CHAPTER III.

RAINFALL AND EVAPORATION.

Early Observations—Various descriptions of Rain Gauges—Effect of the Physical Configuration of the District on Rainfall—Influence of Railways upon Weather—Tables of Rainfall in various Districts—Decadal Law of Rainfall—Estimation of the Maximum and Minimum from the Mean Annual Fall—Available Rainfall—Distribution of Rain over the various Seasons—Maximum Fall in twenty-four hours—Gauge for ascertaining the Rate of Fall—Evaporation and Absorption—Evaporation from Surfaces of Water.

THE dependence of all waterworks upon the supply of rain, either directly, as from ordinary gathering grounds, or indirectly, as from rivers, springs, or wells, is so obvious that it is singular how little interest was taken in the subject until recently, and how many works are even now carried on without that careful registration of rainfall and actual supply which it is equally to the interest of the profession and of the public at large to maintain. Observations of rainfall have been made in this country for nearly two centuries, but until 1860 no uniformity nor regular system of observation was attempted ; the returns were not collected from the different observers, nor from the various publications in which they had from time to time appeared, and no work was issued specially devoted to the subject. The consequence was, that in the absence of accurate information, the wildest estimates were made, and in some of the earlier parliamentary contests compensation water was given to such an extent that thousands of pounds have been lost to the towns in buying up compensation, which would never have been given had the subject of rainfall received the attention it deserved. About ten years since, Mr. G. J. Symons, one of the early members of the British and Scottish Meteorological Societies, took up the question, and printed in 1861 a table of the rainfall in 1860 at about 150 stations, being at that time the largest number ever collected. This was the first of a series of annual publications, which, under the title of 'British Rainfall,' have removed the question of rainfall from the uncertainties of speculation to the rigorous domain of physical facts.

Rain Gauges.—As everything depends on the accuracy of the instruments employed, and the suitability of their position, we may in the first place point out a few of the most common errors and defects. In many cases the rim of the rain gauge is not vertical, as it should be, but is more or less inclined, as at A, fig. 2, or even rounded, as at B.

FIG. 2.

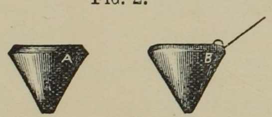
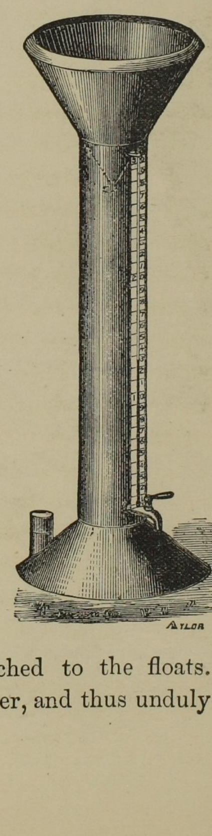
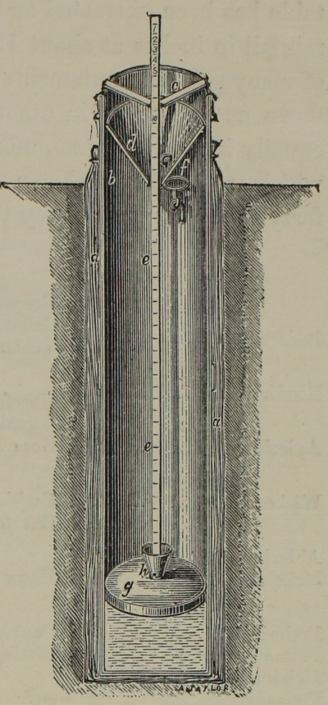


FIG. 3.



In either case, rain which ought to run down outside will, when there is much wind, be blown up the side of the rim and into the funnel (as represented by the dotted lines), thus unduly increasing the quantity collected. Gauges with glass measuring tubes, like fig. 3, are troublesome in frosty weather, from breakage ; are rarely constructed to hold more than $2\frac{1}{2}$ inches, and therefore overflow just when it is of the utmost importance that they should not ; are often emptied, instead of the water being drawn off down to zero, and necessarily have their funnels too high above the ground. Crosley's gauge, in which the water passes over a vibrating pair of buckets, and so sets in motion a train of wheels, may perhaps eventually prove useful, but hitherto it has been comparatively of little value. The works are liable to be deranged, causing a loss of water, which materially affects the total at the end of the year ; they were at one time very common, but are now mostly abandoned, or preserved as curiosities, simple cylinder gauges being substituted. It is important, however, that old gauges should never be at once neglected when new ones have been obtained, but that both should be read together, so that comparison may be made. Float gauges are probably the best for use by the men in charge of reservoirs and others of that class, but it is a radical fault of many such gauges that the rods are attached to the floats. When the rods rise above the orifice of the gauge, they intercept rain which ought to pass over, and thus unduly augment the returns. The best kind of gauge for determining the mean annual fall is that shown in fig. 4, which is simply a double zinc (copper is better, but, being valuable, is often stolen) cylinder, the inner one 8 inches in diameter throughout, and about 4 feet long, with a heavy turned brass rim at the top (to prevent indentation). The apparatus is sunk 3 feet in the ground, so that the orifice is 1 foot above the surface, and that the water is not exposed to the sun, and to consequent loss by evaporation. The water, moreover, is almost entirely covered by a float, on to the centre of which the rod is dropped, when an observation has to be made. Though no gauge will give more correct gross results at the end of a month or series of months, this gauge is hardly sufficiently delicate for accurate daily observations; for such purposes the depth of the water column must be artificially increased either by contracting the cylinder, as in fig. 5, or by adopting the pattern of fig. 6, and measuring the water in the graduated glass therein represented.

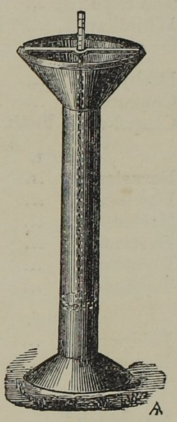
Fig. 4.



Causes of Variation.—The mouth of a rain gauge should be about one foot above the ground; if it is less than that, the true fall will be unduly augmented by 'insplashing' from the surrounding ground; and if it is more than one foot, too little will be collected. A gauge whose mouth is only two inches above the ground will collect about five per cent. too much, and one five feet above it, about five per cent. too little. Gauges on ridges, pillars, terraces, buildings—in fact, on anything but level ground—are very deceptive.

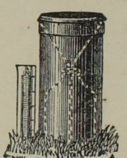
The quantity of rain is mainly ruled by the physical configuration of the district, but also, to a certain extent, by the elevation of the locality, it being found that in many cases the increase amounts to about three per cent. of the total fall at the sea level for every hundred feet above it. Much appears to depend upon the elevation of the country with regard to the region of the rain clouds, which may be said to extend to about 3,000 or 4,000 feet above the sea level. 'The greatest portion of deposit within that range,' says Mr. Bateman, 'takes place at from 700 to 2,200, or 2,300 feet. If the mass of the gathering ground lies within that zone, setting aside local circumstances, that will be the elevation which will give the greatest quantity of rain.'* A larger quantity falls on coast lines on the western side of great continents in the temperate zones than on the eastern side or the interior, but in the tropics more on the eastern side; more rain falls in tropical than in temperate climates, though the number of days on which rain falls is greater in the latter than in the former case. The aspects of the slopes of the basin, in respect to the direction of the prevailing winds, affect the rainfall, more rain falling at equal heights on the windward margin of the basin than on the opposite one.

Fig. 5.



There are many curious facts connected with the subject of rainfall and its variation. In districts once thickly wooded, and now comparatively bare (as, for instance, in colonial settlements), it is found that the rainfall has considerably diminished from what it was formerly. Indeed it would seem to be universal that, other circumstances being the same, the rainfall is considerably greater in rugged or thickly-wooded districts than in open and barren plains. In the latter, however, it has been observed that the construction of railways influences the rainfall to a very great extent. Indeed, 'the opinion seems to be gaining strength,' says an American journal, 'that the Pacific Railroad is working a great change in the climate of the plains. Instead of continuous drought all along the railroad, rain now falls in refreshing abundance. This result has been remarked upon in other sections of the West. In central Ohio, it is said, the climate has been completely revolutionised since iron rails have formed a network all over that region. Instead of the destructive droughts formerly suffered there, for some four or five years there has been rain in abundance—even more than enough to satisfy the wants of the farmers.'

Fig. 6.



Estimation of Mean Annual Fall.—In designing gravitation schemes, and estimating the compensation to be given to millowners, the mean annual rainfall over the gathering ground must be first ascertained. Observations on the ground proposed to be made available are therefore of the highest importance, and if none exist, gauges should be placed at the earliest possible date, and observed with unfailing regularity. But these observations are of practical use only when a proximate long-established gauge exists, and is also regularly noted; then the determination of the true fall on the district is a comparatively easy matter. The

* Evidence given before the Royal Commission on Water-Supply, 1866. See also Report of the Rainfall Committee of the British Association, 1867-68, pp. 435 and 473, where corroborative evidence will be found.

proportion of the fall at the newly-established gauges to that at the long-observed gauges should be carefully ascertained. If, then, the recorded fall at the old-established stations be multiplied by this proportion, a fairly reliable result will be obtained. As a rough guide to the fall in different parts of the country, the following table has been extracted and rearranged from one of Mr. Symons' works, showing approximately the mean annual rainfall in inches at about 150 stations. In the original it is prefaced by a note as to the absurd inconsistencies of many previous statements on the subject, and by a list thereof. For example, in some works Manchester is set down as 25 inches, in others as 43 inches; Plymouth as 30·9 and 46·5; Keswick as 50·3 and 70·6; and other equally inconsistent amounts. The following table is based on the fall observed during the six years 1860–65, which are elsewhere shown to have had in most places, within one or two per cent., the same mean value as the forty years 1810–49; they therefore are probably in most cases very nearly, if not quite correct.

ENGLAND.	
Bedford.	
Bedford	21
Berks.	
Reading	24
Bucks.	
Aylesbury	21
Cambridge.	
Wisbeach...	23
Cheshire.	
Alderley	33
Macclesfield	36
Cornwall.	
Bodmin	47
Falmouth	39
Helston	39
Penzance...	43
Truro	42
Cumberland.	
Carlisle	30
Keswick	59
Seathwaite	140
The Stye...	165
Whitehaven	52
Derby.	
Derby	26
Chatsworth	27
Chapel-en-le-Frith ...	40
Devon.	
Barnstaple	40
Dawlish	32
Exeter	33
Dartmoor	86
Plymouth	40
Teignmouth	34
Dorset.	
Bridport	32
Encombe...	35
Durham.	
Sunderland	25
Essex.	
Epping	25
Witham	21
Gloucester.	
Bristol	33
Cheltenham	32
Cirencester	31
Clifton	33
Hants.	
Gosport	30
Selborne	34
Ventnor	30
Hereford.	
Hereford	30
Leominster	26
Ross...	27
Hertford.	
Berkhampstead ...	28
Hertford	25
Huntingdon.	
Hamerton	23
Kent.	
Canterbury	27
Sittingbourne... ...	28
Lancashire.	
Clitheroe...	43
Coniston	85
Liverpool...	35
Manchester	36
Ormskirk	35
Preston	39
Staleybridge	33
Wigan	43
Leicester.	
Leicester	25
Thornton...	27
Lincoln.	
Boston	22
Grantham	21
Grimsby	21
Horncastle	25
Lincoln	20
Stamford...	20
Middlesex.	
Bushey	24
London	24
Monmouth.	
Monmouth	29
Norfolk.	
Holkham...	23
Norwich	24
Northampton.	
Oundle	23
Northumberland.	
Shields	27
Nottingham.	
Southwell	20
Retford	23
Oxford.	
Oxford	25
Rutland.	
Lyndon	24
Shropshire.	
Oswestry...	36
Shrewsbury	27
Somerset.	
Bath	29
Bridgewater	29
Chard	32
Taunton	29
Suffolk.	
Aldham	25
Bury St. Edmund's	23
Surrey.	
Bagshot	27
Cobham	24
Sussex.	
Chichester	29
Hastings	29
Uckfield	33
Warwick.	
Birmingham	31
Coventry...	23
Westmoreland.	
Ambleside	78
Appleby	35
Kendal	53
Selside	73
The Howe	80
Wilts.	
Salisbury...	30
Worcester.	
Worcester	28
York.	
Ackworth	25
Arncliffe	58
Halifax	31
Sheffield	31
Settle	50
Thirsk	24
York	23
WALES.	
Cardigan.	
Lampeter...	45
Carnarvon.	
Llanberis...	82
Denbigh.	
Llandudno	30
Flint.	
Hawarden	24
Glamorgan	
Cardiff	43
Ystalyfera	63
Pembroke.	
Haverfordwest ...	48
Radnor.	
Rhayader...	46
SCOTLAND.	
Aberdeen.	
Aberdeen...	31
Alford	38
Braemar	33
Argyle.	
Ardnamurchan ...	49
Castle Toward ...	55
Inverary	64
Torosay	80
Tyree	85
Ayr.	
Ayr	44
Brisbane	53
Largs	51
Sorn	42
Bute.	
Cumbrae	42
Cromarty.	
Cromarty	28
Dumbarton.	
Arddarroch	76
Dumfries.	
Applegarth	34
Dumfries...	41
Wanlockhead	65
Edinburgh.	
Edinburgh	24
Glencorse	37
Elgin.	
Elgin	25
Fife.	
Balfour	27
Forfar.	
Arbroath...	30
Dundee	31
Haddington.	
Haddington	28
Inverness.	
Inverness	26
Oronsay	69
Glen Quoich	117
Portree	109
Raasay	75
Kincardine.	
Lawrencekirk... ...	32
Kinross.	
Loch Leven	37
Lanark.	
Baillieston	45
Glasgow	39
Orkney.	
Pomona	33
Peebles.	
Peebles	29
Perth.	
Aberfoyle	60
Glen Gyle	95
Ledard	89
Perth	30
Renfrew.	
Greenock...	64
Ross.	
Stornoway	46
Selkirk.	
Bowhill	35
Shetland.	
E. Yell	40
Stirling.	
Carbeth	42
Ben Lomond	91
Sutherland.	
Cape Wrath	41
Dunrobin	27
Wigton.	
Stranraer	47
IRELAND.	
Belfast	31
Cork	40
Banbridge	29
Dublin	30
Galway	50
Valentia	60
Limerick...	35
Londonderry	41
Waterford	40

The following are forms in use by the observers of Mr. Symons' gauges:—

Register of Rainfall in 1864.

