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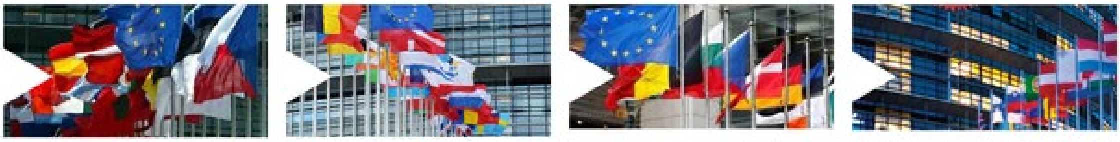

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SFPE Europe Magazine

3rd Quarter - 2022

<u>A word from the Editor</u>

All,

The summer holidays are now long forgotten by most of us and its time to enjoy the autumn/winter, and specifically our Q3 issue of the magazine. This issue is coming to you a bit later than normal but finally we are ready to issue.

There is specifically one of the articles I would like to touch upon a little bit more, our fist article. This article will give you a bit of insight to a problem that we as engineers do not see firsthand and we are rarely doing any type of design work or similar to tackle it. Social injustice and the hurdles that are there for some people are actually putting them in a higher risk group, from a fire point of view, when compared to the rest of the population. The article is focused on US but I am convinced that this is an international problem.

I firmly believe that it is important that we as SFPE also focus and show these types of problems, fire can affect anyone and anywhere. We have just celebrated the Annual Conference & Expo and the opening keynote speech “Systems & Safety: An Equity Perspective” by Adam K. Thiel, Fire Commissioner, Philadelphia Fire Department, was touching upon this very issue. I am sure that it was an eye opener for most of us there.

Back to the articles, as always there is a wide spread of topics, please have a look and read the ones that you believe will be useful or just interesting to you.

If there are readers out there that feel that you have an important subject that you would like to share with the industry do not hesitate to contact us, we can make that happen.

As always, a great thanks to the people who have put in a lot of time and effort to make this issue a reality.

The next issue will come in December.

Yours sincerely,

Jimmy Jönsson, Managing Editor

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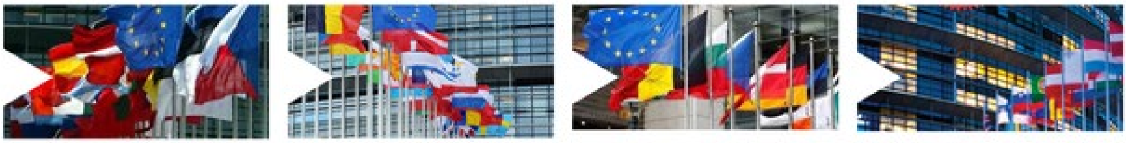

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A Message from the SFPE Europe Chair

Dear SFPE Europe members,

I hope you enjoyed your summer breaks and were able to travel to your favourite places. I deeply missed travelling in the last two summers and enjoyed my time in England and Wales this year.

Before the summer break Kees Both as SFPE Europe past chair and I travelled to Ghent and took part in the celebration of 10 years IMFSE. We were very impressed by the insights from going down memory lane. The IMFSE course is going from strength to strength. Which reminds me to point out that the Master of Advanced Studies in Fire Safety Engineering at ETH has started the second course successfully. And I would like to mention that a new $1^{st}$ Level Master in Fire Safety Engineering course, also based on the SFPE curriculum has started in Bolzano Italy. Congratulations on these courses and may they prosper like IMFSE so that we can celebrate their 10-year anniversaries in the years to come.

The 2022 SFPE Annual Conference & Expo took place this time in Detroit, Michigan USA. I would love to have joined but unfortunately, I was not able to travel. The conference was organized in the professional way just as we have come to know and expect from SFPE. All the feedback I received showed the conference was well visited and everyone enjoyed meeting again in person.

As for SFPE Europe, the biannual SFPE European Conference & Expo on Fire Safety Engineering is taking place from $27^{th}$ till $31^{st}$ March 2023 in Berlin. We are in the middle of organizing it and are pleased that we have received over 70 strong abstracts. The conference organizing committee is doing a very good job in vetting all the abstracts and selecting the speakers. We are also working hard to get the commitment of very well-known key note speakers. We will have an impressive program for the conference and would like to encourage you to reserve the dates and join us. I look forward to meeting you in Berlin!

Enjoy the autumn colours and keep warm during the winter
David Grossmann
SFPE Europe Chair

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# The Invisible U.S. Fire Problem

By: Brian Meacham, Meacham Associates, USA; Sandra Vaiciulyte, Kindling, Mexico; Danielle Antonellis, Kindling, USA; Charles Jennings, John Jay College of Criminal Justice / CUNY, USA

*This article is excerpted with modification from the published report, Antonellis, D., Vaiciulyte, C., Meacham, B.J. and Jennings, C. (2022). The Invisible U.S. Fire Problem, Kindling Inc. and the National Fire Protection Association, [https://www.nfpa.org/-/media/Files/News-and-Research/Fire-statistics-and-reports/US-Fire-Problem/osInvisibleUSFireProblem.pdf](https://www.nfpa.org/-/media/Files/News-and-Research/Fire-statistics-and-reports/US-Fire-Problem/osInvisibleUSFireProblem.pdf), reprinted with permission.*

**Framing the Problem**

The primary narrative about safety to life from fire in the United States (US) is a success story. With the introduction of smoke alarms, social changes such as a reduction in smoking, improvements in building, fire and electrical codes and standards, introduction of other forms of safety protection technologies, and improved emergency response and healthcare for much of the population, fire deaths have reduced dramatically since 1980. But this is not the whole story.

In the US, the demand for affordable housing often outstrips supply. There are also social equity challenges that impact access to funding mechanisms. In response to such socioeconomic and social equity issues, people are often forced to find or create alternative living arrangements. Unfortunately, some of the shelters that people are forced to use fall outside the purview of state legal systems of land ownership and tenure, and of planning, land use, building, public health and safety regulations. These shelters can be considered under-regulated or unregulated. Some people are forced to go unsheltered.

The US housing problem contributes to hundreds of thousands of people being homeless and millions of people living in undesirable conditions due to inadequate shelter conditions: overall, millions of insecurely housed people. Many of these insecurely housed people are at higher risk to life from fire, due both to the shelter vulnerabilities and human vulnerabilities to fire. However, the risk to life from fire of insecurely housed people is generally undocumented and the scope of the problem is largely unknown. Significant research is needed, but where to start?

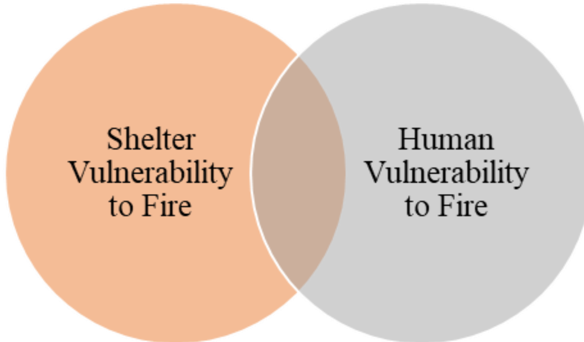


Figure 1. Graphical illustration of intersection of shelter vulnerabilities and human vulnerabilities to fire [1].

