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Full-scale experiments to investigate a smoldering sofa fire incident Lougheed, G. D.

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Full-scale Experiments to Investigate a Smoldering Sofa Fire Incident

G.D. Lougheed
Fire Research Program
National Research Council



National Research
Council Canada

Conseil national
de recherches Canada

Canada 

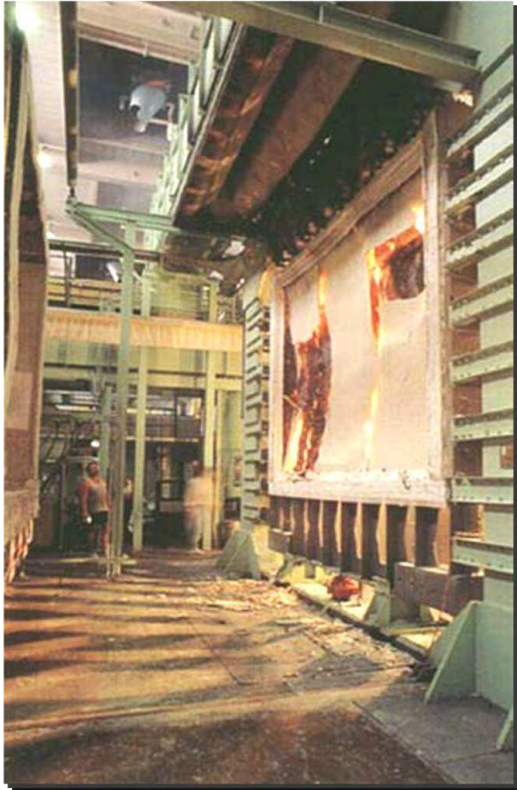
Outline

- Fire Research Program
- Fire Investigation
- Background
 - Fire incident;
 - Cause of fire;
 - Research project.
- Room scale experiments
- Full-scale experiments

Fire Research Program



Fire Resistance



Fire Resistance



Materials



Spatial Separations



Suppression



Smoke Movement and Management



Human Behavior in Fire



Fire Investigation

- Human Behavior
 - World Trade Center;
 - Cook County.
- Submarine Fire
 - Fire characteristics of selected materials;
 - Smoke exposures.

Fire Investigation

- Heritage Building
 - Effect of aging on fire characteristics of materials
 - Input data for models
 - Simulate possible ignition scenario
 - Model fire development
 - Impact of detection system

Fire Investigation

- Material evaluation;
- Input data for models;
- Small- and Full-scale tests to simulate scenarios.

Fire Incident



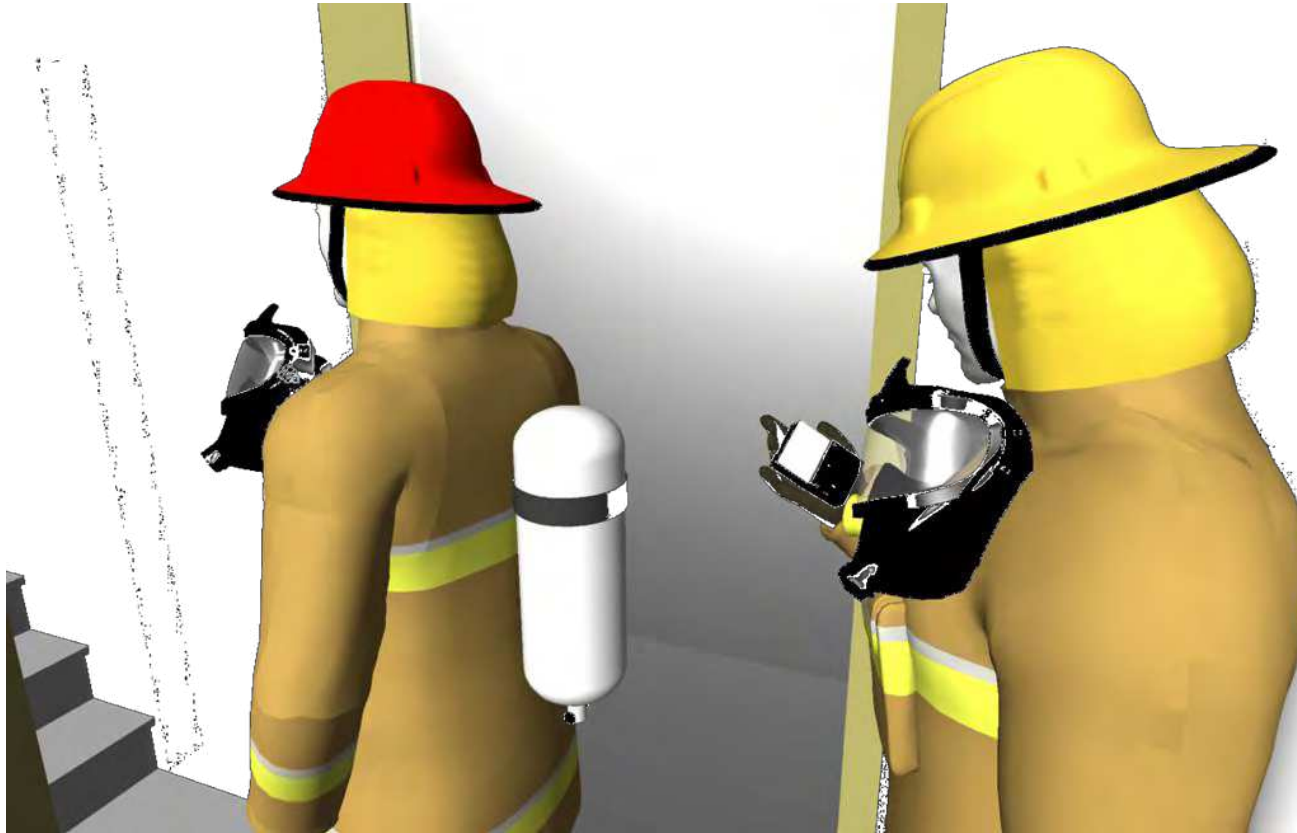
At approximately 3:27 a.m. on January 21, 2006, the Montreal Fire Department dispatched two engines in response to a 9-1-1 call complaining of a strong odor.

Fire Incident



Upon arrival, the firefighters found a number of occupants outside of the three story apartment building. The occupants complained that the odor had been present for approximately 24 h.

Fire Incident



The crew from the first arriving unit entered the building and noticed a strong chemical odor that was not typical of a Class A, Class B or Class C fire. Initially, no smoke was observed and negative results were obtained using a gas detector.

