

CHAPTER 5

SURFACE WIND

5.1. GENERAL

An adequate description of the wind generally requires both speed and direction to be specified. The effect of turbulence near the earth's surface is to produce rapid irregular changes in both the speed and direction of the wind. These fluctuations occur independently, over short intervals of time, and are referred to as 'gustiness'. Wind direction, speed and gustiness are generally best determined instrumentally, but when such determination is not practicable the wind direction and speed are estimated.

At present the official unit of horizontal wind speed in the United Kingdom is the knot (kn).^{*} All speeds quoted in this chapter are in knots but, for some of them, metric equivalents are also given; these are the values that would be used in the United Kingdom if metres/second (m/s) became the official unit of measurement. The figures are not necessarily precise equivalents because, when speeds are expressed in knots, whole numbers are used, whereas speeds in metres/second are often given to the nearest tenth. For example, using the expressions in 5.1.2 below, the lower limit of wind speed in a gale would be 33.4 knots or 17.2 m/s; the former figure is rounded up to 34 but the direct conversion of that (17.5 m/s) is not used. (See table on page 87.)

The wind direction is always specified as that direction from which it is blowing. It is expressed in tens of degrees measured clockwise from true north, or in terms of the points of the compass. Scales relating direction from true north in whole degrees and points of the compass are shown in Figure 6.

The surface wind speed and direction are usually measured at a standard height of 10 metres above the ground in an open situation. Unless otherwise stated, the winds discussed in this chapter will refer to these standard conditions. Corrections to wind speed at other than the standard height are dealt with in 5.2.1.

5.1.1. Reports of surface wind. At each hour of observation an observer will report the surface wind direction in tens of degrees from true north and the wind speed in knots.

Additionally, at synoptic stations, any marked change of direction or speed, times of onset and cessation of gales, extreme speed and gusts will be reported in accordance with the requirements and reporting procedures which are to be found in the *Handbook of weather messages*, Part III. If an observer estimates either the wind direction on a 16-point scale (N, NNE, NE, etc.) referred to true north, or the wind speed on the Beaufort scale, then these are converted to degrees and knots respectively. The conversions

^{*}1 knot = 1 international nautical mile/hour = 1852 metres/hour = 0.514 metres/second. The symbol kn is being increasingly used in international publications to avoid confusion with the kilotonne (kt).

can be made either by using Figure 6 and the Beaufort scale (pages 86–87) or, for climatological observers, the appropriate tables in Metform 3100A (see 1.5.1, page 8).

Observers at climatological stations should, whenever possible, note the occurrence of gales with the times of beginning and ending, and an estimate of the maximum speed attained. These times and comments should be entered in the remarks column of the Pocket Register and in the Weather Diary of the climatological return.

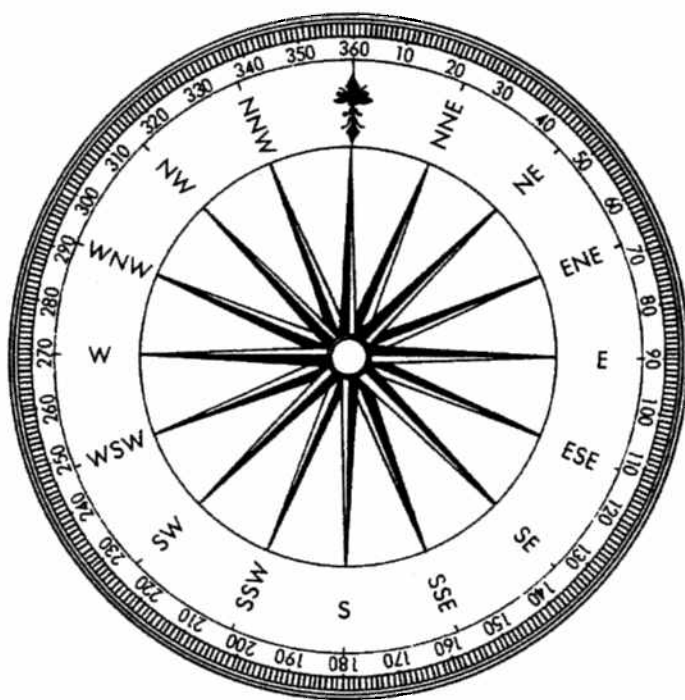


Figure 6. Specification of wind direction

5.1.2. Terminology. Specific terms are used to describe phenomena associated with the surface wind; they are:

5.1.2.1. Gale. A gale is defined as a surface wind of mean speed of 34 knots (17.2 m/s) or more, averaged over a period of 10 minutes. Terms such as 'strong gale', 'storm', etc. are also used to describe winds of 41 knots or greater (see pages 86–87).

