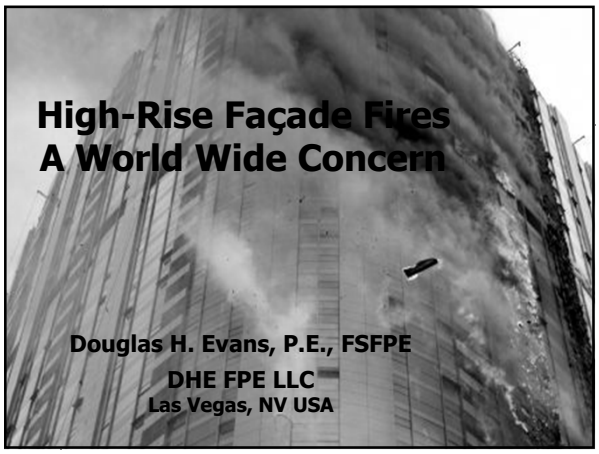


High-Rise Façade Fires
A World Wide Concern

Douglas H. Evans, P.E., FSFPE
DHE FPE LLC
Las Vegas, NV USA

This Presentation will provide An increased understanding of

- Fire protection aspects of High-Rise Building Exterior Facades
- Why these requirements exist
  - fire losses
- Related fire dynamics
- Associated fire tests
- Applicable US (IBC) requirements
- The level of protection intended by those requirements

Overview

In 2013, the USA based National Fire Protection Association (NFPA) Research Foundation initiated a project with the goal of developing the technical basis for evaluation, testing, and fire mitigation strategies for exterior wall systems with combustible components.

They established an international team with the objective of gathering information on fire incidents involving combustible exterior walls, compiling relevant test methods and listing criteria, identifying the knowledge gaps and relevant fire scenarios, as well as a testing approach for future efforts.

A report titled "Fire Hazards of Exterior Wall Assemblies Containing Combustible Components" was published by the Fire Protection Research foundation in June 2014

Information Gathering

For US losses, information was collected from the U.S. Fire Administration's (USFA's) National Fire Incident Reporting System (NFIRS) and the National Fire Protection Association's (NFPA's) annual survey of local/municipal fire departments.

In other portions of the world loss information is not as accessible.

March/April 2016 NFPA Journal quotes Donald Bliss; "Few nations collect detailed information about fire and some won't reveal the data they do collect … even the definition of a "fire death" can vary from country to country."

Phase I of the Study

Included review of available fire statistics, fire incidents, literature and test methods relating to combustible external wall assemblies including:

Primary Contributors Discussed Herein:

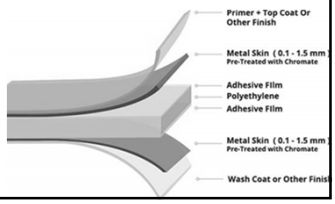
- Metal Composite Material (MCM) cladding
- Exterior Insulation Finish Systems (EIFS, or synthetic stucco)
- External Thermal Insulation Composite Systems (ETICS)

Other Exterior Facade Materials Examined, but not discussed herein:

- High-pressure laminates
- Structural Insulation Panel Systems (SIPS) and insulated sandwich panel systems
- Rain Screen Cladding (RSC) or ventilated facades
- Weather-resistive barriers (WRB) and combustible wall cavity insulation
- External timber panelling and facades including cross laminated timber (CLT)

What are Metal Composite Materials (MCM)?

- Consists of layers (laminates)
- Non-combustible Skin
  - aluminum
- Combustible
  - Polyethylene



What are MCM?

- A MCM is a bonded laminated material usually consisting of three layers (sometimes these layers are referred to as "laminates").
- Laminate: "a material made by bonding together, usually under pressure, two or more layers."
- Light weight
- Excellent façade skin properties
- Easy to install
- Attractive

IBC SECTION 1407
METAL COMPOSITE MATERIALS (MCM)

- The **definition** requires a solid plastic core and, as such, does not allow foam plastic insulation.
- **1407.10.4** Tested in accordance with NFPA 285 in the maximum thickness intended for use.

March 28, 2016

Fire engulfed at least two residential towers in the UAE city of Ajman, causing panic among residents.

Attributed to aluminum composite panel cladding.

