NOTICE: This standard has either been superseded and replaced by a new version or withdrawn.
Contact ASTM International (www.astm.org) for the latest information

Designation: C 835 – 01

Standard Test Method for Total Hemispherical Emittance of Surfaces up to 1400°C[1]

This standard is issued under the fixed designation C 835; 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 calorimetric test method covers the determination of total hemispherical emittance of metal and graphite surfaces and coated metal surfaces up to approximately 1400°C. The upper-use temperature is limited only by the characteristics (for example, melting temperature, vapor pressure) of the specimen and the design limits of the test facility. This test method has been demonstrated for use up to 1400°C.

1.2 *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 and health practices and determine the applicability of regulatory limitations prior to use.* For specific hazard statements, see Section 7.

2. Referenced Documents

2.1 *ASTM Standards:*

C 168 Terminology Relating to Thermal Insulating Materials[2]

E 230 Temperature-Electromotive Force (EMF) Tables for Standardized Thermocouples[3]

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method[4]

3. Terminology

3.1 *Definitions*—The terms and symbols are as defined in Terminology C 168 with exceptions included as appropriate.

3.2 *Symbols:*

e_i = error in the variable i, ± %,
ϵ_1 = total hemispherical emittance of heated specimen, dimensionless,
ϵ_2 = total hemispherical emittance of bell jar inner surface, dimensionless,
σ = Stefan-Boltzmann constant,
= 5.669×10^{-8} W/m^2·K^4,
Q = heat flow rate, W,
T_1 = temperature of heated specimen, K,
T_2 = temperature of bell jar inner surface, K,
A_1 = surface area of specimen over which heat generation is measured, m^2,
A_2 = surface area of bell jar inner surface, m^2,
F = the gray body shape factor, which includes the effect of geometry and the departure of real surfaces from blackbody conditions, dimensionless, and
Pa = absolute pressure, pascal (N/m^2). One pascal is equivalent to 0.00750 mm Hg.

4. Summary of Test Method

4.1 A strip specimen of the material, approximately 13 mm wide and 250 mm long, is placed in an evacuated chamber and is directly heated with an electric current to the temperature at which the emittance measurement is desired. The power dissipated over a small central region of the specimen and the temperature of this region are measured. Using the Stefan-Boltzmann equation, this power is equated to the radiative heat transfer to the surroundings and, with the measured temperature, is used to calculate the value of the total hemispherical emittance of the specimen surface.

5. Significance and Use

5.1 The emittance as measured by this test method can be used in the calculation of radiant heat transfer from surfaces that are representative of the tested specimens, and that are within the temperature range of the tested specimens.

5.2 This test method can be used to determine the effect of service conditions on the emittance of materials. In particular, the use of this test method with furnace exposure (time at temperature) of the materials commonly used in all-metallic insulations can determine the effects of oxidation on emittance.

5.3 The measurements described in this test method are conducted in a vacuum environment. Usually this condition will provide emittance values that are applicable to materials used under other conditions, such as in an air environment. However, it must be recognized that surface properties of materials used in air or other atmospheres may be different. In addition, preconditioned surfaces, as described in 5.2, may be altered in a vacuum environment because of vacuum stripping of absorbed gases and other associated vacuum effects. Thus,

iTeh Standards (https://standards.iteh.ai) Document Preview ASTM C835-01 https://standards.iteh.ai/catalog/standards/sist/2a174ba...70b1/astm-c835-01

[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 Measurements.

Current edition approved Nov. 10, 2001. Published January 2002. Originally published as C 835 – 76. Last previous edition C 835 – 00.

[2] *Annual Book of ASTM Standards*, Vol 04.06.

[3] *Annual Book of ASTM Standards*, Vol 14.03.

[4] *Annual Book of ASTM Standards*, Vol 14.02.

Copyright © ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States.

emittances measured under vacuum may have values that differ from those that exist in air, and the user must be aware of this situation. With these qualifications in mind, emittance obtained by this test method may be applied to predictions of thermal transference.

5.4 Several assumptions are made in the derivation of the emittance calculation as described in this test method. They are that:

5.4.1 The enclosure is a blackbody emitter at a uniform temperature,

5.4.2 The total hemispherical absorptance of the completely diffuse blackbody radiation at the temperature of the enclosure is equal to the total hemispherical emittance of the specimen at its temperature, and

5.4.3 There is no heat loss from the test section by convection or conduction. For most materials tested by the procedures as described in this test method, the effects of these assumptions are small and either neglected or corrections are made to the measured emittance.

