XXXIV. *Defcription and Ufe of a portable Wind Gage.* *By Dr.* James Lind, *Phyfician, at* Edinburgh.

Redde, May 11, 1775.

THIS fimple inftrument confifts of two glafs tubes AB, CD, of five or fix inches in length (TAB. X. fig. 1.). Their bores, which are fo much the better always for being equal, are each about $\frac{4}{10}$ths of an inch in diameter. They are connected together, like a fiphon, by a fmall bent glafs tube *ab*, the bore of which is $\frac{1}{10}$th of an inch in diameter. On the upper end of the leg AB there is a tube of latten brafs, which is kneed or bent perpendicularly outwards, and has its mouth open towards F. On the other leg CD is a cover, with a round hole G in the upper part of it, $\frac{2}{10}$ths of an inch in diameter. This cover and the kneed tube are connected together by a flip of brafs *cd*, which not only gives ftrength to the whole inftrument, but alfo ferves to hold the fcale HI. The kneed tube and cover are fixed on with hard cement or fealing wax. To the fame tube is foldered a piece of brafs *e*, with a round hole in it, to receive the fteel fpindle KL, and at *f* there is juft fuch another piece of brafs foldered to the brafs hoop *gh*, which furrounds both legs of the inftrument. There is a fmall fhoulder on the fpindle at *f*, upon which the inftrument

 refts,

refts, and a fmall nut at *i*, to prevent it from being blown off the fpindle by the wind. The whole inftrument is eafily turned round upon the fpindle by the wind, fo as always to prefent the mouth of the kneed tube towards it. The end of the fpindle has a fcrew on it; by which it may be fcrewed into the top of a poft, or a ftand made on purpofe. It alfo has a hole at L, to admit a fmall lever for fcrewing it into wood with more readinefs and facility. A thin plate of brafs *k* is foldered to the kneed tube, about half an inch above the round hole G, fo as to prevent rain from falling into it. There is likewife a crooked tube AB (fig. 2.), to be put on occafionally upon the mouth of the kneed tube F, in order to prevent rain from being blown into the mouth of the wind-gage, when it is left out all night, or expofed in the time of rain. The force or *momentum* of the wind may be afcertained by the affiftance of this inftrument, by filling the tubes half-full of water, and pufhing the fcale a little up or down, till the o of the fcale, when the inftrument is held up perpendicularly, be on a line with the furface of the water, in both legs of the wind-gage. The inftrument being thus adjufted, hold it up perpendicularly, and turning the mouth of the kneed tube towards the wind, obferve how much the water is depreffed by it in the one leg, and how much it is raifed in the other. The fum of the two is the height of a column of water which the wind is capable of fuftaining at that time; and every body that is oppofed to that wind, will be preffed upon by a force equal to the weight of a column

lumn of water, having its baſe equal to the ſurface that is oppoſed, and its height equal to the altitude of the column of water ſuſtained by the wind in the wind-gage. Hence the force of the wind upon any body where the ſurface oppoſed to it is known, may be eaſily found; and a ready compariſon may be made betwixt the ſtrength of one gale of wind and that of another, by knowing the heights of the columns of water, which the different winds were capable of ſuſtaining. The heights of the columns in each leg will be equal, provided the legs are of equal bores; but unequal, if their bores are unequal. For ſuppoſe the legs equal, and the column of water the wind ſuſtains to be three inches, the water in the leg, which the wind blows into, will be depreſſed one inch and a half below o, and raiſed juſt as much above it in the other leg. But if the bore of the leg which the wind blows into, be double that of the other, the water in that leg will be depreſſed only one inch, whilſt it is raiſed twice as much, or two inches, in the other; and *vice verſâ*, if the ſame wind blow into the ſmaller leg it will depreſs the water in it two inches, whilſt it raiſes it only one inch in the other. The force of the wind may be likewiſe meaſured with this inſtrument, by filling it until the water runs out at the hole G. For if we then hold it up to the wind as before, a quantity of water will be blown out; and, if both legs of the inſtrument are of the ſame bore, the height of the column ſuſtained, will be equal to double the column of water in either leg, or the ſum of what is wanting in both legs

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But if the legs are of unequal bores, neither of theſe will give the true height of the column of water which the wind ſuſtained. But the true height may be obtained by the following *formulæ*.

