Potential Impact of New UL Fire Test Criteria

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Outline

- Background
- Recent History
- Task Group Progress
- Potential Impacts

Background

- UL 217 STP formed a task group on adding new polyurethane foam fire tests
- Task Group Scope - Increase available egress time for non-specific fires by expanding alarm responsiveness to other smoke signatures by expanding the range of smoke colors and particle sizes currently represented by UL 217 test materials.
  - UL developed testing procedures for selected flaming and smoldering polyurethane foam material.
  - Sub-task group analyzed full-scale data to specify performance criteria of the new tests. As part of this, NIST analyzed recent full-scale fire tests to determine improved test acceptance criteria for both flaming and smoldering scenarios.

Recommendations of Fire Safety Organizations

The following organizations recommend using a mix of photoelectric and ionization alarms or dual-sensor alarms for best protection in households:

- NFPA, NFPA 72 Chapter 29 SIG HOU
- USFA
- CPSC
- UL
- IAFC

Recent History

NIST Home Smoke Alarm Study (2000-2002)

- Smoke alarms of either the ionization type or the photoelectric type consistently provided time for occupants to escape from most residential fires, although in some cases the escape time provided can be short. Consistent with prior findings, ionization type alarms provided somewhat better response to flaming fires than photoelectric alarms, and photoelectric alarms provide (often) considerably faster response to smoldering fires than ionization type alarms.
- Escape times in this study were systematically shorter than those found in a similar study conducted in the 1970's. This is related to some combination of faster fire development times for today's products that provide the main fuel sources for fires, such as upholstered furniture and mattresses, different criteria for time to untenable conditions, and improved understanding of the speed and range of threats to tenability.

Recent History

NFPA 72 SIG HOU task group (2009) follow-on study examining photoelectric and Ionization performance.

- The rate at which a particular type of detector did not provide adequate warning was similar for ionization and photoelectric detectors regardless of whether the —Direct Escape or —Indirect Escape was used. As expected, ionization detectors provided earlier warning to flaming fires, while photoelectric detectors provided earlier warning to smoldering fires.
- With the possible exception of response to fires in bedrooms with the doors closed, for non specific fires the response to the —Direct Escape scenarios is generally adequate for either technology. There were only three tests for cases with the bedroom door closed (two flaming and one smoldering). For these cases, smoke density measurements were not made inside the bedroom itself so smoke density tenability for these cases is unknown

Recent History

NFPA 72 SIG HOU task groups (2009) follow-on study examining photoelectric and Ionization performance.

- For those in the majority, one of the reasons cited to continue to permit the use of either stand-alone ionization or photoelectric technology in NFPA 72 was that a requirement to use both technologies would stifle the development and introduction of new technology. Another reason cited was that while NFPA 72 could describe desired equipment performance parameters, detailed test requirements, such as time to alarm for various types of fires, were more properly left to product safety standards ANSI/UL 217 and ANSI/UL 268. This would allow desired test performance to dictate product design, rather than limiting products to existing technologies. (The committee was aware that a revision to ANSI/UL 217 requirements is underway.)
- A minority opinion was issued, recommending that both ionization and photoelectric technologies be required with considerations noted in Appendix C.

UL-FPRF Smoke Characterization Project (2007)

Based upon the results of this Smoke Characterization Project, the following items were identified for further consideration:

- The addition of other test materials such as polyurethane foam in the flaming and non-flaming combustion modes in UL 217.
- Whether a smoke alarm, once triggered, should remain activated unless deactivated manually.
- Requiring the use of combination ionization and photoelectric alarms for residential use in order to maximize responsiveness to a broad range of fires.
- Characterize materials described in UL 217 using a cone calorimeter, smoke particle spectrometer, and analytical testing.

NIST Smoke Alarm Sensitivity Study (2008)

Designed to examine the effects of the following on smoke alarm performance:

