INTERNATIONAL ASSOCIATION OF FIRE FIGHTERS

THE INTERACTIVE FIRE GROUND:

FIRE DYNAMICS, BUILDING CONSTRUCTION, PPE, & TACTICS

- Exposure Reduction

Daniel Madrzykowski, PhD
UL Research Institute
Fire Safety Research Institute

April 26, 2026

Overview

- Objectives
- NFPA 1700 Guide for Structural Fire Fighting
- Fuel Load
- Fire Dynamics
- PPE Capabilities and Limitations
- Building Construction
- Tactics
- Case Study
- Exposure Reduction

NFPA 1700 Guide for Structural Firefighting

Purpose: To provide guidance for the development of policies, procedures, and guidelines, including strategies, and tactics for structural fire-fighting supported by science-based research.

Overview of research conducted with the fire service to support tactical considerations

Fire Science and Fire Dynamics in Structures

Building Construction

Firefighting PPE & Equipment

Natural vs Synthetic Fuels

Intentional E-Scooter Overcharge: Closed Bedroom

Overcharge Time:
01:43:00

Bedroom 1

NFPA 1700 Guide for Structural Firefighting

Strategic Considerations

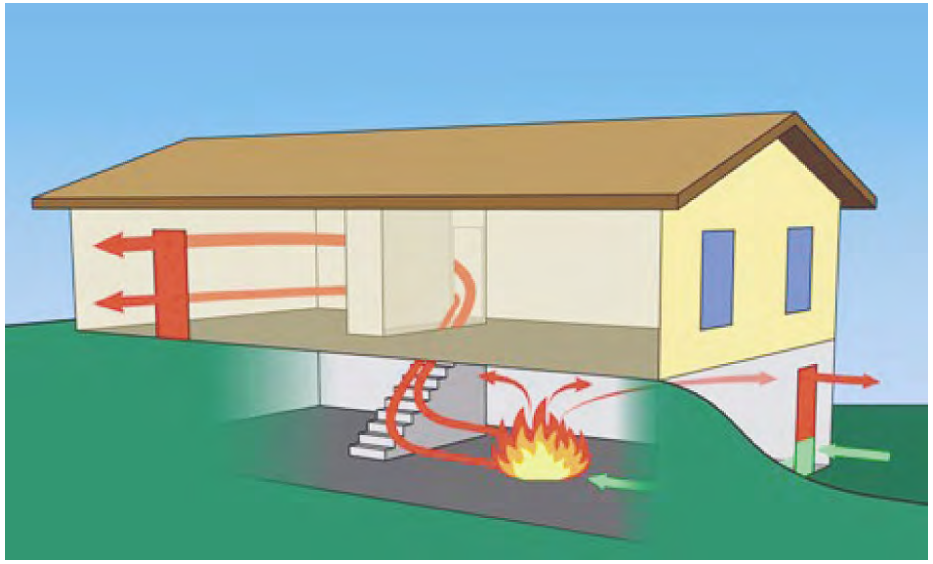
Tactical Considerations for Fire Control & Extinguishment

Exposure & Hygiene Considerations

Fire Specific Tactical Considerations

Tactical Considerations for Search and Rescue

Implementation



Garden apartment: Side A 2 levels, Side C 3 levels

Pre-Vent On 2nd Floor

Post-Vent On 2nd Floor

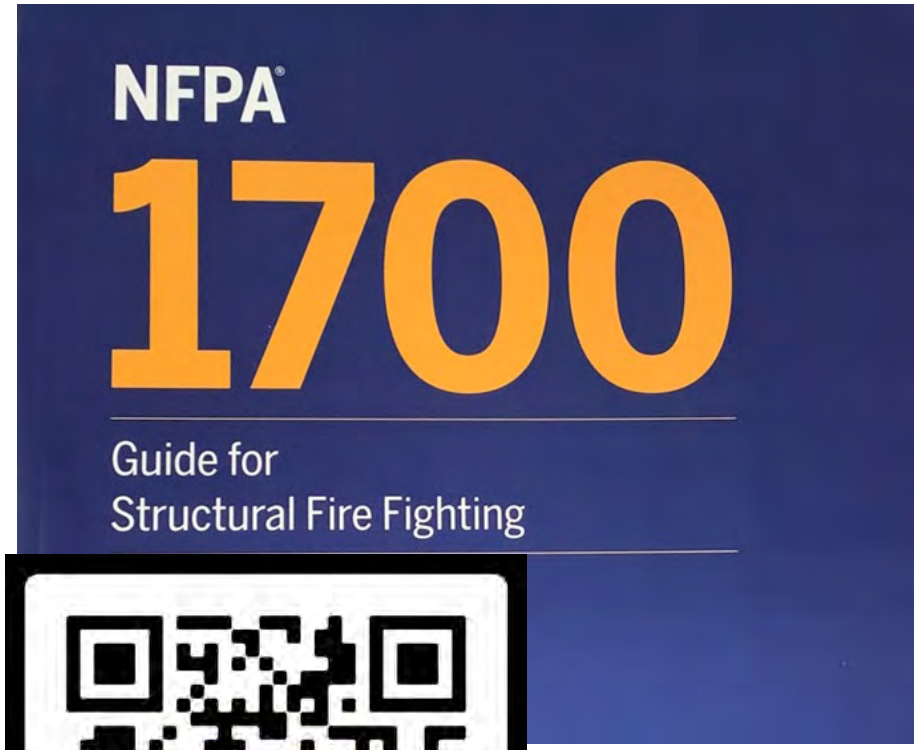
NFPA 1700 Guide for Structural Fire Fighting

Offensive Strategy

The plan for the actions and movements of arriving fire department units to control the fire, effect rescues, start searches for occupants, and extinguish the fire with the intent to commence operations inside the fire building.

Defensive Strategy

The plan for the actions or movements of the arriving fire department units to protect exposures and contain the main body of fire to the already affected areas.



FSRI

1700 TRAINING

Fire Dynamics Summary

1. Fuel, oxygen, and heat are needed for a fire
2. Natural fuels and synthetic fuels are different
3. Smoke is fuel
4. No oxygen, no heat
5. Heat release rate => fire size, fire hazard
6. Hot flows to cold
7. Higher pressure flows to areas of lower pressure
8. Pressure and temperature are related
9. Time

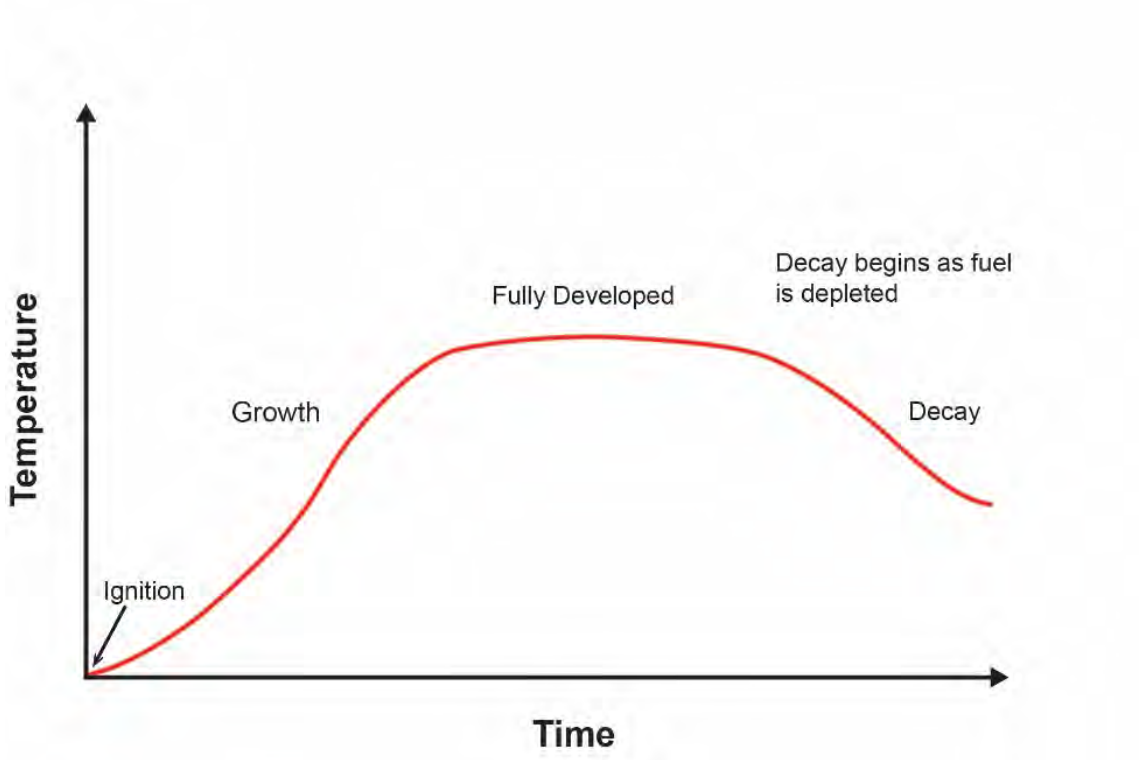
Fire Dynamics in Structures - Summary

- Fuel-limited vs. ventilation-limited fire
- Add air to ventilation-limited fire:
  - –Fire will grow
  - –HRR will increase
  - –Fire hazard will increase
  - –Increase could be rapid
- Air needed for flashover, backdraft

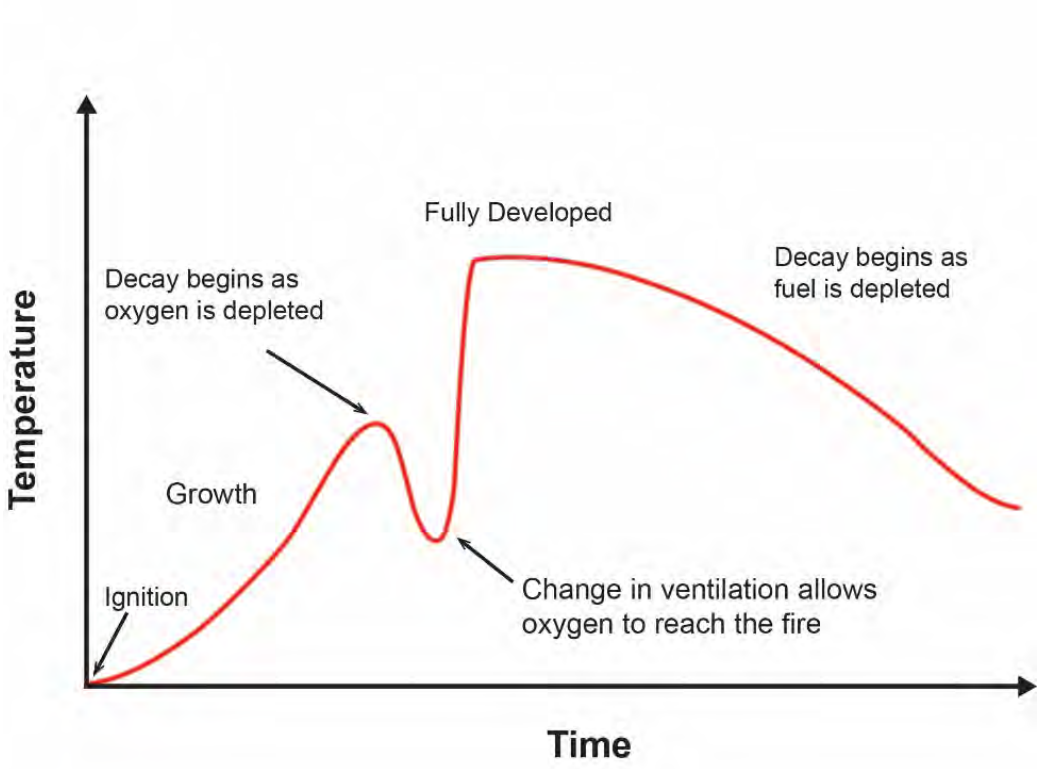
- Flow paths
  - –Operate in the intake (air flow) if possible
  - –Operating in the exhaust (hot gas flow) is a high hazard
- Pressure and flow moves the fire through a structure
- Heated gases expand, cooled gases contract

Fire Dynamics in a Structure

Ideal Fuel-Limited Model



Ideal Ventilation-Limited Model

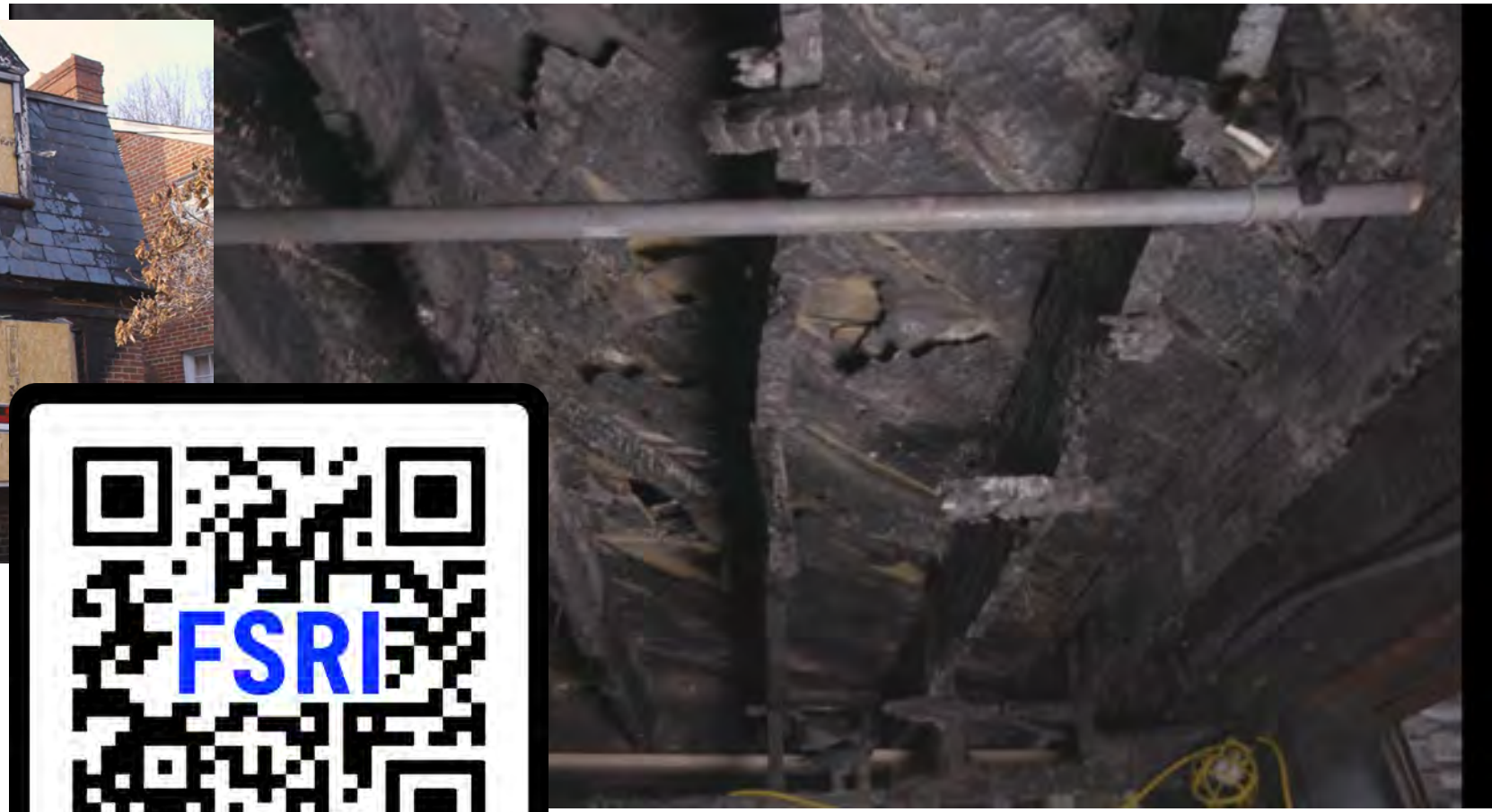


Ventilation Limited Fires: What to look for?

Venting a Ventilation-Limited Fire

2017 Foxhall Road, Washington DC: Near Miss

https://vimeo.com/248510490



FSRI

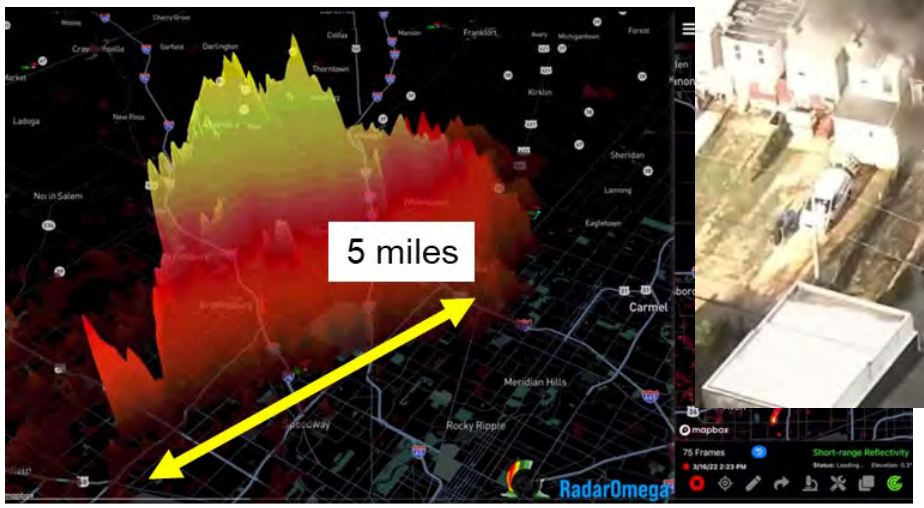
VIDEO


DISTRICT

Where do fire dynamics apply?

- Residential Structures?
- Commercial Structures?
- Outdoor fires?
- Vehicle fires?
- Construction equipment fires?
- Shipboard fires?

Diverse Fire Grounds: Impacts of Fuel Load, Weather, Size & Scale



UL Research Institutes

Fires aren’t limited to structures – are you ready?

A fire along Interstate 10 near downtown Los Angeles, Nov. 11, 2023.

Caltrans District 7 via AP

NIOSH F2024-05

Battalion Chief Chris Eddy
Greene County Fire Rescue

1000 FREDERICK LANE, MORGANTOWN, WV 26508 · 304.285.5916

Career Battalion Chief Dies from Explosion while Fighting Tractor Trailer Fire – Georgia

Executive Summary

On September 4, 2024, a 35-year-old career battalion chief (Battalion 1) died while operating at a tractor trailer fire. He was the command officer at the incident and was killed while investigating the type of cargo that was held within the refrigerated trailer involved in the fire.

At approximately 0921 hours, the local public safety answering point (PSAP) received a call for a vehicle fire. While the incident was being dispatched to the responding units, the call type was updated to a tractor trailer fire with black smoke and multiple callers. Battalion 1 and Engine 11 were dispatched to the incident. Upon hearing the update from the dispatch center, Battalion 1 requested an additional engine

Photo 1: Fire conditions on arrival of Battalion 1.
(Photo courtesy of the fire department)

Insulating Foam




The foam was identified as polyisocyanurate foam using pyrolysis gas chromatography with mass spectrometry (Py/GC-MS) analysis

Heat Release Rate per unit area = 700 kW/m^2 (twice as high a SPF wood)
Heat of Combustion = 20.2 MJ/kg (30% higher than SPF wood)

The fire service take away, even if the refrigerated trailer were empty, it still has a large fuel load, with the potential for significant fire or explosion hazard.

