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.

Designation: C1371 − 15 (Reapproved 2022)

Standard Test Method for Determination of Emittance of Materials Near Room Temperature Using Portable Emissometers[1]

This standard is issued under the fixed designation C1371; 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 test method covers a technique for determination of the emittance of opaque and highly thermally conductive materials using a portable differential thermopile emissometer. The purpose of the test method is to provide a comparative means of quantifying the emittance of materials near room temperature.

1.2 This test method does not supplant Test Method C835, which is an absolute method for determination of total hemispherical emittance, or Test Method E408, which includes two comparative methods for determination of total normal emittance. Because of the unique construction of the portable emissometer, it can be calibrated to measure the total hemispherical emittance. This is supported by comparison of emissometer measurements with those of Test Method C835 (**1**).[2]

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

1.4 *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.*

1.5 *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:*[3]

C168 Terminology Relating to Thermal Insulation

C680 Practice for Estimate of the Heat Gain or Loss and the Surface Temperatures of Insulated Flat, Cylindrical, and Spherical Systems by Use of Computer Programs

C835 Test Method for Total Hemispherical Emittance of Surfaces up to 1400°C

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E408 Test Methods for Total Normal Emittance of Surfaces Using Inspection-Meter Techniques

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

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3. Terminology

3.1 *Definitions*—For definitions of some terms used in this test method, refer to Terminology C168.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *diffuse surface*—a surface that emits or reflects equal radiation intensity, or both, in all directions (**2**).

3.2.2 *emissive power*—the rate of radiative energy emission per unit area from a surface (**2**).

3.2.3 *emissometer*—an instrument used for measurement of emittance.

3.2.4 *Lambert's cosine law*—the mathematical relation describing the variation of emissive power from a diffuse surface as varying with the cosine of the angle measured away from the normal of the surface (**2**).

3.2.5 *normal emittance*—the directional emittance perpendicular to the surface.

3.2.6 *radiative intensity*—radiative energy passing through an area per unit solid angle, per unit of the area projected normal to the direction of passage, and per unit time (**2**).

[1] This test method is under the jurisdiction of ASTM Committee C16 on Thermal Insulation and is the direct responsibility of Subcommittee C16.30 on Thermal Measurement.

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

[3] 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.

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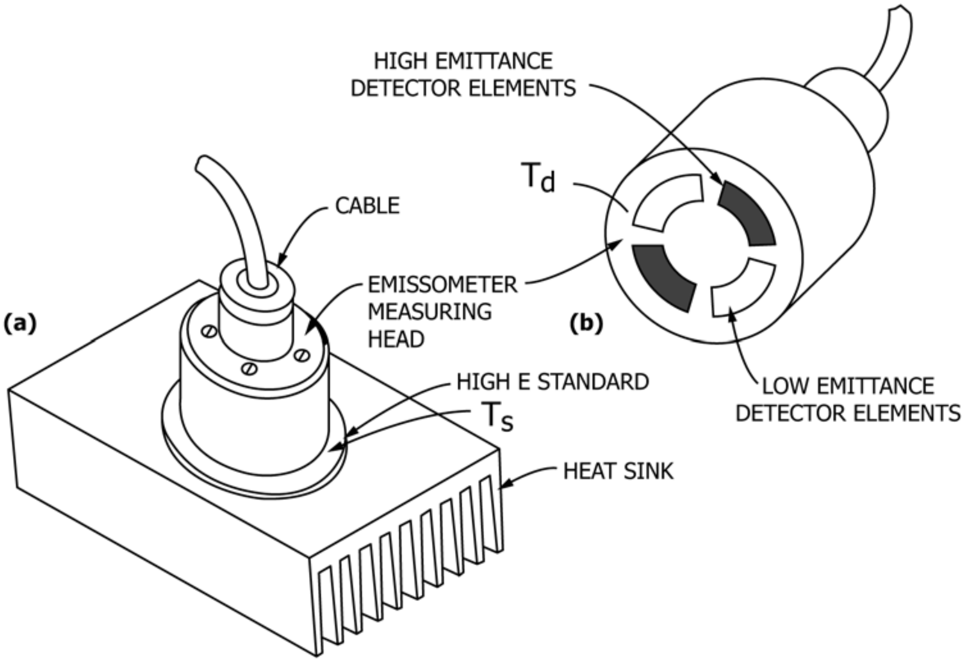

NOTE 1—(a) Emissometer measuring head on high-emittance standard during calibration, showing heat sink and cable to readout device. (b) Bottom view of emissometer measuring head showing high- and low-emittance detector elements. The diameter of the emissometer measuring head is about 50 mm and the detector elements are recessed about 3 mm into the measuring head.

