

## A NEW CORRECTION-SCALE FOR MERCURIAL BAROMETERS.

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## SYNOPSIS.

Corrections, for instrumental errors, the temperature of the mercurial column and for latitude, must be applied before readings of mercurial barometers can be used to represent true atmospheric pressures. Obviously, each operation is a possible source of error, and a direct method of determining correct values is highly desirable.

In 1914, Col. E. Gold, of the British Meteorological Office, suggested a scale to be used with the attached thermometer, by means of which the corrections referred to can be obtained in one reading of the thermometer. This scale, however, can be used for but one pressure; in the present paper the author describes a modified scale from which the same corrections can be obtained for any pressure. The final corrected pressure is obtained in five or less operations instead of six required by other methods, the corrections can be read more accurately, and in addition to the time saved there is a saving of one column of entry in the record-form.

The mercurial barometer, one of the most useful of meteorological instruments, is one of the most inconvenient for ordinary use for the reason that its indications or readings do not usually represent true atmospheric pressures until they have been corrected for temperature, latitude, and instrumental errors such as those of the scale, the "attached" thermometer, and capillarity. The last three, for a fixed station, are practically constant, but require to be redetermined from time to time. Nine distinct operations must be performed in order to obtain the actual pressure at any place, and if this is to be corrected for height, three more are required; every operation is a possible source of error and must be verified if the final values are to be depended upon.

Mechanical methods of obtaining true atmospheric pressures have been proposed, the most satisfactory of which are the various forms of "syphon" barometers and devices for weighing the mercurial column; but most barometers embodying such devices are not easily portable, possess defects as difficult to allow for as the errors of the simpler patterns, and should be used only by experienced observers. Exception must be made in the instance of barographs, of which the most accurate known at the present time are those in which the pressure is determined by weighing and the various corrections are applied automatically and continuously.

Of various methods that have been suggested for simplifying the process of determining true pressures from readings of mercurial barometers, that of combining all constant corrections with that for temperature in a single table appears to be the most satisfactory. In some instances where the height is small the correction for height may be included without serious error; also, when the barometer is moved to a new position higher or lower than its original location a "removal" correction may be included in order that the observations at the two positions may be comparable. This method of combining corrections has one serious defect—a new table must be prepared for every barometer every time the height of the instrument is changed or new corrections become necessary; also, while three of the nine operations referred to are eliminated, the process is indirect, and not automatically a function of the instrument itself.

Methods more direct and more accurate than those referred to have always been desirable, but no important advance appears to have been accomplished until 1914, when Col. E. Gold, of the British Meteorological Office, suggested a device whereby the several corrections already referred to may be combined in a single reading

of a movable scale used with the "attached" thermometer.<sup>1</sup> This device, to which the name "ideal scale" was given by the inventor, is illustrated schematically in

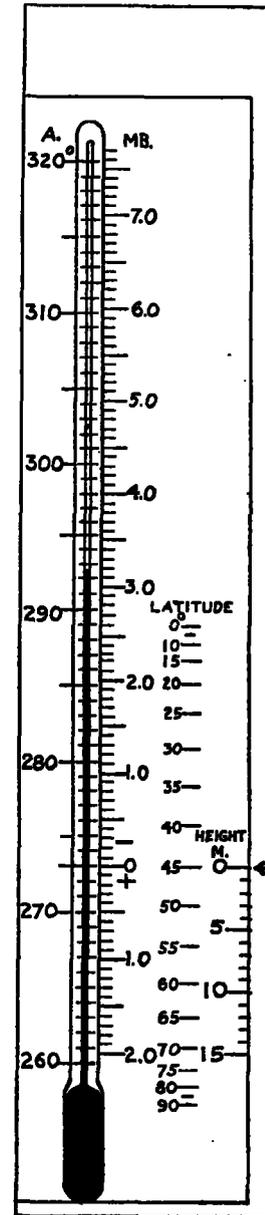


FIG. 1, (GOLD'S "IDEAL" SCALE)  
S.P.F. 1921. (1914.)

