Perimeter Fire Containment

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Course / Learning Objectives

- Why is fire containment important?
- 3 Elements of Life Safety
- Fire Performance of Building Materials
- Building Code Requirements and ASTM E 2307
- Design Principles
- Rated Curtain Wall Assemblies
- What do the ratings mean?
- Spandrel Height and Leap Frog
- Engineering Judgments
- Q&A

Why is fire containment important?

Why is Fire Containment Important?

135 S. Lasalle Building in Chicago

High-Rise Fire at First Interstate Bank in Los Angeles, CA on May 4, 1988

Development of Perimeter Fire Containment

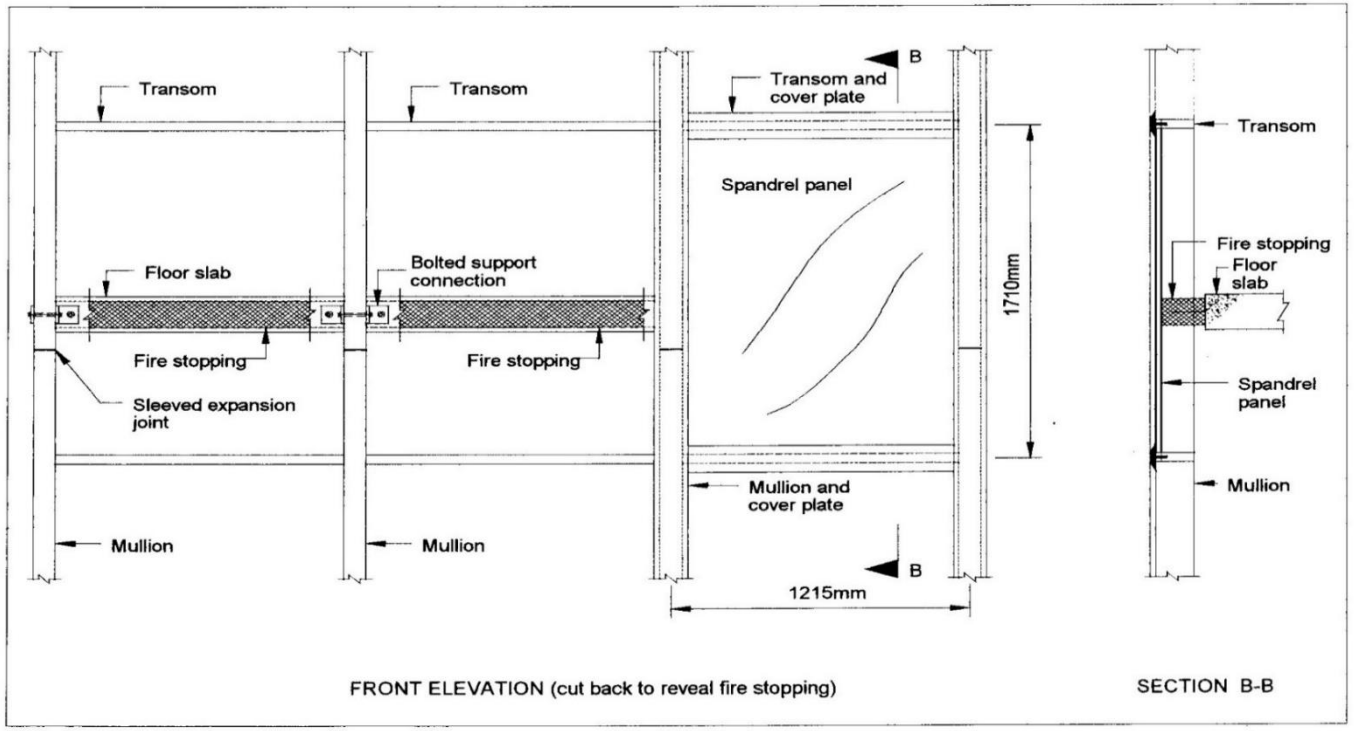
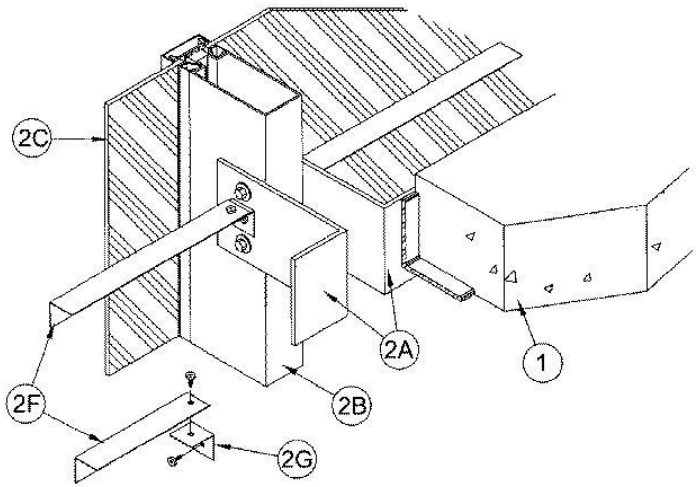
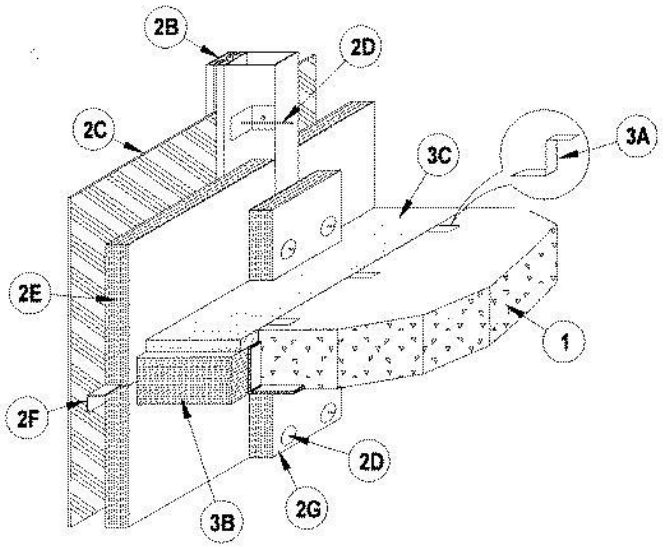


Figure 1 - Typical curtain wall system panel

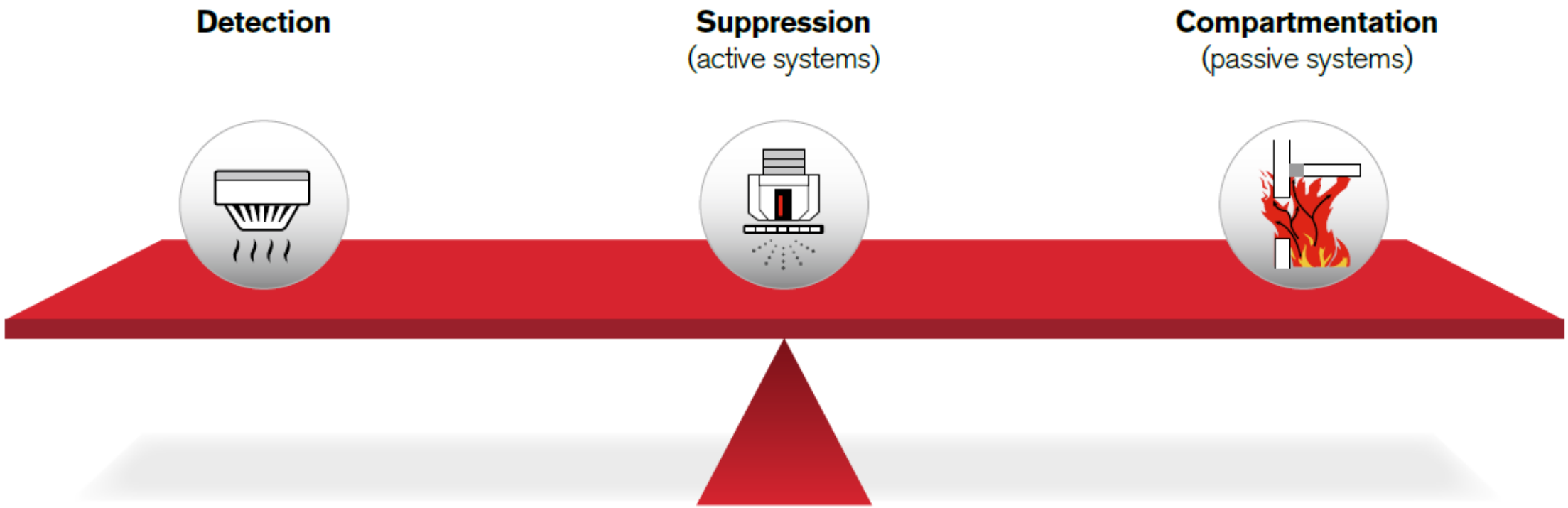
Loss Prevention Council – United Kingdom 1999



Underwriters Laboratories

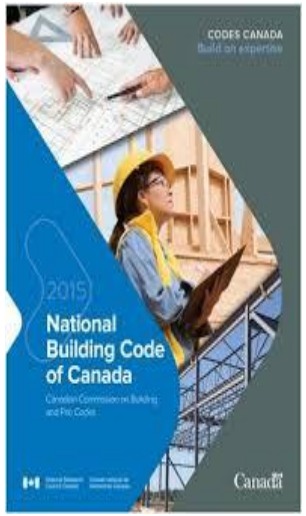


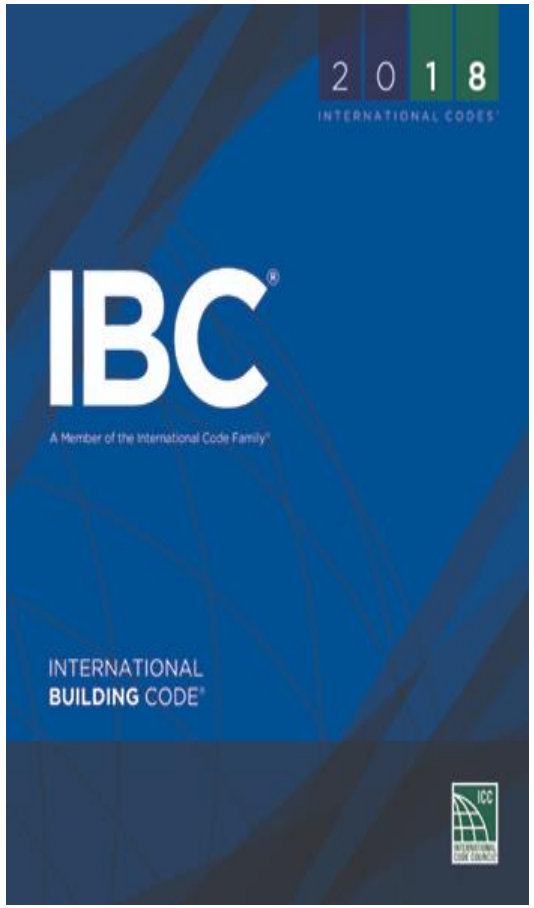
Development of Perimeter Fire Containment



The Balanced Approach

What do the Codes say about PFB joints?




2018
INTERNATIONAL CODES
IBC
A Member of the International Code Family
INTERNATIONAL
BUILDING CODE
ICC

705.8.5 Vertical Separation of Openings

Openings in exterior walls in adjacent stories shall be separated vertically to protect against fire spread on the exterior of the buildings where the openings are within 5 feet (1524mm) of each other horizontally and the opening in the lower story is not a protected opening with a fire protection rating of not less than ¾ hour. **Such openings shall be separated vertically not less than 3 feet (914mm) by spandrel girders, exterior walls or other similar assemblies that have a fire-resistance rating of not less than 1 hour,** rated for exposure to fire from both sides, or by flame barriers that extend horizontally not less than 30 inches (762mm) beyond the exterior wall. Flame barriers shall have a fire-resistance rating of not less than 1 hour. The unexposed surface temperature limitations specified in ASTM E119 or UL 263 shall not apply to the flame barriers unless otherwise required by the provisions of this code.

Exceptions:

1. This section shall not apply to buildings that are three stories or less above grade plane.
2. This section shall not apply to buildings equipped throughout with an automatic sprinkler system in accordance with section 903.3.1.1 or 903.3.1.2.
3. Open parking garages.

715.4 Exterior Curtain Wall/Floor Intersection

Where fire resistance-rated floor or floor/ceiling assemblies are required, **voids created at the intersection of the exterior curtain wall assemblies and such floor assemblies shall be sealed with an *approved* system** to prevent the **interior spread** of fire. **Such systems shall be securely installed and tested in accordance with ASTM E2307 to provide an F rating for a time period not less than the fire- resistance rating of the floor assembly.** Height and fire-resistance requirements for curtain wall spandrels shall comply with Section 705.8.5.

715.4 Exceptions

Voids created at the intersection of the exterior curtain wall assemblies and such floor assemblies **where the vision glass extends to the finished floor level shall be permitted to be sealed with an approved material to prevent the interior spread of fire.** Such material shall be securely installed and **capable of preventing the passage of flame and hot gases sufficient to ignite cotton waste where subjected to ASTM E 119 time-temperature fire conditions** under a minimum positive pressure differential of 0.01 inch (0.254 mm) of water column (2.5 Pa) for the time period equal to the fire-resistance rating of the floor assembly.

715.4.1 Exterior Curtain wall/nonfire-resistance-rated floor assembly intersection

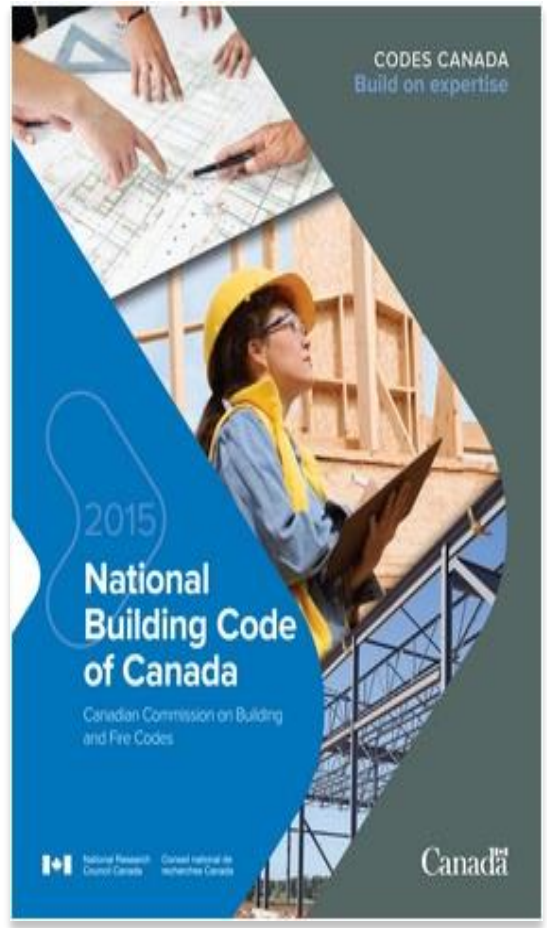
International Building Codes 2015

Section 715.4.1

Voids created at the intersection of exterior curtain wall assemblies and nonfire-resistance-rated floor or floor/ceiling assemblies **shall be sealed with an approved material or system to retard the interior spread of fire and hot gases between stories.**

715.5 Spandrel Wall

Height and fire-resistance requirements for curtain wall spandrels shall comply with Section 705.8.5. **Where Section 705.8.5 does not require a fire-resistance-rated spandrel wall, the requirements of Section 715.4 shall still apply to the intersection between the spandrel wall and the floor.**


CODES CANADA
Build on expertise
2015
National Building Code of Canada
Canadian Commission on Building and Fire Codes
Canada

Building Codes - Canada

National Building Code of Canada
3.1.8.3. Continuity of Fire Separations

4) The continuity of a fire separation shall be maintained where it abuts another fire separation, a floor, a ceiling, a roof, or an exterior wall assembly.
(See Note A-3.8.3.(4).)

