XXXV. On the hydrometer

William Speer Esq.

To cite this article: William Speer Esq. (1802) XXXV. On the hydrometer , Philosophical Magazine Series 1, 14:55, 229-237, DOI: [10.1080/14786440208676188](https://doi.org/10.1080/14786440208676188)

To link to this article: <http://dx.doi.org/10.1080/14786440208676188>

Published online: 18 May 2009.

Submit your article to this journal [↗](#)

Article views: 3

View related articles [↗](#)

backwards, but must have been as represented in the figure, the points thrown out by the spiral twist on each side:—in this position they might have answered in striking down small animals, or in detaching shell-fish from the bottoms of rivers, or even in ascending the banks.

In the elephant the orbit of the eye is situated at C, whereas in the corresponding part at C in the mammoth is a large mass of bone, so that the eye must have been elsewhere: to ascertain where, we must wait until we receive the cranium lately discovered on the Ohio. The cheek of the elephant is formed of two bones; but in the mammoth, besides other variations, there is but one bone. The whole figure of the under-jaw differs most remarkably; first in the length of the condyles or arms from E to B: in the mammoth it is short and angular; but in the elephant D E B forms a semi-circular line, and at D it is long and pointed.

This short reference is sufficient to direct the attention of those who wish to examine them more critically; when they may remark several other characters sufficiently interesting.

XXXV. *On the Hydrometer.* By WILLIAM SPEER, Esq.
Supervisor and Assayer of Spirits in the Port of Dublin.

[Concluded from p. 162.]

I SHALL now proceed to explain Mr. Gilpin's tables, in order to demonstrate their use, and the use of my additional columns. The first I cannot do better than in the words of Sir Charles Blagden himself:

“Tables for reducing the quantities by weight, in any mixture of pure spirit and water, to those by measure; and for determining the proportion, by measure, of each of the two substances in such mixtures, by Mr. George Gilpin, clerk to the Royal Society, communicated by Sir Charles Blagden:

“These tables are founded on the experiments, of which the results were given in the Report and Supplementary Report on the best Method of proportioning the Excise on Spirituous Liquors. They are computed for every degree of heat, from 30° to 80°, and for the addition or subtraction of every one part in a hundred of water or spirit; but as the experiments themselves were made only to every fifth degree of heat, and every five in the hundred of water or spirit, the intermediate places are filled up by interpolation in the usual manner, with allowance for second differences.

“ Every table consists of eight columns, and there are two tables for every degree of heat. In the first column of the *first* of the two tables are given the proportions of spirit and water by weight, 100 parts of spirit being taken as the constant number, to which additions are made successively of one part of water, from 1 to 99 inclusively: the first column in the second table has 100 parts of water for the constant number, with the parts of spirit decreasing successively by unity, from 100 to 1 inclusively.

“ It must be observed, that each of these tables, occupying one page, is divided in the middle for adapting it more conveniently to the size of the paper; but the whole of each page is to be considered as one continued table. The second column of all the tables gives the specific gravities of the corresponding mixtures of spirit and water in the first column, taken from the table of specific gravities in the Supplementary Report, the intermediate spaces being filled up by interpolation. In the third column, 100 parts by measure of pure spirit, at the temperature marked at the top of every separate table, is assumed as the constant standard number, to which the respective quantities of water by measure, at the same temperature, are to be proportioned in the next column.

“ The fourth column, therefore, contains the proportion of water, by measure, to 100 measures of spirit, answering to the proportions by weight in the same horizontal line of the first column. The fifth column shows the number of parts which the quantities of spirit and water, contained in the third and fourth columns, would measure when the mixture has been completed; that is, the bulk of the whole mixture after the concentration or mutual penetration has fully taken place. The sixth column, deduced from the three preceding ones, gives the effects of that concentration, or how much smaller the volume of the whole mixture is, than it would be if there was no such principle as the mutual penetration. The seventh column shows the quantity of pure spirit by measure, at the temperature in the table, contained in an hundred measures of the mixture laid down in the fifth column.”

From this account it will be seen, that every mixture of pure spirit and water possible to be made, is analysed so clearly at every temperature, as to render it a matter of no great difficulty to demonstrate, at a given temperature, all the gradations of strength which the hydrometer should indicate. The mode in which this has been done I shall now explain.

The table which Mr. Gilpin has calculated for the temperature of 55, is that which I have chosen, conceiving it, for

for several reasons, to be the most convenient. And as a reference to it becomes necessary, I have annexed this, with the additional columns to it, by which the hydrometer indications of strength are regularly deduced from the specific gravity of the spirit at this temperature *.