5.5 For satisfactory results in conformance with this test method, the principles governing the size, construction, and use of apparatus described in this test method should be followed. If these principles are followed, any measured value obtained by the use of this test method is expected to be accurate to within ±5 %. If the results are to be reported as having been obtained by this test method, all of the requirements prescribed in this test method shall be met.

5.6 It is not practical in a test method of this type to establish details of construction and procedure to cover all contingencies that might offer difficulties to a person without technical knowledge concerning the theory of heat transfer, temperature measurements, and general testing practices. Standardization of this test method does not reduce the need for such technical knowledge. It is recognized also that it would be unwise to restrict in any way the development of improved or new methods or procedures by research workers because of standardization of this test method.

6. Apparatus

6.1 In general, the apparatus shall consist of the following equipment: a bell jar, power supply and multi-meter for voltage and current measurements, thermocouples and voltmeter or other readout, vacuum system, and specimen holders. A schematic of the test arrangement is shown in Fig. 1. Means must be provided for electrically heating the specimen, and instruments are required to measure the electrical power input to the specimen and the temperatures of the specimen and surrounding surface.

6.2 *Bell Jar*:

6.2.1 The bell jar may be either metal or glass with an inner surface that presents a blackbody environment to the specimen located near the center. This blackbody effect is achieved by providing a highly absorbing surface and by making the surface area much larger than the specimen surface area. The relationship between bell jar size and its required surface emittance is estimated from the following equation for the gray body shape factor for a surface completely enclosed by another surface:

$$F = \frac{1}{\frac{1}{\epsilon_1} + \frac{A_1}{A_2}\left(\frac{1}{\epsilon_2} - 1\right)} \quad (1)$$

For this test method to apply, the following condition must exist:

$$\frac{1}{\epsilon_1} >> \frac{A_1}{A_2}\left(\frac{1}{\epsilon_2} - 1\right) \quad (2)$$

This condition can be satisfied for all possible values of specimen emittance by an apparatus design in which A_1/A_2 has a value less than 0.01 and ϵ_2 has a value greater than 0.8. To ensure that the inner surface has an emittance greater than 0.8, metal and glass bell jars shall be coated with a black paint **(1)**.[5] It is permissible to leave small areas in the glass bell jars uncoated for visual monitoring of the specimen during a test. Metal bell jars can be provided with small-area glass view ports for sample observation.

6.2.2 The bell jar must be opaque to external high energy radiation sources (such as open furnaces, sunlight, and other emittance apparatuses) if they are in view of the specimen. Both the coated metal and coated glass bell jars meet this requirement.

