UNMANNED AUTOMATIC WEATHER OBSERVATIONS AT AIRPORTS

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CHAPTER 1
AUTOMATIC WEATHER OBSERVATIONS

The International Civil Aviation Organization (ICAO) discusses airport automated weather observations primarily in two documents:

- ICAO Annex 3: Meteorological Service for International Air Navigation

ICAO Annex 3 is the main document that contains provisions (standards) and recommendations (recommended practices, recommendations). ICAO Doc9837 contains recommendations on how the automatic weather observations at the airport should be implemented; and how the ICAO Member States and system suppliers have implemented automatic weather observing system algorithms and procedures.

ICAO Annex 3 defines automatic weather observations as follows:

4.7 Reporting meteorological information from automatic observing systems

4.7.1 Recommendation.— METAR and SPECI from automatic observing systems should be used by States in a position to do so during non-operational hours of the aerodrome, and during operational hours of the aerodrome as determined by the meteorological authority in consultation with users based on the availability and efficient use of personnel.

4.7.3 METAR and SPECI from automatic observing systems shall be identified with the word “AUTO”.

According to ICAO, Meteorological Authorities can decide whether they allow automatic weather observations, including METAR and SPECI, at airports or not. In the Manual on Automatic Meteorological Observing Systems at Aerodromes (Doc 9837), ICAO states the known challenges in automatic weather reporting.

Bearing in mind these challenges, various ICAO member states have decided to fully or partially adopt automatic weather observations. Automatic weather observations are used greatly for example in the Netherlands and in the USA. Vaisala airport customers have employed this solution in Portugal and Finland. Generally, users have been quite happy with the quality and usability of the automatic weather observations and automation has not negatively affected airport safety.

Another important consideration is that weather observations made by a human observer have shortcomings and challenges that an automatic system may not have; for example detecting cloud layers especially during night-time, lightning observations for present weather thunderstorm reporting, and determining nighttime visibility. In these and other cases, automatic weather observing systems are superior when compared to inexperienced human observers.
CHAPTER 2
INTRODUCTION TO VAISALA UNMANNED OBSERVATION AUTO METAR CAPABILITIES

The combination of Vaisala’s AviMet software, observation sensor/system products, and aviation research and development has been used to create a powerful offering for deploying unmanned observation auto METAR solutions at airports. Vaisala provides unmatched ICAO and aviation expertise and has already deployed these types of solutions today.

Many METAR fields are already automatically populated today with traditional airport weather observation parameters. Although many airports are not officially classified as providing unmanned auto METAR information, most Vaisala airport customers do not modify numerous METAR fields that are automatically updated/populated using Vaisala AviMet software that is connected to airport weather sensors. According to ICAO requirements and recommendations, AviMet software calculates and reports mean and extreme values; and takes account marked discontinuities as defined by ICAO Annex 3 for calculating mean values for example for wind and RVR. Traditional weather observation parameters processed automatically by a standard AviMet system include:

- Temperature
- Dew point
- Pressure (QNH, QFE)
- Wind speed and direction
- Cloud coverage and height
- Visibility and RVR

However, a fully unmanned airport observation auto METAR solution must also include present weather information and
address concerns related to the representativeness of in situ weather observations for characterizing the weather conditions at the airport. To address these concerns, Vaisala has developed multiple present weather sensor offerings and several multi-sensor algorithms within its AviMet software. These offerings and algorithms will be discussed throughout the rest of this document.

The typical unmanned weather observation sensor suite for a CAT III airport system is shown in Figure 1. Note that in addition to the ICAO required sensors, a single-point lightning detector (Vaisala TSS928) and present weather sensor (FS11P) should be included in the system to detect present weather phenomena such as rain, snow and thunderstorm activity.

Figure 1. Typical unmanned weather observation sensor suite for a CAT III airport system.
CHAPTER 3
CLOUDS

Detecting The Cloud Type

Defining and observing cloud types is not significant for aviation and that is why they are not generally reported in METAR or SPECI reports. However, there are two significant exceptions: (1) Cumulonimbus and (2) Towering Cumulus are seen as operatively significant. Cumulonimbus and Towering Cumulus clouds are associated with weather phenomena such as strong updrafts, wind shear, and hail.

