.



The ends or heads of a cylindrical vessel intended to contain a fluid under pressure, should be designed so as to be as strong as the cylindrical part of the vessel. This can ordinarily be best accomplished by giving the end the form of a portion of a hollow sphere, as shown in the figure, *whose radius equals the diameter of the cylindrical part*, in which case to be equally strong throughout the thickness should be the same as that of the cylindrical part. This is because of the fact that for a given internal fluid pressure, the stress created in the walls of a thin hollow cylinder will be the same as that created, for the same pressure, in the walls of a thin hollow sphere of *double* the diameter.

The use of flat ends should be avoided, except for constructions such as tube plates, where they are desirable because of constructional reasons and can be easily stayed.

HOLLOW, CYLINDRICAL, WROUGHT IRON PILLARS.—BREAKING LOADS IN TONS.

CALCULATED BY GORDON'S FORMULA (TRAUTWINE.) THICKNESS ⅛ INCH.

Length Feet.	Outer Diameters in Inches.									
	¾″	1″	1¼″	1½″	1¾″	2″	2¼″	2½″	2¾″	3″
1	3.64	5.27	6.88	8.50	10.1	11.7	13.2	14.8	16.4	18.0
2	2.94	4.64	6.32	8.00	9.6	11.2	12.8	14.5	16.1	17.8
3	2.30	3.86	5.57	7.28	8.9	10.6	12.2	13.9	15.6	17.3
4	1.77	3.13	4.74	6.36	8.1	9.9	11.6	13.3	15.0	16.7
5	1.36	2.51	4.07	5.66	7.3	9.1	10.8	12.5	14.2	16.0
6	1.04	2.03	3.46	4.91	6.6	8.3	9.9	11.6	13.4	15.2
7	.81	1.65	2.91	4.24	5.7	7.4	9.1	10.8	12.6	14.4
8	.61	1.36	2.46	3.67	5.1	6.7	8.3	9.9	11.7	13.5
9	.50	1.05	2.03	3.18	4.5	6.0	7.5	9.1	10.8	12.6
10	.41	.95	1.75	2.77	4.0	5.4	6.9	8.4	10.1	11.8
11	.34	.81	1.52	2.41	3.6	4.8	6.2	7.7	9.3	11.0
12	.29	.70	1.34	2.14	3.2	4.3	5.6	7.0	8.6	10.2
13	.24	.60	1.16	1.88	2.8	3.9	5.2	6.5	8.0	9.5
14	.21	.53	1.03	1.69	2.5	3.5	4.7	6.0	7.4	8.9
15	.19	.47	.91	1.50	2.3	3.2	4.3	5.5	6.9	8.3
16	.18	.42	.84	1.38	2.1	2.9	4.0	5.1	6.4	7.7
18	.14	.33	.67	1.11	1.7	2.4	3.4	4.4	5.6	6.8
20		.27	.55	.91	1.4	2.0	2.8	3.7	4.7	5.8
25					.9	1.4	2.0	2.6	3.4	4.2

HOLLOW, CYLINDRICAL, WROUGHT IRON PILLARS, ETC.—(CONTINUED) THICKNESS ¼ INCH.

Length Feet.	Outer Diameters in Inches. 2"	2¼"	2½"	2¾"	3"	3½"	4"	4½"	5"	5½"	6"
1	21.9	25.4	28.3	31.4	34.5	40	47	53	60	66	72
2	21.1	24.3	27.6	30.7	33.9	40	47	53	60	66	72
3	19.9	23.1	26.4	29.7	33.0	39	46	52	59	65	71
4	18.6	21.8	25.3	28.5	31.9	38	45	51	58	64	71
5	17.0	20.4	23.5	27.3	30.7	37	44	50	57	63	70
6	15.4	18.8	22.1	25.7	29.2	36	43	49	56	62	69
7	13.9	17.3	20.5	23.8	27.8	34	41	47	54	61	68
8	12.5	15.6	19.1	22.3	25.9	32	40	46	53	60	67
9	11.2	14.2	17.5	20.6	24.3	30	38	44	51	58	65
10	10.0	13.0	16.1	19.1	22.7	29	37	43	50	57	64
11	9.0	10.7	15.7	17.6	21.1	27	35	41	48	55	62
12	8.1	10.6	13.5	16.4	19.6	26	33	40	46	54	61
13	7.3	9.6	12.4	15.1	18.2	24	31	38	44	52	59
14	6.6	8.8	11.3	14.0	17.0	23	30	36	43	51	57
15	6.0	8.0	10.4	12.9	15.8	21	28	34	41	49	55
16	5.5	7.3	9.5	12.0	14.6	20	27	33	40	47	54
18	4.5	6.0	8.0	10.3	12.7	18	24	30	37	43	50
20	3.8	5.1	6.8	8.7	11.0	16	21	27	34	40	47
25					7.9	12	16	21	27	33	39
30							13	17	22	27	32
35							10	14	18	22	27
40									14	18	23
45									11	15	19
50									8	12	16

HOLLOW, CYLINDRICAL, WROUGHT IRON PILLARS, ETC.—(CONTINUED) THICKNESS ½ INCH.

Length Feet.	Outer Diameters in Inches.											
	5″	5½″	6″	6½″	7″	7½″	8″	8½″	9″	10″	11″	12″
2	112	125	139	152	166	177	189	201	214	238	263	290
4	110	123	136	149	163	174	186	199	212	237	262	289
6	106	119	132	145	158	171	184	197	210	235	261	288
8	101	114	127	140	154	167	181	194	207	232	258	284
10	95	108	123	136	149	162	176	189	203	228	254	280
12	89	102	116	129	143	157	171	185	199	224	250	276
14	82	95	108	122	137	151	165	179	194	219	245	272
16	76	89	103	117	131	145	160	173	187	213	240	268
18	70	83	97	110	124	138	153	166	180	207	235	263
20	64	77	91	104	117	131	145	159	173	201	227	257
22	58	70	83	96	109	123	138	151	165	192	220	250
25	52	64	76	89	102	115	129	143	157	183	212	241
30	42	52	63	74	87	100	113	127	141	167	195	224
35	34	43	53	64	75	87	99	112	125	151	178	207
40	27	35	44	53	64	75	86	98	110	135	163	190
45	23	30	38	46	55	65	76	87	98	123	148	174
50	19	24	32	38	47	56	66	76	87	109	133	158
60	15	19	24	29	36	43	51	60	69	88	109	132
70	11	14	18	23	28	34	40	48	56	73	91	111
80	9	11	14	18	22	27	32	37	44	57	74	93
90	7	9	11	14	18	22	26	31	36	49	63	78
100	6	7	9	12	15	18	22	26	30	41	53	66

HOLLOW, CYLINDRICAL, WROUGHT IRON PILLARS, ETC.—(CONTINUED) THICKNESS 1 INCH.

Length Feet.	Outer Diameter in Inches.											
	13″	14″	15″	16″	17″	18″	20″	22″	24″	26″	28″	30″
1	603	653	704	753	805	854	955	1056	1157	1257	1357	1458
10	588	638	691	742	795	846	949	1049	1149	1248	1354	1457
20	543	595	651	702	759	810	913	1016	1120	1223	1327	1430
30	479	538	594	645	699	758	866	973	1077	1186	1289	1394
40	415	470	528	584	636	691	806	912	1027	1130	1237	1348
50	355	405	462	516	570	627	740	848	961	1067	1179	1294
60	300	348	400	452	505	559	669	781	891	1005	1115	1228
70	256	300	348	398	448	499	606	715	824	936	1046	1160
80	215	255	298	344	392	440	543	649	757	868	978	1092
90	185	222	261	303	347	392	489	590	694	800	910	1023
100	157	190	225	262	303	345	436	532	631	735	843	955
110	134	162	193	227	264	302	386	474	568	666	770	877
125	111	135	162	192	225	259	336	416	505	598	697	799
150	82	101	122	145	171	198	262	328	405	485	574	666
175	62	78	95	112	133	155	208	266	331	400	478	560
200	49	60	74	89	106	124	168	216	269	328	395	467

SHEARING AND BEARING VALUE OF RIVETS.

Diam. of Rivet in Inches.		Area of Rivet.	Single Shear at 6,000 lbs. per sq. in.	Bearing Value for different Thicknesses of Plate at 12,000 lbs. per square inch. (= Diameter of Rivet X Thickness of Plate X 12,000 lbs.)										
Fraction	Decimal			1/4"	5/16"	3/8"	7/16"	1/2"	9/16"	5/8"	11/16"	3/4"	13/16"	7/8"
3/8	.375	.1104	660	1130										
7/16	.4375	.1503	900	1310	1640									
1/2	.5	.1963	1180	1500	1880	2250								
9/16	.5625	.2485	1490	1690	2110	2530	2950							
5/8	.625	.3068	1840	1880	2340	2810	3280							
11/16	.6875	.3712	2230		2580	3090	3610	4130						
3/4	.75	.4418	2650		2810	3380	3940	4500	5060					
13/16	.8125	.5185	3110			3660	4260	4880	5480	6090				
7/8	.875	.6013	3610			3940	4590	5250	5910	6560				
15/16	.9375	.6903	4140			4220	4920	5630	6330	7030	7730			
1	1.	.7854	4710				5250	6000	6750	7500	8250	9000		
1 1/16	1.0625	.8866	5320				5580	6380	7190	7970	8770	9560	10360	
1 1/8	1.125	.9940	5960					6750	7590	8440	9280	10130	10970	11810
1 3/16	1.1875	1.1075	6650					7130	8020	8910	9800	10690	11580	12470

SHEARING AND BEARING VALUE OF RIVETS.

Diam. of Rivet in Inches. Fraction	Decimal	Area of Rivet.	Single Shear at 7,500 lbs. per sq. in.	Bearing Value for different Thicknesses of Plate at 15,000 lbs. per square inch (= Diameter of Rivet × Thickness of Plate × 15,000 lbs.) 1/4"	5/16"	3/8"	7/16"	1/2"	9/16"	5/8"	11/16"	3/4"	13/16"	7/8"
3/8	.375	.1104	828	1410										
7/16	.4375	.1503	1130	1640	2050									
1/2	.5	.1963	1470	1880	2340	2810								
9/16	.5625	.2485	1860	2110	2640	3160	3690							
5/8	.625	.3068	2300	2340	2930	3520	4100							
11/16	.6875	.3712	2780		3220	3870	4510	5160						
3/4	.75	.4418	3310		3520	4220	4920	5630	6330					
13/16	.8125	.5185	3890			4570	5330	6090	6860	7620				
7/8	.875	.6013	4510			4920	5740	6560	7380	8200				
15/16	.9375	.6903	5180			5270	6150	7030	7910	8790	9670			
1	1.	.7854	5890				6560	7500	8440	9380	10310	11250		
1 1/16	1.0625	.8866	6650				6970	7970	8960	9960	10960	11950	12950	
1 1/8	1.125	.9940	7460					8440	9490	10550	11600	12660	13710	14770
1 3/16	1.1875	1.1075	8310					8910	10020	11130	12250	13360	14470	15590

WEIGHT OF RIVETS IN POUNDS PER 100.

Length from under head. One cubic ft. weighing 480 lbs.

Length Inches.	3/8" Diam.	1/2" Diam.	5/8" Diam.	3/4" Diam.	7/8" Diam.	1" Diam.	1 1/8" Diam.	1 1/4" Diam.
1 1/4	5.4	12.6	21.5	28.7	43.1	65.3	91.5	123.
1 1/2	6.2	13.9	23.7	31.8	47.3	70.7	98.4	133.
1 3/4	6.9	15.3	25.8	34.9	51.4	76.2	105.	142.
2	7.7	16.6	27.9	37.9	55.6	81.6	112.	150.
2 1/4	8.5	18.0	30.0	41.0	59.8	87.1	119.	159.
2 1/2	9.2	19.4	32.2	44.1	63.0	92.5	126.	167.
2 3/4	10.0	20.7	34.3	47.1	68.1	98.0	133.	176.
3	10.8	22.1	36.4	50.2	72.3	103.	140.	184.
3 1/4	11.5	23.5	38.6	53.3	76.5	109.	147.	193.
3 1/2	12.3	24.8	40.7	56.4	80.7	114.	154.	201.
3 3/4	13.1	26.2	42.8	59.4	84.8	120.	161.	210.
4	13.8	27.5	45.0	62.5	89.0	125.	167.	218.
4 1/4	14.6	28.9	47.1	65.6	93.2	131.	174.	227.
4 1/2	15.4	30.3	49.2	68.6	97.4	136.	181.	236.
4 3/4	16.2	31.6	51.4	71.7	102.	142.	188.	244.
5	16.9	33.0	53.5	74.8	106.	147.	195.	253.
5 1/4	17.7	34.4	55.6	77.8	110.	153.	202.	261.
5 1/2	18.4	35.7	57.7	80.9	114.	158.	209.	270.
5 3/4	19.2	37.1	59.9	84.0	118.	163.	216.	278.
6	20.0	38.5	62.0	87.0	122.	169.	223.	287.
6 1/2	21.5	41.2	66.3	93.2	131.	180.	236.	304.
7	23.0	43.9	70.5	99.3	139.	191.	250.	321.
7 1/2	24.6	46.6	74.8	106.	147.	202.	264.	338.
8	26.1	49.4	79.0	112.	156.	213.	278.	355.
8 1/2	27.6	52.1	83.3	118.	164.	223.	292.	372.
9	29.2	54.8	87.6	124.	173.	234.	306.	389.
9 1/2	30.7	57.6	91.8	130.	181.	245.	319.	406.
10	32.2	60.3	96.1	136.	189.	256.	333.	423.
10 1/2	33.8	63.0	101.	142.	198.	267.	347.	440.
11	35.3	65.7	105.	148.	206.	278.	361.	457.
11 1/2	36.8	68.5	109.	155.	214.	289.	375.	474.
12	38.4	71.2	113.	161.	223.	300.	388.	491.
Heads	1.8	5.7	10.9	13.4	22.2	38.0	57.0	82.0

WEIGHT IN POUNDS OF 100 BOLTS WITH SQUARE HEADS AND NUTS.

One cubic foot weighing 480 lbs.

Length.	Diameter of Bolt, Inches.								
	¼	5/16	⅜	7/16	½	⅝	¾	⅞	1
1½	4.0	6.8	10.6	15.0	23.9	40.5	70.0	.....	.....
1¾	4.4	7.3	11.3	16.1	25.1	42.7	73.1	.....	.....
2	4.7	7.8	12.0	17.2	26.3	44.8	76.2	.....	.....
2¼	5.1	8.4	12.6	18.2	27.7	47.0	79.3	.....	.....
2½	5.4	8.9	13.3	19.2	29.0	49.2	82.4	120.5	.....
2¾	5.8	9.5	14.0	20.2	30.4	51.4	85.5	124.7	.....
3	6.1	10.0	14.7	21.2	31.8	53.5	88.7	128.9	185.0
3½	6.8	11.1	16.0	23.2	34.7	57.9	95.0	137.4	196.0
4	7.5	12.2	17.4	25.2	37.5	62.3	101.2	145.8	207.0
4½	8.2	13.2	18.7	27.2	40.2	66.7	107.5	159.2	218.0
5	8.9	14.3	20.0	29.1	43.0	71.0	113.7	167.7	229.0
5½	9.6	15.4	21.4	31.2	45.7	75.4	120.0	176.1	240.0
6	10.3	16.5	22.8	33.1	48.4	79.8	126.2	184.6	251.0
6½	11.0	17.6	24.1	35.1	51.2	84.1	132.5	193.0	262.0
7	11.7	18.6	25.9	37.1	54.0	88.5	138.7	201.4	273.0
7½	12.4	19.7	27.7	39.1	56.7	92.9	145.0	209.9	284.0
8	13.1	20.8	29.5	41.0	59.4	97.2	151.2	218.3	295.0
9	....	....	33.1	45.0	64.8	106.0	163.7	240.2	317.0
10	....	....	36.7	49.0	70.3	114.7	176.2	257.1	339.0
11	....	....	40.4	53.0	75.8	123.5	188.7	273.9	360.0
12	....	....	44.0	57.0	81.3	132.2	201.0	290.0	382.0
13	....	....	....	....	86.7	140.7	213.4	307.7	404.0
14	....	....	....	....	92.2	149.2	225.9	324.5	426.0
15	....	....	....	....	97.7	157.6	238.3	341.4	448.0
16	....	....	....	....	103.1	166.1	250.8	358.3	470.0
17	....	....	....	....	108.6	174.6	263.2	375.2	492.0
18	....	....	....	....	114.1	183.1	275.6	392.0	514.0
19	....	....	....	....	119.5	191.5	288.1	408.9	536.0
20	....	....	....	....	125.0	200.0	300.5	425.8	558.0
Per in. additional.	1.4	2.2	3.6	4.0	5.5	8.5	12.4	16.9	22.0

APPROXIMATE WEIGHT OF NUTS AND BOLT HEADS IN POUNDS.

Diam. of Bolt in Inches	¼	5/16	⅜	7/16	½	⅝	¾
Weight of Hexagon Nut and Head.....	.017	.042	.057	.109	.128	.267	.43
Weight of Square Nut and Head.....	.021	.049	.069	.120	.164	.320	.55
Diam. of Bolt in Inches	⅞	1	1¼	1½	1¾	2	2½
Weight of Hexagon Nut and Head.....	.73	1.10	2.14	3.78	5.6	8.75	17.0
Weight of Square Nut and Head	.88	1.31	2.56	4.42	7.0	10.5	21.0

Sizes and Weights of Hot Pressed Hexagon Nuts.

The sizes are the usual manufacturers', not the Franklin Institute Standard. Both weights and sizes are for unfinished Nuts. One cubic foot weighing 480 lbs.

Size of Bolt.	Weight of 100 Nuts.	Rough Hole.	Thickness of Nut.	Short Diameter.	Long Diameter.	No. of Nuts in 100 lbs.
1/4	1.3	7/32	1/4	1/2	.58	8000.
5/16	2.4	9/32	5/16	5/8	.72	4170.
3/8	4.1	11/32	3/8	3/4	.87	2410.
7/16	6.8	13/32	7/16	7/8	1.01	1460.
1/2	7.1	7/16	1/2	7/8	1.01	1410.
1/2	9.8	7/16	1/2	1	1.15	1020.
9/16	14.0	1/2	9/16	1 1/8	1.30	710.
5/8	14.7	9/16	5/8	1 1/8	1.30	680.
5/8	19.1	9/16	5/8	1 1/4	1.44	520.
5/8	22.9	9/16	3/4	1 1/4	1.44	440.
3/4	27.2	21/32	3/4	1 3/8	1.59	370.
3/4	39.	21/32	7/8	1 5/8	1.73	256.
7/8	44.	25/32	7/8	1 1/2	1.88	226.
7/8	50.	25/32	1	1 5/8	1.88	198.
1	57.	7/8	1	1 3/4	2.02	176.
1	64.	7/8	1 1/8	1 3/4	2.02	156.
1 1/8	96.	15/16	1 1/4	2	2.31	104.
1 1/4	134.	1 1/16	1 3/8	2 1/4	2.60	75.
1 3/8	180.	1 3/16	1 1/2	2 1/2	2.89	56.
1 1/2	235.	1 5/16	1 5/8	2 3/4	3.18	42.
1 5/8	300.	1 7/16	1 3/4	3	3.46	33.4
1 3/4	370.	1 9/16	1 7/8	3 1/4	3.75	26.7
1 7/8	460.	1 11/16	2	3 1/2	4.04	21.5
2	450.	1 13/16	2	3 1/2	4.04	22.4
2 1/8	560.	1 7/8	2 1/8	3 3/4	4.33	18.0
2 1/4	560.	2	2 1/4	3 3/4	4.33	17.7
2 3/8	680.	2 1/8	2 3/8	4	4.62	14.7
2 1/2	810.	2 1/4	2 1/2	4 1/4	4.91	12.3
2 3/4	980.	2 7/16	2 3/4	4 1/2	5.20	10.2
3	1150.	2 11/16	3	4 3/4	5.48	8.7
3 1/4	1340.	2 15/16	3 1/4	5	5.77	7.5
3 1/2	1580.	3 1/8	3 1/2	5 1/4	6.06	6.3

Sizes and Weights of Hot Pressed Square Nuts.

The sizes are the usual manufacturers', not the Franklin Institute Standard. Both weights and sizes are for unfinished Nuts. One cubic foot weighing 480 lbs.

Size of Bolt.	Weight of 100 Nuts.	Rough Hole.	Thickness of Nut.	Side of Square	Diagonal	No. of Nuts in 100 lbs
1/4	1.5	7/32	1/4	1/2	.71	6800.
5/16	2.9	9/32	5/16	5/8	.88	3480.
3/8	4.9	11/32	3/8	3/4	1.06	2050.
7/16	7.7	13/32	7/16	7/8	1.24	1290.
1/2	8.6	7/16	1/2	7/8	1.24	1170.
1/2	11.8	7/16	1/2	1	1.41	850.
9/16	16.7	1/2	9/16	1 1/8	1.59	600.
5/8	17.7	9/16	5/8	1 1/8	1.59	570.
5/8	22.8	9/16	5/8	1 1/4	1.77	440.
3/4	32.3	21/32	3/4	1 3/8	1.94	310.
3/4	39.8	21/32	3/4	1 1/2	2.12	251.
7/8	53.	25/32	7/8	1 5/8	2.30	190.
7/8	63.	25/32	7/8	1 3/4	2.47	159.
1	68.	7/8	1	1 3/4	2.47	146.
1	94.	7/8	1	2	2.83	106.
1 1/8	103.	15/16	1 1/8	2	2.83	97.
1 1/8	137.	15/16	1 1/8	2 1/4	3.18	73.
1 1/4	145.	1 1/16	1 1/4	2 1/4	3.18	69.
1 1/4	186.	1 1/16	1 1/4	2 1/2	3.54	54.
1 3/8	247.	1 3/16	1 3/8	2 3/4	3.89	41.
1 1/2	319.	1 5/16	1 1/2	3	4.24	31.3
1 5/8	400.	1 7/16	1 5/8	3 1/4	4.60	24.8
1 3/4	500.	1 9/16	1 3/4	3 1/2	4.95	19.9
1 7/8	620.	1 11/16	1 7/8	3 3/4	5.30	16.2
2	750.	1 13/16	2	4	5.66	13.4
2 1/8	780.	1 7/8	2 1/8	4	5.66	12.8
2 1/4	930.	2	2 1/4	4 1/4	6.01	10.7
2 3/8	960.	2 1/8	2 3/8	4 1/4	6.01	10.4
2 1/2	1130.	2 1/4	2 1/2	4 1/2	6.36	8.9
2 3/4	1370.	2 7/16	2 3/4	4 3/4	6.72	7.3
3	1610.	2 11/16	3	5	7.07	6.2
3 1/4	2110.	2 15/16	3 1/4	5 1/2	7.78	4.7
3 1/2	2750.	3 1/8	3 1/2	6	8.49	3.6

STANDARD GAUGES.

No. of Gauge.	Thickness in Decimals of an Inch.						
	Birmingham or Stubb's Iron Wire	Browne & Sharpe	United States	British Imperial	Washburn & Moen Co.	Trenton Iron Co.	Stubs Steel Wire
7°	....	......	.50000	.500	.....	.....	....
6°	....	......	.46875	.464	.....	.....	....
5°	....	......	.43750	.432	.....	.45	....
4°	.454	.46000	.40625	.400	.3938	.40	....
3°	.425	.40964	.37500	.372	.3625	.36	....
2°	.380	.36480	.34375	.348	.3310	.33	....
0	.340	.32486	.31250	.324	.3065	.305	....
1	.300	.28930	.28125	.300	.2830	.285	.227
2	.284	.25763	.26562	.276	.2625	.265	.219
3	.259	.22942	.25000	.252	.2437	.245	.212
4	.238	.20431	.23437	.232	.2253	.225	.207
5	.220	.18194	.21875	.212	.2070	.205	.204
6	.203	.16202	.20312	.192	.1920	.190	.201
7	.180	.14428	.18750	.176	.1770	.175	.199
8	.165	.12849	.17187	.160	.1620	.160	.197
9	.148	.11443	.15625	.144	.1483	.145	.194
10	.134	.10189	.14062	.128	.1350	.130	.191
11	.120	.09074	.12500	.116	.1205	.1175	.188
12	.109	.08081	.10937	.104	.1055	.1050	.185
13	.095	.07196	.09375	.092	.0915	.0925	.182
14	.083	.06408	.07812	.080	.0800	.0800	.180
15	.072	.05707	.07031	.072	.0720	.0700	.178
16	.065	.05082	.06250	.064	.0625	.0610	.175
17	.058	.04526	.05625	.056	.0540	.0525	.172
18	.049	.04030	.05000	.048	.0475	.0450	.168
19	.042	.03589	.04375	.040	.0410	.0400	.164
20	.035	.03196	.03750	.036	.0348	.0350	.161
21	.032	.02846	.03437	.032	.0317	.0310	.157
22	.028	.02535	.03125	.028	.0286	.0280	.155
23	.025	.02257	.02812	.024	.0258	.0250	.153
24	.022	.02010	.02500	.022	.0230	.0225	.151
25	.020	.01790	.02187	.020	.0204	.0200	.148
26	.018	.01594	.01875	.018	.0181	.0180	.146
27	.016	.01419	.01719	.0164	.0173	.0170	.143
28	.014	.01264	.01562	.0148	.0162	.0160	.139
29	.013	.01126	.01406	.0136	.0150	.0150	.134
30	.012	.01002	.01250	.0124	.0140	.0140	.127
31	.010	.00893	.01094	.0116	.0132	.0130	.120
32	.009	.00795	.01016	.0108	.0128	.0120	.115
33	.008	.00708	.00938	.0100	.0118	.0110	.112
34	.007	.00630	.00859	.0092	.0104	.0100	.110
35	.005	.00561	.00781	.0084	.0095	.0095	.108
36	.004	.00500	.00703	.0076	.0090	.0090	.106
37	....	.00445	.00664	.0068	.....	.0085	.103
38	....	.00396	.00625	.0060	.....	.0080	.101
39	....	.00353	......	.....	.....	.0075	.099
40	....	.00314	......	.....	.....	.0070	.097

DECIMALS OF AN INCH AND FOOT FOR EACH 1/64.

Fraction	1/32	1/64	Decimals of an Inch.	Decimals of a Foot.	Fraction	1/32	1/64	Decimals of an Inch.	Decimals of a Foot.
		1	.015625	.0013			33	.515625	.0430
	1		.031250	.0026		17		.531250	.0443
		3	.046875	.0039			35	.546875	.0456
1/16			.062500	.0052	9/16			.562500	.0469
		5	.078125	.0065			37	.578125	.0472
	3		.093750	.0078		19		.593750	.0495
		7	.109375	.0091			39	.609375	.0508
⅛			.125000	.0104	⅝			.625000	.0521
		9	.140625	.0117			41	.640625	.0534
	5		.156250	.0130		21		.656250	.0547
		11	.171875	.0143			43	.671875	.0560
3/16			.187500	.0156	11/16			.687500	.0573
		13	.203125	.0169			45	.703125	.0586
	7		.218750	.0182		23		.718750	.0599
		15	.234375	.0195			47	.734375	.0612
¼			.250000	.0208	¾			.750000	.0625
		17	.265625	.0221			49	.765625	.0638
	9		.281250	.0234		25		.781250	.0651
		19	.296875	.0247			51	.796875	.0664
5/16			.312500	.0260	13/16			.812500	.0677
		21	.328125	.0273			53	.828125	.0690
	11		.343750	.0286		27		.843750	.0703
		23	.359375	.0299			55	.859375	.0716
⅜			.375000	.0313	⅞			.875000	.0729
		25	.390625	.0326			57	.890625	.0742
	13		.406250	.0339		29		.906250	.0755
		27	.421875	.0352			59	.921875	.0768
7/16			.437500	.0365	15/16			.937500	.0781
		29	.453125	.0378			61	.953125	.0794
	15		.468750	.0391		31		.968750	.0807
		31	.484375	.0404			63	.984375	.0820
½			.500000	.0417	1			1.000000	.0833

DECIMALS OF A FOOT FOR EACH INCH.

In	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.
1	.0833	3	.2500	5	.4167	7	.5833	9	.7500	11	.9167
2	.1667	4	.3333	6	.5000	8	.6667	10	.8333	12	1.0000

WEIGHTS OF SHEETS AND PLATES OF STEEL, WROUGHT IRON, COPPER AND BRASS.

