Perimeter Fire Containment

Chuck Knickerbocker *Technical Glass Products*

Mike Pautsch *Superl*

Jim Shriver *Thermafiber, Inc.*

TGP FIRE RATED

Superl Inc.
Innovation in Thermal Envelope Design

Thermafiber®
THE NAME IN MINERAL WOOL™

Perimeter Fire Barrier Education

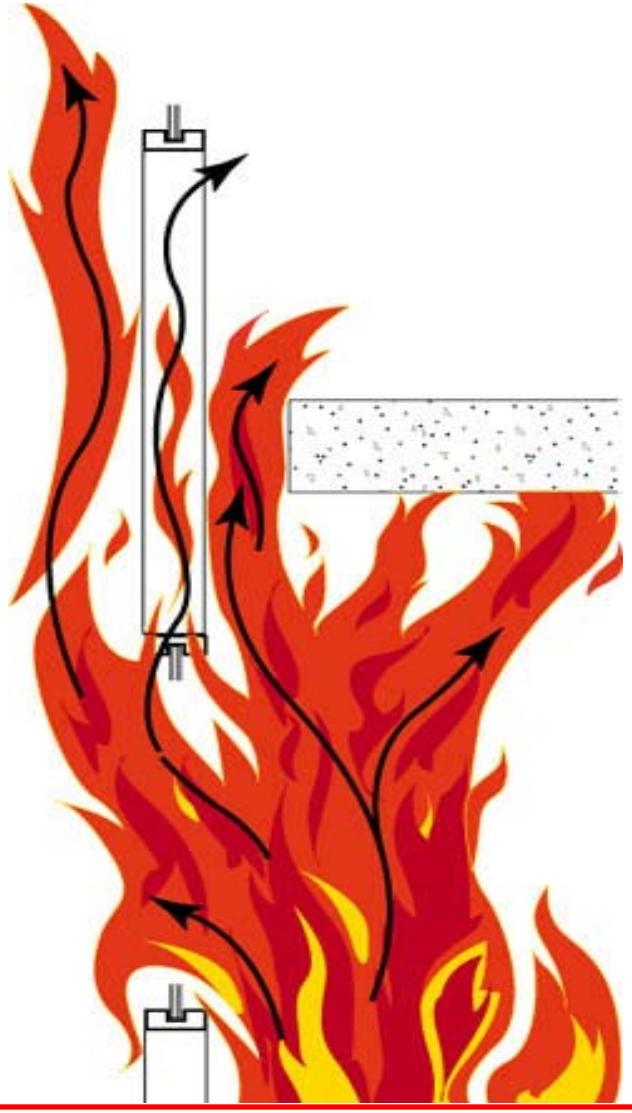
Perimeter Fire Barrier Education

Trump Tower - Chicago

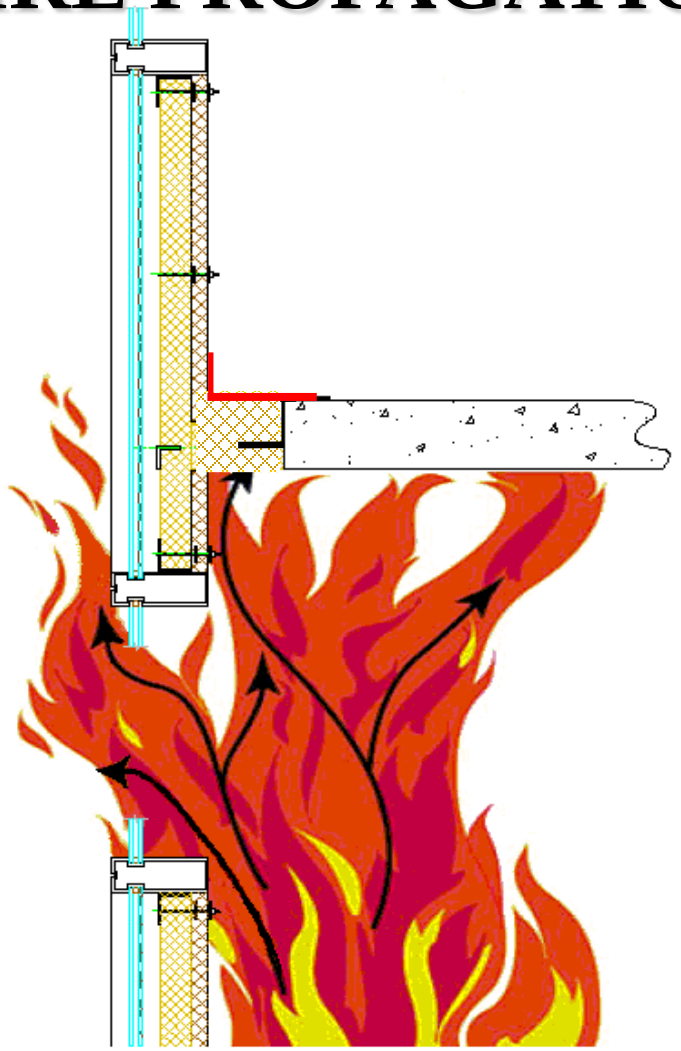
555 Mission St.

World Trade Center 7

Unprotected System

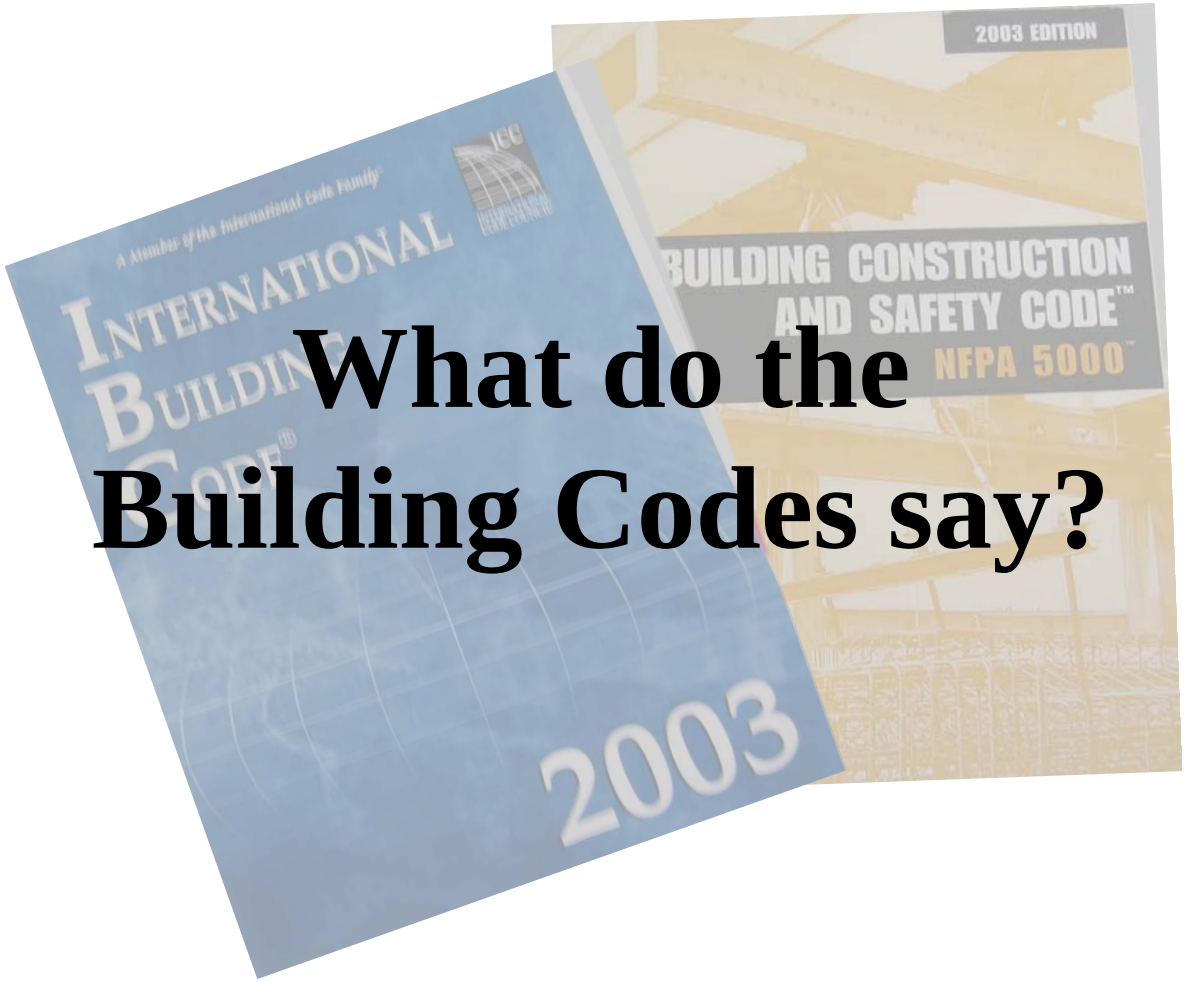


PATHS OF FIRE PROPAGATION BLOCKED



Perimeter Fire Barrier Education

How Is a Fire Like This Contained?



What do the Building Codes say?

Perimeter Fire Barrier Education

IBC 2009

Section 714.4 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 E 2307 **to prevent the passage of flame for the time period at least equal to the fire-resistance rating of the floor assembly** and prevent the passage of heat and hot gases sufficient to ignite cotton waste. Height and fire-resistance requirements for curtain wall spandrels shall comply with Section 705.8.5.

IBC 2009

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 ¾ 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…

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.**

IBC 2009

Section 714.5 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 714.4 shall still apply to the intersection between the spandrel wall and the floor.**

IBC 2009

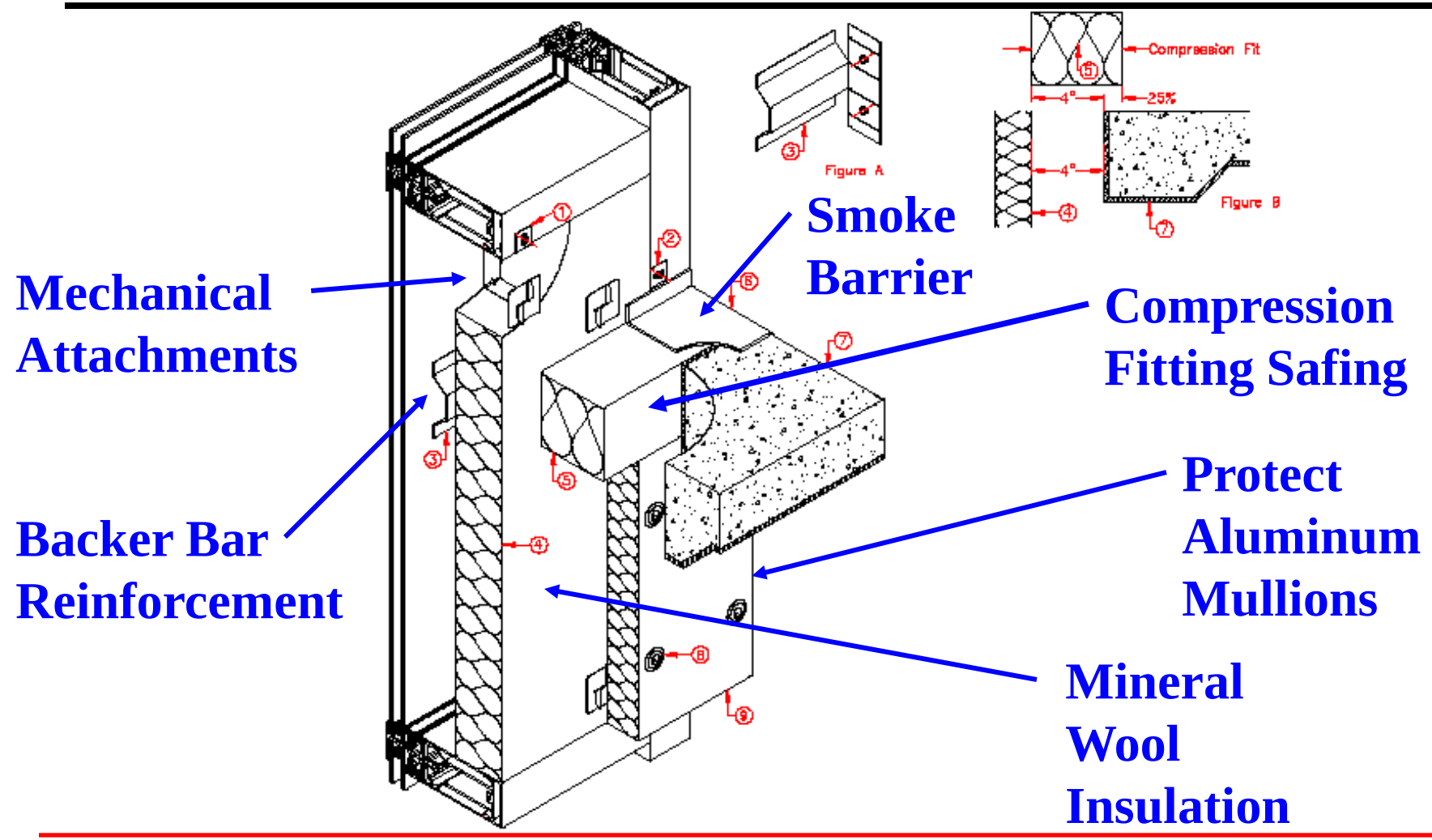
Section 714.4.1 Exterior Curtain Wall and Non Fire-Resistance Rated Floor Assembly Intersection:

Voids created at the intersection of exterior curtain wall assemblies and non-fire-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.**

Within these two directories there are over 250 tested and listed systems.

