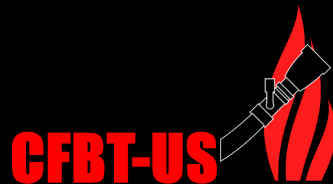




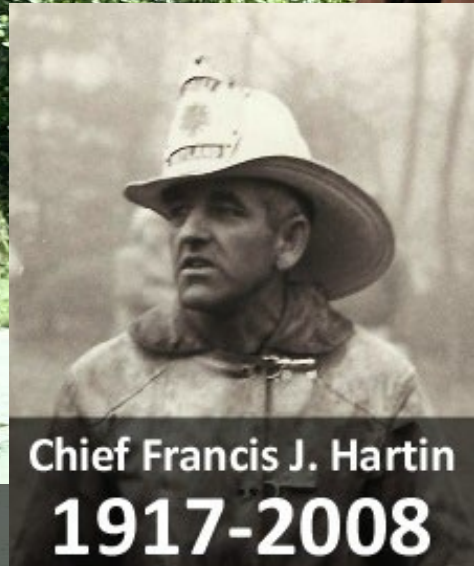
Scientific Approach to Attic and Basement Fires



2026 Washington State Firefighters Association
Annual Fire School & Conference – Wenatchee, Washington



Chief Ed Hartin, MS, EFO, FI FireE, CFO



Chief Francis J. Hartin
1917-2008

Learning the Craft Since ~~1974~~ 1954



23 April 1974



28 February 2025





In order to carry on your business properly, *it is necessary for those who practice it to understand not only what they have to do, but why they have to do it...*

No fireman can ever be considered to have attained a real proficiency in his business until he has thoroughly mastered this *combination of theory and practice.*



Great Fire of London 1666

Fire Protection, *1876*
Sir Eyre Massey Shaw
Chief, London Fire Brigade

A Difficult Question



Why did Ava's
dad die in a fire?

5-7 Lo
Worce
Decem

UL Firefighter Safety Research Institute



Advisory Board • Staff • Technical Panels

Fire Dynamics Fundamentals

From the compressible to the incompressible

Entropy $s(\underline{x}, t)$ defined by Gibbs

$$\Leftrightarrow s = s(e, p) \text{ with } \left(\frac{\partial s}{\partial e}\right)_p = \frac{1}{T} \text{ and } \left(\frac{\partial s}{\partial p}\right)_e = -\frac{1}{p}$$

$$\Rightarrow \text{Budget law: } \frac{de}{dt} = T \frac{ds}{dt} +$$

$$\text{Using } \underline{\sigma} = -p \underline{I} + \underline{\tau} \text{ and } p_c$$

$$p \frac{ds}{dt} = \frac{r}{T} - \frac{div \underline{Q}}{T} + \frac{\underline{\tau} : \underline{D}}{T}$$

Second principle of thermodynamics

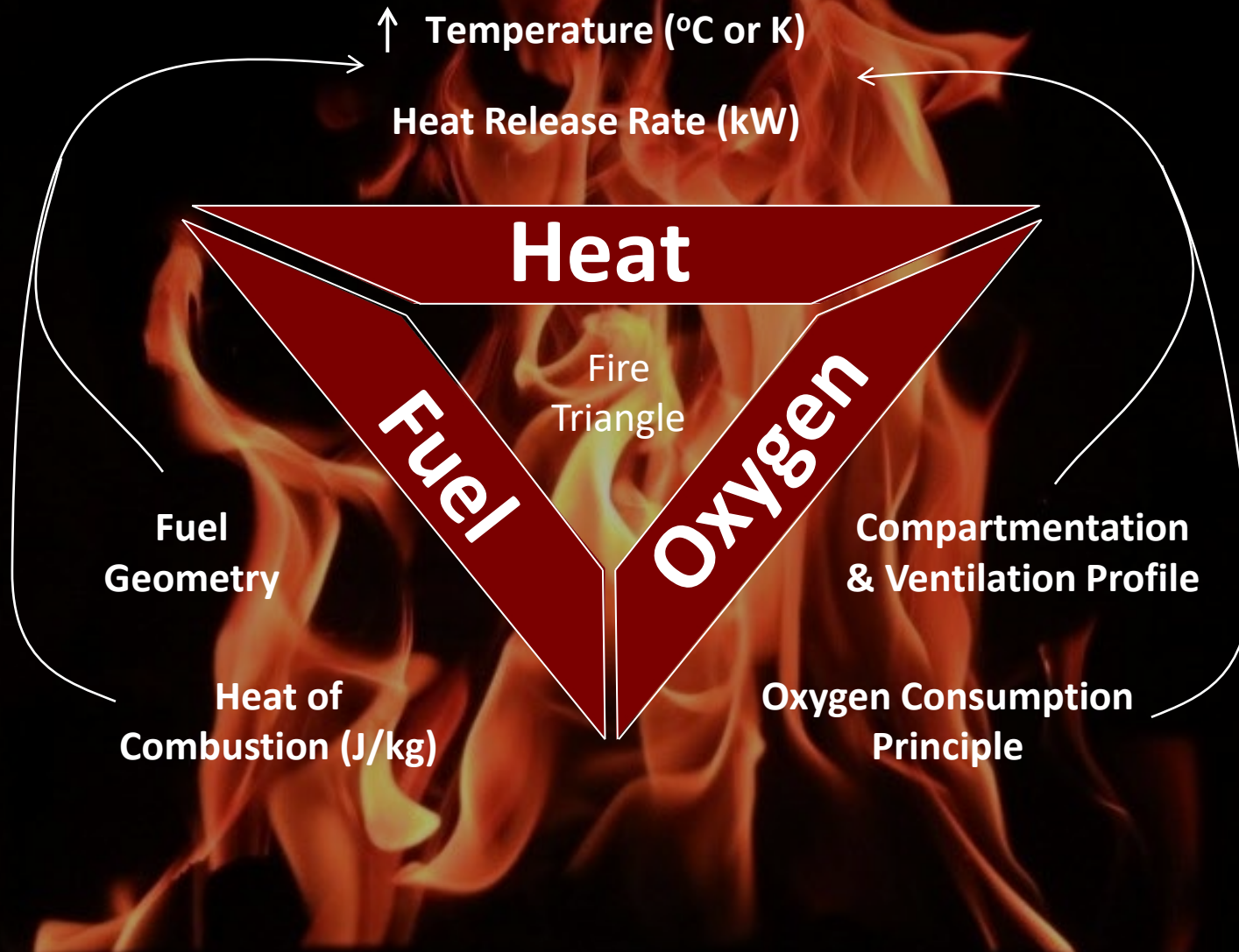
$\Rightarrow$ constraint of behaviour

Compressible Navier-Stokes

$$\rho \frac{d\underline{v}}{dt} = \rho \underline{f}$$

information

Turn it Upside Down





HOME FURNISHING COMPARISON

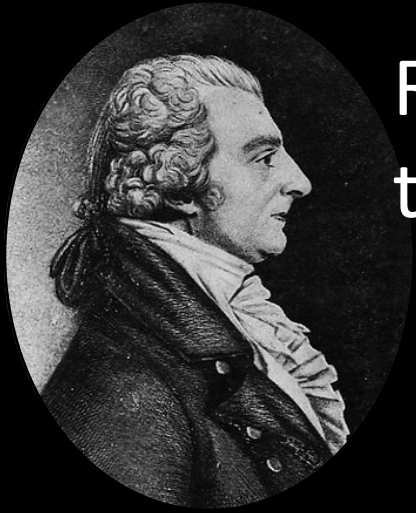


NATURAL



00:04

SYNTHETIC



Release of energy in oxidation is proportional to the mass of oxygen consumed.

William Thornton (1917)
*The Relation of Oxygen to the Heat
of Combustion of Organic Compounds*

51 Years Earlier

The door should be kept shut while the water is being brought, and the air excluded as much as possible, as the fire burns exactly in proportion to the quantity of air which it receives.

James Braidwood (1866)
Fire Prevention and Fire Extinction

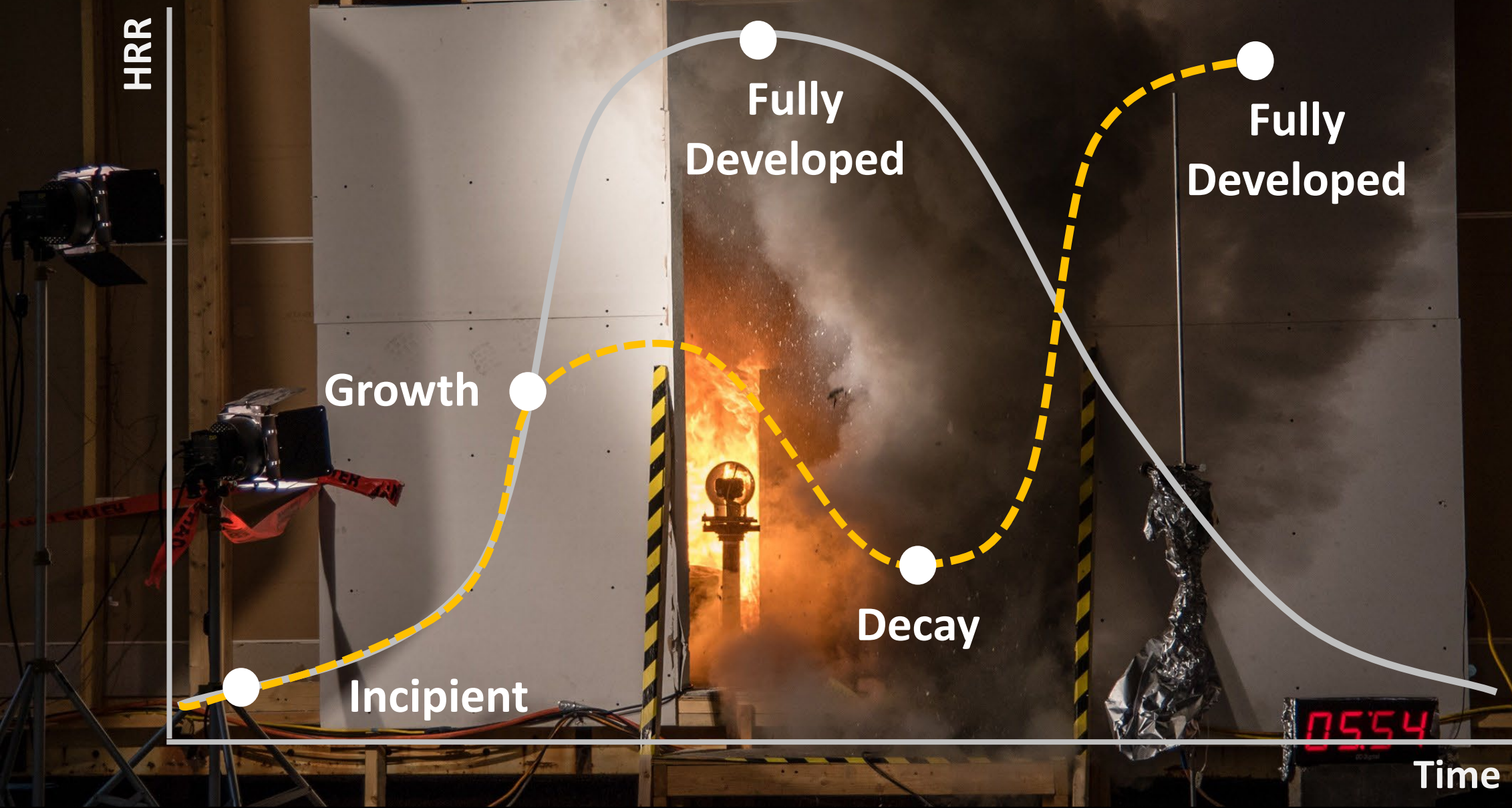


Heat release rate (HRR) is measured in Watts (J/s)

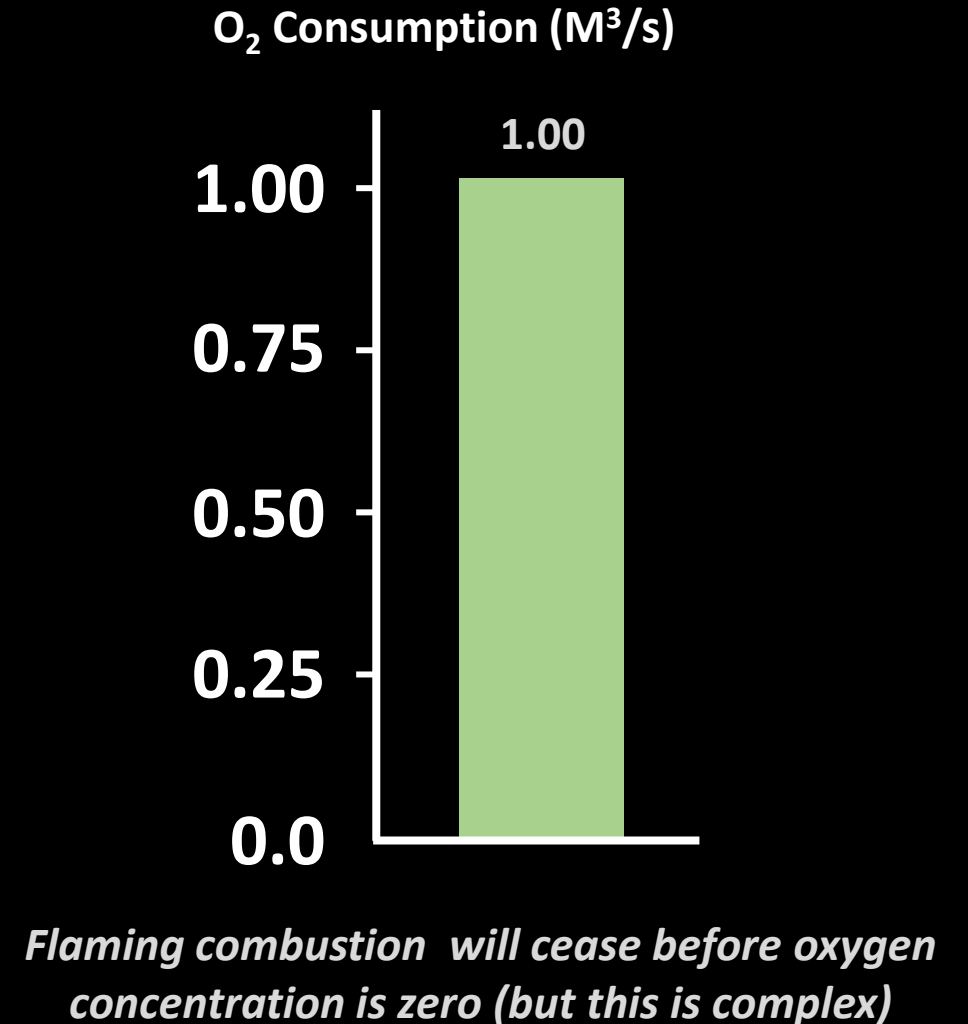
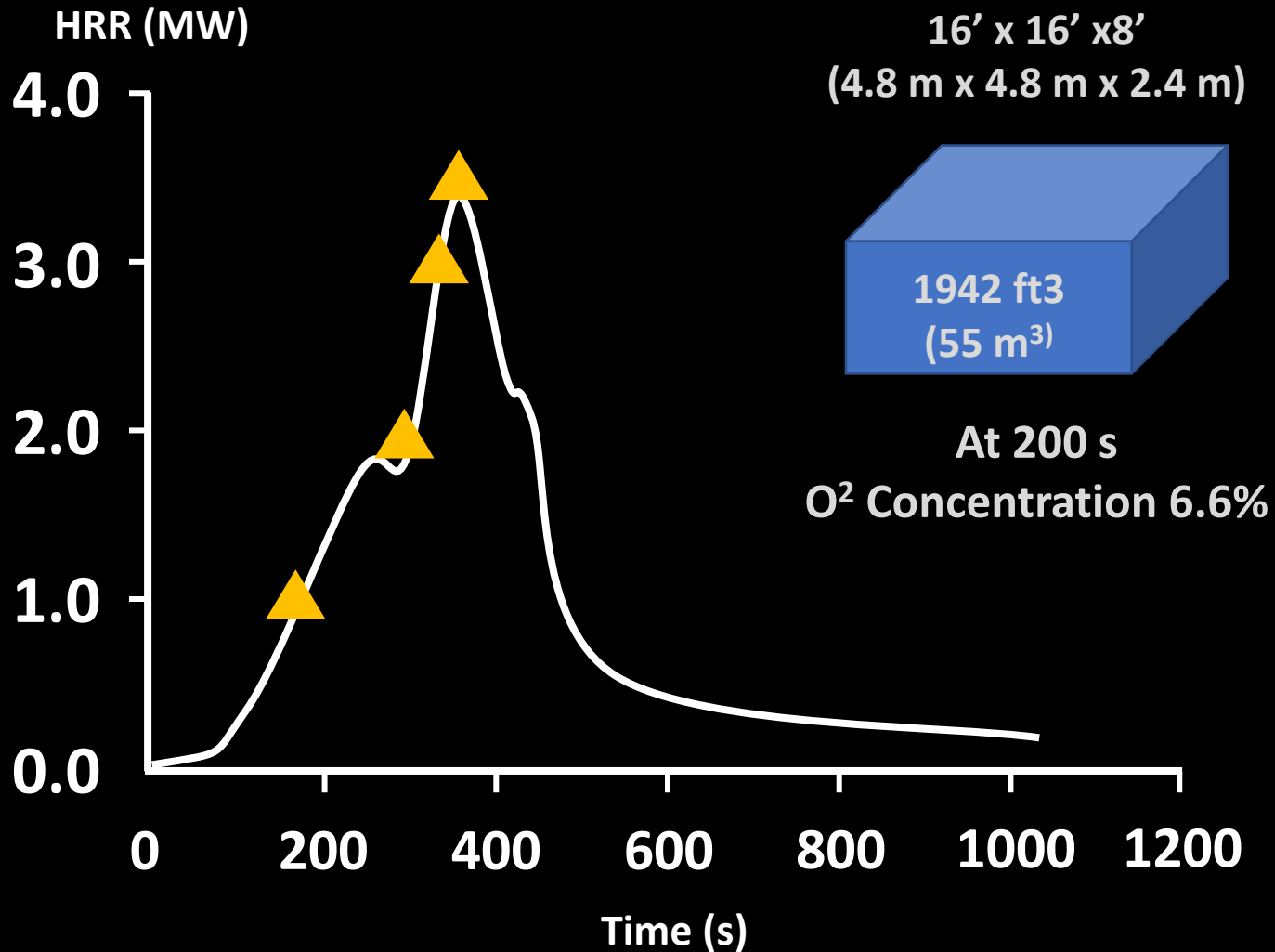


This is a sufficient heat release rate to cause flashover in a typical residential space with a single open door.

