APPENDIX A – THERM Analysis

- The current curtain wall exterior shading pattern is what the glazing industry considers harmful: A) Less than 25% of total glass area is in shade, and B) more than 25% of the glass perimeter lineal footage is in shade. This configuration sets up greater center-to-edge thermal gradient.

- The insulation directly behind the glass without space to allow air to move exacerbates the heat build up in the center region of the glass. The edge of the insulation does not cover the edge of the glass and is also not as tight to the glass as the center, further increasing the thermal gradient.

- As sun moves through the southern sky during the day, the glass experiences different build up of heat. The right jamb is in shade and a small portion of the head (lower sun angle) is in shade in the morning. By about 12:45 p.m. or so, the sun is perpendicular to the south wall and only the head is in shade. However, beyond that point, the left jamb stays in the shade for the remainder of the day while the center of the glass continues to gain heat. This sets up greater thermal differential through the rest of the day.

- The notched-out aluminum frame at anchor and discontinuity of frame at splice joint (every two floors) create gaps allowing cold air to come in contact directly with the edge of the glass.

- The gold-tone mullion just above center of the glass casts a somewhat constant shadow in the center region of the spandrel glass. Its effect may or may not be positive (it puts more glass in shadow, helping to reduce total thermal gradient. However, it may also thermally divide the glass into two regions. This is still being investigated).

- Based on empirical data from prior projects and industry resources, glass can reach temperature in the 200° F to 220° F and the curtain wall frame can reach 160° F to 180° F. Based on the frame being at 160° F and center of glass at 200° F, our computer simulation program produces glass edge temperature in the 130° F range. This is a temperature difference of 70° to 90° F, not enough to cause breakage on a heat-strengthened glass. But when the gasket is loose and pulled away, the glass edge temperature drops to 110° F increasing the temperature difference to 90 to 110 degrees range.

- With gasket being loose, the temperature difference is 110 degrees, getting closer to the 153.6 degree limit as set by the glazing manufacturer (Viracon uses 153.6° F as guideline).

- The thermal stress from the elevated temperature differential imposes thermal stress at the glass edge and likely pushed some form of glass edge defect past the compression skin and caused the thermal break observed.

The fact that the temperature differential is not at the limit, is re-assuring, and is logical. If THERM calculations had indicated a much higher thermal differential, more glass probably would have been broken thermally throughout the history of the building.

MCA believes the above is reasonably true of actual conditions at the building. MCA recommends testing of the glass to find out what its true compression values are before proceeding with the design of corrective measures.

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Modification of the wall cavity (insulation/fire-safing) becomes important during the remedial work. 100% inspection of the spandrel glass edge will be required during remedial work - some replacement is expected (possibly 10% or even higher), to eliminate as many potential defects as possible.

Considering all factors, the current total number of breakage is still well within industry tolerance for glass breakage of 0.8% (BOE has about 1,900 spandrel glass, allowing 15 pieces of breakage). The thermal stress in the coming rainy season should be lower than the past summer (one would surely expect it) therefore reducing the potential for glass breakage. In addition, the complexity of the remedial work and necessary testing for the existing glass properties would make rushing into remedial work this winter a problematic, if not unsafe scenario. MCA feels it would be prudent to accelerate the preliminary design and testing now to complete the design development as soon as possible, complete the bid documents through the winter season, and bid the work late winter to start construction after this rainy season.

If you have any questions, please do not hesitate to contact MCA.

Sincerely,

Yi-Tso Jeff Chen

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Introduction to THERM 5.2

THERM is a state-of-the-art, Microsoft Windows™-based computer program developed at Lawrence Berkeley National Laboratory (LBNL) for use by building component manufacturers, engineers, educators, students, architects, and others interested in heat transfer. Using THERM, you can model two-dimensional heat-transfer effects in building components such as windows, walls, foundations, roofs, and doors; appliances; and other products where thermal bridges are of concern. THERM's heat-transfer analysis allows you to evaluate a product's energy efficiency and local temperature patterns, which may relate directly to problems with condensation, moisture damage, and structural integrity.
THERM's two-dimensional conduction heat-transfer analysis is based on the finite-element method, which can model the complicated geometries of building products.

