

# EL 401 Fire Safety in High-Rise Structures

Course Number: EL401

Date: Thursday, June 21, 2018, 2:15-3:15 PM

Learning Units: 1 CEU

This presentation is protected by U.S. and international copyright laws.

Reproduction, distribution, display and use of the presentation without written permission of the speaker is prohibited.

This program is registered with the AIA/CES for continuing professional education. As such, it does not include content that may be deemed or construed to constitute approval, sponsorship or endorsement by AIA of any method, product, service, enterprise or organization.

The statements expressed by speakers, panelists, and other participants reflect their own views and do not necessarily reflect the views or positions of The American Institute of Architects, or of AIA components, or those of their respective officers, directors, members, employees, or other organizations, groups or individuals associated with them.

Questions related to specific products and services may be addressed at the conclusion of this presentation.

# Speakers List

Angela Ogino- Technical Services Leader, Thermafiber, Inc.

# 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
- Special Conditions
- Engineering Judgments
- Q&A

# Why is fire containment important?



# Content

Content slides may not contain proprietary graphics or branding.

# Why is fire containment important?



# Fire Containment

High-Rise Fire at 135 S. LaSalle Building in Chicago on  
December 6, 2004



Burned for 6 hours  
Fire contained to 29<sup>th</sup> and 30<sup>th</sup>  
floors

# Fire Containment

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



Fire spread through  
12<sup>th</sup> to 16<sup>th</sup> floors  
(of 62 floors)  
Fire extended to floors  
above primarily via  
outer walls

# Development of Perimeter Fire Containment

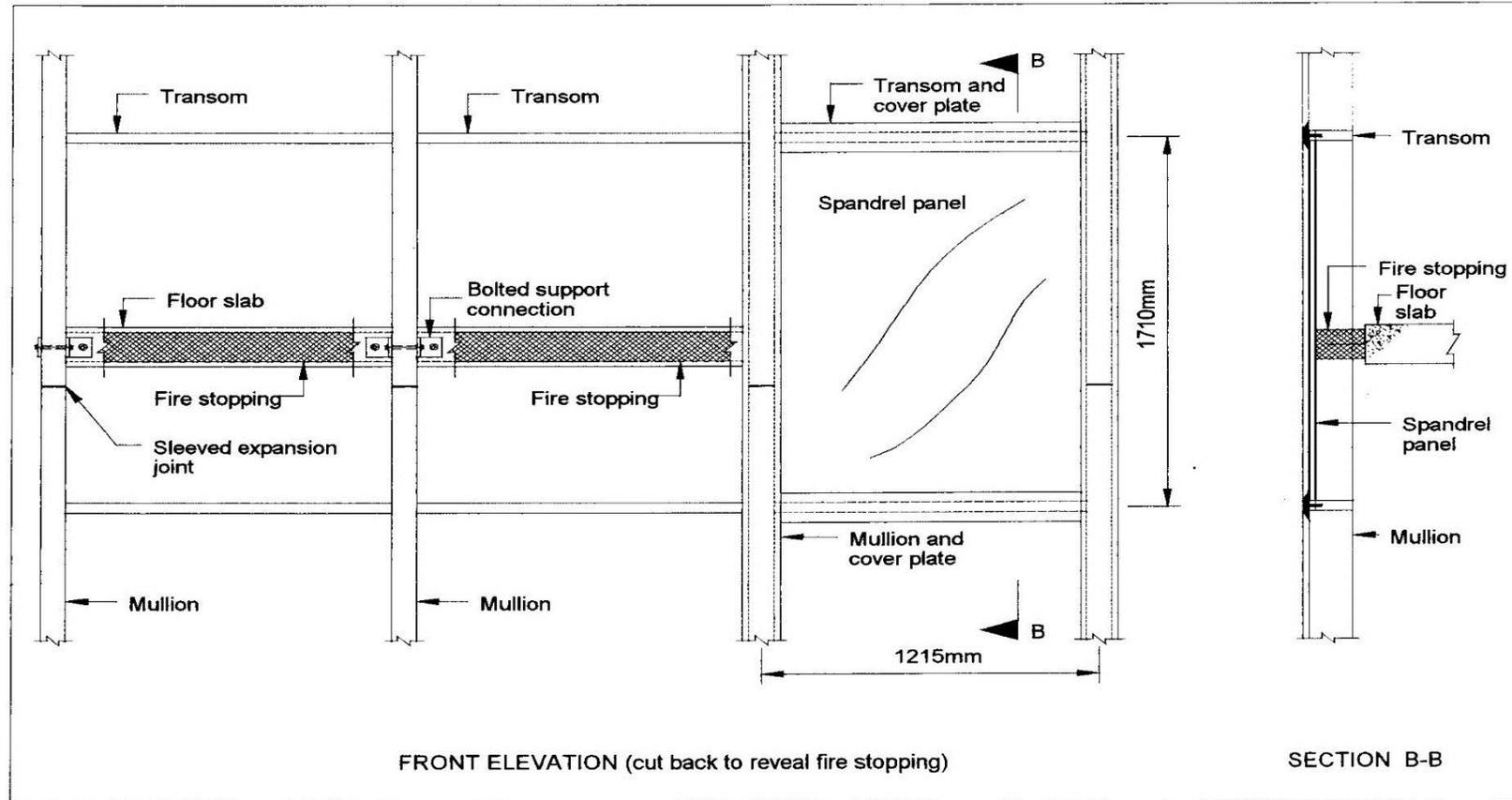
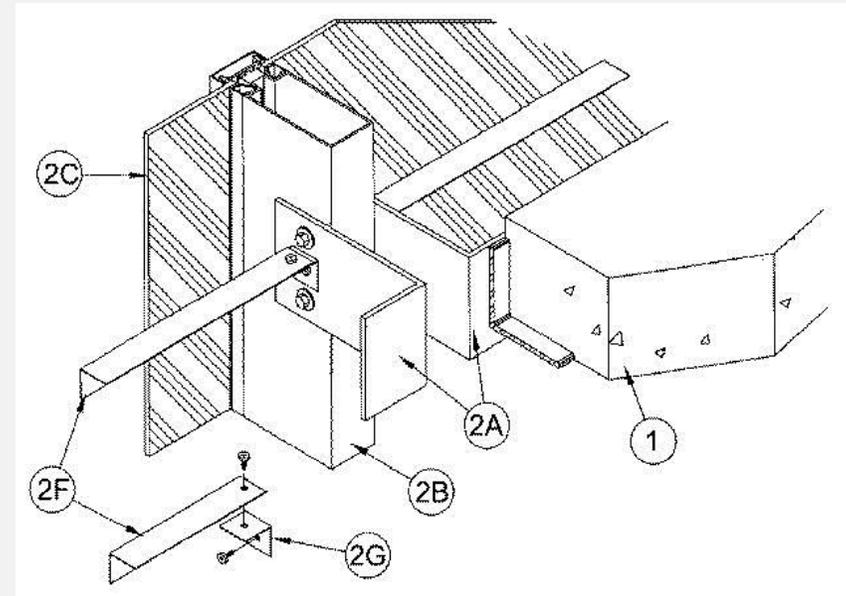
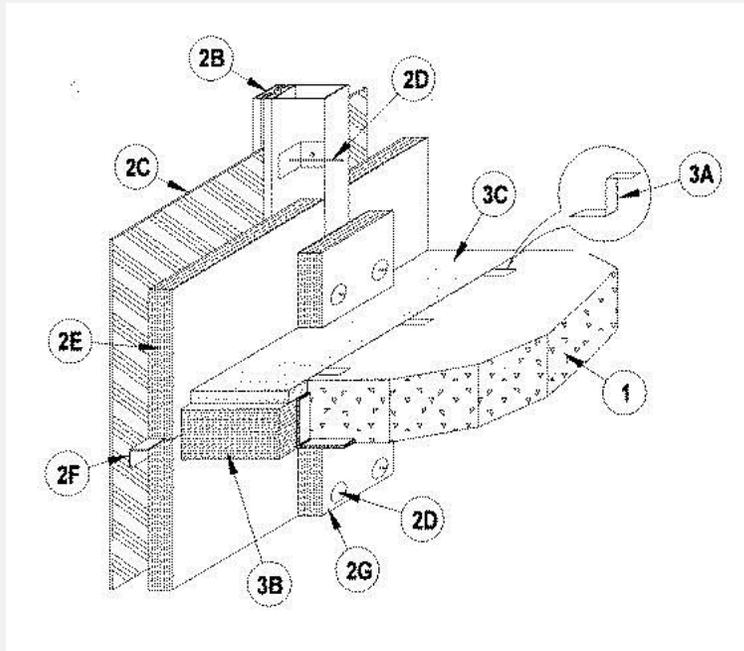


Figure 1 - Typical curtain wall system panel

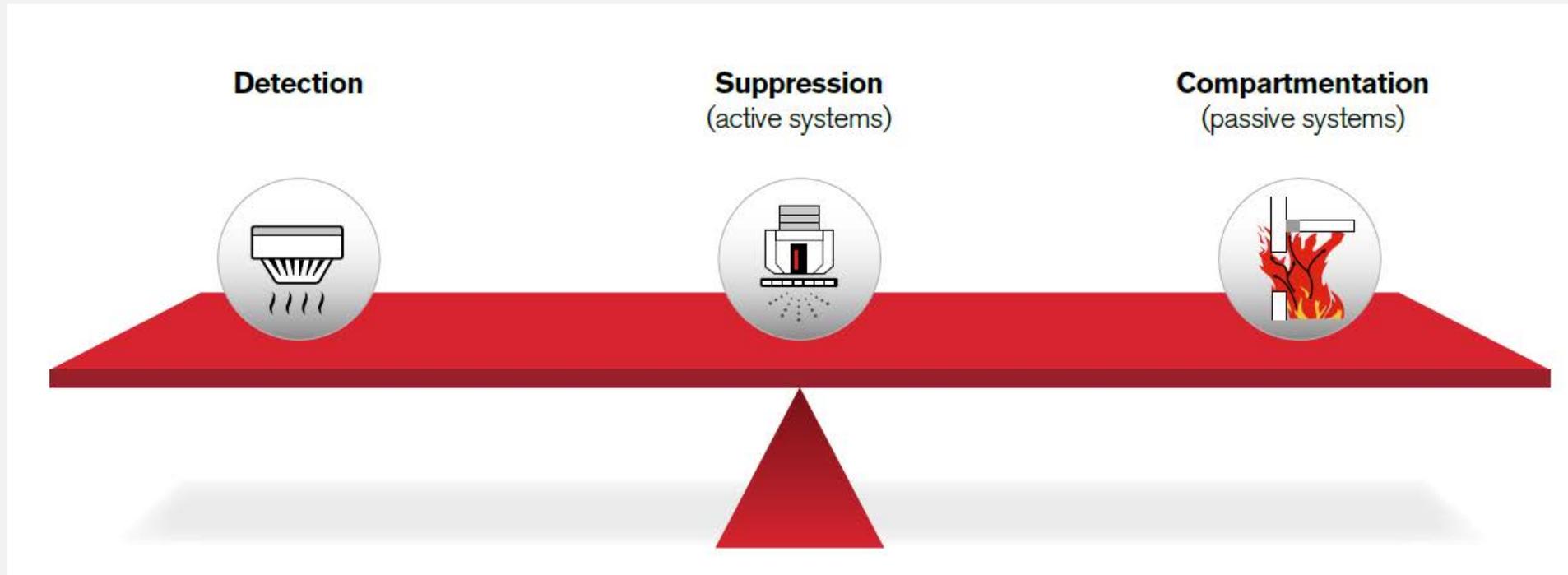
# Development of Perimeter Fire Containment



UL's First Published Curtain Wall Assembly: CW-S-2001

Issued: 4/14/97

# The Balanced Approach



# What do the Building Codes say?



# Building Codes

## International Building Codes 2015

### Section 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  $\frac{3}{4}$  hour. Such openings shall be separated vertically **at least 3 feet** (914mm) by spandrel girders, exterior walls or other similar assemblies that have a fire-resistance rating of at least 1 hour or by flame barriers that extend horizontally at least 30 inches (762mm) beyond the exterior wall. Flame barriers shall have a fire-resistance rating of not less than 1 hour.

#### 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. This section shall not apply to open parking garages.

# Building Codes

## International Building Codes 2015

### Section 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.

#### Exception:

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.

# Building Codes

## International Building Codes 2015

### Section 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.**

### 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.**

# Building Codes - Canada

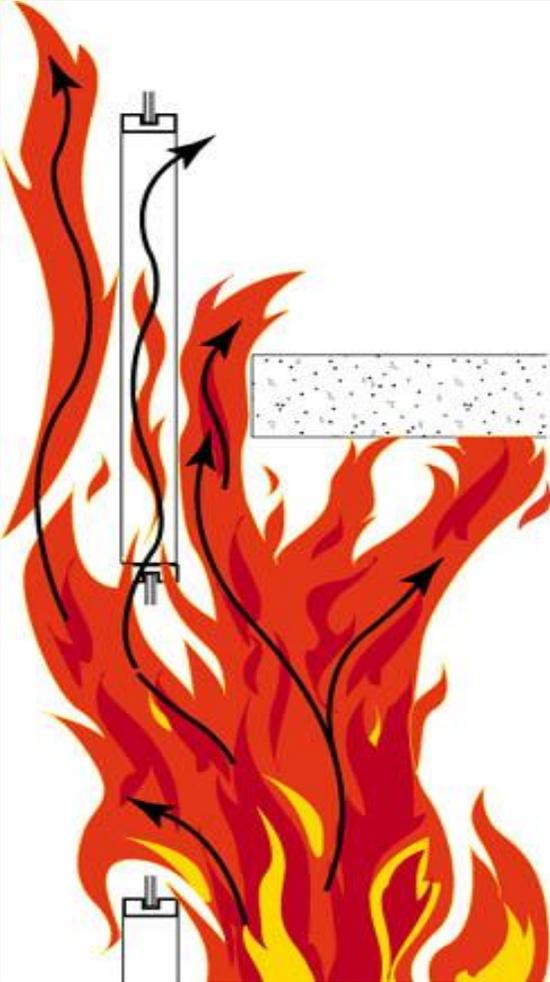
## Canadian National Building Code

### 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.

# Dynamics of Vertical Fire Spread



# ASTM E 119 Temperature Curve

**6 minutes**

**1050° F**  
Glass-fiber  
insulation melts.

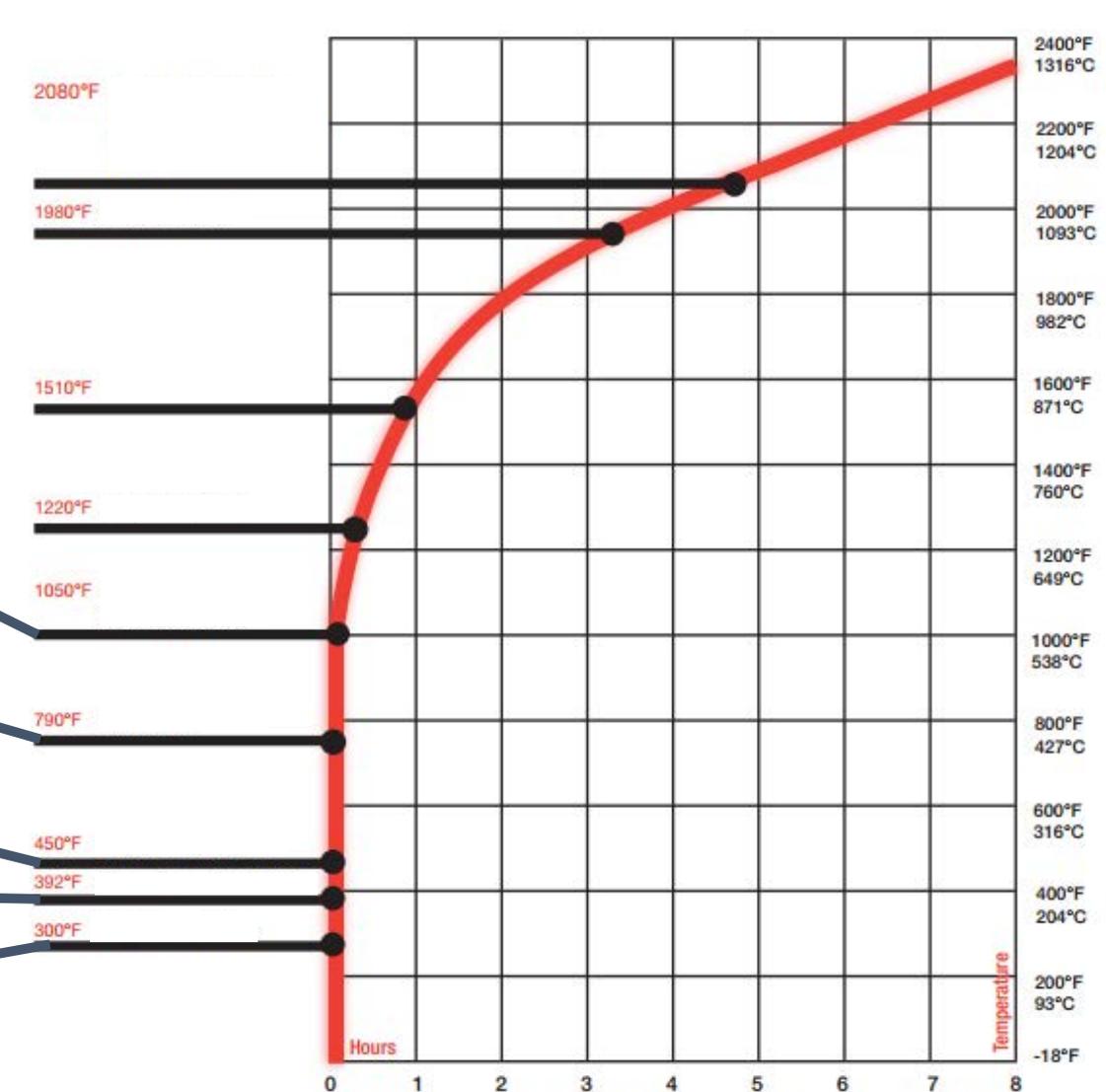
**790° F**  
Zinc melts.

