M.O. 317. **FOR OFFICIAL USE ONLY.**

AIR MINISTRY

METEOROLOGICAL OFFICE

THE
SUPPLY *of* METEOR REPORTS
TO
ARTILLERY UNITS

BY

D. BRUNT, M.A., B.Sc., R. P. BATTY, B.A., AND
C. E. BRITTON, B.Sc.,

Published by the Authority of the Meteorological Committee.

LONDON:
PRINTED AND PUBLISHED BY HIS MAJESTY'S
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THE SUPPLY OF METEOR REPORTS TO ARTILLERY UNITS

By

D. Brunt, M.A., B.Sc., R. P. Batty, B.A., and C. E. Britton, B.Sc.

§1. Introductory.

The motion of a projectile through the air is affected by the meteorological conditions, since the resistance of the air is proportional to its density, and is a complicated function of the velocity of the projectile relative to the air. The range tables used by the gunner are drawn up for certain standard conditions, and when firing takes place under other than these standard conditions allowance must be made for the existing meteorological situation. It is clear, for example, that when the density at all heights is less than the standard, the resistance to the motion of the projectile is decreased and thus a greater range is obtained. Similarly if the wind at all heights blows in the general direction of motion of the projectile, the range will be increased on account of the diminution of the head resistance. Again, a wind blowing across the trajectory from left to right at all heights will cause the projectile to drift towards the right.

The density of air depends upon its temperature, pressure, and humidity, and in practice the correction for density is made through the medium of corrections for temperature and pressure, the effect of variations of humidity being incorporated in the correction for temperature.

In the following pages a brief outline is given of the method of computation to be applied by the meteorologist in order to draw up "meteor telegrams" in the form in which they are required by artillery units. The information thus given enables the gunner to allow for the departure of the actual meteorological conditions from the standard conditions. An earlier pamphlet, M.O. 241, "Notes on the Meteorological Corrections for the Use of Gunners" by Brunt and Durward, gives an introductory account of the methods discussed here.

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§2. The Standard Conditions.

The standard conditions to which reference has been made are as follows :—

(*a*) Still air at all points of the trajectory.

(*b*) Pressure at the ground 30 inches of mercury at 32° Fahrenheit in latitude 45 degrees.

(*c*) Temperature at the ground 60° Fahrenheit.

(*d*) Air half saturated (i.e. relative humidity 50 per cent) at all points of the trajectory.

(*e*) Density at all points in accordance with the formula—

$$\log \frac{\rho_0}{\rho} = \frac{0 \cdot 141h}{10{,}000}$$

where ρ_0 is the density at the ground and ρ the density at height h, h being in feet.

This assumption is equivalent to that of a certain distribution of temperature in the vertical, giving an average lapse rate of 2·1° F. per 1,000 feet from the surface up to 10,000 feet. The standard temperatures are given in detail in § 6 (*a*) below.

The standard condition of distribution of temperature in the vertical is defined by the above equation merely on account of the fact that this is a convenient form for use in ballistic computations, and the new " f " table of densities used in ballistic work is computed from this formula. No claim is made that the standard conditions accurately represent average or normal conditions, though they give a good approximation for ballistic use.

Note.—It should be noted that the units at present used in gunnery are as follows :—

Wind is measured in feet per second and direction in degrees from true north.

Pressure is measured in inches of mercury and temperature in degrees Fahrenheit.

Heights are given in feet and ranges in yards.

Times of flight are measured in seconds.

§3. The Correction for Wind.

(*a*) **The measurement of wind.**—The wind speed near the surface is measured by means of an anemometer, preferably at a height of not less than 15 feet, and the mean wind over a run of at least two minutes is taken in order to avoid short-period fluctuations in the velocity. The wind direction near the surface is best measured by an observation within a few seconds of release of a pilot balloon. If a direction recorder is near at hand, the direction of the surface wind may be taken from the chart, the mean direction for a run of five minutes being adopted.

Winds in the upper air should be measured by means of a pilot balloon followed by two theodolites, or by a pilot balloon with tail followed by one theodolite. It is essential that the height of the balloon should be known by observation and should not be deduced from an assumed rate of ascent of the balloon. This is particularly important in the lower layers of the atmosphere in which ascending and descending currents are relatively frequent, and in which effects of contour may be well marked. The assumption of an incorrect rate of ascent may entirely vitiate the computations of winds.

Wind at particular heights can be obtained by measuring with a Hill mirror the drift of smoke from an anti-aircraft shell fired to burst at the required height. This method can frequently be applied when the sky is partially clouded over, the shell being fired into a patch of blue sky. The observation can be completed within a minute or two and this method will frequently give results when pilot balloon methods fail on account of the balloon being eclipsed by cloud. Details of the computation of winds by this method are given in the " Computer's Handbook."

(*b*) **The effect of wind on the projectile—Weighting factors.**—The gunner requires, not the actual measurements of wind at all heights attained by the projectile, but the " equivalent constant wind." This is a wind, which, if it blew uniformly in velocity and direction at all heights, would produce the same effect on the shell as the distribution of winds actually observed. The equivalent constant wind is a weighted mean of the winds observed from the ground up to the top of the trajectory. The height from the ground to the top of the trajectory is divided into a convenient number of layers and the effect of the wind observed in each of the layers is computed. In practice, the computation consists in multiplying the component winds in each layer by a " weighting factor " appropriate to that layer and summing the products for all the layers. The weighting factor for a layer, for any particular shell, depends upon :—

(i) the total time of flight from gun to target,

(ii) the time spent by the shell in that layer,

(iii) the time spent by the shell after leaving that layer and before reaching the target,

(iv) the density of the air in that layer,

(v) the velocity of the shell in that layer, and

(vi) the inclination of the path of the shell to the horizontal in that layer.

For firing on the flat, the total effect of any layer on the range will be mainly dependent on (ii) and (iv) of these factors, that is, on the time spent by the shell in the layer and on the density of the air in the layer.

The computation of the weighting factors is a lengthy one and need not be discussed further here. Accurate wind weighting factors have been evaluated for a large number of different trajectories. It is found in general that the weighting factors differ for head (or following) winds and cross winds, the differences being considerable in the case of some trajectories.

For experimental work, such as range and accuracy trials, the wind weighting factors appropriate to the gun, projectile, quadrant elevation and muzzle velocity are used and the head (or following) wind and cross wind components are treated separately. In such cases the meteorologist is informed previously of the direction of the line of fire, so that he can evaluate the head and cross components of wind at each height and apply the appropriate corrections. This procedure should also be adopted for all calibrations of guns, as special weighting factors can be supplied for most of the guns and howitzers in use.

For ordinary work in the field, however, the same weighting factors are used for all trajectories attaining the same height and for both head and cross winds. Admittedly there is some inaccuracy involved in this procedure, but as under conditions of firing in the field, the wind cannot usually be measured at the point of firing, nor at the moment of firing, there is an error due to change of wind with time and place which is usually greater than that due to the use of universal weighting factors. The great advantage of using the same weighting factors for both head and cross winds lies in the fact that the equivalent constant wind can be evaluated without consideration of the direction of the line of fire. The form for pilot-balloon ascents (Form 2087), which has been drawn up to facilitate the computation of " meteor telegrams ", should be used for all artillery work.

(*c*) **Computation of the equivalent constant wind.**—There is an approximate formula† connecting the maximum height attained by a projectile and its time of flight. If T is the time of flight in seconds, then the maximum height in feet is $4T^2$. It is customary to give the equivalent constant wind for certain values of the time of flight, T. A time of flight of 50 seconds corresponds to a vertex of 10,000 feet, 40 seconds to 6,400 feet (or 6,000 feet with sufficient accuracy for our purpose) and 30 seconds to 3,600 feet (or 4,000 feet with sufficient accuracy). It will be found in the case of the time of flight of 30 seconds, for example, that the winds are used up to 4,000 feet, but the factors are adjusted so as to give the equivalent constant wind for a vertex of 3,600 feet.

In general the sheet used for the pilot-balloon ascent gives the mean velocities for layers whose thickness will vary with the rate of ascent of the balloon. For times of flight of 30 seconds up to 60 seconds, the layers used are of thickness 2,000 feet, and for each of these we require the mean wind expressed in units of 100 feet per minute. We can obtain the approximate mean

† *Vide* table in 10 d below.

component winds in the following way. In the column giving the height of the pilot balloon on the working sheet look for the heights nearest to 2,000, 4,0000, 6,000 feet, etc. ; if the balloon rises at approximately 500 feet per minute, these will occur at the 4th, 8th, 12th minutes, but if the rate of ascent is irregular they will occur at varying intervals of time. Having selected the approximate minute readings, subtract consecutive values of D_E and D_N, dividing each difference by the appropriate number of minutes which has elapsed. Here D_E and D_N are the components to east and north of the total horizontal drift of the balloon. For example, in the first illustration given on page 28, the following give the minute readings which are nearest to 2,000, 4,000, 6,000, 8,000 and 10,000 feet respectively with the appropriate values of D_E and D_N.

Minute.	*Ht.*	D_E	D_N	*Mean Components.*		
5	2,180	− 28	− 7·5	0– 2,000	−5·6	−1·5
9	4,130	− 47	+ 4·5	2,000– 4,000	−4·7	+3·0
12	5,720	− 61	+ 20	4,000– 6,000	−4·7	+5·2
17	8,050	− 86	+ 59	6,000– 8,000	−5·0	+7·8
21	10,020	−119	+ 83	8,000–10,000	−8·2	+6·0

The computation here reproduced is carried out mentally and the mean components are written down immediately in the appropriate columns on the back of the form, it being assumed that we may, with sufficient accuracy, treat the mean winds from 0–2,180, 2,180–4,130, etc., as the mean winds from 0–2,000, 2,000–4,000 feet, etc. The errors thus introduced are extremely slight. An idea of their magnitude is readily obtained by drawing graphs of the component winds, V_E and V_N, separately, and reading from the graph the corresponding mean components. The error in the equivalent constant wind for 50 seconds deduced from the above observations is of the order of 1 foot per second in velocity and 2 degrees in direction. Such an error is negligible in view of the ordinary errors of observation of wind by means of pilot balloons. The evaluation of the equivalent constant winds for 30, 40, 50 and 60 seconds consists in multiplying the mean component winds in each layer by the appropriate factors using Table I, and then adding the products, finally converting into the resultant wind by the use of Table II. The computation will be most readily understood by an examination of the examples given on pages 28 to 31. Tables I and II are also reproduced on the back of the pilot balloon sheet (Form 2087).

For times of flight of 20 and 10 seconds, we require the mean winds in layers of 500 feet. If the rate of ascent of the balloon is approximately 500 feet per minute, we may take V_{WE} and V_{SN} for the first three minutes without correction. Frequently, however, it will happen that the rates of ascent during the first few minutes are very irregular. Some method of interpolation is necessary. A simple method is the following. Write on a piece of paper the mean height of each one-minute layer and opposite them write the corresponding component winds for the layers. Then interpolate roughly to get the mean winds at 250, 750 and 1,250 feet, using the anemometer observation where necessary. Thus in the first example, we have

Mean ht. of layer ft.	*Component winds*		*Assumed means* ft.		
205	−6½	−2	250	−6½	−2
620	−6½	−2½	750	−6	−3
1,045	−5	−3½	1,250	−5½	−2½
1,525	−6	−1			

The assumed means are entered on the back of the sheet, and multiplying by the appropriate factors in Table II, we obtain the equivalent wind for 20 seconds. The equivalent constant wind for 10 seconds is derived by multiplying the surface wind and the assumed means for 0–500 feet and 500–1,000 feet by the factors ¼, ½ and ¼ respectively, and proceeding as in the other cases.