iTeh Standards (https://standards.iteh.ai) Document Preview ASTM C835-01

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

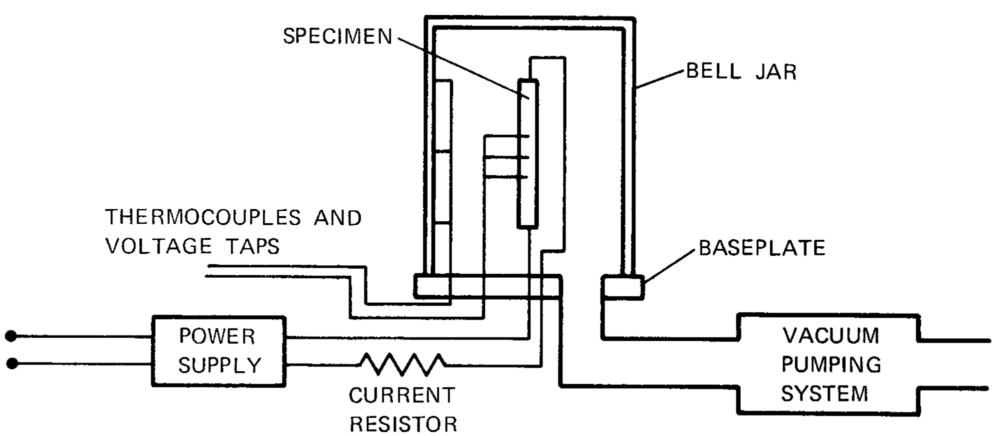


FIG. 1 System Arrangement

6.2.3 The need for bell jar cooling is determined by the lower-use temperature of the particular apparatus and by the maximum natural heat dissipation of the bell jar. A bell jar operating at room temperature (20°C) may be used for specimen temperatures down to about 120°C. At least a 100°C difference between the specimen and the bell jar is recommended to achieve the desired method accuracy. Therefore, for lower specimen temperatures, bell jar cooling is required. If the natural heat dissipation of the bell jar is not sufficient to maintain its temperature at the desired level for any other operating condition, auxiliary cooling of the bell jar is also required. An alternative to bell jar cooling is the use of a cooled shroud (for example, cooled by liquid nitrogen) between the specimen and the bell jar.

6.3 *Power Supply*— The power supply may be either ac or dc and is used to heat the test specimen electrically by making it a resistive part of the circuit. The true electrical power to the test section must be measured within a proven uncertainty of ± 1 % or better.

6.4 *Thermocouples*, are used for measuring the surface temperature of the specimen. The thermocouple materials must have a melting point significantly above the highest test temperature of the specimen. To minimize temperature measurement errors due to wire conduction losses, the use of high-thermal conductivity materials such as copper should be avoided. The size of the thermocouple wire should be the minimum practical. Experience indicates that diameters less than 0.13 mm provide acceptable results.

6.4.1 The test section is defined by two thermocouples equally spaced from the specimen holders. A third thermocouple is located at the center of the specimen. Spot welding has been found to be the most acceptable method of attachment because it results in minimum disturbance of the specimen surface. Swaging and peening are alternative methods prescribed for specimens that do not permit spot welding.

6.4.2 The number of thermocouples used to measure the temperature of the absorbing surface shall be sufficient to provide a representative average. Four thermocouples have been found to be sufficient for the system shown in Fig. 1. Thermocouple locations include three on the bell jar and one on the baseplate.

6.4.3 The voltage drop in the measurement area of the specimen is measured by tapping to similar elements of each of the two thermocouples that bound the test section. A potentiometer, or equivalent instrument, having a sensitivity of 2μV or less is required for measuring the thermocouple emf's from which the test section temperatures are obtained.

6.4.4 Temperature sensors must be calibrated to within the uncertainty allowed by the apparatus design accuracy. For information concerning sensitivity and accuracy of thermocouples, see Table 1 of Tables E 230. For a comprehensive discussion on the use of thermocouples, see Ref **(2)**. For low temperature thermocouple reference tables, see Ref **(3)**.

6.5 *Vacuum System*— A vacuum system is required to reduce the pressure in the bell jar to 1.3 mPa or less to minimize convection and conduction through the residual gas. This effect is illustrated in Fig. 2, which shows the measured emittance of oxidized Inconel versus system pressure. This curve is based upon the *assumption* that all heat transfer from the specimen is by radiation. As pressure increases, gas conduction becomes important.

6.5.1 For the specified pressure level, a pumping system consisting of a diffusion or ion pump and mechanical pump is required. If backstreaming is a problem, cold trapping is required. The specifications of an existing system are included in Table 1 and photographs of a system are included in Fig. 3 and Fig. 4. This information is included as a guide to assist in the design of a facility and is not intended to be a rigid specification.

6.5.2 The specified pressure (1.3 mPa or less) must exist in the bell jar. If measured elsewhere in the pumping system, such as in the diffusion pump inlet, the pressure drop between the measuring location and the bell jar must be accounted for. The vacuum system should also be checked for gross leakage that could allow incoming gas to sweep over the specimen.

