W. B. No. 241.

U. S. DEPARTMENT OF AGRICULTURE.

WEATHER BUREAU.

BAROMETERS

AND THE

MEASUREMENT OF ATMOSPHERIC PRESSURE.

A PAMPHLET OF INFORMATION RESPECTING THE THEORY AND CONSTRUCTION OF BAROMETERS IN GENERAL, WITH SUMMARY OF INSTRUCTIONS FOR THE CARE AND USE OF THE STANDARD WEATHER BUREAU INSTRUMENTS.

CIRCULAR F, INSTRUMENT DIVISION.

SECOND EDITION.

BY

C. F. MARVIN,

PROFESSOR OF METEOROLOGY.

Prepared under direction of WILLIS L. MOORE, Chief U. S. Weather Bureau.

WASHINGTON:

WEATHER BUREAU.

1901.

W. B. No. 241.

U. S. ~~DEPARTMENT OF AGRICU~~LTURE.

WEATHER BUREAU.

BAROMETERS

AND THE

MEASUREMENT OF ATMOSPHERIC PRESSURE.

A PAMPHLET OF INFORMATION RESPECTING THE THEORY AND CONSTRUCTION OF BAROMETERS IN GENERAL, WITH SUMMARY OF INSTRUCTIONS FOR THE CARE AND USE OF THE STANDARD WEATHER BUREAU INSTRUMENTS.

CIRCULAR F, INSTRUMENT DIVISION.

SECOND EDITION.

BY

C. F. MARVIN,

PROFESSOR OF METEOROLOGY.

Prepared under direction of WILLIS L. MOORE, Chief U. S. Weather Bureau.

WASHINGTON:

WEATHER BUREAU.

1901.

LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
WEATHER BUREAU,
Washington, D. C., April 1, 1901.

SIR: I have the honor to transmit herewith the revised copy of a pamphlet prepared by Prof. C. F. Marvin, containing information and instructions to the observers of the Weather Bureau for the care and use of barometric apparatus, and to request that it be published as Circular F, Instrument Division, 2d edition.

Very respectfully,

WILLIS L. MOORE,
Chief U. S. Weather Bureau.

HON. JAMES WILSON,
Secretary of Agriculture.

NOTE TO OBSERVERS.

U. S. Department of Agriculture,
Weather Bureau,
Washington, D. C., April 1, 1901.

The details of information respecting barometers contained in the accompanying pages are furnished for the instruction and guidance of observers, who will keep themselves informed upon the subjects treated, and, in particular, will observe the technical duties relating to the care and use of barometric apparatus summarized for their convenience in Section VII. The provisions of this section, as more fully set forth in the body of the pamphlet, will replace instructions on barometers heretofore issued.

Willis L. Moore,
Chief U. S. Weather Bureau.

CONTENTS.

LIST OF ILLUSTRATIONS.

BAROMETERS AND THE MEASUREMENT OF ATMOSPHERIC PRESSURE.

INTRODUCTORY.

THE BAROMETER.

1. The hydrostatic principle, by virtue of which the pressure of the air is measured by the ordinary barometer, was first formulated at Florence in 1643 by Torricelli, whose famous experiments demonstrated, not only that the air exerted a very great pressure, but that this pressure changed slightly from day to day.

2. *Torricelli's barometer.*—To repeat Torricelli's experiment, fill a clean, dry, preferably warm, glass tube, closed at one end, with pure, dry mercury, so as to carefully exclude all air. The length of the tube must, in general, exceed 30 inches. Close the open end of the tube firmly with the finger tip, and submerge it in an open cup of mercury. Upon removing the finger and causing the tube to stand vertically, a portion of the mercury will pass from the tube into the cup, leaving a vacuous space, known as Torricelli's vacuum, in the top of the tube. The column of mercury remaining in the tube will, at sea-level stations, be about 30 inches high, the weight of this mercury is sustained by and exactly balances the downward pressure of the air upon the surface of the mercury in the cup. The height of such a mercurial column, therefore, becomes a measure of the pressure of the air, and Torricelli seems to have been the first to discover that the height of such a column varied from day to day.

3. *Siphon barometer.*—Instead of constructing the barometer in the manner just described, where the cistern and tube are in separate parts, the tube may be made longer and turned up at the bottom so as to resemble the letter J, forming what is commonly called a siphon barometer, the long arm of which is closed at the top.

4. *Pressure of one atmosphere.*—Suppose the area of the inside of the barometer tube is just 1 square inch, then a 30-inch barometric column will contain just 30 cubic inches of mercury. Now, 1 cubic inch of mercury weighs 0.4906 pound, which, multiplied by 30, gives the ordinary sea-level pressure of the air to be 14.718 pounds per square inch. This quantity is frequently used by engineers, and is called a pressure of one atmosphere.

5. This pressure of 14.7 pounds per square inch is, in the main, nothing more than the weight of an air column having a sectional area of 1 square inch and extending vertically to the upper limits of

the atmosphere. In addition to the weight, pure and simple, however, such influences as the of winds, the rapid heating and cooling in confined layers of air, and other causes also, modify by small amounts the elastic pressure of the air.

6. *Other forms of barometers.*—Within the past fifty or sixty years a form of barometer, made entirely of metal, has been devised, and is widely used at sea, by tourists and others on account of its convenience and portability. This form is commonly designated the aneroid, a word which signifies "containing no liquid." The instrument is also often called the holosteric barometer, meaning "wholly of solids." Aneroids, though often highly sensitive, very convenient, and portable, are, at best, much less accurate than properly constructed mercurial barometers, as will be explained later.

I.—MERCURIAL BAROMETERS.

7. *Fortin barometers, Weather Bureau pattern.*—In order that the height of the mercurial column may represent accurately the true pressure of the air, and in order to detect the comparatively small changes of pressure from day to day, many refinements are necessary in the construction of the instrument and great precision of measurement is required. An excellent form of the mercurial barometer, satisfying the requirements just stated, was devised by Fortin, and is now very widely used the world over. The particular pattern used by the Weather Bureau, sometimes called the Green barometer, is figured on page 13.

8. The barometer consists of a glass tube, about $\frac{1}{4}$-inch inside diameter, closed at the top and surrounded with a thin metal tube, through which large openings are cut on opposite sides, exposing to view the glass tube and mercurial column. The graduated scale is formed at one side of this opening, and a short tube or sleeve, also graduated (shown at *C*, figs. 1 and 2), encircles the barometer tube and slides smoothly within the metal part, motion being given to it by means of the milled head, *D*, and a small rack and pinion inside.

At *E*, fig. 2, is shown what is called the attached thermometer. The bulb of this is entirely concealed within the metal tube, and is between it and the glass barometer tube, so as to show as nearly as possible the mean temperature of both the brass tube and the mercury.

9. *Cistern.*—The ingenious and special feature of the barometer is in the construction of the cistern so that the level of the mercury within may be changed greatly and adjusted to a fixed index point.

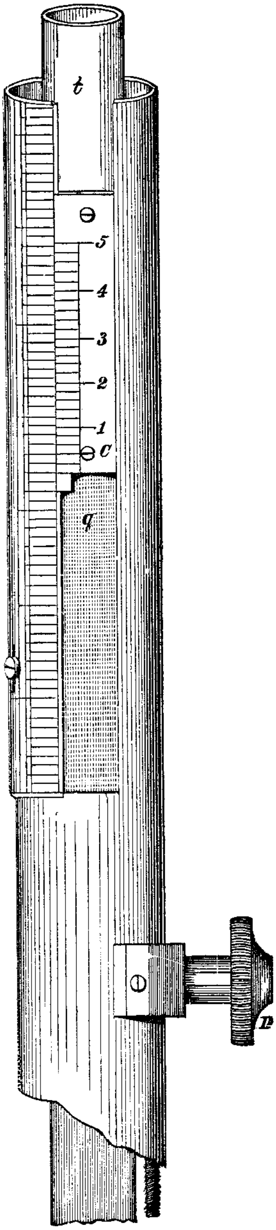


Fig. 1.

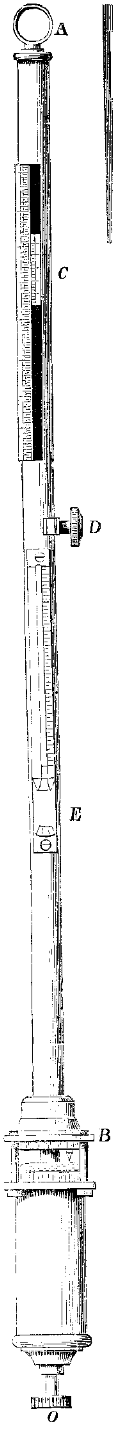


Fig. 2.

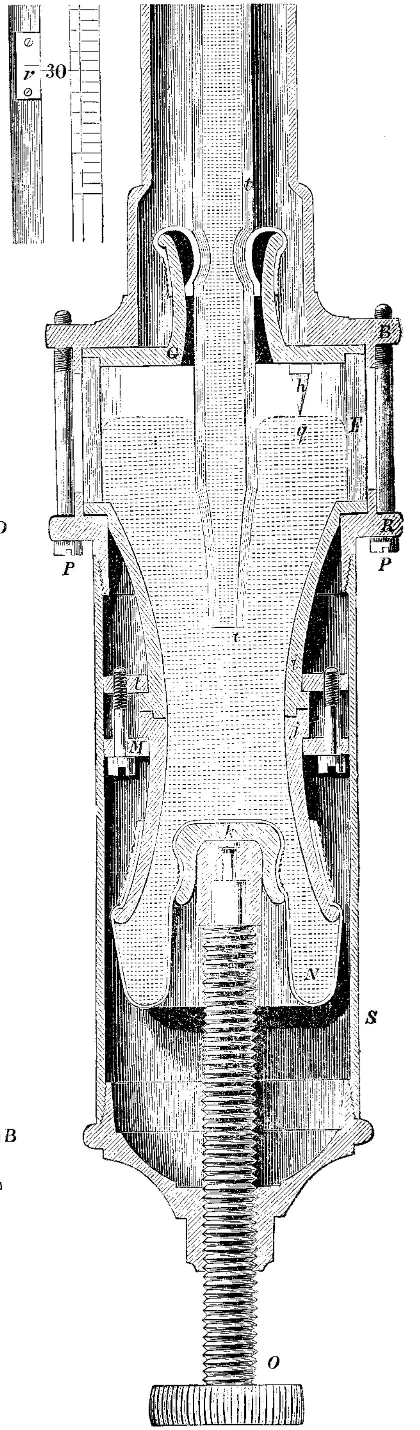


Fig. 3.

Mercurial barometer, with Fortin cistern.

The topmost portion of the cistern consists of a small boxwood piece, *G*, fig. 3. The glass tube, *t*, passes through the central portion of this, to which it is secured by a piece of soft kid leather folded in a peculiar manner and securely wrapped to both the glass tube and the boxwood cap, *G*. The joint thus formed is perfectly flexible, and will not allow the mercury to escape, but permits the passage of air to and from the cistern.

The remaining portions of the cistern are the short glass cylinder, *F*, fig. 3, the two curved boxwood pieces, *i* and *j*, and the kid leather bag, *N*, with adjusting screw, *O*, clamps, etc.

It is plainly seen that on turning the screw, *O*, the leather bag may be folded up into or withdrawn from the curved boxwood chamber, *j*, in a manner to cause any desired change in the level of the mercurial surface.

10. *Ivory point.*—At *h*, fig. 3, is shown what is technically called the "ivory point," which projects downward from the top of the cistern and forms a fixed and very definite point, always the same, and to which the level of the mercury in the cistern can be adjusted in taking readings of the barometer, as will be described hereafter.

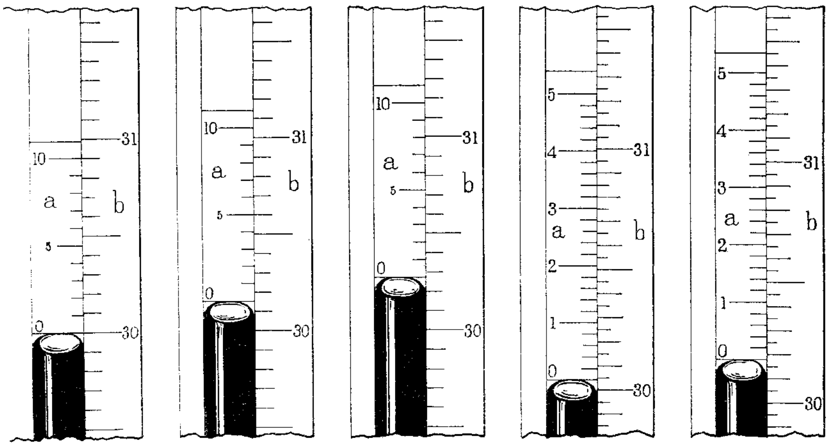
The ivory point is, therefore, the zero end of the scale, from which all the measurements of the height of the column are made.

11. *Scale of barometer and vernier.*—The scale of the barometer is seen on the left of the opening, at the top. It is most conveniently made of a separate strip of metal, although sometimes it is engraved directly on the metal tube itself. The length varies from about 4 inches, for use at stations of only moderate elevation above sea level, to from 10 to 15 inches, or more, for barometers intended to be used in balloons or on lofty mountain summits. The graduations on the scale also vary, being only 10 spaces to the inch in many instances and in others 20; the latter graduation is to be preferred on account of the greater accuracy attainable in readings.

The scale of the barometer when engraved on a separate strip is attached to the metal tube by small screws in such a manner that it may be adjusted slightly up and down, so that the 30-inch mark, for example, of the graduations can be placed at exactly the right distance from the ivory point. This adjustment once made, it is, of course, highly important that the scale should not be moved afterwards.

12. *Vernier.*—A vernier is a very simple and ingenious device by which one is able to accurately ascertain much smaller fractional subdivisions of a graduated scale than could otherwise be observed by the eye without the aid of a microscope. For example, with a scale having only 20 subdivisions to the inch a venier enables us to ascertain accurately the one-thousandth part of an inch. The name of the device is derived from its inventor, Pierre Vernier. This portion of the barometer is the little graduated scale, *C*, fig. 2.

A vernier consists, essentially, of a small graduated scale, the spaces upon which are just a certain amount smaller or larger than those on the main scale. When two such scales are placed together some particular line of the one will always be coincident, or very nearly so, with a line on the other, and from this circumstance the position of the zero-line of the vernier in reference to the scale can be very accurately determined, as will be readily understood from a study of the following figures and explanation:



30.00	30.15	30.277	30.034	30.177
Fig. 4.	Fig. 5.	Fig. 6.	Fig. 7.	Fig. 8.

Verniers.

Fig. 4 exhibits the manner of graduating a vernier so as to subdivide the spaces upon the scale into tenths. In the figure, *b* is the scale and *a* is the vernier. The lower edge of the vernier, which in this case is also the zero line, is exactly opposite or coincident with 30 on the scale. The tenth line on the vernier is coincident with the ninth line above 30—that is, a space of nine divisions on the scale is divided into ten spaces on the vernier, so that each space on the latter is one-tenth part shorter than a space on the scale. In the present case the spaces on the scale represent inches and tenths; hence the difference between the length of a space on the vernier and one on the scale is $\frac{1}{10}$ of $\frac{1}{10} = \frac{1}{100}$ of an inch. This principle of matching two scales having spaces of slightly different magnitude is always followed in the construction of verniers, though, of course, the number of spaces embraced by the vernier is varied to suit the circumstances and the degree of minuteness desired. Moreover, in some instances, the vernier embraces one more space on the scale, instead of one less, than the number of its own subdivisions—that is, ten spaces on the vernier may be made to correspond to eleven spaces on the scale.

If, as we have seen, the spaces on the vernier are one-tenth smaller than on the scale, then, in the adjustment shown in fig. 4, the first line above the zero on the vernier is one-tenth part of the space, the next line two-tenths, the next three-tenths, etc., distant from the line next above on the scale. When, therefore, we find the vernier in such a position as shown in fig. 5, where the fifth line on the vernier is coincident with a scale line, it is very clear that the zero line of the vernier must be just five-tenths above the scale line next below. Now, since we imagine these scales to represent inches and tenths, then fig. 5 will read, 30.15 inches.

13. *Estimation of fractions on a vernier.*—In many cases it will happen that no single line on the vernier will be exactly coincident with a scale line, but that one line will be a little above while the next line on the vernier will be a little below the corresponding scale lines.

In the case shown in fig. 6 the seventh and the eighth lines on the vernier are each nearly in coincidence, but neither one is exactly so. This indicates that the reading is somewhere between 30.27 and 30.28. Moreover, we can clearly see that the eighth line is nearer coincidence than the seventh. We, therefore, estimate that the true reading is about 30.277. We might, probably, with as great accuracy have selected 30.278.

If the scale and vernier are accurately graduated, such readings by a practised observer will rarely be in error by more than 0.002 inch. It is important in estimating the fractions that the eye be exactly in front of the lines being studied.

14. In figs. 7 and 8 are shown verniers applied to a barometer scale having 20 parts to the inch. In this case 24 parts on the scale are divided into 25 parts on the vernier. By the principle already explained in paragraph 12, the value of the subdivisions effected by such a vernier, or, as it is most frequently expressed, the least count of the vernier, will be $\frac{1}{25}$ of $\frac{1}{20} = \frac{1}{500}$ of an inch. In reading the vernier, therefore, each line will represent 0.002 inch, so that the fifth, tenth, fifteenth, twentieth, and twenty-fifth lines will represent 1, 2, 3, 4, and 5 hundredths of an inch, respectively, and are so numbered.

As described in paragraph 13, the lines in this kind of vernier also may not be exactly in coincidence; but in such a case, owing to the smallness of the spaces, it is not of any special advantage in making our estimate to consider whether coincidence is nearer one line than the other. In ordinary practise we simply take midway between. Thus in fig. 8 the reading is between 30.176 and 30.178; we therefore adopt 30.177 as the proper reading.

15. *Caution against error.*—When the zero line of this style of vernier is next above one of the shortest lines on the scale, as was the case in the example above, some attention is necessary in order to take off the correct reading. For example, in fig. 8 we find that

coincidence on the vernier is between lines designated 26 and 28, which corresponds to a reading of 0.026 or 0.028, or, taking midway between, 0.027. On the scale itself, however, we see the graduation next below the first line of the vernier is 30.150. The complete reading is found by adding the parts thus: $30.150 + 0.027 = 30.177$. It frequently happens with beginners that the 0.050 represented by the short line on the scale is overlooked and omitted entirely—that is, the above reading might be called 30.127. Whenever readings are made with a scale and vernier of this character, special pains must be taken not to omit adding 0.050 to the vernier reading when the first line below the zero of the vernier is a short one.

16. *Straining the cistern of a barometer.*—When the mercury is sent up to the top of the tube of a barometer by screwing up the cistern, an internal hydrostatic pressure is produced therein proportional to the amount by which the length of the column has been increased. This pressure tends to force the mercury through the joints of the cistern or the joints and pores of the leather bag. This is more particularly the case with a barometer at an elevated station, for here, owing to the diminished air pressure, the column may need to be raised 10 or 15 inches in filling the tube, greatly endangering the cistern. For this reason the Fortin barometer cistern is not wholly satisfactory, as it is difficult to make and keep the joints so perfectly tight that the mercury will not be able to find its way through some very small crevices, which soon more or less completely impairs the barometer.

17. *Tuch cistern.*—Many of the barometers of the Weather Bureau are fitted with an improved form of cistern, devised by Mr. Charles B. Tuch, of the Instrument Division. The construction of this is shown in fig. 9.

The chamber for the mercury is formed of the iron cylinders, *c*, *k*, provided with windows at the top, and a small glass cylinder, *f*. The glass barometer tube is fastened into a metal piece, *b*, by means of several thicknesses of leather washers, held and clamped by a screw, *e*, above. The piston, *o*, fits the cylinder very snugly and can be moved up and down by means of the milled-head screw, *W*, thereby adjusting the mercury to any desired level.

18. *Fixed cistern barometers.*—It is very evident that as the column of mercury rises and falls in a barometer tube there is a corresponding change in the level of the surface in the cistern, and as long as the quantity of mercury in the whole barometer remains the same, it follows, except for slight temperature effects, that the true height of the column of mercury may always be found simply from readings at the top end, a due allowance being made for the slight rise and fall in the cistern.

Adjustable cistern barometers, such as described in paragraphs 9

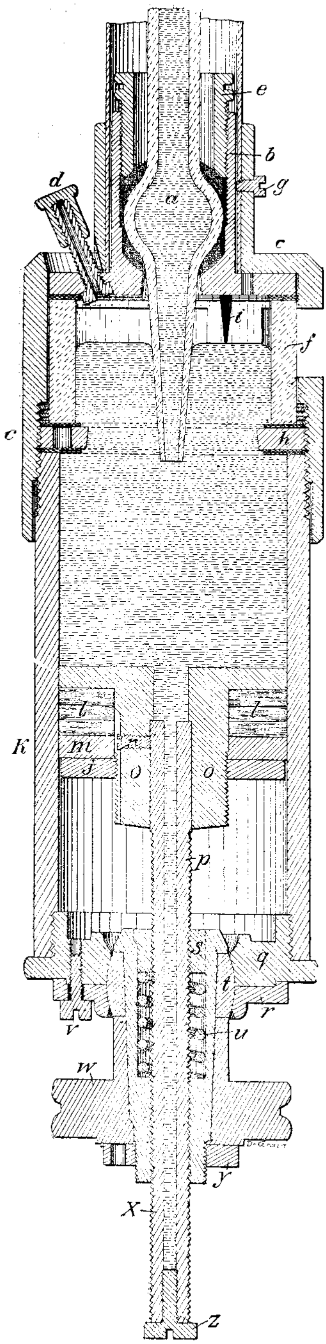


FIG. 9.—Tuch barometer cistern.

and 17, are, in general, the most accurate, as the correction for capillarity, paragraph 26, is usually more constant, and the accidental escape of a little mercury from the cistern does not matter. Still, very accurate results may be obtained by the use of well-made barometers with fixed cisterns, and this form is often adopted in the construction of barometers for use on shipboard.

The relation between the true length of the column and the observed position of its top depends upon the relation between the inside areas of the cistern and barometer tube. When this relation has been once worked out it is then necessary in reading the barometer to observe only the position of the top of the column and apply a "correction for capacity." (See paragraph 24.)

19. *Contracted barometer scale.*—As the correction for capacity in barometers with fixed cisterns remains the same so long as the quantity of mercury within the barometer and the inside area of tube and cistern are unchanged, it will not be necessary to apply a capacity correction to every reading made, provided we use on the barometer a scale having all its divisions shortened by just the proper amount to compensate for the capacity effect. To understand this more clearly, imagine a barometer with the top of the column just 30 inches above the surface of the mercury in the cistern. Suppose the sectional area of the barometer tube at the top is only one-fiftieth as great as that of the cistern (this is about the usual relation). Now, if we imagine the column to rise a distance of 1 inch in the tube, it will then seem to become 31 inches high, but when the column rises 1 inch, the mercury in the cistern falls one-fiftieth of an inch, and, therefore, the real height of the column must be $31\frac{1}{50}$ inches; that is, we may say, that each inch of a scale represents $1\frac{1}{50}$ inches of change in the real

height of the mercurial column. If, therefore, a special scale be prepared having the spaces representing inches, each, one fifty-first part of an inch shorter than a true inch, then readings of our imaginary barometer on such a scale will indicate the true height of the column, presupposing, of course, that the sectional areas of the tube and cistern are uniform, and that the scale is adjusted to a proper distance from the cistern.

20. By methods of calibration manufacturers are able to construct scales and barometers of great accuracy in accordance with the above principles, and they are very convenient to use.

21. It is obvious that if a barometer tube in such an instrument is broken it will be difficult to find another so exactly the same size that it could be used with the old scale; generally, a new scale is also required.

22. In fig. 10 is shown a cut of an excellent barometer of the fixed-cistern type, devised by Schneider Bros., of New York. One of the special features of the barometer is the means provided for filling the cistern and tube with mercury so that the barometer can be shipped safely from place to place.

To fill the cistern with mercury, the barometer is first very carefully and gradually inclined and inverted. When fully inverted the mercury suffices to fill up the cistern just to the throat of the contracted portion at *G*. By screwing up the milled head, *H*, the plate, *G*, closes against the bottom of the cistern and completely imprisons the mercury with only a little free space for expansion. If the barometer is now turned erect the mercurial column can not descend unless the screw, *H*, is loosened, whereupon the mercury flows into the previously unoccupied space below the plate, *G*, and permits the column to resume its normal level.

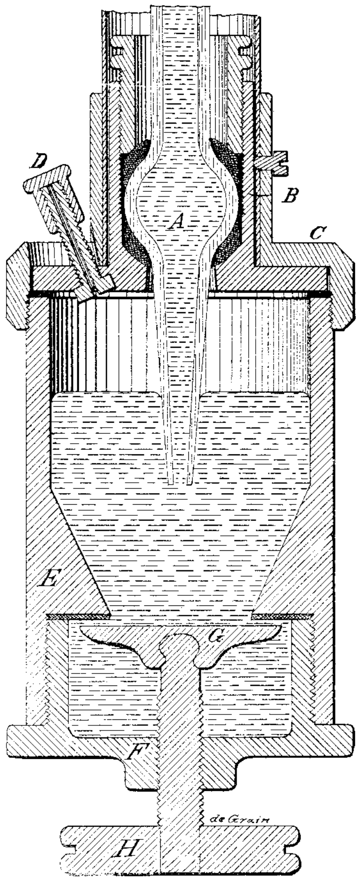


Fig. 10.—Fixed cistern barometer.

23. The capacity correction required for a barometer with fixed cistern and true scale graduated in standard units, and not contracted, as explained in paragraph 19, can be determined from careful measurements of the internal diameters of the tube and cistern made before the barometer is filled, but the accuracy of this

correction should always be checked by subsequent comparisons, as indicated below.

24. *Capacity correction, how found.*—It is evident that by sliding the scale of a fixed-cistern barometer up or down it can be so adjusted that a reading at some one point is just right; for example, we may place the 30-inch mark so that when the top of the column is at this mark the surface of the mercury in the cistern is just 30 inches below. If the sectional area of the tube is a, and that of the cistern A, then, if the mercurial column in the tube rises one scale division, the fall in the cistern will be only the $\frac{a}{A}$ part of one division. That is, the correction for a scale reading just one division above the 30-inch mark is: $+\frac{a}{A}$ divisions; for a reading two divisions above the correction is: $+2\frac{a}{A}$, etc. This, expressed in a mathematical formula, becomes—

$$\text{Correction} = C = (R_0 - h)\frac{a}{A};$$

in which R_0 is the reading at which the correction is zero and h is the observed reading, uncorrected, for temperature. This may be reduced to the following simpler form—

$$C = m - nh;$$

in which m and n are two quantities whose values are best determined from a complete series of readings of the actual height of the mercurial column, as compared with the reading of the top of the column of the fixed-cistern barometer. As the level of the mercury in the cistern is generally not visible in barometers of this type, the direct measurements of the heights of the column can not be made, and the necessary actual heights must, therefore, be obtained from readings of some standard barometer.

To determine the values of m and n accurately by comparisons, observations should be made over a greater range of pressures than ordinarily occur from day to day, and the best results will require observations under pressure artificially changed to suit.

25. Changes of temperature may cause the sectional areas of the tube and cistern to have a different relation than that assumed in the formula above, and may also change the value of R_0, but these effects are slight and are not considered here.

ERRORS OF BAROMETERS.

26. The actual reading of the height of the mercurial column of a barometer does not give exactly the true pressure of the air because of the effects of certain sources of error and disturbing influences for which corrections must be applied. These are:

(1) *Corrections for capillarity.*—In all barometers having comparatively small tubes, that is, of less diameter than from 0.7 to 1 inch, the top of the mercurial column, or meniscus, as the rounded surface is generally called, will nearly always be quite convex on account of the capillary action between the mercury and the glass. In consequence of this the mercury column is actually depressed a slight amount and never indicates the true barometric height. This source of error is one of the most troublesome to which barometers are subject, as the capillarity is never quite constant and there is no practicable method by which its changing value can be accurately determined in the daily use of an instrument.

The error due to capillarity is nearly always eliminated as far as possible from the scale reading by adjusting the scale so that allowance will be made for the average capillary depression. If an ordinary barometer be carefully examined it will be found that the 30-inch mark on the scale is appreciably less than 30 inches from the ivory point. In general, the difference represents the amount the mercurial column is depressed by capillarity. A portion of a barometer scale is shown enlarged at *v*, fig. 2 (at the top and at the right). The index line at *v* is made accurately 30 inches from the ivory point, but the 30-inch line on the scale is shown set slightly below to offset the capillary depression.