Fire Incident



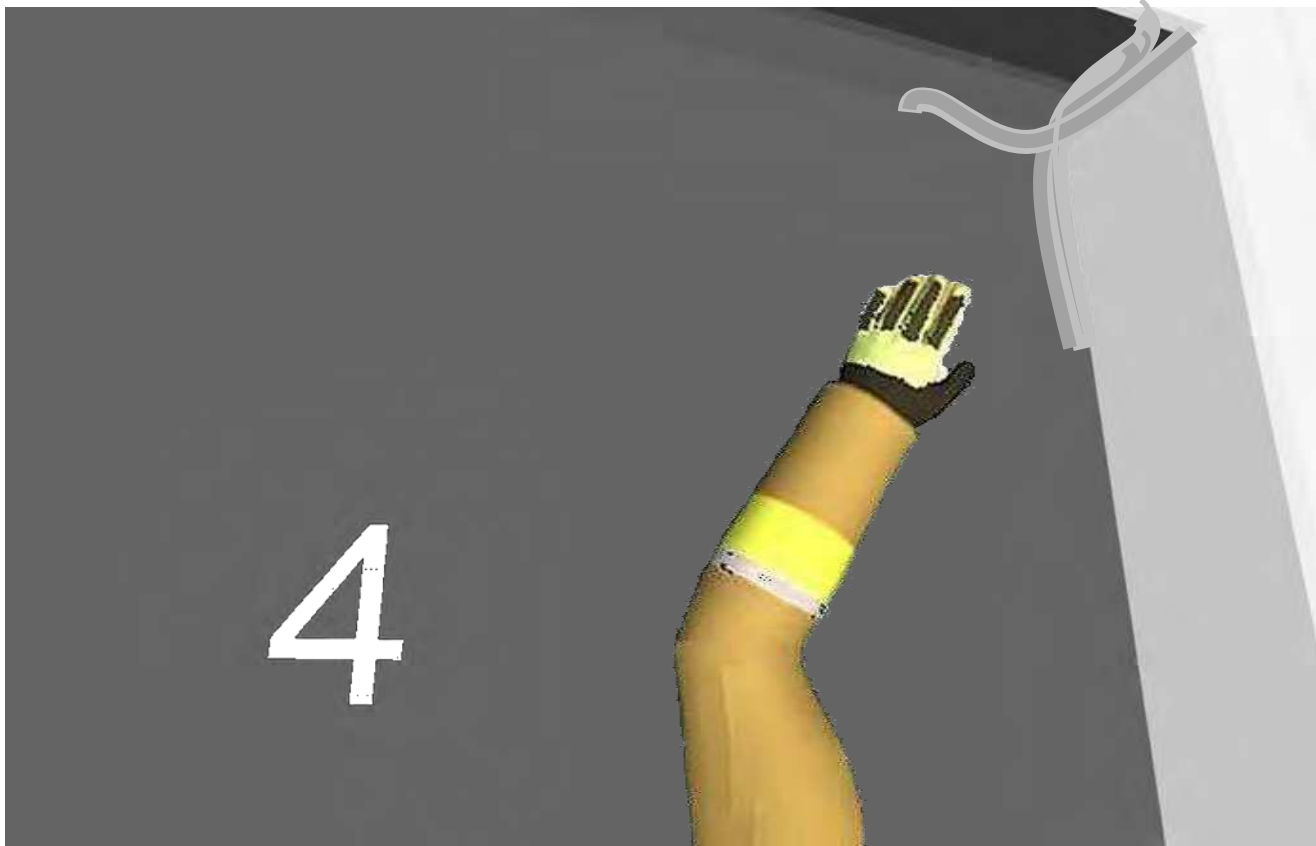
The remaining occupants were asked to vacate the building.

Fire Incident



After the second crew arrived, the building was searched. Nothing was found until the two crews met back on the landing on the first floor. A firefighter noticed white puffs of smoke coming from the light fixture in the landing.

Fire Incident



Pushing on the top of the door to apartment #4 resulted in smoke escaping from the apartment. It was later determined that the occupants of this apartment had been away on vacation for 2 weeks.

Fire Incident



The apartment door was forced open releasing a large cloud of smoke into the stairwell. This smoke engulfed a firefighter on the second floor landing forcing him to enter an apartment to get fresh air on a balcony.

The firefighters entered the apartment on the first floor to search for occupants. Windows and doors in all rooms were opened to ventilate the apartment.

Fire Incident

During ventilation, a smoldering sofa was found.

The firefighters decided to open the window in the room and toss the cushions and sofa out the window.



Fire Incident

Upon moving the sofa, it evolved into a flaming fire, which ignited the curtains on the window and the smokey layer at the ceiling.

Two firefighters in the room escaped. However, a captain was overcome by the flash fire and died.



Cause of Fire



- The fire investigation concluded the fire was caused by a faulty baseboard heater from which the safety systems had been removed.
- The heater was in close contact with a Moroccan style sofa that consisted of a 1650 mm long, 395 mm high and 700 mm deep piece of polyurethane foam covered with a cotton textile material.
- The foam seat was mounted on a 89 mm high wood frame covered with the same textile material.

Research Project

- The Montreal Fire Department requested that NRC undertake a project to investigate the fire incident to determine:
 - Causes of the fire;
 - The composition of the smoldering combustion products;
 - The flame spread in the combustion products;
 - The effects of standard and alternative firefighting tactics.

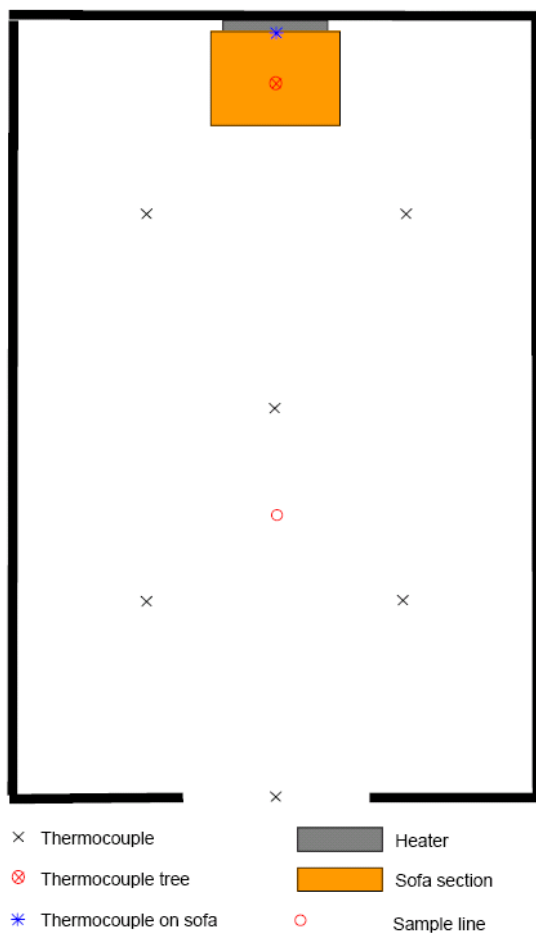
Previous Research

- Stored Foam Rubber Mattresses
 - UK 1974
 - Explosion with 2 deaths
 - BRE Study
 - Smoke produced by smoldering was flammable
 - Could produce explosion if collected in enclosed space