A-3.1.8.3.(4) Fire Separation Continuity. The continuity of a fire separation where it abuts against another fire separation, a floor, a ceiling or an exterior wall assembly is maintained by filling all openings at the juncture of the assemblies with a material that will ensure the integrity of the fire separation at that location.

CAN/ULC-S115-2018

New edition of CAN/ULC-S115 published mid-2018

9. PERIMETER JOINT FIRESTOP SYSTEMS

9.1 GENERAL

9.1.1 Perimeter Joint Firestop Systems shall be tested in accordance with the requirements in ASTM E2307, Standard Test Method for Determining Fire Resistance of Perimeter Fire Barriers Using Intermediate-Scale, Multi-Storey Apparatus.

……

9.4.4.1 The placement and measurement of unexposed surface temperatures shall be in accordance with the requirements in the standard ASTM E2307, Standard Test Method for Determining Fire Resistance of Perimeter Fire Barriers Using Intermediate-Scale, Multi-story Test Apparatus.

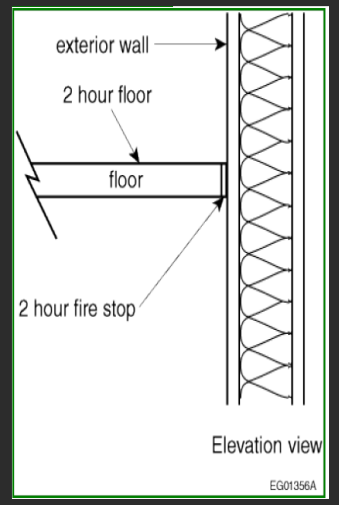
Building Codes - Canada

Firestop related proposals in the current 2020 cycle

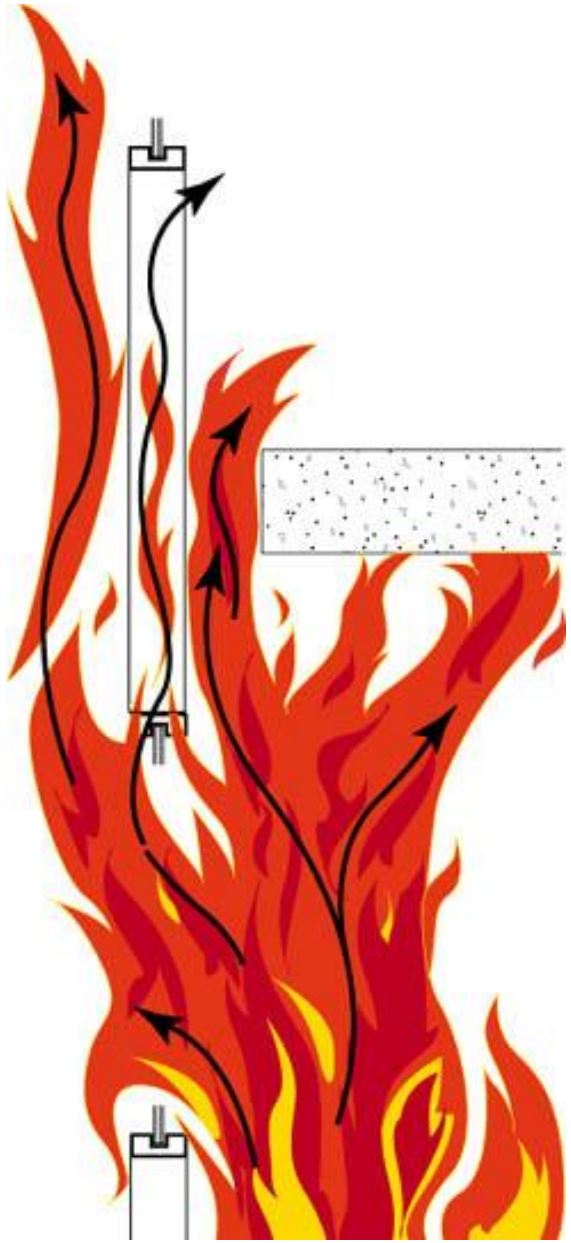
Perimeter Fire Barrier Proposals:

- **Carried over from previous cycle**

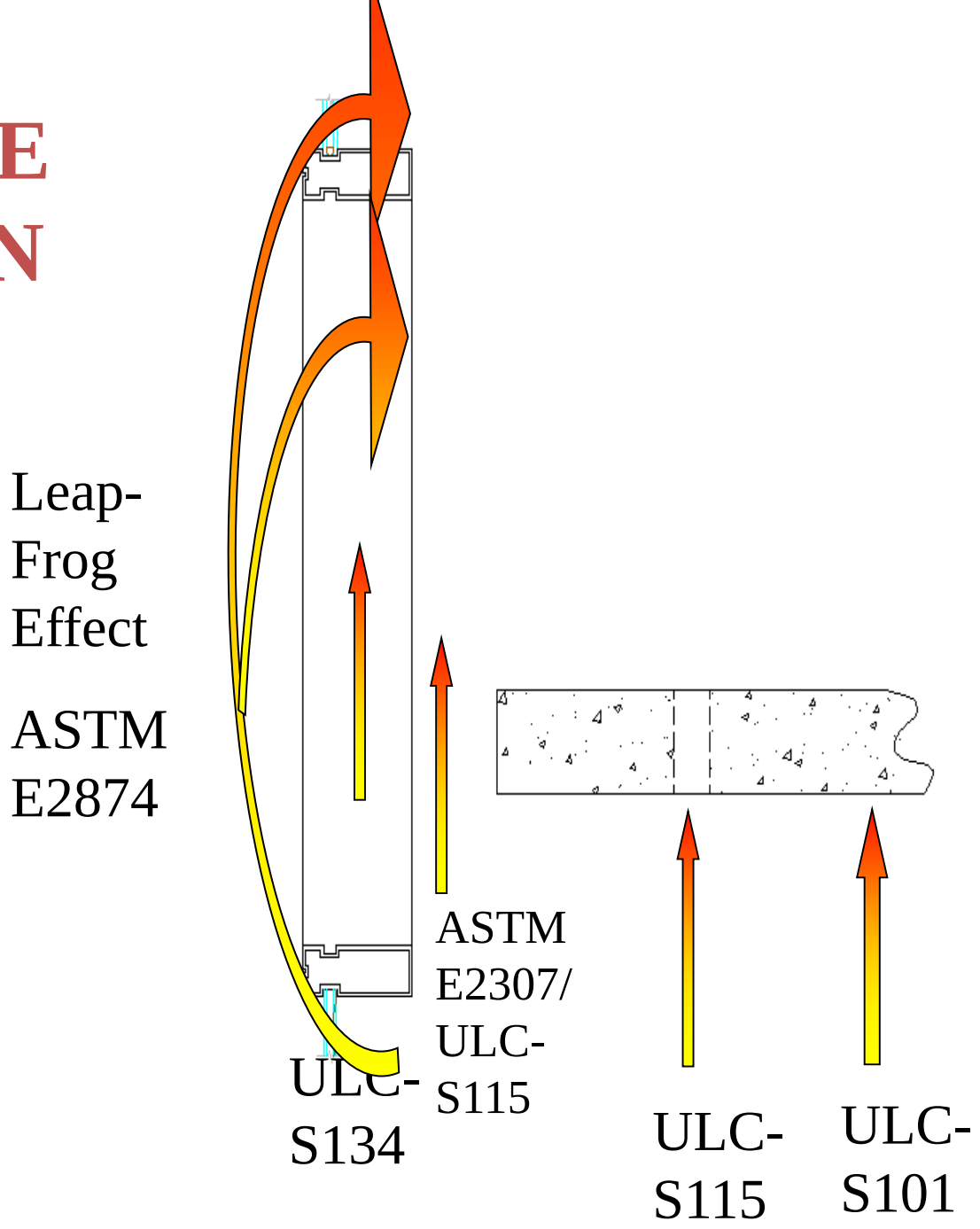
[6] --) Joints located in a horizontal plane between the floor and exterior wall are permitted to be sealed by a *fire stop* that has an F rating not less than the *fire-resistance rating* of the horizontal *fire separation* when subjected to the fire test method in ASTM E 2307 "Determining Fire Resistance of Perimeter Fire Barrier System Using Intermediate Scale, Multi-storey Test Apparatus." (See Appendix A.)



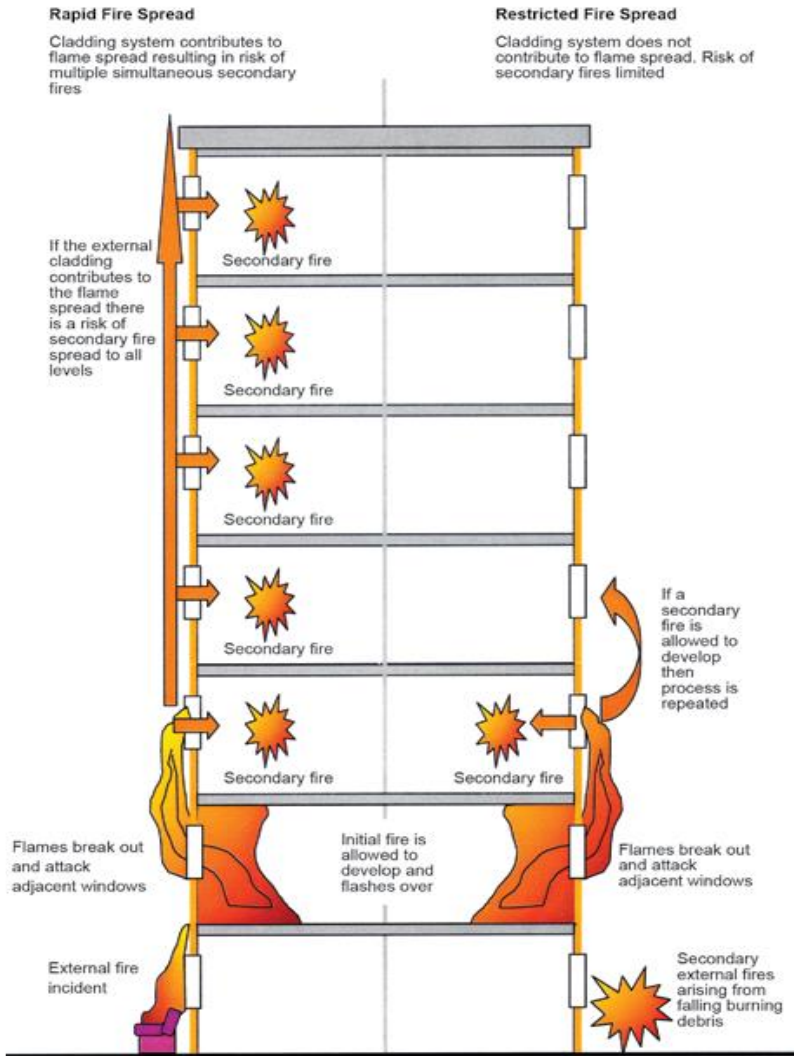
Additional Mechanisms of Vertical Fire Spread



PATHS OF FIRE PROPAGATION



How Do Fires Spread Vertically on a Buidling Exterior?



Façade Testing in North America

Fig. 1. Face of full-scale, permanent, fire-test facility at USG Corporation Research Center is set up for curtain wall fire test. Metal frame supports thermocouples for measuring flame plume temperature. Left side is "THERMAFIBER Curtain Wall Insulation Unit"; right side is "Glass Fiber Unit."

Two-story test apparatus

- Research began 1987, with larger scale facility
- Flames exited window opening and exposed exterior face of wall assembly at 5 minutes
  - Flames 12-15-ft above burn room floor
  - Top of window 7-ft above burn room floor
  - Flame plume very optically thick and sooty
- Temperatures measured on wall panel surface and within combustible wall panel core in test

Façade Testing in North America

Intermediate Scale Multi-Storey Apparatus (ISMA)

- Test wall is 5.3 m high x 4.1 m wide
- Tests a complete system including any external cladding, insulation, external substrate framing and internal wall membrane
- The test wall construction and fastening to the test rig must be representative of the end use
- Includes a single opening 1.98 m wide x 0.76 m high.

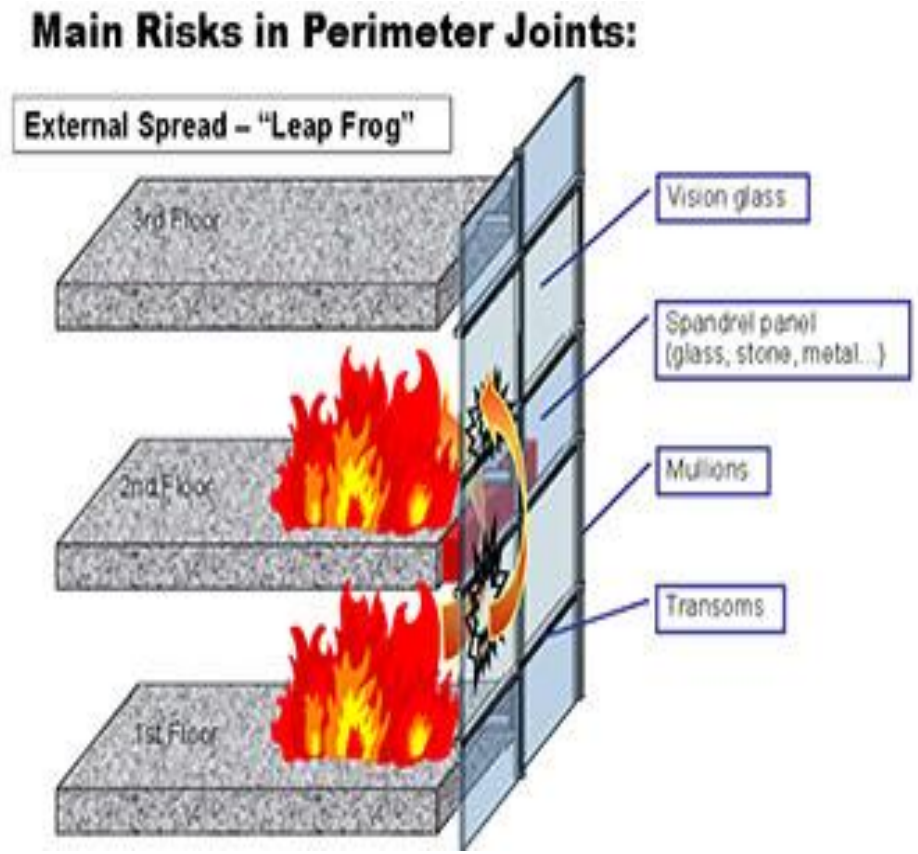
Fire Performance of Exterior Wall Assemblies

NBCC Section 3.1.5.5 permits an exterior, non-loadbearing wall assembly containing combustible components to be used in buildings required to be of noncombustible construction ***provided*** the building:

1. Is unsprinklered and less than 3 storeys in building height, or
2. The building is sprinklered throughout, (and less than 6 stories per OBC), and
3. The interior surfaces of the walls are protected with a thermal barrier, and
4. The wall meets the performance requirements of CAN/ULC-S134 “Fire test of Exterior Wall Assemblies”.