Reframing this issue through a regulatory lens can offer new perspectives. What do we know about under- and unregulated buildings? What do we know about fire in under- and unregulated construction? What fire challenges do occupants of under- and unregulated structures – people who are homeless or insecurely housed – face given the confluence of shelter and human vulnerability to fire? What is the scope of this 'invisible' fire problem?

The answers to these questions are critically important. Understanding the nature of insecurely and vulnerably sheltered persons is important for several reasons, most notably the ability to identify measures to improve fire safety across the range of existing shelter and housing in the US, and the need to situate these measures in the context of the complex US building regulatory system, so that fire risks, and risks to safety from fire in these shelters, can begin to be addressed.

**Shelter Typologies & Fire Vulnerabilities**

For the purposes of our work, shelter is considered from the perspective of five broad categories:

- *Vulnerability-Protected*: Goes beyond minimum aspect of building code and includes additional provisions / enhancements aimed at protecting shelters and their vulnerable populations more robustly from fire than minimally compliant shelters.

- *Minimally Compliant*: Meets building code requirements at time of construction and are maintained to meet that level throughout their lifetime to provide a societally tolerated level of shelter vulnerability to fire.

- *Under-Regulated*: May have met building code at time of construction, or not, and are inadequately maintained, have insufficient fire protection, may have illegal components, may be abandoned, etc. Also, persons may use the space for temporary or permanent shelter, legally or illegally. Occupants may use open flame cooking and heating. Examples include:

    - *Under-Maintained*: The situation of a once compliant building falling into neglect due to an owner unwilling or unable to address maintenance issues. This can occur with owner occupied or rented housing. These buildings are typically considered occupied, even if the level of habitability is poor (see also abandoned or vacant buildings).

    - *Under the Radar*: These are buildings which have not gone through any formal building regulatory process as part of alterations or repurposing. Significant concerns include illegal construction, illegal conversion or subdivision of space, and insecure tenure for occupants. Also, the fire service may be unaware of occupant numbers.

- *Vacant / abandoned*: The buildings are not formally occupied and may be in significant states of disrepair or damage. Many of these buildings lack any type of fire protection measures, do not have active utilities connections (e.g., power, water), and may be filled in part with discarded belongings, trash, or other combustibles. If people are using such buildings for shelter, they may be using open flame for cooking and heating, presenting significant fire ignition hazards. Likely the fire service will not know the building has occupants should a fire occur.

- *Unregulated*: Informal structure built outside of regulatory control or other means of shelter. Informal construction may use temporary materials and methods of construction to provide minimal protection from the environment. The construction likely offers little or no fire protection. Insecure tenure is common. Examples include shacks, lean-to's, tents, tarps, lean-to's, motor vehicles. Occupants may use open flame cooking and heating.

- *Non-sheltered*: No significant form of shelter. Open sleeping, possibly with bedding or other cover (e.g., bridge, doorway, awning, cardboard) for minimal protection against weather conditions. This is the highest level of shelter insecurity and vulnerability. Maybe located adjacent to open flame heat sources.

**Human Vulnerabilities & Fire**

Human vulnerability to fire results from many individual and social factors, in addition to any factor associated with shelter construction. Factors that make humans vulnerable to fire have been studied by many. In our review, we found that some of the suggested predictors are ambiguous or contradictory across the geographically diverse studies. This makes it difficult understand specifically the contribution to risk to life from fire. Furthermore, some of the vulnerability factors can be contextual, which makes it challenging to consider in a comparative manner.

However, from the reviewed literature, we identified 18 broad categories that indicate human social, demographic and economic vulnerability that contributes to risk to life from fire. Generally, individual habits (e.g., use of alcohol drugs, smoking), physical psychological fitness (e.g., mental or physical health conditions), demographics (age and gender, family structure), economic status (identified as either poverty, household income, employment status, or education), and social belonging, often explored on the basis of individual background (e.g., ability to speak local language, ethnicity, inclusion in community) were the recurring predictors of general fire risks.

It is evident from the literature that household income, poverty and family structure have been shown to translate to poor dwelling conditions with most certainty. However, it is also evident that many of the sociodemographic factors are not being explored beyond the 'general risks of fire'. For example, it has been largely unexplored in the sample of the reviewed literature, whether ethnicity, ability to speak the local language, employment status, gender, smoking and use of intoxicating substances bear relationship to any dwelling characteristics. These factors, however, all were shown to matter for general fire risks. Thus, the lack of evidence for specific sociodemographic factors and their relationship to dwelling characteristics limits our ability to understand diversity of insecurely and vulnerably sheltered populations in terms of age, gender, inclusion in community and their income, and how this diversity interacts with fire risk.

**Risk to Life from Fire in Different Shelter Typologies**

The invisible fire risk is a complex problem which has just started to be explored. From a purely qualitative, graphical perspective, review to data suggests a relationship between the fire vulnerability of a shelter and the risk to life from fire of the occupants. This is illustrated in Figure 2.

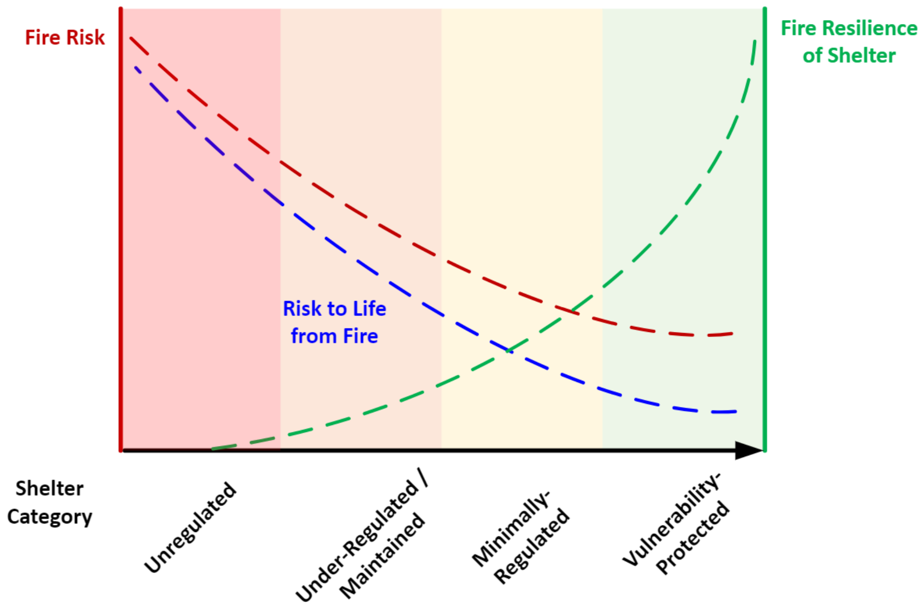


Figure 2. Graphical illustration of risk to life from fire by shelter typology [1].

The red line reflects risk of fire occurring (fire risk) for the different typologies. The green line reflects the inverse – the fire resilience of the typologies. The blue line indicates risk to life from fire, which decreases from left to right indicating unregulated shelters present higher levels of risk to life from fire than the other shelter categories. There is a strong relationship between risk to life from fire and fire risk - they are interrelated. Regulatory mechanisms that prioritize life safety drive fire safety investments therefore reducing fire risk overall. Vulnerability-protected shelters go beyond regulatory requirements and include features that provide additional protection for one or more vulnerability attributes (e.g., could be enhanced fire protection features, enhanced evacuation features, care givers, etc.). under- and unregulated shelters have little or no fire protection, high fire risk, and significant risk to life from fire. This may seem obvious but has not been well studied. Data are lacking. Much needs to be done.