Analysis Performed by McGinnis Chen Associates, Inc. (MCA)

The following pages are results from two-dimensional heat transfer modeling performed by MCA for the Capitol Square Building at 450 N Street, Sacramento, California. The subject of MCA's analysis was the vertical divider between two lights of spandrel glass. This profile was modeled under the following three conditions:

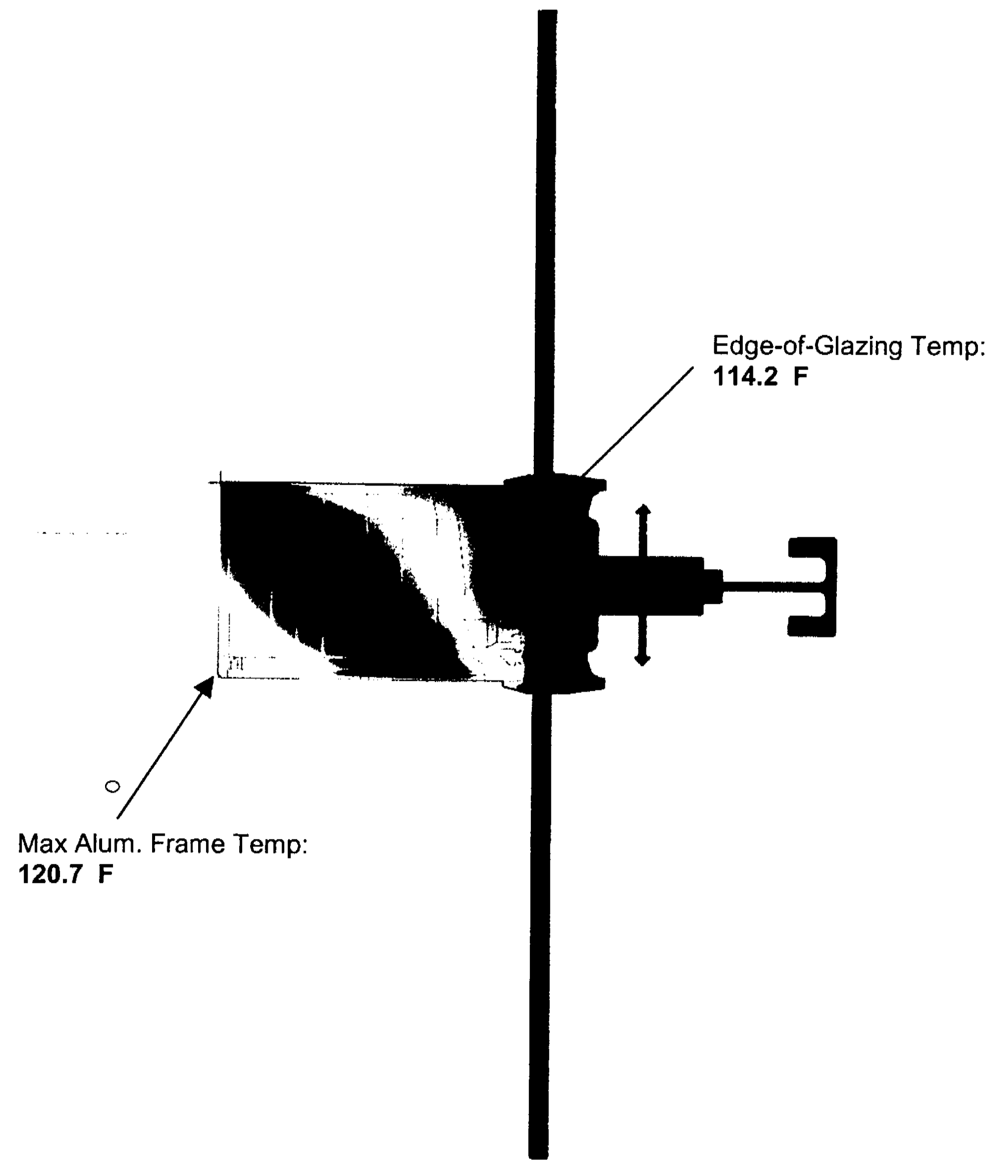
A. Typical profile as-designed with gaskets in place on interior and exterior.
B. Typical profile with interior gaskets out of place, allowing for increased ventilation in the frame cavity.
C. Profile at anchor connections where the profile is milled out and provides no lateral support for interior gaskets.

The maximum assumed temperature of the center-of-glazing used in MCA's analysis was 220 °F, and based on this value, a conservative range of aluminum temperatures was used to evaluate the temperature differential between center- and edge-of-glazing. The range varied from 120 °F to 180 °F, where 120 °F is presumed to be the lowest temperature that the aluminum frame would achieve while the center-of-glazing is simultaneously 220 °F.

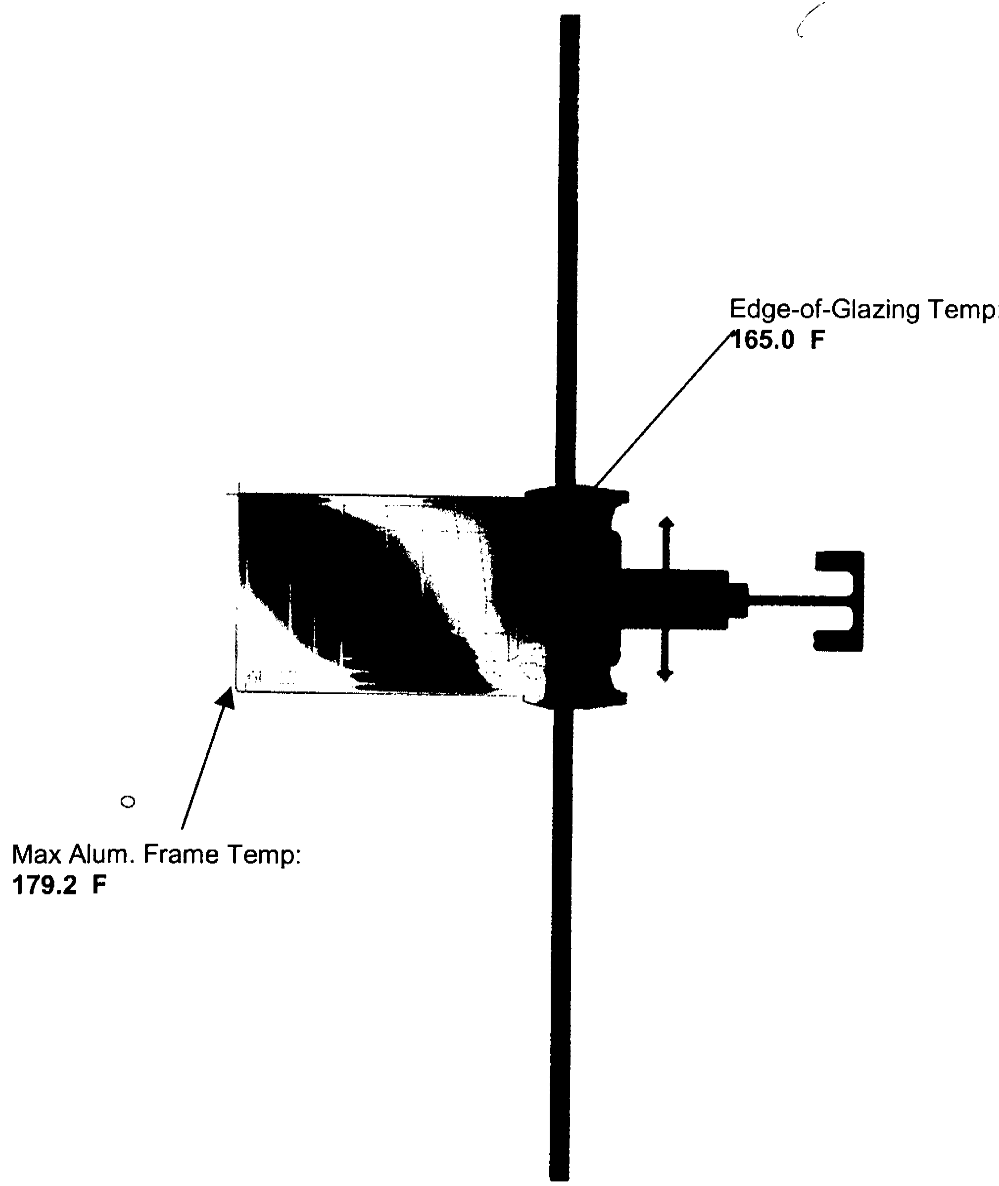
Each of the above three conditions was modeled for an interior ambient temperature of 69.8 °F and exterior ambient temperature of 90 °F. The profiles were then subjected to four boundary conditions with the temperature of the exterior face of the aluminum frame varying between 120 °F, 140 °F, 160 °F, and 180 °F. The results of this modeling are shown graphically in color infrared over the various profile conditions. Included in Appendix A are the most extreme results, which are each of the three profile conditions (A, B, and C) modeled with boundary conditions at 120 °F and 180 °F.

