THE GAS ENGINEER'S

POCKET-BOOK

THE

GAS ENGINEER'S POCKET-BOOK

COMPRISING

Tables, Notes, and Memoranda

RELATING TO

THE MANUFACTURE, DISTRIBUTION, AND USE OF COAL GAS

AND

THE CONSTRUCTION OF GAS WORKS

BY

HENRY O'CONNOR

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SECOND EDITION, REVISED

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Dedicated

TO HIS OLD CHIEFS

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IN ACKNOWLEDGMENT OF MUCH VALUABLE INFORMATION RECEIVED FROM THEM BY THE AUTHOR DURING HIS WORK UNDER THEIR DIRECTION

HENRY O'CONNOR

PREFACE.

In placing this compilation before his readers—and in particular, his brother Engineers of the Gas Industry—it may not be out of place for the Author to indicate the circumstances which have led, in the first instance, to the preparation of the Tables, Notes, and other matter comprised in the volume, and now to their issue in the present form.

Having frequently during the course of his professional career experienced the want of any book containing those numerous tables, data, &c., which, with the spread of engineering knowledge, are every day becoming more and more necessary to the Gas Engineer for reference, he has for many years been in the habit of making and preserving, for his own use, full notes from every available source. These notes have formed the basis of the present work, and the fact that they were originally intended only for his own personal use has rendered it in many cases well-nigh impossible for the Author to acknowledge the sources of his information. He desires, however, to express here his indebtedness to both the *Journal of Gas Lighting* and the *Gas World*, whose full and careful reports, given from time to time, of papers read and discussions held at the various meetings of Engineering Societies, at which questions concerning the Gas Industry have been under review, have afforded him the means of obtaining a considerable portion of the matter here presented.

In deciding the plan upon which the matter should be arranged, it appeared to the Author that the most suitable method was to take the various processes consecutively as they occur in the course of Gas-making, and to treat of the Construction of the Works separately from the Manufacture of the Gas.

The diagrammatic form of tabulating has been followed wherever it seemed to be preferable, and the dimensions of the volume have in consequence been increased from the ordinary pocket-book size, so as to enable the diagrams to be better seen and read.

The Tables have been most carefully checked, and every precaution taken to render them as accurate as possible. Should, however, any error be detected in them, the Author will feel much obliged for information of the fact; while he will welcome any communication upon the subject generally with which readers may be pleased to favour him.

H. O'C.

Edinburgh, 1897.

NOTE TO SECOND EDITION.

It is very gratifying that a new edition has been speedily called for, and the opportunity has been taken of correcting a few errors of the press. The Statutory Regulations for Testing the Illuminating Power and Purity of Gas have also been added, and the text of the book amended where it was found advisable.

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GAS ENGINEER'S POCKET-BOOK.

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No.	Square.	Cube.	Square Root.	Cube Root.	Reciprocal.	Logarithm.	Difference.
1	1	1	1·000	1·000	1·000000	000000	301030
2	4	8	1·414	1·259	·500000	301030	176091
3	9	27	1·732	1·442	·333333	477121	124939
4	16	64	2·000	1·587	·250000	602060	96910
5	25	125	2·236	1·709	·200000	698970	79181
6	36	216	2·449	1·817	·166667	778151	66947
7	49	343	2·645	1·912	·142857	845098	57992
8	64	512	2·828	2·000	·125000	903090	51153
9	81	729	3·000	2·080	·111111	954243	45757
10	100	1,000	3·162	2·154	·100000	000000	41393
11	121	1,331	3·316	2·223	·090909	041393	37788
12	144	1,728	3·464	2·289	·083333	079181	34762
13	169	2,197	3·605	2·351	·076923	113943	32185
14	196	2,744	3·741	2·410	·071429	146128	29963
15	225	3,375	3·872	2·466	·066667	176091	28029
16	256	4,096	4·000	2·519	·062500	204120	26329
17	289	4,913	4·123	2·571	·058824	230449	24824
18	324	5,832	4·242	2·620	·055556	255273	23481
19	361	6,859	4·358	2·668	·052632	278754	22276
20	400	8,000	4·472	2·714	·050000	301030	21189
21	441	9,261	4·582	2·758	·047619	322219	20204
22	484	10,624	4·690	2·802	·045455	342423	19305
23	529	12,167	4·795	2·843	·043478	361728	18483
24	576	13,824	4·898	2·884	·041667	380211	17729
25	625	15,625	5·000	2·924	·040000	397940	17033
26	676	17,576	5·099	2·962	·038462	414973	16391
27	729	19,683	5·196	3·000	·037037	431364	15794
28	784	21,952	5·291	3·036	·035714	447158	15240
29	841	24,389	5·385	3·072	·034483	462398	14723

No.	Square.	Cube.	Square Root.	Cube Root.	Reciprocal.	Logarithm.	Difference.
30	900	27,000	5·477	3·107	·033333	477121	14241
31	961	29,791	5·567	3·141	·032258	491362	13798
32	1,024	32,768	5·656	3·175	·031250	505150	13364
33	1,089	35,937	5·744	3·207	·030303	518514	12965
34	1,156	39,304	5·830	3·239	·029412	531479	12589
35	1,225	42,875	5·916	3·271	·028571	544068	12235
36	1,296	46,656	6·000	3·301	·027778	556303	11899
37	1,369	50.653	6·082	3·332	·027027	568202	11582
38	1,444	54,872	6·164	3·361	·026316	579784	11281
39	1,521	59,319	6·244	3·391	·025641	591065	10995
40	1,600	64,000	6·326	3·419	·025000	602060	10724
41	1,681	68,921	6·403	3·448	·024390	612784	10465
42	1,764	74,088	6·480	3·476	·023810	623249	10219
43	1,849	79,507	6·557	3·503	·023256	633468	9985
44	1,936	85,184	6·633	3·530	·022727	643453	9760
45	2,025	91,125	6·708	3·556	·022222	653213	9545
46	2,116	97,336	6·782	3·583	·021739	662758	9340
47	2,209	103,823	6·855	3·608	·021277	672098	9143
48	2,304	110,592	6·928	3·634	·020833	681241	8955
49	2,401	117,649	7·000	3·659	·020408	690196	8774
50	2,500	125,000	7·071	3·684	·020000	698970	8600
51	2,601	132,651	7·141	3·708	·019608	707570	8433
52	2,704	140,608	7·211	3·732	·019231	716003	8273
53	2,809	148,877	7·280	3·756	·018868	724276	8118
54	2,916	157,464	7·348	3·779	·018519	732394	7969
55	3,025	166,375	7·416	3·802	·018182	740363	7825
56	3,136	175,616	7·483	3·825	·017857	748188	7687
57	3,249	185,193	7·549	3·848	·017544	755875	7553
58	3,364	195,122	7·615	3·870	·017241	763428	7424
59	3,481	205,379	7·681	3·892	·016949	770852	7299
60	3,600	216,000	7·745	3·914	·016667	778151	7179
61	3,721	226,981	7·810	3·936	·016393	785330	7062
62	3,844	238,328	7·874	3·957	·016129	792392	6949
63	3,969	250,047	7·937	3·979	·015873	799341	6839
64	4,096	262,144	8·000	4·000	·015625	806180	6733
65	4,225	274,625	8·062	4·020	·015385	812913	6631
66	4,356	287,496	8·124	4·041	·015152	819544	6531
67	4,489	300,763	8·185	4·061	·014925	826075	6434
68	4,624	314,432	8·246	4·081	·014706	832509	6340
69	4,761	328,509	8·306	4·101	·014493	838849	6249
70	4,900	343,000	8·366	4·121	·014286	845098	6160
71	5,041	357,911	8·426	4·140	·014085	851258	6074
72	5,184	373,248	8·485	4·160	·013889	857332	5991
73	5,329	389,017	8·544	4·179	·013699	863323	5909
74	5,476	405,224	8·602	4·198	·013514	869232	5829

No.	Square.	Cube.	Square Root.	Cube Root.	Recip-rocal.	Loga-rithm.	Differ-ence.
75	5,625	421,875	8·660	4·217	·013333	875061	5753
76	5,776	438,976	8·717	4·235	·013158	880814	5677
77	5,929	456,533	8·744	4·254	·012987	886491	5604
78	6,084	474,552	8·831	4·272	·012821	892095	5532
79	6,241	493,039	8·888	4·290	·012658	897627	5463
80	6,400	512,000	8·944	4·308	·012500	903090	5395
81	6,561	531,441	9·000	4·326	·012346	908485	5329
82	6,724	551,368	9·055	4·344	·012195	913814	5264
83	6,889	571,787	9·110	4·362	·012048	919078	5201
84	7,056	592,704	9·165	4·379	·011905	924279	5140
85	7,225	614,125	9·219	4·396	·011765	929419	5079
86	7,396	636,056	9·273	4·414	·011628	934498	5021
87	7,569	658,503	9·327	4·431	·011494	939519	4964
88	7,744	681,472	9·380	4·447	·011364	944483	4907
89	7,921	704,969	9·433	4·461	·011236	949390	4853
90	8,100	729,000	9·486	4·481	·011111	954243	4798
91	8,281	753,571	9·539	4·497	·010989	959041	4747
92	8,464	778,688	9·591	4·514	·010870	963788	4695
93	8,649	804,357	9·643	4·530	·010753	968483	4645
94	8,836	830,584	9·695	4·546	·010638	973128	4596
95	9,025	857,375	9·746	4·562	·010526	977724	4547
96	9,216	884,736	9·797	4·578	·010417	982271	4501
97	9,409	912,673	9·848	4·594	·010309	986772	4454
98	9,604	941,192	9·899	4·610	·010204	991226	4409
99	9,801	970,299	9·949	4·626	·010101	995635	4360
100	10,000	1,000,000	10·000	4·641	·010000	000000	4321
101	10,201	1,030,301	10·049	4·657	·009901	004321	4279
102	10,404	1,061,208	10·099	4·672	·009804	008600	4237
103	10,609	1,092,727	10·148	4·687	·009709	012837	4196
104	10,816	1,124,864	10·198	4·702	·009615	017033	4156
105	11,025	1,157,625	10·246	4·717	·009524	021189	4117
106	11,236	1,191,016	10·295	4·732	·009434	025306	4078
107	11,449	1,225,043	10·344	4·747	·009346	029384	4040
108	11,664	1,259,712	10·392	4·762	·009259	033424	4002
109	11,881	1,295,029	10·440	4·776	·009174	037426	3967
110	12,100	1,331,000	10·488	4·791	·009091	041393	3930
111	12,321	1,367,631	10·535	4·805	·009009	045323	3895
112	12,554	1,404,928	10·583	4·820	·008929	049218	3860
113	12,769	1,442,897	10·630	4·834	·008850	053078	3827
114	12,996	1,481,544	10·677	4·848	·008772	056905	3793
115	13,225	1,520,875	10·723	4·862	·008696	060698	3760
116	13,456	1,560,896	10·770	4·876	·008621	064458	3728
117	13,689	1,601,613	10·816	4·890	·008547	068186	3696
118	13,924	1,643,032	10·862	4·904	·008475	071882	3665
119	14,161	1,685,159	10·908	4·918	·008403	075547	3634

No.	Square.	Cube.	Square Root.	Cube Root	Reciprocal.	Logarithm.	Difference.
120	14,400	1,728,000	10·954	4·932	·008333	079181	3604
121	14,641	1,771,561	11·000	4·946	·008264	082785	3575
122	14,884	1,815,848	11·045	4·959	·008197	086360	3545
123	15,129	1,860,867	11·090	4·973	·008130	089905	3517
124	15,376	1,906,624	11·135	4·986	·008065	093422	3488
125	15,625	1,953,125	11·180	5·000	·008000	096910	3461
126	15,876	2,000,376	11·224	5·013	·007937	100371	3433
127	16,129	2,048,383	11·269	5·026	·007874	103804	3406
128	16,384	2,097,152	11·313	5·039	·007813	107210	3380
129	16,641	2,146,689	11·357	5·052	·007752	110590	3343
130	16,900	2,197,000	11·401	5·065	·007692	113943	3328
131	17,161	2,248,091	11·445	5·078	·007634	117271	3303
132	17,424	2,299,968	11·489	5·091	·007576	120574	3278
133	17,689	2,352,637	11·532	5·104	·007519	123852	3253
134	17,956	2,406,104	11·575	5·117	·007463	127105	3229
135	18,225	2,460,375	11·618	5·129	·007407	130334	3205
136	18,496	2,515,456	11·661	5·142	·007353	133539	3182
137	18,769	2,571,353	11·704	5·155	·007299	136721	3148
138	19,044	2,620,872	11·747	5·167	·007246	139879	3136
139	19,321	2,685,619	11·789	5·180	·007194	143015	3113
140	19,600	2,744,000	11·832	5·192	·007143	146128	3091
141	19,881	2,803,221	11·874	5·204	·007092	149219	3069
142	20,164	2,863,288	11·916	5·217	·007042	152288	3048
143	20,449	2,924,207	11·958	5·229	·006993	155336	3026
144	20,736	2,985,984	12·000	5·241	·006944	158362	3006
145	21,025	3,048,625	12·041	5·253	·006897	161368	2985
146	21,316	3,112,136	12·083	5·265	·006849	164353	2964
147	21,609	3,176,523	12·124	5·277	·006803	167317	2945
148	21,904	3,241,792	12·165	5·289	·006757	170262	2924
149	22,201	3,307,949	12·206	5·301	·006711	173186	2905
150	22,500	3,375,000	12·247	5·313	·006667	176091	2886
151	22,801	3,442,951	12·288	5·325	·006623	178977	2867
152	23,104	3,511,808	12·328	5·336	·006579	181844	2847
153	23,409	3,581,577	12·369	5·348	·006536	184691	2830
154	23,716	3,652,264	12·409	5·360	·006494	187521	2811
155	24,025	3,723,875	12·449	5·371	·006452	190332	2793
156	24,336	3,796,416	12·489	5·383	·006410	193125	2775
157	24,649	3,869,893	12·529	5·394	·006369	195900	2757
158	24,964	3,944,312	12·569	5·406	·006329	198657	2740
159	25,281	4,019,679	12·609	5·417	·006289	201397	2723
160	25,600	4,096,000	12·649	5·428	·006250	204120	2706
161	25,921	4,173,281	12·688	5·440	·006211	206826	2689
162	26,244	4,251,528	12·727	5·451	·006173	209515	2673
163	26,569	4,330,747	12·767	5·462	·006135	212188	2656
164	26,896	4,410,944	12·806	5·473	·006098	214844	2640

No.	Square.	Cube.	Square Root.	Cube Root.	Recip-rocal.	Loga-rithm.	Differ-ence.
165	27,225	4,492,125	12·845	5·484	·006061	217484	2624
166	27,556	4,574,296	12·884	5·495	·006024	220108	2608
167	27,889	4,657,463	12·922	5·506	·005988	222716	2583
168	28,224	4,741,632	12·961	5·517	·005952	225309	2578
169	28,561	4,826,809	13·000	5·528	·005917	227887	2562
170	28,900	4,913,000	13·038	5·539	·005882	230449	2547
171	29,241	5,000,211	13·076	5·550	·005848	232996	2532
172	29,584	5,088,448	13·114	5·561	·005814	235528	2518
173	29,929	5,177,717	13·152	5·572	·005780	238046	2503
174	30,276	5,268,024	13·190	5·582	·005747	240549	2489
175	30,625	5,359,375	13·228	5·593	·005714	243038	2475
176	30,976	5,451,776	13·266	5·604	·005682	245513	2460
177	31,329	5,545,233	13·304	5·614	·005650	247973	2447
178	31,684	5,639,752	13·341	5·625	·005618	250420	2433
179	32,041	5,735,339	13·379	5·635	·005587	252853	2420
180	32,400	5,832,000	13·416	5·646	·005556	255273	2406
181	32,761	5,929,741	13·453	5·656	·005525	257679	2392
182	33,124	6,028,568	13·490	5·667	·005495	260071	2380
183	33,489	6,128,487	13·527	5·677	·005464	262451	2367
184	33,856	6,229,504	13·564	5·687	·005435	264818	2354
185	34,225	6,331,625	13·601	5·698	·005405	267172	2341
186	34,596	6,434,856	13·638	5·708	·005376	269513	2329
187	34,969	6,539,203	13·674	5·718	·005348	271842	2316
188	35,344	6,644,672	13·711	5·728	·005319	274158	2304
189	35,721	6,751,269	13·747	5·738	·005291	276462	2292
190	36,100	6,859,000	13·784	5·748	·005263	278754	2279
191	36,481	6,967,871	13·820	5·758	·005236	281033	2268
192	36,864	7,077,888	13·856	5·768	·005208	283301	2256
193	37,249	7,189,057	13·892	5·778	·005181	285557	2245
194	37,636	7,301,384	13·928	5·788	·005155	287802	2233
195	38,025	7,414,875	13·964	5·798	·005128	290035	2221
196	38,416	7,529,536	14·000	5·808	·005102	292256	2210
197	38,809	7,645,373	14·035	5·818	·005076	294466	2199
198	39,204	7,762,392	14·071	5·828	·005051	296665	2188
199	39,601	7,880,599	14·106	5·838	·005025	298853	2177
200	40,000	8,000.000	14·142	5·848	·005000	301030	2166
201	40,401	8,120,601	14·177	5·857	·004975	303196	2155
202	40,804	8,242,408	14·212	5·867	·004950	305351	2145
203	41,209	8,365,427	14·247	5·877	·004926	307496	2134
204	41,616	8,489,664	14·282	5·886	·004902	309630	2124
205	42,025	8,615,125	14·317	5·896	·004878	311754	2113
206	42,436	8,741,816	14·352	5·905	·004854	313867	2103
207	42,849	8,869,743	14·387	5·915	·004831	315970	2093
208	43,264	8,998,912	14·422	5·924	·004808	318063	2083
209	43,681	9,123,329	14·456	5·934	·004785	320146	2073

No.	Square.	Cube.	Square Root.	Cube Root.	Recip-rocal.	Loga-rithm.	Differ-ence.
210	44,100	9,261,000	14·491	5·943	·004762	322219	2063
211	44,521	9,393,931	14·525	5·953	·004739	324282	2054
212	44,944	9,528,128	14·560	5·962	·004717	326336	2044
213	45,369	9,663,597	14·594	5·972	·004695	328380	2034
214	45,796	9,800,344	14·628	5·981	·004673	330414	2024
215	46,225	9,938,375	14·662	5·990	·004651	332438	2016
216	46,656	10,077,696	14·696	6·000	·004630	334454	2006
217	47,089	10,218,313	14·730	6·009	·004608	336460	1996
218	47,524	10,360,232	14·764	6·018	·004587	338456	1988
219	47,961	10,503,459	14·798	6·027	·004566	340444	1979
220	48,400	10,648,000	14·832	6·036	·004545	342423	1969
221	48,841	10,793,861	1466·8	6·045	·004525	344392	1961
222	49,284	10,941,048	14·899	6·055	·004505	346353	1952
223	49,729	11,089,567	14·933	6·064	·004484	348305	1943
224	50,176	11,239,424	14·966	6·073	·004464	350248	1935
225	50,625	11,390,625	15·000	6·082	·004444	352183	1925
226	51,076	11,543,176	15·033	6·091	·004425	354108	1918
227	51,529	11,697,083	15·066	6·100	·004405	356026	1909
228	51,984	11,852,352	15·099	6·109	·004386	357935	1900
229	52,441	12,008,989	15·132	6·118	·004367	359835	1893
230	52,900	12,167,000	15·165	6·126	·004348	361728	1884
231	53,361	12,326,391	15·198	6·135	·004329	363612	1876
232	53,824	12,487,168	15·231	6·144	·004310	365488	1868
233	54,289	12,649,337	15·264	6·153	·004292	367356	1860
234	54,756	12,812,904	15·297	6·162	·004274	369216	1852
235	55,225	12,977,875	15·329	6·171	·004255	371068	1844
236	55,696	13,144,256	15·362	6·179	·004237	372912	1836
237	56,169	13,312,053	15·394	6·188	·004219	374748	1829
238	56,644	13,481,272	15·427	6·197	·004202	376577	1821
239	57,121	13,651,919	15·459	6·205	·004184	378398	1813
240	57,600	13,824,000	15·491	6·214	·004167	380211	1806
241	58,081	13,997,521	15·524	6·223	·004149	382017	1798
242	58,564	14,172,488	15·556	6·231	·004132	383815	1791
243	59,049	14,348,907	15·588	6·240	·004115	385606	1784
244	59,536	14,526,784	15·620	6·248	·004098	387390	1776
245	60,025	14,706,125	15·652	6·257	·004082	389166	1769
246	60,516	14,886,936	15·684	6·265	·004065	390935	1762
247	61,009	15,069,223	15·716	6·274	·004049	392697	1755
248	61,504	15,252,992	15·748	6·282	·004032	394452	1747
249	62,001	15,438,249	15·779	6·291	·004016	396199	1741
250	62,500	15,625,000	15·811	6·299	·004000	397940	1734
251	63,001	15,813,251	15·842	6·307	·003984	399674	1727
252	63,504	16,003,008	15·874	6·316	·003968	401401	1720
253	64,009	16,194,277	15·905	6·324	·003953	403121	1713
254	64,516	16,387,064	15·937	6·333	·003937	404834	1706

No.	Square.	Cube.	Square Root.	Cube Root.	Recip-rocal.	Loga-rithm.	Differ-ence.
255	65,025	16,581,375	15·968	6·341	·003922	406540	1700
256	65,536	16,777,216	16·000	6·349	·003906	408240	1693
257	66,049	16,974,593	16·031	6·357	·003891	409933	1687
258	66,564	17,173,512	16·062	6·366	·003876	411620	1680
259	67,081	17,373,979	16·093	6·374	·003861	413300	1673
260	67,600	17,576,000	16·124	6·382	·003846	414973	1668
261	68,121	17,779,581	16·155	6·390	·003831	416641	1660
262	68,644	17,984,728	16·186	6·398	·003817	418301	1655
263	69,169	18,191,447	16·217	6·406	·003802	419956	1648
264	69,696	18,399,744	16·248	6·415	·003788	421604	1642
265	70,225	18,609,625	16·278	6·423	·003774	423246	1636
266	70,756	18,821,096	16·309	6·431	·003759	424882	1629
267	71,289	19,034,163	16·340	6·439	·003745	426511	1624
268	71,824	19,248,832	16·370	6·447	·003731	428135	1617
269	72,361	19,465,109	16·401	6·455	·003717	429752	1612
270	72,900	19,683,000	16·431	6·463	·003704	431364	1605
271	73,441	19,902,511	16·462	6·471	·003690	432969	1600
272	73,984	20,123,648	16·492	6·479	·003676	434569	1594
273	74,529	20,346,417	16·522	6·487	·003663	436163	1588
274	75,076	20,570,824	16·552	6·495	·003650	437751	1582
275	75,625	20,796,875	16,583	6·502	·003636	439333	1576
276	76,176	21,024,576	16·613	6·510	·003623	440909	1571
277	76,729	21,253,933	16·643	6·518	·003610	442480	1565
278	77,284	21,484,952	16·673	6·526	·003597	444045	1559
279	77,841	21,717,639	16·703	6·534	·003584	445604	1554
280	78,400	21,952,000	16·733	6·542	·003571	447158	1548
281	78,961	22,188,041	16·763	6·549	·003559	448706	1543
282	79,524	22,425,768	16·792	6·557	·003546	450249	1537
283	80,089	22,665,187	16·822	6·565	·003534	451786	1532
284	80,656	22,906,304	16·852	6·573	·003522	453318	1527
285	81,225	23,149,125	16·881	6·580	·003509	454845	1521
286	81,796	23,393,656	16·911	6·588	·003497	456366	1516
287	82,369	23,639,903	16·941	6·596	·003484	457882	1510
288	82,944	23,887,872	16·970	6·603	·003472	459392	1506
289	83,521	24,137,569	17·000	6·611	·003460	460898	1500
290	84,100	24,389,000	17·029	6·619	·003448	462398	1495
291	84,681	24,642,171	17·059	6·627	·003436	463893	1490
292	85,264	24,897,088	17·088	6·634	·003425	465383	1485
293	85,849	25,153,757	17·117	6·642	·003413	466868	1479
294	86,436	25,412,184	17·146	6·649	·003401	468347	1475
295	87,025	25,672,375	17·176	6·657	·003390	469822	1470
296	87,616	25,934.336	17·205	6·664	·003378	471292	1464
297	88,209	26,198,073	17·234	6·672	·003367	472756	1460
298	88,804	26,463,592	17·263	6·679	·003356	474216	1455
299	89,401	26,730,899	17·292	6·687	·003344	475671	1450

No.	Square.	Cube.	Square Root.	Cube Root.	Recip-rocal.	Loga-rithm.	Differ-ence.
300	90,000	27,000,000	17·320	6·694	·003333	477121	1445
301	90,601	27,270,901	17·349	6·702	·003322	478566	1441
302	91,204	27,543,608	17·378	6·709	·003311	480007	1436
303	91,809	27,818,127	17·407	6·717	·003301	481443	1431
304	92,416	28,094,464	17·436	6·724	·003289	482874	1426
305	93,025	28,372,625	17·464	6·731	·003279	484300	1421
306	93,636	28,652,616	17·493	6·739	·003268	485721	1417
307	94,249	28,934,443	17·521	6·746	·003257	487138	1413
308	94,864	29,218,112	17·549	6.753	·003247	488551	1407
309	95,481	29,503,629	17·578	6·761	·003236	489958	1404
310	96,100	29,791,000	17·607	6·768	·003226	491362	1398
311	96,721	30,080,231	17·635	6·775	·003215	492760	1395
312	97,344	30,371,328	17·663	6·782	·003205	494155	1389
313	97,969	30,664,297	17·692	6·789	·003195	495544	1386
314	98,596	30,959,144	17·720	6·797	·003185	496930	1381
315	99,225	31,255,875	17,748	6·804	·003175	498311	1376
316	99,856	31,554,496	17·776	6·811	·003165	499687	1372
317	100,489	31,855,013	17·804	6·818	·003155	501059	1368
318	101,124	32,157,432	17·832	6·826	·003145	502427	1364
319	101,761	32,461,759	17·860	6·833	·003135	503791	1359
320	102,400	32,768,000	17·888	6·839	·003125	505150	1355
321	103,041	33,076,161	17·916	6·847	·003115	506505	1351
322	103,684	33,386,248	17·944	6·854	·003106	507856	1347
323	104,329	33,698,267	17·972	6·861	·003096	509203	1342
324	104,976	34,012,224	18·000	6·868	·003086	510545	1338
325	105,625	34,328,125	18·028	6·875	·003077	511883	1335
326	106,276	34,645,976	18·055	6·882	·003067	513218	1330
327	106,929	34,965,783	18·083	6·889	·003058	514548	1326
328	107,584	35,287,552	18·111	6·896	·003049	515874	1322
329	108,241	35,611,289	18·138	6·903	·003040	517196	1318
330	108,900	35,937,000	18·166	6·910	·003030	518514	1314
331	109,561	36,264,691	18·193	6·917	·003021	519828	1310
332	110,224	36,594,368	18·221	6·924	·003012	521138	1306
333	110,889	36,926,037	18·248	6·931	·003003	522444	1302
334	111,556	37,259,704	18·276	6·938	·002994	523746	1299
335	112,225	37,595,375	18·303	6·945	·002985	525045	1294
336	112,896	37,933,056	18·330	6·952	·002976	526339	1291
337	113,569	38,272,753	18·357	6·959	·002967	527630	1287
338	114,244	38,614,472	18·385	6·966	·002959	528917	1283
339	114,921	38,958,219	18·412	6·973	·002950	530200	1279
340	115,600	39,304,000	18·439	6·979	·002941	531479	1275
341	116,281	39,651,821	18·466	6·986	·002933	532754	1272
342	116,964	40,001,688	18·493	6·993	·002924	534026	1268
343	117,649	40,353,607	18·520	7·000	·002915	535294	1264
344	118,336	40,707,584	18·547	7·007	·002907	536558	1261

No.	Square.	Cube.	Square Root.	Cube Root.	Reciprocal.	Logarithm.	Difference.
345	119,025	41,063,625	18·574	7·014	·002899	537819	1257
346	119,716	41,421,736	18·601	7·020	·002890	539076	1253
347	120,409	41,781,923	18·628	7·027	·002882	540329	1250
348	121,104	42,144,192	18·655	7·034	·002874	541579	1246
349	121,801	42,508,549	18·681	7·040	·002865	542825	1243
350	122,500	42,875,000	18·708	7·047	·002857	544068	1239
351	123,201	43,243,551	18·735	7·054	·002849	545307	1236
352	123,904	43,614,208	18·762	7·061	·002841	546543	1232
353	124,609	43,986,977	18·788	7·067	·002833	547775	1228
354	125,316	44,361,864	18·815	7·074	·002825	549003	1225
355	126,025	44,738,875	18·842	7·081	·002817	550228	1222
356	126,736	45,118,016	18·868	7·087	·002809	551450	1218
357	127,449	45,499,293	18·894	7·094	·002801	552668	1215
358	128,164	45,882,712	18·921	7·101	·002793	553883	1211
359	128,881	46,268,279	18·947	7·107	·002786	555094	1209
360	129,600	46,656,000	18·974	7·114	·002778	556303	1204
361	130,321	47,045,881	19·000	7·120	·002770	557507	1201
362	131,044	47,437,928	19·026	7·127	·002762	558709	1198
363	131,769	47,832,147	19·052	7·133	·002755	559907	1195
364	132,496	48,228,544	19·079	7·140	·002747	561101	1192
365	133,225	48,627,125	19·105	7·146	·002740	562293	1188
366	133,956	49,027,896	19·131	7·153	·002732	563481	1185
367	134,689	49,430,863	19·157	7·159	·002725	564666	1182
368	135,424	49,836,032	19·183	7·166	·002717	565848	1178
369	136,161	50,243,409	19·209	7·172	·002710	567026	1175
370	136,900	50,653,000	19·235	7·179	·002703	568202	1172
371	137,641	51,064,811	19·261	7·185	·002695	569374	1169
372	138,384	51,478,848	19·287	7·192	·002688	570543	1166
373	139,129	51,895,117	19·313	7·198	·002681	571709	1163
374	139,876	52,313,624	19·339	7·205	·002674	572872	1159
375	140,625	52,734,375	19·365	7·211	·002667	574031	1157
376	141,376	53,157,376	19·391	7·218	·002660	575188	1154
377	142,129	53,582,633	19·416	7·224	·002653	576341	1151
378	142,884	54,010,152	19·442	7·230	·002646	577492	1148
379	143,641	54,439,939	19·468	7·237	·002639	578639	1145
380	144,400	54,872,000	19·493	7·243	·002632	579784	1141
381	145,161	55,306,341	19·519	7·249	·002625	580925	1138
382	145,924	55,742,968	19·545	7·256	·002618	582063	1135
383	146,689	56,181,887	19·570	7·262	·002611	583199	1132
384	147,456	56,623,104	19·596	7·268	·002604	584331	1129
385	148,225	57,066,625	19·621	7·275	·002597	585461	1126
386	148,996	57,512,456	19·647	7·281	·002591	586587	1124
387	149,769	57,960,603	19·672	7·287	·002584	587711	1121
388	150,544	58,411,072	19·698	7·294	·002577	588832	1118
389	151,321	58,863,869	19·723	7·299	·002571	589950	1115

No.	Square.	Cube.	Square Root.	Cube Root.	Recip-rocal.	Loga-rithm.	Differ-ence.
390	152,100	59,319,000	19·748	7·306	·002564	591065	1112
391	152,881	59,776,471	19·774	7·312	·002558	592177	1109
392	153,664	60,236,288	19·799	7·319	·002551	593286	1106
393	154,449	60,698,457	19·824	7·325	·002545	594393	1103
394	155,236	61,162,984	19·849	7·331	·002538	595496	1101
395	156,025	61,629,875	19·875	7·337	·002532	596597	1098
396	156,816	62,099,136	19·899	7·343	·002525	597695	1095
397	157,609	62,570,773	19·925	7·349	·002519	598791	1092
398	158,404	63,044,792	19·949	7·356	·002513	599883	1090
399	159,201	63,521,199	19·975	7·362	·002506	600973	1087
400	160,000	64,000,000	20·000	7·368	·002500	602060	1084
401	160,801	64,481,201	20·025	7·374	·002494	603144	1082
402	161,604	64,964,808	20·049	7·380	·002488	604226	1079
403	162,409	65,450,827	20·075	7·386	·002481	605305	1076
404	163,216	65,939,264	20·099	7·392	·002475	606381	1074
405	164,025	66,430,125	20·125	7·399	·002469	607455	1071
406	164,836	66,923,416	20·149	7·405	·002463	608526	1068
407	165,649	67,419.143	20·174	7·411	·002457	609594	1066
408	166,464	67,911,312	20·199	7·417	·002451	610660	1063
409	167,281	68,417,929	20·224	7·422	·002445	611723	1061
410	168,100	68,921,000	20·248	7·429	·002439	612784	1058
411	168,921	69,426,531	20·273	7·434	·002433	613842	1055
412	169,744	69,934,528	20·298	7·441	·002427	614897	1053
413	170,569	70,444,997	20·322	7·447	·002421	615950	1050
414	171,396	70,957,944	20·347	7·453	·002415	617000	1048
415	172,225	71,473,375	20·371	7·459	·002410	618048	1045
416	173,056	71,991,296	20·396	7·465	·002407	619093	1043
417	173,889	72,511,713	20·421	7·471	·002398	620136	1040
418	174,724	73,034,632	20·445	7·477	·002392	621176	1038
419	175,561	73,560,059	20·469	7·483	·002387	622214	1035
420	176,400	74,088,000	20·494	7·489	·002381	623249	1033
421	177,241	74,618,461	20·518	7·495	·002375	624282	1030
422	178,084	75,151,448	20·543	7·501	·002370	625312	1028
423	178,929	75,686,967	20·567	7·507	·002364	626340	1026
424	179,776	76,225,024	20·591	7·513	·002358	627366	1023
425	180,625	76,765,625	20·615	7·518	·002353	628389	1021
426	181,476	77,308,776	20·639	7·524	·002347	629410	1018
427	182,329	77,854,483	20·664	7·530	·002342	630428	1016
428	183,184	78,402,752	20·688	7·536	·002336	631444	1013
429	184,041	78,953,589	20·712	7·542	·002331	632457	1011
430	184,900	79,507,000	20·736	7·548	·002326	633468	1009
431	185,761	80,062,991	20·760	7·554	·002320	634477	1007
432	186,624	80,621,568	20·785	7·559	·002315	635484	1004
433	187,489	81,182,737	20·809	7·565	·002309	636488	1002
434	188,356	81,746,504	20·833	7·571	·002304	637490	999

No.	Square.	Cube.	Square Root.	Cube Root.	Recip-rocal.	Loga-rithm.	Differ-ence.
435	189,225	82,312,875	20·857	7·577	·002299	638489	997
436	190,096	82,881,856	20·881	7·583	·002294	639486	995
437	190,969	83,453,453	20·904	7·588	·002288	640481	993
438	191,844	84,027,672	20·928	7·594	·002283	641474	991
439	192,721	84,604,519	20·952	7·600	·002278	642465	988
440	193,600	85,184,000	20·976	7·606	·002273	643453	986
441	194,481	85,766,121	21·000	7·612	·002268	644439	983
442	195,364	86,350,388	21·024	7·617	·002262	645422	981
443	196,249	86,938,307	21·047	7·623	·002257	646404	979
444	197,136	87,528,384	21·071	7·629	·002252	647383	977
445	198,025	88,121,125	21·095	7·635	·002247	648360	975
446	198,916	88,716,536	21·119	7·640	·002242	649335	973
447	199,809	89,314,623	21·142	7·646	·002237	650308	970
448	200,704	89,915,392	21·166	7·652	·002232	651278	968
449	201,601	90,518,849	21·189	7·657	·002227	652246	967
450	202,500	91,125,000	21·213	7·663	·002222	653213	964
451	203,401	91,733,851	21·237	7·669	·002217	654177	962
452	204,304	92,345,408	21·260	7·674	·002212	655138	960
453	205,209	92,959,677	21·284	7·680	·002208	656098	958
454	206,106	93,576,664	21·307	7·686	·002203	657056	956
455	207,025	94,196,375	21·331	7·691	·002198	658011	954
456	207,936	94,818,816	21·354	7·697	·002193	658965	951
457	208,849	95,443,993	21·377	7·703	·002188	659916	949
458	209,764	96,071,912	21·401	7·708	·002183	660865	947
459	210,681	96,702,579	21·424	7·714	·002179	661813	945
460	211,600	97,336,000	21·447	7·719	·002174	662758	943
461	212,521	97,972,181	21·471	7·725	·002169	663701	941
462	213,444	98,611,128	21·494	7·731	·002165	664642	939
463	214,369	99,252,847	21·517	7·736	·002160	665581	937
464	215,296	99,897,345	21·541	7·742	·002155	666518	935
465	216,225	100,544,625	21·564	7·747	·002151	667453	933
466	217,156	101,194,696	21·587	7·753	·002146	668386	931
467	218,089	101,847,563	21·610	7·758	·002141	669317	929
468	219,024	102,503,232	21·633	7·764	·002137	670246	927
469	219,961	103,161,709	21·656	7·769	·002132	671173	925
470	220,900	103,823,000	21·679	7·775	·002128	672098	923
471	221,841	104,487,111	21·702	7·780	·002123	673021	921
472	222,784	105,154,048	21·725	7·786	·002119	673942	919
473	223,729	105,823,817	21·749	7·791	·002114	674861	917
474	224,676	106,496,424	21·771	7·797	·002110	675778	915
475	225,625	107,171,875	21·794	7·802	·002105	676694	913
476	226,576	107,850,176	21·817	7·808	·002101	677607	911
477	227,529	108,531,333	21·840	7·813	·002096	678518	910
478	228,484	109,215,352	21·863	7·819	·002092	679428	908
479	229,441	109,902,239	21·886	7·824	·002088	680336	905

No.	Square.	Cube.	Square Root.	Cube Root.	Recip-rocal.	Loga-rithm.	Differ-ence.
480	230,400	110,592,000	21·909	7·830	·002083	681241	904
481	231,361	111,284,641	21·932	7·835	·002079	682145	902
482	232,324	111,980,168	21·954	7·840	·002075	683047	900
483	233,289	112,678,587	21·977	7·846	·002070	683947	898
484	234,256	113,379,904	22·000	7·851	·002066	684845	896
485	235,225	114,084,125	22·023	7·857	·002062	685742	894
486	236,196	114,791,256	22·045	7·862	·002058	686636	893
487	237,169	115,501,303	22·069	7·868	·002053	687529	891
488	238,144	116,214,272	22·091	7·873	·002049	688420	889
489	239,121	116,936,169	22·113	7·878	·002045	689309	887
490	240,100	117,649,000	22·136	7·884	·002041	690196	885
491	241,081	118,370,771	22·158	7·889	·002037	691081	884
492	242,064	119,095,488	22·181	7·894	·002033	691965	882
493	243,049	119,823,157	22·204	7·899	·002028	692847	880
494	244,036	120,553,784	22·226	7·905	·002024	693727	878
495	245,025	121,287,375	22·248	7·910	·002020	694605	876
496	246,016	122,023,936	22·271	7·915	·002016	695482	874
497	247,009	122,763,473	22·293	7·921	·002012	696356	873
498	248,004	123,505,992	22·316	7·926	·002008	697229	871
499	249,001	124,251,499	22·338	7·932	·002004	698101	869
500	250,000	125,000,000	22·361	7·937	·002000	698970	868
501	251,001	125,751,501	22·383	7·942	·001996	699838	866
502	252,004	126,506,008	22·405	7·947	·001992	700704	864
503	253,009	127,263,527	22·428	7·953	·001988	701568	862
504	254,016	128,024,864	22·449	7·958	·001984	702431	860
505	255,025	128,787,625	22·472	7·963	·001980	703291	859
506	256,036	129,554,216	22·494	7·969	·001976	704151	857
507	257,049	130,323,843	22·517	7·974	·001972	705008	856
508	258,064	131,096,512	22·539	7·979	·001969	705864	854
509	259,081	131,872,229	22·561	7·984	·001965	706718	852
510	260,100	132,651,000	22·583	7·989	·001961	707570	851
511	261,121	133,432,831	22·605	7·995	·001957	708421	849
512	262,144	134,217,728	22·627	8·000	·001953	709270	847
513	263,169	135,005,697	22·649	8·005	·001949	710117	846
514	264,196	135,796,744	22·671	8·010	·001946	710963	844
515	265,225	136,590,875	22·694	8·016	·001942	711807	843
516	266,256	137,388,096	22·716	8·021	·001938	712650	841
517	267,289	138,188,413	22·738	8·026	·001934	713491	839
518	268,324	138,991,832	22·759	8·031	·001931	714330	837
519	269,361	139,798,359	22·782	8·036	·001927	715167	836
520	270,400	140,608,000	22·803	8·041	·001923	716003	835
521	271,441	141,420,761	22·825	8·047	·001919	716838	833
522	272,484	142,236,648	22·847	8·052	·001916	717671	831
523	273,529	143,055,667	22·869	8·057	·001912	718502	829
524	274,576	143,877,824	22·891	8·062	·001908	719331	828

No.	Square.	Cube.	Square Root.	Cube Root.	Recip-rocal.	Loga-rithm.	Differ-ence.
525	275,625	144,703,125	22·913	8·067	·001905	720159	827
526	276,676	145,531,576	22·935	8·072	·001901	720986	825
527	277,729	146,363,183	22·956	8·077	·001898	721811	823
528	278,784	147,197,952	22·978	8·082	·001894	722634	822
529	279,841	148,035,889	23·000	8·087	·001890	723456	820
530	280,900	148,877,000	23·022	8·093	·001887	724276	819
531	281,961	149,721,291	23·043	8·098	·001883	725095	817
532	283,024	150,568,768	23·065	8·103	·001880	725912	815
533	284,089	151,419,437	23·087	8·108	·001876	726727	814
534	285,156	152,273,304	23·108	8·113	·001873	727541	813
535	286,225	153,130,375	23·130	8·118	·001869	728354	811
536	287,296	153,990,656	23·152	8·123	·001866	729165	809
537	288,369	154,854,153	23·173	8·128	·001862	729974	808
538	289,444	155,720,872	23·195	8·133	·001859	730782	807
539	290,521	156,590,819	23·216	8·138	·001855	731589	805
540	291,600	157,464,000	23·238	8·143	·001852	732394	803
541	292,681	158,340,421	23·259	8·148	·001848	733197	802
542	293,764	159,220,088	23·281	8·153	·001845	733999	801
543	294,849	160,103,007	23·302	8·158	·001842	734800	799
544	295,936	160,989,184	23·324	8·163	·001838	735599	798
545	297,025	161,878,625	23·345	8·168	·001835	736397	796
546	298,116	162,771,336	23·367	8·173	·001832	737193	794
547	299,209	163,667,323	23·388	8·178	·001828	737987	793
548	300,304	164,566,592	23·409	8·183	·001825	738781	792
549	301,401	165,469,149	23·431	8·188	·001821	739572	791
550	302,500	166,375,000	23·452	8·193	·001818	740363	789
551	303,601	167,284,151	23·473	8·198	·001815	741152	787
552	304,704	168,196,608	23·495	8·203	·001812	741939	786
553	305,809	169,112,377	23·516	8·208	·001808	742725	785
554	306,916	170,031,464	23·537	8·213	·001805	743510	783
555	308,025	170,953,875	23·558	8·218	·001802	744293	782
556	309,136	171,879,616	23·579	8·223	·001799	745075	780
557	310,249	172,808,693	23·601	8·228	·001795	745855	779
558	311,364	173,741,112	23·622	8 233	·001792	746634	778
559	312,481	174,676,879	23·643	8·238	·001789	747412	776
560	313,600	175,616,000	23·664	8·242	·001786	748188	775
561	314,721	176,558,481	23·685	8·247	·001783	748963	773
562	315,844	177,504,328	23·706	8·252	·001779	749736	772
563	316,969	178,453,547	23·728	8·257	·001776	750508	771
564	318,096	179,406,144	23·749	8·262	·001773	751279	769
565	319,225	180,362,125	23·769	8·267	·001770	752048	768
566	320,356	181,321,496	23 791	8·272	·001767	752816	767
567	321,489	182,284,263	23·812	8·277	·001764	753583	765
568	322,624	183,250,432	23·833	8·282	·001761	754348	764
569	323,761	184,220,009	23·854	8·286	·001757	755112	763

No.	Square.	Cube.	Square Root.	Cube Root.	Recip- rocal.	Loga- rithm.	Differ- ence.
570	324,900	185,193,000	23·875	8·291	·001754	755875	761
571	326,041	186,169,411	23·896	8·296	·001751	756636	760
572	327,184	187,149,248	23·916	8·301	·001748	757396	759
573	328,329	188,132,517	23·937	8·306	·001745	758155	757
574	329,476	189,119,224	23·958	8·311	·001742	758912	756
575	330,625	190,109,375	23·979	8·315	·001739	759668	754
576	331,776	191,102,976	24·000	8·320	·001736	760422	753
577	332,929	192,100,033	24·021	8·325	·001733	761176	752
578	334,084	193,100,552	24·042	8·330	·001730	761928	751
579	335,241	194,104,539	24·062	8·335	·001727	762679	749
580	336,400	195,112,000	24·083	8·339	·001724	763228	748
581	337,561	196,122,941	24·104	8·344	·001721	764176	747
582	338,724	197,137,368	24·125	8·349	·001718	764923	746
583	339,889	198,155,287	24·145	8·354	·001715	765669	744
584	341,056	199,176,704	24·166	8·359	·001712	766413	743
585	342,225	200,201,625	24·187	8·363	·001709	767156	742
586	343,396	201,230,056	24·207	8·368	·001706	767898	740
587	344,569	202,262,003	24·228	8·373	·001704	768638	739
588	345,744	203,297,472	24·249	8·378	·001701	769377	738
589	346,921	204,336,469	24·269	8·382	·001698	770115	737
590	348,100	205,379,000	24·289	8·387	·001695	770852	735
591	349,281	206,425,071	24·310	8·392	·001692	771587	734
592	350,464	207,474,688	24·331	8·397	·001689	772322	733
593	351,649	208,527,857	24·351	8·401	·001686	773055	731
594	352,836	209,584,584	24·372	8·406	·001684	773786	730
595	354,025	210,644,875	24·393	8·411	·001681	774517	729
596	355,216	211,708,736	24·413	8·415	·001678	775246	728
597	356,409	212,776,173	24·433	8·420	·001675	775974	727
598	357,604	213,847,192	24·454	8·425	·001672	776701	726
599	358,801	214,921,799	24·474	8·429	·001669	777427	724
600	360,000	216,000,000	24·495	8·434	·001667	778151	723
601	361,201	217,081,801	24·515	8·439	·001664	778874	722
602	362,404	218,167,208	24·536	8·444	·001661	779596	721
603	363,609	219,256,227	24·556	8·448	·001658	780317	720
604	364,816	220,348,864	24·576	8·453	·001656	781037	719
605	366,025	221,445,125	24·597	8·458	·001653	781755	718
606	367,236	222,545,016	24·617	8·462	·001650	782473	716
607	368,449	223,648,543	24·637	8·467	·001647	783189	715
608	369,664	224,755,712	24·658	8·472	·001645	783904	714
609	370,881	225,866,529	24·678	8·476	·001642	784617	713
610	372,100	226,981,000	24·698	8·481	·001639	785330	711
611	373,321	228,099,131	24·718	8·485	·001637	786041	710
612	374,544	229,220,928	24·739	8·490	·001634	786751	709
613	375,769	230,346,397	24·758	8·495	·001631	787460	708
614	376,996	231,475,544	24·779	8·499	·001629	788168	707

No.	Square.	Cube.	Square Root.	Cube Root.	Recip-rocal.	Loga-rithm.	Differ-ence.
615	378,225	232,608,375	24·799	8·504	·001626	788875	706
616	379,456	233,744,896	24·819	8·509	·001623	789581	704
617	380,689	234,885,113	24·839	8·513	·001621	790285	703
618	381,924	236,029,032	24·859	8·518	·001618	790988	702
619	383,161	237,176,659	24·879	8·522	·001616	791691	701
620	384,400	238,628,000	24·899	8·527	·001613	792392	700
621	385,641	239,483,061	24·919	8·532	·001610	793092	699
622	386,884	240,641,348	24·939	8·536	·001608	793790	698
623	388,129	241,804,367	24·959	8·541	·001605	794488	697
624	389,376	242,970,624	24·980	8·545	·001603	795185	695
625	390,625	244,140,625	25·000	8·549	·001600	795880	694
626	391,876	245,314,376	25·019	8·554	·001597	796574	693
627	393,129	246,491,883	25·040	8·559	·001595	797268	692
628	394,384	247,673,152	25·059	8·563	·001592	797960	691
629	395,641	248,858,189	25·079	8·568	·001590	798651	690
630	396,900	250,047,000	25·099	8·573	·001587	799341	689
631	398,161	251,239,591	25·119	8·577	·001585	800029	688
632	399,424	252,435,968	25·139	8·582	·001582	800717	687
633	400,689	253,636,137	25·159	8·586	·001580	801404	685
634	401,956	254,840,104	25·179	8·591	·001577	802089	684
635	403,225	256,047,875	25·199	8·595	·001575	802774	683
636	404,496	257,259,456	25·219	8·599	·001572	803457	682
637	405,769	258,474,853	25·239	8·604	·001570	804139	681
638	407,044	259,694,072	25·259	8·609	·001567	804821	680
639	408,321	260,917,119	25·278	8·613	·001565	805501	679
640	409,600	262,144,000	25·298	8·618	·001563	806180	678
641	410,881	263,374,721	25·318	8·622	·001560	806858	677
642	412,164	264,609,288	25·338	8·627	·001558	807535	676
643	413,449	265,847,707	25·357	8·631	·001555	808211	675
644	414,736	267,089,984	25·377	8·636	·001553	808886	674
645	416,025	268,836,125	25·397	8·640	·001550	809560	673
646	417,316	269,586,136	25·416	8·644	·001548	810233	672
647	418,609	270,840,023	25·436	8·649	·001546	810904	671
648	419,904	272,097,792	25·456	8·653	·001543	811575	670
649	421,201	273,359,449	25·475	8·658	·001541	812245	669
650	422,500	274,625,000	25·495	8·662	·001538	812913	668
651	423,801	275,894,451	25·515	8·667	·001536	813581	667
652	425,104	277,167,808	25·534	8·671	·001534	814248	666
653	426,409	278,445,077	25·554	8·676	·001531	814913	665
654	427,716	279,726,264	25·573	8·680	·001529	815578	664
655	429,025	281,011,375	25·593	8·684	·001527	816241	663
656	430,336	282,800,416	25·612	8·689	·001524	816904	662
657	431,649	283,593,393	25·632	8·693	·001522	817565	661
658	432,964	284,890,312	25·651	8·698	·001520	818226	660
659	434,281	286,191,179	25·671	8·702	·001517	818885	659

No.	Square.	Cube.	Square Root.	Cube Root.	Recip-rocal.	Loga-rithm.	Differ-ence.
660	435,600	287,496,000	25·690	8·706	·001515	819544	658
661	436,921	288,804,781	25·710	8·711	·001513	820201	657
662	438,244	290,117,528	25·720	8·715	·001511	820858	656
663	439,569	291,434,247	25·749	8·719	·001508	821514	654
664	440,896	292,754,944	25·768	8·724	·001506	822168	653
665	442,225	294,079,625	25·787	8·728	·001504	822822	652
666	443,556	295,408,296	25·807	8·733	·001502	823474	651
667	444,889	296,740,963	25·826	8·737	·001499	824126	650
668	446,224	298,077,632	25·846	8·742	·001497	824776	650
669	447,561	299,418,309	25·865	8·746	·001495	825426	649
670	448,900	300,763,000	25·884	8·750	·001493	826075	648
671	450,241	302,111,711	25·904	8·753	·001490	826723	647
672	451,584	303,464,448	25·923	8·759	·001488	827369	646
673	452,929	304,821,217	25·942	8·763	·001486	828015	645
674	454,276	306,182,024	25·961	8·768	·001484	828660	644
675	455,625	307,546,875	25·981	8·772	·001481	829304	643
676	456,976	308,915,776	26·000	8·776	·001479	829947	642
677	458,329	310,288,733	26·019	8·781	·001477	830589	641
678	459,684	311,665,752	26·038	8·785	·001475	831230	640
679	461,041	313,046,839	26·058	8·789	·001473	831870	639
680	462,400	314,432,000	26·077	8·794	·001471	832509	638
681	463,761	315,821,241	26·096	8·798	·001468	833147	637
682	465,124	317,214,568	26·115	8·802	·001466	833784	637
683	466,489	318,611,987	26·134	8·807	·001464	834421	636
684	467,856	320,013,504	26·153	8·811	·001462	835056	635
685	469,225	321,419,125	26·172	8·815	·001460	835691	634
686	470,596	322,828,856	26·192	8·819	·001458	836324	633
687	471,969	324,242,703	26·211	8·824	·001456	836957	632
688	473,344	325,660,672	26·229	8·828	·001453	837588	631
689	474,721	327,082,769	26·249	8·832	·001451	838219	630
690	476,100	328,509,000	26·268	8·836	·001449	838849	629
691	477,481	329,939,371	26·287	8·841	·001447	839478	628
692	478,864	331,373,888	26·306	8·845	·001445	840106	627
693	480,249	332,812,557	26·325	8·849	·001443	840733	626
694	481,636	334,255,384	26·344	8·853	·001441	841359	625
695	483,025	335,702,375	26·363	8·858	·001439	841985	624
696	484,416	337,153,536	26·382	8·862	·001437	842609	623
697	485,809	338,608,873	26·401	8·866	·001435	843233	622
698	487,204	340,068,392	26·419	8·870	·001433	843855	622
699	488,601	341,532,099	26·439	8·875	·001431	844477	621
700	490,000	343,000,000	26·457	8·879	·001429	845098	620
701	491,401	344,472,101	26·476	8·883	·001427	845718	619
702	492,804	345,948,088	26·495	8·887	·001425	846337	618
703	494,209	347,528,927	26·514	8·892	·001422	846955	617
704	495,616	348,913,664	26·533	8·896	·001420	847573	616

No.	Square.	Cube.	Square Root.	Cube Root.	Reciprocal.	Logarithm.	Difference.
705	497,025	350,402,625	26·552	8·900	·001418	848189	615
706	498,436	351,895,816	26·571	8·904	·001416	848805	614
707	499,849	353,393,243	26·589	8·908	·001414	849419	614
708	501,264	354,894,912	26·608	8·913	·001412	850033	613
709	502,681	356,400,829	26·627	8·917	·001410	850646	612
710	504,100	357,911,000	26·644	8·921	·001408	851258	611
711	505,521	359,425,431	26·664	8·925	·001406	851870	610
712	506,944	360,944,128	26·683	8·929	·001404	852480	610
713	508,369	362,467,097	26·702	8·934	·001403	853090	609
714	509,796	363,994,344	26·721	8·938	·001401	853698	608
715	511,225	365,525,875	26·739	8·942	·001399	854306	607
716	512,656	367,061,696	26·758	8·946	·001397	854913	606
717	514,089	368,601,813	26·777	8·950	·001395	855519	605
718	515,524	370,146,232	26·795	8·954	·001393	856124	604
719	516,961	371,694,959	26·814	8·959	·001391	856729	603
720	518,400	373,248,000	26·833	8·963	·001389	857332	603
721	519,841	374,805,361	26·851	8·967	·001387	857935	602
722	521,284	376,367,048	26·870	8·971	·001385	858537	601
723	522,729	377,933,067	26·889	8·975	·001383	859138	600
724	524,176	379,503,424	26·907	8·979	·001381	859739	599
725	525,625	381,078,125	26·926	8·983	·001379	860338	598
726	527,076	382,657,176	26·944	8·988	·001377	860937	597
727	528,529	384,240,583	26·963	8·992	·001376	861534	597
728	529,984	385,828,352	26·991	8·996	·001374	862131	596
729	531,441	387,420,489	27·000	9·000	·001372	862728	595
730	532,900	389,017,000	27·018	9·004	·001370	863323	594
731	534,361	390,617,891	27·037	9·008	·001368	863917	594
732	535,824	392,223,168	27·055	9·012	·001366	864511	593
733	537,289	393,832,837	27·074	9·016	·001364	865104	592
734	538,756	395,446,904	27·092	9·020	·001362	865696	591
735	540,225	397,065,375	27·111	9·023	·001361	866287	590
736	541,696	398,688,256	27·129	9·029	·001359	866878	589
737	543,169	400,315,553	27·148	9·033	·001357	867467	589
738	544,644	401,947,272	27·166	9·037	·001355	868056	588
739	546,121	403,583,419	27·184	9·041	·001353	868644	587
740	547,600	405,224,000	27·203	9·045	·001351	869232	586
741	549,081	406,869,021	27·221	9·049	·001350	869818	586
742	550,564	408,518,488	27·239	9·053	·001348	870404	585
743	552,049	410,172,407	27·258	9·057	·001346	870989	584
744	553,536	411,830,784	27·276	9·061	·001344	871573	583
745	555,025	413,493,625	27·295	9·065	·001342	872156	583
746	556,516	415,160,936	27·313	9·069	·001340	872739	582
747	558,009	416,832,723	27·331	9·073	·001339	873321	581
748	559,504	418,508,992	27·349	9·077	·001337	873902	580
749	561,001	420,189,749	27·368	9·081	·001335	874482	579

No.	Square.	Cube.	Square Root.	Cube Root.	Recip-rocal.	Loga-rithm.	Differ-ence.
750	562,500	421,875,000	27·386	9·086	·001333	875061	579
751	564,001	423,564,751	27·404	9·089	·001332	875640	578
752	565,504	424,525,900	27·423	9·094	·001330	876218	577
753	567,009	426,957,777	27·441	9·098	·001328	876795	576
754	568,516	428,661,064	27·459	9·102	·001326	877371	576
755	570,025	430,368,875	27·477	9·106	·001325	877947	575
756	571,536	432,081,216	27·495	9·109	·001323	878522	574
757	573,049	433,798,093	27·514	9·114	·001321	879096	573
758	574,564	435,519,512	27·532	9·118	·001319	879669	573
759	576,081	437,245,479	27·549	9·122	·001318	880242	572
760	577,600	438,976,000	27·568	9·126	·001316	880814	571
761	579,121	440,711,081	27·586	9·129	·001314	881385	570
762	580,644	442,450,728	27·604	9·134	·001312	881955	570
763	582,169	444,194,947	27·622	9·138	·001311	882525	569
764	583,696	445,943,744	27·640	9·142	·001309	883093	568
765	585,225	447,697,125	27·659	9·146	·001307	883661	567
766	586,756	449,455,096	27·677	9·149	·001305	884229	566
767	588,289	451,217,663	27·695	9·154	·001304	884795	566
768	589,824	452,984,832	27·713	9·158	·001302	885361	565
769	591,361	454,756,609	27·731	9·162	·001300	885926	565
770	592,900	456,533,000	27·749	9·166	·001299	886491	564
771	594,441	458,314,011	27·767	9·169	·001297	887054	563
772	595,984	460,099,648	27·785	9·173	·001295	887617	562
773	597,529	461,889,917	27·803	9·177	·001294	888179	562
774	599,076	463,684,824	27·821	9·181	·001292	888741	561
775	600,625	465,484,375	27·839	9·185	·001290	889302	560
776	602,176	467,288,576	27·857	9·189	·001289	889862	559
777	603,729	469,097,433	27·875	9·193	·001287	890421	559
778	605,284	470,910,952	27·893	9·197	·001285	890980	558
779	606,841	472,729,139	27·910	9·201	·001284	891537	558
780	608,400	474,552,000	27·928	9·205	·001282	892095	556
781	609,961	476,379,541	27·946	9·209	·001280	892651	556
782	611,524	478,211,768	27·964	9·213	·001279	893207	555
783	613,089	480,048,687	27·982	9·217	·001277	893762	554
784	614,656	481,890,304	28·000	9·221	·001276	894316	554
785	616,225	483,736,625	28·017	9·225	·001274	894870	553
786	617,796	485,587,656	28·036	9·229	·001272	895423	552
787	619,369	487,443,403	28·053	9·233	·001271	895975	551
788	620,944	489,303,872	28·071	9·237	·001269	896526	551
789	622,521	491,169,069	28·089	9·240	·001267	897077	550
790	624,100	493,039,000	28·107	9·244	·001266	897627	549
791	625,681	494,913,671	28·125	9·248	·001264	898176	549
792	627,624	496,793,088	28·142	9·252	·001263	898725	548
793	628,849	498,677,257	28·160	9·256	·001261	899273	547
794	630,436	500,566,184	28·178	9·260	·001259	899821	546

No.	Square.	Cube.	Square Root.	Cube Root.	Reciprocal.	Logarithm.	Difference.
795	632,025	502,459,875	28·196	9·264	·001258	900367	546
796	633,616	504,358,336	28·213	9·268	·001256	900913	545
797	635,209	506,261,573	28·231	9·271	·001255	901458	545
798	636,804	508,169,592	28·249	9·275	·001253	902003	544
799	638,401	510,082,399	28·266	9·279	·001251	902547	543
800	640,000	512,000,000	28·284	9·283	·001250	903090	542
801	641,601	513,922,401	28·302	9·287	·001248	903633	541
802	643,204	515,849,608	28·319	9·291	·001247	904174	541
803	644,809	517,781,627	28·337	9·295	·001245	904716	540
804	646,416	519,718,464	28·355	9·299	·001244	905256	540
805	648,025	521,660,125	28·372	9·302	·001242	905796	539
806	649,636	523,606,616	28·390	9·306	·001241	906335	538
807	651,249	525,557,943	28·408	9·310	·001239	906874	537
808	652,864	527,514,112	28·425	9·314	·001238	907411	537
809	654,481	529,475,129	28·443	9·318	·001236	907949	536
810	656,100	531,441,000	28·460	9·321	·001235	908485	536
811	657,721	533,411,731	28·478	9·325	·001233	909021	535
812	659,344	535,387,328	28·496	9·329	·001232	909556	535
813	660,969	537,366,797	28·513	9·333	·001230	910091	534
814	662,596	539,353,144	28·531	9·337	·001229	910624	533
815	664,225	541,343,375	28·548	9·341	·001227	911158	533
816	665,856	543,338,496	28·566	9·345	·001225	911690	533
817	667,489	545,338,513	28·583	9·348	·001224	912220	532
818	669,124	547,343,432	28·601	9·352	·001222	912753	531
819	670,761	549,353,259	28·618	9·356	·001221	913284	530
820	672,400	551,368,000	28·636	9·360	·001220	913814	529
821	674,041	553,387,661	28·653	9·364	·001218	914343	529
822	675,684	555,412,248	28·670	9·367	·001217	914872	528
823	677,329	557,441,767	28·688	9·371	·001215	915400	527
824	678,976	559,476,224	28·705	9·375	·001214	915927	527
825	680,625	561,515,625	28·723	9·379	·001212	916454	526
826	682,276	563,559,976	28·740	9·383	·001211	916980	526
827	683,929	565,609,283	28·758	9·386	·001209	917506	525
828	685,584	567,663,552	28·775	9·390	·001208	918030	524
829	687,241	569,722,789	28·792	9·394	·001206	918555	523
830	688,900	571,787,000	28·810	9·398	·001205	919078	523
831	690,561	573,856,191	28·827	9·401	·001203	919601	522
832	692,224	575,930,368	28·844	9·405	·001202	920123	522
833	693,889	578,009,537	28·862	9·409	·001200	920645	521
834	695,556	580,093,704	28·879	9·413	·001199	921166	520
835	697,225	582,182,875	28·896	9·417	·001198	921686	520
836	698,896	584,277,056	28·914	9·420	·001196	922206	519
837	700,569	586,376,253	28·931	9·424	·001195	922725	519
838	702,244	588,480,472	28·948	9·428	·001193	923244	518
839	703,921	590,589,719	28·965	9·432	·001192	923762	517

No.	Square.	Cube.	Square Root.	Cube Root.	Recip-rocal.	Loga-rithm.	Differ-ence.
840	705,600	592,704,000	28·983	9·435	·001190	924279	517
841	707,281	594,823,321	29·000	9·439	·001189	924796	516
842	708,964	596,947,688	29·017	9·443	·001188	925312	516
843	710,649	599,077,107	29·034	9·447	·001186	925828	515
844	712,336	601,211,584	29·052	9·450	·001185	926342	514
845	714,025	603,351,125	29·069	9·454	·001183	926857	513
846	715,716	605,495,736	29·086	9·458	·001182	927370	513
847	717,409	607,645,423	29·103	9·461	·001181	927883	513
848	719,104	609,800,192	29·120	9·465	·001179	928396	512
849	720,801	611,960,049	29·138	9·469	·001178	928908	511
850	722,500	614,125,000	29·155	9·473	·001176	929419	511
851	724,201	616,295,051	29·172	9·476	·001175	929930	510
852	725,904	618,470,208	29·189	9·480	·001174	930440	509
853	727,609	620,650,477	29·206	9·483	·001172	930949	509
854	729,316	622,835,864	29·223	9·487	·001171	931458	508
855	731,025	625,026,375	29·240	9·491	·001170	931966	508
856	732,736	627,222,016	29·257	9·495	·001168	932474	507
857	734,419	629,422,793	29·274	9·499	·001167	932981	506
858	736,164	631,628,712	29·292	9·502	·001166	933487	506
859	737,881	633,839,779	29·309	9·506	·001164	933993	505
860	739,600	636,056,000	29·326	9·509	·001163	934498	505
861	741,321	638,277,381	29·343	9·513	·001161	935003	504
862	743,044	640,503,928	29·360	9·517	·001160	935507	504
863	744,769	642,735,647	29·377	9·520	·001159	936011	503
864	746,496	644,972,544	29·394	9·524	·001157	936514	502
865	748,225	647,214,625	29·411	9·528	·001156	937016	502
866	749,956	649,461,896	29·428	9·532	·001155	937518	501
867	751,689	651,714,363	29·445	9·535	·001153	938019	501
868	753,424	653,972,032	29·462	9·539	·001152	938520	500
869	755,161	656,234,909	29·479	9·543	·001151	939020	499
870	756,900	658,503,000	29·496	9·546	·001149	939519	499
871	758,641	660,776,311	29·513	9·550	·001148	940018	498
872	760,384	663,054,848	29·529	9·554	·001147	940516	498
873	762,129	665,388,617	29·546	9·557	·001145	941014	497
874	763,876	667,627,624	29·563	9·561	·001144	941511	497
875	765,625	669,921,875	29·580	9·565	·001143	942008	496
876	767,376	672,221,376	29·597	9·568	·001142	942504	496
877	769,129	674,526,133	29·614	9·572	·001140	943000	495
878	770,884	676,836,152	29·631	9·575	·001139	943495	494
879	772,641	679,151,439	29·648	9·579	·001138	943989	494
880	774,400	681,472,000	29·665	9·583	·001136	944483	493
881	776,161	683,797,841	29·682	9·586	·001135	944976	493
882	777,924	686,128,968	29·698	9·590	·001134	945469	492
883	779,689	688,465,387	29·715	9·594	·001133	945961	491
884	781,456	690,807,104	29·732	9·597	·001131	946452	491

No.	Square.	Cube.	Square Root.	Cube Root.	Recip-rocal.	Loga-rithm.	Differ-ence.
885	783,225	693,154,125	29·749	9·601	·001130	946943	490
886	784,996	695,506,456	29·766	9·604	·001129	947434	490
887	786,769	697,864,103	29·782	9·608	·001127	947924	489
888	788,544	700,227,072	29·799	9·612	·001126	948413	489
889	790,321	702,595,369	29·816	9·615	·001125	948902	488
890	792,100	704,969,000	29·833	9·619	·001124	949390	488
891	793,881	707,347,971	29·850	9·623	·001122	949878	487
892	795,664	709,732,288	29·866	9·626	·001121	950365	486
893	797,449	712,121,957	29·883	9·630	·001120	950851	486
894	799,236	714,516,984	29·900	9·633	·001119	951338	485
895	801,025	716,917,375	29·916	9·637	·001118	951823	485
896	802,816	719,323,136	29·933	9·640	·001116	952308	484
897	804,609	721,734,273	29·950	9·644	·001115	952792	484
898	806,404	724,150,792	29·967	9·648	·001114	953276	484
899	808,201	726,572,699	29·983	9·651	·001112	953760	483
900	810,000	729,000,000	30·000	9·655	·001111	954243	482
901	811,801	731,432,701	30·017	9·658	·001110	954725	482
902	813,604	733,870,808	30·033	9·662	·001109	955207	481
903	815,409	736,314,327	30·050	9·666	·001107	955688	480
904	817,216	738,763,264	30·066	9·669	·001106	956168	480
905	819,025	741,217,625	30·083	9·673	·001105	956649	479
906	820,836	743,677,416	30·100	9·676	·001104	957128	479
907	822,649	746,142,643	30·116	9·680	·001103	957604	478
908	824,464	748,613,312	30·133	9·683	·001101	958086	478
909	826,281	751,089,429	30·150	9·687	·001100	958564	477
910	828,100	753,571,000	30·163	9·690	·001099	959041	477
911	829,121	756,058,031	30·183	9·694	·001098	959518	477
912	831,744	758,550,528	30·199	9·698	·001096	959995	476
913	833,569	761,048,497	30·216	9·701	·001095	960471	475
914	835,396	763,551,944	30·232	9·705	·001094	960946	475
915	837,225	766,060,875	30·249	9·708	·001093	961421	474
916	839,056	768,575,296	30·265	9·712	·001092	961895	474
917	810,889	771,095,213	30·282	9·715	·001091	962363	474
918	842,724	773,620,632	30·298	9·718	·001089	962843	473
919	844,561	776,151,559	30·315	9·722	·001088	963316	473
920	846,400	778,688,000	30·331	9·726	·001087	963788	472
921	848,241	781,229,961	30·348	9·729	·001086	964260	471
922	850,084	783,777,448	30·364	9·733	·001085	964731	471
923	851,929	786,330,467	30·381	9·736	·001083	965202	470
924	853,776	788,889,024	30·397	9·740	·001082	965672	470
925	855,625	791,453,125	30·414	9·743	·001081	966142	469
926	857,476	794,022,776	30·430	9·747	·001080	966611	469
927	859,329	796,597,983	30·447	9·750	·001079	967080	468
928	861,184	799,178,752	30·463	9·754	·001078	967548	468
929	863,041	801,765,089	30·479	9·757	·001076	968016	467

No.	Square.	Cube.	Square Root.	Cube Root.	Recip-rocal.	Loga-rithm.	Differ-ence.
930	864,900	804,357,000	30·496	9·761	·001075	968483	467
931	866,761	806,954,491	30·512	9·764	·001074	968950	466
932	868,624	809,557,568	30·529	9·768	·001073	969416	466
933	870,489	812,166,237	30·545	9·771	·001072	969882	465
934	872,356	814,780,504	30·561	9·775	·001071	970347	465
935	874,225	817,400,375	30·578	9·778	·001070	970812	464
936	876,096	820,025,856	30·594	9·783	·001068	971276	464
937	877,969	822,656,953	30·610	9·785	·001067	971740	463
938	879,844	825,293,672	30·627	9·789	·001066	972203	463
939	881,721	827,936,019	30·643	9·792	·001065	972666	462
940	883,600	830,584,000	30·659	9·796	·001064	973128	462
941	885,481	833,237,621	30·676	9·799	·001063	973590	461
942	887,364	835,896,888	30·692	9·803	·001062	974051	461
943	889,249	838,561,807	30·708	9·806	·001060	974512	460
944	891,136	841,232,284	30·724	9·810	·001059	974972	460
945	893,025	843,908,625	30·741	9·813	·001058	975432	459
946	894,916	846,590,536	30·757	9·817	·001057	975891	459
947	896,809	849,278,123	30·773	9·820	·001056	976350	458
948	898,704	851,971,392	30·790	9·823	·001055	976808	458
949	900,601	854,670,349	30·806	9·827	·001054	977266	457
950	902,500	857,375,000	30·822	9·830	·001053	977724	457
951	904,401	860,085,351	30·838	9·834	·001052	978181	456
952	906,304	862,801,408	30·854	9·837	·001050	978637	456
953	908,209	865,523,177	30·871	9·841	·001049	979093	455
954	910,116	868,250,664	30·887	9·844	·001048	979548	455
955	912,025	870,983,875	30·903	9·848	·001047	980003	455
956	913,936	873,722,816	30·919	9·851	·001046	980458	454
957	915,849	876,467,493	30·935	9·854	·001045	980912	454
958	917,764	879,217,912	30·951	9·858	·001044	981366	453
959	919,681	881,974,079	30·968	9·861	·001043	981819	452
960	921,600	884,736,000	30·984	9·865	·001042	982271	452
961	923,521	887,503,681	31·000	9·868	·001041	982723	452
962	925,444	890,277,128	31·016	9·872	·001040	983175	451
963	927,369	893,056,347	31·032	9·875	·001038	983626	451
964	929,296	895,841,344	31·048	9·878	·001037	984077	450
965	931,225	898,632,125	31·064	9·881	·001036	984527	450
966	933,156	901,428,696	31·080	9·885	·001035	984977	449
967	935,089	904,231,063	31·097	9·889	·001034	985426	449
968	937,024	907,039,232	31·113	9·892	·001033	985875	449
969	938,961	909,853,209	31·129	9·895	·001032	986324	448
970	940,900	912,673,000	31·145	9·899	·001031	986772	447
971	942,841	915,498,611	31·161	9·902	·001030	987219	447
972	944,784	918,330,048	31·177	9·906	·001029	987666	447
973	946,729	921,167,317	31·193	9·909	·001028	988113	446
974	948,676	924,010,424	31·209	9·912	·001027	988559	446

No.	Square.	Cube.	Square Root.	Cube Root.	Recip-rocal.	Loga-rithm.	Differ-ence.
975	950,625	926,859,375	31·225	9·916	·001026	989005	445
976	952,576	929,714,176	31·241	9·919	·001025	989450	445
977	954,529	932,574,833	31·257	9·923	·001024	989895	444
978	956,484	935,441,352	31·273	9·926	·001022	990339	444
979	958,441	938,313,739	31·289	9·929	·001021	990783	443
980	960,400	941,192,000	31·305	9·933	·001020	991226	443
981	962,361	944,076,141	31·321	9·936	·001019	991669	442
982	964,324	946,966,168	31·337	9·940	·001018	992111	442
983	966,289	949,862,087	31·353	9·943	·001017	992554	441
984	968,256	952,763,904	31·369	9·946	·001016	992995	441
985	970,225	955,671,625	31·385	9·950	·001015	993436	441
986	972,196	958,585,256	31·401	9·953	·001014	993877	440
987	974,169	961,504,803	31·416	9·956	·001013	994317	440
988	976,144	964,430,272	31·432	9·960	·001012	994757	439
989	978,121	967,361,669	31·448	9·963	·001011	995196	439
990	980,100	970,299,000	31·464	9·966	·001010	995635	439
991	982,081	973,242,271	31·480	9·970	·001009	996074	438
992	984,064	976,191,488	31·496	9·973	·001008	996512	437
993	986,049	979,146,657	31·512	9·977	·001007	996949	437
994	988,036	982,107,784	31·528	9·980	·001006	997386	437
995	990,025	985,074,875	31·544	9·983	·001005	997823	436
996	992,016	988,047,936	31·559	9·987	·001004	998259	436
997	994,009	991,026,973	31·575	9·990	·001003	998695	435
998	996,004	994,011,992	31·591	9·993	·001002	999131	434
999	998,001	997,002,999	31·607	9·997	·001001	999565	
1000	1,000,000	1,000,000,000	31·623	10·000	·001000		

The common Logarithm of any number is the power to which, if 10 be raised, the said number is the result thus :—

10^2 = 100 therefore Log. = 2·
$10^{2 \cdot 42}$ = 263 ,, ,, = 2·42
$10^{-2 \cdot 42}$ = .0263 ,, ,, = $\bar{2} \cdot 42$

Areas and Circumferences of Circles.

Diameters.			0 Area.	0 Circum.	1 Area.	1 Circum.	2 Area.	2 Circum.	3 Area.	3 Circum.	4 Area.	4 Circum.	5 Area.	5 Circum.
	0		...	...	·7854	3·1416	3·141	6·283	7·068	9·424	12·56	12·56	19·63	15·70
1/12			·00545	·26180	·9217	3·403	3·409	6·545	7·467	9·686	13·09	12·82	20·29	15·97
	·1		·0078	·31416	·9503	3·456	3·464	6·597	7·548	9·739	13·202	12·88	20·48	16·02
		1/8	·01227	·39269	·9940	3·534	3·546	6·675	7·669	9·817	13·36	12·95	20·62	16·10
2/12			·02182	·52360	1·069	3·665	3·687	6·807	7·876	9·948	13·63	13·09	20·96	16·23
	·2		·0314	·62832	1·131	3·769	3·801	6·911	8·042	10·053	13·854	13·19	21·24	16·33
3/12		1/4	·04909	·78539	1·227	3·927	3·976	7·068	8·295	10·21	14·18	13·35	21·64	16·49
	·3		·0706	·94248	1·327	4·084	4·155	7·226	8·553	10·36	14·522	13·50	22·06	16·65
4/12			·08726	1·0472	1·396	4·189	4·276	7·330	8·727	10·47	14·75	13·61	22·34	16·75
		3/8	·11045	1·1781	1·485	4·319	4·430	7·461	8·946	10·60	15·03	13·74	22·69	16·88
	·4		·12565	1·2566	1·539	4·398	4·524	7·539	9·079	10·68	15·205	13·82	22·90	16·96
5/12			·13635	1·3090	1·576	4·451	4·587	7·592	9·168	10·73	15·32	13·87	23·04	17·02
6/12	·5	1/2	·19635	1·5708	1·767	4·712	4·908	7·854	9·621	10·99	15·90	14·13	23·75	17·27
7/12			·26725	1·8326	1·969	4·974	5·241	8·116	10·085	11·26	16·50	14·40	24·48	17·54
	·6		·2827	1·8849	2·011	5·026	5·309	8·168	10·179	11·30	16·619	14·45	24·63	17·59
		5/8	·30680	1·9635	2·074	5·105	5·411	8·246	10·32	11·38	16·80	14·52	24·85	17·67
8/12			·34906	2·0944	2·182	5·236	5·585	8·378	10·559	11·52	17·10	14·66	25·22	17·80
	·7		·3848	2·1991	2·269	5·340	5·725	8·482	10·752	11·62	17·349	14·76	25·52	17·90
9/12		3/4	·44179	2·3562	2·405	5·497	5·939	8·639	11·04	11·78	17·72	14·92	25·96	18·06
	·8		·5026	2·5133	2·545	5·655	6·157	8·796	11·341	11·93	18·095	15·08	26·42	18·22
10/12			·54542	2·6180	2·639	5·759	6·305	8·901	11·541	12·04	18·35	15·18	26·72	18·32
		7/8	·60132	2·7489	2·761	5·890	6·491	9·032	11·79	12·17	18·66	15·31	27·10	18·45
	·9		·6361	2·8274	2·835	5·969	6·605	9·111	11·946	12·25	18·857	15·39	27·34	18·53
11/12			·65995	2·8798	2·885	6·021	6·681	9·163	12·048	12·30	18·98	15·45	27·49	18·59

			Diameters.											
			6		7		8		9		10		11	
			Area.	Circum.	Area.	Circum.	Area.	Circum.	Area.	Circum.	Area.	Circum.	Area.	Circum.
	0		28·27	18·84	38·48	21·99	50·26	25·13	63·61	28·27	78·54	31·42	95·03	34·56
$\frac{1}{12}$			29·06	19·11	39·40	22·25	51·32	25·39	64·80	28·54	79·85	31·68	95·48	34·82
	·1		29·22	19·16	39·59	22·30	51·53	25·44	65·04	28·58	80·12	31·73	96·77	34·87
		$\frac{1}{8}$	29·46	19·24	39·87	22·38	51·84	25·52	65·39	28·66	80·52	31·80	97·20	34·95
$\frac{2}{12}$			29·86	19·37	40·34	22·51	52·38	25·66	65·99	28·80	81·18	31·94	97·93	35·08
	·2		30·19	19·47	40·72	22·61	52·81	25·76	66·48	28·90	81·71	32·04	98·52	35·18
$\frac{3}{12}$		$\frac{1}{4}$	30·67	19·63	41·28	22·77	53·45	25·91	67·20	29·05	82·52	32·20	99·40	35·34
	·3		31·17	19·79	41·85	22·93	54·11	26·07	67·93	29·21	83·32	32·35	100·29	35·50
$\frac{4}{12}$			31·50	19·89	42·24	23·04	54·54	26·18	68·42	29·32	83·86	32·46	100·88	35·60
		$\frac{3}{8}$	31·91	20·02	42·71	23·16	55·08	26·31	69·02	29·45	84·54	32·59	101·62	35·73
	·4		32·17	20·10	43·01	23·24	55·42	26·38	69·39	29·53	84·95	32·67	102·07	35·81
$\frac{5}{12}$			32·34	20·16	43·20	23·30	55·64	26·44	69·64	29·58	85·22	32·72	102·37	35·87
$\frac{6}{12}$	·5	$\frac{1}{2}$	33·18	20·42	44·17	23·56	56·74	26·70	70·88	29·84	86·59	32·98	103·87	36·12
$\frac{7}{12}$			34·04	20·68	45·16	23·82	57·86	26·96	72·13	30·11	87·97	33·25	105·38	36·39
	·6		34·21	20·73	45·36	23·87	58·09	27·01	72·38	30·15	88·25	33·30	105·68	36·44
		$\frac{5}{8}$	34·47	20·81	45·66	23·95	58·42	27·09	72·75	30·23	88·66	33·37	106·14	36·52
$\frac{8}{12}$			34·91	20·94	46·16	24·08	58·99	27·23	73·39	30·37	89·36	33·51	106·90	36·65
	·7		35·26	21·04	46·57	24·19	59·45	27·33	73·89	30·47	89·92	33·61	107·51	36·75
$\frac{9}{12}$		$\frac{3}{4}$	35·78	21·20	47·17	24·34	60·13	27·48	74·66	30·63	90·76	33·77	108·43	36·91
	·8		36·32	21·36	47·78	24·50	60·82	27·64	75·43	30·78	91·61	33·92	109·36	37·07
$\frac{10}{12}$			36·67	21·47	48·19	24·61	61·28	27·75	75·94	30·89	92·17	34·03	109·98	37·18
		$\frac{7}{8}$	37·12	21·59	48·70	24·74	61·86	27·88	76·58	31·02	92·89	34·16	110·75	37·30
	·9		37·39	21·67	49·02	24·81	62·21	27·96	76·98	31·10	93·31	34·24	111·22	37·38
$\frac{11}{12}$			37·57	21·73	49·22	24·87	62·44	28·01	77·24	31·15	93·60	34·29	111·53	37·44

			Diameters. 12		13		14		15		16		17	
			Area.	Circum.	Area.	Circum.	Area.	Circum	Area.	Circum.	Area.	Circum.	Area.	Circum.
	0		113·1	37·70	132·73	40·84	153·94	43·98	176·71	47·12	201·06	50·26	226·98	53·40
1/12			114·67	37·96	134·44	41·01	155·78	44·24	178·68	47·39	203·16	50·53	229·21	53·67
	·1		114·99	38·01	134·78	41·15	156·15	44·29	179·08	47·43	203·58	50·57	229·66	53·72
		1/8	115·47	38·09	135·3	41·23	156·70	44·37	179·67	47·51	204·22	50·65	230·33	53·79
2/12			116·26	38·22	136·16	41·36	157·62	44·51	180·66	47·65	205·27	50·79	231·45	53·93
	·2		116·90	38·32	136·85	41·46	158·37	44·61	181·46	47·75	206·12	50·89	232·35	54·03
3/12		1/4	117·86	38·48	137·89	41·62	159·48	44·76	182·65	47·90	207·39	51·05	233·71	54·19
	·3		118·82	38·64	138·93	41·78	160·61	44·92	183·85	48·06	208·67	51·20	235·06	54·35
4/12			119·47	38·75	139·63	41·89	161·36	45·03	184·66	48·17	209·53	51·31	235·97	54·45
		3/8	120·28	38·87	140·50	42·01	162·30	45·16	185·66	48·30	210·6	51·44	237·1	54·58
	·4		120·76	38·95	141·03	42·09	162·86	45·23	186·27	48·38	211·24	51·52	237·79	54·65
5/12			121·09	39·01	141·38	42·15	163·24	45·29	186·67	48·43	211·67	51·57	238·24	54·72
6/12	·5	1/2	122·72	39·27	143·14	42·41	165·13	45·55	188·69	48·69	213·82	51·83	240·53	54·97
7/12			124·36	39·53	144·91	42·67	167·03	45·81	190·73	48·96	215·99	52·10	242·82	55·24
	·6		124·69	39·58	145·27	42·72	167·42	45·86	191·13	49·00	216·42	52·15	243·28	55·29
		5/8	125·19	39·66	145·8	42·80	167·99	45·94	191·75	49·08	217·08	52·22	243·98	55·37
8/12			126·01	39·79	146·69	42·93	168·95	46·08	192·77	49·22	218·16	52·36	245·13	55·50
	·7		126·68	39·89	147·41	43·03	169·72	46·18	193·59	49·32	219·04	52·46	246·06	55·60
9/12		3/4	127·68	40·05	148·49	43·19	170·87	46·33	194·83	49·48	220·35	52·62	247·45	55·76
	·8		128·68	40·21	149·47	43·35	172·03	46·49	196·07	49·63	221·67	52·78	248·85	55·92
10/12			129·35	40·32	150·29	43·46	172·81	46·60	196·89	49·74	222·55	52·88	249·78	56·03
		7/8	130·19	40·44	151·2	43·58	173·78	46·73	197·93	49·87	223·65	53·01	250·95	56·15
	·9		130·69	40·52	151·75	43·66	174·37	46·80	198·56	49·95	224·32	53·09	251·65	56·23
11/12			131·04	40·58	152·11	43·72	174·76	46·86	198·97	50·00	224·76	53·15	252·12	56·29

			Diameters.											
			18		19		20		21		22		23	
			Area.	Circum.	Area.	Circum.	Area.	Circum.	Area.	Circum.	Area.	Circum.	Area.	Circum.
	0		254·47	56·54	283·53	59·69	314·16	62·83	346·36	65·97	380·13	69·11	415·48	72·26
1/12			256·83	56·81	286·02	59·95	316·78	63·09	349·11	66·24	383·02	69·38	418·49	72·52
	·1		257·30	56·86	286·52	60·00	317·31	63·14	349·68	66·28	383·59	69·42	419·09	72·57
		1/8	258·02	56·94	287·27	60·08	318·10	63·22	350·50	66·36	384·46	69·50	420·00	72·64
2/12			259·20	57·07	288·52	60·21	319·42	63·36	351·88	66·49	385·91	69·63	421·52	72·78
	·2		260·16	57·17	289·53	60·31	320·47	63·46	352·99	66·60	387·08	69·74	422·73	72·88
3/12		1/4	261·59	57·33	291·04	60·47	322·06	63·62	354·66	66·75	388·82	69·90	424·56	73·04
	·3		263·02	57·49	292·55	60·63	323·66	63·77	356·33	66·91	390·57	70·05	426·39	73·19
4/12			263·98	57·60	293·56	60·73	324·72	63·88	357·44	67·02	391·74	70·16	427·60	73·30
		3/8	265·18	57·72	294·83	60·86	326·05	64·01	358·84	67·15	393·20	70·29	429·13	73·43
	·4		265·90	57·80	295·59	60·94	326·85	64·08	359·68	67·22	394·08	70·37	430·05	73·51
5/12			266·39	57·86	296·10	60·99	327·39	64·14	360·24	67·28	394·67	70·42	430·66	73·56
6/12	·5	1/2	268·80	58·11	298·65	61·26	330·06	64·40	363·05	67·54	397·61	70·68	433·74	73·83
7/12			271·23	58·38	301·21	61·52	332·75	64·66	365·87	67·80	400·56	70·94	436·82	74·09
	·6		271·72	58·43	301·72	61·57	333·29	64·71	366·44	67·85	401·15	71·00	437·44	74·14
		5/8	272·45	58·51	302·49	61·65	334·10	64·79	367·28	67·93	402·04	71·07	438·36	74·22
8/12			273·67	58·64	303·77	61·78	335·45	64·92	368·70	68·07	403·52	71·20	439·91	74·35
	·7		274·65	58·74	304·81	61·88	336·54	65·03	369·84	68·17	404·71	71·31	441·15	74·45
9/12		3/4	276·12	58·90	306·35	62·04	338·16	65·19	371·54	68·33	406·49	71·47	443·01	74·61
	·8		277·59	59·06	307·91	62·20	339·79	65·34	373·25	68·48	408·28	71·62	444·88	74·76
10/12			278·58	59·16	308·95	62·31	340·88	65·45	374·39	68·59	409·48	71·73	446·13	74·87
		7/8	279·81	59·29	310·24	62·43	342·25	65·58	375·83	68·72	410·97	71·86	447·69	75·00
	·9		280·55	59·37	311·03	62·51	343·07	65·65	376·68	68·80	411·87	71·94	448·63	75·08
11/12			281·05	59·43	311·55	62·53	343·62	65·71	377·26	68·85	412·47	71·99	449·25	75·14

			Diameters. 24 Area.	24 Circum.	25 Area.	25 Circum.	26 Area.	26 Circum.	27 Area.	27 Circum.	28 Area.	28 Circum.	29 Area.	29 Circum.
	0		452·39	75·40	490·87	78·54	530·93	81·68	572·56	84·82	615·75	87·96	660·52	91·11
1/12			455·53	75·66	494·15	78·80	534·34	81·94	576·09	85·08	619·42	88·23	664·32	91·37
	·1		456·17	75·71	494·81	78·85	535·02	81·99	576·81	85·13	620·16	88·27	665·08	91·42
		1/8	457·11	75·79	495·79	78·93	536·05	82·07	577·87	85·21	621·26	88·35	666·23	91·49
2/12			458·69	75·92	497·44	79·06	537·76	82·21	579·65	85·35	623·10	88·49	668·13	91·63
	·2		459·96	76·02	498·76	79·16	539·13	82·30	581·07	85·45	624·58	88·59	669·66	91·73
3/12		1/4	461·86	76·18	500·74	79·33	541·19	82·47	583·21	85·61	626·79	88·75	671·96	91·89
	·3		463·77	76·34	502·73	79·48	543·25	82·62	585·35	85·76	629·02	88·90	674·26	92·04
4/12			465·04	76·44	504·05	79·59	544·63	82·73	586·78	85·87	630·50	89·01	675·79	92·15
		3/8	466·64	76·57	505·71	79·71	546·35	82·85	588·57	86·00	632·36	89·14	677·71	92·28
	·4		467·59	76·65	506·71	79·79	547·39	82·93	589·65	86·07	633·47	89·22	678·87	92·36
5/12			468·23	76·71	507·37	79·85	548·08	82·99	590·36	86·13	634·21	89·27	679·64	92·41
6/12	·5	1/2	471·44	76·97	510·71	80·11	551·55	83·25	593·96	86·39	637·94	89·53	683·49	92·68
7/12			474·65	77·23	514·05	80·37	555·02	83·51	597·56	86·66	641·67	89·79	687·36	92·94
	·6		475·29	77·28	514·72	80·42	555·72	83·56	598·28	86·70	642·42	89·84	688·14	92·99
		5/8	476·26	77·36	515·72	80·50	556·76	83·64	599·37	86·78	643·55	89·92	689·30	93·06
8/12			477·87	77·49	517·40	80·63	558·51	83·78	601·18	86·92	645·42	90·06	691·24	93·20
	·7		479·16	77·59	518·75	80·73	559·90	83·88	602·63	87·02	646·93	90·16	692·79	93·30
9/12		3/4	481·11	77·75	520·77	80·89	562·00	84·04	604·80	87·18	649·18	90·32	695·13	93·46
	·8		483·05	77·91	522·79	81·05	564·11	84·19	606·99	87·33	651·44	90·47	697·47	93·61
10/12			484·35	78·02	524·14	81·16	565·51	84·30	608·44	87·44	652·95	90·58	699·03	93·72
		7/8	485·98	78·14	525·84	81·28	567·27	84·43	610·27	87·57	654·84	90·71	700·98	93·85
	·9		486·95	78·22	526·85	81·36	568·32	84·50	611·36	87·65	655·97	90·79	702·15	93·93
11/12			487·61	78·28	527·53	81·41	569·03	84·56	612·09	87·70	656·73	90·84	702·94	93·99

			Diameters.											
			30		31		32		33		34		35	
			Area.	Circum.	Area.	Circum.	Area.	Circum.	Area.	Circum.	Area.	Circum.	Area.	Circum.
	0		706·86	94·24	754·77	97·38	804·25	100·5	855·30	103·6	907·92	106·8	962·11	109·9
$\frac{1}{12}$			710·79	94·51	758·83	97·65	808·44	100·8	859·62	103·9	912·38	107·0	966·70	110·2
	·1		711·58	94·56	759·65	97·70	809·28	100·8	860·49	103·9	913·27	107·1	967·62	110·2
		$\frac{1}{8}$	712·76	94·64	760·87	97·78	810·54	100·9	861·79	104·1	914·61	107·2	969·00	110·3
$\frac{2}{12}$			714·73	94·77	762·91	97·91	812·65	101·0	863·96	104·2	916·84	107·3	971·30	110·5
	·2		716·32	94·87	764·54	98·01	814·33	101·1	865·70	104·3	918·63	107·4	973·14	110·5
$\frac{3}{12}$		$\frac{1}{4}$	718·69	95·03	766·99	98·17	816·86	101·3	868·31	104·5	921·32	107·6	975·91	110·7
	·3		721·07	95·19	769·45	98·33	819·40	101·4	870·92	104·6	924·01	107·7	978·68	110·8
$\frac{4}{12}$			722·65	95·29	771·09	98·44	821·09	101·6	872·66	104·7	925·81	107·9	980·53	111·0
		$\frac{3}{8}$	724·64	95·42	773·14	98·56	829·58	101·7	874·85	104·9	928·06	108·0	982·84	111·1
	·4		725·84	95·50	774·37	98·64	824·48	101·7	876·16	104·9	929·41	108·0	984·23	111·2
$\frac{5}{12}$			726·63	95·56	775·19	98·70	825·33	101·8	877·03	105·0	930·31	108·1	985·16	111·3
$\frac{6}{12}$	·5	$\frac{1}{2}$	730·62	95·81	779·31	98·96	829·58	102·1	881·42	105·2	934·82	108·3	989·80	111·5
$\frac{7}{12}$			734·61	96·08	783·44	99·22	833·84	102·4	885·80	105·5	939·34	108·6	994·45	111·8
	·6		735·42	96·13	784·27	99·27	834·69	102·4	886·68	105·5	940·25	108·6	995·38	111·8
		$\frac{5}{8}$	736·62	96·21	785·51	99·35	835·97	102·5	888·00	105·6	941·61	108·8	996·78	111·9
$\frac{8}{12}$			738·62	96·34	787·58	99·48	838·11	102·6	890·20	105·7	943·87	108·9	999·11	112·1
	·7		740·23	96·44	789·24	99·58	839·28	102·7	891·97	105·8	945·69	109·0	1000·9	112·1
$\frac{9}{12}$		$\frac{3}{4}$	742·64	96·60	791·73	99·74	842·39	102·9	894·62	106·0	948·42	109·2	1003·8	112·3
	·8		745·06	96·76	794·23	99·90	844·96	103·0	897·27	106·1	951·15	109·3	1006·6	112·4
$\frac{10}{12}$			746·67	96·87	795·89	100·01	846·68	103·1	899·04	106·3	952·97	109·4	1008·5	112·6
		$\frac{7}{8}$	748·69	96·99	797·98	100·1	848·83	103·3	901·26	106·4	955·25	109·6	1010·8	112·7
	·9		749·91	97·07	799·23	100·2	850·12	103·3	902·59	106·5	956·63	109·6	1012·2	112·7
$\frac{11}{12}$			750·71	97·13	800·06	100·3	850·98	103·4	903·47	106·6	957·54	109·7	1013·2	112·8

			Diameters.											
			36		37		38		39		40		41	
			Area.	Circum.	Area.	Circum.	Area.	Circum.	Area.	Circum.	Area.	Circum.	Area.	Circum.
	0		1017·9	113·1	1075·2	116·2	1134·1	119·3	1194·6	122·5	1256·6	125·6	1320·3	128·8
$\frac{1}{12}$			1022·6	113·4	1080·1	116·5	1139·1	119·6	1199·7	122·8	1261·9	125·9	1325·6	129·0
	·1		1023·5	113·4	1081·0	116·5	1140·1	119·6	1200·7	122·8	1262·9	125·9	1326·7	129·1
		$\frac{1}{8}$	1025·0	113·5	1082·5	116·6	1141·6	119·8	1202·3	122·9	1264·5	126·1	1328·3	129·2
$\frac{2}{12}$			1027·3	113·6	1084·9	116·7	1144·1	119·9	1204·8	123·0	1267·1	126·2	1331·0	129·3
	·2		1029·2	113·7	1086·8	116·8	1146·1	120·0	1206·9	123·1	1269·2	126·2	1333·2	129·4
$\frac{3}{12}$		$\frac{1}{4}$	1032·1	113·9	1089·8	117·0	1149·1	120·2	1210·0	123·3	1272·4	126·4	1336·4	129·6
	·3		1034·9	114·0	1092·7	117·1	1152·1	120·3	1213·0	123·4	1275·6	126·6	1339·6	129·7
$\frac{4}{12}$			1036·8	114·1	1094·7	117·3	1154·1	120·4	1215·1	123·6	1277·7	126·7	1341·8	129·8
		$\frac{3}{8}$	1039·2	114·3	1097·1	117·4	1156·6	120·6	1217·7	123·7	1280·3	126·8	1344·5	130·0
	·4		1040·6	114·3	1098·6	117·4	1158·1	120·6	1219·2	123·7	1281·9	126·9	1346·1	130·0
$\frac{5}{12}$			1041·6	114·4	1099·6	117·5	1159·1	120·7	1220·3	123·8	1282·9	127·0	1347·2	130·1
$\frac{6}{12}$	·5	$\frac{1}{2}$	1046·3	114·6	1104·5	117·8	1164·2	120·9	1225·4	124·0	1288·3	127·2	1352·6	130·3
$\frac{7}{12}$			1051·1	114·9	1109·4	118·1	1169·2	121·2	1230·6	124·3	1293·5	127·5	1358·1	130·6
	·6		1052·1	114·9	1110·4	118·1	1170·2	121·2	1231·6	124·4	1294·6	127·5	1359·2	130·6
		$\frac{5}{8}$	1053·5	115·1	1111·8	118·2	1171·7	121·3	1233·2	124·5	1296·2	127·6	1360·8	130·8
$\frac{8}{12}$			1055·9	115·2	1114·3	118·3	1174·3	121·5	1235·8	124·6	1298·9	127·7	1363·5	130·9
	·7		1057·8	115·2	1116·3	118·4	1176·3	121·5	1237·9	124·7	1301·0	127·8	1365·7	131·0
$\frac{9}{12}$		$\frac{3}{4}$	1060·7	115·5	1119·2	118·6	1179·3	121·7	1241·0	124·9	1304·2	128·0	1369·0	131·2
	·8		1063·6	115·6	1122·2	118·7	1182·4	121·8	1244·6	125·0	1307·4	128·1	1372·3	131·3
$\frac{10}{12}$			1065·5	115·7	1124·2	118·8	1184·4	122·0	1246·2	125·1	1309·5	128·3	1374·5	131·4
		$\frac{7}{8}$	1068·0	115·8	1126·7	119·0	1186·9	122·1	1248·8	125·3	1312·2	128·4	1377·2	131·6
	·9		1069·4	115·9	1128·2	119·0	1188·5	122·2	1250·4	125·3	1313·8	128·4	1378·8	131·6
$\frac{11}{12}$			1070·4	116·0	1129·1	119·1	1189·5	122·3	1251·4	125·4	1314·9	128·5	1379·9	131·7

			Diameters.											
			42		43		44		45		46		47	
			Area.	Circum.	Area.	Circum.	Area.	Circum.	Area.	Circum.	Area.	Circum.	Area.	Circum.
	0		1385·4	131·9	1452·2	135·0	1520·5	138·2	1590·4	141·3	1661·9	144·5	1734·9	147·6
$\frac{1}{12}$			1390·9	132·2	1457·8	135·3	1526·3	138·5	1596·3	141·6	1667·9	144·8	1741·1	147·9
	·1		1392·1	132·2	1458·9	135·4	1527·4	138·5	1597·5	141·6	1669·1	144·8	1742·3	147·9
		$\frac{1}{8}$	1393·7	132·3	1460·7	135·5	1529·2	138·6	1599·3	141·8	1671·0	144·9	1744·2	148·0
$\frac{2}{12}$			1396·5	132·5	1463·5	135·6	1532·1	138·7	1602·2	141·9	1674·0	145·0	1747·3	148·2
	·2		1398·7	132·5	1465·7	135·7	1534·4	138·8	1604·6	142·0	1676·4	145·1	1749·7	148·2
$\frac{3}{12}$		$\frac{1}{4}$	1402·0	132·7	1469·1	135·9	1537·9	139·0	1608·2	142·2	1680·0	145·3	1753·5	148·4
	·3		1405·3	132·8	1472·5	136·0	1541·3	139·1	1611·7	142·3	1683·7	145·4	1757·2	148·5
$\frac{4}{12}$			1407·5	133·0	1474·8	136·1	1543·7	139·3	1614·1	142·4	1686·1	145·6	1759·6	148·7
		$\frac{3}{8}$	1410·3	133·1	1477·6	136·3	1546·6	139·4	1617·0	142·6	1689·1	145·7	1762·7	148·8
	·4		1411·9	133·2	1479·3	136·3	1548·3	139·4	1618·8	142·6	1690·9	145·7	1764·6	148·9
$\frac{5}{12}$			1413·1	133·3	1480·5	136·4	1549·5	139·5	1620·0	142·7	1692·1	145·8	1765·8	149·0
$\frac{6}{12}$	·5	$\frac{1}{2}$	1418·6	133·5	1486·2	136·6	1555·3	139·8	1625·9	142·9	1698·2	146·0	1772·1	149·2
$\frac{7}{12}$			1424·2	133·8	1491·9	136·9	1561·1	140·1	1631·9	143·2	1704·3	146·3	1778·3	149·5
	·6		1425·3	133·8	1493·0	136·9	1562·3	140·1	1633·1	143·2	1705·5	146·3	1779·5	149·5
		$\frac{5}{8}$	1427·0	133·9	1494·7	137·1	1564·0	140·2	1634·9	143·3	1707·4	146·5	1781·4	149·6
$\frac{8}{12}$			1429·8	134·0	1497·6	137·2	1566·9	140·3	1637·9	143·5	1710·4	146·6	1784·5	149·7
	·7		1432·0	134·1	1499·9	137·2	1569·3	140·4	1640·3	143·5	1712·9	146·7	1787·0	149·8
$\frac{9}{12}$		$\frac{3}{4}$	1435·4	134·3	1503·3	137·4	1572·8	140·6	1643·9	143·7	1716·5	146·9	1790·8	150·0
	·8		1438·7	134·4	1506·7	137·6	1576·3	140·7	1647·5	143·9	1720·2	147·0	1794·5	150·1
$\frac{10}{12}$			1440·9	134·6	1509·0	137·7	1578·7	140·8	1649·9	144·0	1722·7	147·1	1797·0	150·3
		$\frac{7}{8}$	1443·8	134·7	1511·9	137·8	1581·6	141·0	1652·9	144·1	1725·7	147·3	1800·1	150·4
	·9		1445·5	134·7	1513·6	137·9	1583·4	141·0	1654·7	144·2	1727·6	147·3	1802·0	150·4
$\frac{11}{12}$			1446·6	134·8	1514·8	138·0	1584·5	141·1	1655·9	144·3	1728·8	147·4	1803·3	150·5

			48 Area.	48 Circum.	49 Area.	49 Circum.	50 Area.	50 Circum.	51 Area.	51 Circum.	52 Area.	52 Circum.	53 Area.	53 Circum.
	0		1809·6	150·7	1885·7	153·9	1963·5	157·0	2042·8	160·2	2123·7	163·3	2206·2	166·5
$\frac{1}{12}$			1815·8	151·1	1892·2	154·2	1970·0	157·3	2049·5	160·5	2130·5	163·6	2213·1	166·8
	·1		1817·1	151·1	1893·4	154·2	1971·4	157·3	2050·8	160·5	2131·9	163·6	2214·5	166·8
		$\frac{1}{8}$	1819·0	151·2	1895·4	154·3	1973·3	157·5	2052·9	160·6	2133·9	163·8	2216·6	166·9
$\frac{2}{12}$			1822·1	151·3	1898·6	154·5	1976·6	157·6	2056·2	160·7	2137·4	163·9	2220·1	167·0
	·2		1824·7	151·4	1901·2	154·5	1979·2	157·7	2058·9	160·8	2140·1	163·9	2222·9	167·1
$\frac{3}{12}$		$\frac{1}{4}$	1828·5	151·6	1905·0	154·7	1983·2	157·9	2062·9	161·0	2144·2	164·1	2227·1	167·3
	·3		1832·3	151·7	1908·9	154·8	1987·1	158·0	2066·9	161·1	2148·3	164·3	2231·2	167·4
$\frac{4}{12}$			1834·8	151·8	1911·5	155·0	1989·8	158·1	2069·6	161·3	2151·0	164·4	2234·0	167·6
		$\frac{3}{8}$	1837·9	152·0	1914·7	155·1	1993·1	158·3	2073·0	161·4	2154·5	164·5	2237·5	167·7
	·4		1839·8	152·0	1916·7	155·1	1995·0	158·3	2075·0	161·4	2156·5	164·6	2239·6	167·7
$\frac{5}{12}$			1841·1	152·1	1917·9	155·2	1996·4	158·4	2076·3	161·5	2157·9	164·7	2241·0	167·8
$\frac{6}{12}$	·5	$\frac{1}{2}$	1847·4	152·3	1924·4	155·5	2003·0	158·6	2083·1	161·8	2164·8	164·9	2248·0	168·0
$\frac{7}{12}$			1853·8	152·6	1930·9	155·8	2009·6	158·9	2089·8	162·0	2171·6	165·2	2255·0	168·3
	·6		1855·1	152·6	1932·2	155·8	2010·9	158·9	2091·2	162·1	2173·0	165·2	2256·4	168·3
		$\frac{5}{8}$	1857·0	152·8	1934·2	155·9	2012·9	159·0	2093·2	162·2	2175·1	165·3	2258·5	168·5
$\frac{8}{12}$			1860·2	152·9	1937·4	156·0	2016·2	159·2	2096·6	162·3	2178·5	165·5	2262·0	168·6
	·7		1862·7	152·9	1940·0	156·1	2018·9	159·2	2099·3	162·4	2181·3	165·5	2264·9	168·7
$\frac{9}{12}$		$\frac{3}{4}$	1866·6	153·2	1943·9	156·3	2022·8	159·4	2103·4	162·6	2185·4	165·7	2269·1	168·9
	·8		1870·4	153·3	1947·8	156·4	2026·8	159·5	2107·4	162·7	2189·6	165·8	2273·3	169·0
$\frac{10}{12}$			1872·9	153·4	1950·4	156·6	2029·5	159·7	2110·1	162·8	2192·3	166·0	2276·1	169·1
		$\frac{7}{8}$	1876·1	153·5	1953·7	156·7	2032·8	159·8	2113·5	163·0	2195·8	166·1	2279·6	169·3
	·9		1878·1	153·6	1955·6	156·7	2034·8	159·9	2115·6	163·0	2197·9	166·1	2281·8	169·3
$\frac{11}{12}$			1879·3	153·7	1957·0	156·8	2036·2	160·0	2116·9	163·1	2199·3	166·2	2283·2	169·4

(Column heading printed above 48–53: DIAMETERS.)

			Diameters. 54		55		56		57		58		59	
			Area.	Circum.	Area.	Circum.	Area.	Circum.	Area.	Circum.	Area.	Circum.	Area.	Circum.
	0		2290·2	169·6	2375·8	172·7	2463·0	175·9	2551·8	179·0	2642·1	182·2	2734·0	185·3
1/12			2297·3	169·9	2383·0	173·0	2470·3	176·2	2559·2	179·3	2649·7	182·5	2741·7	185·6
	·1		2298·7	169·9	2384·5	173·1	2471·8	176·2	2560·7	179·3	2651·2	182·5	2743·3	185·6
		1/8	2300·8	170·0	2386·6	173·2	2474·0	176·3	2563·0	179·5	2653·5	182·6	2745·6	185·7
2/12			2304·4	170·2	2390·3	173·3	2477·7	176·5	2566·7	179·6	2657·3	182·7	2749·4	185·9
	·2		2307·2	170·2	2393·1	173·4	2480·6	176·5	2569·7	179·7	2660·3	182·8	2752·5	185·9
3/12		1/4	2311·5	170·4	2397·5	173·6	2485·1	176·7	2574·2	179·9	2664·9	183·0	2757·2	186·1
	·3		2315·7	170·5	2401·8	173·7	2489·5	176·8	2578·7	180·0	2669·5	183·1	2761·9	186·2
4/12			2318·6	170·7	2404·7	173·8	2492·4	177·0	2581·7	180·1	2672·5	183·3	2765·0	186·4
		3/8	2322·1	170·8	2408·3	174·0	2496·1	177·1	2585·5	180·2	2676·4	183·4	2768·8	186·5
	·4		2324·3	170·9	2410·5	174·0	2498·3	177·1	2587·7	180·3	2678·7	183·4	2771·2	186·6
5/12			2325·7	171·0	2412·0	174·1	2499·8	177·2	2589·2	180·4	2680·2	183·5	2772·7	186·7
6/12	·5	1/2	2332·8	171·2	2419·2	174·3	2507·2	177·5	2596·7	180·6	2687·8	183·7	2780·5	186·9
7/12			2340·0	171·5	2426·5	174·6	2514·6	177·8	2604·3	180·9	2695·5	184·0	2788·3	187·2
	·6		2341·4	171·5	2428·0	174·6	2516·1	177·8	2605·8	180·9	2697·0	184·0	2789·9	187·2
		5/8	2343·5	171·6	2430·2	174·8	2518·3	177·9	2608·0	181·0	2699·3	184·2	2792·2	187·3
8/12			2347·1	171·7	2433·8	174·9	2522·0	178·0	2611·8	181·2	2703·2	184·3	2796·1	187·4
	·7		2350·0	171·8	2436·7	174·9	2525·0	178·1	2614·1	181·2	2706·2	184·4	2799·2	187·5
9/12		3/4	2354·3	172·0	2441·1	175·1	2529·4	178·3	2619·4	181·4	2710·9	184·6	2803·9	187·7
	·8		2358·6	172·1	2445·5	175·3	2533·9	178·4	2623·9	181·5	2715·5	184·7	2808·6	187·8
10/12			2361·5	172·3	2448·4	175·4	2536·9	178·5	2626·9	181·7	2718·5	184·8	2811·7	188·0
		7/8	2365·0	172·4	2452·0	175·5	2540·6	178·7	2630·7	181·8	2722·4	185·0	2815·7	188·1
	·9		2367·2	172·4	2454·2	175·6	2542·8	178·7	2633·0	181·9	2724·7	185·0	2818·0	188·1
11			2368·6	172·5	2455·7	175·7	2544·3	178·8	2634·5	182·0	2726·3	185·1	2819·6	188·2

			Diameters. 60		61		62		63		64		65	
			Area.	Circum.	Area.	Circum.	Area.	Circum.	Area.	Circum.	Area.	Circum.	Area.	Circum.
	0		2827·4	188·4	2922·5	191·6	3019·1	194·8	3117·3	197·9	3217·0	201·0	3318·3	204·2
1/12			2835·3	188·8	2930·5	191·9	3027·2	195·0	3125·5	198·2	3225·4	201·3	3326·8	204·5
	·1		2836·9	188·8	2932·1	191·9	3028·8	195·0	3127·2	198·2	3227·1	201·3	3328·5	204·5
		1/8	2839·2	188·9	2934·5	192·0	3031·3	195·2	3129·6	198·3	3229·6	201·5	3331·1	204·6
2/12			2843·2	189·0	2938·5	192·2	3035·3	195·3	3133·8	198·4	3233·8	201·6	3335·3	204·7
	·2		2846·3	189·1	2941·6	192·2	3038·6	195·4	3137·1	198·5	3237·1	201·6	3338·8	204·8
3/12		1/4	2851·1	189·3	2946·5	192·4	3043·5	195·6	3142·0	198·7	3242·2	201·8	3343·9	205·0
	·3		2855·8	189·4	2951·3	192·5	3048·4	195·7	3147·1	198·8	3247·2	202·0	3349·0	205·1
4/12			2858·9	189·5	2954·5	192·7	3051·6	195·8	3150·3	199·0	3250·6	202·1	3352·4	205·3
		3/8	2862·9	189·7	2958·5	192·8	3055·7	196·0	3154·5	199·1	3254·8	202·2	3356·7	205·4
	·4		2865·3	189·7	2960·9	192·8	3058·2	196·0	3157·0	199·1	3257·3	202·3	3359·3	205·4
5/12			2866·8	189·8	2962·5	192·9	3059·8	196·1	3158·6	199·2	3259·0	202·4	3361·0	205·5
6/12	·5	1/2	2874·8	190·1	2970·6	193·2	3067·9	196·3	3166·9	199·4	3267·5	202·6	3369·6	205·7
7/12			2882·7	190·3	2978·6	193·5	3076·1	196·6	3175·2	199·8	3275·9	202·9	3378·1	206·0
	·6		2884·3	190·3	2980·2	193·5	3077·8	196·6	3176·9	199·8	3277·6	202·9	3379·9	206·0
		5/8	2886·7	190·5	2982·7	193·6	3080·3	196·7	3179·4	199·9	3280·1	203·0	3382·4	206·2
8/12			2890·6	190·6	2986·7	193·7	3084·3	196·9	3183·6	200·0	3284·4	203·2	3386·7	206·3
	·7		2893·8	190·6	2989·9	193·8	3087·6	196·9	3186·9	200·1	3287·8	203·2	3390·2	206·4
9/12		3/4	2898·6	190·9	2994·8	194·0	3092·6	197·1	3191·9	200·3	3292·8	203·4	3395·3	206·6
	·8		2903·3	191·0	2999·6	194·1	3097·5	197·2	3196·9	200·4	3297·9	203·5	3400·5	206·7
10/12			2906·5	191·1	3002·9	194·3	3100·8	197·4	3200·3	200·5	3301·3	203·7	3403·9	206·8
		7/8	2910·5	191·2	3006·9	194·4	3104·9	197·5	3204·4	200·7	3305·6	203·8	3408·3	207·0
	·9		2912·9	191·3	3009·3	194·4	3107·4	197·6	3206·9	200·7	3308·1	203·8	3410·8	207·0
11/12			2914·5	191·4	3011·0	194·5	3109·0	197·7	3208·6	200·8	3309·8	203·9	3412·6	207·1

DIAMETERS.

			66		67		68		69		70		71	
			Area.	Circum.	Area.	Circum.	Area.	Circum.	Area.	Circum.	Area.	Circum.	Area.	Circum.
	0		3421·2	207·3	3525·7	210·4	3631·7	213·6	3739·3	216·8	3848·5	219·9	3959·2	223·0
$\frac{1}{12}$			3429·8	207·6	3534·4	210·7	3640·6	213·9	3748·3	217·0	3857·6	220·2	3968·5	223·3
	·1		3431·6	207·6	3536·2	210·8	3642·4	213·9	3750·1	217·0	3859·5	220·2	3970·4	223·3
		$\frac{1}{8}$	3434·2	207·7	3538·8	210·9	3645·1	214·0	3752·8	217·2	3862·2	220·3	3973·2	223·4
$\frac{2}{12}$			3438·5	207·9	3543·2	211·0	3649·5	214·2	3757·4	217·3	3866·8	220·4	3977·8	223·6
	·2		3442·0	207·9	3546·7	211·1	3653·1	214·2	3761·0	217·3	3870·5	220·5	3981·5	223·6
$\frac{3}{12}$		$\frac{1}{4}$	3447·2	208·1	3552·0	211·3	3658·4	214·4	3766·4	217·6	3876·0	220·7	3987·1	223·8
	·3		3452·4	208·2	3557·3	211·4	3663·8	214·5	3771·9	217·7	3881·5	220·8	3992·7	223·9
$\frac{4}{12}$			3455·8	208·4	3560·8	211·5	3667·4	214·7	3775·5	217·8	3885·2	221·0	3996·5	224·1
		$\frac{3}{8}$	3460·2	208·5	3565·2	211·7	3671·9	214·8	3780·0	217·9	3889·8	221·1	4001·1	224·2
	·4		3462·8	208·6	3567·9	211·7	3674·5	214·8	3782·8	218·0	3892·6	221·1	4003·9	224·3
$\frac{5}{12}$			3464·5	208·7	3569·6	211·8	3676·3	214·9	3784·6	218·1	3894·4	221·2	4005·8	224·4
$\frac{6}{12}$	·5	$\frac{1}{2}$	3473·2	208·9	3578·5	212·0	3685·3	215·1	3793·7	218·3	3903·6	221·4	4015·2	224·6
$\frac{7}{12}$			3481·9	209·2	3587·3	212·3	3694·3	215·5	3802·8	218·6	3912·9	221·7	4024·5	224·9
	·6		3483·7	209·2	3589·1	212·3	3696·1	215·5	3804·6	218·6	3914·7	221·7	4026·4	224·9
		$\frac{5}{8}$	3486·3	209·3	3591·7	212·5	3698·8	215·6	3807·3	218·7	3917·5	221·9	4029·2	225·0
$\frac{8}{12}$			3490·7	209·4	3596·2	212·6	3703·2	215·7	3811·9	218·9	3922·1	222·0	4033·9	225·1
	·7		3494·2	209·5	3599·7	212·6	3706·8	215·8	3815·5	218·9	3925·8	222·1	4037·7	225·2
$\frac{9}{12}$		$\frac{3}{4}$	3499·4	209·7	3605·0	212·8	3712·2	216·0	3821·0	219·1	3931·4	222·3	4043·3	225·4
	·8		3504·6	209·8	3610·4	213·0	3717·6	216·1	3826·5	219·2	3936·9	222·4	4048·9	225·5
$\frac{10}{12}$			3508·1	210·0	3613·9	213·1	3721·2	216·2	3830·1	219·4	3940·6	222·5	4052·7	225·7
		$\frac{7}{8}$	3512·5	210·1	3618·4	213·2	3725·8	216·4	3834·7	219·5	3945·3	222·7	4057·4	225·8
	·9		3515·1	210·1	3621·0	213·3	3728·5	216·4	3837·5	219·5	3948·1	222·7	4060·2	225·8
$\frac{11}{12}$			3516·9	210·2	3622·8	213·4	3730·3	216·5	3839·3	219·6	3949·9	222·8	4062·1	225·9

			72		73		74		75		76		77	
			Area.	Circum.	Area.	Circum.	Area.	Circum.	Area.	Circum.	Area.	Circum.	Area.	Circum.
	0		4071·5	226·1	4185·4	229·3	4300·9	232·4	4417·9	235·6	4536·5	238·7	4656·6	241·9
$\frac{1}{12}$			4080·9	226·5	4194·9	229·6	4310·5	232·7	4427·7	235·9	4546·4	239·0	4666·7	242·2
	·1		4082·8	226·5	4196·9	229·6	4312·5	232·7	4429·7	235·9	4548·4	239·0	4668·7	242·2
		$\frac{1}{8}$	4085·7	226·6	4199·7	229·7	4315·4	232·9	4432·6	236·0	4551·4	239·2	4671·8	242·3
$\frac{2}{12}$			4090·4	226·7	4204·5	229·9	4320·2	233·0	4437·5	236·1	4556·4	239·3	4676·8	242·4
	·2		4094·2	226·8	4208·4	229·9	4324·1	233·1	4441·5	236·2	4560·4	239·3	4680·9	242·5
$\frac{3}{12}$		$\frac{1}{4}$	4099·8	227·0	4214·1	230·1	4330·0	233·3	4447·4	236·4	4566·4	239·5	4686·9	242·7
	·3		4105·5	227·1	4219·9	230·2	4335·8	233·4	4453·3	236·5	4572·4	239·7	4693·0	242·8
$\frac{4}{12}$			4109·3	227·2	4223·7	230·4	4336·7	233·5	4457·2	236·7	4576·3	239·8	4697·0	242·9
		$\frac{3}{8}$	4114·0	227·4	4228·5	230·5	4344·6	233·7	4462·2	236·8	4581·3	239·9	4702·1	243·1
	·4		4116·9	227·4	4231·4	230·5	4347·5	233·7	4465·1	236·8	4584·4	240·0	4705·1	243·1
$\frac{5}{12}$			4118·8	227·5	4233·3	230·6	4349·4	233·8	4467·1	236·9	4586·3	240·1	4707·2	243·2
$\frac{6}{12}$	·5	$\frac{1}{2}$	4128·3	227·7	4242·9	230·9	4359·2	234·0	4477·0	237·1	4596·4	240·3	4717·3	243·4
$\frac{7}{12}$			4137·7	228·0	4252·5	231·2	4368·9	234·3	4486·9	237·5	4606·4	240·6	4727·4	243·7
	·6		4139·7	228·0	4254·5	231·2	4370·9	234·3	4488·8	237·5	4608·4	240·6	4729·5	243·7
		$\frac{5}{8}$	4142·5	228·2	4257·4	231·3	4373·8	234·4	4491·8	237·6	4611·4	240·7	4732·5	243·9
$\frac{8}{12}$			4147·3	228·3	4262·2	231·4	4378·7	234·6	4496·8	237·7	4616·4	240·9	4737·6	244·0
	·7		4151·1	228·3	4266·0	231·5	4382·6	234·6	4500·7	237·8	4620·4	240·9	4741·7	244·1
$\frac{9}{12}$		$\frac{3}{4}$	4156·8	228·6	4271·8	231·7	4388·5	234·8	4506·7	238·0	4626·4	241·1	4747·8	244·3
	·8		4162·5	228·7	4277·6	231·8	4394·3	234·9	4512·6	238·1	4632·5	241·2	4754·0	244·4
$\frac{10}{12}$			4166·3	228·8	4281·5	232·0	4398·3	235·1	4516·6	238·2	4636·5	241·4	4758·0	244·5
		$\frac{7}{8}$	4171·1	228·9	4286·3	232·1	4403·2	235·2	4521·6	238·4	4641·5	241·5	4763·1	244·7
	·9		4173·9	229·0	4289·2	232·1	4406·1	235·3	4524·5	238·4	4644·5	241·5	4766·1	244·7
$\frac{11}{12}$			4175·8	229·1	4291·2	232·2	4408·1	235·4	4526·5	238·5	4646·6	241·6	4768·2	244·8

Diameters.