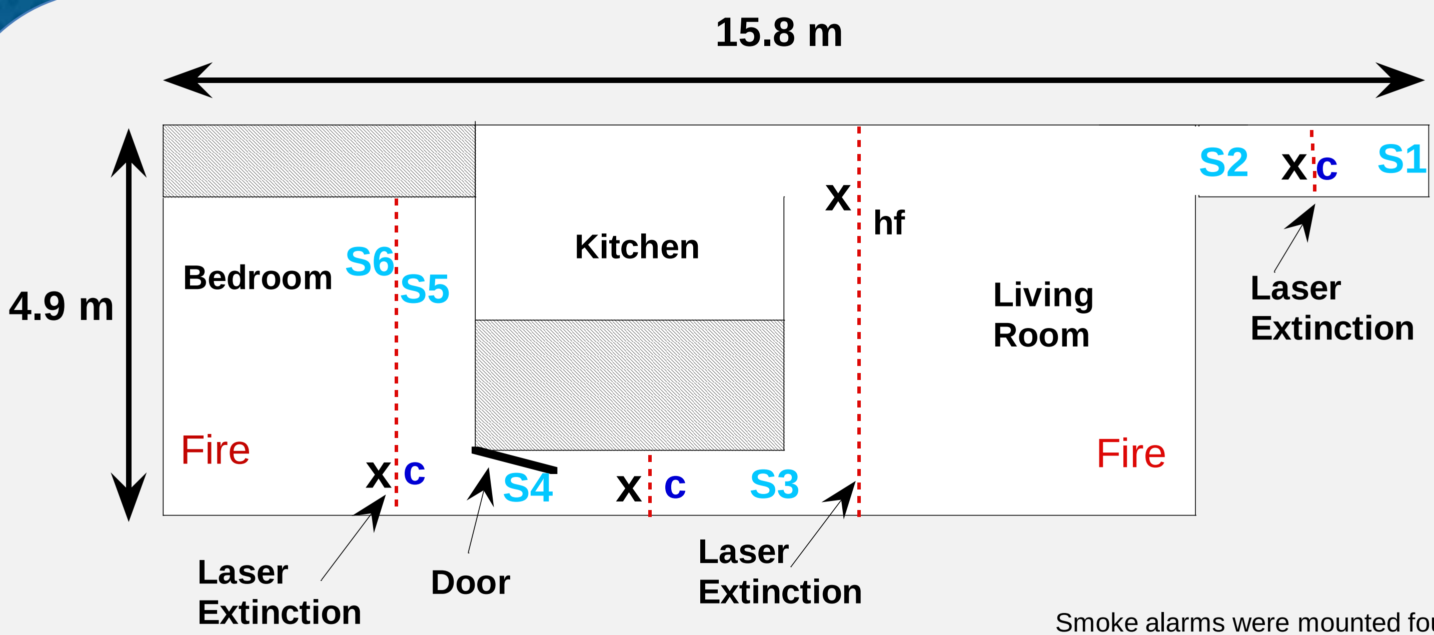
- Alarm type
  - Photoelectric
  - Ionization
  - Dual sensor
- Alarm location
- Fabric type
- Polyurethane foam density
- Ignition scenario
- Room configuration

NIST Smoke Alarm Sensitivity Study (2008)

- Follow-on to NIST Home Smoke Alarm Project (Dunes II).
- Ignition sources were more realistic and had a lower energy input into furniture mockups than Dunes II.
  - Initially flaming fires grew at medium "t^2" fire growth rates (NFPA 72 definition) after a linear growth period up to ~25 kW typically lasting 3 to 4 minutes (based on mass loss measurements during tests and experimentally-determined heat of combustion).
  - Initially smoldering fires upon transition to flaming grew at medium "t^2" fire growth rates except for one characterized as fast after a smoldering period lasting from 81 to 182 minutes.
- Fires progressed much further before suppression than the Dunes II tests in order to achieve multiple tenability limits throughout the test structure.

Test Structure

The fire tests were conducted in a building mock-up designed to represent a portion of an apartment or small home



X - thermocouple tree location
hf - total heat flux gage (1.5 m above the floor and pointing toward the fire)
S1…S6 - alarm set location
c - gas sampling location (1.5 m above the floor)
dashed line - beam path for extinction measurements (1.5 m above the floor)

Smoke alarms were mounted four across on panel boards in random order

P1 photoelectric
I1 Ionization
D1 dual alarm
D2 dual alarm

Fire Source

The fire source configuration was seat and back cushions resting on a metal frame placed inside a pan. The pan rested on a load cell for mass loss measurement. Cushions were non-fire retarded flexible polyurethane foam slabs of either a low density - 21kg/m^3 {1.3 lbs/ft^3} or high density - 29 kg/m^3 {1.8 lbs/ft^3}, cut to fit the cushion covers. A fabric dust ruffle wrapped over the lower seat frame. The covered cushions and dust ruffle weighed approximately 5.5 kg to 8.3 kg, depending on the foam and fabric combination.