The Address Downtown Dubai hotel

Police forensic experts said the fire that engulfed the 63-story hotel on New Year's Eve 2015 was started by an electrical short-circuit,

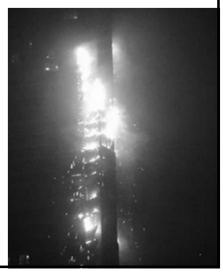
Dubai's government said 14 people suffered minor injuries, one person was moderately injured and another had a heart attack due to overcrowding and smoke at the site. "People started to panic, crushing each other trying to get down the stairs."

"Most Dubai towers built before 2012 'have non fire-rated exterior panels"

Torch Tower Fire; Dubai

Saturday 21 February 2015

Started around the 50th floor on one of the building's balconies and burned until it ultimately reached the roof (86 Stories)



One of the tallest residential buildings in the world (1,105 ft). Opened in 2011.

Hundreds were evacuated and dozens suffered smoke inhalation.

Out of 676 units, 101 apartments were not considered habitable.

SAIF BELHASA BUILDING, TECOM, DUBAI
October 6, 2012

Tamweel Tower, Dubai, November 18, 2012
- Cigarette discarded onto pile of waste materials.

Estimates are that there may be hundreds of high-rise building exterior facades (≈ 70%) in the UAE with non-fire resistant aluminium composite panels.

GROZNY-CITY TOWERS
CHECHNYA, RUSSIA

April 3, 2013

Construction had just completed in this unoccupied, 40-story high rise building. Ignition attributed to a short circuit in an air conditioner on upper floors. Fire spread to engulf the façade from ground level to the roof. Façade materials believed to be metal composite panels, but actual details not reported.

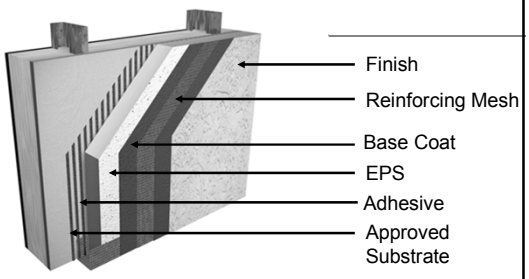
WOOSHIN GOLDEN SUITES
BUSAN, SOUTH KOREA
October 1, 2010

Aluminum composite panels with a 3 mm polyethylene core. The fire started on the fourth floor due to a spark from an electrical outlet. A vertical "U" shaped channel enhanced fire spread through re-radiation and chimney effect.

Mermoz Tower
Roubaix, France
May 14, 2012

Fire spread through external balcony channel lined with 3 mm thick aluminum composite cladding

EIFS: EXTERIOR INSULATION AND FINISH SYSTEMS



To be considered EIFS, the assembly must have all these components in the specified thickness.

Foam Plastic Insulation

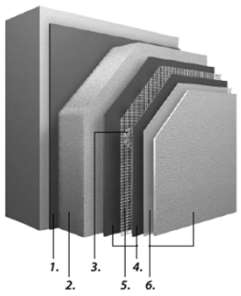
Shortened Definition

- Expanded for insulating or acoustical purposes
- Density less than 20 pounds per cubic foot

IBC §2603.5 - Requirements For Type I, II, III or IV

- §2603.5 applies to buildings of any height
- §2603.5.1 - Maintain fire resistance rating
  - (ASTM E119)
- §2603.5.2 - Foam separated from interior of building by a Thermal Barrier
- §2603.5.3 - Limits thickness of foam (btu/ft^2)
  - NFPA 259
- §2603.5.4 – 25/450 Flame-Spread/Smoke-Developed indices for each combustible component (ASTM E84)
- §2603.5.5 - Meet requirements of NFPA 285
  - (Multi-story fire test)
- §2603.5.6 – Label required
- § 2603.5.7 -No ignition when tested via NFPA 268
  - (Radiant heat exposure test)

External Thermal Insulation Composite System. ETICS



1. Adhesive
2. Thermal insulation material
3. Anchors
4. Base coat
5. Reinforcement, usually glass fiber mesh
6. Finishing layer: finishing coat with a key coat (optional) and/or a decorative coat (optional)
7. Accessories, e.g. fabricated corner beads, connection and edge profiles, expansion joint profiles, base profiles, etc.

The Monte Carlo Façade Fire

January 25, 2008

Jesse J. Beitel
Senior Scientist / Principal
Hughes Associates, Inc.