Gale warnings are issued when mean speeds of 34 knots or more are expected but warnings are also issued if gusts of 43 knots (22 m/s) or more are expected with mean wind speeds of less than 34 knots, provided that these gusts are not isolated such as those accompanying squalls or thunderstorms.

Certain operational procedures have to be followed when gale-force winds are observed. For this purpose it is necessary to define the times of starting and ending of periods of gales.

A gale is said to be ended when there occurs a period of at least 10 minutes during which neither of the criteria used for gale warnings has occurred.

The time of commencement of a gale is the middle of the first 10-minute period in which the mean surface wind exceeded 34 knots or the time of the first gust exceeding 43 knots, whichever is the earlier. The time of cessation of a gale is the middle of the last 10-minute period in which the mean wind

exceeded 34 knots or the time of the last gust exceeding 43 knots, whichever is the later.

5.1.2.2. *Squall*. A squall is a strong wind that rises suddenly, lasts for at least a minute and then dies away comparatively suddenly. It is distinguished from a gust by its longer duration.

The following definition of a squall was adopted in April 1962 by the Third Session of the WMO Commission for Synoptic Meteorology:

'A sudden increase of wind speed by at least 16 knots (8 m/s), the speed rising to 22 knots (11 m/s) or more and lasting for at least one minute. *Note*: when the Beaufort scale is used for estimating wind speed, the following criteria should be used for the reporting of squalls: a sudden increase of wind speed by at least three stages of the Beaufort scale, the speed rising to Force 6 or more and lasting for at least one minute.'

5.1.2.3. *Gust*: a rapid increase in the strength of the wind relative to the mean strength at the time. A gust is of shorter duration than a squall and is followed by a 'lull' or slackening of the wind speed.

5.1.2.4. *Veering*: a clockwise change in wind direction; for example, from south to west through south-west.

5.1.2.5. *Backing*: a counter-clockwise change in wind direction; for example, from south to east through south-east.

5.2. EXPOSURE OF SURFACE WIND SENSORS

The motion of the air near the earth's surface is much affected by such factors as the roughness of the ground, the type of surface, heat sources, the presence of buildings, trees etc.; moreover, wind speed normally increases with height above the earth's surface. It is therefore necessary to specify a standard exposure for making measurements of surface wind so that observations made at different locations may be compared. As mentioned in 5.1, the standard height for surface wind measurements is 10 metres above the ground and they should be made over open and level terrain. Where there are surrounding obstacles such as buildings or trees disturbing the flow of air, it is necessary to increase the height in order to obtain an exposure which is virtually clear of these disturbances but which is as nearly as possible equivalent to that at 10 metres over open level ground nearby. Notes on the siting of anemometers are given in section I.12 of Appendix I.

5.2.1. **Effective height**. Each anemometer is allotted an 'effective height' which is defined as the height above open level terrain in the vicinity at which mean wind speeds would be the same as those actually recorded by the anemometer. For example, if in order to minimize the effect of nearby buildings an anemometer is exposed at a height of 20 metres, but is believed to record mean wind speeds equal to those which would occur at a height of 8 metres in an open situation nearby (if such existed), then the effective height is said to be 8 metres.

It is evident from this definition that the determination of effective heights is, in general, a subjective process and no definite rules can be stated. At each

station with an anemometer, account will be taken of the nature, extent, height and distance of any obstacles to the wind flow and of the actual height of the anemometer itself. The assessment of the effective height is then a matter of judgement; in some more extreme cases this may result in the effective height having a different value according to the wind direction. The final figure for a station is notified by the Climatological Services Branch of the Meteorological Office after consideration of all the factors.

5.2.2. Correction of wind to standard height at land stations. When anemometers have to be installed at effective heights differing substantially from 10 metres, neither mean speeds nor gusts are strictly comparable with those recorded at sites with a standard exposure. Tabulations made for climatological purposes will record speeds actually measured; appropriate corrections will be made at Headquarters when the data are fully analysed and before they are used, for example, to answer enquiries. When making reports for synoptic purposes, gust speeds are similarly sent without corrections, but the following corrections should be applied to all values of 10-minute mean wind speeds before these are encoded.