			Diameters.											
			78		79		80		81		82		83	
			Area.	Circum.	Area.	Circum.	Area.	Circum.	Area.	Circum.	Area.	Circum.	Area.	Circum.
	0		4778·4	245·0	4901·7	248·1	5026·6	251·3	5153·0	254·4	5281·0	257·6	5410·6	260·7
1/12			4788·6	245·3	4912·0	248·4	5037·0	251·6	5163·6	254·7	5291·8	257·8	5421·5	261·0
	·1		4790·6	245·3	4914·1	248·5	5039·1	251·6	5165·7	254·7	5293·9	257·9	5423·7	261·0
		1/8	4793·7	245·4	4917·2	248·6	5042·3	251·7	5168·9	254·9	5297·1	258·0	5426·9	261·1
2/12			4798·8	245·6	4922·4	248·7	5047·5	251·8	5174·2	255·0	5302·5	258·1	5432·4	261·3
	·2		4802·9	245·6	4926·5	248·8	5051·7	251·9	5178·5	255·0	5306·8	258·2	5436·7	261·3
3/12		1/4	4809·1	245·8	4932·8	249·0	5058·0	252·1	5184·9	255·3	5313·3	258·4	5443·3	261·5
	·3		4815·2	245·9	4939·0	249·1	5064·3	252·2	5191·3	255·4	5319·7	258·5	5449·8	261·6
4/12			4819·3	246·1	4943·1	249·2	5068·5	252·4	5195·5	255·5	5324·0	258·7	5454·2	261·8
		3/8	4824·4	246·2	4948·3	249·4	5073·8	252·5	5200·8	255·6	5329·4	258·8	5459·6	261·9
	·4		4827·5	246·3	4951·4	249·4	5077·0	252·5	5204·0	255·7	5332·7	258·8	5462·9	262·0
5/12			4829·5	246·4	4953·5	249·5	5079·0	252·6	5206·1	255·8	5334·8	258·9	5465·1	262·1
6/12	·5	1/2	4839·8	246·6	4963·9	249·7	5089·6	252·8	5216·8	256·0	5345·6	259·1	5476·0	262·3
7/12			4850·1	246·9	4974·3	250·0	5100·1	253·2	5227·5	256·3	5356·4	259·4	5486·9	262·6
	·6		4852·2	246·9	4976·4	250·0	5102·2	253·2	5229·6	256·3	5358·6	259·4	5489·1	262·6
		5/8	4855·3	247·0	4979·5	250·1	5105·4	253·3	5232·8	256·4	5361·8	259·6	5492·4	262·7
8/12			4860·4	247·1	4984·7	250·3	5110·7	253·4	5238·2	256·6	5367·2	259·7	5497·9	262·8
	·7		4864·5	247·2	4988·9	250·3	5114·9	253·5	5242·5	256·6	5371·6	259·8	5502·3	262·9
9/12		3/4	4870·7	247·4	4995·2	250·5	5121·2	253·7	5248·9	256·8	5378·1	260·0	5508·8	263·1
	·8		4876·9	247·5	5001·5	250·6	5127·6	253·8	5255·3	256·9	5384·6	260·1	5515·4	263·2
10/12			4881·0	247·7	5005·6	250·8	5131·8	253·9	5259·6	257·1	5388·9	260·2	5519·8	263·4
		7/8	4886·2	247·8	5010·9	250·9	5137·1	254·1	5264·9	257·2	5394·3	260·4	5525·3	263·5
	·9		4889·3	247·8	5014·0	251·0	5140·3	254·1	5268·2	257·2	5397·6	260·4	5528·6	263·5
11/12			4891·3	247·9	5016·1	251·1	5142·4	254·2	5270·3	257·3	5399·7	260·5	5530·8	263·6

			Diameters.											
			84		85		86		87		88		89	
			Area.	Circum.	Area.	Circum.	Area.	Circum.	Area.	Circum.	Area.	Circum.	Area.	Circum.
	0		5541·8	263·8	5674·5	267·0	5808·8	270·1	5944·7	273·3	6082·1	276·4	6221·2	279·6
1/12			5552·8	264·2	5685·6	267·3	5820·1	270·4	5956·1	273·6	6093·6	276·7	6232·8	279·9
	·1		5555·0	264·2	5687·9	267·3	5822·3	270·4	5958·4	273·6	6096·0	276·7	6235·1	279·9
		1/8	5558·3	264·3	5691·2	267·4	5825·7	270·6	5961·8	273·7	6099·4	276·9	6238·6	280·0
2/12			5563·8	264·4	5696·8	267·6	5831·3	270·7	5967·5	273·8	6105·2	277·0	6244·5	280·1
	·2		5568·2	264·5	5701·3	267·6	5835·9	270·8	5972·1	273·9	6109·8	277·0	6249·1	280·2
3/12		1/4	5574·8	264·7	5707·9	267·8	5842·6	271·0	5978·9	274·1	6116·7	277·2	6256·2	280·4
	·3		5581·4	264·8	5714·6	267·9	5849·4	271·1	5985·8	274·2	6123·7	277·4	6263·2	280·5
4/12			5585·8	264·9	5719·1	268·1	5853·9	271·2	5990·3	274·4	6128·3	277·5	6267·8	280·6
		3/8	5591·4	265·1	5724·7	268·2	5859·6	271·4	5996·1	274·5	6134·1	277·6	6273·7	280·8
	·4		5594·7	265·1	5728·0	268·2	5863·0	271·4	5999·5	274·5	6137·6	277·7	6277·2	280·8
5/12			5596·9	265·2	5730·3	268·3	5865·2	271·5	6001·8	274·6	6139·9	277·8	6279·5	280·9
6/12	·5	1/2	5608·0	265·4	5741·5	268·6	5876·6	271·7	6013·2	274·8	6151·4	278·0	6291·2	281·1
7/12			5619·0	265·7	5752·7	268·9	5887·9	272·0	6024·7	275·2	6163·0	278·3	6303·0	281·4
	·6		5621·2	265·7	5754·9	268·9	5890·2	272·0	6027·0	275·2	6165·4	278·3	6305·3	281·4
		5/8	5624·6	265·9	5758·3	269·0	5893·6	272·1	6030·4	275·3	6169·8	278·4	6308·8	281·6
8/12			5630·1	266·0	5763·9	269·1	5899·2	272·3	6036·1	275·4	6174·6	278·6	6314·7	281·7
	·7		5634·5	266·0	5768·4	269·2	5903·8	272·3	6040·7	275·5	6179·3	278·6	6319·4	281·8
9/21		3/4	5641·2	266·3	5775·1	269·4	5910·6	272·5	6047·6	275·7	6186·3	278·8	6326·4	282·0
	·8		5647·8	266·4	5781·8	269·5	5917·4	272·6	6054·5	275·8	6193·2	278·9	6333·5	282·1
01/21			5652·3	266·5	5786·3	269·7	5921·9	272·8	6059·1	275·9	6197·9	279·1	6338·2	282·2
	.9		5657·8	266·6	5791·9	269·8	5927·6	272·9	6064·9	276·1	6203·7	279·2	6344·1	282·4
11/21			5661·2	266·7	5795·3	269·9	5931·0	273·0	6068·3	276·1	6207·2	279·2	6347·6	282·4
		8/7	5663·4	266·8	5797·6	269·9	5933·3	273·1	6070·6	276·2	6209·5	279·3	6349·9	282·5

			Diameters.									
			90		91		92		´93		94		95	
			Area.	Circum.	Area.	Circum.	Area.	Circum.	Area.	Circum.	Area.	Circum.	Area.	Circum.
	0		6361·7	282·7	6503·9	285·8	6647·6	289·0	6792·9	292·1	6939·8	295·3	7088·2	298·4
$\frac{1}{12}$			6373·5	283·0	6515·8	286·1	6659·7	289·3	6805·1	292·4	6952·1	295·6	7100·7	298·7
	·1		6375·9	283·0	6518·2	286·1	6662·1	289·3	6807·5	292·4	6954·6	295·6	7103·2	298·7
		$\frac{1}{8}$	6379·4	283·1	6521·8	286·3	6665·7	289·4	6811·2	292·6	6958·3	295·7	7106·9	298·8
$\frac{2}{12}$			6385·3	283·3	6527·7	286·4	6671·7	289·6	6817·3	292·7	6964·4	295·8	7113·1	299·0
	·2		6390·0	283·3	6532·5	286·5	6676·6	289·6	6822·2	292·7	6969·4	295·9	7118·1	299·1
$\frac{3}{12}$		$\frac{1}{4}$	6397·1	283·5	6539·7	286·7	6683·8	289·8	6829·5	293·0	6976·8	296·1	7125·6	299·2
	·3		6404·2	283·6	6546·9	286·8	6691·1	289·9	6836·8	293·1	6984·2	296·2	7133·1	299·3
$\frac{4}{12}$			6408·9	283·8	6551·6	286·9	6695·9	290·1	6841·7	293·2	6989·1	296·4	7138·0	299·5
		$\frac{3}{8}$	6414·9	283·9	6557·6	287·1	6701·9	290·2	6847·8	293·3	6995·3	296·5	7144·3	299·6
	·4		6418·4	284·0	6561·2	287·1	6705·6	290·2	6851·5	293·4	6999·0	296·5	7148·1	299·7
$\frac{5}{12}$			6420·8	284·1	6563·6	287·2	6708·0	290·3	6853·9	293·5	7001·4	296·6	7150·5	299·8
$\frac{6}{12}$	·5	$\frac{1}{2}$	6432·6	284·3	6575·6	287·4	6720·1	290·5	6866·2	293·7	7013·8	296·8	7163·0	300·0
$\frac{7}{12}$			6444·5	284·6	6587·5	287·7	6732·2	290·9	6878·4	294·0	7026·2	297·1	7175·5	300·3
	·6		6446·8	284·6	6589·9	287·7	6734·6	290·9	6880·9	294·0	7028·7	297·1	7178·1	300·3
		$\frac{5}{8}$	6450·4	284·7	6593·5	287·8	6738·3	291·0	6884·5	294·1	7032·4	297·3	7181·8	300·4
$\frac{8}{12}$			6456·3	284·8	6599·5	288·0	6744·3	291·1	6890·6	294·3	7038·6	297·4	7188·1	300·5
	·7		6461·1	284·9	6604·3	288·0	6749·2	291·2	6895·6	294·3	7043·5	297·5	7193·1	300·6
$\frac{9}{12}$		$\frac{3}{4}$	6468·2	285·1	6611·5	288·2	6756·5	291·4	6902·9	294·5	7051·0	297·7	7200·6	300·8
	·8		6475·3	285·2	6618·8	288·3	6763·7	291·5	6910·3	294·6	7058·4	297·8	7208·1	300·9
$\frac{10}{12}$			6480·1	285·4	6623·5	288·5	6768·6	291·6	6915·2	294·8	7063·4	297·9	7213·1	301·1
		$\frac{7}{8}$	6486·0	285·5	6629·6	288·6	6774·7	291·8	6921·3	294·9	7069·6	298·1	7219·4	301·2
	·9		6489·6	285·5	6633·2	288·7	6778·3	291·8	6925·0	294·9	7073·3	298·1	7223·2	301·2
$\frac{11}{12}$			6492·0	285·6	6635·6	288·8	6780·7	291·9	6927·5	295·0	7075·8	298·2	7225·7	301·3

			Diameters. 96		97		98		99	
			Area.	Circum.	Area.	Circum.	Area.	Circum.	Area.	Circum.
	0		7238·2	301·5	7389·8	304·7	7543·0	307·8	7697·7	311·0
1/12			7250·8	301·9	7402·5	305·0	7555·8	308·1	7710·7	311·3
	·1		7253·3	301·9	7405·1	305·0	7558·4	308·1	7713·3	311·3
		1/8	7257·1	302·0	7408·9	305·1	7562·2	308·3	7717·2	311·4
2/12			7263·4	302·1	7415·2	305·3	7568·6	308·4	7723·6	311·5
	·2		7268·4	302·2	7420·3	305·3	7573·8	308·5	7728·8	311·6
3/12		1/4	7276·0	302·4	7428·0	305·5	7581·5	308·7	7736·6	311·8
	·3		7283·6	302·5	7435·6	305·6	7589·2	308·8	7744·4	311·9
4/12			7288·6	302·6	7440·7	305·8	7594·4	308·9	7749·6	312·1
		3/8	7294·9	302·8	7447·1	305·9	7600·8	309·1	7756·1	312·2
	·4		7298·7	302·8	7450·9	305·9	7604·7	309·1	7760·0	312·2
5/12			7301·2	302·9	7453·4	306·0	7607·2	309·2	7762·6	312·3
6/12	·5	1/2	7313·8	303·1	7466·2	306·3	7620·1	309·4	7775·7	312·5
7/12			7326·5	303·4	7479·0	306·6	7633·0	309·7	7788·7	312·9
	·6		7329·0	303·4	7481·5	306·6	7635·6	309·7	7791·3	312·9
		5/8	7332·8	303·6	7485·4	306·7	7639·5	309·8	7795·2	313·0
8/12			7339·1	303·7	7491·7	306·8	7645·9	310·0	7801·7	313·1
	·7		7344·2	303·7	7496·9	306·9	7651·2	310·0	7806·9	313·2
9/12		3/4	7351·8	303·9	7504·5	307·1	7658·9	310·2	7814·8	313·4
	·8		7359·4	304·1	7512·2	307·2	7666·6	310·3	7822·6	313·5
10/12			7364·4	304·2	7517·3	307·4	7671·8	310·5	7827·8	313·6
		7/8	7370·8	304·3	7523·8	307·5	7678·3	310·6	7834·4	313·8
	·9		7374·6	304·4	7527·6	307·5	7682·2	310·7	7838·3	313·8
11/12			7377·1	304·4	7530·1	307·6	7684·7	310·8	7840·9	313·9
	0		...	...	...	...	...	...	7854·0	314·2

To find Area of a Segment of a Circle.—From the area of a sector having same arc subtract the area of triangle whose 2 sides = radius of circle and base = chord of segment.

The volume of a sphere = diameter^3 × ·5236.

Area of oval = major diameter × minor diameter × ·7854.

To find the Length of a Side, the diameter being given :—

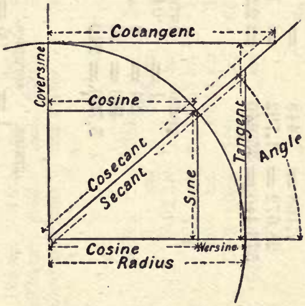
For a Hexagon,	multiply	the	diameter	by	·577
Octagon,	„	„	„	„	·414
Decagon,	„	„	„	„	·325
Dodecagon,	„	„	„	„	·268

The square of any number containing a fraction equals the whole number multiplied by its next higher digit + the square of the fraction, as follows :—

$$(8\tfrac{1}{2})^2 = 8 \times 9 + \tfrac{1}{4}$$
$$(8\tfrac{1}{4})^2 = 8 \times 8\tfrac{1}{2} + \tfrac{1}{16}$$
$$(8\tfrac{1}{8})^2 = 8 \times 8\tfrac{1}{4} + \tfrac{1}{64}$$

Properties of the Circle.

Circumference = diameter × 3·1416 or $3\tfrac{1}{7}$.
Diameter × ·8862 = side of equal square.
Diameter × ·7071 = „ inscribed square.
Diameter^2 × ·7854 = area of circle.
Length of arc of circle = no. of degrees × ·017453.



WEIGHTS AND MEASURES.

Avoirdupois Weight.

grains, troy.	drachms.	ozs.	lbs.	qrs.	cwts.	tons.	French grammes.
27·34375 =	1 =	·0625 =	·0039 =	·000139 =	·000035 =	·00000174 =	1·771846
437·5 =	16 =	1 =	·0625 =	·002232 =	·000558 =	·0000279 =	28·34954
7,000 =	256 =	16 =	1 =	·0357 =	·008928 =	·0004464 =	453·59
	7,168 =	448 =	28 =	1 =	·25 =	·0125 =	12,700
	28,672 =	1,792 =	112 =	4 =	1 =	·05 =	50,802
	573,440 =	35,840 =	2,240 =	80 =	20 =	1 =	1,016,048

Troy Weight.

grains.	dwts.	ozs.	lb.	French grammes.
1 =	·04167 =	·00208 =	·0001736 =	·0648
24 =	1 =	·05 =	·004167 =	1·555
480 =	20 =	1 =	·0833 =	31·1035
5,760 =	240 =	12 =	1 =	373·242

Apothecaries' Weight.

grains.	scruples.	drachms.	ozs.	lbs.	French grammes.
1 =	·05 =	·016 =	·00208 =	·0001736 =	·0648
20 =	1 =	·33 =	·0416 =	·003472 =	1·296
60 =	3 =	1 =	·125 =	·027 =	3·888
480 =	24 =	8 =	1 =	·0833 =	31·1035
5,760 =	288 =	96 =	12 =	1 =	373·242

175 lbs. troy = 144 lbs. avoirdupois ; lbs. troy × ·82286 = lbs. avoirdupois ; lbs. avoirdupois × 1·2153 = lbs. troy.

MEASURES OF LENGTH.

Long Measure.

inches.	feet.	yards.	fathoms.	poles.	furlongs.	mile.	French metres.
1 =	·083 =	·02778 =	·0139 =	·00505 =	·000126 =	·0000158 =	·0254
12 =	1 =	·333 =	·1667 =	·0606 =	·00151 =	·0001894 =	·3048
36 =	3 =	1 =	·5 =	·182 =	·00454 =	·000568 =	·9144
72 =	6 =	2 =	1 =	·364 =	·00908 =	·001136 =	1·8287
198 =	16·5 =	5·5 =	2·75 =	1 =	·025 =	·003125 =	5·0291
7,920 =	660 =	220 =	110 =	40 =	1 =	·125 =	201·16
63,360 =	5,280 =	1,760 =	880 =	320 =	8 =	1 =	1,609·315

Surveying Measure.

nches.	links.	feet	yards.	chains.	mile.	French metres.
1 =	·126 =	·0833 =	·0278 =	·00126 =	·0000158 =	·0254
7·92 =	1 =	·66 =	·22 =	·01 =	·000125 =	·2012
12 =	1·515 =	1 =	·333 =	·01515 =	·000189 =	·3048
36 =	4·545 =	3 =	1 =	·04545 =	·000568 =	·9144
792 =	100 =	66 =	22 =	1 =	·0125 =	20·116
63,360 =	8,000 =	5,280 =	1,760 =	80 =	1 =	1,609·315

Square or Superficial Measure.

inches.	feet.	yards.	perches.	roods.	acre.	square metres.
1 =	·00694 =	·000772 =	·0000255 =	·00000064 =	·000000159 =	·000645
144 =	1 =	·111 =	·00367 =	·0000918 =	·000023 =	·0929
1,296 =	9 =	1 =	·0331 =	·000826 =	·0002062 =	·8361
39,204 =	272·25 =	30·25 =	1 =	·025 =	·00625 =	25·292
1,568,160 =	10,890 =	1,210 =	40 =	1 =	·25 =	1,011·7
6,272,640 =	43,560 =	4,840 =	160 =	4 =	1 =	4,046·7

Square yards × ·000000323	=	square miles.
Acres × ·0015625	=	„ „
27,878,400 square feet	=	1 „ „
3,097,600 square yards	=	1 „ „
640 acres	=	1 „ „
2·471143 „	=	1 hectare.
1 „	=	10 square chains.
1 chain wide	=	8 acres per mile.

Cubic Measure.

inches.	feet.	yards.	cubic metres.
1 =	·0005788 =	·00002144 =	·000016386
1,728 =	1 =	·03704 =	·028315
46,656 =	27 =	1 =	·764513

Ale and Beer Measure (used for ammoniacal liquor).

gills.
4 = 1 pint.
8 = 2 = 1 quart.
32 = 8 = 4 = 1 gallon.
288 = 72 = 36 = 9 = 1 firkin.
576 = 144 = 72 = 18 = 2 = 1 kilderkin.
1,152 = 288 = 144 = 36 = 4 = 2 = 1 barrel.
1,728 = 432 = 216 = 54 = 6 = 3 = 1·5 = 1 hogshead.
2,304 = 576 = 288 = 72 = 8 = 4 = 2 = 1·3 = 1 puncheon.
3,356 = 864 = 432 = 108 = 12 = 6 = 3 = 2 = 1·5 = 1 butt.

Measures of Capacity, or Dry Measure.

pints.	galls.	pecks.	bushels.	quarters.	weys.	last.	cubic feet.	litres.
1 =	·125 =	·0625 =	·01562 =	·00195 =	·00039 =	·000195 =	·020051 =	·5679
8 =	1 =	·5 =	·125 =	·0156 =	·00312 =	·00156 =	·16046 =	4·543
16 =	2 =	1 =	·25 =	·03125 =	·00625 =	·00312 =	·32092 =	9·087
64 =	8 =	4 =	1 =	·125 =	·025 =	·0125 =	1·28367 =	36·34766
512 =	64 =	32 =	8 =	1 =	·2 =	·1 =	10·269 =	290·781
2560 =	320 =	160 =	40 =	5 =	1 =	·5 =	51·347 =	1453·906
5120 =	640 =	320 =	80 =	10 =	2 =	1 =	102·69 =	2907·81

Cubic inches	× ·028848	=	pints.
„ „	× ·014424	=	quarts.
„ „	× ·003606	=	gallons.
„ „	× ·0004508	=	bushels.
„ „	× ·00005635	=	quarters.

1 pint = 34·66 cubic inches.
1 gallon = 277·27384 cubic inches = 10 lbs. distilled water.

Cubic feet	× 6·2355	=	gallons.
Cubic inches	× ·003607	=	„
Cubic feet	× ·78	=	bushels.
Cubic inches	× ·00045	=	„

Decimals of £1 Sterling.

Pence and Shillings.		¼d.	½d.	¾d.
0	...	·0010416̇	·002083̇	·003125
1	·00416̇	·0052083̇	·00625	·0072916̇
2	·0083̇	·009375	·010416̇	·0114583̇
3	·0125	·0135416̇	·014583̇	·015625
4	·016̇	·0177083̇	·01875	·0197916̇
5	·02083̇	·021875	·022916̇	·0239583̇
6	·025	·026416̇	·027083̇	·028125
7	·02916̇	·0302083̇	·03125	·0322916̇
8	·03̇	·034375	·035416̇	·0364583̇
9	·0375	·0385416̇	·039583̇	·040625
10	·0416̇	·0427083̇	·04375	·0447916̇
11	·04583̇	·046875	·047916	·0489583̇
1·0	·05	·0510416̇	·052083̇	·053125
1·1	·05416̇	·0552083̇	·05625	·0572916̇
1·2	·0583̇	·059375	·060416̇	·0614583̇
1·3	·0625	·0635416̇	·064583̇	·065625
1·4	·06̇	·0677083̇	·06875	·0697916̇
1·5	·07083̇	·071875	·072916̇	·0739583̇
1·6	·075	·0760416̇	·077083̇	·078125
1·7	·07916̇	·0802083̇	·08125	·0822916̇
1·8	·083̇	·084375	·085416̇	·0864583̇
1·9	·0875	·0885416̇	·089583̇	·090625
1·10	·0916̇	·0927083̇	·09375	·0947916̇
1·11	·09583̇	·096875	·097916̇	·0989583̇

2·0	·1	8·0	·4	14·0	·7
3·0	·15	9·0	·45	15·0	·75
4·0	·2	10·0	·5	16·0	·8
5·0	·25	11·0	·55	17·0	·85
6·0	·3	12·0	·6	18·0	·9
7·0	·35	13·0	·65	19·0	·95

To Convert £ s. d. into Decimals of £1 by Inspection (approximately).—Place the £'s before the decimal point; in the first place, after the decimal point, insert the florins or half the even number of shillings; fill the second and third places with the number of farthings in any odd shilling, pence, and farthings, adding thereto 1 if the number of farthings be 24, 2 if 48, and 3 if 72 or more (the number of farthings can never amount to 96, because 96 farthings = 2/- = ·1).

By this rule the error cannot amount to 1 farthing.

Decimals of 1 Cwt.

	0	Qrs. 1	Qrs. 2	Qrs. 3
0	...	·25	·5	·75
1	·008928	·258928	·508928	·758928
2.	·017857	·267857	·517857	·767857
3	·026786	·276786	·526786	·776786
4	·035714	·285714	·535714	·785714
5	·044643	·294643	·544643	·794643
6	·053571	·303571	·553571	·803571
7	·0625	·3125	·5625	·8125
8	·071458	·321458	·571458	·821458
9	·080357	·330357	·580357	·830357
10	·089286	·339286	·589286	·839286
11	·098214	·348214	·598214	·848214
12	·107143	·357143	·607143	·857143
13	·116071	·366071	·616071	·866071
14	·125	·375	·625	·875
15	·133928	·383928	·633928	·883928
16	·142856	·392856	·642856	·892856
17	·151785	·401785	·651785	·901785
18	·160714	·410714	·660714	·910714
19	·169643	·419643	·669643	·919643
20	·178572	·428572	·678572	·928572
21	·1875	·4375	·6875	·9375
22	·196428	·446428	·696428	·946428
23	·205357	·455357	·705357	·955357
24	·214286	·464286	·714286	·964286
25	·223214	·473214	·723214	·973214
26	·232143	·482143	·732143	·982143
27	·241071	·491071	·741071	·991071

Ozs.		Ozs.		Ozs.	
1	·000558	7	·003906	13	·007254
2	·001116	8	·004464	14	·007812
3	·001674	9	·005023	15	·008370
4	·002232	10	·005580	¼	·000139
5	·002790	11	·006138	½	·000279
6	·003348	12	·006696	¾	·000418

Decimals of 1 Mile.

500 yards	·284091	20 yards	·011364	1 foot	·0001894
400 „	·227222	10 „	·005682	11 inches	·000174
300 „	·170454	9 „	·005114	10 „	·000158
200 „	·113036	8 „	·004545	9 „	·000142
100 „	·056818	7 „	·003977	8 „	·000126
90 „	·051136	6 „	·003409	7 „	·000111
80 „	·045454	5 „	·002841	6 „	·000095
70 „	·039773	4 „	·002273	5 „	·000079
60 „	·034091	3 „	·001704	4 „	·000063
50 „	·028409	2 „	·001136	3 „	·000047
40 „	·022727	1 „	·000568	2 „	·000032
30 „	·017045	2 feet	·000379	1 „	·000016

Decimals of 1 Year of 365 Days.

300 days	·821918	9 days	·024657	9 hours	·001026
200 „	·547945	8 „	·021918	8 „	·000912
100 „	·273975	7 „	·019178	7 „	·000798
90 „	·246575	6 „	·016438	6 „	·000684
80 „	·219178	5 „	·013698	5 „	·000576
70 „	·191781	4 „	·010959	4 „	·000456
60 „	·164383	3 „	·008219	3 „	·000342
50 „	·136986	2 „	·005479	2 „	·000228
40 „	·109589	1 „	·002739	1 „	·000114
30 „	·082192	12 hours	·001369	3/4 „	·000085
20 „	·054794	11 „	·001254	1/2 „	·000057
10 „	·027397	10 „	·001140	1/4 „	·000028

Decimal Equivalents of an Inch.

1/64	·015625	11/32	·34375	43/64	·671875
1/32	·03125	23/64	·359375	11/16	·6875
3/64	·046875	3/8	·375	45/64	·703125
1/16	·0625	25/64	·390625	23/32	·71875
5/64	·078125	13/32	·40625	47/64	·734375
3/32	·09375	27/64	·421875	3/4	·75
7/64	·109375	7/16	·4375	49/64	·765625
1/8	·125	29/64	·453125	25/32	·78125
9/64	·140625	15/32	·46875	51/64	·796875
5/32	·15625	31/64	·484375	13/16	·8125
11/64	·171875	1/2	·5	53/64	·828125
3/16	·1875	33/64	·515625	27/32	·84375
13/64	·203125	17/32	·53125	55/64	·859375
7/32	·21875	35/64	·546875	7/8	·875
15/64	·234375	9/16	·5625	57/64	·890625
1/4	·25	37/64	·578125	29/32	·90625
17/64	·265625	19/32	·59375	59/64	·921875
9/32	·28125	39/64	·609475	15/16	·9375
19/64	·296875	5/8	·625	61/64	·953125
5/16	·3125	41/64	·640625	31/32	·96875
21/64	·328125	21/32	·65625	63/64	·984375

Inches and Fractions of Inches in Decimals of 1 foot.

	0	1	2	3	4	5	6	7	8	9	10	11
0	·0000	·0833	·1667	·2500	·3333	·4167	·5000	·5833	·6667	·7500	·8333	·9167
$\frac{1}{32}$	·0026	·0859	·1693	·2526	·3359	·4193	·5026	·5859	·6693	·7526	·8359	·9193
$\frac{1}{16}$	·0052	·0885	·1719	·2552	·3385	·4219	·5052	·5885	·6719	·7552	·8385	·9219
$\frac{3}{32}$	·0078	·0911	·1745	·2578	·3411	·4245	·5078	·5911	·6745	·7578	·8411	·9245
$\frac{1}{8}$	·0104	·0938	·1771	·2604	·3438	·4271	·5104	·5938	·6771	·7604	·8438	·9271
$\frac{5}{32}$	·0130	·0964	·1797	·2630	·3464	·4297	·5130	·5964	·6797	·7630	·8464	·9297
$\frac{3}{16}$	·0156	·0990	·1823	·2656	·3490	·4323	·5156	·5990	·6823	·7656	·8490	·9323
$\frac{7}{32}$	·0182	·1016	·1849	·2682	·3516	·4349	·5182	·6016	·6849	·7682	·8516	·9349
$\frac{1}{4}$	·0208	·1042	·1875	·2708	·3542	·4375	·5208	·6042	·6875	·7708	·8542	·9375
$\frac{9}{32}$	·0234	·1068	·1901	·2734	·3568	·4401	·5234	·6068	·6901	·7734	·8568	·9401
$\frac{5}{16}$	·0260	·1094	·1927	·2760	·3594	·4427	·5260	·6094	·6927	·7760	·8594	·9427
$\frac{11}{32}$	·0286	·1120	·1953	·2786	·3620	·4453	·5286	·6120	·6953	·7786	·8620	·9453
$\frac{3}{8}$	·0313	·1146	·1979	·2813	·3646	·4479	·5313	·6146	·6979	·7813	·8646	·9479
$\frac{13}{32}$	·0339	·1172	·2005	·2839	·3672	·4505	·5339	·6172	·7005	·7839	·8672	·9505
$\frac{7}{16}$	·0365	·1198	·2031	·2865	·3698	·4531	·5365	·6198	·7031	·7865	·8698	·9531
$\frac{15}{32}$	·0391	·1224	·2057	·2891	·3724	·4557	·5391	·6224	·7057	·7891	·8724	·9557
$\frac{1}{2}$	·0417	·1250	·2083	·2917	·3750	·4583	·5417	·6250	·7083	·7917	·8750	·9583
$\frac{17}{32}$	·0443	·1276	·2109	·2943	·3776	·4609	·5443	·6276	·7109	·7943	·8776	·9609
$\frac{9}{16}$	·0469	·1302	·2135	·2969	·3802	·4635	·5469	·6302	·7135	·7969	·8802	·9635
$\frac{19}{32}$	·0495	·1328	·2161	·2995	·3828	·4661	·5495	·6328	·7161	·7995	·8828	·9661
$\frac{5}{8}$	·0521	·1354	·2188	·3021	·3854	·4688	·5521	·6354	·7188	·8021	·8854	·9688
$\frac{21}{32}$	·0547	·1380	·2214	·3047	·3880	·4714	·5547	·6380	·7214	·8047	·8880	·9714
$\frac{11}{16}$	·0573	·1406	·2240	·3073	·3906	·4740	·5573	·6406	·7240	·8073	·8906	·9740
$\frac{23}{32}$	·0599	·1432	·2266	·3099	·3932	·4766	·5599	·6432	·7266	·8099	·8932	·9766
$\frac{3}{4}$	·0625	·1458	·2292	·3125	·3958	·4792	·5625	·6458	·7292	·8125	·8958	·9792
$\frac{25}{32}$	·0651	·1484	·2318	·3151	·3984	·4818	·5651	·6484	·7318	·8151	·8984	·9818
$\frac{13}{16}$	·0677	·1510	·2344	·3177	·4010	·4844	·5677	·6510	·7344	·8177	·9010	·9844
$\frac{27}{32}$	·0703	·1536	·2370	·3203	·4036	·4870	·5703	·6536	·7370	·8203	·9036	·9870
$\frac{7}{8}$	·0729	·1563	·2396	·3229	·4063	·4896	·5729	·6563	·7396	·8229	·9063	·9896
$\frac{29}{32}$	·0755	·1589	·2422	·3255	·4089	·4922	·5755	·6589	·7422	·8255	·9089	·9922
$\frac{15}{16}$	·0781	·1615	·2448	·3281	·4115	·4948	·5781	·6615	·7448	·8281	·9115	·9948
$\frac{31}{32}$	·0807	·1641	·2474	·3307	·4141	·4974	·5807	·6641	·7474	·8307	·9141	·9974

Ounces in Decimals of 1 lb.

Ozs.	Lbs.	Ozs.	Lbs.	Ozs.	Lbs.
¼	·015625	5	·3125	10½	·65625
½	·03125	5½	·34375	11	·6875
¾	·046875	6	·375	11½	·71875
1	·0625	6½	·40625	12	·75
1½	·09375	7	·4375	12½	·78125
2	·125	7½	·46875	13	·8125
2½	·15625	8	·5	13½	·84375
3	·1875	8½	·53125	14	·875
3½	·21875	9	·5625	14½	·90625
4	·25	9½	·59375	15	·9375
4½	·28125	10	·625	15½	·9687

Decimals of 1 Ton.

Lbs.	Cwts.... 0				1				2			
	Qrs....0	1	2	3	0	1	2	3	0	1	2	3
0	...	·0125	·025	·0375	·05	·0625	·075	·0875	·1	·1125	·125	·1375
1	·000446	·012946	·025446	·037946	·050446	·062946	·075446	·087946	·100446	·112946	·125446	·137946
2	·000893	·013393	·025893	·038393	·050893	·063393	·075893	·088393	·100893	·113393	·125893	·138393
3	·001339	·013839	·026339	·038839	·051339	·063839	·076339	·088839	·101339	·113839	·126339	·138839
4	·001786	·014286	·026786	·039286	·051786	·064286	·076786	·089286	·101786	·114286	·126786	·139286
5	·002232	·014732	·027232	·039732	·052232	·064732	·077232	·089732	·102232	·114732	·127232	·139732
6	·002678	·015178	·027678	·040178	·052678	·065178	·077678	·090178	·102678	·115178	·127678	·140178
7	·003125	·015625	·028125	·040625	·053125	·065625	·078125	·090625	·103125	·115625	·128125	·140625
8	·003571	·016071	·028571	·041071	·053571	·066071	·078571	·091071	·103571	·116071	·128571	·141071
9	·004018	·016518	·029018	·041518	·054018	·066518	·079018	·091518	·104018	·116518	·129018	·141518
10	·004464	·016964	·029464	·041964	·054464	·066964	·079464	·091964	·104464	·116964	·129464	·141964
11	·004911	·017411	·029911	·042411	·054911	·067411	·079911	·092411	·104911	·117411	·129911	·142411
12	·005357	·017857	·030357	·042857	·055357	·067857	·080357	·092857	·105357	·117857	·130357	·142857
13	·005804	·018304	·030804	·043304	·055804	·068304	·080804	·093304	·105804	·118304	·130804	·143304
14	·00625	·01875	·03125	·04375	·05625	·06875	·08125	·09375	·10625	·11875	·13125	·14375
15	·006696	·019196	·031696	·044196	·056696	·069196	·081696	·094196	·106696	·119196	·131696	·144196
16	·007143	·019643	·032143	·044643	·057143	·069643	·082143	·094643	·107143	·119643	·132143	·144643
17	·00759	·02009	·03259	·04509	·05759	·07009	·08259	·09509	·10759	·12009	·13259	·14509
18	·008036	·020536	·033036	·045536	·058036	·070536	·083036	·095536	·108036	·120536	·133036	·145536
19	·008482	·020982	·033482	·045982	·058482	·070982	·083482	·095982	·108482	·120982	·133482	·145982
20	·008928	·021428	·033928	·046428	·058928	·071428	·083928	·096428	·108928	·121428	·133928	·146428
21	·009375	·021875	·034375	·046875	·059375	·071875	·084375	·096875	·109375	·121875	·134375	·146875
22	·009821	·022321	·034821	·047321	·059821	·072321	·084821	·097321	·109821	·122321	·134821	·147321
23	·010268	·022768	·035268	·047768	·060268	·072768	·085268	·097768	·110268	·122768	·135268	·147768
24	·010714	·023214	·035714	·048214	·060714	·073214	·085714	·098214	·110714	·123214	·135714	·148214
25	·011161	·023661	·036161	·048661	·061161	·073661	·086161	·098661	·111161	·123661	·136161	·148661
26	·011609	·024109	·036609	·049109	·061609	·074109	·086609	·099109	·111609	·124109	·136609	·149109
27	·012054	·024554	·037054	·049554	·062054	·074554	·087054	·099554	·112054	·124554	·137054	·149554

Lbs.	Cwts.... 3				4				5			
	Qrs....0	1	2	3	0	1	2	3	0	1	2	3
0	·15	·1625	·175	·1875	·2	·2125	·225	·2375	·25	·2625	·275	·2875
1	·150446	·162946	·175446	·187946	·200446	·212946	·225446	·237946	·250446	·262946	·275446	·287946
2	·150893	·163393	·175893	·188393	·200893	·213393	·225893	·238393	·250893	·263393	·275893	·288393
3	·151339	·163839	·176339	·188839	·201339	·213839	·226339	·238839	·251339	·263839	·276339	·288839
4	·151786	·164286	·176786	·189286	·201786	·214286	·226786	·239286	·251786	·264286	·276786	·289286
5	·152232	·164732	·177232	·189732	·202232	·214732	·227232	·239732	·252232	·264732	·277232	·289732
6	·152678	·165178	·177678	·190178	·202678	·215178	·227678	·240178	·252678	·265178	·277678	·290178
7	·153125	·165625	·178125	·190625	·203125	·215625	·228125	·240625	·253125	·265625	·278125	·290625
8	·153571	·166071	·178571	·191071	·203571	·216071	·228571	·241071	·253571	·266071	·278571	·291071
9	·154018	·166518	·179018	·191518	·204018	·216518	·229018	·241518	·254018	·266518	·279018	·291518
10	·154464	·166964	·179464	·191964	·204464	·216964	·229464	·241964	·254464	·266964	·279464	·291964
11	·154911	·167411	·179911	·192411	·204911	·217411	·229911	·242411	·254911	·267411	·279911	·292411
12	·155357	·167857	·180357	·192857	·205357	·217857	·230357	·242857	·255357	·267857	·280357	·292857
13	·155804	·168304	·180804	·193304	·205804	·218304	·230804	·243304	·255804	·268304	·280804	·293304
14	·15625	·16875	·18125	·19375	·20625	21875	·23125	·24375	·25625	·26875	·28125	·29375
15	·156696	·169196	·181696	·194196	·206696	·219196	·231696	·244196	·256696	·269196	·281696	·294196
16	·157143	·169643	·182143	·194643	·207143	·219643	·232143	·244643	·257143	·269643	·282143	·294643
17	·15759	·17009	·18259	·19509	·20759	·22009	·23259	·24509	·25759	·27009	·28259	·29509
18	·158036	·170536	·183036	·195536	·208036	·220536	·233036	·245536	·258036	·270536	·283036	·295536
19	·158482	·170982	·183482	·195982	·208482	·220982	·233482	·245982	·258482	·270982	·283482	·295982
20	·158928	·171428	·183928	·196428	·208928	·221428	·233928	·246428	·258928	·271428	·283928	·296428
21	·159375	·171875	·184375	·196875	·209375	·221875	·234375	·246875	·259375	·271875	·284375	·296875
22	·159821	·172321	·184821	·197321	·209821	·222321	·234821	·247321	·259821	·272321	·284821	·297321
23	160268	·172768	·185268	·197768	·210268	·222768	·235268	·247768	·260268	·272768	·285268	·297768
24	·160714	·173214	·185714	·198214	·210714	·223214	·235714	·248214	·260714	·273214	·285714	·298214
25	·161161	·173661	·186161	·198661	·211161	·223661	·236161	·248661	·261161	·273661	·286161	·298661
26	·161609	·174109	·186609	·199109	·211609	·224109	·236609	·249109	·261609	·274109	·286609	·299109
27	·162054	·174554	·187054	·199554	·212054	·224554	·237054	·249554	·262054	·274554	·287054	·299554

Lbs.	Cwts.... 6				7				8			
	Qrs....0	1	2	3	0	1	2	3	0	1	2	3
0	·3	·3125	·325	·3375	·35	·3625	·375	·3875	·4	·4125	·425	·4375
1	·300446	·312946	·325446	·337946	·350446	·362946	·375446	·387946	·400446	·412946	·425446	·437946
2	·300893	·313393	·325893	·338393	350893	·363393	·375893	·388393	·400893	·413393	·425893	·438393
3	·301339	·313839	·326339	·338839	·351339	·363839	·376339	·388839	·401339	·413839	·426339	·438839
4	·301786	·314286	·326786	·339286	·351786	·364286	·376786	·389286	·401786	·414286	·426786	·439286
5	·302232	·314732	·327232	·339732	·352232	·364732	·377232	·389732	·402232	·414732	·427232	·439732
6	·302678	·315178	·327678	·340178	·352678	·365178	·377678	·390178	·402678	·415178	·427678	·440178
7	·303125	·315625	·328125	·340625	·353125	·365625	·378125	·390625	·403125	·415625	·428125	·440625
8	·303571	·316071	·328571	·341071	·353571	·366071	·378571	·391071	·403571	·416071	·428571	·441071
9	·304018	·316518	·329018	·341518	·354018	·366518	·379018	·391518	·404018	·416518	·429018	·441518
10	·304464	·316964	·329464	·341964	·354464	·366964	·379464	·391964	·404464	·416964	·429464	·441964
11	·304911	·317411	·329911	·342411	·354911	·367411	·379911	·392411	·404911	·417411	·429911	·442411
12	·305357	·317857	·330357	·342857	·355357	·367857	·380357	·392857	·405357	·417857	·430357	·442857
13	·305804	·318304	·330804	·343304	·355804	·368304	·380804	·393304	·405804	·418304	·430804	·443304
14	·30625	·31875	·33125	·34375	·35625	·36875	·38125	·39375	·40625	·41875	·43125	·44375
15	·306696	·319196	·331696	·344196	·356696	·369196	·381696	·394196	·406696	·419196	·431696	·444196
16	·307143	·319643	·332143	·344643	·357143	·369643	·382143	·394643	·407143	·419643	·432143	·444643
17	·30759	·32009	·33259	·34509	·35759	·37009	·38259	·39509	·40759	·42009	·43259	·44509
18	·308036	·320536	·333036	·345536	·358036	·370536	·383036	·395536	·408036	·420536	·433036	·445536
19	·308482	·320982	·333482	·345982	·358482	·370982	·383482	·395982	·408482	·420982	·433482	·445982
20	·308928	·321428	·333928	·346428	·358928	·371428	·383928	·396428	·408928	·421428	·433928	·446428
21	·309375	·321875	·334375	·346875	·359375	·371875	·384375	·396875	·409375	·421875	·434375	·446875
22	·309821	·322321	·334821	·347321	·359821	·372321	·384821	·397321	·409821	·422321	·434821	·447321
23	·310268	·322768	·335268	347768	·360268	·372768	·385268	·397768	·410268	·422768	·435268	·447768
24	·310714	·323214	·335714	·348214	·360714	·373214	·385714	·398214	·410714	·423214	·435714	·448214
25	·311161	·323661	·336161	·348661	·361161	·373661	·386161	·398661	·411161	·423661	·436161	·448661
26	·311609	·324109	·336609	·349109	·361609	·374109	·386609	·399109	·411609	·424109	·436609	·449109
27	·312054	·324554	·337054	·349554	·362054	·374554	·387054	·399554	·412054	·424554	·437054	·449554

Lbs.	Cwts.... 9				10				11			
	Qrs....0	1	2	3	0	1	2	3	0	1	2	3
0	·45	·4625	·475	·4875	·5	·5125	·525	·5375	·55	·5625	·575	·5875
1	·450446	·462946	·475446	·487946	·500446	·512946	·525446	·537946	·550446	·562946	·575446	·587946
2	·450893	·463393	·475893	·488393	·500893	·513393	·525893	·538393	·550893	·563393	·575893	·588393
3	·451339	·463839	·476339	·488839	·501339	·513839	·526339	·538839	·551339	·563839	·576339	·588839
4	·451786	·464286	·476786	·489286	·501786	·514286	·526786	·539286	·551786	·564286	·576786	·589286
5	·452232	·464732	·477232	·489732	·502232	·514732	·527232	·539732	·552232	·564732	·577232	·589732
6	·452678	·465178	·477678	·490178	·502678	·515178	·527678	·540178	·552678	·565178	·577678	·590178
7	·453125	·465625	·478125	·490625	·503125	·515625	·528125	·540625	·553125	·565625	·578125	·590625
8	·453571	·466071	·478571	·491071	·503571	·516071	·528571	·541071	·553571	·566071	·578571	·591071
9	·454018	·466518	·479018	·491518	·504018	·516518	·529018	·541518	·554018	·566518	·579018	·591518
10	·454464	·466964	·479464	·491964	·504464	·516964	·529464	·541964	·554464	·566964	·579464	·591964
11	·454911	·467411	·479911	·492411	·504911	·517411	·529911	·542411	·554911	·567411	·579911	·592411
12	·455357	·467857	·480357	·492857	·505357	·517857	·530357	·542857	·555357	·567857	·580357	·592857
13	·455804	·468304	·480804	·493304	·505804	·518304	·530804	·543304	·555804	·568304	·580804	·593304
14	·45625	·46875	·48125	·49375	·50625	·51875	·53125	·54375	·55625	·56875	·58125	·59375
15	·456696	·469196	·481696	·494196	·506696	·519196	·531696	·544196	·556696	·569196	·581696	·594196
16	·457143	·469643	·482143	·494643	·507143	·519643	·532143	·544643	·557143	·569643	·582143	·594643
17	·45759	·47009	·48259	·49509	·50759	·52009	·53259	·54509	·55759	·57009	·58259	·59509
18	·458036	·470536	·483036	·495536	·508036	·520536	·533036	·545536	·558036	·570536	·583036	·595536
19	·458482	·470982	·483482	·495982	·508482	·520982	·533482	·545982	·558482	·570982	·583482	·595982
20	·458928	·471428	·483928	·496428	·508928	·521428	·533928	·546428	·558928	·571428	·583928	·596428
21	·459375	·471875	·484375	·496875	·509375	·521875	·534375	·546875	·559375	·571875	·584375	·596875
22	·459821	·472321	·484821	·497321	·509821	·522321	·534821	·547321	·559821	·572321	·584821	·597321
23	·460268	·472768	·485268	·497768	·510268	·522768	·535268	·547768	·560268	·572768	·585268	·597768
24	·460714	·473214	·485714	·498214	·510714	·523214	·535714	·548214	·560714	·573214	·585714	·598214
25	·461161	·473661	·486161	·498661	·511161	·523661	·536161	·548661	·561161	·573661	·586161	·598661
26	·461609	·474109	·486609	·499109	·511609	·524109	·536609	·549109	·561609	·574109	·586609	·599109
27	·462054	·474554	·487054	·499554	·512054	·524554	·537054	·549554	·562054	·574554	·587054	·599554

Lbs.	Cwts.... 12				13				14			
	Qrs....0	1	2	3	0	1	2	3	0	1	2	3
0	·6	·6125	·625	·6375	·65	·6625	·675	·6875	·7	·7125	·725	·7375
1	·600446	·612946	·625446	·637946	·650446	·662946	·675446	·687946	·700446	·712946	·725446	·737946
2	·600893	·613393	·625893	·638393	·650893	·663393	·675893	·688393	·700893	·713393	·725893	·738393
3	·601339	·613839	·626339	·638839	·651339	·663839	·676339	·688839	·701339	·713839	·726339	·738839
4	·601786	·614286	·626786	·639286	·651786	·664286	·676786	·689286	·701786	·714286	·726786	·739286
5	·602232	·614732	·627232	·639732	·652232	·664732	·677232	·689732	·702232	·714732	·727232	·739732
6	·602678	·615178	·627678	·640178	·652678	·665178	·677678	·690178	·702678	·715178	·727678	·740178
7	·603125	·615625	·628125	·640625	·653125	·665625	·678125	·690625	·703125	·715625	·728125	·740625
8	·603571	·616071	·628571	·641071	·653571	·666071	·678571	·691071	·703571	·716071	·728571	·741071
9	·604018	·616518	·629018	·641518	·654018	·666518	·679018	·691518	·704018	·716518	·729018	·741518
10	·604464	·616964	·629464	·641964	·654464	·666964	·679464	·691964	·704464	·716964	·729464	·741964
11	·604911	·617411	·629911	·642411	·654911	·667411	·679911	·692411	·704911	·717411	·729911	·742411
12	·605357	·617857	·630357	·642857	·655357	·667857	·680357	·692857	·705357	·717857	·730357	·742857
13	·605804	·618304	·630804	·643304	·655804	·668304	·680804	·693304	·705804	·718304	·730804	·743304
14	·60625	·61875	·63125	·64375	·65625	·66875	·68125	·69375	·70625	·71875	·73125	·74375
15	·606696	·619196	·631696	·644196	·656696	·669196	·681696	·694196	·706696	·719196	·731696	·744196
16	·607143	·619643	·632143	·644643	·657143	·669643	·682143	·694643	·707143	·719643	·732143	·744643
17	·60759	·62009	·63259	·64509	·65759	·67009	·68259	·69509	·70759	·72009	·73259	·74509
18	·608036	·620536	·633036	·645536	·658036	·670536	·683036	·695536	·708036	·720536	·733036	·745536
19	·608482	·620982	·633482	·645982	·658482	·670982	·683482	·695982	·708482	·720982	·733482	·745982
20	·608928	·621428	·633928	·646428	·658928	·671428	·683928	·696428	·708928	·721428	·733928	·746428
21	·609375	·621875	·634375	·646875	·659375	·671875	·684375	·696875	·709375	·721875	·734375	·746875
22	·609821	·622321	·634821	·647321	·659821	·672321	·684821	·697321	·709821	·722321	·734821	·747321
23	·610268	·622768	·635268	·647768	·660268	·672768	·685268	·697768	·710268	·722768	·735268	·747768
24	·610714	·623214	·635714	·648214	·660714	·673214	·685714	·698214	·710714	·723214	·735714	·748214
25	·611161	·623661	·636161	·648661	·661161	·673661	·686161	·698661	·711161	·723661	·736161	·748661
26	·611609	·624109	·636609	·649109	·661609	·674109	·686609	·699109	·711609	·724109	·736609	·749109
27	·612054	·624554	·637054	·649554	·662054	·674554	·687054	·699554	·712054	·724554	·737054	·749554

Lbs.	Cwts.... 15				16				17			
	Qrs....0	1	2	3	0	1	2	3	0	1	2	3
0	·75	·7625	·775	·7875	·8	·8125	·825	·8375	·85	·8625	·875	·8875
1	·750446	·762946	·775446	·787946	·800446	·812946	·825446	·837946	·850446	·862946	·875446	·887946
2	·750893	·763393	·775893	·788393	·800893	·813393	·825893	·838393	·850893	·863393	·875893	·888393
3	·751339	·763839	·776339	·788839	·801339	·813839	·826339	·838839	·851339	·863839	·876339	·888839
4	·751786	·764286	·776786	·789286	·801786	·814286	·826786	·839286	·851786	·864286	·876786	·889286
5	·752232	·764732	·777232	·789732	·802232	·814732	·827232	·839732	·852232	·864732	·877232	·889732
6	·752678	·765178	·777678	·790178	·802678	·815178	·827678	·840178	·852678	·865178	·877678	·890178
7	·753125	·765625	·778125	·790625	·803125	·815625	·828125	·840625	·853125	·865625	·878125	·890625
8	·753571	·766071	·778571	·791071	·803571	·816071	·828571	·841071	·853571	·866071	·878571	·891071
9	·754018	·766518	·779018	·791518	·804018	·816518	·829018	·841518	·854018	·866518	·879018	·891518
10	·754464	·766964	·779464	·791964	·804464	·816964	·829464	·841964	·854464	·866964	·879464	·891964
11	·754911	·767411	·779911	·792411	·804911	·817411	·829911	·842411	·854911	·867411	·879911	·892411
12	·755357	·767857	·780357	·792857	·805357	·817857	·830357	·842857	·855357	·867857	·880357	·892857
13	·755804	·768304	·780804	·793304	·805804	·818304	·830804	·843304	·855804	·868304	·880804	·893304
14	·75625	·76875	·78125	·79375	·80625	·81875	·83125	·84375	·85625	·868675	·88125	·89375
15	·756696	·769196	·781696	·794196	·806696	·819196	·831696	·844196	·856696	·869196	·881696	·894196
16	·757143	·769643	·782143	·794643	·807143	·819643	·832143	·844643	·857143	·869643	·882143	·894643
17	·75759	·77009	·78259	·79509	·80759	·82009	·83259	·84509	·85759	·87009	·88259	·89509
18	·758036	·770536	·783036	·795536	·808036	·820536	·833036	·845536	·858036	·870536	·883036	·895536
19	·758482	·770982	·783482	·795982	·808482	·820982	·833482	·845982	·858482	·870982	·883482	·895982
20	·758928	·771428	·783928	·796428	·808928	·821428	·833928	·846428	·858928	·871428	·883928	·896428
21	·759375	·771875	·784375	·796875	·809375	·821875	·834375	·846875	·859375	·871875	·884375	·896875
22	·759821	·772321	·784821	·797321	·809821	·822321	·834821	·847321	·859821	·872321	·834821	·897321
23	·760268	·772768	·785268	·797768	·810268	·822768	·835268	·847768	·860268	·872768	·885268	·897768
24	·760714	·773214	·785714	·798214	·810714	·823214	·835714	·848214	·860714	·873214	·885714	·898214
25	·761161	·773661	·786161	·798661	·811161	·823661	·836161	·848661	·861161	·873661	·886161	·898661
26	·761609	·774109	·786609	·799109	·811609	·824109	·836609	·849109	·861609	·874109	·886609	·899109
27	·762054	·774554	·787054	·799554	·812054	·824554	·837054	·849554	·862054	·874554	·887054	·899554

Lbs.	Cwts... 18				19			
	Qrs...0	1	2	3	0	1	2	3
0	·9	·9125	·925	·9375	·95	·9625	·975	·9875
1	·900446	·912946	·925446	·937946	·950446	·962946	·975446	·987946
2	·900893	·913393	·925893	·938393	·950893	·963393	·975893	·988393
3	·901339	·913839	·926339	·938839	·951339	·963839	·976339	·988839
4	·901786	·914286	·926786	·939286	·951786	·964286	·976786	·989286
5	·902232	·914732	·927232	·939732	·952232	·964732	·977232	·989732
6	·902678	·915178	·927678	·940178	·952678	·965178	·977678	·990178
7	·903125	·915625	·928125	·940625	·953125	·965625	·978125	·990625
8	·903571	·916071	·928571	·941071	·953571	·966071	·978571	·991071
9	·904018	·916518	·929018	·941518	·954018	·966518	·979018	·991518
10	·904464	·916964	·929464	·941964	·954464	·966964	·979464	·991964
11	·904911	·917411	·929911	·942411	·954911	·967411	·979911	·992411
12	·905357	·917857	·930357	·942857	·955357	·967857	·980357	·992857
13	·905804	·918304	·930804	·943304	·955804	·968304	·980804	·993304
14	·90625	·91875	·93125	·94375	·95625	·96875	·98125	·99375
15	·906696	·919196	·931696	·944196	·956696	·969196	·981696	·994196
16	·907143	·919643	·932143	·944643	·957143	·969643	·982143	·994643
17	·90759	·92009	·93259	·94509	·95759	·97009	·98259	·99509
18	·908036	·920536	·933036	·945536	·958036	·970536	·983036	·995536
19	·908482	·920982	·933482	·945982	·958482	·970982	·983482	·995982
20	·908928	·921428	·933928	·946428	·958928	·971428	·983928	·996428
21	·909375	·921875	·934375	·946875	·959375	·971875	·984375	·996875
22	·909821	·922321	·934821	·947321	·959821	·972321	·984821	·997321
23	·910268	·922768	·935268	·947768	·960268	·972768	·985268	·997768
24	·910714	·923214	·935714	·948214	·960714	·973214	·985714	·998214
25	·911161	·923661	·936161	·948661	·961161	·973661	·986161	·998661
26	·911609	·924109	·936609	·949109	·961609	·974109	·986609	·999109
27	·912054	·924554	·937054	·949554	·962054	·974554	·987054	·999554

Equivalent Weights.

Metric.		English.
1 milligramme	=	·0154 grain.
1 centigramme	=	·1543 "
1 decigramme	=	1·5432 "
1 gramme	=	15·4323 "
1 décagramme	=	·3527 oz.
1 hectogramme	=	3·5274 "
1 kilogramme	=	2·20462125 lbs.
1 millier or tonne	=	19·6841 cwts.

English.		Metric.
1 grain	=	·0648 gramme.
1 drachm	=	1·7718 "
1 oz.	=	28·3495 "
1 lb.	=	·4535926 kilogramme.
1 stone	=	6·3503 "
1 quarter	=	12·7006 "
1 cwt.	=	50·8024 "
1 ton	=	1016·048 " 1·01605 metric tonne.

Equivalent Liquid Measures.

Metric.		English.
1 centilitre 10 cubic centimetres	=	·0176 pint.
1 decilitre	=	·1761 "
1 litre	=	·2201 gallon.
1 decalitre	=	2·2009 "
1 hectolitre	=	22·009 "
1 cubic metre	=	220·09 "

English.		Metric.
1 gill or quartern	=	·1420 litre.
1 pint	=	·5679 "
1 quart	=	1·1359 "
1 gallon	=	4·5435 "

Equivalent Measures of Length.

Metric.		English.
1 millimetre	=	·03937 inches.
1 centimetre	=	·3937 "
1 decimetre	=	3·93704 "
1 metre	=	39·3704 " 3·2809 feet.
1 decametre	=	32·8087 "
1 hectometre	=	109·3623 yards.
1 kilometre	=	3280·369 feet. 1093·623 yards. ·62138 mile.

English.		Metric.
1 inch	=	25·4 millimetres.
1 link	=	·2012 metre.
1 foot	=	·3048 ,,
1 yard	=	·91439 ,,
1 fathom	=	1·82878 ,,
1 rod, pole or perch	=	5·02915 ,,
1 chain	=	20·11662 ,,
1 furlong	=	{ 201·1662 ,, 0·20117 kilometre.
1 mile	=	{ 1609·3296 metres. 1·6093296 kilometres.
1 admiralty knot or nautical mile	=	1·85315 ,,

Pounds	×	·00893	=	cwts.
,,	×	·00045	=	tons.
Square inches	×	·007	=	square feet.
Circular inches	×	·00546	=	,, ,,
Cylindrical inches	×	·0004546	=	cubic feet.
Cubic inches	×	·00058	=	,, ,,
,, ,,	×	·003607	=	imperial gallons.
,, feet	×	6·232	=	,, ,,
Cylindrical inches	×	·002832	=	,, ,,
,, feet	×	4·895	=	,, ,,
Cubic inches	×	·281	=	lbs. avoirdupois of wrought iron.
,, ,,	×	·283	=	,, ,, ,, steel.
,, ,,	×	·3225	=	,, ,, ,, copper.
,, ,,	×	·3037	=	,, ,, ,, brass.
,, ,,	×	·26	=	,, ,, ,, zinc.
,, ,,	×	·4103	=	,, ,, ,, lead.
,, ,,	×	·2636	=	,, ,, ,, tin.
,, ,,	×	·4908	=	,, ,, ,, mercury.
Cylindrical inches	×	·2168	=	,, ,, ,, wrought iron.
,, ,,	×	·2223	=	,, ,, ,, steel.
,, ,,	×	·2533	=	,, ,, ,, copper.
,, ,,	×	·2385	=	,, ,, ,, brass.
,, ,,	×	·2042	=	,, ,, ,, zinc.
,, ,,	×	·3223	=	,, ,, ,, lead.
,, ,,	×	·207	=	,, ,, ,, tin.
,, ,,	×	·3854	=	,, ,, ,, mercury.

Metric Equivalents.

To convert grains into grammes	×	0·065
,, ,, grammes into grains	×	15·5
,, ,, drachms into grammes	×	3·9
,, ,, ounces (avoirdupois) into grammes	×	28·4
,, ,, pounds ,, ,, ,,	×	453·6
,, ,, cubic centimetres into grains	×	15·5
,, ,, ,, ,, ,, drachms	×	0·29
,, ,, ,, ,, ,, ounces (avoirdupois)	×	0·036
,, ,, pints into cubic centimetres	×	473
,, ,, litres into ounces (avoirdupois)	×	35·3
,, ,, gallons into litres	×	3·8

To Convert Grammes, Decigrammes, Centigrammes and Milligrammes to Grains.

1 gramme	= 15·4323 grains.	6 grammes	= 92·5938 grains.
2 "	= 30·8646 "	7 "	= 108·0261 "
3 "	= 46·2969 "	8 "	= 123·4584 "
4 "	= 61·7292 "	9 "	= 138·8907 "
5 "	= 77·1615 "		

For the number of grains in a decigramme shift the decimal point one place to the left, thus, 1 decigramme = 1·54323 grains.

For the number of grains in a centigramme shift the decimal point two places to the left, thus, 1 centigramme = ·154323 grains.

For the number of grains in a milligramme shift the decimal point three places to the left, thus, 1 milligramme = ·0154323 grains.

Cubic Feet into Cubic Metres.

Cubic feet.	Cubic metres.	Cubic feet.	Cubic metres.	Cubic feet.	Cubic metres.	Cubic feet.	Cubic metres.
1	·0283	31	·8778	61	1·7272	91	2·5767
2	·0566	32	·9061	62	1·7555	92	2·6050
3	·0849	33	·9344	63	1·7838	93	2·6333
4	·1133	34	·9627	64	1·8122	94	2·6616
5	·1416	35	·9910	65	1·8405	95	2·6899
6	·1699	36	1·0193	66	1·8688	96	2·7182
7	·1982	37	1·0477	67	1·8971	97	2·7466
8	·2265	38	1·0760	68	1·9254	98	2·7749
9	·2548	39	1·1043	69	1·9537	99	2·8032
10	·2831	40	1·1326	70	1·9820	100	2·8315
11	·3115	41	1·1609	71	2·0104	200	5·663
12	·3398	42	1·1892	72	2·0387	300	8·494
13	·3681	43	1·2175	73	2·0670	400	11·326
14	·3964	44	1·2459	74	2·0953	500	14·157
15	·4247	45	1·2742	75	2·1236	600	16·989
16	·4530	46	1·3025	76	2·1519	700	19·820
17	·4814	47	1·3308	77	2·1803	800	22·652
18	·5097	48	1·3591	78	2·2086	900	25·483
19	·5380	49	1·3874	79	2·2369	1,000	28·315
20	·5663	50	1·4157	80	2·2652	1,500	42·472
21	·5946	51	1·4450	81	2·2935	2,000	56·620
22	·6229	52	1·4724	82	2·3218	2,500	70·787
23	·6512	53	1·5007	83	2·3501	3,000	84·944
24	·6795	54	1·5290	84	2·3785	4,000	113·240
25	·7079	55	1·5573	85	2·4068	5,000	141·574
26	·7362	56	1·5856	86	2·4351	6,000	169·888
27	·7645	57	1·6140	87	2·4634	7,000	198·184
28	·7928	58	1·6423	88	2·4917	8,000	226·480
29	·8211	59	1·6706	89	2·5200	9,000	254·814
30	·8494	60	1·6989	90	2·5483	10,000	283·148

Cubic Metres into Cubic Feet.

Cubic metres	Cubic feet.	Cubic metres	Cubic feet.	Cubic metres	Cubic feet.	Cubic metres	Cubic feet.
1	35·3156	31	1094·7836	61	2154·2516	91	3213·7196
2	70·6312	32	1130·0992	62	2189·5672	92	3249·0352
3	105·9468	33	1165·4148	63	2224·8828	93	3284·3508
4	141·2624	34	1200·7304	64	2260·1984	94	3319·6664
5	176·5780	35	1236·0460	65	2295·5140	95	3354·9820
6	211·8936	36	1271·3616	66	2330·8296	96	3390·2976
7	247·2092	37	1306·6772	67	2366·1452	97	3425·6132
8	282·5248	38	1341·9928	68	2401·4608	98	3460·9288
9	317·8404	39	1377·3084	69	2436·7764	99	3496·2444
10	353·1560	40	1412·6240	70	2472·0920	100	3531·560
11	388·4716	41	1447·9396	71	2507·4076	110	3884·716
12	423·7872	42	1483·2552	72	2542·7232	120	4237·872
13	459·1028	43	1518·5708	73	2578·0388	130	4591·028
14	494·4184	44	1553·8864	74	2613·3544	140	4944·184
15	529·7340	45	1589·2020	75	2648·6700	150	5297·340
16	565·0496	46	1624·5176	76	2683·9856	160	5650·496
17	600·3652	47	1659·8332	77	2719·3012	170	6003·652
18	635·6808	48	1695·1488	78	2754·6168	180	6356·808
19	670·9964	49	1730·4644	79	2789·9324	190	6709·964
20	706·3120	50	1765·7800	80	2825·2480	200	7063·120
21	741·6276	51	1801·0956	81	2860·5636	250	8828·900
22	776·9432	52	1836·4112	82	2895·8792	300	10594·468
23	812·2588	53	1871·7268	83	2931·1948	350	12363·46
24	847·5744	54	1907·0424	84	2966·5104	400	14126·24
25	882·8900	55	1942·3580	85	3001·8260	500	17657·80
26	918·2056	56	1977·6736	86	3037·1416	600	21189·36
27	953·5212	57	2012·9892	87	3072·4572	700	24720·92
28	988·8368	58	2048·3048	88	3107·7728	800	28252·48
29	1024·1524	59	2083·6204	89	3143·0884	900	31784·04
30	1059·4680	60	2118·9360	90	3178·4040	1000	38847·16

Sizes of Drawing Paper.

	"	"		"	"
Demy	20	× 15	Columbier	34	× 23
Medium	22	× 17	Atlas	33	× 26
Royal	24	× 19	Double Elephant	40	× 26
Imperial	31	× 21	Antiquarian	52	× 29
Elephant	27	× 23	Emperor	68	× 48

Colours used in Architectural and Engineering Drawings.

For Brickwork in plan or section (to be executed)	= Crimson Lake or Carmine.
,, Brickwork in elevation.	= Venetian red or Crimson Lake and Burnt Sienna (light).
,, Flintwork or parts of brick-work to be removed	= Prussian Blue.
,, Granite	= Violet Carmine.
,, Cement or Stone	= Sepia.
,, Concrete	= ,, mottled with Burnt Umber.
,, Clay Earth	= Burnt Umber.
,, Plaster	= Sepia (light).
,, Slate	= Indigo with Crimson Lake.
,, Tiles	= Indian red.
,, Wood	= Burnt Sienna.
,, English Timber, not Oak	= Raw ,,
,, Oak or Teak	= Burnt ,,
,, Fir Timber	= Indian yellow.
,, Mahogany	= ,, red.
,, Iron, wrought	= Prussian blue.
,, ,, cast	= Payne's Grey.
,, Lead	= Indigo or light Indian-ink.
,, Copper	= Crimson Lake with Gamboge.
,, Brass	= Gamboge.
,, Gunmetal	= Dark Cadmiums.
,, Glass	= Cobalt mottled.
,, Leather	= Vandyke brown.
,, Meadow land	= Hooker's Green.
,, Sky effects	= Cobalt Blue.

Weight of Materials.

Materials.	Weight of One Cubic Foot.	Cubic Feet per Ton.
	lbs.	
Ashes	37	60½
,, 52 feet = 1 chaldron	...	...
Brickwork	100	22¾
,, in cement	110	20⅗
Bricks, red kiln	135	17
,, common	110	20⅗
,, London Stock	115	19¾
,, Welch fire	150	15
Cement, Portland	84	26⅔
,, ,, cask 4 bushels =	5 feet	2 cwt.
,, Roman	60	37⅓
,, ,, cask 5 bushels =	6 feet	4 cwt.
Chalk	140 to 166	15½ to 13¾
Clay	120 to 135	18⅔ to 17

MATERIALS.	Weight of One Cubic Foot.	Cubic Feet per Ton.
	lbs.	
Coal, Cannel and Welsh	84	26⅔
„ Newcastle	80	28
Coke	47	48
Concrete	120	18⅔
Earth	95 to 126	23½ to 18
Flint	164	13⅔
Glass, Crown	157	14¼
„ Flint	187	12
„ Plate	184	12⅙
Gravel	112 to 120	21¾ to 18⅔
Iron, cast	450	5
„ wrought	487	4⅝
Lime, stone	53	42¼
„ chalk	44	51
Mortar, from (old)	88	25½
„ to (new)	119	19
Sand, pit	90	23½ to 25
„ river	118	19
Shingle	...	...
Slate	...	...
Stone, Granite	...	13½
„ Purbeck	...	13¾
„ Yorkshire	...	14½
„ Craigleith	...	14¾
„ Derby	...	15
„ Portland	...	14¾
„ Bath	...	16
Marble	...	12½ to 13
Tiles, average	112	20
Oil of Turpentine	54¾	41
„ Linseed	58¾	38
„ Whale	57¾	39
Rain Water (252 gallons per ton)	62½	35
Sea „ (224 „ „)	64	35

Gallon of water = 10 lbs. = 277¼ cubic inches.
6¼ „ „ = 1 cubic foot nearly.

Roofing—1 square of 100 feet slating			= 10½	cwt.
„ 1 „ „	„	and timbers	= 15½	„
„ 1 „ „	tiling		= 15¼	„
„ 1 „ „	„	and timbers	= 21	„
„ 1 „ „	with 7 lb. lead		= 10	„
„ 1 „ „	„	and timbers	= 17	„
„ 1 „ „	with 6 lb. lead		= 8½	„
„ 1 „ „	„	and timbers	= 15½	„
„ 1 „ „	with 16 gauge zinc		= 3½	„
„ 1 „ „	„	and timbers	= 10½	„

Miscellaneous Articles.

One barrel of tar	= $26\frac{1}{4}$ gallons.
Battens	= boards 7 inches wide.
Bushel of coal	= 80 lbs.
" coke	= 45 "
" quicklime	= 70 "
Chaldron of coal	= $25\frac{1}{2}$ cwts.
" coke	= $12\frac{1}{2}$ to 15 cwts.
Fodder of lead	= $19\frac{1}{2}$ cwts.
Hundred of deals	= 120 in number.
" nails	= 120 "
Load of bricks	= 500 "
" lime (1 ton)	= 32 bushels.
" sand	= 36 "
Planks	= boards 12 inches wide.
Sack of coal	= 224 lbs.
Square of planking	= 100 superficial feet.
" slate	= 100 " "

Weight of Earths, Rocks, etc.

	Cwt.		Cwt.
1 cub. yd. sand	= 30	1 cub. yd. sandstone	= 39
1 " gravel	= 30	1 " shale	= 40
1 " mud	= 25	1 " quartz	= 41
1 " marl	= 26	1 " granite	= 42
1 " clay	= 31	1 " trap	= 42
1 " chalk	= 35 to 36	1 " slate	= 43
1 " cannel coal	= 81 to 87		

Natural Slopes of Earths with the Horizontal or Angles of Repose.

Gravel, average	40°	
" and sand mixed	38°	
Dry sand	37° to 38°	= 1·33 to 1
Sand	21° to 22°	= ·263 to 1
" fine dry	32°	
Vegetable earth or peat	28°	= 1·89 to 1
" " new	34°	
Compact "	48° to 50°	= ·09 to 1
Loamy "	40°	= 1·2 to 1
Shingle, average	39° to 40°	= 1·2 to 1
" clean	36°	
Rubble, average	45°	= 1 to 1
Clay, well dried	45°	= 1 to 1
" stiff or dry mud	45°	= 1 to 1
" wet, average	16°	
" " London	15°	
Coal	33°	= 1·65 to 1

1 cub. yd. rock in large pieces	= when excavated	1·50 c. yds.
1 " " medium as dug	= " "	1·25 to 1·30 c. yds.
1 " chalk	= " "	1·30 c. yds.
1 " sand and gravel	= " "	1·07 "
1 " clay and earth	= " "	1·2 to 1·25 c. yds.

Observed Results of Power (Nystrom).

Description of Works.	Work hours per day.	Force.	Velocity	Effects of ft. lbs. per second.	Horses.
A man can raise a weight by a single fixed pulley . .	6	50	0·8	40	0·072
„ working a crank . .	8	20	2·5	50	0·090
„ on a treadwheel(horizontal)	8	144	0·5	72	0·130
„ in a treadwheel (axis 24° from vertical) . . .	8	30	2·3	69	0·125
„ draws or pushes in a horizontal direction . .	8	30	2·0	60	0·109
„ pulls up or down . . .	8	12	3·7	44·4	0·080
„ can bear on his back . .	7	95	2·5	237·5	
A horse in a horsemill, walking moderately	8	106	3·0	318	0·577
„ „ „ running fast	5	72	9	648	1·178
An ox in a horsemill walking moderately	8	154	2	308	0·518
A mule „ „ „	8	71	3	293	0·308
An ass „ „ „	8	33	2·65	87·4	0·160
On bad foot roads like those in Peru a man can bear . . .	10	50	3·5	175	
Llama of Peru can bear . .	10	100	3·5	350	
Donkey can bear	10	200	3·5	700	
Mule can bear	10	400	5·0	2000	

Man Power.

Efforts exerted for short periods of time. R.A. rule.

Pushing a load horizontally	100 lbs.
Pulling „ „	70 „
Tractive force in dragging a cart	40 „
Lifting a weight from the ground by the hands .	150 „
Carrying on his shoulders	120 „
On a winch for continuous work	15 to 20 lbs.

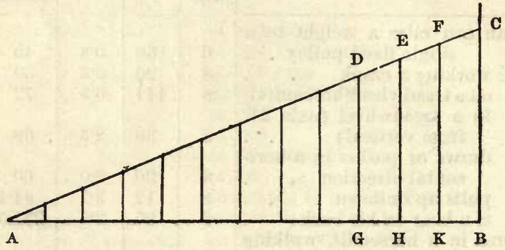
When a number of men are pulling on a rope, the effort per man will average very much below the above quotation, and the greater the number the less the average per man. 24 men will not pull half as much again as 12 men. The most advantageous application of a man's power in hauling is in a slanting direction downwards, as his weight is added to his strength.

Power of Horses.

Rate (miles per hour) =	2	3	3½	4	4½	5
Tractive force in lbs. =	166	125	104	83	62	41

To set out a perpendicular measure a base of 4 parts, perpendicular measuring 3 parts and diagonal 5 parts.

To Divide a given Line into any number of Equal Parts.



Let A B be the line to be divided, then at B erect perpendicular B C, then on the line A C set out the divisions by any convenient scale, and from the points as D E F draw lines perpendicular to A B, which will cut at G H K the divisions required.

This method is useful for making scales to uneven dimensions.

Excavating.—A man can dig from 5 cubic yards in hard gravel to 10 cubic yards in loose ground per day.

1 ton of light soil = 18 cubic feet.

Carts usually hold 2½ tons or 45 cubic feet.

Piles driven until they are in firm ground will stand 1000 lbs. per sq. inch of area of head, but when depending only upon the friction of their sides 200 lbs. per square inch.

On sloping ground step and stair the foundations.

A cubic yard of earth, before digging, will occupy about 1½ cubic yard when dug.

A dobbin cart will contain	¾ cube yard.
Earth waggon, small size .	1½ „ „
„ „ large .	3 „ „
Wheelbarrow . . .	$\frac{1}{10}$ „ „

A single load of earth = 27 cubic feet = 21 bushels.
A double „ „ = 54 „ „
1 cubic yard of gravel = 18 bushels in the pit.
1 „ „ „ = 24 „ when dug.

When formed into embankments gravel sinks nearly ¼ in height and decreases ⅛ in bulk.

If earth is well drained, it will stand in embankments about 1½ to 1.

Foundations.—6 of good aggregate to 1 of ground lias lime will answer every purpose in ordinary cases, and should be about a foot wider than the bottom course of footings, or 6 inches on each side.

Whenever large weights occur, as on foundations of columns, angles of buildings, &c., Portland cement should be used in place of lias lime; the dimensions can be increased if desirable.

Foundations in water are formed sometimes by rows of wooden piles so fastened together as to form a pier for the horizontal beams to be fixed upon, as in wooden bridges. A great objection to wooden piles is the fact that in water, fluctuating by the tide, the timber decays at the water-line and therefore requires to be sheathed with copper.

The following Pressures may be used with safety per superficial foot for Foundations:—

	Tons.
Rock	13
Chalk	4
Solid blue clay and gravel	3 to 6
London clay	2
12 in. by 12 in. piles well driven	20 to 30

Well punned ground will sustain 1 ton per square foot, if punned each foot as filled in; if not, not more than ½ ton per square foot.

Gravel, good in foundation will uphold 5 tons per square foot.

Sandy gravel, near water, 1½ tons per square foot.

Foundation always 2 ft. 6 in. below ground line.

	Tons per sq. ft.
Moist clay and sand (prevented from spreading laterally)	1·36
Coarse sand and dry clay	2·27
Firm bedded broken stones on dry clay	3·18
Loose impermeable beds with piling	1·82
" " " " " and concrete	2·73

It is necessary at all times to allow sufficient room for men to work in a trench where it has to be excavated more than 3 feet deep.

In loose ground a man can throw up about 10 cubic yards per day, but in hard or gravelly soils 5 yards will be a fair day's work. Three men will remove 30 yards of earth a distance of 20 yards in a day.

A yard of concrete requires about 3 hours' labour to mix and throw in, or, if in heavy masses and the materials handy, about 2 hours.

Burning clay into ballast is done by making a fire of small coal or coke breeze, and casing the same with clay, laying alternate layers of fuel and clay until the mass is burnt through. 2 tons of small coals will burn about 25 cube yards of earth. It is used for roads and concrete walls, and very frequently ground for mortar as a substitute for sand, but it is essential that when used for such a purpose it be well burnt. Value, reckoning coals at 15*s.* per ton, 2*s.* 6*d.* per cubic yard.

19 cubic feet of sand, 18 ditto clay, 24 ditto earth, 15½ ditto chalk 20 ditto gravel, will each weigh 1 ton.

Footings.—Projection at bottom on each side should not be less, than half the thickness of wall at base, diminishing in regular offsets, and height not less than projection.

Punn all trenches before putting in concrete for foundations, and drain off all surface water permanently.

Sewerage about 5 feet head per mile is required to maintain a flow and to overcome friction in small pipes.

Temperature increases about 1° F. for every 60 feet below the level of the ground.

Damp Course.—This is to prevent the moisture rising in the walls, and should be placed from 6 to 12 inches above the ground line. It can be made of slates laid in Portland cement, but recently asphalte has been adopted and is effective and economical. A glazed earthenware damp course, with ventilating spaces through its centre, has also been suggested.

Damp Courses for External Walls (Prof. H. Adams) :—

A course of slates throughout the thickness, 3 to 6 inches above ground line.

A double course of slates in cement, 3 to 6 ins. above ground line.

A layer of asphalte, $\frac{1}{4}$ to $\frac{1}{2}$ inch thick, " " " " "

A layer of cement, " " " " " " " "

Taylor's patent glazed and perforated stoneware slabs, above ground line.

A layer of melted pitch with sufficient coal-tar mixed in to prevent it setting too brittle.

A layer of sheet lead 4 lb. to 8 lb. per square foot, with $1\frac{1}{2}$ in. laps (the best).

A layer of asphalted (*i.e.*, tarred) roofing felt laid dry.

Inverted Arches should be turned from pier to pier in all heavy buildings to equalize the weight throughout the building and thus prevent unequal settlement. Arches are generally worked in half-brick rings, thus saving a vast amount of cutting and waste, but a course of headers should be thrown up every 3 or 4 feet, the upper course bonded over the lower, to tie the rings together. If this be properly attended to there will be no fear of the rings separating when the centres are struck.

Hoop-iron bond, usually $1\frac{1}{2}$ in. × $\frac{1}{16}$ in., should be well tarred and sanded before use and laid say every 5 feet in height of wall.

Asphalte damp course usually $\frac{1}{2}$ inch thick at 12 inches above ground line.

Slate damp course, usually 2 courses thick, carefully bedded and laid in floating cement, upper layer overlapping the lower to prevent cracking ; they should project $1\frac{1}{4}$ inches beyond the wall on each side.

A rise of $\frac{1}{8}$ inch per foot span usually allowed in making centres for flat arches for settlements.

Wood slips, about $\frac{3}{8}$ inch thick in joints of brickwork, better than wood bricks, as they are less liable to shrink.

Bricks of 6 parts breeze to 1 of cement will allow nails to be driven in and they do not shrink.

Brickwork.—The roughest and hardest of the stock bricks to be used should be selected for the footings, and worked English bond as high as where the facing commences; or if the building is faced with stone or cement, English bond should be worked all through (excepting 9-inch walls), as it is much stronger than Flemish bond, although not so ornamental. 9-inch walls should in all cases be worked Flemish bond; or, from the unequal length of the bricks, one side will be very rough. Where red bricks or seconds are used for facings, Flemish bond should be worked, and care taken to properly tie it in with the backing; although a certain portion of the headers may be bats, every third should be whole bricks and occasionally cross or diagonal bond should be worked in the backing to prevent the wall splitting. In dry weather the bricks should be thoroughly soaked before laying; each course of bricks must be properly flushed in with the trowel, and grouted every four courses to ensure stability in the work.

Bond.—Hoop iron, $1\frac{1}{4}$ inches wide, is now very generally used and with great advantage. There should be a course of hooping to each half brick in thickness, well tarred and sanded every 5 feet in height, and well lapped at all angles; the course of bricks above and below the hooping should be laid in cement.

The quality of bricks and tiles may be told by the sound and by their appearance when broken. If they are well burnt through and when clapped together produce a good clear ringing sound, they may be considered good bricks.

Size and Weight of Various Materials.

Description.	Size.						Weight.	
	ft.	in.	ft.	in.	ft.	in.	lbs.	oz.
Stock or place brick	0	$8\frac{3}{4}$	0	$4\frac{1}{4}$	0	$2\frac{1}{2}$	5	0
Paving brick	0	9	0	$4\frac{1}{2}$	0	$1\frac{3}{4}$	4	6
Dutch Clinker	0	$6\frac{1}{4}$	0	3	0	$1\frac{1}{4}$	1	8
Pantile	1	$1\frac{1}{2}$	0	$9\frac{1}{2}$	0	$0\frac{1}{2}$	5	0
Bridgewater pantile	1	$1\frac{1}{2}$	1	7	0	$0\frac{1}{2}$	9	0
Plain tiles	0	$10\frac{1}{2}$	0	$6\frac{1}{2}$	0	$0\frac{5}{8}$	2	5
Pavement foot tile	0	$11\frac{3}{4}$	0	$11\frac{3}{4}$	0	$1\frac{1}{2}$	13	0
" " 10 in.	0	$9\frac{3}{4}$	0	$9\frac{3}{4}$	0	1	8	9
Pantile laths, 10 ft. bundles, contains 12 laths	120	0	0	$1\frac{1}{2}$	0	1	4	6
Ditto; a 12 ft. bundle contains 12 laths	144	0	0	$1\frac{1}{2}$	0	1	5	0
Plain tile laths, in 5 ft. bundles, contains 500 laths	500	0	0	1	0	$0\frac{1}{4}$	3	0
Thirty bundles of laths 1 load	...		...		...		cubic.	
A bricklayer's hod	1	4	0	9	0	9	1,296 in.	
A single load of sand	3	0	3	0	3	0	27 ft.	
A double load of sand	3	0	3	0	6	0	54 ft.	
A measure of lime	3	0	3	0	3	0	27 ft.	

Fire Bricks Weigh per 1000.

Sizes.	Martins.				Scotts.				Welsh.			
	Tns.	Cts.	Qr.	Lb.	Tns.	Cts.	Qr.	Lb.	Tns.	Cts.	Qr.	Lb.
9 in. Bricks	2	19	0	0	3	0	0	0	2	17	1	0
7 in. „	2	11	1	0	...		...		...		...	
6 in. „	4	6	2	0	...		...		...		...	
3 in. „	3	13	2	0	3	12	1	0	3	11	3	7
Side Bevels	2	12	2	0	2	4	3	0	1	17	3	0
9 in. end do.	2	14	0	0	2	11	1	21	...		...	
7 in. „ „	1	18	1	0	2	0	2	0	...		...	
F. Edge	1	12	1	0	1	13	1	0	1	6	0	0
Arch	2	18	1	0	2	7	3	0	2	15	3	0
Closers	1	8	1	0	1	10	3	0	...		...	
2 in. Splits	2	2	0	0	2	10	2	0	2	8	0	0
1½ in. „	1	17	2	0	1	16	0	0	1	15	1	0
1 in. „	1	4	1	0	1	6	1	0	1	3	2	0

Resistance to Crushing.

	Exposed Surface, Square inches.	Average Crushing Weight, Tons.
Oldham red bricks	39·33	40
Medway gault bricks	40·15	17
„ pressed	—	48
Stafford blue brick	27·9	50
Fire-clay brick	34·85	65
Wortley blue brick	34·76	72
Portland stone	39·94	47
Bramley fall stone	39·94	91
Yorkshire landing	38·28	96

Bricks made of neat cement 9 × 4¼ × 2¾, subjected to hydraulic pressure, at the following ages:—

3 months old fractured by a pressure of 65 tons.
6 „ „ „ „ „ 92 „
9 „ „ „ „ „ 120 „

The pressure was applied in their bed, having a superficies of 38·25 square inches.

Strength of Columns of brickwork (height = less than thickness).

	Crushing Commences at
Bricks, hard stocks, best quality, set in Portland cement and sand (1 to 1), 3 months old	40 tons.
Bricks, ordinary well burnt London stocks, 3 months old	30 „
„ hard stocks Roman cement and sand (1 to 1), 3 months old	28 „
„ „ „ lias lime and sand (1 to 2), 6 months old	24 „
„ „ „ grey chalk-lime and sand (1 to 2), 6 months old	12 „

Herring.

Brick and Stone Pillars should never be built of a height more than 12 times the thickness at base.

Where height	= 24 times thickness	strength is reduced to	·7
,, ,,	= 30 ,,	,, ,, ,, ,,	·5
,, ,,	= 40 ,,	,, ,, ,, ,,	·3

Safe load should equal $\frac{1}{10}$ breaking load.

Hard red bricks	have sp. gr. 2·136,	and will absorb	4·56 % water.
Soft ,,	,, ,, ,, 1·981,	,, ,,	8·81 % ,,
Fire	,, ,, ,, 2·000,	,, ,,	5·17 % ,,

1,000 stock	bricks weigh	60¾ cwts.
1,000 red kiln	,, ,,	63 ,,
1,000 paving	,, ,,	45 ,,

The essential quality of a brick is hardness, and that it shall not absorb more water than one-sixth its weight. The highly vitrified brick only absorbs one-thirteenth to one-sixteenth its weight.

The characteristics of a good brick are: (1) it should be free from flaws; (2) it should have a good ring when struck; (3) the surfaces of the sides and faces must be level, not hollow or rounded excepting the "frog"; (4) the surfaces must not be too smooth, or the mortar will not adhere thereto; (5) the brick must be well burnt; and (6) a brick should not contain any white patches nor show small stones or rough particles, when broken.

If a brick be made red-hot, and when dropped into water does not break up, it is of very good quality.

Bricks, unless of very bad quality, are not much affected by the solvent power of rainwater or the acids it holds in solution.

Analysis of a Brick Clay of Average Quality.

Silica	49·44
Alumina	34·26
Ferric Oxide	7·74
Lime	1·48
Magnesia	5·14
Alkalies	—
Water	1·94
	100·00

English bond consists of alternate courses of headers and stretchers.

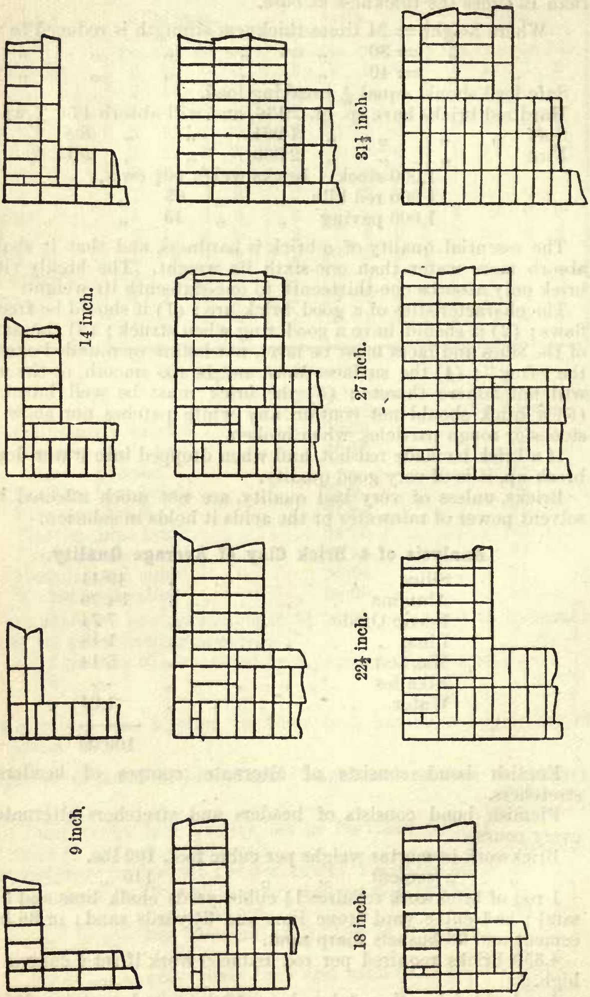
Flemish bond consists of headers and stretchers alternately in every course.

Brickwork in mortar weighs per cubic foot, 100 lbs.
,, ,, cement ,, ,, ,, 110 ,,

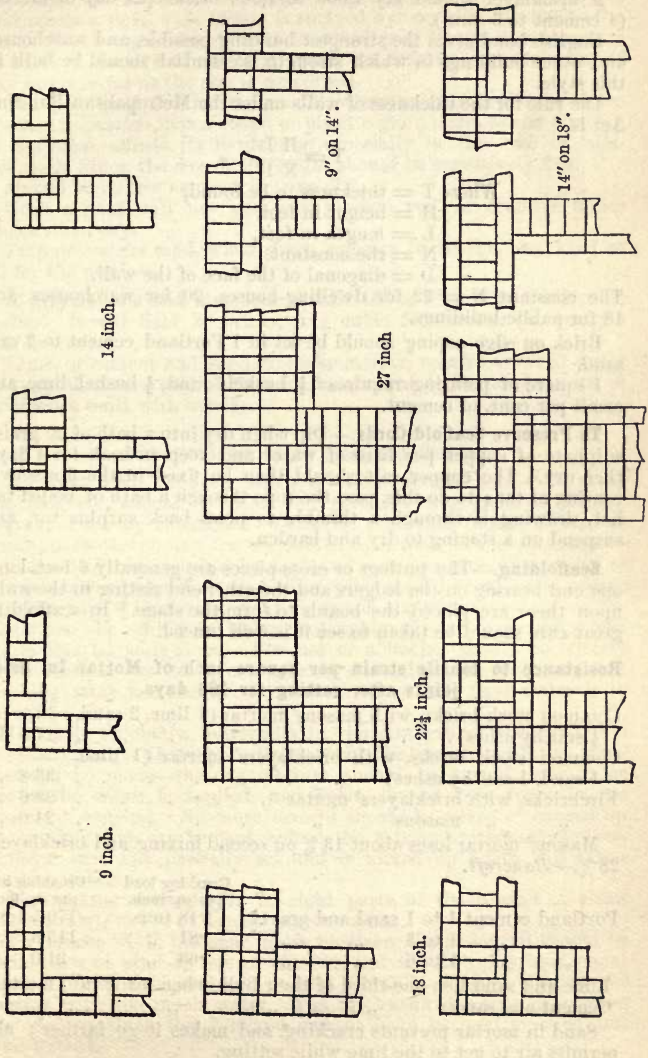
1 rod of brickwork requires 1½ cubic yards chalk lime and 3 yards sand; or 1 cubic yard stone lime and 3½ yards sand; or 36 bushels cement and 36 bushels sharp sand.

4,350 bricks required per rod reduced work if set 4 courses 1 foot high.

1 rod of brickwork weighs about 15 tons and contains 235 cubic feet bricks and 71 cubic feet mortar.



English Bond.



Flemish Bond.

A bricklayer should lay 1,000 to 1,500 bricks per day in mortar (1 cement to 3 sand).

English bond gives the strongest building possible, and warehouses and other buildings in which strength is essential should be built in this style.

The rule for the thickness of walls under the Metropolitan Building Act is,

$$T = \frac{H\ L}{N\ D}$$

Where T = thickness to be found,
H = height in feet,
L = length in feet,
N = the constant,
D = diagonal of the face of the wall.

The constant N = 22 for dwelling-houses, 20 for warehouses, and 18 for public buildings.

Brick on edge coping should be set in 1 Portland cement to 2 or 3 sand.

1 square of pointing requires 1½ bushels sand, ½ bushel lime, and small per cent. of cement.

To Preserve Scaffold Cords.—Dip when dry into a bath of 20 grains sulphate of copper per litre of water and keep in soak for 4 days, then dry. The copper salt should then be fixed in the fibres by a coating of tar ; to do this, pass the rope through a bath of boiled tar, hot, drawing it through a thimble to press back surplus tar, and suspend on a staging to dry and harden.

Scaffolding.—The putlogs or cross-pieces are generally 6 feet long, one end bearing on the ledgers and the other end resting in the wall ; upon these are placed the boards to form the stage. In scaffolding great care should be taken to see it is well braced.

Resistance to tensile strain per square inch of Mortar in Brick joints after setting for 168 days.

Common stock bricks, with masons' mortar (1 lime, 2 sand, ½ smithy ashes)	27·5 lbs.
Common stock bricks, with bricklayers' mortar (1 lime, 1 sand, 1 smithy ashes)	33·8 „
Firebricks, with bricklayers' mortar	28·6 „
„ „ masons' „	24·0 „

Masons' mortar loses about 13 % on second mixing, and bricklayers' 28 %.—*Bancroft.*

	Crushing load per sq. inch.	Crushing load per sq. foot.
Portland cement 1 to 1 sand and gravel	1·18 tons	170·5 tons.
„ „ 1 to 3 „ „	·81 „	115·5 „
„ „ 1 to 6 „ „	·63 „	91·0 „

Lime and sand lose one-third of their bulk when made into mortar.
Cement and sand „ „ „ „

Sand in mortar prevents cracking, and makes it go farther ; also permits air to get to the lime while setting.

Coarse is preferable to fine sand for cement mortar, up to the size that passes a sieve with 12 and is stopped by one with 16 wires to the inch. Below the grade of sand that will pass 40 and be stopped by 60 wires to the inch there is no practical difference in the value of any sands so far as the size is concerned.

The best sand for mortar should, when magnified, show a sharp angular formation, not a round or pisolite grain; and as the porosity of a mortar affects its hardening, especially in the case of non-hydraulic limes, the size of the grains should be excessively fine.

Should be as free as possible from dirt.

Good mortar will not part easily when wet, or crumble under finger when dry.

Trap or granite sand, when sharp, appears to be the best kind of all for the purpose.

A bricklayer's hod measures usually 16" × 9", and = 1,296 cubic inches. It will hold 20 bricks, or ⅝ cubic foot mortar (= nearly a half bushel).

Lime, or cement and sand, to make mortar, require as much water as is equal to one-third of their bulk, or about 5½ barrels for a rod of brickwork built with mortar.

Directions for using Portland Cement.

All sand, gravel, broken bricks, or other material used for making the concrete, should be clean and perfectly free from all loamy, clayey, or earthy substances whatever, otherwise failure is sure to result, notwithstanding the undoubted excellence of the cement.

Clean cold water should be used, and only just sufficient to mix to the consistency of stiff mortar. The water should be added by means of a can with a large rose, so as to spread the water evenly over the materials, the materials being thoroughly turned over and mixed while this is being done. The use of a bucket should be strictly prohibited, so as to avoid risk of deluging the concrete and washing away the cement. For stucco work only fresh water is to be used.

In order to obtain uniformity in the strength of the work, it is necessary that a thorough admixture of the cement with the other material be made—the dry mixture should be turned over twice before the water is applied, and again turned over twice in the process of wetting. No more cement should be mixed or gauged up at one time than can be used before the setting process takes place. Cement that has partially set and is mixed up again will never harden properly.

For making concrete, six to eight parts of sharp sand or clean rough gravel, to one of cement may be used.

For stucco work, the sand must be clean, the undercoat should be three parts of sand to one of cement, and the finishing coat, equal parts of sharp fine sand and cement, carefully avoiding mixing the mortar with too much water. The brickwork or other absorptive material on which the Portland cement is to be used must be first well wetted.

Careful attention to these directions is most essential to obtain a satisfactory result.

When making cement blocks or paving slabs, it is sometimes considered advisable to steep them in a solution of sodium silicate for 10 to 14 days.

The cause of disintegration of mortar during frosty weather is the expansion due to the conversion of the water, contained in the mortar, into ice, the expansion equalling a 10 % increase in volume.

Facings and Pointing.—There is always considerable risk in using a brick for facing, unless it is known to stand the weather; this is especially the case with red bricks. A great diversity of opinion and practice exists as to pointing. Ordinary Tuck pointing consists of well raking out the joints, filling in with coloured mortar, and then laying on a neat parallel joint with white mortar or stopping. The brickwork is also in most cases first coloured to obtain a uniform appearance.

Flat pointing is merely raking out the course joints and filling in again with blue mortar.

Lime is much improved if Portland cement is added thereto, and well mixed with it.

Roman cement is about one-third strength of Portland cement.

Plaster of Paris.

Weight per striked bushel = 64 lbs.
" " cubic foot = 50 "

The adhesive power of Portland cement is at least ⅘ of the cohesive, when new, and in time it will become fully equal to it.

L. J. Affelder and R. C. Brown.

Cement.—Magnesia causes expansion and crumbling or flaking;
Sulphur destroys either stone or concrete.

Coëfficient of expansion of cement = 0·0000145
" " " iron = 0·0000137 to 0·0000148

The Monier system of making concrete has proved itself from 5½ to 12 times as strong as that made in the ordinary way.

It has been proposed to coat ironwork which is to be imbedded in brickwork with cement, instead of asphalte or paint.

Make concrete in foundations three times as wide as the brick wall to be built upon it.

Concrete should be turned at least twice dry and twice wet.

About 25 gallons water required per cubic yard concrete.

Volume of Spaces per Cent. in Concrete Materials.

Limestone, crushed, to pass through	3 inch ring,	51 per cent.
" " "	4 "	48 "
" " "	2½ "	36 "
" " "	2 "	39 "
" " "	1½ "	42 "
Gravel, to pass through	2½ "	34 "

Shingle	33 per cent.
Thames ballast (including sand)	17 "
Limestone and gravel mixed equally, to pass through 3 inch ring	34 "

Good concrete will bear 31·6 tons per square foot in compression, and 3·16 tons per square foot in tension.

Safe Load that may be put upon a superficial foot on—

Granite piers	= 40 tons	(crushing commences at 300 tons)
Portland stone piers	= 13 "	" " 90 "
Bath stone piers	= 6 "	" " 40 "
Brickwork in cement and sand (1 to 1)	= 5 "	" " 40 "
Rubble masonry	= 4 "	" " 40 "
Firebrick	= 6 "	" " 50 "
Lias Lime (concrete foundations)	= 5 "	" " 20 "
Ordinary brickwork in lime mortar	= 3 "	" " 24 "
Pine (yellow)	= 34 "	" " 340 "
Gravel or stiff clay	= 2 "	

Resistance to Crushing (Stones).

	Per square inch.	Per square foot.
Granite, average	5·4	781
Limestone "	3·06	441·1
Sandstone "	1·87	268·9
Victoria stone (granite and Portland cement steeped in solution of flint), average	3·71	534

			lbs. per cubic in.
Crushing commences on	Sandstone,	strong	5,000 to 9,000
" "	"	ordinary	3,000 to 5,000
" "	"	weak	2,000
" "	Limestone,	compact	8,000
" "	"	strong magnesian	7,000
" "	"	weak "	3,000
" "	"	granular	4,000 to 4,500
" "	Chalk		300 to 400
" "	Whinstone		9,000 to 17,000
" "	Granite		6,000 to 11,000

Mungall.

Safe Resistance to Loads per square foot.

Rock	13 tons.
Chalk	4 "
Solid blue clay and gravel	3 to 6 "
London clay	2 "
12″ × 12″ wood piles, well driven to 4 blows = ¼″	20 to 30 "

A factor of safety of one-fifth of crushing weight, if the load be dead, and of one-tenth, if the load be live, may be taken.

In laying stone the joints should be in contact from face to tail, and be thoroughly wetted on surface before laying.

The Test for the Porosity of Stone.—Weigh the stone when dry and weigh it after immersion in a pail of water. If a sandstone absorbs not more than half a gallon per cubic foot it is a good building stone.

Granite consists chiefly of quartz 50 to 60 per cent., felspar 30 to 40 per cent., mica 10 per cent. ; best with most quartz and less mica. The composition of granite is about—

Silica	72·07
Alumina	14·81
Oxide of iron	2·22
Potash	5·11
Soda	2·79
Lime	1·63
Magnesia	0·33
Water, &c.	1·09

Portland Stone.—Average composition :—

Silica	1·20
Carbonate of lime	95·16
Carbonate of magnesia	1·20
Iron and alumina	0·50
Water and loss	1·94
Bitumen	Trace
	100·00

Sandstone should consist of small grains of quartz and only small quantity of carbonate of lime and no uncombined particles of iron.

Bath stone weight is 123 lbs. per foot cube.

York stone weight 156 lbs. per foot cube.—*H. Adams.*

2 inch York paving weighs per square foot	26 lbs.
2½ " " " " " "	32½ "
3 " " " " " "	39 "
4 " " " " " "	52 "
5 " " " " " "	65 "
6 " " " " " "	78 "

Covering Power of Paint.

10 lbs. white lead 1 oz. red lead 2 ozs. litharge 4 pints linseed oil	63 superficial yards, 1st coat.
10 lbs. white lead 2 ozs. litharge 2½ pints linseed oil 1½ pints spirits of turpentine	100 superficial yards, 2nd coat.

10 lbs. white lead 2 oz. litharge 2 pints linseed oil 2 pints spirits of turpentine	113 superficial yards, 3rd and 4th coats.

1 pint varnish will cover about 16 square yards one coat.

100 square yards of painting, 4 coats, will require about 48 lbs. white lead or colour paint, 4 lbs. putty, 7½ quarts oil, 1 lb. red lead, ½ lb. size, 2½ pints turpentine, ½ lb. pumice-stone, 1 quire glass-paper, 1 lb. driers.

Paint should contain 1 pint turps to ¾ gallon raw and ¼ gallon boiled linseed oil.

A good paint for wooden structures should consist of from 66 to 75 per cent. pigment, and the balance oil, &c.

Boiled linseed oil specific gravity should be ·947
Raw " " " " " " ·932 to ·937
" " " flash point " " 500° F.

Oxide of iron paints are said to oxidize their oil and gradually destroy it.

White lead = $Pb.\ C.\ O_3$.

The effect of sulphur upon white lead is to change the carbonate of lead into a sulphide, which becomes soluble in condensed moisture or rain-water.

To Test White Lead.—If pure carbonate it will not lose weight at 212° F. 68 grains should be entirely dissolved in 150 minims of acetic acid diluted with 1 fl. oz. distilled water.

Plumbago mixed with hot coal-tar forms a good coating for rough ironwork.

It is said that none of the metallic oxides, commonly used as pigments, chemically combine with the linseed oil in the painting mixture.

Thickness of Sheet Glass.

No. or Weight in ozs. per sq. ft.	Thickness, inches.	No. or Weight in ozs. per sq. ft.	Thickness, inches.
12	·059	21	·100
13	·063	24	·111
15	·071	26	·125
16	·077	32	·154
17	·083	36	·167
19	·091	42	·200

The Average Weight of the Materials Covering and Bearing on Roofs, &c., may be taken roughly as follows :—

Description of Material.	Weight per Foot Super.
Common rafters	7 lb.
$\frac{3}{4}$-in. boarding	$2\frac{1}{2}$ "
1-in. "	$3\frac{1}{4}$ "
Battens 3-in. by $\frac{3}{4}$-in.	$1\frac{1}{4}$ "
Felt	$\frac{1}{2}$ "
Zinc	$1\frac{3}{4}$ "
Corrugated iron	$2\frac{1}{4}$ "
Slates	9 "
Tiles	20 "
Wind $\frac{1}{4}$ pitch . . . . . . about	22 "
" $\frac{1}{3}$ " . . . . "	25 "
" $\frac{1}{2}$ " . . . . "	27 "
Snow	5 "
Slate, 1 in. thick	15 "
Paving-stone, 2 in. thick	28 "
Tiles, 1 in. thick	9 "
Marble, 2 in. thick	$28\frac{3}{4}$ "

In calculating the safe load on a floor, from $1\frac{1}{4}$ cwt. to $1\frac{1}{2}$ cwt. per superficial foot is generally allowed for ordinary work, and from 2 cwt. to 4 cwt. for factories and warehouses, including the weight of the floor itself.

Table to facilitate the Calculation of the Area of any Roof.

Rise or Pitch.	Angle. °	Angle. ′	Proportion.
One-sixth of span . .	18	25	1 to 1·05 or 1 to $1\frac{1}{20}$
One-quarter of span . .	26	35	1 " 1·12 " 1 " $1\frac{1}{8}$
	30	00	1 " 1·20 " 1 " $1\frac{1}{5}$
One-third of span . .	33	42	1 " 1·20 " 1 " $1\frac{1}{5}$
One-half of span . .	45	00	1 " 1·41 " 1 " $1\frac{2}{5}$
Two-thirds of span . .	53	00	1 " 1·67 " 1 " $1\frac{7}{10}$
Three-quarters of span .	56	20	1 " 1·80 " 1 " $1\frac{4}{5}$
Equilateral	60	00	1 " 2·00 " 1 " 2
Whole pitch	63	30	1 " 2·83 " 1 " $2\frac{4}{5}$

Multiply span by the number found in the proportion column ; this gives the superficial area of the roof on the slope.

Load on roof may be taken as 50 lbs. per foot superficial ; this includes weight of roof, and provides for extra strains thrown on it by snow, wind, &c., from 5 to 6 tons safe load per inch of section of ties.

Slates should not be laid at less than $26\frac{1}{2}°$ with horizontal.

Roof Coverings.—Roofs covered with slates or shingles should have a pitch of not less than one-fourth the width of span; but the roof may be truncated if a lower pitch is required.

Allowance for Wind and Snow.

Weight of snow on horizontal surface .	=	say, 15·5 lbs. per sq. ft.
Wind pressure on surface at right angles to line of impact	=	„ 24·6 „ „
Do. do. in specially exposed positions	=	„ 31·0 „ „

D. K. Clark.

Laths for Queens and slates	should be	12 inches apart.
„ Duchess and Princesses	„	$10\frac{1}{2}$ „ „
„ Countesses	„	$8\frac{1}{2}$ „ „

Provide for removing Rainfall per Hour.

From roofs	5	inches in depth.
Flagged surface . . .	2	„ „
Gravelled	0·5	„ „
Meadows, or grass plots . .	0·2	„ „
Paved surfaces . . .	1	„ „

Rainfall, maximum, may be taken as $1\frac{1}{2}$ inches in 24 hours in calculating size of rain-water pipes.

Slates.	Sizes.	Squares covered by 1000.	Weight per 1000.	Weight per square.
Doubles .	13 in. × 6 in.	2	15 cwts.	$7\frac{1}{2}$ cwts.
Ladies . .	16 „ × 8 „	$4\frac{1}{2}$	25 „	$5\frac{3}{4}$ „
Countesses .	20 „ × 10 „	7	40 „	$5\frac{3}{4}$ „
Duchesses .	24 „ × 12 „	10	60 „	6 „

To test slates, place on edge half immersed in water for 12 hours; if water has spread up to near the top of slate, reject it; if not risen more than $\frac{1}{4}$ inch, may be considered non-absorbent. Or weigh a slate before and after immersion, and the difference will show quantity of water absorbed; should not be more than $\frac{1}{200}$th part of weight of slate.

Good slates should be compact, with a metallic ring when struck, the edge not friable, incapable of absorbing or retaining much moisture hard and rough to the touch.

Weight of Zinc Slating Nails.

1	inch go	about	340	to the pound.
$1\frac{1}{4}$	„	„	290	„
$1\frac{1}{2}$	„	„	220	„
$1\frac{3}{4}$	„	„	140	„
2	„	„	90	„

Curved roofs of 25 to 30 feet span, rise ¼ span may be used if 16 B.W.G. corrugated iron sheets, rivetted together with tie rods every few feet, continuous angle iron skewbacks, and thin rods from the centre, to prevent sagging in tie rods.

Use two nails to fasten each slate, say 1½ inch long, of copper.

Lowest course of laths for slates should be 1 inch higher than the others.

Fall in gutters should be 1 in 50 at least.

Thick asphalted or inodorous felt is made in rolls 25 yards long by 32 inches wide.

Sheathing felt is made in sheets 32 inches × 20 inches.
Dryhair „ „ , 34 „ × 20 „

No. 0, 12 oz.	per sheet.	No. 3, 2 lbs.	per sheet.
No. 1, 1 lb.	„	No. 4, 2½ „	„
No. 2, 1½ lbs.	„	No. 5, 3 „	„

Willesden roofing is supplied in rolls of 50 and 100 yards × 27 inches wide (in two qualities), or 54 inches wide if required.

Allport's patent wire-wove waterproof roofing, a strong covering material made upon japanned or tinned steel wire gauze, is made in sheets 40 in. × 28 in., 42 in. × 26 in., 49 in. × 26 in.; a lighter quality is made in sheets 42 in. × 26 in.

In laying lead, where possible avoid soldered joints.

Use not more than 10 feet sheets, and then fix roll.

Lay to a slope of not less than 1 inch in 10 feet.

Weight and Thickness of Sheet Lead.

Weight in lbs. per square foot.	Thickness in inches.	Weight in lbs. per square foot.	Thickness in inches.
1	·017	7	·118
2	·034	8	·135
3	·051	9	·152
4	·068	10	·169
5	·085	11	·186
6	·101	12	·203

Usual Thickness of Sheet Lead in use.—For aprons, 5 lbs. per square foot; for roofs, flats, gutters, &c., 7 to 8 lbs.; for hips and ridges, 6 to 8 lbs.

Proper Proportion of Tread to Riser on Staircase, projection of Nosing not included.

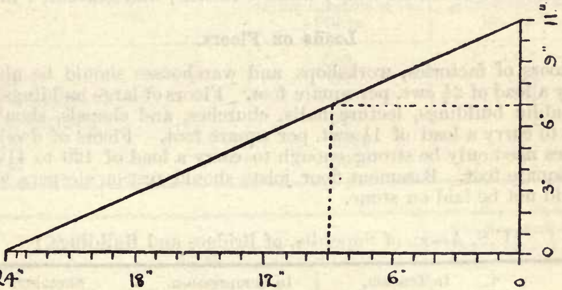
Width of tread 12 inches, rise should be 5½ inches.
„ „ 11½ „ „ „ 5¾ „
„ „ 11 „ „ „ 6 „
„ „ 10½ „ „ „ 6¼ „
„ „ 10 „ „ „ 6½ „
„ „ 9½ „ „ „ 6¾ „
„ „ 9 „ „ „ 7 „

Another method is to multiply the tread by the riser, both in inches, and the sums should equal 72.

Another rule—

Width of tread	6 inches,	height of risers		8½ inches.		
„	„	7	„	„	„	8 „
„	„	8	„	„	„	7½ „
„	„	9	„	„	„	7 „
„	„	10	„	„	„	6½ „
„	„	11	„	„	„	6 „
„	„	12	„	„	„	5 „
„	„	13	„	„	„	5 „

A further method of obtaining the Proportion of Stair Treads and Risers—



Thus 9-inch tread requires 7-inch risers.

Stone steps upheld both ends should have 6-inch bearing at each end.
„ „ „ one end only should have 9 inches built into wall.

Timber.—Timber should never be so enclosed in a building that the air cannot circulate around it, or it will decompose. When timber has to be fixed near the ground, or in any damp place, it may be coated with a thin solution of coal tar and fish oil mixed with finely powdered clinkers from the forge.

All timber should be thoroughly seasoned before any preservative is used.

One method of preserving timber is to dry it and apply a weak solution of corrosive sublimate, or of nitric acid and water, and then paint it with white lead and oil.

Another method is to soak the timber for from 2 to 12 hours in melted napthalene at a temperature of about 200° F.

The timber used in building operations for carpenter's work is imported from Memel, Riga, Dantzic and Sweden; and that for joiner's work from Christiania, Stockholm, Gefle, Onega and other northern ports.

In selecting timber the most convenient sizes are 12 inches square;

choose the brightest in colour, where the strong red grain appears to rise to the surface; avoid spongy hearts, porous grain, and dead knots. (*Laxton.*)

(1) Seasoned timber is about twice as strong as green timber; (2) well seasoned timber loses some of its strength when moisture is re-absorbed; (3) when free from knots and flaws timber in large pieces is as strong, per inch section, as when in smaller pieces; (4) knots weaken timber as greatly whether it is for use as a strut or as a tie; (5) long leafed pine is as strong as average oak; (6) bleeding a tree does not impair the quality of its timber.

Timber joists should, where possible, be left open to the atmosphere at the ends, and not built into the wall. Iron joists should have a space at the ends to allow of expansion, and should be built in pockets.

Planks are 11 inches wide; deals, 9 inches; and battens, 7 inches.

Loads on Floors.

Floors of factories, workshops, and warehouses should be able to carry a load of $2\frac{1}{2}$ cwt. per square foot. Floors of large buildings such as public buildings, lecture halls, churches, and chapels, should be able to carry a load of $1\frac{1}{2}$ cwt. per square foot. Floors of dwelling-houses need only be strong enough to carry a load of 120 to 140 lbs. per square foot. Basement floor joists should rest on sleepers, which should not be laid on stone.

(U.S. Assoc. of Superdts. of Bridges and Buildings.)

	In Tension.		In Compression.		Shearing.	
	With Grain.	Across.	With Grain.	Across.	With Grain.	Across.
White Oak	1,000 lbs.	200 lbs.	900 lbs.	500 lbs.	200 lbs.	1,000 lbs.
„ Pine	700 „	50 „	700 „	200 „	100 „	500 „
Red „	900 „	50 „	800 „	200 „		
Norway „	800 „	—	800 „	200 „		
Cedar . .	800 „	—	800 „	200 „	—	400 „
Chestnut .	900 „	—	1,000 „	250 „	150 „	400 „

All per square inch safe stresses.

To calculate dead distributed safe load on timber (rectangular section—floor joists, &c.)—

$$\frac{4\,b \times d^2 \times \begin{cases}1{,}100, \text{ if fir}\\ 1{,}900, \text{ if oak}\end{cases}}{2\,L} = \text{load in lbs.}$$

b = breadth in inches.
d = depth „ „
L = span „ „ (R. A. Rule.)

A crowd of men closely packed = 120 lbs. per square foot.
A cart horse = 14 cwt.

Strength of Timber. (Rankine's "Civil Engineering.")

Wood.	Resistance to Shearing per Square Inch in lbs.	
	Along the Fibres.	Across the Fibres.
Oak	2,300	4,000
Ash and elm	1,400	
Spruce or white fir	600	
Red pine	500 to 800	

Wood.	Weight required to crush 1 Square Inch in the direction of the Fibres.	Weight required to indent 1 Square Inch $\frac{1}{20}$ inch deep across the Grain.
	Cwt.	Cwt.
Ash	80	$12\frac{1}{2}$
Fir (white)	50	$5\frac{1}{2}$
Fir (yellow)	52	$5\frac{1}{4}$
Oak	$80\frac{1}{4}$	18
Pine	36	$4\frac{1}{2}$

Wood.	Weight required to break a Stick 1 Inch Square by Tensile Stress.
	Tons.
Ash	$4\frac{1}{2}$
Fir (white)	$3\frac{1}{2}$
Fir (yellow)	$3\frac{1}{2}$
Oak	6
Pine	1

Time required for Seasoning. (Laslett.)

	Oak. Months.	Fir. Months.
Pieces 24 inches and upward square require about	26	13
Pieces under 24 inches to 20 " " "	22	11
" " 20 " " 16 " " "	18	9
" " 16 " " 12 " " "	14	7
" " 12 " " 8 " " "	10	5
" " 8 " " 4 " " "	6	3

Breaking Load in Tons on Square Yellow Pine Pillars, firmly fixed and equally loaded.

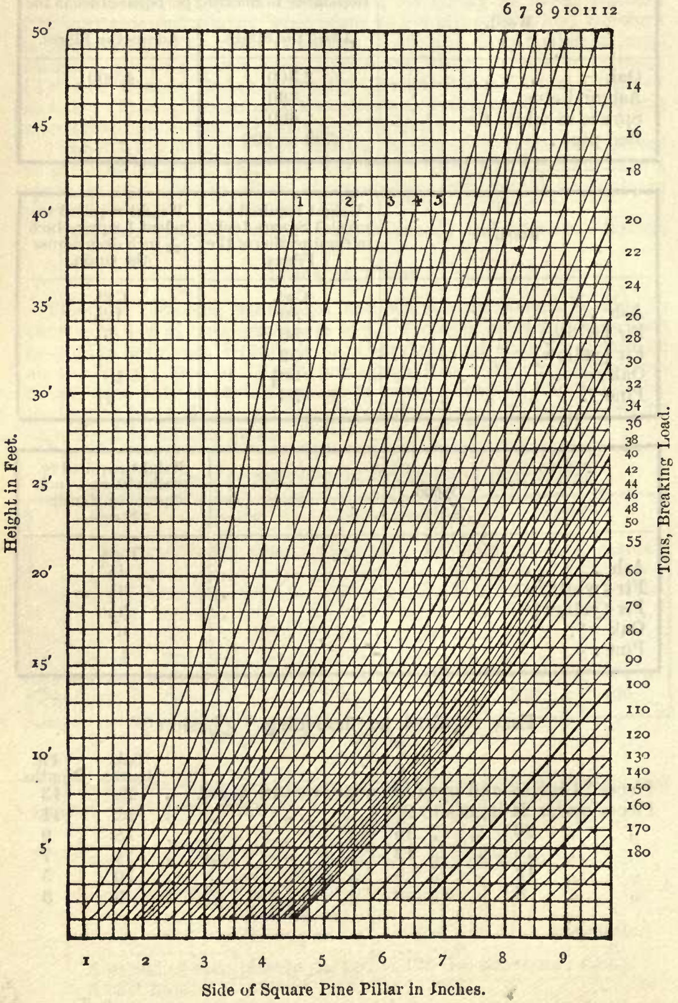
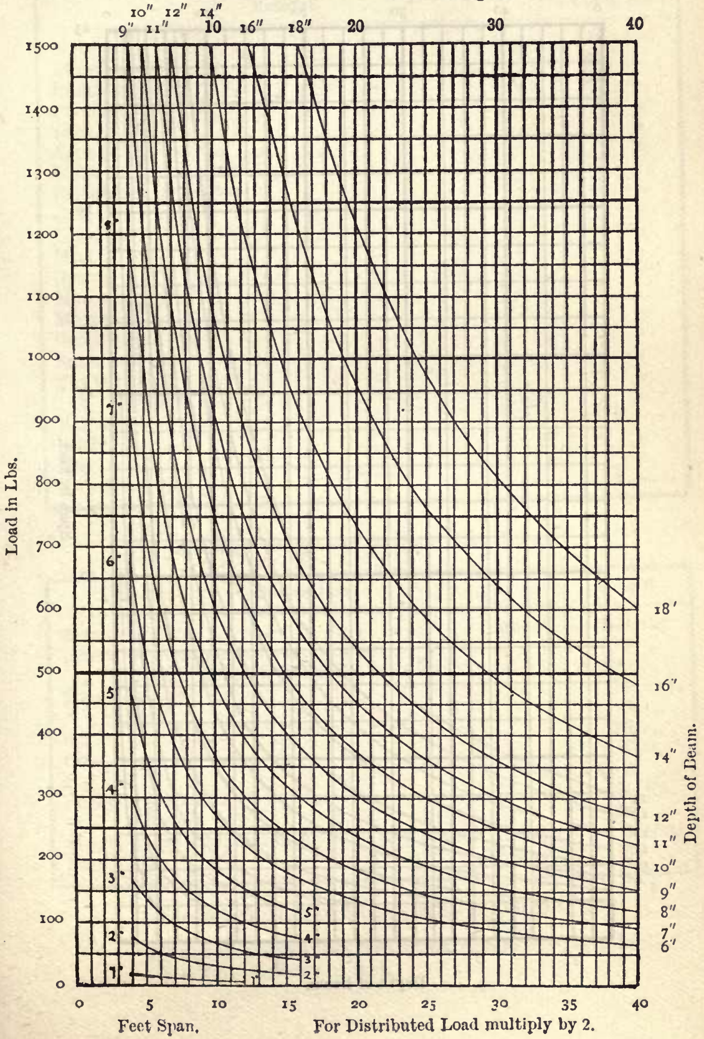
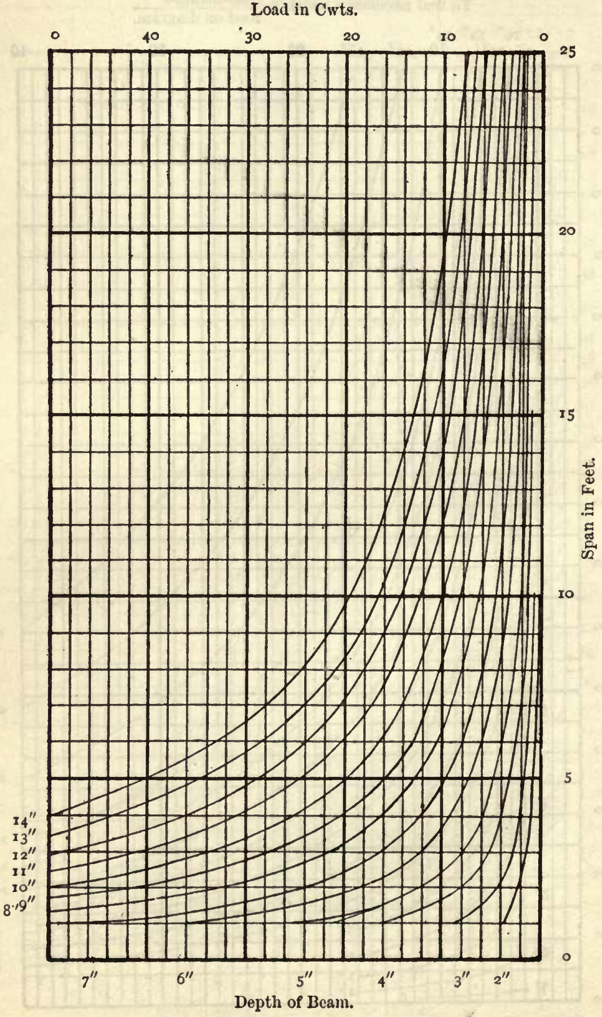


Diagram showing Safe Centre Load on Yellow Pine Beams 1 Inch wide; factor of safety, one fifth. Pitch Pine will carry one fourth more.

To find necessary width = $\frac{\text{actual load}}{\text{load on diagram.}}$



Distributed Safe Load on Timber Joists 1 Inch wide.



Average Dead Load of different Classes of Material that may have to be provided for in the Building Trade. (F. Crocker.)

Material.	Per Cubic Foot.
Slate	180 lbs.
Lime (stone)	60 "
Lime (ground)	54 "
Portland cement	85 "
Tiles	108 "
Asphalt	140 "
Brick	130 "
Brickwork in mortar	112 "
Coal	80 "
Concrete	130 "
Mud	100 "
Gravel	110 "
Masonry	140 "
Mortar	112 "
Sand	100 "
Snow	5 to 12 "
Timber (oak)	50 "
" (deal)	32 "
Water	62¼ "
Seeds	50 "
Hay	8 "
Straw	4½ "

Average Weight of various Live Loads.

Description.	Weight.
Man . . . about	150 lbs.
Crowd of men per foot superficial	86 "
" " densely packed	120 "
Horse (heavy)	14 cwt.
" (light)	8 "
Ox	10 "
Cow	6½ "
Pig . . . from	1 to 2 "
Sheep (small)	65 lbs.
" (large)	90 "
Single-horse load, including horse and vehicle (heavy)	4 tons.
Pair-horse " " " " (heavy)	6½ "

Theoretical H.P. of falling water = ·00189 Q.H.

Q = volume in cubic feet of water flowing per minute.
H = fall of water in feet.

Power of water fall (theoretically) :—

Gallons per minute × 10 lbs. × height of fall in feet ÷ 33,000 = H.P.

Head of water in feet × ·434 = lbs. per square inch.

Velocity of water in a uniform diameter cast iron pipe of smooth bore =

$$48 \sqrt{\frac{\text{head in feet}}{\text{length in feet}} \times \text{diameter in feet.}}$$

(Hawksley.)

Quantity of water discharged from a channel or pipe =

$$100 \text{ sectional area of current in square feet} \sqrt{\frac{\text{head in feet}}{\text{length in feet}} \times \text{hydraulic mean depth.}}$$

(Downing.)

Frictional Loss in Hydraulic Rams.

(" Hicks' Formula.")

$$F = \frac{\cdot 04\ P}{D}$$

P = total load in lbs.
D = diameter in inches.
F = frictional resistance in lbs.

1 inch mercury = 13·4 inches water = 345·4 millimetres.
$\frac{88}{100}$ths inch mercury = 12 inches water.
1 gallon salt water = 10·272 lbs.
1 ton „ „ = 35 cubic feet = 218 gallons.

Specific Heat.

Specific heat = proportion of heat required to heat a substance through 1 degree compared with equal weight of water. Specific heat of water = 1.

Specific Heats.

Brickwork	·192	Glass	·190
Chalk	·215	Graphite	·202
Charcoal	·241	Ice	·504
Coal (anthracite)	·201	Stonework	·197
„ (bituminous)	·241	Wood average	·550
Coke	·203		

Speed of Sound.

In air at 0° = 1,093 feet per second.
Add 2 feet for every degree Centigrade.

In water = 4,780 feet per second.
In copper = 11,666 „ „ „
In iron = 16,822 „ „ „

Comparative Powers of Substances for Reflecting Radiant Heat.

Polished brass	100	Lead	60
Silver	90	Glass	10
Tin	80	Lampblack	0
Steel	60		

Table of Coefficients of Linear Expansion for 1 Degree Centigrade.

Glass	= ·0000085	= $\frac{1}{120000}$
Platinum	= ·0000085	= $\frac{1}{120000}$
Cast iron	= ·00001	= $\frac{1}{100000}$
Wrought iron	= ·000012	= $\frac{1}{85000}$
Copper	= ·000017	= $\frac{1}{58000}$
Lead	= ·000028	= $\frac{1}{35000}$
Zinc	= ·00003	= $\frac{1}{34000}$
Brass	= ·000019	= $\frac{1}{52000}$

Specimens vary in their expansions, and the above Table is only approximate.

Factors of Safety. (Unwin.)

	Dead Load.	Live Load.		In Structures subjected to Shocks.
		Temporary Structures.	Permanent Structures.	
Wrought iron and steel	3	4	4 to 5	10
Cast iron	3	4	5	10
Timber	—	4	10	
Brickwork	—	—	6	
Masonry	20	—	20 to 30	

One B.T. unit of electricity = 1,000 watts for 1 hour.
One H.P. = 746 watts.
One B.T. unit of electricity = $1\frac{1}{3}$ HP. very nearly.

Sizes of Wire Gauges in Decimals of an Inch.

Size.	Birmingham Wire Gauge.	Imperial Standard Gauge.	Size.	Birmingham Wire Gauge.	Imperial Standard Gauge.
1	·312	·300	13	·093	·092
2	·281	·276	14	·078	·080
3	·265	·252	15	·070	·072
4	·234	·232	16	·062	·064
5	·218	·212	17	·054	·056
6	·203	·192	18	·046	·048
7	·187	·176	19	·042	·040
8	·171	·160	20	·038	·036
9	·156	·144	21	·034	·032
10	·140	·128	22	·031	·028
11	·125	·116	23	·028	·024
12	·109	·104	24	·025	·022

Contents of Pipes in Cubic Feet per One Foot in Length.

