INTERNATIONAL STANDARD

ISO 17714

First edition
2007-07-01

Meteorology — Air temperature measurements — Test methods for comparing the performance of thermometer shields/screens and defining important characteristics

Météorologie — Mesurage de la température de l'air — Méthodes d'essai pour comparer les performances d'abris/d'écrans pour thermomètres et définir les caractéristiques importantes

Reference number
ISO 17714:2007(E)

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Published in Switzerland

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Foreword

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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ISO 17714 was prepared by Technical Committee ISO/TC 146, *Air quality*, Subcommittee SC 5, *Meteorology*.

Introduction

Commonly used air temperature sensors require protection from influences such as solar and terrestrial radiation, rain and snow. Screens (also known as shields) protect the thermometers from these influences.

At present, there is no commonly accepted reference screen design, nor are there generally accepted test methods to determine performance characteristics of screens. Screens that protect the temperature sensors from daytime heating and nighttime cooling due to radiation transfer are necessary for proper air temperature measurements. In very general terms, a poor design of the screen will tend to give higher daytime and lower nighttime temperatures.

This International Standard was developed to define the most relevant screen characteristics and to provide the methods to determine or compare screen performances.

Air temperature is a basic meteorological variable. Temperature sensors are widely used in all human activities and are well known and controlled. For the measurement of the outside air temperature, the sensor must be protected against external influence, mainly radiation and hydrometeors (e.g. precipitation, fog). The sensor is usually protected by a screen, but even then, measurement errors of up to 5 K may be encountered.

The general function of a screen for operational temperature measurements used in meteorological applications is given in WMO No. 8 [3]. The following text is an extract from this document.

“Radiation from the sun, clouds, the ground and other surrounding objects passes through the air without appreciably changing its temperature, but a thermometer exposed freely in the open can absorb considerable radiation. As a consequence, its temperature may differ from the true air temperature, the difference depending on the radiation intensity and on the ratio of absorbed radiation to dissipated heat. For some thermometer elements such as the very fine wire used in an open-wire resistance thermometer, the difference may be very small or even negligible, but with the more usual operational thermometers the temperature difference may reach 25 K under extremely unfavourable conditions. Therefore, in order to ensure that the thermometer is at true air temperature it is necessary to protect the thermometer from radiation by a screen or shield which also serves to support the thermometer. This screen also shelters it from precipitation while allowing the free circulation of air around it, and prevents accidental damage. Maintaining a free circulation may, however, be difficult to achieve under conditions of rime ice accretion. Practices for reducing observation errors under such conditions will vary and may involve the use of special designs of screens or temperature-measuring instruments.”

Meteorology — Air temperature measurements — Test methods for comparing the performance of thermometer shields/screens and defining important characteristics

1 Scope

This International Standard defines characteristics of a thermometer shield/screen. It also defines test methods to inter-compare the behaviour of different screen designs.

Although screens are usually used for both air temperature and humidity measurements, this International Standard is applicable only to temperature measurements.

Both naturally and artificially ventilated screens are considered.

2 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

2.1
aspiration rate
rate of air flow passing the thermometer.

NOTE This term is only used for an artificially aspirated screen, and is expressed in metres per second.

2.2
internal ventilation factor
ratio between the internal air speed and the external wind speed, at the thermometer height

NOTE This term is only used for a naturally ventilated screen.

2.3
representative height
height above ground at which the air temperature is supposed to be measured

NOTE 1 For naturally ventilated screens, the representative measurement height is usually the height of the temperature sensor.

NOTE 2 For aspirated screens, the representative height can be different from the height of the temperature sensor. It is design dependent, however it is usually the height of the air intake.

2.4
screen
shield or shelter used to protect the thermometer from radiation, precipitation and accidental damage

2.5
screen reference point
location of the thermometer within the screen

2.6
solar radiation errors
overheating error of the measured air temperature, generated by solar radiation

2.7
system response time
time needed for the temperature recorded by the thermometer within the screen to reach 63 % of a step change in the external temperature, with a given external wind speed of 1 $m \cdot s^{-1}$

NOTE 1 The system response time is a combination of the response times of the screen and the thermometer, and depends on the thermometer time constant.

NOTE 2 The response time of the system is also dependent on wind speed. For this reason, a given air speed of 1 $m \cdot s^{-1}$ is used.

