



Managing Vertical Fire Spread in Multi-Story Buildings Through Effective Perimeter Fire Barrier Systems

March 21, 2018

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Agenda

- 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?



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 29th and 30th floors

Fire Containment

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



- Fire contained 12th to 16th floors (of 62 floors)
- Fire extended to floors above primarily via outer walls

Development of Perimeter Fire Containment

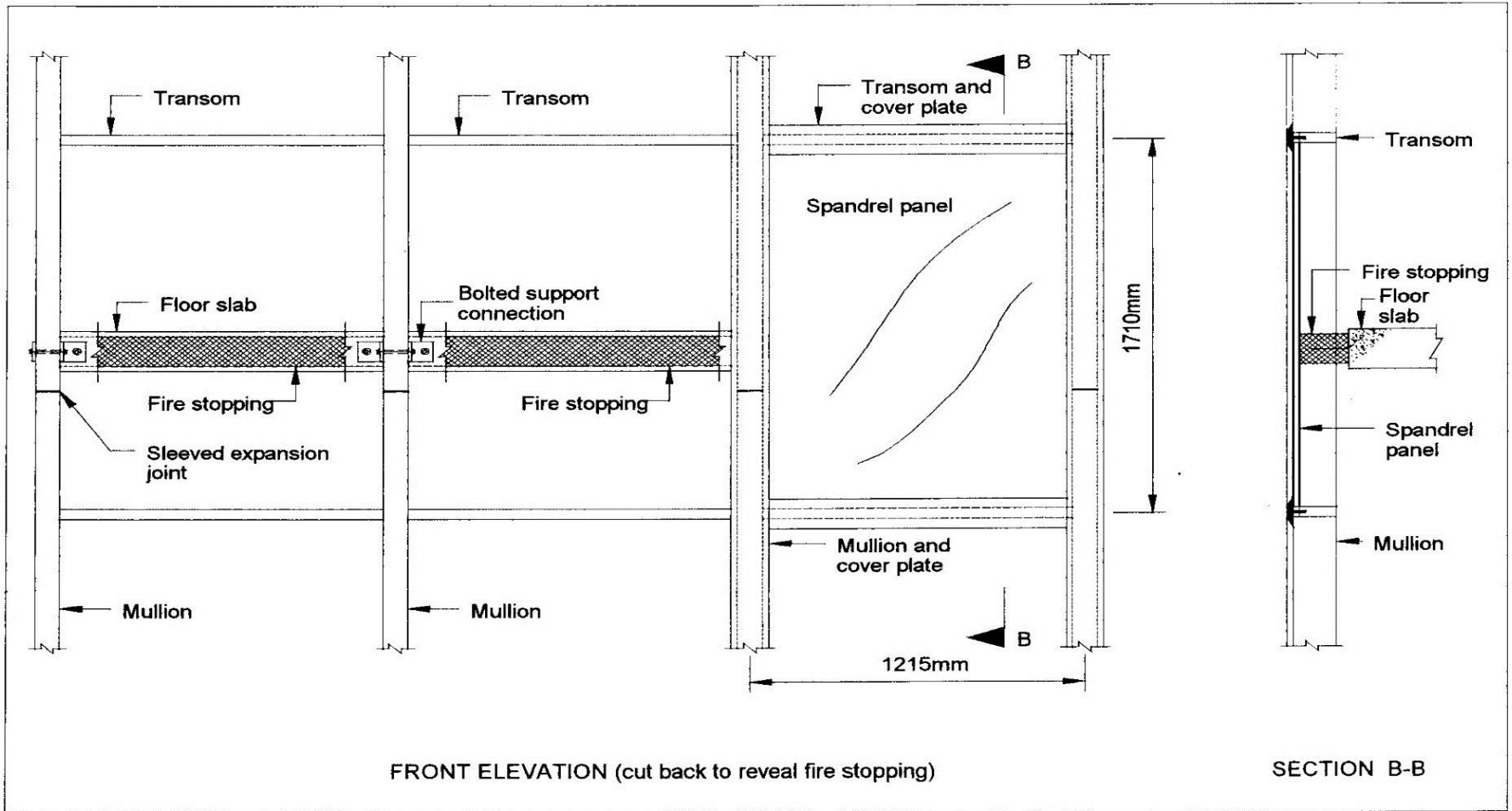
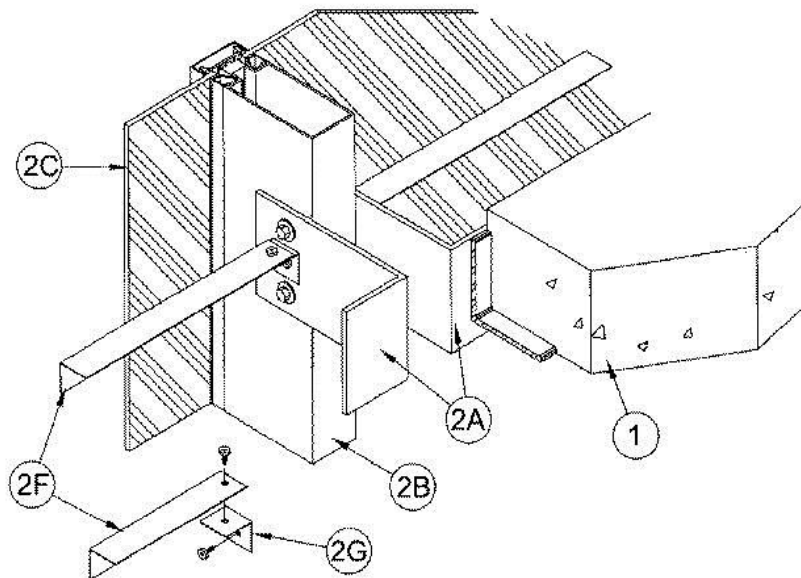
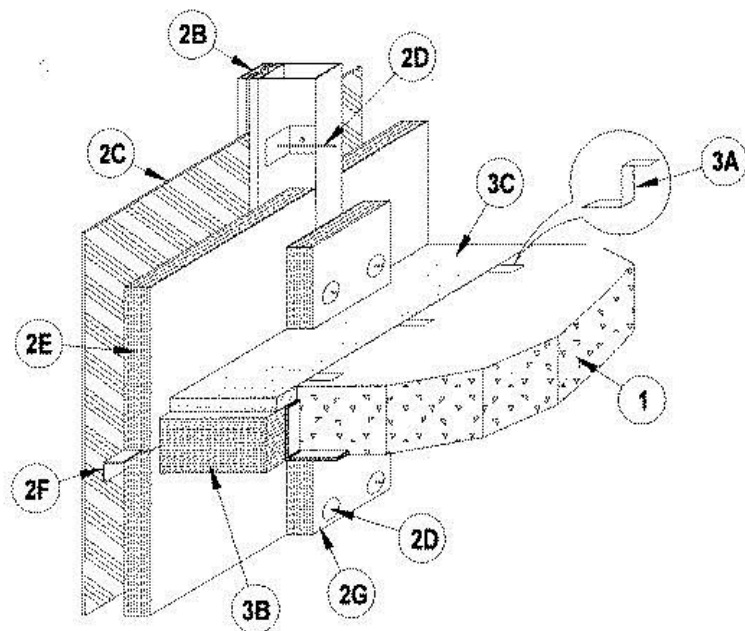


Figure 1 - Typical curtain wall system panel

Development of Perimeter Fire Containment



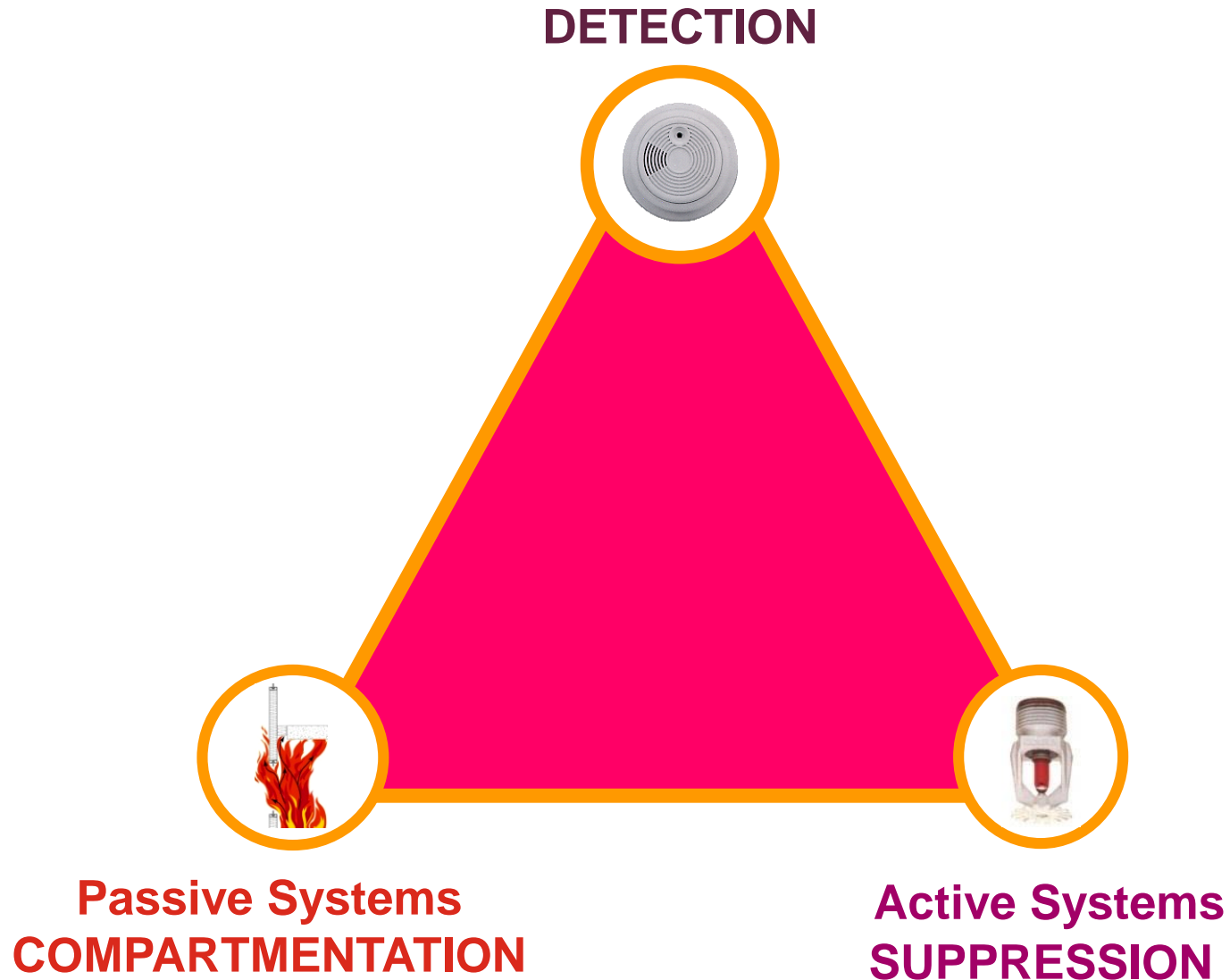
**Underwriters
Laboratories**



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

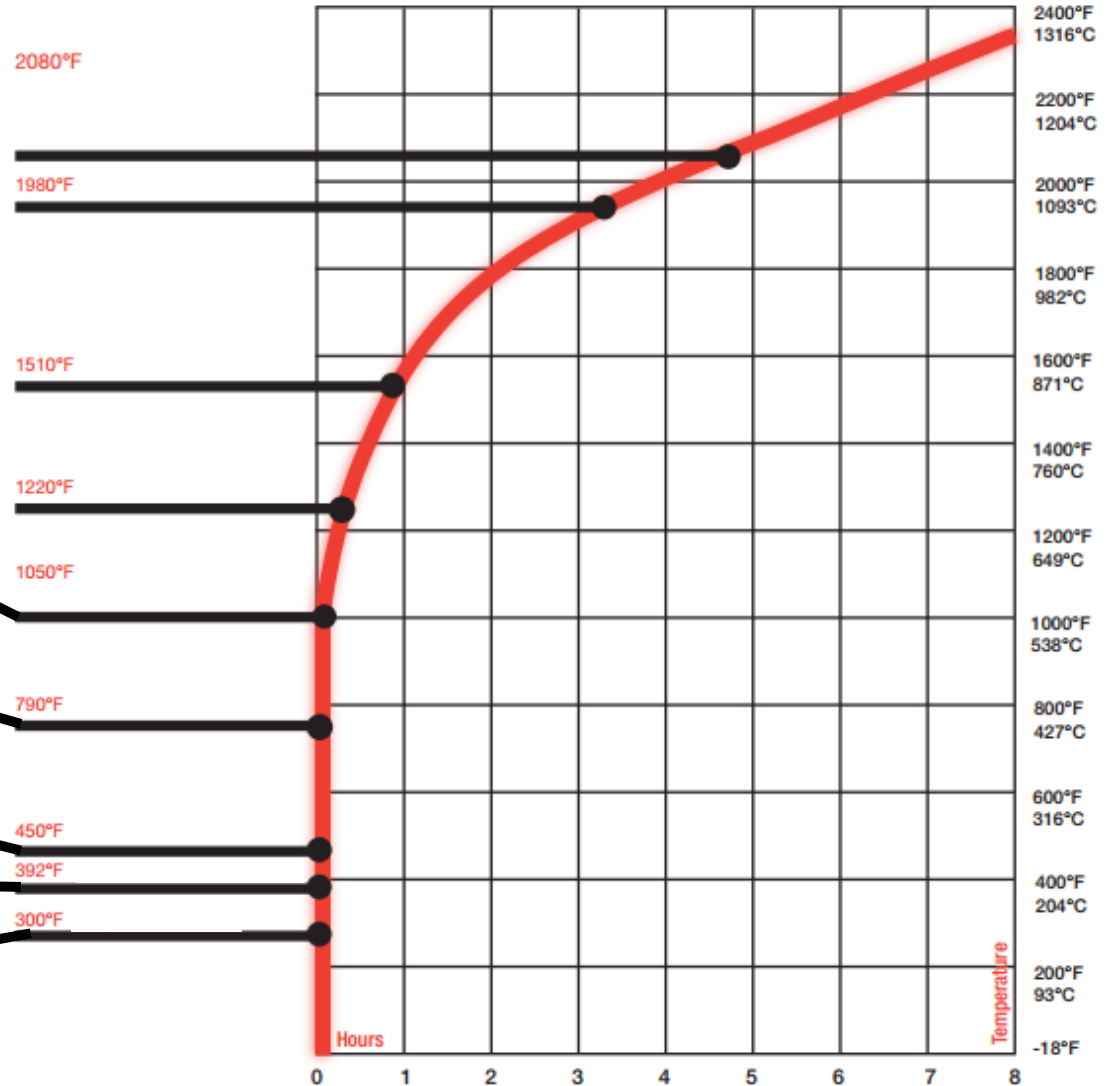
1050° F
Glass-fiber
insulation melts.

790° F
Zinc melts.

450° F
Cellulose pyrolyzes.

392° F
Spray Foam flash point.

300° F
Rigid foam melts.



