pinfa
Phosphorus, Inorganic & Nitrogen Flame Retardants Association

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Interflam 2019

The 40th "Interflam" conference (organiser: Interscience) was organised at the Royal Holloway College campus, University of London, UK, 1st – 3rd July 2019. With over 400 delegates from 50 countries worldwide, nearly 130 presentations (in three parallel sessions) and over 100 posters, Interflam covers all aspects of materials and applications, fire resistance, fire testing and modelling, human behaviour and security and rescue.

Sessions at Interflam 2019 covered the following questions:

- Construction facades
- Fire safety of wood and timber
- Furniture fire safety
- Environment and human health, smoke toxicity
- Fire detection and suppression
- Fire testing, measurement
- Modelling of fire and pyrolysis, fire spread
- Fire prevention, fire risk, fire safety engineering
- Human behaviour
- Compartment fires, pool fires
- Flame retardants
- Fire resistance and fire behaviour of materials

This Newsletter does not attempt to summarise all presentations from the conference, but selects some of the themes of particular topical interest for flame retardant applications.

The conference best paper awards were made to **Colleen Wade (BRANZ Ltd, New Zealand)** for work on modelling the fire dynamics in mass timber enclosures (CLT and glulam) and to **Christopher Lee (University of Maryland, USA)** for work on mitigating lithium ion battery pack thermal runaway propagation, see below.

The Interflam trophy for overall contribution to fire safety science (a large wooden spoon) was awarded to **Patrick Van Hees, Lund University and President of IAFSS** (International Association of Fire Safety Science).

Interflam papers http://www.intersciencecomms.co.uk/html/conferences/Interflam/if19/if19cfp.htm

The next (41st) Interflam will take place in three years (2022)

Façade fires and consequences of Grenfell

A recurrent theme at Interflam was **follow-up from the Grenfell Tower fire catastrophe. (14 June 2017).** Despite previous occurrences of fires in high-rise building exterior cladding, it seems this disaster was necessary for regulators to take action. Several speakers at Interflam underlined the problems of lack of confidence in the construction industry (lack of chain of responsibility, inadequate controls and monitoring, lack of competence), as indicated by the Dame Judith Hackitt report on the Grenfell catastrophe, see pinfa Newsletter n°92.

The conference opened with plenary presentations by **Sir Ken Knight** and **Colin Todd**, respectively **advisors to the UK and to the Scotland Governments** on building fire safety following the Grenfell Tower fire.

Colin Todd indicated that the **Scotland Government has taken significant actions since Grenfell**, but also taking into account other major fires such as the Glasgow Art School fires in 2014 and again in 2018

- changes to building regulations concerning cavities
- only Euroclass specifications now accepted for fire safety of building materials
- Euroclass A1/A2 materials only for cladding for all buildings >11m height (considered to be the height reachable with a water jet, reduced from 18m) and on nearly all hospitals and buildings used for public assembly (except very small)
- from 2021, all households must have installed smoke and heat and carbon monoxide alarms
- evacuation alarm systems (for use only by the fire and rescue service) in all new high rise blocks of flats
- a minimum of two staircases in high rise blocks of flats (over 18m in height)

Sir Ken Knight presented the actions taken since Grenfell in the UK:

- 434 high-rise buildings with ACM cladding similar to that used on Grenfell have been identified and programming of cladding replacement is underway, with approximately:
  - 100 buildings – cladding today replaced
  - 100 – work has started
  - 250 – work is planned
  - 80 – no plan yet in place
- Combustible cladding has been banned on all new buildings >18m high (not retroactive), see pinfa Newsletter n°95
- Other widespread problems in buildings have been identified, indicating generalised failures to respect fire safety requirements, but also failure to respect other specifications, in the construction industry:
  - absence of cavity barriers
  - non-conform fire doors
  - structural problems with large panels

The UK government is working to address the conclusions of the Hackitt report into Grenfell (see pinfa Newsletter n°92), with two priorities: **improving residents' voice**, so that fire safety concerns expressed by residents are heard and taken into account; and **addressing failures of the construction industry chain of responsibility and overseeing** (implementation of a "Clerk of Works").