Effective height metres	Correction
1-2	add 30 per cent
3-4	add 20 per cent
5-7	add 10 per cent
8-13	no correction
14-22	subtract 10 per cent
23-42	subtract 20 per cent
43-93	subtract 30 per cent

The corrections above are based on the following formula:

$$V_h/V_{10} = 0.233 + 0.656 \log_{10} (h + 4.75)$$

where V_h = speed (in knots) at height h

V_{10} = speed at 10 metres

h = height in metres

from which the following ratios are calculated:

Height in metres	1	2	3	4	5	10	15	20	25	30	40	50
Ratio of speed to that at 10 m	0.73	0.78	0.82	0.85	0.88	1.00	1.08	1.15	1.20	1.24	1.32	1.37
Reciprocal	1.37	1.28	1.22	1.18	1.14	1.00	0.93	0.87	0.83	0.81	0.76	0.73

Investigations have indicated that the above values are sufficiently accurate for ordinary use at land stations. Strictly speaking, the rate of change of wind speed with height varies with the lapse rate of temperature (thermal correction), with wind speed (the extent of mechanical turbulent mixing) and with terrain (surface friction and topographically induced eddies), but the observer is not generally required to take account of all of these effects in applying routine corrections. Note that the corrections above should not be applied to wind speeds observed over the sea.

5.2.3. Correction of wind to standard height over the sea. Wind measurements over the sea, for example at data-collecting platforms, are usually made at heights a long way from the standard 10 metres. The principles for correction are the same as those for land stations: corrections are applied at the station only to reports of 10-minute mean wind speeds made for synoptic purposes. In a marine environment, however, the value of the correction to be applied differs significantly from that over land and is more appropriately based on the power law

$$V_h/V_{10} = (h/10)^b$$

where V_h is the mean wind speed (over 10 minutes) at a height of h metres,
 V_{10} is the mean wind speed (over 10 minutes) at a height of 10 metres,
 h is the effective height of the anemometer above mean sea level.

Following the agreement reached by the North Sea Meteorological Panel, the value for the index b has been taken as 0.13. The following ratios are calculated from this power law:

Height in metres	10	20	30	40	50	60	70	80	90	100
Ratio of speed to that at 10 m	1.00	1.10	1.15	1.20	1.23	1.26	1.29	1.31	1.33	1.35
Reciprocal	1.00	0.91	0.87	0.83	0.81	0.79	0.78	0.76	0.75	0.74

The following corrections should therefore be made.

Effective height metres	Correction
10–13	no correction
14–35	subtract 10 per cent
36–90	subtract 20 per cent.

5.3. ESTIMATION OF WIND DIRECTION AND SPEED

In the absence of instruments, or when instruments become unserviceable, it is necessary to estimate the wind direction and speed. Even at stations which have instruments, observers should make a practice of estimating the wind direction and wind force when outside at observation times. Not only does this become a check against possible instrumental errors, but it also develops a skill which will be valuable if the instruments become unserviceable.

In estimating wind direction and force the observer should stand, if possible, in an open situation avoiding the vicinity of buildings, trees or any similar obstruction, because even small obstructions may cause a significant change in wind speed and deviations in wind direction, especially on their lee side.

5.3.1. Estimation of direction by visual observation. A wind vane specially designed for the purpose is the best device for obtaining the wind direction for meteorological purposes. The requirements are:

- (a) It must be sensitive so that it correctly indicates the direction of all but the very lightest winds.

- (b) It must be accurately balanced so that it has no tendency to set in a particular direction.
- (c) It must be freely exposed and high enough above buildings and trees not to be affected by eddies created by them.
- (d) It should be furnished with fixed arms indicating the true directions of the cardinal points and be so placed that the observer can stand nearly under it.

At stations maintained by the Meteorological Office the wind vane supplied for direct visual readings of the wind direction is the standard Meteorological Office wind vane Mk 2B, installed in such a way as to comply with requirements (c) and (d) above. The prime requisite for the mast on which such a vane is mounted is that it should be rigid and vertical and preferably without the impediment of guy wires which constitute a hazard. The vane should not be so high as to be difficult to see from the ground at night. Each site must be judged on its merits and some compromise reached between the often conflicting requirements of exposure, safety and visibility of the vane. Ideally the vane should be installed in an open position on a steel mast approximately 6 metres high. Where the situation is obstructed by trees etc., the vane may be erected on a building or high mast so that it is higher, by at least 3 metres, than the highest obstacle in the immediate vicinity; (see also I.11 (page 196) in Appendix I).

Wind vanes installed on church spires and public buildings rarely meet all the requirements stated above and should not be used. The direction of movement of clouds, however low, should be ignored because wind direction normally changes with height. Visual observation of a drogue or wind-sleeve, a light streamer attached to a suitable mast, or the drift of smoke from low chimneys may be helpful; but care and experience are necessary to eliminate errors due to perspective when the observer cannot stand directly below the indicator.

