XVIII. *On the measurement of Snowdon, by the Thermometrical Barometer.* *By the Rev.* F. J. H. Wollaston, *B.D. F.R.S.*

Read June 29, 1820.

The Royal Society did me the honour to notice in their Transactions, 1817, p. 183, the description of a Thermometrical Barometer, by which it was conceived that accessible heights might with convenience be measured; and may therefore not be uninterested by the account of an actual measurement made with it. Having occasion last summer to visit Carnarvon, which would afford an opportunity of trying the instrument on the known height of Snowdon, and being aware that in 3550 feet the variations of the boiling temperature were not to be considered uniform, as they might in small elevations, on which alone I had before tried the experiment, I wished to provide myself previously with a table for making the necessary corrections; and from Dr. Ure's paper, Philosophical Transactions, 1818, p. 338, was supplied with data for the calculation. The law, which he discovers by approximation and lays down, is this: that, the elastic force of the air, or length of the column of mercury in the barometer being supposed 30 inches when water boils at 212° of Fahrenheit, $\frac{30}{1,23}$ will be the length of the column at 202°; $\frac{30}{1,23 \times 1,24}$ the length at 192°; and so on progressively, adding another increased divisor for every 10° of thermometrical temperature.

For my purpose it was necessary to calculate the variations at smaller intervals than ten degrees, and particularly to obtain those between 212° and 202°, by getting a series of

divisors for each degree, instead of the simple divisor of 1,23 for the whole. By taking the tenth of the logarithm of 1,23, the uniform divisor appears to be 1,021; but to make the successive divisors increase at the lower temperatures, as Dr. URE does, suppose them to be taken thus;

1,02059
1,02068
1,02077
1,02086
1,02095
1,02105
1,02114
1,02123
1,02132
1,02141
10,21000

The mean of which is 1.021.

The logarithms of these divisors, if their differences be equalized by a small change in the last figure, will stand thus:

88501
88892
89282
89673
90063
90454
90844
91234
91625
92105

the sum of these logarithms being 0,902583, the logarithm of 1,23 nearly.

By the use of these logarithms, the series of barometrical heights corresponding with each degree of Fahrenheit, calculated from 30 inches at 212°, downward to 202°, and carried upward to 214°, will be found in the following Table I. in the fifth column of which the difference of the logarithms of the barometric column, which corresponds by a known law with the number of fathoms of elevation, is multiplied by 6, to give the feet of elevation which produces the successive depression of the boiling point one degree of Fahrenheit; and the 6th column gives the total elevation, reckoning from the station where water boils at 212°, to any other station where the boiling temperature is at any degree between 202° and 214°. For the differences between each degree, the elevations may be taken with sufficient accuracy by simple proportion.

Table I.

1	2	3	4	5	6
Heat of boiling water.	Correspondent height of barometer.	Logarithm of height of barometer.	Difference of the Logarithms.	Difference of Logarithm multiplied by six equal feet.	Total feet from 212 degrees.
214	31,2395	4947044	87720	526,320	1054,986
213	30,6149	4859324	88111	528,666	528,666
212	30,0000	4771213	88501	531,006	0
211	29,3948	4682712	88892	533,352	531,006
210	28,7993	4593820	89282	535,692	1064,358
209	28,2133	4504538	89673	538,038	1600,050
208	27,6367	4414865	90063	540,378	2138,088
207	27,0695	4324802	90454	542,724	2678,466
206	26,5115	4234348	90844	545,064	3221,190
205	25,9627	4143504	91234	547,404	3766,254
204	25,4230	4052270	91625	549,750	4313,658
203	24,8923	3960645	92015	552,090	4863,408
202	24,3704	3868630			5415,498

In the application of this table to use, it must be adapted to the scale of the particular thermometrical barometer employed. In my former paper, I observed that a change of 1° Fahrenheit appeared to be produced by 0,589 of the common barometer. This was deduced from the comparison of my long thermometer of 3,98 inches to every degree with a common barometer. But having subsequently compared the same thermometer with a mountain barometer by TROUGHTON, where I could ascertain the adjustment for the height of the mercury in the basin, I found that at a mean of 29,5 inches, 0,603 of barometer corrected was equal to 1° of Fahrenheit. This conclusion agrees very closely with the table deduced from Dr. URE's observations, in which between 211° and 212°, the difference of the mercurial column is 0,605 nearly at the mean height of 29,7, and would be rather less at 29,5. On the scale of the instrument which I have now in use, the half inch is divided into ten parts, and by the Vernier into a hundred; the inch, therefore, into two hundred; and I find by observation, that 1,000 of the corrected barometer equals 372 parts on the scale of the thermometrical barometer, or 1,86 inch; consequently, 0,605 barometer or 1° Fahrenheit, = 225 parts on the scale, or $1\frac{1}{8}$ inch, which is a sensibility entirely sufficient. And those 225 parts being supposed, according to Table I, = 531 feet between 211° and 212°, 100 parts will equal 236 feet at that part of the scale. Between 202° and 203°, 225 parts = 552 feet, and, consequently, 100 parts = 246 feet nearly; and so of every other point; and the following table of heights, corresponding with the scale of my instrument, will be found in the nearest whole numbers.