(2) *Correction for imperfect vacuum.*—It is generally assumed that the space in a barometer tube above the mercurial column is a perfect vacuum, and that there is no downward pressure upon the top of the column of mercury. This, however, is not strictly the case in any instance, and often an appreciable quantity of air or water vapor is present. Any vapor that the mercury may give off is, of course, always present. This latter, however, is very small, and is never considered except in the most refined investigations. If, therefore, any such pressures exist upon the top of the column it will be depressed, and a correction, which may be properly called correction for imperfect vacuum or reduction to perfect vacuum, should be applied. Such a correction will vary with both the temperature and the volume of the space. If the trace of air present is slight, as is nearly always the case in any good barometer, the correction for vacuum will be nearly constant, provided the volume is not changed much by great changes of pressure, as the changes corresponding to ordinary changes in temperature are comparatively small. Therefore, in ordinary observatory barometers this correction, like the one for capillarity, is included in the correction for instrumental error. When, however, a barometer is used at both high and low pressures, the volume of the vacuum space may change many fold, and in such a case any error due to imperfect vacuum is far from being constant.

(3) *Correction for instrumental or scale error.*—Errors arising from

several independent sources are embraced under this designation, as for example: (*a*) the graduated scale may not be adjusted so perfectly that its divisions are at exactly the right distance from the ivory point; (*b*) the sighting edge of the vernier may not be true or in proper correspondence with its zero graduation line; (*c*) the unavoidable errors and irregularities in the graduations of the barometer scale itself also introduce different errors from point to point along the scale. Nevertheless, sufficient precision is easily attainable in scale graduation in only a fairly good scale, and such errors are generally so small as to be unimportant in ordinary barometric observations and are seldom considered.

The combined effect of such sources of error as those just mentioned give rise to what is generally called the correction for instrumental or scale error.

The manufacturer, in adjusting a good barometer, endeavors to eliminate as completely as possible, or at least to reduce to a very small quantity, all the several corrections mentioned above, viz, correction for capillarity, for imperfect vacuum, and for instrumental error. This he can do by sliding the scale up or down a small fraction of an inch until he finds by repeated trials and comparative readings with a standard instrument that the new barometer, when corrected for temperature, as described below, gives the same or nearly the same readings as the standard. Any slight outstanding difference that may finally remain then becomes the "correction for instrumental error, including capillarity," or briefly, "correction for scale errors and capillarity."

By comparing a barometer in a partial vacuum, so as to ascertain the "correction for scale errors and capillarity" at several pressures, such, for example, as at each inch between 20 and 30 inches of pressure, it has been learned in a few interesting cases that very great differences in the correction may be found at different points of the scale; these differences, amounting in one case to eighty-three thousandths of an inch between 25 and 30 inches, could not be explained by any error of the scale or other influences, except that of the irregular capillary action at different points of the tube. These investigations demonstrated the necessity of ascertaining the correction for scale errors and capillarity of each instrument for the particular pressure at which that instrument is to be used.

(4) *Correction for temperature.*—The temperature of a barometer affects the accuracy of its readings in two ways. First, the metal scale expands and contracts with changing temperatures, and is, therefore, continually changing its length. Second, the mercury itself expands and contracts much more than the scale. The 30 cubic inches of warm mercury in a barometer tube, at say, a temperature of 80° F., will be more than 1 ounce lighter than the same volume of mercury at the freezing temperature.

The true pressure of the air, therefore, is not shown by the observed height of the mercurial column until we take into account both the temperature of the scale and the density of the mercury.

For this reason barometric readings require to be reduced to a reading which would have been obtained had the mercury and scale been at certain standard temperatures.

The standard temperature adopted for the mercury is always that of melting ice; that is, 0° C., or 32° F.

When the readings of the scale are taken in inches, the standard temperature for the scale reduction is then 62° F. If, however, the metric measures of length are used the standard temperature is then 0° C. In the latter case the same temperature serves for both the scale and the mercury.

There is thus a disparity between the temperature at which English and metric scales are of standard length; moreover, tables of barometric corrections for temperature usually give the reduction for both the scale and the mercury in one correction, whence it follows from these two circumstances that the corrections in English and in metric tables are not mutually convertible. An error is therefore introduced if the uncorrected reading of a mercurial barometer expressed in metric units is converted into English units, or vice versa, and a temperature correction afterwards applied to the result. The conversion of barometer readings from English to metric or from metric to English units can only be made correctly after each reading has been fully corrected for temperature. A further discussion of this point will be found in the Monthly Weather Review for July, 1898, page 302.

27. *Barometer correction cards.*—Each barometer of the Weather Bureau, when sent out, is accompanied by a correction card (Form No. 1059–Met'l) showing the correction for instrumental error, *and also the corrections of the attached thermometer.* If these latter corrections are as large as half a degree, which is, however, rarely the case, they should be applied to the reading of the attached thermometer *before taking the correction for temperature from the table.*

28. *Tables of temperature corrections.*—Tables of correction for temperature are computed by simple formulæ taking into account the known coefficients of expansion of the mercury and of the metal or material of which the scale is made. The scale in this sense includes all the metal parts between the ivory point and the top of the column of mercury. It is generally assumed that the temperatures of the scale and mercury are the same, and that the temperature is given by the indications of the attached thermometer.

For barometers with brass scales the following formula is used for computing corrections:

$$\text{Correction:} = C = -h\frac{t - 28.634}{1.1123\,t + 10{,}978}$$

in which h is the observed reading of the barometer *in inches*, and t is the temperature of the mercury and scale in degrees Fahrenheit.

The numerical factors in this equation are obtained by using the following values for the expansion of mercury and brass, viz:

Cubical expansion of mercury, .0001010 per degree Fahrenheit.
Linear expansion of brass, .0000102 per degree Fahrenheit.

In section VIII are given full tables of corrections computed by the above formula.

29. *Correction for density of mercury.*—If the density of the mercury is not the same in two barometers that are exactly alike in every other respect, the heights of the mercurial columns will not be the same for the same pressure. In such a case a reduction to mercury of a standard density will be required. The presence of 1 per cent of lead with mercury causes a change in density that would require a correction of about 0.051 of an inch. On the other hand, mercury containing even so little as one one-hundredth of 1 per cent of lead is rendered so exceedingly foul that it could not be used for barometric purposes. It is therefore easily seen that a correction for standard density is a refinement which need not ordinarily be considered.

NORMAL BAROMETER.—STANDARD BAROMETER.

30. It is easily understood, after what has been said above about errors of graduation, errors due to capillarity, to imperfect vaccum, to instrumental imperfection, etc., that even the best of ordinary barometers is liable to be quite incorrect until corrections for these errors have been determined. Moreover, from the nature of things we can not determine these corrections except by comparison with a standard barometer, and the question might properly be asked, "How do we know the standard barometer is right?" We will answer this by saying that the standard barometer ought to be a normal barometer. So few understand clearly the distinction between these words "standard" and "normal" in the present connection, that some explanation is necessary. In the first place the expression *normal barometer* is used a great deal by the Weather Bureau and meteorologists in general when, strictly speaking, the expression, should be normal barometric pressure; by which is meant the average of a great many years' observations of atmospheric pressure at a single station. In the present case the word *normal* has an entirely different meaning.

A standard barometer need not, necessarily, be anything more than an instrument which has been pronounced to be correct by some special authority. For instance, the Congress of the United States might say that the indications of such and such an instrument represent the true atmospheric pressure, and that the particular barometer in question is the standard of the nation. Such an instrument, although formally pronounced to be a standard, might, nevertheless, possess little more than the average accuracy and its indications still be more or less erroneous. Since the several errors to which barometers are subject can not, in the majority of cases, be determined except by comparison with an instrument whose errors are all known, a standard based only on the dictum of some authority can not necessarily be regarded as giving true indications. A normal barometer, however, is one, the construction of which is such that the instrument, fundamentally and independently of all other similar instruments, gives a true and complete measure of the pressure of the air.

Standard barometers should, therefore, generally be, also, normal barometers. It must not be understood that a normal barometer is absolutely without any error. The construction, however, is such that those errors, which can not be wholly eliminated, can yet be ascertained from the indications of the instrument itself. The error for capillary action, for example, is wholly eliminated by employing a tube of very large diameter. On the other hand, if the vacuum is not sufficiently perfect the error from this cause can still be ascertained, for the barometer will be constructed so that readings can be made when the vacuum chamber is large, and again when it is many times smaller and the pressure of the remnant of air therein proportionately increased; from such readings the desired corrections can be computed. So, also, other errors are either eliminated or are ascertained by special investigations, and the reading of the barometer, after all known corrections are made, is regarded as fundamentally correct.

Barometers of this type are generally very elaborate and complete and will not be described here. Several of the European normals are fully described by Professor Abbe in the Annual Report of the Chief Signal Officer, 1887, Part II.

II.—ANEROID BAROMETERS.

31. Figs. 11 and 12 represent two of the more important types of aneroid or holosteric barometers, showing, principally, the internal mechanisms. The first is a rather commoner form, but the second is, in general, somewhat better. The essential element is the same in both instruments and consists of the small metallic box or cell, *M*, the upper and lower walls of which are made of very thin circular sheets of corrugated German silver, which are soldered together on their outer edges, forming a very short cylinder. The air is thoroughly exhausted from this cell through a tube at one side, which, when the vacuum is as perfect as desired, is pinched tightly together, cut off, and hermetically sealed with solder, producing the projection seen at *c*. The flexible corrugated surfaces, which tend to

be collapsed by the pressure of the outside air, are forcibly held apart by the action of a strong steel spring, *R*. As the pressure of the air increases the spring is compressed and the corrugated surfaces approach each other slightly, returning again or separating still farther with diminution of pressure. To measure the atmospheric pressure it is only necessary to measure the minute movements of this flexible cell.

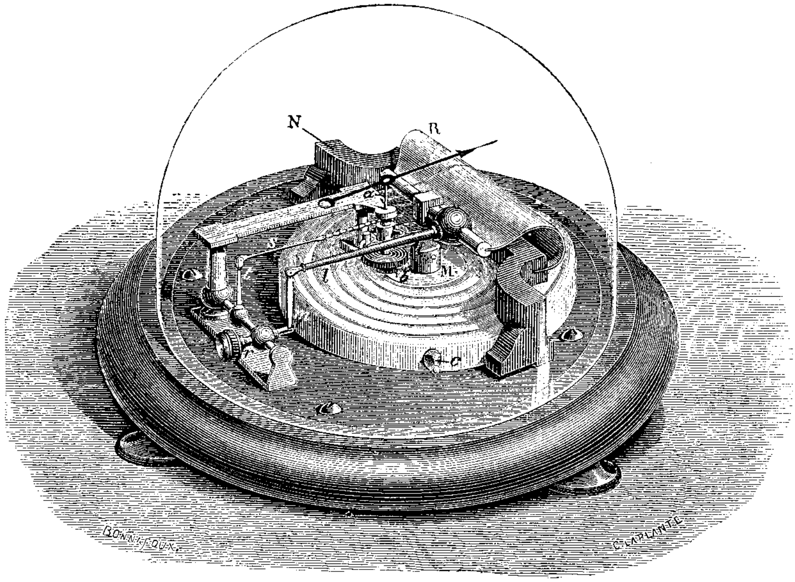


FIG. 11—Aneroid barometer.

The two forms of aneroid figured above differ simply in the manner by which the minute alterations in the elastic yielding of the spring are magnified and rendered measurable.

32. In the common aneroid a lever, *l*, attached directly to the spring connects by a link, *m*, with a very short arm of a sort of bell-crank lever, *r*, *t*, having a horizontal axis on pivots at each end.

The longer arm, *t*, of this bell-crank lever is connected by means of a wire, *s*, with a very fine chain, the other end of which winds around a very small wheel or drum on the axis, *a*, upon which is mounted the hand as seen. At *b* is shown a small spiral steel spring, like the hair-spring of a watch, which serves to take up the slack in the loose connections of the numerous joints, levers, and links.

At *r* is shown, also, a small counterpoise weight attached to the bell-crank lever to aid in securing a more stable position of the index when the barometer is placed in different positions, that is, whether the dial is horizontal, or vertical, or turned to one side or the other.

The point of attachment of the link, *m*, to the bell-crank lever is sometimes adjustable so that the movements of the hand can be made to correspond to the value of the scale graduations.

The steel spring, R, is also slightly adjustable by means of a screw from the underside working into part, N. This permits adjusting the hand to any particular point of the scale to give correct readings.

33. *Effects of temperature.*—The steel spring and the feebler elastic reaction of the composition metal of the vacuum chamber are appreciably weakened by increase of temperature, so that in some cases a rise of the pressure may seem to occur which is really caused by the weakening of the spring. Efforts are made to compensate for this sometimes by leaving a small quantity of air in the vacuum chamber, which when heated increases its pressure upward and tends to offset the weakening effect upon the springs. A better plan is to make the lever, l, of two different metals, viz, brass and iron, firmly brazed together. The differential expansion of these two metals with temperature changes produce flexure in the lever. By filing and adjusting the bimetallic bar, the flexure due to temperature can be made to just about balance the effect of temperature on the spring. The aneroid is then said to be "compensated," and this word is often found on the dial. In many cases this word is there when the compensation is very imperfect, and aneroids are often largely influenced by temperature.

34. *Defects.*—The friction and looseness in the joints of the links and the lack of perfect balance in the various parts give rise to continually changing errors in the readings of the aneroids. This will be shown by tapping the aneroid from different sides and holding it in a variety of positions; different readings will be given for each condition.

35. *Goldschmidt's aneroid.*—The numerous levers and links in the common aneroid are dispensed with in this form, and the minute movements of the cell and spring are measured directly by means of a micrometer screw.

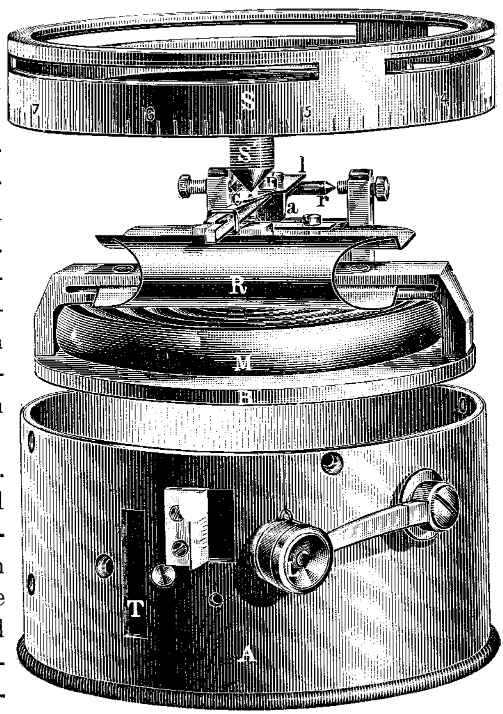


Fig. 12.—Goldschmidt's aneroid.

This is accomplished in several different ways by manufacturers, a common form of instument being shown in fig. 12, where the parts have been separated for a better view. The plate, B, with its attached mechanisms, is secured in the bottom of the box, *A*. The micrometer screw, *S*, works through the cover of the box. The corrugated aneroid vacuum chamber, *M*, is held distended in the usual manner by the steel spring, *R*. A sharp knife-edge projection, *a*, of a double-formed lever, *l*, rests upon a smooth polished spot near the outer end of the spring. This spot is sometimes a bit of glass or agate. The lever, *l*, is pivoted delicately upon an axis at *r*, and is formed of two parts joined near the axis. The upper piece of this lever is a very delicate steel spring, with a flat polished surface at *o*, which by the springiness of the arm presses against the point of the micrometer screw, *S′*. At the ends the spring and lever are formed with little flat surfaces, each having a fine line engraved across the middle. This construction is not clearly seen in the drawing. To observe the air pressure the aneroid must be "set" by bringing the above-mentioned lines into coincidence. For this purpose, and at the same time to measure the movement necessary to bring about such a coincidence, the finely-cut micrometer screw, *S′*, is provided. The large head, *S*, having a scale of graduations engraved upon its outer rim, being turned, the point of the screw presses against the spring at *o*, deflects it so that the lines upon the ends of the spring and lever may be placed in exact coincidence. To facilitate making this adjustment accurately, a small magnifying glass, *L*, is generally provided. The small scale, *P*, is opposite the ends of the lever, *l*, when the mechanisms are in their normal position, and indicates the whole number of turns made by the screw, or, what is the same thing and more convenient, shows the pressure corresponding to the successive positions of the screw. The fractions of a turn are indicated accurately by the graduations on the head of the screw.

36. *Temperature effects.*—The Goldschmidt aneroid is not compensated for temperature, but is generally accompanied by a table of corrections therefor, the temperature being indicated by a small thermometer, the scale of which, in the aneroid shown, is visible through an opening at *T*.

37. *Reading, how made.*—Aneroids of this pattern are read by first turning the micrometer screw until the lines upon the spring and lever come into exact coincidence. The reading on the scale, *P*, is noted, and to this is added the part taken from the graduations on the head.

38. Consult paragraphs 74 and 75 for information respecting the use of the aneroid in determining elevations.

39. *How adjusted to standard pressures.*—The aneroid barometer, no matter how perfectly constructed, does not indicate any particular pressure until by careful comparison with a standard barometer its index is adjusted to give as nearly as possible the same reading as the standard. This adjustment is made by means of the screw, which

in nearly all aneroids is seen just within a small hole in the back of the case.

The Goldschmidt aneroid is similarly adjusted in a variety of ways, of which a common one is to shift the zero or index line at which the reading of the micrometer screw is made.

40. *Errors and defects of aneroids in general.*—After being once adjusted to give accurate pressures, as described in what precedes, the aneroid should be handled with great care. Violent knocks and shaking will, especially with the common aneroid, almost certainly change or shift the various links and levers in their joints and change, more or less permanently, the position of the index. For such reasons aneroids are very liable to acquire unknown and often large accidental errors, and can not, therefore, be regarded as very satisfactory instruments.

41. *Errors due to very slow changes, "creeping."*—If an aneroid adjusted to read correctly under ordinary air pressures is placed within the receiver of an air pump the index will quickly fall to a lower pressure upon a partial vacuum being formed. If, however, the vacuum be maintained at constantly the same pressure for many days in succession the reading of the aneroid will be found to gradually become lower and lower, but after three or four weeks further changes cease, or are very small. The amount of this slow change differs greatly, and may be from one-half inch or less to over an inch, according to the diminution of pressure and other circumstances. Again, when the barometer is removed from the air pump it does not immediately return to its original correct reading, but its indications will be found to be too low, several weeks being again consumed in a slow return to approximately its former correct reading.

This "creeping" action depends, no doubt, upon some molecular changes, as yet not clearly understood, that take place within the materials of the aneroid box and steel springs. In any case the readings are liable to be very seriously in error, and tourists and others who carry with them aneroids for the purpose of ascertaining the elevation of summits and places visited, should have means to determine and eliminate the very serious errors referred to above. A further discussion of these errors will be found in the Monthly Weather Review for September, 1898, page 410.

42. The aneroid barometer is a convenient instrument for showing more or less accurately *the character and the amount of barometric changes* going on from day to day, but the mercurial barometer is the only instrument which gives atmospheric pressures with that degree of precision required in simultaneous meteorological observations.

43. *Test of condition of aneroid.*—Aneroids, seemingly good, are often defective, because some of the joints of the levers and pivots are too

tight, causing the hand to stick and not move with the perfect freedom it should. The condition of an aneroid can be quickly tested in this respect by tapping the instrument on the side or bottom with the fingers or knuckles, or perhaps better by lifting the instrument about one-fourth of an inch from a table or cane-seated chair and placing it back again somewhat sharply. Under this treatment, if the joints and levers are perfectly free, the hand will jump away from its position and return quickly with a vibratory and quivering movement, returning accurately to its original position. If the instrument is defective, the hand in some cases will not respond to the slight knocks, or will do so without exhibiting any vibratory quivering movement, or upon being disturbed, it may move a little, but will not return to its original position.

III.—MISCELLANEOUS BAROMETERS.

44. Many curious and interesting forms of barometers have been devised for the purpose of showing the changes of air pressure in a much more magnified manner than is possible with ordinary barometers, especially of the mercurial pattern. A few of these will be briefly mentioned.

45. *Water barometer.*—This may be constructed in practically the same manner as the mercurial barometer, except that water is used instead of mercury. Now, as mercury is 13.6 times as heavy as water, it will result that the water column will be 13.6 times higher than the mercurial barometer, or about 34 feet high, also a change of one inch in pressure by the mercurial barometer will appear as a change of 13.6 inches in the water barometer.

The great defect of the water barometer, aside from its inconvenient proportions, is the shortening of the column, due to the pressure of water vapor in the vacuum. This shortening amounts to about 10 inches at a temperature of 70° F., and if the temperature were to rise 10° the pressure would seem to fall nearly 4 inches, when really no change of pressure had occurred.

46. *Glycerine barometer.*—Glycerine, sulphuric acid, or nonvolatile oils may also be used in place of mercury, each affording a magnified indication of pressure changes, as in the case of the water barometer, and with the advantage that the errors due to vapor pressures are much less, or are quite inappreciable.

47. *Diagonal, spiral barometers, etc.*—It is easily seen that if the top portion of a barometer tube be bent off at a small inclination upward from a horizontal position, the movement of the mercury along this diagonal portion will exhibit, in a magnified manner, the ordinary fluctuations of atmospheric pressure. The same result is secured by forming the top portion of a barometer tube into a spiral coil having suitable graduations.

48. *Dial barometers.*—Probably the most practical expedient for magnifying the indications of an ordinary siphon mercurial barometer is the form known as the "dial barometer," shown in fig. 13.

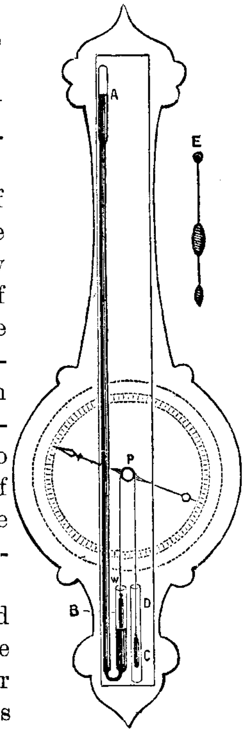


FIG. 13.—Dial barometer.

The action of the instrument will be readily understood from the diagram without further explanation.

49. *Sympiesometer.*—This is another form of sensitive barometer, in which the pressure of the air, acting through a short column of liquid of low specific gravity, is made to compress a portion of air confined within the instrument. In this case it is necessary to make allowance for the expansion and contraction of the confined air with changes of temperature. This is conveniently accomplished by providing the instrument with two scales; one of which, containing the readings of pressure, is set to a certain line on the other scale according to the temperature indicated by the attached thermometer of the apparatus.

50. *Howson's barometer.*—This ingenious and novel device is shown in section in fig. 15. The barometer tube is large in diameter and longer than usual. The cistern is recurved and extends as a long core up inside the barometer tube, reaching within 3 or 4 inches of the top of the column of mercury. The proportions are arranged to be such that the upward pressure of the air on the underside of the cistern is sufficient to sustain the cistern and contents suspended from the end of the barometer tube.

When a change of pressure occurs the cistern is caused either to ascend upon the barometer tube or to move down to a new position of equilibrium, and, by selecting suitable proportions between the internal diameter of the barometer tube and the thickness of its walls, in relation to the diameters of the core and cistern, the movement of the latter up and down the tube with changes of atmospheric pressure can be made to represent pressures upon a greatly magnified scale.

51. *Magnifying siphon barometer.*—Fig. 16 illustrates still another expedient by which the indications of a plain mercurial barometer may be greatly magnified. The short leg of a siphon barometer is extended upward, in the manner shown. The small-bore tube, *a*, is enlarged at the top to have the same diameter as the cistern portion. The portions, *a*, *b*, *c*, of the short leg are filled up to a point at about *h* with colored water, and then above this with kerosene or some other

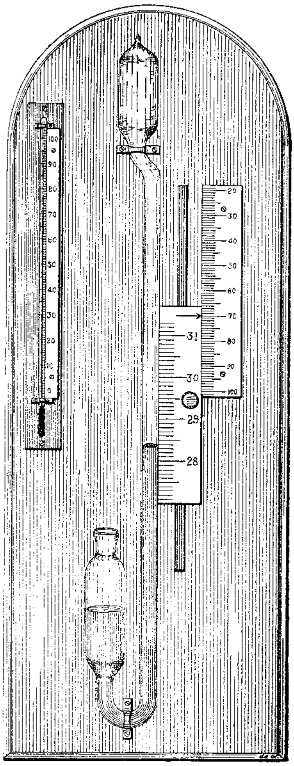


Fig. 14.—Sympiesometer.

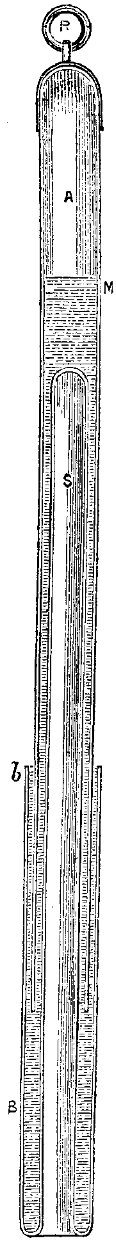


Fig. 15.—Howson's barometer.

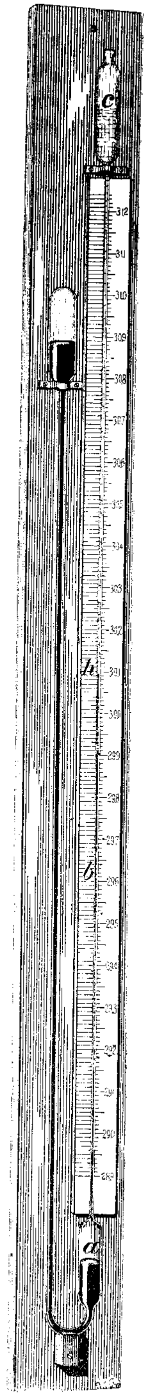


Fig. 16.—Three-liquid barometer.

liquid of nearly the same density as water and with which it does not mix. It is plain that when the level of the mercury in the short leg changes, the meniscus separating the oil from the water in the small-bore tube will be seen to change its position by an amount enlarged in proportion to the relation between the areas of the cistern and the small tube.

52. *General comments on magnifying barometers.*—The special barometers described above are interesting and in many respects curious, but they can not be regarded as anything more than philosophical toys and curiosities. It is impracticable in any of the magnifying instruments to determine the absolute pressure with great precision, for the expedients of magnification introduce sources of both constant and accidental errors that affect the results to a magnified extent, so that even less precision generally results than is attained with well-made mercurial barometers of the simple pattern.

IV.—BAROGRAPHS, OR CONTINUOUSLY RECORDING BAROMETERS.

53. The barograph is a form of barometer with the addition of parts by which a continuous record of the barometric oscillations are traced hour by hour upon a sheet of moving paper, or obtained by photographic processes upon sensitized plates. Many different forms of apparatus have been devised, nearly all of which are more or less elaborate and, in general, are not highly accurate. In most cases, the changing temperature to which the instruments are subjected introduces small errors and the mechanisms effecting continuous registration either obstruct the free action of the barometer proper, or do not perfectly transmit to the record sheet a trace representing exactly the original fluctuations of pressure. The absolute value of the pressure indicated by the position of the tracing point is also subject to uncertainties, and while *changes* of pressure are shown with greater or less accuracy, it is impossible, even with the best instruments, to record the *absolute* pressure with a precision equal to that of an eye-reading of a standard barometer. In general, therefore, the indications of automatic instruments are checked and corrected by reference to occasional eye readings of a standard barometer.

54. It hardly requires to be said that the mercurial barograph is more reliable and gives more accurate results than those of the aneroid type, and many ingenious mechanisms are employed to effect the continuous registration, thus:

(1) In some cases this is accomplished by directly photographing on a moving sheet of sensitized paper or plate the changing positions of the summit of a barometric column, notably the case at the Kew Observatory, England.

(2) In other forms, a float resting upon the mercury in the open leg

of a siphon barometer communicates the motion directly to a lever which carries the recording pen at its end and produces the record on a magnified scale. As, in this latter class, the friction of the pen and magnifying levers obstruct free motion of the float so that incorrect records are made, the construction in some forms is modified and another form results in which clock movements, or electro-magnets, are made to perform the real labor of producing the record, thus:

(3) The motion of the float is communicated to a very delicately poised lever, the slightest movement of which sends a current of electricity through properly disposed magnets, which either alone or acting in conjunction with clockwork, perform the real labor of moving the pen mechanisms and preserving a proper condition in the equilibrium of the float.