CONDITION A	Typical As-Designed Profile of Vertical Divider at Spandrel
BOUNDARY CONDITIONS	Exterior Face of Aluminum Frame at 120 °F

A - Vert Spandrel - As Dsgn (48%)   Therm Version 5.2 (5.2.14) (1 of 1)

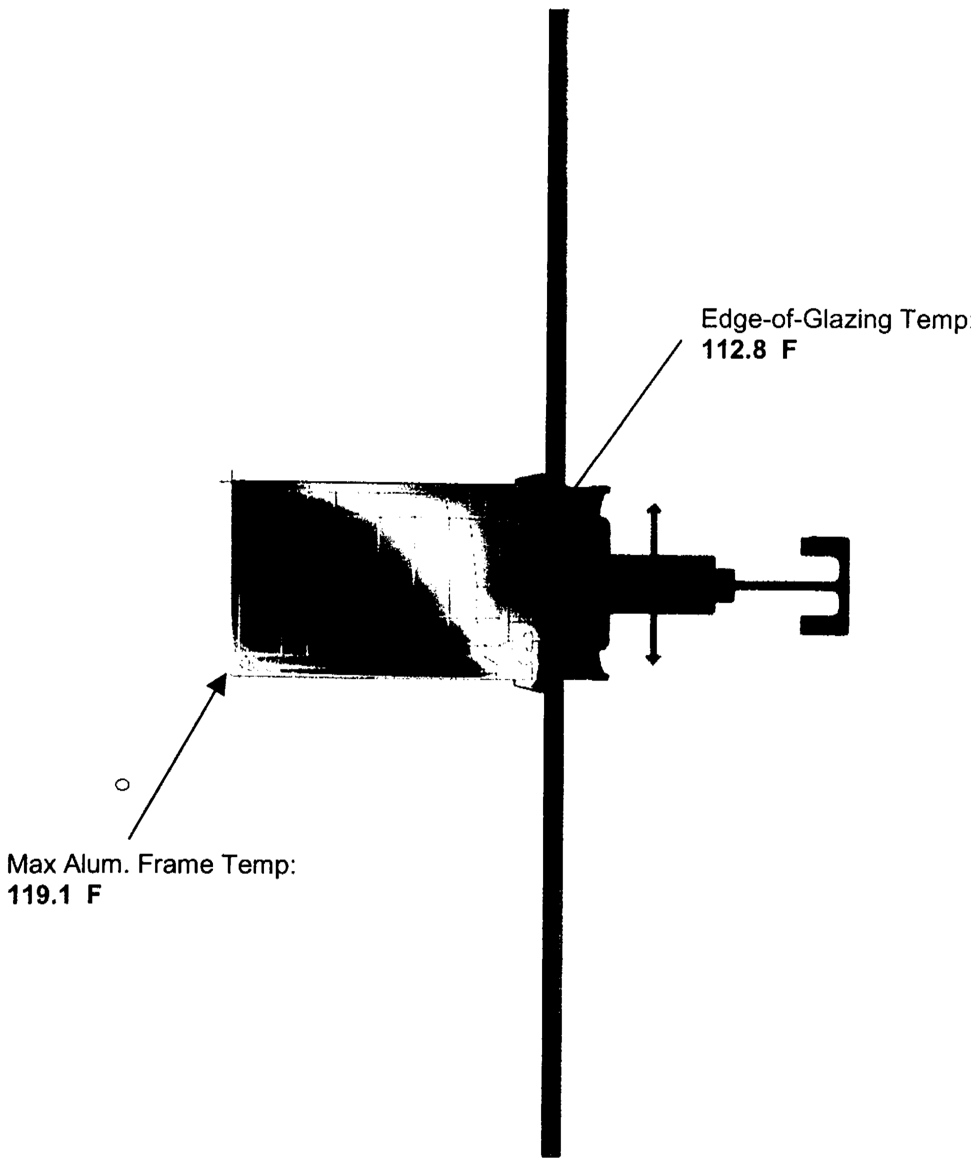


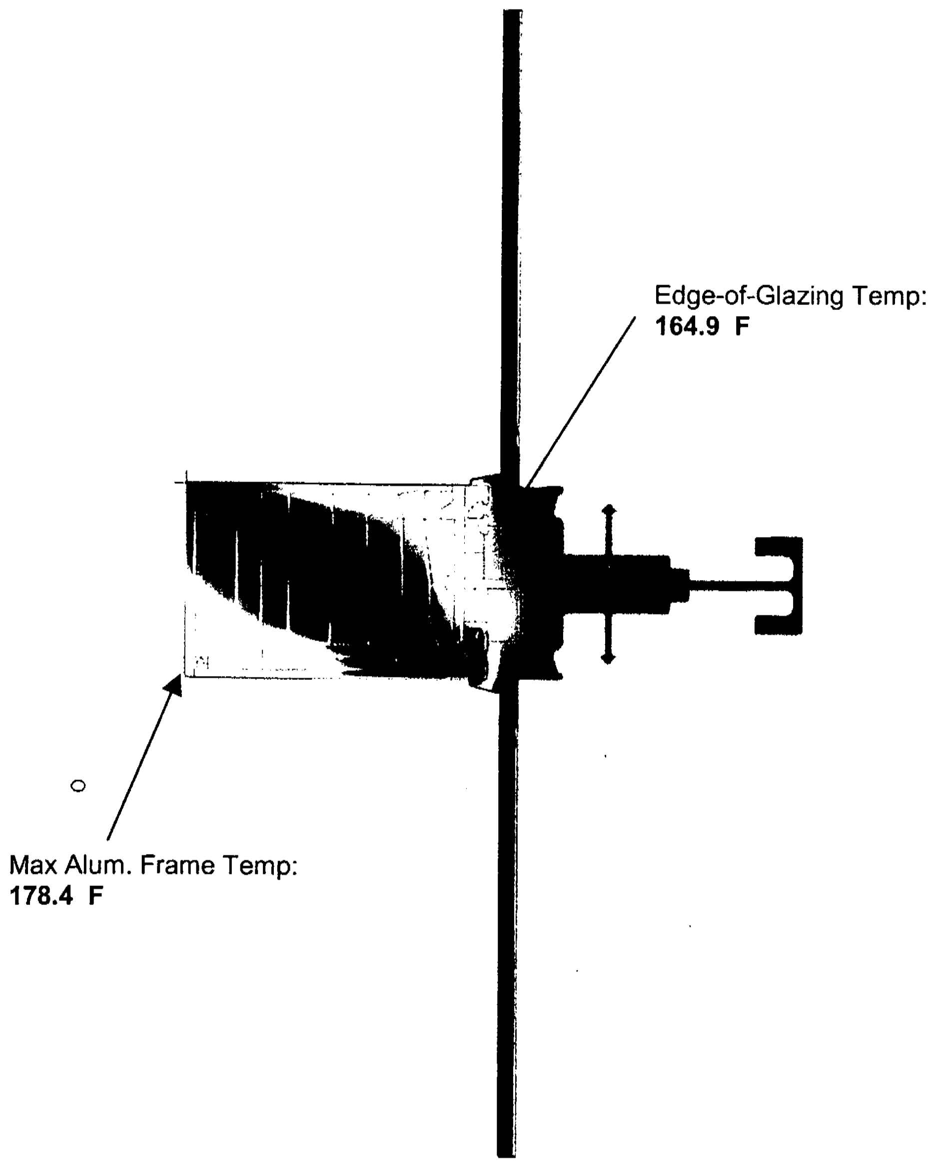
CONDITION A	Typical As-Designed Profile of Vertical Divider at Spandrel
BOUNDARY CONDITIONS	Exterior Face of Aluminum Frame at 180 °F