TABLE II. *For converting observed differences on the Scale of the particular Thermometrical Barometer into feet of elevation.*

Fahrenheit.	Parts on the Scale of the Thermometrical Barometer.	Height in feet.	Correspondent point of Barometer nearly.
	300	702	30,8
213	225	528	,6
	200	469	,54
	100	235	,27
212	0	0	30,0
	100	236	29,73
	200	472	,46
211	225	531	,4
	300	709	29,2
	400	946	28,92
210	450	1064	,8
	500	1184	,65
	600	1422	,4
209	675	1600	,2
	700	1660	28,1
	800	1899	27,85
208	900	2138	
	1000	2378	
	1100	2618	
207	1125	2678	
	1200	2859	
	1300	3100	
206	1350	3221	
	1400	3341	
	1500	3583	
205	1575	3766	
	1600	3826	
	1700	4069	
204	1800	4313	
	1900	4556	
	2000	4800	
203	2025	4863	
	2100	5045	
	2200	5290	
202	2250	5415	24,37

A simple proportion applies this Table to the use of any other thermometrical barometer of greater or less sensibility.

As the instrument I was about to employ had a scale of only four inches, or 800 parts, and could therefore scarcely

measure at its utmost limits 1900 feet, it was necessary, on a height of 3550 feet, to divide the whole measurement into two, or, for greater security, into three lengths, and it became therefore a fair trial of the practical use of the instrument in every respect.

On the 24th of August, having occasion to ride from Carnarvon to Gregory's New Inn, near Llanberis Lake, at the foot of Snowdon, for the purpose of securing accommodations for my party, I took the instrument in my pocket, having previously boiled it on the ground floor of the Vicarage house at Carnarvon, where it stood at 517,5, thermometer 66°, barometer 30,0. In the parlour at Gregory's it stood at 401, thermometer 66°, barometer not changed during my absence; difference at the two stations 116,5.

100 : 116.5 :: 236 : 275 feet, the approximate height:

add the correction 0,089 × 275 from General Roy's table following $\left\{\begin{array}{r} 24.5 \\ \hline 299,5 \end{array}\right.$ feet, the corrected height of Gregory's above the Vicarage.

The descent from the Vicarage to the north end of Carnarvon quay, was taken by levelling, and found 11,25 feet.

August 27. The instrument had been set at Gregory's at 768, before the party began to ascend the hill; but when we came to the place where the guide supposed we had ascended half way, it stood at about 300, showing that we had not gone far enough to take the whole in two lengths of the scale; and we therefore proceeded farther, to a point opposite a pass in the ridge of Snowdon, called Bwlch Cymbrwnog, by which the hill is ascended from Nant. In carrying the instrument incautiously from the former point while

cooling, the mercury was drawn into the tube from the cap at the top, and the previous measure from Gregory's was therefore lost. I mention this, to show how the measure was afterwards recovered on descending.

At this point which I call H, the half height, the thermometrical barometer was set at 792, in the manner directed in my former paper; thermometer 62°. When boiled again on the summit it stood at 86, thermometer 66°. On descending again to H, it boiled at 785, thermometer 63°. From this point, my measurement to Gregory's downward, was to be made for recovering the accidental loss in the ascent; and for that purpose an operation was to be performed on the instrument, by no means so easy as that for taking a succeeding stage upward; for the mercury must in this case be expanded out of the tube into the cap over the flame of the lamp, until on boiling, it stands as near as may be requisite to the bottom of the scale. This was done at H, and the water boiled at 146, thermometer 63°. On carrying it down to the Inn it stood at 695, thermometer 65°. The barometer observed at Carnarvon about the time of boiling at H, on ascending, was at 29,91; and at the time of boiling there the second time, it stood at 29,88, where I found it on my return to Carnarvon.

Between Gregory's and H, the difference $695 - 146 = 549$, mean thermometer 64°, barometer 29,9. Between H and the summit, the difference (from the mean of the two observations at H $\frac{792+785}{2} =$) $788{,}5 - 86 = 702{,}5$, mean thermometer 64°. The mean thermometer being the same in both lengths, they may be calculated together, the total being $549 + 702{,}5 = 1251{,}5$, thermometer 64°. The barometer

being at 29,9, I begin from the corresponding point on Table II, and take out

1250 parts between 50 and 1300 = 1300 — 118 = 2982		
1,5 - - - - - - =	3,5	
1251,5 parts, giving the approximate height -	2985,5	feet.
to this add the correction from Table III, 0,0837 × 2985,5 =	250,0	
the corrected height from Gregory's to the summit	3235,5	feet.
from Vicarage to Gregory's - - -	299,5	
from Quay to Vicarage - - -	11,25	
Total from north end of Quay to summit -	3546,25	feet.