For a time of flight of 5 seconds, we arrive at the speed of the equivalent constant wind as follows :—

The wind speed at 15 feet + ¼ (wind speed for time of flight of 10 seconds less the wind speed at 15 feet).

For the direction of the equivalent constant wind for a time of flight of 5 seconds, assume a direction halfway between the direction at 15 feet and the direction for the 10 seconds time of flight.

These computations will be most readily understood by reference to the specimen computations shown herewith.

When it is *assumed** that the pilot balloon ascends at the rate of 500 feet per minute, the computation is considerably simplified. The mean component winds in a layer of 2,000 feet thickness are then obtained by dividing by four the changes in D_E and D_N within that layer, the interpolation of component winds becoming unnecessary.

When equivalent constant winds are required for a time of flight of 15 seconds, adopt the mean of the values for 10 and 20 seconds. Similarly, if 25 seconds is required, adopt the mean of the values for 20 and 30 seconds and so on.

In unusual circumstances it may happen that equivalent constant winds are required for times of flight of 70, 80, and 90 seconds.

* It is emphasized that it is extremely undesirable to make any assumptions whatever as to the rate of ascent of pilot balloons. They should preferably be followed by two theodolites, failing which a tail should be attached.

The vertex of the trajectory increases as the square of the time of flight and, for times as great as 70, 80 and 90 seconds, it is desirable to use thicker layers of the atmosphere than 2,000 feet. For 70 and 80 seconds use layers of 5,000 feet, and for 90 seconds layers of 6,500 feet.

(*d*) **Computations based on the gradient wind.**—When low cloud prevents the direct measurement of the upper winds, a careful measurement of the gradient wind should be made. This value may be adopted as the equivalent constant wind for a time of flight of 25 seconds. This combined with observations at 15 feet will suffice to give a reasonable approximation for equivalent constant winds of shorter times of flight. The interpolation formulæ are

Equivalent constant wind for 20 seconds =
0·6 (gradient wind) + 0·4 (wind at 15 feet).

Its direction will be ⅗ of the way round from the surface direction to the gradient direction.

Equivalent constant wind for 10 seconds =
0·4 (gradient wind) + 0·6 (wind at 15 feet).

Its direction will be ⅖ of the way round from the surface direction to the gradient direction.

Equivalent constant wind for 5 seconds is derived as explained above for the normal case.

The following general considerations will prove helpful when either the equivalent constant wind or the ballistic temperature (*see* § 6) have to be estimated owing to the impossibility of securing actual observations :—

(i) The variation of wind speed with height is due to the combined effect of the lapse rate of temperature with height and of the horizontal temperature gradient, the latter being the more effective.

(*a*) Wind speed will increase with height if the higher temperature is on the side of higher pressure.

(*b*) Wind speed will decrease with height if the higher temperature is on the side of lower pressure.

(ii) The variation of wind direction with height is due to the existence of a horizontal temperature gradient along the isobars.

(*a*) Wind will veer with height if the temperature decreases along the isobar in the direction towards which the wind blows (northern hemisphere).

(*b*) Wind will back with height if the temperature increases along the isobar in the direction towards which the wind blows (northern hemisphere).

(*c*) Other things being equal, the steeper the barometric gradient, that is, the stronger the wind, the less rapid will be the backing or veering.

(iii) If the temperature is fairly uniform over a wide area the winds in the free air will conform closely to the surface isobars.

(iv) If the horizontal temperature gradients are steep at the surface, then the winds in the free air very quickly show decided shifts from the surface isobars.

(*e*) **A rough check on the computations.**—In cases where the component winds increase or decrease uniformly with height, the equivalent constant wind is approximately equal to the actual wind at ¾ of the height of the trajectory. This may be used as a check on the computations. Assuming that the height of the vertex is $4T^2$ for a time of flight of T seconds, the equivalent constant wind should roughly be that observed at the height $3T^2$ feet. The values of this height are as follows :—

Time of flight (secs.) ..	10	20	30	40	50
Height (feet)	300	1,200	2,700	4,800	7,500

This is merely a rough check, and is of no value whatsoever with light variable winds. But for winds which either increase or decrease fairly regularly with height, the check is usually of value.

§4. Pressure.

The pressure of the atmosphere is obtained from a standard mercury barometer and is read at the time of each pilot-balloon ascent. In messages to artillery units the pressure is given in inches of mercury to the nearest hundredth of an inch, after the necessary correction for temperature, gravity, and height above mean sea level have been made.

In the range tables the corrections for deviations of pressure from normal are expressed in terms of inches of mercury. When a millibar barometer is used, the final reading reduced to mean sea level should be converted into inches before being included in the meteor telegram.

§5. Humidity.

In the range tables a relative humidity of 50 per cent. is assumed throughout the atmosphere. Corrections to the variations from this standard are easily made by increasing or diminishing the actual temperature so that half-saturated air at the corrected temperature has the same density as the actual air under consideration. The temperatures observed in the different layers are thus corrected for humidity by means of Table IV before computing the ballistic temperature, so that the ballistic temperature takes account of variations from standard humidity as well as from standard temperature.

§6. The Correction for Temperature

(*a*) **The ballistic temperature.**—The effect of deviations from standard temperature at any height is evaluated in a somewhat similar manner to the wind correction. In the case of wind, the observed distribution of wind is reduced to a single measurement called the equivalent constant wind. Similarly the observed temperature distribution is reduced to a single measure called the ballistic temperature. As in the case of the wind correction, the trajectory is divided into a convenient number of layers and the effect on range of unit deviation from standard temperature is evaluated. From these computations it is readily possible to deduce a constant deviation from standard temperature which, if it existed at all heights, would produce the same effect upon range as the deviations from standard actually observed. This constant deviation is applied as a correction to the standard ground temperature of 60° F. giving a corrected ground temperature which is called the ballistic temperature. Thus the ballistic temperature may be defined as that ground temperature which must be assumed together with the standard lapse rate and standard relative humidity in order to produce the same effect upon range as the temperature and humidity distribution actually observed. Throughout the remainder of this discussion it is to be understood that observed temperatures have been corrected for humidity in accordance with § 5 above.

The standard temperatures are given in the following table, the air being taken as half saturated at all heights :—

Height. ft.	*Standard temperature.* ° F.	*Height.* ft.	*Standard temperature.* ° F.
0	60·0	18,000	16·7
1,000	58·3	19,000	13·5
2,000	56·4	20,000	10·2
3,000	54·5	21,000	6·7
4,000	52·4	22,000	3·1
5,000	50·4	23,000	− 0·6
6,000	48·3	24,000	− 4·4
7,000	46·1	25,000	− 8·5
8,000	43·8	26,000	−12·6
9,000	41·5	27,000	−16·8
10,000	39·0	28,000	−21·2
11,000	36·6	29,000	−25·7
12,000	34·1	30,000	−30·5
13,000	31·5	31,000	−35·3
14,000	28·8	32,000	−40·2
15,000	26·0	33,000	−45·3
16,000	23·0	34,000	−50·7
17,000	19·9	35,000	−56·1

Weighting factors have been computed for a large number of different trajectories and from these mean temperature weighting factors have been deduced for trajectories corresponding to certain times of flight. For times of flight of 30, 40, 50 and 60 seconds take layers of 2,000 feet thickness and note the temperature at the middle of each layer. From these subtract in each case the standard temperature given in the table above. Multiply the resulting difference by the appropriate weighting factor and add the products for all the layers. To this sum add 60° F. and the result is the ballistic temperature for the time of flight.

An example of the computation of the ballistic temperature for the time of flight 50 seconds is given below, the temperatures given in the second column being observations made in south-east England at 10 h. on the 8th of January, 1920, when there was a surface temperature of 10° F.

Height.	Temperature.			Weighting factor.	Product.
	Observed.	Standard.	Deviation from Standard.		
ft.	°F	°F	°F		
1,000	26	58	−32	0·11	− 3·5
3,000	43	54	−11	0·13	− 1·4
5,000	41	50	− 9	0·14	− 1·3
7,000	36	46	−10	0·16	− 1·6
9,000	30	42	−12	0·28	− 3·4
					−11·2

Ballistic temperature = 60 − 11·2 = 49° F.

It should be noted that the weighting factors for temperature do not add up to unity. This is due to the fact that the use of temperature weighting factors is to correct for *density* variations. A variation of temperature from normal at any level produces, not only a variation of density at that level, but also a variation opposite in sign in the rate of decrease of pressure with height. Thus, if temperature were strictly standard at all heights, except in one layer, the variation from normal temperature in that layer, which for convenience we will suppose to have temperature above normal, would give a diminished rate of fall of pressure with height throughout that layer, and, therefore, a pressure above normal at all heights above that layer. The use of weighting factors for temperature takes account of both these effects, which are readily seen to be opposite in sign. If only the first of these effects were to be allowed for, then the temperature weighting factors should add up to unity. In practice, however, the use of temperature weighting factors adding up to unity would give over-correction for density, since, as we have seen above, the

direct effect upon density of a variation of temperature from normal in any layer is partially compensated by the *indirect* effect upon the density in all higher layers acting through the medium of the pressure effect.

Incidentally, the above example, computed for an occasion when there was a pronounced inversion of temperature near the ground, shows the extreme danger of using the temperature at the surface without allowing for conditions in the upper air. In the example given the surface temperature was 10°, so that the error involved by assuming the surface temperature as a ballistic temperature would be 39°, leading to considerable errors in the range.

The following table gives the weighting factors for layers of 2,000 feet for times of flight of 30, 40, 50 and 60 seconds.

Height.	Standard Temperature.	Time of Flight (secs.). 30	40	50	60
ft.	°F.	Weighting factor.			
1,000	58	·45	·22	·11	·05
3,000	54	·49	·24	·13	·07
5,000	50	·	·43	·14	·08
7,000	46			·16	·09
9,000	42			·28	·10
11,000	37				·11
13,000	32				·27

Table III at the end of this pamphlet gives the product of these factors by integers from 1 up to 20, and for even integers from 22 up to 30, the use of which facilitates the computation.

For times of flight of 20 and 10 seconds, smaller layers must be taken. For 20 seconds take layers of 500 feet and for 10 seconds take layers of 200 feet. The standard temperatures and weighting factors are :—

20 Seconds.

Height.	*Standard Temperature.*	*Weighting Factor.*
ft.	°F.	
250	60	·26
750	59	·28
1,250	58	·44

10 Seconds.

Height.	*Standard Temperature.*	*Weighting Factor.*
ft.	°F.	
100	60	·44
300	59	·55

For a time of flight of 5 seconds assume surface temperature when the lapse rate is small ; but when convection is strong in the middle of the day the decrease of temperature to a height of about 50 feet may be as much as 4° or 5° F. and to obtain the ballistic temperature for a time of flight of 5 seconds the surface temperature should be decreased by, say, 2° to 4° F. When there is an inversion of temperature near the ground after a clear still night the temperature may increase from 7° to 10° at a height of 50 feet. It is dangerous to attempt to follow any general rule in such cases; for heights of 2,000 feet and upwards, it is safer to adopt temperatures based on observations made at the ground late on the previous afternoon, combined with an average lapse rate.