Flaming Ignition Source

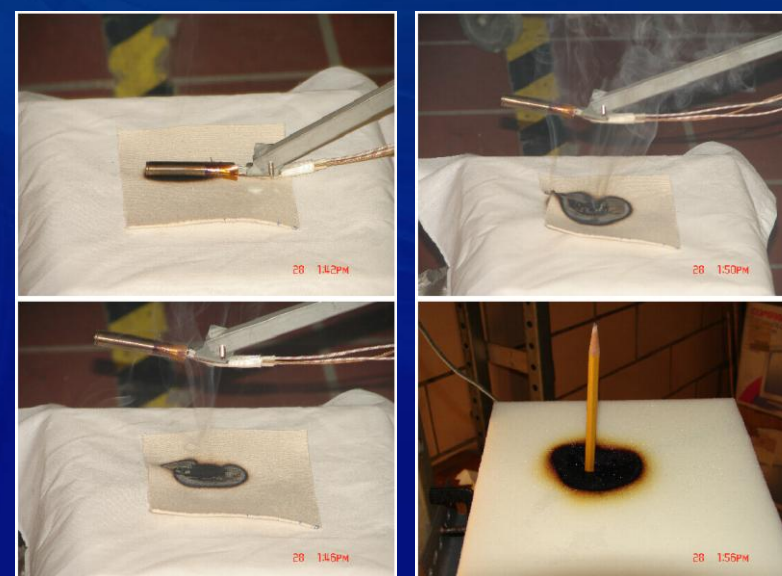
The flaming ignition source was a gas-flame ignition tube similar to British Standard 5852 with a propane fuel flow of 45 ml/min. At least two minutes of pre-burn before flame was positioned on edge of side seat cushion. After 40 seconds flame was removed.

Smoldering Ignition Source

The smoldering ignition source was a 50 W electric cartridge heater, 50 mm long and 10 mm in diameter. The cartridge heater was placed on a 15 cm by 15 cm square of cotton duct fabric resting on the seat cushion to ensure a sustained smoldering fire. Electrical power to the cartridge heater was applied in a controlled fashion to achieve an external temperature sufficient to produce sustained smoldering. After about 6 minutes of total contact time, the cartridge heater was removed.

Smoldering to flaming transition times ranged from 81 to 182 minutes

Small-scale ignition tests



Analyzing the Data
ASET/RSET Concepts

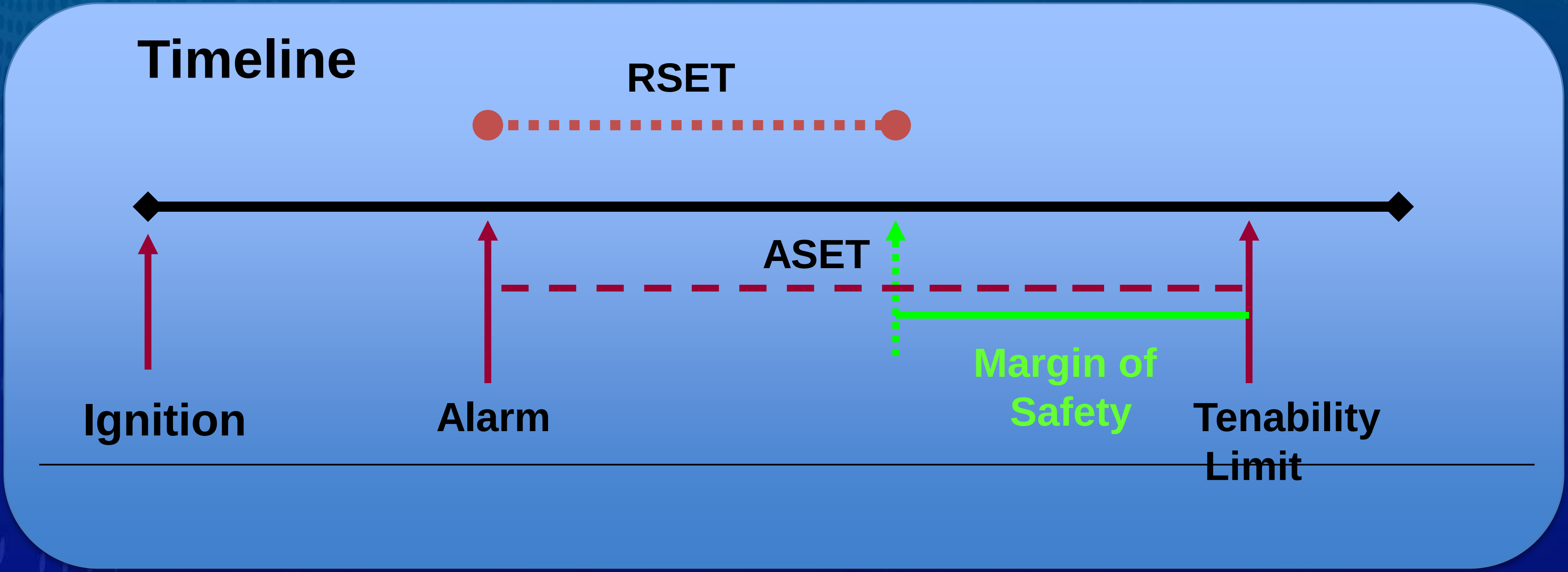
- Available Safe Egress Time - ASET is the time to reach a threshold tenability limit on either combustion gas exposure, thermal exposure, or smoke concentration