6.6 *Specimen Holders*, must be designed to allow for thermal expansion of the specimen without buckling. The lower specimen holder shown in Fig. 4 is designed to move up and down in its support to allow for thermal expansion.Holders should be positioned off-center within the bell jar to minimize normal reflections between the specimen and bell jar inner

iTeh Standards
(https://standards.iteh.ai)
Document Preview
ASTM C835-01

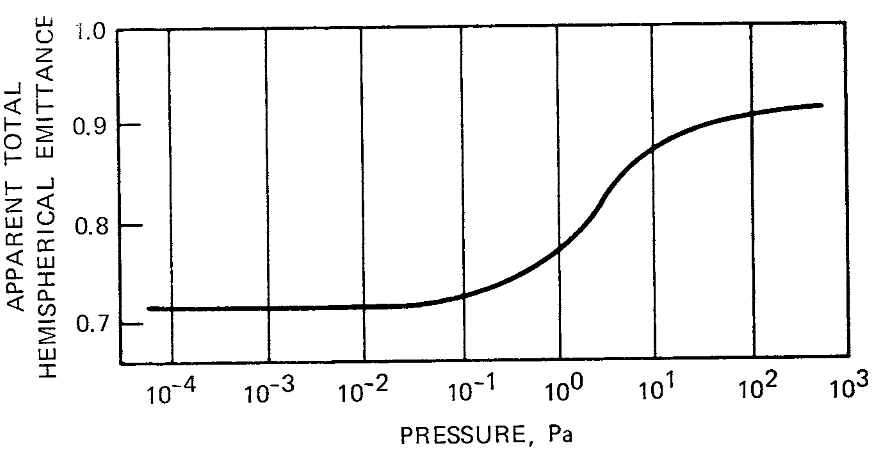


FIG. 2 Example of Effect of Air Pressure on Measured Emittance of Oxidized Inconel

TABLE 1 Specifications for the Emittance Test Facility Shown in Figs. 3 and 4

Vacuum system:
A manual vacuum coater system
Vacuum pumps consisting of an 0.8-m^3/s diffusion pump (100-mm inlet) backed by an 0.0023-m^3/s mechanical pump
A glass bell jar, 0.46 m in diameter by 0.91 m high with an implosion shield
Vacuum gaging, including two thermocouple-type roughing gages and an ionization gage
A specimen holder having a movable lower clamp to allow for thermal expansion
A liquid nitrogen cold trap
Power Supply:
Output voltage—0 to 16 V
Maximum current—100 A
Sample Temperature Range:
Maximum 20 to 1400°C
Sample Size:
Nominal—0.25 by 13 by 250 mm
Maximum length—500 mm
Power Measurement:
Current is determined by measurement of voltage across a precision-calibrated resistor (0 to 100 A)
Voltage is measured by a digital voltmeter.

surface. Specimen holders require auxiliary cooling if end conduction from the specimen causes overheating.

6.7 *Micrometer Calipers*, or other means are needed to measure the dimensions (width and thickness) of the test specimen and the length between voltage taps and thermocouples at room temperature. The specimen dimensions (width and thickness) should be measured to the nearest 0.025 mm. The length between voltage taps should be measured to the nearest 0.5 mm. The length between thermocouples should also be measured to the nearest 0.5 mm.

6.8 All instruments shall be calibrated initially and recalibrated at reasonable intervals.

iTeh Standards (https://standards.iteh.ai) Document Preview
ASTM C835-06

7. Hazards

7.1 Thin metallic specimens provide the possibility for cuts to the handler. Specimens should, therefore, be treated gently and with care.

7.2 Power leads to the apparatus should be well insulated and fused.

7.3 Power to the specimen should be cut off before dismantling has begun.

7.4 Normal safety precautions dictate that an implosion shield be provided if a glass bell jar is used. One example of a problem that can occur with a glass bell jar is the local thermal stress resulting from uneven heating of the bell jar.

8. Test Specimen

8.1 The specimen used for a test must be sufficiently uniform in surface to represent the sample material from which it is taken. Caution must be exercised to prevent contamination of the specimen surface from all sources, and especially from fingerprints.

8.2 The size of the test specimen must be compatible with the power supply and desired maximum test temperature. Fig. 5 shows acceptable overall test specimen dimensions for three materials in use with a 16-V, 100-A ac power supply. Specimens should be prepared so that edges are straight, smooth, and parallel. Edges should have the same surface condition as the rest of the specimen.

