CHAPTER CONTENTS

CHAPTER 2. MEASUREMENTS AND OBSERVATIONS AT AERONAUTICAL METEOROLOGICAL STATIONS

2.1 GENERAL

2.1.1 Definitions

This chapter deals with the requirements for observations at aeronautical meteorological stations and the instruments and methods that are used. Synoptic observations measure at one location a representative value for a rather large area, but meteorological observations for aeronautical purposes are often made at several locations at the aerodrome and in the surrounding area, at more frequent intervals, to be representative of rather limited areas, such as the approach, touchdown and take-off areas.

The meteorological measurements to be taken are for the most part essentially the same as those taken for other applications, and described in other chapters in this Guide. The exceptions are runway visual range (RVR), slant visual range and low level wind shear which are unique to this application.

2.1.2 Units

The units for measuring and reporting meteorological quantities for aeronautical purposes are the same as for other applications, except that:

(a) Surface wind speed may be measured and reported in metres per second or knots;[1] and wind direction[2] reported in degrees measured clockwise from geographic north[3] (see section 2.2.1);

(b) Cloud-base height may be measured in metres or feet.

The choice of units is a matter for national practice, depending on the requirements of the aviation regulatory bodies.

2.1.3 Requirements

The formal requirements for aeronautical observations are stated in the *Technical Regulations*, Volume II (WMO, 2013). Detailed guidance on procedures and practices is found in WMO (2014). Useful guidance on observing and monitoring meteorological conditions is contained in WMO (2003). Special attention should be given to aeronautical meteorological stations established on offshore structures in support of helicopter operations (ICAO, 1996).

The requirements for uncertainty, resolution and range, and for currently achievable performance in meteorological measurements are given in Part I, Chapter 1, and the operationally desirable accuracies of some measurements are provided in the *Technical Regulations*, Volume II, Part II, Attachment A.

Despite the excellent performance of modern aircraft, weather factors still have a marked effect on their operation. The reliability and representativeness of aerodrome observations are very

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[1] The unit of wind speed used is determined by national decision. However, the primary unit prescribed by the *Technical Regulations*, Volume II (WMO, 2013) for wind speed is the metre per second, with the knot permitted for use as a non-SI alternative unit (further information is given in ICAO, 2010).

[2] Direction from which surface wind is blowing.

[3] Because wind direction reported to aircraft for landing or take-off purposes may be converted into degrees magnetic, the display at the air traffic service unit usually presents direction with respect to the magnetic north.

important in ensuring that landings and take-offs are made safely. The wind observation will determine the runway to be used, and the maximum take-off and landing weights. Temperature is also important and affects engine performance. Consequently, the load carried might have to be reduced, or the take-off would require a longer runway, particularly at airports in hot countries.

Routine observations are to be made at aeronautical meteorological stations, at times and frequencies determined by the Member country to meet the needs of national and international air navigation, giving due regard to regional air-navigation arrangements. Special and other non-routine observations are to be made on the same basis. Routine observations at aerodromes should be made at hourly or half-hourly intervals, during all or part of each day, or as necessitated by aircraft operations. Special observations must be made when specified changes occur between routine observations in respect of surface wind, visibility, RVR, present weather and/or cloud. These specified changes are set out in the *Technical Regulations*, Volume II, Part II, Appendix 3, 2.3.2. These observations, in the form of coded reports of the METAR or SPECI types, are exchanged internationally between aeronautical meteorological stations. Other types of reports are intended only for aeronautical operations, and should be prepared in a form defined jointly by the meteorological and airport authorities.

In view of the importance of meteorological observations for aircraft safety, it is essential that observers be correctly trained and have good eyesight. Observer training should include basic courses and regular refresher courses (for further information see the *Technical Regulations*, Volume I, Part II, 4, and WMO, 2012).

Siting, installation and the nature of meteorological systems are specified in the *Technical Regulations*, Volume II, Part I, 4, with technical specifications and detailed criteria in the *Technical Regulations*, Volume II, Part II, Appendix 3. These specifications are summarized below.

Special care is necessary in selecting appropriate sites for making observations, or for the installation of instruments at aeronautical meteorological stations, to ensure that the values are representative of the conditions at or near the aerodrome. In some instances, where information over a large area is required, it may be necessary to provide multiple installations for some instruments to ensure that values reported are representative of the entire area. For example, for long runways or for large aerodromes with several runways, where approach, touchdown and take-off areas may be as much as 2 to 5 km apart, the values of various parameters such as wind, cloud height, RVR, and so forth, measured at one end of a runway may be quite different from the conditions prevailing elsewhere on that runway, or over other areas of the runway complex of interest to aircraft operations.

At all aerodromes, the sites should be such that the measured values of the various meteorological parameters are representative of the aerodrome itself and/or the appropriate area of a particular runway or runway complex. At aerodromes where precision approach and landing operations are not in practice (non-instrument or non-precision approach runways), this criterion on representativeness is less restrictive than with precision approach runways (i.e. with Category I, II or III runways (see WMO, 2014, and ICAO, 2011)).

In selecting locations for instruments at aerodromes, it is particularly important that, while the site and exposure of the instruments meet operational requirements, the instruments or their operation do not present hazards to air navigation; and that the presence or movement of aircraft at the aerodrome (taxiing, take-off runs, landing, parking, etc.) and the various aerodrome installations do not unduly influence the measured values.

The types of instruments to be used, their characteristics and the methods employed for the presentation and reporting of the measured values of the parameters are equally important. Meteorological instruments should be exposed, operated and maintained in accordance with the practices, procedures and specifications promulgated in this Guide. Aeronautical meteorological stations shall be inspected at sufficiently frequent intervals to ensure that a high standard of observations is maintained, that instruments and all their indicators are functioning correctly, and that the exposure of the instruments has not changed significantly (*Technical Regulations*, Volume II, Part I, 4.1.4).

Instrument design should permit remote indication, simultaneously at both the air traffic service (ATS) units and at the meteorological stations and offices, of the appropriate values of surface wind, temperature, dewpoint, atmospheric pressure, present weather, visibility, RVR (if the runways are equipped for take-offs and landings in fog) and cloud height, all of which should be representative of conditions in the touchdown and take-off areas concerned. Automatic instrumental systems for measuring the height of the cloud base and RVR are particularly useful at aeronautical stations.

At aerodromes where precision approaches and, in particular, where Category II, III A and III B operations are affected, and/or at aerodromes with high levels of traffic, it is preferable to use integrated automatic systems for acquisition, processing and dissemination/display in real time of the meteorological parameters affecting landing and take-off operations. These automatic systems should be capable of accepting the manual insertion of meteorological data that cannot be measured by automatic means (*Technical Regulations*, Volume II, Part I, 4.1.7). The requirements for automatic meteorological observing systems are specified in the *Technical Regulations*, Volume II, Part II, Appendix 3.

2.1.4 **Methods**

The methods for taking meteorological measurements at aerodromes are essentially the same as those for other meteorological applications and described in other chapters of this Guide. This chapter describes some siting and sampling requirements, and some algorithms, which are particular to the aeronautical application.

