



# Standard Practice for Determining Steady State Thermal Transmittance of Fenestration Systems<sup>1</sup>

This standard is issued under the fixed designation E 1423; 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 covers standard test specimen sizes and test conditions as well as the calculation and presentation of the thermal transmittance and conductance data measured in accordance with Test Method C 1199. The standard sizes and conditions are to be used for fenestration product comparison purposes. The specifier may choose other sizes and conditions for product development or research purposes.

1.2 This practice deals with the determination of the thermal properties of a fenestration system installed vertically in the absence of solar heat gain and air leakage effects.

NOTE 1—To determine air leakage effects of fenestration systems, Test Method E 283 or E 1424 should be referenced.

1.3 This practice specifies the procedure for determining the standardized thermal transmittance of a fenestration test specimen using specified values of the room-side and weather-side surface heat transfer coefficients,  $h_h$  and  $h_c$ , respectively.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other.

1.5 *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.*

## 2. Referenced Documents

### 2.1 ASTM Standards:

- C 168 Terminology Relating to Thermal Insulating Materials<sup>2</sup>
- C 1199 Test Method for Measuring the Steady State Thermal Transmittance of Fenestration Systems Using Hot Box Methods<sup>2</sup>
- C 1363 Test Method for Thermal Performance of Building

- Assemblies by Means of a Hot Box Apparatus<sup>2</sup>
- E 283 Test Method for Determining the Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen<sup>3</sup>
- E 631 Terminology of Building Constructions<sup>3</sup>
- E 783 Test Method for Field Measurement of Air Leakage Through Installed Exterior Windows and Doors<sup>3</sup>
- E 1424 Test Method for Determining the Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure and Temperature Differences Across the Specimen<sup>3</sup>

## 3. Terminology

3.1 *Definitions*—Definitions and terms are in accordance with Terminology E 631 and C 168, from which the following have been selected and modified to apply specifically to fenestration systems. See Fig. 1 and Fig. 2 for variable identification. (For further information on definitions and procedures, see Appendix X1 or Test Method C 1199.)

3.1.1 *surface heat transfer coefficient, h* (sometimes called *surface conductance* or *film coefficient*)—the time rate of heat flow from a unit area of a surface to its surroundings, induced by a unit temperature difference between the surface and the environment. Subscripts are used to differentiate between room-side ( $1$  or  $r$ ) and weather-side ( $2$  or  $c$ ) surface heat transfer coefficients (see Fig. 1 and Fig. 2).

3.1.2 *test specimen thermal transmittance  $U_s$*  (sometimes called *overall coefficient of heat transfer*)—the heat transfer in unit time through unit area of a test specimen and its boundary air films, induced by unit temperature difference between the environments on each side.

### 3.2 Definitions of Terms Specific to This Standard:

3.2.1 *overall thermal resistance,  $R_s$* —the temperature difference between the environments on the two sides of a body or assembly when a unit heat flow per unit time per unit area is established through the body or assembly under steady-state conditions. It is defined as follows:

$$R_s = \frac{1}{U_s} \quad (1)$$

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 04.06.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 04.11.