(1) Not for service operation at this temperature. Refer to the appropriate Thermalfiber 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

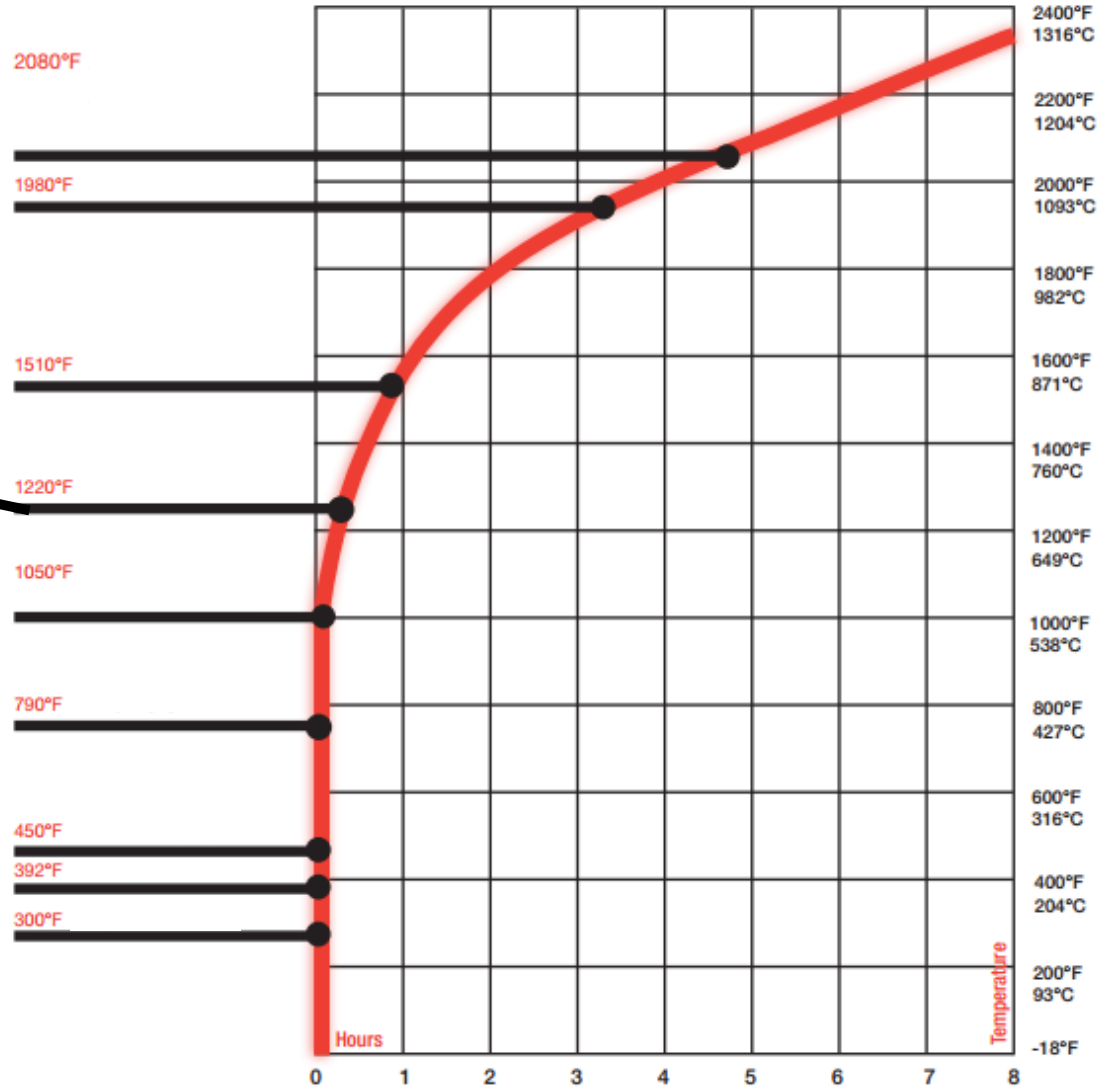


ASTM E 119 Temperature Curve

9 minutes

1220° F

Aluminum melts.



(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

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**

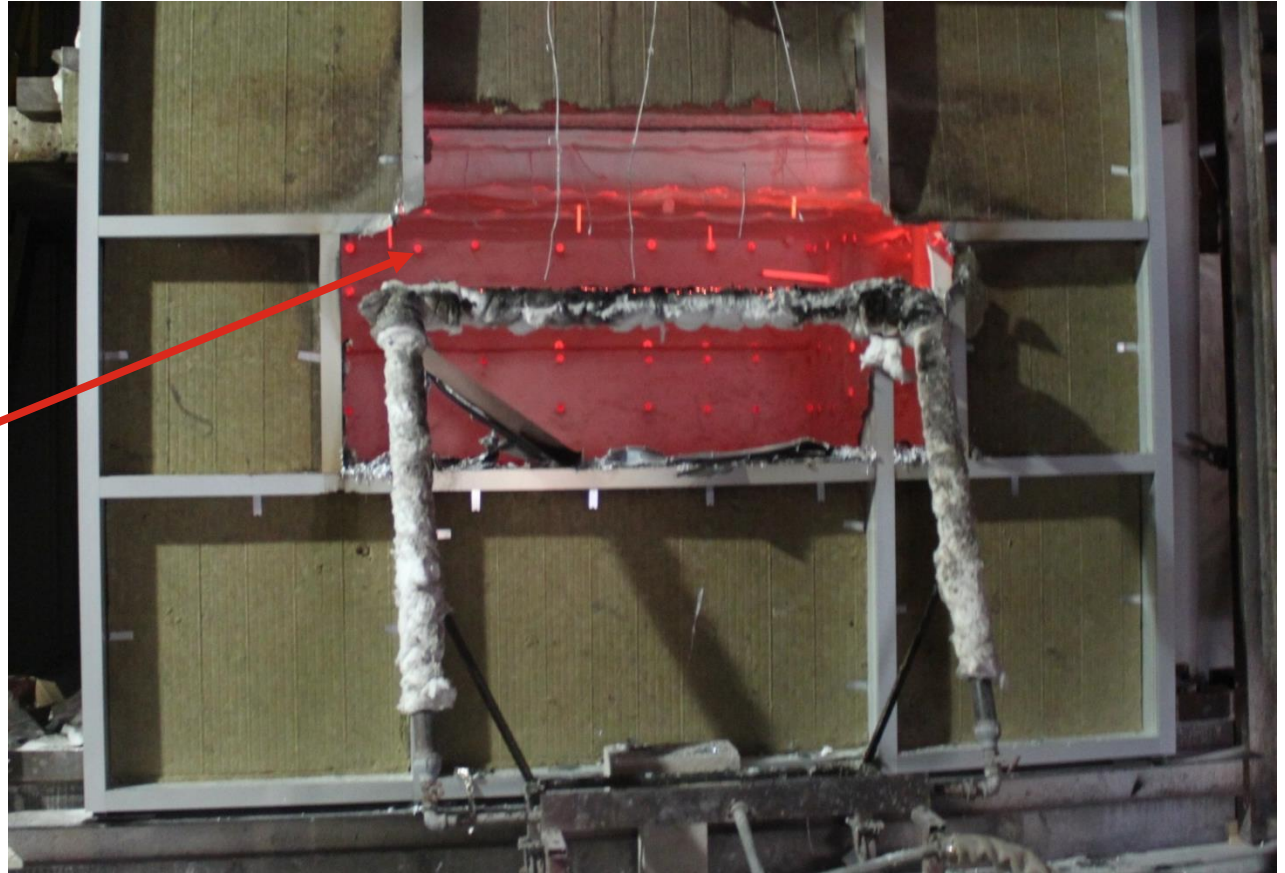
Transom
bending down
11 min. into test



Fire Performance

Mullions and Transoms after exposure to fire test

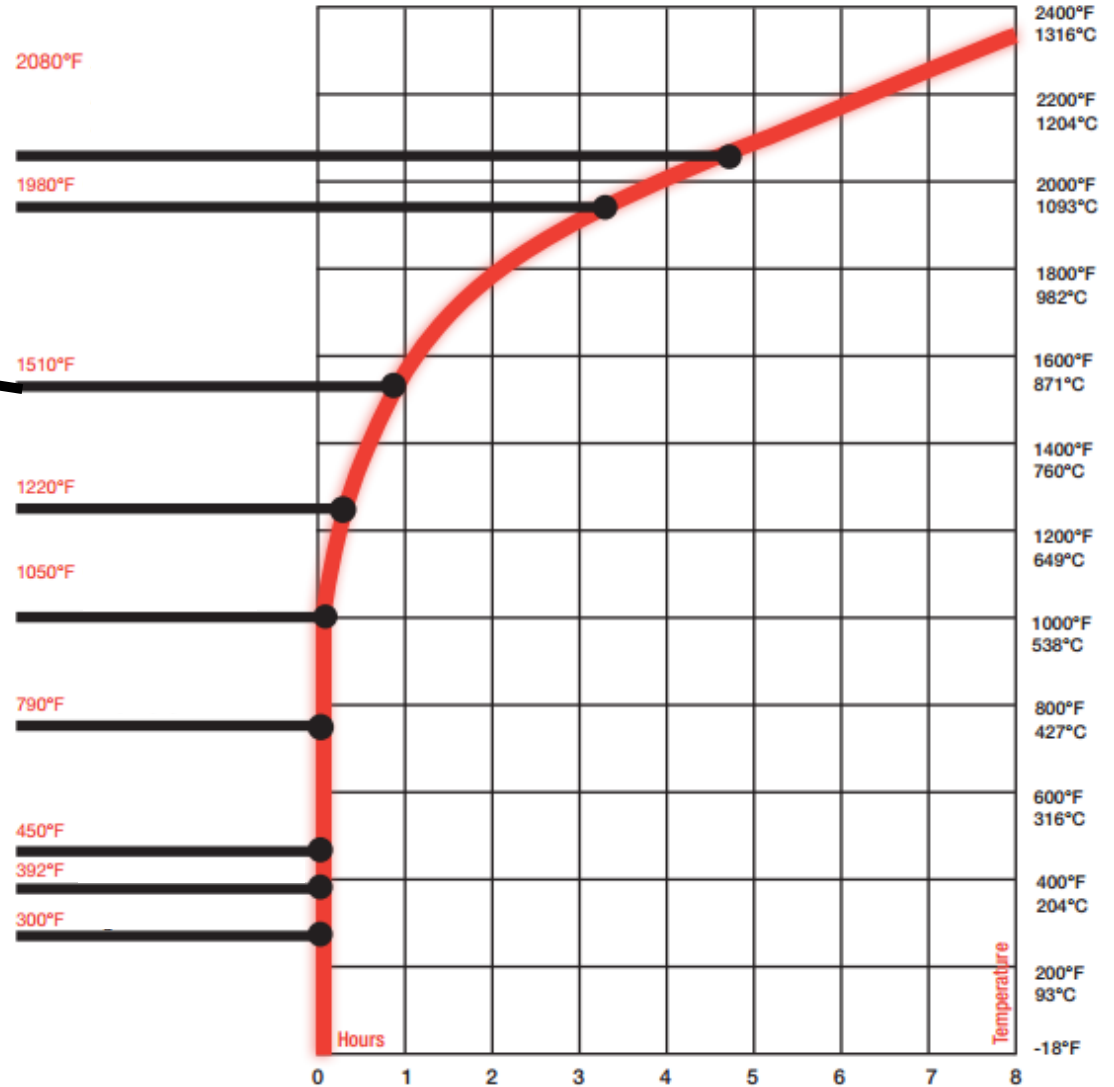
Complete loss of horizontal transom and vertical mullions



ASTM E 119 Temperature Curve

25 minutes

1510° F
Plate glass melts.



(1) Not for service operation at this temperature. Refer to the appropriate Thermalbar 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