2.2 SURFACE WIND

2.2.1 **General**

In aviation, measurements of airflow and low-level wind shear in the vicinity of the landing and take-off areas are of primary interest. The regulations are described in the *Technical Regulations*, Volume II, Part I, 4.1, with details in Part II, Appendix 3. At international aerodromes, ATS units, air traffic control towers, and approach control offices are normally equipped with wind-speed and wind-direction indicators, and air traffic controllers supply arriving and departing aircraft with readings from these indicators. To ensure compatibility, the indicators at the ATS units and the meteorological station should be connected to the same sensors.

The mean direction and speed of the wind are measured as well as gusts and specified significant variations of direction and speed. Wind reports disseminated beyond the aerodrome (*Technical Regulations*, Volume II, Part II, Appendix 3, 4.1.5) have the same content as those in synoptic observations (10 min means, and direction reported with respect to the geographic north),[4] and the values transmitted should be representative of all runways. For local routine and special reports and for wind indicator displays in ATS units (*Technical Regulations*, Volume II, Part II, Appendix 3, 4.1.3.1), the averaging period is 2 min for both speed and direction, and the values should be representative of the runway in use. Although wind direction shall be reported with respect to the geographic north, expressed in “degrees true” (*Technical Regulations*, Volume II, Part I, 4.6.1 and Part II, Appendix 3, 4.1.5.1), it is still common practice that ATS personnel report the aircraft with respect to the magnetic north (“degree magnetic”). Gusts should be determined from 3 s running means. Part I, Chapter 5, and Part IV, Chapter 2, of this Guide should be consulted on the precautions to be taken for sampling the anemometer output to measure the mean, gusts and variability of the wind speed and direction. Vector averaging is to be preferred to scalar averaging.

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[4] Usually referred to as the “true” north, with the unit “degree true”. The word “true” in “true north” or “degree true” should not be confused with the “true wind” (defined by WMO, 1992*a*). “True wind” is represented by the wind vector in relation to the Earth’s surface. For a moving object like an aircraft, it is the vector sum of the apparent wind (i.e. the wind vector relative to the moving object) and the velocity of the object.

The wind measurements needed at aerodromes, such as mean value, extreme values, and so forth, should preferably be determined and displayed automatically, particularly when several sensors are used on different runways. When several sensors are required, the indicators shall be clearly marked to identify the runway and the section of runway monitored by each sensor.

2.2.2 Instruments and exposure

Wind-measuring instruments used at aeronautical stations are generally of the same type as those described in Part I, Chapter 5. The lag coefficients of direction and speed sensors should comply with the requirements of that chapter.

Sensors for direction and speed should be exposed approximately 10 m above the runway and should provide measurements that are representative of the conditions at the average lift-off and touchdown areas of the runway.

If wind sensors installed at aerodromes are to be representative of the conditions at take-off or landing areas, any disturbance or turbulence due to the proximity and passage of the aircraft themselves must be avoided (false gust indications due to landings and take-offs). For similar reasons, they must not be placed too close to buildings or hills or located in areas subject to microclimatic conditions (sea breeze, frequent storms, etc.). The preferred standard exposure of wind instruments is in open terrain, defined as an area where the distance between the anemometer and any obstruction is at least 10 times the height of the obstruction.

It is recommended that back-up or standby equipment should be provided in case of failure of the service instrument in order to avoid any interruption in the transmission of data to the ATS units. Where local conditions so warrant, one or more sets of sensors should be installed for each runway concerned. In such cases, the use of digital techniques is recommended since they enable data from a large number of sensors to be transmitted by one or two telephone cable pairs, and allow digital indicators to be used to display wind measurements using light-emitting diodes of different colours. The displays should show the “instantaneous” wind speed and direction (with a distance constant of 2 to 5 m), the average wind speed and direction over 2 or 10 min, and the minimum and maximum wind speeds. It is sometimes possible to select wind readings for different measurement points on the same indicator (thus reducing the number of indicators required).

When installing wind sensors at the aerodrome, particular attention must be paid to protecting them against atmospheric storm discharge (by the use of lightning conductors, earthing of the mast, and shielded or fibre optic cables); electronic data-processing equipment should also be protected.

In order to maintain the required accuracy, wind-measuring instruments should be kept in good order and regularly checked and recalibrated. Sensor performance must sometimes be checked in the wind tunnel, particularly for analogue systems. The use of digital techniques with the built-in testing of certain functions calls for fewer checks, but does not eliminate errors due to friction. Regular checks are to be made to detect defective components and deterioration of certain parts of the sensors.

The sources of error include friction, poor siting and problems with transmission or display equipment. Errors may also be caused by the design of the sensors themselves and are noticed particularly in light winds (rotation threshold too high, excessive inertia) or variable winds (over- or underestimation of wind speed or incorrect direction due to excessive or inadequate damping).

2.3 VISIBILITY

The definition of the meteorological optical range (MOR) and its estimation or instrumental measurement are discussed in Part I, Chapter 9. The measurement of visibility in aviation is a specific application of MOR. However, the term MOR is not yet commonly used in aviation and the term visibility has been retained in this chapter to describe operational requirements. For aviation purposes, it is common practice to report visual ranges like the RVR and "visibility for aeronautical purposes" (VIS-AERO). Note that the latter is used in reports and indicated as "visibility" only, which differs from the common definition of visibility (see Part I, Chapter 9). Instruments used to measure MOR may also be used to measure RVR (see section 2.4) and VIS-AERO (see section 2.3.1). The *Technical Regulations*, Volume II, Part II, Appendix 3, 4.2 and 4.3 contain the formal descriptions for international aviation.

At international aerodromes, visibility observations made for reports disseminated beyond the aerodrome should be representative of conditions pertaining to the aerodrome and its immediate vicinity. Visibility observations made for reports for landing and take-off and disseminated only within the aerodrome should be representative of the touchdown zone of the runway, remembering that this area may be several kilometres from the observing station.

For aeronautical purposes, the measurement range for visibility is from 25 m to 10 km. Values greater than or equal to 10 km are indicated as 10 km. A sensor must therefore be able to measure values above 10 km or indicate if the measurement is greater than or equal to 10 km. The operationally desirable measurement uncertainty is 50 m up to 600 m, 10% between 600 m and 1 500 m and 20% above 1 500 m (*Technical Regulations*, Volume II, Part II, Attachment A). See Part I, Chapters 1 and 9, for advice on the accuracy of measurements.

In view of the meteorological minima governing the operational decisions on whether an aircraft can or cannot land or take-off, precise, reliable information must be given whenever visibility passes through certain limits, namely whenever visibility drops below or increases beyond the limit values of 800, 1 500 or 3 000 and 5 000 m, in the case, for example, of the beginning, cessation or change in fog or precipitation (*Technical Regulations*, Volume II, Part II, Appendix 3, 2.3.3 (b)).

When there are significant directional variations in visibility, particularly when they affect take-off and landing areas, this additional information should be given with indications of the direction of observation, for example, "VIS 2000 M TO S".

