High-Rise Facade Fires
A WORLD WIDE CONCERN

IN SECTION: HIGH-RISE FACADE FIRES: A WORLDWIDE CONCERN

Although horrific losses in recent years are a wake-up call around the globe, what steps must be taken now to ensure these fires do not reoccur?

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IN 2013, the Fire Protection Research Foundation, an independent nonprofit affiliate of the NFPA, initiated a study of worldwide exterior facade fires. The goals of that initial phase included compiling loss information and existing test methods. An overview of those findings, along with additional losses that have occurred since the initial study concluded, are covered in this article. Although fires involving combustible exterior wall assemblies are low-frequency events, the resulting consequences in terms of property loss and occupant safety can be devastating.

The Tower Block Blaze in West London, 14 June 2024

The Grenfell Tower Fire, London, 14 June 2017

To date, the 24-story Grenfell Tower disaster in Kensington, West London, stands as the greatest loss of life attributed to an exterior facade fire. The building was gutted, and 71 individuals died due to this fire. (8) Although this horrific loss appears to have been a wake-up call to most of the world, it should never have occurred because it should have been foreseeable to those of us responsible for fire protection in major structures. Was this an isolated incident, or is it an indication that similar losses are imminent?

Facade Fire History and Current State

Due to the number of exterior facade fires throughout the world over the past 12 to 15 years, questions have arisen about present regulations and whether test standards and the associated code requirements are sufficient to limit such devastating losses from future occurrences.

The 2013 NFPA Research Foundation project established an international team to gather information on fire incidents involving combustible exterior cladding systems; compile relevant fire loss scenarios; and identify knowledge gaps, applicable test methods, and associated listing criteria. The final report, titled “Fire Hazards of Exterior Wall Assemblies Containing Combustible Components,”[1] was published by the Fire Protection Research Foundation in June 2014. This publication summarized exterior facade fires that occurred prior to publishing. Due to building stock constructed prior to resolving contributing factors, these losses continue.

Over the past several years, exterior facade fires have occurred throughout most of the modern world. Impacted countries include the United Arab Emirates (UAE), China, France, Australia, New Zealand, Scotland, Germany, Russia, Canada, India, Spain, Qatar, Azerbaijan, Hungary, Turkey, and the United States as well as some of the most recent losses in the United Kingdom.

Why do these fires continue? Are the applicable codes and test standards adequate?

Contributing Materials

The NFPA Research Project considered combustible exterior wall systems, including:

- High-pressure laminates (HPL).
- Structural insulated panel systems (SIPS) and insulated sandwich panel systems.
- Rain-screen cladding or ventilated facades (curtain walls).
- Weather-resistive barriers (WRB) and combustible wall cavity insulation.
- External timber paneling and facades including cross-laminated timber (CLT).

Although some of these materials have concerns and should be used within established guidelines, the primary exterior facade fire losses throughout the world have been attributed to metal composite materials (MCMs) and improperly encapsulated foam plastics.

Metal Composite Materials (MCMs, see Figures 1 and 2). Over the last 12 to 15 years, MCMs have been the primary contributor to the greatest number of high-rise exterior facade fires throughout the world. MCMs consist of a thin, metal panel laminated to each face of a combustible plastic core (typically polyethylene). The metal panels are usually aluminum, but may also be steel. As such, these panels are frequently called aluminum composite panels or aluminum composite materials (ACPs/ACMs). They are popular due to their appearance, ease of installation, light weight, and affordability.

Several notable losses in the UAE have been attributed to ACMs. Although the UAE has been working hard to resolve this problem and improved its code requirements in 2012, approximately 70 percent of its standing inventory still includes these inferior panels.[(1)] ACMs have contributed to many losses throughout the world, including the Grenfell fire in London. Six exterior facade fires attributed to MCMs in the UAE include:

- Two residential towers in the city of Ajman on 28 March 2016.
- The 63-story Address Downtown Dubai hotel on New Year's Eve 2015— ignition attributed to an electrical short-circuit.
- The 1,105-foot (336.8 meter) Torch Tower in Dubai — which Initially burned 21 February 2015 and resulted in 101 apartments out of 676 units considered uninhabitable[(3)] — and whose exterior facade burned a second time on 3 August 2017[(4)].
- Tamweel Tower, Dubai, on 18 November 2012 — ignition attributed to a lighted cigarette discarded onto a pile of waste materials[(6)].
- Saif Belhasa building, Tecom, Dubai, on October 6, 2012[(1)].
- Al Tayer Tower, Sharjah, UAE on 28 April 2012 — ignition attributed to a cigarette[(1)].

