Coatings - Linings - Fireproofing

Guide to modern fire loads

A call for improved residential and commercial passive fire protection standards

Chapter 1: Are cellulosic test standards still adequate?

Fully 120 years after the first cellulosic fire curve was published, it remains the basis on which building materials are tested for fire safety today.

It also is important in the scientific assessment of the performance of passive fire protection (PFP) measures.

But they don't make building materials like they used to.

And, for all their performance and cost benefits, the combustion behavior of modern synthetic or hybrid-synthetic materials common in our built environment today demonstrate that they don't make fires like they used to, either.

Now, they're worse. They ignite faster, they burn hotter, they release more toxic smoke, and they're harder to fight. Fire loads have evolved. Is it time for fire safety test standards to do the same?

> **In a future where electric vehicles and energy storage systems proliferate, the way we judge the performance of fire resistive materials needs to evolve.**

Different fuels, different fires

The cellulosic time-temperature curve which formed the basis of what became the ASTM E119 (formerly C19) standard first appeared in 1903, and it turned fire safety from an art to a science. The curve shows temperature rise over actual time in conditions simulating a "standard" cellulosic fire, the primary fuel being wood.

Over time, industry has developed testing methods to understand how well common construction materials contain such a "standard" fire, and based on these materials tests, building code authorities regulate their use.

However, these standards were developed based on a 20th century understanding of fires and the wood, paper, and textile products that fueled them. While they have served as a fundamental benchmark for decades, there is an ongoing debate about their adequacy for assessing the thermal efficiency of fire resistive materials because today's occupied spaces contain vastly different fuels than before.

A principal shortcoming of cellulosic test standards is that they do not adequately account for the behavior of synthetic materials, which feature much higher calorific potentials. The materials are everywhere: building components, home furnishings, and the long list of electronics inside practically every

occupied space. In contrast, cellulosic materials tend to char and insulate better in a fire. These are no longer representative of modern building materials.

Ignition speed: Modern materials usually ignite more quickly than traditional cellulosic materials. The time it takes for a fire to reach critical stages is significantly shorter, meaning that occupants have less time to evacuate, first responders have less time to manage the situation effectively, and the applied stress on the passive fire protection measures intensifies. Cellulosic test standards were developed when fires took longer to develop, so their continued use as fire safety benchmarks can lead to a false sense of security in modern structures.

Toxic smoke and gases: Another critical concern is the toxic smoke and gases produced by modern materials during a fire. Cellulosic test standards primarily focus on temperature and flame spread but do not account for the release of hazardous gases from synthetic materials. These toxic emissions significantly threaten the safety of building occupants and first responders. This is particularly acute in electric vehicle, e-bike, and energy storage system hazard scenarios. These are discussed briefly below, as well as in Chapter 2 of this guide.

Electric vehicles and energy storage systems: Product design and battery chemistry have converged to create a troubling threat scenario. The chemistry required for modern energy storage to be effective also burns quite hot and vents highly toxic gases in the event of a thermal runaway. Unfortunately, the very structural design elements that are meant to contain thermal runaways make it exceptionally difficult for firefighters to meaningfully contain them if those elements fail.

PIPE RACK SUPPORT PROTECTED WITH PYROCRETE WITHSTANDS HYDROCARBON FIRE.

Some of the fire events explored in Chapter 2 of this guide lead us to argue that in a future where EVs and energy storage systems proliferate, the way we rate material safety and judge the performance of fire resistive materials needs to evolve.

Time for different test methods?

The standards and methods we've questioned are essential to our development of cementitious and intumescent PFP products.

So, are they still useful? Do they need updating? Or, is it time to pivot away from cellulosic test standards in certain group occupancy classifications based on understanding of modern day risks?

Such a pivot would not mean wandering aimlessly: Industry already has other standards and methods that assess fire safety and material response in more intense fire events.

Our chemists use hydrocarbon pool and jet fire standards (for example, UL 1709, ISO 22899-1 or RWS) to develop products that can resist the intensity, erosive forces, and higher heat fluxes associated with rapid-rise and intense thermal scenarios. Those standards apply to industrial and transportation environments, but scientific studies as well as actual recent fire events suggest a change may be needed.

Chapter 2: These 4 disasters prove cellulosic standards are obsolete

Habitable spaces today are constructed with more synthetic materials than in the past. And into these spaces we cram all manner of battery-powered devices that burn very hot and release toxic smoke.

In Chapter 1, we wondered if the legacy cellulosic fire test standards that evaluate the thermal responses of materials in residential, commercial, or mixed use occupancies were adequate.

Recent history is rife with near misses and tragic events that prove they are not.

Luton, United Kingdom

An accidental ignition inside a vehicle parked at London Luton Airport Terminal Car Park 2 on Oct. 10, 2023, led to the catastrophic fire during which part of the multi-level structure collapsed.

The incident is recent enough that formal findings remain pending. But a principal criticism that emerged in the immediate aftermath was that Terminal Car Park 2 had no fire suppression sprinklers.

The frenzied claim on social media that an electric vehicle (EV) was the source of the fire was false.

But even though an EV battery thermal runaway did not cause the event, EVs were parked inside the structure, and some fueled the blaze. Law firm Browne Jacobson noted that it takes more than twice the amount of water to douse an EV battery fire compared to a traditional vehicle fire.

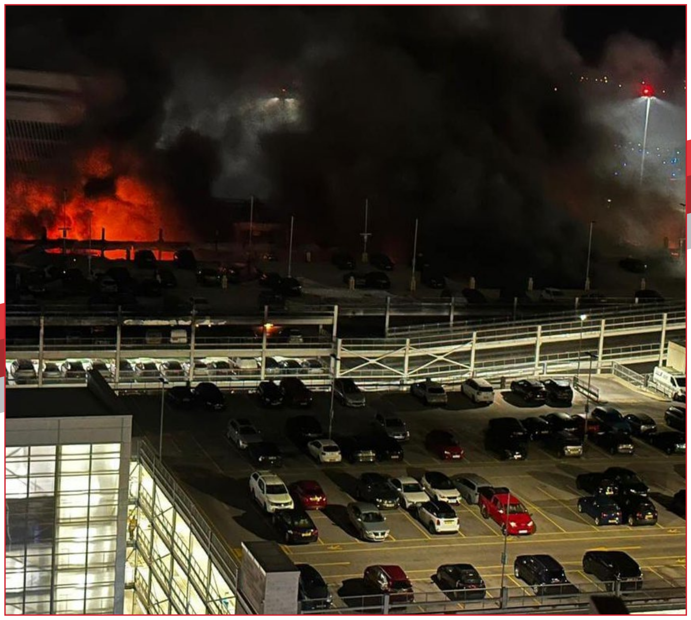
> **In addition to the partial collapse of London Luton Airport's Car Park 2, the catastrophic fire of Oct. 10, 2023, led to the total loss of over 1,400 vehicles parked inside it.**

In fact, firefighters ordinarily elect not to fight battery fires at all because it's safer for everyone. They only initiate a firefight to contain some more catastrophic risk.

EV market penetration will only grow. There will never be fewer of them in parking structures than there are right now.

Fortunately, no one died in the fire, although some firefighters and an airport employee suffered smoke inhalation. But the cost of the Luton disaster will still be mighty, mostly to insurers. The Bedfordshire Fire & Rescue Service said in late 2023 it's unlikely that any of the 1,405 cars they knew to be in the car park at the time of the fire would be usable after what remains of the car park is demolished.

London Luton Airport Terminal Car Park 2



Stavanger, Norway

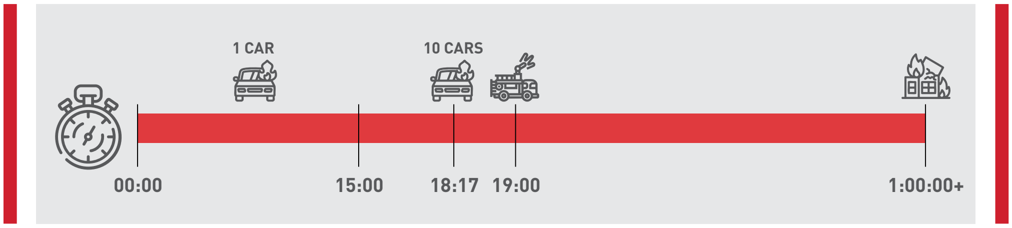
Much more is known about the fire, first response, and aftermath of the Jan. 7, 2020 car park fire at Stavanger Airport Parking Building 3.