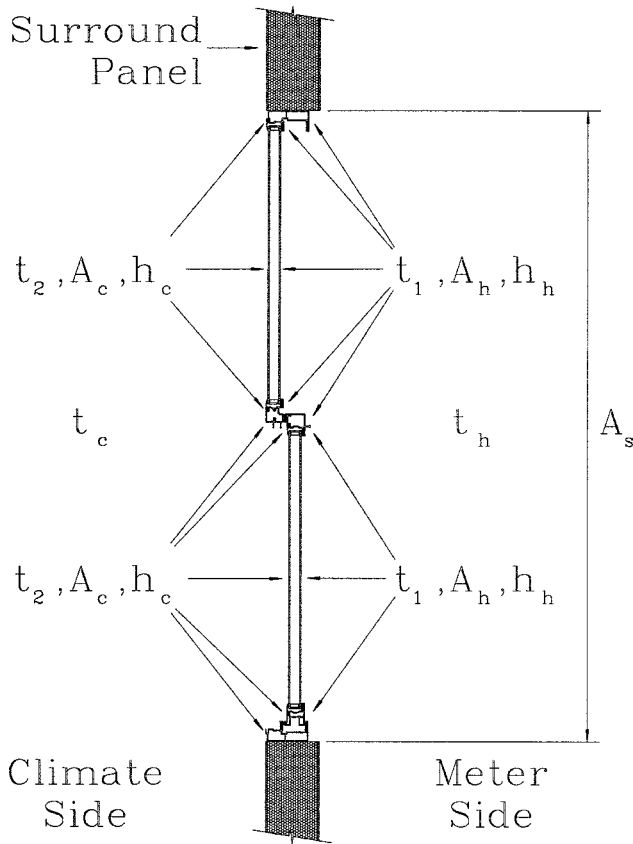


FIG. 1 Window Mounted Flush with Climate Side of Surround Panel

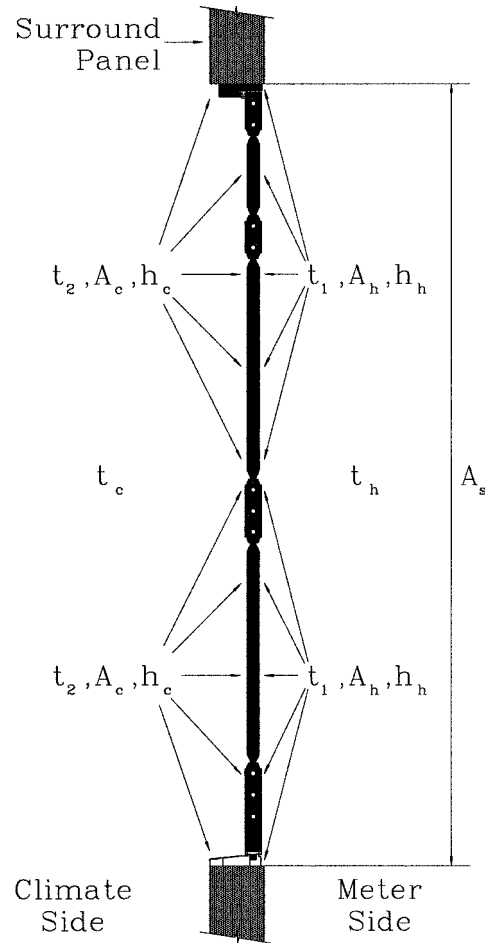


FIG. 2 Door Mounted Flush with Climate Side of Surround Panel

where:

$R_S$  = overall thermal resistance of specimen (air to air under test conditions),  $m^2 \cdot K/W$  ( $ft^2 \cdot hr \cdot ^\circ F/Btu$ ).

3.2.2 *standardized thermal transmittance,  $U_{ST}$* —the heat transfer in unit time through unit area of a specimen (using standardized surface heat transfer coefficients) induced by unit temperature difference between the environments on each side.

3.2.3 *surround panel* (sometimes called the *mask*, *mask wall*, or *homogeneous wall*)—a homogeneous wall in which the test specimen is mounted.

3.2.4 *test specimen*—the fenestration system or product being tested.

3.3 *Symbols*—The symbols, terms, and units used in this test method are as follows:

$A_c$  total heat transfer surface area of test specimen on weather side,  $m^2$

$A_h$  total heat transfer surface area of test specimen on room side,  $m^2$

$A_s$  projected area of test specimen, (same as open area in surround panel),  $m^2$

$h_c$  surface heat transfer coefficient, weather side,  $W/(m^2 \cdot K)$

$h_h$  surface heat transfer coefficient, room side,  $W/(m^2 \cdot K)$

$h_{STc}$  standardized surface heat transfer coefficient, weather side,  $(W/m^2 \cdot K)$

$h_{STh}$  standardized surface heat transfer coefficient, room side,  $(W/m^2 \cdot K)$

$R_S$  overall thermal resistance of test specimen (air to air under test conditions),  $m^2 \cdot K/W$

$t_c$  average temperature of weather side air,  $^\circ C$

$t_h$  average temperature of room side air,  $^\circ C$

$t_1$  average temperature of test specimen, room side surface,  $K$  or  $^\circ C$

$t_2$  average temperature of test specimen, weather side surface,  $K$  or  $^\circ C$

$U_S$  thermal transmittance of test specimen (air to air under test conditions),  $W/(m^2 \cdot K)$

$U_{ST}$  standardized thermal transmittance of test specimen,  $W/(m^2 \cdot K)$

#### 4. Significance and Use

4.1 This practice details the test specimen sizes and test conditions, namely, the room-side and weather-side air temperatures, and the air velocities on both sides of the test specimen, when testing fenestration products in accordance with Test Method C 1199.

