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Notes on The Meteorologic Elements Affecting Artillery

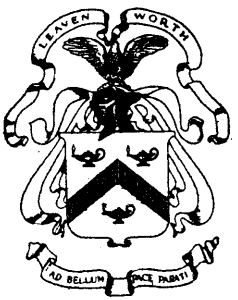
TRANSLATED AND EDITED
AT THE ARMY WAR COLLEGE
OCTOBER, 1917

WASHINGTON
GOVERNMENT PRINTING OFFICE
1917

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WAR DEPARTMENT,
WASHINGTON, *October 26, 1917.*

The following pamphlet translated from a French document, entitled "Note sur les Elements Meteorologiques Interessant L'Artillerie," Annexe 7 to Manuel de L'Officier Orienteur d'Artillerie, is published for the information of all concerned.

[A. G. O. 062.1.]

BY ORDER OF THE SECRETARY OF WAR:

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NOTE ON THE METEOROLOGIC ELEMENTS AFFECTING ARTILLERY.

(Information furnished by the Military Meteorological Bureau of the Ministry of War.)

The meteorologic elements involved in the meteorologic corrections are the wind and the weight of a liter of air at the battery at the moment of fire. The latter is itself a function of the temperature, the pressure, and the hygrometric condition. The range tables assume calm air, a temperature of 15°, a pressure of 750 millimeters, and a quantity of dampness in the atmosphere corresponding to a hygrometric condition equivalent to one-half (or a weight of about 6 milligrams per liter of air). The essential properties of these elements will be studied in the following pages:

1. TEMPERATURE OF THE AIR.

Determination of the temperature of the air.—This determination requires some precautions. On account of the slight conductibility and of the transparency of the air to calorific rays, thermometers in this medium are affected by radiated heat (radiated directly by the sun or indirectly by objects around them).

To avoid this cause of error thermometers are placed under covers in which the air can circulate freely, or, still better, a suspended thermometer is used (a thermometer which turns in the air by means of a string some decimeters in length).

Variations of the temperature.—The temperature varies (*a*) at a given point in the course of a day (daily variation), (*b*) at a given moment, when its altitude is changed (variation of altitude).

(*a*) *Daily variation.*—The temperature of the air at a given moment is the resultant of the quantity of heat that it receives from the sun and of that which it radiates into space. If the curve of a registering thermometer is examined, it is seen that the temperature usually increases from sunrise to about 2 p. m. and then falls until the next day (fig. 1).[1]

[1] There are exceptions to this rule caused by phenomena connected with the larger movements of the atmosphere (the passage of depressions, for instance).

This daily variation is usually greater in summer (when it sometimes exceeds 15 degrees) than in the winter (when it may be zero).

Since a variation of temperature is never negligible as regards fire when it exceeds 2 degrees centigrade, it is obvious that the batteries should be frequently informed of its value.

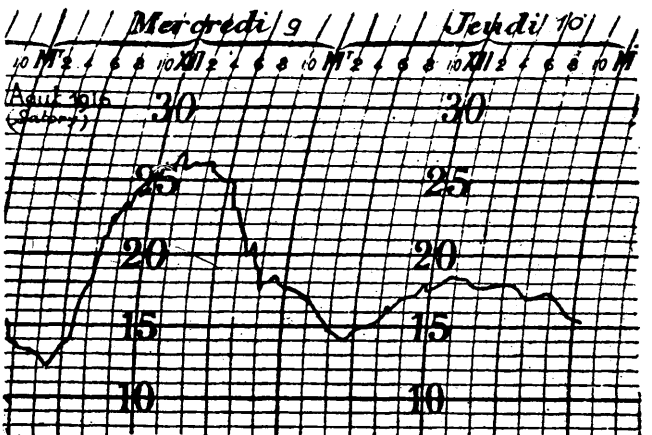


Fig. 1. — Curve of a registering thermometer showing the daily variations from one day to another.