BIRMINGHAM GAUGE.

No. of Gauge.	Thickness in Inches.	Weight per Square Foot.			
		Steel.	Iron.	Copper.	Brass.
0000	.454	18.5232	18.16	20.5662	19.4312
000	.425	17.3400	17.00	19.2525	18.1900
00	.380	15.5040	15.20	17.2140	16.2640
0	.340	13.8720	13.60	15.4020	14.5520
1	.300	12.2400	12.00	13.5900	12.8400
2	.284	11.5872	11.36	12.8652	12.1552
3	.259	10.5672	10.36	11.7327	11.0852
4	.238	9.7104	9.52	10.7814	10.1864
5	.220	8.9760	8.80	9.966	9.4160
6	.203	8.2824	8.12	9.1959	8.6884
7	.180	7.3440	7.20	8.1540	7.7040
8	.165	6.7320	6.60	7.4745	7.0620
9	.148	6.0384	5.92	6.7044	6.3344
10	.134	5.4672	5.36	6.0702	5.7352
11	.120	4.8960	4.80	5.4360	5.1360
12	.109	4.4472	4.36	4.9377	4.6652
13	.095	3.8760	3.80	4.3035	4.0660
14	.083	3.3864	3.32	3.7599	3.5524
15	.072	2.9376	2.88	3.2616	3.0816
16	.065	2.6520	2.60	2.9445	2.7820
17	.058	2.3664	2.32	2.6274	2.4824
18	.049	1.9992	1.96	2.2197	2.0972
19	.042	1.7136	1.68	1.9026	1.7976
20	.035	1.4280	1.40	1.5855	1.4980
21	.032	1.3056	1.28	1.4496	1.3696
22	.028	1.1424	1.12	1.2684	1.1984
23	.025	1.0200	1.00	1.1325	1.0700
24	.022	.8976	.88	.9966	.9416
25	.020	.8160	.80	.9060	.8560
26	.018	.7344	.72	.8154	.7704
27	.016	.6528	.64	.7248	.6848
28	.014	.5712	.56	.6342	.5992
29	.013	.5304	.52	.5889	.5564
30	.012	.4896	.48	.5436	.5136
31	.010	.4080	.40	.4530	.4280
32	.009	.3672	.36	.4077	.3852
33	.008	.3264	.32	.3624	.3424
34	.007	.2856	.28	.3171	.2996
35	.005	.2040	.20	.2265	.2140
36	.004	.1632	.16	.1812	.1712
Specific Gravities.		7.85	7.70	8.72	8.24
Weight of a Cubic Ft.		489.6	480.0	543.6	513.6
" " " In.		0.2833	0.2778	0.3146	0.2972

WEIGHTS OF SHEETS AND PLATES OF STEEL, WROUGHT IRON, COPPER AND BRASS.

AMERICAN OR BROWNE & SHARPE GAUGE.

No. of Gauge.	Thickness in Inches.	Weight per Square Foot.			
		Steel.	Iron.	Copper.	Brass.
0000	.460000	18.7680	18.4000	20.8380	19.6880
000	.409642	16.7134	16.3857	18.5568	17.5327
00	.364796	14.8837	14.5918	16.5253	15.6133
0	.324861	13.2543	12.9944	14.7162	13.9041
1	.289297	11.8033	11.5719	13.1052	12.3819
2	.257627	10.5112	10.3051	11.6705	11.0264
3	.229423	9.3605	9.1769	10.3929	9.8193
4	.204307	8.3357	8.1723	9.2551	8.7443
5	.181940	7.4232	7.2776	8.2419	7.7870
6	.162023	6.6105	6.4809	7.3396	6.9346
7	.144285	5.8868	5.7714	6.5361	6.1754
8	.128490	5.2424	5.1396	5.8206	5.4994
9	.114423	4.6685	4.5769	5.1834	4.8973
10	.101897	4.1574	4.0759	4.6159	4.3612
11	.090742	3.7023	3.6297	4.1106	3.8838
12	.080808	3.2970	3.2323	3.6606	3.4586
13	.071962	2.9360	2.8785	3.2599	3.0800
14	.064084	2.6146	2.5634	2.9030	2.7428
15	.057068	2.3284	2.2827	2.5852	2.4425
16	.050821	2.0735	2.0328	2.3022	2.1751
17	.045257	1.8465	1.8103	2.0501	1.9370
18	.040303	1.6444	1.6121	1.8257	1.7250
19	.035890	1.4643	1.4356	1.6258	1.5361
20	.031961	1.3040	1.2784	1.4478	1.3679
21	.028462	1.1612	1.1385	1.2893	1.2182
22	.025346	1.0341	1.0138	1.1482	1.0848
23	.022572	.92094	.90288	1.0225	.96608
24	.020101	.82012	.80404	.91058	.86032
25	.017900	.73032	.71600	.81087	.76612
26	.015941	.65039	.63764	.72213	.68227
27	.014195	.57916	.56780	.64303	.60755
28	.012641	.51575	.50564	.57264	.54103
29	.011257	.45929	.45028	.50994	.48180
30	.010025	.40902	.40100	.45413	.42907
31	.008928	.36426	.35712	.40444	.38212
32	.007950	.32436	.31800	.36014	.34026
33	.007080	.28886	.28320	.32072	.30302
34	.006305	.25724	.25220	.28562	.26985
35	.005615	.22909	.22460	.25436	.24032
36	.005000	.20400	.20000	.22650	.21400

WEIGHT OF PLATE IRON IN POUNDS PER LINEAL FOOT.

(Based on 480 lbs. per Cubic Foot. For Steel add 2 per cent.)

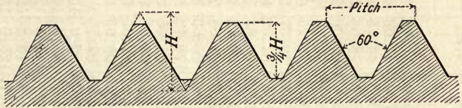
Width in Inches.	Thickness in Inches.							
	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2
12	2.50	5.00	7.50	10.00	12.50	15.00	17.50	20.00
13	2.71	5.42	8.13	10.83	13.54	16.25	18.96	21.67
14	2.92	5.83	8.75	11.67	14.58	17.50	20.42	23.33
15	3 13	6.25	9.38	12.50	15.63	18.75	21.88	25.00
16	3.33	6.67	10.00	13.33	16.67	20.00	23.33	26.67
17	3.54	7.08	10.63	14.17	17.71	21.25	24.79	28.33
18	3.75	7.50	11.25	15.00	18.75	22.50	26.25	30.00
19	3.96	7.92	11.87	15.83	19.79	23.75	27.71	31.67
20	4.17	8.33	12.50	16.67	20.83	25.00	29.17	33.33
21	4.38	8.75	13.13	17.50	21.88	26.25	30.63	35.00
22	4.58	9.17	13.75	18.33	22.92	27.50	32.08	36.67
23	4.79	9.58	14.38	19.17	23.96	28.75	33.54	38.33
24	5.00	10.00	15.00	20.00	25.00	30.00	35.00	40.00
25	5.21	10.42	15.62	20.83	26.04	31.25	36.46	41.67
26	5.42	10.83	16.25	21.67	27.08	32.50	37.92	43.33
27	5.63	11.25	16.88	22.50	28.13	33.75	39.38	45.00
28	5.83	11.67	17.50	23.33	29.17	35.00	40.83	46.67
29	6.04	12.08	18.13	24.17	30.21	36.25	42.29	48.33
30	6.25	12.50	18.75	25.00	31.25	37.50	43.75	50.00
32	6.67	13.33	20.00	26.67	33.33	40.00	46.67	53.33
34	7.08	14.17	21.25	28.33	35.42	42.50	49.58	56.67
36	7.50	15.00	22.50	30.00	37.50	45.00	52.50	60.00
38	7.92	15.83	23.75	31.67	39.59	47.50	55.42	63.33
40	8.33	16.67	25.00	33.33	41.67	50.00	58.33	66.67
42	8.75	17.50	26.25	35.00	43.75	52.50	61.25	70.00
44	9.17	18.33	27.50	36.67	45.84	55.00	64.17	73.33
46	9.58	19.17	28.75	38.33	47.92	57.50	67.08	76.67
48	10.00	20.00	30.00	40.00	50.00	60.00	70.00	80.00
50	10.42	20.83	31.25	41.67	52.08	62.50	72.91	83.33
52	10.83	21.67	32.50	43.33	54.17	65.00	75.83	86.67
54	11.25	22.50	33.75	45.00	56.25	67.50	78.75	90.00
56	11.67	23.33	35.00	46.67	58.33	70.00	81.66	93.33
58	12.08	24.17	36.25	48.33	60.42	72.50	84.58	96.67
60	12.50	25.00	37.50	50.00	62.50	75.00	87.50	100.00

WEIGHT OF PLATE IRON IN POUNDS PER LINEAL FOOT

(CONTINUED.)

Width in Inches.	Thickness in Inches.							
	9/16	5/8	11/16	3/4	13/16	7/8	15/16	1
12	22.50	25.00	27.50	30.00	32.50	35.00	37.50	40.00
13	24.38	27.08	29.79	32.50	35.21	37.92	40.63	43.33
14	26.25	29.17	32.08	35.00	37.92	40.83	43.75	46.67
15	28.13	31.25	34.38	37.50	40.63	43.75	46.88	50.00
16	30.00	33.33	36.67	40.00	43.33	46.67	50.00	53.33
17	31.88	35.42	38.96	42.50	46.05	49.59	53.13	56.67
18	33.75	37.50	41.25	45.00	48.75	52.50	56.25	60.00
19	35.67	39.58	43.54	47.50	51.45	55.41	59.37	63.33
20	37.50	41.67	45.83	50.00	54.17	58.33	62.50	66.67
21	39.38	43.75	48.13	52.50	56.88	61.25	65.63	70.00
22	41.25	45.83	50.42	55.00	59.58	64.17	68.75	73.33
23	43.13	47.92	52.71	57.50	62.30	67.09	71.88	76.67
24	45.00	50.00	55.00	60.00	65.00	70.00	75.00	80.00
25	46.88	52.08	57.29	62.50	67.70	72.91	78.13	83.33
26	48.75	54.17	59.58	65.00	70.42	75.83	81.25	86.67
27	50.63	56.25	61.88	67.50	73.13	78.75	84.38	90.00
28	52.50	58.33	64.17	70.00	75.84	81.67	87.50	93.33
29	54.38	60.42	66.46	72.50	78.55	84.59	90.63	96.67
30	56.25	62.50	68.75	75.00	81.25	87.50	93.75	100.0
32	60.00	66.67	73.33	80.00	86.67	93.33	100.0	106.7
34	63.75	70.83	77.91	85.00	92.08	99.17	106.3	113.3
36	67.50	75.00	82.50	90.00	97.50	105.0	112.5	120.0
38	71.25	79.17	87.09	95.00	102.9	110.8	118.8	126.7
40	75.00	83.33	91.67	100.0	108.3	116.7	125.0	133.3
42	78.75	87.50	96.25	105.0	113.7	122.5	131.3	140.0
44	82.50	91.67	100.8	110.0	119.2	128.3	137.5	146.7
46	86.25	95.83	105.4	115.0	124.6	134.2	143.8	153.3
48	90.00	100.0	110.0	120.0	130.0	140.0	150.0	160.0
50	93.75	104.2	114.6	125.0	135.4	145.8	156.3	166.7
52	97.50	108.3	119.2	130.0	140.8	151.7	162.5	173.3
54	101.3	112.5	123.8	135.0	146.3	157.5	168.8	180.0
56	105.0	116.7	128.3	140.0	151.7	163.3	175.0	186.7
58	108.8	120.8	132.9	145.0	157.1	169.2	181.3	193.3
60	112.5	125.0	137.5	150.0	162.5	175.0	187.5	200.0

UNITED STATES, OR SELLERS SYSTEM OF SCREW-THREADS.



Angle of thread=60°. Flat at top and bottom=1/8 of pitch.

BOLTS AND THREADS.						HEX. NUTS AND HEADS.					
Diam. of Bolt.	Threads per Inch.	Diam. at Root of Thread.	Width of Flat.	Area of Bolt Body in Sq. Inches.	Area at Root of Thread in Sq. Inches.	Short Diam. Rough.	Short Diam. Finish.	Long Diam. Rough.	Thickness, Rough.	Thickness, Finish.	Long Diam. Sq. Nuts Rough.
Ins.		Ins.	Ins.			Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
1/4	20	.185	.0062	.049	.027	1/2	7/16	37/64	1/4	3/16	7/10
5/16	18	.240	.0074	.077	.045	19/32	17/32	11/16	5/16	1/4	10/12
3/8	16	.294	.0078	.110	.068	11/16	5/8	51/64	3/8	5/16	63/64
7/16	14	.344	.0089	.150	.093	25/32	23/32	9/16	7/16	3/8	1 7/64
1/2	13	.400	.0096	.196	.126	7/8	13/16	1	1/2	7/16	1 15/64
9/16	12	.454	.0104	.249	.162	31/32	29/32	1 1/8	9/16	1/2	1 23/64
5/8	11	.507	.0113	.307	.202	1 1/16	1	1 7/32	5/8	9/16	1 1/2
3/4	10	.620	.0125	.442	.302	1 1/4	1 3/16	1 7/16	3/4	11/16	1 49/64
7/8	9	.731	.0138	.601	.420	1 7/16	1 3/8	1 21/32	7/8	13/16	2 1/32
1	8	.837	.0156	.785	.550	1 5/8	1 9/16	1 7/8	1	15/16	2 19/64
1 1/8	7	.940	.0178	.994	.694	1 13/16	1 3/4	2 3/32	1 1/8	1 1/16	2 9/16

UNITED STATES, OR SELLERS SYSTEM OF SCREW-HEADS.—(CONTINUED.)

BOLTS AND THREADS.						HEX. NUTS AND HEADS.					
Diam. of Bolt.	Threads per Inch.	Diam. at Root of Thread.	Width of Flat.	Area of Bolt Body in Sq. Inches.	Area at Root of Thread in Sq. Inches.	Short Diam. Rough.	Short Diam. Finish.	Long Diam Rough.	Thickness, Rough.	Thickness, Finish	Long Diam. Sq Nuts Rough.
Ins.		Ins.	Ins			Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
1 1/4	7	1.065	.0178	1.227	.893	2	1 15/16	2 5/16	1 1/4	1 3/16	2 53/64
1 3/8	6	1.160	.0208	1.485	1.057	2 3/16	2 1/8	2 17/32	1 3/8	1 5/16	3 3/32
1 1/2	6	1.284	.0208	1.767	1.295	2 3/8	2 5/16	2 3/4	1 1/2	1 7/16	3 23/64
1 5/8	5 1/2	1.389	.0227	2.074	1.515	2 9/16	2 1/2	2 31/32	1 5/8	1 9/16	3 5/8
1 3/4	5	1.491	.0250	2.405	1.746	2 3/4	2 11/16	3 3/16	1 3/4	1 11/16	3 57/64
1 7/8	5	1.616	.0250	2.761	2.051	2 15/16	2 7/8	3 13/32	1 7/8	1 13/16	4 5/32
2	4 1/2	1.712	.0277	3.142	2.302	3 1/8	3 1/16	3 5/8	2	1 15/16	4 27/64
2 1/4	4 1/2	1.962	.0277	3.976	3.023	3 1/2	3 7/16	4 1/16	2 1/4	2 3/16	4 61/64
2 1/2	4	2.176	.0312	4.909	3.719	3 7/8	3 13/16	4 1/2	2 1/2	2 7/16	5 31/64
2 3/4	4	2.426	.0312	5.940	4.620	4 1/4	4 3/16	4 29/32	2 3/4	2 11/16	6
3	3 1/2	2.629	.0357	7.069	5.428	4 5/8	4 9/16	5 3/8	3	2 15/16	6 17/32
3 1/4	3 1/2	2.879	.0357	8.296	6.510	5	4 15/16	5 13/16	3 1/4	3 3/16	7 1/16
3 1/2	3 1/4	3.100	.0384	9.621	7.548	5 3/8	5 5/16	6 7/64	3 1/2	3 7/16	7 39/64
3 3/4	3	3.317	.0413	11.045	8.641	5 3/4	5 11/16	6 21/32	3 3/4	3 11/16	8 1/8
4	3	3.567	.0413	12.566	9.963	6 1/8	6 1/16	7 3/32	4	3 15/16	8 41/64
4 1/4	2 7/8	3.798	.0435	14.186	11.329	6 1/2	6 7/16	7 9/16	4 1/4	4 3/16	9 3/16
4 1/2	2 3/4	4.028	.0454	15.904	12.753	6 7/8	6 13/16	7 31/32	4 1/2	4 7/16	9 3/4
4 3/4	2 5/8	4.256	.0476	17.721	14.226	7 1/4	7 3/16	8 13/32	4 3/4	4 11/16	10 1/4
5	2 1/2	4.480	.0500	19.635	15.763	7 5/8	7 9/16	8 27/32	5	4 15/16	10 49/64
5 1/4	2 1/2	4.730	.0500	21.648	17.572	8	7 15/16	9 9/32	5 1/4	5 3/16	11 23/64
5 1/2	2 3/8	4.953	.0526	23.758	19.267	8 3/8	8 5/16	9 23/32	5 1/2	5 7/16	11 7/8
5 3/4	2 3/8	5.203	.0526	25.967	21.262	8 3/4	8 11/16	10 5/32	5 3/4	5 11/16	12 3/8
6	2 1/4	5.423	.0555	28.274	23.098	9 1/8	9 1/16	10 19/32	6	5 15/16	12 15/16

STANDARD SIZES OF SCREW-THREADS FOR BOLTS AND TAPS.

(CHAS. A BAUER.)

1	2	3	4	5	6	7	8	9	10
A	*n*	*D*	*d*	*h*	*f*	*D′-D*	*D′*	*d′*	*H*
		Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches
¼	20	.2608	.1855	.0379	.0062	006	.2668	.1915	.2024
$\frac{5}{16}$	18	.3245	.2403	.0421	.0070	.006	.3305	.2463	.2589
⅜	16	.3885	.2938	.0474	.0078	.006	.3945	.2998	.3139
$\frac{7}{16}$	14	.4530	.3447	.0541	.0089	.006	.4590	.3507	.3670
⅝	13	.5166	.4000	.0582	.0096	.006	.5226	.4060	.4236
$\frac{9}{16}$	12	.5805	.4543	.0631	.0104	.007	.5875	.4613	.4802
¾	11	.6447	.5069	.0689	.0114	.007	.6517	.5139	.5346
⅞	10	.7717	.6201	.0758	.0125	.007	.7787	.6271	.6499
..	9	.8991	.7307	.0842	.0139	.007	.9061	.7377	.7630
1	8	1.0271	.8376	.0947	.0156	.007	1.0341	.8446	.8731
1⅛	7	1.1559	.9394	.1083	.0179	.007	1.1629	.9464	.9789
1¼	7	1.2809	1.0644	.1083	.0179	.007	1.2879	1.0714	1.1039

A=nominal diameter of bolt.
D=actual diameter of bolt.
d=diameter of bolt at bottom of thread.
n=number of threads per inch.
f=flat of bottom of thread.
h=depth of thread.
D' and d'=diameters of tap.
H=diameter of hole in nut before tapping.

$$D=A+\frac{.2165}{n}.$$

$$d=A-\frac{1.29904}{n}.$$

$$h=\frac{.7577}{n}=\frac{D-d}{2}.$$

$$f=\frac{.125}{n}.$$

$$H=D'-\frac{1\cdot 288}{n}=D'-.85(2h).$$

Efficiency of Screw-bolts.—Mr. Lewis gives the following approximate formula for ordinary screw-bolts (V threads, with collars): p=pitch of screw, d=outside diameter of screw, F=force applied at circumference to lift a unit of weight, E=efficiency of screw. For an average case, in which the coefficient of friction may be assumed at 0.15,

$$F=\frac{p+d}{3d}, \qquad E=\frac{p}{p+d}.$$

For bolts of the dimensions given above, ½-inch pitch, and outside diameters 1½, 2½, 3½, and 4½ in., the efficiencies according to this formula would be, respectively, 0.25, 0.167, 0.125, and 0.10.

James McBride (Trans. A.S.M.E., xii. 781) describes an experiment with an ordinary 2-in. screw-bolt, with a V thread, 4½ threads per inch, raising a weight of 7500 lbs., the force being applied by turning the nut. Of the power applied 89.8% was absorbed by friction of the nut on its supporting washer and of the threads of the bolt in the nut. The nut was not faced, and had the flat side to the washer.

STRENGTH OF WROUGHT IRON BOLTS.

(COMPUTED BY A. F. NAGLE.)

Diameter of Bolt, Inches.	Number of Threads.	Diameter of Bottom of Thread, Inches.	Area at Bottom of Thread, Square Inches.	Stress upon Bolt upon Basis of working strength of					Probable Breaking Load.
				3000 lbs. per sq. inch.	4000 lbs. per sq. inch.	5000 lbs. per sq. inch.	7000 lbs. per sq. inch.	10000 lbs. per sq. inch.	
				lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
½	13	.38	.12	350	460	580	810	1160	5800
9/16	12	.44	.15	450	600	750	1050	1500	7500
⅝	11	.49	.19	560	750	930	1310	1870	9000
¾	10	.60	.28	750	1130	1410	1980	2830	14000
⅞	9	.71	.39	1180	1570	1970	2760	3940	19000
1	8	.81	.52	1550	2070	2600	3630	5180	25000
1⅛	7	.91	.65	1950	2600	3250	4560	6510	30000
1¼	7	1.04	.84	2520	3360	4200	5900	8410	39000
1⅜	6	1.12	1.00	3000	4000	5000	7000	10000	46000
1½	6	1.25	1.23	3680	4910	6140	8600	12280	56000
1⅝	5½	1.35	1.44	4300	5740	7180	10000	14360	65000
1¾	5	1.45	1.65	4950	6600	8250	11560	16510	74000
1⅞	5	1.57	1.95	5840	7800	9800	13640	19500	85000
2	4½	1.66	2.18	6540	8720	10900	15260	21800	95000
2¼	4½	1.92	2.88	8650	11530	14400	20180	28800	125000
2½	4	2.12	3.55	10640	14200	17730	24830	35500	150000
2¾	4	2.37	4.43	13290	17720	22150	31000	44300	186000
3	3½	2.57	5.20	15580	20770	26000	36360	52000	213000
3½	3¼	3.04	7.25	21760	29000	36260	50760	72500	290000
4	3	3.50	9.62	28860	38500	48100	67350	96200	385000

When the greatest load that has to be sustained by a bolt is known, and the working strength per sq. in. of the material constituting it is determined, look in the proper column for the given load. Should the load sought be not found, then take the load next larger as found in the column, and opposite to it in the first column read the required size of bolt.

Effect of Initial Strain in Bolts.—Suppose that bolts are used to connect two parts of a machine and that they are screwed up tightly before the effective load comes on the connected parts. Let $P_1 =$ the initial tension on a bolt due to screwing up, and $P_2 =$ the load afterwards added. The greatest load may vary but little from P_1 or P_2, according as the former or the latter is greater, or it may approach the value $P_1 + P_2$, depending upon the relative rigidity of the bolts and of the parts connected. Where rigid flanges are bolted together, metal to metal, it is probable that the extension of the bolts with any additional tension relieves the initial tension, and that the total tension is P_1 or P_2, but in cases where elastic packing, as india rubber, is interposed, the extension of the bolts may very little affect the initial tension, and the total strain may be nearly $P_1 + P_2$. Since the latter assumption is more unfavorable to the resistance of the bolt, this contingency should usually be provided for. (See Unwin, "Elements of Machine Design" for demonstration.)

WEIGHTS
AND
MEASURES.

WEIGHTS AND MEASURES.

AVOIRDUPOIS OR COMMERCIAL WEIGHT.

UNITED STATES AND BRITISH.

Grains.	Ounces.	Pounds.	Hundred-weight.	Gross Tons.
1.	0.002286	0.000143	0.00000128	0.000000176
437.5	1.	0.0625	0.00055804	0.00002790
7000.	16.	1.	0.0089286	0.0004464
784000.	1792.	112.	1.	0.05
5680000.	35840.	2240.	20.	1.

1 pound avoirdupois = 1.215278 pounds troy.
1 net ton = 2000 pounds = 0.892857 gross tons.
1 pound troy = 0.82286 pounds avoirdupois.

LINEAR MEASURE.

UNITED STATES AND BRITISH.

Inches.	Feet.	Yards.	Rods.	Miles.
1.	0.08333	0.02778	0.0050505	0.00001578
12.	1.	0.33333	0.0606061	0.00018939
36.	3.	1.	0.1818182	0.00056818
198.	16.5	5.5	1.	0.003125
63360.	5280.	1760.	320.	1.

GUNTER'S CHAIN MEASURE.

USED IN SURVEYING.

1 link = 7.92 inches = 0.01 chain = 0.000125 mile.
1 chain = 100 links = 66 feet = 4 rods = 0.0125 mile
1 mile = 80 chains = 8000 links.

SQUARE OR SURFACE MEASURE.

UNITED STATES AND BRITISH.

Square Inches.	Square Feet.	Square Yards	Square Rods.	Acres.	Square Miles.
1	0.006944	0.0007716	....	....	....
144	1.	0.111111	....	....	....
1296	9.	1.	0.03306	0.0002066	....
39204	272.25	30.25	1.	0.00625	0.00000977
6272640	43560.	4840.	160.	1.	0.0015625
	27878400.	3097600.	102400.	640.	1.

1 acre = 10 square chains.

CUBIC MEASURE.

1728 cubic inches=1 cubic foot,

27 cubic feet =1 cubic yard=46656 cubic inches,

1 cord wood =4 ft.× 4 ft.×8 ft.=128 cubic feet,

1 perch of masonry=16.5 ft.×1.5 ft.×1 ft.=24.75 cubic feet, but is generally assumed to be 25 cubic feet.

DRY MEASURE.

UNITED STATES ONLY.

Struck Bush.	Pecks.	Quarts.	Pints.	Gallons.	Cubic Inch.
1	4	32.	64	8.	2150.4
	1	8.	16	2.	537.6
		1.	2	0.25	67.2
		0.5	1	0.125	33.6
		4.	8	1.	268.8

The United States standard unit for dry measure is the old English Winchester bushel, which contains 2,150.42 cubic inches, or 1.2445 cubic feet.

The heaped bushel, the cone of which is 6 inches above the brim of the measure, contains 2,747.7 cubic inches.

In New York a bushel contains 2,218.2 cubic inches, or 1.2837 cubic feet, which is the same as the Imperial bushel of England. 33 English or Imperial bushels are equal to 34.04 Winchester or United States bushels.

LIQUID MEASURE.

UNITED STATES ONLY.

Cubic Inch.	Pints.	Quarts.	Gallons.	Barrels.	Hogs-head.
28.875	1.	0.5	0.125	0.003968	
57.75	2.	1.	0.25	0.007937	
231.	8.	4.	1.	0.031746	
7276.5	252.	126.	31.5	1.	0.5
14553.0	504.	252.	63.	2.	1.

The British Imperial gallon = 1.20032 U. S. gallons.

The United States standard unit for liquid measure is the gallon = 231 cu. in. = 8.33888 pounds, avoirdupois, of distilled water at 62° Fahr.

The English standard is the Imperial gallon = 277.2738 cu. in. = 10 pounds, avoirdupois, of distilled water at 62° Fahr.

NAUTICAL MEASURE.

A knot or nautical mile = 1.1527 statute miles = 6086. feet = length of a minute of longitude of the earth at the equator, at the level of sea, as determined by U. S. Coast Survey.

3 knots = 1 league.

SHIPPING MEASURE.

1 Register ton = 100 cubic feet.
1 U. S. Shipping ton = 40 cubic feet.
1 British Shipping ton = 42 cubic feet.

MEASURE OF WORK AND POWER.

A unit of work = one foot pound, or a pressure of one pound exerted through a space of one foot.

A British Thermal unit = 778 foot pounds.

A Horse Power = { 33,000 foot pounds per minute,
550 foot pounds per second,
42.42 heat units per minute,
0.707 heat units per second,
746 watts,
0.746 kilowatt.

THE METRIC SYSTEM OF WEIGHTS AND MEASURES.

In the **Metric System,** the **Meter** is the base of all the weights and measures which it employs.

The **Meter** is the primary unit of length and was intended to be one-ten millionth part of the distance, measured on a meridian of the earth, from the equator to the pole, and equals about 39.37 inches.