Figure 1, which is a copy of the original drawing, and can best be described by the following quotation from Col. Gold's paper:

As we do not use an attached thermometer to give us a temperature which we wish to compare with other temperatures, but merely to enable us to correct the reading of the barometer, it would be a considerable advantage to have the thermometer so graduated that its readings gave the correction direct in millibars; in other words, to

<sup>1</sup> Described before the Royal Meteorological Society, May 20, 1914, in a paper entitled "Barometer Readings in Absolute Units and Their Correction and Reduction," and published in the *Quarterly Journal of the Society*, July, 1914. This paper is very valuable as a summary of present-day information regarding the measurement of pressure and for its descriptions of ingenious and original methods of correcting observations, etc.

make a thermometer for which each scale division corresponded with a correction of 0.1 mb. for a reading of 1,000 mb. The divisions would be about 10 per cent further apart than the divisions for degrees Fahrenheit. Such a thermometer is shown in the diagram (fig. 1). It would be especially advantageous for use at a fixed station at a low level or for a barometer at sea, because, by an appropriate adjustment of the scale by which the thermometer is read, the combined correction would be read off directly from the instrument.

For a fixed station the scale would be set once for all at the appropriate latitude and altitude. It could then be clamped and the observer would thenceforward simply take his barometer reading and read off the necessary correction from the 'thermometer.'

The correction would need modification only if the pressure differed considerably from 1,000 mb.; usually, the correction, as read would be sufficient.

\*\*\* In figure 1 the scale of height at the right-hand side of the diagram is supposed to be movable, relative to the latitude scale; while the whole piece carrying the latitude scale and the ideal scale for the attached thermometer is movable, relative to the thermometer. The thermometer itself is supposed to be fixed to the frame of the barometer, on which is engraved the arrow shown at the right. To set for a reading, the height scale is moved until the "0" comes opposite the latitude of the place of observation; the whole piece is then moved until the number denoting the height of the barometer cistern M. S. L. in metres comes opposite the arrow. The thermometer reading is then taken from the ideal scale, which gives the correction for temperature, gravity, and altitude combined for a pressure of 1,000 mb. This illustrates the theory of the method. For practical application Mr. Whipple has pointed out that simplification is introduced by fixing the latitude scale, relative to the thermometer, and making a single movable piece bearing the ideal scale and the height scale.

It was obvious, on reading the description thereof that modification would be necessary to adapt the original ideal scale to use through the large ranges of pressure experienced near the North Atlantic coast or with barometers whose height may be changed. The error resulting from the use of a single uniformly graduated scale through a range of pressure of 80 mb. (the range recorded at Boston) is about 0.2 mb., a quantity too large to be disregarded and which must be allowed for by applying corrections or by the use of a mechanical adjustment. As in the instance of the table of "total correction" already described, a separate scale would be necessary whenever the height of the barometer is changed. After a few experiments with adjustable scales the tangential scale shown by figures 2 and 3 suggested itself and two experimental models constructed during November 1914 met all requirements very satisfactorily. Pressure of other work and the lack of a suitable ruling machine prevented further experimenting until recently, and the few scales produced have not been tried outside the laboratory; but it is believed that the pattern described herein is not likely to require important modification unless in the direction of greater simplicity.

Assuming that the barometer in use is the well-known "standard" of either Fortin or Kew pattern, and of good quality, the most important of the operations incidental to obtaining true pressures from its readings is that of determining the correction for temperature. This is zero at a certain temperature, which is 0° C. for the International and 28.5° F. for the English scale, at all pressures, and obviously its value at higher or lower temperatures is directly proportionate to the length of the barometric column. The construction of a correction-scale for any definite pressure, such as 1000 mb., has been described in the quotation from Col. Gold's paper. A scale for any range of pressure, as, for example, that of 900 to 1000 mb., is obtained in the following manner: First, the distance, from the common zero, of an extreme value, such as 5.0 mb., at each of these pressures, corresponding to the equivalent reading of the thermometer used is marked on the blank to be ruled; next, this space is divided, by two parallel columns of dots (one for each pressure), at any suitable distance apart. By ruling lines connecting dots representing the same value we produce the tangential scale (B) shown in figures 2 and 3. The lines are

