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Voluntary Test Method for Thermal Transmittance and Condensation Resistance of Windows, Doors and Glazed Wall Sections

AAMA 1503.1-88

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FOREWORD

AAMA started work leading to the development of procedures and equipment suitable for the evaluation of thermal performance of fenestration products in 1972. The first AAMA voluntary standard for thermal performance, 1502.5, was published in 1976. It was developed specifically to measure the condensation resistance of aluminum residential insulating windows and sliding glass doors. Aluminum had long been the most popular framing material for these products. Architects, builders and users preferred aluminum for its excellent operating and performance characteristics, its low maintenance, color, style and design versatility. However, one characteristic of aluminum construction which was not desirable was its susceptibility to condensation under conditions of high inside relative humidity and low outside air temperature.

To provide greater resistance to condensation, many manufacturers had developed thermally improved or "thermalized" windows, doors and glazed wall products. Such products incorporated thermal breaks in the aluminum framing to prevent through metal conductance between the inside air and the outside air. In addition, such products were glazed with two or more panes of glass with air space between the panes to increase the insulation in the vision areas. Thermal breaks in the framing members were generally designed to equal or exceed the condensation resistance of the insulating glass. Through this type of construction the condensation resistance of the entire assembly was uniformly improved.

Since manufacturers used several techniques to make thermalized products it became important that architects, builders and users have a reliable method of evaluating thermal performance, in order to properly match products to the climates and conditions in which they would be used and in order to make valid comparisons of products. AAMA 1502.5 test method made this possible as far as determining a product's condensation resistance was concerned.

The other major area of concern relative to thermal performance is a product's thermal transmittance. It is this property which determines the heat loss through the product. Lower thermal transmittance means higher energy efficiency since less heat is going to be lost through the product. Although there is not necessarily a direct correlation, a design which provides good condensation resistance may also provide good resistance to heat loss. With high .fuel costs, reduction of heat loss is critically important in a building design.

To meet the need for a standard test, AAMA developed and in 1980 published its voluntary standard 1503.1 for the measurement of thermal transmittance of windows, doors and glazed wall sections. This standard was not limited to residential windows and sliding glass doors but covered all categories and types of these products as well as glazed sections for wall systems. The advent of this standard made it possible to measure in a repeatable and reliable manner the heat flow resistance capabilities of a complete window, door or wall section assembly. In 1981, the voluntary standard 1502.7 for condensation resistance was updated so that it too was applicable to all categories and types of windows, doors and glazed wall sections.

To further refine and improve the standard for thermal performance, AAMA contracted in 1981 with the Department of Mechanical Engineering of the University of Pittsburgh for an independent study and evaluation of the thermal transmittance standard to be made under the direction of Professor Eugene Gieger. This study was completed in 1982. A number of constructive recommendations came out of this study, and these recommendations plus testing experience gained since 1503 was published form the basis for the revisions and new material which have been incorporated in this new standard.

This new AAMA voluntary test method for measuring thermal performance brings together in one convenient document the testing procedures for both thermal transmittance and condensation resistance and replaces the previous voluntary standards designated as AAMA 1502.7-1981 and AAMA 1503.1-1980. This is a logical step to take inasmuch as heat flow measurements and temperature measurements needed to calculate thermal transmittance and condensation resistance factors can be made in one test set up with one 2-hour test run once stabilized conditions have been reached in the test chamber. Although this standard was originally developed for testing aluminum windows, it is also applicable to windows of other materials such as wood or plastic. In recognition of the fact that air leakage can be a significant cause for energy loss through windows, doors and glazed wall sections, this standard prescribes a test for air leakage at the pressure difference equivalent of both a 15 mph and a 25 mph wind.

1.0 SCOPE

1.1 This test method measures the thermal characteristics of windows, doors and glazed exterior wall sections under steady-state conditions. Specifically, measurements and calculations made will yield the thermal transmittance or U-Value, the air infiltration rate and the Condensation Resistance Factor, hereafter called "CRP' for these products.

1.2 This method is specifically intended for measurements on heterogeneous constructions with variations in thickness, conductivity and surface profile which are common to windows, doors and glazed wall sections. Typically such constructions have relatively high thermal conductance and may be susceptible to the formation of condensation. Interior and exterior surface air films contribute significantly to lowering the thermal transmittance and raising the resistance to the formation of condensation.

1.3 In this test method, a perpendicular air flow is directed toward the exterior (cold room side) of the test specimen. Cold side surface coefficients are controlled by adjusting the test apparatus to specific performance conditions using a standard calibration panel.

1.4 Similarly, natural convection is simulated on the warm side of the apparatus by the combined effects of the downward flow of cooler air over the face of the specimen due to natural convective currents and by optional (if necessary for calibration) forced convective currents downward and parallel to the specimen. The warm room heating apparatus is adjusted so that the resulting inside film coefficients are within the calibration specifications.

1.4.1 Prior to beginning the tests to determine thermal transmittance and condensation resistance factor, a measurement is made to determine the air infiltration rate at prescribed pressure differences and operating forces for certain prescribed product types. The balance of the thermal testing will not include the effects of air infiltration because the dynamic wind pressure of the exterior will be balanced to a zero differential pressure with a static air pressure on the interior side.

1.4.2 While not an absolute value, the CRF is a rating number obtained under specified test conditions to allow a relative comparison of the condensation performance of the product. It will provide a comparative rating and permit the determination of the conditions beyond which an objectionable amount of condensation may occur. Those aspects of this test method dealing only with the CRF determination may be considered as optional for those products (doors, glazed wall sections, etc.,) where condensation is not traditionally a consideration.

1.5 The test facilities must conform to the calibration specifications contained herein. However, the details of the test apparatus necessary to achieve these conditions may vary. The equipment, calibrated within the tolerance outlined in this specification, will produce results within accepted standards as tested by different facilities.

1.6 Those applying this test method shall be trained in techniques of temperature measurement, shall understand the theory of heat flow, and shall have experience in thermal testing. Since it is undesirable to specify the construction of the test facility in such detail that it would unnecessarily restrict the method to a single arrangement, those applying the method shall have the technical competency to determine the accuracy and operating variables of their respective test facilities.

2.0 APPLICABLE DOCUMENTS

2.1 ASTM C 168, "Standard Definitions of Terms Relating to Thermal Insulating Materials" (applicable definitions from ASTM C 168 are included in the Appendix).

2.2 ASTM E 283, "Standard Test Method for Rate of Air Leakage Through Exterior Windows, Curtain Walls and Doors."

2.3 ASHRAE Handbook of Fundamentals.

3.0 SUMMARY OF METHOD

3.1 To determine the thermal conductance (C), thermal transmittance (U), and thermal resistance (R) of any specimen, it is necessary to know the area (A), the heat flux (q), and the temperature difference LIT. The heat flux and the temperature differential shall be determined under conditions of steady-state heat transfer. The apparatus will establish and maintain the desired steady-state temperature difference across the test specimen for the period of time necessary to ensure constant heat flux and to accurately measure the desired quantities. The area and temperatures can be directly measured.

3.2 To determine the heat flux, (q), a five-sided metering box is placed with its open side against the warm face of the test panel. If the average temperature differential across the walls of the metering box is maintained at a constant zero magnitude, the net transfer of heat between the metering space and the surrounding guard space will be zero in magnitude. The energy input to the metering space will be a measure of the heat flux through the known area of the panel.

3.3 Moisture migration, condensation and freezing within the specimen can cause variations in heat flow. To avoid this, it has been determined that the relative humidity in the warm room must be maintained at or below 30%. Tests in this apparatus, referred to as a guarded hot box, will be conducted on substantially dry test panels with no effort made to impose or account for the effect of water vapor flow through or into the panel during the test.

3.4 A basic principle of the test method is to maintain a zero temperature difference across the metering box wall. Adequate temperature controls and monitoring capabilities are essential. It is recognized that small temperature gradients could occur across the metering box walls due to the limitations of controllers and the effect of the convection currents within the metering box. Since the total wall area of the metering box is often more than twice the metering area of the panel, small temperature gradients through the walls may cause heat flows totaling a significant fraction of the heat input to the metering box. For this reason, the metering box walls should be instrumented so that the heat flow through them can be calculated and a heat flow correction can be applied to the test results.

3.5 As primary system control, this test method utilizes surface coefficients calculated for a standard calibration panel from temperature data taken during the calibration procedure. To effect calibration, the test facility is adjusted until the range, average and deviation of the surface coefficients fall within specified allowances in this test method.

3.6 Test samples of windows, doors and wall sections having irregular surfaces do not have single inside and outside surface coefficients. The utilization of a calibration panel and the selection of and adjustment to representative surface coefficients provides the means by which dissimilar constructions of the same general type can be compared under uniform test conditions, wherein the time rate of heat flow (q) through the same area (A) is the only unknown.

3.7 The first intent of this procedure is to measure the thermal transmittance of test samples exposed to the same conditions. It is not intended to create uniform surface coefficients on the test specimens. Since many constructions have recesses that are not symmetrical, the use of parallel or angular air flows on the cold side of the test specimen could affect thermal transmittance and in turn affect the test reproducibility. A perpendicular air flow on the cold side is specified and very closely defined. Since the warm side surface coefficient is intended to be representative of natural convection, a downward air flow parallel to the plane of the specimen on the warm side is anticipated. Calibration requirements may or may not dictate the application of forced convection fans to simulate this natural convection.

3.7.1 The second intent of this procedure is to determine a rating factor to predict the condensation forming characteristics of the product under test. This CRF is calculated from temperature data taken by prescribed location and roving location thermocouples under stabilized test conditions. Locations of the thermocouples are important factors as their placement is intended to provide representative temperature readings. Four thermocouples are used to locate the coldest sash or frame surfaces. Incorporation of these data points provides a penalizing weighting factor in the calculations.

3.7.2 A primary concern in the thermal evaluation of these products is their air infiltration characteristics under pre-specified (wind) pressure loading conditions. This procedure negates the effect of air infiltration by balancing the dynamic wind loading on the cold side with a static air pressure on the warm side. This test method does not include heat loss due to air infiltration. The performance of a given window, door or wall section will vary in regard to air infiltration. Consequently, heat loss due to air infiltration is a separate determination based on infiltration characteristics of the construction and environmental conditions.

3.8 It is important to achieve precise calibration of cold side and warm side surface coefficients to ensure consistent and reproducible test results. A pressure difference across the test specimen and variations in the water vapor content of the warm side air can cause errors in measuring heat flow. These variables must be reduced or eliminated to ensure a reproducible test method. Pressure difference across the test specimen must be kept to the absolute practical minimum.

3.9 Facilities which incorporate a metering box must be capable of maintaining warm side and cold side surface coefficients with the metering box in place. Facilities which utilize a temperature controlled room enclosure as a guard box must be constructed and instrumented to control and measure heat flow with the same stability and accuracy as those facilities which use a metering box.

4.0 SIGNIFICANCE AND USE

4.1 This test method applies only to vertically oriented construction and is intended specifically for full size windows, doors and representative glazed wall sections.

4.2 Due to changes in the ratio of materials for different size specimens having the same construction, the thermal transmittance and/or CRF could vary with test specimen size. For these reasons, the standard sets forth specific sizes for product test specimens and their mountings.

4.3 The test procedures and equipment may not accurately compare glazed exterior wall sections which have deep exterior to interior projections in relation to smaller size test samples. The exterior incident air pattern on a small test sample may be seriously disrupted by projections which deflect the air movement. Interior convection also may be affected by large interior projections. These conditions may change the heat flow and thus, the outside and inside surface temperatures. Consequently, the size of the test specimen of this type must be sufficient to minimize these conditions. The areas of glass and/or panels, as well as the size and placement of mullions, must be representative of the full size wall.

4.4 This test method provides for repeatability of results within a given facility for a given test specimen. The method of calibration of test facilities also ensures that test results for a given test specimen are repeatable in different facilities when these facilities meet the calibration requirements. This method, therefore, provides a reliable means for measuring and comparing thermal transmittance of products.

4.5 The outside surface coefficient is based on the ASHRAE 15 mph wind for winter conditions. The inside surface coefficient is based on natural convection on a vertical surface.

4.6 Many conditions can influence thermal transmittance and the formation or non-formation of condensation. Some which may affect the thermal performance of windows, doors and glazed wall sections include the following:

4.6.1 Type of wall construction and materials used therein.

4.6.2 For cavity walls, location of thermal break in framing members with respect to the cavity.

4.6.3 Absence or presence of drapes and/or shades.

4.6.4 Depth of reveal (recess at sill, jambs and head).

4.6.5 Location of heat sources and rate of inside air convection.

4.6.6 Positive or negative pressure within the building which may cause an increase in air infiltration or exfiltration.

4.6.7 Wind velocity.

4.6.8 Location of surrounding buildings and type of surrounding terrain.

4.6.9 Variations in wind conditions due to installation height on building elevation and direction of elevation.

4.7 The thermal transmittance value (U) can be used to compare similar products of the same test size. Comparison of test results of different size products, for example, 3'-0" x 4'-0" with 4'-0" x 6'-0" windows may not be appropriate due to the differences in ratio of sample area to glass edge between the two test samples.

4.8 The condensation resistance factor (CRF) may be used for comparative analysis of similar products of the same general configuration. Some interpretative allowances may need to be made in comparing products of dissimilar type or configuration (e.g. , wall sections versus operating windows or versus fixed glazing).

4.8.1 Refer to Fig. 9 & 10 for determination of winter outside design temperatures, recommended maximum inside humidity levels, and minimum recommended CRFs for these conditions.

4.9 The U-Value determined by tests at the standard test conditions can be used in estimating design loads for heating and cooling equipment of most low rise residential buildings, since the surface coefficients are intended to be the same as those recommended in the ASH RAE method of calculating residential loads. Applicability of the test U-Values to other building types should be determined by a competent engineer.

4.10 The test U-Value determined by this method does not include the effects of lower or higher average wind speeds and does not account for solar heat gain. Consequently, the test value should be appropriately evaluated when used in estimating seasonal product performance.

4.11 The most direct application of the CRF value is its use in the prediction of what set of exterior temperatures – interior temperatures - interior humidity conditions will initiate condensation. Note that the test method and rating system are based on the assumption that a relatively small amount of condensation in comparison to the overall area is tolerable and will not result in a less accurate prediction of the overall thermal performance of the product.

4.12 This test method does not include heat loss due to air infiltration. The performance of a given window, door or glazed wall section will vary in regard to air infiltration as indicated in Section 3.7.2. Consequently, heat loss due to air infiltration is a separate determination based on infiltration characteristics of the construction and environmental conditions.

5.0 TERMINOLOGY

5.1 Thermal Conductivity, λ: The time rate of heat flow through unit area and unit thickness of a homogeneous material under steady-state conditions when a unit temperature gradient is maintained in the direction perpendicular to the area. Materials are considered homogeneous when the value of the thermal conductivity is not affected by variation in the thickness or in the size of the sample within the range normally used in construction. It is calculated as follows:

$$\lambda = \frac{q}{A\,(t_1 - t_2)\,(L)} \qquad (1)$$

5.2 Thermal Conductance (C): The time rate of heat flow through a body per unit area from one of its bounding surfaces to the other for a unit temperature difference between the two surfaces, under steady-state conditions. It is calculated as follows:

$$C = \frac{q}{A\,(t_1 - t_2)} \qquad (2)$$

5.3 Surface Coefficient (h): The ratio of steady-state heat exchange between the surface and its external surroundings to the temperature difference between the surface and its surroundings. It is expressed in terms of time rate of heat flow per unit area of a particular surface by the combined effects of radiation, conduction, and convection for a unit temperature difference between the surface and the air. Subscripts $_I$ and $_O$ are used to differentiate between inside and outside surface coefficients, respectively. Surface coefficients are calculated as follows:

$$h_I = \frac{q}{A\,(t_h - t_1)} \qquad (3)$$

$$h_O = \frac{q}{A\,(t_2 - t_c)} \qquad (4)$$

5.4 Thermal Transmittance (U): The time rate of heat flow per unit area under steady-state conditions from the air on the warm side of a body to the air on the cold side, per unit temperature difference between the warm and cold air. It is calculated as follows:

$$U = \frac{q}{A\,(t_h - t_c)} \qquad (5)$$

(U) is referred to as the overall coefficient of heat transfer. It can be calculated from the thermal conductance and surface coefficients as follows:

$$\frac{1}{U} = \frac{1}{h_I} + \frac{1}{C} + \frac{1}{h_O} \qquad (6)$$

5.4.1 Condensation Resistance Factor (CRF): The numerical value determined by the lower of either the weighted frame temperature or average glazing temperature in relation to cold side air temperature t_c and warm side air temperature t_h The weighted frame temperature (FT) is determined from the relationship of the average of 14 predetermined thermocouple temperatures (FT_p) and the average of the coldest sash or frame temperatures determined by 4 roving thermocouples (FT_r). A weighting factor, W, ratios the average predetermined thermocouple temperatures with the average of the coldest sash or frame temperatures determined by 4 roving thermocouples. The weighting factor is calculated as follows:

$$W = \frac{FT_p - FT_r}{FT_p - (t_c + 10)} \times 0.40 \qquad (7)$$

Where: t_c = Temperature of air cold side
10 = Arbitrary temperature adjustment
0.40 = Arbitrary weighting factor

The weighted frame temperature, FT, is calculated as follows:

$$FT = FT_p\,(1\text{-}W) + WFT_r \qquad (8)$$

The average of 6 predetermined thermocouple glazing temperatures (GT) and the weighted frame temperature (FT) are used in calculating the CRF for the glass and frame as follows:

$$CRF_G = \frac{GT - t_c}{t_h - t_c} \times 100 \qquad (9)$$

$$CRF_F = \frac{FT - t_c}{t_h - t_c} \times 100 \qquad (10)$$

Where: 100 = A multiplier to make CRF a whole number.