Safety Bulletin - Large Vehicle Tire Fires

Exclusion Zone: Lethal pressure waves will be generated in a tire explosion. Do not enter unless robust shielding (building, large vehicle, etc.) is present as PPE does not protect from pressure waves Consider the use of tools to reach victims within the exclusion zone.

Immediate Rescue Only Zone: Pressure waves are likely to cause injury. Only operate in this zone for immediate victim rescue to limit exposure time unless robust shielding is present as PPE does not provide protection from pressure waves.

Rescue Only Zone: Only operate in this zone to perform a rescue as projectiles may be expelled into this area. On vehicles with dual tires, the explosion of the inner dual can expel the outer dual out from the vehicle in line with the axle. Full PPE may provide some protection from projectiles and shielding may mitigate the hazard in this zone.

Limited Operation Zone: The hazard of projectiles is reduced, but not eliminated if operations are aligned with the tire treads at the greatest distance from the tire possible. Only operate in this zone if the incident priorities dictate (rescue, prevent extension to other tires or vehicles, etc.). Consider unstaffed hose streams to reduce the time personnel are in this zone. Shielding may mitigate the hazard.

Even after exterior fire is extinguished, tires exposed to heat may continue to undergo a runaway exothermic reaction and explode. Do not immediately approach a tire which has been exposed to significant heat.

Note: Tires exposed to fire may explode due to the production of flammable gases within the tire, producing pressures far greater than would result from a mechanical failure or blowout.

FF Andrew Pontious
County of Los Angeles Fire Department
Last Alarm June 14, 2024

Explosive Hazard Zones: The following figures identify the explosive hazard zones and acceptable operations for two general classifications of large vehicles, tractor-trailers and heavy equipment.

Tractor-Trailer Tire Explosive Hazard Zones

Heavy Equipment Tire Explosive Hazard Zones

UL Research Institutes

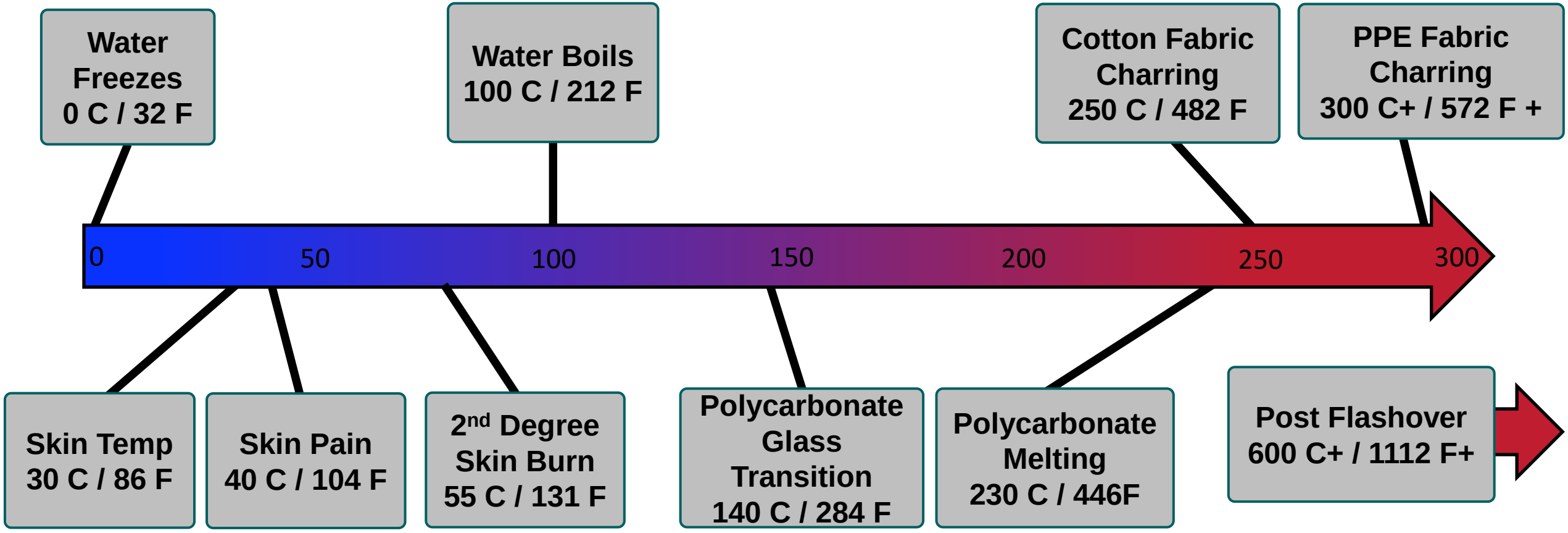
How do fire dynamics interact with your equipment ?

- PPE
- Electronics
- Thermal Imagers

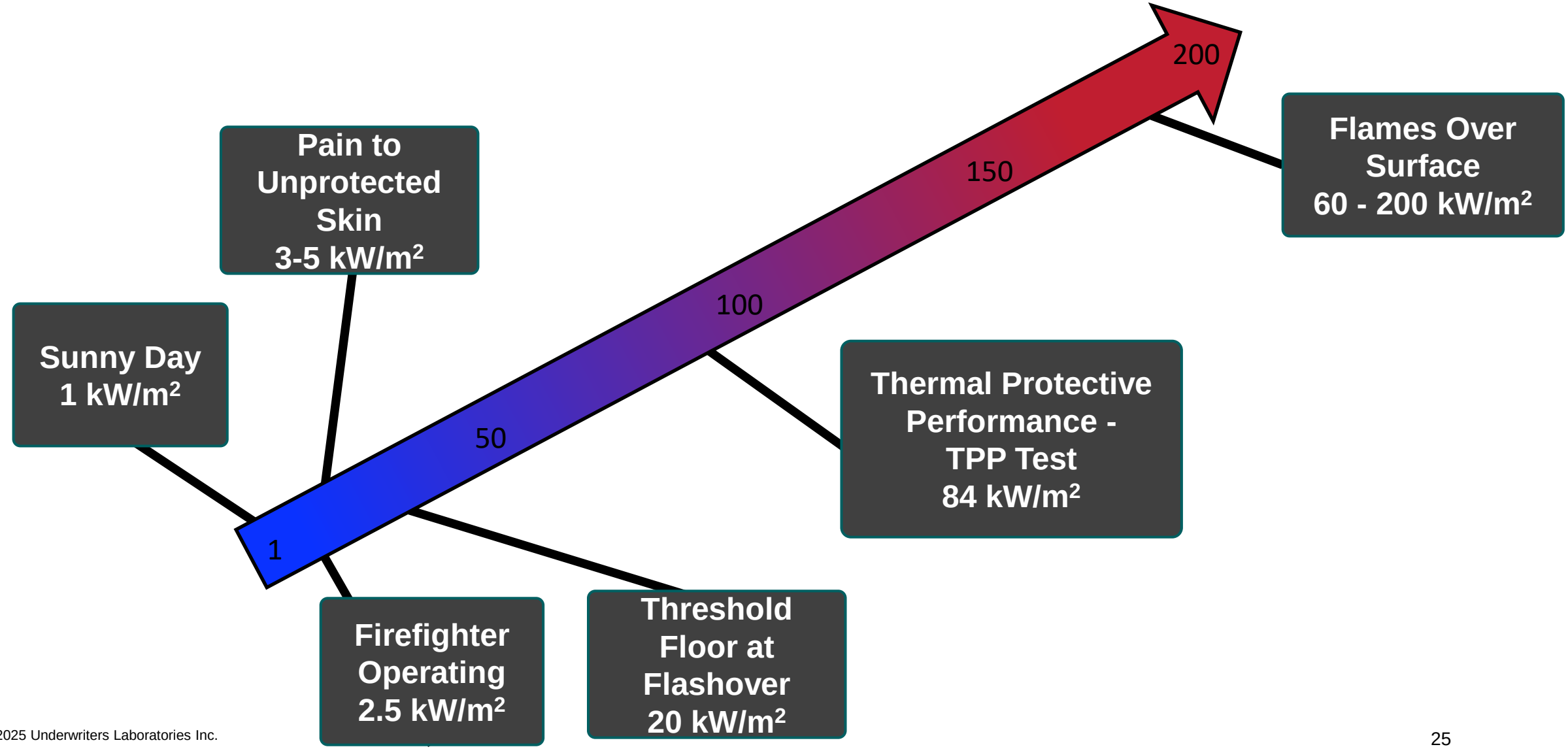
PPE Capabilities and Limitations

- How does your PPE work?
- What is it designed to take?
- What can the person inside take?

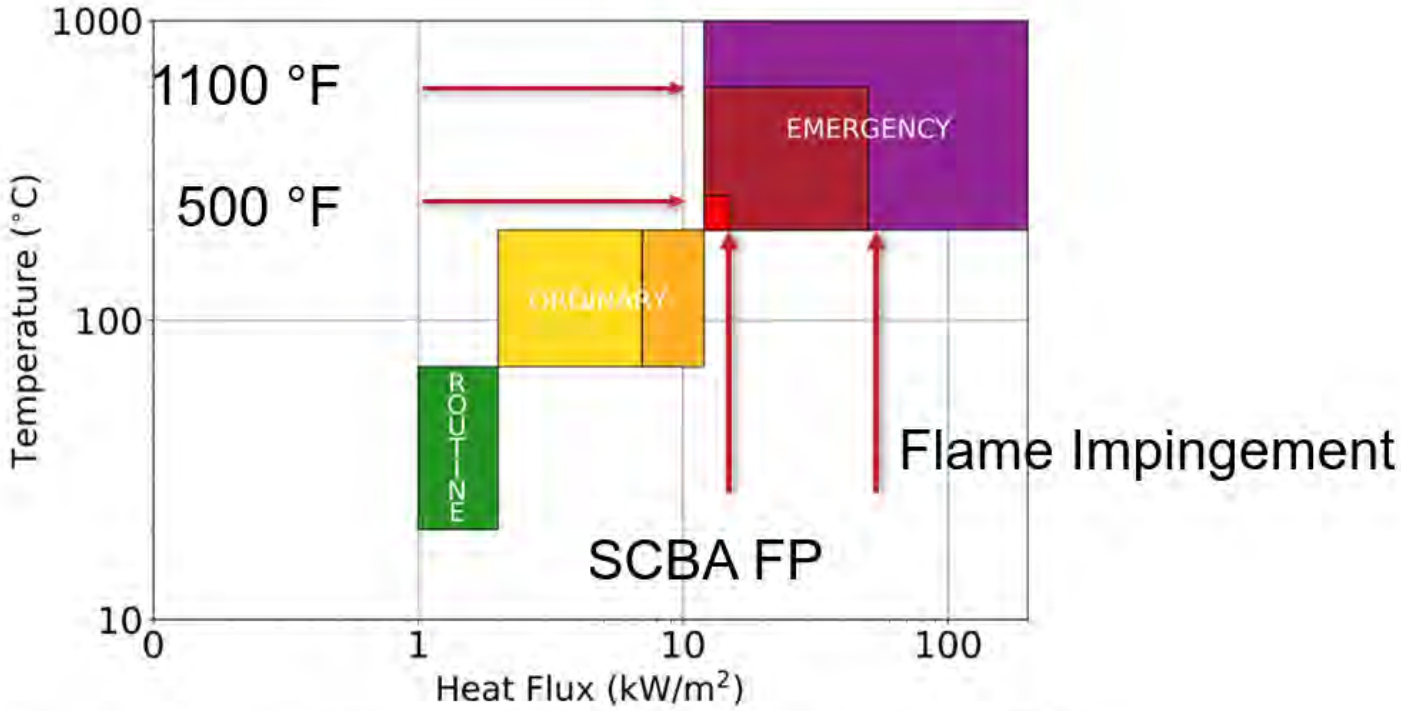
Critical Temperatures



Heat Flux – measure of energy per unit area



Thermal Operating Classes



Operating Class	Temperature Range [°C]	Heat Flux Range [kW/m^2]
Routine	20 – 72	1 – 2
Ordinary I	72 – 200	2 – 7
Ordinary II	72 – 200	7 – 12
Emergency I	200 – 260	12 – 15
Emergency II	260 – 600	15 – 50
Emergency III	> 600	> 50

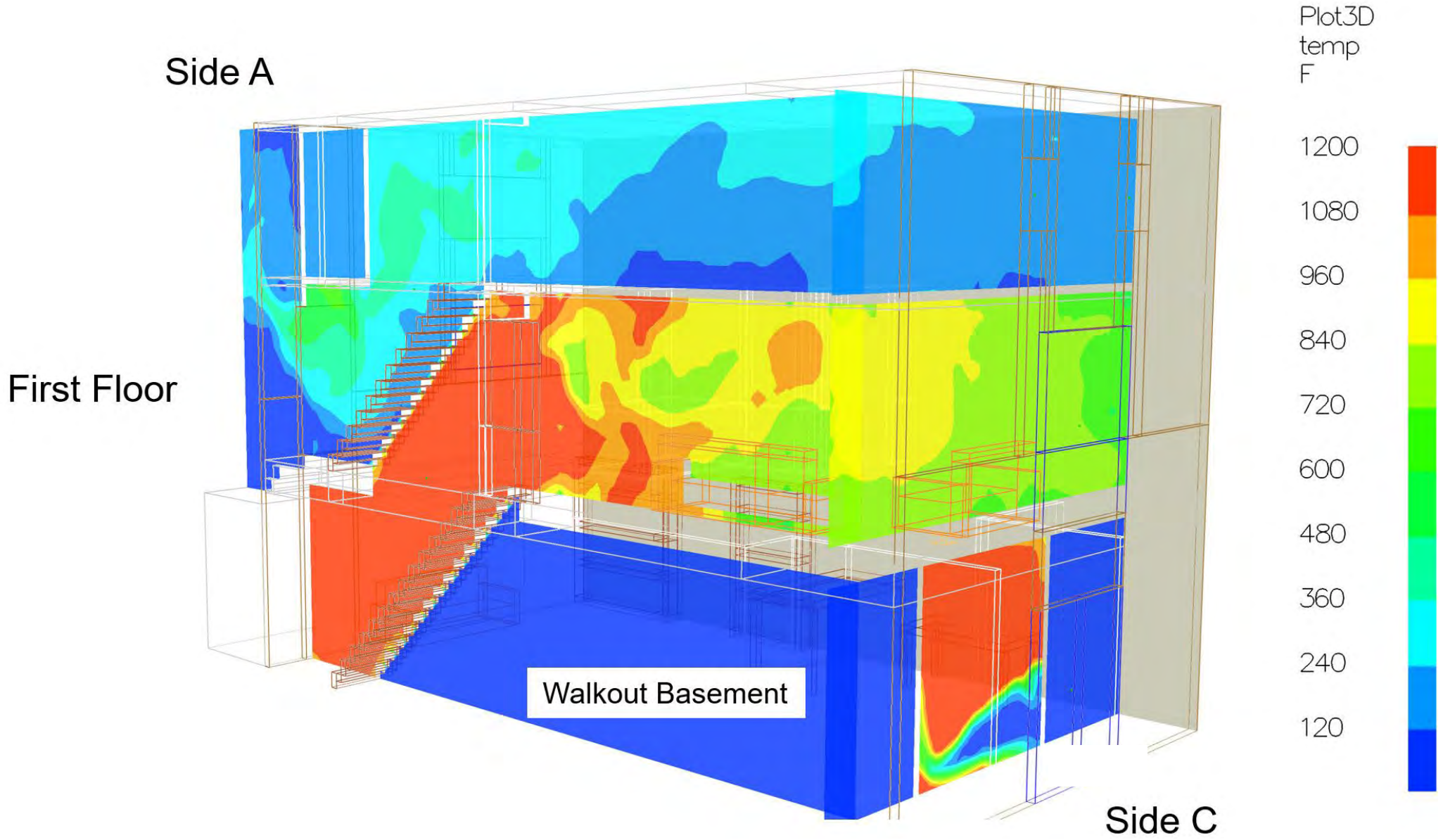
Cherry Road Washington D.C. May 30, 1999

Anthony Sean ‘Sauce’ Phillips Sr.

Louis J. Matthews

District of Columbia Fire & EMS Department

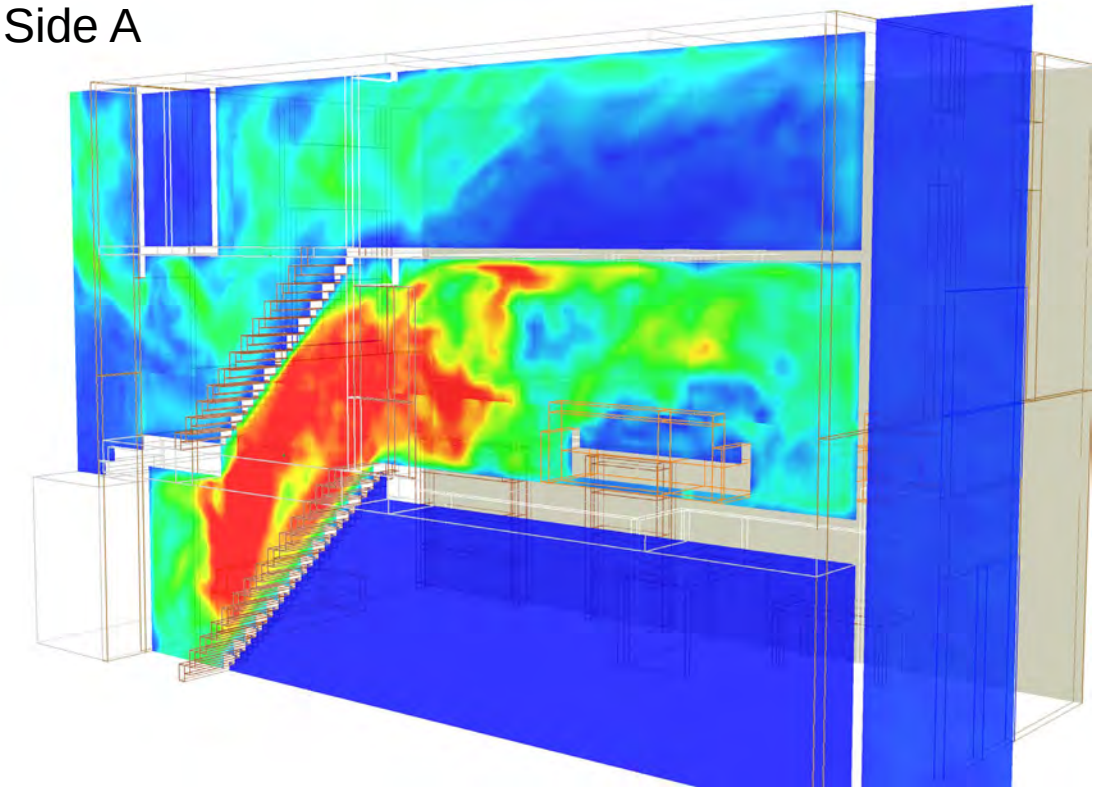
Cherry Road May 1999: 2 LODDs and 3 LODIs
Temperatures after the basement sliding glass door was vented



