12th International Symposium on Fire Safety Science

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**Caption:** The honeycomb effect in this picture is fascinating.

| **Image2** | Laurens van Gelderen, Hamed Farmahini Farahani, Ali Rangwala and Grunde Jomaas | Boilover of a crude oil burning in an ice cavity |

**Caption:** Boilover of a crude oil burning in an ice cavity (diameter of 31 cm). Melting of the ice cavity walls forms a water layer below the hot oil. Because this water sub-layer is fully covered by the oil, the water cannot evaporate as it is heated up. This causes the water to superheat to temperatures of 120 – 150 °C, at which point it violently evaporates through the oil slick, ejecting steam and oil droplets into the flame. The explosive nature of steam and oil droplets inside the flame causes a chain reaction, resulting in the explosive burning known as boilover.

| **Image3** | Matthew Hoehler | Steel beam in flame channel |

**Caption:** The photograph shows the top flange of a steel I-beam (1.25 m long) in an enclosure being heated from below using a natural gas diffusion flame. The beam, which is supported on water-cooled supports at the ends, has undergone large thermal-induced deformation and is sagging under its own weight. On the top of the beam you see a novel fiber optic strain gauge mounted in a glass tube that acts as a strain amplifier, as well as ceramic-fiber sheathed k-type thermocouples that have been peened into the top flange of the beam.

| **Image4** | Matthew Hoehler and Yi Bao | Fiber optic strain gauges in tube furnace |

**Caption:** The photograph shows two fiber optic strain gauges attached to a steel plate in a tube furnace. The experimental strain gauges use Pulse-Prepump Brillouin Optical Time Domain Analysis (PPP-BOTDA) technology and are mounted in glass tubes that act as strain amplifiers. The sensors in the photo are being calibrated for use in structural fire tests.

| **Image5** | Matthew Hoehler and Christopher Smith | Optical measurement on steel plate engulfed in flame |

**Caption:** The photograph shows a steel plate (300 mm x 300 mm) attached to a water-cooled boom mounted on a translation stage (the structure in the back of the photo) engulfed in a natural gas diffusion flames. The setup is being used to verify measurements of the position and deformation of the plate using Digital Image Correlation (DIC) and laser-based techniques.
blue coloring on the translation stage comes from high-intensity near-ultraviolet lighting used to enhance the image of objects engulfed in fire.

**Image6**

Matthew Hoehler, Rodney Bryant, Matthew Bundy, Christopher Smith, Lisa Choe, John Gross and Selvarajah Ramesh

**Caption:** The photograph shows a calibration burn under the 20 MW exhaust hood of the new National Fire Research Laboratory (NFRL) at the National Institute of Standards and Technology (NIST) in Maryland, USA. The structural steel elements surrounding the natural gas burner are positioned for the subsequent experiment. The blue illumination on back wall comes from high-intensity near-ultraviolet lighting used to image objects engulfed in fire.

**Image7**

Delia Murguia-Gutierrez

**Caption:** The picture was taken during the celebration of the 350th anniversary of the great fire of London in 2016. Mock-ups of timber frame buildings were placed on a barge and ignited. The remains of the buildings can be clearly seen in the flames, adding a sense of scale. This provides a stark contrast between the new London, with its modern construction towering in the background, and a good impression of how the great fire of London might have looked like to observers back in the day. Rising firebrands can be seen as well.

**Image8**

Sriram Bharath Hariharan, Michael Gollner and Elaine Oran

**Caption:** The “blue whirl” is a newly discovered flame structure that evolves from a traditional yellow fire whirl under specific conditions of fuel flow and air circulation. While a traditional yellow fire whirl is known to be sooty, the blue whirl (typically ~8 cm high) is seen to be completely blue, indicating the absence of soot in the flame. This image shows an instance of a yellow fire whirl transitioning to a blue whirl. Such transitions show yellow streaks of soot that travel downwards into the flame, and reveal the presence of recirculation zones within the blue conical structure.

This image was captured using a Sony RX 10II at f/2.8 with an exposure time of 40 ms. A visible blue ring forms the edge of the blue conical structure, with the yellow soot trace within it.