- Required Safe Egress Time – RSET is the time it takes for occupants to egress. It depends on pre-movement activities, travel distance and speed

Installed smoke alarms should provide early enough warning such that ASET > RSET

ASET/RSET Concepts

Available Safe Egress Time (ASET) – Required Safe Egress Time (RSET)



ASET Thresholds

- Toxic Gases
  - Time weighted average of asphyxiant gases. Value of fractional effective dose (FED) of 0.3 selected as reasonable criterion to provide the ability to escape for more sensitive populations (ISO 13571).
- Heat Exposure
  - Time weighted average of convected and/or radiated exposures. FED value of 0.3 selected as reasonable criterion to provide the ability to escape for more sensitive populations (ISO 13571).
- Smoke optical density (OD)
  - correlates with visibility distance and travel speed.
  - a limiting threshold value is equated to untenable conditions (Home Smoke Alarm Project used a value of 0.25 m^{-1}, ISO 13571 suggests a value as high as 3.4 m^{-1}).

New Alternative Analysis
Relative Smoke Alarm Effectiveness

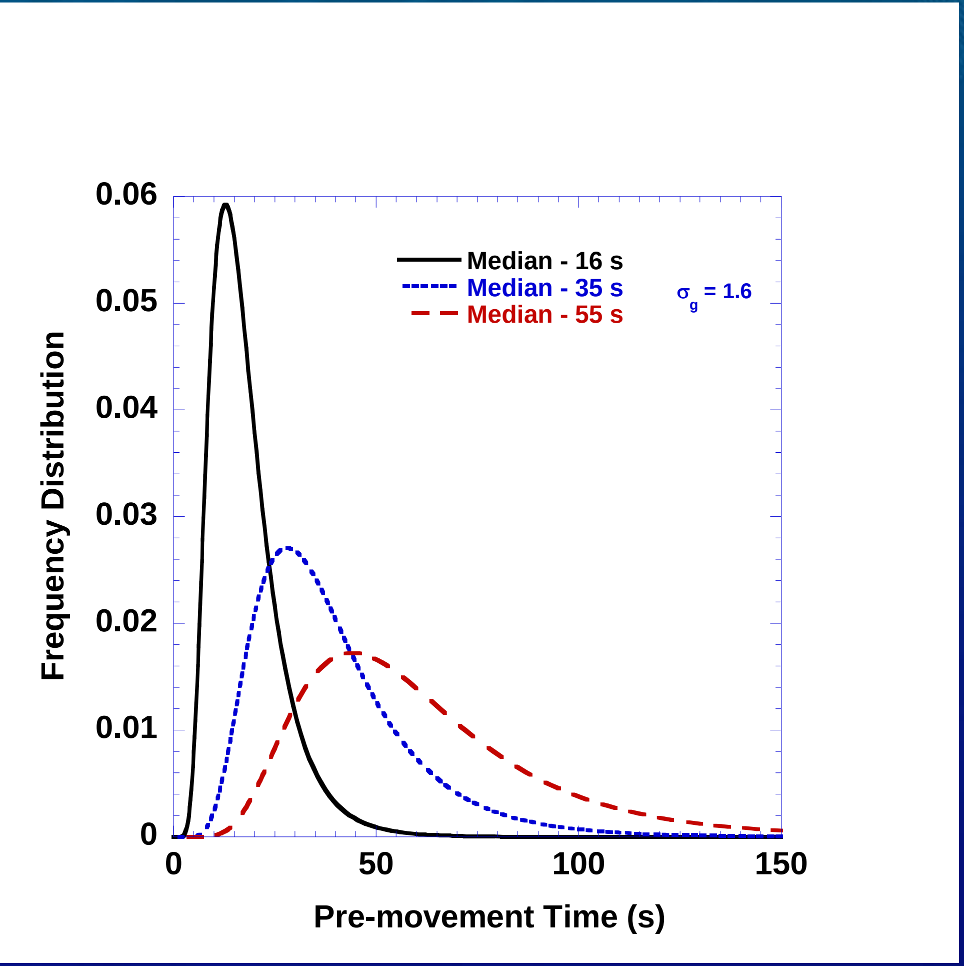
- **Treat pre-movement time as a frequency distribution**
- **Evacuation speed depends on smoke density**
- **Consider multiple direct and indirect evacuation paths**
- **Aggregate results to assess performance**