ASTM Standards Activity

- ASTM “Leap Frog” Standard- E 2874
- Standard evaluates the fire performance of an exterior wall assembly, principally the building perimeter spandrel system, for its ability to prevent the spread of fire to the interior of a room one adjacent storey above via fire spread from the exterior of a building.
- The test sample includes the exterior wall spandrel panel assembly, fasteners, structural supports and any glazed openings.
- Simulates a post flashover fire exposure within a compartment venting to the exterior of the building and spreading to the floor above via the exterior of the building.
- The test facility described in this Standard is modelled on that prescribed in ASTM E2307.



ASTM Standards Activity

- ASTM Leap Frog Standard- E 2874:
  - Test results and data developed using the proposed draft Standard
  - Research conducted at WPI and in literature related to the incident heat fluxes created above openings of different dimensions
  - Research data on the effects of moving the height of the opening on the calibration of the test facility
  - FDS modeling conducted by Students at WPI in response to questions about the flame plume, window geometry, window spacing, and appropriate height for the desired thermal assault needed to impact exterior wall

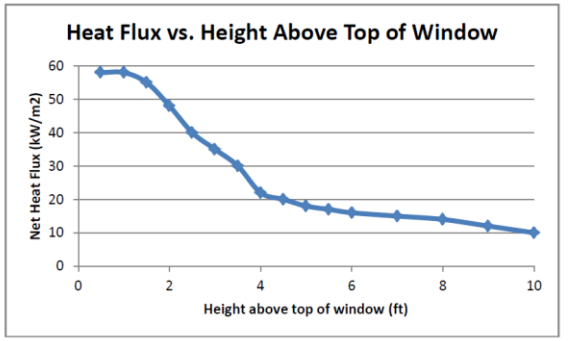


Figure 17: ASTM Test Heat Flux vs. Height above top of window


WPI

ASTM Leap Frog Effect

Project Number: ME-GT-FR09

The design and analysis of a computer fire model to test for flame spread through a building's exterior

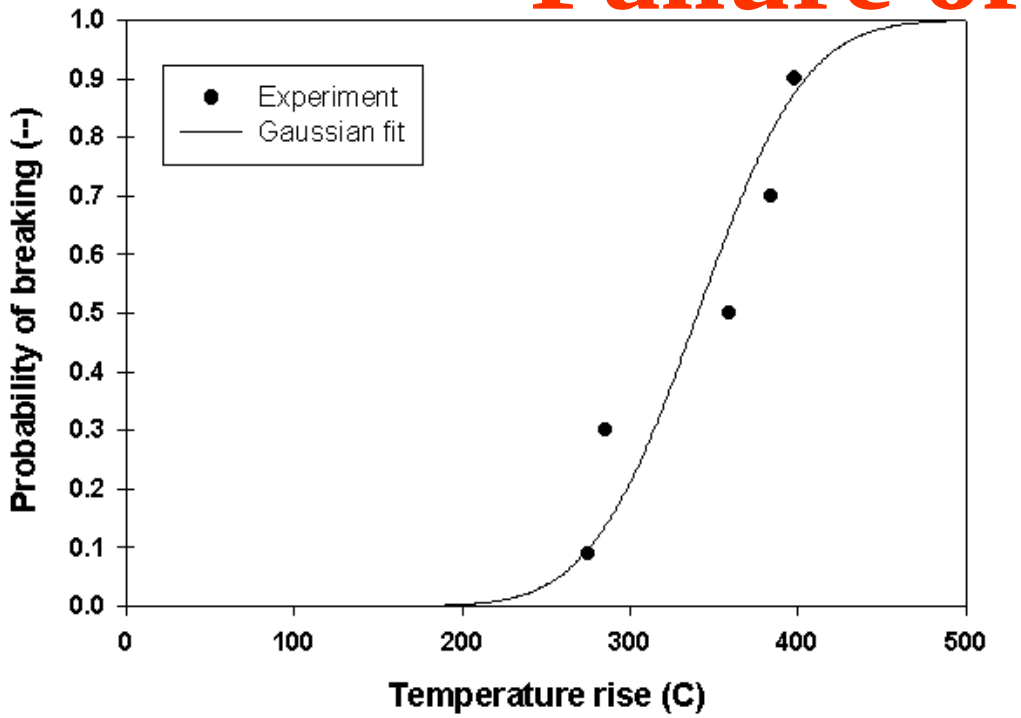
A Major Qualifying Project Report Submitted to the Faculty of Worcester Polytechnic Institute in partial fulfillment of the requirements for the Degree of Bachelor of Science

Submitted by:
Ryan Rogan
&
Edward Shipper
Date: April 12, 2010

Approved by:

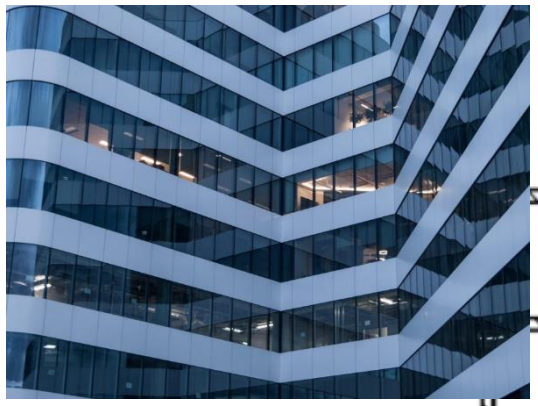
Professor Gretar Tryggvason, Advisor

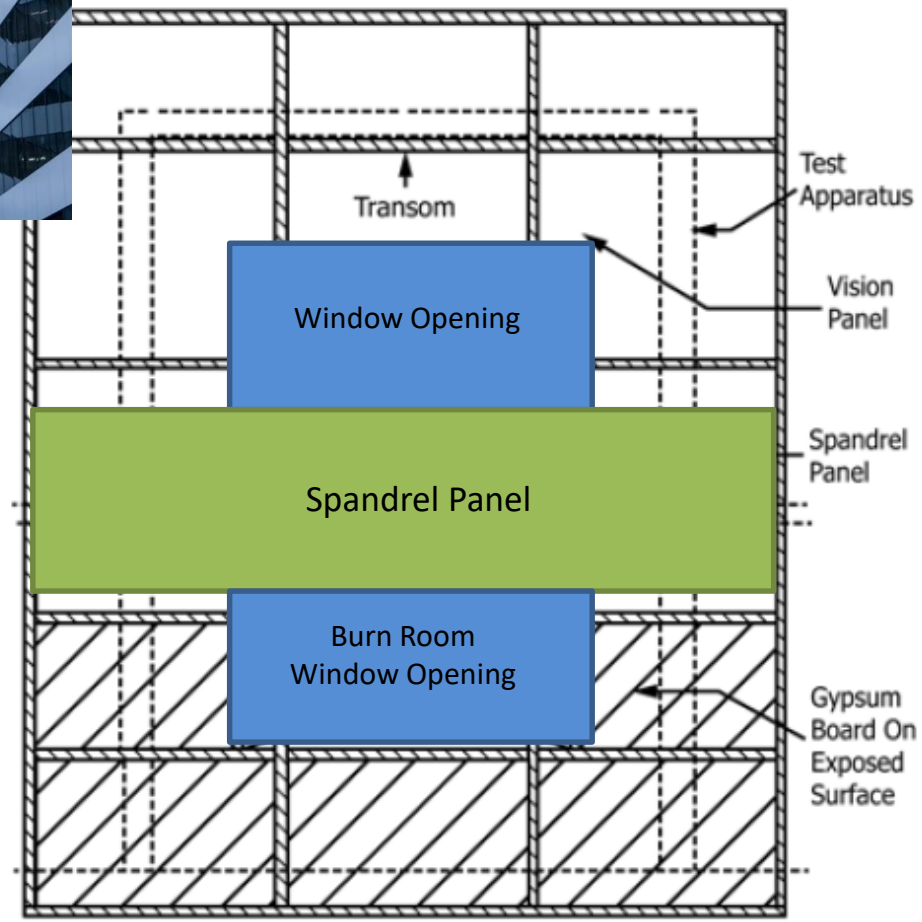
Failure of Plate Glass



Perimeter Fire Barrier Education

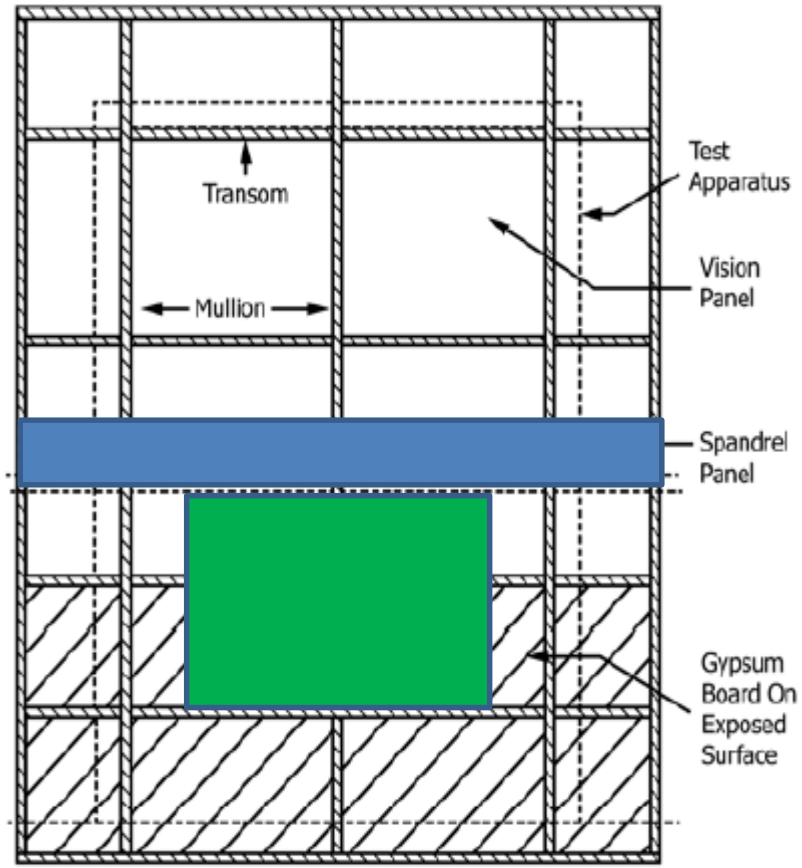
Windows on Adjacent Stories





Center Spandrel Configuration

Window & Spandrel heights vary widely



Narrower Spandrel; Window raised to bottom

But my Building is Sprinklered …?

➢ ***Similarly, NRC/IRC studies published as far back as 1997 also found that various types of glazing will fail at even lower temperatures when water is sprayed onto hot glazing;***

Thermal Shock

Tests with a small-scale radiant panel demonstrated that cold water applied to hot glazing can cause premature failure of the glass.[2] Without water protection, tempered and heat-strengthened glazing can sustain a glazing temperature on the exposed side of more than 350°C. However, when water was sprayed onto the hot glazing, the glazing failed at much lower temperatures. The critical temperatures established for heat-strengthened and tempered glazing are 150–165°C and 200°C, respectively.[2] The critical temperature for plain glass (80–90°C) is too low to allow for effective protection using a sprinkler system. These investigations established that in order for a sprinkler to provide effective protection, it must be activated before the glazing temperature exceeds its critical level.

ASTM E2874-19 Acceptance Criteria

"I" Integrity Rating—The integrity rating of the spandrel-panel assembly shall be determined as the time at which one of the following conditions first occurs:

1. The total heat flux measured by the heat flux transducers in in room above reaches 3 kW/m2, or

2 . The occurrence of flames or hot gases on any portion of the unexposed surface of the test specimen sufficient to ignite the cotton pad.

"T" Rating—The "T" rating of the spandrel-panel assembly shall be determined as the time at which one of the following conditions first occurs:

1. The temperature rise of any of the unexposed surface thermocouples on the unexposed face of the spandrel panel assembly or adjacent supporting construction is more than 325 °F (181 °C) above the initial temperature, and

2. The average temperature rise as indicated by all unexposed surface thermocouples is more than 250 °F (139 °C) above the initial temperature.

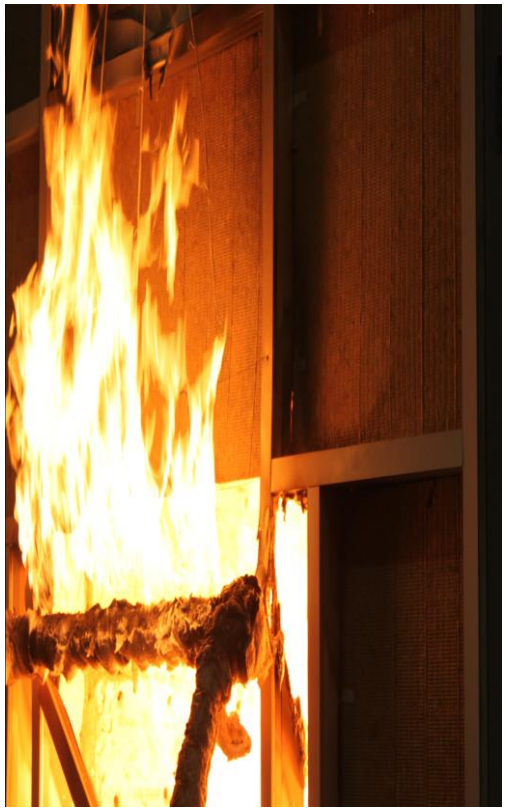
"F" Rating—The "F" rating of the spandrel-panel assembly shall be determined as the time at which visible flame penetration through the building spandrel-panel assembly or around its boundaries, occurs.

When considering floor-to-floor fire spread via openings (e.g. windows), the nature of exterior wall/curtain wall designs is a critical factors that will dictate the relative capability to resist floor-to floor fire spread.

Key factors that impact curtain wall resistance to vertical fire spread, which need to be evaluated by testing, can include:

- Full height or partial height vision glass or spandrel panel design
- Nature of the glass used to construct glazing system
- Nature of the curtain wall components (e.g. framing, spandrel panels, rain screen, air gap)
- Vertical or horizontal projections on exterior that may deflect or enhance flame behavior
- Building geometry at curtain wall – inclined, staggered, sloped, etc.
- Operable windows/openings – size and orientation
- The vertical alignment of windows/openings

A Spandrel-Panel assembly impedes the vertical spread of fire via exterior fire spread, from the floor of origin to the floor(s) above.