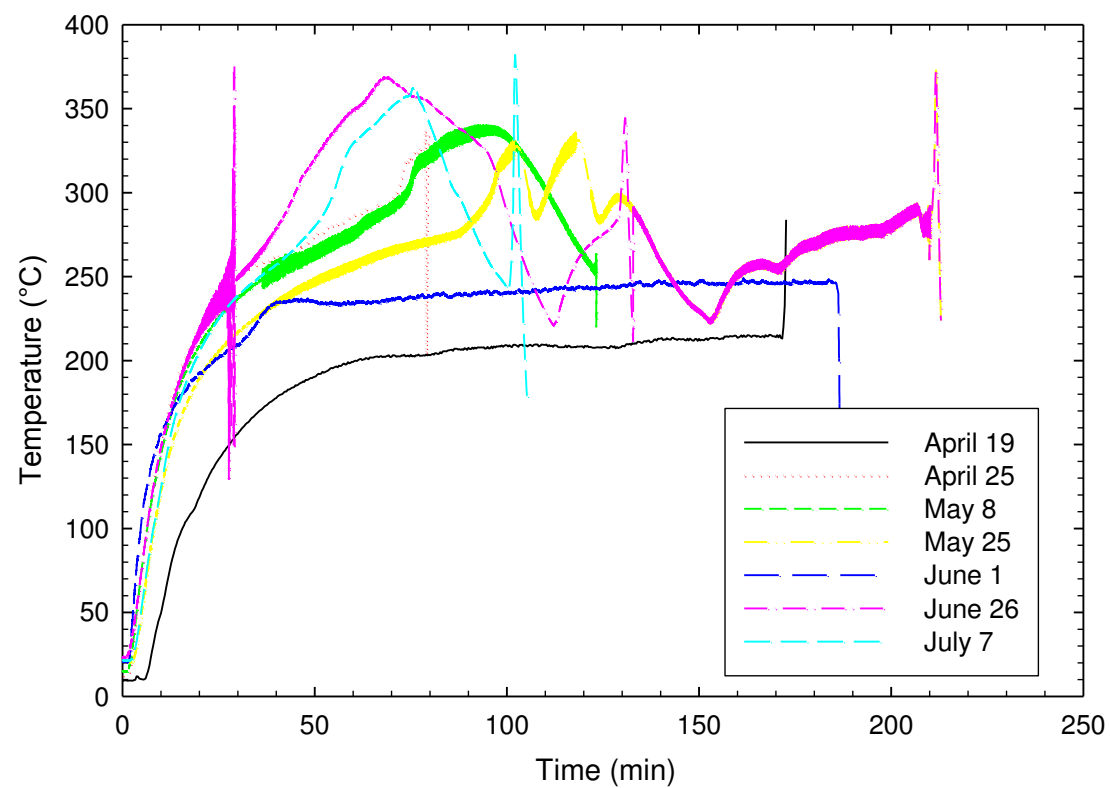
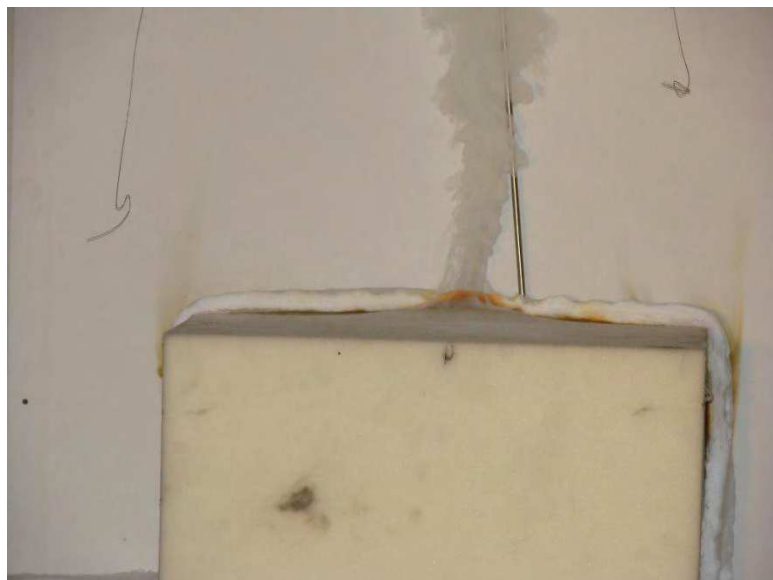
Previous Research

- Sutherland University of Canterbury, NZ
 - Smoldering fires with wood cribs with reduced oxygen could produce flammable smoke;
 - Rapidly developing fires or explosions.
- Fire Incidents
 - Basement fire in Illinois with 2 firefighters killed;
 - Similar situations in UK 2004 and Paris 2006