**Image9**

Francesco Restuccia, Egle Rackauskaite, Xinyan Huang and Guillermo Rein

**Caption:** O-Revealer is a novel technology used to detect landmines buried in peatland sites around the world using controlled smouldering combustion. The picture shows combined infrared and visual imaging of the smouldering front spread in a laboratory experiment. The smouldering front spread rate was around 3 cm/h, and each smaller image is extracted at 120-minute intervals. The large image is taken at the end of the experiment, after 600 minutes of spread, with the O-shaped mine clearly visible at the end of the peat smouldering process.
**Image10**  Francesco Restuccia and Guillermo Rein

**From biomass to ash**

**Caption:** Biomass is an important fuel for power generation, and its use is increasing. However, it is associated with fire issues. As porous reactive media it is prone to self-heating caused by oxidation reactions at low temperatures. Surrogate biomass (rice husk) is heated in an oven at temperatures above 150°C producing torrefied matter. Initially the rice husk is torrefied, with increasing oven temperatures causing charring leading the biomass to ignition above 190°C, leaving only ash (top).

**Image11**  Francesco Restuccia, Egle Rackauskaite, Yuqi Hu and Guillermo Rein

**Firing black to white**

**Caption:** When we burn a solid fuel it chars, with combustion reactions progressively turning it into ash. For a complete combustion process, all the original fuel turns into ash. For incomplete combustion processes, different amounts of char and ash ratios are produced. The picture shows the transition of charcoal fuel (black) to ash (white), with the sample containing only char on the left, followed by each sample containing an ever-increasing amount of ash until the right-most sample containing pure ash from complete combustion.

**Image12**  Yu Wang and Xinyan Huang

**Shattering Fire**

**Caption:** Fire can shatter glass. Once shattered, the entrainment of fresh air significantly accelerates the development of the compartment fires and façade fires. To quantify the vulnerability of glass under fire, a toughened glass pane (100 cm x 100 cm x 0.6 cm) was tested under the attack of a heptane pool fire (maximum 500 kW). The fire development and heat release rate (HRR) were recorded.

The image demonstrates the evolution of the glass structural stability and fire behavior as well as their interaction. The HRR of fire overlaps with the damage of glass. Once the fire breaks the glass pane, it transitions from being ventilation controlled to being fuel controlled. Such change may result in a strong impact on structural response and fire spread, an issue that has long been ignored. Therefore, we present this fire image to highlight the interaction between fire and structure and call for more attention on this important fire safety issue.

**Image13**  Longhua Hu

**"Blooming Fire"**

**Caption:** The image presented is an experimental flame photo captured for propane fire beneath the ceiling (nozzle diameter 6 cm; outlet flush with ceiling; discharge downward; 0.015 m/s; 0.17*10^-3 m3/s; 15.3 kW). This beautiful "blooming flower" flame is broken up into "petals", whose sizes increase with distance from the center. Such gorgeous "blooming fire" is not only esthetically attractive but also a physical nature of thermo-diffusive instability, whose characteristic length scale can be well reflected by the petal sizes. It is this kind of beauty that intrigues our devotion into the art of fire.

**Image14**  Edwin Galea and Lynn Hulse

**Project Lifebid**
Caption: Project LIFEBID (http://fseg.gre.ac.uk/fire/lifebid.html) is aimed at understanding human behaviour in accidental dwelling fires (ADFs) and using this knowledge to reduce the unacceptably high losses associated with these fires. ADFs have consistently been the cause of approximately 60-70% of all fire-related deaths and injuries in the UK, with similar trends around the world. To significantly reduce these losses it is essential that a thorough understanding of human behaviour in ADFs is developed. This real fire is being used to measure risk perception associated with domestic fires in the hope to better understand the high casualty rates that occur in ADFs.

Image 15

Ed Galea, Steven Deere, Lazaros Filippidis, Hui Xie and Lynn Hulse

Caption: The picture depicts a full-scale unannounced evacuation of a large secure site. Normally, to access/exit the site requires finger-print recognition. However, during an emergency, the turnstiles are in free-flow and so finger-print verification isn’t required. All staff working on the site must undergo a thorough safety training course that includes the evacuation procedures and so they are aware of the exiting procedures during evacuation. Nevertheless, it is difficult to break habitual behaviour – staff are seen attempting to use the finger-print recognition system to exit the site, thus wasting precious time during the evacuation, even when instructed by security guards.