**The Invisible Fire Problem Knowledge Iceberg**

Our initial work has identified gaps in research, policy, and action pertaining to fire safety of insecurely and vulnerably sheltered populations in the US. It suggests that fire disproportionately affects populations in under-regulated, unregulated, and non-sheltered living conditions, despite significant challenges quantifying and describing fire risks and consequences on a national level – hence it is termed here the invisible US fire problem. Playing off this imagery of invisibility, an illustration of an iceberg is used to describe known and unknown dimensions of these fire problems (Figure 3).

The tip of the iceberg represents the known areas of fire safety in regulated housing and in unregulated shelter that are commonly engaged with in research, policy making and are present in the news media and activism. These are the ‘known’ areas that support our thinking about fire safety currently. The illustration of the iceberg extends under-the-water, to the ’known unknowns’, to illustrate research, policy making and activism gaps in relation to what is currently known about fire safety in insecure and vulnerable shelters. Currently, no consolidated effort exists to tackle these issues in an integrated, transdisciplinary way, where multiple research objectives converge. The water represents ‘unknown unknowns’, factors that may affect fire safety in these settings, but have not yet been identified.

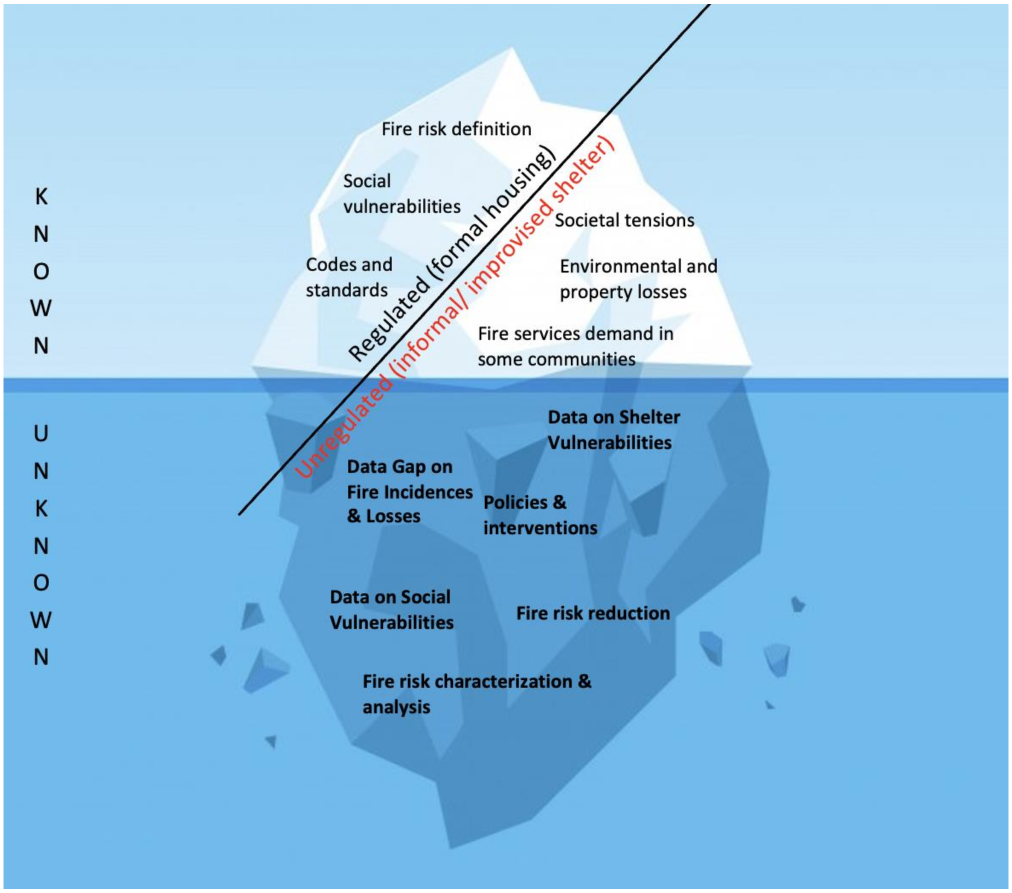


Figure 3. Research gaps specifically for vulnerably sheltered [1].

As shown in Figure 3, several gaps and challenges exist, including:

- Lack of data on shelter vulnerabilities
- Lack of data in fire incidence concerning homeless populations
- Insufficient policies and interventions that address under-regulated, unregulated, and non-sheltered typologies
- Lack of strategies for fire risk reduction
- Lack of data on social vulnerabilities of vulnerably and insecurely housed populations
- Lack of fire risk characterization and analysis methods

**Where to from Here?**

To tackle holistically and urgently the identified gaps and improve fire safety across insecurely and vulnerably shelter contexts, stakeholders need to collaboratively engage with this 'invisible' fire safety problem through research, policy and action that addresses the full spectrum of economic, social, and technical issues. The roles of public health data services, social services engaging with homeless populations, firefighters, fire engineers and academics among others are significant. Convergent transdisciplinary action research is needed. The needs and actions identified in this section should be viewed as a starting point, and not an exhaustive list. It is important to engage with multiple stakeholders to address challenging and emerging fire safety gaps in these settings. In the USA, it is suggested that workshops should be held with relevant stakeholders, such as NFPA, DHS/USFA, HUD, code enforcement entities, the Urban Institute, Vacant Property Research Network, Center for Community Progress, Joint Center for Housing Studies of Harvard University, to develop more specific strategies and to identify funding opportunities for research and action. While not explicitly addressed in this work, it is suggested that the 'invisible' fire safety problem exists in many other countries, and that the approach of convening stakeholder workshops, undertaking research strategy development, and exploring funding opportunities to support research and policy development within this space would be worthwhile in many other countries and regions of the world as well.

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## Lithium batteries – What's the problem?

By: George Hare, BRANZ Ltd, New Zealand

This article will give a brief introduction to lithium-ion batteries (LIBs), describe some of the fire safety challenges around LIBs and address some common misconceptions about them.

Since they became commercially available in the early 1990's, LIBs have become ubiquitous in society. They can be found in everything from toys to electric vehicles (EV's) and even large-scale, grid-connected battery energy storage systems (BESS). The term 'lithium-ion' (often abbreviated using the chemical symbol for lithium to 'Li-ion') refers to a family of electrochemical cell chemistries. However, these cells are rarely marked with the particular chemistry used which makes identification difficult.

| Cathode Material | Nominal Cell Voltage (V) | Specific Energy (Wh/kg) | Charge / Discharge Rate | Cycle Life | Thermal Runaway Temperature |
|---|---|---|---|---|---|
| **$LiCoO_2$ (LCO)** | 3.6 | 150-200 | Charge 0.7-1C Max<br>Discharge 1C Max | 500-1000 | 150°C |
| **$LiMn_2O_4$ (LMO)** | 3.7 | 100-150 | Charge 0.7-1C Typ, 3C Max<br>Discharge 1C Typ, 10C Max, 30C Pulse | 300-700 | 250°C |
| **$LiNiMnCoO_2$ (NMC)** | 3.6-3.7 | 150-220 | Charge 0.7-1C Max<br>Discharge 1C Typ, 2C Max | 1000-2000 | 210°C |
| **$LiFePO_4$ (LFP)** | 3.2-3.3 | 90-120 | Charge 1C Typ<br>Discharge 1C Typ, 25C Max, 40C Pulse | 1000-2000 | 270°C |
| **$LiNiCoAlO_2$** | 3.6 | 200-260 | Charge 0.7C Typ | 500 | 150°C |

| | | | | | |
|---|---|---|---|---|---|
| **(LCA)** | | | Discharge 1C Typ | | |

Table 1. Li-ion cell chemistries (Battery University, 2019).