4.2 The thermal transmittance and conductance of a specimen are affected by its size and three-dimensional geometry. Tests should therefore be conducted using the specimen sizes recommended in 5.1. Should the specimen size differ from those given in 5.1, the actual size shall be reported in the test report.

4.3 Many factors can affect the thermal performance of a fenestration system, including deflections of sealed glazing

units. Care should be exercised to maintain the original physical condition of the fenestration system and to install it in the surround panel to simulate actual installation.

4.4 The thermal transmittance and conductance results obtained do not reflect performances expected from field installations since they do not account for solar radiation and air leakage effects. The thermal transmittance and conductance results are taken from specified laboratory conditions and should be used only for fenestration product comparisons and as input to thermal performance analyses that also include solar and air leakage effects.

## 5. Test Specimen

5.1 *Specimen Sizes*—The specimen sizes given in Table 1 for different types of fenestration systems shall be used when testing fenestration products where the results will be used for product comparison purposes. All dimensions given are  $\pm 5\%$  or  $\pm 100$  mm (4 in.), whichever is less.

## 6. Test Conditions

6.1 *General*—A single set of test conditions does not necessarily define the thermal characteristics of a fenestration system. However, a single set of test conditions is specified to permit comparison of the thermal transmittance of different fenestration products. Thermal transmittance values obtained under this set of test conditions have been shown to be valid for the range of weather conditions typical of the North American climate [weather-side temperatures between 43 and  $-30^\circ\text{C}$  (110 and  $-22^\circ\text{F}$ ) and wind speeds up to 6.7 m/s (15 mph)].

6.2 *Test Conditions for U-Values for Comparison Purposes*—The test specimen shall be tested in accordance with Test Method C 1199. For comparison purposes, the following set of conditions shall be used (see Fig. 1):

$$t_h = 21 \pm 1^\circ\text{C} (70 \pm 2^\circ\text{F}) \quad (2)$$

$$t_c = -18 \pm 1^\circ\text{C} (0 \pm 2^\circ\text{F}) \quad (3)$$

6.2.1 *Room Side (Natural Convection)*—The air velocity should be less than 0.3 m/s (60 ft/min). For comparison

purposes, the standard surface heat transfer coefficient measured on the room side of each calibration transfer standard (CTS) during calibration shall be:

$$h_h = 7.0 \text{ W}/(\text{m}^2\cdot\text{K}) + 10\% (1.2 \text{ Btu}/(\text{hr}\cdot\text{ft}^2\cdot^\circ\text{F}) + 10\%) \quad (4)$$

[allowed CTS calibration range of 7.0 to 7.7 W/(m<sup>2</sup>·K)  
(1.2 to 1.3 Btu/(hr·ft<sup>2</sup>·°F))]

Since this is the natural convection lower limit of the indoor side overall surface heat transfer coefficient, a + 10 % variation in this value is allowed to accommodate some forced convection due to small room side air circulation fans that provide a more uniform flow distribution on the indoor side of the CTS.

NOTE 2—Using the 1997 American Society for Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) Fundamentals Handbook (1)<sup>4</sup>, Fenestration Chapter 29, Table 3, the indoor side of the overall combined natural convection, radiation heat transfer coefficient for a 1.22-m (4-ft) high, 13-mm (0.5-in.) wide cavity, double glazed, low emittance glazing unit is 6.98 W/(m<sup>2</sup>·K) (1.23 Btu/(hr·ft<sup>2</sup>·°F)). For a 1.22-m (4-ft) high, 12.7-mm (0.5-in.) thick high density expanded polystyrene (EPS) foam core CTS with two 4-mm (0.16-in.) glass faces, the indoor side calculated overall combined natural convection, radiation heat transfer coefficient is 7.02 W/(m<sup>2</sup>·K) (1.24 Btu/(hr·ft<sup>2</sup>·°F)), using the same methods and equations that were used to obtain the ASHRAE Chapter 27, Table 3 results. Rounding off these two results gives a nominal standardized surface heat transfer coefficient of 7.0 W/(m<sup>2</sup>·K) (1.23 Btu/(hr·ft<sup>2</sup>·°F)), which is the lower limit for natural convection for this size of CTS.