The definition for operatively significant clouds:

*Cloud of operational significance.* A cloud with the height of cloud base below 1 500 m (5 000 ft) or below the highest minimum sector altitude, whichever is greater, or a cumulonimbus cloud or a towering cumulus cloud at any height.

ICAO Annex 3

Use of CAVOK

2.2 Use of CAVOK

When the following conditions occur simultaneously at the time of observation:

a) visibility, 10 km or more;

Note.— In local routine and special reports, visibility refers to the value(s) to be reported in accordance with 4.2.4.2 and 4.2.4.3; in
METAR and SPECI, visibility refers to the value(s) to be reported in accordance with 4.2.4.4.

b) no cloud of operational significance;

c) no weather of significance to aviation as given in 4.4.2.3 and 4.4.2.5;

**METAR and SPECI messages**

4.5.4.3 Recommendation.— In local routine and special reports and in METAR and SPECI:

a) cloud amount should be reported using the abbreviations “FEW” (1 to 2 oktas), “SCT” (3 to 4 oktas), “BKN” (5 to 7 oktas) or “OVC” (8 oktas);

b) cumulonimbus clouds and towering cumulus clouds should be indicated as “CB” and “TCU”, respectively;

c) the vertical visibility should be reported in steps of 30 m (100 ft) up to 600 m (2 000 ft);

d) if there are no clouds and no restriction on vertical visibility and the abbreviation “CAVOK” is not appropriate, the abbreviation “NSC” should be used;

Generally it can be said that automatic weather observing systems do not distinguish different cloud types, but need other information such as lightning detection, weather radar, and/or satellite systems. This is also observed in ICAO manuals:

**Manual on Automatic Meteorological Observing Systems at Aerodromes**

7.2.3 Cloud type — Detection of cumulonimbus (CB) and towering cumulus (TCU) clouds

7.2.3.1 CB and TCU clouds are identified visually and sometimes acoustically. A cumulonimbus can be buried in a cloud mass, without being directly identifiable by a human observer. Lightning and/or thunder indicate the presence of CB clouds.
7.2.3.2 A weather radar detects the presence of precipitation (and sometimes even clouds) and quantifies its intensity. Intense or deep convective cloud ceilings are visible and result in high reflectivity levels. A proposal is being examined by the WMO Commission for Instruments and Methods of Observation (CIMO) to define CB and TCU clouds or, more precisely, convective clouds using reflectivity levels. A disadvantage of this method is that high levels of reflectivity can also exist during heavy, non-convective precipitation, without the presence of CB and TCU clouds. The combination of radar images with infrared satellite images can fine-tune the diagnostic, since CB and TCU clouds have a large vertical extent; thus, the temperature at their tops is low.

7.2.3.3 Radar and satellite images are commonly used by meteorological forecasters. Products adapted to convective phenomena are becoming available to aeronautical users in certain countries. Development is under way in many countries to extract information on convective clouds from radar and satellite images and integrate it into METAR/SPECI and local reports. A definition of the area around the airport, in which CB/TCU clouds must be indicated, is also necessary. This area should perhaps be related to the area where a thunderstorm might be detected (TS or VCTS). Since a definition does not exist at present, it is possible for the presence of CB clouds to be indicated by a human observer when he sees lightning, even if far away (a distance up to 100 km is possible at night).

7.2.3.4 There are local sensors and/or networks that detect lightning in a defined area corresponding to the zone affected by TS and VCTS. Lightning indicates the presence of CB clouds. Unfortunately, there are many cases of false alarms which rendered this method somewhat unreliable.

7.3.3. Detecting the presence of cumulonimbus (CB) and towering cumulus (TCU) clouds

7.3.3.1 A ceilometer, the only automatic sensor currently capable of measuring the height of cloud base, cannot identify CB or TCU
clouds. This identification can therefore only be done from a secondary source of observation...

7.4 Sources of error

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7.4.4 Identification of cumulonimbus and towering cumulus (TCU) clouds

7.4.4.1 For an observer, the presence of CB clouds can be detected visually (shape of cloud) or deducted from the occurrence of lightning or thunder. A CB cloud buried in a cloud mass can be invisible to an observer and would therefore not be reported. If lightning is visually detected, distant CB clouds can be detected and reported....