In order to explain the manner in which I have calculated these additional columns, I conceive the easiest mode will be by an example.

It being understood by the trade that the specific gravity of proof spirit at this temperature (55) is 922, I look at the table for this specific gravity, and I find that it is a mixture of pure spirit and water, in the following proportions, viz. 100 parts of the former to 81 of the latter (both by weight), but that by measure it is made by mixing 100 gallons of pure spirit with 66 gallons 99 parts of water. I then find that the diminution of bulk, by penetration, on the mixture by measure, (that by weight being unnecessary to attend to in bringing out the result,) is 4 gallons 57 parts, as, instead of producing 166 gallons 99 parts, there will be only 162 gallons 42 parts. I find next, that this mixture contains per cent. of pure spirit 61 gallons 57 parts.

These being the proportions in the standard of proof, to which every other gradation of strength is relative, the Rule of Three demonstrates this relation in a manner requiring to be explained by another example. Suppose a spirituous liquor is produced to ascertain the hydrometer indication; on weighing it in a phial adapted to this purpose, I find that at the temperature of 55, its specific gravity is 848; by looking into the table I perceive that this contains per cent. 93.18 of pure spirit. I then try how much more than proof this is by subtracting 61.57 (the quantity which proof contains), and I find that this has a redundancy of pure spirit, amounting to 31.61.

Therefore, as 100 gallons of pure spirit require 66 gallons 99 parts of water to reduce it to proof, the redundant 31.61 will require 21.17. Add these, and from the amount 52.78 the diminution of bulk by penetration is to be deducted, which, by the ratio in proof spirit being 1.44, the result finally comes out that this spirit is 51 gallons and 34 parts (about one-third) over hydrometer proof. The under proofs require less calculation, the excess of water per cent. over the proportion which proof contains being all that is required.

* It may perhaps be necessary to observe here, that a reference to this table is not required in the use of the hydrometer I have constructed, further than to try whether it be correct.

These examples are, I hope, sufficient to explain this table. The uses to which it is applicable, are, that *as it affords first an unequivocal standard for every gradation of strength*, an hydrometer can be graduated on a certain principle; and, secondly, the errors of those that are graduated otherwise may be discovered by it, and we shall no longer be obliged to rely on a mere assertion, that the instrument is correct, nothing more being required than to compare the specific gravity of the spirit with the indication of strength which it has demonstrated.

On considering how far it might be practicable to simplify the hydrometer, I perceived that the makers of these instruments had fallen into two errors, which had very considerably increased the necessity for those complex additions with which they are incumbered.

First, conceiving that the instrument was to be valued in proportion as it was capable of making *minute* discriminations, (or of its sensibility as it is called,) they have, by attempts to increase this beyond those limits required either in revenue or in commerce, destroyed its simplicity.

In the construction of this instrument, the proportion of the stem to the ball is an important consideration: if the former be too large, the instrument will not be sufficiently sensible; and should it, on the contrary, be too small, the number of gradations of strength it is capable of indicating will proportionably be diminished.

Those who have constructed most of the hydrometers now in use, have run into the latter error; the stem being diminished to a size which rendered it necessary to have recourse to complex additions to supply the place of this injudicious and unnecessary waste of the simple and proper power of the instrument.

From a great variety of experiments to ascertain the proper proportion between the ball and stem, I was finally satisfied that the latter would admit of such enlargement as to be rendered capable of measuring upwards of 66 gradations or per centages of strength, without any weight; and this so clearly and distinctly, as to convince me that its sensibility and accuracy were still fully sufficient.

The second error alluded to has arisen from an attempt to extend the power of the instrument beyond those limits, which, with propriety, and consistently with its simplicity, could be effected.

An hydrometer being a counterpoise to ascertain the weight of a spirituous liquor, may, with propriety, be compared to a

pair of scales *, of which there are various *sizes* and *descriptions*, to answer *different purposes*, by which means their simplicity is uniformly preserved.

On the contrary, it has erroneously been conceived, that an hydrometer would be imperfect that did not, *by one means or another*, ascertain the specific gravity of all liquids at their various temperatures: the simple power of every instrument of this kind being confined within certain limits, this could not be effected without additional complications of various kinds to those which were added, to increase its sensibility, some of which are certainly ingenious, but, I conceive, highly unfit for the purpose of revenue.

Should this ingenuity be exercised on a pair of scales, which it would be proper to use in weighing a portion of eight or ten pounds, and by complex additions render them sufficiently sensible to ascertain a few grains or fraction of a grain, or so extended in their power as to weigh 100 pounds, is it not evident that the simplicity of the balance, which is its great recommendation, would be destroyed?

