FOR OFFICIAL USE.

M.O. 223. Introduction. (2nd Edition.)

AIR MINISTRY.

METEOROLOGICAL OFFICE.

THE COMPUTER'S HANDBOOK.

Introduction.—C.G.S. Units of Measurement in Meteorology with their Abbreviations and their Equivalents.

Published by the Authority of the Meteorological Committee.

LONDON:
PRINTED AND PUBLISHED BY
HIS MAJESTY'S STATIONERY OFFICE
To be purchased through any Bookseller or directly from
H.M. STATIONERY OFFICE at the following addresses
IMPERIAL HOUSE, KINGSWAY, LONDON, W.C.2, and
28, ABINGDON STREET, LONDON, S.W.1;
37, PETER STREET, MANCHESTER;
1, ST. ANDREW'S CRESCENT, CARDIFF;
23, FORTH STREET, EDINBURGH;
or from E. PONSONBY, LTD., 116, GRAFTON STREET, DUBLIN

1921.

Price 3s. 6d. Net.

TABLE OF CONTENTS.

UNITS OF MEASUREMENT IN METEOROLOGY.

International Meteorological Tables.

NOTE.—The Director of the Meteorological Office will be much obliged if any numerical errors detected in the tables may be pointed out to him, as well as any omissions of data necessary for Meteorological Computation.

THE COMPUTER'S HANDBOOK.

INTRODUCTION.

UNITS OF MEASUREMENT IN METEOROLOGY.

It has come to be recognised at the Meteorological Office, for reasons which are set out in the preface to the Seaman's Handbook of Meteorology and elsewhere, that the most suitable units for the expression of the Meteorological elements are those based upon the C.G.S. (centimetre-gramme-second) system with temperatures expressed in degrees upon the scale to which the name of Kelvin is often given, which takes for its zero the datum-point of the absolute thermo-dynamic scale and which uses the centigrade degree as the interval of successive steps of temperature. For practical purposes the scale is the same as that of the hydrogen thermometer starting from a point 273 degrees centigrade below the freezing point of water.

In order to give effect to this conclusion it is necessary to change the ordinary practice of British meteorologists and to express pressures in C.G.S. units of pressure, dynes per square centimetre or in some unit derived therefrom, as the *thousand dynes per square centimetre* known as a millibar (or by some meteorologists and chemists as a kilobar) instead of the inch, temperatures in the Kelvin scale instead of that of Fahrenheit, wind velocities in metres per second instead of miles per hour or feet per second, the depth of rainfall in millimetres instead of inches or "points," heights above sea level in metres and so on. In this way the out-door practice of meteorologists will conform, with certain modifications on scientific lines, to the conventions which are prescribed but not always practised for the measurement of physical quantities in the laboratory.

This is by no means the first change of practice that has come within the experience of meteorologists, and those of us who endeavour to bring the older records into line with modern observations must be prepared to interpret figures which *prima facie* convey no meaning to the modern observer. The study of weather is older than the millimetre, and it would be a considerable loss to the science to write off as unintelligible what can be interpreted with some knowledge of the practice of the past.

The basis of numerical computation for students of meteorology has been set out authoritatively by the International Meteorological Committee in a publication in French, English, and German, dated at Paris and St. Petersburg on 1st June, 1890. It is entitled *International Meteorological Tables published in Conformity with a Resolution of the Congress of Rome, 1879.* The work was carried out mainly at the Bureau Central Météorologique of Paris under the superintendence of Monsieur E. Mascart, the Director of the Bureau, and Monsieur Chauveau, *Météorologiste Adjoint*, and published by Gauthier-Villars et Fils, Quai des Grands-Augustins 55, Paris.

(29360—12) Wt. 12394—370 625 1/21 H. St. G. 3

This publication includes a number of meteorological computations and tables:—for the variation of gravity with latitude and altitude, the length of 1° of meridian in various latitudes and of 1° of longitude in various parallels, the duration of sunshine in various latitudes, the reduction of barometer readings to 32° F. and to sea level, including the influence of gravity upon barometrical measurements, the pressure of aqueous vapour, weight of aqueous vapour in a cubic metre of saturated air, relative humidity computed from the dew point, the mean direction of the wind by Lambert's formula, and the conversion of measures of magnetic force from the British units previously employed to C.G.S. units and *vice-versâ*, and it is prefaced by and amplified by tables of conversion between the fundamental standards and divers British units and metric units; and also between some of the measures which had been in practical use in the past but which had become obsolete or were becoming so with the gradual extension of the metric system.

It has been the object of the meteorological authorities in all countries that the numerical values given in this publication should form the basis of all tables of conversion and computation which are employed by observers and students throughout the world, so that the meaning of any small differences of results should be freed from ambiguity on account of the process of computation.

Meteorological questions nearly always depend for their solution on the comparison of results from different parts of the world and comparability is often more important than extreme numerical precision, so that the values used in the computation of the International Tables are sufficiently accurate for all the computations of meteorological practice and will remain so for many years to come, but in the meantime alterations in the accepted comparisons of fundamental standards of the various countries may receive, and some have received, the sanction of law, and it is hardly permissible to an official to display, or affect to use, tables which are ostensibly based on equivalents which are not lawful.

The most recent values for the metrical equivalents of the fundamental British units are those contained in the Order in Council of 19th May, 1898.

In the first edition of this Introduction many equivalents were copied from the International Tables without modification. Values in accordance with the Order in Council of 1898 have now been substituted. The differences are of course very small, too small to be of significance in practical meteorology. Such cases are indicated by a dagger (†).

The progress in metrological exactitude which naturally follows the establishment of such institutions as the Bureau International des Poids et Mesures, the Reichsanstalt, the National Physical Laboratory, and the Bureau of Standards must not be disregarded; and the horizon of meteorological computation has been much extended by the development of the study of the upper air which requires the tables for computation to be similarly extended over ranges which were outside the meteorological practice of 1890. The present work affords a means of reviewing our position with regard to such matters without undertaking the burden of re-editing the International Tables.

The values taken from the International Tables are marked with an asterisk.*

UNITS OF MEASUREMENT WITH THEIR ABBREVIATIONS AND THEIR EQUIVALENTS.

Measures of Length. (International Tables, Chapter I., Section I.)

The fundamental units of length in the metric and the British systems are the metre and the yard respectively.

The **metre** is the distance, at the melting point of ice, between the centres of two lines engraved upon the polished neutral web surface of a platinum Iridium bar of a nearly X-shaped section called the International Prototype Metre.

The **yard** was defined by the Weights and Measures Act, 1878, as the distance at 62° F. between the central transverse lines in two gold plugs in the bronze bar, called the Imperial Standard Yard, when supported on bronze rollers in such manner as best to avoid flexure of the bar.

Metric Units.

	metre :	1 m.	= †39·37008 in.
			= †3·280840 ft.
			= †1·093613 yd.
	kilometre :	1 k.	= †0·6213712 mi.
C.G.S.	centimetre :	1 cm.	= †0·3937008 in.
	millimetre :	1 mm.	= †0·03937008 in.

Small Units.

micron : 1 $\mu = 10^{-6}$ m. millimicron : 1 $\mu\mu = 10^{-9}$ m.

Ångstrom unit : 1 AU $= 10^{-10}$ m. or (tenth-metre).

Large Units.

Astronomical unit = semi-major axis of earth's orbit
$= 1·495 \times 10^{8}$k. $= 9·289 \times 10^{7}$mi.

Parsec = distance at which the astronomical unit subtends 1″
$= 5·139 \times 10^{11}$k $= 3·193 \times 10^{11}$mi.

Light year = 0·31 parsec.

British Units.

mile : 1 mi.	=	†1609·344 m.
yard : 1 yd.	=	†0·914400 m.
foot : 1 ft.	=	†30·4800 cm.
inch : 1 in.	=	†25·4000 mm.

Nautical mile. *See* page 8 Geodetic Measures.

Ancient French Units.

1 toise = 6 ft.	= *1·9490366 m.	= †2·1314918 yd.
1 foot = 12 inches	= *0·3248394 m.	= †1·0657461 ft.
1 inch = 12 Paris lines	= *27·069953 mm.	= †1·0657461 in.
1 line	= *2·255829 mm.	= †0·0882165 in.

Russian Measures.

1 verst = 1·06678 k. = 0·663 mi. (E.)

(For barometric heights.) 1 demiligne = *·05 in. = *1·27000 mm. at $13\frac{1}{3}°$ R. or 62° F.

NOTE: For the measurement of pressure in Russia the unit of a demiligne ($\frac{1}{20}$ in.) of mercury at 62° F. was employed.

Special Tables for the conversion of the old Russian barometric tables into English and French measures will be found in International Meteorological Tables, Section I., Chapter IV. They are based on the equivalents 1 Russian barometrical half-line = 0·049849 in. = 1·26616 mm.

Measures of Area.

Metric Units.

C.G.S. Square centimetre (sq. cm or cm²).

1 cm² = ·1550 in.²
= ·001076 ft.²
= ·0001196 yd.²
100 m² = 1 are.
= 0·0988 rood.
10,000 m² = 1 hectare.
= 2·4711 acre.

British Units.

1 in.² = 6·4516 cm.²
1 ft.² = 929·03 cm.²
1 yd.² = 8361·3 cm.²
1 acre = 4840 sq. yds.
= 0·4047 hectare.

Measures of Volume.

Metric Units.

C.G.S. Cubic centimetre (cc. or cm.³)

1 cc. = ·0610 c. in.
1 litre = 1000 cc. = ·03531 c. ft.
= 1·7598 pint.
= ·2200 gallon.

British Units.

1 c. in. = 16·387 cc.
1 c. ft. = 28·317 litre = 28317 cc.
1 pint = ·5682 „
1 gallon = 4·5460 „

Measures of Mass. (International Tables, Chapter I., Section II.)

The International Prototype **Kilogramme** is the mass of a cylinder of platinum-iridium, which is a copy of the original Borda kilogramme.

The **pound** is the weight in vacuo of a platinum cylinder called the imperial standard pound.

Metric Units.

Kilogramme : 1 kg. = †15432·356 gr.
= †2·2046223 lb.
C.G.S. Gramme : 1 g. = †15·43256 gr.
Metric Tonne : 1 t. = 1000 kg. = 2204·621 lb. = 0·9842 ton.

British Units.

Pound :	1 lb. = †453·59243 g.
Ounce (Avoir.) :	1 oz. = †28·3495 g.
Ounce (Troy and Apothecary) :	1 ℥ = †31·10348 g.
Grain :	1 gr. = †0·06479892 g.
Ton :	1 ton = †1·016047 × 10^6 g.

Measures of Density.

C.G.S. Gramme per cubic centimetre. (g/cc.)
1 g/cc. = 62·43 lb/c ft.

British Units.

1 lb/c ft. = ·01602 g/cc.

The density of water is given on page 18.

The density of mercury at the normal freezing point of water is 13·5955 g/cc.

The density of dry air varies with the pressure and the temperature in accordance with following formula—

$$\rho = \frac{p}{p_0} \times \frac{T_0}{T} \times \rho_0.$$

From the observations of Regnault, at 760 mm. and 273a. the value of ρ_0 is *1292·78 g/m³, for dry air free from carbon dioxide the formula reduces to $\rho = 348{\cdot}321 \frac{p}{T}$

For atmospheric air containing 0·04 per cent. of carbon dioxide, the value of ρ_0 is increased by 0·021 per cent. and $\rho = 348{\cdot}394 \frac{p}{T}$ from which we compute the following table :—

Pressure. mb.	Temperature. a.	Density. g/m³.
1,000	100	3483·94
„	150	2322·62
„	200	1741·97
„	250	1393·58
„	275	1266·89
„	278·72	1250·00
„	290·33	1200·00
„	300	1161·31

Aqueous vapour may be taken account of by substituting $p - \frac{3}{8}e$ for p in the above formula, e being the vapour pressure in the sample of air. *See* page 15 and Section I. § 3.

For the purpose of meteorological computation we may take the standard density as 1201 g/m³ at 1000 mb. and 290a.

Measures of Angle and Time. (International Tables, Chapter I., Section III.)

Angles, &c.

Length of circumference of circle ÷ diameter, $\pi = 3{\cdot}14159265$
$\log \pi = {\cdot}49715$
$1/\pi = {\cdot}318309886$
$\log (1/\pi) = \bar{1}{\cdot}50285$

Radian. 1 r. π r = 180°
1 r = 57·29578° = 57°17′44″·81
1° = ·017453 r.

Time.

See Observer's Handbook, p. 6.

In both the metric and the British systems the unit of time is the mean solar second, *i.e.*, the 1/86400th part of the mean solar day, the latter being defined as the average interval between successive transits of the centre of the sun across any given meridian. For the greater part of Western Europe[1] the standard time is *Greenwich Mean Civil Time*[2] (G.M.T.) the day commencing at Greenwich

[1] Greenwich Mean Time has now been adopted throughout the British Isles, France, Belgium, Spain, Portugal and the Faroes. For other countries throughout the world a system of *Zone Time* has been adopted by international agreement which has recently been extended for use at sea. In this system time is referred to a standard meridian chosen in such a way that the Standard time differs from G.M.T. by an integral number of hours or half hours.

[2] For the computation of Astronomical Tables such as those contained in the Nautical Almanac, *Greenwich Astronomical Time* in which the day commences at mean noon is customarily employed, but in 1919 the Lords of the Admiralty directed that a day beginning at Greenwich midnight should be substituted for the Astronomical Day in the Nautical Almanac beginning with the edition for 1925.

mean midnight. To obtain the equivalent in *Local Mean Time* of any given time G.M.T. add or subtract 4 minutes of time for each degree of longitude according as the given place is to the east or west of the meridian of Greenwich. *Local Apparent Time* may be obtained from local mean time by applying a correction called the *equation of time* the magnitude of which varies according to the time of the year. Accurate values of the equation of time for each day are given in the Nautical Almanac. A table of approximate values is given in the *Observer's Handbook*.

The dates of the beginning and ending of Summer Time in past years are given in the *Observer's Handbook* and in the *Meteorological Office Calendar*.

Year : 1 year = *365·2422166 mean solar days.

1 mean solar day = *0·002737909 year.
= 1·00273791 sidereal day.
= 24 h. 3 m. 56·56 s. in sidereal time.

1 sidereal day = ·99727 mean solar day.
= 23 h. 56 m. 4·09 s. in mean time.

If 1 year = 360°, 1 mean solar day = 0° 59′ 8·33″.
1 week = 6° 53′ 58″.
30 days = 29° 34′ 10″.

Hour : 1 hr. = *1·140795 × 10^{-4} year.
= *0° 2′ 27·847″.

Minute : 1 min. = *1·90132 × 10^{-6} year.
= 2·464″

Second : 1 s. ≑ *3·168866 × 10^{-8} year.
1 s. = ·041066″.

Length of the seconds pendulum at London = 39·13929 in.

NOTE.—The symbols ′ and ″ should be reserved for minutes and seconds of angle exclusively and not used for minutes and seconds of time nor for feet and inches. It is also desirable that the astrological symbol ° should be reserved for degrees of angle; the practice of using it for degrees of temperature is archaic but quite undesirable, because no statement of temperature is complete without a specification of the scale. For this purpose the abbreviation a will be regarded as sufficient in the case of absolute temperature, without a degree sign.

Rotation of the Earth : relative to a star ω = ·00007292 r/s.
relative to the sun, 1 hr. = 15°.
1° = 4 min.

——	Revolutions.	Radians.	Degrees, &c.
Sidereal Day	1	2π	360°
Mean Solar Day ...	1·00273791	6·300388	360·98565°
Hour	4·178075 × 10^{-1}	2·625162 × 10^{-1}	15·04107°
Minute...	6·963458 × 10^{-4}	4·375270 × 10^{-3}	15·04107′
Second...	1·160576 × 10^{-5}	7·292116 × 10^{-5}	15·04107″

Geodetic Measures. (International Tables, Chapter II.)

The surface of the planet as determined by "sea-level" is approximately an ellipsoid (Clarke's ellipsoid) of which :—

the semi polar axis = 6,356,068 m. and
the semi equatorial axes = 6,378,294 m. and
6,376,350 m. respectively.

It was intended that the kilometre should be $\frac{1}{10,000}$ of the length of the meridian from pole to equator, but according to Clarke's figures the correct relation is

1 quadrant = 10,007 k.

Nautical mile = *1853·152 m. (Admiralty).
= 6,080 ft.
= 1·1515 statute miles

1 cable = 100 fathoms = 600 ft.

The cable is not in use as a precise measure of length, it is doubtful whether it should be defined as $\frac{1}{10}$ nautical mile or as 100 fathoms. The fathom as used in making soundings is definitely 6 ft.

Geographical mile = mean length of arc of one minute of latitude which varies from 1842·7 m. at the equator to 1861·3 m. at the poles.
= 1852 m. (Annuaire du Bureau Central des longitudes).
= 6076·8 ft.

NOTE.—The definition of the nautical mile is that adopted in England and the United States. It is equal to the length of one minute of arc of a great circle on a spherical earth assumed to have the same area as Clarke's Ellipsoid. If the continental value of the nautical mile is adopted the terms "geographical mile" and "nautical mile" are interchangeable.

Gravity. At a point on the earth's surface :—

$$g = {}^{*}980{\cdot}617\ (1 - {\cdot}00259 \cos 2\phi)\left(1 - \frac{5}{4}\frac{h}{E}\right)$$ C.G.S. units where ϕ is the latitude, h the height above sea level, E the earth's radius.

Putting E = 6370000 m. = 20900000 ft.

g = *980·617 (1 — ·00259 cos 2 ϕ) (1 — 1·96 × $10^{-7}h$) where h is in metres

g = *980·617 (1 — ·00259 cos 2 ϕ) (1 — 5·97 × $10^{-8}h$) where h is in ft.

This formula takes into account the additional attraction of the high ground and supposes the mean density of the elevated area to be equal to one half of the mean density of the earth.

980·617 is the value of the gravitational acceleration in C.G.S. units at sea-level in latitude 45°. The corresponding value in the British system is 32·172. For the determination of gravity at points above the earth's surface, the factor $\left(\frac{1}{1 + h/E}\right)^2$ which equals approximately $1 - 2\frac{h}{E}$ replaces $1 - \frac{5}{4}\frac{h}{E}$.

Value of g at sea-level in London = 981·19 cm/s².
Mean density of earth = about 5·5 g/cc.
Mean density of surface of earth = 2·65 g/cc.
Volume of earth = 1·082 × 10^{21} m³.
Mass of earth = 5·98 × 10^{27} g.
= 5·87 × 10^{21} tons.
Area of land (estimated) = 1·45 × 10^{18} cm².
Area of ocean do. = 3·67 × 10^{18} cm².
Mean depth of ocean (Murray) = 3·85 × 10^5 cm.
Volume of ocean = 1·41 × 10^{24} cc.
Mass of ocean = 1·45 × 10^{24} g.
Mass of the atmosphere = 5·34 × 10^{21} g.

The Constant of Gravitation is the constant G in the law of attraction :—

$$\text{force} = G\,\frac{\text{mass} \times \text{mass}}{(\text{dist.})^2}$$

G = 6·6576 × 10^{-8} cm³/gs² (Boys).

Sun.—Distance 1·494 × 10^{11} m = 9·282 × 10^7 miles.
Mass 329390 × earth's mass.
Equatorial Diameter Angular 32′ 2·36″ = 865,980 miles
= 1393338 k.

Moon.—Distance 60·27 × earth's radius.
Mass 1/81·53 × earth's mass.
Diameter 2,163 miles.

Duration of Sunshine in Various Latitudes.

See Book of Normals, Section I.

Definition of sunrise: The time at which the centre of the sun, taking account of refraction, would just appear on the horizon.

Sin ½ (semi-course of the sun) =

$$\sqrt{\frac{\sin\left(\frac{\pi}{4}+\frac{\phi-D+r}{2}\right)\sin\left(\frac{\pi}{4}-\frac{\phi-D-r}{2}\right)}{\cos\phi\cos D.}}$$

where ϕ is the latitude, D the northerly declination of the sun, r the apparent elevation due to refraction.

The duration of Sunshine in hours is obtained by determining the difference of hour angle between Sunrise and noon by the above formula, multiplying by two and converting to mean solar time ($15° = 1$hr.).

The mean value of r (corresponding to $t = 283$a. and $p = 1013$ mb) is 33′ 47″ and may be taken as 34′.

The sun's declination may be taken from the Meteorological Calendar.

Diagrams showing the position of the sun at each hour of the day at stated times of the year for latitudes 50°, 55° and 60°, but taking no account of refraction are given in the Observer's Handbook.

Measures of Velocity.

Metric Units.

C.G.S. centimetre per second : 1 cm/s = †·0328084 ft/s.
= ·022369 mi/hr. = ·019435 knot.
metre per second : 1 m/s = †3·28084 ft/s.
= 2·2369 mi/hr. = 1·9435 knot.

British Units.

foot per second : 1 ft/s. = †·304800 m/s.
mile per hour 1 mi/hr. = ·44707 m/s.
knot 1 knot = ·51453 m/s.

Measures of Acceleration.

C.G.S. 1 gal. = centimetre per second per second : 1 cm/s² = †·0328084 ft/s².
decametre per second per second : 1 leo. (= 1000 cm/sec.²)
= †32·8084 ft/s².
1 milligal = 10 micron/sec.²

Measures of Force.

Metric Units.

C.G.S. 1 dyne or gramme centimetre per second per second : = weight of ·00102 g.

1 kilogramme weight at Lat. 45°	= ·9806 megadynes.	
" " " London	= ·9812	"
" " " the Pole	= ·9781	"
" " " the Equator	= ·983	"

British Units.

1 pound weight = $4·45 \times 10^5$ dynes.
1 poundal = 13825 dynes.

Measures of Work and Energy. Everett ($g = 981$).

Metric Units.

C.G.S. gramme (centimetre per second)².
1 erg $= 2·3731 \times 10^{-6}$ foot poundals.
1 joule $= 10^7$ ergs.
1 kg.m. $= 10^5$ g.cm. $= 9·81 \times 10^7$ ergs.
1 Board of Trade Unit (B.T.U.) = 1 Kilowatt-hour.
$= 3·6 \times 10^{13}$ ergs.

British Units.

Footpound : 1 ft. lb. = 13825g.cm. $= 1·3562 \times 10^7$ ergs.
Foot poundal $= 4·2139 \times 10^5$ ergs.
Foot ton $= 3·097 \times 10^7$ g.cm. $= 3·0380 \times 10^{10}$ ergs.

NOTE.—The equivalent of the foot pound in C.G.S. units is dependent upon the geographical position at which the comparison is made because the value of gravity which enters into the computation varies with latitude.

Measures of Rate of Working.

C.G.S. Erg/s, *i.e.* g. (cm/s)²/s
1 watt $= 10^7$ erg/s = 1 joule per second.
1 horse power $= 7·46 \times 10^9$ erg/s = 746 joules per second.
= ¾ kilowatt (nearly).
1 force de cheval $= 7·36 \times 10^9$ erg/s = 736 joules per second.

Measures of Geopotential.

C.G.S. 1 (cm/s)². 1 leometre $= 10^5$ (cm/s)².

Measures of Temperature. (International Tables, Chapter III., Section I.)

Centigrade Scale.

Freezing point of water under standard conditions 0° C.
Boiling point of water under standard conditions 1013·231 mb.
(760 mm. mercury at 273a lat. 45°) 100° C.

$$C = A - 273 = \frac{5}{9}(F - 32) = \frac{5}{4}R.$$

9 (C − 10) = 5 (F − 50) is convenient for ordinary air temperatures.

Approximate Absolute Scale of centigrade degrees (or "Tercentesimal" scale).

Equivalent intervals 1 a = 1° C. = 1·8° F. = 1·6° R.

The most recent computations of the position of the absolute zero in the centigrade scale of the hydrogen gas-thermometer place it at −273·02°. Taking the starting point of the absolute scale as −273°C. we get the following equivalents between the expression of the same temperature on the absolute scale A, the Fahrenheit scale F, the centigrade scale C, and the Réaumur scale R.

$$A = \frac{5}{9}(459·4 + F) = 273 + C = \frac{5}{4}(218·4 + R).$$

NOTE.—The boiling point of water under a pressure of 1000 mb is 372·65 a.

Fahrenheit Scale.

Freezing point of water under standard conditions 32°F.
Boiling point of water under standard conditions (1013·231 mb) 212° F.

$$F = \frac{9}{5}A - 459·4 = 32 + \frac{9}{5}C = 32 + \frac{9}{4}R.$$

The Fahrenheit scale as originally devised ran from 0° the lowest temperature then reached (the temperature of a mixture of ice and salt) to 8° the temperature of the human body. Subsequently each degree was divided into twelve parts. Eventually the points 212° and 32° were defined so as to agree precisely with 100° and 0°C.

Approximate Absolute Scale of Fahrenheit degrees ("Quingentesimal" scale).

The temperature of the absolute zero on the Fahrenheit scale is −459·44. A scale of Fahrenheit degrees measured from −459°F. would give a scale on which the normal freezing point of water would be 491 and the normal boiling point 671. Temperatures on this scale would differ from the best available estimate of the true thermodynamic temperature only by being ·44q too small. The temperature of 41°F. or 5°C. would be 500, a convenient number to remember with a degree of convenient size.

We may therefore use an approximate absolute scale of Fahrenheit degrees or "quingentesimal scale" with a zero ·44 above the absolute zero. If we denote its unit by q we have equivalent intervals—

$$1q = 9/5a.$$
$$491{\cdot}4q = 273a.$$
$$Q = F + 459 = 9/5\,(A - {\cdot}22a).$$

Kilograd Scale.

Another scale graduated from —273°C. approximating to the absolute scale is proposed by Professor McAdie. The unit is one thousandth part of 273 centesimal degrees. The normal freezing point on this scale is taken as 1000 and the boiling point 1366·3. He calls it the kilograd scale and suggests that k be accepted as representing its unit. That letter has already been allotted to kilometre ; taking kd instead we have

$$1000kd = 273a = 491{\cdot}4q.$$

The Centigrade Thermodynamic Scale is adopted as fundamental by the National Physical Laboratory in view of resolutions of the Fifth General Conference of Weights and Measures held at Paris in October, 1913. The scale of the constant-volume Hydrogen thermometer agrees with the thermodynamic scale at ordinary temperatures. The fixed points are the temperature of pure ice melting under normal atmospheric pressure 1013·23 1 mb and that of the vapour of distilled water in ebullition under the same pressure.

Vide Pamphlet on Tests, N.P.L., Heat Division, 1915.

The scales of the various mercury-in-glass thermometers used at Kew Observatory as standards differed in the period 1854 to 1912, but slightly from this international scale. The departures were not greater than ·05° F. within the range of air temperatures. (Harker *Proc. Royal Soc.* Vol. 78 A. 1906, p. 239.)

The earlier thermometers were made on the assumption that the expansion of mercury in glass was at the same rate throughout the scale. Such thermometers differ* slightly amongst themselves and may differ from the hydrogen scale by as much as ·2° F. By a happy accident English glass gives a scale nearer to the international scale than other glasses such as "verre dur."

Réaumur Scale.

Freezing point of water under standard conditions, 0° R.

Boiling point of water under standard conditions 1013·231 mb.

(760 mm. mercury at 0° lat. 45°) 80° R.

$$R = \frac{4}{5}(A - 273) = \frac{4}{9}(F - 32) = \frac{4}{5}\,C.$$

This scale was until recently the customary scale on the continent for domestic and economic purposes, but it is now generally replaced by the centigrade scale. The editors of the International Tables regarded it as so little in use that it was not necessary to give conversion tables.

Other Scales.—Those which have come to the notice of the Office in manuscript records of meteorological observations are De l'Isle's Scale, in which the boiling point of water is zero and the freezing point 150°, and a scale in which temperatures were measured above and below "temperate" (60° F.) in a scale which had apparently two degrees for each degree Fahrenheit. The temperate mark which is common to many thermometers is apparently 13° C. (55·4° F.).

On Sir Isaac Newton's Scale (Phil. Trans. 1701) the freezing point of water is 0° and the temperature of the human body is 12°.

Reduction of Temperature to Sea Level. (International Tables, Chapter III., Section II.)

The tables on this subject included in the International Meteorological tables are empirical tables based upon the assumption that on the average the rate of fall of temperature with height is proportional to the height with a coefficient which must be determined by observation. The lapses provided for in the tables range from 1° C. in 500 m. to 1° C. in 100 m. and from 1° F. in

* C. Chree. Notes on Thermometry. Phil. Mag. 1898, p. 205.

1,000 ft. to 1° F. in 200 ft., and therefore include the values appropriate for France—viz. :—

In Spring and Autumn a fall of temperature of 1° C. for 180 m.
In Winter 1° C. for 200 m.
In Summer 1° C. for 160 m.

and the value commonly used in England—viz., 1° F. for 300 ft.

Other coefficients have been recently introduced in the preparation of the climatic tables of the Meteorological Office, of which the metric equivalents are given in the following table (*see Book of Normals, Section III.*) :—

TABLE showing ELEVATION in metres corresponding with the REDUCTION of the normal maximum and minimum temperatures of each month and of the year by one tenth of a degree of the centigrade scale.

——	England, Wales and Ireland.		Scotland.	
	Max.	Min.	Max.	Min.
January	14 m.	14 m.	22 m.	16 m.
February	11 ,,	14 ,,	22 ,,	16 ,,
March	11 ,,	14 ,,	16 ,,	16 ,,
April	11 ,,	11 ,,	16 ,,	14 ,,
May	11 ,,	11 ,,	19 ,,	14 ,,
June	11 ,,	14 ,,	25 ,,	16 ,,
July	11 ,,	14 ,,	25 ,,	16 ,,
August	11 ,,	14 ,,	22 ,,	16 ,,
September	11 ,,	16 ,,	19 ,,	16 ,,
October	11 ,,	16 ,,	16 ,,	19 ,,
November	11 ,,	16 ,,	16 ,,	19 ,,
December	14 ,,	14 ,,	19 ,,	16 ,,
Year	12 ,,	14 ,,	20 ,,	16 ,,

Measures of Quantity of Heat.

The gramme-calorie, the heat required to raise the temperature of 1 gramme of water by one degree centigrade is usually adopted as the unit of heat for physical investigations. Unfortunately, however, this unit lacks precision as the heat required to raise a gramme of water by one degree is not the same at all parts of the scale. The definition is made explicit by specifying the range of temperature. Professor Callendar defines the "mean calorie" as one-tenth of the heat required to raise a gramme of water from 288a to 298a. In what follows this "mean calorie" is called simply the calorie.

The British Thermal Unit (B.Th.U.) is the quantity of heat required to raise 1 lb. of water through 1° F. and is therefore $\frac{5}{9} \times 453{\cdot}59$ or 252·00 cal.

Dynamical Equivalent of Heat.—Heat as a form of energy can also be measured in joules, the fundamental relation being 1 calorie = 4·18 joules.

The Capacity for Heat of a material under specified conditions is the quantity of heat required to raise unit mass through one degree of temperature.

The capacity for heat of one gramme of water at various temperatures, interpolated from Kaye and Laby.

Temperature.	Capacity for heat.	Dynamical Equivalent.	Temperature.	Capacity for heat.	Dynamical Equivalent.
a.	cal.	joules.	a.	cal.	joules.
270	1·0130	4·234	290	1.0007	4·183
273	1·0094	4·219	293	1·0000	4·180
275	1·0076	4·212	295	·9997	4·179
280	1·0042	4·198	300	·9990	4·176
285	1·0021	4·189	305	·9985	4·174

Capacity for heat being energy per unit mass per degree has the same dimensions as geopotential and may be expressed in leo-metres per degree. The capacity for heat of water at 293a is 418 leo-metres per degree, *i.e.*, the energy required to raise the temperature of any quantity of water by 1a would suffice to lift it 418 metres in a field of force producing acceleration 1 leo (1000 cm/sec²).

The Specific Heat of a substance is the ratio of the capacity for heat of the substance to the capacity for heat of water at some standard temperature. If the standard temperature is 293a, the specific heat is the same numerically as the capacity for heat in calories per gramme per degree.

Some specific heats.

Water, numerically the same as the capacity for heat (*see* Table above).

Sea Water at 290a	0·94.	
Ice at 260a	0·502.	
Dry Air at constant pressure at 293a (C_p)	0·2417.	(Swann 1909).
„ at constant volume (C_v) ...	0·1715.	(Joly 1891).
Water Vapour at constant pressure at 373a	0·4652.	(Holborn & Henning 1907).
„ „ at constant volume ...	0·340.	(Pier 1909).

In the case of gases the ratio κ of the specific heats $C_p : C_v$ is a quantity of considerable importance. For example :—

Velocity of sound in any gas $= (\kappa p/\rho)^{\frac{1}{2}}$

For a gas expanding adiabatically $pv^{\kappa} =$ const.

The rise of temperature $d\theta$ caused by an adiabatic compression is given by

$$\frac{d\theta}{\theta} = \frac{\kappa - 1}{\kappa}\frac{dp}{p}$$

For dry air $\kappa = 1{\cdot}40$ whence $\kappa - {}^1/_\kappa = 0{\cdot}29$.

Latent Heat of one gramme of water ... 79·77 calories.

„ „ steam, at 273a = 597 cal. = 2495 joule/g. = 249·5 leo-k.

at 373a = 539 cal. = 2252 joule/g.

Measures of Solar Radiation.

The intensity of solar radiation may be measured in work units by indicating the energy received in one second upon a square centimetre exposed to the radiation.

Thus at the Meteorological Office the vertical component of the radiation from sun and sky is measured in milliwatts per square centimetre. The relation to the usual unit is—

1 milliwatt per square centimetre = ·01435 g. cal./cm.² per min.
1 gramme calorie per square centimetre per minute = 69·7 mwatts per cm.²
1 British Thermal unit = 252·00 gramme calories.

The solar constant is the strength of the solar heat stream at the outer boundary of the earth's atmosphere.
Mean value of solar constant=1·93 g. cal. per cm² per min. (Abbot). =135 mwatts per cm². =32·4 kilowatt hours per m² per diem. =11673 joules per cm² per diem.

Measures of Pressure. (International Tables, Chapter IV., Section I.) Observer's Handbook : 1 in. = 2·54000 cm.

C.G.S. dyne per square centimetre = 1 microbar = 2·95306 × 10^{-5} mercury inches = 7·50076 × 10^{-4} mercury millimetres.

millibar : 1 mb. = 0·0295306 mercury inches = 0·750076 mercury millimetres.

Mercury inch : 1 inch of mercury at 32° F. in latitude 45° = 33·8632 mb.
Mercury millimetre : 1 mm. at 0°C. in latitude 45° = 1·333200 mb.
760 mm. „ „ = 1013·231 mb.

Russian half-lines (normal at 62°F.).
600 half-lines = *759·68 mm. = 1012·804 mb.
1 half-line = 1·68801 mb.

British pound per square inch and pound per square foot in London.
1000 mb. = 14·496 lb./in.² = 2087·424 lb./ft.² in London.

Additional Measures.

Gradient γ.—Originally applied by Thos. Stevenson, C.E., to indicate the change of pressure for a defined horizontal distance drawn in a specified direction, and now used to indicate the rate of change of pressure along the line drawn on a map at right angles to the isobar passing through the place for which the gradient is to be given. The direction of the gradient is the line from high pressure to low and the numerical value of the gradient indicates the amount by which the pressure *falls* for a specified distance.

The distance conventionally specified is 60 nautical miles when the pressure difference is given in millimetres, or 15 nautical miles when the pressure difference is in hundredths of an inch. For pressure differences in millibars the corresponding distance would be 45 nautical miles, but the practice in the Meteorological Office is not to evaluate the gradient itself but to obtain directly the *geostrophic wind* (see Section II. § 4) by the use of a suitably graduated scale constructed according to the formula

$$V = \gamma_p \Big/ 2\,\omega\,\rho\,\sin\phi$$

when V is the velocity of the wind in metres per second ω, ρ and ϕ have the usual significance and γ_p is the gradient of pressure in millibars per metre.

In a similar manner we may estimate changes of temperature, humidity and other meteorological elements in a horizontal distance as gradients of temperature γ^T of vapour pressure γ_e and so on.

Lapse rate.—Since the term gradient was introduced a practice has grown up of using it to indicate the change of temperature or other meteorological elements in the vertical. In that case the direction ought always to be clearly specified as vertical or horizontal as the case may be. In practice that precaution is seldom taken and the confusion may be serious. Moreover, the practice is inconvenient when both horizontal and vertical changes of the same element enter into an equation. We, therefore, use the term *lapse* to indicate change in the vertical which is to be reckoned positive when the change is from greater to less with increase of height and *lapse rate* or *lapsus ratio* to indicate the rate of change with height.

On the analogy of γ for gradient θ would be a very good symbol for the lapse rate, but it is so frequently used as a current co-ordinate for angle and for temperature that it can hardly be spared. There seems no alternative but to use $d\theta/dz$ with its sign reversed and perhaps Ⓗ for the numerical value of the lapse rate in degrees absolute per 100k.

Hygrometric Measures. (International Tables, Chapter V.)

Pressure of Aqueous Vapour.

Observations of dew-point give the temperature of saturation of the air. The corresponding vapour-pressure is given in the International Meteorological Tables by a table calculated by Dr. Broch from the classical observations of Regnault. A brief table is given in this Handbook, Section I., § 1.

Percentage Relative Humidity.

The relative humidity is defined as the ratio of the weight of vapour contained in a cubic metre of the air under observation to the weight which the same volume of air would contain if saturated with water vapour without changing its temperature.

To obtain this ratio we require the saturation pressure of aqueous vapour at the temperature of the dew point and at the temperature of the air ; both these can be obtained from the table of saturation pressures and obtaining their ratio is a simple numerical operation. We may represent it by ϖ_{dp}/ϖ_t where the symbol ϖ is used to denote pressure of saturation at the temperature indicated by the suffix. The percentage relative humidity is then obtained by multiplying by 100.

Thus Relative Humidity = $100\,\varpi_{dp} / \varpi_t$.

Wet and Dry Bulbs.

Tables for obtaining the relative humidity and the vapour pressure from readings of the wet and dry bulbs are given in this Handbook, Section I., § 1.

Weight of Vapour in the Air.