2.8
thermometer
device used to measure the air temperature inside a screen

NOTE Examples are platinum resistance thermometer sensors (IEC 60751 [1]) and thermistor sensors (ASTM E 644-04 [2]).

3 Field test conditions

3.1 Field test site

The test site should experience the range of meteorological conditions that are expected at the sites where the screens will be installed. Important influence factors are: radiation, low wind speed, periods with snow cover, falling and blowing snow, blowing dust or sand, wet fog, strong winds and wind-driven precipitation.

It may be necessary to perform testing at more than one site, to address the full range of meteorological conditions.

The meteorological conditions occurring at the site during the intercomparison shall be described, with at least the temperature, wind and daily insolation distribution.

3.2 Respective location of screens

For the field test, all the screens shall be installed above a level area covered by homogeneous natural ground cover. The vegetation at the test site should completely cover the surface and the type of vegetation shall be defined. It should be kept at a height below 10 cm. All screens should be freely exposed to sunshine and wind and should not be shielded by, or close to, trees, buildings and other obstructions (see A.8). The screens should be installed at a minimum distance of 30 m from any heat source or other construction that could artificially influence the air temperature, such as concrete, asphalt, buildings, standing water, etc.

The separation between screens is a compromise, and should be large enough to ensure that interaction between screens is insignificant, while being small enough to minimise temperature variations across the site. The distance between each screen should be at least 3 m. A representative height between 1,25 m and 2 m should be chosen for the test to meet the WMO recommendations. The representative height shall be the same for each screen, with a maximum tolerance of ± 5 % of the height.

When testing artificially ventilated screens, the probe orientation and the inlet/outlet orientations shall be documented, as wind direction may influence the aspiration rate.

3.3 Screens

Two or more screens of each design should be included in the test. This allows assessment of measurement repeatability of a given screen design and also for measurement of homogeneity of the test site.

At least two reference screens with identical thermometers shall be used.

During an intercomparison, observations of the screens are required to determine if they are wet, covered with ice, clogged with snow, dirty, if the aspirator (if any) is working, etc.

3.4 Thermometers

The thermometers and associated data acquisition system(s) should be matched to ensure equivalent response characteristics, such as the time constant. WMO [3] recommends the use of thermometers with a time constant of about 30 s. The sensors and measuring system shall be calibrated and used in such conditions that there is no significant self heating of the thermometer due to an excessive measuring current. The uncertainty of the temperature measurements shall be 0,2 K or better.

3.5 Additional meteorological variables

In addition to the air temperature measurements, the following parameters should be measured and recorded during an intercomparison.

- Solar global radiation on a horizontal plane.

- Sunshine (yes/no).

- Scalar average 1 min or 2 min wind speed and direction. This should be measured at a position that is as close as possible to the representative height of the temperature measurement. Where the test array of screens can shelter the anemometer in certain wind directions, then it is preferred that the anemometer is raised slightly above the level of the top of the screens and this measurement height recorded. The anemometer used should be capable of calibrated measurements of wind speeds at 0,5 m·s^{-1} and above. Sonic anemometers may be good candidates for these measurements.

- Scalar average 1 min or 2 min wind speed and direction at 10 m height (standardized meteorological height). Wind measurements at 10 m allow a comparison between meteorological conditions during the test and climatological conditions (as 10 m measurements are currently used in climatological records).

- Relative humidity of air.

- Cloud cover.

- Precipitation occurrence, type and intensity. Manual observations may be required to determine precipitation occurrence and type.

- Sun azimuth and elevation angle.

- Surface albedo (ground conditions, snow cover, etc.)

It is also desirable to measure

- direct solar radiation, and

- long-wave net radiation or cloud cover at night.

The type of instruments used and their siting shall be documented. The instruments used shall be calibrated and regularly maintained, and should be installed and used following the recommendations of WMO [3].

3.6 Data sampling

When making the screen intercomparison, a data base of all measurements should be constructed to represent averages from samples taken during 1 min periods. The data sampling rate should be at least 6 samples per minute.

For wind measurements, the data sampling rate should be at least 1 Hz.

3.7 Reference values

There is no recognised reference system for measuring the true air temperature. Statistically, radiative errors of any screen lead to warmer (than the true air temperature) temperature measurement during the day, and cooler temperature measurement during the night. So when different screen designs are compared, those that are cooler during the day and warmer during the night are likely to be giving measurements that are closest to the truth. By design, it is generally the case that there will be a fast response thermometer inside an artificially ventilated screen. However, not all designs of artificially ventilated screens that are available on the market are satisfactory for use as a reference.