That which led to the construction which I finally fixed on, was first a *quadrangular stem*, from which I had four temperatures, viz. 35, 45, 55, and 65; and the intermediate degrees I managed with four small weights on the top of the stem, each serving for two degrees of temperature. The instrument having been graduated with these on, if the temperature should be *two* degrees higher than the scale, I removed one weight, in order to lighten the instrument equal to the decrease of specific gravity; if *four* degrees, I removed two weights; if *six* degrees, I removed three weights; and if *eight* degrees, I removed the fourth; and two degrees more brought me to a new scale, or side of the stem: by this means the instrument would accord with the variations arising from temperature, so far as at most to be but one degree different from it. It was adjusted at every tenth degree of temperature.

This was evidently a considerable progress towards the object I was in pursuit of, as it not only remedied the great defect of inattention to temperature which took place in the Irish hydrometer, but, in a great measure, the various defects of the English revenue hydrometer, as, notwithstanding the weights were reduced from 36 to 4, it accorded nearly with

* The name of the instrument, which in strictness should be areometer, (hydrometer being an instrument for weighing water), demonstrates this to be the principle on which it acts; therefore in France it is called *pesse liqueur*, and by some English writers, a water-poise.

the various temperatures, and indicated 66 gradations of strength. I perceived, therefore, that the principle would answer, but that it could be improved still further; and after various efforts I at length fixed on that construction, of which I shall now beg leave to give a description.

This new hydrometer is made of hard brass: the ball is shaped in the form of a pear, being nearly two inches in diameter at its greatest dimension, and two inches and a quarter in length: the lower stem measures one inch and a half, and is in shape a prism, each side measuring one-eighth of an inch: to the lower end of this a round weight is fixed, the diameter of which is seven-eighths of an inch. The upper stem is in length five inches and a half, and is an octagon, each side being somewhat less than an eighth of an inch wide: each of these sides is graduated for a temperature engraved on the top, the lowest being 35, the second 40, and so increasing by five until it reaches 70. The zero, or proof point, is marked $\odot$, and the gradations of strength (numbered at every fourth) amount to sixty-six, and those so clearly distinct, that at the over-proofs they will admit of a sub-division, and by that means indicate a half per cent. These divisions are not at equal distances; an error which takes place in the present Irish and several of the old hydrometers, but widens in proportion as the specific gravity of the spirit diminishes; and, being graduated with spirits of known strengths at every four per cent., the intermediate per centages are adjusted by interpolation.

To prevent any error which might arise from taking the indication of strength from the wrong side of the stem, an index is applied on the top of it, with an opening to show the figures which point out the temperature. This index, which applies *merely* to the purpose here mentioned, may be removed lower to any part of the stem, but above the surface of the liquor, without affecting the accuracy of the instrument, as neither its weight nor dimension is changed; and being of a different colour from the stem (stained steel) it forms a contrast with it, and, as it were, points to the indication sought for, by which every danger of error in this respect is removed.

Although this is the only use of the index, when the temperature shall be found one of those eight marked on the stem, yet it is necessary that the instrument shall accord with the four intermediate degrees between each of the adjoining sides: for this purpose one of two other indexes of different weights are occasionally substituted for the first one, in order to lighten the

the instrument so as to accord with the decrease of gravity which takes place in the spirit by the increase of temperature. Therefore the manner of using the instrument is as follows :

Supposing the temperature to be 50, nothing further is required but to place the index No. 1 (each being marked so as easily to be distinguished) on the side marked 50, and immerse the instrument, which at once shows the strength. Should the temperature be 51 or 52, instead of index No. 1, use that marked No. 2 : should it be 53 or 54, use index No. 3 : the instrument having been adjusted with these two auxiliary indexes, in the one case at a temperature of $51\frac{1}{2}$, and in the other $53\frac{1}{2}$, these four intermediate temperatures are so accorded to, as to be either the actual one, or within *half a degree* of it. And they apply in all cases, to the four intermediate degrees of temperature, and no other appendage required to enable the instrument, in this plain and simple manner, to measure sixty-six gradations of strength with an accuracy which, it is presumed, is fully sufficient for either revenue or commerce *. No weight requiring different immersions to find out that which is the proper one ; no temperature omitted to create doubts, or false indications of strength ; no fraction in the per centage to operate either against the revenue or the merchant ; no gradation of strength left unascertained or determined by conjecture ; no doubt remaining as to the correct strength of all the various gradations ; and no second inspection and subsequent combination to be made, requiring the aid of, and liable to the errors of, a sliding rule.