Room Scale Experiments - Setup



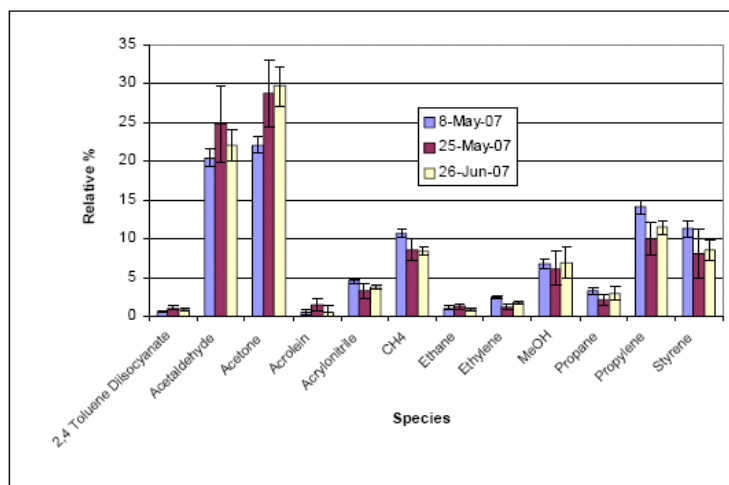
Foam Temperature



Smoke Production

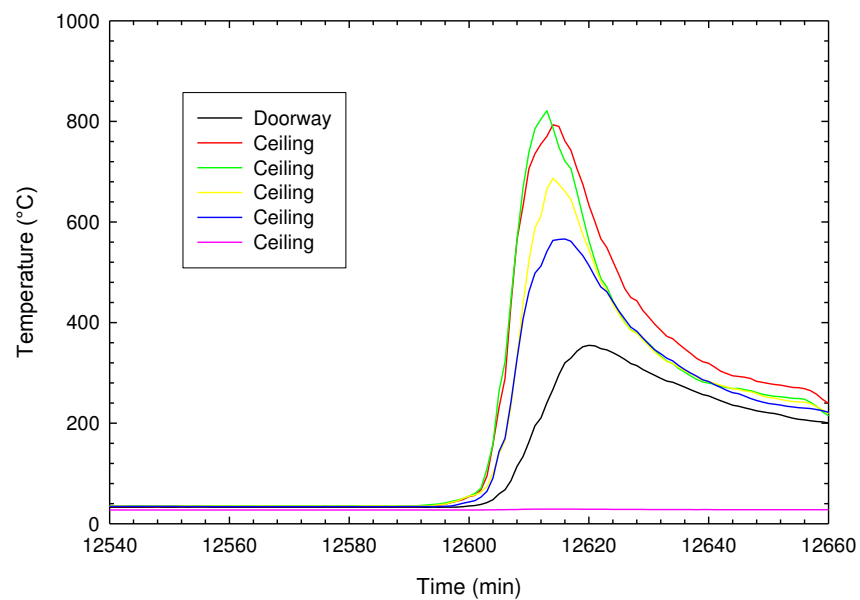


Gas Analysis

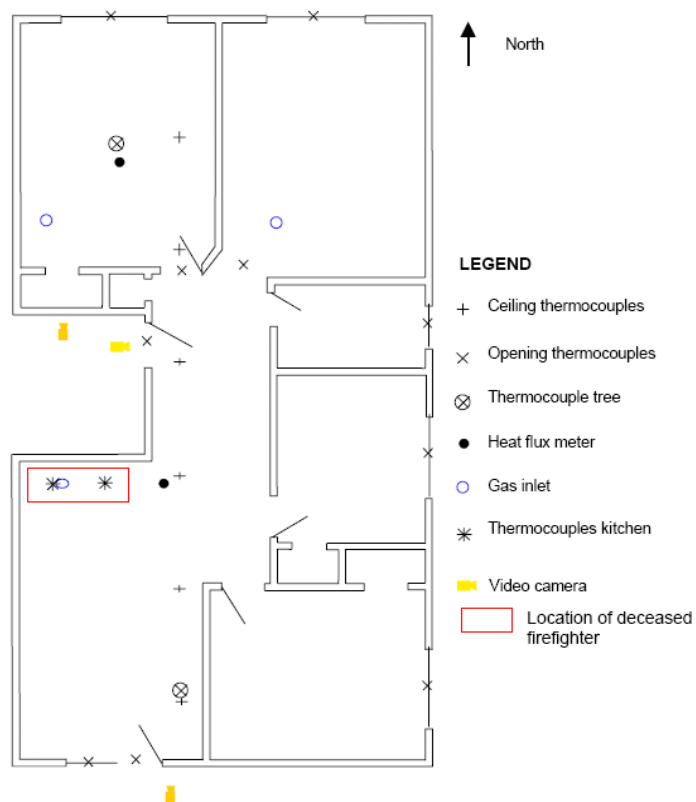


- Multi gas FTIR spectrometer used to determine main components in smoke.
- Lower flammability limit estimated to be 2.6 volume % of air.
- Color and odor consistent with that observed by firefighters.
- Odor most likely due to acetaldehyde and toluene-diisocyanate. Both produce a pungent acrid fruity odor.

Fire Development



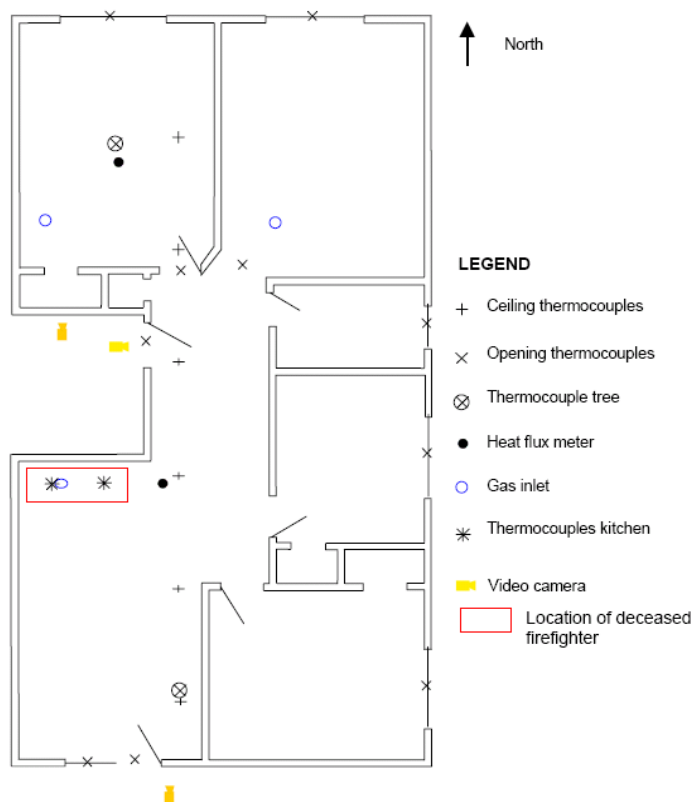
Full Scale Experiments



Fire Scenario

- Room scale experiments indicated difficult to produce a flammable gas mixture at the ceiling of the test facility.
 - Factors such as leakage areas, temperature conditions in apartment.
 - Length of smolder time could not be duplicate.
- Preliminary tests conducted to develop scenario for use in full-scale experiments.

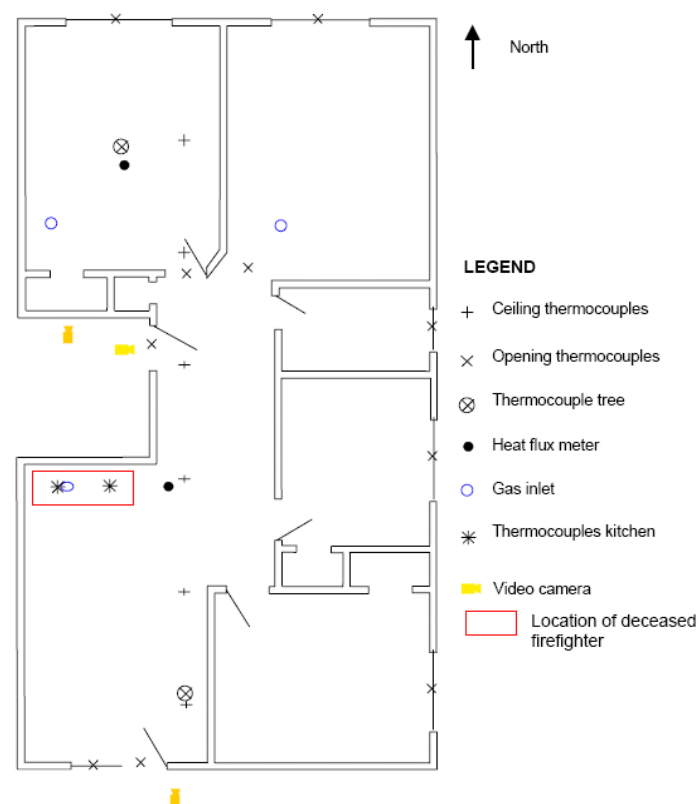
Fire Scenario - Smoldering Fire



Fire Scenario – Flammable Gas



Gary_Nov_27.mpg



Fire Scenario

- Scenario for full-scale experiments:
 - Sofa allowed to smolder for approximately two hours.
 - Methane used to produce upper flammable layer.
 - Methane layer and sofa ignited using a heated coils.
- Three experiments:
 - Test 1 – Methane ignited in room of fire origin + single sofa;
 - Test 2 – Single sofa fire;
 - Test 3 – Methane ignited in room of fire origin and propagated into entryway/kitchen + 4 sofas ignited.

