

Validation of a Smoke Detection Performance Prediction Methodology: Status Report

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Abstract

The University of Maryland and Underwriters Laboratories, Inc., have recently begun work on a FPRF-sponsored research project to validate a smoke detection performance prediction methodology using the FDS fire model. The purpose of this paper is to describe the research plan and to provide a status report on this project.

Introduction

The University of Maryland and Underwriters Laboratories, Inc., have recently begun work on a FPRF-sponsored research project to validate a smoke detection performance prediction methodology using the FDS fire model. The primary objective of this project is to develop a validated smoke detection prediction methodology for incipient fires based on the FDS fire model. This methodology will address both spot-type and aspirated smoke detection systems. To achieve this objective, this project seeks to accomplish the following:

1. Adequately characterize smoldering/incipient fire sources to provide appropriate inputs to the NIST FDS model.
2. Demonstrate that FDS can accurately model the propagation of smoke from smoldering/incipient fires
3. Develop a smoke detection performance methodology based on a validated FDS model for the movement of smoke from smoldering/incipient fires and based on detection smoke alarm threshold criteria and aspiration system design software, all of which can be experimentally validated.

The overall project entails the following five activities, as shown in Figure 1:

- Characterization of the smoke and heat source for a range of incipient fires;
- Evaluation of smoke transport and dilution using the FDS model;
- Evaluation of the smoke concentration history at detector locations using the FDS model;
- Evaluation of the smoke concentration history inside detectors based on submodels included in the FDS model;

- Evaluation of different detection threshold criteria to best matches experimental results with FDS model predictions.

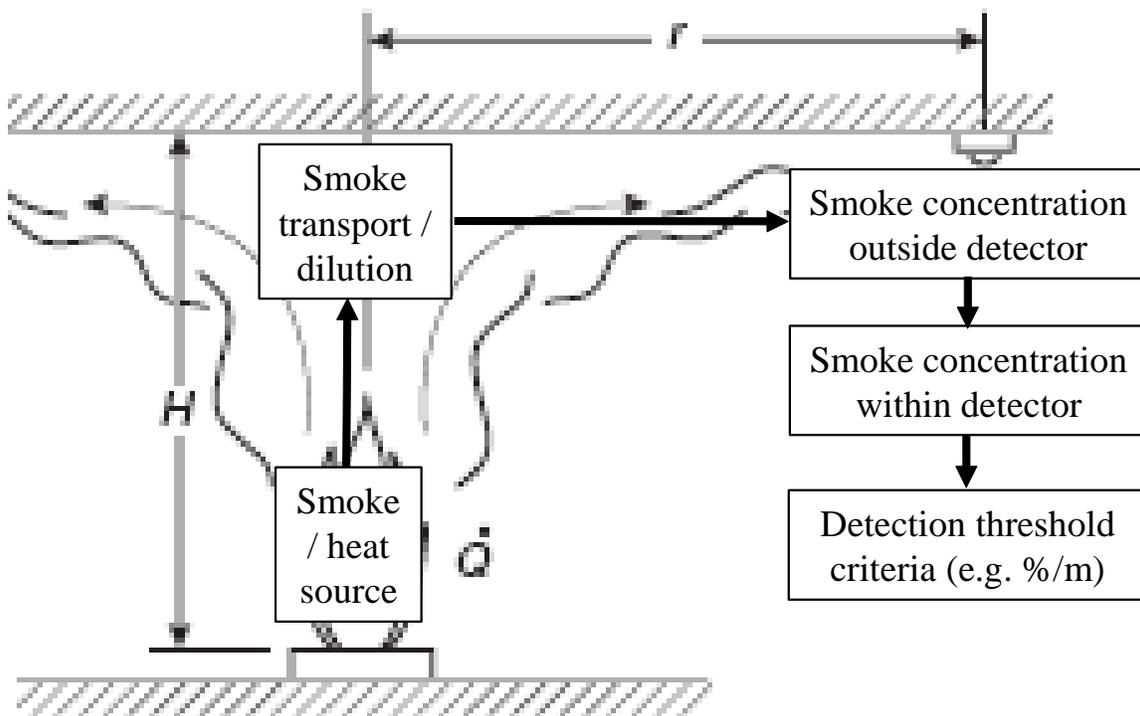


Figure 1. Overview of the elements of the smoke detection prediction methodology.

This validation exercise includes the performance of up to 72 large-scale fire experiments with different incipient fire sources under a range of ventilation conditions. The results of these large-scale experiments will be compared with the results of related FDS simulations.