**450° F**  
Cellulose pyrolyzes.

**392° F**  
Spray Foam flash point.

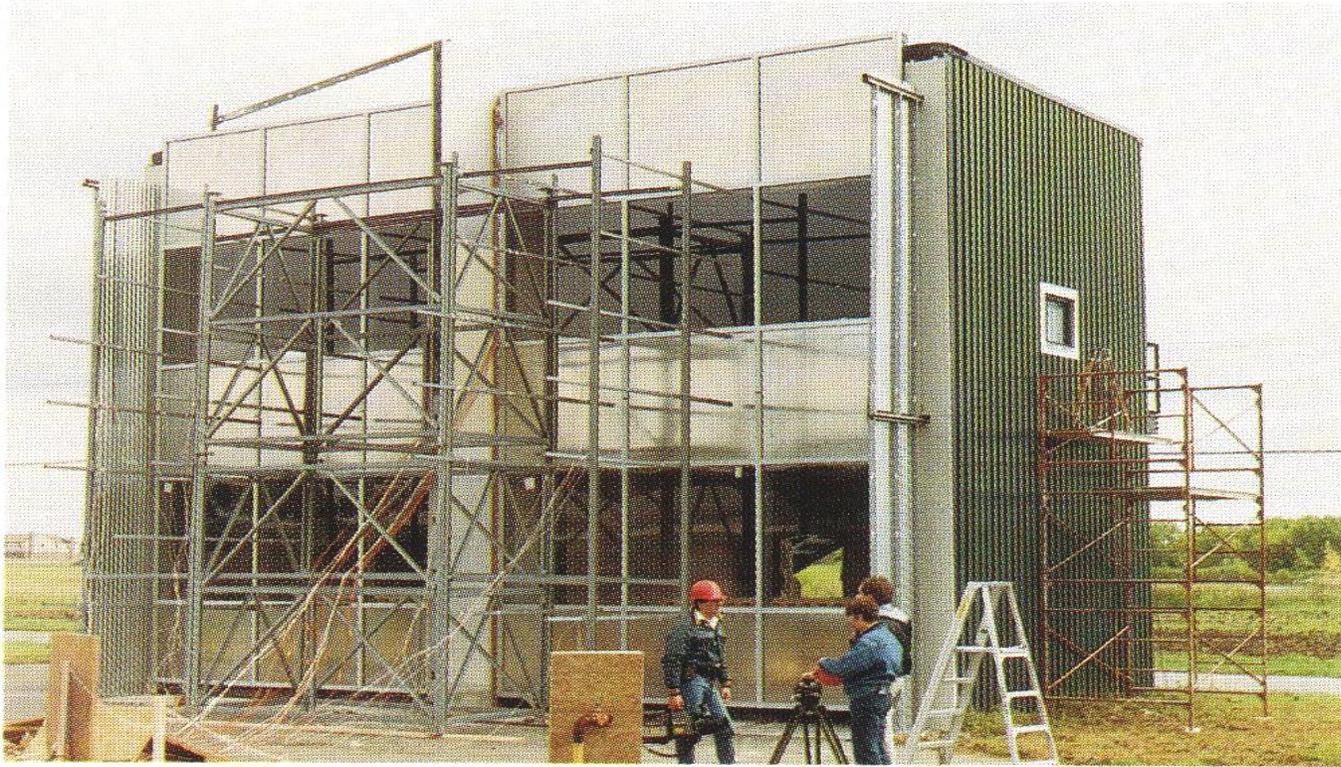
**300° F**  
Rigid foam melts.

cture 2018



(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)

# Fire Performance Testing of Common Insulations - 1987



**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."

# Fire Performance Testing of Common Insulations - 1987

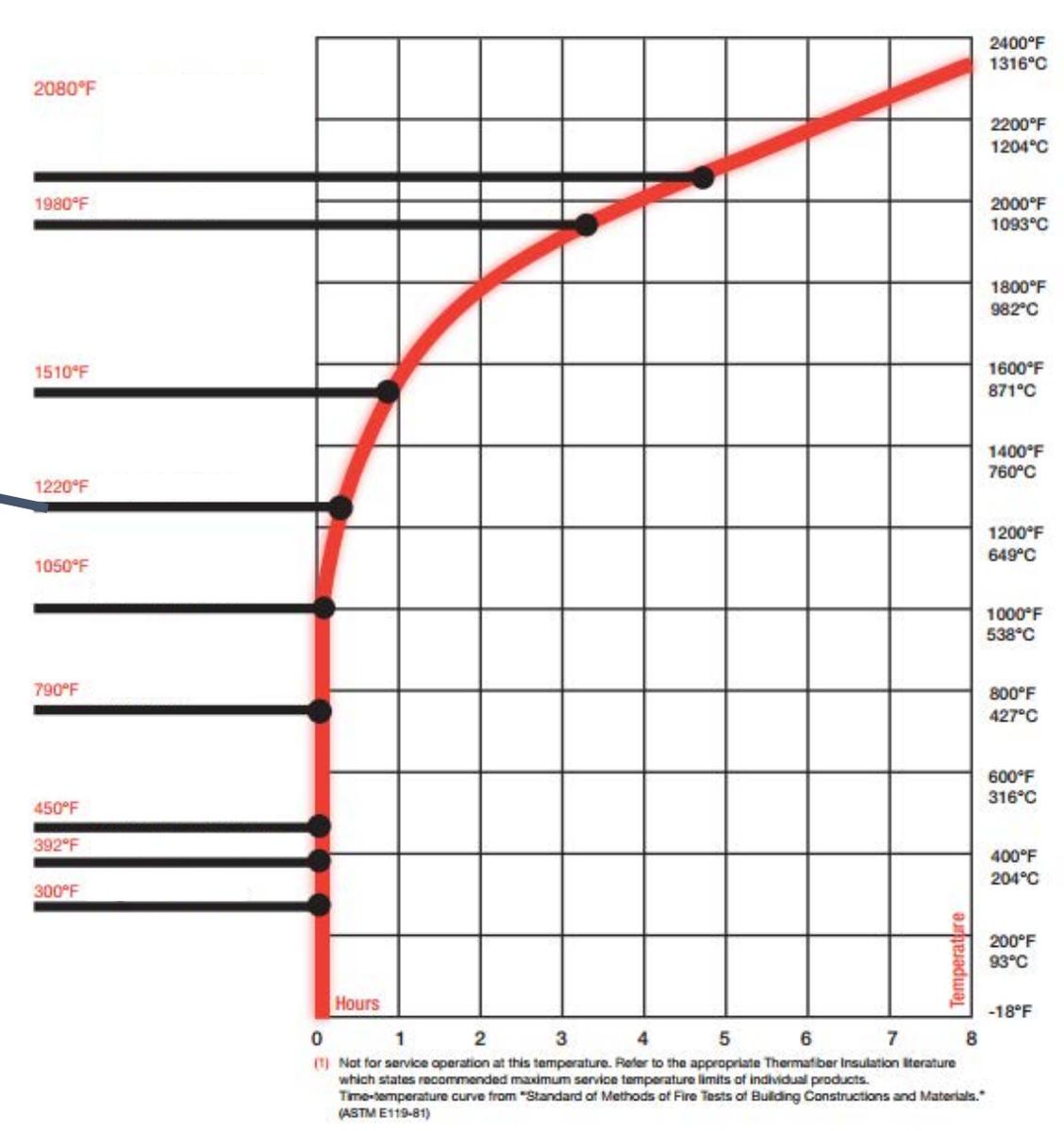


# ASTM E 119 Temperature Curve

9 minutes

1220° F

Aluminum melts.



# Fire Performance

## Mullions and Transoms before fire test

Horizontal  
Transom

Vertical  
Mullions



# Fire Performance

## Mullion exposure to fire test

Exposed side of vertical mullion almost completely melted out



# Fire Performance

Transom exposure  
to fire test

Transom bending  
down 11 min.  
into test



# Fire Performance

**Mullions and  
Transoms  
after exposure  
to  
fire test**

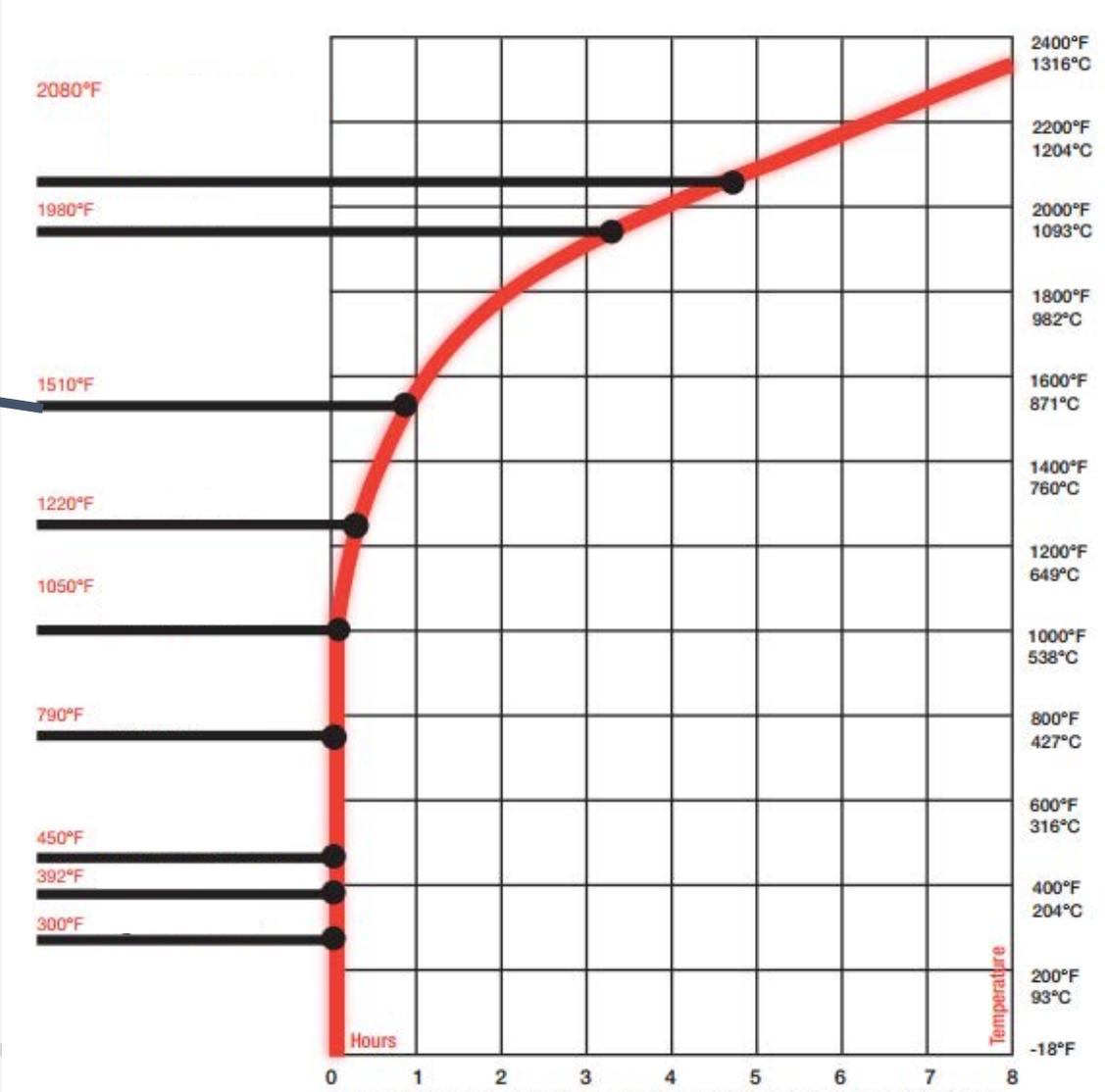
Complete loss of  
horizontal  
transom and  
vertical mullions



# ASTM E 119 Temperature Curve

25 minutes

1510° F  
Plate glass 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)