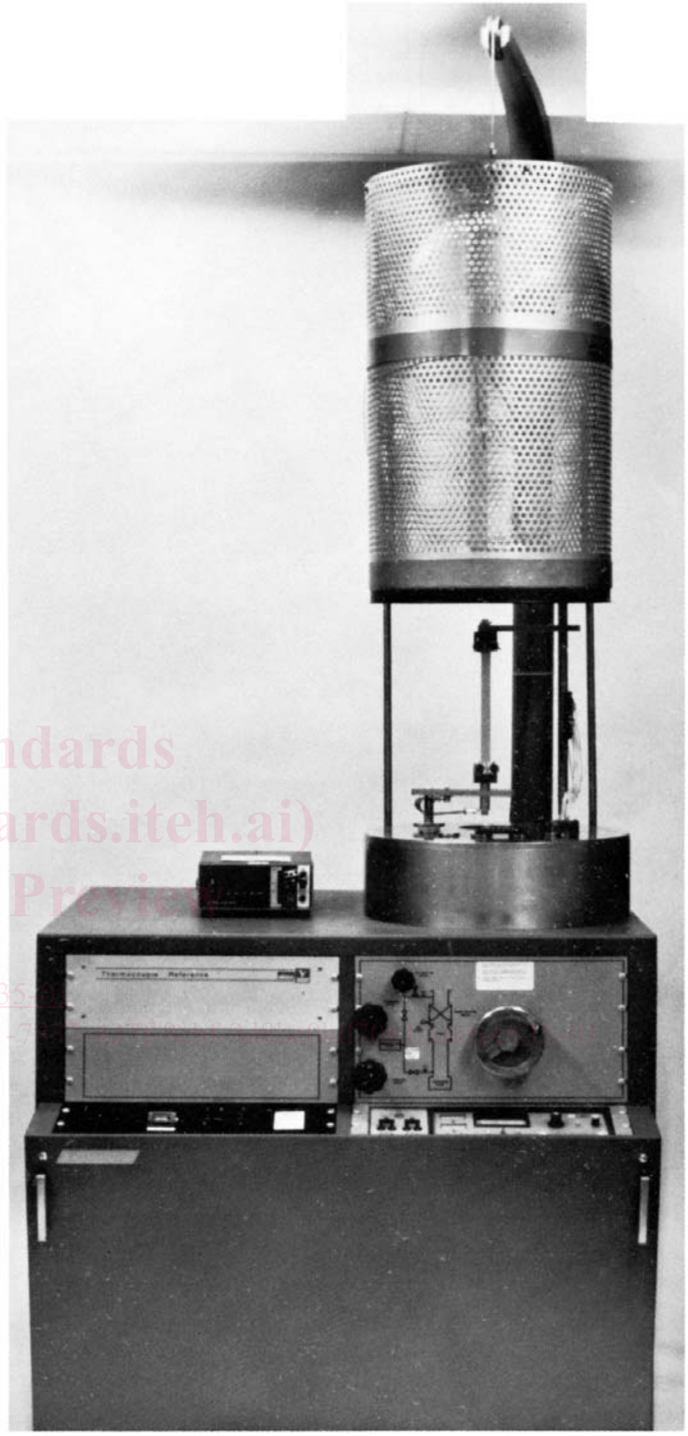


FIG. 3 Example of Vacuum Emittance Test Facility

NOTE 1—Previous editions of Test Method C 835 described reference emittance specimens available from the National Institute of Standards