When observations of temperature are not available in sufficient detail to permit the use of the above tables for times of flight of 10 and 20 seconds, adopt the mean of the surface temperature and the temperature at 1,000 feet for the 20-seconds ballistic temperature. For the ballistic temperature at 10 seconds use the mean of the surface temperature and the ballistic temperature for 20 seconds.

So far as is possible, actual observations of upper air temperatures should be used to avoid the necessity for estimating the ballistic temperatures on general principles.

In exceptional cases it may be necessary to give the ballistic temperature in respect of times of flight of 70, 80 and 90 seconds. The following layers and weighting factors should then be used.

Layer. ft.	Time of Flight. 70 secs.	Time of Flight. 80 secs.	Layer. ft.	Time of Flight. 90 secs.
	Weighting factor.			Weighting factor.
0– 5,000	·10	·08	0– 6,500	·06
5,000–10,000	·12	·09	6,500–13,000	·07
10,000–15,000	·14	·09	13,000–19,500	·07
15,000–20,000	·33	·10	19,500–26,000	·09
20,000–25,000		·22	26,000–32,500	·20

(*b*) **Estimating the ballistic temperature.**—When no observations of temperature are available it becomes necessary to estimate the ballistic temperatures. Some idea of the nature of the possible variations of ballistic temperature with time of flight may be gathered from an inspection of a few typical cases.

(i) Observed lapse rate of temperature 5·5° F. per 1,000 feet, i.e., roughly the dry adiabatic rate. Then for different temperatures the corresponding ballistic temperatures will be as follows:—

Time of Flight.	Surface temperature (°F.). 40	50	60	70
secs.	Ballistic temperatures (°F.).			
20	37	46	56	65
30	34	43	52	61
40	31	40	48	57
50	27	35	42	50
60	21	29	37	45
70	18	25	32	40

This table will be reasonably applicable to the conditions on a fine afternoon when small cumulus clouds appear.

(ii) Observed lapse rate of temperature of 3° per 1,000 feet, i.e., roughly the saturated adiabatic rate. Then for different surface temperatures the corresponding ballistic temperatures are as follows:—

Time of Flight.	Surface temperature (°F.). 40	50	60	70
secs.	Ballistic temperature (°F.).			
20	40	50	60	70
30	40	50	59	69
40	40	49	58	67
50	39	47	56	65
60	39	47	54	63
70	39	47	53	62

Under these conditions the surface temperatures may be adopted with sufficient accuracy for the ballistic temperatures for times of flight of 5, 10 and 20 seconds. These conditions will usually hold above the cloud base when rain has been falling for some time. They will be approximately true down to the ground in the case of rain in the warm sector of a depression. It is thus of importance to observe the surface temperature when the rain ceases, as this temperature, combined with a lapse rate of 3° F. per 1,000 feet will give a good approximation to the upper air temperatures for the next four hours or so.

In the case of rain at a warm or cold front, it will frequently happen that the rain descends from the upper warm sector through the wedge of cold air at the ground. Thus the rule stated above should only be used after consideration has been given to the position of the station in the depression.

(iii) The extreme case of the inversion quoted in a previous table gives the following ballistic temperatures, assuming that the fall of temperature from the ground to 1,000 feet is linear.

Time of flight (secs.)	10	20	30	40	50
Ballistic temperature (° F.) ..	13	24	40	47	49

It would, however, be safer to assume an increase of temperature of 8° from the ground to 100 feet and then an approximately linear fall from 100 to 1,000 feet. This assumption modifies the computed ballistic temperatures giving 20° for 10 seconds and 27° for 20 seconds, but leaves the values for the higher times of flight unchanged.

The tables given under (i) and (ii) above will be helpful in cases where it is possible to postulate convection of dry or saturated air.

It is also of importance to note that in the upper air the diurnal changes of temperature are slight and are almost negligible above 5,000 feet. If then an observation of temperature at 10,000 feet is available at any time, this value may be used for the succeeding 6 hours without appreciable error, unless there has been a considerable change in wind direction in the interval. It should be noted that a change in wind direction may mean a change in the source of origin of the air and consequently a change in the temperature distribution.

The following points should be noted as being of some assistance in estimating the lapse rate of temperature with height :—

(i) Marked deviations from the normal rate of ascent of pilot balloons can in general be attributed to the effect of either contour or convection. Large ascending currents occur only when the lapse rate is equal to or greater than the adiabatic rate. When cumulus clouds form as a result of convection, the temperature of the air at the base of the cloud can be deduced approximately by assuming a lapse rate of 1·6° F. per 300 feet from the ground up to the base of the cloud. The height in feet at which convection should produce a cloud by condensation can be obtained approximately by multiplying the depression of the dew point by 236. The depression of the dew point may be obtained from the " Hygrometric Tables."*

When ascending currents are observed, but no cloud is formed, then either the lapse rate is small and so rising air quickly attains a level where it is in thermal equilibrium with its surroundings without becoming saturated, or else the air is so dry that even an ascent to a considerable height does not produce condensation.

(ii) Practically all varieties of stratus and strato-cumulus clouds are marked by an inversion of the lapse rate extending beyond their upper limits. Such inversions are also sometimes found with haze, when no visible cloud is formed. In cyclonic conditions there may be no actual inversion but only a smaller lapse rate above the cloud as compared with that existing below the cloud level.

(iii) The temperature of the free air usually conforms to that of the surface with respect to the *sense* of the change from normal, the chief exceptions to this rule being associated with inversions.

* Meteorological Office Publication No. 265.

For any particular station it is advisable to draw a graph as shewn in Fig. 1 giving the normal temperature at the surface and at 5,000 feet. The approximately-smoothed monthly mean temperatures for south-east England (after Dines) are as follows :—

Height.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
ft.						Mean temperatures °F.						
0 ..	37	38	41	47	53	59	61	60	55	49	44	39
1,000 ..	35	35	37	43	49	54	56	55	52	47	41	37
3,000 ..	29	29	32	37	43	48	51	50	47	42	36	31
5,000 ..	25	24	26	31	37	42	45	46	43	38	32	27
7,000 ..	20	19	21	25	31	36	40	41	39	34	29	24
9,000 ..	15	14	15	20	25	31	34	36	34	29	23	18
11,000 ..	11	9	11	14	19	25	28	30	28	23	17	12
13,000 ..	4	2	4	7	12	19	22	23	22	16	11	5
15,000 ..	−4	−6	−4	0	6	11	15	17	15	9	4	−2
17,000 ..	−12	−14	−12	−8	−1	4	8	10	10	2	−3	−8
19,000 ..	−20	−20	−18	−15	−9	−3	1	3	0	−5	−9	−16
21,000 ..	−26	−27	−25	−21	−16	−11	−6	−5	−8	−13	−17	−24
23,000 ..	−33	−35	−33	−29	−24	−19	−15	−13	−15	−19	−26	−31
25,000 ..	−40	−42	−40	−36	−30	−26	−22	−21	−22	−26	−33	−38
27,000 ..	−49	−50	−49	−44	−37	−34	−29	−29	−29	−34	−39	−45
29,000 ..	−54	−57	−54	−51	−45	−41	−36	−37	−37	−41	−47	−53
31,000 ..	−59	−61	−59	−56	−52	−49	−44	−46	−46	−49	−53	−58
33,000 ..	−63	−63	−63	−63	−57	−55	−53	−53	−53	−57	−58	−62

An examination of the lapse rate of temperature with height from the surface up to 2 km. at Berlin and Vienna shews that the temperatures prevailing there are approximately the same as those exhibited in the table for south-east England. Further, curves shewing the mean of maximum and minimum monthly mean temperatures for the different parts of the British Isles are of the same form as that of Fig. 1 for the surface temperatures, with a constant difference of −1° for south-west England, −2° for north Wales, −3° for north-east England, and −4° for east Scotland.

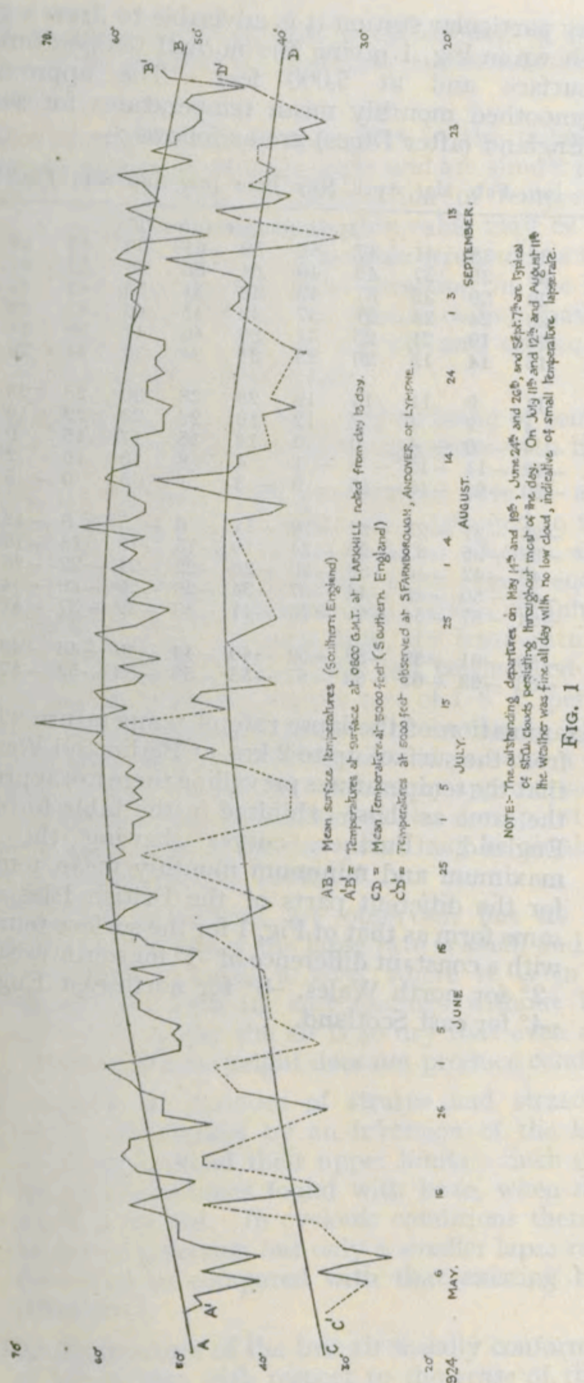

FIG. 1

It has been found that during the months May to September the surface temperatures at 0800 G.M.T. approximate very closely to the mean of the maximum and minimum temperatures. This was true to within 2° F. on over 80 per cent of the days from May to September, 1924 at Larkhill. It is therefore suggested that, at any station at which ballistic temperatures have to be evaluated, the temperature at 0800 G.M.T. should be plotted daily on the graph of Fig. 1, and that the deviation from the mean should be taken as indicating the sense of the departure from normal of the temperatures at 5,000 feet. Probable values of the temperatures at 1,000 and 3,000 feet may be obtained by interpolation between the surface temperature and the assumed temperature for 5,000 feet. The ballistic temperatures for times of flight up to 40 seconds can then be deduced as described above.