In accordance with Dalton's law the water vapour in the atmosphere exerts the same pressure as it would if the air were not present. Knowing the vapour pressure e we therefore obtain δ the weight of vapour in a cubic metre of moist air from the formula

$$\delta = \delta_o \frac{e}{P_o} . \frac{T_o}{T}$$

where δ_o is the density of aqueous vapour under standard pressure and temperature P_o and T_o

$$\text{whence } \delta = 216.7 \ \frac{\varpi_{dp}}{T} \text{ g/m}^3$$

(if ρ be density of dry air *p.*7. $\delta/\rho = 216.7 \div 348{\cdot}32 = 0{\cdot}622 = \frac{5}{8}$ very nearly).

Viscosity.—

The dimensions of a viscosity are $ML^{-1}T^{-1}$ For the capillary-tube method of determining viscosities, Poiseuille's formula is — viscosity $\eta = \frac{\pi p r^4 t}{8 l V}$; where p is the pressure difference between the two ends of the tube, r the radius of the tube, l its length and V the volume of liquid delivered in a time t.

Viscosity of Water (Hosking, 1909).—Determined by an efflux method and corrected for kinetic energy of outflow.

Temp.	0	10	20	30	40	50	60	70	80	90	100
Viscosity in C.G.S. units.	·01793	·01311	·01006	·00800	·00657	·00550	·00469	·00406	·00356	·00316	·00284

Viscosities of Gases η—

	a	η	
Air at	252	164 × 10^{-6}	Breitenbach.
"	273	171	Fisher, 1909.
"	288	181	Markowski.
"	372·6	221	" 1904.
Water Vapour at	273	90	—
" ...	288	97	Kundt and Warburg.
" ...	373	132	Meyer and Schumann.
Hydrogen at ...	273	86	Breitenbach.
" ...	288	89	"
Oxygen at ...	273	187	V. Obermayer.
" ...	288	195	"
Nitrogen at ...	273	166	"

Conductivity.

In the case of a gas the thermal conductivity $k = 1{\cdot}603\, \eta C_v$. k increases with temperature.

For air at 273a, $k = 5{\cdot}22 \times 10^{-5}$.

Eddy Conductivity k.— K

The power possessed by a fluid by virtue of its turbulence of transmitting a quantity such as heat or momentum may be measured in terms of a coefficient K, such that the rate of upward flow of the quality is K times its lapse rate. The dimensions of K are L^2/T.

	C.G.S. units.
At sea over Great Banks from Temperature Distribution (Taylor)	3 × 10^3
Over Salisbury Plain from Wind Distribution (Dobson and Taylor)	5 × 10^4
At Eiffel Tower from Temperature Distribution (Taylor)	10 × 10^4
" " Wind Distribution (Åkerblom) ...	7·6 × 10^4
" " Internal Friction Distribution (Brunt)	7·4 × 10^4
Lindenberg from Wind Distribution (Hesselberg and Sverdrup)	5 × 10^4

L. F. Richardson in **Atmospheric Stirring measured by Precipitation* considers a function ξ which at any given height $= g^2\rho^2K$. He obtains the following values for ξ :—

At 8,500m. ... 3 to 180 $g^2/cm^2\ sec^5$
" 500m. ... 140,000 "
" 0·5m. ... Possibly as low as 1,000 or even less.

See also **The Relation between Wind and Distribution of Pressure*, by Harold Jeffreys, M.A., D.Sc.

Measures of Wind. (International Tables, Chapter VI.)

Any observation of wind should have for its object the determination of the speed and direction of motion of the current of air at the point where the observer or instrument is situated. Non-instrumental observations of wind aim at placing the wind force in one of a number of categories according to its effect on the observer and neighbouring objects. The Beaufort Scale is customarily, but not invariably used for the purpose. We may assume that each Beaufort number is equivalent to a certain speed at a certain standard height above ground in the open. Such equivalents in British and Metric units are given in the *Observer's Handbook.*

The estimation of wind direction without instrumental aid is not usually made with closer refinement than the nearest even point (N., NNE., NE. etc.). In anemometry a closer refinement is possible and all 32 points are in use. The specification in terms of degrees has been carried out in two ways. In the older way the direction was expressed, as, for example, S.20°E. meaning 20° east of south. The standard method is to specify the direction by the number of degrees from N. through E. East will then be indicated by 90°, South by 180°, West by 270° and North by 360°.

Wind Components.

If V is the velocity of the wind in any measure and A the angle of its direction measured in degrees from N. through E.—

the West-East component $V_{270} = V \sin A$
the South-North component $V_{180} = -V \cos A$

The summation of all the winds is effected by resolving each wind into its west-east and south-north components and by determining the algebraical sums of the components V_{270} and V_{180}. The velocity and direction of the resultant wind are given by :—

$$V = \sqrt{(V^2_{270} + V^2_{180})}\ ;\ \tan \overline{A} = V_{270}/V_{180}$$

Components and resultants may be obtained by means of the Traverse Table.

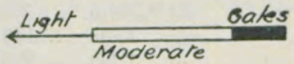
Wind-Roses.

When it is desired to express the velocity or force of wind on a chart it is better to use a diagrammatic representation instead of a numerical one. The almost universal practice is to represent the direction of the wind by an arrow flying with the wind drawn *up to* the point on the chart for which the observation is noted.

The conventions with regard to the representation of force or velocity are various. For the charts of the British Daily Weather Service, in accordance with a practice that is gradually becoming general, the force is represented by the number of feathers on the tail of the direction line. But the length of the line is still often used, and for the purpose of representing frequency of occurrence of winds of selected forces it is very convenient.

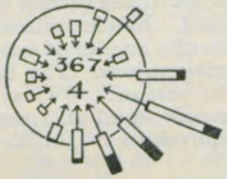
After many trials a form of wind rose has been adopted by the Meteorological Office for expressing average frequencies of calms, light winds, moderate winds and gales, which is thus described. (Report of the Meteorological Council, 1891-2, p. 7.)

* Proc. Roy. Soc., Vol. 96, 1919.

New Wind-Rose.—In the new form of Wind Rose which is given below, the arrows which fly with the wind show by their length the frequency of winds of various directions and by their thickness the various forces; light winds, forces 1 to 3 : moderate winds 4 to 7 : and gales 8 to 12 ().

The circle supplies a scale for estimating the frequency of winds in any direction. The length from the heads of the arrows to the circumference represents 5 per cent. of the whole number of observed winds (100 per cent. = 4 inches). The upper figures in the centre of the wind rose are the total number of observations, the percentage of calms being given underneath.

Example of Wind Rose.



This form of wind-rose is convenient because it enables one to add the variations of some other variable such as temperature, rainfall without disturbing the characteristics of the wind-rose itself.

Alternative forms of wind-rose in use at various times are given in the Meteorological Glossary (p. 353). For many purposes diagrams such as those on Plate XIX of The Weather of the British Coasts are found convenient.

Density of Water. (Addendum to "Density" p. 7.)

Water has a maximum density at 3·98°C. (Chappuis 1897, Thesein, Scheel and Diesselhort : De Coppet 1903).

Density in g/cc under 1 atmosphere of pure water free from air

Temp. *a*	268	273	277	293	323	373
Density	·9993	·9999	1·000	·9982	·9881	·9584

Sea Water in g/cc.

Density of sea-water of known temperature and salinity.

Salinity Salts per Thousand.	Temperature a.					
	273	278	283	288	293	298
0	·9999	1·0000	·9997	·9994	·9982	·9971
15	1·0121	1·0119	1·0115	1·0107	1·0097	1·0084
20	1·0161	1·0159	1·0153	1·0145	1·0134	1·0821
25	1·0201	1·0198	1·0192	1·0183	1·0172	1·0159
30	1·0241	1·0237	1·0231	1·0221	1·0210	1·0196
35	1·0281	1·0277	1·0270	1·0260	1·0248	1·0234
40	1·0322	1·0317	1·0309	1·0299	1·0286	1·0272

Note :—The works to which reference is made in this compilation are :—

International Meteorological Tables. (Gauthier-Villars et Fils, Paris.)

Physical and Chemical Constants. G. W. C. Kaye and T. H. Laby. (Longmans, Green and Co.)

Uniformity in Aerographic Notation. Alex. McAdie (Ann. Ast. Obs. Harvard Coll., Vol. 83, Part iv, 1920).

TABLES.

NUMBERS FOR APPROXIMATE NUMERICAL COMPUTATIONS.

General Instructions for Numerical Computation.

Carry out all numerical computations to one figure, or in cases where precision is necessary, &c., two figures beyond the decimal place which is to be given as correct in the result, in order to avoid the accumulation of errors from a succession of operations.

When the final result is obtained, cast up the last figure retained if the working figure which immediately follows it is 5 or more.

It is a useful practice in the computation of physical quantities, if the measurement is carried to such a number of places that the value of the last figure given in the result is uncertain, to write the uncertain figure a little below the line. Thus, the quoting of a temperature as $252\cdot_3$ would mean that the computation has been carried to tenths of a degree but that the decimal fraction is uncertain on account of possible errors of measurement.

When a large amount of computation of one kind has to be done various calculating machines can be employed. In the Meteorological Office the Comptometer and Burroughs adding machine are employed for adding, but in dealing with the ordinary work of climatological stations, Crelle's tables are used.

$$\pi = 3\cdot14159265 : \quad \frac{1}{\pi} = 0\cdot3183098862.$$

Numbers 1 to 99, their reciprocals, quarter squares, squares, square roots, cubes and cube roots to four figures.

n	$1/n$	$\frac{1}{4}n^2$	n^2	$\sqrt{n}$	n^3	$\sqrt[3]{n}$
1	1	0	1	1	1	1
2	5000	1	4	1·414	8	1·260
3	3333	2	9	1·732	27	1·442
4	2500	4	16	2·000	64	1·587
5	2000	6	25	2·236	125	1·710
6	1667	9	36	2·449	216	1·817
7	1429	12	49	2·646	343	1·913
8	1250	16	64	2·828	512	2·000
9	1111	20	81	3·000	729	2·080
10	1000	25	100	3·162	1000	2·154
11	9091	30	121	3·317	1331	2·224
12	8333	36	144	3·464	1728	2·289
13	7692	42	169	3·606	2197	2·351
14	7143	49	196	3·742	2744	2·410
15	6667	56	225	3·873	3375	2·466
16	6250	64	256	4·000	4096	2·520
17	5882	72	289	4·123	4913	2·571
18	5556	81	324	4·243	5832	2·621
19	5263	90	361	4·359	6859	2·668
20	5000	100	400	4·472	8000	2·714
21	4762	110	441	4·583	9261	2·759
22	4546	121	484	4·690	1065	2·802
23	4348	132	529	4·796	1217	2·844
24	4167	144	576	4·899	1382	2·884

n	$1/n$	$\frac{1}{2}n^2$	n^2	$\sqrt{n}$	n^3	$\sqrt[3]{n}$
25	4000	156	625	5·000	1563	2·924
26	3846	169	676	5·099	1758	2·962
27	3704	182	729	5·196	1968	3·000
28	3571	196	784	5·291	2195	3·037
29	3448	210	841	5·385	2439	3·072
30	3333	225	900	5·477	2700	3·107
31	3226	240	961	5·568	2979	3·141
32	3125	256	1024	5·657	3277	3·175
33	3030	272	1089	5·745	3594	3·208
34	2941	289	1156	5·831	3930	3·240
35	2857	306	1225	5·916	4288	3·271
36	2778	324	1296	6·000	4666	3·302
37	2703	342	1369	6·083	5065	3·332
38	2632	361	1444	6·164	5487	3·362
39	2564	380	1521	6·245	5932	3·391
40	2500	400	1600	6·325	6400	3·420
41	2439	420	1681	6·403	6892	3·448
42	2381	441	1764	6·481	7409	3·476
43	2326	462	1849	6·557	7951	3·503
44	2273	484	1936	6·633	8518	3·530
45	2222	506	2025	6·708	9113	3·557
46	2174	529	2116	6·782	9734	3·583
47	2128	552	2209	6·856	1038	3·609
48	2083	576	2304	6·928	1106	3·634
49	2041	600	2401	7·000	1176	3·659
50	2000	625	2500	7·071	1250	3·684
51	1961	650	2601	7·141	1327	3·708
52	1923	676	2704	7·211	1406	3·733
53	1887	702	2809	7·280	1489	3·756
54	1852	729	2916	7·348	1575	3·780
55	1818	756	3025	7·416	1664	3·803
56	1786	784	3136	7·483	1756	3·826
57	1754	812	3249	7·550	1852	3·849
58	1724	841	3364	7·616	1951	3·871
59	1695	870	3481	7·681	2054	3·893
60	1667	900	3600	7·746	2160	3·915
61	1639	930	3721	7·810	2270	3·936
62	1613	961	3844	7·874	2383	3·958
63	1587	992	3969	7·937	2500	3·979
64	1563	1024	4096	8·000	2621	4·000
65	1539	1056	4225	8·062	2746	4·021
66	1515	1089	4356	8·124	2875	4·041
67	1493	1122	4489	8·185	3008	4·062
68	1471	1156	4624	8·246	3144	4·082
69	1449	1190	4761	8·307	3285	4·102
70	1429	1225	4900	8·367	3430	4·121
71	1408	1260	5041	8·426	3579	4·141
72	1389	1296	5184	8·485	3732	4·160
73	1370	1332	5329	8·544	3890	4·179
74	1351	1369	5476	8·602	4052	4·198
75	1333	1406	5625	8·660	4219	4·217
76	1316	1444	5776	8·718	4390	4·236
77	1299	1482	5929	8·775	4565	4·254
78	1282	1521	6084	8·832	4746	4·273
79	1266	1560	6241	8·888	4930	4·291

n	$1/n$	$\frac{1}{2}n^2$	n^2	$\sqrt{n}$	n^3	$\sqrt[3]{n}$
80	1250	1600	6400	8·944	5120	4·309
81	1235	1640	6561	9·000	5314	4·327
82	1220	1681	6724	9·055	5514	4·344
83	1205	1722	6889	9·110	5718	4·362
84	1191	1764	7056	9·165	5927	4·380
85	1177	1806	7225	9·220	6141	4·397
86	1163	1849	7396	9·274	6361	4·414
87	1149	1892	7569	9·327	6585	4·431
88	1136	1936	7744	9·381	6815	4·448
89	1124	1980	7921	9·434	7050	4·465
90	1111	2025	8100	9·487	7290	4·481
91	1099	2070	8281	9·539	7536	4·498
92	1087	2116	8464	9·592	7787	4·514
93	1075	2162	8649	9·644	8044	4·531
94	1064	2209	8836	9·695	8306	4·547
95	1053	2256	9025	9·747	8574	4·563
96	1042	2304	9216	9·798	8847	4·579
97	1031	2352	9409	9·849	9127	4·595
98	1020	2401	9604	9·899	9412	4·610
99	1010	2450	9801	9·950	9703	4·626

Length of 1° of Longitude in Different Latitudes in Metres, Nautical Miles and Statute Miles.

(International Meteorological Tables.)

Degrees of Latitude.	Metres.	Nautical Miles.	Statute Miles.	Degrees of Latitude.	Metres.	Nautical Miles.	Statute Miles.
0	111,307	60·064	69·164	50	71,687	38·684	44·545
2	111,239	60·027	69·122	52	68,670	37·056	42·670
4	111,037	59·918	68·996	54	65,568	35·382	40·743
6	110,701	59·737	68·788	56	62,385	33·664	38·765
8	110,230	59·482	68·495	58	59,126	31·906	36·740
10	109,627	59·157	68·120	60	55,793	30·107	34·669
12	108,890	58·759	67·662	62	52,392	28·272	32·555
14	108,021	58·290	67·122	64	48,926	26·402	30·402
16	107,022	57·751	66·502	66	45,399	24·498	28·210
18	105,893	57·142	65·800	68	41,816	22·565	25·984
20	104,635	56·463	65·018	70	38,182	20·604	23·726
22	103,250	55·716	64·158	72	34,500	18·617	21·438
24	101,740	54·901	63·219	74	30,775	16·607	19·123
26	100,106	54·019	62·204	76	27,012	14·576	16·785
28	98,350	53·072	61·113	78	23,216	12·528	14·426
30	96,475	52·060	59·948	80	19,391	10·464	12·049
32	94,482	50·984	58·709	82	15,542	8·387	9·658
34	92,374	49·847	57·400	84	11,673	6·299	7·253
36	90,153	48·648	56·019	86	7,790	4·204	4·841
38	87,822	47·391	54·571	88	3,897	2·103	2·422
40	85,384	46·075	53·056	90	0	0·000	0·000
42	82,841	44·703	51·476				
44	80,196	43·275	49·832				
46	77,454	41·796	48·129				
48	74,616	40·264	46·365				

LOGARITHMS OF NUMBERS TO FOUR FIGURES.

Base of "natural" or Napierian logarithms e = 2·718281828.

Modulus or factor of conversion from natural logarithms (base e) to common logarithms (base 10) $\log_{10} e$ = ·43429.

Reciprocal or factor of conversion, $\log_e 10$ = 2·3026.

	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374	4	8	12	17	21	25	29	33	37
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755	4	8	11	15	19	23	26	30	34
12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106	3	7	10	14	17	21	24	28	31
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430	3	6	10	13	16	19	23	26	29
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732	3	6	9	12	15	18	21	24	27
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014	3	6	8	11	14	17	20	22	25
16	2041	2068	2095	2122	2148	2175	2201	2227	2253	2279	3	5	8	11	13	16	18	21	24
17	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529	2	5	7	10	12	15	17	20	22
18	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765	2	5	7	9	12	14	16	19	21
19	2788	2810	2833	2856	2878	2900	2923	2945	2967	2989	2	4	7	9	11	13	16	18	20
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201	2	4	6	8	11	13	15	17	19
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404	2	4	6	8	10	12	14	16	18
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598	2	4	6	8	10	12	14	15	17
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784	2	4	6	7	9	11	13	15	17
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962	2	4	5	7	9	11	12	14	16
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133	2	3	5	7	9	10	12	14	15
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298	2	3	5	7	8	10	11	13	15
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456	2	3	5	6	8	9	11	13	14
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609	2	3	5	6	8	9	11	12	14
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757	1	3	4	6	7	9	10	12	13
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900	1	3	4	6	7	9	10	11	13
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038	1	3	4	6	7	8	10	11	12
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172	1	3	4	5	7	8	9	11	12
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302	1	3	4	5	6	8	9	10	12
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428	1	3	4	5	6	8	9	10	11
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551	1	2	4	5	6	7	9	10	11
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670	1	2	4	5	6	7	8	10	11
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786	1	2	3	5	6	7	8	9	10
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899	1	2	3	5	6	7	8	9	10
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010	1	2	3	4	5	7	8	9	10
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117	1	2	3	4	5	6	8	9	10
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222	1	2	3	4	5	6	7	8	9
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325	1	2	3	4	5	6	7	8	9
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425	1	2	3	4	5	6	7	8	9
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522	1	2	3	4	5	6	7	8	9
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618	1	2	3	4	5	6	7	8	9
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712	1	2	3	4	5	6	7	7	8
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803	1	2	3	4	5	5	6	7	8
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893	1	2	3	4	4	5	6	7	8
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981	1	2	3	4	4	5	6	7	8
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067	1	2	3	3	4	5	6	7	8
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152	1	2	3	3	4	5	6	7	8
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235	1	2	2	3	4	5	6	7	7
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316	1	2	2	3	4	5	6	6	7
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396	1	2	2	3	4	5	6	6	7
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474	1	2	2	3	4	5	5	6	7
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551	1	2	2	3	4	5	5	6	7
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627	1	2	2	3	4	5	5	6	7
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701	1	1	2	3	4	4	5	6	7
59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774	1	1	2	3	4	4	5	6	7
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846	1	1	2	3	4	4	5	6	6
61	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917	1	1	2	3	4	4	5	6	6
62	7924	7931	7938	7945	7952	7959	7966	7973	7980	7987	1	1	2	3	3	4	5	6	6
63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055	1	1	2	3	3	4	5	5	6
64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122	1	1	2	3	3	4	5	5	6
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189	1	1	2	3	3	4	5	5	6
66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254	1	1	2	3	3	4	5	5	6
67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319	1	1	2	3	3	4	5	5	6
68	8325	8331	8338	8344	8351	8357	8363	8370	8376	8382	1	1	2	3	3	4	4	5	6
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445	1	1	2	2	3	4	4	5	6
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506	1	1	2	2	3	4	4	5	6
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567	1	1	2	2	3	4	4	5	5
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627	1	1	2	2	3	4	4	5	5
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686	1	1	2	2	3	4	4	5	5
74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745	1	1	2	2	3	4	4	5	5
75	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802	1	1	2	2	3	3	4	5	5
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859	1	1	2	2	3	3	4	5	5
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915	1	1	2	2	3	3	4	4	5
78	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971	1	1	2	2	3	3	4	4	5
79	8976	8982	8987	8993	8998	9004	9009	9015	9020	9025	1	1	2	2	3	3	4	4	5
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079	1	1	2	2	3	3	4	4	5
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133	1	1	2	2	3	3	4	4	5
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186	1	1	2	2	3	3	4	4	5
83	9191	9196	9201	9206	9212	9217	9222	9227	9232	9238	1	1	2	2	3	3	4	4	5
84	9243	9248	9253	9258	9263	9269	9274	9279	9284	9289	1	1	2	2	3	3	4	4	5
85	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340	1	1	2	2	3	3	4	4	5
86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390	1	1	2	2	3	3	4	4	5
87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440	0	1	1	2	2	3	3	4	4
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489	0	1	1	2	2	3	3	4	4
89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538	0	1	1	2	2	3	3	4	4
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586	0	1	1	2	2	3	3	4	4
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633	0	1	1	2	2	3	3	4	4
92	9638	9643	9647	9652	9657	9661	9666	9671	9675	9680	0	1	1	2	2	3	3	4	4
93	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727	0	1	1	2	2	3	3	4	4
94	9731	9736	9741	9745	9750	9754	9759	9763	9768	9773	0	1	1	2	2	3	3	4	4
95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818	0	1	1	2	2	3	3	4	4
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863	0	1	1	2	2	3	3	4	4
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908	0	1	1	2	2	3	3	4	4
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952	0	1	1	2	2	3	3	4	4
99	9956	9961	9965	9969	9974	9978	9983	9987	9991	9996	0	1	1	2	2	3	3	3	4

TRIGONOMETRICAL RATIOS.

Degrees.	Sin.	Cos.	Tan.	Cot.	Sec.	Cosec.	Degrees.
0°	0	1	0	∞	1	∞	90°
1	·0175	·9999	·0175	57·29	1·000	57·30	89
2	·0349	·9994	·0349	28·64	1·001	28·65	88
3	·0523	·9986	·0524	19·08	1·001	19·11	87
4	·0698	·9976	·0699	14·30	1·002	14·34	86
5	·0872	·9962	·0875	11·43	1·004	11·47	85
6	·1045	·9945	·1051	9·514	1·006	9·567	84
7	·1219	·9926	·1228	8·144	1·008	8·206	83
3	·1392	·9903	·1405	7·115	1·010	7·185	82
9	·1564	·9877	·1584	6·314	1·012	6·392	81
10	·1737	·9848	·1763	5·671	1·015	5·759	80
11	·1908	·9816	·1944	5·145	1·019	5·241	79
12	·2079	·9782	·2126	4·705	1·022	4·810	78
13	·2250	·9744	·2309	4·331	1·026	4·445	77
14	·2419	·9703	·2493	4·011	1·031	4·134	76
15	·2588	·9659	·2680	3·732	1·035	3·864	75
16	·2756	·9613	·2868	3·487	1·040	3·628	74
17	·2924	·9563	·3057	3·271	1·046	3·420	73
18	·3090	·9511	·3249	3·078	1·051	3·236	72
19	·3256	·9455	·3443	2·904	1·058	3·072	71
20	·3420	·9397	·3640	2·747	1·064	2·924	70
21	·3584	·9336	·3839	2·605	1·071	2·790	69
22	·3746	·9272	·4040	2·475	1·079	2·669	68
23	·3907	·9205	·4245	2·356	1·086	2·559	67
24	·4067	·9135	·4452	2·246	1·095	2·459	66
25	·4226	·9063	·4663	2·145	1·103	2·366	65
26	·4384	·8988	·4877	2·050	1·113	2·281	64
27	·4540	·8910	·5095	1·963	1·122	2·203	63
28	·4695	·8830	·5317	1·881	1·133	2·130	62
29	·4848	·8746	·5543	1·804	1·143	2·063	61
30	·5000	·8660	·5774	1·732	1·155	2·000	60
31	·5150	·8572	·6009	1·664	1·167	1·942	59
32	·5299	·8481	·6249	1·600	1·179	1·887	58
33	·5446	·8387	·6494	1·540	1·192	1·836	57
34	·5592	·8290	·6745	1·483	1·206	1·788	56
35	·5736	·8192	·7002	1·428	1·221	1·743	55
36	·5878	·8090	·7265	1·376	1·236	1·701	54
37	·6018	·7986	·7536	1·327	1·252	1·662	53
38	·6157	·7880	·7813	1·280	1·269	1·624	52
39	·6293	·7772	·8098	1·235	1·287	1·589	51
40	·6428	·7660	·8391	1·192	1·305	1·556	50
41	·6561	·7547	·8693	1·150	1·325	1·524	49
42	·6691	·7431	·9004	1·111	1·346	1·494	48
43	·6820	·7314	·9325	1·072	1·367	1·466	47
44	·6947	·7193	·9657	1·036	1·390	1·440	46
45°	·7071	·7071	1·000	1·000	1·414	1·414	45°
Degrees.	Cos.	Sin.	Cot.	Tan.	Cosec.	Sec.	Degrees.

TRAVERSE TABLES.

The components of geometrical resolution for obtaining the "Latitude" and "Departure" from "Course" and "Distance" or the components in the S. to N. and W. to E. direction of a vector whose magnitude and direction measured from North are specified. The vector is in all cases directed towards the origin.

The following table is a common one in books on Navigation and is used to compute the change in the geographical position of a ship from the course and distance run. The effect of the curvature of the earth is disregarded, hence the process is equivalent, with the same limitation, to "resolving" a length drawn in a specified direction into two components along and perpendicular to the meridian. The table is therefore applicable for finding the components of wind velocity from the observed velocity and direction and *vice-versâ*.

Some care is necessary in determining the proper signs to be given to the components indicated for the different angles of direction in the head and foot of the tables. From the point of view of a ship computing its new position, the distance run terminates at the new position—in geometrical language, the vector is drawn *to the origin*. In forming wind components the signs indicated in the table will be correct if the angle assigned to direction gives the point *from* which the wind comes. Thus an East wind has direction 90°.

Direction from 1° to 5° from a cardinal point.

Lat. – / Lat. + / Lat. + / Lat. –	Direction from North measured through East. 359° 181° 179° 1°		358° 182° 178° 2°		357° 183° 177° 3°		356° 184° 176° 4°		355° 185° 175° 5°		Dep. + / Dep. + / Dep. – / Dep. –
Distance.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Distance
1	1·0	0·0	1·0	0·0	1·0	0·1	1·0	0·1	1·0	0·1	1
2	2·0	0·0	2·0	0·1	2·0	0·1	2·0	0·1	2·0	0·2	2
3	3·0	0·1	3·0	0·1	3·0	0·2	3·0	0·2	3·0	0·3	3
4	4·0	0·1	4·0	0·1	4·0	0·2	4·0	0·3	4·0	0·3	4
5	5·0	0·1	5·0	0·2	5·0	0·3	5·0	0·3	5·0	0·4	5
6	6·0	0·1	6·0	0·2	6·0	0·3	6·0	0·4	6·0	0·5	6
7	7·0	0·1	7·0	0·2	7·0	0·4	7·0	0·5	7·0	0·6	7
8	8·0	0·1	8·0	0·3	8·0	0·4	8·0	0·6	8·0	0·7	8
9	9·0	0·2	9·0	0·3	9·0	0·5	9·0	0·6	9·0	0·8	9
10	10·0	0·2	10·0	0·3	10·0	0·5	10·0	0·7	10·0	0·9	10
11	11·0	0·2	11·0	0·4	11·0	0·6	11·0	0·8	11·0	1·0	11
12	12·0	0·2	12·0	0·4	12·0	0·6	12·0	0·8	12·0	1·0	12
13	13·0	0·2	13·0	0·5	13·0	0·7	13·0	0·9	13·0	1·1	13
14	14·0	0·2	14·0	0·5	14·0	0·7	14·0	1·0	13·9	1·2	14
15	15·0	0·3	15·0	0·5	15·0	0·8	15·0	1·0	14·9	1·3	15
16	16·0	0·3	16·0	0·6	16·0	0·8	16·0	1·1	15·9	1·4	16
17	17·0	0·3	17·0	0·6	17·0	0·9	17·0	1·2	16·9	1·5	17
18	18·0	0·3	18·0	0·6	18·0	0·9	18·0	1·3	17·9	1·6	18
19	19·0	0·3	19·0	0·7	19·0	1·0	19·0	1·3	18·9	1·7	19
20	20·0	0·3	20·0	0·7	20·0	1·0	20·0	1·4	19·9	1·7	20
21	21·0	0·4	21·0	0·7	21·0	1·1	20·9	1·5	20·9	1·8	21
22	22·0	0·4	22·0	0·8	22·0	1·2	21·9	1·5	21·9	1·9	22
23	23·0	0·4	23·0	0·8	23·0	1·2	22·9	1·6	22·9	2·0	23
24	24·0	0·4	24·0	0·8	24·0	1·3	23·9	1·7	23·9	2·1	24
25	25·0	0·4	25·0	0·9	25·0	1·3	24·9	1·7	24·9	2·2	25
26	26·0	0·5	26·0	0·9	26·0	1·4	25·9	1·8	25·9	2·3	26
27	27·0	0·5	27·0	0·9	27·0	1·4	26·9	1·9	26·9	2·4	27
28	28·0	0·5	28·0	1·0	28·0	1·5	27·9	2·0	27·9	2·4	28
29	29·0	0·5	29·0	1·0	29·0	1·5	28·9	2·0	28·9	2·5	29
30	30·0	0·5	30·0	1·0	30·0	1·6	29·9	2·1	29·9	2·6	30
31	31·0	0·5	31·0	1·1	31·0	1·6	30·9	2·2	30·9	2·7	31
32	32·0	0·6	32·0	1·1	32·0	1·7	31·9	2·2	31·9	2·8	32
33	33·0	0·6	33·0	1·2	33·0	1·7	32·9	2·3	32·9	2·9	33
34	34·0	0·6	34·0	1·2	34·0	1·8	33·9	2·4	33·9	3·0	34
35	35·0	0·6	35·0	1·2	35·0	1·8	34·9	2·4	34·9	3·1	35
36	36·0	0·6	36·0	1·3	36·0	1·9	35·9	2·5	35·9	3·1	36
37	37·0	0·6	37·0	1·3	36·9	1·9	36·9	2·6	36·9	3·2	37
38	38·0	0·7	38·0	1·3	37·9	2·0	37·9	2·7	37·9	3·3	38
39	39·0	0·7	39·0	1·4	38·9	2·0	38·9	2·7	38·9	3·4	39
40	40·0	0·7	40·0	1·4	39·9	2·1	39·9	2·8	39·8	3·5	40
41	41·0	0·7	41·0	1·4	40·9	2·1	40·9	2·9	40·8	3·6	41
42	42·0	0·7	42·0	1·5	41·9	2·2	41·9	2·9	41·8	3·7	42
43	43·0	0·8	43·0	1·5	42·9	2·3	42·9	3·0	42·8	3·7	43
44	44·0	0·8	44·0	1·5	43·9	2·3	43·9	3·1	43·8	3·8	44
45	45·0	0·8	45·0	1·6	44·9	2·4	44·9	3·1	44·8	3·9	45
46	46·0	0·8	46·0	1·6	45·9	2·4	45·9	3·2	45·8	4·0	46
47	47·0	0·8	47·0	1·6	46·9	2·5	46·9	3·3	46·8	4·1	47
48	48·0	0·8	48·0	1·7	47·9	2·5	47·9	3·3	47·8	4·2	48
49	49·0	0·9	49·0	1·7	48·9	2·6	48·9	3·4	48·8	4·3	49
50	50·0	0·9	50·0	1·7	49·9	2·6	49·9	3·5	49·8	4·4	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
Dep. – / Dep. – / Dep. + / Dep. +	89° 91° 269° 271°		88° 92° 268° 272°		87° 93° 267° 273°		86° 94° 266° 274°		85° 95° 265° 275° Direction measured from North through East.		Lat. – / Lat. + / Lat. + / Lat. –

Vector directed towards origin. "Latitude" is component in S. and N. direction. "Departure" is component in W. and E. direction.

Direction from 6° to 10° from a cardinal point.

Lat. – / Lat. + / Lat. + / Lat. –	Direction measured from North through East. 354° 186° 174° 6°		353° 187° 173° 7°		352° 188° 172° 8°		351° 189° 171° 9°		350° 190° 170° 10°		Dep. + / Dep. + / Dep. – / Dep. –
Distance	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Distance.
1	1·0	0·1	1·0	0·1	1·0	0·1	1·0	0·2	1·0	0·2	1
2	2·0	0·2	2·0	0·2	2·0	0·3	2·0	0·3	2·0	0·3	2
3	3·0	0·3	3·0	0·4	3·0	0·4	3·0	0·5	3·0	0·5	3
4	4·0	0·4	4·0	0·5	4·0	0·6	4·0	0·6	3·9	0·7	4
5	5·0	0·5	5·0	0·6	5·0	0·7	4·9	0·8	4·9	0·9	5
6	6·0	0·6	6·0	0·7	5·9	0·8	5·9	0·9	5·9	1·0	6
7	7·0	0·7	6·9	0·9	6·9	1·0	6·9	1·1	6·9	1·2	7
8	8·0	0·8	7·9	1·0	7·9	1·1	7·9	1·3	7·9	1·4	8
9	9·0	0·9	8·9	1·1	8·9	1·3	8·9	1·4	8·9	1·6	9
10	9·9	1·0	9·9	1·2	9·9	1·4	9·9	1·6	9·8	1·7	10
11	10·9	1·1	10·9	1·3	10·9	1·5	10·9	1·7	10·8	1·9	11
12	11·9	1·3	11·9	1·5	11·9	1·7	11·9	1·9	11·8	2·1	12
13	12·9	1·4	12·9	1·6	12·9	1·8	12·8	2·0	12·8	2·3	13
14	13·9	1·5	13·9	1·7	13·9	1·9	13·8	2·2	13·8	2·4	14
15	14·9	1·6	14·9	1·8	14·9	2·1	14·8	2·3	14·8	2·6	15
16	15·9	1·7	15·9	1·9	15·8	2·2	15·8	2·5	15·8	2·8	16
17	16·9	1·8	16·9	2·1	16·8	2·4	16·8	2·7	16·7	3·0	17
18	17·9	1·9	17·9	2·2	17·8	2·5	17·8	2·8	17·7	3·1	18
19	18·9	2·0	18·9	2·3	18·8	2·6	18·8	3·0	18·7	3·3	19
20	19·9	2·1	19·9	2·4	19·8	2·8	19·8	3·1	19·7	3·5	20
21	20·9	2·2	20·8	2·6	20·8	2·9	20·7	3·3	20·7	3·6	21
22	21·9	2·3	21·8	2·7	21·8	3·1	21·7	3·4	21·7	3·8	22
23	22·9	2·4	22·8	2·8	22·8	3·2	22·7	3·6	22·7	4·0	23
24	23·9	2·5	23·8	2·9	23·8	3·3	23·7	3·8	23·6	4·2	24
25	24·9	2·6	24·8	3·0	24·8	3·5	24·7	3·9	24·6	4·3	25
26	25·9	2·7	25·8	3·2	25·7	3·6	25·7	4·1	25·6	4·5	26
27	26·9	2·8	26·8	3·3	26·7	3·8	26·7	4·2	26·6	4·7	27
28	27·8	2·9	27·8	3·4	27·7	3·9	27·7	4·4	27·6	4·9	28
29	28·8	3·0	28·8	3·5	28·7	4·0	28·6	4·5	28·6	5·0	29
30	29·8	3·1	29·8	3·7	29·7	4·2	29·6	4·7	29·5	5·2	30
31	30·8	3·2	30·8	3·8	30·7	4·3	30·6	4·8	30·5	5·4	31
32	31·8	3·3	31·8	3·9	31·7	4·5	31·6	5·0	31·5	5·6	32
33	32·8	3·4	32·8	4·0	32·7	4·6	32·6	5·2	32·5	5·7	33
34	33·8	3·6	33·7	4·1	33·7	4·7	33·6	5·3	33·5	5·9	34
35	34·8	3·7	34·7	4·3	34·7	4·9	34·6	5·5	34·5	6·1	35
36	35·8	3·8	35·7	4·4	35·6	5·0	35·6	5·6	35·5	6·3	36
37	36·8	3·9	36·7	4·5	36·6	5·1	36·5	5·8	36·4	6·4	37
38	37·8	4·0	37·7	4·6	37·6	5·3	37·5	5·9	37·4	6·6	38
39	38·8	4·1	38·7	4·8	38·6	5·4	38·5	6·1	38·4	6·8	39
40	39·8	4·2	39·7	4·9	39·6	5·6	39·5	6·3	39·4	6·9	40
41	40·8	4·3	40·7	5·0	40·6	5·7	40·5	6·4	40·4	7·1	41
42	41·8	4·4	41·7	5·1	41·6	5·8	41·5	6·6	41·4	7·3	42
43	42·8	4·5	42·7	5·2	42·6	6·0	42·5	6·7	42·3	7·5	43
44	43·8	4·6	43·7	5·4	43·6	6·1	43·5	6·9	43·3	7·6	44
45	44·8	4·7	44·7	5·5	44·6	6·3	44·4	7·0	44·3	7·8	45
46	45·7	4·8	45·7	5·6	45·6	6·4	45·4	7·2	45·3	8·0	46
47	46·7	4·9	46·6	5·7	46·5	6·5	46·4	7·4	46·3	8·2	47
48	47·7	5·0	47·6	5·8	47·5	6·7	47·4	7·5	47·3	8·3	48
49	48·7	5·1	48·6	6·0	48·5	6·8	48·4	7·7	48·3	8·5	49
50	49·7	5·2	49·6	6·1	49·5	7·0	49·4	7·8	49·2	8·7	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
Dep. – / Dep. – / Dep. + / Dep. +	84° 96° 264° 276°		83° 97° 263° 277°		82° 98° 262° 278°		81° 99° 261° 279°		80° 100° 260° 280° Direction measured from North through East.		Lat. – / Lat. + / Lat. + / Lat. –

Vector directed towards origin. "Latitude" is component in S. and N. direction. "Departure" is component in W. and E. direction.