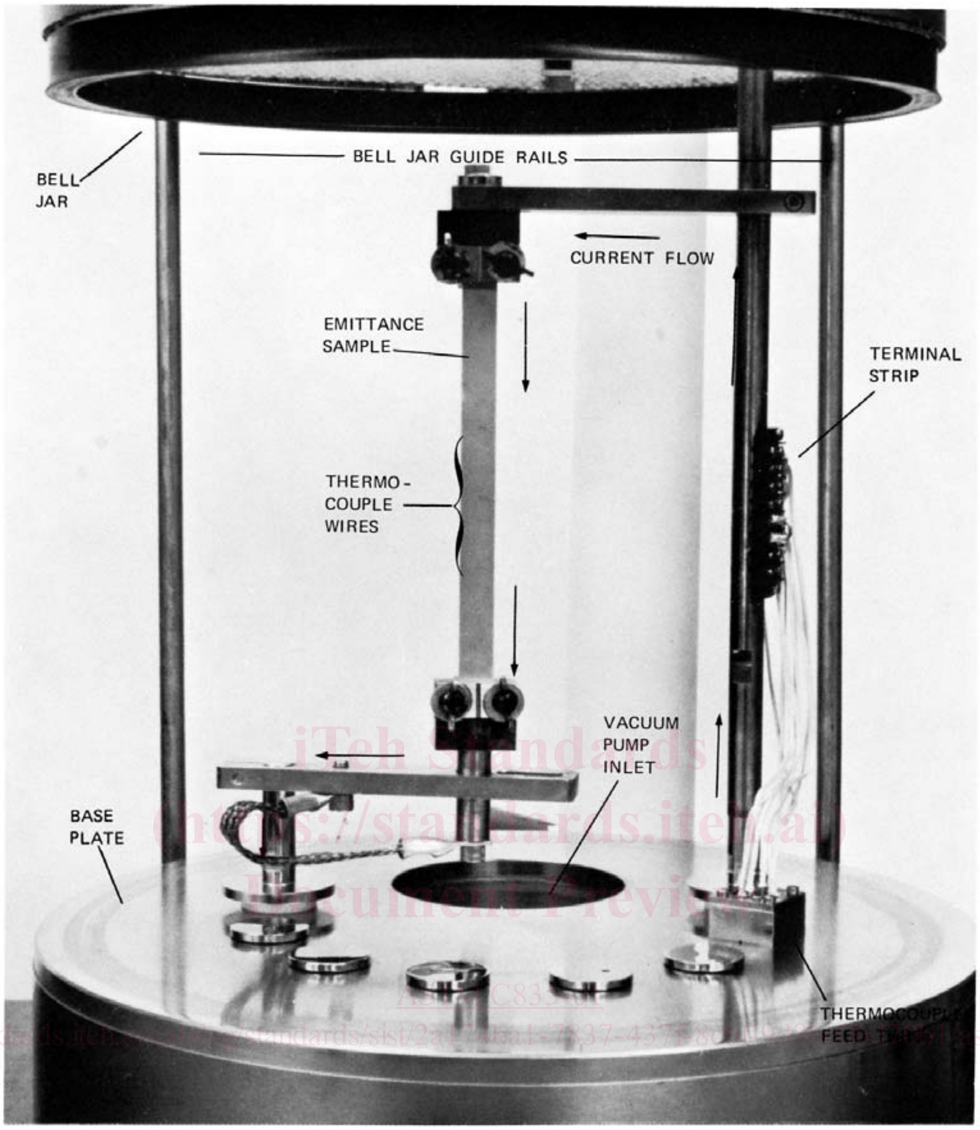


FIG. 4 Example of Emittance Sample in the Test Fixture

iTeh Standards (https://standards.iteh.ai) Document Preview

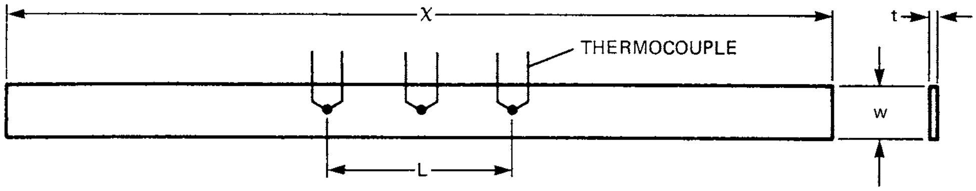
and Technology (NIST). These specimens have been discontinued by the Standard Reference Materials Program at NIST.

8.3 Three thermocouples shall be fastened to the specimen over the test length as indicated in Fig. 5. A suitable test section length, *L*, compatible with the requirements of 8.2, has been found to be about 75 mm. The two wires that comprise a thermocouple should be spot-welded to the specimen surface separately. They can be attached either along a line normal to the specimen axis or displaced slightly (within 0.5 mm) along the axis. These two arrangements are illustrated in Fig. 6. The first arrangement allows a small displacement between the thermocouple wires and can be used with an ac power supply. Any ac pickup can easily be rejected when the thermocouple dc voltage output is measured. The second arrangement would position the thermocouple wires along an equipotential line and is required when a dc power supply is used. In this way, the specimen dc voltage drop will not influence the thermocouple output. Thermocouple wire alignment should be checked by reversing the power supply polarity at each reading. If the wires are properly aligned, the thermocouple output will not change.