Other MCM facade fires throughout the world have occurred in:

- Baku, Azerbaijan, on 19 May 2015, with 16 people killed and 63 injured[(5)].
- The 40-story Grozny-City Towers Chechnya, Russia, on 3 April 2013 – ignition attributed to a short circuit in an air conditioner[(1)].
- Polat Tower, Istanbul, Turkey, on 17 July 2012 — ignition attributed to a faulty air conditioning unit[(6)].
- Mermoz Tower Roubaix, France, on 14 May 2012, which resulted in one fatality and six injuries[(1)].
- The Wooshin Golden Suites in Busan, South Korea, on 1 October 2010 — ignition attributed to a spark from an electrical outlet[(1)].
- Water Club Tower at the Borgata Casino hotel, Atlantic City, New Jersey, on 23 September 2007[(1)].

Improperly Encapsulated Foam Plastics. ACPs, ACMs, and MCMs are not the only exterior cladding contributing to high-rise exterior facade fires. Other losses are attributed to improperly encapsulated foam plastics. Although the materials that led to known losses attributed to improperly encapsulated foam plastics do not appear to meet established guidelines, they are frequently termed either external thermal insulation composite systems (ETICS) or exterior insulation and finish systems (EIFS, see Figure 2). These two assemblies are essentially the same, with EIFS the name used in North America and ETICS the name generally used in Europe.

For both systems, an insulating material (typically foam plastic) is encapsulated between a finish coat and a non-combustible substrate. A fiberglass mesh and other components constitute the assembly. To qualify as actual ETICS or EIFS, these systems must be installed with all components in the same manner as the sample that passed the required fire tests. In the United States, several fire tests are required to ensure a reasonably safe system. These include NFPA 259, 268, and 285 as well as ASTM E 84.

A few exterior facade fires attributed to improperly encapsulated foam plastics include:

- A 28-story residential building in Shanghai on 15 November 2010 where 58 people died and over 70 were injured — ignition attributed to a spark from welding[(2)].
- An 11-story building resulted in three fatalities[(1)] on 15 August 2009, in Miskolc, Hungary.
- The 44-story Central Television headquarters (CCTV Tower) and Mandarin Oriental Hotel in Beijing, China on 9 February 2009 — ignition attributed to illegal fireworks[(1)].
- The Monte Carlo Hotel Tower in Las Vegas, Nevada, on 25 January 2008 – ignition attributed to a spark from welding[(2)].
- The Palace Station in Las Vegas, Nevada, on 20 July 1998 — ignition attributed to an electrical short[(1)].
- A 60-foot (18.2 meter) high by 120-foot (36.6 meter) long sign on the front of the Eldorado Hotel in Reno, Nevada, on 30 September 1997—ignition attributed to an electrical short, although the properly encapsulated EIFS underneath the sign performed exactly as intended and did not propagate[(1)].

Statistics

The initial phase of the Fire Protection Research Foundation's study included compiling loss information and relevant test methods. For all building types analyzed, exterior wall fires accounted for:3 percent of all structure fires, and:

- 3 percent of civilian deaths and injuries.
- 8 percent of property damage.
- 98 percent of exterior wall fires occur in buildings less than six stories high.
- 42 percent of fires started on the exterior wall surface.
- 32 percent when the item first ignited was the exterior wall covering.
- 26 percent where the item contributing most to fire spread was an exterior wall.

Fire Dynamics

Ignition of exterior facades can be from either an interior or exterior ignition source. Interior sources are most often post-flashover fires that break out the window and impinge on the exterior facade. Ignition may also be from a pre-flashover interior fire with an open window. Losses due to exterior ignition have been attributed to electrical shorts, improperly discarded cigarettes, and grills on balconies. Exterior ignition can also be caused by an adjacent burning building, balconies, courts, walking paths, refuse containers, and vehicles. A fundamental property of ignition is that the more heat the ignition source is projecting on a combustible target, the more apt the target is to ignite.