Suppoſe that after a gale of wind, which had blown the water in one of the tubes from A to B (fig. 3.), forcing it at the ſame time through the other tube out at E, the ſurface of the water ſhould be found ſtanding at ſome level DG, and it were required to know what was the height of the column EF or AB, which the wind ſuſtained. In order to obtain which, it is only neceſſary to find the height of the columns DB or GF, which are conſtantly equal to each other: for either of theſe added to one of the equal columns AD, EG, will give the true height of the column of water which the wind ſuſtained.

CASE I.

Let the diameters AC, EH, of the tubes be reſpectively repreſented by c, d; and let a=AD or EG, and x=DB or GF. Then it is evident, that the column DB is to the column EG as c^2x to d^2a. But theſe columns are equal. Therefore, $c^2x=d^2a$; and conſequently, $x=\frac{d^2a}{c^2}$.

EXAMPLE.

If the diameters AC, EH, be reſpectively 10 and 1, and AD or EG=3,96 inches, x will be=,0396 of an inch. For $d^2a=1\times 3,96=3,96$, which divided by $c^2=100$, gives x=,0396.

CASE II.

But if at any inſtant of time, whilſt the wind was blowing, it was obſerved, that when the water ſtood at E, the top of the tube out of which it is forced, it was depreſſed in the other tube to ſome given level BF, the altitude at which it would have ſtood in each, had it immediately ſubſided, may be found in the following manner:

Let b=AB or EF. Then it is evident, that the column DB is equal to the difference of the columns EF, GF. But the difference of theſe columns is as d^2b-d^2x. Therefore $c^2x=d^2b-d^2x$; and conſequently, $x=\frac{d^2b}{c^2+d^2}$.

For the caſes when the wind blows in at the narrow leg of the inſtrument.

Let AB=EF=b, EG or AD=a, GF=DB=x, and the diameters EH, CA, reſpectively $=d$, c, as before. Then it is evident, that the column AD is to the column GF as ac^2 to d^2x. But theſe columns are equal. Therefore, $d^2x=ac^2$; and conſequently, $x=\frac{ac^2}{d^2}$. This anſwers to CASE I.

It is alſo evident, that the column AD is equal to the difference of the columns AB, DB. But the difference of theſe columns is as bc^2-c^2x. Therefore, $d^2x=bc^2-c^2x$. Whence we get $x=\frac{bc^2}{d^2+c^2}$. This correſponds to CASE II.

As there is always a calculation to be made for every experiment when the legs of the inſtrument are of unequal bores, I would recommend it to the makers of theſe inſtruments, to make uſe of tubes that are equal, or at leaſt nearly ſo, that the error may become next to nothing, it being a thing very eaſy to be done. In this manner we can readily determine the greateſt force, which the wind has blown with, during the time the inſtrument has been expoſed to its action. But as it may be ſafely left alone, by ſcrewing its ſpindle into the proper ſtand, or into the top of a poſt, and as the wind never fails to turn the mouth of it towards itſelf, it is not neceſſary for the obſerver to continue always by it; for it may be allowed to ſtand all night, expoſed to the wind, without any inconvenience, though it ſhould even happen to rain very heavily. However, recourſe can only be had to this method of uſing the inſtrument on ſhore: for at ſea it muſt always be held up in a perpendicular poſition in the hand, whether it be uſed when only half full of water, or when quite full; which laſt will be frequently found to be the only practicable method of aſcertaining the force of the wind during the night, when it blows ſo hard that it is impoſſible to keep any lights on deck. A perſon filling the wind-gage, in a calm place, with water, in order to determine the force of the wind, in the way which I have been juſt now deſcribing, will be apt to imagine, that it cannot give the meaſurement correct; for he will find ſuch a repulſion to ariſe from the edges of the hole G, as to ſuſtain a column of water in the kneed or bent tube, perhaps half an inch above the level;

