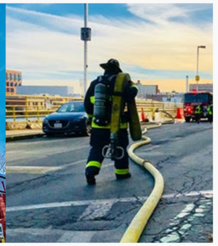
A. MICHAEL MULLANE HEALTH AND SAFETY SYMPOSIUM

Addressing the Occupational Hazards Facing Fire Fighters

May 8-9, 2019







BOSTON FIRE DEPARTMENT, BOSTON FIREFIGHTERS, LOCAL 718 AND THE INTERNATIONAL ASSOCIATION OF FIRE FIGHTERS

2019 A. MICHAEL MULLANE HEALTH AND SAFETY SYMPOSIUM

Fireground Exposure Risks … What Steps Can We Take?

Gavin Horn

Director of Research Programs, IFSI Research

May 8, 2019

IFSI
RESEARCH

AFG FIRE PREVENTION & SAFETY GRANTS

National Institute for Occupational Safety and Health
NIOSH

GLOBE

UIC
UNIVERSITY OF ILLINOIS AT CHICAGO

FIREFIGHTER SAFETY RESEARCH INSTITUTE
SCIENCE EXPERIENCE KNOWLEDGE

SKIDMORE
COLLEGE

Project Components

Fire Dynamics

Thermal & Cardiovascular Strain

Chemical Exposures

Firefighter Health & Safety Risks

- Cardiac events are a leading cause of duty-related deaths and are far more likely to occur after fire suppression activity.
  - Firefighting leads to significant cardiovascular strain.

- Firefighters have an increased risk for several types of cancer.
  - Fires produce hundreds of toxic compounds. Some are carcinogenic.

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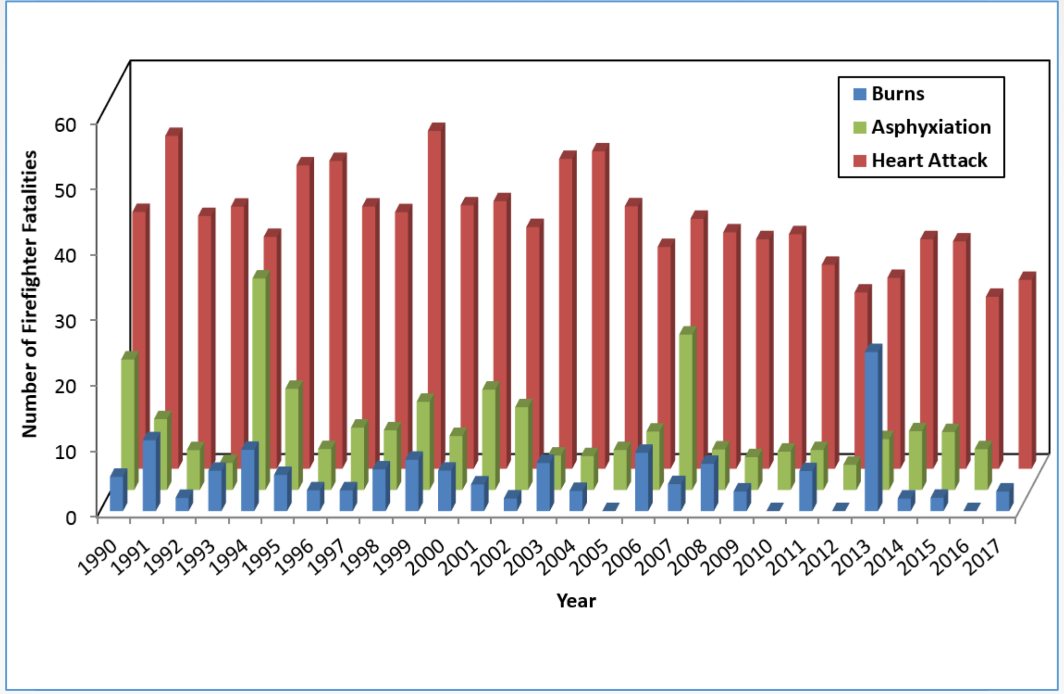

***NFPA Journal* (1991-2018)**

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  - Firefighting leads to significant cardiovascular strain.

- Firefighters have an increased risk for several types of cancer.
  - Fires produce hundreds of toxic compounds. Some are carcinogenic.

Excess Cancer Risk[1]

Outcome	Obs	Mortality SMR[3] (95% CI)	Obs	Incidence SIR[4] (95% CI)
	12,028	0.99 (0.97, 1.01)	NA	NA
All Cancers	3,285	1.14 (1.10, 1.18)	4,461	1.09 (1.06, 1.12)
Esophagus	113	1.39 (1.14, 1.67)	90	1.62 (1.31, 2.00)
Intestine	326	1.30 (1.16, 1.44)	398	1.21 (1.09, 1.33)
Lung	1,046	1.10 (1.04, 1.17)	716	1.12 (1.04, 1.21)
Kidney	94	1.29 (1.05, 1.58)	166	1.27 (1.09, 1.48)
Oral cavity[2]	94	1.40 (1.13, 1.72)	174	1.39 (1.19, 1.62)
Mesothelioma	12	2.00 (1.03, 3.49)	35	2.29 (1.60, 3.19)

1. Cancers with statistically significant excesses in mortality and incidence with U.S rates referent (Daniels et al. Occup Environ Med 2014; 71(6): 388-397).
2. Oral cavity includes lip (excluding skin of the lip), tongue, salivary glands, gum, mouth, pharynx, oropharynx, nasopharynx, and hypopharynx
3. SMR = standardized mortality ratio
4. SIR = standardized incidence ratio

Excess Cancer Risk[1]

Outcome	Obs	Mortality SMR[3] (95% CI)	Obs	Incidence SIR[4] (95% CI)
All Cancers		14%		9%
Esophagus		39%		62%
Intestine		30%		21%
Lung		10%		12%
Kidney		29%		27%
Oral cavity[2]		40%		39%
Mesothelioma		100%		129%

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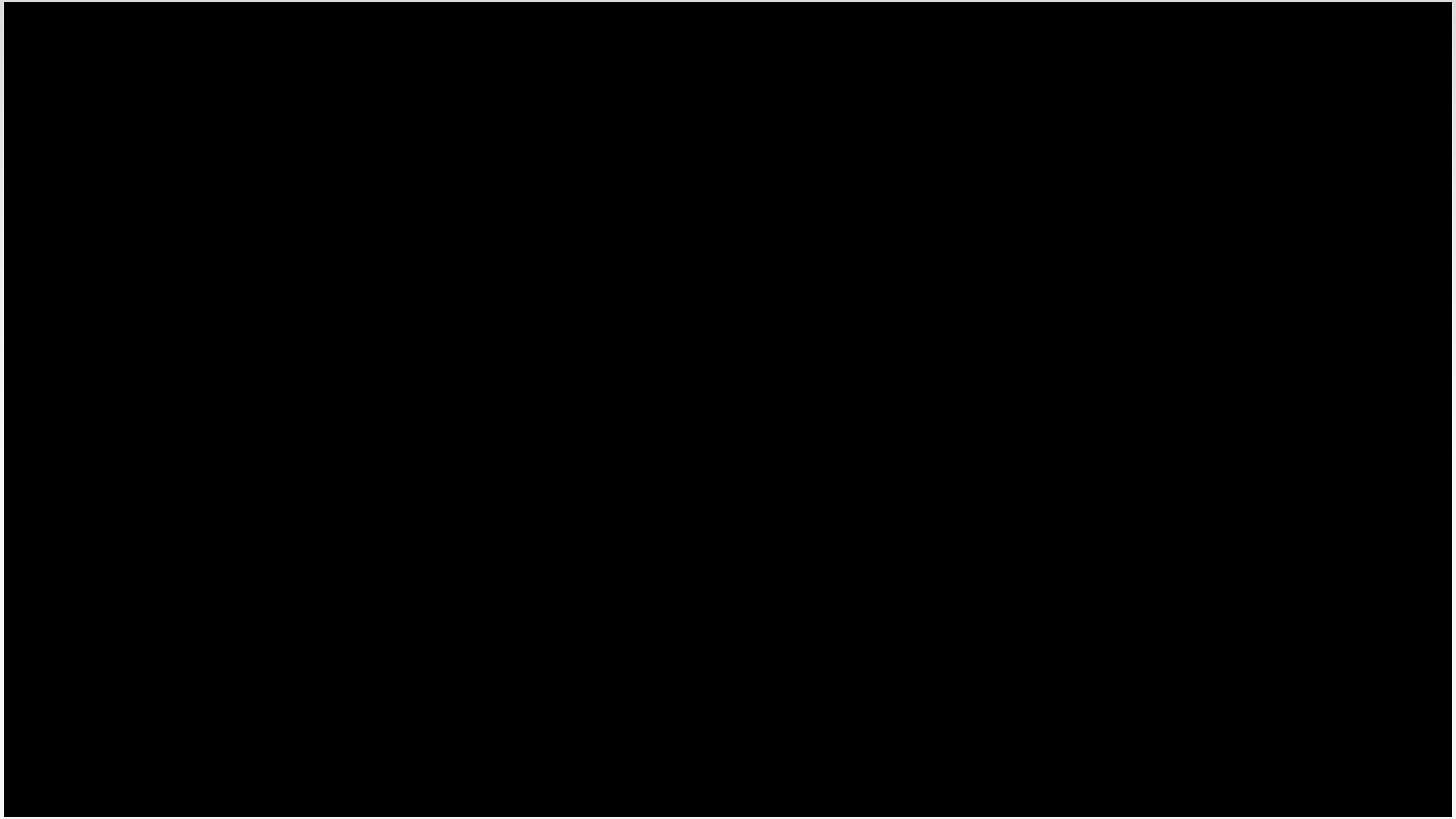
Project Overview



https://www.youtube.com/watch?v=uZO3GO1Nd-E

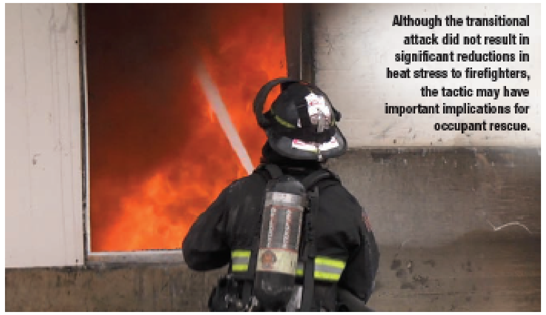
Fireground Roles

- The teams were separated into pairs that completed specific tasks.
  - Compliment of 4 firefighters arriving every 1 minute
  - Engine 1 –
    - A – **Inside** firefighters; fire suppression
    - B – **Outside** firefighters; command &pump operator.
  - Truck 1 –
    - A - **Inside** firefighters; forcible entry then search &rescue
    - B – **Outside** firefighters; ventilation (horizontal and vertical).
  - Engine 2
    - A – Back-up line, supported the first-in engine then **overhaul**
    - B - Rapid intervention team (RIT) then transitioned to **overhaul** operations after the fire was suppressed.

Tactical Considerations Related to Occupant Exposure

1 Getting water on the fire

While UL FSRI and NIST have characterized water application from the exterior and interior of a structure for several years, this study offers an opportunity to compare changes in building temperatures and heat flux that result from *firefighters* conducting different attacks on the same structure. The variability in the way firefighters applied water mimicked typical fireground conditions that would be difficult to achieve in a controlled laboratory setting. Despite this variability, we found no evidence of increased air temperatures or heat flux at the end of the hallway just outside the two fire rooms, regardless of the direction from which water was applied. We also saw no evidence of spikes or abrupt change in gas concentrations at the simulated occupant locations that can be attributed to different water application techniques.



Although the transitional attack did not result in significant reductions in heat stress to firefighters, the tactic may have important implications for occupant rescue.

Importantly, earlier water application consistently resulted in reduced temperatures throughout the structure, lowering the temperatures in which firefighters operated from the front door and through the hallway. These lower temperatures produced only a minor reduction in firefighter skin temperature (neck skin temperature was approximately 1 degree F lower for transitional vs. interior attack) and had no significant impact on core temperature. However, the large ambient temperature reductions can impact occupant tenability within the structure, particularly if an occupant is behind a closed door and will need to be rescued through the interior of the structure (see Consideration #3). Although the transitional attack did not result in significant reductions in heat stress to firefighters, the tactic may have important implications for occupant rescue.

2 The value of the hollow core door

Newer furnishings, homes with more open layouts and modern construction materials allow fires to spread and produce toxic gases much faster, reducing the escape time for occupants. A closed door can offer a layer of protection between people and a fire, and this is important to remember for both occupants and firefighters. Public education messages underscore that if you can't get out, put a closed door between you and the fire to buy valuable time. Sleeping with bedroom doors closed can also buy time to react to a sounding alarm.

In our study, we set up two bedrooms within the structure that were fitted with hollow core interior doors and remained closed throughout the burn. The door to one of these rooms stood along the same hallway that connected to the two fully involved fire rooms. Upon approaching the scene, incident command found smoke and/or flames showing from at least two sides of the structure. However, tenable/survivable conditions were measured behind closed doors less than five feet from the entrance to the fire rooms. As firefighters entered the structure and moved to the hallway, temperatures at crouching level or typical bed height were 600–800 degrees F on the hallway side of the door, but less than 100 degrees F in the bedroom. Even the inexpensive hollow core doors used in this study withstood fire.