Upon the Meter are based the following primary units; the **Square Meter** the **Are,** the **Cubic Meter** or **Stere** the **Liter,** and the **Gram.**

The **Square Meter** or **Centare** is the unit of measure for small surfaces.

The **Are** is the unit of land measure; this is a square whose side is ten meters in length, and which contains one hundred square meters or centares.

The **Cubic Meter,** or **Stere,** is the unit of volume; this is a cube whose edge is one meter in length.

The **Liter** is the unit of capacity; this is the capacity of a cube whose edge is one tenth of a meter, that is, one decimeter in length.

The **Gram** is the unit of weight; this is the weight of distilled water at 4° centigrade, contained in a cube whose edge is the one hundredth part of a meter.

From these primary units the higher and lower orders of units are derived decimally as follows:

Scheme of the Weights and Measures of the Metric System.

Ratios	Lengths	Surfaces	Volumes	Weights
1,000,000.	....	....	....	Millier, or Tonneau
100,000.	....	....	....	Quintal
10,000.	Myr'iameter	....	....	Myr'iagram
1,000.	Kil'ometer	....	Kil'oliter	Kil'ogram, or Kilo
100.	Hec'tometer	Hect'are	Hec'toliter	Hec'togram
10.	Dek'ameter	....	Dek'aliter	Dek'agram
1.	Meter	Are	Li'ter	Gram
0.1	Dec'imeter	....	Dec'iliter	Dec'igram
0.01	Cen'timeter	Cen'tare	Cen'tiliter	Cen'tigram
0.001	Mil'limeter	....	Mil'liliter	Mil'ligram

It will be seen, from this table, that *ten* millimeters equal *one* centimeter, *ten* centimeters equal *one* decimeter, and so on.

Multiples and sub-multiples of the units, **meter, liter** and **gram** are expressed by the prefixes:

Deka =	10	Deci =	0.1
Hecto =	100	Centi =	0.01
Kilo =	1000	Milli =	0.001

ABBREVIATIONS COMMONLY IN USE.

mm,	millimeter,	m^2,	square meter,
cm,	centimeter,	km^2	" kilometer,
dm,	decimeter,	mm^3,	cubic millimeter,
m,	meter,	cm^3 / cc	" centimeter,
km,	kilometer,	dm^3,	" decimeter,
mm^2,	square millimeter,	m^3,	" meter,
cm^2,	" centimeter,		....
dm^2,	" decimeter,		

a, are; ha, hectare; cl, centiliter; l, liter; hl, hectoliter; s, stere; mg, milligram; cg, centigram; g, gram; kg, kilo, or kilogram; t, tonneau, or metric ton.

METRIC AND U. S. CONVERSION TABLE.

MEASURES OF LENGTH.

Metric to U. S.

1 millimeter = 0.03937 inch.
1 centimeter = 0.3937 "
1 meter = 39.37 inches.
1 " = 3.2808 feet.
1 kilometer = 0.6214 mile.

U. S. to Metric.

1 inch = 25.4 millimeters.
1 " = 2.54 centimeters.
1 " = 0.254 meter.
1 foot = 0.3048 "
1 mile = 1.609 kilometers.

MEASURES OF SURFACE.

Metric to U. S.

1 sq. millimeter = 0.00155 sq. inch.
1 " centimeter = 0.155 " "
1 " meter = 10.764 " feet.
1 " " = 1.196 " yards.
1 hectare = 2.471 acres.
1 " = 0.00386 sq. mile.
1 sq. kilometer = 0.3861 " "

U. S. to Metric.

1 sq. inch = 645.14 sq. millimeters.
1 " " = 6.452 " centimeters.
1 " foot = 0.0929 " meter.
1 " yard = 0.8361 " "
1 acre = 0.4047 hectares.
1 sq. mile = 259.00 "
1 " " = 2.59 sq. kilometers.

MEASURES OF VOLUME AND CAPACITY.

METRIC TO U. S.

1 cu. centimeter	=	0.061	cu. inch.
1 " meter	=	35.316	" feet.
1 " "	=	1.308	" yards.

1 liter = 1 cu. decimeter = 61.023 cu. inch.

LIQUID MEASURE.

1 liter	=	1.0567	quart.
1 "	=	0.2642	gallon.
1 cubic meter	=	264.17	gallons.

DRY MEASURE.

1 liter	=	0.908	quart.
1 hectoliter	=	2.8375	bushels

U. S. TO METRIC.

1 cu. inch	=	16.39	cu. centimeters.
1 " foot	=	0.0283	" meter.
1 " yard	=	0.7645	" "
1 " foot	=	28.32	liters.

LIQUID MEASURE.

1 quart	=	0.9463	liter.
1 gallon	=	3.7854	liters.
1 "	=	0.0038	cu. meter.

DRY MEASURE.

1 quart	=	1.1013	litres.
1 bushel	=	0.3524	hectoliter.

WEIGHTS.

METRIC TO U. S.

1 milligram	=	0.0154	grain.
1 gram	=	15.432	grains.
1 kilogram	=	2.2046	lbs. (avoir.)
1 metric ton	=	1.1023	net tons.
1 " "	=	0.9842	gross ton.

U. S. TO METRIC.

1 grain	=	64.80	milligrams.
1 "	=	0.0648	gram.
1 lb. (avoir.)	=	0.4536	kilogram.
1 net ton	=	0.9076	metric ton.
1 gross ton	=	1.0161	" tons.

COMPOUND UNITS.

METRIC TO UNITED STATES.

1 kilogram per meter	= 0.6720	lbs. per foot.
1 kilogram per sq. centimeter	=14.223	lbs. per sq. inch.
1 kilogram per sq. meter	= 0.2048	lbs. per sq. foot.
1 kilogram per cubic meter	= 0.0624	lbs. per cubic ft.
1 kilogram-meter	= 7.233	foot pounds.
1 chevel vapeur (metric H. P.)	= 0.986	horse-power.
1 kilo. watt	= 1.340	" "
1 kilo. per chevel	= 2.235	lbs. per H. P.

UNITED STATES TO METRIC.

1 lb. per foot	= 1.4882	kilograms per meter.
1 lb. per sq. inch	= 0.0703	kilo. per sq. centimeter.
1 lb. per sq. foot	= 4.8825	kilograms per sq. meter.
1 lb. per cubic foot	=16.0192	kilo. per cubic meter.
1 foot pound	= 0.1383	kilogram-meter.
1 horse-power	= 1.014	chevel vapeur (metric H. P.)
1 " "	= 0.746	kilo watt.
1 lb. per horse-power	= 0.447	kilos per chevel.

HEAT INTENSITY.

$$\text{Temp. Centigrade} = \left(\text{temp. Fahr.} - 32^\circ\right)\frac{5}{9}.$$

$$\text{Temp. Fahrenheit} = \left(\text{temp. C.} \times \frac{9}{5}\right) + 32^\circ.$$

HEAT QUANTITY.

A kilogram calorie	= 3.968	British thermal units.
A pound calorie	= 1.8	" " "
A British thermal unit	= 0.252	kilogram calorie
A British thermal unit	= 0.555	pound calorie.

MECHANICAL, ELECTRICAL AND HEAT EQUIVALENTS.

(H. W. LEONARD.)

Unit.	Equivalent Value in Other Units.
1 K. W. Hour =	1,000 watt hours. 1.34 horse-power hours. 2,654,200 ft.-lbs. 3,600,000 joules. 3,412 heat units. 367,000 kilogram metres. 0.235 lb. carbon oxidized with perfect efficiency. 3.53 lbs. water evaporated from and at 212° F. 22.75 lbs. of water raised from 62° to 212° F.
1 H. P. Hour =	0.746 K. W. hours. 1,980,000 ft.-lbs. 2,545 heat-units. 273,740 k. g. m. 0.175 lb. carbon oxidized with perfect efficiency. 2.64 lbs. water evaporated from and at 212° F. 17.0 lbs. water raised from 62° F. to 212° F.
1 Kilowatt =	1,000 watts. 1.34 horse-power. 2,654,200 ft.-lbs. per hour. 44,240 ft.-lbs. per minute. 737.3 ft.-lbs. per second. 3,412 heat-units per hour. 56.9 heat-units per minute. 0.948 heat-unit per second. 0.2275 lb. carbon oxidized per hour. 3.53 lbs. water evaporated per hour from and at 212° F.

MECHANICAL, ELECTRICAL AND HEAT EQUIVALENTS.—(CONTINUED).

Unit.	Equivalent Value in Other Units
1 H. P. =	746 watts. 0.746 K. W. 33,000 ft.-lbs. per minute. 550 ft.-lbs. per second. 2,545 heat-units per hour. 42.4 heat-units per minute. 0.707 heat units per second. 0.175 lbs. carbon oxidized per hour. 2.64 lbs. water evaporated per hour from and at 212° F.
1 Joule =	1 watt second. 0.000000278 K. W. hour. 0.102 k. g. m. 0.0009477 heat-units. 0.7373 ft.-lb.
1 Ft.-lb. =	1.356 joules. 0.1383 k. g. m. 0.000000377 K. W. hours. 0.001285 heat-units. 0.0000005 H. P. hour.
1 Watt =	1 joule per second. 0.00134 H. P. 3.412 heat-units per hour. 0.7373 ft.-lb. per second. 0.0035 lb. water evaporated per hour. 44.24 ft.-lbs. per minute.
1 Watt per sq. in. =	8.19 heat-units per square foot per minute. 6371 ft.-lbs. per square foot per minute. 0.193 H. P. per square foot.

MECHANICAL, ELECTRICAL AND HEAT EQUIVALENTS.—(CONTINUED).

UNIT.	EQUIVALENT VALUE IN OTHER UNITS.
1 Heat unit. =	1,055 watt seconds. 778 ft.-lbs. 107.6 kilogram metres. 0.000293 K. W. hour. 0.000393 H. P. hour. 0.0000688 lb. carbon oxidized. 0.001036 lb. water evaporated from and at 212° F.
1 Heat-unit. per Sq. ft. per min. =	0.122 watt per square inch. 0.0176 K. W. per square foot. 0.0236 H. P. per square foot.
1 Kilogram Metre =	7.233 ft.-lbs. 0.00000365 H. P. hour. 0.00000272 K. W. hour. 0.0093 heat-units.
1 lb. Carbon Oxidized with perfect Efficiency =	14,544 heat-units. 1.11 lb. Anthracite coal oxidized. 2.5 lbs. dry wood oxidized. 21 cubic feet illuminating-gas. 4.26 K. W. hours. 5.71 H. P. hours. 11,315,000 ft.-lbs. 15 lbs. of water evaporated from and at 212° F.
1 lb. Water Evaported from and at 212° F.=	0.283 K. W. hour. 0.379 H. P. hour. 965.7 heat-units. 103,900 k. g. m. 1,019,000 joules. 751,300 ft.-lbs. 0.0664 lb. of carbon oxidized.

MENSURATION,

TRIGONOMETRY

AND

MATHEMATICAL TABLES.

MENSURATION, TRIGONOMETRY AND MATHEMATICAL TABLES.

MENSURATION.

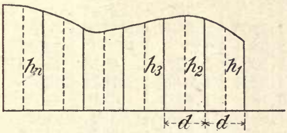
MENSURATION OF SURFACES.

Area of any parallelogram =	base × perpendicular height.
" " " triangle ...... =	base × ½ perpendicular height.
" " " circle .... =	(diameter)^2 × (0.7854, or approx. 11/14.)
" " sector of circle.... =	arc × 1/2 radius.
" " segment of circle . =	area of sector of equal radius and arc less area of triangle.
" " parabola.......... =	base × 2/3 height.
" " ellipse..... ..... =	longest diameter × shortest diameter × 0.7854.
" " cycloid.... .... =	area of generating circle × 3.
" " any regular polygon =	sum of its sides × perpendicular from its center to one of its sides ÷ 2.
Surface of cylinder........ =	area of both ends + (length × circumference.)
" " cone............ =	area of base + (circumference of base × ½ slant height.)
" " sphere...... ...=	(diameter)^2 × (3.1416, or approx. 22/7.)
" " frustum........=	(sum of girt at both ends × ½ slant height) + area of both ends.

Surface of cylindrical ring = thickness of ring added to the inner diameter × by the thickness × 9.8698.

" " segment .... = height of segment × by whole circumference of sphere of which it is a part.

AREA OF AN IRREGULAR PLANE SURFACE.



Divide the surface into any number of parallel strips of equal widths, "d." Take the sum of the middle ordinates h_1, h_2, etc., to h_n, inclusive; then the sum of these middle ordinates, multiplied by "d" will give the area required.

The result, of course, is only approximate, the closeness of the approximation depending upon the number of strips into which the surface is divided.

Any degree of accuracy desired may be attained by making the number of strips sufficiently numerous. In practice it is usually best to determine the area of an irregular figure by the use of a planimeter, an instrument especially designed for measuring areas of plane figures.

REGULAR POLYGONS.

1. To find the area of any regular polygon. Square one of its sides, and multiply this square by the corresponding number in the third column of the following table.

2. Having a side of a regular polygon, to find the radius of a circumscribing circle. Multiply the side by the corresponding number in the fourth column.

3. Having the radius of a circumscribing circle, to find the side of the inscribed regular polygon. Multiply the radius by the corresponding number in the fifth column.

TABLE OF REGULAR POLYGONS.

No. of Sides.	Name of Polygon.	Area = $S^2 \times$	Radius = S ×	Side = R ×	Angle contained between two sides.
3	Equilateral triangle	.433	.5774	1.732	60°
4	Square	1.	.7071	1.4142	90°
5	Pentagon	1.7205	.8507	1.1756	108°
6	Hexagon	2.5891	1.	1.	120°
7	Heptagon	3.6339	1.1524	.8678	128.57°
8	Octagon	4.8284	1.3066	.7654	135°
9	Nonagon	6.1818	1.4619	.684	140°
10	Decagon	7.6942	1.618	.618	144°
11	Undecagon	9.3656	1.7747	.5635	147.27°
12	Dodecagon	11.1962	1.9319	.5176	150°

In the above table S = side of polygon and R = radius of circumscribing circle.

PROPERTIES OF THE CIRCLE.

Diameter × 3.1416 = circumference.

" × 0.8862 = side of an equivalent square.

" × 0.7071 = side of an inscribed square.

$(\text{Diameter})^2 \times 0.7854$ = area of circle.

Radius × 6.2832 = circumference.

Circumference ÷ 3.1416 = diameter.

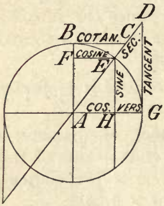
The circle contains a greater area than any plane figure, bounded by an equal perimeter, or outline.

The areas of circles are to each other as the squares of their diameter, radii or circumferences. Thus, a circle whose diameter is double that of another has four times the area of the other.

VOLUMES OF SOLIDS.

Vol. of Cylinder	=	area of one end × length.
" " Sphere	=	cube of diameter × 0.5236.
" " Segment of sphere	=	(cube of the height + three times the square of radius of base × height) × 0.5236.
" " Cone or pyramid	=	area of base × ⅓ perpendicular height.
" " Frustum of cone	=	(product of diameter of both ends + sum of their squares) × perpendicular height × 0.2618.
" " Frustum of pyramid	=	(sum of the areas of the two ends + square root of their product) × by ⅓ of the perpendicular height.
" " Wedge	=	area of base × ½ perpendicular height.
" " Frustum of wedge	=	½ perpendicular height × sum of the areas of the two ends.
" " Ring	=	(thickness + inner diameter) × square of the thickness × 2.4674.

TRIGONOMETRICAL FORMULAE.



Sine of Angle E A H $= \dfrac{EH}{AE}$

Cosine " $= \dfrac{AH}{AE}$

Tangent " $= \dfrac{EH}{AH}$

Cotangent " $= \dfrac{AH}{EH}$

Secant " $= \dfrac{EA}{AH}$

Cosecant " $= \dfrac{EA}{EH}$

TRIGONOMETRICAL EQUIVALENTS.

$\text{Sin} = \sqrt{1 - \cos^2}$

$\text{Sin} = \dfrac{\cos}{\cot}$

$\text{Cos} = \sqrt{1 - \sin^2}$

$\text{Cos} = \dfrac{\sin}{\tan}$

$\text{Cos} = \sin \times \cot$

$\text{Tan} = \dfrac{\sin}{\cos}$

$\text{Tan} = \dfrac{1}{\cot}$

$\text{Cot} = \dfrac{\cos}{\sin}$

$\text{Cot} = \dfrac{1}{\tan}$

$\text{Sec} = \dfrac{1}{\cos}$

$\text{Cosec} = \dfrac{1}{\sin}$

$\text{Vers} = 1 - \cos$

$\text{Covers} = 1 - \sin$

$\text{Sin}^2 + \cos^2 = 1$

FUNCTIONS OF SUM AND DIFFERENCE OF TWO ANGLES.

$$\text{Sin}\,(x + y) = \sin x \cos y + \cos x \sin y$$
$$\text{Sin}\,(x - y) = \sin x \cos y - \cos x \sin y$$
$$\text{Cos}\,(x + y) = \cos x \cos y - \sin x \sin y$$
$$\text{Cos}\,(x - y) = \cos x \cos y + \sin x \sin y$$

$$\text{Tan}\,(x + y) = \frac{\tan x + \tan y}{1 - \tan x \tan y}$$

$$\text{Tan}\,(x - y) = \frac{\tan x - \tan y}{1 + \tan x \tan y}$$

$$\text{Cot}\,(x + y) = \frac{\cot x \cot y - 1}{\cot x + \cot y}$$

$$\text{Cot}\,(x - y) = \frac{\cot x \cot y + 1}{\cot y - \cot x}$$

FUNCTIONS OF HALF AN ANGLE.

$$\text{Sin}\,\tfrac{1}{2} z = \pm\sqrt{\frac{1 - \cos z}{2}}$$

$$\text{Tan}\,\tfrac{1}{2} z = \pm\sqrt{\frac{1 - \cos z}{1 + \cos z}}$$

$$\text{Cos}\,\tfrac{1}{2} z = \pm\sqrt{\frac{1 - \cos z}{2}}$$

$$\text{Cot}\,\tfrac{1}{2} z = \pm\sqrt{\frac{1 + \cos z}{1 - \cos z}}$$

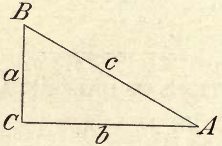
SUMS AND DIFFERENCES OF FUNCTIONS.

$$\text{Sin}\,(x + y) + \sin\,(x - y) = 2 \sin x \cos y$$
$$\text{Sin}\,(x + y) - \sin\,(x - y) = 2 \cos x \sin y$$
$$\text{Cos}\,(x + y) + \cos\,(x - y) = 2 \cos x \cos y$$
$$\text{Cos}\,(x - y) - \cos\,(x + y) = 2 \sin x \sin y$$

Then by making $(x + y) = A$ and $(x - y) = B$, we have $x = \frac{1}{2}(A + B)$ and $y = \frac{1}{2}(A - B)$, whence—

$$\text{Sin } A + \sin B = 2 \sin \tfrac{1}{2}(A + B) \cos \tfrac{1}{2}(A - B)$$
$$\text{Sin } A - \sin B = 2 \cos \tfrac{1}{2}(A + B) \sin \tfrac{1}{2}(A - B)$$
$$\text{Cos } A + \cos B = 2 \cos \tfrac{1}{2}(A + B) \cos \tfrac{1}{2}(A - B)$$
$$\text{Cos } A - \cos B = 2 \sin \tfrac{1}{2}(A + B) \sin \tfrac{1}{2}(A - B)$$
$$\frac{\text{Sin } A + \sin B}{\text{Sin } A - \sin B} = \frac{\tan \frac{1}{2}(A + B)}{\tan \frac{1}{2}(A - B)}$$
$$\frac{\text{Cos } A + \cos B}{\text{Cos } A - \cos B} = \frac{\cot \frac{1}{2}(A + B)}{\tan \frac{1}{2}(A - B)}$$

SOLUTION OF RIGHT TRIANGLE.



Given A and c, to find B, a and b.

$B = 90° - A$; $A = c \sin A$; $b = c \cos A$.

Given A and a, to find B, b and c.

$B = 90° - A$; $b = a \cot A$; $c = \dfrac{a}{\sin A}$.

Given A and b, to find B, a and c.

$B = 90° - A$; $a = b \tan A$; $c = \dfrac{b}{\cos A}$.

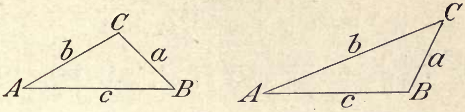
Given c and a, to find A, B and b.

$\text{Sin } A = \dfrac{a}{c}$; $B = 90° - A$; $b = a \cot A$.

Given a and b, to find A, B and c.

$\text{Tan } A = \dfrac{a}{b}$; $B = 90° - A$; $c = \dfrac{a}{\sin A}$.

SOLUTION OF OBLIQUE TRIANGLE.



LAW OF SINES.

$$\frac{a}{b} = \frac{\sin A}{\sin B}; \quad \frac{b}{c} = \frac{\sin B}{\sin C}; \quad \frac{a}{c} = \frac{\sin A}{\sin C}$$

LAW OF COSINES.

$$a^2 = b^2 + c^2 - 2\,b\,c\cos A$$

$$b^2 = a^2 + c^2 - 2\,a\,c\cos B$$

$$c^2 = a^2 + b^2 - 2\,a\,b\cos C$$

LAW OF TANGENTS.

$$\frac{a - b}{a + b} = \frac{\tan \frac{1}{2}(A - B)}{\tan \frac{1}{2}(A + B)}$$

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

$$\frac{b - c}{b + c} = \frac{\tan \frac{1}{2}(B - C)}{\tan \frac{1}{2}(B + C)}$$

Given a, A and B, to find C, b and c.

$$C = 180° - (A + B); \quad b = \frac{a \sin B}{\sin A}; \quad c = \frac{a \sin C}{\sin A}$$

Given a, b and A, to find B, C and c.

$$\sin B = \frac{b \sin A}{a}; \; C = 180° - (A + B); \; c = \frac{a \sin C}{\sin A}$$

Given a, b and C, to find A, B and c.

$$A = \tfrac{1}{2}(A + B) + \tfrac{1}{2}(A - B);$$

$$B = \tfrac{1}{2}(A + B) - \tfrac{1}{2}(A - B);$$

$$c = \frac{b \sin C}{\sin B}, \text{ or } = \frac{a \sin C}{\sin A}, \text{ or } = \sqrt{a^2 + b^2 - 2ab\cos C}.$$

Given a, b and c, to find A, B and C.

$$\sin \tfrac{1}{2} A = \sqrt{\frac{(S - b)(S - c)}{bc}}; \text{ in which } S = \tfrac{1}{2}(a + b + c);$$

$$\cos \tfrac{1}{2} A = \sqrt{\frac{S(S - a)}{bc}}; \quad \tan \tfrac{1}{2} A = \sqrt{\frac{(S - b)(S - c)}{S(S - a)}};$$

$$\sin \tfrac{1}{2} B = \sqrt{\frac{(S - a)(S - c)}{ac}};$$

$$\sin \tfrac{1}{2} C = \sqrt{\frac{(S - a)(S - b)}{ab}};$$

$$\cos \tfrac{1}{2} B = \sqrt{\frac{S(S - b)}{ac}}; \quad \cos \tfrac{1}{2} C = \sqrt{\frac{S(S - c)}{ab}};$$

$$\tan \tfrac{1}{2} B = \sqrt{\frac{(S - a)(S - c)}{S(S - b)}};$$

$$\tan \tfrac{1}{2} C = \sqrt{\frac{(S - a)(S - b)}{S(S - c)}}.$$

AREA OF A TRIANGLE.

Area = ½ a c sin B, that is, the area of a triangle equals ½ the product of two sides multiplied by the sine of the included angle.

$$\text{Also area} = \sqrt{S(S - a)(S - b)(S - c)};$$

$$\text{Where } S = \tfrac{1}{2}(a + b + c).$$

MATHEMATICAL TABLES.

Degrees.	SINE.							
	0′	10′	20′	30′	40′	50′	60′	
0	0.00000	0.00291	0.00582	0.00873	0.01164	0.01454	0.01745	89
1	0.01745	0.02036	0 02327	0.02618	0.02908	0.03199	0.03490	88
2	0.03490	0.03781	0.04071	0.04362	0.04653	0.04943	0.05234	87
3	0.05234	0.05524	0.05814	0.06105	0.06395	0.06685	0.06976	86
4	0.06976	0.07266	0.07556	0.07846	0.08136	0.08426	0.08716	85
5	0.08716	0.09005	0.09295	0.09585	0.09874	0.10164	0.10453	84
6	0.10453	0.10742	0.11031	0.11320	0.11609	0.11898	0.12187	83
7	0.12187	0.12476	0.12764	0.13053	0.13341	0.13629	0.13917	82
8	0.13917	0.14205	0.14493	0.14781	0.15069	0.15356	0.15643	81
9	0.15643	0.15931	0.16218	0.16505	0.16792	0.17078	0.17365	80
10	0.17365	0.17651	0.17937	0.18224	0.18509	0.18795	0.19081	79
11	0.19081	0.19366	0.19652	0.19937	0.20222	0.20507	0.20791	78
12	0.20791	0.21076	0.21360	0.21644	0.21928	0.22212	0.22495	77
13	0.22495	0.22778	0.23062	0.23345	0.23627	0.23910	0.24192	76
14	0.24192	0.24474	0.24756	0.25038	0.25320	0.25601	0.25882	75
15	0.25882	0.26163	0.26443	0.26724	0.27004	0.27284	0.27564	74
16	0.27564	0.27843	0.28123	0.28402	0.28680	0.28959	0.29237	73
17	0.29237	0.29515	0.29793	0.30071	0.30348	0.30625	0.30902	72
18	0.30902	0.31178	0.31454	0.31730	0.32006	0.32282	0.32557	71
19	0.32557	0.32832	0.33106	0.33381	0.33655	0.33929	0.34202	70
20	0.34202	0.34475	0.34748	0.35021	0.35293	0.35565	0.35837	69
21	0.35837	0.36108	0.36379	0.36650	0.36921	0.37191	0.37461	68
22	0.37461	0.37730	0.37999	0.38268	0.38537	0.38805	0.39073	67
23	0.39073	0.39341	0.39608	0.39875	0.40142	0.40408	0.40674	66
24	0.40674	0.40939	0.41204	0.41469	0.41734	0.41998	0.42262	65
25	0.42262	0.42525	0.42788	0.43051	0.43313	0.43575	0.43837	64
26	0.43837	0.44098	0.44359	0.44620	0.44880	0.45140	0.45399	63
27	0.45399	0.45658	0.45917	0.46175	0.46433	0.46690	0.46947	62
28	0.46947	0.47204	0.47460	0.47716	0.47971	0.48226	0.48481	61
29	0.48481	0.48735	0.48989	0.49242	0.49495	0.49748	0.50000	60
30	0.50000	0.50252	0.50503	0.50754	0.51004	0.51254	0.51504	59
31	0.51504	0.51753	0.52002	0.52250	0.52498	0.52745	0.52992	58
32	0.52992	0.53238	0.53484	0.53730	0.53975	0.54220	0.54464	57
33	0.54464	0.54708	0.54951	0.55194	0.55436	0.55678	0.55919	56
34	0.55919	0.56160	0.56401	0.56641	0.56880	0.57119	0.57358	55
35	0.57358	0.57596	0.57833	0.58070	0.58307	0.58543	0.58779	54
36	0.58779	0.59014	0.59248	0.59482	0.59716	0.59949	0.60182	53
37	0.60182	0.60414	0.60645	0.60876	0.61107	0.61337	0.61566	52
38	0.61566	0.61795	0.62024	0.62251	0.62479	0.62706	0.62932	51
39	0.62932	0.63158	0.63383	0.63608	0.63832	0.64056	0.64279	50
40	0.64279	0 64501	0.64723	0.64945	0.65166	0.65386	0.65606	49
41	0.65606	0.65825	0.66044	0.66262	0.66480	0.66697	0.66913	48
42	0.66913	0.67129	0.67344	0.67559	0.67773	0.67987	0.68200	47
43	0.68200	0.68412	0.68624	0.68835	0.69046	0.69256	0.69466	46
44	0.69466	0.69675	0.69883	0.70091	0.70298	0.70505	0.70711	45
	60′	50′	40′	30′	20′	10′	0′	Degrees.
	COSINE							

MATHEMATICAL TABLES. (CONTINUED.)