(4) A distinct class of barographs is obtained by constructing mechanisms which measure and record the barometric oscillations by *weighing* the changing quantities of mercury within a poised barometer tube or cistern. The weighing is effected by suspending the barometer tube, or its cistern, from the beam of a balance which is continuously preserved in a condition of equilibrium by the automatic movement of a counterpoise traveling along the beam of the balance. The movement of the counterpoise is effected either by clockwork, or by electro-magnets, or by both.

(4*a*) A modification of the weighing principle consists in substituting for the balance mechanisms, coiled stéel springs by the deflection of which the changing weights are measured and recorded.

55. *Foreman's barograph.*—This is shown in fig. 17. It belongs to the class mentioned above under (3). Prof. G. W. Hough, director of Dudley Observatory, Albany, N. Y., about 1862, perfected barographs recording on this principle, the form here figured being designed by Mr. H. L. Foreman, who was at one time Professor Hough's assistant. The glass siphon tube of the barograph is at the back at *B*, and is only partly visible, the bend being hidden behind the record cylinder, *A*. The open end of the siphon tube is seen at *C*; an iron float rests lightly upon the surface of the mercury within, being sustained by means of a fine wire, *t*, from the short end of the lever, *l*, which is delicately poised upon steel knife edges at *r*. The long end of this lever at *h* is tipped with platinum and placed between two platinum-pointed screws, both of which nearly, but not quite, touch the tip of the lever when the latter is poised in proper equilibrium. The upper screw is connected by the wire, *W*, with an electro-magnet at the back of the instrument; a corresponding electro-magnet, partly seen at *M*, is connected by the wire, *W'*, with the screw just beneath the tip of the lever. *P* is a strong clockwork driven by the cord, *T*, and set in motion whenever released by the action of the electro-magnets at *M*. The clock movement, *D*, regulated by the pendulum, *F*, gives motion

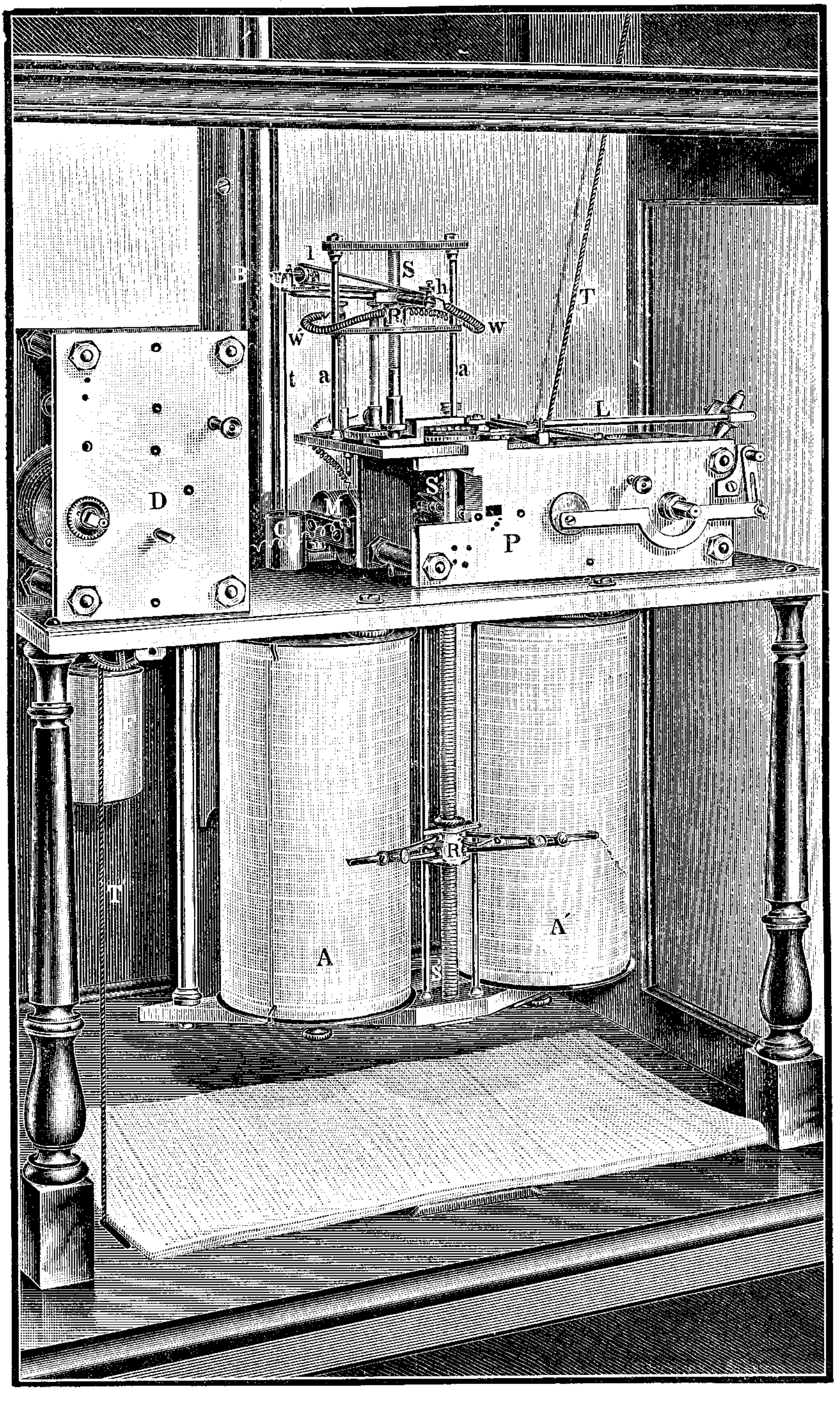


Fig. 17.—Foreman's barograph.

to the recording cylinders, A, A'. The cylinder, A, makes one revolution in twenty-four hours, whereas A' revolves at the much slower rate of about one revolution in sixteen days.

The lever, l, together with the platinum-pointed screws and electrical connections, W, W', are all mounted upon a carrier, R, which is moved by the fine-threaded screw, S, and guided by the columns a, a. The coarse-threaded screw, S', is provided with the double-pen carrier, R', the screws, S' and S, being geared with each other by means of suitable wheels. We will suppose that the mechanisms have been properly set so that the iron float is normally sustained upon the surface of the mercury and the lever, l, poised in equilibrium, in which case the platinum tip, h, will stand about midway between the platinum-pointed screws above and below it, respectively. The pen carrier, R', must also then occupy such a position on the screw that the tracing pens will indicate the true barometric pressure upon the rulings on the record sheet. Appropriate connections with an electric battery being made, the action of the mechanisms will be as follows:

Any minute change in the level of the mercury will alter the position of the iron float, in consequence of which the platinum tip of the lever, l, will move into contact with one or the other of the platinum-tipped screws, causing a current of electricity to be directed through the electro-magnet connected therewith. The action of either electro-magnet releases the clockwork, P. In doing this, however, the one magnet shifts the lever, L, laterally toward the back of the instrument, while this lateral movement will be toward the front if brought about by the action of the other magnet. The movement of the clockwork causes the lever, L, to advance and recede so that a pawl upon the end, engaging a tooth of a ratchet wheel upon the end of the screw, S', revolves the latter a fraction of a turn. This fractional turn will be in one direction if the lever, L, is drawn backward, or in the opposite direction if L is pushed forward, according as the lever, l, has made contact with the upper or under screw. This movement of the screw, S', shifts the pen carrier, R', and the pens upon the record sheet, and, being communicated to the screw, S, causes a proportionate change to take place in the float carrier, R. The clockwork automatically stops after one such cycle of actions. If, after these movements, the lever, l, is again poised in equilibrium, no further action ensues until the contact of h with one or the other of the screws is again made, whereupon the cycle of actions will again be set up and, if necessary, repeated in quick succession until the equilibrium of the poised lever, l, is restored. The movement of the pen carrier, R', corresponding to a change in the position of the float is four times as great as the change in the height of the mercurial column. A change of 1 inch in pressure, therefore, is represented as a change of 4 inches on the sheet. Each closure of the circuit producing $\frac{1}{25}$ revolution of the screw, S', or $\frac{1}{50}$ revolution of S, represents a change in the height of the mercurial column of 0.001 inch, which is the nominal sensitiveness of the instrument. Owing, however, to unavoidable imperfections in screw threads and electric contacts and the capillary action of the mercury in the barometer tube, the probable error of the instrument is much greater than this, no doubt amounting to at least 0.01 inch.

By selecting proper proportions for the long and short legs of a siphon barometer, the effects of temperature can be almost perfectly eliminated. This, however, appears not to have been considered when Foreman's barograph was designed, and the records are subject to small periodic errors due to temperature changes.

Owing to the presence of the float on the surface of the mercury in the short leg, and to other causes, it is practically impossible to make a direct measurement of the actual height of the column of mercury. When, therefore, it is desired to set the recording pens or check their positions in relation to the true air pressure, it is necessary to make a reading of the standard barometer. In the barograph next described the effect of temperature is inappreciable, and the actual height of the mercurial column may be directly measured at any time, thus dispensing with the extra barometer required with Foreman's barograph.

56. *Marvin's normal barograph.*—This instrument is shown in figs. 18 and 19. It belongs to the class mentioned above under (4), wherein the mercurial column is directly weighed upon a balance.

The glass tube which, with the top portion of the mercurial column, may be seen at *B*, is freely suspended by the hook, *h*, from the balance, *A*. The point of the tube dips into the mercury contained in the cistern, *C*, which is suspended by a gimbal joint from the columns, *d*, *d*, by means of the metal tube, *B'*, which forms a sheath and protection for the glass barometer tube proper. The weight of the barometer tube on the short arm of the beam, *A*, is balanced by the rolling carriage, *W*, and a fixed weight (not shown) on the end of the long arm of *A*. Whenever a change occurs in the height of the mercurial column, the weight changes, and the carriage, *W*, must be moved to a new position if equilibrium is to be preserved. In order to make the motions of the carriage, *W*, automatic, a platinum-tipped contact spring is attached to the balance beam at the extreme end, *r*, of the long arm. The slightest displacement of the beam from its position of equilibrium causes the spring to move into contact with one or the other of two platinum-pointed screws, shown enlarged in fig. 19 at *m*, *m'*. These are electrically connected, respectively, with the magnets, *M* and *M'*, so that when the spring, *r*, makes contact with *m* or *m'*, an electric battery being in proper connection, a current is caused to flow through the corresponding electro-magnet, the action of which

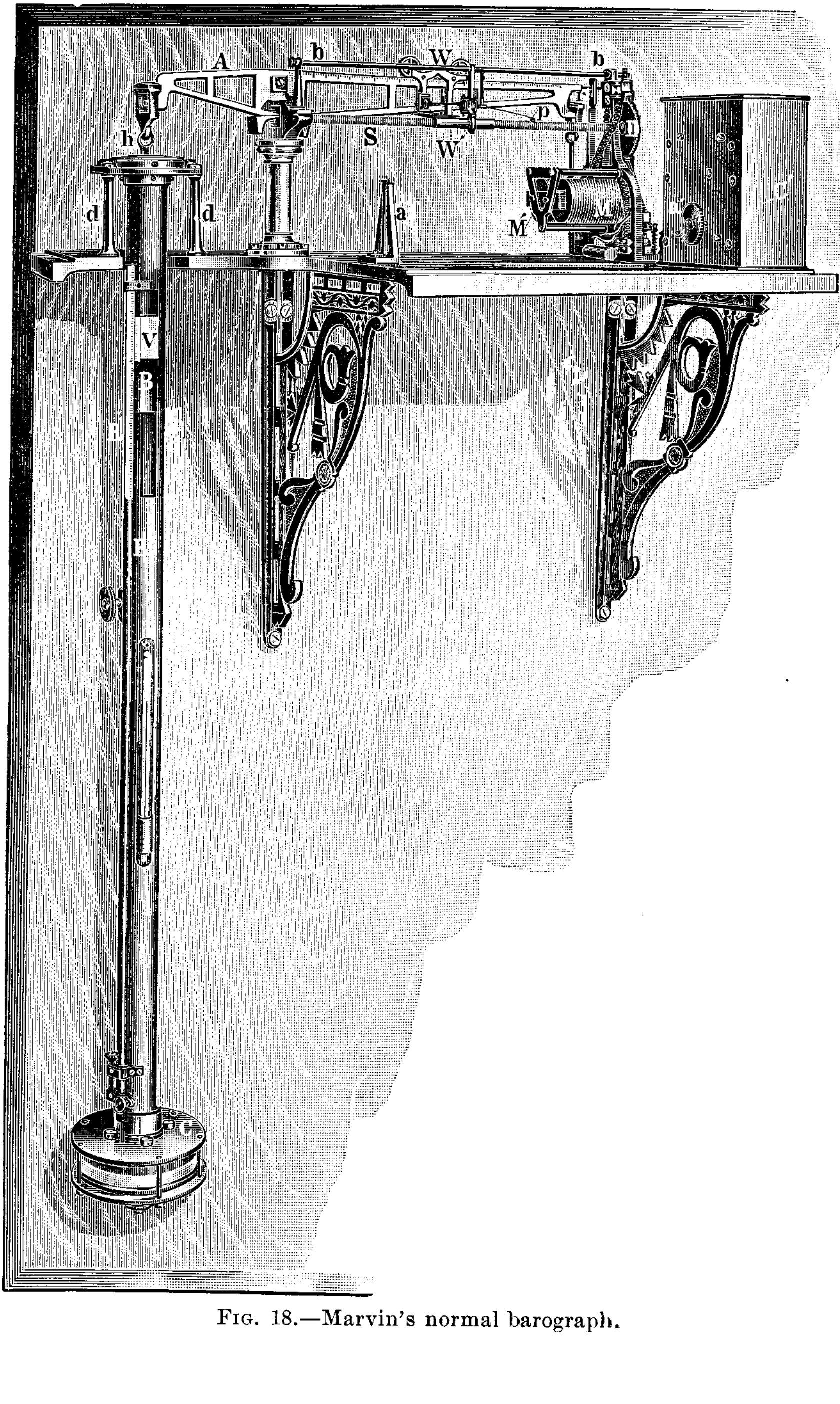


Fig. 18.—Marvin's normal barograph.

causes the pin, *N* or *N′*, to engage the teeth of the notched wheel, *D*, in such a manner as to revolve it tooth by tooth. The long screw, *S*, fig. 18, carries the wheel, *D*, fixed at its end so as to be revolved thereby. The threaded carrier, *W′*, fitted to the screw, *S*, is connected by a double universal linkage to the rolling carriage, *W*. The electro-magnets thus act very directly through the wheel, *D*, and the screw, *S*, to automatically move the carriage, *W*, into such positions as may be required to maintain the equilibrium of the balance; that is, to prevent the contact spring on the beam from remaining continuously in contact with either screw *m* or *m′*.

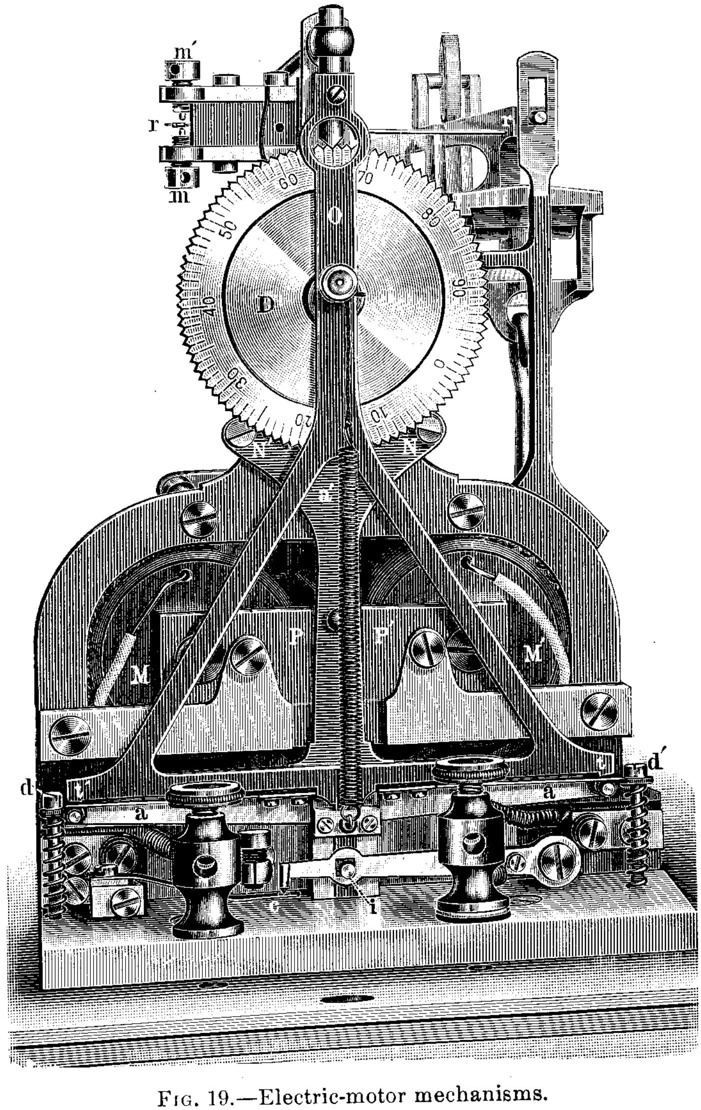


Fig. 19.—Electric-motor mechanisms.

The motor mechanisms act in such a manner that, whenever the equilibrium is disturbed and the electric circuit closed, the armature of whichever electro-magnet is affected makes stroke after stroke, revolving the wheel, *D*, until the equilibrium is restored. Generally one or two strokes only are necessary, representing a change in the carriage corresponding to only the ten-thousandth of an inch of pressure, as explained below.

The continuous record of the pressure, as indicated by the successive positions of the rolling carriage, is obtained in a very direct and simple manner. A delicate spring, adjustably attached to the threaded carrier, *W′*, is fitted with a pen, *p*, fig. 18, and traces the pressure curve upon a large cylinder, not shown in the figure, but mounted with its axis in the bearings *a*, *a′*. The cylinder is revolved regularly by the clock movement, *C′*.

If the height of the mercurial column changes 1 inch, the rolling carriage and recording pen will move 5 inches, thus giving a sufficient magnification to render estimations of the pressure to the one-thousandth part of an inch practicable.

The portion of the long arm of the beam over which the rolling carriage moves is provided with a scale of 20 subdivisions to the inch, which represent hundredths of an inch of pressure. Still further subdivision is effected by reference to the graduations on the face of the notched wheel, *D*. These represent the ten-thousandth part of an inch in pressure. Thus a mere inspection of the position of the carriage on the beam, together with the reading on the notched wheel, gives the air pressure to four decimal places. Owing to the frictional resistances and other influences unavoidable in all such mechanisms, the fourth figure of decimals can not be regarded as having a real pressure significance.

The readings are as accurate, probably, as the best eye readings of a good mercurial barometer; that is, to about one-thousandth of an inch.

The record is not appreciably affected by changes of temperature that affect the whole instrument uniformly.

57. *Aneroid barographs.*—Extremely simple and portable barographs are constructed upon the aneroid principle, of which that of Richard being widely used, is fully described. See fig. 20.

It consists of a cylinder, *A*, on which the recording paper is wound, revolving once a week by means of a clockwork contained inside. A series of corrugated metallic shells, *B*, eight in number, joined one above the other and exhausted of air, form an aneroid system eight times as sensitive as a single chamber. The movement of the shells is still further greatly magnified and transmitted to the recording pen, *C*, by a series of connecting levers. The pen may be released from contact with the paper by pushing the lever, *D*, to the right.

The corrugated shells are the same as used in ordinary aneroids, as described in paragraph 31, the steel springs for distending the shells being placed inside. The shells are made into a vertical column by screwing the one on the other. The lower base of the column being fixed, the upper end rises and falls with every variation in the atmospheric pressure, by a quantity which is the sum of the displacements of each elementary shell.

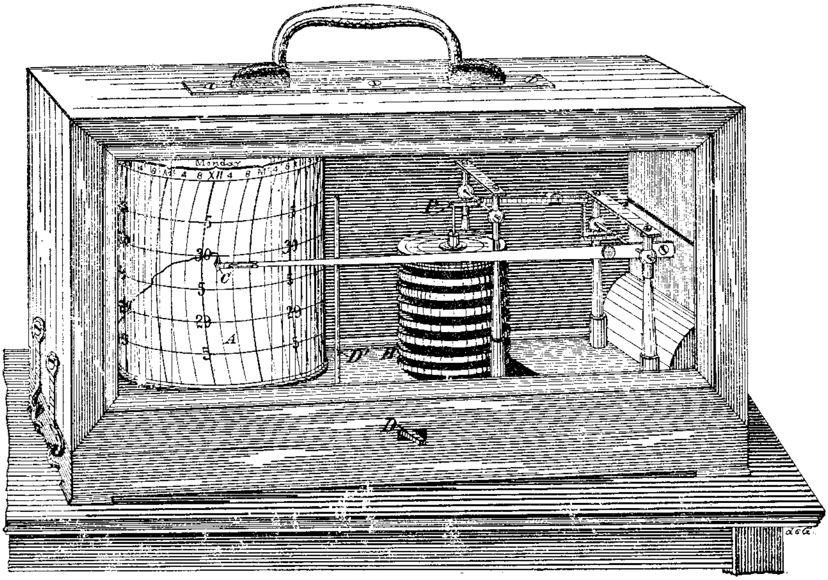


FIG. 20.—Richard's aneroid barograph.

The compensation for temperature is accomplished by leaving a sufficient quantity of air in one of the shells, ascertained by experiment when the instrument is made, so that with a rise of temperature the tendency of the barometer to register too low on account of the weakening of the springs, the expansion of the levers and other parts is counteracted by the increased pressure of the air in the shell. The instrument, however, should be kept at a uniform temperature as far as possible.

V.—GENERAL INSTRUCTIONS.

(A) FOR CARE AND USE OF BAROMETERS.

58. *Exposure of barometers.*—The two important considerations in selecting a proper location for a barometer are (1) that the cistern and top of the mercurial column may be in a good light and (2) that the temperature is as constant as possible. The best conditions for light are obtained when the barometer can be placed between the observer and a window, preferably a north one, covered either with

tissue paper or fitted with ground glass. Very nearly as good results are obtained by a light from one side reflected from clean white paper or white glass immediately back of the barometer. The top of the column should be about the height of the observer's eye. The barometer should not be exposed either to the direct rays of the sun or to the air currents that are always in the vicinity of cracks and crevices in windows.

In establishing stations, officials will use special care in selecting the exposure of the barometers and satisfy the conditions stated above as perfectly as possible. In general, it will be necessary to avoid exposures near windows, as proper temperature conditions can not be found in such locations.

As houses, no matter how tightly built, always permit the free flow of air in and out through innumerable crevices, ventilators, chimneys, etc., it results that the air pressure within is exactly the same as without, except possibly very slight differences of very short duration. If such were not the case it would be necessary to expose barometers out of doors to obtain the real air pressure.

59. *Pumping of barometers.*—Notwithstanding what has just been said about the pressure indoors and out being the same, it often occurs during very windy, gusty occasions that barometers within doors are subjected to very rapid and irregular oscillations of pressure, caused by gusts of wind blowing sometimes into doorways, windows, chimneys, and momentarily increasing the pressure, or equally by blowing across chimney tops and otherwise, so as to produce a sort of suction that momentarily diminishes the general pressure. In consequence of these effects the mercurial column of a barometer may be observed on such occasions to irregularly rise and fall within narrow limits, the motion in many cases being little more than changes in the curvature of the meniscus. This action is called the "pumping" of barometers, and, of course, interferes with accurate pressure observations.

The term "pumping" is also applied to the much more violent oscillation of the mercurial column, such, for instance, as will occur when an ordinary barometer is exposed on a vessel at sea, or when carried in an upright position in the hand. In barometers for use on shipboard this action is prevented by making the lower portion of the glass tube of very fine bore, so that the movement of the mercury is necessarily too slow to follow sudden and irregular oscillations of pressure.

60. *Verticality of barometers.*—For accurate results it is necessary that barometers should be exactly vertical when the adjustments for reading are made. For this purpose the better forms of barometers are arranged to be suspended from rings at the top so that the instrument, itself acts as a plumb line and takes a vertical position with sufficient accuracy. It is desirable, however, for convenience in set-

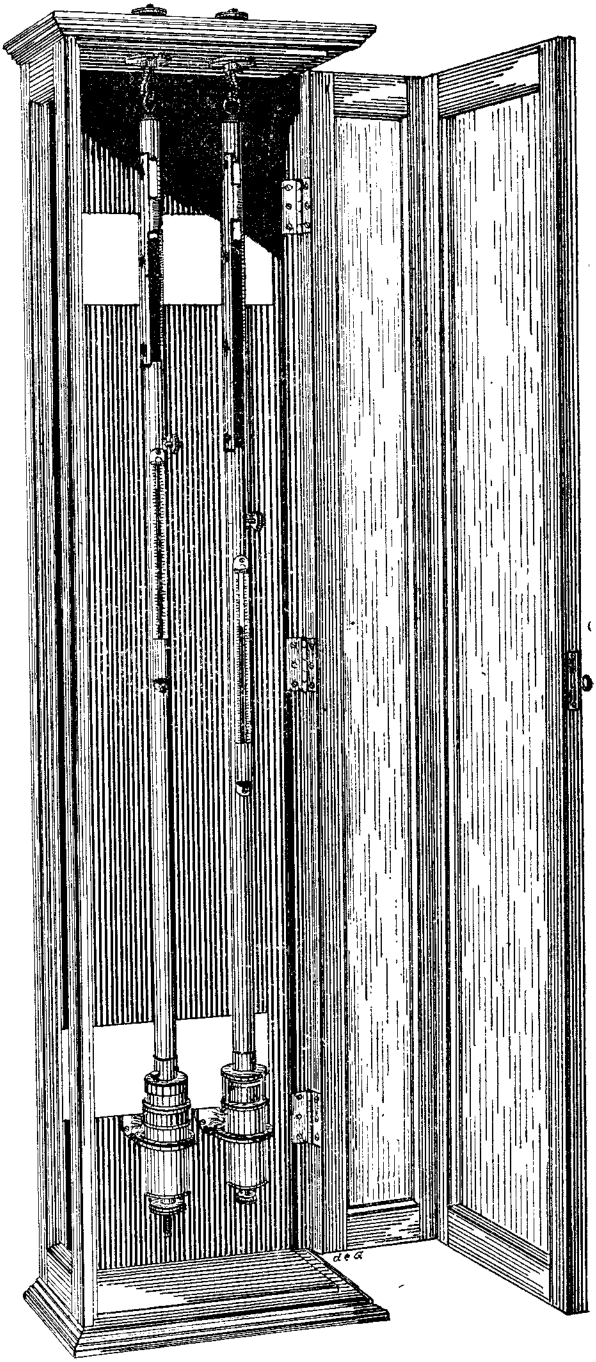


FIG. 21.—Improved barometer box.

ting the barometer as well as to insure the permanent verticality of the instrument, to steady it in supports which are first adjusted once for all, so that the barometer is accurately vertical, as determined by a plumb line applied alternately at the front and one side.

61. *Improved barometer box.*—The standard pattern of barometer box now in use by the Weather Bureau, is shown in fig. 21.

This box must be securely attached to the wall in a position affording good light and not subject to sudden changes of temperature. In many cases it will be necessary to first fasten to the wall hardwood strips, to which the top and bottom of the barometer box can be secured by screws passing through metal plates provided for this purpose. Place the screw for holding the top of the box in the center of the top strip at the place it is desired to hang the box, and suspend the box thereon. When the box is set about vertical (as determined by a plumb line) secure it firmly at the bottom by a screw passing through the metal plate into the wooden strip.

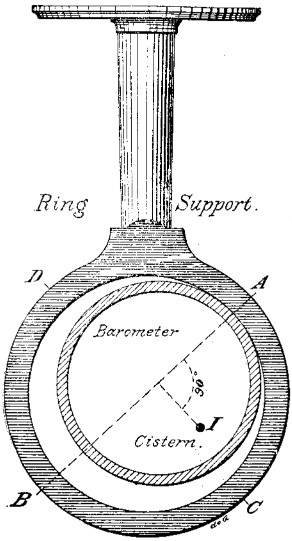


FIG. 22.—Barometer cistern and ring support.