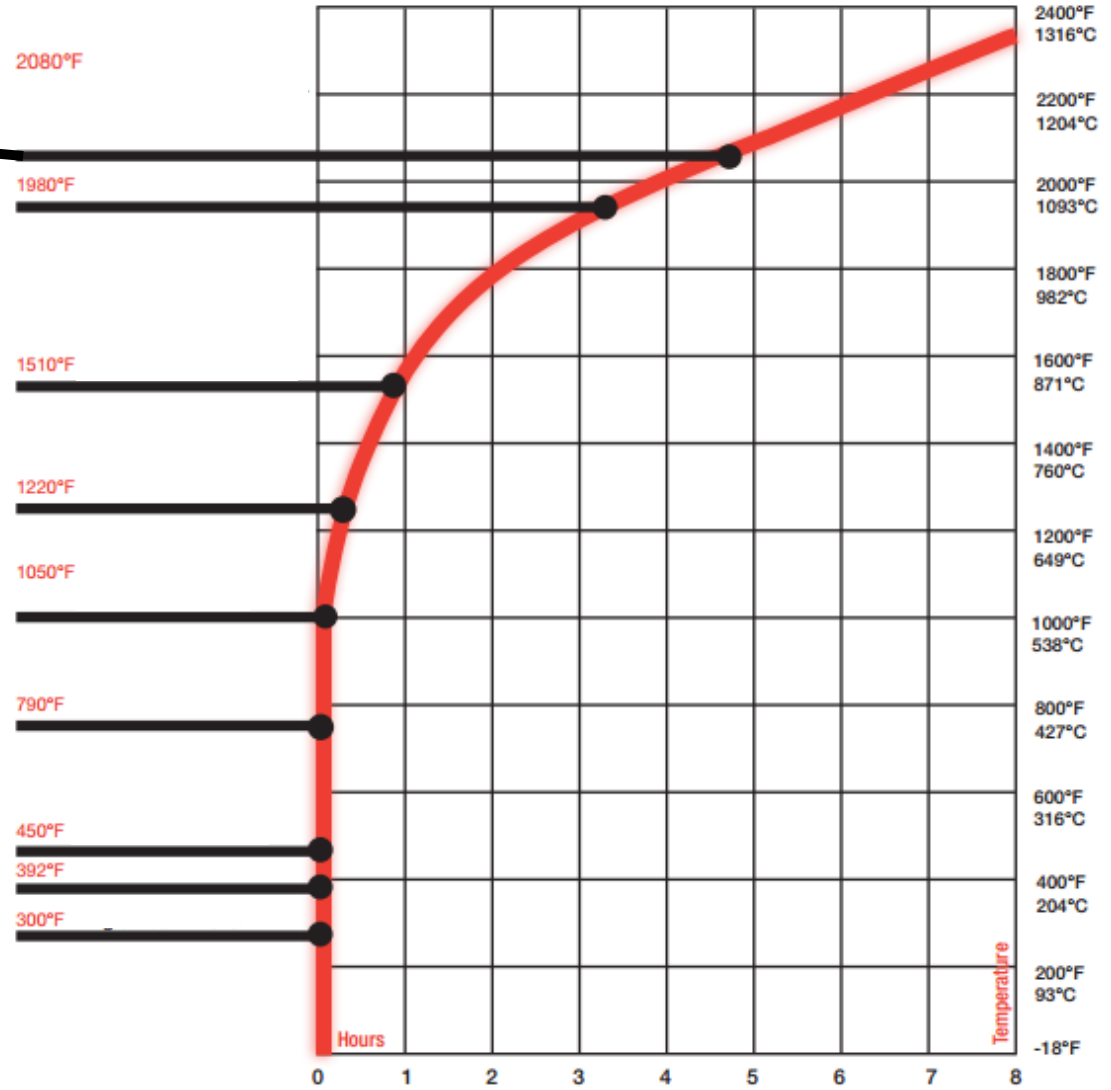


ASTM E 119 Temperature Curve

5 hours +

2080° F

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

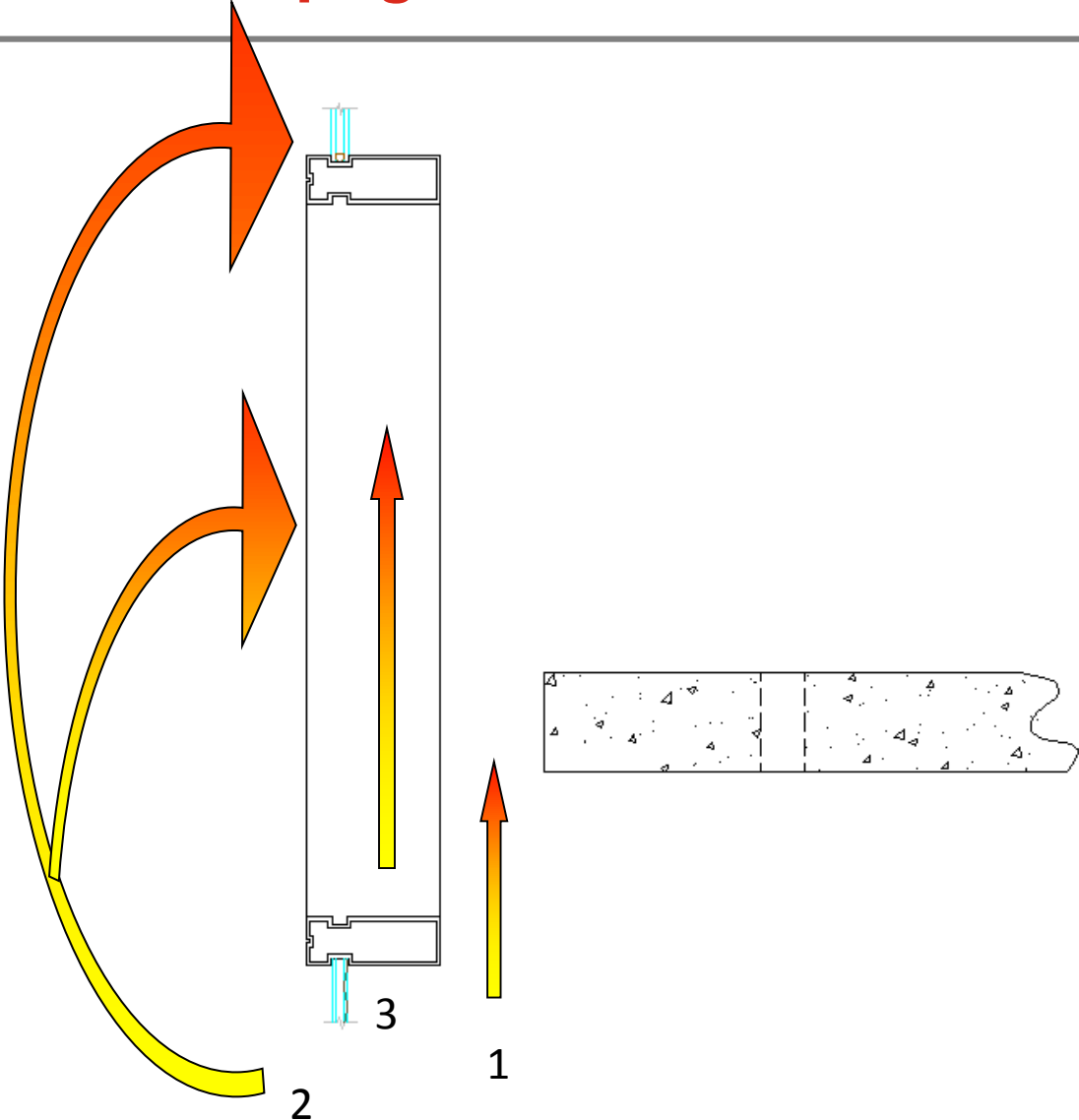


(1) Not for service operation at this temperature. Refer to the appropriate Thermafiber Insulation literature which states recommended maximum service temperature limits of individual products.
Time-temperature curve from "Standard of Methods of Fire Tests of Building Constructions and Materials," (ASTM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

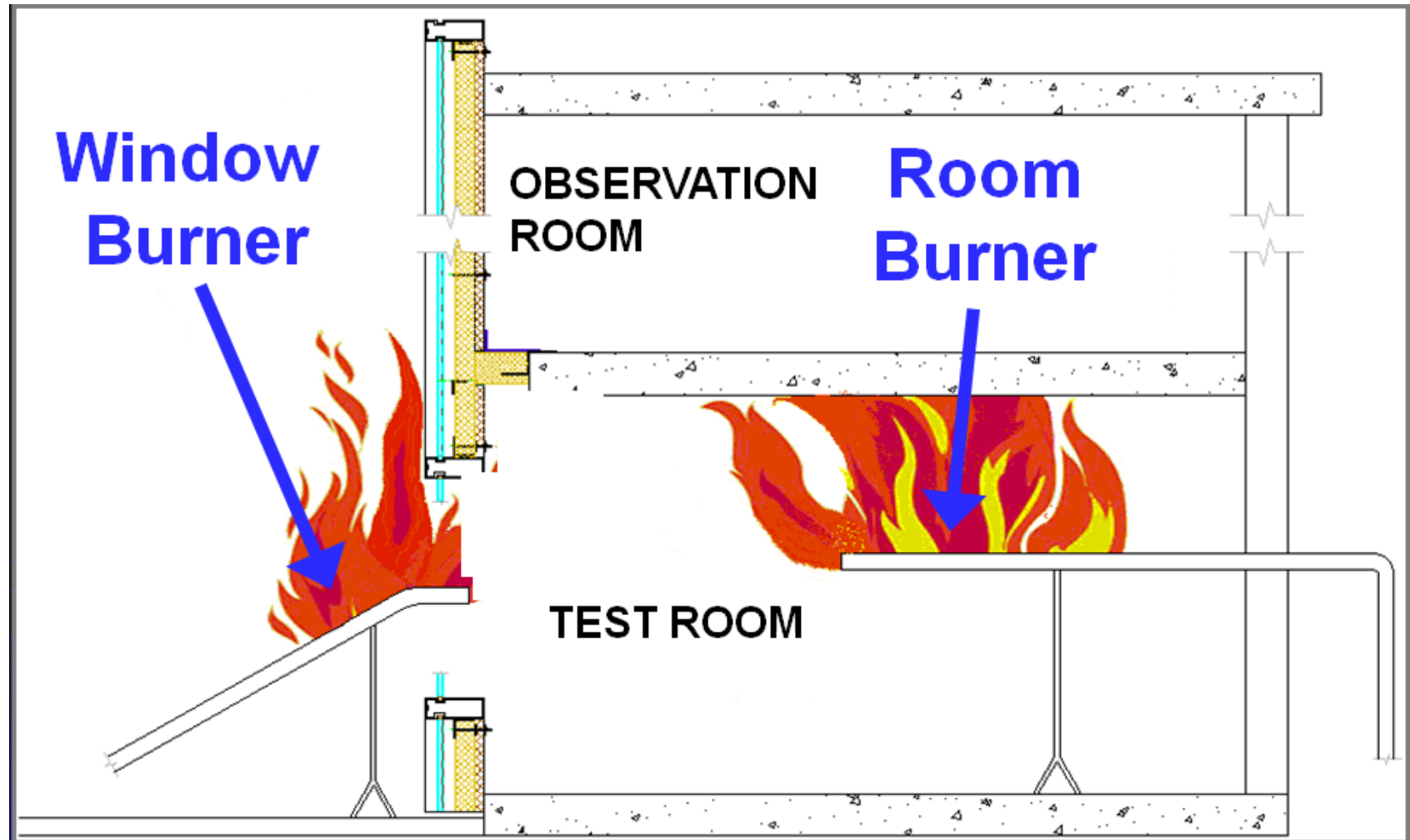
Paths of Fire Propagation



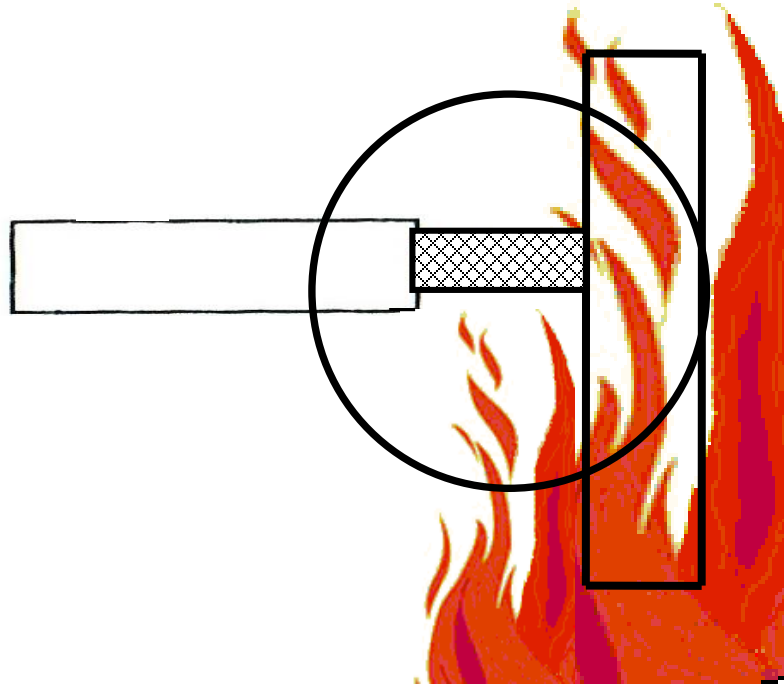
Paths of Fire Propagation



ASTM E 2307



ASTM E 2307



ASTM E 2307



ASTM E 2307 – Result



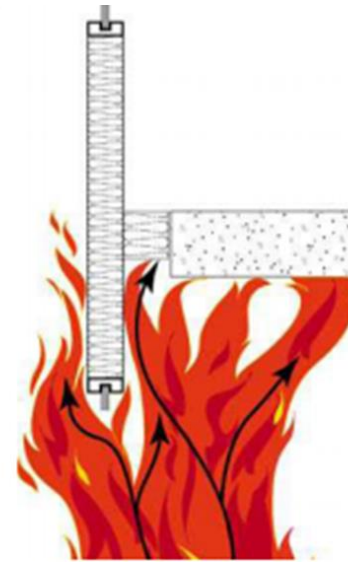
Perimeter Fire Containment



How is a fire like this contained?