(*b*) *Variations due to altitude.*—As a rule (although the rule is not of universal application, especially in the night), the temperature falls with an increase in altitude. There seems to be no fixed law for this phenomenon, at least near the earth. It may be assumed, however, that it is on the average of 1° for every 175 meters.

In general, except in the case of batteries clearly higher than the meteorologic station, the temperature reported by the latter may be used by the batteries, but only on condition that the report is based on observation made very near the hour of fire, on account of the importance of the daily variation. (The reporting of the temperature by the meteorological station is only a makeshift. The best solution would be to provide each battery with a suspended thermometer which would determine successively the temperature of the powder magazine and that of the air.)

2. ATMOSPHERIC PRESSURE.

Definition—Determination—Barometer.—The pressure exerted at any point by the column of air which is supported at that point is called the atmospheric or barometric pressure. It is represented by the height, expressed in millimeters, of a column of mercury which it supports at a temperature of zero centigrade.

The determination of the atmospheric pressure at any point is made by means of barometers devised according to two different principles (not to mention a third class of instruments, the hypsometric thermometers)—(*a*) mercury barometers and (*b*) aneroid barometers.

(*a*) *Mercury barometer.*—This consists of a vacuum glass tube inserted into a bowl of mercury which rises in the tube proportionally to the amount of the pressure. The top of this column of mercury is read on a millimetric scale on the tube, and this reading gives the amount of the pressure.

The corrections for reducing the reading to the temperature of zero are made by means of tables, taking into account the reading of a thermometer attached to the barometer.

These barometers may be regarded as free from derangement, and they alone give the barometric pressure with certainty.

(*b*) *Aneroid barometers.*—The essential feature of these instruments is an assemblage of shells between which a vacuum is formed, and the variations of which, emphasized by means of levers, is transmitted to an index needle which moves along a dial. These barometers are graduated by comparison with mercury barometers. Compensations are generally made for variations of the temperature between 10 and 20°. Outside this interval the compensation is doubtful. (The system of compensation may be extended over a greater interval (0 to 70°), but it is necessary in this case to make application to the maker.) They are, therefore, protected from sudden changes of the temperature by being kept in their closed cases, which are opened only at the moment of taking a reading.

Aneroid barometers are easily deranged by the influence of shocks and detonations. They must, therefore, be frequently compared with a mercury barometer. This comparison can be made every day by the aid of information given by the Army Meteorological Station. It is sufficient to be sure that the difference between the pressure given by this station and the pressure of the aneroid remains practically the same during the day.

Variations of the barometric pressure at the same point.—It is well known that the barometric pressure (reduced to the level of the sea) at a given point experiences frequent variations, chiefly caused by the movements of the atmosphere, under the influence of which the barometer oscillates on an average between 730 and 775 millimeters. These variations do not seem to conform with any known law, and it is not unusual for them to attain 10 millimeters or more in 12 hours and to be scarcely perceptible at other times. (Fig. 2.)

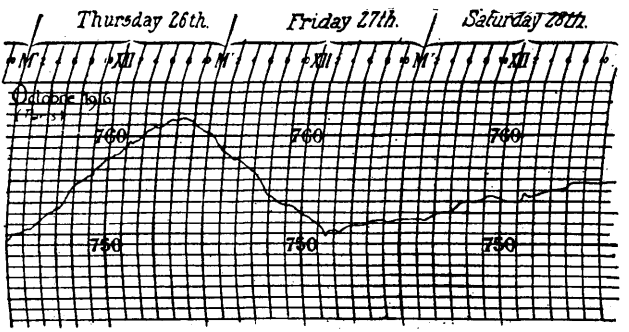


FIGURE 2.—Curve of a registering barometer.

Variations of the barometric pressure with the altitude.—The barometric pressure, by its very nature, diminishes with the altitude, but, in consequence of the elasticity of the air, the law of diminution is not uniform. At a given point it is given by the following equation:

$Z=18293\left(1+2\frac{t_o+t}{1000}\right)\log\frac{H}{H_o}$, when Z=difference in altitude of two stations expressed in meters, H_o=pressure at the lower stations, H=pressure at the higher stations, t_o=temperature in centigrade degrees at the lower station, and t=temperature in centigrade degrees at the upper station. This formula, for $H_o=760$ millimeters and $t_o=3°$, gives an approximate diminution of 1 millimeter for 11 meters of difference of level.