The hooks in the top of the barometer box will, upon examination, be found to be adjustable in their positions. Place them in their central position and hang thereon the "station" and "extra" barometers. Next, find the position at bottom for attaching the ring-shaped guides, one of which is shown in fig. 22. These rings should be slipped over the lower end of the barometer, and placed about the midheight of the cylindrical part of the cistern. Mark the screw holes and fasten the rings to the back of the box. The barometer when at rest should hang freely within this ring, and may be adjusted to do so by the hook at the top. When the rings are fitted with centering screws these should be carefully screwed up until the barometer cistern is very gently clamped and held steadily, but not in the least deflected from its vertical position when free.

Barometers that swing slightly free within the ring support should, in setting, be steadied against one side of the ring, as shown in fig. 22. The following caution must, however, be observed.

62. *Caution against error.*—In adjusting the barometer for reading it is very important that it be steadied against the ring in the proper manner, otherwise an appreciable error is introduced, because of imperfect verticality.

If *I*, fig. 22, is the position of the ivory point, then steady the cistern against the ring at *A* or at *B*, but never at *C* or *D*, or at other points. *A and B should always be in a line exactly at right angles to a line through the ivory point and the center of the cistern.*

A little thought will show the necessity for this. If, for illustration, we imagine the ivory point at one side and just in contact with the mercurial surface and the barometer vertical, it is very clear that if we swing the barometer out of vertical a little either to one side or the other, the ivory point will either dip into the mercury a little or rise above the surface, whereas, if the barometer be deflected backward or forward, there will be little or no perceptible change in the level of the mercury at the ivory point.

63. *Old style barometer boxes.*—The simplest form of box used by this Bureau is shown in an improved form in fig. 23. The top end of the box is made of thick material, which is recessed to receive the top portion of the barometer when suspended upon the long hook, *H*, screwed into the top. For reading, the barometer is drawn out upon the hook, as shown in the figure, and returned to the box after the observation. The lid of the box is fitted to close under the hook so that the whole barometer is thoroughly encased and well protected. Except that the barometer must be shifted out and in the box every time readings are made, and the further disadvantage that the cistern necessarily swings free, this style of box answers the purpose in a very satisfactory manner.

64. The barometer should be carefully lifted along the hook and not made to slide roughly or permitted to knock against the guides in the box.

65. When boxes, such as described in the preceding paragraphs, are not furnished, the barometer may be suspended from almost any suitable hook securely fastened to the wall in such location as will satisfy, as far as possible, the conditions of paragraph 58.

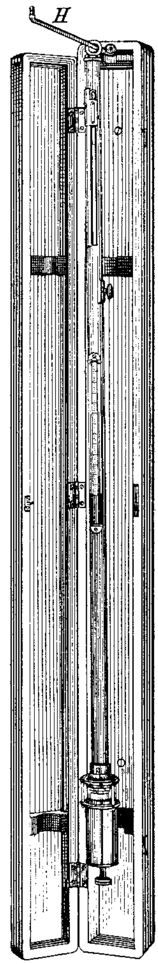


FIG. 23.—Barometer box.

66. *How to set and observe the barometer.*—Having in mind the various sources of error affecting barometers and other peculiarities of the instrument, we may next consider how best to secure accurate readings. The presence of the observer's body near the barometer tends to increase its temperature. The scale and outer parts are affected first, then the thermometer, and much more slowly the mercurial column. Generally, however, this effect is slight, as only a moment or two are required in making a reading. Nevertheless, it is best to first read the attached thermometer. Next, if the barometer

is freely suspended, jostle the cistern a little so that the mercurial surfaces may be detached if they tend to cling to the glass walls. To "set" the cistern of the barometer, the level of the mercury should be lowered a little by turning the milled head, *O*, fig. 3, and raised again until it is just in contact with the ivory point. To make this adjustment of the mercury to the ivory point accurately requires care and sharp scrutiny.

Adjustment of cistern, first method.—One way is to sight between the point and the mercury, and watch for the slightest thread of light that can be detected between the point and the mercury. The screw should be turned very carefully until this thread of light just disappears. This method is believed to be best and is uniformly practised by the experts at the Central Office. It is equally applicable to new barometers with bright mercurial surfaces, and to older ones the mercury of which is more or less oxidized. The light ought to be strong from behind the barometer and the front of the cistern be in shadow.

Second method.—The adjustment of the mercury to the ivory point may also be determined by watching the formation and disappearance of the small, dimple-like depression made in the mercury when the ivory point is pressed into the mercury a little and again withdrawn. When the dimple just disappears the surface may be supposed in contact with the ivory point. The mercury often clings to the ivory point, especially when the ivory is newly cut. This method, however, is not so reliable and accurate, and, in general, can be followed only with clean mercury. Moreover, it is not good practise to lower the mercury any slight amount after it is once raised to the ivory point. The effect of this, generally, is to change simply the convexity of the meniscus at the top of the column, and this gives rise to a new and unknown correction for capillarity. The most uniform results are obtained by gradually raising the mercury until precise contact is secured. If it is imagined the mercury has been raised too much, lower it entirely free from the point and adjust over again.

Third method.—Another method that is often given is to watch closely until the reflected image of the ivory point coincides with the point itself. This also requires clean, bright mercury, and is, therefore, not a general method. Great precision in the adjustment of the contact of the ivory point with the mercury may be attained with a little care and practise, and observers may scarcely be conscious of precisely the manner of making the adjustment.

67. *Adjustment of the vernier.*—The level of the mercury being adjusted to the ivory point, the vernier must next be brought to the top of the column. Greater uniformity and accuracy are insured if the fingers be now tapped smartly against the side of the metal barometer tube. This aids the mercury in detaching itself from the glass and

forming into a normal meniscus. The proper setting of the vernier is made when the light is just cut off from across the extreme summit of the meniscus. The figures on page 15 indicate how the verniers should be set to the mercurial meniscus. The lower edge of the vernier must be brought just to the level of the *extreme summit* of the meniscus. The eye must be held also so that *both front and back edges of the vernier are in the line of vision.*

68. It is needless to say that throughout the setting of the barometer, as described above, the column must be maintained vertical, either because of the fixed supports or by the skillful handling of the freely suspended barometer, so that at the critical moments when contacts are judged to be made the instrument is truly vertical.

69. After the cistern and vernier are adjusted in the manner described above, it remains only to read the scale and vernier in accordance with the instructions in paragraphs 13, 14, and 15.

70. This reading may next be corrected for temperature by applying the proper correction taken from Table I, corresponding to the temperature shown by the attached thermometer, and again further corrected, if necessary, by the addition or subtraction, as the case may be, of all other corrections known for the instrument, such as correction for capillarity, instrumental error, imperfect vacuum, gravity, etc.

71. *Reduction to standard gravity.*—The following will elucidate the nature of the gravity correction as applied to barometric observations—an important matter that is often but indifferently considered in the ordinary text-books of meteorology:

By the well-known principle of hydrostatics on which the action of the mercurial barometer is based, the pressure of the atmosphere is equal to the pressure of the column of mercury that it will support. But this latter pressure is only another name for the weight of the mercury, and, for columns of equal section, the weight varies both with the height of the column and with the force of gravity.

The force of gravity varies with latitude and altitude, therefore the height of the barometer (corrected for temperature and instrumental error) can not be directly used as a true measure of the atmospheric pressure, hence, if observations are to strictly and accurately measure the real pressure of the air, they should be subjected to a small correction for gravity, or, more properly, reduced to a standard force of gravity.

The standard gravity adopted by physicists is that at the level of the sea in latitude 45°.

Tables of corrections for gravity are given in Section VIII.[1]

[1]According to the formula for the force of gravity adopted by the International Bureau of Weights and Measures, we have for the variations in gravity due to the latitude

$$G = g_{45} (1 - 0.00259 \cos 2\phi)$$

72. *Reduction to sea level.*—It was mentioned in paragraph 5 that the atmospheric pressure was in the main nothing more than the weight of a vertical column of air extending to the limits of the atmosphere. It naturally follows that as we go above the general surface of the earth, whether in balloons or by ascending mountains, the atmospheric pressure becomes less and less as we leave more and more of the air beneath us. When it is desired to chart and compare simultaneous observations of atmospheric pressure over extended areas, and at various elevations above sea level, no inference can easily be drawn from the actual pressures themselves, but each must be reduced to some standard level. The sea level plane is most generally adopted, but the selection of a plane 2,000 to 5,000 feet above the sea offers more rational conditions in certain respects and is sometimes advocated. Barometric observations from different stations for comparative purposes, therefore, require a "reduction for elevation."

We can form a clear idea of what is wanted by confining our attention to the case of a barometer in a balloon at an elevated point above the sea. The reduction for elevation is simply a measure, expressed in inches of the mercurial column, of the weight of the column of air between the balloon, that is the barometer cistern and sea level. This weight evidently depends not only upon the elevation above sea, but also upon the mean temperature of the air below the balloon and the amount of moisture it contains.

The variation in the force of gravity for different altitudes is small, and is given by the formula, h being the elevation in feet:

$$G_h = g_0 (1 - 0.0000000597\, h)$$

Neglecting this latter factor, the application of the gravity correction is equivalent to multiplying the height of the barometer by the factor

$$(1 - 0.00259 \cos 2\phi)$$

The dimunition of gravity as we go from latitude 45° to the equator causes the mercury in the barometer to weigh less, and hence for a given pressure in the atmosphere the mercury in the barometer stands higher than it would if the force of gravity preserved the uniform standard value. Therefore, the farther a barometer is removed from latitude 45° the greater its correction becomes, so that at the equator a pressure that appears to be 30.00 inches (at sea level) is really about 29.92 inches.

It should be noticed that when the barometer is thus corrected for its peculiar error due to the influence on it of variations of gravity, the pressure that it then gives is the actual pressure of the air at each latitude expressed in terms of an absolute and not a variable standard.

It is important to remember that the barometric pressure is due, not only to the weight of the air, but also to the prevailing winds, the rapid heating or cooling and consequent expansion or contraction of low layers of air, and to other causes.

In the mercurial barometer we balance this elastic pressure by weight of quiescent mercury; a change of the force of gravity will change the weight of the column of mercury without necessarily changing the atmospheric pressure.

The temperature and moisture conditions are easily conceived of in the case of a barometer in a balloon with a great ocean of air directly beneath, but when we consider the reduction for elevation of barometric observations taken over extended plateaus and at great distances from sea level, such, for example, as the reduction of observations at Denver, Colo., no clear meaning attaches to the temperature and density of the air column, in fact, the air column can not have any real existence, and this constitutes a troublesome difficulty in computing satisfactory values for the reductions for elevations. Approximate values only, therefore, are possible. Considerations such as these lead us to see the advantage of making all reductions to a plane, say, 5,000 feet above sea level, in which case an air column actually exists, and has a definite mean temperature, humidity, etc.

Various more or less arbitrary computations of the temperature to be used in finding the reduction for elevation have been tried from time to time. At present the temperature selected for the reduction of the observations of the Weather Bureau is the mean of the current air temperature and that of the preceding 8 a. m. or 8 p. m. observation.

73. *Determination of height by barometric readings.*—The calculation of elevation above sea level by barometric readings involves all the principles and encounters all the difficulties of the "reduction to sea level" described above. This method, therefore, of measuring heights is to be used only when others are not possible, and numerous observations should be made to eliminate the very large accidental errors to which the method is subject.

As the aneroid barometer is used by tourists and others so largely in connection with determination of elevation, some further discussion of the subject is here given.

74. *Determination of heights by the aneroid.*—A reading of a barometer at a single station, without reference to the air temperature and corresponding pressure at some adjacent points whose elevation is known, gives only the crudest possible idea of the elevation of the station, and the neatly constructed little pocket aneroids in morocco cases on sale in the shops having their dials graduated to feet of elevation above sea level, are to be regarded as extremely inaccurate, especially if the scale of altitudes is graduated upon the same metal plate as the scale of inches. In many aneroids the scale of feet is adjustable, and, on this account, may serve to some advantage for showing small differences of elevation, but, at the best, all direct indications of elevation from readings on the dial of the aneroid are only coarsely approximate.

75. *Adjustable scale of elevations, how used.*—If the scale of feet is adjustable on an aneroid, it may be conveniently used as follows: If a tourist is about to set out on a short expedition to an elevated

point, starting at a station of which the elevation is known, let him set the movable scale of the aneroid so that the proper graduation, marking the known elevation, stands opposite the index hand. On reaching the elevated point the position of the hand on the scale of feet will now indicate, approximately, the new elevation, provided, of course the scale has not been shifted, and provided further, that the real air pressure was uniform throughout the vicinity, and did not change at all during the time occupied in the expedition. If this time was several hours or the distance considerable the result may be very greatly in error. Suppose we know our elevation to be 500 feet and we set the scale to this point. To-morrow the aneroid may indicate only 200, or even 800 feet, the new value being a direct result simply of the changes in air pressure.

A variation of one-tenth of an inch in the barometric pressure affects an observation of altitude by from nearly 100 to nearly 150 feet, according (1) to the elevation itself and (2) the temperature at the time. On this account, and because of the large accidental errors to which aneroids are subject, as described above, they are peculiarly unreliable in the determination of elevations.

76. To determine heights as well as can be done by pressure measurements, it is necessary that simultaneous observations, not only of the barometer, but of the temperature and humidity of the air, be made at one or more adjacent station of which the elevation is known. These observations, by means of suitable tables, will give the difference in elevation of the stations, and the mean result from a large number of such simultaneous readings will give a fairly accurate value for the desired elevation, especially if the difference of elevation and distance between the stations is not very great.

77. *The care and preservation of barometers.*—A barometer is a very delicate instrument, and, in general, must be handled with great care; therefore observers, in handling a barometer, ought first to inform themselves as to the best methods to follow and the various precautions to observe, as embodied in the instructions given below.

78. When a new barometer is received, in unpacking, it should be lifted cistern uppermost from the box, and all wrappings removed while the barometer is in a horizontal position. When moved about the cistern end should be carried uppermost.

79. To turn the barometer, tube end up, bring it first gradually to a horizontal position, watching at the cistern for a small bubble. This should never be very large, nor should it be absent, in which case there may be serious pressure from within, tending to force the mercury out through joints of the cistern, etc. If necessary, the adjusting screw should be turned so that the bubble is not larger than a space within which a 10-cent coin could be placed. The tube may then be gradually elevated to an upright position. The mer-

curial column should not be lowered until the instrument is safely placed upon a hook.

80. Never remove a good barometer from its supports while the mercurial column is at or near its normal height. Always screw up the cistern until the top of the column is just visible at the *top of the opening in the brass case.* Do not subject the barometer to quick movements or sudden changes in its position, especially in the vertical sense; always move it about slowly and regularly and change its position gradually. Do not handle or carry the barometer in an upright position. Handle it horizontally, or upside down as far as possible, preferably the latter. The proper procedure to invert a barometer is as follows:

Examine the cistern to see if there is any special air vent as at *d*, fig. 9, in the Tuch cistern. Screw up the mercury until it reaches the top of the cistern. *Then close tightly the air vent*, and continue screwing up the cistern until the top of the mercurial column reaches the summit of the opening in the metal tube. Always avoid screwing up the cistern until the tube is entirely filled with mercury. It is impossible to tell exactly when the tube is full, and a turn too much of the screw is almost sure to force the mercury through the joints of the cistern or even the pores of the leather bag and lead to very serious injury of the barometer. Do not strain the screw if it goes hard. Mercury may have leaked from the cistern, and what remains is insufficient to fill the tube. A barometer can be safely inverted even if there is quite a deficient supply of mercury in the cistern.

When the mercury is near the top of the tube the barometer may be removed from its supports and slowly inclined, listening, meanwhile, for any little sound or "click" that may be emitted from the top of the barometer. When the tube is nearly horizontal, watch at the cistern end for the appearance of an air bubble showing there is still a small free space within. From the horizontal position the instrument may be turned cistern end up without any special precautions, and may then be handled and carried with ease and safety. It is even advisable now to *turn back the cistern screw a turn, or thereabouts*, so that there can be no doubt whatever but that there is plenty of free space in the cistern.

81. *The "metallic click."*—The so-called "metallic click" is best produced while the barometer is inclined at about 45°, or possibly still more nearly horizontal at high-level stations. The cistern must not be screwed up too much. The "click" occurs just as the mercury moving up the tube reaches the top and completely fills it. If the barometer is quickly inclined, the violent shock of the mercury against the top of the tube is sometimes sufficient to crack the tube. Hence, sudden movements of this sort are always attended with danger to the barometer.

Many think they can judge of the excellence of the vacuum in a barometer by the character of the "metallic click." It is exceedingly deceptive, however, and even experts are able to draw only approximately correct conclusions from its character. The greatest caution should be exercised in producing the click, as, if the vacuum is first class, it tends to injure the barometer. A good plan is to incline the barometer, as described above, until the mercury about reaches the top of the tube; then, holding it in this position, move it somewhat quickly, but very slightly and regularly, back and forth three or four times exactly in the direction of its length, and, if necessary, changing the angle of inclination and increasing, very cautiously, the intensity of the shaking motion until two or three gentle clicks may be heard. Too great care can not be exercised in this respect, and only the most gentle clicks should be produced. Even then, with very perfect vacua, the internal stress is very great and barometer tubes that have been subjected to boiling in the process of filling and are not thoroughly annealed are sometimes in such a state of internal stress as to be very easily cracked and injured.

82. *Handling barometers at elevated stations.*—In the case of stations from 3,000 to 10,000 feet or more above sea level the top of the mercurial column, in extreme cases, is a long distance from the top of the tube. It is not advisable, therefore, when it is desired to invert such a barometer, to immediately screw up the cistern until the column reaches nearly the top of the tube, A better plan is to raise the column only 2 or 3 inches, then, while gradually inclining the instrument, continue to screw up the cistern until the column is about to disappear from view at the top. The object of this is to avoid subjecting the cistern to the considerable hydrostatic pressure that occurs if the column is raised several inches above that which the air pressure itself is capable of supporting.

At an elevated station the barometer must be in a much more nearly horizontal position to produce the "metallic click" than at sea level.

83. The best possible care a barometer can receive is to be protected from accumulations of dust, etc., and left quite alone. When readings must be taken, and the barometer is suspended from a hook upon which it is drawn out to a position convenient for reading, the rough sliding of the barometer along the hook, together with the springing movement up and down, and finally the knocks the cistern is apt to receive when the instrument is returned to the box, are all very injurious to the condition of the barometer and are to be avoided by gentle and careful handling.

84. The results of comparative barometer readings conclusively show that in spite of every care a difference of several thousandths of an inch in the indications of two or more instruments can not on the average be avoided. Any change or substitution of instruments at a

station therefore is apt to make a more or less objectionable break in the strict continuity of the pressure reports from that station and obviously such changes should be made only when absolutely necessary.

85. After continued use the mercury in the cistern of a barometer loses its brilliant surface and becomes coated with a slight film of oxide. This does not impair the barometer to any serious extent, and very accurate readings can yet be made. It is very bad practise to clean the mercury in barometers as soon as it becomes slightly dull and tarnished. Leaks are apt to be started in the joints of the cistern, and slight changes in the position of the ivory point give rise to new and unknown corrections for instrumental error. The mercury itself is apt to become contaminated with impurities and afterwards will remain bright only a very short time.

86. *Comparative barometer readings.*—Each regular Weather Bureau station is supplied with two good barometers to lessen the chances of a break in the record and to guard against erroneous reports from the use of imperfect instruments. Monthly therefore, and on other special occasions, as further specified in paragraph ~~129~~, five compara- 150 tive readings of all barometers on station should be made at uniform intervals of hours, half hours, or quarter hours, as may be most convenient to the observer.

87. As the object of the comparative readings is to ascertain accurately the amount of discordance between the barometers and enable the main office to replace defective instruments, it is important that the observer use more than ordinary care to read the barometers exactly as they are. He should not feel biased or disposed, in the slighest degree, to make the readings come out one way more than another. His whole endeavor should be to make the settings and readings as accurately as possible, without any regard as to how the readings may differ in the end. When the pressure is found to vary rapidly, make the readings of the two or more instruments as quickly as possible, and throughout the series endeavor to keep the temperature stationary.

88. Before each reading the cistern of the barometer should be unscrewed so as to lower the mercury $\frac{1}{16}$ to $\frac{1}{8}$ of an inch below the ivory point and the setting then carefully made.

89. An interval of two or three hours should intervene after barometers are unpacked, cleaned, or moved to a new office and hung in position before comparative readings are commenced.

90. Comparative readings should always be made with new barometers whenever received at a station, and also both before and after instruments are removed from one location to another or cleaned.

91. *Suggestions and instructions for cleaning barometers.*—In a few cases observers are authorized to clean barometers that are very dirty

and can not easily be replaced. See paragraph 154. The following instructions will then guide in the proper performance of the work:

92. Take a series of five comparative readings before the work is begun.

93. Provide one or more very clean, *dry* porcelain or glass cups or saucers. Avoid the use of damp, unclean, or metal vessels. Cleanse the vessels by thorough washing in soap and water and wipe dry with a clean towel, finally polishing the vessel with tissue or similar soft paper. Provide, also, some pieces of clean cloth and sheets of tissue paper for cleansing the glass parts of the cistern, also a few small sheets of clean white paper about 4 by 6 inches for use in filtering the mercury. Calendered letter paper is not so good as the ordinary so-called "book" paper. A most convenient place to clean a barometer is seated in front of a desk with a drawer at the top and side partly opened. This affords convenient corners in which the barometer can be rested in upright positions during the process.

94. The barometer will be removed from its box or support and inverted, as described in paragraph 80.

Unscrew with one hand the portion of the cistern marked *S*, fig. 3, grasping with the other hand *only the narrow flange R.*[2]

95. Next separate the two wooden portions of the cistern marked *i* and *j* by loosening the four screws uniting the split-ring clamp marked *l* and *M*, in fig. 3. It is important that each screw be loosened a little in turn, otherwise an uneven strain may be thrown upon some portion of the fragile wooden flange and chip out a piece. After loosening each of the screws one may be taken out entirely, and the whole system of split rings still interlocked by the screws will generally unfold from around the cistern. Sometimes another screw must be taken out.

If the rings are separated, they should afterwards be united again precisely in the original relation. When removing the wooden piece, *j*, to which the leather bag is attached, lift it cautiously directly up from the part, *i*, so as not to spill out the mercury, which is thereby exposed and should just about fill *i*. Hold a clean, dry vessel close under the flange of *i* and pour out steadily from the cistern all, or

---

[2] If mercury has leaked out of the cistern this will generally be indicated by the presence of minute globules of mercury adhering to the threads of the screw *O*. In such a case the cap at the extreme bottom of the cistern should be unscrewed, instead of the portion marked *S*, thereby preventing the escape of the mercury which has leaked out. As this mercury, by reason of its contact with the metal parts of the cistern, is impure, it must be emptied out separately, and *under no circumstances* afterwards used in the barometer or mixed with good mercury, as the whole will be rendered impure.

To empty this impure mercury from the cistern the finger must be used to force the kid-skin bag up into the cistern while the barometer is inclined and the impure mercury poured out.

nearly all the mercury it contains. The mercury will not leave the open end of the barometer tube so long as the latter is not raised much above a horizontal position, and generally not then unless the opening is large and the tube shaken or jerked a little. Care must be taken to prevent the mercury from passing out of the tube. The barometer is then returned to its inverted position and the remaining parts of the cistern removed by loosening the screws *P* and *P;* here again each screw must be loosened a little in turn to avoid chipping or cracking the glass cylinder. If a small globule of mercury remains in the glass cistern, allow the latter to rest in its position, while the boxwood piece, *i*, the metal flange, *R*, and the screws, *P*, are removed. Then holding the glass cylinder in position with the fingers, empty out what remains of the mercury in the cistern. In handling the little leather washers taken from the parts of the cistern avoid wrinkling or creasing them or otherwise changing their form, as any injury of this kind will probably result in leaks that can not be prevented except by new washers.

96. The barometer tube and attached wooden piece *G*, fig. 3, may be next withdrawn from the metal sheath and all the parts thoroughly cleaned. Before removing the tube notice exactly the position of the ivory point in reference to the outside sheath so that it may be returned to this position, otherwise a change may be introduced in the correction for instrumental error. In all probability small quantities of mercury will be spilled into or remain in various little cracks and crevices while the cistern is being emptied. These, by all means, should be thoroughly dislodged, especially from about the metal parts. With the glass tube removed, the sheath should be tapped and shaken smartly to perfectly remove small globules of mercury. It may then be wiped and cleaned thoroughly with cloths or chamois skin. In case the scale is somewhat dull and tarnished it may be brightened by suitable polishing, but this is a delicate operation and should be avoided rather than otherwise. The danger lies in shifting the position of the scale, and if polishing is absolutely necessary, it should, therefore, be done with very great care.

The upper portion of the glass tube should also be cleansed on the outside with the aid of a damp cloth if necessary.

97. *Air in barometer tubes.*—How air can gain entrance to the vacuum of a barometer otherwise in good condition, which is supposed to have been hanging quietly and undisturbed upon its supports, is a matter that is very difficult both to imagine and to explain. Cases of this sort are not known ever to have occurred among the hundreds of barometers handled at this office, so that when such defects are discovered to have suddenly developed in instruments in use at stations observers in investigating the cause and reporting the matter, should make sure that the barometer has not been tampered

with or roughly handled by unauthorized persons, as, if uninjured in other respects, the supposition of misusage is the most probable explanation of the defect.

98. If an appreciable quantity of air is in the tube at the time of cleaning, it can be seen more or less conspicuously in the shape of a small bubble or bubbles adhering closely to the walls of the tube. If these bubbles appear no larger than good-sized pin-heads, and especially, if they are not more than half-way up the tube, then it is certain that the condition of the vacuum is more likely to be greatly impaired than improved by attempts to remove them.

99. Sometimes the barometers that observers may be called upon by private parties or friends to inspect or repair, seem to have numerous rather flat-shaped air bubbles firmly lodged against the sides of the tube. Generally these are not air bubbles at all but moisture, the presence of which is due to carelessness in the original preparation and filling of the tube. The edges of an air bubble are sharp and the mercury generally remains bright and makes well-defined contact at a steep angle with the glass. If some moisture is present, either alone or with the air, the edges are less clearly defined, the mercury oxidized, and the angle of contact less steep, the bubble itself being very flat.

It is impossible, without entire cleansing, drying, and refilling to do anything with a barometer that contains moisture.

100. If a bubble or so of air is present in a tube the plan that should first be tried to remove it is as follows:

First method.—Incline the tube 45° or thereabouts, with the open end up and tap it gently in the vicinity of the bubble, revolving the tube a little at the same time so as to encourage the bubble to creep along the inclined surface of the glass. If the inclination is too great the bubble will be greatly compressed by the weight of mercury above it; if too small the bubble will not tend to move.

If the treatment is successful and the bubble is removed, the result will probably be beneficial, but, at best, the operation is generally very tedious and often the bubble seems to grow smaller and finally quite disappears, being separated into almost imperceptible portions which remain distributed along the walls of the tube.

Second method.—The following plan is more frequently applied, especially when the quantity of air already in the tube is considerable, is lodged at the top and must be partially removed at least.

Empty out an inch or two of mercury from the tube. Close the open end tightly with the gloved finger and cause a large bubble of air to glide slowly and regularly along the tube until it unites with all the portions of air it is desired to remove. The large bubble is then as slowly and gradually worked to the open end of the tube again, using every possible precaution to prevent small portions of the bubble from separating off and remaining behind. Such a bubble of air may sometimes be successfully passed once into and out of the tube, but even at the best the vacuum in a barometer that has been treated in this manner is very apt to be greatly impaired and can not be restored. The reason of this is that the glass walls of the tube have very strong hygroscopic properties, and while the air bubble is passing along the tube considerable portions of both moisture and air are invisibly retained upon the walls of the tube. While, therefore, a bubble of air may be successfully passed once into and out of the tube, a repetition will be attended with less good effect, as in the meantime the moisture and gases in the tube will already have begun to act upon the mercury, producing oxidized films that will probably adhere to the walls of the tube, so that when bubbles are again passed there will presently be a marked tendency to cling to the tube and leave small detached bubbles imprisoned against the walls. When, afterwards, the barometer is set up the walls in the upper portion and near the vacuum being no longer subjected to the full air pressure as they were while the bubble was passing along the tube, now readily give off both air and moisture, and in many cases numerous little bubbles form against the walls even below the top of the column and probably later work their way into the vacuum.

101. The removal of air from a barometer tube, therefore, can not be perfectly effected in any such way, and should not be undertaken unless the defect is a very serious one. If the comparative readings taken before cleaning a barometer do not show serious errors, any air the tube may be imagined to contain had best be allowed to remain.