Cherry Road: Gas velocities after the sliding glass door was vented

Velocity plane centered on the stairway

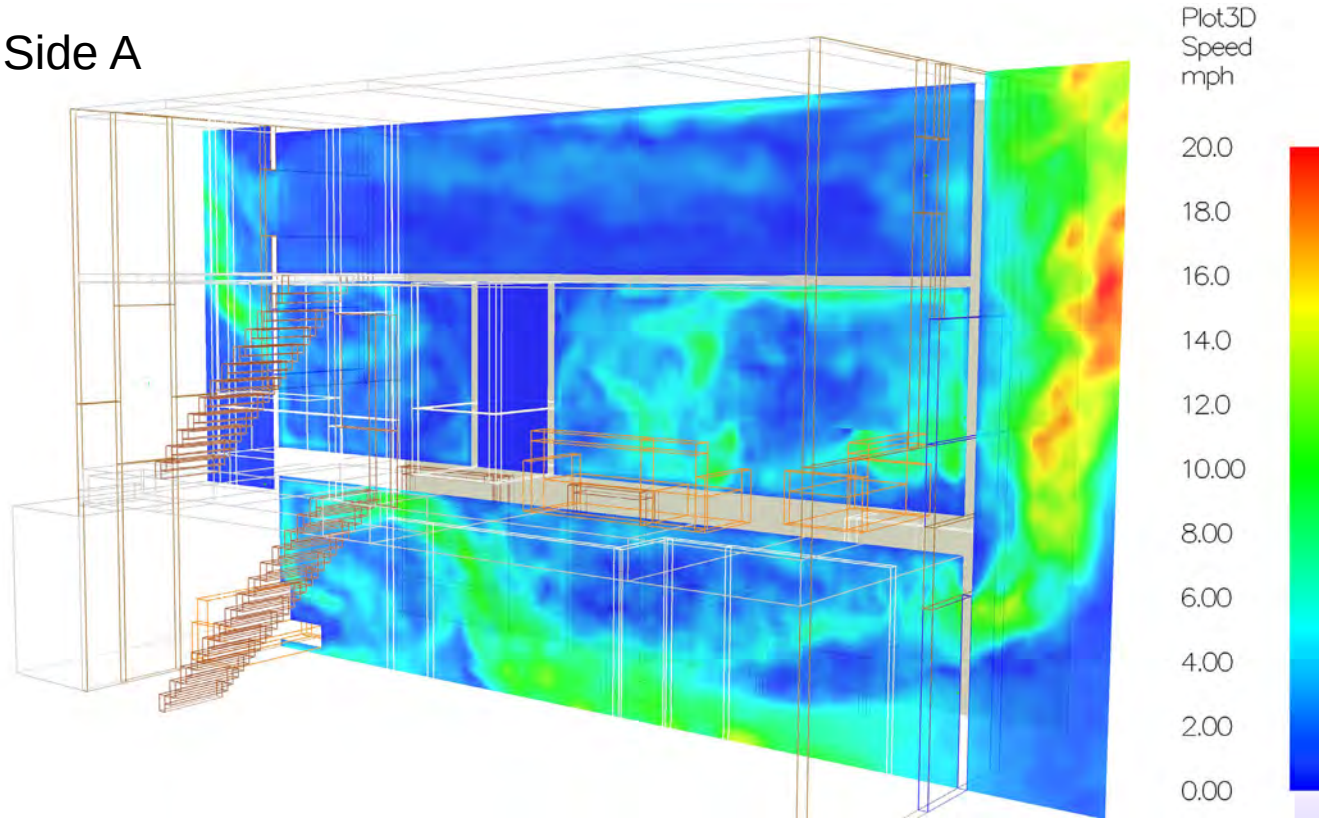
Side A



Side C

Velocity plane centered on front door and sliding glass door

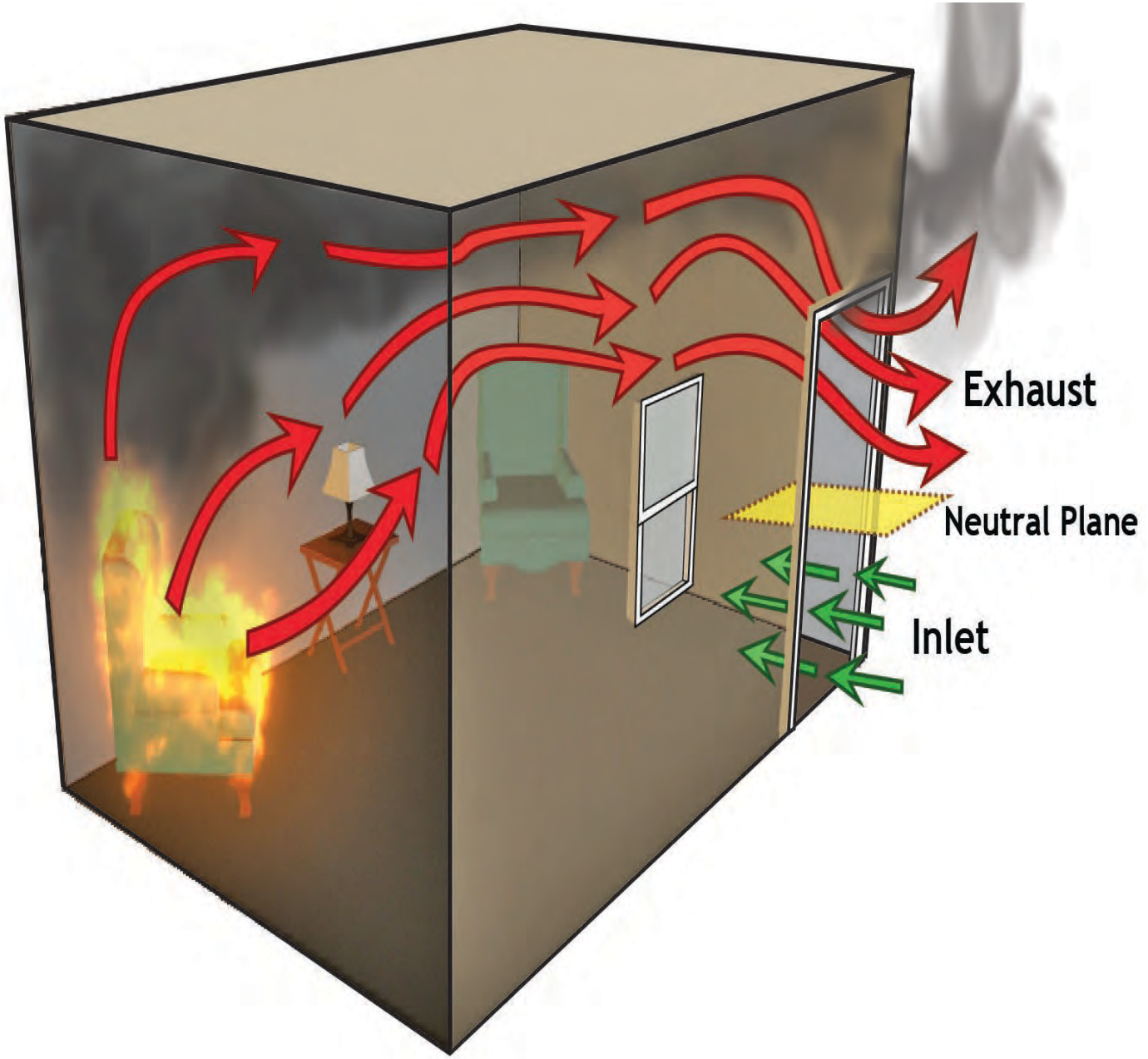
Side A



Side C

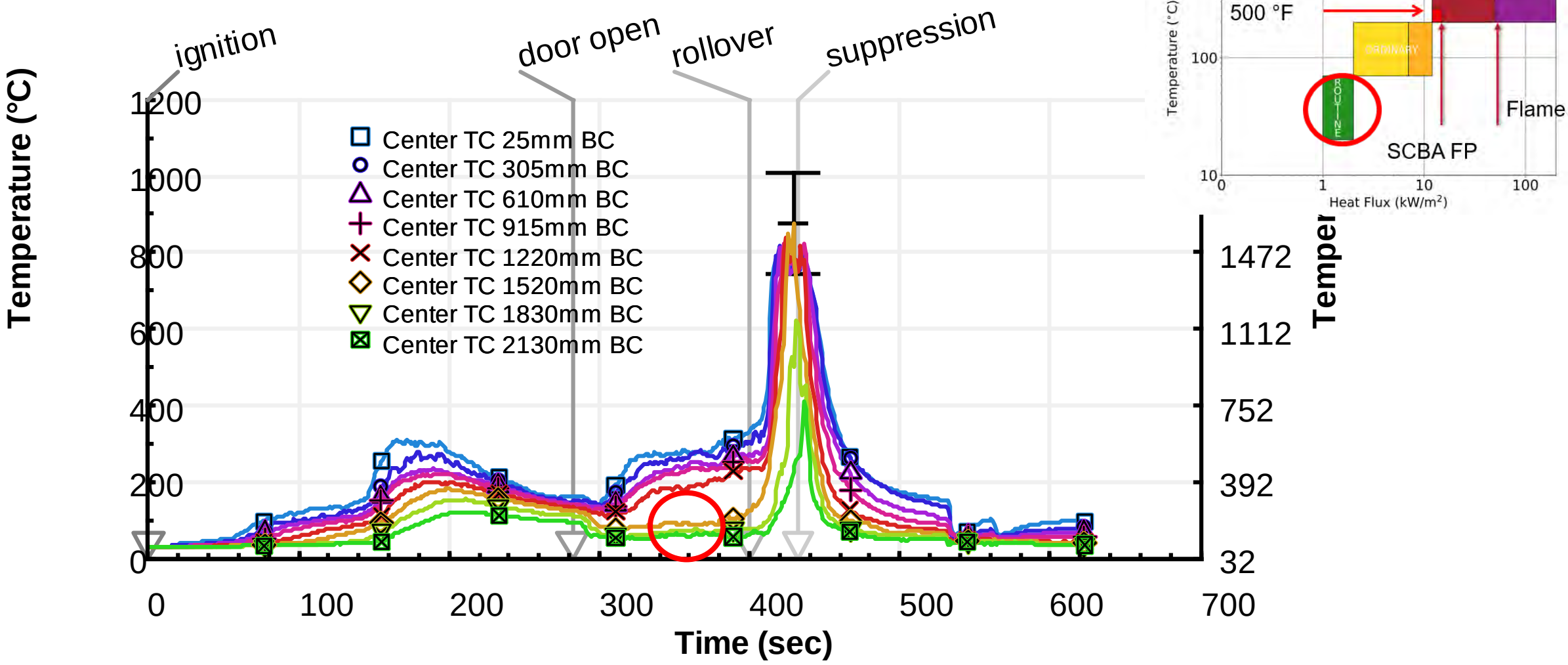
It is essential to understand the limitations of the PPE.

Open Door



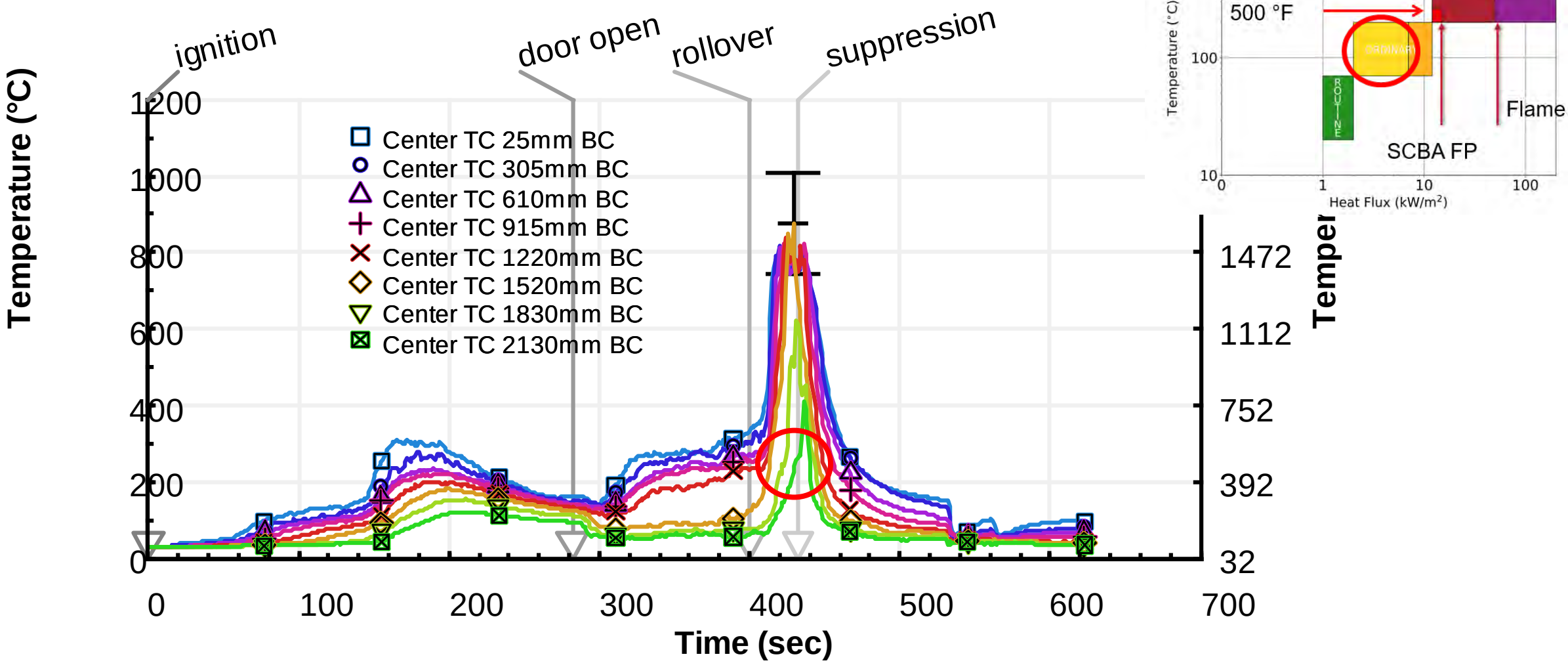

NIST 0:00
5 x Real Speed

Temperature – Center of the Room



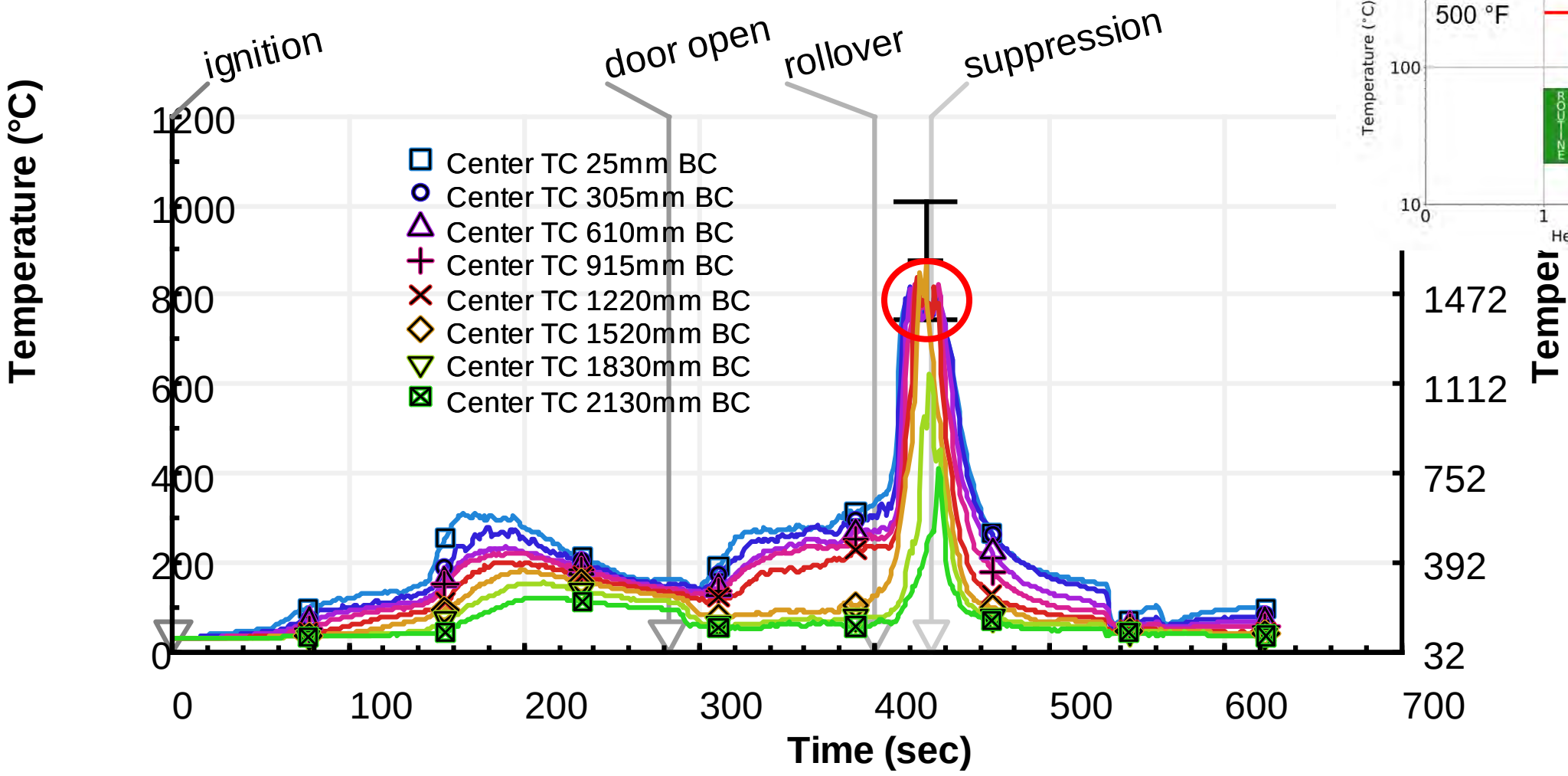
Barowy, A. and Madrzykowski, D. (2012), Thermal Behavior of Structural Fire Fighting Protective Ensemble Samples Modified with Phase Change Material and Exposed in Full-Scale Room Fires., NIST TN 1739, https://tsapps.nist.gov/publication/get_pdf.cfm?pub_id=910937

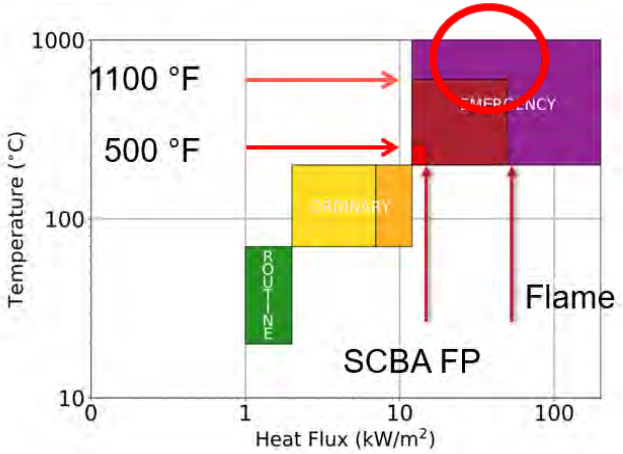
Temperature – Center of the Room



Barowy, A. and Madrzykowski, D. (2012), Thermal Behavior of Structural Fire Fighting Protective Ensemble Samples Modified with Phase Change Material and Exposed in Full-Scale Room Fires., NIST TN 1739, https://tsapps.nist.gov/publication/get_pdf.cfm?pub_id=910937