6.2.2 *Weather-side*—For comparison purposes, the standard surface heat transfer coefficient measured on the weather side of each CTS shall be (perpendicular or parallel):

$$h_c = 29.0 \text{ W}/(\text{m}^2\cdot\text{K}) - 10\% (5.1 \text{ Btu}/(\text{hr}\cdot\text{ft}^2\cdot^\circ\text{F}) - 10\%) \quad (5)$$

[allowed CTS calibration range of 26.0 to 29.0 W/(m<sup>2</sup>·K)  
(4.6 to 5.1 Btu/(hr·ft<sup>2</sup>·°F))]

<sup>4</sup> Available from American Society of Heating, Refrigeration, and Air-Conditioning Engineers, 1791 Tullie Circle N.E., Atlanta, GA 30329.

**TABLE 1 Specimen Size Dimensions<sup>A</sup>**

Window Type	Configuration	Residential Model Size, mm (in.) <sup>B</sup>	Non-residential Model Size, mm. (in.) <sup>B</sup>
<b>I - Window Assemblies</b>			
Vertical slider	XO or XX	914 × 1520 (36 × 60)	1220 × 1830 (48 × 72)
Horizontal slider	XO or XX	1520 × 914 (60 × 36)	1830 × 1220 (72 × 48)
Casement	X	610 × 1220 (24 × 48)	762 × 1520 (30 × 60)
Fixed/Casement	XO	1220 × 1520 (48 × 60)	1220 × 1829 (48 × 72)
Projecting (Awning)	X	1220 × 610 (48 × 24)	1020 × 1020 (40 × 40)
Fixed/Projected Awning	XO	1220 × 1520 (48 × 60)	1220 × 1830 (48 × 72)
Fixed (includes non-standard shapes)	O	1220 × 1220 (48 × 48)	1220 × 1830 (48 × 72)
Glazed wall & roof systems (Site-Built)	OO	2030 × 2030 (80 × 80)	2030 × 2030 (80 × 80)
Skylights	X or O	1220 × 1220 (48 × 48)	1220 × 1220 (48 × 48)
Greenhouse/Garden	X or O	1520 × 914 (60 × 36)	1830 × 1220 (72 × 48)
Dual Action	X	914 × 1520 (36 × 60)	1220 × 1830 (48 × 72)
Pivoted or top hinged	X	1220 × 1220 (48 × 48)	1220 × 1830 (48 × 72)
Sidelites	O	406 × 2080 (16 × 82)	406 × 2080 (16 × 82)
Transoms	X or O	965 × 356 (38 × 14)	1880 × 356 (74 × 14)
<b>II - Door Assemblies</b>			
Swinging door(s) with frame	X, OX or XX	965 × 2080 (38 × 82) <sup>B</sup> or 1830 × 2080 (72 × 82) <sup>C</sup>	965 × 2080 (38 × 82) <sup>B</sup> or 1830 × 2440 (72 × 96) <sup>C</sup>
Sliding Patio doors with frame	XO or XX	1830 × 2080 (72 × 82)	1830 × 2440 (72 × 96)

<sup>A</sup>Select size type based on the manufacturer's average standard size and intended use of the product.

<sup>B</sup>Typical of a single door.

<sup>C</sup>Typical of a double door.

NOTE 3—Again, referring to the 1997 ASHRAE Fundamentals Handbook (1), Fenestration Chapter 29, the recommended design value for the weather side overall combined forced convection, radiation heat transfer coefficient for a nominal 24 km/h (15 mph) wind speed is  $h_c = 29.0 \text{ W}/(\text{m}^2 \cdot \text{K})$  (5.1 Btu/(hr·ft<sup>2</sup>·°F)).

## 7. Test Specimen Installation and Instrumentation

### 7.1 Test Specimen Installation:

7.1.1 *Surround Panel*—A surround panel shall be provided for installation of the test specimen similar to that shown in Fig. 1 (see the description in Test Method C 1199).

7.1.2 *Test Specimen*—The fenestration system to be tested shall be installed in the surround panel as shown in Figs. 1 and 2 for windows and doors. That is, the complete assembly, including all frame elements and operating hardware, shall be in place during the test. Accessory interior or exterior devices, such as trim or insect screens, shall be removed before testing. The test specimen shall be mounted so that it is centered in the metering area of the surround panel, and the frame on the cold side of the fenestration product shall be flush with the weather side of the surround panel. The specimen shall be fixed securely in a plane parallel to the surround panel surfaces, suitable for any wind loads experienced during testing. The installation shall also allow space to accommodate all sash or operating members, or both. If the fenestration system does not fill the opening in the surround panel completely, the space between the surround panel and the fenestration system shall be filled with material of similar thermal conductance to that of the surround panel. Perimeter joints between the specimen and the surround panel shall be sealed on both sides of the wall. In no case shall the tape or caulk cover more than 13 mm (0.50 in.) of the test specimen frame or edge.

7.1.3 *Air Leakage*—All potential air leakage sites on the test specimen, on the surround panel, and at the interface between the surround panel and the test specimen must be sealed with nonmetallic tape or caulking, or both, as close to the primary seal as possible to minimize or eliminate air leakage between the room side and weather side chambers. The thermal performance can be affected by the method and placement of the test specimen air seal. Therefore, the test specimen is to be sealed at the primary seal of the test specimen with tape, caulking, or other material of similar surface emissivity to that of the adhering surface. All weep holes shall also be sealed. Perimeter joints between the test specimen and the surround panel shall be sealed on both sides of the wall. In no case shall the tape or caulk cover more than 13 mm (0.50 in.) of the test specimen frame or edge. As an additional precaution to minimize the potential for leakage of air through and around the sealed test specimen, means may be provided to measure and equalize the pressure difference across the test specimen. For hot boxes that have a perpendicular (to the test specimen weather side surface) wind direction, this is accomplished by balancing the weather side total pressure with the room side static pressure to  $0 \pm 10 \text{ Pa}$  ( $0 \pm 0.21 \text{ Lbf}/\text{ft}^2$ ). For hot boxes that have a parallel (to the test specimen weather side surface) wind direction, this is accomplished by balancing the weather side static pressure with the room side static pressure to  $0 \pm 10 \text{ Pa}$  ( $0 \pm 0.21 \text{ Lbf}/\text{ft}^2$ ). The pressure sensors should be located outside the

boundary layer on the glazing surface and oriented perpendicular to the center of the test specimen room side and weather side surfaces.

NOTE 4—Sealing techniques should be concerned with two primary criteria: (1) The sealant applied should be of similar ( $\pm 0.1$ ) emissivity as the surface to which it is being applied, and (2) the sealant is applied in as minimal amount as possible to achieve the necessary reduction in air leakage.

7.1.3.1 One method to characterize and minimize the air leakage through and around the test specimen is by performing the following steps.

(a) Prior to the thermal tests, conduct an air leakage test with the test specimen installed and sealed in the surround panel. The air leakage test can be Test Method E 283, E 783, or E 1424, whichever is more appropriate for a particular hot box test facility. The recommended test conditions are 27 Pa (0.56 Lbf/ft<sup>2</sup>) and 75 Pa (1.57 Lbf/ft<sup>2</sup>), equivalent to approximately 24 km/h (15 mph) and 40 km/h (25 mph) wind speed, respectively.

(b) After determining the net flow rate at each of these test pressures, the interior of the unit is sealed until the net air leakage is less than the flow equivalent of  $0.0006 \text{ m}^3/\text{min}/\text{m}^2$  ( $0.002 \text{ ft}^3/\text{min}/\text{ft}^2$ ) of fenestration system area at 75 Pa (1.57 Lbf/ft<sup>2</sup>) pressure differential. This would be approximately  $0.0014 \text{ m}^3/\text{min}$  ( $0.05 \text{ ft}^3/\text{min}$ ) total flow for a fenestration test specimen with a 1.52-m (60-in.) by 1.02-m (40-in.) projected area.

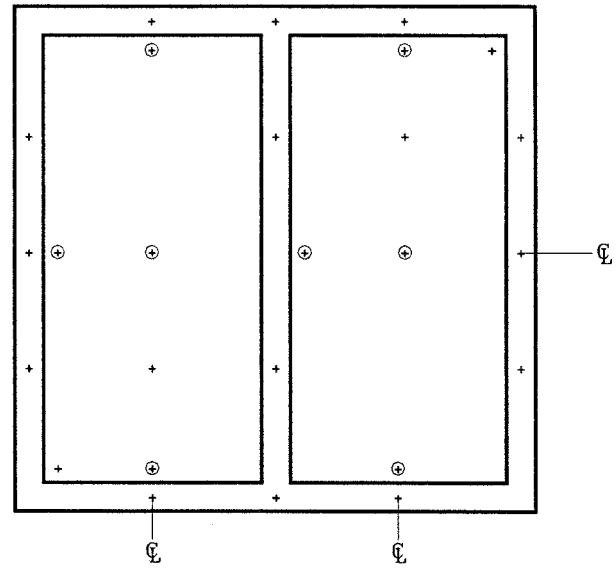
(c) It is intended that employing this level of sealing prior to the thermal test will minimize the air leakage to a level that will not significantly interfere with the conduction heat transfer through the fenestration test specimen during the thermal tests. Good laboratory practice would include periodic assessment of the quality of the sealing methods used by monitoring closely the fenestration test specimen heat flux and temperature measurements during the duration of the thermal tests to ensure that there are no changes in the thermal performance due to losses in the seal integrity.

7.1.3.2 As an alternative method to determine whether or not air leakage exists, the following technique currently in use by one laboratory has been found to be useful. Place a sheet of 0.1 mm (4 mil) polyethylene over the CTS (or fenestration test specimen) on the room side and seal it with tape to the surround panel at least 12 cm (4.7 in.) outside the perimeter of the specimen. Balance the pressure between the room side and weather side chambers as indicated above, and monitor the pressure difference. If the polyethylene sheet has not moved appreciably, it can be assumed that no net air leakage exists and the polyethylene sheet can be removed. Control the pressure balance during the test to  $0 \pm 10 \text{ Pa}$  ( $0 \pm 0.21 \text{ Lbf}/\text{ft}^2$ ). If the polyethylene sheet has moved towards the specimen, it can be assumed that a net air leakage in the direction of infiltration exists. If, after rechecking and modifying, as necessary, the sealing tape or caulk (removable weatherstripping has been used with success here), this situation still exists, the pressure balance setting can be adjusted in 2.5 Pa ( $0.05 \text{ Lbf}/\text{ft}^2$ ) increments until the polyethylene sheet has moved back to its original position or is bowed slightly away from the specimen. Wait at least 5 min after each adjustment before making

observations. The polyethylene sheet can then be removed and the pressure balance controlled during the test to within this new setting  $\pm 10$  Pa ( $\pm 0.21$  Lbf/ft<sup>2</sup>). If the polyethylene sheet has bowed away from the specimen, it can be assumed that a net air leakage in the direction of exfiltration exists. If, after rechecking and modifying, as necessary, the sealing tape or caulk, this situation still exists, the pressure balance setting can be adjusted in 2.5 Pa (0.05 Lbf/ft<sup>2</sup>) increments until the polyethylene sheet has moved back to its original position or is bowed slightly away from the specimen. (Again, wait at least 5 min after each adjustment before making observations.) The polyethylene sheet can then be removed and the pressure balance controlled during the test to within this new setting  $\pm 10$  Pa ( $\pm 0.21$  Lbf/ft<sup>2</sup>). In a similar manner, if air leakage is found to exist through the combination of the CTS (or fenestration test specimen) and the surround panel due to leakage sites at the surround panel/test frame interface, the pressure balance system can be set to allow a minimal amount of exfiltration. However, this should only be done after all attempts to seal these air leakage sites have been exhausted.

7.2 Test Specimen Instrumentation:

7.2.1 Temperature Sensors—If additional temperature sensors are to be mounted on the fenestration system frame and glazing surfaces to determine an average surface temperature for both the weather side and room sides of the test specimen, Fig. 3 shows the preferred locations based on experience with fenestration product testing. If there is further interest in attempting to determine edge (spacer) heat transfer effects,