# Fire Performance

Glass breakage  
approximately 11  
minutes into the  
fire test



# Fire Performance

Glass breakage  
during an actual  
fire

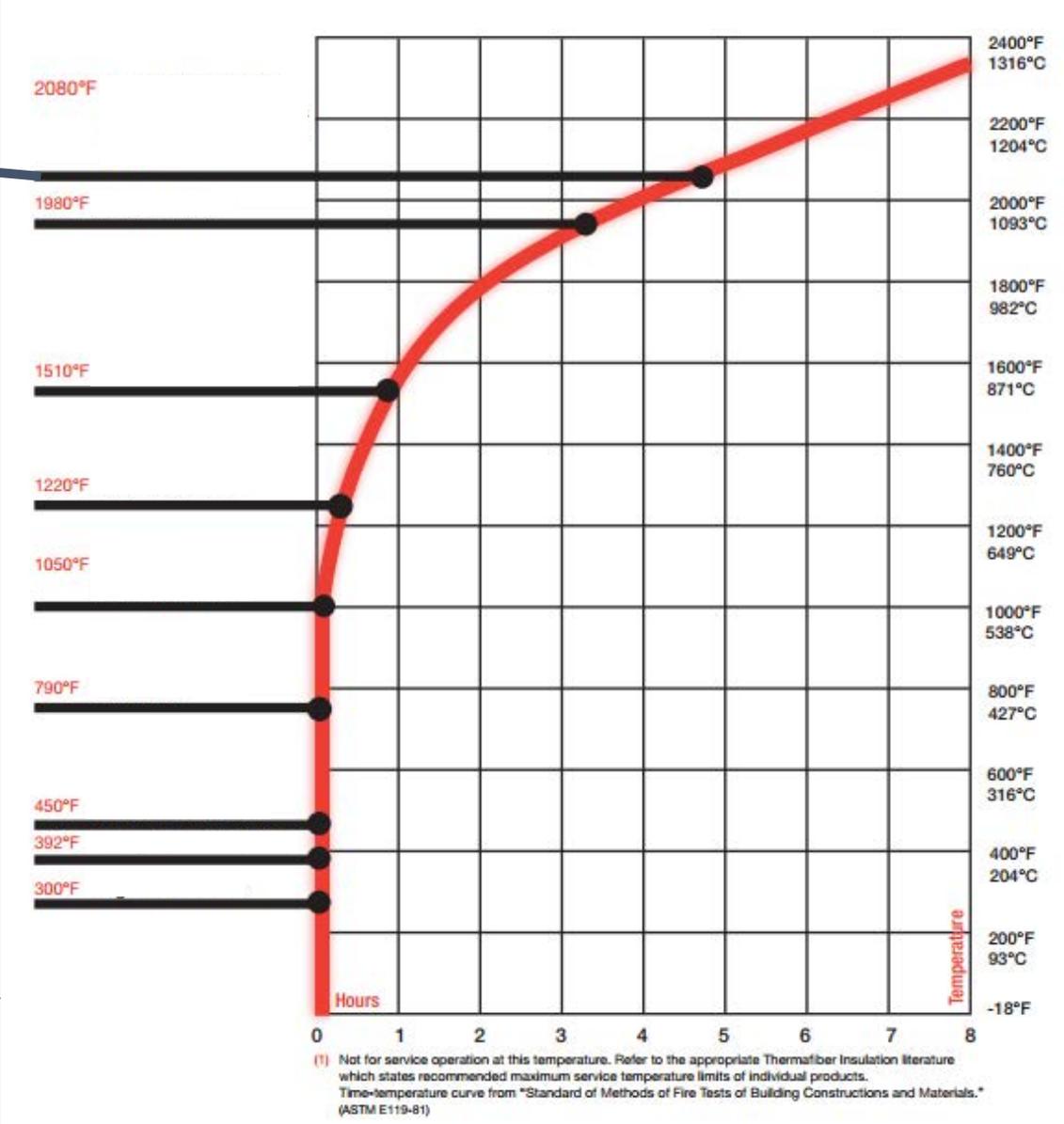


# ASTM E 119 Temperature Curve

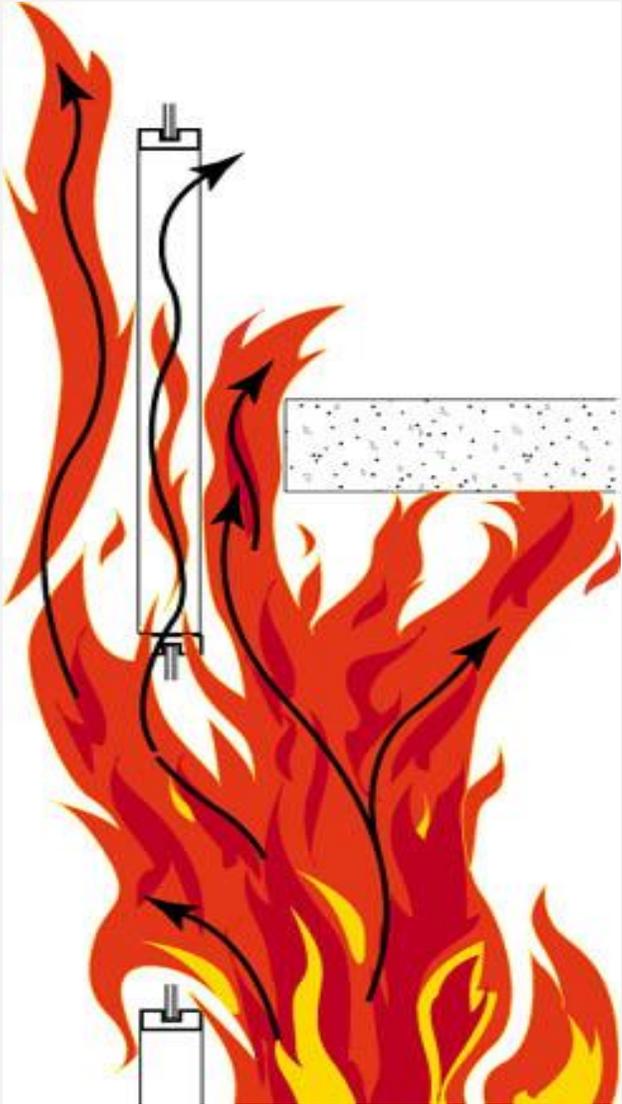
5 hours +

2080° F

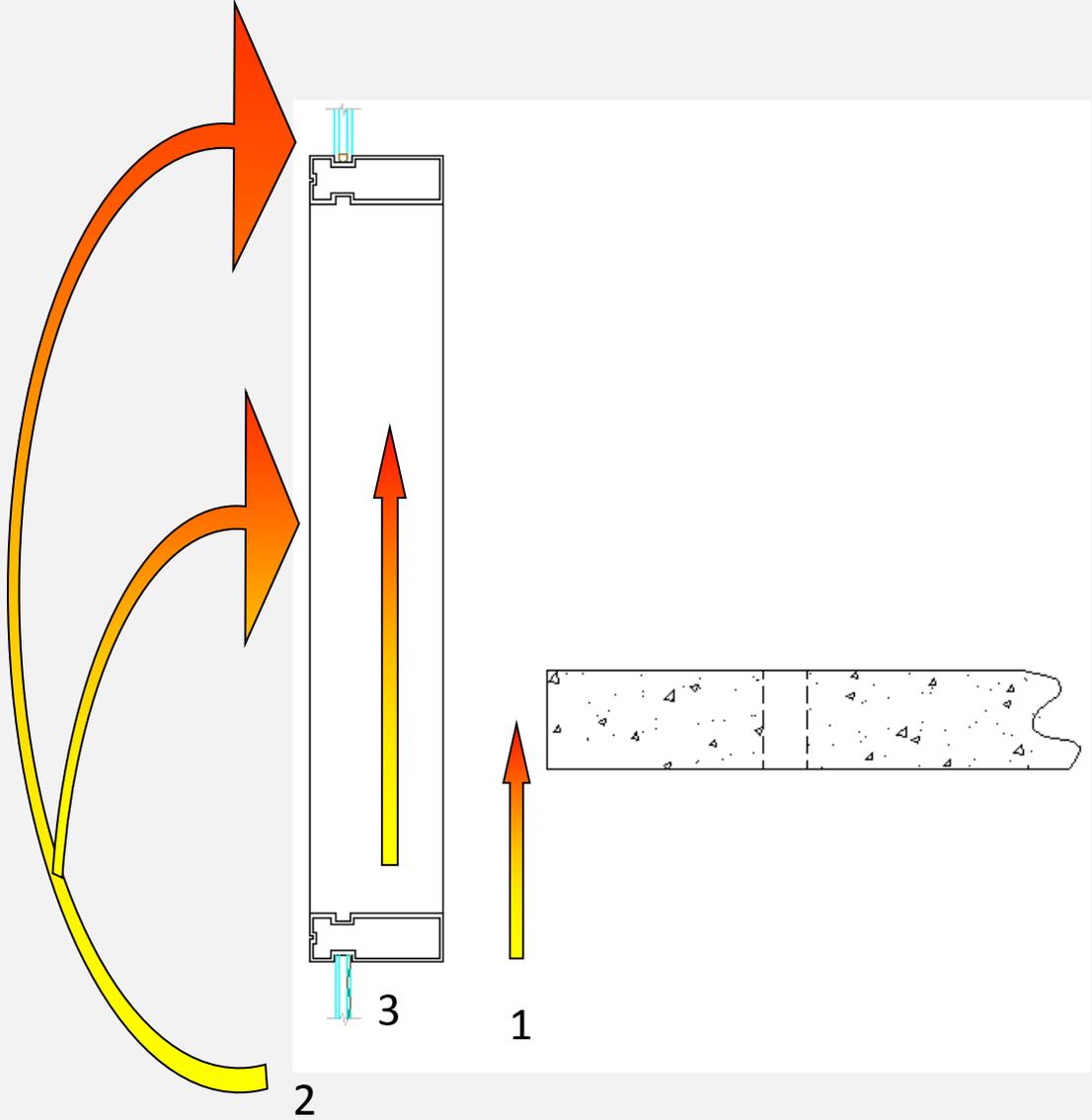
At 5 hours, mineral wool insulation is still intact.  
Test terminated without failure.