Direction from 11° to 15° from a cardinal point.

Lat. − / Lat. + / Lat. + / Lat. −	Direction measured from North through East. 349° 191° 169° 11°		348° 192° 168° 12°		347° 193° 167° 13°		346° 194° 166° 14°		345° 195° 165° 15°		Dep. + / Dep. + / Dep. − / Dep. −
Distance.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Distance.
1	1·0	0·2	1·0	0·2	1·0	0·2	1·0	0·2	1·0	0·3	1
2	2·0	0·4	2·0	0·4	1·9	0·4	1·9	0·5	1·9	0·5	2
3	2·9	0·6	2·9	0·6	2·9	0·7	2·9	0·7	2·9	0·8	3
4	3·9	0·8	3·9	0·8	3·9	0·9	3·9	1·0	3·9	1·0	4
5	4·9	1·0	4·9	1·0	4·9	1·1	4·9	1·2	4·8	1·3	5
6	5·9	1·1	5·9	1·2	5·8	1·3	5·8	1·5	5·8	1·6	6
7	6·9	1·3	6·8	1·5	6·8	1·6	6·8	1·7	6·8	1·8	7
8	7·9	1·5	7·8	1·7	7·8	1·8	7·8	1·9	7·7	2·1	8
9	8·8	1·7	8·8	1·9	8·8	2·0	8·7	2·2	8·7	2·3	9
10	9·8	1·9	9·8	2·1	9·7	2·2	9·7	2·4	9·7	2·6	10
11	10·8	2·1	10·8	2·3	10·7	2·5	10·7	2·7	10·6	2·8	11
12	11·8	2·3	11·7	2·5	11·7	2·7	11·6	2·9	11·6	3·1	12
13	12·8	2·5	12·7	2·7	12·7	2·9	12·6	3·1	12·6	3·4	13
14	13·7	2·7	13·7	2·9	13·6	3·1	13·6	3·4	13·5	3·6	14
15	14·7	2·9	14·7	3·1	14·6	3·4	14·6	3·6	14·5	3·9	15
16	15·7	3·1	15·7	3·3	15·6	3·6	15·5	3·9	15·5	4·1	16
17	16·7	3·2	16·6	3·5	16·6	3·8	16·5	4·1	16·4	4·4	17
18	17·7	3·4	17·6	3·7	17·5	4·0	17·5	4·4	17·4	4·7	18
19	18·7	3·6	18·6	4·0	18·5	4·3	18·4	4·6	18·4	4·9	19
20	19·6	3·8	19·6	4·2	19·5	4·5	19·4	4·8	19·3	5·2	20
21	20·6	4·0	20·5	4·4	20·5	4·7	20·4	5·1	20·3	5·4	21
22	21·6	4·2	21·5	4·6	21·4	4·9	21·3	5·3	21·3	5·7	22
23	22·6	4·4	22·5	4·8	22·4	5·2	22·3	5·6	22·2	6·0	23
24	23·6	4·6	23·5	5·0	23·4	5·4	23·3	5·8	23·2	6·2	24
25	24·5	4·8	24·5	5·2	24·4	5·6	24·3	6·0	24·1	6·5	25
26	25·5	5·0	25·4	5·4	25·3	5·8	25·2	6·3	25·1	6·7	26
27	26·5	5·2	26·4	5·6	26·3	6·1	26·2	6·5	26·1	7·0	27
28	27·5	5·3	27·4	5·8	27·3	6·3	27·2	6·8	27·0	7·2	28
29	28·5	5·5	28·4	6·0	28·3	6·5	28·1	7·0	28·0	7·5	29
30	29·4	5·7	29·3	6·2	29·2	6·7	29·1	7·3	29·0	7·8	30
31	30·4	5·9	30·3	6·4	30·2	7·0	30·1	7·5	29·9	8·0	31
32	31·4	6·1	31·3	6·7	31·2	7·2	31·0	7·7	30·9	8·3	32
33	32·4	6·3	32·3	6·9	32·2	7·4	32·0	8·0	31·9	8·5	33
34	33·4	6·5	33·3	7·1	33·1	7·6	33·0	8·2	32·8	8·8	34
35	34·4	6·7	34·2	7·3	34·1	7·9	34·0	8·5	33·8	9·1	35
36	35·3	6·9	35·2	7·5	35·1	8·1	34·9	8·7	34·8	9·3	36
37	36·3	7·1	36·2	7·7	36·1	8·3	35·9	9·0	35·7	9·6	37
38	37·3	7·3	37·2	7·9	37·0	8·5	36·9	9·2	36·7	9·8	38
39	38·3	7·4	38·1	8·1	38·0	8·8	37·8	9·4	37·7	10·1	39
40	39·3	7·6	39·1	8·3	39·0	9·0	38·8	9·7	38·6	10·4	40
41	40·2	7·8	40·1	8·5	39·9	9·2	39·8	9·9	39·6	10·6	41
42	41·2	8·0	41·1	8·7	40·9	9·4	40·8	10·2	40·6	10·9	42
43	42·2	8·2	42·1	8·9	41·9	9·7	41·7	10·4	41·5	11·1	43
44	43·2	8·4	43·0	9·1	42·9	9·9	42·7	10·6	42·5	11·4	44
45	44·2	8·6	44·0	9·4	43·8	10·1	43·7	10·9	43·5	11·6	45
46	45·2	8·8	45·0	9·6	44·8	10·3	44·6	11·1	44·4	11·9	46
47	46·1	9·0	46·0	9·8	45·8	10·6	45·6	11·4	45·4	12·2	47
48	47·1	9·2	47·0	10·0	46·8	10·8	46·6	11·6	46·4	12·4	48
49	48·1	9·3	47·9	10·2	47·7	11·0	47·5	11·9	47·3	12·7	49
50	49·1	9·5	48·9	10·4	48·7	11·2	48·5	12·1	48·3	12·9	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
Dep. − / Dep. − / Dep. + / Dep. +	79° 101° 259° 281°		78° 102° 258° 282°		77° 103° 257° 283°		76° 104° 256° 284°		75° 105° 255° 285°		Lat. − / Lat. + / Lat. + / Lat. −
	Direction measured from North through East.										

Vector directed towards origin. "Latitude" is component in S. and N. direction. "Departure" is component in W. and E. direction.

Direction from 16° to 20° from a cardinal point.

Lat. − / Lat. + / Lat. + / Lat. −	Direction measured from North through East. 344° 196° 164° 16°		343° 197° 163° 17°		342° 198° 162° 18°		341° 199° 161° 19°		340° 200° 160° 20°		Dep. + / Dep. + / Dep. − / Dep. −
Distance.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Distance.
1	1·0	0·3	1·0	0·3	1·0	0·3	0·9	0·3	0·9	0·3	1
2	1·9	0·6	1·9	0·6	1·9	0·6	1·9	0·7	1·9	0·7	2
3	2·9	0·8	2·9	0·9	2·9	0·9	2·8	1·0	2·8	1·0	3
4	3·8	1·1	3·8	1·2	3·8	1·2	3·8	1·3	3·8	1·4	4
5	4·8	1·4	4·8	1·5	4·8	1·5	4·7	1·6	4·7	1·7	5
6	5·8	1·7	5·7	1·8	5·7	1·9	5·7	2·0	5·6	2·1	6
7	6·7	1·9	6·7	2·0	6·7	2·2	6·6	2·3	6·6	2·4	7
8	7·7	2·2	7·7	2·3	7·6	2·5	7·6	2·6	7·5	2·7	8
9	8·7	2·5	8·6	2·6	8·6	2·8	8·5	2·9	8·5	3·1	9
10	9·6	2·8	9·6	2·9	9·5	3·1	9·5	3·3	9·4	3·4	10
11	10·6	3·0	10·5	3·2	10·5	3·4	10·4	3·6	10·3	3·8	11
12	11·5	3·3	11·5	3·5	11·4	3·7	11·3	3·9	11.3	4·1	12
13	12·5	3·6	12·4	3·8	12·4	4·0	12·3	4·2	12·2	4·4	13
14	13·5	3·9	13·4	4·1	13·3	4·3	13·2	4·6	13·2	4·8	14
15	14·4	4·1	14·3	4·4	14·3	4·6	14·2	4·9	14·1	5·1	15
16	15·4	4·4	15·3	4·7	15·2	4·9	15·1	5·2	15·0	5·5	16
17	16·3	4·7	16·3	5·0	16·2	5·3	16·1	5·5	16·0	5·8	17
18	17·3	5·0	17·2	5·3	17·1	5·6	17·0	5·9	16·9	6·2	18
19	18·3	5·2	18·2	5·6	18·1	5·9	18·0	6·2	17·9	6·5	19
20	19·2	5·5	19·1	5·8	19·0	6·2	18·9	6·5	18·8	6·8	20
21	20·2	5·8	20·1	6·1	20·0	6·5	19·9	6·8	19·7	7·2	21
22	21·1	6·1	21·0	6·4	20·9	6·8	20·8	7·2	20·7	7·5	22
23	22·1	6·3	22·0	6·7	21·9	7·1	21·7	7·5	21·6	7·9	23
24	23·1	6·6	23·0	7·0	22·8	7·4	22·7	7·8	22·6	8·2	24
25	24·0	6·9	23·9	7·3	23·8	7·7	23·6	8·1	23·5	8·6	25
26	25·0	7·2	24·9	7·6	24·7	8·0	24·6	8·5	24·4	8·9	26
27	26·0	7·4	25·8	7·9	25·7	8·3	25·5	8·8	25·4	9·2	27
28	26·9	7·7	26·8	8·2	26·6	8·7	26·5	9·1	26·3	9·6	28
29	27·9	8·0	27·7	8·5	27·6	9·0	27·4	9·4	27·3	9·9	29
30	28·8	8·3	28·7	8·8	28·5	9·3	28·4	9·8	28·2	10·3	30
31	29·8	8·5	29·6	9·1	29·5	9·6	29·3	10·1	29·1	10·6	31
32	30·8	8·8	30·6	9·4	30·4	9·9	30·3	10·4	30·1	10·9	32
33	31·7	9·1	31·6	9·6	31·4	10·2	31·2	10·7	31·0	11·3	33
34	32·7	9·4	32·5	9·9	32·3	10·5	32·1	11·1	31·9	11·6	34
35	33·6	9·6	33·5	10·2	33·3	10·8	33·1	11·4	32·9	12·0	35
36	34·6	9·9	34·4	10·5	34·2	11·1	34·0	11·7	33·8	12·3	36
37	35·6	10·2	35·4	10·8	35·2	11·4	35·0	12·0	34·8	12·7	37
38	36·5	10·5	36·3	11·1	36·1	11·7	35·9	12·4	35·7	13·0	38
39	37·5	10·7	37·3	11·4	37·1	12·1	36·9	12·7	36·6	13·3	39
40	38·5	11·0	38·3	11·7	38·0	12·4	37·8	13·0	37·6	13·7	40
41	39·4	11·3	39·2	12·0	39·0	12·7	38·8	13·3	38·5	14·0	41
42	40·4	11·6	40·2	12·3	39·9	13·0	39·7	13·7	39·5	14·4	42
43	41·3	11·9	41·1	12·6	40·9	13·3	40·7	14·0	40·4	14·7	43
44	42·3	12·1	42·1	12·9	41·8	13·6	41·6	14·3	41·3	15·0	44
45	43·3	12·4	43·0	13·2	42·8	13·9	42·5	14·7	42·3	15·4	45
46	44·2	12·7	44·0	13·4	43·7	14·2	43·5	15·0	43·2	15·7	46
47	45·2	13·0	44·9	13·7	44·7	14·5	44·4	15·3	44·2	16·1	47
48	46·1	13·2	45·9	14·0	45·7	14·8	45·4	15·6	45·1	16·4	48
49	47·1	13·5	46·9	14·3	46·6	15·1	46·3	16·0	46·0	16·8	49
50	48·1	13·8	47·8	14·6	47·6	15·5	47·3	16·3	47·0	17·1	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
Dep. − / Dep. − / Dep. + / Dep. +	74° 106° 254° 286°		73° 107° 253° 287°		72° 108° 252° 288°		71° 109° 251° 289°		70° 110° 250° 290°		Lat. − / Lat. + / Lat. + / Lat. −
	Direction measured from North through East.										

Vector directed towards origin. "Latitude" is component in S. and N. direction. "Departure" is component in W. and E. direction.

Direction from 21° to 25° from a cardinal point.

Direction measured from East through North.											
Lat. − Lat. + Lat. + Lat. −	339° 201° 159° 21°		338° 202° 158° 22°		337° 203° 157° 23°		336° 204° 156° 24°		335° 205° 155° 25°		Dep. + Dep. + Dep. − Dep. −
Distance.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Distance.
1	0·9	0·4	0·9	0·4	0·9	0·4	0·9	0·4	0·9	0·4	1
2	1·9	0·7	1·9	0·7	1·8	0·8	1·8	0·8	1·8	0·8	2
3	2·8	1·1	2·8	1·1	2·8	1·2	2·7	1·2	2·7	1·3	3
4	3·7	1·4	3·7	1·5	3·7	1·6	3·7	1·6	3·6	1·7	4
5	4·7	1·8	4·6	1·9	4·6	2·0	4·6	2·0	4·5	2·1	5
6	5·6	2·2	5·6	2·2	5·5	2·3	5·5	2·4	5·4	2·5	6
7	6·5	2·5	6·5	2·6	6·4	2·7	6·4	2·8	6·3	3·0	7
8	7·5	2·9	7·4	3·0	7·4	3·1	7·3	3·3	7·3	3·4	8
9	8·4	3·2	8·3	3·4	8·3	3·5	8·2	3·7	8·2	3·8	9
10	9·3	3·6	9·3	3·7	9·2	3·9	9·1	4·1	9·1	4·2	10
11	10·3	3·9	10·2	4·1	10·1	4·3	10·0	4·5	10·0	4·6	11
12	11·2	4·3	11·1	4·5	11·0	4·7	11·0	4·9	10·9	5·1	12
13	12·1	4·7	12·1	4·9	12·0	5·1	11·9	5·3	11·8	5·5	13
14	13·1	5·0	13·0	5·2	12·9	5·5	12·8	5·7	12·7	5·9	14
15	14·0	5·4	13·9	5·6	13·8	5·9	13·7	6·1	13·6	6·3	15
16	14·9	5·7	14·8	6·0	14·7	6·3	14·6	6·5	14·5	6·8	16
17	15·9	6·1	15·8	6·4	15·6	6·6	15·5	6·9	15·4	7·2	17
18	16·8	6·5	16·7	6·7	16·6	7·0	16·4	7·3	16·3	7·6	18
19	17·7	6·8	17·6	7·1	17·5	7·4	17·4	7·7	17·2	8·0	19
20	18·7	7·2	18·5	7·5	18·4	7·8	18·3	8·1	18·1	8·5	20
21	19·6	7·5	19·5	7·9	19·3	8·2	19·2	8·5	19·0	8·9	21
22	20·5	7·9	20·4	8·2	20·3	8·6	20·1	8·9	19·9	9·3	22
23	21·5	8·2	21·3	8·6	21·2	9·0	21·0	9·4	20·8	9·7	23
24	22·4	8·6	22·3	9·0	22·1	9·4	21·9	9 8	21·8	10·1	24
25	23·3	9·0	23·2	9·4	23·0	9·8	22·8	10·2	22·7	10·6	25
26	24·3	9·3	24·1	9·7	23·9	10·2	23·8	10·6	23·6	11·0	26
27	25·2	9·7	25·0	10·1	24·9	10·5	24·7	11·0	24·5	11·4	27
28	26·1	10·0	26·0	10·5	25·8	10·9	25·6	11·4	25·4	11·8	28
29	27·1	10·4	26·9	10·9	26·7	11·3	26·5	11·8	26·3	12·3	29
30	28·0	10·8	27·8	11·2	27·6	11·7	27·4	12·2	27·2	12·7	30
31	28·9	11·1	28·7	11·6	28·5	12·1	28·3	12·6	28·1	13·1	31
32	29·9	11·5	29·7	12·0	29·5	12·5	29·2	13·0	29·0	13·5	32
33	30·8	11·8	30·6	12·4	30·4	12·9	30·1	13·4	29·9	13·9	33
34	31·7	12·2	31·5	12·7	31·3	13·3	31·1	13·8	30·8	14·4	34
35	32·7	12·5	32·5	13·1	32·2	13·7	32·0	14·2	31·7	14·8	35
36	33·6	12·9	33·4	13·5	33·1	14·1	32·9	14·6	32·6	15·2	36
37	34·5	13·3	34·3	13·9	34·1	14·5	33·8	15·0	33·5	15·6	37
38	35·5	13·6	35·2	14·2	35·0	14·8	34·7	15·5	34·4	16·1	38
39	36·4	14·0	36·2	14·6	35·9	15·2	35·6	15·9	35·3	16·5	39
40	37·3	14·3	37·1	15·0	36·8	15·6	36·5	16·3	36·3	16·9	40
41	38·3	14·7	38·0	15·4	37·7	16·0	37·5	16·7	37·2	17·3	41
42	39·2	15·1	38·9	15·7	38·7	16·4	38·4	17·1	38·1	17·7	42
43	40·1	15·4	39·9	16·1	39·6	16·8	39·3	17·5	39·0	18·2	43
44	41·1	15·8	40·8	16·5	40·5	17·2	40·2	17·9	39·9	18·6	44
45	42·0	16·1	41·7	16·9	41·4	17·6	41·1	18·3	40·8	19·0	45
46	42·9	16·5	42·7	17·2	42·3	18·0	42·0	18·7	41·7	19·4	46
47	43·9	16·8	43·6	17·6	43·3	18·4	42·9	19·1	42·6	19·9	47
48	44·8	17·2	44·5	18·0	44·2	18·8	43·9	19·5	43·5	20·3	48
49	45·7	17·6	45·4	18·4	45·1	19·1	44·8	19·9	44·4	20·7	49
50	46·7	17·9	46·4	18·7	46·0	19·5	45·7	20·3	45·3	21·1	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
Dep. − Dep. − Dep. + Dep. +	69° 111° 249° 291°		68° 112° 248° 292°		67° 113° 247° 293°		66° 114° 246° 294°		65° 115° 245° 295°		Lat. − Lat. + Lat. + Lat. −
Direction measured from North through East.											

Vector directed towards origin. "Latitude" is component in S. and N. direction. "Departure" is component in W. and E. direction.

Direction from 26° to 30° from a cardinal point.

Direction measured from North through East.											
Lat. − Lat. + Lat. + Lat. −	334° 206° 154° 26°		333° 207° 153° 27°		332° 208° 152° 28°		331° 209° 151° 29°		330° 210° 150° 30°		Dep. + Dep. + Dep. − Dep. −
Distance.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Distance.
1	0·9	0·4	0·9	0·5	0·9	0·5	0·9	0·5	0·9	0·5	1
2	1·8	0·9	1·8	0·9	1·8	0·9	1·7	1·0	1·7	1·0	2
3	2·7	1·3	2·7	1·4	2·6	1·4	2·6	1·5	2·6	1·5	3
4	3·6	1·8	3·6	1·8	3·5	1·9	3·5	1·9	3·5	2·0	4
5	4·5	2·2	4·5	2·3	4·4	2·3	4·4	2·4	4·3	2·5	5
6	5·4	2·6	5·3	2·7	5·3	2·8	5·2	2·9	5·2	3·0	6
7	6·3	3·1	6·2	3·2	6·2	3·3	6·1	3·4	6·1	3·5	7
8	7·2	3·5	7·1	3·6	7·1	3·8	7·0	3·9	6·9	4·0	8
9	8·1	3·9	8·0	4·1	7·9	4·2	7·9	4·4	7·8	4·5	9
10	9·0	4·4	8·9	4·5	8·8	4·7	8·7	4·8	8·7	5·0	10
11	9·9	4·8	9·8	5·0	9·7	5·2	9·6	5·3	9·5	5·5	11
12	10·8	5·3	10·7	5·4	10·6	5·6	10·5	5·8	10·4	6·0	12
13	11·7	5·7	11·6	5·9	11·5	6·1	11·4	6·3	11·3	6·5	13
14	12·6	6·1	12·5	6·4	12·4	6·6	12·2	6·8	12·1	7·0	14
15	13·5	6·6	13·4	6·8	13·2	7·0	13·1	7·3	13·0	7·5	15
16	14·4	7·0	14·3	7·3	14·1	7·5	14·0	7·8	13·9	8·0	16
17	15·3	7·5	15·1	7·7	15·0	8·0	14·9	8·2	14·7	8·5	17
18	16·2	7·9	16·0	8·2	15·9	8·5	15·7	8·7	15·6	9·0	18
19	17·1	8·3	16·9	8·6	16·8	8·9	16·6	9·2	16·5	9·5	19
20	18·0	8·8	17·8	9·1	17·7	9·4	17·5	9·7	17·3	10·0	20
21	18·9	9·2	18·7	9·5	18·5	9·9	18·4	10·2	18·2	10·5	21
22	19·8	9·6	19·6	10·0	19·4	10·3	19·2	10·7	19·1	11·0	22
23	20·7	10·1	20·5	10·4	20·3	10·8	20·1	11·2	19·9	11·5	23
24	21·6	10·5	21·4	10·9	21·2	11·3	21·0	11·6	20·8	12·0	24
25	22·5	11·0	22·3	11·3	22·1	11·7	21·9	12·1	21·7	12·5	25
26	23·4	11·4	23·2	11·8	23·0	12·2	22·7	12·6	22·5	13·0	26
27	24·3	11·8	24·1	12·3	23·8	12·7	23·6	13·1	23·4	13·5	27
28	25·2	12·3	24·9	12·7	24·7	13·1	24·5	13·6	24·2	14·0	28
29	26·1	12·7	25·8	13·2	25·6	13·6	25·4	14·1	25·1	14·5	29
30	27·0	13·2	26·7	13·6	26·5	14·1	26·2	14·5	26·0	15·0	30
31	27·9	13·6	27·6	14·1	27·4	14·6	27·1	15·0	26·8	15·5	31
32	28·8	14·0	28·5	14·5	28·3	15·0	28·0	15·5	27·7	16·0	32
33	29·7	14·5	29·4	15·0	29·1	15·5	28·9	16·0	28·6	16·5	33
34	30·6	14·9	30·3	15·4	30·0	16·0	29·7	16·5	29·4	17·0	34
35	31·5	15·3	31·2	15·9	30·9	16·4	30·6	17·0	30·3	17·5	35
36	32·4	15·8	32·1	16·3	31·8	16·9	31·5	17·5	31·2	18·0	36
37	33·3	16·2	33·0	16·8	32·7	17·4	32·4	17·9	32·0	18·5	37
38	34·2	16·7	33·9	17·3	33·6	17·8	33·2	18·4	32·9	19·0	38
39	35·1	17·1	34·7	17·7	34·4	18·3	34·1	18·9	33·8	19·5	39
40	36·0	17·5	35·6	18·2	35·3	18·8	35·0	19·4	34·6	20·0	40
41	36·9	18·0	36·5	18·6	36·2	19·2	35·9	19·9	35·5	20·5	41
42	37·7	18·4	37·4	19·1	37·1	19·7	36·7	20·4	36·4	21·0	42
43	38·6	18·8	38·3	19·5	38·0	20·2	37·6	20·8	37·2	21·5	43
44	39·5	19·3	39·2	20·0	38·8	20·7	38·5	21·3	38·1	22·0	44
45	40·4	19·7	40·1	20·4	39·7	21·1	39·4	21·8	39·0	22·5	45
46	41·3	20·2	41·0	20·9	40·6	21·6	40·2	22·3	39·8	23·0	46
47	42·2	20·6	41·9	21·3	41·5	22·1	41·1	22·8	40·7	23·5	47
48	43·1	21·0	42·8	21·8	42·4	22·5	42·0	23·3	41·6	24·0	48
49	44·0	21·5	43·7	22·2	43·3	23·0	42·9	23·8	42·4	24·5	49
50	44·9	21·9	44·6	22·7	44·1	23·5	43·7	24·2	43·3	25·0	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
Dep. − Dep. − Dep. + Dep. +	64° 116° 244° 296°		63° 117° 243° 297°		62° 118° 242° 298°		61° 119° 241° 299°		60° 120° 240° 300°		Lat. − Lat. + Lat. + Lat. −
Direction measured from North through East.											

Vector directed towards origin. "Latitude" is component in S. and N. direction. "Departure" is component in W. and E. direction.

Direction from 31° to 35° from a cardinal point.

	Direction measured from North through East.										
Lat. − Lat. + Lat. + Lat. −	329° 211° 149° 31°		328° 212° 148° 32°		327° 213° 147° 33°		326° 214° 146° 34°		325° 215° 145° 35°		Dep. + Dep. + Dep. − Dep. −
Distance.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Distance.
1	0·9	0·5	0·8	0·5	0·8	0·5	0·8	0·6	0·8	0·6	1
2	1·7	1·0	1·7	1·1	1·7	1·1	1·7	1·1	1·6	1·1	2
3	2·6	1·5	2·5	1·6	2·5	1·6	2·5	1·7	2·5	1·7	3
4	3·4	2·1	3·4	2·1	3·4	2·2	3·3	2·2	3·3	2·3	4
5	4·3	2·6	4·2	2·6	4·2	2·7	4·1	2·8	4·1	2·9	5
6	5·1	3·1	5·1	3·2	5·0	3·3	5·0	3·4	4·9	3·4	6
7	6·0	3·6	5·9	3·7	5·9	3·8	5·8	3·9	5·7	4·0	7
8	6·9	4·1	6·8	4·2	6·7	4·4	6·6	4·5	6·6	4·6	8
9	7·7	4·6	7·6	4·8	7·5	4·9	7·5	5·0	7·4	5·2	9
10	8·6	5·2	8·5	5·3	8·4	5·4	8·3	5·6	8·2	5·7	10
11	9·4	5·7	9·3	5·8	9·2	6·0	9·1	6·2	9·0	6·3	11
12	10·3	6·2	10·2	6·4	10·1	6·5	9·9	6·7	9·8	6·9	12
13	11·1	6·7	11·0	6·9	10·9	7·1	10·8	7·3	10·6	7·5	13
14	12·0	7·2	11·9	7·4	11·7	7·6	11·6	7·8	11·5	8·0	14
15	12·9	7·7	12·7	7·9	12·6	8·2	12·4	8·4	12·3	8·6	15
16	13·7	8·2	13·6	8·5	13·4	8·7	13·3	8·9	13·1	9·2	16
17	14·6	8·8	14·4	9·0	14·3	9·3	14·1	9·5	13·9	9·8	17
18	15·4	9·3	15·3	9·5	15·1	9·8	14·9	10·1	14·7	10·3	18
19	16·3	9·8	16·1	10·1	15·9	10·3	15·8	10·6	15·6	10·9	19
20	17·1	10·3	17·0	10·6	16·8	10·9	16·6	11·2	16·4	11·5	20
21	18·0	10·8	17·8	11·1	17·6	11·4	17·4	11·7	17·2	12·0	21
22	18·9	11·3	18·7	11·7	18·5	12·0	18·2	12·3	18·0	12·6	22
23	19·7	11·8	19·5	12·2	19·3	12·5	19·1	12·9	18·8	13·2	23
24	20·6	12·4	20·4	12·7	20·1	13·1	19·9	13·4	19·7	13·8	24
25	21·4	12·9	21·2	13·2	21·0	13·6	20·7	14·0	20·5	14·3	25
26	22·3	13·4	22·0	13·8	21·8	14·2	21·6	14·5	21·3	14·9	26
27	23·1	13·9	22·9	14·3	22·6	14·7	22·4	15·1	22·1	15·5	27
28	24·0	14·4	23·7	14·8	23·5	15·2	23·2	15·7	22·9	16·1	28
29	24·9	14·9	24·6	15·4	24·3	15·8	24·0	16·2	23·8	16·6	29
30	25·7	15·5	25·4	15·9	25·2	16·3	24·9	16·8	24·6	17·2	30
31	26·6	16·0	26·3	16·4	26·0	16·9	25·7	17·3	25·4	17·8	31
32	27·4	16·5	27·1	17·0	26·8	17·4	26·5	17·9	26·2	18·4	32
33	28·3	17·0	28·0	17·5	27·7	18·0	27·4	18·5	27·0	18·9	33
34	29·1	17·5	28·8	18·0	28·5	18·5	28·2	19·0	27·9	19·5	34
35	30·0	18·0	29·7	18·5	29·4	19·1	29·0	19·6	28·7	20·1	35
36	30·9	18·5	30·5	19·1	30·2	19·6	29·8	20·1	29·5	20·6	36
37	31·7	19·1	31·4	19·6	31·0	20·2	30·7	20·7	30·3	21·2	37
38	32·6	19·6	32·2	20·1	31·9	20·7	31·5	21·2	31·1	21·8	38
39	33·4	20·1	33·1	20·7	32·7	21·2	32·3	21·8	31·9	22·4	39
40	34·3	20·6	33·9	21·2	33·5	21·8	33·2	22·4	32·8	22·9	40
41	35·1	21·1	34·8	21·7	34·4	22·3	34·0	22·9	33·6	23·5	41
42	36·0	21·6	35·6	22·3	35·2	22·9	34·8	23·5	34·4	24·1	42
43	36·9	22·1	36·5	22·8	36·1	23·4	35·6	24·0	35·2	24·7	43
44	37·7	22·7	37·3	23·3	36·9	24·0	36·5	24·6	36·0	25·2	44
45	38·6	23·2	38·2	23·8	37·7	24·5	37·3	25·2	36·9	25·8	45
46	39·4	23·7	39·0	24·4	38·6	25·1	38·1	25·7	37·7	26·4	46
47	40·3	24·2	39·9	24·9	39·4	25·6	39·0	26·3	38·5	27·0	47
48	41·1	24·7	40·7	25·4	40·3	26·1	39·8	26·8	39·3	27·5	48
49	42·0	25·2	41·6	26·0	41·1	26·7	40·6	27·4	40·1	28·1	49
50	42·9	25·8	42·4	26·5	41·9	27·2	41·5	28·0	41·0	28·7	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
Dep. − Dep. − Dep. + Dep. +	59° 121° 239° 301°		58° 122° 238° 302°		57° 123° 237° 303°		56° 124° 236° 304°		55° 125° 235° 305°		Lat. − Lat + Lat. + Lat. −
	Direction measured from North through East.										

Vector directed towards origin. "Latitude" is component in S. and N. direction. "Departure" is component in W. and E. direction.

Direction from 36° to 40° from a cardinal point.

	Direction measured from North through East.										
Lat. − Lat. + Lat. + Lat. −	324° 216° 144° 36°		323° 217° 143° 37°		322° 218° 142° 38°		321° 219° 141° 39°		320° 220° 140° 40°		Dep. + Dep. + Dep. − Dep. −
Distance	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Distance.
1	0·8	0·6	0·8	0·6	0·8	0·6	0·8	0·6	0·8	0·6	1
2	1·6	1·2	1·6	1·2	1·6	1·2	1·6	1·3	1·5	1·3	2
3	2·4	1·8	2·4	1·8	2·4	1·8	2·3	1·9	2·3	1·9	3
4	3·2	2·4	3·2	2·4	3·2	2·5	3·1	2·5	3·1	2·6	4
5	4·0	2·9	4·0	3·0	3·9	3·1	3·9	3·1	3·8	3·2	5
6	4·9	3·5	4·8	3·6	4·7	3·7	4·7	3·8	4·6	3·9	6
7	5·7	4·1	5·6	4·2	5·5	4·3	5·4	4·4	5·4	4·5	7
8	6·5	4·7	6·4	4·8	6·3	4·9	6·2	5·0	6·1	5·1	8
9	7·3	5·3	7·2	5·4	7·1	5·5	7·0	5·7	6·9	5·8	9
10	8·1	5·9	8·0	6·0	7·9	6·2	7·8	6·3	7·7	6·4	10
11	8·9	6·5	8·8	6·6	8·7	6·8	8·5	6·9	8·4	7·1	11
12	9·7	7·1	9·6	7·2	9·5	7·4	9·3	7·6	9·2	7·7	12
13	10·5	7·6	10·4	7·8	10·2	8·0	10·1	8·2	10·0	8·4	13
14	11·3	8·2	11·2	8·4	11·0	8·6	10·9	8·8	10·7	9·0	14
15	12·1	8·8	12·0	9·0	11·8	9·2	11·7	9·4	11·5	9·6	15
16	12·9	9·4	12·8	9·6	12·6	9·9	12·4	10·1	12·3	10·3	16
17	13·8	10·0	13·6	10·2	13·4	10·5	13·2	10·7	13·0	10·9	17
18	14·6	10·6	14·4	10·8	14·2	11·1	14·0	11·3	13·8	11·6	18
19	15·4	11·2	15·2	11·4	15·0	11·7	14·8	12·0	14·6	12·2	19
20	16·2	11·8	16·0	12·0	15·8	12·3	15·5	12·6	15·3	12·9	20
21	17·0	12·3	16·8	12·6	16·5	12·9	16·3	13·2	16·1	13·5	21
22	17·8	12·9	17·6	13·2	17·3	13·5	17·1	13·8	16·9	14·1	22
23	18·6	13·5	18·4	13·8	18·1	14·2	17·9	14·5	17·6	14·8	23
24	19·4	14·1	19·2	14·4	18·9	14·8	18·7	15·1	18·4	15·4	24
25	20·2	14·7	20·0	15·0	19·7	15·4	19·4	15·7	19·2	16·1	25
26	21·0	15·3	20·8	15·6	20·5	16·0	20·2	16·4	19·9	16·7	26
27	21·8	15·9	21·6	16·2	21·3	16·6	21·0	17·0	20·7	17·4	27
28	22·7	16·5	22·4	16·9	22·1	17·2	21·8	17·6	21·4	18·0	28
29	23·5	17·0	23·2	17·5	22·9	17·9	22·5	18·3	22·2	18·6	29
30	24·3	17·6	24·0	18·1	23·6	18·5	23·3	18·9	23·0	19·3	30
31	25·1	18·2	24·8	18·7	24·4	19·1	24·1	19·5	23·7	19·9	31
32	25·9	18·8	25·6	19·3	25·2	19·7	24·9	20·1	24·5	20·6	32
33	26·7	19·4	26·4	19·9	26·0	20·3	25·6	20·8	25·3	21·2	33
34	27·5	20·0	27·2	20·5	26·8	20·9	26·4	21·4	26·0	21·9	34
35	28·3	20·6	28·0	21·1	27·6	21·5	27·2	22·0	26·8	22·5	35
36	29·1	21·2	28·8	21·7	28·4	22·2	28·0	22·7	27·6	23·1	36
37	29·9	21·7	29·5	22·3	29·2	22·8	28·8	23·3	28·3	23·8	37
38	30·7	22·3	30·3	22·9	29·9	23·4	29·5	23·9	29·1	24·4	38
39	31·6	22·9	31·1	23·5	30·7	24·0	30·3	24·5	29·9	25·1	39
40	32·4	23·5	31·9	24·1	31·5	24·6	31·1	25·2	30·6	25·7	40
41	33·2	24·1	32·7	24·7	32·3	25·2	31·9	25·8	31·4	26·4	41
42	34·0	24·7	33·5	25·3	33·1	25·9	32·6	26·4	32·2	27·0	42
43	34·8	25·3	34·3	25·9	33·9	26·5	33·4	27·1	32·9	27·6	43
44	35·6	25·9	35·1	26·5	34·7	27·1	34·1	27·7	33·7	28·3	44
45	36·4	26·5	35·9	27·1	35·5	27·7	35·0	28·3	34·5	28·9	45
46	37·2	27·0	36·7	27·7	36·2	28·3	35·7	28·9	35·2	29·6	46
47	38·0	27·6	37·5	28·3	37·0	28·9	36·5	29·6	36·0	30·2	47
48	38·8	28·2	38·3	28·9	37·8	29·6	37·3	30·2	36·8	30·9	48
49	39·6	28·8	39·1	29·5	38·6	30·2	38·1	30·8	37·5	31·5	49
50	40·5	29·4	39·9	30·1	39·4	30·8	38·9	31·5	38·3	32·1	50
Distance	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
Dep. − Dep. − Dep. + Dep. +	54° 126° 234° 306°		53° 127° 233° 307°		52° 128° 232° 308°		51° 129° 231° 309°		50° 130° 230° 310°		Lat. − Lat. + Lat. + Lat. −
	Direction measured from North through East.										

Vector directed towards origin. "Latitude" is component in S. and N. direction. "Departure" is component in W. and E. direction.

Direction from 41° to 45° from a cardinal point.

