XXVI. *Of the Degrees and Quantities of Winds requiſite to move the heavier Kinds of Wind Machines. In a Letter from* John Stedman, *M. D. Fellow of the Royal College of Phyſicians at Edinburgh, to the Reverend* Samuel Horſley, *LL.D. Secretary to the Royal Society.*

SIR, Edinburgh, March 27, 1777.

Read Apr. 24, 1776.

THE irregularity and uncertainty of winds in this country have been found a conſiderable diſcouragement to erect wind machines. It hath frequently happened, that the proprietors of coal and other works, after having reared theſe kinds of engines, and having found them inſufficient for the intended work, have been obliged to open mines, or to erect fire machines. This is chiefly owing to the undertakers reckoning upon more winds of a ſufficient power to move theſe machines, than we commonly have in this country.

Theſe machines are rarely erected with us, unleſs where a conſiderable moving power is neceſſary. This is always the caſe where the larger kind of pump-work is to be kept in motion, or where water is to be extracted from

from deep pits. Having enquired of many people concerned in ſuch works, what may be the proportion of time in which wind machines may be kept in motion, to that in which they cannot move from a defect of wind, I found theſe people differing widely in their conjectures.

Having, however, met with one gentleman of obſervation and accuracy, who had erected a wind machine for draining his coal; he told me that, by the beſt computation he had been able to make, he never could depend upon more than fifty-three or fifty-four hours of wind ſufficient for moving that machine, in a week, taking the year round. This is below what is commonly believed to be the proportion; but, ſo far as this can be rated by an eſtimate in the following manner, it will be found to be much about what may be depended upon for the heavieſt kinds of machines; ſtill making allowance for the differences of expoſures, and for the ſtrength and frequency of winds in one part of the country more than in another. We may here take notice of a circumſtance favourable to the draining of coal-pits; that is, that the periods of the year in which the greateſt quantities of rain fall, are likewiſe obſerved to abound with winds of the higher degrees. This ſeldom fails to hold in hilly countries, and particularly in thoſe of high latitudes; that is, where the differences of heats in ſummer

and of colds in winter are very conſiderable. The periods of the year here meant will generally be found to fall near the Equinoxes.

The only method of bringing the matter to a proper eſtimate is, by comparing the quantities of winds ſufficient for moving theſe machines, with thoſe of winds below that degree, and calms. This computation can only be drawn from journals in which the degrees of winds are noted. In the meteorological regiſter of the Medical Eſſays of the Edinburgh Society, there is a column of winds, and four degrees are noted. This diviſion is ſufficient for the purpoſes for which that regiſter was intended; but, when we conſider the wind as a power acting upon machines, that number of degrees will be found too ſmall.

Thus, from the ſecond in that regiſter to a hurricane, there is but one intermediate degree. As the ſecond degree, which is very moderate, is inſufficient for moving theſe machines; the third is more than juſt enough for that purpoſe. A degree, therefore, which is a mean betwixt theſe two, will be found to be the loweſt that is ſufficient for moving machines of the heavier kinds, particularly ſuch as are uſed for pumping water out of coal-pits.

Theſe

Theſe three degrees of wind, that is the ſecond and third of the Edinburgh regiſter, and an intermediate degree, are very diſtinguiſhable even by the ſenſes, and without the aſſiſtance of any inſtrument, by thoſe who are attentive and have been accuſtomed to make obſervations of this nature.

To aſcertain proportions of this nature, a longer term of years would have been more ſatisfactory; but, in caſe others ſhould afterwards purſue this kind of computation, the proportions are digeſted in two tables at the end of this eſſay, and may be conſulted occaſionally.

In making up theſe tables, *viz.* one of the ſecond degree and above, and the other of the third and upwards, hurricanes are included, though that degree of wind be too high for any machine. But, as the obſervations were taken twice in twenty-four hours, and as winds ſufficient to move theſe machines may be ſuppoſed to have happened ſometimes between the times of obſervation, though at theſe times the wind might have been below the mean; to compenſate this defect, hurricanes are included in the computation.