Uninterrupted combustible voids have contributed to exterior facade fires like the Grenfell disaster. Testing has shown that flame height within a ventilated facade cavity can be 5 to 10 times higher than the flame on the exterior surface.[(9)] As such, using recognized methods for fire blocking are prudent.

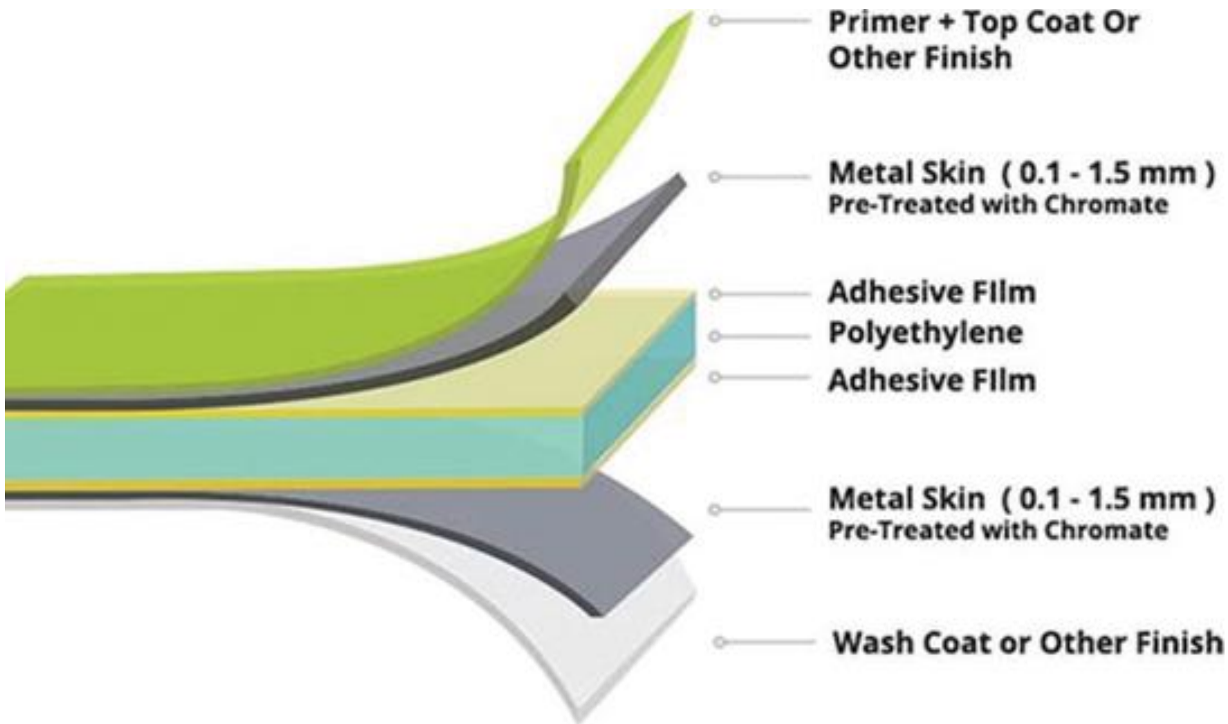

Figure 1: Typical Metal Composite Panel

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Another phenomena observed on exterior facades is the Coandă effect as noted by Forre.[10] This is the tendency of a fluid jet to follow an adjacent flat or curved surface and entrain fluid from the surroundings so that a region of lower pressure develops. This is why flames on exterior facades appear to stick to the facade surface, whether the fire is on the windward or leeward side of the building.

The Fire Protection Research Foundation’s study found that:

- The most common ignition scenario is internal fires that spread to the exterior wall.
- Flames eject from a window, breaking the window above and causing ignition on the floor above (leap-frogging), secondary interior fires, and level-to-level fire spread.
- Corners (facing each other at 90 degrees or less) and U-shaped channels that form chimneys led to more extensive flame spread than flat walls. The effect of balconies forming partial vertical channels” was determined to warrant additional investigation.
- Heat-causing degradation/separation of non-combustible protective skin resulted in flame spread to combustible elements internal to the wall system.
- Flame spreads over the external surface of the wall.
- Flame spreads via vertical or horizontal cavities within the exterior wall assembly.