The following is a table for graduating hydrometers on a certain and invariable principle, showing from the specific gravity of the spirit at the temperature 55, what the hydrometer indication of strength should be of every possible mixture of pure spirit (or alcohol) and water, from the former down to proof spirit.—N. B. This table is calculated on the *supposition* that the standard of proof is 922, temperature 55.

* Even this half degree of temperature may be obtained by holding the jar containing the spirit for a few moments in the hand.

I. Spirit & water by weight.	II. Specific gra- vity at 55°	III. Spirit by measure	IV. Water by measure	V. Bulk of mixture	VI. Diminution of bulk, or con- centration.	VII. Quantity of pure spirit, per cent.	VIII. Pure spirit per cent. redundant.	IX. Water to re- duce redun- dant spirit to proof	X. Diminution of bulk on red. spirit & water	XI. Per Cent over Hydrometer proof.
Sp. + W.										
100 + 0	827,36	100		100,00		100,00	38,43	25,74	1,75	62,42
1	82967		0,83	100,72	0,11	99,29	37,72	25,26	1,72	61,26
2	83192		1,65	101,44	0,21	98,56	37,01	24,79	1,69	60,11
3	83412		2,48	102,16	0,32	97,86	36,31	24,32	1,65	58,98
4	83626		3,31	102,89	0,42	97,19	35,62	23,86	1,62	57,86
100 + 5	83834		4,93	103,62	0,51	96,50	34,93	23,39	1,59	56,73
6	84037		4,16	104,36	0,60	95,82	34,25	22,94	1,56	55,63
7	84235		5,79	105,10	0,69	95,15	33,58	22,49	1,53	54,54
8	84429		6,02	105,84	0,78	94,49	32,92	22,05	1,50	53,47
9	84618		7,44	106,58	0,86	93,83	32,26	21,61	1,47	52,40
100 + 10	84802		8,27	107,32	0,95	93,18	31,61	21,17	1,44	51,34
11	84982		9,10	108,07	1,03	92,54	30,97	20,74	1,41	50,30
12	85158		9,92	108,81	1,11	91,90	30,33	20,31	1,38	49,26
13	85330		10,75	109,56	1,19	91,27	29,70	19,89	1,35	48,26
14	85499		11,58	110,32	1,26	90,65	29,08	19,47	1,32	47,23
100 + 15	85664		12,41	111,07	1,34	90,03	28,46	19,06	1,30	46,22
16	85825		13,23	111,82	1,41	89,43	27,86	18,66	1,27	45,25
17	85984		14,06	112,58	1,48	88,83	27,26	18,26	1,24	44,28
18	86139		14,89	113,34	1,55	88,23	26,66	17,85	1,21	43,30
19	86292		15,71	114,09	1,62	87,64	26,07	17,46	1,19	42,34
100 + 20	86441		16,54	114,86	1,68	87,06	25,49	17,07	1,16	41,40
21	86588		17,37	115,62	1,75	86,49	24,92	16,69	1,13	40,48
22	86732		18,19	116,38	1,81	85,93	24,36	16,31	1,11	39,56
23	86874		19,02	117,14	1,88	85,37	23,80	15,94	1,08	38,66
24	87013		19,85	117,90	1,95	84,82	23,25	15,57	1,06	37,76
100 + 25	87150		20,68	118,67	2,01	84,27	22,70	15,20	1,03	36,87
26	87284		21,50	119,43	2,07	83,73	22,16	14,84	1,01	35,99
27	87415		22,33	120,20	2,13	83,19	21,62	14,48	1,08	35,12
28	87544	100	23,16	120,97	2,19	82,66	21,09	14,12	0,96	34,25
29	87671		23,98	121,74	2,24	82,14	20,57	13,77	0,93	33,41
100 + 30	87796		24,81	122,51	2,30	81,63	20,06	13,43	0,91	32,58
31	87919		25,64	123,28	2,36	81,12	19,55	13,09	0,89	31,75
32	88040		26,46	124,05	2,41	80,62	19,06	12,76	0,87	30,94
33	88160		27,29	124,82	2,47	80,12	18,55	12,42	0,84	30,13
34	88277		28,12	125,59	2,53	79,63	18,06	12,09	0,82	29,33
100 + 35	88393		28,95	126,36	2,59	79,14	17,57	11,77	0,80	28,54
36	88507		29,77	127,13	2,64	78,66	17,09	11,44	0,78	27,75
37	88619		30,60	127,90	2,70	78,18	16,61	11,12	0,76	26,97
38	88729		31,43	128,68	2,75	77,71	16,14	10,81	0,74	26,21
39	88838		32,25	129,45	2,80	77,25	15,68	10,50	0,71	25,47
100 + 40	88945		33,08	130,23	2,85	76,79	15,22	10,19	0,69	24,72
41	89051		33,91	131,00	2,91	76,33	14,76	9,88	0,67	23,97
42	89155		34,74	131,77	2,97	75,88	14,31	9,58	0,65	23,24
43	89258		35,56	132,55	3,01	75,44	13,88	9,29	0,63	22,54
44	89359		36,39	133,33	3,06	75,00	13,43	8,99	0,61	21,81