102. One of the most difficult and delicate parts of the process of cleaning is that about the wooden piece, *G*, and ivory point. The deep and narrow annular space between the glass tube and the boxwood is generally quite covered with oxide of mercury, which should be thoroughly removed by repeated wiping with clean cloths applied upon the ends of slender sticks or by similar means. Tufts of raw cotton will adhere firmly to, and are readily wrapped about, rough sticks, and may serve with advantage in wiping out the narrow spaces. Sometimes, however, the space is so small that it can not be properly cleaned. Care must be observed not only here, but in subsequent operations, to blow away or otherwise remove every vestige of lint, dust, shreds of cotton, etc., as, if allowed to remain about the parts of the cistern, they will quickly find their way to the surface of the mercury, upon which they will float about to the detriment of accurate adjustments.

It is obvious that the delicate ivory point should be handled with great care.

103. The glass cylinder of the cistern should be washed in soap and water and thoroughly rinsed in copious applications of fresh

water. After this *it should not be touched with unprotected hands, especially upon the inside.* Wipe it thoroughly dry with a clean, dry towel or handkerchief, and polish with clean tissue paper. The remaining wooden portions of the cistern should also be wiped thoroughly clean and dry without touching the inside with the bare fingers. Shake out of the bag as far as possible every little particle of mercury that tends to remain in hidden corners and crevices. These little particles are very apt to be mostly dirty and impure, and should, therefore, be removed.

104. The several parts of the barometer should be replaced in the following order:

First, return the glass tube to its sheath, *being careful to place the ivory point in the position in relation to the scale, or front of the barometer, formerly occupied;* also to avoid handling the end portion of the barometer tube where it dips into the cistern with the bare fingers, as a slight film of oil may be communicated to the mercury of the cistern by this means.

The glass cylinder, with its leather washers, one at each end, is next placed in position, followed by the wooden piece, *i*, and the metal flange ring, *R*. The three long screws, *P*, are next to be inserted and partially screwed up. While these various pieces are still loosely held by the screws, it is well to jostle the parts about a little and twist the ring and boxwood pieces upon each other and the glass cylinder. In other words, try and bring the surfaces in the several joints nicely and uniformly into contact with each other, and adjust the ring, *R*, so that the screws are not even imperceptibly askew, but, when properly drawn up, produce a direct, uniformly distributed pressure. When the parts are thus adjusted the screws, *P*, are to be tightened *little by little*, each one a little in turn after the others, until all are drawn down together equally tight. The observer must skillfully judge of this partly by the amount he has turned each screw and partly by the resistance it offers to further turning. It is not necessary that the screws be very tight. A judicious regard for these ideas constitutes in part the skill of the expert and is the secret of perfect joints. To disregard them produces leaky joints and unequal pressures that are apt to break the fragile boxwood flanges or crack the glass.

Before describing the filling of the cistern, some tests and experiments showing the purity and properties of mercury will be mentioned.

105. *Purity of mercury, how tested.*—Pure mercury is beautifully brilliant and mobile, and does not exhibit the slightest adhesion to clean, dry glass or porcelain surfaces, whereas the amalgamation of the mercury with the slightest perceptible traces of foreign substances, such as lead, tin, zinc, etc., changes completely the character of this

peculiar substance. Each observer should try for himself the following very instructive and simple experiment:

Prepare a small, shallow, flat-bottomed porcelain cup or white piece of chinaware, or glass vessel if the others are not to be had. Wash and dry thoroughly without touching the inside with the bare fingers. The vessel may be just a little warm with advantage. Filter into the vessel, through a paper funnel, such as described below, rather less than a teaspoonful of pure mercury. If the mercury has been properly filtered and is of extreme purity, the brilliant globule will roll about the cup with the greatest activity, as the latter is moved a little, and will draw out momentarily into slender cylindrical portions which, if broken asunder, will quickly separate into smaller portions, which draw themselves up into beautiful little spheres or larger rounded buttons, none of which cling in the slightest degree to the clean surface of the vessel. Under favorable conditions and during the rapid movements of the mercury a scarcely audible but still a very characteristic crackling sound can be heard, due to the development of small sparks of electricity. Such is the characteristic behavior of clean, pure mercury in a clean porcelain dish. If, however, the mercury contains the most minute trace of lead, tin, zinc, etc., this fact will be shown by a more or less marked tendency of the little, slender portions of the mercury to draw out into sharply pointed, tapering "tails," the tip ends of which cling to the vessel and remain. If the observer is not in possession of the small quantity of extremely pure mercury needed in the above experiment, the most striking part of it will be lost. After watching the beautiful manner in which the pure mercury rolls about the dish, add to it a small flake of lead or solder. The flake should be the slightest little shaving cut off with a penknife, and should contain not nearly so much material as in the head of the smallest pin. Place this upon the mercury and allow it to remain a moment. It will presently be wholly dissolved. Now repeat the rolling about of the mercury in the cup and observe the wonderful change.

The former brilliant globule has now a dull surface, with its edges clinging at many points to the surface of the dish. The clean white surface of the dish will now be soiled and discolored when the mercury is made to flow over it a few times. The presence of one part of lead in one hundred thousand parts of mercury is readily shown by this test.

Only one who has performed this experiment is prepared to fully appreciate the extreme importance of the absolute cleanliness necessary in barometer cisterns and the avoidance of the slightest metallic contamination with the mercury.

106. Of course, the mercury used in the above experiment can not be again used until purified. This can be done quite well by washing

with dilute nitric acid, about one volume of acid in fifteen volumes of water. The mercury and acid may be placed in a bottle and violently shaken, or the acid may be poured over the mercury and allowed to remain several hours. To ascertain if the acid has thoroughly cleansed the mercury, the latter, upon shaking violently the contents of the bottle, will break up into very fine, little globules which, for a moment, do not coalesce. This formation of the mercury into minute globules in the presence of dilute acid will take place only with quite pure mercury.

107. Returning now to the processes of restoring the barometer, the next step is to filter the mercury and fill up the cistern. Roll up a small sheet of clean paper into a sharp cone, looking through it to the light to see that the opening is very small. Holding the cone over a clean vessel, partly fill it with mercury. By twisting at the folds of the cone in a manner that the observer must learn by trial, the opening at the point may be regulated to any size desired, even while the cone contains mercury. Keep the cone well filled with mercury until all has been added, and do not allow the very last portion to pass through the filter. If the observer has only the supply of pure mercury taken from the barometer, economy must be exercised, but there is no difficulty whatever in being able to filter and utilize the entire quantity of mercury originally in the barometer, and this is sufficient. The purity of some of the filtered mercury may be tested as described above. Another indication of the purity of the mercury is the character of the mark left on the paper cone after filtering. To be able to judge by this, observers must filter both pure and impure mercury and compare the marks.

108. The mercury for the cistern, having been filtered at least once, may next be filtered into the cistern, directing the little stream so as to strike against the glass cistern to avoid inclosing small air bubbles near or upon the barometer tube. The open end of the tube should, in the meantime, be completely filled, and the mercury heaped into a little button on the tip end. This button will unite with the mercury of the cistern as it rises around the tube, and the chances of inclosing air in the tip end of the tube are thus greatly lessened.

In general, the cistern should be filled to the brim of the piece, *i*. Before fitting the piece, *j*, the leather bag should be pushed out from the inside and every effort used to detach and remove all dust, shreds, little particles of leather, etc.

109. In securing the clamp rings the screws should be tightened little at a time, and the precautions cited in paragraph 104 observed to insure a closely fitting and uniformly tight joint.

When the screws are all tightened, the leather bag should be thrust up into the wooden piece, *j*, and held there firmly by the finger while the barometer is gradually turned right side up, watching to see if any leaks show themselves at any of the joints. The mercurial column should not be lowered under any circumstances at this time. If leaks occur, it is probably due to uneven tightening of the joints, and in most cases, it is better to loosen the whole joint and shift it a little before tightening again rather than to strain the screws that are already tight, in the hope of making closer contact.

110. From one to three or more hours after the cleaning operations are completed and the barometer returned to its support a series of five comparative readings with its companion or standard instrument should be made.

111. *Additional suggestions for cleaning barometers with the Tuch cistern.*—The parts of the barometers with Tuch cisterns can be removed only by the aid of a special wrench which will be furnished when any observer is authorized to clean such barometers.

The special points to be observed are as follows:

Before fully screwing up and inverting the barometer, close tightly the air vent, *d*, fig. 9. Consult also paragraph 17.

When about to open the cistern, loosen the screw, *W*, fig, 9, one or two turns. Then unscrew the piece, *q*, being very careful at this time to not unscrew the part, *K*. When completely unscrewed, the piece, *q*, with attached piston, *o*, may be wholly withdrawn, exposing the mercury. All or nearly all of this may be poured out in the manner described in paragraph 96 without danger of starting the mercury from the end of the barometer tube. The small portion of mercury that is apt to remain should be poured out afterwards, removing first the tube or barrel, *K*, then the clamp ring, *h*, holding the glass cistern in position by the hand until the last portion of mercury is emptied out.

To remove the barometer tube from the sheath the cap of the air vent must be first removed.

It is always best not to disturb any more than necessary the various leather washers and fittings.

112. In replacing the parts *be sure the cap of the air vent is screwed up* before introducing the mercury.

After inserting the glass cistern and washers screw down upon it the ring clamp, *h*. Then filter in as much mercury as practicable, observing the precautions mentioned in paragraph 108. Next screw down snugly the tube or barrel, *K*, and add the remaining mercury. Finally replace the piston and cap, *q*.

If the piston does not fit the barrel snugly enough the washers should be tightened by turning up the screw, *j*, using the special wrench. The parts of the piston should not be taken apart nor the washers disturbed, except possibly to tighten screw mentioned above.

During the operation of replacing the piston it should not close down upon the mercury which will be subjected to severe pressure thereby. At last tighten the screw, *Z*.

Before the instrument is placed erect the piston should be screwed up close to the mercury; still leaving a small space, as shown by the air bubble, visible in the cistern when the barometer is held nearly horizontal.

113. *Suggestions about moving and packing barometers.*—Preparatory to moving invert the barometer as described in paragraph 80.

The most approved methods of packing barometers for transportation are to be learned by carefully observing the manner followed in packing instruments sent out by this office. The instrument should be shipped in a horizontal position. The air-bubble space in the cistern should be small, but still sufficient to admit of expansion with temperature changes.

When carried about by hand the cistern should be uppermost.

The barometer should be first wrapped in soft paper, then with a thick layer of cotton sheeting and an outer wrapping of heavy paper. Thus prepared it is then placed in the middle of a strong wooden box and completely and closely surrounded with good excelsior or cotton or similar elastic packing material. The lid of the box must be *screwed* down, not nailed, and a strong handle attached to the middle, so that the box may be carried by one hand in a horizontal position.

114. *Leather carrying cases.*—In using the leather carrying case, supplied when barometers are to be transported by hand, secure the barometer in the hinged wooden sheath, being careful to observe that the latter closes tightly together without straining either the milled head for regulating the vernier or the attached thermometer. The wood should be neatly cut away, if necessary, and only sufficiently to receive these projecting parts. Insert the barometer, *cistern uppermost*, into the leather case.

115. On steamboats or railroads the barometer, if hung up in any manner, should be secured against striking or pounding the side of the room or car. In wheeled vehicles the barometer should be carried by hand, supported by a strap over the shoulder or held upright between the legs; it should not be allowed to rest on the floor, as a severe jolt may break the tube. On stage routes, when impracticable to carry it by hand, hang the barometer on a hook inside the stage and securely fasten the lower end so that it will not swing when being thus transported. If carried on horseback it should be strapped over the shoulders of the rider, where it is not likely to be injured.

116. *Change of location.*—It sometimes becomes necessary to change the location of instruments from one office room to another, or to a different point in the same room and making little or no change of elevation. In such cases the barometer box can be moved bodily with the instruments in place. The first step is to prepare the wall

at the new location by setting up the necessary wood strips and the screw at the top on which the hook of the barometer box can be hung. If no change is to be made in the elevation this screw must be at exactly the same height as the corresponding screw at the old location. After the usual comparative readings have been made, and all is prepared the barometer cisterns will be screwed up until *full* of mercury and the box moved bodily in an upright position and secured at the new location. Comparative readings should not be made after the removal until an interval of two or three hours has elapsed, unless the temperature is practically the same in the two locations.

117. *Shipment of serviceable barometers.*—Every possible care is taken at the Central Office to secure the highest attainable precision in the pressure observations at stations and to ascertain the amount of abnormal errors that sometimes develop in the use of instruments. To this end defective instruments are called in to the Central Office for recomparison, and obviously it is of the highest importance that every precaution be taken in packing such instruments to insure their safe arrival at destination. The special labels furnished must be tacked and pasted on the outside of the box in a conspicuous manner.

118. *Shipment of empty instruments.*—When barometers are so seriously defective that check comparisons can not be made or are valueless, observers will be authorized to forward the barometer to Washington by railway mail, first carefully emptying out all the mercury, which will be preserved on station in a clean bottle, to be disposed of as specified in paragraph 156. The instrument will be packed in a leather carrying case that will be furnished for the purpose. The provisions of paragraph 114, relative to fitting the case to the barometer and packing the same, will be observed.

(B) CARE AND USE OF BAROGRAPHS.

119. *Exposure of barographs.*—The general principles of the exposure of barometers given in paragraph 58 apply to barographs also, except that the matter of light is not so essential. Every precaution, however, must be observed to prevent the instrument from being exposed to great changes of temperature and to direct influence of sunshine, etc.

The instructions following apply particularly to the Richard barograph.

120. *Adjustment to standard pressure.*—When the instrument is first set up at a place, the pen should be made to mark, as nearly as possible, the corrected pressure (see paragraph 139) given by a standard mercurial barometer at the same place. This adjustment is made by raising or lowering the whole series of aneroid shells by means of a screw reached through a hole in the base of the instrument just under

the aneroid shells. This screw is turned by one end of the key supplied for winding the clockwork. The adjustment of the barograph to agree with a standard barometer will rarely prove altogether permanent and will require a little alteration from time to time, there being a slight tendency for an aneroid barometer to read too high with age. It is generally necessary to set the barograph to standard at the time a new sheet is put on, but if the error is small it is better to allow for it than to readjust.

121. *Special adjustment for high elevations.*—The adjustment afforded by the screw underneath the base of the instrument is not sufficient to bring the pen to the proper pressure at stations four or more thousand feet above sea level. In this case, and also to prevent injury to the barometer while in transit over lofty mountain passes, it is sometimes necessary at this office to disconnect the system of levers from the aneroid shells and to provide one or more extra holes in the stem projecting at the top. Barographs found disconnected in this manner upon arrival at stations need simply that the links be united again, placing the small pin in whichever hole will bring the pen nearest the middle of the record sheet. When shipping barographs, if the instrument has to pass over a greater elevation than 3,000 feet, the system of levers should be disconnected, as above.

122. When the pressure at any particular station is such as not to be included in the rulings on the record sheets furnished with the instrument, observers will change the numbering of the lines by some convenient whole number and adjust the pen of the instrument accordingly.

123. The sheets should be changed at about noon on the 1st, 8th, 15th, 22d, and 29th, of each month.

When a barograph is first put in operation the trace on the sheet should start at the proper date and hour, even if near the end of the sheet. The roman numeral, XII, at the top of the sheet indicates noon, and the letter "M." midnight.

If not already done, the lower edge of the sheet should be trimmed accurately parallel to the longitudinal lines and rest closely against the flange at the bottom of the cylinder and the pen be adjusted to the proper pressure, in accordance with instructions in paragraph 120.

124. *Barograph clocks.*—Every effort should be made to properly regulate the barograph clock to correctly keep time, winding once a week, or oftener if found to give better results. The instrument should be inspected each day by the observer in charge, and properly adjusted by him when necessary. Whenever these clocks are adjusted a marginal note stating the fact should be connected with the proper hour. If the clockwork goes too fast or slow, it can be regulated in the same manner as the movement of a watch, through an opening within the cylinder marked *A* (to "accelerate") and *R* (to "retard"),

corresponding to the letters "F" and "S" near the ends of the regulator itself.

125. *Time error of barograph.*—The clock movements of these barographs often keep but imperfect time, and it is important the record be checked in this respect, so that proper correction may be made in compiling the records of hourly readings. This result is secured by gently touching the lever of the recording pen, so as to deflect it and cause a slight lateral mark to be made on the record sheet across the barometric trace. A mark of this character will be made each day at noon, seventy-fifth meridian time; the record sheet will thus always show how much the barograph clock may be in error.

In producing these marks great care must be exercised not to strain the lever mechanism in any way; the weight of any ordinary lead pencil is amply sufficient to make the mark, *which should not be more than one-eighth inch in length.*

126. *Pens.*—Pens should be kept neat and clean. Only the standard register ink should be used. Care must be observed in cleaning a pen not to bend or deform the points and render it unserviceable. (See Circular A, Instrument Division.)

127. *Corrections.*—Owing to imperfections in barographs, more or less frequent comparisons should be made with standard instruments, and corrections applied according to the scheme fully described in Circular A, Instrument Division.

VI.—CONCERNING THE ELEVATION OF STATIONS.

128. In the system of the Weather Bureau the elevation of a station is the height above mean sea level of the zero point, that is, the "ivory point" of the barometer scale, and all measurements and levelings for elevations must be made in reference thereto.

129. *Elevation determined by spirit level.*—Whenever a station is established or an office moved and the elevation of the barometers changed, observers will secure the services of a competent surveyor or city engineer, who will run a line of levels to determine accurately the elevation of the station above or below the "plane of reference." In many instances this survey can be secured without expense through the courtesy of the Government or of the city engineers. In the remaining cases the cost will be included with other items of expense incident to the establishment or removal of the office, authority for the expenditure being procured in the usual manner.

All heights will be given in feet and hundredths or thousandths of a foot.

130. *Fixed point.*—The engineer will establish a so-called "fixed point" or bench mark in a permanent manner on the outer stone work of the building, from which direct measurements of the height

of the barometers can readily be made, or a line of levels conveniently run to the "plane of reference" at any time.

131. *Plane of reference.*—The "plane of reference" should, in general, be the top of rail at depot. In cases, however, where a bench mark of a permanent character and of high precision, such as those erected by the United States Coast Survey, the Lake Survey, the Mississippi River Commission, or the Engineer Corps, has been established, this will be used as "plane of reference." The same plane should be used, as a rule, in all measurements within the same town, and will not be changed except for good reason.

132. All levelings must be run by a competent person and the line will be run over a closed circuit which, in the case of a new station, will be simply from the plane of reference through the "fixed point" to the barometer, and back through the "fixed point" to the plane of reference. In the case of the removal of an office the line will be run from the barometer in the old office to the barometer in the new office, passing through the "fixed points" at both the old and the new office, thence through the "fixed point" at the new office to the "plane of reference," and thence to the point of starting.

A copy of the field notes, certified to by the surveyor running the levels, will be filed with the report of elevation which will be rendered on Form No. 1058–Met'l.

The observer will fully inform the surveyor concerning the foregoing provisions for running the levels.

133. When, for any reason, it is impossible to run the levels provided for in paragraphs 129 to 132, the observer will, in case of the change of location of the barometers, or removal of the office, make a special set of comparative barometer readings; that is to say, the comparative barometer readings always required on changing the location of instruments, will in case levels can not be run, be made in three sets as follows:

First: set before removal. Second: set during removal, that is, station barometer in new office, extra barometer in old office. This set of readings will be recorded as usual on Form No. 1027–Met'l, and will be accompanied by two readings of the exposed thermometer, to be noted on the margin, the first taken immediately before and the second immediately after the set of barometer readings. Third: set after removal; that is, both barometers in new location.

When there is an assistant on station the five readings of the second set must be synchronous, but in case there is no assistant at station, eight readings in all will be made alternately in the two offices, in the following order: No. 1 in new office; Nos. 2 and 3 in old office; Nos. 4 and 5 in the new office; Nos. 6 and 7 in the old office, after which the extra barometer will be carried to the new office and the 8th reading made on the station barometer. Finally, the third set of comparative readings will be made.

The interval between readings should be as nearly uniform as possible, and is left to the convenience of the observer, depending upon the distance between stations, etc.

134. When changes in the location of the barometers that do not alter the elevation are authorized, a line of levels need not be run, and only the usual comparative barometer readings before and after removal will be made.

135. *Reduction of observations to a "station elevation."*—On January 1, 1900, a specific elevation above sea level was adopted for each Weather Bureau station, and for purposes of record and publication all barometric observations will be correlated to this "adopted or station elevation." In case, therefore, an office is moved to new quarters and the elevation of the barometer is thereby changed, a proper correction will be applied to the barometric readings in the new location that will reduce the observed readings to the pressure appropriate to the "station elevation," notwithstanding changes and removals.

The pressure thus ascertained will be designated "station pressure."

136. The "station elevation" for a station in operation January 1, 1900, is its elevation above sea level on that date. For stations closed before 1900, or subsequently established, the elevation will be, in general, the elevation above sea level of the zero point of the barometer at the date of closing or opening the respective stations.

137. Reduction of current observations to a "station elevation" in accordance with the foregoing plan will, therefore, be required only when changes are made in the elevations of the barometers. In all such cases the Instrument Division of the Central Office will furnish a new copy of the barometer correction card (Form No. 1059–Met'l), in which a "removal correction," based on the change made in the elevation of the barometers will be combined with the corrections for local gravity, scale errors, etc. The "sum of corrections" thus determined, together with the "correction for temperature," will be applied to all recorded readings of barometric pressure, and the result will be regarded as the pressure of the air appropriate to the station in question.

138. The following example will elucidate the complete correction of observed barometer readings:

Observed barometer reading (attached thermometer, 76.5°)		30.287
Correction for temperature (Table I)	−0.131	
Sum of corrections, Form No. 1059–Met'l	+0.032	
Total correction	−0.099	−0.099
Station pressure		30.188

The "total correction," as shown above, will be entered on Form No. 1001–Met'l, and applied to the "observed" reading, deriving thereby the pressure of the air appropriate to the adopted elevation of the station, this result will be recorded on Form No. 1001–Met'l, in the columns for "station pressure."

139. The barograph will be adjusted and corrected to correspond with the "station pressure" ascertained as shown in the above example. See also paragraph 120.

140. All pressure observations made at a station and reduced according to the foregoing plan are, therefore, strictly comparable with each other, all being reduced to the adopted elevation. Furthermore, a change of elevation and removal of office does not necessitate a new table of reductions to sea level; that is, all observations will be reduced to sea level, when required, by one and the same table of reduction, namely, that based on the adopted elevation of the station.

141. *Nomenclature.*—The following nomenclature, embracing barometric terms, will be used, as far as practicable, in the correspondence, records, and publications of the Weather Bureau:

Actual elevation.—The height of the zero points of the barometers of a station above sea level.

Station elevation.—The elevation above sea level adopted for a station as the basis to which all pressure observations at the station are correlated.

Observed reading.—The direct result of the reading of an instrument, uncorrected for any errors.

Actual pressure.—Meaning the actual pressure of the air at a barometer, as obtained from the observed reading after applying the necessary corrections for temperature, gravity, and instrumental errors.

Station pressure.—A pressure corresponding to an "adopted or station elevation" which may differ slightly from the actual elevation of the barometer. When the actual elevation is the same as the station elevation, the removal correction will be zero and the actual pressure and the station pressure are then numerically equal.

Reduced pressure.—The actual or station pressure reduced to sea level, or to some other specified plane.

Correction for scale errors, capillarity, etc.—A mean difference between the readings of a given instrument and those of the standard barometer duly corrected. This quantity embraces all outstanding errors in the subdivision of the scale, or its total length; errors in the adjustment of the sighting edge to the zero line of the vernier; errors of capillarity, imperfect vacuum, etc.

Correction for temperature.—The correction depending on the temperature of the mercury and the metallic scale.

Correction for local gravity:

(*a*) *Latitude term.*—The correction based on the variation of the force of gravity with latitude.

(*b*) *Altitude term.*—The correction based on the variation of gravity with altitude above sea level.

Removal correction.—The correction necessitated by the removal of an office, and based on the difference between the actual elevation of the barometers in the new location and the adopted elevation for the station in question.

Sum of corrections.—A term embracing all the corrections that are practically constant for a given instrument and in a given location, namely, the correction for scale errors, capillarity, gravity, and the removal correction. This sum is given on the certificate of corrections (Form No. 1059–Met'l) furnished for each instrument.

Total correction.—The correction for temperature, plus the "sum of corrections" as defined above.

Reduction to sea level.—The quantity which must be added to the "actual" or "station" pressure in order to obtain the "reduced" pressure.

Reduction for elevation.—A quantity which must be added to or subtracted from the pressure at a given elevation in order to deduce therefrom the pressure appropriate to some other specified elevation.

VII.—SUMMARY OF SPECIAL INSTRUCTIONS FOR OBSERVERS OF THE WEATHER BUREAU.

142. *Station and extra barometers.*—It is the intention to keep each station supplied with two good barometers as far as possible. The names *station* and *extra* apply, respectively, to the one used in the regular observations and the one held in reserve. Observers will promptly report, by letter, any defect observed in either instrument, giving full details as to its nature and probable cause.

143. *Exposure of barometers.*—Observers will expose their barometers and barographs in accordance with the provisions of paragraphs 58 and 119.

144. *Cisterns of extra barometers.*—When not in use the cistern of the extra barometer may be screwed up so as to raise the level of the mercury about halfway up around the ivory point. *The cistern should not be filled* nor the mercury forced to the top of the tube, except the barometer is to be moved.

When a barometer cistern is thus filled or partially filled, it is best to lower it an hour or so before readings are made.

145. *Elevation of barometers above sea level.*—At the earliest practicable opportunity after establishing a new station or moving into a new office the observer will ascertain and report, upon Form No. 1058–

Met'l, the elevation of the barometer above sea level. This measurement should refer to the elevation of the lower end of the ivory point of the barometer. Specific instructions in regard thereto are given in paragraphs 128 to 133, and on the back of the form mentioned.

146. When observations are commenced at a new station and the appropriate table of reductions to sea level has not, as yet, been received from the Central Office, only the corrections given on Form No. 1059–Met'l, and for temperature will be applied to barometer readings, and the results will be recorded on all forms required and telegraphed in the usual manner until tables of reduction are received.

147. *Regular barometric observations.*—Settings and readings of the "station" barometer, as required by the instructions providing for the regular observations of the station, will be made in accordance with the provisions of paragraphs 66 to 69, and these readings will be corrected for errors, as illustrated in the example given in paragraph 138.

148. *Reduction of barometric readings to sea level.*—In reducing barometer readings to sea level the special tables supplied each station according to its elevation will be used.

The temperature argument will be obtained by taking the mean of the current, with the previous 8 a. m. or 8 p. m. observation. For example: Dodge, Kans., March 1, 1889, temperature, 8 a. m., 33.7°; 8 p. m., 45.4°; the mean of these, 39.6°, is the temperature to be used in reducing the 8 p. m. reading to sea level.

149. *Provisional removal correction.*—When the elevation of the barometer has been changed by removal or otherwise, and the observer has ascertained with reasonable accuracy the new, that is, the "actual elevation," (see paragraph 141) he will immediately report the same to the Central Office, even if Form No. 1058–Met'l can not be submitted at the same time. Furthermore, pending the receipt of new copies of Form No. 1059–Met'l, he will reduce his daily barometric observations at the new location by the use of a *provisional removal correction* deduced in the manner illustrated in paragraph 165. In his letter the observer will give the value and algebraic sign of the correction he proposes to use.

150. *Comparative barometer readings.*—The provisions of paragraphs 86 to 89 will be observed in making comparative readings; the results will be tabulated and reported on Form No. 1027–Met'l, and the detailed instructions printed on the back thereof fully complied with. Form No. 1027–Met'l will either be duplicated for the station file, or a letter press copy retained for the station record.

Five comparative readings at intervals of hours, half hours, or quarter hours will be made in accordance with the foregoing provisions and on the following occasions:

(*a*) When new barometers are received for the establishment of a station, or, in general, whenever any serviceable Weather Bureau instrument is received at station, by transfer or otherwise.

(*b*) Regular monthly readings will be made on the 15th of each month (or on the 16th if the 15th falls on Sunday).

(*c*) Before and after removal of office or change in the location of the barometers, also, when a line of levels is not run, a set with the station barometer in new office and extra in old office, see paragraph 133.

(*d*) Before and after cleaning a barometer.

151. Except in the case of the regular monthly readings, observers will forward special comparative barometer readings with a letter of transmittal, giving any pertinent remarks relative to the condition of the instruments, the occasion for making the readings and other particulars that may enable the Central Office to more fully understand the matter under consideration.

152. *Barometers not to be changed.*—Barometers will not be changed in location or one instrument substituted for another without authority from the Central Office, except the circumstances are such that immediate action is necessary. Neither the "station" nor the "extra" instrument is to be loaned without authority.