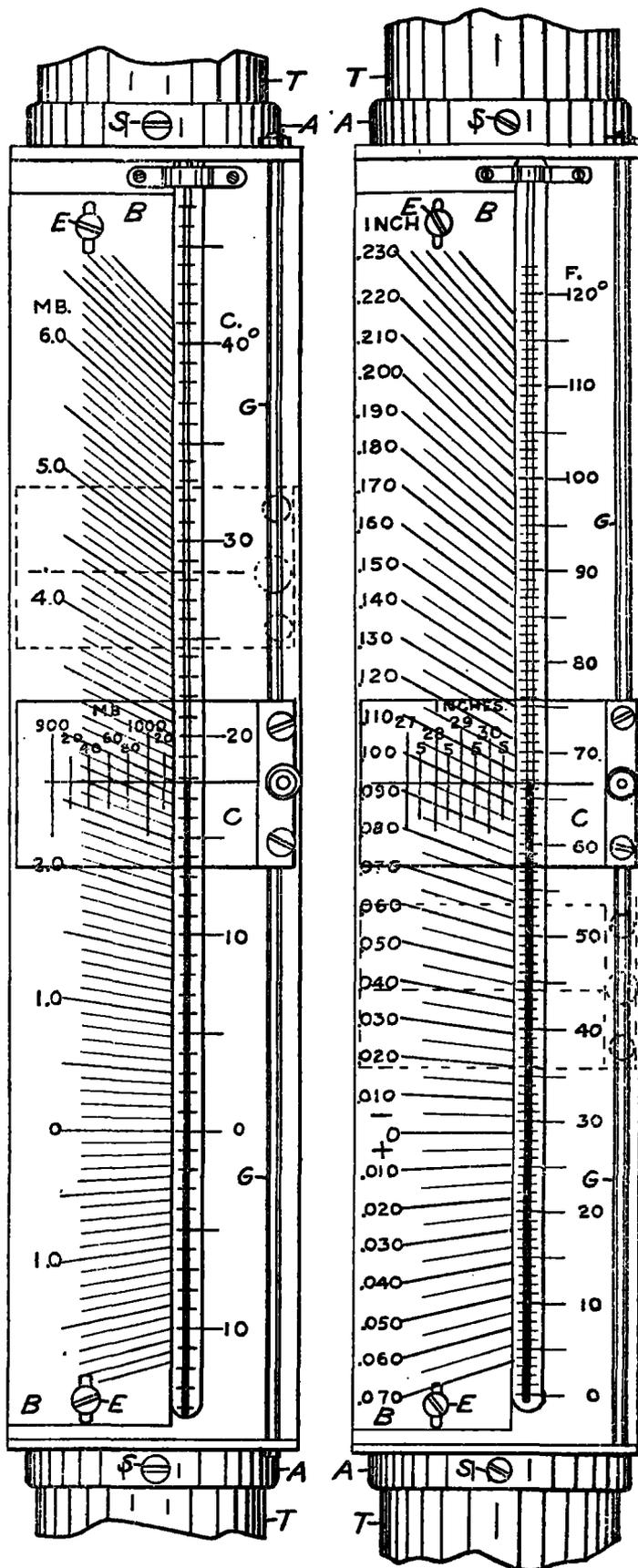


FIG. 2, (MILLIBARS) FIG. 3, (INCHES)  
S.P.F., 1914.