FIG. 1 Schematic of Emissometer

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3.2.7 *spectral*—having a dependence on wavelength; radiation within a narrow region of wavelength (2).

3.2.8 *specular surface*—mirrorlike in reflection behavior (2).

3.3 *Symbols:*

3.3.1 For standard symbols used in this test method, see Terminology C168. Additional symbols are listed here:

α = total absorptance, dimensionless

α_λ = spectral absorptance, dimensionless

ε_{hi} = total emittance of the high-emittance calibration standard, dimensionless

ε_{low} = total emittance of the low-emittance calibration standard, dimensionless

ε_{spec} = apparent total emittance of the test specimen, dimensionless

ε = apparent total emittance of the surface, dimensionless

ε_1 = apparent total emittance of the surface 1, dimensionless

ε_2 = apparent total emittance of the surface 2, dimensionless

ε_d = apparent total emittance of the surface of detector, dimensionless

ε_s = apparent total emittance of the surface of specimen, dimensionless

ε_λ = spectral emittance, dimensionless

λ = wavelength, µm

ρ = total reflectance, dimensionless

σ = Stefan-Boltzmann constant, 5.6696×10^{-8} W/m^2 · K^4

τ = total transmittance, dimensionless

A = area of surface, m^2

k = proportionality constant, V·m^2/W

Q_{rad} = radiation heat transfer, W

q_{rad} = radiative heat flux, W/m^2

T_1 = temperature of the test surface, K

T_2 = temperature of the radiant background, K

T_d = temperature of the detector, K

T_s = temperature of the surface of specimen, K

V_{hi} = voltage output of the detector when stabilized on high-emittance calibration standard

V_{low} = voltage output of the detector when stabilized on low-emittance calibration standard

V_{spec} = voltage output of the detector when stabilized on test specimen

4. Summary of Test Method

4.1 This test method employs a differential thermopile emissometer for total hemispherical emittance measurements. The detector thermopiles are heated in order to provide the necessary temperature difference between the detector and the surface.[4] The differential thermopile consists of one thermopile that is covered with a black coating and one that is covered with a reflective coating. The instrument is calibrated using two standards, one with a high emittance and the other with a low emittance, which are placed on the flat surface of a heat sink (the stage) as shown in Fig. 1. A specimen of the test material is placed on the stage and its emittance is quantified by comparison to the emittances of the standards. The calibration shall be checked repeatedly during the test as prescribed in 7.2.

[4] The sole source of supply of emissometers known to the committee at this time is Devices & Services Co., 10024 Monroe Drive, Dallas, TX 75229. If you are aware of alternative suppliers, please provide this information to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend.

5. Significance and Use

5.1 *Surface Emittance Testing:*

5.1.1 Heat transfer from a surface by radiation transfer is reduced if the surface of a material has a low emittance. Since the controlling factor in the use of insulation is sometimes condensation control or personnel protection, it is important to understand that a low emittance will change the surface temperature of a material. One possible criterion in the selection of these materials is the question of the effect of aging on the surface emittance. If the initial low surface emittance of a material is not maintained during service, then the long-term value of the material is diminished.

5.1.2 This test method provides a means for comparative periodic testing of low emittance surfaces in the field. In this way the effects of aging on the reflective properties can be monitored.

5.1.3 This test method determines the total hemispherical emittance with a precision of better than ±0.02 units.(**1**) The emittances of the calibration standards shall have been obtained from accurate independent measurements of total hemispherical emittance. This test method shall not be used for specimens that are highly anisotropic or transparent to infrared radiation. This test method also shall not be used for specimens with significant thermal resistance (see 7.3.4).

5.1.4 Once a reliable emittance measurement has been determined, the value is available to be used to calculate radiative heat flow from the subject surface. For example, if the temperature of the surface, T_1, and the temperature of the surroundings, T_2, are known, then the radiative heat flow, Q_{rad}, is given by:

$$Q_{rad} = A\ \varepsilon\ \sigma\ (T_1^{\,4} - T_2^{\,4}) \quad (1)$$

where A is the area of the surface, and either A is assumed to be much smaller than the area of the surroundings or the emittance of the surroundings is assumed to be unity. This radiative heat flow when combined with convective and conductive heat flows provides the total heat flow from the surface (a method for calculating total heat flow is described in Practice C680).