Douglas H. Evans, P.E.
Fire Protection Engineer
Clark County Building

Blobs of burning goo raining down on terrified occupants fleeing the towering inferno.

Mandarin Oriental Hotel

44 Stories

Beijing
CHINA

Feb 9, 2009

Ignited by fireworks

Also housed CCTV

The upper portion of the China Central Television headquarters (CCTV) facade was ignited by illegal fireworks. The fire spread to involve the majority of the facade over the entire height of building, which is believed to have included polystyrene insulation.

April 19, 2009

50 Story

Center International Plaza

Nanjing City
China

Shanghai
November 15, 2010

Reported ignition source:
- welder's torch

- 58 killed, 70 injured
- 28-story building destroyed

Additional Losses

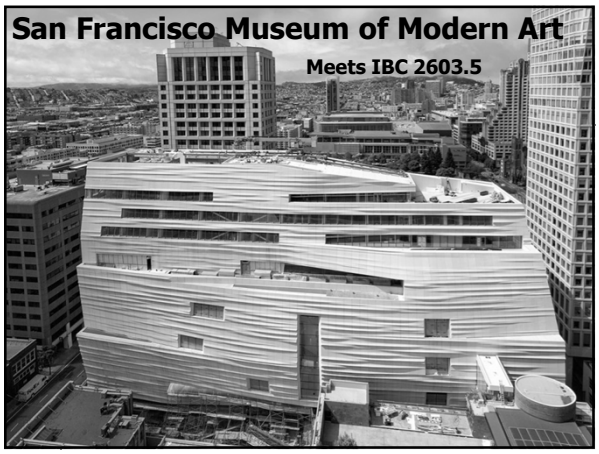
- Baku, Azerbaijan, May 19, 2015
  - 15 people killed; 63 injured
- Polat Tower, Istanbul, Turkey, July 17, 2012
  - Fire started by faulty air conditioning unit
- Al Tayer Tower, UAE April 28, 2012
  - Aluminum Composite Panels Ignited by cigarette butt
- Water Club Tower at the Borgata Casino hotel, Atlantic City, September 23, 2007
  - ACPs with polyethylene core
- And many more…..
- Additional Countries not discussed previously.
  - Australia, New Zealand, Hungary, UK, Scotland, Germany, Canada, India, Spain, Qatar, …

IBC 2612 Fiber-Reinforced Polymers **(Info only. Not part of study)**

- §2612.1 – Fiber-reinforced polymers in and on buildings.
- §2612.2 – Listed and labeled at the job site
- §2612.5 permitted on *exterior walls* of any type of construction when meeting 2603.5. Fireblocking required in accordance with 718.
  - Compliance with 2603.5 not required if quantity, and/or height of fiber-reinforced polymer limited.

San Francisco Museum of Modern Art

Meets IBC 2603.5



Statistics

For all building types analyzed, exterior wall fires accounted for

- 3% of all structure fires,
- 3% of civilian deaths and injuries, and
- 8% of property damage.
- 42% started on the exterior wall surface,
- 32% were where the item first ignited was exterior wall covering, and
- 26% were where the item contributing most to fire spread was an exterior wall.
  - It should be noted that specific construction of the exterior wall cannot be ascertained from the NFIRS data and these statists present a more general view of fires involving exterior walls. 98% of exterior wall fires occur in buildings less than 6 stories high.

OBSERVATIONS

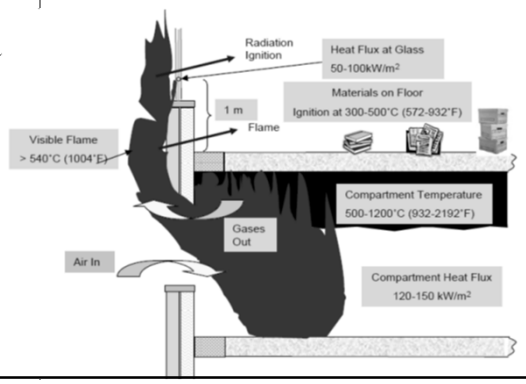
- Exterior wall fires are low frequency events, but the potential for loss can be very high.
- The majority of fire incidents have occurred in countries with poor regulatory controls or where the construction is not in accordance with regulations.
- Internal fires that spread to the exterior wall are the most common ignition scenario.
- Re-entrant corners and channels that form "chimneys" led to more extensive flame propagation.