7.4.4.4 Reporting TCU cloud is more uncertain due the difficulty in identifying a towering cumulus. For an observer, a TCU cloud can be identified only when seen directly. For an isolated TCU cloud a human observation is easy during the day. For cloud buried in a cloud mass, the observation is much more difficult from the ground.

As ICAO clearly indicates, a human observer may have difficulties in cloud type classification: especially when Cumulonimbus (CB) or Towering Cumulus (TCU) clouds are embedded in other clouds such as Stratus clouds. In those circumstances, a proper cloud observation is difficult and prone to errors. During night-time or when the visibility is limited (e.g. rain or fog), determining the cloud type is challenging.

Several Meteorological Services and Institutes have been developing automatic cloud type identification algorithms using some combination of lightning detection, weather radar, and weather satellite systems with varying levels of performance. Vaisala continues to monitor this development and discuss potential internal algorithm development, but currently does not offer this capability.
Assessing The Cloud Amount

ICAO Annex 3

f) when several layers or masses of cloud of operational significance are observed, their amount and height of cloud base should be reported in increasing order of the height of cloud base, and in accordance with the following criteria:

1) the lowest layer or mass, regardless of amount to be reported as FEW, SCT, BKN or OVC as appropriate;

2) the next layer or mass, covering more than 2/8 to be reported as SCT, BKN or OVC as appropriate;

3) the next higher layer or mass, covering more than 4/8 to be reported as BKN or OVC as appropriate; and

4) cumulonimbus and/or towering cumulus clouds, whenever observed and not reported in 1) to 3);

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7.3 Algorithms and reporting

7.3.1 Determining cloud layers using a ceilometer

7.3.1.1. Many algorithms developed by meteorological authorities and/or system designers are used throughout the world to calculate cloud layers using a ceilometer. It is difficult to standardize algorithms precisely but all algorithms use the same method of calculation, developed by the United States with ASOS....

As noted above, automatic sky condition assessment uses one or more ceilometers in an algorithm that is based on the Federal Aviation Administration's (FAA, USA) ASOS-algorithm. Although the algorithm calculates proper altitudes and number(s) of cloud
layers, inhomogeneity of the cloud cover in connection with slow cloud movement can cause incorrect estimates. Situations like this may occur when a stationary front partly covers the sky. Conditions like these are fortunately rare and the effect can be minimized by using multiple (all available) airport ceilometers in the cloud cover algorithm. Vaisala's AviMet AWOS system uses a multi-ceilo sky condition algorithm that has been implemented to minimize erroneous cloud cover observations.

The cloud cover assessment performed by a human observer is always an estimate: because an observer sees the clouds that are far away in a small angle, their coverage is very difficult to judge.

**Manual on Automatic Meteorological Observing Systems at Aerodromes**

7.4.3.1 .... *This effect has been documented by the United States under the name “packing effect” (Figure 7-1 refers), due to the fact that certain holes in cloud covers cannot be seen because of the slant visibility effect. This bias caused by human observation is more significant when the observer is located far from the approach area (extension of the runway threshold), which is usually the case. With a slant observation, it is difficult for the observer to correctly estimate cloud cover in the area: if he is located 4 km from the middle marker (or from an equivalent point), clouds with an altitude of 400 m are seen at an angle of 6°.*

Timing of the observation also causes differences between human and automatic observations: as the cloud observation of a human observer is normally almost instantaneous with duration of about one minute. On the other hand, Vaisala's automatic sky condition algorithm is based on a 30 minute average with a double weight applied to the last 10 minutes.
CHAPTER 4
PRESENT WEATHER

Introduction

Present weather must be observed in both local and METAR/SPECI reports. ICAO Doc9837 discusses automatic present weather observations/reporting in detail.

Manual on Automatic Meteorological Observing Systems at Aerodromes

6.1 Introduction

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6.1.2 The sensors used for the automatic observation of present weather are recent developments. There are several types, using different physical principles; improvements in performance and capacity can be expected. However, automatic systems are not currently capable of reporting all types of present weather.