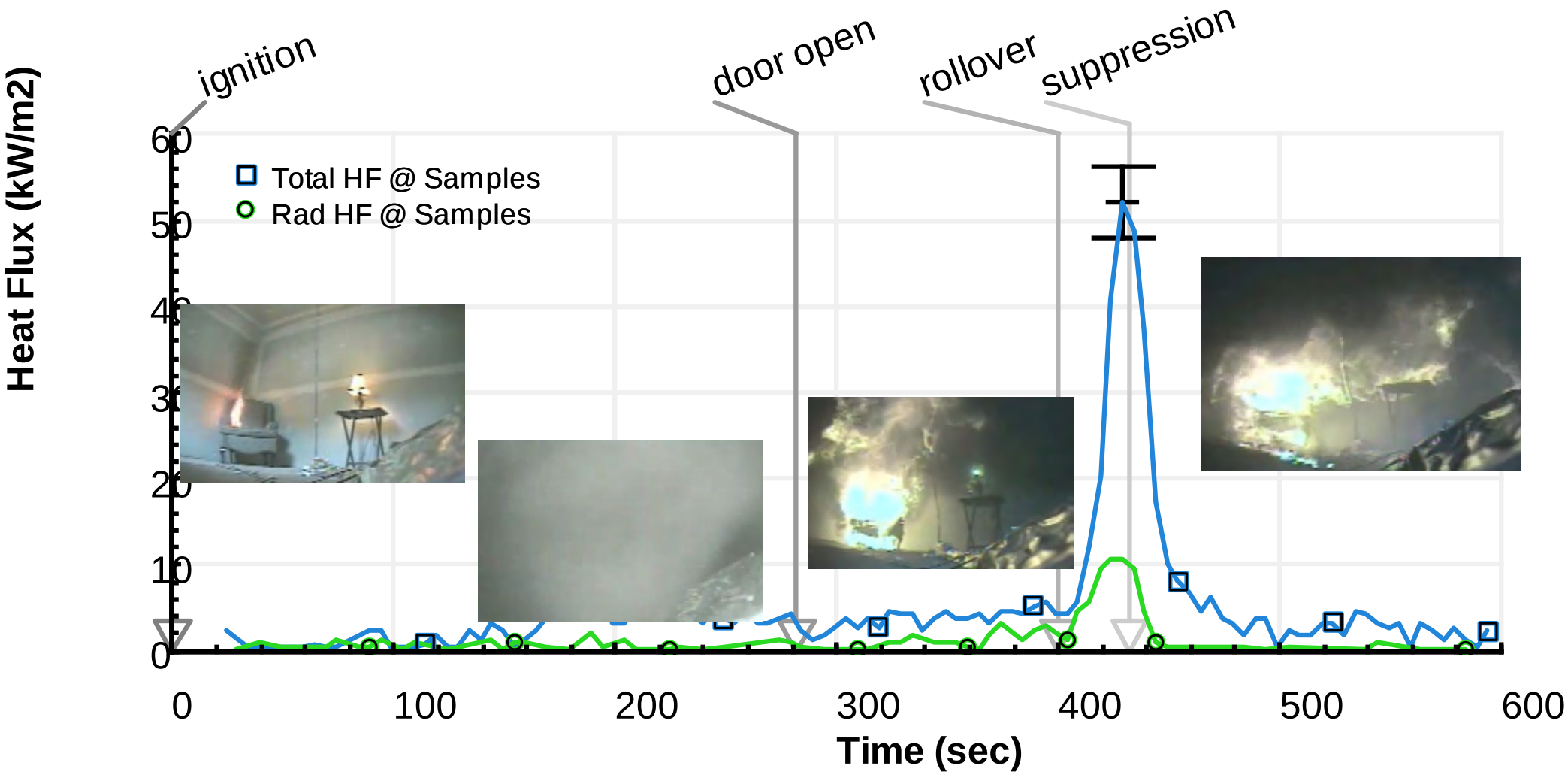
Temperature – Center of the Room



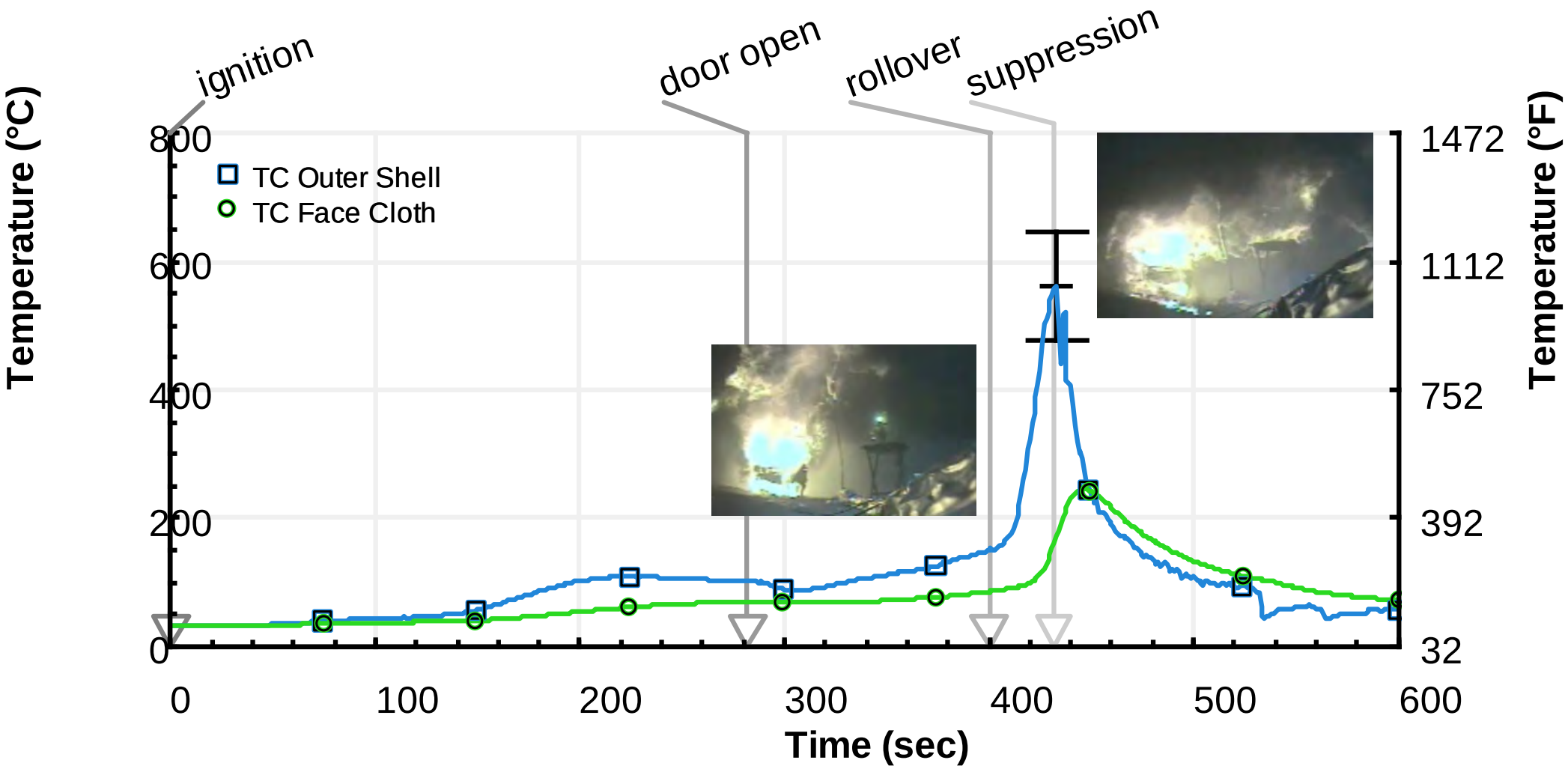


Barowy, A. and Madrzykowski, D. (2012), Thermal Behavior of Structural Fire Fighting Protective Ensemble Samples Modified with Phase Change Material and Exposed in Full-Scale Room Fires., NIST TN 1739, https://tsapps.nist.gov/publication/get_pdf.cfm?pub_id=910937

Total and Radiant Heat Flux



PPE Temperatures



Face Piece Lens Related Incidents

Photo 1. Victim's melted facepiece lens.
(NIOSH Photo.)

Photo 1. Victim FF1's facepiece showing thermal degradation.
(NIOSH photo.)

Photo 3. FF1's facepiece showing thermal degradation.
(NIOSH photo).

NIOSH F2002-34, "Career Lieutenant and Fire Fighter Die in a Flashover During a Live-Fire Training Evolution - Florida"
NIOSH F2005-31, "Career officer injured during a live fire evolution at a training academy dies two days later - Pennsylvania"
NIOSH F2007-12, "Career Fire Fighter Dies in Wind Driven Residential Structure Fire - Virginia"
NIOSH F2007-29, "A Volunteer Mutual Aid Captain and Fire Fighter Die in a Remodeled Residential Structure Fire - Texas"
NIOSH F2008-34, "Volunteer Fire Fighter Dies While Lost in Residential Structure Fire - Alabama,"
NIOSH F2009-11, "Career Probationary Fire Fighter and Captain Die as a Result of Rapid-Fire Progression in a Wind-Driven Residential Structure Fire – Texas"
NIOSH F2011-02, "Volunteer Fire Fighter Caught in a Rapid Fire Event During Unprotected Search, Dies After Facepiece Lens Melts-Maryland"
NIOSH F2014-09 "Lt and Fire Fighter Die and 13 Fire Fighters injured in a Wind-driven fire in a Brownstone – Massachusetts"
NIOSH F2023-11, "Lieutenant and Probationary Firefighter Die after experiencing Thermal Degradation of Self-Contained Breathing Apparatus Facepiece Lenses – Maryland "

Comparison of NFPA PPE Test Conditions

1981 – SCBA (2007 edition)	1982 – PASS 1801 – Thermal Imager	1971 – Turnout Gear
Convective Oven 95°C (203°F) for 15 minutes	Convective Oven 95°C (203°F) for 15 minutes	
Open Flame 1000°C (1832°F) for 10 seconds	Open Flame 1000°C (1832°F) for 10 seconds	
	Convective Oven 260°C (500°F) for 5 minutes Operating NEW for 2007	Convective Oven 260°C (500°F) for 5 minutes
Radiative Flux 15 kW/m^2 for 5 minutes NEW for 2013		Convective + Radiative Flux 84 kW/m^2

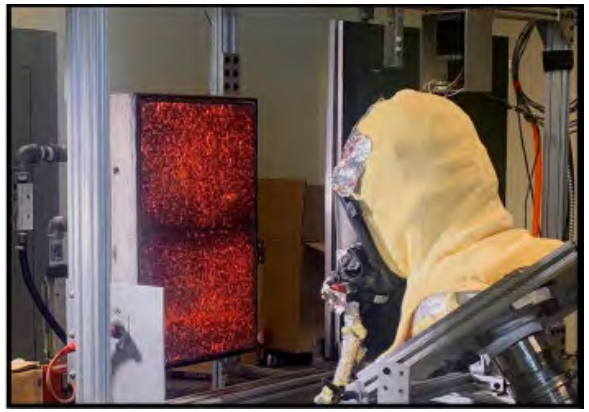
55°C (131°F) - Human skin receives a second degree burn injury

5 kW/m^2 - Pain to skin within seconds

20 kW/m^2 - Threshold flux to floor at Rollover

Comparison of NFPA 1981 2007 vs 2013 SCBA Lenses

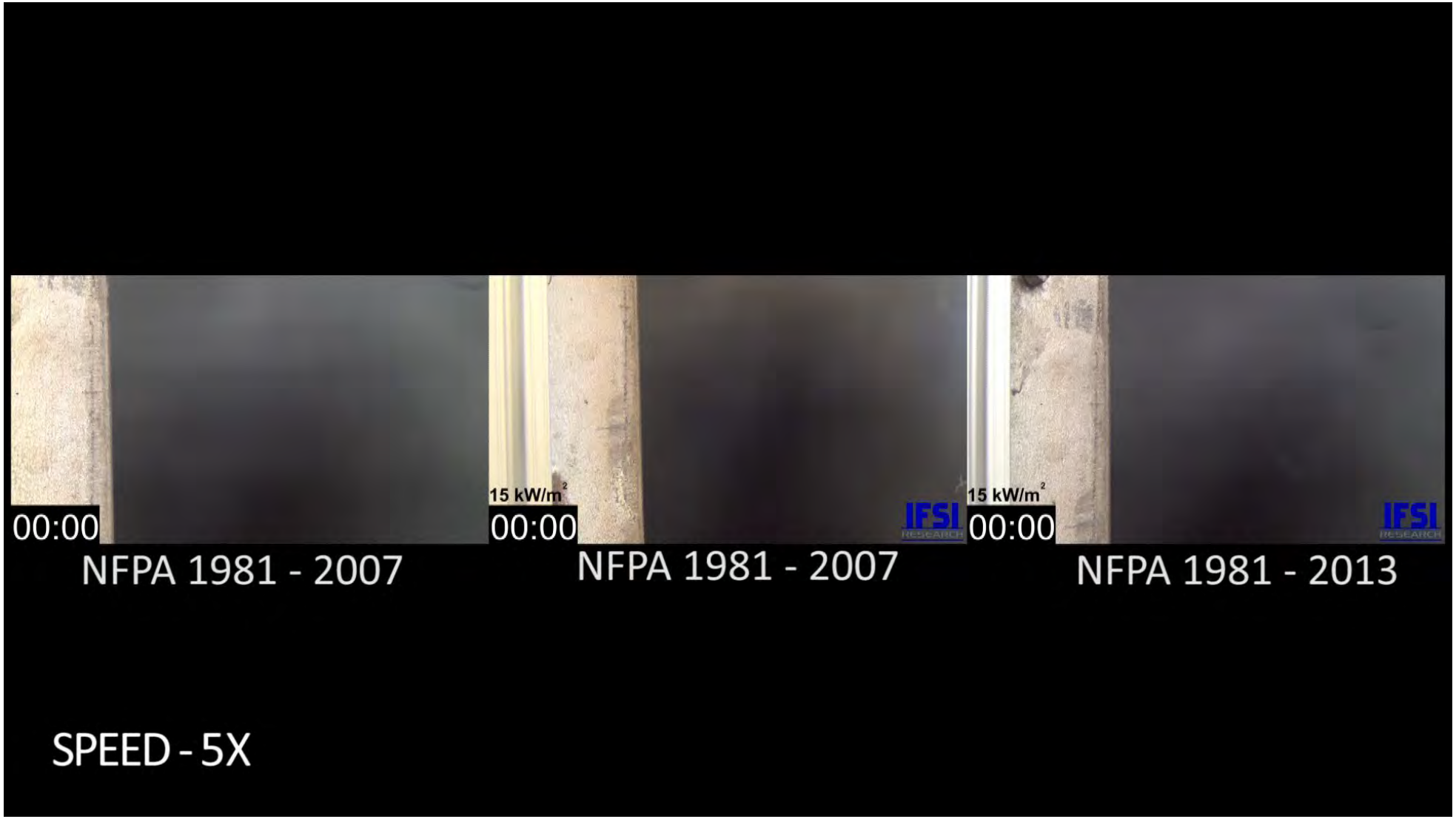
SCBA Facepiece	Description	Mass (g)	Thickness (mm)
107-A	Meets NFPA 1981-2007 edition (Older geometry)	124	2.2
107-B	Meets NFPA 1981-2007 edition (Updated geometry)	143	2.6
1-13	Meets NFPA 1981-2013 edition (Updated geometry)	167	4.1



Ref. Kesler, R. Thermal degradation of SCBA facepiece lenses under radiant thermal loads. FSRI 2023

		Time (min) to thermal degradation for each heat flux			
Degradation	**Facepiece**	**5 kW/m²**	**10 kW/m²**	**15 kW/m²**	**20 kW/m²**
Crazing	1-07A	19.3 (1.2)†	1.3 (0.3)	0.7 (0.1)	0.5 (0.1)
	1-07B	8.3 (1.9)	1.3 (0.1)	0.9 (0.2)	0.7 (0.2)
	1-13	–	3.8 (0.5)*	1.7 (0.1)*	1.1 (0.1)*
Bubbling	1-07A	--	2.6 (0.2)	1.2 (0.1)	0.9 (0.0)
	1-07B	--	2.3 (0.0)	1.4 (0.1)	0.9 (0.0)
	1-13	--	8.2 (2.1)*	2.6 (0.2)*	1.6 (0.0)*

NFPA 1981 – 2007 vs 2013



Source: Kesler, R. , Mitsingas, C. , Quiat, A. , Lee, T. , Madrzykowski, D. and Horn, G. (2018), *Mechanical properties and off gassing characteristics of new and legacy SCBA facepieces.* https://doi.org/10.6028/nist.gcr.18-019

PPE Materials: Library

Material	Melting/Softening Onset (°F [°C])	Decomposition Onset (°F [°C])
Helmet Bourke	374-392 [190-200]	860-896 [460-480]
Helmet Brim Laminate	N/A	410-446 [210-230]
Helmet Brim Edging	266-275 [130-135]	518-590 [270-310]
Helmet Shield	N/A	446-491 [230-255]
Helmet Reflective Sticker	N/A	446-491 [230-255]
Helmet Chin Strap	N/A	419-446 [215-230]
Helmet Buckle	473-482 [245-250]	671-734 [355-390]
SCBA Mask Hard Plastic	356-374 [180-190]	716-761 [380-405]
SCBA Mask Rubber	N/A	518-572 [270-300]
SCBA Bracket	374-383 [190-195]	716-770 [380-410]
SCBA Face Piece Lens (2007)	284-293 [140-145]	779-833 [415-445]
SCBA Face Piece Lens (2018)	392-401 [200-205]	842-887 [450-475]
UEBSS Hose	N/A	446-464 [230-240]
Hood	N/A	419-455 [215-235]
Coat Shell	N/A	932-968 [500-520]
Coat Reflective Trim	N/A	419-455 [215-235]

PPE Performance Under Fire Conditions

1. Gas Temp + Heat Flux ≠ Whole Story
   - –Heat flux can exceed the hazard level of the surrounding gas temperature
   - –Must consider flow and convective heat transfer rate

2. Challenging situations
   - –Stored heat in PPE
   - –Exhaust portion of the flow path
   - –Operating above the fire at the top of the stair
   - –Rapid increase in thermal conditions
   - –Close proximity to the seat of the fire

- Cherry road flow path

PPE Performance Under Fire Conditions

1. Fire officers and fire chiefs must consider the capabilities of the thermal protection that their firefighters have when determining the strategies and tactics of a fire attack.

2. Consider tactics that will keep the gear within the designed operating environment and maintain the safety factor it provides in case of an emergency.

Building Construction

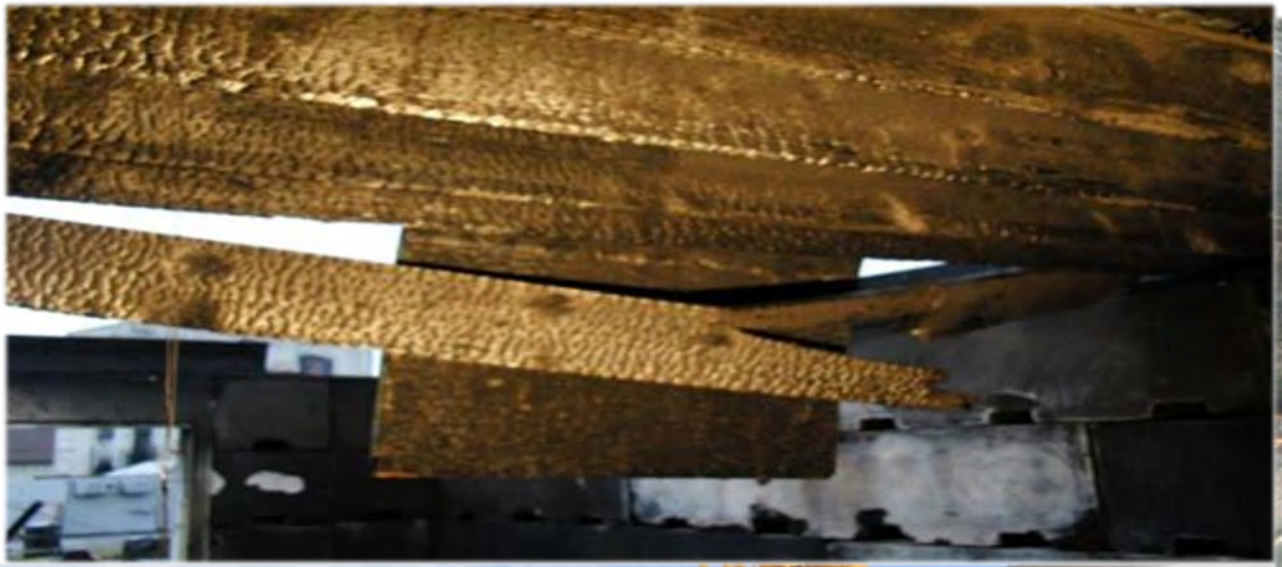
- What does a building rely on for structural integrity?
- Do different construction materials contribute to fire growth?
- Does lightweight construction impact how you respond to a fire?
- What do you look for before operating over an active fire/
- Can building construction impact fire growth?
- Can building construction impact fire fighting tactics?