- Fires spread within cladding (through a combustible core). Failing fires stop between the floor slab edge and exterior wall.
- Falling burning debris can be a significant hazard and cause downward fire spread.
- Secondary external fires spread to lower levels due to falling burning debris.
- Combustible exterior wall systems present an increased fire hazard during installation and construction prior to complete finishing and protection of the systems.
- Although exterior wall fires are low-frequency events, the resulting property loss can be very high.
- For most of the incidents reviewed prior to the Grenfell disaster, the impact on life safety in terms of deaths was relatively low, with the main impacts being smoke exposure rather than direct flame or heat. However, occupants are usually displaced for significant periods of time after the fire incidents.
- Most fire incidents occurred in countries with poor regulatory controls or where construction was not in accordance with regulations.

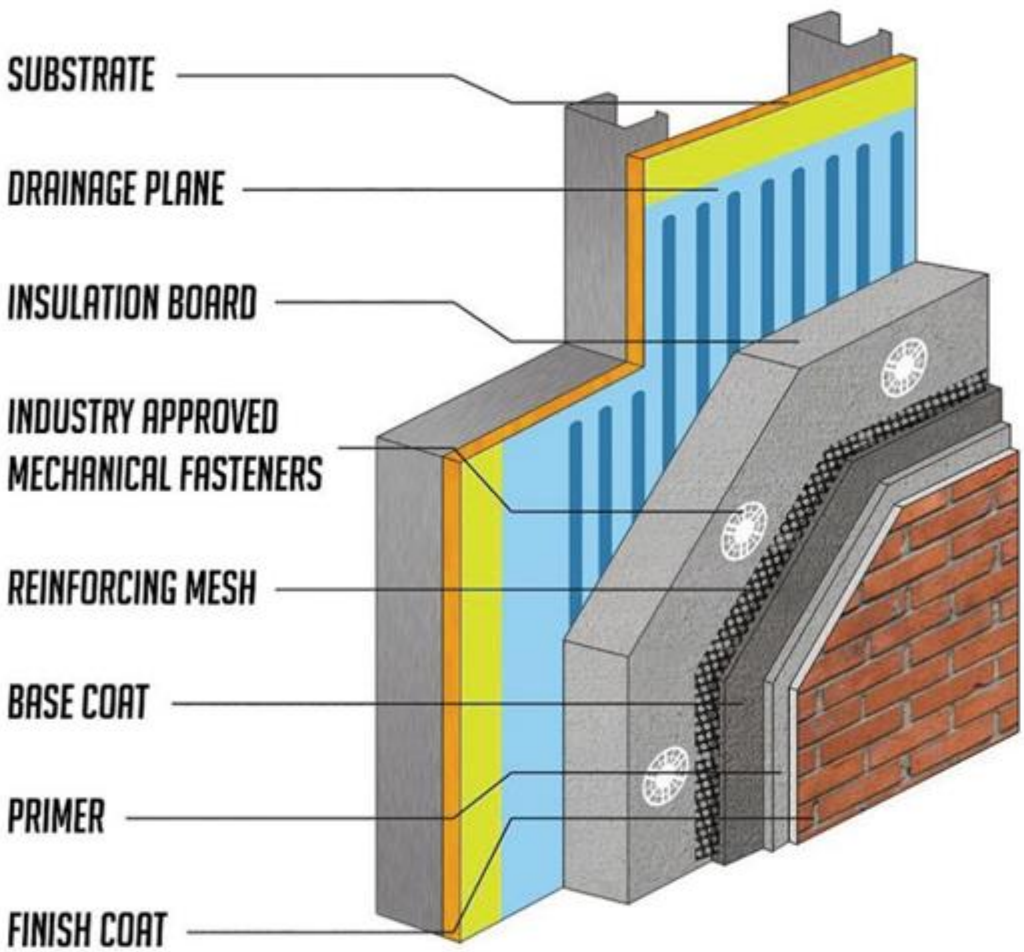

Figure 2: A Standard EIFS Cladding

Fire Tests Used Throughout the World

The NFPA Research Foundation's report includes information on nine full-scale and three intermediate- scale facade tests recognized throughout the world. The findings concluded:

- Most of the full-scale tests simulate a post-flashover fire extending through a window onto the exterior facade.
- Several of the facade 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 26.25 feet (8 meters) high (United Kingdom) — or 18.7 feet (5.7 meters) high (Germany and ISO) — and 4.9 feet (1.5 meters) 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 facade in the range from 20 to 90 kW/m2.
- Test durations, measurements, and acceptance criteria vary.
- The degree to which passive protection and fire spread through joints, voids, and windows are tested vary.
- Large-scale facade tests do not measure key combustibility properties of facade elements for direct input into modeling, but do provide useful validation for fire spread modeling.