It is equally important to realize that the interior doors experienced significant thermal damage during every burn scenario. In some cases, the doors' outward-facing skin was consumed and

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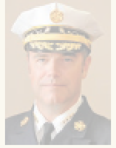

What can be said to chief officers who continue to ignore scientific evidence, and argue that we don't need research to inform our tactics because "we already know all the answers"?

"Since completing my initial firefighter training 25-plus years ago, I've had the opportunity to experience how a lot of fire departments—across the U.S. and the world—approach interior structural firefighting. Each of these organizations has some different characteristics, but in every place I've worked or visited, searching for—and (hopefully) rescuing—trapped occupants is the highest fireground priority.

At the most basic level, these research findings reinforce the importance of what we (should) already know about safely and effectively conducting inside operations: 1) The faster we get water on the fire, the better it is for everyone; 2) door control is absolutely critical; and 3) we must closely—and constantly—coordinate our fire attack, ventilation and search efforts.

As firefighters, saving lives—including those of our brothers and sisters—is what we do. Whatever your department's resources, having more information about fire dynamics and using it to make better tactical decisions—or even review and revise operating practices—is the best way to fulfill our highest calling."

—Adam K. Thiel, Fire Commissioner, City of Philadelphia

The hollow core interior doors that remained closed throughout the fire experienced significant thermal damage; however, the data showed tenable/survivable conditions for occupants on the side of the door opposite the fire.

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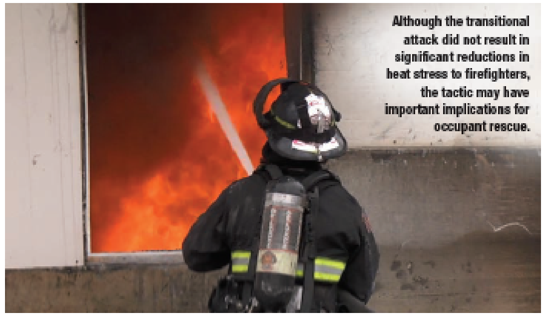

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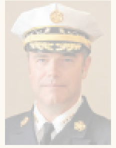

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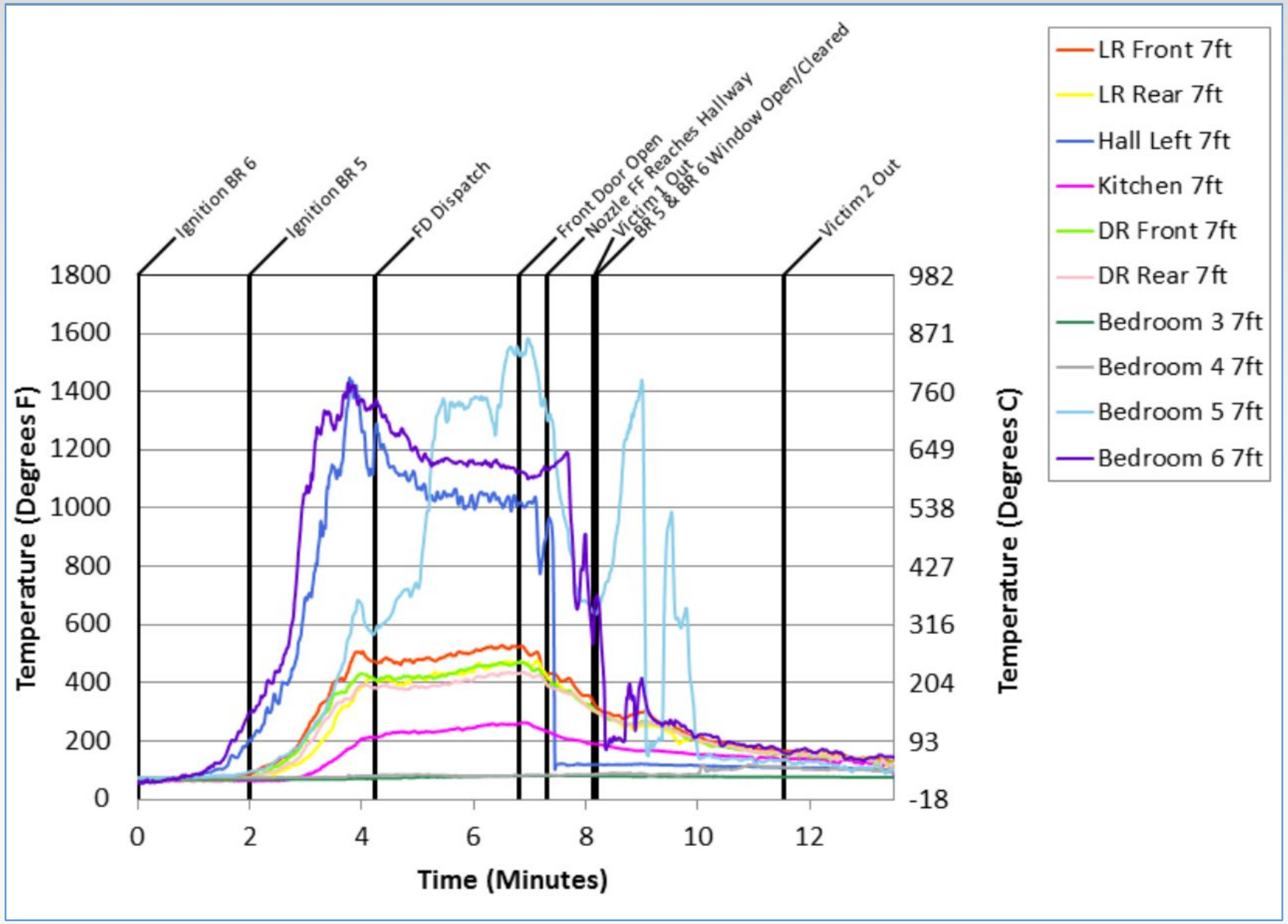
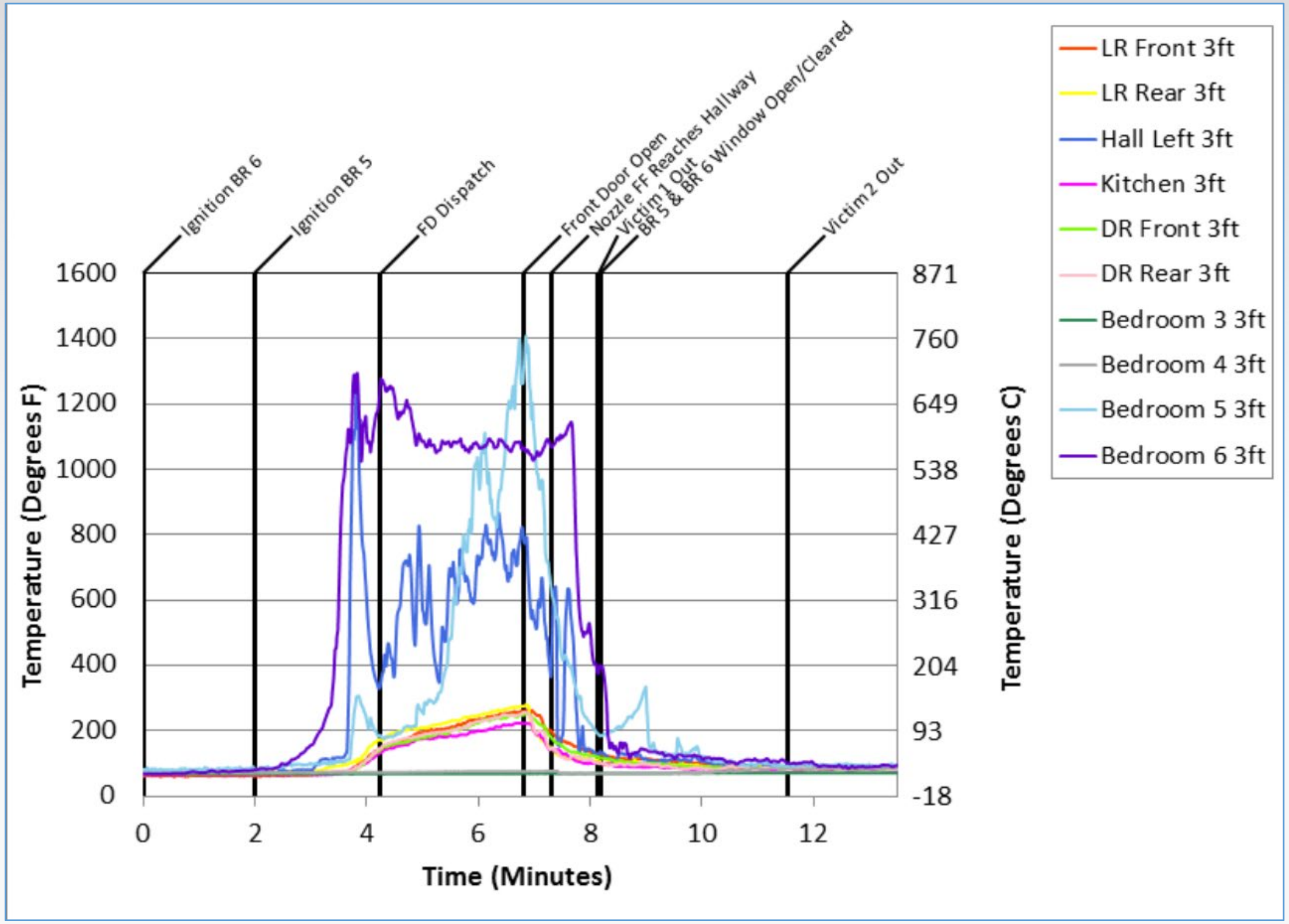
Building Instrumentation

Symbol	Measurement
(orange octagon)	Differential Pressure
(blue circle)	Gas Concentration
(green triangle)	Thermocouple Array
(yellow square)	Heat Flux
(pink camera)	Video Camera

Building Temperatures (Interior Attack)