The fire resulted in a partial collapse of the multi-level parking structure and the destruction of hundreds of vehicles.

A RISE Fire Research report establishes key facts which are crucial to any discussion of modern fire loads and the adequacy of legacy material response test methods.

One is that there were no fire suppression sprinklers, same as Luton.

Another is that the fire originated in a parked car in an upper level, a location which fire service personnel reported was difficult to access with their large apparatus. The report also indicated firefighters initially had difficulty locating fire hydrants, delaying their firefight.



Next, the portion of the parking structure that collapsed was a newer build, utilizing different materials not considered in older fire safety designs which were repurposed for its construction. Newer designs existed but their changes compared to older designs were not adequately emphasized, according to the report.

Also noteworthy is the fire development timeline. For the first 15 or so minutes from ignition, the fire was apparently contained to a single vehicle. But then, witnesses reported hearing a “bang” from an electric vehicle parked near the burning car (the EV, to be clear, was not the cause of the fire). Just a minute after the bang, witnesses observed flames, heard more bangs, and saw several more cars on fire.

After only 18 minutes and 17 seconds, 10 cars were burning. The first fire trucks were not deployed until 19 minutes after ignition. Crews fought the fire for little more than an hour before evacuating ahead of the structure’s imminent collapse.

No fire service response can be instantaneous or perfect. But keep Stavanger in mind as you consider that structural steel loses half its load-bearing integrity once it reaches 1,000°F (538°C), and that an EV battery can reach 1,832°F (1,000°C) in as little as five seconds in a thermal runaway event.

As EVs proliferate, it is urgent that stakeholders scrutinize trends in construction materials, the performance of passive fire protection products, and operative thermal response test methods—and to say so frankly if these all fall short against modern fire loads.

Scan this to read the RISE Fire Research report

Photo credit: www.norwaynews.com

Liverpool, United Kingdom

The fire that destroyed the King's Dock car park in Liverpool on New Year's Eve 2017 also began in a parked combustion-engine car. The Merseyside Fire & Rescue Service protection report published in the aftermath details the convergence of factors that made this as bad as it was.

For one example, the Service's evidence strongly refuted a decades-old assertion that fires in multi-story, reinforced concrete parking structures tend not to spread from floor to floor. In the early stage of the King's Dock fire, intense heat melted plastic and aluminum drainage infrastructure above the burning vehicle which provided a vector for its spread to the floor above.

Another serious hazard was plastic petrol tanks in most of the parked cars. Investigators reported that as tank after tank failed, an intense running fuel fire developed.

Further, there was clear evidence of widespread heat-induced failure of the structure's concrete floor slabs which aided the spread of the fire from level to level.

It could have been far worse. The King's Dock car park was adjacent to the Arena Convention Center of Liverpool, where the Liverpool International Horse Show was in progress at the time of the fire. Thousands of spectators were safely evacuated. Also evacuated were the residents of two apartment buildings erected just beside the car park.

Jecheon firefighters agonized over the decision to try preventing the explosion of a nearby propane storage tank instead of entering the burning building to attempt rescues of people trapped inside. They did not have enough people or equipment to do both at once.

Firefighters noted that the location of these residential structures prevented them from deploying aerial firefighting appliances in ideal positions. Fortunately, those apartment buildings and their occupants survived the fire. Minor injuries were reported, most of them smoke inhalation.

Jecheon, South Korea

Bad as they are, the disasters described above do not represent the worst-case scenario.

But the fire that destroyed the multi-story Jecheon Sports Center in the small town of Jecheon, South Korea, does.