Image 16

Ed Galea, Steven Deere, Hui Xie, Lynn Hulse and Lazaros Filippidis

Caption: There is little known concerning how workers evacuate from high-rise construction sites. This project (http://fseg.gre.ac.uk/fire/construction_sites123.html) is the first systematic fundamental study into evacuation behaviour and performance of workers on high-rise construction sites and will provide important insight into, and quantification of, likely behavioural responses of construction workers during evacuation. How quickly do workers respond to an evacuation alarm? How do the different surfaces impact walking speeds during evacuation? How do workers perform on temporary stairs and on ladders? With this knowledge it will be possible to frame more realistic and achievable evacuation procedures improving the safety of construction workers.

Image 17

Ed Galea, Steven Deere, Hui Xie, David Cooney and Gary Sharp

Caption: These full-scale evacuation trials were undertaken for the UK Government to investigate the impact of security bollards on evacuation performance in crowded places such as rail stations, airports and underground stations. The work quantified for the first time the impact of security bollards on evacuating exit flows. The work enabled the impact of stand-off distance on evacuation performance to be quantified for the first time and also provided a means to validate evacuation models used in this application. The work formed the basis of new government guidance on the recommended placement of security bollards in crowded places, TAL 01/16 (https://www.gov.uk/government/publications/influence-of-bollards-on-pedestrian-evacuation-flow-tal-0116).
| Image18 | Ed Galea, Lazaros Filippidis and David Cooney | Urban-Scale Evacuation |

**Caption:** Urban-scale evacuation, resulting from natural disasters such as wildfires or earthquakes or man-made incidents such as terrorist attacks, may require people to walk long distances, hence suffer fatigue; over different types of surfaces e.g. paved, gravel, open fields; and over terrain of varying gradients. It is thus essential to collect human performance data to quantify the performance of people over these varying terrains if we are to develop reliable urban-scale evacuation models. These images depict full-scale human performance trials undertaken in collaboration with French and Italian partners to establish a data set on human performance in large-scale urban evacuation situations.

| Image19 | Xinyan Huang, Andy Rodriguez and Carlos Fernandez-Pello | Frolicking flames |

**Caption:** Dripping of molten fuel can change fire behaviors, ignite nearby materials and expand fire size. Dripping occurs when gravity overcomes the resistance from surface tension and viscous forces. It involves a complex phase-change process and is most common in fires of electrical wires and heat insulation materials. The image shows the dripping of molten polyethylene insulation in an electrical wire fire. Dripping first ignited the sand soaked with alcohol, and then, started to frolic (interact) with the puffing pool fire. The whole process lasted less than 0.2 s, and was captured by a high-speed camera (500 fps).

| Image20 | Xinyan Huang, Sandra Olson, Reid Wiseman, Paul Ferkul and Carlos Fernandez-Pello | Flame Eclipse |

**Caption:** Fire safety in microgravity has always been a concern in space travel. Very few flame-spread experiments have been conducted in spacecraft environments because of the high cost of long-term microgravity facilities. The presented fire image shows part of the microgravity flame-spread experiments, Burning and Suppression of Solids - II (BASS-II), conducted in the International Space Station.

The flame spread over black PMMA rod was tested under both concurrent and opposed flows. The central fire image shows a vapor jet disrupting the blue flame in the concurrent flow. The surrounding fire images show the opposed flame spread under a low oxygen concentration of 17%. The interval between these images is 1 minute. As the opposed flow slowly decreases from 7.6 cm/s to 0.7 cm/s, the flame changes from yellow to blue and becomes wider. The flame spread rate first increases, and then decreases until extinction.

| Image21 | Andrea Lucherini | The fire-dependent nature of thin intumescent coatings |

**Caption:** The effectiveness and insulating properties of these reactive fire protection materials are strongly dependent on the heating conditions. A virgin fire-protected steel I-profile section (centre) to two expanded char structures of intumescent coatings under two different fire
scenarios: low heating rate (left) versus high heating rate (right). Slow fires and low heating rates can cause an incomplete activation and lead to unsatisfactory insulation to the steel structure.