Sofas in Fire Compartment



Test 1 and Test 2



Test 3

Video of Ignition Sequence

- Sofa and flammable gas in room



Gary_Dec_7.mpg

- Flammable gas ignition – room view



Gary_Dec_18_Room.mpg

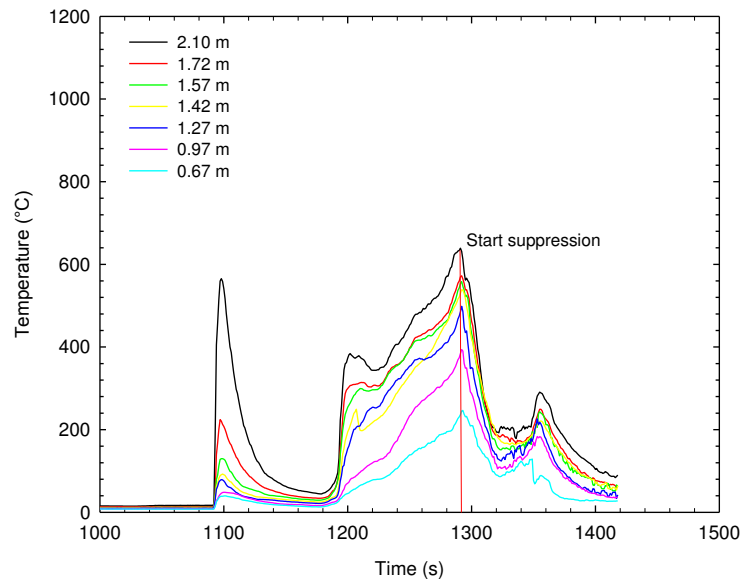
- Flammable gas ignition – long view



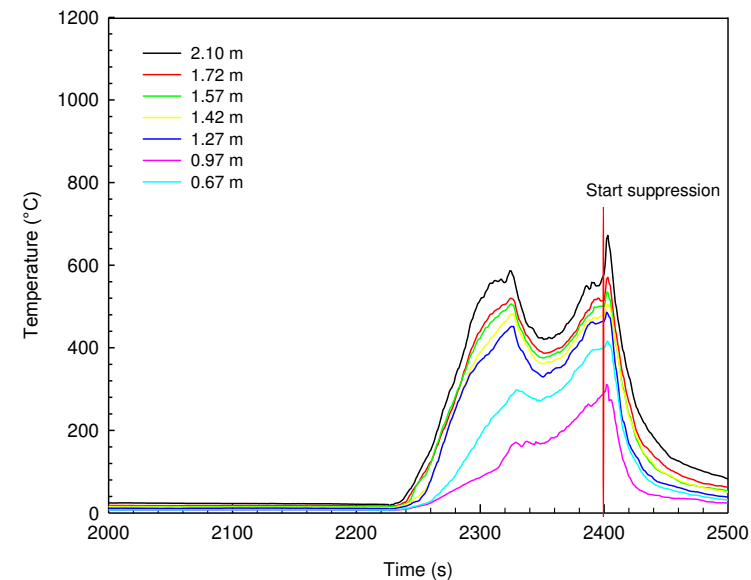
Gary_Dec_18_LongView.mpg

Temperatures - Fire Compartment

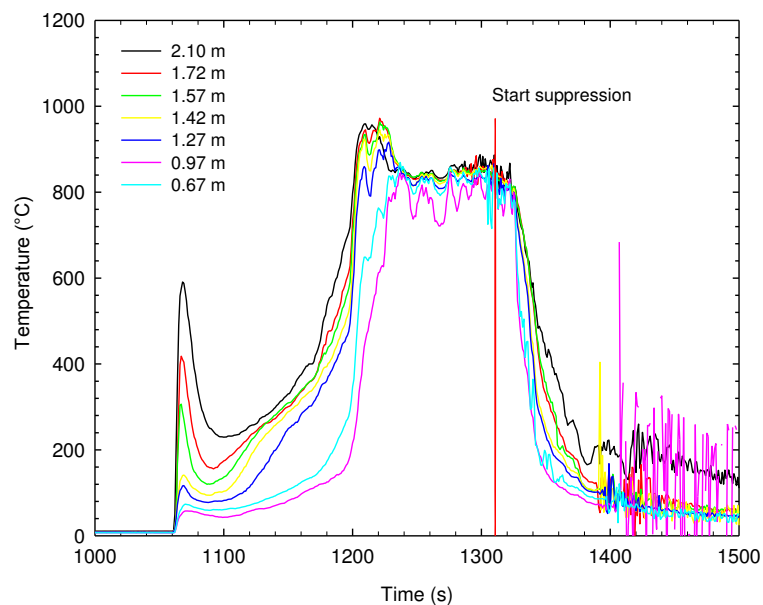
Test 1



Test 2

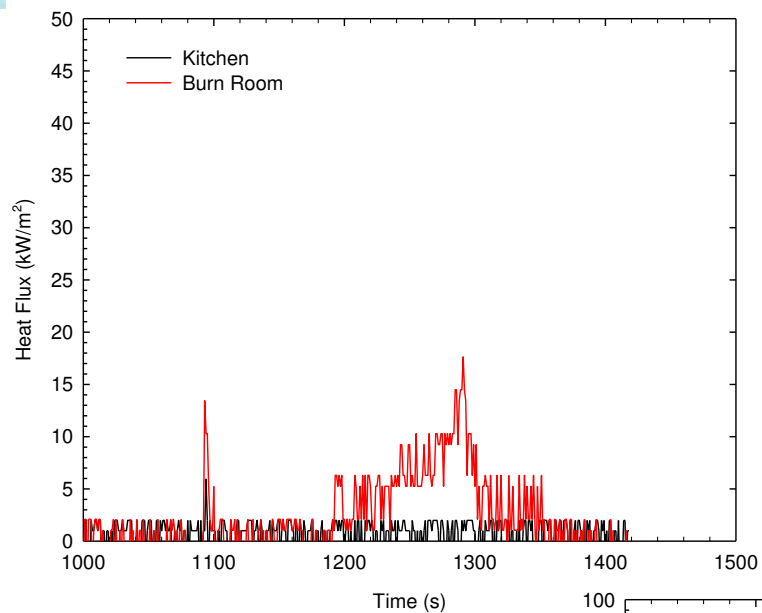


Test 3

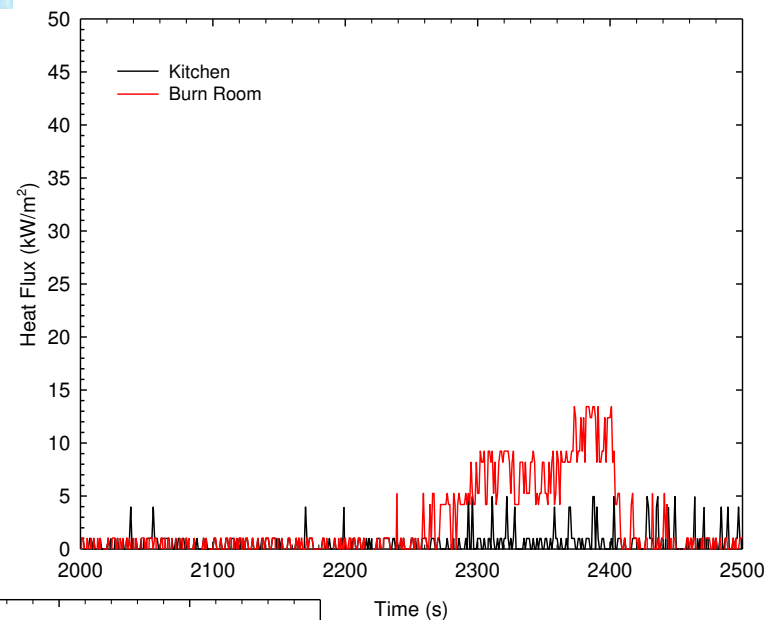


Heat Flux

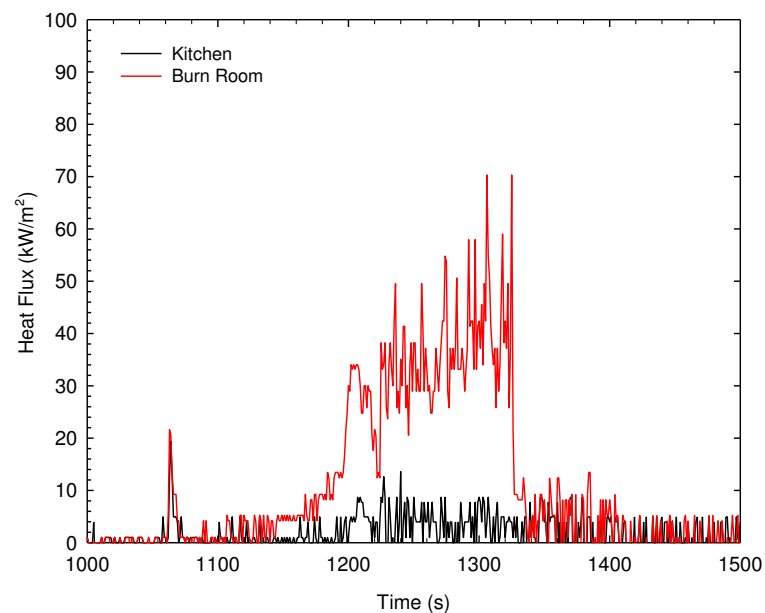
Test 1



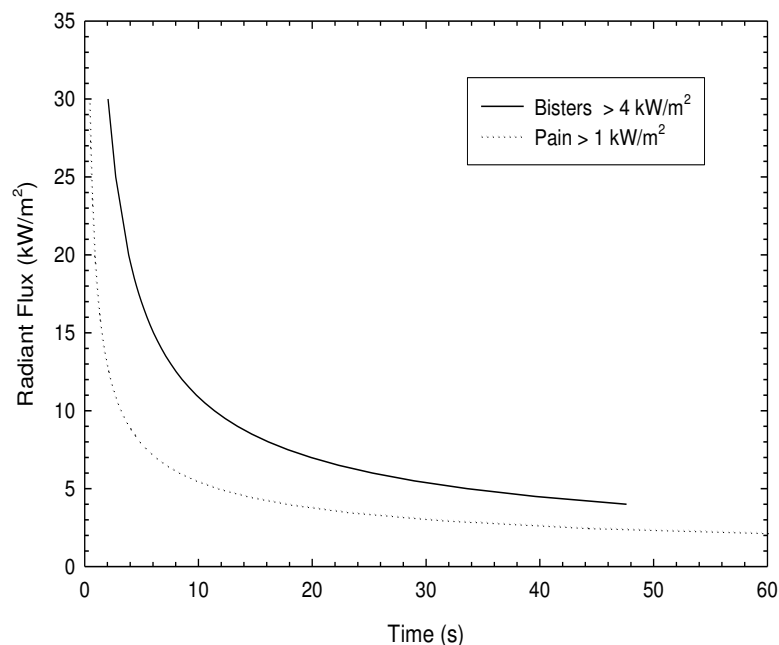