Why Treat Pre-movement Time as a Frequency Distribution?

- RSET “worst case” value is subjective
- Experimental data suggests pre-movement time can be characterized by a log-normal distribution
- More vulnerable populations can be addressed by changing the frequency distribution
- Results can be meaningfully averaged over evacuation scenarios and fire scenarios unlike individual margin of safety values

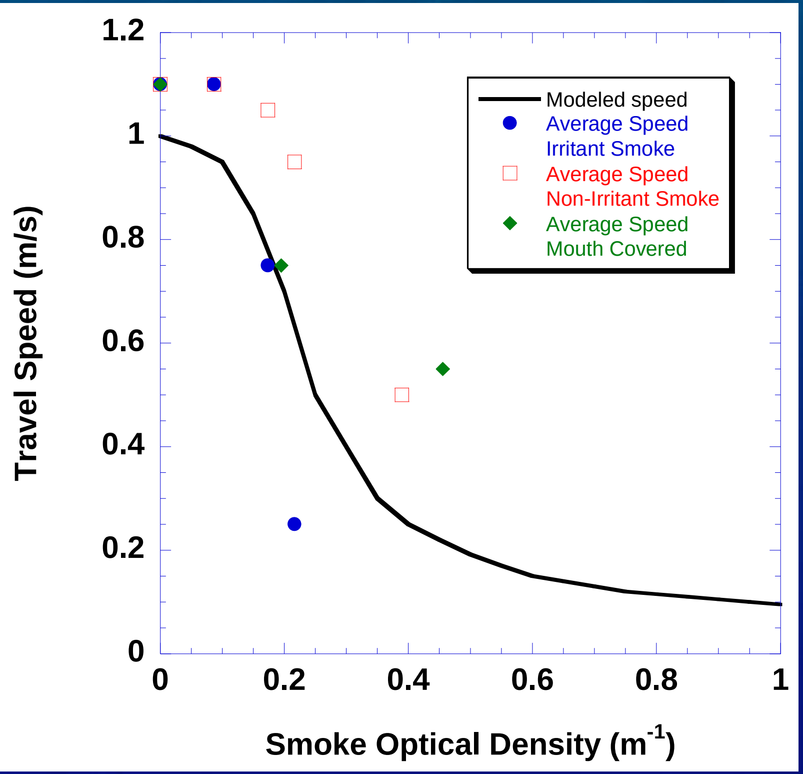
Sample Pre-movement Distributions

- Distribution can represent a distinct population
- Example distributions shown in graph
  - Easily alerted, mobile
  - Somewhat slower to respond
  - More vulnerable, elderly or impaired