CRF numbers shall be whole numbers only. Any number 0.5 and greater shall be rounded to the next whole number. One number, the lower of CRF_G or CRF_F, shall be reported as the product CRF. At the manufacturer's option the second number, CRF_G or CRF_F may be reported *with its proper subscript* and clearly indicating its alternate significance.

5.5 For other definitions relating to thermal insulating materials refer to ASTM C 168.

5.6 Symbols: The symbols used in the foregoing and subsequent paragraphs have the following significance:

λ = Thermal Conductivity, Btu/in/hr/ft^2/°F
C = Thermal Conductance, Btu/in/hr/ft^2/°F
U = Thermal Transmittance, Btu/in/hr/ft^2/°F
q = time rate of heat flow through area A, Btu/hr
A = area normal to heat flow, ft^2
L = length of path of heat flow, in.
t_h = temperature of warm side air, °F
t_1 = temperature of warm surface, °F
t_2 = temperature of cold surface, °F
t_c = temperature of cold side air, °F
h_i = inside surface coefficient, Btu/hr/ft^2/°F
h_o = outside surface coefficients, Btu/hr/ft^2/°F
d_{rms} = root-mean-square deviation of warm side heat transfer coefficients
h_{ave} = average calculated warm side heat transfer coefficients for elevation x_1, Btu/ hr/ft^2/°F
x_1 = location of thermocouple row per Figure 1.
h_{si} = base warm side heat transfer coefficients for elevation x_1, Btu/hr/ft^2/°F
CRF_G = Condensation Resistance Factor for the glass
CRF_F = Condensation Resistance Factor for the frame
FT = Weighted frame temperature
FT_p = Average temperature of 14 predetermined thermocouple locations on frame and sash members
FT_r = Average temperature of 4 roving thermocouple locations on the 4 coldest locations of frame and sash members

W = A weighting factor to ration FT_p. and FT
GT = Average temperature of 6 predetermined thermocouple locations on the glazing
T = Lower of FT or GT

6.0 APPARATUS

6.1 The thermal test facility is intended to subject a test specimen to differential interior and exterior temperatures and a standard wind loading condition and to accurately measure the thermal transmittance, air infiltration rate and surface temperatures of that specimen.

6.2 Construction details, energy metering apparatus, and controls are the responsibility of the test laboratory. See Fig. 1 for reference use.

6.2.1 When the thermal test facility is used to conduct air infiltration tests in accordance with ASTM E 283, as specified in Section 9.3.5, the cold and warm chambers shall be capable of withstanding internal and external pressures required by the test. All joints, corners and other openings shall be carefully and completely sealed.

6.3 Cold Chamber

6.3.1 A means of generating a uniform air flow of nominally 15 mph shall be provided in the cold chamber. Air flow shall be perpendicular to the exterior surface of the test specimens. Horizontal centerline of discharge plenum shall coincide with the geometric center of the specimen to ensure a uniform air flow centered on the specimen.

6.3.2 A refrigeration unit and controls are required to automatically maintain a temperature of 18°F or lower within ± 0.5°F.

6.4 Warm Chamber

6.4.1 A heating device and controls are required to automatically maintain a temperature of 68°F or higher within ± 0.5°F.

6.4.2 A system for controlling the humidity of the warm room air shall be provided, Relative humidity of the warm room shall not exceed 30% at any time during the test. A hygrometer for indicating the relative humidity is required. The instrument shall indicate relative humidity to within 1%.

6.5 A fixed wall or removable panel of very low thermal transmittance shall separate the cold chamber from the warm chamber. All joints shall be sealed. This wall or panel shall have a nominal opening designed to receive a calibration panel as described in Section 7.1.

6.6 Temperature Measuring Equipment

6.6.1 All thermocouples shall be fabricated from the same lot of premium grade 30 gauge copper constantan type T thermocouple wire.

6.6.2 The cold room air temperature shall be determined by a thermocouple junction surrounded by a radiation shield as detailed in Fig. 1.

6.6.3 The warm room air temperature shall be determined by averaging the readings of the 3 thermocouple junctions surrounded by radiation shields as detailed in Fig. 1. The center thermocouple shall be located at the intersection of the vertical and horizontal centerline of the test frame. One thermocouple shall be located 24" directly above and another 24" directly below the center thermocouple. These three thermocouples must be movable to maintain a distance of 3" measured perpendicular to the warm side of the mask as shown in Fig. 1.

6.6.4 Using the geometric center as the reference starting point, the specified number of thermocouples shall be attached to the calibration panel in both the warm and cold rooms according to the geometric pattern established in Fig. 1.

6.6.5 The instrumentation shall indicate temperature readings of the thermocouples within 0.1°F.

6.7 Pressure Measuring Equipment

6.7.1 Cold room air pressure detection shall be accomplished by locating the total pressure sensing element of this pilot tube at the horizontal and vertical centerline and 6 inches inside the discharge plenum as shown in Fig. 1.

6.7.2 The warm room pressure detection point shall be representative of overall room conditions and not located near known sources of air movement.

7.0 CALIBRATION

7.1 The thermal test facility shall be calibrated with a standard calibration panel of known conductance, constructed as shown in Fig. 3 to establish cold and warm side surface coefficients. The facility shall be calibrated prior to initial testing and periodically, at least semiannually, thereafter. The facility shall also be recalibrated if changes or adjustments are made to the equipment or if test data appears questionable.

7.2 Pressure Stabilization

7.2.1 The plenum discharge shall be positioned and the air baffles adjusted such that the 15 mph cold side h_o coefficient is within the tolerance specified in Section 7.4.4. The standard deviation of the 15 air velocity readings measured 6" within the plane of the plenum discharge at locations specified in Fig. 4 shall not exceed 1.1 mph. Velocity readings shall be corrected for air density, barometric and temperature conditions at calibration.

7.2.2 Pressure Differential: During stabilization and calibration runs, the pressure differential between the warm and cold room shall be 0.000 ± 0.002" H_2O.

7.3 Thermal Stabilization: The calibration panel per Fig. 3 shall be used for thermal stabilization measurements. Stabilized conditions are defined as when the individual thermocouple readings, obtained in 6 consecutive observations 10 minutes apart, are within 0.5°F at each individual location.

7.4 Calibration for Standard Condition

7.4.1 For this test method, standard conditions are defined as 18°F cold side, 68°F warm side, natural convection inside and zero pressure differential across the test sample.

7.4.2 The calibration test shall consist of 5 sets of temperature readings, spaced 30 minutes apart, over a 2-hour period and a consecutive measure of the heat loss through the test panel during the prescribed period, wherein individual thermocouple readings are within 0.5°F at each location.

7.4.3 Cold side surface coefficients (h_0) shall be calculated for each of the 21 test points from data taken during the calibration run as follows:

$$h_O = \frac{0.908\,(t_1 - t_2)}{(t_2 - t_c)}$$

Where: 0.908 = Conductance of the calibration panel
t_1 = Warm side surface temperature, °F
t_2 = Cold side surface temperature, °F
t_c = Cold room air temperature, °F

7.4.4 Average the heat transfer coefficients (h_0) at each location. The mean value of the 21 averaged heat transfer coefficients shall be 5.8 ± 0.4 and the standard deviation shall not exceed 1.4.

7.4.5 Warm side surface coefficients (hg) shall be calculated for each of the 21 test points from data taken during the calibration run as follows:

$$h_I = \frac{0.908\,(t_1 - t_2)}{(t_h - t_1)}$$

Where: 0.908 = Conductance of the calibration panel
t_1 = Warm side surface temperature, °F

t_2 = Cold side surface temperature, °F
t_h = Warm side air temperature, °F

7.4.6 Average the warm side heat transfer coefficients (h) at each location. These averaged coefficients are satisfactory if their standard deviation (d) is less than 0.10.

$$d_{rms} = \left[\frac{\sum_{j \text{ is } 1 \text{ to } 7} (h_{avg.\,j} - h_{si})^2}{7} \right]^{1/2}$$

When:
h_{si} = base warm side heat transfer coefficients for evaluation x_1 as indicated in the following chart:

x_1	h_{si} (btu/hr/ft^2/°F)
1	1.75
2	1.40
3	1.37
4	1.35
5	1.32
6	1.30
7	1.20

7.4.7 During the calibration test, the heat loss through the calibration panel shall be determined and shall be within 2% of the theoretical value calculated for the construction of the calibration panel per:

$$\frac{1}{U} = \frac{1}{h_O} + \frac{1}{C} + \frac{1}{h_I}$$

or

$$\frac{1}{U} = \frac{1}{5.8} + \frac{1}{.908} + \frac{1}{1.42}$$

Where: h_I = Average of the seven h_{si} values.

The determination of (q), time rate of heat flow through area (A), must take into account heat losses through the test frame, separating wall or panel, meter box or chamber walls. Heat gains from fans, lights, pumps, dehumidifiers and controls must also be included in the calculations.

7.4.8 As shown on Fig. 2, a column of thermocouples is to be placed 6" from each side and one column on the vertical centerline. If the overall size of the calibration panel is such that the 36" maximum horizontal spacing would be exceeded, additional column(s) must be added symmetrically while maintaining the outside columns at 6" from each side.