In discussion with participants, it was suggested that the US uses flammable cladding, but has considerably fewer major fire incidents, and to date no significant fatalities. One reason for this may be the quality of the US Building Codes which control cladding, including testing of both materials and installation. Another reason may be that the litigation culture in the US may incite architects, project managers and the construction industry to implement better systems of responsibility and overseeing than in Europe, because of fear of law suits from victims or insurance companies in case of fire.

Margaret McNamee (Lund University) underlined the need to marry fire safety with sustainable construction objectives (in particular energy efficiency – insulation). She proposed to **engage dialogue with 'Green' and energy efficiency certification and labelling bodies, such as LEED to foster the inclusion of fire safety considerations into the overall building**

evaluation, but noted that past efforts have been met with a low level of interest from the organisations responsible for developing the green building labelling systems. **Debbie Smith** noted that the BREEAM system does give points for fire safety although only in a simplistic manner and that more work on this matter is needed.

Marcello Hirschler, FSTB (GBH International and **Fire Safety & Technology Bulletin),** https://www.gbhint.com/fire-safety-and-technology-bulletin/ outlined developments in building façade fire safety requirements in the USA. The IBC (International Building Code), which is used throughout the US, specifies in chapter 14 fire testing for both complete façade assemblies and for the separate components of the assemblies. The key fire test for the assemblies is NFPA 285, the scope of which has been expanded (in 2019): assemblies must be tested to NFPA 285 even if the only combustible is a water resistive barrier (unless it has excellent fire performance). The NFPA 285 fire test involves a 30-minute full wall test, with a window in the wall, applicable to all "combustible" claddings for all buildings >40 feet (12m). The 2021 edition of the IBC eliminates exceptions that had allowed, in previous editions, light-transmitting plastics to be incorporated into sprinklered buildings of any height. It also eliminates the use of MCM (metal composite materials) in sprinklered buildings up to any height without testing to NFPA 285. Some other improvements have been added also but the key requirements for fire testing of systems called ETICs (external thermal insulation composite systems) in Europe and EIFS (exterior insulation and finish systems) in the US, have been retained and they are well regulated. The new code also removes certain exceptions for HPLs (high pressure laminates). NFPA 285 is implicitly "always applicable" to all assemblies in new construction. The IBC also contains detailed fire tests for all individual components of cladding assemblies, with emphasis on insulation materials. Furthermore, the new edition of the IEBC (International Existing Building Code) will require fire testing to NFPA 285 for existing buildings when new claddings are being added or major renovations are being made. Mr. Hirschler underlines the importance of both updating building codes and standards frequently, and of ensuring effective implementation. His paper presents in detail the different fire tests used for façade installations worldwide.

Susan Lamont (photo)**, Arup, USA,** and **Birgitte Messerschmidt, NFPA (US National Fire Protection Association)** presented NFPA's EFFECT® Tool, developed by Arup with Jensen Hughes as peer reviewers. This enables a simple, online risk assessment of office, residential or hotel buildings of over 18m height, based on questions on aspects such as façade component materials and installation, cavities, wear and tear, proximity to other buildings, egress routes and evacuation strategies, fire protection systems. A first tier based on simple questions enables identification of buildings potentially with façade fire risk and enables an owner or AHJ (Authority Having Jurisdiction) of a portfolio of buildings to prioritise which buildings need further investigation. A second tier with more detailed questions, provides a more in-depth assessment of the risk. The tool is available to the public at www.nfpaeffect.com with some 450 users today. Feedback is that the information required to respond to tier 2 is often difficult to obtain, but expert analysis in the tool construction shows that meaningful risk assessment is not possible without such detail, for example specifications of the façade materials and structure / installation.