When visibility is less than 800 m it shall be expressed in steps of 50 m in the form VIS 350M; when it is 800 m or more but less than 5 km in steps of 100 m; when it is 5 km or more but less than 10 km, in kilometre steps in the form VIS 7KM; and when it is 10 km or more, it shall be given as 10 km, except when the conditions for the use of CAVOK (Ceiling and Visibility OK) apply (*Technical Regulations*, Volume II, Part II, Appendix 3, 4.2.4.1).

The methods described in Part I, Chapter 9, apply. Meteorological visibility observations are to be made by an observer who has "normal" vision, viewing selected targets of specified characteristics at known distances from the meteorological station. These observations may also be made by using visibility-measuring instruments, such as transmissometers and scatter coefficient meters. The location of the observing sites should be such as to permit continuous viewing of the aerodrome, including all runways.

If a transmissometer is used for visibility measurements, a baseline length of 75 m is suitable for aeronautical operations. However, if the instrument is also to be used for measuring RVR, the baseline length should be chosen after taking into account the operational categories in force at the aerodrome.

2.3.1 **Visibility for aeronautical purposes**

The *Technical Regulations*, Volume II, Part I, 1.1 defines visibility. VIS-AERO is the greater of:

(a) The greatest distance at which a black object of suitable dimensions, situated near the ground, can be seen and recognized when observed against a bright background;

(b) The greatest distance at which lights in the vicinity of 1 000 cd can be seen and identified against an unlit background.

This VIS-AERO is in fact a “visual range” like RVR, involving subjective elements such as the virtual performance of a human eye and artificial lights. Nevertheless, the word “visibility” is commonly used without the addition “for aeronautical purposes” and confusion may arise with the official definition of “visibility” as defined by WMO (see Part I, Chapter 9) which is known as the MOR (meteorological optical range). An optical range is purely based on the physical state of the atmosphere and not on human or artificial elements, and is therefore an objective variable. This visibility (for aeronautical purposes) shall be reported, as in METAR. Because an aeronautical meteorological station may be combined with a synoptic station, visibility in SYNOP reports will differ from visibility in METAR, although it is measured by the same equipment.

Visibility for aeronautical purposes can be measured and calculated similarly to RVR (see section 2.4 for details), except that for the intensity of the light source, I, a constant value of 1 000 cd shall be used. Note that this value holds for lights usually used for the assessment of visibility, which are 10 times more intense than lights of moderate intensity (i.e. 100 cd, see Part I, Chapter 9).

2.3.2 **Prevailing visibility**

Prevailing visibility is defined as the greatest visibility value, observed in accordance with the definition of “visibility (for aeronautical purposes)”, which is reached within at least half the horizon circle or within at least half of the surface of the aerodrome. These areas could comprise contiguous or non-contiguous sectors. This value may be assessed by human observation and/or instrumented systems, but when instruments are installed, they are used to obtain the best estimate of the prevailing visibility (*Technical Regulations*, Volume II, Part I, 1.1). Prevailing visibility should be reported in METAR and SPECI code forms.

2.4 **RUNWAY VISUAL RANGE**

2.4.1 **General**

RVR is the range over which the pilot of an aircraft on the centre line of a runway can see the runway surface markings or the lights delineating the runway or identifying its centre line. It is discussed in the *Technical Regulations*, Volume II, Part I, 4.6.3 and Part II, Appendix 3, 4.3. Details on observing and reporting RVR are given in ICAO (2005). It is recommended that this measurement be taken during periods when horizontal visibility is less than 1 500 m.

A height of approximately 5 m is regarded as corresponding to the average eye-level of a pilot in an aircraft on the centre line of a runway. Note that for wide-bodied aircraft, the pilot’s eye-level may be at least 10 m. In practice, RVR cannot be measured directly from the position of a pilot looking at the runway centre line, but must be an assessment of what he or she would see from this position. Nevertheless, RVR should be assessed at a height of approximately 2.5 m above the runway for instrumented systems or approximately 5 m above the runway by a human observer (*Technical Regulations*, Volume II, Part II, Appendix 3, 4.3.1.1).

The RVR should be reported to the ATS units whenever there is a change in RVR, according to the reporting scale. The transmission of such reports should normally be completed within 15 s of termination of the observation. These reports are to be given in plain language.

2.4.2 **Methods of observation**

The RVR may be measured indirectly, by observers with or without supplementary equipment, by instrumental equipment such as the transmissometer or sensors measuring scattered light, or by video systems. At aerodromes, where precision approaches and, in particular, where

Category I, II, III A and III B operations are executed, RVR measurements should be made continuously by using appropriate instruments, namely transmissometers or forward-scatter meters (*Technical Regulations*, Volume II, Part II, Appendix 3, 4.3.2.1 for Category II and III, and recommended for Category I in Appendix 3, 4.3.2.2).

The RVR can then be assessed for operational purposes using tables or, preferably, by automatic equipment with digital read-out of RVR. It should be computed separately for each runway in accordance with the *Technical Regulations*, Volume II, Part II, Appendix 3, 4.3.5.

2.4.2.1 *Measurement by observers*

The counting of runway lights visible in fog (or lights specially installed parallel to the runway for that purpose) by observers can provide a simple and convenient method of determining RVR (but for precision instrument landing, only if the instrumented system fails). The difficulty arising with this method is related to the resolution capability of the human eye which, beyond a certain distance (dependent on the observer), does not permit the runway lights to be distinguished and counted.

Since the observer's position when observing runway lights is not identical to that of the pilot, the use of conversion curves to determine the true RVR is essential. Specially designed marker boards, spaced out along the side of the runway, may also be used for RVR assessment during the day.

2.4.2.2 *Measurement by video*

To assess RVR using a video system, use is made of a video camera and receiver to observe markers at known distances consisting of either runway lights, special lights, or markers positioned alongside the runway. Such a system is also beneficial for detecting patchy or shallow fog, which cannot be detected by the instruments.

2.4.2.3 *Measurement by transmissometer*

The instrument most commonly used at present for making an assessment of RVR is the transmissometer, which measures the transmission factor along a finite path through the atmosphere (see Part I, Chapter 9). RVR can be determined as follows:

(a) RVR when runway lights are dominant (RVR based on illumination threshold): The RVR depends on the transmission factor of the air, on the intensity of the runway lights and on the observer's (and pilot's) threshold of illuminance, which itself depends on the background luminance. It can be computed from:

$$E_t = I\ R^{-2}\ T^{R/a} \tag{2.1}$$

where E_t is the visual threshold of illuminance of the observer (pilot), which depends on the background luminance L; I is the effective intensity of centre-line or edge lights toward the observer (pilot); T is the transmission factor, measured by the transmissometer; R is the RVR; and a is the transmissometer baseline or optical light path. Note that for the illuminance E of the observer (pilot), it holds that $E = I / R^2$. The requirements for the light intensity characteristics of runway lights are given in ICAO (2013). In fact, it holds for both centre-line and edge light that the illumination of the observer (pilot) is angular dependent and as a consequence I depends on R. Therefore $I = I(R)$ and $E = E(I, R)$. The calculation of R from equation 2.1 can be done only iteratively, which is relatively easy with the help of a simple calculator suitable for numerical mathematics. The value of E_t is determined with the help of a background luminance sensor (see section 2.4.3.3);

(b) Assessment of RVR by contrast (RVR based on contrast threshold): When markers other than lights are used to give guidance to pilots during landing and take-off, the RVR should be based upon the contrast of specific targets against the background. A contrast threshold of 0.05 should be used as a basis for computations. The formula is:

$$R = a\frac{\ln 0.05}{\ln T} \tag{2.2}$$

where R is RVR by contrast. Because the contrast threshold level is 0.05, RVR by contrast is identical to MOR, namely R = MOR. Note that RVR (based on illumination threshold) will always supersede RVR (based on contrast threshold), or RVR ≥ MOR.