Example: a 108" wide panel would have columns at 6", 30", 54", 78" and 1.02" from the starting side. Formulae and numbering systems would be adjusted accordingly to maintain the intent and effect of this specification.

8.0 PREPARATION OF TEST SPECIMEN

8.1 The preparation of standard test specimens for comparative U-Value ratings and CRF ratings is closely specified in this method. These samples must comply with the size requirements specified in Section 8.3 for the product categories into which they fall. They must also conform to the configurations shown in Fig. 5. Test samples must be installed in test frames constructed in accordance with Section 8.2.

8.1.2 For a test specimen not specifically addressed in this test method, it is necessary to select a size and configuration that is representative of the construction to be tested.

8.2 Mask

8.2.1 A mask shall be provided for installation of the test specimen per the details shown in Fig. 6 & 7. Exposed surfaces of the mask shall be painted white.

8.2.2 The mask thickness must not be less than the depth of the test specimen. It shall not be more than 1" thicker than the test specimen frame depth. Masks shall have thicknesses at the exact inch ± 1/16"; (e.g., 3", 4", 5", etc.)

8.2.3 Mount the test specimen centered in the depth of the test specimen wood frame thereby creating an equal recess at both the warm and cold rooms. The test specimen shall be sealed to its frame and the frame sealed to the test mask with duct tape as shown in Fig. 8. Duct tape shall not cover more than 1/4" of the exposed specimen frame.

8.3 Standard test sizes are shown in the list that follows. Exterior frame dimensions should not deviate more than 1/16" from the nominal dimensions given.

Horizontal Sliding Windows
6'-0" Wide x 4'-0" High

All Other Windows (Except Horizontal Sliding Windows)
4'-0" Wide x 6'-0" High

Sliding Glass Door and Small Glazed Wall Sections
6'-0" Wide x 6'-8" High

Swinging Doors
3'-0" Wide x 6'-8" High

Large Glazed Wall Sections
10'-0" Wide x 10'-0" High

Windows for Special Code Requirement Thermal Testing
3'-0" Wide x 4'-0" High

8.4 The test specimen shall be representative of manufacturer's production units or identified as a prototype design. The manufacturer shall provide a complete set of detail drawings and material descriptions.

8.5 As shown in Fig. 8 of this test method, the test specimen is to be mounted in a wood frame to simulate as closely as possible the actual installed mounting conditions anticipated for the product. Accessory exterior or interior trim systems are not to be used unless they constitute an integral inseparable member of the specimen. Blocking, fastening and installation hardware must be typical of manufacturer's standard recommendations. Frame perimeter voids may be filled with insulating products that are typical of manufacturer's recommendations and good installation practice. Perimeter joints between specimen and its frame and the laboratory test mask may be sealed with cloth duct tape. Alternately, the specimen to frame joint may be caulked. In no case shall the tape or caulk cover more than one quarter of an inch of the specimen frame. Specimen shall be held securely in a vertical plane, suitable for the testing loads and conditions and to allow full operation of all sash and/or operating members.

9.0 PROCEDURE

9.1 The standard test conditions of this test method are:

Cold room temperature	18°F
Warm room temperature	68°F

9.2 Standard tests shall be made in a facility which has been calibrated in accordance with the requirements of Section 8.

9.3 Test Procedure

9.3.1 All test specimens submitted for thermal testing shall be mounted in a mask as described in Section 8.2.

9.3.2 Inspect the test specimen for suitability for thermal testing. Where it can be done satisfactorily, repair any damage incurred in shipment. Do not test a specimen if satisfactory repairs cannot be made.

9.3.3 Install mask, complete with specimen between two chambers with the outside face of the test sample toward the cold room. Operate each operating sash or movable element through its complete operating cycle once to ensure a representative functional specimen is submitted for testing. Securely close and lock each operable element.

9.3.4 On double hung (single and triple hung) and horizontal sliding windows, measure the force required to operate the sash after it is in motion. On sliding glass doors, measure the force required to open the movable panel and the force required to operate the panel after it is in motion.

9.3.5 Determine the air infiltration for the test specimen in accordance to ASTM E 283 at a pressure difference of 0.57 psf and 1.57 psf (6.24 psf optional). Calculate the air infiltration per square foot of test specimen area for fixed windows, jalousie windows, sliding glass doors and swinging doors. Calculate the air infiltration per square foot of finished window opening and the plane of the wall for greenhouse windows. Calculate the air infiltration per foot of operable sash or ventilator crack for all windows (except fixed, greenhouse and jalousie windows).

9.3.6 U-Value and CRF Test Procedure: Carefully apply 30 gauge copper constantan thermocouples (20) on each test specimen located as indicated on the particular window design on Fig. 5. Thermocouple locations on wall sections and other windows and doors shall be selected to determine stabilized heat flow conditions. The thermocouples should be applied in the following manner:

9.3.6.1 Clean the surface area where the thermocouples (20) attached with alcohol.

9.3.6.2 Preheat area to which the thermocouple is to be affixed with a portable heat-blower until all evidence of moisture is removed.

9.3.6.3 Attach the thermocouple with the leadwires at right angle to the frame at the desired location with a 1 ¼" long piece of Borden's 1" wide Mystic #7452 tape or equivalent. Apply pressure to the tape with a small roller, back of finger, screwdriver or other suitable tool until it is evident the thermocouple is in direct contact with the surface.

9.3.6.4 Fix the thermocouples to the buck by taping with a 1 ¼" long piece of Borden's 1" wide Mystic #7452 tape or equal.

9.3.6.5 Extend the leadwire along the buck to a point at the horizontal centerline of the test unit. Support the bundled leadwire with a Panduit or equal #SSC2C cable clamp.

9.3.6.6 Attach the leadwires to the terminal board in the order shown on Fig. 5.

9.3.7 Adjust temperature controls for the warm room and the cold room to the standard test temperatures of 68°F and 18°F, respectively. Maintain maximum relative humidity in the warm room of 30%. Turn on refrigeration, cold room fan to impart the required perpendicular air flow and circulation fan heaters. Adjust the pressure controls to provide a net total pressure difference between the warm room and the cold room of 0.000 ± .002 in H_20.

9.3.8 Obtain stabilized temperature and heat flow conditions before beginning the tests to determine U-Value and CRF rating. Stabilized conditions are obtained when three heat flow readings made at 30-minute intervals are within 3% of the lowest reading. Stabilized temperature conditions require that all readings be within 0.5°F. Warm side air temperature shall be 68 ± 0.5°F and the cold side air temperature shall be 18 ± OSF.

9.3.8.1 With a portable indicator and copper constantan thermocouple probe, determine the 4 coldest paints on sash or frame. Locks and hardware are excluded. A cold point is defined to be any single area a maximum of 4 square inches in size or less. Cold point thermocouple spacing on sash or frame is defined as the greater thermocouple separation of either 4 square inches or 4 linear inches on the given member. Carefully apply 30 gauge copper constantan thermocouples on each of the 4 cold paints. All thermocouples should be checked for contact with the surface by checking the temperature of each couple on the indicator.

9.3.9 Check temperatures and pressures to ensure conformity to limits indicated in apparatus Sections 6.3.2 and 6.4.2. If satisfactory, begin the test to establish U-Value rating and CRF rating when stabilized conditions are obtained. Record all temperature paints, warm room relative humidity, pressure difference, cold room static pressure, and power readings every 30 minutes for 2 hours for a total of 5 sets of readings. Stabilized conditions must exist throughout the test.

9.3.10 Shut unit down, remove the test specimen from the chamber and verify that the sample conforms to the drawings and specifications.

10.0 CALCULATIONS

10.1 Calculate (U), the thermal transmittance of the test sample, by means of equation (5) in Section 5.4 using the average values recorded during the entire test period of heat flow from warm room to cold room and air temperatures of these two rooms. Calculate the CAF per formula in Section 5.4.1 using symbols and definitions as needed in Section 5.6.

10.2 Take into account heat losses through the mask, separating wall, metering box or chamber walls, and heat gains from fans, lights, pumps, dehumidifiers and controls in determining the time rate of heat flow (q) through the test sample area (A).

11.0 TEST REPORT

11.1 The test report shall include the following:

11.1.1 Location of test size, date when test was completed and date of issuance of the report.

11.1.2 Name of manufacturer.

11.1.3 Series name, model number or other identification of product tested.

11.1.4 When applicable, specification classification for which product has been previously tested (e.g. ANSI/AAMA 101-88; DH-R20).

11.1.5 Weatherstrip: Type and size.

11.1.6 Weep Holes: Number, size and location.

11.1.7 Glazing: Type and thickness of glazing (each lite employed), spacer width or separation dimension, spacer material if used, presence of desiccant materials, coating or tinting of glazing, presence of gas (other than air) inside insulating unit. Pressure or vacuum condition inside insulating unit. Presence and nature of glazing films if used and any other distinctive characteristics that may affect the thermal performance of the unit.

11.1.8 "Inside" surface finish.

11.1.9 "Outside" surface finish.

11.1.10 Screens, if used during test, shall be fully described in the test report, including frame size and material, screen cloth material and weave, whether full or half screens.

11.1.11 Detailed assembly drawing(s) and components list relative to type, size, shape and location of materials used to reduce thermal transmission in sash, ventilators, panels and/or main framing members. (To be provided by the manufacturer and verified by the testing laboratory to conform to the sample tested.)

11.1.12 Force required to operate test specimen per Section 9.3.4.

11.1.13 Air infiltration of test specimen per Section 9.3.5.

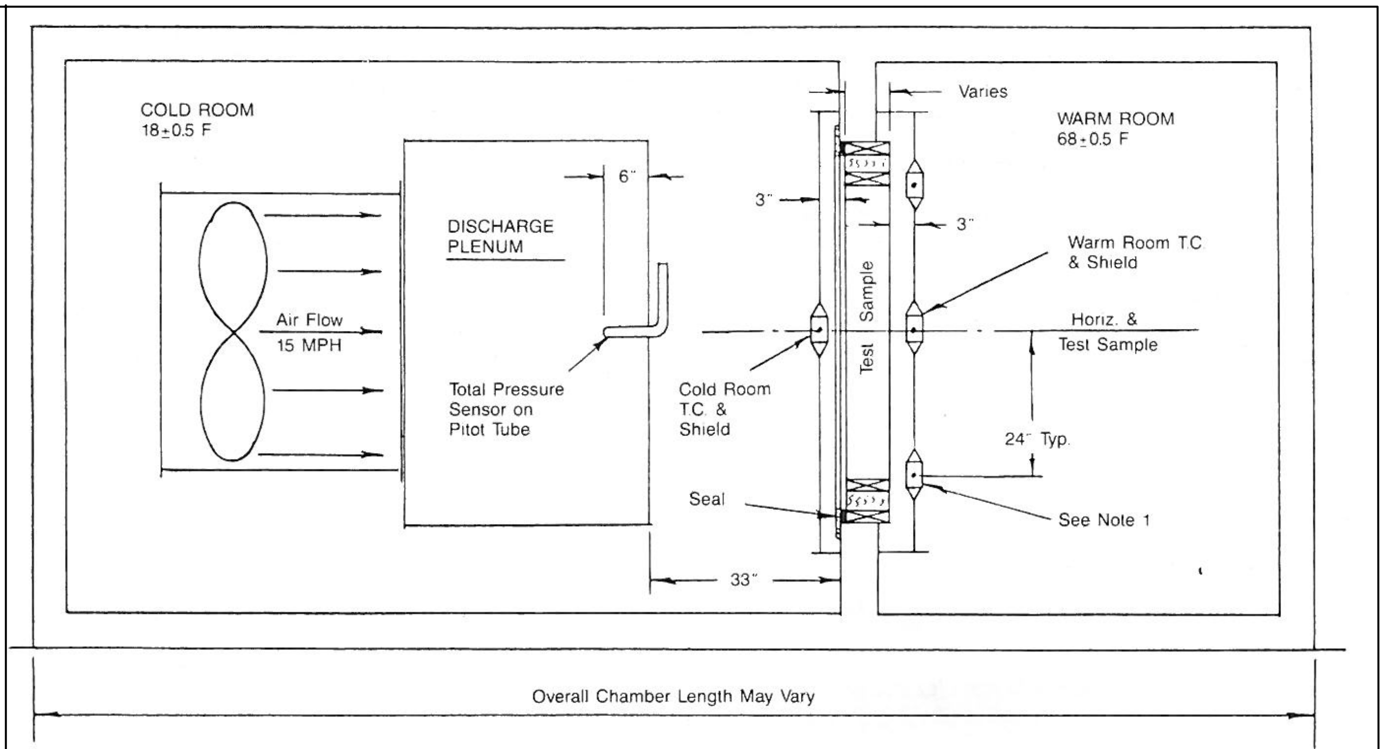
11.1.14 Thermal transmittance of test specimen.

11.1.14.1 CRF number, also values FT, FT_p, FT_r, W, GT, t_c, and t_h.

11.1.14.2 At manufacturers option, report second CRF result as CRF_F or CRF_G in accordance with Section 5.4.1.

11.1.15 A statement that the tests were conducted in accordance with this Standard Test Method and a list of any exceptions to standard conditions, sizes or other specified criteria.

Figure 1: Thermal Chamber Diagram



NOTE: Thermocouples and shields on warm side movable to maintain 3" spacing to the mask.

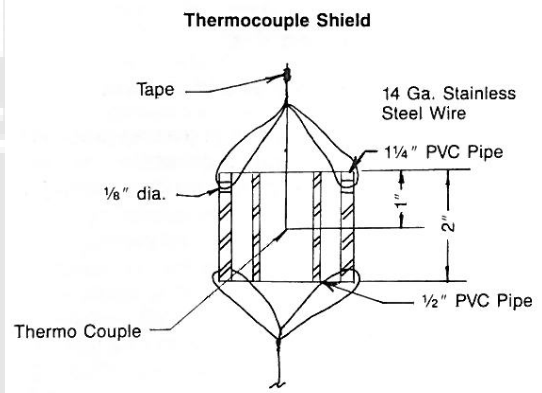


Figure 2: Calibration Panel Thermocouple Locations

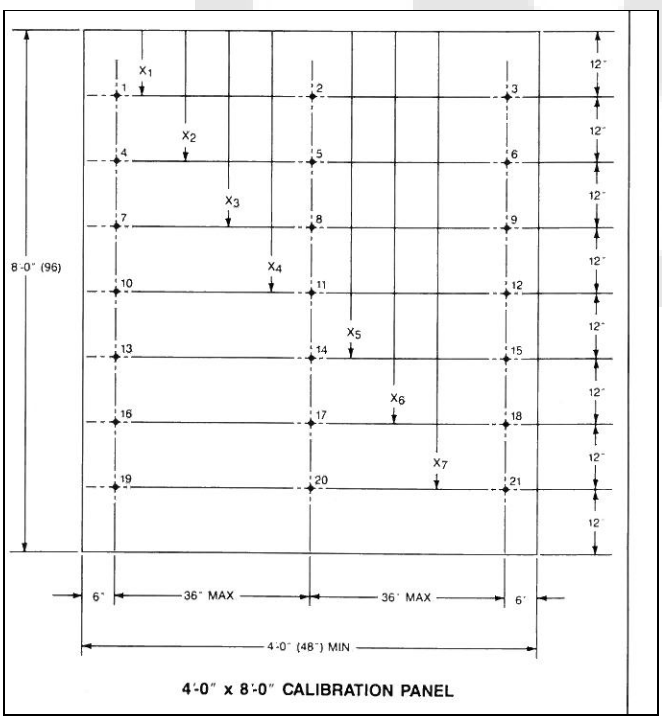


Figure 3: Test Frame Design

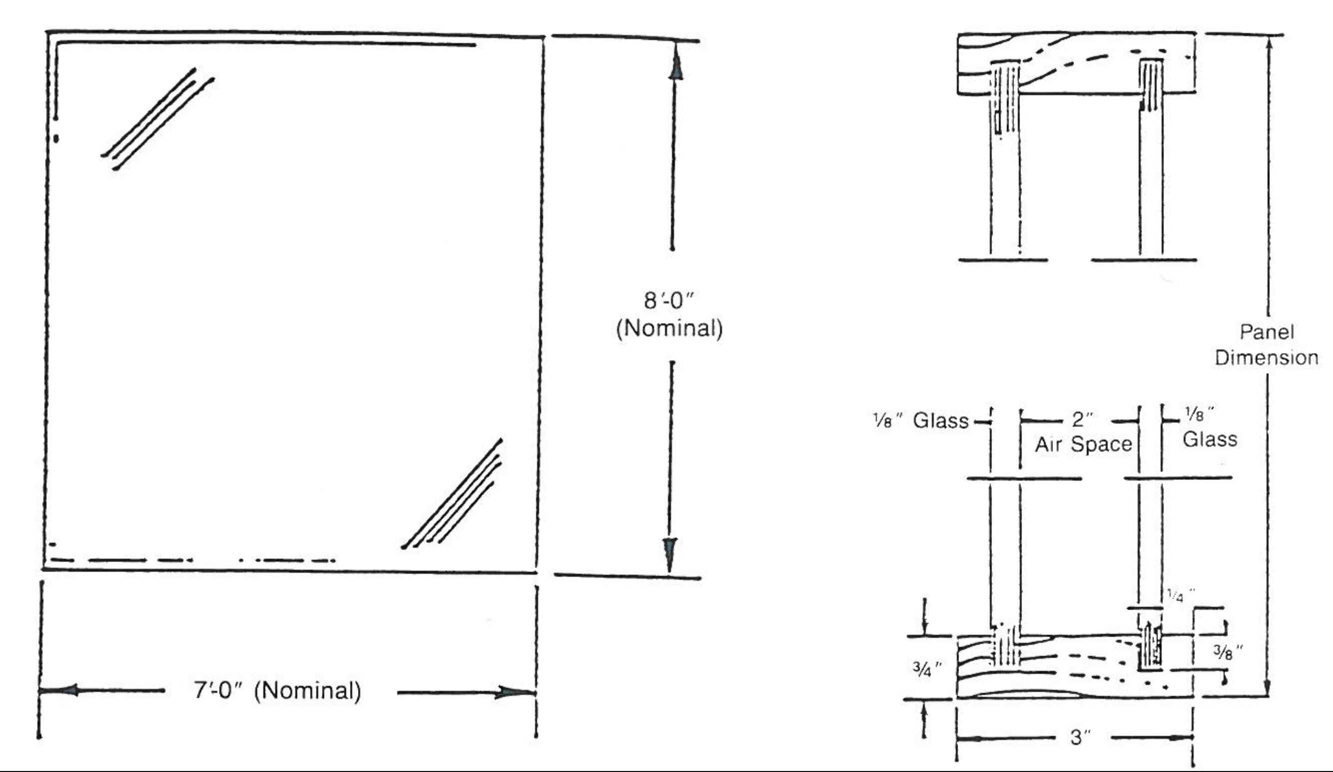


Figure 4: Locations for Air Velocity Readings in Plane of Plenum Discharge

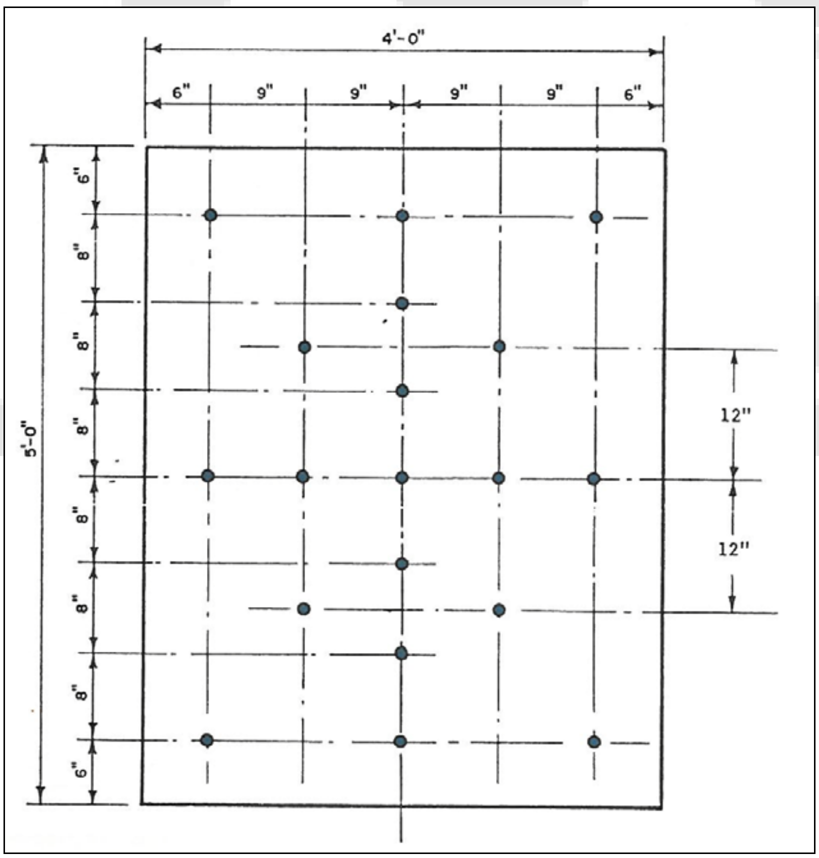


Figure 5: Location of 20 Pre-specified Thermocouples

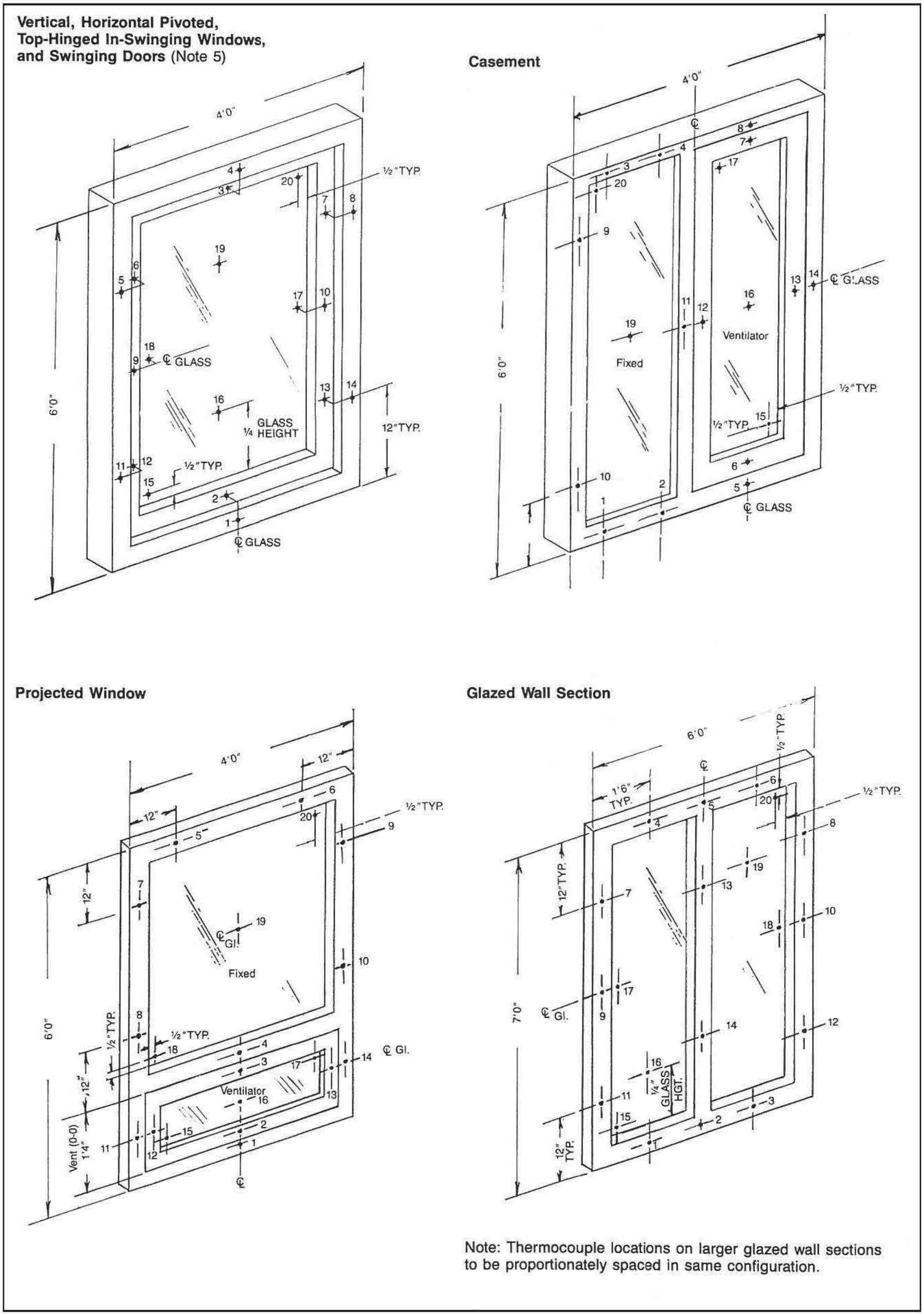
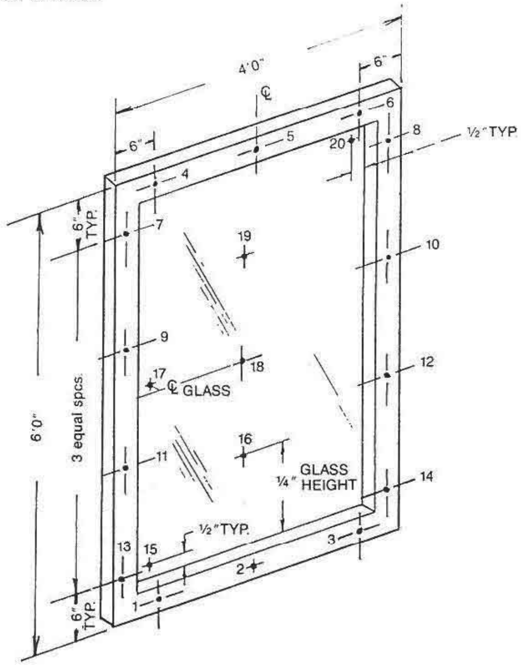
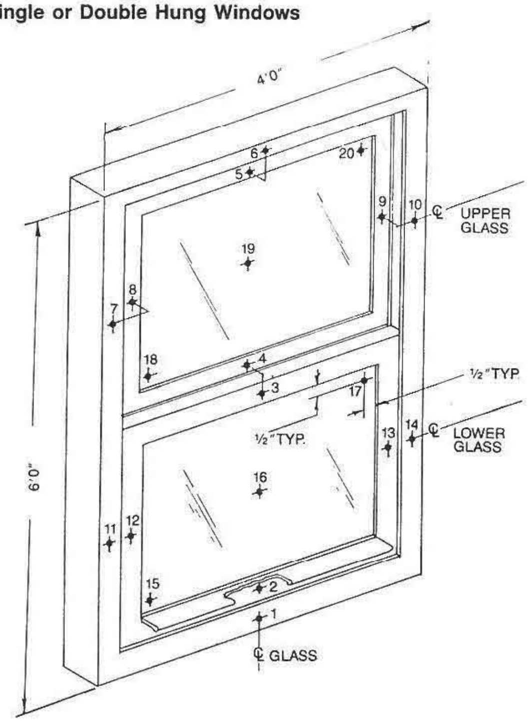


Figure 5 (cont.)