NBCC Fire Blocking

3.1.11.2. Fire Blocks in Wall Assemblies

1) Except as permitted by Sentence (2), fire blocks conforming to Article 3.1.11.7. shall be provided to block off concealed spaces within a wall assembly

a) at every floor level,

b) at every ceiling level where the ceiling forms part of an assembly required to have a fire-resistance rating, and

c) so that the maximum horizontal dimension is not more than 20 m and the maximum vertical dimension is not more than 3 m.

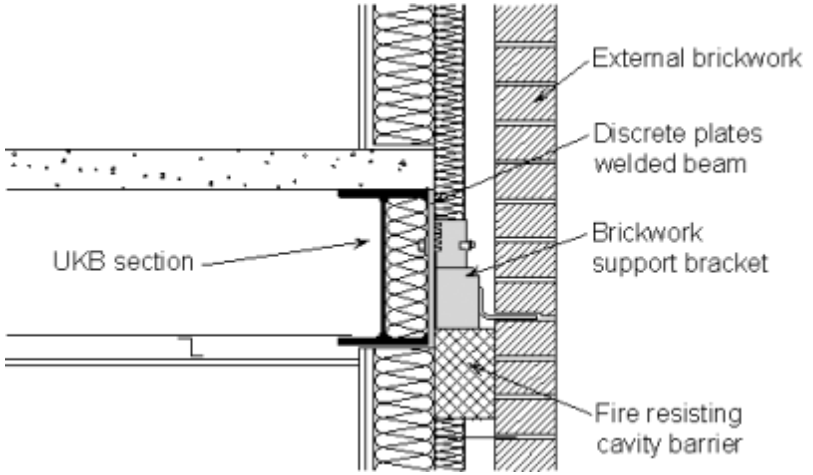
2) *Fire blocks conforming to Sentence (1) are not required, provided*

a) the wall space is **filled** with insulation,

b) the exposed construction materials and any insulation within the wall space are ***noncombustible,***

c) the exposed materials within the space, including insulation but not including wiring, piping or similar services, have a ***flame-spread rating not* more than 25 on any exposed surface**, or on any surface that would be exposed by cutting through the material in any direction, **and *fire blocks are* installed** so that the vertical distance between them is not more than 10 m, or

d) the insulated wall assembly contains **not more than one concealed air space**, and the horizontal thickness of that ***air space is not more than 25 mm.***

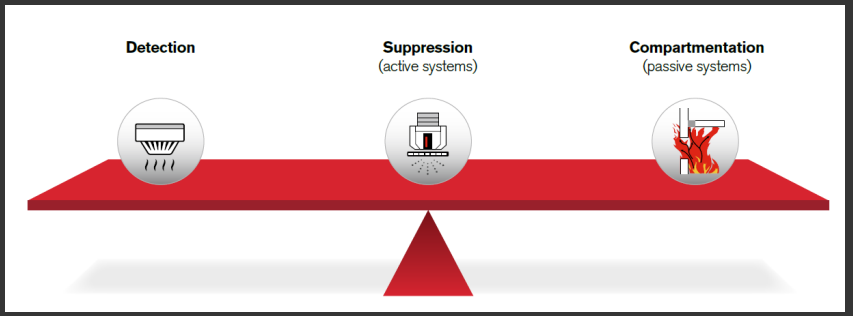


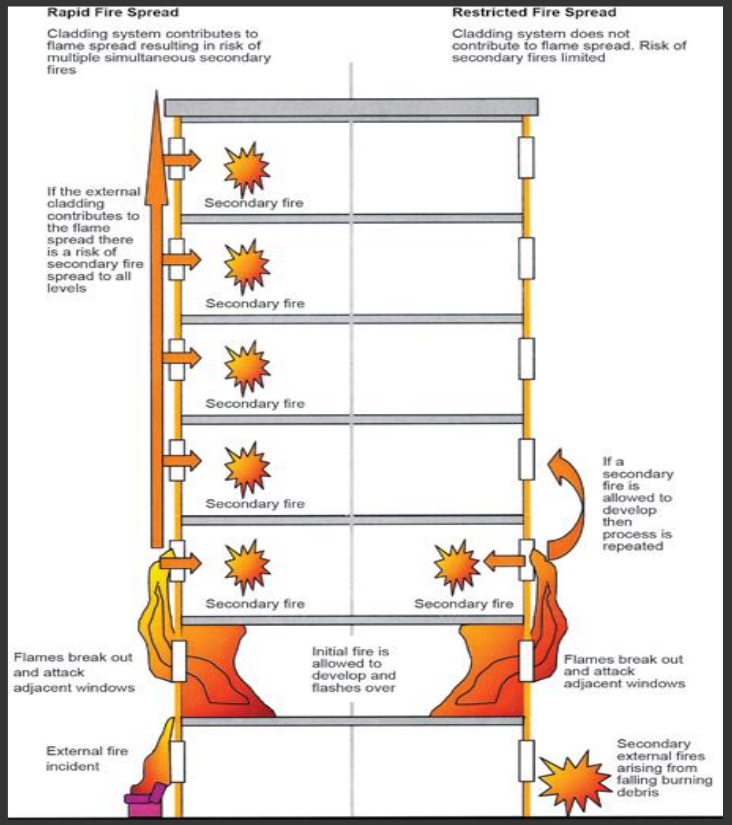
Can’t I Just Sprinkler Instead of all of this ?

- ***In 2014, NFPRF published a report on “Fire Hazards of Exterior Walls with Combustible Components”, which stated:***

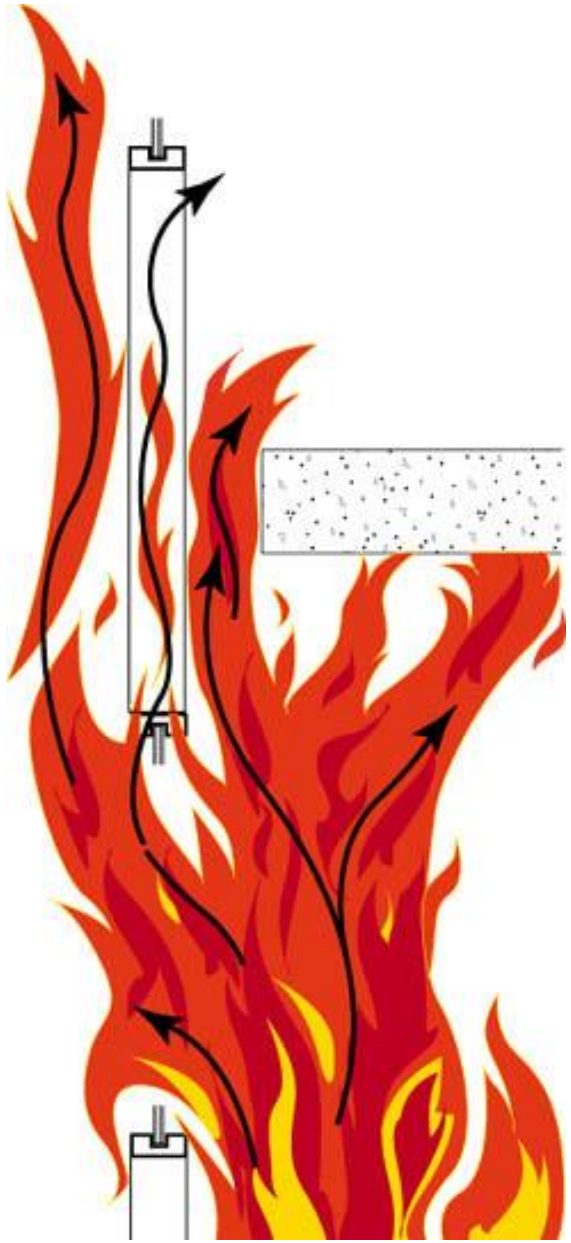
  - ***“The percentage of exterior wall fires occurring in buildings with sprinkler systems installed ranges from 15-39% for the building height groups considered. This indicates that whilst sprinklers may have some positive influence, a significant portion of external wall fires still occur in sprinkler protected buildings, which may be due to both external fire sources or failure of sprinklers.”***

- ***In some cases (i.e Grenfell Tower) the main fire source can be within the exterior wall. Fire <u>could</u> still have “leap-froged” from storey-to-storey via exterior windows.***





Dynamics of Vertical Fire Spread



Common Materials Melt

6 minutes

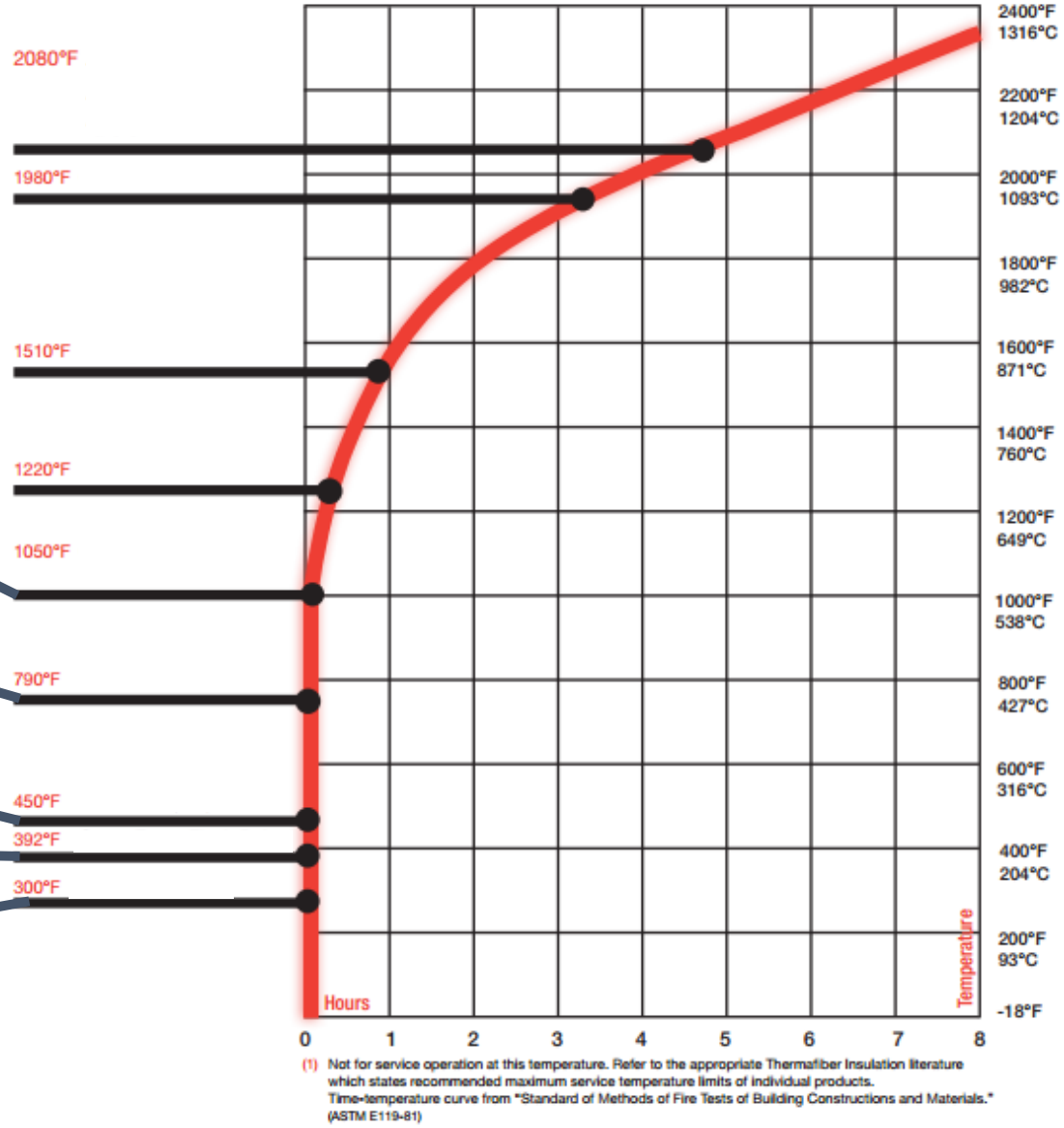
1050° F
Glass-fiber insulation melts.

790° F
Zinc melts.

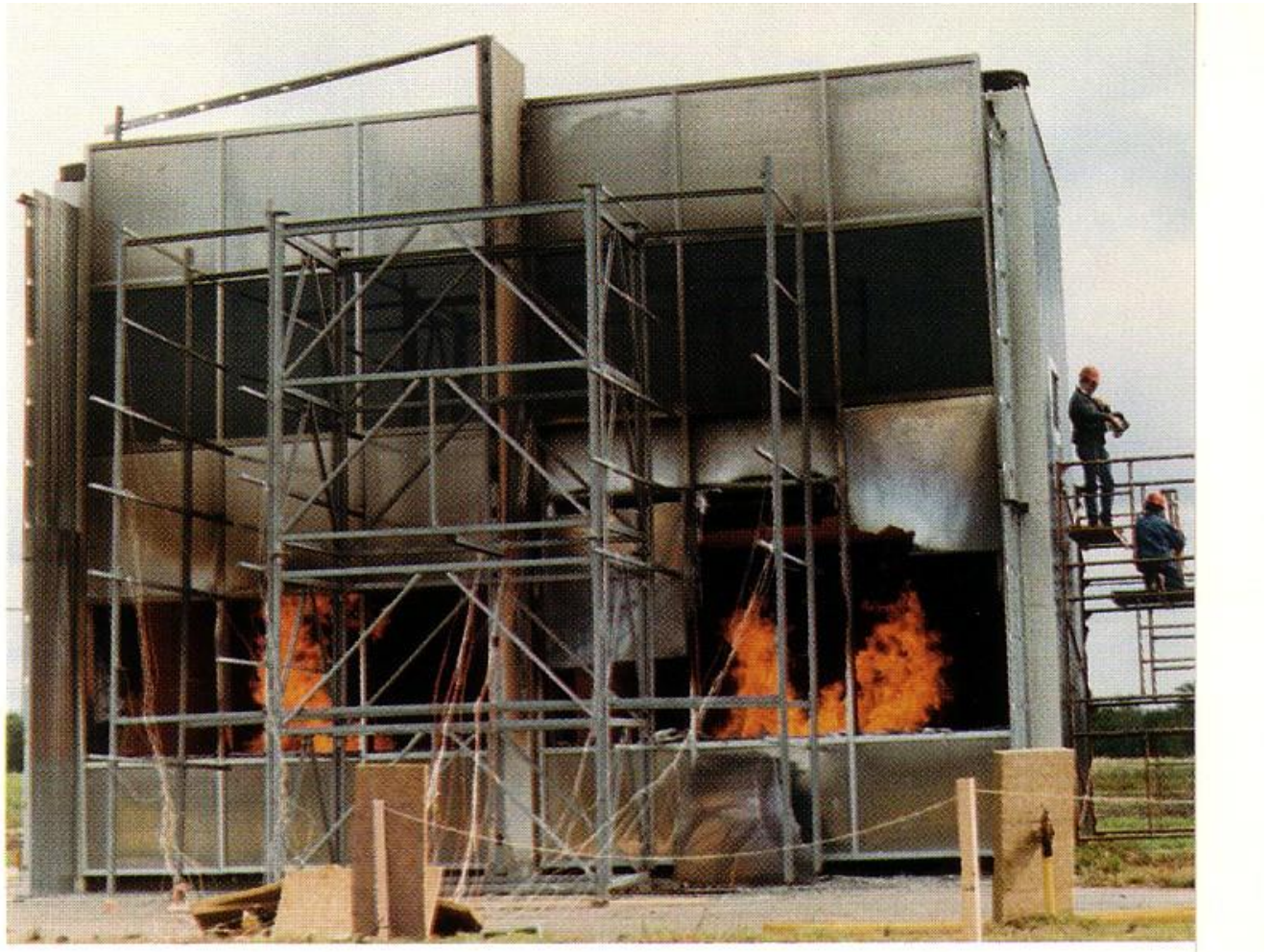
450° F
Cellulose pyrolyzes.