	Direction measured from North through East.										
Lat. − Lat. + Lat. + Lat. −	319° 221° 139° 41°		318° 222° 138° 42°		317° 223° 137° 43°		316° 224° 136° 44°		315° 225° 135° 45°		Dep. + Dep. + Dep. − Dep. −
Distance.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Distance.
1	0·8	0·7	0·7	0·7	0·7	0·7	0·7	0·7	0·7	0·7	1
2	1·5	1·3	1·5	1·3	1·5	1·4	1·4	1·4	1·4	1·4	2
3	2·3	2·0	2·2	2·0	2·2	2·0	2·2	2·1	2·1	2·1	3
4	3·0	2·6	3·0	2·7	2·9	2·7	2·9	2·8	2·8	2·8	4
5	3·8	3·3	3·7	3·3	3·7	3·4	3·6	3·5	3·5	3·5	5
6	4·5	3·9	4·5	4·0	4·4	4·1	4·3	4·2	4·2	4·2	6
7	5·3	4·6	5·2	4·7	5·1	4·8	5·0	4·9	4·9	4·9	7
8	6·0	5·2	5·9	5·4	5·9	5·5	5·8	5·6	5·7	5·7	8
9	6·8	5·9	6·7	6·0	6·6	6·1	6·5	6·3	6·4	6·4	9
10	7·5	6·6	7·4	6·7	7·3	6·8	7·2	6·9	7·1	7·1	10
11	8·3	7·2	8·2	7·4	8·0	7·5	7·9	7·6	7·8	7·8	11
12	9·1	7·9	8·9	8·0	8·8	8·2	8·6	8·3	8·5	8·5	12
13	9·8	8·5	9·7	8·7	9·5	8·9	9·4	9·0	9·2	9·2	13
14	10·6	9·2	10·4	9·4	10·2	9·5	10·1	9·7	9·9	9·9	14
15	11·3	9·8	11·1	10·0	11·0	10·2	10·8	10·4	10·6	10·6	15
16	12·1	10·5	11·9	10·7	11·7	10·9	11·5	11·1	11·3	11·3	16
17	12·8	11·2	12·6	11·4	12·4	11·6	12·2	11·8	12·0	12·0	17
18	13·6	11·8	13·4	12·0	13·2	12·3	12·9	12·5	12·7	12·7	18
19	14·3	12·5	14·1	12·7	13·9	13·0	13·7	13·2	13·4	13·4	19
20	15·1	13·1	14·9	13·4	14·6	13·6	14·4	13·9	14·1	14·1	20
21	15·8	13·8	15·6	14·1	15·4	14·3	15·1	14·6	14·8	14·8	21
22	16·6	14·4	16·3	14·7	16·1	15·0	15·8	15·3	15·6	15·6	22
23	17·4	15·1	17·1	15·4	16·8	15·7	16·5	16·0	16·3	16·3	23
24	18·1	15·7	17·8	16·1	17·6	16·4	17·3	16·7	17·0	17·0	24
25	18·9	16·4	18·6	16·7	18·3	17·0	18·0	17·4	17·7	17·7	25
26	19·6	17·1	19·3	17·4	19·0	17·7	18·7	18·1	18·4	18·4	26
27	20·4	17·7	20·1	18·1	19·7	18·4	19·4	18·8	19·1	19·1	27
28	21·1	18·4	20·8	18·7	20·5	19·1	20·1	19·5	19·8	19·8	28
29	21·9	19·0	21·6	19·4	21·2	19·8	20·9	20·1	20·5	20·5	29
30	22·6	19·7	22·3	20·1	21·9	20·5	21·6	20·8	21·2	21·2	30
31	23·4	20·3	23·0	20·7	22·7	21·1	22·3	21·5	21·9	21·9	31
32	24·2	21·0	23·8	21·4	23·4	21·8	23·0	22·2	22·6	22·6	32
33	24·9	21·6	24·5	22·1	24·1	22·5	23·7	22·9	23·3	23·3	33
34	25·7	22·3	25·3	22·8	24·9	23·2	24·5	23·6	24·0	24·0	34
35	26·4	23·0	26·0	23·4	25·6	23·9	25·2	24·3	24·7	24·7	35
36	27·2	23·6	26·8	24·1	26·3	24·6	25·9	25·0	25·5	25·5	36
37	27·9	24·3	27·5	24·8	27·1	25·2	26·6	25·7	26·2	26·2	37
38	28·7	24·9	28·2	25·4	27·8	25·9	27·3	26·4	26·9	26·9	38
39	29·4	25·6	29·0	26·1	28·5	26·6	28·1	27·1	27·6	27·6	39
40	30·2	26·2	29·7	26·8	29·2	27·3	28·8	27·8	28·3	28·3	40
41	30·9	26·9	30·5	27·4	30·0	28·0	29·5	28·5	29·0	29·0	41
42	31·7	27·6	31·2	28·1	30·7	28·6	30·2	29·2	29·7	29·7	42
43	32·5	28·2	32·0	28·8	31·4	29·3	30·9	29·9	30·4	30·4	43
44	33·2	28·9	32·7	29·4	32·2	30·0	31·7	30·6	31·1	31·1	44
45	34·0	29·5	33·4	30·1	32·9	30·7	32·4	31·3	31·8	31·8	45
46	34·7	30·2	34·2	30·8	33·6	31·4	33·1	32·0	32·5	32·5	46
47	35·5	30·8	34·9	31·4	34·4	32·1	33·8	32·6	33·2	33·2	47
48	36·2	31·5	35·7	32·1	35·1	32·7	34·5	33·3	33·9	33·9	48
49	37·0	32·1	36·4	32·8	35·8	33·4	35·2	34·0	34·6	34·6	49
50	37·7	32·8	37·2	33·5	36·6	34·1	36·0	34·7	35·4	35·4	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
Dep. − Dep. − Dep. + Dep. +	49° 131° 229° 311°		48° 132° 228° 312°		47° 133° 227° 313°		46° 134° 226° 314°		45° 135° 225° 315°		Lat. − Lat. + Lat. + Lat. −
	Direction measured from North through East.										

Vector directed towards origin. "Latitude" is component in S. and N. direction. "Departure" is component in W. and E. direction.

TABLES OF CONVERSION FROM BRITISH TO METRIC UNITS AND VICE VERSA.

List.

INCHES (0·00 TO 4·99) TO MILLIMETRES. RAINFALL.
(From Crelle's Tables, Sheet 254. Values rounded off.)

Hundredths.	·00	·01	·02	·03	·04	·05	·06	·07	·08	·09
Inches.	Millimetres.									
0·0	0	0	1	1	1	1	2	2	2	2
0·1	3	3	3	3	4	4	4	4	5	5
0·2	5	5	6	6	6	6	7	7	7	7
0·3	8	8	8	8	9	9	9	9	10	10
0·4	10	10	11	11	11	11	12	12	12	12
0·5	13	13	13	13	14	14	14	14	15	15
0·6	15	15	16	16	16	17	17	17	17	18
0·7	18	18	18	19	19	19	19	20	20	20
0·8	20	21	21	21	21	22	22	22	22	23
0·9	23	23	23	24	24	24	24	25	25	25
1·0	25	26	26	26	26	27	27	27	27	28
1·1	28	28	28	29	29	29	29	30	30	30
1·2	30	31	31	31	31	32	32	32	33	33
1·3	33	33	34	34	34	34	35	35	35	35
1·4	36	36	36	36	37	37	37	37	38	38
1·5	38	38	39	39	39	39	40	40	40	40
1·6	41	41	41	41	42	42	42	42	43	43
1·7	43	43	44	44	44	44	45	45	45	45
1·8	46	46	46	46	47	47	47	47	48	48
1·9	48	49	49	49	49	50	50	50	50	51
2·0	51	51	51	52	52	52	52	53	53	53
2·1	53	54	54	54	54	55	55	55	55	56
2·2	56	56	56	57	57	57	57	58	58	58
2·3	58	59	59	59	59	60	60	60	60	61
2·4	61	61	61	62	62	62	62	63	63	63
2·5	64	64	64	64	65	65	65	65	66	66
2·6	66	66	67	67	67	67	68	68	68	68
2·7	69	69	69	69	70	70	70	70	71	71
2·8	71	71	72	72	72	72	73	73	73	73
2·9	74	74	74	74	75	75	75	75	76	76
3·0	76	76	77	77	77	77	78	78	78	78
3·1	79	79	79	80	80	80	80	81	81	81
3·2	81	82	82	82	82	83	83	83	83	84
3·3	84	84	84	85	85	85	85	86	86	86
3·4	86	87	87	87	87	88	88	88	88	89
3·5	89	89	89	90	90	90	90	91	91	91
3·6	91	92	92	92	92	93	93	93	93	94
3·7	94	94	94	95	95	95	96	96	96	96
3·8	97	97	97	97	98	98	98	98	99	99
3·9	99	99	100	100	100	100	101	101	101	101
4·0	102	102	102	102	103	103	103	103	104	104
4·1	104	104	105	105	105	105	106	106	106	106
4·2	107	107	107	107	108	108	108	108	109	109
4·3	109	109	110	110	110	110	111	111	111	112
4·4	112	112	112	113	113	113	113	114	114	114
4·5	114	115	115	115	115	116	116	116	116	117
4·6	117	117	117	118	118	118	118	119	119	119
4·7	119	120	120	120	120	121	121	121	121	122
4·8	122	122	122	123	123	123	123	124	124	124
4·9	124	125	125	125	125	126	126	126	126	127

For amounts between 10 and 20 inches, add 254 to the number expressing the units and decimals in millimetres.

Thus: 13·74 = 10 + 3·74 in. = 254 + 95 = 349 mm.

For amounts between 20 inches and 30 inches add 508.

" " " 30 " " 40 " " 762.

" " " 40 " " 50 " " 1,016.

INCHES (5 TO 10·09) TO MILLIMETRES. RAINFALL.
(From Crelle's Tables, Sheet 254. Values rounded off.)

Hundredths.	·00	·01	·02	·03	·04	·05	·06	·07	·08	·09
Inches.	Millimetres.									
5·0	127	127	128	128	128	128	129	129	129	129
5·1	130	130	130	130	131	131	131	131	132	132
5·2	132	132	133	133	133	133	134	134	134	134
5·3	135	135	135	135	136	136	136	136	137	137
5·4	137	137	138	138	138	138	139	139	139	139
5·5	140	140	140	140	141	141	141	141	142	142
5·6	142	142	143	143	143	144	144	144	144	145
5·7	145	145	145	146	146	146	146	147	147	147
5·8	147	148	148	148	148	149	149	149	149	150
5·9	150	150	150	151	151	151	151	152	152	152
6·0	152	153	153	153	153	154	154	154	154	155
6·1	155	155	155	156	156	156	156	157	157	157
6·2	157	158	158	158	158	159	159	159	160	160
6·3	160	160	161	161	161	161	162	162	162	162
6·4	163	163	163	163	164	164	164	164	165	165
6·5	165	165	166	166	166	166	167	167	167	167
6·6	168	168	168	168	169	169	169	169	170	170
6·7	170	170	171	171	171	171	172	172	172	172
6·8	173	173	173	173	174	174	174	174	175	175
6·9	175	176	176	176	176	177	177	177	177	178
7·0	178	178	178	179	179	179	179	180	180	180
7·1	180	181	181	181	181	182	182	182	182	183
7·2	183	183	183	184	184	184	184	185	185	185
7·3	185	186	186	186	186	187	187	187	187	188
7·4	188	188	188	189	189	189	189	190	190	190
7·5	191	191	191	191	192	192	192	192	193	193
7·6	193	193	194	194	194	194	195	195	195	195
7·7	196	196	196	196	197	197	197	197	198	198
7·8	198	198	199	199	199	199	200	200	200	200
7·9	201	201	201	201	202	202	202	202	203	203
8·0	203	203	204	204	204	204	205	205	205	205
8·1	206	206	206	207	207	207	207	208	208	208
8·2	208	209	209	209	209	210	210	210	210	211
8·3	211	211	211	212	212	212	212	213	213	213
8·4	213	214	214	214	214	215	215	215	215	216
8·5	216	216	216	217	217	217	217	218	218	218
8·6	218	219	219	219	219	220	220	220	220	221
8·7	221	221	221	222	222	222	223	223	223	223
8·8	224	224	224	224	225	225	225	225	226	226
8·9	226	226	227	227	227	227	228	228	228	228
9·0	229	229	229	229	230	230	230	230	231	231
9·1	231	231	232	232	232	232	233	233	233	233
9·2	234	234	234	234	235	235	235	235	236	236
9·3	236	236	237	237	237	237	238	238	238	239
9·4	239	239	239	240	240	240	240	241	241	241
9·5	241	242	242	242	242	243	243	243	243	244
9·6	244	244	244	245	245	245	245	246	246	246
9·7	246	247	247	247	247	248	248	248	248	249
9·8	249	249	249	250	250	250	250	251	251	251
9·9	251	252	252	252	252	253	253	253	253	254
10·0	254	254	254	255	255	255	256	256	256	256

For amounts of rainfall between 50 inches and 100 inches add 254 for each ten inches.

Thus: between 50 and 60 ins. add 1,270.

" 60 and 70 " " 1,524.

" 70 and 80 " " 1,778.

INCHES (0·00 TO 4·99) TO MILLIMETRES AND TENTHS. RAINFALL.
From Crelle's Tables, Sheet 254. Values rounded off.

Hundredths. / Inches.	·00	·01	·02	·03	·04	·05	·06	·07	·08	·09
	Millimetres.									
0·0	0·0	0·3	0·5	0·8	1·0	1·3	1·5	1·8	2·0	2·3
0·1	2·5	2·8	3·0	3·3	3·6	3·8	4·1	4·3	4·6	4·8
0·2	5·1	5·3	5·6	5·8	6·1	6·4	6·6	6·9	7·1	7·4
0·3	7·6	7·9	8·1	8·4	8·6	8·9	9·1	9·4	9·7	9·9
0·4	10·2	10·4	10·7	10·9	11·2	11·4	11·7	11·9	12·2	12·4
0·5	12·7	13·0	13·2	13·5	13·7	14·0	14·2	14·5	14·7	15·0
0·6	15·2	15·5	15·7	16·0	16·3	16·5	16·8	17·0	17·3	17·5
0·7	17·8	18·0	18·3	18·5	18·8	19·1	19·3	19·6	19·8	20·1
0·8	20·3	20·6	20·8	21·1	21·3	21·6	21·8	22·1	22·4	22·6
0·9	22·9	23·1	23·4	23·6	23·9	24·1	24·4	24·6	24·9	25·1
1·0	25·4	25·7	25·9	26·2	26·4	26·7	26·9	27·2	27·4	27·7
1·1	27·9	28·2	28·4	28·7	29·0	29·2	29·5	29·7	30·0	30·2
1·2	30·5	30·7	31·0	31·2	31·5	31·8	32·0	32·3	32·5	32·8
1·3	33·0	33·3	33·5	33·8	34·0	34·3	34·5	34·8	35·1	35·3
1·4	35·6	35·8	36·1	36·3	36·6	36·8	37·1	37·3	37·6	37·8
1·5	38·1	38·4	38·6	38·9	39·1	39·4	39·6	39·9	40·1	40·4
1·6	40·6	40·9	41·1	41·4	41·7	41·9	42·2	42·4	42·7	42·9
1·7	43·2	43·4	43·7	43·9	44·2	44·5	44·7	45·0	45·2	45·5
1·8	45·7	46·0	46·2	46·5	46·7	47·0	47·2	47·5	47·8	48·0
1·9	48·3	48·5	48·8	49·0	49·3	49·5	49·8	50·0	50·3	50·5
2·0	50·8	51·1	51·3	51·6	51·8	52·1	52·3	52·6	52·8	53·1
2·1	53·3	53·6	53·8	54·1	54·4	54·6	54·9	55·1	55·4	55·6
2·2	55·9	56·1	56·4	56·6	56·9	57·2	57·4	57·7	57·9	58·2
2·3	58·4	58·7	58·9	59·2	59·4	59·7	59·9	60·2	60·5	60·7
2·4	61·0	61·2	61·5	61·7	62·0	62·2	62·5	62·7	63·0	63·2
2·5	63·5	63·8	64·0	64·3	64·5	64·8	65·0	65·3	65·5	65·8
2·6	66·0	66·3	66·5	66·8	67·1	67·3	67·6	67·8	68·1	68·3
2·7	68·6	68·8	69·1	69·3	69·6	69·9	70·1	70·4	70·6	70·9
2·8	71·1	71·4	71·6	71·9	72·1	72·4	72·6	72·9	73·2	73·4
2·9	73·7	73·9	74·2	74·4	74·7	74·9	75·2	75·4	75·7	75·9
3·0	76·2	76·5	76·7	77·0	77·2	77·5	77·7	78·0	78·2	78·5
3·1	78·7	79·0	79·2	79·5	79·8	80·0	80·3	80·5	80·8	81·0
3·2	81·3	81·5	81·8	82·0	82·3	82·6	82·8	83·1	83·3	83·6
3·3	83·8	84·1	84·3	84·6	84·8	85·1	85·3	85·6	85·9	86·1
3·4	86·4	86·6	86·9	87·1	87·4	87·6	87·9	88·1	88·4	88·6
3·5	88·9	89·2	89·4	89·7	89·9	90·2	90·4	90·7	90·9	91·2
3·6	91·4	91·7	91·9	92·2	92·5	92·7	93·0	93·2	93·5	93·7
3·7	94·0	94·2	94·5	94·7	95·0	95·3	95·5	95·8	96·0	96·3
3·8	96·5	96·8	97·0	97·3	97·5	97·8	98·0	98·3	98·6	98·8
3·9	99·1	99·3	99·6	99·8	100·1	100·3	100·6	100·8	101·1	101·3
4·0	101·6	101·9	102·1	102·4	102·6	102·9	103·1	103·4	103·6	103·9
4·1	104·1	104·4	104·6	104·9	105·2	105·4	105·7	105·9	106·2	106·4
4·2	106·7	106·9	107·2	107·4	107·7	108·0	108·2	108·5	108·7	109·0
4·3	109·2	109·5	109·7	110·0	110·2	110·5	110·7	111·0	111·3	111·5
4·4	111·8	112·0	112·3	112·5	112·8	113·0	113·3	113·5	113·8	114·0
4·5	114·3	114·6	114·8	115·1	115·3	115·6	115·8	116·1	116·3	116·6
4·6	116·8	117·1	117·3	117·6	117·9	118·1	118·4	118·6	118·9	119·1
4·7	119·4	119·6	119·9	120·1	120·4	120·7	120·9	121·2	121·4	121·7
4·8	121·9	122·2	122·4	122·7	122·9	123·2	123·4	123·7	124·0	124·2
4·9	124·5	124·7	125·0	125·2	125·5	125·7	126·0	126·2	126·5	126·7

For amounts above 5 inches and below 10 inches add 127 to the numbers above. Thus 8·63 inches = 5 + 3·63 = 127 + 92·2 = 219·2 mm.
For amounts above 10 inches add 254. Thus 13·63 inches = 254 + 92·2 = 346·2mm.

MILLIMETRES (0 TO 50) AND TENTHS TO INCHES CORRECT TO HUNDREDTHS, ON THE BASIS OF 100 MM. = 3·93701 IN.

Tenths. / mm.	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
	Inches.									
0	·00	·00	·01	·01	·02	·02	·02	·03	·03	·04
1	·04	·04	·05	·05	·06	·06	·06	·07	·07	·07
2	·08	·08	·09	·09	·09	·10	·10	·11	·11	·11
3	·12	·12	·13	·13	·13	·14	·14	·15	·15	·15
4	·16	·16	·17	·17	·17	·18	·18	·19	·19	·19
5	·20	·20	·20	·21	·21	·22	·22	·22	·23	·23
6	·24	·24	·24	·25	·25	·26	·26	·26	·27	·27
7	·28	·28	·28	·29	·29	·30	·30	·30	·31	·31
8	·31	·32	·32	·33	·33	·33	·34	·34	·35	·35
9	·35	·36	·36	·37	·37	·37	·38	·38	·39	·39
10	·39	·40	·40	·41	·41	·41	·42	·42	·43	·43
11	·43	·44	·44	·44	·45	·45	·46	·46	·46	·47
12	·47	·48	·48	·48	·49	·49	·50	·50	·50	·51
13	·51	·52	·52	·52	·53	·53	·54	·54	·54	·55
14	·55	·56	·56	·56	·57	·57	·57	·58	·58	·59
15	·59	·59	·60	·60	·61	·61	·61	·62	·62	·63
16	·63	·63	·64	·64	·65	·65	·65	·66	·66	·67
17	·67	·67	·68	·68	·69	·69	·69	·70	·70	·70
18	·71	·71	·72	·72	·72	·73	·73	·74	·74	·74
19	·75	·75	·76	·76	·76	·77	·77	·78	·78	·78
20	·79	·79	·80	·80	·80	·81	·81	·81	·82	·82
21	·83	·83	·83	·84	·84	·85	·85	·85	·86	·86
22	·87	·87	·87	·88	·88	·89	·89	·89	·90	·90
23	·91	·91	·91	·92	·92	·93	·93	·93	·94	·94
24	·95	·95	·95	·96	·96	·96	·97	·97	·98	·98
25	·98	·99	·99	1·00	1·00	1·00	1·01	1·01	1·02	1·02
26	1·02	1·03	1·03	1·04	1·04	1·04	1·05	1·05	1·06	1·06
27	1·06	1·07	1·07	1·07	1·08	1·08	1·09	1·09	1·09	1·10
28	1·10	1·10	1·11	1·11	1·12	1·12	1·13	1·13	1·13	1·14
29	1·14	1·15	1·15	1·15	1·16	1·16	1·17	1·17	1·17	1·18
30	1·18	1·19	1·19	1·19	1·20	1·20	1·20	1·21	1·21	1·22
31	1·22	1·22	1·23	1·23	1·24	1·24	1·24	1·25	1·25	1·26
32	1·26	1·26	1·27	1·27	1·28	1·28	1·28	1·29	1·29	1·30
33	1·30	1·30	1·31	1·31	1·31	1·32	1·32	1·33	1·33	1·33
34	1·34	1·34	1·35	1·35	1·35	1·36	1·36	1·37	1·37	1·37
35	1·38	1·38	1·39	1·39	1·39	1·40	1·40	1·41	1·41	1·41
36	1·42	1·42	1·43	1·43	1·43	1·44	1·44	1·44	1·45	1·45
37	1·46	1·46	1·46	1·47	1·47	1·48	1·48	1·48	1·49	1·49
38	1·50	1·50	1·50	1·51	1·51	1·52	1·52	1·52	1·53	1·53
39	1·54	1·54	1·54	1·55	1·55	1·56	1·56	1·56	1·57	1·57
40	1·57	1·58	1·58	1·59	1·59	1·59	1·60	1·60	1·61	1·61
41	1·61	1·62	1·62	1·63	1·63	1·63	1·64	1·64	1·65	1·65
42	1·65	1·66	1·66	1·67	1·67	1·67	1·68	1·68	1·69	1·69
43	1·69	1·70	1·70	1·70	1·71	1·71	1·72	1·72	1·72	1·73
44	1·73	1·74	1·74	1·74	1·75	1·75	1·76	1·76	1·76	1·77
45	1·77	1·78	1·78	1·78	1·79	1·79	1·80	1·80	1·80	1·81
46	1·81	1·81	1·82	1·82	1·83	1·83	1·83	1·84	1·84	1·85
47	1·85	1·85	1·86	1·86	1·87	1·87	1·87	1·88	1·88	1·89
48	1·89	1·89	1·90	1·90	1·91	1·91	1·91	1·92	1·92	1·9[illegible]
49	1·93	1·93	1·94	1·94	1·94	1·95	1·95	1·96	1·96	1·96

The table also serves for converting whole millimetres, from 0 to 500, to inches and tenths.

MILLIMETRES (50 TO 100) AND TENTHS TO INCHES, CORRECT TO HUNDREDTHS, ON THE BASIS OF 100 MM. = 3·93701 IN.

Tenths	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
mm.					Inches.					
50	1·97	1·97	1·98	1·98	1·98	1·99	1·99	2·00	2·00	2·00
51	2·01	2·01	2·02	2·02	2·02	2·03	2·03	2·04	2·04	2·04
52	2·05	2·05	2·06	2·06	2·06	2·07	2·07	2·07	2·08	2·08
53	2·09	2·09	2·09	2·10	2·10	2·11	2·11	2·11	2·12	2·12
54	2·13	2·13	2·13	2·14	2·14	2·15	2·15	2·15	2·16	2·16
55	2·17	2·17	2·17	2·18	2·18	2·19	2·19	2·19	2·20	2·20
56	2 20	2·21	2·21	2·22	2·22	2·22	2·23	2·23	2·24	2·24
57	2·24	2·25	2·25	2·26	2·26	2·26	2·27	2·27	2·28	2·28
58	2·28	2·29	2·29	2·30	2·30	2·30	2·31	2·31	2·31	2·32
59	2·32	2·33	2·33	2·33	2·34	2·34	2·35	2·35	2·35	2·36
60	2·36	2·37	2·37	2·37	2·38	2·38	2·39	2·39	2·39	2·40
61	2·40	2·41	2·41	2·41	2·42	2·42	2·43	2·43	2·43	2·44
62	2·44	2·44	2·45	2·45	2·46	2·46	2·46	2·47	2·47	2·48
63	2·48	2·48	2·49	2·49	2·50	2·50	2·50	2·51	2·51	2·52
64	2·52	2·52	2·53	2·53	2·54	2·54	2·54	2·55	2·55	2·56
65	2·56	2·56	2·57	2·57	2·57	2·58	2·58	2·59	2·59	2·59
66	2·60	2·60	2·61	2·61	2·61	2·62	2·62	2·63	2·63	2·63
67	2·64	2·64	2·65	2·65	2·65	2·66	2·66	2·67	2·67	2·67
68	2·68	2·68	2·69	2·69	2·69	2·70	2·70	2·70	2·71	2·71
69	2·72	2·72	2·72	2·73	2·73	2·74	2·74	2·74	2·75	2·75
70	2·76	2·76	2·76	2·77	2·77	2·78	2·78	2·78	2·79	2·79
71	2·80	2·80	2·80	2·81	2·81	2·81	2·82	2·82	2·83	2·83
72	2·83	2·84	2·84	2·85	2·85	2·85	2·86	2·86	2·87	2·87
73	2·87	2·88	2·88	2·89	2·89	2·89	2·90	2·90	2·91	2·91
74	2·91	2·92	2·92	2·93	2·93	2·93	2·94	2·94	2·94	2·95
75	2·95	2·96	2·96	2·96	2·97	2·97	2·98	2·98	2·98	2·99
76	2·99	3·00	3·00	3·00	3·01	3·01	3·02	3·02	3·02	3·03
77	3·03	3·04	3·04	3·04	3·05	3·05	3·06	3·06	3·06	3·07
78	3·07	3·07	3·08	3·08	3·09	3·09	3·09	3·10	3·10	3·11
79	3·11	3·11	3·12	3·12	3·13	3·13	3·13	3·14	3·14	3·15
80	3·15	3·15	3·16	3·16	3·17	3·17	3·17	3·18	3·18	3·19
81	3·19	3·19	3·20	3·20	3·20	3·21	3·21	3·22	3·22	3·22
82	3·23	3·23	3·24	3·24	3·24	3·25	3·25	3·26	3·26	3·26
83	3·27	3·27	3·28	3·28	3·28	3·29	3·29	3·30	3·30	3·30
84	3·31	3·31	3·31	3·32	3·32	3·33	3·33	3·33	3·34	3·34
85	3·35	3·35	3·35	3·36	3·36	3·37	3·37	3·37	3·38	3·38
86	3·39	3·39	3·39	3·40	3·40	3·41	3·41	3·41	3·42	3·42
87	3·43	3·43	3·43	3·44	3·44	3·44	3·45	3·45	3·46	3·46
88	3·46	3·47	3·47	3·48	3·48	3·48	3·49	3·49	3·50	3·50
89	3·50	3·51	3·51	3·52	3·52	3·52	3·53	3·53	3·54	3·54
90	3·54	3·55	3·55	3·56	3·56	3·56	3·57	3·57	3·57	3·58
91	3·58	3·59	3·59	3·59	3·60	3·60	3·61	3·61	3·61	3·62
92	3·62	3·63	3·63	3·63	3·64	3·64	3·65	3·65	3·65	3·66
93	3·66	3·67	3·67	3·67	3·68	3·68	3·69	3·69	3·69	3·70
94	3·70	3·70	3·71	3·71	3·72	3·72	3·72	3·73	3·73	3·74
95	3·74	3·74	3·75	3·75	3·76	3·76	3·76	3·77	3·77	3·78
96	3·78	3·78	3·79	3·79	3·80	3·80	3·80	3·81	3·81	3·81
97	3·82	3·82	3·83	3·83	3·83	3·84	3·84	3·85	3·85	3·85
93	3·86	3·86	3·87	3·87	3·87	3·88	3·88	3·89	3·89	3·89
99	3·90	3·90	3·91	3·91	3·91	3·92	3·92	3·93	3·93	3·93

The table also serves for converting whole millimetres, from 500 to 1,000, to inches and tenths.

TEMPERATURE. DEGREES FAHRENHEIT TO DEGREES ABSOLUTE.

Tenths.	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
Degrees Fah.					Degrees Absolute, 200 +					
	°	°	°	°	°	°	°	°	°	°
−99	·2	·2	·1	·1	·0	—	—	—	—	—
−98	·8	·7	·7	·6	·6	·5	·4	·4	·3	·3
−97	1·3	1·3	1·2	1·2	1·1	1·1	1·0	·9	·9	·8
−96	1·9	1·8	1·8	1·7	1·7	1·6	1·6	1·5	1·4	1·4
−95	2·4	2·4	2·3	2·3	2·2	2·2	2·1	2·1	2·0	1·9
−94	3·0	2·9	2·9	2·8	2·8	2·7	2·7	2·6	2·6	2·5
−93	3·6	3·5	3·4	3·4	3·3	3·3	3·2	3·2	3·1	3·1
−92	4·1	4·1	4·0	3·9	3·9	3·8	3·8	3·7	3·7	3·6
−91	4·7	4·6	4·6	4·5	4·4	4·4	4·3	4·3	4·2	4·2
−90	5·2	5·2	5·1	5·1	5·0	4·9	4·9	4·8	4·8	4·7
−89	5·8	5·7	5·7	5·6	5·6	5·5	5·4	5·4	5·3	5·3
−88	6·3	6·3	6·2	6·2	6·1	6·1	6·0	5·9	5·9	5·8
−87	6·9	6·8	6·8	6·7	6·7	6·6	6·6	6·5	6·4	6·4
−86	7·4	7·4	7·3	7·3	7·2	7·2	7·1	7·1	7·0	6·9
−85	8·0	7·9	7·9	7·8	7·8	7·7	7·7	7·6	7·6	7·5
−84	8·6	8·5	8·4	8·4	8·3	8·3	8·2	8·2	8·1	8·1
−83	9·1	9·1	9·0	8·9	8·9	8·8	8·8	8·7	8·7	8·6
−82	9·7	9·6	9·6	9·5	9·4	9·4	9·3	9·3	9·2	9·2
−81	10·2	10·2	10·1	10·1	10·0	9·9	9·9	9·8	9·8	9·7
−80	10·8	10·7	10·7	10·6	10·6	10·5	10·4	10·4	10·3	10·3
−79	11·3	11·3	11·2	11·2	11·1	11·1	11·0	10·9	10·9	10·8
−78	11·9	11·8	11·8	11·7	11·7	11·6	11·6	11·5	11·4	11·4
−77	12·4	12·4	12·3	12·3	12·2	12·2	12·1	12·1	12·0	11·9
−76	13·0	12·9	12·9	12·8	12·8	12·7	12·7	12·6	12·6	12·5
−75	13·6	13·5	13·4	13·4	13·3	13·3	13·2	13·2	13·1	13·1
−74	14·1	14·1	14·0	13·9	13·9	13·8	13·8	13·7	13·7	13·6
−73	14·7	14·6	14·6	14·5	14·4	14·4	14·3	14·3	14·2	14·2
−72	15·2	15·2	15·1	15·1	15·0	14·9	14·9	14·8	14·8	14·7
−71	15·8	15·7	15·7	15·6	15·6	15·5	15·4	15·4	15·3	15·3
−70	16·3	16·3	16·2	16·2	16·1	16·1	16·0	15·9	15·9	15·8
−69	16·9	16·8	16·8	16·7	16·7	16·6	16·6	16·5	16·4	16·4
−68	17·4	17·4	17·3	17·3	17·2	17·2	17·1	17·1	17·0	16·9
−67	18·0	17·9	17·9	17·8	17·8	17·7	17·7	17·6	17·6	17·5
−66	18·6	18·5	18·4	18·4	18·3	18·3	18·2	18·2	18·1	18·1
−65	19·1	19·1	19·0	18·9	18·9	18·8	18·8	18·7	18·7	18·6
−64	19·7	19·6	19·6	19·5	19·4	19·4	19·3	19·3	19·2	19·2
−63	20·2	20·2	20·1	20·1	20·0	19·9	19·9	19·8	19·8	19·7
−62	20·8	20·7	20·7	20·6	20 6	20·5	20·4	20·4	20·3	20·3
−61	21·3	21·3	21·2	21·2	21·1	21·1	21·0	20·9	20·9	20·8
−60	21·9	21·8	21·8	21·7	21·7	21·6	21·6	21·5	21·4	21·4
−59	22·4	22·4	22·3	22·3	22·2	22·2	22·1	22·1	22·0	21·9
−58	23·0	22·9	22·9	22·8	22·8	22·7	22·7	22·6	22·6	22·5
−57	23·6	23·5	23·4	23·4	23·3	23·3	23·2	23·2	23·1	23·1
−56	24·1	24·1	24·0	23·9	23·9	23·8	23·8	23·7	23·7	23·6
−55	24·7	24·6	24·6	24·5	24·4	24·4	24·3	24·3	24·2	24·2
−54	25·2	25·2	25·1	25·1	25·0	24·9	24·9	24·8	24·8	24·7
−53	25·8	25·7	25·7	25·6	25·6	25·5	25·4	25·4	25·3	25·3
−52	26·3	26·3	26·2	26·2	26·1	26·1	26·0	25·9	25·9	25·8
−51	26·9	26·8	26·8	26·7	26·7	26·6	26·6	26·5	26·4	26·4
−50	27·4	27·4	27·3	27·3	27·2	27·2	27·1	27·1	27·0	26·9

TEMPERATURE. DEGREES FAHRENHEIT TO DEGREES ABSOLUTE.

Tenths.	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
Degrees Fah.	Degrees Absolute, 200 +									
	°	°	°	°	°	°	°	°	°	°
−49	28·0	27·9	27·9	27·8	27·8	27·7	27·7	27·6	27·6	27·5
−48	28·6	28·5	28·4	28·4	28·3	28·3	28·2	28·2	28·1	28·1
−47	29·1	29·1	29·0	28·9	28·9	28·8	28·8	28·7	28·7	28·6
−46	29·7	29·6	29·6	29·5	29·4	29·4	29·3	29·3	29·2	29·2
−45	30·2	30·2	30·1	30·1	30·0	29·9	29·9	29·8	29·8	29·7
−44	30·8	30·7	30·7	30·6	30·6	30·5	30·4	30·4	30·3	30·3
−43	31·3	31·3	31·2	31·2	31·1	31·1	31·0	30·9	30·9	30·8
−42	31·9	31·8	31·8	31·7	31·7	31·6	31·6	31·5	31·4	31·4
−41	32·4	32·4	32·3	32·3	32·2	32·2	32·1	32·1	32·0	31·9
−40	33·0	32·9	32·9	32·8	32·8	32·7	32·7	32·6	32·6	32·5
−39	33·6	33·5	33·4	33·4	33·3	33·3	33·2	33·2	33·1	33·1
−38	34·1	34·1	34·0	33·9	33·9	33·8	33·8	33·7	33·7	33·6
−37	34·7	34·6	34·6	34·5	34·4	34·4	34·3	34·3	34·2	34·2
−36	35·2	35·2	35·1	35·1	35·0	34·9	34·9	34·8	34·8	34·7
−35	35·8	35·7	35·7	35·6	35·6	35·5	35·4	35·4	35·3	35·3
−34	36·3	36·3	36·2	36·2	36·1	36·1	36·0	35·9	35·9	35·8
−33	36·9	36·8	36·8	36·7	36·7	36·6	36·6	36·5	36·4	36·4
−32	37·4	37·4	37·3	37·3	37·2	37·2	37·1	37·1	37·0	36·9
−31	38·0	37·9	37·9	37·8	37·8	37·7	37·7	37·6	37·6	37·5
−30	38·6	38·5	38·4	38·4	38·3	38·3	38·2	38·2	38·1	38·1
−29	39·1	39·1	39·0	38·9	38·9	38·8	38·8	38·7	38·7	38·6
−28	39·7	39·6	39·6	39·5	39·4	39·4	39·3	39·3	39·2	39·2
−27	40·2	40·2	40·1	40·1	40·0	39·9	39·9	39·8	39·8	39·7
−26	40·8	40·7	40·7	40·6	40·6	40·5	40·4	40·4	40·3	40·3
−25	41·3	41·3	41·2	41·2	41·1	41·1	41·0	40·9	40·9	40·8
−24	41·9	41·8	41·8	41·7	41·7	41·6	41·6	41·5	41·4	41·4
−23	42·4	42·4	42·3	42·3	42·2	42·2	42·1	42·1	42·0	41·9
−22	43·0	42·9	42·9	42·8	42·8	42·7	42·7	42·6	42·6	42·5
−21	43·6	43·5	43·4	43·4	43·3	43·3	43·2	43·2	43·1	43·1
−20	44·1	44·1	44·0	43·9	43·9	43·8	43·8	43·7	43·7	43·6
−19	44·7	44·6	44·6	44·5	44·4	44·4	44·3	44·3	44·2	44·2
−18	45·2	45·2	45·1	45·1	45·0	44·9	44·9	44·8	44·8	44·7
−17	45·8	45·7	45·7	45·6	45·6	45·5	45·4	45·4	43·3	45·3
−16	46·3	46·3	46·2	46·2	46·1	46·1	46·0	45·9	45·9	45·8
−15	46·9	46·8	46·8	46·7	46·7	46·6	46·6	46·5	46·4	46·4
−14	47·4	47·4	47·3	47·3	47·2	47·2	47·1	47·1	47·0	46·9
−13	48·0	47·9	47·9	47·8	47·8	47·7	47·7	47·6	47·6	47·5
−12	48·6	48·5	48·4	48·4	48·3	48·3	48·2	48·2	48·1	48·1
−11	49·1	49·1	49·0	48·9	48·9	48·8	48·8	48·7	48·7	48·6
−10	49·7	49·6	49·6	49·5	49·4	49·4	49·3	49·3	49·2	49·2
−9	50·2	50·2	50·1	50·1	50·0	49·9	49·9	49·8	49·8	49·7
−8	50·8	50·7	50·7	50·6	50·6	50·5	50·4	50·4	50·3	50·3
−7	51·3	51·3	51·2	51·2	51·1	51·1	51·0	50·9	50·9	50·8
−6	51·9	51·8	51·8	51·7	51·7	51·6	51·6	51·5	51·4	51·4
−5	52·4	52·4	52·3	52·3	52·2	52·2	52·1	52·1	52·0	51·9
−4	53·0	52·9	52·9	52·8	52·8	52·7	52·7	52·6	52·6	52·5
−3	53·6	53·5	53·4	53·4	53·3	53·3	53·2	53·2	53·1	53·1
−2	54·1	54·1	54·0	53·9	53·9	53·8	53·8	53·7	53·7	53·6
−1	54·7	54·6	54·6	54·5	54·4	54·4	54·3	54·3	54·2	54·2
−0	55·2	55·2	55·1	55·1	55·0	54·9	54·9	54·8	54·8	54·7

TEMPERATURE. DEGREES FAHRENHEIT TO DEGREES ABSOLUTE.