153. Changes in the location of barometers, especially when the elevation is changed, as in the removal of an office, should be made at the end of the month, if practicable, and the station barometer will be moved in the interval between the last observation of the day and the first observation of the following day. The foregoing will also apply, as far as practicable, when a new barometer is substituted for the station instrument.

154. *Authority to clean barometers.*—Authority to clean barometers will be granted only in special cases, and applications therefore should be made with due consideration of the provisions of paragraph 84. Unless otherwise provided for, only one barometer will be cleaned within any given month, and then just after the regular monthly comparative readings have been made. The set of readings required, *after cleaning*, may be made the same or the following day, preferably the latter. The specific instructions for cleaning barometers, paragraphs 92 to 112, will be carefully observed.

155. *Requisition for mercury.*—Mercury will be furnished to stations only on special requisition, which will be made when the mercury is needed for immediate use in connection with the authorized cleaning and repairing of barometers.

156. *Impure mercury.*—Mercury of an impure character that has been removed from barometers, or otherwise acquired on station, should be

carefully preserved, and quantities of from a half pound to a pound or more will be forwarded to the central office, in strong bottles, by mail, securely wrapping the bottle or other receptacle in proper packing material to prevent breakage. The stopper of the bottle should fit tightly and be strongly tied and sealed if practicable. The mercury is easily reduced to great purity at this office, by distillation, etc. The package should be marked: Instrument Division.

157. *Mercury not to be removed.*—When an unserviceable barometer is returned to this office the mercury should not be removed except as provided for in paragraph 118, and it will then be disposed of as specified in paragraph 156.

158. *Barographs.*—The winding and regulating of barograph clocks, the changing of sheets, and the adjustment of pens to standard pressures, will be attended to in accordance with the provisions of Section (B), page 63.

159. *Time error checked.*—The barograph will be checked for time error at 12 noon, each day, in the manner explained in paragraph 125.

160. *Hourly readings.*—Detailed instructions for compiling and transcribing records from barographs are given in Circular A, Instrument Division.

161. *Comparison of private barometers.*—Observers will extend every courtesy to shipmasters and others who may apply at the office for information or submit barometers for comparison, adjustment, etc. The mercurial barometers at a station can not as a rule be removed from the office for comparison and adjustment of barometers on board vessels, etc., but in some cases aneroid barometers serve very conveniently for this purpose. A supply of these is not on hand at the Central Office for issue, however.

A memorandum or tag, showing date of comparison, the correction to be applied, and other pertinent facts should accompany an instrument that has been compared.

A proper note will be made in the Daily Journal giving the name and address of the owner, and the name and maker of the barometer, its number, etc., if practicable, and the results of the comparison.

VIII.—TABLES.

EXPLANATION OF TABLES.

TABLES I AND II.—*Correction for temperature.*

162. Tables I and II give, in English and metric measures, respectively, the corrections that should be applied to the observed readings of a mercurial barometer having a brass scale, in order to eliminate from the barometer reading the effect of temperature in

expanding the mercury and the scale. The following example will elucidate the use of either table:

The attached thermometer of a barometer reads	72.5°
The barometer reads	29.415

In Table I, the pressure nearest 29.415 is 29.5. Horizontally opposite 72.5° in the vertical column under this pressure we find .117, which is the correction required, and we note that it must be subtracted.

The reading corrected for temperature is, therefore	29.415
	—.117
	29.298

163. *Interpolation explained.*—Suppose the pressure had been 29.281, which is about midway between 29.0 and 29.5. The correction in this case should be about midway between .115 and .117, viz, 116. The same rules must be followed if the temperature is intermediate between the values of the table.

TABLES III AND IV.—*Influence of gravity on barometric observations.*

164. Table III gives the correction required to reduce readings of the mercurial barometer to standard gravity at latitude 45°.

There is, in addition to the above, another gravity correction required to eliminate the effect of change of gravity with elevation. This is small and is given in Table IV.

The aneroid barometer does not require any gravity correction.

Example: For latitude 38° and pressure 29 inches, the gravity correction is *minus* .018 of an inch. For an altitude of 2,490 feet and a pressure of 27.3 inches the gravity correction is — .004 of an inch.

TABLE V.—*Pressure in inches corresponding to changes of* 100 *feet in elevation.*

165. Table V is employed for computing "removal corrections," paragraph 149, and its use is illustrated by the following example:

Suppose the "adopted or station elevation" of a given station is 1,482.7 feet, and that after removal the "actual elevation" is 1,516.4, hence the change in elevation will be 33.7 feet.

Suppose, also, that the mean annual temperature at the station is 56°.

Table V gives 0.103 for 1,500 feet and temperature 56°. To reduce, therefore, from the "actual elevation" of 1,516.4 feet to the "station elevation" of 1,482.7 feet, the following correction is necessary, viz, $\frac{33.7}{100} \times 0.103 = 0.035$, which is the "removal correction" required on Form No. 1059–Met'l. The correction in this case must be used with the plus sign.

TABLES VI AND VII.—*Determination of heights by barometer.*

166. The use of these tables requires that at least two observations of the temperature and the pressure of the air be made, simultaneously if possible, at two stations. The elevation of one of the stations must be known.

From Table VI we find the first approximate difference of elevation of the two stations. Table VII gives the allowance that must be made on account of the temperature of the air.

To be strictly accurate, allowance ought also be made for three other effects: (*a*) For the amount of moisture in the air; (*b*) for the effect of gravity on the weight of the air; (*c*) for the effect of gravity on the weight of the mercury (not required when the aneroid is used or when the readings of a mercurial barometer are separately corrected for gravity.) By neglecting these effects in computing a high elevation, say 10,000 feet, other conditions being average, an error of fully 100 feet may be made. Greater inaccuracies than this, however, are likely to result if the computations are based upon only a few barometric and temperature readings, and especially if the readings are not strictly simultaneous. Moreover, the air temperature required is the mean temperature of the whole column between the two stations, but this is only approximately given by the mean of the observed temperatures.

The two tables following are, therefore, sufficiently accurate for use of tourists who desire a knowledge of the approximate altitude corresponding to the more or less limited and incomplete observations they may make. Example:

Barometer reading at base station	27.58 inches.
Barometer reading at upper station	21.47 inches.
Air temperature at base station	68°
Air temperature at upper station	42°

Estimated mean temperature of air column is—

$$\frac{68+42}{2}=\frac{110}{2}=55^\circ=\mathrm{T}.$$

Table III, at 21.47, gives	9,002 feet.
at 27.58, gives	2,195 feet.
First approximate difference of elevation	6,807 feet.

Table IV, for T = 55° and 6,800 feet, gives:

Allowance for temperature of air	+69 feet.
Hence difference of elevation is	6,876 feet.
Suppose the elevation of the base station is	1,851 feet.
Then final elevation of upper station is	8,727 feet.

TABLE I.—*Correction of mercurial barometer for temperature, English measures.*

°F.	Observed reading of the barometer, in inches.														
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
	Inches.						ADD.				*Inches.*				
−20	.075	.080	.084	.089	.093	.098	.102	.107	.111	.115	.120	.124	.129	.133	.138
−19	.074	.078	.083	.087	.091	.096	.100	.104	.109	.113	.117	.122	.126	.130	.135
−18	.072	.077	.081	.085	.089	.094	.098	.102	.106	.111	.115	.119	.123	.128	.132
−17	.071	.075	.079	.083	.087	.092	.096	.100	.104	.108	.112	.117	.121	.125	.129
−16	.069	.073	.077	.081	.086	.090	.094	.098	.102	.106	.110	.114	.118	.122	.126
−15	.068	.072	.076	.080	.084	.088	.092	.096	.100	.103	.107	.111	.115	.119	.123
−14	.066	.070	.074	.078	.082	.086	.089	.093	.097	.101	.105	.109	.113	.117	.121
−13	.065	.068	.072	.076	.080	.084	.087	.091	.095	.099	.103	.106	.110	.114	.118
−12	.063	.067	.070	.074	.078	.082	.085	.089	.093	.096	.100	.104	.107	.111	.115
−11	.061	.065	.069	.072	.076	.080	.083	.087	.090	.094	.098	.101	.105	.108	.112
−10	.060	.063	.067	.070	.074	.077	.081	.085	.088	.092	.095	.099	.102	.106	.109
− 9	.058	.062	.065	.069	.072	.075	.079	.082	.086	.089	.093	.096	.099	.103	.106
− 8	.057	.060	.063	.067	.070	.073	.077	.080	.083	.087	.090	.094	.097	.100	.104
− 7	.055	.058	.062	.065	.068	.071	.075	.078	.081	.084	.088	.091	.094	.097	.101
− 6	.054	.057	.060	.063	.066	.069	.073	.076	.079	.082	.085	.088	.092	.095	.098
− 5	.052	.055	.058	.061	.064	.067	.070	.074	.077	.080	.083	.086	.089	.092	.095
− 4	.051	.054	.056	.059	.052	.065	.068	.071	.074	.077	.080	.083	.086	.089	.092
− 3	.049	.052	.055	.058	.061	.063	.066	.069	.072	.075	.078	.081	.084	.086	.089
− 2	.047	.050	.053	.056	.059	.061	.064	.067	.070	.073	.075	.078	.081	.084	.087
− 1	.046	.049	.051	.054	.057	.059	.062	.065	.067	.070	.073	.076	.078	.081	.084
0	.044	.047	.050	.052	.055	.057	.060	.063	.065	.068	.070	.073	.076	.078	.081
1	.043	.045	.048	.050	.053	.055	.058	.060	.063	.065	.068	.070	.073	.076	.078
2	.041	.044	.046	.049	.051	.053	.056	.058	.061	.063	.065	.068	.070	.073	.075
3	.040	.042	.044	.047	.049	.051	.054	.056	.058	.061	.063	.065	.068	.070	.072
4	.038	.040	.043	.045	.047	.049	.052	.054	.056	.058	.061	.063	.065	.067	.070
5	.037	.039	.041	.043	.045	.047	.049	.052	.054	.056	.058	.060	.062	.065	.067
6	.035	.037	.039	.041	.043	.045	.047	.049	.052	.054	.056	.058	.060	.062	.064
7	.033	.035	.037	.039	.041	.043	.045	.047	.049	.051	.053	.055	.057	.059	.061
8	.032	.034	.036	.038	.039	.041	.043	.045	.047	.049	.051	.053	.054	.056	.058
9	.030	.032	.034	.036	.038	.039	.041	.043	.045	.046	.048	.050	.052	.054	.055
10	.029	.031	.032	.034	.036	.037	.039	.041	.042	.044	.046	.047	.049	.051	.053
11	.027	.029	.030	.032	.034	.035	.037	.039	.040	.042	.043	.045	.047	.048	.050
12	.026	.027	.029	.030	.032	.033	.035	.036	.038	.039	.041	.042	.044	.045	.047
13	.024	.026	.027	.028	.030	.031	.033	.034	.036	.037	.038	.040	.041	.043	.044
14	.023	.024	.025	.027	.028	.029	.031	.032	.033	.035	.036	.037	.039	.040	.041
15	.021	.022	.024	.025	.026	.027	.029	.030	.031	.032	.033	.035	.036	.037	.038
16	.020	.021	.022	.023	.024	.025	.026	.028	.029	.030	.031	.032	.033	.034	.036
17	.018	.019	.020	.021	.022	.023	.024	.025	.026	.027	.029	.030	.031	.032	.033
18	.016	.017	.018	.019	.020	.021	.022	.023	.024	.025	.026	.027	.028	.029	.030
19	.015	.016	.017	.018	.018	.019	.020	.021	.022	.023	.024	.025	.025	.026	.027
20	.013	.014	.015	.016	.016	.017	.018	.019	.020	.020	.021	.022	.023	.024	.024
21	.012	.012	.013	.014	.015	.015	.016	.017	.017	.018	.019	.019	.020	.021	.022
22	.010	.011	.011	.012	.013	.013	.014	.014	.015	.016	.016	.017	.017	.018	.019
23	.009	.009	.010	.010	.011	.011	.012	.012	.013	.013	.014	.014	.015	.015	.016
24	.007	.008	.008	.008	.009	.009	.010	.010	.011	.011	.011	.012	.012	.013	.013
25	.006	.006	.006	.007	.007	.007	.008	.008	.008	.009	.009	.009	.010	.010	.010
26	.004	.004	.005	.005	.005	.005	.005	.006	.006	.006	.006	.007	.007	.007	.007
27	.003	.003	.003	.003	.003	.003	.003	.004	.004	.004	.004	004	.004	.004	.005
28	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.002	.002	.002	.002	.002
	SUBTRACT														
29	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
30	.002	.002	.002	.002	.003	.003	.003	.003	.003	.003	.003	.003	.004	.004	.004
31	.004	.004	.004	.004	.005	.005	.005	.005	.005	.006	.006	.006	.006	.006	.007
32	.005	.006	.006	.006	.006	.007	.007	.007	.008	.008	.008	.009	.009	.009	.009
33	.007	.007	.008	.008	.008	.009	.009	.010	.010	.010	.011	.011	.012	.012	.012
34	.008	.009	.009	.010	.010	.011	.011	.012	.012	.013	.013	.014	.014	.015	.015
35	.010	.010	.011	.012	.012	.013	.013	.014	.014	.015	.016	.016	.017	.017	.018
36	.011	.012	.013	.013	.014	.015	.015	.016	.017	.017	.018	.019	.019	.020	.021
37	.013	.014	.014	.015	.016	.017	.017	.018	.019	.020	.021	.021	.022	.023	.024
38	.014	.015	.016	.017	.018	.019	.020	.020	.021	.022	.023	.024	.025	.026	.026
39	.016	.017	.018	.019	.020	.021	.022	.023	.024	.024	.025	.026	.027	.028	.029
40	.018	.019	.020	.021	.022	.023	.024	.025	.026	.027	.028	.029	.030	.031	.032

TABLE I.—*Correction of mercurial barometer for temperature, etc.*—Continued.

° *F.*	Observed reading of the barometer, in inches.														
	17	17.5	18	18.5	19	19.5	20	20.5	21	21.5	22	22.5	23	23.5	24
				Inches.				SUBTRACT.				*Inches.*			
35	.010	.010	.010	.011	.011	.011	.012	.012	.012	.012	.013	.013	.013	.014	.014
35.5	.011	.011	.011	.012	.012	.012	.012	.013	.013	.013	.014	.014	.014	.015	.015
36	.011	.012	.012	.012	.013	.013	.013	.014	.014	.014	.015	.015	.015	.016	.016
36.5	.012	.012	.013	.013	.014	.014	.014	.015	.015	.015	.016	.016	.016	.017	.017
37	.013	.013	.014	.014	.014	.015	.015	.016	.016	.016	.017	.017	.017	.018	.018
37.5	.014	.014	.014	.015	.015	.016	.016	.017	.017	.017	.018	.018	.019	.019	.019
38	.014	.015	.015	.016	.016	.017	.017	.017	.018	.018	.019	.019	.020	.020	.020
38.5	.015	.016	.016	.016	.017	.017	.018	.018	.019	.019	.020	.020	.021	.021	.021
39	.016	.016	.017	.017	.018	.018	.019	.019	.020	.020	.021	.021	.022	.022	.023
39.5	.017	.017	.018	.018	.019	.019	.020	.020	.021	.021	.022	.022	.023	.023	.024
40	.018	.018	.019	.019	.020	.020	.021	.021	.022	.022	.023	.023	.024	.024	.025
40.5	.018	.019	.019	.020	.020	.021	.022	.022	.023	.023	.024	.024	.025	.025	.026
41	.019	.020	.020	.021	.021	.022	.022	.023	.024	.024	.025	.025	.026	.026	.027
41.5	.020	.020	.021	.022	.022	.023	.023	.024	.025	.025	.026	.026	.027	.027	.028
42	.021	.021	.022	.022	.023	.024	.024	.025	.025	.026	.027	.027	.028	.029	.029
42.5	.021	.022	.023	.023	.024	.025	.025	.026	.026	.027	.028	.028	.029	.030	.030
43	.022	.023	.023	.024	.025	.025	.026	.027	.027	.028	.029	.029	.030	.031	.031
43.5	.023	.024	.024	.025	.026	.026	.027	.028	.028	.029	.030	.030	.031	.032	.032
44	.024	.024	.025	.026	.026	.027	.028	.029	.029	.030	.031	.031	.032	.033	.033
44.5	.024	.025	.026	.027	.027	.028	.029	.030	.030	.031	.032	.032	.033	.034	.035
45	.025	.026	.027	.027	.028	.029	.030	.030	.031	.032	.033	.033	.034	.035	.036
45.5	.026	.027	.028	.028	.029	.030	.031	.031	.032	.033	.034	.034	.035	.036	.037
46	.027	.028	.028	.029	.030	.031	.031	.032	.033	.034	.035	.035	.036	.037	.038
46.5	.028	.028	.029	.030	.031	.032	.032	.033	.034	.035	.036	.036	.037	.038	.039
47	.028	.029	.030	.031	.032	.032	.033	.034	.035	.036	.037	.037	.038	.039	.040
47.5	.029	.030	.031	.032	.033	.033	.034	.035	.036	.037	.038	.038	.039	.040	.041
48	.030	.031	.032	.032	.033	.034	.035	.036	.037	.038	.039	.040	.040	.041	.042
48.5	.031	.032	.032	.033	.034	.035	.036	.037	.038	.039	.040	.041	.041	.042	.043
49	.031	.032	.033	.034	.035	.036	.037	.038	.039	.040	.041	.042	.042	.043	.044
49.5	.032	.033	.034	.035	.036	.037	.038	.039	.040	.041	.042	.043	.044	.044	.045
50	.033	.034	.035	.036	.037	.038	.039	.040	.041	.042	.043	.044	.045	.046	.046
50.5	.034	.035	.036	.037	.038	.039	.040	.041	.042	.043	.044	.045	.046	.047	.048
51	.034	.035	.036	.038	.039	.040	.041	.042	.043	.044	.045	.046	.047	.048	.049
51.5	.035	.036	.037	.038	.039	.040	.041	.042	.044	.045	.046	.047	.048	.049	.050
52	.036	.037	.038	.039	.040	.041	.042	.043	.044	.046	.047	.048	.049	.050	.051
52.5	.037	.038	.039	.040	.041	.042	.043	.044	.045	.047	.048	.049	.050	.051	.052
53	.038	.039	.040	.041	.042	.043	.044	.045	.046	.047	.049	.050	.051	.052	.053
53.5	.038	.039	.041	.042	.043	.044	.045	.046	.047	.048	.050	.051	.052	.053	.054
54	.039	.040	.041	.043	.044	.045	.046	.047	.048	.049	.051	.052	.053	.054	.055
54.5	.040	.041	.042	.043	.045	.046	.047	.048	.049	.050	.052	.053	.054	.055	.056
55	.041	.042	.043	.044	.045	.047	.048	.049	.050	.051	.053	.054	.055	.056	.057
55.5	.041	.043	.044	.045	.046	.047	.049	.050	.051	.052	.054	.055	.056	.057	.058
56	.042	.043	.045	.046	.047	.048	.050	.051	.052	.053	.055	.056	.057	.058	.060
56.5	.043	.044	.045	.047	.048	.049	.050	.052	.053	.054	.056	.057	.058	.059	.061
57	.044	.045	.046	.048	.049	.050	.051	.053	.054	.055	.057	.058	.059	.060	.062
57.5	.044	.046	.047	.048	.050	.051	.052	.054	.055	.056	.058	.059	.060	.061	.063
58	.045	.047	.048	.049	.051	.052	.053	.055	.056	.057	.059	.060	.061	.063	.064
58.5	.046	.048	.049	.050	.051	.053	.054	.055	.057	.058	.060	.061	.062	.064	.065
59	.047	.048	.050	.051	.052	.054	.055	.056	.058	.059	.061	.062	.063	.065	.066
59.5	.048	.049	.050	.052	.053	.055	.056	.057	.059	.060	.061	.063	.064	.066	.067
60	.048	.050	.051	.053	.054	.055	.057	.058	.060	.061	.062	.064	.065	.067	.068
60.5	.049	.050	.052	.053	.055	.056	.058	.059	.061	.062	.063	.065	.066	.068	.069
61	.050	.051	.053	.054	.056	.057	.059	.060	.062	.063	.064	.066	.067	.069	.070
61.5	.051	.052	.054	.055	.057	.058	.060	.061	.062	.064	.065	.067	.068	.070	.071
62	.051	.053	.054	.056	.057	.059	.060	.062	.063	.065	.066	.068	.069	.071	.073
62.5	.052	.054	.055	.057	.058	.060	.061	.063	.064	.066	.067	.069	.071	.072	.074
63	.053	.054	.056	.058	.059	.061	.062	.064	.065	.067	.068	.070	.072	.073	.075
63.5	.054	.055	.057	.058	.060	.062	.063	.065	.066	.068	.069	.071	.073	.074	.076
64	.054	.056	.058	.059	.061	.062	.064	.066	.067	.069	.070	.072	.074	.075	.077
64.5	.055	.057	.058	.060	.062	.063	.065	.067	.068	.070	.071	.073	.075	.076	.078
65	.056	.058	.059	.061	.063	.064	.066	.067	.069	.071	.072	.074	.076	.077	.079
65.5	.057	.058	.060	.062	.063	.065	.067	.068	.070	.072	.073	.075	.077	.078	.080
66	.057	.059	.061	.063	.064	.066	.068	.069	.071	.073	.074	.076	.078	.079	.081
66.5	.058	.060	.062	.063	.065	.067	.069	.070	.072	.074	.075	.077	.079	.081	.082
67	.059	.061	.062	.064	.066	.068	.069	.071	.073	.075	.076	.078	.080	.082	.083

TABLE I.—*Correction of mercurial barometer for temperature, etc.*—Continued.

°F.	Observed reading of the barometer, in inches.														
	24	24.5	25	25.5	26	26.5	27	27.5	28	28.5	29	29.5	30	30.5	31
	Inches.						SUBTRACT.					*Inches.*			
35	.014	.014	.014	.015	.015	.015	.016	.016	.016	.016	.017	.017	.017	.018	.018
35.5	.015	.015	.016	.016	.016	.017	.017	.017	.017	.018	.018	.018	.019	.019	.019
36	.016	.016	.017	.017	.017	.018	.018	.018	.019	.019	.019	.020	.020	.020	.021
36.5	.017	.017	.018	.018	.019	.019	.019	.020	.020	.020	.021	.021	.021	.022	.022
37	.018	.019	.019	.019	.020	.020	.021	.021	.021	.022	.022	.022	.023	.023	.024
37.5	.019	.020	.020	.021	.021	.021	.022	.022	.023	.023	.023	.024	.024	.025	.025
38	.020	.021	.021	.022	.022	.023	.023	.023	.024	.024	.025	.025	.026	.026	.026
38.5	.021	.022	.022	.023	.023	.024	.024	.025	.025	.026	.026	.026	.027	.027	.028
39	.023	.023	.024	.024	.024	.025	.025	.026	.026	.027	.027	.028	.028	.029	.029
39.5	.024	.024	.025	.025	.026	.026	.027	.027	.028	.028	.029	.029	.030	.030	.031
40	.025	.025	.026	.026	.027	.027	.028	.028	.029	.029	.030	.030	.031	.031	.032
40.5	.026	.026	.027	.027	.028	.029	.029	.030	.030	.031	.031	.032	.032	.033	.033
41	.027	.027	.028	.029	.029	.030	.030	.031	.031	.032	.033	.033	.034	.034	.035
41.5	.028	.029	.029	.030	.030	.031	.032	.032	.033	.033	.034	.034	.035	.036	.036
42	.029	.030	.030	.031	.032	.032	.033	.033	.034	.035	.035	.036	.036	.037	.038
42.5	.030	.031	.031	.032	.033	.033	.034	.035	.035	.036	.036	.037	.038	.038	.039
43	.031	.032	.033	.033	.034	.035	.035	.036	.036	.037	.038	.038	.039	.040	.040
43.5	.032	.033	.034	.034	.035	.036	.036	.037	.038	.038	.039	.040	.040	.041	.042
44	.033	.034	.035	.036	.036	.037	.038	.038	.039	.040	.040	.041	.042	.042	.043
44.5	.035	.035	.036	.037	.037	.038	.039	.040	.040	.041	.042	.042	.043	.044	.045
45	.036	.036	.037	.038	.039	.039	.040	.041	.042	.042	.043	.044	.045	.045	.046
45.5	.037	.037	.038	.039	.040	.041	.041	.042	.043	.044	.044	.045	.046	.047	.047
46	.038	.039	.039	.040	.041	.042	.043	.043	.044	.045	.046	.046	.047	.048	.049
46.5	.039	.040	.041	.041	.042	.043	.044	.045	.045	.046	.047	.048	.049	.049	.050
47	.040	.041	.042	.042	.043	.044	.045	.046	.047	.047	.048	.049	.050	.051	.052
47.5	.041	.042	.043	.044	.045	.045	.046	.047	.048	.049	.050	.050	.051	.052	.053
48	.042	.043	.044	.045	.046	.047	.047	.048	.049	.050	.051	.052	.053	.054	.054
48.5	.043	.044	.045	.046	.047	.048	.049	.050	.050	.051	.052	.053	.054	.055	.056
49	.044	.045	.046	.047	.048	.049	.050	.051	.052	.053	.054	.054	.055	.056	.057
49.5	.045	.046	.047	.048	.049	.050	.051	.052	.053	.054	.055	.056	.057	.058	.059
50	.046	.047	.048	.049	.050	.051	.052	.053	.054	.055	.056	.057	.058	.059	.060
50.5	.048	.049	.050	.051	.052	.053	.054	.055	.055	.056	.057	.058	.059	.060	.061
51	.049	.050	.051	.052	.053	.054	.055	.056	.057	.058	.059	.060	.061	.062	.063
51.5	.050	.051	.052	.053	.054	.055	.056	.057	.058	.059	.060	.061	.062	.063	.064
52	.051	.052	.053	.054	.055	.056	.057	.058	.059	.060	.061	.062	.064	.065	.066
52.5	.052	.053	.054	.055	.056	.057	.058	.059	.061	.062	.063	.064	.065	.066	.067
53	.053	.054	.055	.056	.057	.059	.060	.061	.062	.063	.064	.065	.066	.067	.068
53.5	.054	.055	.056	.057	.059	.060	.061	.062	.063	.064	.065	.066	.068	.069	.070
54	.055	.056	.057	.059	.060	.061	.062	.063	.064	.066	.067	.068	.069	.070	.071
54.5	.056	.057	.059	.060	.061	.062	.063	.064	.066	.067	.068	.069	.070	.071	.073
55	.057	.059	.060	.061	.062	.063	.064	.066	.067	.068	.069	.070	.072	.073	.074
55.5	.058	.060	.061	.062	.063	.065	.066	.067	.068	.069	.071	.072	.073	.074	.075
56	.060	.061	.062	.063	.064	.066	.067	.068	.069	.071	.072	.073	.074	.076	.077
56.5	.061	.062	.063	.064	.066	.067	.068	.069	.071	.072	.073	.074	.076	.077	.078
57	.062	.063	.064	.066	.067	.068	.069	.071	.072	.073	.075	.076	.077	.078	.080
57.5	.063	.064	.065	.067	.068	.069	.071	.072	.073	.075	.076	.077	.078	.080	.081
58	.064	.065	.066	.068	.069	.070	.072	.073	.074	.076	.077	.078	.080	.081	.082
58.5	.065	.066	.068	.069	.070	.072	.073	.074	.076	.077	.078	.080	.081	.083	.084
59	.066	.067	.069	.070	.072	.073	.074	.076	.077	.078	.080	.081	.083	.084	.085
59.5	.067	.068	.070	.071	.073	.074	.075	.077	.078	.080	.081	.082	.084	.085	.087
60	.068	.070	.071	.072	.074	.075	.077	.078	.080	.081	.082	.084	.085	.087	.088
60.5	.069	.071	.072	.074	.075	.076	.078	.079	.081	.082	.084	.085	.087	.088	.089
61	.070	.072	.073	.075	.076	.078	.079	.081	.082	.084	.085	.086	.088	.089	.091
61.5	.071	.073	.074	.076	.077	.079	.080	.082	.083	.085	.086	.088	.089	.091	.092
62	.073	.074	.076	.077	.079	.080	.082	.083	.085	.086	.088	.089	.091	.092	.094
62.5	.074	.075	.077	.078	.080	.081	.083	.084	.086	.087	.089	.090	.092	.094	.095
63	.075	.076	.078	.079	.081	.082	.084	.086	.087	.089	.090	.092	.093	.095	.096
63.5	.076	.077	.079	.080	.082	.084	.085	.087	.088	.090	.092	.093	.095	.096	.098
64	.077	.078	.080	.082	.083	.085	.086	.088	.090	.091	.093	.094	.096	.098	.099
64.5	.078	.080	.081	.083	.084	.086	.088	.089	.091	.093	.094	.096	.097	.099	.101
65	.079	.081	.082	.084	.086	.087	.089	.091	.092	.094	.095	.097	.099	.100	.102
65.5	.080	.082	.083	.085	.087	.088	.090	.092	.093	.095	.097	.098	.100	.102	.103
66	.081	.083	.085	.086	.088	.090	.091	.093	.095	.096	.098	.100	.101	.103	.105
66.5	.082	.084	.086	.087	.089	.091	.093	.094	.096	.098	.099	.101	.103	.105	.106
67	.083	.085	.087	.089	.090	.092	.094	.095	.097	.099	.101	.102	.104	.106	.108

TABLE I.—*Correction of mercurial barometer for temperature, etc.*—Continued.

