D10 Examining the Repeatability and Reproducibility of the Heat Release Rate (HRR) From Upholstered Furniture

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Learning Overview: The goals of this presentation are: (1) to understand the potential use of HRRs in the investigation and analysis of fire incidents; (2) to understand the reproducibility and uncertainties of the determination of HRR from oxygen consumption calorimeters; and (3) to provide insight to fire investigators and engineers on the repeatability and the limitations of the HRRs and total heat released generated by burning upholstered furnishings.

Impact on the Forensic Science Community: This presentation will impact the forensic science community by informing attendees that good agreement was found for both the repeatability of the HRRs and reproducibility of the results between the three full-scale oxygen consumption calorimeters used in the study. Care must be used when applying HRRs to the investigation of fires.

Heat release rate is one of the most important input variables for use in numerically simulating a fire.[1] National Fire Protection Association (NFPA) 921, Guide for Fire and Explosion Investigations, considers mathematical modeling techniques as a means to provide the fire investigator with tools for testing hypotheses regarding the origin and cause of the fire and the cause of the resulting damage to property or injury to people. NFPA 921 cautions that "mathematical modeling, whether simplified hand calculations or computer fire models, has inherent limitations and assumptions that should be considered. Models generally rely upon empirical data and are validated via comparison with other empirical data. Care must be taken to assure that the model is being used with due regard for limitations, assumptions, and validation."[2] The National Institute of Justice Technology Working Group Operational Requirements (TWG OR) for Fire Investigation include the need for adequate materials property data inputs for accurate computer models.[3]

A better understanding of the measurement of heat release rates will provide a basis for the improved use of heat release rates in fire investigations. A starting point was the examination of the capabilities of the full-scale calorimeters used to measure heat release rate. Underwriters Laboratories Firefighter Safety Research Institute (UL FSRI) partnered with the Bureau of Alcohol, Tobacco and Firearms (ATF), the National Institute of Standards and Technology (NIST), and UL LLC to conduct a series of natural gas-fueled burner experiments as well as burning replicates of similar upholstered chairs to examine both the repeatability of the experiments at each laboratory and the reproducibility between the three laboratories.

Natural gas-fueled burners were positioned under the oxygen consumption calorimeter. The three different heat release rates selected for examination were 100kW, 500kW, and 1,000kW. Three replicate measurements were made for each heat release rate with each calorimeter. The flow of natural gas was measured with a mass flow controller. The heat release rate was predicted based on the heat content of the natural gas and the mass flow of the natural gas. The predicted heat release rate served as the comparison value for the heat release rate determined with the calorimeter. These experiments provided insight into the uncertainty and repeatability of the oxygen consumption calorimeters as well as an examination of the reproducibility of these baseline HRR measurements.

Fire investigators rarely investigate a fire that involves a natural gas-fueled laboratory burner. Therefore, additional heat release rate experiments were conducted with three types of upholstered chairs. Replicate heat release rate measurements were made with each chair to examine the repeatability of the burning chairs as well as to examine the reproducibility of the heat release rate measurements between the laboratories. Additional heat release rate experiments with additional types of upholstered chairs and sofas were conducted with the UL calorimeter.

Results of each of the sets of measurements will be presented. *This research was supported by United States Department of Justice, National Institute of Justice Grant Award, 2017-DN-BX-0163.*

Reference(s):

1. Babrauskas, V. and Peacock, R. (1992). Heat Release Rate: The Single Most Important Variable in Fire Hazard. *Fire Safety Journal*. 18. 255-272.
2. National Fire Protection Association (2017). *NFPA 921, Guide for Fire and Explosion Investigations.*
3. U.S. Department of Justice, Office of Justice Programs, National Institute of Justice (2019). *Forensic Science Technology Working Group Operational Requirements.*

Heat Release Rate, Fire Investigation, Upholstered Furniture

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