Edge-of-Glazing Temp:
165.0 F
Max Alum. Frame Temp:
179.2 F

CONDITION B	Typical Profile of Vertical Divider at Spandrel Without Interior Gaskets
BOUNDARY CONDITIONS	Exterior Face of Aluminum Frame at 120 °F

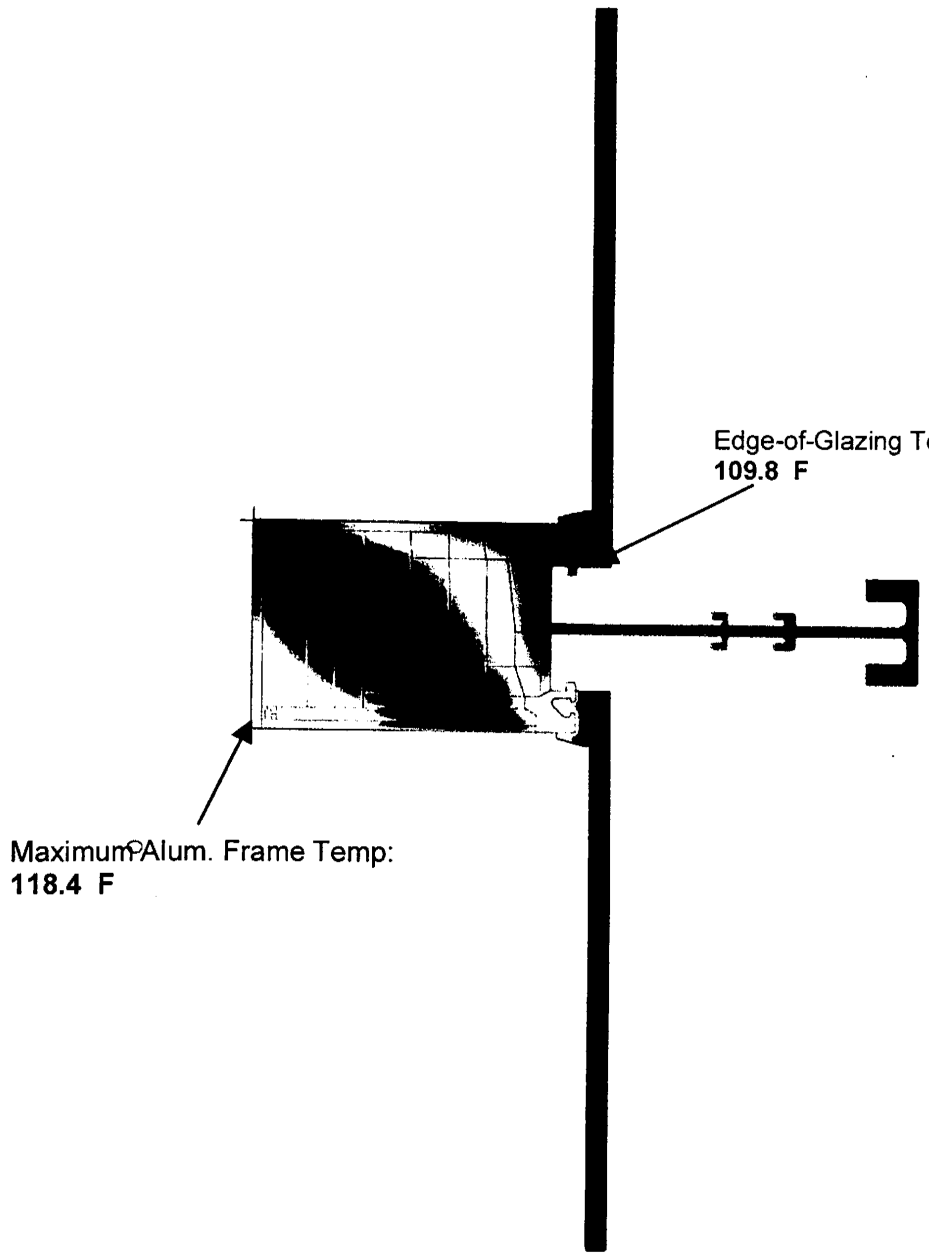
B - Vert Spandrel - No Intr Gasket (48a)   Therm Version 5.2 (5.2.14) (1 of 1)