° *F.*	Observed reading of the barometer, in inches.														
	17	17.5	18	18.5	19	19.5	20	20.5	21	21.5	22	22.5	23	23.5	24
	Inches.						SUBTRACT.					*Inches.*			
67	.059	.061	.062	.064	.066	.068	.069	.071	.073	.075	.076	.078	.080	.082	.083
67.5	.060	.062	.063	.065	.067	.069	.070	.072	.074	.076	.077	.079	.081	.083	.084
68	.061	.062	.064	.066	.068	.069	.071	.073	.075	.077	.078	.080	.082	.084	.085
68.5	.061	.063	.065	.067	.069	.070	.072	.074	.076	.078	.079	.081	.083	.085	.087
69	.062	.064	.066	.068	.069	.071	.073	.075	.077	.079	.080	.082	.084	.086	.088
69.5	.063	.065	.067	.068	.070	.072	.074	.076	.078	.079	.081	.083	.085	.087	.089
70	.064	.065	.067	.069	.071	.073	.075	.077	.079	.080	.082	.084	.086	.088	.090
70.5	.064	.066	.068	.070	.072	.074	.076	.078	.080	.081	.083	.085	.087	.089	.091
71	.065	.067	.069	.071	.073	.075	.077	.079	.080	.082	.084	.086	.088	.090	.092
71.5	.066	.068	.070	.072	.074	.076	.078	.079	.081	.083	.085	.087	.089	.091	.093
72	.067	.069	.071	.073	.075	.076	.078	.080	.082	.084	.086	.088	.090	.092	.094
72.5	.067	.069	.071	.073	.075	.077	.079	.081	.083	.085	.087	.089	.091	.093	.095
73	.068	.070	.072	.074	.076	.078	.080	.082	.084	.086	.088	.090	.092	.094	.096
73.5	.069	.071	.073	.075	.077	.079	,081	.083	.085	.087	.089	.091	.093	.095	.097
74	.070	.072	.074	.076	.078	.080	.082	.084	.086	.088	.090	.092	.094	.096	.098
74.5	.070	.073	.075	.077	.079	.081	.083	.085	.087	.089	.091	.093	.095	.097	.100
75	.071	.073	.075	.078	.080	.082	.084	.086	.088	.090	.092	.094	.096	.099	.101
75.5	.072	.074	.076	.078	.081	.083	.085	.087	.089	.091	.093	.095	.097	.100	.102
76	.073	.075	.077	.079	.081	.084	.086	.088	.090	.092	.094	.096	.098	.101	.103
76.5	.074	.076	.078	.080	.082	.084	.087	.089	.091	.093	.095	.097	.100	.102	.104
77	.074	.077	.079	.081	.083	.085	.087	.090	.092	.094	.096	.098	.101	.103	.105
77.5	.075	.077	.080	.082	.084	.086	.088	.091	.093	.095	.097	.099	.102	.104	.106
78	.076	.078	.080	.083	.085	.087	.089	.091	.094	.096	.098	.100	.103	.105	.107
78.5	.077	.079	.081	.083	.086	.088	.090	.092	.095	.097	.099	.101	.104	.106	.108
79	.077	.080	.082	.084	.086	.089	.091	.093	.096	.098	.100	.102	.105	.107	.109
79.5	.078	.080	.083	.085	.087	.090	.092	.094	.097	.099	.101	.103	.106	.108	.110
80	.079	.081	.084	.086	.088	.091	.093	.095	.097	.100	.102	.104	.107	.109	.111
80.5	.080	.082	.084	.087	.089	.091	.094	.096	.098	.101	.103	.105	.108	.110	.112
81	.080	.083	.085	.088	.090	.092	.095	.097	.099	.102	.104	.106	.109	.111	.114
81.5	.081	.084	.086	.088	.091	.093	.096	.098	.100	.103	.105	.107	.110	.112	.115
82	.082	.084	.087	.089	.092	.094	.096	.099	.101	.104	.106	.108	.111	.113	.116
82.5	.083	.085	.088	.090	.092	.095	.097	.100	.102	.105	.107	.109	.112	.114	.117
83	.083	.086	.088	.091	.093	.096	.098	.101	.103	.106	.108	.111	.113	.115	.118
83.5	.084	.087	.089	.092	.094	.097	.099	.102	.104	.107	.109	.112	.114	.117	.119
84	.085	.088	.090	.093	.095	.098	.100	.103	.105	.108	.110	.113	.115	.118	.120
84.5	.086	.088	.091	.093	.096	.098	.101	.103	.106	.108	.111	.114	.116	.119	.121
85	.087	.089	.092	.094	.097	.099	.102	.104	.107	.109	.112	.115	.117	.120	.122
85.5	.087	.090	.092	.095	.098	.100	.103	.105	.108	.110	.113	.116	.118	.121	.123
86	.088	.091	.093	.096	.098	.101	.104	.106	.109	.111	.114	.117	.119	.122	.124
86.5	.089	.091	.094	.097	.099	.102	.105	.107	.110	.112	.115	.118	.120	.123	.125
87	.090	.092	.095	.098	.100	.103	.105	.108	.111	.113	.116	.119	.121	.124	.126
87.5	.090	.093	.096	.098	.101	.104	.106	.109	.112	.114	.117	.120	.122	.125	.128
88	.091	.094	.096	.099	.102	.105	.107	.110	.113	.115	.118	.121	.123	.126	.129
88.5	.092	.095	.097	.100	.103	.105	.108	.111	.114	.116	.119	.122	.124	.127	.130
89	.093	.095	.098	.101	.104	.106	.109	.112	.114	.117	.120	.123	.125	.128	.131
89.5	.093	.096	.099	.102	.104	.107	.110	.113	.115	.118	.121	.124	.126	.129	.132
90	.094	.097	.100	.102	.105	.108	.111	.114	.116	.119	.122	.125	.127	.130	.133
90.5	.095	.098	.101	.103	.106	.109	.112	.114	.117	.120	.123	.126	.128	.131	.134
91	.096	.099	.101	.104	.107	.110	.113	.115	.118	.121	.124	.127	.129	.132	.135
91.5	.096	.099	.102	.105	.108	.111	.113	.116	.119	.122	.125	.128	.131	.133	.136
92	.097	.100	.103	.106	.109	.112	.114	.117	.120	.123	.126	.129	.132	.134	.137
92.5	.098	.101	.104	.107	.110	.112	.115	.118	.121	.124	.127	.130	.133	.135	.138
93	.099	.102	.105	.107	.110	.113	.116	.119	.122	.125	.128	.131	.134	.137	.139
93.5	.100	.102	.105	.108	.111	.114	.117	.120	.123	.126	.129	.132	.135	.138	.140
94	.100	.103	.106	.109	.112	.115	.118	.121	.124	.127	.130	.133	.136	.139	.142
94.5	.101	.104	.107	.110	.113	.116	.119	.122	.125	.128	.131	.134	.137	.140	.143
95	.102	.105	.108	.111	.114	.117	.120	.123	.126	.129	.132	.135	.138	.141	.144
95.5	.103	.106	.109	.112	.115	.118	.121	.124	.127	.130	.133	.136	.139	.142	.145
96	.103	.106	.109	.112	.115	.119	.122	.125	.128	.131	.134	.137	.140	.143	.146
96.5	.104	.107	.110	.113	.116	.119	.122	.126	.129	.132	.135	.138	.141	.144	.147
97	.105	.108	.111	.114	.117	.120	.123	.126	.130	.133	.136	.139	.142	.145	.148
97.5	.106	.109	.112	.115	.118	.121	.124	.127	.130	.134	.137	.140	.143	.146	.149
98	.106	.109	.113	.116	.119	.122	.125	.128	.131	.135	.138	.141	.144	.147	.150
98.5	.107	.110	.113	.117	.120	.123	.126	.129	.132	.135	.139	.142	.145	.148	.151
99	.108	.111	.114	.117	.121	.124	.127	.130	.133	.136	.140	.143	.146	.149	.152
99.5	.109	.112	.115	.118	.121	.125	.128	.131	.134	.137	.141	.144	.147	.150	.153
100	.109	.113	.116	.119	.122	.126	.129	.132	.135	.138	.142	.145	.148	.151	.154

TABLE I.—*Correction of mercurial barometer for temperature, etc.*—Continued.

°F.	Observed reading of the barometer, in inches.														
	24	24.5	25	25.5	26	26.5	27	27.5	28	28.5	29	29.5	30	30.5	31
	Inches.						SUBTRACT.					*Inches.*			
67	.083	.085	.087	.089	.090	.092	.094	.095	.097	.099	.101	.102	.104	.106	.108
67.5	.084	.086	.088	.090	.092	.093	.095	.097	.098	.100	.102	.104	.106	.107	.109
68	.085	.087	.089	.091	.093	.094	.096	.098	.100	.102	.103	.105	.107	.109	.110
68.5	.087	.088	.090	.092	.094	.096	.097	.099	.101	.103	.105	.106	.108	.110	.112
69	.088	.089	.091	.093	.095	.097	.099	.100	.102	.104	.106	.108	.110	.111	.113
69.5	.089	.091	.092	.094	.096	.098	.100	.102	.104	.105	.107	.109	.111	.113	.115
70	.090	.092	.094	.095	.097	.099	.101	.103	.105	.107	.109	.110	.112	.114	.116
70.5	.091	.093	.095	.097	.098	.100	.102	.104	.106	.108	.110	.112	.114	.116	.117
71	.092	.094	.096	.098	.100	.102	.103	.105	.107	.109	.111	.113	.115	.117	.119
71.5	.093	.095	.097	.099	.101	.103	.105	.107	.109	.110	.112	.114	.116	.118	.120
72	.094	.096	.098	.100	.102	.104	.106	.108	.110	.112	.114	.116	.118	.120	.122
72.5	.095	.097	.099	.101	.103	.105	.107	.109	.111	.113	.115	.117	.119	.121	.123
73	.096	.098	.100	.102	.104	.106	.108	.110	.112	.114	.116	.118	.120	.122	.124
73.5	.097	.099	.101	.103	.105	.108	.110	.112	.114	.116	.118	.120	.122	.124	.126
74	.098	.101	.103	.105	.107	.109	.111	.113	.115	.117	.119	.121	.123	.125	.127
74.5	.100	.102	.104	.106	.108	.110	.112	.114	.116	.118	.120	.122	.124	.126	.129
75	.101	.103	.105	.107	.109	.111	.113	.115	.117	.119	.122	.124	.126	.128	.130
75.5	.102	.104	.106	.108	.110	.112	.114	.117	.119	.121	.123	.125	.127	.129	.131
76	.103	.105	.107	.109	.111	.113	.116	.118	.120	.122	.124	.126	.128	.131	.133
76.5	.104	.106	.108	.111	.113	.115	.117	.119	.121	.123	.125	.128	.130	.132	.134
77	.105	.107	.109	.112	.114	.116	.118	.120	.122	.125	.127	.129	.131	.133	.136
77.5	.106	.108	.110	.113	.115	.117	.119	.121	.124	.126	.128	.130	.133	.135	.137
78	.107	.109	.112	.114	.116	.118	.120	.123	.125	.127	.129	.132	.134	.136	.138
78.5	.108	.110	.113	.115	.117	.119	.122	.124	.126	.128	.131	.133	.135	.137	.140
79	.109	.112	.114	.116	.118	.121	.123	.125	.127	.130	.132	.134	.137	.139	.141
79.5	.110	.113	.115	.117	.120	.122	.124	.126	.129	.131	.133	.136	.138	.140	.143
80	.111	.114	.116	.118	.121	.123	.125	.128	.130	.132	.135	.137	.139	.142	.144
80.5	.112	.115	.117	.120	.122	.124	.127	.129	.131	.134	.136	.138	.141	.143	.145
81	.114	.116	.118	.121	.123	.125	.128	.130	.132	.135	.137	.140	.142	.144	.147
81.5	.115	.117	.119	.122	.124	.127	.129	.131	.134	.136	.139	.141	.143	.146	.148
82	.116	.118	.121	.123	.125	.128	.130	.133	.135	.137	.140	.142	.145	.147	.149
82.5	.117	.119	.122	.124	.127	.129	.131	.134	.136	.139	.141	.144	.146	.148	.151
83	.118	.120	.123	.125	.128	.130	.133	.135	.138	.140	.142	.145	.147	.150	.152
83.5	.119	.121	.124	.126	.129	.131	.134	.136	.139	.141	.144	.146	.149	.151	.154
84	.120	.123	.125	.128	.130	.133	.135	.138	.140	.143	.145	.148	.150	.153	.155
84.5	.121	.124	.126	.129	.131	.134	.136	.139	.141	.144	.146	.149	.151	.154	.156
85	.122	.125	.127	.130	.132	.145	.137	.140	.143	.145	.148	.150	.153	.155	.158
85.5	.123	.126	.128	.131	.134	.136	.139	.141	.144	.146	.149	.152	.154	.157	.159
86	.124	.127	.130	.132	.135	.137	.140	.142	.145	.148	.150	.153	.155	.158	.161
86.5	.125	.128	.131	.133	.136	.138	.141	.144	.146	.149	.152	.154	.157	.159	.162
87	.126	.129	.132	.134	.137	.140	.142	.145	.148	.150	.153	.155	.158	.161	.163
87.5	.128	.130	.133	.136	.138	.141	.144	.146	.149	.151	.154	.157	.159	.162	.165
88	.129	.131	.134	.137	.139	.142	.145	.147	.150	.153	.155	.158	.161	.163	.166
88.5	.130	.132	.135	.138	.141	.143	.146	.149	.151	.154	.157	.159	.162	.165	.168
89	.131	.134	.136	.139	.142	.144	.147	.150	.153	.155	.158	.161	.164	.166	.169
89.5	.132	.135	.137	.140	.143	.146	.148	.151	.154	.157	.159	.162	.165	.168	.170
90	.133	.136	.138	.141	.144	.147	.150	.152	.155	.158	.161	.163	.166	.169	.172
90.5	.134	.137	.140	.142	.145	.148	.151	.154	.156	.159	.162	.165	.168	.170	.173
91	.135	.138	.141	.144	.146	.149	.152	.155	.158	.160	.163	.166	.169	.172	.175
91.5	.136	.139	.142	.145	.148	.150	.153	.156	.159	.162	.165	.167	.170	.173	.176
92	.137	.140	.143	.146	.149	.152	.154	.157	.160	.163	.166	.169	.172	.174	.177
92.5	.138	.141	.144	.147	.150	.153	.156	.159	.161	.164	.167	.170	.173	.176	.179
93	.139	.142	.145	.148	.151	.154	.157	.160	.163	.166	.168	.171	.174	.177	.180
93.5	.140	.143	.146	.149	.152	.155	.158	.161	.164	.167	.170	.173	.176	.179	.181
94	.142	.145	.147	.150	.153	.156	.159	.162	.165	.168	.171	.174	.177	.180	.183
94.5	.143	.146	.149	.152	.155	.158	.160	.163	.166	.169	.172	.175	.178	.181	.184
95	.144	.147	.150	.153	.156	.159	.162	.165	.168	.171	.174	.177	.180	.183	.186
95.5	.145	.148	.151	.154	.157	.160	.163	.166	.169	.172	.175	.178	.181	.184	.187
96	.146	.149	.152	.155	.158	.161	.164	.167	.170	.173	.176	.179	.182	.185	.188
96.5	.147	.150	.153	.156	.159	.162	.165	.168	.171	.174	.178	.181	.184	.187	.190
97	.148	.151	.154	.157	.160	.163	.167	.170	.173	.176	.179	.182	.185	.188	.191
97.5	.149	.152	.155	.158	.162	.165	.168	.171	.174	.177	.180	.183	.186	.189	.193
98	.150	.153	.156	.160	.163	.166	.169	.172	.175	.178	.181	.185	.188	.191	.194
98.5	.151	.154	.158	.161	.164	.167	.170	.173	.176	.180	.183	.186	.189	.192	.195
99	.152	.155	.159	.162	.165	.168	.171	.175	.178	.181	.184	.187	.190	.194	.197
99.5	.153	.157	.160	.163	.166	.169	.173	.176	.179	.182	.185	.189	.192	.195	.198
100	.154	.158	.161	.164	.167	.171	.174	.177	.180	.183	.187	.190	.193	.196	.200

TABLE II.—*Correction of mercurial barometers for temperature, metric measures.*

Temperature, C.	Observed reading of the barometer, in millimeters.														
	640	650	660	670	680	690	700	710	720	730	740	750	760	770	780
0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.0	.10	.11	.11	.11	.11	.11	.11	.12	.12	.12	.12	.12	.12	.13	.13
2.0	.21	.21	.22	.22	.22	.23	.23	.23	.24	.24	.24	.25	.25	.25	.25
3.0	.31	.32	.32	.33	.33	.34	.34	.35	.35	.36	.36	.37	.37	.38	.38
4.0	.42	.42	.43	.44	.44	.45	.46	.46	.47	.48	.48	.49	.50	.50	.51
5.	0.52	0.53	0.54	0.55	0.56	0.56	0.57	0.58	0.59	0.60	0.60	0.61	0.62	0.63	0.64
5.5	.57	.58	.59	.60	.61	.62	.73	.64	.65	.66	.66	.67	.68	.69	.70
6.	.63	.64	.65	.66	.67	.68	.69	.70	.71	.71	.72	.73	.74	.75	.76
6.5	.68	.69	.70	.71	.72	.73	.74	.75	.76	.77	.79	.80	.81	.82	.83
7.	.73	.74	.75	.77	.78	.79	.80	.81	.82	.83	.85	.86	.87	.88	.89
7.5	0.78	0.80	0.81	0.82	0.83	0.84	0.86	0.87	0.88	0.89	0.91	0.92	0.93	0.94	0.95
8.	.84	.85	.86	.87	.89	.90	.91	.93	.94	.95	.97	.98	.99	1.01	1.02
8.5	.89	.90	.92	.93	.94	.96	.97	.98	1.00	1.01	1.03	1.04	1.05	1.07	1.08
9.	.94	.95	.97	.98	1.00	1.01	1.03	1.04	1.06	1.07	1.09	1.10	1.12	1.13	1.15
9.5	.99	1.01	1.02	1.04	1.05	1.07	1.08	1.10	1.12	1.13	1.15	1.16	1.18	1.19	1.21
10.0	1.04	1.06	1.08	1.09	1.11	1.13	1.14	1.16	1.17	1.19	1.21	1.22	1.24	1.26	1.27
.2	.06	.08	.10	.11	.13	.15	.16	.18	.20	.21	.23	.25	.26	.28	.30
.4	.09	.10	.12	.14	.15	.17	.19	.20	.22	.24	.26	.27	.29	.31	.32
.6	.11	.12	.14	.16	.18	.19	.21	.23	.24	.26	.28	.30	.31	.33	.35
.8	.13	.14	.16	.18	.20	.22	.23	.25	.27	.29	.30	.32	.34	.36	.37
11.0	1.15	1.17	1.18	1.20	1.22	1.24	1.26	1.27	1.29	1.31	1.33	1.35	1.36	1.38	1.40
.2	.17	.19	.21	.22	.24	.26	.28	.30	.31	.33	.35	.37	.39	.41	.42
.4	.19	.21	.23	.25	.26	.28	.30	.32	.34	.36	.38	.39	.41	.43	.45
.6	.21	.23	.25	.27	.29	.31	.32	.34	.36	.38	.40	.42	.44	.46	.48
.8	.23	.25	.27	.29	.31	.33	.35	.37	.39	.40	.42	.44	.46	.48	.50
12.0	1.25	1.27	1.29	1.31	1.33	1.35	1.37	1.39	1.41	1.43	1.45	1.47	1.49	1.51	1.53
.2	.27	.29	.31	.33	.35	.37	.39	.41	.43	.45	.47	.49	.51	.53	.55
.4	.29	.31	.33	.35	.37	.39	.42	.44	.46	.48	.50	.52	.54	.56	.58
.6	.31	.34	.36	.38	.40	.42	.44	.46	.48	.50	.52	.54	.56	.58	.60
.8	.34	.36	.38	.40	.42	.44	.46	.48	.50	.52	.54	.56	.59	.61	.63
13.0	1.36	1.38	1.40	1.42	1.44	1.46	1.48	1.50	1.53	1.55	1.57	1.59	1.61	1.63	1.65
.2	.38	.40	.42	.44	.46	.48	.51	.53	.55	.57	.59	.61	.64	.66	.68
.4	.40	.42	.44	.46	.49	.51	.53	.55	.57	.59	.62	.64	.66	.68	.70
.6	.42	.44	.46	.49	.51	.53	.55	.57	.60	.62	.64	.66	.68	.71	.73
.8	.44	.46	.48	.51	.53	.55	.57	.60	.62	.64	.66	.69	.71	.73	.75
14.0	1.46	1.48	1.51	1.53	1.55	1.57	1.60	1.62	1.64	1.67	1.69	1.71	1.73	1.76	1.78
.2	.48	.50	.53	.55	.57	.60	.62	.64	.67	.69	.71	.74	.76	.78	.81
.4	.50	.53	.55	.57	.60	.62	.64	.67	.69	.71	.74	.76	.78	.81	.83
.6	.52	.55	.57	.59	.62	.64	.67	.69	.71	.74	.76	.78	.81	.83	.86
.8	.54	.57	.59	.62	.64	.66	.69	.71	.74	.76	.78	.81	.83	.86	.88
15.0	1.56	1.59	1.61	1.64	1.66	1.69	1.71	1.74	1.76	1.78	1.81	1.83	1.86	1.88	1.91
.2	.59	.61	.63	.66	.68	.71	.73	.76	.78	.81	.83	.86	.88	.91	.93
.4	.61	.63	.66	.68	.71	.73	.76	.78	.81	.83	.86	.88	.91	.93	.96
.6	.63	.65	.68	.70	.73	.75	.78	.80	.83	.86	.88	.91	.93	.96	1.98
.8	.65	.67	.70	.72	.75	.78	.80	.83	.85	.88	.90	.93	.96	1.98	2.01
16.0	1.67	1.69	1.72	1.75	1.77	1.80	1.82	1.85	1.88	1.90	1.93	1.96	1.98	2.01	2.03
.2	.69	.72	.74	.77	.79	.82	.85	.87	.90	.93	.95	1.98	2.01	.03	.06
.4	.71	.74	.76	.79	.82	.84	.87	.90	.92	.95	1.98	2.00	.03	.06	.08
.6	.73	.76	.78	.81	.84	.87	.89	.92	.95	.97	2.00	.03	.06	.08	.11
.8	.75	.78	.81	.83	.86	.89	.92	.94	.97	2.00	.03	.05	.08	.11	.13
17.0	1.77	1.80	1.83	1.86	1.88	1.91	1.94	1.97	1.99	2.02	2.05	2.08	2.10	2.13	2.16
.2	.79	.82	.85	.88	.91	.93	.96	1.99	2.02	.05	.07	.10	.13	.16	.19
.4	.81	.84	.87	.90	.93	.96	1.98	2.01	.04	.07	.10	.13	.15	.18	.21
.6	.83	.86	.89	.92	.95	1.98	2.01	.04	.06	.09	.12	.15	.18	.21	.24
.8	.86	.88	.91	.94	.97	2.00	.03	.06	.09	.12	.15	.17	.20	.23	.26
18.0	1.88	1.91	1.93	1.96	1.99	2.02	2.05	2.08	2.11	2.14	2.17	2.20	2.23	2.26	2.29
.2	.90	.93	.96	1.99	2.02	.05	.07	.10	.13	.16	.19	.22	.25	.28	.31
.4	.92	.95	1.98	2.01	.04	.07	.10	.13	.16	.19	.22	.25	.28	.31	.34
.6	.94	.97	2.00	.03	.06	.09	.12	.15	.18	.21	.24	.27	.30	.33	.36
.8	.96	1.99	.02	.05	.08	.11	.14	.17	.20	.23	.27	.30	.33	.36	.39
19.0	1.98	2.01	2.04	2.07	2.10	2.13	2.17	2.20	2.23	2.26	2.29	2.32	2.35	2.38	2.41
.2	2.00	.03	.06	.09	.13	.16	.19	.22	.25	.28	.31	.34	.38	.41	.44
.4	.02	.05	.08	.12	.15	.18	.21	.24	.27	.31	.34	.37	.40	.43	.46
.6	.04	.07	.11	.14	.17	.20	.23	.27	.30	.33	.36	.39	.43	.46	.49
.8	.06	.10	.13	.16	.19	.22	.26	.29	.32	.35	.39	.42	.45	.48	.51

TABLE II.—*Correction of mercurial barometers for temperature, etc.*—Continued.