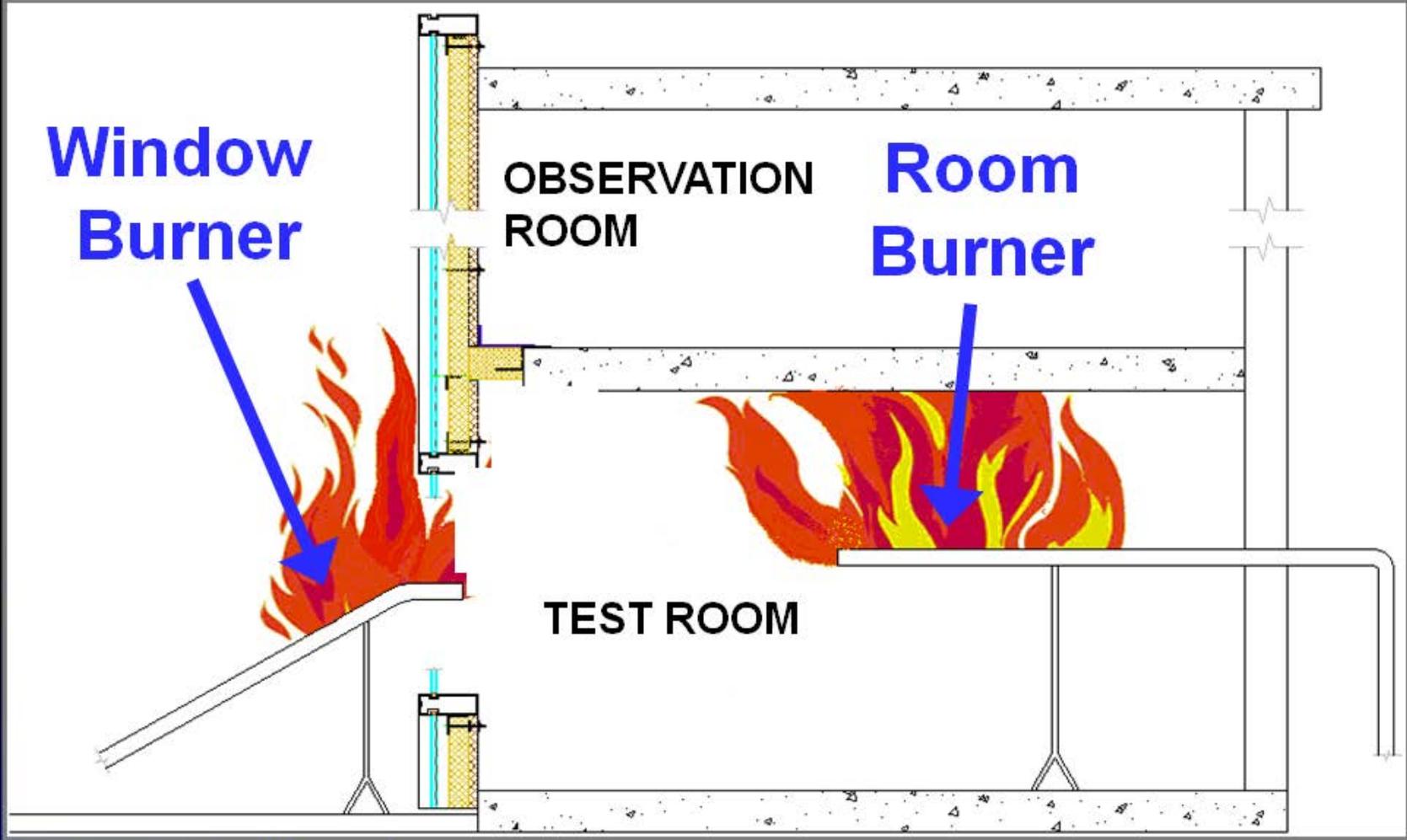
# Paths of Fire Propagation



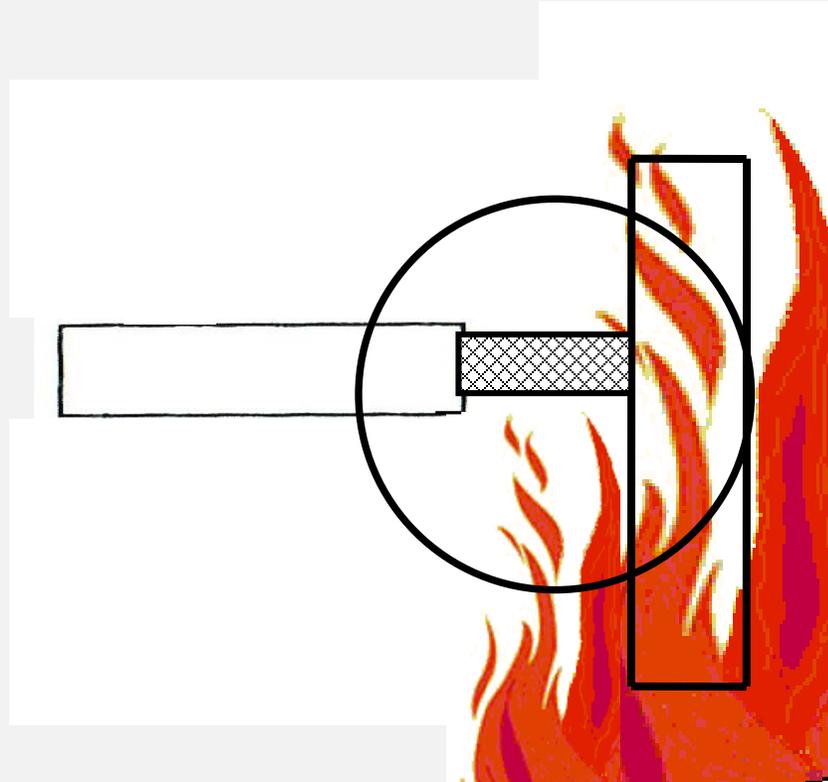
# Paths of Fire Propagation



# ASTM E 2307



# ASTM E 2307



# ASTM E 2307



# ASTM E 2307 – Result

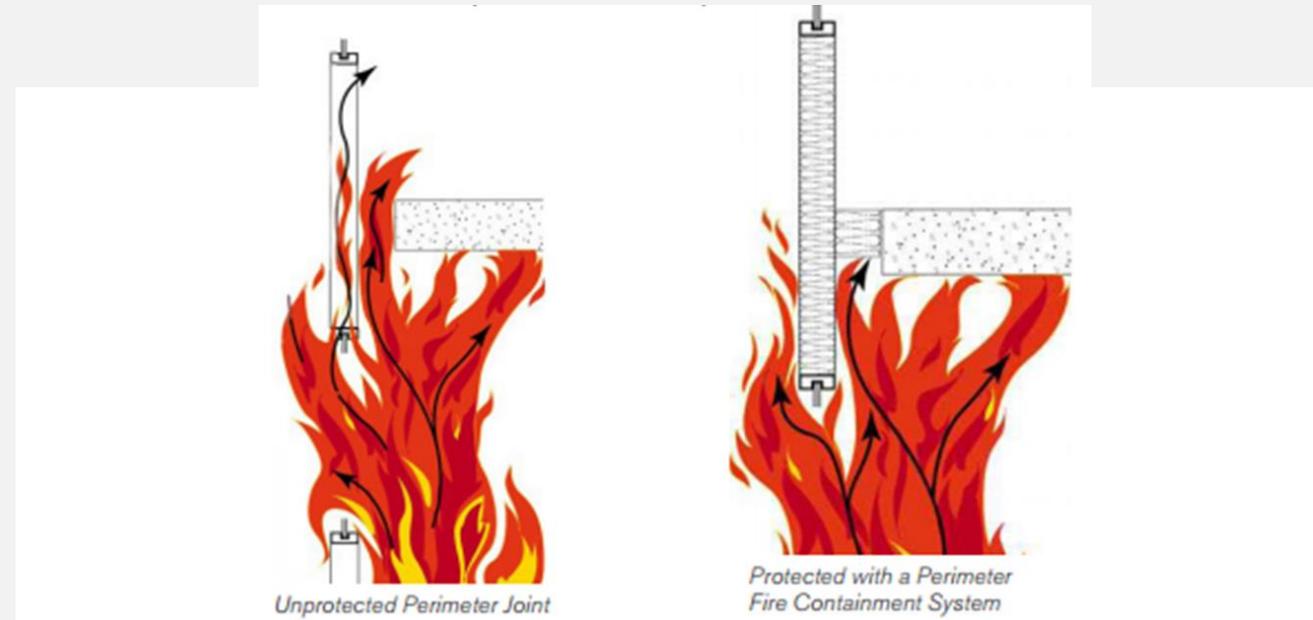


# Perimeter Fire Containment



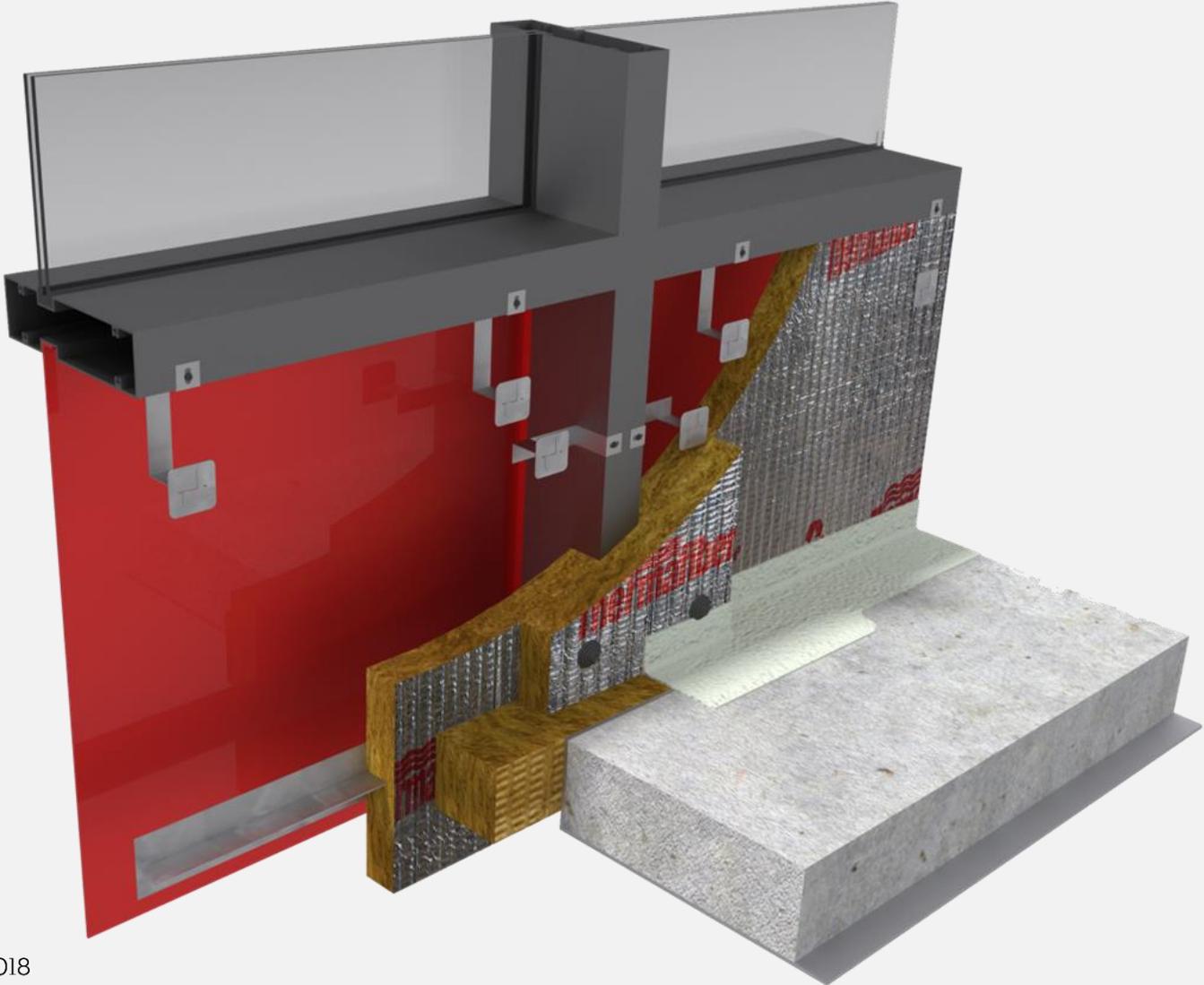
**How is a fire like this contained?**

# Perimeter Fire Containment



# 6 Basic Components of a Listed Perimeter Fire Containment Assembly

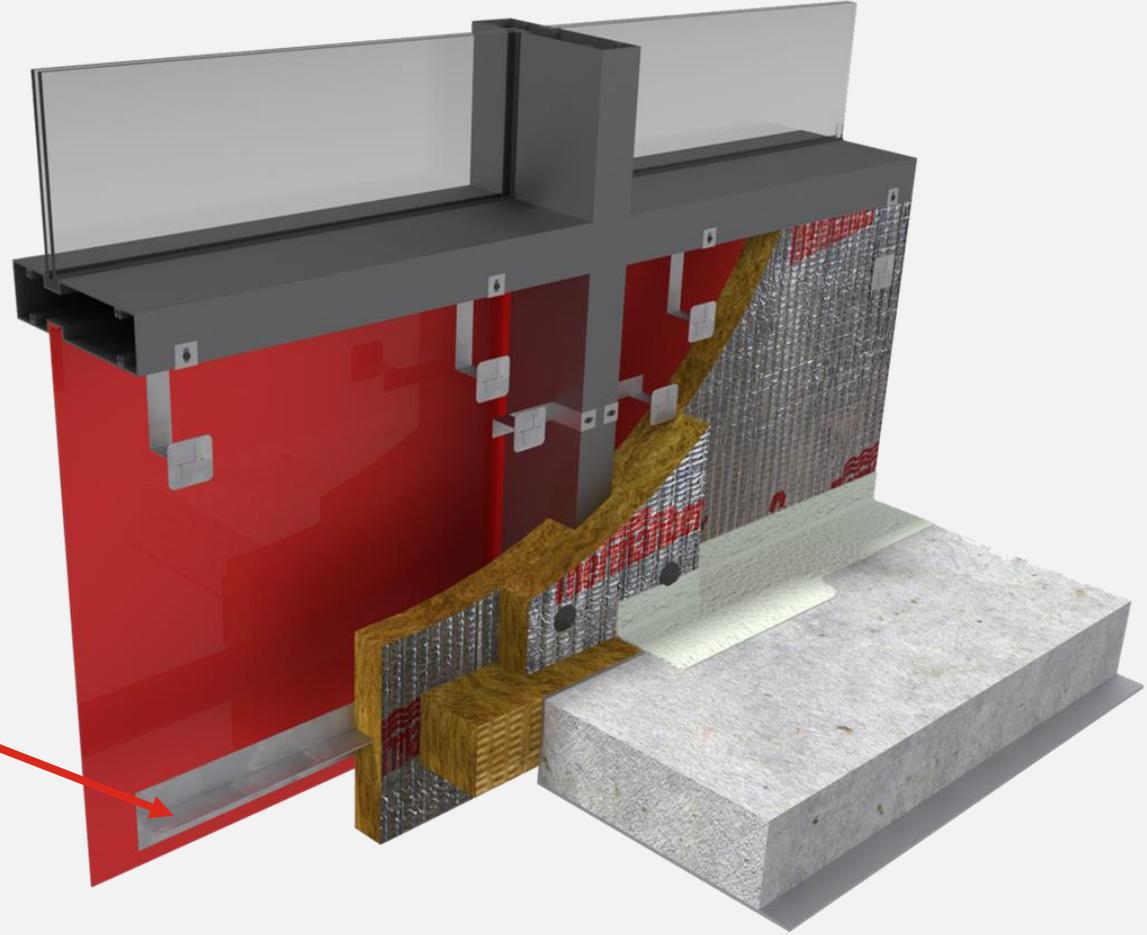
# Perimeter Fire Containment



# Perimeter Fire Containment

## Design Criteria 1:

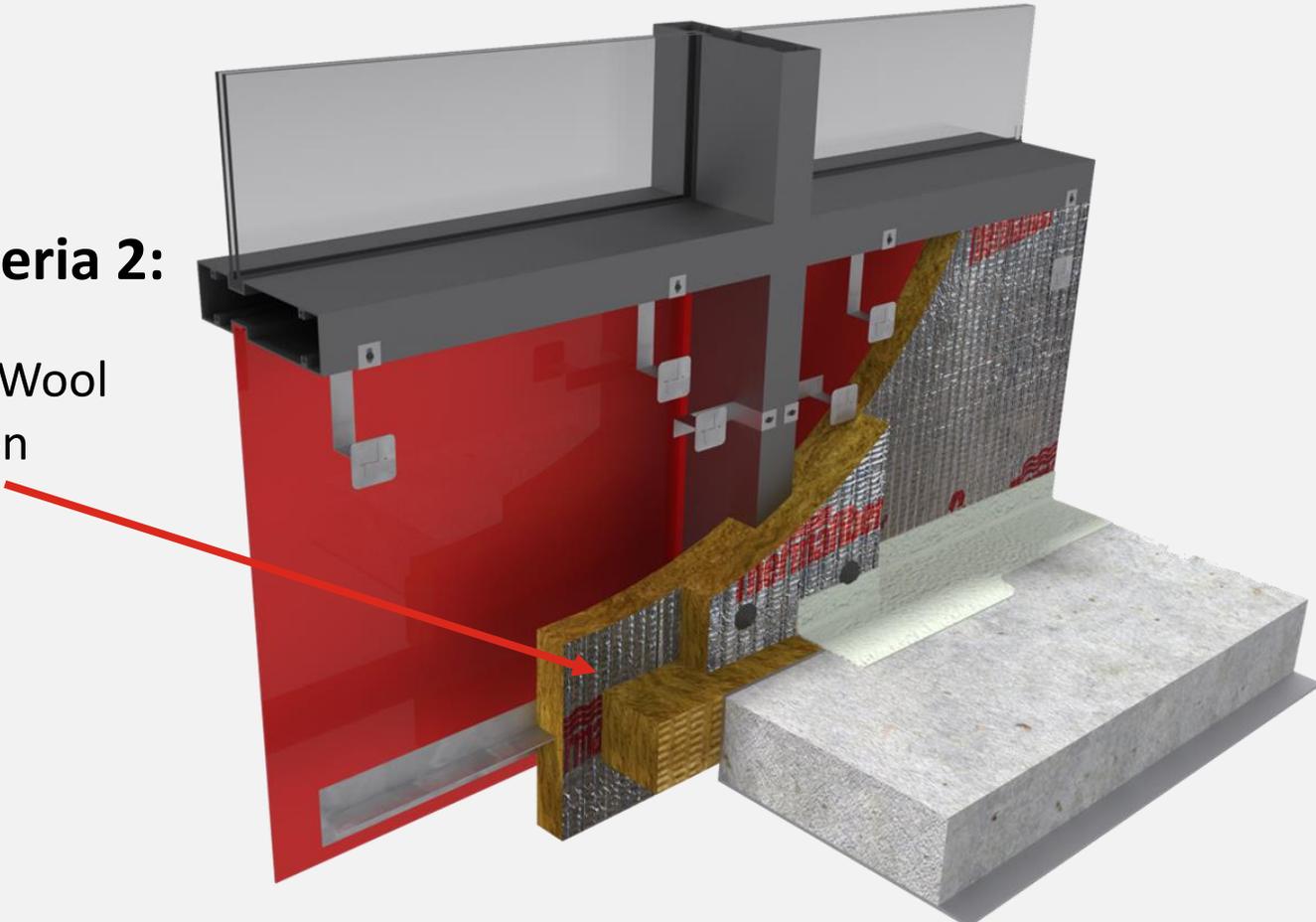
Reinforcement  
Member  
Mechanically  
Attached



# Perimeter Fire Containment

**Design Criteria 2:**

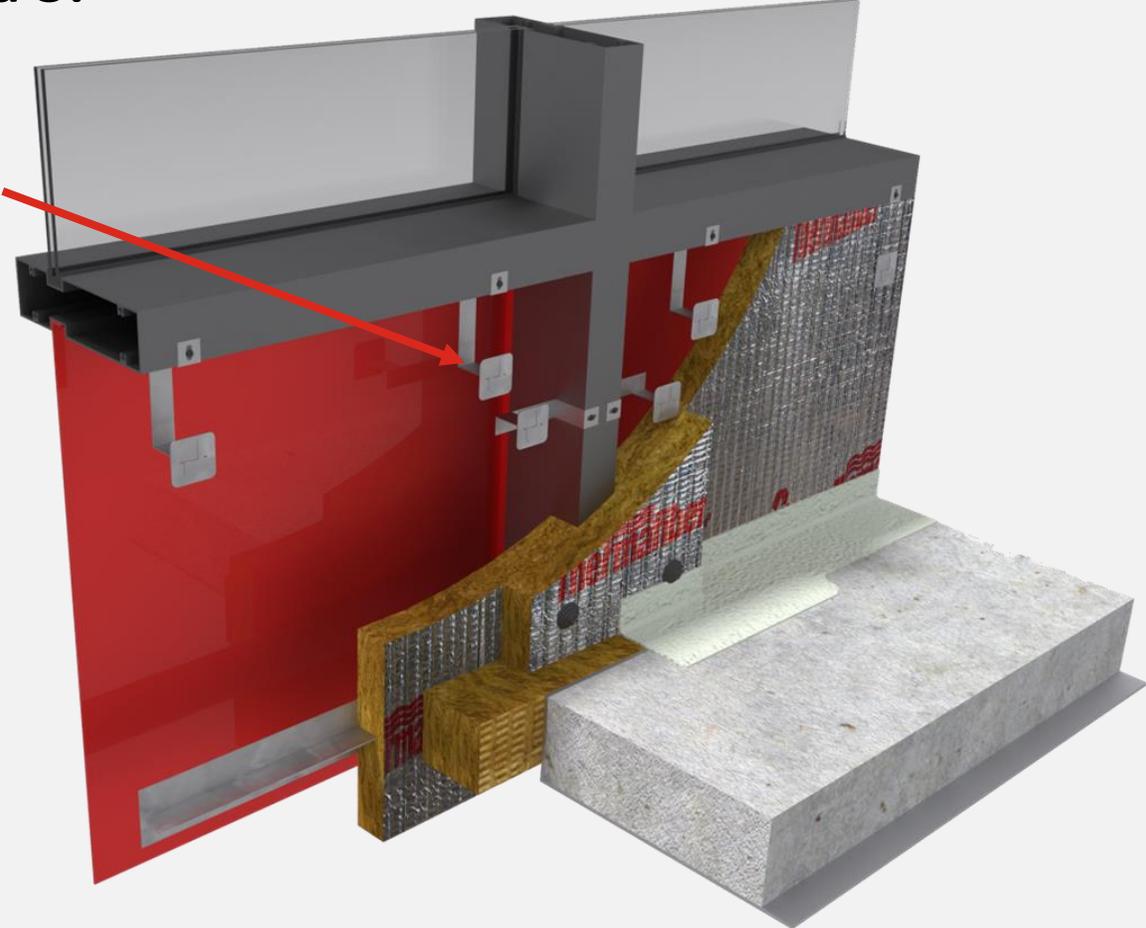
Mineral Wool Insulation



# Perimeter Fire Containment

## Design Criteria 3:

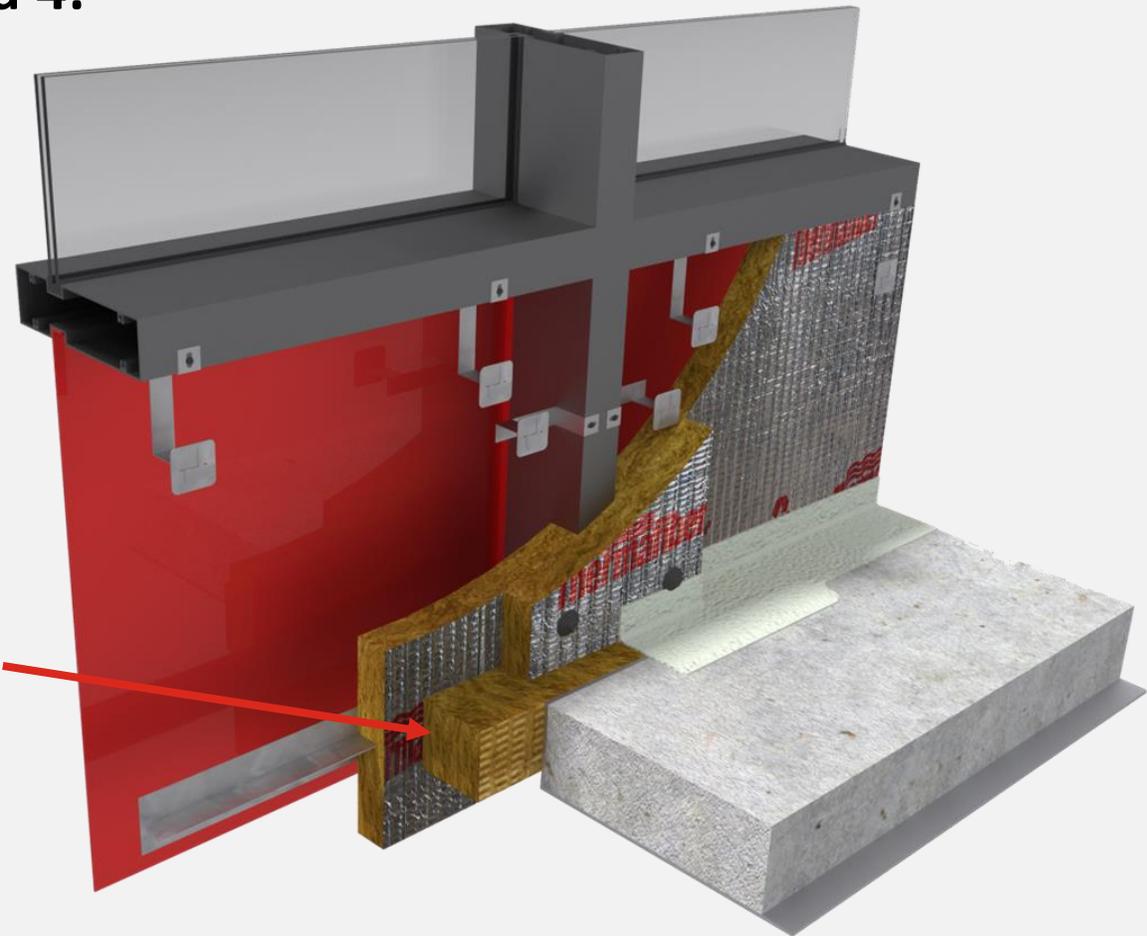
Mineral Wool  
Insulation -  
Mechanically  
Attached



# Perimeter Fire Containment

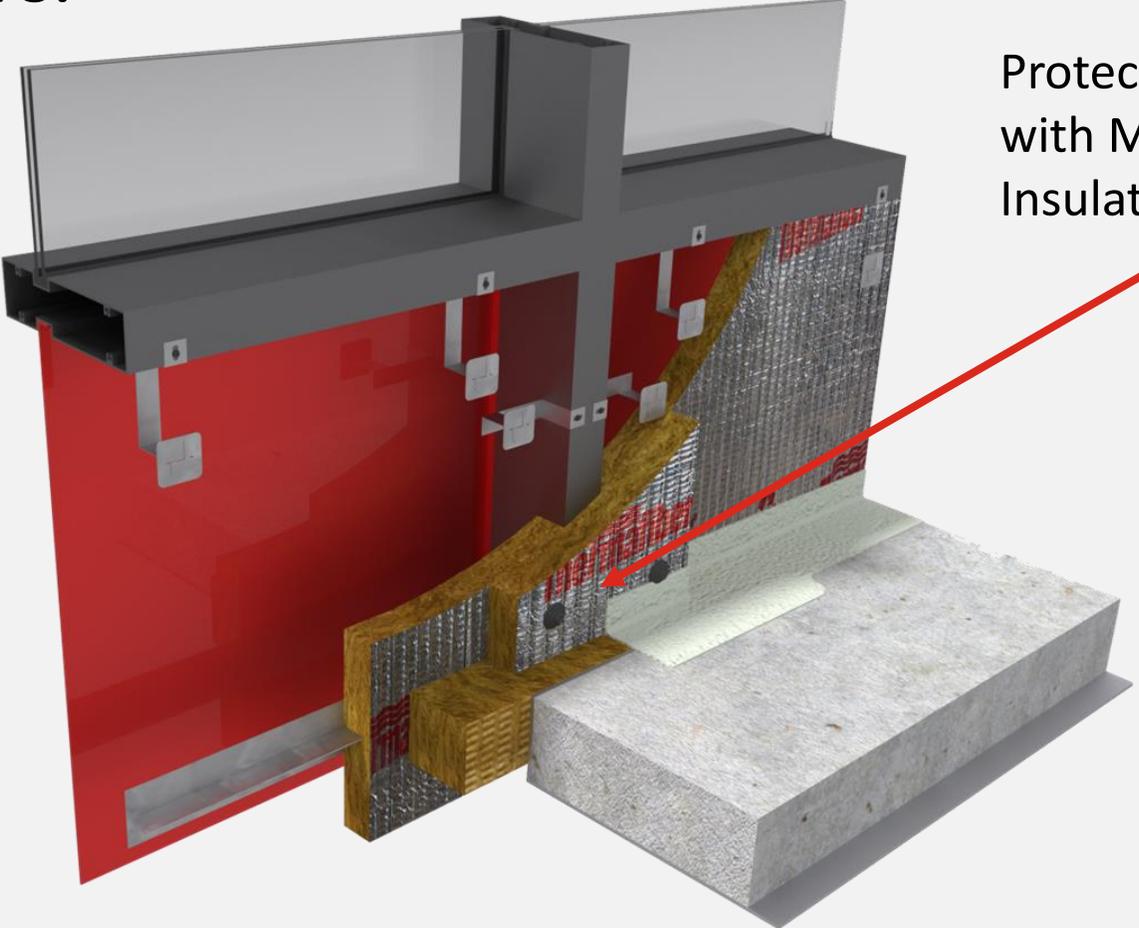
## Design Criteria 4:

Compression Fit  
Safing  
(direction of Safing as  
required per tested  
assembly)