Degrees.	COSINE.							
	0′	10′	20′	30′	40′	50′	60′	
0	1.00000	1.00000	0.99998	0.99996	0.99993	0.99989	0.99985	89
1	0.99985	0.99979	0.99973	0.99966	0.99958	0.99949	0.99939	88
2	0.99939	0.99929	0.99917	0.99905	0.99892	0.99878	0.99863	87
3	0.99863	0.99847	0.99831	0.99813	0.99795	0.99776	0.99756	86
4	0.99756	0.99736	0.99714	0.99692	0.99668	0.99644	0.99619	85
5	0.99619	0.99594	0.99567	0.99540	0.99511	0.99482	0.99452	84
6	0.99452	0.99421	0.99390	0.99357	0.99324	0.99290	0.99255	83
7	0.99255	0.99219	0.99182	0.99144	0.99106	0.99067	0.99027	82
8	0.99027	0.98986	0.98944	0.98902	0.98858	0.98814	0.98769	81
9	0.98769	0.98723	0.98676	0.98629	0.98580	0.98531	0.98481	80
10	0.98481	0.98430	0.98378	0.98325	0.98272	0.98218	0.98163	79
11	0.98163	0.98107	0.98050	0.97992	0.97934	0.97875	0.97815	78
12	0.97815	0.97754	0.97692	0.97630	0.97566	0.97502	0.97437	77
13	0.97437	0.97371	0.97304	0.97237	0.97169	0.97100	0.97030	76
14	0.97030	0.96959	0.96887	0.96815	0.96742	0.96667	0.96593	75
15	0.96593	0.96517	0.96440	0.96363	0.96285	0.96206	0.96126	74
16	0.96126	0.96046	0.95964	0.95882	0.95799	0.95715	0.95630	73
17	0.95630	0.95545	0.95459	0.95372	0.95284	0.95195	0.95106	72
18	0.95106	0.95015	0.94924	0.94832	0.94740	0.94646	0.94552	71
19	0.94552	0.94457	0.94361	0.94264	0.94167	0.94068	0.93969	70
20	0.93969	0.93869	0.93769	0.93667	0.93565	0.93462	0.93358	69
21	0.93358	0.93253	0.93148	0.93042	0.92935	0.92827	0.92718	68
22	0.92718	0.92609	0.92499	0.92388	0.92276	0.92164	0.92050	67
23	0.92050	0.91936	0.91822	0.91706	0.91590	0.91472	0.91355	66
24	0.91355	0.91236	0.91116	0.90996	0.90875	0.90753	0.90631	65
25	0.90631	0.90507	0.90383	0.90259	0.90133	0.90007	0.89879	64
26	0.89879	0.89752	0.89623	0.89493	0.89363	0.89232	0.89101	63
27	0.89101	0.88968	0.88835	0.88701	0.88566	0.88431	0.88295	62
28	0.88295	0.88158	0.88020	0.87882	0.87743	0.87603	0.87462	61
29	0.87462	0.87321	0.87178	0.87036	0.86892	0.86748	0.86603	60
30	0.86603	0.86457	0.86310	0.86163	0.86015	0.85866	0.85717	59
31	0.85717	0.85567	0.85416	0.85264	0.85112	0.84959	0.84805	58
32	0.84805	0.84650	0.84495	0.84339	0.84182	0.84025	0.83867	57
33	0.83867	0.83708	0.83549	0.83389	0.83228	0.83066	0.82904	56
34	0.82904	0.82741	0.82577	0.82413	0.82248	0.82082	0.81915	55
35	0.81915	0.81748	0.81580	0.81412	0.81242	0.81072	0.80902	54
36	0.80902	0.80730	0.80558	0.80386	0.80212	0.80038	0.79864	53
37	0.79864	0.79688	0.79512	0.79335	0.79158	0.78980	0.78801	52
38	0.78801	0.78622	0.78442	0.78261	0.78079	0.77897	0.77715	51
39	0.77715	0.77531	0.77347	0.77162	0.76977	0.76791	0.76604	50
40	0.76604	0.76417	0.76229	0.76041	0.75851	0.75661	0.75471	49
41	0.75471	0.75280	0.75088	0.74896	0.74703	0.74509	0.74314	48
42	0.74314	0.74120	0.73924	0.73728	0.73531	0.73333	0.73135	47
43	0.73135	0.72937	0.72737	0.72537	0.72337	0.72136	0.71934	46
44	0.71934	0.71732	0.71529	0.71325	0.71121	0.70916	0.70711	45
	60′	50′	40′	30′	20′	10′	0′	Degrees.
	SINE.							

MATHEMATICAL TABLES. (CONTINUED.)

Degrees.	TANGENT.							
	0′	10′	20′	30′	40′	50′	60′	
0	0.00000	0.00291	0.00582	0.00873	0.01164	0.01455	0.01746	89
1	0.01746	0.02036	0.02328	0.02619	0.02910	0.03201	0.03492	88
2	0.03492	0.03783	0.04075	0.04366	0.04658	0.04949	0.05241	87
3	0.05241	0.05533	0.05824	0.06116	0.06408	0.06700	0.06993	86
4	0.06993	0.07285	0.08578	0.07870	0.08163	0.08456	0.08749	85
5	0.08749	0.09042	0.09335	0.09629	0.09923	0.10216	0.10510	84
6	0.10510	0.10805	0.11099	0.11394	0.11688	0.11983	0.12278	83
7	0.12278	0.12574	0.12869	0.13165	0.13461	0.13758	0.14054	82
8	0.14054	0.14351	0.14648	0.14945	0.15243	0.15540	0.15838	81
9	0.15838	0.16137	0.16435	0.16734	0.17033	0.17333	0.17633	80
10	0.17633	0.17933	0.18233	0.18534	0.18835	0.19136	0.19438	79
11	0.19438	0.19740	0.20042	0.20345	0.20648	0.20952	0.21256	78
12	0.21256	0.21560	0.21864	0.22169	0.22475	0.22781	0.23087	77
13	0.23087	0.23393	0.23700	0.24008	0.24316	0.24624	0.24933	76
14	0.24933	0.25242	0.25552	0.25862	0.26172	0.26483	0.26795	75
15	0.26795	0.27107	0.27419	0.27732	0.28046	0.28360	0.28675	74
16	0.28675	0.28990	0.29305	0.29621	0.29938	0.30255	0.30573	73
17	0.30573	0.30891	0.31210	0.31530	0.31850	0.32171	0.32492	72
18	0.32492	0.32814	0.33136	0.33460	0.33783	0.34108	0.34433	71
19	0.34433	0.34758	0.35085	0.35412	0.35740	0.36068	0.36397	70
20	0.36397	0.36727	0.37057	0.37388	0.37720	0.38053	0.38386	69
21	0.38386	0.38721	0.39055	0.39391	0.39727	0.40065	0.40403	68
22	0.40403	0.40741	0.41081	0.41421	0.41763	0.42105	0.42447	67
23	0.42447	0.42791	0.43136	0.43481	0.43828	0.44175	0.44523	66
24	0.44523	0.44872	0.45222	0.45573	0.45924	0.46277	0.46631	65
25	0.46631	0.46985	0.47341	0.47698	0.48055	0.48414	0.48773	64
26	0.48773	0.49134	0.49495	0.49858	0.50222	0.50587	0.50953	63
27	0.50953	0.51320	0.51688	0.52057	0.52427	0.52798	0.53171	62
28	0.53171	0.53545	0.53920	0.54296	0.54673	0.55051	0.55431	61
29	0.55431	0.55812	0.56194	0.56577	0.56962	0.57348	0.57735	60
30	0.57735	0.58124	0.58513	0.58905	0.59297	0.59691	0.60086	59
31	0.60086	0.60483	0.60881	0.61280	0.61681	0.62083	0.62487	58
32	0.62487	0.62892	0.63299	0.63707	0.64117	0.64528	0.64941	57
33	0.64941	0.65355	0.65771	0.66189	0.66608	0.67028	0.67451	56
34	0.67451	0.67875	0.68301	0.68728	0.69157	0.69588	0.70021	55
35	0.70021	0.70455	0.70891	0.71329	0.71769	0.72211	0.72654	54
36	0.72654	0.73100	0.73547	0.73996	0.74447	0.74900	0.75355	53
37	0.75355	0.75812	0.76272	0.76733	0.77196	0.77661	0.78129	52
38	0.78129	0.78598	0.79079	0.79544	0.80020	0.80498	0.80978	51
39	0.80978	0.81461	0.81946	0.82434	0.82923	0.83415	0.83910	50
40	0.83910	0.84407	0.84906	0.85408	0.85912	0.86419	0.86929	49
41	0.86929	0.87441	0.87955	0.88473	0.88992	0.89515	0.90040	48
42	0.90040	0.90569	0.91099	0.91633	0.92170	0.92709	0.93252	47
43	0.93252	0.93797	0.94345	0.94896	0.95451	0.96008	0.96569	46
44	0.96569	0.97133	0.97700	0.98270	0.98843	0.99420	1.00000	45
	60′	50′	40	30′	20′	10′	0′	Degrees.
	COTANGENT.							

MATHEMATICAL TABLES. (CONTINUED.)

Degrees.	COTANGENT.							
	0′	10′	20′	30′	40′	50′	60′	
0	∞	343.77371	171.88540	114.58865	85.93979	68.75009	57.28996	89
1	57.28996	49.10388	42.96408	38.18846	34.36777	31.24158	28.63625	88
2	28.63625	26.43160	24.54176	22.90377	21.47040	20.20555	19.08114	87
3	19.08114	18.07498	17.16934	16.34986	15.60478	14.92442	14.30067	86
4	14.30067	13.72674	13.19688	12.70621	12.25051	11.82617	11.43005	85
5	11.43005	11.05943	10.71191	10.38540	10.07803	9.78817	9.51436	84
6	9.51436	9.25530	9.00983	8.77689	8.55555	8.34496	8.14435	83
7	8.14435	7.95302	7.77035	7.59575	7.42871	7.26873	7.11537	82
8	7.11537	6.96823	6.82694	6.69116	6.56055	6.43484	6.31375	81
9	6.31375	6.19703	6.08444	5.97576	5.87080	5.76937	5.67128	80
10	5.67128	5.57638	5.48451	5.39552	5.30928	5.22566	5.14455	79
11	5.14455	5.06584	4.98940	4.91516	4.84300	4.77286	4.70463	78
12	4.70463	4.63825	4.57363	4.51071	4.44942	4.38969	4.33148	77
13	4.33148	4.27471	4.21933	4.16530	4.11256	4.06107	4.01078	76
14	4.01078	3.96165	3.91364	3.86671	3.82083	3.77595	3.73205	75
15	3.73205	3.68909	3.64705	3.60588	3.56557	3.52609	3.48741	74
16	3.48741	3.44951	3.41236	3.37594	3.34023	3.30521	3.27085	73
17	3.27085	3.23714	3.20406	3.17159	3.13972	3.10842	3.07768	72
18	3.07768	3.04749	3.01783	2.98869	2.96004	2.93189	2.90421	71
19	2.90421	2.87700	2.85023	2.82391	2.79802	2.77254	2.74748	70
20	2.74748	2.72281	2.69853	2.67462	2.65109	2.62791	2.60509	69
21	2.60509	2.58261	2.56046	2.53865	2.51715	2.49597	2.47509	68
22	2.47509	2.45451	2.43422	2.41421	2.39449	2.37504	2.35585	67
23	2.35585	2.33693	2.31826	2.29984	2.28167	2.26374	2.24604	66
24	2.24604	2.22857	2.21132	2.19430	2.17749	2.16090	2.14451	65
25	2.14451	2.12832	2.11233	2.09654	2.08094	2.06553	2.05030	64
26	2.05030	2.03526	2.02039	2.00569	1.99116	1.97680	1.96261	63
27	1.96261	1.94858	1.93470	1.92098	1.90741	1.89400	1.88073	62
28	1.88073	1.86760	1.85462	1.84177	1.82906	1.81649	1.80405	61
29	1.80405	1.79174	1.77955	1.76749	1.75556	1.74375	1.73205	60
30	1.73205	1.72047	1.70901	1.69766	1.68643	1.67530	1.66428	59
31	1.66428	1.65337	1.64256	1.63185	1.62125	1.61074	1.60033	58
32	1.60033	1.59002	1.57981	1.56969	1.55966	1.54972	1.53987	57
33	1.53987	1.53010	1.52043	1.51084	1.50133	1.49190	1.48256	56
34	1.48256	1.47330	1.46411	1.45501	1.44598	1.43703	1.42815	55
35	1.42815	1.41934	1.41061	1.40195	1.39336	1.38484	1.37638	54
36	1.37638	1.36800	1.35968	1.35142	1.34323	1.33511	1.32704	53
37	1.32704	1.31904	1.31110	1.30323	1.29541	1.28764	1.27994	52
38	1.27994	1.27230	1.26471	1.25717	1.24969	1.24227	1.23490	51
39	1.23490	1.22758	1.22031	1.21310	1.20593	1.19882	1.19175	50
40	1.19175	1.18474	1.17777	1.17085	1.16398	1.15715	1.15037	49
41	1.15037	1.14363	1.13694	1.13029	1.12369	1.11713	1.11061	48
42	1.11061	1.10414	1.09770	1.09131	1.08496	1.07864	1.07237	47
43	1.07237	1.06613	1.05994	1.05378	1.04766	1.04158	1.03553	46
44	1.03553	1.02952	1.02355	1.01761	1.01170	1.00583	1.00000	45
	60′	50′	40′	30′	20′	10′	0′	Degrees.
	TANGENT.							

CIRCUMFERENCES AND AREAS OF CIRCLES.

Diameter from $\frac{1}{64}$ to 100, advancing chiefly by Eighths.

Diam.	Circum.	Area.
1/64	.04909	.00019
1/32	.09818	.00077
3/64	.14726	.00173
1/16	.19635	.00307
3/32	.29452	.00690
1/8	.39270	.01227
5/32	.49087	.01917
3/16	.58905	.02761
7/32	.68722	.03758
1/4	.78540	.04909
9/32	.88357	.06213
5/16	.98175	.07670
11/32	1.0799	.09281
3/8	1.1781	.11045
13/32	1.2763	.12962
7/16	1.3744	.15033
15/32	1.4726	.17257
1/2	1.5708	.19635
17/32	1.6690	.22166
9/16	1.7671	.24850
19/32	1.8653	.27688
5/8	1.9635	.30680
21/32	2.0617	.33824
11/16	2.1598	.37122
23/32	2.2580	.40574
3/4	2.3562	.44179
25/32	2.4544	.47937
13/16	2.5525	.51849
27/32	2.6507	.55914
7/8	2.7489	.60132
29/32	2.8471	.64504
15/16	2.9452	.69029
31/32	3.0434	.73708
1.	3.1416	.7854
1/16	3.3379	.8866
1/8	3.5343	.9940
3/16	3.7306	1.1075
1/4	3.9270	1.2272
5/16	4.1233	1.3530
3/8	4.3197	1.4849
7/16	4.5160	1.6230
1/2	4.7124	1.7671
9/16	4.9087	1.9175
5/8	5.1051	2.0739
11/16	5.3014	2.2365
3/4	5.4978	2.4053
13/16	5.6941	2.5802
7/8	5 8905	2.7612
15/16	6.0868	2.9483
2.	6.2832	3.1416
1/16	6.4795	3 3410

Diam.	Circum.	Area.
2.1/8	6.6759	3.5466
3/16	6.8722	3.7583
1/4	7.0686	3.9761
5/16	7.2649	4.2000
3/8	7.4613	4.4301
7/16	7.6576	4.6664
1/2	7.8540	4.9087
9/16	8.0503	5.1572
5/8	8.2467	5.4119
11/16	8.4430	5.6727
3/4	8.6394	5.9396
13/16	8.8357	6.2126
7/8	9.0321	6.4918
15/16	9.2284	6.7771
3.	9.4248	7.0686
1/16	9.6211	7.3662
1/8	9.8175	7.6699
3/16	10.014	7.9798
1/4	10.210	8.2958
5/16	10.407	8.6179
3/8	10.603	8.9462
7/16	10.799	9.2806
1/2	10 996	9.6211
9/16	11.192	9.9678
5/8	11.388	10.321
11/16	11.585	10.680
3/4	11.781	11.045
13/16	11.977	11.416
7/8	12.174	11.793
15/16	12.370	12.177
4.	12.566	12.566
1/16	12.763	12.962
1/8	12.959	13.364
3/16	13.155	13.772
1/4	13.352	14.186
5/16	13.548	14.607
3/8	13.744	15.033
7/16	13.941	15.466
1/2	14.137	15.904
9/16	14.334	16.349
5/8	14.530	16.800
11/16	14.726	17.257
3/4	14.923	17.728
13/16	15.119	18.190
7/8	15.315	18.665
15/16	15.512	19.147
5.	15.708	19.635
1/16	15.904	20.129
1/8	16.101	20.629
3/16	16.297	21.135
1/4	16.493	21.648
5/16	16.690	22.166
3/8	16.886	22.691

Diam.	Circum.	Area.
5.7/16	17.082	23.221
1/2	17.279	23.758
9/16	17.475	24.301
5/8	17.671	24.850
11/16	17.868	25.406
3/4	18.064	25.967
13/16	18.261	26.535
7/8	18.457	27.109
15/16	18.653	27.688
6.	18.850	28.274
1/8	19.242	29.465
1/4	19.635	30.680
3/8	20.028	31.919
1/2	20.420	33.183
5/8	20.813	34.472
3/4	21.206	35.785
7/8	21.598	37.122
7.	21.991	38.485
1/8	22.384	39.871
1/4	22.776	41.282
3/8	23.169	42.718
1/2	23.562	44.179
5/8	23.955	45.664
3/4	24.347	47.173
7/8	24.740	48.707
8.	25.133	50.265
1/8	25.525	51.849
1/4	25.918	53.456
3/8	26.311	55.088
1/2	26.704	56.745
5/8	27.096	58.426
3/4	27.489	60.132
7/8	27.882	61.862
9.	28.274	63.617
1/8	28.667	65.397
1/4	29.060	67.201
3/8	29.452	69.029
1/2	29.845	70.882
5/8	30.238	72.760
3/4	30.631	74.662
7/8	31.023	76.589
10.	31.416	78.540
1/8	31.809	80.516
1/4	32.201	82.516
3/8	32.594	84.541
1/2	32.987	86.590
5/8	33.379	88.664
3/4	33.772	90.763
7/8	34.165	92.886
11.	34.558	95.033

CIRCUMFERENCES AND AREAS OF CIRCLES.

(CONTINUED.)

Diam.	Circum.	Area.	Diam.	Circum.	Area.	Diam.	Circum.	Area.
11.⅛	34.950	97.205	17.⅜	54.585	237.10	23.⅝	74.220	438.36
¼	35.343	99.402	½	54.978	240.53	¾	74.613	443.01
⅜	35.736	101.62	⅝	55.371	243.98	⅞	75.006	447.69
½	36.128	103.87	¾	55.763	247.45			
⅝	36.521	106.14	⅞	56.156	250.95	24.	75.398	452.39
¾	36.914	108.43				⅛	75.791	457.11
⅞	37.306	110.75	18.	56.549	254.47	¼	76.184	461.86
			⅛	56.941	258.02	⅜	76.576	466.64
12.	37.699	113.10	¼	57.334	261.59	½	76.969	471.44
⅛	38.092	115.47	⅜	57.727	265.18	⅝	77.362	476.26
¼	38.485	117.86	½	58.119	268.80	¾	77.754	481.11
⅜	38.877	120.28	⅝	58.512	272.45	⅞	78.147	485.98
½	39.270	122.72	¾	58.905	276.12			
⅝	39.663	125.19	⅞	59.298	279.81	25.	78.540	490.87
¾	40.055	127.68				⅛	78.933	495.79
⅞	40.448	130.19	19.	59.690	283.53	¼	79.325	500.74
			⅛	60.083	287.27	⅜	79.718	505.71
13.	40.841	132.73	¼	60.476	291.04	½	80.111	510.71
⅛	41.233	135.30	⅜	60.868	294.83	⅝	80.503	515.72
¼	41.626	137.89	½	61.261	298.65	¾	80.896	520.77
⅜	42.019	140.50	⅝	61.654	302.49	⅞	81.289	525.84
½	42.412	143.14	¾	62.046	306.35			
⅝	42.804	145.80	⅞	62.439	310.24	26.	81.681	530.93
¾	43.197	148.49				⅛	82.074	536.05
⅞	43.590	151.20	20.	62.832	314.16	¼	82.467	541.19
			⅛	63.225	318.10	⅜	82.860	546.35
14.	43.982	153.94	¼	63.617	322.06	½	83.252	551.55
⅛	44.375	156.70	⅜	64 010	326.05	⅝	83.645	556.76
¼	44.768	159.48	½	64.403	330.06	¾	84.038	562.00
⅜	45.160	162.30	⅝	64.795	334.10	⅞	84.430	567.27
½	45.553	165.13	¾	65.188	338.16			
⅝	45.946	167.99	⅞	65.581	342.25	27.	84.823	572.56
¾	46.338	170.87				⅛	85.216	577.87
⅞	46.731	173.78	21.	65.973	346.36	¼	85.608	583.21
			⅛	66.366	350.50	⅜	86.001	588.57
15.	47.124	176.71	¼	66.759	354.66	½	86.394	593.96
⅛	47.517	179.67	⅜	67.152	358.84	⅝	86.786	599.37
¼	47.909	182.65	½	67.544	363.05	¾	87.179	604.81
⅜	48.302	185.66	⅝	67.937	367.28	⅞	87.572	610.27
½	48.695	188.69	¾	68.330	371.54			
⅝	49.087	191.75	⅞	68.722	375.83	28.	87.965	615.75
¾	49.480	194.83				⅛	88.357	621.26
⅞	49.873	197.93	22.	69.115	380.13	¼	88.750	626 80
			⅛	69.508	384.46	⅜	89.143	632.36
16.	50.265	201.06	¼	69.900	388.82	½	89.535	637.94
⅛	50.658	204.22	⅜	70.293	393.20	⅝	89.928	643.55
¼	51.051	207.39	½	70.686	397.61	¾	90.321	649.18
⅜	51.444	210.60	⅝	71.079	402.04	⅞	90.713	654.84
½	51.836	213.82	¾	71.471	406.49			
⅝	52.229	217.08	⅞	71.864	410.97	29.	91.106	660.52
¾	52.622	220.35				⅛	91.499	666.23
⅞	53.014	223.65	23.	72.257	415.48	¼	91.892	671.96
			⅛	72.649	420.00	⅜	92.284	677.71
17.	53.407	226.98	¼	73.042	424.56	½	92.677	683.49
⅛	53.800	230.33	⅜	73.435	429.13	⅝	93.070	689.30
¼	54.192	233.71	½	73.827	433.74	¾	93.462	695.13

CIRCUMFERENCES AND AREAS OF CIRCLES.

(CONTINUED.)

Diam.	Circum.	Area.	Diam.	Circum.	Area.	Diam.	Circum.	Area.
29.⅞	93.855	700.98	36.⅛	113.490	1025.0	42.⅜	133.125	1410.3
			¼	113.883	1032.1	½	133.518	1418.6
30.	94.248	706.86	⅜	114.275	1039.2	⅝	133.910	1427.0
⅛	94.640	712.76	½	114.668	1046.3	¾	134.303	1435.4
¼	95.033	718.69	⅝	115.061	1053.5	⅞	134.696	1443.8
⅜	95.426	724.64	¾	115.454	1060.7			
½	95.819	730.62	⅞	115.846	1068.0	43.	135.088	1452.2
⅝	96.211	736.62				⅛	135.481	1460.7
¾	96.604	742.64	37.	116.239	1075.2	¼	135.874	1469.1
⅞	96.997	748.69	⅛	116.633	1082.5	⅜	136.267	1477.6
			¼	117.024	1089.8	½	136.659	1486 2
31.	97.389	754.77	⅜	117.417	1097.1	⅝	137.052	1494.7
⅛	97.782	760.87	½	117.810	1104.5	¾	137.445	1503.3
¼	98.175	766.99	⅝	118.202	1111.8	⅞	137.837	1511.9
⅜	98.567	773.14	¾	118.596	1119.2			
½	98.960	779.31	⅞	118.988	1126.7	44.	138.230	1520.5
⅝	99.353	785.51				⅛	138.623	1529.2
¾	99.746	791.73	38.	119.381	1134.1	¼	139.015	1537.9
⅞	100.138	797.98	⅛	119.773	1141.6	⅜	139.408	1546.6
			¼	120.166	1149.1	½	139.801	1555.3
32.	100.531	804.25	⅜	120.559	1156.6	⅝	140.194	1564.0
⅛	100.924	810.54	½	120.951	1164.2	¾	140.586	1572.8
¼	101.316	816.86	⅝	121.344	1171.7	⅞	140.979	1581 6
⅜	101.709	823.21	¾	121.737	1179.3			
½	102.102	829.58	⅞	122.129	1186.9	45.	141.372	1590.4
⅝	102.494	835.97				⅛	141.764	1599.3
¾	102.887	842.39	39.	122.522	1194.6	¼	142.157	1608.2
⅞	103.280	848.83	⅛	122.915	1202.3	⅜	142.550	1617.0
			¼	123.308	1210.0	½	142.942	1626.0
33.	103.673	855.30	⅜	123.700	1217.7	⅝	143.335	1634.9
⅛	104.065	861.79	½	124.093	1225.4	¾	143.728	1643.9
¼	104.458	868.31	⅝	124.486	1233.2	⅞	144.121	1652.9
⅜	104.851	874.85	¾	124.878	1241.0			
½	105.243	881.41	⅞	125.271	1248.8	46.	144.513	1661.9
⅝	105.636	888.00				⅛	144.906	1670.9
¾	106.029	894.62	40.	125.664	1256.6	¼	145.299	1680.0
⅞	106.421	901.26	⅛	126.056	1264.5	⅜	145.691	1689.1
			¼	126.449	1272.4	½	146.084	1398.2
34.	106.814	907.92	⅜	126.842	1280.3	⅝	146.477	1707.4
⅛	107.207	914.61	½	127.235	1288.2	¾	146.869	1716.5
¼	107.600	921.32	⅝	127.627	1296.2	⅞	147.262	1725.7
⅜	107.992	928.06	¾	128.020	1304.2			
½	108.385	934.82	⅞	128.413	1312.2	47.	147.655	1734.9
⅝	108.778	941.61				⅛	148.048	1744.2
¾	109.170	948.42	41.	128.805	1320.3	¼	148.440	1753.5
⅞	109.563	955.25	⅛	129.198	1328.3	⅜	148.833	1762.7
			¼	129.591	1336.4	½	149.226	1772.1
35.	109.956	962.11	⅜	129.983	1344.5	⅝	149.618	1781.4
⅛	110.348	969.00	½	130.376	1352.7	¾	150.011	1790.8
¼	110.741	975.91	⅝	130.769	1360.8	⅞	150.404	1800.1
⅜	111.134	982.84	¾	131.161	1369.0			
½	111.527	989.80	⅞	131.554	1377.2	48.	150.796	1809.6
⅝	111.919	996.78				⅛	151.189	1819.0
¾	112.312	1003.8	42.	131.947	1385.4	¼	151.582	1828.5
⅞	112.705	1010.8	⅛	132.340	1393.7	⅜	151.975	1837.9
36.	113.097	1017.9	¼	132.732	1402.0	½	152.367	1847.5

CIRCUMFERENCES AND AREAS OF CIRCLES.

(CONTINUED.)