Building Temperatures (Interior Attack) - 3ft



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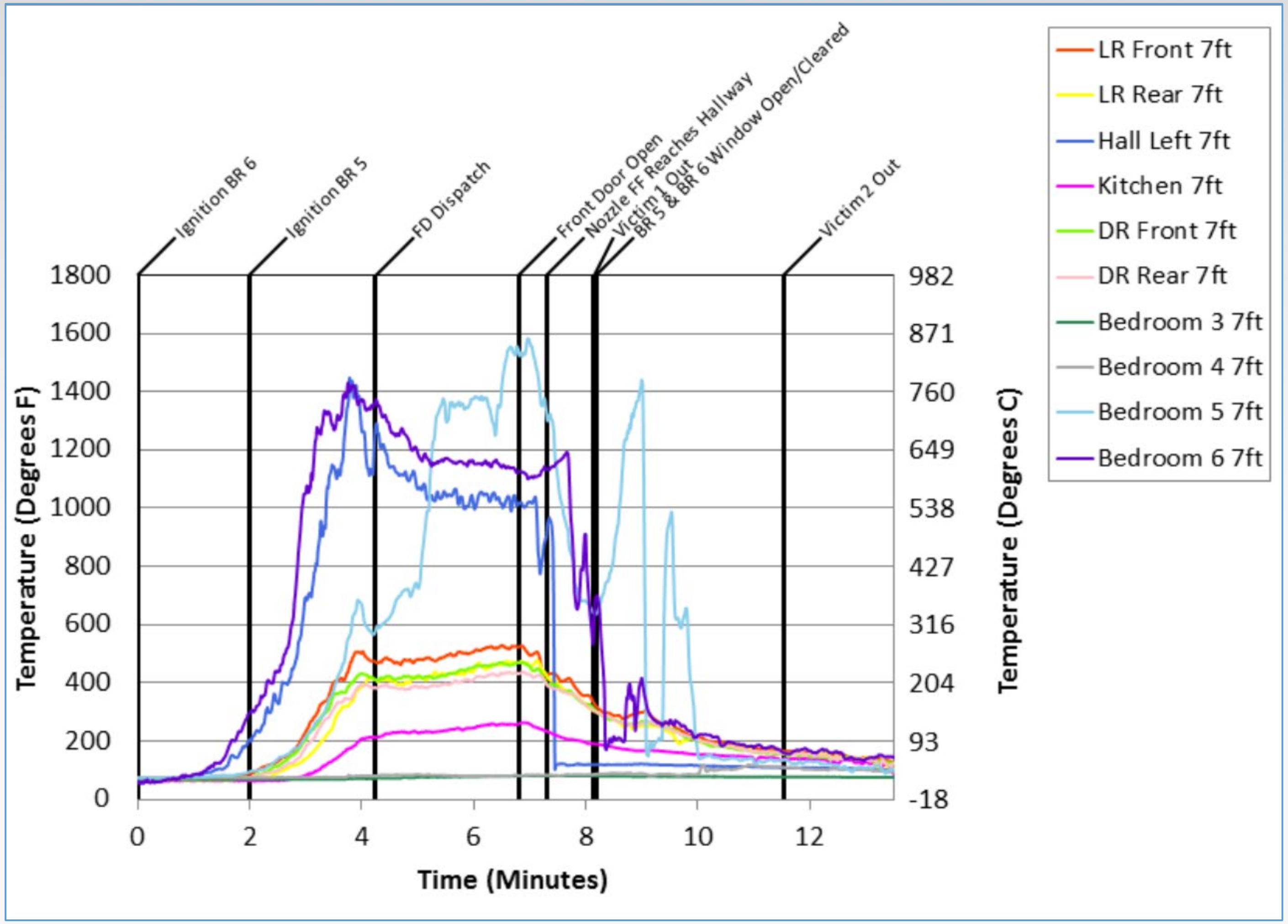
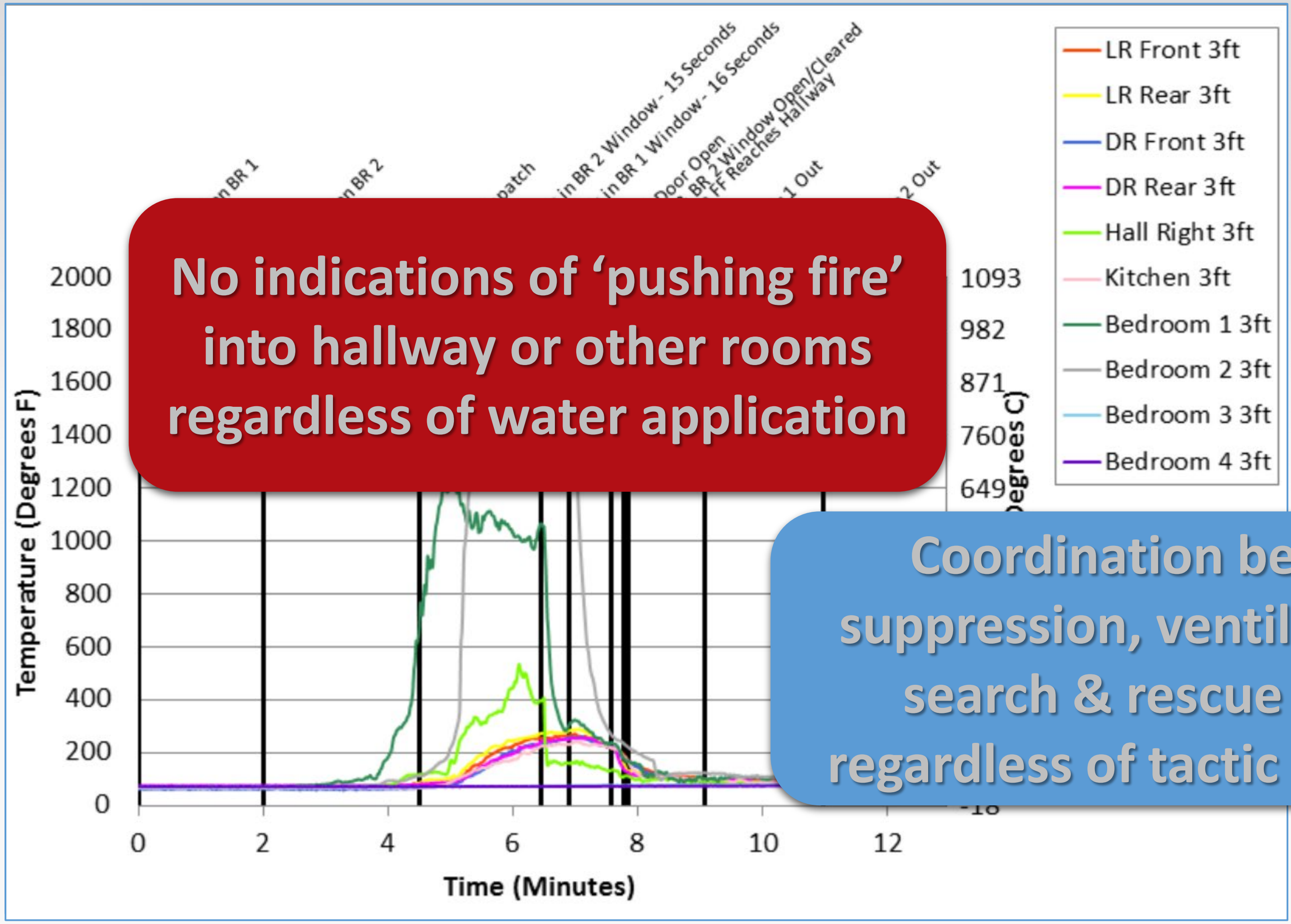


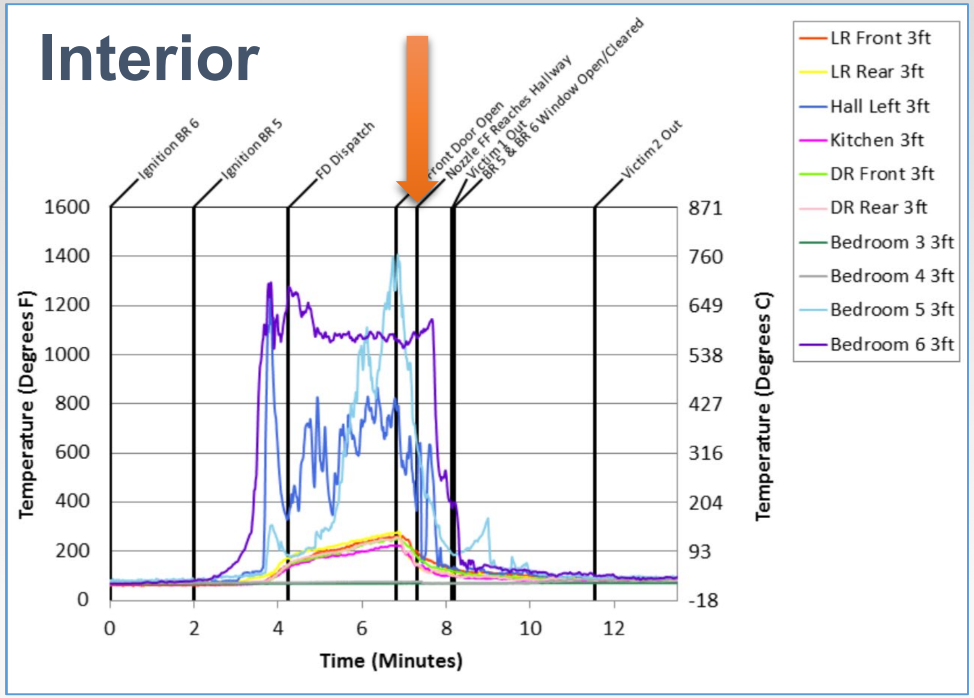
Building Temperatures (Transitional Attack)

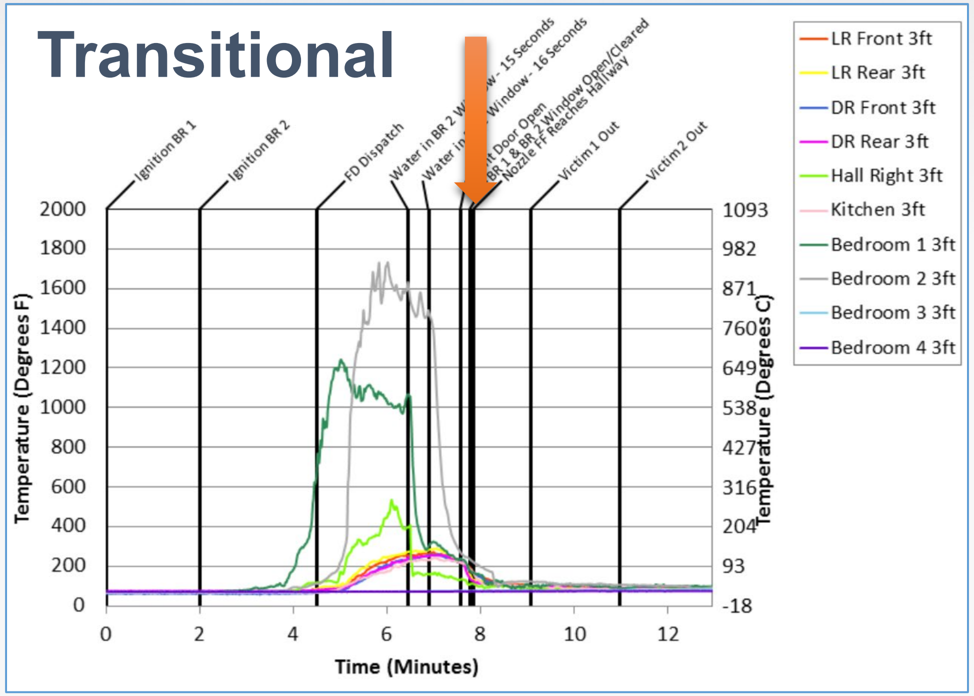


No indications of 'pushing fire' into hallway or other rooms regardless of water application

Coordination between suppression, ventilation and search & rescue critical regardless of tactic employed

During Firefighting Operations





Temps when Nozzle Reaches the Hallway

Interior vs Transitional

		Temperature when 'Inside Attack Reaches Hallway' (° F)							Heat Flux
Height	Tactic	LR Front	LR Rear	DR Front	DR Rear	Hallway	BR2/5	BR 1/6	(kW/m^2)
5 ft	Interior	465	323	409	395	968	1340	1187	19.3
	Transitional	226	226	256	238	276	641	350	5.2

		Temperature when 'Inside Attack Reaches Hallway' (° F)							Heat Flux
Height	Tactic	LR Front	LR Rear	DR Front	DR Rear	Hallway	BR2/5	BR 1/6	(kW/m^2)
3 ft	Interior	238	195	203	211	592	1203	1082	7.9
	Transitional	162	143	147	130	150	654	234	3.0

'Transitional' Timelines:
First water on fire ~50 sec faster than door forced
FF reached hallway ~30 sec* slower than 'Interior'

Horn et al. (2017) **Thermal response to firefighting activities in residential structure fires: Impact of job assignment and suppression tactic**, *Ergonomics*

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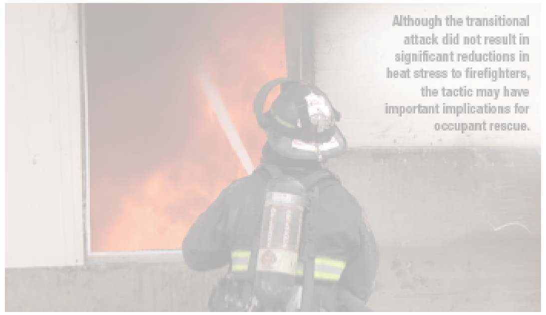

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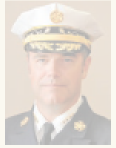

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Behind Closed Doors…

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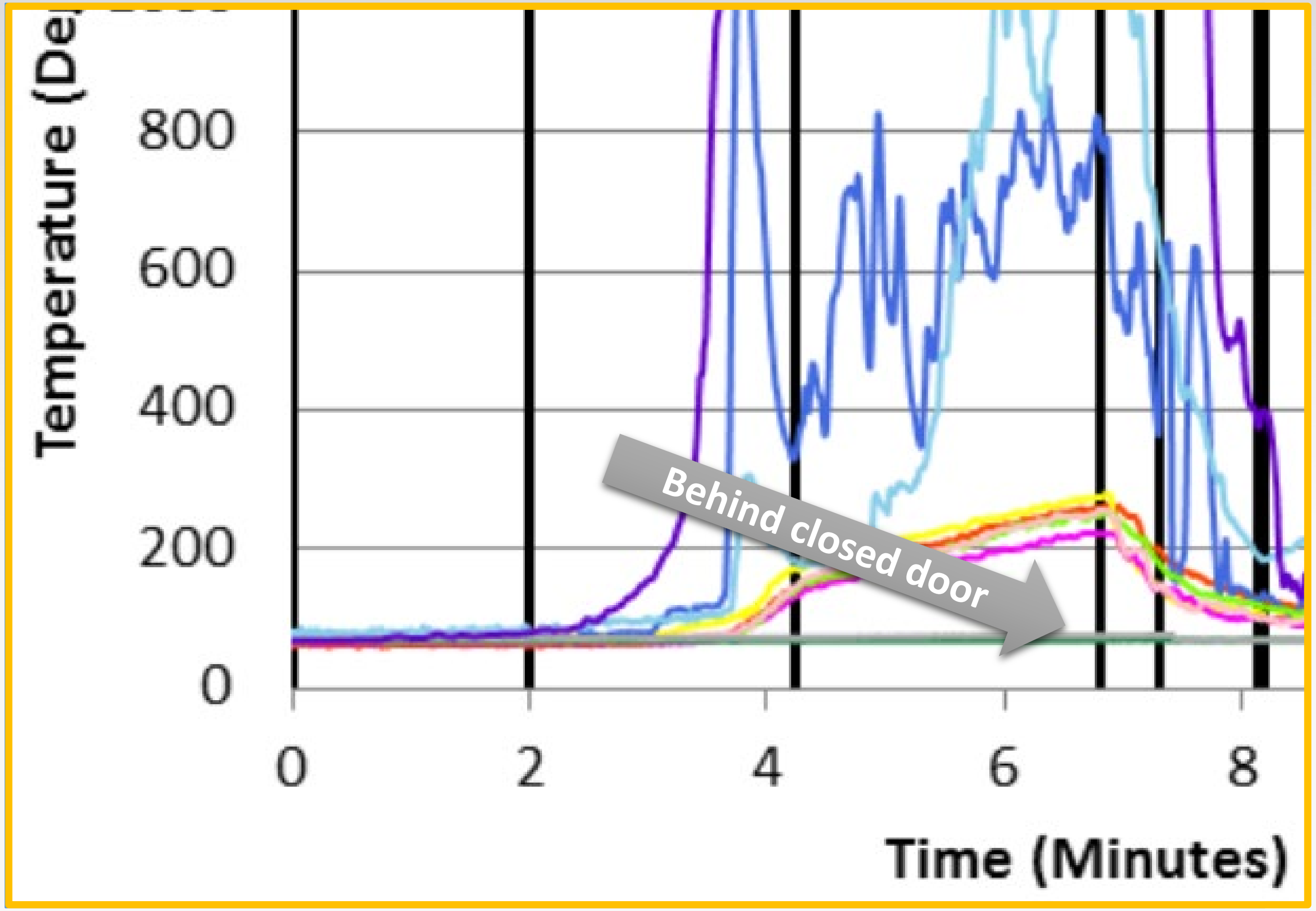


But, you may have limited time…

inward-facing skins were charred. Visible smoke could also be found leaking into the upper level of the room closest to the fire rooms late in some scenarios. Interior doors have an important—but limited—ability to withstand the thermal onslaught of this magnitude. This finding stresses the need for firefighters to rapidly identify safe havens for potentially trapped occupants and either apply water to the fire or conduct rapid search and rescue from these areas (preferably both!).