6. Apparatus

6.1 This test method applies only to emittance tests conducted by means of a heated, differential thermopile emissometer, such as that shown in Fig. 1. The following elements are used:

6.1.1 *Differential Thermopile Radiant Energy Detector*—The differential thermopile consists of elements with high and low emittance that produce an output voltage proportional to the temperature difference caused by different amounts of thermal energy emitted and absorbed by each. The output voltage is proportional to the emittance of the surface that the detector faces.

6.1.2 *Controlled Heater*—Within the emissometer measuring head that maintains the head at a temperature above that of the specimen or calibration standard.

6.1.3 *Readout Device*—Typically a digital millivoltmeter, which sometimes includes a means of conditioning the thermopile output signal so that the emittance can be read directly.

NOTE 1—The emissometer[4] has a direct readout of emittance, with a resolution of ±0.01 units. For the work described in Ref (**1**), the resolution was increased to ±0.001 units.

6.1.4 *Heat Sink Stage*—A heat sink with a flat surface or stage upon which the reference standards and specimen are placed, and which provides a means of maintaining the standards and specimen at the same, stable temperature.

6.1.5 *Reference Standards*—the manufacturer of the emissometer[4] supplies two sets of reference standards, each set consisting of a polished stainless steel standard (emittance about 0.06) and a blackened standard (emittance about 0.9). The standards shall be traceable to measurements made using an absolute test method (for example, Test Method C835). It is recommended that one set be used as working standards and the other set be put aside and used for periodic checks of the emittance of the working standards. The time period between checks of the working standards will depend upon the amount that the working standards are used.

6.1.6 *Sample of the Surface to be Tested,* collected carefully so as to preserve the in-situ surface condition. A specimen slightly larger than the outer dimensions of the emissometer measuring head is carefully cut from the sample.

7. Procedure

7.1 *Set-up*—A sample of the material to be tested shall be collected as near as possible to the time of the test, to control sample conditioning history. The emissometer shall be allowed to equilibrate until the calibrations remain stable. For measurements in the field, the emissometer shall be set up as near as possible to the sample site.

NOTE 2—For the emissometer[4] a warm-up time of one hour has been found to be acceptable.

7.2 *Instrument Calibration:*

7.2.1 Place the high- and low-emittance standards on the heat sink. Thermal contact between the standards and the heat sink is improved by filling the air gaps between the standards and the heat sink with distilled water or other high conductance material.

7.2.2 Place the emissometer measuring head over the high-emittance standard. Allow at least 90 s for the reading to stabilize.

7.2.2.1 If a standard millivoltmeter is used as the readout device, record the output voltage, V_{hi}.

7.2.2.2 If the emittance is read out directly, use the variable gain control on the readout device to adjust the readout to be equal to the emittance of the high-emittance standard.

7.2.3 Place the emissometer measuring head over the low-emittance standard, and again allow at least 90 s for the reading to stabilize.

7.2.3.1 If a standard millivoltmeter is used as the readout device, calculate the expected reading from the low-emittance standard by means of (Eq 2) (see Section 8). Then adjust the offset trimmer on the emissometer measuring head until the readout value agrees with the calculated reading.

7.2.3.2 If the emittance is read out directly, use the offset trimmer control on the emissometer to adjust the readout to be equal to the emittance of the low-emittance standard.

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7.2.4 Place the emissometer measuring head over the high-emittance standard again, and repeat the procedure in 7.2.1 – 7.2.3, until the measuring head can be moved from one standard to the other without requiring any adjustment to obtain the expected reading.

7.3 *Specimen Collection:*

7.3.1 The specimen collection procedure depends on the nature of the material. In general, the procedure shall ensure minimum alteration of the specimen surface. For example, if the emittance of a dust-covered specimen is to be determined, the dust shall not be removed.

7.3.2 All contact with the specimen surface shall be avoided. Furthermore, the specimen surface shall not be exposed to a flow of gas or liquid that is not ordinarily present as installed. If power tools are used, care shall be taken to prevent disturbance of any surface deposit layer (dust, etc.) due to vibration. Handling and time lag before emittance measurement shall be minimized.

7.3.3 The specimen shall be flat to within 0.25 mm over an area equal to that of the emissometer measuring head.

7.3.4 The specimen thermal conductance (that is, thermal conductivity divided by specimen thickness) shall be greater than 1100 W/m^2·K, corresponding to a thermal resistance of less than 0.00091 m^2·K/W. For example, if the specimen material is glass, with a thermal conductivity of about 1.0 W/m·K, then the specimen thickness shall be less than 0.91 mm.