Fire Dynamics
(The Physics)

Fire Sources

- Initiated within the building
  - Often post-flashover
  - May be pre-flashover with open window
- Exterior
  - Examples: Adjacent burning buildings, balconies, courts, walking paths, refuse enclosures, vehicles, …

MECHANISMS OF FIRE SPREAD



MECHANISMS OF FIRE SPREAD

- Flames eject from a window, breaking window above causing ignition on the floor above (leap-frogging), secondary interior fires and level to level fire spread.
- Heat causing degradation/separation of non-combustible protective skin resulting in flame spread to combustible elements internal to the wall system.
- Flame spread over the external surface of the wall.
- Secondary external fires to lower levels due to falling burning debris.
- Flame spread via vertical or horizontal cavities within the exterior wall assembly.
- Fire spread within cladding (through a combustible core).
- Failing fire stopping between the floor slab edge and exterior wall.

Fire Tests used throughout the World

The National Fire Protection Association (NFPA) Research Foundation report includes information on nine full-scale and three intermediate scale façade tests recognized throughout the world.

COMPARISON OF TEST METHODS

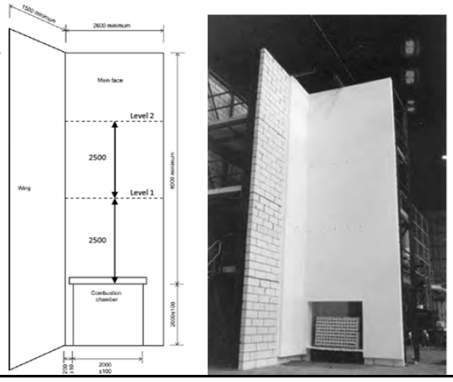
- Many of the full-scale tests simulate a post-flashover fire extending through a window onto the exterior façade.
- Several of the façade tests incorporate two walls that create an "L" shaped corner, which produces a more severe fire and rapid flame spread.
- Dimensions and physical arrangement of facade tests vary. Some large-scale tests involve external corner walls 8 meters high (UK) or 5.7 m high (Germany and ISO) and 2.4 m and 1.3 m wide.
- There are significant differences in the ignition source used to simulate a fire in the room of origin. Wood cribs, liquid pool fires and gas burners are used to generate maximum heat fluxes on the façade in the range of 20 to 90 kW/m2.

COMPARISON OF TEST METHODS

- Test durations, measurements and acceptance criteria vary.
- The degree to which passive protection and fire spread through joints, voids and windows in a façade are tested varies.
- Large-scale facade tests do not measure key combustibility properties of façade elements for direct input into modelling, but do provide useful validation for fire spread modelling.

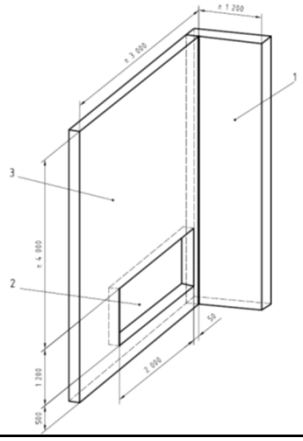
Which of these fire tests represent a reasonable exposure for real life situations?

BS 8414 Part 1



BS 8414 of 300mm EPS with inorganic coating

ISO 13785 Part 2



Front View
ISO 13785 Part 2
5.5 MW Natural gas

DIN 4102-20 (German)

Simulates flames emerging from a window at the base of 5.5 m high wall.

The sample installed as a re-entrant corner arrangement.

The façade is representative of the end use.

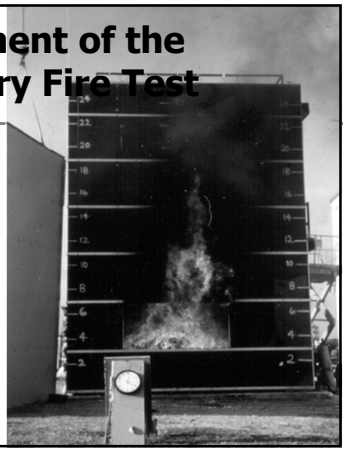
The ignition source is a 320 kW constant HRR linear gas burner or a 25 kg wood crib.