Diameter in Inches.	Diameter in Decimals of a Foot.	Cubic Feet or Area in Sq. Ft.	Diameter in Inches.	Diameter in Decimals of a Foot.	Cubic Feet or Area in Sq. Ft.	Diameter in Inches.	Diameter in Decimals of a Foot.	Cubic Feet or Area in Sq. Ft.	Diameter in Inches.	Diameter in Decimals of a Foot.	Cubic Feet or Area in Sq. Ft.	Diameter in Inches.	Diameter in Decimals of a Foot.	Cubic Feet or Area in Sq. Ft.
1/4	·0208	·0003	3	·2500	·0491	8	·6667	·3491	14	1·167	1·069	29	2·417	4·587
5/16	·0260	·0005	3 1/4	·2708	·0576	8 1/4	·6875	·3712	14 1/2	1·208	1·147	30	2·500	4·909
3/8	·0313	·0008	3 1/2	·2917	·0668	8 1/2	·7083	·3941	15	1·250	1·227	31	2·583	5·241
7/16	·0365	·0010	3 3/4	·3125	·0767	8 3/4	·7292	·4176	15 1/2	1·292	1·310	32	2·667	5·585
1/2	·0417	·0014	4	·3333	·0873	9	·7500	·4418	16	1·333	1·396	33	2·750	5·940
9/16	·0469	·0017	4 1/4	·3542	·0985	9 1/4	·7708	·4667	16 1/2	1·375	1·485	34	2·833	6·305
5/8	·0521	·0021	4 1/2	·3750	·1104	9 1/2	·7917	·4922	17	1·417	1·576	35	2·917	6·681
11/16	·0573	·0026	4 3/4	·3958	·1231	9 3/4	·8125	·5185	17 1/2	1·458	1·670	36	3·000	7·069
3/4	·0625	·0031	5	·4167	·1364	10	·8333	·5454	18	1·500	1·767	37	3·083	7·467
13/16	·0677	·0036	5 1/4	·4375	·1503	10 1/4	·8542	·5730	18 1/2	1·542	1·867	38	3·167	7·876
7/8	·0729	·0042	5 1/2	·4583	·1650	10 1/2	·8750	·6013	19	1·583	1·969	39	3·250	8·296
15/16	·0781	·0048	5 3/4	·4792	·1803	10 3/4	·8958	·6303	20	1·667	2·182	40	3·333	8·727
1	·0833	·0055	6	·5000	·1963	11	·9167	·6600	21	1·750	2·405	41	3·417	9·168
1 1/4	·1042	·0085	6 1/4	·5208	·2131	11 1/4	·9375	·6903	22	1·833	2·640	42	3·500	9·621
1 1/2	·1250	·0123	6 1/2	·5417	·2304	11 1/2	·9583	·7213	23	1·917	2·885	43	3·583	10·085
1 3/4	·1458	·0167	6 3/4	·5625	·2485	11 3/4	·9792	·7530	24	2·000	3·142	44	3·667	10·559
2	·1667	·0218	7	·5833	·2673	12	1 foot	·7854	25	2·083	3·409	45	3·750	11·045
2 1/4	·1875	·0276	7 1/4	·6042	·2867	12 1/2	1·042	·8522	26	2·167	3·687	46	3·833	11·541
2 1/2	·2083	·0341	7 1/2	·6250	·3068	13	1·083	·9218	27	2·250	3·976	47	3·917	12·046
2 3/4	·2292	·0412	7 3/4	·6458	·3276	13 1/2	1·125	·9940	28	2·333	4·276	48	4·000	12·566

Weight of One Lineal Foot of Flat Rolled Iron. One Cubic Foot weighs 480 lbs.

Width in Inches	Thickness in Inches. 1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16	1
1	·208	·417	·625	·833	1·042	1·250	1·458	1·666	1·88	2·090	2·30	2·510	2·72	2·916	3·13	3·333
1 1/8	·234	·469	·703	·938	1·172	1·406	1·640	1·880	2·12	2·344	2·59	2·820	3·06	3·280	3·53	3·750
1 1/4	·260	·521	·781	1·042	1·303	1·563	1·823	2·083	2·35	2·605	2·87	3·125	3·39	3·646	3·92	4·166
1 3/8	·286	·573	·859	1·146	1·432	1·710	2·006	2·292	2·58	2·864	3·15	3·438	3·72	4·012	4·30	4·583
1 1/2	·312	·625	·937	1·250	1·562	1·875	2·188	2·500	2·81	3·125	3·44	3·750	4·06	4·375	4·69	5·000
1 5/8	·338	·677	1·015	1·354	1·692	2·031	2·370	2·708	3·06	3·384	3·72	4·062	4·40	4·740	5·08	5·416
1 3/4	·365	·729	1·094	1 458	1·823	2·188	2·550	2·916	3·29	3·646	4·01	4·375	4·74	5·105	5·47	5·833
1 7/8	·391	·781	1·172	1·562	1·953	2·344	2·735	3·125	3·52	3·906	4·30	4·688	5·08	5·470	5·86	6·250
2	·417	·835	1·25	1·666	2·083	2·500	2·916	3·333	3·76	4·180	4·58	5·000	5·42	5·833	6·25	6·666
2 1/8	·443	·885	1·328	1·771	2·214	2·656	3·098	3·542	3·98	4·428	4·87	5·312	5·76	6·196	6·64	7·083
2 1/4	·469	·937	1·406	1·875	2·344	2·812	3·281	3·750	4·22	4·688	5·16	5·624	6·09	6·562	7·03	7·500
2 3/8	·495	·989	1·484	1·979	2·474	2·968	3·463	3·958	4·45	4·950	5·44	5·936	6·43	6·926	7·42	7·916
2 1/2	·521	1·042	1·562	2·083	2·605	3·125	3·646	4·166	4·69	5·210	5·73	6·250	6·77	7·291	7·81	8·333
2 5/8	·547	1·094	1·641	2·187	2·735	3·282	3·829	4·375	4·92	5·470	6·02	6·564	7·11	7·658	8·20	8·750
2 3/4	·573	1·146	1·719	2·292	2·865	3·438	4·011	4·583	5·16	5·730	6·30	6·876	7·45	8·022	8·59	9·166
2 7/8	·599	1·198	1·797	2·396	2·995	3·594	4·193	4·792	5·39	5·990	6·59	7·188	7·79	8·386	8·98	9·583
3	·625	1·250	1·875	2·500	3·125	3·750	4·375	5·000	5·63	6·250	6·88	7·500	8·13	8·750	9·38	10·00
3 1/8	·652	1·303	1·954	2·605	3·257	3·908	4·560	5·210	5·96	6·514	7·16	7·816	8·47	9·120	9·67	10·42
3 1/4	·677	1·354	2·031	2·708	3·385	4·062	4·739	5·416	6·11	6·770	7·44	8·124	8·80	9·478	10·15	10·83
3 3/8	·703	1·406	2·109	2·812	3·516	4·218	4·921	5·625	6·32	7·032	7·73	8·436	9·14	9·842	10·54	11·25
3 1/2	·729	1·458	2·188	2·916	3·646	4·375	5·105	5·833	6·58	7·291	8·01	8·750	9·48	10·21	10·94	11·66
3 5/8	·756	1·511	2·266	3·021	3·777	4·533	5·288	6·042	6·80	7·554	8·30	9·066	9·82	10·58	11·34	12·08
3 3/4	·781	1·562	2·343	3·125	3·906	4·686	5·468	6·250	7·05	7·812	8·59	9·372	10·15	10·94	11·72	12·50
3 7/8	·807	1·614	2·421	3·229	4·035	4·842	5·650	6·458	7·26	8·070	8·88	9·684	10·49	11·30	12·11	12·92

Weight of One Lineal Foot of Flat Rolled Iron. One Cubic Foot weighs 480 lbs.—*continued*.

Width in Inches	Thickness in Inches.															
	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16	1
4	·833	1·666	2·500	3·333	4·166	5·000	5·833	6·666	7·52	8·333	9·17	10·00	10·83	11·66	12·49	13·33
4⅛	·860	1·719	2·578	3·438	4·297	5·156	6·016	6·875	7·73	8·594	9·45	10·31	11·17	12·03	12·89	13·75
4¼	·886	1·771	2·656	3·542	4·427	5·312	6·198	7·083	7·97	8·854	9·74	10·62	11·51	12·40	13·29	14·16
4⅜	·912	1·823	2·734	3·646	4·557	5·468	6·380	7·291	8·20	9·114	10·03	10·94	11·85	12·76	13·67	14·58
4½	·938	1·875	2·812	3·750	4·687	5·624	6·562	7·500	8·44	9·374	10·31	11·25	12·19	13·12	14·06	15·00
4⅝	·964	1·927	2·891	3·854	4·818	5·782	6·745	7·708	8·77	9·636	10·60	11·56	12·52	13·49	14·44	15·42
4¾	·990	1·979	2·968	3·958	4·947	5·936	6·926	7·917	8·91	9·894	10·78	11·87	12·86	13·85	14·84	15·83
4⅞	1·016	2·031	3·048	4·062	5·080	6·096	7·112	8·125	9·14	10·16	11·18	12·19	13·21	14·22	15·24	16·25
5	1·042	2·083	3·125	4·166	5·210	6·250	7·291	8·333	9·38	10·42	11·46	12·50	13·54	14·58	15·62	16·66
5⅛	1·068	2·136	3·204	4·271	5·340	6·408	7·476	8·542	9·61	10·68	11·77	12·81	13·88	14·95	16·02	17·08
5¼	1·094	2·188	3·282	4·375	5·470	6·564	7·658	8·750	9·84	10·94	12·03	13·13	14·22	15·31	16·40	17·50
5⅜	1·120	2·240	3·360	4·479	5·600	6·720	7·840	8·958	10·08	11·20	12·32	13·44	14·56	15·68	16·80	17·92
5½	1·146	2·292	3·438	4·584	5·730	6·876	8·022	9·167	10·31	11·46	12·61	13·75	14·90	16·04	17·19	18·33
5⅝	1·172	2·344	3·516	4·687	5·860	7·032	8·204	9·375	10·55	11·72	12·89	14·06	15·23	16·40	17·57	18·75
5¾	1·198	2·396	3·594	4·791	5·990	7·188	8·386	9·583	10·78	11·98	13·18	14·37	15·57	16·77	17·97	19·16
5⅞	1·224	2·448	3·672	4·896	6·120	7·344	8·568	9·792	11·02	12·24	13·46	14·69	15·91	17·13	18·35	19·58
6	1·250	2·500	3·750	5·000	6·250	7·500	8·750	10·00	11·25	12·50	13·75	15·00	16·25	17·50	18·75	20·00
6⅛	1·276	2·552	3·828	5·104	6·380	7·656	8·932	10·21	11·49	12·76	14·04	15·31	16·59	17·86	19·14	20·42
6¼	1·302	2·604	3·906	5·208	6·510	7·812	9·114	10·42	11·72	13·02	14·32	15·62	16·92	18·23	19·53	20·83
6⅜	1·328	2·657	3·984	5·313	6·640	7·968	9·297	10·63	11·96	13·28	14·61	15·93	17·26	18·59	19·92	21·25
6½	1·354	2·708	4·063	5·417	6·770	8·126	9·480	10·83	12·19	13·54	14·90	16·25	17·61	18·96	20·31	21·66
6⅝	1·381	2·761	4·143	5·521	6·906	8·286	9·668	11·04	12·42	13·81	15·19	16·57	17·95	19·33	20·71	22·08
6¾	1·406	2·813	4·218	5·625	7·030	8·436	9·843	11·25	12·66	14·06	15·47	16·87	18·28	19·69	21·10	22·50
6⅞	1 432	2·864	4·296	5·729	7·160	8·592	10·02	11·46	12·89	14·32	15·75	17·18	18·61	20·04	21·47	22·92

Weight of One Lineal Foot of Flat Rolled Iron. One Cubic Foot weighs 480 lbs.—*continued.*

Width in Inches	Thickness in Inches.															
	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16	1
7	1·458	2·916	4·375	5·833	7·291	8·750	10·20	11·66	13·13	14·58	16·05	17·50	18·96	20·42	21·88	23·33
7 1/8	1·484	2·969	4·452	5·938	7·420	8·904	10·39	11·87	13·35	14·84	16·32	17·81	19·29	20·78	22·26	23·75
7 1/4	1·511	3·021	4·533	6·042	7·555	9·066	10·58	12·08	13·59	15·11	16·62	18·13	19·64	21·16	22·67	24·16
7 3/8	1·536	3·073	4·608	6·146	7·680	9·216	10·75	12·29	13·83	15·36	16·90	18·43	19·97	21·50	23·04	24·58
7 1/2	1·562	3·125	4·686	6·250	7·810	9·372	10·93	12·50	14·06	15·62	17·19	18·74	20·31	21·86	23·44	25·00
7 5/8	1·588	3·177	4·764	6·354	7·940	9·528	11·12	12·71	14·30	15·88	17·47	19·05	20·64	22·24	23·83	25·42
7 3/4	1·615	3·229	4·845	6·458	8·075	9·690	11·31	12·92	14·54	16·15	17·76	19·38	21·00	22·62	24·24	25·83
7 7/8	1·641	3·281	4·923	6·562	8·205	9·846	11·48	13·13	14·77	16·41	18·05	19·69	21·33	22·96	24·60	26·25
8	1·666	3·333	5·000	6·666	8·333	10·00	11·66	13·33	15·00	16·66	18·33	20·00	21·67	23·33	25·00	26·66
8 1/8	1·693	3·386	5·079	6·771	8·455	10·15	11·85	13·54	15·23	16·91	18·60	20·30	21·99	23·70	25·39	27·08
8 1/4	1·719	3·438	5·157	6·875	8·595	10·31	12·03	13·75	15·47	17·19	18·91	20·61	22·33	24·06	25·78	27·50
8 3/8	1·745	3·489	5·235	6·979	8·725	10·47	12·21	13·96	15·71	17·45	19·20	20·94	22·69	24·42	26·17	27·92
8 1/2	1·771	3·542	5·313	7·083	8·855	10·63	12·40	14·17	15·94	17·71	19·48	21·26	23·02	24·80	26·57	28·33
8 5/8	1·797	3·594	5·391	7·188	8·985	10·78	12·58	14·37	16·17	17·97	19·77	21·56	23·36	25·16	26·96	28·75
8 3/4	1·823	3·646	5·469	7·292	9·115	10·94	12·76	14·58	16·40	18·23	20·05	21·88	23·70	25·52	27·34	29·17
8 7/8	1·849	3·698	5·547	7·396	9·245	11·09	12·94	14·79	16·64	18·49	20·34	22·18	24·03	25·88	27·73	29·58
9	1·875	3·750	5·625	7·500	9·375	11·25	13·12	15·00	16·88	18·75	20·63	22·50	24·38	26·24	28·13	30·00
9 1/8	1·901	3·802	5·703	7·604	9·505	11·41	13·31	15·21	17·11	19·00	20·90	22·81	24·71	26·62	28·52	30·42
9 1/4	1·927	3·854	5·781	7·708	9·635	11·56	13·49	15·42	17·35	19·27	21·20	23·12	25·05	26·98	28·91	30·83
9 3/8	1·953	3·906	5·859	7·812	9·765	11·72	13·67	15·62	17·57	19·53	21·48	23·44	25·39	27·34	29·29	31·25
9 1/2	1·979	3·958	5·937	7·916	9·895	11·87	13·85	15·84	17·82	19·79	21·77	23·74	25·73	27·70	29·69	31·67
9 5/8	2·005	4·010	6·015	8·021	10·02	12·03	14·04	16·04	18·05	20·04	22·05	24·06	26·07	28·08	30·09	32·08
9 3/4	2·031	4·062	6·093	8·125	10·16	12·18	14·21	16·25	18·28	20·32	22·35	24·36	26·39	28·42	30·45	32·50
9 7/8	2·057	4·114	6·171	8·229	10·29	12·34	14·40	16·46	18·52	20·58	22·64	24·68	26·74	28·80	30·86	32·92

Weight of One Lineal Foot of Flat Rolled Iron. One Cubic Foot weighs 480 lbs.—*continued.*

Width	Thickness in Inches.															
	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16	1
Ins.																
10	2·083	4·166	6·250	8·333	10·41	12·50	14·58	16·66	18·75	20·82	22·92	25·00	27·08	29·16	31·25	33·33
10 1/8	2·109	4·219	6·327	8·438	10·55	12·65	14·76	16·87	18·99	21·10	23·20	25·30	27·41	29·52	31·63	33·75
10 1/4	2·135	4·270	6·405	8·541	10·67	12·81	14·94	17·08	19·21	21·34	23·48	25·62	27·75	29·88	32·02	34·17
10 3/8	2·162	4·323	6·486	8·646	10·81	12·97	15·13	17·29	19·46	21·62	23·78	25·94	28·10	30·26	32·42	34·58
10 1/2	2·188	4·375	6·564	8·750	10·94	13·13	15·31	17·50	19·69	21·88	24·06	26·26	28·44	30·62	32·81	35·00
10 5/8	2·214	4·427	6·642	8·854	11·07	13·28	15·50	17·71	19·91	22·14	24·35	26·56	28·78	31·00	33·21	35·42
10 3/4	2·239	4·479	6·717	8·958	11·20	13·43	15·67	17·92	20·18	22·40	24·63	26·86	29·10	31·34	33·59	35·83
10 7/8	2·266	4·531	6·798	9·062	11·33	13·59	15·86	18·12	20·39	22·66	24·92	27·18	29·45	31·72	33·98	36·25
11	2·291	4·583	6·873	9·166	11·46	13·75	16·05	18·33	20·63	22·90	25·21	27·50	29·80	32·08	34·38	36·66
11 1/8	2·318	4·636	6·954	9·271	11·59	13·91	16·22	18·54	20·86	23·18	25·50	27·82	30·13	32·44	34·76	37·08
11 1/4	2·344	4·688	7·032	9·375	11·72	14·06	16·40	18·75	21·10	23·44	25·78	28·12	30·46	32·80	35·15	37·50
11 3/8	2·370	4·740	7·110	9·479	11·85	14·22	16·59	18·96	21·33	23·70	26·07	28·44	30·81	33·18	35·55	37·92
11 1/2	2·395	4·791	7·185	9·582	11·97	14·37	16·77	19·16	21·56	23·94	26·35	28·74	31·15	33·52	35·94	38·33
11 5/8	2·422	4·844	7·266	9·688	12·11	14·53	16·95	19·37	21·80	24·22	26·64	29·06	31·48	33·90	36·32	38·75
11 3/4	2·448	4·896	7·344	9·792	12·24	14·68	17·13	19·58	22·03	24·48	26·92	29·36	31·81	34·26	36·71	39·16
11 7/8	2·474	4·948	7·422	9·896	12·37	14·84	17·32	19·79	22·27	24·74	27·21	29·68	32·16	34·64	37·11	39·58
Ft. In.																
1 0	2·500	5·00	7·500	10·00	12·50	15·00	17·50	20·00	22·50	25·00	27·50	30·00	32·50	35·00	37·50	40·00
1 1	2·71	5·42	8·13	10·83	13·55	16·25	18·96	21·67	24·38	27·08	29·79	32·50	35·21	37·92	40·63	43·34
1 2	2·92	5·83	8·75	11·67	14·58	17·50	20·42	23·33	26·25	29·17	32·09	35·00	37·92	40·84	43·75	46·67
1 3	3·13	6·25	9·38	12·50	15·63	18·75	21·88	25·00	28·13	31·25	34·38	37·50	40·63	43·75	46·88	50·00
1 4	3·33	6·67	10·00	13·34	16·67	20·00	23·34	26·67	30·00	33·34	36·67	40·00	43·34	46·67	50·00	53·34
1 5	3·54	7·08	10·63	14·17	17·71	21·25	24·79	28·33	31·88	35·42	38·96	42·50	46·04	49·59	53·13	56·67
1 6	3·75	7·50	11·25	15·00	18·75	22·50	26·25	30·00	33·75	37·50	41·25	45·00	48·75	52·50	56·25	60·00
1 7	3·96	7·92	11·88	15·84	19·79	23·75	27·71	31·67	35·63	39·59	43·54	47·50	51·46	55·42	59·38	63·34
1 8	4·17	8·33	12·50	16·67	20·84	25·00	29·17	33·33	37·50	41·67	45·84	50·00	54·17	58·33	62·50	66·67
1 9	4·38	8·75	13·13	17·50	21·88	26·25	30·63	35·00	39·38	43·75	48·13	52·50	56·88	61·25	65·63	70·00
1 10	4·58	9·17	13·75	18·33	22·92	27·50	32·09	36·67	41·25	45·83	50·41	55·00	59·59	64·17	68·75	73·33
1 11	4·79	9·58	14·38	19·17	23·96	28·75	33·54	38·33	43·13	47·92	52·71	57·50	62·29	67·08	71·88	76·67

Weight of One Lineal Foot of Flat Rolled Iron. One Cubic Foot weighs 480 lbs.—*continued.*

Width		Thickness in Inches.															
Ft.	In.	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16	1
2	0	5·00	10·00	15·00	20·00	25·00	30·00	35·00	40·00	45·00	50·00	55·00	60·00	65·00	70·00	75·00	80·00
2	1	5·21	10·42	15·63	20·83	26·04	31·25	36·46	41·67	46·87	52·08	57·29	62·50	67·71	72·92	78·12	83·33
2	2	5·42	10·83	16·25	21·67	27·08	32·50	37·92	43·33	48·75	54·17	59·59	65·00	70·42	75·84	81·25	86·67
2	3	5·63	11·25	16·88	22·50	28·13	33·75	39·38	45·00	50·63	56·25	61·88	67·50	73·13	78·75	84·38	90·00
2	4	5·83	11·67	17·50	23·34	29·16	35·00	40·83	46·66	52·50	58·34	64·17	70·00	75·83	81·67	87·50	93·33
2	5	6·04	12·08	18·13	24·17	30·21	36·25	42·29	48·34	54·38	60·42	66·46	72·50	78·54	84·59	90·63	96·67
2	6	6·25	12·50	18·75	25·00	31·25	37·50	43·75	50·00	56·25	62·50	68·75	75·00	81·25	87·50	93·75	100·00
2	7	6·46	12·92	19·38	25·83	32·29	38·75	45·21	51·67	58·13	64·59	71·04	77·50	83·96	90·42	96·88	103·33
2	8	6·67	13·34	20·00	26·67	33·33	40·00	46·67	53·33	60·00	66·67	73·33	80·00	86·67	93·33	100·00	106·67
2	9	6·88	13·75	20·63	27·50	34·38	41·25	48·13	55·00	61·88	68·75	75·63	82·50	89·38	96·25	103·13	110·00
2	10	7·08	14·17	21·25	28·33	35·42	42·50	49·58	56·67	63·75	70·83	77·92	85·00	92·08	99·17	106·25	113·33
2	11	7·29	14·58	21·88	29·17	36·46	43·75	51·05	58·33	65·63	72·92	80·21	87·50	94·80	102·09	109·38	116·67
3	0	7·50	15·00	22·50	30·00	37·50	45·00	52·50	60·00	67·50	75·00	82·50	90·00	97·50	105·00	112·50	120·00
3	1	7·71	15·42	23·13	30·83	38·55	46·25	53·96	61·67	69·38	77·08	84·79	92·50	100·21	107·92	115·63	123·33
3	2	7·92	15·84	23·75	31·67	39·58	47·50	55·42	63·33	71·25	79·17	87·08	95·00	102·92	110·83	118·73	126·67
3	3	8·13	16·25	24·38	32·50	40·63	48·75	56·88	65·00	73·13	81·25	89·38	97·50	105·63	113·75	121·88	130·00
3	4	8·33	16·67	25·00	33·33	41·67	50·00	58·33	66·67	75·00	83·33	91·67	100·00	108·33	116·76	125·00	133·33
3	5	8·54	17·08	25·63	34·17	42·71	51·25	59·79	68·33	76·88	85·42	93·96	102·50	111·04	119·59	128·13	136·67
3	6	8·75	17·50	26·25	35·00	43·75	52·50	61·25	70·00	78·75	87·50	96·25	105·00	113·75	122·50	131·25	140·00
3	7	8·96	17·92	26·88	35·84	44·79	53·75	62·71	71·67	80·63	89·59	98·54	107·50	116·46	125·42	134·38	143·33
3	8	9·17	18·33	27·50	36·67	45·84	55·00	64·17	73·33	82·50	91·66	100·83	110·00	119·17	128·34	137·50	146·67
3	9	9·38	18·75	28·13	37·50	46·88	56·25	65·63	75·00	84·38	93·75	103·13	112·50	121·88	131·25	140·63	150·00
3	10	9·58	19·17	28·75	38·33	47·92	57·50	67·08	76·67	86·25	95·83	105·42	115·00	124·58	134·17	143·75	153·33
3	11	9·79	19·58	29·38	39·17	48·96	58·75	68·54	78·33	88·13	97·92	107·71	117·50	127·29	137·08	146·88	156·67
4	0	10·00	20·00	30·00	40·00	50·00	60·00	70·00	80·00	90·00	100·00	110·00	120·00	130·00	140·00	150·00	160·00

American and Birmingham Gauges.

1 mil. is equal to $\frac{1}{1000}$ inch.

No.	American. Diameter in Mils.	Birmingham. Diameter in Mils.	No.	American. Diameter in Mils.	Birmingham Diameter in Mils.
0000	460	454	8	128·5	165
000	409·6	425	9	114·4	148
00	364·8	380	10	101·9	134
0	324·9	340	12	80·8	109
1	289·3	300	14	64·1	83
2	257·6	284	16	50·8	65
3	229·4	259	18	40·3	49
4	204·3	238	20	32	35
5	181·9	220	30	10	12
6	162	203	40	3·1	5·8
7	144·3	180			

Weight of Vieille-Montagne Zinc Sheeting per Square Foot.

Gauge.	Lb.	Ozs.	Drms.	Gauge.	Lb.	Ozs.	Drms.
9	0	10	5	14	1	2	12
10	0	11	7	15	1	5	12
11	0	13	5	16	1	8	12
12	0	15	2	17	1	11	11
13	1	0	15	18	1	14	11

Thickness of Tin Plates.

IC = 30 B. G.	IXXX = 25·8	IXXXXXX = 23·1	DXX = 24·2
IX = 28·1	IXXXX = 24·8	DC = 27·8	DXXX = 23·0
IXX = 26·8	IXXXXX = 23·9	DX = 25·6	DXXXX = 22·0

Table Showing the Number of Square Feet a Cwt. of Sheet Lead will cover on a Flat Roof or Gutter.

Thickness. Inch.	Weight per Square Foot.		
	4	Milled lead	28 feet 0 inches.
$\frac{1}{12}$th	5	Milled lead	22 " 5 "
$\frac{1}{10}$th	6	Milled lead	18 " 8 "
	7	Cast lead	16 " 0 "
	8	Cast lead	14 " 0 "
	9	Cast lead	12 " $5\frac{1}{2}$ "
$\frac{1}{6}$th	10	Cast lead	11 " 3 "
	11	Cast lead	10 " 2 "
$\frac{1}{5}$th	12	Cast lead	9 " 4 "

Specific gravity = 11·325.
Weight per cubic foot = 708 lbs.

330 $1\frac{1}{4}$-inch galvanised slate nails weigh 1 lb.
50 5-inch lead nails weigh 3 lbs. $2\frac{3}{4}$ ozs.

To unite two pieces of lead, the surfaces to be joined are scraped bright, and between them there is immediately inserted a very thin leaf of lead amalgam—that is, lead-foil that has been saturated with mercury. On passing a soldering iron along the seam, or by heating in some other way, the mercury is vaporised and driven off. The lead is left free in an extremely fine state of division, and in that state readily fuses, and forms a sound joint between the adjacent parts.

Weight of Copper Nails.

1	inch weigh about	3 lbs.	4 ozs.	per 1,000.
1½	" " "	9 "	9 "	" "
2	" " "	11 "	4 "	" "
2½	" " "	29 "	4 "	" "
3	" " "	40 "	0 "	" "

	Cwt.	Qrs.	Lbs.	
16 B.W.G. Corrugated iron weighs per square	3	1	16	allowing for laps.
18 " " " "	2	1	24	
20 " " " "	1	3	23	
22 " " " "	1	2	13	
24 " " " "	1	1	10	

Corrugated Iron Roof Sheeting.

B. Wire Gauge.	Size of Sheets.	Weight per Square Foot.	Weight per 100 Square Feet.			Square Feet per Ton.
	Feet.		Cwt.	Qrs.	Lbs.	
No. 16	6 × 2 to 8 × 3	3·5	3	0	14	800
" 18	6 × 2 to 8 × 3	2·6	2	1	6	1,000
" 20	6 × 2 to 8 × 3	2·05	1	3	6	1,250
" 22	6 × 2 to 7 × 2½	1·75	1	2	7	1,550
" 24	6 × 2 to 7 × 2½	1·36	1	0	24	1,880
" 26	6 × 2 to 7 × 2½	1·12	1	0	6	2,170

$\frac{1}{10}$th weight to be added for lappage.

Relative Heat Conducting Power of Metals. Silver = 1,000.

Metals	Conducting Power.
Silver	1,000
Gold	982
" with 1 per cent. silver	840
Copper, rolled	845
" cast	811
Mercury	677
" with 1·25 per cent. tin	412
Aluminium	665

Relative Heat Conducting Power of Metals. Silver = 1,000 (*continued*).

Metals.	Conducting Power.
Zinc, rolled	641
„ cast vertically	628
„ „ horizontally	608
Cadmium	577
Wrought iron	436
Tin	422
Steel	397
Platinum	380
Sodium	365
Cast iron	359
Lead	287
Antimony, cast horizontally	215
„ „ vertically	192
Bismuth	61
Copper with 1 per cent. arsenic	570
„ „ ·5 „ „	669
„ „ ·25 „ „	771

Relative Electrical Conductivity of Metals.

Silver	100	Iron	12
Copper	74	Lead	8
Brass	24	Platinum	8
Tin	15	Bismuth	2

Melting Point of Metals.

	°F.	Specific Heat.		°F.	Specific Heat.
Aluminium (pure)	1,300	·234	Nickel	2,810	·109
Antimony	810	·051	Platinum	3,080	·039
Bismuth	507	·031	Silver	1,832	·057
Brass	1,650	·094	Steel (hard)	2,370	·117
Copper	—	·095	Steel (mild)	2,550	·117
Gold	2,166	·032	Tin	446	·057
Iron (cast)	1,920 to 2,012	·130	Zinc	736	·096
„ (wrought)	2,912	·110	Phosphorus	110	·288
Lead	612	·031	Spermaceti	120	
Manganese	—	·144	Sulphur	230	·203
Mercury	− 39	·033	Tallow	92	
			Wax (bees')	150	
			„ (paraffin)	114	

Cast iron usually consists of from 3 to 5 per cent. of carbon, which in white iron is thoroughly combined with the iron, and in grey iron 0·6 to 1·5 per cent. is combined, and the remainder crystallises separately as graphite.

Cast iron contracts $\frac{1}{8}$ inch per foot; patterns should therefore be that amount larger, or say 1 per cent.

Usual Allowance for Shrinkage of Castings per Foot.

	Parts of an Inch.	
For cast iron pipes	·125	= $\frac{1}{8}$
„ „ beams and girders	·1	= $\frac{1}{10}$
„ „ cylinders, large	·094	= $\frac{3}{32}$
„ „ „ small	·06	= $\frac{1}{16}$
Brass	·17	= $\frac{3}{16}$
Lead	·31	= $\frac{5}{16}$
Zinc	·25	= $\frac{1}{4}$
Copper	·17	= $\frac{3}{16}$

Babbitt Metal.

Proportions of Babbitt metal for running in cast iron boxes—

1. For light work	50 tin,	5 antimony,	1 copper.
2. „ heavy „	46 „	8 „	4 „

Attrition Metal.

One copper, 3 best tin, 2 regulus of antimony; heat separately and then mix and add 3 more parts tin; on remelting add twice the quantity of tin to one of above mixture.

Delta Metal.

Cast.—Copper, 55·94 per cent.; zinc, 41·61 per cent.; iron, ·81 per cent.; manganese, ·81 per cent.; lead, ·72 per cent.; phosphorus, ·013 per cent.; nickel, a trace.

Wrought.—Copper, 55·8 per cent.; zinc, 40·07 per cent.; lead, 1·82 per cent.; iron, 1·28 per cent.; manganese, ·96 per cent.; phosphorus, ·011 per cent.; nickel, a trace.

Rolled.—Copper, 55·82 per cent.; zinc, 41·41 per cent.; manganese, 1·38 per cent.; iron, ·86 per cent.; lead, ·76 per cent.; nickel, ·06 per cent.; phosphorus, a trace.

Hot-punched Metal.—Copper, 54·22 per cent.; zinc, 42·25 per cent.; lead, 1·1 per cent.; manganese, 1·09 per cent.; iron, ·99 per cent.; nickel, ·16 per cent.; phosphorus, ·02 per cent.

Tensile strength of cast = 35 tons per square inch.
„ „ „ forged = 42 „ „ „ „

Will not weld, but can be soldered.

To Case harden.—Make the surface bright, heat to red heat, rub with prussiate of potash, and quench in water. Or, better, heat the iron in a close box filled with bone dust and cuttings of horn and leather. (Unwin.)

Colours and Temperatures for Hardening Tools.

Pale straw	= 430°F.	for lancets, &c.
Dark yellow	= 470°F.	„ razors.
„ straw	= 470°F.	„ penknives.
Clay yellow	= 490°F.	„ chisels and shears.
Brown „	= 500°F.	„ adzes and plane irons.
Very pale purple	= 520°F.	„ table knives.
Light purple	= 530°F.	„ swords and watch springs.
Dark „	= 550°F.	„ softer swords and watch springs.
„ blue	= 570°F.	„ small fine saws.
Blue	= 590°F.	„ large saws.
Pale blue	= 610°F.	„ saws, the teeth of which are set with pliers.
Greenish blue	= 630°F.	„ very soft temper.

Breaking Strength, Elastic Strength, and Modulus of Elasticity.

Materials.	Breaking Strength. In Lbs. per Square Inch. Tension.	Com-pression.	Shearing.	Elastic Strength. In Lbs. per Square Inch. Tension.	Com-pression.	Shearing.	Modulus of Elasticity. Direct. E.	Transverse. G.
	30,500	130,000	—	—	—	—	23,000,000	—
Cast iron	17,500	95,000	28,500	10,500	21,000	7,900	17,000,000	6,300,000
	10,800	50,000	—	—	—	—	14,000,000	—
	67,000	—	—	—	—	—	—	—
Wrought iron bars	57,500	50,000	50,000	24,000	24,000	20,000	29,000,000	10,500,000
	33,500	—	—	—	—	—	—	—
" " plates, with fibre	50,700	—	—	—	—	—	25,000,000	—
" " " across fibre	46,100	—	—	—	—	—	27,000,000	—
" " " mean	48,400	—	—	20,000	20,000	15,000	26,000,000	9,500,000
Steel boiler plates	66,000	201,600	—	31,000	—	—	29,500,000	—
Rivet steel	65,000	336,000	55,600	—	—	—	30,670,000	—
	100,000	—	—	—	—	—	—	—
Soft " unhardened	80,000	—	—	35,000	—	26,500	30,000,000	11,000,000
	60,000	—	—	—	—	—	—	—
" " hardened	120,000	—	—	70,500	—	53,000	30,000,000	11,000,000
	150,000	—	—	—	—	—	—	—
Cast " untempered	120,000	—	—	80,000	—	64,000	30,000,000	11,000,000
	84,000	—	—	—	—	—	—	—
" " tempered	—	—	—	190,000	—	145,000	36,000,000	13,000,000
Copper	33,000	58,000	—	4,300	3,900	2,900	15,000,000	5,600,000
Brass, yellow	17,500	10,500	—	6,950	—	5,200	9,170,000	3,440,000
	52,000	—	—	—	—	—	—	—
Gun metal	36,000	—	—	6,200	—	4,150	9,873,000	3,700,000
	23,000	—	—	—	—	—	—	—
Muntz metal	49,000	—	—	—	—	—	—	—
Phosphor bronze	58,000	129,920	—	19,700	—	14,500	14,000,000	5,250,000
Cast zinc	7,500	—	—	3,200	—	—	13,680,000	—
Lead	1,900	7,300	—	1,500	—	—	720,000	270,000
Tin	4,700	11,560	—	—	—	—	4,608,000	—
Wood, pine	12,000	6,000	1,200	—	—	—	1,400,000	90,000
" oak	15,000	10,000	2,300	—	—	—	1,500,000	82,000
Leather	4,200	—	—	—	—	—	25,000	—

PROPORTIONS OF BOLTS AND NUTS.

(Unwin.)

Hexagon Nuts.

Diameter across flats $= D = 1{\cdot}5d + 0{\cdot}18$ to $1{\cdot}5d + 0{\cdot}44$ if rough.
„ „ „ $= 1{\cdot}5d + 0{\cdot}06$ to $1{\cdot}5d + 0{\cdot}18$ if bright.
„ „ angles $= D_1 = 1{\cdot}75d + 0{\cdot}16$ to $1{\cdot}75d + 0{\cdot}4$ if rough.
„ „ „ $= 1{\cdot}75d + 0{\cdot}07$ to $1{\cdot}75d + 0{\cdot}2$ if bright.
Height of nut $= d =$ diameter of bolt.
„ „ lock nut $= \frac{d}{2}$

Square Nuts.

Diameter across flats $= 1.5d + 0{\cdot}18$ to $1{\cdot}5d + 0{\cdot}44$ if rough.
„ „ „ $= 1{\cdot}5d + 0{\cdot}06$ to $1{\cdot}5d + 0{\cdot}18$ if bright.
„ „ angles $= 2{\cdot}12d + 0{\cdot}25$ to $2{\cdot}12d + 0{\cdot}6$ if rough.
„ „ „ $= 2{\cdot}12d + 0{\cdot}08$ to $2{\cdot}12d + 0{\cdot}25$ if bright.
Head of bolt may be square, hexagonal, or circular. Its height $\frac{2}{3}d$ to d.

Washers.

Thickness, $0{\cdot}15d$; diameter $\frac{9}{8}D_1$.
Small washers are usually 14 B.W.G. or 0·083 inches thick.
Washers for wood may be $3d$ in diameter and $0{\cdot}3d$ in thickness.

Length of spanner $= 15d$ to $18d$.

A workman exerting a pull of 30 lbs. on a spanner will cause tension in the bolt = 2,460 lbs., a force enough to break a ⅜ inch bolt, and to seriously strain a ½ inch bolt. Therefore bolts of less than ¾ inch diameter should not be used for joints requiring to be tightly screwed up.

Number of Cold-punched Nuts per 100 Lbs.

Inch.	Square.	Hexagon.	Inch.	Square.	Hexagon.
⅜	1,951	3,020	1	109	100
½	812	800	1⅛	81	83
⅝	428	444	1¼	65	62
¾	248	261	1½	34	31
⅞	165	165			

Weight in Lbs. of Nuts and Bolt Heads.

Head and Nut.	Diameter of Bolt in Inches.												
	¼	⅜	½	⅝	¾	⅞	1	1¼	1½	1¾	2	2½	3
Hexagon	·017	·057	·128	·267	·43	·73	1·1	2·14	3·77	5·62	8·75	17·2	28·8
Square.	·021	·070	·164	·321	·553	·882	1·31	2·56	4·42	7·00	10·5	21·0	36·4

Weight of Wrought Iron Hexagon Bolt Heads and Nuts.

(Another Rule.)

$\frac{1}{4}$ inch = ·017 lbs.	$\frac{3}{4}$ inch = ·461 lbs.	$1\frac{1}{2}$ inches = 3·68 lbs.
$\frac{3}{8}$ „ = ·059 „	$\frac{7}{8}$ „ = ·73 „	$1\frac{3}{4}$ „ = 5·86 „
$\frac{1}{2}$ „ = ·137 „	1 „ = 1·09 „	2 „ = 8·74 „
$\frac{5}{8}$ „ = ·267 „	$1\frac{1}{4}$ „ = 2·13 „	

Weight of Washers per 100.

$\frac{3}{8}$ inch = $1\frac{3}{4}$ lbs.	$\frac{3}{4}$ inch = $6\frac{3}{4}$ lbs.	$1\frac{1}{8}$ inch = $18\frac{3}{4}$ lbs.
$\frac{1}{2}$ „ = $2\frac{1}{2}$ „	$\frac{7}{8}$ „ = $8\frac{1}{2}$ „	$1\frac{1}{4}$ „ = 24 „
$\frac{5}{8}$ „ = $4\frac{1}{2}$ „	1 „ = $10\frac{3}{4}$ „	$1\frac{1}{2}$ „ = 30 „

Strength of bolts—allow a factor of safety of 8.

Strength of Bolts. (Unwin.)

Diameter of Bolt.	Strength when there is no stress due to screwing up.	Pull on Spanner.	Stress due to screwing up.	Effective Strength when screwed up against an Elastic Flange.
Inches.	Lbs.	Lbs.	Lbs.	Lbs.
$\frac{1}{2}$	1,008	16	1,312	—
$\frac{5}{8}$	1,836	18	1,476	360
$\frac{3}{4}$	2,736	20	1,640	1,096
$\frac{7}{8}$	3,798	23	1,890	1,908
1	4,986	25	2,050	2,936
$1\frac{1}{8}$	6,273	27	2,214	4,069
$1\frac{1}{4}$	8,046	29	2,380	5,666
$1\frac{3}{8}$	10,044	32	2,624	7,420
$1\frac{1}{2}$	11,700	34	2,790	8,910
$1\frac{3}{4}$	15,750	39	3,200	12,510
2	20,790	43	3,530	17,260
$2\frac{1}{4}$	27,180	47	3,940	23,240
$2\frac{1}{2}$	33,570	52	4,260	29,310
$2\frac{3}{4}$	41,760	57	4,670	37,090
3	48,870	61	5,000	43,870
$3\frac{1}{4}$	58,590	65	5,350	53,240
$3\frac{1}{2}$	68,310	70	5,740	62,570
$3\frac{3}{4}$	79,740	74	6,100	73,640
4	90,090	79	6,500	93,590
5	136,080	97	7,950	128,130
6	212,760	115	9,450	203,310

Proportion of Riveted Joints.

Single Lap Joints. Iron Plates and Rivets, and Steel Plates and Rivets.

Thickness of Plates.	Diameter of Rivets.		Pitch of Rivets.		Centre of Rivets to Edge of Plates.	
	Iron.	Steel.	Iron.	Steel.	Iron.	Steel.
Inch.	Inch.	Inch.	Inches.	Inches.	Inch.	Inch.
$\frac{1}{4}$	$\frac{5}{8}$	$\frac{11}{16}$	$1\frac{1}{2}$	$1\frac{9}{16}$	$\frac{15}{16}$	1
$\frac{5}{16}$	$\frac{11}{16}$	$\frac{3}{4}$	$1\frac{5}{8}$	$1\frac{11}{16}$	1	$1\frac{1}{8}$
$\frac{3}{8}$	$\frac{3}{4}$	$\frac{13}{16}$	$1\frac{13}{16}$	$1\frac{13}{16}$	$1\frac{1}{8}$	$1\frac{1}{4}$
$\frac{7}{16}$	$\frac{13}{16}$	$\frac{7}{8}$	2	2	$1\frac{1}{4}$	$1\frac{5}{16}$
$\frac{1}{2}$	$\frac{7}{8}$	$\frac{15}{16}$	2	2	$1\frac{5}{16}$	$1\frac{3}{8}$
$\frac{9}{16}$	$\frac{15}{16}$	1	$2\frac{1}{8}$	$2\frac{1}{8}$	$1\frac{7}{16}$	$1\frac{1}{2}$
$\frac{5}{8}$	1	$1\frac{1}{16}$	$2\frac{1}{4}$	$2\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{5}{8}$
$\frac{11}{16}$	$1\frac{1}{16}$	$1\frac{1}{8}$	$2\frac{3}{8}$	$2\frac{5}{16}$	$1\frac{5}{8}$	$1\frac{11}{16}$
$\frac{3}{4}$	$1\frac{1}{8}$	$1\frac{3}{16}$	$2\frac{7}{16}$	$2\frac{7}{16}$	$1\frac{11}{16}$	$1\frac{13}{16}$

Double Lap Joints. Iron Plates and Rivets, and Steel Plates and Rivets.

Thick-ness of Plates.	Diameter of Rivets.		Pitch of Rivets.		Centre of Rivets to edge of Plates.		Distance between rows of Rivets.			
							Zigzag.		Chain.	
	Iron.	Steel.	Iron.	Steel.	Iron.	Steel	Iron.	Steel.	Iron.	Steel.
In.	In.	In.	Ins.	Ins.	In.	In.	In.	In.	Ins.	Ins.
$\frac{7}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$2\frac{3}{4}$	$2\frac{11}{16}$	$1\frac{1}{8}$	$1\frac{3}{16}$	$1\frac{3}{8}$	$1\frac{3}{8}$	2	$2\frac{1}{8}$
$\frac{1}{2}$	$\frac{13}{16}$	$\frac{7}{8}$	$2\frac{7}{8}$	$2\frac{7}{8}$	$1\frac{1}{4}$	$1\frac{5}{16}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$2\frac{1}{8}$	$2\frac{1}{4}$
$\frac{9}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	3	$2\frac{15}{16}$	$1\frac{5}{16}$	$1\frac{3}{8}$	$1\frac{9}{16}$	$1\frac{9}{16}$	$2\frac{1}{4}$	$2\frac{3}{8}$
$\frac{5}{8}$	$\frac{15}{16}$	1	$3\frac{1}{8}$	3	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{5}{8}$	$1\frac{5}{8}$	$2\frac{3}{8}$	$2\frac{1}{2}$
$\frac{11}{16}$	1	$1\frac{1}{16}$	$3\frac{1}{4}$	$3\frac{3}{16}$	$1\frac{1}{2}$	$1\frac{9}{16}$	$1\frac{3}{4}$	$1\frac{11}{16}$	$2\frac{1}{2}$	$2\frac{5}{8}$
$\frac{3}{4}$	$1\frac{1}{16}$	$1\frac{1}{8}$	$3\frac{7}{16}$	$3\frac{5}{16}$	$1\frac{5}{8}$	$1\frac{11}{16}$	$1\frac{13}{16}$	$1\frac{3}{4}$	$2\frac{5}{8}$	$2\frac{3}{4}$
$\frac{7}{8}$	$1\frac{3}{16}$	$1\frac{1}{4}$	$3\frac{3}{4}$	$3\frac{5}{8}$	$1\frac{3}{4}$	$1\frac{7}{8}$	$1\frac{15}{16}$	$1\frac{15}{16}$	$2\frac{7}{8}$	3

Proportion of Riveted Joints—*continued.*

Single Riveted Double-butt Joints. Iron Plates and Rivets, and Steel Plates and Rivets.

Thickness of Plates.	Diameter of Rivets.		Pitch of Rivets.		Centre of Rivets to Edge of Plate.		Thickness of Butt Strap.	
	Iron.	Steel.	Iron.	Steel.	Iron.	Steel.	Iron.	Steel.
Inch.	Inch.	Inch.	Inches.	Inches.	Inch.	Inch.	Inch.	Inch.
$\frac{3}{8}$	$\frac{5}{8}$	$\frac{11}{16}$	$1\frac{15}{16}$	$1\frac{15}{16}$	$\frac{15}{16}$	$1\frac{1}{32}$	$\frac{1}{4}$	$\frac{1}{4}$
$\frac{7}{16}$	$\frac{11}{16}$	$\frac{3}{4}$	$2\frac{1}{8}$	$2\frac{1}{8}$	$1\frac{1}{32}$	$1\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{4}$
$\frac{1}{2}$	$\frac{3}{4}$	$\frac{13}{16}$	$2\frac{5}{16}$	$2\frac{5}{16}$	$1\frac{1}{8}$	$1\frac{1}{4}$	$\frac{5}{16}$	$\frac{5}{16}$
$\frac{9}{16}$	$\frac{13}{16}$	$\frac{7}{8}$	$2\frac{7}{16}$	$2\frac{3}{8}$	$1\frac{1}{4}$	$1\frac{5}{16}$	$\frac{3}{8}$	$\frac{3}{8}$
$\frac{5}{8}$	$\frac{7}{8}$	$\frac{15}{16}$	$2\frac{9}{16}$	$2\frac{1}{2}$	$1\frac{5}{16}$	$1\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$
$\frac{11}{16}$	$\frac{15}{16}$	1	$2\frac{11}{16}$	$2\frac{5}{8}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$\frac{7}{16}$	$\frac{7}{16}$
$\frac{3}{4}$	1	$1\frac{1}{16}$	$2\frac{13}{16}$	$2\frac{3}{4}$	$1\frac{1}{2}$	$1\frac{5}{8}$	$\frac{7}{16}$	$\frac{1}{2}$
$\frac{7}{8}$	$1\frac{1}{8}$	$1\frac{3}{16}$	$3\frac{1}{8}$	3	$1\frac{11}{16}$	$1\frac{13}{16}$	$\frac{9}{16}$	$\frac{9}{16}$

Double Riveted Double-butt Joints. Iron Plates and Rivets. Steel Plates and Rivets.

Thickness of Plates.	Diameter of Rivets.		Pitch of Rivets.		Centre of Rivets to Edge of Plates.		Distance between Rows of Rivets.				Thickness of Butt Strap.	
							Zigzag.		Chain.			
	Iron.	Steel.	Iron.	Steel.	Iron.	Steel.	Iron.	Steel.	Iron.	Steel.	Iron.	Steel.
In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
$\frac{9}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$3\frac{1}{2}$	$3\frac{1}{2}$	$1\frac{1}{8}$	$1\frac{3}{16}$	$1\frac{5}{8}$	$1\frac{5}{8}$	2	$2\frac{1}{8}$	$\frac{3}{8}$	$\frac{3}{8}$
$\frac{5}{8}$	$\frac{13}{16}$	$\frac{7}{8}$	$3\frac{11}{16}$	$3\frac{5}{8}$	$1\frac{3}{16}$	$1\frac{5}{16}$	$1\frac{3}{4}$	$1\frac{3}{4}$	$2\frac{1}{8}$	$2\frac{1}{4}$	$\frac{3}{8}$	$\frac{7}{16}$
$\frac{11}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	$3\frac{15}{16}$	$3\frac{13}{16}$	$1\frac{5}{16}$	$1\frac{3}{8}$	$1\frac{7}{8}$	$1\frac{7}{8}$	$2\frac{1}{4}$	$2\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$
$\frac{3}{4}$	$\frac{15}{16}$	1	$4\frac{1}{8}$	4	$1\frac{3}{8}$	$1\frac{1}{2}$	2	2	$2\frac{3}{8}$	$2\frac{1}{2}$	$\frac{7}{16}$	$\frac{9}{16}$
$\frac{7}{8}$	$1\frac{1}{16}$	$1\frac{1}{8}$	$4\frac{5}{8}$	$4\frac{3}{8}$	$1\frac{9}{16}$	$1\frac{11}{16}$	$2\frac{3}{16}$	$2\frac{3}{16}$	$2\frac{3}{8}$	$2\frac{3}{4}$	$\frac{9}{16}$	$\frac{5}{8}$
1	$1\frac{3}{16}$	$1\frac{1}{4}$	$5\frac{1}{16}$	$4\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{7}{8}$	$2\frac{7}{16}$	$2\frac{3}{8}$	$2\frac{7}{8}$	3	$\frac{5}{8}$	$\frac{5}{8}$

Riveted Joints.—Ultimate resistance to shearing
= 22 tons per square inch of rivets if wrought iron.
= 30 to 40 tons per square inch of rivets if steel.

Bolts.—Heads should be at least ·7 times the diameter of screwed ends of bolts.

Nuts.—Should be at least ·83 times the diameter of screwed ends of bolts.

Table of Ultimate Single Strength of Rivets.

Diameter.	Tons.	Diameter.	Tons.	Diameter.	Tons.
$\frac{1}{8}$ inch	·246	$\frac{5}{8}$ inch	6·16	$1\frac{1}{8}$ inch	20
$\frac{1}{4}$ „	·986	$\frac{3}{4}$ „	8·88	$1\frac{1}{4}$ „	24·6
$\frac{3}{8}$ „	2·22	$\frac{7}{8}$ „	12·1	$1\frac{3}{8}$ „	29·8
$\frac{1}{2}$ „	3·94	1 „	15·8		

If the rivet is in double shear it will have double the strength shown in table, *i.e.*

If a butt joint has two cover plates—one each side.

Weight of Rivet Heads (actual).

Two 1-inch rivets (heads only) = $9\frac{3}{4}$ ounces
" $\frac{7}{8}$ " " " = $6\frac{3}{4}$ "
" $\frac{3}{4}$ " " " = $4\frac{3}{4}$ "
" $\frac{5}{8}$ " " " = $3\frac{1}{4}$ "
" $\frac{1}{2}$ " " " = $1\frac{1}{2}$ "

Weight of Rivet Heads.

No. 10 rivet heads, 1 inch diameter = 2·7 lbs.
" " $\frac{7}{8}$ " " = 2·2 "
" " $\frac{3}{4}$ " " = 1·5 "
" " $\frac{5}{8}$ " " = 0·9 " (W. I. G.)

Diameter of Rivets for Plates of Different Thicknesses.

Thickness of Plates = t.	Diameter of Rivets = d.		Diar. of Rivets after Riveting = $1{\cdot}04d$.
Inches.		Inches.	
$\frac{1}{4}$	0·60	$\frac{9}{16}$	0·624
$\frac{5}{16}$	0·67	$\frac{11}{16}$	0·72
$\frac{3}{8}$	0·73	$\frac{3}{4}$	0·78
$\frac{7}{16}$	0·79	$\frac{13}{16}$	0·85
$\frac{1}{2}$	0·85	$\frac{7}{8}$	0·91
$\frac{9}{16}$	0·90	$\frac{7}{8}$	0·91
$\frac{5}{8}$	0·95	$\frac{15}{16}$	0·97
$\frac{3}{4}$	1·04	$1\frac{1}{16}$	1·10
$\frac{7}{8}$	1·12	$1\frac{1}{8}$	1·17
1	1·20	$1\frac{3}{16}$	1·24

Resistance to Shearing.

When rivets fit the holes exactly, shearing stress = P ÷ area of cross-section.

If the section is rectangular, and pressure perpendicular to one side, $= \frac{3}{2}\frac{P}{a}$

If the section is circular or elliptical, and pressure perpendicular to one side, $= \frac{4}{3}\frac{P}{a}$

If the section is square, and pressure acts parallel to a diagonal, $= \frac{9}{8}\frac{P}{a}$

Resistance to Torsion.

$$\text{Twisting moment} = \frac{12 \times 33{,}000 \times \text{HP.}}{2\,\pi\,\text{N}}$$

$$\text{Resistance to twisting} = \text{Shearing stress} \times Z_t$$

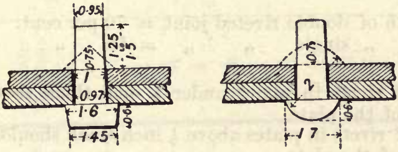
$$Z_t \text{ for cylindrical bars} = 0{\cdot}196\, d^3$$

$$Z_t \text{ ,, hollow do. do.} = 0{\cdot}196\, \frac{d_1^4 - d_2^4}{d_1}$$

$$Z_t \text{ ,, square bars} = 0{\cdot}208\, \text{side}^3$$

Average Proportions of Rivets to Diameter of Hole.

The shearing resistance of steel rivets is little greater than of rivet iron, owing to its necessary soft quality.



Small rivets for plates less than ⅜ inch thick may be riveted cold.

Strength of Riveted Joints to Plates.

Joint.	Riveting.	Cover Straps.	Pitch of Rivets. Diameters.	Strength of Joint to Plate.
Lap	Single	—	3*d*	·55
Butt	,,	1	3*d*	·55
,,	,,	2	3·25*d*	·57
Lap	Double	—	4·5*d*	·69
Butt	,,	1	4·5*d*	·69
,,	,,	2	5·5*d*	·72

Shearing resistance of iron or steel bars = ⅘ths their tenacity.

Rivet iron, shearing resistance, in lbs., per square inch 49,600

,, steel ,, ,, ,, ,, ,, 52,800

Values of Riveted Joints and Apparent Tenacity in Lbs. per Square Inch.

	Iron Plates.	Steel Plates.	Plates	Steel Plates.
Single riveted, drilled .	0·88	1·00	40,500	62,000
,, ,, punched	0·77	0·90	35,400	55,800
Double ,, drilled .	0·95	1·06	43,700	65,700
,, ,, punched	0·85	1·00	39,000	62,000
Treble ,, drilled .	—	1·08	45,000	67,000

Taking iron at 46,000 lbs. per square inch, and steel at 62,000 lbs.

Apparent Shearing Resistance of Rivets in Riveted Joints.

(Unwin.)

Iron rivets in punched holes	...	46,000	lbs. per square inch.
„ „ drilled „	...	43,000	„ „ „
Steel „ punched „	...	53,000	„ „ „
„ „ drilled „	...	49,000	„ „ „

Proportions of Rivets.—The height of a finished snap-head should be from $\frac{5}{8}$ths to $\frac{3}{4}$ths the diameter of shank. Allowance in length necessary for this = $1\frac{1}{4}$ times the diameter; in machine riveting add $\frac{1}{8}$th to $\frac{1}{4}$th more. Allowance for countersunk riveting = diameter of shank.

Strength of double riveted joint = 70 per cent.
„ „ single „ „ = 56 „ (Herring.)

Diameter of rivets in plates under $\frac{1}{2}$ inch thick should be twice the thickness of the plate.

Diameter of rivets in plates above $\frac{1}{2}$ inch thick should be $1\frac{1}{2}$ times the thickness of the plate.

Proportion of rivets to thickness of plate diameter = $1{\cdot}2\sqrt{\text{thickness}}$ of plate. (Unwin.)

Advantage of machine riveting is that the rivet is still hot when the head is finished.

Pressure on rivets by machine = about 25 tons.

Holes in iron should be punched, and afterward drilled out $\frac{1}{8}$th inch larger to prevent starring and damage to the surrounding metal, or drilled full size—in all girder work.

Rivets are not considered reliable in tension.

The best way with steel plates is to anneal them after punching if of $\frac{1}{2}$ inch to $\frac{3}{4}$ inch thickness, or the holes rimered after punching. Above this thickness all plates should be drilled.

The sharp square edge of a drilled hole is not likely to add any strength to the rivet, but rather the reverse.

If the plates through which a rivet is to be passed are more than 6 inches in all it is distinctly better to use bolts.

The old plan of driving a conical drift into the rivet holes is an objectionable method of ensuring agreement, as it injures the plates, but if the holes are rimered when in position the punched hole is improved in strength.

With very soft, ductile plates, it is believed that the injury done in punching is comparatively small if the punch be sharp. But with rigid plates the injury is apparently serious, the plates being weakened 15 per cent. to 30 per cent. (Unwin.)

To fill up the hole and form a head, from 1·3 to 1·7 times the diameter should be allowed in ordinary riveting, and about three-fourths the diameter if countersunk rivets are to be used.

Machine riveted work is slightly stronger than hand work.

Comparison of the Strength of Hemp and Steel Wire Ropes and Iron Chains.

Hemp Rope.			Steel Wire Rope.			Iron Chains.			
Circumference in Inches.	Weight per Fathom of 6 Feet in lbs.	Breaking Weight in Tons.	Circumference in Inches.	Weight per Fathom of 6 Feet in lbs.	Breaking Weight in Tons.	Diameter of Links in Inches.	Weight per Yard in lbs.	Breaking Strain in Tons.	Safe Load in Tons.
1	·26	1/5	1	3/4	1 3/4	1/4	2 1/4	—	1/2
1 1/2	·59	1/2	1 1/4	1	2 1/2	5/16	3 1/4	—	3/4
2	1·04	4/5	1 1/2	1 3/4	4	3/8	4 1/2	—	1
2 1/2	1·70	1 1/4	1 3/4	2	5 1/2	7/16	6	5·25	1 1/2
3	2·34	1 3/4	2	2 3/4	7	1/2	8	6·75	2
3 1/2	3·19	2 1/2	2 1/4	3 3/4	9	9/16	10	8·25	2 1/2
4	4·16	3 1/4	2 1/2	4 1/2	12	5/8	12	10·5	3
4 1/2	5·27	4	2 3/4	5 1/2	15	11/16	15	12·75	4
5	6·50	5	3	7	18	3/4	18	15	5
6	9·36	7 1/4	3 1/4	8	22	7/8	24	20·5	6 1/2
7	12·74	9 3/4	3 1/2	9	26	1	30	27	9
8	16·64	12 3/4	4	12	33	1 1/4	45	42	14
9	21·06	16 1/4	4 1/2	15	39	1 1/2	60	60·75	20

Strength and Weight of Hemp and Wire Ropes.

Tarred Italian Hemp. Hawser Laid.			Wire Rope. Hawser Laid.		
Circumference.	B. W.	Weight of One Fathom.	Iron B. W.	Steel B. W.	Weight of One Fathom.
Inches.	Tons.	Lbs.	Tons.	Tons.	Lbs.
½	·11	·15			
¾	·17	·221			
1	·30	·3	1·0	—	·94
1¼	·89	·43	1·35	—	1·5
1½	·94	·57	2·15	6·25	2·5
2	1·44	·93	4·0	11·2	3·5
2¼	—	—	5·0	—	4·5
2½	2·16	1·5	6·0	19·5	5·75
2¾	—	—	7·73	—	6·5
3	3·0	2·02	9·2	24·5	7·5
3¼	—	—	10·93	27·5	8·5
3½	4·2	2·9	12·5	45·0	10·75
4	5·6	3·8	15·75	54·5	13·25
4½	6·75	4·7	21·0	66·87	17·75
5	8·0	6·0	24·8	—	21·5
5½	11·0	7·1	30·0	83·0	26·5
6	14·25	8·5	36·2	100·0	31·5
6½	16·1	10·0	42·75	—	40·6
7	20·6	11·7	48·35	—	42·5
7½	21·75	13·3	55·0	—	46·75
8	25·75	15·0	59·0	—	51·75
8½	28·0	17·0	65·33	—	58·42
9	30·5	19·0			
9½	33·75	21·3			
10	36·0	23·6			
10½	38·9	26·0			
11	42·0	28·5			
11½	45·1	30·0			
12	48·5	34·0			

Round Ropes of Iron and Steel Wire. (R.A. Rule.)

Circumference in Inches.	Weight per Fathom in lbs.	Iron Wire.		Steel Wire.	
		Safe Load in Tons.	Breaking Load in Tons.	Safe Load in Tons.	Breaking Load in Tons.
1	1	0·33	1·0	0·83	2·5
1¼	1·5	0·58	1·75	1·25	3·75
1½	2	0·7	2·1	2·	6
2	4	1·25	3·75	3·33	10
2½	6	1·86	5·6	5·33	16
3	8	2·95	8·85	8·	24
3½	11·5	3·88	11·65	10·66	32
4	15·5	4·92	14·75	13·33	40
4½	19	6·55	19·65	17·	51
5	23	7·73	23·2	21·	63
5½	28	9 36	28·1	25·33	76
6	34	11·32	33·95	30·	90
6½	40	13·3	40·0	35·33	106
7	46	15·1	45·3	41	123

Steel wire ropes are usually made from ⅜ to ⅞ inch diameter, but can be had up to 3 inches diameter. When made with a hempen core they are more pliable, and for that reason more generally adopted for the purpose of transmitting power, when the wire rope takes the place of the leather straps which are more usually employed. One advantage of the use of rope gearing is the greater distance over which the power can be transmitted.

In testing steel cables, the result will only equal about 75 per cent. of the aggregate strength of the individual wires.

Safe working strain in tons of iron chains $= \dfrac{(\text{diameter in eighths of inches})^2}{10}$

Weight in lbs. per fathom of iron chain = (diameter in eighths of inches)²

Safe working strains in tons of rope $= \dfrac{\text{circumference}^2}{8}$

Weight in lbs. per fathom of tarred rope $= \dfrac{\text{circumference}^2}{4}$

White rope is about ⅐ lighter.

Safe Working Loads in Iron Chains.

Diameter.		Load. Tons.	Cwts.	Diameter.		Load. Tons.	Cwts.
⅜ inch	=	1	0	1 inch	=	7	0
½ ,,	=	1	14	1⅛ ,,	=	9	0
⅝ ,,	=	2	16	1¼ ,,	=	11	0
¾ ,,	=	4	0	1⅜ ,,	=	13	0
⅞ ,,	=	5	10				

Approximate Strength of Chains.

The square of the diameter in eighths = the weight of chain in lbs. per fathom.

The square of the diameter in eighths divided by 2 = breaking weight in tons. Safe load = $\frac{1}{3}$. (F. Rogers.)

Temperature of iron when welding.—1,500 to 1,600° F.

Strains in Ropes round Pulleys. (R. A. Tests.)

Two treble blocks used. Weight lifted = 59 cwt. 109 lbs.

Position where Strain is taken.	Strain.		Holding after Lowering.
	Raising.	Lowering.	
Free End.	15·37	5·91	6·62
1st return	13·28	7·10	7·84
2nd "	12 0	8·42	8·84
3rd "	10·67	9·42	9·60
4th "	9·7	10·56	10·56
5th "	8·7	12·28	11·77
6th "	6·105	13·56	12·0
Total, excluding free end . .	60·45	61·34	60·61

The free end has no share in supporting the weight.

When a weight is being raised, the strain on the running end is greatest, the sum of all the friction being at that end, and on the standing end least. When the weight is being lowered the reverse is the case.

Safe Working Loads on Hemp Ropes.

Circumference.	Load.	Circumference.	Load.
1 inch	= 1¾ cwt.	5½ inches	= 2 tons 14 cwt.
1½ "	= 4 "	6 "	= 3 " 4 "
2 "	= 7 "	6½ "	= 3 " 15½ "
2½ "	= 11 "	7 "	= 4 " 7½ "
3 "	= 16 "	7½ "	= 5 " 0 "
3½ "	= 21 "	8 "	= 5 " 14 "
4 "	= 28½ "	8½ "	= 6 " 7 "
4½ "	= 36 "	9 "	= 7 " 1 "
5 "	= 44½ "		

Testing Iron and Steel.—If a fracture of iron gives long, silky fibres of a leaden grey hue, the fibres cohering and twisting together before breaking, it may be considered a tough soft iron. A medium, even grain mixed with fibres is a good sign. A short blackish fibre indicates badly-refined iron. A very fine grain denotes a hard, steely iron, apt to be cold-short and hard to work with a file. Coarse grain, with brilliant crystallised fracture, and yellow or brown spots, denotes a brittle iron, cold-short, working easily when heated. This iron welds easily. Cracks on the edge of bars are a sign of hot-short iron. Good iron is readily heated soft under the hammer, and throws out but few sparks. Nitric acid will produce a black spot on steel; the darker the spot the harder the steel. Iron, on the contrary, remains bright if touched with nitric acid. Good steel in its soft state has a curved fracture and a uniform grey lustre; in its hard state, a dull, silvery, uniform white. Cracks, thread, or sparkling particles denote bad quality. Good steel will not bear a white heat without falling to pieces, and will crumble under the hammer at a bright red heat, while at a middling heat it may be drawn out under the hammer to a fine point. ("Journal of Gas Lighting.")

Contraction at point of fracture should be about 10 per cent. for plates, 15 per cent. for T and L iron, and 20 per cent. for round or square bars. (Kirkaldy.)

Iron or steel subjected to stresses above half their ultimate strength are permanently disabled.

Breaking strength equals 39 $(1 + C.^2)$ tons per square inch (C. = per cent. of carbon). (Bauschinger.)

In calculating the weight of metals up to 100° C., the temperature can be omitted as the difference is so small ($\frac{1}{11500}$). An iron rod one square inch in section exerts a force of one ton by contraction in decreasing in temperature 9° C.

Wrought iron increases $\frac{1}{10000}$ of its length for every ton per square inch of tension up to the limit of elasticity. (Unwin.)

The expansion due to a tension of one ton per square inch is produced by a rise in temperature of from 12° to 15° F., according to the quality of the iron. Wrought iron expands by heat $\frac{1}{16}$th more than cast iron, while tension causes twice as much stretch in cast iron as in wrought iron when within the elastic limit.

27° F. increase or decrease of temperature causes an expansion or contraction, equals a stress of one ton per square inch, if the metal be fixed at each end.

Strength of wrought iron and steel increases with a rise of temperature up to about 500° F., beyond which point the metals become plastic and will flow under almost any strain. (Professor R. C. Carpenter.)

The tensile strength of steel diminishes as the temperature increases from zero until a maximum 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 lbs. to 8,000 lbs. in steels of over 80,000 lbs. tensile strength. From this minimum the strength increases up to 400° to 650° F.; the maximum being reached earlier in the harder steels, and the increase amounting to from 10,000 lbs. to 20,000 lbs. per square inch above the minimum strength at from 200° to 300° F. (J. E. Howard.)

Effect of Temperature on the Strength of Steel and Wrought Iron.

Taking the initial temperature at 0° C., with an increase of temperature of 200° C., the strength of wrought iron is reduced 5 per cent.

At 300° Cent.	10 per cent.		At 600° Cent.	81 per cent.	
„ 400 „	27 „		„ 800 „	89 „	
„ 500 „	62 „		„ 1,000 „	96 „	

The ratios between cast iron, wrought iron, and steel are 13·34, 10, and 10·7 respectively.

Diminution of Strength of Copper by Heat. (Franklin Institute.)

Temperature above 32 degrees.	Diminution of Strength.	Temperature above 32 degrees.	Diminution of Strength.
Degrees.		Degrees.	
90	0·0175	660	0·3425
180	0·0540	769	0·4389
270	0·0926	812	0·4944
360	0·1513	880	0·5581
450	0·2046	984	0·6691
460	0·2133	1000	0·6741
513	0·2446	1200	0·8861
529	0·2558	1300	1·0000

Weight of Cast Iron Pipes.

In lbs. per lineal foot. The weight of two flanges or one socket may be reckoned weight of 1 foot :—

Bore.	Thickness of Metal.							
Inches.	3/8	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4
2	8·7	12·3	16·1					
3	12·4	17·1	22·2					
4	16·1	22·1	28·3					
5	19·8	26·9	34·4	42·3				
6	23·4	31·9	40·6	49·7				
7	27·1	36·8	46·7	56·8				
8	30·8	41·6	52·8	64·3				
9	34·4	46·0	58·9	71·7				
10	—	51·4	65·1	79·0	93·3			

Weight of Cast Iron Pipes—(*continued*).

In lbs. per lineal foot. The weight of two flanges or one socket may be reckoned weight of 1 foot :—

Bore.	Thickness of Metal.							
Inches.	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$
11	—	56·4	71·0	86·4	101·8			
12	—	—	77·3	93·7	110·4	127·4		
14	—	—	89·6	108·4	127·5	147·0		
15	—	—	—	115·7	136·1	156·8		
16	—	—	—	123·1	144·7	166·6		
18	—	—	—	137·9	161·8	186·2		
20	—	—	—	—	178·9	205·8	260·3	
22	—	—	—	—	—	225·4	284·8	
24	—	—	—	—	—	245·0	309·3	

All cast iron pipes above 6 inches diameter should be cast on end, spigot up, and about 4 or 6 inches cut off afterwards in a lathe to remove the spongy portion.

Rule for the Weight of Pipes. (Molesworth.)

D = outside diameter of pipes in inches.
d = inside " " "
w = weight of a lineal foot of pipe in lbs.

$$w = k\,(D^2 - d^2).$$

k = 2·45 for cast iron = 2·64 for wrought iron = 2·82 for brass = 3·03 for copper = 3·86 for lead.

Ordinary Stock Dimensions of Spigot and Faucet Connections.

The thickness of Metal is in proportion to Pipes.

SHORT BEND.

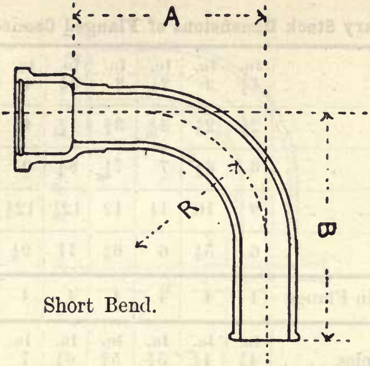
Diameter	¾ in.	1 in.	1¼ in.	1½ in.	1¾ in.	2 in.	2½ in.	3 in.	3½ in.	4 in.	4½ in.	5 in.	6 in.	7 in.	8 in.	9 in.	10 in.	12 in.
A	5	5¾	6½	8¼	8½	9	10½	12¼	11⅛	11¾	13¼	13⅜	14⅝	14½	15½	16¾	17¼	17⅝
B	9¼	9¼	9¼	10¾	11	12	14	14	14½	16	16 7/16	17⅛	18¼	19⅛	20⅝	22	22⅛	22¾
R	4	4	4	5¼	6	6½	6¼	8¼	7¼	9	9¾	10	11¾	11	12	13	13	13½

LONG BEND.

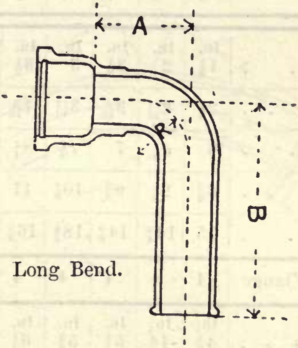
Diameter	¾ in.	1 in.	1¼ in.	1½ in.	1¾ in.	2 in.	2½ in.	3 in.	3½ in.	4 in.	4½ in.	5 in.	6 in.	7 in.	8 in.	9 in.	10 in.	12 in.
A	5	5¾	6½	4½	5	5⅜	5¾	6 3/16	6½	7	8	7½	8¼	9½	12⅝	12⅛	12¾	14¼
B	9¼	9¼	9¼	11⅛	11¼	11½	12½	13	14	14¾	16⅜	17⅝	21¼	19¾	19¾	21⅜	23⅜	25½
R	4	4	4	2¼	2½	2¾	3¼	3⅜	3¾	4	5	4½	4⅞	5¾	8 9/16	8¼	8⅞	10⅛

⅛TH BEND.

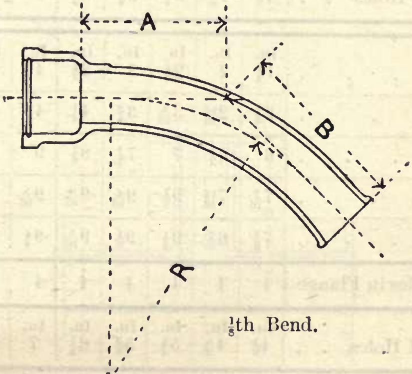
Diameter	¾ in.	1 in.	1¼ in.	1½ in.	1¾ in.	2 in.	2½ in.	3 in.	3½ in.	4 in.	4½ in.	5 in.	6 in.	7 in.	8 in.	9 in.	10 in.	12 in.
A	5¼	5½	6⅝	6¾	7	7¾	9⅛	9	9⅝	10¼	10½	10½	10½	10⅝	12½	13 5/16	15¼	14¼
B	7½	8	7¼	6¾	8½	9	9⅞	10¾	11	11	11½	11¾	12⅜	13⅜	14¼	21¾	19	16
R	11¾	12⅝	13⅜	9¾	12	15½	16¼	17¾	15¼	15⅜	16¼	17⅝	17⅝	16 5/16	20¾	24⅛	35½	24½



Short Bend.



Long Bend.



$\frac{1}{8}$th Bend.

Ordinary Stock Dimensions of Flanged Connections.

¼th Bend

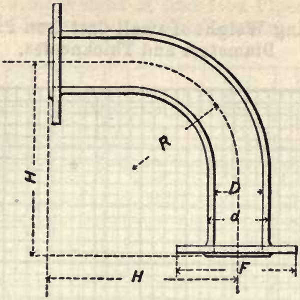
D	In. 1½	In. 2	In. 2½	In. 3	In. 3½	In. 4	In. 4½	In. 5	In. 6
d	2⅛	2⅝	3 3/16	3¾	4 5/16	4⅞	5 5/16	5⅞	6 15/16
F	6	6½	7	7½	8¼	9	10	10½	12
H	9	10	11	12	12⅛	12½	14	16¼	18⅜
R	6	5⅛	6	6⅝	11	9½	10⅜	10	11 11/16
No. of Holes in Flange	4	4	4	4	4	4	4	4	6
Centres of Holes	In. 4⅛	In. 4⅝	In. 5¼	In. 5¾	In. 6½	In. 7	In. 8	In. 8½	In. 10

⅛th Bend.

D	In. 1½	In. 2	In. 2½	In. 3	In. 3½	In. 4	In. 4½	In. 5	In. 6
d	2⅛	2 11/16	3 3/16	3 11/16	4 5/16	4⅞	5⅜	5⅞	6 15/16
F	6	6½	7	7½	8¼	9	10	10½	12
L	8⅜	9⅝	9⅜	10⅞	11	11 5/16	11⅜	12 7/16	12½
R	15	16¾	14⅝	18¼	16½	16¼	16¼	18⅛	13½
No. of Holes in Flange	4	4	4	4	4	4	4	4	6
Centres of Holes	In. 4⅛	In. 4⅝	In. 5¼	In. 5¾	In. 6½	In. 7	In. 8	In. 8½	In. 10

Tees.

D	In. 1½	In. 2	In. 2½	In. 3	In. 3½	In. 4	In. 4½	In. 5	In. 6
d	2⅛	2 11/16	3 3/16	3¾	4¼	4¾	5⅜	6	6 15/16
F	6	6½	7	7½	8¼	9	10	10½	12
A	7 7/16	7 15/16	9⅛	9 5/16	9 3/16	9 3/16	10	12 5/16	12½
B	7⅜	6⅞	9¼	9⅛	9 3/16	9¼	10	12½	12¾
No. of Holes in Flange	4	4	4	4	4	4	4	4	6
Centres of Holes	In. 4⅛	In. 4⅝	In. 5¼	In. 5¾	In. 6½	In. 7	In. 8	In. 8½	In. 10


R
H
D
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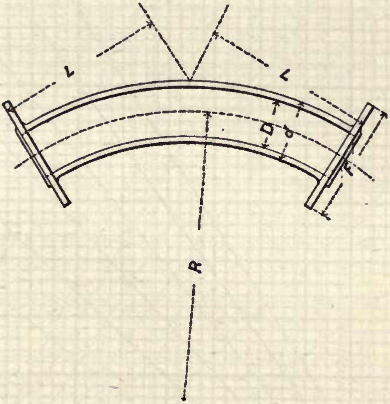
L
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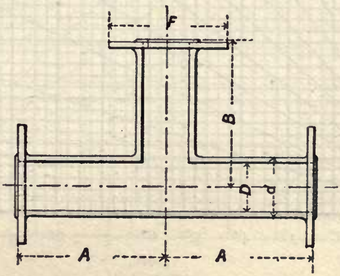

F
B
D
d
A
A

Diagram showing Weight of small Cast Iron Pipes of different Diameters and Thicknesses.

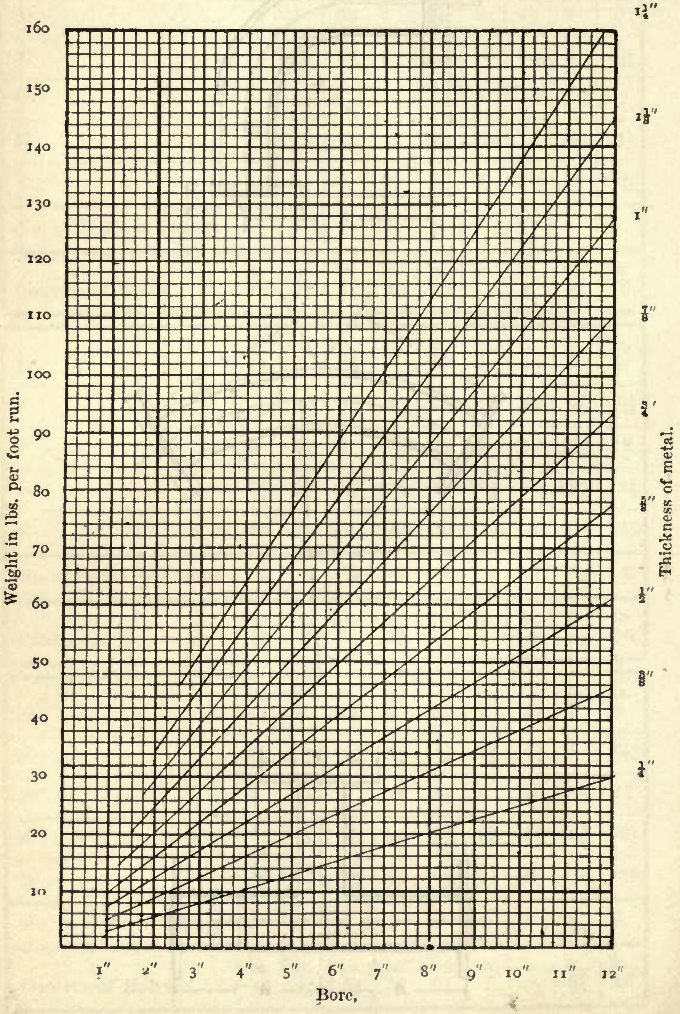
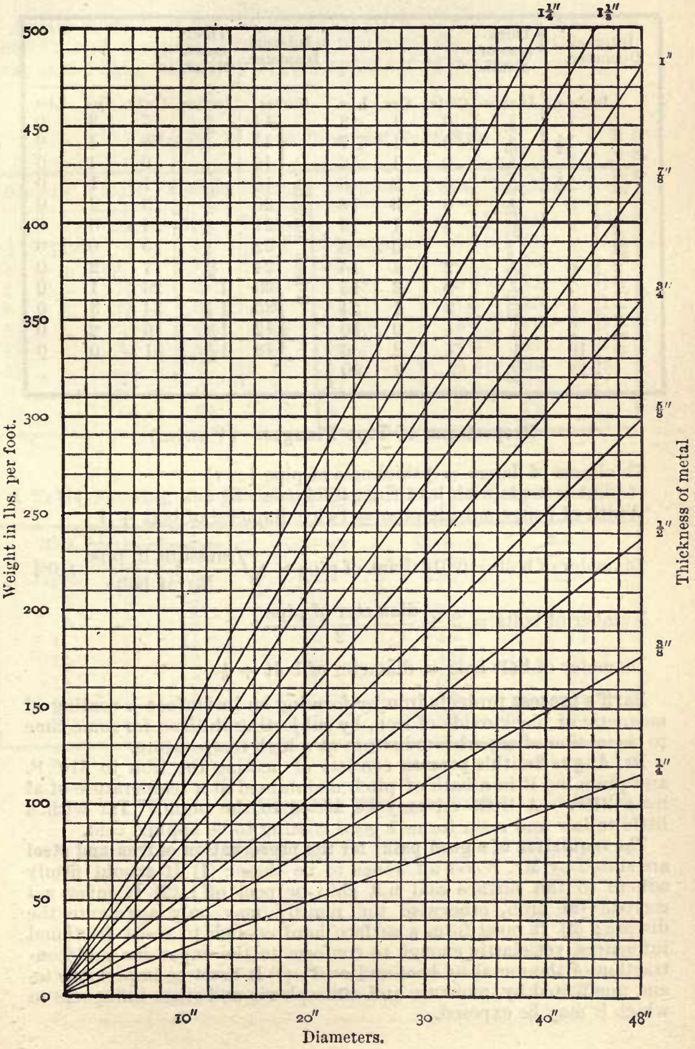


Diagram showing Weight of Cast Iron Pipes of different Diameters and Thicknesses.



Weight of Cast Iron Gas Pipes.

	Internal Diameter.	Thickness of Metal.					Internal Diameter.	Thickness of Metal.			
	Inches.	Inches.	Cwts.	Qrs.	Lbs.		Inches.	Inches.	Cwts.	Qrs.	Lbs.
6 feet lengths.	1	$\frac{5}{16}$	0	1	3	9 feet lengths.	14	$\frac{9}{16}$	7	3	0
6 feet lengths.	$1\frac{1}{2}$	$\frac{5}{16}$	0	1	7	9 feet lengths.	15	$\frac{5}{8}$	8	1	0
6 feet lengths.	2	$\frac{5}{16}$	0	1	16	9 feet lengths.	16	$\frac{5}{8}$	9	1	0
6 feet lengths.	$2\frac{1}{2}$	$\frac{5}{16}$	0	2	8	9 feet lengths.	18	$\frac{11}{16}$	11	1	0
9 feet lengths.	3	$\frac{5}{16}$	0	3	18	9 feet lengths.	20	$\frac{3}{4}$	13	2	0
9 feet lengths.	4	$\frac{11}{32}$	1	1	13	9 feet lengths.	21	$\frac{3}{4}$	14	0	0
9 feet lengths.	5	$\frac{3}{8}$	1	3	8	9 feet lengths.	22	$\frac{3}{4}$	15	0	0
9 feet lengths.	6	$\frac{7}{16}$	2	1	15	9 feet lengths.	24	$\frac{13}{16}$	17	2	0
9 feet lengths.	7	$\frac{7}{16}$	2	3	15	9 feet lengths.	30	1	26	1	0
9 feet lengths.	8	$\frac{13}{32}$	3	1	24	9 feet lengths.	36	$1\frac{1}{8}$	34	3	0
9 feet lengths.	9	$\frac{1}{2}$	4	0	10	9 feet lengths.	42	$1\frac{3}{16}$	46	2	0
9 feet lengths.	10	$\frac{1}{2}$	4	2	6	9 feet lengths.	48	$1\frac{3}{16}$	51	0	0
9 feet lengths.	12	$\frac{9}{16}$	5	2	20						

Proportions of Pipe Flanges. (Unwin.)

Thickness of flange = $\frac{5}{4}$ thickness of pipe (= t)
If joint is made with lead ring, thickness = $\frac{3}{2}\,t$
Width of flange outside pipe = twice diameter of bolt + 1

$$\text{Diameter of bolts} = 0{\cdot}016 \text{ diam. of pipe} \times \sqrt{\frac{\text{pressure in pipe}}{\text{No. of bolts}}} + 0{\cdot}4$$

$$\text{Number of bolts} = 2 + \frac{\text{diameter of pipe}}{2}$$

Diameter of bolt hole = diameter of bolt + $\frac{1}{8}$

Barff's process protects iron by forming on its surface a coating of magnetic or black oxide of iron, by subjecting the iron for some time to the action of superheated steam at a high temperature.

Dr. Angus Smith's process consists of heating the iron to 310° F. and plunging it in a bath of pitch maintained at a temperature of at least 210°. A little oil may be added to the pitch. Tar with a little tallow and resin forms a good coating to be applied cold.

The requisites of a good paint for the preservation of iron and steel are stated by Mr. Woodruff Jones to be these: (1) It should firmly adhere to the surface and not chip or peel off; (2) It must not corrode the iron, otherwise the remedy may only aggravate the disease; (3) It must form a surface hard enough to resist frictional influences, yet elastic enough to conform to the expansion and contraction of the metal by heat and cold; (4) It must be impervious to, and unaffected by, moisture and atmospheric and other influences to which it may be exposed.

A Coating for Cast Iron Pipes.

A bath made up of gas tar, Burgundy pitch, oil and resin, is kept at 400° F., and the pipes are laid in this until they are of the same heat as the bath, when they are set up on end to drain off.

Weight of Lead Pipe per Foot Run.

Diameter.	Light.	Middling.	Strong.	Diameter	Light.	Middling.	Strong
	Lbs.	Lbs.	Lbs.		Lbs.	Lbs.	Lbs.
1/4 in. pipe	2/3	1	1 1/3	2 1/2 in. pipe	6	8 2/5	11 1/5
1/2 " "	1	1 1/3	2	2 3/4 " "	—	10	
3/4 " "	1 3/5	2 1/7	3	3 " "	10	12	13
1 " "	2 2/5	3 1/2	4	3 1/2 " "	11 1/5	13	15
1 1/4 " "	2 1/3	4	5 1/3	4 " "	14	16	17
1 1/2 " "	3	4	5	4 1/2 " "	14	17	22
1 3/4 " "	5	7	8	5 " "	15	22	25
2 " "	5	6	8	5 1/2 " "	—	22	
2 1/4 " "	—	8 1/3	11	6 " "	—	22	

A Table Showing the Weight of Lead Pipes per Length in Lbs.

Bore.	Length.	Common.	Middling.	Strong.
Inches.	Feet.	Lbs.	Lbs.	Lbs.
1/2	15	16		
3/4	15	24	27	30
1	15	30	40	43
1 1/4	12	36	44	53
1 1/2	12	48	56	67
2	10	56	70	83
2 1/2	10	70	89	100

Weight of Composite Pipe per Yard.

	Lbs.	Ozs.
1/4 inch inside diameter	0	13
5/16 " " "	1	0
3/8 " " "	1	5
7/16 " " "	1	10
1/2 " " "	2	2
5/8 " " "	3	4
3/4 " " "	4	4
7/8 " " "	4	12
1 " " "	5	8

Weight of Block Tin Tubes per Yard.

	Lbs. Ozs.		Lbs. Ozs.
¼ inch inside diameter	0 8	⅝ inch inside diameter	1 7
5/16 " " "	0 9½	¾ " " "	1 14
⅜ " " "	0 11	⅞ " " "	2 6
7/16 " " "	0 14	1 " " "	2 15
½ " " "	1 1		

Weight of Copper Pipes.

	Per foot.		Per foot.
2 inches diameter	1½ lbs.	4 inches diameter	3 lbs.
2½ " "	1¾ "	4½ " "	3½ "
3 " "	2¼ "	5 " "	4½ "
3½ " "	2½ "		

Soldering Tin.

Flux may be resin and sweet oil, spirits of salts (hydrochloric acid), killed with zinc cuttings, or Baker's mixture.

Solder.—Two parts tin, 1 lead, melts at 340° F.

Blow Pipe Solder.—1½ parts tin, 1 lead.

Flux.—Dissolve zinc in hydrochloric acid until effervescence ceases; filter the liquid, add ⅓ spirits of sal-ammoniac, and dilute with rain water.

Flux.—One part lactic acid, 1 part glycerine, 8 parts water. These two fluxes will not rust iron or steel.

Weight of Black Sheet Iron and Rolled Brass.

Wire Gauge.	Per Sheet, 72 × 24 in.		Per Sheet, 72 × 30 in.		Per Sheet, 72 × 36 in.		Per sq. foot.	Sheet Brass, per sq. foot.
Nos.	Qrs.	Lbs.	Qrs.	Lbs.	Qrs.	Lbs.	Lbs.	Lbs.
10	2	14	3	4	3	21	5⅝	5¾
11	2	4	2	19	3	6	5	5¼
12	1	25	2	12	2	25	4½	4¾
13	1	20	2	4	2	16	4	4¼
14	1	13	1	23	2	5	3⅜	3¾
15	1	8	1	17	1	26	3	3¼
16	1	2	1	10	1	17	2½	2¾
17	0	27	1	6	1	13	2¼	2½
18	0	24	1	2	1	8	2	2⅛
19	0	21	0	26	1	3	1¾	1¾
20	0	18	0	23	0	27	1½	1⅝
21	0	16	0	21	0	25	1⅜	1⅜
22	0	15	0	19	0	23	1¼	1¼
23	0	14	0	17	0	20	1⅛	1
24	0	12	0	15	0	18	1	15 oz.
25	0	11	0	13	0	16	14 oz.	14 oz.
26	0	10	0	12	0	14	13 oz.	12 oz.

Whitworth's Screw Threads.

Diar. of Screw.	Diar. at bottom of Thread.	Area at bottom of Thread.	No. of Threads per In.	Width of Nuts across Flats.		Depth of Bolt Head.	Diar. of Bolt Head.
Inches.	Inches.	Inches.		Inches.	Inches.	Inches.	Inches
$\frac{1}{8}$	·0929	·006	40	·338	$\frac{5}{16}+\frac{1}{64}$ F	$\frac{1}{16}+\frac{3}{64}$	$\frac{1}{4}$
$\frac{3}{16}$	·1341	·0141	24	·448	$\frac{7}{16}+\frac{1}{64}$ B	$\frac{1}{8}+\frac{1}{32}$	$\frac{5}{16}$
$\frac{1}{4}$	·1859	·0271	20	·525	$\frac{1}{2}+\frac{1}{64}$ F	$\frac{3}{16}+\frac{1}{32}$	$\frac{3}{8}$
$\frac{5}{16}$	·2413	·0457	18	·6014	$\frac{9}{16}+\frac{1}{32}$ F	$\frac{1}{4}+\frac{1}{64}$	$\frac{1}{2}$
$\frac{3}{8}$	·2949	·0883	16	·7094	$\frac{11}{16}+\frac{1}{64}$ F	$\frac{5}{16}+\frac{1}{64}$	$\frac{5}{8}$
$\frac{7}{16}$	·346	·0940	14	·8204	$\frac{13}{16}+\frac{1}{64}$ B	$\frac{3}{8}$ F	$\frac{11}{16}$
$\frac{1}{2}$	·3932	·1214	12	·9191	$\frac{7}{8}+\frac{1}{32}$ B	$\frac{7}{16}$	$\frac{13}{16}$
$\frac{9}{16}$	·4557	·1626	12	1·011	$1+\frac{1}{64}$ B	$\frac{7}{16}+\frac{3}{64}$	$\frac{7}{8}$
$\frac{5}{8}$	·5085	·2027	11	1·101	$1\frac{3}{32}$ F	$\frac{1}{2}+\frac{3}{64}$	1
$\frac{11}{16}$	·571	·2565	11	1·2011	$1\frac{3}{16}+\frac{1}{64}$ B	$\frac{9}{16}+\frac{1}{32}$	$1\frac{1}{8}$
$\frac{3}{4}$	·6219	·3037	10	1·3012	$1\frac{1}{4}+\frac{3}{64}$ F	$\frac{5}{8}+\frac{1}{32}$	$1\frac{3}{16}$
$\frac{13}{16}$	·6844	·3687	10	1·39	$1\frac{3}{8}+\frac{1}{64}$ B	$\frac{11}{16}+\frac{1}{64}$	$1\frac{1}{4}$
$\frac{7}{8}$	·7327	·4026	9	1·4788	$1\frac{7}{16}+\frac{3}{64}$ B	$\frac{3}{4}+\frac{1}{64}$	$1\frac{5}{16}$
$\frac{15}{16}$	·7952	·4966	9	1·5745	$1\frac{9}{16}+\frac{1}{64}$ B	$\frac{13}{16}$ F	$1\frac{7}{16}$
1	·8399	·5540	8	1·6701	$1\frac{5}{8}+\frac{3}{64}$ B	$\frac{7}{8}$	$1\frac{5}{8}$
$1\frac{1}{8}$	·942	·6969	7	1·8605	$1\frac{13}{16}+\frac{3}{64}$ F	$\frac{15}{16}+\frac{3}{64}$	$1\frac{3}{4}$
$1\frac{1}{4}$	1·067	·8941	7	2·0483	$2\frac{3}{64}$ F	$1\frac{3}{32}$	$2\frac{1}{8}$
$1\frac{3}{8}$	1·1615	1·0592	6	2·2146	$2\frac{3}{16}+\frac{1}{32}$ B	$1\frac{3}{16}+\frac{1}{64}$	$2\frac{1}{4}$
$1\frac{1}{2}$	1·2865	1·2999	6	2·4134	$2\frac{3}{8}+\frac{1}{32}$ F	$1\frac{5}{16}$	$2\frac{3}{8}$
$1\frac{5}{8}$	1·3688	1·4715	5	2·5763	$2\frac{9}{16}+\frac{1}{64}$ B	$1\frac{3}{8}+\frac{3}{64}$	$2\frac{1}{2}$
$1\frac{3}{4}$	1·49	1·7525	5	2·7578	$2\frac{3}{4}$ F	$1\frac{1}{2}+\frac{1}{32}$	$2\frac{11}{16}$
$1\frac{7}{8}$	1·5904	1·9865	$4\frac{1}{2}$	3·0183	$3\frac{1}{16}$ F	$1\frac{5}{8}+\frac{1}{64}$	$2\frac{7}{8}$
2	1·7154	2·311	$4\frac{1}{2}$	3·1491	$3\frac{1}{8}+\frac{1}{32}$ B	$1\frac{3}{4}$	$3\frac{1}{16}$
$2\frac{1}{8}$	1·8404	2·6602	$4\frac{1}{2}$	3·337	$3\frac{5}{16}+\frac{1}{32}$ B	$1\frac{13}{16}+\frac{3}{64}$	$3\frac{1}{4}$
$2\frac{1}{4}$	1·9298	2·9249	4	3·546	$3\frac{1}{2}+\frac{3}{64}$ B	$1\frac{15}{16}+\frac{1}{32}$	$3\frac{3}{8}$
$2\frac{3}{8}$	2·0548	3·3161	4	3·75	$3\frac{3}{4}$	$2\frac{1}{16}+\frac{1}{64}$	$3\frac{9}{16}$
$2\frac{1}{2}$	2·1798	3·7318	4	3·894	$3\frac{7}{8}+\frac{1}{64}$ F	$2\frac{3}{16}$	$3\frac{3}{4}$
$2\frac{5}{8}$	2·3048	4·1721	4	4·049	$4\frac{3}{64}$ F	$2\frac{1}{4}+\frac{3}{64}$	$3\frac{7}{8}$
$2\frac{3}{4}$	2·384	4·4637	$3\frac{1}{2}$	4·181	$4\frac{3}{16}$ B	$2\frac{3}{8}+\frac{1}{32}$	4
$2\frac{7}{8}$	2·509	4·9441	$3\frac{1}{2}$	4·3456	$4\frac{5}{16}+\frac{1}{32}$ F	$2\frac{1}{2}+\frac{1}{64}$	$4\frac{3}{16}$
3	2·634	5·4490	$3\frac{1}{2}$	4·531	$4\frac{1}{2}+\frac{1}{32}$ B	$2\frac{5}{8}$	$4\frac{3}{8}$
$3\frac{1}{4}$	2·884	6·5325	$3\frac{1}{4}$				
$3\frac{1}{2}$	3·106	7·5769	$3\frac{1}{4}$				
$3\frac{3}{4}$	3·356	8·8457	3				
4	3·574	10·032	3				
$4\frac{1}{4}$	3·824	11·481	$2\frac{7}{8}$				
$4\frac{1}{2}$	4·055	12·914	$2\frac{7}{8}$				
$4\frac{3}{4}$	4·305	14·556	$2\frac{3}{4}$				
5	4·534	16·145	$2\frac{3}{4}$				
$5\frac{1}{4}$	4·764	17·826	$2\frac{5}{8}$				
$5\frac{1}{2}$	5·014	19·745	$2\frac{5}{8}$				
$5\frac{3}{4}$	5·238	21·548	$2\frac{1}{2}$				
6	5·488	23·654	$2\frac{1}{2}$				

Wrought Iron Bolts (Whitworth Thread).

Diar. of Screw.	Safe Working Load, allowing a Stress 4,000 to 10,000 lbs.						
Inches.	4,000.	5,000.	6,000.	7,000.	8,000.	9,000.	10,000.
1/8	26	33	40	46	53	60	67
3/16	56	70	84	98	112	126	141
1/4	108	135	162	189	216	243	271
5/16	182	228	279	319	365	411	457
3/8	253	347	409	478	546	614	683
7/16	376	470	564	658	752	846	940
1/2	485	607	728	849	971	1,092	1,214
9/16	650	813	975	1,138	1,300	1,463	1,626
5/8	818	1,013	1,216	1,418	1,621	1,824	2,027
11/16	1,026	1,282	1,539	1,795	2,052	2,308	2,565
3/4	1,214	1,518	1,822	2,125	2,429	2,733	3,037
13/16	1,474	1,843	2,212	2,580	2,949	3,318	3,687
7/8	1,660	2,013	2,415	2,818	3,220	3,623	4,026
15/16	1,986	2,483	2,979	3,476	3,972	4,469	4,966
1	2,216	2,770	3,324	3,878	4,432	4,986	5,540
1 1/8	2,787	3,484	4,181	4,878	5,575	6,271	6,969
1 1/4	3,576	4,470	5,364	6,258	7,152	8,046	8,941
1 3/8	4,236	5,296	6,355	7,414	8,473	9,532	10,592
1 1/2	5,199	6,499	7,799	9,099	10,399	11,699	12,999
1 5/8	5,886	7,357	8,829	10,300	11,772	13,243	14,715
1 3/4	7,010	8,762	10,515	12,267	14,020	15,772	17,525
1 7/8	7,946	9,932	11,919	13,905	15,892	17,878	19,865
2	9,244	11,555	13,866	16,177	18,488	20,799	23,110
2 1/8	10,640	13,301	15,961	18,621	21,281	23,941	26,602
2 1/4	11,699	14,624	17,549	20,474	23,399	26,234	29,249
2 3/8	13,264	16,580	19,896	23,212	26,528	29,844	33,161
2 1/2	14,927	18,659	22,390	26,122	29,854	33,586	37,318
2 5/8	16,688	20,860	25,032	29,204	33,376	37,548	41,721
2 3/4	17,854	22,318	26,782	31,245	35,709	40,173	44,637
2 7/8	19,776	24,720	29,664	34,608	39,552	44,496	49,441
3	21,796	27,245	32,694	38,143	43,592	49,041	54,490
3 1/4	26,130	32,662	39,195	45,727	52,260	58,792	65,325
3 1/2	30,307	37,884	45,461	53,038	60,615	68,192	75,769
3 3/4	35,382	44,228	53,074	61,918	70,765	79,611	88,457
4	40,128	50,160	60,193	70,224	80,256	90,288	100,320
4 1/4	45,924	57,405	68,886	80,367	91,848	103,329	114,810
4 1/2	51,656	64,570	77,484	90,398	103,312	116,226	129,140
4 3/4	58,224	72,780	87,336	101,892	116,448	131,004	145,560
5	64,580	80,725	96,870	113,015	123,160	145,305	161,450
5 1/4	71,304	89,130	106,956	124,782	142,608	160,434	178,260
5 1/2	78,980	98,725	118,470	138,215	157,960	177,705	197,450
5 3/4	86,192	107,740	129,288	150,836	172,384	193,932	215,480
6	94,616	118,270	141,924	165,578	189,232	212,886	236,540

Whitworth's Standard Screw Threads.

Outside Diameter in Inches.	Diameter at bottom of Thread.	Nearest Size for Drilling	Number of Threads per Inch.	Outside Diameter in Inches.	Diameter at bottom of Thread.	Nearest Size for Drilling	Number of Threads per Inch.
$\frac{1}{8}$	·093	$\frac{3}{32}$	40	$\frac{9}{16}$	·455	$\frac{15}{32}$	12
$\frac{5}{32}$	·112	$\frac{1}{8}$	32	$\frac{5}{8}$	·508	$\frac{33}{64}$	11
$\frac{3}{16}$	·134	$\frac{9}{64}$	24	$\frac{11}{16}$	·571	$\frac{37}{64}$	11
$\frac{7}{32}$	·165	$\frac{11}{64}$	24	$\frac{3}{4}$	·622	$\frac{5}{8}$	10
$\frac{1}{4}$	·186	$\frac{3}{16}$	20	$\frac{13}{16}$	·684	$\frac{11}{16}$	10
$\frac{5}{16}$	·241	$\frac{1}{4}$	18	$\frac{7}{8}$	·732	$\frac{47}{64}$	9
$\frac{3}{8}$	·295	$\frac{19}{64}$	16	$\frac{15}{16}$	·795	$\frac{51}{64}$	9
$\frac{7}{16}$	·346	$\frac{23}{64}$	14	1	·841	$\frac{27}{32}$	8
$\frac{1}{2}$	·393	$\frac{13}{32}$	12				

Hoop Iron.

B. W. Gauge.	Width in Inches.	Weight per Foot Run.	Weight per 100 Foot Run.	B. W. Gauge.	Width in Inches.	Weight per Foot Run.	Weight per 100 Foot Run.
		Lbs.	Lbs.			Lbs.	Lbs.
12	$2\frac{1}{2}$	·91	91·78	16	$1\frac{1}{4}$	·27	26·52
13	$2\frac{1}{4}$	·71	71·23	17	$1\frac{1}{8}$	·21	20·84
13	2	·63	63·31	18	1	·16	16·16
14	$1\frac{3}{4}$	·48	47·15	19	$\frac{7}{8}$	·12	12·37
15	$1\frac{1}{2}$	·36	36·37	20	$\frac{3}{4}$	·087	8·84
15	$1\frac{3}{8}$	·33	33·34				

Rust Joint Cement for Cast Iron Tanks and Cisterns.

Cast iron borings . . . 5 lbs.
Powdered sal-ammoniac . 1 oz.
Flour of sulphur . . 2 ozs.
} mix with water.

Another and perhaps better cement is—

Cast iron borings . . . 6 lbs.
Powdered sal-ammoniac . 1 oz.
Flour of sulphur . . . $\frac{1}{2}$ oz
} mix with water.

Working Safe Stresses in lbs. per Square Inch.

	Tension.	Compression.	Shearing.
Cast iron . . .	3,600	10,400	2,700
Wrought iron bars . .	10,400	10,400	7,800
" " plates .	10,000	10,000	7,800
Soft steel, untempered .	17,700	17,700	13,000
Cast " " .	52,000	52,000	38,500
Copper . . .	3,600	3,120	2,300
Brass	3,600	—	2,700
Gun metal . . .	3,120	—	2,400
Phosphor bronze . .	9,870	—	7,380

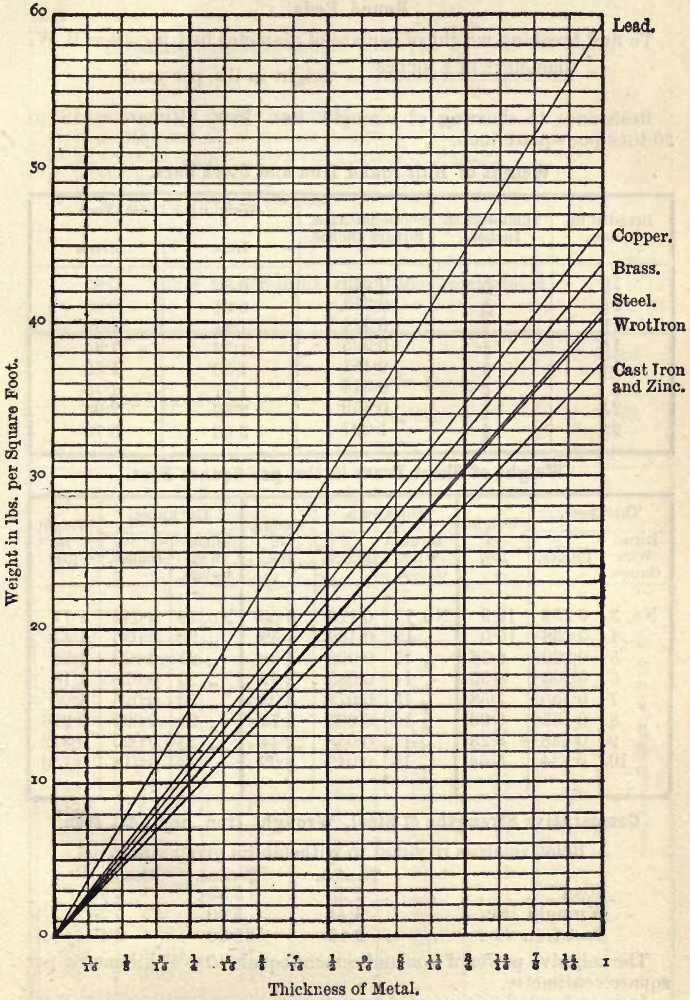
Comparative Weights.

	Cast Iron.	Bar Iron.	Steel.	Brass.	Copper.	Gun Metal.	Lead.	Yellow Pine.
Cast iron =	1	·953	·925	·867	·83	·8288	·64	16·0
Bar iron =	1.048	1	·973	·909	·866	·8687	·67	16·8
Steel =	1·076	1·026	1	·933	·89	·8917	·688	17·0
Brass =	1·153	1·1	1·07	1	·95	·9558	·737	18·8
Copper =	1·213	1·151	1·123	1·05	1	1·0004	·774	19·3
Gun metal =	1·208	1·150	1·121	1·046	·99	1	·773	19·0
Lead =	1·564	1·5	1·453	1·357	1·29	1·292	1	24·0
Yellow pine =	—	—	—	—	—	—	—	1

Weight of a Foot Superficial of Parts of an Inch in Thickness.

	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	Inch.
Steel . .	2·05	5·1	10·2	15·3	20·4	25·5	30·6	35·7	40·8
W. iron .	2·50	5·00	10·00	15·00	20·00	25·00	30·00	35·00	40·00
C. iron .	2·35	4·69	9·37	14·06	18·75	23·44	28·12	32·81	37·50
Brass . .	2·84	5·68	11·35	17·03	22·70	28·38	34·05	39·72	45·40
Copper .	2·89	5·78	11·56	17·34	23·12	28·90	34·68	40·46	46·24
Lead, cast	3·70	7·39	14·78	22·17	29·56	36·95	44·34	51·73	59·12

Weight per Square Foot of Various Thicknesses of Different Metals.



Handy rule for weight of Wrought Iron Plate:—

1 superficial foot of $\frac{1}{4}$ inch plate weighs about 10 lbs.

Round Rods.

To find breaking weight of, square of diameter in $\frac{1}{4}$ inches = B. W.

$$\frac{\text{diameter}^2 \text{ in } \frac{1}{4} \text{ inches}}{2} = \text{weight in lbs. per yard.}$$

Resistance to shearing of wrought iron bars, ultimate = 18 to 20 tons per square inch.

Weight of Half-round Iron and Steel Bars.

Breadth in Inches.	Thickness in Inches.	Sectional Area, Square Inches.	Weight per Lineal Foot.	
			Iron.	Steel.
$1\frac{1}{8}$	$\frac{5}{16}$	0·249	0·83	0·85
$1\frac{1}{4}$	$\frac{5}{16}$	0·273	0·91	0·93
$1\frac{3}{8}$	$\frac{3}{8}$	0·364	1·21	1·24
$1\frac{1}{2}$	$\frac{3}{8}$	0·395	1·32	1·34
$1\frac{3}{4}$	$\frac{3}{8}$	0·451	1·50	1·53
2	$\frac{3}{8}$	0·514	1·71	1·75
$2\frac{1}{2}$	$\frac{1}{2}$	0·859	2·86	2·92
$2\frac{1}{2}$	$\frac{5}{8}$	1·097	3·66	3·73

Weight of Sheet Brass in lbs. per Square Foot.

Thickness.		Weight in lbs.	Thickness.		Weight in lbs.	Thickness.		Weight in lbs.
Birm. Wire Gauge.	Inches.		Birm. Wire Gauge.	Inches.		Birm. Wire Gauge.	Inches.	
No. 3	0·259	10·9	No. 11	0·120	5·05	No. 19	0·042	1·77
„ 4	0·238	10·0	„ 12	0·109	4·59	„ 20	0·035	1·47
„ 5	0·220	9·26	„ 13	0·095	4·00	„ 21	0·032	1·35
„ 6	0·203	8·55	„ 14	0·083	3·49	„ 22	0·028	1·18
„ 7	0·180	7·58	„ 15	0·072	3·03	„ 23	0·025	1·05
„ 8	0·165	6·96	„ 16	0·065	2·74	„ 24	0·022	0·926
„ 9	0·148	6·23	„ 17	0·058	2·44	„ 25	0·020	0·842
„ 10	0·134	5·64	„ 18	0·049	2·06	„ 26	0·018	0·758

Comparative Strengths of Steel, Wrought Iron, and Cast Iron.

Relative areas required to withstand a given strain.

	Tension.	Torsion.	Compression.
Steel	2·23	3·33	1·43
Wrought iron	4·44	5·00	5·23
Cast iron	9·45	36·00	2·45

The cohesive power of iron and cement equals 40 to 47 kilometres per square centimetre.

Iron embedded in cement does not rust.

Strength of Double-Headed Rails (Steel).

$$\text{Breaking weight at centre} = \frac{30\left(4a\,\frac{d\,2''}{d} + 1{\cdot}167\,t\,d^2\right)}{L}$$

a = area of one flange in inches.
d = depth over all of rail in inches.
d'' = vertical distance apart of centres of flanges.
t = thickness of web.
L = length of span in inches.

Table of Wrought Iron Pipe Thicknesses.

Gas and Water Piping.			Hydraulic Piping—Wrought Iron.			To Stand 700 lbs. Hydraulic Piping—Cast Iron.	
Internal Diameter of Pipe.	External Diameter of Pipe.	Number of Threads per Inch. Whitworth Threads.	Internal Diameter to stand 4,000 lbs. per Square Inch.	External Diameter of Pipe.	Number of Threads per Inch. Whitworth Threads.	Internal Diameter of Pipe.	Thickness of Pipe.
Inches.	Inches.		Inches.	Inches.		Inches.	Inches.
$\frac{3}{8}$	0·656	19	$\frac{3}{8}$	$\frac{3}{4}$	14	$1\frac{1}{2}$	$\frac{7}{16}$
$\frac{1}{2}$	0·825	14	$\frac{1}{2}$	1	14	$1\frac{3}{4}$	$\frac{7}{16}$
$\frac{3}{4}$	1·041	14	$\frac{5}{8}$	$1\frac{1}{8}$	14	2	$\frac{1}{2}$
1	1·309	11	$\frac{3}{4}$	$1\frac{1}{4}$	11	$2\frac{1}{4}$	$\frac{9}{16}$
$1\frac{1}{8}$	1·492	11	$\frac{7}{8}$	$1\frac{3}{8}$	11	$2\frac{1}{2}$	$\frac{9}{16}$
$1\frac{1}{4}$	1·650	11	1	$1\frac{1}{2}$	11	3	$\frac{5}{8}$
$1\frac{3}{8}$	1·745	11	$1\frac{1}{8}$	$1\frac{5}{8}$	11	$3\frac{1}{4}$	$\frac{5}{8}$
$1\frac{1}{2}$	1·882	11	$1\frac{1}{4}$	$1\frac{3}{4}$	11	4	$\frac{3}{4}$
$1\frac{5}{8}$	2·021	11	$1\frac{3}{8}$	$1\frac{7}{8}$	11	5	$\frac{7}{8}$
$1\frac{3}{4}$	2·158	11	$1\frac{1}{2}$	2	11	6	1
1^7	2·245	11	$1\frac{5}{8}$	$2\frac{1}{8}$	11		
2	2·347	11	$1\frac{3}{4}$	$2\frac{1}{4}$	11		
$2\frac{1}{8}$	2·467	11	$1\frac{7}{8}$	$2\frac{3}{8}$	11		
$2\frac{1}{4}$	2·587	11	2	$2\frac{1}{2}$	11		
$2\frac{3}{8}$	2·794	11					
$2\frac{1}{2}$	3·001	11					

NOTES ON WROUGHT IRON GIRDERS.

Depth.—The depth of girders in ordinary cases should be from $\frac{1}{10}$ to $\frac{1}{16}$ of span, if intended to serve as a parapet may be increased to $\frac{1}{8}$, in flooring $\frac{1}{24}$.

Weight.—The weight in tons may be found approximately by multiplying the load to be carried by the total length of girder and dividing by 400.

Strain.—The safe strain when not given may be assumed at 5 tons in tension or 4 tons in compression per square inch.

Bearing Surface.—The bearing surface in square feet may be found by dividing the weight on abutment by one of the following constants according to the material of abutment, viz.:—Granite 25, limestone 25, sandstone 15, firebrick 10, strong red brick 7, weak red brick $3\frac{1}{2}$.

Camber.—Half an inch rise per 10 feet length of girder.

Area of Flanges.—Section of top or bottom flange to girder at intermediate points from centre.

1. Distributed load.

$$\frac{W \times \frac{L}{2}}{D \times 4 \times 5} = \text{Section area of top or bottom flange in centre in square inches.}$$

2. d = distance of point from nearest support.

$$\frac{W \times d}{D \times 4 \times 5} = \text{Sectional area of flange at any other point in square inches.}$$

3. x = Sectional area at any point.

$$\frac{x \times D \times 4 \times 5}{W} = \text{distance of such section from nearest support.}$$

Example.—A girder 20 feet long carries a distributed load of 40 tons, and is 2 feet deep,

By (1) $\frac{40 \times 10}{2 \times 4 \times 5} = 10$ inches sectional area.

By (2) Sectional area required 3 feet from end.

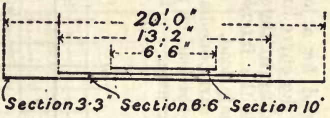
$$\frac{40 \times 3}{2 \times 4 \times 5} = 3 \text{ inches sectional area.}$$

By (3) Suppose flange to be made of 3 plates, each 3·3 inches area, centre section will be 10 inches; section outside first plate will be 6·6 inches; section outside second plate will be 3·3 inches.

$$\frac{10 \times 2 \times 4 \times 5}{40} = 10 \text{ feet distance of section of 10 inches from support.}$$

$$\frac{6{\cdot}6 \times 2 \times 4 \times 5}{40} = 6 \text{ feet 6 inches distance of section of 2 plates from end} = (20 \text{ feet} - 13 \text{ feet 2 inches}) = \text{length of plate 6 feet 6 inches.}$$

$\frac{3 \cdot 3 \times 2 \times 4 \times 5}{40}$ = 3 feet 3 inches distance of section of 1 plate from end = (20 feet − 6 feet 6 inches) = 13 feet 2 inches length of second plate.



In rolled joists $\frac{1}{6}$th of the area of web may be included in each of the areas of the top and bottom flanges when calculating the strength of the joist.

To find the net area of a joist in inches—

$$A = \frac{W\,L}{8\,d} = \text{tons} \begin{cases} \div 5 = \text{inches area if wrought iron.} \\ \div 7 = \text{,, ,, ,, steel.} \end{cases}$$

To find W = distributed load— $\frac{A \times d \times C}{L}$

„ „ d = depth of girder in feet — $\frac{L \times W}{C \times a}$

„ „ a = net section in inches— $\frac{L \times W}{C \times D}$

„ „ L = span— $\frac{A \times d \times c}{W}$

„ „ S = tons strain per square inch— $\frac{L \times W}{8 \times A \times d}$

In the above, C = { 40 for wrought iron. 52 for steel.

Diagram to find the Proper Size of Rolled Iron Joist.

For any given Distributed Load. (Factor of Safety, $\frac{1}{3}$rd.)

When it is required to know the nearest stock size of joist for any load and span, find the load on bottom line, and note the vertical line for this load, then find the span on left hand side, follow the horizontal line opposite the span until it cuts the vertical load line, the next curve line to the right hand indicates the size of joist required.

When it is desired to know the safe load for a joist of a certain size and known span, note where the curve line for the joist cuts the horizontal line corresponding to the span; at the point vertically beneath the intersection will be found the distributed safe load.

A joist will only carry one-half the load if the load be placed in the centre.

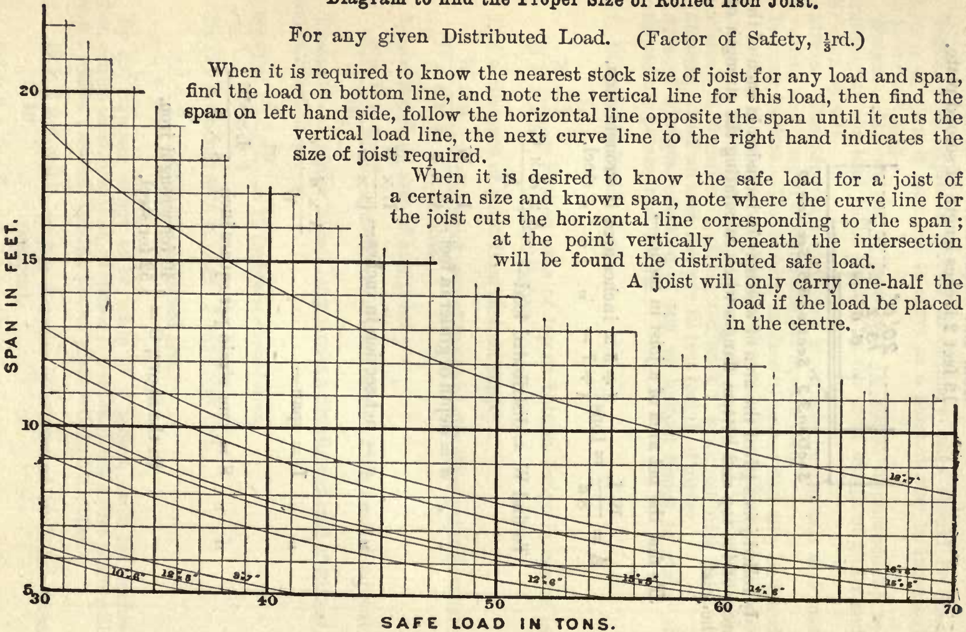
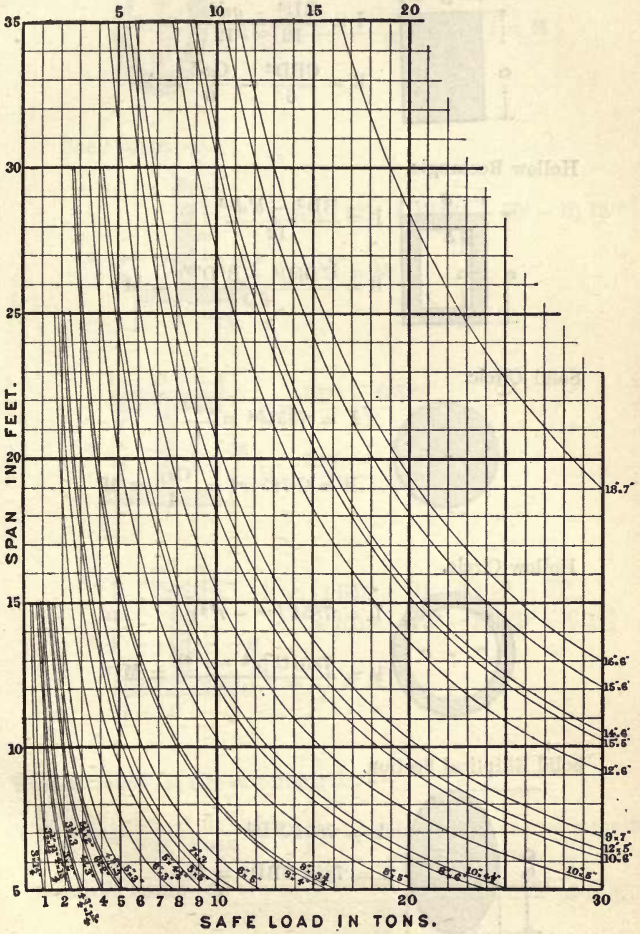


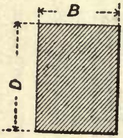
Diagram to find the Proper Size of Rolled Iron Joist.

For any given Distributed Load. (Factor of Safety, ⅓rd)—*continued.*



Moments of Inertia and Resistance of Beams.

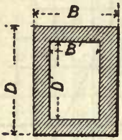
Solid Rectangle.



$$I = \frac{BD^3}{12} = \frac{ad^2}{12}$$

$$R = \frac{CBD^2}{6} = \frac{Cad}{6} = M$$

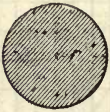
Hollow Rectangle.



$$I = \frac{BD^3 - b'd'^3}{12}$$

$$R = \frac{C\,(BD^3 - B'D'^3)}{6D} = M$$

Solid Circle.



$$I = \cdot 7854 r^4 = \frac{ar^2}{4}$$

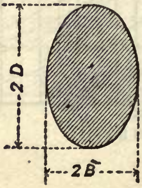
$$R = C \cdot 7854 r^3 = \frac{Car}{4} = M$$

Hollow Circle.

$$I = \cdot 7854\,(r^4 - r'^4)$$

$$R = \frac{\cdot 7854 C\,(r^4 - r'^4)}{r} = M$$

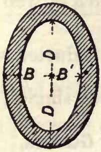
Solid Elliptical Section.



$$I = \cdot 7854\ BD^3$$

$$R = \cdot 7854\ CBD^2 = M$$

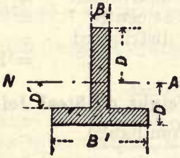
Hollow Elliptical Section.



$$I = \cdot 7854\,(BD^3 - B'D'^3)$$

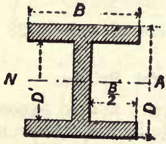
$$R = \frac{\cdot 7854\,C\,(BD^3 - B'D'^3)}{D} = M$$

One Flange.



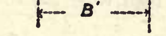
$$I = \tfrac{1}{3}\left\{BD^3 + B'D'^3 - (B' - B)\,D''^3\right\}$$

$$R = \frac{CI}{t} = M$$



$$I = \frac{BD^3 - B'D'^3}{12}$$

$$R = \frac{C\,(BD^3 - B'D'^3}{6D} = M$$



$$I = \left\{\tfrac{1}{3}\,BD^3 - (B - K)\,(D - C)^3 + BD'^3 - (B' - K)\,(D' - C')^3\right\}$$

$$R = \frac{CI}{t} = M$$

Wooden Joists (square or rectangular)—

$$\frac{B \times d^2}{L} \times \left.\begin{array}{l} 0{\cdot}2 \text{ if fir or pine} \\ 0{\cdot}23 \text{ if oak} \end{array}\right\} = \text{Breaking weight in tons on centre.}$$

Cast iron beams—$\dfrac{2d \times \text{area of bottom flange in inches}}{L}$ = B. W.

Area of top flange should equal one-third that of bottom flange.

Wrought iron beams with top and bottom flange—

$$\frac{6d \times \text{area of bottom flange in inches} + \frac{1}{6}\text{th area of web}}{L} = \text{B. W.}$$

B and d in inches, L in feet. Rivet holes deducted when calculating area of web and flange.

Box girders are about 8 per cent. stronger than single plate girders.

Relative Strength of Beams or Girders.

	Relative Strength.
Supported at one end and loaded at the other	= 1
„ „ „ „ load distributed	= 2
„ „ both ends „ „ at centre	= 4
„ „ „ „ „ distributed	= 8
Firmly fixed at both ends and „ „	= 16

Rule for Distributed Breaking Weight on Steel Joists.

$$\frac{8 \times D \times \text{strain on bottom flange}}{L}$$

D = depth.
L = length.
Strain = area of bottom flange + $\frac{1}{6}$th area of web × 28 tons per inch.

Board of Trade Regulations for Bridges.

Greatest stress per square inch in any part not to exceed 5 tons either in tension or compression when made in wrought iron.

When of cast iron the factors for dead load are taken and that portion of the load which is moving is doubled.

When of steel the greatest stress per square inch not to exceed $6\frac{1}{2}$ tons.

Ponts et Chaussées allow 3·81 tons per square inch in wrought iron girders in compression or tension.

Cast Iron Girders.

If supported at both ends and centre load $W = \frac{25ad}{L}$

„ „ „ distributed load $W = \frac{50ad}{L}$

With distributed load, if $d = \frac{1}{12}$ L, W = A 4·17

„ „ „ $= \frac{1}{10}$ L, W = A 5

If load is placed on top flange, area should $= \frac{A}{3}$

If load is placed on bottom flange, area of top flange should $= \frac{A}{2}$

Depth at ends should $= \frac{2d}{3}$

With a test load = $\frac{1}{3}$ W, safe deflection equals $\frac{1}{40}$ inch per foot of span
In the above W = breaking weight in tons.
a = area of bottom flange in inches.
d = depth of girder in inches over both flanges.
L = span of girder in inches.

If the depth of a wrought iron plate girder equals $\frac{L}{8}$, then strain on top or bottom flange at centre in tons equals distributed load.

If the depth of a wrought iron plate girder equals $\frac{L}{10}$, then strain on top or bottom flange at centre in tons equals $1\frac{1}{4}$ distributed load.

If the depth of a wrought iron plate girder equals $\frac{L}{12}$, then strain on top or bottom flange at centre in tons equals $1\frac{1}{2}$ distributed load.

Continuous Girders.

The distance of the point of contrary flexure from pier, when the load on each span is equal, is $\frac{1}{4}$ span. When the load is greater on one span than the other the distance equals

$$\text{span} - \left(\frac{7\ \text{load on first span} - \text{load on the other}}{8\ \text{load on first span}} \times \text{span}\right)$$

The pressure on the abutments

$$= \text{span}\left(\frac{7\ \text{load on first span} - \text{load on the other}}{16}\right)$$

The pressure on centre pier equals $\frac{5}{8}$ span (load on first span + load on the other).

Thickness of Web Plates Required to Resist Diagonal Forces.

(Chas. Light.)