General ROY's measurement trigonometrically makes it 3555,4 feet, and barometrically 3548,9 feet.

During the same visit to Carnarvon, I took the opportunity of trying the instrument on Moel Elio, which stands between that place and Snowdon, and has also been measured by General ROY. On September 6, at the Vicarage, the thermometrical barometer stood at 737, thermometer 59°, barometer 29,8. In the blacksmith's shop at Waen Fawr, at the foot of Moel Elio, water boiled at 550, thermometer 57°. The instrument was here set to 767, and carried to the summit, where by the pile of stones it stood at 25, thermometer 52°.

From Vicarage to Waen Fawr, the difference 737 — 550 = 187, mean therm. 58°.		
187 parts - - - =	441	feet.
Add correction 0,0669 × 441 - - =	29,5	
Corrected height from Vicarage to Waen Fawr -	470,5	feet.
From Waen Fawr to the top, the difference 767 — 25 = 742, mean therm. 55°.		
742 parts taken from 258 to 1000 - - - =	1766	
Add correction 0,0583 × 1766 - - - =	102,8	
Corrected height from Waen Fawr to the top - - -	1868,8	feet.
From Vicarage to Waen Fawr - - - - -	470,5	
From Quay to Vicarage - - - - -	11,25	
Total from north end of Quay to top of Moel Elio - -	2350,55	feet.

General Roy's measurement trigonometrically makes it 2371 feet; barometrically 2391,8 feet. The three measurements in this instance, do not agree so well as at Snowdon: whether this arises in any degree from the different forms of the two mountains, rendering the point of observation less definite in the one case, I will not pretend to say; Snowdon terminates in a point, Moel Elio has a large bare summit.

To save the trouble of reference to General Roy's Paper, Philosophical Transactions, 1777, p. 771, I give here from that Paper, a part of the Table for correction on account of the expansion of the column of air between two stations at different temperatures, in thousandth parts of an observed height.

Table III.

	28,5	difference.	29	difference.	29,5	difference.	30	difference.	30,5	difference.
12°	44,7		45,6		46,6		47,5		48,4	
		2,19		2,24		2,28		2,33		2,37
22	22,8		23,3		23,7		24,2		24,7	
	—	2,28		2,33		2,38		2,42		2,47
32	Subtract above.				Add below this line.					
	+	2,37		2,42		2,47		2,52		2,57
42	23,7		24,2		24,7		25,2		25,7	
		2,46		2,51		2,56		2,61		2,66
52	48,3		49,3		50,3		51,3		52,3	
		2,55		2,60		2,66		2,71		2,76
62	73,8		75,4		76,9		78,4		79,9	
		2,51		2,56		2,61		2,66		2,71
72	98,9		100,9		103,0		105,0		107,1	
		2,46		2,51		2,56		2,61		2,66
82	123,5		126,1		128,6		131,2		133,7	

The instrument with which these experiments were made, had been improved from the original construction as described in the Philosophical Transactions, and I shall mention the particulars of difference. The thermometer itself is straight, and carried up the middle of the scale. The index moves by hand on a square rod on one side of the glass tube,

with an adjustment by a screw at the top. The vernier is applied to the edge of the scale. I recommend that in making these thermometers, the bulb be blown on a piece of tube of $\frac{1}{8}$ inch bore, or nearly, so that the mercury expanded before boiling may be wholly contained in that tube without requiring an upper bulb; for if that bulb be made of a size to allow the mercury to separate in it, a globule may lodge in the upper part of it near the fine thread, and be attended with much inconvenience.

To protect the lamp from wind more effectually than was done by the small tent-stand formerly described, I have made the outside case of thin copper, hard soldered, so as to serve as a lanthorn to contain the lamp burning at bottom; while the boiler, which is made of a drawn tube, with the thermometer, slips down from above, and is also protected from the cold air during the experiment. The inverted boiler screws as before, over the scale of the thermometer, and packs in the centre of the case for carriage, the bulb of the thermometer going downwards into the chimney of the lamp; round the chimney in the lower part of the case, is space sufficient for stowing some matches of the oxymuriate of potash, a bottle of sulphuric acid, a wax candle, a tin bottle of water, a pair of scissors for trimming the lamp, a turnscrew and thermometer. In the upper part is also room for some tow or rag for cleaning, &c.; and the whole, when packed for use, weighs two pounds. Still farther to be guarded against wind, if necessary, I carried, as a walking-stick, a rod cut into three, and jointed at top, which belongs to a theodolite as its stand; and had in my pocket a conical bag of thin cotton, which would cover the whole as a tent,

and might be pegged down to the ground if occasion required. This precaution, though it had been needless on Snowdon, was of use on Moel Elio, where I had a very high wind. The tent has of course an opening on one side, where the instrument, which hangs from a hook in the centre, is accessible.

S. Weald,
June, 1820.