§7. Anti-Aircraft Fire.

Anti-aircraft fire is distinguished by the fact that in general the target is to be reached before the projectile has attained the maximum height of the trajectory, and the correction for meteorological conditions is complicated by that fact and by the necessity for considering both vertical and horizontal displacements. The density weighting factors are not the same for the horizontal and the vertical displacements although the differences are relatively small. It is not practicable, except under experimental conditions, to use different density corrections for targets of varying heights, and for trajectories of varying quadrant elevation. All that can be done is to select average weighting factors for universal use. It turns out that the best values to use, on the whole, are equal weighting factors for each layer, so that in dealing with a target at a given height, all that is required is the average wind from the ground up to that height, and the average deviation of temperatures from standard up to the height.

§8. Form of the Meteor Telegram.

Meteorological reports sent to artillery units should always be given in the following form :—

Larkhill, 26th March, 1924. Bar. M.S.L. 2987 0550 03117
1049 07130 2048 17144 3047 17147 4045 17136
Time 1030.

If required, greater times of flight are added, thus 5045 21176 6044 24175 7043 25170.

The values for 15 seconds and 25 seconds, when required, are obtained by taking the mean values between 10 and 20, and 20 and 30 seconds respectively.

It will be seen that the message gives first the station of origin and the date, followed by the barometric reading, corrected for temperature, height, and latitude and expressed in inches and hundredths to the nearest hundredth of an inch. This is followed by groups which consist of four and five figures alternately. The first two figures of a four-figure group give the time of flight and the succeeding two figures give the ballistic temperature corresponding thereto. The first two figures of the following five-figure group give the speed of the equivalent constant wind in feet per second and the next three figures give its direction in degrees measured clockwise from true north. As an example, the first two groups of the specimen message given are to be interpreted as follows :—

For time of flight of 5 seconds the ballistic temperature is 50° and the equivalent constant wind is 3 feet per second at 117°.

Each subsequent pair of groups is to be interpreted in the same way. In the case where the wind velocity amounts to 100 feet per second or more, the wind group becomes a six-figure group. This will arise very rarely in actual practice.

§9. Meteor Telegrams to Anti-Aircraft Artillery.

The "meteor telegrams" to anti-aircraft units consist of two groups of five figures each, in the following form :—

BBBTT VVDDD

where

BBB is the barometer reduced to mean sea level in inches and tenths ;
TT is the ballistic temperature in degrees Fahrenheit ;
VV is the velocity of the ballistic wind in feet per second ;
DDD is the wind direction in degrees from north.

The ballistic temperature given in the telegram will be the ballistic temperature for a height of target of 12,000 feet. In evaluating this, equal weighting factors should be used. The standard temperatures are shown below in column 2 for the heights shown in column 1. In columns 3 and 4 is given a specimen computation of ballistic temperature.

Height. ft.	*Standard temperature.* °F	*Observed temperature.* °F	*Difference* (O—S).
1,000	58	51	—7
3,000	54	45	—9
5,000	50	36	—14
7,000	46	30	—16
9,000	42	25	—17
11,000	37	18	—19
			6)—82
			—14

Ballistic temperature = 60° — 14° = 46°F.

The following approximate rule will be helpful for the estimation of ballistic temperature in anti-aircraft fire where a set of observations of upper air temperatures is available for the morning of the day of firing. To find the ballistic temperature at a later hour of the day add to the morning ballistic temperature a certain fraction of the increase in the surface temperature. This fraction is one third in the case of medium trajectories of about 10,000 feet and one quarter for high trajectories of about 20,000 feet.

The ballistic wind or equivalent constant wind should be the mean wind from the ground up to the height of 12,000 feet. Take D_E and D_N for the 24th minute, or for height 12,000 feet, and divide by the number of minutes. This gives mean wind components in hundreds of feet per minute. Use the table in the "Computer's Handbook" to convert into feet per second and degrees. When the wind is not measured up to 12,000 feet, give the mean wind up to the height attained. If only shell-burst observations are available give the actual wind observed at 6,000 feet.

§10. Miscellaneous Questions.

(*a*) **Difference of height of battery and target.**—The effect of any layer upon the form of the trajectory is made up of two parts corresponding to the ascending and the descending branches of the trajectory. Whether we consider wind or temperature it is a safe rule that the effect of any layer is greater in the ascending than in the descending portion, and the effect which the wind and temperature distributions in the lowest layers produce in the descending branch of the trajectory is, in practice, negligible.

This point is of importance in the field. If the target is higher than the battery, no serious meteorological error is introduced by the fact that the trajectory stops short at this point. If the target is lower than the battery, no material error is made on account of the prolongation of the trajectory below the horizontal plane containing the battery. The meteorological effect of the part of the trajectory comprised between target level and the horizontal plane through the battery is always negligible provided that the height of the vertex of the trajectory is at least twice as great as the height of the target above battery level. In evaluating the *range* a correction is naturally made by the gunner taking into account the angle of descent of the projectile.

(*b*) **The effect of vertical currents.**—Vertical currents, when present, may produce very considerable effects on range. It is possible to work out weighting factors to give the effect of any combination of upward or downward currents on a given shell. But in practice, on account of the known variability of vertical currents with time and place, and the great uncertainty as to whether the shell will pass through the same currents as the pilot balloon no such correction is evaluated. The usual procedure, when considerable vertical currents are observed, is to warn artillery units of their existence, particularly in the case of range and accuracy trials and calibration of guns.

As an example of the comparative effect of a vertical wind, we may take the case of a 60-pr. B.L. gun, firing at a muzzle velocity of 2,080 feet per second and having a time of flight of ten seconds. A vertical wind of 5 feet per second throughout the trajectory could produce a change in range of 32 yards. It would require an equivalent constant wind of about 22 feet per second along the line of fire to produce a similar change of range. It may be noted that the relative effect of vertical winds is greatest for the smaller times of flight. Take, for instance, the case of the 6-inch B.L. gun, firing at muzzle velocity 2,100 feet per second and time of flight 40 seconds. In this case, a vertical wind of 5 feet per second through the whole trajectory will produce a change of range of 37 yards. This is the equivalent of a change in range produced by a following wind of 4 feet per second.

(*c*) **The effect of cloud, rain and fog.**—The effect of cloud, rain, fog and other forms of precipitation has not been ascertained with any accuracy, and until this is known, it is not considered advisable that a meteorologist should endeavour to allow for it by any modification of the other factors (wind, temperature, pressure) in his meteorological report.

(*d*) **Height of the vertex of the trajectory.**—It was stated in an earlier paragraph that the height of the vertex of the trajectory is given by the formula $h = 4T^2$, but a nearer approximation can be given in the form $h = kT^2$, where k takes the values shown in the table below.

Piece.	*Value of k.*
All howitzers	4·05
14-inch gun	4·05
12-inch gun, red. charge	4·10
12-inch gun, full charge	4·15
13-pr. and 18-pr. gun	4·15
9·2-inch gun, red. charge	4·15
9·2-inch gun, full charge	4·20
60-pr. and 4·7-inch guns	4·20
6-inch gun, reduced charge	4·25
6-inch gun, full charge	4·30

The approximations using these values of k are very close for elevations below 15°. When the computed height is below 5,000 feet, for meteorological purposes it should be rounded off to the nearest 50 feet. Similarly greater heights should be rounded off to the nearest 100 feet.

(*e*) **Elasticity temperature.**—Variations of temperature not only affect the resistance of the air through the medium of the variation in density but also produce elasticity variations. The resistance to the motion of a shell at velocity v is denoted by p(v). Now

$$p\,(v) = a\,\rho\,v^2\,f\left(\frac{v}{V}\right)$$

where V is the velocity of sound in air under the given conditions. The elasticity variations produced by a change of temperature are allowed for by evaluating an "elasticity temperature" which is computed in precisely the same way as the ballistic temperature except that elasticity weighting factors are used instead of temperature weighting factors.

At velocities of the projectile below 900 feet per second, elasticity effects are negligible but they may be considerable at velocities approaching that of sound in air. In accurate experimental work, the elasticity temperature should be evaluated. A specimen computation will be found in § 11 below in the computation of the meteor report for a calibration trial.

§11. A Specimen Calibration Report.

When great accuracy is required for shooting in the field as, for example, in the calibration of guns, the special weighting factors appropriate to the conditions of firing are used. The actual weighting factors to be used will depend upon the gun, the projectile, the muzzle velocity, and the quadrant elevation. When the meteorologist is asked for a special meteor report for a calibration trial, he should obtain a statement giving the nature of the gun and shell to be used, the expected muzzle velocity, and the quadrant elevation at which firing is to take place. The bearing of the line of fire, with respect to true north, will also be required. Weighting factors for most of the guns and howitzers in use can be supplied for cross and line winds, for temperature and elasticity.

Pilot balloon ascents are made at intervals of about 40 minutes and the winds in all the layers are resolved along and across the line of fire, the components thus obtained being plotted on squared paper against the mid-point of the appropriate layer. When the height of the trajectory is less than 2,000 feet, the pilot balloon should be given a slower rate of ascent than the customary 500 feet per minute. 400 feet per minute will be found more suitable. The height of the trajectory can be found from the formula already given.

The trajectory height is divided into five layers if that height is 2,500 feet or less, and into 10 layers if the height is over 2,500 feet. The components of the wind along and across the line of fire are obtained from the pilot-balloon graphs by reading off at the mid-point of each layer into which the trajectory has been divided. The time of shooting can be taken to be the mean time of firing of the first and last rounds of the series. These components of the winds are multiplied by the appropriate head (or following) and cross wind weighting factors, the sums giving the equivalent constant head (or following) wind and the equivalent constant cross wind. The sense of the cross wind, whether right to left or left to right, must be specified.

The magnitude of the vertical winds must be noted. If they exceed 5 feet per second a note should be added at the end of the report giving the magnitude of the vertical current, whether ascending or descending, and also the height at which it was observed.

The barometric pressure is read at the time of each pilot balloon ascent, and is noted on the pilot balloon ascent form in inches of mercury to hundredths of an inch after the usual corrections have been made.

With regard to temperature and humidity variations, the observations obtained from aeroplane or kite ascent are plotted against the corresponding height on squared paper, the temperature at each height being corrected for deviation of relative humidity from 50 per cent. Table IV is used for this purpose.

For the purpose of evaluating the ballistic and elasticity temperatures, the trajectory need only be divided into five layers irrespective of the magnitude of the vertex height. The temperature is read off at the heights of the mid-points of these layers and the differences of these temperatures from the standard temperatures at the same heights are obtained. These differences are multiplied by the appropriate weighting factors for temperature and the algebraic sum of the products so obtained gives the amount which must be added to the standard temperature of 60° to give the ballistic temperature.

From the ballistic temperature a quantity known as the tenuity factor is evaluated. The tenuity factor is merely a measure of the density of the air in the trajectory when the density as set out by the standard conditions is taken as unity. The formula is :—

$$\text{Tenuity factor} = \frac{(\text{Barometric pressure in inches}) \times 519\cdot4}{30\cdot00 \times (459\cdot4 + \text{ballistic temperature})}.$$

The term in the bracket in the denominator is the value of the ballistic temperature on the absolute Fahrenheit scale, absolute zero being $-$ 459·4° F. The term 519·4 in the numerator is the standard temperature of 60° F. on the absolute Fahrenheit scale.