Anja Hofmann, BAM Germany and **Alex Webb, CSIRO Australia,** summarised building regulations relevant to facades in the UK (see above), Germany and Australia. The German fire services have identified 125 fires concerning ETIC (external thermal insulation cladding) in German buildings 2001 – 2018, with most occurring in recent years. These fires led to 11 fatalities and 140 injuries. Full scale testing carried out by German Building Ministry concluded that fires starting outside the building (e.g. in waste containers or cars next to the building) pose higher risks for façade materials than fires inside the building. The presenters conclude that German regulations for claddings are complex to understand, with specific additional requirements for buildings >18m high, but that roles and responsibilities are relatively clear, with requirements for relevant training of personnel, independent verification for certain building types, and a strong accent on enforcement. Façade fires both worldwide and in Australia (e.g. Neo2000, 4th February 2019) are driving tighter fire safety requirements in Australia, including amendments to the National Construction Code (NCC) including the new testing method AS 5113-2016 (including flame spread, flaming falling debris …), clarification of provisions applicable to external claddings, sprinkler requirements for balconies. Australian States have brought in additional requirements, and are carrying our audits to identify buildings at risk. Modelling and testing of façade materials was further discussed by **Gaurav Agarwal, FM Global, USA, Pergiocomo Cancalliere, Italy Fire Rescue Service** and **Virginie Drean, Efectis, France**.

In discussion, participants indicated that facade fire risks are essentially not linked to smoke toxicity, but to the size and the spread of the fire, and that smoke risks are mainly related to the quantity of material burning, not to its nature.

It was also indicated that more information needs to be developed on flame retardant plastic containing façade insulation systems: different solutions available and their different characteristics, performance in large scale installations in complex façade systems, new materials and developments.

Need for integrated approach to fire safety

Patrick Van Hees, Lund University, underlined that fire safety is increasingly complex, with new materials and evolving building design, so that reliance on past fire scenarios is inadequate. Fire safety be based on a holistic approach, taking into account building design, different functions, equipment, risks for firefighters and multi-material building components. Important challenges include preventing fire spread through windows, taking into account changing uses of building spaces (e.g. attics), risks from falling parts or materials, specific electric and design risks related to photovoltaics. Ensuring fire safety can be in conflict with building functions such as insulation, ventilation, water barriers. Fire tests for materials are small scale, and there is a real need to improve understanding of how such testing can predict fire safety performance in full scale installations (e.g. in façade systems), in order to allow cost-effective material design and screening.

Chris Jelenewicz, SFPE (Society of Fire Protection Engineers), presented the SFPE fire safety engineering R&D roadmap, published in 2017 and undergoing regular updates. He emphasised the transparency and inclusive process, with over 500 SFPE members having given input in writing or in meetings during the development of this roadmap. It identifies both the range of fire safety research needs, and priorities, in different themes covering buildings, non-building fires, reliance – sustainability, human behaviour, fire service, etc. Priorities identified include: smart buildings, smart fire safety systems and smart egress; impacts of changing populations; energy storage; fire risks related to sustainable construction; environmental impacts of fire. Update is underway and comments on the roadmap are welcome to engineering@sfpe.org SFPE is also working to promote engagement of fire safety research along the themes and priorities identified.

Birgitte Messerschmidt, NFPA (US National Fire Protection Association), explained the holistic approach to fire safety developed by NFPA "Fire Life & Safety Ecosystem". A concern is that regulators are not prioritising fire safety, which is treated as less important as sustainability and recycling, and of course cost. At the same time, industry aims only for compliance, which does not always imply safety, whereas the public "assumes" fire safety. Priorities for action should

include enforcement of fire safety regulation compliance (inspections), building and fire system maintenance, new tools for firefighters to understand the fire risks of modern synthetic materials and spatial management policies to reduce wildfire risks and impacts.

Lotta Alm, Lund University / BRIAB Sweden, presented the "Action against fire" public information campaign engaged by Swedish authorities. Objectives included promotion of fire alarms and fire extinguishers in homes, particularly targeting vulnerable populations. Results of monitoring surveys are contradictory, with 90% of interviewees saying they want fire safety, but also 90% saying that they believe they are not at risk of fire in their own home.

Antonio Cicione, Stellenbosch University, South Africa, underlined the massive fire safety challenge of growing urban populations in developing countries. South Africa has already experienced several major, tragic fires in informal urban settlements, with national fire fatalities increasing from 300 to 600 from 2003 to 2015. Challenges are that international fire codes are seen as too complex and expensive to implement. Compliance verification is nearly inexistent. Training of engineers in fire safety is needed.