8.4 Similar elements of the two end thermocouples are used as voltage taps to measure the test section voltage drop.

8.5 The length of the test specimen between end connectors and end voltage taps must be sufficient to minimize conduction errors due to the heat sinks provided by the end connectors. The analytical results shown in Fig. 7 are included as guidelines to assist in the selection of test specimen and test section lengths. The four curves shown include combinations of emittance and thermal conductivity that cover a wide range of possible test specimen properties. These predictions are based upon a total conduction loss out of the test section equal to about 2.5 % of the power input to the test section.

8.5.1 The curve for aluminum illustrates that materials with high thermal conductivity and low emittance require the longest test specimen length and the shortest test section



MATERIAL	t	w	L	X
INCONEL	0.25	13	75	250
STAINLESS STEEL	0.25	13	75	250
ALUMINUM	0.25	13	50	500

NOTE 1—All dimensions are in millimetres.

FIG. 5 Typical Test Specimen Dimensions

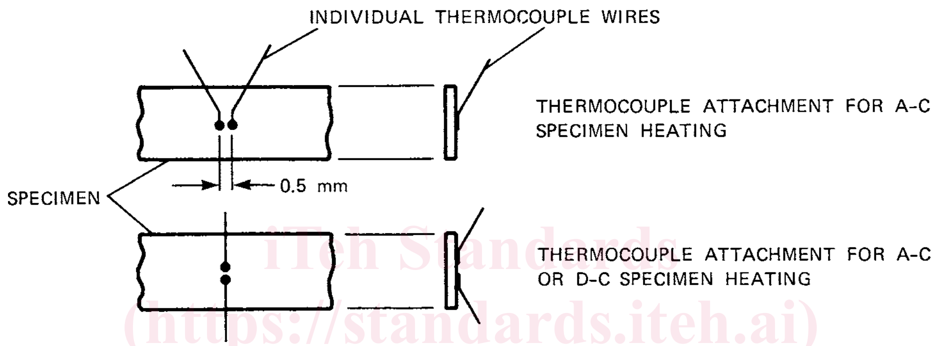


FIG. 6 Thermocouple Attachment

iTeh Standards
(https://standards.iteh.ai)
Document Preview
ASTM C835-01

length. These effects are most pronounced for low test temperatures because the radiated power is at a minimum relative to the power conducted out of the test section.

8.5.2 If the original three thermocouples indicate a temperature gradient in the test section, additional thermocouples should be installed about 6 mm outside one or both ends of the test section. These extra thermocouples are used to better define the test section temperature profile.

8.5.3 Alternative means of minimizing end conduction errors are discussed in 12.4.

9. Verification

9.1 When sufficient apparatuses become available, they shall be verified by interlaboratory comparison testing on two specimens with emittances that span the expected range to be tested. If practical, the thermal conductivities of these specimens should also span the expected use range. Both specimens should be tested at several temperatures that span the use temperature of the test apparatus. Stable materials will need to be selected for verification purposes. The apparatus shall be considered successfully verified when measured emittance values from interlaboratory comparison testing can be duplicated to ±5 %.

10. Procedure

10.1 After connecting the electrical leads to the specimen and completing the hookup of thermocouples and voltage taps to available indicators or recorders, evacuate the bell jar to the desired pressure.

10.2 Heat the specimen electrically to the desired test temperature and allow power and temperature indications to stabilize.

10.3 After steady-state conditions have been attained, continue the test at the steady state with the necessary observations being made to determine the average surface temperature of the specimen, the average temperature of the bell jar inner surface, and the electrical energy input to the test section (central portion of test specimen). Continue the observations at intervals of not less than 5 min until three successive sets of observations give emittance values differing by not more than 1 %.

10.4 For some materials, the surface may change at high temperatures in a vacuum environment **(4)**. Some materials oxidize in an imperfect vacuum and require purging the bell jar with nitrogen if this is a problem. To ensure that the surface has not changed during testing, the specimen shall be retested at one or more of the lower test temperatures after the maximum temperature has been tested. If the retested emittance value at a particular temperature has changed by more than 2 % of the original measured value, this test method shall not be applicable for the higher tested temperatures.

11. Calculations

11.1 Based on the assumption that the test specimen is a *small* radiating body surrounded by a large absorbing surface, the total hemispherical emittance of the specimen can be calculated as follows: