Impact of Convective Heat on Firefighter Turnout Gear

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About Myself

Hometown - Broomall Pennsylvania

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Advisor and Group

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Division – Fire Research Division

Group – Fire Fighting Technology

Project Background

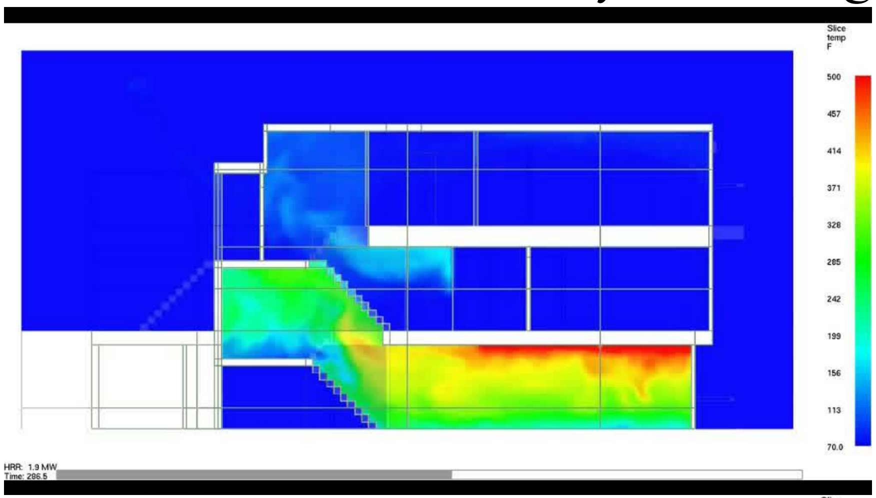
Firefighters perform their duties in an inherently dangerous environment

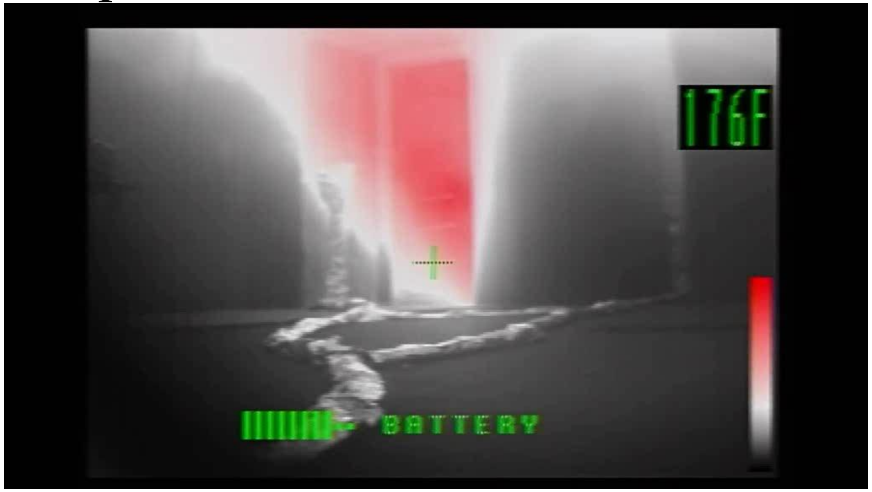
There are many situations that their gear needs to be able to handle