The pressure which the batteries should use is the pressure at their altitude, and not the pressure reduced to the level of the sea. This pressure can be derived from the reduced pressure by means of tables, or more readily by means of diagrams I and II given at the end of this pamphlet. Diagram I does not take the temperature into account, and is less accurate than diagram II, which does.

Reduction to the level of the sea.—In order that the pressures observed in stations of different altitude may be compared, they are reduced to a common plane of comparison by means of the formula just given. This plane of comparison is generally that of the sea.

Isobaric maps.—When it is desired to study the general situation of the atmosphere over a large area, especially for forecasting the weather, the barometrical pressures observed approximately at the same time, at a certain number of stations, are reduced to the level of the sea and transferred to a map on a small scale. The lines of equal pressure (isobaric lines) are then drawn on it.

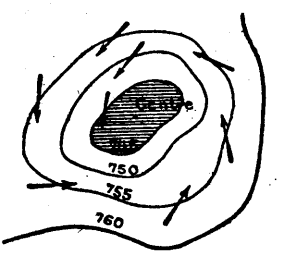


FIGURE 3.—Depression.

An investigation of isobaric maps shows that they are usually formed in a manner analogous to the topographical surfaces where hollows (depressions, fig. 3) or ridges (anticyclones, fig. 4) are chiefly represented.

Gradient.—The gradient of a point of an isobaric surface is the millimetric slope of the surface taken at this point. Even in the case where the slope is very pronounced, the gradient rarely attains 1 millimeter for 40 kilometers. It is not necessary, therefore, to consider, for the atmospheric corrections of fire, the variations of pressure due to gradient between the batteries and the Army Meteorological Station when the latter gives us the pressure.

3. HYGROMETRIC CONDITION.

Definition.—The hygrometric condition E of the air is the term applied to the relation of the amount of vapor it contains to the amount at the point of saturation (maximum amount).

If p and P represent the weight of vapor corresponding to the amounts f and F, we have, by definition, $E=\frac{f}{F}=\frac{p}{P}$, from which we derive $p=EP=E\,1.203\times0.623\left(\frac{F}{760}\right)\left(\frac{1}{1+0.00367t}\right)=.00106$ gr. (E) (P) (F) (1—.00367t).

It is apparent that the hygrometric condition at a given moment can only be utilized, for the determination of the weight of a liter of air, if the temperature of the air at the given moment is known.

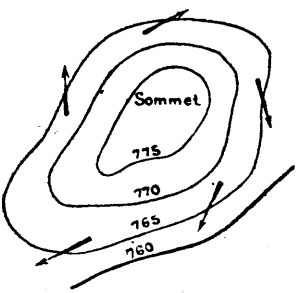


Fig. 4. — ANTICYCLONE.

While E varies considerably (concurrently with the temperature), the weight p of the vapor is, on the contrary, relatively constant during the day. (Fig. 5.)

The corrections, occasioned by the variations in the hygrometric condition, are generally negligible except, perhaps, for guns of very long range.

Determinations.—The hygrometric condition is measured in practice either by hygrometers or by psychrometers. The hygrometers are generally employed. They are based on the property of certain substances (hair, for instance) of varying length under the effect of vapor. They give the hygrometric condition directly. They are graduated from zero (no vapor) to 100 (maximum amount of vapor).

The psychrometer is based on the difference of temperature given by two adjacent thermometers, one of which is dry while the other is kept constantly wet. The difference of the temperatures enable us, by means of tables, to calculate the hygrometric conditions.

4. WIND.

Definition—Determination.—Wind is caused by displacement of the air. This displacement is itself a consequence of the general situation of the atmosphere and of its transformations.