Tenths.	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
Degrees Fah.	Degrees Absolute, 200 +									
	°	°	°	°	°	°	°	°	°	°
0	55·2	55·3	55·3	55·4	55·4	55·5	55·6	55·6	55·7	55·7
1	55·8	55·8	55·9	55·9	56·0	56·1	56·1	56·2	56·2	56·3
2	56·3	56·4	56·4	56·5	56·6	56·6	56·7	56·7	56·8	56·8
3	56·9	56·9	57·0	57·1	57·1	57·2	57·2	57·3	57·3	57·4
4	57·4	57·5	57·6	57·6	57·7	57·7	57·8	57·8	57·9	57·9
5	58·0	58·1	58·1	58·2	58·2	58·3	58·3	58·4	58·4	58·5
6	58·6	58·6	58·7	58·7	58·8	58·8	58·9	58·9	59·0	59·1
7	59·1	59·2	59·2	59·3	59·3	59·4	59·4	59·5	59·6	59·6
8	59·7	59·7	59·8	59·8	59·9	59·9	60·0	60·1	60·1	60·2
9	60·2	60·3	60·3	60·4	60·4	60·5	60·6	60·6	60·7	60·7
10	60·8	60·8	60·9	60·9	61·0	61·1	61·1	61·2	61·2	61·3
11	61·3	61·4	61·4	61·5	61·6	61·6	61·7	61·7	61·8	61·8
12	61·9	61·9	62·0	62·1	62·1	62·2	62·2	62·3	62·3	62·4
13	62·4	62·5	62·6	62·6	62·7	62·7	62·8	62·8	62·9	62·9
14	63·0	63·1	63·1	63·2	63·2	63·3	63·3	63·4	63·4	63·5
15	63·6	63·6	63·7	63·7	63·8	63·8	63 9	63·9	64·0	64·1
16	64·1	64·2	64·2	64·3	64·3	64·4	64·4	64·5	64·6	64·6
17	64·7	64·7	64·8	64·8	64·9	64·9	65·0	65·1	65·1	65·2
18	65·2	65·3	65·3	65·4	65·4	65·5	65·6	65·6	65·7	65·7
19	65·8	65·8	65·9	65·9	66·0	66·1	66·1	66·2	66·[illegible]	66·3
20	66·3	66·4	66·4	66·5	66·6	66·6	66·7	66·7	66·8	66·8
21	66·9	66·9	67·0	67·1	67·1	67·2	67·2	67·3	67·3	67·4
22	67·4	67·5	67·6	67·6	67·7	67·7	67·8	67·8	67·9	67·9
23	68·0	68·1	68·1	68·2	68·2	68·3	68·3	68·4	68·4	68·5
24	68·6	68·6	68·7	68·7	68·8	68·8	68·9	68·9	69·0	69·1
25	69·1	69·2	69·2	69·3	69·3	69·4	69·4	69·5	69·6	69·6
26	69·7	69·7	69·8	69·8	69·9	69·9	70·0	70·1	70·1	70·2
27	70·2	70·3	70·3	70·4	70·4	70·5	70·6	70·6	70·7	70·7
28	70·8	70·8	70·9	70·9	71·0	71·1	71·1	71·2	71·2	71·3
29	71·3	71·4	71·4	71·5	71·6	71·6	71·7	71·7	71·8	71·8
30	71·9	71·9	72·0	72·1	72·1	72·2	72·2	72·3	72·3	72·4
31	72·4	72·5	72·6	72·6	72·7	72·7	72·8	72·8	72·9	72·9
32	73·0	73·1	73·1	73·2	73·2	73·3	73·3	73·4	73·4	73·5
33	73·6	73·6	73·7	73·7	73·8	73·8	73·9	73·9	74·0	74·1
34	74·1	74·2	74·2	74·3	74·3	74·4	74·4	74·5	74·6	74·6
35	74·7	74·7	74·8	74·8	74·9	74·9	75·0	75·1	75·1	75·2
36	75·2	75·3	75·3	75·4	75·4	75·5	75·6	75·6	75·7	75·7
37	75·8	75·8	75·9	75·9	76·0	76·1	76·1	76·2	76·2	76·3
38	76·3	76·4	76·4	76·5	76·6	76·6	76·7	76·7	76·8	76·8
39	76·9	76·9	77·0	77·1	77·1	77·2	77·2	77·3	77·3	77·4
40	77·4	77·5	77·6	77·6	77·7	77·7	77·8	77·8	77·9	77·9
41	78·0	78·1	78·1	78·2	78·2	78·3	78·3	78·4	78·4	78·5
42	78·6	78·6	78·7	78·7	78·8	78·8	78·9	78·9	79·0	79·1
43	79·1	79·2	79·2	79·3	79·3	79·4	79·4	79·5	79·6	79·6
44	79·7	79·7	79·8	79·8	79·9	79·9	80·0	80·1	80·1	80·2
45	80·2	80·3	80·3	80·4	80·4	80·5	80·6	80·6	80·7	80·7
46	80·8	80·8	80·9	80·9	81·0	81·1	81·1	81·2	81·2	81·3
47	81·3	81·4	81·4	81·5	81·6	81·6	81·7	81·7	81·8	81·8
48	81·9	81·9	82·0	82·1	82·1	82·2	82·2	82·3	82·3	82·4
49	82·4	82·5	82·6	82·6	82·7	82·7	82·8	82·8	82·9	82·9
50	83·0	83·1	83·1	83·2	83·2	83·3	83·3	83·4	83·4	83·5

Temperature. Degrees Fahrenheit to Degrees Absolute.

Tenths.	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
Degrees Fah.	Degrees Absolute, 200 +									
	°	°	°	°	°	°	°	°	°	°
50	83·0	83·1	83·1	83·2	83·2	83·3	83·3	83·4	83·4	83·5
51	83·6	83·6	83·7	83·7	83·8	83·8	83·9	83·9	84·0	84·1
52	84·1	84·2	84·2	84·3	84·3	84·4	84·4	84·5	84·6	84·6
53	84·7	84·7	84·8	84·8	84·9	84·9	85·0	85·1	85·1	85·2
54	85·2	85·3	85·3	85·4	85·4	85·5	85·6	85·6	85·7	85·7
55	85·8	85·8	85·9	85·9	86·0	86·1	86·1	86·2	86·2	86·3
56	86·3	86·4	86·4	86·5	86·6	86·6	86·7	86·7	86·8	86·8
57	86·9	86·9	87·0	87·1	87·1	87·2	87·2	87·3	87·3	87·4
58	87·4	87·5	87·6	87·6	87·7	87·7	87·8	87·8	87·9	87·9
59	88·0	88·1	88·1	88·2	88·2	88·3	88·3	88·4	88·4	88·5
60	88·6	88·6	88·7	88·7	88·8	88·8	88·9	88·9	89·0	89·1
61	89·1	89·2	89·2	89·3	89·3	89·4	89·4	89·5	89·6	89·6
62	89·7	89·7	89·8	89·8	89·9	89·9	90·0	90·1	90·1	90·2
63	90·2	90·3	90·3	90·4	90·4	90·5	90·6	90·6	90·7	90·7
64	90·8	90·8	90·9	90·9	91·0	91·1	91·1	91·2	91·2	91·3
65	91·3	91·4	91·4	91·5	91·6	91·6	91·7	91·7	91·8	91·8
66	91·9	91·9	92·0	92·1	92·1	92·2	92·2	92·3	92·3	92·4
67	92·4	92·5	92·6	92·6	92·7	92·7	92·8	92·8	92·9	92·9
68	93·0	93·1	93·1	93·2	93·2	93·3	93·3	93·4	93·4	93·5
69	93·6	93·6	93·7	93·7	93·8	93·8	93·9	93·9	94·0	94·1
70	94·1	94·2	94·2	94·3	94·3	94·4	94·4	94·5	94·6	94·6
71	94·7	94·7	94·8	94·8	94·9	94·9	95·0	95·1	95·1	95·2
72	95·2	95·3	95·3	95·4	95·4	95·5	95·6	95·6	95·7	95·7
73	95·8	95·8	95·9	95·9	96·0	96·1	96·1	96·2	96·2	96·3
74	96·3	96·4	96·4	96·5	96·6	96·6	96·7	96·7	96·8	96·8
75	96·9	96·9	97·0	97·1	97·1	97·2	97·2	97·3	97·3	97·4
76	97·4	97·5	97·6	97·6	97·7	97·7	97·8	97·8	97·9	97·9
77	98·0	98·1	98·1	98·2	98·2	98·3	98·3	98·4	98·4	98·5
78	98·6	98·6	98·7	98·7	98·8	98·8	98·9	98·9	99·0	99·1
79	99·1	99·2	99·2	99·3	99·3	99·4	99·4	99·5	99·6	99·6
80	99·7	99·7	99·8	99·8	99·9	99·9	100·0	100·1	100·1	100·2
81	100·2	100·3	100·3	100·4	100·4	100·5	100·6	100·6	100·7	100·7
82	100·8	100·8	100·9	100·9	101·0	101·1	101·1	101·2	101·2	101·3
83	101·3	101·4	101·4	101·5	101·6	101·6	101·7	101·7	101·8	101·8
84	101·9	101·9	102·0	102·1	102·1	102·2	102·2	102·3	102·3	102·4
85	102·4	102·5	102·6	102·6	102·7	102·7	102·8	102·8	102·9	102 9
86	103·0	103·1	103·1	103·2	103·2	103·3	103·3	103·4	103·4	103 5
87	103·6	103·6	103·7	103·7	103·8	103·8	103·9	103·9	104·0	104·1
88	104·1	104·2	104·2	104·3	104·3	104·4	104·4	104·5	104·6	104·6
89	104·7	104·7	104·8	104·8	104·9	104·9	105·0	105·1	105·1	105·2
90	105·2	105·3	105·3	105·4	105·4	105·5	105·6	105·6	105·7	105·7
91	105·8	105·8	105·9	105·9	106·0	106·1	106·1	106·2	106·2	106·3
92	106·3	106·4	106·4	106·5	106·6	106·6	106·7	106·7	106·8	106·8
93	106·9	106·9	107·0	107·1	107·1	107·2	107·2	107·3	107·3	107·4
94	107·4	107·5	107·6	107 6	107·7	107·7	107·8	107·8	107·9	107·9
95	108·0	108·1	108·1	108·2	108·2	108·3	108·3	108·4	108·4	108·5
96	108·6	108·6	108·7	108·7	108·8	108·8	108·9	108·9	109·0	109·1
97	109·1	109·2	109·2	109·3	109·3	109·4	109·4	109·5	109·6	109·6
98	109·7	109·7	109·8	109·8	109·9	109·9	110·0	110·1	110·1	110·2
99	110·2	110·3	110·3	110·4	110·4	110·5	110·6	110·6	110·7	110·7
100	110·8	110·8	110·9	110·9	111·0	111·1	111·1	111·2	111·2	111·3

Temperature. Degrees Fahrenheit to Degrees Absolute.

Tenths.	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
Degrees Fah.	Degrees Absolute, 200 +									
	°	°	°	°	°	°	°	°	°	°
100	110·8	110·8	110·9	110·9	111·0	111·1	111·1	111·2	111·2	111·3
101	111·3	111·4	111·4	111·5	111·6	111·6	111·7	111·7	111·8	111·8
102	111·9	111·9	112·0	112·1	112·1	112·2	112·2	112·3	112·3	112·4
103	112·4	112·5	112·6	112·6	112·7	112·7	112·8	112·8	112·9	112·9
104	113·0	113·1	113·1	113·2	113·2	113·3	113·3	113·4	113·4	113·5
105	113·6	113·6	113·7	113·7	113·8	113·8	113·9	113·9	114·0	114·1
106	114·1	114·2	114·2	114·3	114·3	114·4	114·4	114·5	114·6	114·6
107	114·7	114·7	114·8	114·8	114·9	114·9	115·0	115·1	115·1	115·2
108	115·2	115·3	115·3	115·4	115·4	115·5	115·6	115·6	115·7	115·7
109	115·8	115·8	115·9	115·9	116·0	116·1	116·1	116·2	116·2	116·3
110	116·3	116·4	116·4	116·5	116·6	116·6	116·7	116·7	116·8	116·8
111	116·9	116·9	117·0	117·1	117·1	117·2	117·2	117·3	117·3	117·4
112	117·4	117·5	117·6	117·6	117·7	117·7	117·8	117·8	117·9	117·9
113	118·0	118·1	118·1	118·2	118·2	118·3	118·3	118·4	118·4	118·5
114	118·6	118·6	118·7	118·7	118·8	118·8	118·9	118·9	119·0	119·1
115	119·1	119·2	119·2	119·3	119·3	119·4	119·4	119·5	119·6	119·6
116	119·7	119·7	119·8	119·8	119·9	119·9	120·0	120·1	120·1	120·2
117	120·2	120·3	120·3	120·4	120·4	120·5	120·6	120·6	120·7	120·7
118	120·8	120·8	120·9	120·9	121·0	121·1	121·1	121·2	121·2	121·3
119	121·3	121·4	121·4	121·5	121·6	121·6	121·7	121·7	121·8	121·8
120	121·9	121·9	122·0	122·1	122·1	122·2	122·2	122·3	122·3	122·4
121	122·4	122·5	122·6	122·6	122·7	122·7	122·8	122·8	122·9	122·9
122	123·0	123·1	123·1	123·2	123·2	123·3	123·3	123·4	123·4	123·5
123	123·6	123·6	123·7	123·7	123·8	123·8	123·9	123·9	124·0	124·1
124	124·1	124·2	124·2	124·3	124·3	124·4	124·4	124·5	124·6	124·6
125	124·7	124·7	124·8	124·8	124·9	124·9	125·0	125·1	125·1	125·2
126	125·2	125·3	125·3	125·4	125·4	125·5	125·6	125·6	125·7	125·7
127	125·8	125·8	125·9	125·9	126·0	126·1	126·1	126·2	126·2	126·3
128	126·3	126·4	126·4	126·5	126·6	126·6	126·7	126·7	126·8	126·8
129	126·9	126·9	127·0	127·1	127·1	127·2	127·2	127·3	127·3	127·4
130	127·4	127·5	127·6	127·6	127·7	127·7	127·8	127·8	127·9	127·9
131	128·0	128·1	128·1	128·2	128·2	128·3	128·3	128·4	128·4	128·5
132	128·6	128·6	128·7	128·7	128·8	128·8	128·9	128·9	129·0	129·1
133	129·1	129·2	129·2	129·3	129·3	129·4	129·4	129·5	129·6	129·6
134	129·7	129·7	129·8	129·8	129·9	129·9	130·0	130·1	130·1	130·2
135	130·2	130·3	130·3	130·4	130·4	130·5	130·6	130·6	130·7	130·7
136	130·8	130·8	130·9	130·9	131·0	131·1	131·1	131·2	131·2	131·3
137	131·3	131·4	131·4	131·5	131·6	131·6	131·7	131·7	131·8	131·8
138	131·9	131·9	132·0	132·1	132·1	132·2	132·2	132·3	132·3	132·4
139	132·4	132·5	132·6	132·6	132·7	132·7	132·8	132·8	132·9	132·9
140	133·0	133·1	133·1	133·2	133·2	133·3	133·3	133·4	133·4	133·5
141	133·6	133·6	133·7	133·7	133·8	133·8	133·9	133·9	134·0	134·1
142	134·1	134·2	134·2	134·3	134·3	134·4	134·4	134·5	134·6	134·6
143	134·7	134·7	134·8	134·8	134·9	134·9	135·0	135·1	135·1	135·2
144	135·2	135·3	135·3	135·4	135·4	135·5	135·6	135·6	135·7	135·7
145	135·8	135·8	135·9	135·9	136·0	136·1	136·1	136·2	136·2	136·3
146	136·3	136·4	136·4	136·5	136·6	136·6	136·7	136·7	136·8	136·8
147	136·9	136·9	137·0	137·1	137·1	137·2	137·2	137·3	137·3	137·4
148	137·4	137·5	137·6	137·6	137·7	137·7	137·8	137·8	137·9	137·9
149	138·0	138·1	138·1	138·2	138·2	138·3	138·3	138·4	138·4	138·5
150	138·6	138·6	138·7	138·7	138·8	138·8	138·9	138·9	139·0	139·1

Pressure.

Equivalents in Millibars of Inches of Mercury at 32° F. and Latitude 45°.*

Inches of Mercury.	Hundredths of Inches. 0	1	2	3	4	5	6	7	8	9
	Millibars.									
27·0	914·3	914·6	915·0	915·3	915·7	916·0	916·3	916·7	917·0	917·4
27·1	917·7	918·0	918·4	918·7	919·0	919·4	919·7	920·1	920·4	920·7
27·2	921·1	921·4	921·8	922·1	922·4	922·8	923·1	923·4	923·8	924·1
27·3	924·5	924·8	925·1	925·5	925·8	926·2	926·1	926·8	927·2	927·5
27·4	927·9	928·2	928·5	928·9	929·2	929·5	929·9	930·2	930·6	930·9
27·5	931·2	931·6	931·9	932·3	932·6	932·9	933·3	933·6	933·9	934·3
27·6	934·6	935·0	935·3	935·6	936·0	936·3	936·7	937·0	937·3	937·7
27·7	938·0	938·3	938·7	939·0	939·4	939·7	940·0	940·4	940·7	941·1
27·8	941·4	941·7	942·1	942·4	942·8	943·1	943·4	943·8	944·1	944·4
27·9	944·8	945·1	945·5	945·8	946·1	946·5	946·8	947·2	947·5	947·8
28·0	948·2	948·5	948·8	949·2	949·5	949·9	950·2	950·5	950·9	951·2
28·1	951·6	951·9	952·2	952·6	952·9	953·2	953·6	953·9	954·3	954·6
28·2	954·9	955·3	955·6	956·c	956·3	956·6	957·c	957·3	957·7	958·0
28·3	958·3	958·7	959·0	959·3	959·7	960·0	960·3	960·7	961·0	961·4
28·4	961·7	962·1	962·4	962·7	963·1	963·4	963·7	964·1	964·4	964·8
28·5	965·1	965·4	965·8	966·1	966·5	966·8	967·1	967·5	967·8	968·1
28·6	968·5	968·8	969·2	969·5	969·8	970·2	970·5	970·9	971·2	971·5
28·7	971·9	972·2	972·6	972·9	973·2	973·6	973·9	974·2	974·6	974·9
28·8	975·3	975·6	975·9	976·3	976·6	976·9	977·3	977·6	978·0	978·3
28·9	978·6	979·0	979·3	979·7	980·0	980·3	980·7	981·0	981·4	981·7
29·0	982·0	982·4	982·7	983·0	983·4	983·7	984·1	984·4	984·7	985·1
29·1	985·4	985·8	986·1	986·4	986·8	987·1	987·5	987·8	988·1	988·5
29·2	988·8	989·1	989·5	989·8	990·2	990·5	990·8	991·2	991·5	991·9
29·3	992·2	992·5	992·9	993·2	993·5	993·9	994·2	994·6	994·9	995·2
29·4	995·6	995·9	996·3	996·6	996·9	997·3	997·6	997·9	998·3	998·6
29·5	999·0	999·3	999·6	1000·0	1000·3	1000·7	1001·0	1001·3	1001·7	1002·0
29·6	1002·4	1002·7	1003·0	1003·4	1003·7	1004·0	1004·4	1004·7	1005·1	1005·4
29·7	1005·7	1006·1	1006·4	1006·8	1007·1	1007·4	1007·8	1008·1	1008·4	1008·8
29·8	1009·1	1009·5	1009·8	1010·1	1010·5	1010·8	1011·2	1011·5	1011·8	1012·2
29·9	1012·5	1012·8	1013·2	1013·5	1013·9	1014·2	1014·5	1014·9	1015·2	1015·6
30·0	1015·9	1016·2	1016·6	1016·9	1017·3	1017·6	1017·9	1018·3	1018·6	1018·9
30·1	1019·3	1019·6	1020·5	1020·3	1020·6	1021·0	1021·3	1021·7	1022·0	1022·3
30·2	1022·7	1023·0	1023·3	1023·7	1024·0	1024·4	1024·7	1025·0	1025·4	1025·7
30·3	1026·1	1026·4	1026·7	1027·1	1027·4	1027·7	1028·1	1028·4	1028·8	1029·1
30·4	1029·4	1029·8	1030·1	1030·5	1030·8	1031·1	1031·5	1031·8	1032·2	1032·5
30·5	1032·8	1033·2	1033·5	1033·8	1034·2	1034·5	1034·9	1035·2	1035·5	1035·9
30·6	1036·2	1036·6	1036·9	1037·2	1037·6	1037·9	1038·2	1038·6	1038·9	1039·3
30·7	1039·6	1039 9	1040·3	1040·6	1041·0	1041·3	1041·6	1042·0	1042·3	1042·6
30·8	1043·0	1043·3	1043·7	1044·0	1044·3	1044·7	1045·0	1045·4	1045·7	1046·0
30·9	1046·4	1046·7	1047·1	1047·4	1047·7	1048·1	1048·4	1048·7	1049·1	1049·4

* This table is based on the equivalents :—1 mercury inch = 33·8632 mb.
1,000 mb. = 29·531 mercury inches.

Mercurial barometers issued by the Meteorological Office are graduated to read either in inches or millibars or both. Apart from errors of graduation the inch scale reads correctly when the temperature of the mercury is 32° F. and the temperature of the brass scale is 62° F. This is equivalent to the statement that the inch scale reads correctly when the whole instrument is at a temperature of 28·5° F. (271·1a). On the other hand the millibar scale is arranged to read correctly (except for errors of graduation) when the temperature of the whole instrument is 285a. Consequently if a barometer is graduated both in inches and millibars readings on the two scales for any setting of the vernier will not conform to the equivalents set out in the above table, but will differ by an amount of about 2·3 mb. or ·066 inch, the millibar scale apparently reading too low in reference to the inch scale.

Pressure in Millimetres of Mercury at 0° C. in Latitude 45° to Millibars.

1000 mm. = 1333·20 mb.

Tens.	0	10	20	30	40	50	60	70	80	90
Millimetres.	Millibars.									
0										
100	133	147	160	173	187	200	213	227	240	253
200	267	280	293	307	320	333	347	360	373	387
300	400	413	427	440	453	467	480	493	507	520
400	533	547	560	573	587	600	613	627	640	653
500	667	680	693	707	720	733	747	760	773	787
600	800	813	827	840	853	867	880	893	907	920
700	933	947	960	973	987	1000	1013	1027	1040	1053
800	1067	1080	1093	1107	1120	1133	1147	1160	1173	1187
900	1200	1213	1227	1240	1253	1267	1280	1293	1307	1320
1000	1333	1347	1360	1373	1387	1400	1413	1427	1440	1453

Increments for changes by millimetre intervals.

mm.	1	2	3	4	5	6	7	8	9
mb.	1·3	2·7	4·0	5·3	6·7	8·0	9·3	10·7	12·0

Pressure in Millibars to Millimetres of Mercury at 0° C. in Latitude 45°.

1000 mb. = 750·076 mm.

Tens.	0	10	20	30	40	50	60	70	80	90
Millibars.	Millimetres at 0° C. and latitude 45°.									
100	75·0	82·5	90·0	97·5	105·0	112·5	120·0	127·5	135·0	142·5
200	150·0	157·5	165·0	172·5	180·0	187·5	195·0	202·5	210·0	217·5
300	225·0	232·5	240·0	247·5	255·0	262·5	270·0	277·5	285·0	292·5
400	300·0	307·5	315·0	322·5	330·0	337·5	345·0	352·5	360·0	367·5
500	375·0	382·5	390·0	397·5	405·0	412·5	420·0	427·5	435·0	442·5
600	450·0	457·5	465·0	472·5	480·0	487·5	495·1	502·6	510·1	517·6
700	525·1	532·6	540·1	547·6	555·1	562·6	570·1	577·6	585·1	592·6
800	600·1	607·6	615·1	622·6	630·1	637·6	645·1	652·6	660·1	667·6
900	675·1	682·6	690·1	697·6	705·1	712·6	720·1	727·6	735·1	742·6
1000	750·1	757·6	765·1	772·6	780·1	787·6	795·1	802·6	810·1	817·6
1100	825·1	832·6	840·1	847·6	855·1	862·6	870·1	877·6	885·1	892·6
1200	900·1	907·6	915·1	922·6	930·1	937·6	945·1	952·6	960·1	967·6

Increments for changes by millibar intervals.

mb.	1	2	3	4	5	6	7	8	9
mm.	·8	1·5	2·3	3·0	3·8	4·5	5·3	6·0	6·8

MILLIMETRES OF MERCURY (680·0 TO 779·9) WITH TENTHS AT 0° C. IN LATITUDE 45° TO MILLIBARS AND TENTHS.

Tenths.		·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
mm.		Millibars.									
680	9	06·6	06·7	06·8	07·0	07·1	07·2	07·4	07·5	07·6	07·8
681	9	07·9	08·0	08·2	08·3	08·4	08·6	08·7	08·8	09·0	09·1
682	9	09·2	09·4	09·5	09·6	09·8	09·9	10·0	10·2	10·3	10·4
683	9	10·6	10·7	10·8	11·0	11·1	11·2	11·4	11·5	11·6	11·8
684	9	11·9	12·0	12·2	12·3	12·4	12·6	12·7	12·8	13·0	13·1
685	9	13·2	13·4	13·5	13·6	13·8	13·9	14·0	14·2	14·3	14·4
686	9	14·6	14·7	14·8	15·0	15·1	15·2	15·4	15·5	15·6	15·8
687	9	15·9	16·0	16·2	16·3	16·4	16·6	16·7	16·8	17·0	17·1
688	9	17·2	17·4	17·5	17·6	17·8	17·9	18·0	18·2	18·3	18·4
689	9	18·6	18·7	18·8	19·0	19·1	19·2	19·4	19·5	19·6	19·8
690	9	19·9	20·0	20·2	20·3	20·4	20·6	20·7	20·8	21·0	21·1
691	9	21·2	21·4	21·5	21·6	21·8	21·9	22·0	22·2	22·3	22·4
692	9	22·6	22·7	22·8	23·0	23·1	23·2	23·4	23·5	23·6	23·8
693	9	23·9	24·0	24·2	24·3	24·4	24·6	24·7	24·8	25·0	25·1
694	9	25·2	25·4	25·5	25·6	25·8	25·9	26·0	26·2	26·3	26·4
695	9	26·6	26·7	26·8	27·0	27·1	27·2	27·4	27·5	27·6	27·8
696	9	27·9	28·0	28·2	28·3	28·4	28·6	28·7	28·8	29·0	29·1
697	9	29·2	29·4	29·5	29·6	29·8	29·9	30·0	30·2	30·3	30·4
698	9	30·6	30·7	30·8	31·0	31·1	31·2	31·4	31·5	31·6	31·8
699	9	31·9	32·0	32·2	32·3	32·4	32·6	32·7	32·8	33·0	33·1
700	9	33·2	33·4	33·5	33·6	33·8	33·9	34·0	34·2	34·3	34·4
701	9	34·6	34·7	34·8	35·0	35·1	35·2	35·4	35·5	35·6	35·8
702	9	35·9	36·0	36·2	36·3	36·4	36·6	36·7	36·8	37·0	37·1
703	9	37·2	37·4	37·5	37·6	37·8	37·9	38·0	38·2	38·3	38·4
704	9	38·6	38·7	38·8	39·0	39·1	39·2	39·4	39·5	39·6	39·8
705	9	39·9	40·0	40·2	40·3	40·4	40·6	40·7	40·8	41·0	41·1
706	9	41·2	41·4	41·5	41·6	41·8	41·9	42·0	42·2	42·3	42·4
707	9	42·6	42·7	42·8	43·0	43·1	43·2	43·4	43·5	43·6	43·8
708	9	43·9	44·0	44·2	44·3	44·4	44·6	44·7	44·8	45·0	45·1
709	9	45·2	45·4	45·5	45·6	45·8	45·9	46·0	46·2	46·3	46·4
710	9	46·6	46·7	46·8	47·0	47·1	47·2	47·4	47·5	47·6	47·8
711	9	47·9	48·0	48·2	48·3	48·4	48·6	48·7	48·8	49·0	49·1
712	9	49·2	49·4	49·5	49·6	49·8	49·9	50·0	50·2	50·3	50·4
713	9	50·6	50·7	50·8	51·0	51·1	51·2	51·4	51·5	51·6	51·8
714	9	51·9	52·0	52·2	52·3	52·4	52·6	52·7	52·8	53·0	53·1
715	9	53·2	53·4	53·5	53·6	53·8	53·9	54·0	54·2	54·3	54·4
716	9	54·6	54·7	54·8	55·0	55·1	55·2	55·4	55·5	55·6	55·8
717	9	55·9	56·0	56·2	56·3	56·4	56·6	56·7	56·8	57·0	57·1
718	9	57·2	57·4	57·5	57·6	57·8	57·9	58·0	58·2	58·3	58·4
719	9	58·6	58·7	58·8	59·0	59·1	59·2	59·4	59·5	59·6	59·8
720	9	59·9	60·0	60·2	60·3	60·4	60·6	60·7	60·8	61·0	61·1
721	9	61·2	61·4	61·5	61·6	61·8	61·9	62·0	62·2	62·3	62·4
722	9	62·6	62·7	62·8	63·0	63·1	63·2	63·4	63·5	63·6	63·8
723	9	63·9	64·0	64·2	64·3	64·4	64·6	64·7	64·8	65·0	65·1
724	9	65·2	65·4	65·5	65·6	65·8	65·9	66·0	66·2	66·3	66·4
725	9	66·6	66·7	66·8	67·0	67·1	67·2	67·4	67·5	67·6	67·8
726	9	67·9	68·0	68·2	68·3	68·4	68·6	68·7	68·8	69·0	69·1
727	9	69·2	69·4	69·5	69·6	69·8	69·9	70·0	70·2	70·3	70·4
728	9	70·6	70·7	70·8	71·0	71·1	71·2	71·4	71·5	71·6	71·8
729	9	71·9	72·0	72·2	72·3	72·4	72·6	72·7	72·8	73·0	73·1

MILLIMETRES OF MERCURY (680·0 TO 779·9) WITH TENTHS AT 0° C. IN LATITUDE 45° TO MILLIBARS AND TENTHS.

Tenths.		0	·1	·2	·3	·4	·5	·6	·7	·8	·9
mm.		Millibars.									
730	9	73·2	73·4	73·5	73·6	73·8	73·9	74·0	74·2	74·3	74·4
731	9	74·6	74·7	74·8	75·0	75·1	75·2	75·4	75·5	75·6	75·8
732	9	75·9	76·0	76·2	76·3	76·4	76·6	76·7	76·8	77·0	77·1
733	9	77·2	77·4	77·5	77·6	77·8	77·9	78·0	78·2	78·3	78·4
734	9	78·6	78·7	78·8	79·0	79·1	79·2	79·4	79·5	79·6	79·8
735	9	79·9	80·0	80·2	80·3	80·4	80·6	80·7	80·8	81·0	81·1
736	9	81·2	81·4	81·5	81·6	81·8	81·9	82·0	82·2	82·3	82·4
737	9	82·6	82·7	82·8	83·0	83·1	83·2	83·4	83·5	83·6	83·8
738	9	83·9	84·0	84·2	84·3	84·4	84·6	84·7	84·8	85·0	85·1
739	9	85·2	85·4	85·5	85·6	85·8	85·9	86·0	86·2	86·3	86·4
740	9	86·6	86·7	86·8	87·0	87·1	87·2	87·4	87·5	87·6	87·8
741	9	87·9	88·0	88·2	88·3	88·4	88·6	88·7	88·8	89·0	89·1
742	9	89·2	89·4	89·5	89·6	89·8	89·9	90·0	90·2	90·3	90·4
743	9	90·6	90·7	90·8	91·0	91·1	91·2	91·4	91·5	91·6	91·8
744	9	91·9	92·0	92·2	92·3	92·4	92·6	92·7	92·8	93·0	93·1
745	9	93·2	93·4	93·5	93·6	93·8	93·9	94·0	94·2	94·3	94·4
746	9	94·6	94·7	94·8	95·0	95·1	95·2	95·4	95·5	95·6	95·8
747	9	95·9	96·0	96·2	96·3	96·4	96·6	96·7	96·8	97·0	97·1
748	9	97·2	97·4	97·5	97·6	97·8	97·9	98·0	98·2	98·3	98·4
749	9	98·6	98·7	98·8	99·0	99·1	99·2	99·4	99·5	99·6	99·8
750	9	99·9	00·0	00·2	00·3	00·4	00·6	00·7	00·8	01·0	01·1
751	10	01·2	01·4	01·5	01·6	01·8	01·9	02·0	02·2	02·3	02·4
752	10	02·6	02·7	02·8	03·0	03·1	03·2	03·4	03·5	03·6	03·8
753	10	03·9	04·0	04·2	04·3	04·4	04·6	04·7	04·8	05·0	05·1
754	10	05·2	05·4	05·5	05·6	05·8	05·9	06·0	06·2	06·3	06·4
755	10	06·6	06·7	06·8	07·0	07·1	07·2	07·4	07·5	07·6	07·8
756	10	07·9	08·0	08·2	08·3	08·4	08·6	08·7	08·8	09·0	09·1
757	10	09·2	09·4	09·5	09·6	09·8	09·9	10·0	10·2	10·3	10·4
758	10	10·6	10·7	10·8	11·0	11·1	11·2	11·4	11·5	11·6	11·8
759	10	11·9	12·0	12·2	12·3	12·4	12·6	12·7	12·8	13·0	13·1
760	10	13·2	13·4	13·5	13·6	13·8	13·9	14·0	14·2	14·3	14·4
761	10	14·6	14·7	14·8	15·0	15·1	15·2	15·4	15·5	15·6	15·8
762	10	15·9	16·0	16·2	16·3	16·4	16·6	16·7	16·8	17·0	17·1
763	10	17·2	17·4	17·5	17·6	17·8	17·9	18·0	18·2	18·3	18·4
764	10	18·6	18·7	18·8	19·0	19·1	19·2	19·4	19·5	19·6	19·8
765	10	19·9	20·0	20·2	20·3	20·4	20·6	20·7	20·8	21·0	21·1
766	10	21·2	21·4	21·5	21·6	21·8	21·9	22·0	22·2	22·3	22·4
767	10	22·6	22·7	22·8	23·0	23·1	23·2	23·4	23·5	23·6	23·8
768	10	23·9	24·0	24·2	24·3	24·4	24·6	24·7	24·8	25·0	25·1
769	10	25·2	25·4	25·5	25·6	25·8	25·9	26·0	26·2	26·3	26·4
770	10	26·6	26·7	26·8	27·0	27·1	27·2	27·4	27·5	27·6	27·8
771	10	27·9	28·0	28·2	28·3	28·4	28·6	28·7	28·8	29·0	29·1
772	10	29·2	29·4	29·5	29·6	29·8	29·9	30·0	30·2	30·3	30·4
773	10	30·6	30·7	30·8	31·0	31·1	31·2	31·4	31·5	31·6	31·8
774	10	31·9	32·0	32·2	32·3	32·4	32·6	32·7	32·8	33·0	33·1
775	10	33·2	33·4	33·5	33·6	33·8	33·9	34·0	34·2	34·3	34·4
776	10	34·6	34·7	34·8	35·0	35·1	35·2	35·4	35·5	35·6	35·8
777	10	35·9	36·0	36·2	36·3	36·4	36·6	36·7	36·8	37·0	37·1
778	10	37·2	37·4	37·5	37·6	37·8	37·9	38·0	38·2	38·3	38·4
779	10	38·6	38·7	38·8	39·0	39·1	39·2	39·4	39·5	39·6	39·8

Inches (27·00 to 31·99) with tenths and hundredths to Millimetres with tenths and hundredths.

1 inch = 25·4000 mm.

Hundredths		·00	·01	·02	·03	04	·05	·06	·07	·08	·09
Inches and Tenths.		Millimetres.									
27·0	6	85·80	86·05	86·31	86·56	86·82	87·07	87·32	87·58	87·83	88·09
27·1	6	88·34	88·59	88·85	89·10	89·36	89·61	89·86	90·12	90·37	90·63
27·2	6	90·88	91·13	91·39	91·64	91·90	92·15	92·40	92·66	92·91	93·17
27·3	6	93·42	93·76	93·93	94·18	94·44	94·69	94·94	95·20	95·45	95·71
27·4	6	95·96	96·21	96·47	96·72	96·98	97·23	97·48	97·74	97·99	98·25
27·5	6	98·50	98·75	99·01	99·26	99·52	99·77	*00·02	00·28	00·53	00·79
27·6	7	01·04	01·29	01·55	01·80	02·06	02·31	02·56	02·82	03·07	03·33
27·7	7	03·58	03·83	04·09	04·34	04·60	04·85	05·10	05·36	05·61	05·87
27·8	7	06·12	06·37	06·63	06·88	07·14	07·39	07·64	07·90	08·15	08·41
27·9	7	08·66	08·91	09·17	09·42	09·68	09·93	10·18	10·44	10·69	10·95
28·0	7	11·20	11·45	11·71	11·96	12·22	12·47	12·72	12·98	13·23	13·49
28·1	7	13·74	13·99	14·25	14·50	14·76	15·01	15·26	15·52	15·77	16·03
23·2	7	16·28	16·53	16·79	17·04	17·30	17·55	17·80	18·06	18·31	18·57
28·3	7	18·82	19·07	19·33	19·58	19·84	20·09	20·34	20·60	20·85	21·11
28·4	7	21·36	21·61	21·87	22·12	22·38	22·63	22·88	23·14	23·39	23·65
28·5	7	23·90	24·15	24·41	24·66	24·92	25·17	25·42	25·68	25·93	26·19
28·6	7	26·44	26·69	26·95	27·20	27·46	27·71	27·96	28·22	28·47	28·73
28·7	7	28·98	29·23	29·49	29·74	30·00	30·25	30·50	30·76	31·01	31·27
28·8	7	31·52	31·77	32·03	32·28	32·54	32·79	33·04	33·30	33·55	33·81
28·9	7	34·06	34·31	34·57	34·82	35·08	35·33	35·58	35·84	36·09	36·35
29·0	7	36·60	36·85	37·11	37·36	37·62	37·87	38·12	38·38	38·63	38·89
29·1	7	39·14	39·39	39·65	39·90	40·16	40·41	40·66	40·92	41·17	41·43
29·2	7	41·68	41·93	42·19	42·44	42·70	42·95	43·20	43·46	43·71	43·97
29·3	7	44·22	44·47	44·73	44·98	45·24	45·49	45·74	46·00	46·25	46·51
29·4	7	46·76	47·01	47·27	47·52	47·78	48·03	48·28	48·54	48·79	49·05
29·5	7	49·30	49·55	49·81	50·06	50·32	50·57	50·82	51·08	51·33	51·59
29·6	7	51·84	52·09	52·35	52·60	52·86	53·11	53·36	53·62	53·87	54·13
29·7	7	54·38	54·63	54·89	55·14	55·40	55·65	55·90	56·16	56·41	56·67
29·8	7	56·92	57·17	57·43	57·68	57·94	58·19	58·44	58·-0	58·95	59·21
29·9	7	59·46	59·71	59·97	60·22	60·48	60·73	60·98	61·-4	61·49	61·75
30·0	7	62·00	62·25	62·51	62·76	63·02	63·27	63·52	63·78	64·03	64·29
30·1	7	64·54	64·79	65·05	65·30	65·56	65·81	66·06	66·32	66·57	66·83
30·2	7	67·08	67·33	67·59	67·84	68·10	68·35	68·60	68·86	69·11	69·37
30·3	7	69·62	69·87	70·13	70·39	70·64	70·89	71·14	71·40	71·65	71·91
30·4	7	72·16	72·41	72·67	72·92	73·18	73·43	73·68	73·94	74·19	74·45
30·5	7	74·70	74·95	75·21	75·46	75·72	75·97	76·22	76·48	76·73	76·99
30·6	7	77·24	77·49	77·75	78·00	78·26	78·51	78·76	79·02	79·27	79·53
30·7	7	79·78	80·03	80·29	80·54	80·80	81·05	81·30	81·56	81·81	82·07
30·8	7	82·32	82·57	82·83	83·08	83·34	83·59	83·84	84·10	84·35	84·61
30·9	7	84·86	85·11	85·37	85·62	85·88	86·13	86·38	86·64	86·89	87·15
31·0	7	87·40	87·65	87·91	88·16	88·42	88·67	88·92	89·18	89·43	89·69
31·1	7	89·94	90·19	90·45	90·70	90·96	91·21	91·46	91·72	91·97	92·23
31·2	7	92·48	92·73	92·99	93·24	93·50	93·75	94·00	94·26	94·51	94·77
31·3	7	95·02	95·27	95·53	95·78	96·04	96·29	96·54	96·80	97·05	97·31
31·4	7	97·56	97·81	98·07	98·32	98·58	98·83	99·08	99·34	99·59	99·85
31·5	8	00·10	00·35	00·61	00·86	01·12	01·37	01·62	01·88	02·13	02·39
31·6	8	02·64	02·89	03·15	03·40	03·66	03·91	04·16	04·42	04·67	04·93
31·7	8	05·18	05·43	05·69	05·94	06·20	06·45	06·70	06·96	07·21	07·47
31·8	8	07·72	07·97	08·23	08·48	08·74	08·99	09·24	09·50	09·75	10·01
31·9	8	10·26	10·51	10·77	11·02	11·28	11·53	11·78	12·04	12·29	12·55

*7.