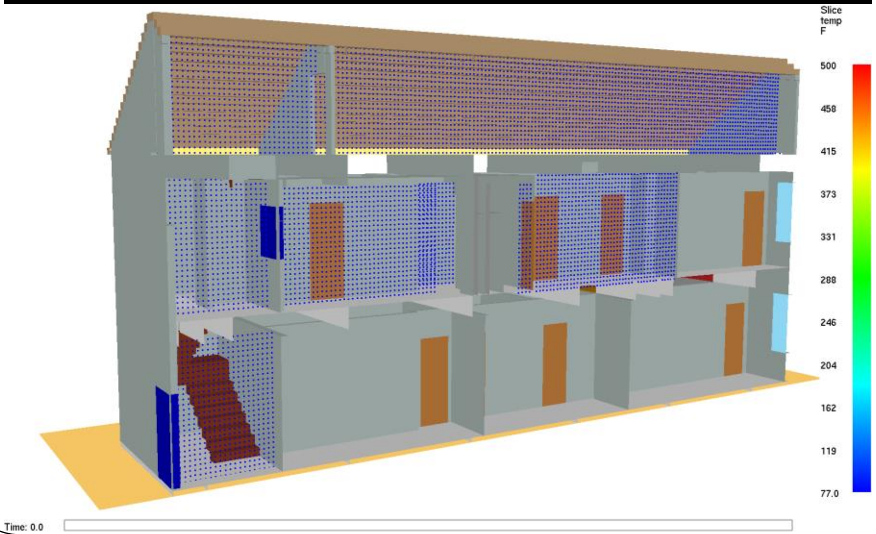
Project Goals

Determine impact of convective heat on turnout gear

Determine a suitable way of testing this impact







Turnout Gear Basics

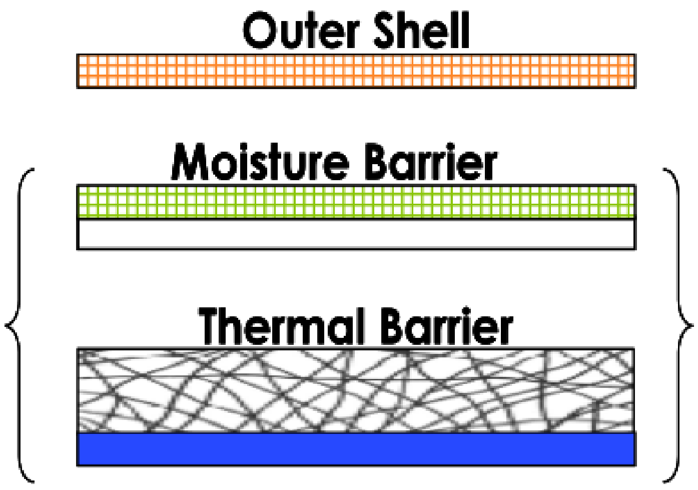
There are several components that go into the firefighter’s full ensemble

http://www.fireapparatusmagazine.com/articles/print/volume-14/issue-8/features/ppe-manufacturers-solicit-design-ideas-from-firefighters.html

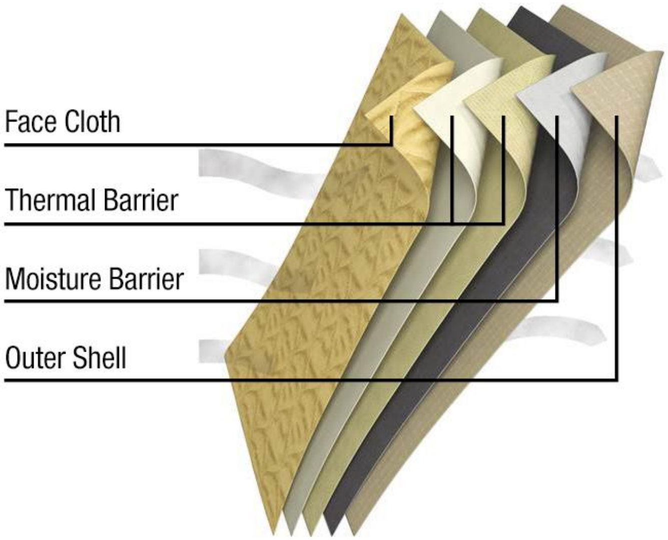
Turnout Gear Contd.

The project herein focused on the jacket and pants

Comprised of three basic layers



http://ithappenedinseconds.org/personal-protective-equipment/



http://www.prweb.com/releases/dupont_protection_tech/LION_turnout_gear/prweb10362363.htm

Current Standard

NFPA 1971: Standard On Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting

https://twitter.com/NFPA

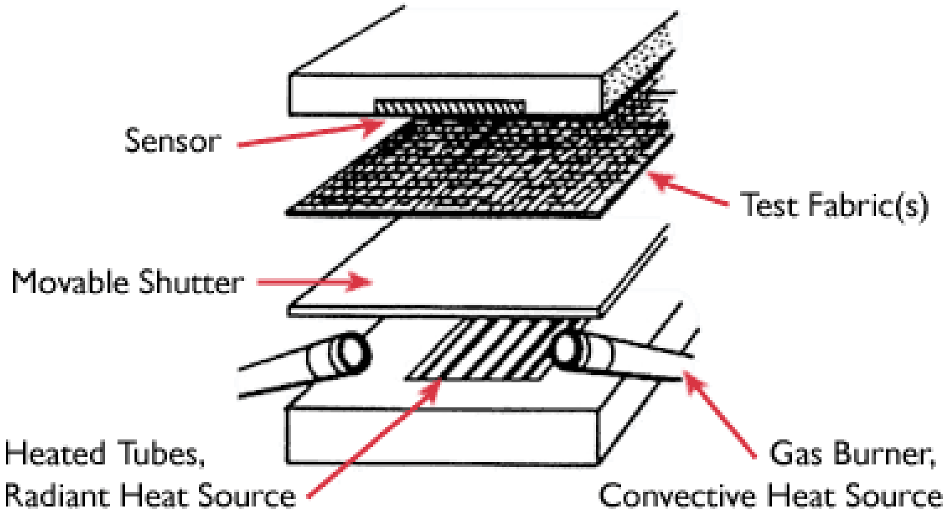
Thermal Protective Performance Test (TPP)

Only standardized test to calculate the time for heat to transfer through the layers of turnout gear.

Apparatus used creates both radiative and convective heat.

Exposure Heat Flux of 2 cal/cm² (84 kW/m²)

Measured by a copper calorimeter



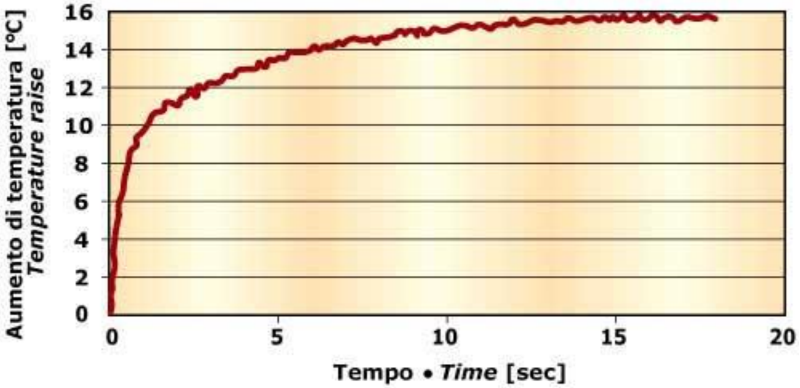
http://www.globeturnoutgear.com/resources/nfpa-test-methods/thermal-protection-performance-tpp

http://www.tx.ncsu.edu/tpacc/heat-and-flame-protection/thermal-protective-performance.cfm

TPP Test and the Fire Service

Exposure Time (s)	Heat Flux kW/m²	Total Heat kJ/m²	ΔT °C
1	50	50	8.9
2	31	61	10.8
3	23	69	12.2

*Stoll Curve



TPP number comes from the predicted time to 2nd degree burn and is multiplied by the heat exposure (2 cal/cm²)

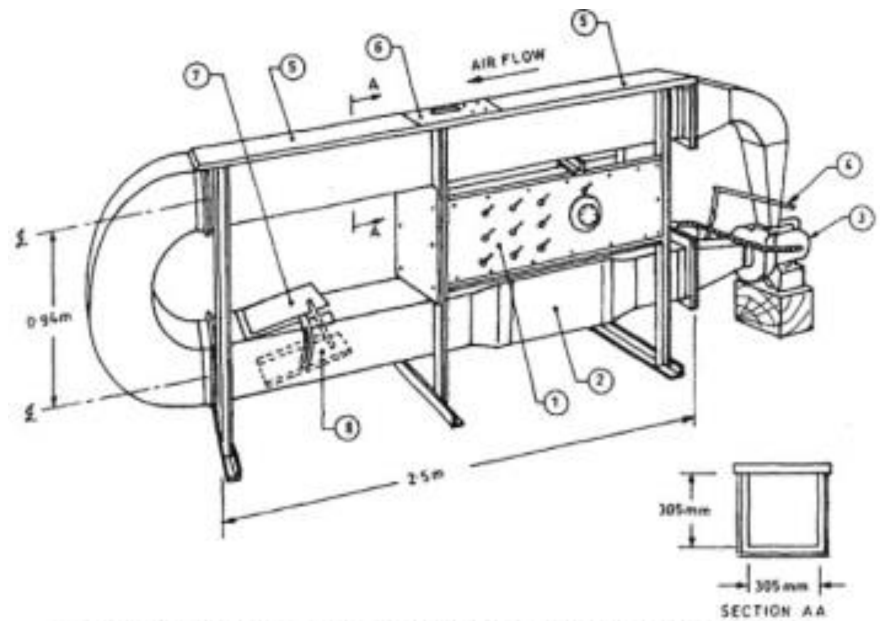
Minimum TPP number for NFPA compliant coats and pants is 35. So the coat and pants at a minimum must provide 17.5 seconds of protection from 2nd degree burns.