**Image22**
Andrea Lucherini, Carmen Gorska Putynska, Aaron Bolanos, Angela Solarte, Diana Soriguer, Mateo Gutierrez Gonzalez, Richard Emberley, Kathryn Humphreys, Juan P. Hidalgo, Cristian Maluk, Angus Law and Jose L. Torero

**Caption:** A large-scale fire test was conducted on a compartment constructed from cross-laminated timber (CLT). The internal faces of the compartment were lined with non-combustible board, with the exception of one wall and the ceiling where CLT was exposed directly to the fire inside the compartment. Extinction of the fire occurred without intervention. In addition, self-extinction of the exposed CLT was achieved at approximately the same time in the wall and in the ceiling.

**Image23**
Andrea Lucherini

**Caption:** Thin intumescent coatings are organic fire-protection materials that are strongly influenced by the fire scenario. Their expansion, effectiveness and insulating properties depend on the heating conditions and, in particular, on the time-history of the exposing heat flux. The figure compares several intumescent coatings char structures obtained from cone calorimeter tests.

**Image24**
Angela Solarte, Andrea Lucherini, Carmen Gorska Putynska, Aaron Bolanos, Diana Soriguer, Mateo Gutierrez Gonzalez, Richard Emberley, Kathryn Humphreys, Juan P. Hidalgo, Cristian Maluk, Angus Law and Jose L. Torero

**Caption:** In the past years, there has been several testing carried out to understand the fire behaviour of CLT, and the possibility of exposing these elements in buildings. This photograph was taken at a large-scale test carried out by a group of researchers at the University of Queensland. The picture reflects that under the condition of this test, after the compartment reached flashover, self-extinguishment occurred. Instrumentation like, pressure probes, thermocouples, TSCs, among other where used to measure data.

**Image25**
Michael Stromgren

**Caption:** Suppression test with corner fire and plate thermometers
**Caption:** "Corner fire during a suppression test led by Magnus Arvidson, RISE, in January 2017 with four visible plate thermometers in the set up."

**Image26**  
Jiao Lei and Congcong Ji  
**Flame patterns of a methane fire under imposed external circulation**

**Caption:** The figure shows the instantaneous flame images of a 7.50 kW methane fire established on a 5-cm-diameter gas burner in a large range of imposed external circulation. The external circulation was imposed by a small-scale cylindrical rotating screen with diameter of 50 cm and height of 200 cm. From left to right, the imposed external circulation are 0, 0.33, 0.40, 0.65, 0.98, 1.31, 1.48, 1.81, 2.07, 2.82, 4.01, 4.52 and 5.40 m^2/s, respectively.

**Image27**  
Richard Emberley and Jeronimo Carrascal  
**Large Calorimeter Fire Whirl**

**Caption:** Fire whirl produced during a preliminary test of the large calorimeter at The University of Queensland. The 3.5 meter-tall whirl was formed from an approximately 10kW n-heptane pool fire with an average flame height of around 0.3 meters.

**Image28**  
Fumiaki Takahashi  
**Fire Blankets can Protect Homes from Forest Fires**

**Caption:** The prescribed-burn experiment was conducted in the Pitch Pine forest, in New Jersey, USA. A wooden structure (3.1 m W x 2.4 m D x 3.3 m H) with cedar bevel siding and roof shingles was wrapped with four different fire blanket materials: (1) 100% fiberglass with laminated aluminum foil, (2) fiberglass with aluminized coating, (3) amorphous silica with aluminized coating, and (4) fiberglass with aluminized polyester coating. The fire storm engulfed and passed the structure, leaving behind the scorched land, but nonetheless it survived.
Fire can shatter glass. Once shattered, the entrainment of fresh air significantly accelerates the development of the compartment fires and façade fires. To quantify the vulnerability of glass under fire, a toughened glass pane (100 cm x 100 cm x 0.6 cm) was tested under the attack of a heptane pool fire (maximum 500 kW). The fire development and heat release rate (HRR) were recorded.

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FROLICKING FLAMES

Xinyan Huang, Andy Rodriguez, and Carlos Fernandez-Pello
Department of Mechanical Engineering, University of California, Berkeley
FLAME ECLIPSE

X. Huang¹, S. Olson², R. Wiseman³, P. Ferkul², C. Fernandez-Pello¹

¹University of California, Berkeley; ²NASA Glenn Research Center; ³NASA Johnson Space Center