Fire test requirements throughout the world, as well as the associated performance-based considerations and exemptions, is a discussion on its own.

In Wooshin Golden Suites Busan, South Korea[1], a vertical, U-shaped channel enhanced fire spread through reradiation and chimney effect.

Fully Sprinklered Buildings Are Not Immune

Some individuals and jurisdictions have argued that the combustibility of exterior facades need not be highly regulated. Their contention is that high-rise buildings are fully sprinkler protected and that multiple, protected means of evacuation are provided from each level.

In most instances, sprinklers will limit the size of an interior fire and keep it from reaching the exterior facade. This reduces the potential for an interior fire igniting combustible facade materials. But keep in mind that sprinklers are not 100 percent reliable. In addition, sprinklers are not designed to limit ignition or propagation of an exterior facade fire or keep it from gaining access into the building. Sprinkler systems are typically designed to flow 12 to 15 sprinklers simultaneously. The Monte Carlo exterior facade fire in Las Vegas (which was relatively insignificant compared with many of the other exterior facade fires) broke out several windows and activated 17 sprinklers.[(2)]

After too many sprinklers activate, the sprinkler system will not achieve sufficient water flow and pressure to effectively limit interior fire propagation. Studies have not been performed to determine how many sprinklers can effectively keep fire out of a building during a high-rise exterior facade fire, but estimates indicate possibly up to 20 heads flowing water simultaneously. This estimate is primarily because sprinklers will not all be flowing from the same floor/zone, and fire pumps are typically needed for tall buildings.

A facade fire propagates up, around, and even down the exterior of the building breaking windows, which allows it access into the building. At some point, the exterior facade fire will overwhelm the sprinklers and cause substantial interior damage in addition to devastating the exterior facade. This has been demonstrated in exterior facade fires, including the initial 86-story Touch Tower fire in the UAE on 21 February 2015, after which 101 of the 676 apartments were deemed uninhabitable.[(4)]

Figure 3: Mechanisms of Fire Spread[(1)]. When these fires occur, occupants have little choice but to evacuate; however, stairs are not designed for full-building evacuation, and evacuating occupants will encounter stairs overflowing with other evacuating occupants. As observed during the 63-story Address Hotel fire in Dubai on New Year's Eve 2015, these situations increase the tendency to panic and cause crushes.

In addition, most stair pressurization systems take outside air from the roof. Smoke from an exterior facade fire can be forced into the stairway via the pressurization system. Even if the smoke concentration is within tenable limits, this would not be a comfortable situation for evacuating occupants.