To obtain the elasticity temperature the same observed differences from standard temperature are used but they are now multiplied by the appropriate elasticity weighting factors. The sum of the products with due regard to sign added to 60° F. gives the elasticity temperature.

The following is an example of the details of a calibration trial.

26th March, 1924. 1000 h.

18-pr. Calibration trial. M.V. 1,615 ft./sec. Q.E. 17° 30′.

Line of fire 342°. Time of flight 22·2 seconds.

Height of trajectory = 4·15 × (22·2)² = 2,050 feet.

Take five layers with mid-points at 205, 615, 1,025, 1,435, 1,845 feet.

Observed winds. ft.			*Resolved along and across the line of fire.* ft./sec.	ft./sec.
15	02	103	1·0 following	1·7 right to left.
240	05	115	3·4 ,,	3·6 ,,
720	16	139	14·7 ,,	6·2 ,,
1,185	22	148	21·3 ,,	5·3 ,,
1,645	20	160	20·0 ,,	0·7 ,,
2,145	17	151	16·7 ,,	3·2 ,,

Percentage wind weighting factors :—

Following ..	5·3	10·7	17·5	30·5 and	36·0
Cross	16·5	17·7	18·4	17·2 and	30·2

The computation is as follows :—

ft.	*Following.* ft./sec.	*Cross wind (right to left).* ft./sec.
205	3 × 5·3 = 15·9	3 × 16·5 = 49·5
615	12 × 10·7 = 128·4	6 × 17·7 = 106·2
1,025	19 × 17·5 = 332·5	6 × 18·4 = 110·4
1,435	20 × 30·5 = 710·0	3 × 17·2 = 51·6
1,845	19 × 36·0 = 684·0	2 × 30·2 = 60·4
	1,870·8	378·1

Hence the equivalent constant following wind is 19 ft./sec. and the equivalent constant cross wind is 4 ft./sec. from right to left.

The temperatures observed were :—

50·0° F. at the surface	Relative humidity	75 per cent.
44·0 at 1,000 feet.	,, ,,	75 ,,
38·5 at 3,000 feet.	,, ,,	75 ,,

These temperatures when corrected for humidity become :—

50·6° at the surface, 44·5 at 1,000 ft., and 38·9 at 3,000 ft.

The percentage temperature weighting factors are :—

18·1 17·2 16·1 16·2 28·7

and the percentage elasticity weighting factors are :—

$-$ 0·3 11·2 22·9 42·3 23·9

The computation proceeds as follows :—

Height. (*ft.*)	*Obsd. Temp.*	*Stand. Temp.*	*Diff.*	*Temp. w. f.*	*Prod.*	*Diff.*	*Elast. w. f.*	*Prod.*
205	49·3	59·6	−10·3	18·1	−186	−10·3	−0·3	+ 3
615	46·8	59·0	−12·2	17·2	−210	−12·2	11·2	−137
1,025	44·4	58·3	−13·9	16·1	−224	−13·9	22·9	−318
1,435	43·4	57·5	−14·1	16·2	−228	−14·1	42·3	−596
1,845	42·4	56·7	−14·3	28·7	−410	−14·3	23·9	−342
					−12·58			−13·90

Hence the ballistic temperature is 60·0 − 12·6 = 47·4° F.
and the elasticity temperature is 60·0 − 13·9 = 46·1° F.
Barometer (corrected) 29·87 in.

$$\text{Tenuity factor} = \frac{29{\cdot}87 \times 519{\cdot}4}{30{\cdot}00 \times (459{\cdot}4 + 47{\cdot}4)} = 1{\cdot}020$$

METEOROLOGICAL REPORT.

18-pounder calibration trial. March 26th, 1924. 1000 hours.
M.V. 1,615 ft./sec. ; Q.E. 17° 30′ ; Line of fire 342°.

Following wind	19 ft./sec.
Cross wind. (R. − L.)	4 ft./sec.
Ballistic temperature	47·4° F.
Elasticity temperature	46·1° F.
Tenuity factor	1·020
Barometer (M.S.L.)	29·87 in.

§12. Glossary of Technical Terms.

The **axis** of the gun is the straight line passing down the centre of the bore. This line is a tangent to the trajectory at the muzzle of the gun.

The **trajectory** is the curve described by the centre of gravity of the shell during flight.

The **quadrant elevation** is the angle between the axis of the piece and the horizontal plane. It is denoted by the letters Q.E.

The **quadrant depression.** When in very rare cases it is necessary to lay the gun below the horizontal plane, the angle between the axis of the piece and the horizontal is called the Quadrant Depression (Q.D.).

The **muzzle velocity** is the instantaneous velocity with which the projectile leaves the muzzle of the gun.

The **line of sight** is the straight line passing through the sights of the gun and the point at which aim is being taken.

The **angle of sight** is the angle between the line of sight and the horizontal plane.

The **tangent elevation.** This is the angle between the axis of the gun and the line of sight. It is denoted by T.E.

The distinction between tangent and quadrant elevation should be noted

Q.E. = T.E. *plus* angle of sight.

The **range** is strictly defined as the distance from the muzzle of the gun to the intersection of the trajectory with the line of sight. The range table gives ranges reduced to the standard case of the horizontal plane and the word range is generally restricted to this meaning.

The **time of flight** is the time elapsing between the departure of the projectile from the muzzle of the gun and its arrival at the target. In the range tables, the target is the point at which the trajectory reaches the horizontal plane through the muzzle. In anti-aircraft fire the phrase " time of flight " signifies the time elapsing between the departure of the projectile from the muzzle and the instant of bursting.

Flat fire. When ranges on the horizontal plane are being considered, as in the range tables, or in experimental work, they are generally distinguished as ranges on the flat. Firing under these conditions is usually called firing on the flat or flat fire.

High-angle fire. Anti-aircraft fire is usually referred to as " high-angle " fire.

Tail Method. **PILOT BALLOON ASCENT, NUMBER 78.** Date 22 July, 1924.

Time of start, 08h. 15m. Balloon lost, in cloud. Weather, bc.

Day Ascent. 20 gm. Rubber Balloon. Free lift 63 gm. + 14.
Night Ascent. gm. Rubber Balloon. Free lift gm. Lantern gm.

Tail length(s) = 30 ft.; weight = 7 gm.
V by formula = 500 ft./min. (q = 275).

Surface Wind (15 ft. above ground) 9 f/s at 67°. Temp. 61°.

t	m	A	E	$\frac{k\,l}{2\,m}$	h	**V** Vertical	De	Dn	**V**w to E	**V**s to N	φ	V	Telegram
½													
1	32·0	253·2	30·6	4·7	410	− 90	−6½	− 2	−6½	−2	73	11	
2	16·0	251·6	31·1	9·3	830	− 80	13	4½	6½	2½	69	11	
3	10·8	246·5	32·7	13·9	1,260	− 70	18	8	5	3½	65	10	
4	7·9	248·9	35·0	19·0	1,790	+ 30	24	9	6	1	81	10	
5	6·6	255·1	37·0	22·7	2,180	−110	28	7½	4	+1½	111	7	
6	5·5	261·3	38·0	27·3	2,640	− 40	33	5	5	2½	117	9	
7	4·7	267·5	39·1	31·9	3,110	− 30	38	1½	5	3½	125	10	
8	4·1	272·2	40·6	36·6	3,610	0	42	+1½	4	3	127	8	
9	3·6	275·8	41·4	41·7	4,130	+ 20	47	4½	5	3	121	10	
10	3·3	278·9	41·6	45·5	4,510	−120	50	8	3	3½	139	8	
11	2·9	283·0	42·1	51·7	5,120	+110	55	13	5	5	135	12	
12	2·6	287·9	41·8	57·7	5,720	+100	61	20	6	7	139	15	
13	2·3	292·1	40·4	65·2	6,430	+210	70	29	9	9	135	21	
14	2·1	296·4	39·1	71·4	6,990	+ 60	77	38	7	9	142	19	
15	2·0	299·9	38·1	75·0	7,280	−210	80	46	3	8	159	14	
16	1·9	302·5	37·7	78·9	7,600	−180	83	53	3	7	157	13	
17	1·8	304·3	37·8	83·3	8,050	− 50	86	59	3	6	153	11	
18	1·7	306·2	37·4	88·2	8,490	− 60	90	66	4	7	150	13	
19	1·6	306·8	36·4	93·7	8,900	− 90	97	72	7	6	131	15	
20	1·5	305·9	35·2	100·0	9,410	+ 10	108	78	11	6	119	21	
21	1·4	304·8	34·6	107·1	10,020	+110	119	83	11	5	114	20	

h	MEAN COMPONENTS		60 Secs		50 Secs		40 Secs		30 Secs	
1000's FEET	V_E	V_N	V_E	V_N	V_E	V_N	V_E	V_N	V_E	V_N
0 - 2	-5·6	-1·5			-0·8	-0·2	-1·2	-0·3	-2·6	-0·7
2 - 4	-4·7	+3·0			-0·7	+0·4	-1·1	+0·8	-2·5	+1·6
4 - 6	-4·7	+5·2			-0·8	+0·8	-2·6	+2·8	-5·1	+0·9
6 - 8	-5·0	+7·8			-1·0	+1·5	-4·9	+3·3	08	101
8 - 10	-8·2	+6·0			-3·0	+2·2	10	123	For 5 Secs.	
SUM					-6·3	+4·7	$V_5 = V_\Delta + \frac{1}{4}(V_{10} - V_\Delta)$ and Direction is the mean of that of V_Δ and V_{10}.			
RESULTANT					13	127				

h	MEAN COMPONENTS		20 Secs		10 Secs		For 10 Secs. the factors are
1000's FEET	V_E	V_N	V_E	V_N	V_E	V_N	
0 - 0·5	-6·5	-2·0	-1·2	-0·4	-1·3	-0·5	
0·5 - 1·0	-6·0	-3·0	-1·4	-0·7	-3·2	-1·0	
1·0 - 1·5	-5·5	-2·5	-3·2	-1·5	-1·5	-0·7	·25
SUM			-5·8	-2·6	-6·0	-2·2	·5
RESULTANT			11	066	11	070	·25
SURFACE WIND (V_Δ) in 100's of FEET per MINUTE					-5·0	-2·1	
5 Secs.					10	068	

DATE 22 - 7 - 24.

TIME 08·15 G.M.T.

ASCENT No. 78

COMPUTERS ....

....

METEOR TELEGRAM SENT AT 09·30 BY								
BAR. 2985	0561	10068	1060	11070	2059	11066	3058	08101
4058	10123	5055	13127	60	70		80	
90								

Tail Method. **PILOT BALLOON ASCENT, NUMBER 828.** Date 28/9/1927

Time of start 10h. 05m. Balloon lost, Burst. Weather BZ_o.

Day Ascent. 31 gm. Rubber Balloon. Free lift 73 gm. + 16. Tail length(s) = 30 and 120 ft.; weight = 8 gm.

