ART. XXIII.—*Barometer* ; by JAMES LEWIS.

IN the present condition of meteorological science, there is a growing demand for facilities of observation that invites the aid of mechanical appliances which have for their purpose to make automatic records of phenomena practically free from sensible errors. The remarks about to be made are suggested by experiments and calculations that have been made preliminary to the construction of a compensated, self-registering barometer. The form of instrument to which they relate is an improvement upon the apparatus called the "Syphon Barometer." In the course of the experiments referred to, a syphon of steel was made, the dimensions of which are approximately as follows, viz: vacuum chamber—length=4·5 inches; diameter=0·41 inch. Section of tube connecting the vacuum chamber with the base of the syphon—length=28·75 inches; diameter=0·3 inch. A capillary passage through the base connects these parts with the short arm of the syphon. Before filling the tube with mercury, a piston with a porous packing was introduced into the detached and inverted long arm of the syphon, the open end of the tube being embraced by a suitable funnel to prevent loss of mercury. Mercury was then filtered into the tube, above the packing of the piston, until the whole tube was filled, the funnel around its open end embracing an excess. The piston was then made to wipe the walls of the vacuum chamber, and was afterward withdrawn from the tube by a pumping process—wiping and pumping successive portions of the tube repeatedly, the mercury filtering through the porous packing of the piston into a vacuum. Tests for vacuum expanded any remaining bubbles of air, and the pumping process again repeated reduced the tube and its contained mercury to a condition indicative of a perfect vacuum which has maintained its integrity through a period of over six months under circumstances well calculated to test it. The process of boiling, usually deemed essential, was omitted. The operations of this syphon indicate that the diameters of the short arm and vacuum chambers are nearly large enough to remedy the resistance of capilarity and adhesion to the free movement of the mercury. The syphon is supported by an adjusting screw beneath its base. In the short arm of the syphon, and in contact with its contained mercury, is an iron float, the diameter of which where it touches the mercury, is about 0·25 inch. The contact is perfected by amalgamation. The float is suspended by a slender thread of untwisted silk, which passes around a wheel $\frac{3}{8}$ inch in diameter, the axis of which is about 0·02 inch in diameter, and rests on four friction wheels. One end of the axis of the wheel carries an index which points to divisions on

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a dial graduated to hundredths of an inch; the spaces between the divisions are sufficiently wide to be readily divided into tenths (= thousandths of an inch) by an experienced eye. Behind the index, and attached to the same axis, is a very light skeleton wheel three inches in diameter, the periphery of which is grooved for the reception of a very fine silk cord which supports a light metallic frame carrying a registering point, the movements of which are restricted to a vertical path by means of a very slender guide-wire. The metallic frame and registering-point are rather more than counter-poised by the weight of the float that communicates with the mercury. The amount of friction involved in these parts is slight and does appreciably interfere with the movements of the mercury. The pulley which is embraced in this arrangement, and which transmits the movements of the mercury to the registering point, multiplies precisely eight times; but as only one half of the barometrical fluctuation is manifested in the short arm of the syphon, the scale of record requires four standard inches for the measurement of a barometrical inch.

The registering apparatus embraces a number of cylinders (the axes of which are parallel with the vertical path of the registering point) for the purpose of moving a fillet of paper six inches wide, so as to receive impressions from the registering point; also, a registering hammer with a radius of $\frac{3}{4}$ inch, consisting of a bar of metal six inches long, revolving about an axis parallel with itself and the axis of the cylinders, so as to impinge on the registering point at any part of its traverse across the fillet of paper. It would be better were these parts designed to embrace eight instead of six inches movement of the registering point. The registering apparatus is operated by clock work which imparts motion at stated intervals, as one hour, a half or a quarter, as may be determined by shifting the position of a lever arranged for that purpose. The announcement may be new that a syphon barometer contains within itself the elements by means of which it may be successfully compensated for temperature.

Compensation, outside of, and separate from the tube itself, is objectionable for two reasons: first, the error of temperature varies with the height of the barometrical column, and also with the quantity of mercury in the syphon—these two conditions determine another condition which establishes compensation *at one point of elevation* of the barometrical column, above or below which the error of temperature is variable, *plus* or *minus*; second, any system of compensation outside of the syphon, will necessarily involve mechanical complexities liable to disturbance by slight causes.

These additions will of course involve additional items of cost, which, if bestowed upon the compensation of the tube itself, would permanently obviate all difficulties.

The question of compensation will now be examined, requiring only the comprehension and aid of the artisan that it may be wrought into a *practical* solution, at once available for the purposes of the meteorologist.

Proceeding upon the assumption that the maximum elevation of the mercury in the barometer is below the limit of 32 inches, let there be supposed a syphon of iron or steel free from flaws, the long arm of which has an elevation of 32 inches, the short arm an elevation of 6 or more inches, their diameters being any convenient unit and equal.¹ The communication between the two arms of the syphon may be a small orifice (say 0.03 inch in diameter) through the base, large enough to permit free passage for the mercury, and small enough to admit of handling the syphon in the necessary manipulations of erection without endangering loss of its contents by a sudden movement. The contents of the passage through the base may be disregarded in the calculations on which the compensation depends. Now, regard the long arm and the passage through the base of the syphon as having been filled with mercury at the temperature of 32° F.

The elements which enter into the compensation of the syphon require to be considered, viz: a unit of volume of mercury at 32° F., becomes at 212°, 1.018018 (Guyot's Tables)=A; a linear unit of iron at 32°, becomes at 212°, 1.0012534363 (Hassler)=B.