6.1.3 Sensor diagnostics are generally not used directly but are combined with other parameters to limit errors and increase their reliability and the types of present weather that can be reported (for example, a precipitation described as "liquid", with an air temperature less than -0.5°C, is almost always freezing precipitation). Hence, the algorithms associated with present weather sensors are of critical importance.
Measurement Methods

Manual on Automatic Meteorological Observing Systems at Aerodromes

6.2 Measurement methods

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6.2.3 Optical sensors of the scatter meter type

6.2.3.1 These sensors, marketed by many manufacturers, measure visibility and detect and identify certain categories of hydrometeors.

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6.2.3.3 Another manufacturer uses a scatter meter initially designed to measure visibility and has added a precipitation detector. The low volume of optical scatter means that individual particles can be detected. Using the optical signal, the sensor calculates the intensity of precipitation. The precipitation detector with a capacitive grid reacts to the quantity of water and gives an intensity. The optical and capacitive intensities are related where liquid precipitation is concerned, while optical intensity is higher for solid precipitation (low water content). Temperature measurement aids the sensor and is also used to determine whether precipitation is freezing rain. Theoretically, this sensor is capable of identifying many different types of hydrometeors: drizzle, rain, snow, hail, snow grains, ice crystals' and mixed precipitation. Tests have shown good recognition of types like rain and snow and, to a lesser extent (50 per cent), drizzle, but a low recognition of some types like hail, recognized as heavy rain. The sensitivity of this sensor has a threshold of approximately 0.05 mm/h. It identifies freezing precipitation by temperature analysis (i.e. liquid precipitation combined with a negative temperature). The same manufacturer also markets two other sensors using the same principles but with a more limited visibility range and fewer hydrometeoric types recognized.

Vaisala's FS11P present weather sensor operates according to the principles discussed in this ICAO section (section 6.2.3.3). Specifically, the Present Weather Sensor FS11P is a forward scatter
A measuring instrument. It consists of a (1) Measurement Unit (FSM102), (2) Interface Unit (FSI102), (3) one of several optional masts, (4) Precipitation Identifier (PWD32) and (5) interconnecting cables.

The Precipitation Identifier PWD32 measures the intensity and amount of both liquid and solid precipitation. PWD32 measures precipitation using the principle of forward scatter measurement. Light scatters from precipitation particles with the signal being proportional to the size of the particle. The attached PWR212 RAINCAP® sensor provides information for determining the equivalent water amount of the precipitating particles. PWD32 also uses the FSM102 visibility and temperature information to determine the correct present weather code.

6.2.10 Lightning detectors

There are several sensors that detect lightning within a 50-km radius, using the magnetic and electrostatic signature of the lightning. By assessing the distance and direction of the lightning, these sensors can provide local information on thunderstorms. An alternative to a local sensor is a lightning detection network.

Vaisala's TSS928 single-point lightning sensor generally operates according to the principles discussed in this ICAO section (section 6.2.10). Specifically, the TSS928 sensor detects and reports cloud-to-ground within a 30 nautical mile (56 km) radius from the sensor installation location to automate thunderstorm present weather reporting within METAR/SPECI reports created using Vaisala AviMet software. In addition, overhead cloud lightning detection provides early thunderstorm reporting for storms that develop directly over an airport.

Patented Vaisala TSS928 lightning algorithms provide the most precise ranging of any stand-alone lightning sensor available in the world today. The optical coincidence requirement eliminates reporting of non-lightning events.
Multi-Sensor Algorithms

Manual on Automatic Meteorological Observing Systems at Aerodromes

6.4 ALGORITHMS AND REPORTING

6.4.1 General

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6.4.1.2 Potentially, the final diagnostic of present weather could be greatly improved with a combination of different sensors or parameters. The use of air temperature is the most obvious example, but there are other useful parameters or other inter-parametric correlations. Thus, supplementary, more "classical" sensors, such as temperature measurements, can be installed and used. Data combination algorithms permit the identification of complementary types of present weather or the correction of initial diagnostics sent by the present weather sensor. In this case, some algorithms can be specific to the sensor used and its known faults.

6.4.1.3 Many States and/or meteorological services develop and use such algorithms. It is not easy to gain an overview as few of these algorithms are clearly documented and sometimes they are regarded as having commercial value. At present, it is not possible to standardize these algorithms, nor to cite them.