Millimetres (705–799) with tenths to Inches and thousandths. (1 metre = 39·3701 inches.)

		Tenths of a Millimetre.									
		0	1	2	3	4	5	6	7	8	9
		English Inches.									
705	2	7·756	7·760	7·764	7·768	7·772	7·776	7·780	7·783	7·787	7·791
706	2	7·795	7·799	7·803	7·807	7·811	7·815	7·819	7·823	7·827	7·831
707	2	7·835	7·839	7·843	7·846	7·850	7·854	7·858	7·862	7·866	7·870
708	2	7·874	7·878	7·882	7·886	7·890	7·894	7·898	7·902	7·906	7·909
709	2	7·913	7·917	7·921	7·925	7·929	7·933	7·937	7·941	7·945	7·949
710	2	7·953	7·957	7·961	7·965	7·969	7·972	7·976	7·980	7·984	7·988
711	2	7·992	7·996	8·000	8·004	8·008	8·012	8·016	8·020	8·024	8·028
712	2	8·032	8·035	8·039	8·043	8·047	8·051	8·055	8·059	8·063	8·067
713	2	8·071	8·075	8·079	8·083	8·087	8·091	8·094	8·098	8·102	8·106
714	2	8·110	8·114	8·118	8·122	8·126	8·130	8·134	8·138	8·142	8·146
715	2	8·150	8·154	8·157	8·161	8·165	8·169	8·173	8·177	8·181	8·185
716	2	8·189	8·193	8·197	8·201	8·205	8·209	8·213	8·217	8·220	8·224
717	2	8·228	8·232	8·236	8·240	8·244	8·248	8·252	8·256	8·260	8·264
718	2	8·268	8·272	8·276	8·280	8·283	8·287	8·291	8·295	8·299	8·303
719	2	8·307	8·311	8·315	8·319	8·323	8·327	8·331	8·335	8·339	8·343
720	2	8·346	8·350	8·354	8·358	8·362	8·366	8·370	8·374	8·378	8·382
721	2	8·386	8·390	8·394	8·398	8·402	8·406	8·409	8·413	8·417	8·421
722	2	8·425	8·429	8·433	8·437	8·441	8·445	8·449	8·453	8·457	8·461
723	2	8·465	8·469	8·472	8·476	8·480	8·484	8·488	8·492	8·496	8·500
724	2	8·504	8·508	8·512	8·516	8·520	8·524	8·528	8·531	8·535	8·539
725	2	8·543	8·547	8·551	8·555	8·559	8·563	8·567	8·571	8·575	8·589
726	2	8·583	8·587	8·591	8·594	8·598	8·602	8·606	8·610	8·614	8·618
727	2	8·622	8·626	8·630	8·634	8·638	8·642	8·646	8·650	8·654	8·657
728	2	8·661	8·665	8·669	8·673	8·677	8·681	8·685	8·689	8·693	8·697
729	2	8·701	8·705	8·709	8·713	8·717	8·720	8·724	8·728	8·732	8·736
730	2	8·740	8·744	8·748	8·752	8·756	8·760	8·764	8·768	8·772	8·776
731	2	8·780	8·783	8·787	8·791	8·795	8·799	8·803	8·807	8·811	8·815
732	2	8·819	8·823	8·827	8·831	8·835	8·839	8·843	8·846	8·850	8·854
733	2	8·858	8·862	8·866	8·870	8·874	8·878	8·882	8·886	8·890	8·894
734	2	8·898	8·902	8·906	8·909	8·913	8·917	8·921	8·925	8·929	8·933
735	2	8·937	8·941	8·945	8·949	8·953	8·957	8·961	8·965	8·969	8·972
736	2	8·976	8·980	8·984	8·988	8·992	8·996	9·000	9·004	9·008	9·012
737	2	9·016	9·020	9·024	9·028	9·031	9·035	9·039	9·043	9·047	9·051
738	2	9·055	9·059	9·063	9·067	9·071	9·075	9·079	9·083	9·087	9·091
739	2	9·094	9·098	9·102	9·106	9·110	9·114	9·118	9·122	9·126	9·130
740	2	9·134	9·138	9·142	9·146	9·150	9·154	9·157	9·161	9·165	9·169
741	2	9·173	9·177	9·181	9·185	9·189	9·193	9·197	9·201	9·205	9·209
742	2	9·213	9·217	9·220	9·224	9·228	9·232	9·236	9·240	9·244	9·248
743	2	9·252	9·256	9·260	9·264	9·268	9·272	9·276	9·280	9·283	9·287
744	2	9·291	9·295	9·299	9·303	9·307	9·311	9·315	9·319	9·323	9·327
745	2	9·331	9·335	9·339	9·343	9·346	9·350	9·354	9·358	9·362	9·366
746	2	9·370	9·374	9·378	9·382	9·386	9·390	9·394	9·398	9·402	9·406
747	2	9·409	9·413	9·417	9·421	9·425	9·429	9·433	9·437	9·441	9·445
748	2	9·449	9·453	9·457	9·461	9·465	9·469	9·472	9·476	9·480	9·484
749	2	9·488	9·492	9·496	9·500	9·504	9·508	9·512	9·516	9·520	9·524
750	2	9·528	9·531	9·535	9·539	9·543	9·547	9·551	9·555	9·559	9·563
751	2	9·567	9·571	9·575	9·579	9·583	9·587	9·591	9·594	9·598	9·602
752	2	9·606	9·610	9·614	9·618	9·622	9·626	9·630	9·634	9·638	9·642
753	2	9·646	9·650	9·654	9·657	9·661	9·665	9·669	9·673	9·677	9·681
754	2	9·685	9·689	9·693	9·697	9·701	9·705	9·709	9·713	9·717	0·720

MILLIMETRES (755–799) WITH TENTHS TO INCHES AND THOUSANDTHS.
(1 metre = 39·3701 inches.)

Milli-metres.		Tenths of a Millimetre. 0	1	2	3	4	5	6	7	8	9
		English Inches.									
755	2	9·724	9·728	9·732	9·736	9·740	9·744	9·748	9·752	9·756	9·760
756	2	9·764	9·768	9·772	9·776	9·780	9·783	9·787	9·791	9·795	9·799
757	2	9·803	9·807	9·811	9·815	9·819	9·823	9·827	9·831	9·835	9·839
758	2	9·843	9·846	9·850	9·854	9·858	9·862	9·866	9·870	9·874	9·878
759	2	9·882	9·886	9·890	9·894	9·898	9·902	9·906	9·909	9·913	9·917
760	2	9·921	9·925	9·929	9·933	9·937	9·941	9·945	9·949	9·953	9·957
761	2	9·961	9·965	9·968	9·972	9·976	9·980	9·984	9·988	9·992	9·996
762	3	0·000	0·004	0·008	0·012	0·016	0·020	0·024	0·028	0·031	0·035
763	3	0·039	0·043	0·047	0·051	0·055	0·059	0·063	0·067	0·071	0·075
764	3	0·079	0·083	0·087	0·091	0·094	0·098	0·102	0·106	0·110	0·114
765	3	0·118	0·122	0·126	0·130	0·134	0·138	0·142	0·146	0·150	0·154
766	3	0·157	0·161	0·165	0·169	0·173	0·177	0·181	0·185	0·189	0·193
767	3	0·197	0·201	0·205	0·209	0·213	0·217	0·220	0·224	0·228	0·232
768	3	0·236	0·240	0·244	0·248	0·252	0·256	0·260	0·264	0·268	0·272
769	3	0·276	0·280	0·283	0·287	0·291	0·295	0·299	0·303	0·307	0·311
770	3	0·315	0·319	0·323	0·327	0·331	0·335	0·339	0·343	0·346	0·350
771	3	0·354	0·358	0·362	0·366	0·370	0·374	0·378	0·382	0·386	0·390
772	3	0·394	0·398	0·402	0·406	0·409	0·413	0·417	0·421	0·425	0·429
773	3	0·433	0·437	0·441	0·445	0·449	0·453	0·457	0·461	0·465	0·468
774	3	0·472	0·476	0·480	0·484	0·488	0·492	0·496	0·500	0·504	0·508
775	3	0·512	0·516	0·520	0·524	0·528	0·531	0·535	0·539	0·543	0·547
776	3	0·551	0·555	0·559	0·563	0·567	0·571	0·575	0·579	0·583	0·587
777	3	0·591	0·594	0·598	0·602	0·606	0·610	0·614	0·618	0·622	0·626
778	3	0·630	0·634	0·638	0·642	0·646	0·650	0·654	0·657	0·661	0·665
779	3	0·669	0·673	0·677	0·681	0·685	0·689	0·693	0·697	0·701	0·705
780	3	0·709	0·713	0·717	0·720	0·724	0·728	0·732	0·736	0·740	0·744
781	3	0·748	0·752	0·756	0·760	0·764	0·768	0·772	0·776	0·780	0·783
782	3	0·787	0·791	0·795	0·799	0·803	0·807	0·811	0·815	0·819	0·823
783	3	0·827	0·831	0·835	0·839	0·843	0·846	0·850	0·854	0·858	0·862
784	3	0·866	0·870	0·874	0·878	0·882	0·886	0·890	0·894	0·898	0·902
785	3	0·905	0·909	0·913	0·917	0·921	0·925	0·929	0·933	0·937	0·941
786	3	0·945	0·949	0·953	0·957	0·961	0·965	0·968	0·972	0·976	0·980
787	3	0·984	0·988	0·992	0·996	1·000	1·004	1·008	1·012	1·016	1·020
788	3	1·024	1·028	1·031	1·035	1·039	1·043	1·047	1·051	1·055	1·059
789	3	1·063	1·067	1·071	1·075	1·079	1·083	1·087	1·091	1·094	1·098
790	3	1·102	1·106	1·110	1·114	1·118	1·122	1·126	1·130	1·134	1·138
791	3	1·142	1·146	1·150	1·154	1·157	1·161	1·165	1·169	1·173	1·177
792	3	1·181	1·185	1·189	1·193	1·197	1·201	1·205	1·209	1·213	1·217
793	3	1·220	1·224	1·228	1·232	1·236	1·240	1·244	1·248	1·252	1·256
794	3	1·260	1·264	1·268	1·272	1·276	1·280	1·283	1·287	1·291	1·295
795	3	1·299	1·303	1·307	1·311	1·315	1·319	1·323	1·327	1·331	1·335
796	3	1·339	1·343	1·346	1·350	1·354	1·358	1·362	1·366	1·370	1·374
797	3	1·378	1·382	1·386	1·390	1·394	1·398	1·402	1·405	1·409	1·413
798	3	1·417	1·421	1·425	1·429	1·433	1·437	1·441	1·445	1·449	1·453
799	3	1·457	1·461	1·465	1·468	1·472	1·476	1·480	1·484	1·488	1·492

HEIGHT TABLE. METRES TO FEET.

1 metre = 3·28084 feet.

Metres.	0	1	2	3	4	5	6	7	8	9
	Feet.									
0	0·00	3·28	6·56	9·84	13·12	16·40	19·68	22·97	26·25	29·53
10	32·81	36·09	39·37	42·65	45·93	49·21	52·49	55·77	59·06	62·34
20	65·62	68·90	72·18	75·46	78·74	82·02	85·30	88·58	91·86	95·14
30	98·43	101·71	104·99	108·27	111·55	114·83	118·11	121·39	124·67	127·95
40	131·23	134·51	137·80	141·08	144·36	147·64	150·92	154·20	157·48	160·76
50	164·04	167·32	170·60	173·88	177·17	180·45	183·73	187·01	190·29	193·57
60	196·85	200·13	203·41	206·69	209·97	213·25	216·54	219·82	223·10	226·38
70	229·66	232·94	236·22	239·50	242·78	246·06	249·34	252·62	255·91	259·19
80	262·47	265·75	269·03	272·31	275·59	278·87	282·15	285·43	288·71	291·99
90	295·28	298·56	301·84	305·12	308·40	311·68	315·96	318·24	321·52	324·80
100	328·08	331·36	334·65	337·93	341·21	344·49	347·77	351·05	354·33	357·61
110	360·89	364·17	367·45	370·73	374·02	377·30	380·58	383·86	387·14	390·42
120	393·70	396·98	400·26	403·54	406·82	410·11	413·39	416·67	419·95	423·23
130	426·51	429·79	433·07	436·35	439·63	442·91	446·19	449·48	452·76	456·04
140	459·32	462·60	465·88	469·16	472·44	475·72	479·00	482·28	485·56	488·85
150	492·13	495·41	498·69	501·97	505·25	508·53	511·81	515·09	518·37	521·65
160	524·93	528·22	531·50	534·78	538·06	541·34	544·62	547·90	551·18	554·46
170	557·74	561·02	564·30	567·59	570·87	574·15	577·43	580·71	583·99	587·27
180	590·55	593·83	597·11	600·39	603·67	606·96	610·24	613·52	616·80	620·08
190	623·36	626·64	629·92	633·20	636·48	639·76	643·04	646·33	649·81	652·89

Metres	0	10	20	30	40	50	60	70	80	90
	Feet.									
200	656·17	688·98	721·79	754·59	787·40	820·21	853·02	885·83	918·64	951·44
300	984·25	1017·06	1049·87	1082·68	1115·49	1148·29	1181·10	1213·91	1246·72	1279·53
400	1312·34	1345·14	1377·95	1410·76	1443·57	1476·38	1509·19	1541·99	1574·80	1607·61
500	1640·42	1673·23	1706·04	1738·85	1771·65	1804·46	1837·27	1870·08	1902·89	1935·70
600	1968·50	2001·31	2045·12	2066·93	2099·74	2132·55	2165·35	2198·16	2230·97	2263·78
700	2296·59	2329·40	2362·20	2395·01	2427·82	2460·63	2493·44	2526·25	2559·06	2591·86
800	2624·67	2657·48	2690·29	2723·10	2755·91	2788·71	2821·52	2854·33	2887·14	2919·95
900	2952·76	2985·56	3018·37	3051·18	3083·99	3116·80	3149·61	3182·41	3215·22	3248·03
1000	3280·84	3313·65	3346·46	3379·27	3412·07	3444·88	3477·69	3510·50	3543·31	3576·12

WIND VELOCITY.

A.—Miles per hour to Metres per second.

1 Mile per hour = 0·44704 Metres per second.

Miles per hour.	0	1	2	3	4	5	6	7	8	9
	Metres per second.									
0	0·0	0·5	0·9	1·3	1·8	2·2	2·7	3·1	3·6	4·0
10	4·5	4·9	5·4	5·8	6·3	6·7	7·2	7·6	8·1	8·5
20	8·9	9·4	9·8	10·3	10·7	11·2	11·6	12·1	12·5	13·0
30	13·4	13·9	14·3	14·8	15·2	15·7	16·1	16·5	17·0	17·4
40	17·9	18·3	18·8	19·2	19·7	20·1	20·6	21·0	21·5	21·9
50	22·4	22·8	23·3	23·7	24·1	24·6	25·0	25·5	26·0	26·4
60	26·8	27·3	27·7	28·2	28·6	29·1	29·5	30·0	30·4	30·9
70	31·3	31·7	32·2	32·6	33·1	33·5	34·0	34·4	34·9	35·3
80	35·8	36·2	36·7	37·1	37·6	38·0	38·4	38·9	39·3	39·8
90	40·2	40·7	41·1	41·6	42·0	42·5	42·9	43·4	43·8	44·3
100	44·7	45·2	45·6	46·0	46·5	46·9	47·4	47·8	48·3	48·7
110	49·2	49·6	50·1	50·5	51·0	51·4	51·9	52·3	52·8	53·2
120	53·6	54·1	54·5	55·0	55·4	55·9	56·3	56·8	57·2	57·7
130	58·1	58·6	59·1	59·5	59·9	60·4	60·8	61·2	61·7	62·1
140	62·5	63·0	63·5	63·9	64·4	64·8	65·3	65·7	66·2	66·6

B.—Metres per second to Miles per Hour.

1 Metre per second = 2·23694 Miles per hour.

Metres per second.	Miles per hour.	Metres per second.	Miles per hour.	Metres per second.	Miles per hour.	Metres per second.	Miles per hour.
1	2·24	**16**	35·79	**31**	69·35	**46**	102·90
2	4·47	**17**	38·03	**32**	71·58	**47**	105·14
3	6·71	**18**	40·27	**33**	73·82	**48**	107·37
4	8·95	**19**	42·50	**34**	76·06	**49**	109·61
5	11·18	**20**	44·74	**35**	78·29	**50**	111·85
6	13·42	**21**	46·98	**36**	80·53	**51**	114·09
7	15·66	**22**	49·21	**37**	82·77	**52**	116·32
8	17·90	**23**	51·45	**38**	85·01	**53**	118·56
9	20·13	**24**	53·69	**39**	87·24	**54**	120·80
10	22·37	**25**	55·92	**40**	89·48	**55**	123·03
11	24·61	**26**	58·16	**41**	91·72	**56**	125·27
12	26·84	**27**	60·40	**42**	93·95	**57**	127·51
13	29·08	**28**	62·64	**43**	96·19	**58**	129·74
14	31·32	**29**	64·87	**44**	98·43	**59**	131·98
15	33·55	**30**	67·11	**45**	100·66	**60**	134·22

Increments by 0·1 m/s intervals.

m/s	·1	·2	·3	·4	·5	·6	·7	·8	·9
mi/h	·22	·45	·67	·00	1·12	1·34	1·57	1·79	2·01

FOR OFFICIAL USE.

M.O. 223. Section II. (2nd Edition.)

AIR MINISTRY.

METEOROLOGICAL OFFICE.

THE COMPUTER'S HANDBOOK.

Section II—Subsection I—The Computation of Wind Components from observations of Pilot Balloons and Shell Bursts.

(2nd EDITION.)

Published by the Authority of the Meteorological Committee.

LONDON:
PRINTED BY HIS MAJESTY'S STATIONERY OFFICE
And to be purchased from the METEOROLOGICAL OFFICE, Air Ministry, Kingsway, London, W.C.2, or Exhibition Road, London, S.W.7.

Price 2s. 0d. Net.

TABLE OF CONTENTS.

NOTE.—Pages 3 to 15 and Appendix II. are reprinted with slight modifications from S.S. 77 "Meteorological Notes and Instructions for the Use of Observers" by permission of the Army Council.

COMPUTER'S HANDBOOK.

SECTION II.

DYNAMICAL METEOROLOGY. CALCULUS OF THE UPPER AIR.

Subsection I.—The Computation of Wind Speed and Direction at various heights from observations of Pilot Balloons and Shell Bursts.

Rate of Ascent of Pilot Balloons.

1. The fundamental assumption made is that the balloon picks up almost immediately the horizontal velocity of the air in which it is moving. A little reflection shows that this cannot be exactly true, in fact that it can be at the best only an approximation; but the variations of wind from layer to layer are usually sufficiently slow for the assumption to be a reasonable working hypothesis.

2. Taking assumption (1) to be satisfied, the velocity of the wind can be determined with strict accuracy if the balloon is watched by two theodolites at the ends of a base line and the readings taken with sufficient refinement. This method is not so readily applicable, however, in the field, and it requires a large number of observers. Consequently a modification has hitherto been used.

3. The one-theodolite method depends for its usefulness on the fact that a balloon rises at a nearly constant rate, determined by the weight of the balloon and its free lift. [The free lift takes some account implicitly of the diameter of the balloon.] It has been established by observation that this is roughly true on the average, but the law is usually not exactly fulfilled in an individual case. The shape of the balloon, the effect of sunshine on it, and vertical currents (or eddies) modify the rate of ascent; but the modifications are usually small enough to permit of the assumption giving reasonably good results.

A discussion of the effect of vertical currents on wind velocities as determined by the one-theodolite method will be found in Appendix I.

4. The formula used to connect the free lift "L," weight "W" and upward velocity "V" of a rubber balloon is :—

$$V = q\, L^{\frac{1}{2}}/(L + W)^{\frac{1}{3}} \quad . \; . \; . \; . \; . \; . \quad \text{i}$$

where q is approximately constant.

The formula is derived from

$$L = k\, \rho\, v^2\, r^2 \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad \text{ii}$$

$$L + W = A\, \rho\, r^3 \quad . \; . \; . \; . \; . \; . \; . \; . \quad \text{iii}$$

Here ii connects the resistance $k \rho v^2 r^2$ of the air to the motion of the balloon with the net upward force on the balloon "L." [The air resistance for low velocities varies as the square of the velocity v: it will also vary approximately as the area of the diametral section of the balloon πr^2 and as the density of the air ρ.] In iii the weight of air displaced by the balloon ($\frac{4}{3} \pi r^3 \rho$) is equated to the total upward force + the weight of the hydrogen ($L + W + \frac{4}{3} \pi r^3 \rho^1$) where ρ^1 is the density of the hydrogen. As $\frac{\rho^1}{\rho}$ = constant = C if there is no appreciable difference of pressure between the inside and the outside of the balloon, we may write $\frac{4}{3} \pi r^3 \rho \left(1 - \frac{\rho^1}{\rho}\right)$ as $A \rho r^3$.

Eliminating r between ii and iii we get—

$$v = \frac{L^{\frac{1}{2}}}{(L + W)^{\frac{1}{3}}} \cdot \frac{A^{\frac{1}{3}}}{k^{\frac{1}{2}} \rho^{\frac{1}{6}}}$$

$$\text{Thus } q = A^{\frac{1}{3}} / k^{\frac{1}{2}} \rho^{\frac{1}{6}}$$

and q therefore increases with height owing to the decrease in ρ so long as there is no leak of hydrogen from the balloon and so long as the difference of pressure between the inside and the outside of the balloon is small compared with the actual pressure.

The value* of q near the earth's surface is about 275 if L and W are expressed in grammes and v in feet per minute. But q depends to some extent on the size of the balloon used, being greater for balloons having a free lift above 150 grammes and being nearly constant for balloons with a free lift below 150 grammes. [J. S. Dines : Notes on Hesselberg's paper, *Q.J. Roy. Met. Soc.*, April, 1918, p. 131.]

In the case of the one-theodolite method the arithmetic is simplified by arranging the free lift to give a fixed round number for the rate of ascent. For the balloons used in this country a convenient number is 500 feet per minute.

The following are approximate relations used for obtaining the necessary free lift for balloons of different weight and for balloons carrying lanterns. For low ascents smaller balloons may be used ascending at 400 feet per minute, the relations for these have been added.

I. Free lift to give upward velocity of 500 feet per minute.

(*a*) 15 g. balloon : no load
$$L = 58 + 1{\cdot}1\ (W - 15).$$
(*b*) 25 g. balloon : no load
$$L = 65 + 0{\cdot}9\ (W - 25).$$
(*c*) 30 g. balloon : no load
$$L = 72 + 0{\cdot}9\ (W - 30).$$
(*d*) 30 g. balloon, 25 g. lantern
$$L = 93 + 0{\cdot}7\ (W + w - 55).$$

II. Free lift to give vertical velocity of 400 feet per minute.

(*a*) 8 g. balloon : no load
$$L = 19 + 0{\cdot}8\ (W - 8).$$
(*b*) 15 g. balloon, 25 g. lantern
$$L = 39 + 0{\cdot}5\ (W + w - 40).$$

Herein L = free lift in grammes.

i.e., total weight which balloon would just lift over and above weight of string, lantern, candle, &c. (if any).

W = balloon's weight in grammes.

w = (lantern and candle) weight in grammes.

Thus for a 30 g. balloon which is intended to carry a 25 g. lantern, the total weight which the balloon should lift is 93 + 25 = 118 g.

NOTE.—*All chalk should be carefully shaken out of the balloons before they are weighed.*

The Single Theodolite Method.

5. (i) Consider the diagram for elevation (Fig. 1). If P_n is the position of balloon at the end of the nth minute, and B_n the point on the earth vertically beneath P_n.

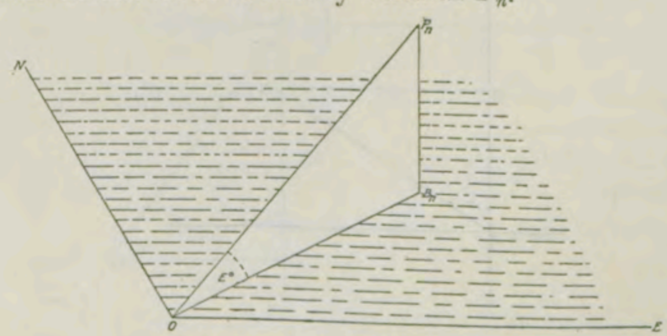


FIG. 1.

* If a lantern and candle are suspended below the balloon, then as these offer some resistance to upward motion, the value of "q" would be decreased on that account. But it is found that the lantern and candle exercise a steadying influence on the motion of the balloon, which influence tends to increase q.

For the lanterns and candles normally used in meteorological work the two effects approximately balance ; and the same value of "q" applies for both day and night ascents, *i.e.* if "w" is the weight of the lantern and candle, then

$$v = q\, L^{\frac{1}{2}} / (L + W + w)^{\frac{1}{3}}.$$

Note carefully that in this case the free lift "L" is the nett free lift, *i.e.*, the balloon is filled until, at total weight, it lifts "$L + w$" grammes when L is the number of grammes attached temporarily before release, and w is the number of grammes attached permanently in the form of lantern and candle.

then P_nB_n = height of balloon = h
and OB_n = $h \cot E$ where E = angle of elevation.

(ii) Imagine the theodolite set on the balloon; now by moving the altitude screws, and, *without moving the azimuth at all*, bring the telescope down to the horizontal; clearly the telescope will then be in the direction of the point on the horizontal plane which is vertically beneath the balloon, *i.e.*, in the direction OB_n.

Therefore, if ON is the North direction, the angle between ON and OB_n is the azimuth angle.

Also, the distance the balloon has travelled in a horizontal direction is OB_n, because B_n is vertically beneath P_n.

Therefore, to obtain the horizontal velocity, P_n may be disregarded and attention given only to OB_n.

Four diagrams are wanted to consider the four cases of the azimuth being between

(*a*) 0° and 90°
(*b*) 90° „ 180°
(*c*) 180° „ 270°
(*d*) 270° „ 360°.

In what follows it is assumed that the theodolite is set so that when it is pointing North the reading on the azimuth scale is 0°.

Case 1.—(In all the four cases the actual azimuth angle will be denoted by a curved arrow.)

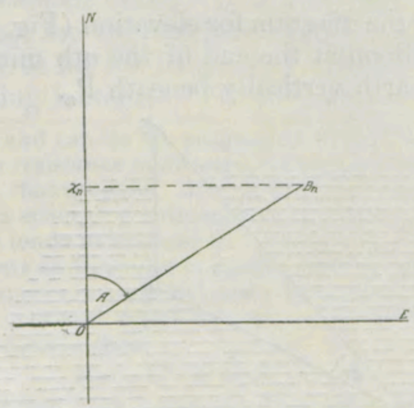


FIG. 2A.

Azimuth between 0° and 90° (Fig. 2A).

OB_n is as in the elevation diagram (Fig. 1) and equals $h \cot E$.

D_n = distance towards North = $OX_n = OB_n \cos A = h \cot E \cos A$
D_e = „ „ East = $X_nB_n = OB_n \sin A = h \cot E \sin A$

Rule for signs is D_n is +, D_e is +.

Case 2.—Azimuth between 90° and 180° (Fig. 2B). Here subtract 90° from the original azimuth to give angle $EOB_n = \alpha$.

Clearly α = angle OB_nX_n.

D_n = distance towards North = $-OX_n = -OB_n \sin \alpha$
$= -h \cot E \sin \alpha$

D_e = „ „ East = $X_nB_n = OB_n \cos \alpha$
$= h \cot E \cos \alpha$

Therefore, rule for signs is D_e is +, D_n is −.

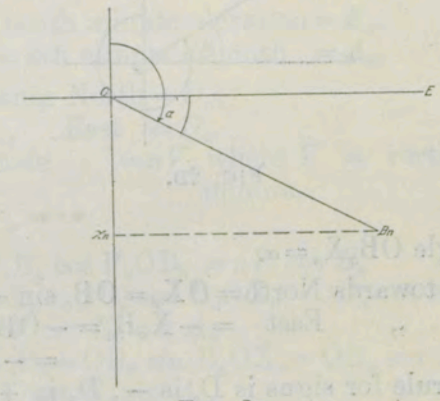


FIG. 2B.

Case 3.—Azimuth between 180° and 270° (Fig. 2C). Subtract 180° from the original azimuth to get angle X_nOB_n, which is the angle A' referred to in the following:

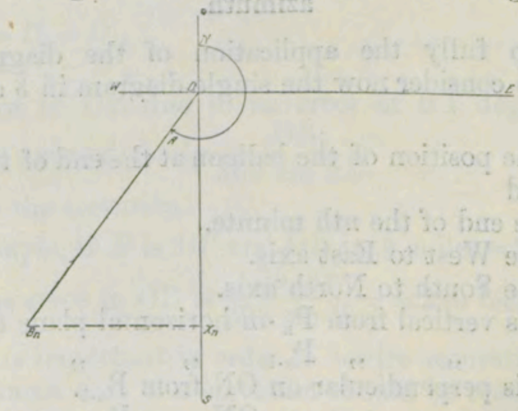


FIG 2C.

D_n = distance towards North $= -OX_n$

$= -OB_n \cos A' = -h \cot E \cos A'$

D_e = " " East $= -X_nB_n$

$= -OB_n \sin A' = -h \cot E \sin A'$

Therefore, rule for signs is D_e is $-$, D_n is $-$.

Case 4.—Azimuth between 270° and 360° (Fig. 2D). Subtract 270° from the original azimuth to get angle B_nOW, angle α as in sketch.

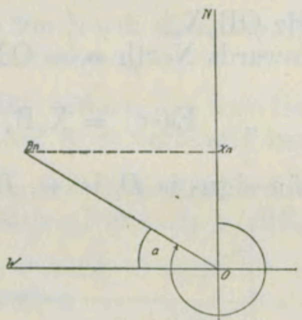


Fig. 2D.

Clearly angle $OB_nX_n = \alpha$.

D_n = distance towards North $= OX_n = OB_n \sin \alpha = h \cot E \sin \alpha$

D_e = " " East $= -X_nB_n = -OB_n \cos \alpha$

$= -h \cot E \cos \alpha$.

Therefore, rule for signs is D_e is $-$, D_n is $+$.

In the above description—

A is used for azimuth.

α " " an angle differing by 90° or 270° from azimuth.

To grasp fully the application of the diagrams it is desirable to consider now the single diagram in 3 dimensions (Fig. 3).

P_{n-1} is the position of the balloon at the end of the $(n\text{-}1)$th minute, and

P_n at the end of the nth minute.

OE is the West to East axis.

ON is the South to North axis.

P_nB_n is vertical from P_n on horizontal plane through O.

$P_{n-1}B_{n-1}$ " " P_{n-1} " " " O.

$B_{n-1}X_{n-1}$ is perpendicular on ON from B_{n-1}.

B_nX_n " " ON " B_n.

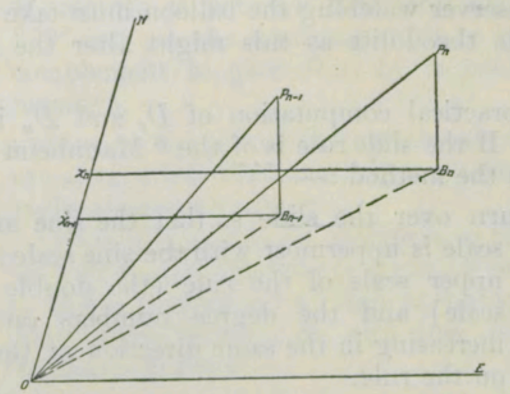


Fig. 3.

The angles read off on the theodolite are then

$P_nOB_n = n$th minute elevation $= E_n$.

$NOB_n = n$th minute azimuth $= A_n$.

OX_n = distance North $= D_n$.

B_nX_n = " East $= D_e$.

P_nB_n = altitude $= nV$, where V = vertical speed per minute.

Thus

$OB_n = P_nB_n \cot P_nOB_n = nV \cot E_n$

$D_n = OX_n = OB_n \cos B_nOX_n = OB_n \cos A_n$

$= n\,V \cot E_n \cos A_n$

$D_e = X_nB_n = OB_n \sin B_nOX_n = OB_n \sin A_n$

$= nV \cot E_n \sin A_n$.

Similarly

$D'_n = (n\text{-}1)\,V \cot E_{n-1} \cos A_{n-1}$

$D'_e = (n\text{-}1)\,V \cot E_{n-1} \sin A_{n-1}$.

Now

$V_{we} = D_e - D'_e$

$V_{sn} = D_n - D'_n$.

The error in OB due to an error of 0·1 degree in the elevation is approximately $\dfrac{OB}{300 \sin 2E}$ where E is the elevation.

For example, if E is 10° and OB is 5 miles = 25,000 feet roughly the error in OB is $\dfrac{25{,}000}{300 \sin 20°} = 250$ feet nearly.

Thus it is important in order to secure accurate values at great distances that the elevation should be read very carefully and that the instrument should be levelled accurately.

Also the observer watching the balloon must take care not to *press* on the theodolite as this might alter the level considerably.

6. The practical computation of D_e and D_n is done by slide rule. If the slide rule is of the "Mannheim" type, the following is the method :—

(*a*) Turn over the slide so that the sine and tangent scale is uppermost with the sine scale against the upper scale of the rule (the double logarithm scale) and the degree numbers on the slide increasing in the same direction as the numbers on the rule.

(*b*) Set the cursor on the number on the upper scale of the rule representing the altitude (in hundreds of feet). The left-hand sector of the upper scale is usually the most convenient one to use for numbers which begin with a digit greater than 2.

(*c*) Move the slide until the altitude angle on the tangent scale comes under the line on the cursor. Then proceed as in (*d*). [If the altitude angle is greater than 45° set 90° on the sine scale under the number on the upper scale of the rule corresponding to the height, set the cursor to the complement of the altitude on the tangent scale and shift the slide so that 90° on the sine scale comes under the line under the cursor. Then proceed as in (*d*).]

(*d*) Set the cursor on the azimuth angle on the sine scale and read off on the upper scale of the rule the corresponding number which gives the value of D_e. (For sign of D_e *see below.*)

(*e*) Set the cursor on the complement of the azimuth angle on the sine scale. This gives D_n. (For sign of D_n *see below.*)

(*f*) (i) If azimuth is between 0° and 90° (*d*) and (*e*) apply directly and D_e and D_n are both plus.

(ii) If azimuth is between 90° and 180°, subtract 90° and use the resulting angle to give D_n (note specially D_n and not D_e), and the complement to give D_e. In this case D_n is negative and D_e is positive.

(iii) If azimuth is between 180° and 270°, subtract 180° and use the resulting angle to give D_e, complement to give D_n. Both D_e and D_n are negative.

(iv) If azimuth is between 270° and 360°, subtract 270° and use the resulting angle to give D_n and complement to give D_e. D_n is positive, D_e is negative.

(*g*) Numbers to the left of the cursor as originally set are always less than the height ; numbers to the right always greater.

Thus if height is 10, numbers to the left will be 1 to 9, and numbers to right 10 to 100.

If the altitude is '*n*' figures, no number with more than $(n+1)$, or with less than $(n-1)$ figures will occur.

(*h*) If the azimuth and its complement do not both come within the limits of the rule-scales, read off one and then set the cursor at the end of the tangent scale. Move the slide throughout its length, to right usually, read off the complement on the sine scale against the upper scale of the rule. This will give the value of D_e or D_n as the case may be, but it will be 10 times smaller than if the slide had not been moved. (If the motion of the slide had been to the left it would be 10 times bigger.)

6A. The Pilot - Balloon Slide - Rule differs from the "Mannheim" pattern in having—

(i) The tangent scale as the lower fixed scale of the rule and the sine scale as the upper fixed scale of the rule ; the sine scale for angles 10° to 90° is repeated so as to ensure all cases coming within the compass of the rule without the need for taking complementary angles or moving the slide. For a similar reason the logarithmic scale on the slide is repeated 3 times. Also to save mental arithmetic the cosine scale is engraved upon the sine scale.

