FLASH FIRE

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Duration and Heat Flux

Over the past two decades there have been some reasonable debates and some less reasonable marketing on the duration and energy of hydrocarbon flash fires, despite the fact that existing North American standards are quite clear on the subject. National Fire Protection Association (NFPA) and Canadian General Standards Board (CGSB) both define flash fire with identical technical language: the main factors being diffuse fuel in air, an ignition source, a rapidly moving flame front, and a consequent duration of 3 seconds or less. The NFPA 2112 standard requires a mannequin test duration of 3 seconds precisely because it is viewed as the practical upper limit of a flash fire. Groundbreaking research was recently conducted to answer the debate and vet the standards.

Key difference

The key differential between a fire and a flash fire is the fuel. In a fire, the fuel is concentrated (pool fires, jet fires, etc.) with no significant limiting factor in duration; it will burn for minutes or hours or even days if not actively extinguished. Conversely, in a flash fire the fuel is diffused in air (gas leak, vapor cloud, combustible dust, etc.) meaning it will be consumed very quickly once ignited as the flame front moves very rapidly from the ignition point to the source and/or to the limit of the cloud, and burns out. Thus, the duration of heat levels sufficient to ignite flammable clothing or cause second-degree burns to exposed skin is very brief in any single location within the flash.

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This short duration is what makes these events survivable without respiratory protection, and with a single layer of FR clothing, as opposed to SCBAs and turnout gear worn by firefighters. (Flame resistant clothing will not ignite and continue to burn, but single layer, breathable FR does not provide sufficient insulation against protracted fire exposures.)

Testing and reporting

While the science and standards seem clear, the sales and marketing of FR clothing sometimes does not. Some companies merely report that they pass the NFPA 2112 mannequin test (less than 50 percent total second- and third-degree body burn at a 3 second test duration), while others report the exact percentage with which they pass. Very few spend the time and the money to conduct complete research and publish graphs that fully characterize body burn from inception of burn through the fabric, to or beyond failure (>50 percent burn). The mannequin test required by NFPA 2112 utilizes the ASTM International F1930 standard test method. The ASTM F1930 features a full size mannequin wearing a standardized coverall in a burn chamber with propane torches capable of fully engulfing it. The mannequin has more than 100 thermocouples evenly distributed over its surface to predict the extent, severity and location of body burn.

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Further complicating matters are the three ASTM F1930 mannequin chambers in North America; two are independent university labs, and the other is owned and operated by a company with commercial interest in FR clothing. Data can vary marginally from lab to lab, but should not vary significantly when testing is performed in compliance with the standards.

Decision makers are faced with evaluating performance data that can be presented as a "pass" or a number; or a graph where you can see different data on the same product from the various labs. This

Moment of flash fire starting.

Flame front.

environment has understandably caused reasonable confusion and disagreement about what is correct and what is relevant. It has also fostered significant leeway in the marketing of performance comparisons. Some product marketers prefer to show end-users a particular niche in the performance spectrum because that is the only place they record an advantage.

Controversy

The two primary points of contention are duration and heat flux. The NFPA 2113 standard historically defines flash fire duration as "3 seconds or less" predicated on the science of a flame front moving rapidly through a diffuse fuel. As noted earlier, NFPA 2112 accordingly set the pass/fail performance test at 3 seconds to characterize performance in a "worst case" scenario. Heat flux measures the rate of heat energy transfer per unit area per unit time, and is typically expressed as calories/square centimeter second (kilowatts per square meter). It is important to understand this because heat "flows." What matters is average heat flux over the course of a single event. Average heat flux of diffuse hydrocarbons burning in air was known to be about 2 cal/cm2*sec (84kW/m2), so the standard selected is based on propane fuel and a 2 cal/cm2*sec heat flux. However, when results of this standardized testing are less than favorable to the commercial interests of a fabric, data has been presented at longer or shorter durations along with arguments about higher or lower heat flux.

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Many things are theoretically possible, but standardized testing focuses on what is probable. Independent consensus standards organizations like NFPA and CGSB attempt to quantify and protect the greatest number of people from the most prevalent hazards based on real world conditions and experience. Given the frequency and scope of the debate, it was time to quantify the duration and heat flux of actual outdoor flash fires and confirm whether the standards were on target.

Testing challenges

The first two challenges in initiating such testing would be finding or creating enough field-deployable sensors and a facility capable of reliably, repeatedly and safely creating the flash fires. The University of Alberta is one of only two independent facilities in North America with an ASTM F1930 flash fire mannequin lab. Professor Mark Ackerman was responsible for the flash fire mannequin lab at the University of Alberta and developed portable versions of the same thermal sensors used in the Protective Clothing & Environmental Research Facility (PCERF) to create 3-D models of wildfires. These sensors proved perfect for the research.

With equipment capable of quantifying the answers in hand, what was still needed was an outdoor, full-scale fire field. After an exhaustive search Texas Engineering Extension Service (TEEX), part of Texas A&M University in College Station, Texas was selected. TEEX's Brayton Fire Training Field is the largest industrial fire training facility in the United States with 279 acres on which dozens of rigs, pipelines, industrial plant structures, tankers, railcars, etc. (called "props"), are all designed to intentionally create huge fires, allowing firefighters and other emergency personnel to train under real conditions.

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What Disney World is to children, TEEX is to those of us interested in fire science. The Brayton Fire Field is designed to train industrial firefighters, not conduct research, but TEEX personnel immediately realized the value of the work and agreed to participate in flash fire experimentation.

The ideal experimental design would feature a large, open outdoor area with a centrally located pipe to release hydrocarbon vapor; 360 degrees of unimpeded space to allow natural vapor cloud movement in all wind conditions; externally operable ignition sources to create the flash; mounting surfaces adaptable to thermocouples and data loggers; good sightlines for HD cameras; and independent university labs and personnel. During a scouting trip to the TEEX Fire Field, Prop 66 proved to be nearly perfect and was selected for the experiments.

More than 60 experiments were conducted in prevailing environmental conditions over several days with major success in quantifying the energy, brief duration and rapidly moving nature of flash fires. Please look for the details, results and conclusions in the next issue of *Well Servicing*.

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