Stress the importance of closed doors to the public and fellow firefighters. For more information visit closeyourdoor.org.

3 VEIS from the inside?

Vent, enter, isolate and search are each important fireground tasks that, while often taught independently, should be combined in a properly coordinated fashion to achieve success on the fireground. Using isolation during a systematic interior search can allow you to vent as you go without impacting the fire, while making search conditions more favorable. It can also provide several advantages and options for rescue if you find an occupant.

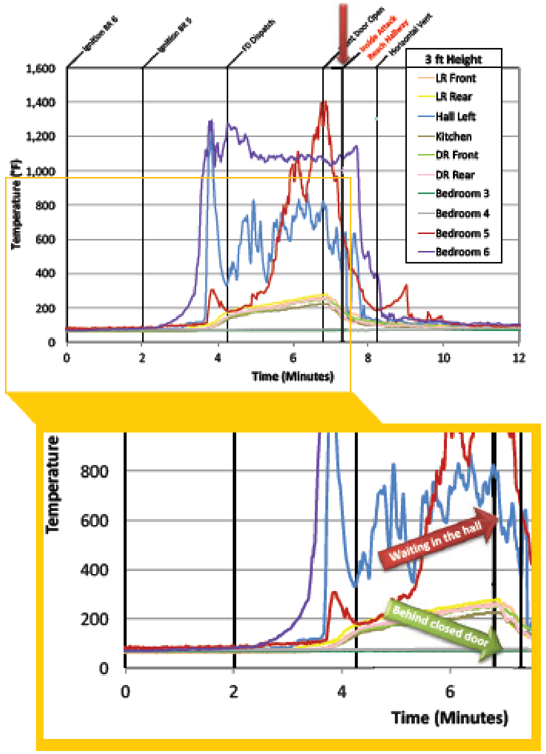
Many fire service classes explore the dynamics of the coordinated Vent-Enter-Isolate-Search (VEIS) process, which often includes minimizing the time a firefighter and an occupant are in the flow path by quickly shifting from the Vent to the Isolate tasks. Additionally, such classes also explore the fire dynamics of door control, typically focusing on the front door.

Expanding on these principles and examining interior door control and ventilation/search operations leads us to consider a new order to the acronym we all know so well: Enter-Isolate-Vent-Search (EIVS). Putting these pieces together this way allows for a better understanding of a tactical option for conducting an interior search with limited to zero visibility—an option or alternative to chocking doors as you search. When you enter a room and close the door behind you to search, (isolating yourself from the flow path/fire), you can now ventilate the windows in that room without impacting the fire or the safety of other firefighters in the structure. (*Note:* The door must be able to be closed to isolate the search team from the fire, and you may need to close multiple doors. While this will typically work in bedrooms that have one or two doors, this will not work in areas that don't have doors, such as living rooms, family rooms and kitchens.) Due to the isolation from the fire, smoke can lift and temperatures will decrease, which would improve conditions for the occupant and increase visibility for a more thorough search.

This consideration is particularly important if you search a room that already had the door closed, as conditions will worsen once it's opened. As previously addressed, temperatures in the hallway adjacent to the fire rooms were often 600–800 degrees F three feet from the floor just as firefighters put water on the fire, yet were less than 100 degrees F at the same height behind closed doors with light smoke conditions. As soon as the compartmentalization is removed by opening the door to search, high-temperature gases (with high concentrations of carbon monoxide, hydrogen cyanide and others) will begin to fill a room where viable occupants may be found. Limiting the time a door stays open as you pass through will curtail additional exposure to the potential victim.

Finding an occupant leads to the important question of what is best for the survivability of that person. Removing them from the structure is the priority, but does it do any good to take the occupant through the interior without the same protections that firefighters have (turnout gear and SCBA)? When you are isolating, you have several options: Open the door and go out the way you came in; keep them isolated until conditions improve; or remove them through a window or another door in the room. Consider the condition of the occupant, the structure, the fire and other firefighters when making your decision.

If you don't find an occupant and you're ready to extend your search to another room, remember that if water is not yet on the fire, you should close the door as you exit to keep that room out of the flow path. Once water is applied to the fire and it becomes a fuel-limited fire, you can leave the door open to help improve conditions because you now have the upper hand, and the smoke and heat can exit the already vented window.



Air temperatures measured 3 feet from the floor throughout the building during a typical Interior fire attack scenario. Note the temperatures in the hallway and Bedroom 4, separated only by a hollow core door. (Note: Figure adapted from Reference 1.)

Exposure Considerations for Outside & Overhaul Operations

4 Heat stress during outside vent and overhaul

Heat stress is a well-known risk that results from muscular work in heavy PPE and heat from a fire during firefighting operations.

A commonly held belief is that firefighters working on the inside of a structure will experience the most significant heat strain. However, in these scenarios, the overhaul and outside vent crews had the highest measured maximum core temperatures (peak at 101.4–102 degrees F). On average, core temperatures increased by more than 3 degrees F during overhaul and outside vent activities compared to approximately 2 degrees F during inside work (fire attack and search activities).

Strenuous physical work in heavy, insulating firefighting PPE—the type of work performed during overhaul—can result in significantly increased core temperatures.

Firefighters' Core Temperature Changes for Different Jobs

Job Assignment	Maximum Core Temp (°F)	Core Temp Change Before-to-After Activity (°F)
Outside Command/Pump	99.9	1.4
Outside Vent	101.4	3.2
Inside (Attack, Search)	100.3	1.9
Overhaul	102.0	3.2

Maximum core temperatures experienced by firefighters working particular job assignments as well as the core temperature change from before to after the activity.

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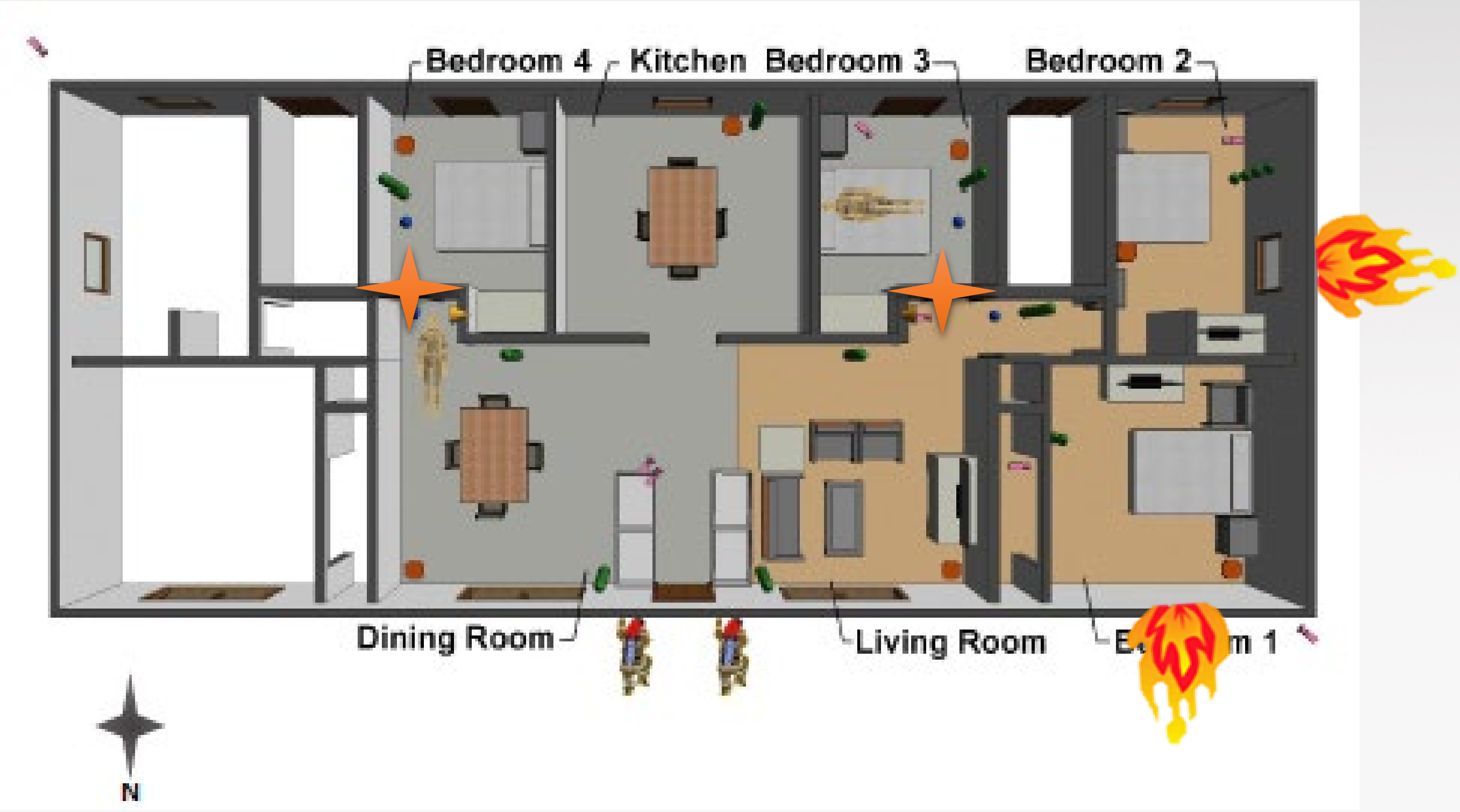