This slide-rule is not intended or suited for ordinary calculations apart from the pilot-balloon work.

(ii) The slide is double to facilitate computation for balloons ascending with rates different from the normal 500 ft./ min. in cases where the *thickness of the layer* is not material. This double slide has no practical advantage, and may be misleading in cases where the computation is required for 500 foot layers, in accordance with the usual practice ; the two sections of the slide should therefore be made coincident and clamped, and the slide-rule used throughout with heights in the usual way, and not with times.

To Use the Pilot-Balloon Slide-Rule.—(*a*) Set the lower cursor on the elevation angle. Move the slide till the figure giving the height in hundreds of feet comes under the line of the cursor. Select that one of the 3 lower scales on the slide which will on the one hand bring the left-hand limit of the upper scale on the slide to the left of the 1° angle of the sine scale, and on the other hand will not bring the right-hand limit of the upper scale on the slide to the left of the angle marked 90° in the middle of the upper fixed scale.

(*b*) Set one of the upper cursors on the azimuth angle on the sine scale and read off on the slide the number which gives D_e. If the height figure (in hundreds of feet) contains 2 digits then the value of D_e will contain 1, 2 or 3 digits according as the logarithmic scale giving D_e is to the left, coincident with, or to the right of the logarithmic scale on which the lower cursor is set (*i.e.*, the logarithmic scale selected under (*a*) for the height scale). [If the latter is the left-hand scale of the three, and D_e is found on the right-hand scale of the three, then D_e contains 2 more digits than the height ; it contains 2 digits less than the height if the order is reversed.]

(*c*) Set the other upper cursor on the azimuth angle on the cosine scale, and read off on the slide the number which gives D_n. The rules about the number of digits given under (*b*) apply for D_n also.

(*d*) If the azimuth is between 0° and 90°, D_e and D_n are both +.

If the azimuth is between 90° and 180° D_e is + and D_n is −.

(The angle used should be the complementary angle $A-90°$ and D_e read off from the cosine scale, D_n from the sine scale.)

If the azimuth is between 180° and 270°, D_e is − D_n is −.

The angle used should be $A-180°$, D_e is then read from the sine scale, D_n from the cosine scale.

If the azimuth is between 270° and 360° D_e is −, D_n is +.

The angle used should be the complementary angle $A-270°$.

D_e is then read from the cosine scale, D_n from the sine scale.

(*e*) The auxiliary sine and cosine scale to the right of the rule may be used if the azimuth and its complement do not come within the limits of the slide. The values got by using this scale must be divided by 10.

6B. The final angle ϕ and final speed are, as explained in para. 7, usually obtained by means of the printed table, but, if need be, they can be obtained from the "Mannheim" slide-rule as follows :—

Having got V_e and V_n by subtracting consecutive values of D_e and D_n, set the right-hand end of the slide against the larger of V_e and V_n on the upper scale of the rule ; set the cursor on the smaller of V_e and V_n, also on the upper scale of the rule, and read under the cursor on the tangent scale the azimuth of the wind. The azimuth is measured from E (or W) if V_e is the greater, and from N (or S) if V_n is the greater.

If V_e is + and V_n + resultant velocity is in 1st quadrant and wind direction in 3rd quadrant.

If V_e is + and V_n − resultant velocity is in 2nd quadrant and wind direction in 4th quadrant.

If V_e is − and V_n − resultant velocity is in 3rd quadrant and wind direction in 1st quadrant.

If V_e is − and V_n + resultant velocity is in 4th quadrant and wind direction in 2nd quadrant.

[NOTE.—The direction of the wind, being that direction from which the wind is blowing, always comes in the opposite quadrant to the line representing velocity in the ordinary mathemathical sense.]

If V_e is the greater and +, wind is between NW and SW.
If V_e is the greater and −, wind is between NE and SE.
If V_n is the greater and +, wind is between SW and SE.
If V_n is the greater and −, wind is between NW and NE.

Having determined the azimuth angle as above (magnitude only is required for this) move the slide so that this azimuth angle, read on the sine scale, comes under the line on the cursor. The resultant speed is then read off at the end of the tangent scale.

The direction and magnitude of the resultant velocity can also be found from its components by using the pilot-balloon slide-rule in the following way :—

(i) Set V_{sn} on the lower scale of the slide opposite 45° on the tangent scale and read the angle opposite V_{we}. This angle ϕ^1 is the angle with the resultant wind direction makes with the NS line and the actual angle ϕ is 180° ± ϕ^1 or 360 - ϕ^1.

(ii) Move the slide until the value of V_{we} on the upper scale of the slide falls under the angle ϕ^1 on the sine scale. The value of V will be found under 90° on the sine scale.

7. Having obtained D_e and D_n *and their respective signs*, as described in para. 6, V_{we} and V_{sn} are obtained by subtraction. One D_e subtracted from the next D_e gives the distance the balloon has gone in the W.-E. direction in the minute ending at the time of the second D_e, *i.e.*, it gives V_{we}; similarly for D_n and V_{sn}; *due regard must be paid to signs in each case.* It must be remembered that a velocity *towards* North is a *South* wind; so that the angle used for specifying the direction of the wind is 180° greater than the angle which would be used in the conventional mathematical way of expressing the resultant velocity.

The angle found in the printed table is, however, always an angle = to or < 45°. This is not usually the direction to be put down as the wind direction; the wind direction is obtained from it by the rules on the tables which are deduced in the following way: consider the attached diagram (Fig. 4). The balloon is at B. That means that, starting from O as centre, it has been blown during the minute into position B and, as it blows always with the wind, the wind must be blowing from C along line COB.

A copy of the printed table referred to herein is reproduced in Appendix II.

FIG. 4.

The angle found from the printed table is the angle SOB or EOB, *whichever is the smaller.* In the diagram angle SOB is the smaller; then the wind direction (always denoted by the number of degrees from true North, working clockwise) will be 360°—angle CON
that is 360°—angle SOB.

Other positions B of the balloon are considered in a similar way.

8. If pilot balloon ascents have to be done at night it will be necessary to illuminate the balloon and the scales of the theodolite.

The former object is secured in the following way:—A small white-paper lantern containing a lighted candle is suspended from the neck of the balloon by means of a piece of thin string: this lantern should hang about 12 feet from the balloon when the string is fully extended.

The addition of the lantern, candle and string will, of course, alter the free lift to be given to the balloon so that it may rise at the required number of feet per minute. The formula for a 30g. balloon carrying a lantern and accessories, total weight, 25g., and for a 15g. balloon carrying a similar load but rising 400 feet per minute, will be found in para. 4. The significance of "L" in these two cases should be carefully noted: "L" is the free lift of the balloon *over and above* the weight of the lantern and accessories.

The illumination of the theodolite scales is most easily performed by the observer switching an electric torch upon them at the time of reading. The torch should be small enough to be carried easily in the right hand and yet leave the operator free enough to turn the altitude screw with the same hand. The light should not be too bright, as the balloon will then be difficult to pick up after a reading.

In night ascents care is required to avoid getting on a star when the balloon is some distance away. If a star is being watched, consecutive readings, both of altitude and of azimuth, will be almost identical: all cases where this identity is seen to exist should be carefully examined and the results discarded unless the evidence for their correctness is very strong.

When the observations of elevation and azimuth are obtained from the theodolite, the computation of the required wind directions and velocities is carried out exactly as has already been described.

Pilot Balloon Ascent, Number 836. Date, Sept. 24, 1918.
Station, Shoeburyness. Height above M.S.L. Time of start 08h. 20m.
DAY ASCENT. 22 g. Rubber Balloon. Free lift 66 g.
Upward V = 500 ft./min. (q = 81).
Mark for Azimuth Ferry Point bearing 64·3° from N.
Balloon lost—abandoned.
Surface Wind (100 ft. above ground) 14 f/s. at 275°. Weather b.
NOTE.—First $\phi = 180° + A$. First $V = 500 \div E\ (E < 20°) = 450 \div E$ $(E = 20°$ to $40°)$ approx. TEMP. 52·5. 49·5.

Time from start Minutes. t	Azimuth Degrees from N. A	Elevation E	Height. 100's of feet. h	Distance East. D_E	Distance North. D_N	$V_{W\ to\ E}$	$V_{S\ to\ N}$	Wind Direction. Degrees from N. ϕ	Wind Velocity. f/s. V
½	103·0	27·5	2·5	+4·7	−1·1	+4·7	−1·1	1283	16
1	108·5	27·5	5	9·1	3·0	4·5	1·9	292	16
2	122·2	22·0	10	21·0	13·2	11·9	9·8	309	26
3	126·5	22·6	15	29	21	8	8	315	19
4	125·4	22·8	20	39	28	10	7	305	20
5	126·0	23·3	25	47	34	8	6	307	17
6	127·0	23·5	30	55	42	8	8	315	19
7	126·4	23·3	35	66	48	11	6	299	21
8	125·4	23·2	40	76	54	10	6	301	19
9	124·8	23·3	45	86	60	10	6	301	19
10	125·1	23·3	50	95	67	9	7	308	19
11	125·7	23·5	55	103	74	8	7	311	18
12	124·7	23·7	60	113	78	10	4	292	18
13	124·2	23·7	65	123	83	10	5	297	19
14	124·2	23·8	70	131	89	8	6	307	17
15	124·7	23·9	75	140	96	9	7	308	19
16	124·4	23·8	80	150	102	10	6	301	19
17	124·1	23·7	85	161	109	11	7	302	22
18	123·5	23·5	90	173	114	12	5	293	22
19	123·0	23·3	95	185	120	12	6	297	22
20	122·5	23·0	100	199	127	+14	−7	297	26
21	122·0	22·9	105	+210	−132	+11	−5	294	20

9. In the worked out example 180° has been subtracted from the original azimuths in order that the results in paragraph 6 may be directly applicable. Distances are written down in hundreds of feet; component velocities are thus in hundreds of feet per minute and the table given in Appendix II gives V directly in ft/s and an angle ϕ' from which ϕ is found by the addition of 270°.

10. Single theodolite ascents can also be worked up by graphical methods. The procedure is substantially that described in paragraph 11 for double theodolite ascents: the only difference is that in the case of the single theodolite ascent, the horizontal distance $h \cot E$ must be determined either by a slide rule or by the use of tables which give $h \cot E$ for all values of h and E, or from a diagram. This length is then measured along the radial line corresponding to the azimuth, and the length and direction of the line joining successive points so obtained, gives the wind velocity and direction.

Double Theodolite Ascents.

11. Whilst the single theodolite method is, without doubt, the most suitable for use in the field, its accuracy is affected by vertical currents which may altogether falsify the wind results obtained for individual layers of air.

Both graphical and slide-rule methods have been employed to work out results given in two theodolite ascents. The following mainly graphical method is adapted from that employed at Shoeburyness for artillery purposes for which the double theodolite method is eminently suitable.

On a large drawing board there are fixed two of the radial charts supplied by the Meteorological Office, joined so as to have lines radiating to the left as well as to the right. The common centre of these charts represents the home station. A paper protractor (obtained by cutting up a radial chart) is arranged so that its centre is at a distance from the centre of the radial charts equal to the length of the base between the theodolite stations on a scale of 1 cm. to 300 ft.; the bearing of the centre of the protractor is the bearing of the distant from the home station. The whole is covered with a sheet of tracing paper on which the path of the balloon is plotted. The tracing paper is renewed when necessary, but the radial charts seldom require renewal. Two Chesterman steel-tapes are pivoted, one at the centre of the radial chart and the other at the centre of the protractor.

The home theodolite is set with azimuth N = 360° and the distant theodolite with zero = bearing of the home station. The steel tapes are set according to the simultaneous readings of the azimuth of the balloon, and their intersection on the plotting table gives the projection of the balloon. Successive positions at intervals of one minute are plotted in this way. The wind speed is obtained directly in feet per second by measuring the distance between successive points. As the scale is 1 cm. to 300 ft. the speed is measured on the scale of 1 cm. to 5 ft/s., *i.e.*, the number of mms. between successive points divided by two gives the speed in ft/s. The wind direction is obtained by setting a rolling parallel ruler along the line joining two successive points; the ruler is then rolled until it coincides with one of the lines of the radial charts. This gives the wind direction directly. The distances from the intersections on the charts to the origins are read off on the steel tapes and entered in the appropriate columns as so many hundreds of feet : on the scale given above the distance in cms. multiplied by three will give the run of the balloon in hundreds of feet. These distances are equivalent to $h \cot E$ where h is the height above the station from which the elevation is E. From this the height of the balloon above each station can be calculated. A pilot-balloon slide-rule is used : the distance from one station is set above 45° on the tangent scale and the height read off opposite the value of E on the tangent scale.

The ends of the base and the office where the computing is done are connected by telephone. The installation is arranged so that any observer who is using the telephone can speak to and hear either of the other two. This is the case whichever base is used. Six observers are required, being allocated as follows :—

Two at the station from which the balloon is being released (the home station).

Two at the other station.

Two in the office computing.

At the home station, one of the observers follows the balloon. The other, who is at the telephone, gives the necessary time signals and transmits the observations of his own station to the office ; one of the observers at the distant station transmits the observations on hearing the time signals given by the home observer. To prevent any confusion the routine adopted is for the distant station to send their readings through first, and for the home station to send theirs immediately afterwards.

In the office there are two computers. The one who is wearing the telephone receives the observations and notes them on the special form, at the same time giving them verbally to the second computer, who plots them on his radial chart and reads off the values of $h \cot E$ in hundreds of feet, wind speed and direction. He gives these to the first computer, who enters them on the form and by means of the slide-rule, calculates the height of the balloon above each station.

With skilled observers and suitable telephones, the distribution of personnel could be altered, *e.g.*, at the distant station one good observer would suffice and at the home station three would do provided the theodolite were set up in close proximity to the office.

A worked out specimen of a double theodolite ascent performed at Shoeburyness by this method is given on page 19. The same ascent worked out as a single theodolite ascent is given in paragraph 9. The two results should be compared.

NOTE.—AC is $h \cot E_a$ where h is the height above A and similarly BC is $h \cot E_b$.

Form 3611. METEOROLOGICAL OFFICE, LONDON.

PILOT BALLOON ASCENT (TWO THEODOLITES). Number 836.

Observatory, Shoeburyness. Date, September 24, 1918. Time of Start, 08h. 20m.

Position of Theodolites. (Balloon sent up from A.)	Height above sea level.	Type of Balloon—rubber.	
A. Station L	3 m.	Weight = W = 22 g.	Balloon in sight at A 20 min. How lost, abandoned. At B 20 min. How lost, abandoned.
B. " F	5 m.	Free lift = L = 66 g.	Wind by anemometer Average for a few minutes after start } Dir^n. °, Vel^y. m./sec.
Mean	4 m.	Lifting Velocity = q $L^{\frac{1}{2}} (W + L)^{\frac{1}{3}}$ = 500 feet per minute	Geostrophic Wind } Dir^n. °, Vel^y. m./sec.
Distance AB = 4,300 feet.		assuming q = 84. [M.O. Circular, No. 27, 1918.]	Atmosphere Clouds Nil.
Bearing of zero reading of A from North = K = 0°.			Bearing of station from centre of cyclone or other features of the isochronous chart.
			NOTES.—Dry bulb, 52·5. Wet bulb, 49·5.

t.	Home Station. A.	Home Station. E_a.	Out Station. B.	Out Station. E_b.	C.	AC. 100's feet.	BC. 100's feet.	A.+K.	Balloon E. of A.	Balloon N. of A.	Velocity. W. to E.	Velocity. S. to N.	Resultant. ϕ	Resultant. V. f/s.	Height above A. feet.	Height above B. feet.	Rate of Ascent f/m. A.	Rate of Ascent f/m. B.	Rate of Ascent f/m. Mean	Vertical Current. f/s.
½	103·0	27·5	355·2	4·0		5·6	38·8						283	19	290	270	290	270	280	1·0
1	108·5	27·5	347·3	9·6		11·4	35·7						294	20	590	600	590	600	595	1·6
2	122·2	22·0	318·3	17·4		29·0	36·9						310	30	1170	1160	580	560	570	1·2
3	126·5	22·6	302·2	21·3		42·2	44·1						316	23	1750	1750	580	590	585	1·4
4	125·4	22·8	289·5	24·3		54·5	50·5						301	21	2290	2275	540	525	533	0·5
5	126·0	23·3	282·0	25·4		65·3	58·5						309	18	2810	2830	520	555	538	0·6
6	127·0	23·5	277·0	25·8		76·5	68·4						313	19	3310	3310	500	480	490	−0·2
7	126·4	23·3	271·7	26·0		88·0	77·7						302	19	3795	3790	485	480	483	−0·3
8	125·4	23·2	267·0	26·0		99·6	87·4						298	20	4250	4250	455	460	458	−0·7
9	124·8	23·3	263·5	26·1		111·2	98·1						299	20	4760	4760	510	510	510	0·2
10	125·1	23·3	261·5	26·0		120·9	106·8						308	16	5210	5210	450	450	450	−0·8
11	125·7	23·5	260·2	25·9		132·8	118·5						312	20	5750	5750	540	540	540	0·7
12	124·7	23·7	257·7	26·2		142·1	126·3						287	16	6210	6205	460	455	458	−0·7
13	124·2	23·7	255·5	26·2		157·8	141·2						301	26	6900	6900	690	695	693	3·2
14	124·2	23·8	254·4	26·1		167·5	150·6						304	16	7400	7380	500	480	490	−0·2
15	124·7	23·9	254·0	26·1		176·4	159·5						311	16	7800	7800	400	420	410	−1·5
16	124·4	23·8	252·8	25·9		188·4	174·1						303	25	8430	8440	630	640	635	2·3

12. Below 5,000 or 6,000 feet a double theodolite ascent possesses considerable advantage over a single theodolite ascent. But above this height, unless the instruments are in very good adjustment and the observers very skilled, considerable errors may be introduced. Of course, a double theodolite ascent can be changed into a single one at any time.

13. Double theodolite ascents can, however, be worked up by purely slide-rule methods. Using the pilot-balloon slide-rule, the method is as follows :—

The form used for the computation is to a large extent self-explanatory, the letters and equations used being fully explained on the reverse side. The points A and B represent the positions of the observing stations, and C the point on the Earth's surface immediately under the balloon. The angles A and B are the bearings of the balloon measured on the azimuth scale of the theodolites at the points A and B. The angle K is the azimuth of the base line, *i.e.*, the angle between base line and North, measured in a clockwise direction. If the azimuth zeros are adjusted in the manner recommended on the forms, the readings will in general all be between 0° and 180°. These angles are more easily dealt with in the subsequent calculations than angles which fall between 180° and 360°.

For each simultaneous set of readings of the two theodolites the computation consists in determining the distance AC of the balloon from the starting point A and resolving it into two components, E and N of A. In addition to this it is necessary to find the height of the balloon above the points A and B. The formulæ used are :—

$$\left.\begin{aligned} AC &= \frac{AB}{\sin C} \times \sin B \\ BC &= \frac{AB}{\sin C} \times \sin A \end{aligned}\right\} \quad \ldots\ldots\ldots \text{i}$$

where C is $A \sim B$.

$$\left.\begin{aligned} \text{Distance East of A} &= \text{AC} \sin (A + K) \\ \text{,, North of A} &= \text{AC} \cos (A + K) \end{aligned}\right\} \quad \ldots \text{ii}$$

$$\left.\begin{aligned} \text{Height above A} &= \text{AC} \tan E_a \\ \text{,, ,, B} &= \text{BC} \tan E_b \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots \text{iii}$$

The manipulation of the pilot-balloon slide-rule to make the actual calculations is as follows :—

Clamp the inner slide so that it reads parallel to the main slide. Set the cursor at the angle C on the sine scale, move

the slide till the length of the base line AB falls under the line on the cursor. Read off AC on the slide opposite the angle B on the sine scale and BC opposite the angle A on the sine scale. Having noted the values of AC and BC, move the slide until AC falls under 90° on the sine scale. Read off component to E under $A + K$ on the sine scale and the component to N under $A + K$ on the cosine scale. Without moving the slide read off the height above A opposite the angle E_a on the tangent scale. Now move the slide so that BC falls above 45° on the tangent scale and read off the height above B opposite E_b on tangent scale.

If the slide-rule be used for determining the resultant wind, the procedure is as indicated in paragraph 6B. The most expeditious way of obtaining V and ϕ is by using the appropriate table in Appendix II.

The ascent already worked out as a single theodolite ascent (p. 16) and as a double theodolite ascent on the graphical method (p. 19) is worked out on page 22 by purely slide-rule methods. It is to be noted that the angles A and B have been altered to fit the scheme of theodolite orientation recommended on Form 3611. The tables on pages 16, 19 and 22 should be compared.

The computation explained above assumes that the points A and B are at the same level. If they are not at one level, the horizontal projection of AB must be used instead of AB in equations (1). The calculated heights of the balloon above A and B should differ by a constant amount—the difference of height between the two stations.

Form 3611. METEOROLOGICAL OFFICE, LONDON.

PILOT BALLOON ASCENT (TWO THEODOLITES).

Number 836.

Observatory, Shoeburyness. Date, September 24, 1918. Time of Start, 08h. 20m.

Position of Theodolites. (Balloon sent from A.)	Height above sea level.	Type of Balloon—rubber.	Elevation of B at A 0·1°; Azimuth of B at A 0° at start, 0° at finish.
A. Station L B. Station F	3 m. 5 m.	Weight = W = 22 g. Free lift = L = 66 g.	" " A at B 0·1°; " " A at B 180° " 180° "
Mean	4 m.	Lifting Velocity = q L½/(W + L)⅓	It is convenient to set up the Theodolites with Azimuths 0° at A, 180° at B or *vice versa*. The rule is: Look at the other station; if the wind blows left to right make the Azimuth of the other station 0°; if right to left 180°.
Distance AB = 4,300 feet.		= 500 feet per minute	Balloon in sight at A 20 min. How lost, abandoned. At B 20 min. How lost, abandoned.
Bearing of zero reading of A from North = K = 64·3°.		assuming q = 84. [M.O. Circular, No. 27, 1918.]	Wind by anemometer / Average for a few minutes after start } Dirⁿ. °, Velʸ. m./sec. Geostrophic Wind } Dirⁿ. °, Velʸ. m./sec. Atmosphere Clouds Nil. Bearing of station from centre of cyclone or other features of the isochronous chart. NOTES.—Dry bulb, 52·5. Wet bulb, 49·5.

t.	Home Station.		Out Station.		C.	AC. 100's of feet.	BC.	A.+K.	Balloon E of A.	Balloon N. of A.	Velocity.		Resultant.		Height above		Rate of Ascent.			Vertical Current. f/s.
	A.	Ea.	B.	Eb.							W. to E. h.f.m.	S. to N. h.f.m.	ϕ	V. f/s.	A.	B.	A.	B.	Mean	
½	38·7	27·5	175·2	4·0	136·5	5·2	39·0	103·0	+5·0	−1·2	+10	−2·4	283	18	270	272	270	272	271	0·7
1	44·2	27·5	167·3	9·6	123·1	11·3	36·7	108·5	10·7	3·6	10·7	3·6	293	21	590	620	590	620	605	1·8
2	57·9	22·0	138·3	17·4	80·4	29·0	36·9	122·2	24·5	15·4	13·8	11·8	311	31	1170	1160	580	540	560	1·0
3	62·2	22 6	122·2	21·3	60·0	42·0	44·0	126·5	33·8	25·0	9	10	318	22	1750	1720	580	560	570	1·2
4	61·1	22·8	109·5	24·3	48·4	53·0	50·0	125·4	44·0	31	10	6	301	19	2270	2260	520	540	530	0·5
5	61·7	23·3	102·0	25·4	40·3	64·1	58·1	126·0	52	38	8	7	311	18	2760	2760	490	500	495	−0·1
6	62·7	23·5	97·0	25·8	34·3	75·4	67·7	127·0	60	45	8	7	311	18	3250	3280	490	520	505	0·1
7	62·1	23·3	91·7	26·0	29·6	87·0	76·9	126·4	70	52	10	7	305	20	3750	3760	500	480	490	−0·2
8	61·1	23·2	87·0	26·0	25·9	98·0	87·0	125·4	80	57	10	5	297	19	4220	4250	470	490	480	−0·3
9	60·5	23·3	83·5	26·1	23·0	109·0	95·5	124·8	89	62	9	5	299	17	4680	4680	460	430	445	−0·9
10	60·8	23·3	81·5	26·0	20·7	120·0	106·0	125·1	98	69	9	7	308	19	5190	5190	510	510	510	+0·2
11	61·4	23·5	80·2	25·9	18·8	130·8	117·0	125·7	106	76	8	7	311	18	5700	5700	510	510	510	+0·2
12	60·4	23·7	77·7	26·2	17·3	140·0	125·5	124·7	115	80	9	4	294	16	6190	6190	490	490	490	−0·2
13	59·9	23·7	75·5	26·2	15·6	153·5	137·5	124·2	127	86	12	6	297	22	6730	6780	540	590	565	+1·1
14	59·9	23·8	74·4	26·1	14·5	164·5	148·0	124·2	136	93	9	7	308	19	7300	7260	570	480	525	+0·4
15	60·4	23·9	74·0	26·1	13·6	175 0	159·0	124·7	144	100	8	7	311	18	7770	7780	470	520	495	−0·1
16	60·1	23·8	72·8	25·9	12·7	186·0	170·0	124·4	154	105	10	5	297	19	8250	8250	480	480	480	−0·3

14. A simple check on the value of ϕ is obtained in the following way. If the theodolite is orientated in the way recommended for single theodolite ascents and for double theodolite ascents which are to be worked on the graphical method, the angle A is the bearing of the balloon from North; and the bearing of the balloon at the first reading (at the end of ½ minute or 1 minute) must be opposite to the average wind direction up to that time. In other words the first entry in the ϕ column must differ by 180° from the first entry in the A column.

When the theodolites are set up as recommended for a double theodolite ascent to be worked out by slide-rule only, the first ϕ will differ by 180° from the first value in the $A + K$ column, provided the proper value of K has been taken.

Subsequent values of ϕ will lie in the same quadrant provided neither the W to E nor the S to N component of velocity changes its sign. The actual value of ϕ is found from ϕ' (angle given in red type in printed table) by the following rule—

$$V_{we} > V_{sn},\ \phi = 270° \pm \phi' \text{ or } 90° \pm \phi'.$$
$$V_{sn} > V_{we},\ \phi = 180° \pm \phi', \text{ or } 360° - \phi', \text{ or } \phi'.$$

Referring to the ascent No. 1782 worked out on next page, the first entry in the $(A + K)$ column is 95·8°; the first entry in the ϕ column will therefore be 276°. At the third minute the S to N component has changed sign and ϕ must now lie in the third quadrant. This holds until the ninth minute when the S to N component changes sign again and ϕ lies in the fourth quadrant. So long as the W to E component is > S to N component ϕ will be got by the addition of ϕ' (angle given in red type in printed table) to 270°. At the 14th minute the S to N component becomes the greater and ϕ is then found by subtracting ϕ' from 360°.

This check on the value of ϕ is to be recommended whether ϕ' is obtained by a slide-rule or by the use of the table of components.

Form 3611. METEOROLOGICAL OFFICE, LONDON.

PILOT BALLOON ASCENT (TWO THEODOLITES). Number 1782.

Observatory, Butler's Cross, Salisbury Plain. Date, September 8, 1918. Time of Start, 15h. 30m.

Position of Thodolites. (Balloon sent up from A.)	Height above sea level.	
A. Butler's Cross.	152 m.	Type of Balloon—white, 90″.
B. Breach Hill	139 m.	Weight = W = 31 g.
Mean	146 m.	Free lift = L = 72 g.

Lifting Velocity $= q\,L^{\frac{1}{2}}/(W + L)^{\frac{1}{3}}$

= 503 feet per minute.

assuming q = 84. [M.O. Circular, No. 27, 1918.]

Distance AB = 5,067 feet.

Bearing of zero reading of A from North = K = 33·5°.

Elevation of B at A °; Azimuth of B at A 180° at start, ° at finish.
" " A at B °; " " A at B 0° " ° "

It is convenient to set up the Theodolites with Azimuths 0° at A, 180° at B or *vice versa*. The rule is: Look at the other station; if the wind blows left to right make the Azimuth of the other station 0°; if right to left 180°.

Balloon in sight at A 15 min. How lost, abandoned. At B 14 min.
How lost, ballon bad colour.

Wind by anemometer Average for a few minutes after start } Dirⁿ· 275°, Velʸ· 4·5 $\frac{m.}{sec.}$

Geostrophic Wind. } Dirⁿ· °, Velʸ· $\frac{m.}{sec.}$

Atmosphere, clear. Clouds, Ci. St. 10.

Bearing of stations from centre of cyclone or other features of the isochronous chart.

NOTES.—Bar, M.S.L., 30·30″. Dry bulb, 69·5° F. Wet bulb, 63·3.

t.	Home Station.		Out Station.		C.	AC.	BC.	A.+K.	Balloon E. of A.	Balloon N. of A	Velocity.		Resultant.		Height above		Rate of Ascent.			Vertical Current. f/s.
	A.	Ea.	B.	Eb.							W. to E.	S. to N.	φ	V.	A.	B.	A.	B.	Mean	
1	62·3	27·6	8·4	5·3	53·9	9·1	55·5	95·8	+9·0	−0·9	+9	−0·9	276	15	475	515	475	470	473	−0·5
2	60·4	25·7	15·3	8·5	45·1	18·7	62·0	93·9	18·6	1·3	9·6	−0·4	272	16	900	930	425	415	420	−1·3
3	58·0	23·9	20·4	10 5	37·6	29·0	70·3	91·5	29·0	−0·7	10·4	+0·6	267	17	1290	1310	390	380	385	−1·9
4	54·7	25·1	23·0	12·8	31·7	38·0	79·0	88·2	38	+1	9	+1·7	256	15	1780	1810	490	500	495	−0·1
5	51·6	24·0	24·8	13·5	26·8	47·0	88·0	85·1	47	4	9	3	252	16	2100	2110	320	300	310	−3·3
6	46·9	23·9	24·8	14·4	22·1	56·5	98·0	80·4	55	9	8	5	238	16	2500	2510	400	400	400	−1·7
7	43·5	25·6	24·2	16·1	19·3	63·0	106·0	77·0	61	14	6	5	230	13	3030	3050	530	540	535	+0·6
8	42·6	27·4	25·0	17·9	17·6	70·8	113·0	76·1	68	17	7	+3	247	13	3650	3650	620	600	610	+1·8
9	45·1	27·9	27·5	19·1	17·6	77·0	118·5	78·6	75	15	7	−2	286	12	4080	4100	430	450	440	−1·0
10	49·0	28·4	31·2	20·2	17·8	85·6	125·0	82·5	85	11	10	4	292	18	4600	4600	520	500	510	+0·2
11	53·0	28·4	35·0	21·2	18·0	94·0	130·0	86·5	94	6	9	5	299	17	5090	5080	490	480	485	−0·3
12	54·2	28·5	37 0	22·0	17·2	103·0	139·0	87·7	103	4	9	2	283	15	5600	5620	510	540	525	+0·4
13	56·1	29·0	39·1	23·0	17·0	110·0	144·0	89·6	110	+1	7	3	293	13	6100	6110	500	490	495	−0·1
14	59·7	29·6	42·5	24·0	17·2	116·0	148·0	93·2	116	−6	6	−7	319	15	6600	6600	500	490	495	−0·1

The tail method of finding the rate of ascent of pilot balloons.*

DESCRIPTION OF THE METHOD.

15. The method consists in observing the apparent length, or distance apart in the eye piece of a telescope, of objects or points forming the top and bottom of a tail attached to the balloon.

It is useful in cases where the wind is fairly strong so that the angle of elevation of the balloon does not exceed 30° or 40°, but it is not much use when the angle is large. It will be best explained by means of a diagram.

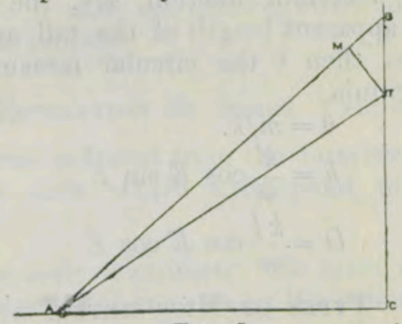


FIG. 5.

Let B represent the centre of the balloon, T some visible object (the "pendant") hanging from the balloon at a known distance BT, A the observer, AC a horizontal line, and TC a vertical one.

Then, the length BT being known as well as the angles BAT and BAC, the height CB can be found.

Let TM be the perpendicular from T on AB and let θ be the circular measure of the angle BAT.

As the angle MAT is small MT cannot be distinguished from part of a circular arc with radius AM and therefore we may write $\theta = MT/AM$ and $AM = MT/\theta$.

Now let l be the length of the tail BT and let E be the elevation BAC of the balloon.

Then $MTB = 90° - MBT = BAC = E$.

so that $MT = l \cos E$.

Hence $AM = \dfrac{l \cos E}{\theta}$.

The actual distance of the balloon from the observer is AB, but the distinction between AM and AB may be ignored in practice and we write $AB = \dfrac{l \cos E}{\theta}$.

* See also *Advisory Committee for Aeronautics*, Reports and Memoranda (New Series), No. 309, "On the Tail Method of Observing Pilot Balloons."

Knowing AB we can calculate the height and the horizontal displacement by the formulæ $h = \frac{l \cos E}{\theta} . \sin E$

and $D = \frac{l \cos E}{\theta} . \cos E.$

THE USE OF THE MICROMETER.

The angle θ is measured by a micrometer which gives the apparent length of the tail as seen in the telescope. There are various forms of micrometer, but whichever form be used the unit of its scale must correspond to some small angle which is a certain fraction, say, the kth part of a radian. If the apparent length of the tail as given by the micrometer is m then θ the circular measure of BAT is given by the formula,

$$\theta = m/k.$$

Accordingly
$$h = \frac{kl}{m} \cos E \sin E$$
$$D = \frac{k\,l}{m} \cos E \cos E$$

TYPES OF MICROMETER.

The micrometer is in some theodolites a glass scale at the focus of the object glass. The scale is divided into millimetres and tenths.

Against this pattern the objection has been urged that specks of dust on the glass may be mistaken for the balloon at a great distance, and the majority of modern instruments have a movable spider's thread in addition to the fixed threads.

The number of units by which the moving thread is displaced from the centre of the field is shown on the milled head of the micrometer. Completed turns of the head are counted either by reference to a serrated scale at the edge of the field of view or by estimation aided by the provision of additional fixed spider threads.

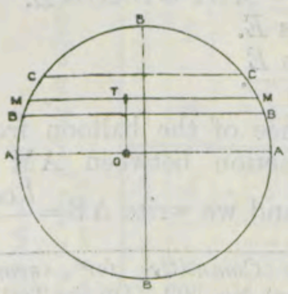


FIG. 6.

The figure represents the field of view in one pattern, AA, BB, CC being fixed threads, and MM the thread carried by the micrometer.

Ten units correspond to one turn of the micrometer screw. When MM is at AA the micrometer reading is 0, at BB it is 50, at CC it is 100. In the position shown in the figure, the reading is estimated at about 70, and if the unit figure shown on the head was 9 the observation would be entered as 69.

The scale value of the micrometer should be obtained from the maker: if it is not known, either of the following methods may be adopted.

ESTIMATION OF SCALE VALUE.

The scale value is found from the number of divisions on the micrometer scale which correspond to some definite small angle.

With a glass-scale micrometer the most convenient way is to use the diameter of the sun, or if a coloured glass is not available, of the moon. The diameter for any given date can be obtained from a good almanack. Suppose it to be 32′ and let this diameter correspond to 48 divisions in the micrometer; this is the case with the theodolite used at Benson.

The circular measure of 32′ is $\frac{32}{60} \times \frac{\pi}{180}$ or $\frac{1}{107 \cdot 6}$ and therefore the number of divisions to the radian is $107 \cdot 6 \times 48$ or 5160.

This method is not available with the spider-thread micrometer, as the thread can not be seen except when it shows against the bright background of the sun, and it can not be adjusted to the tangential position.

With such a micrometer the scale-value may be determined approximately by comparison with the scale of the altitude circle of the theodolite. A distant point is sighted and brought near to the centre of the field. The telescope is adjusted so that the altitude reading comes to an exact tenth of a degree. Suppose the altitude is $2 \cdot 3°$ and the micrometer reading is $7 \cdot 4$. Now lower the telescope until the object appears at the top of the field. Suppose the altitude is exactly $1 \cdot 4°$ and the micrometer reading is $156 \cdot 4$. In this case 149 micrometer divisions correspond to ·9° and the scale value is $149 \times \frac{180}{\pi} \times \frac{10}{9}$ or 9500 units to the radian.

A better method is to use the micrometer to measure the apparent length of a two-foot rule set up at a considerable distance, say, 200 feet away. If the micrometer reading was 94·5 the scale-value would be 94·5 × 200/2 or 9450 units to the radian. It should be noted that when precision is aimed at in the use of this method the distance of the object should be measured from the principal focus in front of the object glass. For example, if the focal length were about 18 inches and the distance of the object from the focus were required to be 200 feet, the distance of the object from the object glass would have to be 201 feet 6 inches.

Length and Form of the Tail.

Two points require consideration, the length of the tail and its form.

The longer the tail the greater the proportional accuracy in the micrometer reading, but, on the other hand, when the balloon is quite near, a long tail more than covers the field of view and the method cannot be used. On the whole, for pilot balloons, about 10 metres is a suitable length of tail: in general, this will afford observations from the fourth to the twentieth minute of an ascent. The length of the tail is measured from the centre of the balloon to the middle of the pendant.

The other point is the nature of the pendant. A half-sheet of white foolscap paper gummed together along the shorter edges to form a cylinder and hung from the balloon by cotton will serve. The cylinder should be hung vertically from a cotton loop, and its steadiness is increased if it is made to spin by cutting the paper upwards for an inch or two from the bottom in a few places and turning the corners outwards. All the corners should be turned out in the same way. Another type of pendant can be made from a circular disc of paper cut along a spiral nearly to the centre. When hung from the centre the outer rings of the spiral drop and it forms a sort of cone which will rotate as it is raised.

The best colour for this paper depends on the background and differs according to the time of day. It has been suggested that in cases when the observations for the first minute or two are important two pendants should be used, one being placed halfway along the tail.

The Observations.