Thickness of Web.	Net Unsupported Distance in Inches, whether between Pillars or Booms.									
	24	27	30	33	36	39	42	45	48	51
Inches.										
$\frac{1}{4}$	1·5	1·2	1·0	·8	·7	·6	·5	·45	·4	·36
$\frac{5}{16}$	2·8	2·2	1·8	1·5	1·3	1·2	1·0	·9	·8	·7
$\frac{3}{8}$	4·3	3·5	3·0	2·6	2·2	1·9	1·7	1·5	1·3	1·2
$\frac{7}{16}$	6·3	5·3	4·5	3·9	3·4	2·9	2·6	2·3	2·0	1·8
$\frac{1}{2}$	8·7	7·4	6·3	5·5	4·8	4·2	3·7	3·3	3·0	2·7
$\frac{9}{16}$	11·2	9·8	8·5	7·4	6·5	5·7	5·1	4·6	4·2	3·8
$\frac{5}{8}$	14·0	12·3	10·8	9·5	8·4	7·5	6·7	6·0	5·4	4·9
$\frac{11}{16}$	17·0	15·0	13·4	11·9	10·6	9·5	8·5	7·6	6·8	6·3
$\frac{3}{4}$	20·0	17·9	16·1	14·5	13·0	11·7	10·5	9·5	8·6	7·8

Tabular numbers show safe thrust in tons per foot width of plate.
Tabular numbers under distance required must not be less than the shearing force per foot of plate.

Limits of Weights, &c., of Wrought Iron that can be used without Increase of Cost.

	Length.	Width.	Area.	Weight.	Depth.
Plates . .	15 ft.	4 ft.	28 sq. ft.	4 cwt.	
Bar Iron .	30 to 35 ft.	flat bars, 6in.	—	4 „	
L & T bars .	35 ft.	breadth and depth added $8\frac{1}{2}$	—	4 „	
Channel or R.J. . .	35 ft.	—	—	4 „	7 ins.

Transverse Strength of Plates. (Deduced from Rankine.)

Plate supported at 2 sides, distributed load, strength $= \frac{8kbd^2}{L}$

Square „ 4 „ „ „ „ $= \frac{16kbd^2}{L}$

„ „ 4 „ central „ „ $= \frac{48kbd^2}{L}$

Circular, supported all round, distributed load, strength

$$= \frac{3{\cdot}1416 \times 8kbd^2}{L}$$

Circular, supported all round, central load, strength

$$= \frac{9{\cdot}42 \times 8kbd^2}{L}$$

If firmly riveted to an immovable abutment, strength equals 1·5 above strengths.

Formula to obtain Ultimate Strength of Angle, or Tee Iron or Steel Struts (as for struts in roof trusses).

Breaking load in lbs. per square inch of area of cross-section of pillar =

$$\frac{\text{Coefficient}}{1 + \dfrac{\text{length in inches}^2}{\text{least radius of gyration}^2 \times K}}$$

Coefficient for wrought iron equals 40,000. K = if both ends flat or fixed, 36,000 to 40,000.

Coefficient for cast iron equals 80,000. K = if both ends hinged, 18,000 to 20,000.

Coefficient for soft steel equals 52,000. K = if one end flat or fixed, other hinged, 24,000 to 30,000.

Least Radius of Gyration. (Adapted from "Trautwine.")

Equal Angles.			
$1 \times 1 \times \frac{1}{8}$ = ·20	$1\frac{3}{4} \times 1\frac{3}{4} \times \frac{3}{8}$ = ·35	$2\frac{3}{4} \times 2\frac{3}{4} \times \frac{1}{4}$ = ·55	$4 \times 4 \times \frac{3}{8}$ = ·81
$1 \times 1 \times \frac{1}{4}$ = ·20	$2 \times 2 \times \frac{3}{16}$ = ·40	$2\frac{3}{4} \times 2\frac{3}{4} \times \frac{1}{2}$ = ·54	$4 \times 4 \times \frac{3}{4}$ = ·80
$1\frac{1}{4} \times 1\frac{1}{4} \times \frac{1}{8}$ = ·26	$2 \times 2 \times \frac{3}{8}$ = ·38	$3 \times 3 \times \frac{1}{4}$ = ·60	$5 \times 5 \times \frac{7}{16}$ = 1·00
$1\frac{1}{4} \times 1\frac{1}{4} \times \frac{1}{4}$ = ·26	$2\frac{1}{4} \times 2\frac{1}{4} \times \frac{1}{4}$ = ·45	$3 \times 3 \times \frac{5}{8}$ = ·59	$5 \times 5 \times 1$ = ·98
$1\frac{1}{2} \times 1\frac{1}{2} \times \frac{3}{16}$ = ·31	$2\frac{1}{4} \times 2\frac{1}{4} \times \frac{7}{16}$ = ·44	$3\frac{1}{2} \times 3\frac{1}{2} \times \frac{3}{8}$ = ·70	$6 \times 6 \times \frac{7}{16}$ = 1·19
$1\frac{1}{2} \times 1\frac{1}{2} \times \frac{3}{8}$ = ·31	$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{4}$ = ·50	$3\frac{1}{2} \times 3\frac{1}{2} \times \frac{5}{8}$ = ·69	$6 \times 6 \times 1$ = 1·17
$1\frac{3}{4} \times 1\frac{3}{4} \times \frac{3}{16}$ = ·36	$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{2}$ = ·49		

Unequal Angles.			
$3 \times 2 \times \frac{1}{4}$ = ·46	$4 \times 3 \times \frac{3}{8}$ = ·67	$5 \times 3\frac{1}{2} \times \frac{3}{8}$ = ·80	$6 \times 4 \times \frac{7}{16}$ = ·92
$3 \times 2 \times \frac{1}{2}$ = ·46	$4 \times 3 \times \frac{5}{8}$ = ·65	$5 \times 3\frac{1}{2} \times \frac{3}{4}$ = ·79	$6 \times 4 \times 1$ = ·91
$3 \times 2\frac{1}{2} \times \frac{5}{16}$ = ·54	$4 \times 3\frac{1}{2} \times \frac{3}{8}$ = ·74	$5 \times 4 \times \frac{3}{8}$ = ·87	$6\frac{1}{2} \times 4 \times \frac{7}{16}$ = ·94
$3 \times 2\frac{1}{2} \times \frac{1}{2}$ = ·54	$4 \times 3\frac{1}{2} \times \frac{5}{8}$ = ·73	$5 \times 4 \times 1$ = ·86	$6\frac{1}{2} \times 4 \times 1$ = ·93
$3\frac{1}{2} \times 2\frac{1}{2} \times \frac{5}{16}$ = ·56	$4\frac{1}{2} \times 3 \times \frac{3}{8}$ = ·69	$5\frac{1}{2} \times 3\frac{1}{2} \times \frac{3}{8}$ = ·81	$7 \times 3\frac{1}{2} \times \frac{5}{8}$ = ·85
$3\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{2}$ = ·56	$4\frac{1}{2} \times 3 \times \frac{5}{8}$ = ·68	$5\frac{1}{2} \times 3\frac{1}{2} \times \frac{5}{8}$ = ·80	$7 \times 3\frac{1}{2} \times 1$ = ·84
$3\frac{1}{2} \times 3 \times \frac{11}{32}$ = ·64	$5 \times 3 \times \frac{3}{8}$ = ·70	$6 \times 3\frac{1}{2} \times \frac{7}{16}$ = ·82	
$3\frac{1}{2} \times 3 \times \frac{5}{8}$ = ·64	$5 \times 3 \times \frac{3}{4}$ = ·69	$6 \times 3\frac{1}{2} \times 1$ = ·81	

Equal Tees.		Unequal Tees.	
$1 \times 1 \times \frac{1}{4}$ = ·26	$2\frac{1}{4} \times 2\frac{1}{4} \times \frac{5}{16}$ = ·47	$2 \times 1 \times \frac{1}{4}$ = ·26	$4 \times 3 \times \frac{3}{8}$ = ·86
$1\frac{1}{4} \times 1\frac{1}{4} \times \frac{1}{4}$ = ·27	$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{13}{32}$ = ·53	$2 \times 1\frac{1}{2} \times \frac{1}{4}$ = ·43	$4 \times 3\frac{1}{2} \times \frac{3}{4}$ = ·88
$1\frac{1}{2} \times 1\frac{1}{2} \times \frac{1}{4}$ = ·32	$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{15}{32}$ = ·55	$2\frac{1}{2} \times 1\frac{1}{4} \times \frac{1}{4}$ = ·33	$4\frac{1}{2} \times 3\frac{1}{2} \times \frac{5}{8}$ = ·91
$1\frac{3}{4} \times 1\frac{3}{4} \times \frac{1}{4}$ = ·37	$3 \times 3 \times \frac{1}{2}$ = ·62	$3 \times 1\frac{1}{2} \times \frac{1}{4}$ = ·41	$5 \times 2\frac{1}{2} \times \frac{1}{2}$ = ·72
$2 \times 2 \times \frac{5}{16}$ = ·43	$3\frac{1}{2} \times 3\frac{1}{2} \times \frac{1}{2}$ = ·74	$3 \times 2\frac{1}{2} \times \frac{1}{2}$ = ·63	$5 \times 2\frac{1}{2} \times \frac{9}{16}$ = ·70
$2\frac{1}{4} \times 2\frac{1}{4} \times \frac{1}{4}$ = ·50	$4 \times 4 \times \frac{1}{2}$ = ·84	$3 \times 3\frac{1}{2} \times \frac{1}{2}$ = ·61	$5 \times 3\frac{1}{2} \times \frac{11}{16}$ = 1·04
		$4 \times 2 \times \frac{7}{16}$ = ·58	$5 \times 4 \times \frac{9}{16}$ = 1·0

Roughly, weight of wrought iron bridge may be assumed—

For 30 feet spans,	single line,	5 cwt. per foot run			
60	”	”	” 6	”	”
100	”	”	” 9	”	”
150	”	”	” 12	”	”
200	”	”	” 15	”	”

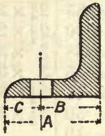
Dense crowds average 120 lbs. per square foot.

For flooring, $1\frac{1}{2}$ cwt. to 2 cwt. per square foot, exclusive of weight of flooring.

In storehouses, from 2 cwt. to 4 cwt. per square foot.

Under no circumstances is a girder of less than $\frac{1}{25}$th of the span advisable.

Bolt Centres in Angle Irons.



A.	B.	C.	A.	B.	C.
$1\frac{1}{2}$	$\frac{7}{8}$	$\frac{5}{8}$	$3\frac{1}{4}$	$1\frac{7}{8}$	$1\frac{3}{8}$
$1\frac{3}{4}$	1	$\frac{3}{4}$	$3\frac{1}{2}$	2	$1\frac{1}{2}$
2	$1\frac{1}{8}$	$\frac{7}{8}$	4	$2\frac{1}{2}$	$1\frac{1}{2}$
$2\frac{1}{2}$	$1\frac{3}{8}$	$1\frac{1}{8}$	$4\frac{1}{2}$	$2\frac{3}{4}$	$1\frac{3}{4}$
3	$1\frac{3}{4}$	$1\frac{1}{4}$	5	3	2

Rolled T Iron $\dfrac{4d \times \text{area of web below centre of gravity}}{L} =$ breaking weight.

A distributed load causes stresses only one-half as great as a centre load.

A load at end of a projecting beam or cantilever causes stresses four times as great as a centre load.

Size of L Iron Laths for Slate Roofs.

Distance Apart of Principals.	Laths 12 Inches Apart.	Laths $10\frac{1}{2}$ Inches Apart.	Laths $8\frac{1}{2}$ Inches Apart.
5 0	1″ × 1″ × 8 w. g.	$1\frac{1}{8}$″ × $1\frac{1}{8}$″ × 9 w. g.	$1\frac{1}{8}$″ × $1\frac{1}{8}$″ × 9 w. g.
5 6	1″ × 1″ × 8 w. g.	$1\frac{1}{8}$″ × $1\frac{1}{8}$″ × 9 w. g.	$1\frac{1}{8}$″ × $1\frac{1}{8}$″ × 9 w. g.
6 0	$1\frac{3}{8}$″ × $1\frac{3}{8}$″ × 6 w. g.	$1\frac{1}{4}$″ × $1\frac{1}{4}$″ × 8 w. g.	$1\frac{1}{8}$″ × $1\frac{1}{8}$″ × 9 w. g.
6 6	$1\frac{3}{8}$″ × $1\frac{3}{8}$″ × 6 w. g.	$1\frac{1}{4}$″ × $1\frac{1}{4}$″ × 8 w. g.	$1\frac{1}{8}$″ × $1\frac{1}{8}$″ × 9 w. g.
7 0	$1\frac{1}{2}$″ × $1\frac{1}{2}$″ × $\frac{1}{4}$″	$1\frac{3}{8}$″ × $1\frac{3}{8}$″ × 6 w. g.	$1\frac{1}{4}$″ × $1\frac{1}{4}$″ × 8 w. g.

Tie Rods should have end eyes of the following proportions.

Proportions of Plate, Flanges, and Bolts. (Unwin.)

Bolt diameter = d = $\frac{5}{4}$ths thickness of plate + $\frac{1}{8}$th (but not less than $\frac{3}{4}$ inch).

Pitch of bolts about $6d$, or less if necessary for strength.
Width of chipping strip equals $\frac{5}{4}$ thickness of plate.
Width of flange equals $2d + \frac{3}{4}$.

Approximate rule for depth of arches:—

$C\sqrt{r} = D$ C = coefficient = for stone ·3, brick ·4, rubble ·45.
r = radius of curve.

Minimum thickness of abutments for arches of 120 degrees where the depth does not exceed 3 feet

$$\sqrt{6r + \left(\frac{3r}{2h}\right)^2} - \frac{3r}{2h} = t$$

r equals radius; h equals height of abutment to spring; t equals thickness of abutment.

The abutments are assumed to be without counterforts or wing walls.

Strength of Flat Plates. (Grashof.)

If supported on a circular support and uniformly loaded—

$$\text{Greatest stress} = \frac{5}{6}\,\frac{\text{radius of support}^2}{\text{thickness of plate}^2} \times \text{W. per square inch.}$$

If encastre at the edge—

$$\text{Greatest stress} = \frac{2}{3}\,\frac{\text{radius}^2}{\text{thickness}^2} \times \text{W. per square inch.}$$

If supported only and with central load—

$$\text{Greatest stress} = \left(\frac{4}{3}\log.\frac{r}{r_0} + 1\right)\frac{P}{\pi t^2}$$

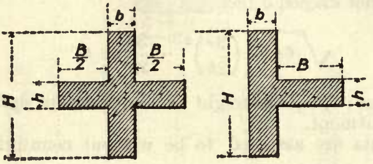
$\frac{r}{r_0}$ =	10	20	30	40	50
$\frac{4}{3}\log.\frac{r}{r_0} + 1$ =	4·07	5·00	5·53	5·92	6·22

Modulus of Elasticity.

Wrought iron	29,000,000
Steel	30,000,000
Cast iron	17,000,000
Wood, hard	1,500,000
„ soft	1,400,000

Moments of Inertia.

Circular section (diameter = d), 0·0491 d^4
Annular section (diameters = d_1, d_2), 0·0491 $(d_1{}^4 - d_2{}^4)$
Square section (length of side = s), $\frac{1}{12}s^4$
Rectangular section (longer side b, shorter h), $\frac{1}{12}bh^3$
Cross-shaped section, if bending, is parallel to H, $\frac{1}{12}(bH^3—Bh^3)$.



Cupolas for Melting Iron.—Average Sizes.

Diameter of Shell.	Quantity of Metal Melted per hour.	Height about.	Diameter of Shell.	Quantity of Metal Melted per hour.	Height about.
Ft. Ins.		Ft. Ins.	Ft. Ins.		Ft. Ins.
1 10	10 cwt.	12 10	3 9	3½ tons	20 9
2 0	15 „	13 6	4 0	4 „	22 0
2 6	1 ton	15 0	4 6	5	25 0
2 9	1½ „	16 3	4 9	5½	26 0
3 0	2 „	17 6	5 0	6	28 0
3 6	3 „	20 0			

Water will ooze through cast iron ½ inch thick at 250 lbs. per square inch.

Water is only compressible $\frac{1}{1000}$th part by a pressure of 324 lbs. per square inch, or 22 atmospheres, and regains its bulk on removal of the pressure.

UNLOADING MATERIAL AND STORAGE

21 bushels coke = 1 cubic yard.
72 „ „ = 1 ton.

To measure a heap of coals, from 40 to 43 cubic feet should be taken for each ton.

Cannel coal, 45 cubic feet per ton.

Mr. Wyatt says $2\frac{1}{3}$ acres are required per 1,000,000 cubic feet per day.

Coal store should equal 6 weeks' supply.

Coal storage, Newbigging's rule, 6 to 8 weeks' maximum make.

Space Occupied per Ton of Different Coals.

		Weight per Cubic Foot.
Welsh anthracite	= 39 cubic feet	58·25 lbs.
„ bituminous	= 43 „ „	53 „
Lancashire	= 44 „ „	53 „
Newcastle	= 45 „ „	50 „
Scotch	= 43 „ „	53 „
Navy allowance for storage	= 48 „ „	

Coke in bays measures per chaldron 52 to $52\frac{1}{2}$ cubic feet per chaldron.

Coke diminishes in weight by exposure to the weather. (See also p. 232.)

Average Weight of Various Coals.

	Per Cub. Ft. Solid.	Per Cub. Ft Heaped.	Cub. Ft. per Ton. Heaped.	Per Cub. Yd. Solid.
Anthracite	85·4 lbs.	58·3 lbs.	38·4 c. ft.	2,160 lbs.
Bituminous	78·3 „	49·8 „	45·3 „	2,100 „
Cannel	76·8 „	48·3 „	46·4 „	2,190 „
Coal as stored	—	—	—	1,150 „

Coal Stores.

Coal stores in the open should be paved with a slope to carry off rain water.

Ventilation of coal stacks may be effected by constructing open piers of brickwork or wood, or inserting perforated pipes, round which the coal is laid ; or wicker tubes.

In designing walls for coal stores the object to be attained is to keep the centre of gravity of the mass of the wall as much towards the inner side as possible, as the strength of a wall to resist side pressures varies as the distance from the centre of gravity to the outside edge of the wall at the base, and as the weight on the foundations. On this account walls with panels sunk in are usually adopted.

There can be little or no assistance from cross walls inside coal stores, or from the end walls, more especially when the walls are thick, a necessity where much coal has to be stored. The corners of such buildings frequently develop cracks from top to bottom of the walls nearly vertical, which would entirely remove any advantage which the side walls might have otherwise given. Probably the cause of these cracks is the expansion taking place in long walls exposed to the sun while the end walls are cool and shaded.

Iron ties are not reliable when imbedded in the coals, as when the latter heat the ties extend, and the tension on the walls is relaxed; and this may cause the wall to overturn through the upsetting of the centre of gravity of the wall.

Mr. F. Marshall has designed a coal store with the floor a series of inverted pyramids, the sides of which are built of "Monier" concrete arches, the bottom points of the pyramids being so arranged that the coal may pass out in a regulated quantity on to a conveyer, and by this carried to the retort house.

Stabling.

Floor space required in stables per horse . .	120 square feet.
Width of stalls for horses	6 feet.
Width of building from wall to wall for stables	18 „
Height of stables	12 „
A horse requires about 30 to 40 lbs. food per day.	
Capacity of oat bins required per ton . . .	75 cubic feet.
Capacity of hay lofts required per ton . .	500 „ „

Roads.

A layer of hydraulic concrete at least 8 inches thick, or a foundation of 12 inches of gravel, well rammed in, with 1 inch of sand on top, should be laid under paved roads.

Asphalt for roadways and for traffic should be 2 inches thick; pavement of yards, covering of roofs, ½ inch to 1 inch thick; damp courses, ¼ inch to ¾ inch.

The road surfacing asphalt is crushed, heated to 275° or 300° F., spread uniformly where wanted, and stamped, rolled, and smoothed with heated irons.

Coke breeze for tar paving footpaths best made by using water with the tar to ensure the distribution through the whole of the breeze. Twenty-four gallons tar to the yard of breeze is sufficient.

Grooves in Hobson's floor plates are best filled in with 112 lbs. pitch, 85 lbs. sand, and 56 lbs. cement, with a little creosote oil on second boiling to make it pliable; remainder filled in with tar concrete and rendered with 4 parts coarse sand to 1 part cement.

Resistance to Traction on Common Roads. (F. V. Greene.)

Iron	10 lbs. per ton.
Asphalt	15 ,, ,,
Wood	21 ,, ,,
Best stone blocks	33 ,, ,,
Inferior stone blocks	50 ,, ,,
Average cobble stone	90 ,, ,,
Macadam	100 ,, ,,
Earth	200 ,, ,,

Resistance of Surface of Different Roads.

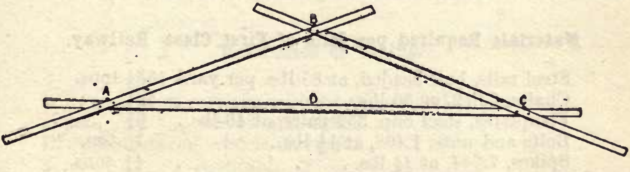
Stone tramway, exclusive of gravity	20 lbs. per ton.
Paved roads ,, ,,	33 ,, ,,
Macadamised roads ,, ,,	44 to 67 ,, ,,
Gravel ,, ,,	150 ,, ,,
Soft sandy or gravelly ground, exclusive of gravity	210 ,, ,,

The limiting gradients in ordinary roads are—Asphalt 1 in 60; wood, 1 in 25; macadam, 1 in 20; and granite, 1 in 15; but there are instances of macadam roads as steep as 1 in 6.

The average resistance to traction upon road tramways is about 30 lbs. per ton with a minimum of 15 lbs. and maximum of 60 lbs. per ton.

Sir G. Molesworth stated (1895) that the greatest economical gradient for ordinary locomotives was 1 in 40.

To set out a curve make a template to sketch.



Where A C = the chord
B D = versed sine.

A pencil held at B when the template is moved round and kept close to nails at A and C will mark the curve required.

Unloading Materials.

To find Tractive Force of Locomotives.

T = tractive force in lbs.
p = mean effective pressure in the piston.
d = diameter of cylinder in inches.
s = stroke in inches.
D = diameter of driving wheel in inches.

$$T = \frac{P \times d^2 \times s}{D}$$

Tractive Power of Locomotives. (Another rule.)

D = diameter of cylinder in inches.
L = length of stroke in inches.
T = tractive force on rails in lbs.
P = mean pressure of steam in cylinders in lbs. per square inch.
W = diameter of driving wheel in inches.

$$T = \frac{D^2PL}{W}$$

In Permanent Way Work.

Eight yards run of metals require—

2 lengths rail	cost (1894)	£4 7*s.* 9*d.* per ton.
8 sleepers	" "	2*s.* 4*d.* each.
2 pairs fishplates	" "	10*d.* pair.
8 bolts at 1 lb. (6 = 5 lbs. 11 ozs.) .	" "	11*s.* per cwt.
32 bolts (6 = 3 lbs. 10 ozs.) . . .	" "	8*s.* 10*d.* per cwt.

Labour costs, say, 1*s.* per yard run.

Average weight of cast steel crossings (Vicker's patent), say 5 cwt.; price, 1894, 32*s.* per cwt.

Average cost of switchrails and stockrails, 1894, £5.

Materials Required per Mile of First Class Railway.

Steel rails, bull headed, at 85 lbs. per yard	133½ tons.
Chairs, 3,872, at 50 lbs.	86½ "
Fishplates, steel clip, 352 pairs, at 40 lbs..	6¼ "
Bolts and nuts, 1,408, at 1½ lbs.. . . .	1 ton.
Spikes, 7,744, at 1¼ lbs.	4¼ tons.
Trenails, solid oak, 7,744	
Keys, oak . 3,872	
Sleepers, creosoted, 1,936	

In relaying, the old materials may be credited at 55 per cent. of the cost of the new work.

Usual Type of Rail used on English railways.—The bull head of steel of 90 lbs. per yard of an average length of 30 feet. Bessemer steel is most used. Rails are drilled at ends, and the bolts are of steel. Test for rails is one to three blows of a 1-ton weight falling from various heights; the rail, placed on bearings 3 feet 6 inches apart, must not show any signs of fracture or exceed a given permanent set; sometimes a further test is made by hanging a dead weight of 40 tons in centre of 3 feet bearings, giving a maximum deflection of ⅝-inch and no permanent set after one hour's suspension.

Resistance of Curves. (Morrison.)

W = weight of vehicle.
R = radius of curve.
F = coefficient of friction of wheels on rails = ·1 to ·27 according to weather.
D = distance of rails apart from tread to tread.
L = length of rigid wheel base.

$$\text{Resistance due to curve} = \frac{WF\,(D+L)}{2R}$$

Elevation of Outer Rail on Curves.

$$\frac{\text{Width of gauge in feet} \times \text{velocity in miles per hour}^2}{1{\cdot}25 \text{ radius of curve in feet}} = \left\{ \text{elevation in inches.} \right.$$

Axle Tests are that they should be placed on solid bearings 3 feet 6 inches apart, and subjected to five blows of a 2,000 lbs. weight falling 20 feet, the axle being reversed after each. For wagons the ultimate tensile resistance should be 35 to 40 tons and 25 per cent. elongation in three inches.

Resistance of Trains.

W = weight of carriage without wheels and axles.
w = " " wheels and axles.
D = diameter of wheels on tread.
d = " " journal.
F = coefficient of axle friction = say ·035 with grease, ·018 with oil.
f = " " rolling friction = about ·001.
R = resistance of vehicle $= f\,(W + w) + \left(WF\,\frac{d}{D}\right)$

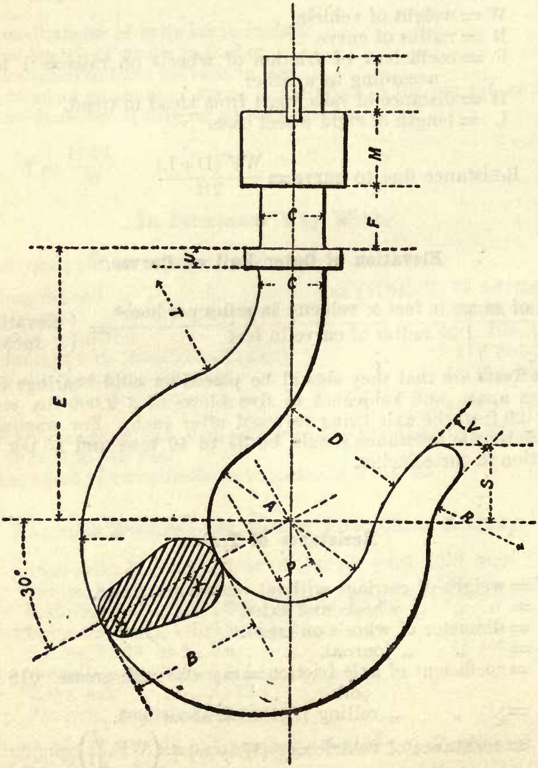
Crane Hooks, deduced from Experiments at London and North Western Railway Company's Works.

$$\left(\frac{\text{Diameter of link of chain in }\frac{1}{8}\text{ths of an inch}}{3}\right)^2 = \text{working load in tons.}$$

θ = diameter of chain.

$$K = \begin{cases} 1{\cdot}15 \text{ times diameter due to twice area of } \theta \text{ up to 10 tons.} \\ 1{\cdot}2 \quad \text{,,} \quad \text{,,} \quad \text{,,} \quad \text{,,} \quad \text{,,} \quad \text{,,} \quad \text{,,} \quad \text{,, above 10 tons.} \end{cases}$$

$A = 3 \times \sqrt{\theta} + C$, $B = \frac{1}{2} A + {\cdot}9\, C$, $E = 1\frac{3}{4} A$, $D = A \times {\cdot}8$.
$S = A \times \frac{1}{2}$, $T = A \times \frac{5}{8}$, $R = A$, $M = C$, $F = C$.
$X = \frac{5}{8} C$, $V = \frac{5}{8} C$, $Y = \frac{5}{8} X$, $P = A \times \frac{1}{4}$, $U = \frac{1}{3} C$.



RETORT HOUSE.

Best site for a Gas Works is the lowest point to be served, and, at the same time, close to the point of delivery of the raw material, such as a railway, canal, or river.

Average consumption per head 2,000 cubic feet per annum in large towns; 1,600 cubic feet per annum in medium sized towns; 1,000 cubic feet per annum in small towns.

Area of ground required for 7,000,000 cubic feet per day, 17 acres inclusive. (A. Colson.)

Hydraulic Power pressure usually adopted 700 lbs. per square inch.

Old Beckton Hydraulic Cranes, nine in number, lift a total weight of 20 cwt. each—designed to discharge 40 tons an hour with a lift of 60 feet. Two horizontal high pressure pumping engines equals 75 horse-power each, with 17 inches diameter and 17 feet stroke accumulator —each engine would work the nine cranes; but with a lift of 90 feet, as afterwards arranged, both engines are required. Cranes are multiplied 10 to 1, lifting chain travelling at 60 feet in 10 seconds, and the ram 6 feet in same time. Even with 90 feet lifts the cranes can easily lift 40 tons per hour, and have done considerably over that quantity. On the same pier are six steam cranes of the best type, requiring two 30 horse-power boilers to keep them going, whereas, with hydraulic power, two 20 horse-power boilers work one pair of pumping engines sufficient to actuate six cranes.

The practical efficiency of the distribution of hydraulic power in towns may be taken as 50 per cent. to 60 per cent. of the power developed at the works.

Loss of head due to velocity in hydraulic pipes

$$\frac{(\text{Gallons per minute})^2 \times \text{length of pipe in yards}}{3 \times \text{diameter of pipe in inches}}$$

Friction of the ram of an accumulator may be taken as $2\frac{1}{4}$ per cent.

Friction in steam engine pumping into accumulator may be taken as 8·3 per cent.

Thickness of Hydraulic Cylinders.

$$d = D\sqrt{\frac{C \times p}{C - p}}$$

Where d = external diameter of the cylinder in inches, D = internal diameter of the same, also in inches.

Loss of power by multiplying gear upon hydraulic rams varies from 7 per cent. when direct acting, to 50 per cent. when multiplying 16 to 1.

Velocity of water in feet per second $= 8\sqrt{\text{height of fall in feet}}$, where there is no deduction from the force for friction or other resistance.

Saving by use of Conveyor and Priestman Grab.

At a works using about 49,000 tons per annum—

Old style—In barge	4 men	6*s.*	} per day.
On run	2 „	6*s.*	
On crane	1 man	6*s.*	
	7 men		

plus wear and tear of trucks and run equals about 4*d.* per ton.

New style—In barge	1 man	4*s.* 5*d.*	} per day.
Conveyor engine	1 „	3*s.* 9*d.*	
Crane	1 „	4*s.* 5*d.*	
	3 men		

plus wear and tear of elevator, conveyor engine, fuel, and interest on £1,200 (cost of elevator, conveyor, and engine), about 1·80*d.* per ton.

		d.	
Craneman	=	·45	per ton.
Engineman and bargeman	=	·60	„ „
Interest, wear and tear	=	·42	„ „
Coke, 6 sacks per day, and oil	=	·33	„ „
		1·80	„ „

Average Composition of Fireclays.

Silica.	Alumina.	Peroxide of Iron.	Lime.	Magnesia.	Potassa.	Titanic Acid.	Soda.
65·0	28·0	4·6	0·3	0·35	1·2	0.25	0·3

Composition of Fireclay.

Silica (SiO_2)	59 to 96 per cent.
Alumina (Al_2O_3)	2 to 36 „ „
Oxide of Iron (Fe_2O_3)	2 to 5 „ „
Lime, Magnesia, Potash, Soda	traces.

The more alumina that there is in proportion to the silica, the more infusible the fireclay. (J. Hornby.)

Stourbridge clay consists of—

Silica	63·7
Alumina	22·7
Oxide of Iron	2·0
HO_2	11·6
	100·0

Silica in ordinary Stourbridge firebricks = 65 per cent.
„ „ „ Welsh „ = 95 „ „
Specific heat of fireclay . . . . = 0·21

Tests of Firebricks at Royal Arsenal.

	Cracked At.	Crushed At.
Stourbridge .	1,478 lbs. per square inch	2,400 lbs. per square inch
„ . .	1,156 „ „ „ „	1,156 „ „ „ „
Newcastle .	889 „ „ „ „	1,512 „ „ „ „
Plympton .	1,689 „ „ „ „	2,666 „ „ „ „
Dinas . . .	1,123 „ „ „ „	1.288 „ „ „ „
Kilmarnock .	2,134 „ „ „ „	3,378 „ „ „ „
Glenboig . .	1,067 „ „ „ „	1,556 „ „ „ „

Cubes 1½ inch sides, cut from soaps, were used and placed between pieces of sheet lead.

Fireclay Blocks Weigh per 100.

Inches.					
18× 9×3	1	8	3	0	Ellis and Grahamsley's, Newcastle.
24×16×3½	3	17	1	0	
24×12×3½	2	19	1	0	
12× 9× 6×3⅝	1	15	0	0	Welsh.
9× 9× 6×3⅝	1	3	0	0	
12× 9× 6×3⅝	1	11	2	1	Mobberley and Perry's.

General Notes.

Ewell bricks are soft and not suitable for use where clinker bars are liable to be used, and should be set in Ewell loam.

Dinas firebricks fuse at about 3,880° to 3,930° F.

Firebricks from magnesia are being made, and recommended for very high heats, containing 95 to 97·8 per cent. pure magnesia ; they are set in a mortar made up of magnesia powder.

About ½ ton of fireclay is required per 1,000 Newcastle firebricks used.

If there be a thick joint or the broken corner of a brick where the flames from the furnace can get a hold upon, it will rapidly hollow out the brickwork at that point ; joints should therefore be very thin. Fireclay suffers no deterioration of quality from rain.

Twenty-one cubic feet of dry ground fireclay firmly packed = 1 ton ; 17½ cubic feet of blocks = 1 ton.

Retorts.

A good retort will sound metallic when struck, but if under-burnt or unduly cracked will give a dull sound.

H. Reissner's Rule (Berlin Gas Works), 15 per cent. retorts in reserve in midwinter.

For machine stoking with 20 feet through retorts, Mr. West suggests a space of 21 feet 6 inches in front of beds each side at least, and 18 feet extra length from the centre of the end retort to enable the machines to be run out of the way.

The lowest point of the roof trusses should be 32 feet high from stage or floor line, at 11 feet from face of retort stack.

Height of tie-beam of roof in retort house should be at least 20 feet above floor line.

It is best not to allow floor joists in stage retort houses to bear upon the brickwork of the setting, owing to the great expansion and contraction of the latter.

Openings in the roof of retort houses near the eaves have been objected to as likely to drive the smoke downwards.

The openings in side walls of retort houses for ventilation should be above the level of the top of beds.

Provide as few doorways on floor line as possible in retort house.

Concrete under retort settings should be at least 1 foot below floor line.

Space in front of benches should be 22 feet or 25 feet if machinery is to be used.

It is likely to be cheaper to build the retort house of sufficient width to erect upon the stages the ordinary coal hoppers and bins, from which the coal can be elevated direct to charging hopper at any part of the machine's progress along the stage, by an elevator attached to the machine. (A. F. Browne.)

Mr. Wyatt's Rule—1 foot run of retort house per ton carbonised per day or 6,000 cubic feet with floor area of 1,000 feet per ton per day, and costs 18 per cent. of total capital at a rate of 4*d.* per cubic foot all provided.

Drain pipes to stoke-holes 9 inches diameter best laid with a fall of 3 inches in each 100 feet run, with 3 feet × 3 feet manholes to about every 100 feet (1 foot 9 inches of ground above the shallowest end).

The loss of power in distributing energy by compressed air equals 50 per cent.

Heat of one bed of retorts has heated a boiler 3 feet 6 inches diameter 9 feet long after heating the retorts, but this heat would have been better utilised if heating the retorts.

A temperature of 1,500° F. is often found in flues of moderate sized works.

Jointing for Mouthpieces to Clay Retorts.—Two parts of sulphate of lime mixed with water, mixed well with six parts iron borings, with solution of sal-ammoniac, or three parts fireclay and 1 part iron borings (by weight) mixed with ammoniacal liquor.

Cross Tie Rods to Benches should be capable of resisting a breaking strain of 60 tons, and longitudinal tie rods 100 tons, it is practically impossible to prevent the expansion of a setting when first lighted up, and the tie rod nuts should be only hand tight, and should be slackened if found necessary.

End Buckstaves for Stage Setting should be 12 inches × 5 inches H iron, 4 at each end, and tie rods to same 2 inches diameter.

The top of a setting should be well covered or blanketed to prevent loss of heat by radiation.

Division walls of settings should be not less than 18 inches thick.

Space around Retorts should not be more than 4 inches wide at any point in clay retort settings.

Clay retorts should be not less than 3 inches thick.

Smooth inside surfaces to retorts assist in preventing the accumulation of carbon and in its subsequent removal.

No setting should be used until at least 14 days after completion, and then gradually heated.

Twenty-one inches × 15 inches × 20 feet D retorts will easily carbonise 5½ cwt. of Newcastle coals in 6 hour charges.

Through retorts are more economical than singles.

Circular retorts allow a large space above the charge, and are therefore bad.

The use of Thicker Walls in front of the bench has been advocated for the stoppage of the ascension pipe trouble.

Coke is sometimes removed hot by a conveyor under the mouthpieces, and carried by it to an elevator where it is quenched by water from a perforated pipe, raised and piled in place, the elevator being so arranged that a swivel spout at the top allows it to be placed where desired.

The Size of the Mouthpiece should never be made, in any direction, smaller than the retort, as the coke can then be easily removed without jamming; neglect of this precaution has caused the mouthpiece to be removed when drawing coke with machinery.

"Use plenty of walls to support retorts, and of good thickness, the small increased quantity of fuel required to heat them is more than compensated by the life of the retorts and setting generally."

"The brickwork in a setting should only be sufficient to uphold the retort, and to be of as small an area as possible at many points rather than large areas at few points."

Allow 25 square inches Air Space per retort between fire bars in open hearth furnaces.

In ordinary furnaces allow plenty of room above the fuel so that the CO may be converted into CO_2 before it passes among the retorts, say equal to the area of the fuel.

Ordinary furnaces evaporate 12 cubic feet of water per 24 hours.

With coal in furnaces, more space in flue ways required with increased supply of air.

About 50 per cent. of the heat generated in an ordinary furnace escapes unused up the chimney.

Allow about twice the theoretical quantity of air to ordinary furnaces, or some of the CO will pass away without being converted into CO_2

Each 3 lbs. C requires 8 lbs. O, or 40 lbs. (525 cubic feet) of atmospheric air, for complete combustion.

To estimate furnace efficiency:—

If T = temperature of smoke gases, t = temperature of air, c = specific heat of a cubic metre of CO_2 (= up to 150° C. = 0·41, from 150° to 200° = 0·43, from 200° to 250° = 0·44, from 250° to 300° = 0·45, from 300° to 350° = 0·46), c = specific heat of a cubic metre of O or N (about 0·31), then the loss of heat, x, in the furnace for every kilogramme of carbon burnt, expressed in calories,

$$\text{is } x = 1{\cdot}854\,(T - t)\,c + 1{\cdot}854\,(T - t)\frac{100 - n}{n}\,C.$$

Calorific value of 1 kilogramme carbon is 8080 calories;

therefore $\frac{100\,x}{8080}$ = proportionate heat lost by fire gases.

1 kilogramme carbon forms 1·854 cubic metres of CO_2 at 0° C. and 760 minimum pressure. (Dr. G. Lunge.)

Structural Cost per Mouthpiece of Different Settings.

(W. R. Chester, 1894.)

	£	s.	d.	
Ordinary settings	14	0	0	life 500 days.
Klönne gaseous fired setting . .	32	4	6	,, 300 ,,
Siemens ,, ,, ,, ...	25	5	0	,, 104 ,,
West ,, ,, ,, . . .	27	17	0	,, 406 ,,
Siemens-Foulis gaseous fired setting .	27	15	0	,, 500 ,,
Chester ,, ,, ,, .	17	0	0	,, 500 ,,

Materials Required for a Regenerator Setting of Nine D Retorts

(13½ inches × 20 inches × 20 feet long, 4½ inch walls).

From springing of furnace arch to level of first line of retorts :—

Stourbridge Goods.

9 inches × 2½ inches × 4½ inches	= 1010	Ewell N.N.	1664.
9 ,, × 2 ,, × 4½ ,,	= 120	9	172.
9 ,, × 1½ ,, × 4½ ,,	= 230		
9 ins. × 2½ ins. × 2½ ins. Clubs	= 110		
Bevel side	= 100		
Bevel ends	= 200		
Feather edge	= 100		
Arch	= 30		

From level of first line of retorts :—

Stourbridge Goods.

9 inches	= 822
14 ,,	= 16
2 ,,	= 172
1½ ,,	= 237
1 inch	= 82
Bevel ends	= 146
,, sides	= 62
Clubs	= 128
Arch	= 145
Feather edge	= 392

From stage line :—

Stourbridge Goods.

14 inches	=	64	Ewell.	
9 „	=	2212	S.S.	9″ = 460.
3 „	=	44	N.N.	9″ = 250.
2 „	=	216	N.N. arch	= 700.
$1\frac{1}{2}$ „	=	224		
1 inch	=	110		
Clubs	=	184		
Feather edge	=	742		
Bevel sides	=	144		
„ ends	=	50		
Arch	=	118		

Regenerative Furnaces.—Provide for a good depth of fuel.

The adoption of gaseous firing greatly increases the lives of the retorts.

Generator settings are those in which a portion of the heat given off by the furnace is utilised to heat the air for secondary supply.

Regenerator settings utilise the heat of the waste gases after they have left the setting proper.

Generator furnaces should be from 4 to 6 feet deep, and of comparatively even thickness, usually 4 to 6 feet long, and 2 to 3 feet wide. (J. Hornby.)

The introduction of gaseous firing with greatly enlarged combustion chambers has not only effected great economy of fuel, but has increased the durability of retort settings above 66 per cent., while wear and tear in furnaces has been reduced in a far higher ratio.

Beds of retorts run two years continuously, when a few bricks in furnaces, on clinker line, have to be cut out and replaced. (A. F. Browne.)

The yield per mouthpiece has been increased 30 per cent. by the introduction of Regenerative furnaces.

Allow a considerable depth of fuel in generator not less than 3 feet 6 inches.

The simplest arrangement of flues, if of sufficient length and area, is quite as satisfactory as more elaborate methods.

The gases in a retort setting should be made to travel so that the heat is evenly distributed among all the retorts and throughout their length.

It is equally necessary to provide a good system of distribution of heat as to get a good regeneration.

Slowness of travel and opportunity for the heat to pass through the material separating the waste gases from the air to be heated is the main point to be observed in designing regenerative furnaces.

A large number of inlets for secondary air and for CO from generator is advisable in combustion chamber arranged so that an intimate admixture may take place.

The principal point to aim at in regenerator settings is to have an equal distribution of the secondary air and the gas along the line of the setting, so that combustion may be taking place in many places instead of in one only.

Long passages for the warming of secondary air not necessary, as dry air quickly absorbs heat when in contact with hot surfaces.

The combustion chamber should be sufficiently large to prevent any flames passing into the flues.

Roomy combustion chambers assist in equal distribution of high heats.

Heat should be applied at the bottom of a retort, where the coal lies, rather than to the top and sides, where it would injure the Illuminating Power of the gas passing out.

Only a slightly excess quantity of secondary air above the theoretical suffices to cause complete combustion of the gases in the combustion chamber.

About one fourth the available heat is produced in the generator of a regenerator setting.

It has been suggested that the steam used at the bottom of a regenerative furnace should be superheated by passing through pipes surrounding the ash-pit.

Flues should be built of best firebricks only, and made absolutely tight, all cracks being repaired immediately noticed.

Pressure on retorts should be reduced by fixing large-sized mains and avoiding all obstructions, and, if necessary, counterbalancing the gasholders in works where no exhauster is provided.

Main Flues are generally 450 square inches in small works, increasing to 1,500 square inches in large works.

Chimney required for 2,000,000 per day retort house, 4 feet 6 inches square inside and about 113 feet high. (A. Colson.)

Chimney area per ton of coal per day should equal 24 square inches.

Another rule says the flue and chimney area should be from 30 to 40 square inches per ton of coal carbonised per diem.

The flue entrance from each furnace should be about 12 inches square.

One square inch of damper space per mouthpiece usually sufficient if draught is good.

Good or bad chimney construction may cause a difference of 50 per cent. in the fuel account.

It is said that firebricks will increase the pull upon a chimney 33 per cent. over that where common red bricks are in use, and 66 per cent. over that where stonework is employed. This is probably owing to the excellent non-conducting properties of firebricks.

Chimneys from retort benches need only be lined with firebricks.

A draught of from $\frac{8}{10}$ inch to $\frac{10}{10}$ inch necessary for high heats.

Chimneys to each bed allow an easy regulation of draught, but the same effect may be gained by the use of shield plates or thin walls, to direct the gases in all cases towards the chimney, and the use of a damper to each setting.

Division plates should also be fixed at the entrance to the chimney when currents of gases are meeting from each side. In all cases avoid collision between gases going in different directions. Chimneys of ample dimensions without a division plate have often proved inadequate when settings on each side have been alight.

A division wall carried up some 8 feet in the middle of a chimney having flues in each side serves to give the gases an upward current before meeting.

Fit up a small pipe in bottom of retort house chimney to attach a pressure gauge to indicate the vacuum in chimney. Nine-tenths equals moderate draught.

Lightning conductors should be of copper, $\frac{1}{2}$ inch diameter, or in bands, say $1\frac{1}{2}$ inch by $\frac{1}{3}$ inch—the latter for preference. If of iron, either 1 inch round rods or in bands say 2 inch by $\frac{3}{8}$ inch.

Newbigging's rule for retort house chimneys under 70 feet high equals $1\frac{1}{2}$ square inch area per lineal foot of retort, or 15 square inches per mouthpiece.

Hydraulic Mains.

The size of the hydraulic main should be such as to allow of a sufficiency of liquid to rise in the dip pipes up to the maximum back pressure likely to occur.

It is absolutely necessary that the hydraulic main be kept level.

Hydraulic mains should be large, and separated as to water level for each bench, and made easily cleanable.

The hydraulic main should be sufficiently far from the bench, so that the heat of the latter may not form pitch in the former.

Provide plenty of handholes in hydraulic mains for removal of tar and pitch.

The heavy tar in the hydraulic mains, if kept long in contact with the gas, is liable to rob it of its lighter hydrocarbons, but if the gas be cooled gradually with the lighter tar, which would be deposited by it between 150° and 100° F., for a time the gas may absorb some of the lighter hydrocarbons, which, with rapid cooling and separation from the tar, would be lost, and in this way deposition of napthalene in mains and services may be avoided.

Hydraulic mains should never be supported from the brickwork of the settings, as the unequal expansion of the latter causes them to rapidly get out of level, and the seals of the different dip pipes are thereby altered. They can be supported by rolled joists, which at the same time form the tie-rods at top of the bench, or upon brackets upon the upright buckstaves, or on cast iron columns in front of the bench division walls. The hydraulic main is sometimes fixed immediately over the rising pipes, but it then becomes subjected to considerable heat, and also prevents the easy cleaning of the ascension pipes.

A perforated plate is often used in the hydraulic main to help to separate the tar by friction.

A weir arrangement at the end of the hydraulic main, which reaches nearly to the bottom and is above the level of the liquor and just in front of the overflow, permits only the heavier liquid to run away, and consequently the seal remains a light one. The overflow should be square, and not round, so that the liquid can easily flow away.

The thickness of ascension pipes may be kept down to $\frac{3}{8}$ inch without any detriment to their usefulness.

Jointing for Ascension Pipes.—Slaked lime or fireclay well pressed down.

Curves in rising and arch pipes should be as gradual as possible.

Keep all curves in arch pipes gradual, as sharp corners produce stoppages.

Ascension pipes should be at least 8 inches from face of brickwork.

Weight of 6-inch pipes and bends in ascension dip bridge pipes and covers to a setting of nine retorts 21 inches by 15 inches; hydraulic main cover 9 feet $3\frac{3}{8}$ inches from under side of top of upper mouthpiece equals 4 tons 0 cwt. 3 qrs. 9 lbs.

Dip pipes should be carried to, say, within 3 inches of the bottom of hydraulic main, so as to keep the liquid agitated at this portion of the main.

If the dip of the pipes in the hydraulic be kept at $\frac{3}{4}$ inch, and provision made for a water seal instead of a tar one, most of the objections to dip pipes are removed.

Four or 5 inches of liquid is quite sufficient in the bottom of the hydraulic main, as then the whole of the liquor and tar is kept agitated by the passage of the gas, and the deposition of thick tar prevented, and constant cleaning out rendered unnecessary.

Dip Pipes with light seals give equal results to anti-dip pipes. (W. A. Valon.)

Mr. Valon has abandoned anti-dip pipes for $\frac{1}{2}$-inch seal, which he considers better, as, if the former were used, leaking retorts from over-exhaustion are very frequent.

The advantages of removing the dip-pipe seals:—Improved illuminating power, increased yield of gas, less carbon deposits and napthalene, better utilisation of the heats, longer life of the retorts, fewer stoppages in the ascension pipes, &c. (Ulysse André.)

A mouthpiece for a 21-inch by 15-inch D retort weighs about 3 cwt. 1 qr. 9 lbs. (this is with a 6-inch round hole on upper side for outlet and four holes for fixing flange of rising pipe with bolts). Lid, cross-bar lever, &c. (Morton's lids) weigh about 78 lbs. for same mouthpiece.

Joints in dip and rising pipes in sockets may be made with fireclay and iron borings wetted with ammoniacal liquor.

Join iron mouthpiece to clay retort with fireclay, iron borings, and sal-ammoniac.

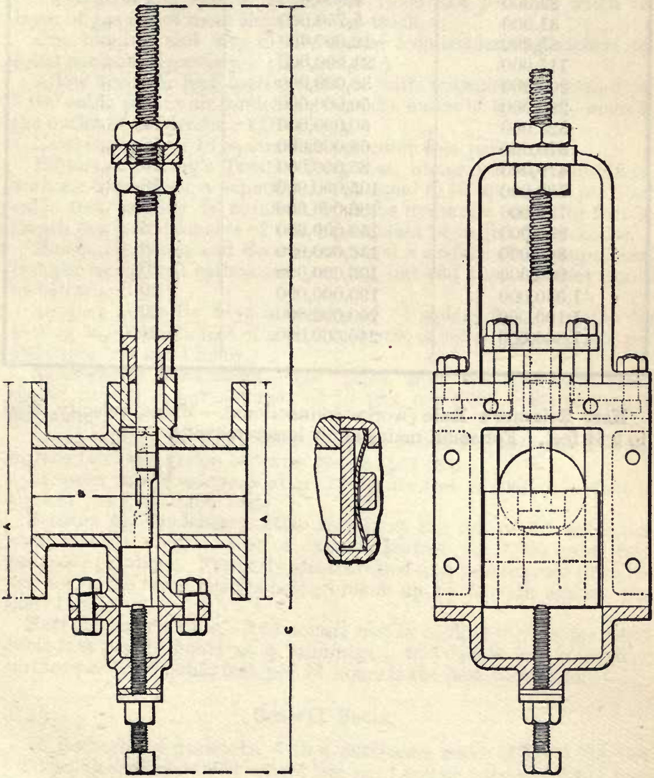
Fireclay and iron borings wetted with ammoniacal liquor may be used on all socket joints as well as mouthpieces.

Foul main temperature often 130° F.

Foul main area should equal 125 per cent. area of connections in works.

The gas, on leaving the hydraulic main, should be allowed to flow slowly, and be kept at a temperature of about 140° F. in the collecting main; then the small proportion of benzol serves to arrest the napthalene in the condensers. (MM. Delsaux and Renard.)

Hydraulic Main Valve.



Size of Connections Usual in Gasworks.

Make per Day.	Make per Annum.	Diameter of Connections.
22,000	4,000,000	4 inches.
31,000	5,750,000	6 "
65,000	12,000,000	8 "
115,000	21,000,000	10 "
208,000	38,000,000	12 "
285,000	50,000,000	14 "
325,000	60,000,000	14 "
370,000	68,000,000	16 "
470,000	85,000,000	16 "
580,000	105,000,000	18 "
720,000	130,000,000	18 "
830,000	150,000,000	18 "
865,000	156,000,000	18 "
900,000	165,000,000	20 "
1,050,000	190,000,000	20 "
1,100,000	200,000,000	20 "
1,300,000	240,000,000	24 "

Herr Reissner's Rule (works connections).—Mains, velocity, 6·56 to 9·84 feet. For small mains allow lesser velocity.

CONDENSERS.

Wyatt's Rule.—136 cubic feet of structure inside walls, 850 to 1,000 gallons per diem.

Clegg gives 150 superficial feet per 1,000 feet per hour when the layer of gas is not more than 3 inches thick.

One hundred and fifty to 200 square feet condensing surface per 1,000 per hour necessary. (Butterfield.)

Allow 5 square feet cooling surface with wrought iron mains per 1,000 cubic feet in air condensers from the outlet of hydraulic main to the outlet of condenser. (Herring.)

Newbigging says 10 square feet per cubic foot per minute.

Editors of "King's Treatise" say that, under ordinary conditions, with air condensers, a superficial area equal to 10 square feet per 1,000 cubic feet per day is required from the hydraulic main, 20 feet of length per inch diameter of this pipe should be in the retort house.

Messrs. Dempster and Sons recommend a surface of 100 superficial feet per ton of coal carbonised per day, but add that 120 feet would be better.

Another authority says a surface of 54 square feet is ample for cooling 35,000 cubic feet of gas in 24 hours, equal to 1 square foot per 650 cubic feet in 24 hours.

Atmospheric Condensers.—The pipes from the hydraulic main should have a superficial area of 10 feet per 1,000 cubic feet made per diem.

Area required for condensation equals about 4 square feet cooling surface (air) per gallon of water yielded per ton.

In water tube condensers about 2½ square feet of cooling surface is allowed per 1,000 cubic feet.

Beckton Air Condensers.—Gas travels at the rate of 6·3 miles per hour, and has 4 square feet of exposed surface per 1,000 cubic feet gas made per diem. Formerly gas travelled at a greater rate (9 miles per hour), the tarry vesicles being broken up by friction against the side of main.

Herr Reissner's Rule.—3·65 square feet of cooling surface per 1,000 cubic feet per 24 hours as a minimum. 4·56 square feet of cooling surface per 1,000 cubic feet per 24 hours is the best allowance.

General Notes.

At Rotherhithe gasworks, with a maximum make of 5,000,000, the condensing surface is 6·76 square feet per 1,000 and the speed 655 feet per minute, but the final removal of tar is not effected until the gas reaches the washers.

Long pipe condensers, through which gas passes rapidly, will break up the tarry vesicles by the friction on the sides of the pipes, the rate of travel at Beckton being 15 to 20 miles per hour. Another method is to pass the gas three or four times through a series of fine orifices, causing it to impinge on a plate. This also breaks up the vesicles.

Another plan is to pass the gas slowly through large pipes and gradually cool and condense the tarry vesicles. Speed, say one mile per hour.

It is said that slow condensation, say four or five miles per hour, causes a decrease in the deposition of napthalene.

With annular condensers the inner air pipes should be fitted with valves to regulate the quantity of air passing through and to prevent undue condensation of the gas.

Excess of Temperature of Gas.	Quantity of Heat Lost by a Square Unit of Exterior Surface. Air.	Water.
10° F.	8	88
20°	18	266
30°	29	5,353
40°	40	8,944
50°	53	1,3437

(Peclet.)

Condensation should be sufficiently complete to clear the gas of any redundant napthalene vapours, but should not be carried so far as to take out the hydrocarbons so necessary for increasing its illuminating power. Contact of the gas with the tar should be as limited as possible, as this substance has been proved incontestably to cause dissolution of the light-giving hydrocarbons.

Gas should be cooled down to a temperature equal to, or even below, that of the coldest appliance it would have to traverse in its passage to the burner.

"The temperature of the gas should be rapidly brought down to about 60° F." (MM. Delseaux and Renard.)

Another authority says:—"Gas should be cooled very slowly, and not below 50° F., or some of the lighter hydrocarbons will be deposited."

If napthalene in dangerous preponderance is to be kept out of the gas, good condensation must be adopted, and maintained uniformly. It is possible to select a gas coal or mixture of gas coals which will yield a good illuminating gas with a fair minimum of napthalene. The specific gravity of the tar affords a fair criterion of the amount of napthalene present in the tar.

"Mere cooling by unobstructed flow through pipes and chambers will not deprive gas of the whole of its suspended tar—its complete removal being only effected by means of friction." (A. F. Browne.)

"To prevent tar going forward to the scrubber, fix some wooden discs with holes of varying size, according to the make of gas, and between them some grids constructed of 1-inch and ½-inch bars set ⅜ inch apart, so that the whole of the gas as made is forced through the hole in the disc and impinges upon the iron grids." (W. R. Cooper.)

At 14 inches pressure 9,000 cubic feet of gas per hour will pass through a hole 1 square inch area.

So long as the temperature of the tar is above 90° F. there is no fear of clogging of perforated plates used for separation of tar from liquor, the plates being said to increase the illuminating power owing to the retention of the napthalene vapour.

After the tar has been separated from the gas it is well to ensure a prolonged association of the gas with its aqueous vapour, which, when later on condensed, consists of 8 or 9 oz. liquor containing much CO_2 and H_2S.

Tarry vapours are more easily condensible under pressure.

It has been proposed to use atmospheric condensers sufficient for mid-winter use, and supplement these in summer by the use of water-tube condensers.

Friction tends to the deposition of napthalene, especially at low temperatures; therefore anything rough on inside of pipe should be removed and easy bends always used where possible. Small mains likewise cause deposition of napthalene.

Condenser mains should have a fall of 1 inch per 9 feet length.

The weight of wrought iron mains is only about one fourth to one fifth that of cast iron mains of equal calibre, and they are quite strong enough for use above ground and where they can be examined for rusting, &c., and above moderate sizes are cheaper than cast iron.

Works mains may be made of wrought iron or steel, 20 feet long, with L iron flange joints.

Byepasses should be fixed to each piece of apparatus in the works.

All valves and blank flanges in works should have wells dug out around them with brick or timber sides, and timbers laid over them with ½-inch blocks to keep them slightly apart.

Cost of fitting up 12-inch pipes, eight tiers high, to form condensers, 7½*d.* per yard run of pipe (1893); this included fixing vertical struts and making lead joints.

A small balanced holder at outlet of condensers serves to prevent any oscillation on the retorts, and is especially useful where more than one retort house is worked from one exhauster.

Give mains in works inclination of from ½ inch to 1 inch per pipe.

Allow a fall of 1 inch in 9 feet in works mains containing much tar.

Newcastle coal yields about 12 gallons water per ton.
Derbyshire „ „ „ 26 „ „ „ „

TAR TANKS—LIQUOR TANKS.

Tar and liquor tanks should be of sufficient capacity to hold 850 gallons per ton per day; or, say, five or six weeks' make.

Tar and liquor storage for 2,000,000 plant, 500,000 gallons, or four weeks' make. (A. Colson.)

One ton coal makes about 28 gallons 10 ounces liquor.

Allow not less than space for six weeks' production in tar and liquor tanks.

Tar and liquor tanks should equal four to six weeks' stock as a minimum. (Herring.)

Cover tar and liquor tanks to prevent escape of the ammonia gas, and danger from fire.

BOILERS, ENGINES, PUMPS, AND EXHAUSTERS.

Exhauster Plant.

A horse-power (H.P.) is the quantity of work equivalent to the raising of 33,000 lbs. through 1 foot in 1 minute, or to equivalent motion against resistance.

This is the usual unit by which the power of any steam engine is calculated.

To calculate horse-power of any engine :—

P = The mean effective pressure of steam in lbs. per square inch.

A = The area of the piston in square inches. If the piston rod runs through cylinder its area should be deducted ; if only on one side of piston, half the area should be deducted.

L = Length of stroke in feet.

N = Number of strokes per minute = revolution per minute × 2.

H.P. = Horse-power of engine

$$H.P. = \frac{PLAN}{33,000}$$

Nominal horse-power (N.H.P.).—Ten circular inches of piston-area are usually provided for each N.H.P.

Brake horse-power (B.H.P.) is the actual power given off by an engine at the end of its crank shaft or rim of flywheel.

Unit of heat, or British Thermal Unit (B.T.U.), is the amount of heat required to raise 1 lb. of water 1° at 39·1°

Joule's mechanical equivalent of heat equals 778 foot-pounds.

To raise 1 lb. of water 1° F. requires the same energy as to lift 1 lb. weight through a height of 778 feet, or 778 lbs. 1 foot.

Mechanical efficiency of a steam engine, about 85 to 90 per cent.

Thermal	„	„	„	„	10 to 14	„
Thermal	„	gas	„	„	18 to 23	„

Wyatt's Rule.—120 cubic feet of building to house boilers and details, and floor area 385 superficial feet per ton per day. Cubical contents of boilers (net outside measurements) not less than 5 cubic feet per ton per day.

To house engines and exhausters 105 cubic feet, or 3 square feet per ton per diem.

Herr Reissner's Rule.—Exhausters. Have one in reserve at each works.

Horse Power Required to Give 24 Inches Pressure.
(Gwynne & Co.)

Cubic Feet per Hour.	H.P. Required.	Revolutions per Minute.	Cubic Feet per Hour.	H.P. Required.	Revolutions per Minute.
2,200	½	250	63,000	6	75
3,000	½	250	68,200	7	75
5,300	1	230	73,500	7	75
10,500	1	200	78,700	8	75
15,700	2	150	84,000	8	70
21,000	2	100	94,500	9	70
26,200	3	95	105,000	10	68
31,500	3	85	126,000	12	63
36,700	4	85	147,000	15	61
42,000	4	85	160,000	16	60
47,200	5	84	180,000	19	60
52,500	5	80	210,000	20	60
57,700	6	75	300,000	30	60

Exhausters improve the yield of gas about 11 per cent. without deteriorating the quality, and with cannel coals the improvement is still greater.

Exhausters should work with a minimum amount of power, and have as few parts to get out of order as possible, and at the same time give a steady pull without oscillation.

Exhausters only pass 75 per cent. of estimated quantity by measurement.

Theoretical Horse-Power Required to pass Gas at Various Pressures without any Allowance for Friction of Exhauster.
(Edwin B. Donkin, 1894.)

Size.	Total Pressure of Gas in Inches of Water.										
	6 In.	9 In.	12 In.	15 In.	18 In.	20 In.	24 In.	30 In.	36 In.	40 In.	50 In.
5,000	0·08	0·12	0·16	0·19	0·24	0·26	0·31	0·39	0·47	0·53	0·66
10,000	0·16	0·24	0·31	0·39	0·47	0·53	0·63	0·79	0·95	1·05	1·31
15,000	0·24	0·36	0·47	0·58	0·71	0·79	0·94	1·18	1·42	1·58	1·97
20,000	0·31	0·47	0·63	0·79	0·95	1·05	1·26	1·58	1·90	2·10	2·63
25,000	0·39	0·59	0·79	0·98	1·18	1·31	1·58	1·97	2·37	2·63	3·29
30,000	0·48	0·71	0·94	1·18	1·42	1·57	1·89	2·36	2·83	3·15	3·94
40,000	0·62	0·94	1·26	1·58	1·90	2·10	2·52	3·15	3·78	4·21	5·26
50,000	0·79	1·18	1·58	1·97	2·36	2·63	3·15	3·94	4·73	5·25	6·57
60,000	0·94	1·41	1·89	2·36	2·84	3·15	3·79	4·73	5·67	6.30	7·89
80,000	1·24	1·84	2·52	3·16	3·80	4·20	5·04	6·30	7·56	8·42	10·5
100,000	1·58	2·37	3·16	3·94	4·73	5·26	6·31	7·89	9·47	10·5	13·15
150,000	2·37	3·54	4·72	5·90	7·09	7·87	9·46	11·8	14·2	15·8	19·7
200,000	3·16	4·74	6·32	7·88	9·46	10·5	12·6	15·8	18·9	21·0	26·3
250,000	3·95	5·92	7·90	9·85	11·8	13·1	15·7	19·7	23·6	26·2	32·9
300,000	4·74	7·11	9·48	11·8	14·1	15·7	18·9	23·6	28·4	31·5	39·4

Percentage to add to power shown on previous tables to ascertain horse-power required to drive exhausters at various pressures—

10,000 at 12 inches pressure	. .	100 per cent.
20,000 „ 18 „ „	. . .	90 „ „
50,000 „ 24 „ „	. . .	70 „ „
100,000 „ 30 „ „	. . .	50 „ „
200,000 „ 36 „ „	. . .	45 „ „
300,000 „ 50 „ „	. . .	40 „ „

Sizes of Cylinders of Steam Engines required to drive exhauster, allowing 25 per cent. to 35 per cent. margin over power shown by previous tables.

Size of Exhauster.		20,000	30,000	40,000	50,000	80,000	100,000	150,000	200,000
Gas pressure		In. 18	In. 20	In. 22	In. 24	In. 26	In. 30	In. 33	In. 36
Boiler „ 40	diameter	$4\frac{1}{2}$	6	6	7	10	$10\frac{1}{2}$	12	14
	stroke	$4\frac{1}{2}$	6	12	12	14	15	18	18
„ „ 60	diameter		—	—	6	$8\frac{1}{2}$	10	$10\frac{1}{2}$	12
	stroke		—	—	12	14	14	15	18
„ „ 80	diameter		—	—	—	7	$8\frac{1}{2}$	10	10
	stroke		—	—	—	12	14	14	18

In calculating size of exhauster required, the maximum rate of gas made per hour having been ascertained, 20 per cent. to 25 per cent. should be added to allow for the extra flow after the retorts are freshly charged, allowing also for the difference in temperature between gas at exhauster and at station meter. If a byepass is used to regulate the pressure or exhaust, a further percentage should be added, varying with the amount of the difference of pressure and exhaust.

In the best modern type of engine and good boiler, the combined efficiency is only 14·01 per cent. or $\frac{1}{7}$th of the heat value of the fuel used.

10 per cent. to 20 per cent. can be saved by properly applied steam jackets to engine cylinders. Covers should also be steam jacketed.

In the cylinder of a non-condensing steam engine, with saturated steam at 60 lbs. pressure, the temperature is 293° F., and at 100 lbs. pressure 338° F.

Thickness of engine cylinders =

$$\frac{\text{diameter} \times \text{pressure of steam in lbs. per square inch}}{\text{2,400 if vertical, or 2,000 if horizontal}}$$

or,

$$T = \frac{dp}{4000} + \frac{1}{2}$$

or,

$$T = \frac{\sqrt{d}}{5} + \frac{3}{200}d$$

Ends = T × 1·2

Effective Pressure of Steam upon Piston Surface.

Boiler pressure assumed at 100 lbs. per square inch. Different rates of expansions.

					Effective Pressure.
Steam	cut off at	$\frac{3}{4}$	of stroke	=	90 lbs.
,,	,,	$\frac{2}{3}$	,,	=	80 ,,
,,	,,	$\frac{1}{2}$	,,	=	69 ,,
,,	,,	$\frac{1}{3}$	,,	=	50 ,,
,,	,,	$\frac{1}{4}$	,,	=	40 ,,

To Calculate the Indicated Horse-Power of a Steam Engine.

Radius of cylinder^2 equals I.H.P. at 42 lbs. mean pressure and 250 feet per minute piston speed.

Any other pressure and speed may be calculated from above by direct proportion.

Proportions of Indicated Horse-Power of Lancashire and Cornish Boilers.

Kind of Boiler.	Diameter Ft.	Diameter Ins.	Length. Ft.	Length. Ins.	No. and Diameter of Flues. Ins.	Length of Grate. Ft.	Length of Grate. Ins.	Grate Area in Square Feet.	Heating Surface Square Feet.	Ratio of Grate Area to Heating Surface.	Approximate I.H.P. at 60 lbs. Sq. In. High Pressure Engines.		Grate Area per I.H.P. Sq. Ft.	Heating Surface per I.H.P. Sq. Ft.	Coal burned per Hour in Lbs.	Coal per Hour in Lbs. per Sq. Ft. of Grate Area.	Water Evaporated per Hour in Lbs.	Water Evaporated in Lbs. per Sq. Ft. Heating Surface.	Water Evaporated in Lbs. per Hour per I.H.P.	Water Evaporated in Lbs. per 1 lb. of Coal from feed at Various Temperatures.	Coal burned in Lbs. per Hour per I.H.P.	Remarks.
Lancashire	8	0	32	0	2 at 39	6	6	42·25	1171	27·7 to 1	160	For condensing engines—I.H.P. given × 1·4 = I.H.P. approximate. For compound ,, × 1·8 = I.H.P.	·26	7·3	718	17·	5,774	4·9	For compound engines 18 lbs. water evapord. per I.H.P. per hr. For condensing ,, 26 lbs. ,, ,, For high pressure ,, 36 lbs. ,, ,,	8 lbs. of water evaporated per 1 lb. of coal from feed at 52°. 8·3 lbs. ,, ,, ,, ,, 100°. 9 lbs. ,, ,, ,, ,, 180°. 9·3 lbs. ,, ,, ,, ,, 212°.	For compound engines 2·25 lbs. of coal per hour per I.H.P. For condensing ,, 3·25 lbs. ,, ,, For high pressure ,, 4·5 lbs. ,, ,,	This Table has been compiled as an aid in proving boiler power for a given I.H.P. of engine, the duty allotted to the boiler being well WITHIN ITS CAPACITY IF IN FAIR WORKING ORDER.
,,	7	6	30	0	2 ,, 36	6	6	39·	974	25· ,, 1	139		·28	7·0	624	16·	4,992	5·1				
,,	7	0	28	0	2 ,, 33	6	0	33·	839	25· ,, 1	117		·28	7·17	528	16·	4,224	5·0				
,,	6	9	26	0	2 ,, 31	6	0	31·4	744	23·7 ,, 1	101		·31	7·3	455	14·5	3,640	4·9				
,,	6	6	24	0	2 ,, 30	5	6	27·5	660	24· ,, 1	88		·31	7·5	398	14·5	3,184	4·82				
,,	6	0	22	0	2 ,, 27	5	6	24·75	543	22· ,, 1	72		·34	7·5	322	13·	2,576	4·74				
Cornish	5	9	22	0	1 ,, 36	6	0	18·	446	24·8 ,, 1	64		·28	7·0	288	16·	2,304	5.16				
,,	5	6	22	0	1 ,, 36						61											
,,	5	6	20	0	1 ,, 35	5	6	16·	389	24· ,, 1	57		·28	7·0	256	16·	2,048	5·2				
,,	5	0	18	0	1 ,, 33	5	0	13·75	321	23·3 ,, 1	49		·28	6·5	220	16·	1,760	5·48				
,,	4	9	16	0	1 ,, 31	4	6	11·6	261	22·5 ,, 1	37		·31	7·6	168	14·5	1,344	5·15				
,,	4	6	14	0	1 ,, 29	4	0	9·6	222	23· ,, 1	31		·31	7·16	139	14·5	1,112	5·0				
,,	4	0	12	0	1 ,, 26	4	0	8·64	168	19·5 ,, 1	25		·34	6·72	112	13·	898	5·32				
,,	3	9	10	0	1 ,, 24	3	6	7·0	130	18·7 ,, 1	18		·39	7·2	80	11·5	644	5·0				
,,	3	6	9	0	1 ,, 22	3	6	6·4	106	16·6 ,, 1	16		·4	6·65	74	11·5	592	5.58				

The heating surface is obtained by taking the whole area of flue + $\frac{2}{3}$ area of one end (without deducting area of end of flue) + $\frac{5}{9}$ area of cylindrical area of shell.

Proportions of Steam Boilers per Nominal Horse-Power.

1 cubic foot water per hour.
1 square yard of heating surface.
1 ,, foot of fire grate surface.
1 cubic yard capacity.
28 square inches of flue area.
18 ,, ,, ,, ,, ,, over bridge.
$13\frac{1}{2}$,, ,, of chimney area.

$$\frac{L \times D \text{ (in feet)}}{6} = \text{H.P. nominal of any boiler approximately.}$$

Equation for Examining the Data when Designing a Steam Boiler. (Prof. A. Huet.)

Pounds coal burnt per hour . .	per	1 square foot grate surface.
Grate surface	per	boiler heating surface.
Boiler heating surface square feet	per	pounds water evaporated per hour.
Pounds water evaporated . .	per	pounds coal burnt.
Total	should equal	Total

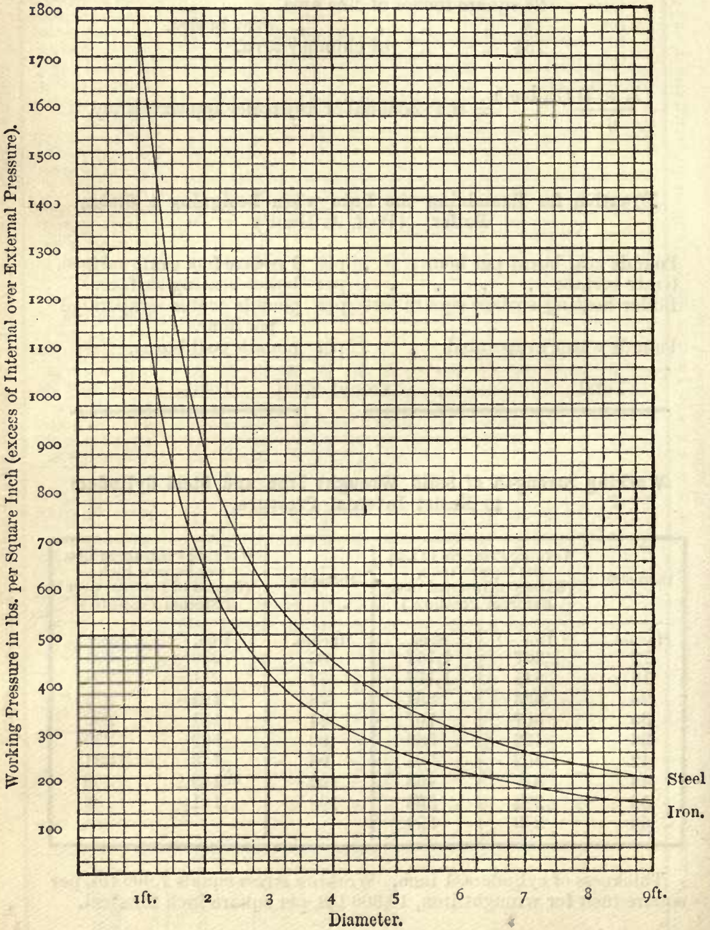
Working Strength of Solid Wrought Iron and Steel Cylinders to Resist Internal Pressure.

Diameter.	Working Pressure in Lbs. per Square Inch. (Excess of Internal over External Pressure.)		Diameter.	Working Pressure in Lbs. per Square Inch. (Excess of Internal over External Pressure.)	
Inches.	Iron.	Steel.	Inches.	Iron.	Steel.
12	1,267	1,767	66	230	321
18	845	1,177	72	211	294
24	633	884	78	195	272
30	507	707	84	181	252
36	422	589	90	169	235
42	362	505	96	158	221
48	317	463	102	149	208
54	282	393	108	141	196
60	253	354			

Thickness of cylinders, 1 inch. Working stress equals 7,600 lbs. per square inch for wrought iron, 10,600 lbs. per square inch for steel.

Diagram showing Working Strength of Solid Wrought Iron and Steel Cylinders to Resist Internal Pressure per 1 inch thick.

(Deduced from Unwin.)



Notes on Lancashire Boilers. (M. Longridge.)

Abandon 6 feet grates if a shorter length will burn coal at 16 to 21 lbs. per hour.

Reduce draught as much as the fuel will permit.

Obtain and use dry fuel and weigh ashes as well as fuel used.

Stop all leaks in boiler settings.

Aim to keep up CO_2 in chimney to 10 or 11 per cent.

The hotter the furnace the better.

An ordinary furnace requires 24 lbs. of air or 300 cubic feet of air for the consumption of each 1 lb. of coal ; if a blast or steam jet is used this may be reduced to 18 lbs. or 220 cubic feet.

From 13 to 20 lbs. of coal may be consumed per square foot of fire grate ; $\frac{3}{4}$ foot of fire grate required to evaporate 1 cubic foot of water.

Strength of Boilers.

Bursting strength of shell : $P = \frac{T \times C}{4D}$

Where—

P = bursting pressure in lbs. per square inch.
T = thickness of plate in sixteenths of an inch.
D = diameter of shell in feet.

C = for wrought iron	(single riveting)	1,097
" " "	(double ")	1,372
" steel	(" ")	2,156
" "	(single ")	1,722

Collapsing pressure of tubes : $P = \frac{87{\cdot}4 \times T^2}{L \times D}$

Where—

P = collapsing pressure in lbs. per square inch.
T = thickness of tube in thirty-seconds of an inch.
L = length in feet.
D = diameter in inches.

Thickness of fire bars, $\frac{1}{2}$ to $\frac{3}{4}$ inch ; space, $\frac{3}{8}$ to $\frac{1}{2}$ inch ; inclination of bars, 1 in 10 to 1 in 12 ; height of dead plate above floor, 2 feet 8 inches ; minimum height of water over flue, 4 inches ; average height of water over flue, 9 inches ; inclination of boiler towards blow-off cock in setting, $\frac{1}{2}$ inch in 10 feet.

Cornish or Lancashire boilers firegrate area $\times$ 4 = H. P.

Cornish or Lancashire boilers usually require 7 square feet heating surface per horse-power. Heating surface should be 20 times, and never less than 10 times, firegrate area ; or,

$$H.P. = \frac{\text{Diameter of cylinder in inches}^2 \times \sqrt[3]{\text{stroke in inches}}}{3{\cdot}25}$$

If more than one cylinder D^2 = sum of the squares of the diameters of the pistons.

Approximate rule for the nominal horse-power of cylindrical two-flued boiler is $\frac{L^1 \times D^1}{6} = \text{H.P.}$

Safe Pressure on a Circular Boiler.

$$P = \frac{2tfv}{dk}$$

P = safe pressure in pounds per square inch.
t = thickness of shell in inches.
f = tensile strength of plate in pounds per square inch.
f { = for ordinary iron boiler plates, 20 tons.
  = for steel boiler plates, 28 tons.
d = diameter of boiler in inches.
k = in ordinary cases 6. k = factor of safety.
r { = for single riveting 40 per cent.
  = for double riveting 60 per cent.
  = for butt joints 70 per cent.
v = efficiency of the riveted joints.

Pressure in Boilers.

Circumferential bursting pressure is numerically equal to the area of the end × the pressure per square inch.

Bursting pressure longitudinally equals pressure per square inch × diameter in inches.

In a cylindrical shell the intensity of longitudinal stress is only half as great as the intensity of circumferential stress.

Safe Working Pressure on Boiler Furnace Tubes.

$$P = \frac{C \times t^2}{(L + 1) \times D}$$

P should not exceed $\frac{8{,}000\,t}{D}$

P = safe pressure.
t = thickness of plate in inches.
L = length of tube in feet.
C = 60,000 if seams are lap-jointed, single riveted, and punched.
D = diameter of tube in inches.

Safe Working Pressure on Iron Tubes (M. Longridge.)

lbs. per square inch working pressure = $\frac{50t^2}{d\sqrt{L}}$

t = thickness in 32nds inch.
d = diameter in inches.
L = length of tubes in feet.

Duty Obtained from Coke-Fired Water-Tube Boilers.

Evaporative duty per pound coke = 10·05 lbs. water.
Mean steam pressure per square inch = 143·3 lbs.
Mean temperature of feed-water = 185° F.
Mean temperature of waste gases = 527° F.
Air supplied per pound of combustible = 22·39 lbs.
Coke used = ashes and cinders = 8·26 per cent.
Coke used = calorific value per pound = 13,186·98 British thermal units.
Heat communicated to water = 79·21 per cent.

A Flaw in the Thickness of a Boiler Plate or the least separation between two plates when bolted together is almost sure, if exposed to too strong a heat, to cause injury to the boiler.

Rate of Transmission of Corrected Heat through metal plates equals 2 to 5 British thermal units per hour per square foot of surface per 1° F. of difference of temperature. (D. K. Clark.)

A Boiler is said to have been Overheated when the boiler plate has become red hot at any given spot, and the phenomenon is recognised by the bluish shade the iron assumes when cold, due to the formation of a layer of oxide. Overheating alters the quality of the metal and disintegrates the joints, and, unless at once detected and remedied, it ultimately results in an explosion.

The reason generally assigned is an insufficient supply of feed-water.

If the boiler plates overlap, the transmission of heat is more or less impeded. Even a well made joint ought not to be exposed to too fierce a fire. (J. Hirsch.)

Proportion of Riveted Joints of Maximum Strength.

(D. K. Clark.)

Thickness of plate	= 1
Diameter of rivets	= 2
Pitch of rivets (single)	= 5⅓
Pitch of rivets (double)	= 8
Diagonal pitch of rivets (double)	= 6
Spacing (double)	= 4½
Lap (single)	= 6
Lap (double)	= 10½

Single riveted joint = about ·56 of the plate.
Double " " = " ·7 " "
Single butt straps should be 1⅛ times as thick as the plates.
Double butt straps should be each ⅝ times as thick as the plates.

Size of Rivets for Various Thicknesses of Boiler Plates.

$\frac{3}{8}$ and $\frac{7}{16}$ inch plates—$\frac{3}{4}$ inch rivets.
$\frac{1}{2}$ " $\frac{9}{16}$ " " —$\frac{13}{16}$ " "
$\frac{11}{16}$ " $\frac{5}{8}$ " " —$\frac{7}{8}$
$\frac{3}{4}$ " 1 " " —$\frac{15}{16}$

Safety Valves.—According to the Board of Trade rules the area of a safety valve for a boiler working at 50 lbs. pressure is 576 square inches per square foot of firegrate.

Another rule is $A = \frac{W}{50\ P} + a$

Where a = area of guides of valve, P = absolute pressure of steam in pounds per square inch, W = weight of steam evaporated per hour in pounds, A = area of valve in square inches.

Theoretically, only 7·5 per cent. of the calories developed in the furnace of a boiler appears as work in the engine. (Hirsch.)

At a rough computation, petroleum burnt as fuel under a boiler should need only three-fifths the storage room of coal for the same duty; and whatever further advantage calcium carbide has in point of compactness is mainly due to the superior efficiency of the gas engine to the steam engine.

A non-condensing engine requires 3 lbs. of coal per I.H.P. per hour.
A condensing " " 2 lbs. " " " "

Set Boilers in mortar made of soft sand 2 parts, lime 1½ parts, sharp sand 1½ parts, except where the bricks or lumps touch the boilers, when fireclay should be used.

Mr. C. Gandon found that the foundations of a boiler made of furnace clinker and cement, with three layers of firebrick bedded in fireclay, had caught fire from the flues, and the whole mass of the foundations was on fire.

Large flues around boilers cause a slow passage of gases.

$$\text{Area of chimney} = \frac{1{\cdot}5\ (\text{area of firegrate in square feet})}{\sqrt{\text{height of chimney in feet}}}$$

Superheaters in boiler flues for superheating steam give a gain of 10 per cent. to 25 per cent., according to type of engine used.

In Lancashire boilers all furnace flue seams should be below the grate bars, longitudinal joints of shell butted and fitted with covers inside and out, double riveted zigzag, with outer rows twice the pitch of the inner ones.

For ordinary draught, when, say, from 20 to 25 lbs. of coal is burnt per hour per square foot of firegrate, the average proportions to allow per I.H.P. are—

⅛ square foot of firegrate.
2½ " of heating surface.
1¼ cubic feet of water space.
¾ " of steam space.

English coal will evaporate 8 to 9·88 lbs. water at and from 212° F.
Scotch coal will evaporate 6·69 lbs. water at and from 212° F.
Fuel consumption per I.H.P. may be anything from 1·3 lbs., according to class of boiler, engine, and method of working.

Boiler Chimneys.

Allow 3½ square feet chimney area for each full-sized Lancashire boiler, or 4 square feet for a single boiler; height of chimney same as others in neighbourhood, preferably not less than 90 feet high.

Dimensions of Chimneys. (R. Wilson.)

Height of Chimney. Feet.	Lbs. of Coal per Hour per 1 Foot Area at Top of Chimney.	Height in Inches of Water Balanced by Draught Pressure.	H.P. of each Square Foot of Chimney at 7 lbs. Coal per H.P.	Area of Top of Chimney in Feet per H.P. for 1 or 2 Boilers.	Area of Top of Chimney in Feet per H.P. where several Boilers work together.	Area of Flue in Feet per H.P.
30	78·24	·218	7·3	·146	·091	·182
40	90·35	·296	8·4	·126	·077	·155
50	101·01	·364	9·4	·113	·070	·140
60	110·65	·437	10·3	·103	·064	·129
70	119·52	·5	11·2	·095	·059	·119
80	127·77	·58	11·9	·089	·055	·111
90	135·52	·656	12·6	·084	·052	·105
100	142·85	·729	13·3	·08	·05	·100
125	159·71	·911	14·9	·071	·044	·089
150	174·96	1·09	16·3	·065	·04	·082
175	188·98	1·26	17·6	·060	·038	·075
200	202·03	1·45	18·8	·056	·035	·070
225	214·28	1·64	20·0	·053	·033	·066
250	225·87	1·82	21·0	·05	·031	·063
275	236·90	1·99	22·0	·048	·03	·06
300	247·43	2·18	23·0	·046	·028	·057

Armstrong proposes from 20 to 40 per cent. above these sizes, and to allow for additions to boilers it would be advisable to exceed above sizes to that extent.

Proportion of Chimneys.

Diameter of base, $\frac{1}{10}$th height.
Brickwork 9 inches thick for the top 25 feet.
Brickwork 14 inches thick from 25 to 50 feet from the top.
Brickwork 18 inches thick from 50 to 75 feet from the top.
Brickwork 23 inches thick from 75 to 100 feet from the top.
Increasing $4\frac{1}{2}$ inches thick for every extra 25 feet.

Rule for Area of Chimney if 21 lbs. of Coal are Consumed per Square Foot Grate Area per Hour.

Area of firegrate, in square feet, $\times 1\frac{1}{2} \div \sqrt{\text{height in feet}} =$ area in square feet.

Or, one-eighth to one-tenth grate area = area of chimney.

Coal Consumed per Hour.	Height of Shaft.
Up to 100 lbs.	60 feet.
„ 500 „	100 „
„ 1,000 „	120 „
„ 2,000 „	140 „
„ 3,000 „	160 „
„ 4,000 „	180 „
„ 5,000 „	200 „

Or, chimneys should batter inside 1 inch in every 10 feet of height.

To Find Size of Chimney Required.

For a low-pressure engine, when above 10 H.P., the area of the chimney in square inches should be 280 times the horse-power of the engine divided by the square root of the height of the chimney in feet. (Joshua Milne, of Oldham.)

Or, multiply the square root of the chimney height in feet by the square of its narrowest internal diameter in feet; half the product will be the horse-power the chimney is equal to.

Or, for circular chimney, the diameter $= \dfrac{90 \times \text{H.P.}}{\sqrt{\text{height in feet}}}$

Or, firegrate should have 1 foot area per horse-power, one-fifth area of firegrate, gradually diminishing to a chimney which shall have one-tenth area of firegrate, is excellent proportion. (Cresy.)

Or, $\dfrac{2 \times 112 \times \text{cubic feet evaporated per hour}}{\sqrt{\text{height in feet}}} =$ square inches area.

Coal Consumable by Chimneys of Different Sizes. (D. K. Clark.)

Chimney.		Coal per Hour.	Grate Area.	Chimney.		Coal per Hour.	Grate Area.
Height.	Diameter.			Height.	Diameter.		
Feet.	Ft. Ins.	Lbs.	Sq. Ft.	Feet.	Ft. Ins.	Lbs.	Sq. Ft.
40	1 4	142	9·5	110	3 8	1777	118·4
50	1 8	248	16·5	120	4 0	2208	147·2
60	2 0	390	26·0	135	4 6	2964	197·6
70	2 4	574	38·3	150	5 0	3858	257·2
80	2 8	801	53·4	165	5 6	4896	326·4
90	3 0	1076	71·7	180	6 0	6086	405·7
100	3 4	1394	93·0	200	6 8	7920	526·6

Diameter = $\frac{1}{30}$th height; coals consumed, 15 lbs. per square foot per hour.

Metropolitan Board of Works Regulations as to Factory Chimneys.

Base of shaft to be solid up to top of footings; projection of footings equal all round, and to thickness of wall at base.

Width of shaft at base, just above footings :—

If square on plan, at least $\frac{1}{10}$th total height.

If octagonal on plan, at least $\frac{1}{11}$th total height.

If circular on plan, at least $\frac{1}{12}$th total height.

Batter at least $2\frac{1}{2}$ inches in every 10 feet, or 1 in 48.

Brickwork at least $8\frac{1}{2}$ inches thick at top and for 20 feet down, and increased $4\frac{1}{2}$ inches for every 20 feet additional height; firebrick lining to be separate, and not included in above thicknesses.

Cornice not to project more than the thickness of walls.

Velocity of gases up the chimney being proportional to the square root of the height, increased duty would be better obtained by larger diameter than by greater height.

The heavier the materials of which a shaft is built the greater would be its stability, the foundations being good.

Batter of chimneys may equal 1 in 36.

Theoretical draught power of chimneys with external air = 60° F.; internal heated air = 580° F. (coefficient in practice ·3).

Height of Chimney in Feet.	Draught in Inches of Water.	Theoretical Velocity in Feet per Second.	
		Cold Air Entering.	Hot Air at Outlet.
50	·367	40·0	80·8
60	·440	43·8	87·6
70	·514	47·3	94·6
80	·587	50·6	101·2
90	·660	53·7	107·4
100	·734	56·6	113·1
120	·880	62·0	123·9
150	1·101	69·3	138·6
175	1·285	74·8	149·6
200	1·468	80·0	160·0
225	1·652	84·8	169·7
250	1·836	89·4	178·9
275	2·020	93·8	187·6
300	2·203	98·0	196·0

(Bancroft.)

The wind pressure on chimney shafts may be taken as acting upon the centre of gravity and in a horizontal direction, and the overturning moment equals the height of the centre of gravity (h) above the point at which it is desired to obtain the strength, as at $a\ b$, × wind pressure on chimney; the least moment of stability must therefore exceed this (*for figure see next page*).

The pressure of the wind will tend to move the centre of pressure on $a\ b$, towards the leeward side.

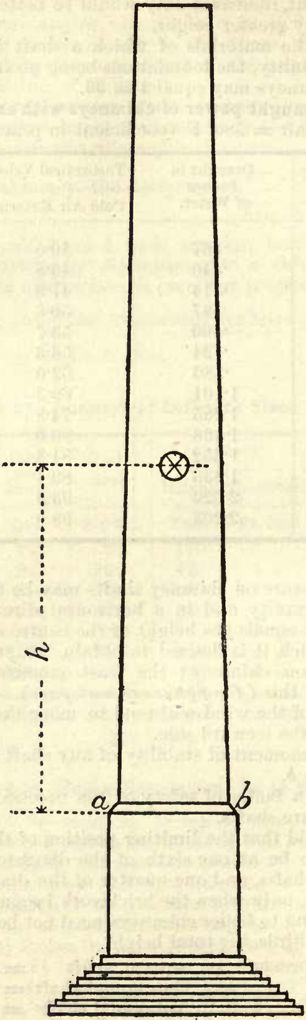
To obtain the moment of stability of any shaft take weight of shaft above $a\ b \times \frac{1}{2}\ a\ b$.

Rankine says a factor of safety of 2 is necessary for round shafts and of $\frac{3}{2}$ for square shafts.

It has been said that the limiting position of the centre of pressure is permissible to be at one sixth of the diameter from the leeward side for square shafts, and one quarter of the diameter from the side for round shafts, only when the brickwork becomes infinitely thin.

Firebrick lining to boiler chimneys need not be more than one half, or at most two thirds, the total height.

If wind pressure on square shaft = 1
then „ „ „ hexagonal shaft = ·75
„ „ „ „ octagonal shaft = ·7
„ „ „ „ circular shaft = ·5 (Bancroft.)


h
a
b

Chimney shafts should not be joined to any other work of buildings, in case of settlement or expansion.

Grouting is not advisable, as wet mortar possesses little adhesive power; and the building should not proceed at a greater rate than 2 feet to 3 feet per diem. Only one course of headers should be used in large chimneys to three or four of stretchers. Capping stones should be light and joined with copper cramps at joints, as iron rusts and expands, when the stone may split and fall.

Stock bricks will bear a heat of 600° F. without damage.

Higher heat at exit of chimney than 580° F. or 305° C. is wasteful.

Less exhaust than $\frac{1}{2}$ inch water bad.

580° F. gives a head of external air equal to half the height of chimney.

By the usual rule, the external diameter at base of chimney should be about $\frac{1}{10}$th of the height, and the batter $\frac{3}{16}$ inch to $\frac{1}{4}$ inch per foot on each side.

It is frequently stated in treatises on chimney designs that the diameter at the base should be $\frac{1}{10}$th to $\frac{1}{12}$th the height, but, having regard to the paramount importance of width of base, the width obtained by this rule is insufficient.

For further remarks on chimney shafts, see Bancroft on "Design of Tall Chimneys."

Lightning Conductors.

Copper is the best; but, when corrosion is not anticipated, iron of larger dimensions may be used (conductivity of iron equals $\frac{1}{5}$th that of copper).

General dimensions of copper conductors :—Rods $\frac{1}{2}$ inch diameter, tubes $\frac{5}{8}$ inch diameter, $\frac{1}{8}$ inch thick; or bands $1\frac{1}{2}$ inch wide $\frac{3}{8}$ inch thick.

General dimensions of iron conductors :—Rods 1 inch diameter, bands 2 inches wide $\times \frac{3}{8}$ inch thick.

Radius of protection of lightning conductors equals height from ground.

Sir William Thomson's (Lord Kelvin's) note advocates the use of the flat (tape or sheet) form of conductor in preference to the tubular or solid; and, if copper be used, its weight should be about 6 oz. to the foot; if iron, about 35 oz. It quotes Lodge's recommendation that the conductor should be connected with the water or gas mains if in any part of its course it goes near them, but concedes that independent grounds are preferable. It gives the usual advice as to electrical connection with masses of metal built into a building, and warns against the neighbourhood of small-bore fusible gas pipes and indoor gas pipes in general. It prefers clusters of points, or groups of two or three, along the ridge rod, to other arrangements, and regards chain or link conductors as of little use. That the area protected is one of a radius equal to twice the height of the rod from the ground, or even, as some conductor manufacturers aver, a radius equal to the height, is denied. No such thing as a definite area exists. That lightning follows the path of least resistance is also controverted, for, in exceptional instances, when the flash is of a certain kind any part of a building is liable to be struck. whether there is a conductor or not.

Lightning may also, contrary to what is generally held, strike twice in the same place. Doorways of barns, chimneys, and fireplaces are dangerous places, but the smaller articles of steel, such as knives, &c., have no influence on the path of discharge. The best made-ground for the earth-plates is, for some flashes, but a very poor one; damp earth or running water are still the best terminations known.

Steam Pipes.

Thickness of steam pipe in 16ths of an inch equals diameter (inches) + 4 up to 100 lbs. pressure.

$$\text{Above this } T = \frac{D\,P}{4{,}000} + \tfrac{1}{2} \qquad T = \text{thickness in inches.}$$

Steam should have a velocity of about 6,000 feet per minute through steam pipes; same for ports of engine.

To find diameter of steam pipes for any engine:

$$\sqrt{\frac{\text{Sq. of cylinder diar. in inches} \times \text{piston speed in feet per min.}}{6{,}000}}$$

= The required diameter of steam pipe.

100 feet of 4-inch pipe would waste as much heat per annum as the consumption of 50 tons of coal would supply. With an efficient lagging it is to be supposed that most, if not all, of this would be saved. (Mr. Geipel.)

Allow 1 inch expansion in 50 feet in steam pipes.

A 4 H.P. engine requires only 2-inch diameter steam connections.

Exhaust Pipe.

To prevent undue back pressure velocity of steam should not be greater than 4,000 feet per minute.

To find diameter of exhaust pipe:

$$\frac{\text{Square of cylinder diameter} \times \text{piston speed in feet per minute}}{4{,}000.}$$

The square root of the quotient gives diameter of pipe in inches; same for ports of engine.

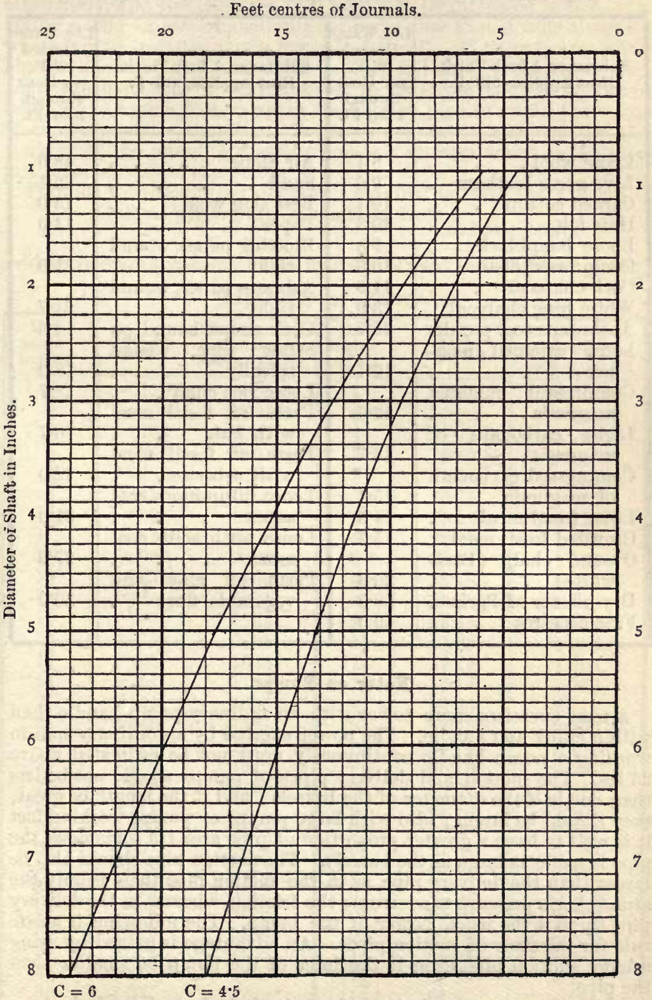
Condensation.

The water required for condensation is about 20 times that required for the feed – approximate area of condensing surface = heating surface × 0·7.

Comparative Efficiency of Non-conducting Materials. (Emery.)

Wood felt	1·000	Loam, dry and open	·550
Mineral wool, No. 2	·832	Slaked lime	·480
" " with tax	·715	Retort carbon	·470
Sawdust	·680	Asbestos	·363
Mineral wool, No. 1	·676	Coal ashes	·345
Charcoal	·632	Coke in lump	·277
Pine wood, across fibre	·553	Air space undivided	·136

Diagram showing Span between Bearings of Shafts.



From the rule $S = C\sqrt[3]{D^2}$, where D = diameter of shaft.

S = span between bearings in feet. C = { 5 to 6 for shaft only, without pulleys. 4·5 to 5 for shaft, with ordinary number of pulleys and wheels.

Non-Conductors for Steam Pipes. (Prof. J. M. Ordway.)

Substance, 1 Inch Thick. Heat Applied, 310° F.	Lbs. Water Heated 10° F. per Hour through 1 Sq. Ft.	Substance, 1 Inch Thick. Heat Applied, 310° F.	Lbs. Water Heated 10° F. per Hour through 1 Sq. Ft.
Loose wool	8·1	Air alone	48·0
Live-geese feathers	9·6	Sand	62·1
Carded cotton	10·4	Best slag wool	13·0
Hair felt	10·3	Paper	14·0
Loose lampblack	9·8	Blotting paper, wound tight	21·0
Compressed ditto	10·6	Asbestos paper, wound tight	21·7
Cork charcoal	11·9	Cork strips, bound on	14·6
White pine charcoal	13·9	Straw rope, wound spirally	18·0
Anthracite coal powder	35·7	Loose rice chaff	18·7
Loose calcined magnesia	12·4	Paste of fossil meal with hair	16·7
Compressed calcined magnesia	42·6	Paste of fossil meal with asbestos	22·0
Light carbonate of magnesia	13·7	Loose bituminous coal ashes	21·0
Compressed carbonate of magnesia	15·4	Loose anthracite coal ashes	27·0
Loose fossil meal	14·5	Paste of clay and vegetable fibre	30·9
Crowded fossil meal	15·7		
Ground chalk (Paris white)	20·6		
Dry plaster of Paris	30·9		
Fine asbestos	49·0		

Notes on Pumps.

A man exercises more power with an ordinary pump handle than with a crank and handle. The power exerted by an ordinary man in working a pump handle continuously must not be estimated above 25 lbs. The suction and delivery pipes of pumps should not be less than one half the diameter of the barrels; and if the length be great, they should be larger; also with large pumps or pumps working fast it is well to have a greater proportion of pipe area (in some cases the pipe is made as large as the barrel). The suction pipe should also be larger than the delivery pipe, as in the suction pipe there is only the atmospheric pressure to overcome the friction, whereas in the delivery pipe there is the whole power of the pump. The following is a safe rule for the sizes of suction pipes. An advantage is gained by using a large suction pipe, even if the inlet of the pump be smaller than the pipe.

	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.
Size of pump	2	$2\frac{1}{2}$	3	$3\frac{1}{2}$	4	5	6
Size of suction	$1\frac{1}{4}$	$1\frac{1}{2}$	2	2	$2\frac{1}{2}$	3	4

These sizes hold good for double pumps, as each barrel draws alternately, and therefore the pipe need not be increased in size. In laying a long length of suction pipe make sure that it falls along its whole length from the pump towards the well. If there is any point higher than the pump end of the pipe it will form a pocket or trap from which it will be very difficult to draw the air. It is always desirable to have a foot valve in the suction pipe to retain the water when the pump is standing. To avoid concussion and equalise the working of the pump it is well to place a vacuum vessel on the pipe just before it enters the pump.

Formula for calculating the power required to raise water :—

$$\frac{\text{Gallons per minute} \times \text{height in feet}}{3{,}300} = \text{horse-power}$$

Add for friction according to the machinery used and length of piping.

Capacities of Pumps.

Diameter. Inches.	Area in Inches.	Displacement in Gallons per Foot of Travel.	Diameter. Inches.	Area in Inches.	Displacement in Gallons per Foot of Travel.
$\frac{1}{8}$	·0129	·0005	$4\frac{1}{4}$	14·18	·6125
$\frac{1}{4}$	·0490	·0021	$4\frac{1}{2}$	15·90	·6868
$\frac{3}{8}$	·1104	·0047	$4\frac{3}{4}$	17·72	·7655
$\frac{1}{2}$	·1963	·0084	5	19·63	·8480
$\frac{5}{8}$	·3068	·0132	$5\frac{1}{4}$	21·54	·9348
$\frac{3}{4}$	·4417	·0190	$5\frac{1}{2}$	23·75	1·026
$\frac{7}{8}$	·6018	·0259	$5\frac{3}{4}$	25·96	1·121
1	·7854	·0339	6	28·27	1·221
$1\frac{1}{8}$	·9940	·0429	$6\frac{1}{4}$	30·67	1·325
$1\frac{1}{4}$	1·227	·0530	$6\frac{1}{2}$	33·18	1·433
$1\frac{3}{8}$	1·484	·0641	$6\frac{3}{4}$	35·78	1·545
$1\frac{1}{2}$	1·767	·0763	7	38·48	1·662
$1\frac{5}{8}$	2·073	·0895	$7\frac{1}{4}$	41·28	1·783
$1\frac{3}{4}$	2·405	·1038	$7\frac{1}{2}$	44·17	1·908
$1\frac{7}{8}$	2·761	·1192	$7\frac{3}{4}$	47·17	2·037
2	3·141	·1356	8	50·26	2·171
$2\frac{1}{8}$	3·546	·1531	$8\frac{1}{4}$	53·45	2·309
$2\frac{1}{4}$	3·970	·1717	$8\frac{1}{2}$	56·74	2·451
$2\frac{3}{8}$	4·430	·1913	$8\frac{3}{4}$	60·13	2·597
$2\frac{1}{2}$	4·908	·2120	9	63·61	2·747
$2\frac{5}{8}$	5·411	·2337	$9\frac{1}{4}$	67·20	2·903
$2\frac{3}{4}$	5·939	·2565	$9\frac{1}{2}$	70·88	3·062
$2\frac{7}{8}$	6·491	·2804	$9\frac{3}{4}$	74·66	3·225
3	7·068	·3053	10	78·54	3·393
$3\frac{1}{8}$	7·669	·3313	$10\frac{1}{4}$	82·51	3·564
$3\frac{1}{4}$	8·295	·3583	$10\frac{1}{2}$	86·59	3·740
$3\frac{3}{8}$	8·946	·3864	$10\frac{3}{4}$	90·76	3·920
$3\frac{1}{2}$	9·621	·4156	11	95·03	4·105
$3\frac{5}{8}$	10·32	·4458	$11\frac{1}{4}$	99·40	4·294
$3\frac{3}{4}$	11·04	·4769	$11\frac{1}{2}$	103·8	4·484
$3\frac{7}{8}$	11·79	·5193	$11\frac{3}{4}$	108·4	4·682
4	12·56	·5426	12	113·0	4·881

The following rule shows how to determine the dimensions of the feed pump :—

Let D = diameter of steam cylinder in inches.
L = length of stroke up to point of cut-off in inches.
s = stroke of pump.
d = diameter of pump.
v = volume of steam obtained from 1 cubic foot of water at the given pressure.

Then $d = 2\text{D}\sqrt{\frac{\text{L}}{vs}}$

Force pumps should be twice the diameter of the pipes in connection.

Horse-power required to raise water equals quantity of water to be raised in gallons per minute × 10 × height to be lifted in feet divided by 33,000. Add $\frac{1}{3}$ to $\frac{2}{3}$ for losses by slip of valves and friction.

Table of Pedestal Proportions. (Unwin.)

Diameter of Journal. Inches.	Length of Bearing. Inches.	Height to Centre.	Diameter of Bolts.	Size of Bolt Holes.	Length of Base.	Centres of Cap Bolts.	Centres of Base Bolts.	Thickness of Step at Bottom.
$1\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{1}{8}$	$\frac{1}{2}$	$\frac{5}{8} \times 1$	$8\frac{7}{8}$	$3\frac{1}{2}$	$7\frac{1}{4}$	$\frac{1}{4}$ to $\frac{5}{16}$
2	3	$2\frac{3}{4}$	$\frac{5}{8}$	$\frac{3}{4} \times 1\frac{1}{4}$	11	$4\frac{3}{8}$	9	$\frac{5}{16}$ „ $\frac{3}{8}$
$2\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{1}{4}$	$\frac{3}{4}$	$\frac{7}{8} \times 1\frac{1}{2}$	$13\frac{1}{4}$	$5\frac{1}{4}$	$10\frac{7}{8}$	$\frac{5}{16}$ „ $\frac{7}{16}$
3	4	$3\frac{3}{4}$	$\frac{7}{8}$	$1 \times 1\frac{5}{8}$	$15\frac{1}{2}$	$6\frac{1}{8}$	$12\frac{5}{8}$	$\frac{3}{8}$ „ $\frac{1}{2}$
$3\frac{1}{2}$	$4\frac{1}{2}$	$4\frac{5}{16}$	1	$1\frac{1}{8} \times 1\frac{3}{4}$	$17\frac{1}{2}$	7	$14\frac{3}{8}$	$\frac{3}{8}$ „ $\frac{1}{2}$
4	5	$4\frac{7}{8}$	$1\frac{1}{8}$	$1\frac{1}{4} \times 2$	20	$7\frac{7}{8}$	$16\frac{1}{4}$	$\frac{7}{16}$ „ $\frac{9}{16}$
5	6	6	$1\frac{3}{8}$	$1\frac{3}{8} \times 2\frac{1}{4}$	24	$9\frac{5}{8}$	$19\frac{7}{8}$	$\frac{1}{2}$ „ $\frac{3}{4}$
6	7	7	$1\frac{5}{8}$	$1\frac{7}{8} \times 2\frac{1}{2}$	$28\frac{1}{2}$	$11\frac{3}{8}$	$23\frac{3}{8}$	$\frac{9}{16}$ „ $\frac{13}{16}$
7	8	$8\frac{1}{8}$	Two $1\frac{1}{4}$	$1\frac{3}{8} \times 2\frac{1}{4}$	—	$12\frac{1}{4}$	—	$\frac{5}{8}$ „ $\frac{7}{8}$
8	9	$9\frac{1}{8}$	„ $1\frac{1}{2}$	$1\frac{3}{4} \times 2\frac{1}{2}$	—	14	—	$\frac{13}{16}$ „ 1
9	10	$10\frac{1}{4}$	„ $1\frac{5}{8}$	$1\frac{7}{8} \times 2\frac{1}{2}$	—	$15\frac{3}{4}$	—	$\frac{3}{4}$ „ 1
10	11	$11\frac{1}{2}$	„ $1\frac{3}{4}$	$2 \times 2\frac{3}{4}$	—	$17\frac{1}{2}$	—	$\frac{7}{8}$ „ $1\frac{1}{8}$
12	13	$13\frac{1}{2}$	„ $2\frac{1}{8}$	$2\frac{3}{8} \times 3\frac{1}{8}$	—	21	—	1 „ $1\frac{1}{8}$

From seven inches upwards the pedestals have two bolts on each side, both in cap and base plate.

Length of Engine Journals.

The higher the speed the greater the length of journal required. At 150 revolutions per minute one diameter is sufficient ; at 1,500 revolutions per minute 6 or 8 diameters are better.

Coefficient of Friction with Dry Surfaces.

Metal on metal	0·15 to 0·20
Wood „ „	0·25 to 0·30
Millboard „	0.20

When polished steel moves on steel or pewter properly oiled the friction is about $\frac{1}{4}$ of its weight; on copper or lead $\frac{1}{5}$, on brass $\frac{1}{6}$.

Metals working on same metals give more friction than when on different metals.

$$\text{Diameter of engine crank shafts} = \sqrt[3]{\frac{P \times l}{K}}$$

P = pressure of steam on piston.
l = length of crank in feet.
K = 80 for iron, 120 for steel.

Safe Speed for Flywheels.

Maximum safe circumferential velocity of cast iron flywheels is 80 feet per second. Speed should not exceed in revolutions per minute

$$\frac{1530}{\text{mean diameter in feet.}}$$

Width of Rim of Pulley for Belts of Various Widths. (Unwin.)

	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
Width of belt	2	3	4	5	6	8	10	12
Width of pulley	$2\frac{3}{4}$	$3\frac{7}{8}$	5	6	$7\frac{1}{4}$	$9\frac{1}{2}$	$11\frac{3}{4}$	14

Thickness of edge of rim equals 0·7 thickness of belt + ·005 times the diameter of pulley.

Radius of rim face equals 3 times to 5 times the breadth of rim.

Diameter of pulleys should not be less than 6 to 8 times the diameter of a wrought iron shaft suitable for transmitting the power transferred to the belt, and the diameter of the smaller of two pulleys should not be less than about 18 times the belt thickness.

Breaking weight of machine belting, leather, per square inch equals 1·9 tons.

Leather hose and driving belts for machinery treated with castor oil have been found to last longer, and when impregnated will not slip. A 3-inch belt treated with castor oil equals a $4\frac{1}{2}$-inch belt without oil, and will last more than twice as long.

Proportion of Teeth of Wheels.

Depth	= pitch × ·75	Thickness	= pitch × ·45
Working depth	= „ × ·70	Width of space	= „ × ·55
Clearance	= „ × ·05	Play	= „ × ·10

Length beyond pitch line = pitch × ·35.

Common Proportion of Keys. (Unwin.)

Diameter of eye of wheel or boss of shaft $= d$

Width of key $= b = \frac{1}{4}d + \frac{1}{8}$

Mean thickness of sunk key $= t = \frac{1}{8}d + \frac{1}{8}$

„ „ key in flat $= t_1 = \frac{1}{10}d + \frac{1}{16}$

In toothed wheels T. of tooth = ·48 pitch.
Width of space = ·3 pitch.
Height above pitch line = ·3 pitch.
Depth below pitch line = ·4 pitch.

A good new leather belt has a tenacity of from 3,000 to 5,000 lbs. per square inch of section.

Coefficient of friction is about ·423 between ordinary belting and cast iron pulleys.

If leather belting has a tenacity of 1,000 lbs. per inch of width the strength of a riveted joint may be taken at 400 lbs., a butt-laced joint at 250 lbs., and an ordinary overlapped laced joint at 470 lbs.

Effective working stress of ordinary single belts		50 lbs.
" "	light double "	70 "
" "	heavy double "	90 "

Diameter of pulley should be more than 100 times the thickness of the belts around it. Ratio between two pulleys ought not to exceed 6 to 1. Convexity of pulleys equals ½ inch per foot in width.

Centrifugal action on belts may be ignored at ordinary speeds up to 3,000 feet per minute.

Internal friction in ropes driving pulleys is the principal destructive agent.

Breaking strain of good ropes = 4 tons per square inch.
Working " " = 300 lbs. per square inch.

Ropes should not be driven above 4,700 feet per minute.

Cotton appears to be best for driving pulleys.

It is said that belts should be made heavier and run more slowly than ordinary rules state to save cost in long run and prevent stoppages for relacing and repairing. At intervals of three months each belt should be scraped clean and dubbed.

Working Tension of Belts (Leather).

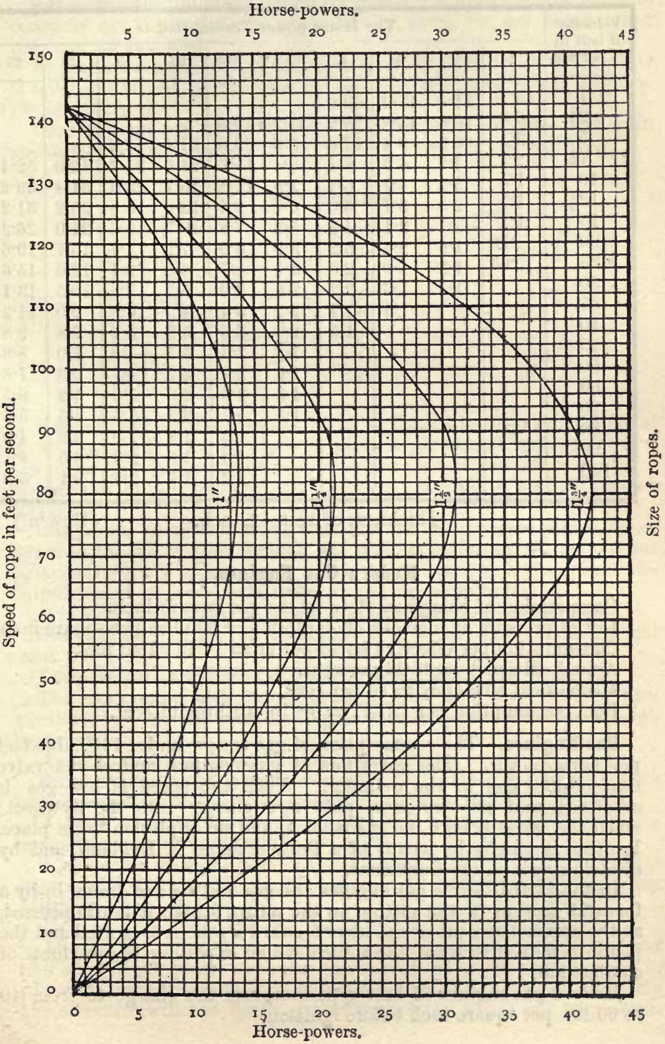
Thickness of Belt (in Inches)	3/16	7/32	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4
Tension in Lbs. per Inch Width	60	70	80	100	120	140	160	180	200	220	240
	Single.				Double.						

Usual Proportions.

Width of Belt (in Inches)	2	3	4	6	8	10	12	15
Thickness (Inch)	0·14	·17	·20	·24	·28	·32	·35	·39
Working Tension in Lbs. per Inch of Width	45	55	64	78	90	101	110	124

Horse-power of different sized Manilla Ropes at different speeds

Working stress = $\frac{1}{36}$th, breaking stress = $\frac{1}{25}$th strength of splice.



Width of Belts in Inches when—

Velocity of belt in Ft. per Sec.	The Horse-power Transmitted is									
	1	2	3	4	5	7½	10	15	20	25
1	15·7	31·4	47·0	63·0						
2½	6·3	10·6	18·8	25·2	31·2	46·8				
5	3·1	6·3	9·4	12·6	15·6	23·6	31·4	47·2		
7½	2·1	4·2	6·3	8·4	10·4	15·6	21·0	31·2	42·0	52·4
10	1·5	3·2	4·7	6·4	7·8	11·8	15·7	23·6	31·4	39·2
12½	1·3	2·5	3·7	5·0	6·4	9·4	12·6	18·8	25·2	31·2
15	1·1	2·1	3·1	4·2	5·2	7·8	10·5	15·6	21·0	26·2
20	·79	1·6	2·4	3·2	3·9	5·9	7·9	11·7	15·7	19·6
25	·63	1·3	1·9	2·6	3·1	4·7	6·3	9·4	12·6	15·6
30		1·1	1·6	2·2	2·6	3·9	5·2	7·8	10·5	13·1
35			1·3	1·7	2·2	3·4	4·5	6·8	9·0	11·2
40				1·5	2·0	2·9	3·9	5·9	7·8	9·8
45					1·8	2·6	3·5	5·2	7·0	8·8
50					1·6	2·4	3·2	4·7	6·3	7·8
60					1·3	2·0	2·6	3·9	5·2	6·5
70					1·1	1·7	2·2	3·4	4·5	5·6
80						1·5	2·0	2·9	3·9	4·9
90						1·3	1·8	2·6	3·5	4·4
100						1·2	1·6	2·4	3·1	3·9

Thickness of belt—$\frac{7}{32}$ inch. (Unwin.)

Modern Gas Engines.

Compression of charge = 89 to 90 lbs. per square inch.
Initial pressure at moment of explosion = 300 lbs. per square inch.
Consumption per effective horse-power = 16·48 cubic feet.
Actual efficiency = 28·26 per cent.
Mechanical efficiency = 86 per cent.
Fuel consumption per I.H.P. = 0·8 lb. anthracite coal.

Gas Engines.—The consumption of gas is now under 16½ cubic feet per horse-power. The governors of gas engines control the valve that admits gas to the cylinder. When the speed is low gas is admitted, and an explosion puts new energy into the flywheel; when the speed is high, no gas is let in and no explosion takes place. Ignition is chiefly by means of a Bunsen flame in England, and by electric spark on the Continent.

In the "Otto" cycle gas engines the gas and air are drawn in by a forward motion of the piston, on the return stroke it is compressed, at the commencement of the next forward stroke it is ignited and the piston is moved forward, the return stroke expelling the products of combustion.

Modern gas engines of best type compress the charge to from 40 to 60 lbs. per square inch before ignition.

Mean effective pressure in "Otto" cycle gas engines = 50 to 60 lbs. per square inch.

Gas engines of 100 brake horse-power and upwards are now made to consume not more than 20 cubic feet of town gas per horse-power per hour at full load.

Experiments made show that the deleterious effect of burnt gases is much overrated in the case of coal gas products in gas engines. (F. Grover.)

Consumption per brake horse-power per hour at half load with gas or steam engines is about 40 per cent. more than at full load.

Gas Engines.

	B.H.P.	Cubic Feet Gas per B.H.P. Hour.
Simplex	8·79	20·38
Atkinson Cycle	4·89	22·5
Forward	4·8	23·97
Otto Crossley	14·7	24·1
Atkinson's Differential	2·6	25·7
Griffin	12·5	28·5
Clerk's Engine	7·2	30·4

Horse-power of Gas Engine.—The indicated horse-power is equal to the mean effective pressure in pounds per square inch multiplied by the length of the stroke in feet by the area of the piston in square inches and by the number of explosions per minute, and divided by 33,000.

Gas engine diagrams prove that the rise in pressure which takes place in the gas engine through the gas exploding at the dead point relatively slowly is not more rapid than that which occurs on the admission of high-pressure steam to the steam cylinder.

Mechanical efficiency of a gas engine, about 80 to 85 per cent.

Gas engines can be run to within 3 to 4 per cent. of the normal rate.

Temperature in cylinder of gas engines, 2,500° F. to 3,000° F.

The work expended in compressing gas does not increase proportionally with the pressure, but is relatively much less with high pressures.

Average gas, 1 to 8 to 12 of air in gas engine.

Only 2½ times the power is needed to increase a pressure of 10 atmospheres tenfold—*i.e.*, to raise it to 100 atmospheres.

A good steam engine develops one I.H.P. per kilogramme coal of a calorific power of 8,500 calories.

A cubic metre of gas develops 5,300 calories, and one I.H.P. in a gas engine with a thermal duty of 50 per cent. in favour of the gas engine. (Hirsh.)

Exhaust pipes from gas engines should have easy bends.

At ordinary atmospheric pressure and temperature mixtures of gas and air will not ignite explosively, if at all, when the air amounts to about fourteen times the bulk of a given quantity of gas, and similarly the mixtures will not ignite explosively if too much gas be present, One pound of a mixture of oxygen and coal gas in the proportions required for complete combustion would upon ignition develop about the same energy as 3½ lbs. of gunpowder.

With coal gas at 3*s.* per 1,000 cubic feet and coal at 15*s.* per ton the gas engine consuming 20 feet per I.H.P. per hour = a steam engine consuming 9 lbs. of coal per I. H.P. per hour. (T. L. Millar.)

With lighting gas the cost of running large gas engines is about the same as for steam engines, lighting gas being much dearer than generator gas for power purposes, especially for engines above 12 H.P.

Gas consumption in Dessau tramcars worked by gas engines = 31·2 cubic feet per mile run, including loss in compression, which is very little. (Herr von Oechelhauser.)

Gas Engines for Tramcars.—An 8 H.P. engine (Otto type): charge of compressors = 8 miles supply, cost = 1*d.* per mile for gas.

From 4 to 6 gallons water are required per I.H.P. to cool gas engine cylinders.

In cooling the cylinders of gas engines 35 per cent. of the thermal units in the gas are lost.

Capacity of circulating tanks should equal 23 to 30 gallons per I.H.P.

To Find Size of Dry Meter for Gas Engines.

Brake horse-power × 3·4 + 5 = number of lights.

The size of supply pipe to engine can be found by reference to table of meter dimensions.

To Find Size of Exhaust Pipe.

From 1 to 5 brake horse-power, 1 inch to 1¾ inches diameter.

Above that size, diameter in inches $= 0{\cdot}528 \times \text{H.P.}^{0{\cdot}57}$.

The heat of exhaust pipes is great, and likely to burn wood if too near. Bends of 6 inches or more radius only should be used; no elbows or tees. Turn the outlet of the pipe to look downwards.

To Prevent Excessive Noise in Exhaust Pipe.

The pipe can be carried into a drained pit and surrounded with stones, over which a covering of straw can be placed.

Quantity of Water Required for Cooling Cylinder.

About 5 gallons per I.H.P. per hour if taken direct from mains, and led to under side of jacket at clearance end of cylinder, and removed from upper side at the opposite end. If hard water is used, add a handful of washing soda to tank every month.

Circulating Tank's Capacity.

Twenty to 30 gallons per I.H.P. with pipes from 1 inch to 3 inches diameter, according to size of engine. The return pipe is usually a little larger than the flow, with a rise of at least 2 inches per foot leading to the tank at the normal water level.

Value of Explosive Mixtures. (Dugald Clerk.)

Mixture.		Maximum Pressure of Explosion above Atmosphere in lbs. per Square Inch.	Time of Explosion.
Gas.	Air.		
1 vol.	13 vols.	52	0·28 second.
1 "	11 "	63	0·18 "
1 "	9 "	69	0·13 "
1 "	7 "	89	0·07 "
1 "	5 "	96	0·05 "

Temperature before explosion, 64° F. Pressure before explosion, atmospheric.

Examine the ignition tube occasionally to see that no soot has been deposited by the Bunsen flame.

Before starting compress the gas bag and then turn on gas, turning the engine meanwhile to remove the air which may have accumulated in the gaspipes.

To stop the engine shut the gas-cock near cylinder—not at the meter.

The ratio of heat converted into work in a gas engine is greater than in a steam engine.

Average heat units lost in the jacket or cooling water, 35 per cent.
" " " " " exhaust, 37 per cent.

Otto or Four-Cycle Gas Engines.—An explosion takes place every four strokes, or one per double revolution of the crank shaft, viz., piston advances, drawing in the explosive charge; it then returns, compressing the mixture; next ignition takes place, the piston is driven forward, and on retiring finally expels the waste products of combustion.

The consumption of ordinary illuminating gas in modern gas engines equals from 20 to 26 cubic feet per I.H.P. per hour for moderate to small powers, and for larger powers 18 to as low as 15 cubic feet has been obtained, and with the compound type as low as 10. This, if supplied with Dowson gas, means only ·8 lbs. of coal per I.H.P. per hour. The mechanical efficiency may be taken as from 80 to 85 per cent. at full power, and from 70 to 75 per cent. at half power.

Messrs. Crossley state that with town gas at 3*s.* per 1,000 the working cost of a gas engine of 14 horse-power nominal and upwards is greater than that of a steam engine.

It has been proved that by scavenging the power of a gas engine can be increased 10 per cent., or the consumption of gas reduced, keeping the power the same.

With coal gas it is a moot point if the products of combustion hurt the next charge in gas engines.

Gas engines are most economical at full power.

A speed test made with a Moscrop recorder on a single-cylinder double-acting "Kilmarnock" Otto cycle engine showed a variation of 2¼ per cent. at powers varying from normal full load down to one third.

Value of Coal Gas of Different Candle Powers for Motive Power.
(C. Hunt.)

Candle Power.	Consumption Cubic Feet per I.H.P.	Relative Value for Motive Power.	Relative Value for Lighting.
11·96	30·31	1·000	1·000
15·00	24·41	1·241	1·254
17·20	22·70	1·335	1·438
22·85	17·73	1·709	1·910
26·00	16·26	1·864	2·173
29·14	15·00	2·020	2·436

Oil Engines.

The oil consumed per hour equals from ·7 lb. with American oil to ·86 lb. with Russian per indicated horse-power.

A Priestman oil engine, using oil above 75° F. flashing point, developed 1 brake horse-power per 1·25 lb. oil. (W. Anderson.)

In a **Priestman oil engine** tested by Professor Unwin—

·69 and ·86 lb. oil used per I.H.P.
·84 „ ·94 „ „ „ B.H.P.

Thermal efficiency 13 31 per cent. Loss of heat in cooling water 47·54 per cent. Mechanical efficiency 82 to 91 per cent. Loss of heat in exhaust gases 26·72 per cent.