New fire safety challenges for wood products

Presentations noted the strong growth potential of wood-based materials, as a sustainable and 'desirable' construction material, but also the specific fire safety challenges to address.

Colleen Wade, Branz Ltd, New Zealand, noted that wood structure construction is in demand, because of sustainability objectives, but also because of lower costs resulting from rapid, off-site modular construction and lower weight (lower foundation costs). Her paper (**Interflam conference paper prize**) presented development of a fire model for mass timber construction, including kinetic wood pyrolysis modelling, compared with five enclosure fire tests (4.5 x 2.4 x 2.7 m) with CLT (cross laminated timber) panels and glulam structural elements. In these experiments, gas temperatures in the enclosure reached over 1000°C around 20 minutes after ignition by wooden cribs.

Fire safety questions are posed concerning fire behaviour of CLT (cross laminated timber, see below) and risk of continuing pyrolysis and delamination during the decay phase of the fire.

Marc Janssens, SwRI (Southwest Research Institute), USA, discussed the development of a room fire test method used to identify CLT adhesives that can degrade at a relatively low temperature resulting in delamination, fire re-growth and a second flashover during the decay phase of the fire.

Fire behaviour studies of wooden construction products and CLTs were further discussed by **Robert McNamee, Lund University, Sweden**. **Jean-Christophe Mindefula, Bordeaux University, France**. **Bernard Girardin, Efectis, France**, discussed engineering methods for fire contribution of wood (ISO 9705). **Katrin Nele Mager, Tallinn University of Technology**, summarised design for fire resistance of timber-based joists. **Christian Gonzalez Crespo, Carleton University, Canada**, discussed the fire performance of concealed steel moment-resisting mass timber connections.

Interview / vision – Colleen Wade, best paper award

The predictability of heavy timber (or mass timber) structures in fire is often given as a benefit, and while this is generally true in relation to standard fire resistance tests, it is not necessarily the case in real fire events. To enable engineers to better design structures to not collapse during or following a fire event, it is essential to consider how the additional fuel contributed by the timber structure changes the fire severity and what the maximum resultant depth of char is likely to be. Char depths depend on a range of factors, including situation and fire conditions and nature of the wood and of adhesives. Fire protection methods for structural timber include encapsulation by non-combustible boards or the application of coatings that affect the combustion process, as *well as fire sprinkler systems. Relying solely on results obtained from standard fire resistance tests may lead to some structures that are vulnerable to failure during or after fire particularly in jurisdictions where the prescriptive fire resistance requirements are relatively low. There are still many research questions needing to be answered including: the conditions needed for burning extinction of mass timber, the performance of structural connections, the effect of wind on burning behaviour in fire, as well as understanding the basic fire dynamics. While there are many advantages and opportunities for constructing more buildings using heavy timber there is also a need for caution and a considered approach to their fire design.*

Environment and health challenges for fire fighters

Margaret Macnamee, Lund University, presented the Fire Impact Tool (developed from the ENVECO tool), to provide decision support and training information to firefighters on LCA (Life Cycle Analysis) and ERA (local Environmental Risk Assessment) related to different fire interventions. The tool indicates risk of emissions to air, surface and ground water and to soil, depending on the products engaged in the fire or at risk and of possible fire service intervention strategies.

Adhiraj Shinde, North Carolina State University, presented results on off-gassing of toxic contaminants in used firefighters' gear (protective clothing) using a technique known as Headspace sampling-GC-MS. The main toxins found, phenols and phthalates were at higher levels in the new gear, presumably because they are present in synthetic materials that are being increasingly used in recent years. Perfluoro alcohols were found at higher levels in the older gear possibly because some of these chemicals were recently banned. High boiling compounds such as PAHs were not found, which could be a limitation of the method. An interesting observation was that all the three layers of the turnout gear (outer shell, moisture barrier and thermal liner) off-gassed a wide range of contaminants. It was an observation worth noting that there was a substantial increase in the amount of chemicals released from the gear at elevated temperatures. Headspace sampling proves to be an effective screening method for the release of chemicals from a solid or liquid sample, when it is heated.