392° F
Spray Foam flash point.

300° F
Rigid foam melts.



Fire Performance Testing of Common Insulations - 1987

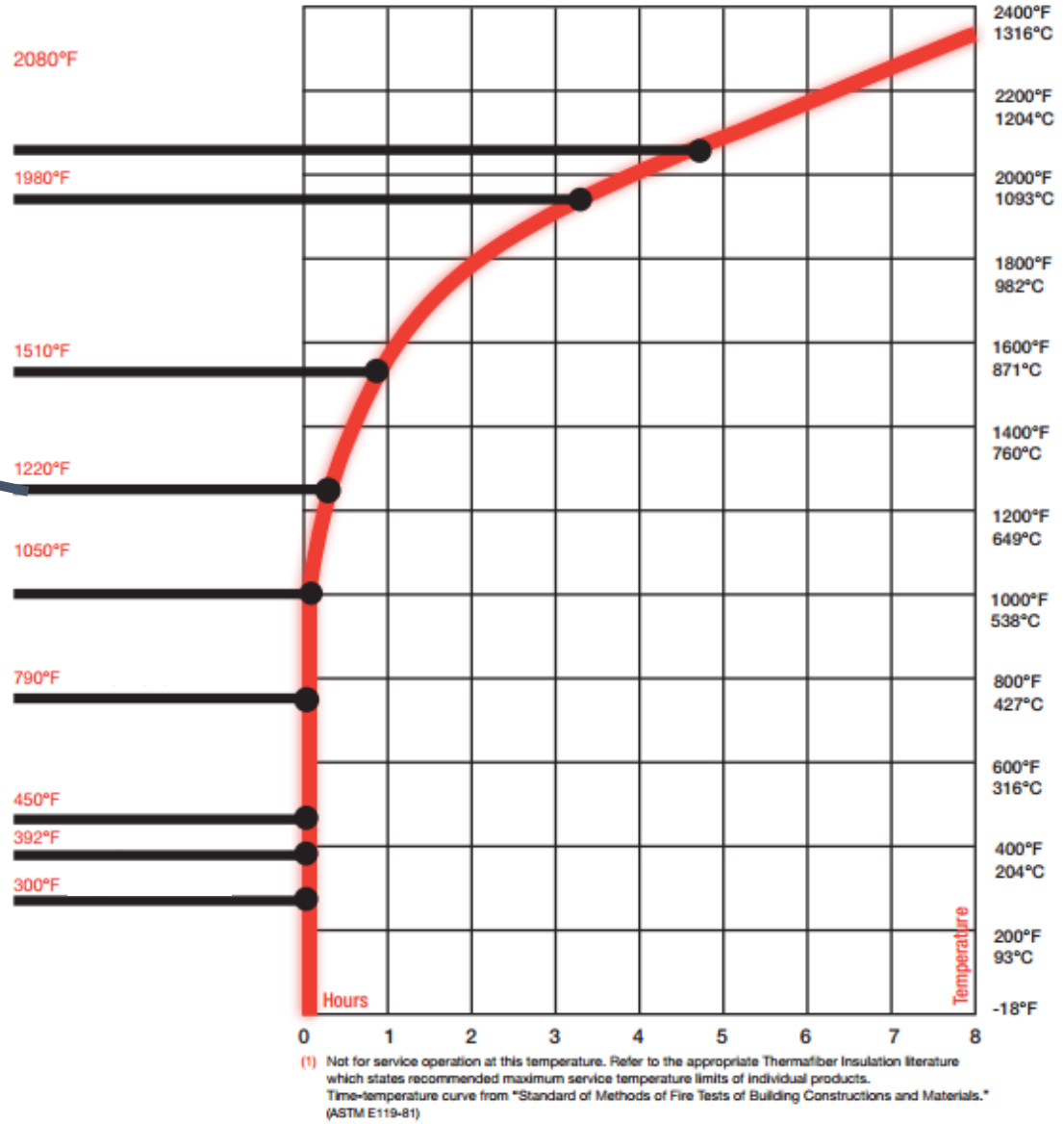


Aluminum Melts

9 minutes

1220° F

Aluminm melts.



(1) Not for service operation at this temperature. Refer to the appropriate Thermafiber Insulation literature which states recommended maximum service temperature limits of individual products.
Time-temperature curve from "Standard of Methods of Fire Tests of Building Constructions and Materials." (ASTM E119-81)

Assembly Pre-Fire Exposure

Lower Transom Softening

Aluminum Melting Out

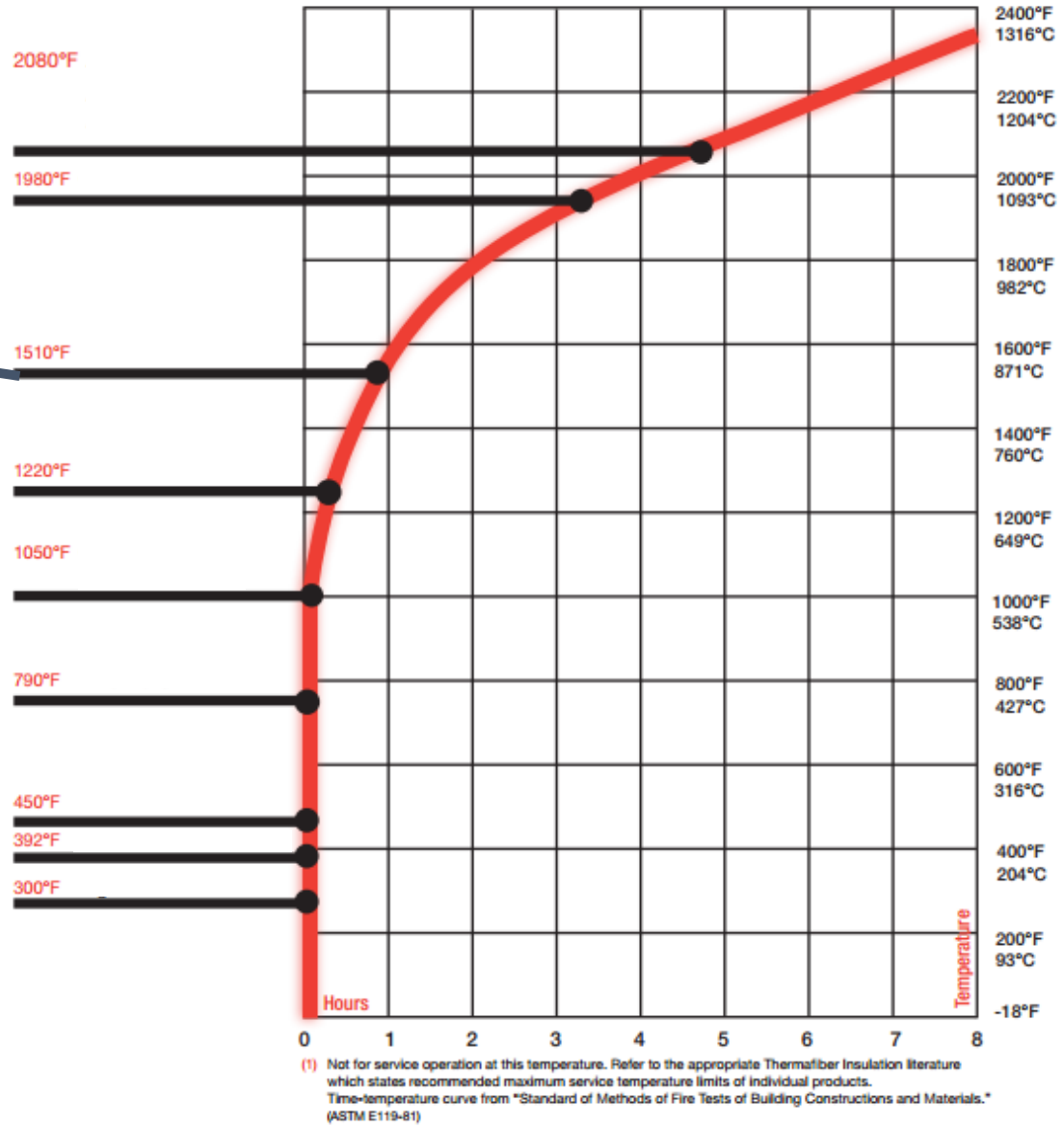
Post Fire Exposure

Glass Melts

25 minutes

1510° F

Plate glass melts.