From theſe tables then we have the following proportions of the two degrees of winds and upwards, to thoſe below; and likewiſe of the mean betwixt thoſe two degrees.

Winds

	Days.
Winds of the ſecond degree and upwards in each week, — —	4.283
Calms and winds below the ſecond degree,	2.717
Winds of the third degree and upwards,	0.902
Calms and winds below the third degree,	6.098
Winds of a mean proportion between the two preceding degrees, — —	2.592
Calms and winds below the mean degree,	4.408

The proportion of theſe winds in the year comes out in weeks and fractional parts thus:

	Weeks.
Winds of the ſecond degree and upwards in the year, — — —	31.903
Calms and winds below the ſecond degree,	20.239
Winds of the third degree and upwards,	6.719
Calms and winds below the third degree,	45.423
Winds of a mean proportion between the two preceding, — — —	19.307
Calms and winds below the mean, —	32.835

From this computation we have 2.592 days in a week, or 19,307 weeks in a year, in which wind machines of

the heavier kinds, and of conſiderable friction, may be ſuppoſed to be kept in motion; which, to the times wherein they cannot go, is as 10 to 17.

It may be obſerved, that the reſiſtance to the machine, or its weight and friction, being diminiſhed, though in a ſmall degree, will add conſiderably to the frequency and length of times in which it can go; ſince it often happens that there are winds immediately below the loweſt degree in the preceding eſtimate, ſufficient to keep the lighter machines in motion. Hence thoſe who have machines which are not abſolutely of the heavieſt kind, will be apt to conclude this computation erroneous. Beſides, there are few who make allowance for, or attend to, the univerſal law which obtains in mechanics, that in larger machines, their power doth not increaſe in a proportion ſo high as their bulk and the reſiſtance ariſing from their friction.

Computations of this nature, if carried on for a ſufficient length of time, might be of ſome uſe in regulating inſurances, or in pointing out the riſks of nautical adventurers, when made in the ſame climates with the calculation of winds.

Here I ſhould have concluded; but having, after writing what is above, committed theſe tables and obſervations to the examination of a learned member of your Society,

ciety, much converſant in theſe matters, I had the ſatiſfaction to find that he thought them worthy to be communicated to the Royal Society; but remarked, that the materials, which I had proceeded upon, were not ſo applicable to the purpoſe as could have been wiſhed. He thinks, that the degrees of winds, being only diſtinguiſhed into four in the journals from whence thoſe tables have been compiled, are much too few to take in thoſe of the weaker kind, that will however turn well-conſtructed wind-mills. Indeed I regretted that the table from which I made my eſtimate contained ſo few degrees; but it was for that reaſon I calculated an intermediate degree between the ſecond and the third of our meteorological regiſter. Now as all the degrees above that intermediate degree are ſufficient to move the heavieſt machine, and the degrees below it inſufficient for that purpoſe, ſo far as I have been able to obſerve, it comes to be the ſame as if the table, from which I made the eſtimate, had conſiſted of eight degrees, ſuppoſing a mean proportion to be found between the other degrees: thus, 0, $\frac{1}{2}$, 1, $1\frac{1}{2}$, 2, $2\frac{1}{2}$, &c. this laſt number $2\frac{1}{2}$, being the loweſt degree which I find ſufficient for the heavieſt machines, would have been 5, had theſe fractional parts been integers in the table, ſo that the higheſt degree, inſtead of 4 would have been 8. The mean, therefore,

between 2 and 3 being found, will, if I miſtake not, anſwer the preceding objection.