When the visual observation of vanes or other low-level indicators cannot be made the observer should determine the wind direction by standing in the most exposed part of the observation area and facing into wind; the direction from which the wind is coming may then be determined by reference to the true direction of known landmarks. However, care should always be taken to guard against mistaking local eddies due to buildings, trees, etc. for the general drift of the wind.

5.3.2. Estimation of wind speed. At stations not equipped with an anemometer the strength of the wind must be estimated. Estimates are based on the effect of the wind on movable objects and on the observer's own sensations. The effect of buildings and trees on the mean wind has been mentioned above. When estimating wind speed the observer should stand on flat open ground, well away from such obstructions. Wind speed will be particularly affected on their lee side.

A convenient scale for estimating wind strength is the Beaufort scale of wind speed, so named after its originator Admiral Sir Francis Beaufort. The specifications of the scale now differ from those originally devised by him in 1806 but the present scale has continued in use, substantially unchanged, for many years. The observer should first estimate the force on the Beaufort

BEAUFORT SCALE: SPECIFICATIONS

Force	Description	Specifications for use on land	Specifications for use at sea
0	Calm	Calm; smoke rises vertically.	Sea like a mirror.
1	Light air	Direction of wind shown by smoke drift, but not by wind vanes.	Ripples with the appearance of scales are formed, but without foam crests.
2	Light breeze	Wind felt on face; leaves rustle; ordinary vanes moved by wind.	Small wavelets, still short but more pronounced. Crests have a glassy appearance and do not break.
3	Gentle breeze	Leaves and small twigs in constant motion; wind extends light flag.	Large wavelets. Crests begin to break. Foam of glassy appearance. Perhaps scattered white horses.
4	Moderate breeze	Raises dust and loose paper; small branches are moved.	Small waves, becoming longer; fairly frequent white horses.
5	Fresh breeze	Small trees in leaf begin to sway; crested wavelets form on inland waters.	Moderate waves, taking a more pronounced long form; many white horses are formed. Chance of some spray.
6	Strong breeze	Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty.	Large waves begin to form; the white foam crests are more extensive everywhere. Probably some spray.
7	Near gale	Whole trees in motion; inconvenience felt when walking against wind.	Sea heaps up and white foam from breaking waves begins to be blown in streaks along the direction of the wind.
8	Gale	Breaks twigs off trees; generally impedes progress.	Moderately high waves of greater length; edges of crests begin to break into spindrift. The foam is blown in well-marked streaks along the direction of the wind.
9	Strong gale	Slight structural damage occurs (chimney-pots and slates removed).	High waves. Dense streaks of foam along the direction of the wind. Crests of waves begin to topple, tumble and roll over. Spray may affect visibility.
10	Storm	Seldom experienced inland; trees uprooted; considerable structural damage occurs.	Very high waves with long overhanging crests. The resulting foam, in great patches, is blown in dense white streaks along the direction of the wind. On the whole the surface of the sea takes a white appearance. The 'tumbling' of the sea becomes heavy and shock-like. Visibility affected.
11	Violent storm	Very rarely experienced; accompanied by widespread damage.	Exceptionally high waves (small and medium-size ships might be for a time lost to view behind the waves). The sea is completely covered with long white patches of foam lying along the direction of the wind. Everywhere the edges of the wave crests are blown into froth. Visibility affected.
12	Hurricane	—	The air is filled with foam and spray. Sea completely white with driving spray; visibility very seriously affected.

AND EQUIVALENT SPEEDS

Force	Specifications for coastal use	Equivalent speed at 10 m above ground					
		Knots		Miles per hour		Metres per second	
		Mean	Limits	Mean	Limits	Mean	Limits
0	Calm.	0	<1	0	<1	0.0	0.0-0.2
1	Fishing smack* just has steerage way.	2	1-3	2	1-3	0.8	0.3-1.5
2	Wind fills the sails of smacks which then travel at about 1-2 knots.	5	4-6	5	4-7	2.4	1.6-3.3
3	Smacks begin to careen and travel at about 3-4 knots.	9	7-10	10	8-12	4.3	3.4-5.4
4	Good working breeze, smacks carry all canvas with good list.	13	11-16	15	13-18	6.7	5.5-7.9
5	Smacks shorten sail.	19	17-21	21	19-24	9.3	8.0-10.7
6	Smacks have double reef in mainsail. Care required when fishing.	24	22-27	28	25-31	12.3	10.8-13.8
7	Smacks remain in harbour and those at sea lie-to.	30	28-33	35	32-38	15.5	13.9-17.1
8	All smacks make for harbour, if near.	37	34-40	42	39-46	18.9	17.2-20.7
9	—	44	41-47	50	47-54	22.6	20.8-24.4
10	—	52	48-55	59	55-63	26.4	24.5-28.4
11	—	60	56-63	68	64-72	30.5	28.5-32.6
12	—	—	≥64	—	≥73	—	≥32.7