# Perimeter Fire Containment

## Design Criteria 5:



Protect Mullions  
with Mineral Wool  
Insulation

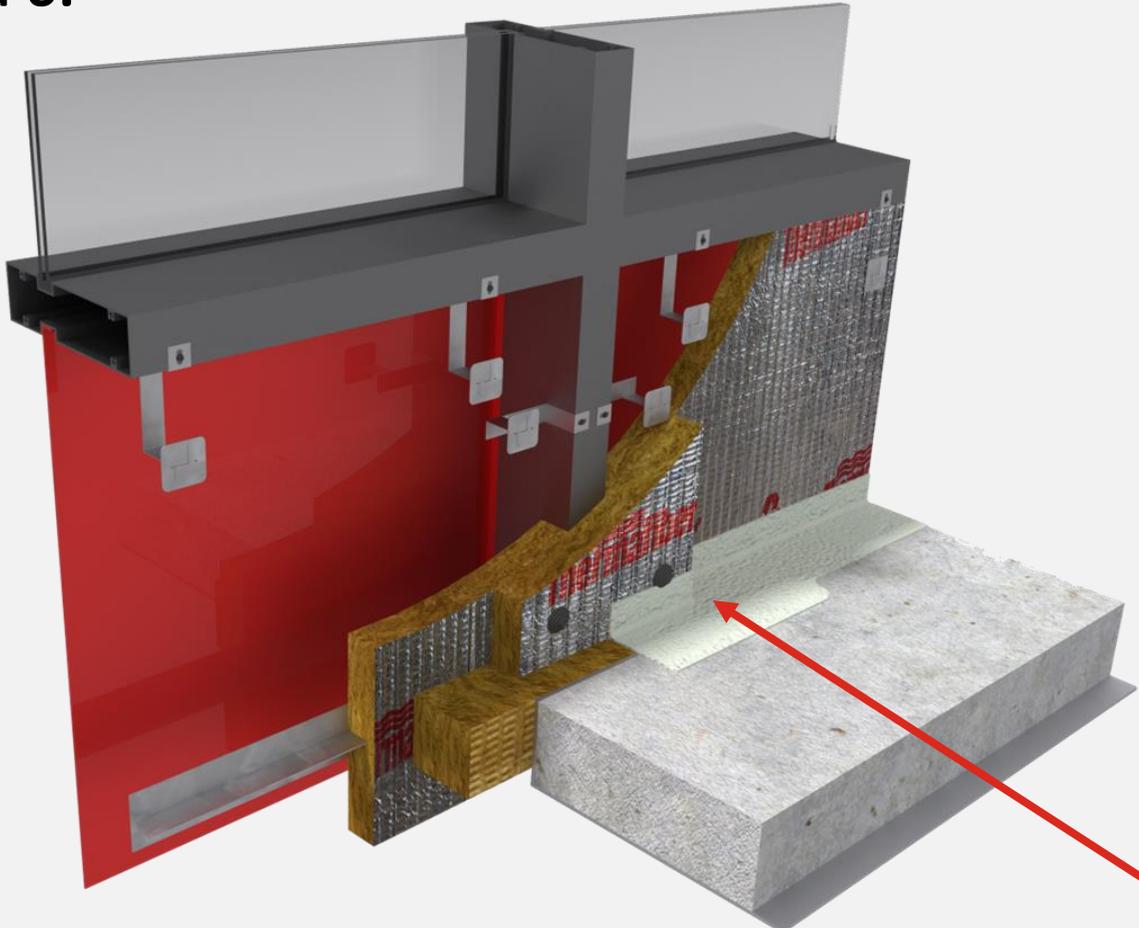
# Smoke – The known killer

**The major contributor of fire related deaths is smoke inhalation**



# Perimeter Fire Containment

## Design Criteria 6:



Smoke Barrier

# Perimeter Fire Containment

## The 6 Basic Design Principles

Mineral Wool  
Insulation -  
Mechanically  
Attached

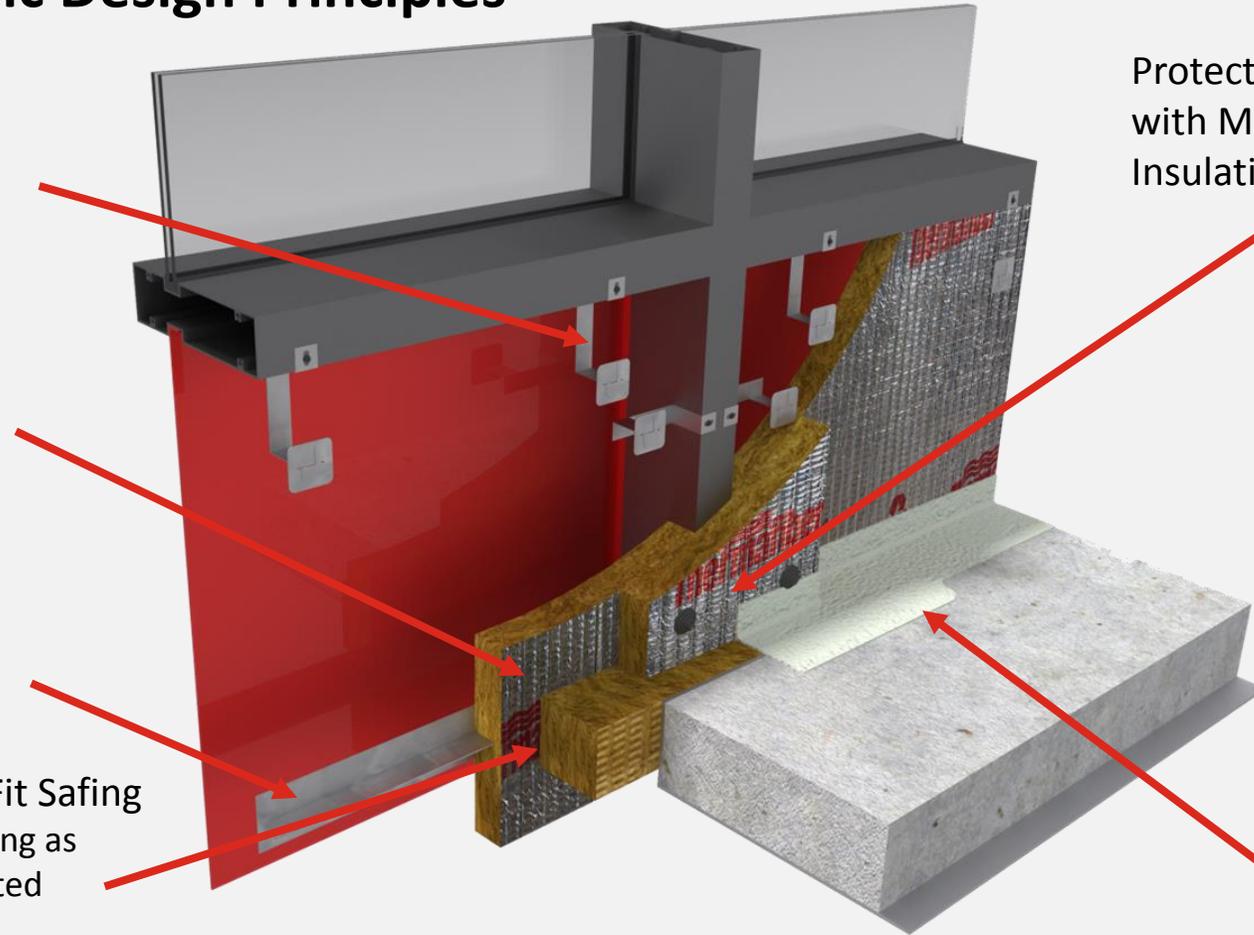
Mineral Wool  
Insulation

Reinforcement  
Member  
Mechanically  
Attached

Compression Fit Safing  
(direction of Safing as  
required per tested  
assembly)

Protect Mullions  
with Mineral Wool  
Insulation

Smoke Barrier

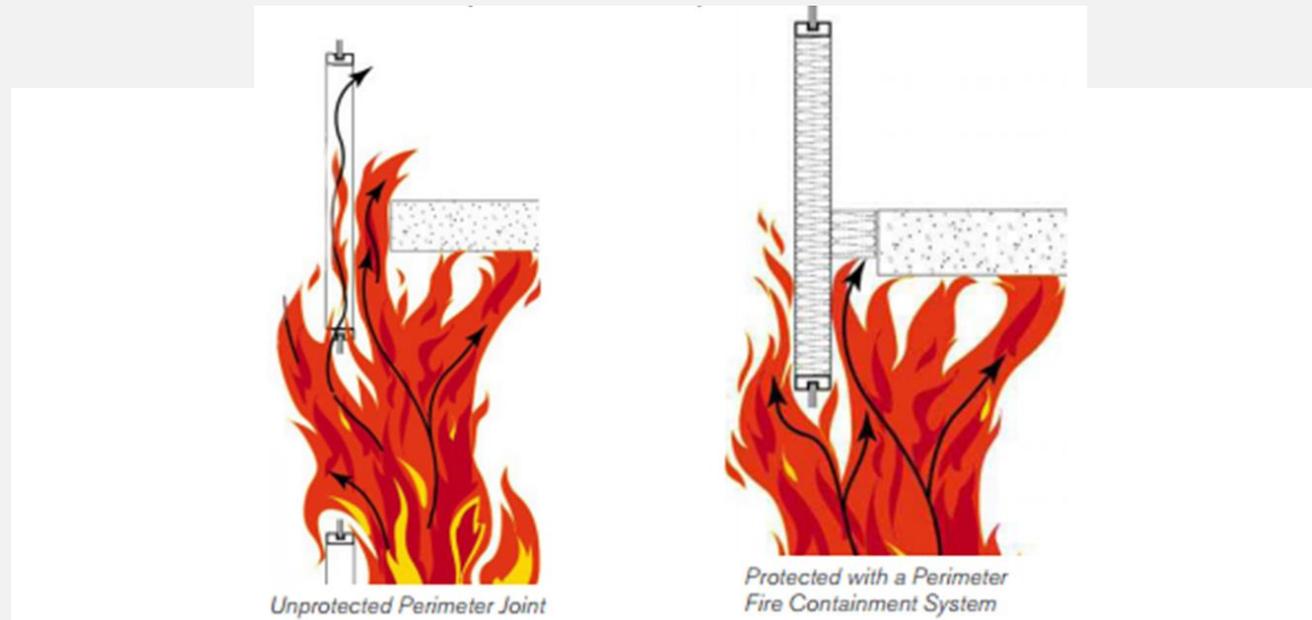


# Perimeter Fire Containment

## The Six Basic Components of Any Listed Perimeter Fire Containment System

1. Mineral Wool Insulation
2. Provide Backing/Reinforcement at the Safing Line
3. Mechanically Attached Curtain Wall Insulation
4. Compression-fit Safing Insulation
5. Protect Aluminum Mullions
6. For “Smoke Containment,” Apply a Smoke Barrier System
7. Protect Exposed Curtain Wall Anchor at the Safing Line

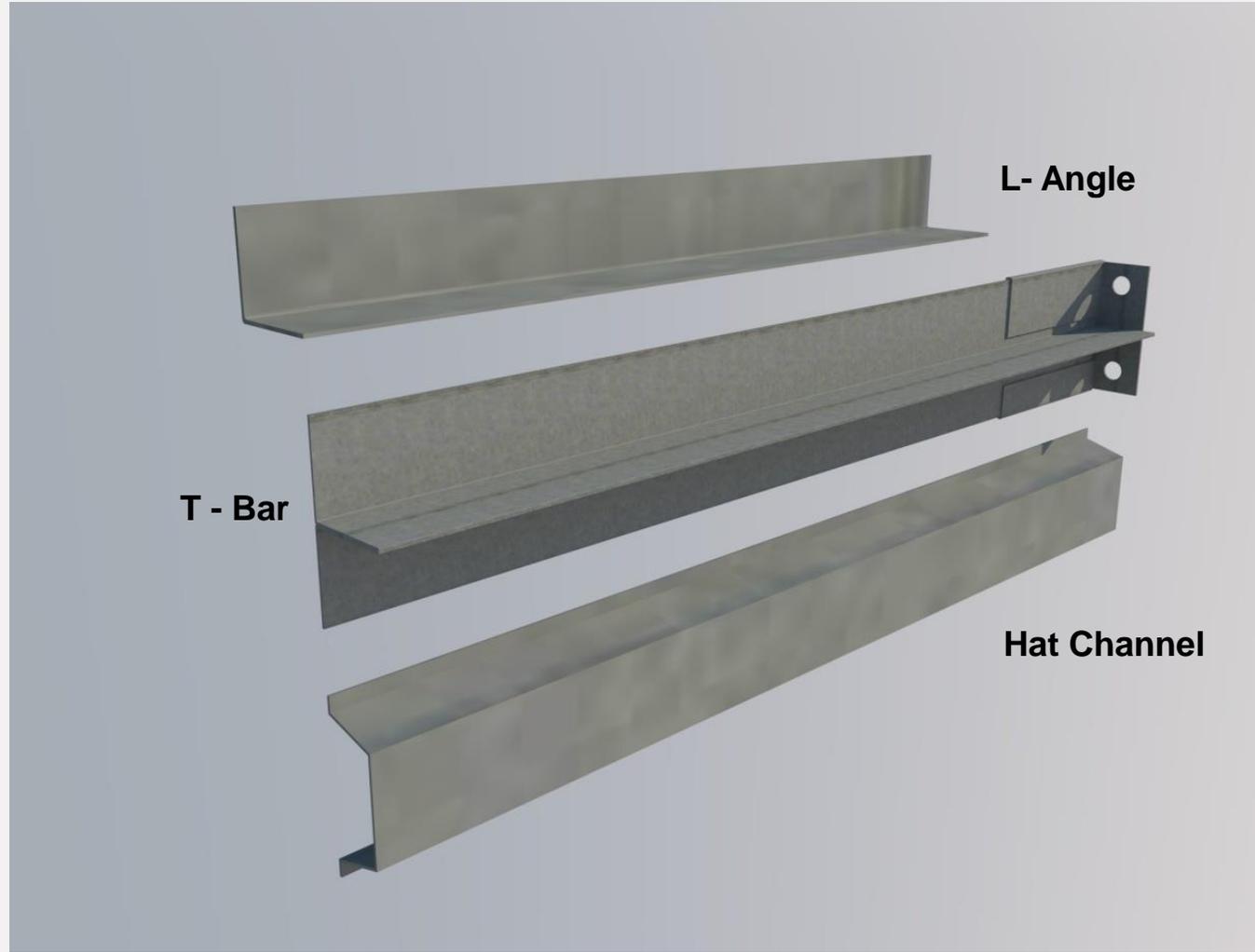
# Installation



# Installation



# Installation



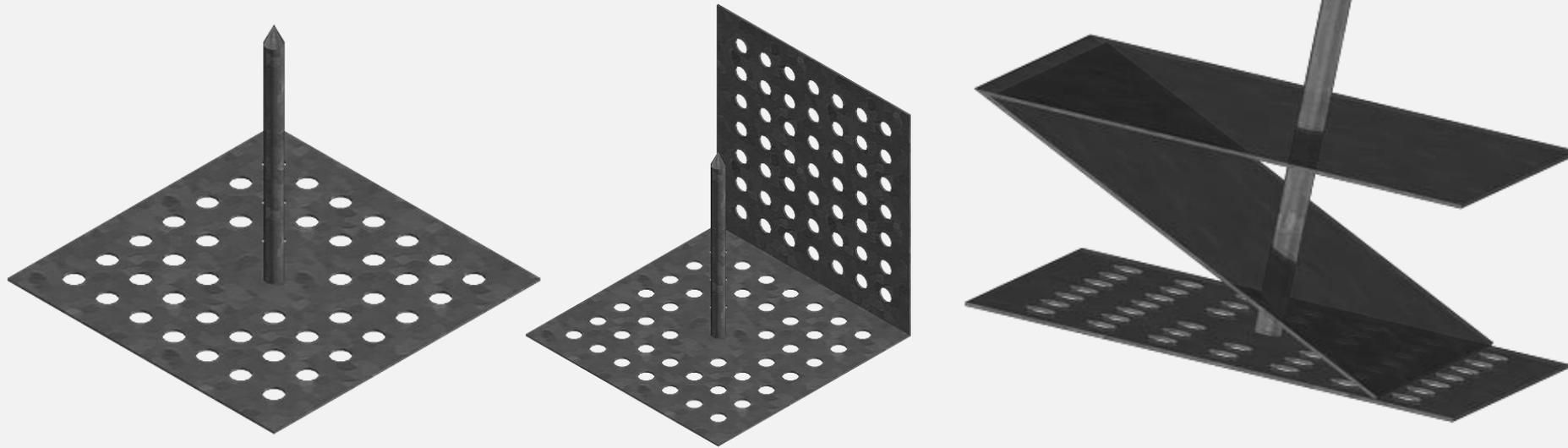
# Installation



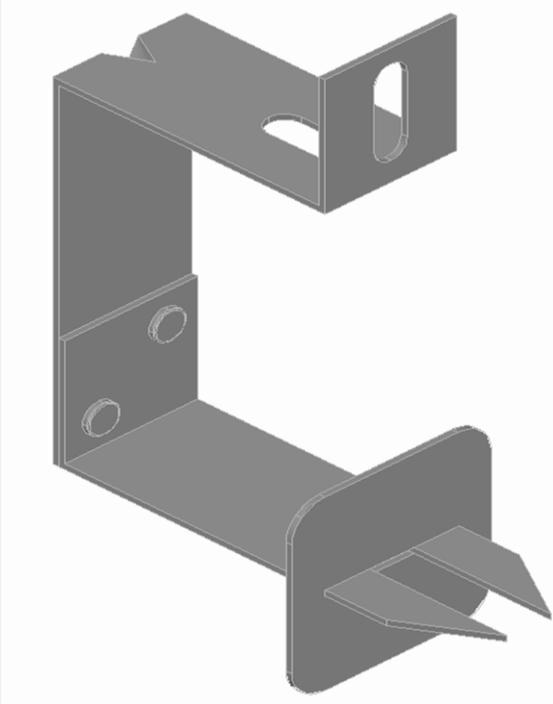
# Installation



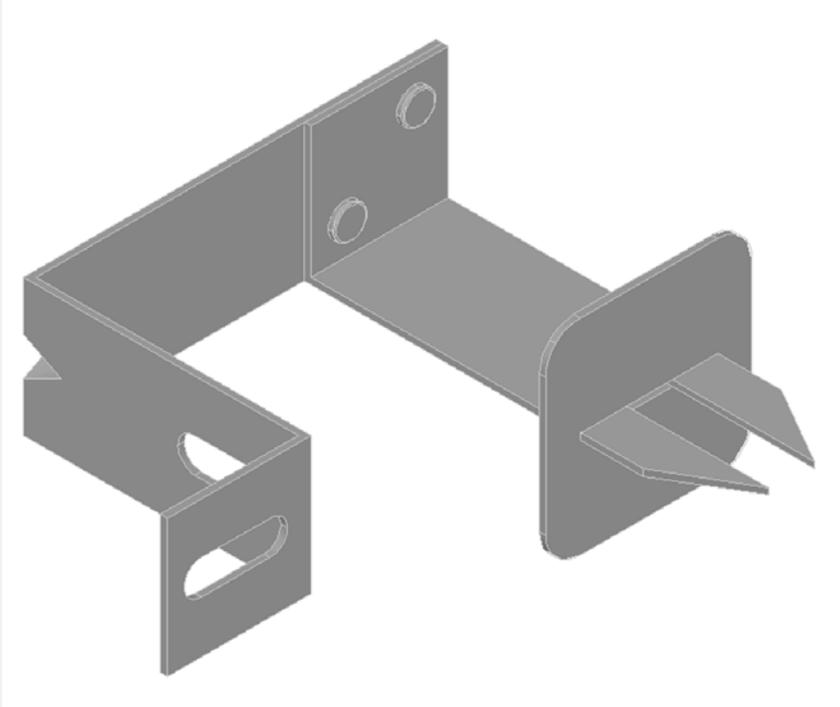
# Installation – older style hangers



# Installation – newer style hangers



Horizontal Hanger



Vertical Hanger

# Installation



# Installation



# Installation



# Installation



# Understanding Perimeter Fire Containment Designs



# Where are listed systems?



Within these two directories,  
there are  
**over 300 tested and listed**  
perimeter fire containment  
systems



# Reading Designs



Intertek Design Nomenclature Example: TF-BPF-120-01*			
2-3 digit client reference	Code that ties to the CSI designation	Rating in minutes	Sequential number for design listing for particular client
TF (Thermafiber)	BPF (Building Perimeter Firestopping)	120	01
*see specific design for movement capabilities			

# Reading Designs



UL Design Nomenclature Example: CW-D-1014 & CW-S-1001		
CW	D or S	XXXX
Curtain Wall	Dynamic or Static	Max Clearance Distance Between Curtain Wall & Floor  0000-0999 Less than or equal to 2 in. 1000-1999 Greater than 2 in. and less than or equal to 6 in. 2000-2999 Greater than 6 in. and less than or equal to 12 in.