Diam.	Circum.	Area.	Diam.	Circum.	Area.	Diam.	Circum.	Area.
48.⅝	152.760	1857.0	54.⅞	172.395	2365.0	61.	191.637	2922.5
¾	153.153	1866.5				⅛	192.030	2934.5
⅞	153.545	1876.1	55.	172.788	2375.8	¼	192.423	2946.5
			⅛	173.180	2386.6	⅜	192.815	2958.5
49.	153.938	1885.7	¼	173.573	2397.5	½	193.208	2970.6
⅛	154.331	1895.4	⅜	173.966	2408.3	⅝	193.601	2982.7
¼	154.723	1905.0	½	174.358	2419.2	¾	193.993	2994.8
⅜	155.116	1914.7	⅝	174.751	2430.1	⅞	194.386	3006.9
½	155.509	1924.4	¾	175.144	2441.1			
⅝	155.902	1934.2	⅞	175.536	2452.0	62.	194.779	3019.1
¾	156.294	1943.9				⅛	195.171	3031.3
⅞	156.687	1953.7	56.	175.929	2463.0	¼	195.564	3043.5
			⅛	176.322	2474.0	⅜	195.957	3055.7
50.	157.080	1963.5	¼	176.715	2485.0	½	196.350	3068.0
⅛	157.472	1973.3	⅜	177.107	2496.1	⅝	196.742	3080.3
¼	157.865	1983.2	½	177.500	2507.2	¾	197.135	3092.6
⅜	158.258	1993.1	⅝	177.893	2518.3	⅞	197.528	3104.9
½	158.650	2003.0	¾	178.285	2529.4			
⅝	159.043	2012.9	⅞	178.678	2540.6	63.	197.920	3117.2
¾	159.436	2022.8				⅛	198.313	3129.6
⅞	159.829	2032.8	57.	179.071	2551.8	¼	198.706	3142.0
			⅛	179.463	2563.0	⅜	199.098	3154.5
51.	160.221	2042.8	¼	179.856	2574.2	½	199.491	3166.9
⅛	160.614	2052.8	⅜	180.249	2585.4	⅝	199.884	3179.4
¼	161.007	2062.9	½	180.642	2596.7	¾	200.277	3191.9
⅜	161.399	2073.0	⅝	181.034	2608.0	⅞	200.669	3204.4
½	161.792	2083.1	¾	181.427	2619.4			
⅝	162.185	2093.2	⅞	181.820	2630.7	64.	201.062	3217.0
¾	162.577	2103.3				⅛	201.455	3229.6
⅞	162.970	2113.5	58.	182.212	2642.1	¼	201.847	3242.2
			⅛	182.605	2653.5	⅜	202.240	3254.8
52.	163.363	2123.7	¼	182.998	2664.9	½	202.633	3267.5
⅛	163.756	2133.9	⅜	183.390	2676.4	⅝	203.025	3280.1
¼	164.148	2144.2	½	183.783	2687.8	¾	203.418	3292.8
⅜	164.541	2154.5	⅝	184.176	2699.3	⅞	203.811	3305.6
½	164.934	2164.8	¾	184.569	2710.9			
⅝	165.326	2175.1	⅞	184.961	2722.4	65.	204.204	3318.3
¾	165.719	2185.4				⅛	204.596	3331.1
⅞	166.112	2195.8	59.	185.354	2734.0	¼	204.989	3343.9
			⅛	185.747	2745.6	⅜	205.382	3356.7
53.	166.504	2206.2	¼	186.139	2757.2	½	205.774	3369.6
⅛	166.897	2216.6	⅜	186.532	2768.8	⅝	206.167	3382.4
¼	167.290	2227.0	½	186.925	2780.5	¾	206.560	3395.3
⅜	167.683	2237.5	⅝	187.317	2792.2	⅞	206 952	3408.2
½	168.075	2248.0	¾	187.710	2803.9			
⅝	168.468	2258.5	⅞	188.103	2815.7	66.	207.345	3421.2
¾	168.861	2269.1				⅛	207.738	3434.2
⅞	169.253	2279.6	60.	188.496	2827.4	¼	208.131	3447.2
			⅛	188.888	2839.2	⅜	208.523	3460.2
54.	169.646	2290.2	¼	189.281	2851.0	½	208.916	3473.2
⅛	170.039	2300.8	⅜	189.674	2862.9	⅝	209.309	3486.3
¼	170.431	2311.5	½	190.066	2874.8	¾	209.701	3499.4
⅜	170.824	2322.1	⅝	190.459	2886.6	⅞	210.094	3512.5
½	171 217	2332.8	¾	190.852	2898.6			
⅝	171.609	2343.5	⅞	191.244	2910.5	67.	210.487	3525.7
¾	172.002	2354.3				⅛	210.879	3538.8

CIRCUMFERENCES AND AREAS OF CIRCLES.

(CONTINUED.)

Diam.	Circum.	Area.
67.¼	211.272	3552.0
⅜	211.665	3565.2
½	212.058	3578.5
⅝	212.450	3591.7
¾	212.843	3605.0
⅞	213.236	3618.3
68.	213.628	3631.7
⅛	214.021	3645.0
¼	214.414	3658.4
⅜	214.806	3671.8
½	215.199	3685.3
⅝	215.592	3698.7
¾	215.984	3712.2
⅞	216.377	3725.7
69.	216.770	3739.3
⅛	217.163	3752.8
¼	217.555	3766.4
⅜	217.948	3780.0
½	218.341	3793.7
⅝	218.733	3807.3
¾	219.126	3821.0
⅞	219.519	3834.7
70.	219.911	3848.5
⅛	220.304	3862 2
¼	220.697	3876.0
⅜	221.090	3889.8
½	221.482	3903.6
⅝	221.875	3917.5
¾	222.268	3931.4
⅞	222.660	3945.3
71.	223.053	3959.2
⅛	223.446	3973.1
¼	223.838	3987.1
⅜	224.231	4001.1
½	224.624	4015.2
⅝	225.017	4029.2
¾	225.409	4043.3
⅞	225.802	4057.4
72.	226.195	4071.5
⅛	226.587	4085.7
¼	226.980	4099.8
⅜	227.373	4114.0
½	227.765	4128.2
⅝	228.158	4142.5
¾	228.551	4156.8
⅞	228.944	4171.1
73.	229.336	4185.4
⅛	229.729	4199.7
¼	230.122	4214.1
⅜	230.514	4228.5

Diam.	Circum.	Area.
73.½	230.907	4242.9
⅝	231.300	4257.4
¾	231.692	4271.8
⅞	232.085	4286.3
74.	232.478	4300.8
⅛	232.871	4315.4
¼	233.263	4329.9
⅜	233.656	4344.5
½	234.049	4359.2
⅝	234.441	4373.8
¾	234.834	4388.5
⅞	235.227	4403.1
75.	235.619	4417.9
⅛	236.012	4432.6
¼	236.405	4447.4
⅜	236.798	4462.2
½	237.190	4477.0
⅝	237.583	4491.8
¾	237.976	4506.7
⅞	238.368	4521.5
76.	238.761	4536.5
⅛	239.154	4551.4
¼	239.546	4566.4
⅜	239.939	4581.3
½	240.332	4596.3
⅝	240.725	4611.4
¾	241.117	4626.4
⅞	241.510	4641.5
77.	241.903	4656.6
⅛	242.295	4671.8
¼	242.688	4686.9
⅜	243.081	4702.1
½	243.473	4717.3
⅝	243.866	4732.5
¾	244.259	4747.8
⅞	244.652	4763.1
78.	245.044	4778.4
⅛	245.437	4793.7
¼	245.830	4809.0
⅜	246.222	4824.4
½	246.615	4839.8
⅝	247.008	4855.2
¾	247.400	4870.7
⅞	247.793	4886.2
79.	248.186	4901.7
⅛	248.579	4917.2
¼	248.971	4932.7
⅜	249.364	4948.3
½	249.757	4963.9
⅝	250.149	4979.5

Diam.	Circum.	Area.
79.¾	250.542	4995.2
⅞	250.935	5010.9
80.	251.327	5026.5
⅛	251.720	5042.3
¼	252.113	5058.0
⅜	252.506	5073.8
½	252.898	5089.6
⅝	253.291	5105.4
¾	253.684	5121.2
⅞	254.076	5137.1
81.	254.469	5153.0
⅛	254.862	5168.9
¼	255.254	5184.9
⅜	255.647	5200.8
½	256.040	5216.8
⅝	256.433	5232.8
¾	256.825	5248.9
⅞	257.218	5264.9
82.	257.611	5281.0
⅛	258.003	5297.1
¼	258.396	5313.3
⅜	258.789	5329.4
½	259.181	5345.6
⅝	259.574	5361.8
¾	259.967	5378.1
⅞	260.359	5394.3
83.	260.752	5410.6
⅛	261.145	5426.9
¼	261.538	5443.3
⅜	261.930	5459.6
½	262.323	5476.0
⅝	262.716	5492.4
¾	263.108	5508.8
⅞	263.501	5525.3
84.	263.894	5541.8
⅛	264.286	5558.3
¼	264.679	5574.8
⅜	265.072	5591.4
½	265.465	5607.9
⅝	265.857	5624.5
¾	266.250	5641.2
⅞	266.643	5657.8
85.	267.035	5674.5
⅛	267.428	5691.2
¼	267.821	5707.9
⅜	268.213	5724.7
½	268.606	5741.5
⅝	268.999	5758.3
¾	269.392	5775.1
⅞	269.784	5791.9

CIRCUMFERENCES AND AREAS OF CIRCLES.

(CONTINUED.)

Diam.	Circum.	Area.
86.	270.177	5808.8
⅛	270.570	5825.7
¼	270.962	5842.6
⅜	271.355	5859.6
½	271.748	5876.5
⅝	272.140	5893.5
¾	272.533	5910.6
⅞	272.926	5927.6
87.	273.319	5944.7
⅛	273.711	5961.8
¼	274.104	5978.9
⅜	274.497	5996.0
½	274.889	6013.2
⅝	275.282	6030.4
¾	275.675	6047.6
⅞	276.067	6064.9
88.	276.460	6082.1
⅛	276 853	6099.4
¼	277.246	6116.7
⅜	277.638	6134.1
½	278.031	6151.4
⅝	278.424	6168.8
¾	278.816	6186.2
⅞	279.209	6203.7
89.	279.602	6221.1
⅛	279.994	6238.6
¼	280.387	6256.1
⅜	280.780	6273.7
½	281.173	6291.2
⅝	281.565	6308.8
¾	281.958	6326 4
⅞	282.351	6344.1
90.	282.743	6361.7
⅛	283.136	6379.4
¼	283.529	6397.1
⅜	283.921	6414.9
½	284.314	6432.6
⅝	284.707	6450.4
¾	285.100	6468.2
90.⅞	285.492	6486.0
91.	285.885	6503.9
⅛	286.278	6521.8
¼	286.670	6539.7
⅜	287.063	6557.6
½	287.456	6575.5
⅝	287.848	6593.5
¾	288.241	6611.5
⅞	288.634	6629.6
92.	289.027	6647.6
⅛	289.419	6665.7
¼	289.812	6683.8
⅜	290.205	6701.9
½	290.597	6720.1
⅝	290.990	6738.2
¾	291.383	6756.4
⅞	291.775	6774.7
93.	292.168	6792.9
⅛	292.561	6811.2
¼	292.954	6829.5
⅜	293.346	6847.8
½	293.739	6866.1
⅝	294.132	6884.5
¾	294.524	6902.9
⅞	294.917	6921 3
94.	295.310	6939.8
⅛	295.702	6958.2
¼	296.095	6976.7
⅜	296.488	6995.3
½	296.881	7013.8
⅝	297.273	7032.4
¾	297.666	7051.0
⅞	298.059	7069.6
95.	298.451	7088.2
⅛	298.844	7106.9
¼	299.237	7125.6
⅜	299.629	7144.3
½	300.022	7163.0
95.⅝	300.415	7181.8
¾	300.807	7200.6
⅞	301.200	7219.4
96.	301.593	7238.2
⅛	301.986	7257.1
¼	302.378	7276.0
⅜	302.771	7294.9
½	303.164	7313.8
⅝	303.556	7332.8
¾	303.949	7351.8
⅞	304.342	7370.8
97.	304.734	7389.8
⅛	305.127	7408.9
¼	305.520	7428.0
⅜	305.913	7447.1
½	306.305	7466.2
⅝	306.698	7485.3
¾	307.091	7504.5
⅞	307.483	7523.7
98.	307.876	7543.0
⅛	308.269	7562.2
¼	308.661	7581.5
⅜	309.054	7600.8
½	309.447	7620.1
⅝	309.840	7639.5
¾	310.232	7658.9
⅞	310.625	7678.3
99.	311.018	7697.7
⅛	311.410	7717.1
¼	311.803	7736.6
⅜	312.196	7756.1
½	312.588	7775.6
⅝	312.981	7795.2
¾	313.374	7814.8
⅞	313.767	7834.4
100.	314.159	7854.0

FIFTH ROOTS AND FIFTH POWERS.

Power.	No. or Root.	Power.	No. or Root.	Power.	No. or Root.
.0000100	.1	.000796	.240	.034503	.51
.0000110	.102	.000883	.245	.038020	.52
.0000122	.104	.000977	.250	.041820	.53
.0000134	.106	.001078	.255	.045917	.54
.0000147	.108	.001188	.260	.050328	.55
.0000161	.110	.001307	.265	.055073	.56
.0000176	.112	.001435	.270	.060169	.57
.0000193	.114	.001573	.275	.065636	.58
.0000210	.116	.001721	.280	.071492	.59
0000229	.118	.001880	.285	.077760	.60
.0000249	.120	.002051	.290	.084460	.61
.0000270	.122	.002234	.295	.091613	.62
.0000293	.124	.002430	.300	.099244	.63
.0000318	.126	.002639	.305	.107374	.64
.0000344	.128	.002863	.310	.116029	.65
.0000371	.130	.003101	.315	.125233	.66
.0000401	.132	.003355	.320	.135012	.67
.0000432	.134	.003626	.325	.145393	.68
.0000465	.136	.003914	.330	.156403	.69
.0000500	.138	.004219	.335	.168070	.70
.0000538	.140	.004544	.340	.180423	.71
.0000577	.142	.004888	.345	.193492	.72
.0000619	.144	.005252	.350	.207307	.73
.0000663	.146	.005638	.355	.221901	.74
.0000710	.148	.006047	.360	.237305	.75
.0000754	.150	.006478	.365	.253553	.76
.0000895	.155	.006934	.370	.270678	.77
.000105	.160	.007416	.375	.288717	.78
.000122	.165	.007924	.380	.307706	.79
.000142	.170	.008459	.385	.327680	.80
.000164	.175	.009022	.390	.348678	.81
.000189	.180	.009616	.395	.370740	.82
.000217	.185	.010240	.400	.393904	.83
.000248	.190	.011586	.41	.418212	.84
.000282	.195	.013069	.42	.443705	.85
.000320	.200	.014701	.43	.470427	.86
.000362	.205	.016492	.44	.498421	.87
.000408	.210	.018453	.45	.527732	.88
.000459	.215	.020596	.46	.558406	.89
.000515	.220	.022935	.47	.590490	.90
.000577	.225	.025480	.48	.624032	.91
.000644	.230	.028248	.49	.659082	.92
.000717	.235	.031250	.50	.695688	.93

Fifth Roots and Fifth Powers. (CONTINUED.)

Power.	No. or Root.	Power.	No. or Root.	Power.	No. or Root.
.733904	.94	15.9495	1.74	525.219	3.50
.773781	.95	16.8874	1.76	563.822	3.55
.815373	.96	17.8690	1.78	604.662	3.60
.858734	.97	18.8957	1.80	647.835	3.65
.903921	.98	19.9690	1.82	693.440	3.70
.950990	.99	21.0906	1.84	741.577	3.75
1.	1.	22.2620	1.86	792.352	3.80
1.10408	1.02	23.4849	1.88	845.870	3.85
1.21665	1.04	24.7610	1.90	902.242	3.90
1.33823	1.06	26.0919	1.92	961.58	3.95
1.46933	1.08	27.4795	1.94	1024.00	4.00
1.61051	1.10	28.9255	1.96	1089.62	4.05
1.76234	1.12	30.4317	1.98	1158.56	4.10
1.92541	1.14	32.0000	2.00	1230.95	4.15
2.10034	1.16	36.2051	2.05	1306.91	4.20
2.28775	1.18	40.8410	2.10	1386.58	4.25
2.48832	1.20	45.9401	2.15	1470.08	4.30
2.70271	1.22	51.5363	2.20	1557.57	4.35
2.93163	1.24	57.6650	2.25	1649.16	4.40
3.17580	1.26	64.3634	2.30	1745.02	4.45
3.43597	1.28	71.6703	2.35	1845.28	4.50
3.71293	1.30	79.6262	2.40	1950.10	4.55
4.00746	1.32	88.2735	2.45	2059.63	4.60
4.32040	1.34	97.6562	2.50	2174.03	4.65
4.65259	1.36	107.820	2.55	2293.45	4.70
5.00490	1.38	118.814	2.60	2418.07	4.75
5.37824	1.40	130.686	2.65	2548.04	4.80
5.77353	1.42	143.489	2.70	2683.54	4.85
6.19174	1.44	157.276	2.75	2824.75	4.90
6.63383	1.46	172.104	2.80	2971.84	4.95
7.10082	1.48	188.029	2.85	3125.00	5.00
7.59375	1.50	205.111	2.90	3450.25	5.10
8.11368	1.52	223.414	2.95	3802.04	5.20
8.66171	1.54	243.000	3.00	4181.95	5.30
9.23896	1.56	263.936	3.05	4591.65	5.40
9.84658	1.58	286.292	3.10	5032.84	5.50
10.4858	1.60	310.136	3.15	5507.32	5.60
11.1577	1.62	335.544	3.20	6016.92	5.70
11.8637	1.64	362.591	3.25	6563.57	5.80
12.6049	1.66	391.354	3.30	7149.24	5.90
13.3828	1.68	421.419	3.35	7776.00	6.00
14.1986	1.70	454.354	3.40	8445.96	6.10
15.0537	1.72	488.760	3.45	9161.33	6.20

Fifth Roots and Fifth Powers. (CONTINUED.)

Power.	No. or Root.	Power.	No. or Root.	Power.	No. or Root.
9924.37	6.30	176234.	11.2	3043168.	19.8
10737.	6.40	192541.	11.4	3200000.	20.0
11603.	6.50	210034.	11.6	3363232.	20.2
12523.	6.60	228776.	11.8	3533059.	20.4
13501.	6.70	248832.	12.0	3709677.	20.6
14539.	6.80	270271.	12.2	3893289.	20.8
15640.	6.90	293163.	12.4	4084101.	21.0
16807.	7.00	317580.	12.6	4282322.	21.2
18042.	7.10	343597.	12.8	4488166.	21.4
19349.	7.20	371293.	13.0	4701850.	21.6
20731.	7.30	400746.	13.2	4923597.	21.8
22190.	7.40	432040.	13.4	5153632.	22.0
23730.	7.50	465259.	13.6	5392186.	22.2
25355.	7.60	500490.	13.8	5639493.	22.4
27068.	7.70	537824.	14.0	5895793.	22.6
28872.	7.80	577353.	14.2	6161327.	22.8
30771.	7.90	619174.	14.4	6436343.	23.0
32768.	8.00	663383.	14.6	6721093.	23.2
34868.	8.10	710082.	14.8	7015834.	23.4
37074.	8.20	759375.	15.0	7320825.	23.6
39390.	8.30	811368.	15.2	7636332.	23.8
41821.	8.40	866171.	15.4	7962624.	24.0
44371.	8.50	923896.	15.6	8299976.	24.2
47043.	8.60	984658.	15.8	8648666.	24.4
49842.	8.70	1048576.	16.0	9008978.	24.6
52773.	8.80	1115771.	16.2	9381200.	24.8
55841.	8.90	1186367.	16.4	9765625.	25.0
59049.	9.00	1260493.	16.6	10162550.	25.2
62403.	9.10	1338278.	16.8	10572278.	25.4
65908.	9.20	1419857.	17.0	10995116.	25.6
69569.	9.30	1505366.	17.2	11431377.	25.8
73390.	9.40	1594947.	17.4	11881376.	26.0
77378.	9.50	1688742.	17.6	12345437.	26.2
81537.	9.60	1786899.	17.8	12823886.	26.4
85873.	9.70	1889568.	18.0	13317055.	26.6
90392.	9.80	1996903.	18.2	13825281.	26.8
95099.	9.90	2109061.	18.4	14348907.	27.0
100000.	10.0	2226203.	18.6	14888280.	27.2
110408.	10.2	2348493.	18.8	15443752.	27.4
121665.	10.4	2476099.	19.0	16015681.	27.6
133823.	10.6	2609193.	19.2	16604430.	27.8
146933.	10.8	2747949.	19.4	17210368.	28.0
161051.	11.0	2892547.	19.6	17833868.	28.2

Fifth Roots and Fifth Powers. (CONTINUED.)

Power.	No. or Root.	Power.	No. or Root.	Power.	No. or Root.
18475309.	28.4	28629151.	31.0	60466176.	36.0
19135075.	28.6	31013642.	31.5	64783487.	36.5
19813557.	28.8	33554432.	32.0	69343957.	37.0
20511149.	29.0	36259082.	32.5	74157715.	37.5
21228253.	29.2	39135393.	33.0	79235168.	38.0
21965275.	29.4	42191410.	33.5	84587005.	38.5
22722628.	29.6	45435424.	34.0	90224199.	39.0
23500728.	29.8	48875980.	34.5	96158012.	39.5
24300000.	30.0	52521875.	35.0	102400000.	40.0
26393634.	30.5	56382167.	35.5		

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

(FROM CARNEGIE HAND BOOK.)

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

Squares, Cubes, Square Roots, Cube Roots, Logarithms, Etc.

(CONTINUED.)

No	Sq.	Cube.	Square Root.	Cube Root.	Log.	1000 X Recip.	No = Dia. Circ'm	Area.
46	2116	97336	6.7823	3.5830	1.66276	21.7391	144.51	1661.90
47	2209	103823	6.8557	3.6088	1.67210	21.2766	147.65	1734.94
48	2304	110592	6.9282	3.6342	1.68124	20.8333	150.80	1809.56
49	2401	117649	7.0000	3.6593	1.69020	20.4082	153.94	1885.74
50	2500	125000	7.0711	3.6840	1.69897	20.0000	157.08	1963.50
51	2601	132651	7.1414	3.7084	1.70757	19.6078	160.22	2042.82
52	2704	140608	7.2111	3.7325	1.71600	19.2308	163.36	2123.72
53	2809	148877	7.2801	3.7563	1.72428	18.8679	166.50	2206.18
54	2916	157464	7.3485	3.7798	1.73239	18.5185	169.65	2290.22
55	3025	166375	7.4162	3.8030	1.74036	18.1818	172.79	2375.83
56	3136	175616	7.4833	3.8259	1.74819	17.8571	175.93	2463.01
57	3249	185193	7.5498	3.8485	1.75587	17.5439	179.07	2551.76
58	3364	195112	7.6158	3.8709	1.76343	17.2414	182.21	2642.08
59	3481	205379	7.6811	3.8930	1.77085	16.9492	185.35	2733.97
60	3600	216000	7.7460	3.9149	1.77815	16.6667	188.50	2827.43
61	3721	226981	7.8102	3.9365	1.78533	16.3934	191.64	2922.47
62	3844	238328	7.8740	3.9579	1.79239	16.1290	194.78	3019.07
63	3969	250047	7.9373	3.9791	1.79934	15.8730	197.92	3117.25
64	4096	262144	8.0000	4.0000	1.80618	15.6250	201.06	3216.99
65	4225	274625	8.0623	4.0207	1.81291	15.3846	204.20	3318.31
66	4356	287496	8.1240	4.0412	1.81954	15.1515	207.35	3421.19
67	4489	300763	8.1854	4.0615	1.82607	14.9254	210.49	3525.65
68	4624	314432	8.2462	4.0817	1.83251	14.7059	213.63	3631.68
69	4761	328509	8.3066	4.1016	1.83885	14.4928	216.77	3739.28
70	4900	343000	8.3666	4.1213	1.84510	14.2857	219.91	3848.45
71	5041	357911	8.4261	4.1408	1.85126	14.0845	223.05	3959.19
72	5184	373248	8.4853	4.1602	1.85733	13.8889	226.19	4071.50
73	5329	389017	8.5440	4.1793	1.86332	13.6986	229.34	4185.39
74	5476	405224	8.6023	4.1983	1.86923	13.5135	232 48	4300.84
75	5625	421875	8.6603	4.2172	1.87506	13.3333	235.62	4417.86
76	5776	438976	8.7178	4.2358	1.88081	13.1579	238.76	4536.46
77	5929	456533	8.7750	4.2543	1.88649	12.9870	241.90	4656.63
78	6084	474552	8.8318	4.2727	1.89209	12.8205	245.04	4778.36
79	6241	493039	8.8882	4.2908	1.89763	12.6582	248.19	4901.67
80	6400	512000	8.9443	4.3089	1.90309	12.5000	251.33	5026.55
81	6561	531441	9.0000	4.3267	1.90849	12.3457	254.47	5153.00
82	6724	551368	9.0554	4.3445	1.91381	12.1951	257.61	5281.02
83	6889	571787	9.1104	4.3621	1.91908	12.0482	260.75	5410.61
84	7056	592704	9.1652	4.3795	1.92428	11.9048	263.89	5541.77
85	7225	614125	9.2195	4.3968	1.92942	11.7647	267.04	5674.50
86	7396	636056	9.2736	4.4140	1.93450	11.6279	270.18	5808.80
87	7569	658503	9.3274	4.4310	1.93952	11.4943	273.32	5944.68
88	7744	681472	9.3808	4.4480	1.94448	11.3636	276.46	6082.12
89	7921	704969	9.4340	4.4647	1.94939	11.2360	279.60	6221.14

Squares, Cubes, Square Roots, Cube Roots, Logarithms, Etc.

(CONTINUED.)

No.	Sq.	Cube.	Square Root.	Cube Root.	Log.	1000 X Recip.	No. = Dia. Circ'm	Area.
90	8100	729000	9.4868	4.4814	1.95424	11.1111	282.74	6361.73
91	8281	753571	9.5394	4.4979	1.95904	10.9890	285.88	6503.88
92	8464	778688	9.5917	4.5144	1.96379	10.8696	289.03	6647.61
93	8649	804357	9.6437	4.5307	1.96848	10.7527	292.17	6792.91
94	8836	830584	9.6954	4.5468	1.97313	10.6383	295.31	6939.78
95	9025	857375	9.7468	4.5629	1.97772	10.5263	298.45	7088.22
96	9216	884736	9.7980	4.5789	1.98227	10.4167	301.59	7238.23
97	9409	912673	9.8489	4.5947	1 98677	10.3093	304.73	7389.81
98	9604	941192	9.8995	4.6104	1.99123	10.2041	307.88	7542.96
99	9801	970299	9.9499	4.6261	1.99564	10.1010	311.02	7697.69
100	10000	1000000	10.0000	4.6416	2.00000	10.0000	314.16	7853.98
101	10201	1030301	10.0499	4.6570	2.00432	9.90099	317.30	8011.85
102	10404	1061208	10.0995	4.6723	2.00860	9.80392	320.44	8171.28
103	10609	1092727	10.1489	4.6875	2.01284	9.70874	323.58	8332.29
104	10816	1124864	10.1980	4.7027	2.01703	9.61538	326.73	8494.87
105	11025	1157625	10.2470	4.7177	2.02119	9.52381	329.87	8659.01
106	11236	1191016	10.2956	4.7326	2.02531	9.43396	333.01	8824.73
107	11449	1225043	10.3441	4.7475	2.02938	9.34579	336.15	8992.02
108	11664	1259712	10.3923	4.7622	2.03342	9.25926	339.29	9160.88
109	11881	1295029	10.4403	4.7769	2.03743	9.17431	342.43	9331.32
110	12100	1331000	10.4881	4.7914	2.04139	9.09091	345.58	9503.32
111	12321	1367631	10.5357	4.8059	2.04532	9.00901	348.72	9676.89
112	12544	1404928	10.5830	4.8203	2.04922	8.92857	351.86	9852.03
113	12769	1442897	10.6301	4.8346	2.05308	8.84956	355.00	10028.7
114	12996	1481544	10.6771	4.8488	2.05690	8.77193	358.14	10207.0
115	13225	1520875	10.7238	4.8629	2.06070	8.69565	361.28	10386.9
116	13456	1560896	10.7703	4.8770	2.06446	8.62069	364.42	10568.3
117	13689	1601613	10.8167	3.8910	2.06819	8.54701	367.57	10751.3
118	13924	1643032	10.8628	4.9049	2.07188	8.47458	370.71	10935.9
119	14161	1685159	10.9087	4.9187	2.07555	8.40336	373.85	11122.0
120	14400	1728000	10.9545	4.9324	2.07918	8.33333	376.99	11309.7
121	14641	1771561	11.0000	4.9461	2.08279	8.26446	380.13	11499.0
122	14884	1815848	11.0454	4.9597	2.08636	8.19672	383.27	11689.9
123	15129	1860867	11.0905	4.9732	2.08991	8.13008	386.42	11882.3
124	15376	1906624	11.1355	4.9866	2.09342	8.06452	389.56	12076.3
125	15625	1953125	11.1803	5.0000	2.09691	8.00000	392.70	12271.8
126	15876	2000376	11.2250	5.0133	2.10037	7.93651	395.84	12469.0
127	16129	2048383	11.2694	5.0265	2.10380	7.87402	398.98	12667.7
128	16384	2097152	11.3137	5.0397	2.10721	7.81250	402.12	12868.0
129	16641	2146689	11.3578	5.0528	2.11059	7.75194	405.27	13069.8
130	16900	2197000	11.4018	5.0658	2.11394	7.69231	408.41	13273.2
131	17161	2248091	11.4455	5.0788	2.11727	7.63359	411.55	13478.2
132	17424	2299968	11.4891	5.0916	2.12057	7.57576	414.69	13684.8
133	17689	2352637	11.5326	5.1045	2.12385	7.51880	417.83	13892.9
134	17956	2406104	11.5758	5.1172	2.12710	7.46269	420.97	14102.6

Squares, Cubes, Square Roots, Cube Roots, Logarithms, Etc.