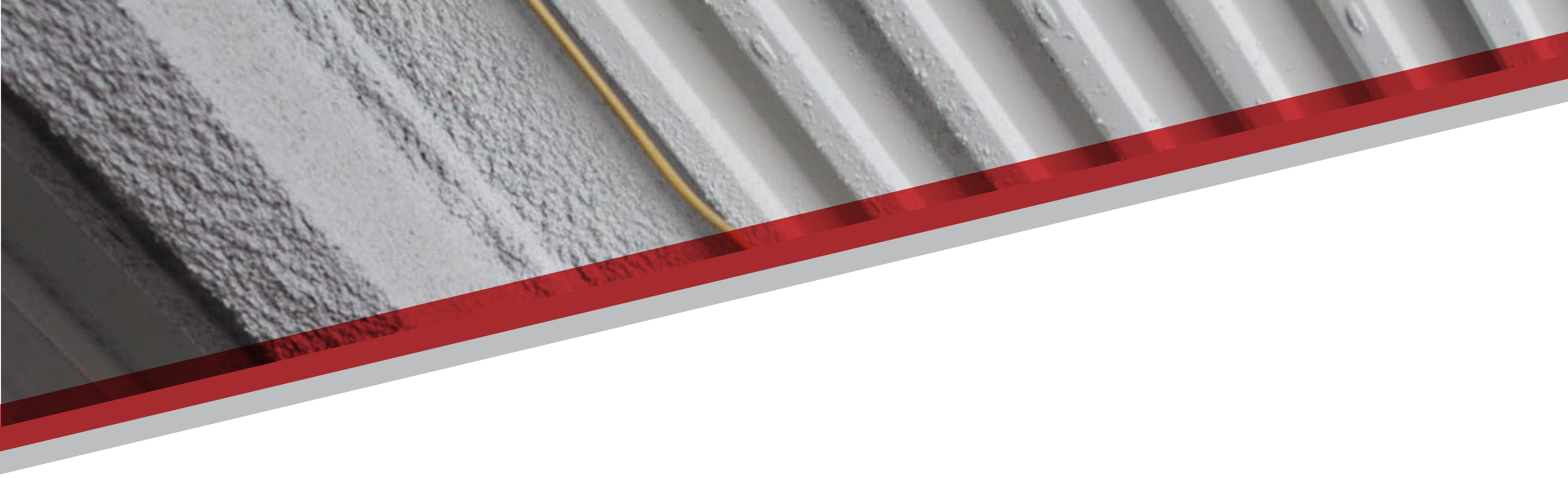
Twenty-nine people died and dozens more were injured on Dec. 17, 2017, after a fire that started in the ceiling above a partially enclosed ground-floor parking area spread quickly upward.

According to the investigation following the fire, a faulty electrical wire installed to prevent piping from freezing sparked the blaze which spread rapidly once it encountered insulation in the ceiling of the parking area.

This small town's firefighters were completely overwhelmed, the most agonizing example being their choice to try preventing the explosion of a nearby propane storage tank instead of entering the building to attempt immediate rescues. They did not have enough people or equipment to do both at once.

That the Jecheon Sports Center did not collapse only demonstrates that a structural failure is not a prerequisite for tragedy. Thick plumes of toxic smoke and an under-equipped, under-staffed fire service were the culprits here.

Scan this to read the fire service protection report



What must change?

The events narrated above do not constitute anything like an exhaustive list. The more we looked, the more examples we found.

Nor does our selection of the events suggest that EVs are bad or that we should be afraid of parking structures.