Kept at Seathwaite, Borrowdale; Latitude 54° 31′ North; Longitude 3° 13′ West. Time of Observation, 9 A.M.

Height of Receiver of Rain Gauge.—Above Ground, 1 ft.; Above Sea Level, 422 ft.

Date	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
1	...	1·76	·36	·33	...	...	·23	·73	...	...	...	·11
2	...	·70	...	...	1·98	·08	1·11	·82	·36	...	...	...
3	...	·33	...	·58	...	...	1·87	...	1·31	...	...	3·10
4	...	·60	...	·19	...	...	·09	1·49	1·02	...	...	5·95
5	...	...	·87	1·04	·50	...	...	·84	·71	...	·35	6·47
6	...	...	·08	...	·40	1·98	...	·43	·40	...	...	1·11
7	...	...	1·06	·21	·37	·49	...	...	·20	...	...	1·28
8	...	...	·30	...	...	...	...	1·35	·54	...	...	1·21
9	...	...	...	...	...	...	...	...	·32	...	...	·44
10	...	...	·18	...	...	·53	...	·10	1·14	...	...	1·01
11	·46	...	·94	...	...	...	...	...	·90	...	...	...
12	1·53	2·10	...	...	...	·30	...	...	·05	...	...	1·20
13	...	·41	1·35	...	...	·17	...	...	·11	...	...	·18
14	...	...	·95	...	...	...	...	...	3·06	...	1·21	·14
15	·10	...	3·23	...	...	·74	...	...	·26	...	·15	...
16	...	...	...	·25	...	·13	...	...	·68	·30	·05	...
17	·93	1·81	...	...	...	1·87	...	...	·60	·83	...	...
18	...	...	...	·18	...	·58	...	...	·72	...	3·17	...
19	·97	...	...	·26	...	...	...	...	1·25	1·49	·19	·35
20	·65	...	·67	...	...	·28	...	...	...	1·48	·05	·10
21	·38	...	...	...	·17	1·56	...	...	·72	·29	...	...
22	2·34	...	...	...	·12	·46	1·52	·04	·47	·86	1·40	...
23	1·28	...	...	...	...	·62	·28	...	·70	·43	·42	...
24	...	...	...	...	...	...	...	·06	1·03	...	·26	...
25	...	...	...	...	...	1·12	·32	...	...	...	·06	...
26	...	...	·10	...	...	...	...	...	...	·02	2·47	...
27	1·73	...	·14	...	...	...	...	...	...	...	1·27	...
28	1·03	·36	·16	...	...	...	...	1·47	...	·67	2·25	...
29	...	2·40	...	...	·41	·23	...	·56	...	...	·59	·26
30	·24		·70	...	...	·48	1·15	...	...	...	2·21	·54
31	1·59		1·05		·58		1·00	1·83		...		·24
Totals	13·23	10·11	12·14	3·04	4·53	11·62	7·57	9·72	16·55	6·37	16·10	23·69
Totals from Jan. 1	13·23	23·34	35·48	38·52	43·05	54·67	62·24	71·96	88·51	94·88	110·98	134·67

Manchester, Sheffield, and Lincolnshire Railway.—Monthly Statement of Rainfall in the Year ending December 31, 1868.

Cup Gauge.