*The fishing smack in this table may be taken as representing a trawler of average type and trim. For larger or smaller boats and for special circumstances allowance must be made.

scale, making use of the criteria set out on page 86, and record the equivalent mean wind speed in knots in the Register. It should be emphasized that the criteria for use on land are not intended to be in any way precise, but are merely to indicate the kind of effect produced by different forces. Force 8 is uncommon inland and represents a wind which is unmistakably 'blowing a gale' and difficult to walk against. The (archaic) coastal specifications (page 87) were based on the behaviour of a fishing smack and may be of assistance to observers on the coast who are knowledgeable in the management of small sailing craft. Where the station commands a good view of the open sea the specifications for use at sea are applicable, but they should not be applied to harbours or other enclosed waters.

Comparisons between estimates of force (B) on the Beaufort scale and measurements of the speed (V) of the wind at an effective height of 10 metres above the ground have led to the establishment of the following relationship between B and V expressed in various units:

$$V = 1.87 \sqrt{B^3} \text{ when } V \text{ is measured in miles per hour.}$$

$$V = 1.625 \sqrt{B^3} \text{ when } V \text{ is measured in knots.}$$

$$V = 0.836 \sqrt{B^3} \text{ when } V \text{ is measured in metres per second.}$$

A table based on these relationships is given on page 87.

5.4. WIND SPEED MEASUREMENT

Instruments used for measuring the wind speed are called anemometers. In the United Kingdom horizontal wind speed is reported in knots (kn) for both climatological and synoptic purposes. Other units such as metres per second, feet per second, miles per hour and kilometres per hour are, or have been, used in certain circumstances and the relations between them are shown in the following table.

m/s	kn	mile/h	ft/s	km/h
1	1.944	2.237	3.281	3.600
0.514	1	1.151	1.688	1.852
0.447	0.869	1	1.467	1.609
0.305	0.592	0.682	1	1.097
0.278	0.540	0.621	0.911	1

Some instruments do not respond to wind speeds of less than 5 knots (2.5 m/s) and so speeds of less than 5 knots must often be estimated.

5.4.1. Cup anemometers. The standard instruments used by the Meteorological Office for measuring wind speed are called cup anemometers. Three or more cups, roughly conical in cross-section, are mounted symmetrically on arms set at right angles into a vertical spindle. The wind blowing into the cups causes the spindle to rotate, and in standard instruments the design of the cups is such that the rate of rotation is directly proportional to the speed of the wind to a sufficiently close approximation.

The rotation of the cups can be utilized in several ways to obtain values of wind speed. The various cup anemometers used by the Meteorological Office are described below.

5.4.1.1. *Counter anemometers.* The Meteorological Office anemometer, cup counter, Mk 2, is designed primarily for measuring the run of wind over a period of hours or a whole day, rather than over the short period required for synoptic purposes. The short spindle to which the three conical cups are attached is connected by worm-gearing to a revolution counter. The gear ratio is so chosen that the counter indicates directly in miles, tenths and hundredths. Some instruments have the counter window in a vertical position and others have the counter window angled to facilitate reading from the ground.

This instrument is used at many agrometeorological stations to record the run of wind at 2 metres above ground level, an observation used, for example, in the estimation of potential evapotranspiration.

5.4.1.2. *Contact anemometers.* These anemometers are fitted with a switch mechanism which makes an electrical contact at a frequency proportional to the wind speed.

The Meteorological Office cup generator/contact anemometer, Mk 4A, in addition to the generator (see 5.4.1.4), has a micro-switch which is actuated by a falling weight. A worm-wheel from the cup spindle operates on a cam which is raised by the action of the worm-wheel and then released. In falling, it operates the micro-switch. The 'on' period of the switch is therefore independent of the wind speed and the switch cannot remain in the 'on' position. In this way the possibility of the switch remaining in the 'on' position during a calm, or of very long contacts in a light wind, is avoided. The micro-switch is actuated once every 49 revolutions of the cup spindle, this being equivalent to two contacts in 10 minutes per knot of mean wind speed.

The contacts can either be counted by means of a remote audio signal or registered on an electromagnetic counter unit.

5.4.1.3. *Hand anemometers.* The Meteorological Office hand anemometer (see Plate XVII) is based on the magnetic-drag principle and is used to obtain values of wind speed at the level of the observer. The instrument consists of three or four small cups mounted on a vertical spindle. The mechanism and indicating scale are mounted in a cylindrical housing below the cups, and below the housing is a short handle by which the instrument is held. The indicating scale is calibrated in knots over a range of 0 to 60. Each instrument is supplied with a calibration card, and instruments supplied by the Meteorological Office should be returned for recalibration at regular intervals of about one year. Any instrument corrections should be applied before effective height corrections.