To find Leaks in connections under Suction.

By fixing a small governor on the byepass of the exhauster, weighted to 2 inches, a pressure will be thrown on the plant up to the hydraulic, any leaks showing themselves and explosions prevented.

SCRUBBERS AND WASHERS.

Herr Reissner's Rule.—5 cubic feet to 6 cubic feet per 1,000 cubic feet per 24 hours of scrubbers.

Wyatt's Rule.—100 cubic feet internal capacity of vessels (scrubbers and washers) with a gas contact of from 15 to 27 minutes per ton per diem. Gas in scrubbers should equal 1 per cent. of the maximum daily make to give requisite contact time.

Horizontal net sectional area of all the scrubbers is 2 square feet per ton per day maximum make.

Capacity of scrubbers should be 15 cubic feet per 1,000 feet of gas per diem, the vessel being one third the diameter of its height. (Richards.)

Another Rule.—Scrubbers should be equal to allowing a contact for 10 to 15 minutes of greatest make. Height is an advantage, so that the gas may be easier broken up and wetted surfaces presented.

Tower scrubbers usually 6 or 7 times the diameter high.

Scrubbers should be cylindrical. Height equal to 6 or 7 times the diameter. Capacity equal to 9 cubic feet per 1,000 cubic feet per diem maximum make. (Herring.)

Newbigging's Rule for tower scrubbers, 9 cubic feet per 1,000 cubic feet gas made per day.

The washer or scrubber wherein the gas is broken up into small streams passing in contact with wetted surfaces is preferable to that in which the water is divided into small drops and which fall through the gas, as the bulk of the gas is at least 100 times, and more often 1,000 times, that of the liquid.

A good scrubber should so distribute the water or liquor that the whole of the surfaces exposed to the gas in its passage should be evenly wetted, with length of contact and such contact ensured.

The use of a washer requiring a separate engine must be compared with the extra cost of the fuel required, in one throwing some 3 or 4 inches pressure upon the exhauster.

Scrubbers filled with coke will collect tar and cause a lowering of illuminating power by absorption of light-giving hydrocarbons.

When coke is used in a tower scrubber a space of 6 inches is usually left above each layer before the next tier of sieves.

Average Surface presented to Gas in Scrubbers.

When filled with coke . . .	·3	or 8½	sq. feet per cubic foot.
" " 3-inch drain pipes	·54	" 17	" " "
" " 2 " " "	·66	" 21	" " "
" " boards . .	1·00	" 31	" " "

Scrubber Boards should be ½ inch thick with ⅜ inch or ½ inch space between.

Boards 11 inches deep, ¼ inch thick, set ¾ inch apart, are used in tower scrubbers with success.

Ten volumes of water at 60° F. and 30 inches pressure will absorb—

7,800	volumes	ammonia.
25·3	„	sulphuretted hydrogen.
10·0	„	carbonic acid.
1·25	„	olefiant gas and probably other hydrocarbons.
·37	„	oxygen.
·156	„	carbonic oxide.
·156	„	nitrogen.
·156	„	hydrogen.
·160	„	light carburetted hydrogen.

When water has been saturated with one gas and is exposed to the influence of a second it usually allows part of the first absorbed to escape, while an equivalent quantity of the second takes its place. Thus a large volume of an easily soluble gas can be expelled by a small quantity of a difficultly soluble one. (Dr. Frankland.)

Liquor distributers sometimes fixed half way up scrubbers where only one scrubber is in use.

The whole of the ammonia can be removed from the gas in practical working by using 3 gallons water per ton of coal carbonised, and the quantity of NH_3 per 1,000 cubic feet need not exceed ·3 to ·4 grains at the outlet of the clean scrubber.

Quantity of water required in tower scrubbers from 10 to 18 gallons per 10,000 cubic feet gas made.

When more than one washer is used the liquor should be made to flow from the one the gas enters last through to the first, so that the gas meets the stronger liquor first.

Provide byepasses to all the different parts of the works.

Washers.

About 28 gallons of liquor of 10 oz. strength can be obtained from 1 ton Newcastle coal.

Reaction of cyanides (Prussian blue) :—

$$6NH_4CN + FeSO_4 = (NH_4)_4Fe(CN)_6 + (NH_4)_2SO_4$$

$$3NH_4Fe(CN)_6 + 2Fe_2Cl_6 = 3Fe''Cy_2,2Fe'''_2Cy_6$$

$$\text{or } Fe_7Cy_{18} + 12AmCl.$$

Pressure thrown by washers varies from 1 to 4 inches.

PURIFIERS.

In fixing upon size of purifiers note should be taken of the quality of coal likely to be used for manufacturing gas. Some Midland coals produce gas containing nearly double the amount of H_2S which is to be found in Newcastle coal. Have the purifiers large enough is an excellent rule.

Scotch coals produce large quantities CO_2.

Clegg's Rule for Area of Purifiers.—1 foot area per 3,600 cubic feet, maximum make, per diem.

Hughes' Rule for Area of Purifiers.—1 square yard sieve per 1,000 cubic feet, maximum make, per diem.

Newbigging's Rule for Area of Purifiers.

$$\frac{\text{Maximum daily make} \times 6}{1000} = \text{square feet area each purifier.}$$

Newbigging's Rule for Area of Purifiers Connections.

$$\text{Inches, diameter} = \sqrt{\text{area of purifiers in feet}}$$

For large purifiers deduct one-eighth.

Beckton practice : 1 square foot of purifier area per 2,500 cubic feet made per diem.

Allow, say, 1 square yard of active grid per 1,000 feet of gas.

Sulphur purification requires for 2,000,000 plant 8 boxes 32 feet × 32 feet × 6 feet deep, with 4 trays for lime and 3 for oxide. (A. Colson.)

Purifying shed for above, 320 feet × 60 feet. (A. Colson.)

Rate of passage of gas through lime purifiers should not exceed 2,000 cubic feet per foot of surface per 24 hours. (G. Anderson.)

Purifiers (where lime only is used and no sulphur clauses) should allow a contact of 15 minutes of greatest make, or cubical contents = ¼ hour's make, with 5 tiers lime, each 2½ inches thick.

C. Hunt's Rule for Area of Each Purifier in a series is not less than 0·1 square foot for every ½ per cent. by volume of the maximum quantity of CO_2 experienced. CO_2 varies from 1½ to over 3 per cent.

Lime and oxide purifiers when worked in conjunction require from 20 to 30 square feet per ton. (C. Hunt.)

G. C. Trewby's Rule.—320 feet for each vessel per 1,000,000 cubic feet of daily manufacture.

Four feet area per box per ton of coal carbonised per day with 6 purifiers in the series, 4 for lime and 2 (catch) for oxide. (F. Livesey.)

Wyatt's Rule.—100 superficial feet of sieves per ton per day 1,620 cubic feet to house the purifiers with a floor area of 50 square feet per ton per diem, 133 cubic feet total capacity of vessels, gas contact of 15 to 27 minutes, area of covers of purifiers 3 square feet per ton per diem.

Lime and oxide sheds: 810 cubic feet of building structure floors area of 25 square feet per ton per diem.

Wyatt's Rule.—33 cubic feet or 50 superficial feet per ton per day, contact time 5 to 8 minutes.

The useful surface for passage of gas should be $\frac{1}{3}$rd the volume of the oxide, time of contact 48 seconds, bulk should equal $\frac{1}{20}$th of the gas passed per hour, with 1 layer 24 inches thick; material showed 15·65 per cent. total sulphur and 11·75 per cent. free sulphur, while with 4 layers each 6 inches thick it showed 14·96 and 9·03 per cent. respectively. (Messrs. Delseaux and Renard.)

In the Beckton method of 8 purifiers an area of 0·4 foot per 1,000 cubic feet of gas per vessel is sufficient. (L. T. Wright.)

Allow half a square foot per 1,000 cubic feet maximum daily make for area of each purifier. (Herring.)

Purifying surface may range from 1·3 to 4 square feet per 1,000 cubic feet gas per day.

Area of each purifier should equal 676 square feet per million per day.

Speed of gas through purifiers should be as slow as possible.

Herr Reissner's Rule.—Purifiers. Five trays with oxide in each, 1·17 square feet area per 1,000 cubic feet in 24 hours if 4 purifiers, all included in above. Catch purifier with 4 to 6 trays sawdust.

Use purifiers of large area: with lime, 2 to 4 tiers of sieves with layer of lime 6 to 9 inches thick; with oxide, 2 or 3 tiers of sieves with layer of oxide 18 inches deep on each.

Purifiers (construction notes).—Thickness of cast iron purifier plates should never be less than $\frac{5}{8}$ inch. The usual width of same 5 feet. Flanges of bottom plates should be $2\frac{3}{4}$ inches × $\frac{3}{4}$ inch over and above the thickness of plate.

Strong and deep brackets should be fixed under lute, as strain is greatest at this point. (F. S. Cripps.)

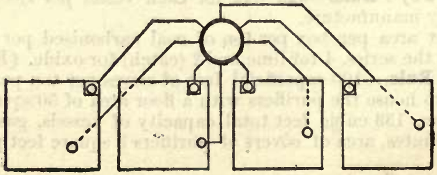
Cast iron plates for purifiers, if made larger than 5 feet by 5 feet, are liable to twist in casting. Flanges should not be less than 3 inches deep, and thickness about $\frac{1}{2}$ inch to $\frac{7}{8}$ inch; plates $\frac{1}{8}$ inch thinner.

Depth of water lute in purifiers varies from 12 inches in small purifiers to 30 inches in larger ones; width from $4\frac{1}{2}$ inches to 8 inches.

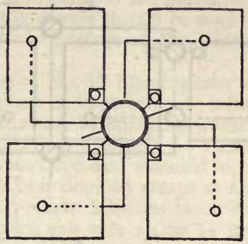
Seals of purifiers should never be less than 18 inches deep.

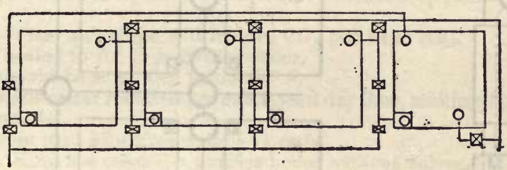
Diameter in inches of pipes in connections to purifiers should equal the square root of area of purifiers in feet.

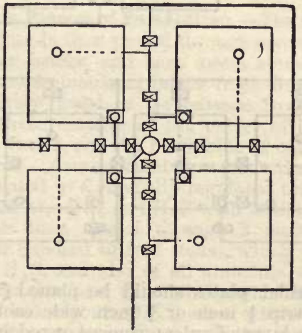
Arrangements of Purifier Connections. (Dempster.)

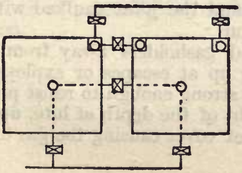


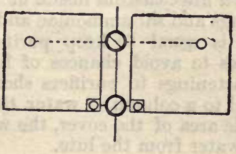
Arrangements of Purifier Connections. (Dempster)—*continued.*



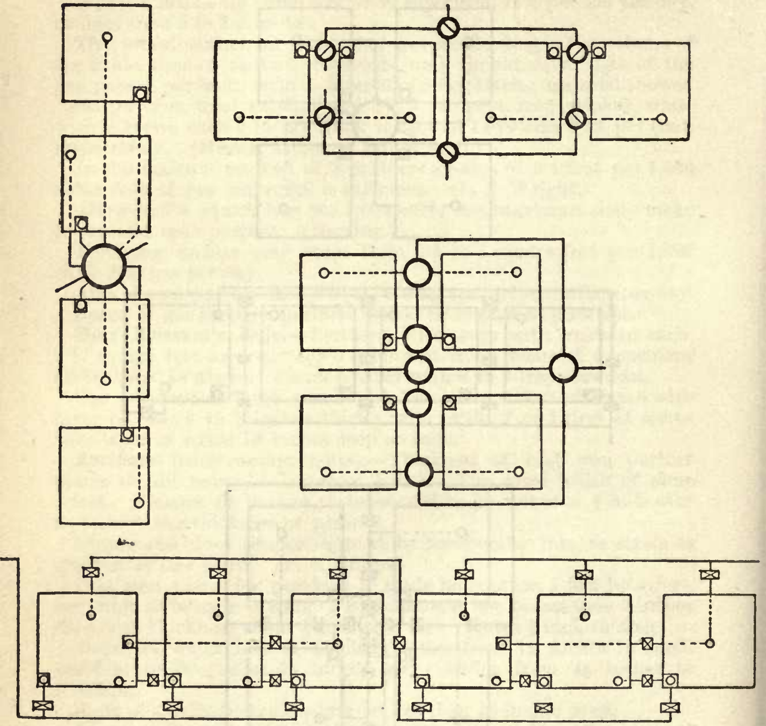








Arrangements of Purifier Connections. (Dempster)—*continued.*



Flanges of purifier plates should be planed (not necessarily the whole width, a strip $\frac{5}{8}$ inch or $\frac{3}{4}$ inch wide each side and at ends being sufficient), a layer of vulcan cement or red and white lead being put into the joint before it is bolted up. The alternative method is to have a fillet cast on inside of flange and the joint caulked with iron borings and sal-ammoniac and sulphur.

It is usual to keep purifiers and gasholders away from retort houses to avoid chances of lighting up at escapes or explosions.

Fastenings to purifiers should be strong enough to resist pressure, equal to a column of water the height of the depth of lute, upon the whole area of the cover, the weight of cover causing the gas to blow the water from the lute.

Valves or ground plugs should be provided for permitting the air to enter while the cover is lifted, and should at least equal one-third the diameter of the connections to the purifiers.

Side sheets of purifier covers should be made thicker than the top sheets, as the level of the surface of the water is where the plates will first rust.

Crown sheets may be of No. 12 Birmingham wire gauge.

Purifiers in the open can be kept warm in winter by the use of hay or straw, and cool in summer by spraying water over the covers.

If the top of the purifiers are kept 18 inches above ground the material can be easily removed and wheeled in.

Lifting of purifiers is best done by straps at the sides of the covers.

Purifier sieves usually made 2 inches thick with ⅜-inch taper deal bars, and distance blocks, oak side strips 1¼ inch by 2 inches, and fastened by ⅜-inch bolts or rivets.

Usual thickness of layers.—Oxide, 2 feet 6 inches deep ; lime, 1 foot deep.

About 70 lbs. quicklime will remove CO_2 per 1 ton coal.

Oxide heated to 70° C. revivifies easier.

Lime should be sulphided below 40° F.

135 gallons water required per cubic yard dry lime, making 2¼ yards slaked material.

One cubic yard kiln lime weighs 11 cwts.

Mr. W. King has erected a purifier house without valves—U tubes, which can be filled with water to prevent the passage of the gas, being used.

The Claus Ammonia Process of Purification.—The gas, having passed through a tar extractor, is then passed through several scrubbers filled with broken ganister bricks, and here meets ammonia gas, and in the first two scrubbers ammoniacal liquor freed from CO_2 and H_2S, the gas being entirely freed in its passage from CO_2 and H_2S, while of ammonia there remains at the outlet of the last scrubber only the usual faint traces, and the bisulphide of carbon is reduced by from 20 to 70 per cent. Arrangements are made that in 5 towers the scrubber liquor is heated to a carefully regulated temperature for the purpose of driving off the CO_2 and H_2S with as little loss as possible of ammonia. It is then passed through 3 more towers, in the second of which it is exposed to free steam, which deprives it of all traces of CO_2 and H_2S, and also of all ammonia, except what may be present as fixed in the form of sulphocyanide of ammonium ; in the third tower the hot vapours (187°) are condensed to 120° or less, and are then ready for use again to remove the impurities. All the sulphur gases driven off from the liquor are deposited in a chamber in the form of pure sulphur, equal to from 10 lbs. to 14 lbs. per ton of coal used.

GASHOLDER TANKS.

As a general rule the bearing capacity of ground 30 or 40 feet below the surface is greater than at the surface itself, but in all cases bore-holes should be made to see that the solid ground upon which it is proposed to lay the bottom of the tank is fairly level, and that it is of sufficient depth. In some cases the strata of, say, ballast, which would safely carry the tank walls, &c., have been cut through, or nearly so, and when the tank has been completed the level of the walls has varied considerably.

The larger the number of the borings taken around a proposed gas-holder tank site the better to ensure that the foundation is level and equally weight-resisting.

If any doubts exist as to the solidity of the ground where the tank is proposed to be placed it is better to put up an iron or steel one, which may be made to rest on piles and cross timbers.

It is often better to raise the level of the wall of the tank when water is found in the subsoil which may afterwards injure the nature of the foundation.

For tanks up to 36 feet deep and inside diameters of 150 feet:

$\frac{1}{10}$th the depth of tank = thickness of concrete walls.
$\frac{1}{8}$th „ „ = „ piers.
$\frac{1}{7}$th „ „ = width of piers.

(Wyatt, 30th April, 1889.)

The well or sump which is sunk before commencing a tank may be lined with steining (open brickwork without mortar), or merely timbered with stout timbers if it is proposed to fill up the sump when the tank is completed. In some cases large pipes (cast iron) have been let in as the excavation proceeded, without jointing, and thus formed an excellent backing to prevent the sides falling in.

The sump should be at least 3 to 5 feet deeper than the lowest part of the excavation to be made for the tank; often a considerable amount deeper will lessen the after expense with tanks in bad ground.

Sometimes more than one sump is found necessary, or drain pipes have to be laid to convey the water to the pumps, which should always be in duplicate.

Natural Slopes of Earths with the Horizontal Line or Angles of Repose.

Gravel average	40 degrees	or 1·2	to 1
Dry sand average	38 „	or 1·30	to 1
Sand average	22 „	or 0·27	to 1
Vegetable earth average	28 „	or 1·89	to 1
Compact earth average	50 „	or 0·7	to 1
Shingle average	39 „	or 1·25	to 1
Rubble average	45 „	or 1·0	to 1
Clay, well dried, average	45 „	or 1·0	to 1
Clay, wet, average	16 „	or 3·3	to 1
Peat average	28 „	or 1·89	to 1

General Tank Notes.

An Iron or Steel Tank saves excavation and expenditure on foundations in many cases.

Steel tanks should be well grouted in, in many places, when lowered on to their bed.

Steel tanks require more maintenance than stone or brick ones, and more steam for preventing freezing of the water during frosty weather.

Cost of a steel tank usually one-half to two-thirds that of an excavated brick or concrete one.

Cost of steel tanks about 3·3*d.* to 3·7*d.* per cubic foot capacity.

Cost of brickwork tanks about 4·4*d.* to 5·9*d.* per cubic foot capacity.

The plates in the bottom row of a 50 feet deep × 190 feet diameter tank have been made $1\frac{3}{4}$ inch thick × 4 feet 4 inches wide × 24 feet 9 inches long.

It is usual to put the flanges of cast iron tank bottom plates inside and the flanges of the side plates outside.

Tanks may with advantage be left large enough to allow of an extra lift when being first designed and laid out, although it may not be at the moment required.

The larger the volume of water in a tank the less the liability to freeze.

Thickness of Tank Walls at any point in inches =

$$\frac{\text{Pressure of water (pounds per square inch)} \times \text{radius of tank in inches}}{\text{Cohesive force of wall in pounds per square inch} - \text{pressure of water.}}$$

Force of water tending to burst a tank outwards = 62·5 × diameter of tank × $\frac{1}{6}$ (depth).

Pressure on wall of tank due to earth backing therefore equals resistance of earth × outside diameter of tank × $\frac{1}{2}$ (depth^2).

Resistance of the weight of wall equals half the cubic contents of the wall in feet × weight of 1 cubic foot of the wall.

Resistance of the cohesion of the material of the wall equals cohesive force × height^2 × average thickness of wall.

Cohesive force of bricks in cement 1 (cement to 3 sand) equal to 31,680 lbs. per square foot.

Resistance of earth backing dry equal to $\frac{1}{2}$ an equal column of water. (Sir B. Baker.)

Resistance of earth backing, water-logged, equal to $1\frac{1}{2}$ an equal column of water. (Sir B. Baker.)

Resistance of earth backing, clay or earth, equal to 1,200 lbs. per square foot. (Newbigging.)

Ultimate Resistance of Loam Earth per Square Foot in lbs.— R. A. Tests.

Mean Depth of Anchorage below Surface.	Inclination of Force drawing the Anchorage (in a Direction perpendicular to its Face).				
	Vertical.	$\frac{1}{1}$	$\frac{1}{2}$	$\frac{1}{3}$	$\frac{1}{4}$
1 foot	808	933	1,244	1,300	1,430
1 foot 6 inches . .	1,040	1,458	2,100	2,180	2,360
2 feet	1,925	2,700	3,880	4,032	4,370
3 feet	3,024	4,400	5,860	6,160	6,750
4 feet	5,470	8,000	10,660	11,200	12,260
5 feet	14,112	22,000	29,330	30,800	33,730

In damp sand the resistance would be half that in earth.
A factor of safety in tank walls of 3 is ample.

Resistance of Different Earths to Horizontal Compression. (M. Arson.)

Sand	2,050	lbs. per square foot.
White tufa (a light stony powder)	1,640	" " " "
Vegetable earth mixed with gravel	900	" " " "

The earths were well watered and punned.

The Backing to Gasholder Tank Walls should be well punned and watered to cause it to have direct pressure upon the wall, as cracks are almost invariably found in a vertical direction and only open a very slight distance, which would suggest that the walls have then taken up the support of the backing.

Clay has often been known to sustain a pressure of water of 15 lbs. per square inch, or about 1 ton per square foot.

One cubic yard puddle weighs about 2 tons.

Puddle may be thrown from a height of 20 feet with advantage, but should not be laid in layers of more than 10 inches at a time.

Where clay is to be found upon the site it will probably be cheaper to construct a puddle tank than a rendered one.

Puddle.—Work the clay well up with water to break up the original formation, and bring about a new arrangement of the particles, adding sufficient water to fill up every pore.

If possible, expose the clay before tempering for a considerable time to the air. It should be opaque, not crystallised, with a dull earthy fracture, and exhale an argillaceous smell.

Tenacity and power to retain water is the principal requirement. If a roll well worked up by hand to eight or ten times its thickness be suspended, while wet, by one end it should not break. It should retain its original quantity of water when formed into a basin and filled for 24 hours, if covered up to prevent evaporation. (W. Gallon.)

Puddle should be put in in layers of not more than one foot, and should be thrown in with force to cause it to adhere to that already in. The top of the puddle should be carefully covered when any dirt is being put in to form a backing, as any grit in the puddle may cause a leak, owing to the grit preventing a thorough adherence of the two layers of puddle.

Puddle should be laid over the whole of the surface of the dumpling and connected all round to that under and on the outside of the wall without any break.

Brick tanks with $\frac{3}{4}$ inch cement (neat), in two coats, can be made without puddle, and will prove quite tight.

Should a leak show itself when the pumping has stopped for testing the soundness of the tanks stock-ramming may be employed to fill up the space where the leak occurs. In doing this a hole is first cut in the wall or floor of the tank and a pipe inserted down to the puddle level, and then cartridges of clay are put in the pipe and forced down with rammers. These latter are frequently made with the heads so that several men can use their strength to ram the clay well into the hole.

In puddled tanks the pressure of the water is thrown upon the puddle and earth backing, and not upon the wall itself, while with a cement-rendered tank the pressure is upon the wall.

Hoop iron or thicker wrought iron bands are often imbedded in the cement of a tank wall, and considerably add to the strength. They should be bent round and turned back at the ends, and laid so that they hook one into the other and form a continuous band.

Where no backing is used to help Tank Sides to resist the pressure of Water the thickness of the Cylinder may be calculated as follows :—

When the thickness is less than $\frac{1}{30}$th the radius the thickness =

$$\frac{\text{Pressure in lbs. per square inch}}{\text{Safe strength in lbs. per square inch}} \times \text{radius in inches.}$$

This regards the material as only subjected to tensile strain.

To find the Thickness at base of Wall to resist the overturning with the pressure of quiet water level with its top and no backing (wall with vertical back and sloping face) :—

Thickness of base at foot =

$$\sqrt{\frac{(Ht^2 \text{ ft.} \times \text{factor of safety*}) + (\text{batter}^2 \text{ ft.} \times \text{sp. gr. of wall})}{3 \times \text{sp. gr. of wall.}}}$$

$$\text{*Factor of safety} = \frac{\text{Required moment of stability of wall}}{\text{Overturning moment of water.}}$$

Where cylindrical hoops are placed around tanks, to find the distance apart at which they should be fixed to each to sustain the same strain—

Fix upon the number of straps required then for the first,

$$\sqrt{\frac{1 \times \text{total No. of straps} \times \text{depth of tank}}{\text{Total No. of straps}}}$$

= Distance from top of tank for 1st strap.

For the second strap, $\sqrt{\frac{2 \times \text{total No. of straps} \times \text{depth of tank}}{\text{Total No. of straps.}}}$

= Distance from top of tank for 2nd strap.

And so on for each strap, substituting for the 1 and 2 in above formulæ the number of the strap from the top.

To find the Pressure of Water against a Tank Side.

Multiply the vertical depth in feet of its centre of gravity below the surface of the water × the area of surface pressed in square feet × 62·5 = pressure in lbs.

The pressure of liquids being always perpendicular to the surface at any point, if the wall be vertical the pressure is horizontal.

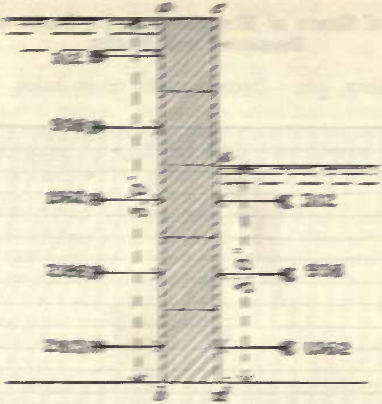
The centre of pressure is always one third of the vertical depth from the bottom.

Table showing the Pressure in lbs. per Square Foot, and Pressure against a Plane 1 Foot Wide from Top to those Depths.

Depth in Feet.	Pressure per Square Foot.	Pressure on Plane.	Depth in Feet.	Pressure per Square Foot.	Pressure on Plane.
1	62	31	26	1,625	21,125
2	125	125	27	1,687	22,781
3	187	281	28	1,750	24,500
4	250	500	29	1,812	26,281
5	312	781	30	1,875	28,125
6	375	1,125	31	1,937	30,031
7	437	1,531	32	2,000	32,000
8	500	2,000	33	2,062	34,031
9	562	2,531	34	2,125	36,125
10	625	3,125	35	2,187	38,281
11	687	3,781	36	2,250	40,500
12	750	4,500	37	2,312	42,781
13	812	5,281	38	2,375	45,125
14	875	6,125	39	2,437	47,531
15	937	7,031	40	2,500	50,000
16	1,000	8,000	41	2,562	52,531
17	1,062	9,031	42	2,625	55,125
18	1,125	10,125	43	2,687	57,781
19	1,187	11,281	44	2,750	60,500
20	1,250	12,500	45	2,812	63,281
21	1,312	13,781	46	2,875	66,125
22	1,375	15,125	47	2,937	69,031
23	1,437	16,531	48	3,000	72,000
24	1,500	18,000	49	3,062	75,031
25	1,562	19,531	50	3,125	78,125

When water is pressing on each side of a wall at different levels the pressure at any point can be found by setting off at, say, each foot depth the pressure on the wall due to the one height of water and upon the other side the pressure due to the other height. Deducting the lesser pressure from the greater gives the pressure upon the wall.

Example.—A wall 10 feet long has water to its full height, 5 feet on one side and 3 feet high on the other; the pressures are as shown in fig. on next page. The excess of pressure on the high water side is always equal to the pressure on that portion of it at the low water level.



In calculating the strength of Tank Walls the tank may be supposed to break in two halves upon the axis of the cylinder; the force tending to open the two halves is the pressure of the water, and the opposing forces are the backing, the cohesive nature of the material in the wall, and the weight of the masonry.

The overturning moment of the water in lbs. = 62·5 × diameter of tank × $\frac{\text{depth of tank}^3}{6}$

The moment of resistance of the earth backing = constant × external diameter of wall × $\frac{\text{depth of tank}^3}{3}$

Moment of resistance of the weight of the masonry =

$$\frac{112 \times \text{thickness of walls}^2 \times \text{external diameter of walls} \times \text{depth of tank}}{2}$$

Moment of resistance due to cohesion = 10,000 × depth of tank² × thickness of walls. Dimensions all in feet.

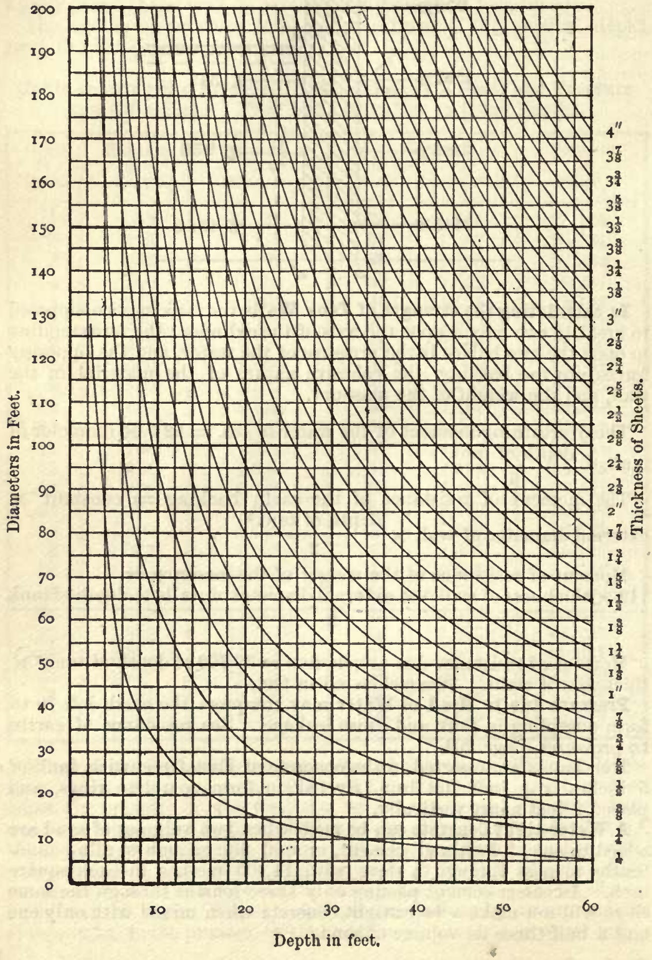
Pressure due to Head of Water may compress the earth left in to form dumpling in tank and cause leakage. See resistance of earths to pressure, page 2[illegible].

Iron bands are inserted in the concrete at East Greenwich tank of 3 inches × ½ inch flat iron, riveted to form complete rings, and placed 2 feet apart vertically.

A Water-tight Concrete can be made when two volumes of sand are added to one of Portland cement, ground fine enough to allow nine-tenths to pass through a sieve with 14,400 meshes in each square inch. A coarser cement passing only three-fourths through the same sieve will not make a water-tight concrete when mixed with only one and a half times its volume of sand.

Thickness of Sheets of Wrought Iron for Tanks of Different Diameters and Depths.

Factor of safety, ⅕th. Deduction for rivet holes, 40 per cent.



When the first batch of concrete is mixed, the quantity of water per bushel of dry materials should be noted, and the same proportions held to with the other batches, uniformity in this respect being of the utmost importance. As much water should be added as will give a mixture that allows a man treading over it to sink in to a depth of at least 6 inches. No stones used for concrete should be larger than will pass through a mesh 2 inches square. Concrete should not be dropped or made to slide down a shoot, and inferentially it should be laid with a spade without a fall of any kind, and then it requires to be trodden down.

Stout bars of flat iron laid into the walls of a concrete tank, and hooked together to form a complete ring on edge are said to give great strength to the same. The expansion of iron and cement concrete being nearly equal prevents fracture between the two materials.

Firebrick rubbish and furnace clinkers form with sand or sharp grit excellent material for concrete.

Concrete composed of 1 part cement to 10 or 12 coke breeze is porous.

A good coat of asphalt will render a tank quite water-tight.

A coating of hot asphalt and tar is also used to render cement tanks water-tight.

Rendering is usually done with equal parts Portland cement and sand, and laid on from ½ inch to ¾ inch thick, with a final layer of neat cement carefully trowelled on about ¼ inch thick.

French engineers usually specify a much greater thickness of cement and sand in equal parts, without the neat cement layer.

Portland cement rendering usually made of 1 cement to 3 of well washed sand.

External mouldings and linings to water tanks neat cement.

A simple Rule to avoid loss in Cupping is, when constructing, to make the tank measured from the rest-stones the full depth of the various lifts, plus a depth equal to the difference between the displacement of the inner and outer lifts, and add a margin of 3 inches.

Pumps for gasholders should be made with an outer casing to the bottom of the pipes to be pumped, so that the pump may be removed for repairs without an escape of gas.

Tank, 114 feet × 31 feet deep, at Wellingborough, made with Portland cement concrete 7 to 1, and puddled at back, no rendering, concrete over dumpling (of clay) 6 inches thick.

Wall of tank 123 feet diameter × 30 feet deep = 3 feet 6 inches thick at bottom to 2 feet thick at top.

A cast iron tank 112 feet diameter × 25 feet deep has been erected, weighing about 500 tons.

Concrete made with clinkers and broken firebricks and retorts said to be stronger in tension than if made all Thames ballast.

GASHOLDERS.

General Notes.

Mr. G. Livesey stated (1882) that 20*l.* per 1,000 cubic foot capacity was a usual cost of gasholders of moderate size.

Two holders of about equal size should be provided in all works.

When extending, holder capacity should be doubled by the addition of one holder of equal capacity to all the previous ones combined.

Single lift holders should not be used except for less than 10,000 cubic feet capacity.

Height of lift should $= \frac{\text{diameter}}{4}$

Holders above 500,000 cubic feet capacity should be three lifts.

When weight is required to give necessary pressure increase the thickness of sheets and cups.

No necessity to break joint in side sheets, as load is much below the strength of the sheets.

It should be borne in mind that the larger the sheets the less rivets are required, and the liability to leakage is reduced.

The strain on top sheets diminishes in exact proportion to the rise, and is uniform throughout the top sheets.

Usual rise $= \frac{\text{diameter}}{20}$. Shape of dome equals segment of a sphere.

With rise $= \frac{\text{diameter}}{20}$, No. 11 Birmingham wire gauge sheets are sufficient up to, say, 175 feet diameter, but when larger, No. 10 sheets and an increased rise would be better. Rivets $\frac{5}{16}$ inches diameter.

The crown curb in trussed holders has not much work to do.

The best form of curb is an angle iron or steel, but in larger holders where the compressing strain may equal 200 tons other pattern curbs must be adopted.

Mr. Livesey considers 40 lbs. per foot as the maximum wind force likely to be exerted on a gasholder; and 57 per cent. of this force is exerted on the cylinder as compared with a flat surface.

When diagonal bracing of sufficient strength is in use, the side strength of the columns or posts need not be great as the strain is resisted by the bracing.

For moderate sized gasholders, Mr. G. Livesey and Mr. C. Hunt prefer cast iron columns.

Theoretically if pressure is brought upon a cylinder it tends to expand it in all directions.

In a gasholder at New Jersey, U.S.A., which overturned in a gale, all the columns but one fell outwards.

Mr. Foulis considers 50 lbs. per square foot should be allowed for as wind pressure on gasholders.

Mr. Cripps suggests gussets to connect the first row of top sheets with the top row of side sheets in small holders.

To find the strain on top sheets—

$$18{\cdot}3\ \frac{\text{Weight of side sheets in tons}}{\text{angle of top in degrees}} = \text{strain}$$

or,

$$\frac{(\text{Half diameter of holder}^2 + \text{rise}^2) \times \text{effective pressure of gas} \times \text{diameter of holder in feet}}{8 \times \text{rise}} = \text{strain}$$

It is essential that gasholders should be maintained perfectly level.

The Old Kent Road type of gasholder "is one of that class of structures in which it is impossible to foresee the exact intensity and nature of the stresses." (Sir B. Baker.)

Steel curbs are better than iron as they stand a higher compressive strain.

Two angles, one set at each end of the first and thicker row of top sheets, is the easiest and simplest method of constructing a curb where considerable strain has to be resisted, as each inch of section is profitably utilised.

Radial rollers spread the wind pressure on one quarter of the guides.

Tangential rollers spread the wind pressure on one half of the guides.

The two combined spread the wind pressure on three quarters of the guides.

Mr. Webber considers the two combined spread the wind pressure on two-thirds of the guides.

With tangential, or these combined with radial rollers, the pressure from the curb is better distributed, and the strain upon the guides is thrown in a tangential direction, thereby bringing the diagonal bracing directly into use in the position it is best able to resist the strain.

Stays to inner lifts of gasholders are usually made of T iron trussed, but in large holders channel and H iron frequently take the place of the T.

Channel iron forms, on the outer lifts, both a stay and also a guide path for the next inner lift roller.

Vertical stiffeners require securely fastening to cups and grips.

Vertical rows of thicker section plate are not advisable, as the riveting to the next rows on either side is not so tight.

Sometimes the stiffeners are riveted to the side sheets by rivets at very close pitch, sometimes at 1 foot apart, and at others only attached to cup and grip.

Gasholder sheets should never be allowed to oxidise, but receive a coat of boiled oil immediately they are planished and punched.

An average gasholder contains more than 40 feet run of riveting and joint per 100 cubic feet.

It is not considered advisable to rivet crown sheets to trussing in holders, as it prevents the sheeting ballooning out into a spherical shape, and throws great strain on the rivets.

Weight of bell of holder is almost equal to that of the guide framing in wrought iron or steel.

All rivets should be well brought up with the set, firmly held and properly riveted, if a sound job is to be secured.

All holders should be well painted every year.

Wyatt says about 20 lbs. weight of wrought iron is used per superficial foot of sheeting (inclusive of the guide framing). Of this 12 lbs. is the holder proper and 8 lbs. the framing. (October, 1887.)

Side sheets vary in thickness from No. 11 in large holders to 17 Birmingham wire gauge in small ones.

The depth of each lift must never be less than $\frac{1}{7}$th of the diameter of the holder; and it will work better if it be $\frac{1}{4}$th or $\frac{1}{5}$th the diameter.

With holders up to 120 feet diameter, it is cheaper to put in a light trussing than to place a wooden framing in the tank; but above this size it is more economical to put a timber framing to receive the holder when down. The trussing of a gasholder should never be more than 10 to 12 per cent. of the floating weight.

Useless weight due to trussing of holders may cause an increase of 10 to 12 per cent. in the fuel account of the boiler supplying steam to the exhauster engine.

Large single lift gasholders are often made so light that weights are required to cause them to throw sufficient pressure. In this case water troughs should be employed so that the water can be run in at night when pressure is required, and the back pressure in works relieved during the day in running off the water.

Mr. C. Hunt prefers cast iron columns for holders of moderate size, as a cast iron column is cheap and easy to construct.

It has been proposed to carry the pipe from the meter to the governor house, and there connect it by a valve to the town mains before leading it to the gasholders, so that in case of a stoppage at the gasholders it can be at once turned on direct into the town, a governor being used to give warning of the necessity of turning on the valve.

Rivets Required to Join Different Thickness Plates in Gasholder Construction. (C. and W. Walker.)

$\frac{3}{4}$ inch	to	$\frac{5}{8}$ inch	require	$\frac{7}{8}$ inch	rivets at	$2\frac{1}{2}$	inches pitch.
$\frac{5}{8}$,,	,,	$\frac{5}{8}$,,	,,	$\frac{3}{4}$,,	,, ,,	$2\frac{1}{4}$	,, ,,
$\frac{5}{8}$,,	,,	$\frac{1}{4}$,,	,,	$\frac{3}{4}$,,	,, ,,	$2\frac{1}{4}$	,, ,,
$\frac{1}{4}$,,	,,	$\frac{1}{4}$,,	,,	$\frac{5}{8}$,,	,, ,,	2	,, ,,
$\frac{1}{4}$,,	,,	10 B.W.G.	,,	$\frac{1}{2}$,,	,, ,,	$1\frac{1}{2}$	,, ,,
10 B.W.G.	,,	10 B.W.G.	,,	$\frac{1}{4}$,,	,, ,,	1	inch ,,
10 B.W.G.	,,	$\frac{3}{16}$ inch	,,	$\frac{3}{8}$,,	,, ,,	$1\frac{3}{8}$	inches ,,
$\frac{3}{16}$ inch	,,	$\frac{3}{16}$,,	,,	$\frac{3}{8}$,,	,, ,,	$1\frac{3}{8}$	,, ,,
$\frac{3}{16}$,,	,,	$\frac{3}{8}$,,	,,	$\frac{1}{2}$,,	,, ,,	$1\frac{1}{2}$	,, ,,

Riveting (single) to No. 11 plates = $\frac{1}{35}$th weight of plates.
,, (double) ,, ,, = $\frac{1}{18}$th ,, ,, ,,
,, (single) $\frac{5}{8}$ inch plates $1\frac{1}{2}$ inch pitch = $\frac{1}{9}$th ,, ,, ,,
,, (double) ,, ,, ,, ,, = $\frac{1}{4}$th ,, ,, ,,

Riveting to irons $2\frac{1}{2}$ inches to 6 inches pitch average $\frac{1}{8}$th of weight of plates.

Not possible to join a thin plate to a thick one and make a gas-tight joint, therefore the second plate from curb should be half way between outer plate and crown sheeting in thickness.

Reduce the thickness of sheets gradually to ensure tightness.

Always rivet a thin sheet to a thick one.

Allowance for lap of plates—

When the lap equals $1\frac{1}{8}$ inches add $\frac{1}{14}$ inch or 7 per cent. (no rivets).

Allowance for waste on rivets, 10 per cent.

" for rivets, bolts, and laps over and above plates $\frac{1}{5}$ to $\frac{1}{6}$.

Expansion of cast iron 100 feet long $= \frac{3}{4}$ inch for 100° F. (Horton.)
" wrought iron " " " $= \frac{9}{10}$ " " 100° F.
" copper " " " $= 1{\cdot}28$ " " 100° F.

Iron expands with tension and contracts with compression $\frac{1}{12000}$th of its length per ton per square inch.

Table showing the Strains on a Holder 200 feet diameter, with Different Rises of Crown. (V. Wyatt.)

Rise of Crown of Holder in Feet.	Surface of Domeequals 6·2832 R. V. SquareFeet.	Ratios of Dome to Plane Surface Area.	Radius of Dome.	Tension on $\frac{1}{4}$ of Dome.	Tension on 1 Foot in Length of Dome.	Compression on One Section of Top Curb.
0	31416	1·0000	0			
10	31730	1·0100	505	528	3·40	331
15	32091	1·0214	340	348	2·20	213
20	32672	1·0400	260	272	1·80	161
25	33300	1·0600	212	222	1·40	126
40	36442	1·1600	145	151	0·96	70
50	39250	1·2500	125	131	0·83	51
100	62832	2·0000	100	$104\frac{1}{2}$	0·67	00

Doubling the rise of the crown reduces the strain on the top sheeting one half; here it is well to break joints as strength is required, and 96 per cent of the plates can be ordinary square sheets. Strain being equal on all crown sheets, they should be of equal thickness.

Radiating strips are unnecessary. Usual rise of crown $= \frac{\text{diameter}}{20}$ in the form of a segment of a sphere, in this case No. 11 gauge sheets are sufficient for gasholders of moderate size, but for 200 feet diameter holders No. 10 gauge sheets better and larger rise. Rivets in crown sheets should be $\frac{5}{16}$ inch diameter.

Trussed holders require only moderate curbs.

Cheapest (and easiest and simplest to construct) curb, is two angles of iron or steel, one at each end of a flat plate.

Messrs. C. and W. Walker construct all their holders to one curve for the top, which is an arc of a circle 405 feet radius, but for holders under 50 feet diameter give them a greater rise than this.

Strain on crown sheeting varies almost inversely as the rise.

Rise of crown sometimes made ·875 of an inch per foot in diameter, which is the form it would take with a bursting pressure.

It has been suggested that a radius of 400 feet for gasholder crowns should be used, as $\frac{1}{8}$ inch sheets are then strained to what they will safely bear in most gasholders.

Pressure of snow may cause a load of 5 lbs. per square foot over $\frac{1}{4}$th the area of a holder, and the centre of gravity may be (say) $\frac{1}{6}$th diameter from edge. (F. S. Cripps.)

1 cubic foot fresh snow 5 to 12 lbs. . . . Trautwine.
1 „ „ snow compacted by rain 15 to 50 lbs. „

Weight of gasholder bell equals weight of 1 cubic foot water × area on water line in feet × pressure thrown in feet, or,

Area × 5·2083 = lbs. per inch pressure.

Equilibration chains to gasholders.

Formula for required weight of chains :

w = weight of 1 foot vertical of gasholder in lbs.
G = specific gravity of iron in ditto.
W = weight of 1 foot of chain in lbs.
N = number of chains.

$$W = \frac{w}{2\,G\,N}$$

To find the weight of a gasholder—

W = weight in lbs.
A = area of water surface in sq. ft.
p = pressure in inches thrown.
then, W = A 5·2 p.

To find pressure of a gasholder :—

W = weight in tons.
d = diameter in feet.
p = pressure in inches.

$$p = \frac{547\,W}{d^2}$$

Force of the Wind.

Velocity.		Force.	
Miles per Hour.	Feet per Second.	Lbs. per Square Foot.	
1	1·47	·005	Hardly perceptible.
2	2·93	·012	
3	4·40	·044	Just perceptible.
4	5·87	·048	
5	7·33	·123	Gentle pleasant breeze.
	10·0	·229	
10	14·67	·300	Pleasant brisk gale.
	20·0	·915	
15	22·0	1·107	
20	29·34	1·968	
	30·0	2·059	
25	36·67	3·075	Very brisk gale.
	40·0	3·660	
30	44·01	4·429	
	50·0	5·718	
35	51·34	6·027	High winds.
40	58·68	7·873	
	60·0	8·234	Hard gale.
	70·0	11·207	
50	73·35	12·300	Very high winds.
	80·0	14·638	
60	88·12	17·715	A storm.
	90·0	18·526	
	100·0	22·872	A great storm.
	110·0	27·675	
80	117·36	31·490	A hurricane.
	120·0	32·926	
	130·0	38·654	
90	132·02	39·852	
	140·0	44·830	
100	146·7	49·200	
	150·0	51·462	
120	176·04	70·860	

Velocity and Pressure of Wind. (Another Rule.)

Miles per Hour.	Feet per Second.	Lbs. per Square Foot.	Miles per Hour.	Feet per Second.	Lbs. per Square Foot.	Miles per Hour.	Feet per Second.	Lbs. per Square Foot.
1	1·46	0·005	18	26·40	1·620	35	51·33	6·125
2	2·93	0·020	19	27·86	1·805	36	52·80	6·480
3	4·40	0·045	20	29·33	2·000	37	54·26	6·845
4	5·86	0·080	21	30·80	2·205	38	55·73	7·220
5	7·33	0·125	22	32·26	2·420	39	57·20	7·605
6	8·80	0·160	23	33·73	2·645	40	58·66	8·000
7	10·26	0·245	24	35·20	2·880	41	60·13	8·405
8	11·73	0·320	25	36·66	3·125	42	61·60	8·820
9	13·20	0·405	26	38·13	3·380	43	63·06	9·245
10	14·66	0·500	27	39·60	3·645	44	64·53	9·680
11	16·13	0·605	28	41·06	3·920	45	66·00	10·125
12	17·60	0·720	29	42·53	4·205	46	67·46	10·580
13	19·06	0·845	30	44·00	4·500	47	68·93	11·045
14	20·53	0·980	31	45·46	4·805	48	70·40	11·520
15	22·00	1·125	32	46·93	5·140	49	71·86	12·005
16	23·46	1·280	33	48·40	5·445	50	73·33	12·500
17	24·93	1·445	34	49·86	5·780	60	88·00	18·000

Formula for obtaining the Velocity of High Winds from the Pressure.

$$\text{Velocity} = \sqrt{10 \times \text{pressure.}}$$

Formula for obtaining the Pressure of High Winds from the Velocity.

$$\text{Pressure} = \frac{\text{velocity}^2}{10}$$

A maximum wind pressure of 56 pounds per square foot is recommended in calculations for railway bridges and viaducts.

Greatest pressure of wind recorded in pounds per square foot at :—

Aberdeen	41	Liverpool	90
Armagh	27	London	20·2
Birmingham	27	Valentia	65·6
Edinburgh	35	Yarmouth	42·2
Falmouth	53·7	Brussels	22
Glasgow	47	Paris	17
Greenwich	42	Bombay	38
Halifax	30·2	Calcutta	40
Holyhead	64	Madras	34
Kew	27		

Allowance for Wind and Snow.

Weight of snow on horizontal surface	=	say 15·5 lbs. per square foot.
Wind pressure on surface at right angles to line of impact	=	„ 24·6 lbs. „ „ „
Wind pressure on surface in specially exposed positions	=	„ 31·0 lbs. „ „ „

(D. K. Clark.)

According to returns from the Greenwich Observatory during 20 years the greatest pressure equal to 28 lbs. per square foot from the west.

Velocity of the wind (feet per second) squared × ·002283 = lbs. pressure per square foot.

At the Eiffel Tower it was found that the wind was 3 times as strong at 303 metres from the ground as it was at 21 metres, the velocity at the higher level in summer exceeding 8 metres per second during 39 per cent. of the time and 10 metres per second during 21 per cent.

Observations at the Eiffel Tower show an increase of 33 per cent. in velocity and pressure of wind per 100 feet in height.

Within certain limits the intensity of wind-pressure increases with the area of the receiving surface ; but over large areas the maximum is not reached in practice, owing to the wind moving in concentrated gusts. In designing structures, although 56 lbs. per square foot might be looked upon as the standard, this should be modified according to the circumstances of the case, viz.: with the height from ground level, the unsupported width, and the angle of incidence. Pressures, according to received tables, varied from 16 lbs. at ground level, to 80 lbs. at a height of 200 feet ; and, in the latter case, from 80 lbs. at a width of 10 feet to 40 lbs. at a width of 1,000 feet, while the multiplier for angle varied from 0·45 at 5 degrees to 1·00 at 60 to 90 degrees. (Professor Adams.)

Sir G. Stokes recommends that the rate of travel of cup anemometer should be multiplied by 2·4 instead of 3 to get the velocity, and that velocity $^2 \times 0{\cdot}0035$ should equal pressure instead of velocity $^2 \times 0{\cdot}005$.

Maximum wind pressure usually allowed $= 0{\cdot}01\ v^2$; $v =$ velocity of wind by cup anemometer.

In France velocity of storms is taken at 100 miles per hour, and pressures up to 60 lbs. per square foot over the effective area of 1 truss of a solid truss bridge, or 1·5 trusses of an open trussed bridge.

In America wind pressures of 30 lbs. per square foot are allowed on large surfaces and from 40 to 50 lbs. per square foot on small surfaces.

$$\text{Velocity of high winds} = \sqrt{10\,p}$$

$$\text{Pressure in lbs. per square foot} = \frac{v^2}{10}$$

Greatest wind pressures observed at the Forth Bridge were by large fixed gauge 27 lbs., by small fixed gauge 41 lbs., and by revolving gauge 35 lbs. per square foot.

If pressure be exerted against a cylinder it tends to extend the cylinder radially in all directions. (C. Hunt.)

Gasholders are now made to stand a maximum crushing strain equalling a pressure of 20 lbs. on the square foot, exerted on a plane represented by 50 per cent. of the area of vertical transverse section of the holder. (Newbigging, August 28th, 1888.)

Pressure on guide columns usually taken as equal to the total wind pressure divided among the guide columns upon which the rollers bear at one time, and this again divided among the different rollers to each lift.

With the upright guide form of standard they are capable of resisting the pressure of the radial rollers, while the diagonals resist the lateral strains.

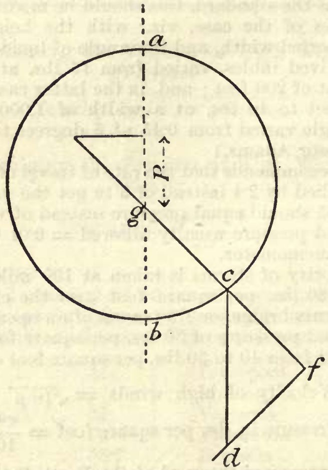
Johnson's "Theory of Framed Structures"—Wind pressure $P = 0{\cdot}004\, v\, 2$; where $v =$ velocity in miles per hour.

Mr. Cripps uses a wind pressure of 34 lbs. per square foot.

Pressure of wind on a gasholder equals 16 lbs. per square foot over the entire diametrical section. (F. S. Cripps.)

Wind Pressure on Circular Objects.

Let $dc = p$, force of wind acting parallel to the diameter $b\ a$. Resolve this into its component parts acting at right angles to one another at the point c, one of them, $f\ c$, being a normal to the curve; we then have $f\ c$ as representing the force of the wind acting towards



the centre of the circle, and $f\ c = p\ cos.$ angle $d\ c\ f$. Resolving this force $f\ c$ at the point g, so as to measure the effective force exerted in the direction g, and parallel to the wind we have the effective pressure $P = p\ cos.^2$ angle $d\ c\ f$. This angle $d\ c\ f$ ranges from 0° to 90°, and taking a sufficient number of angles we obtain *cos.*² angle $d\,c\,f =$ about ·5 ; therefore mean effective pressure of wind against semi-circumference $P = \cdot 5p$. (Bancroft.)

Greatest wind likely to press upon gasholder equals 26 lbs. per square foot of diametrical section of the bell.

For the reduction of wind pressure on a circular surface to an equivalent plane area (such as an arched roof or a gasholder)—

Prof. Rankine	gives	0·5
M. Arson	,,	0·46
R. J. Hutton	,,	0·67
W. H. Y. Webber	,,	0·5
Molesworth	,,	0·75
G. Livesey	,,	0·57
Prof. Adams	,,	0·7854
Walmisley	,,	0·56
V. Wyatt	,,	1·0 (October, 1887)
Bancroft	,,	0·5
Cripps	,,	0·3
Sir B. Baker	,,	0·41
Newbigging	,,	0·5 area of section.
Trautwine	,,	0·5 ,, ,,
Prof. Kernot (of Melbourne University)	gives	0·5 ,, ,,

Prof. Kernot, of Melbourne University, found pressure on one side of a cube = 0·9 that on a thin plate of the same area ; and in lattice work, in which openings = 50 per cent. total area, the pressure = 80 per cent. of that upon a plate = the total area. Pressure on octagonal prism = 20 per cent. more than upon circumscribing cylinder.

Pressure on sphere = 0·36 of a thin circular plate of equal diameter. Prof. Kernot also recommended 20 lbs. per square foot as a maximum upon areas of not less than 300 square feet, and 30 lbs. for smaller surfaces in position of full exposure.

To find approximate area of a segment of a circle, multiply versed sine by ·6 × chord = area.

Cost of six-lift holder, at East Greenwich, of 12,000,000 cubic feet capacity, two upper lifts to go outside ; framing designed by F. Livesey.

Contract amount, £41,915.

Wrought iron used		1,840 tons
Cast iron	,,	60 ,,
Steel	,,	320 ,,
		2,220 ,,

Cost per 1,000 cubic feet £3 10*s*. Cost of tank and holder, say £5.

Cost of gasholders equals cost of the remaining manufacturing plant. (C. Hunt.)

Cost of gasholders equals one-third of the remaining manufacturing plant. (G. Livesey.)

Notes on Guide Framing.

Guide framing must be strong enough to resist all strain from snow and wind, jamming of rollers, and guides out of plumb.

The lighter forms of guide framing depend largely upon the strength of the curb and grips to prevent distortion, but it is better to ignore this strength when calculating the guide framing, and make the latter strong enough to do all the resisting itself.

If the diagonal bracing is properly placed and of sufficient strength the greatest portion of the strain may be resisted by it.

Diagonal bracing with the old-fashioned ring for tightening in the centre is weak, coupling screws serving the purpose much better with clips where the braces cross.

Make the standard strong enough to transmit the strain from the front to the outside member.

The strain upon the uprights of a gasholder framing is a cantilever one.

In designing gasholder framing use, as far as possible, the same size and section of iron, to avoid the expense of having a number of different pattern bars rolled. (J. Somerville.)

Wrought iron in gasholder framing has been objected to on the score of rusting, but a coat of paint every two or three years will cure this.

Gasholder guides should be fixed leaning inward slightly, according to the contraction of the curb when fully inflated.

All the wrought iron in gasholder construction should withstand a tensile strain of 21 tons per square inch, and should be absolutely tested. (J. Somerville.)

By tangential rollers the strain is thrown mainly upon the tension rods and cross girders of the framing.

Make as many triangles in the guide framing as possible in preference to parallelograms.

The yielding of wrought iron or steel framing to gasholders is said to be of advantage, cast iron columns and girders having often broken through undiscovered flaws, and caused wrecking of the whole structure.

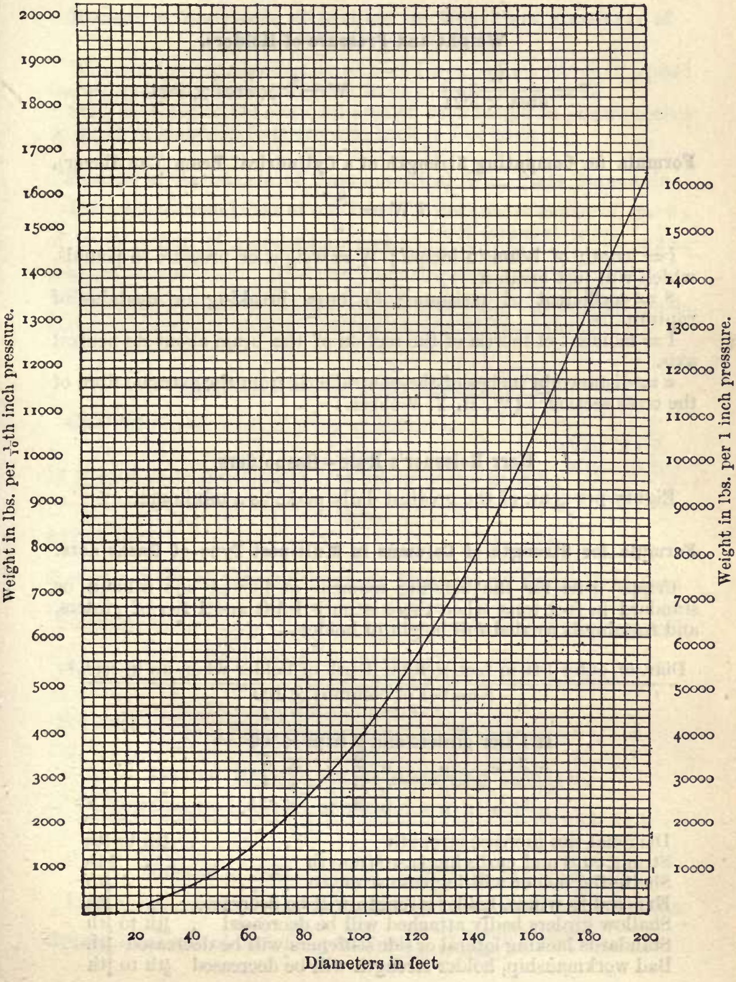
"The steadiness of a holder depends far more upon the tightness of the bottom rollers than upon any other condition. It is the practice of good gasholder erectors to make the bottom rollers fit the tank guides as tightly as they can be dropped into place." (W. H. Y. Webber.)

In Gadd and Mason's spiral guided gasholders the guides are usually set an angle of 45°.

To obtain Weight of any Holder.

Diameter² × pressure in $\frac{1}{10}$th inch × ·4091 = weight of holder in pounds.

Diagram of Pressures thrown by Holders of Different Weights and Diameters; also Weights of Holders per one-tenth and 1 inch Pressures.



To obtain Pressure which a Holder will throw.

$$\frac{\text{Weight of holder in lbs.}}{\text{Diameter}^2 \times \cdot 4091} = \text{pressure in } \tfrac{1}{10}\text{th inch.}$$

Weight and Pressure of Holders.

$$P = \frac{W}{\text{area} \times 5{\cdot}21} \qquad W = P \times \text{area} \times 5{\cdot}21.$$

Formula for Computing Strength of a Cylindrical Beam (Cantilever).

$$l\,W = \frac{S.I}{x}$$

l = length of beam in inches; W = weight or pressure in pounds, which will just break it.

S = coefficient of resistance to cross breaking or modulus of rupture.

I = moment of inertia of the section of the beam about its neutral axis.

x = distance in inches of the neutral axis from the extreme fibre of the cross section. (W. H. Y. Webber.)

Herr Reissner's Rule—Gasholders.

Eighty per cent. of the greatest daily make as a minimum.

Formula for Strength of Columns in Multipost Type of Gasholders.

Cripps' rule for the bending moment at foot of one column or standard in foot tons, when there is only 1 lift and 1 tier of girders, and framing is carried full height of holder—

$$\frac{\text{Diar. of outer lift in feet} \times \text{total depth of holder when up in feet.}^2}{\text{Number of columns} \times 100}$$

If 1 tier girders and 2 lifts × ·66
„ 2 „ „ „ 2 „ × ·5
„ 2 „ „ „ 3 „ × ·4
„ 3 „ „ „ 3 „ × ·34

Diagonal ties increase strength	$\tfrac{1}{6}$th to $\tfrac{1}{5}$th
Strong cups and curbs increase strength	$\tfrac{1}{10}$th
Sheltering holder will increase strength	$\tfrac{1}{4}$th
Exposed to winds, holder strength will be decreased .	$\tfrac{1}{4}$th
Shallow girders badly attached will be decreased .	$\tfrac{1}{6}$th to $\tfrac{1}{5}$th
Standards lacking lateral or side stiffeners will be decreased	$\tfrac{1}{5}$th
Bad workmanship, holder strength will be decreased	$\tfrac{1}{6}$th to $\tfrac{1}{4}$th

Moment of Resistance of Round Cast Iron Columns.

$$\frac{\text{Sectional area of column in sq. ins.} \times \text{diar. of column in ft.}}{1{\cdot}6} = \text{foot tons.}$$

Moment of Resistance of Latticed or Web Plate Standards of Symmetrical Cross Section.

Wrought iron equals effective sectional area of back flange in square inches × depth of standard from front to back in feet × 5.

Steel equals effective sectional area of back flange in square inches × depth of standard from front to back in feet × 8.

Moment of Resistance of Unsymmetrical Web Plate Standards.

Effective sectional area of one flange × distance of centre of gravity of cross section of standard in feet $\times \left\{\begin{matrix}\text{5, if wrought iron}\\ \text{8, if steel}\end{matrix}\right\} \times 2 =$ moment of resistance. (Deduced from Cripps.)

For reasons of above and further information on gasholders' guide framing, see Cripps on the "Guide Framing of Gasholders."

GASHOLDERS OF CANTILEVER TYPE.

Overturning moment of wind and snow =

$$\frac{8 \times \text{diar. of col. circle in ft.} \times \text{depth of holder in ft.}^2 + \dfrac{\text{diar. of col. circle in ft.}^3}{3}}{2{,}240}$$

= foot tons.

Sectional Area of Single Column or Standard to Resist Dead Load.

For cast iron, $\dfrac{24 \times \text{depth}^2 + \text{diameter}^2}{3{,}360 \times \text{No. of columns}} = \text{sectional area required.}$

For wrot. iron, $\dfrac{24 \times \text{depth}^2 + \text{diameter}^2}{5{,}040 \times \text{No. of columns}} =$ " " "

For steel, $\dfrac{24 \times \text{depth}^2 + \text{diameter}^2}{6{,}720 \times \text{No. of columns}} =$ " " "

Bending Moment Due to Distorting Influence.

$$\frac{\text{Distance centre to centre of standards} \times \text{height}^2}{270} = \text{inch tons.}$$

Moment of Resistance to Distorting Influence.

Distance of centre of gravity of standard from back flange × effective sectional area of back flange $\times 2 \times \left\{\begin{matrix}\text{5, if wrought iron.}\\ \text{8, if steel.}\end{matrix}\right.$

Formula for Vertical Sheer.

$$\frac{24 \times \text{depth}^2 + \text{diameter}^2}{10{,}000} = \text{foot tons.}$$

This must be resolved in direction of tie rods and struts, and divided into the different panels according to their number, in the proportion of $1 + 2 + 3 + 4$, &c. $= x$. Therefore tension in top tie rod $= \frac{1}{x} \times$ resolved sheer in direction of tie rods, by which strength necessary in each tie rod may be calculated.

And for calculating strength for each strut, $\frac{1}{x} \times$ resolved sheer in direction of struts.

NOTES ON CUPS AND GRIPS.

Weight of steel forming crown curb of $5\frac{1}{2}$ million holders at Old Kent Road equals 8 per cent. of the floating weight.

Depth of cup must allow for evaporation and tilting of holder.

Cups and grips usually have half-round iron as a bead riveted at edges.

Two channel irons have been used by Mr. C. Woodall, one at each end of first row of crown sheets, joined underneath by a second plate to form a box girder to resist compressional strains.

Use strong bottom curbs and well adjusted rollers to them.

Blocks should be fastened in bottom of all cups for grip of next outer lift to rest on.

Guide rollers and carriages should be made strong enough to resist sudden strains, especially if no provision has been made for keeping them always close up to the guides.

The pin should be fixed and the guide roller revolve upon it.

Rule for determining the stability of the inner lift when cupped— $D^2 \times 16$ must not exceed weight hanging on the inner lift in pounds. $D =$ depth in feet.

Steam should be run into lute at distances of not more than 200 feet apart, and this can be made to raise the temperature of the water to 50° F.

Inlet and Outlet Pipes to Holders should be of such size as to allow a maximum velocity of 16 feet per second when the gas is passing through them.

Horizontal and Compression Strains in tons on crown curb and on any one section of same, taken at any point, clear of all cover plates $= C =$

$$\left(\frac{\text{Vertical effective pressure in tons on } \tfrac{1}{4}\text{th crown area} \times \text{diameter}}{4 \text{ versed sine}} - \frac{\text{Vertical effective pressure in tons on } \tfrac{1}{4}\text{th crown area} \times \text{versed sine}}{\text{diameter}}\right) 0{\cdot}64$$

or,

$$\left(T - \frac{\dfrac{\text{vertical effective pressure in tons on } \tfrac{1}{4}\text{th crown area} \times}{2 \text{ versed sine}}}{\text{diameter}} \right) 0{\cdot}64$$

or,

$$\frac{\left(\left\{ \dfrac{\text{Diar.}}{2} \right\}^2 - \text{ver. sine}^2 \right) \text{effective pressure of gas in lbs. per square foot of crown} \times 2 \text{ versed sine}}{8 \text{ versed sine}}$$

Tension strain on one foot vertical of side plates in tons = S =

$$\frac{\dfrac{\text{Diameter}}{2} \times \text{pressure of gas per square foot of crown and side sheets}}{2{,}240}$$

Radius of crown in feet = R =

$$\frac{\text{Diameter}^2}{8 \text{ versed sine}} + \frac{\text{versed sine}}{2}$$

or,

$$\frac{\dfrac{\text{Diameter}^2}{2} \times \text{versed sine}^2}{2 \text{ versed sine}}$$

Mr. Wyatt says that not more than 33 per cent. of the strength of the solid unpunched plate is obtained by ordinary riveted gasholder sheet joints, and suggests using a double line of rivets to the joints, say, $\frac{3}{8}$ inch diameter for $\frac{1}{8}$ inch plates, put in hot without tape, and a thick coat of red lead paint in the joint; lap say, $1\frac{7}{8}$ inch; centre to centre of rivets diagonally, $1\frac{1}{8}$ inch; centre to centre of rivets longitudinally, $1\frac{7}{8}$ inch; distance between centres of rows of rivets, $\frac{9}{16}$ inch; by which means about 70 per cent. of the strength of the plate may be obtained.

Ordinary practice is single riveting equal to 50 per cent. strength of plate in gasholder work.

Wyatt's Rules for Strains in Gasholders.

Tangential tension strain in tons from $\frac{1}{4}$th crown area (= portion acting on one sectional area of crown curb) = T =

$$\frac{\text{Vertical effective pressure in tons on } \tfrac{1}{4}\text{th crown area} \times \text{diameter of holder in feet}}{4 \text{ versed sine (rise in crown)}}$$

or,

$$\frac{\text{Vertical effective pressure in tons on } \tfrac{1}{4}\text{th crown area} \times \text{radius of crown in feet}}{\tfrac{1}{2} \text{ diameter}}$$

Tangential tension strain in tons on 1 foot length of crown sheeting, taken in any direction, and also on 1 foot of crown curb $= T' =$

$$\frac{\left\{\left(\frac{\text{diameter}}{2}\right)^2 \times \text{versed sine}^2\right\} \times \left\{\begin{matrix}\text{effective pressure of gas in lbs.}\\ \text{per square foot of crown}\end{matrix}\right.}{4 \times \text{versed sine}}$$

or,

$$\frac{\text{Radius of crown in ft.} \times \frac{\text{effective press. of gas in lbs. per sq. ft. of crown}}{2}}{2{,}240}$$

or,

$$\frac{\text{Tangential tension strain in tons from } \frac{1}{4}\text{th crown area}}{\frac{1}{4}\text{th circumference of holder}}$$

To find the thickness of Crown Sheets (safe strain = 5 tons per square inch) add the square of half the diameter of holder to the square of rise of crown, and multiply the sum by the effective pressure of gas in pounds per square foot, and divide the result by 5376 times the rise, multiplied by the percentage which the strength of joint bears to the solid plate. It is necessary to allow something for wear and tear, oxidation, unsound joints, riveting to thick plates, &c. (F. S. Cripps.)

To find the shearing strain on the rivets in top sheets per foot lineal, add the square of half the diameter of holder to the square of rise of crown, and multiply the sum by the effective pressure of gas in pounds per square foot, and divide the result by four times the rise = strain. (F. S. Cripps.)

Mr. Livesey found an average contraction on a holder 180 feet diameter of 0·6125 inch on lifting the inner holder, a further contraction of 0·3375 inch on lifting the outer holder, making a total contraction of 0·95 inch, of which 0·169 inch contraction remained as a permanent contraction when the holders were again landed.

The cup and lower curb plate should be made stronger than the rest as they cannot be painted.

It can be shown that only a few of the outer rings of crown sheets are in compression, say two or three rows and one row of side sheets.

Formula to Obtain the Tension on the Sheet Iron next Curb.
(Arson.)

$$\frac{\text{Weight of sides}}{\pi \text{ diameter} \times \text{sin. of angle of top sheets with horizontal}}$$

Formula to Obtain the Tensile Stress on the Rivets. (Arson.)

$$\frac{\text{Weight of sides}}{\pi \text{ diameter}} \text{ cos. of angle.}$$

Formula to Obtain the Crushing Stress on the Curb. (Arson.)

$$18{\cdot}3 \frac{\text{Weight of sides}}{\text{angle of top sheets with horizontal}}$$

Rule to Find the Compressive Strain on a Gasholder Curb.

$$\frac{(\text{Half the diameter of holder}^2 - \text{rise}^2) \times \text{pressure of gas in lbs. per square foot} \times \text{diameter of holder}}{\text{Rise} \times 8} =$$

Strain (compressive) in pounds due to the pull of the top sheets ; to this add depth of inner lift $\times$ 6·5 $\times$ diameter of holder for the pressure of wind, less $\frac{\text{diameter of holder}}{\text{10 or 16}} \times$ depth $\times$ actual pressure of gas for the pressure of gas on the sides.

The constant 10 is used for vertical stays fastened all the way up. The constant 16 is used for vertical stays loose. Difference equals compressive strain on top curb. (Deduced from Cripps.)

WORKSHOP NOTES.

Wyatt's Rule.—Three hundred and seventy cubic feet of workshops and offices required per ton per diem (dwelling-house included).

Best Speed for Cutting Tools when Working.

Steel . . .	12 feet per minute.	
Cast iron . .	18 " "	
Brass . . .	24 " "	
Wrought iron .	24 " "	
Wood . .	2,000 " "	when material revolves.
" . .	3 000 " "	when tool revolves.
Grindstone .	800 " "	

Circular saws should be run at about 9,000 feet per minute on the teeth.

Band saws should be run at about 4,000 feet per minute.

Planing and moulding rotary cutters, 5,000 feet to 7,000 feet per minute on cutting edge.

Emery discs, 4,000 feet to 6,000 feet per minute on periphery.

Drills for wrought iron should have circumferential speed of 140 to 160 inches, and for cast iron 80 to 120 inches.

Another authority gives—

Speed of Cutting Tools.

For Cast iron	150 to 190 inches	per minute.
" " (boring)	80 "	"
Wrought-iron	260 to 280 "	"
Yellow brass	300 "	"
Band saw for metal	250 feet	"
" " " wood	4,000 "	"
Teeth of circular saws	9,000 "	"
Cutter blocks for planing and moulding wood (cutting edge) . .	6,000 "	"
Irregular moulding and shaping machines, wood (cutting edge) .	5,000 "	"
Saw and cutter sharpening machine	5,000 "	"

General Notes.

A man will pull or exert an effective power of 35 lbs. in fair working.

Angles of cutting tools :—Wood, 30 to 40 degrees ; wrought iron, 60 degrees ; cast iron, 70 degrees ; brass 80 degrees.

Circumferential velocity of drill should equal about 100 inches per minute for cast iron and 150 inches for wrought iron.

Circumferential speed of emery wheels, about 5,000 feet per minute.
" " of grindstones, " 800 " "

The diameter of the hole in the die should exceed the diameter of the punch by about one fifth of the thickness of the metal to be punched.

The die first used was 36 millimetres in diameter; afterwards one of 39 millimetres in diameter was substituted without altering the size of the punch. The hole made with the 36-millimetre die underneath was cylindrical, but with the 39-millimetre die it was conical.

The amount of clearance between punch and die should equal one fifth the thickness of metal to be punched.

Diameter of die equals diameter of cutting edge of punch + 0·2 × thickness of plate to be punched.

Two pieces of aluminium or platinum pressed together for eight hours at 330° C. will cohere.

Iron castings contract about ⅛th inch per foot; brass castings, about $\frac{3}{16}$ths inch per foot.

Allow ⅔rds of the width of rails for mortices and ⅓rd for haunching.

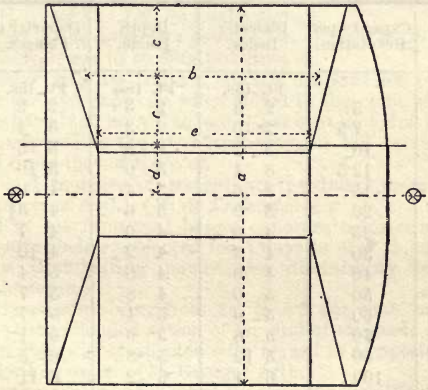
Approximate quantity of air required for welding in a smith's forge equals about 150 cubic feet per minute.

Station Meters.

Choose a station meter in which the spout is kept well above the water line, and see that the bearings and stuffing box can easily be got at for examination and repair. See that no useless metal is put into the drum, causing weight and consequent pressure to turn. Have sufficiently large openings in the hoods to allow an easy passage of the gas on both inlet and outlet ends of the drum.

To Find the Capacity of a Station Meter Drum.

Find the area of a circle of equal diameter to the diameter of the drum (a). Multiply by the average depth from centre of hood space on outlet end to centre of hood space on inlet end (b) above



the water line, and deduct from this a square equal to twice the water line above the centre of the drum (d) multiplied by length from inlet to outlet sides of drum on water line (e).

Herr Reissner's Rule—Station Meters.—Allow 80 revolutions per hour as a maximum.

The openings in the centres of station and other meters should be such as to allow the water to pass easily from one chamber to another, so as to relieve the pressure upon the partition. The same applies to the raising of the water line, which may cause the immersion of the partitions to such an extent as to cause a perceptible drag on the revolution of the drum.

Dimensions of Square Station Meters.

Capacity per Hour at 100 Revolutions.	Capacity per 1 Revolution.	Side to Side.		Front to Back.		Height.		Diameter of Drum.		Length of Drum.		Diameter of Connections.
		Ft.	Ins.	Ft.	Ins.	Ft.	Ins.	Ft.	Ins.	Ft.	Ins.	Inches.
20,000	200	9	3	8	6	9	6	8	0	7	6	12
25,000	250	9	3	9	3	9	6	8	2	8	0	12
30,000	300	10	0	10	0	10	9	8	7	8	6	14
40,000	400	11	3	11	3	12	0	9	9	9	0	15
50,000	500	12	0	12	0	13	0	10	6	10	6	16
60,000	600	12	0	13	0	13	0	10	6	11	6	18
80,000	800	13	6	13	6	14	0	12	0	11	6	20
100,000	1,000	15	4	15	0	16	6	13	6	11	6	24
125,000	1,250	15	4	15	0	16	6	14	0	12	4	24
150,000	1,500	15	6	17	6	15	5	13	6	14	2	24
250,000	2,500	20	6	19	3	21	0	18	0	15	0	30

Round Station Meters.

Capacity per Hour.	Capacity per Revolution.	Diameter Inside.		Depth Inside.		Diameter of Flanges.		Diameter of Connections.
		Ft.	Ins.	Ft.	Ins.	Ft.	Ins.	Inches.
600	5	2	3	2	3	2	9	2
900	7·5	2	10	2	3	3	4	3
1,200	10	3	2	2	8	3	8	3
1,500	12·5	3	4	3	0	3	10	4
1,800	15	3	6	3	4	4	0	4
2,400	20	3	9	3	6	4	3¼	4
3,000	25	4	0	4	0	4	7	5
3,600	30	4	3	4	2	4	10	6
4,000	40	4	9	4	6	5	4	6
5,000	50	5	0	4	8	5	7	6
6,000	60	5	0	5	4	5	7	8
7,000	70	5	6	5	6	6	1	8
8,000	80	5	10	5	8	6	5	8
10,000	100	6	4	6	2	6	11	9
12,500	125	6	10	6	2	7	5	10
15,000	150	7	0	7	10	7	7	10
17,500	175	7	3	7	6	7	10	12
20,000	200	8	0	7	6	8	7	12
25,000	250	8	0	9	6	8	7	12
30,000	300	8	5	9	8	9	0	14

STORING MATERIALS

Coal when exposed to the air changes in character, the change consisting in a diminution of agglomerating as well as of lighting power, and probably also of heating power.

The change is more rapid the higher the temperature and the more divided the coal.

In the small pieces the change in the character of the coal is greater on the surface than in the interior. In heaps of coal permeated by the air the change is greater in the centre than on the surface. When the air cannot penetrate to the centre the surface undergoes the greatest change.

Small coal washed is less liable to change than unwashed.

Large pieces of coal are only liable to change after a certain number of years' exposure to the air. The small coal is affected very quickly if it happens to be under conditions likely to raise its temperature.

In a few months it is capable of entirely losing its agglomerating and lighting power. Heaps of small coal become heated, but stacks of large coal do not heat to an appreciable degree.

Small coal should not be stacked in too large heaps.

Coal stacked in low heaps does not become heated. Heat increases with the height of the stack, and at about the height of 3 or 4 metres the temperature rises progressively and then descends without having exceeded 60° C. or 70° C.

The inner temperature of a stack 2 metres high does not usually exceed 40° C. to 50° C. (M. de Lachomette.)

Storing coal in the open may cause a loss of from 30 to 40 per cent. in the quantity of gas to be obtained from it.

North Wales coals and certain cannels are said not to depreciate appreciably through exposure when stored in the open, while certain Scotch coals have been known to lose 50 per cent. in value in 3 months.

All coals exposed to the air absorb oxygen, the volume of which may be 100 times that of the coal.

The loss and increase of weight are produced more slowly the larger the pieces of coal. (M. de Lachomette.)

The yield of gas from coal before exposure being equal to 26·36, fell to 6·60 after being subjected for 4 days to 400° C., and at 8 days to nil. The illuminating power also diminishing very quickly. (M. de Lachomette.)

Powdered coal containing from 1·6 to 8·3 per cent. oxygen when subjected to the prolonged action of air and of stagnant and running water is not appreciably affected with regard to composition, yield of coke, or calorific power. (M. Georges Arth.)

The drier the coal when stacked the less the liability to heat, and all trampling or compression should be avoided.

The only thing to be done with heated coal is to open it out and allow it to cool, or the heating will spread.

M. Morin suggests connecting the two ends of a thin platinum wire, about 0·0008 inch diameter, laid through the thermometer to a battery and galvanometer, when the varying resistance due to the rise and fall of the mercury will be shown upon the galvanometer, and the temperature of anything may be observed at a distance, such as in a heap of coals.

Another form of indicator for showing when coals are heated above a certain temperature might be made by means of the two wires from a battery covered with gutta-percha and the one wound round the other, so that when a sufficient heat was formed to melt the covering the two wires would be in contact, and could be made to ring an electric bell.

Igniting Points of Coals. (V. B. Lewes.)

Cannel	698° F.	= 370° C.
Hartlepool . . .	766° „	= 408° „
Lignite	842° „	= 450° „
Welsh steam . . .	870½° „	= 477° „

When Wire Ropes have to run over small pulleys or capstans the number of wires should be increased. In the case of cranes sometimes as many as 270 are used.

Average consumption of Coal per Passenger Train Mile equals 30 lbs., or about 1¼ lb. to 1¾ lb. for hauling 10 tons 1 mile. Consumption of coal per square foot of firegrate per hour varies from 60 lbs. to 80 lbs.

When large Stocks of Coke are stored in the open an increase in weight of 15 to 20 per cent., due to wet weather, has at times been found. (C. Gandon, Gas Institute, 1887.) See also p. 145.

Stacking coke in large quantities deteriorates the quality.

100 lbs. coke can absorb 50 lbs. water.

Increased quantity of breeze due to use of coke breaker only about 5 per cent. of coke broken, or 1 cwt. per ton of broken coke for sale. Less when broken while warm (say 1½ bushels per ton).

Oils flashing below 73° F. are not allowed to be stored in warehouses or shops in England.

RETORT HOUSE MANUFACTURE.

The gas produced in part of the retort nearest the front is not usually so good in quality or quantity as that from other parts.

Uneven charging reduces the temperature of the retorts and makes a poorer coke.

Uneven charges cause the evolution of gases of little or no illuminating power from the thin portion, while the thicker portion is not properly burnt off in the allotted time, and gas is lost.

Retorts which allow but little room above the coals are to be preferred, as then the gas passes quickly away from contact with the heated surface of the retort, which causes the decomposition of some of the olefiant gas.

The production of the hydrocarbon compounds from the coal takes place at a comparatively low temperature; these hydrocarbon compounds are then broken up into simpler forms by the passage through the retort and exposure to its heated sides.

Deep charges cause caking of the outer portion before the inner is worked off, the outer portion having been quickly gassified. The coke then is giving off sulphur. The thick charge cools the retort, and the gas then made is less and the tar high. (G. Anderson.)

Charge should fill the retort as full as will allow convenient charging and drawing.

Deep charges of coal cause caking on the exterior for some hours before the interior of the charge is worked off.

The whole of the outer surface is giving off sulphur for some hours after it has given off its gas.

The large mass cools the retorts for some time, while tarry vapours are being formed instead of gas.

Large retorts at low heats conduce to deposition of soot and napthalene.

The sulphur given off from damp coals is greater than from dry.

At high temperatures the gas produced contains methane (CH_4) and free H; and more free C in the tar and in the compounds of carbon belonging to the aromatic series derived from benzene (C_6H_6) and H is separated, and napthalene, anthracene, phenanthrene, chrysene, &c. are formed. (Dr. Lunge.)

At low temperatures the hydrocarbons formed belong to the paraffin series (methane), having the general formula CnH_2n+2, along with olefines (CnH_2n). (Dr. Lunge.)

With low heats the yield of ammonia is generally lower, which is also the case with high makes.

Low temperatures, with 9,000 cubic feet of gas per ton, will yield, with a certain coal, 16 gallons tar, but the same coal at high temperatures will yield 9 gallons tar and 11,000 cubic feet of gas. (Davis.)

If coal were distilled at low temperatures and the gases afterwards subjected to greater heat in separate retorts, where the heat could be accurately controlled, better results might accrue. (Foulis.)

Mr. Hunt, testing in a small iron retort, found that the greatest number of candles per ton was obtained with a temperature of

1,600° F., and he considers the best heat for ordinary working is the lowest that will thoroughly carbonize in the allotted time, the stopped pipes with high heats causing loss beyond the gain by the higher temperatures.

There is a certain temperature at which each coal may be made to yield the best results, both as to quantity and quality.

When gas is being evolved from coal the temperature of the retort is not even along the length of the retort.

When a substance is subjected to a high heat and to an advanced state of decomposition the products produced are generally of a simple nature.

The higher the heats the greater the proportion of hydrogen and methane and the lower that of C.

Temperature in retorts = 1,800° to 2,000° F. = temperature in hydraulic main of only 140° to 180° F. = 110° to 150° F. at outlet of latter. (J. Hornby.)

Temperature in retorts rarely more than 2,200° F.

Cherry red is the best heat for iron retorts.

A good orange is about right for clay retorts.

If the heat of retorts is 1,000° C. (1,832° F.) before the charge is in the heat of the coals near the walls will be about 800° C. (1472° F.) and in the centre of the coals 400° C. (752° F.).

The upper layer of evolved gas will be at a temperature of 1,000° C., and the lower, near the coal, 600° C. (1,112° F.) (Prof. Lewes.)

If a long piece of gas piping, closed at one end, is passed through a hole in the retort lid with the open end to the air it can be used to obtain the heat of the retort at different points. (L. T. Wright.)

The velocity of gas in its passage through highly heated retorts is about 5 feet per second during the maximum evolution of the gas.

Damp coals cause steam in the retort, which is afterwards condensed in the condensers, and which has a tendency to lower the temperature of the retort.

Loss between working in summer and winter equals 9·6 per cent. in favour of the former, in the sperm value obtained from similar coals.

Very high yields of gas are only obtainable with excessive use of fuel.

Clay retorts usually worked at 1,082° C.

At a yield of 118 cubic feet per square foot of retort, cast iron could be melted (= + 2,100° F.) in the top flue, and silver in the bottom flue (= + 1,749° F.).

The greater proportion of the CS_2 is formed after the useful gases have been driven off from the coal, and is increased if the coal be wet when put in the retort.

Best temperature for Newcastle coal is dull orange or 2,010° F.

Clay retorts are bad absorbers of heat compared with iron retorts.

Water vapour in the retort seems to have some protective action on napthalene. (L. T. Wright.)

The maximum production per square foot of retort surface may be taken as 126 cubic feet per ton, or 14·7 tons of coal carbonized per 1,000 square feet per 24 hours.

There are certain paraffin hydrocarbons in the coal which are split up into simpler members of the same series and into olefines

Fractional distillation is a means of separating liquids with boiling points at least 30° F. apart.

Cannel coal carbonizes in about five-sixths the time of caking coal, and the greatest quantity of gas is evolved during the first hour of charge.

Temperature of gas as it leaves the coal about 170° F.

The more rapidly the coal is carbonized the better are the results. (W. Foulis.)

Products of Distillation of Newcastle Coal at Usual Heats.
(Prof. Wanklyn.)

	lbs.	per cen
Gas (10,000 cubic feet)	380	17·0
Tar (10 gallons)	115	5·1
Virgin ammoniacal liquor	177	7·9
Coke (absolute)	1568	70·0

Residuals and Impurities at Outlets of Retorts in Percentage by Weight of Crude Gas. (Prof. Wanklyn.)

Tar	33	per cent.
Watery vapour	50	„
Ammonia	2	„
CO_2	5	„
H_2S	2 to 5	„
S. as sulphuret of carbon and organo-sulphur compounds	·15 to ·3	„

Result of Heating to about 1000° C. (Prof. Lewes.)

Ethane becomes ethylene and hydrogen.
Ethylene „ methane and acetylene.
Acetylene „ benzene, styrolene, retene, &c.

Variation in Quantity of CO_2 and H_2S according to the Heat of Distillation. (Lewis T. Wright.)

Yield of Gas per Ton.	Grs. of CO_2 per Cubic Foot.	Grs. of H_2S per Cubic Foot.
CAKING COALS.		
7,856	16·92	3·16
8,547	18·38	4·69
11,128	19·37	5·87
CANNEL COAL.		
7,853	32·60	4·80
10,047	39·27	4·97

The "salts" usually found mixed with tar in the hydraulic and foul mains are probably sal-ammoniac, and are formed by high heats.

Crude gas contains about 1 per cent. ammonia, weighing from 5½ lbs. to 8 lbs., and about 5 per cent. CO_2 and H_2S.

Result of Carbonization at Different Temperatures.

(L. T. Wright.)

Temperature.	Gas. Cubic Feet perTon	Illuminating power	Candles per Ton.	H. per Cent.	Methene per Cent.	Olefines per Cent.	CO. per Cent.	N. per Cent.
Dull red. .	8,250	20·5	33,950	38·09	42·72	7·55	8·72	2·92
Hotter .	9,693	17·8	34,510	43·77	34·50	5·83	12·50	3·40
,, . .	10,821	16·7	36,140	Test lost	Test lost	Test lost	Test lost	Test lost
Bright orange	12,006	15·6	37,460	48·02	30·70	4·51	13·96	2·81

At a low rate of distillation nearly all the gas is evolved at 1,340° F.

At the highest rate of distillation 66 per cent. of gas is evolved at 1,339° F.

When the yield of gas per ton is under 9,000 cubic feet the temperature of the bottom flue is not above 1,580° F., but with a temperature there of 1,680° F. the yield increased to 9,378 cubic feet per ton. (L. T. Wright).

Temperature of Retort.	Make of Gas.	Gallons of Tar.	Remarks.
	Feet per ton.		
600° F.	400		coke very friable.
750° to 800° F.	1,400	68	
1000° F.	6,000		faint red heat.
1830° F.	8,300	13 to 14 gals.	bright cherry red heat.
2010° F.	10,000	9	orange heat.

Low temperatures give little ammonia.

Medium temperatures give most ammonia.

Higher temperatures give rather less ammonia but more CS_2, H_2S, and cyanogen.

Make per Ton, Cubic Feet.	NH_3 per Ton.	Percentage of Coal as NH_3
	lbs.	
11,620	7·411	0·331
10,162	7·894	0·352
9,431	7·504	0·335
7,512	6·391	0·285

Temperature of Retort.	Make of Gas.	Illuminating power	Illuminants.
	Per Ton.	Candles.	Lbs. Sperm.
2,000° F.	9,800	16·54	525½
2,160° F.	11,000	12·00	452½

(L. T. Wright.)

Coal carbonized at 2,000° yielding 9,800 cubic feet of 16·54 candle gas equal to 555½ lbs. illuminating matter, but if carbonized at 2,160° will yield 11,000 cubic feet gas of 12 candle-power equal to 452½ lbs. illuminating matter.

If caking coal be carbonized at 600° F. (hardly red in a dark place) only 400 cubic feet of gas per ton are evolved, and most of the hydrocarbons are resolved into tar.

At low heats 600° F. tar and oils are formed but little gas, while at higher heats gas is formed with less tar.

At a low red heat in daylight about 6,500 feet are produced per ton.

At 750° to 800° F. about 1,400 cubic feet gas and 68 gallons tar or crude oil are given off; at 1,000° (a faint red in subdued daylight) about 6,000 cubic feet gas; and at 1,830° (a bright cherry red) about 8,300 cubic feet with 13 or 14 gallons tar are evolved; and at 2,010° (orange) about 10,000 cubic feet per ton with 9 gallons tar. (Gesner.)

Composition of Gas from Newcastle Coal Carbonized at Different Heats. (Thorpe.)

Gas per ton of coal, cubic feet	8,250	9,692	12,006
Illuminating power, candles	20·59	17·80	15·60
Unsaturated Hydrocarbons, per cent.	7·55	5·83	4·51
Marsh Gas	42·72	34·50	30·70
Carbon Monoxide	8·72	13·50	13·96
H.	38·09	43·77	48·02
N.	2·92	2·40	2·81

Percentage and Specific Gravity of Gas during each of Five Hours' Charge.

First hour	46·6 per cent. gas given off	·677	average specific gravity.
Second hour	27·4 " " " "	·419	" " "
Third hour	16·0 " " " "	·400	" " "
Fourth hour	7·3 " " " "	·322	" " "
Fifth hour	2·7 " " " "	—	

Another experiment gives

First hour	51·3 per cent. gas given off	specific gravity not taken.
Second hour	33·5 " " " "	" " " "
Third hour	11·8 " " " "	" " " "
Fourth hour	3·4 " " " "	" " " "

1 ton coal distilled at about 1,650° F. will be carbonized in 6 hours.
" " " " 2,010° F. " " 5 "
" " " " 2,190° F. " " 4 "

The greatest quantity of gas from caking coal is evolved during the second hour.

Wigan Cannel (1 ton) produced

First hour	3,320 cubic feet.
Second hour	2,940 ,,
Third hour	2,660 ,,
Fourth hour	1,040 ,,

(Herring.)

Six-hour Charges.

At end of first hour one-sixth of the total quantity of gas is given off, at commencement of second hour the coal becomes soft, and during the second, third, and fourth hours yields gas from innumerable small jets, at the fifth hour it is compact and doughy, the gas issuing from throughout the mass. At the commencement of the sixth hour it is still black as at first, and the evolution of gas, which has been fairly uniform, commences to decrease very rapidly. At 5½ hours gas almost ceases to issue, and coke becomes incandescent and brittle.

Quality of gas nearly uniform for first five hours, but deteriorates greatly the last hour, often being not more than 3 candles.

Four-hour Charges.

Periods of three-quarters of an hour correspond to those of one hour in above remarks.

The work done in the retort during the last hour of the charge, amounting to about 5 per cent. of the whole, is also getting the retort in a condition of heat to receive the next charge. It has been proposed by the "Journal of Gas Lighting" to connect the mouth-piece of the retort by means of, say, a 2-inch or 3-inch tube, provided with a cock, with the interior of the setting, and divert the gas yielded during the last hour of the 6-hour charge, so that it may assist in heating the retorts, and not deteriorate the quality of the gas already made.

First hour $\frac{1}{7}$ volume of 10 candles; second hour and half, $\frac{1}{2}$ volume of 17 to 18 candles; third hour, $\frac{1}{5}$ volume of 14 candles; remainder, 8 to 10 candles at high heats, making 11,000 feet gas of 14 candles. (Butterfield.)

Hours.	Gas made per cent.	
1	16·6	Gas strongly impregnated with tar.
2	. . . .	Coal becomes soft.
3	. . . .	In a state of intumescence and yielding.
4	. . . .	Gas from innumerable small jets.
5	. . . .	A compact and doughy mass.
6	. . . .	Coal still black, yield of gas decreasing rapidly, sulphur compounds being evolved, quality about 3 candles.

From tests of a Scotch coal, giving an average of 11,250 cubic feet per ton of 30·18 candle power, Mr. W. Wallace, F.I.C., found a variation both in illuminating power and pounds of sperm per ton, according to the temperature :—

	Lbs. Sperm per Ton.	Illuminating Power.
In January	1,136	29·44
„ February	1,140	29·56
„ March	1,122	29·08
„ April	1,135	29.41
„ May	1,218	31·58
„ June	1,208	31·32
„ July	1,209	31·34
„ August	1,209	31·34
„ September	1,178	30·54
„ October	1,146	29·72
„ November	1,139	29·53
„ December	1,124	29·14
Average	1,164	30·18

Or by temperatures—

Degrees Fahr.	Lbs. Sperm per Ton.	Illuminating Power.
36 to 40	1,108	28·73
41 to 45	1,124	29·14
46 to 50	1,142	29·61
51 to 55	1.182	30·65
56 to 60	1,206	31·27
61 to 69	1,215	31·50
Average	1,163	30·15

Proportions of coal, coke, and tar used per ton in firing retorts :—

2¾ cwts. of coke are used per ton of coal carbonized with gaseous regenerative firing.

3½ to 4½ cwts. of coke are used per ton of coal carbonized with ordinary furnaces.

1 ton of tar is equal to about 2 tons of coke in firing.

Experiments as to quantity of fuel required in a regenerative setting ; 1 generator to 2½ settings per diem :—

	Tons.	Cwts.	Qrs.	Lbs.
Breeze consumed		14	3	10
Cold coke	4	13	3	4
Clinker extracted	2	0	1	12
Coal carbonized (estimated)	27	0	0	0

Gas made per mouthpiece (estimated) 5,700 cubic feet.

Pounds fuel used per 100 lbs. coal carbonized :—

Coke . . . . . . 17·36 lbs.
Breeze . . . . 2·74 lbs.

The above are calculated from the quantity used in a week of 6½ days.—March 21st, 1892.

Composition of Gases in Generator Furnaces.

Ebelman's Gasogene.		Siemen's Generator.	
	Air.	Air and Steam.	
CO	33·3	27·2	26·0
CO_2	0·5	5·5	4.5
N	63·4	53·3	67·5
O	—	—	0·5
H	2·8	14·0	—
	100·0	100·0	100·0

First analysis most like the exact chemical proportions for the entire conversion of carbon into CO without CO_2 which are 34½ per cent. CO and 65½ per cent. N.

Amount of Primary and Secondary Air should be tried and fixed in each case when using regenerator furnaces.

Best materials only should be used in such settings.

Areas of openings for introduction of primary and secondary air and gas ducts vary considerably, and should all be made so that they can be altered as required by a sliding brick or tile.

Only a comparatively low temperature is required to convert fuel to CO, and thus the admission of cold air under the furnace bars enables the furnace to last long, owing to less wear and tear, and prevents the formation of clinker, ash only being found between the bars.

In regenerator furnaces the gases, before combustion, should be of uniform quality and temperature, and should then be directed into and distributed over all the interior of the setting.

The arrangement should be such that combustion shall not be complete until just before the burnt gases are leaving the setting and are about to enter the flues of the regenerator.

The limit of heat which may be employed in a setting is the fusible point of the brickwork in the hottest part, and the producing power of the setting is governed by the temperature of its coldest part.

It is impossible to introduce air into a gas-fired retort setting and properly distribute it for combustion, without it becomes heated to the necessary temperature for combustion with the primary gases.

It is only by analysis of the gases that it can be accurately ascertained if the primary and secondary air are being used in their proper proportions.

With ordinary settings M. Euchène calculates that 12·8 per cent. of heat evolved from the coke, etc., is lost by radiation through walls, etc

Secondary air should be heated to about 1,800° F.

One half the heat generated by the combustion of fuel is made when CO has been formed, a further half being generated when this is converted into CO_2

Saving in fuel with generator settings = about 25 per cent.
" " " " regenerator " = " 50 "
Theoretically 1,100° F. are required in the producer.
Practically 1,800° F. " " " "

Composition of producer gases by volume.

CO	25·7 per cent.
CH_4	2·75 "
H	14·06 "
N	52·74 "
CO_2	4·75 "

Temperature at combustion chamber .	2,600° F.
" " crown of setting . .	2,400° F.
" " entrance to regenerators	2,150° F.
" " outlet of last waste gas flue	1,000° F.

The smaller the percentage of ash in the coke used for regenerative firing the better, but, if porous, 10 per cent. of ash can give good results.

A vacuum of three-fifths is sufficient at outlet of last waste gas flue.

Analysis of gas at last waste gas flue :—

CO	0·7	O	0
CO_2	16·6	N	83·3

Of each 1 lb. coke placed in regenerator furnaces,

18 per cent. is ash,
$78\frac{3}{4}$ " " carbon,
$3\frac{1}{4}$ " " H.

Of the carbon 90 per cent. is converted to CO and requires for complete combustion about ·45 lbs. O.

For the hydrogen about ·26 lbs. O is required, or a total of ·71 lbs. O equal to 3·1 lbs. of ordinary air to be raised, say 1,800° F.

Specific heat of air = 0·2374, therefore 3·1 lbs. × 0·2374 × 1800 = 1324·7 units of heat.

There is always a considerable loss of heat through the N. passing away hot into the air.

No gain of energy with gaseous fuel, but rather a loss. The advantages being that the absolute conversion into CO_2 can be made to take place at any or several desired points, which might be impossible to reach by means of direct firing, and, again, the loss of heat which is radiated from the furnace in a direct fired oven is not so great, as the intensest heat is only obtained at the point where the heat is required.

Heat in recuperators should not be more than a dull red below the secondary air inlet, as this will probably mean too little secondary air being used.

No blue flame should be visible at outlet of flue, as this shows unconsumed CO.

About one-third the total heat evolved by the fuel is used in transforming the solid into gaseous fuel.

Producer gas in Siemen's furnace with coal containing 70 per cent. fixed carbon, 16 per cent. of coal gas, 14 per cent. ash oxygen and nitrogen (coal equals about 7,200 calories). Producer gas consists by weight of 16 parts coal gas, 163·3 of CO, and 222 of N.

Coal gas = 10,000 calories, CO = 2,400 calories, then the total calories = 551,920 against 700,000 for the coal proper. (Sir J. Lowthian Bell.)

2 to 3	per cent. CO_2 in generator gases shows	very good working.
5 to 6	" " " "	fair "
10	" " " "	defective "

(W. Thörner.)

Wide furnaces prevent the fire burning too low.

There should be no exhaust on furnace except when drawing up the heats.

Less air is required with a light than a heavy coke.

Ordinary furnaces allow a large proportion of the CO to escape without being oxidized to CO_2.

About 25 per cent. of the heat evolved in an ordinary furnace passes up the chimney, of which only one-fourth is required for the necessary draught.

Breeze consists of much earthy matter, and but little carbon, which makes it a weak fuel, and much scoriae is deposited when burning it.

Briquettes are made on the Continent to burn coke dust and tar or pitch for heating the furnaces. Tar and coke dust are sometimes mixed on the retort house floor and then used as fuel.

Briquettes are also made by hydraulic pressure, the proportions being 10 per cent. pitch to the quantity of breeze.

Clegg stated that when tar was less than *3d.* per gallon it paid to burn it in the furnaces, at present it only pays to burn when less than $\frac{3}{4}$*d.*

Advantage of tar firing is the slow and even rate of supply as compared with coke firing, by which the necessary air supply is much lessened, and the consequent cooling effect of the inert gases is not so great.

The superiority of liquid fuel over solid is principally due to the H contained in it, H evolving five times the heat, weight for weight that carbon does on combustion.

The use of steam does not appear to have any beneficial effect when employed to inject tar into retort furnaces; it has been shown by Mr. Dexter that no increased heat can possibly result by its use, but that rather does it tend to lower the heats.

Twenty gallons tar required to carbonize 1 ton coal equals about 6 gallons tar per 3 bushels coke.

Provide a good quantity of water in the ash pans as the steam prevents the formation of clinker, and prevents the over-heating of the fire-bars.

It is a moot point if the water gas made from the evaporation in the ash pans is an advantage or not, the amount of heat absorbed in converting water to O and H being very great, but being taken from the lower layers of the furnace it does not materially affect the heat of the bulk of the fuel, while the gain from the burning of the hydrogen is considerable.

A jet of steam is of assistance under the bars of generator settings.

The steam from the ash pans is converted into CO and H in passing through the red-hot fuel in the furnace.

Quantity of water evaporated per furnace per hour equals about 3 gallons.

Steam required for producer equals about 32 lbs. per 100 lbs. C consumed or 3·70 lbs. water per 100 lbs. coal carbonized.

Clinkering is reduced about one-third in regenerator settings.

Clinkering should be done often enough to prevent such an accumulation as will stop the air-way between the fire-bars.

Clinker is due to the combination, under the influence of heat, of the inorganic, or incombustible matter of the coke (the ash of the coal). This consists principally of silica, alumina, lime, iron, &c., which fuses together to form a kind of slag. (Hornby.)

Furnaces require repair about every six months.

Average life of clay retort 900 working days.

Clay retorts will carbonize about 4,000,000 cubic feet.

Iron retorts about 650,000 cubic feet of gas, and they are done.

The broken surface of a brick is much sooner acted on by heat than is the smooth face which has a protecting skin upon it. Lumps are therefore to be preferred where possible.

The saving due to the producer may be taken at	52·26	per cent.
" " regenerator " "	47·74	"
	100·00	

If a blue flame is seen at outlet of chimney of regenerative retort settings CO is being passed away, and more secondary air should be let in.

Generator gas should consist of 34·7 per cent. CO and 65·3 per cent. N.

Chimney gases should contain 21 per cent. CO_2, 1 per cent. O and 78 per cent. N.

Air rapidly absorbs heat, and when passed over heated surfaces it becomes raised in temperature approximating closely to that of its surroundings.

The waste gases in a regenerator setting have been known to be reduced in temperature from 1,200° F. to 500° to 600° F. by the incoming of the secondary air, all of which heat is being saved and used again in the furnaces.

1 lb. C converted to CO_2 yields 14,544 heat units.

About double the necessary air required in a direct fired furnace.

By the higher heats of regenerative furnaces Mr. Foulis increased the producing power of the works 60 per cent.

One-half per cent. of free O in the waste gases may be considered good working.

The depth of fuel should be kept as regular as possible.

The use of tar as fuel causes difficulty in controlling furnaces, and regular and complete combustion.

The loss of gas from clay retorts in good working order is not at all important. (L. T. Wright.)

However hot the retort, an immediate and heavy fall in temperature must follow the introduction of the charge, to be worked up again to its maximum in the allotted period. (A. F. Browne.)

4 per cent. air reduces the illuminating power 25 per cent.

1 per cent. of common air diminishes the illuminating power 6 per cent.

45 per cent. of air renders the gas non-illuminative.

1-inch back-pressure in retorts equals 1-24th candle power lost.

The sulphur compounds are decomposed at a temperature of about 400° F.

In gas from wet coals the olefiant gas is reduced one-third.

Crude gas contains 4 per cent. by volume of gaseous impurities (H_2S and CO_2 gas).

About 1 per cent. by volume of the crude gas is ammoniacal

About 3 per cent. by volume of the crude gas is CO_2.

About 1½ per cent. by volume of the crude gas is H_2S.

Luting generally made of 2 parts clay to 1 part spent lime.

If the coke were drawn immediately it became incandescent, say about half-an-hour before the charge was done, much of the trouble with the sulphur compounds would be avoided.

High heats give a harder coke generally.

Gas coke contains C, N, S, H, and O.

Coke contains about 88 per cent. carbon.

Coke when drawn from the retort and slaked contains about 25 per cent. moisture.

Coke averages 1,360 lbs. per ton of coal, with about 4 per cent. ash in the coke. About 34 gallons water required to quench 1 ton coke, of which not more than 67lbs. water remains permanently in the coke.

If steam be introduced along with the air into a coke-making plant, a larger percentage of ammonia can be extracted.

59 lbs. slack coal required in furnaces to carbonize 2 cwt. coal.

41 lbs. lump coal required in furnaces to carbonize 2 cwt. coal, say 570lbs. coal per ton.

In the petroleum-heated locomotives on the Great Eastern Railway, a thin coal fire 6 inches thick (an ordinary one being 18 to 24 inches), mixed with lumps of chalk to keep the bars covered, is used so as to keep sufficient heat up, when stopping, to re-light the oil when re-starting.

Men Employed in Making say 3,000,000 Cubic Feet per Diem (Hand Charging).

		s.	d.
Retort house work only, 17 (first-class) men, made up of firemen and scoop drivers . . .	at	5	7
1 Foreman	„	7	6
20 (second-class) Men (stokers) . . .	„	5	4
10 (third-class) Men (fire-rakers) . . .	„	4	5
7 Coal trimmers	„	4	0
1 Pipe cleaner	„	5	9
1 Scurfer	„	5	9
1 Flue cleaner	„	5	6
1 Lobby boy	„	3	6
1 Fitter	„	5	0

The above represents the number of men employed on each shift of eight hours.—(January 13th, 1893.)

Total Number of Men Required to Charge 240 Retorts with 240 Tons of Coal per Diem at Glasgow, Working 8-hour Shifts.

(A. Wilson.)

Manual Labour.	Machine Work.
60 Stokers	6 Charging machine men
15 Firemen	6 Drawing machine men
15 Ashmen	15 Firemen
30 Coalbreakers	15 Ashmen
10 Bogie drivers	10 Coke men
10 Coke men	6 Pipe cleaners
3 Water boys	1 Lid cleaner
3 Foremen	6 Lid men
146 men.	3 Coal breaker men
	3 Locomotive boys
Also 7 horses to draw out the coke.	3 Shunters
	3 Foremen
	77 men.

Number of Men Employed on Furnaces (during 8 hours).

1⅓ firemen clean 2 fires and fill 4.
4 firemen in 24 hours attend 4 fires (cleaned every 6 hours).
1 fireman attends the equivalent of 6·01 fires (on the ordinary open double grate system).
Number of men employed on furnaces (during 8 hours) of 15 sets. "Buffalo Bill" settings (1 furnace to five sets).
2½ firemen clean 4 fires and feed from the top every 2 hours.
7½ firemen in 24 hours attend 3 fires (fires cleaned every 6 hours).

1 fireman attends the equivalent of 12 fires (on the ordinary open double-grate system).

Each stoker may be made to handle an average of 4 ton coal per day.

Charging should be performed in rather less that one minute.

The air compressor at the South Metropolitan Gasworks used with the West stoking machinery, shows a high duty, the mechanical efficiency is 80·3 per cent., the compression efficiency is 82·1 per cent., and the air delivery equals 369·3 cubic feet per I.H.P. per hour.

To Prevent Stopped Pipes they should be kept cool, and light seals in the hydraulic maintained in liquor and not tar.

Space between ascension pipes and front wall of bench should not be less than 8 inches.

Water may be introduced at the top of the ascension pipe and allowed to trickle down the sides of the pipe.

Stopped pipes sometimes attributed to oscillation and pressure in the retorts from the dip and the exhauster.

Thick tar and soot and stopped ascension pipes are sometimes caused by porous parts in retorts, either new or recently cleared from carbon, which allow the gas to pass through and burn in the setting, while the soot and tar are carried up and deposited in the ascension pipe and hydraulic. The obvious cure is to paint the inside of the retort after such clearing of carbon and when new, with thin fire-clay mortar, and thus close the pores.

Suggestions for the Curing of Stopped Ascension Pipes.

Allow water to trickle down the interior from the top.

Place a bowl of water, or rag, or waste soaked in oil, small coal soaked in water, or pieces of solid grease, inside the retort, just below the bottom of the ascension pipe.

Keep open all doors, windows, or other available apertures.

Bring a supply of cold air, from outside, to the front of the bench by means of pipes.

Keep the retorts charged to their utmost capacity.

Lower the heats of the retorts ; this also clears the hydraulic by causing oily tar to pass off from the coal.

Loss from stopped pipes has been known to exceed 10 per cent. of the gas to be obtained from the coal.

Stopped ascension pipes usually caused through excessive heat from setting.—To diminish the trouble, walls in front of benches should be 14 inches and not 9 inches thick.

Rapid radiation of heat and smooth interior surface, said to obviate stopped pipes.

To prevent stopped ascension pipes, leave the retort mouthpiece and the pipe open to the air.

The temperature of the pipes must be moderated by a supply of water which is led into them by a U-shaped tube screwed into their upper ends. The water drips into this tube from a supply above it. 63 to 70 ounces water per retort per hour required.

The gas in the ascension pipes is usually of a temperature of about 200° F.

Air circulating round the pipes and mouthpieces.

Water supplied internally or externally.

Liquor supplied internally or externally.

A lump of coal in the mouthpiece.

A handful of oily waste in the mouthpiece.

Animal fat in the mouthpiece.

Increase in length of rising pipe.

Plate or plates inside mouthpieces to prevent radiation of heat from inside retort.

Lining mouthpiece with fire-clay.

Air or water jacket to ascension pipe.

Carbon deposited in the retorts is generally increased by increase of pressure.

An oscillation caused by a badly working exhauster causes a greater deposit of carbon than a steady exhaust.

Pressure and oscillation are the chief causes of deposition of carbon.

The pressure on retorts is sometimes as high as 15 inches water where an exhauster is not in use and the carbon deposit is then considerable.

The carbon deposited in the retorts consists of the richest illuminants of the gas which have been solidified instead of carried forward in the gas.

If there be a heavy pressure in retorts some of the hydrocarbons are deposited as carbon in the retorts.

Under pressure some of the most valuable hydrocarbons are deposited in the retort as carbon or scurf.

The removal of the carbon from sloping retorts is easy, as the position of the latter causes a current of cool air to pass up when both doors are opened.

Carbon or scurf is removed by a chisel bar, or by allowing the oxygen of the air to burn the deposit until it is thin enough to remove easily; this should be done about once a month.

The carbon in a retort being highly non-conducting, causes considerable waste of fuel, and should therefore never be allowed to get very thick.

Clay retorts are practically gas-tight up to about ½-inch pressure.

To prevent carbon deposits, reduce the dip and the back pressure as much as possible.

Table of the Effects of Heat.

	Degrees. Fahr.		Degrees Fahr.
Soft iron melts	3,945	Brass melts (copper 3 parts, zinc 1 part)	1,690
Cast iron melts	2,786	Brass melts (copper 2 parts, zinc 2 parts)	1,672
Gold melts	2,016	Diamond burns	1,552
Copper melts	1,996	Bronze melts (copper 7 parts, tin 1 part)	1,534
Silver „	1,873		
Bronze „ (copper 15 parts, tin 1 part)	1,750		

Table of the Effects of Heat—*continued.*

	Degrees. Fahr.		Degrees. Fahr.
Bronze melts (copper 3 parts, tin 1 part)	1,446	Steel becomes a full yellow	470
Enamel colours burn	1,392	Steel becomes a pale straw colour	450
Iron red hot in daylight	1,272	Tin melts	442
Iron red hot in twilight	884	Steel becomes a very faint yellow	430
Iron red hot in dark	800	Tin 3 + lead 2 + bismuth 1 melts	334
Charcoal burns	802	Tin and bismuth, equal parts, melts	283
Heat of a common fire	790	Sulphur melts	218
Zinc melts	773	Bismuth 5 + tin 3 + lead 2 melts	212
Mercury boils	660	Water boils	212
Linseed oil boils	640	Wax melts	149
Lowest ignition of iron in the dark	635	Tallow melts	92
Lead melts	612	Acetic acid congeals	50
Steel becomes dark blue, verging on black	600	Olive oil congeals	36
Steel becomes a full blue	560	Water freezes	32
Sulphur burns	560	Milk freezes	30
Steel becomes blue	550	Vinegar freezes	28
Steel becomes purple	530	Sea water freezes	28
Steel becomes brown, with purple spots	510	Strong wine freezes	20
Steel becomes brown	490	Turpentine freezes	14
Bismuth melts	476		

Colours of Different Temperatures. (Becquerel.)

	Degrees. Fahr.		Degrees. Fahr.
Faint red	960	White heat	2,370
Dull red	1,290	Bright white heat	2,550
Brilliant red	1,470	Brilliant white heat	2,730
Cherry red	1,650	Melting point of cast iron	2,786
Bright cherry red	1,830	Welding heat	2,800
Orange	2,010	Greatest heat of iron blast furnaces	3,300
Bright orange	2,190		

600° F. Faint red in dark room.
662° F. Mercury boils.
810° F. Antimony melts.
1,869° F. Brass melts.
1,873° F. Silver melts.
1,996° F. Copper melts.
2,786° F. Cast Iron melts.

Temperature of iron when red glow has disappeared, 404° C.

It is said that no reliability can be placed on Wedgewood's pyrometer.

Pyrometers.

One part of zinc and 4 parts of copper melts at 1,050° C.; 1 part of zinc and 6 parts of copper melts at 1,130° C.; 1 part of zinc and 8 parts of copper, at 1,160° C.; 1 part of zinc and 12 parts of copper, at 1,230° C.; and 1 part of zinc and 20 parts of copper, at 1,300° C. The difficulty of getting pure metals to make these alloys, and of keeping them at the initial proportion, is against their use. The expansion of metals, clays, liquids and gases under heat is also used with varying success. The Lamy pyrometer, based on the decomposition of carbonate of lime under heat, is one of the best; but it will only register between 700° and 900° C.

Herr C. Schneider proposes the use of nitrifiable test cones, containing silica 65 per cent., alumina 8·3 per cent., ferric oxide 8·7 per cent., lime 10·6 per cent., and potash 7·6 per cent., or in varying proportions, to test the heat of chambers with heats from 1,150° C. to 1,700° C. The greater the quantity of silica the more refractory the cone, the above mixture melting at 1,150° C.; and by the substitution of 8 per cent. of boracic acid for the equivalent of silica the melting point equals 960° C. Or crystallized borax 193 parts, marble 50 parts, china clay 52 parts, sand 96 parts, will melt at 960° C.

Seger's standard fusible cones are used to determine the temperatures at which fusion occurs. These cones are tetrahedra, compounded of mixtures of clay and sand with certain fluxes. For temperatures from 1,300° to 1,700° F., soda and lead oxide form the flux; while boric acid is used for temperatures from 1,700° to 2,050° F. The same flux is used with gradually increasing proportions of alumina and silica up to 3,450° F. The last cones of the series, which are stated to fuse at temperatures from 3,500° to 3,950° F., consist of pure aluminium silicate.

Mr. P. Mahler's calorimeter consists of a shell or hollow cylindrical vessel, enclosed in another containing water at a known temperature. The shell being hermetically closed, pure oxygen, at a pressure of several atmospheres, is admitted, and the fuel fired by an electric spark, when the pressure of the compressed oxygen causes complete and almost instantaneous combustion. The heat generated is transmitted to the water surrounding the shell, the temperature of which rises immediately. Mr. Mahler uses only one grain of combustible. When gas is tested a vacuum must be produced in the shell before gas is admitted, and the quantity of oxygen necessary for combustion previously determined. Illuminating gas ignites with oxygen at a pressure of five atmospheres, producer gas requires a pressure of about half an atmosphere in the oxygen.

To Estimate Temperatures Roughly by the Appearance of Metal.

	Degrees. Fahr.		Degrees. Fahr.
Red, just visible .	977	Orange, deep .	2,010
„ dull . .	1,290	„ clear . .	2,190
„ cherry dull .	1,470	White heat . .	2,370
„ „ full .	1,650	„ bright .	2,550
„ „ clear	1,830	„ dazzling .	2,730

Temperature of Fusion.

	Degrees. Fahr.		Degrees. Fahr.
Tallow	92	Antimony . .	810
Spermaceti . .	120	Brass . . .	1,650
Wax, white . .	154	Silver, pure. .	1,830
Sulphur . . .	239	Gold, coin . .	2,156
Tin	455	Iron, cast, medium	2,010
Bismuth . . .	518	Steel . . .	2,550
Lead	630	Wrought iron .	2,910
Zinc	793		

Melting Points of Fusible Alloys.

Tin.	Lead.	Bismuth.	Degrees. Fahr.	Tin.	Lead.	Bismuth.	Degrees. Fahr.
2	3	5	199	8	15	—	430
1	1	4	201	1	2	—	440
3	2	5	212	8	17	—	450
4	1	5	246	4	10	—	470
1	1	1	255	1	3	—	480
2	2	1	292	4	14	—	490
3	3	1	310	8	33	—	500
4	4	1	320	1	5	—	510
1½	1	—	330	4	25	—	520
2	1	—	340	4	30	—	530
4	1	—	365	1	10	—	540
1	1	—	370	1	12	—	550
6	1	—	380	1	25	—	560
4	7	—	420				

An average sample of coal gives the following figures :—

Carbon (C)	82·12 per cent.
Hydrogen (H)	5·31 „
Nitrogen (N)	1·35 „
Sulphur (S)	1·24 „
Oxygen (O)	5·69 „
Ash	4·29 „

(*Lancet.*)

Percentage of coal in its use :—

10,000 cubic feet gas	= 17 per cent.
10 gallons tar	= 5·1 „
Condensed liquor	= 7·9 „
Coke	= 70 „

(Professor Lewes, 1894.)

Approximate composition of bituminous coal:—

C	80·0 per cent.	N	1·5 per cent.
H	5·0 "	O	5·0 "
S	1·5 "	Ash	3·0 "

Moisture 4·0 per cent. Calorific value 8,020 thermal units.—(Professor Lewes.)

Cannel coal – specific gravity 1·1 to 1·4, organic matter consists of C = 70 to 85 per cent.; O = 5 to 15 per cent.; H = 5·5 to 10·0 per cent.; N = 1 to 2·5 per cent.: S = 0·5 to 2·5 per cent.; Ash 5 to 20 per cent.

Ash from average Newcastle coals:—

Silica	66
Peroxide of iron	16
Alumina	12
Lime	10
Potash	1
Magnesia	1

2 to 4 gallons of water per ton is the average moisture in mechanical combination.

Laboratory tests of coals are generally 15 to 20 per cent. higher than actual working results.

About 16 gallons of water are produced by carbonizing 1 ton coals.

Gas made per ton Gas Light & Coke Co. ½ year to December, 1892, 10,949 cubic feet.

Coke made ·617 ton per ton.
Breeze " ·064 " "

CO_2 in crude gas . . . . . 2·5 to 3 per cent.
H_2S " " . . . . 1 to 2 "

CS_2 is formed by the action of sulphur vapour upon red hot carbon.

Tar can be carbonized in ordinary clay retorts if allowed to run into the ascension pipe on to a fire clay tile fitted in the mouthpiece to prevent any accumulation of tar behind the lids, 40 gallons being burnt off in 6 hours. Iron retorts are however better. Tar conduit pipes should be large, say 2-inch.

Paper becomes charred at 400° F.

Table showing conversion of the elements of coal on carbonization

C, H } = CH_4 & C_2H_4 etc.
H, O } = H_2O
(H, N) } = NH_3
(C, N) } = CN
(H, S) } = H_2S.
(C, S) } CS_2
(C, O) } CO & CO_2
N . 14·5 1·56
{ 35·26 free in gas and in tar, 48·68 in coke.
S

A good gas coal should contain as large a percentage of H over and above that required to combine with the O as possible, and this should not be less than 4 per cent., while 5 per cent. will show a high quality coal. To obtain the quantity of H which will oxidize on carbonization divide the percentage of O by 8 and deduct the dividend from the percentage of H.

Total quantity of carbon in coal = 82 per cent.
Gas contains ,, ,, = 16 ,,
Coke and tar ,, ,, = 66 ,,

Caking coal has specific gravity 1·25 to 1·35, and the organic matter in it consists of 80 to 90 per cent. C, 4·5 to 6·0 per cent. H, 5 to 13 per cent. O, and 1 to 2·5 per cent. N, average ash 7·5 per cent., sulphur 0·5 to 2·5 per cent. (Butterfield.)

	Lancashire Coal.	Newcastle Coal.	Welsh Coal.	Scotch Coal.
C per cent.	80·70	83·60	86·26	78·50
H ,,	5·50	5·28	4·66	8·33
O ,,	8·48	4·65	2·60	8.33
N ,,	1·12	1·22	1·45	1·14
S ,,	1·50	1·25	1·77	1·45
Ash ,,	2·70	4·00	3·26	4·00

Coal contains from 50 to 80 per cent. by weight, of carbon.

Average composition 80 per cent. C, 5 per cent. H, 8 per cent. O, 4 per cent. ash, 1¼ per cent. S, 1⅓ per cent. N. Coke equals 61 per cent., specific gravity equals 1·279, weight per cubic foot equals 80 lbs. Bituminous coal contains from 6 to 10 per cent. water.

In most Tars there are 40 per cent. of compounds capable of conversion into illuminating gases.

An ordinary sample of tar will yield at least 16,000 cubic feet of 15 candle gas per ton of 200 gallons, with coke, free from ash, weighing about 10 cwt., and if produced at proper temperatures equal to foundry coke, ammonia equal to the production of 16 lbs. sulphate per ton of tar.

The theory of the tar process as used at Widnes is that a fresh charge of coal cools the retort for a time, during which a considerable quantity of tarry vapours are being given off from the coals, and these tarry vapours are carried along the duct, as the second retort is called, and there gasified into permanent gases instead of being deposited in the condenser mains as tar.

The volume of Gas from Wood Charcoal amounts to 250 litres per kilogramme, and, when prepared on a large scale, it contains CO_2 9·14 per cent., CO 18·08 per cent., H 49·11 per cent., CH_4 16·04 per cent., O 0·26 per cent., N 7·37 per cent. (Comptes Rendus.)

Wood Gas gives about 8,000 cubic feet per ton of poor gas.

Mr. W. King, of Liverpool, found that the average yield per ton of tar thoroughly dried at 212° F. before carbonization was 12,000 cubic feet of 4-candle gas, 5¼ cwt. charcoal (worthless for fuel), 33 per cent. CO, and very little tar.

By the Dinsmore process, following a coal gas carbonization, about 10,000 cubic feet per ton of 19-candle gas are obtained from a poor coal.

One Ton Split Wood yields 11,000 cubic feet per ton of 16 candles, with 4 cwts. charcoal, and 1 to 1½ cwts. of tar, with a large quantity of CO_2 (9 to 18 per cent.).

Cork refuse made 18,000 cubic feet gas per ton of good quality and purity. (N. H. Humphrey.)

Pine Wood Sawdust carbonized at 1,500° F. yields 12,300 to 15,700 cubic feet per ton of dried material of 15 candles (specific gravity ·590 to ·620), and contains about 7·5 per cent. illuminants, 33 per cent. H, 27 per cent. CH_4, 32 per cent. CO.

Peat perfectly dried and compressed yields at red heat 11,000 cubic feet per ton of 17 to 18 candle gas with 9 cwts. coke, 15 gals. tar, and a quantity of ammonia. (Butterfield.)

High heats, light charges, and plenty of red-hot surface have been found the best when carbonizing wood for gas-making purposes.

Gas made from Resin is said to deposit a viscid matter in pipes and fittings.

The tar should be removed as soon as its temperature is down to 100° to 110° F.

Gas washed with the heavier hydrocarbons, as in a tar seal in a hydraulic main, absorbs a number of the lighter hydrocarbons which would otherwise remain in the gas and give it a higher illuminating power.

If too much tar is allowed to remain in the hydraulic main, the heat of the incoming gas gradually boils off the lighter oils and causes the formation of pitch.

The gas which enters the hydraulic main from the ascension pipe, carries with it a number of hydrocarbon vapours, condensing at from 140° to 160° F.

Mr. L. T. Wright proposed to run in water to keep the temperature of the hydraulic main at about 100° F., and thereby reduce the quantity of impurities in the gas.

The lighter hydrocarbons which condense at temperatures above 100° F., do not injure the illuminating power of the gas, and may absorb any excess of napthalene. (Herring.)

If a hot liquid is used in the hydraulic mains, weak ammoniacal liquor would be likely to liberate its ammonia, and increase the amount of that impurity to be removed later on.

Gas as it leaves the retorts is enveloped in very minute tarry vesicles which require friction to break them up.

Gas on leaving the dip-pipe should pass through water and not tar.

Liquor may be run in to replace tar in hydraulic twice a day.

Hydraulic main tar will, at 130° F., dissolve upwards of 70 per cent. of napthalene, so that it will be seen what a powerful factor in removing this is eliminated by using liquor seals in the hydraulic mains.