Flooring Assemblies

Collapse Times less than 5 minutes

Experiment Number	Floor Support	Ventilation Description	Time from Ignition to Collapse	ΔT Time to Collapse – Time to fire spread to floor assembly.
1	Dimensional Lumber (2 x12)	Max Vent	11:09	7:11
2	Dimensional Lumber (2 x12)	Sequenced Vent	12:45	10:45
3	Engineered Wood I-Joist (12 in.)	Max Vent	6:00	2:45
4	Engineered Wood I-Joist (12 in.)	No Vent	6:49	4:06
5	Engineered Wood I-Joist (12 in.)	No Vent/No boxes	8:27	4:42
6	Engineered Wood I-Joist (12 in.)	Max Vent/Furnace DHS load	6:49	2:29
7	Steel C-Joist (12 in.)	Max Vent	8:15 (6:11 exceeds ISO 834:1)	5:15
8	Steel C-Joist (12 in.)	Sequenced Vent	14:04* (10:08 exceeds ISO 834:1)	10:32
9	Parallel Chord MPCWT	No Vent	6:08	3:42
10	Parallel Chord MPCWT	Max Vent	3:28	1:50

Post Fire Damage



Methods and Materials of Construction: Legacy vs Modern

Tendency for subfloor burn through

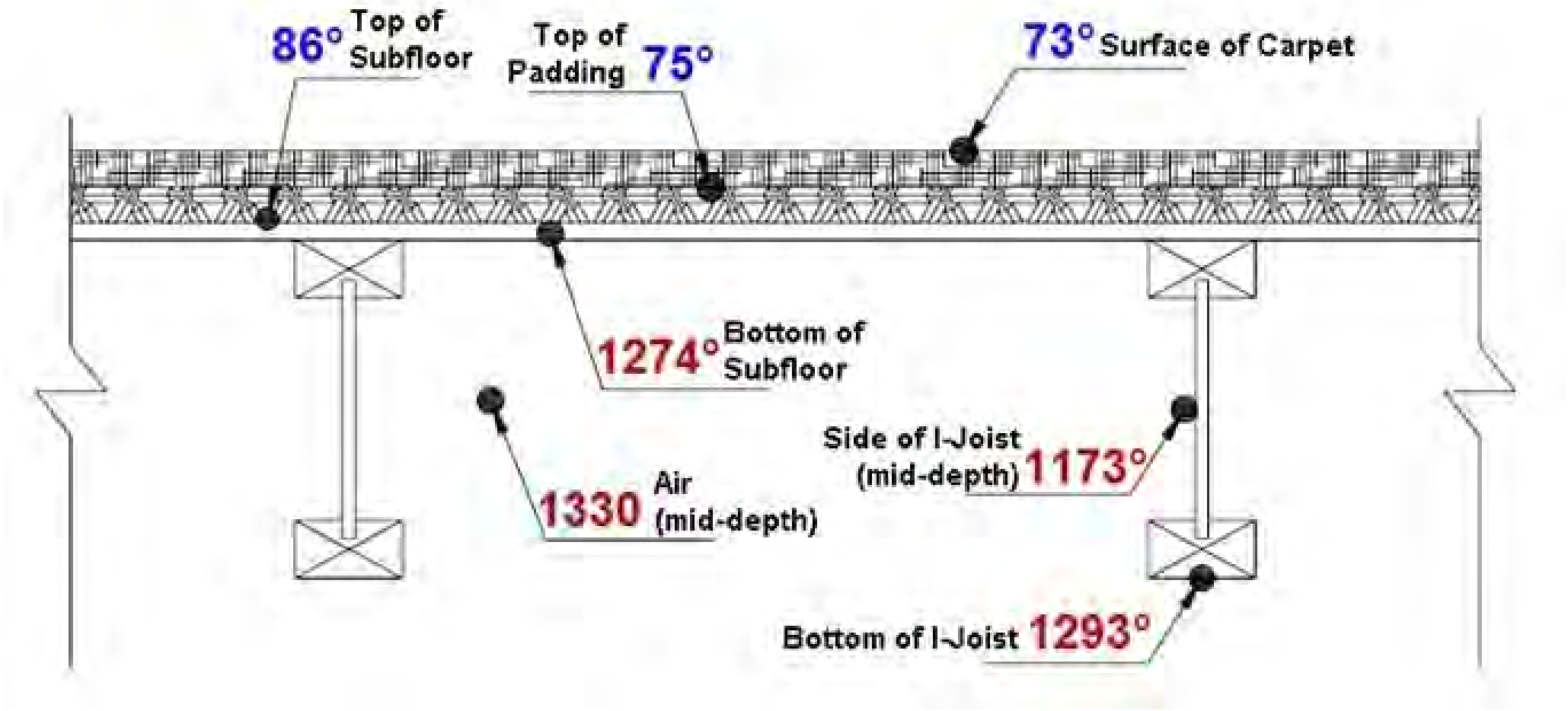
Tendency for joist failure

Lightweight engineered wood I-joist supported floors can collapse after less than 5 minutes of burning.

Floor Support Type	Ventilation Description	Time from ignition of the fuel load to collapse	Time from ignition of floor assembly due to fire spread to collapse
Nominal Dimension 2 x 12	On-plane vent open at ignition	11:09	7:11
Nominal Dimension 2 x 12	On-plane vent open at 8:30 after ignition	12:45	10:45
Lightweight Engineered Wood I-Joist	On-plane vent open at ignition	6:00	2:45
Lightweight Engineered Wood I-Joist	No vent	6:49	4:06
Lightweight Engineered Wood I-Joist	No Vent	8:27	4:42
Lightweight Engineered Wood I-Joist	On-plane vent open at ignition	6:49	2:29

A Thermal Imager is Not an X-Ray Device

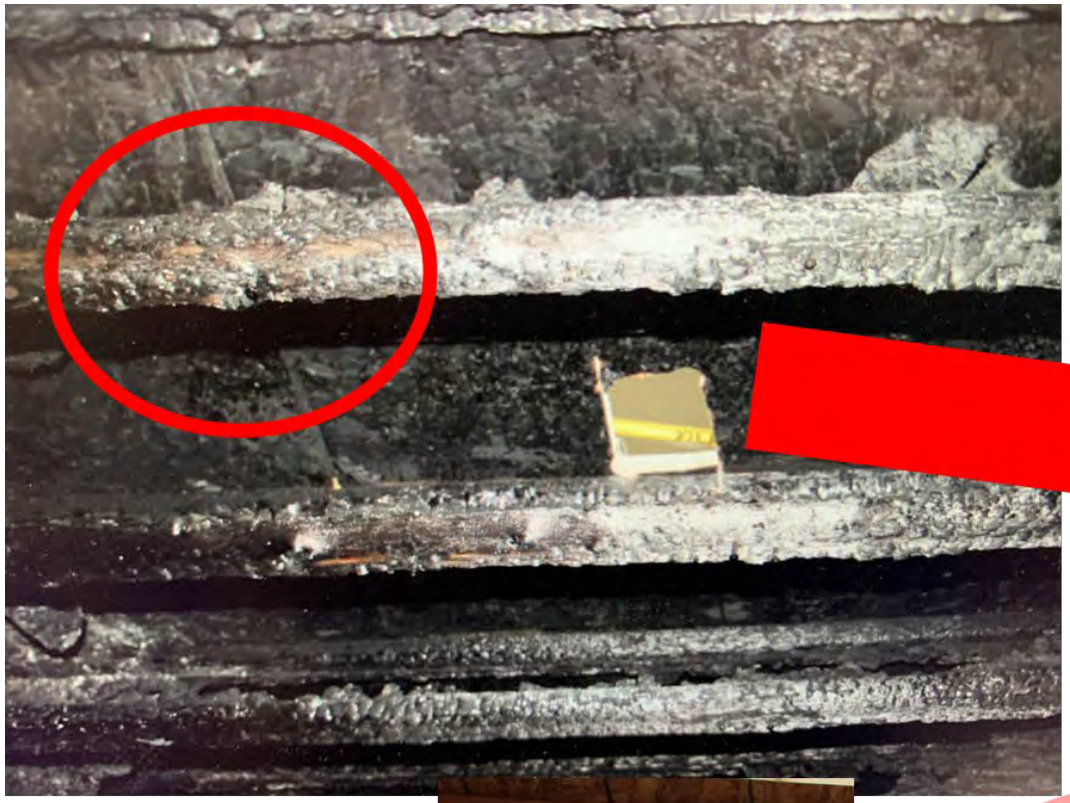
TICs and Floor Collapse




F
1200
900
600
300
2010-06-30 08:40

Looking at the floor, above the basement

Looking at the basement ceiling vs I Joist



Why Sounding is unreliable

Sounding (striking) the floor

Lightweight floor system collapse

Vertical Shafts and Voids

FIRE DEPARTMENT CITY OF NEW YORK

SAFETY COMMAND

INVESTIGATIVE REPORT

BROOKLYN BOX 3-3 2075

10826 AVENUE N, BROOKLYN, NY

APRIL 24, 2022

CASE NUMBER SB 03/22

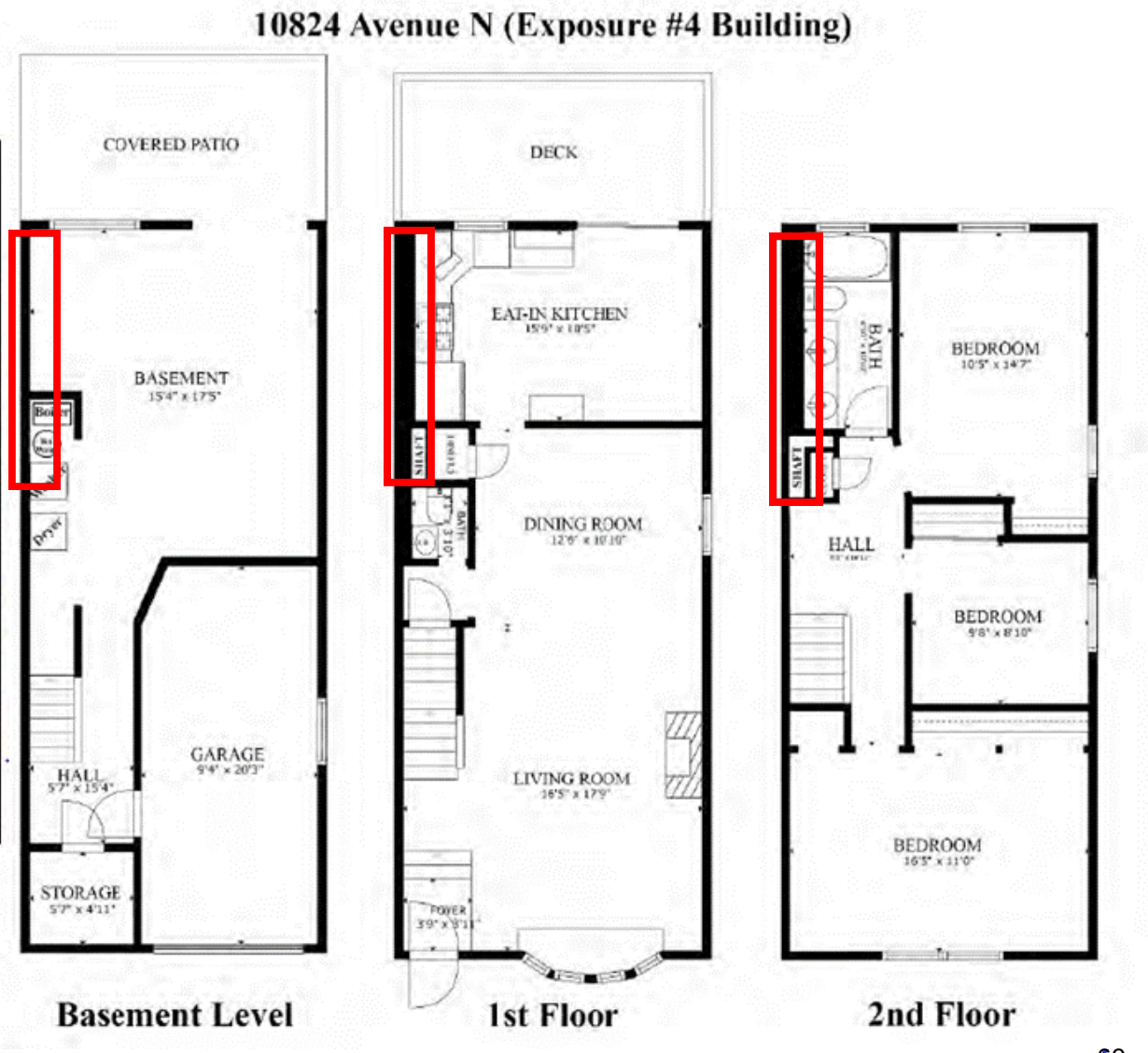
FATAL INJURY

FIREFIGHTER TIMOTHY PATRICK KLEIN

LADDER COMPANY 170

DETAILED TO ENGINE COMPANY 257

Vertical Shafts and Voids



UL Research Institutes

Understanding Flow Paths:

Low-Intake and High-Exhaust

VIDEO

Fire Safety Research Institute

FIRE DEPARTMENT CITY OF NEW YORK

Training resource developed in partnership with FDNY

Subtítulos en español disponibles

HANDOUT

UL Research Institutes

Understanding Flow Paths:
Low-Intake and High-Exhaust

Fire Safety Research Institute

Training resource developed in partnership with FDNY

Subtítulos en español disponibles

Continuing the Conversation

Low-Intake, High-Exhaust Flow Paths

Review the key takeaways about low-intake, high-exhaust flow paths on this side. Use the reflection questions and additional training resources on the reverse side to extend your learning.

KEY TAKEAWAYS

For a low-intake, high-exhaust flow path to occur, three factors must exist:

This type of flow path creates a powerful, unidirectional flow from the fire to the exhaust point. In this scenario, the speed and intensity of fire spread happen too quickly before firefighters operating in the exhaust portion of the flow path can have time to safely exit.

To potentially prevent this fire scenario, perform a 360° size-up to identify:

- The location and extent of the fire
- Current and potential flow paths
- Grade differences that are not obvious from only one side of the structure
- Wind conditions

To successfully operate in these challenging conditions:

- Control flow paths whenever possible
- Operate in the **intake** portion of the flow path and avoid the **exhaust** portion
- Keep the wind at your back
- Fight the fire on its own level

Continuing the Conversation

Low-Intake, High-Exhaust Flow Paths

Use these reflection questions and additional training resources to extend your learning.

REFLECTION QUESTIONS

1. How does your department train on and execute a 360 degree size-up? Who performs the size-up and what are you looking for? How does that information get communicated? If the structure, topography, or incident parameters don't allow you to get a 360, how else can you fill in that picture?
2. In what situations would you consider controlling the exhaust vs. the intake ventilation openings? What tools and tactics does your agency have to achieve flow path control?
3. How would your agency, with its own unique resource and staffing model, coordinate resources to handle a low-intake, high-exhaust flow path scenario?

ADDITIONAL TRAINING RESOURCES

Cherry Road, a townhouse fire in Washington D.C. that claimed the lives of two firefighters, is an example of a low-intake, high-exhaust flow path scenario. Watch the incident video.

Review how wind direction can impact fire development and potentially jeopardize the safety of an advancing crew.

Watch Adam Thiel, former Philadelphia Fire Commissioner, discuss tactical considerations to avoid getting caught in the flow path while fighting a basement fire.

View the Understanding and Fighting Basement Fires summary video to examine the dynamics of below-grade fires and explore the most effective research-based tactics for fighting them.

Key Building Construction/Fire Dynamics Issues

1. Size-up of building
   - –Height, size, stability, number of stories (side A and C)
   - –Occupancy
   - –Construction type (structure as well as interior and exterior finish)
   - –Fire protection systems
2. Size-up of fire in the building
   - –Location and extent of fire
   - –Ventilation-limited fire?
   - –Has the fire vented?
   - –Structural collapse potential
   - –Existing or potential flow paths or paths of fire growth

Water Usage in Multi-Family Dwellings

Early Water Wins (Single 1 ¾” Handline): 185 Gal

Experiment 4: Window Initiated Search, Isolate BR 2

Experiment 4: Pre-Suppression Window Initiated Search


1842

Search Summary

Search Ahead of Suppression:

1. Isolation to the fire compartment was effective at reducing flame spread and toxic/thermal exposure
2. Isolation of searchable spaces was effective at reducing toxic/thermal exposure
3. Ventilation of isolated spaces was effective at improving conditions

Search During or Post Suppression:

1. De-isolation and ventilation was effective at reducing toxic exposure (Get all doors and windows in IDLH open – FAST)

Rescue & Removal Summary

Victim Removal:

1. Lower elevations shown to result in a lower accumulated exposure compared to higher elevations (1 ft vs. 3 ft above the floor)
2. Prior to suppression, delayed removal or alternate pathways (avoid passing fire compartment) reduces exposure

Tactics & Communications

Are your strategies and tactics based on fire dynamics, building construction, PPE capabilities, and experience?

How do you train to improve radio communications?

What’s your approach to this fire?