Unprotected Perimeter Joint

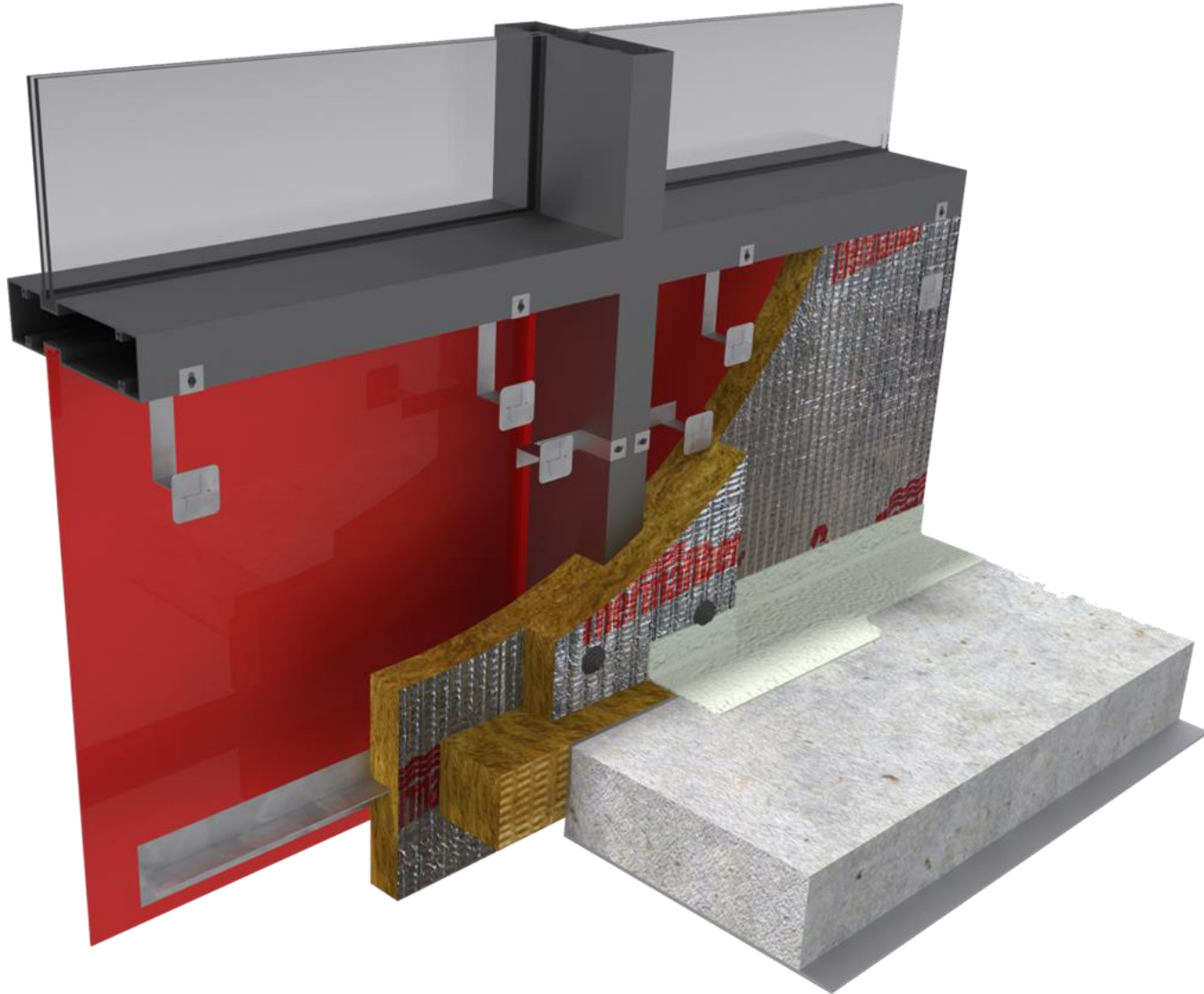


*Protected with a Perimeter
Fire Containment System*

Perimeter Fire Containment

6 Basic Components of a Listed Perimeter Fire Containment Assembly

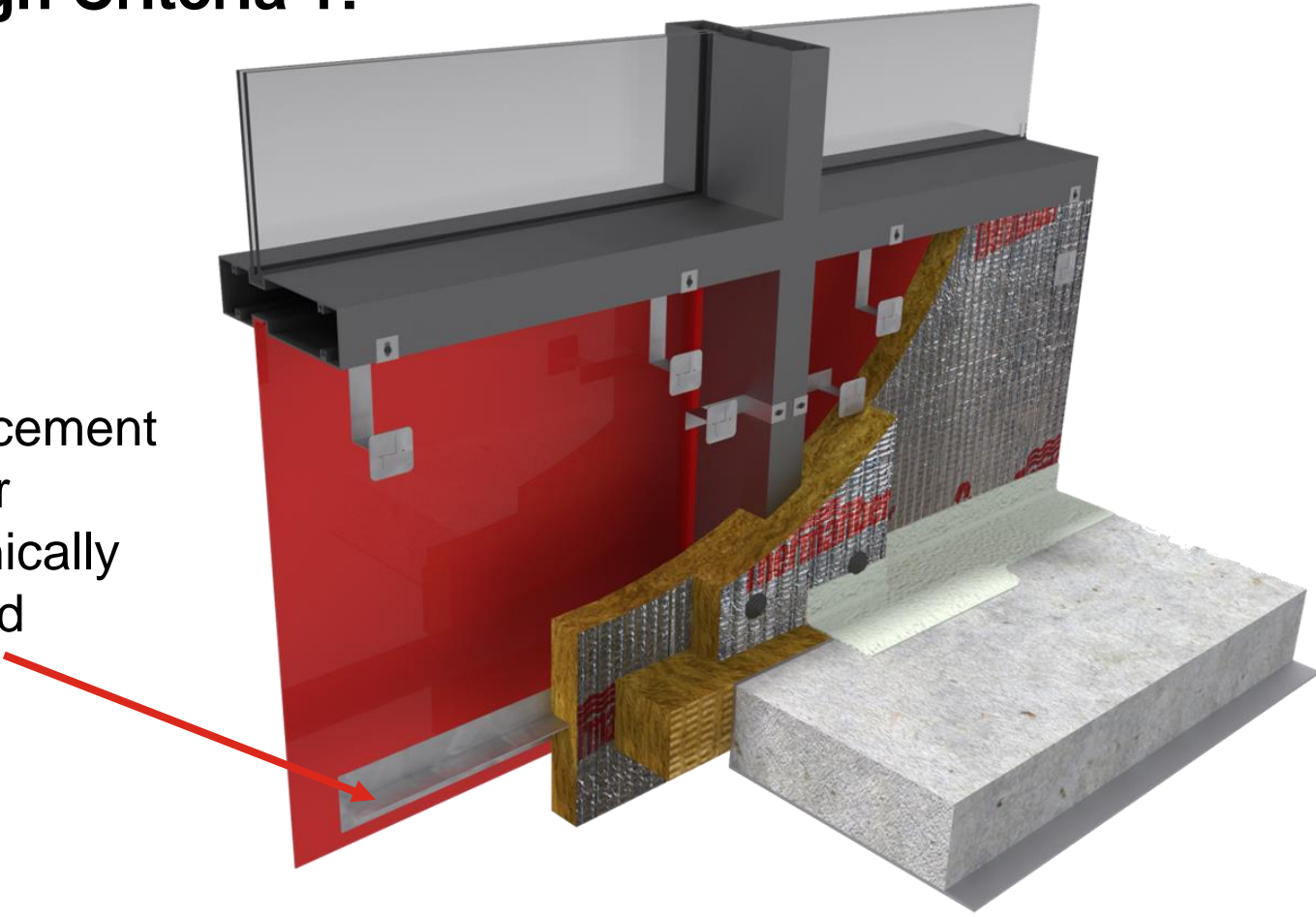
Perimeter Fire Containment



Perimeter Fire Containment

Design Criteria 1:

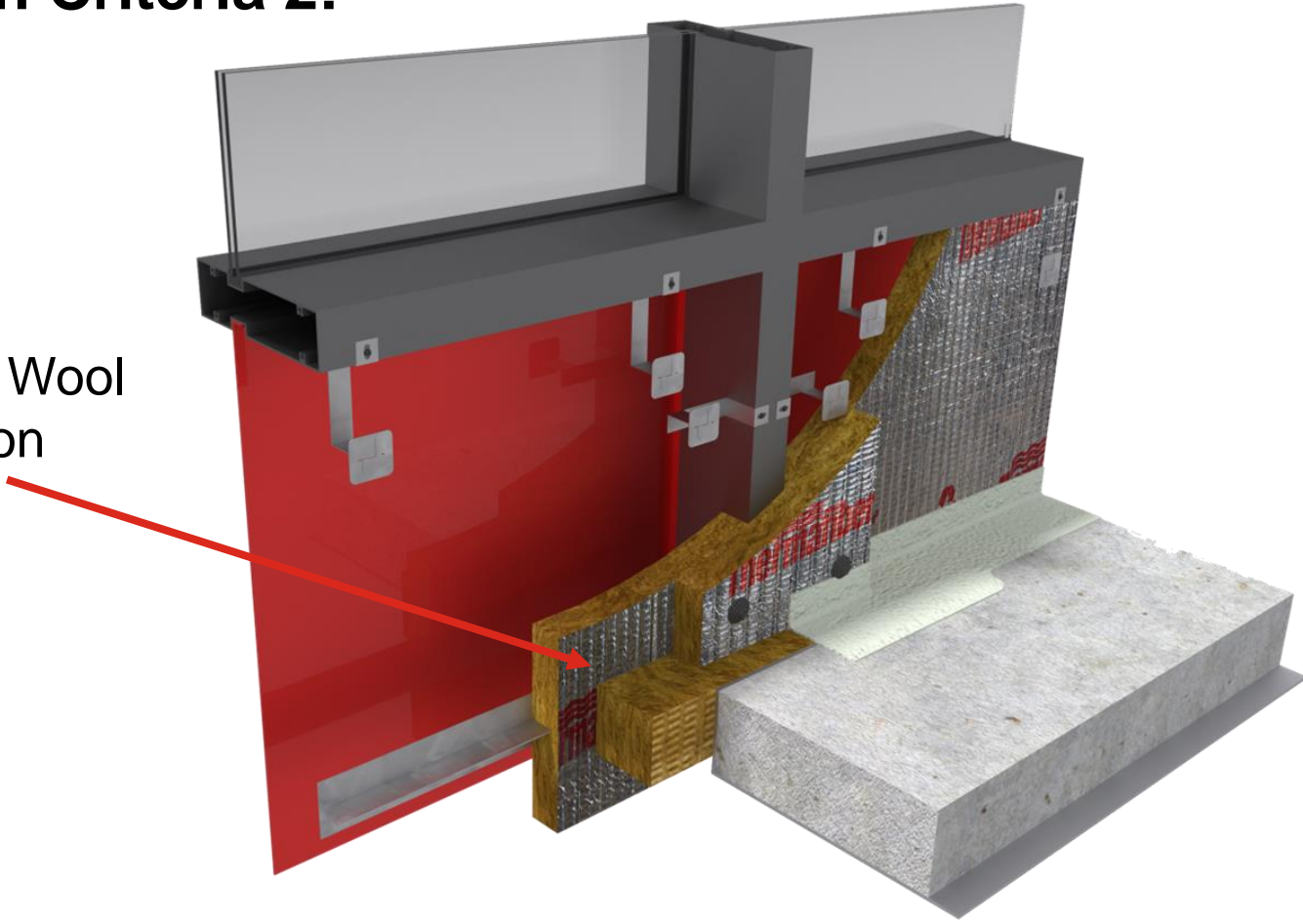
Reinforcement
Member
Mechanically
Attached



Perimeter Fire Containment

Design Criteria 2:

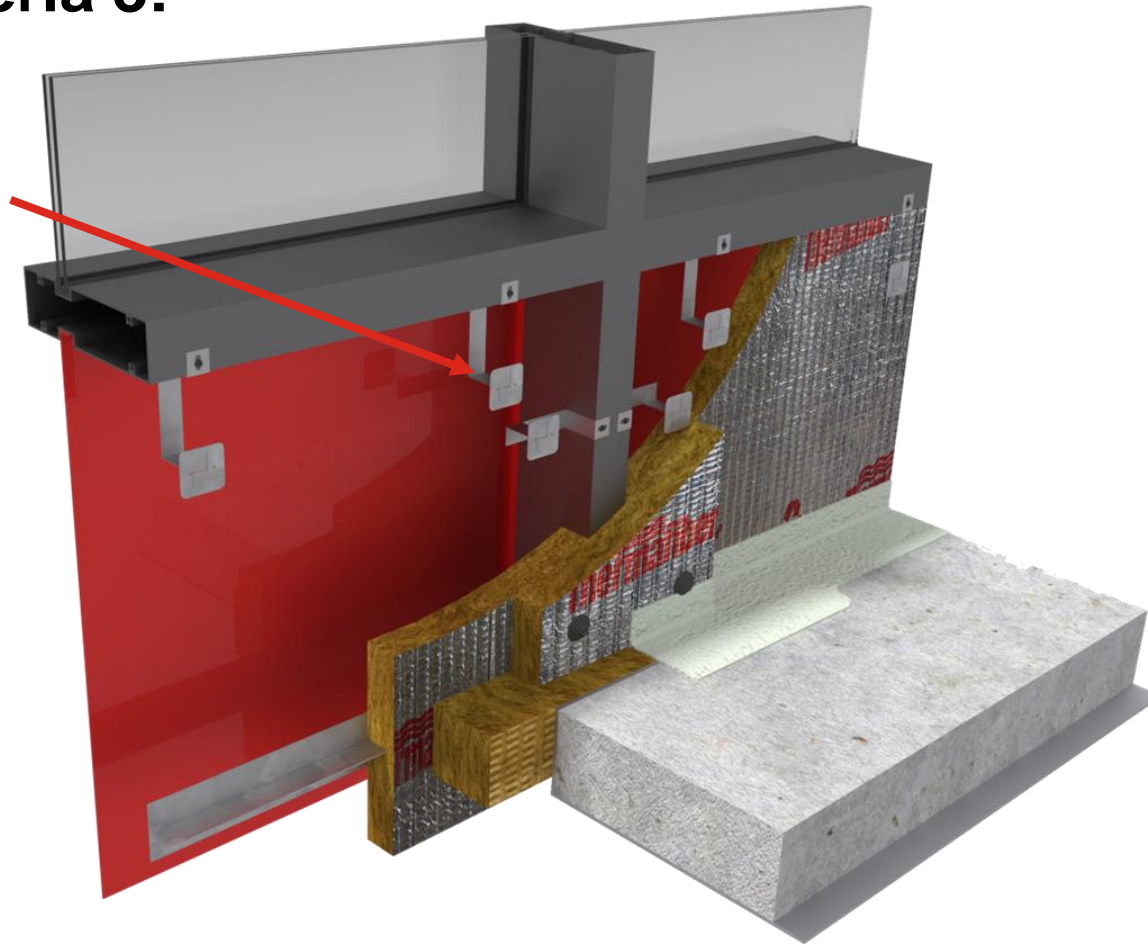
Mineral Wool
Insulation



Perimeter Fire Containment

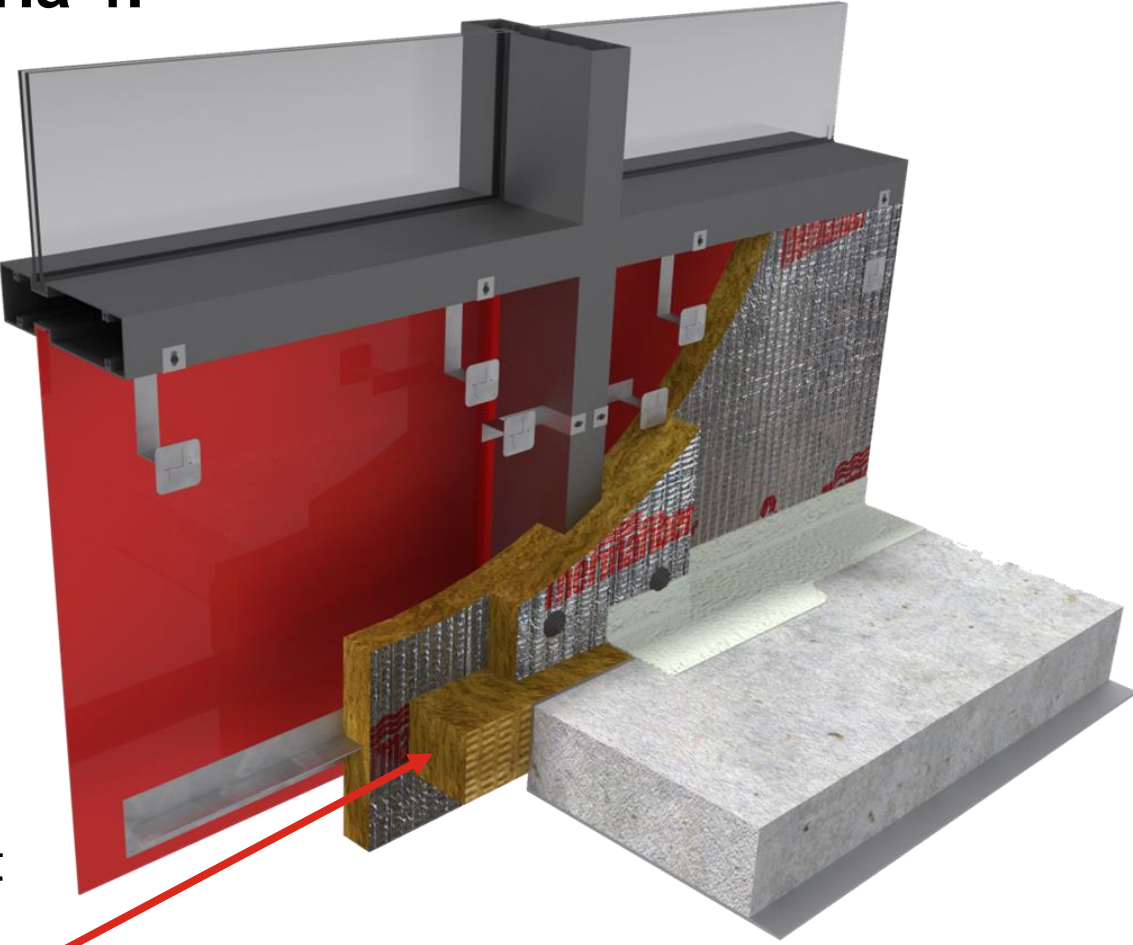
Design Criteria 3:

Mineral Wool
Insulation -
Mechanically
Attached



Perimeter Fire Containment

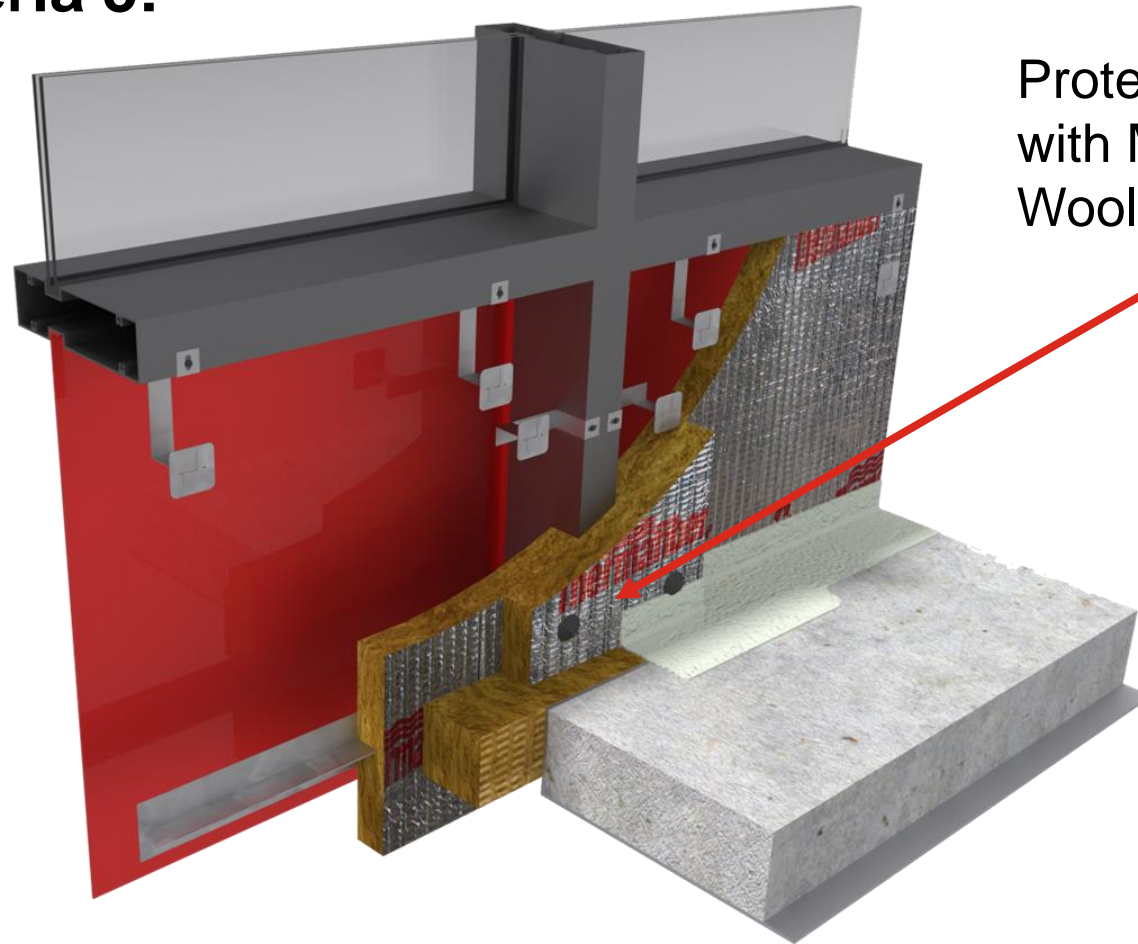
Design Criteria 4:



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

Perimeter Fire Containment

Design Criteria 5:



Protect Mullions
with Mineral
Wool Insulation

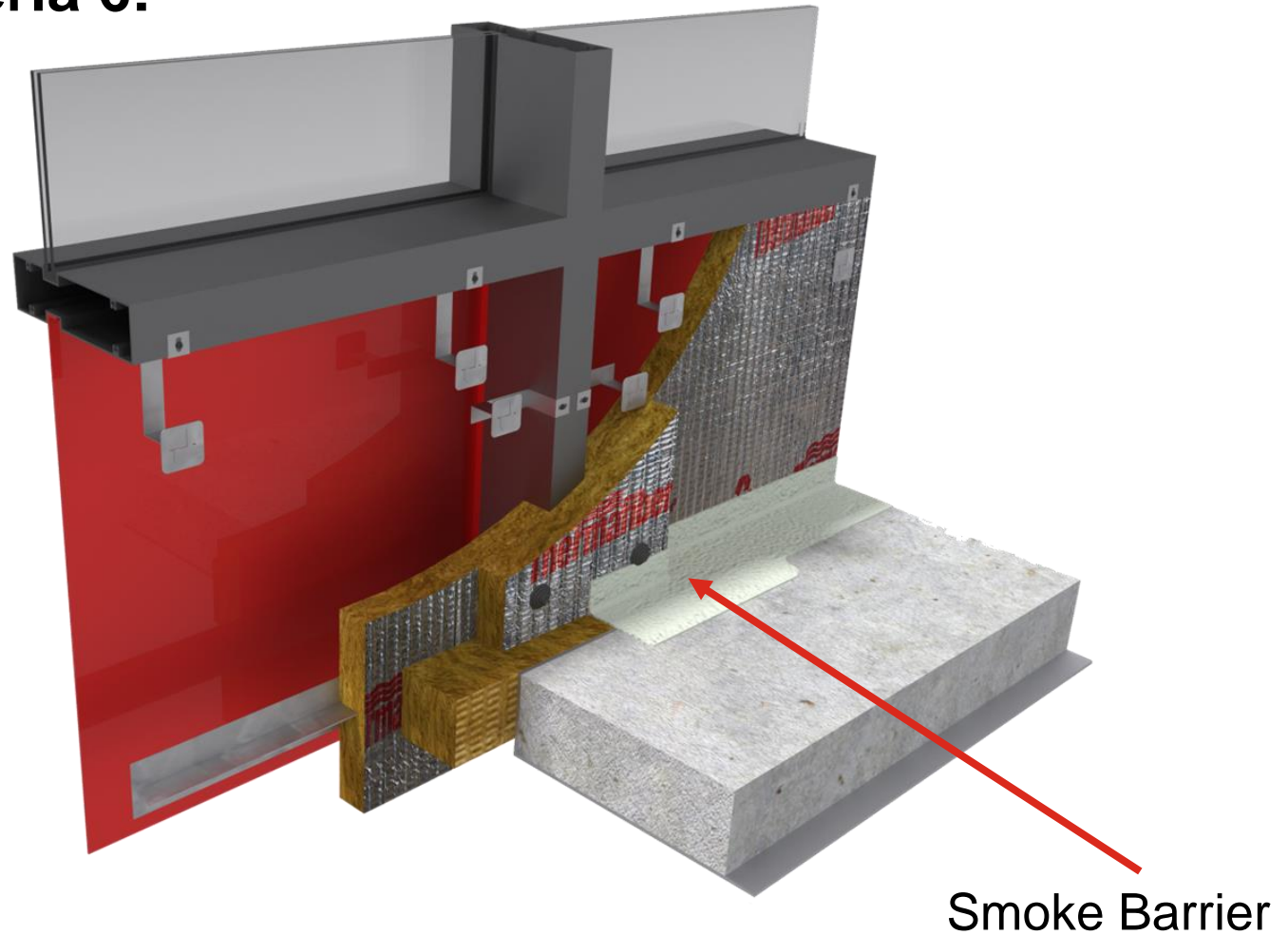
Smoke – The known killer

The major contributor of fire related deaths is smoke inhalation



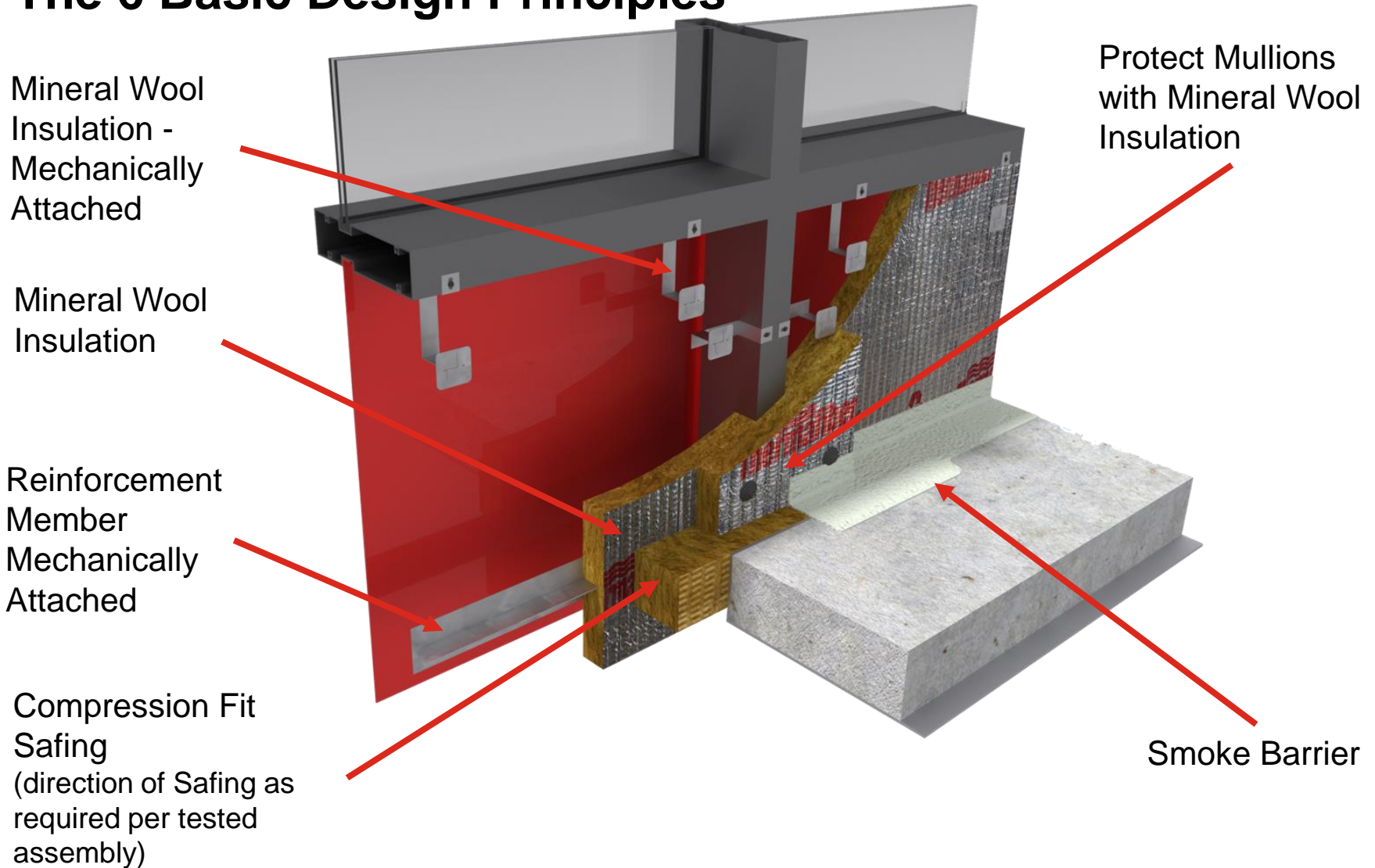
Perimeter Fire Containment

Design Criteria 6:



Perimeter Fire Containment

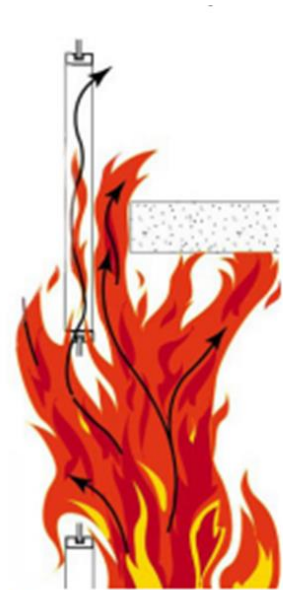
The 6 Basic Design Principles



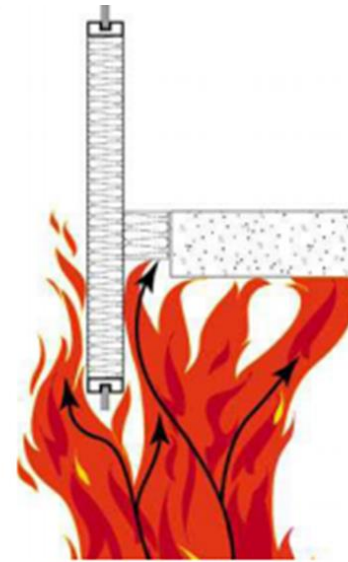
Perimeter Fire Containment

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



Unprotected Perimeter Joint



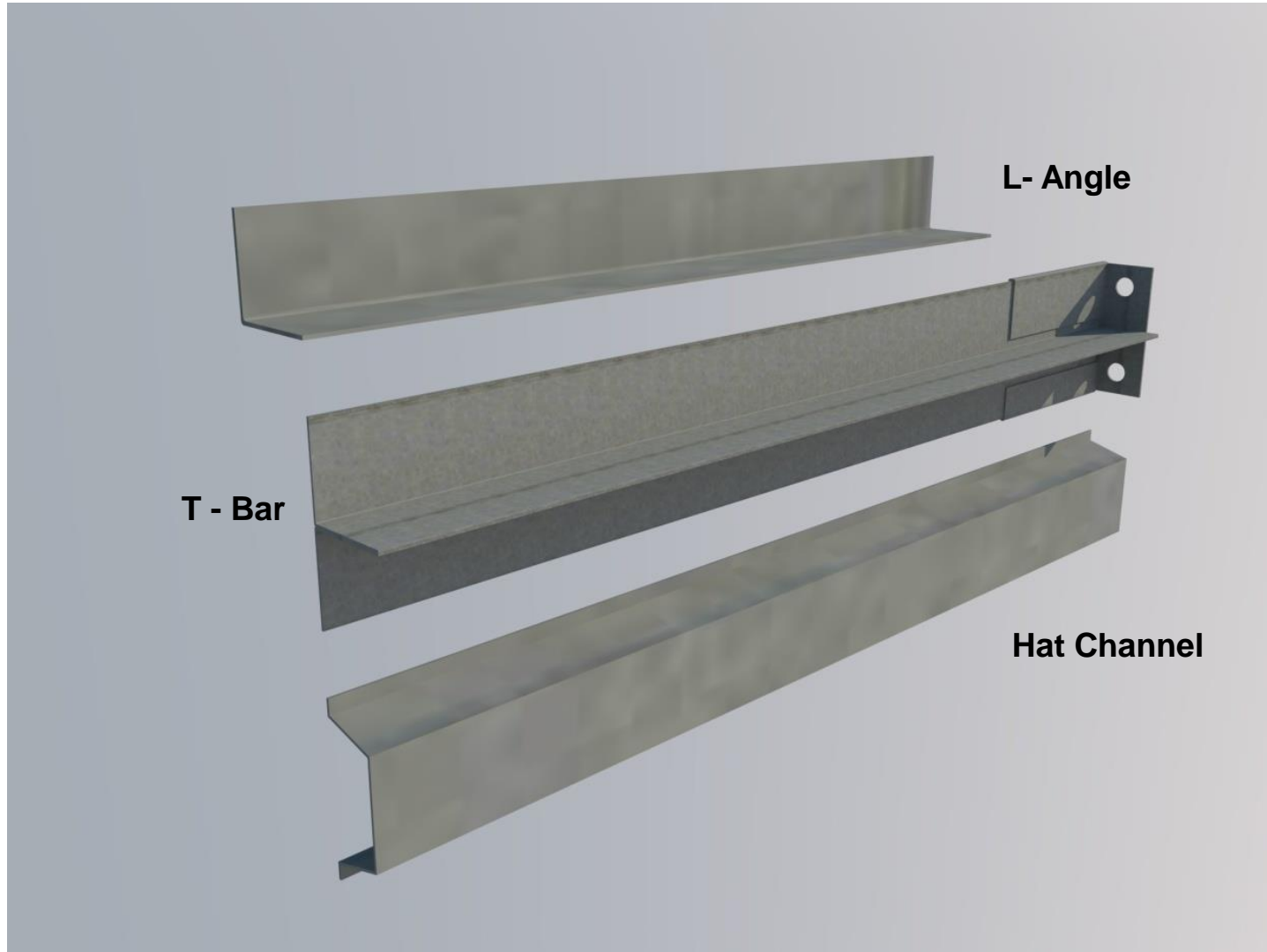
*Protected with a Perimeter
Fire Containment System*