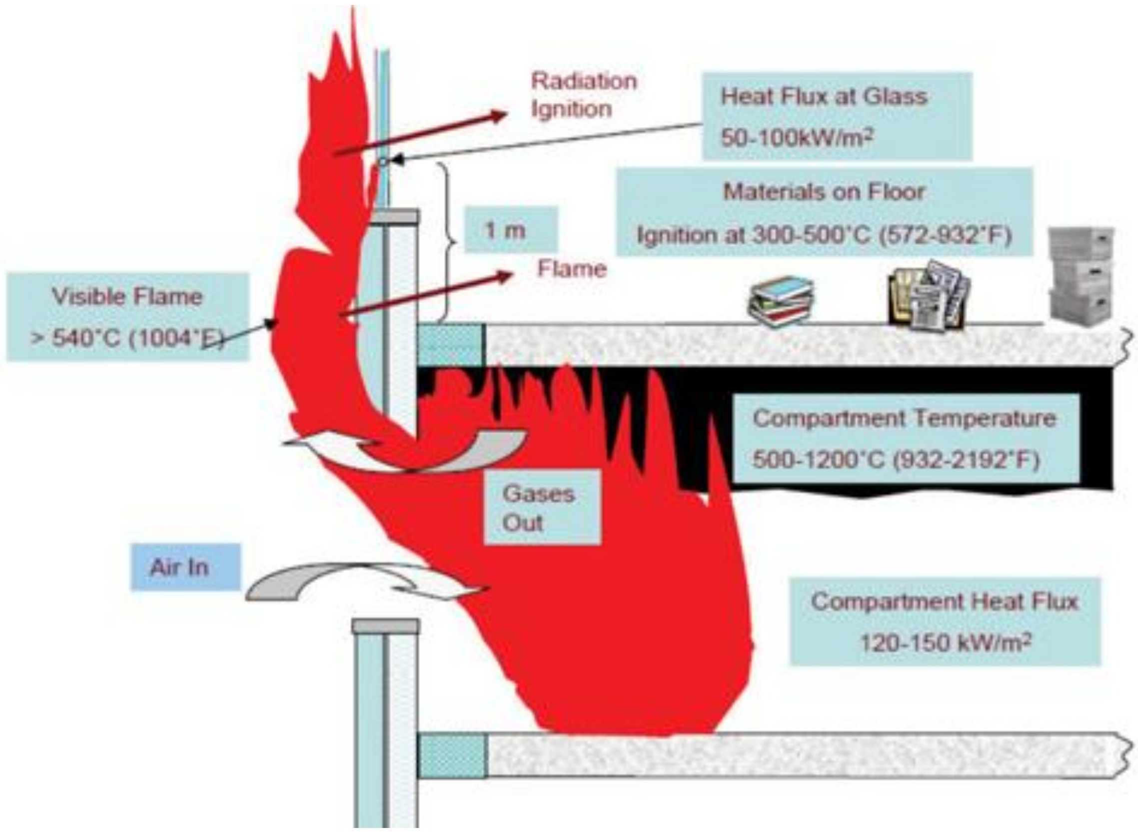

Figure 3: Mechanisms of Fire Spread[1]

One additional hazard to evacuating occupants is the substantial amount of debris, some still burning, raining down as occupants discharge the stair towers at grade. Falling debris, whether burning or not, can also interfere with fire department access to the structure. As such, relying on sprinklers to protect from an exterior facade fire is, at best, inappropriate.

Present Efforts for Resolution

The International Building and Fire Codes (IBC and IFC) are presently in a revision cycle. Concerns with present allowances for certain exterior façade systems and associated test standards have been expressed and a number of proposed revisions to the 2018 editions of these documents were recently debated. Although results of the recent hearings are still subject to revision prior to final determination of the 2021 editions of these documents, present indications are that more restrictive requirements will apply to specific exterior cladding systems, but more restrictive testing requirements will not be mandated by the International Codes. (MCMs require more rigorous testing, but the actual test standard is not changed).

NFPA recently released the Exterior Facade Fire Evaluation and Comparison Tool (EFFECT™)[7] which provides an online fire risk assessment of high-rise buildings with combustible exterior facade systems. This computer-based questionnaire asks a series of questions to determine the potential hazard of an exterior facade assembly. The methodology provides a two-tier process to assist an enforcement authority to: Tier 1—prioritize buildings in their jurisdiction, and Tier 2—conduct initial fire risk assessments of each building, assessing the highest priority buildings first. EFFECT is not intended as a design tool.

Other countries and organizations concerned with combustible exterior facade materials are working to resolve this international crisis. All indications are that the assemblies and materials contributing to exterior facade fires throughout the world will be scrutinized, and more conservative measures will be incorporated to help ensure poor performers do not continue contributing to additional future losses. Hopefully, these changes will take a reasonable, physics-based approach to limit such losses from occurring and not take us back to the Stone Age where all exterior facades were required to be of entirely non-combustible materials.

The More Challenging Fire Tests for Exterior Cladding Systems Used Worldwide

- USA — NFPA 285. A three-quarter scale mock-up uses gas burners to simulate an interior fire projecting out a window.
- USA — ANSI/FM 4880. These 25- (7.6 meter) and 50-foot (15.2 meters) tests use a 750 lb (340 kg), 5-foot (1.5 meter) high stack of wooden pallets.
- Canada — CAN/ULC S134. This test uses a 5.5 MW propane burner or 0.74 ton (675 kg) wood crib.
- Europe — ISO 13785. Part 1 uses a 5.5 MW propane burner.
- UK — BS8414. Parts 1 and 2 use a wood crib with a peak HRR of 3 ± 0.5 MW.

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