The liquor in the hydraulic main consists of sulphocyanide and hyposulphate of ammonia, also some carbonate and sulphide.

Anti-dip-pipes should be worked so that there is a pressure in the retorts, and then no deleterious gases are drawn in through cracks in the retorts.

Mr. Gandon found an increase of 300 to 400 feet per ton with anti-dip pipes.

At outlet of hydraulic main ·3 to ·5 of the condensable constituents are deposited. (Professor Wanklyn.)

Half to one-third the condensable vapours are deposited in the hydraulic mains.

Crude gas contains about 143 grains ammonia per 100 cubic feet, 2·95 per cent. H_2S., 2·04 per cent. CO_2.

In the hydraulic main, for every 100 volumes free ammonia there are about 24 volumes CO_2 and 11 volumes H_2S.

Temperatures found in Ascension Pipe. (W. Foulis.)

18 Inches from Mouthpiece.	12 Feet from Mouthpiece.	22 Feet from Mouthpiece.
890° to 518° F.	444° to 167° F.	246° to 144° F.

Temperature in retort, 18 inches from mouthpiece, 1,110° to 1,640° F.

Temperatures fell as above during charge, always getting lower as charge was worked off. Gas made equalled 10,000 cubic feet per ton.

If only 6,000 cubic feet per ton were being made, temperature, at 18 inches from mouthpiece, in ascension pipe would probably be only 400° to 500° F.

Temperature of gas leaving hydraulic main, 50° to 60° C., or 110° to 150° F.

Temperature of gas leaving condenser, 15·5° C.

Temperature of foul main averages about 110° F. to 138° F.

Usually considered, the temperature of gas in leaving the retort equals 200° to 300° F., but unless it is as high as 480° F. thickening of the tar in the hydraulic, and choking of the ascension pipe will certainly occur.

The gas leaving a retort freely has only a temperature of 220° to 330° F., owing to the great absorption of heat on its assuming a gaseous form.

Temperature of gas 3 feet above mouthpiece 150° to 170° F.; 17 feet from mouthpiece 120° to 135° F.

M. Euchène gives (1900) chimney gases, ordinary retorts, 1,787° F. Temperature in gas in retort, at first 1,166° F., at end of charge 1,355° F., average 1,260° F., but as the volatile products come off early, average taken as 1,202° F. Temperature in retort mouthpiece from 788° F. to 824° F. Temperature in hydraulic main 176° F. Temperature in charge in retort 932° F. in first half-hour, rising to 1,740° F. during distillation.

CONDENSING.

The Products of one Ton of Newcastle Coal after Carbonization are:—

	Lbs.	Per Cent.
10,000 cubic feet of gas	380	17·0
10 gallons of tar	115	5·1
Virgin gas liquor	177	7·9
Coke	1,568	70·0
	2,240	100·0

One ton of coal yields 5 per cent. weight of tar (approximately). (Wanklyn.)

About 8 feet of H_2S is contained per 1,000 cubic feet of Newcastle coal gas.

About 25 cubic feet of CO_2 is contained per 1,000 cubic feet of Newcastle coal gas.

7 to 12 per cent. CO is present in coal gas.

CO has a greater diluting effect than H.

H has a greater diluting effect than marsh gas.

10 to 13 gallons tar, and 13 to 30 gallons water are deposited by the time the gas reaches the outlet of the condensers.

The idea which some engineers had of leaving the gas with the tar as long as possible was, that they believed the latter absorbed CO_2 and H_2S, but the quantity of rich hydrocarbons also absorbed was not taken into account.

Doing away with the condenser at Richmond practically raised the illuminating power of the gas ¾ candle. (T. May.)

If gas be condensed below 45° F. the illuminating power is reduced, extreme cold having a detrimental effect on the illuminating power.

The tar should be removed from the gas as soon as possible until the latter has been cooled to about 105° F.

If the heavy tar oils and pitch are allowed to continue with the gas which is above 90° F. they absorb hydrocarbons from the gas.

The gas enters the condenser main at about 122° F.

The temperature of the gas should be gradually reduced to 90° F. before it enters the condensers.

Condensation is required to remove all the tarry vesicles, and if this be done the temperature of the gas may be left to take care of itself as it will be cooled later on to atmospheric temperature.

The condensers are best kept at the normal temperature of the air. If above or below this, the action of the purifier is interfered with.

Much inconvenience in scrubbers and washers may be avoided by arranging condensers so that the gas is not cooled excessively.

If the gas is not properly condensed before it enters the scrubbers the efficiency of the latter will be impaired.

The richer the gas the greater the loss of hydrocarbons by exposure to low temperature.

When the condensation is carried below 60° F., and friction is made to take place napthalene is frequently deposited.

It is better to have napthalene in the works than in the district.

Napthalene deposition in the works can be prevented by the use of liquor seals in place of tar, by quickly removing the tar from contact with the gas, and by long condensing or foul mains.

Keeping up the temperature at outlet of condensers to 60° to 75° F. will prevent the deposition of napthalene at that point, but may send it into the district.

It has been suggested to keep the temperature of the tar and liquor in the hydraulic main at about 100° F. so that the tar may retain a portion of the napthalene and bi-sulphide of carbon which it will not do at 160° F.

If gas is thoroughly dried no napthalene is deposited.

One method of clearing the napthalene from condensers is to run a small stream of liquor periodically into the first three or four compartments.

Poor gas may tend to the deposition of napthalene as certain hydrocarbons have the power of carrying others of different specific gravity.

A sudden cooling of the gas causes deposits of hydrocarbons and napthalene.

Napthalene fuses at 176° F., boils at 423° F., is not soluble in water.

To cure this trouble avoid wet coal—keep your heats as even as possible.

Tests for Napthalene.

Dilute ammoniacal liquor with sulphuric acid, and if napthalene be present it becomes rose colour and smells of napthalene.

Redden liquor with nitric acid super-saturated with muriatic acid. If napthalene be present it will tinge a piece of firwood a rich purple.

In order to dissolve napthalene in the condensers, Mr. Carpenter arranged a condenser to be reversible. When the outlet became partly choked it was made the inlet. The tarry vapours of the hot gas dissolved the deposit, which was quickly run off by the seals.

The liquor from the condensers contains sulphocyanide, sulphate and hyposulphite among the fixed salts of ammonia.

Analysis of Crude Gas leaving Condensers. (Butterfield.)

NH_3	0·65	to	0·95	per cent. by volumes.
CO_2	1·2	„	1·8	„ „
H_2S	0·9	„	1·5	„ „
CS_2	0·020	„	0·035	„ „
Cyanogen	0·05	„	0·10	„ „

Analysis of Crude Gas Leaving Condensers.

(Professor Wanklyn at South Metropolitan Gas Co., Old Kent Road.)

In 1000 volumes	SH_2 equals	12·1	volumes.
" "	CO_2 equals	15	"
" "	NH_3 equals	3·6	"

Impurities in Condensed but Unwashed Gas.

(Lewis T. Wright.)

	CO_2		H_2S	
	Grains per Cubic Foot.	Volume per Cent.	Grains per Cubic Foot.	Volume per Cent.
Newcastle . .	12	1·5	9	1·4
Yorkshire Silkstone	12	1·5	8	1·3
Derbyshire "	12 to 19	1·5 to 2·3	6 to 12	1 to 2·0
Cannels . . .	30	3·7	3 to 6	0·5 to 1·0

Tar made per ton, Gas Light and Coke Co., half-year to December, 1892, 10·58 gallons.

Average Analysis of Gas (Newcastle Coal) after Condensers.

H	47 per cent.	N	3·0 per cent.
Methane . . .	35 "	H_2S . . .	1·7 "
Carbon Monoxide .	5 "	NH_3	0·7 "
Hydrocarbons	3·5 "	Cyanogen . .	0·1 "
" light	1·0 "	CS_2	0·03 "
CO_2	1·5 "		

(Butterfield.)

EXHAUSTERS, ETC.

By exhausting at 120° F., and passing gas direct to the scrubbers, an increase of from ·5 to ·75 candle resulted at Croydon. To relieve the consequent back pressure in scrubbers, warm water was tried, but nearly double the water was required to remove the ammonia from the gas.

When byepassing the condenser the exhauster frequently becomes choked with sticky tar.

Temperature of gas at exhauster usually 110° to 120° F. without condensers giving 110° F. at inlet of condenser.

Increase of pressure raises the inflammability of gaseous mixtures having a combustible gas as one of their ingredients.

One of the evils of over-exhausting is the admission of furnace gases with the coal gas, and the consequent deterioration of the illuminating power of the latter; another is the increase of fixed ammonia and reduction of free ammonia by the admission of air or furnace gases.

1 per cent. air has no effect on illuminating power.
2½ per cent. air lowered 17-candle gas to 13·45 candles at Ramsgate.
3 " " " " 13·04 " "
5 " " " " 10·59 " "

Use Creosote Oil as a Lubricant for foul gas exhausters (Mr. Bacon, of B. Donkin & Co.). It is also said that castor oil forms the best lubricant for exhauster, and should have specific gravity ·960; if below ·955 it is impure. Another test of purity consists in adding zinc chloride, and then, if pure, the oil will turn yellow.

Sperm oil may also be tested with zinc chloride, but this, if pure, turns milky.

For lubrication of the working parts of the exhauster, a mixture of pure colza, tar, oil, and naptha has been found the best for the purpose.

In the use of oil for lubrication uniformity of distribution is as important as the regularity of supply. A dry spot on a bearing will at once cause heating, and, if allowed to continue, cutting will be the result. No oil has yet been made that can economically lubricate all the journals of a mill. An oil running a heavy engine would not do to run a spindle or a fast-revolving dynamo. The former runs slowly, and has great pressure and strain on its journals, and consequently requires an oil that will not spread too quickly, but with low gravity and high viscosity. The latter needs a pure mineral oil, viscous and quick spreading, to enable it to enter into the closest parts of the bearing as rapidly as the speed at which it revolves necessitates. Mineral lubricants, or compounds of mineral and animal, are the safest, and produce the best results. Professor Thurston says, "Rancid oil will attack and injure machinery. Mineral oil does not absorb oxygen, whether alone or in contact with cotton waste, and cannot, therefore, take fire spontaneously; animal and vegetable oils do. Mineral lubricating oils are used on all kinds of machinery: they are the safest and cheapest lubricants, and generally superior to animal and vegetable oils and greases." A mineral oil flashing below 300° is unsafe. Gumming is due to the action of free acid upon the metal bearings of machinery. J. J. Redwood remarks, "Mineral oil has the least action on metals, none on iron or brass; tallow oil has most action on iron; castor, olive, and lard oils have most action on brass; rape seed has most action on copper."

Heat of Combustion of Various Fuels.

Substance.	Average Heat from 1 lb. Fuel. Thermal Units.	Equivalent Evaporation from and at 212° F. per lb. of Fuel, in lbs. Water.
Carbon (pure)	14,560	15·07
Coal gas	17,800	18·43
Coal gas, per cubic foot, at 62° F.	630	0·70
Coal, good average quality	14,700	15·22
Coke	13,500	13·87
Hydrogen	62,000	64·20
Peat (dessicated)	10,000	10·35
Peat, 25 per cent. moisture	7,000	7·25
Petroleum oils (benzine, etc.)	27,500	28·56
Petroleum crude	20,400	21·13
Petroleum refuse, "astaki"	20,000	20·70
Straw	8,000	8·40
Sulphur	4,000	4·14
Wood, air dried	8,000	8·28
Wood, dessicated	11,000	11·39
Wood, charcoal dessicated	13,000	13·46

Theoretically, 11 lbs. air is required per 1 lb. coal to supply the necessary oxygen; practically, 22 lbs. air is required.

1 lb. coke evaporates about 9 lbs. water.
1 lb. " " " $\frac{1}{7}$th cubic foot water.
1 lb. coal " " 9 lbs. water.
1 lb. slack " " 4 lbs. "

Pounds of Water Evaporated per lb. of Fuel.

(B. Donkin & Co.)

Breeze or dust gas coke as burnt on Perret's grate, 5¼ lbs. water.
Dust Welsh coal " " " 8½ "
Ordinary Welsh coal on ordinary grate . . 9 "
Large gas coke " " . . 7½ "

Another authority gives :—

Lbs. of water evaporated at 212° per lb. of fuel.
7·4 lbs. per lb. breeze.
7·5 lbs. per lb. coke.
11·4 lbs. per lb. Welsh coal.

Relative Heating Power of Fuel. (Fritz.)

Fuel.	Theoretical.	Lbs. of Water Evaporated by 1 lb. of Fuel. In Steam Boilers.	In Open Boilers.
Anthracite . . .	12·46	—	—
Coal	11·51	5·2 to 8	5·2
Charcoal	10·77	6 „ 6·75	3·7
Coke	9 to 10·8	5 „ 8	—
Brown Coal . . .	7·7	2·2 „ 5·5	1·5 to 2·3
Peat	5·5 to 7·4	2·5 „ 4·5	1·7 „ 2·3
Wood	4·3 to 5·6	2·5 „ 3·75	1·85 „ 2·1
Straw	3·0	1·86 „ 1·93	—
Gas reduced to lbs. coal .	—	4 „ 6	—

In heating boilers the average amount of theoretical heating power of fuel that is utilised is only 47 per cent., the remainder being lost through imperfect combustion, radiation, and other causes.

Evaporative Power of Fuel.

Another set of tests gave :—

1 lb. coke evaporates 9 lbs. water (feed water supplied at 212° F.).
1 „ coal „ 9 „ „
1 „ slack „ 4 „ „
1 „ oak (dry) „ 4½ „ „
1 „ pine „ 2½ „ „

An average of 27 coals for fuel measured about 40½ cubic feet per ton.

Cost of evaporating 10 lbs. of water from steam boilers.

Breeze at 4/6 per ton = 0·036*d.*
Coke at 12/- per ton = 0·097*d.*
Welsh coal at 20/- per ton = 0·107*d.*

Coke and coal are usually considered of equal calorific value, weight for weight.

Boiler should be fed by small quantities and often, so that the draught of the chimney does not carry away the fuel improperly combined to form a permanent invisible gas; smoke is only the recondensing of gases that having been liberated by heat, have been allowed to cool back again and lapse back to their constituent parts before chemical union has arranged their molecules so as to render them invisible, when they enter the atmosphere and become absorbed in it.

Andrew's patent fuel for boilers and retort furnaces consists of 40 gallons tar to 1 chaldron (21½ cwt.) breeze, and sets hard in a few days.

Average Water Consumption in Steam Engines.

Non-condensing . . .	25 to 40 lbs.	per I.H.P. per hour.
Condensing . . .	18 „ 30 „	„ „
Compound . . .	16 „ 20 „	„ „
Triple expansion . .	13½ „ 15 „	„ „

Heat feed water of boilers to 212° F. if possible.

The usual course adopted by the engine and boiler minders is to inject tallow into the boiler to prevent priming.

To Prevent Boiler Incrustations.

Two ounces muriate of ammonia in boiler twice a week.

Carbonate of soda.

Frequent blowing off.

Any fatty deposit on the interior surface of a boiler-plate greatly hinders the transmission of heat. (J. Hirsh.)

Use caustic soda and soda ash for prevention of depositions of carbonate and sulphate of lime in boilers. 1½ ounces pure caustic soda per 1,000 gallons for each grain carbonate of lime in feed water, and 1¾ ounces carbonate of soda (soda ash) per 1,000 per grain.

Remove all sediment from boiler through blow-off cock every twelve hours.

Ordinary feed water may be said to contain ·05 per cent. solid matter, or 35 grains per gallon (in a boiler of 100 H.P. this equals 1 lb. solid matter deposited per hour). By heating the feed water a large proportion of this may be kept out of the boilers.

Carbonates of lime and magnesia are deposited slowly at 150° F., but at from 280° to 300° the deposition is rapid (except 2 or 3 grains per gallon, which remains dissolved).

Sulphate of lime is deposited at 307°.

11 lbs. air required theoretically for 1 lb. coal burnt, but double this necessary with natural draught in boilers.

The proportion of carbonic acid gas in the boiler flue should lie between 11 per cent. with bituminous and 15 per cent. with anthracite coals, with a small percentage of oxygen and no carbonic oxide.

Heat at outlet of chimney may be reduced to 300° C. without injury to draught.

When a jet photometer is fixed in the exhauster house, the gas should be purified by means of small lime and oxide purifiers before admission to the photometer.

WASHING AND SCRUBBING.

Gas should be free from tar before it enters the washers and scrubbers, or the efficient working of the latter will be impaired.

Clean water scrubbers require from 2 to 3 gallons water per 1,000 cubic feet of gas passed through them.

Quantity of water required in standard washer scrubber 10 gallons per ton. This removed 241 grains NH_3 and reduced the CO_2 and H_2S some 30 per cent.; 50 square feet of wetted surface is exposed to the gas per cubic foot of machine.

13·7 gallons of water used in Kirkham Hulett and Chandler's washers per ton of coal carbonized and liquor produced was of 15 ounces strength. (King's Cross Works, 1881.)

Water at ordinary temperature absorbs 700 times its volume of ammonia gas.

Cold water will absorb about 1,000 times its bulk of ammonia gas.

Water in scrubbers should not be lower than 50° or hydrocarbons will be deposited.

At a temperature of 60° F. liquor of 14 ounces strength cannot reduce the ammonia in the gas it is in contact with to a lower degree than 54 grains per 100 cubic feet. (L. T. Wright.)

At a temperature of 183° F. water will not absorb ammonia.

Where there is plenty of washing and scrubbing room, water at 70° F. has been used and good results obtained.

If the water used to abstract ammonia is warm it will afterwards freely give off ammonia into the air.

The water used in scrubbing has a distinctly deteriorative action on the illuminating power of the gas.

If gas be lowered in temperature below 40° F. it has to be raised in scrubbers, and napthalene will be deposited in them.

Average yield of ammonia per ton equals 6·8 lbs., or 1·5 per cent. by volume, or 467 grains per 100 cubic feet at outlet from retorts.

About one-half of the total ammonia in the gas is removed by the scrubbers.

NH_3 removed by condensation	. . .	42·7 per cent.
NH_3 „ first scrubber	. . .	43·3 „
NH_3 „ second „	. . .	14·0 „

(C. Hunt.)

Ammonia is produced in a greater amount during the earlier period of the charge, and cyanogen during the latter hours.

Lancashire and Yorkshire coal generally contains a larger proportion of ammonia than Durham coal.

The ammonia in Midland Counties coal varies from 62·7 to 141·2 ounces per ton.

Equal and thorough wetting of the material in the scrubber is necessary to ensure good working.

With tower scrubbers extreme cold may have a detrimental effect on the illuminating power.

About 26 to 36 gallons of 10 ounce liquor are produced per ton of coal.

If gas be passed through a coke or clinker-filled scrubber, saturated with tar, it will injure the gas by as much as 2 candles.

A lead-lined scrubber containing weak acid might be used for the elimination of the last few grains of ammonia, and thus water be saved.

If liquor which has once passed through a scrubber be purified partly from H_2S and CO_2, it can be made to remove nearly all the H_2S and much of the CO_2 when used again in the scrubber.

In ammoniacal liquor, $\frac{4}{5}$ths of the ammonia is combined with CO_2 and H_2S and can be freed by boiling, the remaining $\frac{1}{5}$th is combined with hydrochloric, sulphuric, and other acids which cannot be freed by boiling.

1000 cubic feet crude Newcastle coal gas contains about 8 cubic feet H_2S, 25 cubic feet CO_2.

About eight times the ammonia present in the crude gas would be required to eliminate all the CO_2 and H_2S in the gas.

A strong solution of ammoniacal liquor is required to effectually remove as large a proportion as possible of the H_2S and CO_2 from the gas in the washers.

Of the total volume of ammonia in the gas there will be 1·2 per cent. available for combining with the CO_2 and the hydro-sulphuric acids which will be able to remove 0·6 per cent. of CO_2 and 0·18 per cent. H_2S.

One combining equivalent NH_3 will absorb CO_2 or H_2S to the extent of $1\frac{1}{6}$ to $1\frac{1}{4}$ combining equivalent of one or both of these acid bodies. (Butterfield.)

100 volumes NH_3 combine with about $12\frac{1}{2}$ volumes H_2S.

100 volumes NH_3 combine with about 50 volumes CO_2.

In a washer using 7 ounce liquor which thus became one of 14 ounce strength, the latter was found to contain 5,000 cubic inches of CO_2 and H_2S equal to 357 cubic inches per ounce of strength, and the cost of dry purification by the dry process was reduced by 20 per cent.

Maximum tension of ammonia gas in coal gas is about 0·45 inches mercury.

When the quantity of water is reduced owing to smaller makes, the impurities in the gas travel further forward in the apparatus before being removed from the gas.

Scrubbers remove about 2 grains CS_2 per 100 cubic feet.

Ammoniacal liquor will remove ammonia from the gas in proportion to its own strength of ammonia only, therefore too strong ammonia used over the first scrubber may have the effect of increasing the quantity of the ammonia in the gas if the amount present before the gas enters the scrubber is less than the equivalent quantity in the liquor being used for washing purposes.

In gas liquor of average strength there is generally from 60 to 70 per cent. by volume of carbonic and hydro-sulphuric acid in proportion to the volume of ammonia.

1 gallon 10 ounce liquor contains 4,704 cubic inches CO_2 and 1,362 cubic inches H_2S, with 6,066 cubic inches other foul gases or equal to 57 cubic feet CO_2, 16 cubic feet H_2S. (G. Livesey.)

1 cubic foot $NH_3 = 316·77$ grs.

The most probable proportion of ammonia to CO_2 in gas liquor would be 2 volumes NH_3 to 1 volume CO_2, but with NH_3 and H_2S, 1 of NH_3 to 1 of H_2S is more likely.

Ammonia combines with CO^2 to form ammonium bicarbonate (NH_4HCO_3).

Ammonia combines with H_2S to form ammonium sulphohydrate (NH_4HS); or,

Ammonia combines with CO_2 to form ammonium monocarbonate $(NH_4)_2CO_3$.

Ammonia combines with H_2S to form ammonium sulphide.

Ammoniacal liquor is a weak solution of ammonium bicarbonate (NH_4HCO_3), ammonium sulpho-hydrate (NH_4HS), together with appreciable quantities of sulpho-cyanide (NH_4CNS) and thio-sulphate $(NH_4)_2S_2O_3$. (*Lancet.*)

Analysis of Ammoniacal Liquor. (Professor Lewes.)

		Grammes per Litre.
Ammonia sulphide	Free	3·03
" carbonate	Free	39·16
" chloride	Fixed	14·23
" thio-cyanate	Fixed	1·80
" sulphate	Fixed	0·19
" thio-sulphate	Fixed	2·80
" ferro-cyanide	Fixed	0·41

Water will dissolve at 60° F. and 30 inches barometer, an equal volume of CO_2.

Water will dissolve at 32° F. $1\frac{3}{4}$ volume of CO_2.

Water will dissolve at 23° F. 4·37 volumes of H_2S, and ·001 volume of CS_2.

Water will dissolve at 60° F. and 30 inches barometer 783 volumes of NH_3.

Water will dissolve at 183° F. no NH_3.

1° Twaddel equals about two ounces strength by distillation.

Factor for Rendering Degrees Twaddel into Ounces Strength.
(Lewis T. Wright.)

Description of Liquor.	Saturation.	Distillation.
Natural	2·18	2·54
"	1·80	2·43
" cannel coal . . .	1·68	2·22
Final product	1·62	2·00
" "	1·68	2·04
" "	1·59	1·92
From clean water scrubbers .	—	1·64 to 1·83

Hill's process of "ammonia purification" consists of bringing the liquor, after use in the scrubbers, to nearly boiling point, when the CO_2 and H_2S are driven off and the ammonia can then be used again in the scrubbers for the further elimination of CO_2 and H_2S.

Caking coals contain from 1·56 to 1·9 per cent. N, but of this amount only 11·59 to 15·72 per cent. comes off as NH_3 during distillation.

Yield of ammonia greatest at medium heats. (L. T. Wright.)

Of the total N in the coal, 14·5 per cent. passes off as ammonia, 1·56 per cent. as cyanogen, 48·68 per cent. in coke, 35·26 per cent. in the gas. (Professor W. Foster.)

The greater the proportion of fixed ammonia the less the purifying power of the liquor for the elimination of H_2S or CO_2.

The liquor from the scrubbers contains carbonate and sulphide of ammonium, some free alkali and sulphocyanide, hyposulphite and sulphate.

If sufficient ammonia be presented to the crude gas all the H_2S, CO_2, and CS_2 will be removed.

If liquor could be made to give off the H_2S and CO_2 which it has taken up in the scrubbers and could be used over again these impurities might be removed almost entirely by the ammonia.

By Hill's process the liquor was heated to 180° F., when the CO_2 and H_2S were driven off as follows:—$NH_4HCO_3 = NH_3 + H_2O + CO_2$, and $NH_4HS = NH_3 + H_2S$.

To prevent the loss of ammonia the gases were passed through a scrubber supplied with liquor at 160° F. which it was supposed would arrest any ammonia gases. To obtain sufficient ammonia to remove all the CO_2 from the crude gas, the liquor has to be treated twice for the removal of the CO_2 previously taken up.

Cyanogen.—The quantity of cyanogen recoverable from coal gas varies with the temperature of carbonization, from 5,000 grains with low heats to 10,000 grains with high heats per ton of coal.

The most favourable temperature in the retorts for the formation of cyanides equals 2,200° F.

Cyanogen is the gaseous compound of carbon and nitrogen.

To Recover the Cyanogen.

First remove all the NH_3 and then pass the gas through soda or potash in solution in presence of an iron salt, when from 4 to 4½ lbs. of crystallized ferrocyanide of soda or potash is recoverable per ton of coal.

Spent products in gas works rarely contain more than 15 per cent. of ferrocyanide of potassium. (M. Perthuis.)

Ammoniacal liquor made per ton, Gas Light and Coke Co. half year to December, 1892 :—·279 butts per ton of 10 ounce strength by distillation.

Impurities in Coal Gas after passing Scrubbers.

(Butterfield.)

H_2S	500 to 800 grains	per 100 cubic feet.
CO_2	700 to 1,100 "	
CS_2	30 to 45 "	

Average Composition of Gas after leaving Scrubbers.

(Professor V. B. Lewes.)

H	48·55	per cent. by volume.
Methane	39·70	" "
Illuminants	3·30	" "
CO_2	2·50	" "
CO.	2·00	" "
O	0·45	" "
N	3·50	" "

If the scrubbing is properly done, the gas should not contain more than 1·4 per cent. CO_2, 0·3 per cent. H_2S, and from 38 to 42 grains CS_2 per 100 cubic feet with no ammonia.

Gas after leaving scrubbers contains about 400 grains H_2S and 35 to 40 grains CS_2 and other sulphur compounds.

PURIFYING.

Gas loses about 3 per cent. by volume in passing through the purifiers, due to the elimination of the CO_2 (2·25 per cent.) and H_2S (0·75 per cent.).

25 cubic feet of CO_2 per 1,000 cubic feet gas reduces illuminating power about two candles, or, in other words, 1 per cent. CO_2 diminishes illuminating power 7 per cent.

CO is present in coal gas to the extent of from 3 to 8 per cent.

1·1 per cent. S in coal equals 1·2 per cent. of H_2S in the gas. (Butterfield.)

Crude gas contains about 8 feet of sulphuretted hydrogen per 1,000 feet of gas from Newcastle coal.

Sulphuretted hydrogen is 1 part H, 16 parts S; specific gravity is 1·178; 100 cubic inches weigh 36·51 grains.

In ordinary use a purifier is turned off before it has ceased to remove H_2S, the usual test being that the next box shows a foul test.

Oxide of iron will at times absorb CS_2, but will again give this off quite suddenly, possibly owing to the affinity of S for CS_2, which can be disturbed by a slight increase in temperature.

If gas containing CS_2 is passed through a mixture of sawdust and sulphur the quantity of CS_2 will be reduced 50 per cent.

Oxide of iron, after fouling, contains some free sulphur and iron sulphide; and revivification converts this into sulphur and hydrated iron oxide by the action of moisture and air.

Analysis of Bog Ore (Dry basis).

Ferric oxide	60 to 70 per cent.
Organic matter	15 to 25 ,,
Silica	4 to 6 ,,
Alumina	1 ,,

When in use the material would contain about 30 to 40 per cent. water.

Bog ore is a hydrated sesquioxide of iron (Fe_2, O_3, 3 H_2O).

Composition of Bog Ore:—

H_2O		50 per cent.
Hydrated oxide of iron, active .	20	32 ,,
,, ,, ,, inactive .	12	
Vegetable matter		18 ,,

Bog ore when ready to place in purifier should only contain 25 per cent. moisture.

Westbury Natural Oxide contains about—

66 per cent. hydrated peroxide of iron,
28 ,, earthy matter,
6 ,, uncombined water.

(N. H. Humphreys.)

Bog ore contains 30 per cent. Fe_2, O_3, and 55 per cent. moisture.

Analysis of O'Neill's Oxide. (June, 1875.)

Water per cent.	22·30
Fibre	11·60
Peroxide of iron	65·42
Silica	·57
Loss	·11
	100·00

One cubic foot of oxide weighs 56 lbs.

"One ton of oxide should eliminate the H_2S from 3,000,000 cubic feet of Newcastle coal gas, which contains about 8 cubic feet of H_2S."

"An average quantity of oxide for 2,000,000 cubic feet of gas is one ton when oxide only is used."

"One ton bog ore should purify from 1,250,000 to 1,500,000 cubic feet of gas from H_2S before becoming spent."

It is better when using new oxide for the first time to mix a little old with it, to reduce the percentage of moisture.

A little old oxide mixed with new assists its action at first, as will also the presence of a slight quantity of ammonia in the gas.

One equivalent of hydrated peroxide combines with about three equivalents of H_2S.

36 parts of hydrated peroxide of iron will combine with 17 parts of H_2S.

Room must be allowed for expansion of material upwards when revivified *in situ*.

Oxide should be laid in layers of from 12 to 18 inches thick.

Best method of using oxide is 2 layers of 18 inches thick.

(Hawkins.)

Oxide of iron is laid as thick as 2 feet 6 inches in some purifiers.

A thick layer of oxide, say 3 feet thick, will often have to be turned off, on account of back pressure, when only just put to work, but, as a rule, with thick layers of oxide no great increase of pressure need be feared if there be good scrubbing and washing beforehand.

Oxide usually laid about 10 inches to 12 inches thick on the grids.

Oxide should be laid about 10 inches thick to revivify.

Gas should not be allowed to enter a purifier much above the temperature of the oxide therein.

The avoidance by every possible means of high temperatures in the purifiers, or during the revivification, of the spent material is advisable. (M. Godinet.)

Gas purified by oxide of iron is said to have a yellow tinge, while that purified by lime is whiter, the colour of the former being due probably to the presence of CO_2.

Reaction in Oxide Purifiers.

$$Fe_2O_3H_2O + 3\,H_2S = Fe_2S_3 + 4\,H_2O\text{; or}$$
$$Fe_2O_3H_2O + 3\,H_2S = 2\,Fe\,S + S + 4\,H_2O.$$

Action of air when revivifying upon $Fe_2S_3 + 4\ H_2O$.

$$2\ Fe_2S_3 + 3\ O_2 = 2\ Fe_2\ O_3 + 3\ S_2.$$
$$12\ Fe\ S + 9\ O_2 = 6\ Fe_2\ O_3 + 6\ S_2.$$

Oxide (bog ore) should remove 1st time 16 per cent., 2nd 6 per cent., 3rd 5 per cent. sulphur.

Another authority gives—

Reaction of Oxide of Iron.

$$Fe_2O_3H_2O + 3\ H_2S = Fe_2S_3 + 4\ H_2O.$$

When revivifying—

$$Fe_2S_3 + 3\ O + H_2O = Fe_2O_3H_2O + 3\ S.$$

Also hydrated oxide of iron removes H_2S as per equation :—

$Fe_2O_33\ H_2O + 3\ H_2S = 2\ Fe\ S + 6\ H_2O + S$, and is revivified in the air as follows :—$2\ FeS + 3\ H_2O + 2\ O = 3\ O + Fe_2O_2H_2O + 2\ S$.

H_2S unites with the iron and forms sulphide of iron, the H, combining with O in the oxide forming water. After use in purifier the oxide is in the form of sulphide of iron, the iron absorbs O and leaves the sulphur in a free state.

It is not advisable to use oxide containing more than 55 per cent. to 60 per cent. free sulphur, as its utility is impaired, but when revivified *in situ* it can be made to take up 75 per cent.

When S in oxide equals 55 per cent. the oxide is useless for purification. (Richards.)

Oxide can be used until it has taken up 60 per cent. by weight of sulphur, but has no action upon CO_2.

New oxide, when revivifying, combines very rapidly with the O in the air, causing rapid evolution of heat.

Value of spent oxide should be sufficient to purchase all purifying material necessary for purification of gas from H_2S.

It has been found that by treating spent oxide with caustic, lime, and soda sulphate at a certain temperature, an increased yield of sulphocyanates and ferrocyanides are obtained equal to about 40 per cent. above that obtainable by treatment with water.

Analysis of Spent Oxide. (J. Hepworth.)

	Per Cent.
H_2O	14·0
S	60·0
Organic substances insoluble in alcohol	3·0
Organic substances soluble in alcohol consisting of calcium ferrocyanide and sulphaequinde, ammonium cyanidequinde, sal-ammoniac hydrocarbon	1·5
Clay and sand	8·0
Calcium carbonate, ferric oxide, &c.	13·5
	100·0

About one-half the total sulphur present in coal passes forward to the purifiers.

The quantity of H_2S requiring to be removed by the purifier may range from 200 to 2,000 grains per 100 cubic feet

Order of Value for Purifying Coal Gas of the Principal Limestones of this Country. (Hughes.)

1. The white chalk limestone of Merstham, Dorking, Charlton, Erith, and other parts of the chalk range surrounding the metropolis.
2. The grey chalk limestone, from the lower beds of chalk.
3. The blue beds of the upper and middle Oolites.
4. The lower white and grey limestones of the Oolites.
5. The most calcareous and crystalline beds of the carboniferous or mountain limestone, colours grey and bluish.
6. The magnesian limestone of Yorkshire and Derbyshire.
7. The white lias limestone.
8. The blue lias limestone.
9. The Silurian limestone of Wenlock, Dudley, &c., and the coraline limestones of Plymouth and the neighbourhood.

Theoretical value of chalk when made into lime is 100 lbs. chalk equals 56 lbs. CaO as per equation :—

$$CaCO_3 = Co_2 + CaO.$$
$$100 = 44 + 56$$

In practice 1 ton chalk makes on an average 1 yard lime; (13,596 tons chalk made 13,300 yards lime). (Actual experiment, 17th May, 1893.)

Lime.

25 striked bushels or 100 pecks equals 1 hundred of lime.

46,656 cubic inches, 1 cubic yard, or 27 cubic feet containing $21\frac{3}{5}$ bushels, equal 100 lime.

1 bushel of quick lime	weighs about	70 lbs.
1 cubic foot stone	„ „ „	54 „
1 cubic yard quick	„ „ „	1,460 „
1 ton	„	equals 32 bushels.

About 40 lbs. of lime are required to purify a ton of coals in large works.

Lime used in large and medium sized works in purification with oxide or other supplemental method ranges from 3·3 to 5·5 cubic yards per million cubic feet of gas.

By the rotation method of purifying, 1 yard unslaked lime is required per 35 tons of coal used.

165 lbs. Irish unslaked lime will clean about 35,000 cubic feet of gas.

Quantity of lime required to extract CO_2, about 3·3 yards per million cubic feet.

Chalk lime is best for purification of gas from CO_2.

Lime often contains 5 to 20 per cent. of earthy matters which may cause it to become caked in the purifiers.

Lime ready for the purifiers generally contains 30 to 40 per cent. of water above that required for the making of hydrate of lime.

1 bushel quick lime increases to 2½ when slaked, and this should purify 10,000 cubic feet of gas. (Richards.)

Caustic lime when slaked about doubles in bulk as $CaO + H_2O$ equals CaH_2O_2.

28 parts of lime combine with 9 parts of water to form hydrate of lime or slaked lime.

28 parts of pure lime will combine with 22 parts of CO_2.

28 parts of pure lime will combine with 17 parts of H_2S.

74 parts by weight of pure lime should combine with 44 parts of CO_2 or with 34 parts of H_2S.

Sometimes when lime is used to remove CO_2, H_2S and CS_2 an oxide vessel is used last, to act as a catch purifier to take up any H_2S that may be driven off from the sulphide vessel.

When lime only is used for purification the sulphur is wasted.

Wet lime will purify double or treble the gas dry lime will.

(S. Anderson.)

Dry CO when present in a purifier containing dry hydrate of lime will not combine with it, but the addition of moisture causes the $CaOH_2O + CO_2$ to become $CaOCO_2 + H_2O$.

When water is added to lime calcic hydrate is formed as per equation :—

$$CaO + H_2O = CaOH_2O.$$

Excessive water in the lime will cause the latter to cake and then impede the passage of the gas.

Lime usually laid about 4 inches thick on the grids.

1,650 lbs. of lime will take up about 425 gallons of water when being mixed up for the purifier, or about 1 gallon of water to 4 lbs. of lime.

Lime will cleanse about 35,000 cubic feet of gas per 165 lbs.

Lime should be slaked two or three days prior to use in purifiers or it may cake; slaking increases the bulk about 2½ times; it should be as pasty as possible, and take the form of nodules about ¾ inch to 1 inch in diameter. Dry lime is not so porous or so efficacious as a purifying material.

Mr. F. Egner (U.S.A.) proposes to prepare lime for purifying as follows:—a thin layer, 4 or 5 inches deep, of unslaked lime should be laid out, and nearly the whole quantity of water poured over the lime. As the lime slakes it is turned over with long pronged rakes, then one-tenth of its bulk of screened coke breeze added and thoroughly mixed and moistened until a handful will stick together when tightly squeezed

Removal of Carbonic Acid.

Here lime purification should be adopted; the material to be hot and divided in several layers. No special system of revivification need be followed.

Pressure thrown by a lime purifier with sieves covered with from 12 to 15 inches of lime should never exceed 1 inch during its working.

Pressure thrown by 8 layers of lime 10 inches thick has been as low as 1½ inch for a considerable period.

Lime is usually placed in layers of 4 to 6 inches thick.

Approximate action of lime on H_2S in purification is expressed probably by the following equation :—

$$CaOH_2O + H_2S = CaS + 2\ H_2O$$

Lime meeting CO_2 in gas without H_2S forms calcium carbonate

$$CaO + CO_2 = CaCO_3$$

Lime first attacks both the CO_2 and H_2S, forming carbonate and sulphide of calcium, but later the CO_2, having a greater affinity for the lime, drives off the H_2S and forms carbonate of calcium only.

When gas containing CO_2 and H_2S meets lime :—

$$\left.\begin{array}{l} CaH_2O + 2\ H_2S = CaS,\ H_2S + 2\ H_2O \\ \qquad\text{or} \\ CaH_2O_2 + H_2S\ = CaS + 2\ H_2O \\ \qquad\text{and} \\ CaO + CO_2\quad = CaCO_3 \end{array}\right\}\text{formed simultaneously,}$$

afterwards the

$$CaS + CO_2 + H_2O = CaCO_3 + H_2S$$

the H_2S being driven forward owing to the greater affinity of the CO_2 decomposing the CaS ; but if air is admitted a certain portion of the H_2S is converted into free sulphur and it cannot then be sent forward.

About 70 lbs quicklime is required per ton of coal in small works.
" 130 " " " " " " cannel.

1 bushel quicklime	weighs about	70 lbs.	=	1·3 cubic feet.
1 cubic foot chalk lime	" "	45 "	=	0·771 bushels.
1 cubic yard	" "	" 1,460 "	=	20.9 "
1 ton	" measures "	32 bushels.		

Lime ready slaked for the purifiers should weigh about 90 lbs. per bushel.

Mr. Forstall has suggested passing the slaked lime through sieve with 1 inch square mesh set at an angle of 70° with the floor, and the lime should not be wet enough to cling to the sieve.

If lime be allowed to become too dry and powdery CO_2 will speedily slip, and if too wet the result is not satisfactory; both extremes should be avoided. If cold gas be introduced into a hot material the latter is rendered powdery, and if hot gas is introduced into a cold material it is made too wet.

Removal of the Sulphur Compounds.

The cost of removing the sulphur compounds may be taken as over 1*d*. per thousand cubic feet.

Where oxide of iron is used there should be a large purifying surface and prolonged contact with the purifying material, which should be in one or several layers according to the use or non-use of inert materials. Where revivification is effected in the open air, the material should be heaped up on its removal from the purifiers, and, as soon as it becomes heated, spread in layers from 8 to 12 inches thick. Where continuous revivification is employed the volume of air or oxygen should be injected without interruption and in exact proportion to the make of gas, the material to be kept warm and moist. In the case of purification by lime the material should be divided into several layers and used cold if it is desired to retain more of the sulphide of carbon, otherwise hot. Oxygen should be employed for revivification.

Quantity of Sulphur Compounds from Same Coal.

Yield of Gas per Ton.	Sulphur per 100 Cubic Feet other than H_2S. grains.
6,893	13·9
8,370	19·1
9,431	26·7
10,772	36·9
11,620	44·1

If CO_2 be allowed to pass into a sulphided lime purifier it will liberate some of the H_2S and CS_2 already taken up and form carbonate of calcium in its place.

If H_2S be allowed to pass into a properly sulphided lime purifier it changes the monosulphide to a polysulphide, which has no effect upon the CS_2.

Of the 45 grains S. other than H_2S in coal gas per 100 cubic feet, the CO_2 purifiers remove 10 grains, the sulphided purifiers remove 25 grains.

Carbon bisulphide (CS_2) is usually removed by a lime purifier, through which a quantity of gas free from CO_2 but containing H_2S has been passed, the H_2S combining with the lime to form sulphide of lime, which latter will remove practically all the CS_2.

The removal of the sulphur compounds is not rendered more certain by the admission of 1 to 2 per cent. of air at Nos. 3 or 4 purifiers at Rotherhithe. (A. F. Browne.)

Probable action in sulphided lime purifiers.

$$CaS + CS_2 = CaCS_3$$

or,

$$CaSH_2O + CS_2 = CaCS_3 + H_2O$$

or,

$$CaS_5 + CS_2 = CaS_2CS_2 + S_3$$

The calcium pentasulphide may also combine with the O admitted in the air thus :—

$$CaS_5 + O_3 = CaS_2O_3 + S_3$$
$$CaS_5 + O_3 = CaSO_3 + S_4$$

or with CO_2 thus :—

$$CaS_5 + CO_2 + H_2O = CaCO_3 + H_2S + S_4$$

Laming material consists of sulphate of iron, 250 kilogrammes; slaked lime in powder, 4 hectolitres, inert material, 7 hectolitres.

The stability of the sulphide of lime, as measured by the action upon it of CO_2, depends largely upon the temperature at which the sulphide is formed.

The energy of union as between calcium sulphide and CS_2 is sharper and much more complete when the sulphide is prepared from hot lime, and is maintained at about the temperature of 75° F. Sulphide so made and used is said to have 30 per cent. greater efficiency; and by chilling the vessel the efficiency can be reduced to nil.

A very small quantity of CO_2 passing into a sulphide vessel materially decreases the efficiency.

Weldon mud is a bye product from the manufacture of bleaching powder with lime and air, and consists principally of hydrated oxides of manganese (MnO_2 and MnO) and of calcium.

Weldon mud will absorb about four to five times the H_2S that oxide of iron will, forming sulphide of manganese and water.

Weldon mud equals about 52 per cent. water and 26 per cent. manganese dioxide, and should remove 28·1 per cent. S first time, 16·7 per cent. second time, 5·8 per cent. third time.

About 1 per cent. of air is considered best with Weldon mud when it is used for the first removal of H_2S.

About 10 to 15 grains H_2S per 100 cubic feet is contained in the gas when it reaches the check purifiers, where lime or Weldon mud is found more active for such small quantities than oxide of iron. Weldon mud with about $\frac{1}{4}$ per cent. of air has continued active in this position for two to three years, and is said to represent a labour saving as against lime of 1 to 16; the pressure thrown decreases with time, whereas with lime and oxide it increases.

Comparative quantity of oxide shifted at Beckton per 100,000,000 cubic feet gas made, 503 cubic yards as against 50 cubic yards of Weldon mud; this refers to the material used in the primary elimination of H_2S.

In the all lime purifying method about $1\frac{1}{2}$ per cent. air is about the best quantity.

The use of air greatly mitigates the bad smells given off by oxide when it is first removed from the purifiers, and doubles the length of time the purifiers will last without recharging.

Air used with lime purifiers will cause the sulphur taken up by the lime to be converted into free sulphur to the extent of 10 per cent., instead of being driven off by the CO_2.

The use of air ($1\frac{1}{2}$ per cent.) in purification enables the oxide to absorb some 25 per cent. sulphur before it need be removed for complete revivification.

Purifiers by the air process have been filled with oxide, and not again discharged until the material contains nearly 60 per cent. of sulphur.

More than 3 per cent. air not only reduces the illuminating power, but is inclined to cake the oxide and to raise the temperature of the material.

The admission of air or oxygen to the purifiers effects an oxidation of the sulphur compounds of the lime, and sulphur is deposited as such in the foul lime. (Butterfield.)

Air may be used in a sulphide vessel to reconvert a polysulphide into a monosulphide, or to render a box sulphided at a low temperature active.

Steam, when used to inject air into purifiers, has been found to prevent the caking of the oxide; it has been suggested to introduce it at the inlet to first purifier so as to raise the temperature to 100°.

Revivification by steam jet *in situ* may set fire to the grids.

Mr. Carpenter admits 1 per cent. air into the third or fourth purifier and thus obtains the desired effect on the ones required for the removal of the sulphur compounds.

When air is used (2 per cent.) to aid purification in oxide vessels the use of ammonium hydrate (ammoniacal liquor 4° Twaddel) sprinkled on the oxide before use is found to increase the life of the charge from 80 to 100 per cent. (R. G. Shadbolt.)

Two and a half per cent. air used in purification lowered 17·3 candle gas to 13·45 candles.

Three per cent. air used in purification lowered 17·3 candle gas to 13·04 candles.

Five per cent. air used in purification lowered 17·3 candle gas to 10·59 candles.

Seventeen and a half per cent. air used in purification lowered 17·3 candle gas to 1·0 candle.

An arrangement for pumping into the gas at the inlet of the purifiers 3 per cent. air carburetted with tar of specific gravity 1·196, kept at a temperature of 170° by a steam coil, was patented by Mr. Hawkins, to remove the loss of illuminating power occasioned by the use of such a large quantity of air. The specific gravity of the tar after leaving the carburettor was 1·218. The only objection appeared to be the possibility of a deposit of napthalene in the mains during severe winter weather. The illuminating power appears to have been maintained throughout the district.

The quantity of air necessary, according to theory, for continuous revivification of oxide is 2½ per cent. air for 1 per cent. H_2S. A slight margin in excess is, however, necessary in practice for safety.

It is said that the higher temperature in a purifier, due to the increased chemical activity of the purifying material when air is used, prevents the deposition of some of the valuable hydrocarbons, which in the ordinary way would be condensed; the napthalene on the under side of a purifier cover in winter clearly showing that such a deposition will take place.

Advantages claimed for the use of O with oxide of iron purification are—Almost complete revivification of oxide *in situ;* increased illuminating power; greatly augmented percentage of sulphur in spent oxide, and consequent higher market value; the purification more efficiently conducted, with half the purifying space and two-thirds of the material; a corresponding saving in capital and labour.

Lime can be wholly used in conjunction with oxygen for the purification of gas. By the regulation of quantity of O to quantities of impurities sulphur compounds can be removed. Purifying space and plant now required for lime reduced by more than one-half, lime used by nearly one-half, and labour in proportion. Auxiliary oxide of iron purifiers are rendered unnecessary. Very considerable saving is caused by improvement in illuminating power. Sulphur deposited possibly recoverable. (W. A. McI. Valon.)

With oxygen and lime only and average of 620 grains S per 100 cubic feet at inlet, 2 cubic yards lime per million cubic feet kept sulphur compounds down to an average of 6 to 8 grains per 100 cubic feet, and the illuminating power maintained at 16·5 candles. (W. A. McI. Valon.)

Proportion of Oxygen Required for Purification.

0·1 per cent., by volume of oxygen for every 100 grains, H_2S per 100 cubic feet removes all the H_2S and CO_2, and reduces the sulphur compound to 7 or 8 grains per 100 cubic feet of purified gas.

One foot pure O is sufficient to remove 1,000 grains H_2S in the crude gas; or ·1 per cent. by volume of O per 100 grains H_2S per 100 cubic feet.

One half the volume of H_2S in the gas is required of oxygen to revivify the oxide *in situ*.

No increase in heat is found in the oxide when using O.

When oxygen is used with lime purifiers the H_2S first taken up by the lime is not expelled again by the CO_2, but the S is thrown down in the form of grains of pure sulphur, leaving the lime as active for the CO_2 as if no sulphur had been retained.

To Prepare Oxygen.

When air is compressed over water, the components of the atmosphere are taken up in direct ratio of the pressures employed. On releasing the pressure, there is proportionally more oxygen in the evolved gases; by repeating the process eight times 97·3 per cent. oxygen can be obtained.

Composition after Successive Pressures.

N.	79	66·67	52·5	37·5	25·0	15·0	9·0	5·0	2·7
O.	21	33·33	47·5	62·5	75·0	85·0	91·0	95·0	97·3

For a material to revivify *in situ* it must have a strong affinity for O, so as to combine with it energetically as it passes through the gas.

Cyanogen.

It would appear from the reactions expressing these changes that the cyanogen exists in coal gas exclusively in the forms of cyanide and sulphocyanide of ammonium.

Ferrocyanide of iron is formed if cyanogen and ammonia in only small traces are allowed to get to the oxide purifiers; this reduces the activity of the oxide for the removal of H_2S.

A large portion of the cyanogen combines with the iron in the purifiers to form a ferrocyanide or Prussian blue, but the quantity is reduced if first passed through lime.

Average per cent. of sulphocyanic acid, ammonia, and potassium ferrocyanide obtained from 12 German gasworks—

$$HCNS = 2{\cdot}62, \quad NH_3 = 1{\cdot}87, \quad K_4FeCy_6 + 3aq = 5{\cdot}1.$$

One ton of coal by the Claus ammonia process yields ½ lb. Prussian blue and 1¾ lbs. copper sulphocyanide.

Leybold found cyanogen equal to about 4 lbs. of ferrocyanide in 10,000 cubic feet of gas, of which nearly 95 per cent. remained in the scrubbed gas. When lime is used for purifying the gas, the cyanogen is lost; and if iron be used the cyanogen is converted largely into sulphocyanide in which form it is not so readily available. But when the gas after it leaves the scrubber is brought into intimate contact with precipitated oxide of iron, suspended in an alkaline solution, as recommended by Knublauch, the cyanogen is easily obtained as ferrocyanide, almost free from sulphocyanide.

Removal of the Cyanogen Compounds.

To ensure material rich in Prussian blue keep the stuff very moist at a low temperature, have a large purifying surface and long contact. When revivifying in the open air spread the material in very thin layers kept quite moist; but if *in situ* inject cold air saturated with moisture at great speed. In the case of continuous revivification the opposite process must be adopted, owing to the presence of less sulphide of iron in the purifiers.

Oil gas tar will remain on the sides of purifier covers, also petroleum oil.

Composition of Purified Illuminating Gas.

Authority.	Permanent Gases, H, CO, Hc, &c.	Illuminating Compounds or Light Bearers.	Impurities, H_2S, CO_2, NH_3, &c.
COMMON GAS.			
Bunsen . . .	87·12	6·56	6·42
Letheby (12 candle gas)	93·00	3·80	3.20
Odling	96·42	3·05	0·53
”	93·92	3·56	2·53
”	89·83	3·67	6·50
”	90·03	3·63	0·40
”	96·01	3·53	0·46
CANNEL GAS.			
Letheby (22 candle gas)	84·05	13·00	2·50
Odling	88·00	10·81	1·19
Two analyses of water gas as sold in New York	78·90	15·29	4·8
	81·16	15·29	3·5

Composition of Purified Coal Gas.

(Professor V. B. Lewes, 1890.)

	Per Cent.
H	47·9
Illuminants, ethylene series	3·5
" benzene "	0·9
" methane "	7·9
Methane	33·3
CO	6·0
CO_2	0·0
O	0·5
N	0·0
	100·0

GASHOLDERS (CARE OF).

It takes a considerable time for the diffusion of gases of different densities even when of great difference of density, when in conditions usual in gasholders.

Diffusion of Gases.

The velocity of diffusion of different gases is inversely proportional to the square roots of their densities.

	Density. Air=1	$\frac{1}{\sqrt{\text{Density.}}}$	Velocity of diffusion. Air=1
Hydrogen . .	0·06926	3·7790	3·830
Nitrogen. . . .	0·97130	1·0150	1·014
Oxygen . . .	1·10560	0·9510	0·949
Carbon dioxide . .	1·52900	0·8087	0·812

(Graham.)

Gases of different specific gravity will mix in time, but, owing to the temperature of either the incoming gas or the heat of that in the holder, the mixing may take a considerable time, the warmer gas keeping to the top of the holder. From the heat of the sun, the crown of a gasholder becomes so hot that it cannot be touched with the hand, being at least from 113° to 122° F. (W. Leybold.)

The contact of ordinary coal gas with water is found to cause a rapid diminution in illuminating power. (Irwin.)

Carburetted water gas stored in a holder for 17 days, lost 1½ candles in value at Blackburn.

Napthalene in gas holder inlet pipes is usually found to commence at and continue below the level of the surrounding water.

Do not lower a telescopic holder in a gale so as to leave the upper lift only exposed. As the centre of gravity is very near the crown, it is the more easily overturned, while, if the second lift is out of the water its weight brings the centre of gravity considerably lower.

Frost has been known to cause the sides of brick tanks to bulge inwards and prevent the holder moving up and down.

Painting Notes.

Gasholders should be first made clean by scrubbing and brushing with wire brushes, any bubbles of the old paint being scraped off with an old file sharpened at the edge.

Before painting a holder well scrape the old paint and remove old blisters and scales which might cause a lodgment of water and consequent oxidation of the plates.

With paint, too much oxide is not good for the oil which is then oxidized too quickly and rendered natureless, so that the paint eventually powders off. (Wood.)

A Coating for Gasholders.—Mix and raise to boiling point, 1 gallon of tar and ½ lb. asphalte, then add 1 pint coal naptha and ½ lb. tallow. Use warm.

The outer surface of gasholders may be covered with paint, or tar mixed with tallow, and it has been proposed to do this in the spring and also autumn each year.

Oil gas tar is an excellent paint for gasholders.

Tar for painting should only be raised sufficiently high in temperature to drive off all the water, should be fluid when cold, too thick for use, and can be thinned with turpentine, 1 turps. to 4 tar; 1 gallon will cover 64 square yards of metallic surface.

Red lead sets harder and sooner than white lead.

Contents of crown, to find: Square the radius of the holder, multiply this square by 3; to the product add the square of the rise and multiply by ·5236.

In filling the holder with gas it is best to use a high-class coal, and so compensate for the air in crown, as it is difficult to expel the latter.

DISTRIBUTION.

Mains. Services. Meters.

Quantity of gas, in cubic feet, discharged per hour by any main can be found as follows :—

$$X = 1350\, d^2 \sqrt{\frac{h\ d}{S\ L}}$$

Where—

h = pressure of gas in inches of water.
d = diameter of pipes in inches.
S = specific gravity of gas (air = 1)
L = length of pipe in yards.

(Dr. Pole.)

Another rule is—

$$X = 1{,}000 \sqrt{\frac{d^5\ h}{S\ L}}$$

(Molesworth's Pocket Book.)

And another is—

$$X = 1{,}000 \sqrt{\frac{h\ d^5}{\frac{1}{2}L}}$$

(Spon's Pocket Book.)

The first is the most correct.

Flow of Air in Pipes. (Hawksley.)

Velocity in feet per second =

$$396 \sqrt{\frac{\text{head in inches of water} \times \text{diameter of pipe in feet}}{\text{length of pipe in feet}}}$$

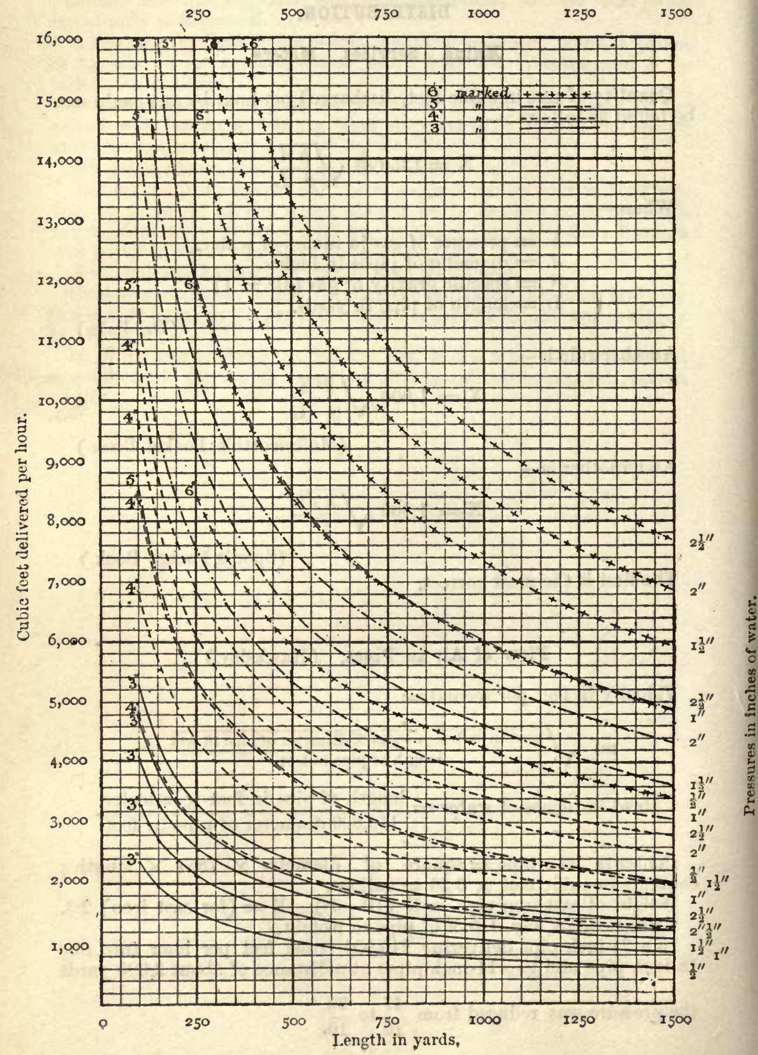
$$\text{Head in inches of water} = \frac{\text{length of pipe in feet} \times \text{velocity}}{156{,}800 \text{ diameter of pipe in feet}}$$

Contents of pipe = square of diameter × ·7854 × length ; contents in cubic feet × 6·26 = gallons.

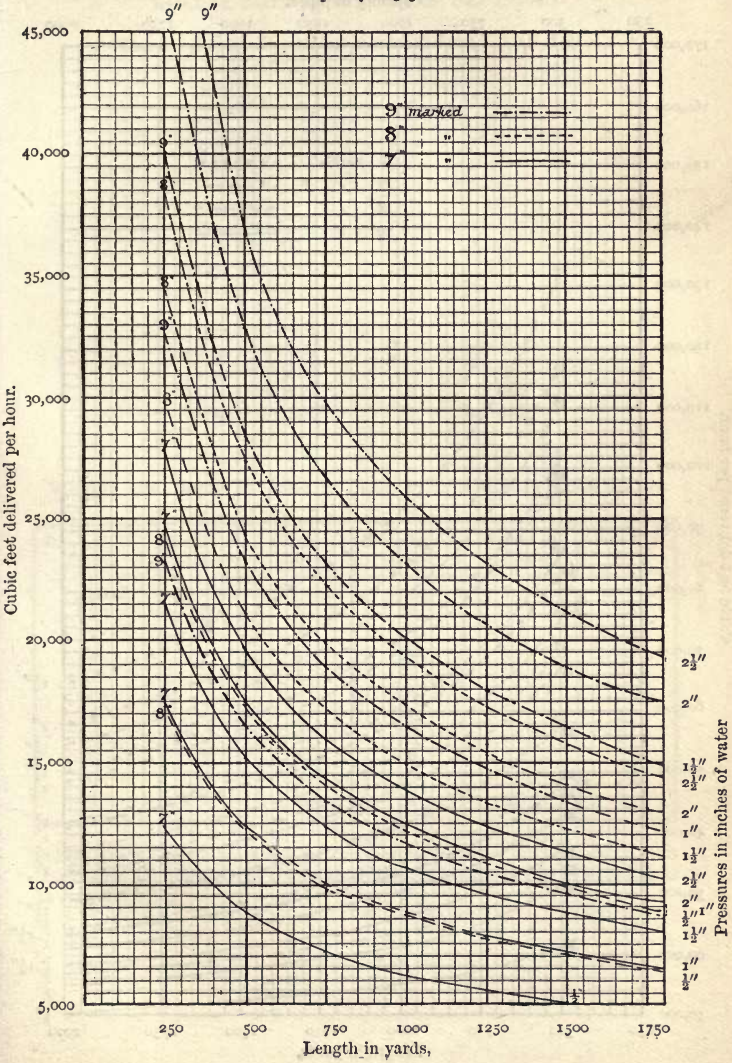
Weight of cast iron pipe = K ($D^2 - d^2$). K = (for cast iron) 2·5. Flange equals, say, 1 foot of pipe in weight.

In a 24-inch pipe delivering 240,000 cubic feet per hour into one 18-inch pipe and two 14-inch pipes at a distance of about 2,000 yards the pressure was reduced from $\frac{47}{10}$ to $\frac{20}{10}$.

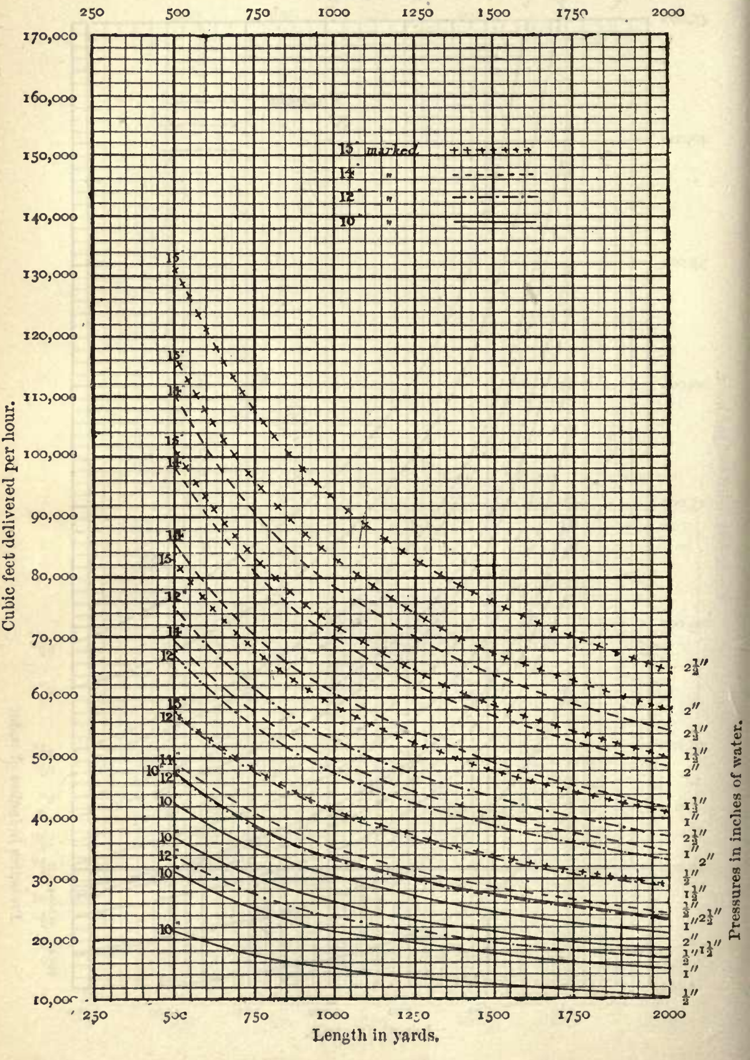
Capacity of pipes.



Capacity of pipes.



Capacity of pipes.



Relative Carrying Capacity of Gas Pipes.

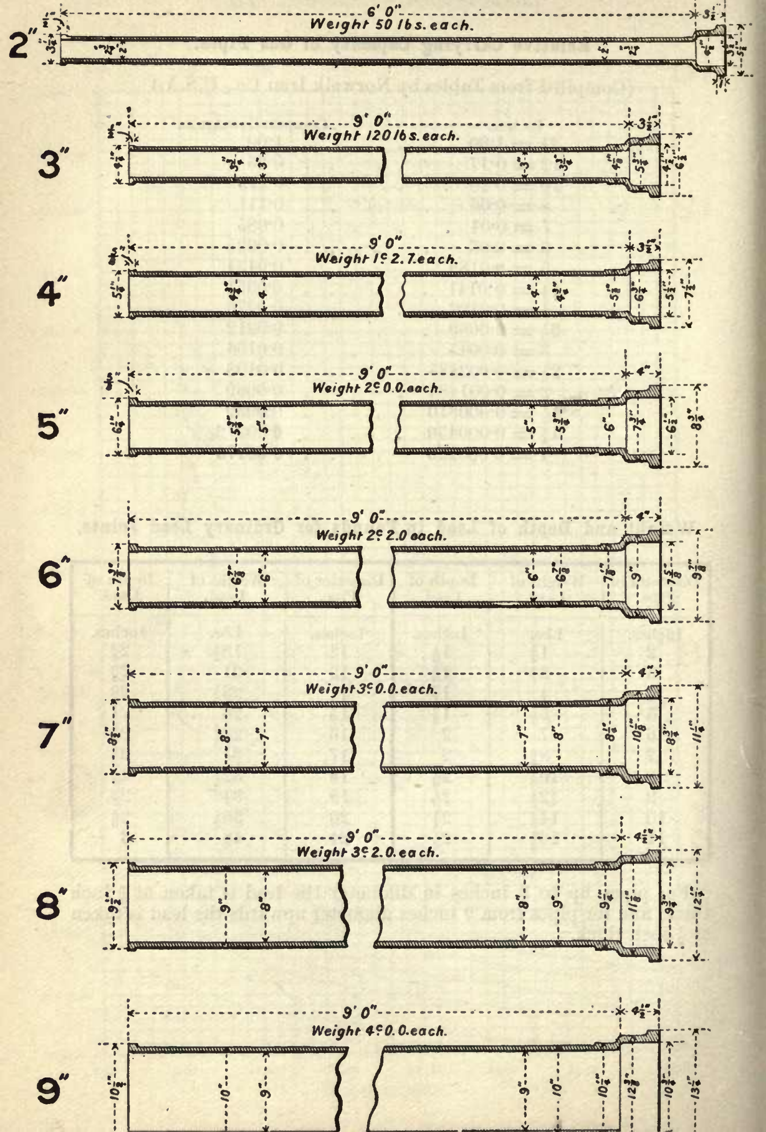
(Compiled from Tables by Norwalk Iron Co., U.S.A.)

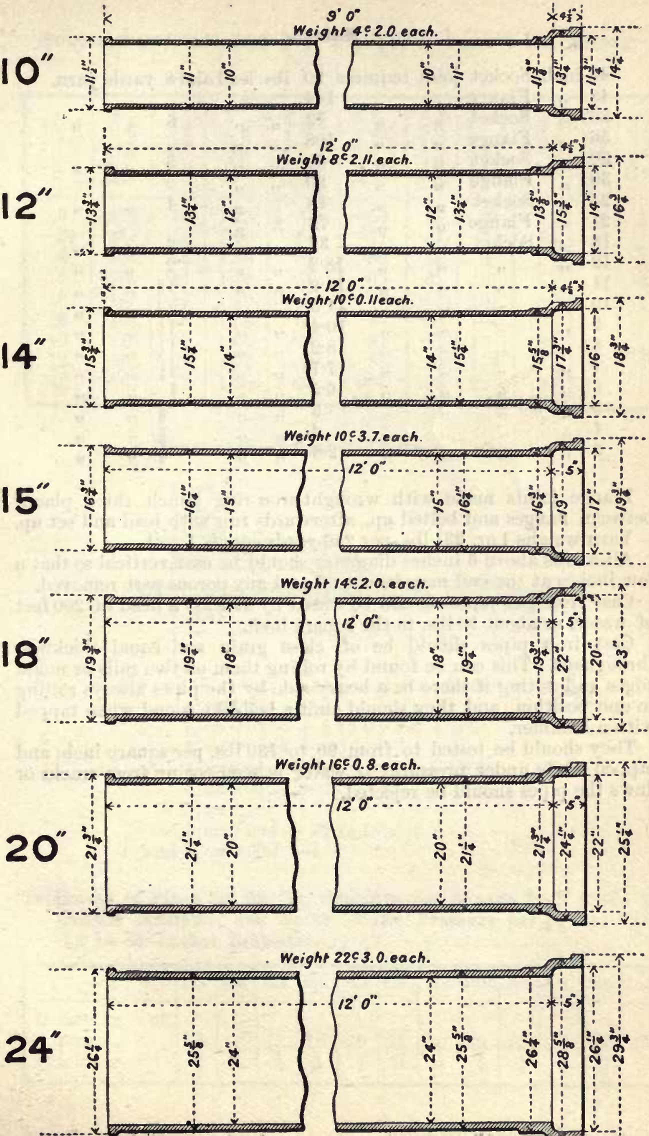
Inches.	Comparative Areas.
24 = 1·00	1·00
12 = 0·17	0·25
10 = 0·10	0·175
8 = 0·06	0·111
7 = 0·04	0·085
6 = 0·03	0·0625
5 = 0·0189	0·0434
4½ = 0·0141	0·0351
4 = 0·0102	0·0278
3½ = 0·0069	0·0212
3 = 0·0045	0·0156
2½ = 0·002835	0·0108
2 = 0·001485	0·0069
1½ = 0·000810	0·0039
1¼ = 0·000450	0·00272
1 = 0·000225	0·00173

Weight and Depth of Lead in Pounds for Ordinary Lead Joints.

Diameter of Pipe.	Weight of Lead.	Depth of Lead.	Diameter of Pipe.	Weight of Lead.	Depth of Lead.
Inches.	Lbs.	Inches.	Inches.	Lbs.	Inches.
2	1¾	1½	12	18½	2⅜
3	2¾	1⅝	13	21	2⅜
4	4	1¾	14	23½	2⅜
5	5½	1⅞	15	26	2½
6	7	2	16	28½	2½
7	8¾	2	17	31	2½
8	10½	2⅛	18	32½	2⅝
9	12½	2⅛	19	34	2⅝
10	14½	2¼	20	35½	2⅝
11	16½	2¼	24	48	3

For pipes up to 8 inches in diameter the lead is taken at ⅜ inch thick, and for pipes from 9 inches diameter upwards the lead is taken at ½ inch thick.


2"
6' 0"
Weight 50 lbs. each.
3"
9' 0"
Weight 120 lbs. each.
4"
9' 0"
Weight 1C 2.7. each.
5"
9' 0"
Weight 2C 0.0. each.
6"
9' 0"
Weight 2C 2.0 each.
7"
9' 0"
Weight 3C 0.0. each.
8"
9' 0"
Weight 3C 2.0. each.
9"
9' 0"
Weight 4C 0.0. each.


10"
9' 0"
Weight 4c 2.0. each.
12"
12' 0"
Weight 8c 2.11. each.
14"
12' 0"
Weight 10c 0.11 each.
15"
Weight 10c 3.7. each.
12' 0"
18"
Weight 14c 2.0. each.
12' 0"
20"
Weight 16c 0.8. each.
12' 0"
24"
Weight 22c 3.0. each.
12' 0"

Mains.

48-inch	Socket	joint	requires	90	lbs.	lead and	8	yards	yarn.
48 ,,	Flange	,,	,,	144	,,	,,			
36 ,,	Socket	,,	,,	72	,,	,,	6	,,	,,
36 ,,	Flange	,,	,,	108	,,	,,			
30 ,,	Socket	,,	,,	60	,,	,,	5	,,	,,
30 ,,	Flange	,,	,,	90	,,	,,			
24 ,,	Socket	,,	,,	48	,,	,,	4	,,	,,
24 ,,	Flange	,,	,,	72	,,	,,			
18 ,,	Socket	,,	,,	32	,,	,,	3	,,	,,
12 ,,	,,	,,	,,	18·2	,,	,,	2	,,	,,
11 ,,	,,	,,	,,	14·9	,,	,,	$1\frac{5}{6}$	,,	,,
10 ,,	,,	,,	,,	11·5	,,	,,	$1\frac{2}{3}$	,,	,,
9 ,,	,,	,,	,,	10·4	,,	,,	$1\frac{1}{2}$	,,	,,
8 ,,	,,	,,	,,	8·2	,,	,,	$1\frac{1}{3}$	,,	,,
7 ,,	,,	,,	,,	7·7	,,	,,	$1\frac{1}{6}$	,,	,,
6 ,,	,,	,,	,,	6·5	,,	,,	1	,,	,,
5 ,,	,,	,,	,,	5	,,	,,	$\frac{5}{6}$	,,	,,
4 ,,	,,	,,	,,	4	,,	,,	$\frac{2}{3}$	,,	,,
3 ,,	,,	,,	,,	2·6	,,	,,	$\frac{1}{2}$	,,	,,

Flange joints made with wrought-iron ring $\frac{1}{2}$-inch thick placed between flanges and bolted up, afterwards run with lead and set up.

Yarn weighs 1 qr. $23\frac{1}{2}$ lbs. per 250 yards equals 1 coil.

All mains above 6 inches diameter should be cast vertical so that a few inches at the end may be cut off and any porous part removed.

Cast iron gas pipes should be tested by at least a head of 200 feet of water, or about 90 lbs. to the square inch.

Cast iron pipes should be of close grain and equal thickness throughout. This can be found by rolling them on two rails or metal edges and noting if there be a heavy side by the pipes always rolling to one position, and they should emit a bell-like sound when tapped with a hammer.

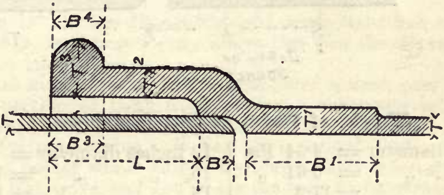
They should be tested to from 90 to 130 lbs. per square inch, and tapped while under pressure; if water is seen oozing from cracks or flaws the pipes should be rejected.

Dimensions of Cast Iron Pipe Flanges to bear 75 lbs. Pressure.

(Briggs.)

Internal Diameter of Pipe.	Thickness of Body.	Thickness of Boss.	Length of Boss.	Thickness of Flange Finished.	Thickness of Flange Rough.	Diameter of Bolt Holes.	Outside Diameter of Flange.	Diameter of Bolts Inside.	Number of Bolts	Diameter of Bolts.
3	·328	·40	1·25	·50	·56	·55	$6\frac{1}{2}$	$5\frac{1}{4}$	4	$\frac{1}{2}$
$3\frac{1}{2}$	·341	·42	1·28	·51	·57	·61	$7\frac{1}{4}$	$5\frac{9}{10}$	4	$\frac{9}{16}$
4	·354	.43	1·30	·53	·59	·61	8	$6\frac{7}{16}$	5	$\frac{9}{16}$
5	·380	·46	1·35	·56	·63	·61	9	$7\frac{1}{2}$	6	$\frac{9}{16}$
6	·406	·49	1·40	·60	·67	·68	$10\frac{1}{4}$	$8\frac{11}{16}$	6	$\frac{5}{8}$
8	·458	·55	1·50	·66	·74	·68	$12\frac{1}{2}$	$10\frac{8}{10}$	8	$\frac{5}{8}$
10	·510	·61	1·60	·73	·81	·81	15	$13\frac{3}{16}$	10	$\frac{3}{4}$
12	·563	·67	1·70	·80	·89	·93	$17\frac{3}{4}$	$15\frac{9}{16}$	10	$\frac{7}{8}$
16	·667	·79	1·90	·93	1·01	·93	22	$19\frac{8}{10}$	14	$\frac{7}{8}$

Dimensions of Socket Joints. (Unwin.)



Where t = thickness of pipe and d = diameter of pipe.

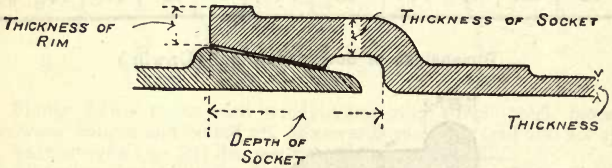
$$t^1 = 1{\cdot}07t + \tfrac{1}{16}$$
$$t_2 = 0{\cdot}025d + \tfrac{1}{4} \text{ to } 0{\cdot}025d + 0{\cdot}6$$
$$t_3 = 0{\cdot}045d + 0{\cdot}8$$
$$s = 0{\cdot}01d + {\cdot}25 \text{ to } 0{\cdot}01d + {\cdot}375$$
$$b_1 = 0{\cdot}075d + 2\tfrac{1}{4}$$
$$b_2 = t_2$$
$$l = 0{\cdot}09d + 2\tfrac{3}{4} \text{ to } 0{\cdot}1d + 3$$
$$b_3 \text{ and } b_4 = 0{\cdot}03d + 1$$

Thickness of Pipes for 90 lbs. Pressure per Square Inch up to 20 Inches Diameter, and up to 75 lbs. Pressure per Square Inch up to 60 Inches Diameter.

	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
Diameter of Pipe . .	4	8	12	16	20	24	30	36	42	48	54	60
Thickness . .	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	1

Dimensions of Turned and Bored Pipes in Inches.

Diameter of Pipe.	Thickness.	Depth of Socket.	Thickness of Rim.	Thickness of Socket.	Diameter of Pipe.	Thickness.	Depth of Socket.	Thickness of Rim.	Thickness of Socket.
Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
2	$\frac{5}{16}$	3	$\frac{7}{8}$	$\frac{1}{2}$	11	$\frac{9}{16}$	$4\frac{1}{2}$	$1\frac{13}{16}$	$\frac{15}{16}$
3	$\frac{3}{8}$	$3\frac{3}{4}$	1	$\frac{5}{8}$	12	$\frac{9}{16}$	$4\frac{1}{2}$	$1\frac{13}{16}$	$\frac{15}{16}$
4	$\frac{7}{16}$	4	$1\frac{1}{4}$	$\frac{11}{16}$	13	$\frac{19}{32}$	$4\frac{1}{2}$	$1\frac{7}{8}$	$\frac{15}{16}$
5	$\frac{7}{16}$	4	$1\frac{3}{8}$	$\frac{11}{16}$	14	$\frac{19}{32}$	$4\frac{1}{2}$	$1\frac{7}{8}$	$\frac{15}{16}$
6	$\frac{1}{2}$	$4\frac{1}{2}$	$1\frac{1}{2}$	$\frac{3}{4}$	15	$\frac{19}{32}$	5	2	1
7	$\frac{1}{2}$	$4\frac{1}{2}$	$1\frac{9}{16}$	$\frac{3}{4}$	16	$\frac{5}{8}$	5	2	1
8	$\frac{1}{2}$	$4\frac{1}{2}$	$1\frac{5}{8}$	$\frac{13}{16}$	17	$\frac{5}{8}$	$5\frac{1}{4}$	$2\frac{1}{8}$	$1\frac{1}{16}$
9	$\frac{1}{2}$	$4\frac{1}{2}$	$1\frac{11}{16}$	$\frac{7}{8}$	18	$\frac{11}{16}$	$5\frac{1}{4}$	$2\frac{1}{8}$	$1\frac{1}{16}$
10	$\frac{1}{2}$	$4\frac{1}{2}$	$1\frac{3}{4}$	$\frac{7}{8}$	20	$\frac{11}{16}$	$5\frac{1}{4}$	$2\frac{1}{4}$	$1\frac{1}{8}$



Weight of Socket of Cast Iron Pipes.

2 inches diameter	= 4·54 lbs.	12 inches diameter	= 90·54 lbs.
$2\frac{1}{2}$ " "	= 6·64 "	15 " "	= 112·36 "
3 " "	= 11·2 "	18 " "	= 147·64 "
4 " "	= 14·45 "	20 " "	= 179·0 "
5 " "	= 21·0 "	21 " "	= 188·0 "
6 " "	= 24·8 "	24 " "	= 250·0 "
7 " "	= 33·0 "	30 " "	= 346·0 "
8 " "	= 37·36 "	36 " "	= 480·0 "
9 " "	= 41·7 "	42 " "	= 589·0 "
10 " "	= 52·36 "	48 " "	= 707·0 "
11 " "	= 57·27 "		

Weight of socket equals ·9 foot of pipe.

Weight of socket turned and bored and thickened spigot equal to 1·1 feet of pipe.

Weight of flange equals 1 foot of pipe.

	Depth of Socket.	Jointing Space.
2 inches and 3 inches diameter	3 inches	$\frac{3}{8}$ inch
4 " to 8 " "	4 "	$\frac{3}{8}$ "
9 " " 20 " "	$4\frac{1}{2}$ "	$\frac{1}{2}$ "
21 " " 30 " "	5 "	$\frac{1}{2}$ "
Above " " "	6 "	$\frac{1}{2}$ "

To Test Mains in District.

The portion of main to be tested must be isolated by bagging or water-logging, and a pressure put upon it by a motive power meter or small holder. The quantity of gas or air required to keep up the initial pressure equals the loss through leakage.

Coating for Pipes.

A composition of Burgundy pitch, oil, resin, and gas tar is made up in a bath, into which the pipes are lowered, where they remain until they attain the heat of this composition, which is about 142° F. They are then taken out and placed in such a position as to allow all unnecessary matter to run off.

To find the force tending to dive off a bend on a line of pipes subjected to internal pressure. The resultant force in the straight pipe on either side of the bend being equal to the area, A, of the pipe, × the intensity, p, of the pressure, and acting axially. The resultant of these two forces is $A \times p \times 2 \sin. \frac{\theta}{2}$ where θ is the angle subtended by the bend.

Pipes up to 9 inches diameter should never have less than 1 foot 9 inches of ground above them ; above this size the depth should be increased at least 6 inches.

Pipes laid in clinkers and ashes will, after a time, part with a considerable portion of their iron, leaving a substance which can be easily scraped with a penknife. Clay, however, forms a most excellent soil for pipe laying. It has been noticed that gas pipes are attacked at points where electricity leaves them when in proximity to electric tramways, and not where the current penetrates them.

Pipes with rough interior surface have been known to reduce delivery of liquids 33 per cent. from that delivered when smooth. (Fitzgerald.)

Never drill a larger hole than ½ inch in a 2-inch main. Never drill a larger hole than 1 inch in a 3-inch main.

In small mains a ¾-inch bend may be fixed to a reducing socket and a 1-inch service carried from that without materially reducing the quantity of gas which may be passed, and at the same time this method renders a small main less liable to leak.

Allow a fall of 3 inches per 100 yards in street mains ; or better, mains should have a fall of about 1 inch in 20 yards as a minimum.

Lay mains with a fall of not less than ⅛ to ¼ inch to every 9 feet length.

Where pipes have to be carried across exposed positions, as when they are slung or fixed outside bridges, &c., they should be covered with felt or other non-conducting material.

Sleepers may be used with advantage under mains when laying in bad and soft ground.

The ground should be well consolidated under mains to prevent subsequent uneven settlement.

To find a leak try with a pricking bar near each socket, and to the full depth of the bottom of the main; and if gas be present, even in a very small quantity, it will burn with a more or less blue light.

A broken pipe may be temporarily bandaged with stout calico well plastered with white and red lead, until a new pipe can be laid.

When lead pipes are used for services they must be supported their entire length, to prevent sagging and subsequent accumulation of water and stoppage of supply.

Service pipes may be made to last longer by receiving one or two coats of good oxide paint or hot tar.

It is better to use soap and water (soft soap is best) than to employ a light to try if a joint in a main be tight or no.

Millboard joints should be well soaked in water and painted both sides with red and white lead.

Gas valves should stand 5 lbs. pressure on side opposite springs.

One or more trunk mains should always come from the works and terminate at central points, whence the distributing pipes may start.

A piece of tallow in the "gate" of the joint when running with lead prevents blowing even if the yarn or pipe be wet.

If too much lead is left on the outside of a joint the caulking up may split the socket.

The yarn should not occupy more than half the depth of the socket when driven hard in with the tool.

Ordinary putty may be used instead of lead for temporary joints after the yarn is well rammed in.

It is the return currents of electricity which are responsible for the electrolytic action; and it seems to have the same effect on galvanised, tar coated, or so-called "rustless" pipes.

Cement for the Repair of Leaks in Gas and Other Pipes.

To 5 parts of Paris white add 5 parts of yellow ochre, 10 parts of litharge, 5 parts of red lead, and 4 parts of black oxide of manganese. The constituents should be well mixed and a small quantity of asbestos and boiled oil added. The cement hardens in from two to five hours after application to the leaks, and exposes no fresh holes on drying. As the use of the cement does not involve the removal of the pipes it is especially adapted for the repair of those which are difficult to get at.

In South Boston, U.S.A., all mains are laid with cement joints, made by using two hard-twisted rolls of lath-yarn, and a mixture of 2 parts of common cement, one part Portland cement, and one part sand.

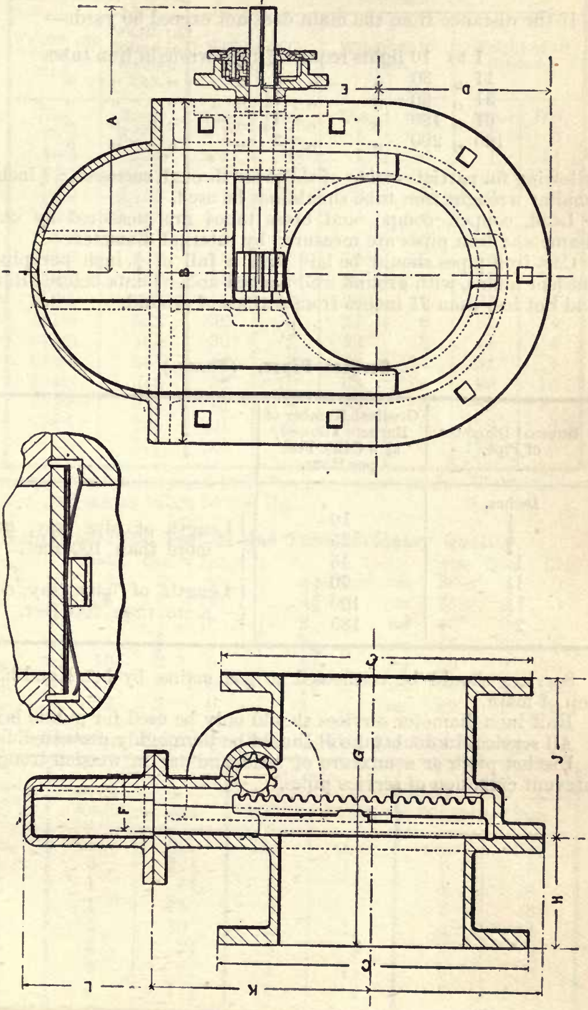
Turned and bored pipes are cheaper to lay, but do not allow of any settlement, and consequently break easier than the open lead joint.

Dimensions of Rack and Pinion Gas Valves.

Diameter of Valve.	Diameter of Flanges.		Diameter of Circle through centre of Bolt Holes.		Length from face to face of Flanges.		Number of Bolts.		Diameter of Bolt Holes.	
	Scotch.	English.	Scotch.	English.	Scotch.	English.	Scotch.	English.	Scotch.	English.
Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
2	6½	6½	5⅛	5⅛	8½	8½	4	4	⅝	⅝
3	8	8½	6	6½	10½	10¼	4	4	⅝	¾
4	9½	10	7½	8	11½	11½	4	4	⅝	¾
5	10½	10½	8½	9	11¾	11½	4	4	⅝	¾
6	12	12	9½	10	11¾	11¾	4	4	⅝	¾
7	13	14½	10½	12	12	11¾	6	6	¾	1
8	14	15½	12	13	12½	12¼	6	6	¾	1
9	15	17	13	14½	13	13½	6	6	¾	1
10	16	18	14	15½	13½	13¾	6	6	¾	1
12	19	20½	16½	17	16	16	6	6	¾	1⅛
14	21	22	18½	19	17	16¼	6	6	⅞	1¼
15	22	23	19½	20	18	17	6	6	⅞	1¼
16	23	24½	20½	21	18½	18	8	6	⅞	1¼
18	26	26½	23½	23	20	18	8	6	⅞	1¼
20	28	29	25½	25	20½	20	8	8	⅞	1¼
21	29	30	26½	26½	20½	20	10	8	⅞	1¼
22	30	31	27½	27	20½	20	10	8	⅞	1¼
24	32	33	29½	29½	20½	20	10	8	⅞	1¼
26	35	35	32½	32½	21	20	10	8	⅞	1¼
27	36	36	33½	32½	21½	20	10	8	⅞	1¼
30	38	39	35½	35½	22½	22	12	10	⅞	1¼
36	45	46	42½	42½	23	23	14	12	1	1¼
48	57	58	54	54½	31	31	16	16	1	1¼

Dimensions of Rack and Pinion Gas Valves (Alley & MacLellan, Glasgow).

Size of Valve.	A	B	C	D	E	F	G	H	J	K	L	Size of Valve.
Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
2	$9\frac{3}{8}$	$6\frac{1}{4}$	$6\frac{1}{2}$	$3\frac{1}{8}$	$1\frac{3}{4}$	$1\frac{7}{8}$	$8\frac{1}{2}$	$3\frac{3}{8}$	$5\frac{1}{8}$	$3\frac{3}{4}$	2	2
3	$10\frac{1}{8}$	$7\frac{1}{8}$	8	$3\frac{9}{16}$	$2\frac{9}{16}$	2	$10\frac{1}{2}$	$4\frac{1}{4}$	$6\frac{1}{4}$	$4\frac{3}{4}$	$2\frac{3}{8}$	3
4	$10\frac{3}{4}$	$8\frac{3}{4}$	$9\frac{1}{2}$	$4\frac{3}{8}$	$3\frac{3}{16}$	$2\frac{1}{2}$	$11\frac{1}{2}$	5	$6\frac{1}{2}$	$5\frac{3}{8}$	$3\frac{1}{2}$	4
5	$11\frac{3}{8}$	$9\frac{7}{8}$	$10\frac{1}{2}$	$4\frac{15}{16}$	$3\frac{9}{16}$	$2\frac{1}{4}$	$11\frac{3}{4}$	$5\frac{3}{8}$	$6\frac{3}{8}$	$6\frac{3}{8}$	$4\frac{5}{16}$	5
6	$13\frac{1}{2}$	$11\frac{3}{8}$	12	$5\frac{11}{16}$	$4\frac{1}{2}$	$2\frac{1}{2}$	$11\frac{3}{4}$	$4\frac{7}{8}$	$6\frac{7}{8}$	9	$3\frac{1}{4}$	6
7	14	$12\frac{3}{8}$	13	$6\frac{3}{16}$	$4\frac{15}{16}$	$2\frac{1}{2}$	12	5	7	$9\frac{3}{8}$	$4\frac{1}{8}$	7
8	$14\frac{3}{4}$	$14\frac{3}{4}$	14	$7\frac{3}{8}$	$4\frac{1}{2}$	$2\frac{13}{16}$	$12\frac{1}{2}$	$4\frac{1}{8}$	$8\frac{3}{8}$	$9\frac{3}{8}$	$5\frac{9}{16}$	8
9	$15\frac{1}{4}$	16	15	8	$5\frac{3}{4}$	$2\frac{13}{16}$	13	$5\frac{3}{8}$	$7\frac{5}{8}$	$10\frac{5}{8}$	$6\frac{5}{16}$	9
10	$16\frac{1}{2}$	$17\frac{1}{2}$	16	$8\frac{3}{4}$	$6\frac{1}{2}$	$2\frac{13}{16}$	$13\frac{1}{2}$	$5\frac{1}{2}$	8	$11\frac{7}{8}$	$7\frac{1}{2}$	10
12	$17\frac{3}{4}$	$19\frac{1}{2}$	19	$9\frac{3}{4}$	8	$3\frac{3}{4}$	$16\frac{1}{4}$	$7\frac{1}{8}$	$9\frac{1}{8}$	14	$9\frac{1}{2}$	12
14	18	$22\frac{5}{8}$	21	$11\frac{5}{16}$	$11\frac{1}{8}$	$5\frac{1}{8}$	17	$4\frac{3}{4}$	$12\frac{1}{4}$	$19\frac{1}{2}$	$9\frac{1}{2}$	14
15	$18\frac{1}{2}$	$23\frac{5}{8}$	22	$11\frac{13}{16}$	$11\frac{5}{8}$	$5\frac{1}{8}$	18	$5\frac{1}{4}$	$12\frac{3}{4}$	$20\frac{3}{4}$	$9\frac{9}{16}$	15
16	$19\frac{1}{4}$	25	23	$12\frac{1}{2}$	12	$5\frac{1}{2}$	$18\frac{1}{2}$	$5\frac{1}{4}$	$13\frac{1}{4}$	$22\frac{1}{2}$	$10\frac{1}{2}$	16
18	$20\frac{3}{8}$	$27\frac{3}{8}$	26	$13\frac{11}{16}$	$13\frac{5}{8}$	$5\frac{1}{2}$	20	6	14	$24\frac{3}{8}$	$11\frac{1}{2}$	18
20	$21\frac{1}{2}$	$29\frac{3}{4}$	28	$14\frac{7}{8}$	$14\frac{3}{4}$	$5\frac{1}{2}$	$20\frac{1}{2}$	$6\frac{1}{2}$	14	$27\frac{1}{2}$	$12\frac{5}{16}$	20
21												21
22	$22\frac{1}{2}$	32	30	16	$15\frac{3}{4}$	$5\frac{1}{2}$	$20\frac{1}{2}$	$6\frac{1}{2}$	14	$29\frac{5}{8}$	$13\frac{5}{16}$	22
24	32	34	32	17	$17\frac{3}{8}$	6	$20\frac{1}{2}$	$6\frac{1}{2}$	14	$31\frac{1}{2}$	$14\frac{7}{8}$	24
26												26
27												27
30	31	$41\frac{1}{2}$	38	$20\frac{3}{4}$	$20\frac{1}{2}$	$6\frac{3}{8}$	$22\frac{1}{2}$	$7\frac{3}{4}$	$14\frac{3}{4}$	$37\frac{1}{2}$	$18\frac{1}{2}$	30
36	34	$47\frac{1}{2}$	45	$23\frac{3}{4}$	$23\frac{3}{8}$	$6\frac{3}{8}$	23	8	15	44	$21\frac{1}{2}$	36



Rack and Pinion Gas Valves.

Service Pipes.

If the distance from the main does not exceed 30 yards—

1 to 10	lights require	$\frac{3}{4}$	inch wrought iron tube.
11 " 30	" "	1	" " " "
31 " 60	" "	$1\frac{1}{4}$	" " " "
61 " 120	" "	$1\frac{1}{2}$	" " " "
120 " 200	" "	2	" " " "

Allowing for partial closing of the pipes through corrosion; $\frac{1}{2}$ inch and smaller wrought iron tube should not be used.

Lead, copper, compo. and brass tubes are measured by outside diameter; iron pipes are measured by internal diameter.

Cast iron pipes should be laid with a fall of $\frac{1}{4}$ inch per pipe for outdoor mains, with ground well packed under joints before filling in, and not less than 21 inches from surface of ground.

Service Pipes. (Shaw.)

Internal Diameter of Pipe.	Greatest Number of Burners allowed, at 5 Cubic Feet per Hour.	
Inches.		
$\frac{1}{2}$	10	Length of pipe, say, not more than 100 feet.
$\frac{3}{4}$	25	
1	45	
$1\frac{1}{4}$	70	Length of pipe, say, not more than 200 feet.
$1\frac{1}{2}$	100	
2	185	

Services should be connected to gas mains by bend and hole in top of main.

Half inch diameter services should only be used for public lamps.

All services in doubtful soil should be thoroughly protected.

Use hot pitch or a mixture of sand and tar in wooden troughs to prevent corrosion of service pipes.

Average Weight of Butt-welded Gas Tubes and Fittings.

Bore.	Tubes (length = 14 ft.)		Fittings.					
	Weight per 100 Feet Run.	Length required to weigh 1 Ton.	Weight of 10 Elbows.		Weight of 10 Tees.		Weight of 10 Crosses.	
Inches.	Lbs.	Feet.	Lbs.	Ozs.	Lbs.	Ozs.	Lbs.	Ozs.
⅛	26·3	8,502	1	1	1	0	1	8
¼	40·5	5,532	1	7	1	8	1	14
⅜	57·5	3,892	1	13	2	4	2	3
½	82·9	2,700	2	15	3	0	3	4
¾	122·0	1,836	4	6	5	4	5	11
1	174·9	1,281	6	4	7	10	9	2
1¼	244·3	917	10	10	12	15	14	11
1½	310·2	722	15	8	16	7	18	10
1¾	359·5	623	15	12	20	0	21	4
2	421·0	532	22	6	27	0	31	4
2¼	515·0	435	30	2	32	8	41	4
2½	610·4	367	46	2	50	15	51	4
2¾	658·8	340	55	10	68	8	80	10
3	759·3	295	73	8	85	5	88	12
3½	878·4	255	101	0	121	0	129	0
4	1,032·3	217	126	0	144	0	158	0

Gas tubes are usually tested to 50 lbs. per square inch. Water tubes to 300 lbs., and steam tubes to 500 lbs.

Weight of 1,000 Feet of Gas Tube, Ordinary Quality.

		Cwts.	Qrs.	Lbs.			Cwts.	Qrs.	Lbs.
⅛ inch	=	2	2	0	1½ inch	=	26	2	0
¼ "	=	3	2	18	1¾ "	=	35	0	0
⅜ "	=	5	1	18	2 "	=	40	0	4
½ "	=	7	3	2	2¼ "	=	47	2	0
¾ "	=	10	2	0	2½ "	=	59	2	16
1 "	=	16	0	0	2¾ "	=	74	3	26
1¼ "	=	22	2	0	3 "	=	82	1	26

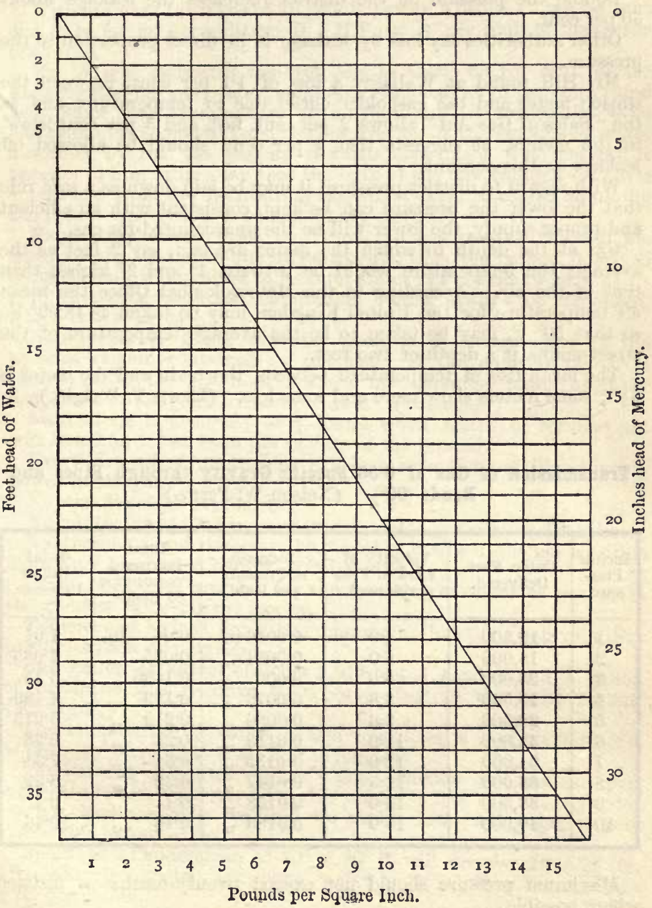
Table Showing Weight per Foot of Wrought Iron Tubing.

Internal Diameter.	Gas.		Water.		Steam.	
	Weight per Foot.		Weight per Foot.		Weight per Foot.	
Inches.	Lbs.	Ozs.	Lbs.	Ozs.	Lbs.	Ozs.
½	0	14½	0	15	0	15½
¾	1	5½	1	7½	1	8
1	1	15	2	1	2	3¾
1¼	2	10	2	14	3	4
1½	3	2½	3	9	4	0
2	4	6½	4	14	5	8
2½	5	10½	6	4	7	0

Whitworth Threads for Gas and Water Pipes.

Internal Diameter of Pipe.	External Diameter of Pipe.	Diameter at Bottom of Thread.	No. of Threads per Inch.	Internal Diameter of Pipe.	External Diameter of Pipe.	Diameter at Bottom of Thread.	No. of Threads per Inch.
Inches.	Inches.	Inches.		Inches.	Inches.	Inches.	
$\frac{1}{8}$	·3825	·3367	28	$1\frac{7}{8}$	2·245	2·1285	11
$\frac{1}{4}$	·518	·4506	19	2	2·347	2·2305	11
$\frac{3}{8}$	·6563	·589	19	$2\frac{1}{8}$	2·467	2·351	11
$\frac{1}{2}$	·8257	·7342	14	$2\frac{1}{4}$	2·5875	2·471	11
$\frac{5}{8}$	·9022	·8107	14	$2\frac{3}{8}$	2·794	2·678	11
$\frac{3}{4}$	1·041	·9495	14	$2\frac{1}{2}$	3·0013	2·882	11
$\frac{7}{8}$	1·189	1·0975	14	$2\frac{5}{8}$	3·124	3·009	11
1	1·309	1·1925	11	$2\frac{3}{4}$	3·247	3·1305	11
$1\frac{1}{8}$	1·492	1·3755	11	$2\frac{7}{8}$	3·367	3·251	11
$1\frac{1}{4}$	1·65	1·5335	11	3	3·485	3·3685	11
$1\frac{3}{8}$	1·745	1·6285	11	$3\frac{1}{4}$	3·6985	3·5815	11
$1\frac{1}{2}$	1·8825	1·705	11	$3\frac{1}{2}$	3·912	3·7955	11
$1\frac{5}{8}$	2·022	1·965	11	$3\frac{3}{4}$	4·1255	4·0085	11
$1\frac{3}{4}$	2·16	2·042	11	4	4·340	4·223	11

Comparison of Pressures in Inches of Mercury, Feet of Water, and Pounds per Square Inch.



30 lbs. pressure per square inch equals about a head of 70 feet, with a velocity of 66 feet per second. Therefore, area of pipe × feet per second equals discharge per second.

Double pressure equals 1½ times delivery.

Four times length of main equals ½ delivery.

Double the pressure on the district increases the leakage about 50 per cent.

Other authorities say loss by leakage is in direct proportion to the pressure.

Mr. Hill found at Wallasey a loss of 1·7 per cent. between the station meter and the gasholder outlet due to temperature, and as the "Sales of Gas Act" allows 2 per cent. fast, and 3 per cent. slow, in the meters, he suggests that ½ per cent. should be allowed off leakage on this account.

With regard to district pressures it may be laid down as a safe rule that the lower the pressure can be kept, consistent with an efficient and proper supply, the lower will be the unaccounted-for gas.

Gas at the depth to which the mains are laid, say 2 feet as the average, the temperature would be between 1° and 2° higher than that of the air. According to the Meteorological Office the mean air temperature for the United Kingdom may be taken as 48·69° F., so that 50° F. may be taken to be the average temperature of the street-mains at a depth of two feet.

The mean rise of temperature between the main and the meter is 6½°; some meters show more and some less. (Lewis T. Wright.)

Transmission of Gas of 0·55 Specific Gravity through Pipes and Bends (90°). (Nelson W. Perry.)

Inches Pressure.	Cubic Feet. Delivered.	Velocity of Flow in Feet per Second.	Increase of Pressure per Bend.	Total Increased Pressure for 25 Bends.	Total Initial Pressure.
1	12,500	4·0	0·0016 in.	0·04 in.	1·04
2	18,000	6·0	0·0034 "	0·085 "	2·085
3	23,000	8·0	0·006 "	0·1495 "	3·15
4	25,500	8·8	0·0076 "	0·189 "	4·189
5	28,000	9·6	0·0086 "	0·215 "	5·215
6	32,000	11·0	0·0113 "	0·28 "	6·28
7	34,000	12·0	0·0135 "	0·34 "	7·34
8	36,000	12·5	0·0147 "	0·39 "	8·39
9	38,500	13·0	0·0158 "	0·4 "	9·4
10	40,000	14·0	0·0183 "	0·46 "	10·46

Maximum pressure should not exceed twenty-tenths on district where possible.

1½ to 2 inches pressure at works may be sufficient if the distributing mains are of sufficient capacity, and the district fairly level.

Gas, after travelling ten miles, has been found to lose only about 3 per cent. in illuminating power.

It is far cheaper to transmit the coal by railroad, and generate electricity on the spot, than to generate it and transmit the current through wires.

With ordinary town gas of 16 candle power, 3,000 H.P. can be sent one mile for an expenditure of 1 H.P. = $\frac{1}{30}$ per cent. of the power conveyed.

Mr. Wright estimates the true loss as about 65 per cent. of the unaccounted-for gas; later, by another method, at 75 per cent.; and now, from such examinations of the results of the inferential as he has been able to make (from the observation of the amount of water absorbed by the gas passing through consumers' wet meters), it appears to him safe to say that the bulk of the unaccounted-for gas is actual loss from the distributing system, always, of course, assuming the meter registration to be reasonably correct.

Napthalene arises from the H of the gas passing through the main, by the action of the exosmose, and thus the carbon, deprived of its diluent, is deposited in its solid state. (Dr. Frankland.)

If this were the case napthalene would always be deposited, which is not the case.

Napthalene is found wherever there is a condensation of the aqueous vapour contained in the gas. If the aqueous vapour is removed from the gas, napthalene is not deposited under ordinary conditions of temperature and pressure. (Brémond.)

Napthalene is generally only found when mains or services are laid less than 1 foot from the surface of the ground.

Every deposit of napthalene equals a reduction of illuminating power in the gas.

Naptha dissolves napthalene.

No napthalene found in mains since water gas used at Blackburn.

Napthalene is not likely to be found in mains if the gas contains more than 2 per cent. benzol. (Col. Sadler.)

Of all enrichers, benzene, for the average consumer of gas, gives the greatest value for the money.

Toluene and xylene are better enrichers; but their non-volatility precludes their employment.

One gallon of benzol enriches 9,500 feet 1 candle, and 1 gallon of carburine will improve 2,800 cubic feet to the same extent. (Mr. Hunt.)

The temperature at which benzol volatilizes is a convenient one, as ordinary steam heat is all that is required.

The amount of benzol vapour which common coal gas can permanently retain, viz., over 50 grains per cubic foot at 0° C., is greater by far than anything required to enrich low-quality gas to any reasonable extent.

Benzol at a temperature of 70° to 80° C. will dissolve $2\frac{1}{2}$ to $2\frac{3}{4}$ lbs. of sulphur per gallon, but when cooled to 25° C. it will only retain $\frac{1}{4}$ lb. per gallon.

Between 7 and 9 grains of benzol vapour will improve 1 cubic foot of gas between 4 and 5 candles. (Dr. Bunte.)

The results of disillumined gas plus benzene are—

0·0221 gramme per litre gives	1·3 candles	
0·0385 ,, ,, ,, ,,	4·1 ,,	
0·0544 ,, ,, ,, ,,	7·6 ,,	
0·0630 ,, ,, ,, ,,	9·6 ,,	
0·0863 ,, ,, ,, ,,	21·0 ,,	
0·0881 ,, ,, ,, ,,	20·2 ,,	
0·1231 ,, ,, ,, ,,	30·0 ,,	(Irwin.)

Benzene gives about ·4 candles per gallon per 1,000 cubic feet.

	Gas enriched 1 Candle by 1 Gallon of the Liquid.
Benzol (chemically pure)	13,300 cubic feet.
Benzol (90°)	12,500 ,, ,,
Carburine (680 specific gravity) . . .	5,700 ,, ,,
Common petroleum spirit (700 specific gravity)	4,300 ,, ,,

In an enricher a carbon atom combined with H_4 or H_3 is useless; a carbon atom combined with H_2 possesses enriching power; a carbon atom combined with H_1 possesses two or three times the enriching power of the foregoing; and a carbon atom combined only with other carbon atoms again possesses two or three times the enriching power of a carbon atom combined with H. (W. Irwin.)

By admitting alcohol vapour, in regulated amount, to the gas main, the illuminating power of the gas is unaffected thereby, though the freezing-up of the services is prevented. The alcohol is vaporized by steam or direct heating just before admission to the main, and the quantity is regulated according to the amount of gas passing per hour and the prevailing degree of cold. (Dr. J. Buel.)

Disillumined Gas and Heptane (prepared by Fractionating Petroleum Spirit).

0·0528 gramme per litre gives	2·15 candles.
0·1010 ,, ,, ,,	6·35 ,,
0·1516 ,, ,, ,,	11·10 ,,

Napthalene is the cheapest and greatest enricher, but it cannot be supplied with gas from the gas-works because of its non-volatility. It could, however, be used for the street lamps with a carburetting apparatus, which would give 50 per cent. more light for a mere fraction. Were separate mains employed and water gas used in connection with napthalene, the cost of street lighting would be reduced to a minimum. (W. Irwin.)

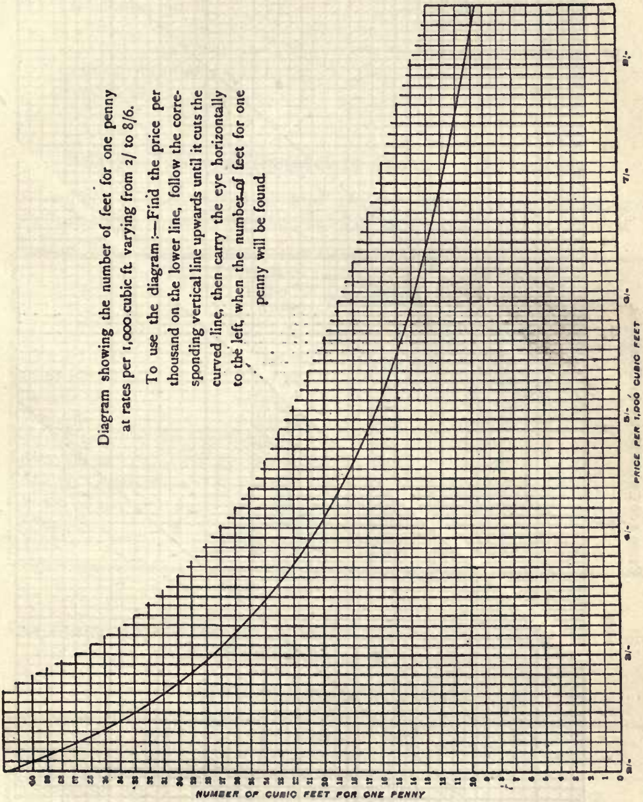
In napthalene not more than 44 per cent. of the weight added to the gas is really utilized in emitting light.

The napthalene in the gas in street mains may be held in suspension, by admitting gasolene into the main outlet pipe leading from the works to the street main system, by reason of its greater affinity for it than moisture has.

Napthalene melts at 174° F. and boils at 428° F.

Diagram showing the number of feet for one penny at rates per 1,000 cubic ft. varying from 2/ to 8/6.

To use the diagram:—Find the price per thousand on the lower line, follow the corresponding vertical line upwards until it cuts the curved line, then carry the eye horizontally to the left, when the number of feet for one penny will be found.



Comparison of Prices of Gas in Sterling and French Monies.

Price per 1,000 Cubic Feet.

Price per 1,000 Cubic Feet in Shillings and Pence.

Service Yielded by Ordinary Burners Consuming 16·5 Candle Gas.

(Professor Lewes, June, 1893.)

Burners.	Illuminating Value per Cubic Foot of Gas.
Flat flame No. 6	2·5 candles.
" " " 5	2·1 "
" " " 4	1·9 "
London Argand	3·3 "
Regenerative	10·0 "

Relative Values of Illuminating Agents. (Dr. Letheby.)

In respect to their vitiating and heating effects on the atmosphere, when burning so as to give the light of 12 standard sperm candles.

	Thermal Units of Heat.	Oxygen Consumed.	Carbonic Acid Produced.	Air Vitiated.
		Cubic Feet.	Cubic Feet.	Cubic Feet.
Cannel Gas	1·950	3·30	2·01	50·2
Common Gas	2·786	5·45	3·21	80·2
Sperm Oil	2·325	4·75	3·33	83·3
Benzol	2·326	4·46	3·54	88·5
Paraffin	3·619	6·81	4·50	112·5
Camphine	3·251	6·65	4·77	119·2
Sperm Candles	3·517	7·57	5·27	131·7
Wax "	3·831	8·41	5·90	149·5
Stearic "	3·747	8·82	6·25	156·2
Tallow "	5·034	12·06	8·73	218·3

Gas Consumed and Carbon Dioxide Produced per Hour to Yield an Illumination of 48 Candles.

(Professor Lewes, June, 1893.)

	Gas Consumed.	CO_2 Produced.	No. of Adults to Produce CO_2
Flat flame No. 6	19·2	10·1	16·8
" " " 5	22·9	12·1	20·1
" " " 4	25·3	13·4	22·3
London Argand	15·0	7·9	13·1
Regenerative	4·8	2·5	4·1
Paraffin Lamps	—	13·5	22·5
Candles, sperm	—	19·62	32·7

Duty in Candles of Various Burners at 5 feet per Hour.

(J. H. Cox, Junior.)

	Duty in Candles.
Standard Argand	16
Public lamps, average	13½
Good batswing after 1 year's use, rather dirty	10
Good batswing after being cleaned	13¼
Iron batswing, corroded and old	7¼
Iron fishtail, corroded and old	8¼
Iron batswing, corroded and old	6
Iron batswing, corroded and old	3¾
Wasteful Argand	5½
Peebles' 5 feet regulator burner	14¼
Bray's No. 8 flat flame burner	14
Borrowdail's governor burner.	13¾
Sugg's Christiania burner	14
A good unregulated burner under unnecessary pressure	8
Same burner regulated	12½
Number 1 Argand, at 5 cubic feet per hour	16
Number 1 Argand turned down to 3 cubic feet	8
Wenham lamp ground glass shade, at 45°	22
Average of above 18 burners	11½

Other Illuminants under Best Conditions. (J. H. Cox, Junior.)

In candles per 1*d*.

Electricity (incandescent), at ¼*d*. per hour per 8 candle lamp	3¼
Candles—Palmatine candles 6 to 1 lb., at 10*d*. per pound, 9 inches long burning 1 inch per hour. Illuminating power corrected to 120 grains per hour, 1¼ standard candles	⅔
Oil—Petroleum burnt under best conditions in a 20 candle duplex lamp (oil at 1*s*. per gallon)	9⅓

Burners when lighted use less gas than when turned on and not lighted; a No. 3 burner lighted consumes 3 cubic feet, unlighted 3½ cubic feet per hour.

Effects of different pressures on a No. 4 union jet burner:—

Pressure in inches	0·5	1·0	1·5	2·0	2·5	3·0
Consumption, cubic feet	3·9	5·6	7·0	8·45	9·6	10·5
Unit efficiency, candles	3·0	2·4	1·9	1·5	1·35	1·11

Carbon and Hydrogen Escaping Unconsumed per 100 parts C., Completely Burned. (W. Thomson, 1890.)

	Carbon.	Hydrogen.
Petroleum lamp, not burning at the full .	—	—
" " with flame turned full on	1·204	0·309
Argand gas flame	—	0·025
" "	0·011	0·254
Bray burner, consuming 4 cubic feet per hour	1·112	0·095
Welsbach burner	1·5	0·379
Marsh-Greenall's heating-stove burning :		
5·62 cubic feet per hour	1·26	0·3
5·74 " " "	3·76	1·18
7·10 " " "	9·74	1·21
Thos. Fletcher's heating stove :—		
with 8 Bunsen burners	4·33	2·46
burning 6·81 cubic feet per hour . .	6·63	2·0
with 20 Bunsen burners with asbestos and fire-clay back consuming 8·14 cubic feet per hour	13·89	1·17
Heating stove	20·0	—

	Vitiates per Hour.	Units of Heat Generated.
	Cubic Feet.	
An adult man	215	190
Each cubic foot of gas burned .	8·5	600
Each pound of oil burned . .	150	} 16,000
" " candles burned .	160	

Daylight on a well exposed table equals 4·6 foot candles.

Minimum required for reading without fatigue equals 1 candle at 1 foot.

Minimum required for fluent reading equals 1·4 to 2·3 candles at 1 foot.

Minimum required for street lighting equals 0·09 candles at 1 foot. (Cohn and Wybauw.)

The light from the edge of a petroleum lamp flame equals 62 to 63 per cent. of that from the flat side.

The reflective power of a whitewashed ceiling equals a loss of light of only 20 per cent. (H. E. Harrison.)

The intensity of illumination on a given surface is inversely as the square of the distance from the source of light.

The intensity of illumination which is received obliquely is proportional to the cosine of the angle which the luminous rays make with the normal to the illuminated surface.

Adults inhale about 1 pint of air at each breath and take 18 to 20 breaths a minute.

The heat evolved by a gas flame is the best of all ventilating mediums, provided a simple means is secured for conveying the products of combustion out of the room.

It is said that the injury done to books by gaslights is not due to the sulphur in the gas but by what is called carbon oxysulphide, condensing on any object a foot or so below the ceiling.

If a chimney is properly constructed it may be used for a ventilating flue, and be able to give a pull of one and half to two tenths of an inch vacuum, which is sufficient to convey away all the vitiated air from a room if the flue pipes are large enough.

Temperature of air in rooms should not be more than 10° higher at 1 foot from the ceiling than at 1 foot from the floor.

Two-tenths of an inch draught gives a velocity of air of about 6 feet per second.

Inflowing air should, if possible, be warmed to within 10° or 15° of the temperature of the room.

The rarer the atmosphere the larger the flame; the denser the atmosphere the smaller the flame.

When coal gas is burnt sulphur is liberated as sulphur dioxide, but this is not further oxidized to sulphuric acid (H_2SO_4) unless the temperature falls so greatly that water is deposited.

A certain amount of sulphurous acid is no doubt formed wherever gas is burnt, and this may, in the presence of moisture, be converted into sulphuric acid, but when ordinary ventilation is used, the amount must be very trifling.

Dust collected in rooms where no gas is burnt is found to contain an equal quantity of sulphates as that found in gas-lighted rooms.

No instance of imperfect combustion has been ever substantiated against lighting-burners, nor even against heating-burners of good class when employed under their normal working conditions. (L. T. Wright.)

CO_2 in gas has more effect on a flat flame than in an Argand in reducing the light, the depreciation being less the higher the candle power.

No trace of CO or acetylene was found in the products of combustion from Welsbach, Argand, and Bray burners. (*Lancet.*)

Two cubic feet H + 1 cubic foot O forms 2 cubic feet aqueous vapour.

By heating the air and gas before combustion, the carbon particles in the gas are liberated earlier and brought to a higher temperature, at the same time they are kept at this temperature for a longer period.

The burner tip should be of a non-conducting nature, as steatite, so as not to reduce the intensity of combustion.

In Argand burners the supply pipes to the ring are generally of smaller area than the sum of the areas of the holes in the latter so as to reduce the pressure at the point of consumption.

Angle at which the mean intensity of flat flame burners is obtained varies from 1·5° to 10·25°, average 4·68°. (A. C. Humphreys.)

Sizes of Internal Pipes, Lead and Iron, According to Number of Burners Required, as Allowed by Blackpool Corporation Gas Department.

Internal Diameter of Pipe.	Greatest Length Allowed.	Greatest No. of Burners.	Internal Diameter of Pipe.	Greatest Length Allowed.	Greatest No. of Burners.
Inches.	Feet.		Inches.	Feet.	
$\frac{3}{8}$	20	3	1	80	40
$\frac{1}{2}$	30	6	$1\frac{1}{4}$	100	60
$\frac{5}{8}$	40	12	$1\frac{1}{2}$	150	100
$\frac{3}{4}$	50	20	2	200	200

Light absorbed by clear glass globes . .	12 per cent.
„ „ „ „ engraved globes . .	24 „ „
„ „ „ globe of ordinary pattern .	35 „ „
„ „ „ „ obscured all over .	40 „ „
„ „ „ white opal globe . .	60 „ „
„ „ „ painted opal globe . .	64 „ „

Clear glass prevents 10·57 of the light from passing through it, ground glass stops 29·48, smooth opal glass over 52·83, and ground opal more, 55·85.

Formula for determining the height of lamps for a known radius of lighting—

$$h = l \sqrt{2} = 0{\cdot}7\, l$$

The proper height of any light should be 0·7 of the area to be lighted by any one light. (Electrical Committee Chicago Exhibition.)

The proper height of any light should be such as to give an angle of 7° to the most distant point it is intended to serve. (Professor H. Robinson.)

For comparisons of lighting he reduces the various distances, etc., to a co-efficient.

$$\frac{\text{Candle power of lamp} \times \text{height of lamp in feet}}{\text{distance from lamp to farthest point served in feet}^3}$$

With Argand or flat flame burners free to the air, the distribution of light upon a circumscribing sphere of radius 1 is equal, but this is not the case with regenerative or incandescent burners. (W. Hy. Webber.)

Table of Lighting. (Deduced from R. Richards.)

Street lighting. .	Road or pavement	$\frac{1}{10}$ candle foot.
„ „ . .	Walls	$\frac{1}{8}$ „ „
Church „ . .	General	$\frac{1}{4}$ „ „
„ „ . .	Pew or reading desk . 2 to	$3\frac{1}{3}$ „ „
Theatre „ . .	Auditorium	$\frac{1}{3}$ „ „
Public halls lighting	General area	$\frac{1}{3}$ „ „
Workshop „ .	„ „	$\frac{1}{5}$ „ „

Table of Lighting. (Deduced from R. Richards)—*continued.*

Workshop lighting	Benches	$3\frac{1}{3}$	candle foot.
" "	Optical or fine work	5	" "
Domestic "	Corridors, passages, halls, etc.	$\frac{2}{5}$	" "
" "	Living rooms	$\frac{1}{2}$	" "
" "	Library, study, or bedroom	$\frac{1}{4}$	" "
" "	Table lighting	2	" "

The sun's light equals about 5,600 candles placed at a distance of 30 centimetres.

The moon's light equals about $\frac{1}{144}$th candle placed at a distance of 3·65 metres.

The sun's light equals 5,500 candles placed at a distance of 12 inches (another authority).

Formula to Find the Intensity of Light any Distance.

$$\text{Intensity} = \frac{\text{Initial power of the light}}{\text{distance}^2}$$

Formula to find the Initial Intensity of any Light.

Initial intensity = intensity found at any point × distance of that point from the source of light ^{2}.

Formula to find distance at which any Intensity will be found.

$$\text{Distance} = \sqrt{\frac{\text{Initial power of the light}}{\text{Intensity desired}}}$$

Formula to find Intensity of Light falling upon a point in a horizontal plane from a source above it.

$$\frac{\text{Illuminating power of source} \times \text{vertical height above plane}}{\text{Slant distance}^3}$$

German Experiments show that a light of 1 candle power can be seen 1·4 mile on a clear dark night, and 1·0 mile on a rainy night.

American Experiments show that in clear weather a light of

1 candle power is visible at		1 mile.
3 " " "	(with a binocular)	2 miles.
10 " " "	" "	4 "
20 " " "	(faintly)	5 "
33 " " "	(easily)	5 "

Dutch Experiments show that a light of

1 candle power is visible at	1 mile
$3\frac{1}{2}$ " " " "	2 miles
16 " " " "	5 "

A green light to be seen at

1 mile at sea must be of 2 candle power.						
2 miles	,,	,,	,,	15	,,	,,
3	,,	,,	,,	51	,,	,,
4	,,	,,	,,	106	,,	,,

The shade of green recommended is a clear blue green; the shade of red a coppery red. Red lights show better than green ones at the same distance.

One light of whatever intensity is not perceptible to our eyes in presence of a light 64 times brighter. (Bouguer.)

The intensity of illumination which is received obliquely is proportional to the cosine of the angle which the luminous rays make with the normal to the illuminated surface. (Dr. Atkinson.)

Freshly fallen snow reflects		78 per cent. of light.		
White paper	,,	70	,,	,,
,, sandstone	,,	24	,,	,,
Ordinary earth, road surfaces, etc.	,,	8	,,	,,

Old Rule for Numbers of Burners Required for Effective Lighting—

$$\frac{\text{Floor area in square feet}}{50}$$

Ventilation Notes.

Ventilation should be arranged so as to change the air in a room in 10 minutes as a maximum.

With a 6-inch vertical flue 12 feet long the most economical burner to use is one of 1 cubic foot per hour capacity, this will remove 2,460 cubic feet of air per hour.

The maximum consumption of gas in a ventilating flue should not exceed 5 cubic feet per hour for each circular foot area of section.

The atmospheric and illuminating flame is the same in all cases where a large quantity of air has to be heated to a low temperature. The consumption of 1 cubic foot of gas in a ventilating shaft can be made to remove more than 2,400 times its own bulk.

Normal air contains 0·364 grains CO_2 per foot.

Air to be pure should not contain more than 7 grains CO_2 per cubic foot.

Adult expires 15 cubic feet of air per hour, containing 4½ per cent. $CO_2 = \cdot 8$ cubic feet per hour.

Air at 60° should not contain more than 5 grains moisture.

	1 Adult.	1 Cubic Foot Gas.
Cubic feet of CO_2 per hour given off by .	0·8	0·5
Heat units given off by	480	620
Grains per cubic foot of water vapour .	200	440
Cubic feet of air actually used by . .	15	60
,, ,, ,, vitiated in an unventilated room . . .	1,200	800

Ventilation should be 2,000 to 3,000 cubic feet per hour.

About 3 cubic feet to 4 cubic feet per minute of air is required for each adult. Sleeping apartments should have about 1,000 cubic feet per occupant. Workshops and living rooms not less than 600 cubic feet per person.

For each lamp or gas burner from 30 to 60 cubic feet of air is required per hour.

A 4-inch shaft 8 feet long, with the help of a jet of gas burning ½ to ¾ of a cubic foot per hour, will aspirate upwards of 1,100 cubic feet of air per hour in a still atmosphere, and with further assistance of a wind moving across the ventilator at a velocity of 4½ feet per second, it will aspirate 3,126 cubic feet per hour.