Karolina Storesund, RISE Fire Research Norway, presented development of a testing method to assess risk of PAH and particle penetration to firefighters, with simulated work in a smoke chamber. Some soot and PAHs were shown to reach the body despite protective clothing. The study aimed to develop a methodology, not to quantify exposure.

Per Blomqvist, RISE Sweden, investigated different bench scale testing methods for their applicability regarding smoke toxicity from combustion. 12 different materials (11 different insulation materials and one thermoplastic, PMMA) were tested under various test conditions. He underlined that a valid bench scale test should replicate real fire condition, and that an under-ventilated fire is the type of fire producing the most toxic smoke gases. Only the ISO/TS 19700 steady state tube furnace generally enabled prolonged steady flaming combustion conditions at under-ventilated conditions. For the controlled atmosphere cone calorimeter (ISO 5660-1 with ventilation control box) it was difficult to predict the influence of vitiation and there were limitations in reaching under-ventilated conditions. The smoke chamber (ISO 5659-2) tests often resulted in non-flaming conditions and in cases of flaming combustion there was limited global oxygen consumption pointing at overall well-ventilated conditions.

Tomorrow's fire safety applications

Brian Lattimer, Jensen Hughes (now with Virginia Tech), USA, summarised challenges for fire safety requirements in railways in the USA. The USA, in NFPA130 and 49CFR238.103, currently specifies the radiant panel test and accepts higher heat emissions, whereas the EU uses

ISO 5660-1 (in EN 45545-2). He estimates that nearly a third of materials currently in use in railways in the US could cause flashover in a fire. Smoke density testing is required in the USA, but not currently smoke toxicity (which is required in the EU).

Christopher Lee, University of Maryland, USA, (**Interflam conference paper prize**) presented experimental testing of thermal runaway propagation of lithium ion battery arrays. Tests used lithium cobalt oxide cathode, nominal 3.7 V, 2600 mAh batteries, in arrays of 12 or 15, testing different charge levels and separation of the cells, under nitrogen, so that all gas and heat production measured were generated directly from the batteries. Thermal runaway was induced by applying heat to one battery using an electrical element, showing thermal runaway onset temperatures of 105 – 180 °C. Results showed that once one battery failed, the heat generated caused failure of adjacent batteries within times between a few seconds and approximately two minutes, and in all cases all batteries underwent thermal runaway. Spacing of 5 mm slowed propagation, and partly charged batteries were even more effective at slowing propagation (less stored energy to release). Heat generated was 0.8 – 1.4 kJ/g (the lower value for partly charged cells). Mass loss was 20 – 38%, depending in particular on whether the steel case of the battery ruptured. On a mass basis, gases generated were mainly carbon dioxide, carbon monoxide and THC (total hydrocarbons).

Conference paper prize winners interviews

Stanislav Stoliarov & Christopher Lee, University of Maryland

Most of the current fire safety solutions were developed in response to and based on fire accidents that occurred in the past, often some time ago. This model of reactive fire safety engineering may become unsustainable in the future. To ensure that fire safety is maintained or improved, we need to learn how to keep up with emerging technologies in construction, transportation and energy storage. We need to be able to identify and address fire safety issues associated with these technologies before they manifest themselves in the form of fire events. Flame retardants, when used in sufficient quantities, represent one of the most effective ways to improve fire safety. The largest challenge to deployment of flame retardants is their negative public image. The role of flame retardants in future fire safety solutions will depend, to a large degree, on whether their public perception can be changed in the next few years. Flame retardant formulations that can be customized to perfectly balance effectiveness, environmental impact, cost and impact on other material properties critical for a particular application will represent the ideal solution. Finding such solutions will require development of sophisticated models that relate the material composition and its performance.

Furniture fire safety

Konrad Wilkens Flecknoe-Brown, DBI (Danish Institute of Fire & Security Technology), presented fire tests of polyurethane slabs (1.2m x 0.6m x 50mm), showing that flame spread, time to peak heat release, and peak heat release rate are all very variable and dependent on the point of ignition (edge and corner effects). Flame spread rate varied from 3 to 7 mm/second and peak heat release rate varied from 100 to 250 kW.