Vaisala's AviMet automated weather observing system has an advanced multi-sensor present weather algorithm, that uses the weather information fused from several sensors at the airport. The multi-sensor algorithm amends and possibly corrects the information from the present weather sensor(s) to facilitate more accurate present weather detection.

Freezing rain is a phenomena that has a drastic effect on airport operations both by creating ice cover on aircraft surfaces and by reducing the friction on runways, taxiways and aprons.
6.4.12 Identification of freezing rain (FZRA) and freezing drizzle (FZDZ)

Freezing rain or freezing drizzle often occur when the air temperature is below zero. Liquid precipitation is almost always freezing when $T_{\text{air}} < -0.5^\circ\text{C}$. This is a simple and relatively reliable way of identifying the freezing nature of precipitation, on condition that the precipitation was detected and properly identified as liquid. For very light precipitation, an icing sensor that reacts to a small amount of ice is required. Whether or not to install this sensor in an automatic system depends on the frequency of freezing phenomena.

The Vaisala multi-sensor present weather algorithm has been tested at several airports by comparing the observations of a human observer with the results from the algorithm. The results for freezing rain are presented in Figures 1 and 2.

Figure 1. The results from the multi-sensor present weather algorithm: A human observer has observed freezing rain. One year observation data.
According to tests performed with Vaisala’s multi-sensor present weather algorithm, it detected all instances (70 out of 70 cases) when the human observer reported freezing rain. When the human observer did not report freezing rain, Vaisala’s multi-sensor present weather algorithm reported freezing rain in only 14 out of 1807 cases. This so called over-reporting occurred in under 1% of the cases.

**Figure 2.** The results from the multi-sensor present weather algorithm: A human observer has observed non-freezing rain. One year observation data.

**Fog**

The following is a brief discussion regarding automatic weather observing systems having one-to-several visibility sensors that detect atmospheric obscurations such as fog (FG) and mist (BR).

According to ICAO, the height of the visibility measurement should be 2.5 meters. The maximum height for shallow fog (MIFG) is 2.0
meters, meaning that a normal weather system cannot automatically detect shallow fog.

Other weather phenomena that are difficult to detect automatically are fog patches (BCFG) or partial fog (PRFG). During these occasions, only some of the visibility sensors may detect fog causing difficulties in determining the coverage of the fog. It is also possible that the fog is in an area that is void of visibility sensors making the weather observation erroneous.

Due to the different thermal capacity between concrete and grass, a more common issue occurs when grassy fields are covered with fog, but the runway area is fog-free. During these circumstances, the visibility sensors situated on grassy areas outside of the runway detect fog that may not be affecting airport operations.

Fog can be very a local and time-dependent phenomenon meaning that proximity to open water or wetlands can cause local foggy areas. Seasonal radiation fogs are most common during spring and fall. A cold sea or lake during spring can induce a thick fog that may advect over adjacent land areas, including airports.
Figure 3. Types of fog. Source: Comet program (http://www.meted.ucar.edu/bom/fog/print_fog_topics.htm).
CHAPTER 5
VISIBILITY

Visibility and RVR (Runway Visual Range) is a critical parameter for aeronautical operations. Low visibility and RVR can prevent certain types of aircraft, and in extreme cases, depending on the ILS category, all aircraft, from utilizing a runway. ICAO Doc9837 describes the concept of prevailing visibility in detail.

Manual on Automatic Meteorological Observing Systems at Aerodromes

4.1 Introduction

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4.1.3 Visibility in a METAR/SPECI must be representative of the aerodrome, which is a wide area over which significant changes in visibility can take place, so it was necessary to find a synthetic way of describing these changes. Amendment 73 to Annex 3 introduced "prevailing visibility" (Chapter 2 refers).

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4.3.2 Changes in visibility

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4.3.2.3 However, for spatial variations in visibility, the indication provided by a sensor only represents where it is installed.

4.3.2.4 For local reports, it is recommended that the visibility be representative of conditions along the runway for departing aircraft and the touchdown zone of the runway for arriving aircraft. Instruments located along the runway and runway thresholds are very well placed to be representative of these zones. Thus, the local representation of instrumented
measurements is an asset. A human observer does not have the same advantages during observations, when visibility is low and/or not homogeneous, since the observer is rarely capable of seeing all of the areas concerned.