Test 2



Test 3



Effects of Exposures



- Effect of radiant exposure on bare skin

$$t_{\text{rad}} = 6.9q^{-1.56}$$

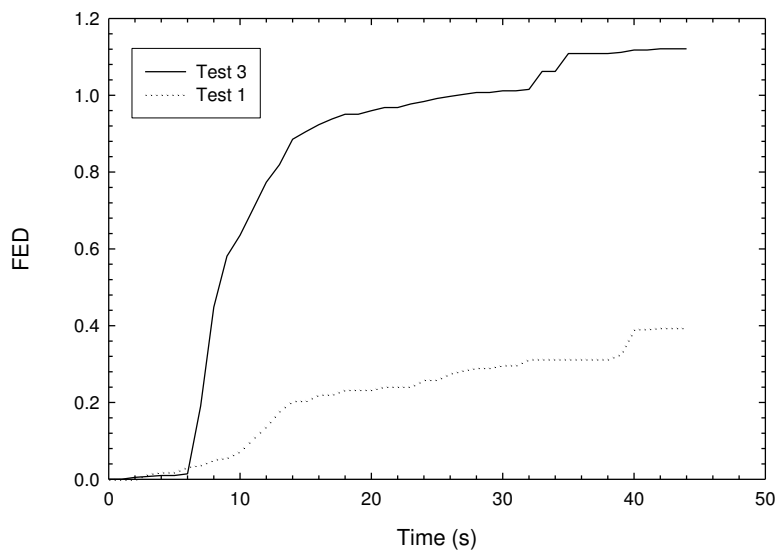
- Effect of temperature

$$t_{\text{conv}} = 5 \times 10^7 T^{-3.4}$$

- Fractional effective dosage

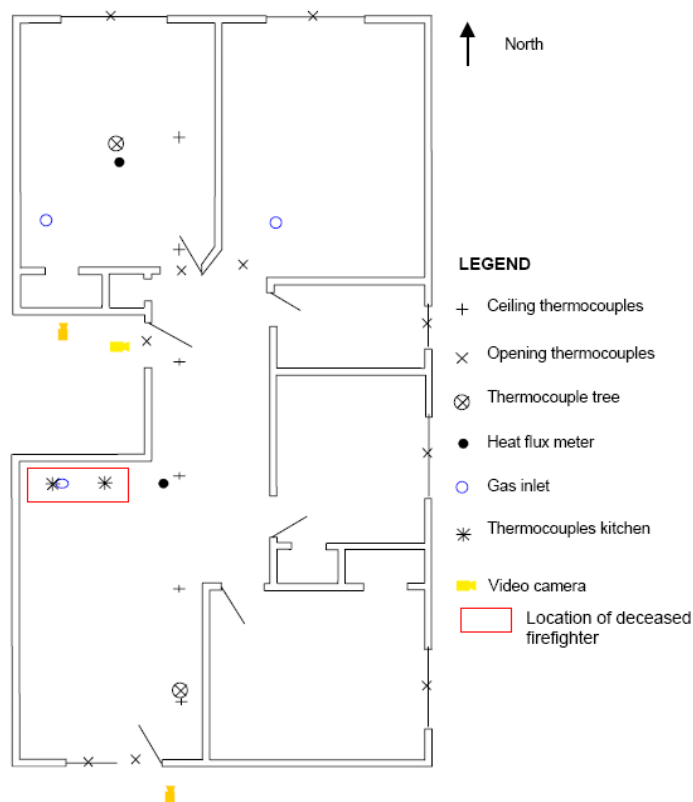
$$\text{FED} = \sum_{t_1}^{t_2} \left(\frac{1}{t_{\text{rad}}} + \frac{1}{t_{\text{conv}}} \right) \Delta t$$

Effects of Exposures



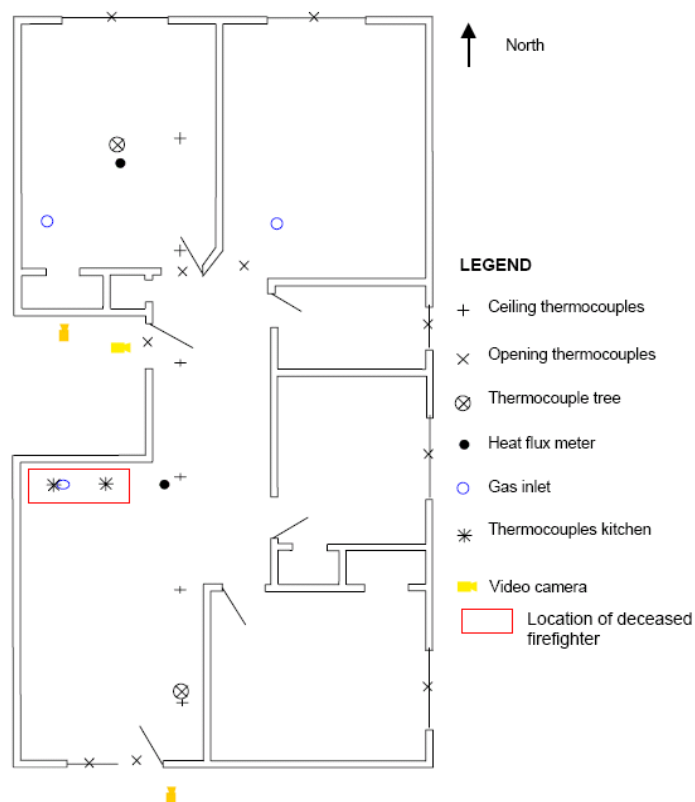
- Average heat flux measured in fire compartment and entryway.
- Average temperature at 1.57 m height measured in fire compartment and kitchen.