Karolina Storesund, RISE Fire Research, Norway, summarised an ongoing project looking at fire safe and sustainable loose furnishings (**CircleSafe**, funded by Brandforsk, Sweden) Objectives are to ensure repairability and durability (circular economy) and to optimise the life cycle assessment. Wool and cotton show much higher overall energy input in production. Flame retardant selection should target non-toxic chemicals, compatible with recycling. The project report is expected Autumn 2019. She also presented results of life cycle analysis studies and model scale fire testing of different materials for upholstered furniture. She suggests that polyurethane shows relatively (our main comparison was latex) poor LCA results (on sustainability, mainly energy consumption in production and environmental impact (global warming, terrestrial ecotoxicity, mineral resource scarcity). In fire tests, barriers combining inherently flame-resistant fibres (e.g. Lenzing) and fibres such as cotton, wool or polyester provide some fire protection, but can increase smoke generation. A 3D-web of thermoplastic fibre material for filling was shown to have better fire performance that polyurethane foam for some material combinations. Cost aspects are not addressed, and tests did not assess conformity to specifications such as TB117.

Dow reactive polymer polyol solution for flexible PU foams

Paul Cookson, Global Innovation leader for Consumer Comfort at Dow, presented the Company's non-halogenated polymer polyol which reacts into the polyurethane during polymerisation reducing overall emissions. This polyol acts by preferentially degrading in fire (at ~200 C), absorbing heat energy and releasing CO_2 to inhibit burning. It can be effectively combined with PIN flame retardants such as melamine, which inhibits burning by decomposing in heat to absorb energy, releasing nitrogen and forming char. The polyol is compatible with a wide latitude of foam processing conditions, using foamers' existing equipment to produce conventional and high resilience combustion modified foams across the density and hardness range. Polyol – melamine (PIN FR) foam can achieve Crib 5 fire performance with compatibility with Oekotex emissions and chemical requirements.

"Combining fire safety and low emissions in bedding and furniture: an industry challenge or opportunity", P. Cookson, poster at Interflam 2019

Dow (Dow Inc. and its subsidiaries) is a sustainable materials science company with a broad technology set. Dow's portfolio includes performance materials, industrial intermediates and plastics for segments such as packaging, infrastructure and consumer care. Dow operates 113 manufacturing sites in 31 countries, employs approximately 37,000 people and delivered sales of approximately $50 billion in 2018. www.dow.com or @DowNewsroom on Twitter.

Mark Gratkowski, US Department of Justice, presented 108 full scale tests (27 configurations) of bedding, carried out to try to understand how fire had developed in a real motel fire. The bedding consisted of cotton/polyester sheet and quilted bedspread, and was placed on a non-flammable ceramic fibres mat on a frame (not a mattress). Bedding was cut to half or a quarter of real full bedding set, and the tests were terminated when flame transitioned to the top of the surrogate mattress. In nearly all the tests, the bedding was ignited from a fire source consisting of a burning 'book' of paper matches placed on or next to the bedding, and in three quarters of the tests ignition occurred within ten seconds. Heat release in the first two minutes reached up to 150 kW.

Andrew Lock, US Consumer Product Safety Commission (CPSC), summarised developments in the US on furniture fire safety. The US federal legislation (Flammable Fabrics Act) gives the CPSC authority to regulate fire safety hazards for domestic furniture, taking into account addressability, technically practicality, and cost effectiveness. Domestic furniture is the main cause of home fire deaths in the USA, and is a critical contributor to flashover. Most deaths are related to smouldering ignition, and this is decreasing. Small flame ignition is related to many fewer deaths, but is not significantly decreasing. Full scale tests of chairs, using non FR foam with different types of barrier, show that peak heat release can be reduced and delayed, but barriers can generate smouldering which can develop into flames. The CPSC recently granted a petition and began rulemaking to ban additive organohalogen flame retardants, and NAS (National Academy of Sciences) has recently concluded that these can be dealt with by subclasses (see pinfa Newsletter n°103). A proposed US federal bill ("SOFFA" = S.3551)I currently under discussion (since 2018) would if adopted require all sold in the US (but not mattresses or bedding) to respect the current California furniture fire safety standard (smouldering cigarette resistance, TB117 Interf(2013).

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