In use, the anemometer is held with its axis vertical at arm's length and with the arm at right angles to the wind direction to ensure that the disturbance of the airflow, caused by the observer's body, is reduced as much as possible.

At least two readings of mean wind speed (each reading being taken over at least 15 seconds) are taken within the overall period of observation. When the readings differ by less than 10 knots their average is reported. When the readings differ by 10 knots or more a third reading is taken. If this third reading is within 10 knots of the first reading then the average of all three readings is reported. If the third reading differs by 10 knots or more from the first reading, but is within 10 knots of the second reading, then the change is

taken as real and the average of the last two readings alone is reported. Additional mean values are taken, if necessary, to fulfil these conditions.

When the measured wind speed is required for synoptic reports, the speed must be corrected to the standard height of 10 metres (see 5.2.2, or 5.2.3 if over the sea). If the observer stands at ground level the speed reading has to be increased by 30 per cent.

The hand anemometer must be treated with great care; rough handling and vibration may cause demagnetization, resulting in a change of calibration. To protect it from damage it must be stowed in its box when not in use and it must not be put down where it is liable to be affected by stray magnetic fields, especially alternating ones, caused by adjacent electrical apparatus such as motors, relays, transformers, etc. The cups are particularly liable to damage just before, or after, an observation when the cups may be rotating at speed. If they inadvertently strike an object at this stage then the damage can be severe. Even minor damage will change the calibration.

5.4.1.4. Generator anemometers. The rotation of the cups in this pattern of anemometer is used to drive an electrical generator; the voltage generated increases with the speed of the wind and this voltage is indicated on a dial graduated directly in knots. Cup generator anemometers are listed below.

- (a) Anemometer, cup generator, Mk 2, suitable for operating a recorder and up to six indicating dials connected in parallel. It may be fitted with a strengthened cup assembly capable of withstanding speeds up to 180 knots. When mounted above a Mk 3B wind vane the 'in-line' assembly forms the head of the Meteorological Office electrical anemograph Mk 2.
- (b) Anemometer, cup generator/contact, Mk 4A (see 1 in Plate XVIII), suitable for operating a recorder and up to six indicating dials connected in parallel. It will withstand wind speeds up to 180 knots. When mounted above a Mk 4G wind vane the 'in-line' assembly forms the head of the Meteorological Office electrical anemograph Mk 4A.
- (c) Anemometer, cup generator, Mk 5, is externally identical to the Mk 4 but has a starting speed of about $2\frac{1}{2}$ knots due to the use of a generator with lower magnetic drag, and is described in 5.7 (page 94).

The types described in (a) and (b) can both be used independently of their respective wind vanes.

5.4.2. Readings from anemometers. At a station equipped only with an indicating dial anemometer the observer should take at least two readings of mean wind speed (each reading being averaged over at least 15 seconds) within the overall period of the observation and should report the average of these readings. When these readings differ by 10 knots or more, a further 15-second mean reading should be taken. If this third reading agrees with the first reading, within a limit of 10 knots, the mean of all three values should be reported. If the third reading does not agree with the first but agrees with the second, the change should be taken as real and the mean of only the last two readings is reported. Additional mean values are taken, if necessary, to provide a set of two or three successive readings that fulfil these conditions.

5.4.3. Sudden change of wind speed. Particulars of any sudden change of wind speed should be noted in the remarks column of the Register.

5.5. WIND DIRECTION MEASUREMENT

Continuous remote indication of wind direction is provided by means of synchronous transmitters and receivers. The transmitting unit is mounted directly above the vane and its rotor is connected through gearing to the vane spindle. The movements of the vane are transmitted to the receivers and thence to the dial pointers. Either a 12-volt d.c. Desynn system or a 50-volt a.c. magslip system can be employed. The wind vanes used by the Meteorological Office are listed below.

- (a) Wind vane, remote-transmitting, Mk 3B, which drives, through gearing, a magslip transmitter. Above the vane and transmitter is a platform to which the base of a Mk 2 anemometer may be bolted so that the vane and the anemometer form a single transmitting head for the Meteorological Office electrical anemograph, Mk 2.
- (b) Wind vane, remote-transmitting, Mk 4A, which drives, through gear wheels and a countershaft, a Desynn transmitter. At the top of the casing containing the Desynn is a platform to which the base of a Mk 4A anemometer may be fastened so that the vane and anemometer form a single transmitting head. Alternatively, if the vane is used by itself, a cap is fitted to the top in place of the anemometer.
- (c) Wind vane, remote-transmitting, Mk 4G (illustrated in Plate XVIII as forming part of the Meteorological Office Mk 4 wind system), is similar to the Mk 4A described in (b), but a magslip transmitter is employed.