Fuel vs. Vent Limited Fire



Oxygen Consumption



COMPARTMENT FIRE DYNAMICS



COMPARTMENT WITH OPEN DOOR

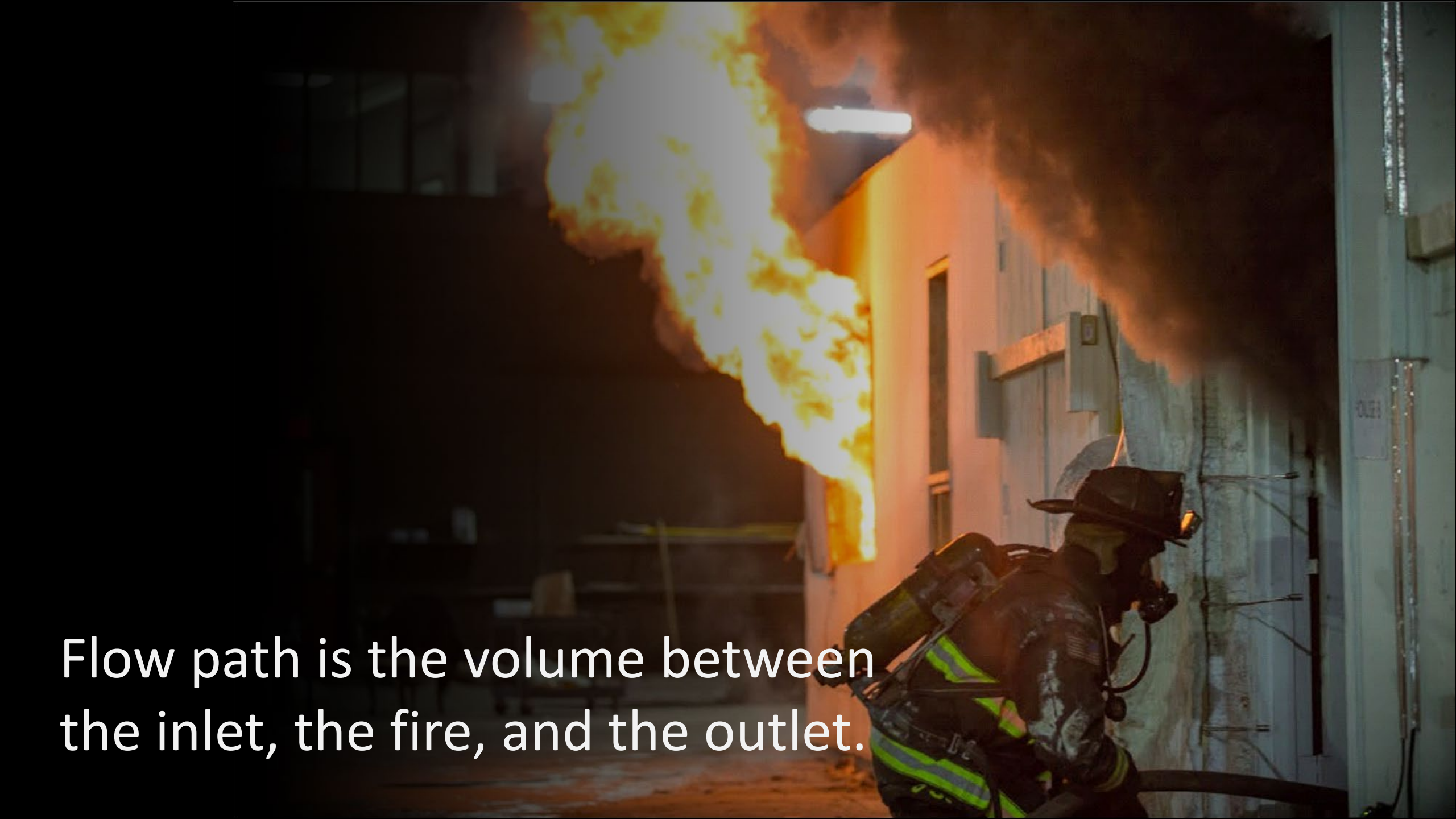


COMPARTMENT WITH CLOSED DOOR



01:50





Flow path is the volume between the inlet, the fire, and the outlet.

Air Track vs Flow Path

- Unidirectional-Out
- Unidirectional-In
- Bi-Directional

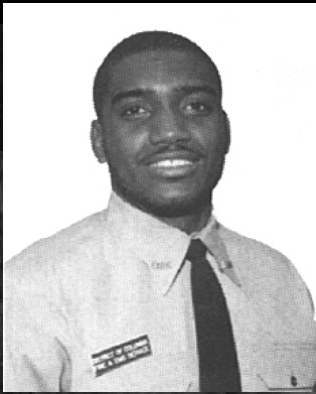


Smoke Movement

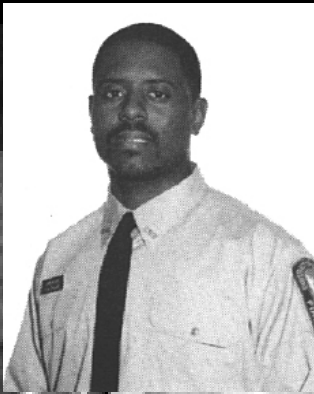


Pressure or Density?

Cherry Road, Washington DC



Louis
Matthews



Anthony
Phillips



May 30, 1999





Many firefighting tactics were developed based on fire behavior under legacy conditions.

Squire Meat Packing Plant
Somerville, MA
September 1, 1978
10 Alarms

Research With the Fire Service

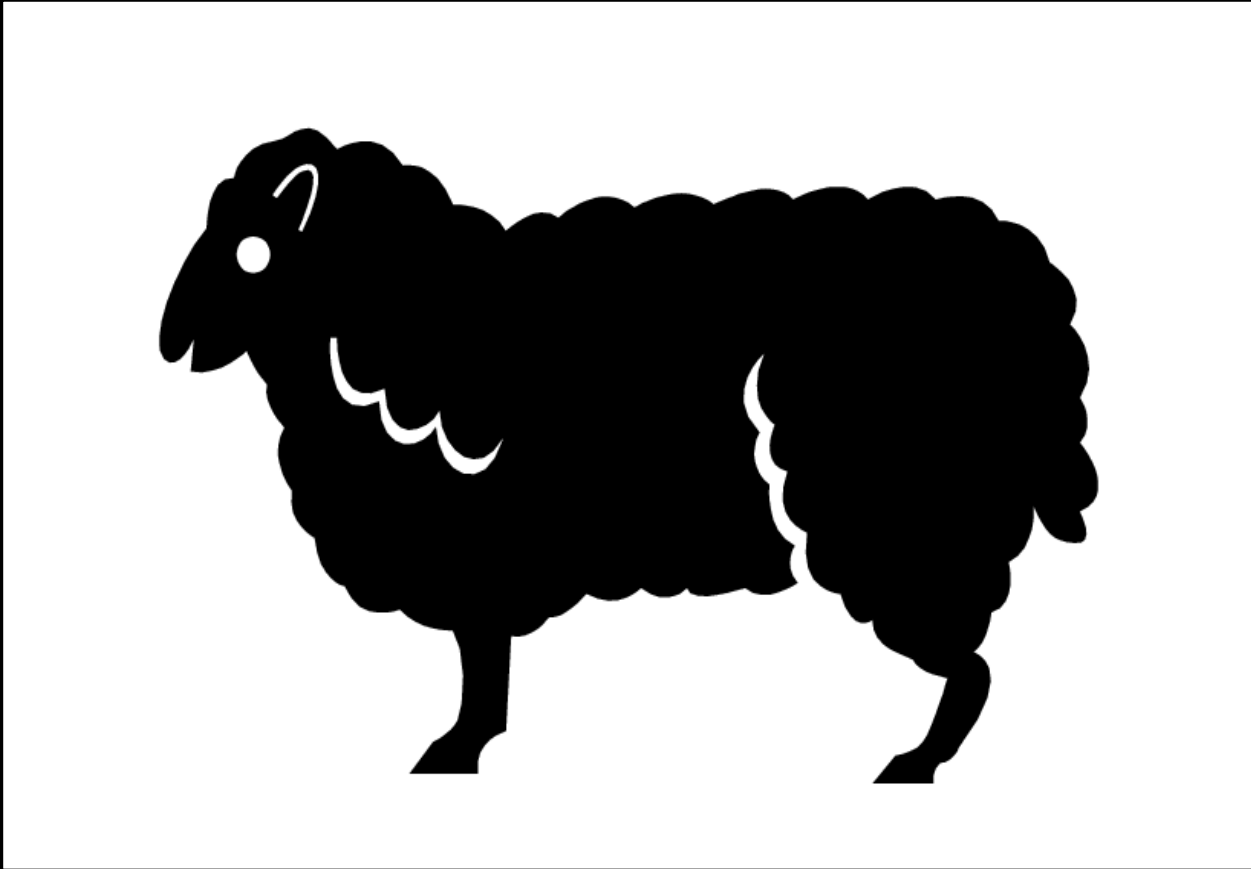


- Wind Driven Fires
- Engineered Lumber
- Horizontal Ventilation
- Vertical Ventilation
- O'Hare Airport
- Governors Island, NY
- Spartanburg, SC
- **Attic Fires**
- Positive Pressure Ventilation
- **Basement Fires**
- Interior and Exterior Streams
- Coordinated Fire Attack
- Cardiovascular and Chemical Risks
- Fire Service Training Environment
- Size-Up/Search and Rescue
- Fire Patterns & Fire Investigation



NIST

Limits of Observation



*A scientist, an engineer,
and a firefighter...*



*What conclusions do we
draw from our experience?*

What Danger Lurks in Attics and Basements?



Building Construction & Fire Behavior

Mayday, Mayday, Mayday!



Project Mayday

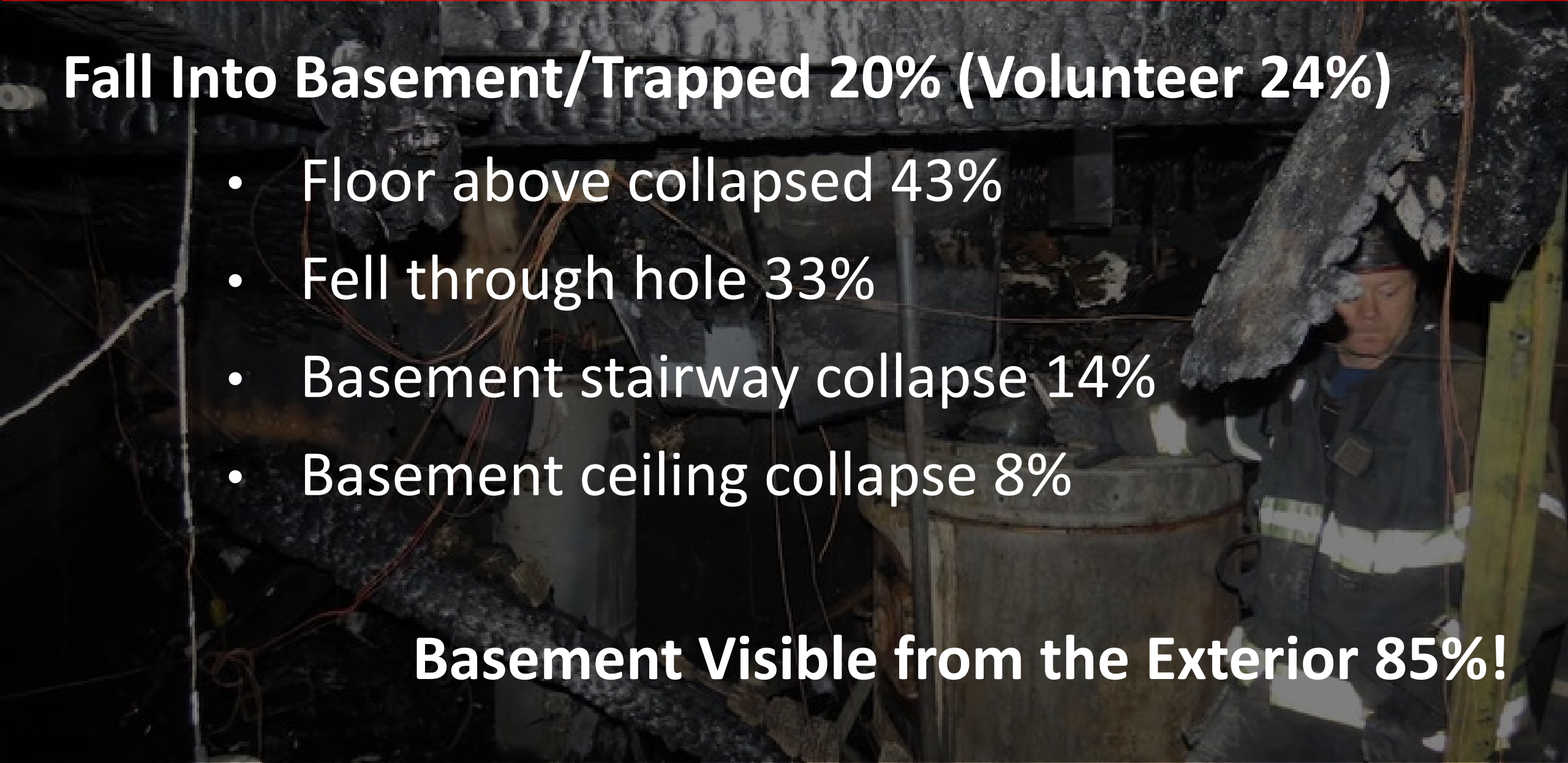
Type of Mayday	Career	Volunteer
Lost/separated from hoseline	24%	19%
Falls into basements	20%	24%
Falls through/off roofs	17%	5%
Air problems	17%	14%
Entanglement	10%	14%
Gas explosions/collapse	6%	6%
Medical	-	16%
No communications	-	5%
Other	-	3%

Project Mayday

Fall Into Basement/Trapped 20% (Volunteer 24%)

- Floor above collapsed 43%
- Fell through hole 33%
- Basement stairway collapse 14%
- Basement ceiling collapse 8%

Basement Visible from the Exterior 85%!



Project Mayday

Roof Operations 17% (Volunteer 5%)

- Fall through the roof 84%
- Fell off a ladder or the roof 16%

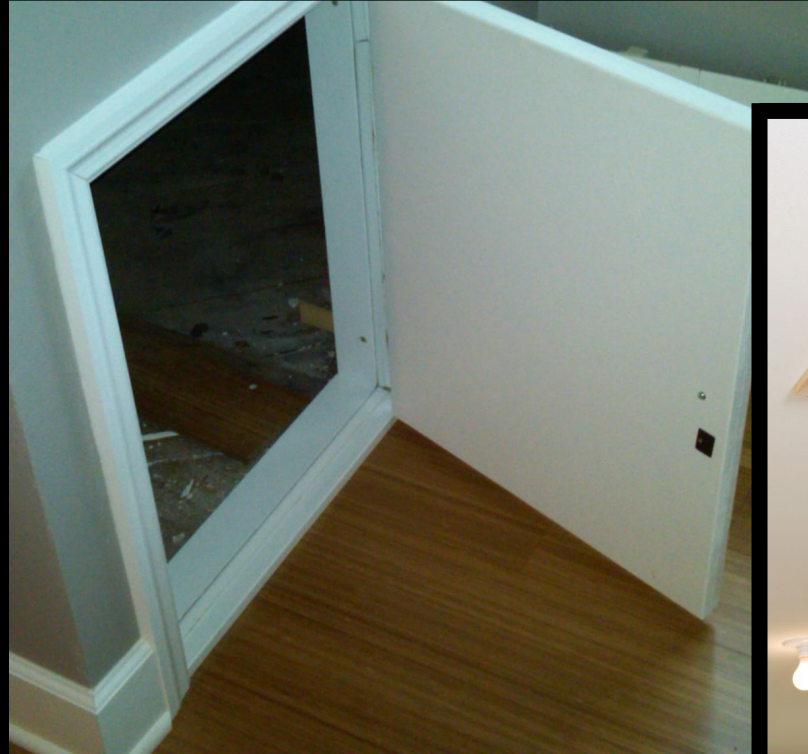
Two thirds of falls through the roof occurred during roof travel and the remainder occurred during ventilation operations

Common Terminology

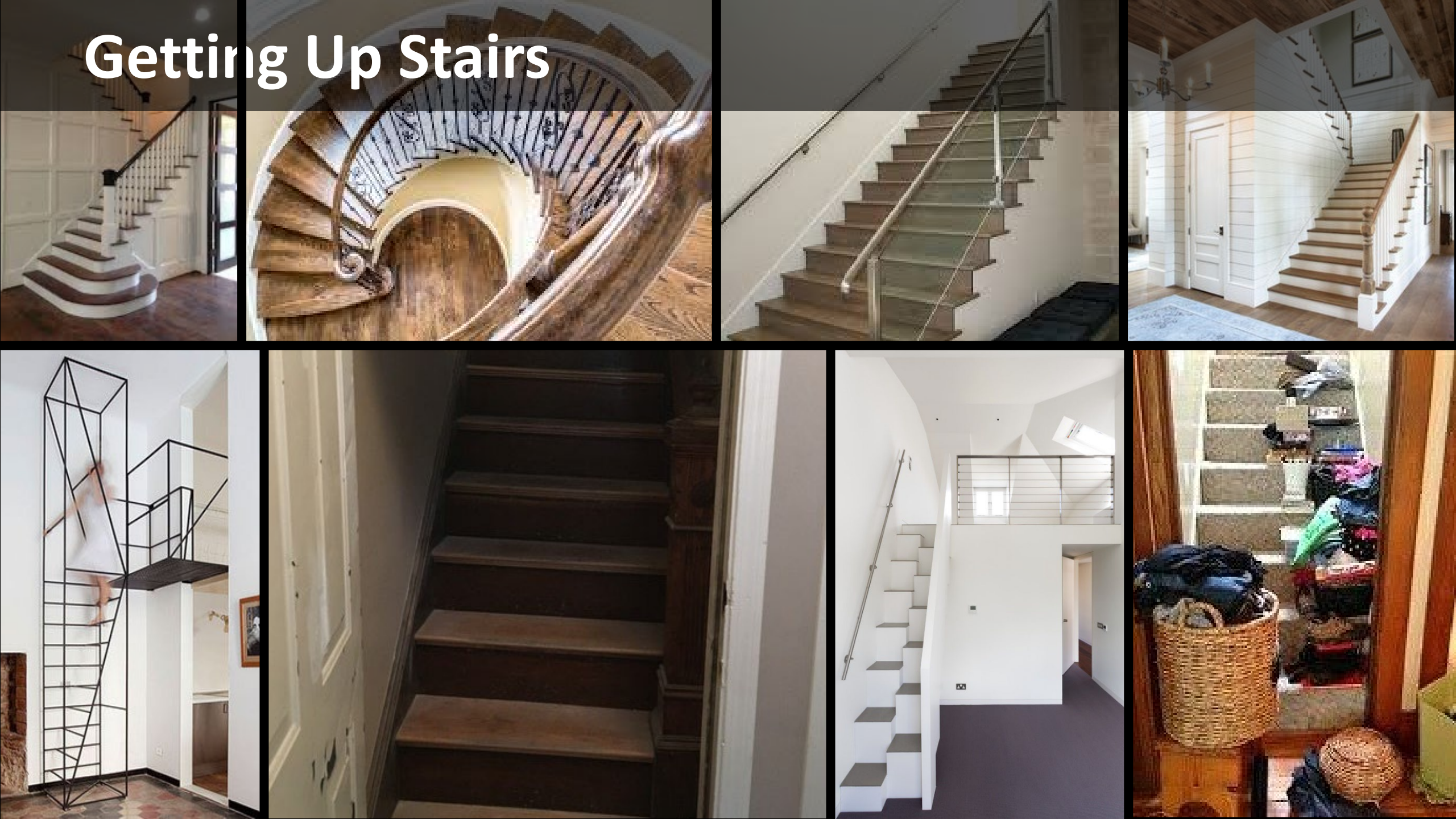
- **Attic:** When a steep pitched roof is built to shed snow or heavy rain loads, or for appearance
- **Cockloft:** A small space created when the roof is raised above the level of the flat beams to provide a pitch to drain rain and a vented air space to reduce top-floor temperatures.