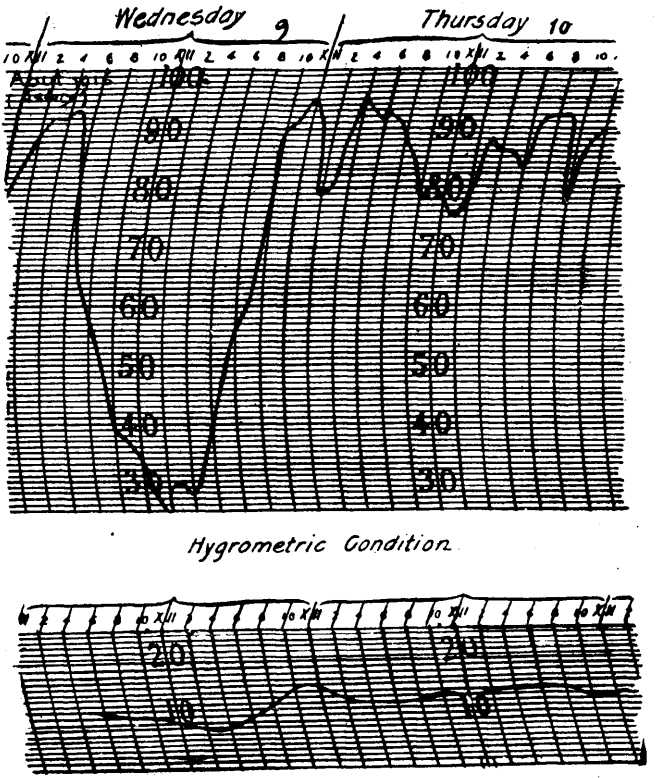


FIGURE 5.

Wind is defined by the direction from which it comes and its velocity. The direction, which is obtained by means of vanes, is referred to the geographic north and expressed in decigrades in

respect to a circle graduated like figure 6 (north 0, east 10, south 20, west 30. Thus 18 indicates a wind blowing from the south-southeast). The velocity, obtained by means of instruments, is expressed in terms of meters per second.

Relation of the wind to the isobars.—When the direction of the surface wind and its force are drawn on an isobaric map at the different stations (the velocity represented conventionally by a proportional number of feathers), it is seen that these elements bear a relation to the isobars (figs. 3 and 4). In the depressions the winds are arranged around the center, blowing in the counter-clockwise direction and almost tangent to the isobars, with a centripetal component varying inversely with the force of the wind. In the anticyclones, the wind blows in the

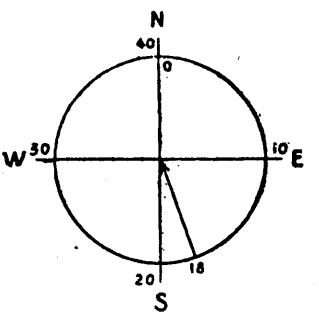


FIGURE 6.—Conventional figures indicating the direction of the wind.

counter-clockwise direction, almost tangent to the isobars, with a centrifugal component generally more accentuated than the centripetal component of the depressions. In a general way the wind in both cases is proportional to the gradient.

Variations of the wind on the vertical.—Aereological soundings show that the wind varies with increasing height, both in direction and velocity, and that the variation is, as a rule, especially noticeable between 0 and 400 meters. This variation is due to obstacles of all sorts in the paths of the molecules of air, which modify their velocity and their direction by friction and by reflection. The effect of these obstacles varies inversely with the force of the wind. It has been observed in all cases that the wind becomes tangent to the isobars at an altitude about

500 to 1,000 meters. (This can be readily seen by noticing the passage of clouds.)

When the atmospheric situation is well defined and the wind has some force (velocity greater than 5 meters), the wind generally blows with regularity, and its variations increase with the altitude.