5.5.1. Reading the direction indicator. At a station equipped with a wind vane which has remote-indicating dials, the observer should take at least two readings of mean wind direction (each reading being a mean over at least 15 seconds) within the overall period of the observation and should report the average of these readings. When the first two readings differ by 30 degrees or more, a third final 15-second mean reading should be taken. If this final reading agrees with the first reading, within the limit of 30 degrees, the mean of all three values should be reported. If the final reading does not agree with the first one but agrees with the second, the change may be taken as real and the mean of only the last two readings is reported. It is possible that on occasions of light air (Beaufort force 1) all three readings will differ by 30 degrees or more. In that case the last reading will be reported.

5.5.2. Sudden change of wind direction. Particulars of any sudden change of wind direction should be noted in the remarks column of the Register, but discretion is needed on occasions of very light or no wind when the direction indicator may vary over a wide range of directions in a comparatively short space of time.

5.6. ANEMOGRAPHS

Strictly speaking, an anemograph is an instrument for recording the speed of the wind but, by convention, the term is used in the United Kingdom to cover direction also. The standard instrument used by the Meteorological Office is the electrical anemograph which records the wind speed from the output of a

cup generator anemometer and the wind direction from a remote-transmitting wind vane.

The Meteorological Office electrical anemograph, Mk 4, is illustrated in Plate XVIII. The anemograph recorder and dials may be sited at a distance of approximately 500 metres from the transmitting head, depending on the conductor resistance of the cable link. Six indicating dials for speed and direction may be connected in parallel with the recorder.

5.6.1. Anemograph recorder. The recorder consists of speed and direction units mounted side by side with pens recording on a dual-scaled double-width chart (see 5 in Plate XVIII). The chart mechanism is driven by a synchronous motor which has a standard speed of 1 inch per hour and the chart is capable of taking a continuous record for 31 days.

The recorder is fitted with a range-change switch by which the range can be changed from 0–90 knots to 0–180 knots. The switch is usually kept in the 0–90 position, but when a wind speed of 70 knots is first recorded the switch is moved to the 0–180 knot position. When the mean wind speed falls below 50 knots the switch is reset to the normal range. Recorders at certain stations have the manual range-changing switch removed and an additional unit coupled to the recorder which will automatically switch to the longer range when the wind speed exceeds 70 knots. A red indicator lamp is illuminated when this occurs. Once switched over, the recorder will remain on the 0–180 knot range until the 0–90 knot reset button is pressed. This should not be done until the mean wind speed falls below 50 knots. See 5.6.3 for instructions on noting the times in the Register and indicating on the chart the duration of the change.

Plate XIX shows a section of a typical trace from an electrical anemograph. The upper trace is the record of wind direction and the lower that of wind speed. The direction trace illustrates the effects of turbulence which causes short-period fluctuations of the wind, and therefore of the pen. The result is a broadening of the trace to produce a typical spread of 40 or 50 degrees (or even more at some stations). The lower record of wind speed is also broadened by fluctuations and shows gusts and lulls. The average difference between the speeds of the gusts and lulls is usually a substantial percentage of the mean speed. This percentage, known as the 'gustiness factor' varies with the nature of the terrain in the vicinity of the anemometer. For British stations it is likely to be in the range 25 to 100 per cent. It is smallest over the open sea and greatest in urban or woodland sites because of eddies in the wind stream set up by obstacles to the surface flow. To illustrate the variation in the 'mean wind' a white line has been drawn over the speed record. At open unobstructed sites, and with no neighbouring topographical features that would tend to produce larger-scale eddying flows (mainly in the vertical), the line of the mean wind on the record may usually be assumed to lie midway between imaginary lines drawn through the peaks of the gusts and the troughs of the lulls. This is not true, however, for obstructed sites where the gustiness is greater and eddying circulations will be induced both in the horizontal and the vertical. In such cases the gusts are likely to rise higher above the mean line than the lulls fall below it, since the effect of the obstructions will at times be to direct the stronger wind flow at higher levels down towards the surface. Where there are circulations generated by topographical features, such as those in the lee of hills, the topographically induced eddy may at times oppose

the flow of the free wind. The uncritical use of the observed lulls to arrive at the mean free wind speed would then lead to an underestimate. Similarly it would also be possible to choose other, not too distant, observing points for the wind, where the air motions generated by the ground-surface contours commonly lead to an overestimate of the free wind.