uniformly spaced, but since the values of corrections for low pressures are smaller than those for higher pressures, the distance between the lines must be progressively larger as the pressure decreases. Referring to figure 2, the temperature equal to a correction of 5.0 mb. at a pressure of 1000 mb. is 30°.5 C.; that for a pressure of 900 mb. is 33°.8, or, otherwise expressed, the correction at 900 mb. for a temperature of 30°.5 is 4.5 mb. instead of 5.0 mb., the value for 1000 mb. To obtain values for pressures between 900 and 1000 mb. vertical lines for any interval desired can be ruled on the scale itself, or preferably, as shown, on a transparent index-plate (C), which can be adjusted and possesses the further advantage that the numbers of the vertical lines are always near the central index-line, where the readings are made. The index (C) slides on a guide (G) parallel to the scale (B) and the thermometer tube. The various parts are secured to a base (A), fitted and clamped to the outer metal tube of the barometer (T) by screws (S). To obtain corrections the central horizontal line on the index-plate (C) is set at the top of the thermometric column and the correction read at the point representing the current pressure; as shown in figure 2, where the temperature is 17°.8, the correction for a pressure of 985 mb. is -2.82 mb. In figure 3 the correction for a temperature of 66°.7 and a pressure of 29.51 inches is -0.1015 inch. Allowance for constant errors or corrections already referred to is accomplished as follows, the values given indicating the method only:

Correction for instrumental error.....	+0.15 mb.
Mean correction applied to attached thermometer, -0.2°, equal to.....	+0.25 mb.
Correction for latitude.....	-1.12 mb.
"Removal" correction.....	+0.92 mb.
<b>Total correction.....</b>	<b>+0.20 mb.</b>

This value, thereafter, is automatically added to all readings by moving the scale (B), until its zero is 0.20 mb. below the zero of the attached thermometer (0° C.), and clamping it in position by means of the screws (E), (E). If, for example, the total constant correction indicated is to be added to the correction for temperature already obtained in the example shown for figure 2, the final value will be -2.62 instead of -2.82.

It is obvious that even if the ordinary "attached" thermometer with a short scale is employed, these correction-scales may be ruled direct to 0.1 mb. or 0.005 inch, and values to 0.01 mb. or 0.0005 inch estimated with considerable precision, an accuracy impossible with the ordinary table of corrections determined for intervals of half degrees and ten millibars or half inches. Even in the extreme case of the use of a mountain barometer, where the correction-scale may be much compressed and the diagonal lines at high temperatures are very steep, the errors are smaller than those of the tables described. Obviously, if there is no objection to increasing the bulk of the instrument, the tangential scale (B) can be made wider and ruled to fit a thermometer with a long scale; but this is unnecessary except in the instance of a standard barometer where readings of extreme precision are desired. Ordinarily, the tangential correction-scale need not occupy appreciably more space than does the usual "attached" thermometer.

When used with a barometer carried to great heights, where the pressure may be as low as 400 mb. one side of the scale-plate (B) may be ruled for pressures between 1050 and 600, and the other for pressures below 700 mb., and the clamp screws (E), (E), so placed that the scale

will be in the proper position with either side in use. The vertical lines on the transparent index-plate (C) will serve for both sides of (B), and only require to be numbered at the top for one scale and at the bottom for the other. Ordinarily, however, only one ruling will be needed for the average "station" barometer at any height below 3,000 meters.

Differences between the customary method of reading the barometer and correcting the observations by a table and that provided by the new correction-scale are shown in the following comparison:

To read the mercurial barometer and determine the "station" pressure by present method, recording data in Form 1083 or form 1001—

- (1) Read attached thermometer and enter reading in Form 1083.
- (2) Adjust mercury in cistern.
- (3) Set vernier.
- (4) Read vernier and enter reading in Form 1083.
- (5) Ascertain total correction from table and enter in Form 1083.
- (6) Apply correction and enter "station" pressure in Form 1083.

In addition to the six operations indicated, four columns in Form 1001 are required for the observations and corrected data and there must be accessible at all times a special table of "total correction" for every barometer and every station and elevation; if any change of height or correction occurs a new table must be prepared.

To read barometer and determine "station" pressure by means of the tangential correction-scale, recording data in Form 1083 or Form 1001—

- (1) Set index of correction-scale at current reading of attached thermometer, read and enter total correction in Form 1083.
- (2) Adjust mercury in cistern.
- (3) Set vernier.
- (4) Read vernier and enter reading in Form 1083.
- (5) Deduct total correction from observed reading and enter "station pressure" in Form 1083.