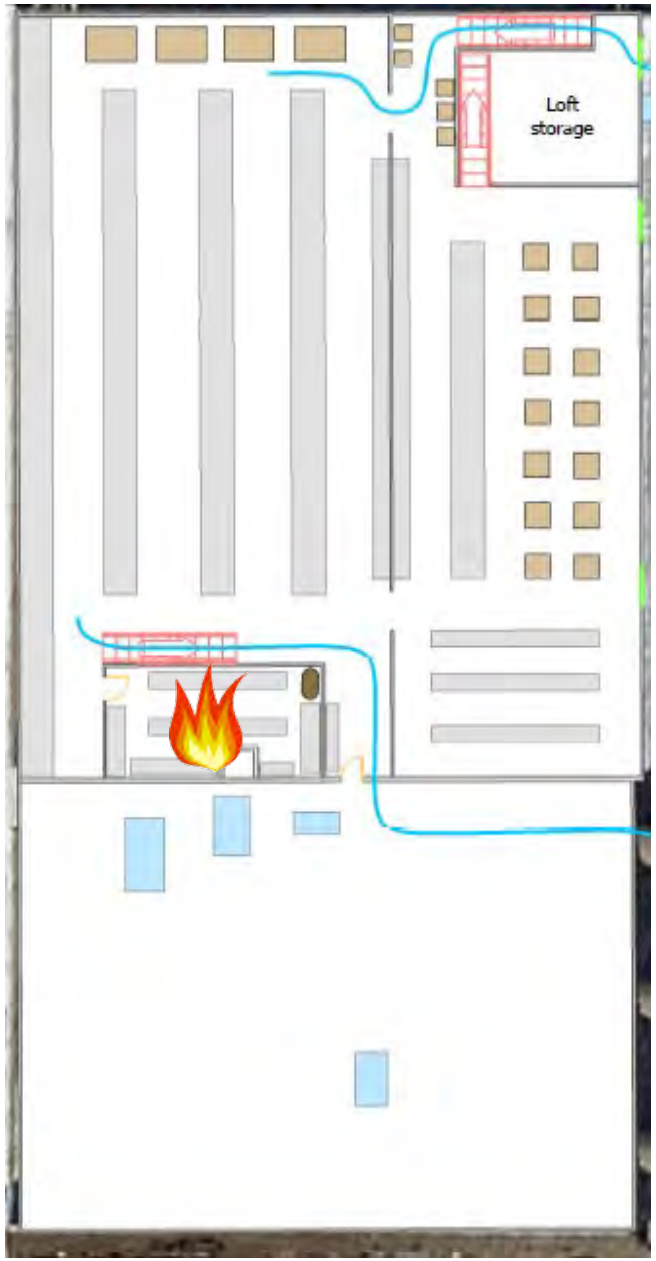
Fire development after interior fire attack and vertical ventilation

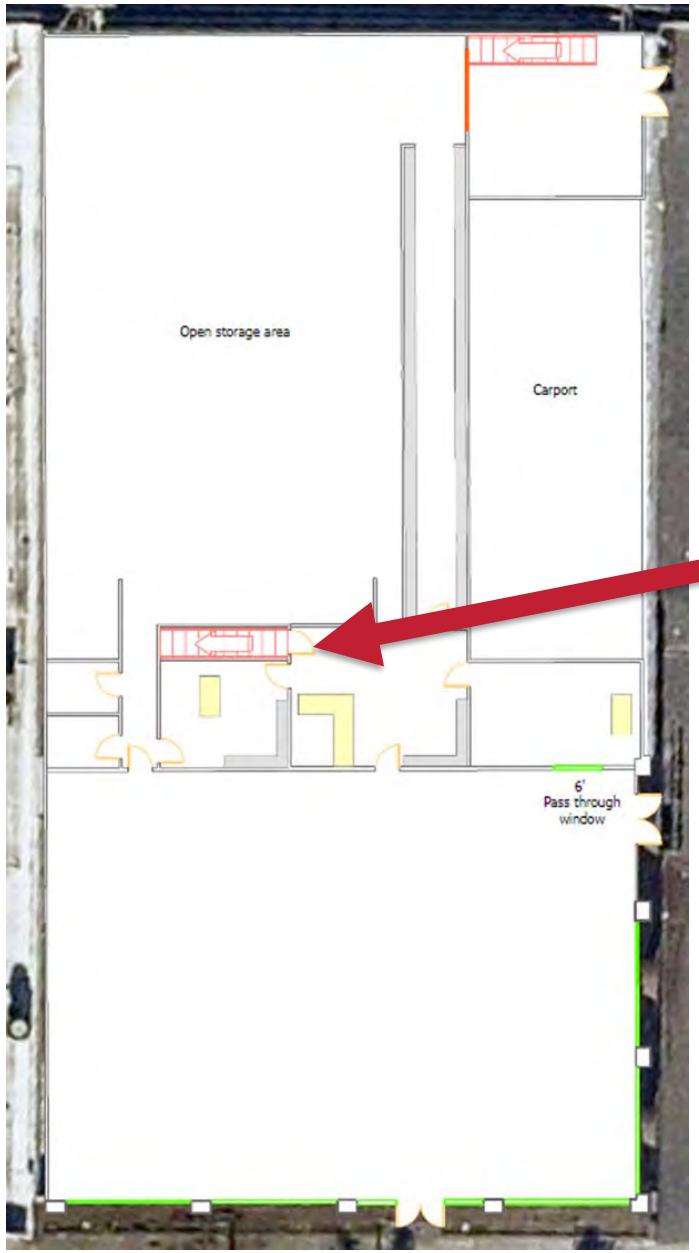
Chula Vista Warehouse Fire Report

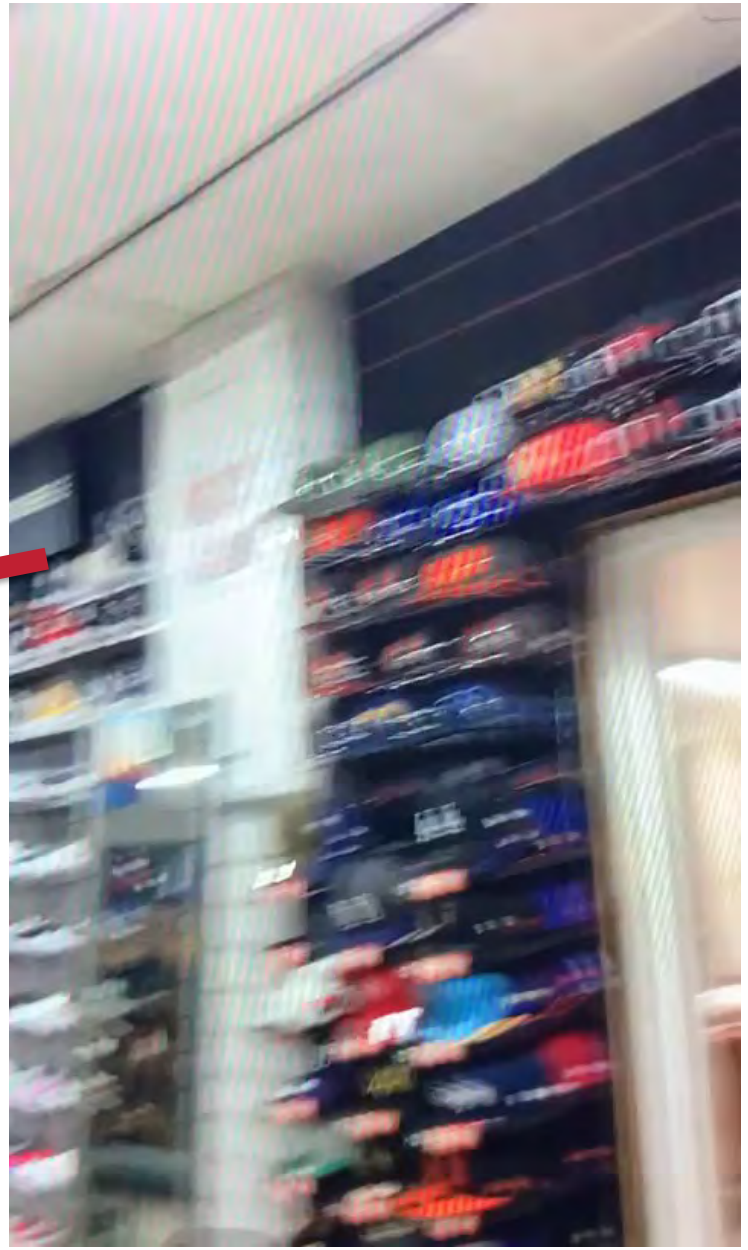
January 25, 2021 @ 1740 Hours

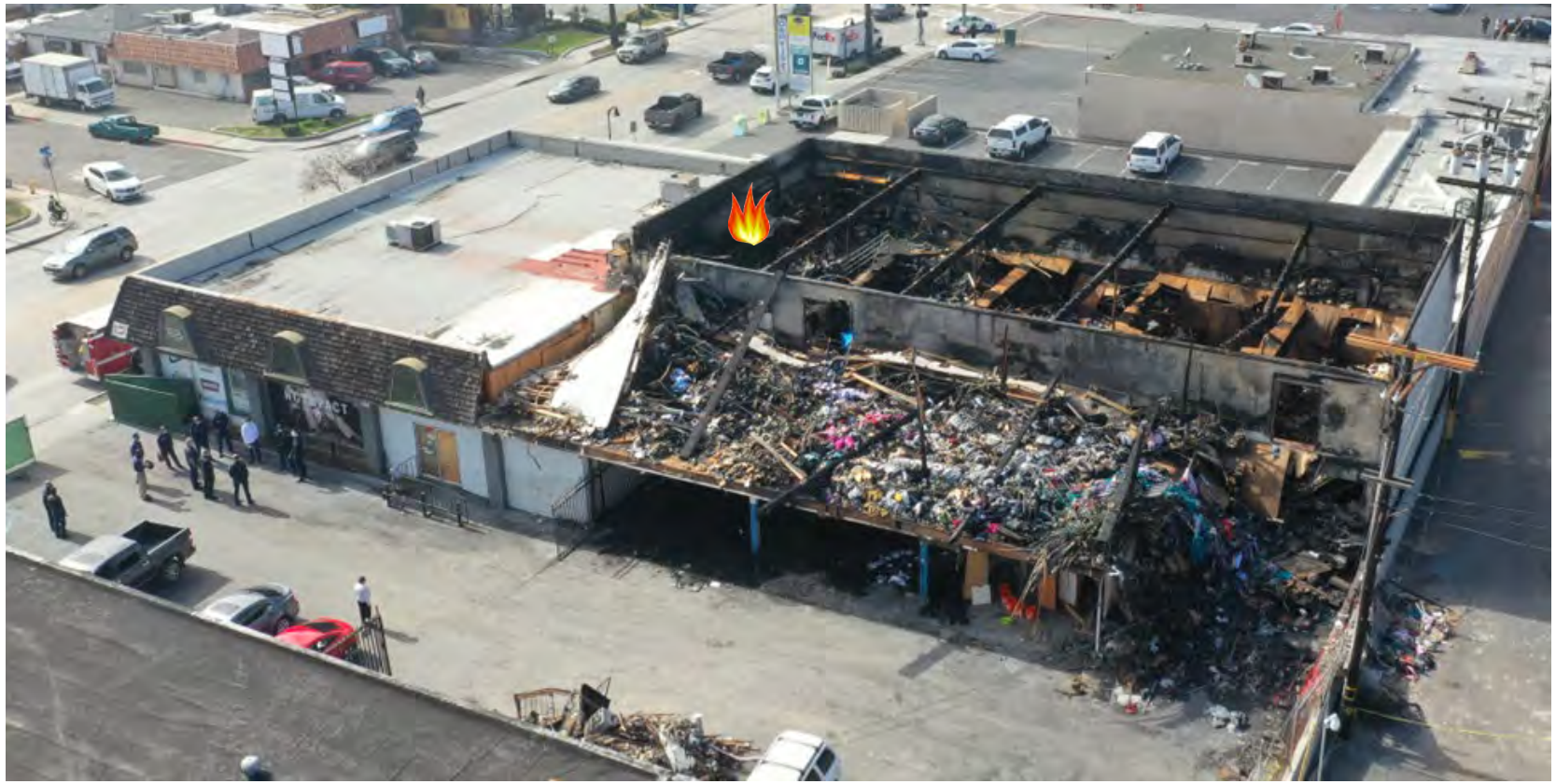
Dispatched for the “fire on the roof” 655 H Street

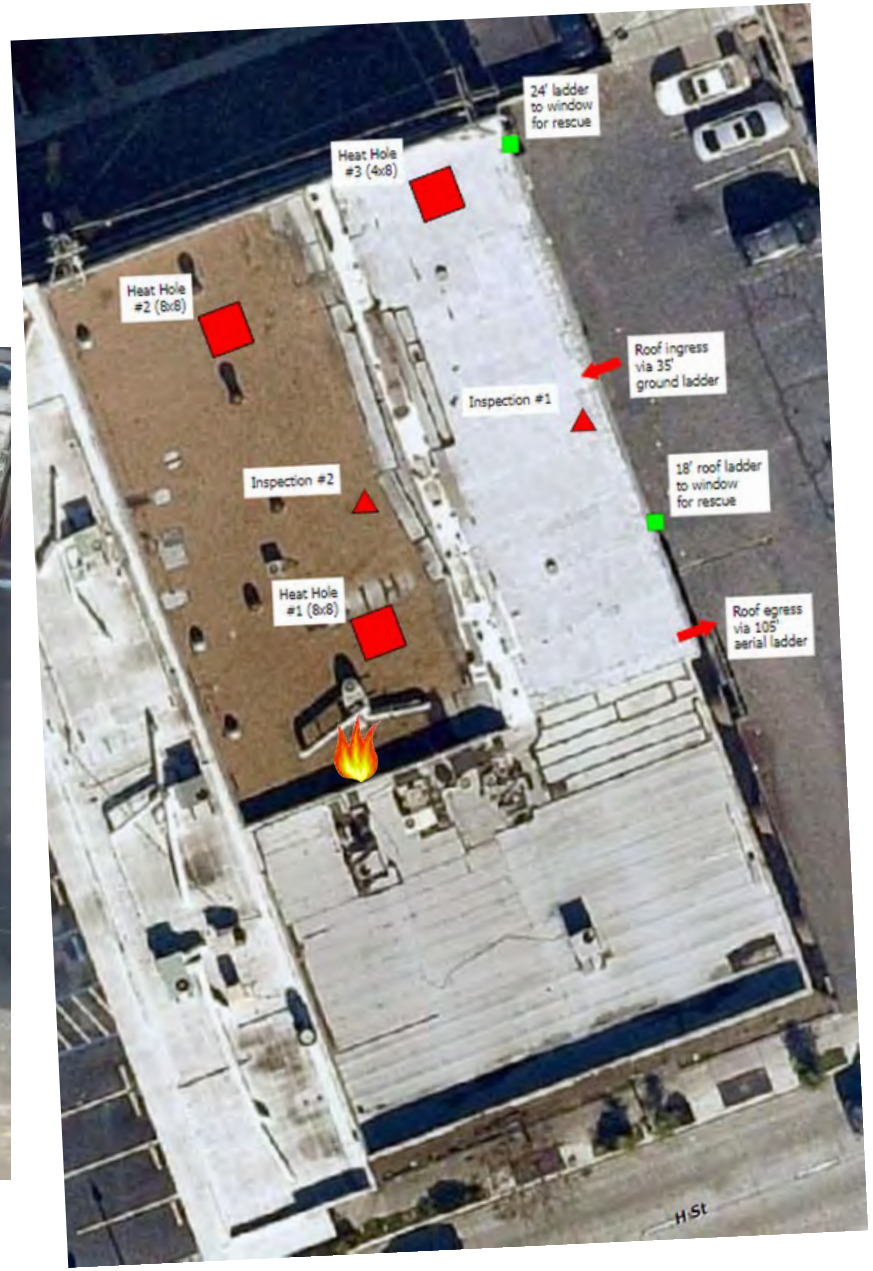
Chula Vista Warehouse Fire


Loft
storage


Open storage area
Carport
6'
Pass through
window






24' ladder to window for rescue
Heat Hole #3 (4x8)
Heat Hole #2 (8x8)
Roof ingress via 35' ground ladder
Inspection #1
Inspection #2
18' roof ladder to window for rescue
Heat Hole #1 (8x8)
Roof egress via 105' aerial ladder
H St

Contributing Factors

Warehouse Construction

Building Occupancy

Situational Awareness

Flow Path Control

Tactical Considerations

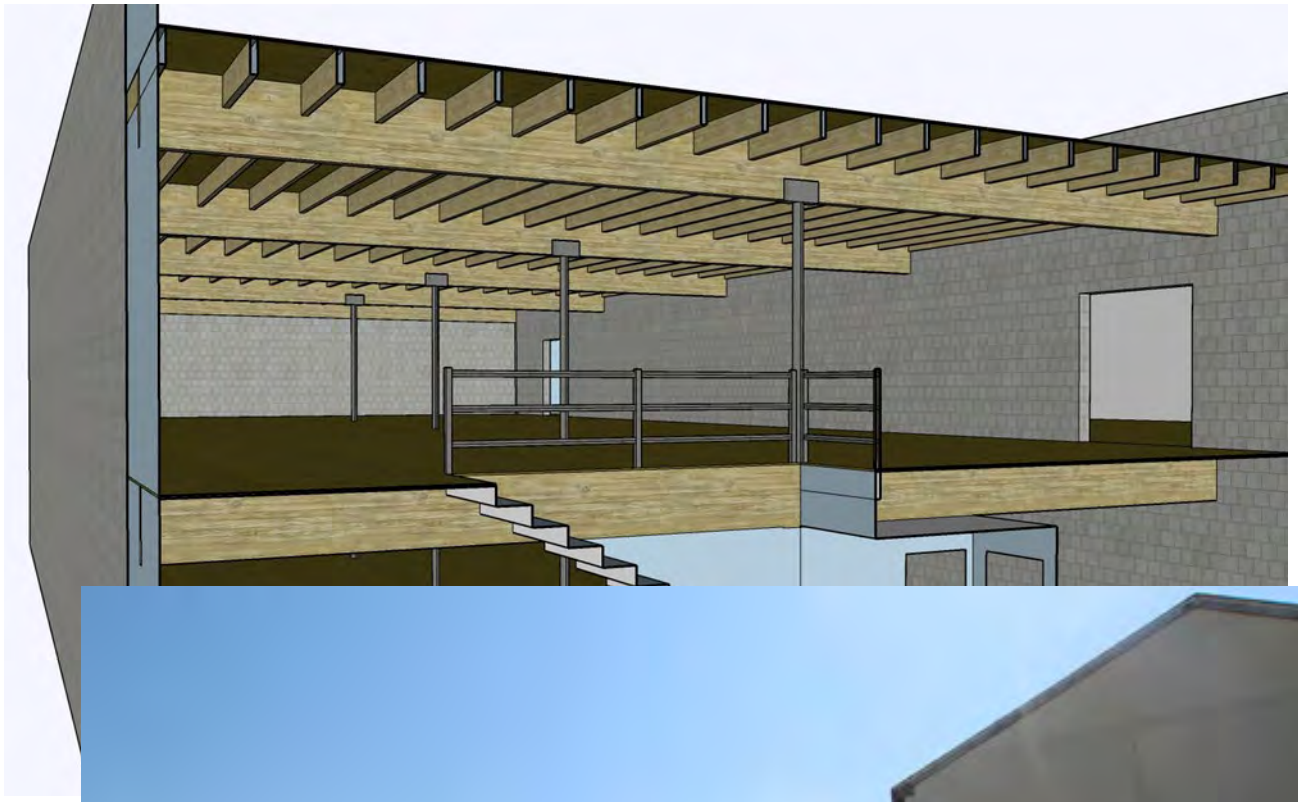
Commercial Building Size-Up

Suppression Fundamentals

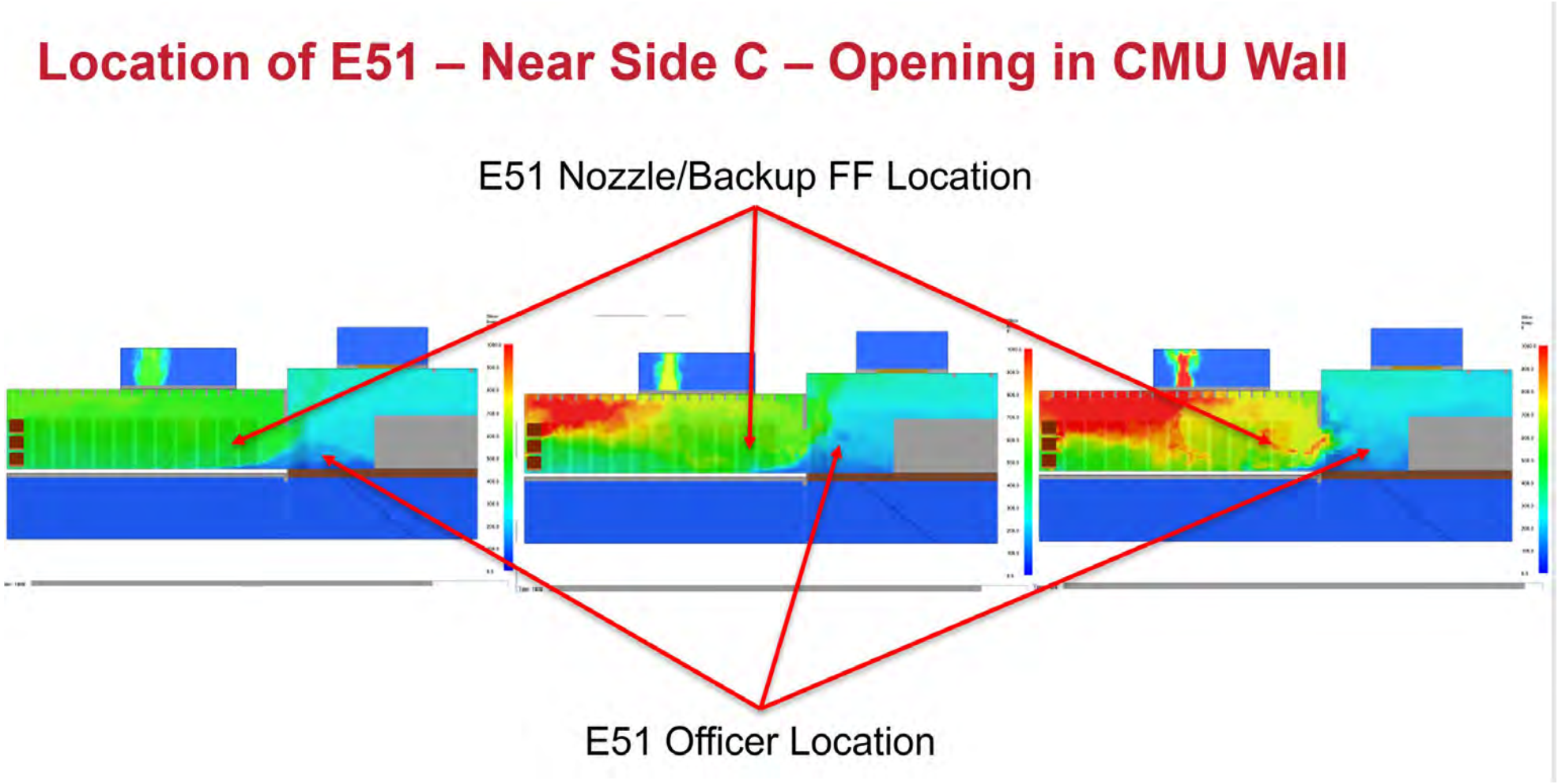
Fireground Coordination & Accountability

