Validation of Modeling Tools for Detection Design in High Air Flow Environments, Phase 2

Project Summary

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Background: Information-technology and telecommunications (IT/telecom) facilities provide critical services in today's world. From a risk standpoint, the indirect impact of fire loss due to business interruption and loss of critical operations, sometimes geographically very distant from the IT/telecom facility itself, can far outweigh the direct property loss.

In the past few years, there have been dramatic changes in the equipment housed in these facilities, which have placed increased demands on HVAC systems. As a result, airflow containment solutions are being introduced to increase energy efficiency. From a fire safety design perspective, the use of airflow containment creates a high airflow environment that dilutes the smoke, which poses challenges for providing adequate detection, and affects the dispersion of suppression agents.

Fire protection requirements for IT/telecom facilities are directly addressed by NFPA 75, *Protection of Information Technology Equipment*, and NFPA 76, *Fire Protection of Telecommunications Facilities*. Installation of detection systems are covered by NFPA 72, *National Fire Alarm and Signaling Code*, which is referenced by both NFPA 75 and NFPA 76. Annex Section B.4.5 of NFPA 72, *National Fire Alarm and Signaling Code*, states, "There currently are no quantitative methods for estimating either smoke dilution or airflow effects on locating smoke detectors." Although tools exist to model fire development, detection time, and suppression agent dispersion, they have not been validated for this application.

Phase 1 of this study identified several candidate models for this application. However, while these models have the ability to simulate detection performance in high air flow environments, they have not been validated for this specific application. In addition, the Phase 1 work identified four knowledge gaps:

- Specification of the fire and smoke inputs: There is very limited data for representative sources in IT/telecom facilities that have been characterized in a way that it is usable as an input to a model.
- Smoke Transport: There is a need to assess the importance of being able to predict smoke deposition and spatial particle size distributions (e.g. the adequacy of treating smoke as a gas verse particles) on the ability of models to adequately predict detection performance.

- Smoke detector performance: There is no data to reliably predict detection performance at high flow rates. The ability to correlate conditions predicted by a model (e.g., smoke concentration) at the location of a smoke detector/ASD sampling port to an alarm condition within the detector is a significant gap.
- The existence of large scale integral test data is limited. There is no work that completely validates the full process of imputing representative fire sources into a model and predicting a detection response for a high air flow environment.

Research Goal: The goal of this project is to validate a CFD model that can be used for providing reliable analysis of detection performance in IT/telecom facilities with high air flows as well as provide guidance to the Technical Committees for new requirements and guidance by using the validated model to run various scenarios.

Project Tasks:

The tasks below were recommended during Phase 1 to fill in the knowledge gaps identified in order to achieve the research goal. For more detail on the recommendations from Phase 1, the report is available on the Foundation website: www.nfpa.org/foundation.

1) **Task 1: Select CFD Model(s).** Select at least one model to be used in the validation study based on the Phase 1 findings. The model(s) should be widely available and be validated generally for use as a fire/smoke modeling tool. The selected model(s) should be documented in accordance with SFPE *Guidelines for Substantiating a Fire Model for a Given Application* and in compliance with NFPA Standards Council policy and ANSI patent policy with proprietary use and licensing.
2) **Task 2: Fire Source Characterization.** In order to accurately prescribe the fires as inputs to CFD models, fire data representative of the types of materials, likely ignition scenarios, and burning environments must be developed experimentally.
    a. Task 2a: Develop a set of candidate fire sources, which will be mutually agreed upon with the Project Technical Panel. The fire sources must be representative of the range of materials expected in IT/telecom facilities, the potential ignition scenarios, and the burning configurations and associated local air flow velocities. The materials chosen should bind the fire problem within each of the major types of materials.
    b. Task 2b: Candidate source fire testing to identify bounding fire sources and quantify the heat release rate (HRR) and smoke production.
    c. Task 2c: Develop a set of standardized model input design fire sources based on the information from Task 2b.
3) **Task 3: Detector Response Characterization.** While a computer model will predict the temperature, velocity, and smoke concentration properties at a detector/sample port location, the ability to correlate a specific detector response to a specific fire source in a high air flow environment is highly uncertain. Therefore, a relationship between the environmental conditions and the detector response must be developed.
    a. Task 3a: Develop detection scenarios. Identify and obtain applicable detection devices and define detailed test parameters. A plan for detection scenario testing will be developed by the contractor and mutually agreed upon with the Project Technical Panel. The following detector technologies should be evaluated: air sampling smoke detectors, photoelectric smoke detectors, spot type heat detectors, multi-criteria detectors (excluding ionization type), and video based smoke detection. A range of detector models from leading manufacturers should be selected.