Curtain Wall Fire Containment Systems-

6 Basic Design Principles



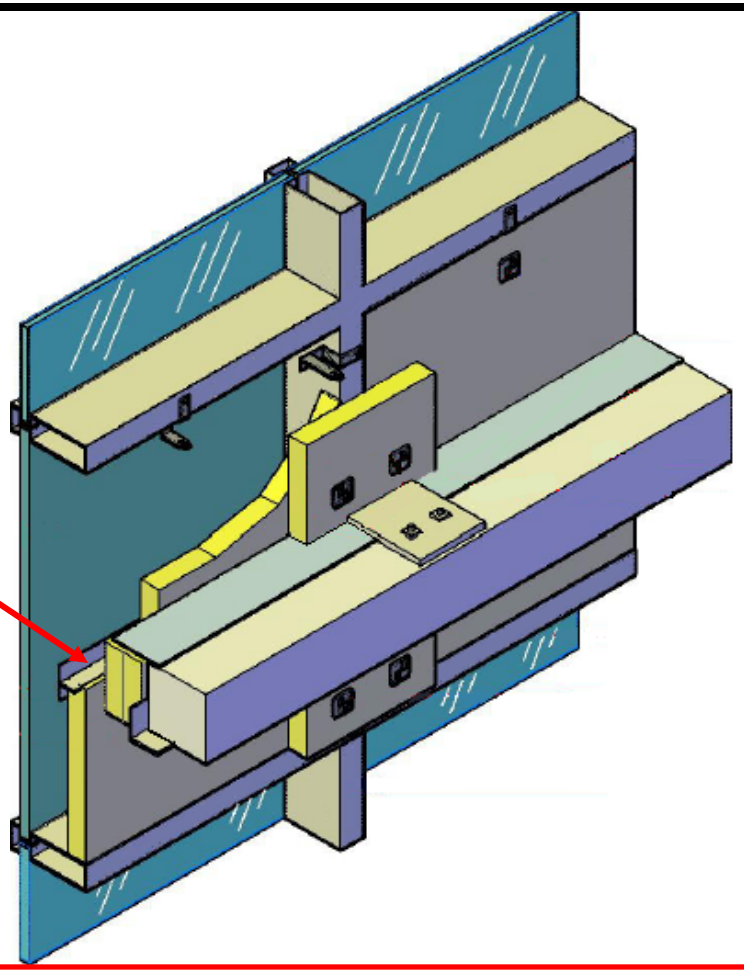
Perimeter Fire Barrier Education

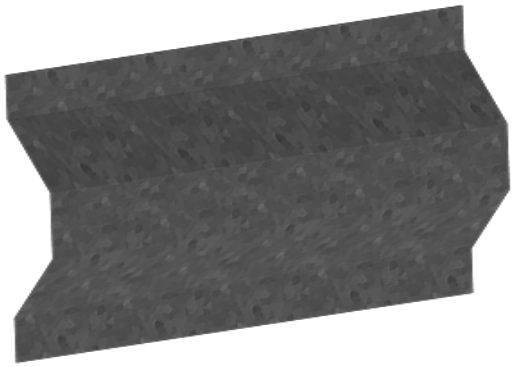
Curtain Wall Fire Containment Systems

Basic Design Principles

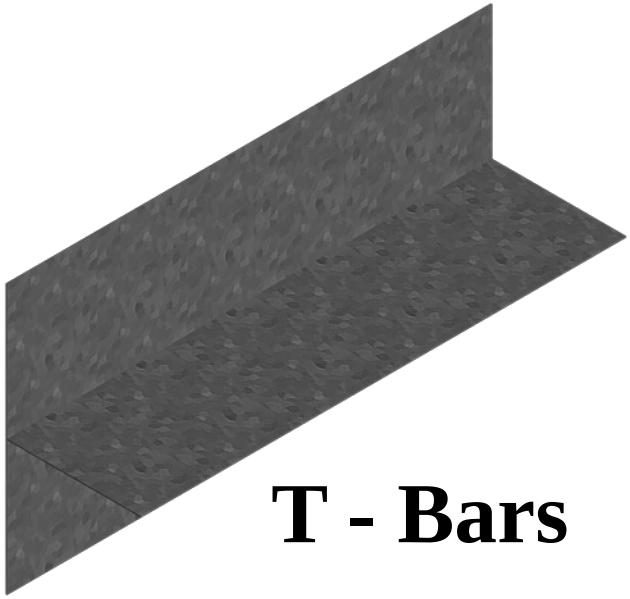
1

Reinforcement Member Mechanically Attached



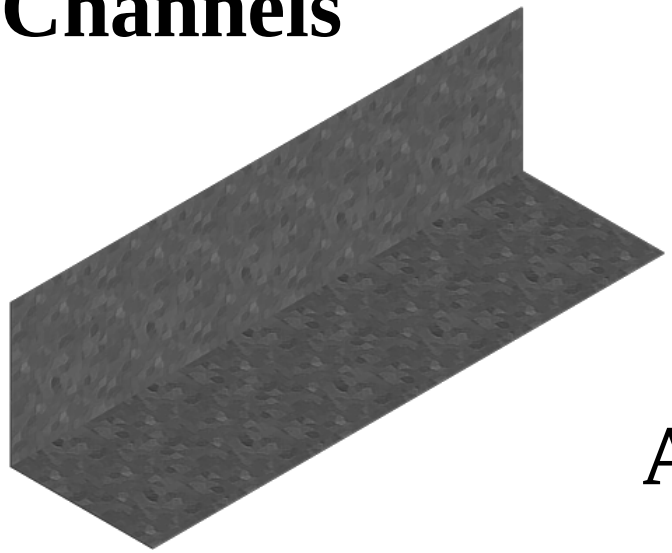


Hat Channels

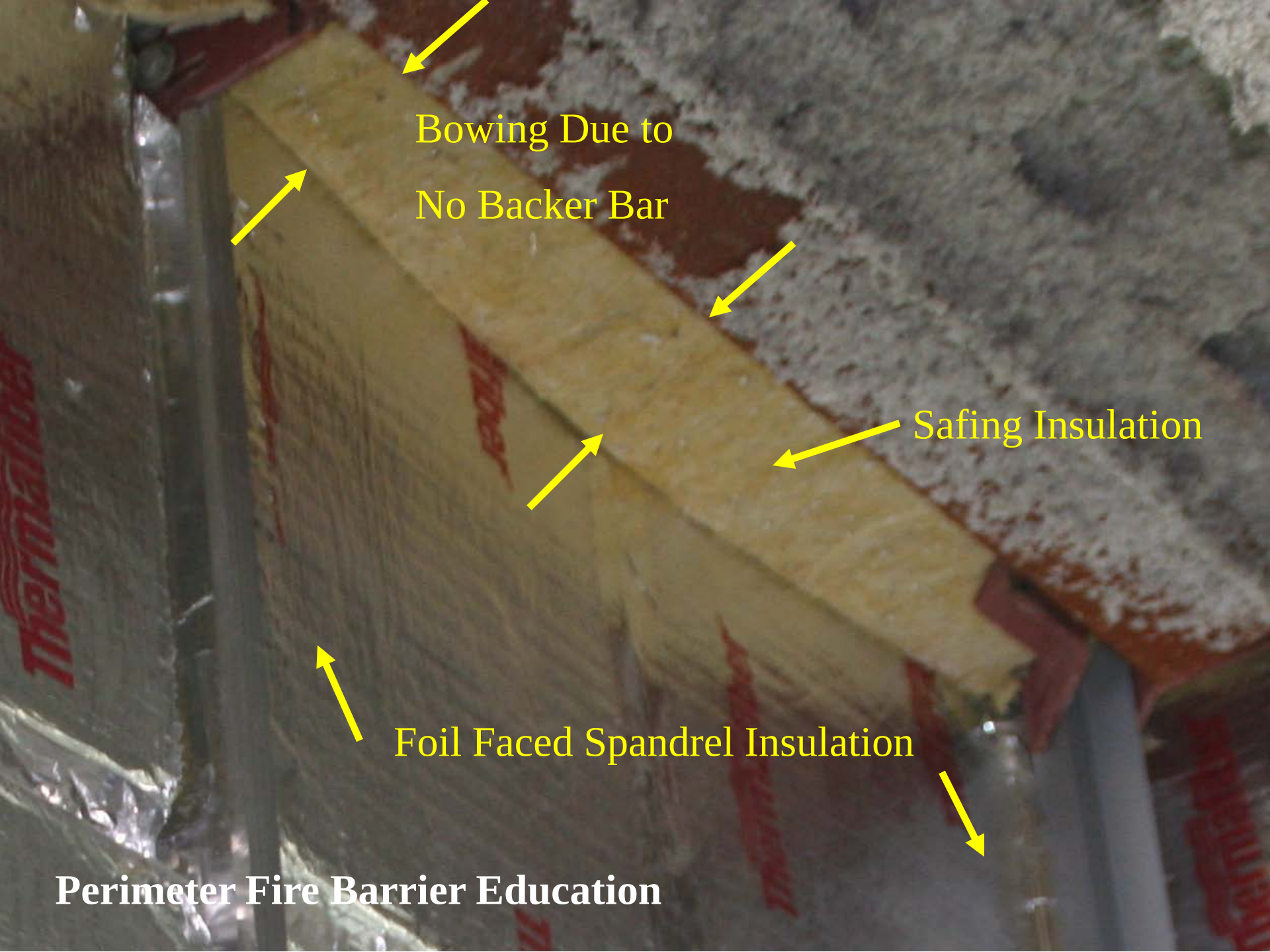


T - Bars

Backer Bars



Angles



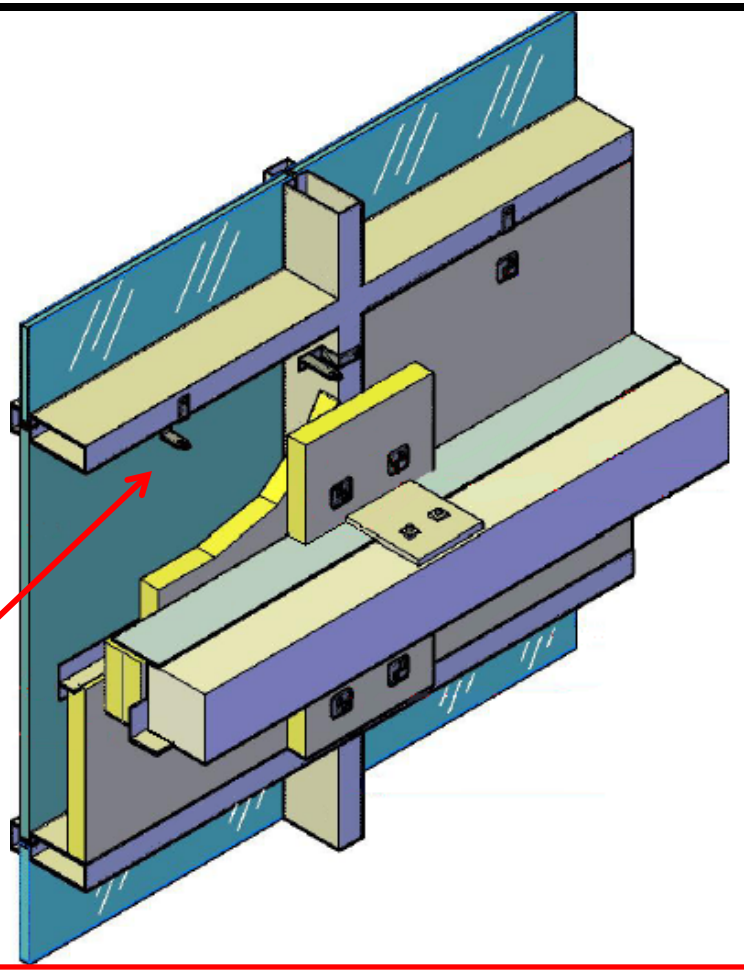
Perimeter Fire Barrier Education

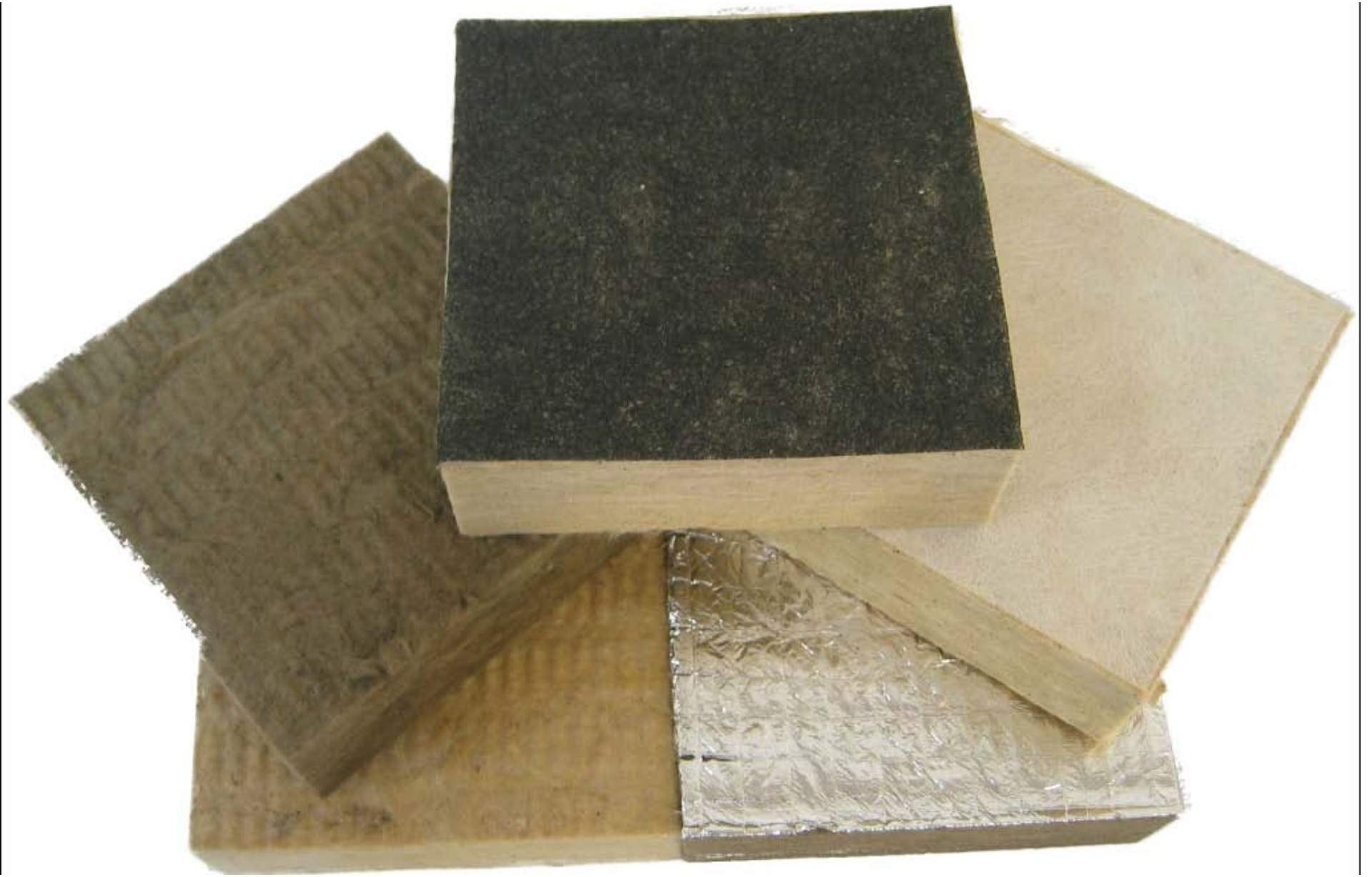
Curtain Wall Fire Containment Systems

Basic Design Principles

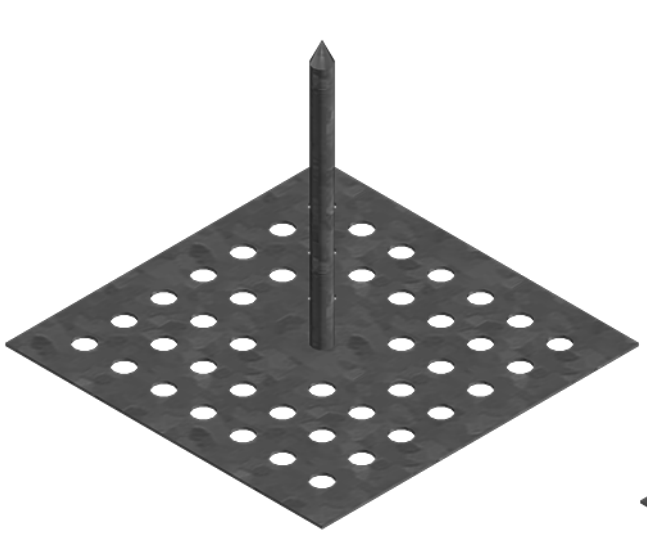
Mineral Wool Insulation - Mechanically Attached

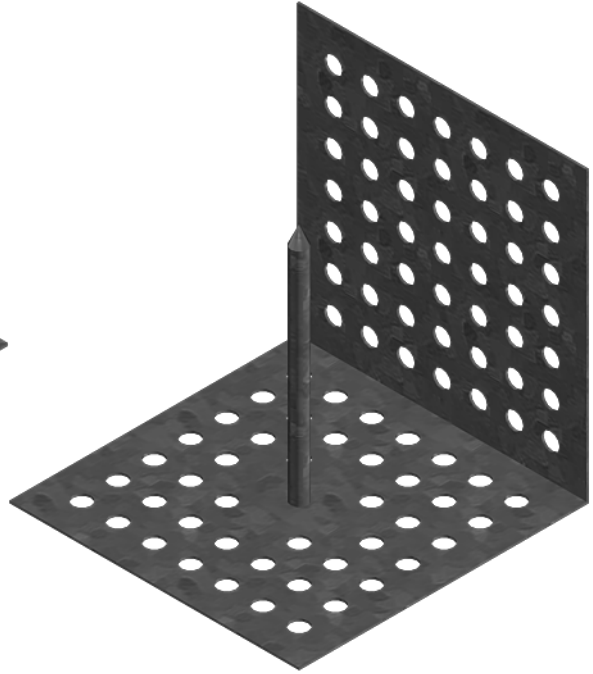
2

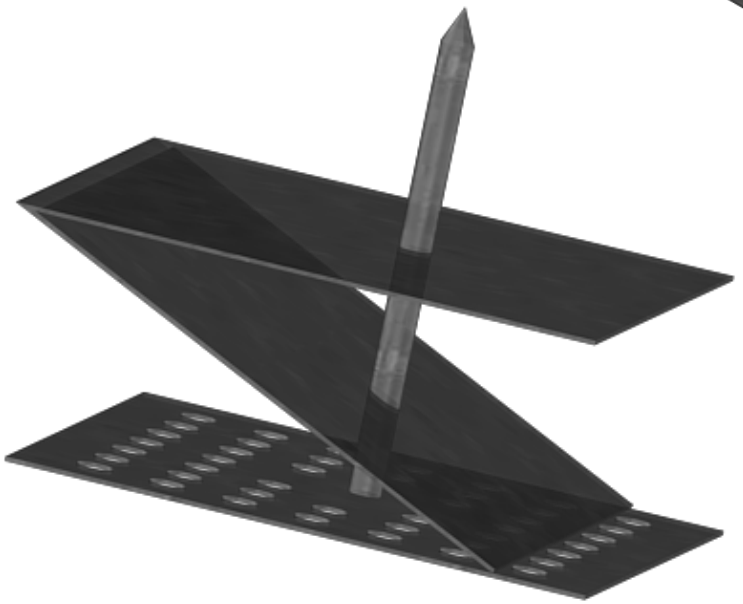


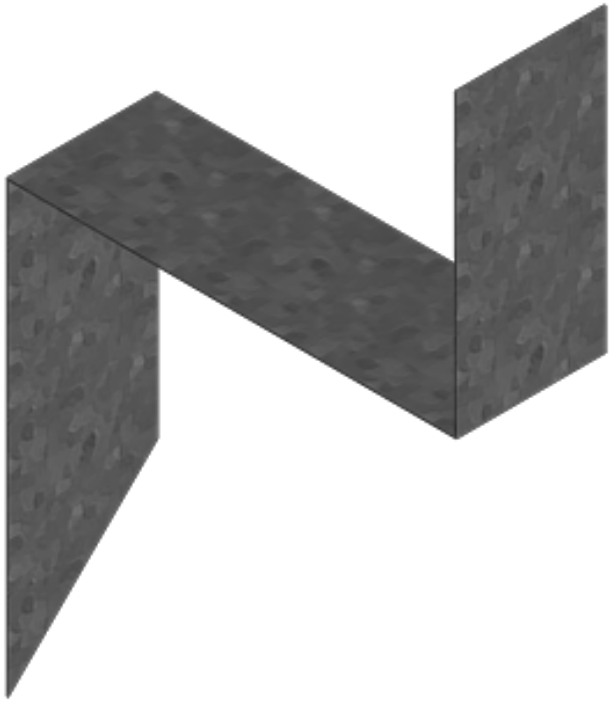


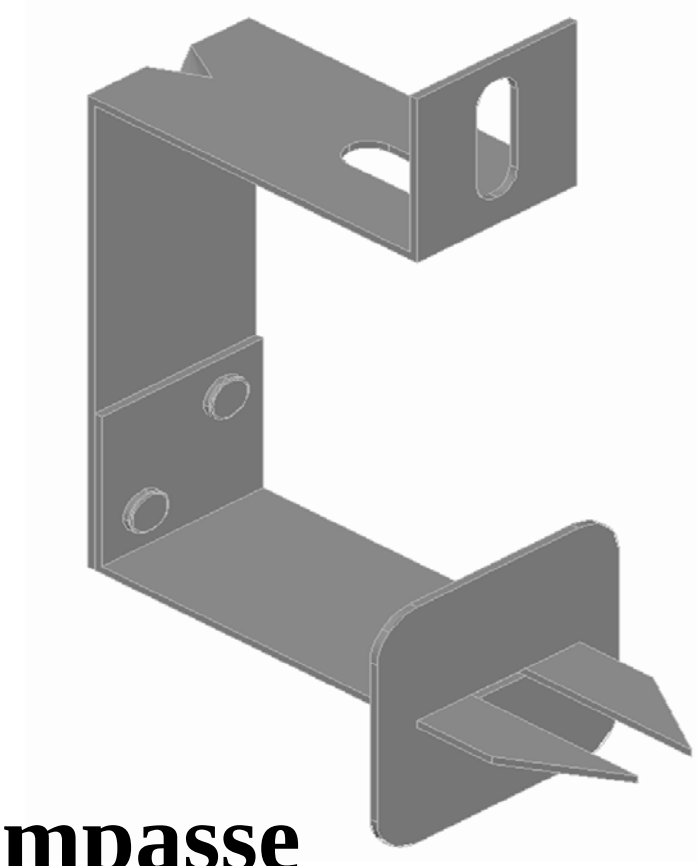
Original Style Hangers









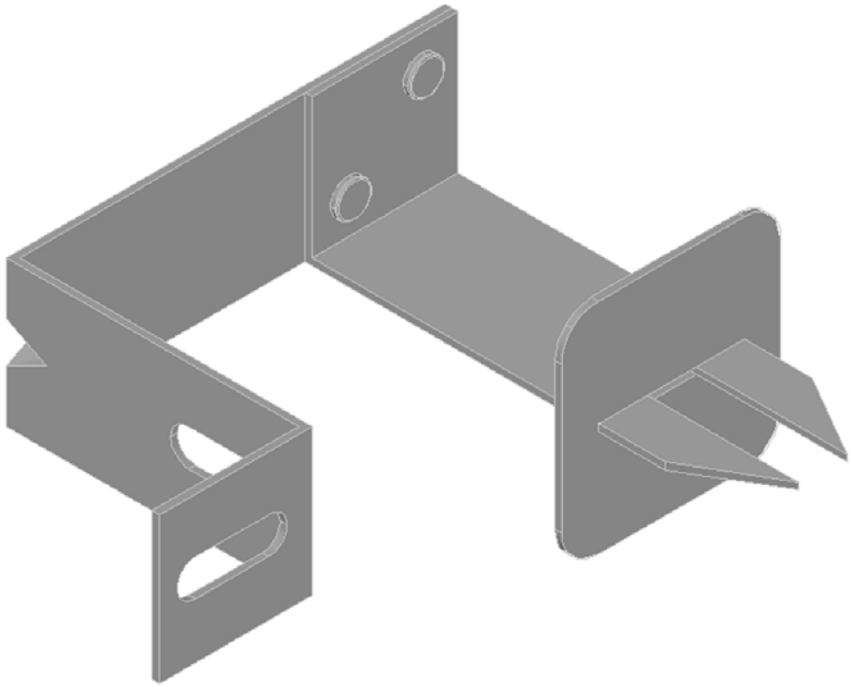


Impasse

Horizontal Hanger

Impasse

Vertical Hanger

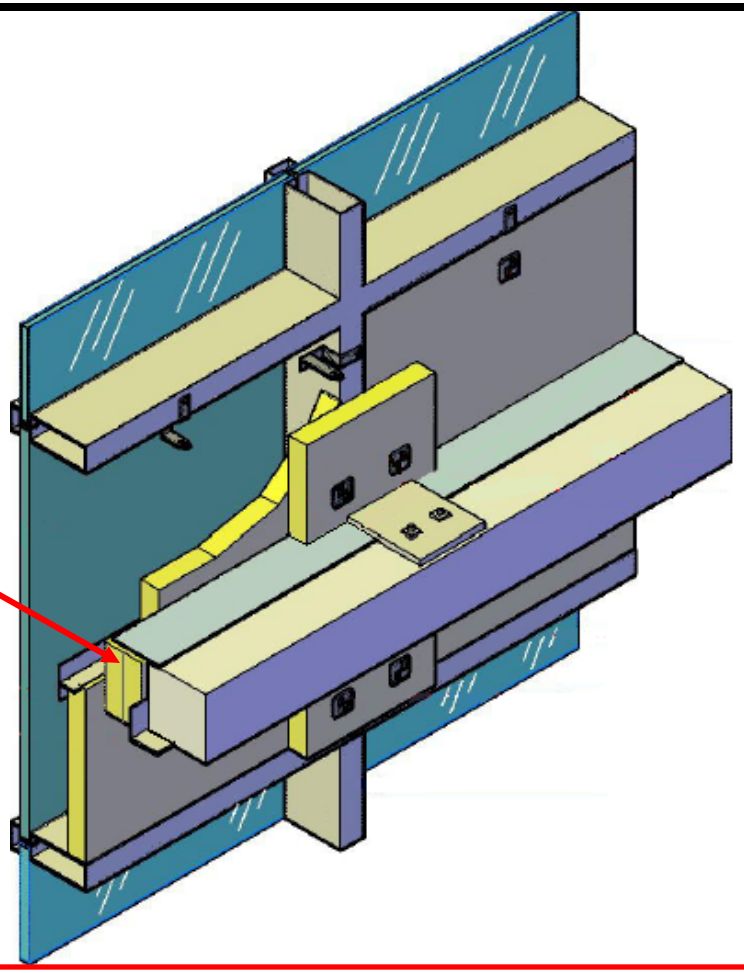


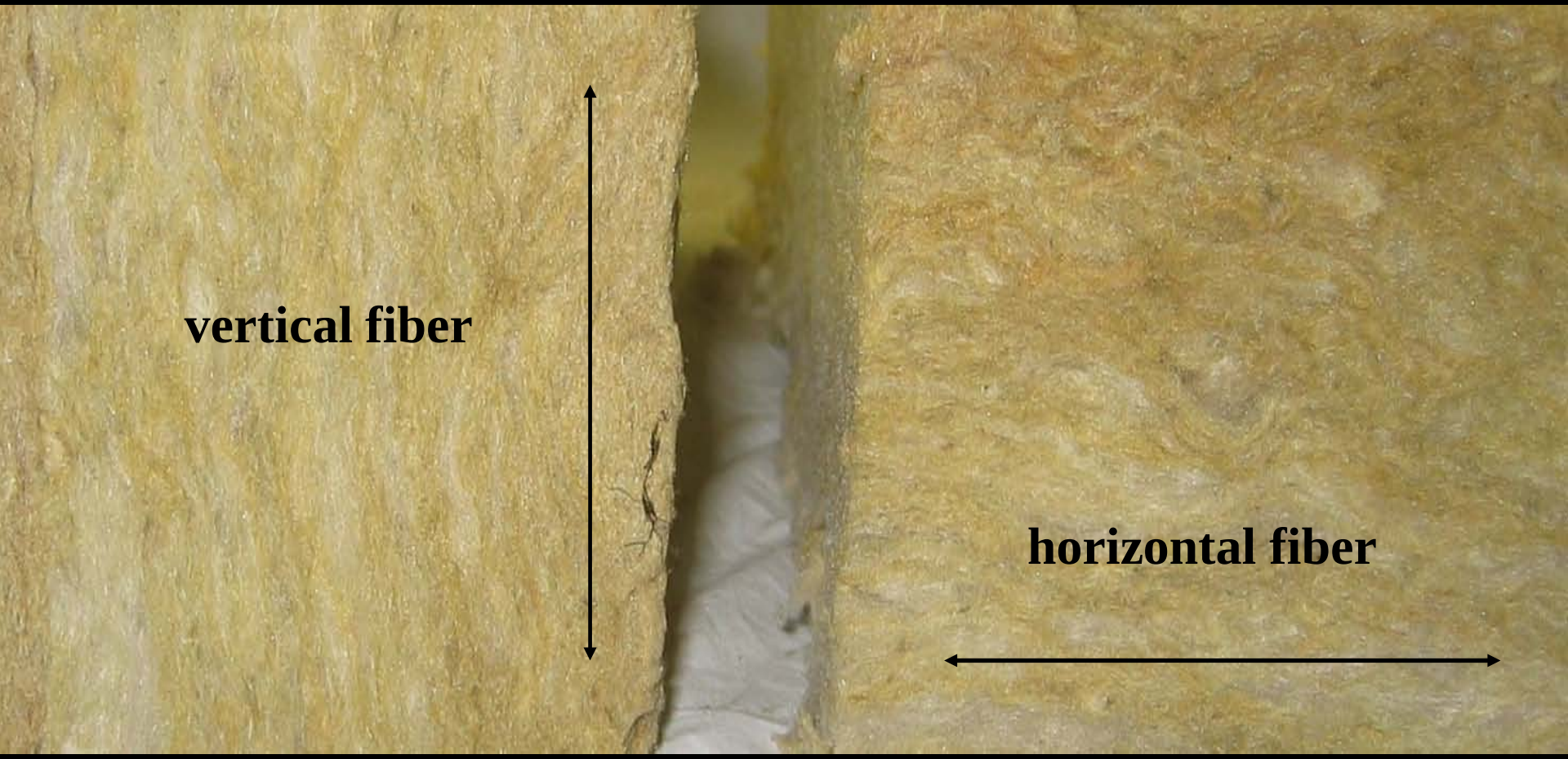
Curtain Wall Fire Containment Systems

Basic Design Principles

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

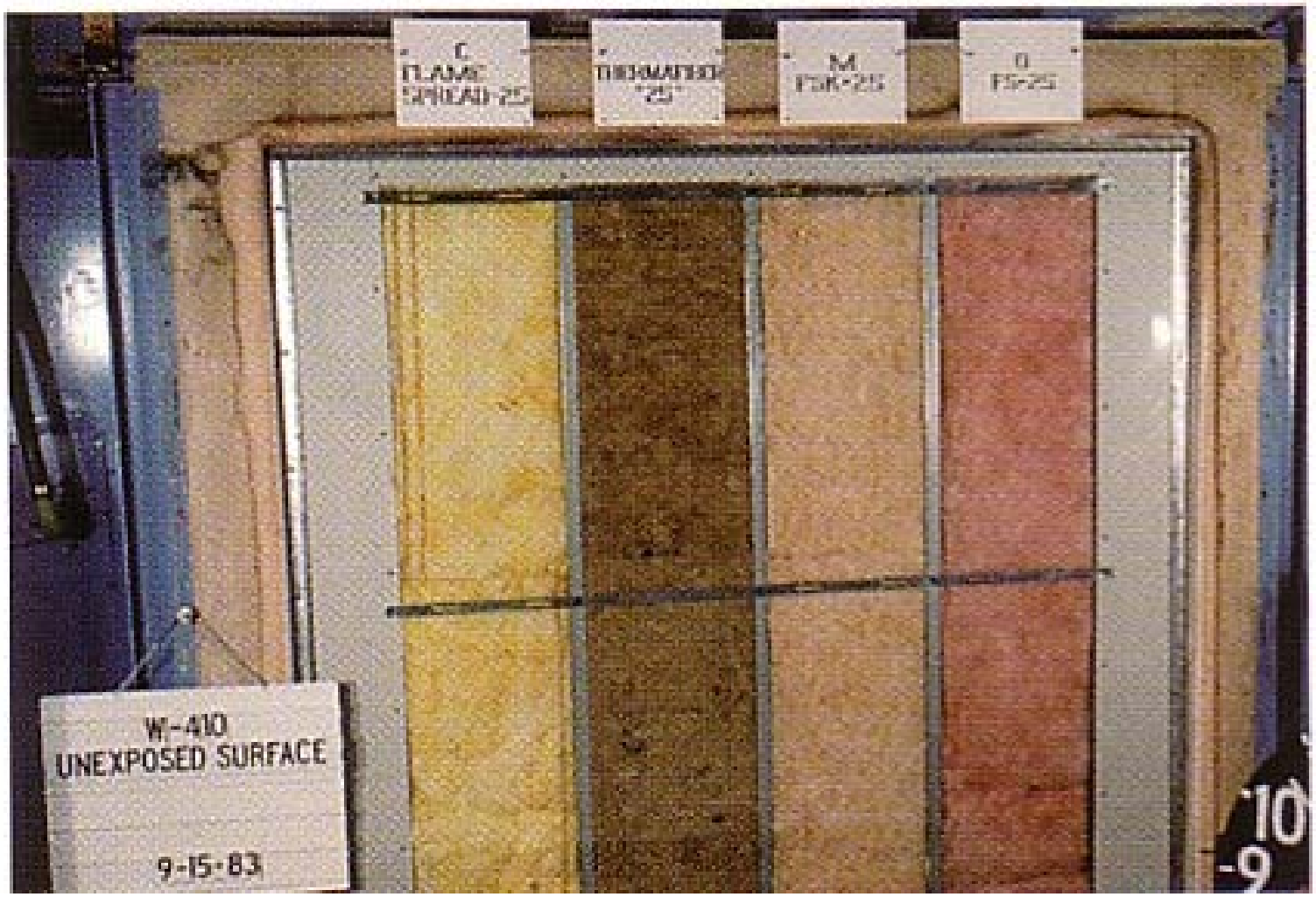
3



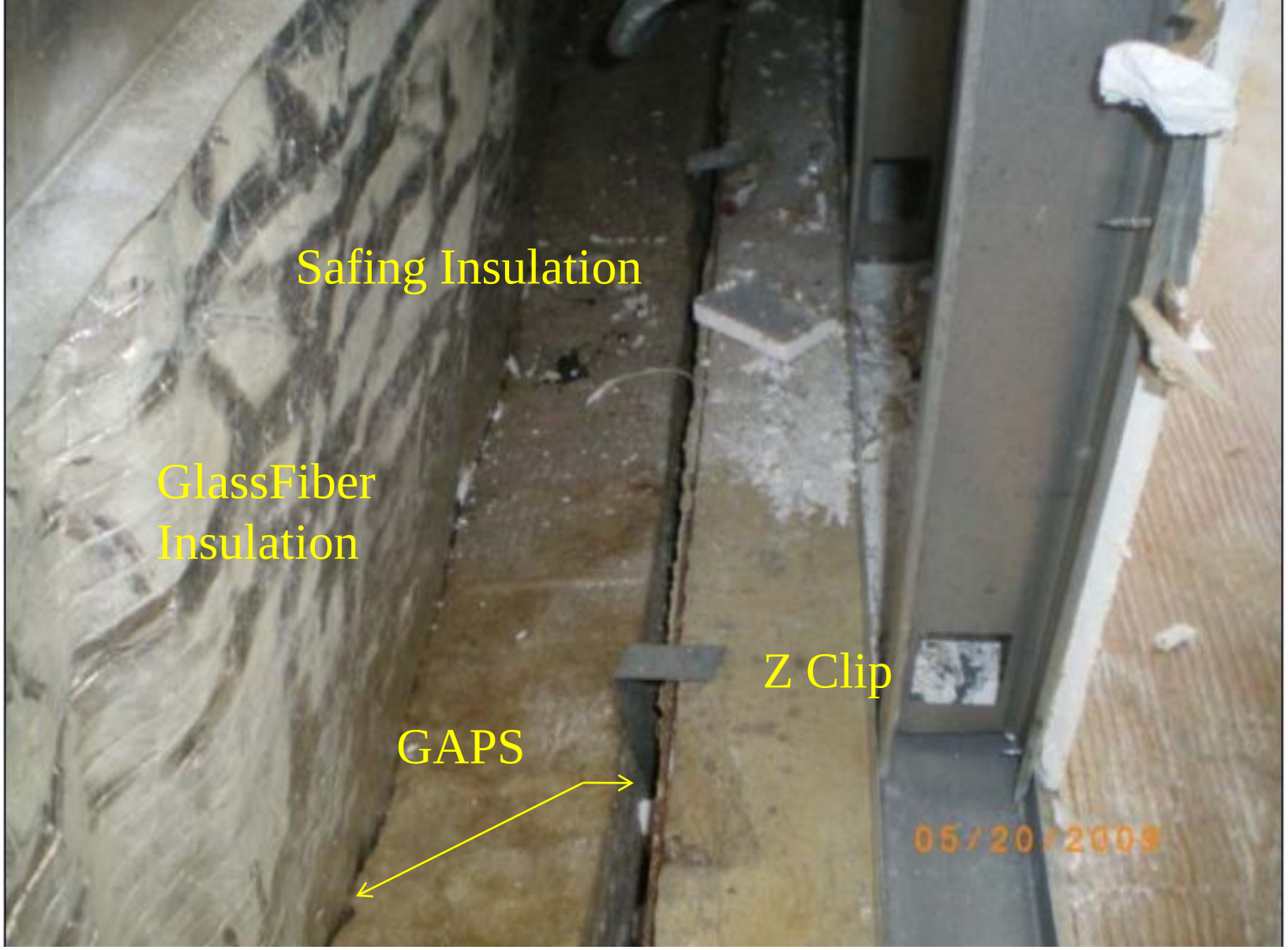

vertical fiber
horizontal fiber


Thermafiber

Insulation before test.



Insulation at 17 minutes into fire test.