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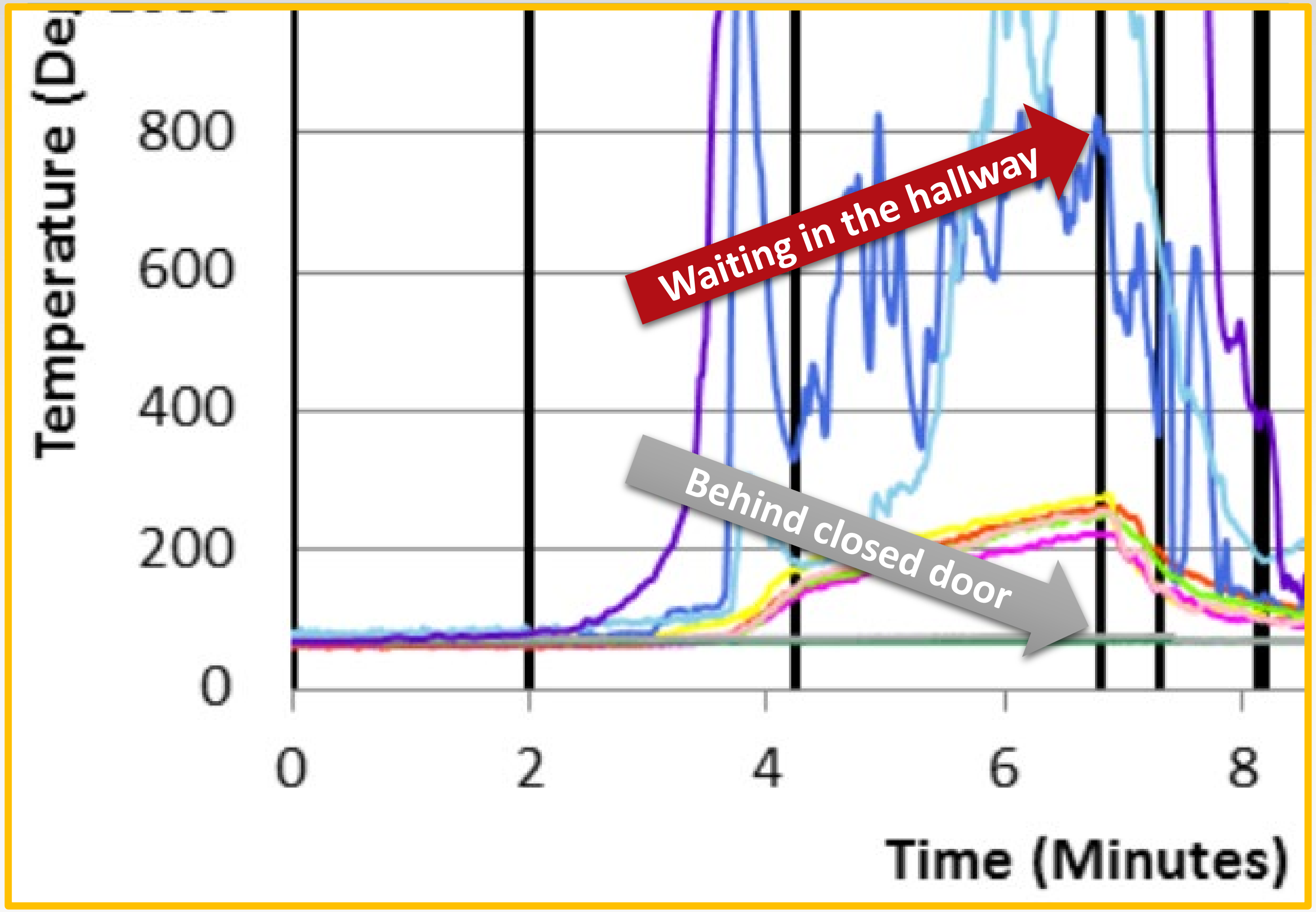
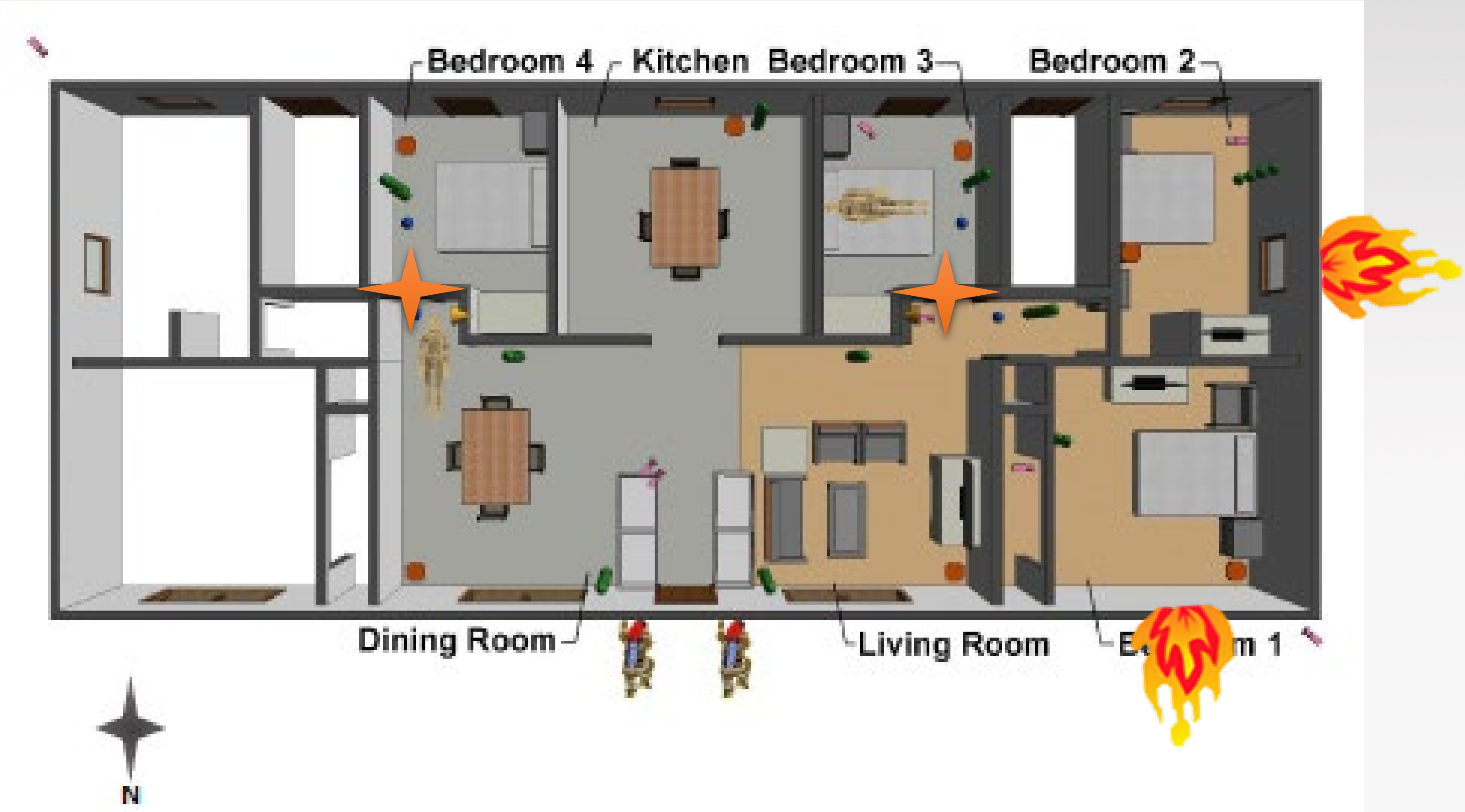


Staying Behind Closed Doors…?



Other options…?

Height	Tactic	Temperature when 'Inside Attack Reaches Hallway' (° F)							Heat Flux (kW/m²)
		LR Front	LR Rear	DR Front	DR Rear	Hallway	BR2/5	BR 1/6	
5 ft	Interior	465	323	409	395	968	1340	1187	19.3
	Transitional	226	226	256	238	276	641	350	5.2

Height	Tactic	Temperature when 'Inside Attack Reaches Hallway' (° F)							Heat Flux (kW/m²)
		LR Front	LR Rear	DR Front	DR Rear	Hallway	BR2/5	BR 1/6	
3 ft	Interior	238	195	203	211	592	1203	1082	7.9
	Transitional	162	143	147	130	150	654	234	3.0

inward-facing skins were charred. Visible smoke could also be found leaking into the upper level of the room closest to the fire rooms late in some scenarios. Interior doors have an important—but limited—ability to withstand the thermal onslaught of this magnitude. This finding stresses the need for firefighters to rapidly identify safe havens for potentially trapped occupants and either apply water to the fire or conduct rapid search and rescue from these areas (preferably both!).

Stress the importance of closed doors to the public and fellow firefighters. For more information visit closeyourdoor.org.

3 VEIS from the inside?

Vent, enter, isolate and search are each important fireground tasks that, while often taught independently, should be combined in a properly coordinated fashion to achieve success on the fireground. Using isolation during a systematic interior search can allow you to vent as you go without impacting the fire, while making search conditions more favorable. It can also provide several advantages and options for rescue if you find an occupant.

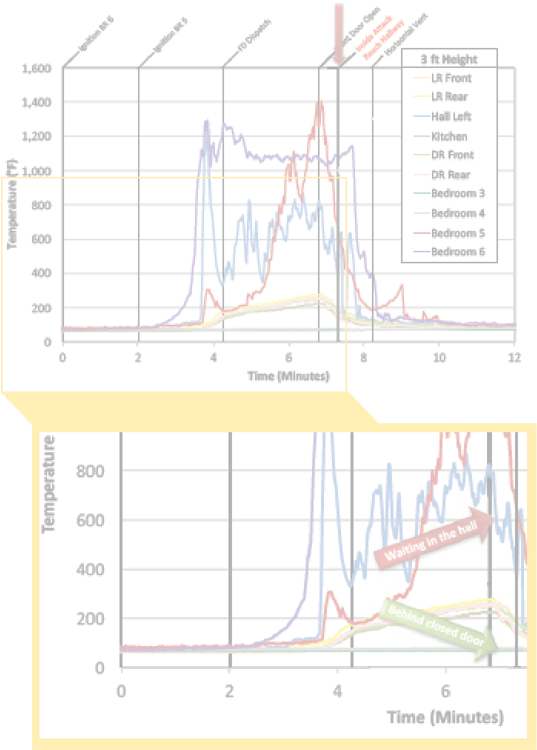
Many fire service classes explore the dynamics of the coordinated Vent-Enter-Isolate-Search (VEIS) process, which often includes minimizing the time a firefighter and an occupant are in the flow path by quickly shifting from the Vent to the Isolate tasks. Additionally, such classes also explore the fire dynamics of door control, typically focusing on the front door.

Expanding on these principles and examining interior door control and ventilation/search operations leads us to consider a new order to the acronym we all know so well: Enter-Isolate-Vent-Search (EIVS). Putting these pieces together this way allows for a better understanding of a tactical option for conducting an interior search with limited to zero visibility—an option or alternative to chocking doors as you search. When you enter a room and close the door behind you to search, (isolating yourself from the flow path/fire), you can now ventilate the windows in that room without impacting the fire or the safety of other firefighters in the structure. (*Note:* The door must be able to be closed to isolate the search team from the fire, and you may need to close multiple doors. While this will typically work in bedrooms that have one or two doors, this will not work in areas that don't have doors, such as living rooms, family rooms and kitchens.) Due to the isolation from the fire, smoke can lift and temperatures will decrease, which would improve conditions for the occupant and increase visibility for a more thorough search.

This consideration is particularly important if you search a room that already had the door closed, as conditions will worsen once it's opened. As previously addressed, temperatures in the hallway adjacent to the fire rooms were often 600–800 degrees F three feet from the floor just as firefighters put water on the fire, yet were less than 100 degrees F at the same height behind closed doors with light smoke conditions. As soon as the compartmentalization is removed by opening the door to search, high-temperature gases (with high concentrations of carbon monoxide, hydrogen cyanide and others) will begin to fill a room where viable occupants may be found. Limiting the time a door stays open as you pass through will curtail additional exposure to the potential victim.

Finding an occupant leads to the important question of what is best for the survivability of that person. Removing them from the structure is the priority, but does it do any good to take the occupant through the interior without the same protections that firefighters have (turnout gear and SCBA)? When you are isolating, you have several options: Open the door and go out the way you came in; keep them isolated until conditions improve; or remove them through a window or another door in the room. Consider the condition of the occupant, the structure, the fire and other firefighters when making your decision.

If you don't find an occupant and you're ready to extend your search to another room, remember that if water is not yet on the fire, you should close the door as you exit to keep that room out of the flow path. Once water is applied to the fire and it becomes a fuel-limited fire, you can leave the door open to help improve conditions because you now have the upper hand, and the smoke and heat can exit the already vented window.



Air temperatures measured 3 feet from the floor throughout the building during a typical Interior fire attack scenario. Note the temperatures in the hallway and Bedroom 4, separated only by a hollow core door. (Note: Figure adapted from Reference 1.)

Exposure Considerations for Outside & Overhaul Operations

4 Heat stress during outside vent and overhaul

Heat stress is a well-known risk that results from muscular work in heavy PPE and heat from a fire during firefighting operations.

A commonly held belief is that firefighters working on the inside of a structure will experience the most significant heat strain. However, in these scenarios, the overhaul and outside vent crews had the highest measured maximum core temperatures (peak at 101.4–102 degrees F). On average, core temperatures increased by more than 3 degrees F during overhaul and outside vent activities compared to approximately 2 degrees F during inside work (fire attack and search activities).

Strenuous physical work in heavy, insulating firefighting PPE—the type of work performed during overhaul—can result in significantly increased core temperatures.

Firefighters' Core Temperature Changes for Different Jobs

Job Assignment	Maximum Core Temp (°F)	Core Temp Change Before-to-After Activity (°F)
Outside Command/Pump	99.9	1.4
Outside Vent	101.4	3.2
Inside (Attack, Search)	100.3	1.9
Overhaul	102.0	3.2

Maximum core temperatures experienced by firefighters working particular job assignments as well as the core temperature change from before to after the activity.

Temps during Interior Firefighting Ops

		Temperature when 'Inside Attack Reaches Hallway' (^{o} F)							Heat Flux
Height	Tactic	LR Front	LR Rear	DR Front	DR Rear	Hallway	BR2/5	BR 1/6	(kW/m^2)
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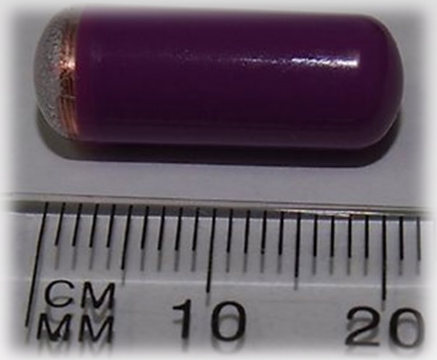
Horn et al. (2017) **Thermal response to firefighting activities in residential structure fires: Impact of job assignment and suppression tactic**, *Ergonomics*

Core & Skin Temperatures

- Ingestible core temperature capsules
- Dermal patches
- Wireless transmission to continuous data recording

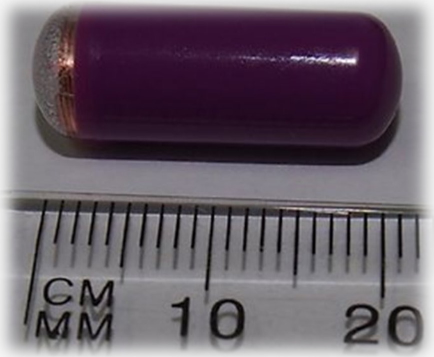


Firefighters' Skin Temperatures

Measure	Job Assignment	Interior Attack	Transitional Attack
Arm Skin (°F)	Outside Command/Pump	97.1	97.0
	Outside Vent	99.8	100.0
	Inside	99.5	99.0
	Overhaul	99.8	100.3
	Total	99.2	99.2

Tactic has small effect (on neck for Inside FF)
Job assignment has important effect

Firefighters' Core Temperatures



Measure	Job Assignment	Interior Attack	Transitional Attack
Maximum Core Temp (°F)	Outside Command/Pump	100.0	99.8
	Outside Vent	101.5	101.3
	Inside	100.2	100.4
	Overhaul	102.0	101.9
	Total	101.0	100.9

Tactic has no effect
Job assignment has large effect

Overhaul and outside vent assignments may intuitively be considered to be at lower risk for heat stress because they do not occur in a superheated fire environment. However, strenuous physical work in heavy, insulating firefighting PPE can result in significantly increased core temperatures.

It is important to note that in these scenarios, the time for outside vent work (average of 22 minutes) and overhaul work (average of 11 minutes outside and 17 minutes inside structure) were longer than the times the fire attack and search crews worked inside the structure (11 minutes). This difference in work time is common for a typical room and contents fire.