Edge-of-Glazing Temp:
164.9 F
Max Alum. Frame Temp:
178.4 F

CONDITION C Milled Profile at Anchor Connections Without Gaskets

BOUNDARY CONDITIONS Exterior Face of Aluminum Frame at 120 °F

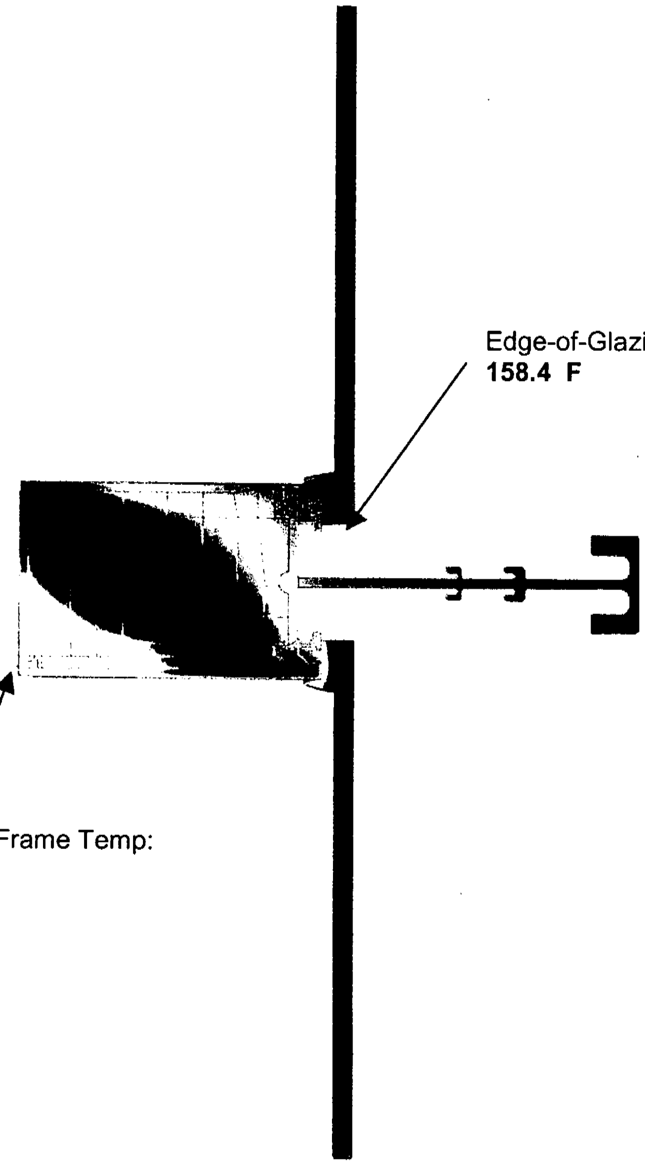

Edge-of-Glazing Temp:
109.8 F
Maximum Alum. Frame Temp:
118.4 F

CONDITION B Typical Profile of Vertical Divider at Spandrel Without Interior Gaskets

BOUNDARY CONDITIONS Exterior Face of Aluminum Frame at 180 °F

CONDITION C Milled Profile at Anchor Connections Without Gaskets

BOUNDARY CONDITIONS Exterior Face of Aluminum Frame at 180 °F


Edge-of-Glazing Temp:
158.4 F
Max Alum. Frame Temp:
176.8 F