Effect on Captain



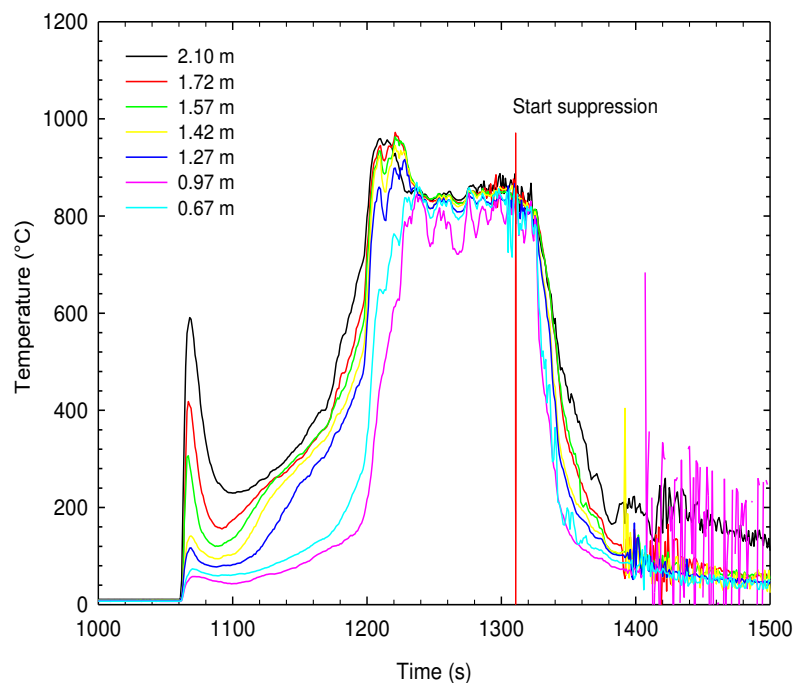
- Captain last seen in entryway.
- Looking back at flames entering area through doorway to room of fire origin.
- Not wearing SCBA mask.
- Effect of exposure on face.
- Effect of flash on vision.

Suppression



- Firefighters suppressed fire for each test.
- Test 1 – Solid stream applied water intermittently on ceiling and upper part of walls.
- Test 2 - Fog stream with 30° angle water on ceiling and upper part of walls.
- Test 3 – A solid stream used to apply water on sofas.

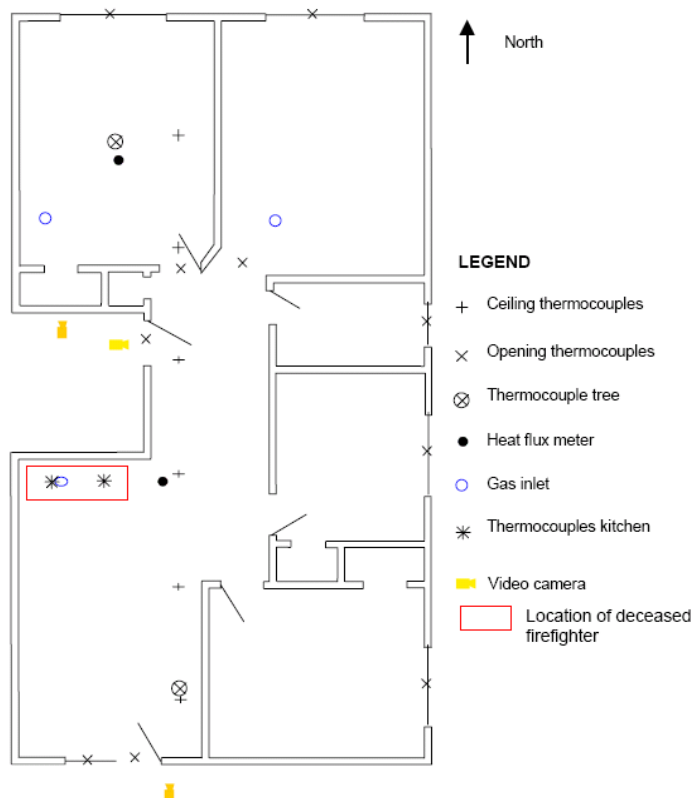
Results Suppression



Test 3

- Temperatures in room of fire origin reduced to < 200 °C in < 60 s.
- Temperatures reduced to < 100 °C in < 100 s.
- Fire in room of origin could be achieved swiftly and safely by applying water from main entrance door to apartment.

Experiment 4



- First 3 experiments focused on early stage of fire.
- Fourth and fifth experiments conducted to investigate conditions in kitchen with extended fire.