*http://www.esps.ca/data/1/rec_docs/102_Oberon_WP_Understanding_the_Stoll_Curve.pdf

Plunge Test

Used to test response time of sprinkler heads that are subjected to a ceiling jet. And to find the Response Time Index (RTI) of the sprinkler head.

$$\text{RTI} = \tau \times \sqrt{v}$$



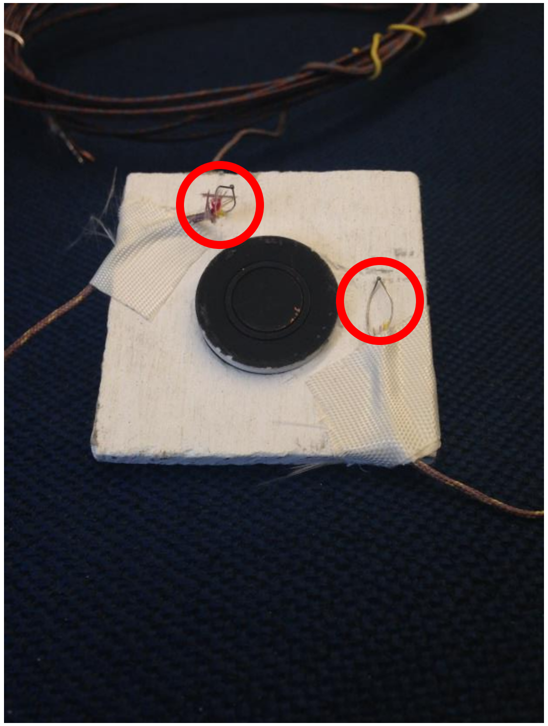
1. Control panel with nine switches for coarse control and autotransformer for fine control of heaters in 2.
2. Heater compartment with ten 1 kW heater elements.
3. 74.6 W 2 850 rev/min motor blower.
4. Manual control for shutter controlling air flow.
5. Removalable asbestos sheet covers.
6. Cover of sprinkler test compartment with glass inspection window.
7. Exhaust port.
8. Inlet port coupled to exhaust port to facilitate rapid cooling.