(CONTINUED.)

No.	Sq.	Cube.	Square Root.	Cube Root.	Log.	1000 X Recip.	No. = Dia.	
							Circ'm	Area.
135	18225	2460375	11.6190	5.1299	2.13033	7.40741	424.12	14313.9
136	18496	2515456	11.6619	5.1426	2.13354	7.35294	427.26	14526.7
137	18769	2571353	11.7047	5.1551	2.13672	7.29927	430.40	14741.1
138	19044	2628072	11.7473	5.1676	2.13988	7.24638	433.54	14957.1
139	19321	2685619	11.7898	5.1801	2.14301	7.19424	436.68	15174.7
140	19600	2744000	11.8322	5.1925	2.14613	7.14286	439.82	15393.8
141	19881	2803221	11.8743	5.2048	2.14922	7.09220	442.96	15614.5
142	20164	2863288	11.9164	5.2171	2.15229	7.04225	446.11	15836.8
143	20449	2924207	11.9583	5.2293	2.15534	6.99301	449.25	16060.6
144	20736	2985984	12.0000	5.2415	2.15836	6.94444	452.39	16286.0
145	21025	3048625	12.0416	5.2536	2.16137	6.89655	455.53	16513.0
146	21316	3112136	12.0830	5.2656	2.16435	6.84932	458.67	16741.5
147	21609	3176523	12.1244	5.2776	2.16732	6.80272	461.81	16971.7
148	21904	3241792	12.1655	5.2896	2.17026	6.75676	464.96	17203.4
149	22201	3307949	12.2066	5.3015	2.17319	6.71141	468.10	17436.6
150	22500	3375000	12.2474	5.3133	2.17609	6.66667	471.24	17671.5
151	22801	3442951	12.2882	5.3251	2.17898	6.62252	474.38	17907.9
152	23104	3511808	12.3288	5.3368	2.18184	6.57895	477.52	18145.8
153	23409	3581577	12.3693	5.3485	2.18469	6.53595	480.66	18385.4
154	23716	3652264	12.4097	5.3601	2.18752	6.49351	483.81	18626.5
155	24025	3723875	12.4499	5.3717	2.19033	6.45161	486.95	18869.2
156	24336	3796416	12.4900	5.3832	2.19312	6.41026	490.09	19113.4
157	24649	3869893	12.5300	5.3947	2.19590	6.36943	493.23	19359.3
158	24964	3944312	12.5698	5.4061	2.19866	6.32911	496.37	19606.7
159	25281	4019679	12.6095	5.4175	2.20140	6.28931	499.51	19855.7
160	25600	4096000	12.6491	5.4288	2.20412	6.25000	502.65	20106.2
161	25921	4173281	12.6886	5.4401	2.20683	6.21118	505.80	20358.3
162	26244	4251528	12.7279	5.4514	2.20952	6.17284	508.94	20612.0
163	26569	4330747	12.7671	5.4626	2.21219	6.13497	512.08	20867.2
164	26896	4410944	12.8062	5.4737	2.21484	6.09756	515.22	21124.1
165	27225	4492125	12.8452	5.4848	2.21748	6.06061	518.36	21382.5
166	27556	4574296	12.8841	5.4959	2.22011	6.02410	521.50	21642.4
167	27889	4657463	12.9228	5.5069	2.22272	5.98802	524.65	21904.0
168	28224	4741632	12.9615	5.5178	2.22531	5.95238	527.79	22167.1
169	28561	4826809	13.0000	5.5288	2.22789	5.91716	530.93	22431.8
170	28900	4913000	13.0384	5.5397	2.23045	5.88235	534.07	22698.0
171	29241	5000211	13.0767	5.5505	2.23300	5.84795	537.21	22965.8
172	29584	5088448	13.1149	5.5613	2.23553	5.81395	540.35	23235.2
173	29929	5177717	13.1529	5.5721	2.23805	5.78035	543.50	23506.2
174	30276	5268024	13.1909	5.5828	2.24055	5.74713	546.64	23778.7
175	30625	5359375	13.2288	5.5934	2.24304	5.71429	549.78	24052.8
176	30976	5451776	13.2665	5.6041	2.24551	5.68182	552.92	24328.5
177	31329	5545233	13.3041	5.6147	2.24797	5.64972	556.06	24605.7
178	31684	5639752	13.3417	5.6252	2.25042	5.61798	559.20	24884.6
179	32041	5735339	13.3791	5.6357	2.25285	5.58659	562.35	25164.9

Squares, Cubes, Square Roots, Cube Roots, Logarithms, Etc.

(CONTINUED.)

No.	Sq.	Cube.	Square Root.	Cube Root.	Log.	1000 X Recip.	No. = Dia. Circ'm	Area.
180	32400	5832000	13.4164	5.6462	2.25527	5.55556	565.49	25446.9
181	32761	5929741	13.4536	5.6567	2.25768	5.52486	568.63	25730.4
182	33124	6028568	13.4907	5.6671	2.26007	5.49451	571.77	26015.5
183	33489	6128487	13.5277	5.6774	2.26245	5.46448	574.91	26302.2
184	33856	6229504	13.5647	5.6877	2.26482	5.43478	578.05	26590.4
185	34225	6331625	13.6015	5.6980	2.26717	5.40541	581.19	26880.3
186	34596	6434856	13.6382	5 7083	2.26951	5.37634	584.34	27171.6
187	34969	6539203	13.6748	5.7185	2.27184	5.34759	587.48	27464.6
188	35344	6644672	13.7113	5.7287	2.27416	5.31915	590.62	27759.1
189	35721	6751269	13.7477	5.7388	2.27646	5.29101	593.76	28055.2
190	36100	6859000	13.7840	5.7489	2.27875	5.26316	596.90	28352.9
191	36481	6967871	13.8203	5.7590	2.28103	5.23560	600.04	28652.1
192	36864	7077888	13.8564	5.7690	2.28330	5.20833	603.19	28952.9
193	37249	7189057	13.8924	5.7790	2.28556	5.18135	606.33	29255.3
194	37636	7301384	13.9284	5.7890	2.28780	5.15464	609.47	29559.2
195	38025	7414875	13.9642	5.7989	2.29003	5.12821	612.61	29864.8
196	38416	7529536	14.0000	5.8088	2.29226	5.10204	615.75	30171.9
197	38809	7645373	14.0357	5.8186	2.29447	5.07614	618.89	30480.5
198	39204	7762392	14.0712	5.8285	2.29667	5.05051	622.04	30790.7
199	39601	7880599	14.1067	5.8383	2.29885	5.02513	625.18	31102.6
200	40000	8000000	14.1421	5.8480	2.30103	5.00000	628.32	31415.9
201	40401	8120601	14.1774	5.8578	2.30320	4.97512	631.46	31730.9
202	40804	8242408	14.2127	5.8675	2.30535	4.95050	634.60	32047.4
203	41209	8365427	14.2478	5.8771	2.30750	4.92611	637.74	32365.5
204	41616	8489664	14.2829	5.8868	2.30963	4.90196	640.89	32685.1
205	42025	8615125	14.3178	5.8964	2.31175	4.87805	644.03	33006.4
206	42436	8741816	14.3527	5.9059	2.31387	4.85437	647.17	33329.2
207	42849	8869743	14.3875	5.9155	2.31597	4.83092	650.31	33653.5
208	43264	8998912	14.4222	5.9250	2.31806	4.80769	653.45	33979.5
209	43681	9129329	14.4568	5.9345	2.32015	4.78469	656.59	34307.0
210	44100	9261000	14.4914	5.9439	2.32222	4.76190	659.73	34636.1
211	44521	9393931	14.5258	5.9533	2.32428	4.73934	662.88	34966.7
212	44944	9528128	14.5602	5.9627	2.32634	4.71698	666.02	35298.9
213	45369	9663597	14.5945	5.9721	2.32838	4.69484	669.16	35632.7
214	45796	9800344	14.6287	5.9814	2.33041	4.67290	672.30	35968.1
215	46225	9938375	14.6629	5.9907	2.33244	4.65116	675.44	36305.0
216	46656	10077696	14.6969	6.0000	2.33445	4.62963	678.58	36643.5
217	47089	10218313	14.7309	6.0092	2.33646	4.60829	681.73	36983.6
218	47524	10360232	14.7648	6.0185	2.33846	4.58716	684.87	37225.3
219	47961	10503459	14.7986	6.0277	2 34044	4.56621	688.01	37668.5
220	48400	10648000	14.8324	6.0368	2.34242	4.54545	691.15	38013.3
221	48841	10793861	14.8661	6 0459	2.34439	4.52489	694.29	38359.6
222	49284	10941048	14.8997	6.0550	2.34635	4.50450	697.43	38707.6
223	49729	11089567	14.9332	6.0641	2.34830	4.48431	700.58	39057.1
224	50176	11239424	14.9666	6.0732	2.35025	4.46429	703.72	39408.1

Squares, Cubes, Square Roots, Cube Roots, Logarithms, Etc.

(CONTINUED.)

No.	Sq.	Cube.	Square Root.	Cube Root.	Log.	1000 X Recip.	No. = Dia. Circ'm	Area.
225	50625	11390625	15.0000	6.0822	2.35218	4.44444	706.86	39760.8
226	51076	11543176	15.0333	6.0912	2.35411	4.42478	710.00	40115.0
227	51529	11697083	15.0665	6.1002	2.35603	4.40529	713.14	40470.8
228	51984	11852352	15.0997	6.1091	2.35793	4.38596	716.28	40828.1
229	52441	12008989	15.1327	6.1180	2.35984	4.36681	719.42	41187.1
230	52900	12167000	15.1658	6.1269	2.36173	4.34783	722.57	41547.6
231	53361	12326391	15.1987	6.1358	2.36361	4.32900	725.71	41909.6
232	53824	12487168	15.2315	6.1446	2.36549	4.31034	728.85	42273.3
233	54289	12649337	15.2643	6.1534	2.36736	4.29185	731.99	42638.5
234	54756	12812904	15.2971	6.1622	2.36922	4.27350	735.13	43005.3
235	55225	12977875	15.3297	6.1710	2.37107	4.25532	738.27	43373.6
236	55696	13144256	15.3623	6.1797	2.37291	4.23729	741.42	43743.5
237	56169	13312053	15.3948	6.1885	2.37475	4.21941	744.56	44115.0
238	56644	13481272	15.4272	6.1972	2.37658	4.20168	747.70	44488.1
239	57121	13651919	15.4596	6.2058	2.37840	4.18410	750.84	44862.7
240	57600	13824000	15.4919	6.2145	2.38021	4.16667	753.98	45238.9
241	58081	13997521	15.5242	6.2231	2.38202	4.14938	757.12	45616.7
242	58564	14172488	15.5563	6.2317	2.38382	4.13223	760.27	45996.1
243	59049	14348907	15.5885	6.2403	2.38561	4.11523	763.41	46377.0
244	59536	14526784	15.6205	6.2488	2.38739	4.09836	766.55	46759.5
245	60025	14706125	15.6525	6.2573	2.38917	4.08163	769.69	47143.5
246	60516	14886936	15.6844	6.2658	2.39094	4.06504	772.83	47529.2
247	61009	15069223	15.7162	6.2743	2.39270	4.04858	775.97	47916.4
248	61504	15252992	15.7480	6.2828	2.39445	4 03226	779.12	48305.1
249	62001	15438249	15.7797	6.2912	2.39620	4.01606	782.26	48695.5
250	62500	15625000	15.8114	6.2996	2.39794	4.00000	785.40	49087.4
251	63001	15813251	15.8430	6.3080	2.39967	3.98406	788.54	49480.9
252	63504	16003008	15.8745	6.3164	2.40140	3.96825	791.68	49875.9
253	64009	16194277	15.9060	6.3247	2.40312	3.95257	794.82	50272.6
254	64516	16387064	15.9374	6.3330	2.40483	3.93701	797.96	50670.7
255	65025	16581375	15.9687	6.3413	2.40654	3.92157	801.11	51070.5
256	65536	16777216	16.0000	6.3496	2.40824	3.90625	804.25	51471.9
257	66049	16974593	16.0312	6.3579	2.40993	3.89105	807.39	51874.8
258	66564	17173512	16.0624	6.3661	2.41162	3.87597	810.53	52279.2
259	67081	17373979	16.0935	6.3743	2.41330	3.86100	813.67	52685.3
260	67600	17576000	16.1245	6.3825	2.41497	3.84615	816.81	53092.9
261	68121	17779581	16.1555	6.3907	2.41664	3.83142	819.96	53502.1
262	68644	17984728	16.1864	6.3988	2 41830	3.81679	823.10	53912.9
263	69169	18191447	16.2173	6.4070	2.41996	3.80228	826.24	54325.2
264	69696	18399744	16.2481	6.4151	2.42160	3.78788	829.38	54739.1
265	70225	18609625	16.2788	6.4232	2.42325	3.77358	832.52	55154.6
266	70756	18821096	16.3095	6.4312	2.42488	3.75940	835.66	55571.6
267	71289	19034163	16.3401	6.4393	2.42651	3.74532	838.81	55990.3
268	71824	19248832	16.3707	6.4473	2.42813	3.73134	841.95	56410.4
269	72361	19465109	16.4012	6.4553	2.42975	3.71747	845.09	56832.2

Squares, Cubes, Square Roots, Cube Roots, Logarithms, Etc.

(CONTINUED.)

No.	Sq.	Cube.	Square Root.	Cube Root.	Log.	1000 X Recip.	No. = Dia. Circ'm	No. = Dia. Area.
270	72900	19683000	16 4317	6.4633	2.43136	3.70370	848.23	57255.5
271	73441	19902511	16.4621	6.4713	2.43297	3.69004	851.37	57680.4
272	73984	20123648	16.4924	6.4792	2.43457	3.67647	854.51	58106.9
273	74529	20346417	16.5227	6.4872	2.43616	3.66300	857.66	58534.9
274	75076	20570824	16.5529	6.4951	2.43775	3.64964	860.80	58964.6
275	75625	20796875	16.5831	6.5030	2.43933	3.63636	863.94	59395.7
276	76176	21024576	16.6132	6.5108	2.44091	3.62319	867.08	59828.5
277	76729	21253933	16.6433	6.5187	2.44248	3.61011	870.22	60262.8
278	77284	21484952	16.6733	6.5265	2.44404	3.59712	873.36	60698.7
279	77841	21717639	16.7033	6.5343	2.44560	3.58423	876.50	61136.2
280	78400	21952000	16.7332	6.5421	2.44716	3.57143	879.65	61575.2
281	78961	22188041	16.7631	6.5499	2.44871	3.55872	882.79	62015.8
282	79524	22425768	16.7929	6.5577	2.45025	3.54610	885.93	62458.0
283	80089	22665187	16.8226	6.5654	2.45179	3.53357	889.07	62901.8
284	80656	22906304	16.8523	6.5731	2.45332	3.52113	892.21	63347.1
285	81225	23149125	16.8819	6.5808	2.45484	3.50877	895.35	63794.0
286	81796	23393656	16.9115	6.5885	2.45637	3.49650	898.50	64242.4
287	82369	23639903	16.9411	6.5962	2.45788	3.48432	901.64	64692.5
288	82944	23887872	16.9706	6.6039	2.45939	3.47222	904.78	65144.1
289	83521	24137569	17.0000	6.6115	2.46090	3.46021	907.92	65597.2
290	84100	24389000	17.0294	6.6191	2.46240	3.44828	911.06	66052.0
291	84681	24642171	17.0587	6.6267	2.46389	3.43643	914.20	66508.3
292	85264	24897088	17.0880	6.6343	2.46538	3.42466	917.35	66966.2
293	85849	25153757	17.1172	6.6419	2.46687	3.41297	920.49	67425.6
294	86436	25412184	17.1464	6.6494	2.46835	3.40136	923.63	67886.7
295	87025	25672375	17.1756	6.6569	2.46982	3.38983	926.77	68349.3
296	87616	25934336	17.2047	6.6644	2.47129	3.37838	929.91	68813.5
297	88209	26198073	17.2337	6.6719	2.47276	3.36700	933.05	69279.2
298	88804	26463592	17.2627	6.6794	2.47422	3.35570	936.19	69746.5
299	89401	26730899	17.2916	6.6869	2.47567	3.34448	939.34	70215.4
300	90000	27000000	17.3205	6.6943	2.47712	3.33333	942.48	70685.8
301	90601	27270901	17.3494	6.7018	2.47857	3.32226	945.62	71157.9
302	91204	27543608	17.3781	6.7092	2.48001	3.31126	948.76	71631.5
303	91809	27818127	17.4069	6.7166	2.48144	3.30033	951.90	72106.6
304	92416	28094464	17.4356	6.7240	2.48287	3.28947	955.04	72583.4
305	93025	28372625	17.4642	6.7313	2.48430	3.27869	958.19	73061.7
306	93636	28652616	17.4929	6.7387	2.48572	3.26797	961.33	73541.5
307	94249	28934443	17.5214	6.7460	2.48714	3.25733	964.47	74023.0
308	94864	29218112	17.5499	6.7533	2.48855	3.24675	967.61	74506.0
309	95481	29503629	17.5784	6.7606	2.48996	3.23625	970.75	74990.6
310	96100	29791000	17.6068	6.7679	2.49136	3.22581	973.89	75476.8
311	96721	30080231	17.6352	6.7752	2.49276	3.21543	977.04	75964.5
312	97344	30371328	17.6635	6.7824	2.49415	3.20513	980.18	76453.8
313	97969	30664297	17.6918	6.7897	2.49554	3.19489	983.32	76944.7
314	98596	30959144	17.7200	6.7969	2.49693	3.18471	986.46	77437.1

Squares, Cubes, Square Roots, Cube Roots, Logarithms, Etc.

(CONTINUED.)

No.	Sq.	Cube.	Square Root.	Cube Root.	Log.	1000 X Recip	No = Dia. Circ'm	Area.
315	99225	31255875	17.7482	6.8041	2.49831	3.17460	989.60	77931.1
316	99856	31554496	17.7764	6.8113	2.49969	3.16456	992.74	78426.7
317	100489	31855013	17.8045	6.8185	2.50106	3.15457	995.88	78923.9
318	101124	32157432	17.8326	6.8256	2.50243	3.14465	999.03	79422.6
319	101761	32461759	17.8606	6.8328	2.50379	3.13480	1002.2	79922.9
320	102400	32768000	17.8885	6.8399	2.50515	3.12500	1005.3	80424.8
321	103041	33076161	17.9165	6.8470	2.50651	3.11527	1008.5	80928.2
322	103684	33386248	17.9444	6.8541	2.50786	3.10559	1011.6	81433.2
323	104329	33698267	17.9722	6.8612	2.50920	3.09598	1014.7	81939.8
324	104976	34012224	18.0000	6.8683	2.51055	3.08642	1017.9	82448.0
325	105625	34328125	18.0278	6.8753	2.51188	3.07692	1021.0	82957.7
326	106276	34645976	18.0555	6.8824	2.51322	3.06749	1024.2	83469.0
327	106929	34965783	18.0831	6.8894	2.51455	3.05810	1027.3	83981.8
328	107584	35287552	18.1108	6.8964	2.51587	3.04878	1030.4	84496.3
329	108241	35611289	18.1384	6.9034	2.51720	3.03951	1033.6	85012.3
330	108900	35937000	18.1659	6.9104	2.51851	3.03030	1036.7	85529.9
331	109561	36264691	18.1934	6.9174	2.51983	3.02115	1039.9	86049.0
332	110224	36594368	18.2209	6.9244	2.52114	3.01205	1043.0	86569.7
333	110889	36926037	18.2483	6.9313	2.52244	3.00300	1046.2	87092.0
334	111556	37259704	18.2757	6.9382	2.52375	2.99401	1049.3	87615.9
335	112225	37595375	18.3030	6 9451	2.52504	2.98507	1052.4	88141.3
336	112896	37933056	18.3303	6.9521	2.52634	2.97619	1055 6	88668.3
337	113569	38272753	18.3576	6.9589	2.52763	2.96736	1058.7	89196.9
338	114244	38614472	18.3848	6.9658	2.52892	2.95858	1061.9	89727.0
339	114921	38958219	18.4120	6.9727	2.53020	2.94985	1065.0	90258.7
340	115600	39304000	18.4391	6.9795	2.53148	2.94118	1068.1	90792.0
341	116281	39651821	18.4662	6 9864	2.53275	2.93255	1071.3	91326.9
342	116964	40001688	18.4932	6.9932	2.53403	2.92398	1074.4	91863.3
343	117649	40353607	18.5203	7.0000	2.53529	2.91545	1077.6	92401.3
344	118336	40707584	18.5472	7.0068	2.53656	2.90698	1080.7	92940.9
345	119025	41063625	18.5742	7.0136	2.53782	2.89855	1083.8	93482.0
346	119716	41421736	18.6011	7.0203	2.53908	2.89017	1087.0	94024.7
347	120409	41781923	18.6279	7.0271	2.54033	2.88184	1090.1	94569.0
348	121104	42144192	18.6548	7.0338	2.54158	2.87356	1093.3	95114.9
349	121801	42508549	18.6815	7.0406	2.54283	2.86533	1096.4	95662.3
350	122500	42875000	18.7083	7.0473	2.54407	2.85714	1099.6	96211.3
351	123201	43243551	18.7350	7.0540	2.54531	2.84900	1102.7	96761.8
352	123904	43614208	18.7617	7.0607	2.54654	2.84091	1105.8	97314.0
353	124609	43986977	18.7883	7.0674	2.54777	2.83286	1109.0	97867.7
354	125316	44361864	18.8149	7.0740	2.54900	2.82486	1112.1	98423.0
355	126025	44738875	18.8414	7.0807	2.55023	2.81690	1115.3	98979.8
356	126736	45118016	18.8680	7.0873	2 55145	2.80899	1118.4	99538.2
357	127449	45499293	18.8944	7.0940	2.55267	2.80112	1121.5	100098
358	128164	45882712	18.9209	7.1006	2.55388	2.79330	1124.7	100660
359	128881	46268279	18.9473	7.1072	2.55509	2.78552	1127.8	101223

Squares, Cubes, Square Roots, Cube Roots, Logarithms, Etc.

(CONTINUED.)

No.	Sq.	Cube.	Square Root.	Cube Root.	Log.	1000 X Recip.	No. = Dia. Circ'm	Area.
360	129600	46656000	18.9737	7.1138	2.55630	2.77778	1131.0	101788
361	130321	47045881	19.0000	7.1204	2.55751	2.77008	1134.1	102354
362	131044	47437928	19.0263	7.1269	2.55871	2.76243	1137.3	102922
363	131769	47832147	19.0526	7.1335	2.55991	2.75482	1140.4	103491
364	132496	48228544	19.0788	7.1400	2.56110	2.74725	1143.5	104062
365	133225	48627125	19.1050	7.1466	2.56229	2.73973	1146.7	104635
366	133956	49027896	19.1311	7.1531	2.56348	2.73224	1149.8	105209
367	134689	49430863	19.1572	7.1596	2.56467	2.72480	1153.0	105785
368	135424	49836032	19.1833	7.1661	2.56585	2.71739	1156.1	106362
369	136161	50243409	19.2094	7.1726	2.56703	2.71003	1159.2	106941
370	136900	50653000	19.2354	7.1791	2.56820	2.70270	1162.4	107521
371	137641	51064811	19.2614	7.1855	2.56937	2.69542	1165.5	108103
372	138384	51478848	19.2873	7.1920	2.57054	2.68817	1168.7	108687
373	139129	51895117	19.3132	7.1984	2.57171	2.68097	1171.8	109272
374	139876	52313624	19.3391	7.2048	2.57287	2.67380	1175.0	109858
375	140625	52734375	19.3649	7.2112	2.57403	2.66667	1178.1	110447
376	141376	53157376	19.3907	7.2177	2.57519	2.65957	1181.2	111036
377	142129	53582633	19.4165	7.2240	2.57634	2.65252	1184.4	111628
378	142884	54010152	19.4422	7.2304	2.57749	2.64550	1187.5	112221
379	143641	54439939	19.4679	7.2368	2.57864	2.63852	1190.7	112815
380	144400	54872000	19.4936	7.2432	2.57978	2.63158	1193.8	113411
381	145161	55306341	19.5192	7.2495	2.58093	2.62467	1196.9	114009
382	145924	55742968	19.5448	7.2558	2.58206	2.61780	1200.1	114608
383	146689	56181887	19.5704	7.2622	2.58320	2.61097	1203.2	115209
384	147456	56623104	19.5959	7.2685	2.58433	2.60417	1206.4	115812
385	148225	57066625	19.6214	7.2748	2.58546	2.59740	1209.5	116416
386	148996	57512456	19.6469	7.2811	2.58659	2.59067	1212.7	117021
387	149769	57960603	19.6723	7.2874	2.58771	2.58398	1215.8	117628
388	150544	58411072	19.6977	7.2936	2.58883	2.57732	1218.9	118237
389	151321	58863869	19.7231	7.2999	2.58995	2.57069	1222.1	118847
390	152100	59319000	19.7484	7.3061	2.59106	2.56410	1225.2	119459
391	152881	59776471	19.7737	7.3124	2.59218	2.55755	1228.4	120072
392	153664	60236288	19.7990	7.3186	2.59329	2.55102	1231.5	120687
393	154449	60698457	19.8242	7.3248	2.59439	2.54453	1234.6	121304
394	155236	61162984	19.8494	7.3310	2.59550	2.53807	1237.8	121922
395	156025	61629875	19.8746	7.3372	2.59660	2.53165	1240.9	122542
396	156816	62099136	19.8997	7.3434	2.59770	2.52525	1244.1	123163
397	157609	62570773	19.9249	7.3496	2.59879	2.51889	1247.2	123786
398	158404	63044792	19.9499	7.3558	2.59988	2.51256	1250.4	124410
399	159201	63521199	19.9750	7.3619	2.60097	2.50627	1253.5	125036
400	160000	64000000	20.0000	7.3681	2.60206	2.50000	1256.6	125664
401	160801	64481201	20.0250	7.3742	2.60314	2.49377	1259.8	126293
402	161604	64964808	20.0499	7.3803	2.60423	2.48756	1262.9	126923
403	162409	65450827	20.0749	7.3864	2.60531	2.48139	1266.1	127556
404	163216	65939264	20.0998	7.3925	2.60638	2.47525	1269.2	128190

Squares, Cubes, Square Roots, Cube Roots, Logarithms, Etc.

(CONTINUED.)