Glass Deformation in 11 Minutes

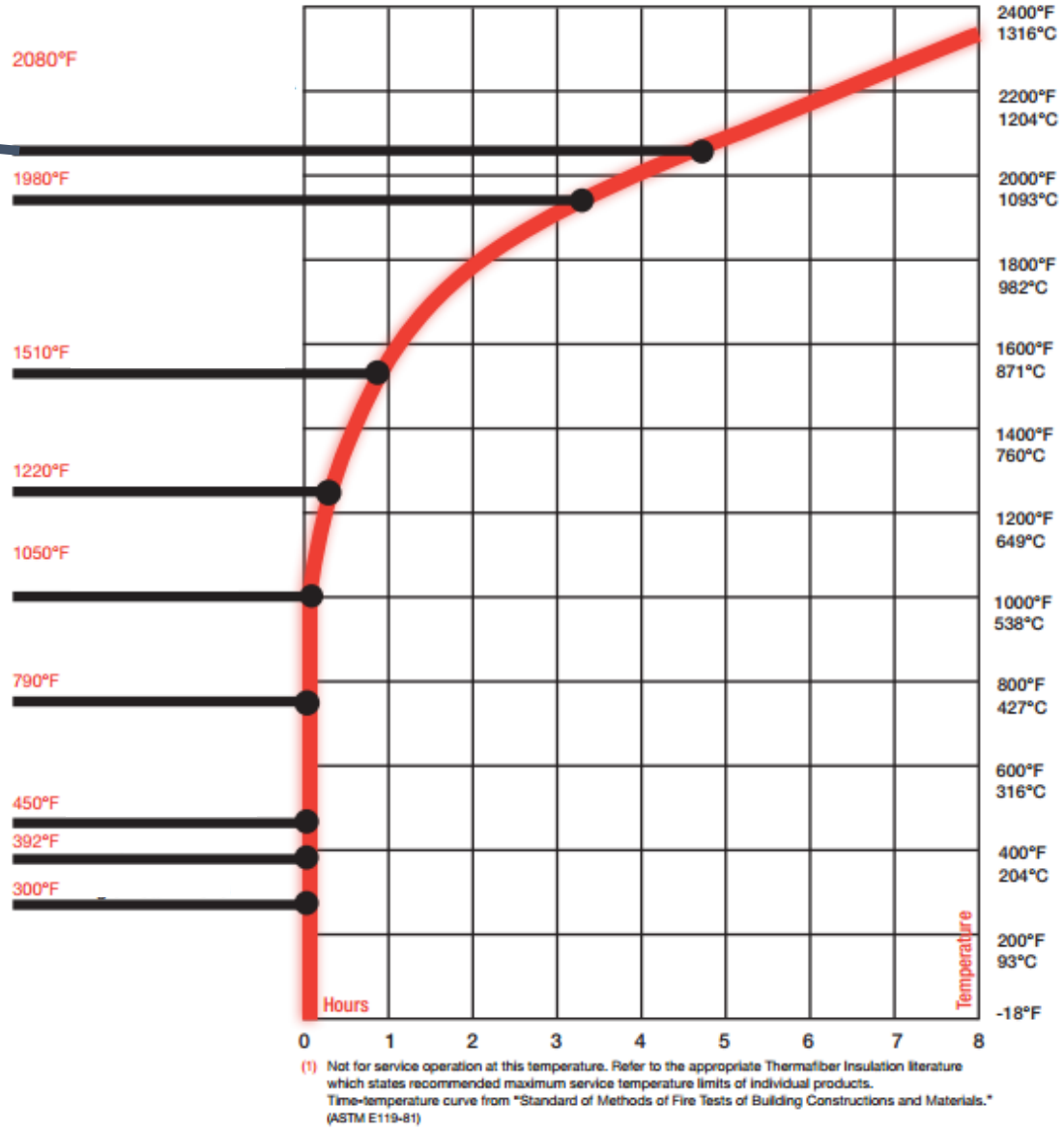

Glass
Shattering
Under Fire
Exposure

Mineral Wool Remains

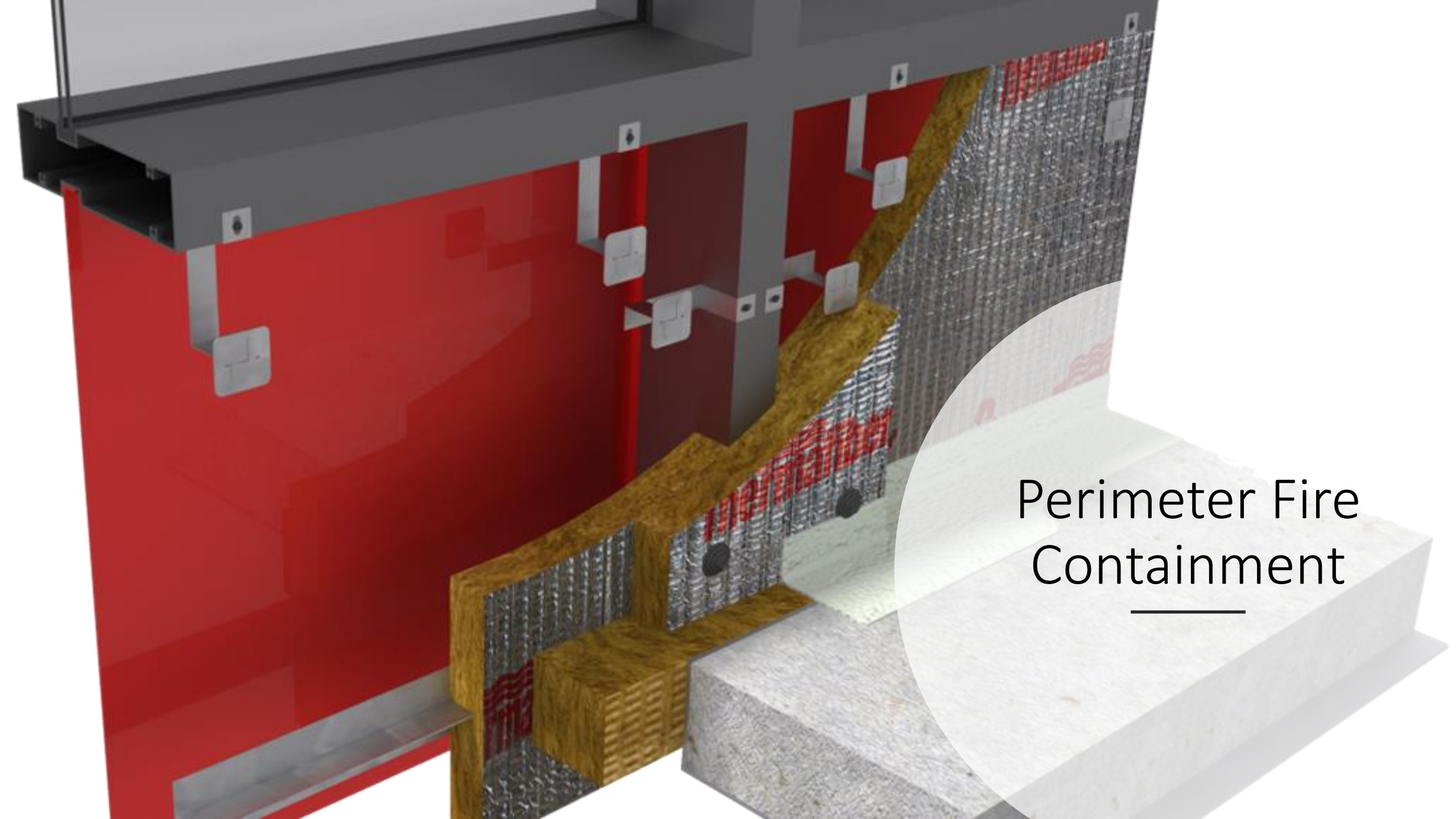
5 hours +

2080° F

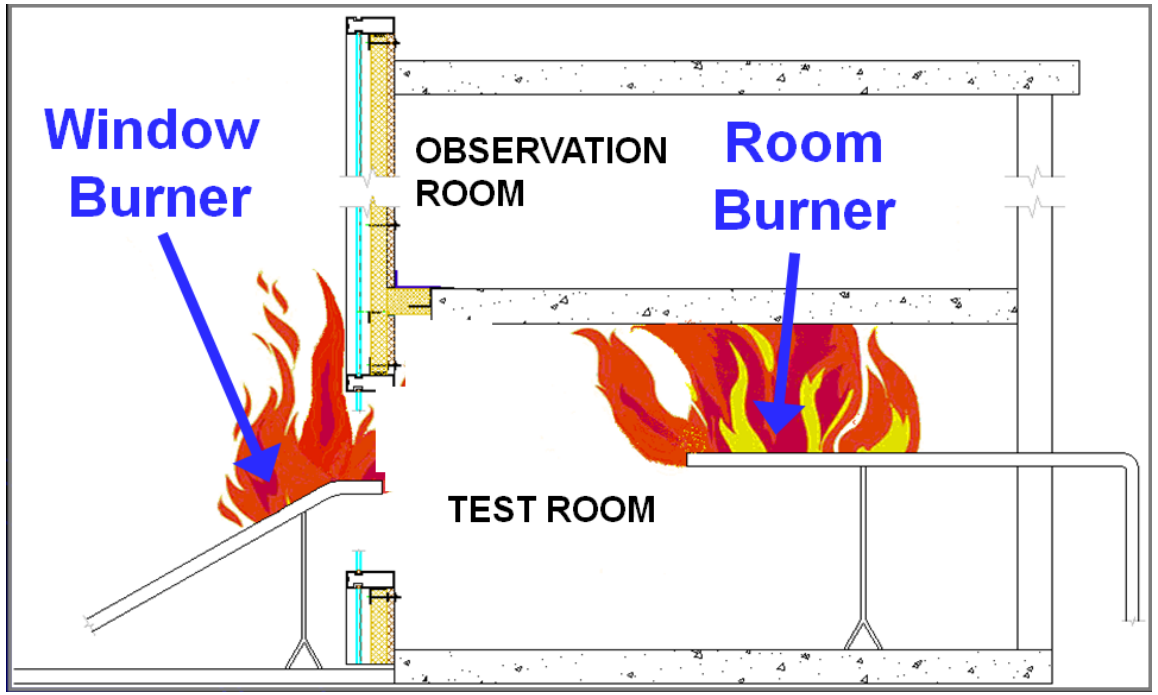
At 5 hours, mineral wool insulation is still intact.
Test terminated without failure.