level: but by either blowing acroſs the round hole, or moving his finger over it, he will ſoon bring the water in the kneed tube to ſtand at the ſame level with it, by taking off gradually the convex ſuface of the water, which projects out at the hole in the form of a drop or *ſpherule*. And this effect the wind very ſoon produces itſelf. There ought always to be a cover on the top of the tube out of which the water is expelled by the wind; but it ſhould be made very thin. For if there be no ſuch cover, and the mouth of the kneed tube be ſtopped, after the inſtrument is quite full of water, in order to prevent the wind from having any influence in raiſing it, you will find, upon expoſing it to a ſtrong gale, that in a very ſhort time it will blow out perhaps half an inch of water. Whence it appears, that a very conſiderable error would ariſe from uſing the wind-gage in this ſtate. But in all the experiments which I have made with this inſtrument, whilſt it had the cover and the round hole of $\frac{2}{10}$ths of an inch in diameter in the middle of it, I have not been able to diſcover any error. The uſe of the ſmall tube of communication *ab* (fig. 1.) is to check the undulation of the water, ſo that the height of it may be read off from the ſcale with eaſe and certainty. But it is particularly deſigned, to prevent the water from being thrown up to a much greater or leſs altitude, than the true height of the column, which the wind is able at that time to ſuſtain, from its receiving a ſudden impulſe, whilſt it is vibrating either in its aſcent or deſcent. For water in the legs of a ſiphon is capable of being put

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into a vibrating motion like a pendulum (a); and therefore, if acted upon when in the aſcent, the height which it aſcends to will come out greater than the truth; and leſs, if acted on in the deſcent.

The height of the column of water ſuſtained in the wind-gage being given, the force of the wind upon a foot ſquare is eaſily had by the following table, and conſequently on any known ſurface.

TABLE I.

Height of the water in the wind-gage.	Force of the wind on the foot ſquare in avoirdupois pounds.	Common deſignation of ſuch a wind.
12 inches	62,5	
11	57,293	
10	52,083	moſt violent hurricane.
9	46,875	moſt violent hurricane.
8	41,667	very great ditto.
7	36,548	great hurricane.
6	31,75	hurricane.
5	26,041	very great ſtorm.
4	20,833	great ditto.
3	15,625	ſtorm.
2	10,416	very high wind.
1	5,208	high wind.
$0\frac{1}{2}$	2,604	briſk gale.
$0\frac{1}{10}$	,521	freſh breeze.
$0\frac{1}{20}$	,260	pleaſant wind.
$0\frac{1}{40}$	,130	a gentle wind.

(a) NEWTONI Princip. Mathemat. lib. II. prop. XLIV. theor. XXXV.

EXAMPLE.

EXAMPLE.

If it were required to know the force of the wind, when the column of water ſuſtained was equal to $4\frac{6}{10}$ inches. Then, by TAB. I.

	Pounds.
4 inches =	20,833
0,5 or $\frac{1}{2}$ inch =	2,604
0,1 =	0,521
Sum 4,6 =	23,958 = force on every ſquare foot.

Any change that can happen in the ſpecific gravity of the water from heat or cold, will make no ſenſible alteration on experiments made with this inſtrument.

A cubic foot of water is generally ſuppoſed to weigh 1000 Avoirdupois ounces; and from ſome experiments made by Mr. MUSSCHENBROEK it would appear, that betwixt freezing and boiling, or in 180° on FAHRENHEIT'S ſcale, it increaſes only $\frac{1}{85}$ = ,0117 of its whole bulk, or volume (b). I cannot, however, find any author that mentions at what preciſe degree of heat a cubic foot of water was weighed. Mr. FAHRENHEIT indeed made ſeveral of his curious experiments on the ſpecific gravities of bodies when the water raiſed his thermometer to 48° (c). Now if we ſuppoſe the greateſt heat of the water which

(b) MUSSCHEN. Introd. ad Philoſ. Natur. tom. II. p. 625.