Thermal Operating Environments & Personal Protective Equipment (PPE)

Thermal Imager Usage & Limitations

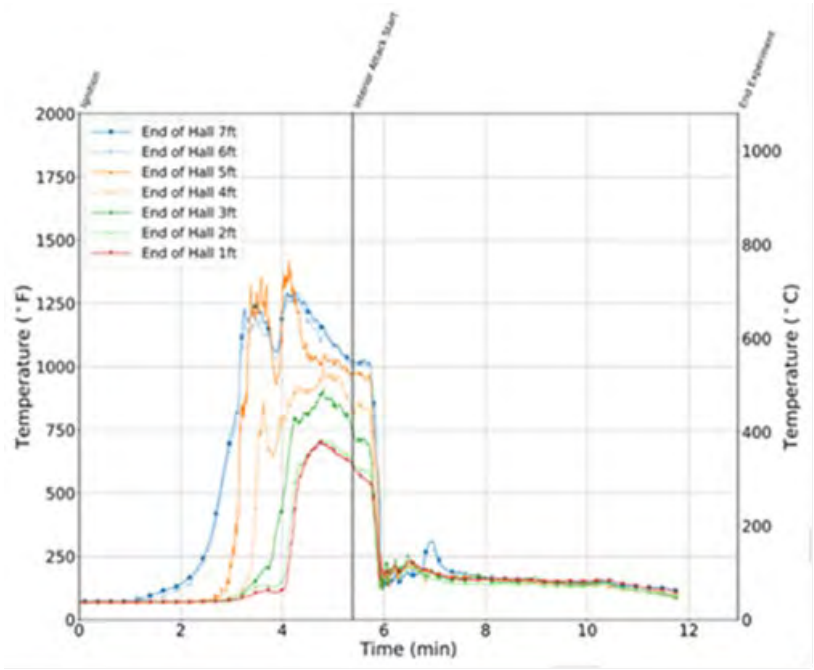


Understand Thermal Imager Capabilities & Limitations

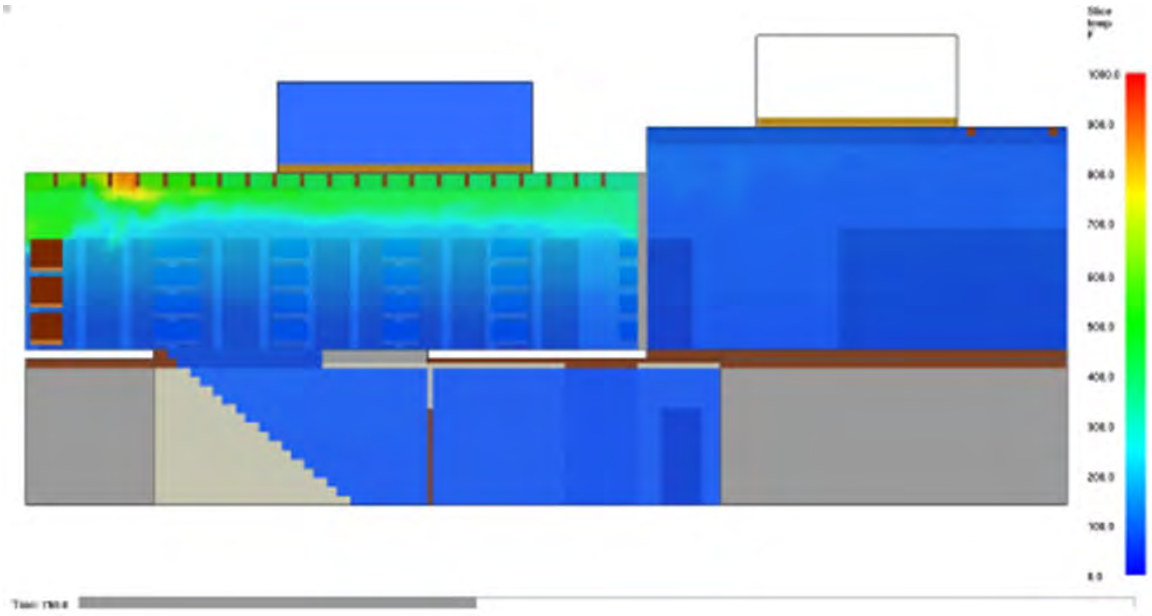


Interior Visibility: Just Inside Front Door

A thermal imager is an unreliable thermometer

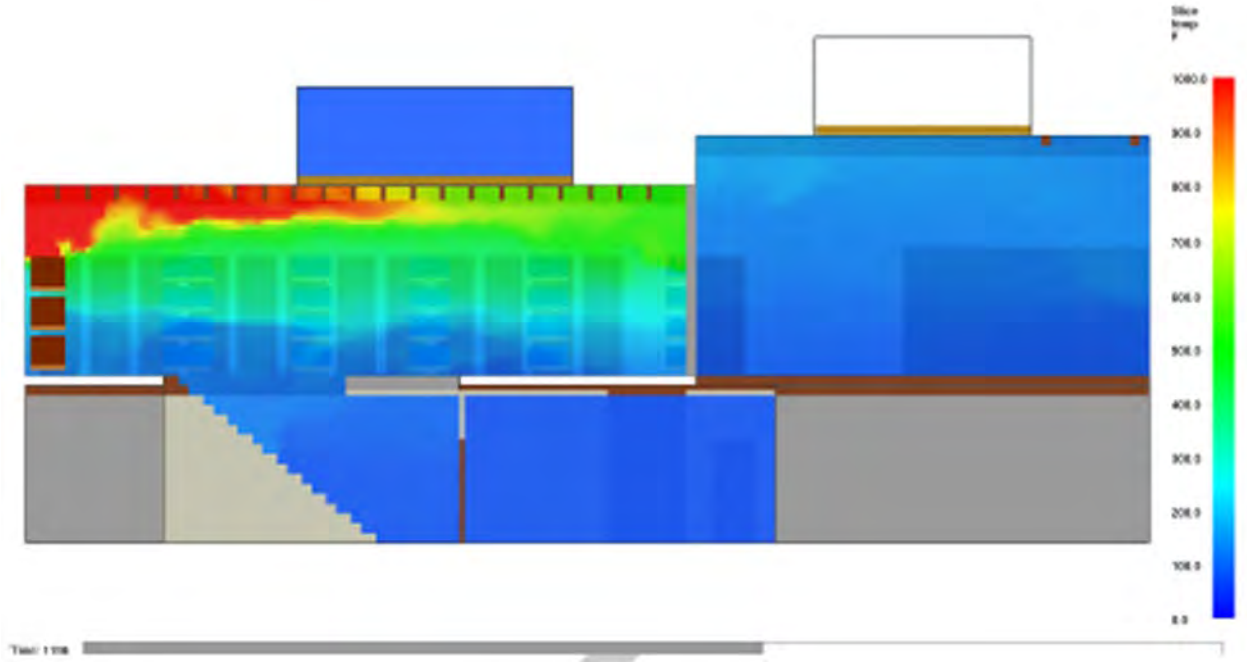


Flow Path Control – Office Door – Close Intake

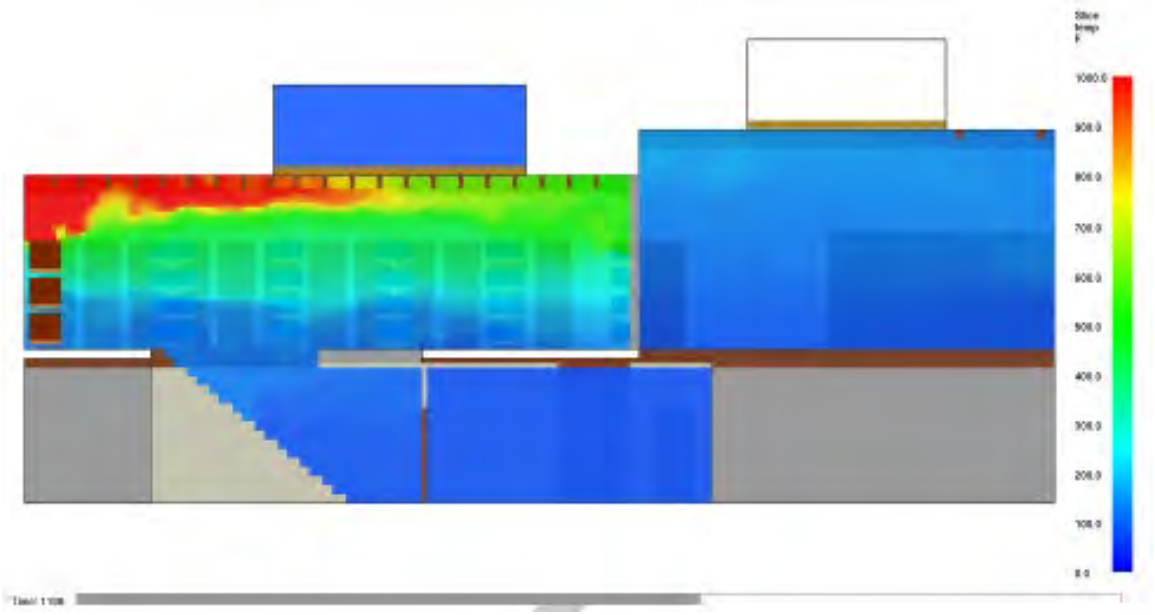


Temperature (Fire Growth) Prior to
FF's Opening Office Door to 2nd Floor

Temperature (Fire Growth) After FF's
Opened Office Door to 2nd Floor

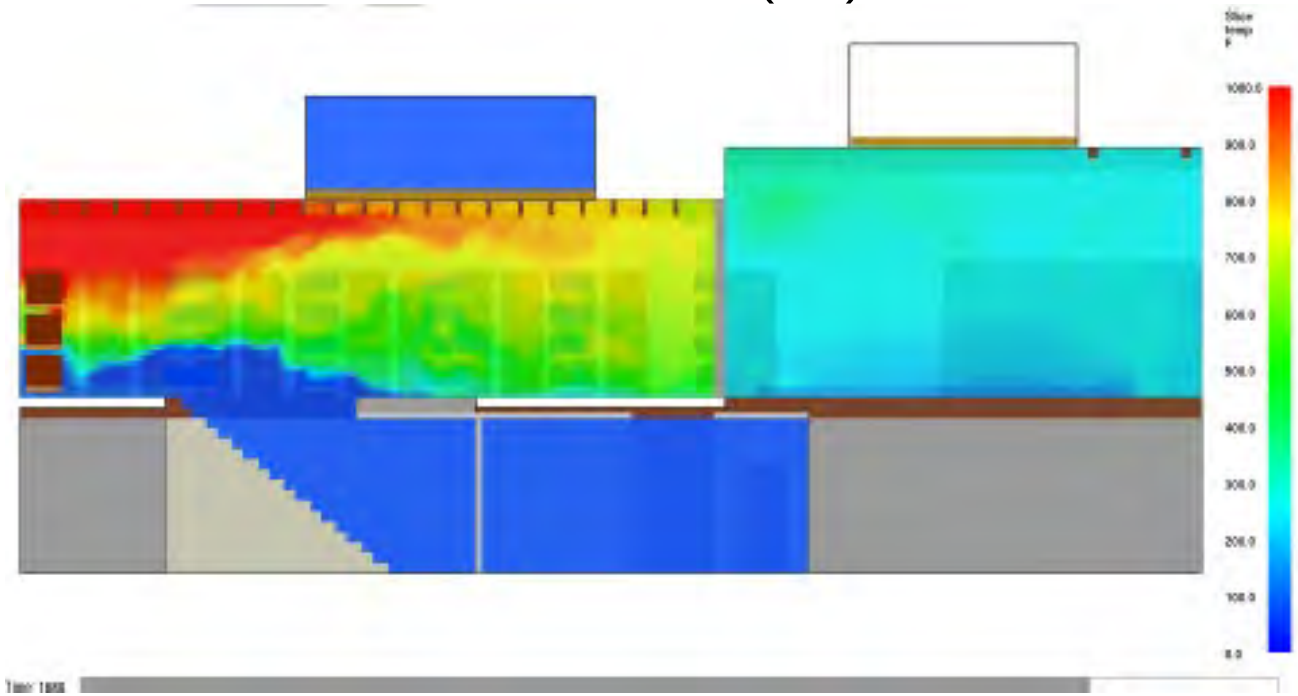


Flow Path Control – First Offensive Heat Hole



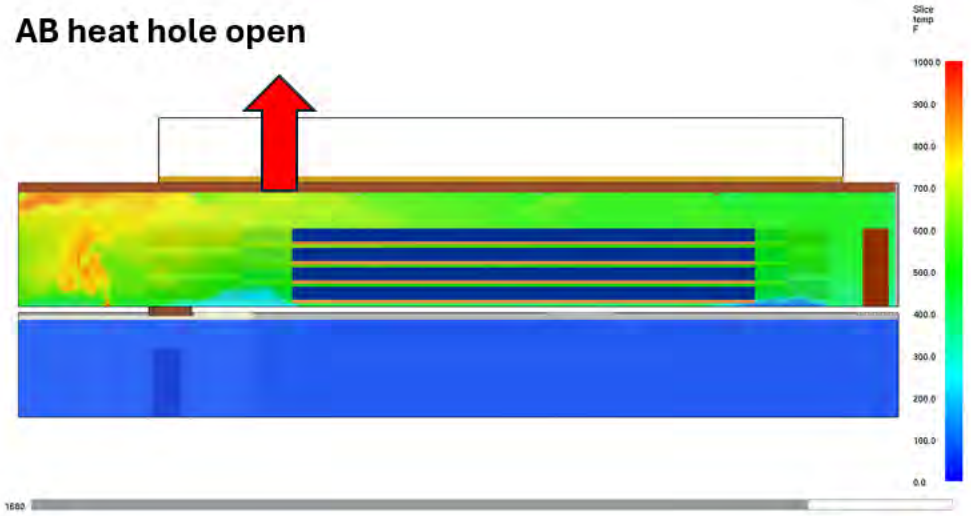
Temperature (Fire Growth) Prior to FF's Opening First Offensive Heat Hole (AB)

Temperature (Fire Growth) After FF's Opened First Offensive Heat Hole (AB)