Temperature, C.	Observed reading of the barometer, in millimeters.														
	640	650	660	670	680	690	700	710	720	730	740	750	760	770	780
19.8	2.06	2.10	2.13	2.16	2.19	2.22	2.26	2.29	2.32	2.35	2.39	2.42	2.45	2.48	2.51
20.0	2.08	2.12	2.15	2.18	2.21	2.25	2.28	2.31	2.34	2.38	2.41	2.44	2.47	2.51	2.54
.2	.10	.14	.17	.20	.24	.27	.30	.33	.37	.40	.43	.47	.50	.53	.57
.4	.13	.16	.19	.23	.26	.29	.32	.36	.39	.42	.46	.49	.52	.56	.59
.6	.15	.18	.21	.25	.28	.31	.35	.38	.41	.45	.48	.52	.55	.58	.62
.8	.17	.20	.23	.27	.30	.34	.37	.40	.44	.47	.51	.54	.57	.61	.64
21.0	2.19	2.22	2.26	2.29	2.32	2.36	2.39	2.43	2.46	2.50	2.53	2.56	2.60	2.63	2.67
.2	.21	.24	.28	.31	.35	.38	.42	.45	.48	.52	.55	.59	.62	.66	.69
.4	.23	.26	.30	.33	.37	.40	.44	.47	.51	.54	.58	.61	.65	.68	.72
.6	.25	.29	.32	.36	.39	.43	.46	.50	.53	.57	.60	.64	.67	.71	.74
.8	.27	.31	.34	.38	.41	.45	.48	.52	.55	.59	.63	.66	.70	.73	.77
22.0	2.29	2.33	2.36	2.40	2.43	2.47	2.51	2.54	2.58	2.61	2.65	2.69	2.72	2.76	2.79
.2	.31	.35	.38	.42	.46	.49	.53	.57	.60	.64	.67	.71	.75	.78	.82
.4	.33	.37	.41	.44	.48	.52	.55	.59	.62	.66	.70	.73	.77	.81	.84
.6	.35	.39	.43	.46	.50	.54	.57	.61	.65	.68	.72	.76	.80	.83	.87
.8	.37	.41	.45	.49	.52	.56	.60	.63	.67	.71	.75	.78	.82	.86	.89
23.0	2.40	2.43	2.47	2.51	2.54	2.58	2.62	2.66	2.69	2.73	2.77	2.81	2.84	2.88	2.92
.2	.42	.45	.49	.53	.57	.60	.64	.68	.72	.76	.79	.83	.87	.91	.94
.4	.44	.47	.51	.55	.59	.63	.67	.70	.74	.78	.82	.86	.89	.93	.97
.6	.46	.50	.53	.57	.61	.65	.69	.73	.76	.80	.84	.88	.92	.96	3.00
.8	.48	.52	.56	.59	.63	.67	.71	.75	.79	.83	.87	.90	.94	2.98	.02
24.0	2.50	2.54	2.58	2.62	2.66	2.69	2.73	2.77	2.81	2.85	2.89	2.93	2.97	3.01	3.05
.2	.52	.56	.60	.64	.68	.72	.76	.80	.83	.87	.91	.95	2.99	.03	.07
.4	.54	.58	.62	.66	.70	.74	.78	.82	.86	.90	.94	2.98	3.02	.06	.10
.6	.56	.60	.64	.68	.72	.76	.80	.84	.88	.92	.96	3.00	.04	.08	.12
.8	.58	.62	.66	.70	.74	.78	.82	.86	.90	.94	2.99	.03	.07	.11	.15
25.0	2.60	2.64	2.68	2.72	2.77	2.81	2.85	2.89	2.93	2.97	3.01	3.05	3.09	3.13	3.17
.2	.62	.66	.71	.75	.79	.83	.87	.91	.95	2.99	.03	.07	.12	.16	.20
.4	.64	.69	.73	.77	.81	.85	.89	.93	2.97	3.02	.06	.10	.14	.18	.22
.6	.66	.71	.75	.79	.83	.87	.91	.96	3.00	.04	.08	.12	.16	.21	.25
.8	.69	.73	77	.81	.85	.90	.94	.98	.02	.06	.11	.15	.19	.23	.27
26.0	2.71	2.75	2.79	2.83	2.88	2.92	2.96	3.00	3.04	3.09	3.13	3.17	3.21	3.26	3.30
.2	.73	.77	.81	.85	.90	.94	2.98	.03	.07	.11	.15	.20	.24	.28	.32
.4	.75	.79	.83	.88	.92	.96	3.01	.05	.09	.13	.18	.22	.26	.31	.35
.6	.77	.81	.85	.90	.94	2.99	.03	.07	.11	.16	.20	.24	.29	.33	.37
.8	.79	.83	.88	.92	.96	3.01	.05	.09	.14	.18	.22	.27	.31	.36	.40
27.0	2.81	2.85	2.90	2.94	2.99	3.03	3.07	3.12	3.16	3.20	3.25	3.29	3.34	3.38	3.42
.2	.83	.87	.92	.96	3.01	.05	.10	.14	.18	.23	27	.32	.36	.41	.45
.4	.85	.90	.94	2.98	.03	.07	.12	.16	.21	.25	.30	.34	.39	.43	.47
.6	.87	.92	.96	3.01	.05	.10	.14	.19	.23	.28	.32	.37	.41	.46	.50
.8	.89	.94	2.98	.03	.07	.12	.16	.21	.25	.30	.34	.39	.43	.48	.53
28.0	2.91	2.96	3.00	3.05	3.10	3.14	3.19	3.23	3.28	3.32	3.37	3.41	3.46	3.51	3.55
.2	.93	2.98	.03	.07	.12	.16	.21	.25	.30	.35	.39	.44	.48	.53	.58
.4	.95	3.00	.05	.09	.14	.19	.23	.28	.32	.37	.42	.46	.51	.56	.60
.6	2.98	.02	.07	.11	.16	.21	.25	.30	.35	.39	.44	.49	.53	.58	.63
.8	3.00	.04	.09	.14	.18	.23	.28	.32	.37	.42	.46	.51	.56	.60	.65
29.0	3.02	3 06	3.11	3.16	3 21	3.25	3.30	3.35	3.39	3.44	3.49	3.54	3.58	3.63	3.68
.2	.04	.08	.13	.18	.23	.27	.32	.37	.42	.46	.51	.56	.61	.65	.70
.4	.06	.11	.15	.20	.25	.30	.34	.39	.44	.49	.54	.58	.63	.68	.73
.6	.08	.13	.18	.22	.27	.32	.37	.42	.46	.51	.56	.61	.66	.70	.75
.8	.10	.15	.20	.24	.29	.34	.39	.44	.49	.54	.58	.63	.68	.73	.78
30.0	3 12	3.17	3.22	3.27	3.32	3.36	3.41	3.46	3.51	3.56	3.61	3.66	3.71	3.75	3.80
.2	.14	.19	.24	.29	.34	.39	.44	.48	.53	.58	.63	.68	.73	.78	.83
.4	.16	.21	.26	.31	.36	.41	.46	.51	.56	.61	.66	.71	.75	.80	.85
.6	.18	.23	.28	.33	.38	.43	.48	.53	.58	.63	.68	.73	.78	.83	.88
.8	.20	.25	.30	.35	.40	.45	.50	.55	.60	.65	.70	.75	.80	.85	.90
31	3.22	3.27	3.32	3.37	3.43	3.48	3.53	3.58	3.63	3.68	3.73	3.78	3.83	3.88	3.93
31.5	.28	.33	.38	.43	.48	.53	.58	.63	.68	.74	.79	.84	.89	3.94	3.99
32	.33	.38	.43	.48	.54	.59	.64	.69	.74	.79	.85	.90	3.95	4.00	4.05
32.5	.38	.43	.48	.54	.59	.64	.70	.75	.80	.85	.91	3.96	4.01	.07	.12
33	.43	.48	.54	.59	.64	.70	.75	.81	.86	.91	.97	4.02	.07	.13	.18
33.5	3.48	3.54	3.59	3.65	3.70	3.75	3.81	3 86	3.92	3.97	4.03	4.08	4.13	4.19	4.24
34	.53	.59	.64	.70	.75	.81	.87	.92	3.98	4.03	.09	.14	.20	.25	.31
34.5	.59	.64	.70	.75	.81	.87	.92	3.98	4.03	.09	.15	.20	.26	.31	.37
35	.64	.69	.75	.81	.86	.92	3.98	4.03	.09	.15	.21	.26	.32	.38	.43
35.5	.69	.75	.80	.86	.92	.98	4.03	.09	.15	.21	.26	.32	.38	.44	.50

TABLE III.—*Influence of gravity on barometric observations, English units.*

[Abridged from International Tables.]

REDUCTION TO LATITUDE 45°.

For latitudes............ { above 45° / below 45° } the values are to be........ { added. / subtracted.

Latitude.		Reading of the barometer, in inches.												
		18	19	20	21	22	23	24	25	26	27	28	29	30
°	°													
0	90	.047	.049	.052	.054	.057	.060	.062	.065	.067	.070	.073	.075	.078
5	85	.046	.048	.051	.054	.056	.059	.061	.064	.066	.069	.071	.074	.077
6	84	.046	.048	.051	.053	.056	.058	.061	.063	.066	.068	.071	.073	.076
7	83	.045	.048	.050	.053	.055	.058	.060	.063	.065	.068	.070	.073	.075
8	82	.045	.047	.050	.052	.055	.057	.060	.062	.065	.067	.070	.072	.075
9	81	.044	.047	.049	.052	.054	.057	.059	.062	.064	.067	.069	.071	.074
10	80	.044	.046	.049	.051	.054	.056	.058	.061	.063	.066	.068	.071	.073
11	79	.043	.046	.048	.050	.053	.055	.058	.060	.062	.065	.067	.070	.072
12	78	.043	.045	.047	.050	.052	.054	.057	.059	.062	.064	.066	.069	.071
13	77	.042	.044	.047	.049	.051	.054	.056	.058	.061	.063	.065	.068	.070
14	76	.041	.043	.046	.048	.050	.053	.055	.057	.059	.062	.064	.066	.069
15	75	.040	.043	.045	.047	.049	.052	.054	.056	.058	.061	.063	.065	.067
16	74	.040	.042	.044	.046	.048	.051	.053	.055	.057	.059	.061	.064	.066
17	73	.039	.041	.043	.045	.047	.049	.052	.054	.056	.058	.060	.062	.064
18	72	.038	.040	.042	.044	.046	.048	.050	.052	.054	.057	.059	.061	.063
19	71	.037	.039	.041	.043	.045	.047	.049	.051	.053	.055	.057	.059	.061
20	70	.036	.038	.040	.042	.044	.046	.048	.050	.052	.054	.056	.058	.060
21	69	.035	.037	.038	.040	.042	.044	.046	.048	.050	.052	.054	.056	.058
22	68	.034	.035	.037	.039	.041	.043	.045	.047	.048	.050	.052	.054	.056
23	67	.032	.034	.036	.038	.040	.041	.043	.045	.047	.049	.050	.052	.054
24	66	.031	.033	.035	.036	.038	.040	.042	.043	.045	.047	.049	.050	.052
25	65	.030	.032	.033	.035	.037	.038	.040	.042	.043	.045	.047	.048	.050
26	64	.029	.030	.032	.033	.035	.037	.038	.040	.041	.043	.045	.046	.048
27	63	.027	.029	.030	.032	.033	.035	.037	.038	.040	.041	.043	.044	.046
28	62	.026	.028	.029	.030	.032	.033	.035	.036	.038	.039	.041	.042	.043
29	61	.025	.026	.027	.029	.030	.032	.033	.034	.036	.037	.038	.040	.041
30	60	.023	.025	.026	.027	.028	.030	.031	.032	.034	.035	.036	.038	.039
31	59	.022	.023	.024	.026	.027	.028	.029	.030	.032	.033	.034	.035	.036
32	58	.020	.022	.023	.024	.025	.026	.027	.028	.030	.031	.032	.033	.034
33	57	.019	.020	.021	.022	.023	.024	.025	.026	.027	.028	.029	.031	.032
34	56	.017	.018	.019	.020	.021	.022	.023	.024	.025	.026	.027	.028	.029
35	55	.016	.017	.018	.019	.019	.020	.021	.022	.023	.024	.025	.026	.027
36	54	.014	.015	.016	.017	.018	.018	.019	.020	.021	.022	.022	.023	.024
37	53	.013	.014	.014	.015	.016	.016	.017	.018	.019	.019	.020	.021	.021
38	52	.011	.012	.013	.013	.014	.014	.015	.016	.016	.017	.018	.018	.019
39	51	.010	.010	.011	.011	.012	.012	.013	.013	.014	.015	.015	.016	.016
40	50	.008	.009	.009	.009	.010	.010	.011	.011	.012	.012	.013	.013	.013
41	49	.006	.007	.007	.008	.008	.008	.009	.009	.009	.010	.010	.010	.011
42	48	.005	.005	.005	.006	.006	.006	.006	.007	.007	.007	.008	.008	.008
43	47	.003	.003	.004	.004	.004	.004	.004	.005	.005	.005	.005	.005	.005
44	46	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.003	.003	.003
45	45	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000

TABLE IV.—*Influence of gravity on barometric observations, English units.*

[From International Tables.]

REDUCTION FOR ALTITUDE.

To be subtracted.

Height, in feet.	Reading of the barometer, in inches.													
	18	19	20	21	22	23	24	25	26	27	28	29	30	31
0	......	......	......	......	......	......	......	......	......	0.000	0.000	0.000	0.000	0.000
500	......	......	......	......	......	......	......	......	......	.001	.001	.001	.001	.001
1,000	......	......	......	......	......	......	......	......	......	.002	.002	.002	.002	.002
1,500	......	......	......	......	......	......	......	......	0.002	.002	.003	.003	.003	......
2,000	......	......	......	......	......	......	......	......	.003	.003	.003	.003	.004	......
2,500	......	......	......	......	......	......	......	0.004	0.004	0.004	0.004	0.004	......	......
3,000	......	......	......	......	......	......	......	.004	.005	.005	.005	.005	......	......
3,500	......	......	......	......	......	......	0.005	.005	.005	.006	.006	......	......	......
4,000	......	......	......	......	......	......	.006	.006	.006	.006	.007	......	......	......
4,500	......	......	......	......	......	0.006	.006	.007	.007	.007	......	......	......	......
000	......	......	......	......	......	0.007	0.007	0.007	0.008	0.008	......	......	......	......
5,500	......	......	......	......	0.007	.008	.008	.008	.009	......	......	......	......	......
6,000	......	......	......	......	.008	.008	.009	.009	.009	......	......	......	......	......
6,500	......	......	......	0.008	.009	.009	.009	.010	......	......	......	......	......	......
7,000	......	......	......	.009	.009	.010	.010	.010	......	......	......	......	......	......
7,500	......	......	0.009	0.009	0.010	0.010	0.011	......	......	......	......	......	......	......
8,000	......	......	.010	.010	.011	.011	.011	......	......	......	......	......	......	......
8,500	......	0.010	.010	.011	.011	.012	......	......	......	......	......	......	......	......
9,000	......	.010	.011	.011	.012	.012	......	......	......	......	......	......	......	......
9,500	0.010	.011	.011	.012	.012	......	......	......	......	......	......	......	......	......
10,000	0.011	0.011	0.012	0.013	0.013	......	......	......	......	......	......	......	......	......

TABLE V.—*Pressure, in inches, corresponding to changes of* 100 *feet in elevation.*

[BIGELOW.]

Height, in feet.	Temperature, Fahrenheit.											
	—20	—10	0	10	20	30	40	50	60	70	80	90
0	.128	.125	.122	.119	.117	.114	.112	.110	.108	.106	.104	.102
500	.125	.122	.120	.117	.115	.112	.110	.108	.106	.104	.102	.100
1,000	.122	.120	.118	.115	.113	.110	.108	.106	.104	.102	.100	.098
1,500	.120	.117	.115	.112	.110	.108	.106	.104	.102	.100	.098	.096
2,000	.118	.115	.113	.110	.108	.106	.104	.102	.100	.098	.096	.094
2,500	.115	.112	.110	.108	.106	.104	.102	.100	.098	.096	.094	.092
3,000	.113	.110	.108	.106	.104	.102	.100	.098	.096	.094	.092	.090
3,500	.111	.108	.106	.104	.102	.100	.098	.096	.094	.092	.090	.088
4,000	.108	.106	.104	.102	.100	.098	.096	.094	.092	.090	.088	.086
4,500	.106	.104	.102	.100	.098	.096	.094	.092	.090	.088	.086	.084
5,000	.104	.102	.100	.098	.096	.094	.092	.090	.088	.086	.084	.082
5,500	.102	.100	.098	.096	.094	.092	.090	.088	.086	.084	.082	.081
6,000	.100	.098	.096	.094	.092	090	.088	.086	.084	.082	.081	.080
6,500	.098	.096	.094	.092	.090	.088	.086	.085	.083	.081	.080	.079
7,000	.097	.095	.093	.091	.089	.087	.085	.084	.082	.080	.079	.078

TABLE VI.—*Determination of heights by the barometer, English measures.*

[Abridged from the Smithsonian Tables.]

Values of 60368 [1 + 0.0010195 × 36] log. $\frac{29.90}{B.}$

Barometric pressure, B.	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
Inches.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
17.00	15347	15331	15315	15299	15283	15267	15251	15235	15219	15203
.10	15187	15172	15156	15140	15124	15108	15092	15076	15061	15045
.20	15029	15013	14997	14982	14966	14950	14934	14919	14903	14887
.30	14871	14856	14840	14824	14809	14793	14777	14762	14746	14730
.40	14715	14699	14684	14668	14652	14637	14621	14606	14590	14575
17.50	14559	14544	14528	14512	14497	14481	144 6	14451	14435	14420
.60	14404	14389	14373	14358	14342	14327	14312	14296	14281	14266
.70	14250	14235	14219	14204	14189	14173	14158	14143	14128	14112
.80	14097	14082	14067	14051	14036	14021	14006	13990	13975	13960
.90	13945	13930	13914	13899	13884	13869	13854	13839	13824	13808
18.00	13793	13778	13763	13748	13733	13718	13703	13688	13673	13658
.10	13643	13628	13613	13598	13583	13568	13553	13538	13523	13508
.20	13493	13478	13463	13448	13433	13418	13404	13389	13374	13359
.30	13344	13329	13314	13300	13285	13270	13255	13240	13226	13211
.40	13196	13181	13166	13152	13137	13122	13107	13093	13078	13063
18.50	13049	13034	13019	13005	12990	12975	12961	12946	12931	12917
.60	12902	12888	12873	12858	12844	12829	12815	12800	12785	12771
.70	12756	12742	12727	12713	12698	12684	12669	12655	12640	12626
.80	12611	12597	12583	12568	12554	12539	12525	12510	12496	12482
.90	12467	12453	12438	12424	12410	12395	12381	12367	12352	12338
19.00	12324	12310	12295	12281	12267	12252	12238	12224	12210	12195
.10	12181	12167	12153	12138	12124	12110	12096	12082	12068	12053
.20	12039	12025	12011	11997	11983	11969	11954	11940	11926	11912
.30	11898	11884	11870	11856	11842	11828	11814	11800	11786	11772
.40	11758	11744	11730	11716	11702	11688	11674	11660	11646	11632
19.50	11618	11604	11590	11576	11562	11548	11534	11520	11507	11493
.60	11479	11465	11451	11437	11423	11410	11396	11382	11368	11354
.70	11340	11327	11313	11299	11285	11272	11258	11244	11230	11217
.80	11203	11189	11175	11162	11148	11134	11121	11107	11093	11080
.90	11066	11052	11039	11025	11011	10998	10984	10970	10957	10943
20.00	10930	10916	10903	10889	10875	10862	10848	10835	10821	10808
.10	10794	10781	10767	10754	10740	10727	10713	10700	10686	10673
.20	10659	10646	10632	10619	10605	10592	10579	10565	10552	10538
.30	10525	10512	10498	10485	10472	10458	10445	10431	10418	10405
.40	10391	10378	10365	10352	10338	10325	10312	10298	10285	10272
20.50	10259	10245	10232	10219	10206	10192	10179	10166	10153	10139
.60	10126	10113	10100	10087	10074	10060	10047	10034	10021	10008
.70	9995	9982	9968	9955	9942	9929	9916	9903	9890	9877
.80	9864	9851	9838	9825	9812	9799	9786	9772	9759	9746
.90	9733	9720	9707	9694	9681	9668	9655	9642	9629	9617
21.00	9604	9591	9578	9565	9552	9539	9526	9513	9500	9487
.10	9474	9462	9449	9436	9423	9410	9397	9384	9372	9359
.20	9346	9333	9320	9307	9295	9282	9269	9256	9244	9231
.30	9218	9205	9193	9180	9167	9154	9142	9129	9116	9103
.40	9091	9078	9065	9053	9040	9027	9015	9002	8989	8977
21.50	8964	8951	8939	8926	8913	8901	8888	8876	8863	8850
.60	8838	8825	8813	8800	8788	8775	8762	8750	8737	8725
.70	8712	8700	8687	8675	8662	8650	8637	8625	8612	8600
.80	8587	8575	8562	8550	8538	8525	8513	8500	8488	8475
.90	8463	8451	8438	8426	8413	8401	8389	8376	8364	8352
22.00	8339	8327	8314	8302	8290	8277	8265	8253	8240	8228
.10	8216	8204	8191	8179	8167	8154	8142	8130	8118	8105
.20	8093	8081	8069	8056	8044	8032	8020	8008	7995	7983
.30	7971	7959	7947	7935	7922	7910	7898	7886	7874	7862
.40	7849	7837	7825	7813	7801	7789	7777	7765	7753	7740
22.50	7728	7716	7704	7692	7680	7668	7656	7644	7632	7620
.60	7608	7596	7584	7572	7560	7548	7536	7524	7512	7500
.70	7488	7476	7464	7452	7440	7428	7416	7404	7392	7380
.80	7368	7356	7345	7333	7321	7309	7297	7285	7273	7261
.90	7249	7238	7226	7214	7202	7190	7178	7166	7155	7143

TABLE VI.—*Determination of heights by the barometer, etc.*—Continued.

Barometric pressure, B.	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
Inches.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
23.00	7131	7119	7107	7096	7084	7072	7060	7048	7037	7025
.10	7013	7001	6990	6978	6966	6954	6943	6931	6919	6907
.20	6896	6884	6872	6861	6849	6837	6825	6814	6802	6790
.30	6779	6767	6755	6744	6732	6721	6709	6697	6686	6674
.40	6662	6651	6639	6628	6616	6604	6593	6581	6570	6558
23.50	6546	6535	6523	6512	6500	6489	6477	6466	6454	6443
.60	6431	6420	6408	6397	6385	6374	6362	6351	6339	6328
.70	6316	6305	6293	6282	6270	6259	6247	6236	6225	8213
.80	6202	6190	6179	6167	6156	6145	6133	6122	6110	6099
.90	6088	6076	6065	6054	6042	6031	6020	6008	5997	5986
24.00	5974	5963	5952	5940	5929	5918	5906	5895	5884	5872
.10	5861	5850	5839	5827	5816	5805	5794	5782	5771	5760
.20	5749	5737	5726	5715	5704	5693	5681	5670	5659	5648
.30	5637	5625	5614	5603	5593	5581	5570	5558	5547	5536
.40	5525	5514	5503	5492	5480	5469	5458	5447	5436	5425
24.50	5414	5403	5392	5381	5369	5358	5347	5336	5325	5314
.60	5303	5292	5281	5270	5259	5248	5237	5226	5215	5204
.70	5193	5182	5171	5160	5149	5138	5127	5116	5105	5094
.80	5083	5072	5061	5050	5039	5028	5017	5006	4995	4985
.90	4974	4963	4952	4941	4930	4919	4908	4897	4886	4876
25.00	4865	4854	4843	4832	4821	4810	4800	4789	4778	4767
.10	4756	4745	4735	4724	4713	4702	4691	4681	4670	4659
.20	4648	4637	4627	4616	4605	4594	4584	4573	4562	4551
.30	4540	4530	4519	4508	4498	4487	4476	4465	4455	4444
.40	4433	4423	4412	4401	4391	4380	4369	4358	4348	4337
25.50	4326	4316	4305	4295	4284	4273	4263	4252	4241	4231
.60	4220	4209	4199	4188	4178	4167	4156	4146	4135	4125
.70	4114	4104	4093	4082	4072	4061	4051	4040	4030	4019
.80	4009	3998	3988	3977	3966	3956	3945	3935	3924	3914
.90	3903	3893	3882	3872	3861	3851	3841	3830	3820	3809
26.00	3799	3788	3778	3767	3757	3746	3736	3726	3715	3705
.10	3694	3684	3674	3663	3653	3642	3632	3622	3611	3601
.20	3590	3580	3570	3559	3549	3539	3528	3518	3508	3497
.30	3487	3477	3466	3456	3446	3435	3425	3415	3404	3394
.40	3384	3373	3363	3353	3343	3332	3322	3312	3301	3291
26.50	3281	3270	3260	3250	3240	3230	3219	3209	3199	3189
.60	3179	3168	3158	3148	3138	3128	3117	3107	3097	3087
.70	3077	3066	3056	3046	3036	3026	3016	3005	2995	2985
.80	2975	2965	2955	2945	2934	2924	2914	2904	2894	2884
.90	2874	2864	2854	2843	2833	2823	2813	2803	2793	2783
27.00	2773	2763	2753	2743	2733	2723	2713	2703	2692	2682
.10	2672	2662	2652	2642	2632	2622	2612	2602	2592	2582
.20	2572	2562	2552	2542	2532	2522	2512	2502	2493	2483
.30	2473	2463	2453	2443	2433	2423	2413	2403	2393	2383
.40	2373	2363	2353	2343	2334	2324	2314	2304	2294	2284
27.50	2274	2264	2254	2245	2235	2225	2215	2205	2195	2185
.60	2176	2166	2156	2146	2136	2126	2116	2107	2097	2087
.70	2077	2067	2058	2048	2038	2028	2018	2009	1999	1989
.80	1979	1970	1960	1950	1940	1930	1921	1911	1901	1891
.90	1882	1872	1862	1852	1843	1833	1823	1814	1804	1794
28.00	1784	1775	1765	1755	1746	1736	1726	1717	1707	1697
.10	1688	1678	1668	1659	1649	1639	1630	1620	1610	1601
.20	1591	1581	1572	1562	1552	1543	1533	1524	1514	1504
.30	1495	1485	1476	1466	1456	1447	1437	1428	1418	1408
.40	1399	1389	1380	1370	1361	1351	1342	1332	1322	1313
28.50	1303	1294	1284	1275	1265	1256	1246	1237	1227	1218
.60	1208	1199	1189	1180	1170	1161	1151	1142	1132	1123
.70	1113	1104	1094	1085	1075	1066	1057	1047	1038	1028
.80	1019	1009	1000	990	981	972	962	953	943	934
.90	925	915	906	896	887	878	868	859	849	840
29.00	831	821	812	803	794	784	775	765	756	746
.10	737	728	718	709	700	690	681	672	663	653
.20	644	635	625	616	607	597	588	579	570	560
.30	551	542	532	523	514	505	495	486	477	468
.40	458	449	440	431	421	412	403	394	384	375

TABLE VI.—*Determination of heights by the barometer, etc.*—Continued.

Barometric pressure, B.	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
Inches.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
29.50	366	357	348	338	329	320	311	302	292	283
.60	274	265	256	247	237	228	219	210	201	192
.70	182	173	164	155	146	137	128	118	109	100
.80	+ 91	+ 82	+ 73	+ 64	+ 55	+ 45	+ 36	+ 27	+ 18	+ 9
.90	0	− 9	− 18	− 27	− 36	− 45	− 55	− 64	− 73	− 82
30.00	− 91	−100	−109	−118	−127	−136	−145	−154	−163	−172
.10	−181	−190	−199	−208	−217	−226	−235	−244	−253	−262
.20	−271	−280	−289	−298	−307	−316	−325	−334	−343	−352
.30	−361	−370	−379	−388	−397	−406	−415	−424	−433	−442
.40	−451	−460	−469	−478	−486	−495	−504	−513	−522	−531
30.50	−540	−549	−558	−567	−576	−585	−593	−602	−611	−620
.60	−629	−638	−647	−656	−665	−673	−682	−691	−700	−709
.70	−718	−727	−735	−744	−753	−762	−771	−780	−788	−797
.80	−806	−815	−824	−833	−841	−850	−859	−868	−877	−885

TABLE VII.—*Determination of heights by the barometer, English measures.*

[Abridged from the Smithsonian Tables.]

Term for temperature: 0.002039 (T—50°) z.

For temperatures { above 50° F. / below 50° F. } the values are to be { added. / subtracted.

Mean temperature T.		Approximate elevations obtained from Table VI.									
		1,000	2,000	3,000	4,000	5,000	6,000	7,000	8,000	9,000	10,000
° *F.*	° *F.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
49	51	2	4	6	8	10	12	14	16	18	20
48	52	4	8	12	16	20	24	29	33	37	41
47	53	6	12	18	24	31	37	43	49	55	61
46	54	8	16	24	33	41	49	57	65	73	82
45	55	10	20	31	41	51	61	71	82	92	102
44	56	12	24	37	49	61	73	86	98	110	122
43	57	14	29	43	57	71	86	100	114	128	143
42	58	16	33	49	65	82	98	114	130	147	163
41	59	18	37	55	73	92	110	128	147	165	184
40	60	20	41	61	82	102	122	143	163	184	204
39	61	22	45	67	90	112	135	157	179	202	224
38	62	24	49	73	98	122	147	171	196	220	245
37	63	27	53	80	106	133	159	186	212	239	265
36	64	29	57	86	114	143	171	200	228	257	285
35	65	31	61	92	122	153	184	214	245	275	306
34	66	33	65	98	130	163	196	228	261	294	326
33	67	35	69	104	139	173	208	243	277	312	347
32	68	37	73	110	147	184	220	257	294	330	367
31	69	39	77	116	155	194	232	271	310	349	387
30	70	41	82	122	163	204	245	285	326	367	408
29	71	43	86	128	171	214	257	300	343	385	428
28	72	45	90	135	179	224	269	314	359	404	449
27	73	47	94	141	188	234	281	328	375	422	469
26	74	49	98	147	196	245	294	343	391	440	489
25	75	51	102	153	204	255	306	357	408	459	510
24	76	53	106	159	212	265	318	371	424	477	530
23	77	55	110	165	220	275	330	385	440	495	551
22	78	57	114	171	228	285	343	400	457	514	571
21	79	59	118	177	236	296	355	414	473	532	591
20	80	61	122	184	245	306	367	428	489	551	612
19	81	63	126	190	253	316	379	442	506	569	632
18	82	65	130	196	261	326	391	457	522	587	652
17	83	67	135	202	269	336	404	471	538	606	673
16	84	69	139	208	277	347	416	485	555	624	693
15	85	71	143	214	285	357	428	500	571	642	714
14	86	73	147	220	294	367	440	514	587	661	734
13	87	75	151	226	302	377	453	528	604	679	754
12	88	77	155	232	310	387	465	542	620	697	775
11	89	80	159	239	318	398	477	557	636	716	795
10	90	82	163	245	326	408	489	571	652	734	816
9	91	84	167	251	334	418	502	585	669	752	836
8	92	86	171	257	343	428	514	599	685	771	856
7	93	88	175	263	351	438	526	614	701	789	877
6	94	90	179	269	359	449	538	628	718	807	897
5	95	92	184	275	367	459	551	642	734	826	918
4	96	94	188	281	375	469	563	657	750	844	938
3	97	96	192	287	383	479	575	671	767	862	958
2	98	98	196	294	391	489	587	685	783	881	979
1	99	100	200	300	400	500	599	699	799	899	999
0	100	102	204	306	408	510	612	714	816	918	1020

INDEX.