Variations on the horizontal plane.—The direction and the velocity of the wind, as we have observed above, bear a relation to the isobars, and vary in conformity with them. The study of the dimensions of which, often attaining 500 to 2,000 kilometers in diameter, are susceptible of moving at great velocity (50 to 75 kilometers an hour), even after having remained approximately stationary. It therefore follows:

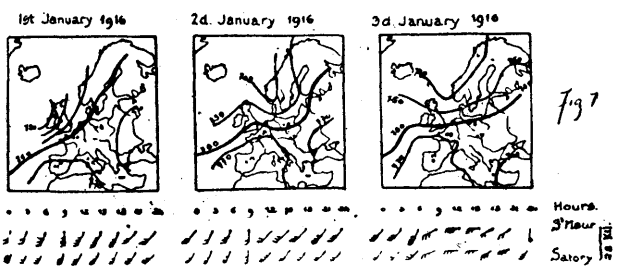


Fig 7

(*a*) That the wind, at the same altitude, is approximately the same over a considerable area (and notably one as great as the front of an army) when the isobars have the same direction over this area.

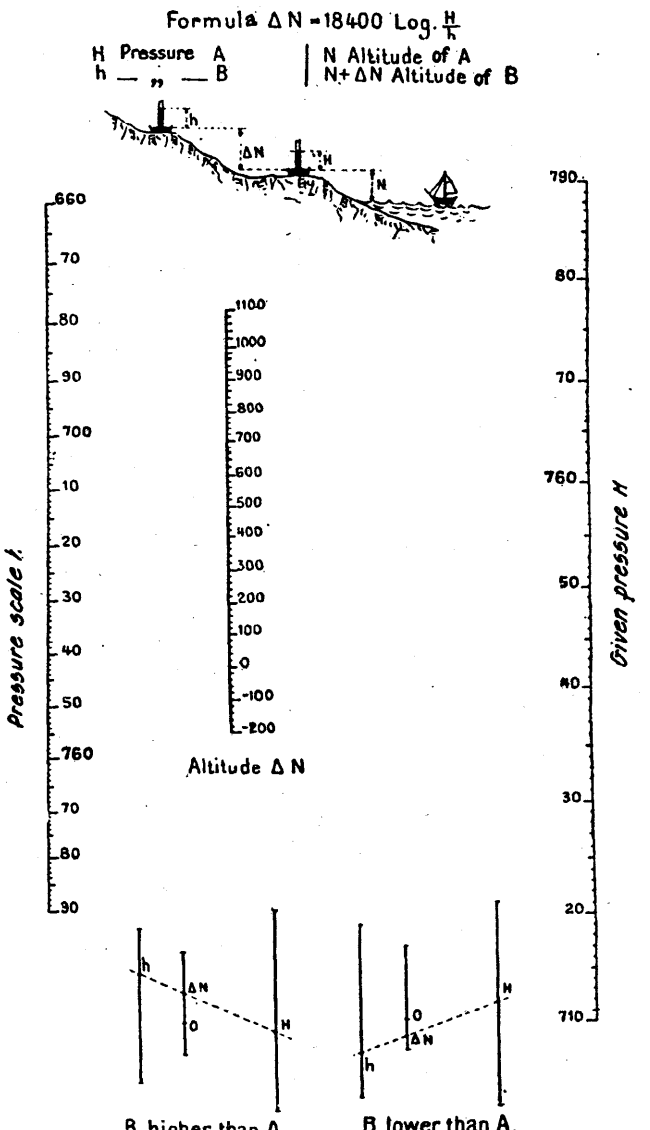
(*b*) That it varies very little as long as the atmospheric situation remains the same, notably when the depressions remain stationary.

(*c*) That, on the contrary, it may change very rapidly when the depressions are displaced.

It would be erroneous to suppose, therefore, that the wind is generally a capricious element, ever varying in time and space. On the contrary, it blows regularly in an approximately constant direction, for periods of one or more days, and these periods are separated by relatively short intervals when the wind changes quite rapidly (fig. 7).

We see from fig. 7 (*a*) the relation of the wind with the isobars; (*b*) the constancy of the wind, even on the ground; and (*c*) the slight duration of the sharp variations of the wind.

BAROMETRIC DIAGRAM No.1.



BAROMETRIC DIAGRAM No.2.