6 Basic Components of a Listed Perimeter Fire Containment Assembly

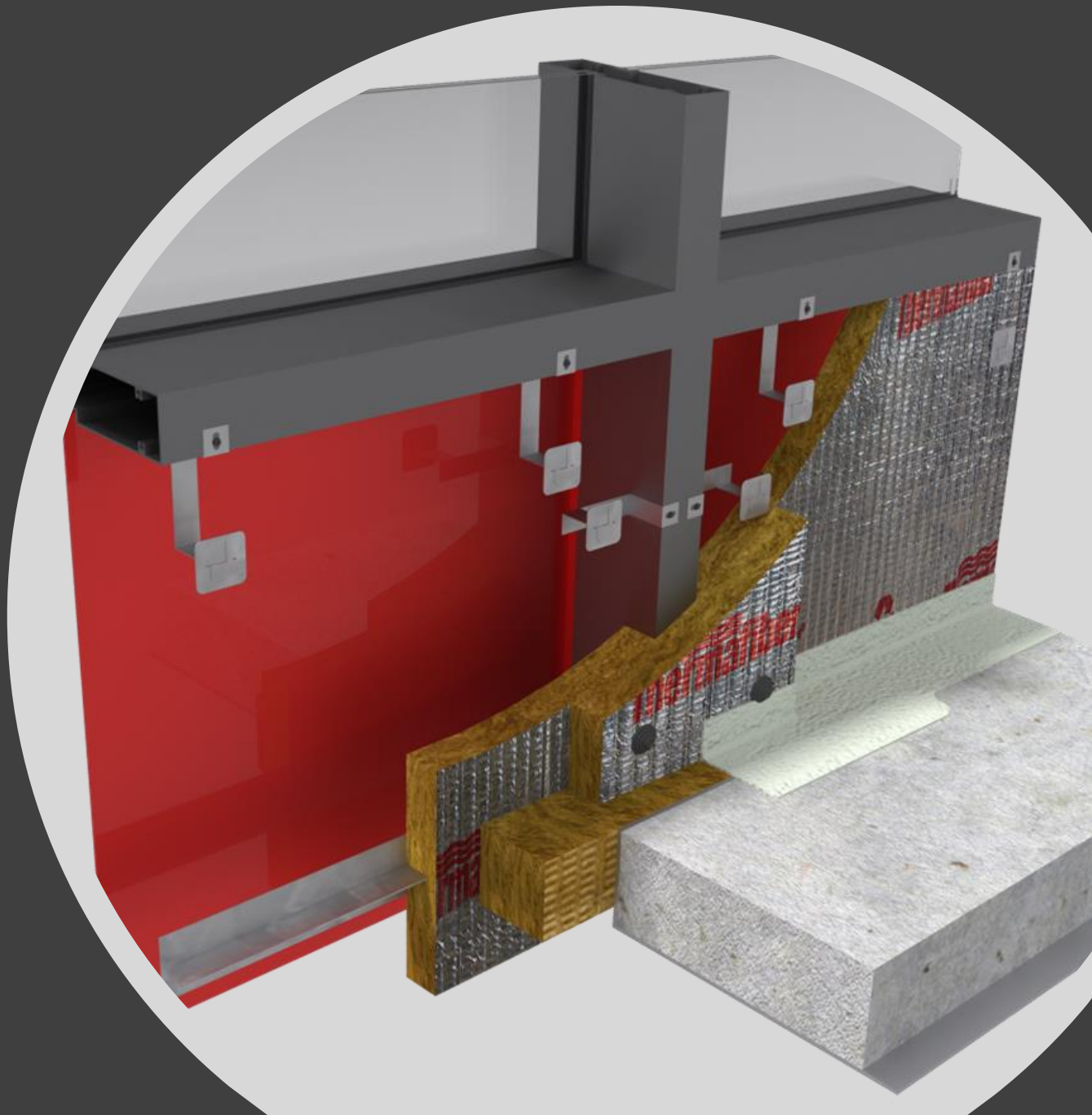


Perimeter Fire Containment

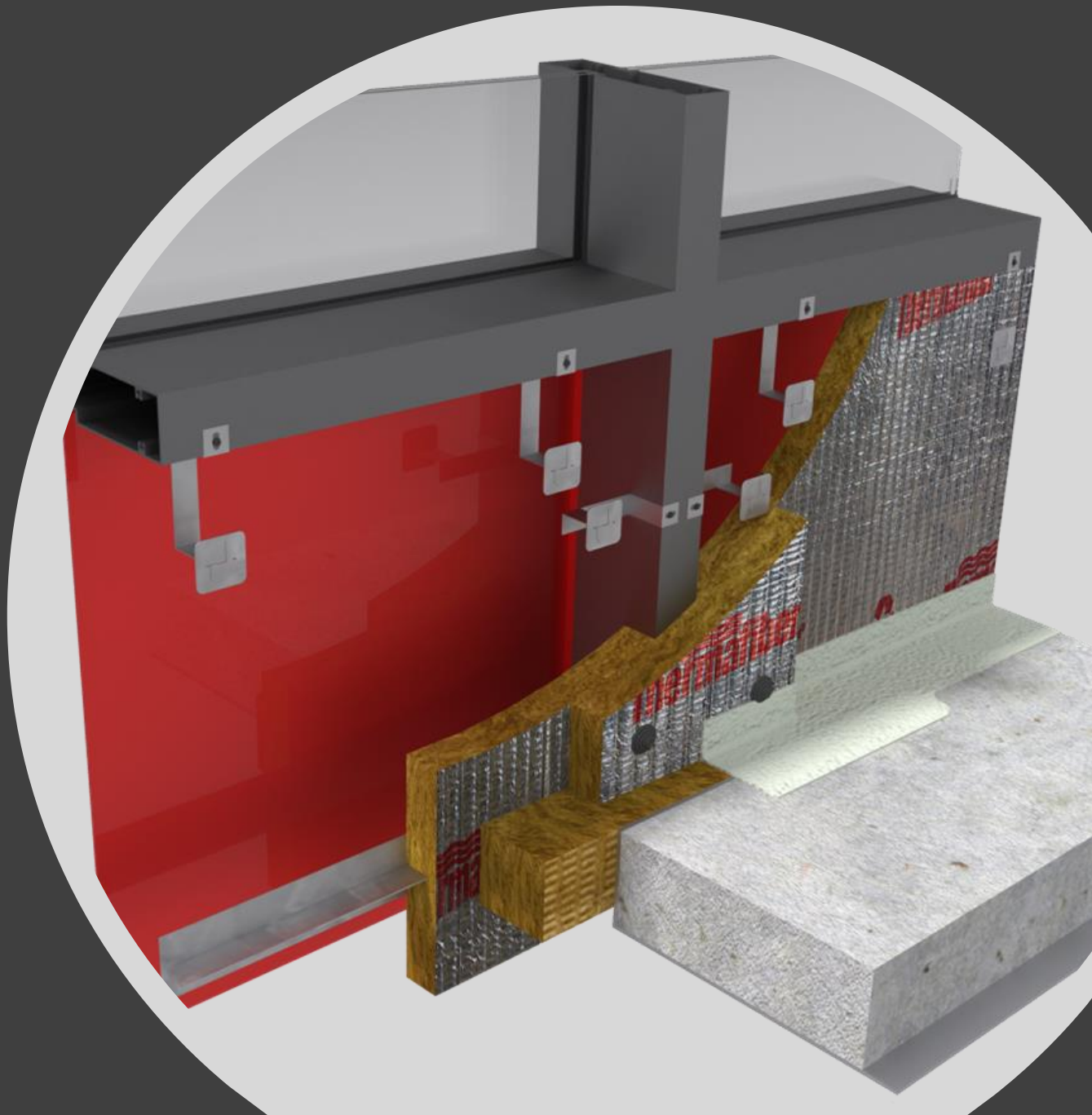


ASTM E 2307

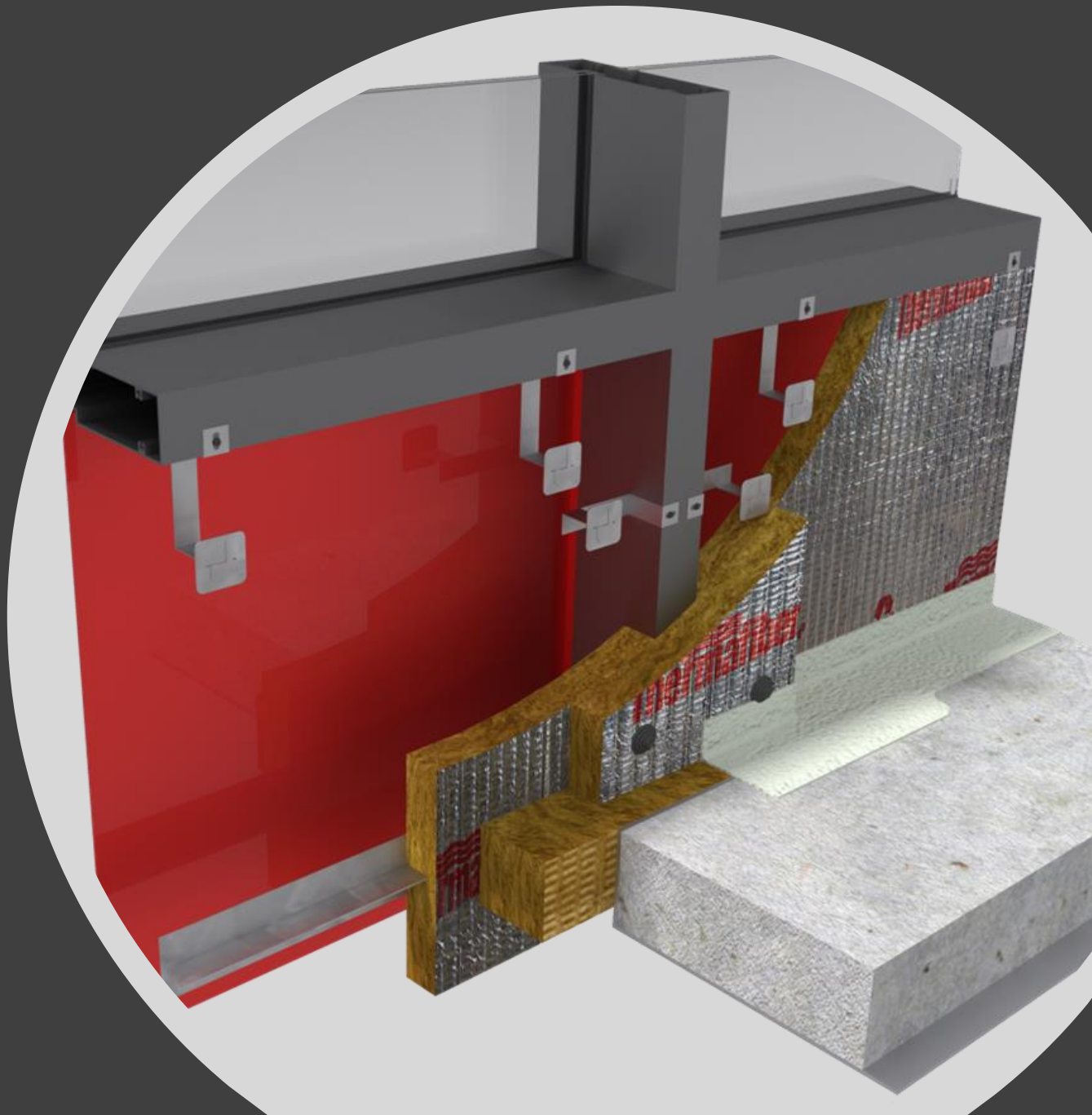
Design Criteria 1: Reinforcement Member



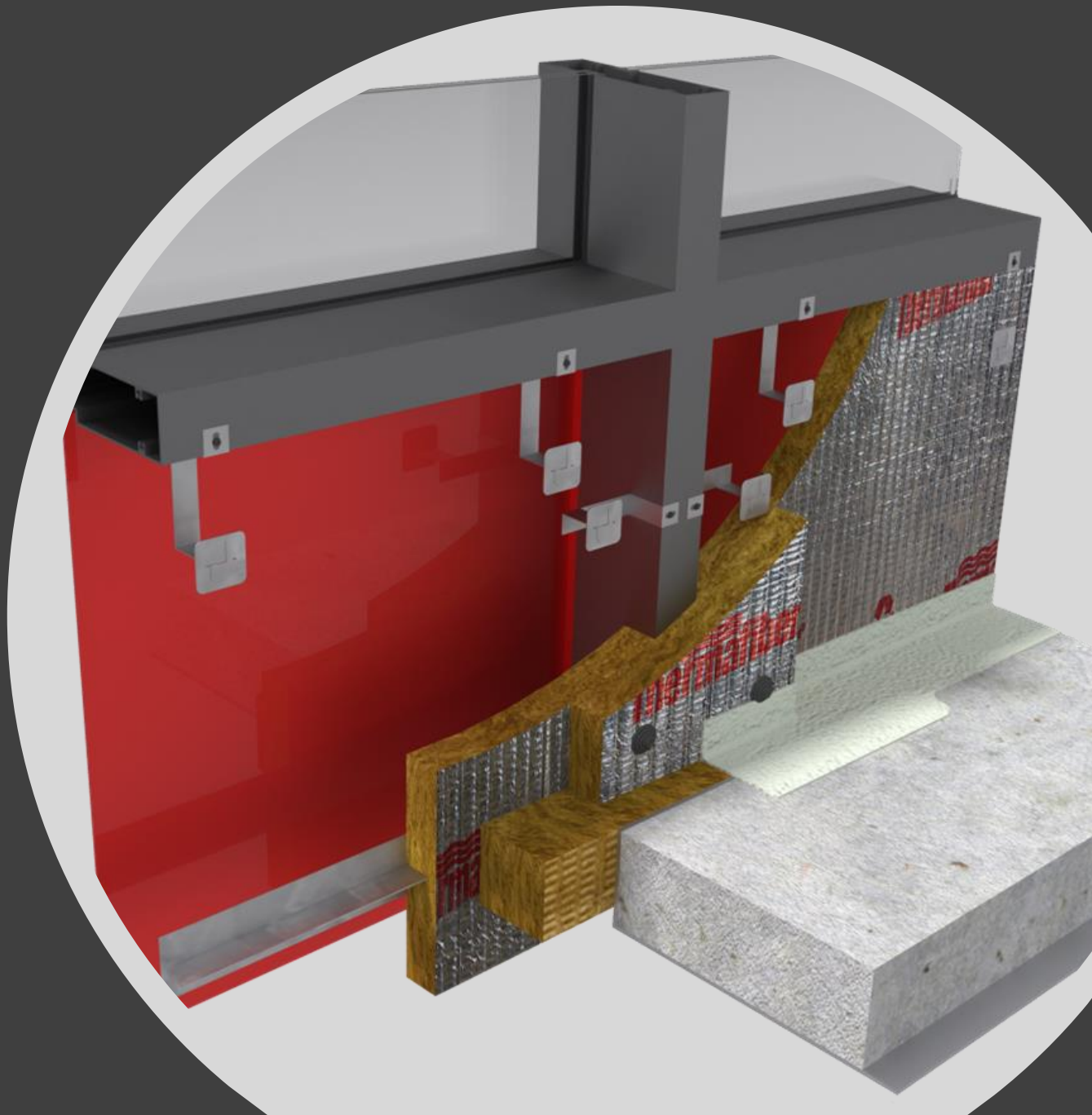
Design Criteria 2: Mineral Wool



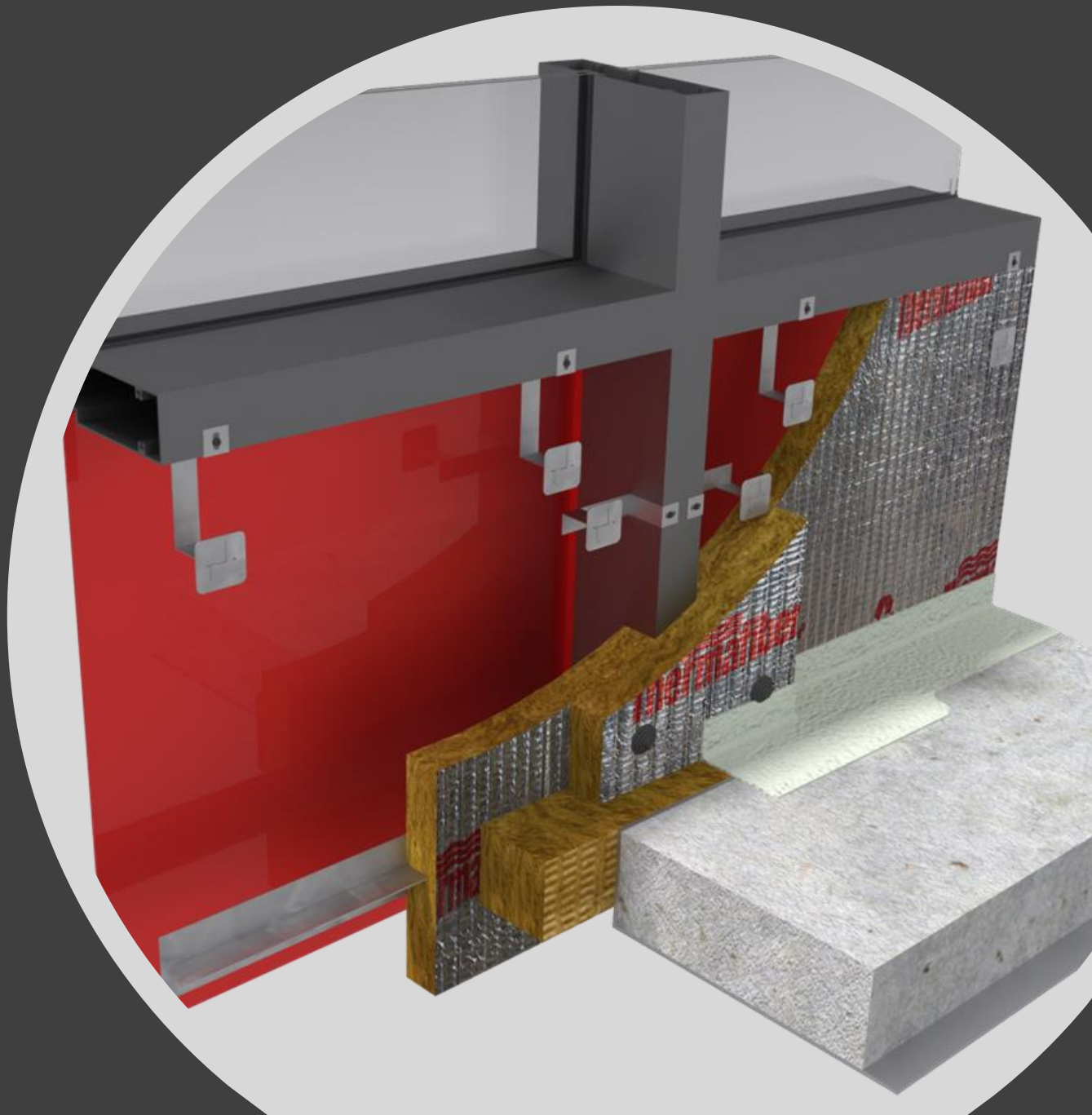
Design Criteria 3: Mechanical Attachment