Station	Elevation above Ordnance datum — Feet	January — No. of days it fell	January — Inches	February — No. of days it fell	February — Inches	March — No. of days it fell	March — Inches	April — No. of days it fell	April — Inches	May — No. of days it fell	May — Inches	June — No. of days it fell	June — Inches	July — No. of days it fell	July — Inches	August — No. of days it fell	August — Inches	September — No. of days it fell	September — Inches	October — No. of days it fell	October — Inches	November — No. of days it fell	November — Inches	December — No. of days it fell	December — Inches	Total in Year — No. of days it fell	Total in Year — Inches	Average — Days — Yrs.	Average — Days — No. of days	Average — Fall — Yrs.	Average — Fall — Inches	Average — Inches
Manchester, Piccadilly	194	16	2·07	19	2·12	21	3·88	13	1·50	11	1·01	5	0·52	6	0·32	15	2·73	9	1·67	24	4·87	20	2·93	30	7·79	189	31·41	9	186	17	34·29	− 2·88
Fairfield	312	21	2·95	20	2·66	20	4·42	16	2·10	12	1·71	7	0·60	4	0·48	11	2·87	7	1·67	25	5·65	16	2·99	30	9·47	189	37·57	9	191	17	35·59	+ 1·98
Waterhouses, near Oldham	345	13	2·82	21	2·56	18	5·30	10	1·70	10	1·14	3	0·47	4	0·29	14	2·74	7	1·54	21	5·00	18	2·81	27	7·94	166	34·31	9	158	17	32·49	+ 1·82
Newton	396	15	2·94	19	2·07	19	3·32	13	1·64	6	1·06	2	0·14	2	0·31	8	2·78	6	1·39	15	4·01	8	2·15	18	6·04	131	27·85	9	184	16	29·40	− 1·55
Mottram, Matleysfield	399	15	3·01	17	2·62	19	4·72	14	2·29	12	1·52	8	0·16	2	0·15	11	2·37	10	1·79	24	5·35	16	2·72	30	8·67	178	35·37	9	179	14	34·04	+ 1·33
„ Hill End	680	16	3·24	19	2·86	19	5·23	14	2·54	12	1·71	8	0·28	5	1·70	14	2·90	10	1·93	23	5·64	14	2·85	30	8·97	184	39·85	8	206	8	40·68	− ·83
Woodhead	878	20	4·51	21	4·32	18	6·99	17	3·47	13	1·86	7	0·46	7	0·58	14	3·80	13	3·75	24	7·29	19	3·74	29	10·96	202	51·73	9	187	15	45·76	+ 5·97
Dunford Bridge	954	21	5·95	21	5·23	20	8·97	16	4·41	10	1·28	6	0·32	6	0·97	16	4·49	16	5·50	26	9·57	17	5·59	29	15·01	204	67·29	9	204	12	52·84	+14·45
Carlcotes	1075	17	7·99	20	5·96	20	9·39	16	4·06	13	1·63	4	0·25	5	1·03	14	4·55	13	5·25	21	8·90	19	6·09	28	15·26	190	70·36	8	195	8	58·43	+11·93
Penistone	717	21	3·11	18	1·97	21	3·36	12	1·94	9	0·63	6	0·24	4	0·45	13	2·18	15	3·63	22	3·30	24	2·32	29	8·22	194	31·35	9	176	14	27·62	+ 3·73
Sheffield Station	188	16	2·45	15	2·16	19	2·51	14	1·96	12	0·99	5	0·31	3	0·16	13	2·54	10	3·73	20	3·03	14	1·56	30	8·50	171	29·90	9	176	13	25·70	+ 4·20
„ The Edge	336	20	2·74	18	2·44	21	3·30	15	2·42	10	1·08	6	0·53	2	0·10	13	2·66	13	3·62	18	3·56	7	1·98	28	9·53	181	33·96	8	195	8	32·26	+ 1·70
Chesterfield	248	10	1·69	9	1·72	14	2·48	7	1·93	4	1·05	1	0·55	—	—	7	2·28	7	2·46	10	2·80	8	1·04	27	7·47	104	25·47	9	116	13	26·92	− 1·45
Norwood	238	20	2·02	15	1·62	18	1·51	10	1·73	5	1·09	3	0·31	3	0·38	12	2·04	10	2·65	15	2·31	19	1·15	29	7·16	159	23·97	9	175	13	24·79	− ·92
Worksop	127	17	1·87	12	1·75	19	1·24	8	1·25	5	1·06	1	0·09	—	—	10	2·39	4	0·96	16	2·23	12	0·87	24	5·76	128	19·47	9	154	13	22·79	− 3·32
Retford	52	11	1·74	9	1·12	9	1·47	7	1·58	6	1·66	1	0·34	1	0·09	6	3·59	5	1·50	9	2·26	6	0·94	20	5·38	90	21·67	9	128	13	22·59	− ·92
Stockwith	21	8	1·58	10	1·30	8	1·00	9	1·36	8	1·00	2	0·45	5	0·33	8	3·35	9	2·76	10	2·10	7	0·92	24	5·33	108	21·48	9	96	12	21·43	+ ·05
Gainsborough	76	17	1·01	7	1·12	15	0·65	10	0·94	3	0·94	2	0·55	3	0·21	12	5·23	8	2·83	11	1·78	9	0·75	19	5·10	116	21·11	9	136	9	21·26	− ·15
Gate Burton	96	16	1·63	6	1·74	10	1·04	12	1·50	6	1·12	3	0·74	5	0·46	12	3·56	9	2·82	18	2·05	14	1·43	28	5·76	139	23·85	8	160	8	22·44	+ 1·41
Lincoln	26	14	1·39	6	1·59	10	1·30	12	0·96	9	0·23	3	0·49	10	0·41	14	2·37	8	1·92	16	2·21	24	0·94	28	5·83	154	19·64	9	114	9	20·51	− ·87
Market Rasen	100	12	2·37	5	1·73	7	0·94	7	1·68	2	0·20	2	0·30	2	0·24	6	2·52	6	2·22	8	1·80	16	2·09	23	5·26	96	21·35	9	136	9	23·16	− 1·81
Brigg	16	18	1·34	11	1·45	13	1·02	10	1·76	6	0·69	4	0·46	4	0·44	7	3·44	10	2·27	13	2·32	12	1·85	27	5·03	135	22·07	9	140	9	24·05	− 1·98
Barnetby	51	18	1·58	13	1·57	14	1·26	7	1·98	6	0·61	2	0·58	3	0·59	7	2·94	6	1·86	11	2·26	14	1·75	26	5·40	127	22·38	9	150	9	21·58	+ ·8
New Holland	18	16	1·60	11	1·66	20	1·75	14	2·27	6	0·47	5	0·89	6	0·84	6	3·08	12	1·74	15	2·55	20	1·78	28	5·99	159	24·62	9	169	9	22·59	+ 2·03
Grimsby	42	19	1·34	8	1·53	17	1·97	13	2·29	4	0·22	3	0·79	6	0·72	8	3·56	8	1·86	11	2·59	16	1·10	28	5·56	141	23·53	9	137	9	20·88	+ 2·65
Marple Aqueduct	321	20	2·67	20	1·89	20	3·57	16	1·88	12	1·42	7	0·28	4	0·27	14	2·85	9	1·66	20	4·08	14	2·93	25	7·42	181	30·92	9	195	17	29·93	+ ·99
„ Top Lock House	543	20	3·43	17	2·06	19	4·00	14	2·31	12	1·45	7	0·27	5	0·37	15	2·80	9	1·60	20	3·89	14	2·99	25	7·57	177	32·74	9	182	12	32·15	+ ·59
Whaley	602	21	3·31	21	2·92	21	6·08	14	3·18	11	1·82	11	0·37	6	0·31	15	3·18	11	1·92	23	5·76	14	2·82	29	9·62	197	41·31	9	182	18	38·07	+ 3·24
Combs Reservoir	710	20	4·55	21	3·07	22	6·07	15	3·59	12	1·56	7	0·31	5	0·24	16	3·77	10	3·01	18	4·82	14	3·43	28	11·01	188	45·55	9	190	15	43·42	+ 2·13
* „ Moss	1669	—	4·90	—	3·30	—	6·35	—	5·93	—	1·46	—	0·68	—	0·22	—	3·49	—	3·45	—	5·53	—	2·92	—	8·90	—	47·13	—	—	13	45·27	+ 1·86
Chapel-en-le-Frith, top of inclined plane	965	15	2·36	21	3·66	22	5·65	13	3·17	10	1·54	6	0·50	7	0·34	14	3·95	11	2·63	21	5·61	14	2·53	26	9·20	180	41·14	9	195	15	38·65	+ 2·49
*Shonds Hill, near Bollington	1279	—	2·78	—	1·84	—	3·31	—	2·78	—	1·77	—	0·34	—	0·25	—	2·83	—	1·80	—	4·27	—	2·11	—	7·59	—	31·67	—	—	14	36·07	− 4·40
Macclesfield	539	9	1·94	15	2·02	17	3·83	9	2·74	8	1·93	3	0·17	3	0·39	11	3·42	7	1·94	19	4·60	10	1·64	27	7·89	138	32·51	9	150	13	32·38	+ ·13
Bosley Minns	1210	8	1·39	12	1·88	14	3·30	6	2·13	8	1·80	4	0·30	3	0·43	9	2·74	6	2·08	15	4·69	8	1·96	22	9·11	115	31·81	9	125	17	32·53	− ·72
„ Reservoir	590	9	1·80	18	2·05	17	3·96	9	2·01	10	1·41	2	0·18	4	0·32	13	3·46	7	1·74	19	4·69	10	1·79	25	6·82	143	30·23	9	153	14	30·04	+ ·19
Barnsley	175	15	2·04	8	0·91	10	1·28	13	1·66	7	0·58	3	0·57	2	0·37	12	2·85	12	2·78	13	2·32	11	1·25	25	6·67	131	23·28	1¾	132	1¾	23·09	+ ·19
Worsborough	225	16	1·39	13	1·67	19	1·59	16	1·93	9	0·69	5	0·59	2	0·35	12	2·41	12	3·22	15	2·44	16	1·07	28	6·78	163	24·13	1¾	157	1¾	24·18	− ·05
Doncaster	35	15	1·73	10	1·09	16	0·94	11	1·26	5	0·71	2	0·31	1	0·16	6	2·14	7	2·64	12	2·20	7	0·59	25	6·56	117	20·33	1¾	126	1¾	25·45	− 5·12
Rotherham	85	8	2·79	7	1·43	14	1·57	12	2·33	6	0·76	3	0·29	2	0·23	8	2·24	11	3·26	11	2·58	12	1·17	22	6·93	116	25·58	1¾	111	1¾	25·59	—
Elsecar	175	17	1·43	14	1·82	19	1·60	14	1·75	9	0·71	3	0·51	1	0·29	10	2·36	12	2·57	13	2·61	12	1·01	27	6·94	151	23·60	1¾	154	1¾	24·29	—
Keadby	10	12	1·33	9	1·14	13	0·96	11	1·24	5	1·64	3	0·75	3	0·18	6	2·02	10	2·73	13	2·19	15	1·71	24	5·09	124	20·98	1¾	132	1¾	21·99	—

Rainfall at Rugby, Warwickshire.