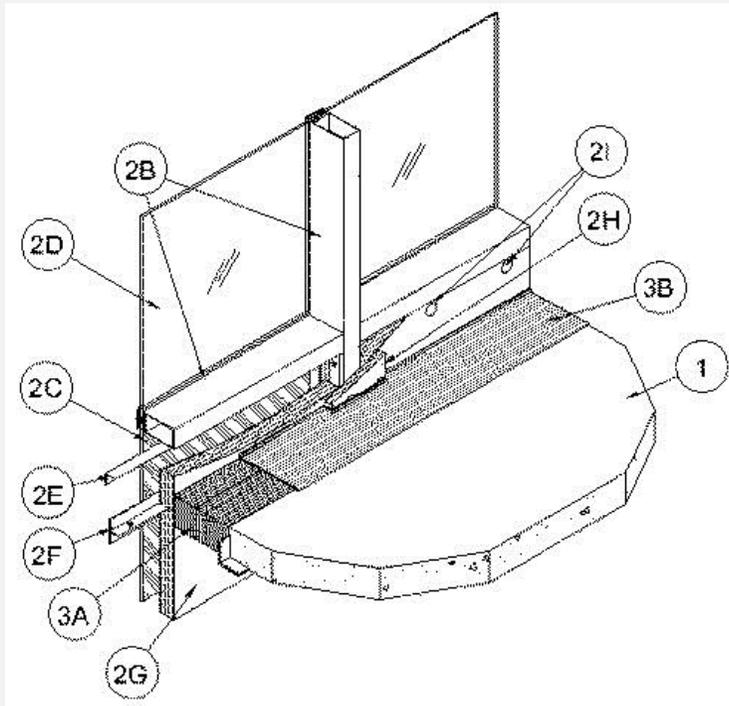
# Understanding Designs



Rating	Description	Code Requirement?
F Rating	the ability of the design to prevent flame and hot gasses from passing through the interior of the system between the edge of the slab and interior face of the CW.	Yes, per IBC section 715.4
Integrity Rating	Barrier to interior fire passage and leap frog	No, recognized as a design criteria by government agencies and the healthcare industry
L Rating- Hour	Measure of air leakage in CFM/Linear Ft. @ ambient & 400° F	
Insulation Rating- Hour	(Max temp rise not to exceed 325° F max individual or 250° F average above the starting temp on unexposed surface or 1" above)	
Movement Capabilities (Vertical Shear)		
Movement Class	Min No. of Cycles	Min Cycling Rate (cycles per min)
Class I	500	1
Class II	500	10
Class III	100	30

# Understanding Designs

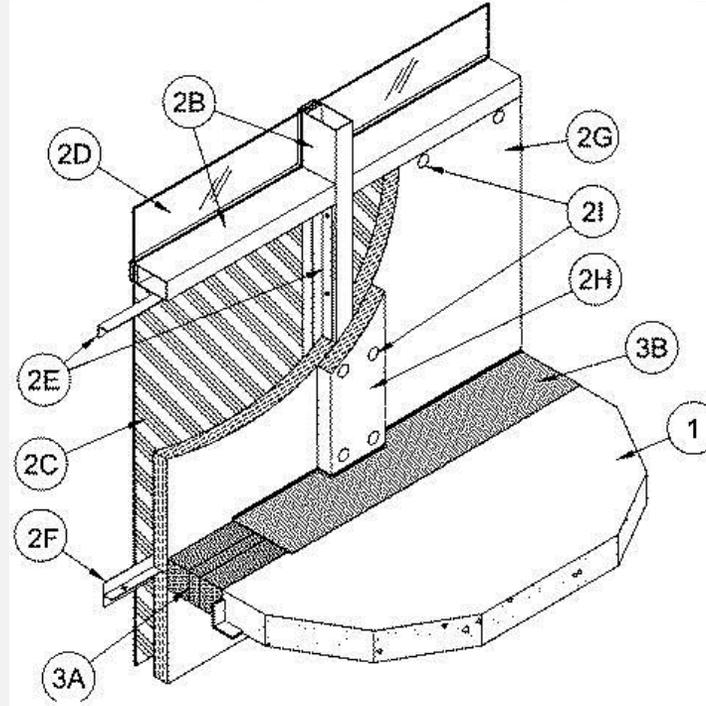
**F- Rating- Hour**  
**Integrity Rating- Hour**



F Rating — 2 Hr

Integrity Rating — 0 Hr

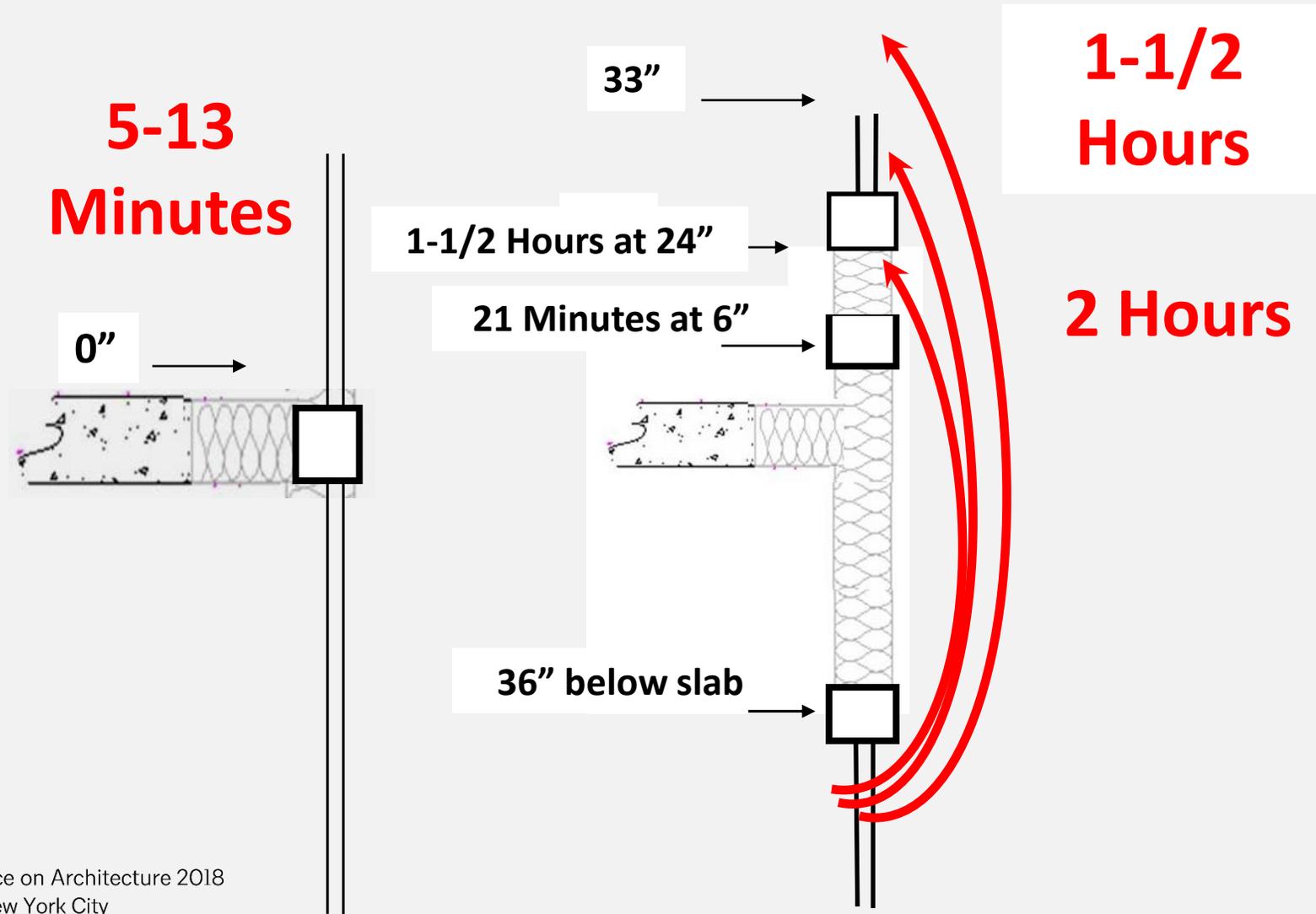
**(Interior Spread per ASTM E 2307)**  
**(Interior Spread & Leap Frog)**



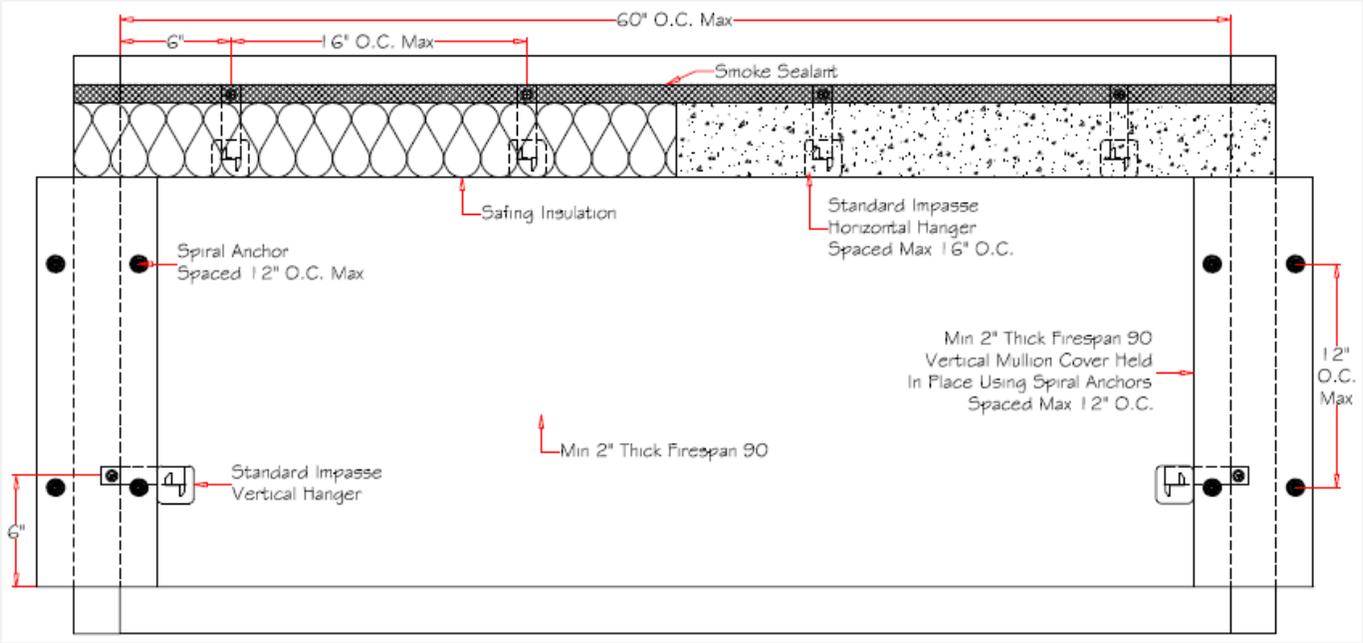
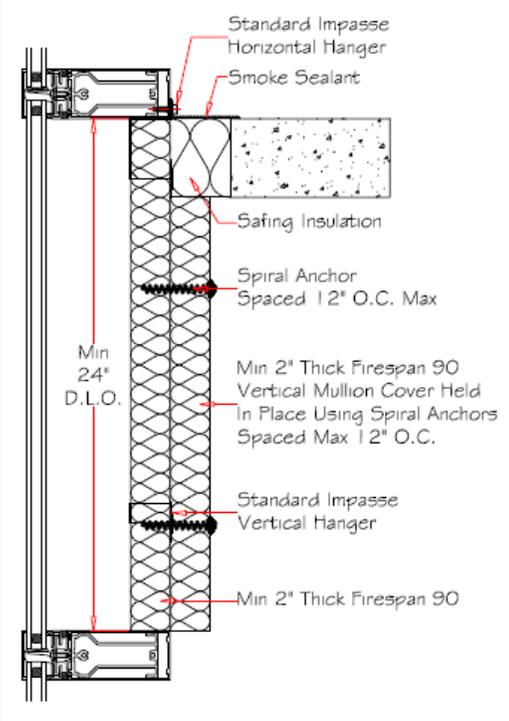
F Rating — 2 Hr

Integrity Ratings — 1-1/2 and 2 Hr  
(determined by spandrel height)

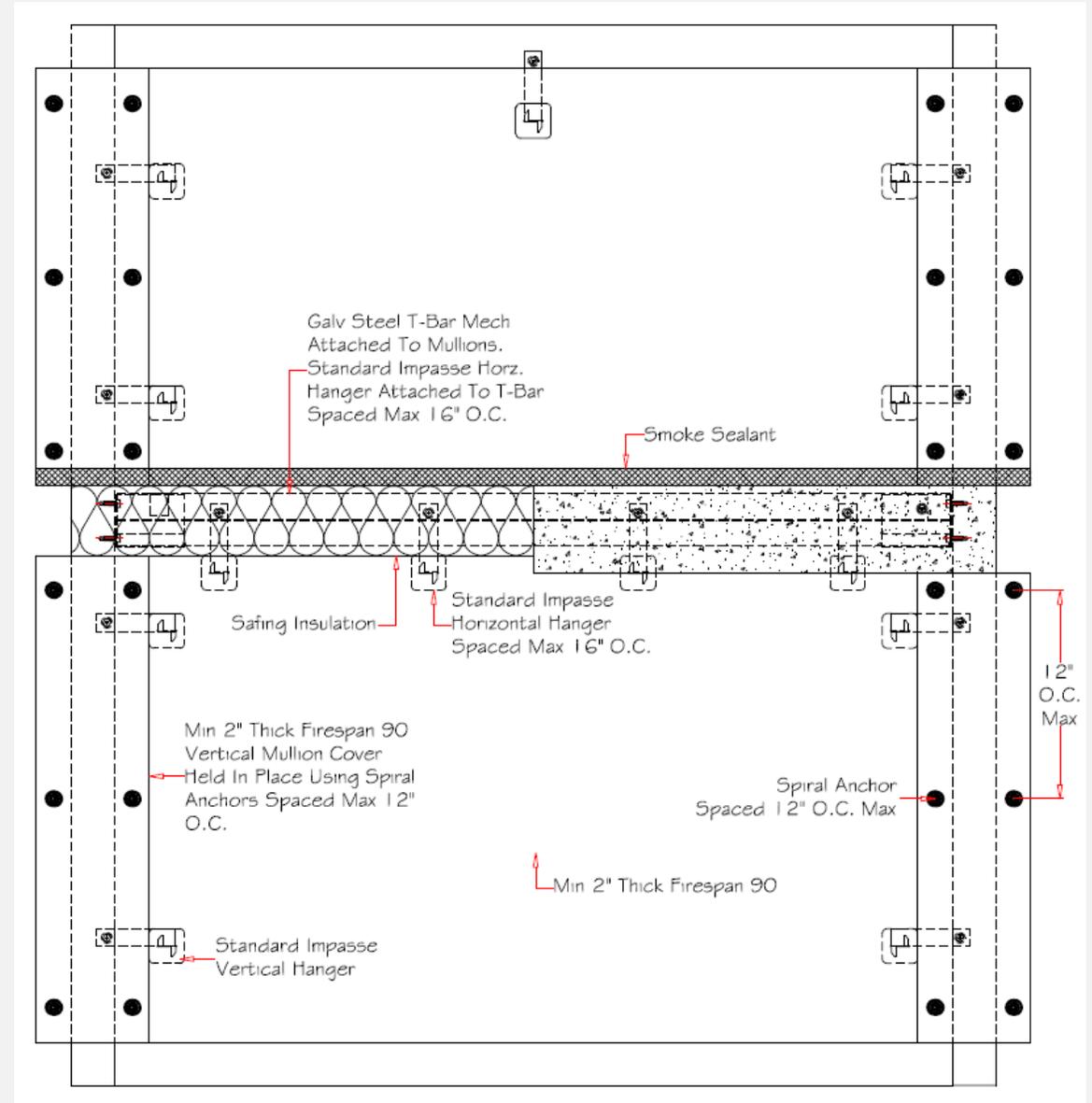
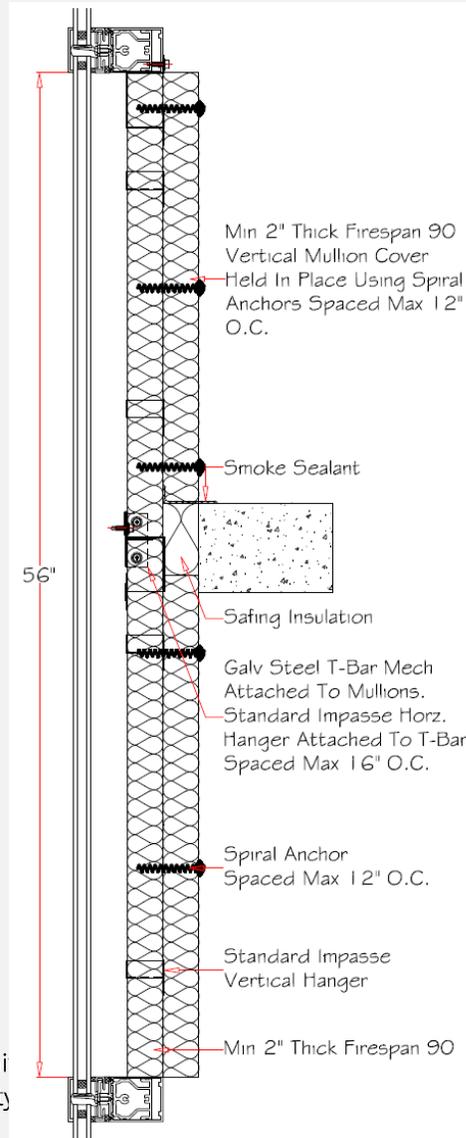
# Leap Frog