Attic Access Challenges



Getting Up Stairs



Attic Construction



Attic Construction



Ceiling Construction



Ceiling Construction



Ceiling Height



Commercial

2020s



1950s

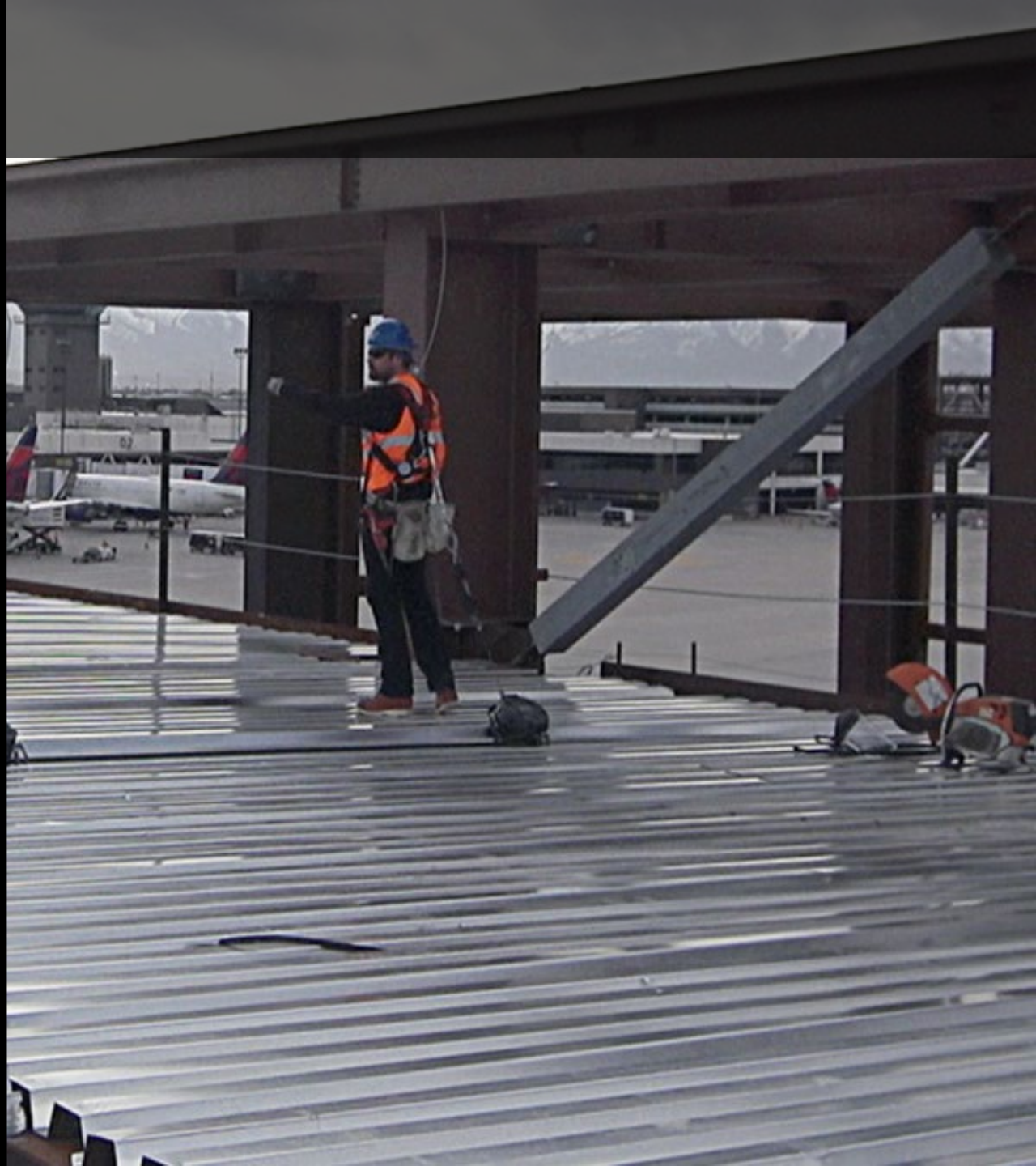
Ceiling Construction



Roof Construction



Roof Construction



Roof Covering



Roof Covering



PV Panels



Roof/Attic Insulation



Roof/Attic Insulaiton



Draft Stop



Churchville, NY
May 10, 2013

Fire Wall



Attic Ventilation



Extension From the Outside In



Residential Attic Fires

Wall Experiments

Full Scale Attic Experiments

Knee Wall and Attic Field Experiments



A 2-year study to examine fire service attic fire mitigation tactics and the hazards posed to firefighter safety by the changing modern residential fire environment and construction practices.

Wall Experiments



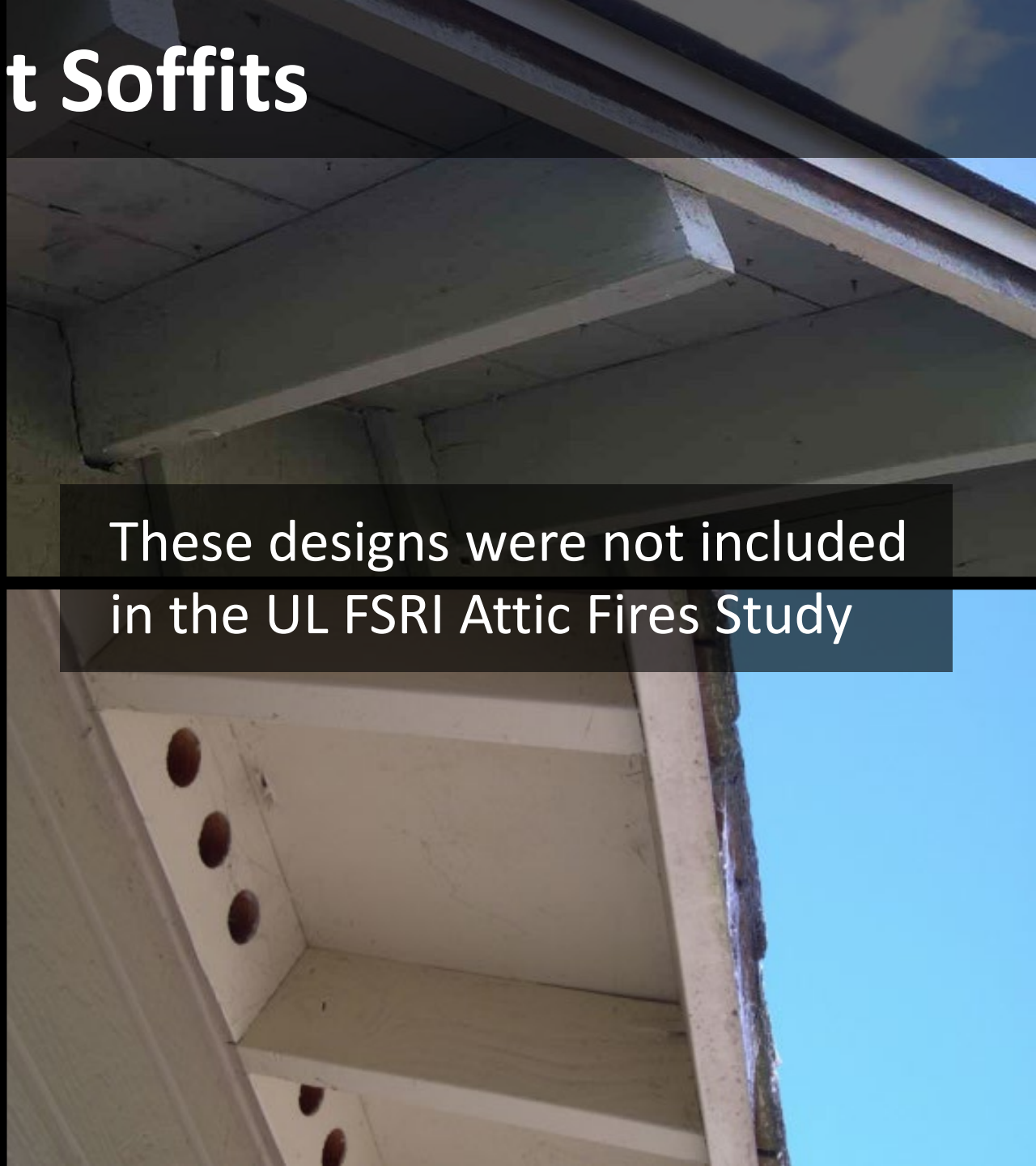
Siding and sheathing play an important role in fire growth!

Vinyl siding, polystyrene sheathing, and foam wall cavity insulation lead to more severe fires

Eave Assemblies



Eaves With and Without Soffits



These designs were not included
in the UL FSRI Attic Fires Study

Transition to an Attic Fire



Eave design and insulation significantly impact fire spread into the attic space.



Full Scale Attic Experiments

Evaluation of fire dynamics and suppression effectiveness of four fire suppression tactics in ventilated and unventilated attics.

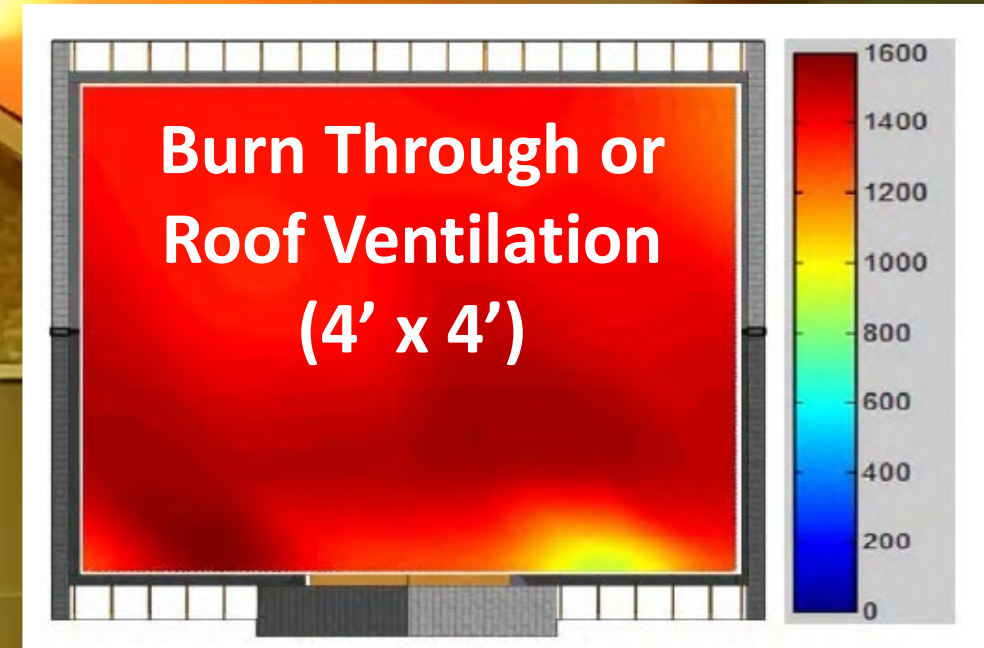
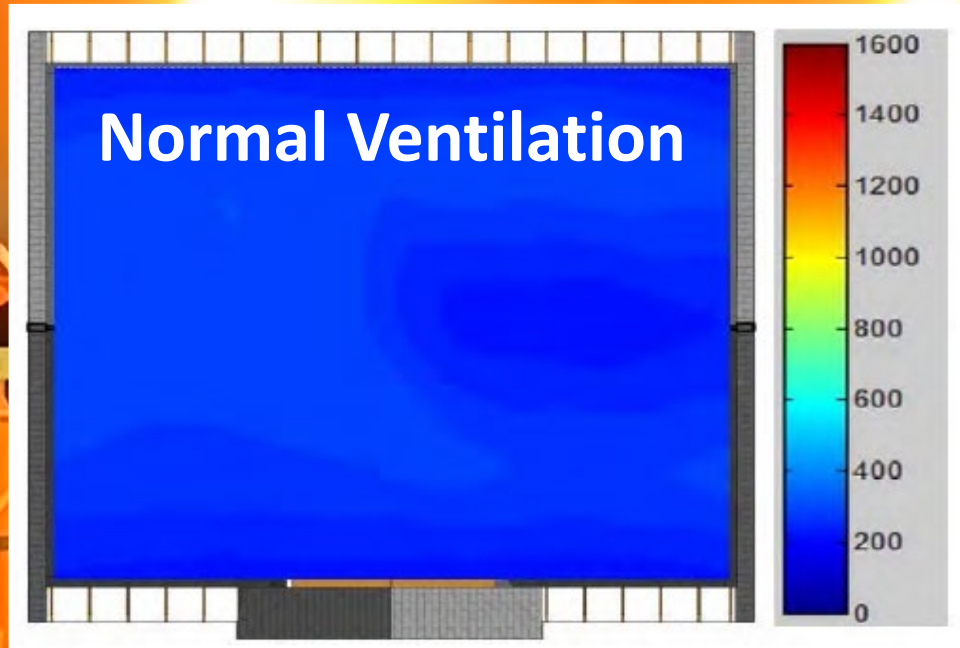


Design & Construction



30' x 36' with a 6-12 Pitch Wood Truss Roof with OSB Sheathing and Vinyl Soffits and Ridge Vent. Fiberglass insulation was placed on the floor of the attic. The fuel load in the attic was comprised of boxes of plastic cups and structural materials.

Fire Dynamics



Fire Suppression Tactics

Interior Attack – Small Opening



Interior – Attack Large Opening



Exterior – Gable Attack



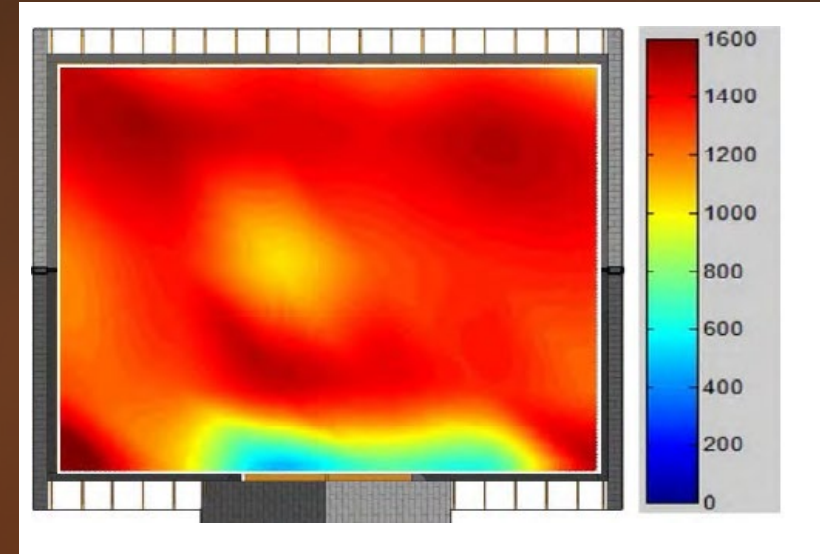
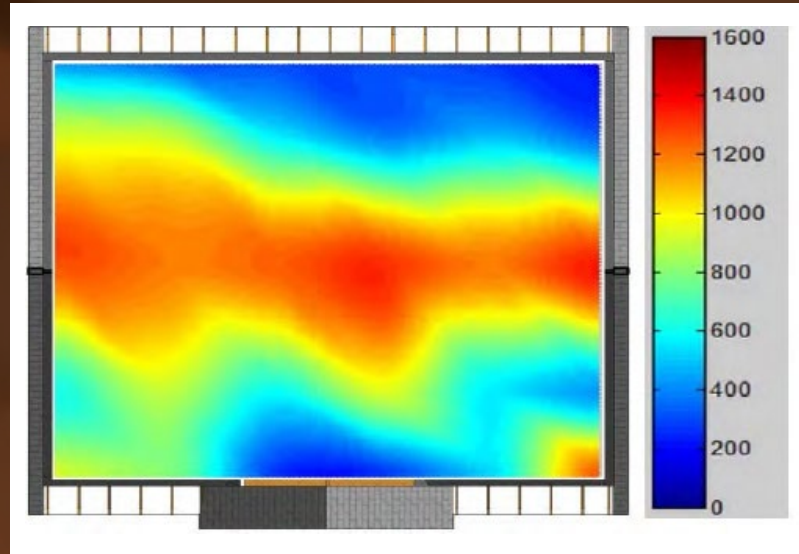
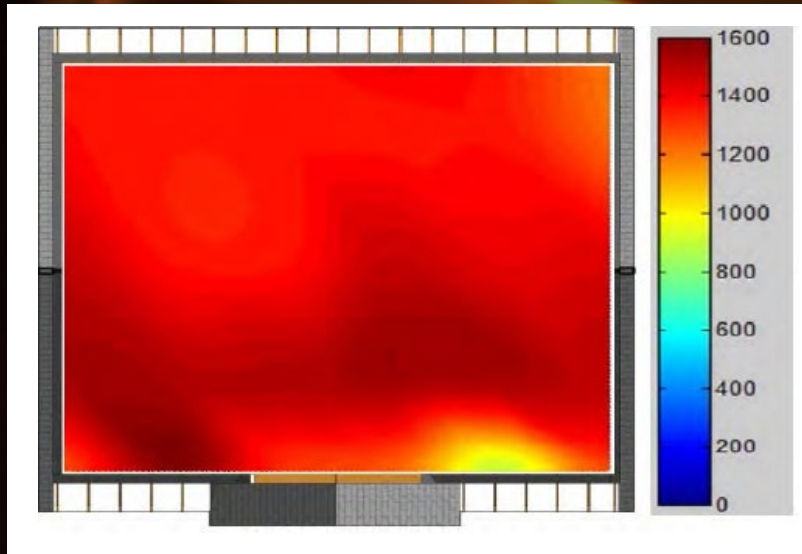
Exterior – Eave Attack