V by formula = 500 ft./min. (q = 275). Surface Wind (40 ft. above ground) 15 f/s. at 185°. Temp. 56° F.

t	m	A	E	$\frac{k\,1}{2\,m}$	h	**V** Vertical	De	Dn	**V**w to E	**V**s to N	φ	V	Telegram
½													
1	23·0	12·1	26·7		520	+ 20	+2·2	+10·1	+2·2	+10·1	192	18	
2	12·2	22·8	25·9		970	− 50	7·7	18·3	5·5	8·2	215	16	
3	8·0	32·8	24·8		1,420	− 50	16·6	25·9	8·9	7·6	230	19	
4	6·0	40·0	24·5		1,880	− 40	26	32	9·4	6	237	19	
5	17·5	42·7	24·3		2,560	+180	38	42	12	10	230	27	
6	15·2	43·3	23·7		2,900	−160	46	48	8	6	233	16	
7	12·5	42·1	22·9		3,420	+ 20	54	60	8	12	214	24	
8	10·8	40·0	22·5		3,920	—	61	72	7	12	210	24	
9	9·0	39·5	21·8		4,580	+160	73	89	12	17	215	36	
10	7·7	39·4	20·8		5,180	+100	86	105	13	16	219	34	
11	7·3	39·2	20·1		5,500	−380	92	113	6	8	217	16	
12	6·7	39·3	19·7		5,680	−120	101	123	9	10	222	22	
13	6·0	40·0	19·6		6,300	+120	114	136	13	13	225	31	
14	5·6	40·8	19·7		6,800	—	124	144	10	8	231	22	
15	5·3	41·8	19·9		7,280	− 20	133	149	9	5	241	18	
16	4·8	42·8	20·0		8,020	+240	149	162	16	13	231	34	
17	4·5	43·3	20·2		8,600	+ 80	160	170	11	8	234	22	
18	4·3	43·7	20·1		9,000	−100	169	178	9	8	228	21	
19	4·1	44·8	20·1		9,400	−100	181	183	12	5	247	22	
20	3·8	45·7	20·2		10,200	+300	199	194	18	11	239	36	
21		46·5	20·4		10,600		207	196	8	2	256	13	
22		47·2	20·7		11,000		214	197	7	1	262	12	
23		47·8	21·2		11,500		219	199	5	2	248	9	
24		47·9	21·5		12,000		226	204	7	5	234	15	
25		47·9	21·8		12,500		232	210	6	6	225	15	
26		48·2	22·1		13,000		239	214	7	4	240	13	
27		48·8	22·5		13,500		245	214	6	0	270	10	
28		49·8	22·8		14,000		253	215	8	1	263	13	
29		50·6	23·1		14,500		263	217	10	2	259	18	
30		50·8	23·4		15,000		268	218	5	1	259	9	
31		51·4	23·9		15,500		273	218	5	0	270	9	
32		52·0	24·5		16,000		277	216	4	−2	297	7	
33		52·6	25·0		16,500		280	215	3	1	288	6	
34		53·2	25·7		17,000		283	212	3	3	315	7	
35		53·8	26·4		17,500		284	208	1	4	346	7	
36		54·0	27·4		18,000		280	203	−4	−5	39	10	
37		53·9	28·2		18,500		277	203	3	0	90	6	
38		54·0	29·4		19,000		272	198	5	−5	45	12	
39		54·4	30·5		19,500		270	193	2	5	22	9	
40		55·9	31·8		20,000		266	182	4	11	20	19	

h (1000's feet)	Mean components V_E	Mean components V_N	60 Secs V_E	60 Secs V_N	50 Secs V_E	50 Secs V_N	40 Secs V_E	40 Secs V_N	30 Secs V_E	30 Secs V_N
0 2	6·8	8·0	0·6	0·7	0·9	1·1	1·5	1·7	3·2	3·8
2 4	8·5	10·3	0·9	1·0	1·3	1·5	2·3	2·5	4·5	5·5
4 6	10·5	13·0	1·2	1·4	1·8	2·2	5·7	7·0	7·7	9·3
6 8	11·7	9·0	1·3	1·0	2·3	1·7	9·5	11·2	20	219
8 10	12·3	8·0	1·5	1·0	4·5	2·9	25	221	For 5 Secs.	
10 12	6·7	2·5	1·1	0·4	10·8	9·4	$V_5 = V_\delta + \frac{1}{4}(V_{10} - V_\delta)$			
12 14	6·8	2·8	2·2	0·8	25	229	and Direction is the mean of that of V_δ and V_{10}			
SUM			8·7	6·3						
RESULTANT			18	232						

h (1000's feet)	Mean components V_E	Mean components V_N	20 Secs V_E	20 Secs V_N	10 Secs V_E	10 Secs V_N
0 05	2·1	10·0	0·4	1·9	0·25	2·2
05 1·0	5·6	8·3	1·2	1·9	1·05	5·0
1·0 1·5	9·0	7·3	5·2	4·3	1·4	2·1
SUM	·		6 8	8·1	2·7	9·3
RESULTANT			18	221	16	195
Surface wind (V_δ) in 100's of feet per minute	5 Secs.				15	190

h (1000's feet)	Mean components V_E	Mean components V_N	70 Secs V_E	70 Secs V_N
0-5	8·5	10·4	1·7	2·0
5-10	11·2	8·9	2·1	1·7
10-15	7·0	2·4	1·4	0·5
15-20	-0·2	-3·6	-0·1	-1·4
SUM			5·1	2·8
RESULTANT			10	240

METEOR TELEGRAM SENT AT		BY							
BAR	3023	0555	15190	1054	16195	2053	18221	3050	20219
4048	25221	5047	25229	6045	18232	7043	10240	80	
90									

TABLE III.—For the Computation of the Ballistic Temperature for Different Times of Flight.

Height (ft.)	Surface	1,000	3,000	5,000	7,000	9,000	11,000	13,000	15,000	17,000	19,000
Standard temperature (°F.)	60	58	54	50	46	42	37	32	26	20	13

Difference from standard.	30 secs.		40 secs.			50 secs. time of flight.				
	1,000 ft.	3,000 ft.	1,000 ft.	3,000 ft.	5,000 ft.	1,000 ft.	3,000 ft.	5,000 ft.	7,000 ft.	9,000 ft.
°F.										
1	·45	·49	·22	·24	·43	·11	·13	·14	·16	·28
2	·9	1·0	·4	·5	·9	·2	·3	·3	·3	·6
3	1·3	1·5	·7	·7	1·3	·3	·4	·4	·5	·8
4	1·8	2·0	·9	1·0	1·7	·4	·5	·6	·6	1·1
5	2·3	2·5	1·1	1·2	2·1	·5	·7	·7	·8	1·4
6	2·7	2·9	1·3	1·4	2·6	·7	·8	·8	1·0	1·7
7	3·1	3·4	1·5	1·7	3·0	·8	·9	1·0	1·1	2·0
8	3·6	3·9	1·8	1·9	3·4	·9	1·0	1·1	1·3	2·2
9	4·1	4·4	2·0	2·2	3·9	1·0	1·2	1·3	1·4	2·5
10	4·5	4·9	2·2	2·4	4·3	1·1	1·3	1·4	1·6	2·8
11	4·9	5·4	2·4	2·6	4·7	1·2	1·4	1·5	1·8	3·1
12	5·4	5·9	2·6	2·9	5·2	1·3	1·6	1·7	1·9	3·4
13	5·9	6·4	2·9	3·1	5·6	1·4	1·7	1·8	2·1	3·6
14	6·3	6·9	3·1	3·4	6·0	1·5	1·8	2·0	2·2	3·9
15	6·7	7·3	3·3	3·6	6·5	1·7	1·9	2·1	2·4	4·2
16	7·2	7·8	3·5	3·8	6·9	1·8	2·1	2·2	2·6	4·5
17	7·7	8·3	3·7	4·1	7·3	1·9	2·2	2·4	2·7	4·8
18	8·1	8·8	4·0	4·3	7·7	2·0	2·3	2·5	2·9	5·0
19	8·5	9·3	4·2	4·6	8·2	2·1	2·5	2·7	3·0	5·3
20	9·0	9·8	4·4	4·8	8·6	2·2	2·6	2·8	3·2	5·6
22	9·9	10·8	4·8	5·3	9·5	2·4	2·9	3·1	3·5	6·2
24	10·8	11·8	5·3	5·8	10·3	2·6	3·1	3·4	3·8	6·7
26	11·7	12·7	5·7	6·2	11·2	2·9	3·4	3·6	4·2	7·3
28	12·6	13·7	6·2	6·7	12·0	3·1	3·6	3·9	4·5	7·8
30	13·5	14·7	6·6	7·2	12·9	3·3	3·9	4·2	4·8	8·4

Difference from standard.	60 seconds time of flight.							70 secs. time of flight.			
	1,000 ft.	3,000 ft.	5,000 ft.	7,000 ft.	9,000 ft.	11,000 ft.	13,000 ft.	2,500 ft.	7,500 ft.	12,500 ft.	17,500 ft.
°F.											
1	·05	·07	·08	·09	·10	·11	·27	·10	·12	·14	·33
2	·1	·1	·2	·2	·2	·2	·5	·2	·2	·3	·7
3	·2	·2	·2	·3	·3	·3	·8	·3	·4	·4	1·0
4	·2	·3	·3	·4	·4	·4	1·1	·4	·5	·6	1·3
5	·3	·4	·4	·5	·5	·6	1·4	·5	·6	·7	1·6
6	·3	·4	·5	·5	·6	·7	1·6	·6	·7	·8	2·0
7	·4	·5	·6	·6	·7	·8	1·9	·7	·8	1·0	2·3
8	·4	·6	·6	·7	·8	·9	2·2	·8	1·0	1·1	2·6
9	·5	·6	·7	·8	·9	1·0	2·4	·9	1·1	1·3	3·0
10	·5	·7	·8	·9	1·0	1·1	2·7	1·0	1·2	1·4	3·3
11	·6	·8	·9	1·0	1·1	1·2	3·0	1·1	1·3	1·5	3·6
12	·6	·8	1·0	1·1	1·2	1·3	3·2	1·2	1·4	1·7	4·0
13	·7	·9	1·0	1·2	1·3	1·4	3·5	1·3	1·6	1·8	4·3
14	·7	1·0	1·1	1·3	1·4	1·5	3·8	1·4	1·7	2·0	4·6
15	·8	1·1	1·2	1·4	1·5	1·7	4·1	1·5	1·8	2·1	4·9
16	·8	1·1	1·3	1·4	1·6	1·8	4·3	1·6	1·9	2·2	5·3
17	·9	1·2	1·4	1·5	1·7	1·9	4·6	1·7	2·0	2·4	5·6
18	·9	1·3	1·4	1·6	1·8	2·0	4·9	1·8	2·2	2·5	5·9
19	1·0	1·3	1·5	1·7	1·9	2·1	5·1	1·9	2·3	2·7	6·3
20	1·0	1·4	1·6	1·8	2·0	2·2	5·4	2·0	2·4	2·8	6·6
22	1·1	1·5	1·8	2·0	2·2	2·4	5·9	2·2	2·6	3·1	7·2
24	1·2	1·7	1·9	2·2	2·4	2·6	6·5	2·4	2·9	3·4	7·9
26	1·3	1·8	2·1	2·3	2·6	2·9	7·0	2·6	3·1	3·6	8·6
28	1·4	2·0	2·2	2·5	2·8	3·1	7·6	2·8	3·4	3·9	9·2
30	1·5	2·1	2·4	2·7	3·0	3·3	8·1	3·0	3·6	4·2	9·9

TABLE IV.—FOR THE DETERMINATION OF THE CORRECTION TO DRY OR SATURATED AIR TO GIVE THE SAME DENSITY AS THAT OF HALF-SATURATED AIR.