Five operations as indicated, and three columns or spaces in the form are required. The correction-scale forms a permanent part of the barometer, is instantly adjustable to any change of the corrections, and is ready for use at any height. No separate table of corrections necessary.

Examples of entries in Form 1001, in English and International units when present method is employed:

International units.				English units.			
Attached therm.	Observed reading.	Total correction.	Station pressure.	Attached therm.	Observed reading.	Total correction.	Station pressure.
18.8°	985.55	-2.87	985.68	66.7°	29.922	-0.103	29.819

When new correction-scale is employed:

International units.			English units.		
Observed reading.	Total cor'n. <sup>1</sup>	Station pressure.	Observed reading.	Total cor'n. <sup>1</sup>	Station pressure.
985.55	-2.87	985.68	29.922	-0.1025	29.819

<sup>1</sup> From correction-scale—read and entered first.

The classification of operations adopted may be objected to for the reason that three items are included in the operation of obtaining the correction from the scale; but actual comparison shows that much more time is consumed and there is larger probability of error in the use of a loose table, particularly when double interpolation becomes necessary, than is the case with the new correction-scale.

In the extremely rare instance of the need of the temperature of the attached thermometer, this can be ascertained in a few seconds by deducting the constants from the total correction as recorded and looking up the equivalent temperature.

The preceding description and comparison may be summarized as follows:

(1) The tangential correction-scale described is a means of determining the true pressure from observations of a mercurial barometer wherever it may be used, without

(5) Errors in reading the attached thermometer, usually very difficult to detect, are entirely eliminated by the use of the scale, the index line of the transparent scale being set at the top of the thermometric column when a reading is to be made.

(6) Errors in estimating values on the tangential scale are not so easily made nor are they so important as errors in interpolating from the usual printed table of corrections.

(7) When the correction-scale is employed the column in Form 1001 for readings of the attached thermometer becomes unnecessary. The extremely rare instances where this temperature is desired are easily provided for by ascertaining the temperature corresponding to any correction.

(8) As shown in the figures, the new correction-scale is constructed as a complete unit that may be secured to the outer tube of the barometer in the position usually