Interior – Small Opening

150 gpm

38 s



>1000° F

60 s

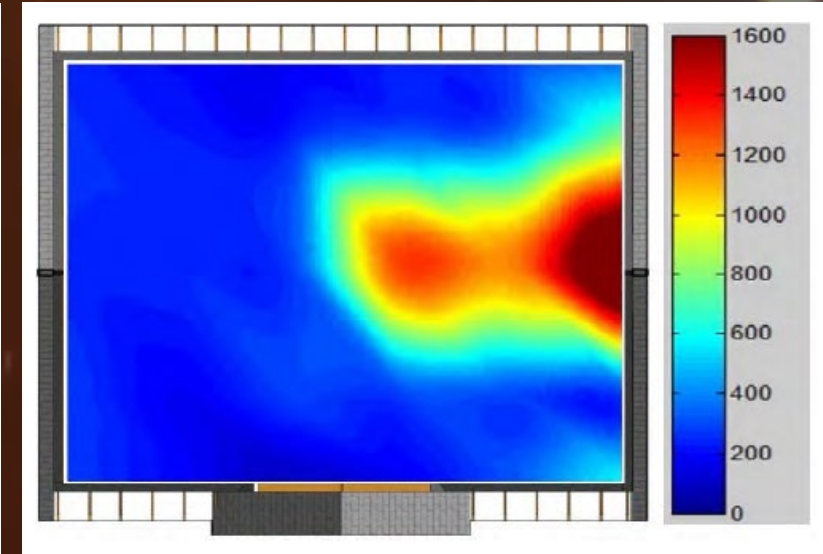
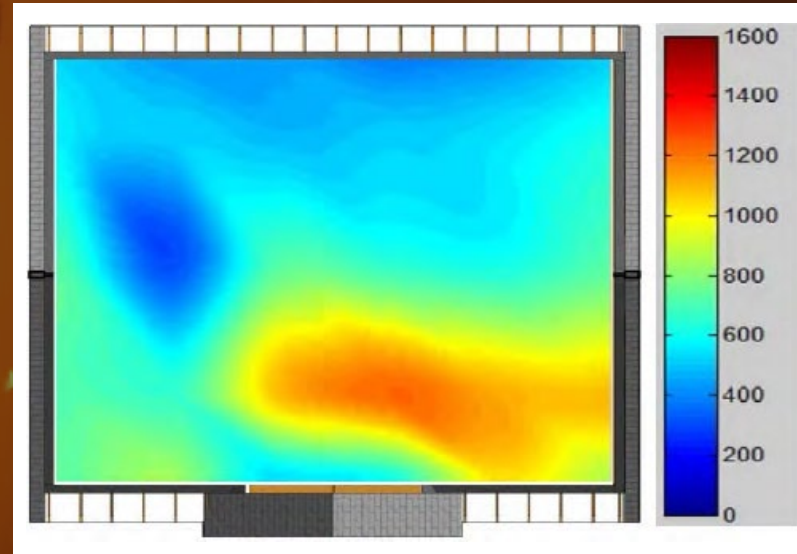
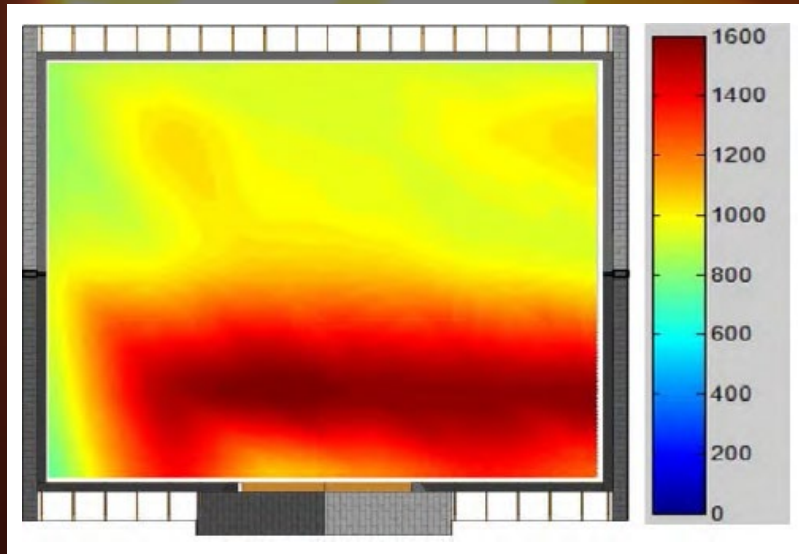
A fog stream was used for Experiment 1

Vented/Burn Through

Interior – Large Opening

150 gpm

15 s



>800° F

60 s

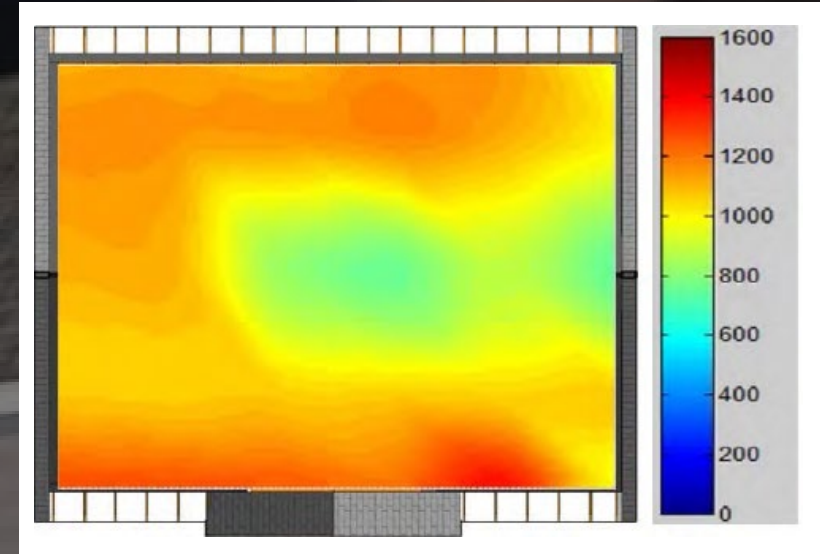
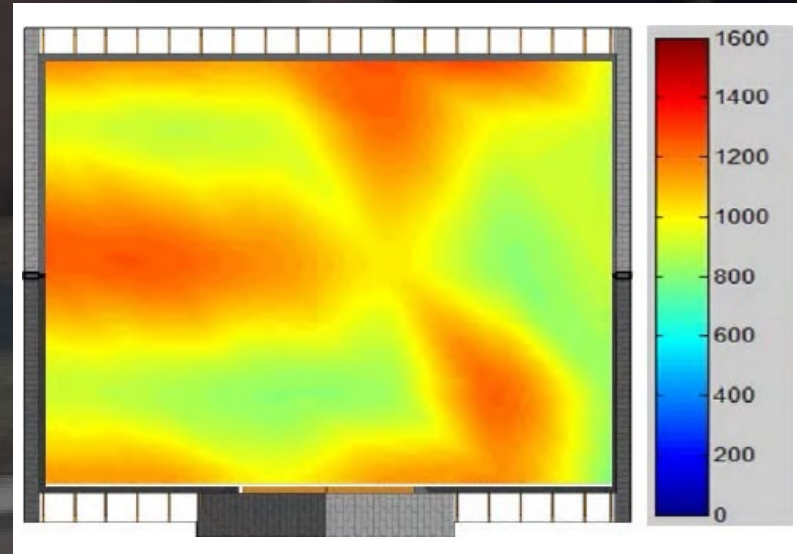
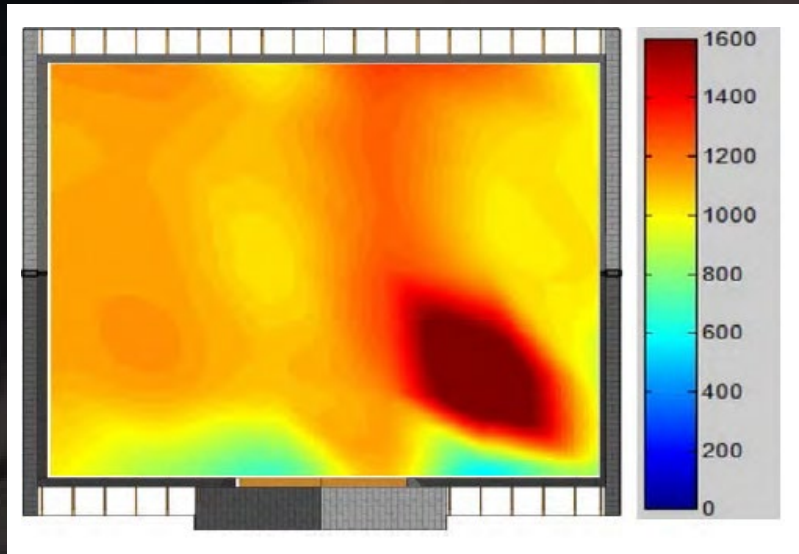
No major difference in performance between straight and fog streams in Experiments 2A and 2B

Vented/Burn Through

Exterior – Gable

150 gpm

20 s



>1000° F

60 s

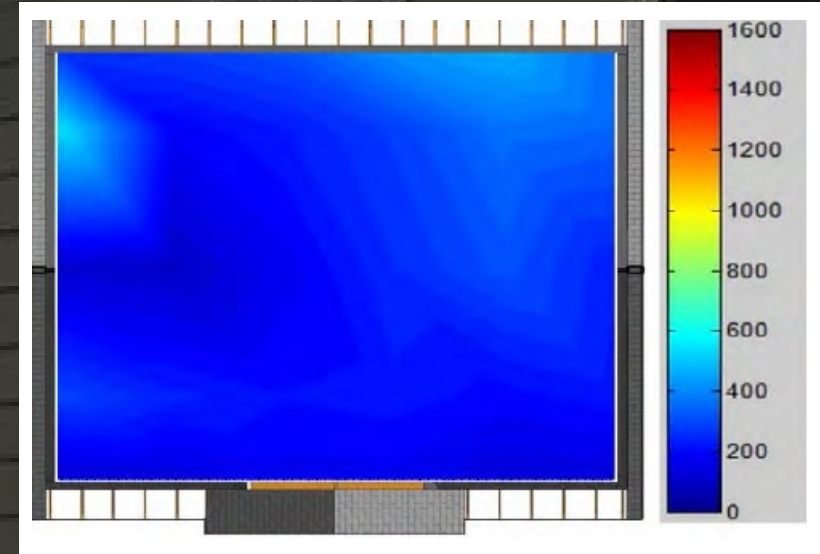
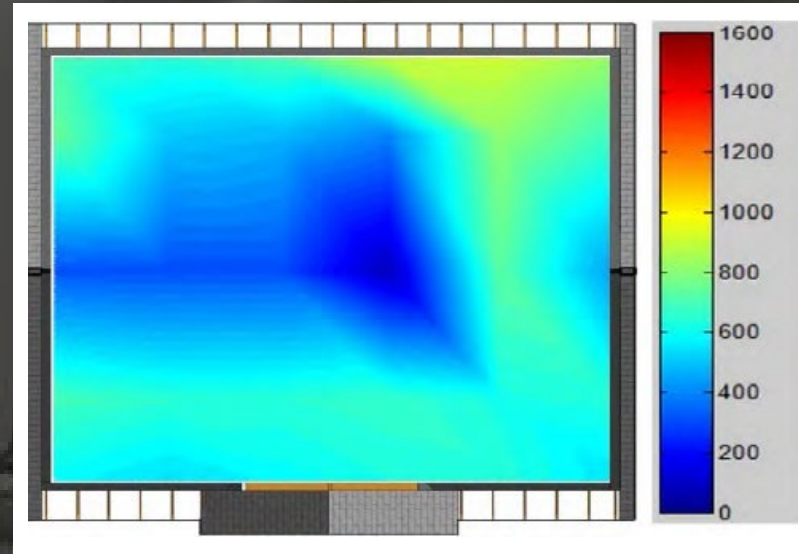
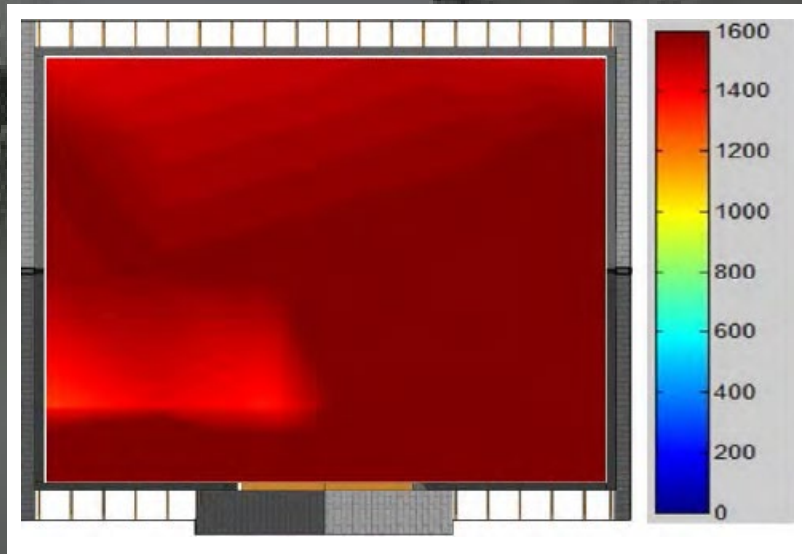
A straight stream was used for Experiment 3A

Vented/Burn Through

Exterior – Eave

150 gpm

27 s



>1000° F

60 s

A straight stream was used for Experiment 4C

Vented/Burn Through

Tactics Not Examined



Tactics Not Examined



**Ultra-High Pressure
Cutting Extinguisher**



**High Pressure
Fog Nails**

UL FSRI Ventilation Research

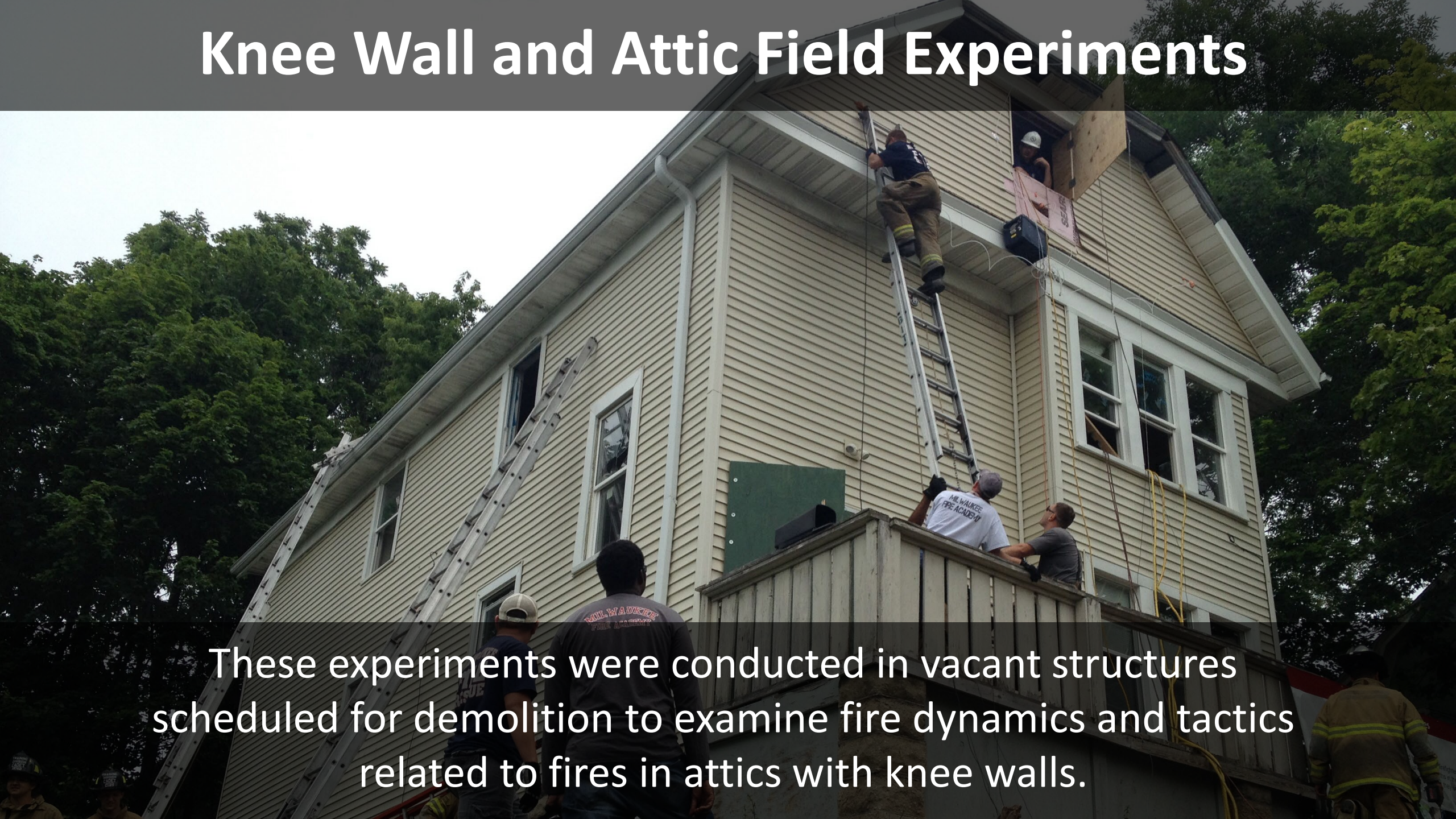
Horizontal

PPV

Vertical

Strip Malls

Knee Wall and Attic Field Experiments



These experiments were conducted in vacant structures scheduled for demolition to examine fire dynamics and tactics related to fires in attics with knee walls.