Glazed Wall Section

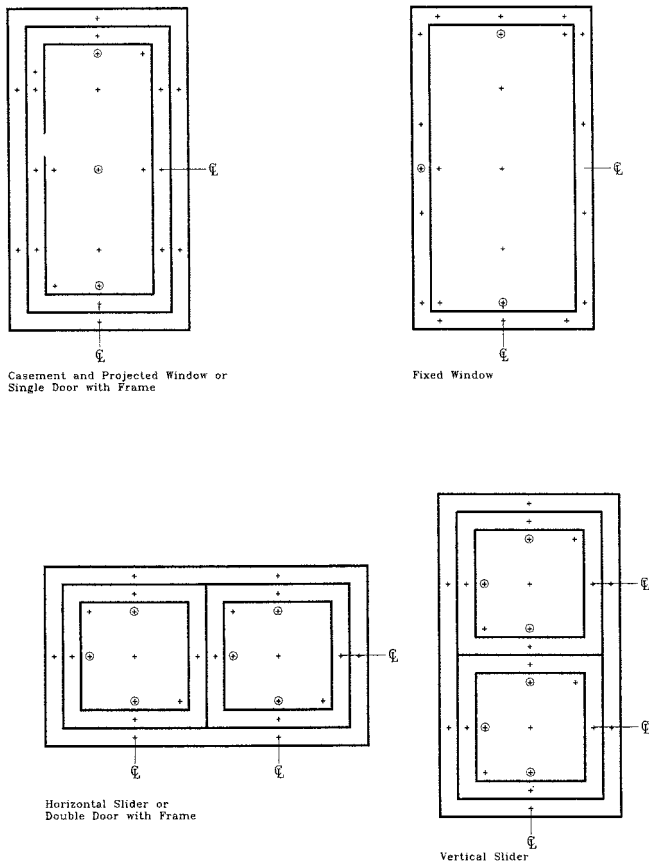
Note: cir  
**FIG. 3 Thermocouple Locations (continued)**

additional temperature sensors should be mounted in the region of the glazing near the frame, especially in the glazing/frame corners. Paragraph 6.10 of Test Method C 1363 provides the requirements for the temperature sensor accuracy, which is presumed to be met by using Type T thermocouples with diameters no larger than 0.51 mm (No. 24 AWG). Alternative arrangements may be used if comparative measurements or calculations reveal that the basic requirements are met.

NOTE 5—Fig. 3 indicates the temperature sensor locations for a limited sample of window types as an alternative to calculation of the window surface temperatures. The following guidelines are recommended for other window types, doors, glazed curtain walls, glass block walls, and so forth: (1) a minimum of 20 temperature sensors should be used, with a minimum of 6 being placed on the glazing and a minimum of 14 placed on the sash/frame components of the test specimen; (2) additional temperature sensors should be added for thermal bridges or other frame elements with high thermal conductance; and (3) the temperature sensors are to be placed in locations as close as possible to those found in Fig. 3.

7.2.2 Temperature Sensor Attachment—Surface temperature sensors shall be applied to the test specimen as described in 6.10.1 of Test Method C 1363. If thermocouples are used to measure the surface temperature, a minimum of 100 mm (4 in.) of thermocouple wire must be adhered to the surface. The emittance of the tape or sealant used to adhere the temperature sensor bead and lead wire should closely match ( $\pm 0.05$ ) the emittance of the surface to which it is being attached. Care should be taken to avoid having the temperature sensor cause any significant disturbance to the flow fields and the test specimen heat transfer. To avoid thermal shunting, route temperature sensor lead wires so that they do not bridge areas of expected large temperature difference.

7.2.3 Average Area Weighted Surface Temperatures of Test Specimen—The individual surface temperature measurements of the test specimen shall be area weighted to determine the



**FIG. 3 Thermocouple Locations**

average surface temperature of the room side of the test specimen,  $t_1$ , and the average surface temperature of the weather side of the test specimen,  $t_2$ . Proper measurement of the average surface temperature of each side of the fenestration test specimen requires that (1) the surface area of the test specimen be accurately measured and (2) the individual temperature sensors be attached to the test specimen surface at locations representing areas of minimal surface temperature gradient. The individual temperature sensors shall be located in the center of surface areas that are considered to be relatively isothermal (see Fig. 3). The sum of the individual surface areas on the room side and the weather side of the test specimen must equal the total measured surface areas of the room side,  $A_r$ , and weather side,  $A_w$ , respectively.

**7.2.3.1 Surface Area Measurement**—The total surface area of each side of the test specimen must be determined.

**NOTE 6**—When using the CTS method in Test Method C 1199, the surface area of the test specimen can be estimated using the projected height and depth of the frame and sash components. When using the area weighting method in Test Method C 1199, more careful measurement of the “wetted” surface area of the test specimen may be necessary, including the surface areas of finger holds, fins, channels, and convoluted moldings on the frame or sash. Construction drawings of cross sections of the test specimen frame can assist in determining the total surface area of the test specimen, provided that the distance measurements can be made to the proper scale. If construction drawings of the test specimen are not available, it is possible to measure the length of a convoluted surface on a frame in one direction with tape. Place a piece of masking tape on the convoluted frame surface that you want to measure. After marking the edges of each individual area on the tape with a pen, remove the tape and place it on a ruler in such a way as to measure the distance between the marks.