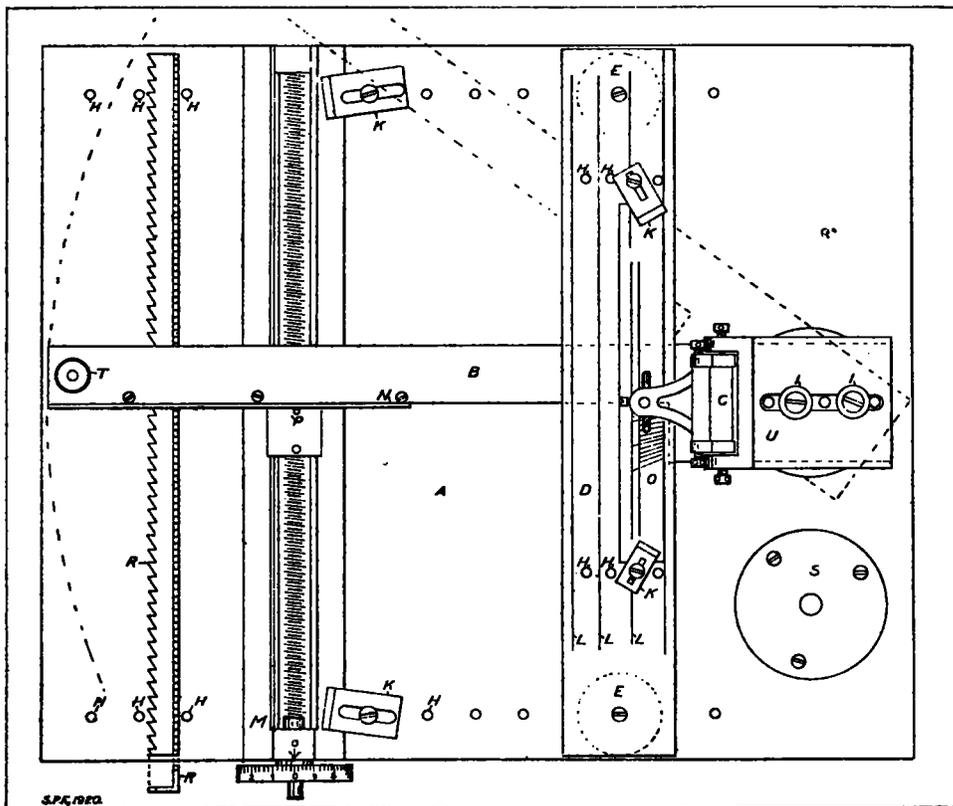


FIG. 4. MACHINE FOR RULING TANGENTIAL SCALES.

the use of a separate table of corrections which may be lost or mislaid and is always an inconvenience. This scale forms a part of the barometer, as does the customary attached thermometer which it is intended to replace.

(2) The scale can be adjusted to allow for constant errors or corrections and the total correction obtained in one reading of the attached thermometer. Any change of correction is allowed for by a simple adjustment, and no adjustment is required for a change of height.

(3) The number of operations required to obtain the "station" or actual pressure is smaller and the whole process simpler than is the case when the customary separate table of correction is employed.

(4) Corrections for barometers of the ordinary or station pattern can be read to 0.01 mb. or 0.0005 inch at intervals of 5 mb. or 0.05 inch; when barometers of precision with wide-scale thermometers are used smaller values are easily obtained. Equal precision can be secured only by the use of special tables.

occupied by the attached thermometer and in the same manner. When the distance between the two screws (S), (S), (figs. 2 and 3) is known, the scale-base (A) can be bored accordingly and the correction-scale, complete, shipped to a distant station to be attached by the observer; it will not usually be necessary to send barometers to a central point or a shop when scales are to be fitted or changed.

(9) The new correction-scale increases the cost of the barometer slightly, but it is believed that the advantage and convenience of having the means of correcting the readings form an inseparable part of the barometer itself will more than outweigh the additional cost.

The accuracy required in ruling the tangential scales is easily attained by the ordinary dividing engines usually found in shops and laboratories; but, because of the peculiar character of the ruling required, the graduation can be performed much more easily and with greater rapidity by means of the special dividing machine shown

in Figure 4. This apparatus consists essentially of a pivoted bar (B), carrying an ordinary ruling mechanism (C), a plate (D), upon which is secured the blank to be ruled, and means for spacing which may be either the micrometer (M), or the ratchet rack (R). These parts are mounted on a substantial cast-iron base (A). To rule a tangential scale, the limits of the space to be ruled and the distance between the zero and some extreme value, such as 5.0 mb. (determined by reference to the thermometer to be used), are marked on the blank which is placed on the plate (D) and so adjusted that when the bar (B) is in a central position the zero line of the scale to be ruled will be normal or perpendicular to the reference lines (L), (L). During the process of ruling the blank is firmly held by clamps (K), (K). A wide range of adjustment is provided by additional tapped holes, (H), (H), for different positions of the clamps, also, the plate (D) may be secured in different positions on the base, (A), by means of screws (E), (E). In the figure, (O) indicates a partially-ruled blank in position. The engraving mechanism (C) can be adjusted to rule a scale of unusual width by loosening the screws (I), (I), and moving the slotted base (U) backward or forward as may be desired; also, additional sockets, (S), are provided for the purpose of ruling scales with zeros near one end.

If the scale is to be spaced by a micrometer (M), the edge of the bar, (B), is held against a pin (P) in the slide of the micrometer, by a spring (not shown), so that when the screw is rotated the bar will move in the path indicated by dotted lines. For convenience in spacing, two rows of tapped holes (H), (H), in the base (A), afford means of securing the micrometer in any position by the clamps (K), (K).