7.4 *Measurement of Specimen Emittance*—The procedure given in 7.4.1 – 7.4.4.2 shall be used to measure the emittance of the specimen of material.

7.4.1 Check the emissometer calibration as using 7.2.

7.4.2 Leave the high-emittance standard in place, but remove the low-emittance standard from the heat sink and replace it with the specimen. For non-hygroscopic specimens, a few drops of distilled water or other high conductance material shall be used to improve the thermal contact between the specimen and the heat sink. Do not use water with hygroscopic specimens, such as paper. Allow at least 90 s for temperatures to stabilize.

7.4.3 Place the emissometer measuring head over the high-emittance standard, and wait for the output reading to stabilize. If a standard millivoltmeter is used, record the output voltage reading.

7.4.4 Place the emissometer measuring head over the specimen, and wait for the output reading to stabilize.

7.4.4.1 If the emittance is read out directly, record the value for the specimen.

7.4.4.2 If a standard millivoltmeter is used, the emittance of the specimen shall be calculated using (Eq 3).

8. Calculations

8.1 The expected reading of low emittance standard (standard millivoltmeter) is given by:

$$V_{low} = \varepsilon_{low} \times V_{hi} / \varepsilon_{hi} \quad (2)$$

8.2 The emittance of specimen (standard millivoltmeter) is given by:

$$\varepsilon_{spec} = V_{spec} \times \varepsilon_{hi} / V_{hi} \quad (3)$$

9. Report

9.1 Report the following information:

9.1.1 Name and any other pertinent identification of the material, including a physical description.

9.1.2 Description of the specimen and its relationship to the sample, including a brief history of the specimen, if known.

9.1.3 Thickness of the specimen as received and as tested.

9.1.4 Temperature of the room in which the measurements were conducted, °C.

9.1.5 Source and assigned emittance values of the calibration standards.

9.1.6 Measured values of emittance. At least two measured values shall be reported to demonstrate repeatability of the instrument for the particular type of surface.

9.1.7 Date of the test, and time periods involved in the test.

9.1.8 Statement of compliance with list of any exceptions. A suggested wording is: "This test conformed with all requirements of ASTM C1371 with the exception of (a complete list of exceptions follows)."

9.1.9 Estimated or calculated uncertainty in reported values.

10. Precision and Bias

10.1 *Interlaboratory Test Program*—An informal interlaboratory comparison was conducted during 1988 and 1989 (**1**). Specimens of Type 304L stainless steel (ε ~ 0.12) and electrolytic tough pitch copper (ε ~ 0.04) were specially prepared.

10.1.1 Test determinations were made on one specimen of each material at one laboratory on 23 different days spanning a time period of about one year. On each day, two test determinations were made by a single operator on each specimen, for a total of 46 test results per material. Another specimen of each material was prepared. A single operator at the same laboratory made two test determinations on each specimen on one day. A single operator at another laboratory made two test determinations on each specimen on one day and four test determinations on each specimen three days later. Yet another specimen of each material was prepared. A single operator at the first laboratory made two test determinations on each specimen on one day. A single operator at a third laboratory made four test determinations on each specimen on one day. These data were analyzed by the methods given in Practice E691 to determine repeatability and reproducibility limits. The fact that many of the test determinations were made over an extended period of time was ignored in this analysis.

10.1.2 Additional specimens of stainless steel and copper were prepared. Each specimen was measured at the first laboratory using an emissometer. The first laboratory also measured the total hemispherical emittance of a specimen of stainless steel using Test Method C835. Three other laboratories used absolute techniques to determine the total hemispherical emittance of each of the materials. The techniques were a calorimeter, a reflectometer, and an infrared thermometer.

10.2 *Test Result*—Each separate test determination from the three laboratories was treated as a test result, for a total of 60 test results per material.

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10.3 *Precision*—The numerical values are in dimensionless emittance units. Repeatability limit and reproducibility limit are used as specified in Practice E177. The respective standard deviations among test results is obtained by dividing the above limit values by 2.8.