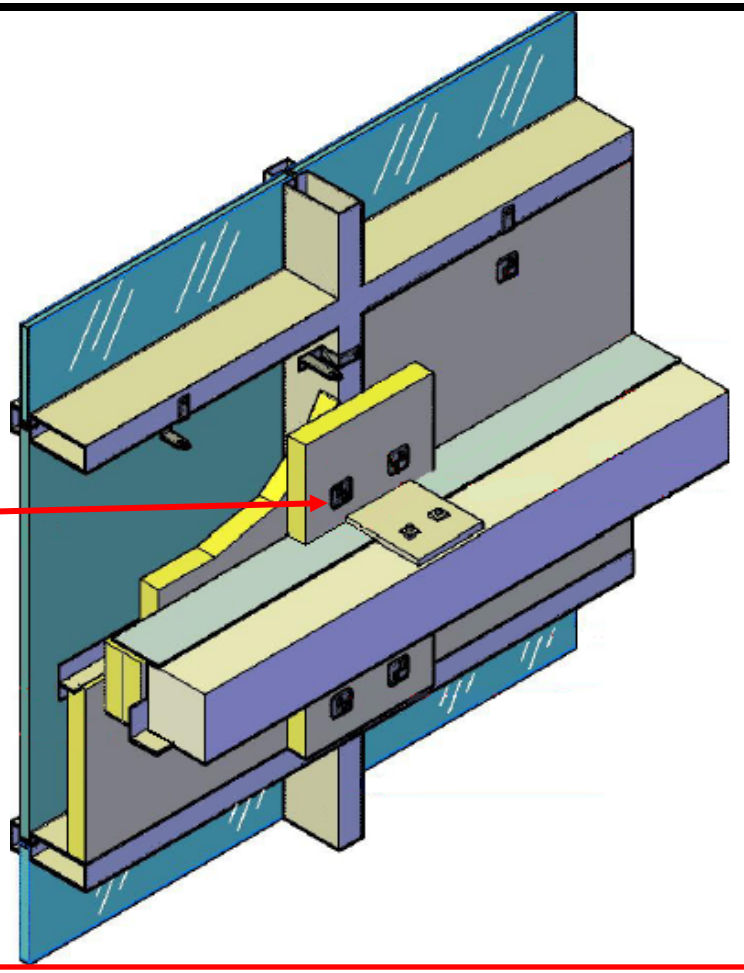
Perimeter Fire Barrier Education

Curtain Wall Fire Containment Systems

Basic Design Principles

Protect Mullions with Mineral Wool Insulation

4



Spiral Anchors

Perimeter Fire Barrier Education

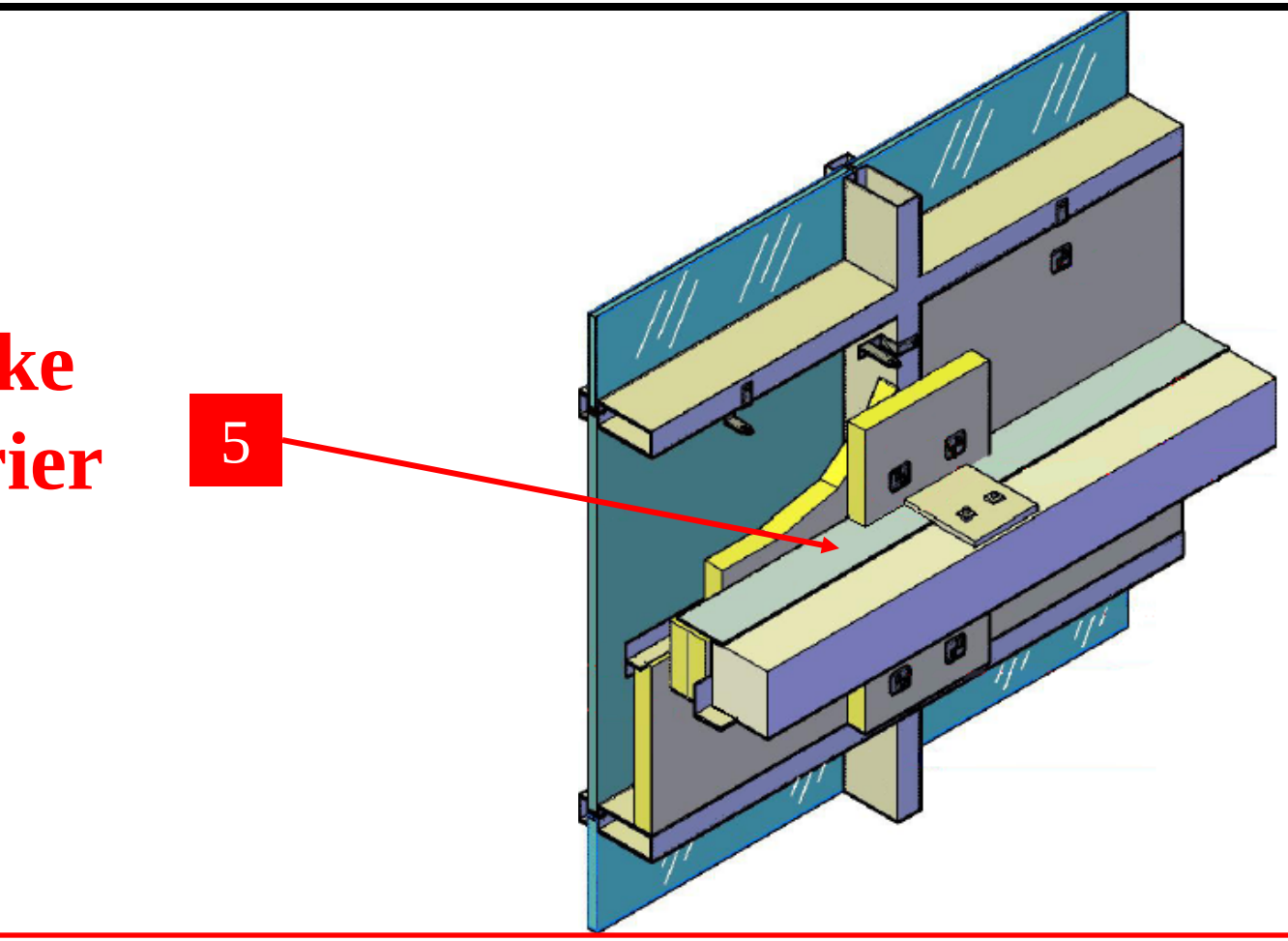
Smoke- The known killer

75% of fire related deaths are caused by smoke inhalation

Curtain Wall Fire Containment Systems

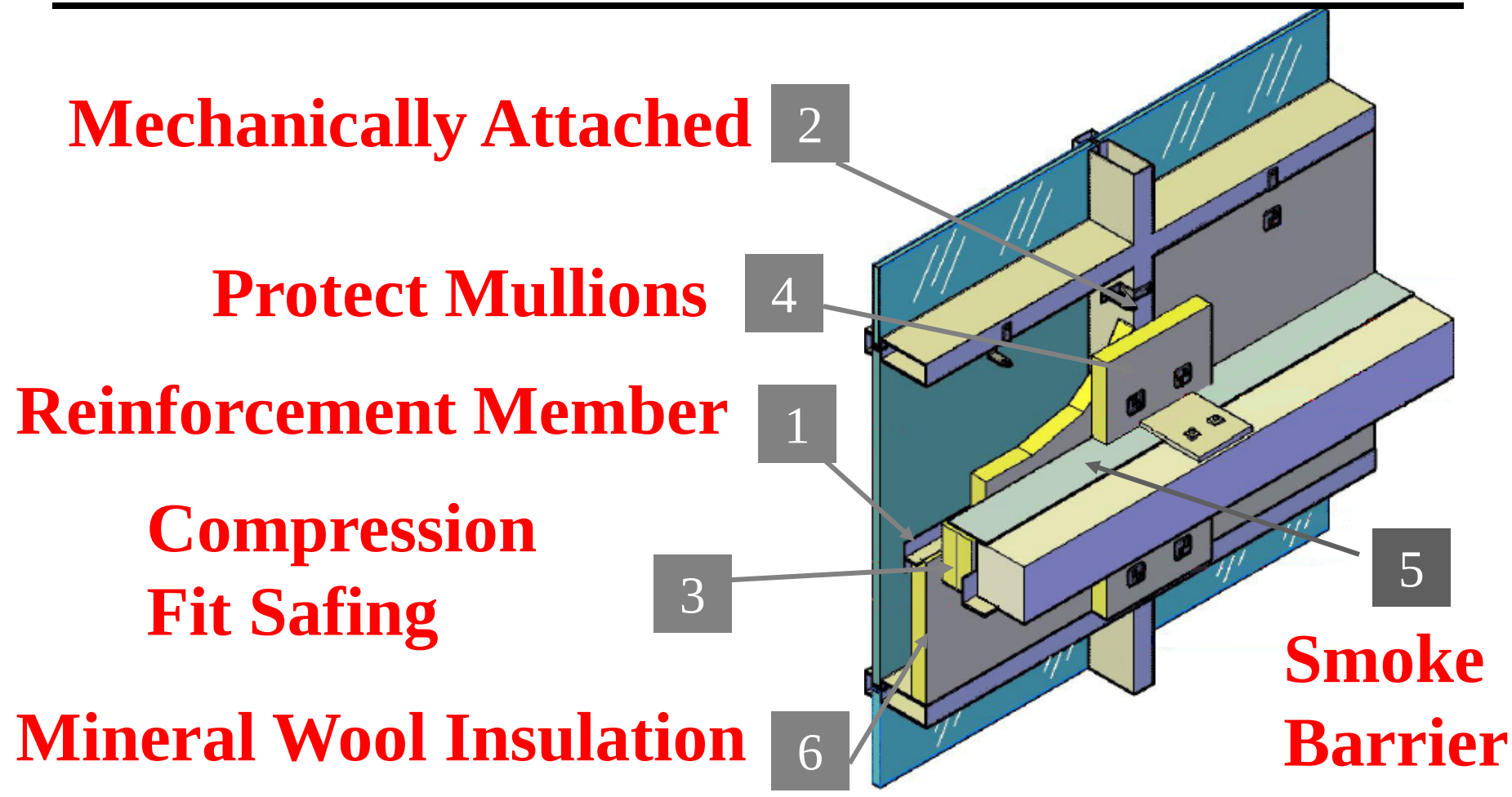
Basic Design Principles

Smoke Barrier

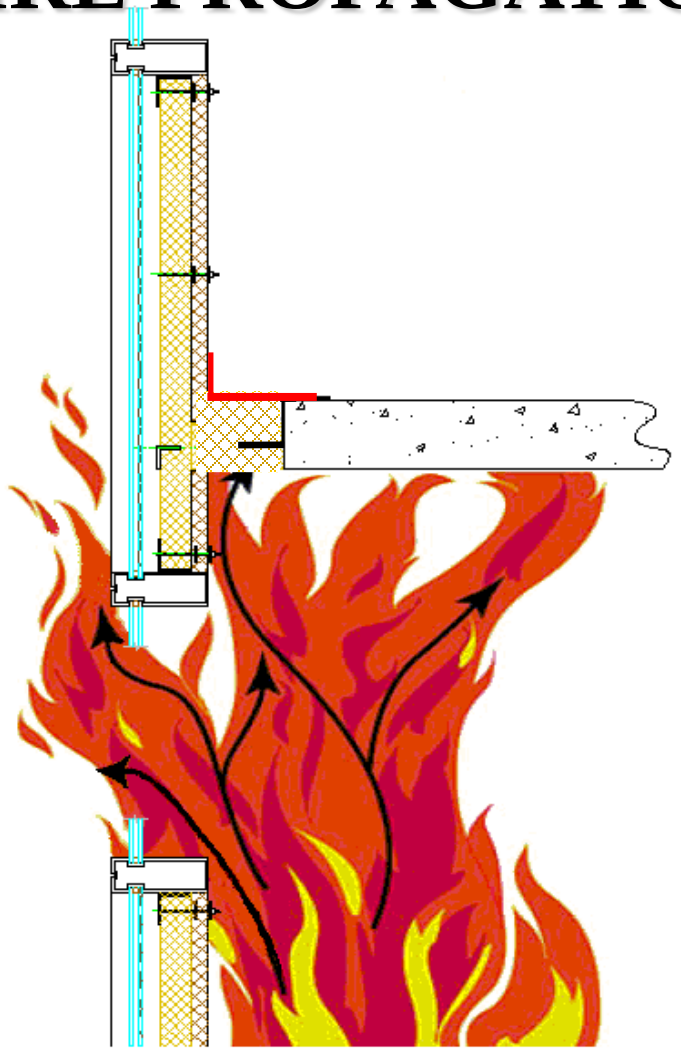


Curtain Wall Fire Containment Systems

Basic Design Principles



PATHS OF FIRE PROPAGATION BLOCKED



Perimeter Fire Barrier Education

What have we learned from recent testing?

Perimeter Fire Barrier Education

Perimeter Fire Barrier Education


Mullions and Transoms after exposure to fire test
Less than 45 minutes of exposure

Design No. CEJ 318 P

PERIMETER FIRE BARRIER SYSTEM

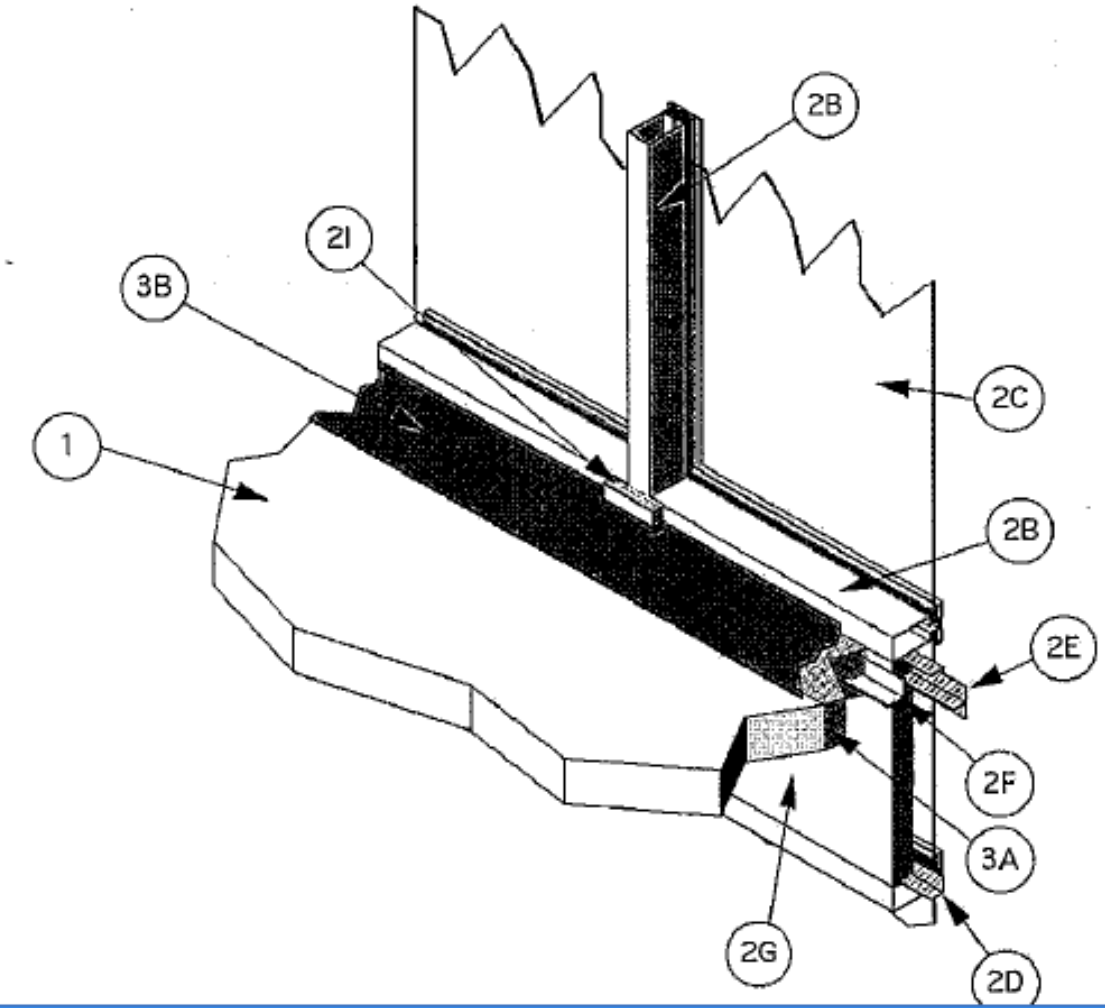
T-Rating – 1-1/4 hr.

F-Rating - 2 hr.

L-Rating <1 SCFM/LF

Rated for ± 12.5% horizontal movement

Rated for ± 6.25% vertical shear movement



ASTM E 2307 - Leap Frog Effect

Project Members: Ryan Rogan Edward Shipper
Advisors: Gretar Tryggvason Sponsor: Jonathan Barnett
Mechanical Engineering Department

Abstract

The large-scale fire test specified in ASTM Standard E 2307 is used to evaluate a perimeter fire containment system in a building. It is used to predict flame spread through a building's exterior via windows through a phenomenon known as leap-frogging. This project developed computer-based tools to assist in the development of modifications to ASTM E 2307 to account for leap-frogging. We used the Computational Fluid Dynamics model Fire Dynamics Simulator for this task. As a result of our work the ASTM task group modifying ASTM E 2307 will be able to look at the effect of test apparatus geometry modifications including spandrel height and window size, height and width, on the propensity for leap-frogging.

Introduction

The spread of fire during a multi-story building fire can occur via a "leap frog" effect in which fire migrates floor to floor by "jumping" through exterior wall openings. Much research and testing has been performed to test the fire perimeter protection systems put in place in high-rise buildings today. All buildings in which a fire barrier is required in NFPA codes are required to have these systems in place as per ASTM E 2307. However when a fire occurs, the possibility exists for the fire to propagate throughout the building by leaping up the building via windows. The ASTM E 2307 test features an apparatus in which a burner is located within the burn room to simulate a fire while a second burner, activated a five minutes after first burner ignition, simulates the growth of the fire to a point where the fire has expanded out of the window. The purpose of our MQP is to determine if the current ASTM E 2307 test can accurately simulate the leap frog effect observed in high-rise building fires and if not, to determine if modification of the current test or creation of a new test is necessary. It has been found that in order for a single 5mm thick glass panel to break out with a high probability, a heat flux of 25 kW/m^2 must be achieved. There is also a slight chance of glass fallout with a heat flux of 6 kW/m^2, so these are the heat flux values we focused on in making our conclusions.