A 6-inch similar cowl, with a burner consuming 4 cubic feet of gas per hour, will, in a still atmosphere, aspirate about 2,500 cubic feet of air per hour, and with the assistance of wind moving at the velocity of 9 feet per second it will aspirate 6,840 feet per hour. (W. Sugg.)

Professor Smithells concludes that when compounds of carbon and hydrogen meet oxygen the C is first oxidised and the H liberated, which is then converted into steam by oxidation. The light of the flame being due to carbon formed by the decomposition of hydrocarbons by the heat of the primary combustion, according to the equation:—$3\ C_2H_4 = 2\ CH_4 + 4\ CH + 2\ H_2$.

Professor Lewes believes that the H rapidly, and the methanes slowly, diffuse to the outside of the flame, and are burned, producing heat sufficient to raise the temperature of the gas to 1,000° C., at which temperature the unsaturated hydrocarbons and the higher saturated carbons and hydrogen compounds being decomposed into acetylene, the heat rising to 1,200° C. changes the acetylene into C and O, and the C becoming incandescent gives off the light.

Gas-flames with an ample supply of primary air when in contact with incandescent surfaces, do not discharge combustible gases among the products of combustion.

Professor Macadam found that with 4·85 candle power per foot gas, the best value with a Welsbach **S** burner was 10·66 candle power per foot, with 7·12 candle power per foot gas it was 12·75 candle power per foot, and with 2·80 candle power per foot gas it was 13·63 candle power per foot.

The loss by different glasses, etc., is shown as follows :

Clear glass 1 cubic foot	= 12·81	candle power.
Mica	= 12·81	„ „
Amber glass 1 cubic foot	= 12·18	„ „
Ruby glass . .	= 9·06	„ „

When gas gets much above 24 candle power, it is not advantageous to employ the ordinary form of Welsbach **C** burner as supplied by the company at the time (1895). (Professor W. I. Macadam.)

By a more perfect admission of gas and air in a Bunsen burner, a corresponding heat development ensues, and a light equal to 27 candles per cubic foot can be obtained with 16 candle gas and without a chimney with the Welsbach-Denayrouze burner.

Number of Candle-power Hours which can be Provided at the Same Cost. (Prof. D. E. Jones.)

Wax	33
Stearine	77
Incandescent electric light	440
Coal gas (slit burner)	625
Acetylene and air (slit burner)	716
Oil gas	1,660
Water gas and benzene	1,666
Electric arc	2,322
Schulke's petroleum-gas lamp	2,250
Auer-Welsbach burner with coal gas	2,300
Auer-Welsbach burner with water gas	4,350

Comparative Cost of Different Illuminants (Germany).

Gas Argand burner	943*d.*
" small Wenham burner	483*d.*
" carburetted with napthalene, No. 2 Bray burner	574*d.*
" Welsbach burner	305*d.*
Petroleum, large centre draught burner	449*d.*
" small burner	589*d.*
Electric glow lamp	1954*d.*

The comparative cost of a duplex lamp, with paraffin at 8*d.* a gallon equals 5·63*d.* per 1,000 candles per hour.

The comparative cost of a Lamp Belge, with paraffin at 1*s.* a gallon equals 7·9*d.* per 1,000 candles per hour.

The comparative cost of Schulke regenerative lamp, with gas at 2*s.* 3*d.* per 1,000 feet equals 2·9*d.* per 1,000 candles per hour.

The comparative cost of Wenham regenerative lamp, with gas at 2*s.* 3*d.* per 1,000 feet equals 4·1*d.* per 1,000 candles per hour.

The comparative cost of ordinary flat flame burner equals 8·3*d.* per 1,000 candles per hour. (L. T. Wright.)

Incandescent Electric Lamps.

Number of Hours the Lamp has been alight.	Illuminating Power.	Number of Hours the Lamp has been alight.	Illuminating Power.
0	14·8	453	10·8
96	14·0	520	11·5
168	13·3	612	10·5
307	11·5	709	10·5
357	11·8	761	10·5

Relative Cost of Illuminants.

Gas at 3*s*. per 1,000 cubic feet (16 candle) equals 1.

Composite candles, each burning 136 grains per hour at 1*s*. per lb. equals 16·6.

Mould tallow candles, each burning 145 grains per hour at 6*d*. per lb. equals 18·0.

Wax candles, each burning 165 grains per hour at 1*s*. per lb. equals 22·6.

Sperm candles, each burning 133 grains per hour at 2*s*. per lb. equals 34·3.

Some 20 to 60 per cent. more sulphur is given off from paraffin lamps than from gas lamps.

Table Showing the Luminous Effect of a Square Centimetre of Flame Area. (M. Monnier.)

In a jet gas flame	0·06 candle.
„ an Argand burner	0·3 „
„ a Siemen's burner	0·6 „
„ incandescent electric lamps . .	30·0 „
„ the electric arc	480·0 „

Gas Stove Notes. (*Lancet.*)

1. It is desirable that the stove should afford radiant heat only.
2. For this purpose some form of clay "fuel" is best.
3. Attention should be given to the packing of the "fuel" so as to avoid undue clogging or impeding the flow of the flames.
4. The stove should be supplied with separate burners with taps.
5. Some means of controlling the supply should be adopted. Governors or regulators are indicated.
6. A simple arrangement appears to be necessary by which undue drying of the warmed air may be avoided.
7. Indestructible enamel, or enamel little affected by the heat, should be used for coating the stove; common paint, varnish or ordinary enamel should be avoided.
8. An efficient flue should in all cases be provided with gas fires, however, the flue pipe may be much smaller than the chimney required by coal fires.
9. The burner should be as far as possible noiseless.

Pressure for gas stoves should not be less than four-tenths.

One volume of gas requires 5½ volumes air for complete combustion.

Average mixture of gas and air in gas stove Bunsen burners is 1 to 2·3.

On a large scale one pound of meat can be cooked by 1 cubic foot of gas.

Gases in flues of gas stoves consist of about :—Oxygen, 12 per cent.; Nitrogen, 84 per cent.; CO_2 4 per cent.

40 cubic feet of gas in an average gas stove raised the temperature of a room 1,080 cubic feet, 5° F.

Size of Pipes and Lengths Allowed for Gas Stoves by Blackpool Corporation Gas Department.

Average Inside Size of Oven.	Distance of Stove from Meter.	Pipe Required.
11 inches × 11 inches × 14 inches	under 30 feet	½ inch.
11 " × 11 " × 14 "	if 60 "	⅝ "
14 " × 14 " × 24 "	if 30 "	⅝ "
14 " × 14 " × 24 "	if 60 "	¾ "
15½ " × 15½ " × 24 "	if 30 "	¾ "
15½ " × 15½ " × 24 "	if 60 "	1 "
19 " × 18 " × 24 "	if 30 "	1 "
19 " × 18 " × 24 "	if 60 "	1¼ "

Connect all gas stoves with a large gas supply and with full-way taps and fittings. The chimney should be closed with a wrought iron plate with a hole in it to allow the flue of the gas stove to pass through.

One degree F. rise in temperature per 15·4 cubic feet gas consumed. Seven lbs. coal required for same rise in temperature. (Professor Lewes.)

Total calorific value of gas is constant, whether Bunsen or luminous flames are used, if complete combustion is assured. The latter, however, must be kept sufficiently far from the object being heated so that the flame may not impinge upon its surface, or soot will be deposited, forming a non-heat-conducting layer, and so diminish the energy of the flame.

As regards the calorific value of the gas—

Carburetted water gas	145°	per 4½ cubic feet.
Coal gas . . .	136°	
Mixed gas . . .	136°	

The permanent gas from the flue of a gas stove consists wholly of CO_2, N and O. (*Lancet.*)

Warming by Steam.

When the external temperature is 10° below freezing point, in order to maintain a temperature of 60°—

One square foot steam pipe for each 6 square feet glass in windows.

One square foot steam pipe for every 6 cubic feet of air escaping for ventilation per minute.

One square foot steam pipe for every 120 feet of wall, roof, or ceiling.

One cubic foot of boiler is required for every 2,000 cubic feet of space to be heated.

One horse-power boiler is sufficient for 50,000 cubic feet of space. Steam should be about 112°.

Heating.—1 square foot of pipe surface heated to 200° will cause an average of 58° of heat in 150 cubic feet of air.

Heating Rooms.—1 square foot of pipe surface is required for 80 cubic feet of space; 1 cubic foot of boiler is required for 1,500 cubic feet of space; 1 horse-power boiler is sufficient for 40,000 cubic feet of space.

Allow 1 square foot pipe surface per 120 feet wall and ceiling space for steam heating.

Allow 1 cubic foot for every 1,300 square feet wall surface when once warmed, but for preliminary heating about four times this amount is required, which also allows for ventilation.

The length of piping required to represent 1 square foot of heating surface—

36 inches of 1 inch wrought iron tubing to 1 square foot.
28 „ $1\frac{1}{4}$ „ „ „ „ „
24 „ $1\frac{1}{2}$ „ „ „ „ „
20 „ 2 „ „ „ „ „
16 „ $2\frac{1}{2}$ „ „ „ „ „
13 „ 3 „ cast iron „ „ „
10 „ 4 „ „ „ „ „

The allowance would be 18 square feet of heating surface for living rooms, 13 feet for bedrooms, and 20 feet for halls for each 1,000 cubic feet of air in the place to be warmed. 1 inch main will supply up to 70 square feet. $1\frac{1}{4}$ inch main will supply up to 150 square feet. $1\frac{1}{2}$ inch main will supply up to 300 square feet. 2 inch main will supply up to 600 square feet. $2\frac{1}{2}$ inch main will supply up to 800 square feet. (G. Chasser.)

Percentage of Heat Evolved by Open Grates and Close Stoves.

(D. K. Clark.)

	Open Grates.	Close Stoves.
Heat carried up the chimney . .	43 per cent.	24 per cent.
Radiated and conducted heat absorbed by the walls	42 „	54 „
Heat lost by radiation and conduction externally, and heat lost by imperfect combustion	15 „	22 „
	100	100

One pound of coal burnt in an ordinary grate requires for its combustion 300 cubic feet of air having a temperature of 620° F. (Sir Douglas Galton.)

Quantity of soot given off by a coal fire burning house coal of different qualities.—The amount is said to be on the average $6\frac{1}{2}$ per cent. of the carbon in coal.

One volume gas requires $5\frac{1}{2}$ volumes air for complete combustion.

Dowson gas gives about 160 thermal units per cubic foot. Explosive force equals 1 to 3·8 for London gas.

To Prevent Stoves from Rusting.—Melt 3 parts lard with 1 part powdered resin; add black lead if desired. Brush over in a thin coat.

Best Heats for Cooking.

Roasting pork .	320° F.	Beef	310° F.
Veal	320°	Mutton	300°
Pastry	320°	Meat pies . .	290°
„ puff . . .	340°		

Heats of Different Fires.

Heat of a common wood fire	= 800° to 1,140° F.
„ charcoal fire	= 2,200° (about).
„ coal fire	= 2,400°

Number of Grammes of Water Raised 1° through Equal Thickness of Plate.

Copper	918	Tin	150
Zinc	292	Steel . . .	from 111 to 62
Iron	156	Lead	79

Breeze mixed with tar (40 gallons to the ton) does not produce a smoky fuel, and retains its shape.

The pitch used for agglomerating briquettes must not have had its binding qualities destroyed by the removal of its anthracene and heavy oils. A suitable pitch should soften at 75° C., melt at 100° to 120° C., remain hard at the normal temperature, and be capable of carriage in bulk. Its fracture should be dead black, conchoidal, clean and soft, without being greasy to the touch; and the edges should not splinter when bitten by the teeth. So prepared, coke would burn as freely as bituminous coal. (W. Colquhoun.)

Tar for making pavements should be heated until converted to pitch that will harden on cooling. If overheated it loses its elasticity, and pavements made with it disintegrate rapidly. Refuse materials, such as clinkers, may be employed, and the pitch should be run straight from the boiler on to them, well mixed and laid and rolled at once. One barrel of boiled tar will make 50 cubic feet of pavement.

Proportions of Tar Concrete.

Aggregate	7 parts.
Sharp sand (clean)	2 ,,
Coal tar	6 ,,
Lias lime or Portland cement	2 ,,

For the manufacture of tar paving it is usual to heat the stones over an iron plate, and then add tar which has been heated in open boilers, and the lighter oils evaporated at about 194° F. The time taken for this heating varies from four to twelve hours, as it is not desirable that the creosote oils should be distilled off.

Briquettes.

Good coal briquettes contain 5 per cent. of pitch if strongly pressed, or 7 to 8 per cent. if pressed with inferior or hard pitch.

Balloons.

The lifting power of a balloon is the difference between its weight and that of the air which it displaces.

1 cubic foot air weighs approximately ·075 lb.
1 ,, hydrogen ,, ·005 ,,
1 ,, coal gas ,, ·043 ,,
1 ,, air heated to 200° C. weighs approximately ·042 lbs.

Therefore lifting power of coal gas = ·075 − ·043 = ·032 lb. for each cubic foot contained in the balloon.

The lifting power of hydrogen equals 60 to 70 lbs. per 1,000 cubic feet, that of coal gas being about 35 lbs.

Comparative Cost per Horse-power per Hour. (Herr C. Korte.)

Size of Motor (horse-power).		$\frac{1}{4}$	$\frac{1}{2}$	1	2	3	4	6
Class of Motor.	Hours daily.	d.	d.	d.	d.	d.	d.	d.
Gas motor (gas at 3*s*. 4*d*. per 1,000 cubic feet)	5	7·92	5·76	3·72	2·88	2·52	2·40	2·28
	10	5·76	4·08	2·64	2·88	2·04	1·92	1·80
Hydraulic motor (water at 6¼*d*. per 1,000 gallons) 90 lbs.	5	12·12	10·80	9·72	9·00	—	—	—
	10	10·56	9·84	9·12	8·64	—	—	—
Electric motor (Berlin tariff)	5	8·88	7·22	5·88	5·04	4·68	—	—
	10	7·56	6·48	5·40	4·80	4·44	—	—
Compressed air motor (Paris tariff)	5	15·00	11·64	8·40	6·96	6·00	5·40	4·32
	10	13·08	10·44	7·68	6·48	5·84	5·16	4·08
Steam motor, with coal at 12*s*. 6*d*. per ton	5	—	—	4·20	2·88	2·40	2·04	1·80
	10	—	—	2·88	2·04	1·68	1·44	1·32
Steam motor, with coal at 20*s*. per ton	5	—	—	4·92	3·48	3·00	2·82	2·28
	10	—	—	3·48	2·52	2·16	1·92	1·68
Hot air motor, with coal at 12s. 6d. per ton	5	11·28	6·72	4·44	3·36	—	—	—
	10	6·48	4·08	2·76	2·16	—	—	—

Consumption of Gas per head of Population.

London	5,000 cubic feet.	France	560 cubic feet.
England	2,450 „	Germany	350 „

Approximate Composition of London Coal Gas. (Professor Lewes.)

	Volume.	Weight.
H	52·0	9·6
C_2H_4 } Unsaturated hydrocarbons	3·0	7·7
C_6H_6 }	1·0	7·1
Saturated hydrocarbons (CH_4)	34·0	49·9
CO	5·0	12·8
N	4·5	11·5
CO_2	0·0	0·0
O	0·5	1·4
	100·0	100·0

Calorific value, 11,918 thermal units.

A weighted lever is better than a spring for keeping the pencil point up to the paper on a registering pressure gauge, but a weighted boat-shaped pen is better still.

Use a constant water level gauge in station meters, and keep a continuous stream of water running in.

A groaning station meter may be quieted by pumping in below the water line a hot water solution of soft soap.

Wet Meters.

Lights.	Capacity of Drum. Cubic Feet.	Capacity per Hour. Cubic Feet.	Diameter of Inlet.	Dimensions over all. Height.	Width.	Back to Front.
			Inches.	Inches.	Inches.	Inches.
2	·083	12	½	15¼ ×	10 ×	7⅞
3	·125	18	⅝	17 ×	12½ ×	8⅜
5	·25	30	¾	18⅝ ×	15⅛ ×	9⅞
10	·5	60	1	21⅛ ×	19¼ ×	12¼
15	·75	90	1	24 ×	21¾ ×	14¼
20	1	120	1¼	26⅛ ×	23¾ ×	15⅝
30	1·5	180	1¼	28¾ ×	26⅞ ×	17⅝
50	2·5	300	1½	28¾ ×	26⅞ ×	22½
60	3	360	1½	28¾ ×	26⅞ ×	25
80	4	480	2	33⅜ ×	30⅞ ×	28¾
100	5	600	2½	38¼ ×	35⅞ ×	29¼
150	7·5	900	3	40 ×	39 ×	31¾
200	10	1,200	3	43¾ ×	42½ ×	32½
250	12·5	1,500	To order.	46 ×	45¼ ×	32¾
300	15	1,800		46 ×	45¼ ×	45¾
400	20	2,400		49⅜ ×	48¾ ×	48½
500	25	3,000		51½ ×	50½ ×	62½
600	30	3,600		51½ ×	50½ ×	65½

Dry Meters.

Lights.	Diameter of Inlet.	Capacity per Revolution.	Capacity per Hour.	Dimensions over all. Height.	Width.	Back to Front.
	Inches.		Cubic Feet.	Inches.	Inches.	Inches.
2	$\frac{1}{2}$	·083	12	$14\frac{1}{4}$ ×	$10\frac{1}{8}$ ×	$7\frac{1}{4}$
3	$\frac{5}{8}$	·125	18	$15\frac{1}{2}$ ×	$11\frac{1}{2}$ ×	8
5	$\frac{3}{4}$	·16	30	17 ×	13 ×	$8\frac{3}{4}$
10	1	·3	60	$19\frac{1}{4}$ ×	15 ×	$10\frac{1}{2}$
15	1	·416	90	$21\frac{1}{2}$ ×	16 ×	$11\frac{5}{8}$
20	$1\frac{1}{4}$	·5	120	24 ×	$18\frac{1}{4}$ ×	$12\frac{1}{4}$
30	$1\frac{3}{8}$	·83	180	$25\frac{3}{4}$ ×	$20\frac{1}{2}$ ×	14
40	$1\frac{3}{8}$	1·25	240	$29\frac{3}{8}$ ×	23 ×	17
50	$1\frac{5}{8}$	1·428	300	$32\frac{1}{4}$ ×	$25\frac{1}{2}$ ×	21
60	$1\frac{3}{4}$	1·6	360	$33\frac{1}{2}$ ×	$27\frac{1}{2}$ ×	21
80	2	2·5	480	$38\frac{1}{4}$ ×	$31\frac{1}{4}$ ×	22
100	2	2·857	600	$40\frac{3}{4}$ ×	$32\frac{1}{4}$ ×	$23\frac{1}{2}$
120	$2\frac{1}{2}$	3·3	720	$46\frac{1}{2}$ ×	$35\frac{1}{4}$ ×	26
150	3	5·0	900	$48\frac{1}{2}$ ×	38 ×	27
200	$3\frac{1}{2}$	6·6	1,200	$56\frac{3}{4}$ ×	$42\frac{1}{2}$ ×	29
250	$3\frac{1}{2}$	7·3	1,500	56 ×	45 ×	$32\frac{1}{2}$
300	4	8·3	1,800	62 ×	48 ×	37
400	4	12·5	2,400	70 ×	52 ×	40
500	5	14·285	3,000	$73\frac{3}{4}$ ×	58 ×	46
600	6	22·222	3,600	77 ×	58 ×	50
800	7	25·0	4,800	88 ×	61 ×	52
1000	8	33·333	6,000	90 ×	64 ×	54

(Inlets for 120 to 1000 lights: Flanged Side Connections.)

Standard Sizes of Unions for Connecting Gas Meters.
(Board of Trade Standards Department.)

Size of Meter.	Boss. Mean Diameter of External Screws.	Boss. Number of Threads per Inch.	Boss. Internal Diameter.	Cap. Mean Diameter of Internal Screw.	Cap. Number of Threads per Inch.	Cap. Height of Cap.	Lining. External Diameter to Outer Boss.
Lights.	Inches.	Threads	Inches.	Inches.	Threads	Inches.	Inches.
1 & 2	·88	19	·57	·84	19	·40	·55
3	·98	19	·67	·94	19	·50	·65
5	1·15	14	·83	1·10	14	·50	·81
10	1·45	11	1·05	1·40	11	·60	1·03
20	1·80	11	1·42	1·75	11	·60	1·40
30	2·05	11	1·55	2·00	11	·70	1·53
50	2·25	11	1·80	2·25	11	·70	1·75
60	2·45	11	2·00	2·40	11	·80	1·98
80 & 100	3·00	11	2·30	2·95	11	1·00	2·28
150	3·68	9	3·05	3·65	9	1·20	3·03

Meters.

Theoretical capacity of meters to pass gas is 6 feet per hour per light, though in practice larger quantities can be passed.

All meters should be fixed perfectly level.

The meter which is correct at a low pressure would be found to be slow at a high pressure.

In America the average tests of dry meters in one town was $\frac{1}{2}$ per cent. slow, and in another town $\frac{1}{4}$ per cent. slow.

Dry meters are liable to absorb the illuminants of the gas on the leathers which are always oily. Even the water in the photometer meter may have a thin stratum of oil on the surface which will sometimes absorb the illuminants, and it ought, therefore, to be washed out occasionally, and filled only with distilled water having about 2 per cent. of pure glycerine in it.

To Keep Wet Meters from Freezing.

To prevent wet meters from freezing, pack horse manure round them, or

Turn off main cock and light a jet in house to consume the pressure in the pipes, unscrew plug and pour in, say, two table-spoonfuls of glycerine (for a three-light meter), allow a few minutes for the glycerine to come to the surface, and then shut off cock in house and turn main cock on again.

Use 5 per cent. pure glycerine in water for experimental and other meters.

Glycerine is said to have the effect of reducing the illuminating power of the gas when used with water in a gas meter.

Mixture used in R.A. Hydraulic Jacks to Prevent Freezing.

Methylated spirits	7 gallons.
Distilled water	$3\frac{1}{4}$,,
Mineral oil	$\frac{1}{4}$,,
Carbonate of soda	250 grains.

Fluids transmit pressure equally in every direction.

A governor cone should be heavy enough to prevent oscillation, and a parabolic curve of a length equals twice the diameter.

To force gas down, say a mine, a jet of water may be sprayed into the top of pipe, and will cause an injector action according to the quantity of water in use.

Velocity of discharge due to head of water equals $\sqrt{\text{head}} \times 8$ per second.

Area of governor bell sometimes taken at 20 times area of base of cone.

TESTING.

Elementary Bodies.

	Symbols.	Combining Weights.	Specific Gravity.	Melting Points. C.
Aluminium .	Al	27·0	2·67	
Antimony . .	Sb	120·0	6·71	425°
Arsenic . .	As	74·9	{ 5·67 5·9	
Barium .	Ba	136·8	4·0	
Beryllium .	Be	9·2		
Bismuth . .	Bi	208·0	9·8	270°
Boron . .	B	11·0	2·69	
Bromine . .	Br	79·75	2·966	
Cadmium . .	Cd	111·9	8·65	315°
Caesium . .	Cs	133·0		
Calcium . .	Ca	39·9	1·58	
Carbon . . .	C	11·97		
Cerium . .	Ce	139·9		
Chlorine . .	Cl	35·37		
Chromium .	Cr	52·1	7·3	
Cobalt . . .	Co	58·6	{ 7·81 8·5	
Copper . .	Cu	63·1	8·93	1090°
Didymium . .	D	142·0		
Erbium . .	E	166·0		
Fluorine . .	F	19·1		
Gallium . .	G	69·8	—	+ 30°
Gold . . .	Au	196·2	19·3	
Hydrogen . .	H	1·0	·06926	
Indium . . .	In	113·4	7·42	
Iodine . .	I	126·53	4·95	
Iridium . . .	Ir	192·7	22·38	
Iron . . .	Fe	55·9	7·8	1050° to 1600°
Lanthanum . .	La	138·0		
Lead . . .	Pb	206·4	11·35	334°
Lithium . . .	Li	7·01	0·594	
Magnesium .	Mg	24·3	1·74	
Manganese .	Mn	55·0	8·01	
Mercury . .	Hg	199·8	13·59593	at 0° C. – 40°
Molybdenum .	Mo	95·8		
Nickel . .	Ni	58·6	8·8	
Niobium . .	Nb	94·0		
Nitrogen . .	N	14·01	·97137	
Osmium . . .	Os	198·6	22·5	21·4°
Oxygen . .	O	15·96	1·10563	
Palladium . .	Pd	106·2	11·4	
Phosphorus .	P	30·96	1·77	

Elementary Bodies—*continued.*

	Symbols.	Combining Weights.	Specific Gravity.	Melting Points. C.
Platinum . .	Pt	194·5	21·5	
Potassium . .	K	39·04	0·865	62·5°
Rhodium . .	Rh	104·1	12·1	
Rubidium . .	Rb	85·2	1·52	
Ruthenium . .	Ru	103·5	12·29	
Scandium . .	Sc	44·0		
Selenium . .	Se	78·0	4·3	
Silver . .	Ag	107·66	10·5	1000°
Silicon . . .	Si	28·0		
Sodium . .	Na	22·99	0·974	95·60°
Strontium . .	Sr	87·2	2·54	
Sulphur . .	S	31·98	2·00	
Tantalum . .	Ta	182·0		
Tellurium . .	Te	125·0	6·25	
Terbium . .	Tb	148·5		
Thallium . .	Tl	203·6	11·85	
Thorium . .	Th	231·5		
Tin . . .	Sn	117·8	7·29	235°
Titanium . .	Ti	48·0		
Tungsten . .	W	184·0		
Uranium . .	U	240·0	18·4	
Vanadium .	V	51·2		
Ytterbium . .	Yb	173·2		
Yttrium . .	Y	89·0		
Zinc . . .	Zn	65·1	6·8 to 7·2	433°
Zirconium . .	Zr	90·0	(In the case of gases, air = 1. „ „ „ „ solids, water = 1.)	

Air, Gas and Water.

Pressure of atmosphere = 14·7 lbs. per square inch = 2116·8 lbs. per square foot.

Pressure of atmosphere equals 29·9 inches of mercury at sea level.

„ „ „ 33·9 feet of water at sea level.

29 cubic feet of coal gas equals 1 lb. approximately.

1 cubic foot of air at 62° F. equals ·076 lbs.

Gas or air expands $\frac{1}{492}$nd of its bulk at 32° F. for each degree F.

Water is at its maximum density at 39·2° F. (4° C.) and expands $\frac{1}{10}$th part of its bulk on freezing.

Centre of pressure $\frac{2}{3}$rds depth from surface.

1 litre of fresh water = 1 kilogramme = ·001 cubic metre = ·22 gallons = 2·2 lbs. = ·0353 cubic feet = 61 cubic inches.

1 ton of fresh water equals 1,016 kilogrammes, 1·0165 cubic metres, 1,016 litres.

1 ton of fresh water = 35·9 cubic feet = 224 gallons.

1 cubic metre of fresh water = 1,000 litres = 1,000 kilogrammes. 35·316 cubic feet = 220 gallons = 2,200 lbs.

1 cubic foot of fresh water = 62·425 lbs. = ·557 cwts. = ·028 tons.

1 cubic foot of fresh water equals 6·24 gallons, or salt water 64 lbs.
1 cubic inch of fresh water = ·03612 lbs. = ·003612 gallons.
1 gallon of fresh water = 10 lbs. = ·16 cubic feet.
1 cwt. of fresh water = 1·8 cubic feet = 11·2 gallons.
Head of water in feet equals pressure in lbs. per square inch × 2·307.
Pressure in lbs. per square inch equals height in feet × ·4335.

Pressure of a Column of Water per Square Inch and per Square Foot in Lbs.

Head.	Pressure per Square Inch.	Pressure per Square Foot.	Head.	Pressure per Square Inch.	Pressure per Square Foot.
Inches.	Lbs.	Lbs.	Feet.	Lbs.	Lbs.
1/20	...	·260	25	10·82	1562·4
1/10	...	·520	30	12·99	1874·9
2/10	...	1·041	35	15·16	2187·4
3/10	...	1·562	40	17·32	2499·8
4/10	...	2·083	45	19·49	2812·3
5/10	...	2·604	50	21·65	3124·8
6/10	...	3·124	55	23·82	3437·3
7/10	...	3·645	60	25·99	3749·8
8/10	...	4·166	65	28·15	4062·2
9/10	...	4·687	70	30·40	4374·7
1	·0362	5·208	75	32·48	4687·2
2	·0723	10·416	80	34·65	4999·7
3	·1085	15·624	85	36·82	5312·2
4	·1446	20·833	90	38·98	5624·6
5	·1808	26·040	95	41·15	5937·1
6	·217	31·248	100	43·31	6249·6
7	·253	36·457	110	47·64	6874·6
8	·289	41·666	120	51·98	7499·5
9	·325	46·872	130	56·31	8124·5
10	·362	52·08	140	60·64	8749·4
11	·398	57·29	150	64·97	9374·4
12	·434	62·5	200	86·63	13124
Feet.			250	108·29	16249
2	·86	125·0	300	129·95	19374
3	1·30	187·5	350	151·61	22499
4	1·73	250·0	400	173·27	26248
5	2·16	312·5	450	194·92	29373
6	2·59	375·0	500	216·58	32498
7	3·03	437·5	600	259·90	38748
8	3·46	500·0	700	302·22	45622
9	3·89	562·5	800	346·54	52496
10	4·33	624·9	900	389·86	58746
15	6·49	937·4	1000	433·18	64996
20	8·66	1249·9			

To Bend Glass Tubes. (Spon.)

If a sudden bend is wanted, heat only a small portion of the tube to a dull red heat, and bend it with the hand held at the opposite ends. If the bend is to be gradual, heat an inch or two of it in length previous to bending it. If a gradual bend on the one side and a sharp one on the other, as in retorts, a little management of the tube in the flame, moving it to the right and left alternately at the same time as it is turned round, will easily form it of that shape. In bending glass, the part which is to be concave is to be the part most heated. An ordinary gas flame is quite sufficient to bend glass by, but that of a spirit lamp is better.

Series I.—Paraffin Series, Marsh Gas. Saturated Hydrocarbons.
(E. L. Price.)
Generic Formulæ $CnH_2n + 2$.

Name of Hydrocarbon.	Formula.	Boiling Point F.	Specific Gravity Water = 1.	Illuminating Power. Candles. per 5 Cubic Feet.	Volume of Gas from 1 Gallon 60° F. 30 Inches Barometer.
Methane .	CH_4	gas	gas	5·0	
Ethane .	C_2H_6	gas	gas	35·0	
Propane .	C_3H_8	gas	gas	53·9	
Butane .	C_4H_{10}	34°	·6	—	37
Pentane .	C_5H_{12}	98°—102°	$·626^{62°.6}$ F.	—	31
Hexane .	C_6H_{14}	156°	$·663^{62°.6}$ F.	—	27
Heptane .	C_7H_{16}	209°	$·700^{32°}$ F.	—	25
Octane .	C_8H_{18}	258°	$·719^{32°}$ F.	—	22
Nonane .	C_9H_{20}	297°	$·728^{56°.5}$ F.	—	20
Decane .	$C_{10}H_{22}$	331°—334°	$·739^{56°.5}$ F.	—	18
Endecane .	$C_{11}H_{24}$	356°—359°	$·765^{61°}$ F.	—	17
Dodecane .	$C_{12}H_{26}$	392°—395°	$·757^{64°.4}$ F.	—	16

Series II.—Olefine Series, Saturated Hydrocarbons. (E. L. Price.)
Generic Formula CnH_2n.

Name of Hydrocarbon.	Formula.	Boiling Point F.	Specific Gravity Water = 1.	Illuminating Power. Candles. per 5 Cubic Feet.	Volume of Gas from 1 Gallon 60° F. 30 Inches Barometer.
Ethylene .	C_2H_4	gas	gas	$68·5^4$	
Propylene .	C_3H_6	gas	gas		
Butylene .	C_4H_8	gas	gas	$123·0^5$	
Pentylene .	C_5H_{10}	91°—108°	$·655^{50°}$ F.	—	33
Hexylene .	C_6H_{12}	154°—158°	$·699^{32°}$ F.	—	30
Heptylene .	C_7H_{14}	205°	$·739^{63°.5}$ F.	—	27
Octylene .	C_8H_{16}	257°	$·723^{62°.6}$ F.	—	23

Ordinary coal gas of 15 to 16 candle power contains about 2 per cent. benzene.

The effect of washing gas with mineral oil of ·840 specific gravity is to reduce the illuminating power of the gas by about 50 per cent.

The stability of nearly all hydrocarbons is destroyed when subjected to temperatures above 2,000° F. (B. H. Thwaite.)

Bromide of potassium or concentrated sulphuric acid will absorb unsaturated hydrocarbons, but does not affect in diffused daylight the gaseous members of the saturated hydrocarbons.

A piece of rag moistened with a mixture of terebene, linseed oil, and turpentine, and rolled into a ball, rose in temperature from 20° C. to 87° C. in the first hour, and began to fume; and in the next hour increased to 310° C., fuming strongly; half-an-hour later the rag burnt at a temperature of 360° C. (T. Wilton.)

Corks freshly cut have been found to contain an appreciable quantity of ammonia, and may cause errors in gasworks analysis.

Elastic Force or Tension of Aqueous Vapour in Inches of Mercury.

Temp.	Temp.	Force.	Force.	Temp.	Temp.	Force.	Force.
Fahr.	Cent.	Inches.	M.m.	Fahr.	Cent.	Inches.	M.m.
32°0	0°	·181	4·6	67	19·4	·662	16·8
33	0·55	·188	4·8	68	20·0	·685	17·391
34	1·1	·196	5·0	69	20·5	·709	17·9
35	1·65	·204	5·2	70	21·1	·733	18·6
36	2·2	·212	5·4	71	21·65	·758	19·25
37	2·75	·220	5·6	72	22·2	·784	19·9
38	3·3	·229	5·8	73	22·75	·811	20·55
39	3·85	·238	6·05	74	23·3	·839	21·3
40	4·4	·248	6·3	75	23·85	·868	21·95
41	5°	·257	6·534	76	24·4	·897	22·7
42	5·5	·267	6·75	77	25·0	·927	23·5
43	6·1	·278	7·0	78	25·5	·958	24·3
44	6·6	·288	7·3	79	26·05	·990	25·05
45	7·15	·299	7·55	80	26·6	1·023	25·9
46	7·7	·311	7·9	81	27·15	1·057	26·75
47	8·25	·323	8·15	82	27·7	1·092	27·6
48	8·8	·335	8·5	83	28·25	1·128	28·45
49	9·45	·348	8·85	84	28·8	1·165	29·4
50	10°	·361	9·165	85	29·45	1·203	30·55
51	10·55	·374	9·5	86	30·0	1·242	31·548
52	11·11	·388	9·9	87	30·55	1·282	
53	11·65	·403	10·25	88	31·1	1·324	
54	12·2	·418	10·6	89	31·65	1·366	
55	12·75	·433	10·95	90	32·2	1·410	
56	13·3	·449	11·4	91	32·75	1·455	
57	13·85	·466	11·8	92	33·3	1·501	
58	14·45	·482	12·25	93	33·85	1·548	
59	15°	·500	12·7	94	34·4	1·597	
60	15·55	·518	13·15	95	35·0	1·647	
61	16·05	·537	13·55	96	35·5	1·698	
62	16·06	·556	14·1	97	36·05	1·751	
63	17·15	·576	14·55	98	36·6	1·805	
64	17·7	·596	15·1	99	37·15	1·861	
65	18·3	·617	15·7	100	37·7	1·918	
66	18·9	·639	16·2				

Volume of 1 lb. Air at Atmospheric Pressure equals 14·7 lbs. per Square Inch.

Temperature.	Volume	Temperature.	Volume.	Temperature.	Volume.
Degrees Fahr.	Cubic Feet.	Degrees Fahr.	Cubic Feet.	Degrees Fahr.	Cubic Feet.
0	11·583	230	17·362	525	24·775
32	12·387	240	17·612	550	25·403
40	12·586	250	17·865	575	26·031
50	12·840	260	18·116	600	26·659
62	13·141	270	18·367	650	27·915
70	13·342	280	18·621	700	29·172
80	13·593	290	18·870	750	30·428
90	13·845	300	19·121	800	31·685
100	14·096	320	19·624	850	32·941
120	14·592	340	20·126	900	34·197
140	15·100	360	20·630	950	35·453
160	15·603	380	21·131	1,000	36·710
180	16·106	400	21·634	1,250	42·990
200	16·606	425	22·262	1,500	49·274
210	16·860	450	22·890	2,000	61·836
212	16·910	475	23·518	2,500	74·400
220	17·111	500	24·146	3,000	86·962

To Find the Weight of Aqueous Vapour in Air.

(1) Weigh calcium chloride in a small basin; cover the basin with a bell jar. Suppose the bell jar contains 1 cubic foot of air, weigh the basin after some time. The increase in weight will be the amount of aqueous vapour in 1 cubic foot of air.

(2) Place calcium chloride, or pumice-stone dipped in strong sulphuric acid, in tubes (both substances absorb aqueous vapour). Weigh the tubes; then pass 20 gallons of air through them. The increase in weight equals the amount of aqueous vapour in 20 gallons. This forms a chemical hygrometer.

The maximum pressure of a vapour depends upon temperature and the kind of liquid used.

At different temperatures the maximum pressure of water vapour has been carefully determined.

Temperature C.	Pressure in Millimetres.	Temperature C.	Pressure in Millimetres.
—32°	0·320	15°	12·699
—20	0·927	18	15·357
—10	2·093	20	17·391
0	4·600	50	91·981
4	6·097	70	233·093
10	9·165	90	525·450
12	10·457	100	760·000

Weight of 1 cubic foot dry air at 60° F. and 30 inches press of mercury is about 537 grains.

Composition of the Atmosphere.

By volume oxygen	= 20·8,	by weight = 23
„ nitrogen	= 79·2,	„ = 77

It also contains a little ammoniacal gas, and from 3 to 6 parts in 10,000 of its volume of CO_2.

Carbon dioxide in atmosphere equals about 4 volumes per 10,000 of air.

1 cubic foot water at ordinary temperature and pressure dissolves 1 cubic foot CO_2.

The higher the temperature, the greater the amount of aqueous vapour held in suspension in the gas.

The corrected volume of dry gases for both temperature and pressure equals

$$\frac{\text{observed volume} \times \text{observed pressure} \times 17{\cdot}33}{\text{observed temperature} + 460}$$

because the product of the volume and pressure of a gas is proportional to the absolute temperature.

The density of liquid air is 910. (Dewar.)

Minimum Quantity of Oxygen that will Support Combustion.

(Professor Clowes.)

Paraffin flame	16·6	per cent. oxygen.
Candle „	15·7	„ „
Methane „	15·6	„ „
CO „	13·35	„ „
Coal gas „	11·35	„ „
Hydrogen „	5·5	„ „

The quantity of moisture in coal gas saturated 20° C. and 760 millimetres equals 2 per cent. which has the effect of reducing the illuminating power 3·3 per cent.

To Find the Speed of Sound in Air.

Let A = distance between the observer and the cannon in feet.
B = seconds that elapse between seeing the flash and hearing the report.
C = feet per second.

$$C = \frac{A}{B}$$

Force of Explosive Mixtures of Air and Glasgow Coal Gas.

(Dugald Clerk.)

Mixture.		Maximum Pressure of Explosives in lbs. per Square Inch.	Time of Explosion.
Gas.	Air.		
1 volume	13 volumes	52	0·28 seconds.
1 "	11 "	63	0·18 "
1 "	9 "	69	0·13 "
1 "	7 "	89	0·07 "
1 "	5 "	96	0·05 "

Heat of explosion of gun cotton = 2650° C. = 4802° F.

Explosive mixtures are more readily kindled upwards by a flame placed below them, than downward by one placed above them.

Limiting Explosive Mixtures of Gases and Air.

(Professor Clowes.)

	Upward Kindling.	Downward Kindling.	
	Per cent. Gas.	Per cent. Gas.	Per cent. Gas.
Methane	5 to 13	6	11
Coal gas	5 to 28	9	22
Water gas	9 to 55		
Hydrogen	5 to 72		
CO	13 to 75		
Ethylene	4 to 22		

Coal gas, horizontal tube, 10·3 per cent. to 23 per cent. (L. T. Wright.)

10·3 per cent. of coal gas (18·75 candles and ·45 specific gravity (air equals 1)) and 89·7 per cent. air is the lowest limit of an explosive mixture.

23 per cent. coal gas as above and 77 per cent. air is the highest limit. (L. T. Wright.)

The limiting percentages of explosive gaseous mixtures are :—For methane, 5 and 13 ; for hydrogen, 5 and 72 ; for carbon monoxide, 13 and 75 ; for ethylene, 4 and 22 ; for water gas, 9 and 55 ; for coal gas, 5 and 28. It was also proved that many mixtures which were outside, but close to, the above limits, and which could not be fired from above could be fired from below.

An exceedingly small quantity of coal dust in air is sufficient to cause an explosion.

Expansion by Heat and Melting Points (F.).

	Expansion.		Melting point in degrees F.
	1° 1 Part in	180° 1 Part in	
Fire brick	365,220	2,029	
Granite . . from	187,560	1,042	
,, . . . to	228,060	1,267	
Glass rod	221,400	1,230	
,, tube	214,200	1,190	
,, crown	211,500	1,175	
,, plate	209,700	1,165	
Platina	208,800	1,160	4,593
Marble, granular white dry	173,000	961	
,, ,, ,, moist	128,000	711	
,, ,, black compact	405,000	2,250	
Antimony	166,500	925	883
Cast iron	162,000	900	1,920 to 2,800
Slate	173,000	961	
Steel	151,200	840	2,370 to 2,550
,, blistered	159,840	888	
,, untempered	167,400	930	
,, tempered yellow	131,400	730	
,, hardened	146,800	816	
,, annealed	147,600	820	
Iron, rolled	149,940	833	3,000 to 3,500
,, soft forged	147,420	819	
,, wire	146,340	813	
Bismuth	129,600	720	500
Gold, annealed	123,120	684	2,058
Copper . . average	104,400	580	1,975
Sandstone	103,320	574	
Brass . . average	97,740	543	1,853
,, wire	94,140	523	
Silver	95,040	528	1,866
Tin . . . average	87,840	488	443
Lead . . . average	62,180	351	612
Pewter	78,840	438	
Zinc (most of all metals)	61,920	344	680 to 772
White pine	440,530	2,447	

Lbs. Water Heated and CO_2 Produced from Various Gases.

(Letheby.)

	Per lb.			Lbs. of Water Heated, 1° F.		
	O Required.	Air Vitiated.	CO_2 Produced.	Per lb.	Per Cubic Foot.	Per lb. O used.
	Cubic Feet.	Cubic Feet.	Cubic Feet.	Lbs.	Lbs.	Lbs.
H.	93·4	467	—	62,030	329	7,754
Marsh gas	47·2	826	23·6	23,513	996	5,878
Olefiant gas	40·5	878	27·0	21,344	1,585	6,225
Propylene	40·5	878	27·0	21,327	2,376	6,220
Butylene	40·5	878	27·0	21,327	3,168	6,220
Acetylene	36·3	909	29·1	18,197	1,251	5,914
Benzole	36·3	909	29·1	18,197	3,860	5,915
CO_2	6·7	371	13·5	4,325	320	7,569
CS_2	14·9	689	5·0	6,120	1,239	4,845
H_2S	16·7	630	—	7,444	671	5,271
Cyanogen	14·5	435	14·5	6,712	925	5,142
Coal gas (common)	37·5	618	17·6	21,060	650	6,816
„ „ (cannel)	31·0	698	22 0	20,140	760	6,503
Wood spirit	25·3	422	11·8	9,547	819	6,363

Lbs. Water Heated and CO_2 Produced from Various Substances.

(Letheby.)

	Per lb.			Lbs. of Water Heated, 1° F.		
	O Required.	Air Vitiated.	CO_2 Produced.	Per lb.	Per Cubic Foot.	Per lb. O used.
	Cubic Feet.	Cubic Feet.	Cubic Feet.	Lbs.	Lbs.	Lbs.
Alcohol	24·6	533	16·4	12,929	1,597	6,195
Camphine	38·9	880	27·8	19,573	7,134	5,942
Carbon	31·0	943	31·5	14,544	—	5,447
Ether	30·9	664	20·4	16,249	3,217	6,158
Paraffin	40·5	878	27·0	21,327	—	6,220
„ oil	40·5	878	27·0	21,327	—	6,220
Rape oil	38·7	801	24·3	17,752	—	6,123
Sperm oil	38·7	801	24·3	17,230	—	6,088
Spermacetti	37·0	815	25·2	17,589	—	6,088
Stearic acid	34·6	783	24·0	17,050	—	6,061
Stearine	34·4	527	14·2	18,001	—	6,143
Wax	37·7	829	25·6	15,809	—	4,995

Temperature of Combustion. (Letheby and Others.)

	Open Flames.		Closed Vessel.	
	In O.	In Air.	In O.	In Air.
	Degrees.	Degrees.	Degrees.	Degrees.
H	14,510	5,744	19,035	7,852
Marsh gas	14,130	4,762	18,351	6,680
Olefiant gas	16,535	5,217	21,344	7,200
Propylene	16,522	5,239	21,327	7,177
Butylene	16,522	5,232	21,327	7,177
Acetylene	17,146	5,142	22,006	7,009
Benzole	17,146	5,142	22,006	7,009
CO_2	12,719	5,358	16,173	7,225
CS_2	15,280	4,314	20,031	5,917
H_2S	13,688	4,388	17,542	6,026
Cyanogen	13,488	5,028	17,645	6,167
Coal gas (luminous)	14,320	5,228	18,101	7,001
Cannel gas	14,826	5,121	19,046	7,186
Wood spirit	11,435	4,641	14,902	6,347
Alcohol	13,305	4,831	17,223	6,629
Ether	14,874	5,150	19,225	6,953
Camphine	16,271	5,026	20,953	6,922

Expansion of Liquids, from 32° to 212° F. Volume at 32° = 1.

Liquid.	Volume at 212°	Expansion.	Liquid.	Volume at 212°	Expansion.
Alcohol	1·1100	$\frac{1}{9}$	Sea water	1·0500	$\frac{1}{20}$
Nitric acid	1·1100	$\frac{1}{9}$	Water	1·0466	$\frac{1}{22}$
Olive oil	1·0800	$\frac{1}{12}$	Mercury	1·018	$\frac{1}{56}$
Turpentine	1·0700	$\frac{1}{14}$	Spirits of wine	1·110	$\frac{1}{9}$
Air	1·374	$\frac{1}{3}$			

To find the weight of water that can be evaporated from and at 212° F. in lbs. per lb. of fuel—

$$\cdot 15 \left\{ \% \text{ of C} + (4{\cdot}28 \times \% \text{H}) \right\} \text{ or,}$$

$$\frac{\text{Total heat of combustion}}{966}$$

Coefficient of the Expansion of Gases. (Charles's Law.)

All gases expand $\frac{1}{273}$rd part of their volume for every degree Centigrade increase in temperature above 0°; or, in decimals, 0·003665.

Expansion and Weight of Water from 32° to 500° F.

Temperature.	Relative Volume by Expansion.	Weight of 1 Cubic Foot.	Weight of 1 Gallon.	Temperature.	Relative Volume by Expansion.	Weight of 1 Cubic Foot.	Weight of 1 Gal on.
Deg. F.		Lbs.	Lbs.	Deg. F.		Lbs.	Lbs.
32	1·00000	62·418	10·0101	125	1·01239	61·654	9·887
35	·99993	62·422	10·0103	130	1·01390	61·563	9·873
39·1	·99989	62·425	10·0112	135	1·01539	61·472	9·859
40	·99989	62·425	10·0112	140	1·01690	61·381	9·844
45	·99993	62·422	10·0103	145	1·01839	61·291	9·829
46	1·00000	62·418	10·0101	150	1·01989	61·201	9·815
50	1·00015	62·409	10·0087	155	1·02164	61·096	9·799
52·3	1·00029	62·400	10·0072	160	1·02340	60·991	9·781
55	1·00038	62·394	10·0063	165	1·02589	60·843	9·757
60	1·00074	62·372	10·0053	170	1·02690	60·783	9·748
62	1·00101	62·355	10·0000	175	1·02906	60·665	9·728
65	1·00119	62·344	9·9982	180	1·03100	60·548	9·711
70	1·00160	62·313	9·9933	185	1·03300	60·430	9·691
75	1·00239	62·275	9·9871	190	1·03500	60·314	9·672
80	1·00299	62·232	9·980	195	1·03700	60·198	9·654
85	1·00379	62·182	9·972	200	1·03889	60·081	9·635
90	1·00459	62·133	9·964	205	1·0414	59·93	9·611
95	1·00554	62·074	9·955	210	1·0434	59·82	9·594
100	1·00639	62·022	9·947	212	1·0466	59·64	9·565
105	1·00739	61·960	9·937	250	1·06243	58·75	9·422
110	1·00889	61·868	9·922	300	1·09563	56·97	9·136
115	1·00989	61·807	9·913	400	1·1	54·25	8·700
120	1·01139	61·715	9·897	500	1·2	51·16	8·204

Freezing Points.

Substances.	Centigrade.		Fahrenheit.
Bromine freezes at . . .	—20°	=	—40°
Oil anise „ . . .	10°	=	50°
„ olive „ . . .	10°	=	50°
„ rose „ . . .	15°	=	60°
Quicksilver „ . . .	—39·4°	=	—39°
Water „ . . .	0°	=	32°

Melting Points and Expansions of Metals.

Metals.	Specific Heat.	Melting Point. C.	Melting Point. F.	Coefficient of Expansion. Per Degree F.
Aluminium, pure	·234	704 to 899	1,300 to 1,650	·00001235
Antimony	·0508	432 to 621	810 to 1,150	·00000601
Asphalt	—	100	212	
Bismuth	·031	264	507	·0000078
Brass	·094	899	1,650	·00001047
Bronze	—	921	1,690	
Copper	·0951	1,091	1,996	·000001
Gold, standard	·095	1,180	2,156	·00000821
„ pure	—	1,250	2,282	
Iron, cast (grey)	·130	1,124	2,056	·00000616
„ „ (white)	·129	1,050 to 1,100	1,922 to 2,012	
„ wrought	·110	1,600	2,912	·00000657
Lead	·031	324	615	·00001555
Mercury	·033	39·4	– 39	·00009984
Nickel	·109	1,543	2,810	·00000695
Platinum	·038	1,693	3,080	·00000493
Palladium	—	1,500	2,732	
Silver	·057	1,001	1,834	·00001063
Steel, hard	·117	1,300	2,732	·00000695
„ mild		1,400	2,552	·00000672
Tin	·057	230	444	·0000121
Zinc	·096	401	754	·00001636

Melting Points of Solids.

Substance.	Melting Points. C.	Melting Points. F.	Substance.	Melting Points. C.	Melting Points. F.
Butter	33·0	91	Sodium chloride	776	1,429
Calcium chloride	726	1,339	„ sulphate	865	1,589
CO_2	—	—108	Spermaceti	49	120
Ice	0	32	Stearine	43 to 49	109 to 120
Iodine	115	239			
Nitro-glycerine	7	45	Sulphur	112	234
Phosphorus	44	111	Tallow	33	92
Potassium iodate	560	1,040	Turpentine	—10	14
„ iodide	634	1,173	Wax, bees'	65	150
Silver nitrate	198	389	„ paraffin	45	114

Melting Points of Alloys.

Tin.	Lead.	Bismuth.	Softens at.	Melts at.
			Degrees F.	Degrees F.
5	3	8	—	202
1	1	1	—	254
2	2	1	—	292
4	4	1	—	320
2	1	—	—	340
4	1	—	—	365
1	1	—	365	371
6	1	—	—	381
2	6	—	372	383
2	7	—	377·5	388
2	8	—	395·5	408
1	2	—	—	441
1	3	—	—	482
1	5	—	—	511

Boiling Points, Latent Heat of Evaporation, and Heat from 32° F. of 1 lb.

	Boiling Point.		Latent heat of Evaporation of 1 lb.	Volume at 32° F. = 1. Volume at 212° F. equals.	Total heat from 32° F. of 1 lb.
	C.	F.			
Alcohol	78	173	374	1·110	461·7
Ammonia	60	140			
Benzine	80	176			
Bisulphide of carbon	47	116			
Bromine	63	145			
Ether	35	95			
„ nitrous	14	57			
Iodine	181	347			
Linseed oil	314	597			
Mercury	342	648	—	1·018	
Nitric acid	—	—	—	1·110	
Olive oil	315	600	—	1·080	
Paraffin	280	536			
Petroleum	158	316			
Quicksilver	350	662			
Salt	413	775			
Sulphur	236	447			
Sulphuric ether	38	100	175	—	210·4
Sulphurous acid	—10	14			
Turpentine	157	315	124	1·070	256·6
Water	100	212	965·2	1·047	1146·1
„ sea	101	213·2	—	1·050	
„ saturated brine	108	226			
Wood spirit	66	150	475	—	545·9
Zinc	1,040	1,904	—	1·0029	

The specific heat of a body is the ratio of the quantity of heat required to raise that body 1° in temperature, compared to the quantity of heat required to raise an equal weight of water from 39° to 40° F.

Specific Heats.

Acid hydrochloric	·600	Petroleum	·434
Alcohol	·659	Phosphorus	·2503
Benzene	·3932	Quicklime	·2169
Brickwork	·192	Soda	·2311
Chalk	·2148	Stonework	·197
Carbon	·2411	Sulphur	·2026
Charcoal	·2415	Sulphuric acid, density 1·87	·3346
Coal, anthracite	·2017	„ „ „ 1·30	·6614
„ bituminous	·2411	Sulphate of lead	·0872
Coke	·203*	„ „ lime	·1966
Ether	·521	Turpentine	·416
Glass	·1937	Vinegar	·92
Graphite	·2019	Water at 32° F.	1·0
Ice	·504	„ „ 212° F.	1·013
Magnesium limestone	·2174	Wood, average	·550
Marble	·2129	„ spirit	·6009
Olive oil	·3096		

* Increases as temperature rises.

The atomic specific heat of carbon is expressed by the following formulæ :—From 0° to 250° C., it is $C = 1·92 + 0·0077t$; from 250° to 1,000° C., it is $C = 3·54 + 0·0246t$. (MM. Uchène and Biju-Duval.)

Specific Heats of Gases, &c.

	Equal Pressure.	Equal Volume.		Equal Pressure.	Equal Volume.
Acetone	0·4125	0·8244	Hydrogen	3·4046	0·2359
Air	0·2377	0·2374	H_2S	0·2432	0·2857
Alcohol	0·4534	0·7171	Hydrochloric acid	0·1845	0·2333
„ vapour	0·4513	0·3200			
Ammonia	0·5083	0·2966	Light carburetted hydrogen	0·5929	0·4683
Benzole	0·3754	1·0114	Marsh gas	0·5929	0·3277
Binoxide of nitrogen	0·2315	0·2406	Nitrogen	0·2440	0·2370
Bromine	0·0555	0·3040	Nitric acid	0·2317	0·2406
Chlorine	0·1210	0·2962	„ oxide	0·2262	0·3447
CO	0·2479	0·2370	Oxygen	0·2182	0·2405
CO_2	0·2164	0·3307	Steam, saturated	—	0·3050
CS_2	0·1570	0·4140	„ gas	0·4750	0·2984
Chloroform	0·1567	0·6461	Sulphurous anhydride	0·1553	0·3414
Ether	0·4810	1·2296			
Ethylene	0·4040	0·4106	Turpentine	0·4160	2·3776

Specific Heat of Water at Different Temperatures.

Temperature, F.	Specific Heat.	Heat to Raise 1 lb. Water from 32° F. to given Temperature.	Temperature, F.	Specific Heat.	Heat to Raise 1 lb. Water from 32° F. to given Temperature.
Degrees.		Units.	Degrees.		Units.
32	1·0000	0·000	248	1·0177	217·449
50	1·0005	18·004	266	1·0204	235·791
68	1·0012	36·018	284	1·0232	254·187
86	1·0020	54·047	302	1·0262	272·628
104	1·0030	72·090	320	1·0294	291·132
122	1·0042	90·157	338	1·0328	309·690
140	1·0056	108·247	356	1·0364	328·320
158	1·0072	126·378	374	1·0401	347·004
176	1·0089	144·508	392	1·0440	365·760
194	1·0109	162·686	410	1·0481	384·588
212	1·0130	180·900	428	1·0524	403·488
230	1·0153	199·152	446	1·0568	422·478

Freezing Mixtures.

	Fall in Temperature.	Degrees Cold produced.
Nitrate of ammonia . 1 part Water . . . . . 1 ,,	From + 50° to + 4° F.	46° F.
Dilute sulphuric acid . 2 ,, Snow . . . . . 3 ,,	,, + 32 ,, − 23 ,,	55 ,,
Muriate of lime . . ,, Snow . . . . . ,,	,, + 20 ,, − 48 ,,	68 ,,
Phosphate of soda . 9 ,, Nitrate of ammonia . 6 ,, Dilute nitric acid . 4 ,,	,, + 50 ,, − 21 ,,	71 ,,
Common salt . . . 1 ,, Snow or powdered ice 2 ,,	From any temperature to − 5° F.	
Common salt . . 5 ,, Nitrate of ammonia . 5 ,, Snow or powdered ice 12 ,,	From any temperature to − 25° F.	
Sulphate of sodium . 3 ,, Dilute nitric acid . . 2 ,,	From 10° C. to − 18° C.	
Phosphate of sodium . 6 ,, Dilute nitric acid . 5 ,,	,, ,, ,, − 29 ,,	
Crystallized calcium chloride . . . 10 ,, Snow . . . . . 7 ,,	,, ,, ,, − 50 ,,	

Water (H_2O) when freezing expands from 1 volume to 1·09.

Expansion of Liquids in Volume from 32° to 212°.

1,000 parts of water	. .	become	1,046
" " oil	. . .	"	1,080
" " mercury	. . .	"	1,018
" " spirits of wine		"	1,110
" " atmospheric air		"	1,376

Latent Heat is the heat absorbed by any substance, without raising its temperature, in changing from the solid to the liquid state, or from the liquid to the gaseous state.

Latent Heats of Fusion.

Mercury	2·8	Bismuth	12·6
Lead	5·4	Silver	21·1
Sulphur	9·4	Water	80·2

Latent Heat Liquefaction.

Water at 39° F	142·65	Silver	37·93
Bismuth	22·75	Tin	25·65
Lead	9·67	Zinc	50·63
Mercury	5·09		

Comparative Powers of Solids for Conducting Heat.

Gold	1,000	Aluminium	305
Platinum	981	Tin	304
Silver	973	Lead	180
Copper	892	Marble	24
Brass	749	Bismuth	18
Iron, cast	562	Porcelain	12
" wrought	374	Terra Cotta	11
Zinc	363		

Relative Heat Conductivity of Metals. Silver equals 1,000.

Silver	1,000	Tin	422
Gold	981	Steel	397
Copper	845	Platinum	380
Mercury	677	Cast Iron	359
Aluminium	665	Lead	287
Zinc	641	Antimony	215
Wrought Iron	436	Bismuth	61

Comparative Powers of Solids for Absorbing or Radiating and Reflecting.

	Reflecting.	Absorbing.
Silver, polished	97 per cent.	3 per cent.
Gold	95 ,, ,,	5 ,, ,,
Copper	93 ,, ,,	7 ,, ,,
Brass, bright polished	93 ,, ,,	7 ,, ,,
,, dead ,,	89 ,, ,,	11 ,, ,,
Speculum metal	86 ,, ,,	14 ,, ,,
Tin	85 ,, ,,	15 ,, ,,
Steel, polished	83 ,, ,,	17 ,, ,,
Platinum, sheet	83 ,, ,,	17 ,, ,,
,, polished	80 ,, ,,	20 ,, ,,
Zinc	81 ,, ,,	19 ,, ,,
Mercury	77 ,, ,,	23 ,, ,,
Iron, wrought, polished	77 ,, ,,	23 ,, ,,
,, cast, ,,	75 ,, ,,	25 ,, ,,
Silver leaf on glass	73 ,, ,,	27 ,, ,,
Ice	15 ,, ,,	85 ,, ,,
Glass	10 ,, ,,	90 ,, ,,
Writing paper	2 ,, ,,	98 ,, ,,
Water	0 ,, ,,	100 ,, ,,
Marble	2 to 7 ,, ,,	98 to 93 ,, ,,

Quantity of Heat Lost per Square Unit of Surface. (Peclet.)

Excess of Temperature of Gas over Air.	Loss in Air.	Loss in Water.
10°	8	88
20°	18	266
30°	29	5,353
40°	40	8,944
50°	53	13,437

Effect of Mixing Water at Different Temperatures.

1 lb. of water at 0° C. + 1 lb. of water at 16° C. equals 2 lbs. of water at 8° C.

1 lb. of water at 0° C. + 1 lb. of water at 35° C. equals 2 lbs. of water at 17·5° C.

1 lb. of water at 16° C. + 1 lb. of water at 35° C. equals 2 lbs. of water at 25·5° C.

1 lb. of water cooling from 16° to 8° raised the temperature of 1 lb. from 0° to 8°.

Convection is the transference of heat by particles.

Conduction is the transmission from particle to particle.

Board of Trade Thermal Unit equals quantity of heat necessary to raise 1 lb. pure water 1° F. from 39·1° to 40·1°.

Calorie equals quantity of heat necessary to raise 1 kilogramme pure water 1° C. at or about 4° C.

B. T. U. × ·252 = Calories, or Calories × 3·968 = B. T. U.

Joule's Law —1 B. T. U. equals 772 foot lbs. work performed.

Joule's law shows that the quantity of work required to raise the temperature of 1 lb. of water, weighed in vacuum, from 60° to 61° F. equals 772·55 foot lbs. at sea level in the latitude of Greenwich; or the amount of work that is converted into heat by raising 1 lb. of water 1° C. is 1,390 foot lbs. ($\frac{9}{5}$ths of 772).

Metals all possess the same atomic heat = 6·4.

To convert Fahrenheit to Centigrade $\frac{5\,(F. - 32)}{9} = C.$

To convert Centigrade to Fahrenheit $\frac{9\,C.}{5} + 32 = F.$

Comparison of the Value of Coal Gas for Motive Power and Lighting at Different Candle Powers. (C. Hunt.)

Illuminating Power of Gas. Candles.	Consumption per I.H.P. per Hour. Cubic Feet.	Value for Motive Power.	Value for Lighting.
11·96	30·31	1·000	1·000
15·00	24·41	1·241	1·254
17·20	22·70	1·335	1·438
22·85	17·73	1·709	1·910
26·00	16·26	1·864	2·173
29·14	15·00	2·020	2·436

Calorific Value of Coal Gas. (T. L. Millar.)

	Illuminating Power.	Heating Power per Cubic Feet.
Glasgow . . .	$21\frac{1}{3}$ candles	813 heat units
Liverpool . . .	21 ,,	770 ,, ,,
Kilmarnock . .	25 ,,	680 ,, ,,
Manchester . . .	16 and $19\frac{1}{2}$ candles	654 ,, ,,
Birmingham . .	$17\frac{1}{4}$ candles	639 ,, ,,
London . . .	16 ,,	624 ,, ,,
Hoboken . .	—	617 ,, ,,
Berlin . . .	—	549 ,, ,,

Theoretical value in heat units of 1 cubic foot of gas equals 660 to 670 (1 lb. water heated 1° F.).

The number of heat units obtainable in practice is:—In the best bath heaters, about 600; in the best boiling burners, about 375.

Effective heating duty of coal gas in small vessels equals 300 to 320 units.

Effective heating duty of coal gas in ordinary flat-bottomed vessels with projecting rivets equals 520 units.

Effective heating duty of coal gas in domestic pans and kettles equals 300 units.

Effective heating duty of coal gas in small pans and kettles equals 150 units. (T. Fletcher.)

15 candle gas gives	620 heat units per cubic foot.			
19 „ „	800	„	„	
28 „ „	950	„	„	

(N. H. Humphreys.)

1 lb. H	burning to H_2O	gives off	62,535	heat units.
1 lb. C	„ CO_2	„	12,906	„
1 lb. C	„ CO	„	2,495	„
1 lb. CO	„ CO_2	„	4,478	„

(Dulong.)

Carbon, when combined with hydrogen to form olefiant gas (C_2H_4) and acetylene (C_2H_2), has a locked-up heat energy, as compared with the carbon forming marsh gas (CH_4) of 31,300 and 75,430 heat units respectively which are developed as light and heat when the gases are burned. (W. Young.)

Heat Units Generated by Complete Combustion per lb.

Hydrogen	62,000 heat units.
Carbon	14,500 „
Sulphur	4,000 „

The maximum temperature obtainable by the combustion of C equals about 5,000° F.

The maximum temperature obtainable by the combustion of H equals about 5,800° F.

Heat Units per lb.	Favre and Silbermann.
H	34,462
C	7,770
Coke (dessicated)	7,000
CO	2,400

Heat unit equals 1 kilo. water raised 1° C.

Calorific value of H = 34,500 units.
„ „ Methane = 8,080 „

Sulphur evolves 2,220 units of heat per lb.

Average coke yields 12,000 heat units per lb. when burnt to CO_2.

Pure carbon yields 14,500 heat units per lb. when burnt to CO_2.

For every lb. H combined with O to form water, sufficient heat is evolved to raise 34,400 lbs. water 1° C.

One ton coal	= 8,353,846·640 calories.
10,000 cubic feet gas . . .	= 1,635,000·000 „

An average Lancashire coal is said to have a calorific power of 13,890, which means that 1 lb. of the coal would raise 13,890 lbs. water through 1° F. of temperature.

Relative calorific intensity of coke per lb. = 2,114° C.
„ „ tar „ = 2,486° C.
(F. G. Dexter.)

1 lb. H + 8 lbs. O will raise 34,462 lbs. water 1° C.

Latent heat of steam . . .	536 thermal units
„ water	79 „ „
Maximum heat obtainable by air blast . .	2,500°

The boiling point of hydrogen is found to be 234·5° below zero.
Benzene or benzol (C_6H_6) boils at 81° and freezes at 0° C.
Napthalene ($C_{10}H_8$) melts at 80° and boils at 217° C.
Anthracene ($C_{14}H_{10}$) melts at 213° and boils at a little above 360° C.

To prepare Acetate of Lead Test Papers.

Moisten sheets of bibulous paper with a solution of 1 part sugar of lead in 8 or 9 parts water and hold each sheet, while still damp, over the surface of a strong solution of ammonia for a few moments.

Such papers will become tinged if subjected to gas containing 0·001 per cent. by volume of H_2S for 24 hours, light being excluded during that time.

To make Turmeric Papers.

Six parts methylated spirit to 1 of turmeric powder by weight, to be well shaken from time to time for 3 days. Decant clear liquid and soak sheets of botanical or filtering paper in it, dry and keep in the dark. The papers should be a full yellow colour. One grain or more NH_3 per 100 cubic feet will cause the colour to change to brownish tint.

To make Red Litmus Paper.

Dissolve 1 oz. powdered blue litmus in 6 ozs. cold distilled water and shake well, allow to dissolve and filter, add gradually dilute H_2SO_4 until it is changed to a red tint; soak sheets of glazed paper in it and dry. These papers turn blue when exposed to gas containing NH_3.

To make Lime Water.

Dissolve 4 ozs. caustic lime in 1 quart water, shake occasionally, decant the clear liquid and keep it free from CO_2.

If gas containing CO_2 is bubbled through a portion of above, it forms $CaCO_3$, the liquid becoming milky, thus:

$$CaO + CO_2 = CaCO_3.$$

If still clear, after bubbling for 3 minutes, the gas is probably quite free from CO_2.

All H_2S must be removed from the gas by means of oxide of iron before making above test.

To prepare Litmus for Indicating Acids and Alkalies.

Digest solid litmus in hot water and evaporate to a certain degree, add a small quantity acetic acid. Evaporate again and add methylated spirit. Filter the precipitate and wash with spirit, dissolve with warm water and add a small quantity nitric acid. Keep exposed to the air to preserve the colour. Free CO_2 effects the change in colour of the solution.

To prepare Cochineal for Analysis of Ammonia.

Take 1 part methylated spirit and 4 parts water, keep at a gentle heat for some hours with about 10 grammes cochineal powder to every 1,000 cubic centimetres of the solution, cool and decant the clear liquid. Its yellow colour is changed to red by alkalies, and to yellow again by mineral acids and is not affected by CO_2.

The acid must be added to the alkali solution when using this indicator.

To prepare Methyl-orange for estimating Ammonia in Gas.

Dissolve 1 gramme of methyl-orange, in powder, in methylated spirit and make up to 1 litre with a solution of one part water and one part methylated spirit.

The colour is changed to yellow by alkalies and then to red by acids ; it is not affected by CO_2.

To prepare Phenol-phthalein.

Make an alcoholic solution which should be colourless, but an alkali causes it to become red, and this is again destroyed by an acid. Phenol-phthalein is affected by the presence of ammonia salts or CO_2.

Standard Solution.

For testing gas liquor (Will's test)—

125 cubic centimetres NH_3 (specific gravity ·880) to 1 litre H_2O.
10 per cent. acid (specific gravity of strong acid).
$\begin{cases} 1{\cdot}067 = 9{\cdot}8 \text{ per cent. acid.} \\ 10 \text{ parts to } 90 \text{ of water.} \end{cases}$
10 per cent. acid = 1064·4 specific gravity.

To prepare Standard Acid Solution for test of Ammonia.

Measure a gallon of distilled water in a clean earthenware jar or other suitable vessel. Add to this 94 septems of pure concentrated sulphuric acid and mix thoroughly. Take exactly 50 septems of the liquid and precipitate it with barium chloride in the manner prescribed for the sulphur test. The weight of barium sulphate which 50 septems of the test acid should yield is 13·8 grains. The weight obtained with the dilute acid prepared as above will be somewhat greater, unless the sulphuric acid used had a specific gravity below 1·84. Add now to the dilute acid a measured quantity of water, which is to be found by subtracting 13·8 from the weight of barium sulphate obtained in the experiment and multiplying the difference by 726. The resulting number is the number of septems of water to be added. If these operations have been accurately performed, a second precipitation and weighing of the barium sulphate obtainable from 50 septems of the test acid will give nearly the correct number of 13·8 grains. If the weight exceeds 13·9 grains, or falls below 13·7 grains more water or sulphuric acid must be added, and fresh trials made until the weight falls within these limits. The test-acid thus prepared should be transferred at once to stoppered bottles which have been well drained, and are duly labelled. (Metropolitan Gas Referees.)

To prepare the Standard Solution of Ammonia.

Measure out as before a gallon of distilled water, and mix with it 20 septems of strong solution ammonia (specific gravity 0·88). Try whether 100 septems of the test alkali thus prepared will neutralize 25 of the test acid, proceeding according to the direction given subsequently as to the mode of testing. If the acid is just neutralized by the last few drops, the test-alkali is of the required strength; but if not, small additional quantities of water or of strong ammonia solution must be added, and fresh trials made, until the proper strength has been attained. The bottles in which the solution is stored should be filled nearly full and well stoppered. (Metropolitan Gas Referees.)

To prepare Potassium Hydroxide for determining CO_2.

Use commercial stick potash, not purified by alcohol, dissolve 8 ozs. in a pint of distilled water for careful and exact tests, but for ordinary work, a more dilute solution may be used.

To prepare Bromine for determining the Hydrocarbons.

Make an aqueous solution of bromine almost saturated. Before measuring the absorption the vapour of the bromine must be removed by potassium hydroxide solution.

A solution of bromine in potassium bromide is sometimes used.

To prepare Cuprous Chloride Solution for determining CO.

For the hydrochloric acid solution, place 100 grammes of precipitated cuprous chloride in a bottle and pour on 500 cubic centimetres of concentrated hydrochloric acid, into which put some copper spirals so as to reach to the top of the liquid.

For the ammoniacal solution, place 40 grammes of precipitated cuprous chloride in a bottle and fill up with 400 cubic centimetres of water, into this bubble some ammonia gas, made by boiling some strong ammonia solution, the fumes from which are carried into the bottle containing the cuprous chloride, until the latter assumes a pale blue colour, then make the solution up to 500 cubic centimetres, and carefully stopper the bottle.

To prepare Sulphuric Acid for determining the Hydrocarbons.

The acid to be used must be strongly fuming acid (Nordhausen) which on cooling to a slight degree below usual temperatures, deposits crystals readily. It is used either on coke balls thoroughly saturated or in absorption pipettes with glass balls inside. Before measuring the absorption, the acid vapours must be removed by potassium hydroxide solution.

To prepare Pyrogallic Acid Solution for determining Oxygen.

Dissolve fresh pyrogallic acid in 3 times its weight of water (distilled). After pouring this into the absorption tube, put in eight times the volume of caustic potash solution. The absorption of oxygen is slow and requires about 5 minutes' agitation.

To prepare Normal Oxalic Acid.

This solution should contain 63 grammes per litre. Dissolve this quantity in distilled water and make up to 1 litre. Test against normal alkali. Do not use this acid with methyl-orange, and keep it out of direct sunlight.

To prepare Normal Hydrochloric Acid.

This solution should contain 36·5 grammes per litre. Dilute strong hydrochloric acid with distilled water and make it of 1·10 specific gravity at 60° F. Test against normal solution of sodium hydrate and dilute to normal strength.

To prepare Normal Sulphuric Acid Solution.

This should contain 49 grammes pure H_2SO_4 per litre. Add strong sulphuric acid to distilled water, and when cool test by means of standard sodium carbonate solution, and add water to reduce to normal strength. When the solution is correct an equal quantity of the acid should exactly neutralize an equal quantity of the alkali.

To prepare Normal Solution of Sodium Carbonate.

The solution should contain 53 grammes pure Na_2CO_3 per litre and the Na_2CO_3 should be dissolved in the water, and, when at normal temperature, the amount made up to the exact quantity by adding distilled water.

To prepare Normal Sodium Hydrate Solution.

This solution should contain 40 grammes per litre. Dissolve about 44 grammes caustic soda, purified by alcohol, in distilled water, recently boiled and cooled, Or use 25 grammes clean metallic sodium in distilled water. Test with normal acid solution and dilute to proper strength. Specific gravity of solution 50 grammes per litre equals 1·05.

25 septems standard acid neutralize 1 grain NH_3.
100 „ „ ammonia contain 1 grain NH_3.

Equivalent Normal Solutions.

Nitric acid	63 grams per litre.
Anhydrous carbonate of soda . . .	53 „ „ „
Sulphuric acid	49 „ „ „
Sodic hydrate	40 „ „ „
Hydrochloric acid	36·5 „ „ „
Ammonia	17 „ „ „

Degrees of Twaddell's Hydrometer compared with Specific Gravity.

Twaddell.	Specific Gravity.	Twaddell.	Specific Gravity.	Twaddell.	Specific Gravity.	Twaddell.	Specific Gravity.
0	1·000	6	1·030	13	1·065	19	1·095
1	1·005	7	1·035	13·4	1·067	20	1·100
1·4	1·007	7·4	1·037	14	1·070	21	1·105
2	1·010	8	1·040	15	1·075	21·6	1·108
2·8	1·014	9	1·045	16	1·080	22	1·110
3	1·015	10	1·050	16·6	1·083	23	1·115
4	1·020	10·2	1·052	17·0	1·085	23·2	1·116
4·4	1·022	11	1·055	18·0	1·090	24	1·120
5	1·025	12	1·060	18·2	1·091	25	1·125
5·8	1·029						

Degrees Twaddell × 5 + 1·000 equals specific gravity.

$$\frac{\text{Specific gravity} - 1{\cdot}000}{5} = \text{Degrees Twaddell.}$$

To find the volume of air required to chemically combine with any fuel to support complete combustion :—

$$1{\cdot}52 \left\{ \text{per cent. of C} + 3 \text{ (per cent. of H)} - {\cdot}4 \text{ (per cent. of O)} \right\}$$

equals cubic feet per lb. fuel, of air as at 62° F. and at one atmosphere.

In above no notice is taken of the air required by the sulphur, which is only nominal.

To find the volume of gaseous products on complete combustion of 1 lb. fuel as at 62° F. at one atmosphere.

$$(1{\cdot}52 \times \text{per cent. of C}) + (5{\cdot}52 \times \text{per cent. of H})$$

To find the weight of gaseous products on complete combustion of 1 lb. fuel as at 62° F. at one atmosphere :—

$$({\cdot}126 \times \text{per cent. of C}) + ({\cdot}358 \times \text{per cent. of H})$$

To find the total heat of combustion of any fuel containing C and H :—

$$145 \left\{ \text{per cent. of C} + (4{\cdot}28 \times \text{per cent. H}) \right\}$$

The richer the gas the greater the quantity of O required for complete combustion.

1 volume gas requires 5½ volumes air for complete combustion.

Results of different mixtures of Gas and Air on Light given by Incandescent Burners. (W. Foulis.)

Glasgow Gas.	Air.	Illuminating Power per Cubic Foot.
1	7	13·0 candles.
1	5·8	28·2 „
1	4	17·3 „

With gases of over 50 candle power the addition of small quantities of O increases the illuminating power by combining rapidly with the H of the hydrocarbons and therefore not requiring the use of a similar quantity of O combined with N from the air, the N acting merely as a diluent, with low quality gases the quantity of O possible to effect an increase is very minute.

The addition of a small proportion of oxygen to coal gas was found by Dr. P. Frankland to sensibly increase the illuminating power, but the addition of even a small quantity of nitrogen materially decreases it. 1 per cent. N reduced the luminosity 1 per cent.

Loss of Light by the addition of air to Coal Gas. (Wurtz.)

Air.	Loss of Light.
3·00	15·69 per cent.
4·96	23·83 „ „
11·71	41·46 „ „
16·18	57·53 „ „
25·00	84·00 „ „

Loss of Light per Cent. by Mixing Air with Coal Gas.

Air, per cent.	1	2	3	4	5	6	7	8	9	10	15	20	30	40
Loss of Light, per cent.	6	11	18	26	33	44	53	58	64	67	80	93	98	100

The reason CO_2 is a more harmful substance than N is that the specific heat of CO_2 is nearly half as much again as that of N and consequently the amount of heat taken up by CO_2 in being raised to the temperature of the flame is greater than that taken up by nitrogen.

One per cent. CO_2 reduces the illuminating power about 4 per cent.

CO_2, air, N, and water vapour, cool and dilute flames.

H and CO dilute only.

The addition of N to pure ethylene reduces luminosity in proportion to its volume, but probably when N is added to coal gas some of the tarry vapours are carried forward by it, and the luminosity is therefore not decreased to the same extent.

Comparative Duty of Different Burners with 16-candle Gas.

(Professor Lewes.)

Burner.	Light per Cubic Foot of Gas.	Burner.	Light per Cubic Foot of Gas.
Flat flame, No. 0	0·59	Flat flame, No. 6	2·15
" " " 1	0·85	" " " 7	2·44
" " " 2	1·22	Ordinary Argand	2·90
" " " 3	1·63	Standard "	3·20
" " " 4	1·74	Regenerative	10·00
" " " 5	1·87		

Efficiency of Incandescent Burners with Different Quality Gases.

(Foulis.)

Ordinary Burner (Flat Flame).		Incandescent Burner.	
Illuminating Power Corrected to 5 Cubic Feet.	Candles per Cubic Foot.	Illuminating Power Corrected to 5 Cubic Feet.	Candles per Cubic Foot.
23·1	4·6	117·3	23·40
17·9	3·6	90·3	18·07
16·2	3·2	87·9	17·59
14·6	2·9	84·4	16·89
13·5	2·7	81·9	16·39

The following Table gives the results obtained with Edinburgh gas when consumed from various burners :—

Five cubic feet are equal to :—

	Candle Power.
Bray No. 8	25·00
Bray "Special" No. 8	29·43
Bray Adjustable " 3/0	21·72
" " 4/1	26·66
" " 5/2	28·37
" " 6/3	30·39
" " 7/4	36·16
" " 8/5	36·76
Milne's Old Regulator	36·87
Spon's Deflector and No. 7 Bray	28·00
Noleton Duplex (No. 0 Bray)	32·35
Parkinson Regulator and No. 7. Bray	18·12
Peeble's Regulator, No. 4/2	20·75
" " 6/4	25·00
" " 7/6	23·75
" " 8/8	28·57
" Street Burner	19·41
Welsbach "S" Burner	53·30
" "C" "	61·95

(Professor W. I. Macadam.)

With a Union jet CH_4 and C_2H_6 are non-luminous.

Average Composition of London Gas. (Dr. Letheby.)

	Common Gas.	Cannel Gas.
	Twelve Candle.	Twenty Candle.
Hydrogen	46·0	27·7
Light carburetted hydrogen	39·5	50·0
Condensable hydrocarbons	3·8	13·0
Carbonic acid	0·6	0·1
Carbonic oxide	7·5	6·8
Aqueous vapour	2·0	2·0
Oxygen	0·1	0.0
Nitrogen	0·5	0·4
	100·0	100·0

Analysis of London Gas at probably 12 Candle Power.

(Thwaite.)

	Per Cent.
Unsaturated hydrocarbons	3·84
Benzol	1·04
Marsh Gas	35·63
Carbon anhydride	1·41
CO	6·15
H	47·73
O	0·30
N	3·90

Analysis of Coal Gas, London. (*Lancet.*)

	By Volume.	By Weight.
Benzene (C_6H_6)	0·55	3·98
Olefines (C_2H_4)	4·45	11·76
Carbon monoxide (CO)	7·80	20·00
Hydrogen (H)	52·90	9·84
Methane (CH_4)	31·80	48·00
Nitrogen (N)	2·50	6·42

Average Composition of 16 to 17 Candles Caking Coal Gas.

(L. T. Wright.)

	Per Cent.
Hydrocarbons capable of absorption, say (CnHm)	4
Paraffins, treated as Marsh gas (CH_4)	38
CO	6
H	48 to 50
N	2

Composition of London Gas, 26th May, 1893.

(Professor Lewes.)

	South Metropolitan Gas Company.	Gas Light and Coke Company.
Hydrogen	50·16	53·36
Unsaturated hydrocarbons	3·50	3·58
Saturated hydrocarbons	36·25	32·69
CO	5·68	7·05
N	4·10	2·50
CO_2	0·00	0·61
O	0·31	0·21
H_2S	*nil*	*nil*
	100·00	100·00

Composition of London Gas Companies' Coal Gas.

(Professor Lewes.)

	South Metropolitan.	Gas Light and Coke.	Commercial.
Hydrogen	52·22	53·36	52·96
Unsaturated hydrocarbons	3·47	3·58	3·24
Saturated hydrocarbons	34·76	32·69	34·20
CO	4·23	7·05	4·75
CO_2	0·60	0·61	0·75
N	4·23	2·50	5·10
O	0·49	0·21	0·00

Approximate Analysis of London Coal Gas.

(Professor V. B. Lewes.)

H	by volume	52·0	per cent.,	by weight	9·6	per cent.
Unsaturated hydrocarbons, C_2H_4	,,	3·0	,,	,,	7·7	,,
Saturated hydrocarbons, C_6H_6	,,	1·0	,,	,,	7·1	,,
Saturated hydrocarbons, CH_4	,,	34·0	,,	,,	49·9	,,
CO	,,	5·0	,,	,,	12·8	,,
N	,,	4·5	,,	,,	11·5	,,
CO_2	,,	0·0	,,	,,	0·0	,,
O	,,	0·5	,,	,,	1·4	,,

The illuminating power is far more dependent upon the mode in which the C is combined than upon the actual percentage present in the gas. (W. Young.)

Composition of Coal Gas by Volume.

H . . .	34 to 53 per cent.	O and CO_2 .	1 to 0·3 per cent.
CH_4 marsh gas	43 to 36 „	C_4H_6 Olefines	13 to 3·0 „
CO . . .	6 to 2·7 „	N . . .	3 to 5·0 „

Composition in 100 Volumes. (Sir H. Roscoe.)

	Illuminating Power in Candles per 5 Cubic Feet.	H.	CH_4.	C_nH_{2n}.	C_2H_4.	CO.	N O CO_2.
Cannel gas	34·4	25·82	51·20	13·06	(22·08)	7·85	2·07
Coal gas .	13·0	47·60	41·53	3·05	(6·97)	7·82	

Average Composition of Natural Gas in America.

H	= 22	per cent.
Marsh gas	= 67	„
Other bodies in small quantities	= 11	„
	100	„

Composition of Coal Gas, Water Gas, and a Mixture.

(E. G. Love, 1889.)

	Coal.	Water.	Mixture.
Hydrogen	39·78	29·16	34·47
Marsh gas	45·16	24·42	34·79
CO	7·04	28·33	17·685
Ethylene	4·34	12·46	8·40
Ethane	—	0·78	0·39
Benzol vapour	2·04	2·88	2·46
CO^2	1·08	—	0·54
O	0·06	0·21	0·135
N	0·50	1·76	1·13
	100·00	100·00	100·00
Specific gravity (calculated) .	0·4644	0·6551	0·5597
Calorific power, heat units .	19233·6	13913·6	16114·4
Air required for combustion of 1 lb. of gas, lbs. . . .	14·70	10·22	13·08

(Extract from paper by E. G. Love, at Baltimore, U.S.A., 1889.)

Comparative Analysis of Coal Gas and Carburetted Water Gas.

(A. E. Broadberry.)

Description of Gas.	H_2S.	CO_2.	Illuminants.	O.	CO.	H.	Marsh Gas.	*Balance.
Unpurified carburetted water gas . . .	0·4	6·0	8·8	0·5	27·4	32·3	20·5	4·1
Unpurified coal gas from scrubber outlet .	1·4	1·3	2·3	1·1	5·2	43·0	37·1	8·6
Combined gas, purified equals 35 per cent. carburetted water gas . .	—	—	4·8	0·2	13·8	41·1	32·7	7·4

* Probably N.

Specific gravity of combined gases, ·5, H_2S and CO_2, calculated by explosion and absorption.

Napthalene is a white, shining, crystalline substance, fusing at 176° F., and boiling at 423° F., but volatilizing when brought into contact with steam. It is not soluble in water, but readily dissolves in alcohol, chloroform, naptha, ether, or carbon disulphide. When napthalene is found, the condition of the coal should first be looked after. The use of wet coal, particularly if slack, should be avoided.

A test is to neutralise the liquor with dilute sulphuric acid. If napthalene be present, the liquor assumes a rose colour, and the sulphate solution gives off the peculiar odour distinctly characteristic of napthalene.

Carbon Monoxide (CO) is colourless, and has no taste, burns with a lambent blue flame on admixture with oxygen and forms CO_2.

Can be absorbed by a solution of cuprous chloride (Cu_2 Cl_2).

Carbonic oxide is a colourless gas which burns with a bright blue flame forming CO_2, 2 or 3 per cent. in the air may prove fatal, it has no odour. Specific gravity is ·968, 100 cubic inches, weighs 30 grains.

Carbon Dioxide (CO_2) is colourless and has no smell, and is formed whenever carbon is burnt in excess of air or oxygen.

Ethylene or Olefiant Gas (C_2 H_4) is colourless and of a sweet taste, burns with a smoky luminous flame in air, explodes loudly when mixed with 3 volumes O and fired, the same quantity being required to cause complete combustion.

Methane or Marsh Gas (CH_4) is colourless, and burns with a non-luminous flame, is tasteless, and has no odour ; 1 volume CH_4 and 3 volumes O explode with a light when 1 volume O remains.

Marsh gas weighs 17·41 grains per 100 cubic inches. Density is ·559.

Relative, Calculated, and Found Values of Gases.

(Professor V. B. Lewes.)

	Illuminating Value. Calculated.	Found.
Methane	8·4	5·2
Ethane	35·0	35·0
Ethylene	60·9	68·5
Acetylene	202·2	240·0

At between 1,500° and 1,600° F., ethylene is broken up into acetylene and methane, with formation of benzene ; and at 1,832° F. napthalene and other bodies are formed, and at 2,000° F. are again broken down to acetylene, which then decomposes into C and H. (Professor V. B. Lewes.)

Not more than 2 cubic feet per hour of ethylene or ethane can be used in a "London" Argand burner without smoking.

The boiling point of ethane is 89·5 at 735 millimetres pressure.

The density of liquid ethane was found to be 0·446 at 0° and 0·396 at + 10·5°. (Dewar.)

Illuminating value of ethane 35, ethylene 68, acetylene 240.

Propane is a perfectly colourless liquid, but much more viscous than liquid carbon dioxide.

Heptane was found practically insoluble in water.

Boiling point of phenanthrene equals 350° C.

Olefiant gas burns well, 100 cubic inches weigh 30·57 grains. Density is ·981.

Acetylene is colourless and burns with a very brilliant flame. Specific gravity is ·920. If chlorine is added to acetylene the mixture explodes.

Specific gravity of CS_2 equals 1·29.

CS_2 boils at 46° C.

CS_2 vapour ignites at 300° F. (149° C.) when ethylene is not present.

Benzene C_6H_6.
Toluene C_7H_8.
Xylene C_8H_{10}.
Napthalene $C_{10}H_8$.
Heptane C_7H_{16}.

Propane is obtained in a state of purity by heating propyliodide with aluminium chloride in a sealed tube to 130°. After subjection to this temperature for twenty hours the tube is allowed to cool and subsequently placed in a freezing mixture. (A. E. Tutton.)

Lithium hydride is formed by raising metallic lithium to a red heat in an atmosphere of hydrogen. The gas is absorbed by the metal forming a white powder on which the atmosphere acts only very feebly. When wetted the powder restores the hydrogen it has absorbed and the quantity given off is greater weight for weight than is obtainable from any other material.

Argon density equals 19·940 to 19·941.

Argon viscosity equals 121. Air equals 100.

Specific gravity of graphite equals 2·15 to 2·35.

Specific gravity of hydrogen gas equals ·069.

A column of any perfect gas expands from 1 to 1·3665 between 0° C. and 100° C.

One cubic foot hydrogen weighs 37 grains, therefore to obtain weight of 1 cubic foot in gas of any gas, multiply half molecular weight if a compound gas, or molecular weight if a simple gas × 37.

The atomic weight of an elementary gas × ·0691 equals its specific gravity.

Half the atomic weight of a compound gas or vapour × ·0691 equals its specific gravity.

One litre H gas at 0° C., and 760 millimetres pressure, weighs 0·0896 grains.

H liquefies at about – 200° C.

Specific gravity O equals 1·1056, liquefies at – 14° C., and a pressure of 320 atmospheres.

To obtain weight in grains of any gas: specific gravity × 537 (weight of 1 cubic foot air) = grains per cubic foot.

The correct temperature of the boiling point of propane is found to be – 37° at 760 millimetres pressure. (Tutton.)

Ammonia density, ·589; weight of 100 cubic inches is 18·26 grains.

The hydrocarbons in unenriched coal gas, which give it its luminosity, are principally methane, ethylene, and benzene vapour.

Usually accepted theory of light is, that there are three distinct zones; the inner zone consisting of unburned gas, the middle luminous zone, where the H changes into water, developing heat, and consequent incandescence of C, and the outer zone, where the C becomes carbon anhydride.

Flame Temperatures. (Professor V. B. Lewes.)

Inner zone temperature rises from a comparatively low point at the mouth of the burner, to between 1,000° and 1,100° at the apex of the zone. Here takes place the conversion of the hydrocarbons into acetylene: the luminous zone, in which the temperature ranges from 1,100° to a little over 1,300°, with a decomposition of the elements of the acetylene formed in the inner zone; the extreme outer zone, in which the cooling and diluting influence of the entering air renders a thin layer non-luminous, and finally extinguishes it.

Temperature of Different Portions of Flame in Different Gases.

(Professor V. B. Lewes.)

	Acetylene.	Ethylene.	Coal Gas.
	Degrees C.	Degrees C.	Degrees C.
Non-luminous zone . . .	459	952	1,023
Commencement of luminosity . .	1,411	1,340	1,658
Near top of luminous zone . .	1,517	1,865	2,116

Temperature of the mantle of a coal gas flame is above the melting point of platinum. (Smithells.)

Hydrogen and CO only require half their volume of O for complete combustion, and therefore obtaining this quickly, give only a short flame. Methane requires twice its volume of O, and thus gives a flame nearly four times as long.

A flame of a given size requires a volume of gas, larger or smaller, according to the illuminating power of the gas.

The cause of luminosity in coal gas flames is not attributable to any one hydrocarbon, but to the combined action of all that are present in the gas. (Professor Lewes.)

The illuminating property of gas depends upon the presence of about 4 per cent. of unsaturated hydrocarbons.

Illuminating Value of Hydrocarbons per 5 Cubic Feet of Vapour.

(Professor Lewes, 1890.)

	Candles.		Candles.
Methane	5·2	Acetylene	240·0
Ethane	35·7	Benzene	420·0
Propane	56·7	Toluene	741·7
Ethylene	70·0	Napthalene	900·0
Propene	123·0		

The illuminating value of hydrocarbon gas, when consumed alone, may be approximately calculated from the heat of formation or stored-up potential energy of the elements present in each hydrocarbon.

	Illuminating Value. Calculated.	Illuminating Value. Found.
Methane	8·4	5·2
Ethane	35·0	35·0
Ethylene	60·9	68·5
Acetylene	202·2	240·0

(Professor Lewes.)

	Illuminating Power, 5 Cubic Feet.	Oxygen required per Cubic Foot Consumed.	Yield CO_2.	Water Vapour.	Quantity Present in Coal Gas.
	Candles.	Cubic Feet.	Cubic Feet.	Cubic Feet.	
Marsh gas	5·2	2	1	2	40 to 50 per cent.
Ethylene	70	3	2	2	
Benzene	420* 820†	$7\frac{1}{2}$	6	3	
Acetylene	400	$2\frac{1}{2}$	2	1	Minute quantity.

* Frankland. † Knublauk.

Mr. W. Young has shown that where feebly luminous gas, which contains a large surplus of potential or heat energy, is carburetted, this heat energy is utilized in raising the potential of the added hydrocarbons, with a consequent increase of light.

Table Showing the Comparative Quantities of Various Gases of Different Qualities Required to Evaporate an Equal Quantity of Water. (J. Travers.)

Cannel gas . . .	of 24 candles .	18·50 cubic feet.
" "	" 22 " .	19·75 " "
" "	" 20 " .	20·50 " "
Newcastle coal gas	" 16·5 " .	21·75 " "
" " " . . .	" 14·5 " .	22·00 " "
" " "	" 13·5 " .	22·50 " "
South Wales	" 10·5 " .	28·00 " "
" " and 20 % cannel	" 14·0 " .	23·50 " "

The Value of Coal Gas at Different Candle Powers for Lighting and Heating. (D. Wallace.)

Candle Power of Gases.	Comparative Specific Gravity.	Value for Heating.	Value for Lighting.
14·75	1·000	1·000	1·000
26·24	1·187	1·295	1·769
33·07	1·298	1·496	2·230

The products of combustion of gas are, H_2O, caused by the combination of the hydrocarbons of the gas with the O of the air, and CO_2, from the combination of the C with the O of the air.

The proportion of sulphur in the products of the combustion of coal gas, which is converted directly into sulphurous anhydride, ranges from 89 to 99 per cent.

Cannel enriched London 16-candle coal gas gives about a 3-inch flame in a "London" Argand burner.

Carburetted water gas, 22-candle power, gives only about a 2-inch flame, owing to the presence of less methane. (Professor Lewes.)

The quantity of air admitted to the flame is principally influenced by the pressure at which the gas issues from the orifice.

5 cubic feet of gas at $\frac{18}{10}$ths pressure equals 11·14 candle power.

5 cubic feet of same at $\frac{5}{10}$ths pressure equals 20 candle power. (Professor W. I. Macadam.)

Size of flame from carburetted water gas is less than with coal gas for same illuminating power. (Professor Lewes.)

Light moves with a velocity of about 180,000 miles per second.

The mechanical equivalent of light equals 749 foot lbs. per hour per candle. (Professor Julius Thomsen.)

Professor F. Clowes finds that an atmosphere of 16·4 per cent. C. 80·5 per cent. N, and 3·1 per cent. CO_2 will extinguish a candle, but can support a coal gas flame or life, whereas an atmosphere that will extinguish a coal gas flame will not support life.

A paraffin flame will not burn in less than			16·6	per cent.		O.
A candle	"	"	15·7	"	"	O.
A methane	"	"	15·6	"	"	O.
A CO	"	"	13·35	"	"	O.
A coal gas	"	"	11·35	"	"	O.
A H	"	"	5·5	"	"	O.

(Professor Clowes.)

Temperature of a Bunsen Flame.

Henry W. J. Wäggener found that the highest temperature he could get was 1,704° C. or 3,100° F., which is only a little below the melting point of platinum (1,780° C.).

The Temperature of Bunsen Flame. (Professor Warburg.)

The highest temperature found was 1,704° C.

Strontium flame is rose coloured.

Sodium flame is blue green.

Mr. Macpherson showed (1878) that there was a proportionate relation between the hydrocarbons absorbed by bromine, the durability of a 5-inch flame, and the illuminating power; and that the illuminating power and the durability bore a fixed relation to the percentage of C in the gas.

Durability test is ascertaining the time that a cubic foot of gas will make a flame 5 inches high.

With the durability test, and a jet of $\frac{1}{40}$th inch diameter, and 5 inches flame, Dr. Fyfe found that the quantity consumed was directly as the square root of the pressure.

In setting the jet photometer to work it should be calibrated by means of a Bunsen photometer, and with gases of different qualities.

The water line in a jet photometer should be adjusted at least once a day by turning off the gas and letting out all pressure, and setting the hand at zero by adding more water as required.

$$\frac{8{\cdot}8 \text{ inches}}{10} \text{ Mercury} = 12 \text{ inches water pressure.}$$

One cubic inch of mercury weighs 0·49 lbs.

Mercury gauges are about 13½ to 14 times shorter than water gauges.

When the two tubes of a pressure gauge are unequal the quantity of liquid displaced in each tube is equal, and in inverse ratio to their sectional areas.

Different sizes of tubes in U pressure gauges have no effect upon the correct registration of the gauge, the absolute difference of level being the same for a given pressure despite the inequality of the glasses.

Photometers, &c.

The Board of Trade Standards Department has settled that the cubical contents of the photometrical room is not to be less than 1,000 cubic feet. This is best about 12 feet long by 9 feet wide by 10 feet high. This will take a photometer 100 inches or 60 inches long between the gas and candles. But if the room is larger it will be better for the purpose—1,500 or 2,000 feet cubic contents are not too much.

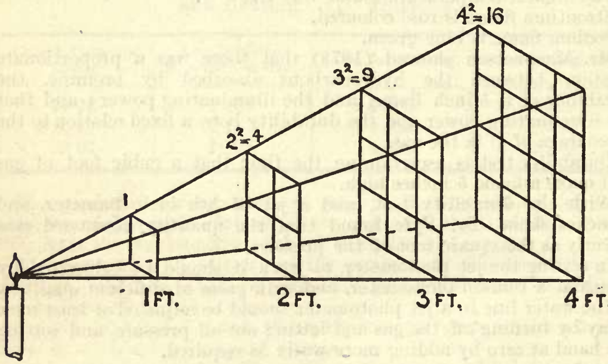
Such ventilation is required that there shall be an ample air supply moving at a low velocity.

Ventilation of the photometer room is a very important point.

The air removed from a photometer room should be 2,000 to 3,000 cubic feet per hour.

Mr. J. Methven found that air at increasing temperatures, saturated with moisture, decreased the light emitted from a flame rapidly equals 10 per cent. between 50° and 75° F.

The area which the light covers equals 1 at 1 foot, but at 2 feet equals 4, at 3 equals 9, and at 4 equals 16.



With the shadow photometer, square the distances of the two sources of light from the screen, and divide the one into the other.

It has been found that the normal eye can detect a difference in strength of light and shadow of $\frac{59}{60}$ths.

With a Rumford photometer the error in reading need not be more than $\frac{1}{64}$th, and should not in usual cases be more than 1 per cent.

On a 100-inch photometer bar the divisions are more easily read than on a 60-inch one.

60-inch bar in photometer is preferable to 100-inch for ordinary gases from 14 to 30 candle power, owing to the better illumination of the disc.

If fog is present the 60-inch photometer bar is best, owing to the difference in value between the gas and candles causing the greater obstruction on the one side. If the standard should be made more nearly equal this advantage of the 60-inch bar would disappear.

Formula for calculating the comparative light of two sources: divide the distance of one from the screen by the distance of the other and square the quotient.

To Graduate Photometer Bar.

100 inches.—The distance from the candle to any mark $= \dfrac{100\sqrt{a} - 1}{a - 1}$

where $a =$ the number to be placed upon the mark.

60 inches.—The distance from the candle to any mark $= \dfrac{60\sqrt{a} - 1}{a - 1}$

To Find the Distance of any Mark in a Photometer Bar from the Standard.

$$\frac{\text{Distance between lights} \times (\sqrt{\text{number of candles}} - 1)}{\text{Number of candles} - 1} = \text{distance to mark.}$$

To prove this—

$$\frac{\text{distance from mark to light}^2}{\text{distance from mark to standard}^2} = \text{Number of times the one light exceeds the other in intensity.}$$

With a Fixed Distance for the Standard from Disc.

$$\sqrt{\text{Number of candles}} \times \text{fixed distance} = \text{distance of mark from light.}$$

With a Fixed Distance for the Light to be Tested from the Disc.

$$\frac{\text{fixed distance}}{\sqrt{\text{Number of candles required}}} = \text{distance from standard.}$$

The disc should be examined that it be not too dry or too old or have been badly made; sometimes the two sides of a Bunsen disc will give a different reading, through the different temperatures to which the sides are subjected.

The Gas Referees for London insist that 5 of the 10 tests shall be made with the one side of the disc to the gas, and the other five with the opposite side.

After making 5 of the 10 tests reverse the disc, so as to equalize any difference in colour of the two sides of the disc.

If the disc in a Bunsen photometer is made with 3 spots fixed horizontally and the disc placed slightly obliquely, the per cent. of error is considerably reduced in reading. (Mr. Heschus.)

A chisel-shaped crayon has been used instead of a grease-spot paper in a photometer. The crayon is cut to a chisel edge and fixed with the edge in a vertical position; the light falling upon it through two slits in a $\frac{3}{4}$-inch tube in the axis of which the crayon is fixed, when the lights are even the edge disappears, and the surface appears as a flat.

A photometer has been made in which the decomposition by light of ioduret of nitrogen, prepared by the action of a pure aqueous solution of ammonia at 20° upon iodine, and noting the quantity of nitrogen produced in a given time, and the distance of the light from the liquid. (Léon.)

For obtaining the illuminating power from the calorific value of a coal gas Mr. B. H. Thwaite recommends the following formula:

$$\text{photometric value in candles decimally graduated} = \frac{\text{calorific value} - 2280}{352 \cdot 6}$$

the Berthelot-Mahler calorimeter being used.

The candle balance should be sufficiently sensitive to weigh $\frac{1}{50}$th grain.

Photometers with sliding candles are not now stamped by the Standards Department of the Board of Trade.

Standard candles should be $8\frac{3}{4}$ inches from base to shoulder and are made of spermaceti with from 4 to 5 per cent. beeswax.

The Gas Referees Instructions allow the use of a candle burning within 5 per cent. of the prescribed amount.

The chief error in the amount of light emitted by a candle is due to variations in the character of the wick employed.

Variation in Light-giving Power due to Position of Wick.

(J. Methven.)

Plane of curvature of both wicks parallel to plane of disc equals 1·999 candles.

Plane of curvature of both wicks at right angles to plane of disc and bent away from disc equals 1·957 candles.

Plane of curvature of both wicks at right angles to plane of disc and bent towards disc equals 1·933 candles.

The cone at the top end of sperm candles should not be used in photometry, but a good cup should be made under the wick by revolving the candle in the hand when lighted, allowing the grease to fall off, the extra length of wick should be removed. They should now be burnt until the wicks bend over, a red point is seen showing through the flame, which should be of its maximum size.

No candles should be used that gutter badly, smoke, or form badly shaped "cups" around the wick, or have the wicks greatly out of the centre, or too closely or too tightly woven wicks. The candles should burn at least 10 minutes before commencing to test, and they should be placed that the plane of the wicks are at right angles to each other.

Flames of candles vary 13 per cent. in a range of 22° F.

Flames of Argand gas burners vary $8\frac{3}{4}$ per cent. in a range of 22° F. (J. Methven.)

A comparison between different candles showed a maximum variation of 22·7 per cent., and in one case the average of 10 experiments gave a difference of as much as 15 per cent. (Report of Committee on Photometrical Standards, 1881.)

Candles which have been kept about 8 years show a reading about 8 per cent. higher than new candles will do.

Professor Lewes considers the candles of the present day emit less light than those in use at the time the Act was passed prescribing the standard.

At 50° F. the light from 120 grains of sperm equals 1·198 candles or + 20 per cent.

At 72° F. the light from 120 grains of sperm equals 1·041 candles or + 4 per cent.

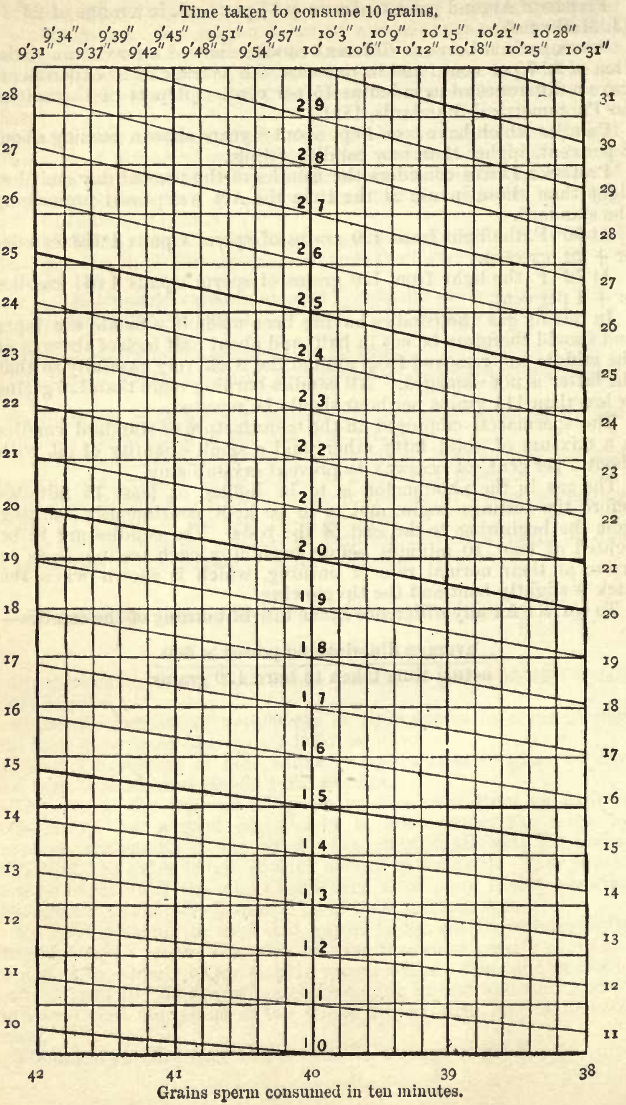
In testing gas the candles having been made in a mould are taper and should therefore be cut in half, and about half inch of the wax at the middle end removed from around the wick very carefully so that the latter is not damaged. All candles burning more than 126 grains or less than 114 grains per hour should be rejected.

The spermaceti employed in the manufacture of standard candles is a mixture of solid fatty ethers and a small quantity of oil, with about 5 per cent. of beeswax to prevent crystallizing.

The gas in the photometer is to be lighted at least 15 minutes before the testings begin, and is to be kept continuously burning from the beginning to the end of the tests. The candles are to be lighted at least 10 minutes before beginning each testing, so as to arrive at their normal rate of burning, which is shown when the wick is slightly bent and the tip glowing.

To correct for any difference in the rate of burning of the candles—

$$\frac{\text{average illuminating power} \times 600}{\text{actual time taken to burn 120 grains.}}$$


Time taken to consume 10 grains.
9'31" 9'34" 9'37" 9'39" 9'42" 9'45" 9'48" 9'51" 9'54" 9'57" 10' 10'3" 10'6" 10'9" 10'12" 10'15" 10'18" 10'21" 10'25" 10'28" 10'31"
28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10
29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10
31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11
42 41 40 39 38
Grains sperm consumed in ten minutes.

To obtain the Correction for the Irregular Burning of the Candles by the Diagram.

Find by the sloping cross lines, the actual candle power, and immediately above the figure corresponding to the number of grains burnt in 10 minutes, or below the figure corresponding to the time taken to consume 40 grains, proceed horizontally, and note the figure above "40;" this will give the candle-power corrected for the quantity of grains consumed.

The service into the photometer room from the main ought to be of small diameter, and also be of lead lined with tin or a pure tin pipe laid inside an iron one to protect it. The reason for this is that a smooth polished surface does not present any hold for napthalene to attach itself to, and it can be readily washed out with hot water.

A very important matter in relation to the supply of gas to a photometer is that the gas should come direct from the main and not through any meter before it gets to the photometer.

Photometric Standards Committee recommend that the rate of burning shall be regulated to that which gives the best value for the quality of gas used, calculation being made to bring it to the standard rate of 5 cubic feet per hour.

An Argand burner is the only one which can be relied upon to maintain a steady, vertical light in a photometer, and to give fair comparative results should the quality of the gas vary a candle or so up and down.

Equal areas of the flames of gases, with illuminating power from 12 to 60 candles, have equal illuminating powers.

To correct for any difference in the rate of burning of the gas—

$$\frac{\text{average illuminating power} \times 5}{\text{actual rate of burning.}}$$

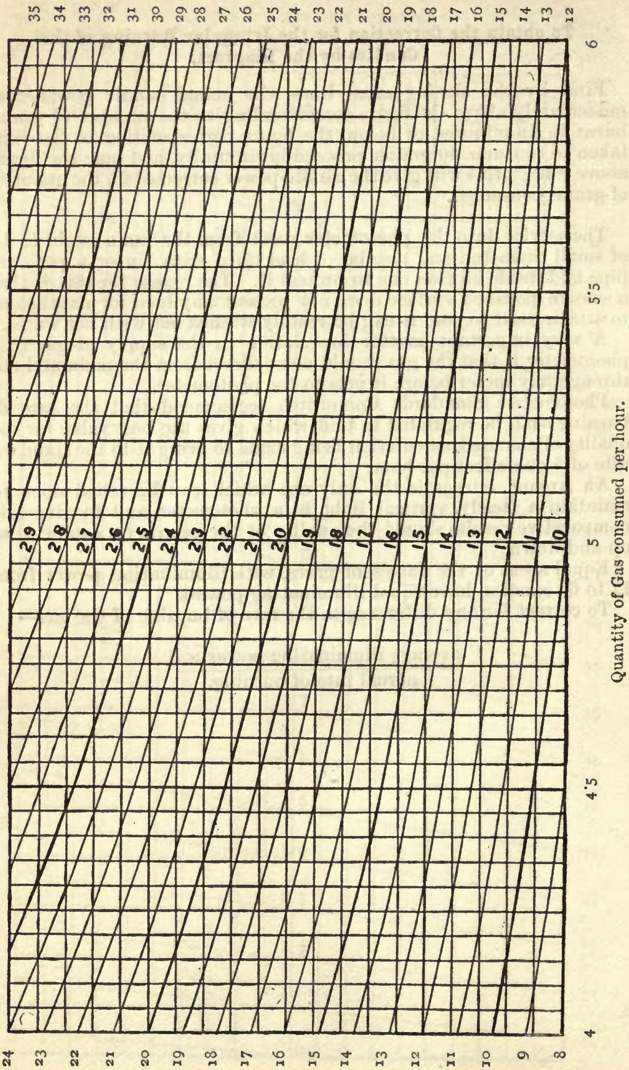

35 34 33 32 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12
29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10
30
24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8
6
5·5
5
4·5
4
Quantity of Gas consumed per hour.

Diagram to find Corrected Candle-power of Gas according to Quantity burnt per hour.

To Use the Diagram.—Find the vertical line corresponding to the quantity of gas consumed in ten minutes, and the sloping curved line corresponding to the candle-power corrected from the point where these cross, proceed horizontally to the centre line, when the figures thereon will show the actual candle power corrected for the quantity of gas consumed.

Boyle's or Mariotte's Law.

The volume of a given mass of any gas varies inversely as the pressure, thus—

1 volume gas at 4 pressures =
2 " " " 2 " =
4 " " " 1 "

therefore if a volume of gas is measured at any barometrical pressure the volume at 30 inches is

30 : observed pressure : : volume of gas : required volume.

The corrected volume of gas + water vapour for both temperature and pressure equals

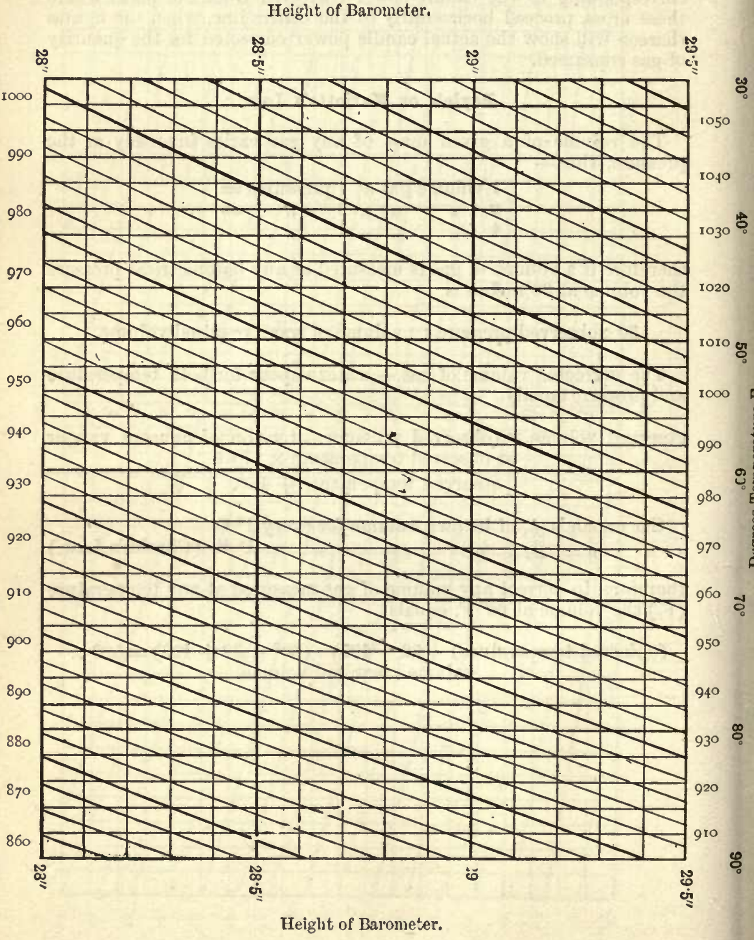
$$\frac{\text{observed volume} \times (\text{observed pressure} - \text{tension of aqueous vapour at observed temperature} \times 17{\cdot}64}{\text{observed temperature} + 460.}$$

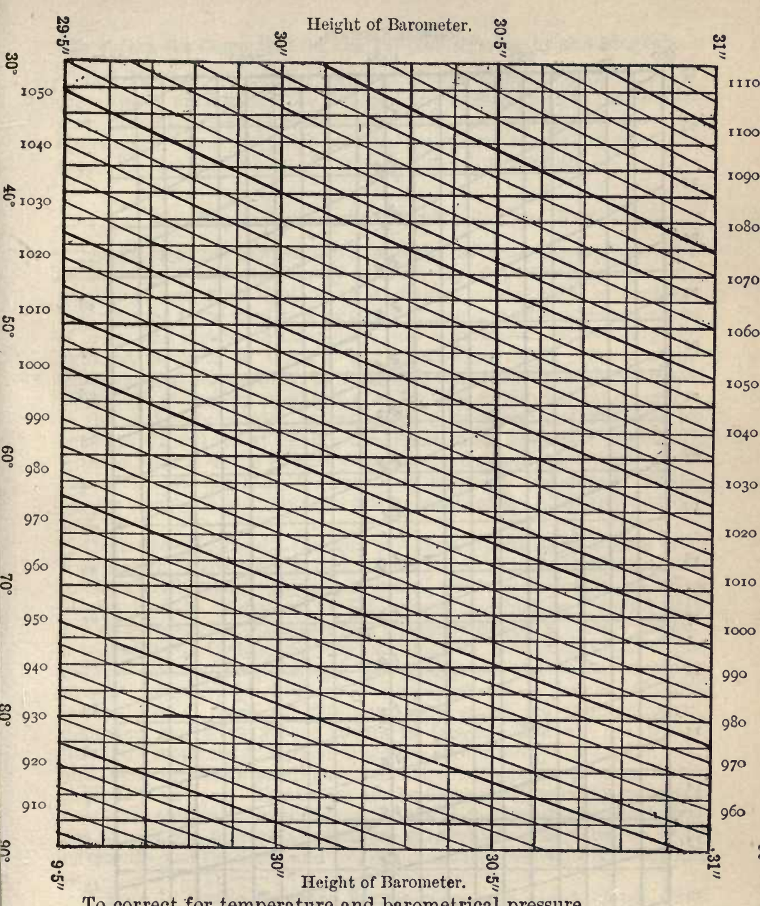
Gas expands $\frac{1}{273}$ of its own volume for every 1° C.
" " $\frac{1}{492}$ " " " 1° F. (Charles's Law.)

therefore, to correct any volume of gas measured at any temperature (F.) the volume at 60° F. equals

(observed temperature) − 32 + 492) : (60° − 32 + 492) = 520 :: volume : required volume.

To Use the Diagram.—Find the horizontal line corresponding to the barometrical pressure, and the vertical line corresponding to the temperature of the room; at the point where these two lines cross note the tabular number by the diagonal curved lines.



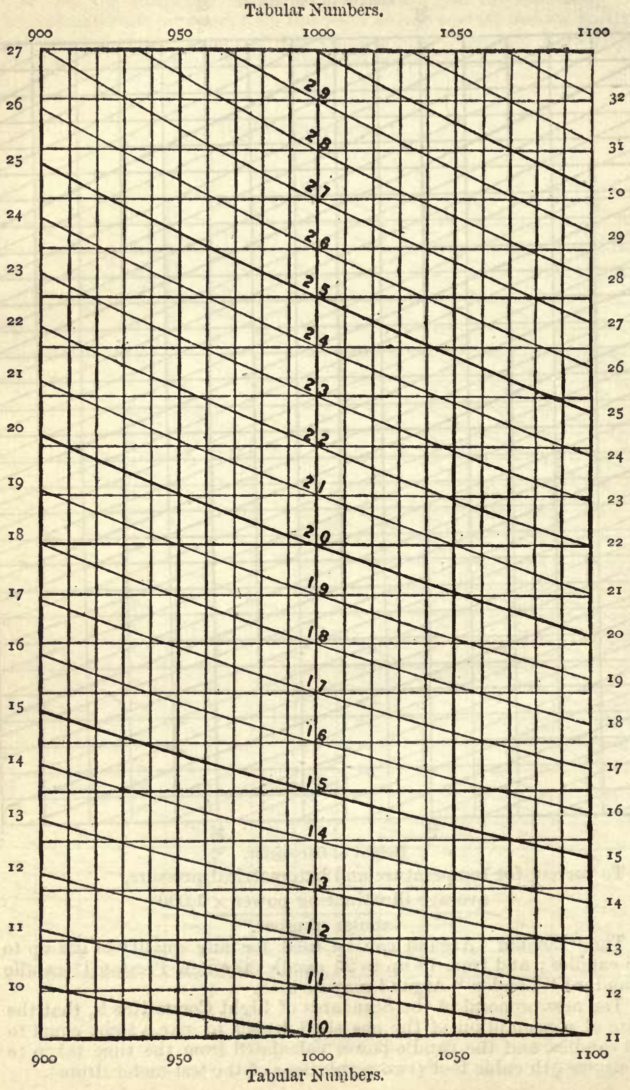


To correct for temperature and barometrical pressure,

$$\frac{\text{average illuminating power} \times 1{,}000}{\text{tabular number.}}$$

The "London" Argand can be used for any quality of gas up to 18 candles; and from 18 up to 25 candles the new Preston 18-candle standard "London" Argand may be used.

The new proposal of the Standards of Light Committee is, that the rate of consumption of the gas shall be set to give a light equal to 16 candles, and the candle-power calculated from the time taken to consume $\frac{1}{6}$th cubic foot (two revolutions of the test-meter drum).


Tabular Numbers.
900
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Tabular Numbers.

To obtain the Correction for the Tabular Number by the Diagram.

Note the tabular number, proceed up the line immediately above these figures until it cuts the sloping line corresponding to the candle-power found by the photometer, proceed horizontally, and note the figure above the 1,000; this will be the actual candle-power of the gas at 60° temperature and 30-inch barometrical pressure.

Mr. Vernon Harcourt's 1-Candle Pentane Unit.

The gas used for this standard is made by bringing together in a gasholder, air and the highly volatile liquid pentane, in the proportion of one cubic foot of air and three cubic inches of pentane. The pentane to be used is a mixture of pentane with some paraffins of lower and higher boiling-points, and is prepared by distilling the light petroleum at 60° C., at 55° C., and twice at 50° C. The pentane thus prepared must satisfy the following tests: On agitation with $\frac{1}{20}$th of its bulk of fuming sulphuric acid for five minutes it must impart to the acid only a faint brown colour; its liquid density must be between ·62 and ·63 at 62° F.; the liquid must evaporate absolutely without residue at the ordinary temperature when the tension of its vapour is not less than 7·5 inches of mercury; the density of the vapour compared with air must not be less than 2·47, nor greater than 2·53.

The standard 1-candle pentane unit burner consists of a brass tube 4 inches in length and 1 inch in diameter, which the gas enters towards the bottom. The upper end of the tube is closed by a brass plug $\frac{1}{2}$ inch in thickness, in the middle of which is a round hole $\frac{1}{4}$ inch in diameter. Around the burner is placed a glass cylinder, 6 inches by 2 inches, the top of which is level with that of the burner, air entering through the gallery on which the chimney stands. Above the burner is supported, at a height of 63·5 millimetres, a piece of platinum wire about 0·6 millimetres in diameter, and from 2 to 3 inches in length. The air gas passes through a small meter delivering at each revolution $\frac{1}{60}$th of a cubic foot, and then through a small governor fitted to regulate the flow to 0·5 cubic foot an hour. The height of the flame is adjusted by means of a delicate stop-cock until the top of the flame appears to touch, but not to pass, the horizontal platinum wire which is adjusted so as to be exactly over the flame and to extend not less than half inch beyond it.

A Sugg 16-candle Standard Burner gives only about 0·6 per cent. of the full mechanical equivalent, while a Welsbach incandescent burner only gives 1·4 per cent., while electricity only employs about the same per cent. of the original heat energy of the coal used for generating. (Dr. H. Morton.)

The burner used for Dibdin's 10-candle pentane standard is a modification of Sugg's standard "London" Argand burner.

The height of the screen in the 10-candle pentane standard should be 2·15 inches above the steatite.

Herr Von Hefner-Alteneck's Standard of Light.

The unit of light should be a free burning flame, in still pure air, supplied by a section of solid wick and fed with amyl-acetate; the wick-tube to be circular and of German silver, measuring 8 millimetres internal diameter, 83 millimetres external diameter, 25 millimetres high.

Flames to be 40 millimetres high, measured from the edge of the wick-tube at least 10 minutes after lighting the lamp.

A variation of 0·02 is allowed in the light measurement.

$$\frac{\text{The German standard candle with a 45 millimetre flame}}{\text{Hefner unit}} = 1{\cdot}2.$$

$$\frac{\text{English standard candle}}{\text{Hefner unit}} = 1{\cdot}14.$$

The amyl-acetate lamp, devised by Herr Hefner-Alteneck, is practically a spirit lamp burning the vapour of amyl-acetate. The wick is contained in a round tube of German silver, 8 millimetres in diameter and 25 millimetres high. It is formed of a strand of cotton yarns, and is so regulated as to produce a flame 40 millimetres in height. It is supposed to give a light equal to one candle, but Mr. Dibdin found that the height must be increased to 51 millimetres to equal the light of one candle by the Methven standard.

The Carcel (French photometrical standard) is now proved to be 10 candles (English standard) as against the hitherto variously estimated 9·2, or 9·5, or 9·8 candles. (*Journal of Gas Lighting*, July 11th, 1893.)

Messrs. Kirkham and Sugg found the carcel to equal 9·6 candles.

Table Showing the Illuminating Power of Different Gases after Carburetting with Gasolene in the same Carburettor.

(J. Methven.)

Quality of Gas before Carburetting.	Quality of Gas after Carburetting.	
10·1	73·98	average of 2 tests.
10·0	71·18	" 2 "
16·0	70·05	" 3 "
22·0	67·77	" 2 "
27·5	70·09	" 2 "

It will be noticed that the resulting quality of the gas is about equal in each case.

Mr. Vernon Harcourt's 1-candle pentane unit burner consists of a brass tube 4 inches in length and 1 inch in diameter, the upper end of which is closed by a brass plug ½ inch in thickness, in the middle of which is a round hole ¼ inch in diameter. A glass cylinder 6 inches long × 2 inches in diameter is placed with the top level with that of the burner, air entering at the bottom. A piece of platinum wire, about 0·6 millimetres diameter, is fixed at 63·5 millimetres above the burner. The air gas is delivered at the rate of about half a cubic foot per hour, and the flame is adjusted so that the tip just touches the platinum wire. The gas is a mixture of 1 cubic foot of air and 3 cubic inches of pentane. The pentane used is mixed with a distillation of the lighter petroleums at 60° C., at 55° C., and twice at 50° C., and must pass the following tests: It must be of ·62 to ·63 liquid density at 62° F., and when agitated with 5 per cent. by volume of fuming sulphuric acid for 5 minutes, must only turn the acid a faint brown colour. It must entirely evaporate at ordinary temperatures when its vapour tension is above 7·5 inches of mercury. Its vapour density must be between 2·47 and 2·53. In regulating the height of the flame the eye should be screened from the luminous portion of the flame.

As long as the bottom of the carburettor is covered by the pentane it does not matter what depth of the liquid is present.

With the 10-candle standard the light is constant between 42° and 75° F.

Pentane, 1 volume, air 576 volumes, measured at 60° F.; or as gases, 20 volumes of air to 7 of pentane gas.

Pentane is a product of the distillation of petroleum spirit, having a specific gravity of ·630 and can be made always exactly alike; a certain quantity of pentane will be taken up by atmospheric air if allowed to pass over its surface.

The pentane employed to produce the air gas used in Mr. Harcourt's 1-candle standard and in the carburettor of the 10-candle pentane Argand was obtained by purifying light petroleum by the successive action of sulphuric acid and soda solution, and then distilling at 60° C., at 55° C., and twice at 50° C.

Dibdin's Pentane Argand Burner Dimensions.