Li-ion cells come in three main physical formats: Cylindrical, (such as the common 18 mm diameter, 65 mm long, 18650 cell), prismatic and pouch cells. Although they are different shapes and sizes, they all share a similar internal construction with cathode and anode layers separated by a layer containing a semi-permeable membrane and electrolyte. In prismatic or pouch cells these layers are flat. In cylindrical cells these layers are rolled up in a configuration often referred to as the ‘jelly roll’ as shown in Figure 1, but otherwise the configuration is the same. A battery is made up of a number of cells, but for the purposes of this article, the terms ‘battery’ and ‘cell’ are used inter-changeably.

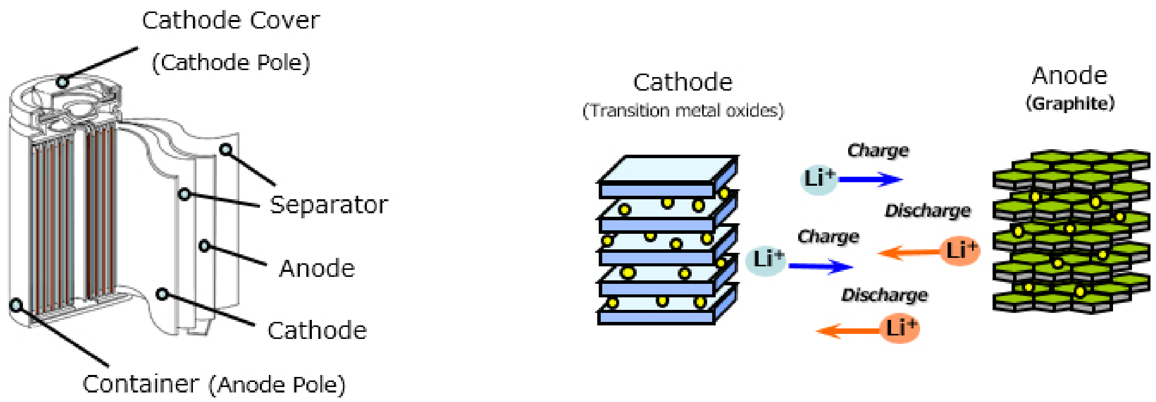


Figure 1 Li-ion cell construction (https://industrial.panasonic.com/ww/products/pt/lithium-ion)

The copper anode is coated with graphite, while the aluminium cathode is coated with the metal oxide. Between the electrodes is a very thin (12-25 µm) semi-permeable membrane separator. Lithium hexafluorophosphate is dissolved in a hydrocarbon based liquid electrolyte (usually ethyl carbonate or diethyl carbonate).

The primary fire safety challenge from these cells is thermal runaway (TR). This can be split into two driving mechanisms, either external heating or internal heating.

External heating may occur as a result of adjacent cells overheating or any other heating source, for example a fire, unrelated to the cells.

Internal heating is normally the result of abuse, either physical or electrical. Manufacturing defects, such as contamination, weld splatter, material defects, or creases can also cause internal heating. Any damage to the thin membrane separator will allow a short circuit between the anode and cathode within the cell and localised heating around the short. Electrical abuse in the form of charging/discharging at excessively high currents can cause internal heating due to the internal resistance of the electrodes. Overcharging (normally the result of using the wrong charging equipment) can have the same effect. Over discharging a cell can also result in damage, where at very low states of charge, the lithium contained within the electrolyte can plate onto the electrodes, forming small finger-like projections, called dendrites, which can then puncture the membrane separator causing a short circuit.

Figure 2. Pressurised pouch cell.

All of these failure mechanisms result in the heating of a cell.  Once a cell is heated sufficiently, the electrolyte starts to boil, increasing the pressure within the cell.  In pouch type cells, this is evident when they look like a pillow, as seen in

Figure *2*.  However, this pressure increase is not visually evident in cylindrical and prismatic cells until the pressure relief valve activates, releasing flammable gases.

**Myth 1: Lithium iron phosphate (LFP) batteries don't catch fire, you can hammer a nail through them!**

There have been many instances of LFP batteries catching fire, they are just less prone to it compared with other chemistries.  In Table 1 you will see the TR temperature of LFP is much higher than that of LCO or LCA cells, but they will eventually reach TR.

Some terminology used with batteries:

- **State of Health** (**SoH**) – the current maximum capacity of a battery at a point in time vs. the maximum capacity of that battery at the time of manufacture.  This will decrease over the life of the battery.
- **State of Charge** (**SoC**) – the current capacity of a battery at a point in time compared to its maximum capacity at its current SoH.  This will go up and down during use as the battery is being charged and discharged.


Figure 3. Battery SoC vs SoH (image by David Phan - *https://www.thebatteryclinic.co.nz/*).

Figure 3 shows the 'fuel' gauge on a Nissan Leaf, indicating a full SoC shown by the twelve long bars and a SoH of eight out of twelve small bars (approximately 66% of the original capacity) hence the reduced range indication of 113 km.

Monitoring the battery is a key function of a Battery Management System (BMS). A BMS provides a number of functions:

- **Charge management** – shutting off the incoming charging voltage when the battery is full and shutting off the output when the battery voltage drops below the minimum recommended voltage.
- **Cell balancing** – a BMS will monitor the individual cell voltages within a battery and is able to shut the battery down in the event of a cell imbalance, some may also provide alerts. More sophisticated systems are able to discharge cells that are higher than other cells, in order to bring them back into balance.
- **Thermal management** – some BMS are able to monitor the temperature within the battery, shutting the battery down if it gets too hot. More sophisticated systems, such as those in some BESS and EV's, are able to control cooling systems, to keep the battery within thermal operating limits.
- **Capacity monitoring** – some BMS are able to monitor the energy required to fully charge the battery and therefore work out the SoH.

**Myth 2: A good BMS will stop a thermal runaway!**

A BMS can help reduce the likelihood of a TR event. However, there are events outside the control of a BMS that will trigger a TR and the BMS cannot prevent or stop a TR if it occurs.

When a LIB goes into TR, they react differently depending upon the SoC. This is not generally something that first responders need consider when dealing with an internal combustion engine vehicle fire. Batteries with a high SoC will generally be more volatile than those with a lower SoC and may produce a more intense but shorter fire.

Using oxygen calorimetry, commercially available 2.9 Ah pouch cells were tested. At 100% SoC, the peak heat release (HRR) was measured at 21 kW burning for around 20 s. At 50% SoC, that peak HRR dropped to 13 kW, but the cell burned for 50-100 s. At 0% SoC, the peak HRR was just 2.6 kW, but the cells burned for 300 s (Ribière P., 2011).

Evidence would also suggest that a SoC over 50% is more likely to result in spontaneous ignition of combustible gases during TR, while a SoC less than 50% is more likely to result in a flammable vapour cloud which, if sufficiently well mixed, can result in an explosion if ignited in a confined space (Christensen, et al., 2021). An example of this is the APS McMicken BESS explosion, which injured nine first responders, including eight firefighters, four seriously (DNV.GL, 2020).

Batteries undergoing TR also give off a variety of toxic products, including carbon monoxide and hydrogen fluoride (HF). The same cells tested by Ribiére *et al*. were tested at both 100% SoC and 0% SoC and HF production measured. At 100% SoC, approximately 400 mg of HF was released. At 0% SoC, the quantity of HF released was higher, approximately 750 mg. Worksafe New Zealand (the New Zealand occupational health and safety regulator) have three measures for toxic exposure, a Time Weighted Average (TWA) over an 8-hour period, a Short-Term Exposure Limit (STEL) for exposure over any 15-minute period during a working day and a ceiling exposure. The published ceiling exposure for HF is just 3 ppm or 2.6 mg/m$^3$, but Worksafe New Zealand does not publish a TWA or STEL for HF (Worksafe New Zealand, 2022). The European exposure limits, based on indicative occupational exposure limit values (IOELV) are IOELV:TWA of 1.8 ppm or 1.5 mg/m$^3$ and IOELV:STEL of 3 ppm or 2.5 mg/m$^3$ (European Chemicals Bureau, 2001).

**Myth 3: You can't put water on a lithium-ion battery fire, it'll explode!**

LIBs do not contain metallic lithium which reacts with the water. The lithium is contained in salt form in the electrolyte and oxide form in the cathode which does not react with water.

Extinguishing LIB fires can be challenging and, in some cases, where circumstances allow, it may be quicker and more beneficial to allow the battery to burn, consuming the flammable electrolyte and using much less water. If a fire must be extinguished for life-safety, property protection or environmental reasons, water is still the 'go to'. Gaseous or dry powder extinguishers have been used but they are only effective at putting the immediate fire out. Because the thermal runaway is still occurring within the battery, flammable gasses continue to evolve, and it is highly likely the fire will re-ignite. Foam extinguishers also have the added effect of insulating the batteries, further increasing the rate of TR. Water has the benefit of extinguishing the fire and, at the same time, cooling the cells, thus slowing the TR.

First responders in Europe have adopted the strategy of putting EV's into large containers of water in order to extinguish the fire and to cool the whole battery pack, as shown in Figure 4. The BMW i8 shown was only removed from the container once there were no observations of bubbles rising to the surface, this indicating that all of the cells had stopped off-gassing.

Fortunately, instances of EV traction battery fires are rare, with only around 260 confirmed globally since 2010, many of which have involved high-speed collisions. They do however garner plenty of media attention when they do happen. Tesla claim five EV fires for every billion miles travelled, compared with the national average in the US of 53 vehicle fires per billion miles travelled (InsideEVs, 2022).

Figure 4. BMW i8 in container of water (Image: Brandweer Midden- en West-Brabant).

In LIB fires where the immersion technique cannot be used, large volumes of water are required to be continuously pumped onto the batteries for cooling for an extended period of time. Such approaches generally require committing many first responders over the duration. For example, the 25 MWh LFP fire on top of a Beijing shopping mall required 235 firefighters, with 47 appliances from 15 stations. Two firefighters were sadly lost in the initial explosion. In another example, the 300 MW, 450 MWh Victoria Big Battery fire in Australia (shown in Figure 5), over 100 firefighters attended.  Following the fire, 900,000 L of contaminated water was removed from the site, although it is estimated that close to 6,000,000 L were pumped onto the fire and in the subsequent cooling phase.  The incident lasted almost 4 days (Fisher Engineering Inc and Energy Safety Response Group, 2022).

Figure 5. Victoria Big Battery fire (Image: Fire Rescue Victoria (FRV), Aviation RPAS Unit).

Although large batteries pose extraordinary challenges to first responders due the scale of the incidents, smaller batteries are having a bigger impact on fire safety in the home.  Electric mobility devices such as e-bikes, e-scooters and e-skateboards are increasingly involved in fire-related deaths around the world.  The Vancouver Fire Department has reported seven fire-related deaths from the start of the year until mid-June, of those, five were attributed to LIBs (Little, 2022).  In June 2022, the New York City Housing Authority proposed to prohibit e-bikes and e-scooters in their public housing to limit the fire risk (Verzoni, 2022).

LIBs are also causing fire safety challenges in the waste streams.  LIBs are often discarded in both normal and recycling waste streams.  However, when they are crushed, in compactor trucks, or in waste sorting facilities, they can catch fire, causing huge losses (United States Environmental Protection Agency, 2021).

In conclusion, LIBs are everywhere in society and a classic example of new technologies developing faster than regulatory controls, leaving first responders on the backfoot.  Like most technologies, when working as intended, LIBs are a key enabler in modern society.  However, when they go wrong, they pose a range of threats from fire and explosion to toxicity.  LIBs will be in use for many years to come while new technologies are developed.  In the meantime, we must adapt, by updating building regulations to account for new technological risks and by undertaking the research required to provide our first responders with doctrine that is fit-for-purpose.

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## Exploring 'wait and see' responses in French and Australian WUI wildfire emergencies

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*This article is the short version of the published paper "Exploring 'wait and see' responses in French and Australian WUI wildfire emergencies".*

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**Introduction**

In the event of wildfire, a timely response upon the receipt of the first fire cues is vital to human survival in wildfire-prone urban areas. From the past wildfire events in Australia, for example, evidence has shown that residents often 'wait and see' how the situation unfolds before taking protective action, such as evacuation or shelter-in-place [1]. Such decision-making delay has in the past been detrimental to people's survival [2], thus advising largely against a 'wait and see' strategy [3]. Yet, media reports from as recent as Victoria's 2019–2020 bushfire season reveal that some people are still willing to 'wait and see', even after receiving an evacuation order, and could be tempted to do so even more as the COVID-19 pandemic has seen many people self-isolate and be reluctant to leave [4;5]. Importantly, the 'wait and see' responses in populations reactions to wildfires have received research attention in Australia and North America. However, it is unclear whether the findings extend to European regions, given the scarcity of such research there.

Thus, research is needed to better understand the circumstances under which a 'wait and see' response manifests during wildfires, the circumstances under which this response diminishes, or where it is unlikely to occur. Such knowledge would improve wildfire emergency response planning (illustrated in recent wildfires in Greece, see [6]), including support the use of urban-scale evacuation modelling [7;8], simulating population responses beyond the binary 'stay' or 'go'.

**Influence in decision-making**

Several factors have been found across the literature to impact 'wait and see' responses, namely demographic characteristics of residents (e.g. gender, age, medical impairments, etc.); differences in risk perception in relation to culture and other contextual factors [9]; contextual factors such as a region's official wildfire policy, by showing a preference for one type of protective action [10].

Different wildfire policies exist across geographies, as for example, in the South of France where 'shelter-in-place is preferred over evacuation. Moreover, residents are accustomed to rely upon instruction from authorities during an incident [11]. Therefore, it is possible that relatively more residents in South of France would choose to 'wait and see' upon a wildfire threat. Nonetheless, little research exists on the wildfire-related behaviours of European populations [12], and no research has investigated 'wait and see' responses in Europe.