Task 1: Identify and characterize incipient fire sources

For the first task, existing standards will be reviewed to develop an understanding of their scope and applicability for ignition of products and equipment found in representative commercial facilities. Ignition sources will be characterized to develop input source terms for the FDS program. Tests will be conducted under a small-hood calorimeter on typical products and components found in representative commercial facilities. The test methodology, instrumentation and data developed in the FPRF-sponsored Smoke Characterization Research Project will be used as applicable.

The focus of this project is on “incipient” fire sources, which can be considered to be fire sources that are generally smaller than those used in the UL 217/268 room tests. The eight fire sources shown in Table 1 are currently planned for this task.

Table 1. “Incipient” fire sources planned for characterization.

Test Series	Fuel Source	Ignition Source
1	Office paper	Small flame
2	PU foam/fabric	Small flame
3	PU foam/sheet	Cigarette
4	Ponderosa pine	UL 217 hotplate
5	Cotton linens	UL 217 hotplate
6	PVC insulated wire	Electrical overload
7	Computer case	Small flame
8	PC board	Small flame

Task 2: Validate FDS smoke transport predictions

For the second task, up to 72 large-scale fire experiments will be conducted to develop data for comparison with FDS simulations. The proposed test matrix for the 72 large-scale fire experiments is shown in Table 2. These experiments will be conducted in a large-scale enclosure using the smoldering/incipient fire sources characterized in the first task. A range of ventilation conditions will be used to simulate representative commercial facilities.

The large-scale experiments will be conducted in one of two enclosed test rooms with nominal mechanical ventilation rates of up to 12 air changes per hour. Experiments under unventilated conditions will be conducted in the standard 36 ft x 22 ft x 10 ft UL smoke room. Experiments under mechanically ventilated conditions will be performed in a 24 ft x 24 ft x 10 ft room with floor/ceiling plenums. Smoke detectors and measurement instrumentation will be provided at various locations within test enclosure in order to characterize the smoke and flow conditions at different locations for comparison with FDS model predictions.

Table 2. Proposed test matrix for 72 large-scale fire experiments.

Test Series	Fuel Source	Ignition Source	Air flow rate ¹	Number of Replicates	Total Number of Tests
1	Office paper	Small flame	N,M,H	3	9
2	PU foam/fabric	Small flame	N,M,H	3	9
3	PU foam/sheet	Cigarette	N,M,H	3	9
4	Ponderosa pine	UL 217 hotplate	N,M,H	3	9
5	Cotton linens	UL 217 hotplate	N,M,H	3	9
6	PVC insulated wire	Electrical overload	N,M,H	3	9
7	Computer case	Small flame	N,M,H	3	9
8	PC board	Small flame	N,M,H	3	9

Notes: 1 – N: No air exchange; M: Med. air exchange rate (~6 ach); H: High air exchange rate (~12 ach)

2 – Mechanical ventilation will be provided through ducted supply vents and plenum return vents distributed in the test room ceiling.

Task 3: Develop and validate the FDS smoke detection prediction methodology

For the third task, a methodology will be developed to model the alarm times of spot-type and aspiration smoke detection systems. Development of this methodology will include a comparison of the smoke detection alarm threshold criteria included in the literature as well as the aspiration system design software with the experimental data acquired in Tasks 1 and 2. New algorithms will be developed as appropriate to better model the response characteristics of smoke detectors in terms of the FDS fire model.

This task will evaluate and build on the FDS smoke detection prediction methodology already incorporated in FDS for spot-type detectors. This methodology models smoke detectors as one-chamber (Heskestad model) or two-chamber (Cleary model) devices that have characteristic lag times associated with smoke entry into these chambers. These lag times are functions of chamber geometry, characterized in terms of a characteristic length parameter, and the smoke velocity outside the detection device.

For aspirated detectors, a new framework will be developed that considers the smoke concentration at each aspiration port and the lag times and mixing associated with the transport of smoke from the aspiration ports to the central smoke sensing chamber.

Summary

An overview has been provided of a recently commissioned FPRF project on validation of a smoke detection performance prediction methodology. This methodology is based on the FDS fire model that is under ongoing development at the National Institute of Standards and Technology. At the time this presentation and paper were prepared, this project is in its very early stages. Consequently, this paper has presented an overview of the research plan. Future reports will include more details about the experimental data and analysis as they are developed.