4.3.3 Visibility in METAR/SPECI

4.3.3.1 In METAR/SPECI, it is recommended that visibility be representative of the aerodrome and, where applicable, provide an indication of changes in direction. The visibility to be reported is the prevailing visibility (Chapter 2 refers). When the visibility is not the same in different directions and when the lowest visibility is different from the prevailing visibility, and less than 1 500 metres or less than 50 per cent of the prevailing visibility, the lowest visibility should also be reported and its general direction in relation to the aerodrome indicated.

4.3.3.2 The advantage of having a human observe visibility using the meteorological station as a reference point is that the observation is based on an overview that covers a large volume of the atmosphere. However, there are limitations related to how effectively objects or lights can be detected by the human eye. For example, as shown in Figure 4 (4-1 in ICAO Doc9837) a), if the meteorological station and observer are located in a foggy area with a visibility of 300 m, the observer does not see anything beyond those 300 m. Without instruments, the observer therefore cannot be aware of visibility conditions beyond 300 m. The visibility representative of the whole aerodrome is therefore unknown. Conversely, if partial fog is located 2 000 m from the observer as shown in Figure 4 (4-1 in ICAO Doc9837) b), with a visible mark at 2 000 m, the observer indicates a visibility of 2 000 m, even though visibility in the partial fog is much less (for example, 300 m indicated by a sensor).
4.3.3.3 It is therefore important to understand that instrumented and human visibility observations are comparable only when the atmosphere is homogeneous. When this is not the case, human observation and automatic observation each have their limitations.

4.3.3.4 The concept of prevailing visibility and how it may be established using automatic systems can be explained with the aid of Tables 1 and 2 (Tables 4-1 and 4-2 in ICAO Doc9837). In the case of one sensor, only one visibility value can be reported with no directional variations available (NDV); therefore, the abbreviation "NDV" should be attached to the "prevailing" visibility value reported.

4.3.3.5 Table 2 (Table 4-2 in ICAO Doc9837) provides four examples of how to report visibility with automatic systems using five sensors which are located along the runways and in various sectors in relation to the aerodrome reference point as shown in column one. Example 1 demonstrates a straightforward case whereby measurements from all of the sensors are similar and hence the visibility around such an aerodrome would be homogeneous. In this case, the median value \( V_3 = 3422 \text{ m} \) should be taken as the prevailing visibility and would be reported as \( 3400 \text{ m} \). The median value is taken rather than the mean.
value to ensure that the prevailing visibility actually represents the true value as observed in part of the aerodrome. Otherwise, it would be possible to have a reported value that was not strictly observed at any part of the aerodrome.

4.3.3.6 Example 2 demonstrates a situation whereby the five sensor readings are split into two groups, i.e. three readings in the range 3 300 m to 3 500 m and two readings in the range 2 400 m to 2 500 m. However, if it is assumed that all the sensors cover an equal area of aerodrome, the definition of prevailing visibility suggests that the visibility would still be reported as the median value (3 333 m which would be reported as 3 300 m).

4.3.3.7 Examples 3 and 4 demonstrate situations whereby both the prevailing visibility and the minimum visibility should be reported. Example 3 contains a series of measurements including one measurement below the critical value of 1 500 m. In this case, the prevailing visibility should be reported as 1 900 m (the median value V3) with a minimum visibility also reported at 1 300 m. Example 4 shows a similar situation whereby the lowest reading of 1 611 m is less than 50 per cent of the prevailing visibility value of 3 333 m (the median value V3). In this case, both the prevailing visibility and the minimum visibility should be reported as 3 300 m and 1 600 m, respectively.

### Table 1. Determining prevailing visibility with one to five sensors.
Source Table 4-1 in ICAO Doc9837.

The minimum visibility may also have to be reported, in accordance with criteria in Annex 3, Appendix 3, 4.2.4.4.