A much less costly and almost equally accurate method of spacing is obtained by the use of a metal angle (R), on the edges of which are cut ratchet racks of different pitches. With two sets of teeth of 2mm and 5mm pitch, respectively, correct spacing of every scale likely to be needed can be obtained by clamping the rack in the proper position on the base (A). To avoid the slight error caused by spacing a diagonal with a rack of appreciable thickness the perpendiculars of the teeth are rounded slightly. All looseness or backlash is avoided by the use of a beveled knife edge (N), which is kept in mesh with the rack by a stiff flat spring, and which is easily and quickly lifted and set in a new position by the knob (T).

This ruling machine, including the rack but not including the micrometer or the engraving mechanism, was built from materials found in the instrument shop of the Weather Bureau at a cost smaller than the price quoted by manufacturers for a single tangential scale. A scale of either pattern described herein can be ruled in about one hour, of which time the larger part must be devoted to adjusting the ruling machine.

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#### RELATIONS BETWEEN WEATHER AND MENTAL AND PHYSICAL CONDITION OF MAN PRESENTED ON THE BASIS OF STATISTICAL RESEARCH.<sup>1</sup>

By ERNST BREZINA and WILHELM SCHMIDT.

[Translated and reviewed by W. W. REED, Weather Bureau, Atlanta, Ga.]

The behavior of the nervous system under different weather conditions is the chief subject of an investigation having for test persons census clerks, school chil-

dren, and epileptics confined in hospital. Investigation was made for all meteorological elements, using current values and changes in value, also for general conditions such as distribution of pressure. These data were entered on cards daily for one year and opposite were placed comparative values characterizing performance of mental work in office or school and condition or behavior in hospital. The following summary based on these data omits mention of those elements for which there appeared no plain relations.

Relative to the influence of change in air pressure it appeared that a certain relation exists for light mental work only; this probably proceeds best with uniform pressure. Neither the number of epileptic patients affected nor the number of attacks shows any decided dependence on air pressure changes, and it is assumed that opposite results are to be referred to a simultaneously changing condition of some kind. It is stated, however, that there appeared plainly an effect of pressure oscillations with periods of 4 to 10 minutes extending for the most part over 24 hours, unfavorable results accompanying the larger amplitudes. It seems probable that these rapid oscillations have essential significance in foehn sickness. Only the marked negative pressure departures proved bad for normal persons, while negative departures generally were found so for epileptics.

In the consideration of the thermal factor there was evident striking difference between the effect upon clerical force and that upon persons affected with epilepsy, which is summarized thus: light mental work is not well done at the time of high temperature or of marked temperature departure, especially in the case of a duration of two days; while epileptics appear sensitive to cold.

For vapor pressure relations were found but little decided; there is to be noted, however, the generally favorable conditions for office force and also for epileptics existing with the normally high vapor pressure of summer. Maximum values of this element are, to be sure, unfavorable. Much more decided results were obtained for relative humidity, and this element appears to have independent significance like that of air pressure and temperature. In winter the best clerical work was done during high humidities (observations taken in the open), but this was due, of course, to their modification to mean values by the heating of offices. Increase in the number of epileptic attacks with high humidity was very plainly shown in winter and was noticeable in summer. Low humidity was found to have bad effect.

Contrary to the prevalent idea, a manifestation of influence by ozone was hardly to be recognized; and at most only a slight effect was to be ascribed to the wind, any influence other than mechanical is presumed explained by other simultaneous conditions.

The relation between meteorological elements that is founded on their connection with position of high and low pressure areas differed so greatly that it could not be accepted as very serviceable. In general, however, the weather prevailing with fall region at the point of observation and with region of rising pressure to the west manifested itself as most unfavorable for office force and pupils, while just the opposite was the case with epileptics.

From the results obtained, the authors believe that this method has proven well adapted and may be especially useful in disclosing the actually effective causes because of the opposite behavior of healthy and sick persons.

The review and discussion of related literature is interesting, especially so since weather effects are given

<sup>1</sup> *Sitzb. Akad. Wiss., Wien. mathem.-naturw. Klasse, Band 123, Abt. 3. Oht.-Diz. 1914.*