The current research effort specifically looked at risk from wildfire populations in South of France and Australia and with the help of two kinds of questionnaires: actual experience and hypothetical wildfire, assessed the participants' 'wait and see' behaviors generally, as well as under circumstances such as social cues (media notifications, seeing other people evacuate), environmental cues (smoke, embers, fire), and a combination of the two.

**Key findings**

*<u>'Wait and see' responses under different circumstances</u>*

There were several findings pertaining to 'wait and see' behaviors in Australia and South of France. Firstly, on who was more or less likely to 'wait and see': Australian participants in a hypothetical wildfire intending to wait were in line with the summarised findings from literature (in [13]), i.e. between 3% to 32%. Similarly, Australian participants who actually experienced a wildfire, reported waiting closer to the lower end of the previously reported results (25% to 58% – see [13]). In contrast, there were more participants who reported intending to wait or actually waiting in South of France, but far lower than that reported previously for American communities (intending = approximately 71%, actually waiting = between 54% and approximately 85%) [14;15]. These differences show that while past research from outside Europe has been important in highlighting a global problem, those findings cannot be wholly generalised to other parts of the world. Also, Australian participants' more decisive behaviour was likely influenced in part by an awareness of the tragic 2009 Black Saturday bushfires – an event of a magnitude that France has not experienced this century, and so the French population would likely have less media exposure to information regarding the negative effects of 'wait and see' responses.

Secondly, our findings show that different circumstances, such as social, environmental cues and the mixture of the two also influence the 'wait and see' decision. For example, the receipt of just social cues was not found to have a decisive effect on all participants' decision-making (e.g., wildfire notification via the media, and unofficial cues such as seeing neighbours' reactions). However, official cues in the form of a direct order to evacuate did appear to reduce waiting, as has been noted elsewhere (e.g. [14]). As for the environmental cues, they were more effective in reducing intentions to wait, both when presented alone and in combination with social cues. However, influence of environmental cues was nuanced. The results suggested that, in both the hypothetical and real-life situations, participants were not entirely sure what to do in response to seeing smoke, while more decisiveness was usually displayed in response to seeing embers and certainly in response to seeing flames. So, practitioners should be made aware that their expectations are not necessarily reflected in the manner in which the public is likely to respond. On the other hand, embers and flames are indicators of a fire being in very close proximity, meaning a potential danger to life and property and very little time to act.

Thirdly, pre-event risk perception did not appear to uniformly influence participants' decision-making, and neither did preparedness (i.e. having a plan). Nonetheless, having insurance was significantly associated with taking action rather than waiting, but only for the South of France sample with actual wildfire experience. It could be that having appropriate insurance cover means that the financial cost of losing property is covered. As such, people's priorities could be less conflicted during a fire, and attention could be immediately turned to acting to protect self and family from harm. Thinking ahead about one's evacuation destination was significantly associated with less waiting, but only in the Australian hypothetical wildfire sample. There, more participants planned to go to a nearby town during evacuation rather than escape to closer locations such as a public hall in their own town.

Finally, when it comes to socio-demographic factors, there was no overlap between the two study regions or experience samples, suggesting that there could be both regional differences and other ways in which wildfire experiences shape diverse populations' responses. Age being an important factor in the Australian sample for a hypothetical fire can potentially indicate that younger and older adults, who have not yet experienced a wildfire and might be prone to reacting slowly, perhaps because they feel less able to make a critical decision or take action for themselves in a situation without any sign of support or involvement from authority figures. Therefore, interventions targeting different age groups could be formed more intentionally. For the South of France participants with actual experience, having pets/livestock was significantly associated with choosing to take action, as was having dependents, indicating the importance of livestock and dependents on evacuation decision-making (also reported in [16;17]).

*Study implications*

The findings of this study have implications for practitioners and policy makers. They call for their attention when designing effective communication during wildfire emergencies, highlighting a need to ensure instructions are clear about action to be taken, authoritative, and incentivising. They also call for attention when designing preparedness initiatives for wildfire events, especially in at-risk areas where populations may be largely inexperienced. Preparedness should focus on assisting residents to swiftly and correctly interpret environmental cues such as smoke, or identify physiological symptoms and their implications for the ability to carry out protective action safely. Residents should also be helped to identify safe refuges within their locality and alternate routes to reach the safe locations, which can be factored into fire plans. Additionally, more consideration should be given as to how to reach out to residents in their homes – not just residents deemed vulnerable, such as those living with young children or the elderly, but also those without dependents. Educational safety campaigns may be effective but need to capture interest and are likely to be conducted for a limited time. Thus, policy makers should seek to identify and collaborate with alternative information sources such as insurance companies – their marketing campaigns and policies are likely to be viewed by more people and more frequently when policies need renewing, and these could contain reminders about the benefits of wildfire preparedness.

The observed effects of environmental and social cues on 'wait and see' responses also have implications for urban-scale evacuation modelling. Firstly, the differences in the extent of waiting seen in France compared to Australia (and the USA) mean caution should be exercised when applying research findings to simulation models across geographies, even when the models are capable of simulating such environmental and social effects. Secondly, there is a potential for over-reliance on the effects of social cues in initiating a protective action response, as it seems that some people will 'wait and see' under certain official and unofficial social cues. Thus, developers of evacuation models should consider the integration of hazard data within their models, to enable scenarios where evacuation is triggered by different progressing environmental cues in addition to social cues. Finally, for evacuation simulations to more accurately reflect reality, it is important to consider that response behaviour of individuals with experience of wildfires and those without.

*Future research efforts*

The study confirms the urgent need to conduct further human behaviour research in European contexts, based on the evidence that South of France participants exhibited more prominent 'wait and see' behaviors. To enable this, policy makers should commission and use local research. This will support evidence-based planning, which in turn should help authorities direct resources to where they may have the greatest effect in minimising waiting.

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## Fire Safe Use of Wood in Buildings – Global Design Guide

By: Birgit Östman Linnaeus University Sweden, Andrew Buchanan PTL Structural Consultants New Zealand and Michael Klippel ETH Zürich Switzerland

An international guideline for the fire safe use of wood products and timber structures in a wide range of buildings has been published recently [1]. It aims to provide state-of-the-art scientific knowledge on a global level for practical applications. The guideline includes extended use of design codes and standards, practical guidance and examples of fire-safe design and principles of performance-based design.

The guideline is based on the 2010 European guideline, Fire Safety in Timber Buildings [2], enhanced with the latest outcomes from the recently completed COST Action FP1404 - Fire Safe Use of Bio-Based Building Products [3], to which many of the guideline authors actively contributed. It is also inspired by recent code changes to allow taller and larger timber buildings in Australia, Canada, Europe and the US.

Many well-known fire scientists and engineers worldwide wrote the different chapters to guarantee its quality and relevance for use in all countries, see Table 1. More than 20 expert co-authors supported the lead authors. Andrew Buchanan and Birgit Östman edited the book and Michael Klippel served as chairman of the steering committee.

**Technical content**

The guideline consists of 14 chapters, starting with a description of wood products and various types of timber buildings, moving on to in-depth chapters dealing with design for different fire performance criteria as shown in Table 1.