<table>
<thead>
<tr>
<th>Number of sensors</th>
<th>Visibility values observed (Note: VKV2&lt;V3&lt;V4&lt;V5)</th>
<th>Prevailing visibility to be reported</th>
</tr>
</thead>
<tbody>
<tr>
<td>1*</td>
<td>V1</td>
<td>V1</td>
</tr>
<tr>
<td>2</td>
<td>V1,V2</td>
<td>V1</td>
</tr>
<tr>
<td>3</td>
<td>V1,V2,V3</td>
<td>V2</td>
</tr>
<tr>
<td>4</td>
<td>V1,V2,V3,V4</td>
<td>V2</td>
</tr>
<tr>
<td>5</td>
<td>V1,V2,V3,V4,V5</td>
<td>V3</td>
</tr>
</tbody>
</table>

*No directional variations can be detected when one sensor is in use; therefore, the visibility value should be followed by "NDV" (no directional variations available).
Table 2. Examples of reporting visibility in METAR and SPECI using five sensors. Source Table 4-2 in ICAO Doc9837.

<table>
<thead>
<tr>
<th>Sensor (and its location*)</th>
<th>Example 1</th>
<th>Example 2</th>
<th>Example 3</th>
<th>Example 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor 1 (SE)</td>
<td>3 333</td>
<td>3 333</td>
<td>1 357</td>
<td>3 333</td>
</tr>
<tr>
<td>Sensor 2 (NW)</td>
<td>3 455</td>
<td>3 455</td>
<td>1 850</td>
<td>4 455</td>
</tr>
<tr>
<td>Sensor 3 (NE)</td>
<td>3 372</td>
<td>3 372</td>
<td>1900</td>
<td>2 844</td>
</tr>
<tr>
<td>Sensor 4 (NE)</td>
<td>3 422</td>
<td>2 400</td>
<td>2 026</td>
<td>1611</td>
</tr>
<tr>
<td>Sensor 5 (SW)</td>
<td>3 520</td>
<td>2 424</td>
<td>1 977</td>
<td>3 520</td>
</tr>
<tr>
<td>Values to be reported</td>
<td>3 400</td>
<td>3 300</td>
<td>1 900 1 300SE</td>
<td>3 300 1 600NE</td>
</tr>
</tbody>
</table>

*With reference to the aerodrome reference point.

4.3.3.8 The examples discussed above make the assumption that each of the sensors used represents an equal part of the aerodrome concerned (e.g. 20 per cent each in Table 2 or Table 4-2 in ICAO Doc9837) and therefore carries an equal weighting in any calculations made. In some cases, the local climatology of the aerodrome may indicate that sensors may be representative of fog-prone areas or simply may represent more operationally significant parts of the aerodrome. Such considerations should be carried out on an individual basis. In these cases, it would be necessary to establish the percentage of the area of the aerodrome that is nominally to be represented by each sensor. Following this, the prevailing visibility can be derived using its definition which requires that the prevailing visibility is the visibility value reached or exceeded within at least half of the surface of the aerodrome.

Vaisala's AviMet Prevailing Visibility Multi-Sensor Algorithm operates according to the methodology discussed in the previous ICAO Doc9837 sections of this chapter.
The Vaisala ICAO Complaint Auto METAR code elements are shown in Table 3. Limitations related to present weather observing/reporting are listed in detail in code element 5 of the table.

Table 3. Vaisala ICAO Metar code with its elements. Note that if the AUTO-keyword is inserted after the METAR or SPECI keyword, it indicates that the report is done without human intervention. In practice that tells the end users that certain sections of the code may be missing or incomplete.

<table>
<thead>
<tr>
<th>Code element</th>
<th>Example</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Identification</td>
<td>METAR AUTO</td>
<td>METAR – aviation routine report, SPECI –Special aviation report AUTO-METAR or SPECI code reported automatically, without possibility for human input.</td>
</tr>
<tr>
<td>Location indicator</td>
<td>EGLL 291020Z</td>
<td></td>
</tr>
<tr>
<td>Date/time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Wind</td>
<td>31015G27KT</td>
<td>Wind speed is given to the closest 10 degrees. Wind direction is given in degrees true North. Gust speed is only given if 10 KT higher than mean. VRB = variable, when the mean wind direction cannot be determined. 00000KT = calm.</td>
</tr>
<tr>
<td>Wind direction/speed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extreme direction</td>
<td>280V350</td>
<td>Wind direction variation given in clockwise direction when mean speed is greater than 3 KT and wind direction variation greater than 60 degrees.</td>
</tr>
<tr>
<td>3. Prevailing Visibility Minimum</td>
<td>3200 1200SW</td>
<td>0000 = ‘less than 50 meters ‘9999 = ‘ten kilometers or more’. The minimum visibility is also included when the visibility in one direction, which is not the prevailing visibility, is less than 1,500 meters or less than 50% of the</td>
</tr>
</tbody>
</table>
prevailing visibility and less than 5000 meters. A direction is also added if possible, as N, NE, E, SE, S, SW, W and NW. If the direction cannot be determined like in AUTO metar, NDV (No directional visibility) keyword can be used.