Knee Wall and Attic Field Experiments



Fire Suppression Tactics



Exterior Attack

Interior Attack (Simulated)

Eave Attack

Master Stream Attack

Residential vs Commercial Attic Fires



NIOSH Death in the Line of Duty Reports

Attic/Roof Void Fires 18.93%

Structure Fires Trauma n=169

96-17 Commercial

97-09 Commercial

97-16 Residential Fire

98F-04 Commercial

98F-07 Commercial

99F-04 Church

F2000-13 Commercial

F2001-03 Church

F2002-50 Commercial

F2003-18 Commercial

F2004-10 Commercial

F2005-13 Apartment

F2006-07 Commercial

F2005-09 Residential

F2004-37 Church

2006-19 Residential

2007-01 Strip Mall

2007-32 Commercial

2008-03 Commercial*

2008-34 Residential

2009-11 Residential

2010-18 Residential

2010-38 Commercial

2011-05 Apartment

2011-14 Church

* Multiple Injury



2011-20 Apartment

2012-08 Commercial

2012-28 Residential

2013-27 Residential

2014-15 Residential

2014-18 Commercial

2016-07 Strip Mall

2017-14 Strip Mall



NIOSH
Fire Fighter Fatality Investigation
and Prevention Program

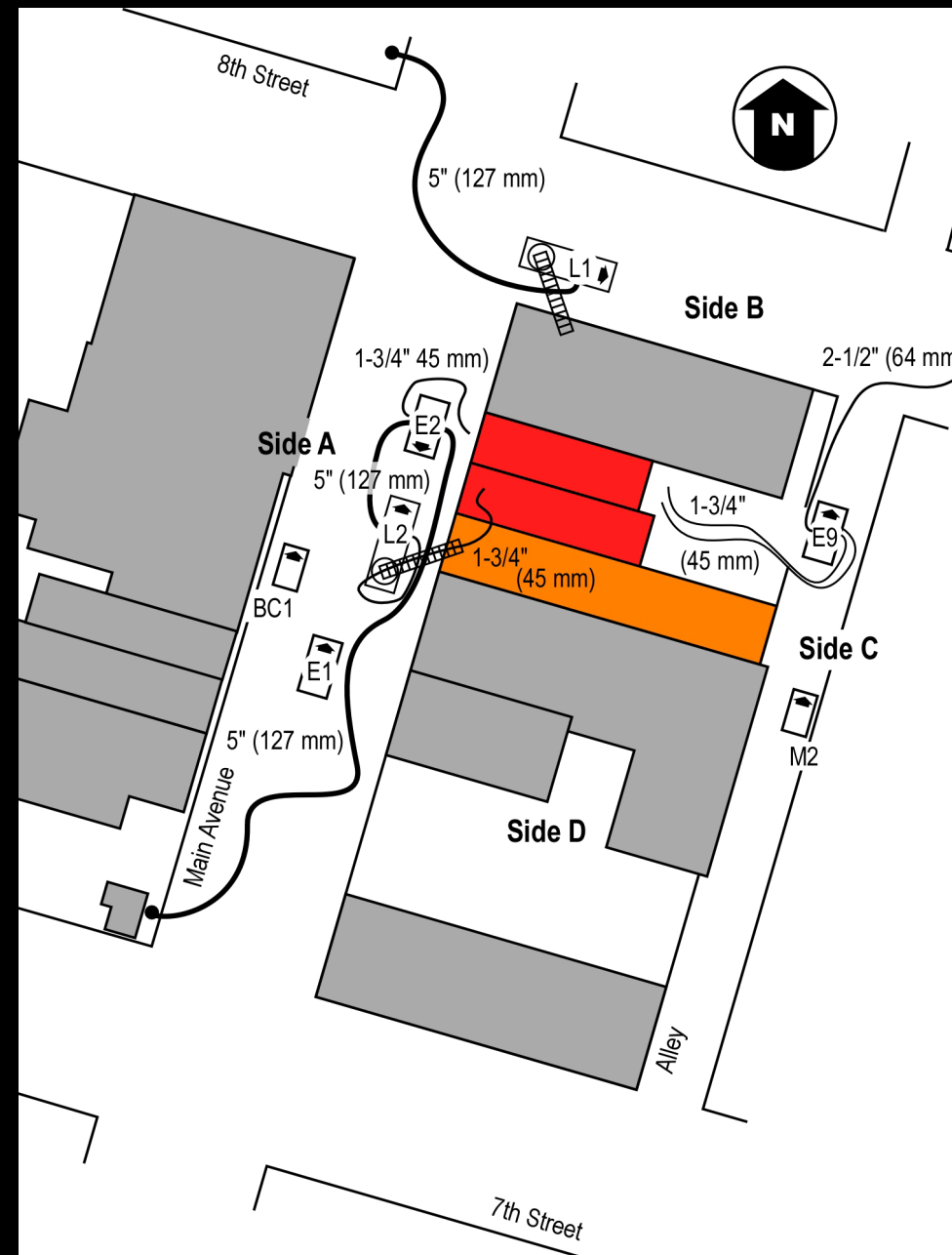
Injury in the line of duty...

A summary of a NIOSH fire fighter fatality investigation

April 17, 2009

**Nine Fire Fighters from a Combination Department Injured in an Explosion
at a Restaurant Fire – Colorado**

Durango, CO
February 22, 2008



NOISH F2008-03 Recommendations

- Ensure ventilation techniques are established and implemented.
- Conduct pre-planning
- Ensure SOPs are followed
- Ensure staffing levels are sufficient
- Ensure the incident commander has sufficient aides and has a view of the building
- Ensure thermal imaging cameras are used.

Tactical Considerations

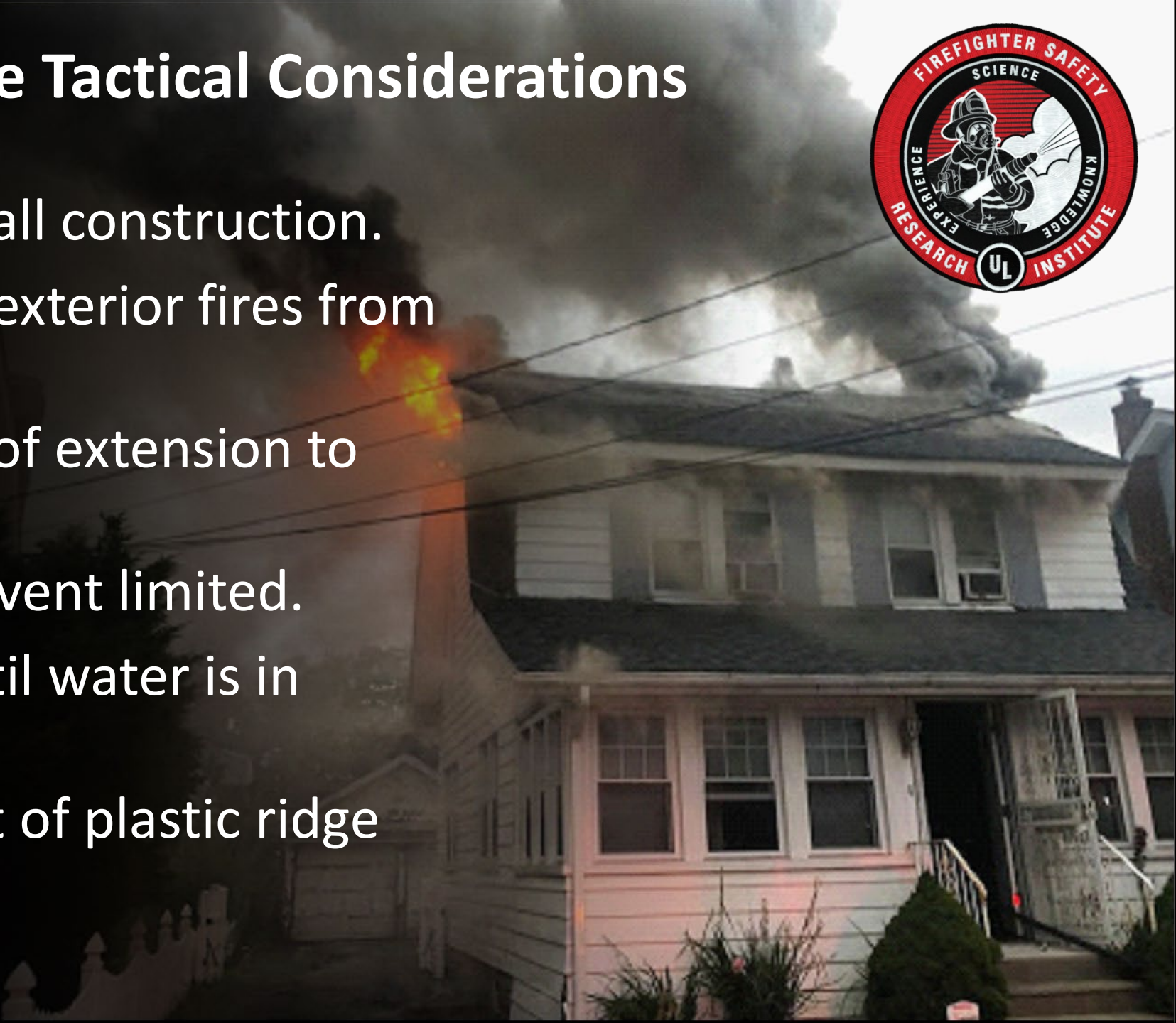


Tactical considerations are concepts to consider. These considerations increase knowledge of the fire service and should be incorporated into training and procedures, if deemed applicable.

Residential Attic Fire Tactical Considerations



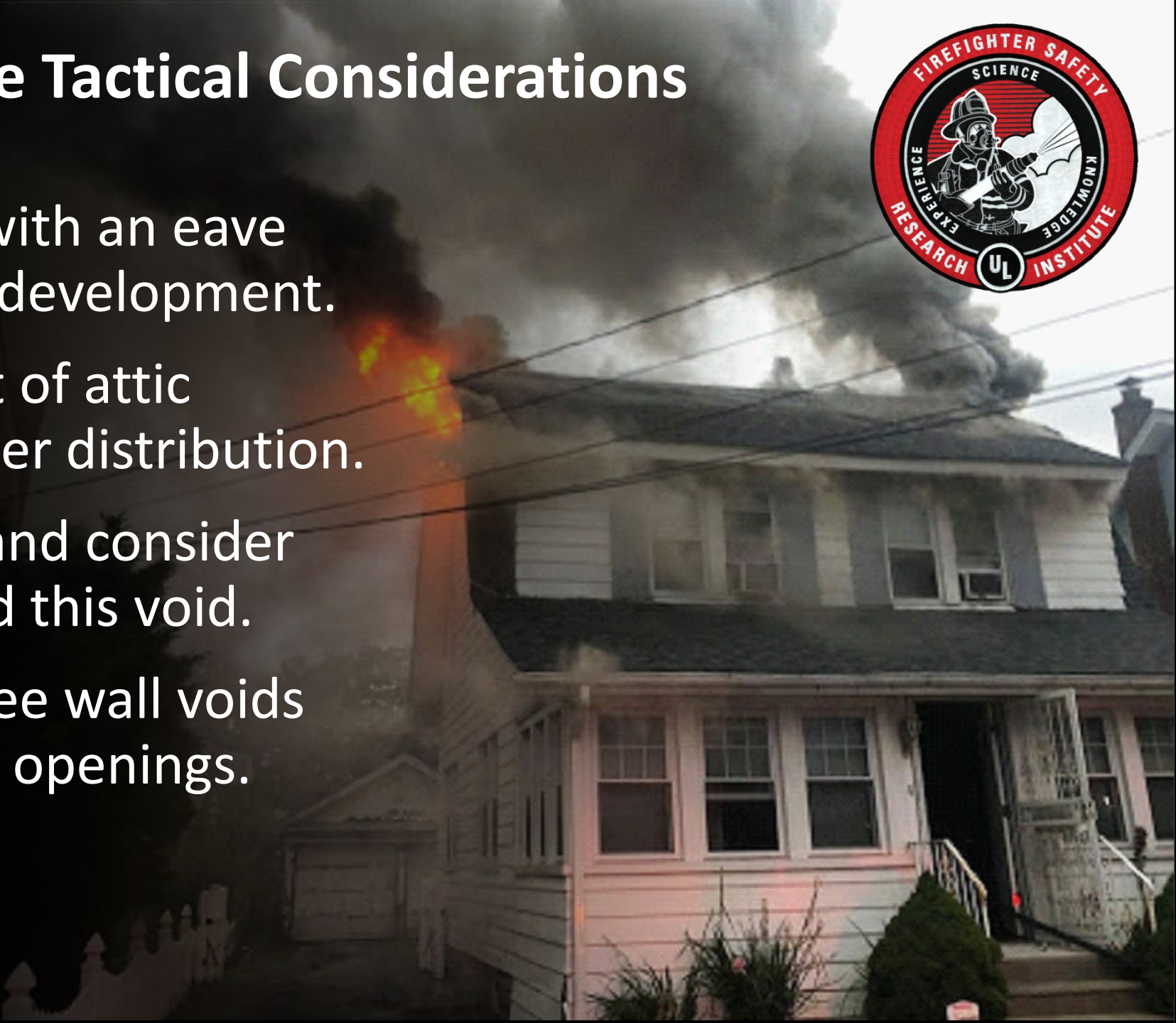
- Consider exterior wall construction.
- Start fire control of exterior fires from the outside.
- Anticipate avenues of extension to the attic.
- Attic fires are often vent limited.
- Limit ventilation until water is in the attic.
- Consider the impact of plastic ridge vents



Residential Attic Fire Tactical Considerations



- Wetting sheathing with an eave attack can slow fire development.
- Consider the impact of attic construction on water distribution.
- Beware knee walls and consider how the fire entered this void.
- Apply water into knee wall voids before making large openings.



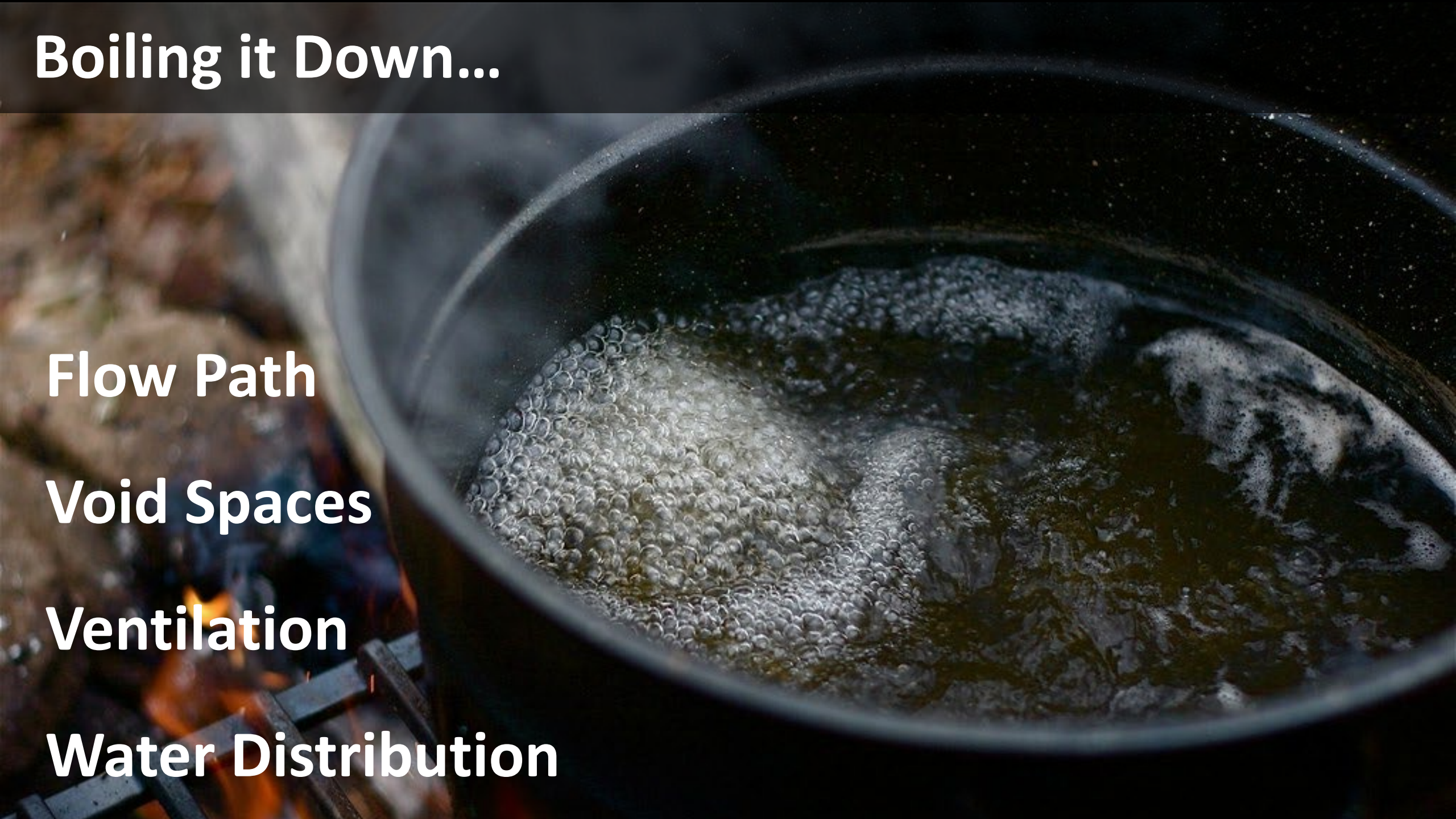
Boiling it Down...