Evacuation Speed a Function of Smoke Concentration

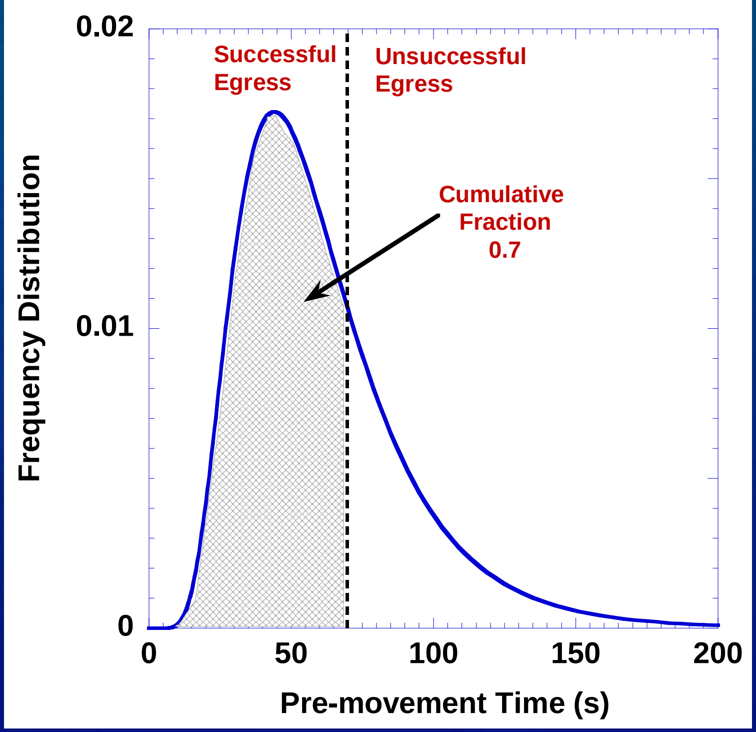
- RSET normally computed using mean travel speed in normal lighting and no smoke obscuration
- Here, the travel speed is a function of the optical density an occupant is traversing through.
  - The assignment of a reduced travel speed through smoke accounts for some of the negative impact of reduced visibility.
  - Furthermore, since smoke obscuration tends to increase as a fire progresses, an increase in pre-movement time will cause an increase in travel time for a particular scenario.



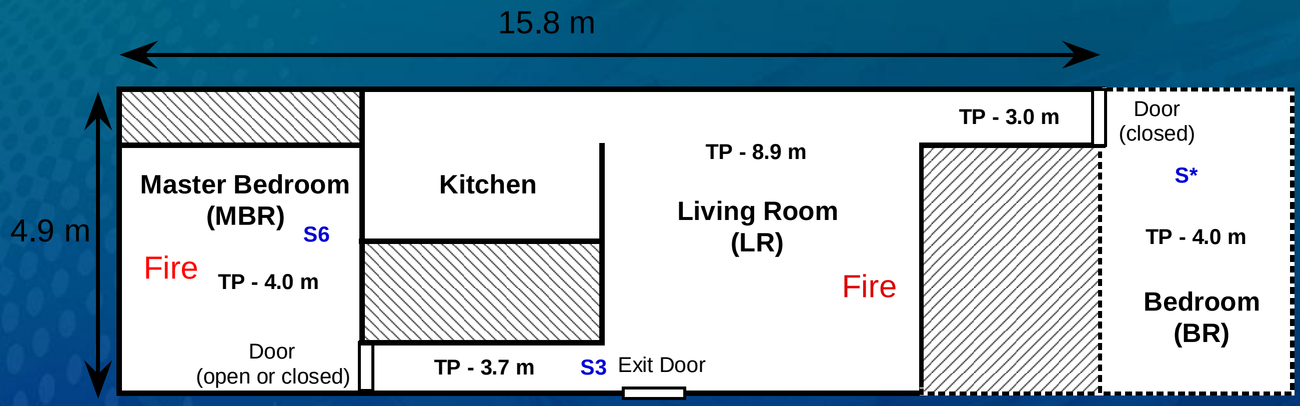
Data points from:
Jin, T., Yamada, T., “Irritating Effects on Fire Smoke on Visibility,” Fire Science and Technology, Vol. 5, No. 1, 1985.

Computing Cumulative Fractions of Successful Outcomes

- Given an alarm configuration (type and location of alarms)
  - For a given fire and egress scenario
    - Compute evacuation times (RSET) and tenability times (ASET) for incremented pre-movement times
    - Determine the pre-movement time where ASET<RSET (unsuccessful egress)
    - Compute the cumulative fraction of the frequency distribution where ASET≥RSET
  - Average the cumulative fractions over all egress scenarios and representative fire scenarios for the total fraction of successful egress outcomes
- Assess the performance of different alarm configurations by comparing the total fraction of successful egress outcomes



