MOUNTAIN MEASUREMENTS.

II.—AIR-PRESSURE INSTRUMENTS.

By J. C. Barnett.

In the year 1745 Torricelli performed his famous experiment that led to the construction of the mercurial barometer. He took a glass tube, 33 inches long, closed one end of it, and then filled it with mercury. Having placed his thumb on the open end, he inverted the tube so that that end was placed below the surface of the mercury contained in an open vessel, and then removed his thumb. He noted that the mercury in the tube fell until 30 inches of mercury remained supported above the level of the mercury in the vessel. Pascal proved the truth of the experiment that same year, and affirmed that the mercury in the tube was supported by the downward pressure of the air, and that, in fact, the weight of the mercury in the tube was exactly equal to the weight of a column of air of the same diameter, but reaching upward to the top of the air ocean. Six years later, Perrier noticed that the height of the mercurial column depended on the state of the weather. In 1665, Boyle proposed it as an instrument for determining the heights of mountains, and now, in the hands of our engineering surveyors, it proves to be a most valuable instrument indeed, especially when its results are checked by the hypsometer.

The mountain barometer is an ordinary cistern barometer, supported on a tripod, with a screw adjustment by which the mercury in the cistern can be raised or lowered to the zero point of an attached scale. The height of the column of mercury is read from this scale by a vernier giving the true height to the third decimal place. Above the cistern is an attached thermometer, which indicates the temperature of the mercury, and an unattached thermometer is also required to denote the temperature of the surrounding air.

To determine differences of level two of each of these instruments are required, one set to make observations at the lower station and the other to make observations at the upper. These observations must be made with the utmost exactness and with the greatest care. The unattached thermometers should be kept in the shade, and both thermometers and barometer should be read rapidly and without breathing upon them, as the heat of the body would soon communicate itself to the instruments and vitiate the results. If only approximate correctness be required, note the heights of the barometer at the two stations, and then the following proportion will give the difference of level:—

Sum of barometric heights : diff. of heights : : 52,000 ft.

Thus, if the reading at the lower station was 29·922 inches, and at the upper 28·185, then the proportion would be:—

58·107 : 1·737 : : 52,000 : 1,554 feet.

This is Sir John Leslie's method. In barometric observations where exactness is of importance, two corrections require to be made, one for the depression of the mercury in the barometer tube due to capillary attraction, and the other for temperature, which not only expands the mercury itself, but the tube in which it is contained and even the scale by which the height of the column is measured. No really reliable results can be obtained when the temperature is neglected. Sir John Leslie advises the addition of one ten-thousandth part of the height calculated for each degree of temperature above 32°.

A very simple rule has been given by Sir Henry James, R.E., to the officers of the engineers for taking meteorological observations and deducing heights therefrom:—

If from the simultaneous readings of the barometers in inches, and the attached and detached thermometers in degrees, it is required to determine the difference of level of the two stations.

Then to the tabular number corresponding to the mean of the two barometers add the sum of the detached thermometers and multiply the sum thus found by the difference between the barometric readings. From this subtract 2½ times the difference between the attached thermometers, and the result will be the difference of level expressed in feet.

MEAN READING OF BAROMETERS.

Inches.	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
25	1004·9	999·9	995·0	990·1	985·3	980·5	975·8	971·1	966·5	961·9
26	857·4	952·9	948·4	944·0	939·7	935·4	931·1	926·9	922·8	918·6
27	914·5	910·5	906 5	902·5	908·6	894·7	890·8	887·0	883·3	879·5
28	875·8	872·1	868·5	864·9	861·3	857·8	854·3	850·8	847·4	844·0
29	840·6	837·2	833·9	830·6	827·3	824·1	820·9	817·7	814·5	811·4
30	808·3	805·2	802·1	799·0	796·0	793·0	790·0	787·0	784·1	781·2

Let the readings be as follows :—

	Barometers.	Attached Thermometers.	Detached Thermometers.
At base, - -	29·922	52°	48°
At summit, -	28·185	34°	32°
	2) 58·107	Diff., 18°	Sum, 80°
Mean, - -	29·053		

To 80 add 848 (the number corresponding to mean height) = 928, which multiply by 1·737 (the difference between the barometric readings) = 1612, and from this deduct 45 ($2\frac{1}{2}$ times the difference between the attached thermometers) = 1567 feet = height of the mountain.

Another simple, and approximately accurate, rule for ascertaining the relative elevation of two stations is to multiply by 900 the difference in barometrical readings between them and reckon the product as feet. In the above instance the height would be :—

$$1{\cdot}737 \times 900 = 1563{\cdot}3 \text{ feet.}$$

The use of the hypsometer in conjunction with the mountain barometer has already been referred to. This is an instrument for determining very exactly the boiling point of a liquid. It consists of a very sensitive and strong thermometer, large enough to be graduated so as to show the tenth of a degree, and a vessel containing water which can be boiled by a spirit lamp placed beneath. The bulb of the thermometer is placed in the steam rising from the boiling water, and thus is bathed in pure vapour whatever may be the kind of the water employed.

As the boiling point of any liquid depends on the pressure of the air, and as the pressure of the air diminishes as we ascend, it is clear that the boiling point will furnish an indication of the height above sea level. It has been found by experiment that the boiling point is lowered 1° by an ascent of 519 feet, but we have to ascend to more than twice that distance to cause a fall of two degrees. A very simple and marvellously accurate rule of thumb for determining the elevation from a knowledge of the boiling point may be thus stated:—If at sea level the boiling point is 212° Fah., what is the elevation of a station where water boils at 209° Fah.? Here the boiling point is lowered 3°. Multiply 519 feet by 3 and add the square of $3 = 1557 + 9 = 1566$ feet.

Before leaving the subject of mountain measurements by calculations based on variations of air pressure, one cannot omit a reference to the aneroid barometer, which, owing to its convenient size and portability, has become so extensively used of late. Its mechanism consists of a hollow metal cylinder with thin corrugated sides, which contract or expand according to the pressure of the atmosphere, the air within having been previously exhausted by the air-pump. The motions of the sides act upon levers, which in turn act upon a roller which moves an index. The instrument is graduated experimentally, as it cannot measure pressure absolutely, but can only afford indications relatively to a mercurial barometer. Aneroids are compensated for temperature, and are very sensitive, but do not preserve their accuracy owing to rust, or the alteration of the force of their springs. It is, therefore, advisable to frequently compare aneroids with standard barometers.