The guideline addresses structural fire engineering by providing the latest detailed guidance on structural design of separating and load-bearing elements of timber structures. It also contains guidance on design for surface flammability and prevention of fire spread. The importance of proper detailing in building design is stressed with examples of practical solutions to prevent the spread of fire or smoke. Active fire protection and building execution and control are presented as important means of fulfilling fire safety objectives.

National and international building codes in different regions of the world are compared, further details are given in [4]. The guideline is of benefit to building designers and fire engineers in all countries, educational establishments, and of special interest to code writers in countries where timber buildings are not yet widely used.

**Chapter 1 Timber structures and wood products** gives an overview of wood-based materials and construction techniques.

**Chapter 2 Fire safety in timber buildings** is a summary of design principles for providing fire safety in all buildings, with particular attention to timber construction.

**Chapter 3 Fire dynamics** introduces the fire dynamics of burning wood, moving from basic physics to compartment fires, and calculation methods for assessing the contribution of exposed wood to the fuel load.

**Chapter 4 Fire safety in different regions** gives a summary of international regulations for the fire safe use of structural timber elements and visible wood surfaces in interior and exterior applications, presented in tables and maps.

**Chapter 5 Reaction to fire performance** describes the systems used for compliance with prescriptive regulations in different regions for internal and external wood surface finishes.

**Chapter 6 Fire separating assemblies** gives design principles for timber used as fire-resistance-rated separating assemblies to provide compartmentation for life safety and property protection, including walls, floors and roof constructions.

**Chapter 7 Load bearing timber** provides guidance for the structural design of load-bearing timber members exposed to a standard fire, with an overview of the principles needed to predict the effect of charring and heating. Simplified design models include design models from the proposed second generation of Eurocode 5.

**Chapter 8 Timber connections** is an introduction to connection types, potential failure modes, and structural design methods to provide fire resistance to connections in timber buildings.

**Chapter 9 Prevention of fire spread** gives recommendations for design to prevent fire from spreading into, within and through timber structures, including detailing of construction joints and penetrations.

**Chapter 10 Active fire protection by sprinklers** covers the effects of active fire protection systems on design of timber buildings for fire safety.

**Chapter 11 Performance-based design** introduces concepts for performance-based fire design of timber buildings, with a summary of risk-based design methods.

**Chapter 12 Robustness in fire** describes general approaches and design guidance to achieve structural robustness in the fire design of timber structures.

**Chapter 13 Building execution and control** provides guidance for design and construction processes to ensure that the fire safety of timber buildings is maintained during and after construction.

**Chapter 14 Firefighting considerations** describes firefighting practices that may differ in timber buildings compared with other structural building systems, and addresses concerns of fire services specific to timber building construction.

The technical content has been peer-reviewed by fire engineers, scientists and experts from various countries, providing additional international credibility and applicability.

**Availability**

The Global Design Guide is published both as a hard-bound book and as an open access version available for free PDF download via the Fire Safe Use of Wood website (www.fsuw.com). It is expected to be of use to a wide range of stakeholders involved in designing timber buildings, including architects, engineers, educators, regulatory authorities and the building industry.

**Acknowledgements**

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*Table 1. List of chapters and lead authors*

| Chapters | Lead author |
|---|---|
| 1. Timber structures and wood products | Christian Dagenais, FPInnovations, Canada |
| 2. Fire safety in timber buildings | Andrew Buchanan, PTL Structural Consultants, New Zealand |
| 3. Fire dynamics | Colleen Wade, Fire Research Group, New Zealand |
| 4. Fire safety in different regions | Birgit Östman, Linnaeus University, Sweden |
| 5. Reaction to fire performance | Marc Janssens, Southwest Research Institute, USA |
| 6. Fire separating assemblies | Norman Werther, Technical University of Munich, Germany |
| 7. Load bearing timber | Alar Just, TalTech, Estonia |
| 8. Timber connections | David Barber, Arup Fire, Australia |
| 9. Prevention of fire spread | Esko Mikkola, KK-Fireconsult, Finland |
| 10. Active fire protection by sprinklers | Birgit Östman, Linnaeus University, Sweden |
| 11. Performance-based design | Paul England, EFT Consulting, Australia |

| | |
|---|---|
| 12. Robustness in fire | Michael Klippel, ETH Zürich, Switzerland |
| 13. Building execution and control | Andrew Dunn, Timber Development Association, Australia |
| 14. Firefighting considerations | Ed Claridge, Auckland Council, New Zealand |

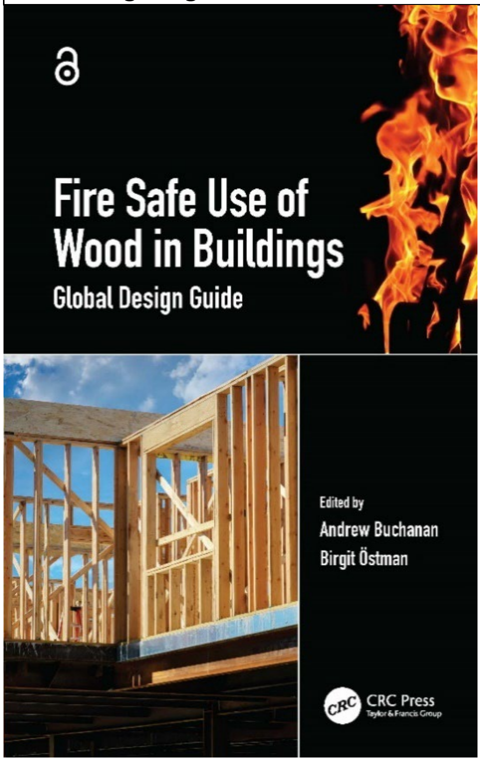


*Figure 1. The Global Design Guide is published both as a hard-bound book and as an open access version available for free PDF download via the Fire Safe Use of Wood website (www.fsuw.com)*

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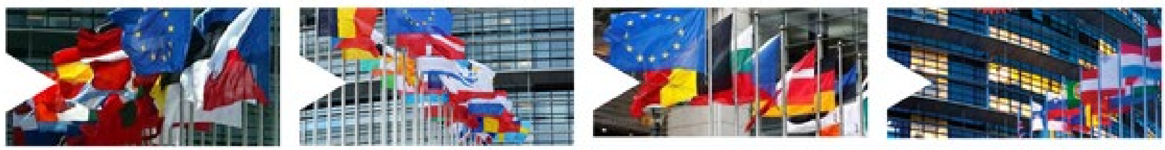

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# Fast and preliminary method for identifying the portions of a plant that must undergo a quantitative explosion risk assessment (Part 1/2)

By: Baldassare Genova (P.E.) – National Fire Brigade – Ministry of the Interior (Rome) Italy

The occurrence of explosions in industrial plants handling hazardous substances, especially those with a major accident hazard, can pose a serious risk to the surrounding population as well as to assets, infrastructure and the environment.

For this reason, the "so-called" Seveso III Directive (Directive 2012/18/EU), requires that a risk assessment, not limited to the explosion risk, be carried out for these plants.
In this article, a fast and preliminary method is proposed for identifying the portions of a plant that must undergo a quantitative risk assessment (QRA); the method is especially addressed to plants in which explosive materials are present.

This first article will illustrate the main principles of the method to select plant units that should undergo a quantitative assessment with an increased level of detail. Part 2 will deal with explosion risk assessment quantified in terms of probability of occurrence and associated severity.