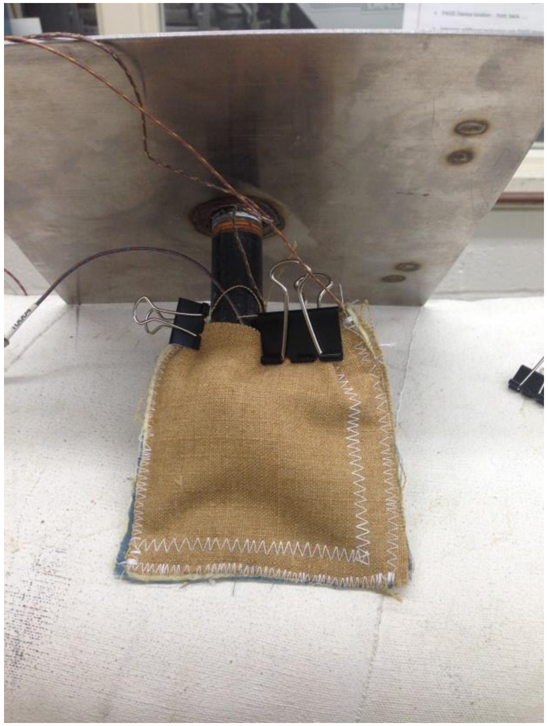
Testing

Baseline Tests were performed

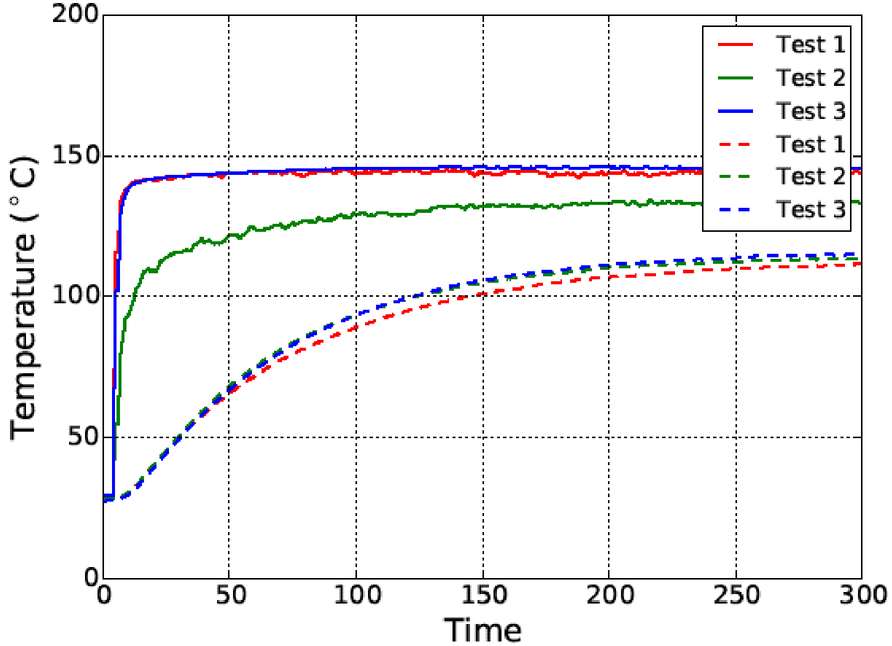
Mock gear sample tests with a copper calorimeter were performed

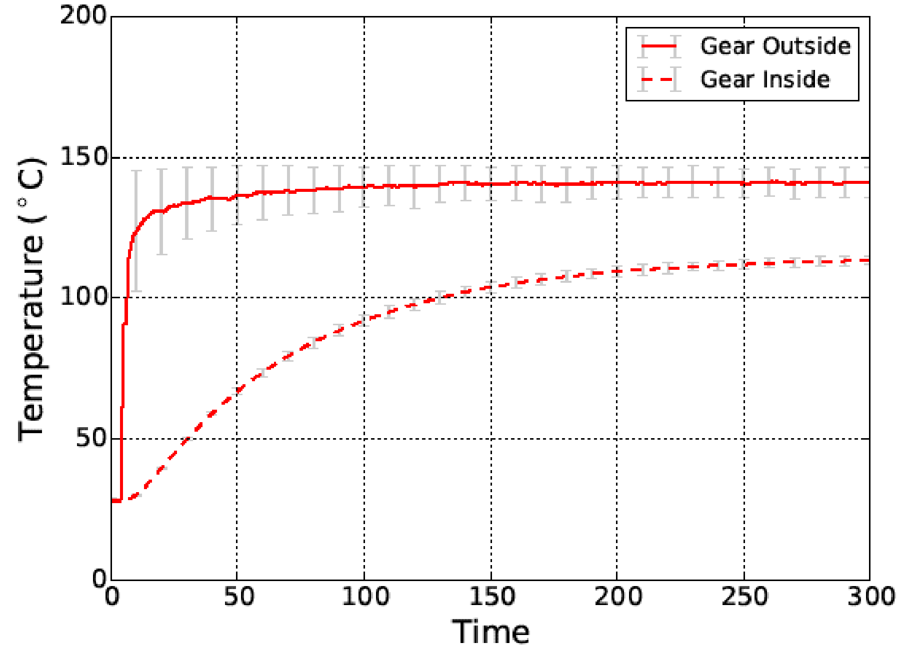
Mock gear samples without a copper calorimeter were performed

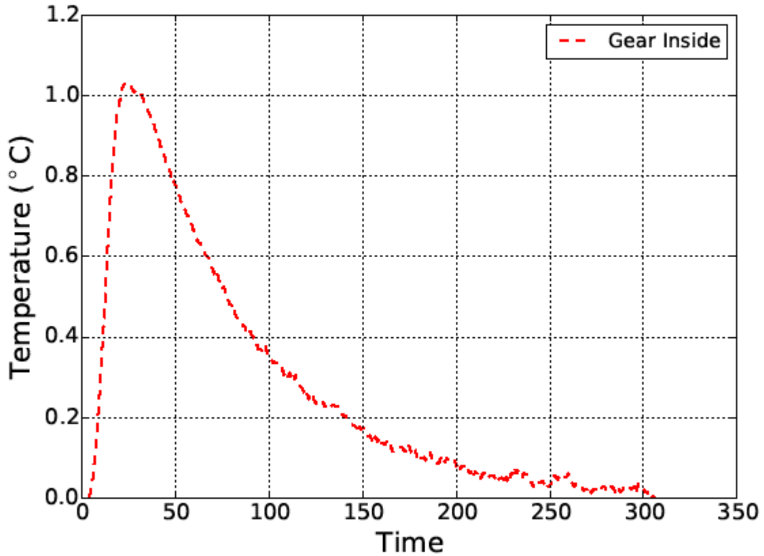




Results


Temperature (°C)
Time
Test 1
Test 2
Test 3
Test 1
Test 2
Test 3
0
50
100
150
200
0
50
100
150
200
250
300