2.4.2.4 *Measurement by forward-scatter or backscatter meters*

Instruments for measuring the forward-scatter or backscatter coefficient (sometimes known as scatterometers) are discussed in Part I, Chapter 9. Because of the physical principles of light scattering by aerosols, the measurement uncertainty of a forward-scatter meter (scatter-angle about 31°–32°) is smaller than with backscatter meters. Therefore, a forward-scatter meter is to be preferred. With these instruments the extinction coefficient σ can be determined, which is the principal variable to calculate RVR. Experience and studies with forward-scatter meters have demonstrated their capability to measure RVR for aeronautical applications (WMO, 1990, 1992*b*).

Since accuracy can vary from one instrument design to another, performance characteristics should be checked before selecting an instrument for assessing RVR. Therefore, the calibration of a forward-scatter meter has to be traceable and verifiable to a transmissometer standard, the accuracy of which has been verified over the intended operational range (*Technical Regulations*, Volume II, Part II, Appendix 3, 4.3.2).

A scatter meter determines, from the received scattered light, the extinction coefficient σ of the atmosphere at the position of the optical volume (see Part I, Chapter 9). Because σ is a direct measure for the visibility, R can be determined relatively easily (from σ or MOR, where MOR = –ln 0.05/σ ≈ 3/MOR). The RVR can be determined as follows:

(a) RVR when runway lights are dominant (RVR based on illumination threshold): RVR will be calculated in a similar way as with a transmissometer except that σ is used and not T. It can be computed from:

$$R = \frac{1}{\sigma}\left(\frac{I(R)}{E_t \cdot R^2}\right) \tag{2.3}$$

where R is the runway visual range; σ is the extinction coefficient (or 3/MOR); E_t is the visual threshold of illuminance of the observer (pilot), which depends on the background luminance; and I is the effective intensity of centre-line or edge lights toward the observer (pilot). As with a transmissometer, R should be calculated iteratively;

(b) Assessment of RVR by contrast (RVR based on contrast threshold): When markers other than lights are used to give guidance to pilots during landing and take-off, the RVR should be based upon the contrast of specific targets against the background. A contrast threshold of 0.05 should be used as a basis for computations. The formula is:

$$R = -\ln 0.05 / \sigma = \text{MOR} \tag{2.4}$$

where R is RVR by contrast. Note that RVR (based on illumination threshold) will always exceed RVR (based on contrast threshold), namely RVR ≥ MOR.

2.4.3 **Instruments and exposure**

Instrumented systems may be based on transmissometers or forward-scatter meters to assess RVR. Runway visual range observations should be carried out at a lateral distance of not more than 120 m from the runway centre line. The site for observations that are representative of the touchdown zone should be located about 300 m along the runway from the threshold.

The sites for observations that are representative of the middle and far sections of the runway should be located at a distance of 1 000 to 1 500 m along the runway from the threshold and at a distance of about 300 m from the other end of the runway (*Technical Regulations*, Volume II, Part II, Appendix 3, 4.3.1.2). The exact position of these sites and, if necessary, additional sites (for long runways), should be determined after considering aeronautical, meteorological and climatological factors, such as swamps and other fog-prone areas. Runway visual range should be observed at a height of approximately 2.5 m above the runway for instrumented systems or approximately 5 m above the runway by a human observer (*Technical Regulations*, Volume II, Part II, Appendix 3, 4.3.1.1).

The units providing air traffic and aeronautical information services for an aerodrome should be informed without delay of changes in the serviceability status of the RVR observing system.

A computer is usually used to compute the RVR at several measurement points and to display the measurements on screen with the time of observation, the transmission factors, the luminance measured at one or more points on the aerodrome and the runway light intensity. The data are sent to display panels at the ATS and meteorological and other units concerned, or to printers for recording.

The runway light intensity should be entered automatically in the computer in accordance with the procedure described in the *Technical Regulations*, Volume II, Part II, Appendix 3, 4.3.5 or as formally agreed upon between the ATS units and the local meteorological unit.

Analogue or digital graphic recorders (with time base) for transmission factors T and background luminance L may also be used. A graphic display of the RVR should also properly show the record of E_t and I (see equation 2.1).

2.4.3.1 ***Transmissometers***

A description of transmissometers, their installation on site and their maintenance and sources of error is given in Part I, Chapter 9, with references to other literature.

A transmissometer system consists of a projector that directs a light of known intensity onto a photoelectric receiving device placed at a known distance from the projector. The variations in atmospheric transmission, due to fog or haze, and so on, are continuously measured and recorded. The instrument is calibrated to be direct-reading, giving the transmission factor in per cent.

The transmitter and receiver must be mounted at the same height on rigid, secure and durable stands, which, if possible, are not frangible and in such a way that shifting soil, frost, differential heating of towers, and so forth, do not adversely affect the alignment of the two units. The height of the optical path should not be less than 2.5 m above the level of the runway.

In one type of transmissometer, the transmitter and receiver are incorporated in the same unit (see Part I, Chapter 9). In this case, a reflector (for example, mirror) is installed at the normal receiver location. The light travels out and is reflected back, with the baseline length being twice the distance between the transmitter/receiver and the reflector. The transmissometer may have a single or double base, depending on whether one or two receivers or retro-reflectors, positioned at different distances, are used.

The transmissometer baseline length, namely, the length of the optical path covered by the light beam between transmitter and receiver, determines the RVR measurement range. For an RVR between 50 and 1 500 m, the most commonly used baseline lengths are between 15 and 75 m.

However, for shorter transmissometer baseline lengths, a higher transmission factor measurement accuracy and better system linearity are necessary. If low RVRs must be measured for Category II and III landing requirements, a short base transmissometer should be selected. However, the maximum RVR that can be measured is then relatively low. A compromise must be found. Double-base transmissometers exist, offering a wider measurement range by the selection of one base or the other, but care must be taken when switching baselines to ensure that the RVR measurements remain consistent with each other.

Higher RVR values can be measured by using longer transmissometer baseline lengths, but greater luminous power is needed for transmission to compensate for light attenuation between the transmitter and receiver in dense fog, and a narrower reception angle is required to avoid scatter disturbance phenomena. The measurement of the weakest signals is also dependent on background noise in the measuring equipment.

Transmissometers are generally aligned parallel to the runway. However, direct (or reflected) sunlight should be avoided as this may cause damage. The optical axis should, therefore, be positioned in an approximate north-south direction horizontally (for latitudes below 50°). Otherwise, a system of baffles should be used.