Flow Path

Void Spaces

Ventilation

Water Distribution





Basement Fire Hazards

- Unexpected Floor Collapse
- High Heat Conditions

Unexpected?

Common Terminology

- **Crawl Space:** Below a building that is less than full height.
- **Cellar:** Storage of specific items
- **Basement:** Fully or partially below ground and full height



Crawl Spaces

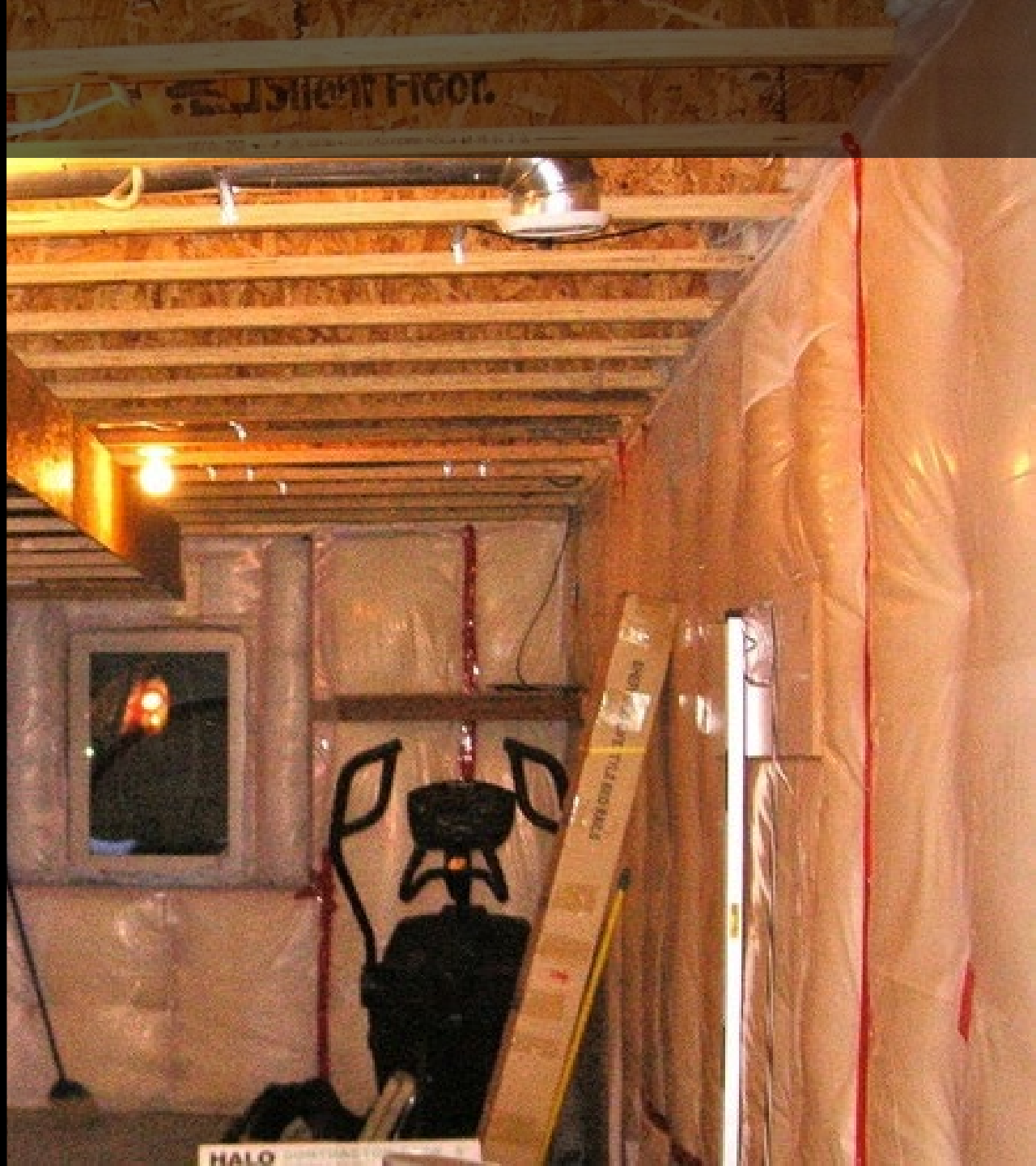


Crawl Space to Basement

You never know what you will find...