Egress Scenarios



Egress Scenario	Travel Path	Travel Segments	Travel Distance (m)
1	MBR – Exit	2	7.7
2	LR – Exit	1	8.9
3	BR – Exit	3	15.9
4	MBR – BR – Exit	7	35.5
5	BR – MBR – Exit	6	27.3
6	LR – BR – Exit	5	27.8
7	LR – MBR – Exit	4	20.3
8	LR – BR – MBR – Exit	8	39.2
9	LR – MBR – BR – Exit	9	48.1
10	MBR – LR – MBR – Exit	6	28
11	BR – LR – BR – Exit	7	34.8
12	MBR – BR – MBR – Exit	10	46.9
13	BR – MBR – BR – Exit	11	55.1

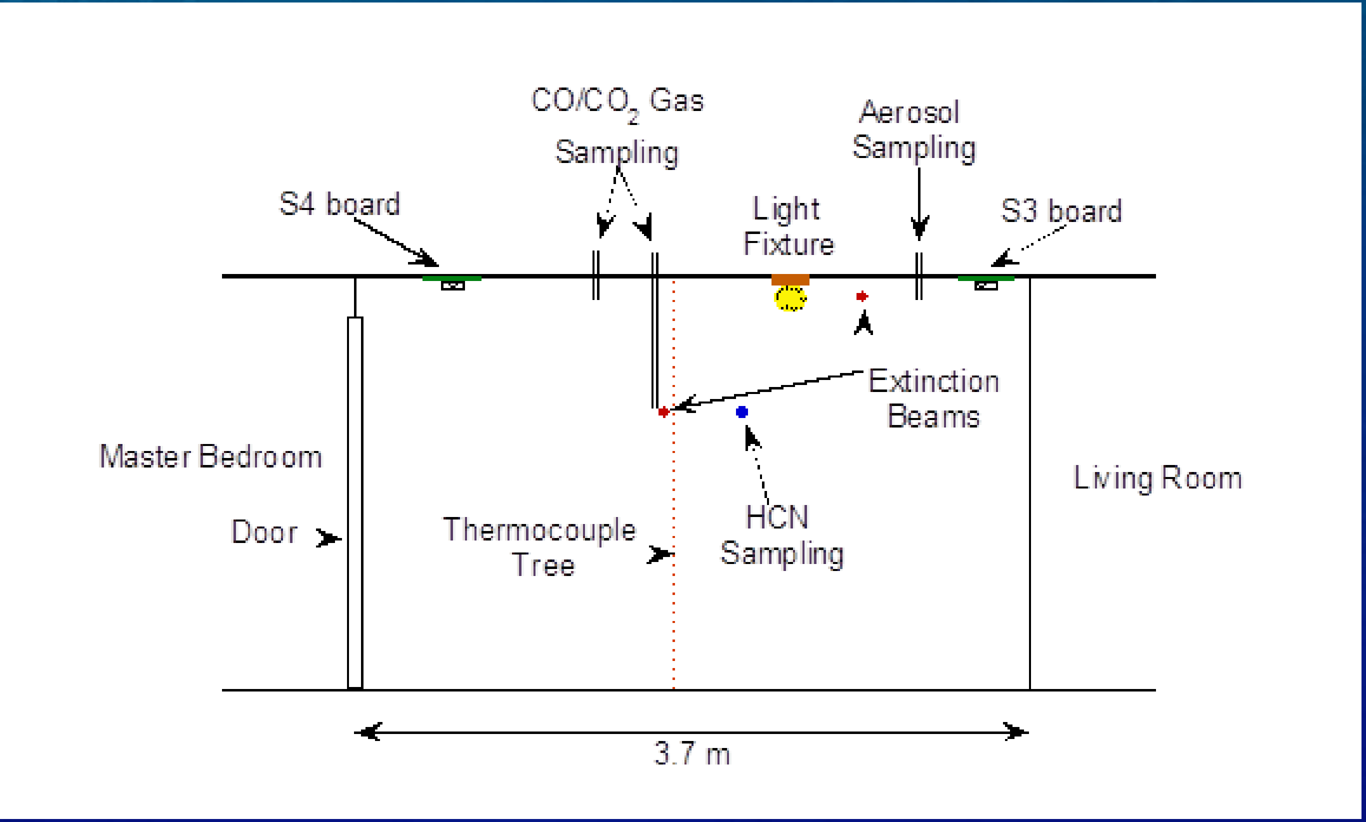
Objective of The Analysis for the Task Group

Estimate proposed alarm activation times and corresponding ceiling smoke obscurations for flaming and smoldering fire scenarios subject to ASET and RSET assumptions for a desired performance metric.