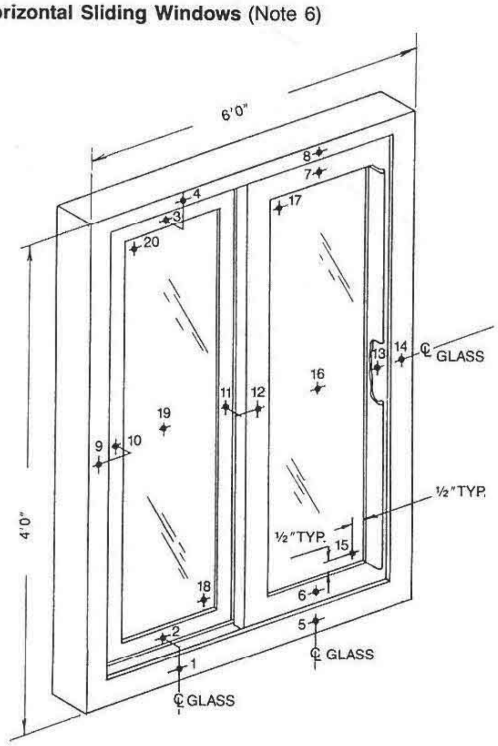
Fixed Window



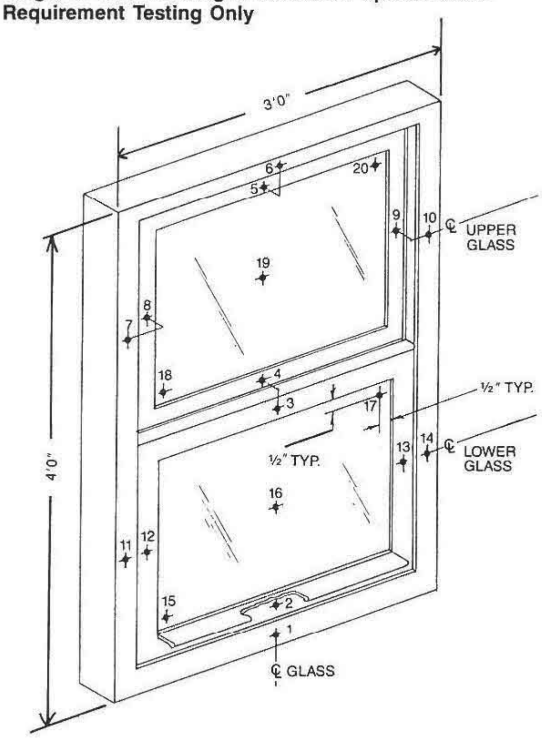
Single or Double Hung Windows



Horizontal Sliding Windows (Note 6)



Single or Double Hung Windows for Special Code Requirement Testing Only



Notes:

1. All drawings show inside views.
2. Thermocouples are to be placed on the centerline (excluding hardware) of the surface parallel to the plane of the glass whenever possible. If parallel surfaces cannot be used, attach thermocouples to adjacent surfaces, as close to prescribed surface as practical.
3. For projected windows, thermocouple 3 shall be on the ventilator and thermocouple 4 on the meeting rail.
4. For casements, thermocouple 12 shall be on the ventilator and thermocouple 11 on the meeting rail.
5. For swinging doors, dimensions shall be 3'-0" wide by 6'-8" high.
6. For sliding glass doors, dimensions shall be 6'-0" wide by 6'-8" high.