Methodology

To observe the leap frog effect of a fire from one floor to another via an exterior window opening we implemented a program called PyroSim. PyroSim is a graphical user interface that is used to create the command lines for FDS, the Fire Dynamics Simulator. A fire dynamics simulator is a computational fluid dynamics model of fire driven fluid flow. The software numerically solves a form of the Navier-Stokes equations appropriate for low speed, thermally driven flow with an emphasis on smoke and heat transport from fires. Smokeview is a program that is used to visually simulate the output of the FDS program. The National Institute of Standards and Technology (NIST) develop the Fire Dynamics Simulator and Smokeview programs.

Project Objectives

- Study previous fire tests involving leap frogging
- Model ASTM E 2307 using PyroSim/FDS
- Vary window dimensions to determine when leap frog occurs
- Observe heat flux and flame propagation onto exterior wall

FDS Governing Equations

Conservation of Mass

$$\frac{\partial \rho}{\partial t} + \nabla \cdot \rho \mathbf{u} = \dot{m}'''$$

Conservation of Species

$$\frac{\partial \rho Y_\alpha}{\partial t} + \nabla \cdot \rho Y_\alpha \mathbf{u} = \nabla \cdot \rho D_\alpha \nabla Y_\alpha + \dot{m}'''_\alpha$$

Conservation of Momentum

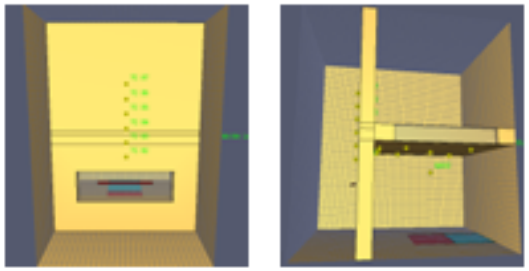
$$\frac{\partial \mathbf{u}}{\partial t} + \mathbf{u} \cdot \nabla \mathbf{u} + \nabla H = \frac{1}{\rho}\left(\mathbf{f} - \rho_\infty g \mathbf{k}\right) + \frac{1}{\rho}\nabla \cdot \tau_{ij}$$

Pressure Equation

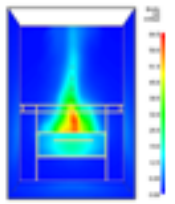
$$\nabla^2 H = -\frac{\partial \nabla \cdot \mathbf{u}}{\partial t} - \nabla \cdot \mathbf{F} \quad ; \quad \mathbf{F} = \mathbf{u} \cdot \nabla \mathbf{u} + \frac{1}{\rho}\left(\mathbf{f} - \rho_\infty g \mathbf{k}\right) + \frac{1}{\rho}\nabla \cdot \tau_{ij}$$

Equation of State

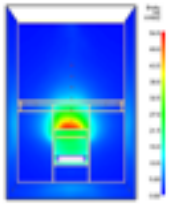
$$p_\alpha(x,t) = \rho R T \sum_\alpha Y_\alpha / W_\alpha$$



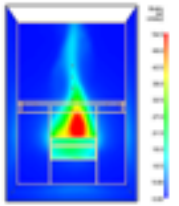
Front and side views of the ASTM E 2307 FDS Model



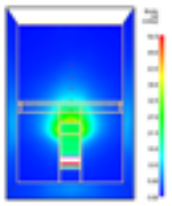
ASTM Test Model Heat Flux



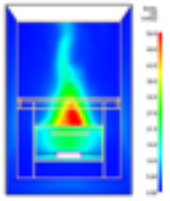
3 x 3 ft. Window Heat Flux



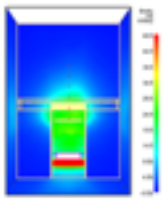
2.125 x 4.25 ft. Window Heat Flux



4.25 x 2.125 ft. Window Heat Flux



3.1875 x 6.375 Window Heat Flux

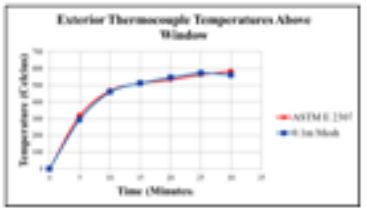


6.375 x 3.1875 ft. Window Heat Flux

Results

- A summary of the different model simulations can be seen in the table below.