Design Criteria 4: Compression Fit SAFing

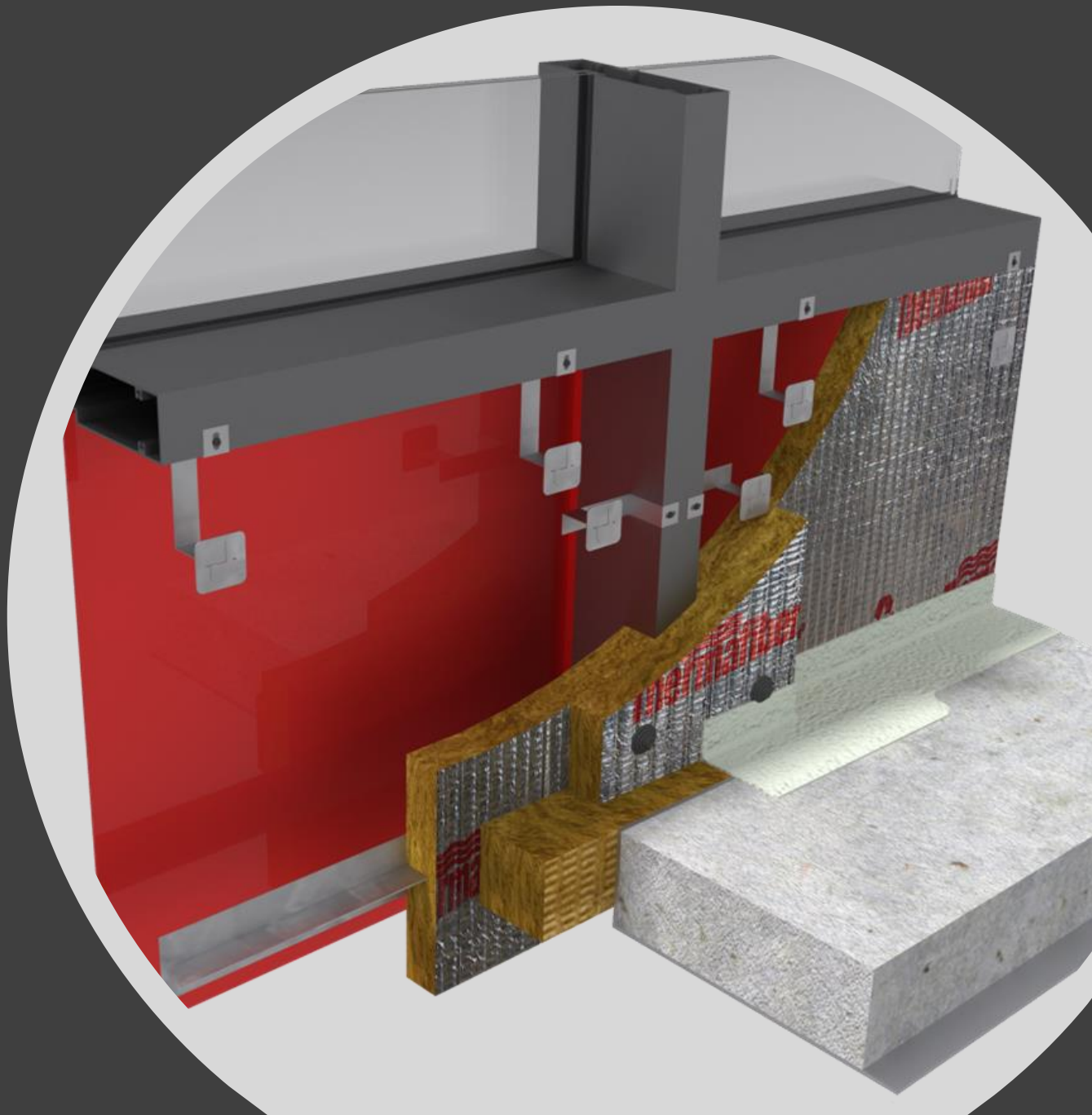


Design Criteria 5: Mullion Covers



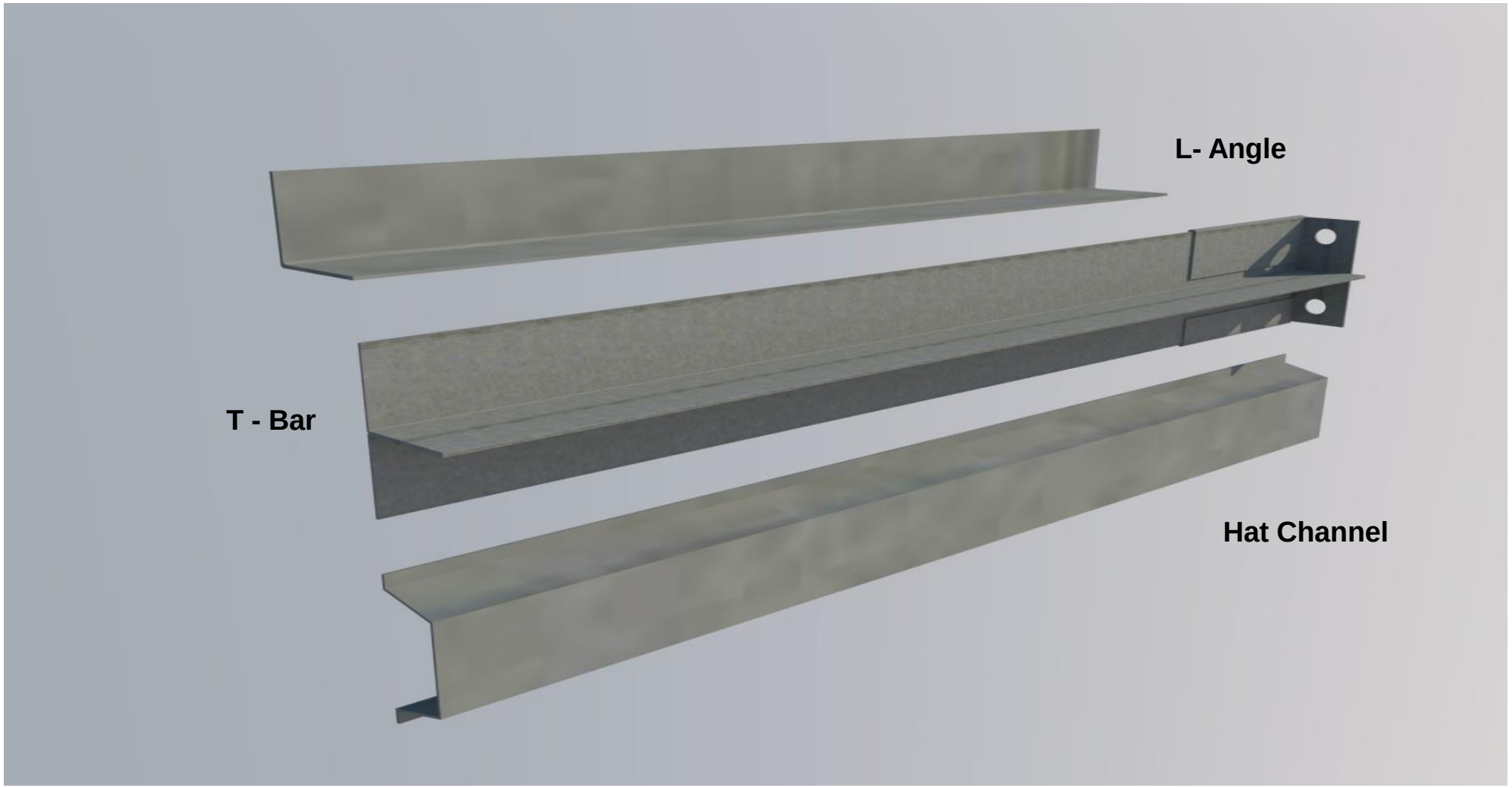
Smoke – The known killer

Design Criteria 6: Smoke Barrier



Installation

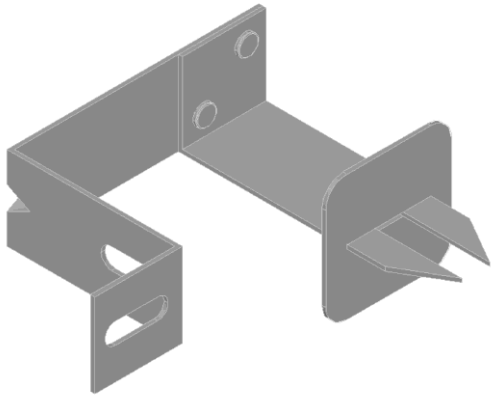
Installation



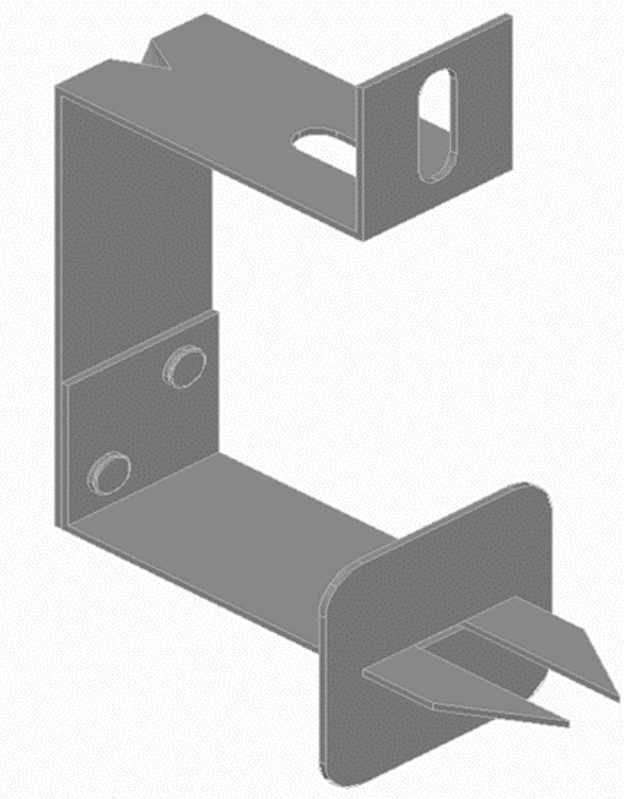
Spandrel Insulation

Top Panel

Installation – older style hangers



Installation – newer style hangers

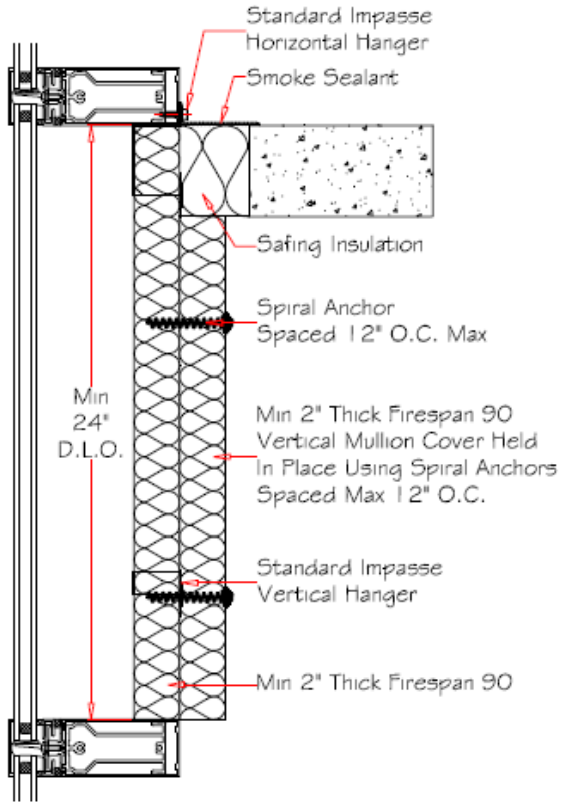


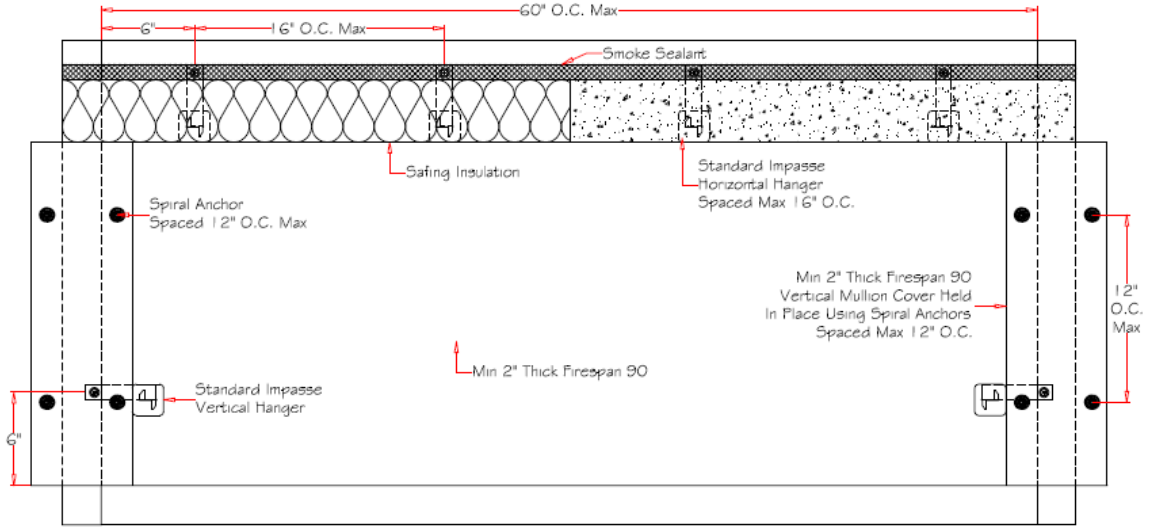
Mechanical Attachment

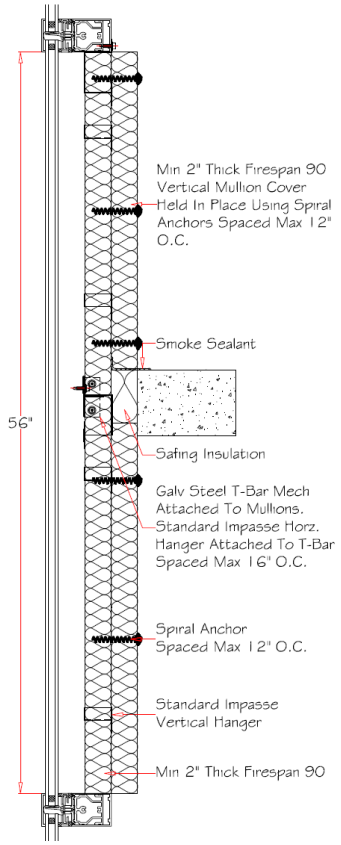
Safing

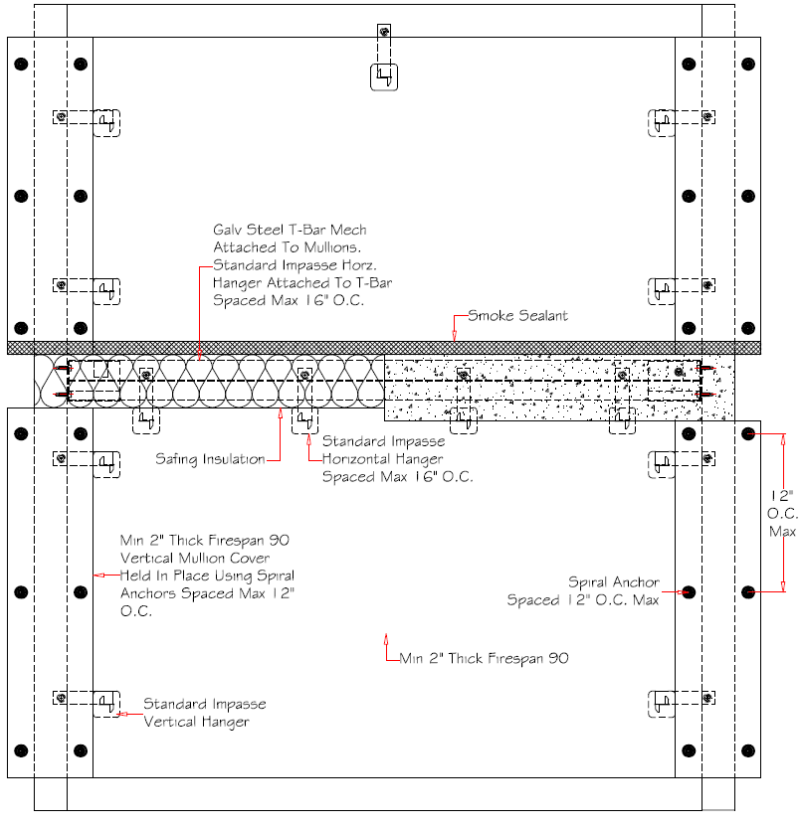
Mullion Covers

CW-D-1014


Standard Impasse
Horizontal Hanger
Smoke Sealant
Safing Insulation
Spiral Anchor
Spaced 12" O.C. Max
Min
24"
D.L.O.
Min 2" Thick Firespan 90
Vertical Mullion Cover Held
In Place Using Spiral Anchors
Spaced Max 12" O.C.
Standard Impasse
Vertical Hanger
Min 2" Thick Firespan 90


60" O.C. Max
6"
16" O.C. Max
Smoke Sealant
Safing Insulation
Standard Impasse
Horizontal Hanger
Spaced Max 16" O.C.
Spiral Anchor
Spaced 12" O.C. Max
Min 2" Thick Firespan 90
Vertical Mullion Cover Held
In Place Using Spiral Anchors
Spaced Max 12" O.C.
12"
O.C.
Max
Min 2" Thick Firespan 90
Standard Impasse
Vertical Hanger
6"


Min 2" Thick Firespan 90
Vertical Mullion Cover
Held In Place Using Spiral
Anchors Spaced Max 12"
O.C.
Smoke Sealant
56"
Safing Insulation
Galv Steel T-Bar Mech
Attached To Mullions.
Standard Impasse Horz.
Hanger Attached To T-Bar
Spaced Max 16" O.C.
Spiral Anchor
Spaced Max 12" O.C.
Standard Impasse
Vertical Hanger
Min 2" Thick Firespan 90


Galv Steel T-Bar Mech
Attached To Mullions.
Standard Impasse Horz.
Hanger Attached To T-Bar
Spaced Max 16" O.C.
Smoke Sealant
Safing Insulation
Standard Impasse
Horizontal Hanger
Spaced Max 16" O.C.
12"
O.C.
Max
Min 2" Thick Firespan 90
Vertical Mullion Cover
Held In Place Using Spiral
Anchors Spaced Max 12"
O.C.
Spiral Anchor
Spaced 12" O.C. Max
Min 2" Thick Firespan 90
Standard Impasse
Vertical Hanger

CW-D-2039

Special Conditions

- **Short spandrel height**
- **Back pans**
- **Exposed curtain wall anchors at the floor line**
- **Combustible building materials**

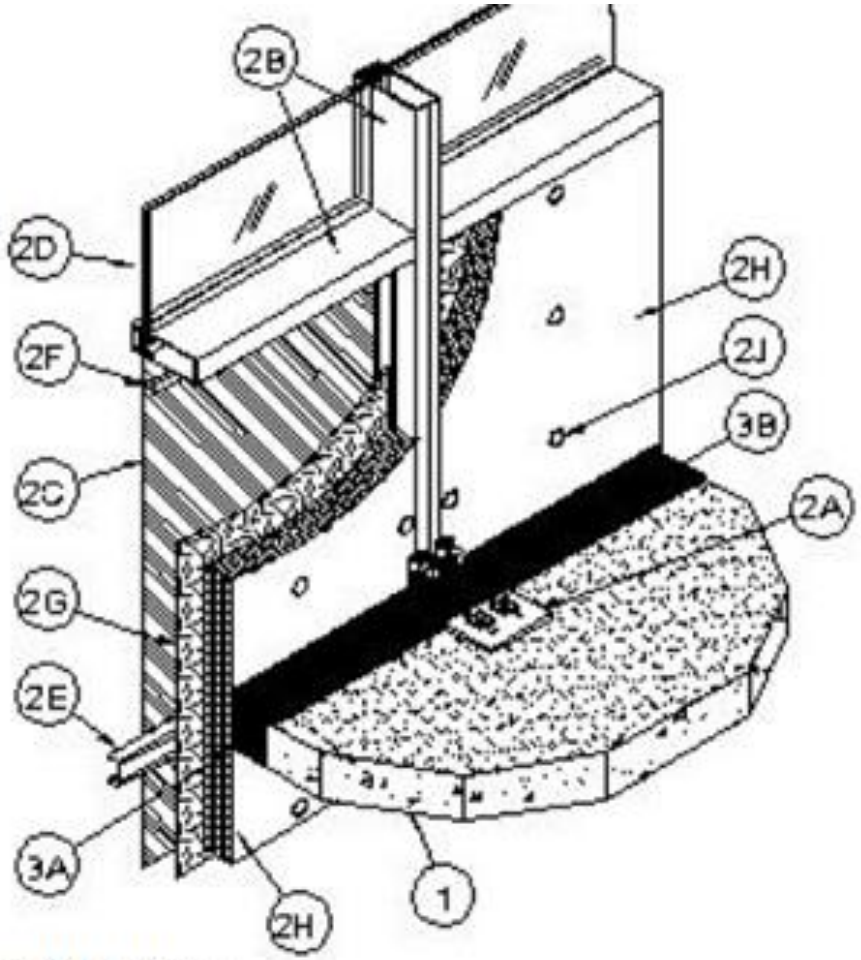
Short Spandrel Height

Considerations

- Shortest spandrel tested and listed is 10 inches
- Minimum exposed spandrel below floor slab is 5.5 inches
- Significant steel reinforcement is required
  - 20-ga. steel perimeter frame
  - Horizontal 3” 20-ga. steel T bar in front of spandrel insulation
  - 20-ga. continuous 1”x1.5” perimeter spandrel angle behind the spandrel insulation
- Mechanical attachment
  - At 8 inch frequency by pin method

Steel Back Pans

Basic Backpan with Spandrel Insulation on the Inside of the Backpan



Perimeter Fire Barrier Education

International Firestop Council

Questions?

Thank you!

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