Figure 6: Specifications for Masks

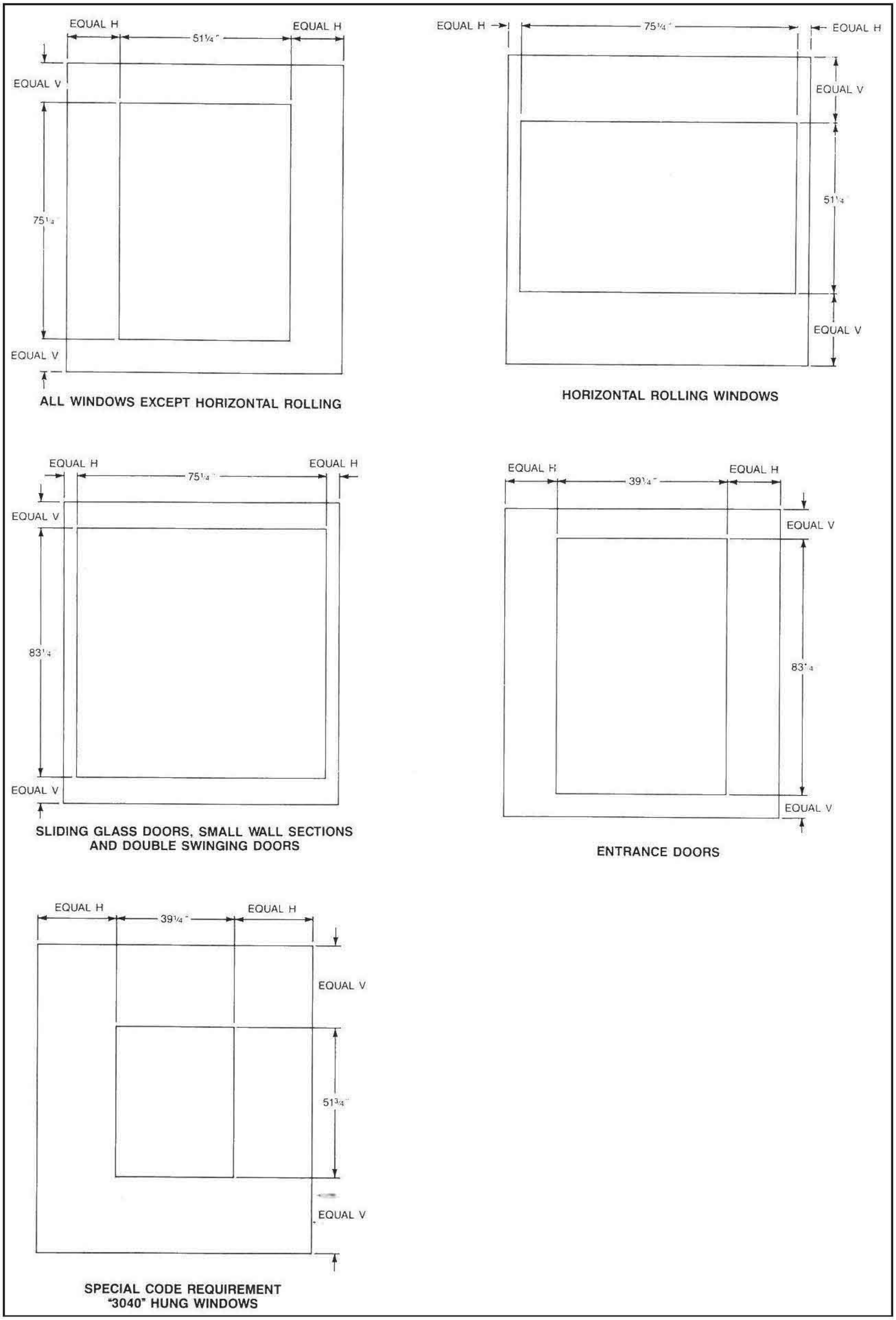


Figure 7: Mask Details

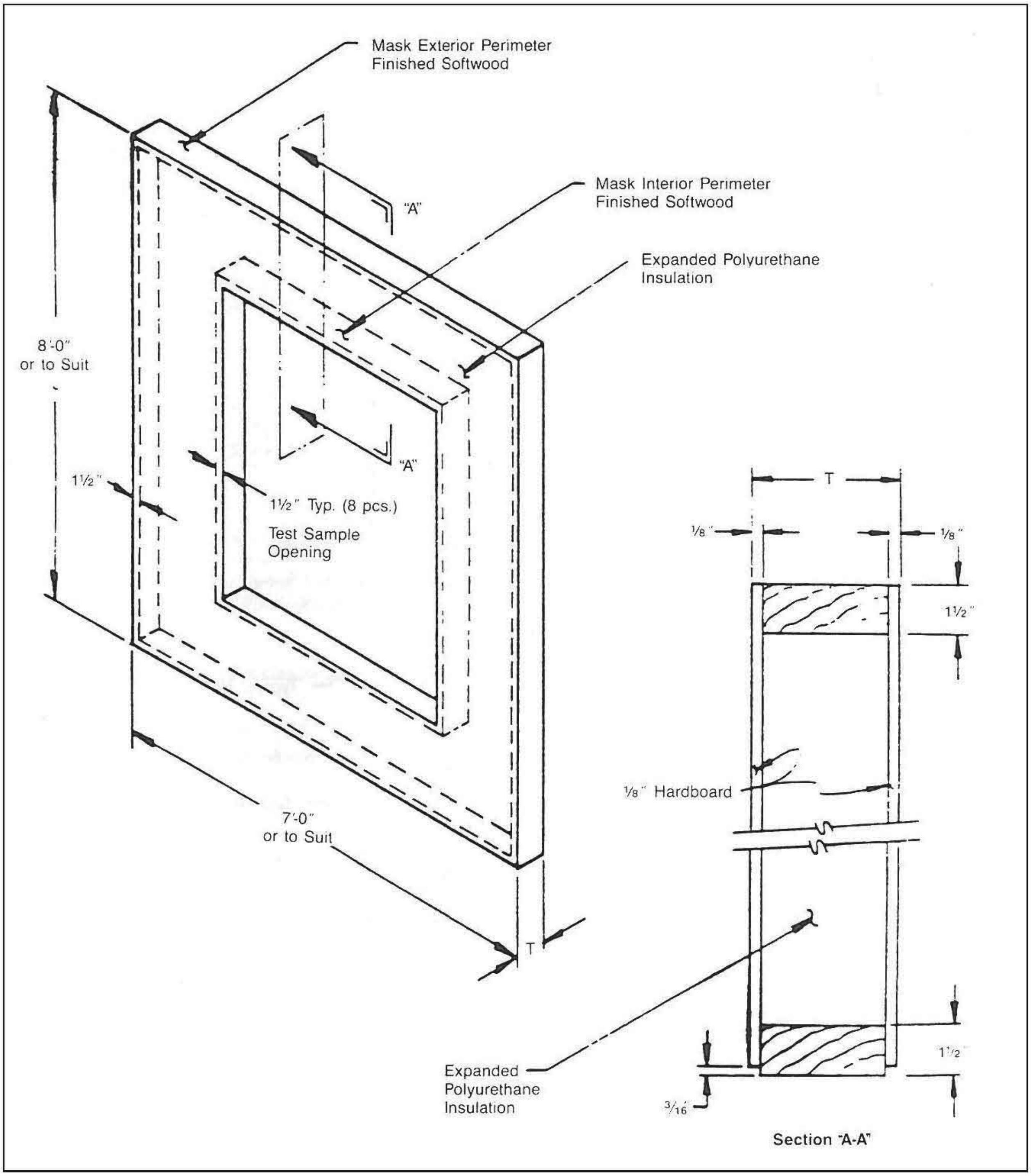


Figure 8: Test Mask and Sample Assembly

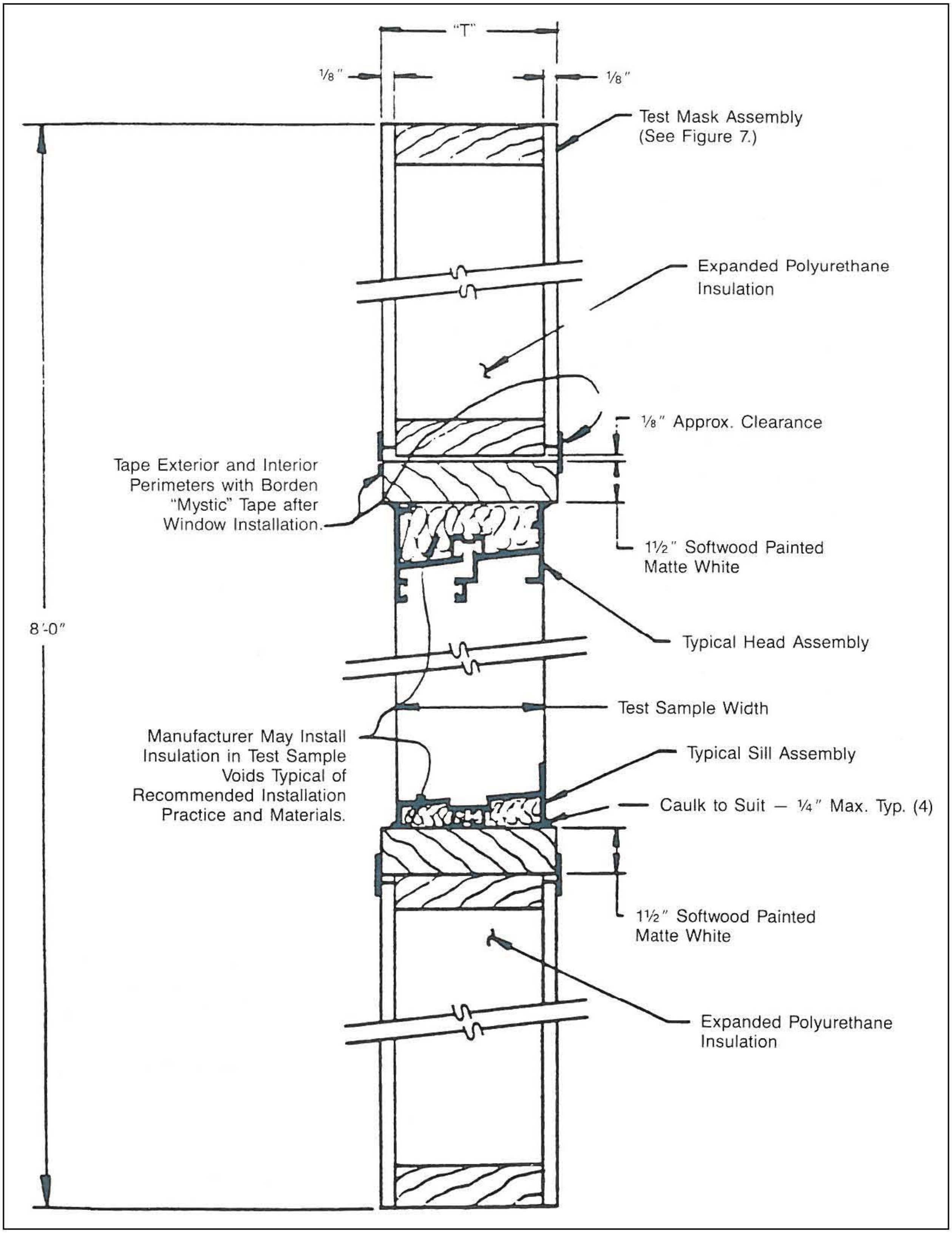
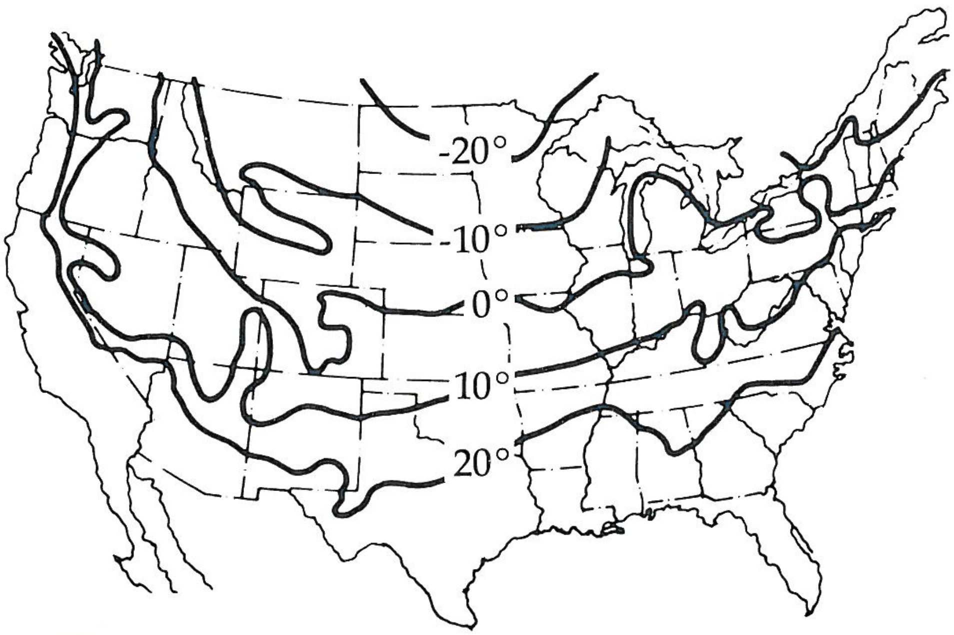


Figure 9: Winter Outside Design Temperature



During the months of December, January, and February, the temperature will not be at or below the indicated design temperature 97.5% of the time. Temperature data for specific locations are given in Chapter 33, Weather Data and Design Conditions, *ASHRAE Handbook of Fundamentals,* published by American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

Figure 10: Condensation Resistance Factor Curves