- Our FDS model was able to simulate the ASTM E 2307 test fairly accurately as seen in the graph below.



- Flames are closer to the wall when using wider sized windows, which means the heat flux on the wall is also higher.
- Tall narrow windows have a separation between the wall and the flames.

Wide Window

Square Window

Tall Window

Conclusions

After running many computer simulations, we have concluded that the setup that would best model a leap frog scenario would be the 3.1875 x 6.375 foot wide window. The flame height from this sized window is taller than any of the other windows that were tested. The heat fluxes against the exterior wall are sufficient enough to have a possibility to cause glass breakage over 10 feet above the top of the window. Leap frogging has caused substantial damage to high rise buildings in the past, and with our results the ASTM committee will be able to construct a test to help prevent leap frogging in future buildings.

Fire Protection

Perimeter Fire Barrier Education

Energy Efficiency

Life Safety Is Our #1 Priority

<u>Shouldn't it be yours?</u>

Perimeter Fire Barrier Education

Why passive fire protection?

What is mineral wool?

Areas where fire can propagate

Design Principles

Perimeter Fire Containment

Questions-??

Testing parameters

ASTM E119

Testing Labs

Theory to application

Code requirements

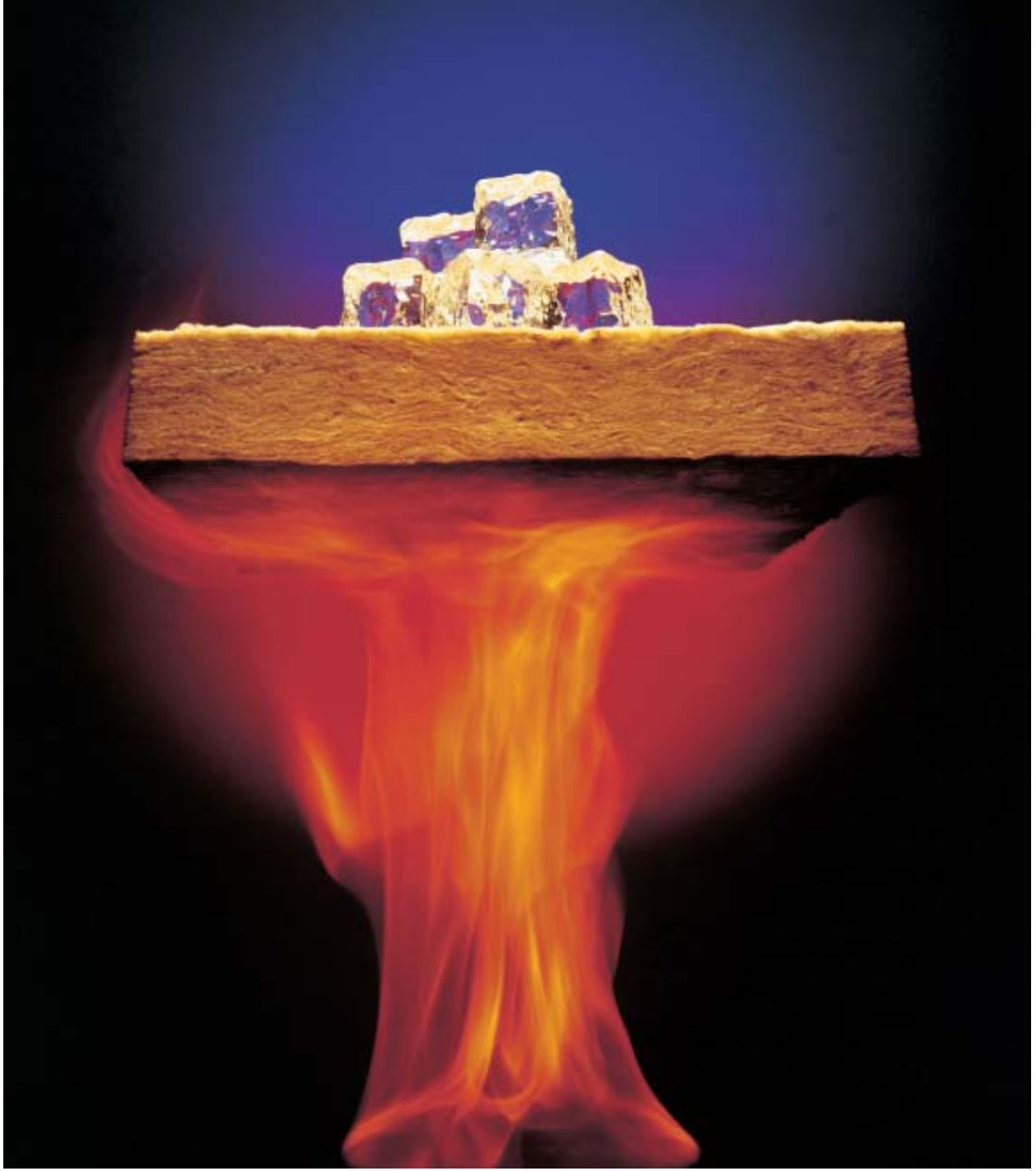
The 3 Elements of life safety

Perimeter fire containment assemblies installed in major high rises throughout the world.

Petronas Towers- Kuala Lumpur

Sears Tower- Chicago

Taipei 101- Taipei, Taiwan



IBC 2006

Section 713.4 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 material or system** to prevent the **interior spread** of fire. **Such material or systems shall be securely installed and capable of preventing the passage of flame and hot gases** sufficient to ignite cotton waste where subjected ***EITHER*** to ASTM E 119 time-temperature fire conditions under a minimum positive pressure differential of 0.01 inch of water column (2.5 Pa), ***or installed as tested in accordance with ASTM E 2307*** **for the time period at least equal to the fire- resistance rating of the floor assembly.** Height and fire-resistance requirements for curtain wall spandrels shall comply with Section 704.9.

Perimeter Fire Barrier Education

Codes Today- IBC (2006)

Section 704.9 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 building 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 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…

Exceptions:

1) **This section shall not apply to buildings that are three stories or less in height.**

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.**

Perimeter Fire Barrier Education

Codes Today- IBC (2006)

NEW

Section 713.5 Spandrel Wall

Height and fire-resistance requirements for curtain wall spandrel panels shall comply with section 704.9. Where Section 704.9 does not require a fire resistance-rated spandrel wall, the requirements of Section 713.4 shall still apply to the intersection between the spandrel wall and the floor.

Why is High-Rise Fire Safety Necessary?

Atlanta Fire- June 30, 1989

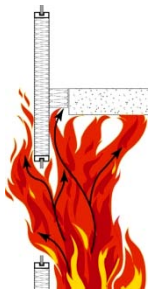
Program Overview

- History of Perimeter Fire Containment & Testing
- 3 Elements of Life Safety
- The Building Codes
- AAMA Publication
- ASTM Teting
- Design Principles
- Rated Curtain Wall Assemblies
- Questions and Answers

These three elements of Life Safety represent a

DETECTION

Balanced System



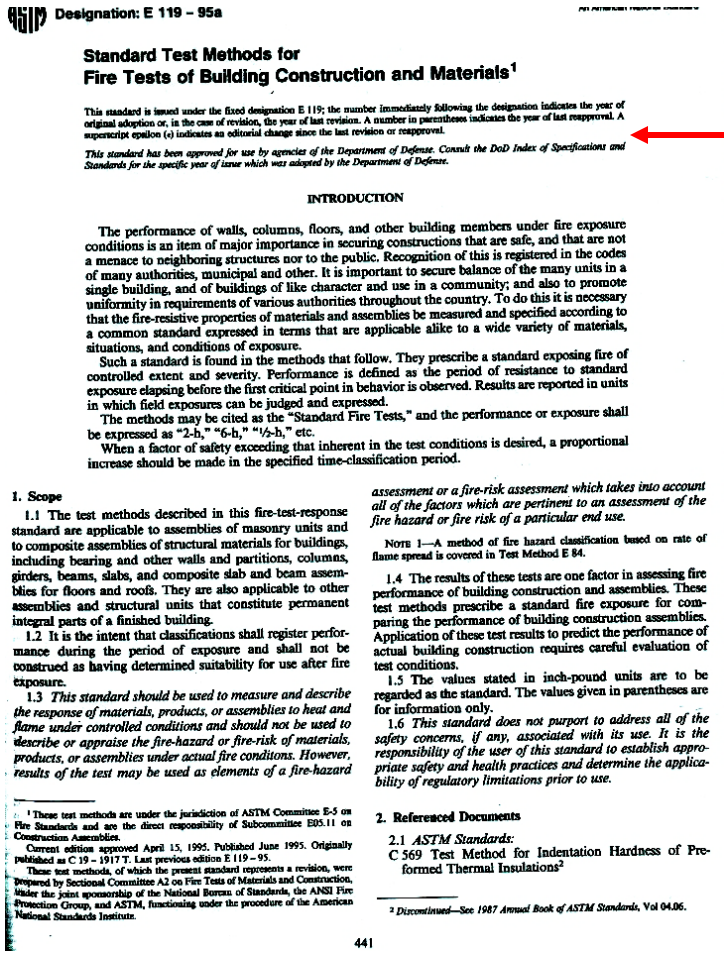
Passive Systems

COMPARTMENTATION

Active Systems

SUPPRESSION

ASTM E 119- Standard Test Methods for Fire Tests of Building Construction and Materials



Designation: E 119 – 95a

Standard Test Methods for Fire Tests of Building Construction and Materials[1]

This standard is issued under the fixed designation E 119; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which was adopted by the Department of Defense.

INTRODUCTION

The performance of walls, columns, floors, and other building members under fire exposure conditions is an item of major importance in securing constructions that are safe, and that are not a menace to neighboring structures nor to the public. Recognition of this is registered in the codes of many authorities, municipal and other. It is important to secure balance of the many units in a single building, and of buildings of like character and use in a community; and also to promote uniformity in requirements of various authorities throughout the country. To do this it is necessary that the fire-resistive properties of materials and assemblies be measured and specified according to a common standard expressed in terms that are applicable alike to a wide variety of materials, situations, and conditions of exposure.

Such a standard is found in the methods that follow. They prescribe a standard exposing fire of controlled extent and severity. Performance is defined as the period of resistance to standard exposure elapsing before the first critical point in behavior is observed. Results are reported in units in which field exposures can be judged and expressed.

The methods may be cited as the "Standard Fire Tests," and the performance or exposure shall be expressed as "2-h," "6-h," "½-h," etc.

When a factor of safety exceeding that inherent in the test conditions is desired, a proportional increase should be made in the specified time-classification period.

1. Scope

1.1 The test methods described in this fire-test-response standard are applicable to assemblies of masonry units and to composite assemblies of structural materials for buildings, including bearing and other walls and partitions, columns, girders, beams, slabs, and composite slab and beam assemblies for floors and roofs. They are also applicable to other assemblies and structural units that constitute permanent integral parts of a finished building.

1.2 It is the intent that classifications shall register performance during the period of exposure and shall not be construed as having determined suitability for use after fire exposure.

1.3 *This standard should be used to measure and describe the response of materials, products, or assemblies to heat and flame under controlled conditions and should not be used to describe or appraise the fire-hazard or fire-risk of materials, products, or assemblies under actual fire conditons. However, results of the test may be used as elements of a fire-hazard assessment or a fire-risk assessment which takes into account all of the factors which are pertinent to an assessment of the fire hazard or fire risk of a particular end use.*

NOTE 1—A method of fire hazard classification based on rate of flame spread is covered in Test Method E 84.

1.4 The results of these tests are one factor in assessing fire performance of building construction and assemblies. These test methods prescribe a standard fire exposure for comparing the performance of building construction assemblies. Application of these test results to predict the performance of actual building construction requires careful evaluation of test conditions.

1.5 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 569 Test Method for Indentation Hardness of Preformed Thermal Insulations[2]

[1] These test methods are under the jurisdiction of ASTM Committee E-5 on Fire Standards and are the direct responsibility of Subcommittee E05.11 on Construction Assemblies.

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These test methods, of which the present standard represents a revision, were prepared by Sectional Committee A2 on Fire Tests of Materials and Construction, under the joint sponsorship of the National Bureau of Standards, the ANSI Fire Protection Group, and ASTM, functioning under the procedure of the American National Standards Institute.

[2] *Discontinued—See 1987 Annual Book of ASTM Standards*, Vol 04.06.