5 Hydrogen cyanide exposure to outside vent crews

Hydrogen cyanide (HCN) has long been considered an acute hazard that firefighters may encounter during fire responses. The combustion of common household materials—especially those containing polymers, foams, glues and resins—can produce high levels of HCN. However, few studies have measured the air concentrations of HCN for firefighters responding to residential fires where synthetic materials are likely to be abundant.

We set out to measure the air inside the structure (area air concentrations) and surrounding the individual firefighters (personal air concentrations) for combustion byproducts, including HCN, produced during the controlled residential fires with modern furnishings. Area air measurements were collected from the structure during the active fire and overhaul. Personal air measurements were collected from firefighters assigned to attack, search, overhaul, outside vent and command/pump positions.

Several of the HCN air measurements collected at a height of three feet inside the structure during active fire were well above the immediately dangerous to life and health (IDLH) level of 50 ppm. HCN is lighter than air, so concentrations are expected to be higher toward the ceiling or within the smoke layer.

The interior firefighters generally crawled below the smoke layer, lessening their exposure to HCN. Even so, the majority of the personal air concentrations measured from attack firefighters were well above the NIOSH short-term exposure limit of 4.7 ppm, and maximum levels measured from attack and search firefighters exceeded IDLH (50 ppm).

Personal air concentrations for the outside vent firefighters were, on average, above the NIOSH short-term exposure limit of 4.7 ppm, with a maximum level above IDLH (while working outside!). Firefighters performing horizontal and vertical ventilation are likely to be exposed to rising gases where HCN concentrations could easily exceed IDLH.

These results provide strong evidence that SCBA should be used when conducting ventilation of a structure fire, even when working outside. To not wear SCBA during this assignment may put firefighters at risk of chemical asphyxiation and adverse cardiovascular outcomes.

Short-duration exposure to high levels of HCN may be likely when firefighters perform horizontal and vertical ventilation.

6 High concentrations of PAHs & particulate exposure on the fireground

Air samples were collected on the fireground to characterize potential exposures to command/pump personnel not wearing respiratory protection. These samples were located either near the engine or near the truck, depending on the wind direction.

Particulate measurements on the fireground were, on occasion, substantially higher than background levels. In addition, average levels of total polycyclic aromatic hydrocarbons (PAHs) and benzene were above background levels. When the samples were positioned downwind of the apparatus, diesel exhaust contributed to the particulate concentrations. In such situations, particle counts from diesel exhaust were similar to particle counts from the fire smoke plume (>100,000 particles/cm^3). Diesel exhaust is a known human carcinogen.

Not surprisingly, we found that fireground concentrations of benzene, total PAHs, and particulate were highest when collected downwind of the structure and when ground-level smoke was heaviest. Particles measured were generally in the respirable or sub-micron size range. Particles in this size range are capable of depositing into the lower respiratory system where clearance mechanisms, such as increased mucous production and coughing, are less effective and lung inflammation can occur. These particles would likely be composed of a variety of toxicants, and at this location in the lungs, systemic absorption is likely, further contributing to firefighters taking in potential carcinogens.

Exposure to particulates can also play a role in triggering a cardiovascular event. Numerous epidemiology studies have shown strong relationships between high levels of fine particulate concentrations in the air and increases in hospital admissions and death rates due to cardiovascular events in the general population.

These results suggest that firefighters should try to establish command and pump location upwind of the structure when feasible. If that cannot be done, and ground-level smoke and/or diesel exhaust is evident, respiratory protection should be worn.

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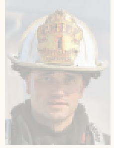
How Do I Best Protect Myself Against Cancer and Cardiovascular Disease?



The answer to each concern is often the same: increase fitness, avoid excess weight, eat fruits and vegetables, participate in regular medical screenings, and avoid unnecessary exposures on the fireground.

"Research has been able to now prove and painfully illustrate that all career and volunteer firefighters are at greater risk for work-related cardiovascular events and cancer diagnosis than the typical civilian. Fortunately, there are many things we can do to reduce our risk, with many being at little expense and others costing a bit more.

The answer is personal accountability. All of us can be leaders and set the example for others to see and emulate. Be physically fit. Don't use tobacco. Know your family history. Get an actual NFPA 1582 physical from a qualified medical professional and then follow up on the findings. Wash your hands, and shower after every exposure. Keep your gear clean, and work toward attaining more than one set. Be smart with your fireground orders and decisions. Be as aggressive at taking care of yourself and your people as you are in the execution of your fireground duties.

It's simply unacceptable to have thousands of firefighters gather for a funeral when many of the same people won't change a single thing after attending it. We have a dangerous job and don't need to tempt fate. Be the change and do it now for your family, your department, your company and you."

— Matthew Haerter, Battalion Chief, Kenosha, WI, Fire Department

<u>HCN</u> – STEL 4.7 ppm, IDLH 50 ppm

Attack: median 22 ppm, max 55 ppm

Search: median 0.1 ppm, max 38 ppm

Outside vent: median 14 ppm, max 28 ppm

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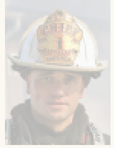

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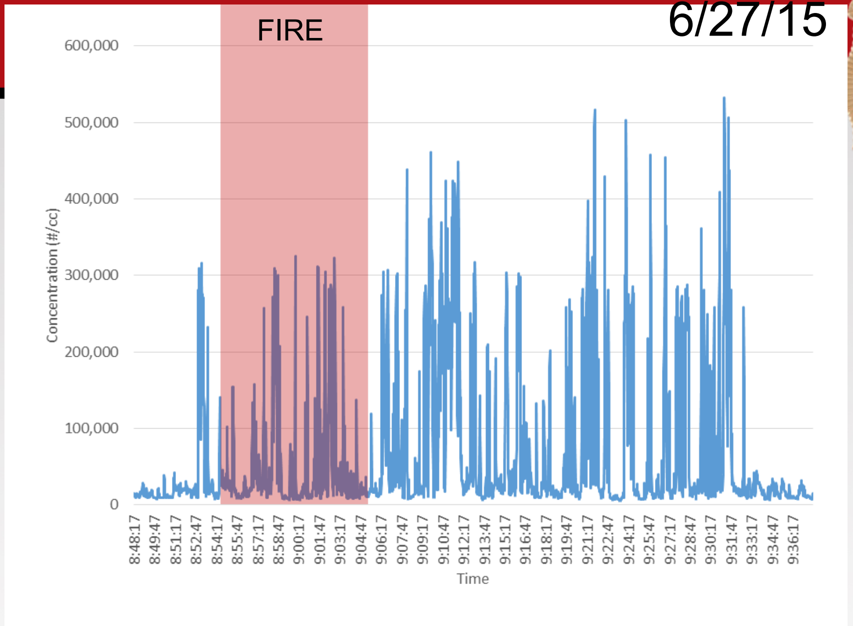
Air concentrations of VOCs (ppm) measured in the fireground (south of Engine 1) on 6/27/2015 and 6/30/2015.

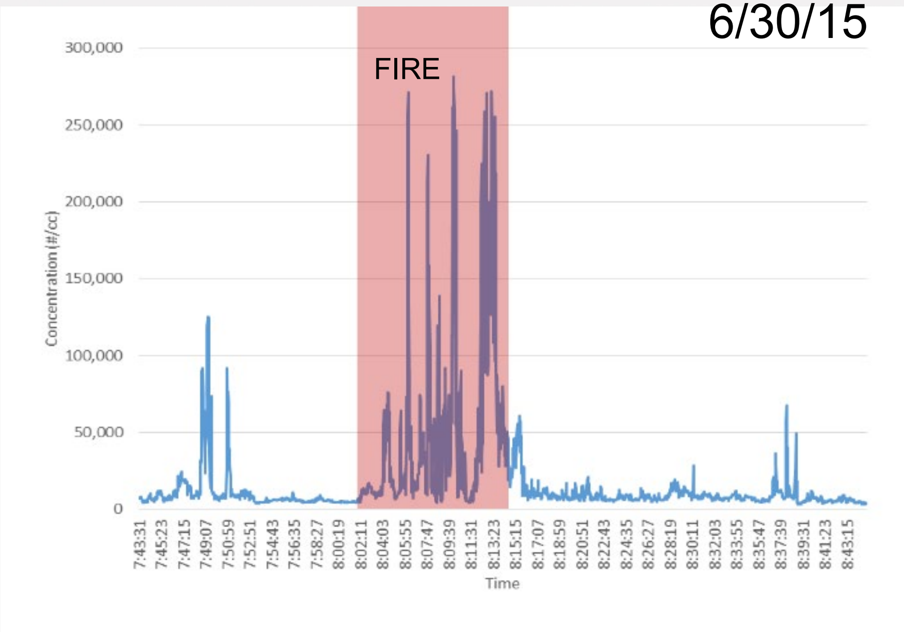
Compound measured	6/27/2015	6/30/2015
Benzene	0.029	0.060
Toluene	0.0034	0.0061
Ethyl benzene	< 0.0004	0.0012
Xylenes	< 0.0008	0.0032

Below applicable short-term exposure limits

Downwind of diesel exhaust



Downwind of smoke plume



Cleaning and Decon Considerations after the Fire

Rehab & Hygiene—a Critical Combination

Get out, get cool, get hydrated and get clean! Decon your face and neck as soon as possible after exiting the building.

"Fireground rehab policies have been evolving, both in their development and their adoption, over the last several years. Hydration, rest/recovery, cooling, nourishment and medical monitoring continue to be essential aspects of rehab, with a recently added focus on firefighter decontamination. It is clearly time to add rehab/decon/hygiene as an integrated and essential fireground function.

Firefighters reporting to formalized rehab should remove contaminated PPE and begin the cleaning process whenever possible, taking into consideration ambient temperature conditions and/or rehab being conducted outside of an enclosed area. Protecting against secondary contamination from PPE off-gassing in an enclosed area is now recognized as a serious safety consideration.

After firefighters doff their PPE, they should take steps to decontaminate their skin, particularly on their hands, face and neck. If a firefighter has contaminated hands, this material can transfer to other areas of the body when wiping away sweat or using the bathroom. Furthermore, nutrition provided during rehab commonly requires eating with the hands. Without proper hand hygiene, this could result in the inadvertent ingestion of contaminants."

— Craig A. Haigh, Fire Chief, Hanover Park, IL, Fire Department

Attack and search firefighters had the highest maximum levels of exposure on the neck. Interestingly, several outside vent firefighters also had high neck exposure, most likely from inconsistent use of hoods.

7 PPE and skin contamination

As part of this study, we measured the amount of PAH contamination on turnout jackets and skin following the structure fire responses. As expected, contamination levels varied by job assignment. We found higher contamination on turnout jackets worn by attack and search crews, followed by overhaul crews and then outside vent and command/pump operators. Just by looking at it, you might expect that the gear worn by the overhaul crew was most in need of cleaning due to the drywall dust, but it had much less PAH contamination than the interior crews' gear. Without gross decon being performed, contamination levels increased on turnout jackets with successive use in fires.

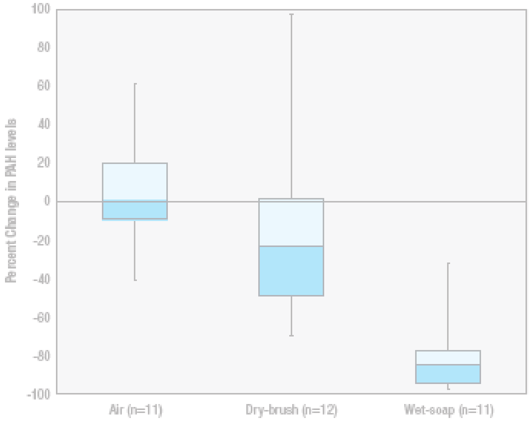
A critical new insight from this study was that glove contamination was also abundant. On one pair of gloves (worn by a firefighter assigned to search), we measured a variety of flame retardants added to household furnishings and products. Results from the analysis of other gloves are pending. However, it is likely that positions requiring handling of burnt items (overhaul) and interior operations (attack and search) will see substantial glove contamination. Like PAHs, certain brominated flame retardants are persistent and will remain on clothing for years unless removed by decontamination or laundering.

Skin contamination with PAHs followed a similar pattern. We measured higher PAH levels on the hands of firefighters assigned to fire attack (135 μg/m²) and search (226 μg/m²) than other positions (<11 μg/m²). Importantly, several outside vent firefighters had quite high neck exposure (half the group exceeding 30.5 μg/m²), most likely from inconsistent use of hoods. However, attack and search firefighters had the highest maximum levels of exposure on the neck (1080 and 780 μg/m², respectively). Knowledge of PPE contamination and dermal exposures by position may be useful to decision-makers in prioritizing decontamination/cleaning procedures and policies.

Wet-soap decon: Approximately 3 fluid ounces of dish soap was added to a 3-gallon pump sprayer and filled with water. A garden hose was used to pre-rinse the turnout gear. The soap/water mixture was then sprayed onto the gear and scrubbed with a stiff-bristled brush, followed by a final rinse.