Temperature (°C)
Time
Gear Outside
Gear Inside
0
50
100
150
200
0
50
100
150
200
250
300


Temperature (°C)
Time
Gear Inside
0.0
0.2
0.4
0.6
0.8
1.0
1.2
0
50
100
150
200
250
300
350

Analysis

Lumped capacitance model for convective heat transfer

$$hA\left(T_{gas} - T_{initial}\right) = \mathrm{m}c\ \left(\frac{dT}{dt}\right)$$

Solution for differential equation

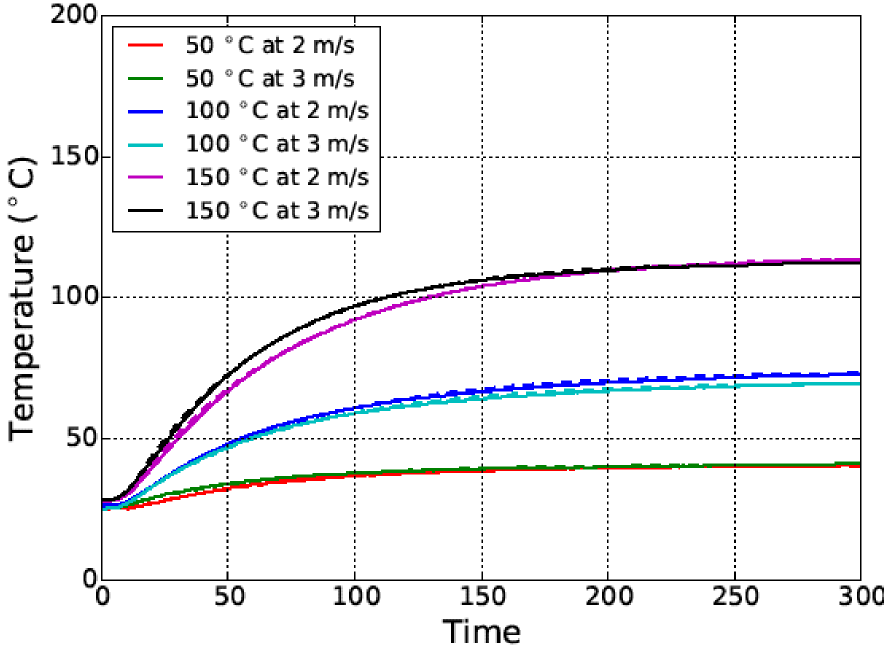
$$T(t) = T_{gas} + (T_{gas} - T_{initial})e^{-t/\tau}$$