2.4.3.2 ***Forward-scatter meters***

Forward-scatter meters should be sited near the runway in a similar fashion to transmissometers. The positioning of forward-scatter meters requires fewer precautions than for transmissometers. Nevertheless, care should be taken to avoid direct or scattered sunlight which might influence (or damage) the receiver. In particular, sunlight may influence the receiver after scattering by snow cover, or lake or sea surface. Modern instruments compensate for contamination of the optical components.

2.4.3.3 ***Background luminance sensor***

The threshold of illuminance E_t must be known when computing the RVR. A background luminance sensor should be placed at the end of the runway along which one or more transmissometers or scatter meters have been installed. One or more luminance sensors may be installed at the airport depending on the number of runways covered.

The background luminance sensor measures the luminance of the horizon or sky in the direction opposite the sun. The illuminance thresholds are introduced in the RVR computation either as a continuous or a step function (two to four steps). The curve for converting background luminance to illumination threshold is given in the *Technical Regulations*, Volume II, Part II, Attachment D, and in ICAO (2005). The recommended relation used for this curve is:

$$\log_{10} E_t = 0.05\left(\log_{10} L\right)^2 + 0.573 \log_{10} L - 6.667 \tag{2.5}$$

where L is the luminance of the horizon sky.

The background luminance sensor consists of a photodiode placed at the focal point of a lens with an angular aperture of about 10° to 20°, aligned in a north-south direction (to avoid direct sunlight) and at an angle of elevation of approximately 30° to 45° to the horizon.

2.4.4 **Instrument checks**

It is essential that regular periodic checks be made on all components of the transmissometer – or scatter meter – RVR system to ensure the proper operation and calibration of the system. In general, the literature provided by the companies manufacturing and developing such equipment will give detailed instructions for making such checks and will indicate the corrective action to be taken when specified instrumental tolerances are not met. For a transmissometer, when the visibility exceeds 10 to 15 km, it is simple to check that the equipment indicates a transmissivity of approximately 100% (see Part I, Chapter 9). For scatter meters, “scatter plates” may be used, which emulate certain extinction values. However, the calibration of a forward-scatter meter should be traceable and verifiable to a transmissometer standard (see section 2.4.2.4).

Correct maintenance and calibration are necessary in order to:

(a) Prevent dirt from accumulating, on optical surfaces;

(b) Check variations in the light intensity of the transmitter;

(c) Avoid drift after calibration;

(d) Check the alignment of transmitters and receivers.

Frequent maintenance is necessary at heavily polluted sites. Care is to be taken so that not all equipment is taken out of service at the same time during maintenance, and so that this interruption of service is not of long duration, particularly during periods when fog is forecast.

When fog persists for several consecutive days, the projector should be checked to ensure that its light intensity is steady and the equipment should be checked for drift. Checking optical settings is difficult, if not impossible, in very dense fog; it is therefore vital that instruments should be mechanically reliable and optically stable.

2.4.5 Data display

The RVR data display for the units concerned is updated according to the local agreements in force: every 15 to 60 s, and even every 2 min on some occasions. Changes in RVR should normally be transmitted within 15 s after termination of the observation.

2.4.6 Accuracy and reliability of runway visual range measurements

If scattered light sensors are used, as distinct from transmissometers, the equations for RVR are acceptable in the case of fine water droplets as fog, but not when visibility is reduced by other hydrometeors such as freezing fog, rain, snow or lithometeors (sandstorms). In which case, MOR and RVR measurements must be used with much caution since satisfactory relations for such cases have not yet been accepted.

Divergence between the RVR for a pilot and the measured value may reach 15% to 20%, with an assumed standard deviation of not more than 10%. In the case of observers, there are divergences in visual threshold and in observing conditions that, together, can cause differences in reported visual range amounting to 15% or 20%.

RVR measurements taken using transmissometers or scatter coefficient meters are representative of only a small volume of the atmosphere. In view of the considerable fluctuations of fog density in time, as well as in space, a mean value established over a large number of samples or measurements is essential. Rapid changes in RVR may give rise to difficulties for the ATS units when transmitting the information to aircraft. For these reasons, an averaging period of between 30 s and 1 min is recommended, computed as a mean or a sliding mean.

Operationally desirable accuracies of RVR measurement or observation are specified in the *Technical Regulations*, Volume II, Part II, Attachment A.

2.5 PRESENT WEATHER

The observation and reporting of present weather is discussed in Part I, Chapter 14, and the procedures are described in the *Technical Regulations*, Volume II, Part I, 4.6.4 with details in Part II, Appendix 3, 4.4. For aviation, emphasis is placed upon observing and reporting the onset, cessation, intensity and location of phenomena of significance to the safe operation of aircraft, for example, thunderstorms, freezing precipitation and elements that restrict flight visibility.

For take-off and landing, present weather information should be representative, as far as practicable, of the take-off and climb-out area, or the approach and landing area. For information disseminated beyond the aerodrome, the observations of present weather should be representative of the aerodrome and its immediate vicinity.

Most observations relating to present weather are made by visual means. Care should be taken to select observing sites that afford adequate views in all directions from the station. Instruments may be used to support the human observations, especially for measuring the intensity of precipitation.

Detectors used to identify the type of precipitation (rain, snow, drizzle, etc.) or visibility-reducing phenomena other than precipitation (fog, mist, smoke, dust, etc.) can assist the human observer and this can help if done by automation. They are based essentially on the measurement of the extinction coefficient or scintillation, and may also make use of relations between weather phenomena and other quantities, such as humidity. At present, there is no international agreement on the algorithms used for processing data to identify these phenomena. There is no vital need for this equipment in aeronautical meteorology while human observers are required to be present.

Descriptions of phenomena reported in present weather appear in Part I, Chapter 14, as well as in WMO (1975, 1987, 1992*a*, 2011*a*) and ICAO (2011).

Specifications for special reports regarding present weather are contained in the *Technical Regulations*, Volume II, Part II, Appendix 3, 4.4.2. The abbreviations and code figures used in METAR or SPECI plain language reports appear in the *Technical Regulations*, Volume II, Part II, Appendix 3, 4.4.2.3–4.4.2.9.

2.6 CLOUD

2.6.1 General

Observations and measurements of clouds are discussed in Part I, Chapter 15. For aviation applications (see the *Technical Regulations*, Volume II, Part I, 4.6.5 and Part II, Appendix 3, 4.5), cloud information (amount, base height, type) is required to be representative of the aerodrome and its immediate vicinity and, in reports for landing, of the approach area. Where cloud information is supplied to aircraft landing on precision approach runways, it should be representative of conditions at the instrument landing system middle marker site, or, at aerodromes where a middle marker beacon is not used, at a distance of 900 to 1 200 m from the landing threshold at the approach end of the runway (*Technical Regulations*, Volume II, Part II, Appendix 3, 4.5.1).