Installation

Installation



Installation



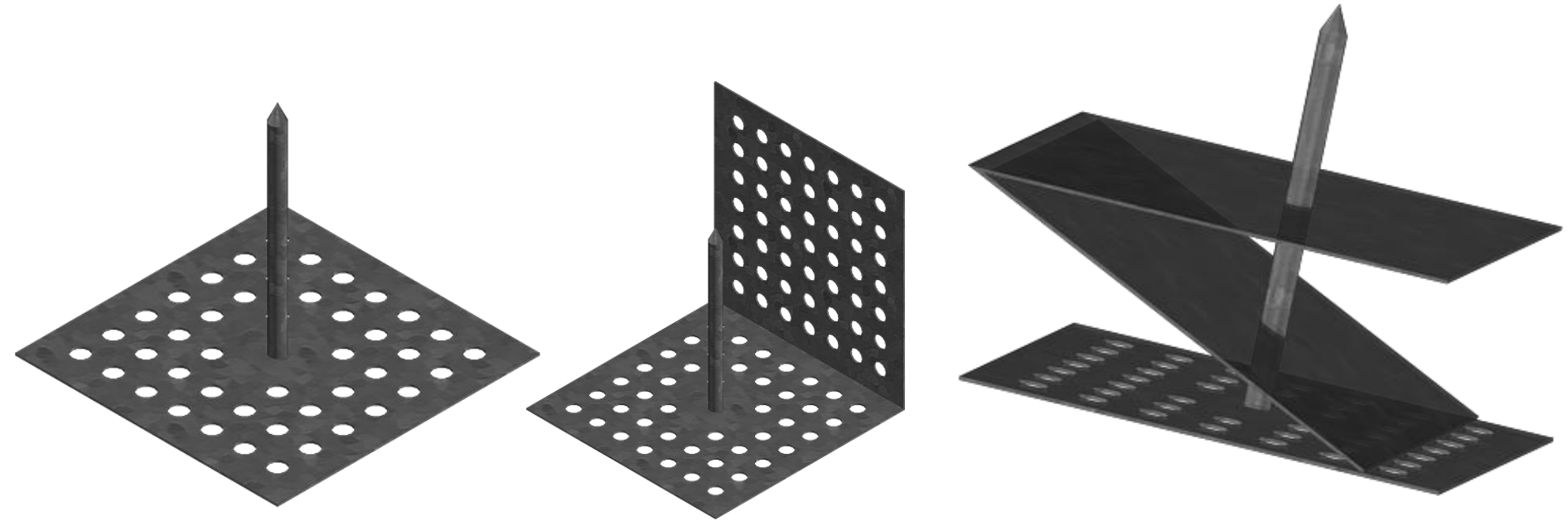
Installation



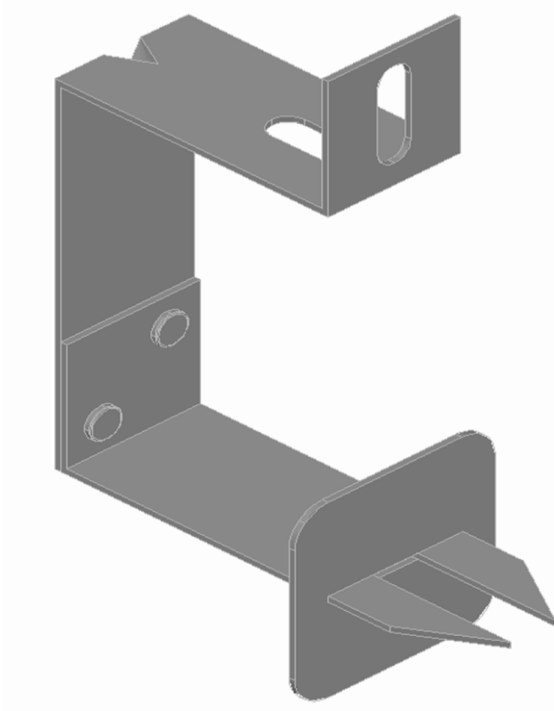
Installation



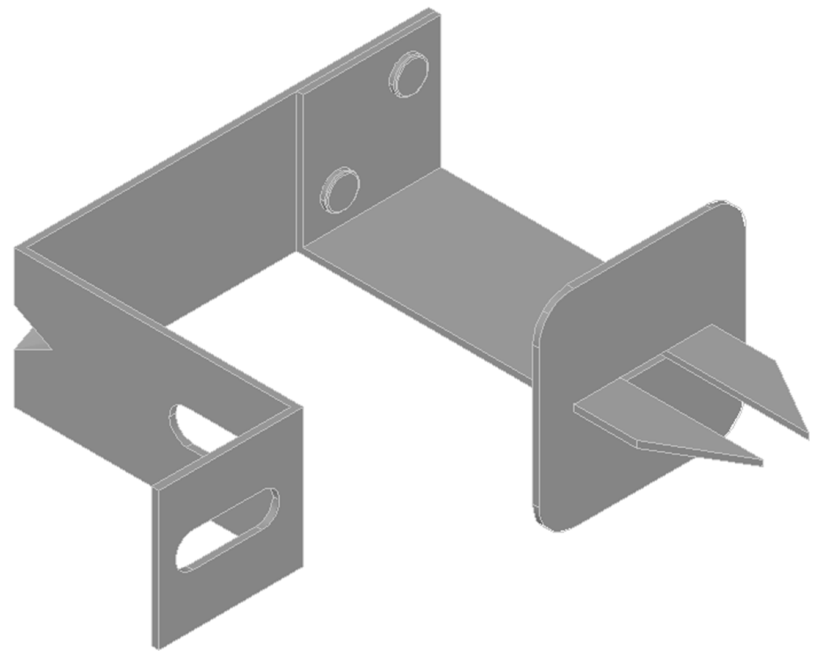
Installation – older style hangers



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



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

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



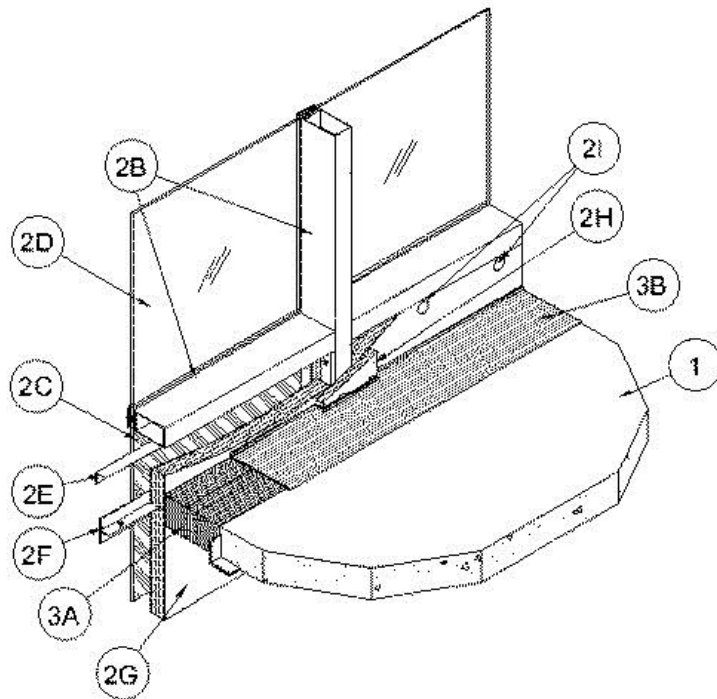
Rating	Description	Code Requirement?
F Rating	the ability of the design to prevent flame and hot gasses from passing through the interior of the system between the edge of the slab and interior face of the CW.	Yes, per IBC section 715.4
Integrity Rating	Barrier to interior fire passage and leap frog	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

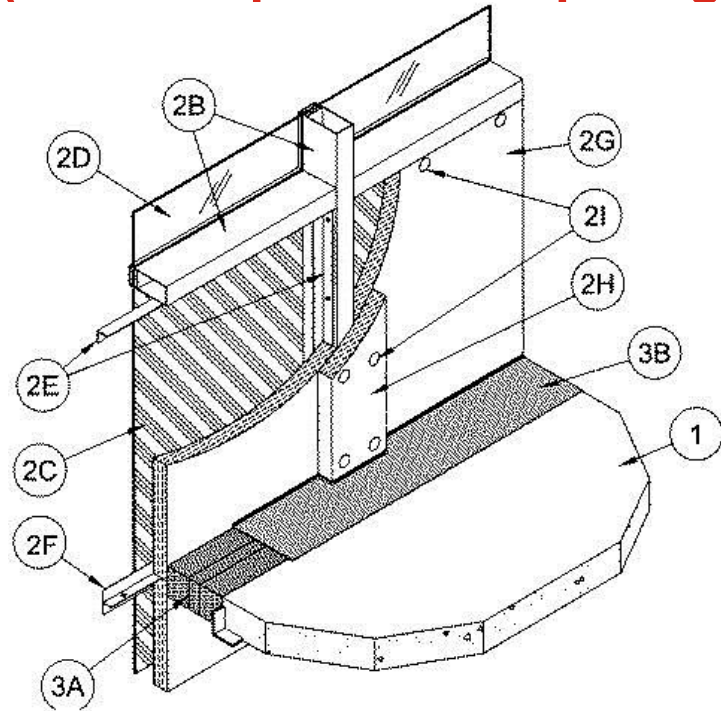
F- Rating- Hour
Integrity Rating- Hour



F Rating — 2 Hr

Integrity Rating — 0 Hr

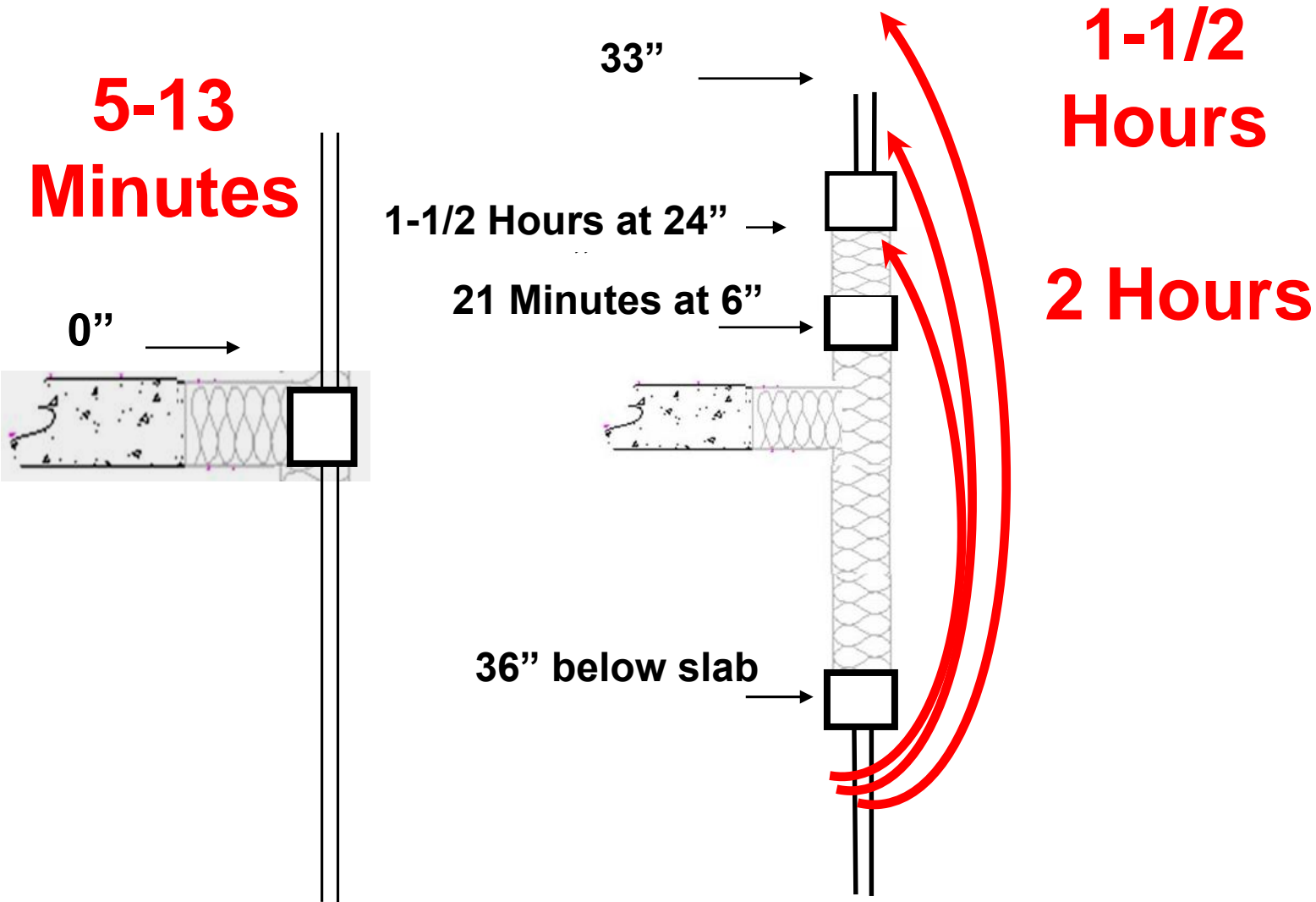
(Interior Spread per ASTM E 2307)
(Interior Spread & Leap Frog)



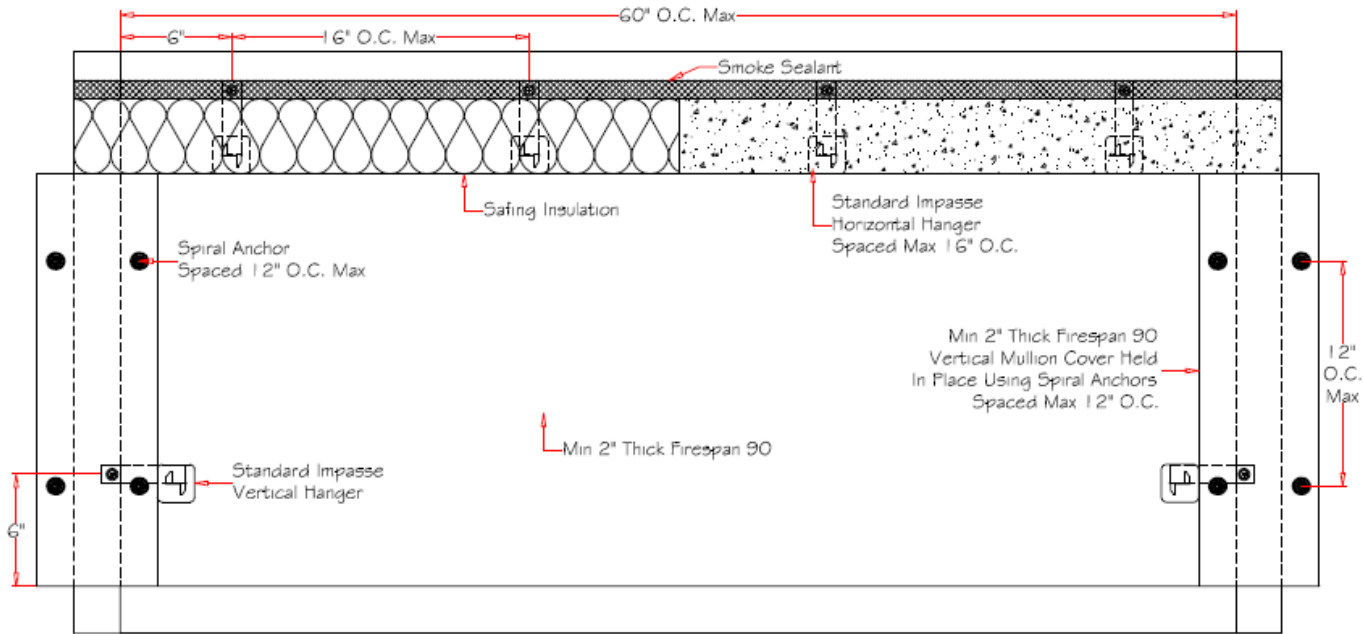
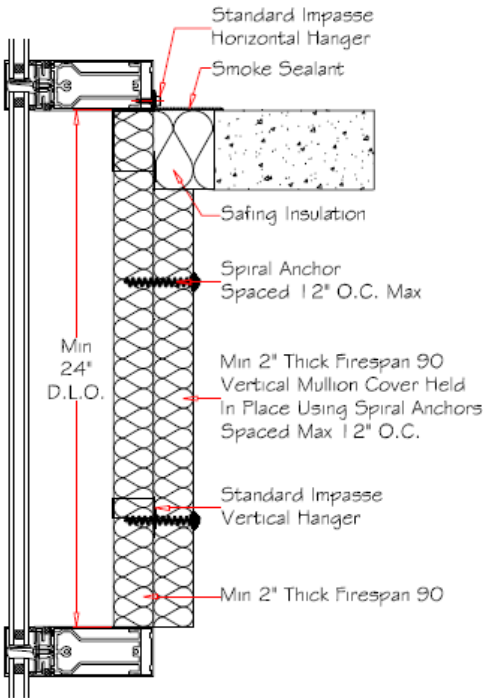
F Rating — 2 Hr