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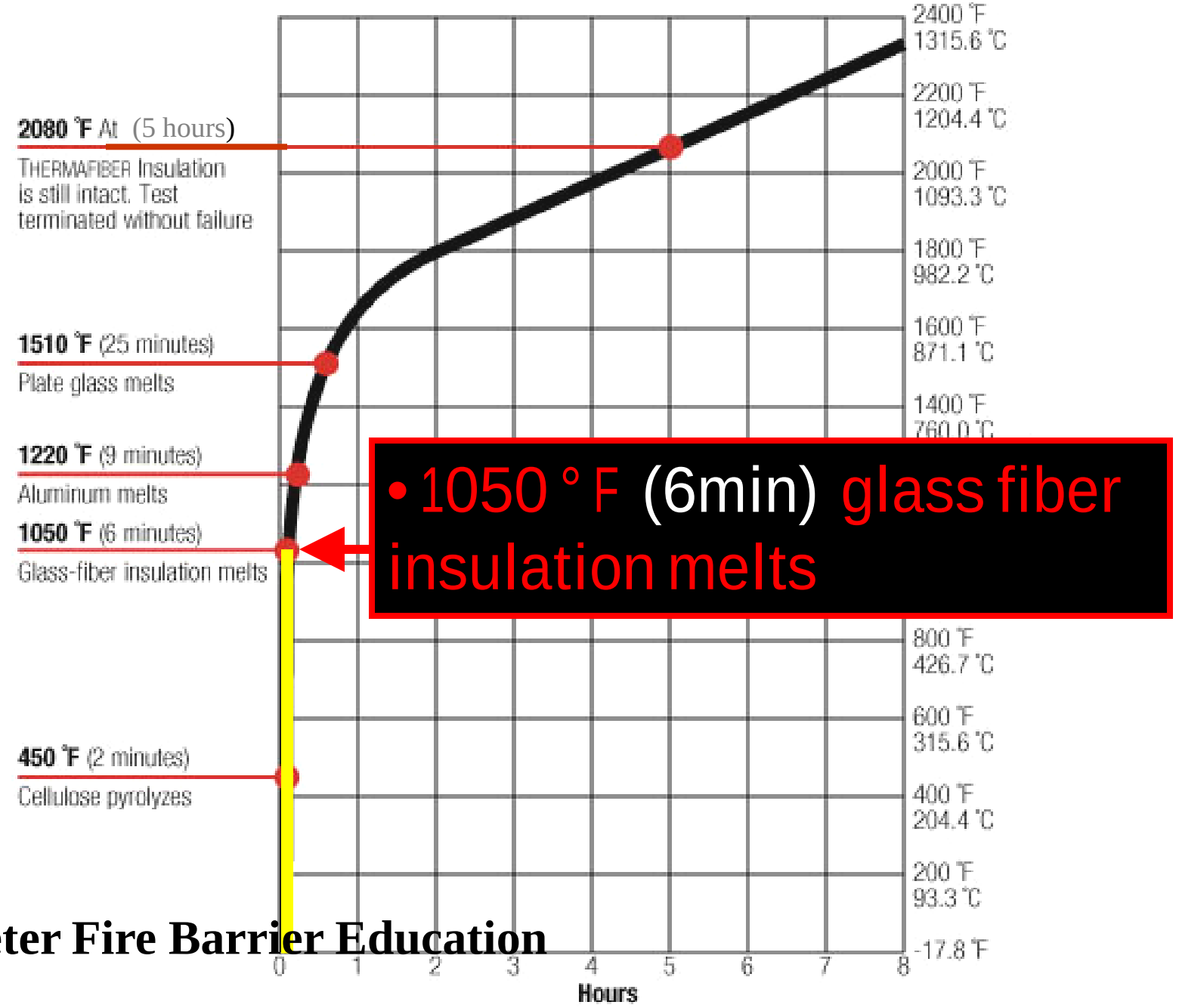
ASTM E 119 TIME - TEMPERATURE CURVE



Perimeter Fire Barrier Education

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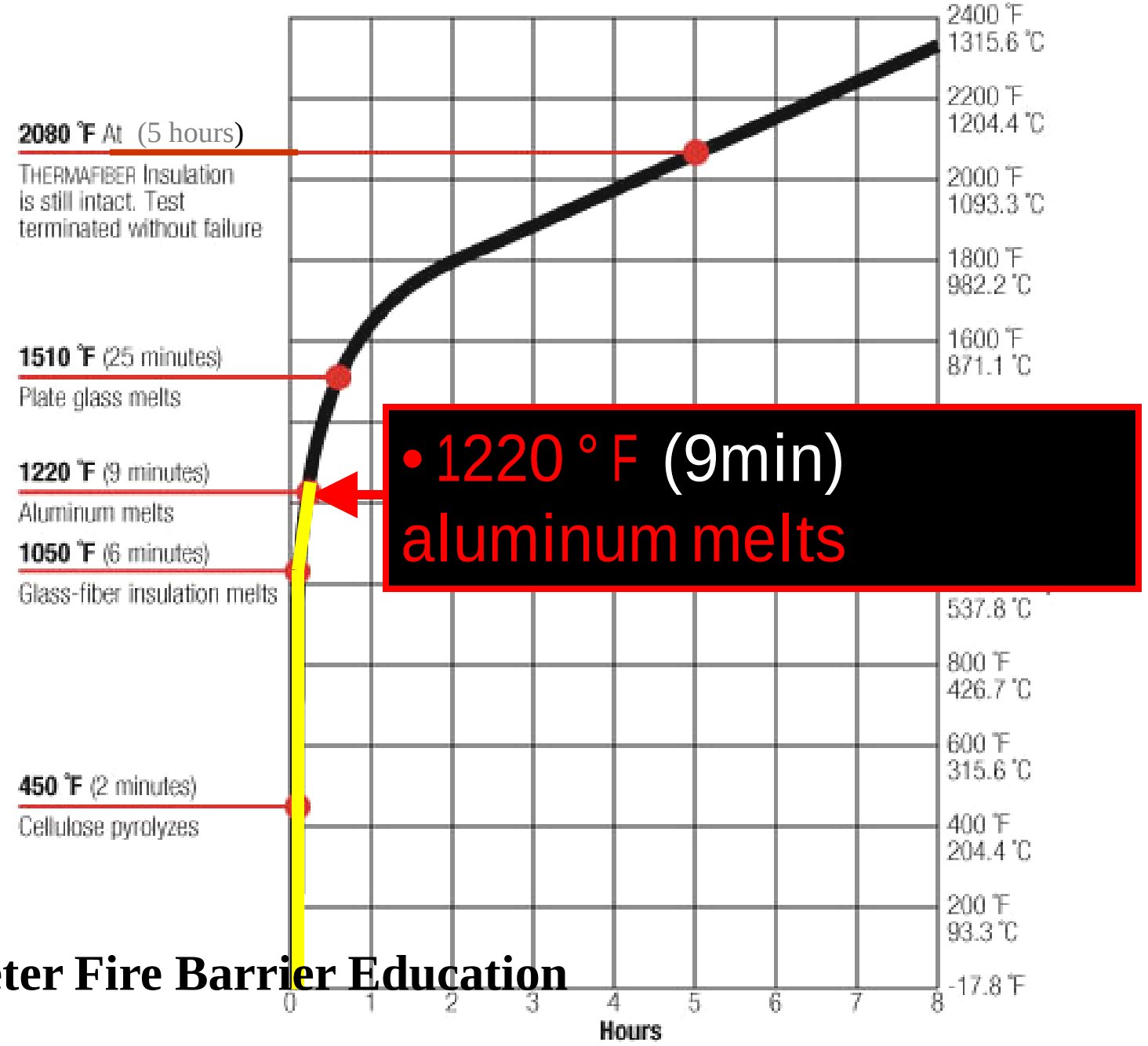
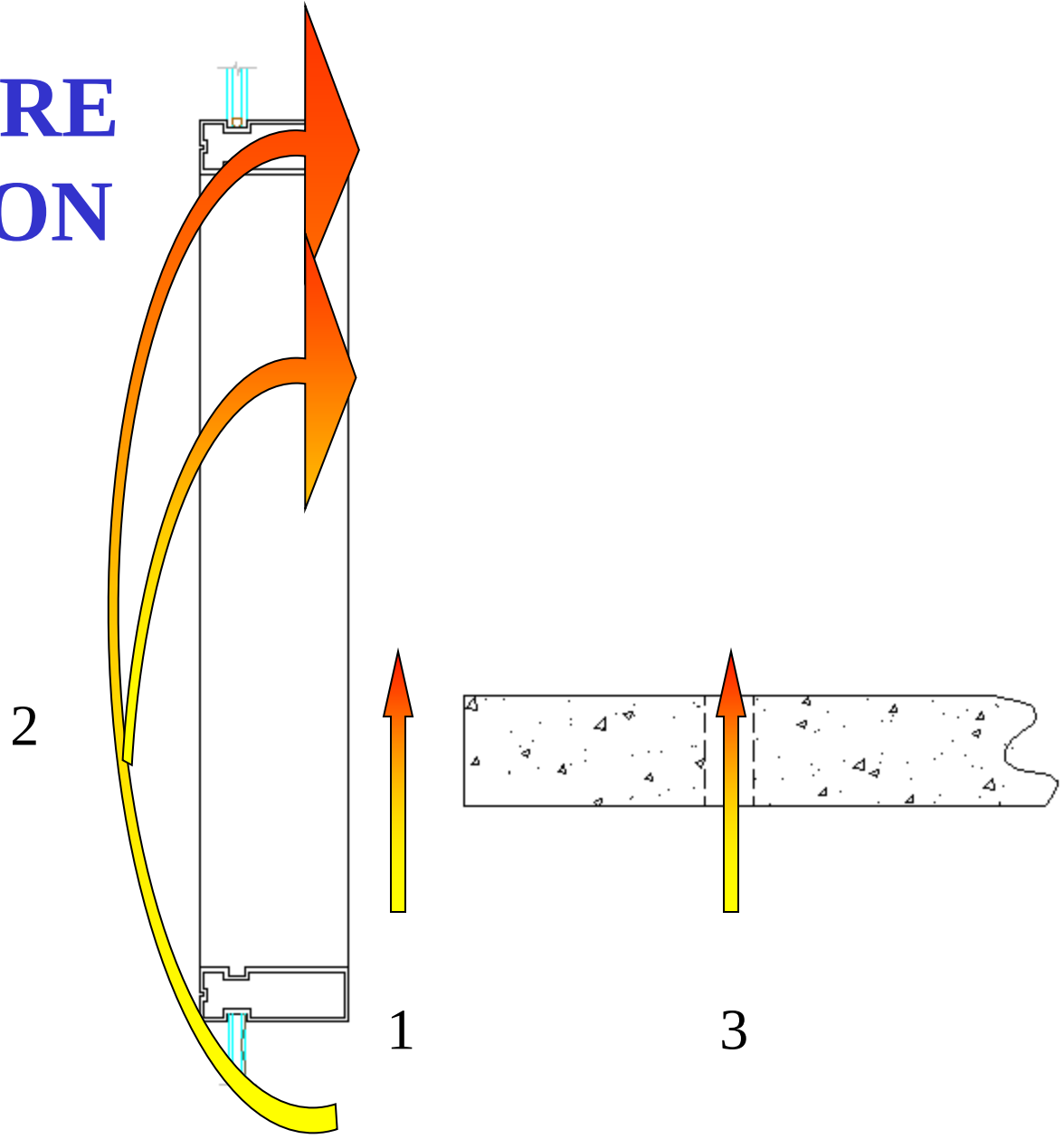


Perimeter Fire Barrier Education

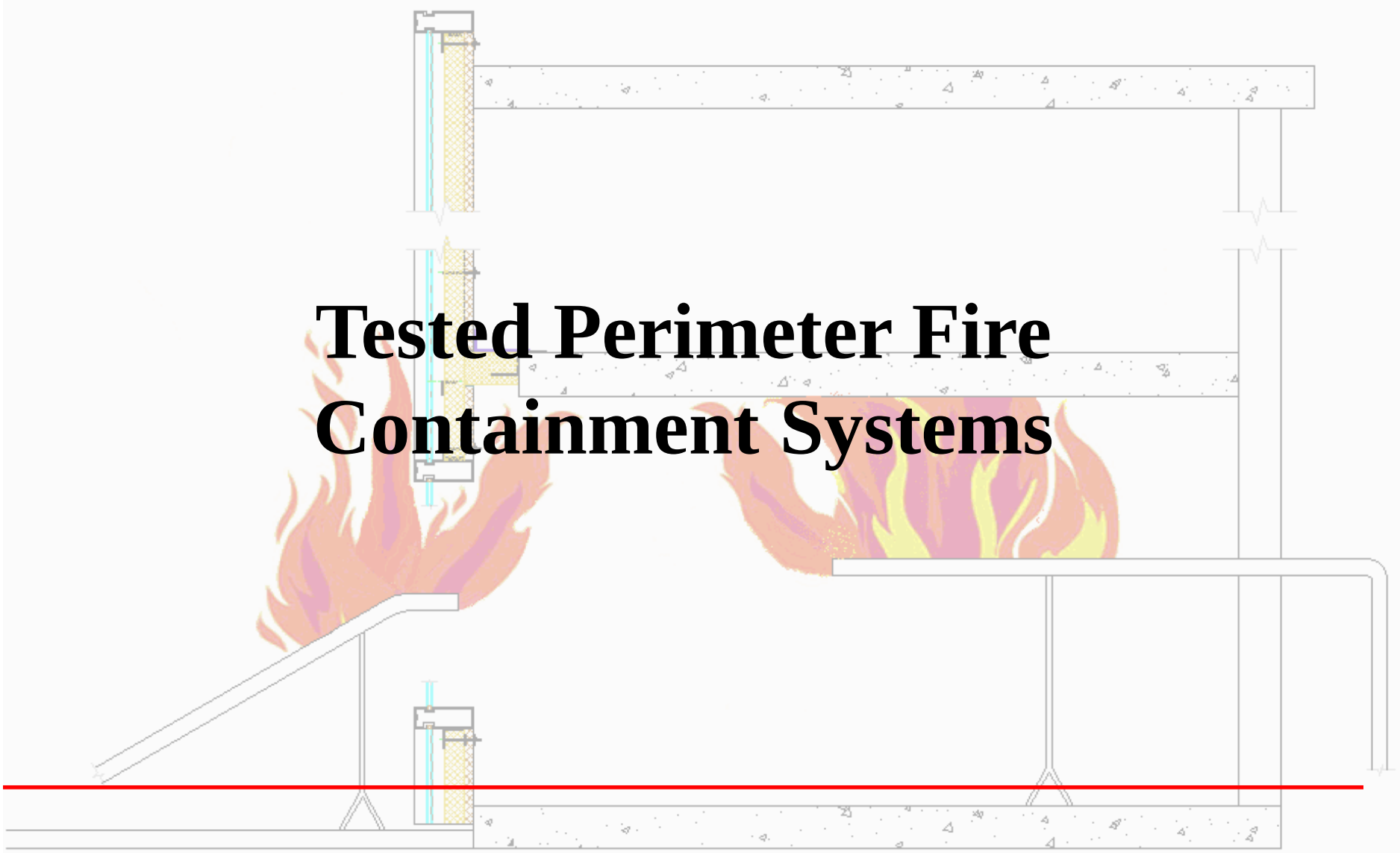
Mullions and Transoms after exposure to fire test