Performance Metric

A performance metric of 85 % successful escape attempts for all egress scenarios across all flaming or initially smoldering fires was chosen as a balance between over-specifying performance to an unobtainable goal and under-specifying performance and thus not providing enhanced available safe egress time.

Evaluation Location: Hallway between MB and Living Room



Fire Scenarios

- Smoldering ignition (9 experiments)
  - Fire in living room, low density foam (3x)
  - Fire in living room, high density foam (3x)
  - Fire in bedroom, low density foam (3x)
- Flaming ignition (9 experiments)
  - Fire in living room, cotton fabric (3x)
  - Fire in living room, polyester fabric (3x)
  - Fire in bedroom, polyester fabric (3x)

ASET and RSET Assumptions

- Perform calculations assuming two smoke optical density (OD) limits (at 5 ft height):
  - OD = 0.25 m^{-1} (NIST Dunes II study, low smoke concentration, conservative)
  - OD = 0.43 m^{-1} (NFPA 72 smoke alarm task group 2)
- Perform calculations assuming two lognormal pre-movement distributions:
  - 35 s median σ_g =1.6 (faster responding population)
  - 55 s median an σ_g =1.6 (slower responding population)

Task Group Calculations

- NIST conducted ASET/REST model calculations for the task group, and NIST is in the process of publishing results.
- Task group considered the calculations in regard to performance criteria for flaming and smoldering PU foam tests.

For the more vulnerable population and conservative 0.25 m^{-1} optical density limit, the ceiling obscuration value suggested by the smoldering scenarios significantly challenge ionization technology, and in the flaming fire scenarios significantly challenge photoelectric technology.

UL 217 Task Group Status

- At November task group meeting, a proposal was accepted to split the heretofore single flaming/smoldering proposal into two separate proposals: one for a flaming foam test and one for smoldering foam test for consideration by Standards Technical Panel (STP).
- Task group voted to proceed with the smoldering test proposal with a fixed performance criterion (~ 12 %/ft obs.)
- Task group voted to table the flaming test proposal, then voted to include the test with no fixed performance criterion.
- The test proposal is being submitted to the STP for comment and a mid-March STP meeting is scheduled.

- What does the future hold?

Observations Regarding New UL 217 PU Foam Fire Test Requirements

- The implementation of only a new smoldering test will not improve the detection capability for both smoldering and flaming fires.
- The implementation of only a new flaming test will not improve the detection capability for both smoldering and flaming fires.
- The implementation of both smoldering and flaming tests that require detector or alarm performance equivalent to that of a mix of current photoelectric and ionization alarms is consistent with the recommendations of many fire safety organizations.

Potential Impacts of a Smoldering Fire Test as Proposed with No Companion Flaming Fire Test

- A de facto ban on standalone ionization alarms with no additional challenge to existing photoelectric alarms will not provide a technology-neutral performance basis.
- NFPA 72 SIG HOU will most-likely have to revisit dual photoelectric/ionization alarms as a requirement internally and through proposals.
- State and local jurisdictions are likely to consider dual photoelectric/ionization alarm mandates where they feel flaming fires are the primary hazard or at least of equal concern to smoldering fires.

Potential Impacts of a Smoldering Fire Test as Proposed with no Companion Flaming Fire Test Cont.

- Fire safety organizations that recommend a mix of photoelectric and ionization alarms or dual alarms will have to modify their messaging to a recommendation of dual alarms only.
- Given the lack of a robust flaming fire test (the current flaming fire test does not sufficiently challenge photoelectric technology) the most probable outcome of nuisance source test(s) is likely a reduction in the sensitivity setting of photoelectric alarms, further reducing their sensitivity to flaming fires.

Quote from John Hall's INTERFLAM 2010 Paper

"Making the Biggest Difference: Selecting Priorities for Fire Safety Science and Engineering"

The vigorous debate that typically surrounds any major strategy will include claims and counterclaims about impact. If you have some influence on the decision to go ahead or not go ahead with a major strategy, then you will want to be alert to certain types of inaccuracies that often surface in claims from supporters or opponents: …

<u>The product is effective but no more effective than the alternative</u>. A new product may have different strengths and weaknesses but not be more effective overall. For example, ionization and photoelectric smoke alarms are both effective on most types of fires, and the fires where there performance differs most account for roughly equal shares of home fire deaths. A strategy that chooses one over the other cannot produce a large benefit for these reasons, but a strategy that encourages or requires use of both may be able to improve performance.

Thank you for your attention