Lat. 52° 22′ N.; Long. 1° 16′ W. Receiving surface 12 inches diameter, 2 ft. 4 in. above ground, and 284 ft. above sea.

	1855	1856	1857	1858	1859	1860	1861	1862	1863	1864	1865	1866	1867	1868	Mean of 14 years
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January	·07	2·92	2·64	·28	1·09	2·56	1·37	2·29	2·07	·92	2·04	2·15	3·09	2·34	1·85
February . . .	1·00	1·65	·76	·98	1·46	·84	1·52	·39	·45	1·45	2·17	2·58	1·42	1·54	1·30
March	1·22	·67	1·89	·62	1·41	1·89	2·07	3·58	·31	2·81	1·22	1·22	2·57	2·08	1·68
April	.57	1·69	2·51	2·47	1·94	1·21	·55	1·56	1·41	1·48	·68	1·23	2·37	1·40	1·50
May	1·19	2·78	·85	1·92	1·23	2·96	1·03	2·34	·44	1·39	1·62	1·40	2·39	·53	1·58
June	2·41	1·40	2·23	1·36	2·51	5·36	1·88	3·32	3·72	·87	2·47	2·33	3·25	·26	2·38
July	6·82	1·53	2·26	1·76	1·39	1·40	4·62	1·89	·66	·28	3·85	3·14	2·46	·30	2·31
August	1·22	1·65	3·84	2·22	2·23	3·16	·86	1·90	2·02	·73	3·47	4·08	3·43	3·34	2·44
September . . .	1·03	1·52	3·87	2·17	1·79	2·51	1·97	3·28	2·23	1·37	·24	6·20	3·49	2·16	2·42
October	4·46	1·72	2·18	2·16	2·42	2·29	1·23	2·59	2·13	1·67	4·60	1·97	2·69	2·28	2·46
November . . .	1·16	1·35	1·56	·45	1·88	2·01	2·51	·75	1·97	1·65	2·29	1·74	·49	1·44	1·52
December . . .	.67	1·67	·61	2·04	1·75	1·36	1·22	1·30	1·10	1·79	1·29	1·87	1·86	5·48	1·71
Yearly Total . .	21·82	20·55	25·20	18·43	21·10	27·55	20·83	25·19	18·51	16·41	25·94	29·91	29·51	23·15	23·15

Glasgow Corporation Waterworks.

Rainfall in the Loch Katrine and Gorbals Districts.

DATE	LOCH KATRINE DISTRICT											GORBALS DISTRICT			
	Elevation 275 feet — At Loch Vennachar	Elevation 420 feet — At Loch Drunkie	Elevation 270 feet — At Bridge of Turk	Elevation 1,800 feet — Between Glen Finlas and Ben Ledi	Elevation 380 feet — At Glengyle, head of Loch Katrine	Elevation 330 feet — On summit of hill above tunnel at Loch Katrine	Elevation 325 feet — At Loch Dhu	Elevation 60 feet — At the Inn at Aberfoyle	Elevation 1,500 feet — On hills between Loch Ard and Loch Katrine Ledard	Elevation 1,800 feet — Head of Duckray Valley — Ben Lomond	Elevation 320 feet — At Mugdock Reservoir	Elevation 280 feet — No. 1. Waulk Glen Reservoir	Elevation 310 feet — No. 2. Ryat Linn Reservoir	Elevation 550 feet — At Middleton	Elevation 700 feet — At Nether Cairn — Black Loch
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
1854	...	...	64·5	61·9	103·3	...	...	56·1	67·1	109·0	...	43·28	45·92	...	57·55
1855	...	...	39·0	56·1	65·5	...	...	34·6	...	69·9	...	31·68	29·93	35·50	39·90
1856	...	...	48·3	...	79·3	...	...	36·7	74·1	81·0	...	39·75	38·00	42·25	51·50
1857	...	...	54·8	48·3	91·6	...	...	47·6	74·2	85·5	...	35·84	34·25	41·70	45·70
1858	...	...	60·2	55·2	84·8	...	...	41·5	97·1	90·4	...	44·55	43·33	51·70	—
1859	...	...	65·2	48·0	93·7	...	...	52·6	85·3	91·8	...	53·35	48·70	57·65	—
1860	...	...	59·8	53·8	94·2	...	...	40·4	73·5	83·5	...	41·50	39·45	44·72	—
1861	72·7	71·7	74·4	70·4	112·5	89·2	93·2	71·6	103·1	99·9	...	58·70	55·30	66·08	69·25
1862	69·0	78·1	71·9	66·0	105·1	96·9	101·1	77·0	102·7	114·7	60·6	58·95	56·25	68·98	68·70
1863	61·5	73·1	68·5	70·7	105·5	87·5	94·7	67·3	95·2	117·0	54·8	54·80	52·31	62·55	68·75
1864	55·5	62·5	56·1	69·0	80·6	71·2	77·8	57·8	76·1	68·0	40·3	44·30	43·80	51·70	49·20
1865	46·2	46·8	45·0	57·7	72·2	61·7	64·9	46·3	81·2	67·2	34·9	35·50	35·80	40·03	38·75
1866	63·9	72·5	70·9	...	100·7	89·8	96·4	75·0	89·8	100·1	55·2	55·90	52·55	61·46	59·60
1867	55·2	57·2	50·7	53·0	98·9	73·4	78·5	50·0	...	...	40·1	45·60	42·80	54·05	49·95
1868															
January	9·3	10·0	8·2	7·5	17·0	11·8	15·2	10·9	16·3	17·0	8·4	9·25	7·90	9·00	6·40
February . . .	6·9	10·5	5·3	5·0	17·4	13·8	12·8	8·1	11·4	12·4	8·3	8·35	7·15	8·60	7·70
March	6.3	7·2	5·6	5·6	...	10·1	10·2	7·7	8·7	9·6	6·2	6·00	5·95	7·50	6·25
April	3·9	4·2	4 3	3·5	...	5·1	5·8	4·4	6·0	4·8	3·1	3·65	3·85	4·30	4·15
May	4·3	5·3	4·8	6·3	...	5·9	6·4	4·5	6·1	7·4	2·8	2·85	3·00	3·60	3·55
June	1·7	2·3	1·8	1·8	...	2·9	3·25	2·7	1·8	4·2	2·0	1·90	1·90	2·60	2·25
July	0·9	1·3	1·0	1·2	1·95	1·5	1·65	0·6	0·7	1·6	1·1	0·50	0·50	0·70	1·00
August	8·2	9·9	7·9	8·5	11·95	8·6	9·5	8·9	9·0	11· 6	4·3	5·15	5·30	5·50	5·50
September . . .	2·6	2·8	2·2	5·1	3·6	3·0	3·4	3·0	3·8	4·2	2·8	2·40	2·60	3·15	2·80
October	7·6	8·4	7·2	4·6	12·6	10·2	10·9	7·7	10·6	11·6	5·5	5·95	5·75	6·60	5·95
November . . .	3·9	3·9	3·6	2·8	6·1	6·1	7·2	3·7	6·9	5·7	5·5	4·05	3·95	4·70	4·35
December . . .	9·9	12·2	9·8	10·7	17·7	15·9	15·9	10·7	16·4	13·1	6·9	7·35	7·40	8·45	7·30
Totals	65·5	78·0	61·7	62·6	...	94·9	102·2	72·9	97·7	103·2	56·9	57·40	55·25	64·70	57 20
Averages . . .	61·2	67·5	59·4	59·4	92·0	83·1	88·6	55·2	85·9	91·5	49·0	46·7	44·9	53·1	54·7