Add to the observed temperature in the case of saturated air. **Subtract** in the case of dry air.

Height. (ft.)	Observed temperature (°F.). 80	70	60	50	40	30	20
0	3·5	2·4	1·7	1·2	0·8	0·5	0·3
2,000		2·6	1·8	1·2	0·8	0·5	0·3
4,000			2·0	1·4	0·9	0·6	0·3
6,000				1·5	1·0	0·6	0·4
8,000				1·6	1·1	0·7	0·4
10,000					1·2	0·8	0·5
12,000						0·8	0·5
14,000						0·9	0·6
16,000						0·9	0·6
18,000							0·7

For intermediate humidities proportional corrections should be taken, e.g. for a relative humidity of 80 per cent. add three-fifths of the above corrections.

For temperatures below 20° F., the humidity correction may be neglected.

Printed by H.M.S.O. Press, Harrow.

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Add to the observed temperature in the case of saturated air. **Subtract** in the case of dry air.

Height. (ft.)	Observed temperature (°F.). 80	70	60	50	40	30	20
0	3·5	2·4	1·7	1·2	0·8	0·5	0·3
2,000		2·6	1·8	1·2	0·8	0·5	0·3
4,000			2·0	1·4	0·9	0·6	0·3
6,000				1·5	1·0	0·6	0·4
8,000				1·6	1·1	0·7	0·4
10,000					1·2	0·8	0·5
12,000						0·8	0·5
14,000						0·9	0·6
16,000						0·9	0·6
18,000							0·7

For intermediate humidities proportional corrections should be taken, e.g. for a relative humidity of 80 per cent. add three-fifths of the above corrections.

For temperatures below 20° F., the humidity correction may be neglected.

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TABLE I - FACTORS AND PRODUCTS FOR COMPUTING BALLISTIC WIND FOR DIFFERENT TIMES OF FLIGHT FROM THE MEAN COMPONENTS OF THE WIND IN DIFFERENT LAYERS.

MEAN COMPONENTS	0 - 500	500 - 1000	1000 - 1500	0 - 2000				2000 - 4000				4000-6000			6000 - 8000		8000 - 10000		10000 - 12000	12000 - 14000
	20	20	20	30	40	50	60	30	40	50	60	40	50	60	50	60	50	60	60	60
1	·19	·23	·58	·47	·21	·13	·09	·53	·24	·15	·10	·54	·17	·11	·19	·11	·36	·13	·15	·31
2	·4	·4	1·2	·9	·4	·3	·2	1·1	·4	·3	·2	1·1	·3	·2	·4	·2	·7	·3	·3	·6
3	·6	·7	1·7	1·4	·6	·4	·3	1·6	·8	·4	·3	1·6	·5	·3	·6	·3	1·1	·4	·5	·9
4	·8	·9	2·3	1·9	·8	·5	·4	2·1	1·0	·6	·4	2·2	·7	·4	·8	·4	1·4	·5	·6	1·3
5	1·0	1·1	2·9	2·4	1·1	·7	·4	2·6	1·2	·7	·5	2·7	·8	·5	1·0	·6	1·8	·6	·8	1·6
6	1·1	1·4	3·5	2·8	1·3	·8	·5	3·2	1·5	·9	·6	3·2	1·0	·6	1·1	·7	2·2	·8	·9	1·9
7	1·3	1·6	4·1	3·3	1·5	·9	·6	3·7	1·7	1·1	·7	3·8	1·2	·7	1·3	·8	2·5	·9	1·1	2·2
8	1·5	1·8	4·7	3·8	1·7	1·1	·7	4·2	2·0	1·2	·8	4·3	1·3	·9	1·5	·9	2·9	1·0	1·2	2·5
9	1·7	2·1	5·2	4·2	1·9	1·2	·8	4·8	2·2	1·4	·9	4·9	1·5	1·0	1·7	1·0	3·2	1·1	1·4	2·8
10	1·9	2·3	5·8	4·7	2·1	1·3	·9	5·3	2·4	1·5	1·0	5·4	1·7	1·1	1·9	1·1	3·6	1·3	1·5	3·1
11	2·1	2·5	6·4	5·2	2·3	1·5	1·0	5·8	2·7	1·6	1·1	6·0	1·8	1·2	2·1	1·2	4·0	1·4	1·7	3·4
12	2·3	2·7	7·0	5·7	2·6	1·6	1·1	6·3	2·9	1·8	1·2	6·5	2·0	1·3	2·3	1·3	4·3	1·5	1·8	3·8
13	2·5	2·9	7·6	6·1	2·8	1·7	1·2	6·9	3·2	1·9	1·2	7·0	2·2	1·4	2·5	1·5	4·7	1·6	2·0	4·1
14	2·7	3·2	8·1	6·6	3·0	1·9	1·3	7·4	3·4	2·1	1·3	7·6	2·3	1·5	2·7	1·6	5·0	1·8	2·1	4·4
15	2·9	3·4	8·7	7·1	3·2	2·0	1·4	7·9	3·7	2·2	1·4	8·1	2·5	1·6	2·9	1·7	5·4	1·9	2·3	4·7
16	3·1	3·6	9·3	7·5	3·4	2·1	1·5	8·5	3·9	2·4	1·5	8·7	2·7	1·7	3·0	1·8	5·8	2·0	2·4	5·1
17	3·3	3·8	9·9	8·0	3·6	2·3	1·5	9·0	4·2	2·6	1·6	9·2	2·8	1·8	3·2	1·9	6·1	2·2	2·6	5·4
18	3·4	4·1	10·5	8·5	3·8	2·4	1·6	9·5	4·4	2·7	1·7	9·8	3·0	2·0	3·4	2·0	6·5	2·3	2·7	5·7
19	3·7	4·3	11·0	8·9	4·1	2·5	1·7	10·1	4·6	2·9	1·8	10·3	3·2	2·1	3·6	2·1	6·8	2·4	2·9	6·0
20	3·9	4·5	11·6	9·4	4·3	2·7	1·8	10·6	4·9	3·0	1·9	10·8	3·3	2·2	3·8	2·2	7·2	2·5	3·1	6·3
22	4·2	5·0	12·8	10·4	4·7	2·9	2·0	11·6	5·4	3·3	2·1	11·9	3·7	2·4	4·2	2·5	7·9	2·8	3·3	6·9
24	4·6	5·5	13·9	11·3	5·1	3·2	2·2	12·7	5·9	3·6	2·3	13·0	4·0	2·6	4·6	2·7	8·6	3·0	3·6	7·6
26	5·0	5·9	15·1	12·2	5·6	3·5	2·3	13·8	6·3	3·9	2·5	14·1	4·3	2·8	4·9	2·9	9·4	3·3	4·0	8·2
28	5·4	6·4	16·2	13·2	6·0	3·7	2·5	14·8	6·8	4·2	2·7	15·2	4·7	3·0	5·3	3·1	10·1	3·6	4·3	8·8
30	5·8	6·8	17·4	14·1	6·4	4·0	2·7	15·9	7·3	4·5	2·9	16·3	5·0	3·2	5·7	3·4	10·8	3·8	4·6	9·4
32	6·1	7·3	18·6	15·1	6·9	4·3	2·9	16·9	7·8	4·8	3·1	17·3	5·3	3·4	6·1	3·6	11·5	4·1	4·9	10·0
34	6·5	7·7	19·8	16·0	7·3	4·5	3·0	18·0	8·3	5·1	3·3	18·4	5·7	3·7	6·5	3·8	12·2	4·3	5·2	10·7
36	6·9	8·2	20·9	17·0	7·7	4·8	3·2	19·0	8·8	5·4	3·5	19·5	6·0	3·9	6·8	4·0	13·0	4·6	5·5	11·3
38	7·3	8·6	22·1	17·9	8·1	5·1	3·4	20·1	9·3	5·7	3·6	20·6	6·3	4·1	7·2	4·3	13·7	4·8	5·8	12·0
40	7·7	9·1	23·2	18·8	8·5	5·3	3·6	21·2	9·8	6·0	3·8	21·7	6·7	4·3	7·6	4·5	14·4	5·1	6·1	12·6

MEAN COMPONENTS	0 - 5000		5000 - 10000		10000 - 15000		15000 - 20000		20000 - 25000	0 - 6500	6500 - 13000	13000 - 19500	19500 - 26000	26000 - 32500
	70	80	70	80	70	80	70	80	80	90	90	90	90	90
1	·19	·14	·19	·15	·21	·15	·41	·17	·39	·17	·16	·16	·17	·34
2	·3	·3	·4	·3	·4	·3	·9	·3	·8	·3	·3	·3	·4	·7
3	·6	·4	·6	·4	·6	·5	1·2	·5	1·2	·5	·5	·5	·5	1·0
4	·8	·5	·8	·6	·8	·6	1·6	·7	1·6	·7	·6	·6	·7	1·4
5	1·0	·7	1·0	·7	1·0	·8	2·0	·8	2·0	·8	·8	·8	·9	1·7
6	1·2	·8	1·2	·9	1·2	·9	2·4	1·0	2·4	1·0	1·0	1·0	1·0	2·0
7	1·4	1·0	1·4	1·0	1·4	1·1	2·8	1·2	2·7	1·2	1·1	1·1	1·2	2·4
8	1·6	1·1	1·5	1·2	1·6	1·2	3·3	1·4	3·1	1·3	1·3	1·3	1·4	2·7
9	1·7	1·3	1·7	1·3	1·9	1·4	3·7	1·5	3·5	1·5	1·4	1·5	1·5	3·1
10	1·9	1·4	1·9	1·5	2·1	1·5	4·1	1·7	3·9	1·7	1·6	1·6	1·7	3·4
11	2·1	1·5	2·1	1·6	2·3	1·7	4·5	1·9	4·3	1·9	1·8	1·8	1·9	3·7
12	2·3	1·7	2·3	1·8	2·5	1·8	4·9	2·0	4·7	2·0	1·9	1·9	2·1	4·1
13	2·5	1·8	2·5	1·9	2·7	2·0	5·3	2·2	5·1	2·2	2·1	2·1	2·2	4·4
14	2·7	2·0	2·7	2·1	2·9	2·1	5·7	2·4	5·4	2·4	2·2	2·2	2·4	4·8
15	2·9	2·1	2·9	2·2	3·1	2·3	6·1	2·6	5·8	2·5	2·4	2·4	2·6	5·1
16	3·1	2·3	3·1	2·4	3·3	2·4	6·5	2·7	6·2	2·7	2·6	2·6	2·7	5·4
17	3·3	2·4	3·3	2·5	3·5	2·6	6·9	2·9	6·6	2·9	2·7	2·7	2·9	5·8
18	3·5	2·5	3·5	2·7	3·7	2·7	7·3	3·1	7·0	3·0	2·9	2·9	3·1	6·1
19	3·7	2·7	3·7	2·8	3·9	2·9	7·7	3·2	7·4	3·2	3·0	3·1	3·2	6·5
20	3·9	2·8	3·9	3·0	4·1	3·0	8·1	3·4	7·8	3·4	3·2	3·2	3·4	6·8
22	4·3	3·1	4·2	3·3	4·5	3·3	9·0	3·7	8·6	3·7	3·5	3·5	3·8	7·5
24	4·7	3·4	4·6	3·6	4·9	3·6	9·8	4·0	9·4	4·1	3·8	3·8	4·1	8·2
26	5·0	3·6	5·0	3·9	5·4	3·9	10·6	4·4	10·2	4·4	4·2	4·2	4·4	8·8
28	5·4	3·9	5·4	4·2	5·8	4·2	11·4	4·8	10·9	4·7	4·5	4·5	4·8	9·5
30	5·8	4·2	5·8	4·5	6·2	4·5	12·2	5·1	11·7	5·1	4·8	4·8	5·1	10·2
32	6·2	4·5	6·2	4·8	6·6	4·8	13·0	5·4	12·5	5·4	5·1	5·1	5·5	10·9
34	6·6	4·8	6·6	5·1	7·0	5·1	13·8	5·8	13·2	5·8	5·4	5·4	5·8	11·6
36	7·0	5·0	6·9	5·4	7·4	5·4	14·7	6·1	14·0	6·1	5·8	5·8	6·1	12·2
38	7·4	5·3	7·3	5·7	7·8	5·7	15·5	6·5	14·8	6·4	6·1	6·1	6·5	12·9
40	7·8	5·6	7·7	6·0	8·2	6·0	16·3	6·8	15·6	6·8	6·4	6·4	6·8	13·6