At any rate after the first few minutes of a flight, observations of the positions of the balloon and of apparent length of the tail can be taken at alternate half-minutes. One hand is used for setting the altitude all the time, the other hand is alternately used for setting the azimuth and adjusting the micrometer.

Working up the Observations.

Owing to the swinging of the tail a single observation, however accurate it may be, will not afford a reliable value of the angle BAT, especially if the angle of elevation is large, for if T is not vertically under B the error produced in the angle BAT may be considerable. Oscillations in the vertical plane through the line of sight produce more effect on the angle than oscillations in the perpendicular plane. If the elevation is small the errors will be small, and if the elevation is moderate the positive and negative errors are approximately equal. Hence if the observations be plotted and a smooth curve drawn through them fairly reliable values can be obtained. The smoothing process cuts out the use of a single observation, and it is not possible to say how much of the irregularity of the unsmoothed curve is due to ascending and descending currents and how much is due to the swinging of the tail; there is also a small systematic error because the swinging must take the mean value of BAT too small.

The formula for the height of the balloon is :—

$$h = \frac{kl}{m} \cos E \sin E = \frac{kl}{2m} \sin 2E.$$

k is the scale value, l the length of the tail, m the micrometer reading and E the elevation. It is convenient to keep to the same length of tail and to make a table of values of $\frac{kl}{2m}$ corresponding to the values of m. When $\frac{kl}{2m}$ is known h is found by a single operation with the slide-rule and from h the displacements can be found in the usual way.

With the pilot-balloon-slide-rule the table of values of $kl/2m$ can be dispensed with if the following instructions are followed.

Lock the t scale so that unity on that scale agrees with $\frac{1}{2}kl$ on the D scale. Suppose that $h = \tan \phi$; then if the rule is set so that m on the D scale is against $2E$ on the sine scale, unity on the t scale is against ϕ on the tangent scale. Keep the tangent-scale cursor at ϕ and move the slide until the t scale is in the position it occupies when the rule is shut up. Then h on that scale comes under the cursor.

Example.

Tail 30 feet long. Scale value 5200 units to radian.
Micrometer reading 24. Elevation 20°. Azimuth 37°.

Here $\frac{l\,k}{2} = 78000$ ft. ; $\frac{l\,k}{2\,m} = 3250$ ft.

$$h = \frac{l\,k}{2\,m} \sin 40° = 2090 \text{ ft.}$$

$$D = 2090/\tan 20° = 5740 \text{ ft.}$$

$$D_N = 5740 \cos 37° = 3450 \text{ ft.}$$

$$D_E = 5740 \sin 37° = 4580 \text{ ft.}$$

Observations with the self-recording theodolite.

16. The self-recording attachment is fitted to the ordinary type of balloon theodolite and is so arranged that changes in altitude and azimuth are recorded by two separate pens upon a common clock drum. To the carriage on the theodolite which turns about a vertical axis is attached a horizontal platform upon which the clock and other parts of the recording mechanism are placed. The general arrangement is shown in the photograph. It will be seen that the clock is placed on the right-hand side of the central upright and drives the horizontal drum through a shaft, this drum being on the left hand. The two pen-carriages run horizontally along the front of the drum and are actuated by fine chains which pass over suitable pulleys to grooves cut in the periphery of the vertical and horizontal circles. Movement of the telescope in a vertical or horizontal direction causes the corresponding chain to be wrapped round its circle and in this manner the pen-carriage is drawn along on the guide rod through a distance directly proportional to the angular movement of the telescope. The return movement of the pen-carriage is brought about either by means of a spring mechanism, or in the instrument illustrated by a balance weight which hangs in the tube seen on the extreme left-hand side. Owing to the limitations imposed by the length of the clock drum a horizontal turning movement through 200° only is provided for, this movement corresponding with a movement of the pen from one end of the chart to

To face page 30.

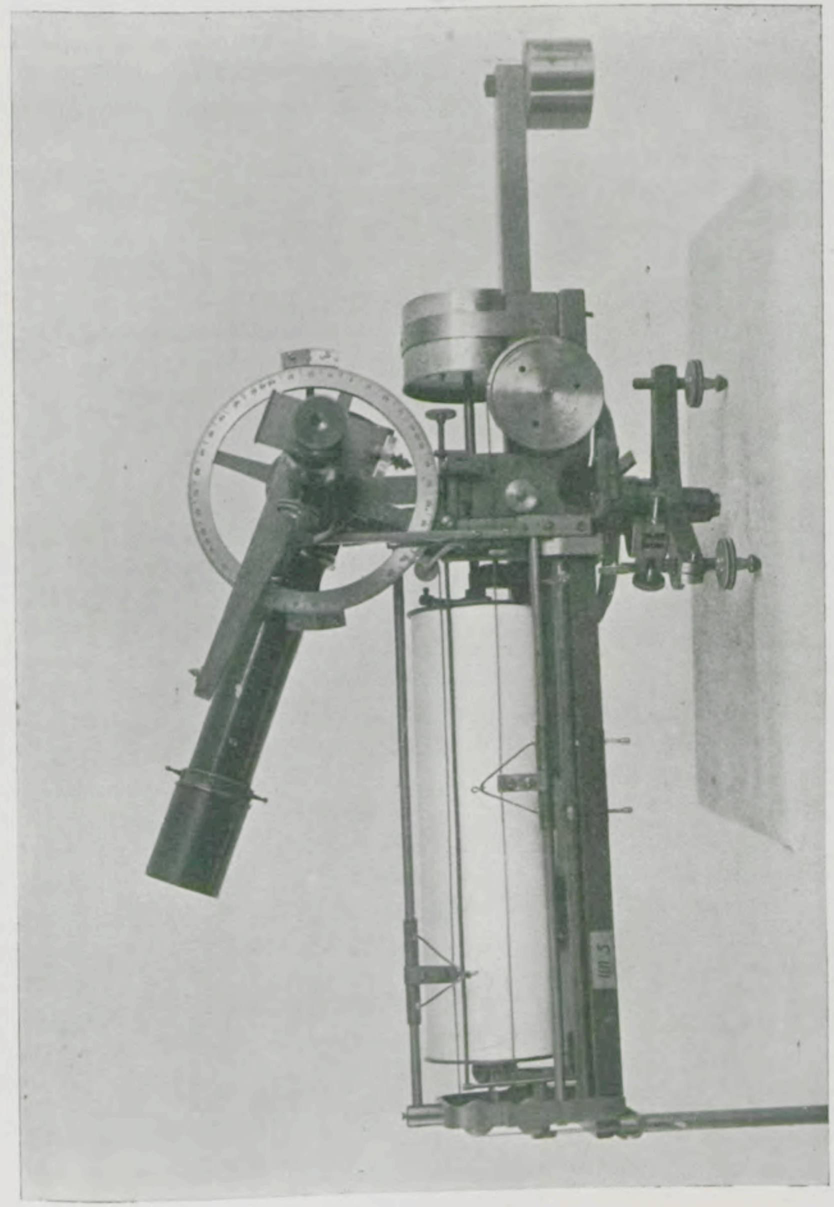


FIG. 7. SELF-RECORDING THEODOLITE.

the other. By setting up the theodolite suitably at the commencement it is generally possible to avoid any trouble through this angular range of movement being exceeded. In those cases where this trouble does occur it is generally possible to a skilled observer to reset the azimuth circle during the flight without losing the balloon from the field of vision.

The clock is arranged to revolve the drum once per hour. No special provision is made for attaching the charts to the clock drum. It is found convenient to fasten the overlapping edges together with gummed paper so that if the duration of the flight exceeds one hour the pens ride over the joint and no record is lost. Provision is made for making time marks either by depressing the actuating chains and so momentarily moving the pens to one side or else by lifting them simultaneously from the paper for a few seconds. The latter is to be preferred. When the instrument is fitted with this device it is customary to make a mark at every minute during the flight, the pens being lifted from the chart exactly at the even minute. The measurements can then be made at the end of each continuous portion of the trace with an accuracy which is certainly equal to that commonly obtained with eye readings. It is recommended that plain charts be used for the record, and the base lines from which the measurements are made should be ruled while the chart is still in position upon the clock drum. To do this the telescope is clamped in position at each even 10° of altitude and azimuth throughout those parts of the scales which have been traversed during the ascent and the clock drum is rotated under the pens to rule these 10° lines, so that at each part of the trace there is a 10° line of reference from which measurements may be made. Glass scales on which whole and half degree lines are ruled over a range of 10° are used for the tabulations.

A somewhat more detailed description of the instrument may be found in the Second Report on Wind Structure, Report of the Advisory Committee for Aeronautics, 1910–1911. This refers to one of the earliest instruments made and the details have been somewhat modified in later patterns.

Determination of Upper Winds by means of Shell Bursts.

17. A method due to Captain A. V. Hill for determining the direction and velocity of upper winds consists in sending

up an anti-aircraft shell to burst at the height at which an observation is required. The drift of the smoke cloud from the burst is watched in a specially designed mirror or pair of mirrors.

The arrangement of the "Hill" Mirror and accessories set up ready for observation of shell bursts is shown in Fig. 8.

The mirror itself consists of a sheet of plate-glass silvered on its lower surface, and is about 80 cms. square. It is mounted within a substantial wooden frame, which is supported on a very rigid three-legged stand.

The silvered face of the mirror, with the exception of a space of 10 cms. round the edges, is ruled with two sets of fine black lines running at right angles to each other and spaced 1 cm. apart. The whole surface is thus divided into centimetre squares. Every tenth line is coloured blue and the intermediate fives, red, these lines also being numbered at their ends.

The frame which carries the mirror is pivoted at its centre in order to facilitate its orientation. This is performed by laying two fiducial marks on the frame on to a well-defined distant object, which, in the double mirror method, is the mirror at the other station. In addition to the pivot, three levelling screws are provided to support the frame. The surface of the mirror is levelled in the usual manner by means of the spirit level, which is seen in the figure near the centre of the mirror.

It is found convenient to leave the mirror and its stand always in position, a substantial wooden cover being placed over the whole when the observations are completed. By this means only small adjustments have to be made each time before commencing to observe.

Towards the far side of the mirror is seen one of the apertures which are used. The aperture proper is rigidly attached to the top of a steel rod mounted on a massive V-shaped iron base. The weight of this base minimises the risk of shifting the aperture whilst an observation is in progress. Three apertures are in common use in which the peep holes are at heights of 20, 30, and 40 cms. respectively above the mirror. The height of the peep hole can be adjusted by means of two lock nuts, and a set of three rods to be used as distance pieces is provided for setting them at the correct heights.

When using the two mirror method, it becomes necessary to set the centre of the aperture vertically over the intersection of certain selected rulings on the mirror. This is

To face page 32.

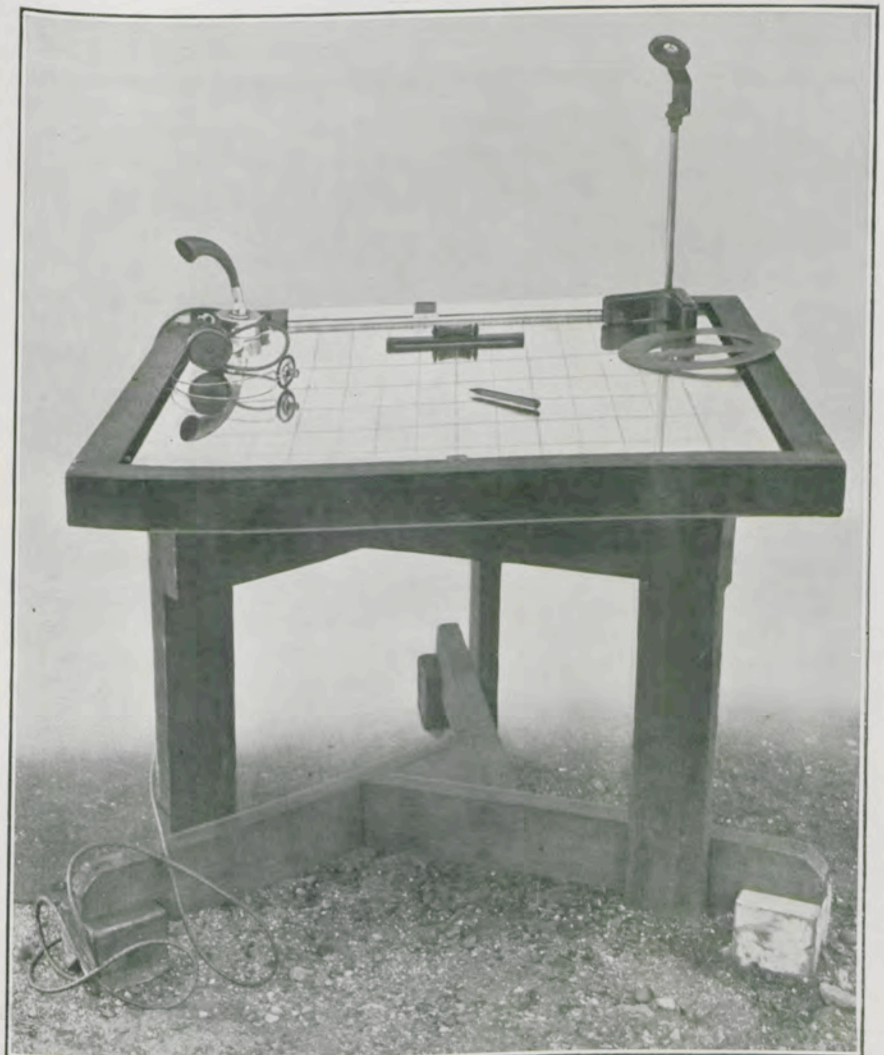


FIG. 8. THE DARWIN-HILL MIRROR.

27625

facilitated by painting the under side of the aperture white, which enables its reflection to be easily seen. All that has to be done then is to adjust the position of the aperture until linear coincidence is obtained between the reflection of the aperture, the intersection of the lines on the mirror and the aperture itself. In practice, the highest aperture is used which the angular elevation of the shell burst will permit.

A stylographic pen is used to record the apparent positions of the shell bursts in the mirror, the ink used consisting of a mixture of water, glycerine and a powerful red dye such as rosaniline.

When determining the upper wind direction and velocity by the single mirror method, the height of the shell burst has to be assumed. The quadrant elevation and fuze setting are selected so that the burst occurs near the top of the trajectory. By this means the effect of irregularities in the rate of fuze burning is reduced to a minimum. As a check, the time to burst is observed; if it is found to differ widely from the Range Table value, then it is known that the assumed height of the burst is liable to some error.

Starting at any arbitrary time, the track of the image across the mirror is plotted for every five seconds for as long as possible. The time of observation should extend over at least half a minute; and it is found that one minute is usually a convenient interval from which to compute the velocity. The length of the track corresponding to a minute is measured up as accurately as possible by means of the millimetre scale on the edge of the slide-rule. A line is then drawn through the points and its bearing is determined by using a 6-inch circular protractor.

In the two mirror method, the apertures are set over suitably selected origins on their respective mirrors and field telephones are used to establish communication between observers. One of the observers at the "home" (or gun) station starts his stop watch at the time of burst and proceeds to count seconds. As he calls "five," both observers mark simultaneously the apparent position of the burst in their mirrors and repeat at every successive five seconds. From these simultaneous observations, the positions of the burst in space are determined, thus giving the height of the burst and the wind velocity and direction at that height.

An example of a double mirror shell-burst observation is now given. Here, x, y; x^1, y^1 are the co-ordinates of the burst as seen in the mirrors, measured from the ends of the base line.

If $x_1, y_1; x_1^1, y_1^1$ are corresponding distances in space, h height of aperture above mirror and H height of burst above mirror

$$\frac{x}{x_1} = \frac{y}{y_1} = \frac{x^1}{x_1^1} = \frac{y^1}{y_1^1} = \frac{h}{H+h} = \frac{h}{H}$$

since h is small compared with H.

Thus,

$$\frac{x + x^1}{x_1 + x_1^1} = \frac{h}{H} = \frac{x + x^1}{\text{Length of base line}}$$

$$\text{or, } H = \frac{\text{Base line} \times h}{x + x^1}$$

The mean value of Distance (column 5) divided by 60 (time interval) and multiplied by $\frac{H}{h}$ gives the wind velocity in ft/s., and the direction of the trace on the mirror gives wind direction.

18. The second method, also to a large extent independent of atmospheric conditions, consists in sending up small balloons loaded with bombs which burst after a certain time, the position of the burst being determined by sound ranging from the ground. The average rate and direction of travel of the balloon up to the level of the burst is thus obtained. By arranging for several bombs to burst at different heights the average wind current in each intermediate layer of air can be determined. (*See* Comptes Rendus 167, 1919, pp. 769–772.)

Another method in which shell bursts are employed is used for the determination of wind direction and velocity above a cloud sheet.

A number of shells (four to six) are caused to burst at a known interval of time (say 60 secs.) at the height required. The smoke from the successive bursts is carried along by the wind, the average distance between each puff being 60_u where u is the average wind velocity.

An aeroplane then flies along the line of smoke drift: If V be the speed of the aeroplane and t the average time taken to pass successive puffs

$$V_t = 60_u$$

$$\text{or} \quad u = \frac{V_t}{60}.$$

The wind direction is deduced from the direction of flight of the aeroplane as read from the compass.

EXPERIMENTAL ESTABLISHMENT, SHOEBURYNESS No. 24.

Double Mirror Shell-burst Observation, September 1, 1919.

Base, 7,740 feet.

—		Station : Landwick							Station : "A" Battery							MEANS				
Time fired	Round	Ap. cm	Time Interval secs.	Dist. cm.	X cm.	Y cm.	V f.s	φ	Ap. cm.	Time Interval secs.	Dist. cm.	X¹ cm.	Y¹ cm.	V f.s.	φ	X+X¹ cm.	Ht. ft.	Vel. f.s.	Vel. m.h.	φ
0650	1	40	60	17·9	27·4	38·6	45	285°	40	60	17·7	23·3	38·5	41	286°	50·7	6100	45	30	285°
0652	2	"	"	10·8	13·6	30·6	42	272	"	"	10·4	19·5	30·4	40	275	33·1	9300	41	28	273
0655	3	"	"	12·0	8·8	31·3	56	279	"	"	12·1	19·0	31·0	56	279	27·8	11000	56	37	279
0700	4	"	"	13·0	1·6	30·2	78	266	"	"	12·9	19·8	30·1	78	268	21·4	14400	78	52	267

19. The Darwin-Hill mirror, under certain conditions, may be used as a nephoscope for the measurement of the velocity and direction of cloud movement. It is obvious that its use for this purpose is limited to those occasions on which cloud forms are sufficiently well defined to allow of a definite point being selected and kept under observation.

The use of the double mirror method is rendered nearly impossible owing to the inability of the two observers to make certain that they are both observing the same point on a given cloud. The difficulty is augmented by the difference in appearance of even a well defined cloud as seen from two different view points.

On the few occasions when this method can be employed, the procedure is identical with that adopted in the case of shell bursts.

A single mirror may be used as a nephoscope in the following manner. Using an aperture of the greatest height permissible, a well defined feature of a cloud is selected and the track of its reflected image is followed across the mirror, its apparent position at regular intervals being recorded by means of the pen. Then the orientation of the track referred to true North gives the direction of the cloud movement immediately.

Also, if h is the height of the aperture and d the length of the track traced out in time t, then the angular velocity of the movement of the cloud is d/ht radians or $1000d/ht$ milliradians.

In order to obtain the linear velocity of the cloud, it is necessary to know its height in addition to the above information. The approximate height of a particular cloud may sometimes be estimated with sufficient accuracy to enable a rough value for the velocity to be obtained. For example, the height at which a Pilot Balloon becomes lost in cloud may be taken as a measure of the cloud height.

Another and better method of determining the cloud height that is sometimes applicable is by the use of a Range and Height Finder. The method is not susceptible of any great accuracy unless a strongly featured cloud with marked contrasts is available. In this case the Height and Range Finder is placed close beside the mirror. The observer tracks the path of the cloud across the mirror and then immediately moves to the Range Finder and makes a series of settings on the same point as he has been observing in the mirror. By employing the same observer to make both the mirror and the Range Finder observations, it is possible

to make certain that the same point of the cloud is observed in each case. It is, of course, essential to make sure that the Range Finder is accurately levelled and it will generally be found that the red filter gives the best results.

If H is the height of the cloud as determined by any of these methods, then the linear cloud velocity is given by

$$V = Hd/ht \text{ feet per second,}$$

t being measured in seconds, and h and d in any units, provided that they are the same.

APPENDIX I.

THE EFFECT OF VERTICAL CURRENTS ON WIND VELOCITIES AS CALCULATED BY THE SINGLE THEODOLITE METHOD.

If D_e and D_n are the distances of the balloon from the theodolite in an East and North direction, H is the height of the balloon above the ground and A the azimuth or bearing from North,

$$D_e = H \cot E \sin A$$
$$D_n = H \cot E \cos A$$

Let W be the vertical velocity of the balloon in feet per minute and U and V the velocities in an East and North direction, also in feet per minute.

Then $U = H \cot E \sin A + (H + W) \cot E \sin A$
$V = H \cot E \cos A + (H + W) \cot E \cos A.$

Errors arise only—

(1) through faulty values of H,

(2) through faulty values of W,

as all the E's and A's are observed.

Let true value of H be $H + h$.

Let true value of W be $W + w$.

Then true value of U will be $U + u$ when—

$$U + u = -(H+h)\cot E_1 \sin A_1 + (H + h + W + w)\cot E_2 \sin A_2$$
$$= U - h \cot E_1 \sin A_1 + h \cot E_2 \sin A_2 + w \cot E_2 \sin A_2$$
$$= U + \frac{h}{H}(U - W \cot E_2 \sin A_2) + w \cot E_2 \sin A_2$$
$$= U\left(1 + \frac{h}{H}\right) + \cot E_2 \sin A_2 \left(w - \frac{Wh}{H}\right)$$

$$\text{or } u = \frac{Uh}{H} + \cot E_2 \sin A_2 \left(w - \frac{Wh}{H}\right)$$

Similarly—

$$V + v = V - h \cot E_1 \cos A_1 + h \cot E_2 \cos A_2 + w \cot E_2 \cos A_2$$

$$= V\left(1 + \frac{h}{H}\right) + \cot E_2 \cos A_2 \left(w - \frac{Wh}{H}\right)$$

$$\text{or } v = \frac{Vh}{H} + \cot E_2 \cos A_2 \left(w - \frac{Wh}{H}\right)$$

If h is zero, *i.e.*, if the height has been taken correctly the correction merely involves the addition of—

$w \cot E_2 \sin A_2$ to U

and $w \cot E_2 \cos A_2$ to V

or, alternatively, the superposition of a velocity $w \cot E_2$, along the line of sight, on the velocity as computed by the one theodolite method.

But usually where there are appreciable errors in W there will be appreciable errors also in H, especially in the earlier part of the ascent.

Consider a numerical example using the actual azimuths and elevations of an ascent save that we know that in—

		A.	E.
1st minute balloon rises 400 feet	...	55·0	22·5
2nd minute balloon rises 300 feet	...	64·3	18·0
3rd minute balloon rises 600 feet	...	73·0	14·5
4th minute balloon rises 500 feet	...	76·5	12·2

these being variations from the assumed 500 feet per minute velocity, which are caused by vertical currents.

The velocities found by using the 500 feet per minute assumption are set out below side by side with the true velocities as calculated from the preceding paragraph.

Time from Start in Minutes.	Assumed Height.	True Height.	Velocity as found by 500 ft./min. Assumption.	Direction as found on 500 ft./min. Assumption.	True Velocity.	True Direction.
	Feet.	Feet.	Ft./sec.		Ft./sec.	
1	500	400	19·5	234	16	235
2	1,000	700	32	251	20·2	252
3	1,500	1,300	46·5	263	47	259
4	2,000	1,800	58	262	55	262

The following table shows the average results of observations made near Paris by two theodolites. The balloons used were given the requisite free lift for an ascensional velocity of 200 metres per minute. They are considerably larger therefore than the balloons used in the Meteorological Office.

TABLE I. APPENDIX II.

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

Angles in Red.
Resultants in Black

(Each cell below: Angle / Resultant)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
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
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
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
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
5					45/12	40/13	36/14	32/16	29/17	27/19	24/20	23/22	21/23	20/25	18/26
6						45/14	41/15	37/17	34/18	31/19	29/21	27/22	25/24	23/25	22/27
7							45/16	41/18	38/19	35/20	32/22	30/23	28/25	27/26	25/27
8								45/19	40/20	39/21	36/23	34/24	32/25	30/27	28/28
9									45/21	42/22	39/24	37/25	35/26	33/28	31/29
10										45/24	42/25	40/26	38/27	36/29	34/30
11											45/26	43/27	40/28	38/30	36/31
12												45/28	43/29	41/31	39/32
13													45/31	43/32	41/33
14														45/33	43/34
15															45/35

	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
1	4/27	3/28	3/30	3/32	3/33	3/35	3/37	2/38	2/40	2/42	2/43	2/45	2/47	2/48	2/50	1
2	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	4/50	2
3	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	6/50	3
4	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	8/50	4
5	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	9/51	5
6	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	11/51	6
7	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	13/51	7
8	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	15/52	8
9	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	17/52	9
10	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	18/53	10
11	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	20/53	11
12	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	22/54	12
13	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	23/54	13
14	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	25/55	14
15	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	27/56	15
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	28/57	16
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	30/57	17
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	31/58	18
19				45/45	44/46	42/47	41/48	40/50	38/51	37/52	36/54	35/55	34/56	33/58	32/59	19
20					45/47	44/48	42/50	41/51	40/52	39/53	38/55	37/56	36/57	35/59	34/60	20
21						45/49	44/51	42/52	41/53	40/54	39/56	38/57	37/58	36/60	35/61	21
22							45/52	44/53	43/54	41/56	40/57	39/58	38/59	37/61	36/62	22
23								45/54	44/55	43/57	41/58	40/59	39/60	38/62	37/63	23
24									45/57	44/58	43/59	42/60	41/61	40/63	39/64	24
25										45/59	44/60	43/61	42/63	41/64	40/65	25

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 above, 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+	W < S	180 + A
	W > S	90 − A		W > S	270 − A
W− S+	W > S	90 + A	W+ S−	W > S	270 + A
	W < S	180 − A		W < S	360 − A

2243. Wt 39955. 625. 3/20

H. & C. GRAHAM LTD LITHRS LONDON, S.E.

TABLE 2.

TABLE FOR OBT
FROM COM

	1	2	3	4	5	6	7	8	9
1	45 / 2	27 / 3	18 / 4	14 / 5	11 / 6	9 / 7	8 / 8	7 / 9	6 / 10
2		45 / 3	34 / 4	27 / 5	22 / 6	18 / 7	16 / 8	14 / 9	1 / 10
3			45 / 5	37 / 6	31 / 7	27 / 8	23 / 9	21 / 10	1 / 11
4				45 / 6	39 / 7	34 / 8	30 / 9	27 / 10	2 / 11
5					45 / 8	40 / 9	36 / 11	32 / 11	2 / 12
6						45 / 10	41 / 10	37 / 11	3 / 12
7							45 / 11	41 / 12	3 / 13
8								45 / 13	4 / 14
9									4 / 14
10									

Angles in Red.
Resultants in Black.

For Components larger than those s
halve both Components: use these h
values in the table and double the R
speed (But not the Angle)

If A is the Angle given above, follo
obtaining actual wind direction in
from North. The letters W and S de
and South to North components res

W - S	W < S	A	W+ S	
	W < S	90 - A		
W - S	W < S	90 + A	W+ S	
	W < S	180 - A		

2258

TABLE 3.

TABLE FOR OBTAINING RESULTANT WIND SPEED IN METRES PER SECOND FROM COMPONENTS IN HUNDREDS OF FEET PER MINUTE.

(Each cell: Angle / Resultant)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	45 / ·7	27 / 1·1	18 / 1·6	14 / 2·1	11 / 2·6	9 / 3·1	8 / 3·6	7 / 4·1	6 / 4·6	6 / 5·1	5 / 5·6	5 / 6·1	4 / 6·6	4 / 7·1	4 / 7·6
2		45 / 1·4	34 / 1·8	27 / 2·3	22 / 2·7	18 / 3·2	16 / 3·7	14 / 4·2	13 / 4·7	11 / 5·2	10 / 5·7	10 / 6·2	9 / 6·7	8 / 7·2	8 / 7·7
3			45 / 2·2	37 / 2·5	31 / 3·0	27 / 3·4	23 / 3·9	21 / 4·3	18 / 4·8	17 / 5·3	15 / 5·8	14 / 6·3	13 / 6·8	12 / 7·3	11 / 7·8
4				45 / 2·9	39 / 3·3	34 / 3·7	30 / 4·1	27 / 4·5	24 / 5·0	22 / 5·5	20 / 5·9	18 / 6·4	17 / 6·9	16 / 7·4	15 / 7·9
5					45 / 3·6	40 / 4·0	36 / 4·4	32 / 4·8	29 / 5·2	27 / 5·7	24 / 6·1	23 / 6·6	21 / 7·0	20 / 7·6	18 / 8·0
6						45 / 4·3	41 / 4·7	37 / 5·1	34 / 5·5	31 / 5·9	29 / 6·4	27 / 6·8	25 / 7·3	23 / 7·7	22 / 8·2
7							45 / 5·0	41 / 5·4	38 / 5·8	35 / 6·2	32 / 6·6	30 / 7·1	28 / 7·5	27 / 7·9	25 / 8·4
8								45 / 5·7	40 / 6·1	39 / 6·5	36 / 6·9	34 / 7·3	32 / 7·8	30 / 8·2	28 / 8·6
9									45 / 6·5	42 / 6·8	39 / 7·2	37 / 7·6	35 / 8·0	33 / 8·5	31 / 8·9
10										45 / 7·2	42 / 7·5	40 / 7·9	38 / 8·3	36 / 8·7	34 / 9·2
11											45 / 7·9	43 / 8·3	40 / 8·6	39 / 9·0	36 / 9·4
12												45 / 8·6	43 / 9·0	41 / 9·4	39 / 9·8
13													45 / 9·3	43 / 9·7	41 / 10·1
14														45 / 10·1	43 / 10·4
15															45 / 10·8

	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
1	4 / 8·1	3 / 8·6	3 / 9·2	3 / 9·7	3 / 10·2	3 / 10·7	3 / 11·2	2 / 11·7	2 / 12·2	2 / 12·7	2 / 13·2	2 / 13·7	2 / 14·2	2 / 14·7	2 / 15·2	1
2	7 / 8·2	7 / 8·7	6 / 9·2	6 / 9·7	6 / 10·2	5 / 10·7	5 / 11·2	5 / 11·7	5 / 12·2	5 / 12·7	5 / 13·2	4 / 13·8	4 / 14·3	4 / 14·8	4 / 15·3	2
3	11 / 8·3	10 / 8·8	9 / 9·3	9 / 9·8	9 / 10·3	8 / 10·8	8 / 11·3	7 / 11·8	7 / 12·3	7 / 12·8	7 / 13·3	6 / 13·8	6 / 14·3	6 / 14·8	6 / 15·3	3
4	14 / 8·4	13 / 8·9	13 / 9·4	12 / 9·9	11 / 10·4	11 / 10·9	10 / 11·4	10 / 11·9	9 / 12·4	9 / 12·9	9 / 13·4	9 / 13·9	8 / 14·4	8 / 14·9	8 / 15·4	4
5	17 / 8·5	16 / 9·0	16 / 9·5	15 / 10·0	14 / 10·5	13 / 11·0	13 / 11·5	12 / 12·0	12 / 12·5	11 / 13·0	11 / 13·4	10 / 13·9	10 / 14·4	10 / 14·9	9 / 15·4	5
6	21 / 8·7	19 / 9·2	18 / 9·6	18 / 10·1	17 / 10·6	16 / 11·1	15 / 11·6	15 / 12·1	14 / 12·6	13 / 13·1	13 / 13·6	13 / 14·1	12 / 14·5	12 / 15·0	11 / 15·5	6
7	24 / 8·9	22 / 9·3	21 / 9·8	20 / 10·3	19 / 10·8	18 / 11·2	18 / 11·7	17 / 12·2	16 / 12·7	16 / 13·2	15 / 13·7	15 / 14·2	14 / 14·7	14 / 15·2	13 / 15·6	7
8	27 / 9·1	25 / 9·5	24 / 10·0	23 / 10·5	22 / 10·9	21 / 11·4	20 / 11·9	19 / 12·4	18 / 12·8	18 / 13·3	17 / 13·8	17 / 14·3	16 / 14·8	15 / 15·3	15 / 15·8	8
9	29 / 9·3	28 / 9·8	27 / 10·2	25 / 10·7	24 / 11·1	23 / 11·6	22 / 12·1	21 / 12·5	21 / 13·0	20 / 13·5	19 / 14·0	18 / 14·5	18 / 15·0	17 / 15·4	17 / 15·9	9
10	32 / 9·6	30 / 10·0	29 / 10·5	28 / 10·9	27 / 11·4	25 / 11·8	24 / 12·3	23 / 12·7	23 / 13·2	22 / 13·7	21 / 14·2	20 / 14·6	20 / 15·1	19 / 15·6	18 / 16·1	10
11	35 / 9·9	23 / 10·3	31 / 10·7	30 / 11·2	29 / 11·6	28 / 12·0	27 / 12·5	26 / 13·0	25 / 13·4	24 / 13·9	23 / 14·3	22 / 14·8	21 / 15·3	21 / 15·8	20 / 16·2	11
12	37 / 10·2	35 / 10·6	34 / 11·0	32 / 11·4	31 / 11·8	30 / 12·3	29 / 12·7	28 / 13·2	27 / 13·6	26 / 14·1	25 / 14·5	24 / 15·0	23 / 15·5	22 / 15·9	22 / 16·4	12
13	39 / 10·5	37 / 10·9	36 / 11·3	34 / 11·7	33 / 12·1	32 / 12·5	31 / 13·0	29 / 13·4	28 / 13·9	27 / 14·3	27 / 14·8	26 / 15·2	25 / 15·7	24 / 16·1	23 / 16·6	13
14	41 / 10·8	39 / 11·2	38 / 11·6	36 / 12·0	35 / 12·4	34 / 12·8	32 / 13·2	31 / 13·7	30 / 14·1	29 / 14·6	28 / 15·0	27 / 15·4	27 / 15·9	26 / 16·4	25 / 16·8	14
15	43 / 11·1	41 / 11·5	40 / 11·9	38 / 12·3	37 / 12·7	36 / 13·1	34 / 13·5	33 / 13·9	32 / 14·4	31 / 14·8	30 / 15·2	29 / 15·7	28 / 16·1	27 / 16·6	27 / 17·0	15
16	45 / 11·5	43 / 11·9	42 / 12·2	40 / 12·6	39 / 13·0	37 / 13·4	36 / 13·8	35 / 14·2	34 / 14·7	33 / 15·1	32 / 15·5	31 / 15·9	30 / 16·4	29 / 16·8	28 / 17·3	16
17		45 / 12·2	43 / 12·6	42 / 13·0	40 / 13·3	39 / 13·7	38 / 14·1	36 / 14·5	35 / 14·9	34 / 15·4	33 / 15·8	32 / 16·2	31 / 16·6	30 / 17·1	30 / 17·5	17
18			45 / 12·9	43 / 13·3	42 / 13·7	41 / 14·1	39 / 14·4	38 / 14·8	37 / 15·2	36 / 15·6	35 / 16·1	34 / 16·5	33 / 16·9	32 / 17·3	31 / 17·8	18
19				45 / 13·6	44 / 14·0	42 / 14·4	41 / 14·8	40 / 15·2	38 / 15·6	37 / 16·0	36 / 16·4	35 / 16·8	34 / 17·2	33 / 17·6	32 / 18·0	19
20					45 / 14·4	44 / 14·7	42 / 15·1	41 / 15·5	40 / 15·9	39 / 16·3	38 / 16·7	37 / 17·1	36 / 17·5	35 / 17·9	34 / 18·3	20
21						45 / 15·1	44 / 15·4	42 / 15·8	41 / 16·2	40 / 16·6	39 / 17·0	38 / 17·4	37 / 17·8	36 / 18·2	35 / 18·6	21
22							45 / 15·8	44 / 16·2	43 / 16·5	41 / 16·9	40 / 17·3	39 / 17·7	38 / 18·1	37 / 18·5	36 / 18·9	22
23								45 / 16·5	44 / 16·9	43 / 17·3	41 / 17·6	40 / 18·0	39 / 18·4	38 / 18·8	37 / 19·2	23
24									45 / 17·2	44 / 17·6	43 / 18·0	42 / 18·3	41 / 18·7	40 / 19·1	39 / 19·5	24
25										45 / 18·0	44 / 18·3	43 / 18·7	42 / 19·1	41 / 19·4	40 / 19·8	25

Angles in Red.
Resultants in Black.

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 above, following are Rules for obtaining actual wind direction in degrees measured from North. The W and S denoting West to East and South to North Components respectively.

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

H. & C. GRAHAM LTD LITHRS LONDON, S.E.

Vertical Velocity in Metres per Minute for the first 4 minutes of ascent of Pilot Balloon at the Meteorological Station at R.G.A. near Paris. Results computed from two theodolites ascents.

Cloud Amount.	Total Number of Occasions.	Mean Vertical Velocity (metres per minute).				Average Height of Balloon at end of 4th Minute.
		1st Minute.	2nd Minute.	3rd Minute.	4th Minute.	
						Metres.
Nil.	45	203	190	191	179	763
1–5	80	213	210	197	186	806
6–10	47	207	194	188	187	776
0–10	172	209	200	191	184	784

It will he seen that the vertical velocity falls off at Paris with these balloons at the rate of about 9 metres per minute during the first 4 minutes: at subsequent heights there was not much change from the 4th minute value.

In individual cases, the vertical speed differed in some layers by more than 50 per cent. from the assumed value (200 metres per minute). The average height of the balloon at the end of the 3rd minute was 600 metres: at the end of the 4th minute 784 metres. If the average elevation at these times were 10°, the error made in the 4th minute run by assuming a vertical velocity of 200 metres per minute would be about 90 metres, say 300 feet, *i.e.*, the error in the deduced speed would be 5 feet per second.

The Computer's Handbook. Section II., Sub-section 1.

Corrigenda.

APPENDIX II.

Tables 1, 2 and 3. For components 9 and 8, angle should read "42."

Table 2. For components 7 and 5, velocity should read "10."

Tables 2 and 3. The rules for obtaining actual wind direction in degrees measured from North should read :—

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

(30958)—625