'Within the tropics there is a rainy and a dry season, and in the tropical countries of the New World the mean annual fall is about 115 inches, while in the Old World it is not more than 76 inches, giving a general mean for the tropics of 95½ inches. In the temperate zone of the northern hemisphere there is less difference between the eastern and western continents, the mean being 37 inches; but the extremes in each case exhibit very wide ranges. In the south temperate zone the fall averages 26 inches only, and in the frigid zones it has not been measured with sufficient accuracy, but is very much smaller. It would appear that between three and four times the total quantity of water retained at one time in the atmosphere in the form of invisible aqueous vapour, or clouds, falls annually on that portion of the earth's surface marked by the presence of land; a striking proof of the frequency of change in the condition of the atmosphere in this respect, and the rapid transmission of aqueous vapour through it.'

The following table will give approximately the distribution and absolute quantity of water falling on the land in different districts of the earth. It must be understood that in the two frigid zones, and, indeed, in the temperate zones, the estimate includes the whole fall of water whether as rain or snow :*—

	Area of Land in square miles	Total Annual Rainfall	
		In cubic feet	In tons weight
North and South Torrid Zones . . .	19,400,000	4,282,750,000,000,000	119,177,000,000,000
North Temperate Zone	25,150,000	2,160,500,000,000,000	60,000,000,000,000
South Temperate Zone	4,350,000	261,500,000,000,000	7,275,000,000,000
North and South Frigid Zones . . .	2,600,000	70,250,000,000,000	2,000,000,000,000
General Total	51,500,000	6,775,000,000,000,000	188,452,000,000,000

It is one of the principal aims of meteorology to discover the laws of the several variations to which the fall of rain is liable ; although of late years a great advance has been made, this department of science is in its infancy, and nowhere does it receive greater tests than in connection with catchment areas for the supply of water to towns. It has not as yet been determined, for instance, for how many years observations must be conducted before they will fairly represent a cycle, as it were, of the variations in the fall, from which the *maximum* and *minimum* falls for one year, and for different terms of years, may be ascertained with confidence. It has been supposed that the law of rainfall is decadal, and the accompanying table of the rainfall at Greenwich Observatory may be taken as an illustration of this view, if the forty years from 1828 to 1867 be regarded. But if we take the decade immediately preceding, namely, from 1818 to 1827, the mean rises from about 24½ to 28¼

Rainfall at Greenwich Observatory.

Year	Total fall	Year	Total fall	Year	Total fall	Year	Total fall
1828	31·5	1838	23·8	1848	30·2	1858	17·8
1829	25·2	1839	29·6	1849	23·9	1859	25·9
1830	27·2	1840	18·3	1850	19·7	1860	32·0
1831	30·8	1841	33·3	1851	21·6	1861	20·3
1832	19·3	1842	22·6	1852	34·2	1862	26·5
1833	23·0	1843	24·6	1853	29·0	1863	19·8
1834	19·6	1844	24·9	1854	18·7	1864	16·8
1835	24·9	1845	22·4	1855	21·1	1865	28·6
1836	27·1	1846	25·3	1856	22·2	1866	30·1
1837	21·0	1847	17·8	1857	21·4	1867	28·5
	249·6		242·6		242·0		246·3
Average . .	24·9	Average . .	24·2	Average . .	24·2	Average . .	24·6

* An Elementary Course of Geology, &c. By Professor Anstead.

inches. In his observations on meteorology, the Rev. W. Jenyns gives an instance where, with terms of ten years, the mean annual rainfall varied from 18½ to 26 inches. But even if a period of ten years were long enough to determine the mean annual fall with sufficient accuracy, it is evident that a much longer term is necessary to include the maximum and minimum of single years, and of two, three, or more consecutive years. It would seem that if less than half a century be relied on, a considerable margin of safety should be allowed.

Maximum and Minimum Fall.—The mean fall at any place being known, an approximate idea of other rainfall elements may be formed from the following rough rules. It must be understood that they are only approximations, and that observed facts are infinitely preferable where they can be obtained. Where they cannot be obtained, the departure of extreme years from the mean may be estimated at 33 per cent. in excess for the wettest year, and the same amount for defect in the driest. The three driest consecutive years have ordinarily about 80 or 85 per cent. of the mean annual fall; and this value, or its equivalent—five-sixths of the mean—is generally taken as the basis of calculations in questions of water-supply. It would appear, from the records of rainfall at the Greenwich Observatory, that the term of three consecutive dry years occurs at intervals of about twenty-two years.

The distribution of the fall over the various months is very different in mountainous tracts from what it is in flatter and drier ones. In the former it is greater in the winter months, in the latter in the summer: in the former, January is the wettest month; in the latter, July or sometimes October.

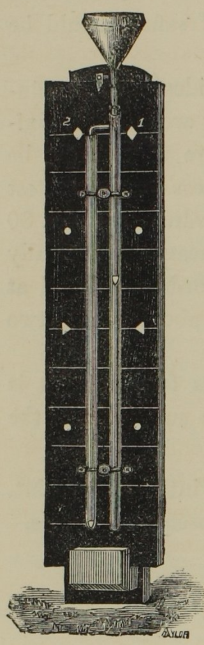
The following table, taken from Symons' 'British Rainfall' for 1867, will illustrate this interesting point. The falls in the decennial period 1850-9 have been found to bear a close analogy to those in subsequent periods.