(c) Philoſophical Tranſactions, N° 383.

we make uſe of in the wind-gage to be 90°, which exceeds 48° by 42, the greateſt change produced will be only ,0027 or $\frac{27}{10000}$ parts of the whole. So that if the altitude of the column of water ſuſtained by the wind were even to be five inches, the part of this effect, ariſing from the diminution of the ſpecific gravity of the water, occaſioned by the greateſt heat, will only amount to 0,0135, or $\frac{135}{10000}$ parts of an inch, a change which cannot be meaſured by the inſtrument. It may be ſometimes neceſſary to employ other fluids beſides water, particularly if the degree of cold be below freezing: for then we muſt uſe a fluid that will not freeze in the degree of cold in which we expoſe the inſtrument, otherwiſe the wind can have no influence on it, and the liquor freezing in the tube will break it. I ſhall, therefore, mention a few liquors in the following table that will anſwer the purpoſe, as alſo ſubjoin a general method of reducing them all to one common meaſure. But of all the fluids I am acquainted with, when the effects of froſt are to be feared, I know none better adapted to our purpoſe than a ſaturated ſolution of ſea-ſalt; ſince it does not freeze till the thermometer falls to 0 degrees, and is a fluid conſtantly of the ſame ſpecific gravity. Spirit of wine, independent of its being more variable in reſpect of ſpecific gravity by the influence of heat and cold, is alſo more or leſs ſo, as it is more or leſs rectified. And although the true ſpecific gravity were known at the beginning of the operation, it would even change during the time of uſing it, by imbibing moiſture from the air.

Let w reprefent the weight of a column of water, having its altitude meafured by one of the divifions on the fcale, and its bafe to any given furface whatever; and let n denote in general the number of thefe divifions which meafures the whole length of the column of the water which the wind fuftains. Then nw will reprefent always its weight, and will ferve as a common multiplier for the fpecific gravities of all other liquors.

TABLE II.

Names of liquors.	Specific gravities.	Common multiplier.	Weight meafuring the forces of the wind.
Water,	1,000	nw	nw
Sat fol. of falt,	1,244	nw	$1{,}244 \times nw$
Urine,	1,030	nw	$1{,}030 \times nw$
Ditto,	1,016	nw	$1{,}016 \times nw$
Alkohol,	0,825	nw	$0{,}825 \times nw$
Proof fpirits,	0,927	nw	$0{,}927 \times nw$
&c.	&c.		&c. &c.

EXAMPLE.

Let w reprefent the weight of a column of water $\frac{1}{20}$th of an inch high, ftanding on a fquare foot; and let $n=80=4$ inches. Then (by TAB. I.) nw is equal to 20,833 Avoirdupois pounds. Therefore $1{,}244 \times 20{,}833$ =weight of a faturated folution of fea falt of the fame altitude, and $\frac{4}{1{,}244}$ = the altitude of a column of a faturated folution of the fame, weighing 20,833 pounds Avoirdupois;

dupois. *w* may repreſent a ſquare yard, the ſurface of a ſail, &c.

If the velocity and denſity of the wind in any particular caſe were accurately determined, this inſtrument, which gives its force or *momentum*, would enable us to aſcertain the velocity in every other caſe, the denſity being known. For it appears from experiments, made by Mr. JAMES FERGUSON, F. R. S. on the whirling-table, that its force is as the ſquare of its velocity. But as the denſity, which is one of the *data* requiſite for determining the velocity by this inſtrument, was not taken into conſideration in theſe experiments, all that we can do at preſent is to ſuggeſt the idea.

It may not, perhaps, be improper to take notice, that evaporation will have ſome effect in diminiſhing the altitude of the column of water; though its influence, for the moſt part, will be very inconſiderable. The more frequently, therefore, the inſtrument is examined, it will be ſo much the better. If it be expoſed to the action of the wind, whilſt it happens to ſnow, it will be neceſſary to look at it frequently, leaſt the ſnow ſhould choak up the mouth of the wind-gage.

Extract of a letter from Dr. LIND to Col. ROY. Dated Edinburgh, May 26, 1775.

The wind-gage ought to be ſomewhat longer than that I lately ſent Sir JOHN PRINGLE. For we had a gale here on the 9th current, which ſupported a column of water of of $6\frac{7}{10}$ inches, whereas that I ſent was not ſo long. The force of this gale on a ſquare foot was equal to 34,921 pounds Avoirdupois, and it has done great damage to our gardens. Weſt India hurricanes would require gages of a ſtill greater length to meaſure them.