| 4. RVR       | R27R/1100D R24/0950V1100 | RVR tendency (difference between the first and last 5 minute period during last 10 minutes) U = increasing; D = decreasing; N = no change is added after figure.
P2000 = more than 2000 m; M0050 = less than 50 m.
If the 1-minute runway visual range values during the 10-minute period vary from the mean value by more than 50 m or more than 20 per cent of the mean value, whichever is greater, the 1-minute mean minimum and the 1-minute mean maximum values should be reported instead of the 10-minute mean value. |

| 5. Present weather | +SHRA | + = Heavy (well developed in the case of +FC and +PO);
-= Light;
no qualifier = Moderate. |
|                   |      | • BC = Patches |
|                   |      | • BL = Blowing |
|                   |      | • BR = Mist |
|                   |      | • DR = Drifting, |
|                   |      | • DS = Dust storm |
|                   |      | • DU = Dust |
|                   |      | • DZ = Drizzle |
|                   |      | • FC = Funnel cloud |
|                   |      | • FG = Fog |
|                   |      | • FU = Smoke |
|                   |      | • FZ = Freezing |
|                   |      | • GR = Hail (>5 mm) |
- **GS** = Small hail or snow pellets
- **HZ** = Haze
- **IC** = Ice crystals
- **MI** = Shallow
- **PL** = Ice pellets
- **PO** = Dust devils
- **PR** = patches
- **RA** = Rain
- **SA** = Sand
- **SH** = Showers
- **SG** = Snow grains
- **SN** = Snow
- **SQ** = Squalls
- **SS** = Sandstorm
- **TS** = Thunderstorm
- **VA** = Volcanic ash
- **VC** = In vicinity
- **UP** = Unidentified precipitation (only in AUTO METARs)

Up to three groups may be present, constructed by selecting and combining from the above. Group omitted if no weather to report.

The weather types detected by a Vaisala FS11P present weather sensor combined with a Vaisala lightning detection system bolded.

<table>
<thead>
<tr>
<th>6. Cloud</th>
<th>FEW005 SCT010CB BKN025</th>
</tr>
</thead>
</table>

**FEW** = ‘few’ (1-2 oktas), **SCT** = ‘Scattered’ (3-4 oktas), **BKN** = ‘Broken’ (5-7 oktas), **OVC** = ‘Overcast’, **NSC** = no significant cloud (none below 5,000 ft and no TCU or CB) There are only two cloud types
reported; TCU = towering cumulus and CB = cumulonimbus. VV/// = ‘state of sky obscured’ (cloud base not discernable). Figures in lieu of ‘///’ give vertical visibility in hundreds of feet. Up to three, but occasionally more, cloud groups may be reported. Cloud heights are given in feet above airfield height. NCD = no cloud detected (AUTO METARS only) If the AUTO METAR cannot determine the cloud type (CB or TCU) instead of cloud type, missing data mark “///” can be used after cloud height.

7. CAVOK | CAVOK | Visibility greater or equal to 10 km, no cumulonimbus or towering cumulus, no cloud below 5,000 ft or highest minimum sector altitude (MSA) (whichever is the greater) and no weather significant to aviation.

8. Temp and dew point | 10/03 | If dew point is missing, example would be reported as 10///. M indicates a negative value.

9. QNH | Q0995 | Q indicates millibars. If the letter A is used, QNH is in inches and hundredths.
CHAPTER 7
REFERENCES

ICAO Annex 3: Meteorological Service for International Air Navigation

ICAO Doc9837: Manual on Automatic Meteorological Observing Systems at Aerodromes

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