If the sky is obscured or not visible, the cloud-base height is replaced by a vertical visibility in the local routine (MET REPORT) and local special (SPECIAL) reports (*Technical Regulations*, Volume II, Part I, 4.5.1(i)) and in weather reports METAR and SPECI (WMO, 2011*a*, FM 15/FM 16, paragraph 15.9). Vertical visibility is defined as the maximum distance at which an observer can see and identify an object on the same vertical as himself or herself, above or below. Vertical visibility can be derived from the optical extinction profile, determined by a LIDAR-based ceilometer. Assuming that the total extinction σ at altitude h can be derived from the backscatter extinction coefficient σ_B at that altitude after appropriate calibration for the whole altitude range, and assuming that a contrast threshold of 5% is applicable similar to MOR, it should hold for the vertical visibility VV that:

$$\int_0^{VV} \sigma(h)\cdot dh = \ln\left(\frac{I(VV)}{I_0}\right) = \ln(0.05) = 3 \qquad (2.6)$$

Because LIDAR-based ceilometers determine the local extinction coefficient for fixed intervals Δh, VV may be derived relatively easily from:

$$\sum_{i=1}^{N} \sigma_i \cdot \Delta h = 3, \text{ with } h_N = VV \tag{2.7}$$

Typical code words like CAVOK, SKC (sky clear), NCD (no clouds detected) and NSC (nil significant clouds) are used in reports when the state of the atmospheric or weather will not affect the operations of take-off and landing; replacing the quantitative information with simple acronyms is beneficial. Details on the use of these practices are given in the *Technical Regulations*, Volume II, Part II, Appendix 3, 2.2 and 4.5.4.3. For instance, CAVOK shall be used when cloud and present weather is better than the prescribed values or conditions, but if the specified conditions are met. Great care should be taken when using these abbreviations with automated measuring systems, which are not capable of measuring clouds or vertical visibility within the stated requirements.

The height of clouds bases shall be reported above aerodrome elevation. However, when a precision approach runway is in use which has a threshold elevation of 15 m or more below the aerodrome elevation, local arrangements shall be made in order that the height of the clouds reported to arriving aircraft shall refer to the threshold elevation.

2.6.2 **Observation methods**

The principal methods used for determining the height of the cloud base are:

(a) Cloud-base searchlight;

(b) Rotating-beam ceilometer;

(c) Laser ceilometer;

(d) Ceiling balloon;

(e) Visual estimation;

(f) Aircraft reports.

Cloud-base height should be obtained by measurement whenever possible. At busy or international aerodromes with precision approach systems, cloud-base measurements should be taken automatically so that this information and any changes can be available on a continuous basis.

The ceiling-balloon method is too slow and too prone to errors to be a routine method for measuring cloud-base height at aerodromes, and the visual method is also too prone to error, especially at night, to be used where the observations are critical. Aircraft reports of cloud-base height can provide the observer with useful supplementary information. Care should be taken when interpreting pilots’ information due to the fact that the information may be several kilometres from the surface observation point.

2.6.3 **Accuracy of cloud-base height measurements**

The ragged, diffuse and fluctuating nature of many cloud bases limit the degree of accuracy with which cloud-base heights can be measured. Isolated or infrequent measurements, such as those obtainable by the use of cloud-base height balloons, may be unrepresentative of the cloud conditions as a whole. The best estimate requires the study of a quasi-continuous recording over a period of several minutes provided by one of the instruments mentioned above.

The accuracy of instrumental measurements indicated by manufacturers is usually obtained by using solid or artificial targets. Operational accuracy is, however, more difficult to achieve in view of the fuzzy nature of the cloud base.

2.7 AIR TEMPERATURE

A general discussion of instruments and methods of observation for air temperature may be found in Part I, Chapter 2. For air navigation purposes (see the *Technical Regulations*, Volume II, Part I, 4.1 and 4.5.1(j)), it is necessary to know the air temperature over the runway. Normally, data from well-sited, properly ventilated screens give sufficient approximations of the required values. Rapid fluctuations in air temperature (2 °C to 3 °C per half-hour) should be notified immediately to ATS units, principally in tropical and subtropical areas.

Temperature sensors should be exposed in such a way that they are not affected by moving or parked aircraft, and should yield values that are representative of general conditions over the runways. Thermometers with a time constant of 20 s should preferably be used to avoid excessively small fluctuations in temperature (average wind speed of 5 m s^{-1}), or, in cases of automatic measurements, an appropriate digital averaging or resistance/capacitance filtering should be applied. Remote indicating and recording systems are an advantage. Moreover, aerodromes with runways intended for Category II and III instrument approach and landing operations, require automated measuring equipment and displays at the automatic retrieval system site. Temperature measurements have become more integrated into automatic stations or data acquisition systems, and are displayed in digital form. The displayed temperature should represent an average value over 1 to 10 min, obtained after linearization of the sensor output signal. The value obtained should be rounded off to the nearest whole degree for aeronautical use.

2.8 DEWPOINT

Atmospheric moisture at aeronautical stations is usually expressed in terms of the dewpoint temperature. The reading is rounded off to the nearest whole degree as in the case of air temperature. The procedures are described in the *Technical Regulations*, Volume II, Part I, 4.1 and 4.5.1(j). Observation methods are described in Part I, Chapter 4.

Modern humidity sensors allow the use of remote indicators and recorders. For manual observations the psychrometer is commonly used. A psychrometer of the ventilated type is to be preferred to meet the stated measurement uncertainty. The types of instruments commonly in use are as follows:

(a) Capacitive sensors based on the measurement of a capacitor's capacitance, in which the value of the polymer dielectric varies as a function of the water vapour content of the ambient air. In practice, the measured capacitance is fairly linear with relative humidity. Dewpoint is calculated using the ambient air temperature (measured separately and at a very short distance) ($t_d = t_d(t, U)$). The appropriate formulae are given in Part I, Chapter 4, Annex 4.B. To avoid condensation, which may last long after $U < 100\%$ and which might be trapped by the filter protecting the sensor, the sensor may be heated. For such a practice, the ambient air temperature should not be used, rather a temperature value should be used that represents the heated air around the sensor. In practice, the appropriate procedure can only be achieved after careful calibration in well-designed climate chambers;

(b) Dewpoint hygrometers, measuring the temperature at which a very light deposit of dew occurs on a mirror. The mirror is heated or cooled, most frequently by the Peltier effect, to obtain the point of equilibrium at which dew is deposited. The mirror is used with an associated photo-electronic dew-detection system. Although such systems deliver dewpoint temperature directly, pollution and deterioration of the mirror may cause significant biases. In particular, frost may destroy the mirror. At least every six months the mirror should be inspected, but only by skilled personnel. Great care should be taken when cleaning the mirror and the manufacturer's instructions should be followed precisely.