# Current Assemblies



# Current Assemblies



# Special Conditions

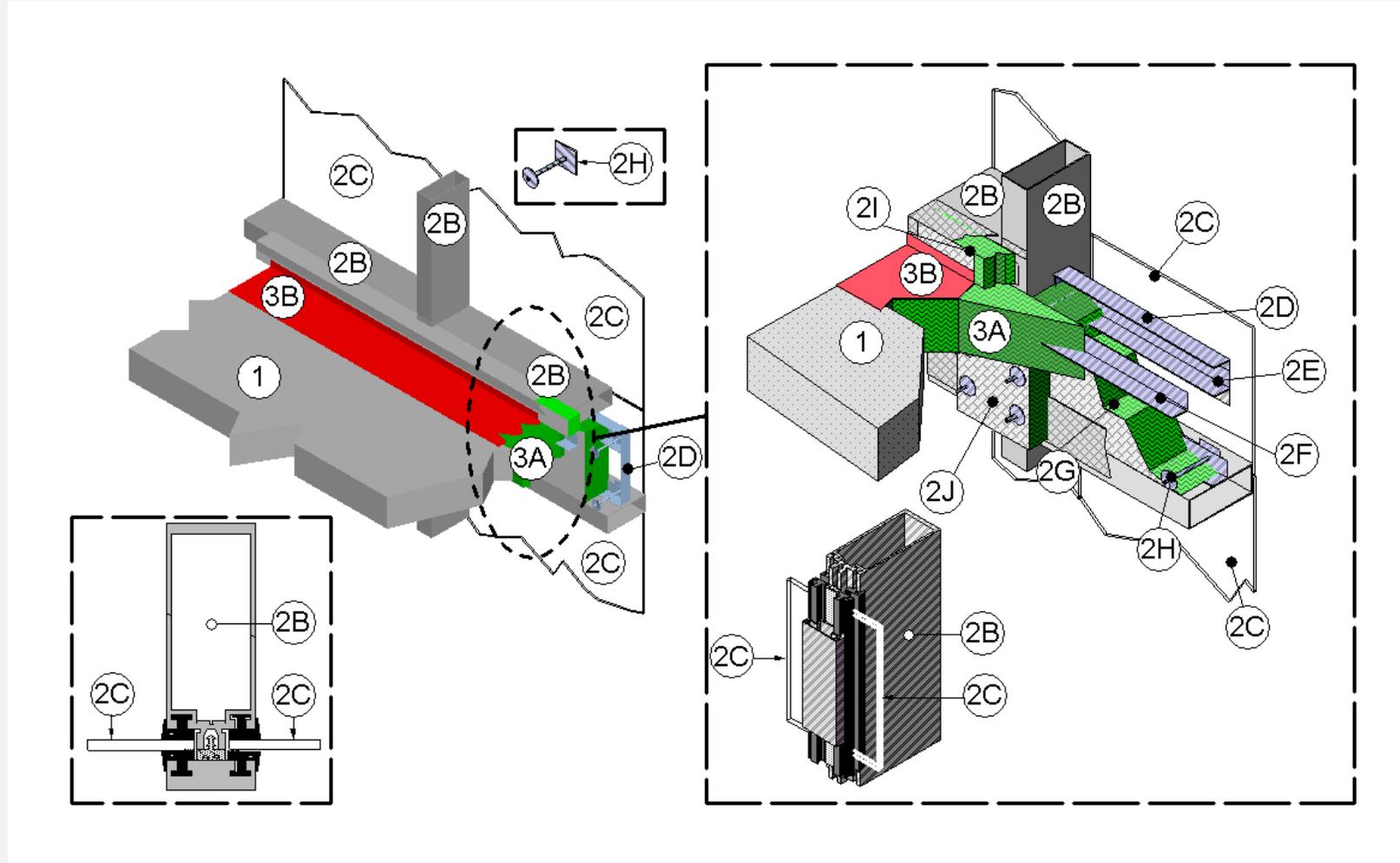
- **Short spandrel height**
- **No backer bar/reinforcement**
- **Back pans**
- **Wide spandrel**
- **Wide Safe-Off Area**
- **Geometry of spandrel wall**
- **Exposed curtain wall anchors at the floor line**
- **Combustible building materials**

# 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

# Short Spandrel Height



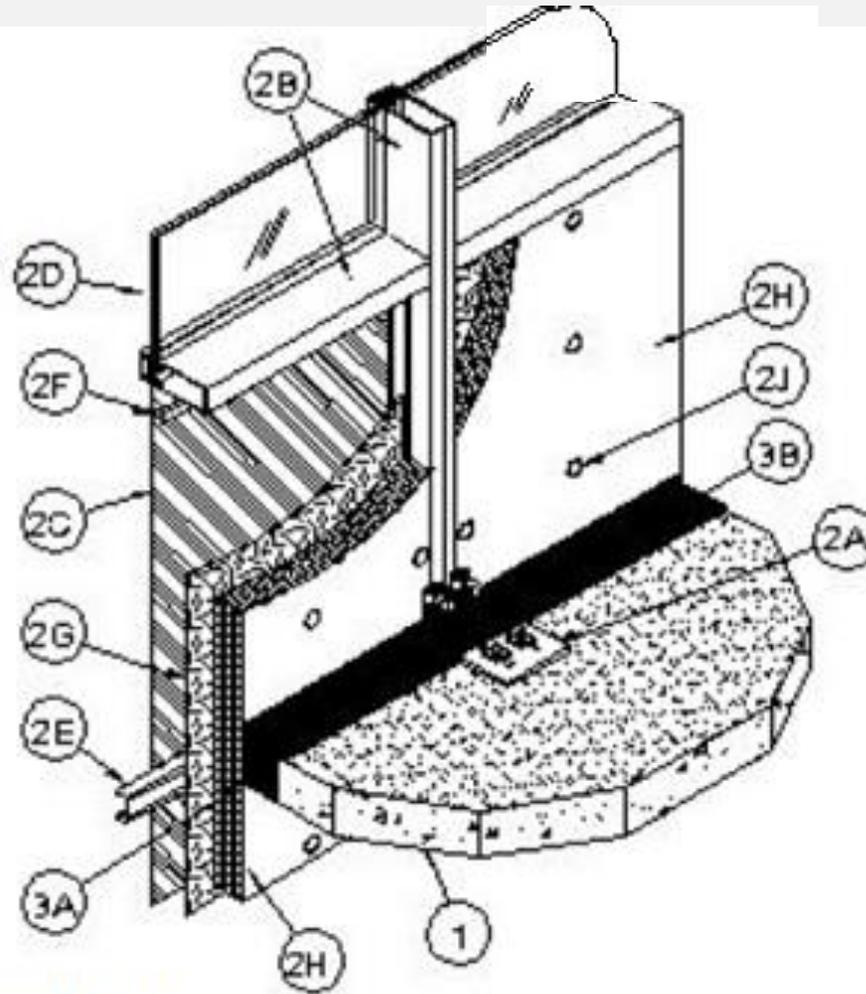
# No Backer Bar/Reinforcement

## Considerations

- Situations where there is no access to install backer reinforcement
- Conditions where window sill transom is in close proximity of top of floor slab
- Installation of continuous pieces of curtain wall insulation
- Curtain wall anchor bracket connection to vertical mullions limits the access for installation of backer reinforcement member

# Steel Back Pans

Basic Backpan  
with Spandrel  
Insulation on the  
Inside of the  
Backpan



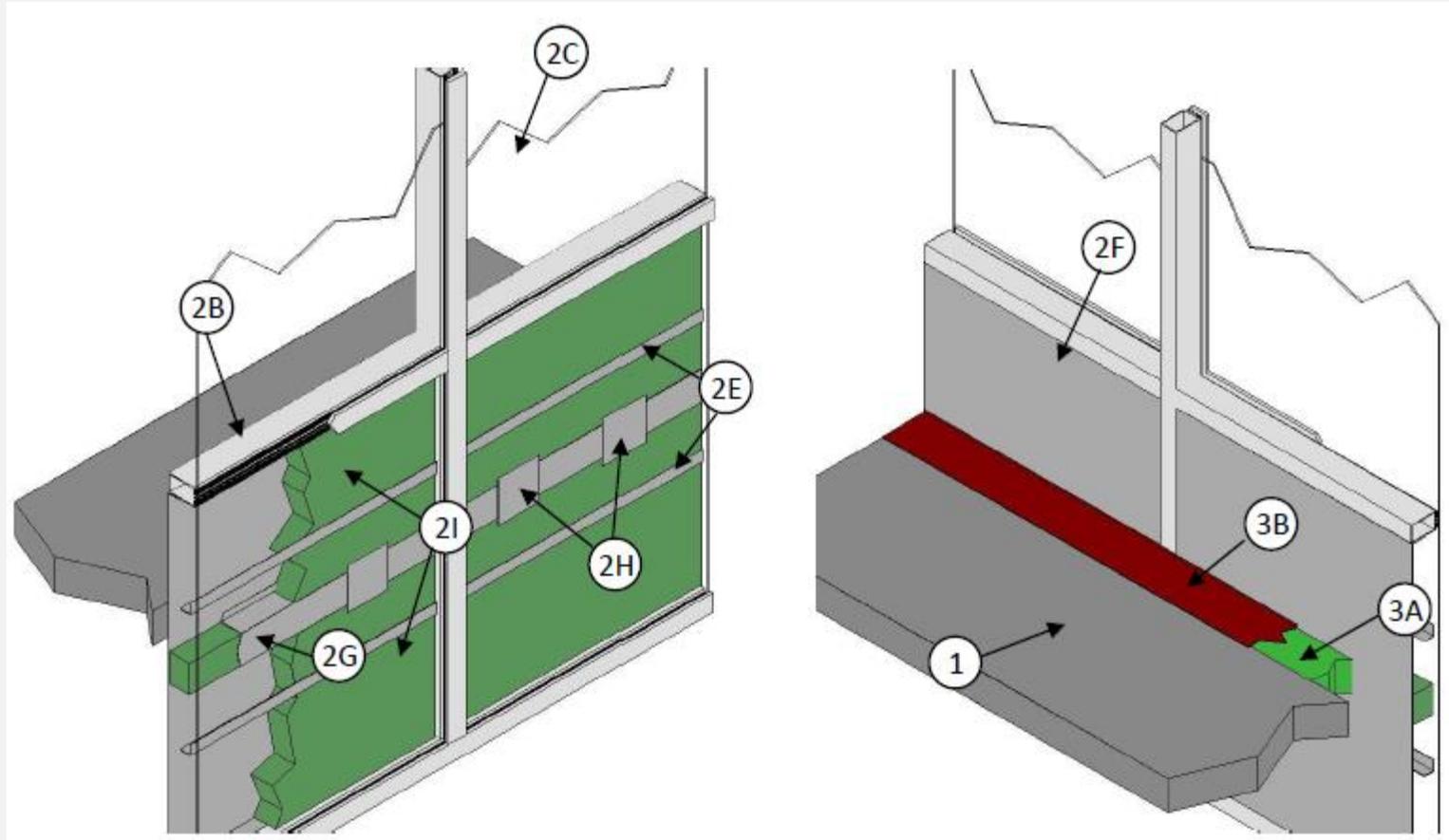
# Steel Back Pans



Steel Backpan  
Oil Can Effect

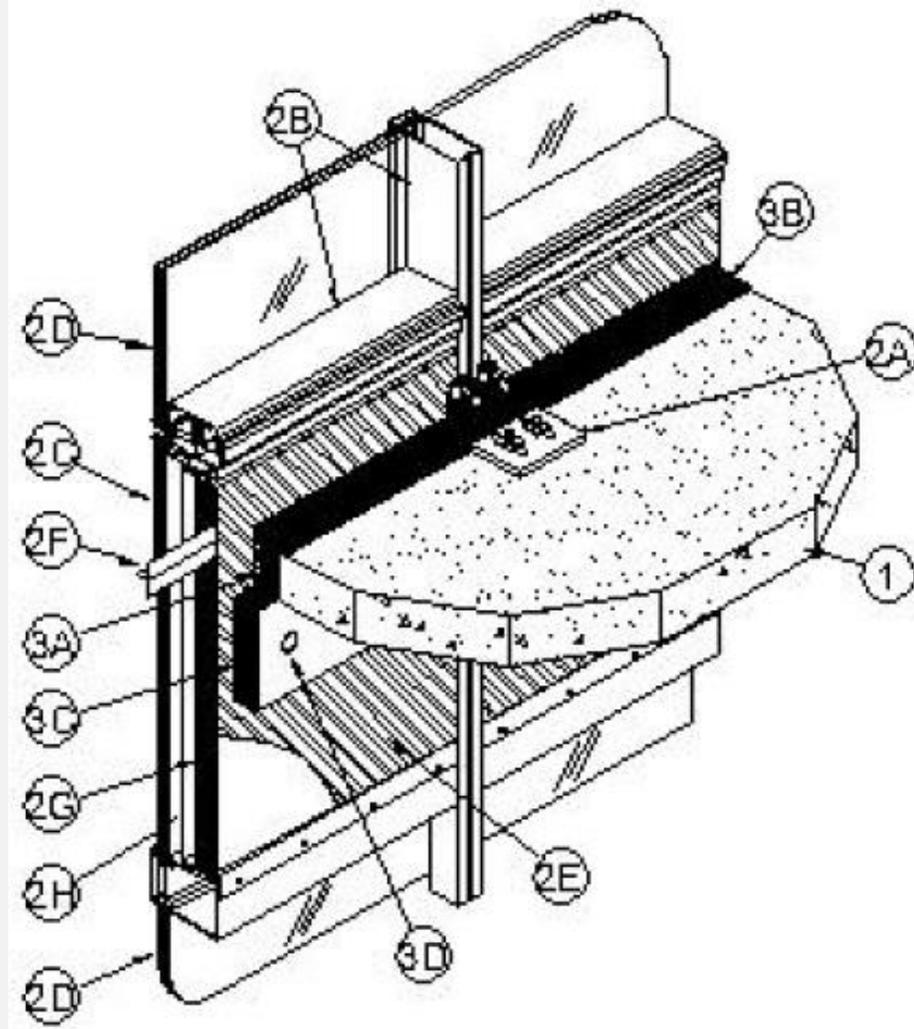
Perimeter Fire Barrier Education

# Steel Back Pans



# Steel Back Pans

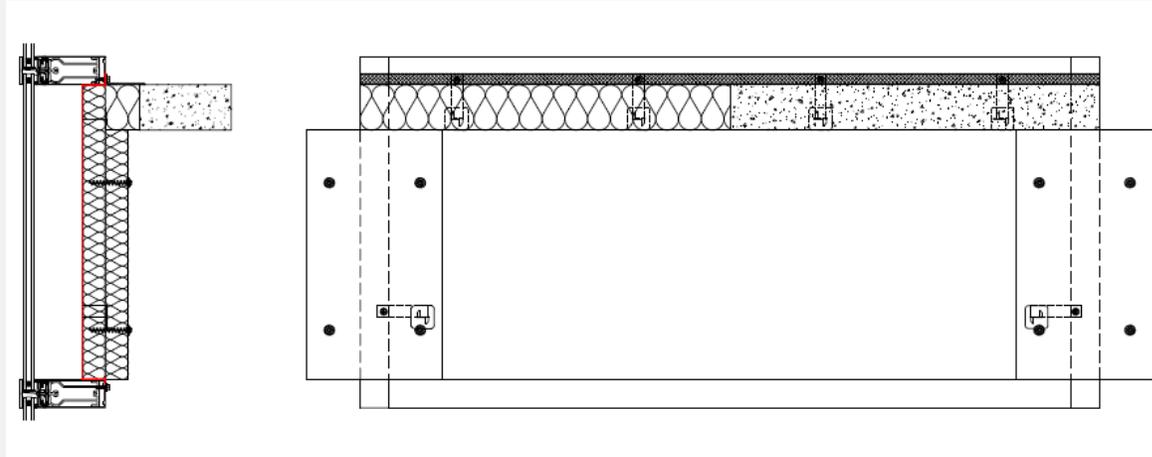
Backpan with  
Spandrel  
Insulation to  
the outside of  
the Backpan