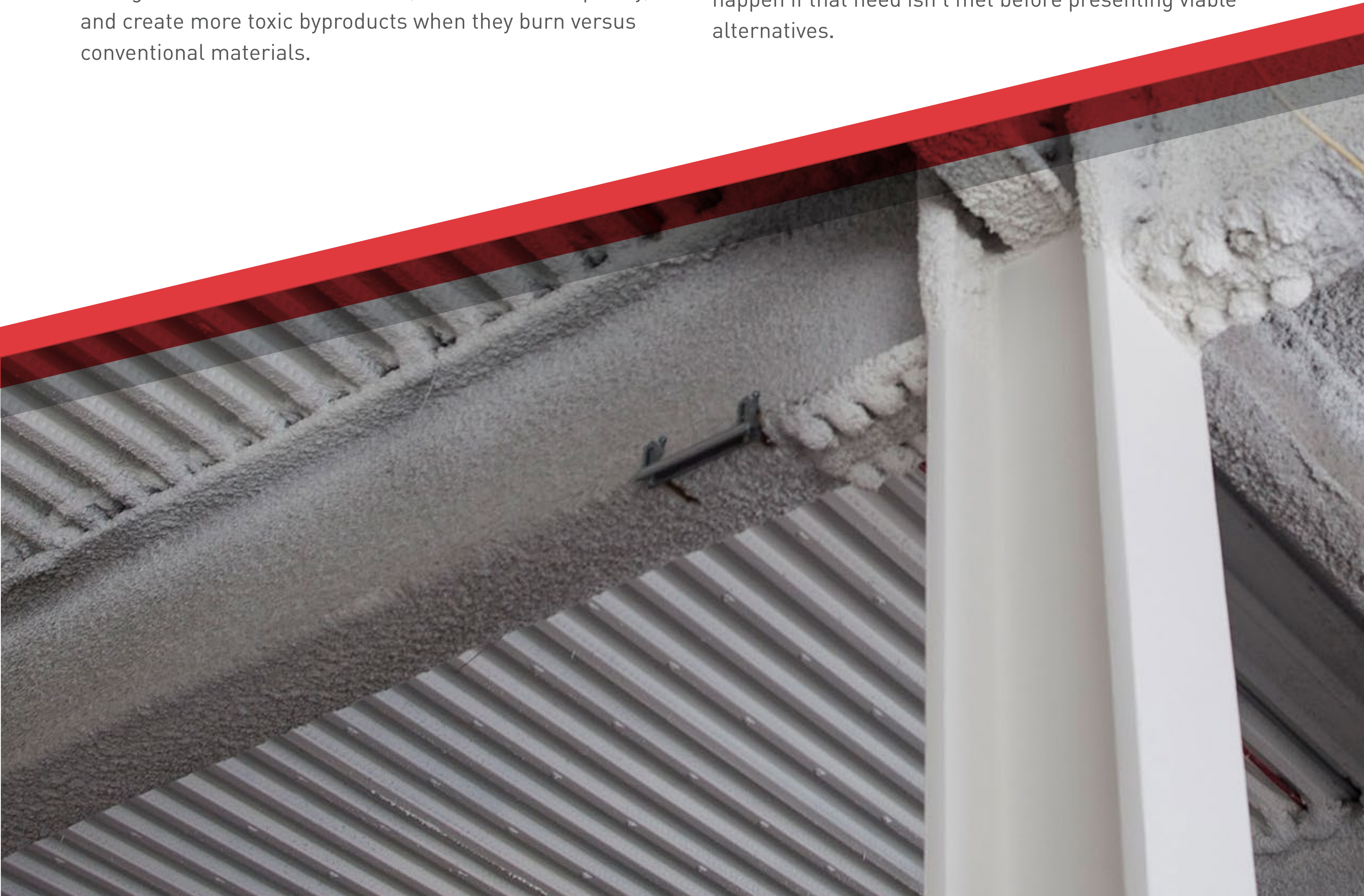
But these examples are instructive in demonstrating the many and complex hazards that modern fire loads pose in today's built environment:

First, EVs and even larger, grid-scale energy storage systems will proliferate. Thermal runaways did not cause these fires, but it is still true that EVs and other energy storage assets release more heat, release it more quickly, and create more toxic byproducts when they burn versus conventional materials.

Second, the construction of mixed-use spaces favoring higher density will continue accelerating. So will the use of synthetic building materials and furnishings, which feature higher calorific potentials than the traditional materials on which today's thermal response testing methods are based.

Third, parking structures are an exceptionally difficult venue for firefighters because they often impede access and cause decisive action to be delayed. When these structures are incorporated within a mixed-use envelope, the difficulties and risks each compound.

Fire curves that more closely reflect the way fires develop today are needed. In chapter 3, we explore what could happen if that need isn't met before presenting viable alternatives.



Chapter 3: Viable alternatives to obsolete cellulosic test standards

Our discussion so far has stayed tightly focused on the development and behavior of modern fires, and how these can challenge the ensuing emergency response.

But the effects of clinging onto inadequate legacy fire test standards ripple out wider than that:

- What are builders, lenders, insurers, or code-writing authorities to do?
- Will it become harder to finance new construction? More expensive to insure it?
- What about insurance policies on older structures built according to last generation's fire protection criteria? Will insurers hike up premiums? Will the prevalence of synthetics be their basis for denying claims?
- And what constitutes resolution of this problem? If current fire test standards are inadequate, what should take their place?

Questions of finance, insurability, and public safety

Today's confluence of finance, insurance, code compliance, and construction works somewhat well. Not everyone is happy about everything all the time, but compromises are reached and buildings are built.