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

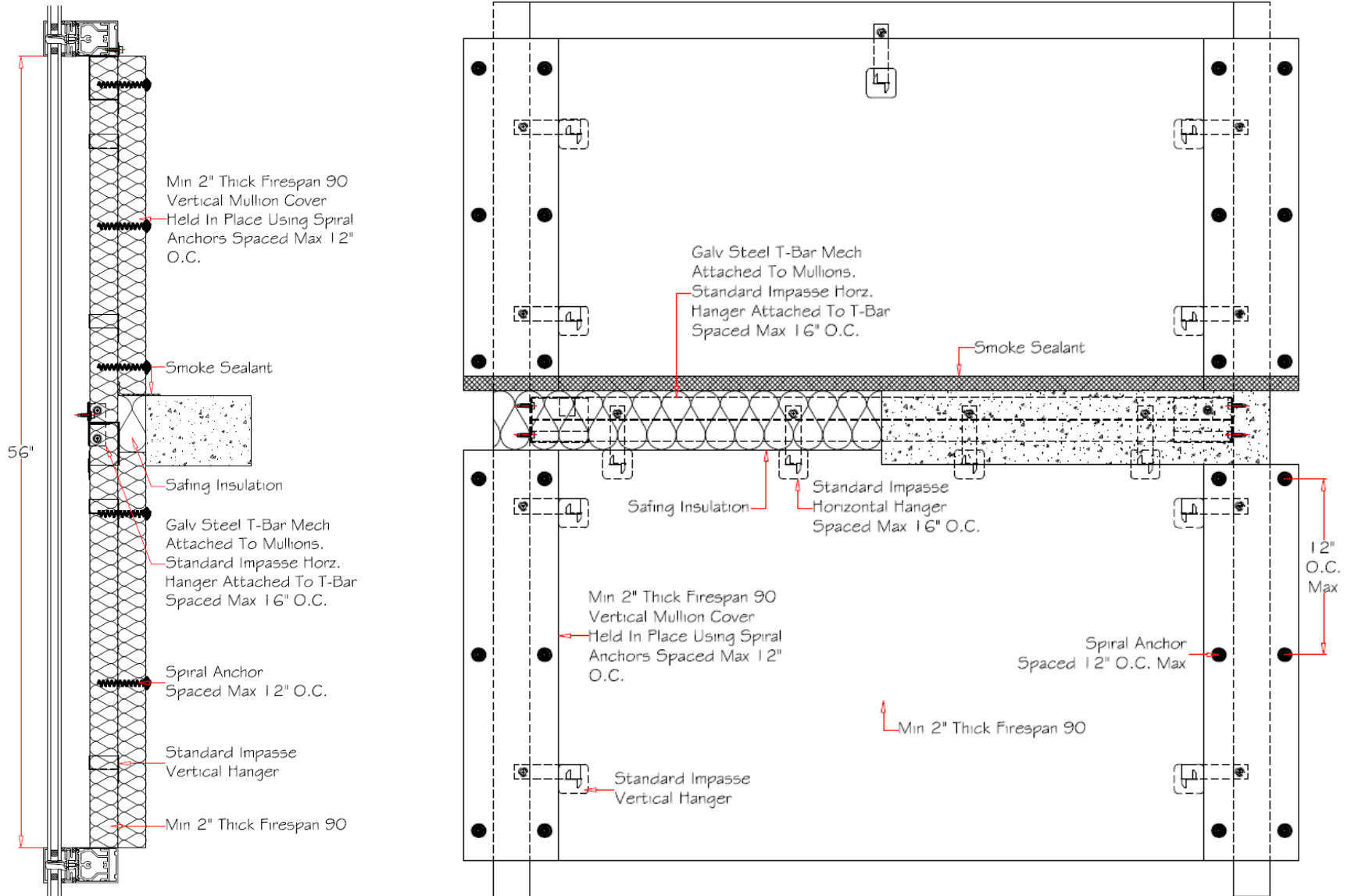
Leap Frog



Current Assemblies



Current Assemblies



Special Conditions

- **Short spandrel height**
- **Back pans**
- **Wide spandrel**
- **Wide Safe-Off Area**
- **Geometry of spandrel wall**
- **Exposed curtain wall anchors at the floor line**
- **Combustible building materials**

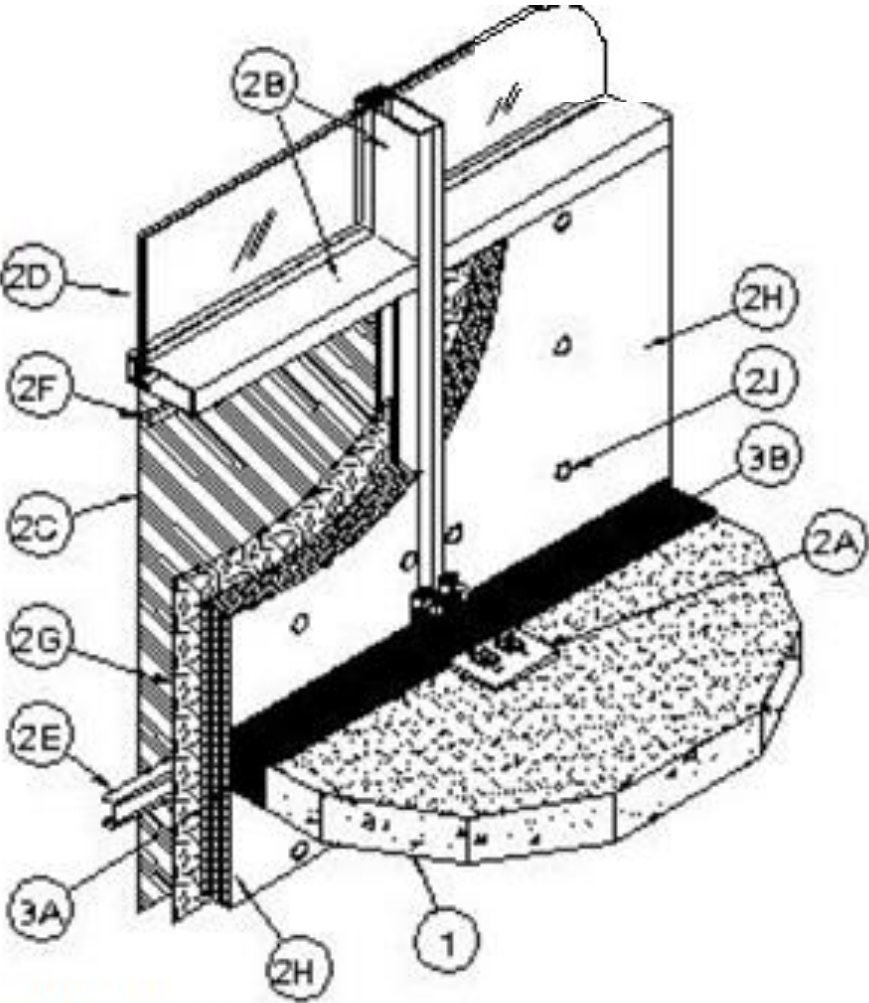
Short Spandrel Height

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

Steel Back Pans

Basic Backpan
with Spandrel
Insulation on the
Inside of the
Backpan

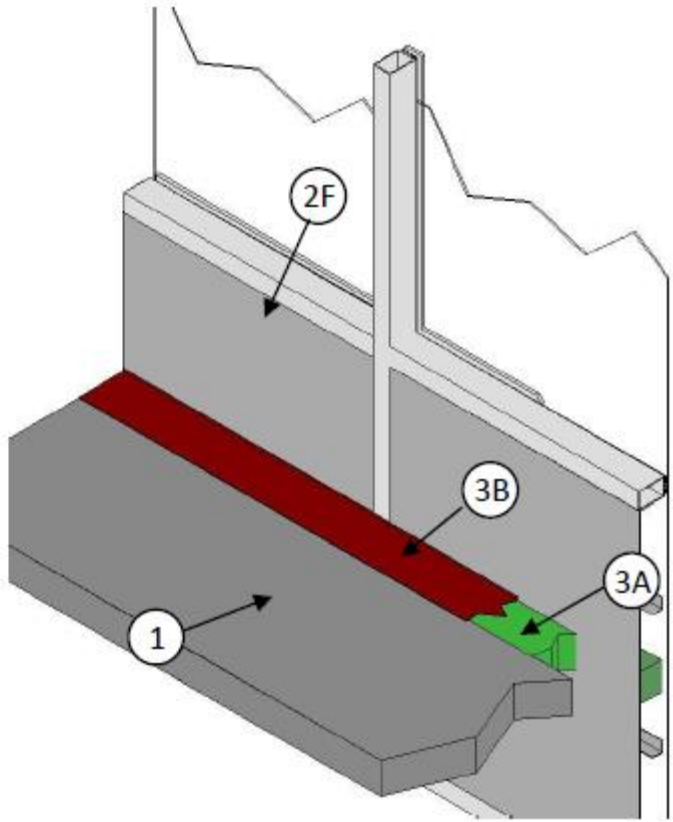
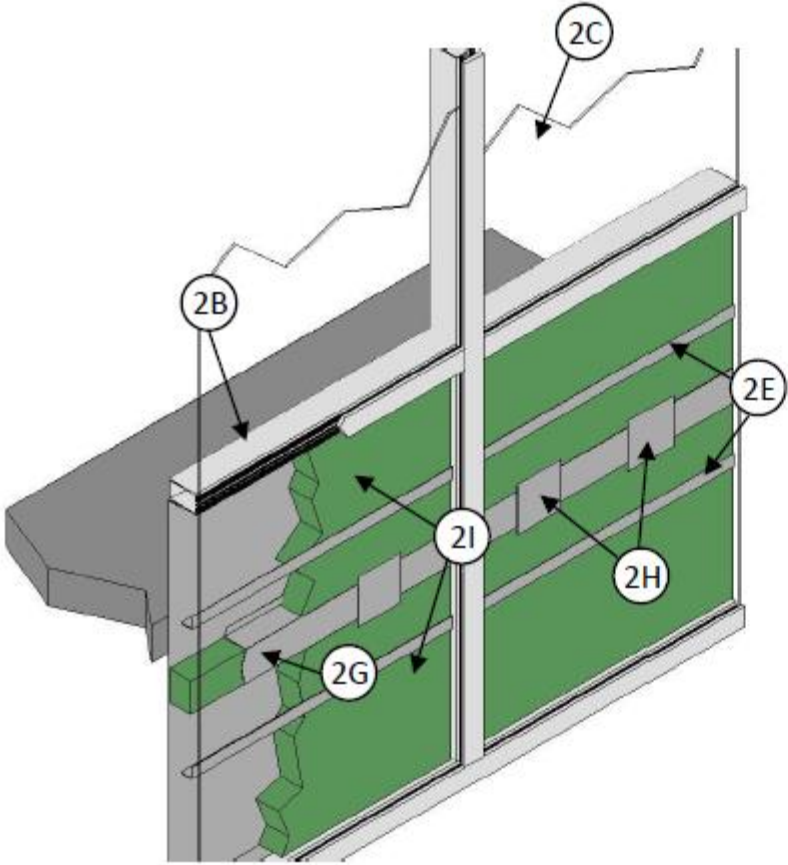


Perimeter Fire Barrier Education

Steel Back Pans

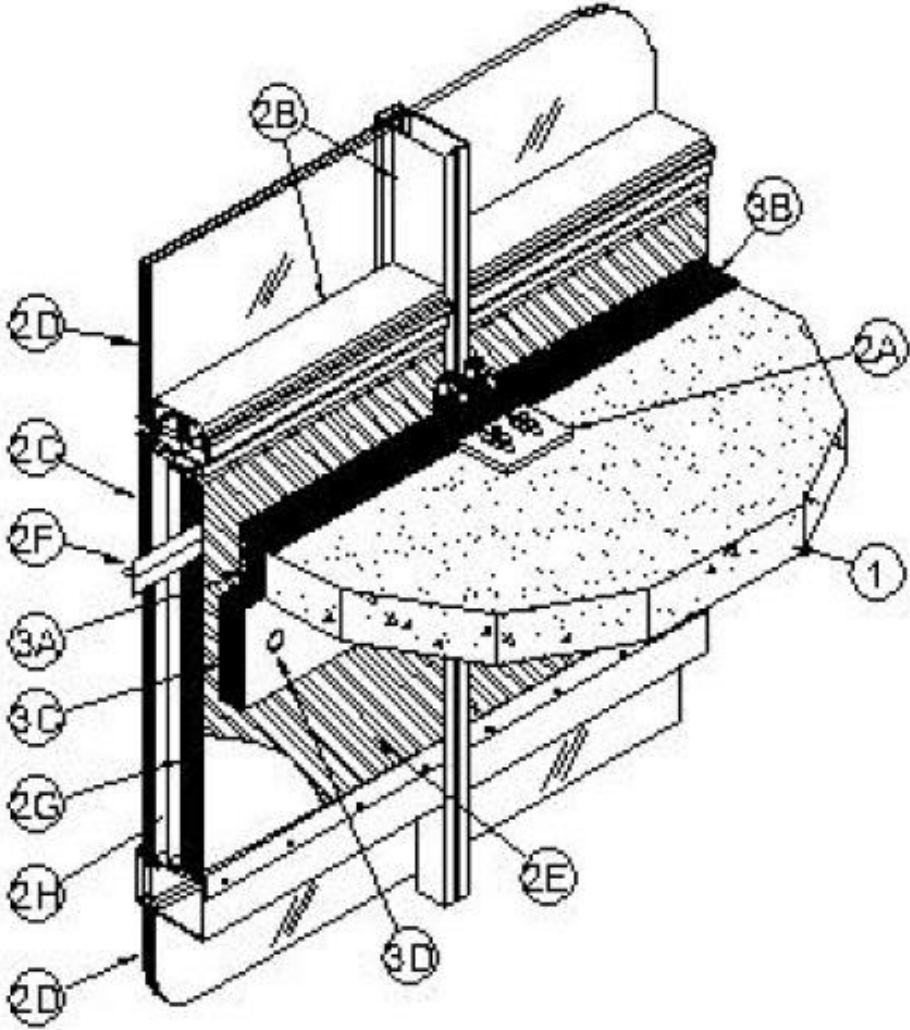


Steel Back Pans



Steel Back Pans

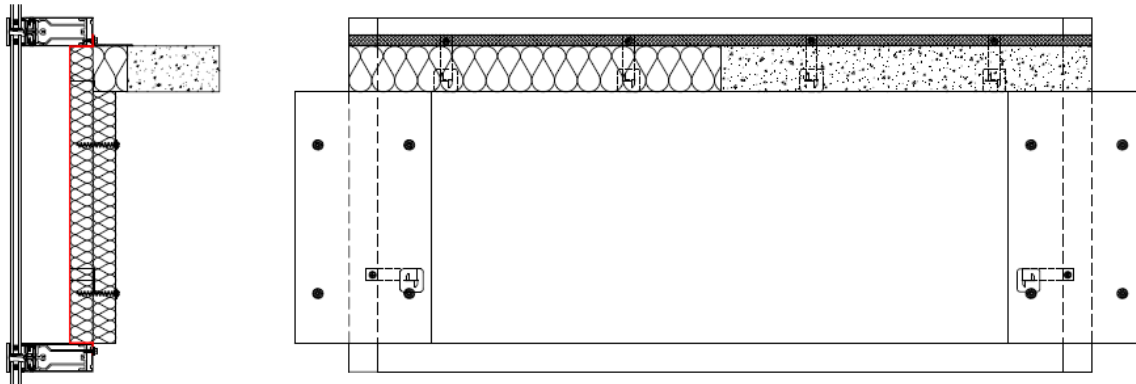
Backpan with
Spandrel
Insulation to
the outside of
the Backpan