Time constant for thermal lag

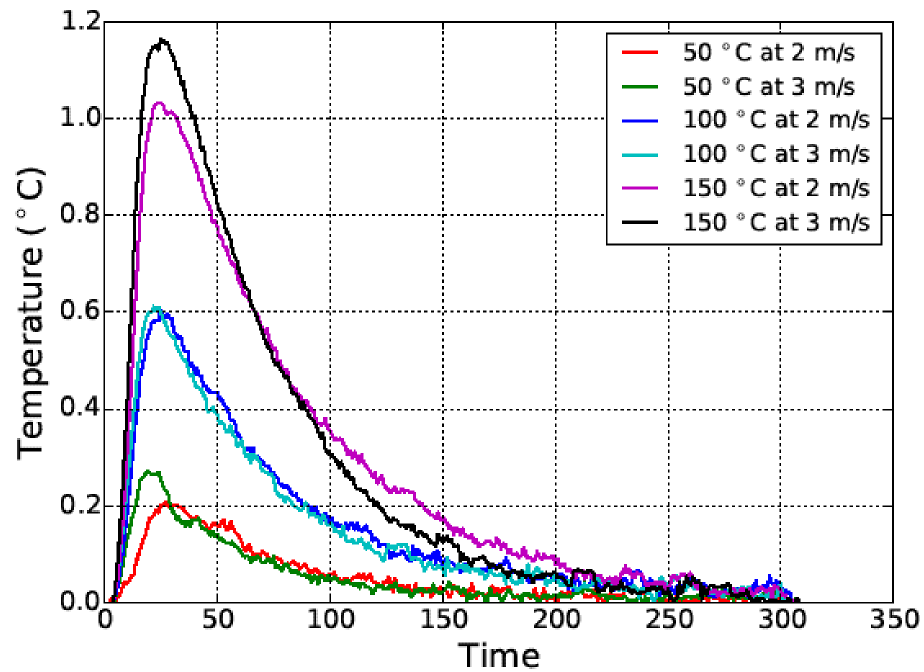
$$\tau = \frac{mc}{hA}$$

Mass (kg)	**Area (m^2)**	**Specific Heat (kJ/kg K)**
0.013	0.206	1.24-1.75

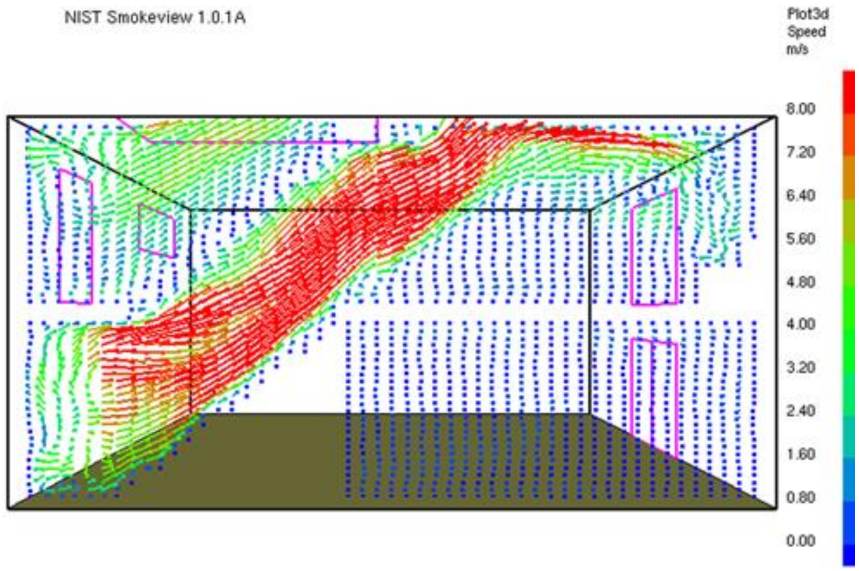
Analysis Contd.

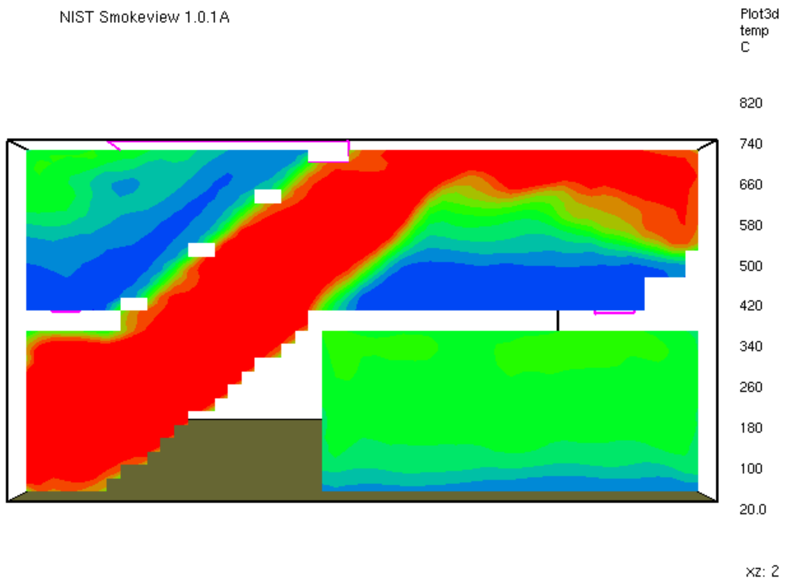


Temperature °C	τ @ 2 m/s	τ @ 3 m/s
50	65	60
100	70	65
150	68	55



Live Fire Experiments





Questions?