The theoretical elevation of a barometrical column of 32 inches by a change of temperature from 32° to 212° F., will be 32 A. The excess over its former elevation may be expressed by the terms 32 (A-1). In the syphon, the iron tube expands by the rate B in each of its three cubic dimensions, two of which (involved in the square of the diameter) *tend to diminish* the elevation of the mercury by enlarging its sectional area, so that the elevation of the column might be expressed by $32 \frac{A}{B^2}$,

referring to a tube closed at its base and open at top; the excess over its original elevation may be expressed by the terms

$32 \left(\frac{A}{B^2} - 1 \right)$. This last expression is less than the unit of excess of elevation due to temperature = 32(A-1) which it is necessary should be attained in the long arm of the syphon, to establish compensation, (presuming that it is attainable as a *theoretical* consideration). The decimal proportion of the actual excess of elevation of the mercury in the tubes to the *required* excess of

elevation may be obtained from the expression $\frac{32 \left(\frac{A}{B^2} - 1 \right)}{32(A-1)}$. In

¹ The minimum diameter should not be less than half an inch; the maximum diameter, on the other hand, need not exceed one inch. A compromise between cost and efficiency may suggest something between these extremes.

the general application of this expression to the computation of

the compensation of the syphon, the expression is $\frac{32\left(\frac{B^2}{A}-1\right)}{H(A-1)}$, in

which H is made successively equal to 32, 31, 30, 29, &c., as far as it may be necessary to proceed. The difference in value of the numerator and denominator of this fraction, represents the error of temperature for 212°. Regarding the expression

$\frac{32\left(\frac{A}{B^2}-1\right)}{H(A-2)}$ as being but a fractional portion of the required

unit of excess of elevation for temperature, it will be understood that the volume of mercury which it represents *may have its altitude increased by diminishing its sectional area*. Thus, if the expression be regarded as a unit of *elevation* but a fraction of sectional area, the square root of the expression becomes a diameter. This process modifies the form of the upper end of the long arm of the syphon, converting it to a truncated chamber of the form of a solid of revolution, the smaller end at top. The lines of vertical section of this solid are curves, the asymptote of which is the axis of the tube. The diameter of the conical chamber, beginning at top and measuring at intervals of half an inch, are in the following values, which relate to the original unit of diameter:

0.0 inch.	diameter, 0.926629
0.5 "	" 0.941456
1.0 "	" 0.957017
1.5 "	" 0.973379
2.0 "	" 0.990609
2.5 "	" 1.008785
3.0 "	" 1.028002
3.5 "	" 1.048359
4.0 "	" 1.069975
4.5 "	" 1.092992

The curve which defines the outlines of the chamber is so slight a departure from a right line (0.004433 in the limits of the available part of the cavity) that it may be regarded as a straight line in the calculations which define the proper length of the solid of revolution without involving sensible errors in the compensation. The solid of revolution becomes then a cone. This cone should embrace the same cubic space as an equal length of the original tube, and it must therefore have the same mean sectional area; make x = base of cone, d = truncated top (diameters), the value of x may be found from $\frac{x^2+dx+d^2}{3}=1$.

$x=1.071618$. This value occurs between the diameters 1.069975 and 1.092992, and its location is determined by the proportion

of its difference from the first of these two stated diameters, to their own difference. The length of the cone by this process is 4.035700 inches, a very small fraction too short (when the curvature is considered) for *perfect* compensation; but the resulting errors are inappreciable.

In the proposed compensated syphon, the interior capacity and mercurial contents are intended to be the same as if the tube were of uniform diameter. The object sought is to secure in the long arm of the syphon the theoretically required elevation due to temperature, so that no errors of temperature will be differentiated between the two arms of the syphon. The conical chamber will accomplish this object by imparting the required elevation at the expense of diameter. But this modification of the upper end of the long arm changes its relation to the previously cylindrical short arm of the syphon, and requires that the short arm should be an *inverted fac simile* of the conical chamber, so that under the influence of barometrical changes, a given portion of the column of mercury transferred from the contents of one arm to the contents of the other shall not undergo any change of vertical dimensions. In effect, the full cubic contents of the conical vacuum chamber will occupy the *same conical space* (at the temperature 32°) at all elevations of the barometrical column, the vacancy in the vacuum chamber being equalled by the space occupied by mercury in the short arm of the syphon.

The tendency of the surface of the mercury to assume a spherical form with increased elevation may require a trifling adjustment. Another adjustment may also be necessary on account of the tendency of the mercury to seek that position in a conical space which least diminishes its sphericity.

At the temperature 32° F. the lower limit of utility of the syphon will be reached with a barometrical pressure of 23.929 inches, the upper limit being 32 inches. The point at which the tube would be self-compensating, if cylindrical, corresponds to the pressure 27.483489 inches at 32°. Above that point the error has the same sign as in the ordinary barometer; below that point the sign of the error is inverted.

The point of self-compensation for a cylindrical tube corresponds to the section of mean diameter, or rather, diameter of mean sectional area of the conical chambers.

The following table exhibits the temperature errors of a *cylindrical* syphon of 32 inches range, for 212°.

23 inches,	Error, 0.081	28 inches,	Error, 0.099
24 "	" 0.063	29 "	" 0.027
25 "	" 0.045	30 "	" 0.045
26 "	" 0.027	31 "	" 0.063
27 "	" 0.009	32 "	" 0.082

Mohawk, N. Y.