Cleverly Named Title To Describe Our Awesome Work

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UNDERWRITERS LABORATORIES™

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UL	Underwriters Laboratories
UL FSRI	UL Firefighter Safety Research Institute

Acknowledgments

Generic Table

Name	Awesomeness
Neil Armstrong	First person to walk on the moon
Edith Clarke	First female ECE professor
John Goodenough	Rechargeable Lithium-Ion battery
Nikola Telsa	Modern alternating current

Abstract

1 Introduction

1.1 Motivation

1.2 Objectives

2 Literature Review

3 Experimental Configuration

3.1 Experimental Structure

3.2 Instrumentation

3.2.1 Measurement Locations

3.2.2 Measurement Uncertainty

Note: this template contains uncertainty information for a variety of different measurement types. Be sure to remove any types that aren't mentioned.

Additionally, although this section provides information about measurement uncertainty in paragraphs that are sufficient for a technical report, ***it's highly recommended that the content obtained from this section is still reviewed after being copied to a technical report to verify the accuracy and applicability of the information.****For example, it should be verified that the instrumentation described in the paragraphs below resemble the same type used during the experiments mentioned in the technical report.*

There are different components of uncertainty in the measured values reported in this document, specifically gas temperature, total heat flux, pressure, gas velocity, gas concentration, heat release rate, length, mass, structure leakage, and water flow rate. Uncertainties are grouped into two categories according to the method used to estimate them. Type A uncertainties are those evaluated by statistical methods, and Type B are those evaluated by other means [1]. Type B analysis of systematic uncertainties involves estimating the upper (+ a) and lower (− a) limits for the quantity in question such that the probability that the value would be in the interval (± a) is essentially 100 %. After estimating uncertainties by either Type A or B analysis, the uncertainties can be combined in quadrature to yield the combined standard uncertainty. Multiplying this combined standard uncertainty by a coverage factor of two results in an expanded uncertainty with a 95 % confidence interval (2σ). For some components, such as the zero and calibration elements, uncertainties were derived from referenced instrument specifications. For other components, referenced research results and past experience with the instruments provided input for the uncertainty determination.

Gas Temperature

According to Omega Engineering, the manufacturer of the thermocouple wire utilized during the experiments, the standard uncertainty in the temperature of the thermocouple wire itself is ± 2.2 °C at 277 °C and ± 9.5 °C at 871 °C [2]. In addition to the uncertainty of the sensor itself, radiative effects to the thermocouple should be considered. Several studies have attempted to quantify these effects on thermocouple measurement uncertainty in compartment fires [3, 4]. These studies indicated that when the thermocouple is located in the upper gas layer, the actual temperature of the surrounding gas is typically higher than the measured temperature, although this difference is not as pronounced as when the thermocouple is in the lower layer. When the thermocouple is in the lower layer, particularly during a fully involved compartment fire, the percent error in measured temperature can be much larger. Because of these radiative contributions, the expanded total uncertainty is estimated as ± 15 %.

Heat Flux

The manufacturer of the heat flux gauges, Medtherm Corporation, reports a ± 3 % calibration expanded uncertainty for the devices [5]. Results from an international study on total heat flux gauge calibration and response demonstrated that the total expanded uncertainty of a Schmidt-Boelter gauge is typically ± 8 % [6].

Pressure

Differential pressure reading uncertainty components were derived from pressure transducer instrument specifications and previous experience with pressure transducers. Each transducer was factory calibrated by the manufacturer to verify that the zero and span of the transducer resulted in an accuracy of ± 1 % [7]. The total expanded uncertainty associated with the pressure data from these experiments is estimated to be ± 10 %.

Gas Velocity

A gas velocity measurement study that focused on flow through doorways during pre-flashover compartment fires yielded total expanded uncertainties ranging from ± 14 % to ± 22 % for measurements from BDPs similar to those used throughout the experiments described in this report [8]. The total expanded uncertainty for gas velocity measured during these experiments is estimated to be ± 18 %.

Gas Concentration

The oxygen concentration measurement range of the OxyMat6 was 0–25 %. The gas sampling instruments used throughout the experiments described in this report have demonstrated a relative expanded uncertainty of ± 1 % when compared to span gas volume fractions [9]. According to a study by Lock et al. [10], the non-uniformities and movement of exhaust gases in addition to the limited amount of sampling points considered in each experiment result in an estimated expanded uncertainty of ± 12 %.

Heat Release Rate

Will depend upon technique used to measure HRR. Need to specify fuels for which HRR was characterized.

To understand the energy release of the fuel loads (i.e., the primary ignition source) used in these experiments, fuels were burned in Underwriters Laboratory's oxygen consumption calorimetry laboratory in Northbrook, Ill was The oxygen consumption calorimeter is sized to handle up to a 10 MW fire with a 31 ft (9.4 m) diameter conical hood. In a previous study, Bryant and Mullholland [11] estimated the uncertainty of oxygen consumption calorimeters measuring high heat release rate fires at ± 11%. They identified several sources of error within the calorimeter, with one of the primary sources being the uncertainty in the gas concentration measurements.

Length

Length measurements, such as the room dimensions and instrumentation locations, were made with either a hand held laser measurement device having an accuracy of 0.25 in. (± 6.0 mm) over a range of 2 ft (0.6 m) to 50 ft (15.2 m) [12] or ± 0.02 in. (± 0.51 mm) resolution steel measuring tapes manufactured in compliance with NIST Manual 44 [13], which specifies a tolerance of ± 0.06 in. (± 1.5 mm) for 30 ft (9.1 m) tapes and ± 0.25 in. (± 6.4 mm) for 100 ft (30.5 m) tapes. These uncertainties are all well within the precision of the reported dimensions, which are typically rounded to the nearest inch. Some issues, such as levelness of the device and "soft" edges on upholstered furniture, result in an estimated expanded uncertainty of ± 1.0 % for reported length measurements.