How long will that last? Will the chronic risk of more intense fires in occupied mixed-use developments create too much new tension for stakeholders to bear? Consider the following premises:

Most construction projects are paid for by loans, and in many cases "takeout loans" in turn pay off construction loans. But banks commonly do not approve takeout loans until they believe a building is worth more than its construction cost. But what happens if banks consider a building's fire protection in any calculation of worth? If a new building is poorly protected and a lender's criteria no longer align with building codes, will that building ever be judged as worth more than its cost to construct?

Not all lenders are the same, a prime example being the loans offered by any government. What government loans lack in profit motive, they make up for in strings attached. Could one of those strings be enhanced fire protection in recognition of today's higher risks? Is a cheaper loan worth the potential higher construction cost?

Fire protection codes update slowly and, even then, it is no guarantee that every state, county, or local building authority will continuously mandate that new construction complies with the most recent edition of a fire protection code. For example, in the U.S., it's common for counties or municipalities to adopt a certain edition of the International Fire Code, but then leapfrog over the next one or two editions before again adopting the most recent one a handful of years later. This is done to give builders and developers periods of consistency to plan and execute projects. But if you're a builder, whose guidance do you follow when a lender or insurer insists on meeting one edition while the municipality holds you to another?

Insurers pay most of the high cost of catastrophic fires. They can account for enhanced risks of modern fire loads when writing new policies by charging a higher premium without surprising anyone. But it's more complicated for older structures under older policies. Will those insurance premiums skyrocket? Will insurers force landlords to impose draconian risk-mitigating rules like "no lithium-ion batteries" or "no synthetic carpet"? Will they deny claims on losses on grounds that an occupant could have avoided such a hot, destructive fire if they didn't have a laptop or cell phone? Rents are already high. Will they climb higher?

These premises do not comprise a comprehensive list, but you get the idea. Perhaps some of these questions are already being asked in the aftermath of a disastrous fire in Valencia, Spain, that quickly gutted two apartment buildings in late February 2024.

Some suggested in the aftermath that synthetic exterior cladding on the buildings contributed to the fire's rapid spread, similar to the Grenfell Tower disaster in London in 2017. A recent headline from The Conversation asks the same question we do: Can safety regulations keep up with innovation in construction?

Well, in this case, they probably can. As you'll read in the sections below, we have the tools we need. It's just a matter of pulling them out of their original contexts and applying them to a new one.

Read a more comprehensive overview of UL 1709 here.

"Rapid rise" and UL 1709

Legacy cellulosic fire curves represent the behavior of cellulosic fires; namely, they reach a comparatively lower maximum temperature, and it takes comparatively longer to get there.

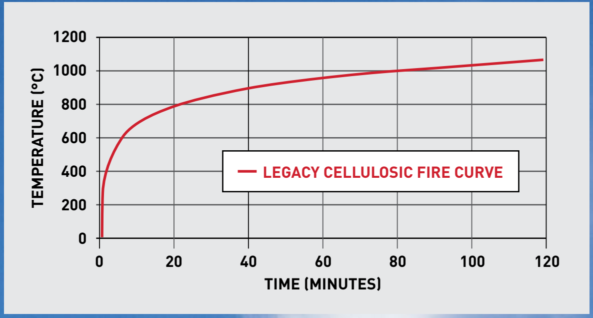
But not all fires consume cellulosic fuels. Hydrocarbon-based synthetics make up more and more of the fuel in the built environment. These materials burn hotter and reach their maximum temperatures much faster than their cellulosic counterparts.

The phenomenon is known as "rapid rise." The risk of such an event in oil and gas facilities spurred fire safety stakeholders to develop new testing that could evaluate passive fire protection materials in these more intense conditions.

Underwriters Laboratories published what has since become the most widely adopted standard rapid-rise test method—UL 1709—in 1991. The method offers guidance on:

- How the furnace providing the heat for a test must be calibrated, and what temperature tolerances are acceptable for a test to be valid
- The number, placement, and proper calibration of thermocouples measuring the temperature inside the furnace and on the surface of a test specimen
- How a PFP material must be applied to a test specimen
- Necessary durability testing (under a separate test method) for any PFP material to pass UL 1709

In our view, treating UL 1709 as a springboard as the industry considers alternatives to outdated cellulosic fire tests for materials in residential/commercial spaces makes sense because they would not be starting from scratch. It is a ready-made rapid-rise test method that matches modern fire loads.