It is outmost important to highlight that the decision process aimed to the identification of critical areas requires attention considering that authorities having jurisdiction should verify the demonstrations given by the plant owners in safety reports/safety cases of the installations, in many cases being a very large industrial plant with multiple units with a certain degree of complexity. Proposed approach may grant benefits to both the end-users and to authorities. For the first as a tool to evaluate their entire plant with a graded and staged approach, for the latter as a tool to verify the approach that should be preliminarily focused to those area presenting a significant fire and explosion risk level.

Chemical plants are complex environments where potential hazardous material and processes are often present. Work-owners must consider the risks related to substances and process conditions and individuate potential accident scenario and consequences as to grant working activities are performed in safe and secure ambiances to safeguard operators' life and environment.

The principal methodologies to be compliant with the Seveso III directive are 30 years old (the first dated back to 1980) and updated in the early '90s. Their development derives from the need for insurance companies to evaluate adequate insurance fees quickly. The most used are the Dow F&EI [1] and the Mond Index methods [2], both thought to be explicitly applied to the oil & gas industry. While for explosive substances plants at the moment the most current approaches are those based on consequence assessment with specific correlations or calculation tools, dealing mainly with the severity of the outcomes rather than on the risk as a factor composed by probability and magnitude that may be different considering all the units of such large installations.

The method draws its origins also on the previous work by [3].

**The methodological approach**

The proposed method consists of a succession of distinct phases, the exemplification of which is shown in the diagram reported in Figure 1. This method could find his opportunity also in initial inherent safety studies during incipient design stages of new installations or existing premises modifications.

The following paragraphs describe the steps that make up the method.

*Divide the plant into separate installations*

The first step of the method is to divide the plant into a number of separate (or independent) units. This is a complex process and can be the subject of discussion and shared choices among experts. Please note that the criteria below can only be considered a guideline for the definition itself. An important criterion that helps define what constitutes an independent installation is one that takes into account the loss of containment that affects it, which, if it occurs, must not result in the release of significant quantities of the substance from other installations.
Consequently, two installations are considered separate or independent if they can be isolated from each other within a very short time following an accident.

*Calculate A for each installation*

The intrinsic hazard of an installation depends on the substance hold-up, the physical and toxic properties of the substance and the typical process conditions. The indicative number "A" is calculated as a measure of the intrinsic hazard of an installation. It is a dimensionless number defined, in general, as [4]:

$$A = \frac{Q \cdot O_1 \cdot O_2 \cdot O_3}{G}$$

Where:
Q is the quantity of substance present in the installation [kg]
$O_i$ is the factors for the process conditions
G is the limit value [kg]

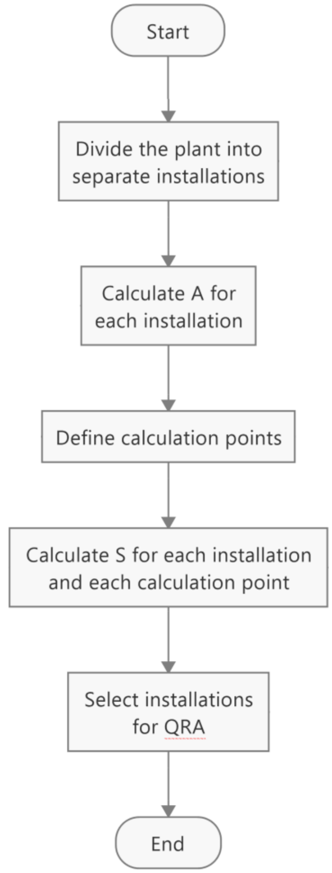


Figure 1. Representation of phases

*Calculation of Q (hold-up)*

The hold-up present in an installation is the amount contained within it, in which possible developments in the process of desired or undesired events, including possible loss of control, must be considered. The following rules apply:

- Preparations and mixtures can be distinguished into two different types, namely (1) a dangerous substance in a non-hazardous solvent, and (2) a mixture of dangerous substances;
  - if a hazardous substance is dissolved in a non-hazardous substance, only the amount of the hazardous substance needs be considered
  - if a mixture of several hazardous substances has defined chemical-physical and toxic properties, it should be treated in the same way as if it were a pure substance;
- if hazardous substances are stored as small packaging units at a site, and containment losses are likely to occur simultaneously for a large number of packaging units, the total amount of substance stored at that site should be considered. Examples are the storage of explosives or fireworks, and the release of toxic combustion products during a fire.

*The process conditions factor, Oi*

The factors for process conditions apply only to toxic and flammable substances and reference should be made to [1]. For explosives, the different factors are unified and become $O_1=O_2=O_3=1$.

*Limit Value, G.*

The limit value, $G$, is a measure of the hazardousness of the substance based on both the physical and the toxic/flammable/explosive properties of the substance. For explosive substances, the limit value is the quantity (in kg) that releases an energy equivalent to 1000 kg of TNT (the explosion energy of TNT is assumed to be 4600 kJ/kg).

*Calculation of the indicative number $A_i$*

The indicative number $A_i$ of an installation for a substance $i$ is calculated as:

$$A_i = \frac{Q_i}{G_i}$$

with:

$Q_i$ the quantity of explosive present in an installation [kg]
$G_i$ the limit value of substance $i$ [kg]

Various substances and process conditions may be present in an installation. In this case an indicative number, $A_{i,p}$ is calculated for each substance $i$, and for each process condition, $p$. The indicative number, $A$ for an installation is calculated as the sum of all indicative numbers:

$$A = \sum_{i,p} A_{i,p}$$

*Define calculation points*

The calculation points are defined as the target sites along the plant boundary that must be checked against the explosion risk.
The distance between two adjacent sites must not be greater than 50 m.

*Calculate S for each installation and each calculation point*

The selection number, $S$, gives a measure of the danger posed by an installation in relation to a specific site and is calculated by multiplying the installation's own target number $A$ by a factor typical for explosive and flammable substances of $(100/L)^3$. Therefore, the selection number is given by:

$$S = \left(\frac{100}{L}\right)^3 \cdot A$$

Where $L$ is the distance between the installation and the specific site, measured in [m], assuming a minimum value of 100 m. The selection number must be calculated for each installation at a minimum of 8 sites on the plant boundary. The selection number must be calculated for the entire boundary line of the plant, even if the plant adjoins a similar plant.
If the plant adjoins a water surface, the selection number must be calculated on the bank opposite the plant.
In addition to the calculation on the plant boundary, the selection number $S$ must be calculated for each installation on the site in the nearest existing or planned residential area to the plant.

*Select installations for detailed QRA*

An installation is selected for QRA analysis if:

- the calculated installation selection number (*S*) is larger than 1 (one) at a site on the boundary of the installation (or on the shore of the body of water opposite the installation) and larger than 50% of the maximum selection number at that site or
- the calculated installation selection number is larger than one at a site in the nearest existing or planned residential area to the installation.

**Conclusions**

The fast and preliminary method proposed in the present article allows to identify the portions of a plant that must undergo a quantitative risk assessment (QRA) in a major accident hazard context. The proposed workflow is linear and the requested parameters can be easily calculated.

The workflow can be selected as a basis for the development of a risk indexing method, which could be applied to all industrial realities, not only limited to large explosive employing plants, similarly to the methods already employed for fire initial risk assessment and risk screening (such as those derived from the Dow & Mond index method for industries operating with flammable substances).

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