US TEST - NFPA 285 Multi-Story Fire Test

- Can the wall covering/panel resist:
  - Flame propagation over face of the wall covering
  - Vertical flame propagation within the combustible core or components
  - Flame propagation over interior surface from one floor to the next
  - Lateral Flame propagation to adjacent compartments
- Does not address floor-line joint per se.

Development of the Multi-Story Fire Test

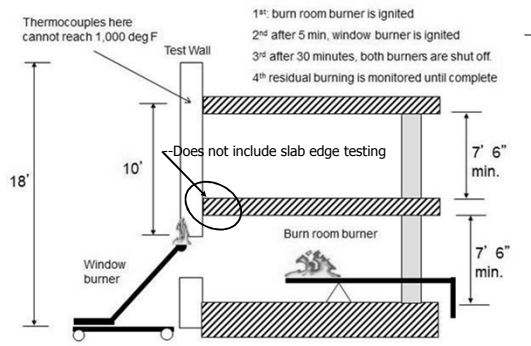
Developed in
The mid 1980s
As a 2 story
Full scale – test



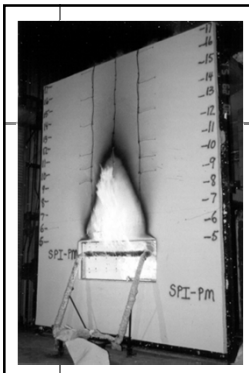
Multi-Story Fire Test
2nd Generation

- In the late 1990s the test was modified to a ¾ scale test assembly and allow the test to be performed inside rather than outside.
- Test was became NFPA 285 in 1998 and titled "Standard Fire Test Method for Evaluation of Fire Propagation Characteristics of Exterior Non-load-bearing Wall Assemblies Containing Combustible Components"
- NFPA 285 is referenced in the International Building Code (IBC).

NFPA 285 – Test Apparatus

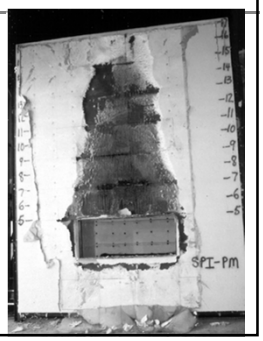


NFPA 285



Test in progress

Post-test damage



Additional US Requirements

High-Rise Buildings

- DEFINITION
  - Buildings with an occupied floor more than 75 feet (23 m) above the lowest level of fire department vehicle access.
- §403 HIGH-RISE BUILDINGS
  - Essentially non-combustible

IBC SECTION 1403
PERFORMANCE REQUIREMENTS

1403.5 Vertical and lateral flame propagation.

- Exterior walls … greater than 40 feet (12 192 mm) above grade that contain a combustible water-resistive barrier shall be tested in accordance with and comply with the acceptance criteria of NFPA 285.

IBC SECTION 1406
COMBUSTIBLE MATERIALS ON THE EXTERIOR SIDE OF EXTERIOR WALLS

- 1406.2.1.1 Ignition resistance.
  - Tested in accordance with NFPA 268.
- 1406.2.3 Where the combustible exterior wall covering is furred out from the exterior wall the concealed space shall be fireblocked.

IBC §2603.5.7 NFPA 268 Radiant Heat Exposure Test

- Addresses ignition potential of exterior wall coverings exposed to a radiant heat source.
- Commonly accepted threshold for piloted ignition of wood is 12.5 kW/m^2.
- Exterior walls should be designed to limit the radiant heat transfer to adjacent structures to 12.5 kW/m^2
- Thus, exterior walls should not ignite at radiant heat exposures $\leq$ 12.5 kW/m^2.

NFPA 268

IBC §2603.5.3 - NFPA 259 Potential Heat Test

- Potential heat (calculated based on area) of the foam plastic is not allowed to exceed that tested via NFPA 285 (multi-story test).
- Uses NFPA 259 – Measures amount of heat released when burned in pure O_2
  - Bomb calorimeter test
- Data from test expressed in Btu/lb (mJ/kg).
  - EPS has ~ 18,000 Btu/lb (~41.8 mJ/kg)
- Convert this to Btu/ft^2 (mJ/m^2) using thickness and density of foam plastic.
- Allows calculation for different densities/thickness combinations.

Presentation Focused On

- Fire protection aspects of High-Rise Building Exterior Facades
- Why these requirements exist
  - fire losses
- Related fire dynamics
- Associated fire tests
- Applicable US (IBC) requirements
- The level of protection intended by those requirements