**7.2.3.2 Surface Temperature Sensor Location**—Surface temperature sensors shall be placed in the center of isothermal areas as shown in Fig. 3. If surface temperature sensors are placed in locations other than shown in Fig. 3, those locations must be identified in the test report. On frames containing elements of high thermal conductance, extra temperature sensors may be needed to measure the temperature of that element and its surrounding area.

**NOTE 7**—Because there is such a large variety of shapes and configurations in frame and sash profiles on modern fenestration products, it is impossible to give guidance on where to properly locate every surface temperature sensor on the frame and sash. Typically, the surface temperature of surfaces on appendages or elements that protrude, such as channel fins and hand rails, have less of an influence on the overall thermal transmittance of the fenestration product than the temperature of surfaces connected to the body of the frame or sash. In those frames that have internal air cavities (that is, vinyl or aluminum extrusions), it is more important to measure the surface temperature of elements that bound internal air cavities than to measure the surface temperature of thin, protruding elements that do not bound internal air cavities. Ultimately, proper surface temperature sensor placement will depend on the experience and judgement of the test laboratory operator.

## 8. Glazing Deflection

8.1 Variations in the pressure in the space between the sheets of glass in sealed glazing units can cause deflections in the glass. In extreme cold weather cases, the glass surfaces can bow and come into contact with each other at their center-points. This change in the enclosed space dimensions can significantly affect the thermal transmittance,  $U_S$ , of the test specimen. The glazing deflection of each insulated glass unit shall be measured and reported in accordance with Test Method C 1199.

## 9. Report

9.1 Report all of the information specified in Section 9 of Test Method C 1199.

9.2 Report the standardized thermal transmittance,  $U_{ST}$ , and specify its estimated uncertainty. If the test specimen size and configuration are different than those specified in 5.1, include the nonstandard size and configuration in the report.

9.3 Include the test conditions used, such as room-side and weather-side air and surface temperatures, wind speed, and direction, in the report.

## 10. Keywords

10.1 doors; fenestration; heat; hot box; R-value; steady state; testing; thermal transmission; U-value; windows

## APPENDIX

### (Nonmandatory Information)

#### X1. RELATED PUBLISHED MATERIAL

AAMA Standard 1503-98 Voluntary Test Method for Thermal Transmittance and Condensation Resistance of Windows, Doors and Glazed Wall Sections<sup>5</sup>

ASHRAE Handbook, 1997 Fundamentals Volume<sup>4</sup> American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc.

Bowen, R. P., and Solvason, K. R., “A Colarimeter for Determining Heat Transmission Characteristics of Windows,” Thermal Insulated Materials and Systems, *ASTM STP 922*, ASTM.

<sup>5</sup> Available from American Architectural Manufacturers Association, 1827 Waldron Office Square, Suite 104, Schaumburg, IL 60173.

BS 874 Part 3: Section 3.1: 1987 Methods for Determining Thermal Insulation Properties, Part 3 Tests for Thermal Transmittance and Conductance, Section 3.1 Guarded Hot Box Method<sup>4</sup>

BS 874 Part 3: Section 3.2: 1990, Methods for Determining Thermal Insulation Properties, Part 3. Tests for Thermal Transmittance and Conductance, Section 3.2 Calibrated Hot Box Method<sup>4</sup>

BS 874: Methods for Determining Thermal Insulation Properties with Definitions of Thermal Insulating Terms<sup>4</sup>

C 177 Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus<sup>2</sup>

C 236 Test Method for Steady-State Thermal Performance of Building Assemblies by Means of a Guarded Hot Box<sup>2</sup>

C 518: Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus<sup>2</sup>

C 976 Test Method for Thermal Performance of Building Assemblies by Means of a Calibrated Hot Box<sup>2</sup>

C 1045 Practice for Calculating Thermal Transmission Properties from Steady-State Conditions<sup>2</sup>

C 1114 Test Method for Steady-State Thermal Transmission Properties by Means of the Thin-Heater Apparatus<sup>2</sup>

C 1363 Test Method for the Thermal Performance of Building Assemblies by Means of a Hot Box Apparatus<sup>2</sup>

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<sup>6</sup> Available from National Institute of Building Sciences, 1200 L Street, Washington, DC 20005-4042.

<sup>7</sup> Available from National Fenestration Rating Council, 1300 Spring Street, Suite 500, Silver Spring, MD 20910.

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