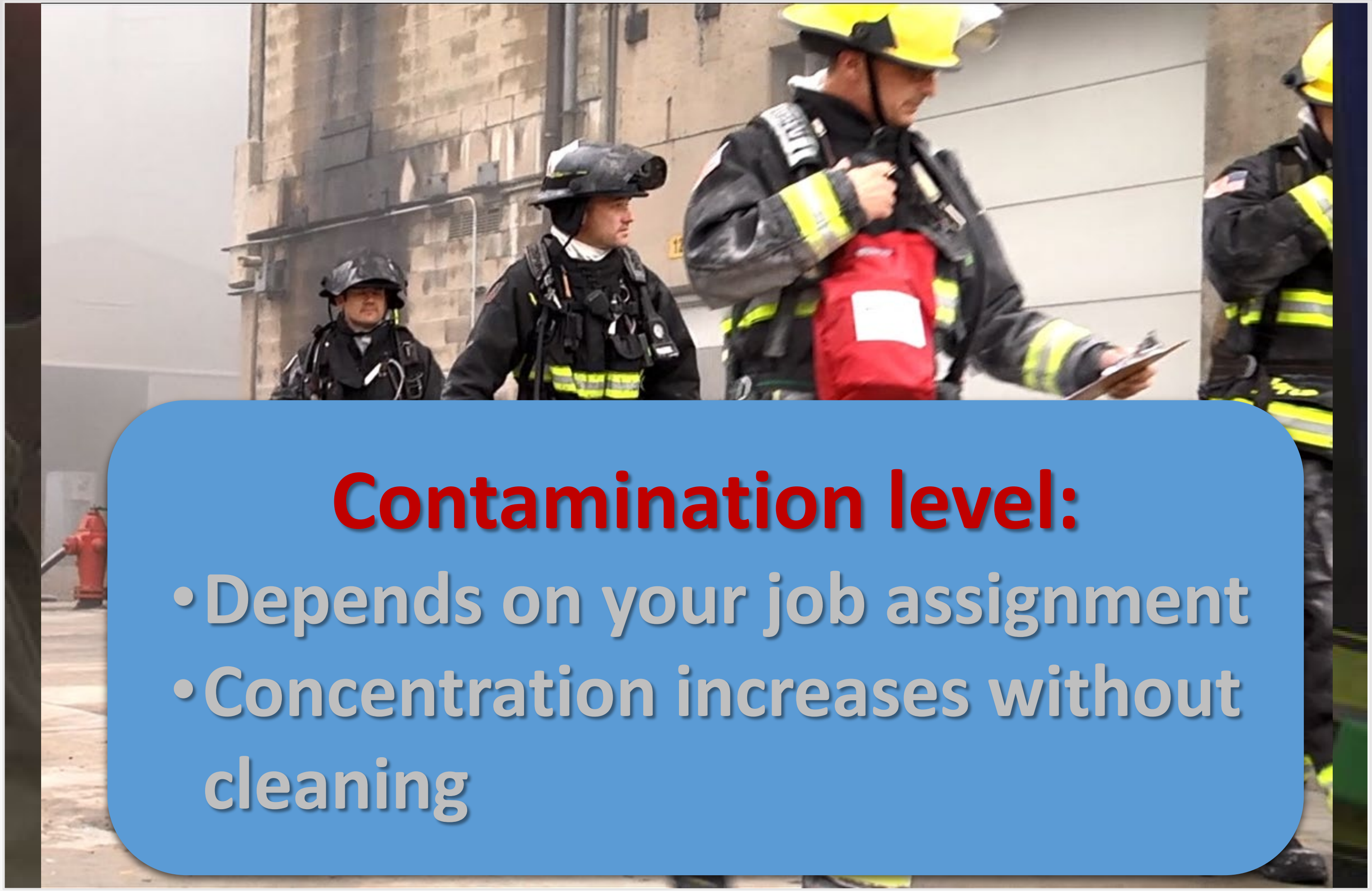
8 Gross decontamination

We also wanted to measure the effectiveness of gross on-scene decon of turnout gear following the structure fires. Three types of decon methods were evaluated: 1) air-based decon with a modified electric leaf-blower; 2) dry-brush decon with a stiff-bristled brush; and 3) wet-soap decon with water and dish soap applied to the turnout gear, scrubbed with a brush and then rinsed. Of the three types of decon, wet-soap decon was by far the most effective, removing an average of 85 percent of PAH contamination present on turnout gear after firefighting.



This box-and-whisker plot shows the percent difference in PAH levels measured on turnout jackets before and after decontamination and the variability of the processes. The boxes show the 25th percentile (bottom line of darker blue boxes), 50th percentile (midline between colored boxes) and 75th percentile (top line of lighter blue boxes), while the "whiskers" show the absolute minimum and maximum values that were measured. (Note: Figure adapted from Reference 2.)

Bunker Gear Contamination Levels



PAH Contamination on Neck after Fire

Job assignment	Skin site	% Detectable Levels	Median (µg/m²)	Interquartile range (µg/m²)
Attack	Neck			
Search	Neck			
Overhaul/RIT	Neck			
Outside Vent	Neck			
Outside Command/Pump	Neck			

PAH Contamination Removal after Fire

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Contamination of firefighter personal protective equipment and skin and the effectiveness of decontamination procedures

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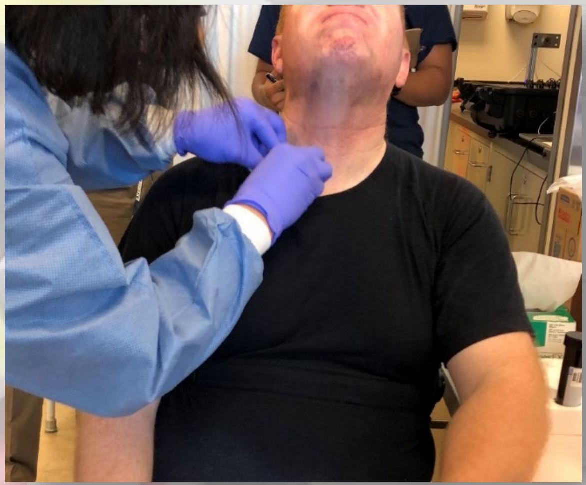

Key Finding…

54% reduction
in neck contamination using
skin cleansing wipes

Reinforce the Message:

Shower ASAP is still important!!

PAH Contamination on Hands after Fire

Job assignment	Skin site	% Detectable Levels	Median (µg/m²)	Interquartile range (µg/m²)
Attack	Neck			
	Hands			
Search	Neck			
	Hands			
Overhaul/RIT	Neck			
	Hands			
Outside Vent	Neck			
	Hands			
Outside Command/Pump	Neck			
	Hands			

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7 PPE and skin contamination

As part of this study, we measured the amount of PAH contamination on turnout jackets and skin following the structure fire responses. As expected, contamination levels varied by job assignment. We found higher contamination on turnout jackets worn by attack and search crews, followed by overhaul crews and then outside vent and command/pump operators. Just by looking at it, you might expect that the gear worn by the overhaul crew was most in need of cleaning due to the drywall dust, but it had much less PAH contamination than the interior crews' gear. Without gross decon being performed, contamination levels increased on turnout jackets with successive use in fires.

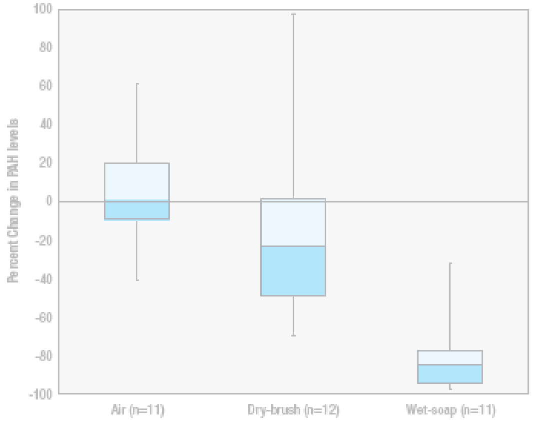
A critical new insight from this study was that glove contamination was also abundant. On one pair of gloves (worn by a firefighter assigned to search), we measured a variety of flame retardants added to household furnishings and products. Results from the analysis of other gloves are pending. However, it is likely that positions requiring handling of burnt items (overhaul) and interior operations (attack and search) will see substantial glove contamination. Like PAHs, certain brominated flame retardants are persistent and will remain on clothing for years unless removed by decontamination or laundering.

Skin contamination with PAHs followed a similar pattern. We measured higher PAH levels on the hands of firefighters assigned to fire attack (135 $\mu g/m^2$) and search (226 $\mu g/m^2$) than other positions (<11 $\mu g/m^2$). Importantly, several outside vent firefighters had quite high neck exposure (half the group exceeding 30.5 $\mu g/m^2$), most likely from inconsistent use of hoods. However, attack and search firefighters had the highest maximum levels of exposure on the neck (1080 and 780 $\mu g/m^2$, respectively). Knowledge of PPE contamination and dermal exposures by position may be useful to decision-makers in prioritizing decontamination/cleaning procedures and policies.

8 Gross decontamination

We also wanted to measure the effectiveness of gross on-scene decon of turnout gear following the structure fires. Three types of decon methods were evaluated: 1) air-based decon with a modified electric leaf-blower; 2) dry-brush decon with a stiff-bristled brush; and 3) wet-soap decon with water and dish soap applied to the turnout gear, scrubbed with a brush and then rinsed. Of the three types of decon, wet-soap decon was by far the most effective, removing an average of 85 percent of PAH contamination present on turnout gear after firefighting.

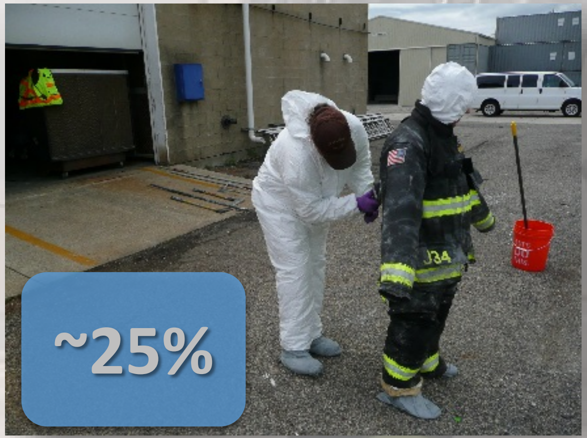
Wet-soap decon: Approximately 3 fluid ounces of dish soap was added to a 3-gallon pump sprayer and filled with water. A garden hose was used to pre-rinse the turnout gear. The soap/water mixture was then sprayed onto the gear and scrubbed with a stiff-bristled brush, followed by a final rinse.

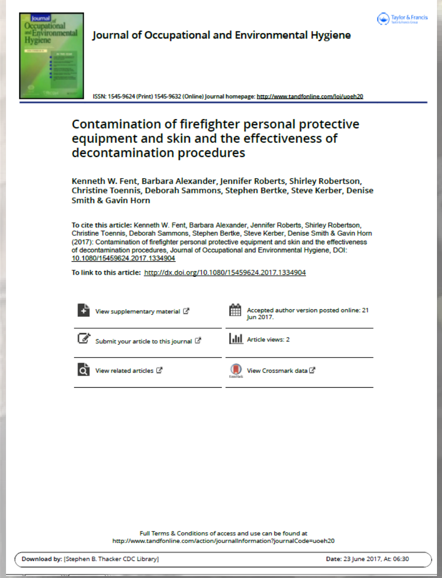


This box-and-whisker plot shows the percent difference in PAH levels measured on turnout jackets before and after decontamination and the variability of the processes. The boxes show the 25th percentile (bottom line of darker blue boxes), 50th percentile (midline between colored boxes) and 75th percentile (top line of lighter blue boxes), while the "whiskers" show the absolute minimum and maximum values that were measured. (Note: Figure adapted from Reference 2.)

Preliminary Exposure Reduction Data

Dry Decon – Air & Brush





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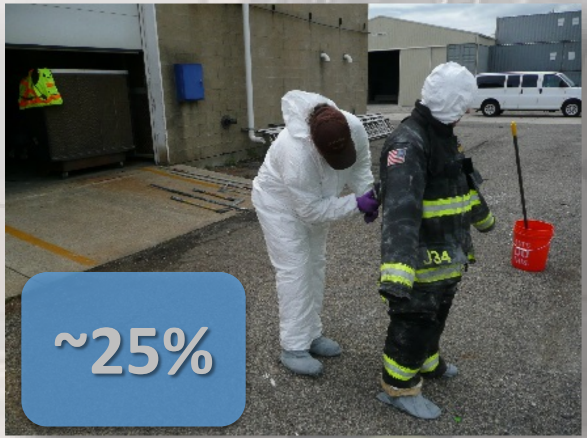
To link to this article: http://dx.doi.org/10.1080/15459624.2017.1334904

Wet Soap Decon (PER)

Dry Decon "Lessons from the Field"

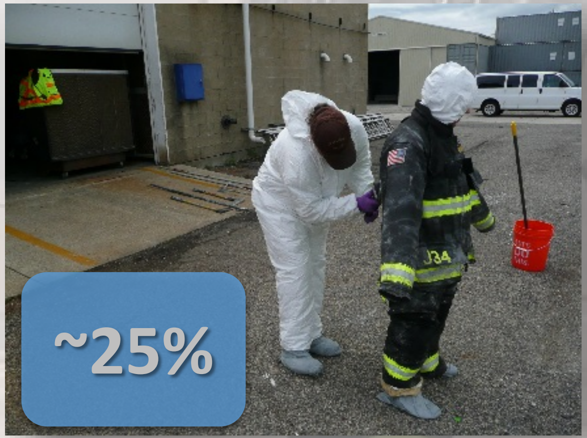
Dry Decon – Air & Brush



- While not as effective at removing surface PAHs, there may be other reasons to implement this method
  - May be easier to remove large debris
  - Environmental conditions
- Where does the contamination go?
  - Airway protection
    - Firefighter
    - Decon staff
    - Who is 'downwind'?
  - Be sure to clean up the tools
- Be careful of later cross contamination

Preliminary Exposure Reduction Data

Dry Decon – Air & Brush



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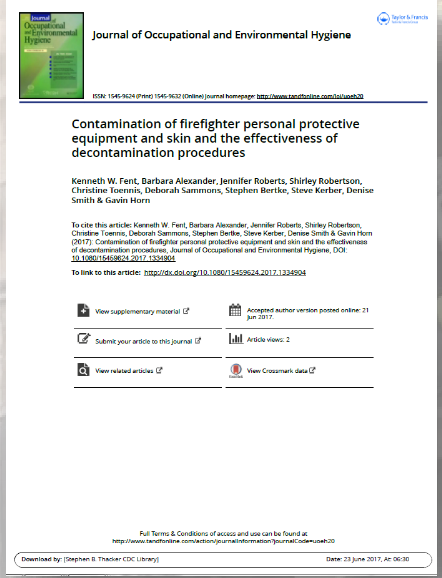

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Wet Soap Decon (PER)

~85%

Wet Soap Decon "Lessons from the Field"

- Do I really need a garden sprayer to apply soap?
  - In line educator
  - Bucket and brush
- How much water do you need to apply?
  - Training is important to learn technique
  - Consider balancing wet and dry methods when large pieces of debris are present
- Think about when to expand to multiple lines/stations
- What to do with PPE afterwards?
  - NFPA 1851 guidance
  - What are your SOPs for wet gear?