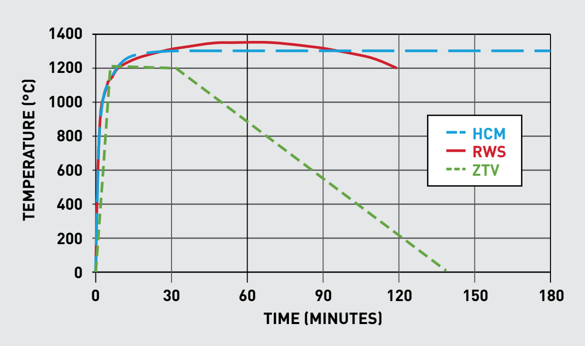


What about tunnel fire curves?

Tunnel fire test curves assess the thermal performance of materials in conditions simulating the unique and acutely dangerous rapid-rise conditions that occur during fires in road or railway tunnels.

Though these fit-for-purpose tests were not meant to assess thermal response of materials in occupied commercial or residential environments, those environments sometimes are designed and built such that a fire can develop in a similar way. Again, these could serve as decent starting points in the search for better assessments that replace cellulosic fire curves.

Modified hydrocarbon curve (HCM) – This fire curve was developed by French authorities following the 1999 Mont Blanc Tunnel fire. The fire began in a truck hauling margarine and flour; the burning margarine plus combustion of fuel of nearby vehicles made this event very similar to what the oil and gas industry calls a hydrocarbon pool fire. It was worsened by the fact that it occurred in a tunnel over seven miles long. Temperatures reached 1,832°F (1,000°C) during the fire. The HCM curve's maximum temperature is 2,372°F (1,300°C), reached in about 30 minutes.



RABT-ZTV curves – These German testing methods are separated for car fires and train fires. Their maximum temperature is a bit lower—2,192°F (1,200°C)—compared to the HCM curve, but that temperature is reached within five minutes. The RABT curves also include cool-downs, with the automobile version beginning to cool after 30 minutes and the train version cooling after an hour.

RWS curve – This Dutch standard is the most severe testing method currently in publication and was based on what that country's ministry of transport judged was a worst-case scenario: An oil or fuel tanker truck hauling 50 m^3 (13,209 gallons) catching fire and burning for two hours. The curve reaches 2,084°F (1,140°C) in 10 minutes, hits a maximum of 2,462°F (1,350°C) after an hour, drops back to 2,192°F (1,200°C) at the two-hour mark, and stays there for another hour.

Drawing inspiration from tunnel fire curves is not the overkill some might think it is.

If a development is connected to an open-air parking garage—which is more and more often the case as land values rise—then similar principles of ventilation are in play. Many code-writing authorities publish guidelines about how "open" an open-air car park should be, recommending specific sizes of exterior wall openings as a percentage of total square footage of the envelope to ensure the space ventilates adequately during a fire.

In fact, in the King's Dock fire summarized in chapter 2, investigators wondered if advertising banners hung on the outside of the parking structure impeded ventilation enough to exacerbate conditions. (According to the fire service, they did not.)

Tunnel fire curves are even more applicable when assessing materials that are used to protect enclosed underground parking garages, especially those with occupied quarters built on top of them. The heat from a fire is likely to re-radiate in any space where the means of directing it outside are limited.

You can see why, in a rapid-rise fire event, it is essential to have a strong, comprehensive fire protection system in place that is quite apart from any emergency first response. Recall from chapter 2 the difficulties fire crews reported in accessing parking structures. Even the fastest-responding fire crews will have exceptional difficulty meaningfully controlling a fire that reaches 1,832°F (1,000°C) in five minutes.

> **Fortunately, we have the tools we need to apply existing, more intense industrial fire curves to the new context of occupied spaces threatened by the risk of modern fire loads.**

Where to go from here

Though the topic of this guide is far from cheerful, we are not trying to scare anyone.

Rather, we view this as our sober and informed contribution to a discussion that we trust stakeholders have already begun.

And if those stakeholders end up saving even a tiny bit of time or effort because the solutions we propose gave them someplace more solid to start, that's a mission accomplished.

Those little savings could add up to lives saved.

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