Mass

The load cell used to weigh the fuels prior to the experiments had a range of 0 lb (0 kg) to 441 lb (200 kg) with a resolution of 0.11 lb (0.05 kg) and a calibration uncertainty within 1 % [14]. The total expanded uncertainty for the fuel weights measured by the load cell that are presented in this report is estimated to be less than ± 5 %.

Structure Leakage

To characterize ventilation within the structure, an air leakage measurement system (Model 5101) was used to measure the amount of leakage associated with the training prop before each test [15]. *ASTM E779-10, Standard Test Method for Determining Air Leakage Rate by Fan Pressurization* was followed to determine the air leakage rate of the prop before each experiment [16]. The measured leakage rates were recorded in units of air changes per hour at 50 Pa (ACPH50). Retrotec, the manufacturer of the leakage measurement system, reports an accuracy of $\pm$ 5 % for the system.

Water Flow Rate

Water flow rate was measured with a 1.5 in. (3.8 cm) diameter electromagnetic flow meter from Badger Meter, Inc. (Model M2000). The meter consisted of stainless steel pipe lined with a non-conductive material. Energized coils on the outside of the non-conductive material imposed a magnetic field across the pipe, and when the conductive fluid (water) flowed across the magnetic field, a voltage proportional to flow velocity was produced. The manufacturer reports a $\pm$ 0.25 % calibration uncertainty for the accuracy of the measurement [17].

3.3 Fuel Load

4 Experimental Procedure

The following structure should be used to define tables:

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    \centering
    \caption{Example of Style in which Table Caption Should be
        Written}
    \label{tab:<ref_name>}
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        <row\_2\_content>     & <row\_2\_content>     \\
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Table 4.1: Example of Style in which Table Caption Should be Written

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<row_2_content>	<row_2_content>

Example of Figure Definition

5 Results & Discussion

6 Tactical Considerations

7 Research Needs

8 Summary

References

[1] B.N. Taylor and C.E. Kuyatt. Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results. NIST Technical Note 1297, National Institute of Standards and Technology, Gaithersburg, Maryland, 1994.

[2] Omega Engineering Inc., Stamford, Connecticut. *The Temperature Handbook*, 2004.

[3] L.G. Blevins. Behavior of bare and aspirated thermocouples in compartment fires. In *National Heat Transfer Conference, 33rd Proceedings*, pages 15–17, 1999.

[4] W.M. Pitts, E. Braun, R. Peacock, H. Mitler, E. Johnson, P. Reneke, and L.G. Blevins. Temperature uncertainties for bare-bead and aspirated thermocouple measurements in fire environments. *ASTM Special Technical Publication*, 1427:3–15, 2003.

[5] Medtherm Corporation, Huntsville, Alabama. *64 Series Heat Flux Transducers*, 2003.

[6] W.M. Pitts, A.V. Murthy, J.L. de Ris, J. Filtz, K. Nygård, D. Smith, and I. Wetterlund. Round robin study of total heat flux gauge calibration at fire laboratories. *Fire Safety Journal*, 41(6):459–475, 2006.

[7] Setra Systems, Boxborough, Massachusetts. *Setra Model 264 Very Low Pressure Transducer Data Sheet Rev E.*, 2002.

[8] R.A. Bryant. A comparison of gas velocity measurements in a full-scale enclosure fire. *Fire Safety Journal*, 44:793–800, 2009.

[9] M. Bundy, A. Hamins, E.L. Johnsson, S.C. Kim, G.H. Ko, and D.B. Lenhart. Measurements of Heat and Combustion Products in Reduced-Scale Ventilated-Limited Compartment Fires. NIST Technical Note 1483, National Institute of Standards and Technology, Gaithersburg, MD, 2007.

[10] A. Lock, M. Bundy, E.L. Johnsson, A. Hamins, G.H. Ko, C. Hwang, P. Fuss, and R. Harris. Experimental study of the effects of fuel type, fuel distribution, and vent size on full-scale underventilated compartment fires in an ISO 9705 room. NIST Technical Note 1603, National Institute of Standards and Technology, Gaithersburg, MD, 2008.

[11] R.A. Bryant and G. Mullholland. A guide to characterizing heat release rate measurement uncertainty for full-scale fire tests. *Fire and Materials*, 32:121–139, 2008.

[12] Stanley Hand Tools, New Britain, Connecticut. *User Manual TLM 100*, 2013.

[13] T. Butcher, S. Cook, L. Crown, and R. Harshman. NIST Handbook 44: Specifications, Tolerances, and Other Technical Requirements for Weighing and Measuring Devices. *National Institute of Standards, Gaithersburg, MD*, 2012.

[14] Ohaus Corporation, Pine Brook, New Jersey. *Manual for SD Series Bench Scale*, 2000.

[15] Retrotec, Everson, WA. *Retrotec 5101 Classic Blower Door Specifications*, 2017.

[16] ASTM International. *Standard E 779: Standard Test Method for Determining Air Leakage Rate by Fan Pressurization*, 2010.

[17] Badger Meter, Milwaukee, Wisconsin. *M-Series M2000 Electromagnetic Flow Meter*, MAG-DS-01047-EN-06 edition, 2015.