No.	Sq.	Cube.	Square Root.	Cube Root.	Log.	1000 X Recip.	No. = Dia. Circ'm	Area.
405	164025	66430125	20.1246	7.3986	2.60746	2.46914	1272.3	128825
406	164836	66923416	20.1494	7.4047	2.60853	2.46305	1275.5	129462
407	165649	67419143	20.1742	7.4108	2.60959	2.45700	1278.6	130100
408	166464	67917312	20.1990	7.4169	2.61066	2.45098	1281.8	130741
409	167281	68417929	20.2237	7.4229	2.61172	2.44499	1284 9	131382
410	168100	68921000	20.2485	7.4290	2.61278	2.43902	1288.1	132025
411	168921	69426531	20.2731	7.4350	2.61384	2.43309	1291.2	132670
412	169744	69934528	20.2978	7.4410	2.61490	2.42718	1294.3	133317
413	170569	70444997	20.3224	7.4470	2.61595	2.42131	1297.5	133965
414	171396	70957944	20.3470	7.4530	2.61700	2.41546	1300.6	134614
415	172225	71473375	20.3715	7.4590	2.61805	2.40964	1303.8	135265
416	173056	71991296	20.3961	7.4650	2.61909	2.40385	1306.9	135918
417	173889	72511713	20.4206	7.4710	2.62014	2.39808	1310.0	136572
418	174724	73034632	20.4450	7.4770	2.62118	2.39234	1313.2	137228
419	175561	73560059	20.4695	7.4829	2.62221	2.38664	1316.3	137885
420	176400	74088000	20.4939	7.4889	2.62325	2.38095	1319.5	138544
421	177241	74618461	20.5183	7.4948	2 62428	2.37530	1322.6	139205
422	178084	75151448	20.5426	7.5007	2.62531	2.36967	1325.8	139867
423	178929	75686967	20.5670	7.5067	2.62634	2.36407	1328.9	140531
424	179776	76225024	20.5913	7.5126	2.62737	2.35849	1332.0	141196
425	180625	76765625	20.6155	7.5185	2.62839	2.35294	1335.2	141863
426	181476	77308776	20.6398	7.5244	2.62941	2.34742	1338.3	142531
427	182329	77854483	20.6640	7.5302	2.63043	2.34192	1341.5	143201
428	183184	78402752	20.6882	7.5361	2.63144	2.33645	1344.6	143872
429	184041	78953589	20.7123	7.5420	2.63246	2.33100	1347.7	144545
430	184900	79507000	20.7364	7.5478	2.63347	2.32558	1350.9	145220
431	185761	80062991	20.7605	7.5537	2.63448	2.32019	1354.0	145896
432	186624	80621568	20.7846	7.5595	2.63548	2.31482	1357.2	146574
433	187489	81182737	20.8087	7.5654	2.63649	2.30947	1360.3	147254
434	188356	81746504	20 8327	7.5712	2.63749	2.30415	1363.5	147934
435	189225	82312875	20.8567	7.5770	2.63849	2.29885	1366.6	148617
436	190096	82881856	20.8806	7.5828	2.63949	2.29358	1369.7	149301
437	190969	83453453	20.9045	7.5886	2.64048	2 28833	1372.9	149987
438	191844	84027672	20.9284	7.5944	2.64147	2.28311	1376.0	150674
439	192721	84604519	20.9523	7.6001	2.64246	2.27790	1379.2	151363
440	193600	85184000	20.9762	7.6059	2.64345	2.27273	1382.3	152053
441	194481	85766121	21.0000	7.6117	2.64444	2.26757	1385.4	152745
442	195364	86350888	21.0238	7.6174	2.64542	2 26244	1388.6	153439
443	196249	86938307	21.0476	7.6232	2.64640	2.25734	1391.7	154134
444	197136	87528384	21.0713	7.6289	2.64738	2.25225	1394.9	154830
445	198025	88121125	21.0950	7.6346	2.64836	2.24719	1398.0	155528
446	198916	88716536	21.1187	7.6403	2.64933	2.24215	1401.2	156228
447	199809	89314623	21.1424	7.6460	2.65031	2.23714	1404.3	156930
448	200704	89915392	21.1660	7.6517	2.65128	2.23214	1407.4	157633
449	201601	90518849	21.1896	7.6574	2.65225	2.22717	1410.6	158337

Squares, Cubes, Square Roots, Cube Roots, Logarithms, Etc.

(CONTINUED.)

No.	Sq.	Cube.	Square Root.	Cube Root.	Log.	1000 X Recip.	No. = Dia.	
							Circ'm	Area.
450	202500	91125000	21.2132	7.6631	2.65321	2.22222	1413.7	159043
451	203401	91733851	21.2368	7.6688	2.65418	2.21730	1416.9	159751
452	204304	92345408	21.2603	7.6744	2.65514	2.21239	1420.0	160460
453	205209	92959677	21.2838	7.6801	2.65610	2.20751	1423.1	161171
454	206116	93576664	21.3073	7.6857	2.65706	2.20264	1426.3	161883
455	207025	94196375	21.3307	7.6914	2.65801	2.19780	1429.4	162597
456	207936	94818816	21.3542	7.6970	2.65896	2.19298	1432.6	163313
457	208849	95443993	21.3776	7.7026	2.65992	2.18818	1435.7	164030
458	209764	96071912	21.4009	7.7082	2 66087	2.18341	1438.9	164748
459	210681	96702579	21.4243	7.7138	2.66181	2.17865	1442.0	165468
460	211600	97336000	21.4476	7.7194	2.66276	2.17391	1445.1	166190
461	212521	97972181	21.4709	7.7250	2.66370	2.16920	1448.3	166914
462	213444	98611128	21.4942	7.7306	2.66464	2.16450	1451.4	167639
463	214369	99252847	21.5174	7.7362	2.66558	2.15983	1454.6	168365
464	215296	99897344	21.5407	7.7418	2.66652	2.15517	1457.7	169093
465	216225	100544625	21.5639	7.7473	2.66745	2.15054	1460.8	169823
466	217156	101194696	21.5870	7.7529	2.66839	2.14592	1464.0	170554
467	218089	101847563	21.6102	7.7584	2.66932	2.14133	1467.1	171287
468	219024	102503232	21.6333	7.7639	2.67025	2.13675	1470.3	172021
469	219961	103161709	21.6564	7.7695	2.67117	2.13220	1473.4	172757
470	220900	103823000	21.6795	7.7750	2.67210	2.12766	1476.5	173494
471	221841	104487111	21.7025	7.7805	2.67302	2.12314	1479.7	174234
472	222784	105154048	21.7256	7.7860	2.67394	2.11864	1482.8	174974
473	223729	105823817	21.7486	7.7915	2.67486	2.11417	1486.0	175716
474	224676	106496424	21.7715	7.7970	2.67578	2.10971	1489.1	176460
475	225625	107171875	21.7945	7.8025	2.67669	2.10526	1492.3	177205
476	226576	107850176	21.8174	7.8079	2.67761	2.10084	1495.4	177952
477	227529	108531333	21.8403	7.8134	2.67852	2.09644	1498.5	178701
478	228484	109215352	21.8632	7.8188	2.67943	2.09205	1501.7	179451
479	229441	109902239	21.8861	7.8243	2.68034	2.08768	1504.8	180203
480	230400	110592000	21.9089	7.8297	2.68124	2.08333	1508.0	180956
481	231361	111284641	21.9317	7.8352	2.68215	2.07900	1511.1	181711
482	232324	111980168	21.9545	7.8406	2.68305	2.07469	1514.3	182467
483	233289	112678587	21.9773	7.8460	2.68395	2.07039	1517.4	183225
484	234256	113379904	22.0000	7.8514	2.68485	2.06612	1520.5	183984
485	235225	114084125	22.0227	7.8568	2.68574	2.06186	1523.7	184745
486	236196	114791256	22.0454	7.8622	2.68664	2.05761	1526.8	185508
487	237169	115501303	22.0681	7.8676	2 68753	2.05339	1530.0	186272
488	238144	116214272	22.0907	7 8730	2.68842	2.04918	1533.1	187038
489	239121	116930169	22.1133	7.8784	2.68931	2.04499	1536.2	187805
490	240100	117649000	22.1359	7.8837	2.69020	2.04082	1539.4	188574
491	241081	118370771	22.1585	7.8891	2.69108	2.03666	1542.5	189345
492	242064	119095488	22.1811	7.8944	2.69197	2.03252	1545.7	190117
493	243049	119823157	22.2036	7.8998	2.69285	2.02840	1548.8	190890
494	244036	120553784	22.2261	7.9051	2.69373	2 02429	1551.9	191665

Squares, Cubes, Square Roots, Cube Roots, Logarithms, Etc.

(CONTINUED.)

No.	Sq.	Cube.	Square Root.	Cube Root.	Log.	1000 X Recip.	No. = Dia. Circ'm	Area.
495	245025	121287375	22.2486	7.9105	2.69461	2.02020	1555.1	192442
496	246016	122023936	22.2711	7.9158	2.69548	2.01613	1558.2	193221
497	247009	122763473	22.2935	7.9211	2.69636	2.01207	1561.4	194000
498	248004	123505992	22.3159	7.9264	2.69723	2.00803	1564.5	194782
499	249001	124251499	22.3383	7.9317	2.69810	2.00401	1567.7	195565
500	250000	125000000	22.3607	7.9370	2.69897	2.00000	1570.8	196350
501	251001	125751501	22.3830	7.9423	2.69984	1.99601	1573.9	197136
502	252004	126506008	22.4054	7.9476	2.70070	1.99203	1577.1	197923
503	253009	127263527	22.4277	7.9528	2.70157	1.98807	1580.2	198713
504	254016	128024064	22.4499	7.9581	2.70243	1.98413	1583.4	199504
505	255025	128787625	22.4722	7.9634	2.70329	1.98020	1586.5	200296
506	256036	129554216	22.4944	7.9686	2.70415	1.97629	1589.7	201090
507	257049	130323843	22.5167	7.9739	2.70501	1.97239	1592.8	201886
508	258064	131096512	22.5389	7.9791	2.70586	1.96850	1595.9	202683
509	259081	131872229	22.5610	7.9843	2.70672	1.96464	1599.1	203482
510	260100	132651000	22.5832	7.9896	2.70757	1.96078	1602.2	204282
511	261121	133432831	22.6053	7.9948	2.70842	1.95695	1605.4	205084
512	262144	134217728	22.6274	8.0000	2.70927	1.95312	1608.5	205887
513	263169	135005697	22.6495	8.0052	2.71012	1.94932	1611.6	206692
514	264196	135796744	22.6716	8.0104	2.71096	1.94553	1614.8	207499
515	265225	136590875	22.6936	8.0156	2.71181	1.94175	1617.9	208307
516	266256	137388096	22.7156	8.0208	2.71265	1.93798	1621.1	209117
517	267289	138188413	22.7376	8.0260	2.71349	1.93424	1624.2	209928
518	268324	138991832	22.7596	8.0311	2.71433	1.93050	1627.3	210741
519	269361	139798359	22.7816	8.0363	2.71517	1.92678	1630.5	211556
520	270400	140608000	22.8035	8.0415	2.71600	1 92308	1633.6	212372
521	271441	141420761	22.8254	8.0466	2.71684	1.91939	1636.8	213189
522	272484	142236648	22.8473	8 0517	2.71767	1 91571	1639.9	214008
523	273529	143055667	22.8692	8.0569	2.71850	1.91205	1643.1	214829
524	274576	143877824	22.8910	8.0620	2.71933	1.90840	1646.2	215651
525	275625	144703125	22.9129	8.0671	2.72016	1.90476	1649.3	216475
526	276676	145531576	22.9347	8.0723	2.72099	1.90114	1652.5	217301
527	277729	146363183	22.9565	8.0774	2.72181	1.89753	1655.6	218128
528	278784	147197952	22.9783	8.0825	2.72263	1.89394	1658.8	218956
529	279841	148035889	23.0000	8.0876	2.72346	1.89036	1661.9	219787
530	280900	148877000	23.0217	8.0927	2.72428	1.88679	1665.0	220618
531	281961	149721291	23.0434	8.0978	2.72509	1.88324	1668.2	221452
532	283024	150568768	23.0651	8.1028	2.72591	1.87970	1671.3	222287
533	284089	151419427	23.0868	8.1079	2.72673	1.87617	1674.5	223123
534	285156	152273304	23.1084	8.1130	2.72754	1.87266	1677.6	223961
535	286225	153130375	23.1301	8.1180	2.72835	1.86916	1680.8	224801
536	287296	153990656	23.1517	8.1231	2.72916	1.86567	1683.9	225642
537	288369	154854153	23.1733	8.1281	2.72997	1.86220	1687.0	226484
538	289444	155720872	23.1948	8.1332	2.73078	1.85874	1690.2	227329
539	290521	156590819	23.2164	8.1382	2.73159	1.85529	1693.3	228175

Squares, Cubes, Square Roots, Cube Roots, Logarithms, Etc.

(CONTINUED.)

No.	Sq.	Cube.	Square Root.	Cube Root.	Log.	1000 X Recip.	No. = Dia. Circ'm	Area.
540	291600	157464000	23.2379	8.1433	2.73239	1.85185	1696.5	229022
541	292681	158340421	23.2594	8.1483	2.73320	1.84843	1699.6	229871
542	293764	159220088	23.2809	8.1533	2.73400	1.84502	1702.7	230722
543	294849	160103007	23.3024	8.1583	2.73480	1.84162	1705.9	231574
544	295936	160989184	23.3238	8.1633	2.73560	1.83824	1709.0	232428
545	297025	161878625	23.3452	8.1683	2.73640	1.83486	1712.2	233283
546	298116	162771336	23.3666	8.1733	2.73719	1.83150	1715.3	234140
547	299209	163667323	23.3880	8.1783	2.73799	1.82815	1718.5	234998
548	300304	164566592	23.4094	8.1833	1·73878	1.82482	1721.6	235858
549	301401	165469149	23.4307	8.1882	2.73957	1.82149	1724.7	236720
550	302500	166375000	23.4521	8.1932	2.74036	1.81818	1727.9	237583
551	303601	167284151	23.4734	8.1982	2.74115	1.81488	1731.0	238448
552	304704	168196608	23.4947	8.2031	2.74194	1.81159	1734.2	239314
553	305809	169112377	23.5160	8.2081	2.74273	1.80832	1737.3	240182
554	306916	170031464	23.5372	8.2130	2.74351	1.80505	1740.4	241051
555	308025	170953875	23.5584	8.2180	2.74429	1.80180	1743.6	241922
556	309136	171879616	23.5797	8.2229	2.74507	1.79856	1746.7	242795
557	310249	172808693	23.6008	8.2278	2.74586	1.79533	1749.9	243669
558	311364	173741112	23.6220	8.2327	2 74663	1.79211	1753.0	244545
559	312481	174676879	23.6432	8.2377	2.74741	1.78891	1756.2	245422
560	313600	175616000	23 6643	8.2426	2.74819	1.78571	1759.3	246301
561	314721	176558481	23.6854	8.2475	2.74896	1.78253	1762.4	247181
562	315844	177504328	23.7065	8.2524	2.74974	1.77936	1765.6	248063
563	316969	178453547	23.7276	8.2573	2.75051	1.77620	1768.7	248947
564	318096	179406144	23.7487	8.2621	2.75128	1.77305	1771.9	249832
565	319225	180362125	23.7697	8.2670	2.75205	1.76991	1775.0	250719
566	320356	181321496	23.7908	8.2719	2.75282	1.76678	1778.1	251607
567	321489	182284263	23.8118	8.2768	2.75358	1.76367	1781.3	252497
568	322624	183250432	23.8328	8.2816	2.75435	1.76056	1784.4	253388
569	323761	184220009	23.8537	8.2865	2.75511	1.75747	1787.6	254281
570	324900	185193000	23.8747	8.2913	2.75587	1.75439	1790.7	255176
571	326041	186169411	23.8956	8.2962	2.75664	1.75131	1793.9	256072
572	327184	187149248	23.9165	8.3010	2.75740	1.74825	1797.0	256970
573	328329	188132517	23.9374	8.3059	2.75815	1.74520	1800.1	257869
574	329476	189119224	23.9583	8.3107	2.75891	1.74216	1803.3	258770
575	330625	190109375	23.9792	8.3155	2.75967	1.73913	1806.4	259672
576	331776	191102976	24.0000	8.3203	2.76042	1.73611	1809.6	260576
577	332929	192100033	24.0208	8.3251	2.76118	1.73310	1812.7	261482
578	334084	193100552	24.0416	8.3300	2.76193	1.73010	1815.8	262389
579	335241	194104539	24.0624	8.3348	2.76268	1.72712	1819.0	263298
580	336400	195112000	24.0832	8.3396	2.76343	1.72414	1822.1	264208
581	337561	196122941	24.1039	8.3443	2.76418	1.72117	1825.3	265120
582	338724	197137368	24.1247	8.3491	2.76492	1.71821	1828.4	266033
583	339889	198155287	24.1454	8.3539	2.76567	1.71527	1831.6	266948
584	341056	199176704	24.1661	8.3587	2.76641	1.71233	1834.7	267865

Squares, Cubes, Square Roots, Cube Roots, Logarithms, Etc.

(CONTINUED.)

No.	Sq.	Cube.	Square Root.	Cube Root.	Log.	1000 X Recip.	No. = Dia.	
							Circ'm	Area.
585	342225	200201625	24.1868	8.3634	2.76716	1.70940	1837.8	268783
586	343396	201230056	24.2074	8.3682	2.76790	1.70649	1841.0	269701
587	344569	202262003	24.2281	8.3730	2.76864	1.70358	1844.1	270624
588	345744	203297472	24.2487	8.3777	2.76938	1.70068	1847.3	271547
589	346921	204336469	24.2693	8.3825	2.77012	1.69779	1850.4	272471
590	348100	205379000	24.2899	8.3872	2.77085	1.69492	1853.5	273397
591	349281	206425071	24.3105	8.3919	2.77159	1.69205	1856.7	274325
592	350464	207474688	24.3311	8.3967	2.77232	1.68919	1859.8	275254
593	351649	208527857	24.3516	8.4014	2.77305	1.68634	1863.0	276184
594	352836	209584584	24.3721	8.4061	2.77379	1.68350	1866.1	277117
595	354025	210644875	24.3926	8.4108	2.77452	1.68067	1869.3	278051
596	355216	211708736	24.4131	8.4155	2.77525	1.67785	1872.4	278986
597	356409	212776173	24.4336	8.4202	2.77597	1.67504	1875.5	279923
598	357604	213847192	24.4540	8.4249	2.77670	1.67224	1878.7	280862
599	358801	214921799	24.4745	8.4296	2.77743	1.66945	1881.8	281802
600	360000	216000000	24.4949	8.4343	2.77815	1.66667	1885.0	282743
601	361201	217081801	24.5153	8.4390	2.77887	1.66389	1888.1	283687
602	362404	218167208	24.5357	8.4437	2.77960	1.66113	1891.2	284631
603	363609	219256227	24.5561	8.4484	2.78032	1.65837	1894.4	285578
604	364816	220348864	24.5764	8.4530	2.78104	1.65563	1897.5	286526
605	366025	221445125	24.5967	8.4577	2.78176	1.65289	1900.7	287475
606	367236	222545016	24.6171	8.4623	2.78247	1.65017	1903.8	288426
607	368449	223648543	24.6374	8.4670	2.78319	1.64745	1907.0	289379
608	369664	224755712	24.6577	8.4716	2.78390	1.64474	1910.1	290333
609	370881	225866529	24.6779	8.4763	2.78462	1.64204	1913.2	291289
610	372100	226981000	24.6982	8.4809	2.78533	1.63934	1916.4	292247
611	373321	228099131	24.7184	8.4856	2.78604	1.63666	1919.5	293206
612	374544	229220928	24.7386	8.4902	2.78675	1.63399	1922.7	294166
613	375769	230346397	24.7588	8.4948	2.78746	1.63132	1925.8	295128
614	376996	231475544	24.7790	8.4994	2.78817	1.62866	1928.9	296092
615	378225	232608375	24.7992	8.5040	2.78888	1.62602	1932.1	297057
616	379456	233744896	24.8193	8.5086	2.78958	1.62338	1935.2	298024
617	380689	234885113	24.8395	8.5132	2.79029	1.62075	1938.4	298992
618	381924	236029032	24.8596	8.5178	2.79099	1.61812	1941.5	299962
619	383161	237176659	24.8797	8.5224	2.79169	1.61551	1944.7	300934
620	384400	238328000	24.8998	8.5270	2.79239	1.61290	1947.8	301907
621	385641	239483061	24.9199	8.5316	2.79309	1.61031	1950.9	302882
622	386884	240641848	24.9399	8.5362	2.79379	1.60772	1954.1	303858
623	388129	241804367	24.9600	8.5408	2.79449	1.60514	1957.2	304836
624	389376	242970624	24.9800	8.5453	2.79518	1.60256	1960.4	305815
625	390625	244140625	25.0000	8.5499	2.79588	1.60000	1963.5	306796
626	391876	245314376	25.0200	8.5544	2.79657	1.59744	1966.6	307779
627	393129	246491883	25.0400	8.5590	2.79727	1.59490	1969.8	308763
628	394384	247673152	25.0599	8.5635	2.79796	1.59236	1972.9	309748
629	395641	248858189	25.0799	8.5681	2.79865	1.58983	1976.1	310736

Squares, Cubes, Square Roots, Cube Roots, Logarithms, Etc.

(CONTINUED.)

No.	Sq.	Cube.	Square Root.	Cube Root.	Log.	1000 X Recip.	No. = Dia.	
							Circ'm	Area.
630	396900	250047000	25.0998	8.5726	2.79934	1.58730	1979.2	311725
631	398161	251239591	25.1197	8.5772	2.80003	1.58479	1982.4	312715
632	399424	252435968	25.1396	8.5817	2.80072	1.58228	1985.5	313707
633	400689	253636137	25.1595	8.5862	2.80140	1.57978	1988.6	314700
634	401956	254840104	25.1794	8.5907	2.80209	1.57729	1991.8	315696
635	403225	256047875	25.1992	8 5952	2.80277	1.57480	1994 9	316692
636	404496	257259456	25.2190	8.5997	2.80346	1.57233	1998.1	317690
637	405769	258474853	25.2389	8.6043	2.80414	1.56986	2001.2	318690
638	407044	259694072	25.2587	8.6088	2.80482	1.56740	2004.3	319692
639	408321	260917119	25.2784	8.6132	2.80550	1.56495	2007.5	320695
640	409600	262144000	25.2982	8.6177	2.80618	1.56250	2010.6	321699
641	410881	263374721	25.3180	8.6222	2 80686	1.56006	2013.8	322705
642	412164	264609288	25.3377	8.6267	2.80754	1.55763	2016.9	323713
643	413449	265847707	25.3574	8.6312	2.80821	1.55521	2020.0	324722
644	414736	267089984	25.3772	8.6357	2.80889	1.55280	2023.2	325733
645	416025	268336125	25.3969	8.6401	2.80956	1.55039	2026.3	326745
646	417316	269586136	25.4165	8.6446	2.81023	1.54799	2029.5	327759
647	418609	270840023	25.4362	8.6490	2.81090	1.54560	2032.6	328775
648	419904	272097792	25.4558	8.6535	2.81158	1.54321	2035.8	329792
649	421201	273359449	25.4755	8.6579	2.81224	1.54083	2038.9	330810
650	422500	274625000	25.4951	8.6624	2.81291	1.53846	2042.0	331831
651	423801	275894451	25.5147	8.6668	2.81358	1.53610	2045.2	332853
652	425104	277167808	25.5343	8.6713	2.81425	1.53374	2048.3	333876
653	426409	278445077	25.5539	8.6757	2.81491	1.53139	2051.5	334901
654	427716	279726264	25.5734	8.6801	2.81558	1.52905	2054.6	335927
655	429025	281011375	25.5930	8.6845	2.81624	1.52672	2057.7	336955
656	430336	282300416	25.6125	8.6890	2.81690	1.52439	2060 9	337985
757	431649	283593393	25 6320	8.6934	2.81757	1.52207	2064.0	339016
758	432964	284890312	25.6515	8.6978	2.81823	1.51976	2067.2	340049
659	434281	286191179	25.6710	8.7022	2.81889	1.51745	2070.3	341084
660	435600	287496000	25.6905	8.7066	2.81954	1.51515	2073.5	342119
661	436921	288804781	25.7099	8.7110	2.82020	1.51286	2076.6	343157
662	438244	290117528	25 7294	8.7154	2.82086	1.51057	2079.7	344196
663	439569	291434247	25.7488	8.7198	2.82151	1.50830	2082.9	345237
664	440896	292754944	25.7682	8.7241	2.82217	1.50602	2086.0	346279
665	442225	294079625	25.7876	8.7285	2.82282	1.50376	2089.2	347323
666	443556	295408296	25.8070	8.7329	2.82347	1.50150	2092.3	348368
667	444889	296740963	25.8263	8.7373	2.82413	1.49925	2095.4	349415
668	446224	298077632	25.8457	8.7416	2.82478	1.49701	2098.6	350464
669	447561	299418309	25.8650	8.7460	2.82543	1.49477	2101.7	351514
670	448900	300763000	25.8844	8.7503	2.82607	1.49254	2104.9	352565
671	450241	302111711	25.9037	8.7547	2.82672	1.49031	2108.0	353618
672	451584	303464448	25.9230	8.7590	2.82737	1.48810	2111.2	354673
673	452929	304821217	25.9422	8.7634	2.82802	1.48588	2114.3	355730
674	454276	306182024	25.9615	8.7677	2.82866	1.48368	2117.4	356788

Squares, Cubes, Square Roots, Cube Roots, Logarithms, Etc.

(CONTINUED.)

No.	Sq.	Cube.	Square Root.	Cube Root.	Log.	1000 X Recip	No. = Dia. Circ'm	Area.
675	455625	307546875	25.9808	8.7721	2.82930	1.48148	2120.6	357847
676	456976	308915776	26.0000	8.7764	2.82995	1.47929	2123.7	358908
677	458329	310288733	26.0192	8.7807	2.83059	1.47711	2126.9	359971
678	459684	311665752	26.0384	8.7850	2.83123	1.47493	2130.0	361035
679	461041	313046839	26.0576	8.7893	2.83187	1.47275	2133.1	362101
680	462400	314432000	26.0768	8.7937	2.83251	1.47059	2136.3	363168
681	463761	315821241	26.0960	8.7980	2.83315	1.46843	2139.4	364237
682	465124	317214568	26.1151	8.8023	2.83378	1.46628	2142.6	365308
683	466489	318611987	26.1343	8.8066	2.83442	1.46413	2145.7	366380
684	467856	320013504	26.1534	8.8109	2.83506	1.46199	2148.9	367453
685	469225	321419125	26.1725	8.8152	2.83569	1.45985	2152.0	368528
686	470596	322828856	26.1916	8.8194	2.83632	1.45773	2155.1	369605
687	471969	324242703	26.2107	8.8237	2.83696	1.45560	2158.3	370684
688	473344	325660672	26.2298	8.8280	2.83759	1.45349	2161.4	371764
689	474721	327082769	26.2488	8.8323	2.83822	1.45138	2164.6	372845
690	476100	328509000	26.2679	8.8366	2.83885	1.44928	2167.7	373928
691	477481	329939371	26.2869	8.8408	2.83948	1.44718	2170.8	375013
692	478864	331373888	26.3059	8.8451	2 84011	1.44509	2174.0	376099
693	480249	332812557	26.3249	8.8493	2.84073	1.44300	2177.1	377187
694	481636	334255384	26.3439	8.8536	2.84136	1.44092	2180.3	378276
695	483025	335702375	26.3629	8.8578	2.84198	1.43885	2183.4	379367
696	484416	337153536	26.3818	8.8621	2.84261	1.43678	2186.6	380459
697	485809	338608873	26.4008	8.8663	2.84323	1.43472	2189.7	381554
698	487204	340068392	26.4197	8.8706	2.84386	1.43267	2192.8	382649
699	488601	341532099	26.4386	8.8748	2.84448	1.43062	2196.0	383746
700	490000	343000000	26.4575	8.8790	2.84510	1.42857	2199.1	385845
701	491401	344472101	26.4764	8.8833	2.84572	1.42653	2202.3	385945
702	492804	345948408	26.4953	8.8875	2.84634	1.42450	2205.4	387047
703	494209	347428927	26.5141	8 8917	2.84696	1.42248	2208.5	388151
704	495616	348913664	26.5330	8.8959	2.84757	1.42046	2211.7	389256
705	497025	350402625	26.5518	8.9001	2 84819	1.41844	2214.8	390363
706	498436	351895816	26.5707	8.9043	2.84880	1.41643	2218.0	391471
707	499849	353393243	26.5895	8 9085	2.84942	1.41443	2221.1	392580
708	501264	354894912	26.6083	8.9127	2.85003	1.41243	2224.3	393692
709	502681	356400829	26.6271	8.9169	2.85065	1.41044	2227.4	394805
710	504100	357911000	26 6458	8.9211	2.85126	1.40845	2230.5	395919
711	505521	359425431	26.6646	8.9253	2.85187	1.40647	2233.7	397035
712	506944	360944128	26.6833	8.9295	2.85248	1.40449	2236.8	398153
713	508369	362467097	26.7021	8.9337	2.85309	1.40253	2240.0	399272
714	509796	363994344	26.7208	8.9378	2.85370	1.40056	2243.1	400393
715	511225	365525875	26.7395	8.9420	2.85431	1.39860	2246.2	401515
716	512656	367061696	26.7582	8.9462	2.85491	1.39665	2249.4	402639
717	514089	368601813	26.7769	8.9503	2.85552	1.39470	2252.5	403765
718	515524	370146232	26.7955	8.9545	2.85612	1.39276	2255.7	404892
719	516961	371694959	26.8142	8.9587	2.85673	1.39082	2258.8	406020

Squares, Cubes, Square Roots, Cube Roots, Logarithms, Etc.