Mean Annual Fall from	15 in. to 20 in.	20 in. to 25 in.	25 in. to 30 in.	30 in. to 35 in.	35 in. to 40 in.	40 in. to 45 in.	45 in. to 50 in.	50 in. to 60 in.	Above 60 in.	Mean of all Stations
January . .	7·7	8·0	8·8	9·4	10·3	11·4	9·3	11·8	14·0	10·08
February . .	4·7	4·9	5·0	5·9	6·5	7·3	7·7	7·3	9·4	6·52
March . . .	5·3	5·2	5·4	5·7	6·6	6·6	5·3	6·1	5·9	5·79
April . . .	6·9	7·1	7·2	7·2	6·9	6·8	5·6	6·5	5·6	6·64
May . . .	7·3	7·9	7·5	6·4	6·0	5·9	4·9	5·5	4·1	6·17
June . . .	8·7	9·1	8·1	8·3	8·4	7·7	9·4	7·5	6·4	8·18
July . . .	12·4	11·6	10·2	8·7	8·3	7·7	9·4	7·7	7·0	9·22
August . .	11·8	10·6	9 6	9·3	8·9	8·6	10·9	8·8	9·1	9·73
September . .	9·3	9·0	8·9	8·8	8·3	7·6	8·6	8·1	7·1	8·41
October . .	10·7	11·8	12·6	12·1	11·8	10·9	10·9	10·7	9·9	11·27
November . .	8·9	8·5	9·0	9·1	8·8	9·2	8·7	9·0	8·9	8·89
December . .	6·3	6·3	7·7	9·1	9·2	10·3	9·3	11·0	12·6	9·10
Number of Stations	4	29	28	10	6	4	2	3	3	89

The greatest fall in twenty-four hours is an element of much importance, and is generally conformable to the following rule:—With a mean fall of 20 inches it is 16 per cent. of the mean annual fall (i.e. 3·20 inches); for each increase of four inches in the mean annual fall it decreases one per cent. until the latter reaches 60 inches; beyond that point it remains stationary at six per cent., however great the mean annual fall may be. For example, Seathwaite, mean annual fall 140 inches; $1·40 \times 6 = 8·40$ = the computed maximum fall in twenty-four hours. The greatest fall yet recorded at that station is 6·60, thus confirming the above rule.

Serious damage frequently results from unexpected floods, and it is difficult to say what fall of rain ought to be provided for; it would be as unwise to provide in drainage works for such a flood as that experienced in Scarborough in 1857 (when more than nine inches of rain fell in one night) as it would be to abandon the erection of lofty chimneys, because an earthquake might shake them down. The rule we have just quoted shows that falls of three or four inches in twenty-four hours may be expected to occur in all parts of the country, in the driest as well as in the wettest, and there seems some evidence that this may all fall in a couple of hours. If, as seems to be the case, such a fall will not occur in any one place oftener than once in a century, it approaches, if it does not pass, the limit beyond which 'visitation of God' may be pleaded, and, even if the plea were held invalid, the damages would hardly be more costly than the construction and maintenance of inordinately large works.

Fig. 7.



In order to meet the difficulty hitherto existing of determining with accuracy the rate at which rain falls in violent storms, Mr. Symons (who has given great attention to this subject) has designed, and Messrs. Pastorelli, of Piccadilly, have constructed, a very simple instrument (see fig. 7). If the numerous observers who furnish returns to the designer from the various stations would also use this instrument, there is no doubt better data would be supplied on this very important subject.

'The area of the funnel, as compared with that of the glass tube, is so large that an inch of rain is about two feet long on the tube; therefore, as each tenth of an inch is about three inches long, the water can be seen gradually rising in the tube as the rain continues, and the quantity in any interval, however short, may be easily noted. In order to facilitate reading at a distance, floats are placed in each tube, and these, being white while the board is black, are clearly visible at 60 feet distance. Each division on the scale is a tenth of an inch, and it will be seen that the first tube being filled up to the top line (i.e. ten tenths, or one inch), the rain flows into the second, and that float begins to rise until two inches have fallen.'

Evaporation and Absorption.—Intimately connected with the subject of rainfall—indeed, forming a necessary part of it in its practical bearing—is that of evaporation. There is the evaporation of the rain immediately upon its falling to the ground, and while being temporarily retained by the latter; and there is the evaporation from the surface of large bodies of water, such as lakes and reservoirs. Again, a vast amount of the water which falls in the shape of rain is absorbed by vegetation: partly to be retained in the body and fibres of the tree or plant, and partly to be evaporated from its leaves. In either case, however, it is lost as far as the purposes of water-supply are concerned. The evaporation from the ground surface will depend on the temperature, the physical configuration, and the geological formation of the district, the state of the drainage, the nature of the surface of the ground, and the rate at which the rain falls. The absorption of vegetation will of course depend upon the amount and nature of the vegetation. When in the warmer seasons of the temperate zones the showers come very lightly on a loose absorbent soil, they are registered in the rain gauge; but the rain neither sinks into the ground sufficiently to appear again in the form of springs, nor does it flow into the rivers and streams, and become available for impounding, but is evaporated in many instances almost as fast as it falls. On the other hand, with a steep descent and on an impermeable surface, the rainfall is less likely to be lost. The extreme cases are—for the maximum evaporation, a flat spongy district, with a retentive substratum, as in boggy parts; and for the minimum, a steep, bare, and impermeable surface, such as the slated roof of a house, from which there is scarcely any evaporation.

It has been popular in this branch of engineering to suppose that, on the average, one-third of the rainfall is lost by evaporation and absorption by vegetation; one-third is drained into rivers and streams; and one-third percolates into the ground, to appear again in the form of springs. It would seem, however, that in a given district the loss by evaporation and absorption is rather a constant quantity than one directly proportionate to the rainfall: for, as the rainfall increases in any season, the proportion of it which is lost will decrease, and *vice versâ*. Indeed, it is nearer the truth to consider that the proportion of the rainfall lost by evaporation will vary inversely as some higher power of the rainfall. Thus, when at Liverpool, 'in 1862, the rainfall was 48·51 inches, the ratio of impounded water to the rainfall was 82·63 per cent. In 1865, when the rainfall was 34·8 inches, the proportion of available water flowing off was only 67·12 per cent.; so that, apart from the deficient rainfall, that which did fall yielded less by 15·51 per cent. than the rainfall of 1862;' so that while the rainfall was less by 28·3 per cent., the proportion of it which was lost increased 89·3 per cent., and even the absolute loss by evaporation increased from 8·43 inches to 11·44 inches, or nearly 36 per cent. This is merely one instance, but numerous others could readily be given. The cause is obviously to be found in the diminished humidity of the atmosphere, and in many cases the increased temperature in the seasons of less rain; and it is for the same reason that the absolute evaporation is greater in those districts where the mean rainfall is less. Again, the loss will depend greatly upon the distribution of the rain in the different seasons of each year; for, as the proportion of rain falling in the summer months becomes greater, the loss from evaporation will also be greater. It has been shown that in the districts where there is less rain annually, the tendency is for the bulk of the rain to fall in the summer months; there is thus an additional cause for the loss to be greater in the districts of less rain.