2.9 ATMOSPHERIC PRESSURE

2.9.1 General

A general discussion on the observations of atmospheric pressure may be found in Part I, Chapter 3, and that for aviation purposes is found in the *Technical Regulations*, Volume II, Part I, 4.6.7. Pressure measurements for setting aircraft altimeters are essential at an aeronautical station. They are computed in tenths of hectopascals (0.1 hPa). They are referred to in the Q code as QFE and QNH, where:

(a) QFE (field elevation pressure) is defined as the pressure value at an elevation corresponding to the official elevation of the aerodrome (*Technical Regulations*, Volume II, Part II, Appendix 3, 4.7.2). Aerodrome reference point, elevation and runway elevation are described in ICAO (2013);

(b) QNH (atmospheric pressure at nautical height) is defined as the pressure value at which an aircraft altimeter is set so that it will indicate the official elevation of the aerodrome when the aircraft is on the ground at that location. QNH is calculated using the value for QFE and the pressure altitude relationship of the ICAO standard atmosphere. In fact, the ICAO standard atmosphere is a sub-range of the International Standard Atmosphere, which is documented by the ISO 2533:1975 standard and developed in liaison with the Committee on Space Research, ICAO and WMO. This standard atmosphere is a static atmosphere, with a fixed pressure and temperature at sea level and a fixed temperature gradient. Details of the standard atmosphere and its predefined constants are given in WMO (1966) and ICAO (1993). For the calculation of QNH from QFE, namely the reduction to mean sea level, this virtual atmosphere is used, and not the current true state of the atmosphere. As a consequence, QNH will differ from the reported atmospheric pressure reduced to sea level as described in Part I, Chapter 3, 3.11 and for which the actual temperature is used. The calculation of QNH from QFE is based on a slide rule relationship (for stations below about 3 000 to 4 000 m):

$$\mathrm{QNH} = A + B \times \mathrm{QFE} \tag{2.8}$$

where A and B depend on the geopotential altitude of the station (for details, see WMO, 1966, Introduction to Table 3.10). To derive QNH, the following three-step procedure should be followed:

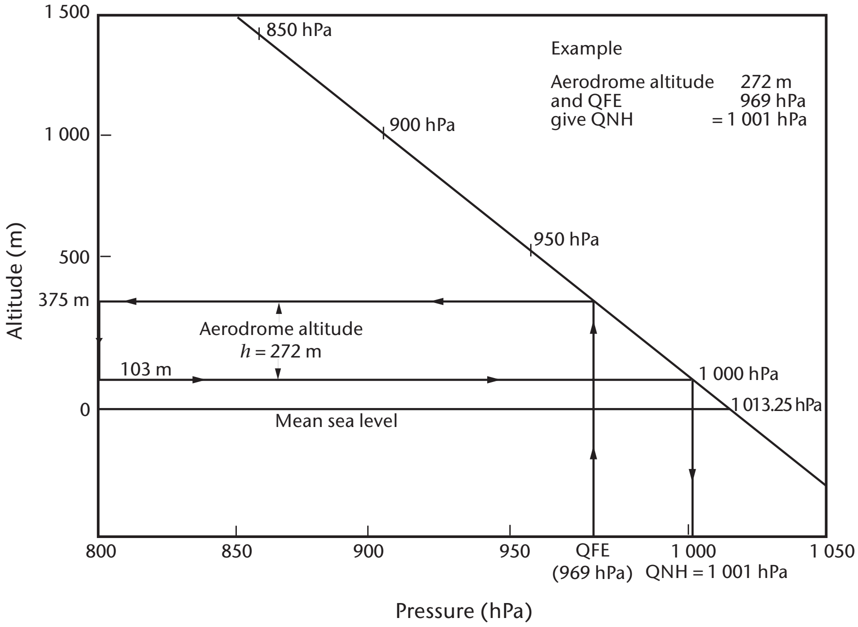
(i) Determine the pressure altitude of the station from the QFE (the pressure altitude is calculated from QFE using the formulae of the standard atmosphere);

(ii) Subtract (or add for stations below mean sea level) from this pressure altitude the elevation of the station with respect to mean sea level to give the pressure altitude at mean sea level (may be positive or negative);

(iii) Derive from this pressure altitude the associated pressure value according to the standard atmosphere, which will be QNH.

An example of this procedure to derive QNH from QFE is shown in the figure below. The measured pressure and QNH and/or QFE values should be computed in tenths of a hectopascal. In local reports and reports disseminated beyond the aerodrome, QNH and QFE values should be included and the values should be rounded down to the nearest whole hectopascal. The ATS units, should be notified of rapid major changes in pressure.

The curve represents the standard atmosphere (pressure altitude as a function of pressure).



The relation between QFE and QNH

2.9.2 Instruments and exposure

The instrumental equipment used at an aeronautical station for pressure measurement is identical to that at a synoptic station, except that greater use is often made of precision automatic digital barometers for convenience and speed of reading in routine observations. Aeronautical stations should be equipped with one or more well-calibrated barometers traceable to a standard reference. A regular schedule should be maintained for comparing the instruments against this standard instrument. Both manual and automated barometers are suitable, provided that temperature dependence, drift and hysteresis are sufficiently compensated. Details of suitable barometers are given in Part I, Chapter 3.

The exposure of barometers at an aeronautical station is the same as at a synoptic station. If barometers have to be exposed inside a building, sensors should be vented to the outside, using an appropriately located static-tube arrangement. Owing to wind impacts on a building, pressure differences inside and outside the building may be larger than 1 hPa. To prevent such bias, which may extend to about plus or minus 3 hPa with high wind speeds, the static-tube should be placed sufficiently far away from this building. Also, air conditioning may have impacts on pressure measurements, which will be avoided by using such a static tube.

Direct-reading instruments for obtaining QNH values are available and may be used in place of the ordinary aneroid or mercury barometer, which require reference to tables in order to obtain the QNH values. For such devices, correct values of A and B, which are a function of the station geopotential altitude (see equation 2.8), shall be entered. The readings given by these instruments must be compared periodically with QNH values calculated on the basis of measurements obtained using the mercury barometer.

2.9.3 Accuracy of and corrections to pressure measurements

Pressure values used for setting aircraft altimeters should have a measurement uncertainty to 0.5 hPa or better (*Technical Regulations*, Volume II, Part II, Attachment A). All applicable corrections should be applied to mercury barometer readings, and corrections established through regular comparisons between the mercury and aneroid instruments routinely used in observations must be applied to all values obtained from the latter instruments. Where aneroid altimeters are used in ATS tower positions, corrections different from those used in the observing station must be provided, for proper reduction to official aerodrome or runway level (*Technical Regulations*, Volume II, Part II, Appendix 3, 4.7).

The pressure values used for setting altimeters must refer to the official elevation for the aerodrome. For non-precision approach runways, the thresholds of which are 2 m or more below or above the aerodrome elevation, and for precision approach runways, the QFE, if required, should refer to the relevant threshold elevation.

2.10 OTHER SIGNIFICANT INFORMATION AT AERODROMES

2.10.1 General

Observations made at aeronautical stations should also include any available information on meteorological conditions in the approach and climb-out areas relating to the location of cumulonimbus or thunderstorms, moderate or severe turbulence, horizontal and/or vertical wind shear and significant variations in the wind along the flight path, hail, severe line squalls, moderate or severe icing, freezing precipitation, marked mountain waves, sandstorms, dust storms, blowing snow or funnel clouds (tornadoes or waterspouts), for example, SURFACE WIND 320/10 WIND AT 60M 360/25 IN APCH or MOD TURB AND ICE INC IN CLIMB OUT.

2.10.2 Slant visual range

Despite the development work carried out in various countries, no instrument for measuring the slant visual range has been made operational. The rapid technological development of all-weather landing systems has made it possible to reduce the set landing minima at aerodromes (Categories II, III A and III B) and has gradually resulted in this parameter being considered less important. No recommendation has been established for measuring this parameter.