(CONTINUED.)

No.	Sq	Cube.	Square Root.	Cube Root.	Log.	1000 X Recip.	No. = Dia.	
							Circ'm	Area
720	518400	373248000	26.8328	8.9628	2.85733	1.38889	2261.9	407150
721	519841	374805361	26.8514	8.9670	2.85794	1.38696	2265.1	408282
722	521284	376367048	26.8701	8.9711	2.85854	1.38504	2268.2	409416
723	522729	377933067	26.8887	8.9752	2.85914	1.38313	2271.4	410550
724	524176	379503424	26.9072	8.9794	2.85974	1.38122	2274.5	411687
725	525625	381078125	26.9258	8.9835	2.86034	1.37931	2277.7	412825
726	527076	382657176	26.9444	8.9876	2.86094	1.37741	2280.8	413965
727	528529	384240583	26.9629	8.9918	2.86153	1.37552	2283.9	415106
728	529984	385828352	26.9815	8.9959	2.86213	1.37363	2287.1	416248
729	531441	387420489	27.0000	9.0000	2.86273	1.37174	2290.2	417393
730	532900	389017000	27.0185	9.0041	2.86332	1.36986	2293.4	418539
731	534361	390617891	27.0370	9.0082	2.86392	1.36799	2296.5	419686
732	535824	392223168	27.0555	9.0123	2.86451	1.36612	2299.7	420835
733	537289	393832837	27.0740	9.0164	2.86510	1.36426	2302 8	421986
734	538756	395446904	27.0924	9.0205	2.86570	1.36240	2305.9	423138
735	540225	397065375	27.1109	9.0246	2.86629	1.36054	2309.1	424293
736	541696	398688256	27.1293	9.0287	2.86688	1.35870	2312.2	425448
737	543169	400315553	27.1477	9.0328	2.86747	1.35685	2315.4	426604
738	544644	401947272	27.1662	9.0369	2.86806	1.35501	2318.5	427762
739	546121	403583419	27.1846	9.0410	2.86864	1.35318	2321.6	428922
740	547600	405224000	27.2029	9.0450	2.86923	1.35135	2324.8	430084
741	549081	406869021	27.2213	9.0491	2.86982	1.34953	2327.9	431247
742	550564	408518488	27.2397	9.0532	2.87040	1.34771	2331.1	432412
743	552049	410172407	27.2580	9.0572	2.87099	1.34590	2334.2	433578
744	553536	411830784	27.2764	9.0613	2.87157	1.34409	2337.3	434746
745	555025	413493625	27.2947	9.0654	2.87216	1.34228	2340.5	435916
746	556516	415160936	27.3130	9.0694	2.87274	1.34048	2343.6	437087
747	558009	416832723	27.3313	9.0735	2.87332	1.33869	2346.8	438259
748	559504	418508992	27.3496	9.0775	2.87390	1.33690	2349.9	439433
749	561001	420189749	27.3679	9.0816	2.87448	1.33511	2353.1	440609
750	562500	421875000	27.3861	9.0856	2.87506	1.33333	2356.2	441786
751	564001	423564751	27.4044	9.0896	2.87564	1.33156	2359.3	442965
752	565504	425259008	27.4226	9.0937	2.87622	1.32979	2362.5	444146
753	567009	426957777	27.4408	9.0977	2.87680	1.32802	2365.6	445328
754	568516	428661064	27.4591	9.1017	2.87737	1.32626	2368.8	446511
755	570025	430368875	27.4773	9.1057	2.87795	1.32450	2371.9	447697
756	571536	432081216	27.4955	9.1098	2.87852	1.32275	2375.0	448883
757	573049	433798093	27.5136	9.1138	2.87910	1.32100	2378.2	450072
758	574564	435519512	27.5318	9.1178	2.87967	1.31926	2381.3	451262
759	576081	437245479	27.5500	9.1218	2.88024	1.31752	2384.5	452453
760	577600	438976000	27.5681	9.1258	2.88081	1.31579	2387.6	453646
761	579121	440711081	27.5862	9.1298	2.88138	1.31406	2390.8	454841
762	580644	442450728	27.6043	9.1338	2.88196	1.31234	2393.9	456037
763	582169	444194947	27.6225	9.1378	2.88252	1.31062	2397.0	457234
764	583696	445943744	27.6405	9.1418	2.88309	1.30890	2400.2	458434

Squares, Cubes, Square Roots, Cube Roots, Logarithms, Etc.

(CONTINUED.)

No.	Sq.	Cube.	Square Root.	Cube Root.	Log	1000 x Recip.	No. = Dia. Circ'm	Area
765	585225	447697125	27.6586	9.1458	2.88366	1.30719	2403.3	459635
766	586756	449455096	27.6767	9.1498	2.88423	1.30548	2406.5	460837
767	588289	451217663	27.6948	9.1537	2.88480	1.30378	2409.6	462042
768	589824	452984832	27.7128	9.1577	2.88536	1.30208	2412.7	463247
769	591361	454756609	27.7308	9.1617	2.88593	1.30039	2415.9	464454
770	592900	456533000	27.7489	9.1657	2.88649	1.29870	2419.0	465663
771	594441	458314011	27.7669	9.1696	2.88705	1.29702	2422.2	466873
772	595984	460099648	27.7849	9.1736	2.88762	1.29534	2425.3	468085
773	597529	461889917	27.8029	9.1775	2.88818	1.29366	2428.5	469298
774	599076	463684824	27.8209	9.1815	2.88874	1.29199	2431.6	470513
775	600625	465484375	27.8388	9.1855	2.88930	1.29032	2434.7	471730
776	602176	467288576	27.8568	9.1894	2.88986	1.28866	2437.9	472948
777	603729	469097433	27.8747	9.1933	2.89042	1.28700	2441.0	474168
778	605284	470910952	27.8927	9.1973	2.89098	1.28535	2444.2	475389
779	606841	472729139	27.9106	9.2012	2.89154	1.28370	2447.3	476612
780	608400	474552000	27.9285	9.2052	2.89209	1.28205	2450.4	477836
781	609961	476379541	27.9464	9.2091	2.89265	1.28041	2453.6	479062
782	611524	478211768	27.9643	9 2130	2.89321	1.27877	2456.7	480290
783	613089	480048687	27.9821	9.2170	2.89376	1.27714	2459.9	481519
784	614656	481890304	28.0000	9.2209	2.89432	1.27551	2463.0	482750
785	616225	483736625	28.0179	9.2248	2.89487	1.27389	2466.2	483982
786	617796	485587656	28.0357	9.2287	2.89542	1.27226	2469.3	485216
787	619369	487443403	28.0535	9.2326	2.89597	1.27065	2472.4	486451
788	620944	489303872	28.0713	9.2365	2.89653	1.26904	2475.6	487688
789	622521	491169069	28.0891	9.2404	2.89708	1.26743	2478.7	488927
790	624100	493039000	28.1069	9.2443	2.89763	1.26582	2481.9	490167
791	625681	494913671	28.1247	9.2482	2.89818	1.26422	2485.0	491409
792	627264	496793088	28.1425	9.2521	2.89873	1.26263	2488.1	492652
793	628849	498677257	28.1603	9.2560	2.89927	1.26103	2491.3	493897
794	630436	500566184	28.1780	9.2599	2.89982	1.25945	2494.4	495143
795	632025	502459875	28.1957	9.2638	2.90037	1.25786	2497.6	496391
796	633616	504358336	28.2135	9.2677	2.90091	1.25628	2500.7	497641
797	635209	506261573	28.2312	9.2716	2.90146	1.25471	2503.8	498892
798	636804	508169592	28.2489	9.2754	2.90200	1.25313	2507.0	500145
799	638401	510082399	28.2666	9.2793	2.90255	1.25156	2510.1	501399
800	640000	512000000	28.2843	9.2832	2.90309	1.25000	2513.3	502655
801	641601	513922401	28.3019	9.2870	2.90363	1.24844	2516.4	503912
802	643204	515849608	28.3196	9.2909	2.90417	1.24688	2519.6	505171
803	644809	517781627	28.3373	9.2948	2.90472	1.24533	2522.7	506432
804	646416	519718464	28.3549	9.2986	2.90526	1.24378	2525.8	507694
805	648025	521660125	28.3725	9.3025	2.90580	1.24224	2529.0	508958
806	649636	523606616	28.3901	9.3063	2.90634	1.24069	2532.1	510223
807	651249	525557943	28.4077	9.3102	2.90687	1.23916	2535.3	511490
808	652864	527514112	28.4253	9.3140	2.90741	1.23762	2538.4	512758
809	654481	529475129	28.4429	9.3179	2.90795	1.23609	2541.5	514028

Squares, Cubes, Square Roots, Cube Roots, Logarithms, Etc.

(CONTINUED.)

No.	Sq.	Cube.	Square Root.	Cube Root.	Log.	1000 X Recip	No. = Dia. Circ'm	No. = Dia. Area.
810	656100	531441000	28.4605	9.3217	2.90849	1.23457	2544.7	515300
811	657721	533411731	28.4781	9.3255	2.90902	1.23305	2547.8	516573
812	659344	535387328	28.4956	9.3294	2.90956	1.23153	2551.0	517848
813	660969	537367797	28.5132	9.3332	2.91009	1.23001	2554.1	519124
814	662596	539353144	28.5307	9.3370	2.91062	1.22850	2557.3	520402
815	664225	541343375	28.5482	9.3408	2.91116	1.22699	2560.4	521681
816	665856	543338496	28.5657	9.3447	2.91169	1.22549	2563.5	522962
817	667489	545338513	28.5832	9.3485	2.91222	1.22399	2566.7	524245
818	669124	547343432	28.6007	9.3523	2.91275	1.22249	2569.8	525529
819	670761	549353259	28.6182	9.3561	2.91328	1.22100	2573.0	526814
820	672400	551368000	28.6356	9.3599	2.91381	1.21951	2576.1	528102
821	674041	553387661	28.6531	9.3637	2.91434	1.21803	2579.2	529391
822	675684	555412248	28.6705	9.3675	2.91487	1.21655	2582.4	530681
823	677329	557441767	28.6880	9.3713	2.91540	1.21507	2585.5	531973
824	678976	559476224	28.7054	9.3751	2.91593	1.21359	2588.7	533267
825	680625	561515625	28.7228	9.3789	2.91645	1.21212	2591.8	534562
826	682276	563559976	28.7402	9.3827	2.91698	1.21065	2595.0	535858
827	683929	565609283	28.7576	9.3865	2.91751	1.20919	2598.1	537157
828	685584	567663552	28.7750	9.3902	2.91803	1.20773	2601.2	538456
829	687241	569722789	28.7924	9.3940	2.91855	1.20627	2604.4	539758
830	688900	571787000	28.8097	9.3978	2.91908	1.20482	2607.5	541061
831	690561	573856191	28.8271	9.4016	2.91960	1.20337	2610.7	542365
832	692224	575930368	28.8444	9.4053	2.92012	1.20192	2613.8	543671
833	693889	578009537	28.8617	9.4091	2.92065	1.20048	2616.9	544979
834	695556	580093704	28.8791	9.4129	2.92117	1.19904	2620.1	546288
835	697225	582182875	28.8964	9.4166	2.92169	1.19760	2623.2	547599
836	698896	584277056	28.9137	9.4204	2.92221	1.19617	2626.4	548912
837	700569	586376253	28.9310	9.4241	2.92273	1.19474	2629.5	550226
838	702244	588480472	28.9482	9.4279	2.92324	1.19332	2632.7	551541
839	703921	590589719	28.9655	9.4316	2.92376	1.19190	2635.8	552858
840	705600	592704000	28.9828	9.4354	2.92428	1.19048	2638.9	554177
841	707281	594823321	29.0000	9.4391	2.92480	1.18906	2642.1	555497
842	708964	596947688	29.0172	9.4429	2.92531	1.18765	2645.2	556819
843	710649	599077107	29.0345	9.4466	2.92583	1.18624	2648.4	558142
844	712336	601211584	29.0517	9.4503	2.92634	1.18483	2651.5	559467
845	714025	603351125	29.0689	9.4541	2.92686	1.18343	2654.6	560794
846	715716	605495736	29.0861	9.4578	2.92737	1.18203	2657.8	562122
847	717409	607645423	29.1033	9.4615	2.92788	1.18064	2660.9	563452
848	719104	609800192	29.1204	9.4652	2.92840	1.17925	2664.1	564783
849	720801	611960049	29.1376	9.4690	2.92891	1.17786	2667.2	566116
850	722500	614125000	29.1548	9.4727	2.92942	1.17647	2670.4	567450
851	724201	616295051	29.1719	9.4764	2.92993	1.17509	2673.5	568786
852	725904	618470208	29.1890	9.4801	2.93044	1.17371	2676.6	570124
853	727609	620650477	29.2062	9.4838	2.93095	1.17233	2679.8	571463
854	729316	622835864	29.2233	9.4875	2.93146	1.17096	2682.9	572803

Squares, Cubes, Square Roots, Cube Roots, Logarithms, Etc.

(CONTINUED.)

No.	Sq.	Cube.	Square Root.	Cube Root.	Log.	1000 X Recip.	No. = Dia Circ'm	Area.
855	731025	625026375	29.2404	9.4912	2.93197	1.16959	2686.1	574146
856	732736	627222016	29.2575	9.4949	2.93247	1.16822	2689.2	575490
857	734449	629422793	29.2746	9.4986	2.93298	1.16686	2692.3	576835
858	736164	631628712	29.2916	9.5023	2.93349	1.16550	2695.5	578182
859	737881	633839779	29.3087	9.5060	2.93399	1.16414	2698.6	579530
860	739600	636056000	29.3258	9.5097	2.93450	1.16279	2701.8	580880
861	741321	638277381	29.3428	9.5134	2.93500	1.16144	2704.9	582232
862	743044	640503928	29.3598	9.5171	2.93551	1.16009	2708.1	583585
863	744769	642735647	29.3769	9.5207	2.93601	1.15875	2711.2	584940
864	746496	644972544	29.3939	9.5244	2.93651	1.15741	2714.3	586297
865	748225	647214625	29.4109	9.5281	2.93702	1.15607	2717.5	587655
866	749956	649461896	29.4279	9.5317	2.93752	1.15473	2720.6	589014
867	751689	651714363	29.4449	9.5354	2.93802	1.15340	2723.8	590375
868	753424	653972032	29.4618	9.5391	2.93852	1.15207	2726.9	591738
869	755161	656234909	29.4788	9.5427	2.93902	1.15075	2730.0	593102
870	756900	658503000	29.4958	9.5464	2.93952	1 14943	2733.2	594468
871	758641	660776311	29.5127	9.5501	2.94002	1.14811	2736.3	595835
872	760384	663054848	29.5296	9.5537	2.94052	1.14679	2739.5	597204
873	762129	665338617	29.5466	9.5574	2.94101	1.14548	2742.6	598575
874	763876	667627624	29.5635	9.5610	2.94151	1.14416	2745.8	599947
875	765625	669921875	29.5804	9 5647	2.94201	1.14286	2748.9	601320
876	767376	672221376	29.5973	9.5683	2.94250	1.14155	2752.0	602696
877	769129	674526133	29.6142	9.5719	2.94300	1.14025	2755.2	604073
878	770884	676836152	29.6311	9.5756	2.94349	1.13895	2758.3	605451
879	772641	679151439	29.6479	9.5792	2.94399	1.13766	2761.5	606831
880	774400	681472000	29.6648	9.5828	2.94448	1.13636	2764.6	608212
881	776161	683797841	29.6816	9.5865	2.94498	1.13507	2767.7	609595
882	777924	686128968	29.6985	9.5901	2.94547	1.13379	2770.9	610980
883	779689	688465387	29.7153	9.5937	2.94596	1.13250	2774.0	612366
884	781456	690807104	29.7321	9.5973	2.94645	1.13122	2777.2	613754
885	783225	693154125	29.7489	9.6010	2.94694	1.12994	2780.3	615143
886	784996	695506456	29.7658	9.6046	2.94743	1.12867	2783.5	616534
887	786769	697864103	29.7825	9.6082	2.94792	1.12740	2786.6	617927
888	788544	700227072	29 7993	9.6118	2 94841	1.12613	2789.7	619321
889	790321	702595369	29.8161	9.6154	2.94890	1.12486	2792.9	620717
890	792100	704969000	29.8329	9.6190	2.94939	1.12360	2796.0	622114
891	793881	707347971	29.8496	9.6226	2.94988	1.12233	2799.2	623513
892	795664	709732288	29.8664	9 6262	2.95036	1.12108	2802.3	624913
893	797449	712121957	29.8831	9.6298	2.95085	1.11982	2805.4	626315
894	799236	714516984	29.8998	9.6334	2.95134	1.11857	2808.6	627718
895	801025	716917375	29.9166	9.6370	2.95182	1.11732	2811.7	629124
896	802816	719323136	29.9333	9.6406	2.95231	1.11607	2814.9	630530
897	804609	721734273	29.9500	9.6442	2.95279	1.11483	2818.0	631938
898	806404	724150792	29.9666	9.6477	2.95328	1.11359	2821.2	633348
899	808201	726572699	29.9833	9.6513	2.95376	1.11235	2824.3	634760

Squares, Cubes, Square Roots, Cube Roots, Logarithms, Etc.

(CONTINUED.)

No.	Sq.	Cube.	Square Root.	Cube Root.	Log.	1000 X Recip.	No. = Dia. Circ'm	Area.
900	810000	729000000	30.0000	9.6549	2.95424	1.11111	2827.4	636173
901	811801	731432701	30.0167	9.6585	2.95472	1.10988	2830.6	637587
902	813604	733870808	30.0333	9.6620	2.95521	1.10865	2833.7	639003
903	815409	736314327	30.0500	9.6656	2.95569	1.10742	2836.9	640421
904	817216	738763264	30.0666	9.6692	2.95617	1.10619	2840.0	641840
905	819025	741217625	30.0832	9.6727	2.95665	1.10497	2843.1	643261
906	820836	743677416	30.0998	9.6763	2.95713	1.10375	2846.3	644683
907	822649	746142643	30.1164	9.6799	2.95761	1.10254	2849.4	646107
908	824464	748613312	30.1330	9.6834	2.95809	1.10132	2852.6	647533
909	826281	751089429	30.1496	9.6870	2.95856	1.10011	2855.7	648960
910	828100	753571000	30.1662	9.6905	2.95904	1.09890	2858.8	650388
911	829921	756058031	30.1828	9.6941	2.95952	1.09769	2862.0	651818
912	831744	758550528	30.1993	9.6976	2.95999	1.09649	2865.1	653250
913	833569	761048497	30.2159	9.7012	2.96047	1.09529	2868.3	654684
914	835396	763551944	30.2324	9.7047	2.96095	1.09409	2871.4	656118
915	837225	766060875	30.2490	9.7082	2.96142	1.09290	2874.6	657555
916	839056	768575296	30.2655	9.7118	2.96190	1.09170	2877.7	658993
917	840889	771095213	30.2820	9.7153	2.96237	1.09051	2880.8	660433
918	842724	773620632	30.2985	9.7188	2.96284	1.08932	2884.0	661874
919	844561	776151559	30.3150	9.7224	2.96332	1.08814	2887.1	663317
920	846400	778688000	30.3315	9.7259	2.96379	1.08696	2890.3	664761
921	848241	781229961	30.3480	9.7294	2.96426	1.08578	2893.4	666207
922	850084	783777448	30.3645	9.7329	2.96473	1.08460	2896.5	667654
923	851929	786330467	30.3809	9.7364	2.96520	1.08342	2899.7	669103
924	853776	788889024	30.3974	9.7400	2.96567	1.08225	2902.8	670554
925	855625	791453125	30.4138	9.7435	2.96614	1.08108	2906.0	672006
926	857476	794022776	30.4302	9.7470	2.96661	1.07991	2909.1	673460
927	859329	796597983	30.4467	9.7505	2.96708	1.07875	2912.3	674915
928	861184	799178752	30.4631	9.7540	2.96755	1.07759	2915.4	676372
929	863041	801765089	30.4795	9.7575	2.96802	1.07643	2918.5	677831
930	864900	804357000	30.4959	9.7610	2.96848	1.07527	2921.7	679291
931	866761	806954491	30.5123	9.7645	2.96895	1.07411	2924.8	680752
932	868624	809557568	30.5287	9.7680	2.96942	1.07296	2928.0	682216
933	870489	812166237	30.5450	9.7715	2.96988	1.07181	2931.1	683680
934	872356	814780504	30.5614	9.7750	2.97035	1.07066	2934.2	685147
935	874225	817400375	30.5778	9.7785	2.97081	1.06952	2937.4	686615
936	876096	820025856	30.5941	9.7819	2.97128	1.06838	2940.5	688084
937	877969	822656953	30.6105	9.7854	2.97174	1.06724	2943.7	689555
938	879844	825293672	30.6268	9.7889	2 97220	1.06610	2946.8	691028
939	881721	827936019	30.6431	9.7924	2.97267	1.06496	2950.0	692502
940	883600	830584000	30.6594	9.7959	2.97313	1.06383	2953.1	693978
941	885481	833237621	30.6757	9.7993	2.97359	1.06270	2956.2	695455
942	887364	835896888	30.6920	9.8028	2.97405	1.06157	2959.4	696934
943	889249	838561807	30.7083	9.8063	2.97451	1.06045	2962.5	698415
944	891136	841232384	30.7246	9.8097	2.97497	1.05932	2965.7	699897

Squares, Cubes, Square Roots, Cube Roots, Logarithms, Etc.

(CONTINUED.)

No.	Sq.	Cube.	Square Root.	Cube Root.	Log.	1000 X Recip	No. = Dia. Circ'm	Area.
945	893025	843908625	30.7409	9.8132	2.97543	1.05820	2968.8	701380
946	894916	846590536	30.7571	9.8167	2.97589	1.05708	2971.9	702865
947	896809	849278123	30.7734	9.8201	2.97635	1.05597	2975.1	704352
948	898704	851971392	30.7896	9.8236	2.97681	1.05485	2978.2	705840
949	900601	854670349	30.8058	9.8270	2.97727	1.05374	2981 4	707330
950	902500	857375000	30.8221	9.8305	2.97772	1.05263	2984.5	708822
951	904401	860085351	30.8383	9.8339	2.97818	1.05152	2987.7	710315
952	906304	862801408	30.8545	9.8374	2.97864	1.05042	2990.8	711809
953	908209	865523177	30.8707	9.8408	2.97909	1.04932	2993.9	713306
954	910116	868250664	30.8869	9.8443	2.97955	1.04822	2997 1	714803
955	912025	870983875	30.9031	9.8477	2.98000	1.04712	3000.2	716303
956	913936	873722816	30.9192	9.8511	2.98046	1.04603	3003.4	717804
957	915849	876467493	30.9354	9.8546	2.98091	1.04493	3006.5	719306
958	917764	879217912	30.9516	9.8580	2.98137	1.04384	3009.6	720810
959	919681	881974079	30.9677	9.8614	2.98182	1.04275	3012.8	722316
960	921600	884736000	30.9839	9.8648	2.98227	1.04167	3015.9	723823
961	923521	887503681	31.0000	9.8683	2.98272	1.04058	3019.1	725332
962	925444	890277128	31.0161	9.8717	2.98318	1.03950	3022.2	726842
963	927369	893056347	31.0322	9.8751	2.98363	1.03842	3025.4	728354
964	929296	895841344	31.0483	9.8785	2.98408	1.03734	3028.5	729867
965	931225	898632125	31.0644	9.8819	2.98453	1.03627	3031.6	731382
966	933156	901428696	31.0805	9.8854	2.98498	1.03520	3034.8	732899
967	935089	904231063	31.0966	9.8888	2.98543	1.03413	3037.9	734417
968	937024	907039232	31.1127	9.8922	2.98588	1.03306	3041.1	735937
969	938961	909853209	31.1288	9.8956	2.98632	1.03199	3044.2	737458
970	940900	912673000	31.1448	9.8990	2.98677	1.03093	3047.3	738981
971	942841	915498611	31.1609	9.9024	2.98722	1.02987	3050.5	740506
972	944784	918330048	31.1769	9.9058	2.98767	1.02881	3053.6	742032
973	946729	921167317	31.1929	9.9092	2.98811	1.02775	3056.8	743559
974	948676	924010424	31.2090	9.9126	2.98856	1.02669	3059.9	745088
975	950625	926859375	31.2250	9.9160	2 98900	1.02564	3063.1	746619
976	952576	929714176	31.2410	9.9194	2.98945	1.02459	3066.2	748151
977	954529	932574833	31.2570	9.9227	2.98989	1.02354	3069.3	749685
978	956484	935441352	31.2730	9.9261	2.99034	1.02249	3072.5	751221
979	958441	938313739	31.2890	9.9295	2.99078	1.02145	3075.6	752758
980	960400	941192000	31.3050	9.9329	2.99123	1.02041	3078.8	754296
981	962361	944076141	31.3209	9.9363	2.99167	1.01937	3081.9	755837
982	964324	946966168	31.3369	9.9396	2.99211	1.01833	3085.0	757378
983	966289	949862087	31.3528	9.9430	2.99255	1.01729	3088.2	758922
984	968256	952763904	31.3688	9.9464	2.99300	1.01626	3091.3	760466
985	970225	955671625	31.3847	9.9497	2.99344	1.01523	3094.5	762013
986	972196	958585256	31.4006	9.9531	2.99388	1.01420	3097.6	763561
987	974169	961504803	31.4166	9.9565	2.99432	1.01317	3100.8	765111
988	976144	964430272	31.4325	9.9598	2.99476	1.01215	3103.9	766662
989	978121	967361669	31.4484	9.9632	2.99520	1.01112	3107.0	768214

Squares, Cubes, Square Roots, Cube Roots, Logarithms, Etc.

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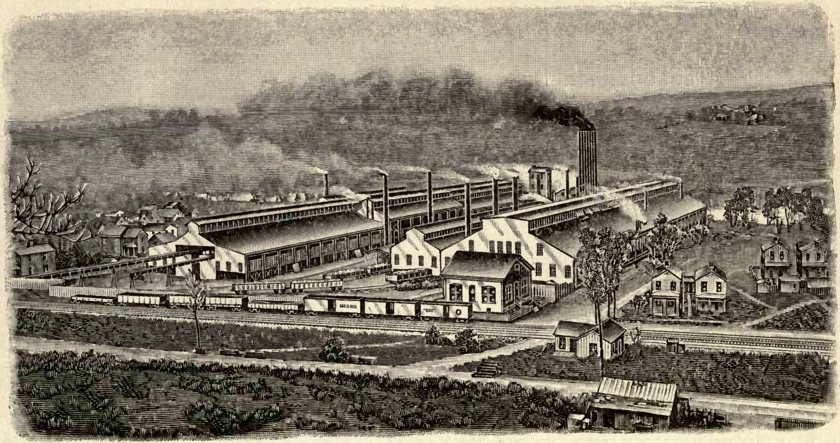
No.	Sq.	Cube.	Square Root.	Cube Root.	Log	1000 x Recip.	No = Dia. Circ'm	Area.
990	980100	970299000	31.4643	9.9666	2.99564	1.01010	3110.2	769760
991	982081	973242271	31.4802	9.9699	2.99607	1.00908	3113.3	771325
992	984064	976191488	31.4960	9.9733	2.99651	1.00806	3116.5	772882
993	986049	979146657	31.5119	9.9766	2.99695	1.00705	3119.6	774441
994	988036	982107784	31.5278	9.9800	2.99739	1.00604	3122.7	776002
995	990025	985074875	31.5436	9.9833	2.99782	1.00503	3125.9	777564
996	992016	988047936	31.5595	9.9866	2.99826	1.00402	3129.0	779128
997	994009	991026973	31.5753	9.9900	2.99870	1.00301	3132.2	780693
998	996004	994011992	31.5911	9.9933	2.99913	1.00200	3135.3	782260
999	998001	997002999	31.6070	9.9967	2.99957	1.00100	3138.5	783828



U. S. SEAMLESS MILL, McKEESPORT PA.

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