2009 BFRL Project Description

Project Title: Analysis of Fire Plume/Wall Interactions and Burn Pattern Repeatability

September 15, 2008

Principal Investigator: Daniel Madrzykowski

Co-Investigator(s): Kevin McGrattan

BFRL Program: Advanced Fire Service Technologies

Objectives: To assess the repeatability of burn patterns on gypsum board, by developing methods to measure and analyze the burn area of gypsum board exposed to a range of source fires. To develop the input data needed to reliably enable FDS/Smokeview to re-create burn patterns.

Problem:

What is the problem? Previous research by the National Institute of Justice (NIJ), the National Institute of Standards and Technology (NIST), and the United States Fire Administration (USFA) have shown that fire patterns provide data useful for the determination of fire origin. The reports noted the impact of ventilation on the development of the burn patterns. A large number of other factors affect the formation of these patterns: burn time, heat release rate of the fire source, fire exposure, target fuel composition, adjacent fuel(s) and compartmentation, to name a few. Given the limited number of experiments in the literature and the large number of variables it has been difficult to fully understand a cause and effect relationship between the fire scenarios and the resulting patterns.

Why is it hard to solve? Given the large number of parameters that impact the development of a burn pattern, the research problem has been designed to minimize the number of variables and develop an improved understanding of burn pattern development. Even with a limited set of scenarios, issues of phase change within the gypsum board dramatically effects the heat transfer and hence the development of the burn pattern. Significant thermal measurements are required to characterize the fires (energy sources) and gypsum board (targets) to develop an understanding of the process.

How is it solved today, and by whom? While the number of studies focused on the development of burn patterns in furnished rooms is small, there is a larger body of knowledge on the transfer of heat to walls and ceilings. To date questions regarding the repeatability of burn patterns or the capability to re-create burn patterns reliably has not been demonstrated.

Why NIST? BFRL is an international leader in measurement science and predictive tools for the fire safety and investigation community. This project requires advanced fire measurement, analysis and modeling techniques which are central to one of BFRL's Core Competencies of fire protection and fire spread within buildings and communities and aligns with the BFRL Strategic Priority on measurement science for innovative fire protection.

Approach:

What is the new technical idea? This project deconstructs the problem in order to develop a thorough understanding of burn pattern development. Traditional intrusive point source measurement methods will be combined with non-intrusive field measurements, such as thermal imaging and post-test imaging to assess the heat transfer into the gypsum board. In addition, oxygen consumption calorimetry performed during the experiments to monitor the energy release of the source fire.

Why can we succeed now? BFRL has the unique mix of expertise, instrumentation, laboratory facilities, computational facilities and OA funding to conduct the tasks to address this research need.

What is the research plan? This proposed project will leverage resources to improve the analysis and application of the results from an NIJ/OLES sponsored project which NIST is conducting. The NIJ/OLES project includes several series of real-scale, replicate fire experiments to examine the repeatability of burn patterns. The stages of the project are given below.

- **Literature Search** – While the number of studies focused on the development of burn patterns in furnished rooms is small, there is a larger body of knowledge on the transfer of heat to walls and ceilings. It is important to review and document the relevant studies as part of the specific experiment design.
- **Characterization of Source Fires** – Experiments will be conducted with a gas fueled, mass flow controlled burner, a liquid fueled burner, and a solid fuel. The burners/solid fuel will be calibrated for heat release rate with an oxygen consumption calorimeter. The burners/solid fuel will be calibrated for a range of heat release rates per unit area, approximately 300 to 1500 kW/m^2. Solid fuels, such as polyurethane foam blocks, with and without liquid hydrocarbon accelerants, will also be examined and characterized.
- **Impact of Construction** – Comparative experiments will be conducted to examine the impact of the method of construction and support of the walls and corner sections on the development of the burn patterns. Construction parameters to be examined include: wood studs, insulation and an enclosure. Thermal imaging will be used to examine the heat transfer to the walls. Heat flux sensors and thermocouples will also be used. The results of these experiments will determine the construction of the walls and corners used in subsequent phases of this study.
- **Critical Heat Flux** – Conduct a series of experiments on the gypsum board and hardboard paneling to determine the repeatability of a "critical heat flux" that results in a clear line of demarcation, a "burn/no burn" line. The flooring radiant panel and/or the lift apparatus may be used to examine this value.

- **Wall Fires** – Free- standing wall sections will be built from three different types of materials; non-combustible, painted gypsum board, and hardboard paneling. The non-combustible wall will be instrumented to measure the heat transfer of the fire to the wall. The fires will initially be away from the wall and will be moved toward the wall until the burner is adjacent to the wall. At least 3 experiments will be conducted in each position. The same burner procedure would be repeated with the gypsum board and paneling. The burn patterns will be documented and analyzed for repeatability. A partial ceiling will be installed over the wall.
- **Corner Fires** – Free-standing corner sections will be built from three different types of materials; non-combustible, painted gypsum board, and hardboard paneling. The non-combustible wall will be instrumented to measure the heat transfer from the fire to the walls. The fires will initially be away from the corner and will be moved toward the corner until the burner is adjacent to the wall. The burner will also be moved away from the corner along one of the walls to examine the change in fire pattern. At least 3 experiments will be conducted in each position. The same burner procedure would be repeated with the gypsum board and paneling. The burn patterns will be documented and analyzed for repeatability. A partial ceiling will be installed over the corner.

- **Burn Pattern Re-creation** – FDS and Smokeview will be used to examine the ability to reproduce a critical heat flux experiment. If successful, FDS will then be used to model the wall and corner experiments. Comparison between the experiments and the model will provide valuable validation data for the model.
- **Documentation** - Each of the experiments will be documented in report form. The final results will be presented to the NFPA 921 committee and shared with other stakeholder groups. The final report will be available on the NIST website and others as appropriate.

Recent Results: New project in FY 2008. A series of full-scale burn pattern experiments examining burn pattern repeatability at the ATF Fire Research Laboratory was completed in October 2007. Madrzykowski was accepted into the Fire Engineering PhD program at the University of Canterbury. The source term characterization experiments and an additional series of full-scale burn pattern experiments examining the impact of wall construction were conducted at the NIST Large Fire Research Laboratory in May 2008.

Standards and Codes: Dissemination of results and technology transfer will occur through several means including: the NPFA Technical Committee on Fire Investigations, the International Association of Arson Investigators, the National Fire Academy Fire Investigation Program, and the ATF CFI Re-certification Program.

Madrzykowski is a member of the NFPA Technical Committee on Fire Investigations and is the Chair of the IAAI Engineering Committee.