Fire Compartment and Kitchen



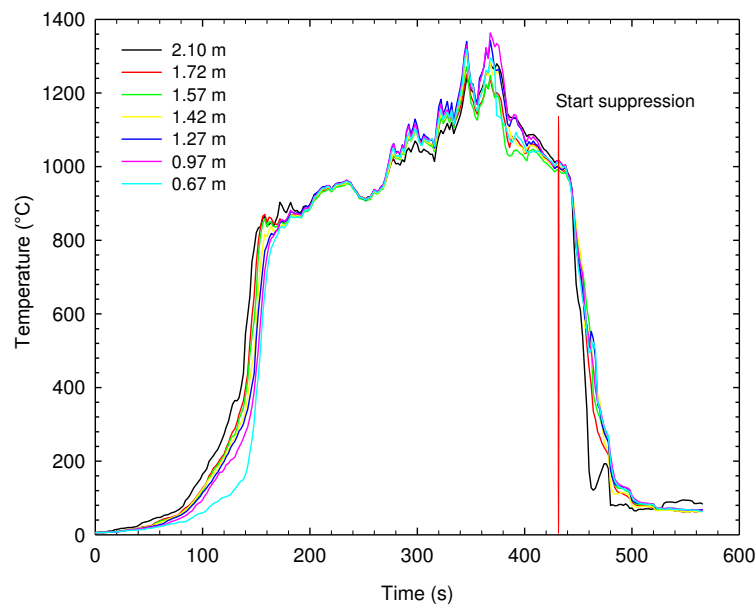
Living Room and Bedrooms



Results Experiment 4

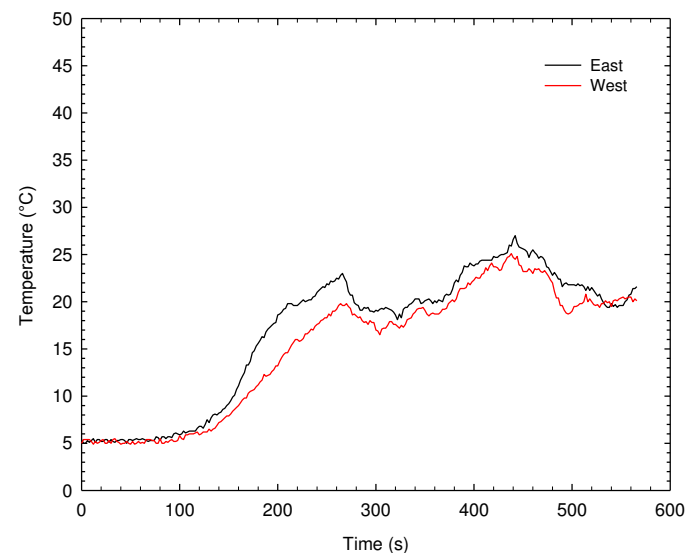
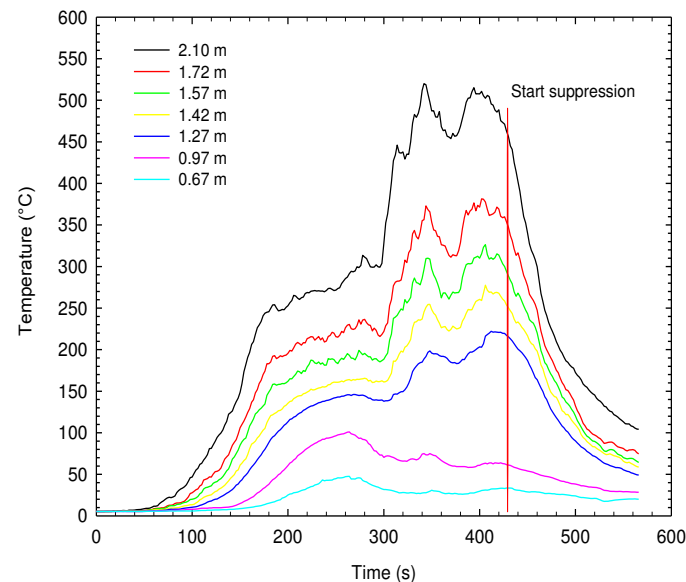
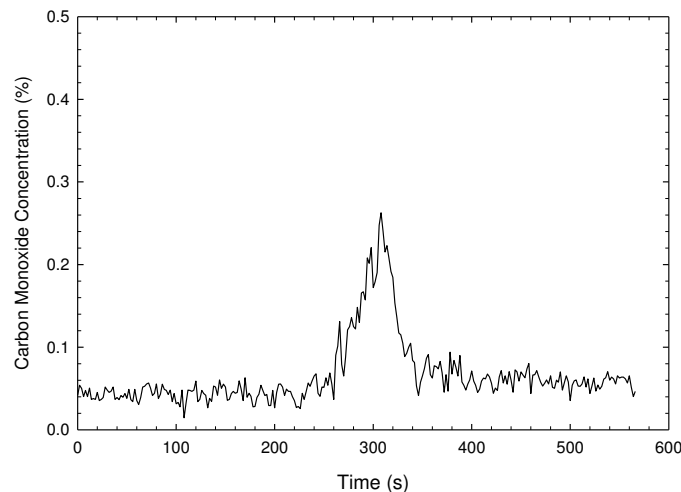


- Propane T-burner used to ignite foam.
- Rapid fire growth.
- Initial temperatures approximately 900 C.
- Increased temperatures in later stages.



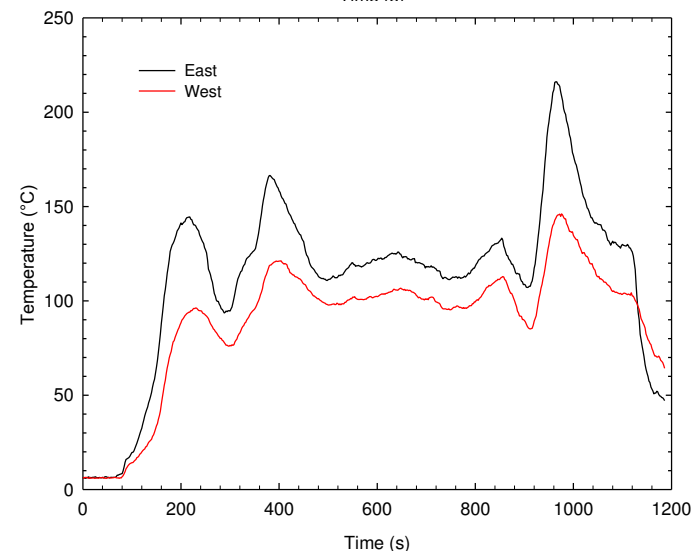
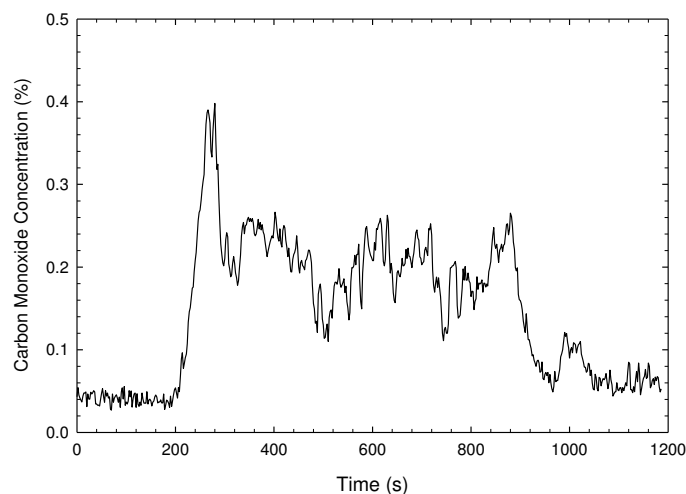
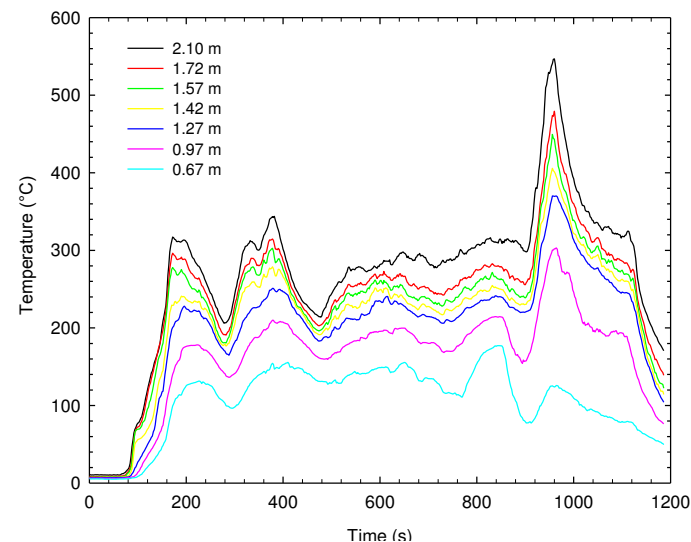
Results Experiment 4

- Fire did not propagate into entryway.
- Maximum temperatures in kitchen approximately 500 °C.
- Minimal temperature and CO increase at floor level.



Experiment 5

- Single sofa in fire compartment. Same fuel load as experiment 4 in all other rooms.
- Sofa entryway sprayed with accelerant and ignited with propane torch. Sofa fire compartment ignited with propane burner.



Results Experiments 4 and 5

- In Test 4, a fully-developed fire was produced in the room of fire origin. Minimal temperature increase or CO measured at floor level in kitchen.
- In Test 5, sofa fire in entryway produced increased temperature and CO levels at floor level in kitchen.
- Effects of fire would increase with flashover in kitchen.
- Conservative estimate of time for this to occur is 180 – 210 s after ignition of sofa in room of fire origin.

Conclusions

- Research project investigated possible scenarios for fire incident.
- Experiments with combined flammable gas and sofa fire resulted in initial flames through doorway into entryway in <10 s.
- A fully-developed fire in room of fire origin would have limited effects on conditions at floor level in kitchen.

Conclusions

- Fire in entryway could lead to conditions at floor level that were untenable.
- Results indicate that a person in kitchen may have been able to survive until kitchen reached flashover.
- Limited water was used in suppression tests with objective of rapidly lowering tests. In all tests, temperature in fire compartment reduce to $< 100\text{ C}$ in $< 100\text{ s}$.

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