2.10.3 Wind shear

Wind shear is a spatial change in wind speed and/or direction (including updraughts and downdraughts). Wind shear intensity may be classified into light, moderate, strong or violent according to its effect on aircraft. Low-level wind shear, that may affect landing and take-off operations, may exist as a vertical wind gradient in the lower layers of a thermally stable atmosphere, or it may be due to the effect of obstacles and frontal surfaces on wind flow, the effect of land and sea breezes, and to wind conditions in and around convection clouds, particularly storm clouds. Violent storms are by far the major cause of low-level wind shear, and a cause of fatal accidents for aircraft both on approach and landing, and during take-off.

The preparation and issuing of wind-shear warnings for climb-out and approach paths are described in the *Technical Regulations*, Volume II, Part II, Appendix 3, 4.8.1.4.

The measurement of vertical wind shear based on the information presented in Part I, Chapter 5, may be determined directly by anemometers on tall masts, which must be at a certain distance from the airport. Remote-sensing systems include Doppler Radar, Lidar, Sodar and the wind profiler. The Lidar uses laser light, the Sodar is based on acoustic radiation, and the wind profiler radar employs electromagnetic radiation at a frequency of around 50 MHz, 400 MHz or 1 000 MHz.

Horizontal wind shear is usually detected by a system of anemometers over the entire aerodrome. This system is designated as a low-level wind shear alert system. Computer-processed algorithms enable a wind-shear warning to be given. This system is used particularly in tropical and subtropical regions where frequent, intense storm build-up occurs.

Global coverage of this subject is given in the *ICAO Manual on Low-level Wind Shear* (Doc. 9817), first edition, 2005.

Although wind shear may have a significant impact on aircraft operations, no recommendation or criteria has yet been established. Nevertheless, details on wind-shear warnings are given in ICAO (2011), Chapter 4.

2.10.4 Marked temperature inversions

Information on marked temperature inversions exceeding 10 °C between the surface and levels up to 300 m should be provided, if available. Data are usually obtained from balloon-borne radiosondes, remote-sensing, aircraft observations (for example, AMDAR) or by meteorological inference.

2.11 AUTOMATED METEOROLOGICAL OBSERVING SYSTEMS

Specially-designed instrument systems have become common practice at aeronautical stations for measuring, processing, remotely indicating and recording values of the various meteorological parameters representative of the approach, landing, take-off and general runway conditions at the airport (*Technical Regulations*, Volume II, Part I, 4.1).

These automated systems comprise the following:

(a) An acquisition system for converting electrical analogue measurements (volts, milliamperes, resistance, capacitance) to digital values in the appropriate units, and for the direct introduction of digital data;

(b) A data pre-processing unit (averaging of readings over a time period of 1 to 10 min depending on the parameter measured and minimum, maximum and average values for the various parameters);

(c) A computer, used, for example, to prepare SYNOP, METAR and SPECI reports, and telecommunication software.

The observer should be able to include in these reports those parameters which are not measured by the automatic station; these may include present weather, past weather, cloud (type and amount) and, sometimes, visibility. For aviation purposes, these stations are, therefore, often only an aid for acquiring meteorological data and cannot operate without observers.

Instruments at the automatic station should be checked and inspected regularly. Quality checks are necessary and recommended in order to avoid major errors and equipment drift. Measurements taken by automatic weather stations are dealt with in detail in Part II, Chapter 1. Quality assurance and other management issues can be found in Part IV, Chapter 1. To guarantee the stated performance of the automated instruments, a detailed evaluation plan should be established with details on maintenance and calibration intervals, and with feedback procedures to improve the observing system.

Recommendations on reporting meteorological information from automatic observing systems are given in the *Technical Regulations*, Volume II, Part II, Appendix 3, 4.

2.12 RADAR

At aerodromes with heavy traffic, weather radars have become indispensable since they provide effective, permanent, real-time surveillance by producing additional observations to the usual meteorological observations for landings and take-offs. A radar can provide information over a wider area of up to 150 to 200 km. It is also an aid to short-range forecasting – within the hour or a few hours following the observation (possible aid in preparing the TREND report).

The echoes received are interpreted to identify the type of precipitation around the station: precipitation from stratus or convective clouds; isolated or line precipitation; or precipitation due to storms and, under certain conditions, detection of precipitation in the form of snow or hail. The image received enables the paths of squall lines or fronts to be followed and their development (intensification or weakening) to be monitored. If the radar is equipped with a Doppler system, the speed and direction of movement of these echoes can be computed.

The most widely used radars operate on wavelengths of 3, 5 or 10 cm. The choice depends on the region of the globe and the intended purpose, but the present general trend is towards the use of a 5 cm wavelength.

In certain regions, centralizing centres collect radar images from a series of radar stations in the country or region and assemble a composite image. Images are also exchanged between the various centres so that radar protection is provided over the largest possible area.

A general discussion on radar observations may be found in Part II, Chapter 7.

2.13 ICE SENSOR

This type of instrument, described in Part I, Chapter 14, is installed at a number of aerodromes to provide information on runway conditions in winter. The temperature at the surface and a few centimetres below the runway, the presence of snow, water, clear ice or white ice and the presence of salts or de-icing products, if any, are measured or detected. These sensors, in the form of a compact unit, are placed at a certain number of points on the runways or taxiways with their number depending on the size of the aerodrome and the number of runways to be protected. Atmospheric sensors are also placed close to the runways for the measurement of air temperature and humidity, wind and precipitation.

A data-acquisition and data-processing system displays the parameters measured and their variations with time. Depending on the type of software used, warning systems alert the airport authority responsible for aerodrome operations to the presence of clear ice or forecasts of dangerous conditions for aircraft.

2.14 LIGHTNING DETECTION

Systems for locating thunderstorms based on the detection of the low-frequency electromagnetic radiation from lightning have been developed in recent years (see Part II, Chapter 6). These systems measure the time taken for the signal to arrive and/or the direction from which it comes. Also, some systems analyse the characteristics of each radio impulse to identify cloud-to-ground lightning strokes. In certain regions, a number of these units are installed to measure and locate these phenomena in an area of 50 to 100 km around the aerodrome.

2.15 OTHER RELEVANT OBSERVATIONS

Additional information should be provided if the atmosphere is affected by dangerous pollution, for example, during volcanic eruptions. Information should also be provided to support rescue operations, especially at off-shore stations. If relevant for aircraft operations during take-off and landing, information on the state of the runway should be reported in METAR and SPECI, provided by the appropriate airport authority.

Volcanic ash should be reported (in SIGMET reports) as part of the supplementary information (*Technical Regulations*, Volume II, Part II, Appendix 3, 4.8). Details on observing volcanic ash, radioactive material and toxic chemical clouds are given in ICAO (2004, 2007).

In METAR and SPECI, information on sea-surface temperature and the state of the sea or the significant wave height should be included from aeronautical meteorological stations established on offshore structures in support of helicopter operations (*Technical Regulations*, Volume II, Part II, Appendix 3, 4.8.1.5).

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