Wet Soap Decon (PER)

Wet Soap Decon "Lessons from the Field"

- Implementation in the cold
  - Address cold stress concerns as part of integrated rehab
  - Prioritize based on conditions
  - Make ice melt available
  - Warming station may be important
- Implementation in the heat
  - Address heat stress concerns as part of integrated rehab
  - Prioritize based on conditions
  - Hydration where feasible
  - Open up coat while waiting?

Video Credit: Chief Frank Leeb
Watch the full video at:
https://www.youtube.com/watch?v=kA7TbIqoueQ

~85%

The "Salty" Firefighter Conundrum

Many bosses can be very focused on having their crews diligently clean their apparatus every morning, polish tools and conduct station inspections, but then overlook dirty gear, unnecessary exposures and soot-covered faces.

"When a new firefighter goes through their recruit academy, we often stress the importance of maintaining clean tools and apparatus as a critical behavior to instill early in a firefighter's career. If tools are not cleaned or hose is loaded in a sloppy manner, these are commonly taken as indicators of a lack of focus on the details from the new firefighter.

It is important that firefighters take pride in the appearance and readiness of tools and apparatus. However, this pride is not always translated into cleaning of the firefighter's own personal PPE. The "salty" appearance of well-used helmets, coats and gloves may be taken as a badge of honor, as opposed to an indication of an unnecessary exposure.

While in recent years the fire service has made great strides to address this apparent conundrum, the irony of this double standard is still present in many places. It's time for all of us to be role models and take the same pride in cleaning our bunker gear that we do to ensure our tools are free from debris and rust."

— Todd Harms, Fire Chief, Sacramento, CA, Metropolitan Fire District

Although we do not know how this compares to water-only decon, we suspect that the dish soap (containing a surfactant) was useful for removing fat-soluble compounds, like PAHs. In situations where turnout gear cannot be immediately laundered (or prior to laundering), wet-soap decon can be an effective way of removing contamination. Further research is needed to determine the effectiveness of wet-soap decon against other contaminants, such as flame retardants, and how wet-soap decon compares in terms of effectiveness and PPE degradation to laundering.

9 Hood laundering

Unlaundered Nomex sock hoods worn by firefighters for four structure fire responses were tested for residual flame retardants and PAHs that were embedded in the fabric and compared to similar hoods that were laundered after each fire.

The laundered hoods in our study certainly looked cleaner. However, our preliminary results indicate that while most of the PAH contamination was removed, much of the brominated flame-retardant contamination remained. Additionally, a 2016 study reported that a high percentage (>80 percent) of brominated flame retardants were retained in laundered fabrics. The authors of this study (Saini and colleagues) attributed this finding to the difficulty of removing fat-soluble compounds from fabrics using traditional laundering practices.

These results suggest that traditional laundering techniques (extractors with commercial detergent), may not effectively remove fat-soluble compounds, like brominated flame retardants, from hoods, which could present a prolonged exposure for firefighters. How much this exposure pathway contributes to systemic exposures in firefighters is yet to be determined.

It is important to determine whether more effective means of laundering exist and if chemicals contaminating the hoods can transfer to other hoods or items during laundering (cross-contamination). It is also possible that new particle blocking hoods could lessen the amount of contamination available to contact the neck skin as contamination may be isolated to the exterior of the hood.

Visual comparison of unlaundered hoods (left) and laundered hoods (right) may not tell the whole story of residual contamination.

Leadership—Let's Make Sure It Is by Example

How can a fire chief set the example for their firefighters with regards to cancer or cardiac risks?

"With cancer rates in the fire service hitting what I feel is a critical and unacceptable level, members of the fire service need to better understand the contamination that is occurring on the fireground. This research illustrates the significant contamination on the fireground and the associated hazards for both interior and exterior firefighters. Better understanding of these hazards and continued research on how to limit exposure and perform decontamination procedures is vital, as is the education that will help ensure compliance with best practices.

A fundamental change must occur in the fire service. Decon should be required after all fireground operations, and the wearing of soiled contaminated gear can no longer be tolerated. Individual members must make the commitment to properly wear their gear, wear their SCBA throughout the fire and overhaul, and commence gross decon upon exiting the IDLH environment, followed by a prompt shower upon return to quarters.

Most importantly, we as company and command officers must do these things ourselves to make sure we lead by example. We owe it to ourselves and each other to make this a priority."

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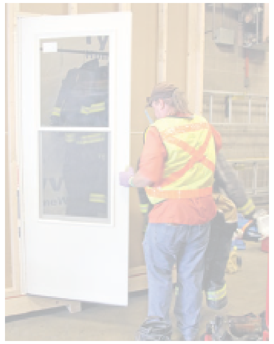
10 PPE off-gassing

During fireground use, personal protective ensembles will absorb volatile organic compounds (VOCs). Once the gear is removed from the IDLH environment, it will begin to release VOC back to the air through a process called "off-gassing." If turnout gear is worn or stored on the inside of an enclosed apparatus cabin during the ride back to the station (or personally operated vehicle heading home), firefighters are likely to be exposed to several airborne VOCs, including known carcinogens like benzene.

We measured the levels of VOCs and HCN off-gassing from turnout gear before and after the fires as well as after decon had been completed. Six sets of turnout gear were placed inside an enclosed structure about the size of a modern apparatus cab. The off-gas levels increased after firefighting, but were well below applicable short-term exposure limits. The off-gas levels returned to near background concentrations after gross on-scene decon (regardless of type).

However, similar "near background" levels were measured simultaneously from turnout gear that did not undergo decontamination. This suggests that the 17–36 minutes required to perform decon was enough for the majority of the VOCs to off-gas naturally. It should be noted, however, that semi-volatile compounds (with higher molecular weights than VOCs) may take much longer to off-gas and were not evaluated in our study.

Because of this potential route of exposure, turnout gear should be left outdoors to off-gas, bagged and/or transported in an unoccupied compartment on the apparatus or other vehicle.



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References

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Hood Contamination & Cleaning

- Good things happening
  - Hood exchange programs
  - “Wash your hood Sunday”
  - Significant research & development on new hood systems
- Information we still need
  - Effectiveness of laundering processes
    - Evidence that laundering reduces some contamination
      - PAHs
      - Flame retardants (mixed results)
  - How effective are
    - Hood designs
    - Cleaning techniques

    at reducing skin exposure?

Hood Contamination & Cleaning


Journal of Occupational and Environmental Hygiene ›
Latest Articles

Articles

Firefighter hood contamination: Efficiency of laundering to remove PAHs and FRs

Alexander C. Mayer, Kenneth W. Fent, Stephen Bertke, Gavin P. Horn, Denise L. Smith, Steve Kerber & Mark J. La Guardia

Show less

Received 18 Jul 2018, Accepted 10 Oct 2018, Accepted author version posted online: 14 Nov 2018

Lesson from Recent Study

1. Laundering hoods is effective at removing a large portion of PAH contamination
   - By far the most abundant contaminant on the hoods
2. Consider segregating firefighter hoods by contamination level to reduce the potential for cross contamination.
   - If a firefighter responds to a call but is exposed to low levels of contamination compared to the rest of the crew, it may be beneficial to avoid washing with other crew member's hoods.
3. Do not launder hoods with base layers or station wear to reduce the risk for cross contamination
4. This study suggests the *possibility* that contamination on turnout gear outer shells might transfer to inner liner
   - Separate during laundering as recommended by NFPA and others.

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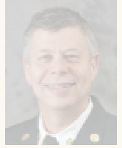

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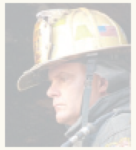

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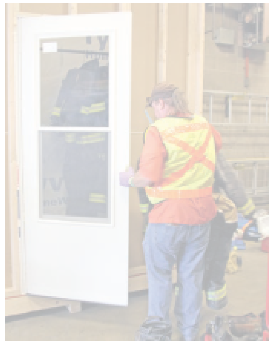

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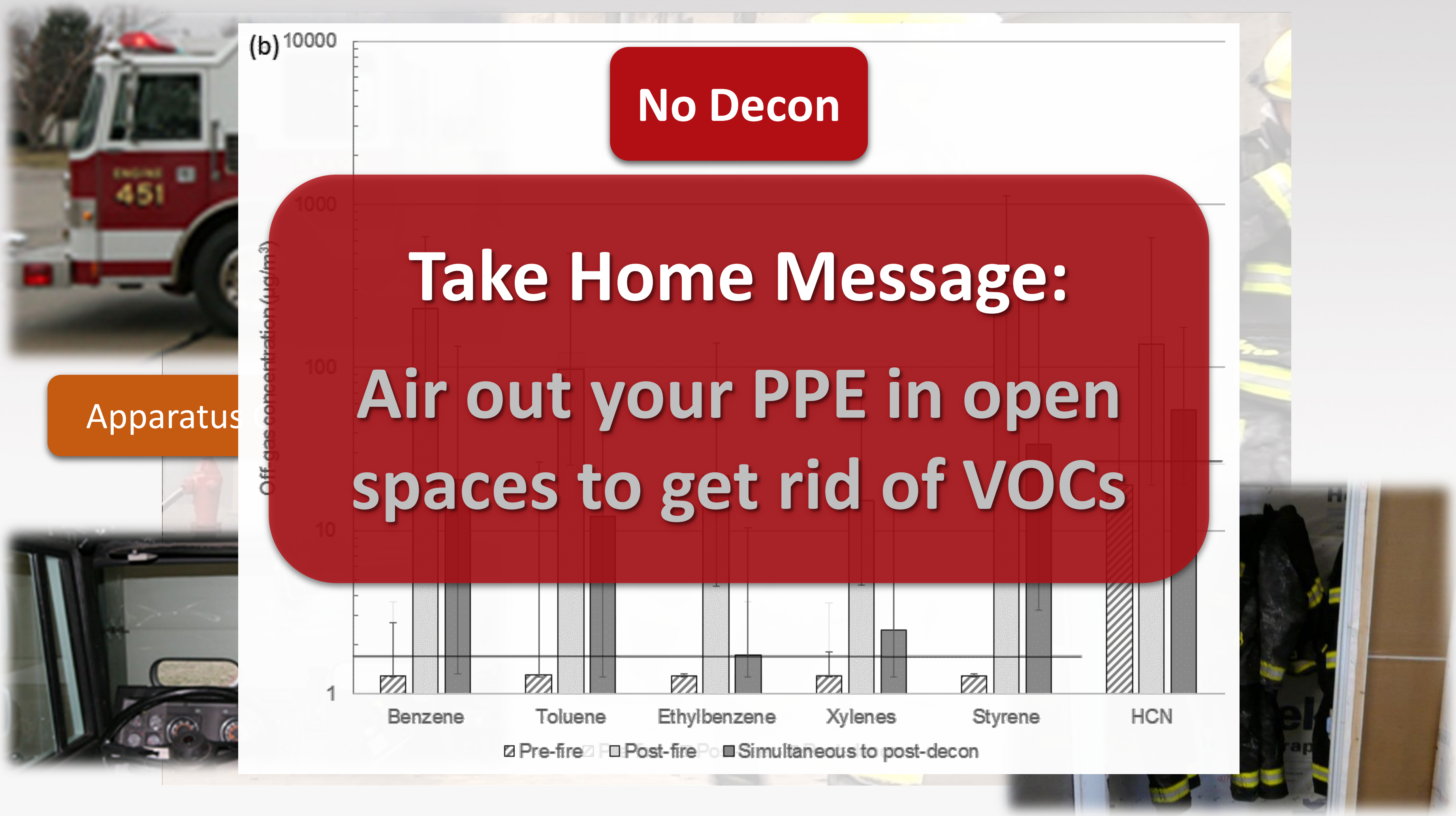
Bunker Gear Off-Gassing



No Decon

Take Home Message:

Air out your PPE in open spaces to get rid of VOCs

Where to get more information?

Toolkit: https://www.fsi.illinois.edu/CardioChemRisks/

Facebook & Twitter: @IFSIresearch