F2009 BFRL Project Description

Project Title: Heat Release Rate Uncertainty in Large-Scale Fire Measurement

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BFRL Program: Reduced Risk of Fire Spread in Buildings

Objective: To improve and document the performance of a quantitative large fire heat release rate (HRR) measurement system in the NIST Large Fire Laboratory (LFL) and to develop tools for analyzing the components of uncertainty in the heat release rate (HRR) measurement.

Problem:

What is the problem? There is a new demand for accurate calorimetry measurements due to recent furniture flammability regulations that impose limits on HRR of furniture exposed to an open flame.[1] The measured HRR must be accurate in order to be meaningful.

The Large Fire Laboratory serves as the BFRL laboratory for a wide range of moderate and large-scale experimental projects; almost all of the studies rely on the heat release rate (HRR) measurement, which is the most fundamental characterization of a fire. Current HRR measurement capabilities in the LFL are limited. The ability to quantify the uncertainty of dynamic (non-steady) HRR measurements is lacking, leaving questions about HRR results for all realistic experimental configurations. If the next generation of fire models are to ever be used to predict flame spread in buildings with real furnishings,[2] then a quantitative understanding of HRR uncertainty will be needed for model development and validation. The combined expanded relative uncertainty of the HRR measurement in the largest and the middle-sized calorimeters in the LFL are currently greater than 25 % and 14 % for fires greater than approximately 3 MW and 1 MW, respectively. Work is underway to attain a target heat release rate measurement uncertainty of less than 10 % of full scale.

The lack of measurement science (including standard test methods and methodologies to interpret the test results) creates a significant barrier to the development and introduction of innovative fire protection. Improved proficiency of large-scale HRR measurements is needed by

[1] The *Standard for the Flammability (Open-Flame) of Mattress Sets*, codified at 16 CFR Part 1633, establishes flammability requirements that all mattress sets (as defined in Section 1633.2(c)) must meet before sale or introduction into commerce manufactured on or after July 1, 2007 in accordance with regulatory, compliance, and enforcement purposes under the Flammable Fabrics Act.

[2] See the NIST project description for the Predictive Methods Project.

commercial fire testing laboratories in the U.S. (such as the NAFTL) to provide accurate measurements with a well-characterized amount of uncertainty.[3]

Why is it hard to solve? Reducing the uncertainty of the HRR measurement is difficult due to the large number (more than 30) of independent measurement parameters, space limitations of the facility, the different time response of the instrumentation, and the wide variation in the nature of the burning objects being studied (e.g. fast burning trees, underventilated-room fires, fire suppression tests). The dynamic nature of a fire will require consideration of the various instrument time responses in the development of HRR measurement uncertainty.

How is it solved today, and by whom? The principle of large fire oxygen consumption calorimetry was originally developed at NIST in the 1980's. Since that time numerous university, government and private research laboratories in the US, Europe and Asia have developed and implemented the large scale HRR measurement technique. A previous effort at NIST[4] was successful in characterizing the uncertainty of the 3 MW calorimeter in the LFL and providing a roadmap for further improvements. The problem of reducing and characterizing the uncertainty in the LFL's 10 MW calorimeter remains unsolved.

Why NIST? The NIST LFL is in a unique position to lead the world fire research community on quantitative large fire calorimetry measurements. The study of large fire calorimetry is consistent with the BFRL mission to meet the measurement science, standards, and technology needs of the U.S. building and fire safety industries.

Approach:

What is the new technical idea? The new idea is to analyze all contributing factors to the HRR measurement uncertainty and to reduce each of the significant uncertainty components in a meticulous manner. Furthermore, use computational fluid dynamic (CFD) modeling to study the HRR measurement system and optimize the design to minimize uncertainty. Also, an averaging pitot tube will be implemented to determine the exhaust mass flow rate, which will reduce the combined expanded relative uncertainty to less than 10 % for each of the three LFL hoods. Recent modeling and measurement results have demonstrated that significant remodeling of the exhaust ductwork will be required to reduce the uncertainty of the 10 MW calorimeter. As new techniques are implemented they will be systematically evaluated and documented.

Why can we succeed now? This study provides an opportunity for NIST to have a positive impact on the fire testing industry through collaboration with the North American Fire Testing Laboratories (NAFTL) consortium. Recent advances in technology such as a new water filtering device are facilitating improvements in the HRR measurement. New analysis methods developed through this project, and complementary instrumentation, will allow correction of the HRR measurement for smoke and unburned hydrocarbons.

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[3] Measurement Needs for Fire Safety: Proceedings of an International Workshop. National Institute of Standards and Technology. April 4-6, 2000, Gaithersburg, MD, Ohlemiller, T. J.; Johnsson, E. L.; Gann, R. G., Editor(s)(s), 186-206 pp, NISTIR 6527, 2000.

[4] R.A.Bryant, T.J.Ohlemiller, E.L.Johnsson, A.Hamins, B.S.Grove, A.Maranghides, G.W.Mulholland, and W.F.Guthrie, The NIST 3 Megawatt Quantitative Heat Release Rate Facility - Description and Procedure, NIST IR 7052 (2004).

What is the research plan? The 10 MW calorimeter will be reconfigured and instrumented using the results of CFD modeling and experience gained improving the HRR measurement in the 500 kW (furniture) calorimeter. A new section of exhaust duct will be installed on the roof of the lab to improve flow shape and mixing characteristics. A significant amount of work will be performed to characterize and document the new measurement system including a detailed analysis of uncertainty. Measurement of convective enthalpy emission from a fire will be added to the suite of key measurements that enable characterization of the global aspects of a fire.

A new proficiency study involving HRR is planned for the association of North American Fire Testing Laboratories (NAFTL). The 500 kW calorimeter in the LFL will be used to participate in this study. In phase I of this study HRR data from well controlled gas and liquid fires will be analyzed. Phase II of the study will include HRR results from a standard mattress flammability test (CFR 1633).

Recent Results:

Outputs

- Two peer reviewed papers.[5,6]
- A collaborative effort was established with the North American Fire Testing Laboratories (NAFTL) consortium to initiate a new HRR proficiency study.

Outcomes

- Improved measurement capabilities demonstrated for the LFL 500 kW calorimeter with uncertainty reduced by a factor of two.

Standards and Codes: This work feeds into ISO TC92 SC1 work on calorimetry.

[5] Kim, S.C., Bundy, M., "Numerical Model of a Large-Scale Oxygen Consumption Fire Calorimeter" to appear, Journal of Thermal Analysis and Calorimetry, 2008.
[6] Bryant, R.A, Mulholland, G.W." A guide to characterizing heat release rate measurement uncertainty for full-scale fire tests", *Fire Mater.* 32:121–139, 2008.