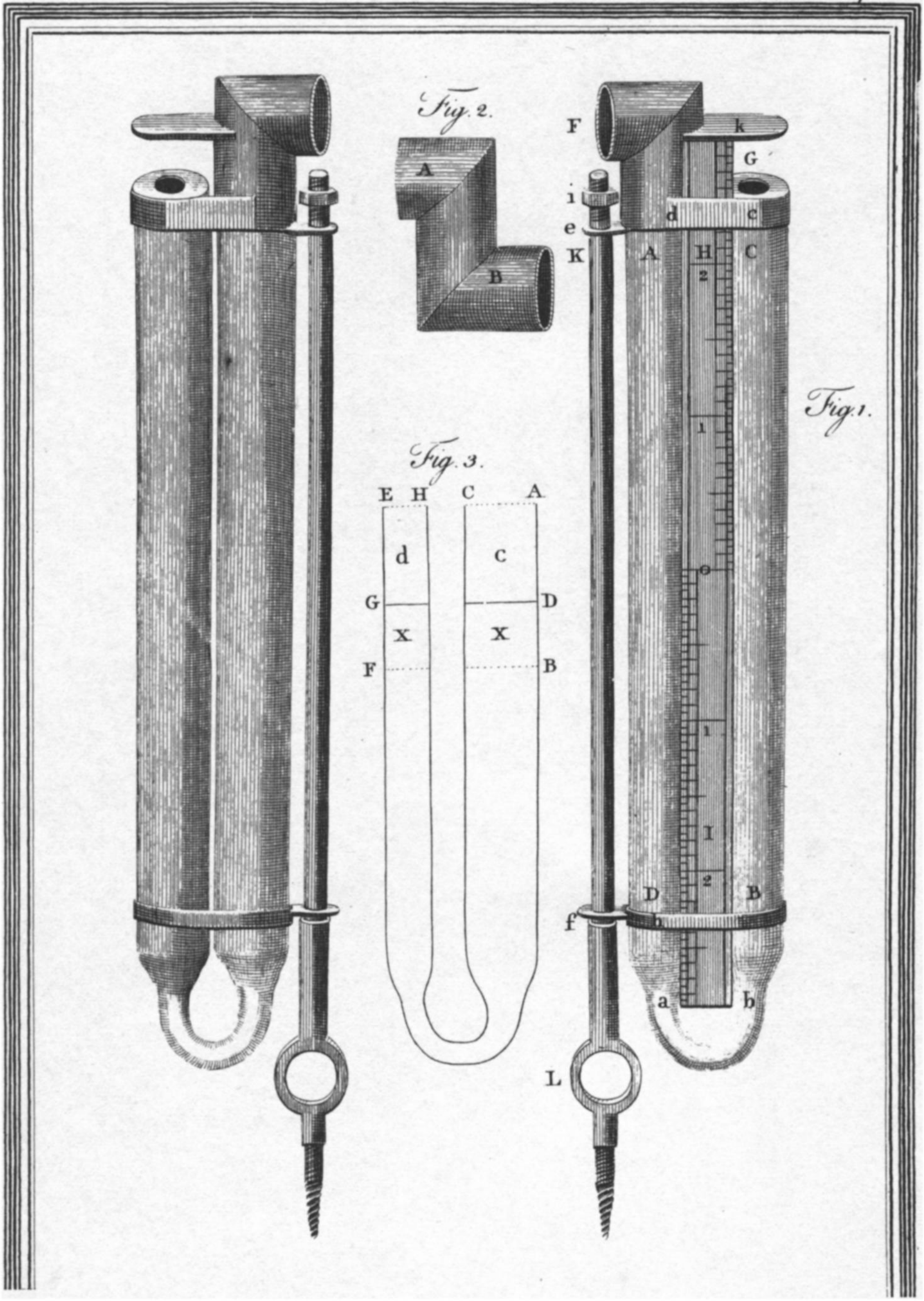
Fig. 2.
A
B
Fig. 3.
E H C A
d c
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X X
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Fig. 1.
F
k
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K A H C
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