I. Spirit & water by weight.	II. Specific gra- vity at 55.	III. Spirit by measure.	IV. Water by measure.	V. Bulk of mixture.	VI. Diminution of bulk or con- centration.	VII. Quantity of pure spirit per cent.	VIII. Pure spirit per cent. redundant.	IX. Water to re- duce redund. spirit to proof.	X. Diminution of bulk on red. spirit & water	XI. Per cent. over Hydrometer proof.
Sp. + W.										
100 + 45	.89458		37,22	134,11	3,11	74,57	13,00	8,70	0,59	21,11
46	.89556		38,04	134,88	3,16	74,11	12,57	8,42	0,57	20,42
47	.89653		38,87	135,66	3,21	73,71	12,14	8,13	0,55	19,72
48	.89748		39,70	136,44	3,26	73,29	11,72	7,85	0,53	19,04
49	.89841		40,52	137,22	3,30	72,88	11,31	7,57	0,51	18,37
100 + 50	.89933		41,35	138,00	3,35	72,47	10,90	7,30	0,49	17,71
51	.90023		42,18	138,78	3,40	72,06	10,49	7,02	0,47	17,04
52	.90111		43,01	139,56	3,45	71,65	10,08	6,75	0,46	16,37
53	.90196		43,83	140,34	3,49	71,25	9,68	6,48	0,44	15,72
54	.90283		44,66	141,15	3,55	70,86	9,29	6,22	0,42	15,09
100 + 55	.90367	100	45,49	141,91	3,58	70,47	8,90	5,96	0,40	14,46
56	.90450		46,31	142,70	3,61	70,08	8,51	5,70	0,38	13,83
57	.90531		47,14	143,48	3,66	69,69	8,12	5,43	0,37	13,18
58	.90611		47,97	144,27	3,70	69,31	7,74	5,18	0,35	12,57
59	.90690		48,79	145,05	3,74	68,94	7,37	4,93	0,33	11,97
100 + 60	.90768		49,62	145,84	3,78	68,57	7,00	4,68	0,31	11,37
61	.90845		50,45	146,63	3,82	68,20	6,63	4,44	0,30	10,77
62	.90921		51,28	147,42	3,86	67,83	6,26	4,19	0,28	10,17
63	.90996		52,10	148,20	3,90	67,48	5,91	3,95	0,26	9,60
64	.91070		52,93	148,99	3,94	67,12	5,55	3,71	0,25	9,01
100 + 65	.91144		53,76	149,78	3,98	66,77	5,20	3,48	0,23	8,45
66	.91217		54,58	150,57	4,01	66,42	4,85	3,24	0,22	7,77
67	.91289		55,41	151,35	4,06	66,07	4,50	3,01	0,20	7,31
68	.91361		56,24	152,14	4,10	65,73	4,16	2,78	0,18	6,76
69	.91432		57,07	152,93	4,14	65,39	3,82	2,55	0,17	6,20
100 + 70	.91502		57,89	153,71	4,18	65,06	3,49	2,33	0,15	5,67
71	.91571		58,72	154,50	4,22	64,73	3,16	2,11	0,14	5,13
72	.91639		59,55	155,29	4,26	64,40	2,83	1,89	0,12	4,60
73	.91706		60,37	156,08	4,29	64,07	2,50	1,67	0,11	4,06
74	.91772		61,20	156,87	4,33	63,75	2,18	1,45	0,08	3,55
100 + 75	.91837		62,03	157,66	4,37	63,43	1,86	1,24	0,08	3,02
76	.91901		62,85	158,45	4,40	63,11	1,54	1,03	0,07	2,50
77	.91963		63,68	159,24	4,44	62,80	1,23	0,82	0,05	2,00
78	.92024		64,51	160,04	4,47	62,49	0,92	0,61	0,04	1,49
79	.92085		65,34	160,83	4,51	62,18	0,61	0,40	0,02	0,99
100 + 80	.92145		66,16	161,62	4,54	61,87	0,24	0,16	0,01	0,39
81	.92205		66,99	162,42	4,57	61,57	0,00	0,00	0,00	Proof

N. B. When this Table shall be finally calculated, the fractions in the second and last column are to be rendered into whole numbers.