   b. Task 3b: Detection scenario testing to quantify local smoke and/or gas properties and detection response in representative IT/telecom environments. Once detector options and operating conditions have been identified, a complete bench scale analysis of the various detection options should be conducted to identify the detection response. Detection simulations should include both "standard" detector sensitivity settings and sensitivity levels as required by Chapter 8 of NFPA 76.
   c. Task 3c: Model detection response correlations. Based on the results of Task 3b, produce a set of correlations relating detector response to local smoke properties that candidate models are capable of calculating.

4) **Task 4: Full Scale Model Verification and Validation.** Conduct full scale testing for direct comparison with model predictions. A full scale testing and model evaluation plan will be developed by the contractor and mutually agreed upon with the Project Technical Panel.
   a. Task 4a: Identify a functional IT/telecom facility or create a full scale mockup facility and conduct fire detection testing. The test facility should incorporate each of the major components of a typical IT/telecom facility (subfloor, electrical cabinets, main aisles, plenums, return air grills, etc). Instrumentation should be carefully selected and justified by type and location to provide measurements necessary to estimate all types of detector response in all of the identified facility configurations and design fire scenarios.
   b. Task 4b: Develop a computer model simulation identical to the full scale mock facility and simulate fire detection testing.
   c. Task 4c: Compare the results from Task 4a and 4b and provide a detailed assessment of the evaluation of the model. The evaluation should assess whether the CFD model's prediction in the following areas: air velocity, temperature, air flow direction and dynamics (including dilution of smoke), smoke concentration, and detector activation, is within experimental accuracy. Successful validation efforts should provide an 80% confidence level or better (test data and CFD modeling results should be within +/- 20% accuracy of one another) for each critical model parameter. Even if a model is considered validated, all limitations of the model should be described in the report. The evaluation process shall be in accordance with ASTM E1355-12 *Standard Guide for Evaluating Predictive Capability of Deterministic Fire Models*.

5) **Task 5: Perform CFD Simulations.** If the CFD model is successfully validated in Task 4 perform and analyze a variety of simulations using the CFD model in order to provide information to the NFPA 75 and 76 Technical Committees for the purpose of developing requirements and/or informative annex material on detection in high air flow environments. A diagram that lists the knowledge gaps is provided as Annex A. Scenarios should consider geometry of real IT/telecom facilities, ventilation scenarios broad enough to provide guidance, design fire scenarios representative of real hazards, air flow boundary conditions that affect dilution of the concentration of the target species, and IT equipment heat loads. In addition, the sensitivity of the model (to grid size, input parameters, etc) should be assessed. A modeling plan that lists all of the scenarios and modeling parameters will be developed by the contractor and mutually agreed upon with the Project Technical Panel.

   If consensus on the adequacy of the CFD model is not achieved in Task 4, contractor shall suggest an alternative path forward, which will be mutually agreed upon with the Project Technical Panel and implemented as Task 5.

Implementation: This research program will be conducted under the auspices of the Fire Protection Research Foundation and will be guided by a Project Technical Panel. The final report for Phase 2 will be issued by February 1, 2014.