Designation: D6176 – 97 (Reapproved 2022)

Standard Practice for Measuring Surface Atmospheric Temperature with Electrical Resistance Temperature Sensors[1]

This standard is issued under the fixed designation D6176; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice provides procedures to measure representative near-surface atmospheric (outdoor air) temperature for meteorological purposes using commonly available electrical thermometers housed in radiation shields mounted on stationary or portable masts or towers.

1.2 This practice is applicable for measurements over the temperature range normally encountered in the ambient atmosphere, –50 to +50 °C.

1.3 Air temperature measurement systems include a radiation shield, resistance thermometer, signal cables, and associated electronics.

1.4 Measurements can be made at a single level for various meteorological purposes, at two or more levels for vertical temperature differences, and using special equipment (at one or more levels) for fluctuations of temperature with time applied to flux or variance measurements.

1.5 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D1356 Terminology Relating to Sampling and Analysis of Atmospheres

E344 Terminology Relating to Thermometry and Hydrometry

E644 Test Methods for Testing Industrial Resistance Thermometers

E1137/E1137M Specification for Industrial Platinum Resistance Thermometers

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this practice, refer to Terminology D1356 and E344. Some definitions are repeated in this section for the reader's convenience.

3.1.2 *connecting wires*—the wires which run from the element through the cable end closure and external to the sheath.

3.1.3 *interchangeability*—the extent to which the thermometer matches a resistance-temperature relationship.

3.1.4 *inversion*—the increase in potential temperature with an increase in height (see 3.1.5 and 3.2.7).

3.1.5 *lapse rate*—the change in temperature with an increase in height (see 3.1.4 and 3.2.7).

3.1.6 *resistance thermometer*—a temperature-measuring device comprised of a resistance thermometer element, internal connecting wires, a protective shell with or without means for mounting, a connection head or connecting wire with other fittings, or both (see also 3.2.3).

3.1.7 *resistance thermometer element*—the temperature-sensitive portion of the thermometer composed of resistance wire, film or semiconductor material, its supporting structure, and the means for attaching connecting wires.

[1] This practice is under the jurisdiction of ASTM Committee D22 on Air Quality and is the direct responsibility of Subcommittee D22.11 on Meteorology.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

3.1.8 *thermistor*—a semiconductor whose primary function is to exhibit a monotonic change (generally a decrease) in electrical resistance with an increase in sensor temperature.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *ambient*—the portion of the atmosphere where the air temperature is unaffected by local structural, terrain, or heat source or sink influences.

3.2.2 *sensor*—used interchangeably with resistance thermometer (see 3.1.6) in this practice.

3.2.3 *shield*—a ventilated housing designed to minimize the effects of solar and terrestrial radiation on a temperature sensor while maximizing convective heat transfer between the sensor and the passing air, and to protect the sensor from contact with liquid moisture; also known as radiation shield.

3.2.4 *temperature differential*—the difference between two or more simultaneous temperature measurements, typically separated vertically at a single location; see 3.1.4 and 3.1.5.

3.2.5 *temperature variance*—a statistical measure, the deviation of individual temperature measurements from the mean of those measurements obtained over a user-defined sampling period.

3.2.5.1 *Discussion*—Temperature variance describes temperature variability at a fixed point in the atmosphere. The covariance of temperature and vertical velocity defines the sensible heat flux.

3.2.6 *transfer function*—the functional relationship between temperature sensor electrical resistance and the corresponding sensor temperature.

3.2.7 *vertical temperature gradient*—the change of temperature with height ($\Delta T/\Delta Z$ or $\delta T/\delta Z$), frequently expressed in °C/m; also known as lapse rate for temperature decrease, or inversion for a temperature increase (see 3.1.4 and 3.1.5).

3.3 *Symbols:*

agl = above ground level
ΔT = difference between two temperatures, also δT
ΔZ = difference between two heights above ground level, also δZ
T = temperature, degrees in appropriate scale, typically Celsius, °C
Z = height above ground level, typically metres
τ = time constant, the time for a sensor to change to approximately 63.2 % (1−l/e) of the value of the temperature change.

4. Significance and Use

4.1 *Applications*—Ambient atmospheric temperature measurements can be made using resistance thermometers for many purposes. The application determines the most appropriate type of resistance thermometer and data recording method to be used. Examples of three typical meteorological applications for temperature measurements follow.

4.1.1 Single-level, near-surface measurements for weather observations (**1**)[3], thermodynamic computations for industrial applications, or environmental studies (**2**).

4.1.2 Temperature differential or vertical gradient measurements to characterize atmospheric stability for atmospheric dispersion analyses studies (**2**).

4.1.3 Temperature fluctuations for heat flux or temperature, or variance computations, or both. Measurements of heat flux and temperature variance require high precision measurements with a fast response to changes in the ambient atmosphere.

4.2 *Purpose*—This practice is designed to assist the user in selecting an appropriate temperature measurement system for the intended atmospheric application, and properly installing and operating the system. The manufacturer's recommendations and the U.S. Environmental Protection Agency handbook on quality assurance in meteorological measurements (**3**) should be consulted for calibration and performance audit procedures.

5. Summary of Practice

5.1 Ambient air temperature measurements using resistance thermometers are typically made using either thermistors or platinum wire or film sensors, though sensors made from other materials with similar resistance properties related to temperature could also be suitable. The sensors are housed in naturally ventilated or mechanically aspirated shields. The sensor temperature is intended to be representative of the ambient air. To accomplish this, the sensor material and exposure in the shield are chosen to maximize convective heat transfer between the air and the sensor, and minimize solar or terrestrial radiation exchange with the sensor. The resistance thermometer (sensor) should be sufficiently rugged to withstand the operating environment without damage. The sensors are connected to electronic circuits capable of measuring the sensor resistance, and displaying or recording, or both, the corresponding temperature. Operational procedures containing quality control and quality assurance tasks suitable to the intended measurements are recommended (**1**, **2**, **3**, **4**).

6. Resistance Thermometers

6.1 *Temperature Measurement Requirements*—Define the range, resolution, response time, precision, and bias suitable for purposes of the measurement. The maximum recommended accuracy specification is an absolute error of ±0.5 °C over the expected temperature range. For vertical temperature gradient measurements, there is an additional accuracy specification of a relative error between sensors of ±0.1 °C over the range of expected temperature difference (**2**). The maximum recommended resolution is 0.1 °C for most single-level measurements, and 0.01 °C for vertical temperature difference and temperature fluctuation measurements. The recommended response time should be 5 s or less for typical measurements.

[3] The boldface numbers in parentheses refer to the list of references at the end of this standard.