Unfinished Basement



Finished Basement



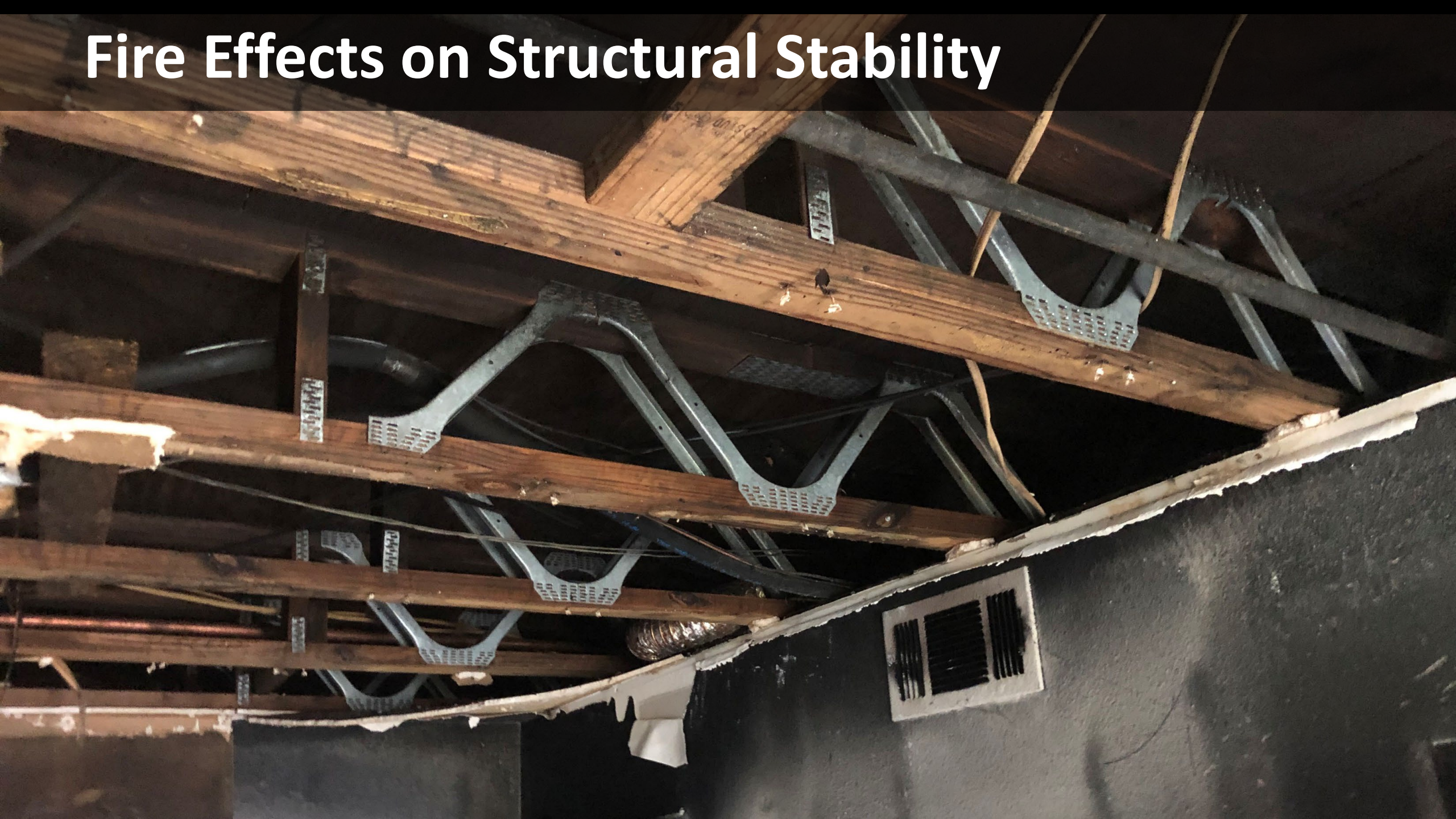
Foundation Construction



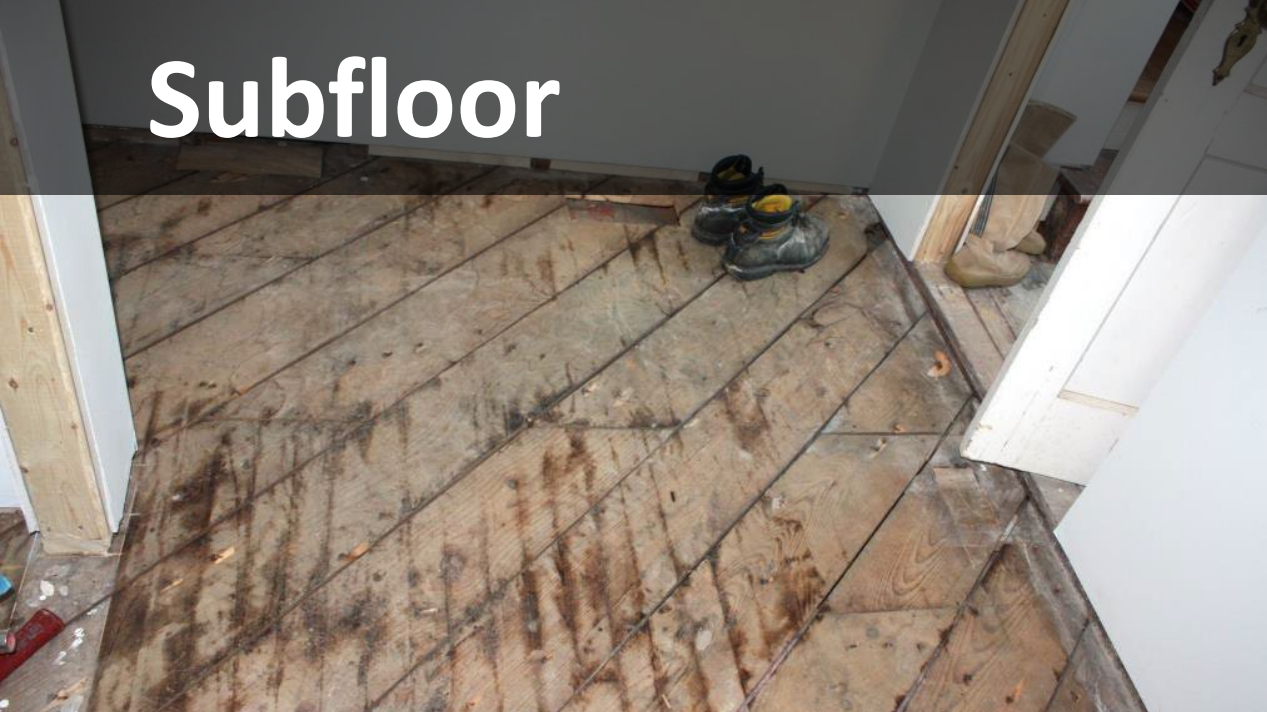
Foundation Construction



Fire Effects on Structural Stability



Subfloor



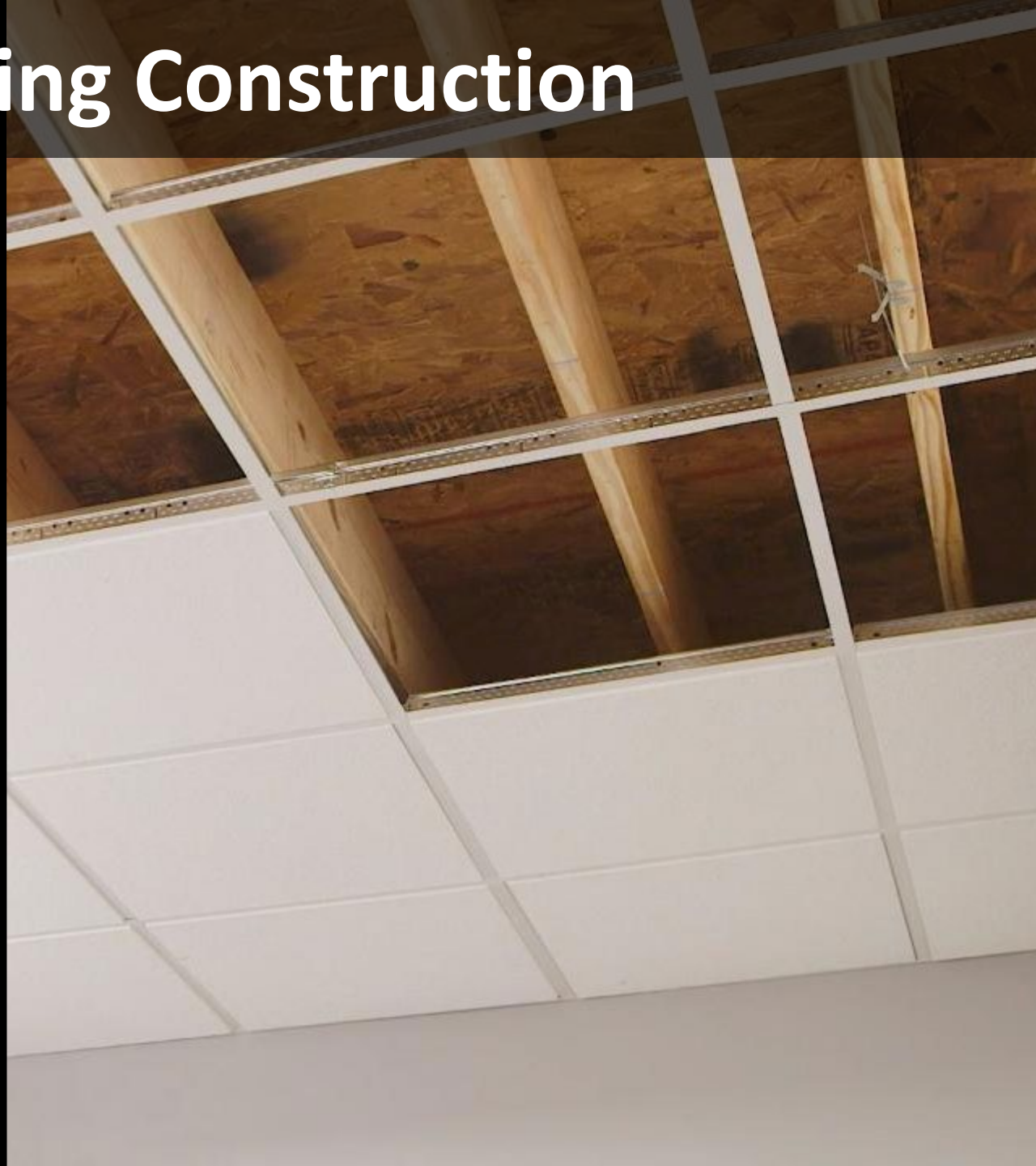
Flooring/Floor Covering



Why Floor Construction is Important



Finished Basement Ceiling Construction



The 1960s Compartment Linings



Finished or Unfinished Consideratoins



Basement Access

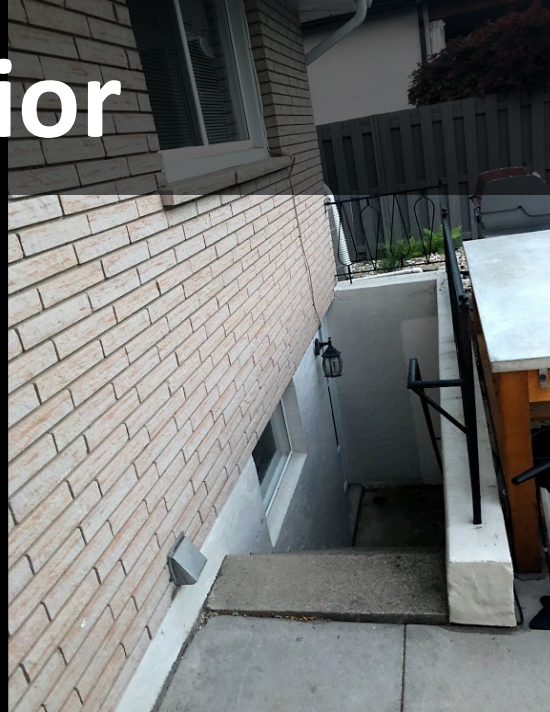
Exterior Access

Limited Exterior Access

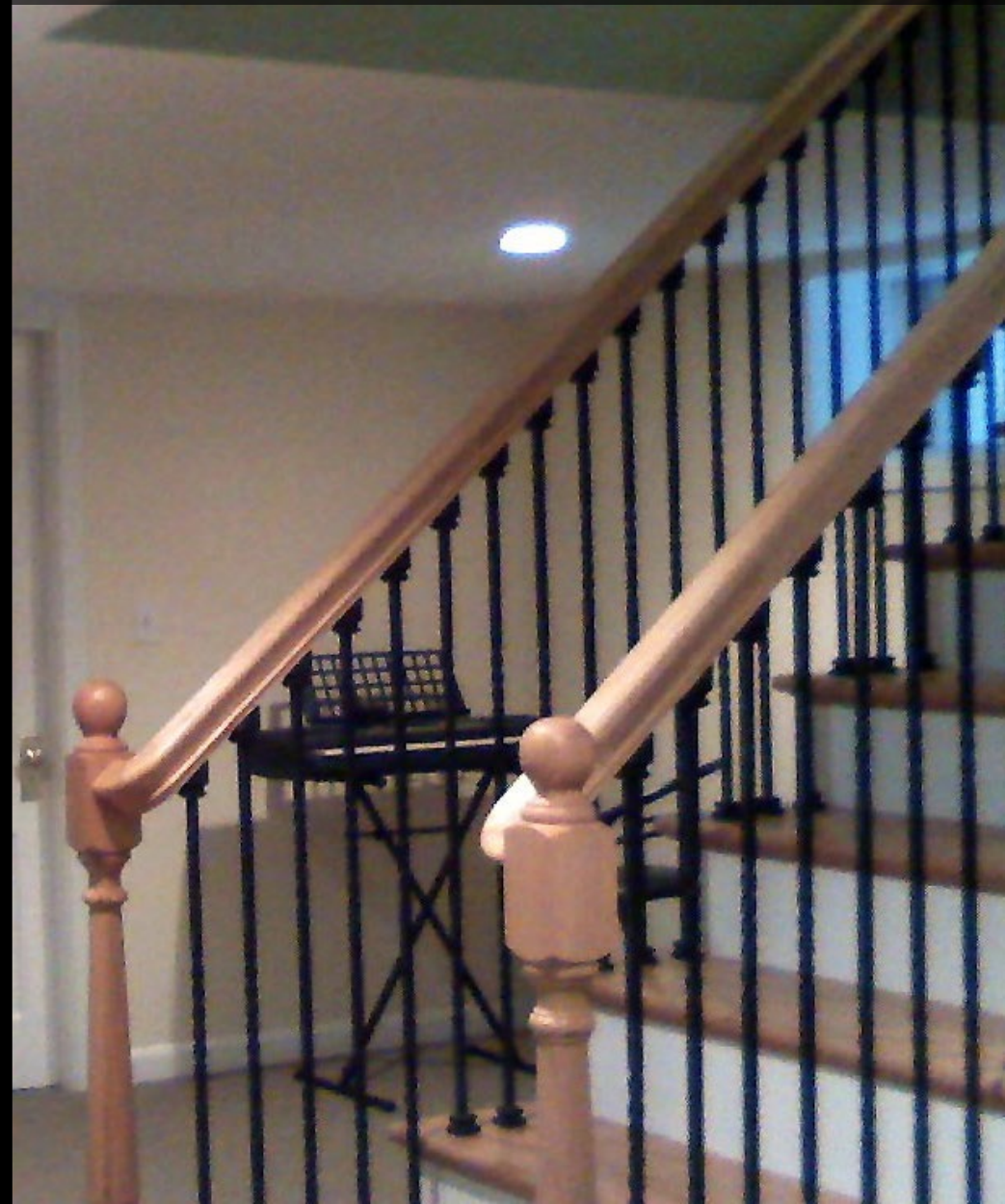
No Exterior Access



Basement Access-Exterior



Basement Access-Interior



Void Spaces & Penetrations



Basement Fuel Load



Basement Fuel Load



Basement Fuel Load



Basement Fires

Nozzles

No Exterior Access to Basement

Limited Exterior Access to Basement

Exterior Access to Basement

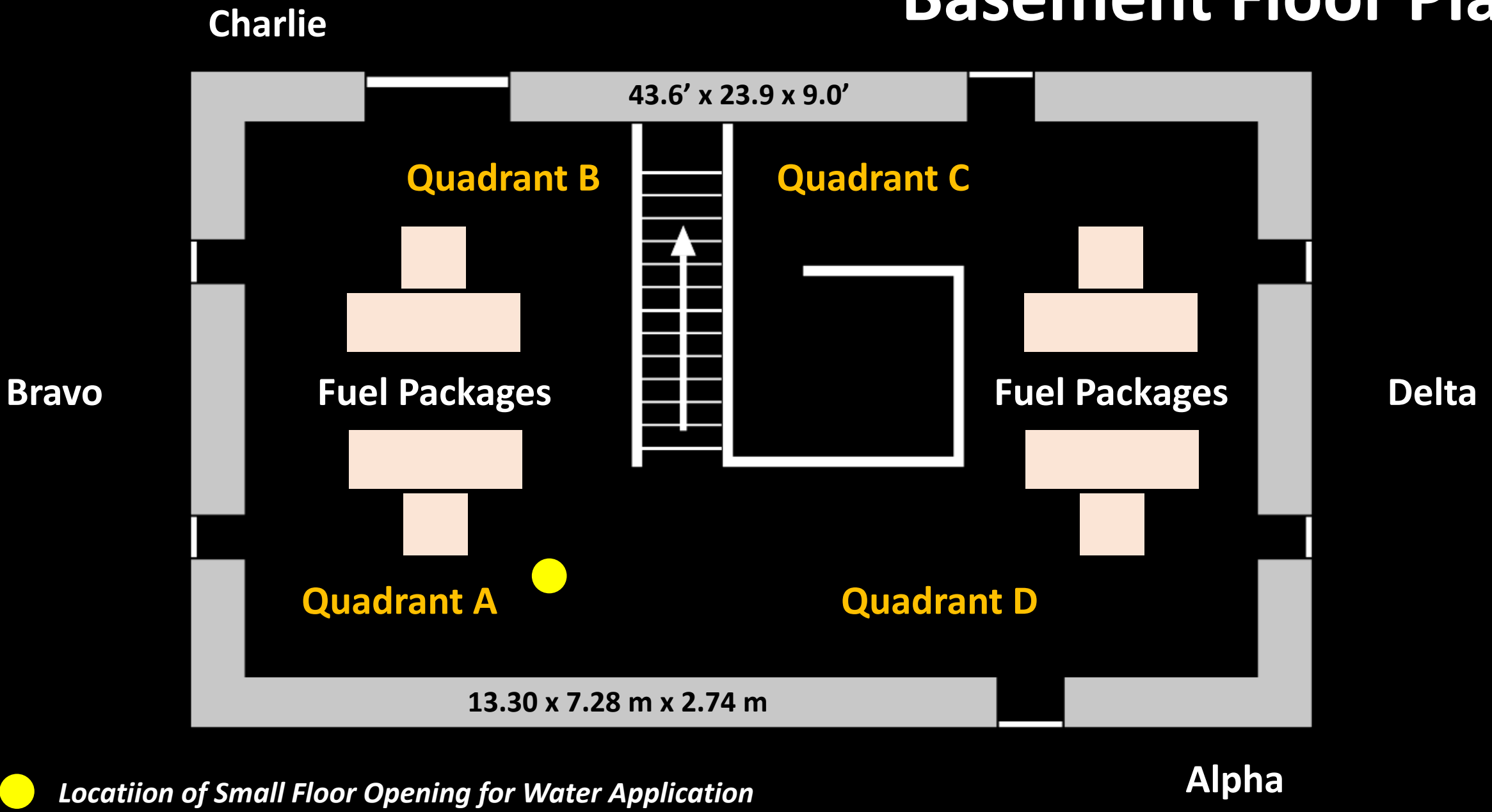


This study examined the impact of access, size, ventilation, and water distribution on fire dynamics and control of basement fires.

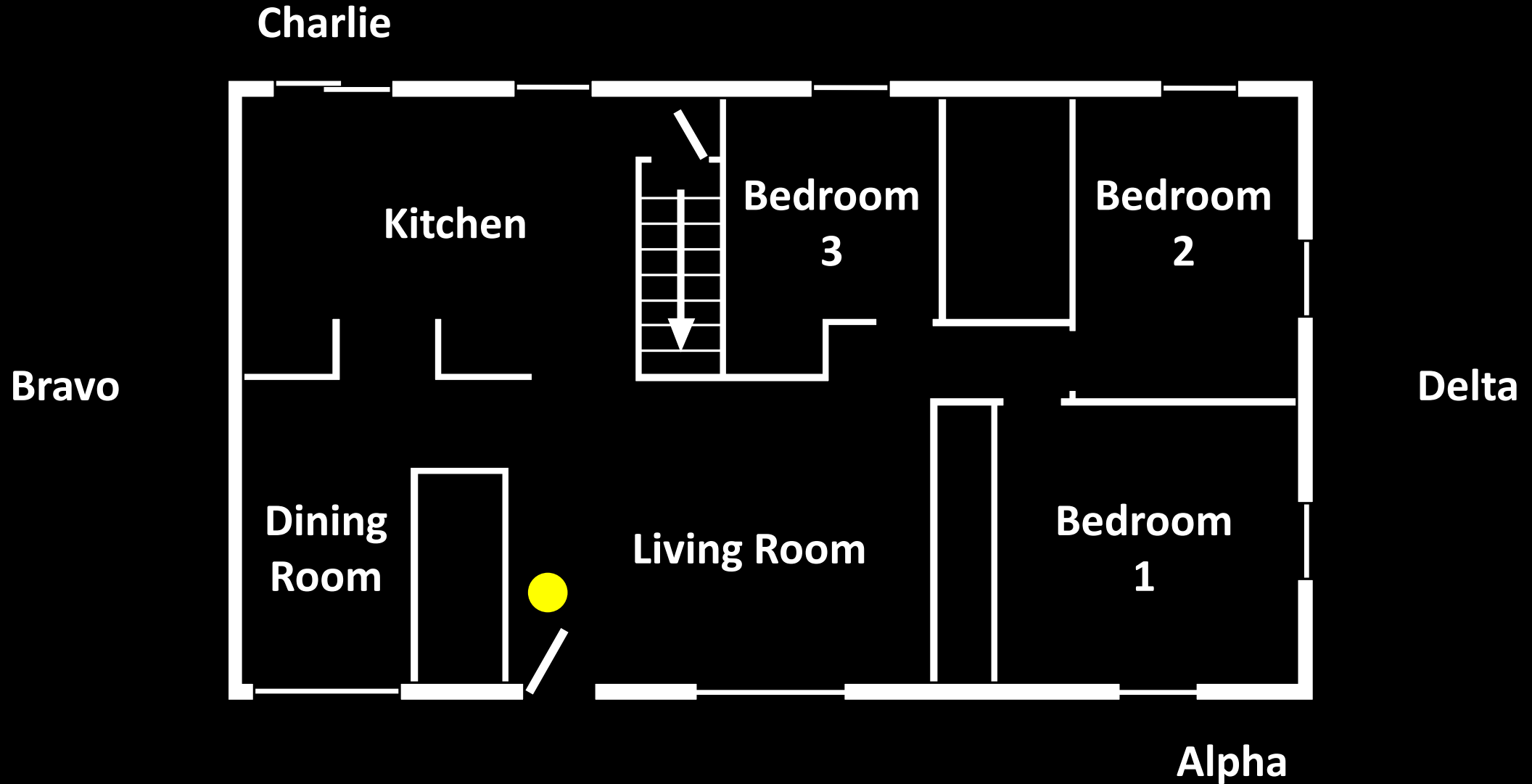
The Building



Basement Floor Plan



Floor Plan



● *Locatiion of Small Floor Opening for Water Application*

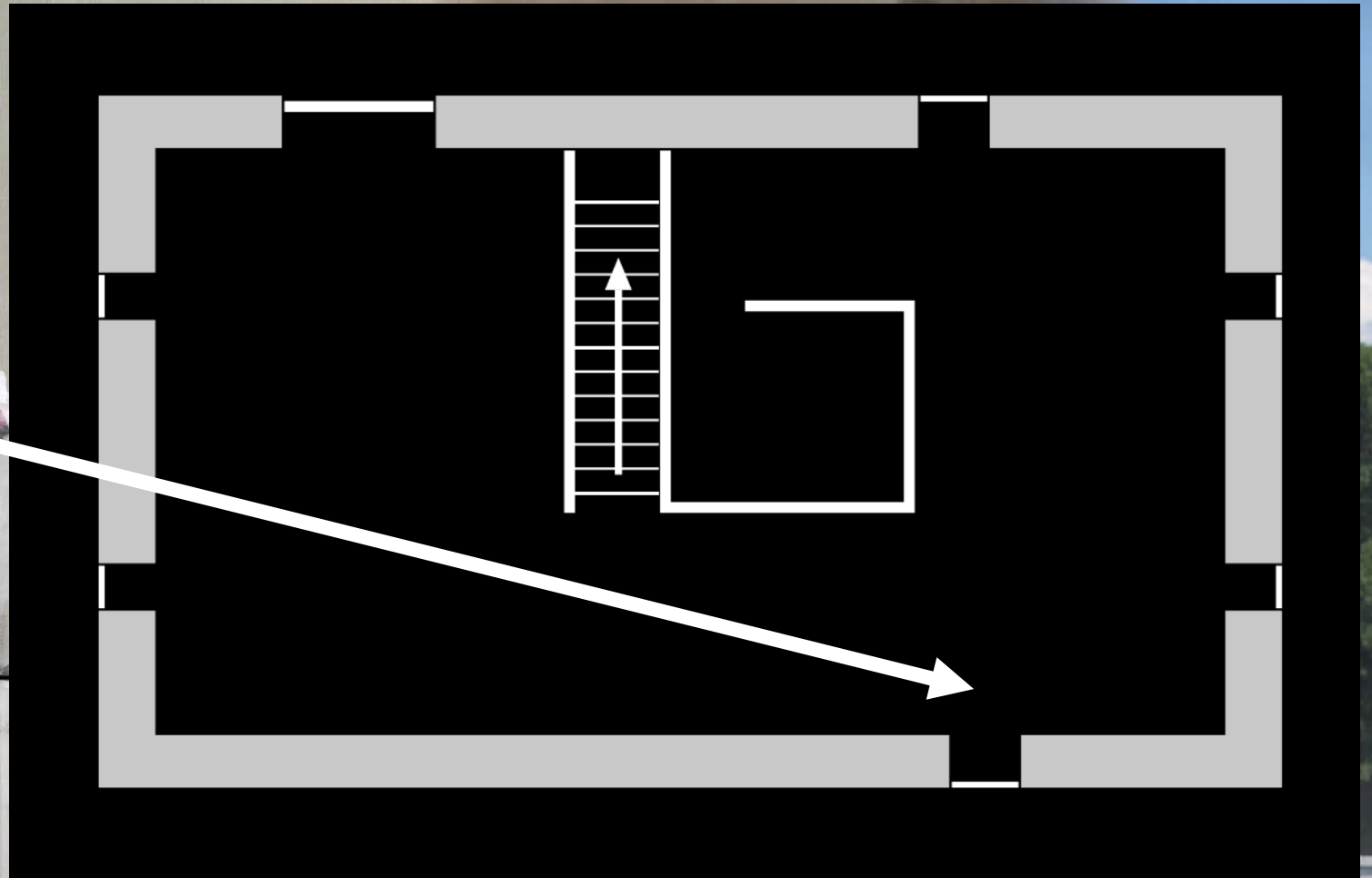
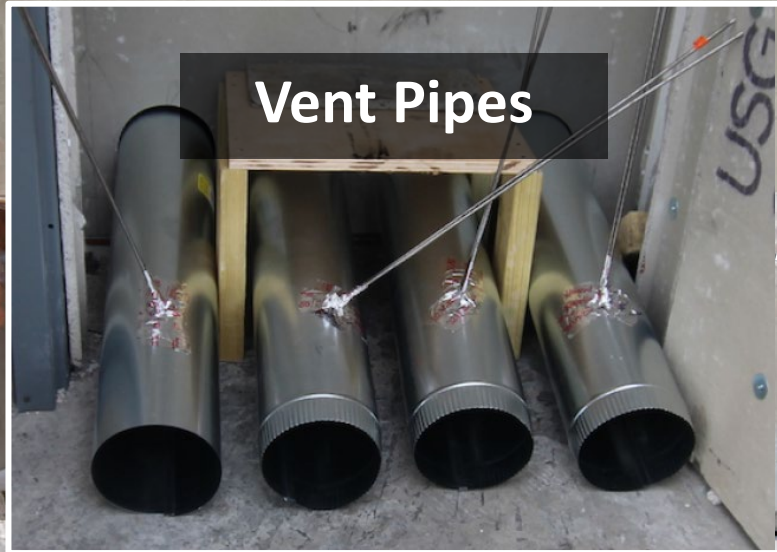
Nozzles & Water Distribution



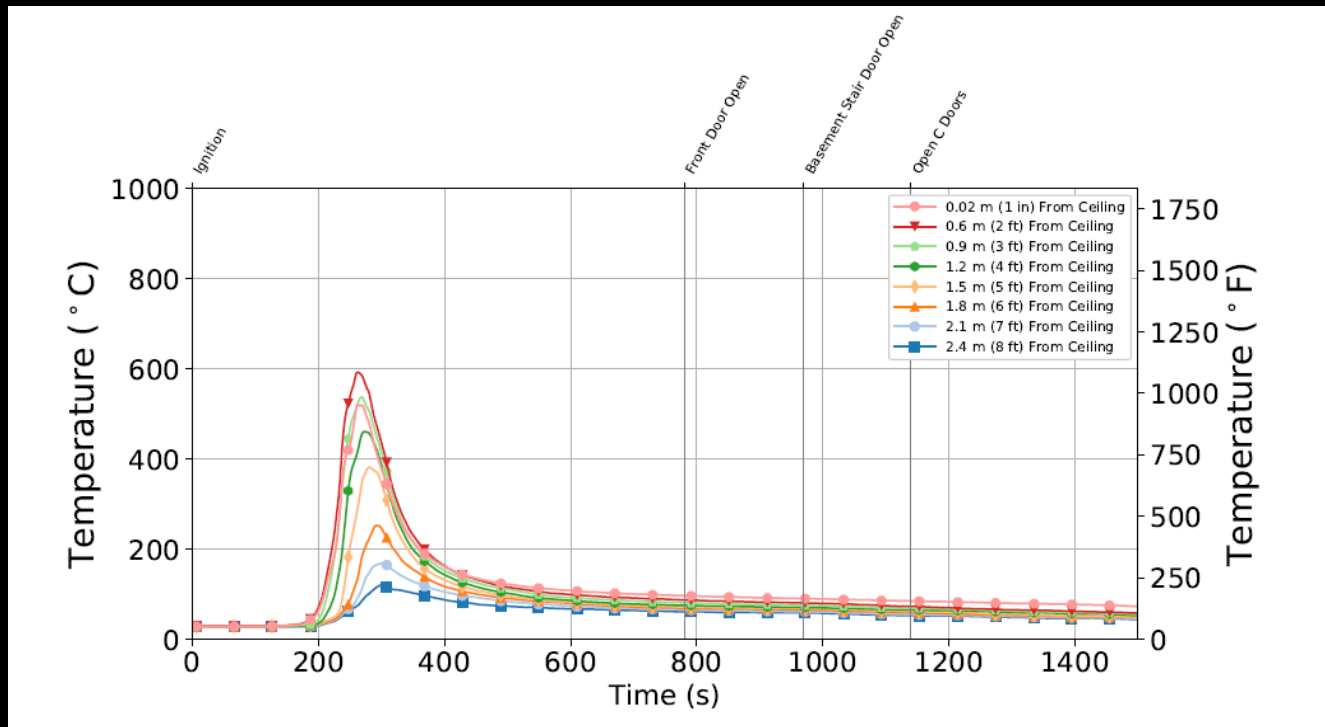
Basement Fuel Load



Ventilation



No Exterior Access (Interior Stairwell Only)