This worthy member, at the end of his obſervations, ſays, a mill ſo conſtructed may be expected to go the half of the year; that is, I preſume, a wind-mill conſtructed in the neateſt and moſt ingenious manner. But this, I have reaſon to believe, is far from being the caſe with wind-mills in this country, they being for the moſt part clumſy. I doubt not but wind-mills, the conſtruction of which this ingenious gentleman hath directed, though of the ſame ſize and conſiſting of the ſame numbers with thoſe I have ſeen here, will nevertheleſs be moved by a lower degree of wind, and conſequently will go a greater proportion of time, though they have the ſame reſiſtance to overcome as others leſs artificially conſtructed. Indeed the ſame wind machine, as is well known, will require a degree of wind conſiderably higher when its joints are dry or become gummy, than when they are ſufficiently greaſed. In my eſtimate I have all along had an eye to the wind machines which have the greateſt reſiſtance to overcome, and conſequently the machines themſelves of the largeſt kind. But when the learned gentleman ſuppoſes a machine to go one half of the year, he may perhaps not underſtand one abſolutely of the

the largeſt kind. Now as the powers of ſimilar machines, but of different magnitudes, are as their cubes, but the reſiſtance ariſing from their weight and friction as the fourth power; it follows, that a ſmall difference in the ſize of two or more wind machines will require conſiderable differences in the winds neceſſary for their movements.

I am, &c.

TABLE

TABLE I.

Shewing the Proportion of winds of the ſecond degree and upwards, to thoſe of the firſt and below, for five years.

	Proportion of winds of the 2d degree to thoſe of the firſt, &c. in 1731 and 1732.		Proportion, &c. in 1732 and 1733.		Proportion, &c. in 1733 and 1734.		Proportion, &c. in 1734 and 1735.		Proportion, &c. in 1735 and 1736.		Sum of each month for five years.	
	Winds.	Calms, &c.	Winds.	Calms, &c.	Winds.	Calms, &c.	Winds.	Calms, &c.	Winds.	Calms, &c.	Winds.	Calms, &c.
June	16	44	46	14	26	34	24	36	41	19	153	147
July	7	55	44	18	39	23	29	33	43	19	162	148
Auguſt	8	54	27	35	20	42	28	34	47	15	130	180
September	30	30	24	36	40	20	34	26	34	26	162	138
October	26	36	13	49	36	26	31	31	35	27	141	169
November	39	21	18	42	51	9	16	44	33	25	157	141
December	43	19	29	33	38	24	46	16	41	21	197	113
January	55	7	43	19	35	27	58	4	45	17	236	74
February	45	13	46	10	48	8	47	9	42	16	228	56
March	39	23	50	12	40	22	53	9	46	16	228	82
April	44	16	34	26	42	18	46	14	46	14	212	88
May	54	8	28	34	36	26	55	7	57	5	230	80
Sum of years and months,	406	326	402	328	451	279	467	263	510	220	2236	1416

TABLE II.

Shewing the proportion of winds of the third degree and upwards, to thoſe of the ſecond and below, for five years.

	Proportion, of winds of the 3d degree to thoſe of the firſt, &c. in 1731 and 1732.		Proportion, &c. in 1732 and 1733.		Proportion, &c. in 1733 and 1734.		Proportion, &c. in 1734 and 1735.		Proportion, &c. in 1735 and 1736.		Sum of each month for five years.	
	Winds.	Calms, &c.	Winds.	Calms, &c.	Winds.	Calms, &c.	Winds.	Calms, &c.	Winds.	Calms, &c.	Winds.	Calms, &c.
June	1	59	–	60	3	57	2	58	1	59	7	233
July	1	61	7	55	11	51	5	57	1	61	25	285
Auguſt	–	62	–	62	8	54	3	59	–	62	48	252
September	13	47	9	51	10	50	8	52	8	52	11	299
October	9	53	1	61	12	50	11	51	2	60	35	275
November	11	49	8	52	19	41	2	58	6	54	46	254
December	17	45	4	58	12	50	9	53	4	58	46	264
January	5	57	11	51	9	53	18	44	6	56	49	261
February	24	34	20	36	24	32	12	44	7	51	87	197
March	12	50	10	52	18	44	6	56	5	57	51	259
April	9	51	5	55	9	51	8	52	5	55	36	264
May	7	55	–	62	9	53	10	52	4	58	30	280
Sum of years and months,	109	623	75	655	144	586	94	636	49	683	471	3183

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