Steel Back Pans

Considerations

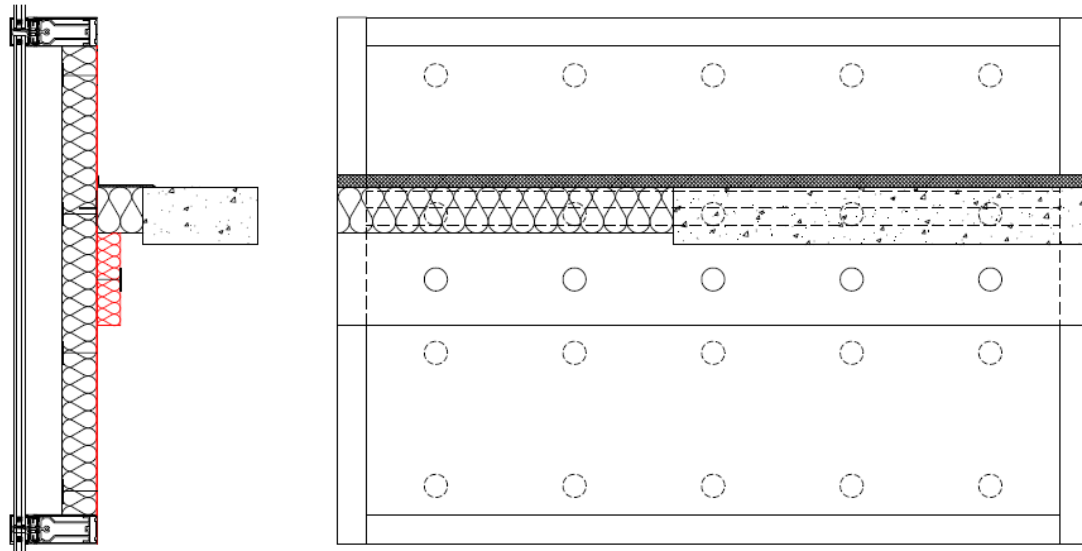
- Back Pan and/or Shadow Box on Front Side
 - Treat as if the back pan is not there
 - Complete perimeter fire containment is installed



Steel Back Pans

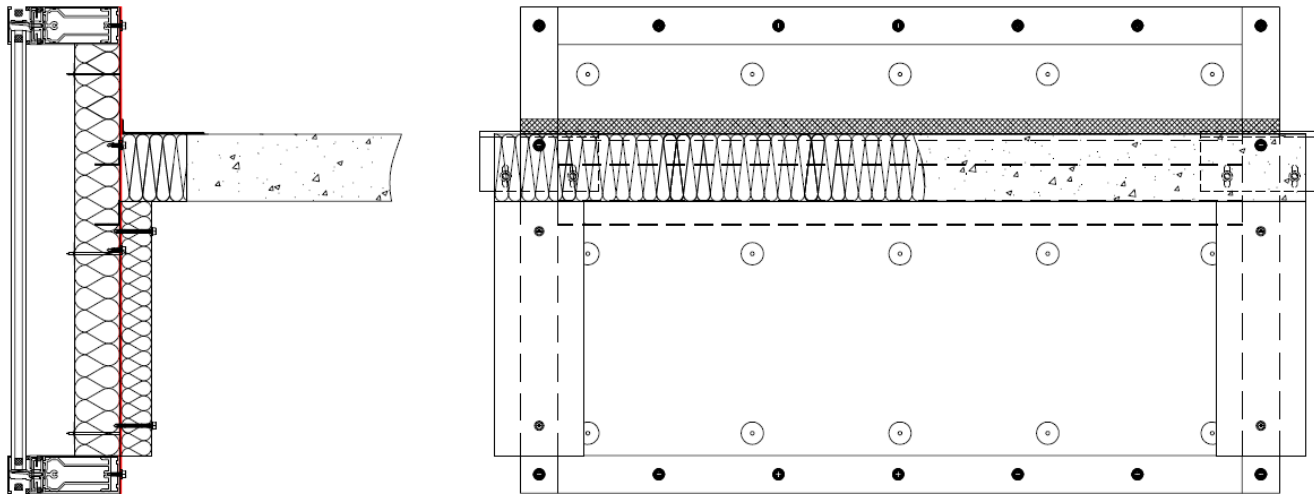
Considerations

- 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

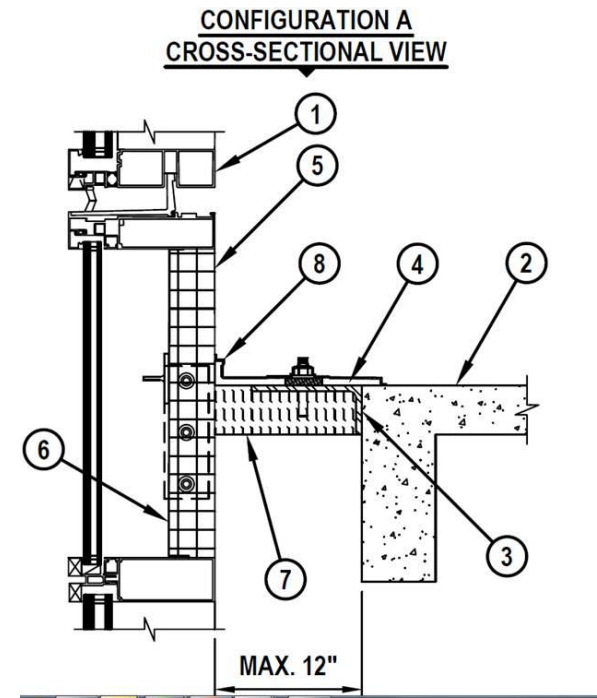
Considerations

- 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 Siding line
 - No framing member for mechanical attachment

Wide Safe-Off Area

Considerations

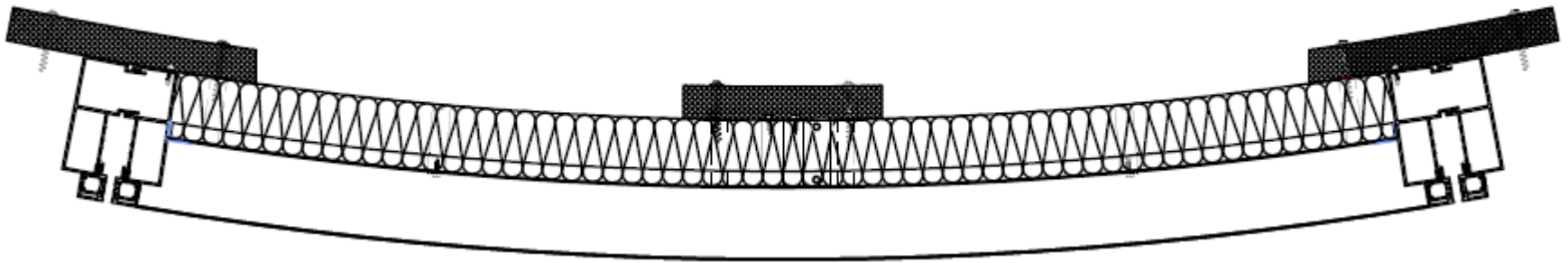
- Typical joint range is 2 to 6 inches wide
- Safing joints greater than 6 inches wide have difficulty keeping compression when unsupported over a wider span
 - Mineral wool insulation manufacturers should provide material recommendations based on the performance of Safing insulation under fire exposure
 - 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

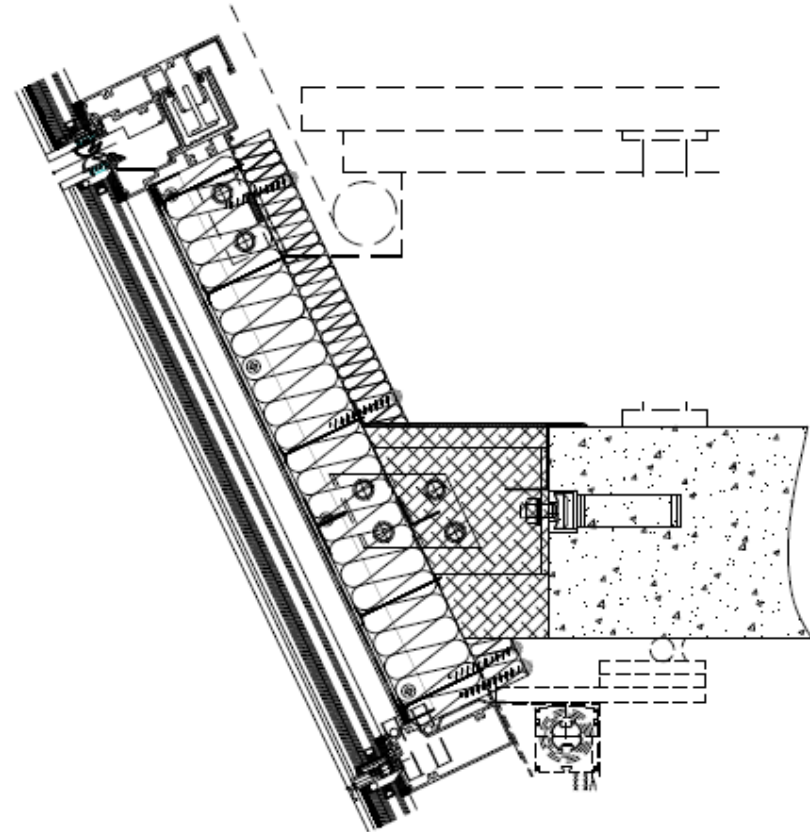
- No tested or listed assembly for curved curtain wall
- Conformance of spandrel insulation to the arc
 - Depends on degree of radius
- Limited mechanical attachment options
 - High cost custom mechanical fasteners required
- Custom support members
 - Radius backer reinforcement required in front of 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

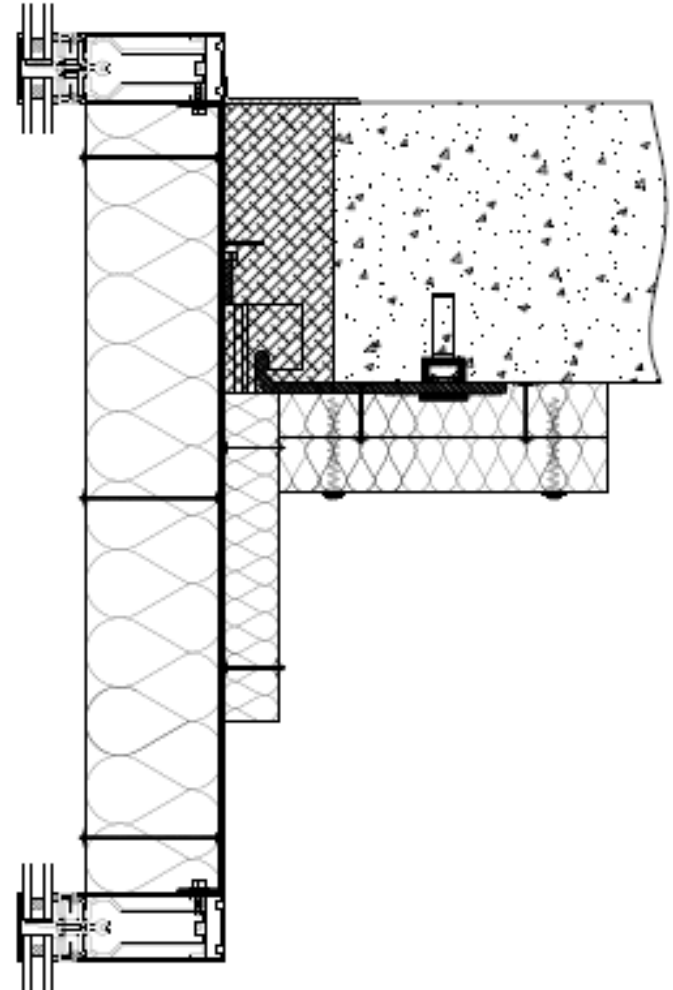
- No tested or listed assembly for angular curtain wall
- Limited mechanical attachment options
 - High cost custom mechanical fasteners required
- Custom support members
 - Securing the Safing insulation in the linear joint
 - Compression percentage of Safing
 - Flame impingement – more fire exposure 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



INTERNATIONAL FIRESTOP COUNCIL

THE Source of Firestop Expertise™

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:

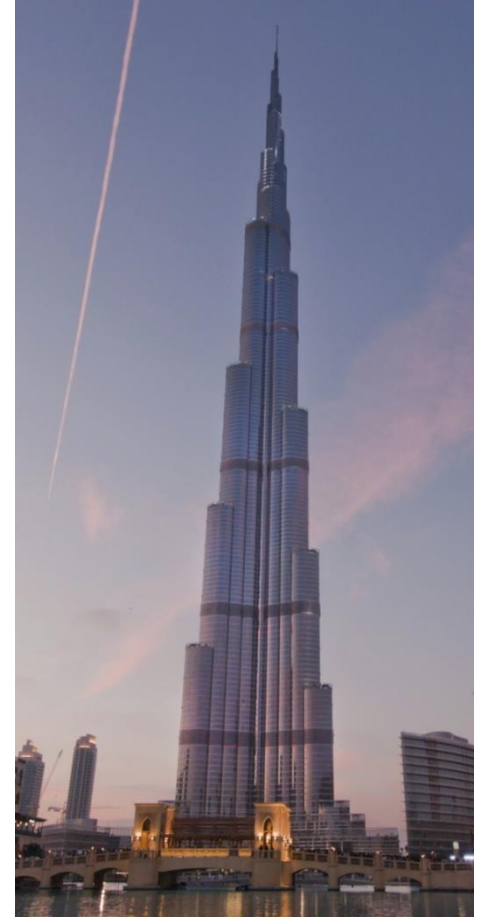
- accepted engineering principals
- fire science and fire testing guidelines
(e.g. ASTM E 2032 – Standard Guide for Extension of Data from Fire Endurance Tests)

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?



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