Number of holes	42		
Diameter "	0·028 inches	=	0·71 millimetres
Inside diameter of steatite . .	0·390 "	=	9·9 "
Outside " " . .	0·750 "	=	19·05 "
Diameter of inside of metal cone at top	0·930 "	=	23·62 "
Chimney length	6·000 "	=	152·4 "
Chimney, inside diameter . .	1·5 "	=	33·1 "
Height of cut-off	2·15 "	=	54·61 "

The centre of the flame should be immediately over the terminal of the photometer bar.

Dibdin's 10-Candle Pentane Argand Air Gas Standard.

The burner is a specially constructed tri-current Argand burner, the annular steatite ring being perforated with 42 holes, each hole being 0·71 millimetre in diameter. The inner perforated cone is punctured with ten apertures 0·25 inch in diameter. The dimensions of the chimney being 6 inches high and 1½ inches inside, the top of the flame should be maintained as nearly as possible at three inches above the steatite. The middle portion of the screen is cut away so as to leave, above the top of the steatite burner, an opening 2·15 millimetres in height and 1·4 inches in width, the lower portion of this opening being exactly level with the top of the steatite.

The carburettor for the 10-candle pentane Argand consists of a circular vessel constructed of tinned plate 203·2 millimetres (8 inches) in diameter and 50·8 millimetres (2 inches) in depth, having a spiral division 25·4 millimetres (1 inch) in width. This division is made by soldering in a spiral strip of metal 4 feet 6 inches in length and 2 inches wide, gas-tight to the under side of the top of the carburettor, so that when the top is fixed on, the bottom of the strip comes close to the bottom of the vessel and is sealed by the pentane, so that the air has to pass over pentane for a distance of about 4 feet 6 inches, and becomes thoroughly saturated. At the end of the spiral division, near the side of the carburettor, a bird fountain is fixed for charging the carburettor and keeping it charged at a constant level with liquid pentane. The lower end of the inlet fountain is closed, and rests upon the bottom of the tank. Through the side of the tube, which is 0·4 inch (10·1 millimetres) in diameter, 16 holes, 1 millimetre in diameter, are bored, close to the bottom, and through these the pentane enters the carburettor. At one side of the inlet-tube, 1 inch from the lower end, a small tube 3 millimetres in diameter and 20 millimetres in length is connected thereto and turned upwards. The fountain inlet-tube is carried up through the top of the carburettor, and continued in the form of a bulb having a capacity of about 200 cubic centimetres.

When the carburettor is being charged the gas must be extinguished, to avoid the risk of the vapour firing and causing an explosion.

To Test Lime for its Purifying Value.—Take a small quantity of lime, weigh and add sufficient water to slake; dry and re-weigh, when increased weight shows quantity of water required to convert the caustic to hydrate; then, as 56 parts caustic lime will absorb 18 parts water, the percentage of the former can easily be ascertained.

To test if lime has been thoroughly burnt, add dilute hydrochloric acid, when no great effervescence should be given off.

To Find the Quantity of CO_2 or H_2S that a Sample of Lime will absorb—

$$5 \times \frac{\text{per cent. pure lime}}{100} = \text{number of cubic feet of } CO_2 \text{ or } H_2S \text{ absorbable.}$$

1 lb. pure Fe_2O_3 will unite with 0·603 lb. or 6·7 cubic feet H_2S.

Water will take up $\frac{1}{778}$th of its weight of lime, and is then saturated.

When limestone is burnt the CO_2 is expelled as per equation—

$$CaCO_3 = CaO + CO_2.$$

One part pure $CaOH_2O$ will unite with ·586 parts CO_2, or ·453 H_2S, or 1 lb. pure lime will unite with 5 cubic feet of either CO_2 or H_2S.

To Test Caustic Lime.—Take a sample of known weight and thoroughly slake it, dry in an air bath at 250° F., and weigh; the increase of weight will indicate the quantity of water taken up in rendering the caustic lime into hydrate. Nine parts of water will be absorbed for every 28·5 grains caustic lime, then

$$\frac{28{\cdot}5 \times \text{difference in weight}}{9} = \text{quantity of caustic lime.}$$

If, however, any of the lime has absorbed moisture from the air, this will not show it.

Hydrated peroxide of iron equals Fe_2O_3, 3 H_2O, which unites with 3 H_2S to form 2 FeS + 6 H_2O + S, and on revivification 2 FeS + 3 H_2O + 3 O equals Fe_2O_3, 3 H_2O + 2S. Sulphate of iron equals FeO, SO_3, which unites with H_2S and NH_3 to form FeS + NH_4O, SO_3.

Lime equals CaO, which unites with the equivalent of H_2O to form $CaOH_2O$, equals hydrate of lime, which combines with CO_2 to form $CaOCO_2$ + H_2O, or with H_2S to form CaS + $2H_2O$.

When lime which has taken up H_2S and become CaS + H_2O is presented to CO_2 it becomes $CaOCO_2$ + H_2S, the H_2S being driven off, owing to the greater affinity of CaO for CO_2.

Sulphide of lime (CaS) combines with CS_2 to form CaS, CS_2 equals sulphocarbonate of lime, which requires a longer contact for combination than is necessary with H_2S or CO_2.

Hydrochloric acid will dissolve hydrated ferric oxide, but has little effect on anhydrous ferric oxide.

To Test Spent Oxide of Iron, Lime, or Weldon Mud for Sulphur.— Dry the sample at 212° F. until a constant weight is obtained, then place in a test tube with a little cotton wool at the bottom, pass a quantity of CS_2 (about three or four times the bulk of the oxide) through it, and allow the solution to fall into a flask, evaporate the CS_2 with heat, when the S will remain in the flask and the quantity can be easily found.

Mr. A. J. Bale proposed to so arrange the apparatus for testing spent oxide for sulphur that the bisulphide of carbon is evaporated and condensed, and then to pass through the oxide to the evaporating flask to again go through the cycle until all the sulphur has been removed from the oxide, and by this means reduce the quantity of bisulphide necessary.

When testing oxide by the bisulphide method, care should be taken that the oxide has been thoroughly revivified.

Place dilute hydrochloric acid in a wide-mouthed bottle and stand in this a small vessel containing the spent oxide, connect to measuring tube immersed in water, overturn the oxide into the acid, when the quantity of H_2S driven off will be found by the displacement of the water in the measuring tube. Twenty-five grammes spent oxide is the best amount, and, when fresh from the purifier, will evolve about 250 cubic centimetres of H_2S.

Four days will usually suffice to revivify oxide.

Temperature of oxide while revivifying, and in presence of ample moisture, may reach 140° to 160° F.

One ton of good oxide should purify $1\frac{1}{4}$ to $1\frac{1}{2}$ millions cubic feet before becoming spent.

Beckton Purifying Method.

2 carbonate	vessels	for the	elimination of	CO_2
2 oxide	"	"	"	H_2S
2 sulphide	"	"	"	CS_2 etc.
2 weldon mud	"	"	"	H_2S driven off from sulphide vessels.

100 Volumes Water at 60° F. and 30 Inches Barometer will absorb—

	Volumes.		Volumes.
Ammonia	78,000	Oxygen	3·7
Sulphurous acid	3,300	CO	1·56
H_2S	253	N	1·56
CO_2	100	H	1·56
Olefiant gas	12·5	Light carburetted hydrogen	1·60

(Dr. Frankland.)

One volume H_2O at 0° C. dissolves 4·37 volumes H_2S.
H_2S unites with an equal weight of NH_3.
22 parts CO_2 unite with 17 parts NH_3.

Quantities of Gases Absorbed by Water at 20° C. at 760 Millimetres Pressure.

Hydrogen	1·9	per cent.	of the volume	of water.
N	1·4	"	"	"
O	2·9	"	"	"
Methane	3·5	"	"	"
CO	2·3	"	"	"
CO_2	90·0	"	"	"
Ethylene	15·0	"	"	"
Acetylene	95·0	"	"	"
H_2S	291·0	"	"	"
NH_3	74,000·0	"	"	"

To Find the Amount of CO_2 in Gas Liquor.

Add an excess of barium chloride to a known quantity of gas liquor, digest for 30 minutes at a gentle heat, filter, then dry, ignite, and weigh the precipitate. Every 98·5 parts of barium carbonate contains 22 parts CO_2.

To Estimate the Quantity of Free Ammonia in Liquor.

Take a glass measure graduated into 16 parts, fill with liquor and empty into a glass beaker, rinse the measure with distilled water and add rinsings to liquor in beaker with a few drops of methyl orange indicator. Rinse the measure with a little 10 per cent. acid solution and throw away rinsings, fill up measure with 10 per cent. acid solution (specific gravity, 1,064·4 at 60° F.), and pour acid very gradually into beaker until the liquor is neutralized. The number of divisions of acid solution used equals ounces strength of liquor.

To Estimate the Quantity of Ammonia in Liquor.

Mix a known quantity of the liquor with an excess of caustic lime or soda, heat, and lead the evolved fumes of ammonia through a solution of sulphuric acid (10 per cent.) until all the gases of ammonia are evolved, titrate the acid solution with 10 per cent. alkaline solution, note quantity of latter necessary to neutralize, deduct from quantity of acid solution used, equals strength of ammonia in liquor.

Ounces strength of ammoniacal liquor is the number of ounces by weight of H_2SO_4 (specific gravity 1,064·40 at 60°) required to neutralize a gallon of the liquor.

To convert degrees Twaddell to specific gravity (water equals 1)—

(Degrees × ·005) + 1.

To convert specific gravity into degrees Twaddell—

Deduct 1 and divide by ·005.

Every ounce strength of ammoniacal liquor equals ·347 ounces of absolute ammonia.

Specific Gravity of 10 per cent. Acid Solution at Various Temperatures. (L. T. Wright.)

Temperature.		Specific Gravity.	Temperature.		Specific Gravity.	Temperature.		Specific Gravity.
F.	C.		F.	C.		F.	C.	
40	4·45	1068·10	54	12·23	1065·64	68	20·00	1062·72
41	5·00	1067·94	55	12·78	1065·45	69	20·56	1062·51
42	5·56	1067·78	56	13·34	1065·24	70	21·11	1062·30
43	6·11	1067·62	57	13·90	1065·03	71	21·67	1062·08
44	6·67	1067·46	58	14·45	1064·82	72	22·23	1061·86
45	7·23	1067·30	59	15·00	1064·61	73	22·78	1061·64
46	7·78	1067·12	60	15·56	1064·40	74	23·34	1061·42
47	8·34	1066·94	61	16·11	1064·19	75	23·90	1061·20
48	8·89	1066·76	62	16·67	1063·98	76	24·45	1060·97
49	9·45	1066·58	63	17·23	1063·77	77	25·00	1060·74
50	10·00	1066·40	64	17·78	1063·56	78	25·56	1060·51
51	10·56	1066·21	65	18·34	1063·35	79	26·12	1060·28
52	11·11	1066·02	66	18·89	1063·14	80	26·67	1060·05
53	11·67	1065·83	67	19·45	1062·93	85	29·45	1058·95

Test for Sulphuretted Hydrogen.

The gas is dried and passed through U tubes containing cupric phosphate on one side and non-alkaline calcium chloride on the other, the difference in weight of the U tube giving the quantity of sulphuretted hydrogen in the amount of gas passed. (L. T. Wright.)

Another Test for Sulphuretted Hydrogen.

The gas is made to bubble through an acid solution of cadmium chloride in two or three Woulffe's bottles, when cadmium sulphide is precipitated, which may be washed, filtered and weighed, and the quantity of H_2S thus obtained.

Sheard's Test for Ammonia, H_2S and CO_2 in Gas.

Four absorption tubes are required and a filter tube containing cotton wool to absorb tarry matters when testing crude gas. In the first tube a certain quantity of half deci-normal strength sulphuric acid is placed; in the second a quantity of cupric sulphate 1 part and water 10 parts (30 cubic centimetres of this should absorb all the H_2S from 500 cubic centimetres crude gas); in the third and fourth tubes, say, 30 cubic centimetres and 20 cubic centimetres of barium hydrate. The first tube is the test for NH_3, the second for H_2S, and the other two for CO_2. Pass, say, 500 cubic centimetres of gas slowly through the apparatus, and then 1,000 cubic centimetres of air to ensure that the whole of the gas has passed over the whole of the apparatus. Wash out the glass scrubber of each absorption tube with a little distilled water. Titrate the contents of the first tube with $\frac{N}{20}$ ammonia HO, using cochineal as an indicator, note the quantity required to neutralize, and deduct this from the quantity of sulphuric acid placed in the tube $\times$ 74 = grains of ammonia per 100 cubic feet gas. Titrate the second tube with similar ammonia solution, and use methyl orange as indicator $\times$ 74 = grains H_2S per 100 cubic feet gas. (Each cubic centimetre $\frac{N}{20}$ acid = 74 grains NH_3 per 100 cubic feet of gas. Each cubic centimetre $\frac{N}{20}$ ammonia required to neutralize = 74 grains H_2S per 100 cubic feet gas.) Titrate the washings of the third and fourth tubes with $\frac{N}{20}$ HCl, deduct the quantity required to neutralize from equivalent of $\frac{N}{10}$ Ba HO, first put in tube $\times$ 0·24 = volumes per cent. of CO_2.

Harcourt's Colour Test for H_2S.

Here the gas is passed straight through the acetate of lead solution until the correct colour is obtained, when the quantity of gas passed contains 0·0025 grains S, and as S exists in H_2S in the proportion of 32 to 2 H by weight, the quantity of H_2S can be readily found.

Harcourt's Colour Test for CS_2.

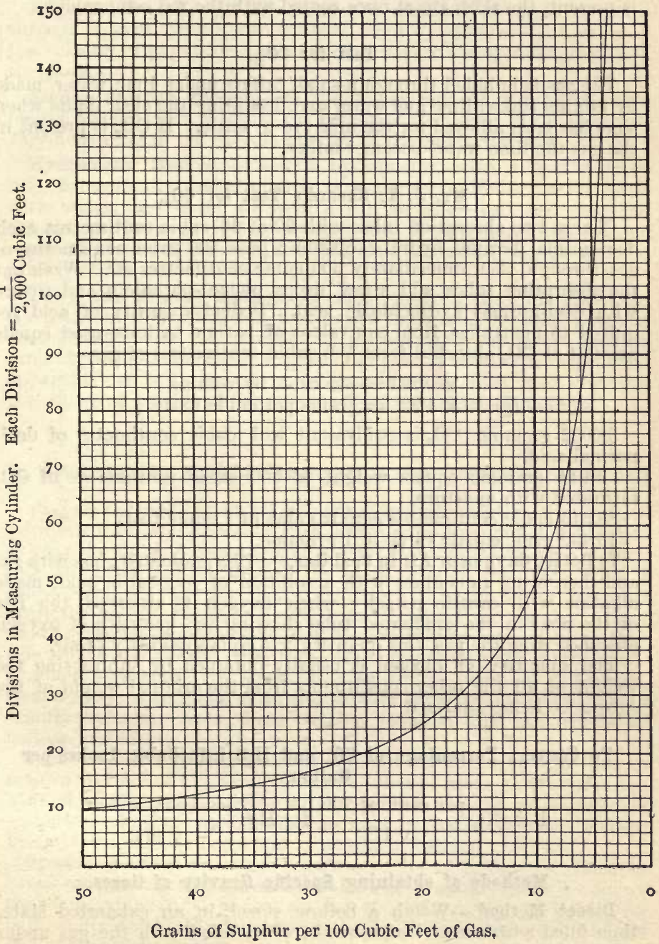
The gas containing CS_2 is made to pass over heated platinised pumice, when the equivalent amount of H_2S is formed and made to bubble through a solution of acetate of lead until the latter is turned to a brown shade of a certain tint, when the quantity of gas passed over the pumice is noted, and to effect this an amount of H_2S equal to 0·0025 grains S must have been in the gas, from which the quantity per 100 cubic feet may be ascertained. 7 or 8 grains per 100 cubic feet should be added to the quantity found by above test for other sulphur compounds not acted upon by above method.

If the gas is not already freed from H_2S it must be passed through an oxide purifier before being allowed to get to the pumice.

A diagram to facilitate the calculation of S from the divisions of the measuring cylinder commonly used, which latter equal $\frac{1}{2000}$th cubic feet is shown.

Diagram for use with Harcourt's Colour Test.

$$\text{Grains of Sulphur} = \frac{500}{\text{Divisions of Measuring Cylinder.}}$$



To Test for Presence of Acetylene.

/ Bring the gas into contact with ammoniacal cuprous chloride solution when red acetylide of copper is formed; aspirate the gas into a flask containing the blue cuprous chloride, agitate, and, if acetylene is present, the sides are at once coated with the red compound.

Test for CO_2.

The gas is bubbled through a small orifice under lime water, made by mixing slaked lime and water and decanting the clear liquid when time has been allowed for the mixture to settle. If CO_2 is present in the gas the lime water becomes milky.

Mr. J. T. Sheard's Test for CO_2.

Charge two absorption tubes with 20 or 30 cubic centimetres each deci-normal barium hydrate solution; pass 500 cubic centimetres of gas through, then immediately 500 cubic centimetres air. Wash out the absorption tubes, add a few drops phenol-phthalein and titrate with deci-normal hydrochloric acid. Deduct quantity of acid required to neutralize from equivalent of barium hydrate used equals amount of CO_2 absorbed from 500 cubic centimetres of gas—

$\times$ 0·241 = per cent. by volume
$\times$ 1·92 = grains per cubic foot

0·0022 gramme CO_2 is equivalent to 1 cubic centimetre of deci-normal acid.

0·914 gramme equals weight of 500 cubic centimetres of CO_2 saturated with moisture.

28,315 cubic centimetres equals value of 1 cubic foot.

15,432 grns. equals value of 1 gramme.

To Detect Oxygen or Air in Coal Gas.—Fill a graduated glass with gas and then bring in contact with a solution of pyrogallic acid, made alkaline with caustic potash; when oxygen is absorbed, the rise of the acid in the graduated tube showing the quantity of oxygen absorbed from the gas, this quantity $\times$ 5 equals quantity of air.

The quantity of oxygen is usually obtained by subtracting the weight of all the other constituents from the original weight of the substance being analysed.

To Convert Percentage of CO_2 and H_2S into Cubic Inches per Gallon.

$$\text{For } CO_2 \ \frac{\text{per cent.} \times 700}{0{\cdot}47}, \quad \text{for } H_2S \ \frac{\text{per cent.} \times 700}{0{\cdot}364}$$

Methods of obtaining Specific Gravity of Gases.

Direct Method.—Weigh a hollow vessel, in an exhausted state, then filled with air, and afterwards, when filled with the gas under test, weight of air $\div$ weight of gas equals specific gravity.

Aërostatic Method.—A balloon of, say, 1 cubic foot capacity is filled with the gas and the balloon weighted until it is just prevented rising in the air. Weight of air displaced by balloon − weight of balloon when weighted equals weight of gas; then weight of air displaced ÷ weight of gas equals specific gravity.

Effusion Method.—If any gases are expelled at same pressure through a small aperture in walls of minute thickness the squares of the velocity of expulsion are in inverse ratio to the specific gravity of the gases.

Liquid Balance Method.—If the lower end of a tube of some length be immersed in liquid the height of the liquid in the tube will vary according to the specific gravity of the gas in the tube.

Hydrometer Method.—Place a hydrometer, with a hollow glass ball, hermetically sealed at top, into a glass cylinder partly filled with water, and cover all with a further glass bell and pass gas through the latter so that hydrometer ball is surrounded by the gas, when the hydrometer will rise and fall according to the specific gravity of the gas.

Lux's Gas Balance Method.—Pass air through the globe and note the position of pointer, and move scale to equal 1·00, then pass gas through and note the position of pointer, and the figure against same at pointer equals specific gravity of gas. The sensitiveness of the apparatus can be increased by, or diminished by, raising or lowering the centre of gravity of the balance from the centre of motion.

To Determine the Specific Gravity of a Gas. (Greville Williams.)

Pass air through one bottle potassium hydrate solution, two bottles sulphuric acid, 6 U-tubes of very active soda-lime, and 4 U-tubes of calcic chloride, and then through a glass globe with stop-cock at each side, and after passing through the globe through one more tube of calcic chloride. The air should be drawn through by an aspirator until the weight becomes constant and temperature regular. Shut tap of globe on aspirator side and remove rubber connection on that side and then close the other tap. Wipe the globe with a silk handkerchief and hang by platinum wire to one side of a balance. Counterpoise with globe of a little smaller capacity, using weights to exactly balance. Note these weights required and call weight of balloon and air.

Pass the gas to be tested slowly through 6 U-tubes of soda-lime to remove all trace of CO_2, and through 4 tubes of calcic chloride for one hour, then through the globe with a further tube of calcic chloride on outlet. Shut off the inlet tap and then immediately the outer tap. Fix and weigh as before equal to weight of balloon and gas.

Specific gravity of the gas equals capacity of balloon or globe in cubic centimetres multiplied by weight of 1 cubic centimetre air at the temperature in °C. of the test, less the difference in weight of the balloon divided by the capacity of the balloon multiplied by weight of 1 cubic centimetre air.

To Obtain the Specific Gravity of any Coal.

Weigh a small piece in and out of distilled water (62° F.) then

$$\frac{\text{Weight in air}}{\text{loss of weight when weighed in water}} = \text{specific gravity.}$$

Specific gravity of any substance × 1,000 equals weight in ounces (avoirdupois) per cubic foot.

To Obtain Value of Gas in Grains Sperm per Cubic Foot.

$$\frac{\text{Illuminating power} \times 120}{5}$$

To Obtain Value of Coal per Ton in lbs. Sperm.

$$\frac{\text{Value in grains sperm per cubic foot} \times \text{cubic feet made per ton}}{7{,}000}$$

or,

$$\frac{\frac{\text{Cubic feet made per ton}}{5} \times \text{illuminating power} \times 3}{175}$$

Average Analysis of Bituminous Coal.

	Caking.	Non-caking.
Specific gravity . . .	1·267	1·279
C	80·05	77·19
H.	5·92	5·26
O	8·98	12·01
N.	2·21	1·89
S	1·13	·64
Ash	1·72	3·02

Determination of the Caking of Coal. (Louis Campredon.)

The coal is powdered to pass through a sieve of 2,580 meshes per square inch, and a fixed quantity—say 1 gramme—of it is mixed with various amounts of uniformly fine sand. Each sample of coal and sand is heated to redness in a small porcelain crucible, and the character of the residue is observed when cool. From the various samples, the maximum quantity of sand which may be added to the given weight of coal with the production of a firm cake on heating is found. The weight of coal is taken as unity in the scale of comparison; and the caking power of coal which leaves a powdery residue is of course nil. The highest result found with any coal was 17° on this scale; pitch gave 20°.

The illuminating power of 146 samples of caking coal varied from 12·5 to 18·5 candles, and the quantity purified by 1 cwt. lime varied from 10,000 to 18,000 cubic feet.

Table Showing the Changes Wood Undergoes in Becoming Coal.
(Roscoe and Schorlemmer.)

	C.	H.	O and N.
Wood	50·00	6·00	44·00
Irish peat	60·02	5·88	34·10
Lignite from Cologne	66·96	5·25	27·76
Earthy coal from Dax	74·20	5·89	19·90
Cannel coal from Wigan	85·81	5·85	8·34
Newcastle Hartley	88·42	5·61	5·97
Welsh anthracite	94·05	3·38	2·57
Graphite	100·00	0·00	0·00

Average Analysis of Welsh Anthracite. (J. Hornby.)

	Per Cent.
Fixed carbon	89·84
Ash	1·20
Sulphur	0·80
Moisture	2·25
Volatile matter	6·01

Lignite specific gravity equals 1·15 to 1·3.
Bituminous coal, specific gravity equals 1·25.

Tests of Coal.

Dry coal at 100° C., weigh every 2 hours, and note lowest weight to obtain amount of moisture.

To obtain quantity of coke or volatile matter, weigh coal in platinum crucible, burn off over powerful Bunsen flame until all gas is driven off, allow to cool in dessicator and weigh; residue = coke. Original weight − coke = gases.

To estimate quantity of ash, weigh coal in a platinum boat and heat it in a glass tube to red heat, air being slowly drawn through the glass tube; cool and weigh boat.

To find total quantity of sulphur, weigh coal with four times its weight of sodium and potassium carbonates mixed in molecular proportions in platinum crucible. Heat over Argand spirit lamp, and slowly increase to just below visible redness until coal becomes faintly grey, then raise heat to a faint red for 40 to 60 minutes; cool.

Products of Distillation of 1 Ton Newcastle Coal. (Gesner.)

Temperature of Distillation, 1,000° to 1,200° F.

Gas	7,450 cubic feet.
Tar	18½ gallons.
Coke	1,200 lbs.

Products of the Tar.

Benzol	3 pints.
Coal tar naphtha	3 gallons.
Heavy oil and naphthalene	9 "
	12⅜ "

Temperature of Distillation, 750° to 800° F.

Gas	1,400 cubic feet
Crude oil	68 gallons.
Coke	1,280 lbs.

Products of the Crude Oil.

Eupion	2 gallons.
Lamp oil	22½ "
Heavy oil and paraffin	24 "
	48½ "

Composition of Fuels (Ash being Deducted). (Sir H. Roscoe.)

Description of Fuel.	Percentage Composition.		
	C.	H.	N and O.
1. Woody fibre	52·65	5·25	42·10
2. Peat from the Shannon	60·02	5·88	34·10
3. Lignite from Cologne	66·96	5·24	27·76
4. Earthy coal from Dax	74·20	5·89	19·90
5. Wigan cannel	85·81	5·85	8·34
6. Newcastle Hartley	88·42	5·61	5·97
7. Welsh anthracite	94·05	3·38	2·57

The above shows the alteration in composition which wood has undergone in passing into coal.

Average carbon in average gas coke equals 88 per cent. Average carbon in average anthracite equals 90 per cent.

The O in purified coal gas does not result from the distillation of the coal, but must have been admitted with the air either intentionally or accidentally.

Gas only forms about 15 per cent. of the total products obtained from the distillation of coal.

Experiments on small quantities of coal usually give results 7 per cent. in favour of the coal over working results.

Sulphur in Coal. (J. Hepworth.)

		Sulphur in Volatile Products per Ton of Coal.		Sulphur in Coke per Ton of Coal.		Total Quantity of Sulphur per Ton of Coal.	
		Lbs.	Percentage.	Lbs.	Percentage.	Lbs.	Percentage.
Coal.	A	4·35	·19	8·51	·38	12·86	·57
Coal.	B	7·84	·35	4·92	·21	12·76	·56
Coal.	C	4·70	·21	7·61	·34	12·31	·55
Cannel.	D	18·16	·81	15·0	·67	33·16	·48
Cannel.	E	9·18	·41	6·04	·27	15·22	·68
Cannel.	F	9·04	·44	7·76	·31	16·80	·75

Average sulphur per ton of coal, 13·80 lbs.

Left in coke	6·53 lbs.
Removed by purification from volatile products	7·27 „
Coal	13·80 „

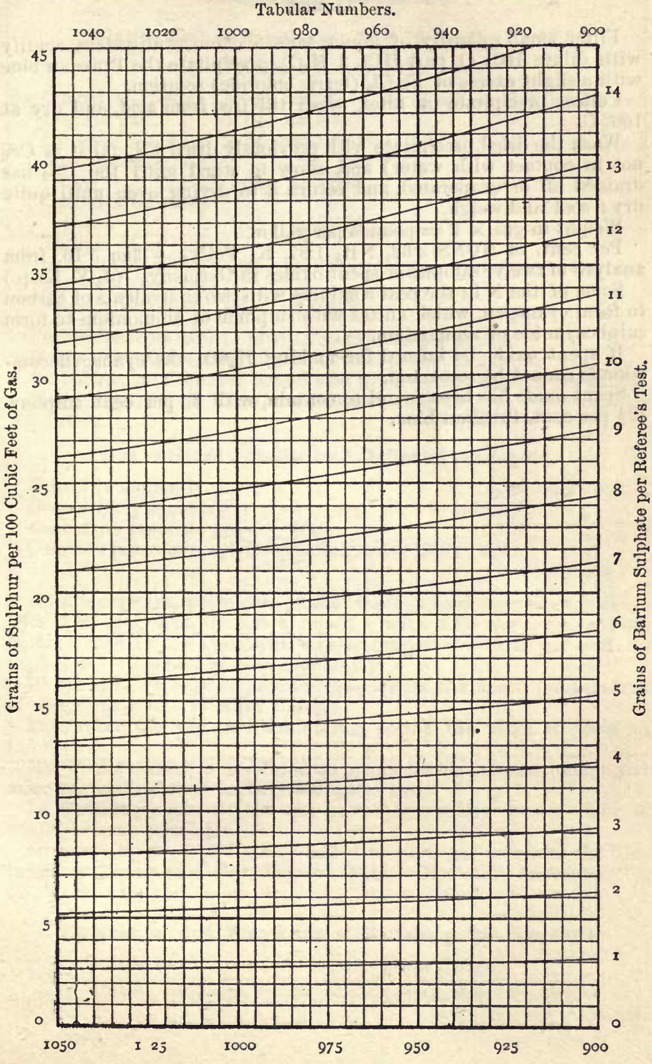
Bituminous coals contain sulphur, principally combined with iron, in the form of bisulphide of iron (FeS_2) or pyrites which become sulphide or protosulphuret of iron (FeS) on the application of heat.

Coal gas contains about 7 per cent. CO.

According to the Gas Referee's Reports gas always contains about 10 grains sulphur per 100 cubic feet when sent out.

The whole of the sulphur in coal gas is converted into sulphur dioxide during combustion. (W. C. Young.)

Diagram showing Grains of Sulphur per 100 Cubic Feet for each Grain of Barium Sulphate (corrected for Temperature and Pressure).



To Estimate Lbs. of Prussian Blue in Gallons of Cyanogen Liquor.

Filter small quantity of liquor, take 5 cubic centimetres, acidify with dilute HCl (1 part HCl, 3 H_2O), precipitate the Prussian blue with a slight excess of Fe_2Cl_6 (ferric chloride) solution.

Collect precipitate on filter, wash till free from acid, and dry at 100° C.

Wash the dried precipitate with previously dried CS_2 (that is CS_2 not in contact with water) and allow to stand until the CS_2 has drained off or evaporated, and return it to drying oven until quite dry; cool and weigh.

Weight in gas $\times$ 2 = pounds per gallon.

Per cent. of HCNS 2·62, NH_3 1·87, K_4 $FeCy_6$ + 3aq 5·10, from analysis of twelve samples of spent oxides in Germany. (J. V. Esop.)

Some of the N in the coal combines with two equivalents of carbon to form cyanogen, which unites with sulphide of ammonium to form sulphocyanide of ammonium.

If spent oxide be burned for making H_2SO_4 the cyanogen compounds cannot be recovered.

Spent oxide has been found to contain, with 25 per cent. sulphur, 12½ per cent. Prussian blue.

ENRICHING PROCESSES.

Relative Cost of Enrichment from 16 Candles to 17·5.

(Professor Lewes, 1891.)

By Cannel (Livesey)	4·00*d.*	= 2·667*d.*	per candle	per 1,000	cubic feet
„ Pintsch gas . .	3 64	= 2·427	„	„	„
„ Oil gas (Foulis) .	2·34	= 1·560	„	„	„
„ Maxim-Clark process . . .	1·64	= 1·093	„	„	„
„ Carburetted water gas . . .	1·01	= 0·673	„	„	„
„ Tatham Oxy-oil process (probable)	0·91	= 0·607	„	„	„
„ Tatham Oxy-oil process (claimed)	0·50	= 0·333	„	„	„

Peebles process said to give 1,750 candles per gallon.
Water gas process said to give 1,400 candles per gallon.
Carburine, gasoline and benzol said to give 1,600 candles per gallon.
Pintsch gas, liquid from compression, said to give 3,000 candles per gallon.

Gas enriched 1 Candle by 1 Gallon of the Liquid.

Benzol (chemically pure)	13,300 cubic feet.
Benzol (90 per cent.)	12,500 „
Carburine (specific gravity ·680) . . .	5,700 „
Common petroleum spirit (specific gravity ·700)	4,300 „

(T. Stenhouse.)

With 5 per cent. petroleum vapour there is no danger of explosion; with 6·25 per cent. a feeble report; with 8·30 per cent. a loud report; with 11 to 14 per cent. a violent report; with 20 per cent. no explosion. (*Journal of Gas Lighting.*)

70 per cent. by bulk of producer gas lowers the flame temperature of water gas 400°. (Walter Clark.)

The lower the gas in illuminating power the more it costs to improve it.

Mr. Foulis considers undiluted oil gas is better for enrichment and more economical than carburetted water gas.

In distilling shale oil the gas has to be rapidly drawn off, or it would become permanent.

Oxygen (up to ½ per cent.) added to pure gas increases the illuminating power (see *Gas Journal*, 1885, "Midland Association"). (B. W. Smith.)

Formula to find Proportion of Enriching Gas Required.

$$100 \div \frac{\text{Initial candle-power} \backsim \text{candle-power desired}}{\text{Initial candle-power} \backsim \text{candle-power of enriching gas}} = \text{percentage required.}$$

Formula to find Quantity in Cubic Feet to be added to Initial 1,000 Cubic Feet.

$$1{,}000 \div \frac{\text{Initial candle-power} \backsim \text{candle-power desired}}{\text{Candle-power of enriching gas} \backsim \text{candle-power desired}}$$
= quantity in cubic feet per 1,000.

$1\frac{3}{4}$ gallons carburine (specific gravity 68) per 10,000 cubic feet gas required to enrich 1 candle by Clark carburettors.

Enriching Value of Oil Gas due to Temperature of Distillation.

(W. Foulis.)

Coal Gas. Illuminating Power, corrected to 5 Cubic Feet per Hour.	Oil Gas. Illuminating Power, corrected to 5 Cubic Feet per Hour.	Percentage of Oil Gas added.	Illuminating Power of combined Gas corrected to 5 Cubic Feet per Hour.	Enrichment Value of Oil Gas calculated to 5 Cubic Feet.	Average Retort Temperature.
20·74	64·05	4·20	24·28	105·20	1,100° F.
20·45	60·88	4·90	23·69	86·60	1,135° F.
18·51	62·11	4·52	21·59	86·60	1,145° F.
16·84	61·10	4·38	20·85	108·30	1,070° F.
14·65	74·00	4·00	19·77	117·00	1,000° F.

Gasoline boils at about 40° C.

Carburine boils at about 67° C. Specific gravity 0·680.

Benzene boils at about 80·5° C. Specific gravity 0·885 at 15° C.

Russian mineral oil (·908 specific gravity) contains 20·5 grains sulphur per gallon.

Russian burning mineral oil contains 10·3 grains sulphur per gallon.

American ,, ,, ,, 16·3 ,, ,, ,,

American water white mineral oil contains 8·1 grains sulphur per gallon.

American burning safety mineral oil contains 14·0 grains sulphur per gallon.

Scotch mineral oil (for gas making) contains 49·8 grains sulphur per gallon. (W. Fox and D. G. Riddick.)

Petroleum contains about 85 per cent. C, 13 per cent. H, 2 per cent. O; specific gravity ·87; weight 8·7 lbs. per gallon.

Petroleum oil contains about 73 per cent. C, 27 per cent. H; specific gravity ·71; weight 7·10 lbs. per gallon.

162 cubic feet of 16-candle gas will retain the vapour from 1 gallon carburine at 59° F., and 30 inches pressure. (Professor W. Foster.)

Where cannel is used for enrichment there is seldom much napthalene deposited.

To produce gas from iron and steam, for every 1,000 cubic feet hydrogen produced, rather less than 1 cwt. iron would be required. (H. Kendrick.)

The "Browne" Process of Making, Lighting, and Heating Gas from Crude Petroleum.

An emulsion of 5 or 6 volumes of crude petroleum is made with 95 or 94 volumes of water. This emulsion is pumped slowly through a tube about 300 feet long under a pressure of 100 lbs. on the square inch. One end of the tube is at the temperature of the air, the other is sufficiently hot to bring about chemical action between the vaporised contents, and hydrogen and carbon monoxide are liberated as permanent gases that are then passed through a coke-water scrubber and may afterwards be stored in a holder for use. The heat applied to the converting tube increases gradually from end to end. The light-giving value of the gas can be raised by allowing a greater proportion of petroleum to be added when about half-way through the converting tube.

Mixtures of ethylene and oxygen in insufficient quantity to form explosive mixtures possess greater illuminating power than pure ethylene, the highest luminosity observed being with 75 per cent. ethylene and 25 per cent. oxygen. An increase of oxygen above this diminished the illuminating power.

Wood Gas.

One retort about 21 inches diameter by 9 feet 6 inches long will produce 12,000 cubic feet per day.

One ton of wood will produce 8,000 to 11,000 cubic feet of 9 to 16-candle gas. Residuals, charcoal 4 cwt., tar $1\frac{1}{4}$ cwt.

Benzene is as 500 to 900 candles per 5 cubic feet vapour, compared with napthalene. (Professor V. B. Lewes.)

Benzene is probably not efficient when the gas requires enriching more than 1 to 2 candles.

Benzene vapour should have an illuminating power of 700 candles per 5 cubic feet, with an enriching value of 3·9. (Professor V. B. Lewes.)

A gallon of benzol has an enrichment value of only 4,500 candles, and carburine is only one-fourth as effective. (Mr. W. Young, of Peebles.)

One gallon of benzol will enrich from 12,000 to 15,000 cubic feet, adding 1 candle-power to it. The cost to enrich 1,000 cubic feet to the extent of 1 candle-power with benzol is from $\frac{3}{4}d.$ to $1d.$

Four to 5 candles can be added to gas with 600 to 700 grammes benzol, and would be stable at 32° F. At 77° F. gas will hold four times the quantity of benzol which it will at 30° F. (Dr. Schilling.)

Temperature required to vaporise benzol = + 212° F.

It is unnecessary to heat benzol when using it as an enricher, except in very cold weather.

The molecular structure of the benzol molecule is such that, of all the liquid hydrocarbons known, it is the one which may be expected to break up most readily into that wonderful acetylene, which, according to some authorities, puts everything into the shade as a light producer. (T. Stenhouse.)

Vapour tension of benzene (90° benzol) at 59° F. equals 58·9 millimetres.

One gallon benzol will raise 24,500 cubic feet 16-candle gas 1 candle. (Dr. H. Bunte.)

Benzol boils at 177° F.

1,000 parts of water dissolve 1·45 parts of benzene, 0·57 parts of toluene, and 0·12 part of xylene.

Benzene can be obtained by keeping acetylene for a long time just below a red heat. (Professor Mills.)

From Manchester gas 3·5 gallons benzene per 10,000 cubic feet were obtained, 1882. (Wilfrid Irwin.)

From Manchester gas 3·7 to 4·25 gallons of liquid per 10,000 cubic feet were dissolved out, containing 80 per cent. hydrocarbons of the benzene series (1884), with an enrichment value of 4,500 candles per gallon. (G. E. Davis.)

At least three times the amount of petroleum spirit is required to repair the loss of a certain quantity of benzene, and there is also a great difficulty in getting the required amount into the gas without condensation. (Wilfrid Irwin.)

One cubic foot gas will permanently retain alone 50 grains benzol vapour at a temperature of 32° F. (T. Stenhouse.)

One gallon benzol will enrich 9,500 cubic feet gas 1 candle. (Hunt.)

One gallon petroleum spirit will enrich 2,800 cubic feet gas 1 candle. (Hunt.)

One gallon benzol will enrich 3,900 cubic feet gas 4 candles. (Schilling.)

One gallon benzol will enrich 8,500 cubic feet gas 1 candle.

One gallon benzol (90 per cent.) will enrich 13,800 cubic feet gas 1 candle.

One gallon benzol will enrich 20,000 cubic feet gas 1 candle. (J. F. Bell.)

One cubic foot benzol equals 40 candles (L. T. Wright).
" " " 147 " (Professor Falkland).
" " " 181 " (Knublauch).

The purity of the benzol is not stated in each case, hence the difference in results.

Benzene freezes at 32° F., and boils at 177° F.; specific gravity at 60° F. 0·8833.

Each grain absorbed per cubic foot of common gas increases illuminating power 10 per cent. (Letheby.)

Enrichment per Gallon per 10,000 Cubic Feet with Benzene.

			Candles Enrichment.
Bunte	gives	. . . .	3·6
Frankland	"	. . . .	2·9
Hunt	"	. . . .	0·9
Knublauch	"	. . . .	3·7
Stenhouse	"	. . . .	1·3
L. T. Wright	"	. . . .	0·8
W. Irwin	"	with flat flame burner	2·7
"	"	" Argand " . .	0·5

To enrich with benzol, the coal gas is made to pass over the surface of cold benzol, and the vapour rising from this is taken up and combines with the gas at once, the quantity absorbed being regulated by the area of benzol surface exposed and the rate at which the gas passes through the benzoliser.

Gas enriched to 17 or 18 candles with benzene would be far better appreciated by the average consumer than 20-candle gas owing its illuminating power largely to olefines.

Benzol will separate when the gas is exposed to great cold. (Dr. Buel.)

Commercial benzol if used for enrichment may contain sufficient sulphur to cause an increase of 10 grains S per 100 cubic feet of gas per 1 candle of enrichment.

Ninety per cent. benzol contains 25 per cent. toluol, therefore it is best to use the purest benzol for enriching, as the evaporation is not so rapid with toluol, nor the enriching value so great.

The higher the boiling-point of the paraffin series of hydrocarbons the greater is their enriching value. (Wilfrid Irwin.)

While for carburetting feebly illuminating coal gas about 8·8 grains of benzol or toluol, or 31·7 grains of pentane or hexane per candle per hour are required, with hydrogen double the quantity is required, and with carbonic oxide treble is required. (Dr. H. Bunte.)

		Candle Enrichment.		Cubic Feet of Gas.
1 gallon	pure benzol	= 1	per	13,300
1 „	commercial benzol	= 1	„	12,500
1 „	carburine (·689 specific gravity)	= 1	„	5,700
1 „	common petroleum spirit (·700 specific gravity)	= 1	„	4,300

(T. Stenhouse.)

Gas will carry 3 per cent. benzol at 32° F. (Dr. Bunte.)

0·0033 gramme per litre per candle enrichment is required with toluene.

0·0034 gramme per litre per candle enrichment is required with benzene.

0·0028 gramme per litre per candle enrichment is required with benzene and H.

0·0115 gramme per litre per candle enrichment is required with heptane.

0·0027 gramme per litre per candle enrichment is required with xylene.

0·0026 gramme per litre per candle enrichment is required with napthalene and H.

0·0020 gramme per litre per candle enrichment is required with napthalene.

0·0064 gramme per litre per candle enrichment is required with phenol. (W. Irwin.)

To Test between Petroleum Benzene and Benzene from Coal Tar.

Use Syrian asphalte washed thoroughly with petroleum naptha to remove all constituents soluble. The colour of the mixture of the two benzenes after treatment with the asphalte varies from straw colour to dark brown according to the quantity of the coal tar benzene present, and these colours can be made to indicate the proportion of each benzene in the mixture. (*Journal of the Society of Chemical Industry.*)

Value of Acetylene as an Enricher of Coal Gas.

(Professor V. B. Lewes.)

Composition of the Mixture.		Illuminating Value.		Enrichment Value of 1 Per Cent. in Candles.
Coal Gas.	Acetylene.	Coal Gas.	Mixture.	
99·10	0·90	13	13·9	1·00
97·90	2·10	13	15·1	1·00
96·00	4·00	13	17·3	1·07
95·20	4·80	13	18·4	1·12
91·00	9·00	13	23·5	1·16
89·50	10·50	13	25·3	1·17
85·00	15·00	13	33·0	1·33
83·25	16·75	13	36·1	1·36
66·90	33·10	13	60·5	1·43
55·50	44·50	13	76·7	1·43
16·70	83·30	13	175·2	1·94
00·00	100·00	0	240·0	2·40

The theoretical yield of acetylene is 25 lbs. per 60 lbs. of carbide approximate—more correctly, 26 lbs. to 64 lbs.

The following data for a 1,000 horse-power engine are based on the estimates of D. Adolph Frank, of Charlottenberg, and are intended to show the saving in space obtained. The engine is supposed to be run for 600 hours, and at 1·54 lb. of coal per horse-power per hour would require about 420 tons, which would occupy about as many cubic metres. Liquid acetylene at 39 lbs. per horse-power per hour would weigh about 108 tons, and occupy about 300 cubic metres, while carbide of calcium with 36 per cent. by weight of acetylene, need not occupy much more than 150 cubic metres, even after allowing for protective apparatus. In the latter cases the space occupied at present by the boilers would not be required.

Acetylene with different proportions of air gives the following results: When 1,000 cubic inches of the mixture contain less than 77 cubic inches of acetylene, it will burn completely, producing water and carbon dioxide. When the proportion of acetylene is increased so that it forms from 77 to 174 cubic inches per 1,000 of the mixture, the product consists of water, carbon dioxide, carbon monoxide and hydrogen, and the combustion is therefore imperfect. With larger proportions of acetylene free carbon and unaltered acetylene are left. When anything between 28 and 650 cubic inches of acetylene are present in 1,000 of the mixture it will take fire. (M. Le Chatelier.)

Calcium carbide, $CaC_2 + H_2O = C_2H_2 + CaO$.

1 lb. CaC_2 makes about 6 cubic feet acetylene (C_2H_2) of about 48 candle-power per foot.

10 volumes water will absorb 11 volumes acetylene gas at ordinary temperature and pressure.

Iron burners are not suitable for use with acetylene gas, as the gas destroys the metal and enlarges the holes.

Gas is evolved from calcic carbide until a pressure of 1,100 lbs. per square inch is present.

87½ lbs. lime to 56½ lbs. C yield 100 lbs. calcium carbide and 43¾ lbs. CO.

100 lbs. carbide yields 40·62 lbs. acetylene and 115·62 lbs. slaked lime, or 5·9 cubic feet of acetylene per lb. carbide.

Calcic carbide has specific gravity 2·262.

„ „ is liquefied at 32° F. by a pressure of 21½ atmospheres.

1 lb. liquefied calcic carbide will expand to 14½ cubic feet at atmospheric pressure.

Space required in generator 80 cubic inches per 1 lb. carbide.

1 volume acetylene + 1¼ volumes air is slightly explosive.
1 „ „ + 12 „ „ very „
1 „ „ + 20 „ „ not „

Acetylene or ethine (C_2H_2) is colourless, and burns with an intensely luminous flame, of the odour of rotten vegetables. Is made by the action of H_2O upon calcium carbide (CaC_2), the latter the produce of carbon and calcium burnt in an electrical furnace.

Acetylene has approximately 15 times the lighting value of common gas, but has only two and a half times the heating value.

When acetylene is subjected to a pressure of 22 atmospheres at 0° C. it is condensed to a colourless mobile liquid lighter than water.

The Toxicity of Acetylene.—M. Gréhant found it is poisonous if inhaled in large quantities between 40 and 79 per cent.

The amount of acetylene in Manchester gas never exceeds 0·05 per cent.

6·35 cubic feet C_2H_2 gives 1 H.P.

Specific gravity $C_2H_2 = 0·91$.

Comparison of Illuminating Value to Proportions of Acetylene.
(Professor V. B. Lewes.)

Analysis of Mixture.		Acetylene at Top of Non-luminous Zone.	Illuminating Value of Flame per 5 Cubic Feet.
H.	Acetylene.		
65·5	34·5	3·72	14·0
43·5	56·5	8·42	87·0
0·0	100·0	14·95	240·0

Purified Lowe oil gas contains :—

H	22·6
Saturated hydrocarbons, methane, &c.	31·9
,, carbon, ethylene, &c.	13·4
CO	29·2
O	0·6
N	2·3
	100·0

(Professor Lewes, 1893.)

Average Composition of Water Gas (Non-luminous).
(Professor Lewes.)

H	48·31 per cent.	Methane	1·05 per cent.
CO	35·93 ,,	H_2S	1·20 ,,
CO_2	4·25 ,,	O	0·51 ,,
N	8·75 ,,		

Analysis of Water Gas. (*Lancet*).

	Per Cent. by Volume.
Hydrogen (H)	49·17
Methane (CH_4)	0·31
Carbon monoxide (CO)	43·75
Carbonic acid (CO_2)	2·71
Nitrogen (N)	4·06

26 candle-power water gas consists of :—

	Per Cent. by Volume.
Hydrogen	34
Methane	15
Hydrocarbons absorbable by fuming sulphuric acid	12·5
CO	33
Nitrogen	from 0·5 to 5

Specific gravity equals 0·62 (air 1). (Butterfield.)

Analysis of Carburetted Water Gas at Outlet of Exhausters.

CO_2	4·6
CO	14·8
C_nH_{2n}	21·2
CH_4	30·7
H	18·4
O	1·0
N	9·3
	100·0

Generator of ½ million plant, generally 18 feet high, 10 feet diameter, with fire bars 4 feet from bottom, with 4 cleaning doors 8 feet from bottom, the upper portion coned to an opening about 2 feet diameter.

Carburettor same size, but no doors, filled with checker bricks.

Superheater 24 feet high, 10 feet diameter, also filled with checker bricks up to within 4 feet from top.

Scrubber, 20 feet high, 6 feet diameter, filled with layers of wood strips placed checkerwise.

Condenser, 20 feet high, 6 feet diameter, filled with 2-inch tubes.

The generator, carburettor, and superheater are usually lined with fire-clay blocks 10 inches thick, with space of 2 inches between shells and bricks, tightly packed with a non-conductor. The blast inlet to the generator is below the fire bars, where the steam is also admitted. The blast inlet to the carburettor is at the top, and to the superheater at the bottom.

Superheater usually 6 to 8 feet higher than the carburettor.

Maximum pressure in shells, ordinary working, 40 inches water.

Average „ „ „ 30 „ „

Pressure at which shells should be gas tight, 3 lbs. per square inch.

Pressure of air blast, 12 to 15 inches of water.

Pressure of steam, 130 lbs. per square inch.

Blast mains usually No. 18 Birmingham wire gauge galvanized iron; average blast 14 inches water.

Blowers usually work 2,000 revolutions per minute.

Temperature in generator should not be allowed to get below 1,000° C., and fuel of sufficient depth to convert the CO_2 to CO, provided, and the C should be in excess. Best temperature, about 1,100° C.

Superheater must be kept at a temperature just below that required to separate the C from the oil vapours.

Gradually increasing heats in carburettor and superheater best for fixing oil gas. Oil injected at from 25 to 30 lbs. per square inch.

Too low heats give a tarry stain on white paper held to pet cock on superheater.

Too high heats give a deposit of carbon particles on white paper held to pet cock on superheater.

Coke for feeding generators should be of even size and screened, giving little ash so that the steam may not pass through the fuel too freely. Coke must be fed regularly, say every two hours.

Superheated steam obtained by use of boilers working at 130 lbs. pressure.

Blast pipes are often made of 16 Birmingham wire gauge, and are all connected by small pipes, so that the pressure is in all even when the fans are not running in every set.

Two-inch safety tube is fixed just outside blast valve, so that if oil is leaking back through blast stop-valves on vessels the pressure causes a smoke to issue from the tube.

One foreman superintends the work of gas making and clinkering.

A gang of four men clinker three fires twice during eight-hour shift.

A safety valve is fixed outside each blast inlet valve of the same bore as the pipe.

Seal in seal pot, 3 inches.

Tubes in condenser which comes after the scrubber, 1½ inches diameter.

In lighting up, fill up generator with coke and open the stack valve, shut generator charging door and turn on blast at generator; when the brickwork of carburettor is red hot turn on blast there until superheater is red hot, and then put blast there until all are cherry red hot.

If coke is required in generator before all are hot, shut all blast off and close stack valve, and then open charging door.

In working, shut off blast first from generator, then carburettor, and then superheater, shut stack valve, then open oil feeder, and next turn on steam to generator and oil pumps.

When gas making is finished, shut off oil, then steam to generator, open stack valve, and then open blast on superheater, carburettor, and generator.

Average fuel required per 1,000 cubic feet gas made, 45 lbs.

Average oil required per 1,000 cubic feet gas made (distillate from Russian crude), 5·46.

Candle power per gallon oil developed, 9·03.

Percentage volume CO_2 in crude gas, 4 per cent. by volume.

Illuminating power of gas, 24·68 candles.

Low heats or excess steam produce increase of CO_2.

Half million per day plant can be started in full working order in 3½ hours.

Temperature at which C decomposes water vapour to CO_2 and $2\ H_2$ equals 600° C.

Temperature at which C decomposes water vapour to CO and H_2 equals 1,000° C.

When steam superheated, or at, say, 130 lbs. per square inch, is passed through fuel at 1,000° C., $CO + H_2$ are formed with about 3 per cent. CO_2.

To avoid explosions when lighting up, fill the generator to the top with fuel under slow fire without blast, and when blast is put on do not open the generator until it is at a working heat.

Checker work requires renewing every six months (about) and should have superficial area of 16 square feet per 1,000 cubic feet made per diem, not including linings.

By superheating, a considerable increase of illuminating power can be obtained with either crude petroleum (naptha) or pure paraffins. (Dr. H. Bunte.)

The quantity of water gas produced from 1 lb. of carbon is about 61 cubic feet at 600° F., and to produce this 4,200 heat units are absorbed, or about 70 units per cubic foot.

With carburetted water gas on a commercial scale 1,000 cubic feet of 22-candle gas can be produced from 50 lbs. coke and 4 gallons oil.

Mix rich gases with poor ones as early as possible during manufacture.

Analysis of Heating Gases at—

	Outlet of Producer.	Outlet of Superheater.
CO_2	7·94	15·10
CO	23·21	0·10
O	—	3·80
N	68·85	81·00

Proportions of CO_2 per Minute of Run.

Minutes	1	2	3	4	5	Average.
CO_2	0·5	1·7	4·1	6·2	7·9	4·05

Percentage of CO_2 at End of Each Minute of a Five Minutes' Run, at Outlet of Generator. (Butterfield.)

1st minute	= 0·3	per cent.	CO_2
2nd „	= 0·6	„	„
3rd „	= 1·4	„	„
4th „	= 2·6	„	„
5th „	= 4·2	„	„
Average	1·82		

Proportion of CO_2 increases according to length of run.

CO_2 in water gas varies from 1½ to 4 per cent.

Only 3 per cent. CO_2 should be present in water gas, as it reduces the illuminating power of the gas.

Percentage of CO_2 in uncarburetted water gas usually 4 to 5 per cent.

CS_2 in carburetted water gas is about 4 grains.

CO in crude carburetted water gas at Blackburn equals 28 or 29 per cent.

Analysis of Crude Carburetted Water Gas. (Paddon and Goulden.)

(Class of oil used, a rough distillate from Russian crude.)

H	21·8	H_2S and CO_2	3·8
CH_4	30·7	O	0·5
CnH_2N	12·9	N	2·2
CO	28·1		

At Blackburn, the total of five experimental runs with water gas (carburetted), 17,560,000 cubic feet gas of 22·77 illuminating power was made from 57,992 gallons "solar distillate" ·875 specific gravity. 648,267 lbs. coke was used, and 1,162,000 gallons water.

Analysis of Water Gas.

	American Practice.	English Practice.
CO_2	3·5	3·87
CO	43·4	45·87
H	51·8	49·55
N	1·3	0·71

Carburetted water gas from coke should contain about 3 per cent. CO_2.

Carburetted water gas from coke should contain about 2 per cent. H_2S.

Sulphur compounds not exceeding 10 grains per 100 cubic feet.

Cost of purifying carburetted water gas equals 1·043*d.* per 1,000 cubic feet.

Carburetted water gas making requires only half the labour of coal gas, and saves ·17*d.* per 1,000 cubic feet for purification.

Water gas can be enriched at the rate of 0·006 gramme per litre per candle.

26-candle carburetted water gas contains 60 per cent. by volume of pure water gas.

26-candle gas is the most economical to make.

Enriching value of 20 to 25 candle-power water gas (carburetted) equals about 20 per cent. more than its nominal value. (J. Methven.)

Water gas *per se* has not any illuminating power.

Solar distillate has specific gravity about ·875 of flashing point 170° F.

Solid residue from oil should not exceed 2 per cent. by weight.

Water required for condensing carburetted water gas equals 90 gallons per 1,000 cubic feet. (A. G. Glasgow, 1892.)

Approximate Analysis of Oil Gas Tar, from Condensers.

(Paddon and Goulden.)

Special gravity of Tar ·996.

	Per Cent. by Volume.	Per Cent. by Volume Without Water.
Water	76·5	
Benzene	0·28	1·19
Toluol	0·90	3·83
Light paraffins, &c.	2·0	8·51
Solvent naptha (zyloete)	4·15	17·96
Phenol	only a trace	only a trace
Middle oils (naptha, &c.)	6·92	29·44
Creosote oil and green oil	5·70	24·26
Napthalene	0·30	1·28 per cent. by weight
Anthracene cake	0·22 contains 8·33 per cent. anthracene	0·93
Coke	2·30	9·80
	99·27	97·20
Loss	0·73	2·80
	100·00	100·00

Carburetted water gas tar contains about 70 per cent. water as it leaves the apparatus.

Water used for cooling and scrubbing about 70 gallons per 1,000 cubic feet gas made, but this quantity is being reduced in modern plants to about 40 gallons.

In America the production of oil gas tar by the Lowe process is about 12½ per cent. of the oil used.

To adequately protect petroleum tanks from lightning, it is necessary that all openings through which vapour can escape should be guarded with wire netting upon the principle of the Davy safety lamp. (Professor Neesen.)

Joints in pipes for petroleum carrying should, preferably, be screwed, and when all oil has been removed from the threads, a good thick shellac varnish should be applied to the outside and inside threads.

Yellow soap, treacle, honey, glue, mucilage, or glycerine are all quite petroleum proof. Canvas saturated with shellac varnish makes a good washer and might be used as the strip in riveted joints.

Analysis of Belfast Carburetted Water Gas.

CO_2	nil.	
O	nil.	
Unsaturated hydrocarbons	10·7	per cent.
CO	31·9	"
Saturated hydrocarbons	16·2	"
H	33·7	"
N	7·5	"
	100·0	"

CO_2 in crude gas	3·5	per cent.
SH_2 " "	·2	"

In water gas plant, at end of first minute gas should contain 0·3 per cent. CO_2; at end of second minute gas should contain 0·6 per cent. CO_2; at end of third minute gas should contain 1·4 per cent. CO_2; at end of fourth minute gas should contain 2·6 per cent CO_2; at end of fifth minute gas should contain 4·2 per cent. CO_2. (Butterfield.)

Crude water gas from coke (carburetted) will contain about 90 to 150 grains H_2S per 100 cubic feet, and about 3 per cent. CO_2, no ammonia, sulphur compounds not more than 10 grains per 100 cubic feet. Purification of water gas from CO_2 is twice that of coal gas. (Butterfield.)

If air is forced through red hot coke, 1 lb. of carbon in burning to CO liberates 4,451·4 units of heat; but if burnt to carbon anhydride, 14,544 units.

If there be sufficient body of carbon for this latter gas to pass through, it is decomposed with the absorption of 10,000 units of heat.

One pound C requires $1\frac{1}{4}$ lbs. O, and forms $2\frac{1}{4}$ lbs. CO, but air would contain for $1\frac{1}{4}$ lbs. O about $4\frac{1}{2}$ lbs. N.

If steam is forced through 1 lb. C requires $1\frac{1}{2}$ lbs. steam to form CO, and this steam contains $1\frac{1}{4}$ lbs. O and $\frac{1}{6}$ lb. H.

One pound H burnt to water, yields 62,500 heat units, this $\div$ 6 = 10,416 heat units equal to quantity absorbed by the hydrogen; and less 1,723 heat units (the heat already absorbed by the steam) equals 8,693 units, of which 4,500 will be supplied by the forming of CO, leaving 4,200 units to come from the previously heated coke.

In practice more is taken from the coke, as the gases escape hot. (Norton H. Humphreys.)

Steam brought into contact with an excess of carbon at 1,000° F. is decomposed into its component gases H and O, and combines with the carbon to form CO + H.

Equation of water gas production—

First action . $4\,(H_2O) + 2\,C = 2\,CO_2 + 8\,H.$
Second action . $2\,CO_2 + 8\,H + 2\,C = 4\,CO + 8\,H.$

(B. H. Thwaite.)

The O of steam attacks not only the surplus carbon, but also the hydrocarbon when mutually decomposing, as in water gas plants, bringing about the destruction of a large quantity of illuminating matter. (Young.)

Ordinary producer gas contains about 30 per cent. by volume of combustible gases, and has a calorific value of about $\frac{1}{8}$th that of 16-candle gas.

If producer and water gas were mixed the mixture would consist of 30·5 H, 60 CO, and 60 N.

Minimum temperature for formation of pure water gas, 1,800° F.

To form sufficient heat for the production of 1 volume water gas 1·4 volumes producer gas are required.

Temperature in water gas generator should never be lower than 1,000° C., and fuel should be of sufficient thickness to ensure as complete a conversion of the CO_2 to CO as possible.

With hard anthracite coal it is possible to so arrange the temperature in the generator that practically no CO_2 is formed, but with coke a percentage of the product is almost bound to be produced. H_2S is also absent when anthracite is used, as it is formed from the S in the coke.

Carburetted water gas plant at Blackburn—

Coke used per 1,000 cubic feet	30·8 lbs. for generator.
" " " "	6·1 " " boiler.
" " " "	36·9 total.
Oil, candles per gallon . .	6·97
Oil, specific gravity . . .	·878

Mr. Foulis found that with ordinary water gas apparatus he required 30 lbs. to 40 lbs. coke per 1,000 cubic feet of 30-candle gas using 6 gallons oil.

Uncarburetted water gas has only about half the calorific power of coal gas, but when carburetted to about 22 to 23 candles is about 85 per cent. to 95 per cent. the power.

Semi water gas contains from 80 to 85 per cent. of the heating value of coal, and is the cheapest gas if supplied within a reasonable distance from the place of production. (A. Kitson.)

Water gas from anthracite coal has a calorific value of 290 heat units. Water gas from bituminous coal has a calorific value of 350 heat units. (B. Loomis.)

Difference in heating value of carburetted water gas and coal gas is as 9 to 10.

Water gas, hydrogen, or mixtures of the two, when carburetted by the vapours obtained by decomposing hydrocarbons yield a flame which, although it may be of high illuminating value, is far shorter and smaller than the flame obtained from ordinary coal gas, and that in consequence of this it has to be burnt in larger quantities in order to obtain a flame which shall in appearance equal that of coal gas. This is due to the coal gas containing from 36 to 46 per cent. of methane, or light carburetted hydrogen, which gives body and length to the flame, and which only exists in carburetted water gas or hydrogen to the extent of from about 16 to 26 per cent. (Professor V. B. Lewes.)

Carburetted water gas gives a small flame and lower durability than coal gas of equal illuminating power.

Coal gas carburetted by petroleum gives larger flame and higher durability.

The enriching value of 33-candle carburetted water gas is from 6 to 8 per cent. higher, and 47-candle carburetted water gas is 10 per cent. higher than when tested alone in the photometer. (A. Wilson.)

Messrs. Frankland and Wright, and Dr. J. Louttit found by experiments with young rabbits that the effects of carbonic oxide were not more poisonous than ordinary coal gas.

Approximate Cost of Water Gas per 1,000 Cubic Feet at 25 Candles.

	s.	*d.*
Oil, 4 gallons at 3½*d.*	1	2
45 lbs. coke for generator, and 12 lbs. for steam, equal to 57 lbs. at 12*s.* 6*d.* per ton	0	3¾
Labour	0	3
Purification	0	1
Wear and tear	0	0½
	1	10¼

By the Van Steenbergh process 30 lbs. to 40 lbs. foundry coke are required per 1000 cubic feet gas made and carburetted with from 3 to 3½ gallons naptha. Illuminating power equal to 22 candles; loss of illuminating power by storage in cold weather, 2 candles. CO equal to 15 to 20 per cent.

Composition and Illuminating Power of Gas from Van Steenbergh Process, with Different Fuels and 76° Naptha. (V. B. Lewes.)

	Foundry Coke.	Gas Coke.		Anthracite.	
		Unpurified.	Purified.	Unpurified.	Purified.
H	33·44	—	39·05	—	38·44
Marsh gas	23·38	—	26·71	—	19·30
Illuminants . . .	11·14	—	9·27	—	7·49
CO	19·00	—	13·50	—	23·81
CO_2	2·24	6·01	1·02	2·16	0·42
N	9·50	—	9·72	—	9·69
O	1·30	—	0·73	—	0·85
H_2S	nil	0·35	nil	trace	nil
Illuminating power corrected . .	22·4 candles	—	22·9 candles	—	21.8 candles

Manufacture of Dowson Producer Gas.

Superheated steam and air are passed through a generator containing a good body of incandescent fuel (preferably anthracite coal, but coke will do), the air supporting combustion; the steam is decomposed, the O combining with the C of the fuel, first making CO_2, but on passing through the remainder of the hot fuel is reduced to CO, which is necessary to ensure that it has a sufficient affinity for O to explosively combine with the O of the air in the gas engine cylinders, while it must be remembered that each molecule of CO_2 makes two of CO. The gases are led through coolers and condensers when they are ready for use. 10 lbs. of anthracite yield about 1.000 cubic feet of gas, but to this must be added 2 lbs. of coke, required for the steam boiler.

With Dowson gas 1 lb. of fuel per I.H.P., or 1¼ lbs. per break horse-power can be attained in a gas engine.

Dowson gas is about equal to coal gas at 1*s.* 6*d.* per 1,000 cubic feet, as about four or five times the quantity is required, and larger engines are necessary.

One pound steam per 1 lb. Welsh anthracite is usually allowed in Dowson gas. The producer must be kept hot, or tarry matters will be deposited.

Dowson water gas has about one fourth or one fifth the explosive force of coal gas, but requires for its production only 14 lbs. of anthracite coal per 1,000 cubic feet.

Dowson producer gas contains from 45 to 48 per cent. N.

Siemens producer gas generally contains 60 to 70 per cent. N, which renders rapid ignition difficult.

Heating value of Dowson gas, 150 British thermal units per cubic foot. Air required for complete combustion of Dowson gas equals 1 to 1, to 1½ to 1, by volume of the gas. With Dowson gas the products of combustion must be expelled.

In the Dowson producer 1 lb. of steam is required per pound of anthracite.

Dowson gas requires one and a half volumes of atmospheric air per volume of the gas for complete combustion.

The initial pressure in gas engines is more than double that usually adopted in steam engines, and this gives the gas engine an advantage.

A steam engine cannot convert into work more than 30 per cent. of the heat energy. A hot-air engine cannot convert into work more than 50 per cent. of the heat energy. An internally fired gas engine cannot convert into work more than 80 per cent. of the heat energy. (Professor Kennedy.)

Coke for use in Dowson producers should be clean (not mixed with small coal or yard sweepings) and in pieces about 1 inch to 1½ inches cube.

About 80 cubic feet Dowson gas made from coke are required per I. H. P. per hour.

Gasholder required for Dowson gas for 100 I. H. P. plant is 8 feet diameter × 8 feet deep; contents 400 cubic feet.

Dowson gas has about one-fourth the explosive force of ordinary coal gas.

The generator gas contains a large proportion of nitrogen and some CO_2.

CO does not ignite as rapidly as H.

It is necessary to use a higher compression for a charge of generator gas than for ordinary town gas, so as to bring the molecules together.

The volume of exhaust steam and products of combustion in a steam power plant is reduced 90 per cent. when gas power is used.

If coal gas be subjected to sudden and severe refrigeration it will part with some of its valuable hydrocarbons, and this to a greater extent if the gas be stagnant.

Nineteen to twenty candle gas, which has been purified by 2½ per cent. air, does not lose any appreciable quantity of illuminating power during a travel of eight or nine miles through the town mains.

Fuel Gas.

Semi-water gas contains from 80 to 85 per cent. of the heating value of coal, and is the cheapest gas if supplied within a reasonable distance from the place of production.

The producer consists essentially of a cylindrical shell of boiler-plate lined with fire brick. The internal diameter of the brick-work is 21 inches and the height from the grate to the top of the furnace is 3½ feet. The grate is connected at one side with a steam and air injector, and on the other side with a gas supply-pipe. It is surrounded by a cast iron ashpit. A small reservoir or boiler is placed at one side, connected with which are two coils contained in the brickwork, the lower of which supplies steam and the upper one of which superheats it. Air channels are formed in the brickwork, arranged spirally, through which air is drawn by the injector and heated before mixing with the steam. The grate is provided with mechanism giving it a rotary and up-and-down movement to break up clinker or caking soft-coal. Five hundred cubic feet of gas per hour can be produced from 6 lbs. or 7 lbs. of coal. (A. Kitson.)

Peebles Process.

The retorts used in the Peebles process yield 500 cubic feet of gas per hour, and 5½ cwts. (per ton of oil decomposed) of hard graphite coke.

Heat required for fresh oil in Peebles process retorts equals 1,100 to 1,200° F. For condensible products, 1,400 F.

Oil of ·850 specific gravity gave 5 cwt. coke per ton at Perth.

Enriching value of Peebles oil gas is 50 per cent. higher than the illuminating power when burnt alone. (S. Glover.)

Peebles oil gas used as an enricher has prevented the stoppage of services with napthalene during the most severe winter.

One ton of tar from Durham coal by the Peebles process yields 15,000 cubic feet of 25 candle gas, and 15 cwt. coke of good quality. (Bell.)

Dr. Stevenson Macadam stated (1887) that he considered 6,885 lbs. of sperm light as the theoretic value of the gas from 1 ton of oil.

He found mixing oil, gas, and air entailed a loss of illuminating power ; after making all allowance for the admixture, he advocated the use of water gas as a diluent for oil gas.

To gasify tar permanently about 2,000° F. is required.

It has been suggested when supply of gas is short to mix about 2 gallons of tar per charge with the coals, and thus keep up the illuminating power.

Gases passed over Gasolene at 50° F. will completely evaporate it, giving air an illuminating power of 60 candles, and poor gas an illuminating power of 80 candles.

No condensation has been found in the syphon boxes in the district in Rochdale, when carburine has been used as an enricher.

It is best when enriching with a cold process to put the enriching apparatus on the delivery pipe from the works.

One Gallon Carburine (specific gravity 0·680) will raise 8,000 cubic feet 1 candle.

Yield of Gas in Pintsch System equals 81 to 83 cubic feet per gallon of 51 candles ; compression to 150 lbs. per square inch, reduces illuminating power to 38 candles, and deposits one gallon hydrocarbon per 1,000 cubic feet. (J. Tomlinson.)

Cost of fitting gas to railway carriages (Pintsch or Pope systems) equals about £5 per lamp, including its proportion of reservoirs, pipes, gauges, &c. Cost of working about $\frac{2}{10}$ths of a penny per lamp per hour equals about one-half that of oil. Maintenance costs about 2*s.* per lamp per year.

Loss in Volume of Coal Gas when Compressed. (C. E. Botley.)

Illuminating power of gas 16·50 candles.

Pressure.		Volume.		Loss.	
Lbs. per Square Inch.	Atmospheres.	Gas put into Cylinder.	Gas used per Meter.	Cubic Feet.	Per Cent.
45	3	510	510	*nil.*	*nil.*
75	5	850	860	10	1·16
105	7	1,190	1,205	15	1·24
135	9	1,530	1,570	40	2·54
165	11	1,870	1,920	50	2·60
195	13	2,210	2,330	120	5·15
200	13⅛	2,267	2,450	183	7·47

PRODUCTS WORKS.

Chimneys in chemical works should be at least 250 feet high.

The simplest form of sulphate plant is a boiler in which the liquor is heated, and from which a pipe to convey the vapours is carried to the sulphuric acid in the saturator where sulphate crystals are formed. The addition of lime or caustic soda to the liquor in the boiler causes the ammonia, combined with other gases which are in the liquid, to pass off as gas, and consequently be converted into sulphate.

Seventeen parts pure ammonia combine with 49 parts pure sulphuric acid to form 65 parts sulphate of ammonia ($2\ (NH_4)\ SO_4$).

Reaction of Ammoniacal Liquor and Sulphuric Acid.

$$2\ NH_3 + H_2\ SO_4 = 2\ (NH_4)\ SO_4.$$

The volatilization of the ammonia from gas liquor in all modern plant is effected by means of continuous working stills, viz., distilling a regular stream of liquor as it flows by its own gravity through the intricacies of a still heated by direct steam.

To calculate amount of Sulphate of Ammonium to be obtained from Liquor.

Ounce strength × 1·347 × gallons of liquor equals ounces weight of sulphate; or, ounce strength × ·0841 equals lbs. sulphate per gallon.

2,000 gallons of 8-ounce liquor will produce 15 cwt. sulphate, requiring also 13½ cwt. of sulphuric acid, or, say, 1 ton sulphate per 100 tons of coal in small works.

One per cent. N in coal equals 105 lbs. ammonium sulphate (pure). (Butterfield.)

Coal may be said to contain 1½ per cent. N equal to 140 lbs. sulphate of ammonia per ton; it is not usual to obtain more than 27 or 28 lbs. sulphate.

In sulphate plant it is necessary that the condensers and purifiers be of ample capacity.

Mr. Croll proposed to make sulphate of ammonia by passing the products of combustion from a coke furnace through a "coffey" still containing ammoniacal liquor, and then precipitating the sulphate in the usual saturator. He thus obtained an increase of sulphate per gallon of acid, and greatly lessened the quantity of H_2S given off.

Of the 1·7 per cent. of N in the coal, only about ·25 per cent. appears as ammonia after carbonization. Some coals contain as much as 2 per cent. N. If all the N were converted into NH_3, sulphate would equal 215 lbs. per ton of coal. About 50 per cent. of the N remains in the coke. About ·027 per cent. of the N in the coal forms in the purifiers calcium cyanide and calcium cyanate. If steam, water gas or hydrogen were passed through heated coke, a large proportion of the N could be removed, and afterwards converted, and with that already evolved with the gas a make of about 1 cwt. of sulphate per ton could be obtained.

One ton sulphate equals about 5 cwt. NH_3

One ton 10-ounce liquor equals about 51 lbs. NH_3 equals $2\frac{1}{4}$ per cent.

One ton sulphate equals 11 tons 10-ounce liquor.

One ton coal produces 35 to 40 gallons 10-ounce liquor equal to 30 to 35 lbs. sulphate.

7,000 gallons liquor require—

	Hours.	Yield as Compared with Theory. Per Cent.
When heated by open fire from without	22	90·0
When heated by a steam coil (indirect steam)	18	92·0
When open steam is blown in	14	98·5

(Dr. Lunge.)

The liquor in the saturator should be kept about 54° Twaddell.

Efficient sulphate plant requires about 8 cwt. fuel per ton sulphate made.

Temperature in sulphate well equals 75°, after passing jet elevator 116°.

In the economiser 180°. (S. Ellery.)

The waste gases from the saturator have usually a temperature of 186° F., and by utilizing these the liquor can be raised to about 113° F.

According to the reports of the Chief Inspector under the Alkali Works Regulation Act, the make of sulphate of ammonia was—

For 1894.	Tons.
In Gasworks	110,748
„ Ironworks	11,000
„ Shaleworks	23,105
„ Coke and Carbonizing Works	4,973
Totals	149,826

To manufacture sulphuric acid, burn S, and pass with peroxide of nitrogen, air and steam, in regulated quantities to a large chamber, where H_2SO_4 condenses, and is of sufficient strength for the manufacture of sulphate (equation $2\ SO_2 + NO_4 + 2\ H_2O = 2\ H_2SO_4 + NO_2$).

Sulphate of ammonia contains 20 per cent. of nitrogen, and nitrate of soda only 15 per cent. Three-quarters of a ton of sulphate has in it as much food for a crop as a ton of nitrate. Of course it is true that the nitrogen in the nitrate is accepted as being more effective than the nitrogen in the sulphate, but the outside difference in manurial power is certainly not more than 10 per cent.

When it is also remembered that the more concentrated nature of sulphate means a saving of 25 per cent. on the carriage, and that it can often be bought at still lower rates from local gasworks, it is clear that for any other than very light sandy soils, sulphate rather than nitrate should be bought at present.

Professor Somerville states that sulphate of ammonia and nitrate of soda are nearly of equal value per unit of nitrogen as manures, therefore 86 lbs. sulphate equals 112 lbs. nitrate.

Sulphate of ammonia has proved itself a better nitrogenous manure for mangolds than nitrate of soda.

One-eighth cwt. sulphate of ammonia per acre on hay land is the best dressing; or $\frac{3}{4}$ cwt. sulphate equals 1 cwt. nitrate of soda.

Preliminary nitrification of sulphate of ammonia is not necessary when using the latter as a manure.

From **Coal Tar** are obtained by distillation the following valuable bodies: benzene, toluene, naptha, carbolic acid, creosote, anthracene, napthalene, and a residue of pitch. The benzene and toluene yield aniline whence the dyes magenta and methyl violet are obtained; the phenol and creosote form the basis of valuable antiseptic and disinfectant preparations, and the first-named is also the source of the dye aurine; naptha is valuable chiefly as a rubber solvent; napthalene yields napthylamine, abeta-napthol, vermillene, scarlet, and napthol yellow; anthracene gives on treatment alizarin, from which a great number of beautiful dyes are prepared. By itself, also, coal tar has many applications, as, for instance, for making gas as fuel, and as a preservative for building materials. Then should be mentioned the legion of coal tar derivatives: antipyrin, antifebrin, analgen, exalgine, salol, saccharin, and salicylic acid. (*Lancet.*)

Constituents of Coal Tar.

	Average Formula.	Weight Per Cent.	Proportionate Weight of Constituents.		Calorific Value.	
			C.	H.	C.	H.
					Units.	Units.
First runnings	C_5H_{10}	3	·025714	·004286	200	148
Light oil . .	C_8H_{14}	7	·061091	·008910	474	307
Middle oils .	$C_{12}H_{20}$	27	·237073	·032927	1,842	1,145
Heavy oils . .	$C_{14}H_{16}$	7	·063913	·006087	497	210
Pitch (56 per cent.) composed of Oils	$C_{16}H_{10}$	17·5	·166336	·008663	1,292	298
Carbon . . .	C	27·5	·275000	—	2,137	
Gases and Water (H, NH_3) . . .	—	11				
Total			·829127	·060873	6,442	2,108
			0·89		8,550	

The number of constituents taken was: First runnings, 17; light oil, 26; middle oils, 5; heavy oils, 15; and pitch oils, 4.

The boiling points were respectively: Up to 110° C.; 110° to 210° C.; 210° to 240° C.; 240° to 270° C. and upwards; and 360° C. and upwards. (F. G. Dexter.)

Average yield of tar per ton of coal equals 1 cwt. equal to 10 gallons.

When tar is distilled the first portion volatilized is principally NH_3 and some gases suspended in the hydrocarbons, then ammoniacal liquor and a small quantity of brown oil, or naptha, or "light" oil, of which from 5 to 20 per cent. is contained in the tar. At a higher heat first some almost colourless light oils come over, and then an olive or greenish heavy oil ("dead oil"), next a greenish yellow fluid which becomes almost like butter. The contents of the retort consist of pitch.

Results of Distillation of Tar. (Professor Wanklyn.)

	Per Cent.		Per Cent.
Ammoniacal liquor	4·0	Creosote oils	22·0
First light oils	1·5	Anthracene oils	4·0
Second „	1·5	Pitch	67·0

Composition of Tar (London). (Professor Lewes.)

	Per Cent.		Per Cent
C	77·53	S	0·61
H	6·33	O	14·50
N	1·03		

Analysis of Tar from Caking Coal at Different Temperatures.

(L. T. Wright.)

Yield of Gas Per Ton.	Specific Gravity of Tar.	Pitch.	Light Naptha.
Cubic Feet.		Per Cent.	Per Cent.
6,600	1·086	29·89	
7,200	1·120	—	9
8,900	1·140		
10,160	1·154	—	3
11,700	1·206	64·08	1

Average Analysis of Tar.

	London.	Country.
Ammoniacal water	4·7 per cent.	4 per cent.
Total light oils	2·4 „	3 „
Carbolic and creosote oils	20·3 „	22 „
Anthracene oils	13·0 „	4 „
Pitch (grams per 100 cubic centimetres,	59·6 „	67 „

Average Percentage of Products from Ordinary Tar.

Ammoniacal liquor, gases and loss	9·2 per cent.
Light oils	1·4 „
Second light oils	1·6 „
Creosote oils	20·5 „
Anthracene oils	6·9 „
Pitch	60·4 „

The expression "light oils" means those oils which are lighter than water.

Distillation of tar (extreme case) average difficult to obtain.

Result of Distillation of 1,200 Gallons Tar.

	Lancashire.	London.
Ammoniacal liquor	30 gallons.	50 gallons.
First light oils	33 „	20 „
Second light oils	157 „	20 „
Creosote oils	104 „	250 „
Anthracene oils	229 „	50 „
Pitch	$3\frac{1}{4}$ tons.	4 tons.

Analysis of Coal Tar. (E. J. Mills.)

Constituents.	London.	Scotch Cannel.
Carbon	77·53	85·33
Hydrogen	6·33	7·33
Nitrogen	1·03	0·85
Sulphur	0·61	0·43
Oxygen	14·50	6·06

Tar from a gasworks where Boghead cannel was used gave the following results :—

Water, ammonia, salts, &c.	6·0 per cent.
Light oil	16·5 „
Heavy oil	30·0 „
Pitch	41·5 „
Permanent gases	5·0 „

The quantity of tar increases with the percentage of O in the coal. (Dr. Bünte.)

Products from Distillation of Lancashire Coal Tar.

1,000 gallons Tar, 1·16 specific gravity equals 5·3 tons.

	Per 1,000 Gallons.	Percentage by Weight.	Per Ton.
a. Ammonia liquor, 4 ozs. .	25 gallons	= 2·2	4¾ gallons.
b. First light oils	28 ,,	= 2·2	5¼ ,,
c. Second light oils	131 ,,	= 10·6	24¾ ,,
d. Creosote oils	87 ,,	= 7·6	16½ ,,
e. Anthracene oils	191 ,,	= 16·9	36 ,,
f. Pitch.	3¼ tons	= 60·5	12⅛ cwts.

On further rectification, these distillates yiel l—

b. 90 per cent. benzol	about 6 gallons.
c. Solvent naptha	,, 74 ,,
d. Carbolic acid	,, 6½ ,,
e. 30 per cent. anthracene	,, ·50 cwt.
Equal to pure anthracene	,, ·15 ,,

Specific gravity of coal tar . . = 1·12 to 1·16.
Specific gravity of cannel coal tar = ·98 to 1·06.
1 gallon tar at 1·16 specific gravity = 11·6 lbs.
1 cubic foot tar ,, ,, ,, = 72·5 lbs.

Analysis of Coal Tar. (A. Colson.)

Coal used, Derbyshire, 18 per cent. ; Nottingham cannel (producing 10,436 cubic feet of 17-candle gas), 9 per cent. ; Yorkshire, 73 per cent. :—

Crude naptha, 30 per cent. at 120° C. . .	6·79 gallons.
Carbolic acid, crude, 60°	1·14 ,,
Heavy naptha, 20 per cent. at 160° C. .	3·55 ,,
Creosote	58·04 ,,
Ammoniacal liquor, 10 ozs.	5·00 ,,
Napthalene	33·91 lbs.
Anthracene, 33 per cent.	13·60 ,,
Pitch	12·67 ,,

Products from One Ton of Tar (1886). (J. T. Lewis.)

Benzol (50/90)	5 gallons.
Naptha	2 ,,
Carbolic acid	5 ,,
Creosote oil	50 ,,
Anthracene	30 lbs. of 35 per cent.
Napthalene	2 cwts.
Pitch.	11 ,,

Tar from Newcastle coals contains much napthalene and anthracene.
Tar from Wigan coals contains much benzol and phenol. (Hornby.)

Aniline ($C_{12}H_7N$) is obtained from the heavy tar oils by agitation with hydrochloric acid, and decomposed by a slight excess of potash or soda and twice distilled.

STATUTORY AND OFFICIAL REGULATIONS FOR TESTING THE ILLUMINATING POWER AND PURITY OF GAS.*

Extract from the Gasworks Clauses Act, 1871.

SECTION 28.

The undertakers shall cause to be provided, at the place prescribed and within the prescribed time, a testing place, with apparatus therein, for the purposes following, or such of them as may be prescribed by the special Act, that is to say:—

1. For testing the illuminating power of the gas supplied.
2. For testing the presence of sulphuretted hydrogen in the gas supplied.

The said apparatus shall be in accordance with the regulations prescribed in Part I. of the Schedule A. to this Act annexed, or according to such rules as may from time to time be substituted in lieu thereof by any special Act, and shall be so situated and arranged as to be used for the purpose of testing the illuminating power and purity of the gas supplied by the undertakers, and the undertakers shall at all times thereafter keep and maintain such testing place and apparatus in good repair and working order.

SCHEDULE A. PART I.

Regulations in respect of Testing Apparatus.

1. The apparatus for testing the illuminating power of the gas shall consist of the improved form of Bunsen's photometer, known as Letheby's open 60-inch photometer, or Evans' enclosed 100-inch photometer, together with a proper meter, minute clock, governor, pressure gauge and balance.

The burner to be used for testing the gas shall be such as shall be prescribed.

The candles used for testing the gas shall be sperm candles of six to the pound, and two candles shall be used together.

2. The apparatus—(*a*) for testing the presence in the gas of sulphuretted hydrogen.—A glass vessel containing a strip of bibulous paper moistened with a solution of acetate of lead containing 60 grains of crystallized acetate of lead dissolved in one fluid ounce of water.

SCHEDULE A. PART II.

1. *Mode of Testing for Illuminating Power.*

The gas in the photometer is to be lighted at least fifteen minutes before the testings begin, and it is to be kept continuously burning from the beginning to the end of the tests.

Each testing shall include ten observations of the photometer, made at intervals of a minute.

* I am indebted to the proprietors of "The Gas World Year-Book" for permission to reproduce from that volume the illustrations in this section.—H. O'C.

The consumption of the gas is to be carefully adjusted to 5 cubic feet per hour.

The candles are to be lighted at least ten minutes before beginning each testing, so as to arrive at their normal rate of burning, which is shown when the wick is slightly bent and the tip glowing. The standard rate of consumption for the candles shall be 120 grains each per hour. Before and after making each set of ten observations of the photometer, the Gas Examiner shall weigh the candles, and if the combustion shall have been more or less per candle than 120 grains per hour, he shall make and record the calculations requisite to neutralise the effects of this difference.

The average of each set of ten observations is to be taken as representing the illuminating power of that testing.

2. *Mode of Testing for Sulphuretted Hydrogen.*

The gas shall be passed through the glass vessel containing the strip of bibulous paper moistened with the solution of the acetate of lead for a period of three minutes, or such longer period as may be prescribed; and if any discolouration of the test paper is found to have taken place, this is to be held conclusive as to the presence of sulphuretted hydrogen in the gas.

Extract from Memorandum issued by the Standards Department of the Board of Trade (July 1st, 1891), requiring Photometers to be verified and stamped.

Where the photometer, or apparatus for testing the illuminating power of gas, consists of the improved form of Bunsen's photometer, known as Letheby's open 60-inch photometer, or Evans' enclosed 100-inch photometer, then the official verification will, in accordance with established practice, include the burner, meter, minute clock, scale, governor, pressure gauge, and other subsidiary measuring instruments. A certificate of verification is, however, only issued if such photometers are of the Evans or Letheby forms hitherto recognised by the Department.—[The Board now also certify the table photometer.]

Directions for Using Standard Sperm Candles.

Cut a candle into halves, cut round half an inch from the new end of each piece, care being taken not to cut the wick, and slip off the small piece of spermaceti; light the wicks and let them burn for about five minutes; see if the wicks are central. If they are, let them burn for about twenty minutes, till they are in proper burning order, before commencing experiment.

When it is desired to extinguish the candles, touch the wicks first with a piece of spermaceti.

The candles should be kept in a cool place, in a proper tin candle-box.

NOTIFICATION OF THE METROPOLITAN GAS REFEREES—1900-1901.

As to the Service Pipes to the Testing Places.

Each testing place shall be connected with the main or mains specified by the Gas Referees by a service pipe, one service pipe to each main, which proceeds directly from the street main or mains, and is without tap or branch or provision for connection of any kind outside the testing place. If obstruction of the service pipe is found, or if there is reason to think that the quality of the gas is suffering from any change occurring within the service pipe, the service pipe may be washed out in the presence of and by arrangement with the Gas Examiner, either with hot water alone or with any usual solvent, such as benzol, naphtha, or petroleum, but the use of such solvents is to be followed by a washing with hot water. In every case where the service pipe is washed out the gas company shall send a letter to the Gas Referees explaining why the washing was considered necessary. No testing for illuminating power is to be made until after the lapse of an hour since the last washing out. The gas companies may, if they think fit, provide a tap and funnel in any testing place for the purpose of such washing out.

As to the Standard Lamp to be used for Testing Illuminating Power.

The standard to be used in testing the illuminating power of gas shall be a pentane 10-candle lamp which has been examined and certified by the Gas Referees. [The lamp is figured on p. 423.] The residue of pentane in the saturator shall, at least once in each calendar month, be removed, and it shall not be used again in any testings.

All pentane provided by the gas companies will be examined and certified by the Gas Referees, and will be sent to the testing places in one-pint cans which have been both sealed and labelled by them; and no pentane shall be used in the testing places other than that which has been thus certified.

As to the Times and Mode of Testing for Illuminating Power.

The testings for illuminating power shall be three in number daily. But if the average of three testings of illuminating power falls below the prescribed illuminating power, a fourth testing shall be made.

It is required (Gas Light and Coke and other Gas Companies Act Amendment Act, 1880, sect. 7): "That the tests for illuminating power shall be taken at intervals of not less than one hour." Also (sect. 8) "the average of all the testings at any testing place on each day of the illuminating power of the gas supplied by the company, at such testing place, shall be deemed to represent the illuminating power of such gas on that day at such testing place."

The photometer to be used in the testing places shall be the Table Photometer [figured on page 425]. The air-gas in the lamp is to be kept burning so that the flame is near its proper height for at least ten minutes before any testing is made. At the completion of every testing the air-gas is to be turned off; but if the interval between two testings does not much exceed one hour and the Gas Examiner is present during the interval, he may, instead of turning it off, turn it down low.

The gas burner attached to each photometer shall be a standard burner corresponding with that which has been deposited with the

Warden of the Standards in accordance with. among others, section 37 of the Gas Light and Coke Company's Act, 1876. A description of the standard burner to be used for testing gas is given [on page 422]. No burner shall be used for testing the illuminating power of gas that does not bear the lead seal of the Gas Referees.

A clean chimney is to be placed on the burner before each testing.

The gas under examination is to be kept burning so that the flame is about the usual height for at least fifteen minutes before any testing is made ; and no gas shall pass through the meter attached to the photometer except that which is consumed by the standard burner in testing or during the intervals between the testings made on any day and that which is used in proving the meter.

The paper used in the photoped of the photometer shall be white in colour, unglazed, of fine grain, and free from water marks. It shall be as translucent as is possible, consistently with its being sufficiently opaque to prevent any change in the apparent relative brightness of the two portions of the illuminated surface when the head is moved to either side. This paper should, when not in use, be covered, to protect it from dust ; and if it has been in any way marked or soiled, a fresh piece is to be substituted.

Each testing shall be made as follows :—

The index of the regulating tap shall be so turned that the gas flame gives rather less light on the photoped than the standard, and shall then be gradually turned on until equal illumination has been obtained. The position of the index shall then be noted. Next, the tap shall be so turned that the gas flame appears to give rather more light than the standard, and shall then be turned off until equality is again attained, and the position of the index shall be again noted. The double operation shall be repeated. In making these adjustments, a small alternating movement of the tap may be employed if the Gas Examiner finds that he can by this means make more consistent readings ; but, as stated, the tap is to be turned before each setting, alternately too high or too low. The mean of the four index positions shall be taken as that which gives true equality of illumination. The index shall be set to this mean position, the equality of illumination verified, and the time that the hand of the meter takes to make two complete revolutions shall be observed.

In order to make this observation, a stop-clock shall be used by which the time which has elapsed since the clock was started can be read with an accuracy of at least half a second. The clock shall be started at the moment when the meter-hand points either to zero or to some other convenient mark, and a note shall be immediately made of the mark chosen. Exactly at the completion of the second turn of the meter-hand the Gas Examiner shall stop the clock. The time of two revolutions thus indicated by the clock is to be read to the nearest half-second, and found in the table given (page 426). From this and the reading of the aerorthometer, or a determination of the tabular number deduced from readings of the thermometer and barometer, the illuminating power of the gas is to be obtained, either directly or by interpolation. Only one figure after the decimal point need be entered when the result is above 16 ; where a lower result is found, both figures should be noted and entered. A diagram giving the tabular numbers for different temperatures and pressures is given (pages 366–7).

The method of finding the illuminating power from the Table by interpolation may be illustrated by the two following examples:—

I.—Time, 1 min. 53 sec. Reading of aerorthometer, 1·073. By the Table the illuminating power corresponding to this time of consumption and to the reading 1·070 is 16·12, while for the reading 1·080 it is 16·27. Thus, in this part of the scale, when the reading is 10° higher, the illuminating power is greater by 0·15 candle. Hence, when the reading is 3° above 1·070, the corresponding illuminating power is $16{\cdot}12 + \frac{3}{10} \times 0{\cdot}15 = 16{\cdot}165$ candles, and the number to be returned is 16·2.

II.—Time, 2 min. $1\frac{1}{2}$ sec. Reading of aerorthometer, ·984. The numbers in the Table under ·980 are 15·81 for 2 min. 1 sec., and 15·94 for 2 min. 2 sec.; therefore, the number corresponding to $1\frac{1}{2}$ sec. is the halfway number, 15·875; the number found similarly under ·990 is 16·035. The increase for 10° is here 0·16; the number corresponding to the reading ·984 is accordingly $15{\cdot}875 + \frac{4}{10} \times 0{\cdot}16 = 15{\cdot}939$; and the number to be returned is 15·94.

If, in very exceptional circumstances, the aerorthometer scale of the tables do not include the conditions that are met with, the Gas Examiner shall determine the illuminating power by means of one or other of the formulæ printed below the tables.

Each testing place must be provided with a chemical thermometer, divided into degrees on the Fahrenheit scale, and with a standard clock that will go for a week without rewinding.

The Gas Examiner shall, at least once a week, compare the stop-clock in the testing place with the standard clock or with his watch.

The Gas Examiner shall enter in his book the particulars of every testing of illuminating power made by him at the testing places, during or immediately after such testing; and in the case of any testing which he rejects he shall also state the cause of rejection. No testing is to be rejected on the ground that the result seems improbable.

Times and Modes of Testing for Purity.

The testings for purity shall extend over not less than fifteen hours of each day, and shall be made upon ten cubic feet of gas. The gas shall be tested successively for sulphuretted hydrogen, ammonia, and sulphur compounds other than sulphuretted hydrogen, in the manner hereinafter prescribed. These testings must be started between 9 a.m. and 5.30 p.m., and must be concluded before 9 a.m. on the following morning. They are concluded by the action of an automatic lever-tap attached to the meter, which stops the passage of the gas when ten cubic feet have passed. A clock connected with the lever-tap is stopped at the same moment, leaving a record of the time; and the tap of an aerorthometer is turned, leaving a record of the final conditions under which the gas was measured by the meter.

The liquids in the sulphur and ammonia tests, and the slips of paper in the tests for sulphuretted hydrogen, then contain the sulphur and ammonia which were present in the gas supplied to the testing place during the day which ended at 9 a.m. The chemical examination of these liquids may be made on the following day, that is to say, after 9 a.m.

All connections between the following pieces of apparatus, in which the purity of the gas is tested, are to be on or above the surface of the table on which the apparatus stands.

I.—Sulphuretted Hydrogen.

The gas, as it leaves the service pipe, shall be passed through a small dry governor, and thence through an apparatus in which are suspended slips of bibulous paper, impregnated with basic acetate of lead.

The test paper from which these slips are cut is to be prepared from time to time by moistening sheets of bibulous paper with a solution of one part of sugar of lead in eight or nine parts of water, and holding each sheet, while still damp, over the surface of a strong solution of ammonia for a few moments. As the paper dries all free ammonia escapes.

If distinct discolouration of the surface of the test paper is found to have taken place, this is to be held as conclusive evidence that sulphuretted hydrogen is present in the gas. Fresh test-slips are to be placed in the apparatus every day.

In the event of any impurity being discovered, one of the test-slips shall be placed in a stoppered bottle and kept in the dark at the testing place; the remaining slips shall be forwarded with the daily report.

II.—Ammonia.

The gas which has been tested for sulphuretted hydrogen shall pass next through an apparatus consisting of a glass cylinder filled with glass beads which have been moistened with a measured quantity of standard sulphuric acid. A set of burettes, properly graduated, is provided.

The maximum amount of ammonia allowed is 4 grains per 100 cubic feet of gas; and the examination of the liquid shall be made so as to show the exact amount of ammonia in the gas.

Two test-solutions are to be used—one consisting of dilute sulphuric acid of such strength that 25 measures (septems) will neutralise 1 grain of ammonia; the other a weak solution of ammonia, 100 measures of which contain one grain of ammonia.

The correctness of the result to be obtained depends upon the fulfilment of two conditions:—

1. The preparation of test-solutions having the proper strength;
2. The accurate performance of the operation of testing.

To prepare the test-solutions the following processes may be used by the Gas Examiner:—

Measure a gallon of distilled water into a clean earthenware jar, or other suitable vessel. Add to this 94 septems of pure concentrated sulphuric acid, and mix thoroughly. Take exactly 50 septems of the liquid and precipitate it with barium chloride in the manner prescribed for the sulphur test. The weight of barium sulphate which 50 septems of the test-acid should yield is 13·8 grains. The weight obtained with the dilute acid prepared as above will be somewhat greater, unless the sulphuric acid used had a specific gravity below 1·84.

Add now to the diluted acid a measured quantity of water, which is to be found by subtracting 13·8 from the weight of barium sulphate obtained in the experiment, and multiplying the difference by 726. The resulting number is the number of septems of water to be added.

If these operations have been accurately performed, a second precipitation and weighing of the barium sulphate obtainable from 50 septems of the test-acid will give nearly the correct number of 13·8 grains. If the weight exceeds 13·9 grains, or falls below 13·7 grains, more water or sulphuric acid must be added, and fresh trials made until the weight falls within these limits. The test-acid thus prepared should be transferred at once to stoppered bottles which have been well drained and are duly labelled.

To prepare the standard solution of ammonia, measure out, as before, a gallon of distilled water, and mix with it 50 septems of strong solution of ammonia (sp. gr. 0·88). Try whether 100 septems of the test-alkali thus prepared will neutralise 25 of the test-acid, proceeding according to the directions given subsequently as to the mode of testing. If the acid is just neutralised by the last few drops, the test-alkali is of the required strength. But if not, small additional quantities of water, or of strong ammonia solution, must be added, and fresh trials made, until the proper strength has been attained. The bottles in which the solution is stored should be filled nearly full and well stoppered.

The mode of proceeding is as follows :—Take 50 septems of the test-acid (which is more than enough to neutralise any quantity of ammonia likely to be found in the gas), and pour it into the glass cylinder, so as to well wet the whole interior surface, and also the glass beads. Connect one terminal tube of the cylinder with the gas supply and the other with the meter, and make the gas pass at the rate of not more than two-thirds of a cubic foot per hour. Any ammonia that is in the gas will be arrested by the sulphuric acid, and a portion of the acid (varying with the quantity of ammonia in the gas) will be neutralised thereby. At the end of each period of testing, wash out the glass cylinder and its contents with distilled water, and collect the washings in a glass vessel. Transfer one-half of this liquid to a separate glass vessel, and add a quantity of a neutral solution of litmus, or other indicator in ordinary use, just sufficient to colour the liquid. Then pour into the burette 100 septems of the test-alkali, and gradually drop this solution into the measured quantity of the washings, stirring constantly. As soon as the colour changes (indicating that the whole of the sulphuric acid has been neutralised), read off the quantity of liquid remaining in the burette. To find the number of grains of ammonia in 100 cubic feet of the gas, multiply by 2 the number of septems of test-alkali remaining in the burette, and move the decimal point one place to the left.

The remaining half of the liquid is to be set aside, in case it should be desirable to repeat the volumetric analysis. This portion of the liquid is to be used in either of the two following cases :—

1. If the analysis of the first portion of the liquid show an excess

of impurity, the Gas Examiner shall forthwith give the notice ... vided for in the Acts of Parliament (the Gas Light and Coke Company ... Act, 1876, sect. 40, and others); and if the company think fit to be represented by some officer, the second portion of the liquid shall be examined in his presence.

2. If the analysis of the first portion of the liquid should miscarry, or the Gas Examiner have any reason to distrust the result, he shall be at liberty to make an analysis of the second portion, provided that before doing so he give notice to the company, in order that they may, if they think fit, be represented by some officer.

Unless thus used it is to be preserved, in a bottle properly labelled, for a week.

III.—Measurement of Gas and of the Rate of Flow.

The gas which has been tested for sulphuretted hydrogen and ammonia shall pass next through a meter by means of which the rate of flow can be adjusted, and which is provided with a self-acting movement for shutting off the gas when 10 cubic feet have passed, for stopping a clock so as to indicate the time at which the testings terminated, and for turning the tap of the recording aerorthometer. The Gas Examiner shall enter in his book the time thus indicated, as also the time at which the testings began.

The clock required is a good pendulum clock, with a wire passing transversely through the case, behind the pendulum. Outside the case a lever arm is clamped to the wire, so that when liberated the arm will drop and turn the wire. Inside the case an arm is clamped to the wire, and at the end of the arm a flexible wire is fastened; when the lever drops this flexible wire is brought into gentle frictional contact with the pendulum, so as to stop it without shock.

The clock should be wound from the front, and both hands should be mounted so that they can be set independently, also from the front. It is desirable that the clock should be able to go for a week with one winding, and the Gas Examiner must satisfy himself, from time to time, that the rating is nearly correct.

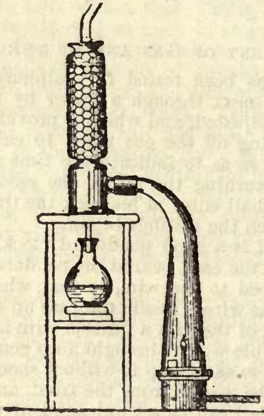
IV.—Sulphur Compounds other than Sulphuretted Hydrogen.

The testing shall be made in a room or closet where no gas is burning other than that which is being tested for sulphur and ammonia.

Pieces of sesquicarbonate of ammonia, from the surface of which any efflorescence has been removed, are to be placed round the stem of the burner. The index of the meter is to be then turned forward to the point at which the catch falls and will again support the lever-tap in the horizontal position. The lever is then made to rest against the catch so as to turn on the gas. The index is then turned back to a little short of zero, and the burner lighted. When the index is close to zero, the trumpet-tube is placed in position on the stand, and its narrow end connected with the tubulure of the condenser. At the same time the long chimney-tube is attached to the top of the condenser.

As soon as the testing has been started a reading of the aerorthometer is to be made and recorded. The mechanism for stopping the clock is then to be connected with the lever-tap of the meter, so that both may be stopped at the same moment, when 10 cubic feet of gas have passed through the meter. The clock is to be started and set right, and the time is to be recorded.

After each testing, the flask or beaker which has received the liquid products of the combustion of the 10 cubic feet of gas is to be emptied into a measuring cylinder, and then replaced to receive the washings



of the condenser. Next the trumpet-tube is to be removed and well washed out into the measuring cylinder. The condenser is then to be flushed twice or thrice by pouring quickly into the mouth of it 40 or 50 cubic centimetres of distilled water. These washings are brought into the measuring cylinder, whose contents are to be well mixed, and divided into two equal parts.

One half of the liquid so obtained is to be set aside in case it should be desirable to repeat the determination of the amount of sulphur which the liquid contains. This portion is to be examined under the same conditions as have been prescribed for the examination of the second portion of the liquid obtained from the apparatus used in testing for ammonia ; unless thus previously used, it is to be preserved, in a bottle properly labelled, for one week.

The remaining half of the liquid is to be brought into a flask or beaker, covered with a large watch-glass, treated with hydrochloric acid sufficient in quantity to leave an excess of acid in the solution, and then raised to the boiling point. An excess of a solution of barium chloride is now to be added, and the boiling continued for five minutes.

The vessel and its contents are to be allowed to stand till the barium sulphate has settled at the bottom of the vessel, after which the clear liquid is to be, as far as possible, poured off through a paper filter. The remaining liquid and barium sulphate are then to be poured on to the filter, and the latter is to be well washed with hot distilled water. (In order to ascertain whether every trace of barium chloride and ammonium chloride has been removed, a small quantity of the washings from the filter should be placed in a test-tube, and a drop of a solution of silver nitrate added; should the liquid, instead of remaining perfect y clear, become cloudy, the washing must be continued until, on repeating the test, no cloudiness is produced.) Dry the filter, with its contents, and transfer it into a weighed platinum crucible. Heat the crucible over a lamp, increasing the temperature gradually, from the point at which the paper begins to char up to bright redness. (An equally good and more expeditious method is to drop the filter with its contents, drained but not dried, into the red-hot crucible.) When no black particles remain, allow the crucible to cool; place it, when nearly cold, in a desiccator over strong sulphuric acid, and again weigh it. The difference between the first and second weighings of the crucible will give the number of the grains of barium sulphate. Multiply this number by 11 and divide by 4; the result is the number of grains of sulphur in 100 cubic feet of the gas.

This number is to be corrected for the variations of temperature and atmospheric pressure in the manner indicated under the head of Illuminating Power, with this difference, that the mean of the aerorthometer readings found at the beginning and at the end of any testing shall be taken as the reading for that testing. The reading at the beginning of the testing is to be made by the Gas Examiner, who, before leaving the testing place, will set the columns of mercury level in the two tubes of the instrument, and will connect the lever-tap of the aerorthometer with that of the meter. The fall of the lever of the meter will release a similar lever turning a tap which closes the tube of the aerothometer. The reading of the aerothometer as it stood at the end of the testing will require a small correction for the difference in level of the mercury in the two tubes, which is to be made in the following manner:—

Let R be the corrected reading, r_1 the actual reading of the aerorthometer, r_2 the reading of the companion tube, h the mean height of the barometer in units of the aerorthometer scale, a number which will be printed on each instrument, and is commonly 0·76. Then

$$R = r_1 \times \frac{h + r_1 - r_2}{h}.$$

The correction by means of the aerorthometer reading may be made most simply, and with sufficient accuracy, in the following manner:—

When the aerorthometer reading is between

	·955-·965,	·966-·975,	·976-·985,	·986-·995,
diminish the number of grains of sulphur by	4,	3,	2,	1 per cent.

When the aerorthometer reading is between ·996-1·005, no correction need be made.

When the aerorthometer reading is between

When the aerorthometer reading is between	1·006-1·015,	1·016-1·025,	1·026-1·035,
increase the number of grains of sulphur by . .	1,	2,	3 per cent.

Example :—

Grains of barium sulphate from 5 cubic feet of gas	4·3	Aerorthometer reading, 1·018
Multiply by 11, and divide by 4	11	
	4)47·3	
Grains of sulphur in 100 cubic feet of gas (uncorrected) . .	11·82	
Add $11·8 \times \frac{2}{100}$	·24	Result :
Grains of sulphur in 100 cubic feet of gas (corrected) . . .	12·06	12·1 grains.

The aerorthometer reading is the reciprocal of the tabular number. The Gas Examiner shall, not less often than once a month, compare the aerorthometer reading with the reciprocal of the tabular number deduced from observations of the barometer and thermometer, and if there is a difference of more than one-half per cent., the instruments are to be readjusted.

As to the Mode of Testing the Pressure at which Gas is supplied.

Testings of pressure shall be made at such times and in such places as the Controlling Authority may from time to time appoint. In order to make this testing the Gas Examiner shall unscrew the governor and burner of one of the ordinary public lamps, and shall attach in their stead a portable pressure-gauge. In places where incandescent burners are used for street lighting, one street lamp in each street or group of streets may be provided under the lantern with a branch closed by a screw stopper. The Gas Examiner shall in such cases connect the pressure-gauge by screwing to it an L-shaped pipe fitted with a union, by means of which it may be connected to the service pipe in the place of the screw stopper. The L-shaped pipe is to be of such dimensions as to enable the pressure-gauge to be fixed outside the lantern but at about the same level as the incandescent burner. It should be provided with a tap.

The gauge to be used for this purpose consists of an ordinary pressure-gauge enclosed in a lantern, which also holds a candle for throwing light upon the tubes and scale. The difference of level of the water in the two limbs of the gauge is read by means of a sliding-scale, the zero of which is made to coincide with the top of the lower column of liquid.

The Gas Examiner having fixed the gauge gas-tight, and as nearly as possible vertical on the pipe of the lamp, and having opened the cocks of the lamp and gauge, shall read and at once record the pressure shown. From the observed pressure one-tenth of an inch is to be deducted to correct for the difference between the pressure of gas at the top of the lamp column and that at which it is supplied to the basement of neighbouring houses.

The pressure prescribed in the Acts of the three metropolitan gas companies is to be such as to balance from midnight to sunset a column of water not less than six-tenths of an inch in height, and to balance from sunset to midnight a column of water not less than one inch in height.

Meters.

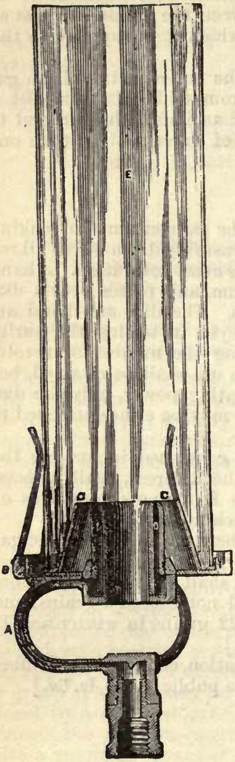
Each of the meters used for measuring the gas consumed in making the various testings is constructed with a measuring drum which allows one-twelfth of a cubic foot of gas to pass for every revolution. A hand is fastened directly to the axle of this drum, and passes over a dial divided into one hundred equal divisions. The dial and hand are protected by a glass. In the meter employed in testing the purity of the gas, the pattern of dial for showing the number of revolutions and the automatic cut-off hitherto in use shall be retained, but in the meter employed for testing illuminating power, only the dial above described is needed. The stop-clock may be either attached to the meter or separate.

The meters used for measuring the gas consumed in making the various testings, having been certified by the Referees, shall, at least once in seven days, be proved by the Gas Examiners, by means of the Referees' one-twelfth of a cubic foot measure.

No meter other than a wet meter shall be used in testing the gas under these instructions.

[The Gas Referees prescribe that the gas shall be wholly free from sulphuretted hydrogen, that ammonia shall not exceed 4 grains, and that sulphur compounds shall not exceed 22 grains in winter and 17 grains in summer per 100 cubic feet of gas.]

[Official copies of the Gas Referees' notification, containing a number of appendices, can now be purchased by the public, price 1*s.* 6*d.*]



GAS REFEREES' STANDARD BURNER.

(Applicable to both Old and New Regulations.)

The burner which has been adopted as the Standard Burner for testing gas was designed by Mr. Sugg, and was called by him "Sugg's London Argand, No. 1."

A half-sized section is appended, in which A represents a supply pipe, B the gallery, C the cone, D the steatite chamber, E the chimney.

The following are the dimensions of those parts of the burner upon which its action depends :—

	Inch.
Diameter of supply pipes . . .	0·08
External diameter of annular steatite chamber	0·84
Internal diameter of do. . . .	0·48
Number of holes	24
Diameter of each hole	0·045
Internal diameter of cone :—	
At the bottom	1·5
At the top	1·08
Height of upper surface of cone and of steatite chamber above floor of gallery	0·75
Height of glass chimney . . .	6
Internal diameter of chimney .	1·875

TEN-CANDLE PENTANE LAMP.

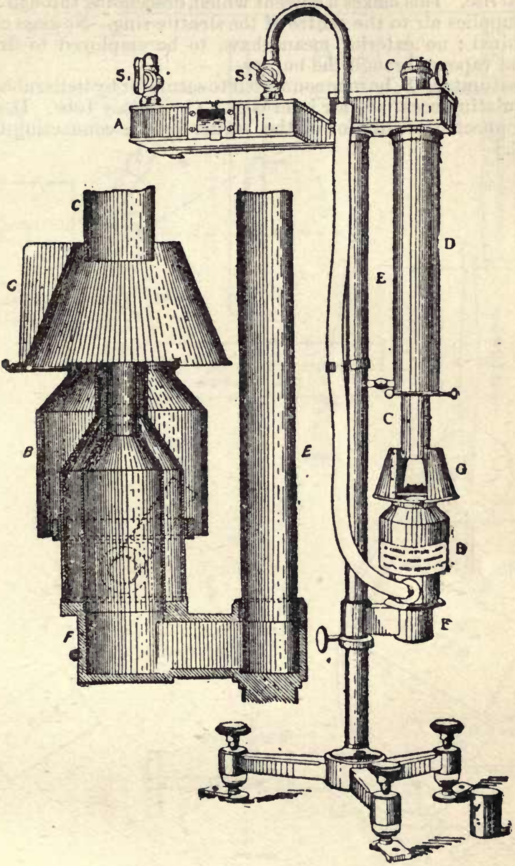


Fig. 2. Fig. 1.

Mr. Harcourt's 10-candle pentane lamp is one in which air is saturated with pentane vapour, the air gas so formed descending by its gravity to a steatite ring burner. The flame is drawn into a definite form, and the top of it is hidden from view by a long brass chimney above the steatite burner. The chimney is surrounded by a larger brass tube, in which the air is warmed by the chimney, and so tends to rise. This makes a current which, descending through another tube, supplies air to the centre of the steatite ring. No glass chimney is required ; no exterior means have to be employed to drive the pentane vapour through the burner.

[A, saturator. B, burner connected to saturator by indiarubber tube. S_2, regulating cock. S_1, air inlet cock. C, chimney tube. D, exterior tube connected to interior of the burner by the connecting-box and tube E.]

THE TABLE PHOTOMETER.

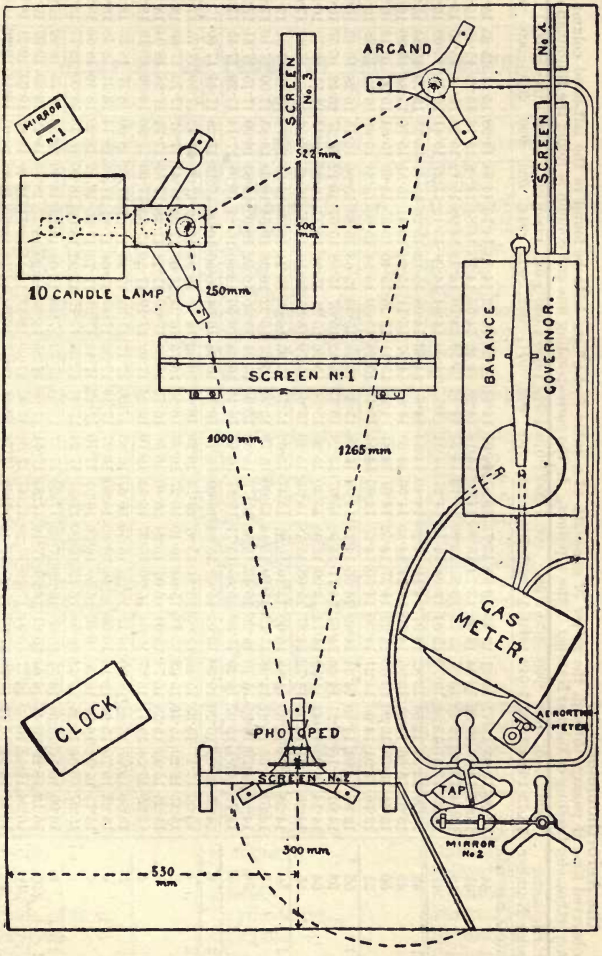


Table giving the Illuminating Power of Gas from Observations of the Rate of Consumption required to yield the Light of 16 Candles, and from Readings of the Barometer, Thermometer, and Referees' Tables, or of the Aerorthometer.

The observed time of passage through the meter of one-sixth of a cubic foot of gas is to be found in the left-hand column, and the Aerorthometer Reading or Tabular Number in the top lines. In the corresponding line and column is found the Illuminating Power

Aerorthometer ..		·930	·940	·950	·960	·970	980	·990	1·000	1·010	1·020	1·030	1·040	1·050	1·060	1·070	1·080	1·090	1·100	1·110	1·120
Tabular Number		1·075	1·064	1·053	1·042	1·031	1·020	1·010	1·000	·990	·980	·971	·962	·953	·944	·935	·926	·918	·909	·901	·893
Minutes.	Seconds																				
1	44	12·90	13·03	13·17	13·31	13·45	13·59	13·73	13·87	14·01	14·14	14·28	14·42	14·56	14·70	14·84	14·98	15·11	15·25	15·39	15·53
	45	13·02	13·16	13·30	13·44	13·58	13·72	13·86	14·00	14·14	14·28	14·42	14·56	14·70	14·84	14·98	15·12	15·26	15·40	15·54	15·68
	46	13·14	13·29	13·43	13·57	13·71	13·85	13·99	14·13	14·27	14·42	14·56	14·70	14·84	14·98	15·12	15·26	15·41	15·55	15·69	15·83
	47	13·27	13·41	13·55	13·70	13·84	13·98	14 12	14·27	14·41	14·55	14·69	14·84	14·98	15·12	15·27	15·41	15·55	15·69	15·84	15·98
1	48	13·39	13·54	13·68	13·82	13·97	14·11	14·26	14·40	14·54	14·69	14·83	14·98	15·12	15·26	15·41	15·55	15·70	15·84	15·98	16·13
	49	13·52	13·66	13·81	13·95	14·10	14·24	14·39	14·53	14·68	14·82	14·97	15·11	15·26	15·41	15·55	15·70	15·84	15·99	16·13	16·28
	50	13·64	13·79	13·93	14·08	14·23	14·37	14·52	14·67	14·81	14·96	15·11	15·25	15·40	15·55	15·69	15·84	15·99	16·13	16·28	16·43
	51	13·76	13·91	14·06	14·21	14·36	14·50	14·65	14·80	14·95	15·10	15·24	15·39	15·54	15·69	15·84	15·98	16·13	16·28	16·43	16·58
1	52	13·89	14·04	14·19	14·34	14·49	14·63	14·78	14·93	15·08	15·23	15·38	15·53	15·68	15·83	15·98	16·13	16·28	16·43	16·58	16·73
	53	14·01	14·16	14·31	14·46	14·61	14·77	14·92	15·07	15·22	15·37	15·52	15·67	15·82	15·97	16·12	16·27	16·42	16·57	16·72	16·87
	54	14·14	14·29	14·44	14·59	14·74	14·90	15·05	15·20	15·35	15·50	15·66	15·81	15·96	16·11	16·26	16·42	16·57	16·72	16·87	17·02
	55	14·26	14·41	14·57	14·72	14·87	15·03	15·18	15·33	15·49	15·64	15·79	15·95	16·10	16·25	16·41	16·56	16·71	16·87	17·02	17·17
1	56	14·38	14·54	14·69	14·85	15·00	15·16	15·31	15·47	15·62	15·78	15·93	16·09	16·24	16·39	16·55	16·70	16·86	17·01	17·17	17·32
	57	14·51	14·66	14·82	14·98	15·13	15·29	15·44	15·60	15·76	15·91	16·07	16·22	16·38	16·54	16·69	16·85	17·00	17·16	17·32	17·47
	58	14·63	14·79	14·95	15·10	15·26	15·42	15·58	15·73	15·89	16·05	16·21	16·36	16·52	16·68	16·83	16·99	17·15	17·31	17·46	17·62
	59	14·76	14·91	15·07	15·23	15·39	15·55	15·71	15·87	16·03	16·18	16·34	16·50	16·66	16·82	16·98	17·14	17·29	17·45	17·61	17·77
2	0	14·88	15·04	15·20	15·36	15·52	15·68	15·84	16·00	16·16	16·32	16·48	16·64	16·80	16·96	17·12	17·28	17·44	17·60	17·76	17·92
2	1	15·00	15·17	15·33	15·49	15·65	15·81	15·97	16·13	16·29	16·46	16·62	16·78	16·94	17·10	17·26	17·42	17·59	17·75	17·91	18·07
	2	15·13	15·29	15·45	15·62	15·78	15·94	16·10	16·27	16·43	16·59	16·75	16·92	17·08	17·24	17·41	17·57	17·73	17·89	18·06	18·22
	3	15·25	15·42	15·58	15·74	15·91	16·07	16·24	16·40	16·56	16·73	16·89	17·06	17·22	17·38	17·55	17·71	17·88	18·04	18·20	18·37
	4	15·38	15·54	15·71	15·87	16·04	16·20	16·37	16·53	16·70	16·86	17·03	17·19	17·36	17·53	17·69	17·86	18·02	18·19	18·35	18·52
2	5	15·50	15·67	15·83	16·00	16·17	16·33	16·50	16·67	16·83	17·00	17·17	17·33	17·50	17·67	17·83	18·00	18·17	18·33	18·50	18·67
	6	15·62	15·79	15·96	16·13	16·30	16·46	16·63	16·80	16·97	17·14	17·30	17·47	17·64	17·81	17·98	18·14	18·31	18·48	18·65	18·82
	7	15·75	15·92	16·09	16·26	16·43	16·59	16·76	16·93	17·10	17·27	17·44	17·61	17·78	17·95	18.12	18·29	18·46	18·63	18·80	18·97
	8	15·87	16·04	16·21	16·38	16·55	16·73	16·90	17·07	17·24	17·41	17·58	17·75	17·92	18·09	18·26	18·43	18·60	18·77	18·94	19·11
2	9	16·00	16·17	16·34	16·51	16·68	16·86	17·03	17·20	17·37	17·54	17·72	17·89	18·06	18·23	18·40	18·58	18·75	18·92	19·09	19·26
	10	16·12	16·29	16·47	16·64	16·81	16·99	17·16	17·33	17·51	17·68	17·85	18·03	18·20	18·37	18·55	18·72	18·89	19·07	19·24	19·41
	11	16·24	16·42	16·59	16·77	16·94	17·12	17·29	17·47	17·64	17·82	17·99	18·17	18·34	18·51	18·69	18·86	19·04	19·21	19·39	19·56
	12	16·37	16·54	16·72	16·90	17·07	17·25	17·42	17·60	17·78	17·95	18·13	18·30	18·48	18·66	18·83	19·01	19·18	19·36	19·54	19·71

$$\text{Illuminating power} = \frac{\text{Aerorthometer Reading} \times \text{Time in Seconds}}{7\cdot5} \text{ or } = \frac{\text{Time in Seconds.}}{7\cdot5 \times \text{Tabular Number.}}$$

GLOSSARY OF TERMS IN USE IN GASWORKS.

(Sugg.)

English.	*French.*	*German.*
Air.	Air.	Luft.
Ash.	Cendre.	Asche.
Bisulphide of carbon.	Bisulphure de carbone.	Doppelt Schwefelkohleustoff.
Burner.	Bec.	Brenner.
Candle.	Bougie.	Kerze.
Cannel.	Cannelcoal.	Kännelkohle.
Carbonic acid.	Acide carbonique.	Kohlensauer.
Carbonic oxide.	Oxyde de carbone.	Kohlenoxyd.
Cast iron.	Fer fonte.	Gusseisen Roheisen.
Cement.	Ciment.	Cement.
Chimney (lamp).	Cheminée verre.	Lampenglas.
Clay.	Argile.	Thon.
Coal.	Houille charbon.	Steinkohle.
Coke.	Coke.	Coke.
Exhauster.	Extracteur.	Auszicher.
Fire brick.	Brique refractaire.	Chamottestein.
Fire clay.	Argile "	Chamotte.
Gas fittings.	Appareils à gaz.	Gaseinrichtung.
Gasholder.	Gazomètre.	Gasbehälter.
Gasholder curb.	Cornière.	
Gas kitchener.	Cuisinière à gaz.	Gas-kock und Brat-Herd.
Gas main.	Tuyau à gaz.	Strassengasrohr.
Gas pipe.	Conduit à gaz.	Gasrohr.
Gas stove.	Fourneau à gaz.	Gasofeu.
Gasworks.	Usine à gaz.	Gasaustalt.
Hydrogen.	Hydrogène.	Wasserstoff.
Inlet pipe.	Tuyau d'entrée.	Einflussrohr.
Iron.	Fer.	Eisen.
Lamp.	Lampe.	Lamp.
Lime.	Chaux.	Kalk.
Marsh gas (methane).	Gaz de marais.	Sumpfgas-Grübengas.
Meter.	Compteur.	Gasuhr.
Nitrogen.	Azote.	Stickstoff.
Outlet.	Sortie.	Ausfluss.
Oxide of iron.	Oxyde de fer.	Eisenoxyd.
Oxygen.	Oxygène.	Sauerstoff.
Pitch.	Brai.	Pech.
Pressure register.	Mouchard.	
Retort.	Cornue.	Retorte.

Glossary of Terms in Use in Gasworks. (Sugg.)—*continued.*

English.	*French.*	*German.*
Shade.	Abat-jour.	Lichtschirm.
Sheet iron.	Tole.	Schwarzes Blech.
Sperm candle.	Bougie de spermaceti.	Walrathlight.
Sperm oil.	Huile de baleine.	Walrathoel.
Standard light.	Etalon photometrique.	Normallicht.
Steam.	Vapeur.	Dampf.
Steel.	Acier.	Stahl.
Stop-cock.	Robinet.	Hahn.
Sulphur.	Soufre.	Schwefel.
Sulphuretted hydrogen.	Hydrogène sulfuré.	Schwefelwasserstoff.
Tallow.	Suif.	Talg.
Tap.	Robinet.	Hahn.
Tar.	Goudron.	Theer.
Valve.	Valve.	Ventil.
Water.	Eau.	Wasser.
Wax.	Cire.	Wachs.
Wood.	Bois.	Holz.
Wrought iron.	Fer battu.	Abschlageisen.

INDEX.

THE END.

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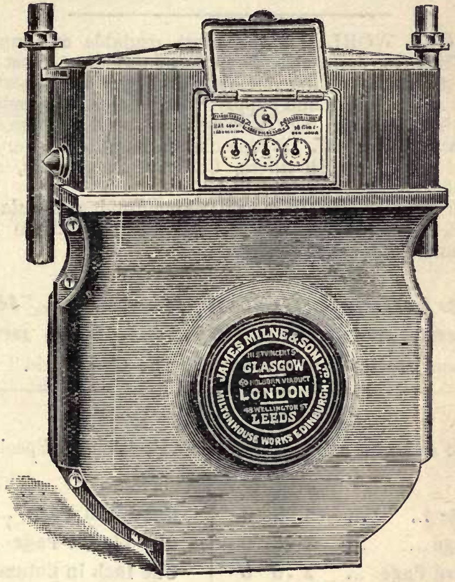

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