The foregoing considerations have reference more especially to the mean *annual* evaporation, but it is necessary further to regard the proportion borne to the annual evaporation by that which occurs during the drier seasons, when the amount of available rainfall is of most consequence. The same principles, however, will be found to obtain, namely, that in the dry season the proportion lost by evaporation will be enormously increased, sometimes amounting to 70 or 80 per cent. of the rainfall, even when taken over a period of five or six months. The available rainfall of the dry season is measured by the 'dry-weather flow,' to which reference will be made hereafter. In England the loss by evaporation and absorption is found to range from about 9 to 19 inches per annum; and the average seems to be about 13 or 14 inches. But, from what has already been said, it will be seen that in matters affecting the water-supply of towns, the mean annual loss is, like the mean annual fall, to be used merely for estimating the quantity that will be actually available in dry years. It is evident that to speak definitely.with confidence on a subject, the conditions and circumstances of which are liable to so much variation, would be folly. It is only from direct and careful observation, either in the district under consideration or in analogous positions, that any reliable estimates can be formed.

Evaporation from Surfaces of Water.—It would at first sight appear that the determination of the amount of evaporation from a given surface of water would be a very simple operation. Such, however, is not the case, and the discrepancies between the records of careful observers have been almost incredible. The chief causes of inaccuracy are to be found, no doubt, in the comparatively diminutive size of the instruments in general use, the small quantity of water becoming unduly heated, and the recorded evaporation being in consequence greatly in excess of that from large bodies of water. In the 'Annales des Ponts-et-Chaussées' is an account of some large experimental evaporators at Dijon and other places on the Burgundy canal. They consisted of masonry tanks, of about eight feet square and one foot four inches deep, lined with zinc, so as to be perfectly water-tight, and sunk into the ground. The evaporation was found to be less than half that generally adopted by the highest authorities; indeed, a small evaporator, or rather one about the ordinary full size (one foot square), placed near the large one, gave results 50 per cent. greater than the latter.

Experiments conducted under shelter by Mr. Luke Howard, of Plaistow, in 1812–15, gave 21·13 inches of evaporation per annum, against 23·15 inches of rainfall; and out of the former quantity, 10·41 inches were evaporated in the four months from July to October.

From the evaporators at Dijon, eight feet square, just referred to, Vallé found, during seven years, from 1846 to 1852, a mean annual evaporation of 26·1 inches, against a rainfall of 26·9 inches.

Mr. Bateman estimates the evaporation at 'a trifle more than $\frac{1}{10}$th of an inch in the hottest day in summer, when the weather is most suitable for the absorption of moisture.'

In an article entitled 'Physical Geography,' published by the Society for Promoting Useful Knowledge, the following remarks on this important subject appear:—'Other things being equal, evaporation is the more abundant the greater the warmth of the air above that of the evaporating body, and least of all when their temperature is the same. Neither does much take place whenever the atmosphere is more than 15 degrees colder than the surface upon which it acts. Winds powerfully promote evaporation, because they bring the air into continual, as well as into closer and more violent, contact with the surface acted upon; and also, in the case of liquids, increase, by the agitation which they occasion, the number of points of contact between the atmosphere and the liquid.

'In the temperate zone, with a mean temperature of 52½°, the annual evaporation has been found to be between 36 and 37 inches. At Cumana, on the coast of South America, N. lat. 10_{2}°, with a mean temperature of 81·86°, it was ascertained to be more than 100 inches in the course of the year. At Guadaloupe, in the West Indies, it has been observed to amount to 97 inches. The degree of evaporation very much depends upon the difference between the quantity of vapour which the surrounding air is able to contain *when saturated* and the quantity which it actually contains. M. Humboldt found that, in the torrid zone, the quantity of vapour contained in the air is much nearer to the point of saturation than in the temperate zone. The evaporation within the tropics, and in hot weather in temperate zones, is on this account less than might be supposed from the increase of the temperature.'

'In India,' says Mr. Arthur Jacob, in a paper read before the Society of Engineers, 'where, from the extreme dryness of the atmosphere, the evaporation is found to be considerable, the usual allowance made by engineers for the evaporation from the surface of storage reservoirs is at the rate of half an inch of depth per diem for eight months in the year. Regarding the results that have been arrived at in Bombay, this allowance would appear to be about double what is necessary, for the observations, extending over five years, give a mean daily evaporation of less than a quarter of an inch. In Bombay, however, the atmosphere is much more humid than that experienced on the great table-land of the Deccan; and in Madras, where reservoirs are the speciality, it is probable that the actual loss is not far from being a mean between the two fractions. In Great Britain the mean daily evaporation is found to average less than the tenth of an inch.'

Of more importance, however, than the mean annual evaporation, is the evaporation during the dry season of the year, when reservoirs are being taxed to their utmost capacity, and when, therefore, the elements of loss have to be more closely watched. Mr. Burnell, in his 'Rudiments of Hydraulic Engineering,' says that, 'the experience derived from the use of reservoirs on canals appears to indicate that, during the summer months, it is necessary to allow for an evaporation ranging between one-sixth and one-eighth of an inch per day.' In an important matter like this, it is perhaps advisable, in order to be on the safe side, to allow for daily loss during the dry season of not less than one-fifth of an inch.

In Symons' 'British Rainfall' for 1869 will be found much valuable information concerning evaporation and the various forms of evaporating gauges in use; and in the corresponding work for 1870 details of some very elaborate experiments now in progress at the expense of the Royal Society. One or two articles also have appeared in the Proceedings of the Meteorological Society, and the following is an epitome of the present state of knowledge of the subject.

A body of water is either decreasing by evaporation or increasing by condensation, at every temperature but one, the point of quiescence being that known by meteorologists as the dew-point temperature. We have said a 'body of water' but evidently, as evaporation can only proceed from the surface, it is with surface temperatures alone that we are concerned. A few pints of water in a metal vessel exposed to the sun will obviously become far hotter than the surface of a lake (probably 20° or 30°), hence the loss from such a vessel is enormously in excess of the true loss from a reservoir or canal, and therefore old records of evaporation in England of 40 or 50 inches are simply delusive. With respect to large and deep reservoirs one rather singular condition must apparently prevail. Owing to the diathermancy of clear water a large proportion of the heat rays penetrate it to great depths and the surface water is but slightly warmed. We do not know of any records of the surface temperatures of large reservoirs, but putting it at 65° on a hot day in summer, when the shade temperature is 85° and the wet bulb 80°, conditions with which a burning sunshine is quite consistent, the dew-point temperature would be 76·7°, and the reservoir, instead of evaporating, would actually be condensing vapour from the layer of air in contact with it. As far as we are aware, there are no published records of the daily evaporation from large surfaces of water, and we have therefore quoted the above startling illustration of the necessity which exists for caution in dealing with this subject. Ordinarily, especially in Great Britain, the air is drier than in the illustration just quoted, but the liability to what may be called negative evaporation both in summer and winter must not be overlooked. There is no trustworthy basis for generalisation as to this question; it is one now under examination, and all that can be said is that the annual loss from a large water surface seems to be about 20 or 25 inches, that the summer loss is least from the largest and deepest bodies of water, but that they lose more in winter than shallower reservoirs.