Less than
45 minutes
of exposure

PATHS OF FIRE PROPAGATION



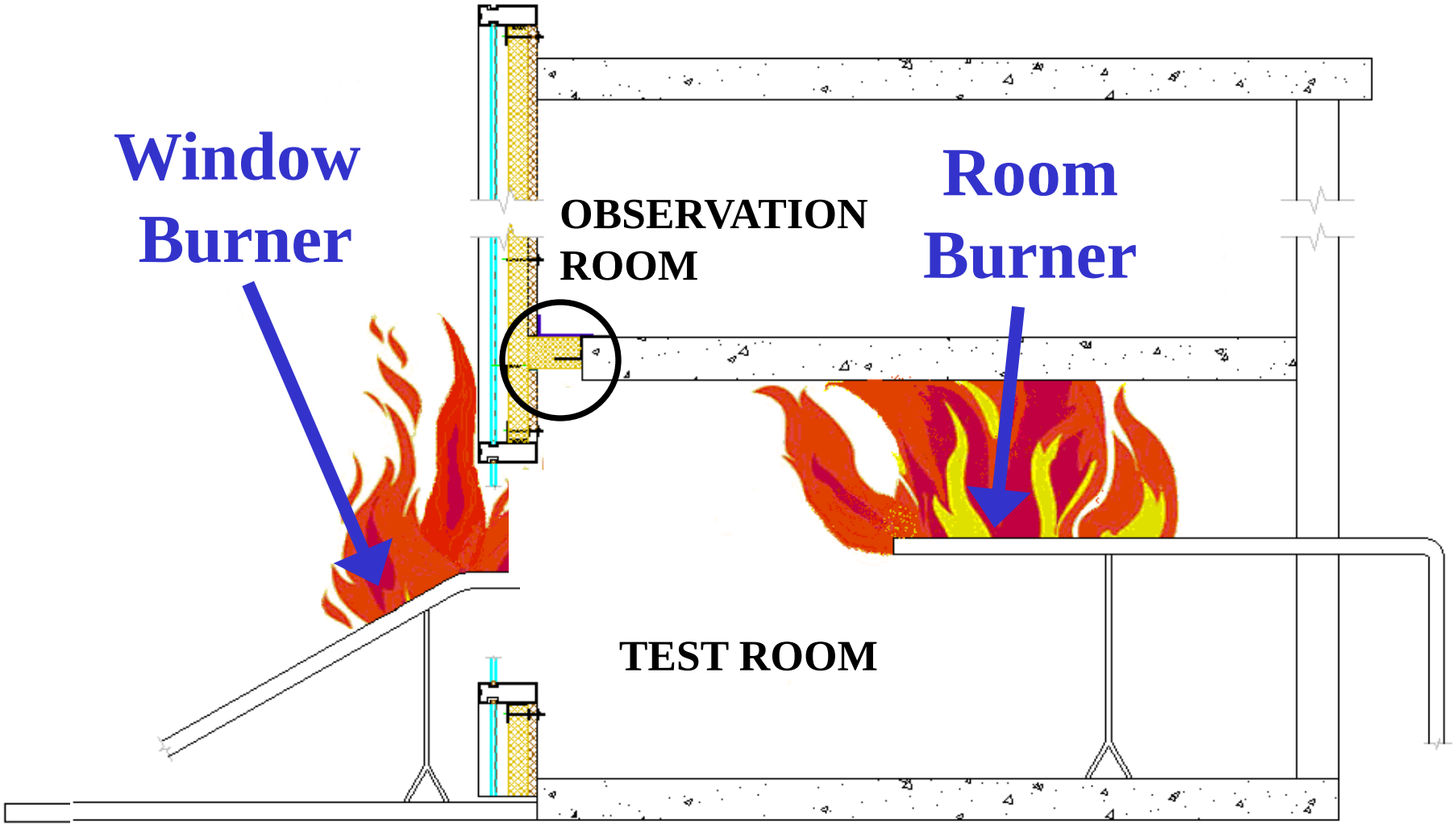
Perimeter Fire Barrier Education



Tested Perimeter Fire Containment Systems

Perimeter Fire Barrier Education

ASTM E 2307- Standard Test Method for Determining Fire Resistance of Perimeter Fire Barrier Systems Using the Intermediate-Scale Multi-story Test Apparatus

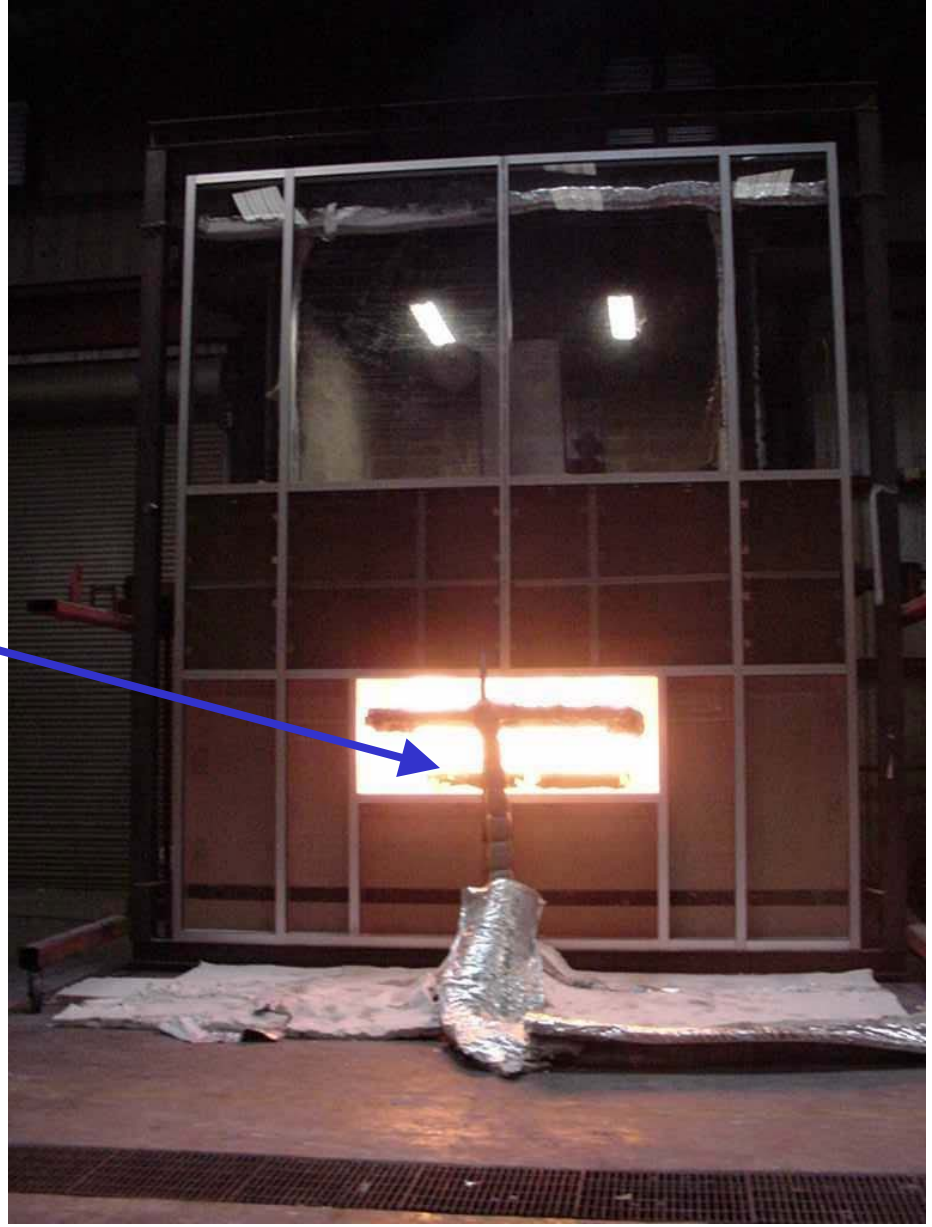


Intermediate Scale Multi-story Test Apparatus

Perimeter Fire Barrier Education

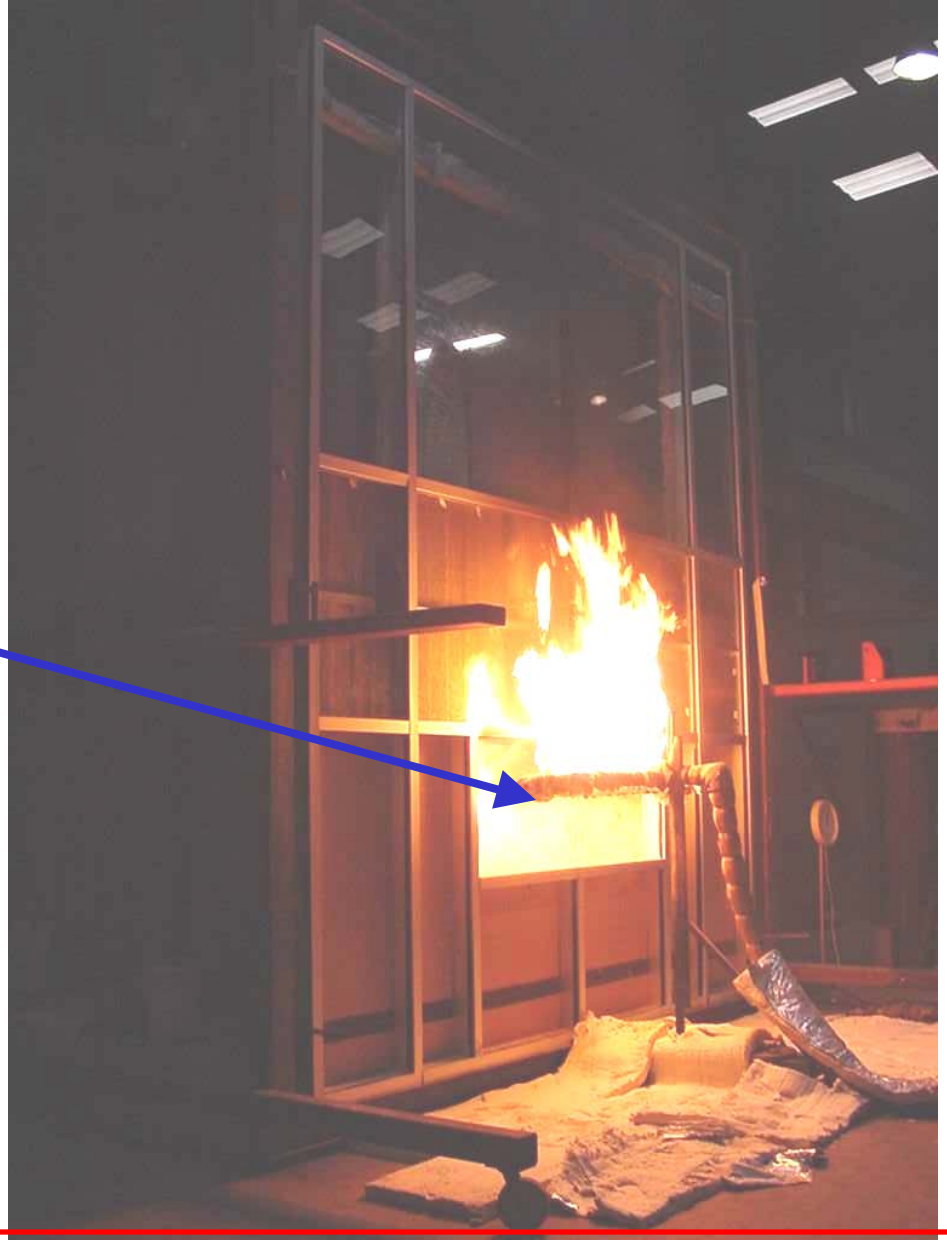
ASTM E 2307

Showing the room burner from the outside of the test apparatus.



ASTM E 2307

After room burner burns for 5 minutes, the window burner is ignited.



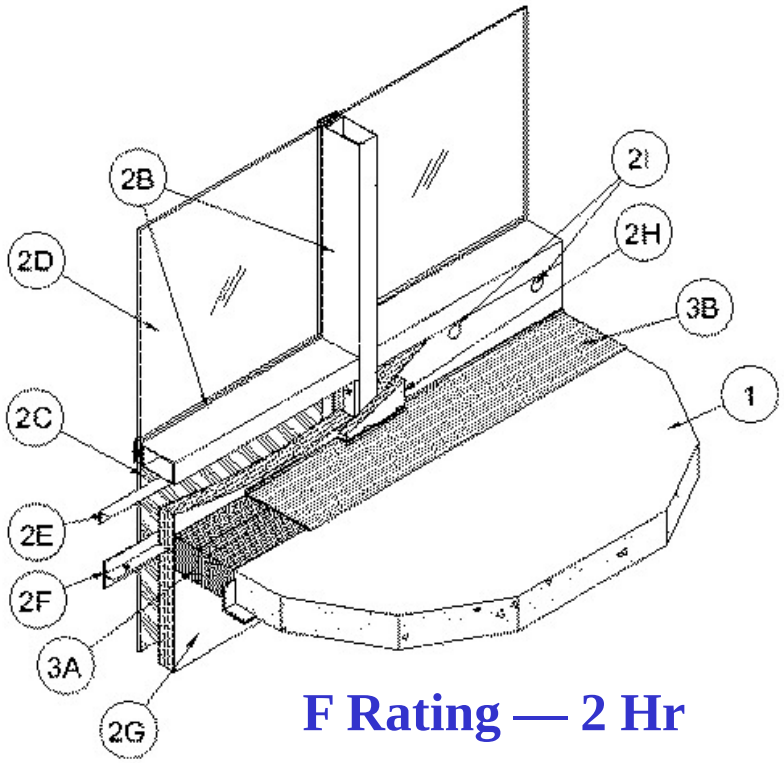
ASTM E 2307

Window burner

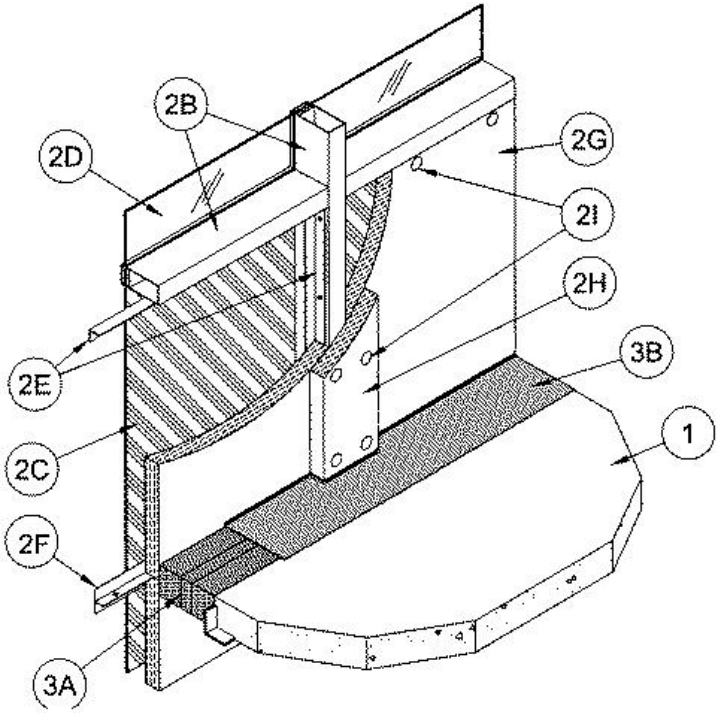
Curtain wall system after fire test

F- Rating- Hour **(Interior Spread per ASTM E 2307)**

Integrity Rating- Hour **(Interior Spread & Leap Frog)**



F Rating — 2 Hr



Integrity Ratings — 1-1/2 and 2 Hr

Perimeter Fire Barrier Education

Leap Frog Effect