These remarks are intended to emphasize the general need for caution in the selection of observing sites and in the interpretation of the records obtained.

5.6.2. Readings from anemographs. At a synoptic station equipped with an anemograph the observer reports the mean wind speed and mean wind direction recorded over the last 10 minutes. However, when there has been a change of 10 knots or more in mean wind speed and/or 30 degrees or more in the mean direction, and this has been maintained for at least 3 minutes, the observer reports the new speed and/or direction. For synoptic reports the mean wind speed should be corrected, if necessary, for effective height.

At a synoptic station there is also a requirement for reporting additional information about times of onset and cessation of gales, extreme speed and gusts etc. Details of requirements and reporting procedures are to be found in the *Handbook of weather messages*, Part III.

5.6.3. Time marks and notations on the chart. When the range-change switch (see 5.6.1) is in use and the recorder is on the 0–180 knot range, it is most important that a note should be written on the chart giving the time of the change-over; another note should be written on the chart when the change back to normal response is made, and a firm line, of a distinctive colour, should be drawn above the speed trace throughout the duration of the reduced chart scale.

Daily time marks can best be made by using a soft pencil or ball-point pen to make a short stroke or legible dot at a place on the speed chart, in line with the pen, not covered by the trace. The exact time should be noted in the Daily Register, where one is kept, or in a separate notebook. Dates and times should be written against the marks on the chart either at the same time or subsequently after the chart roll has been removed from the recorder.

5.6.4. Care of the recorder. The recorder should need little attention other than keeping it clear of dust and spilt ink, topping up the ink-wells and changing the chart as necessary. When topping up the ink-wells, care should be taken to avoid both dislodging the pen from the pen stirrup and overfilling the ink reservoir. Excess ink can damage the pen mechanisms and even cause seizing of the speed movement. A small kit of accessories is supplied with each anemograph which allows for the cleaning or replacement of the pens.

About once a month check that all speed dials, where fitted, agree with each other and with the recorder to within 2 knots below 40 knots and to within 4 knots above that value. Direction dials, if fitted, should agree with each other and the recorder to within 6 degrees. All pointers and pens should be moving freely and smoothly at all times. During flat calms or when the recorder is switched off for any purpose, check that the zero of the speed pen lies accurately on the zero of the chart. Any significant faults shown up by the above checks should be reported to the appropriate authority.

5.7. THE METEOROLOGICAL OFFICE Mk 5B WIND SYSTEM

In the electrical anemograph, Mk 4 (5.6 refers), the voltage generated by the anemometer passes directly through cables to the dials and chart recorder. In this system the calibration is based on having a fixed resistance value for the circuit and this is provided by the dial and recorder and by fixed resistors which may be removed as dials are added. However, this system is unsuitable if many additional displays are required or where the length of the cable between the anemometer tower and the displays has too high a resistance. In such circumstances the Mk 5B wind system may be used. The heart of the system is the Mk 5B converter unit which takes the outputs from a Mk 4G wind vane and either a Mk 4A or Mk 5 cup generator anemometer.

The wind-vane input data are converted into d.c. voltages over the range 0–10 volts, representing a range of 540 degrees. Logic circuits shift the scale reading by 360 degrees whenever the extreme values of 0 and 540 degrees are approached. This avoids any discontinuities when the wind vane passes through north.

The cup generator anemometers produce voltages, the amplitude and frequency of which increase or decrease according to the wind speed. A converter is used to convert the frequency to a d.c. voltage in the range 0–10 volts, representing 0–200 knots.

The sensors can be linked by cable to the Mk 5B converter unit over distances up to 3 km with further cable links of about 500 metres to the Mk 5C wind speed and direction meters, and 100 metres for the Mk 5B recorders. For distances greater than 3 km a Mk 5B telemetry system, operating over telephone lines, has to be employed.

The Mk 5B recorder (see Plate XX) produces a record very similar to that of the Mk 4G. The chart drive speed is 30 mm per hour. A control unit may be added which will automatically change the range of the recorder to 0–200 knots when the wind speed exceeds 70 knots. A warning light is illuminated when this occurs. The recorder will remain on the extended range until manually reset.

5.8. OTHER WIND SYSTEMS

In addition to the wind systems and sensors described above, a number of other systems are employed in the Meteorological Office. Some are characterized by smaller size and lower inertia of the cup rotors and vanes and generally employ photoelectric devices to detect motion. They are usually associated with automatic weather stations of various types and in all cases their use will have had prior approval from Meteorological Office Headquarters.