If an artificially ventilated screen is to be used as a reference, then its performance shall be fully tested.

— Check for potential psychrometric cooling effects after high humidity events or dew deposition.

— Check the effect of the ambient wind on the airflow in an artificially ventilated screen, as designs have been found where airflow across the thermometer is reduced or reversed in some wind conditions.

— Check if a large aspiration rate may cause heating of the air.

— Check if the air exhausted by the fan may re-circulate and influence the incoming air.

— Check the sensor and screen for dirt and contamination that could obstruct the airflow or influence the temperature.

A potential candidate for measuring the reference air temperature is the use of a very thin resistive wire (thickness < 15 µm, [4, 5] in the Bibliography), acting as a thermometer. If it is very thin, the wire may be exposed freely to the air, with no radiation screen. The problem with this technique is how to design a wire that has stable characteristics and will survive for long enough periods outside in all weather conditions; a suitable sensor has yet to be designed.

If the purpose of the intercomparison is to check the behaviour of new designs against a specific screen model widely used (in a country and/or in the past), this screen may be used as a ‘relative’ reference. In this case, the new screen may exhibit better characteristics than the reference, and the performance may be explained by considering the influence factors detailed in Annex A.

In any case, the reference screen used should be fully described: geometry, sensors and their time constants, materials used in the construction of both the screen and its supporting structure, any attached boxes, airflow tests and other relevant matters.

3.8 Quality control

Data quality control shall be carried out before and during the analysis, to avoid erroneous data from being used. Times and details of any interventions during the test that could cause erroneous measurements to be recorded shall be noted, so that such data are not used.

Automatic checking of the data usually allows the detection of gross errors, such as out-of-range values.

The use of two identical screens of each type under test (including the reference), enables checks of differences between similar pairs, to reveal any data that are significantly different.

Another effective quality-control check is to visualise the different parameters to detect strange or abnormal behaviour using time graphs of all data on a daily basis. It is also possible to detect potential anomalies by looking for extreme values during the data analysis; the time of occurrence of these extreme values should be noted and the data should be graphically displayed during these occurrences. This method is also a good way to detect the specific behaviour of screens during the typical conditions listed in 3.10.

3.9 Long-term intercomparison

It is very difficult to generate and control all the factors that influence the performance of a screen in the laboratory. By making measurements of performance at a field test site, most important meteorological conditions will be experienced, if sufficient time is allocated for the test. A long-term intercomparison is therefore recommended, extending over the summer and winter periods and typically of one year duration for a comprehensive test. If the test is conducted in an area with less seasonal change, the duration of the test can be reduced.

During this long-term intercomparison, the effects of the following combinations of influence factors should be analysed:

— solar radiation;

— wind;

— solar radiation and low wind speed (< 1 $m \cdot s^{-1}$); a sensitive anemometer is required;

— insolation relating to the sun's elevation and wind speed (as direct radiation is a major influence factor, this analysis may be more representative than the previous one);

— cloud cover at night, combined with wind speed, to assess long-wave radiation cooling;

— precipitation, fog and rime events, their onset, duration and termination;

— cleanliness and aging of the screen.

These effects should be analysed using the whole database and specific filters on the influence parameters.

3.10 Typical conditions

The advantage of long-term comparisons is that they enable data collection during a wide range of meteorological conditions representative of the test site.

A disadvantage may be that the conditions leading to extreme measurement errors of the air temperature are not readily apparent. This can be overcome by identifying extreme differences between the tested screen and the reference, and then investigating the current meteorological conditions during these differences. If the screens have different time constants and the air temperature variation with time is high, this may be the cause of such differences. Therefore, such a comparison is more representative when conducted on daily extreme values.

Another solution is to identify typical meteorological conditions and to analyse the behaviour of the tested screens to get a detailed knowledge of the screen behaviour in known conditions. This may allow an extrapolation of the screen behaviour in climatic regions other than the test site.

Typical conditions could be periods of at least 6 h with the following conditions.

— Day with a clear sky and periods with wind speed below 1 $m \cdot s^{-1}$ (for solar radiation effects).

— Day with a clear sky and periods with wind speed above 5 $m \cdot s^{-1}$ (for solar radiation effects).