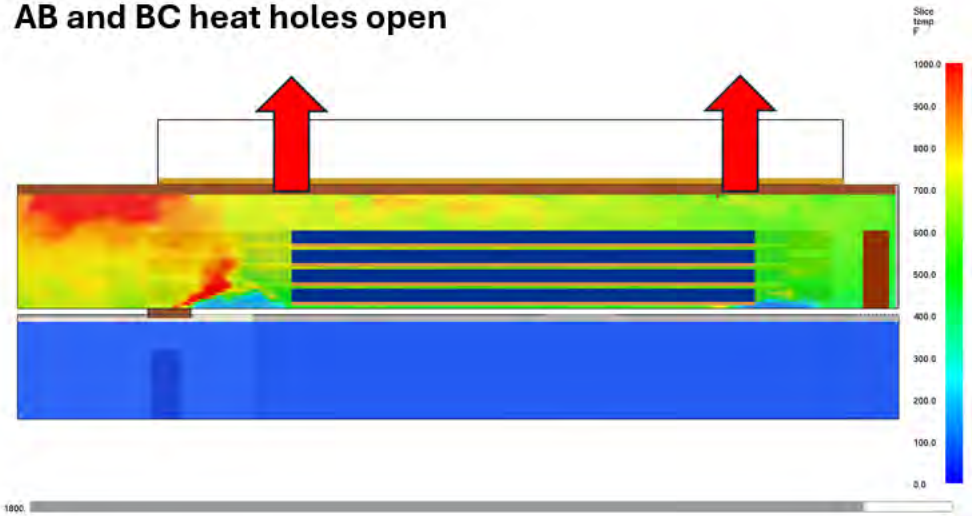


Impact of ventilation of a ventilation limited fire w/o effective suppression

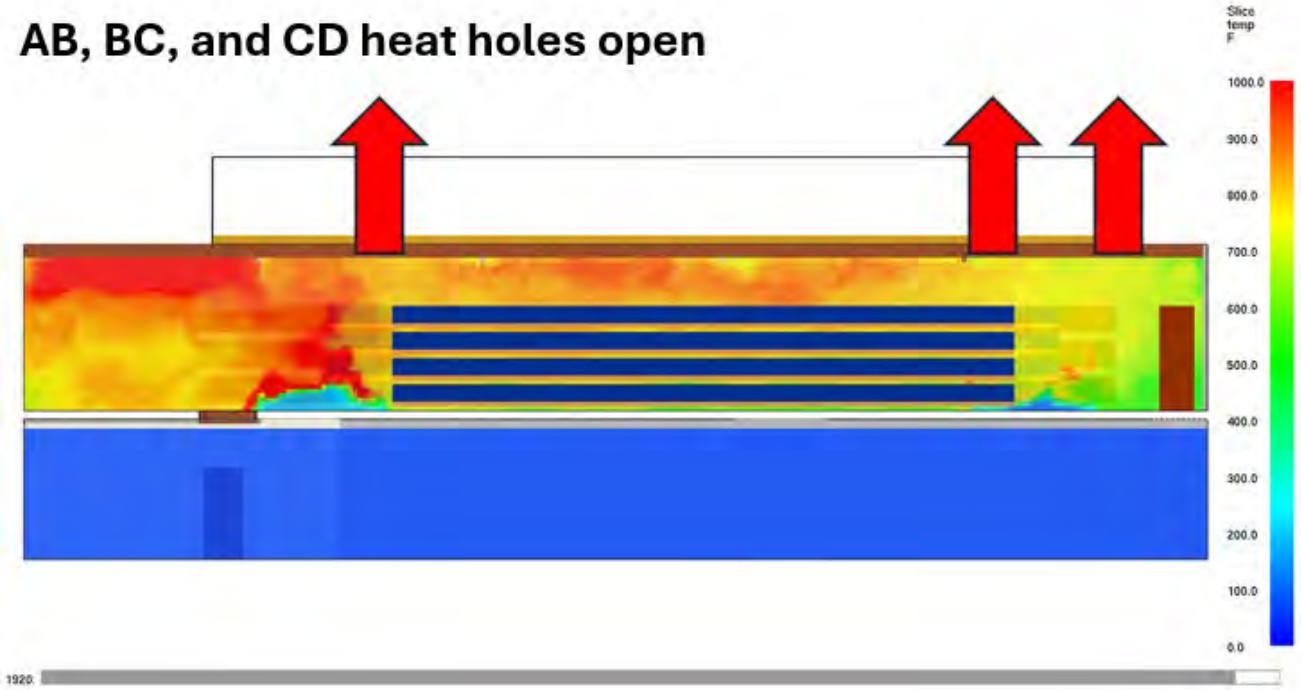
AB heat hole open



AB and BC heat holes open



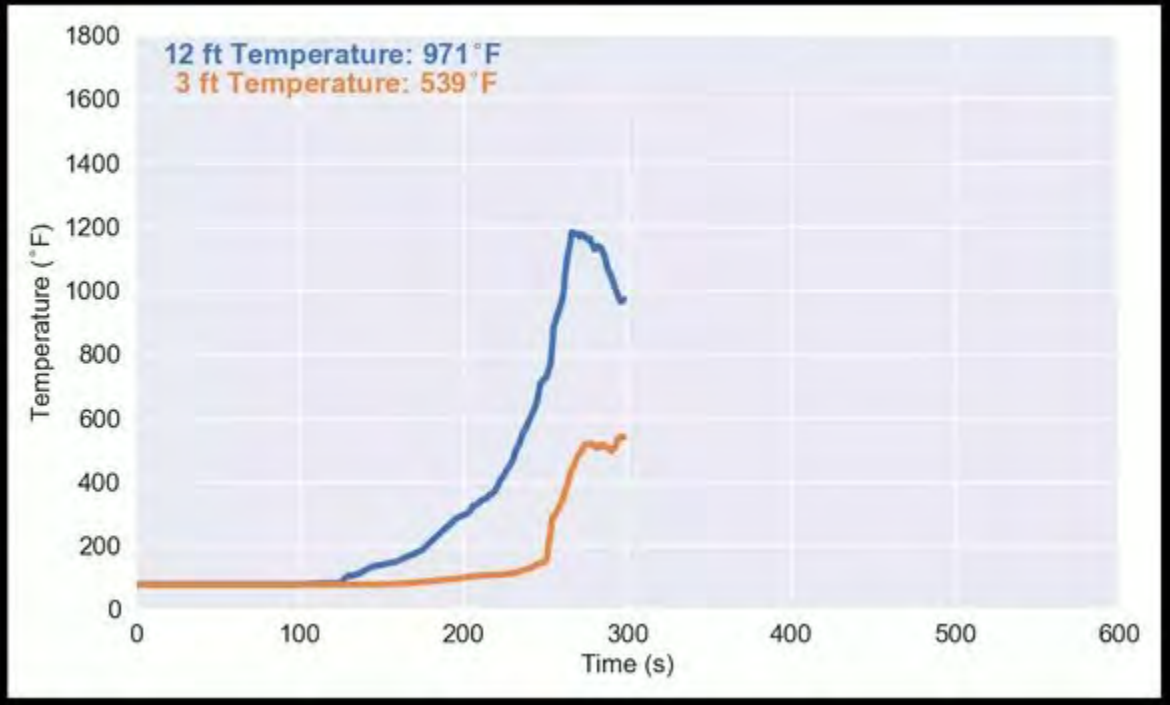
AB, BC, and CD heat holes open



Uncoordinated Fire Attack

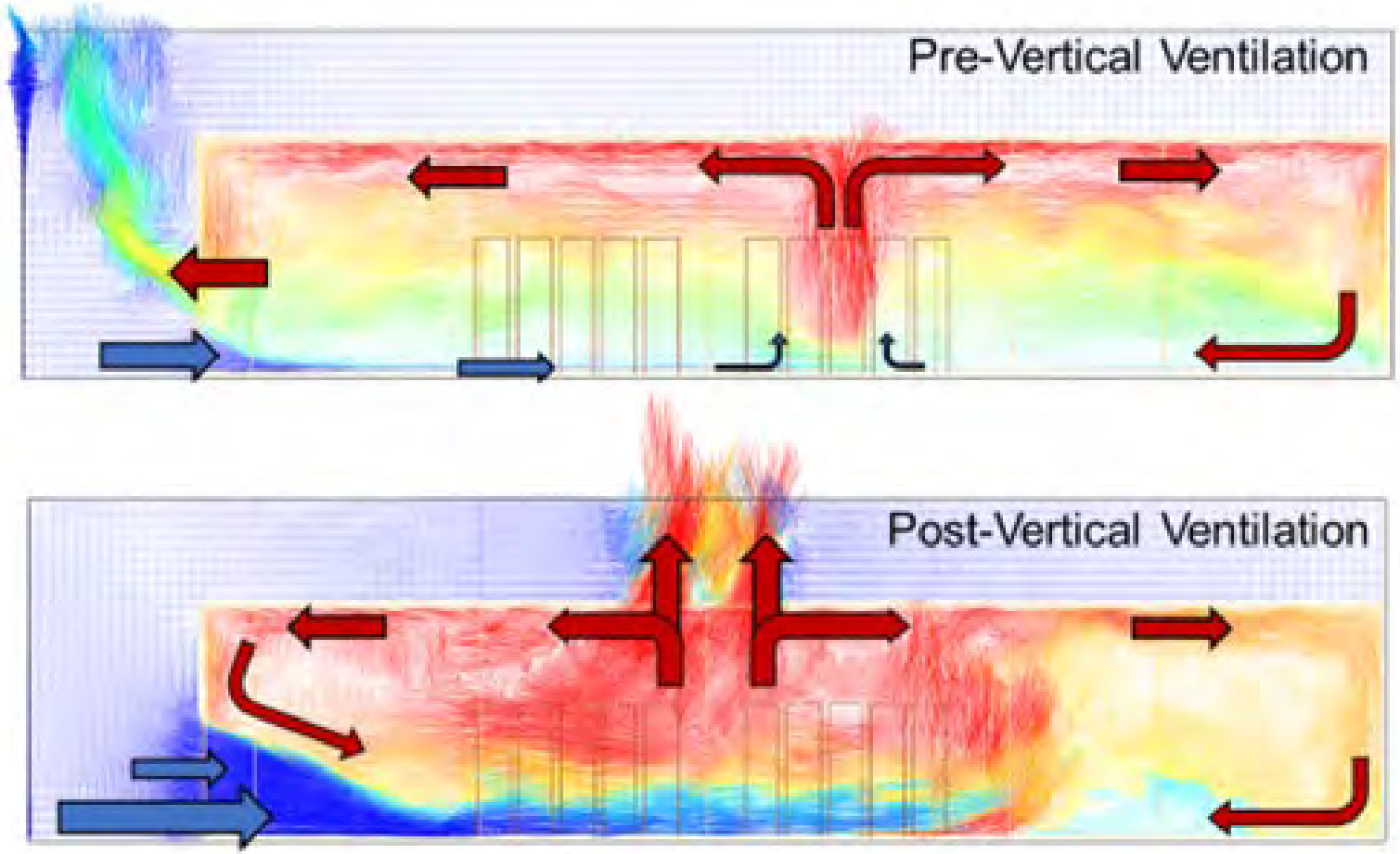
Total Vertical Ventilation: 0 ft²

Time From Ignition: 05:00

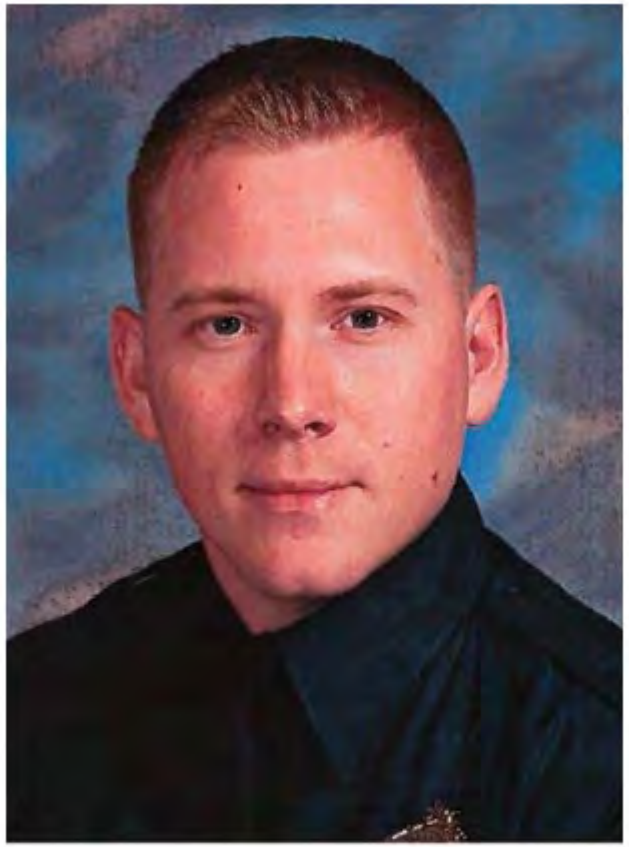


No smoke flow out of the door ≠ to lift
It could be a reversal of flow

Impact of ventilation



Strip Mall Fire LODD



Firefighter Scott P. Deem, 31
San Antonio Fire Department

2017
14

Death in the line of duty...

National Institute for Occupational Safety and Health
NIOSH

A report from the NIOSH Fire Fighter Fatality Investigation and Prevention Program *August 13, 2018*

Career Fire Fighter Dies and Another is Seriously Burned Fighting Arson Fire at a Commercial Strip Mall — Texas

Executive Summary

On May 18, 2017, a 31-year-old male career fire fighter died after fire conditions rapidly deteriorated inside a commercial strip mall. Ladder 35 was the first-apparatus on-scene at 2117 hours. The Ladder 35 captain sized up the scene, assumed incident command, and directed Engine 35, the first arriving engine company, to pull a pre-connected hose line while the two Ladder 35 fire fighters forced open the front entrance door to a fitness center where smoke was showing. The Ladder 35 captain directed the Engine 35 lieutenant to take the charged hose line inside for

Street view of commercial strip mall where 31-year-old career fire fighter died.
(Photo adapted from Google Earth Street View)

Four minutes after arrival of Ladder 35 (first apparatus)

	2121:18	Engine 35 officer radios command that there is zero visibility with heavy smoke coming from front door. Requests ventilation be set up.
	2121:28	Command (Ladder 35 captain) advises Dispatch that Engine 26 is searching computer store on Side Delta exposure.
Dispatch advises Command – 10 minutes into event.	2121:59	

Within 7 minutes after arrival of Ladder 35 Uncoordinated ventilation

The Engine 35 crew (lieutenant and 2 fire fighters) slowly advanced their hose line through the front door and turned to the right.

The fire fighters interviewed by NIOSH reported the smoke was much thicker and they felt increased heat conditions when they reentered the front door. They were only able to advance inside the structure about 10 – 15 feet due to the smoke, heat, and exercise equipment restricting movement of their hose line.

Engine 35 fire fighters reported that their thermal imager screen whited out as they advanced inside.

The Ladder 35 fire fighters advanced past the Engine 35 hose line crew and made their way toward Side Charlie where they began opening up ceiling tiles looking for the seat of the fire

	2124:32	Ladder 35 Fire Fighter 2 (injured FF) radioed Command "**We have found the fire, the fire is in the attic, have the motor crew do a right hand search and bring the nozzle back here to us.**" Ladder 35 captain acknowledges.
	2125:13	Battalion Chief 3 advises Ladder 35 captain that he has Command now and the captain can go meet up with his crew. Battalion Chief 3 advises Aerial Platform 32 to set up behind Engine 26.
Fire through roof at rear of structure.	2125:37	Engine 44 radios Command – "We're back here behind the building with fire through the roof. We can open a door and put a line on it." Command advises Engine 44 to open the door but don't put any water on fire because he doesn't want to push the fire back onto the crews inside.
Heavy smoke, zero visibility, high heat.	2126:13	Engine 35 Lieutenant advises Command that there are lightweight trusses in the roof, there is zero visibility inside, zero ventilation going on and lots of heat inside.

UL Research Institutes

Within 11 minutes after arrival of Ladder 35

Fire burning in concealed cockloft exposing roof support system.	2127:14	Engine 35 officer advises Command that there is zero visibility inside and the fire is in the roof where the trusses are.
	2127:27	Command radios Engine 35, Engine 26, Engine 27 and Ladder 35 and says – "If you are inside I want you to come out till they get ventilation started. Command radios Engine 44 to open up the back so they can see what they have.
	2128:16	Ladder 35 Fire Fighter 2 (injured FF) – "MAYDAY, MAYDAY."

Failure of Fire Dynamics Training for the Fire Service ?

15 minutes on the fireground – ventilation but no effective water flowing

	2129:40	Ladder 35 Fire Fighter 2 (injured FF) radios "MAYDAY… somebody break windows. I can't get out of here."
	2130:38	Command asks Engine 27 if they can go inside for RIT.
	2130:49	Engine 27 officer radios they are RIT looking for missing Ladder 35 fire fighter.
Door at rear (Side Charlie) of fire building open, heavy smoke inside, zero visibility inside. Line is in place but not in operation.	2132:51	Engine 44 advises Command that they have opened door at Side Charlie, have heavy smoke and zero visibility inside, and have a line down and are waiting for orders.

NIST SP1118: Technical Study of the Sofa Super Store Fire - South Carolina, June 18, 2007

“Meanwhile, the fire at the back of the main showroom and the gas mixture below the suspended ceiling were both still fuel rich. When the front windows were broken out or vented, the inflow of additional air allowed the heat release rate of the fire to intensify rapidly and added air to the layer of unburned fuel below the suspended ceiling enabling the ignition of the unburned fuel/air mixture. The fire swept from the rear to the front of the main showroom extremely quickly, and then into the west and east showrooms. Nine fire fighters were killed in the Sofa Super Store fire. “

UL Research Institutes

Sequence from 1935 to 1938 hours

Main Takeaways: For a Ventilation Limited Fire

Pre-suppression ventilation should be limited, potentially to the fire compartment only, and closely timed with the beginning of suppression.

Post-suppression ventilation should be focused on the areas of greatest hazard for potentially trapped occupants to remove the continued exposure to fire gases.

Main Takeaways: Strategy, Tactics, and Tasks

- Size up is critical especially when it comes to Existing Flow Paths → Potential Flow Paths (need info from all sides)
- Ventilation limited fires – nothing showing means nothing
- Impact of ventilation on a vent limited fire = Increased Growth (HRR)
- Water on the fire, ASAP from a position of advantage

Fire dynamics knowledge is needed to understand observations

Proper PPE can reduce chemical exposure.

Actions after the incident can reduce it even further.

After the Fire – Contamination Reduction

- PPE – Preliminary Exposure Reduction
  - Soapy brush and water rinse removes 85% of **surface** PAHs
  - Laundering recommended as soon as possible

- Skin
  - Use **cleansing wipes** on scene for neck, face, and hands
  - Take a **shower ASAP**

Proper PPE Use and Doffing Reduces Exposure

- Wear full PPE throughout the incident – including during overhaul

- Treat exposed gear as contaminated
  - Perform Preliminary Exposure Reduction
  - Doff gloves and hood properly
  - Launder gear as soon as possible

- Clean skin ASAP
  - Wipe neck and hands on-scene
  - Shower and wash hands as soon as possible

Evidence-Based Considerations for Your Fireground Playbook

A modern guide designed to help you build a customized, effective fireground strategy.

- Clear, proven strategies, built for the fireground, to help firefighters make the right decisions at the right time.
- Covers best practices, strategic considerations, and training considerations for every stage of response.
- Built on a flexible framework, adaptable to your department's staffing and resources.

Progress doesn't happen by accident, it happens by action.
Let's get to work.

FSRI

Fire Safety Academy
Free, online training for the fire service

Backed by Research
Grounded in the latest research and developed with the fire service.

Learn Anywhere, Anytime
Access user-friendly courses on demand, from anywhere.

Seamless Integration
Easily integrates with your existing programs for a continuous stream of applicable training.

Free Unlimited Access
Our entire resource library is offered at no cost to you and your department.

Get started at **training.fsri.org**

FSRI
FIRE SAFETY ACADEMY

Stay connected with FSRI

@fsri.org

@ulfsri

@fsri-org

@firesafetyresearchinstitute

UL Research Institutes

Fire Safety Research Institute

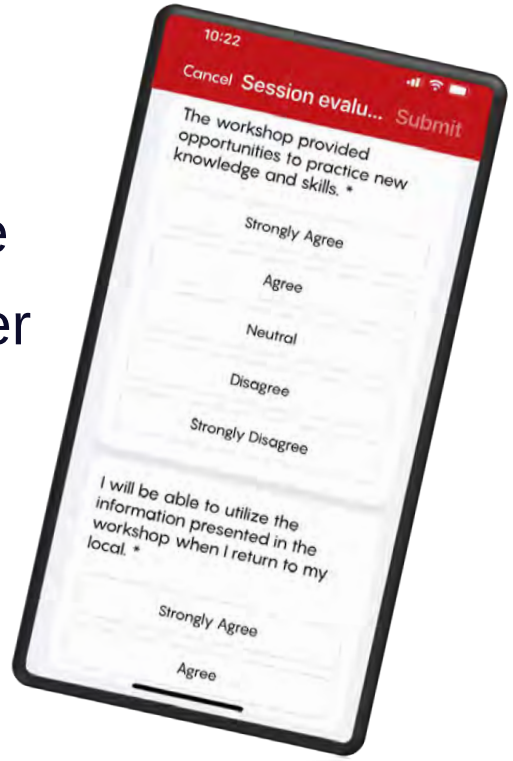
THANK YOU!
ANY QUESTIONS?

Daniel Madrzykowski

Daniel.Madrzykowski@ul.org

EVALUATION AND WIN AN IPAD!

- **Submit your workshop and overall evaluations to be automatically entered in two drawings for a new iPad!**
- **Complete your evaluations using the IAFF app:**
  1. Download the IAFF app and sign in with your iaff.org username
  2. Tap the 2026 Strive for Excellence Summit event image to enter the event's dashboard
  3. Tap "Sessions" and tap on the workshops you attended
  4. Tap "Evaluation" and complete the evaluation
  5. Tap "Submit"



For the event's overall evaluation, follow steps 1 and 2, then tap "Event Evaluation" located in the event's Dashboard.