STANDARD TEMPERATURE HEIGHT 1000s Ft	°F
0	60
1	58
2	56
3	54
4	52
5	50
6	48
7	46
8	44
9	41
10	39
11	37
12	34
13	31
14	29
15	26
16	23
17	20
18	17
19	13
20	10
21	7
22	3
23	-1
24	-4
25	-8
26	-13
27	-17
28	-21
29	-26
30	-30
31	-35
32	-40
33	-45
34	-51

Computation for 10 seconds Time of Flight from Mean Components and Surface Wind Components.

$\frac{1}{4}$ (components 500 - 1,000 ft.).
$+\frac{1}{2}$ (components 0 - 500 ft.).
$+\frac{1}{4}$ V_s, where V_s is the component of the surface wind in hundreds of feet per minute.
Direction - as computed from these components

Computation for 5 Seconds Time of Flight from Surface Wind and 10 seconds Wind.

$$\frac{1}{4}V_{10} + \frac{3}{4}V_s = V_s + \frac{1}{4}(V_{10} - V_s)$$

Direction = that midway between V_s and V_{10}, where V_s is the surface wind.

NOTE.— This table is used normally with mean components in hundreds of feet per minute.
If balloons ascending at 400 feet per minute are used, and readings taken every $1\frac{1}{4}$ minutes, then use mean components in hundreds of feet per $1\frac{1}{4}$ minutes throughout, and reduce the values obtained by 20%.
The time of flight is indicated by the figures at the head of each column; the layers to which the mean components refer are shown in feet at top of the table; the heights are measured from ground level.

P2520. 26126,C 1715, 1000, 5/29.

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TABLE II – FOR OBTAINING THE RESULTANT WIND SPEED IN FEET PER SECOND AND WIND DIRECTION IN DEGREES FROM THE COMPONENTS IN HUNDREDS OF FEET PER MINUTE

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
1	*45* **2**	*27* **4**	*18* **5**	*14* **7**	*11* **8**	*9* **10**	*8* **12**	*7* **13**	*6* **15**	*6* **17**	*5* **18**	*5* **20**	*4* **22**	*4* **23**	*4* **25**	*4* **27**	*3* **28**	*3* **30**	*3* **32**	*3* **3**	*3* **35**	*3* **37**	*2* **38**	*2* **40**	*2* **42**	*2* **43**	*2* **45**	*2* **47**	*2* **48**
2		*45* **5**	*34* **6**	*27* **7**	*22* **9**	*18* **11**	*16* **12**	*14* **14**	*13* **15**	*11* **17**	*10* **19**	*9* **20**	*9* **22**	*8* **24**	*8* **25**	*7* **27**	*7* **29**	*6* **30**	*6* **32**	*6* **33**	*5* **35**	*5* **37**	*5* **38**	*5* **40**	*5* **42**	*4* **43**	*4* **45**	*4* **47**	*4* **48**
3			*45* **7**	*37* **8**	*31* **10**	*27* **11**	*23* **13**	*21* **14**	*18* **16**	*17* **17**	*15* **19**	*14* **21**	*13* **22**	*12* **24**	*11* **25**	*11* **27**	*10* **29**	*9* **30**	*9* **32**	*9* **34**	*8* **35**	*8* **37**	*7* **39**	*7* **40**	*7* **42**	*7* **44**	*6* **45**	*6* **47**	*6* **49**
4				*45* **9**	*39* **11**	*34* **12**	*30* **13**	*27* **15**	*24* **16**	*22* **18**	*20* **20**	*18* **21**	*17* **23**	*16* **24**	*15* **26**	*14* **27**	*13* **29**	*13* **31**	*12* **32**	*11* **34**	*11* **36**	*10* **37**	*10* **39**	*9* **41**	*9* **42**	*9* **44**	*8* **45**	*8* **47**	*8* **49**
5					*45* **12**	*40* **13**	*36* **14**	*32* **16**	*29* **17**	*27* **19**	*24* **20**	*23* **22**	*21* **23**	*20* **25**	*18* **26**	*17* **28**	*16* **30**	*16* **31**	*15* **33**	*14* **34**	*13* **36**	*13* **38**	*12* **39**	*12* **41**	*11* **42**	*11* **44**	*10* **46**	*10* **47**	*10* **49**
6						*45* **14**	*41* **15**	*37* **17**	*34* **18**	*31* **19**	*29* **21**	*27* **22**	*25* **24**	*23* **25**	*22* **27**	*21* **28**	*19* **30**	*18* **32**	*18* **33**	*17* **35**	*16* **36**	*15* **38**	*15* **40**	*14* **41**	*13* **43**	*13* **44**	*13* **46**	*12* **48**	*12* **49**
7							*45* **16**	*41* **18**	*38* **19**	*35* **20**	*32* **22**	*30* **23**	*28* **25**	*27* **26**	*25* **27**	*24* **29**	*22* **31**	*21* **32**	*20* **34**	*19* **35**	*18* **37**	*18* **38**	*17* **40**	*16* **42**	*16* **43**	*15* **45**	*15* **46**	*14* **48**	*14* **50**
8								*45* **19**	*42* **20**	*39* **21**	*36* **23**	*34* **24**	*32* **25**	*30* **27**	*28* **28**	*27* **30**	*25* **31**	*24* **33**	*23* **34**	*22* **36**	*21* **37**	*20* **39**	*19* **41**	*18* **42**	*18* **44**	*17* **45**	*17* **47**	*16* **49**	*15* **50**
9									*45* **21**	*42* **22**	*39* **24**	*37* **25**	*35* **26**	*33* **28**	*31* **29**	*29* **31**	*28* **32**	*27* **34**	*25* **35**	*24* **37**	*23* **38**	*22* **40**	*21* **41**	*21* **43**	*20* **44**	*19* **46**	*18* **47**	*18* **49**	*17* **51**
10										*45* **24**	*42* **25**	*40* **26**	*38* **27**	*36* **29**	*34* **30**	*32* **31**	*30* **33**	*29* **34**	*28* **36**	*27* **37**	*25* **39**	*24* **40**	*23* **42**	*23* **43**	*22* **45**	*21* **46**	*20* **48**	*20* **50**	*19* **51**
11											*45* **26**	*43* **27**	*40* **28**	*38* **30**	*36* **31**	*35* **32**	*33* **34**	*31* **35**	*30* **37**	*29* **38**	*28* **40**	*27* **41**	*26* **42**	*25* **44**	*24* **46**	*23* **47**	*22* **49**	*21* **50**	*21* **52**
12												*45* **28**	*43* **29**	*41* **31**	*39* **32**	*37* **33**	*35* **35**	*34* **36**	*32* **37**	*31* **39**	*30* **40**	*29* **42**	*28* **43**	*27* **45**	*26* **46**	*25* **48**	*24* **49**	*23* **51**	*22* **52**
13													*45* **31**	*43* **32**	*41* **33**	*39* **34**	*37* **36**	*36* **37**	*34* **38**	*33* **40**	*32* **41**	*31* **43**	*29* **44**	*28* **45**	*27* **47**	*27* **48**	*26* **50**	*25* **51**	*24* **53**
14														*45* **33**	*43* **34**	*41* **35**	*39* **37**	*38* **38**	*36* **39**	*35* **41**	*34* **42**	*32* **43**	*31* **45**	*30* **46**	*29* **48**	*28* **49**	*27* **51**	*27* **52**	*26* **54**
15															*45* **35**	*43* **37**	*41* **38**	*40* **39**	*38* **40**	*37* **42**	*36* **43**	*34* **44**	*33* **46**	*32* **47**	*31* **49**	*30* **50**	*29* **51**	*28* **53**	*27* **54**
16																*45* **38**	*43* **39**	*42* **40**	*40* **41**	*39* **43**	*37* **44**	*36* **45**	*35* **47**	*34* **48**	*33* **49**	*32* **51**	*31* **52**	*30* **54**	*29* **55**
17																	*45* **40**	*43* **41**	*42* **42**	*40* **44**	*39* **45**	*38* **46**	*36* **48**	*35* **49**	*34* **50**	*33* **52**	*32* **53**	*31* **55**	*30* **56**
18																		*45* **42**	*43* **44**	*42* **45**	*41* **46**	*39* **47**	*38* **49**	*37* **50**	*36* **51**	*35* **53**	*34* **54**	*33* **55**	*32* **57**
19																			*45* **45**	*44* **46**	*42* **47**	*41* **48**	*40* **50**	*38* **51**	*37* **52**	*36* **54**	*35* **55**	*34* **56**	*33* **58**
20																				*45* **47**	*44* **48**	*42* **50**	*41* **51**	*40* **52**	*39* **53**	*38* **55**	*37* **56**	*36* **57**	*35* **59**
21																					*45* **49**	*44* **51**	*42* **52**	*41* **53**	*40* **54**	*39* **56**	*38* **57**	*37* **58**	*36* **60**
22																						*45* **52**	*44* **53**	*43* **54**	*41* **56**	*40* **57**	*39* **58**	*38* **59**	*37* **61**
23																							*45* **54**	*44* **55**	*43* **57**	*41* **58**	*40* **59**	*39* **60**	*38* **62**
24																								*45* **57**	*44* **58**	*43* **59**	*42* **60**	*41* **61**	*40* **63**
25																									*45* **59**	*44* **60**	*43* **61**	*42* **63**	*41* **64**

Angles in Italics
Resultants in Clarendon

For components larger than those shown halve both components: use these halved values in the table and double the resultant speed, but not the angle.

If 'A' is the angle given by the table, following are rules for obtaining actual wind direction in degrees measured from North. The letters 'W' and 'S' denoting West to East and South to North components respectively:–

W– S–	W < S	A
	W > S	90 – A
W– S+	W > S	90 + A
	W < S	180 – A
W+ S+	W < S	180 + A
	W > S	270 – A
W+ S–	W > S	270 + A
	W < S	360 – A

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