# Steel Back Pans

## Considerations

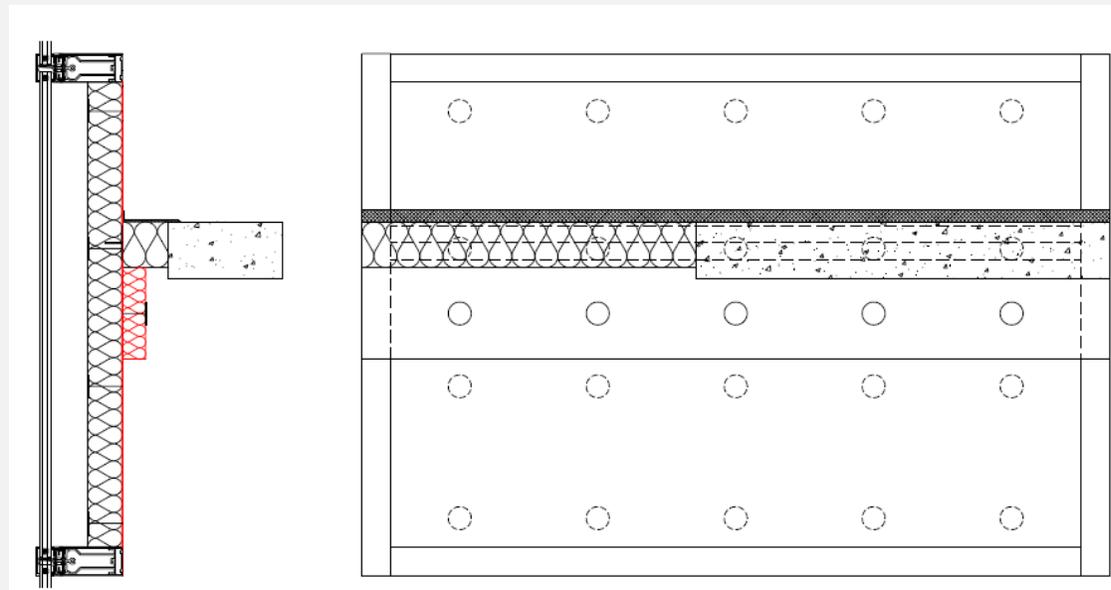
- Back Pan and/or Shadow Box on Front Side
  - Treat as if the back pan is not there
  - Complete perimeter fire containment is installed



# Steel Back Pans

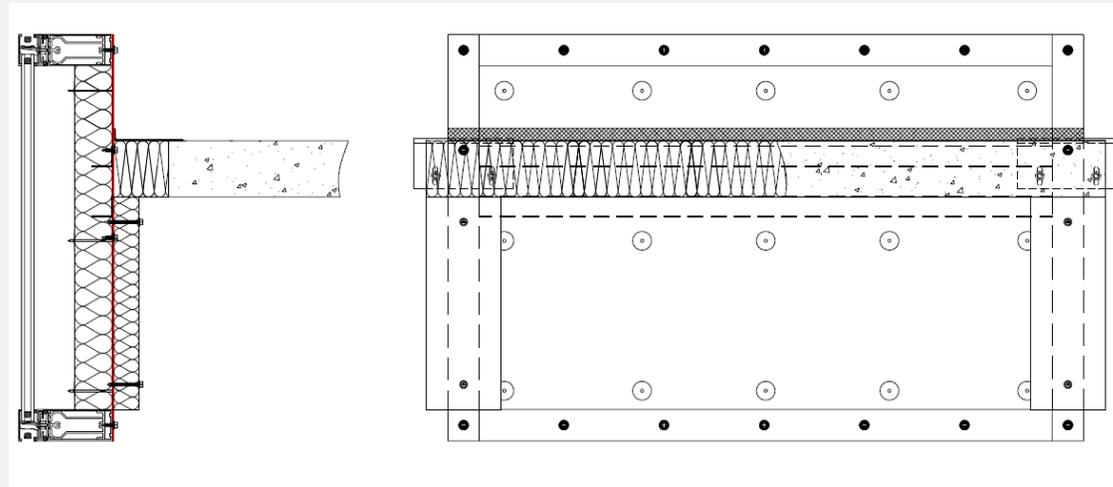
## Considerations

- Back Pan on Back Side
  - Most difficult configuration to hold together during fire testing
  - Increased reinforcement required to keep back pan in plane
  - Difficult to inspect
  - Mechanical attachment of spandrel insulation is a minimum of 12” on center across the entire



# Steel Back Pans

- Back Pan on Back Side
  - Newer systems are available that eliminate the need for the Safing shelf
  - Same principles are required for providing additional reinforcement at the safe-off line
    - Mechanical attachment of spandrel insulation is a minimum of 12" on center across the entire



# Wide Spandrel

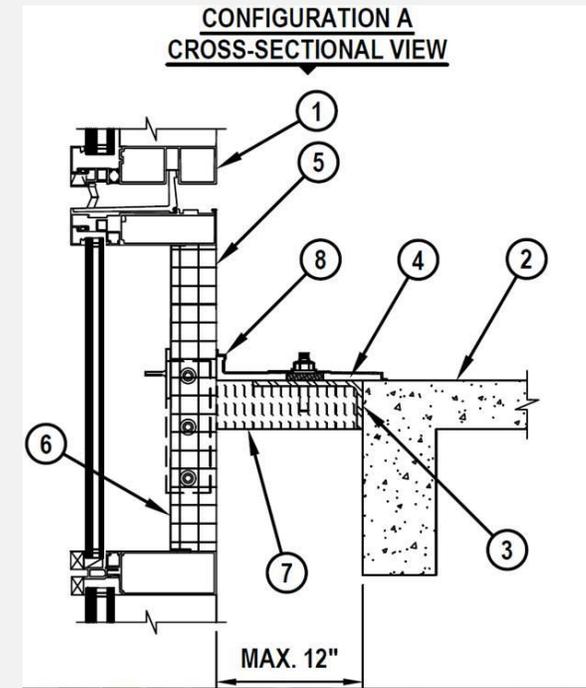
## Considerations

- No current method of evaluating
- Limitations of apparatus in ASTM E 2307
- Anything wider than 60” on center
  - Manufacturing limitations
- 98% of current systems do not allow for vertical seam
  - Only a few assemblies allow for a vertical seam
    - 4” thick or greater for curtain wall insulation
    - All hat channel designs with multiple horizontal steel structural members
    - Considerations of vertical seam:
      - Shrinkage
      - Allows for fire to pass through the Saming line
      - No framing member for mechanical attachment

# Wide Safe-Off Area

## Considerations

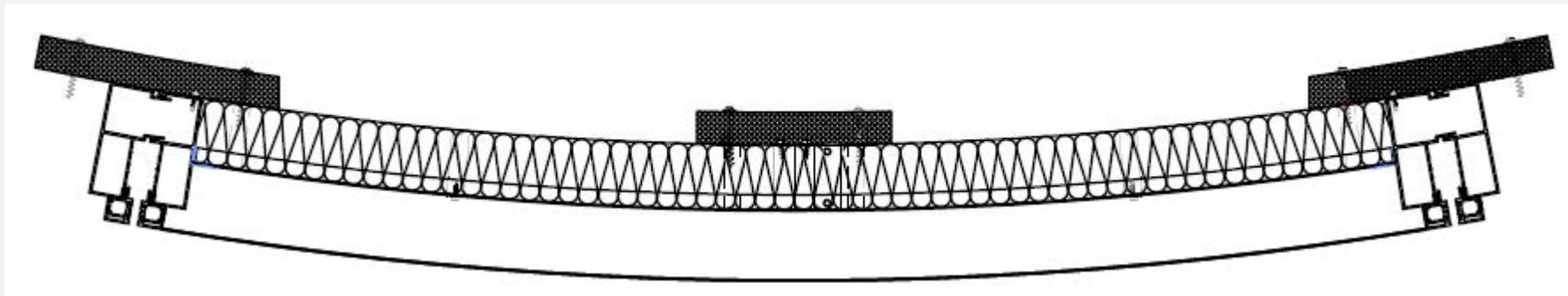
- Typical joint range is 2 to 6 inches wide
- Safing joints greater than 6 inches wide have difficulty keeping compression when unsupported over a wider span
  - Mineral wool insulation manufacturers should provide material recommendations based on the performance of Safing insulation under fire exposure
  - Recommendations are typically as follows:
    - Reference a tested system to ASTM E 2307 that evaluates wider Safe-off joints
    - Additional material thickness, mechanical support, or compression may be required where linear joint is wider than what is outlined in the respective listing



# Geometry of Spandrels - Curved

## Considerations

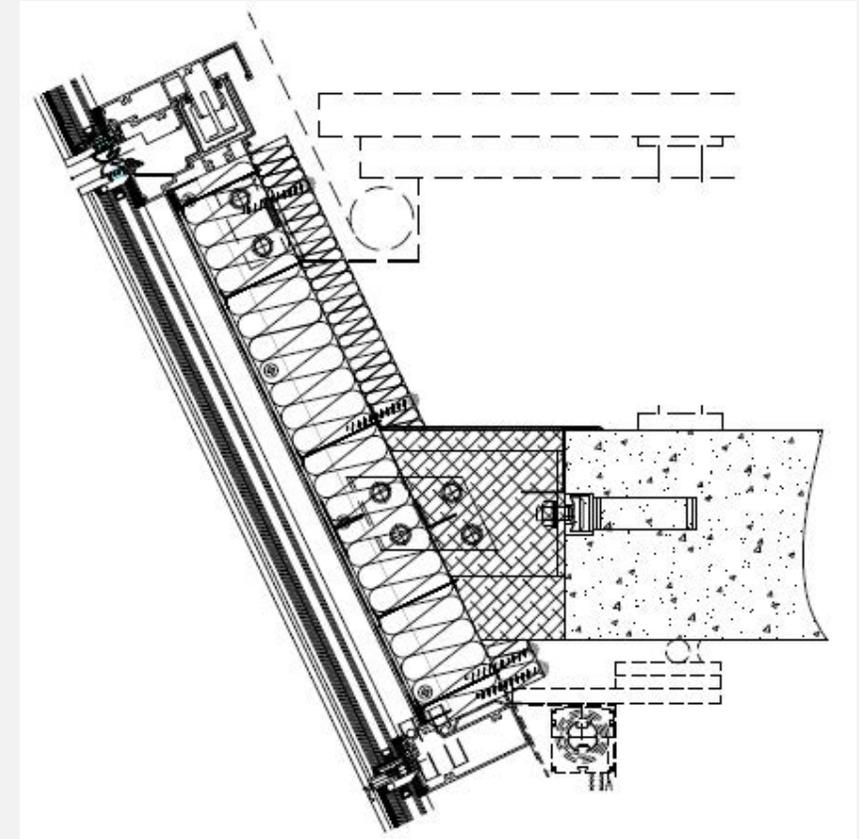
- No tested or listed assembly for curved curtain wall
- Conformance of spandrel insulation to the arc
  - Depends on degree of radius
- Limited mechanical attachment options
  - High cost custom mechanical fasteners required
- Custom support members
  - Radius backer reinforcement required in front of the spandrel insulation with same arc as the slab
  - Accommodate where there are varied joint width between slab and spandrel insulation



# Geometry of Spandrels - Angular

## Considerations

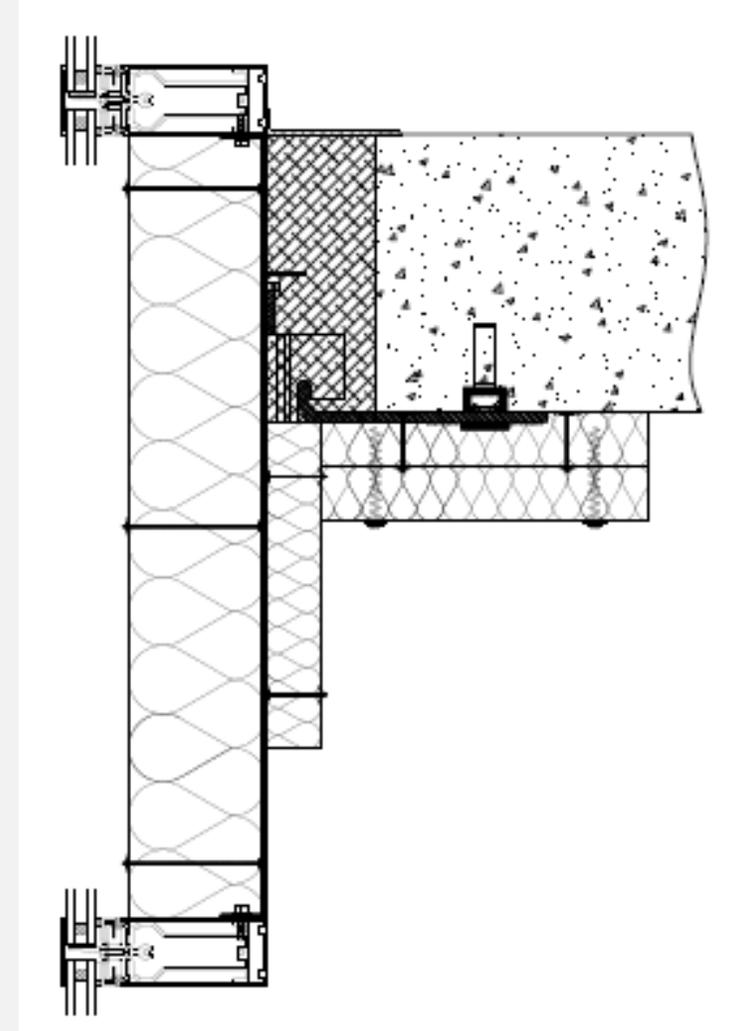
- No tested or listed assembly for angular curtain wall
- Limited mechanical attachment options
  - High cost custom mechanical fasteners required
- Custom support members
  - Securing the Safing insulation in the linear joint
  - Compression percentage of Safing
  - Flame impingement – more fire exposure when angling out
- Varying linear joint widths creates difficulty in achieving Safing compression requirements
  - May require mechanical attachment to keep from dislodging over lifetime of the building



# Exposed Anchors

## Considerations

- UL Fire Resistance Directory states: “Curtain wall spandrel panel dead load anchors located below the concrete floor should be protected from direct fire exposure.”
  - Unprotected curtain wall anchors exposed below the floor line create a higher probability of complete system failure
- UL has created a new category (XHDI) for perimeter fire barrier accessories, which includes an anchor protection component



# Combustible Building Materials

## Requirements for Exterior Walls Containing Combustible Materials in the IBC

Material	Code Section
Foam plastic insulation	2603.5
Metal composite materials (MCM)	1407.10
Fiber-reinforced polymers	2612.6
High-pressure laminates (HPL)	1409.10
Water-resistive barrier (WRB)	1403.5

# Combustible Building Materials

## Considerations

- Provide additional fuel load under fire conditions
- Untested exterior facade panels
  - Unknown panel performance when exposed to ASTM E 2307 conditions
  - Should be NFPA 285 compliant, at the very least
  - Should be attached independent from the perimeter fire barrier system
  - Should not provide structural support of the perimeter fire barrier system
- Other untested building materials
  - Materials with known fuel sources should not be installed to a perimeter fire barrier assemblies to achieve targeted thermal values



# International Firestop Council



# Engineering Judgments



## **RECOMMENDED IFC GUIDELINES FOR EVALUATING FIRESTOP SYSTEMS IN ENGINEERING JUDGEMENTS (EJ's)**

### **PERIMETER FIRE BARRIER SYSTEMS**

The International Firestop Council, IFC, is a not-for-profit association of manufacturers and users of fire protective materials and systems. IFC's mission is to promote the technology of fire containment in modern building construction through research, education programs, and the development of safety standards and code provisions. These recommended guidelines are presented as part of the IFC's educational information program. They are for informational and educational purposes.

#### THE PREMISE OF FIRESTOP SYSTEMS

Perimeter Fire Barrier systems protect against the passage of fire, hot gasses and toxic smoke through the void between the floor slab edge and the curtain wall.

These systems are required by building codes to be tested and rated as part of an assembly in accordance with ASTM E 2307, Standard Test Method for Determining Fire Resistance of Perimeter Fire Barrier Systems Using Intermediate-Scale, Multi-Story Test Apparatus, or with an approved material capable of preventing the passage of flame and hot gases sufficient to ignite cotton waste when subject to ASTM E119 time-temperature conditions under a positive pressure differential of 0.01 inch water column.

All elements of a tested and rated perimeter fire barrier system, including the assembly into which the system is installed, constitute a specific and inseparable engineered unit that must be utilized as such. These systems (designs) are tested and listed by independent testing agencies and the specific elements of each design become a part of the listing and a necessity for the performance of the system.

# IFC Engineering Guidelines

## Perimeter Fire Barrier system engineering judgments should:

1. Not be used in lieu of tested systems when tested systems are available.
2. Be issued only by firestop manufacturer's qualified technical personnel or, in concert with the manufacturer, by a knowledgeable registered Professional Engineer, or Fire Protection Engineer, or an independent testing agency that provides listing services for the systems.
3. Be based upon interpolation of previously tested perimeter fire barrier systems that are either sufficiently similar in nature or clearly bracket the conditions upon which the judgment is to be given.

Additional knowledge and technical interpretations based upon:

accepted engineering principals

fire science and fire testing guidelines

(e.g. ASTM E 2032 – Standard Guide for Extension of Data from Fire Endurance Tests)

# IFC Engineering Guidelines

## Perimeter Fire Barrier system engineering judgments should:

4. ...It is important to understand that although it is the joint between the slab edge and curtain wall that is evaluated during testing, **the surrounding construction components** and insulation of the system is also important in insuring acceptable joint performance.
5. Be limited **only to the specific conditions and configurations** upon which the engineering judgment was rendered...
6. Be accepted **only for a single specific job** and location and should not be transferred to any other job or location without a thorough review of all aspects of the next job or location's circumstances.

# Questions?



Thank you!