	Stainless Steel	Copper
95 % repeatability limit (within laboratory)	0.011 units	0.015 units
95 % reproducibility limit (between laboratories)	0.015 units	0.019 units

10.4 *Bias*—Statistical analyses were performed on the results of paired measurements by the emissometer and the absolute techniques. Separate analyses were performed for the stainless steel and copper specimens. The analyses showed no statistically significant difference (at the 5 % significance level) between the average values obtained with the emissometer and the absolute techniques. It is concluded that there is no statistically significant bias in this test method.

11. Keywords

11.1 emissometer; emittance; portable ; total hemispherical emittance; radiation

APPENDIX

(Nonmandatory Information)

X1. HEMISPHERICAL EMITTANCE MEASUREMENTS

X1.1 Because of the application to aging of reflective insulations, there is considerable interest in employing this test method for measurements of hemispherical emittance. This appendix details the pros and cons of using the test method to quantify hemispherical emittance.

X1.1.1 This test method is different from either of two other techniques (Test Method C835 and Test Method E408) for measurement of hemispherical emittance. Instruments for measuring hemispherical emittance typically comprise an enclosed highly reflective envelope, the only absorbing/emitting surfaces being the specimen and the detector or flux source, or both. Alternatively, the specimen is heated, and the total flux through the specimen is measured. The manufacturer of the one instrument known to conform to this test method intended for their instrument to measure the total hemispherical emittance, but because of the directional properties of many real surfaces (especially metals), the property that is measured is somewhere between the hemispherical and normal emittance values (**3**).

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X1.1.2 Note that the detector plane is parallel to the plane of the specimen in Fig. X1.1. For the instrument of this test method, the source of emitted thermal energy is the exposed surface of the detector itself, and the heat flow is from the detector surface to the specimen surface. Since the absolute temperature of the detector is known and the heat flow is measured—and since the instrument is calibrated against standards of known emittance, at the same temperature as a test specimen—the emittance of the test specimen can be solved from:

$$V = k \times \sigma \left(\frac{(T_s^{\,4} - T_d^{\,4})}{(1/\varepsilon_s + 1/\varepsilon_d - 1)} \right) \quad (X1.1)$$

where k is a proportionality constant.

X1.1.3 The arrangement of the detector is such that its voltage response is a function of its own diffuse radiation of heat energy (**4**), and that the emitted radiation is attenuated by the energy reflected from the specimen surface over a detector exposure angle of about 168–169° (± about 84° from normal). This is illustrated in Fig. X1.1.

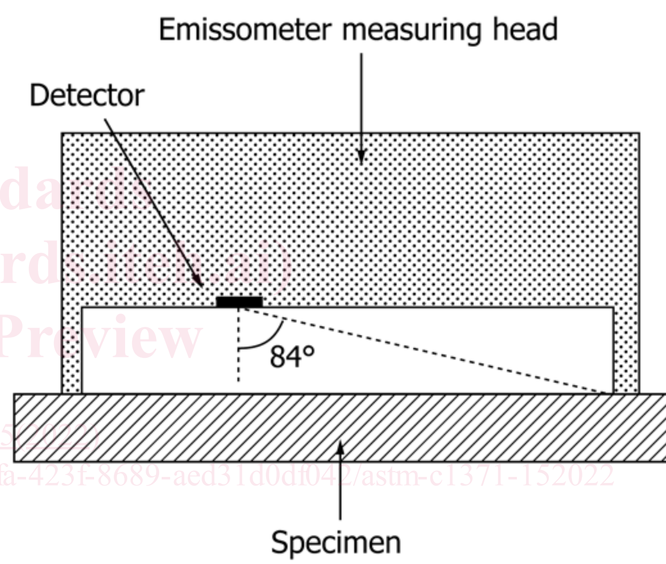

FIG. X1.1 Cross-section of Emissometer Measuring Head, Showing Plane Angle Subtended by Detector Element

X1.1.4 Fig. X1.2(a) shows the directional emittance of some smooth metal surfaces, while Fig. X1.2(b) shows a similar plot for some dielectric materials (**5**). Note that for aluminum, the emittance is about 0.04 for angles of 0 to about 38° from normal. For angles greater than 38° from normal, the emittance increases, reaching about 0.14 at an angle of about 83° from normal. The average of the integral of this curve (the hemispherical emittance) appears to be about 0.057—a difference of almost 42 % from the normal emittance. This high degree of sensitivity to direction signifies the existence of a large specular component to the reflectance of such a surface (there will be some diffuse emittance/reflectance, as well).

X1.1.5 For aluminum oxide, the directional emittance is about 0.82 at the normal angle, rises to a peak of probably