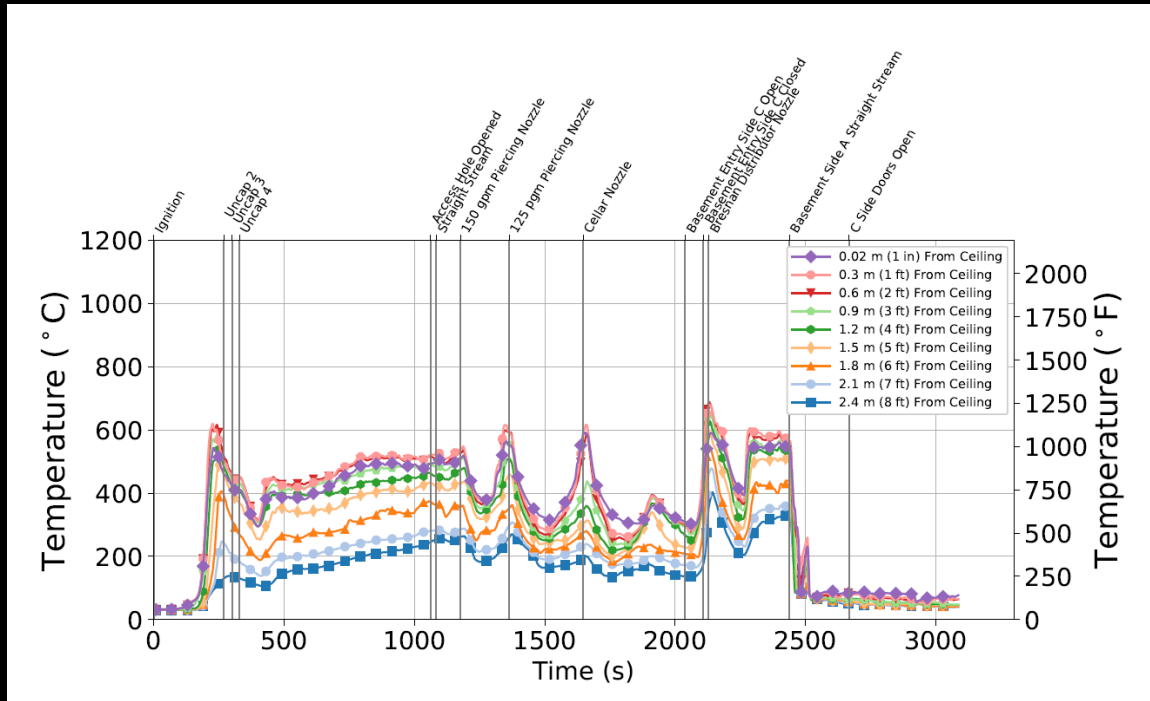


Experiment 1 No Suppression

*No ventilation, stairwell
door **closed** prior to ignition*

Similar results with stairwell door open (front door closed) in Experiment 2 and with stairwell and front doors open in Experiment 3

No Exterior Access – Suppression



Experiment 4 – Multiple Methods

1. 150 gpm Straight Stream
2. 150 gpm Piercing Nozzle
3. 125 gpm Piercing Nozzle
4. 140 gpm Cellar Nozzle

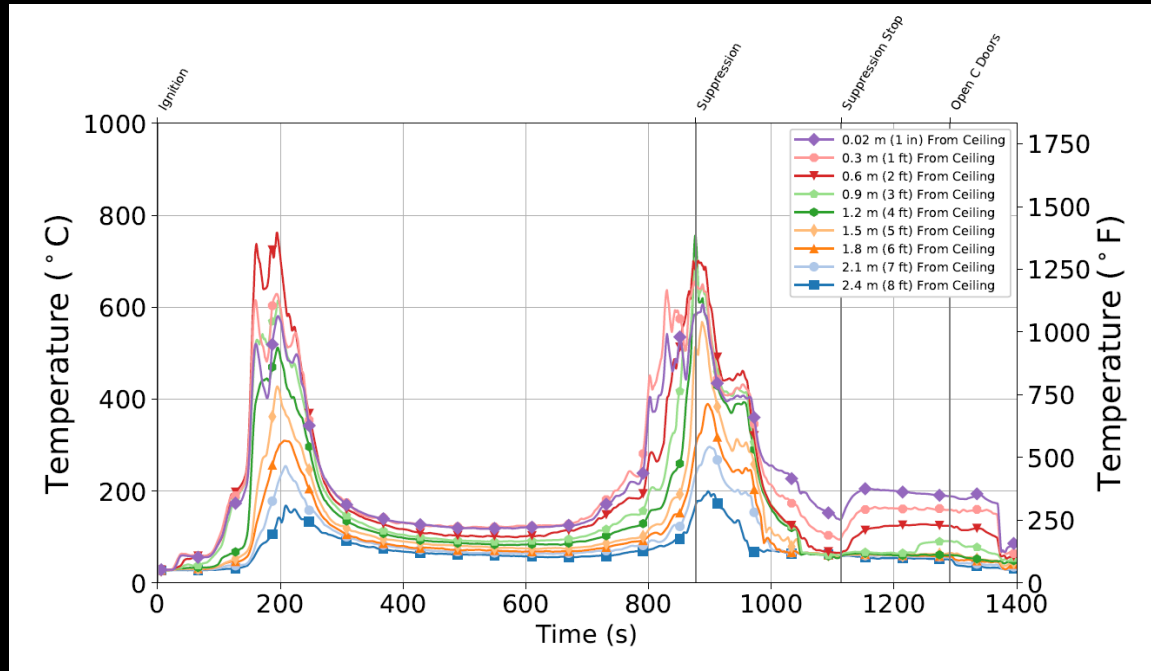
Stairwell door & one vent pipe open prior to ignition

Ignition of fuel packages on the Delta Side of the basement (shielded fire)

Fire suppression through the floor

No Exterior Access – Suppression

Experiment 11 - 125 gpm Piercing Nozzle



*Stairwell door, front door, & four vent pipe **open** prior to ignition*

Ignition of fuel packages on the Delta Side of the basement (shielded fire)

Fire suppression through the floor

Limited Access (Lookout Basement)

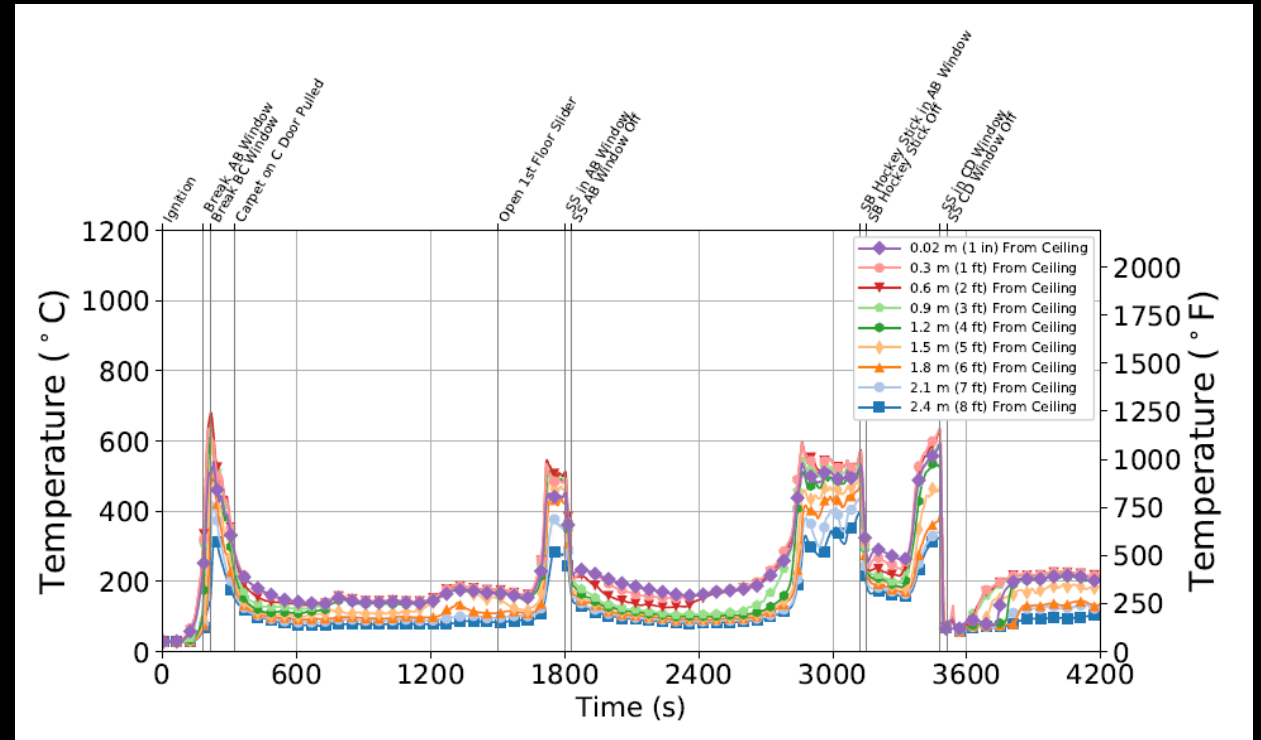
Experiment 6 Multiple Methods

1. 150 gpm Straight Stream
2. 180 gpm Solid Stream

*Front door, stairwell door, and
Side D windows open prior to ignition,
Side B windows broken at 180 s
Floor 1 slider opened at 1480s*

Ignition of fuel packages on the Delta Side of the basement (shielded fire)

Fire suppression through the look out windows (not shielded)



Limited Access (Lookout Basement)

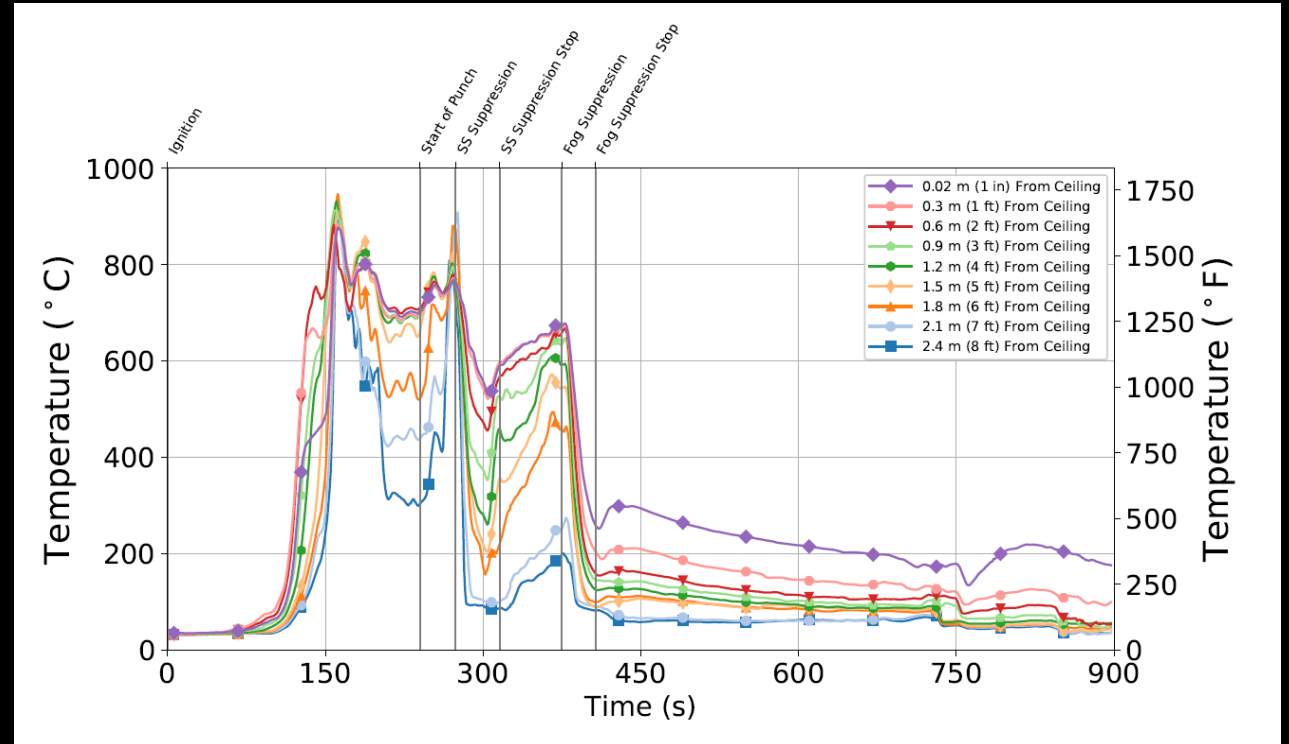
Experiment 7 Multiple Methods

1. 150 gpm Straight Stream
2. 180 gpm Solid Stream

Front door, kitchen slider, stairwell door, and all basement windows open prior to ignition

Ignition of fuel packages on the Bravo Side of the basement

Fire suppression through the floor (not shielded)

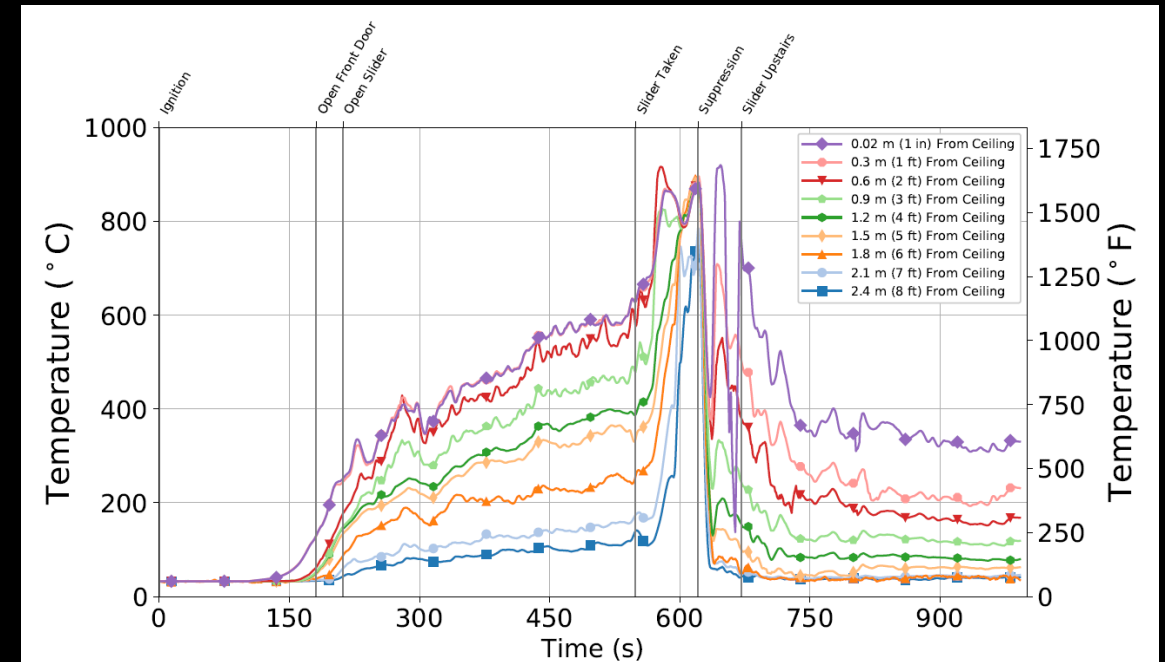


Exterior Access (Walk Out Basement)

Experiment 8 – Unfinished,
Uncoordinated, Attack Through Slider

Stairwell door and two vent pipes open prior to ignition, front door opened at 180s, slider opened at 210s and fully cleared at 550s.

Ignition of fuel packages on the Delta Side of the basement



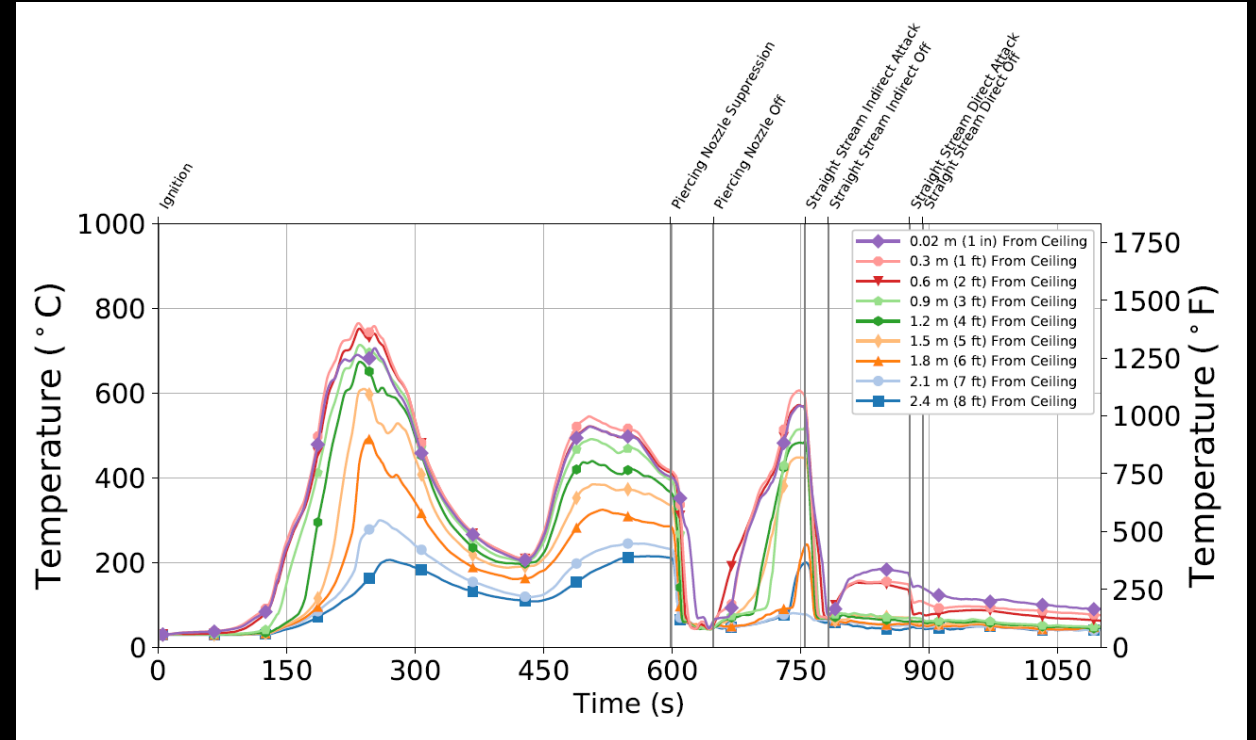
Exterior Access (Walk Out Basement)

Experiment 9 – Finished, Coordinated, Attack Through Large Window

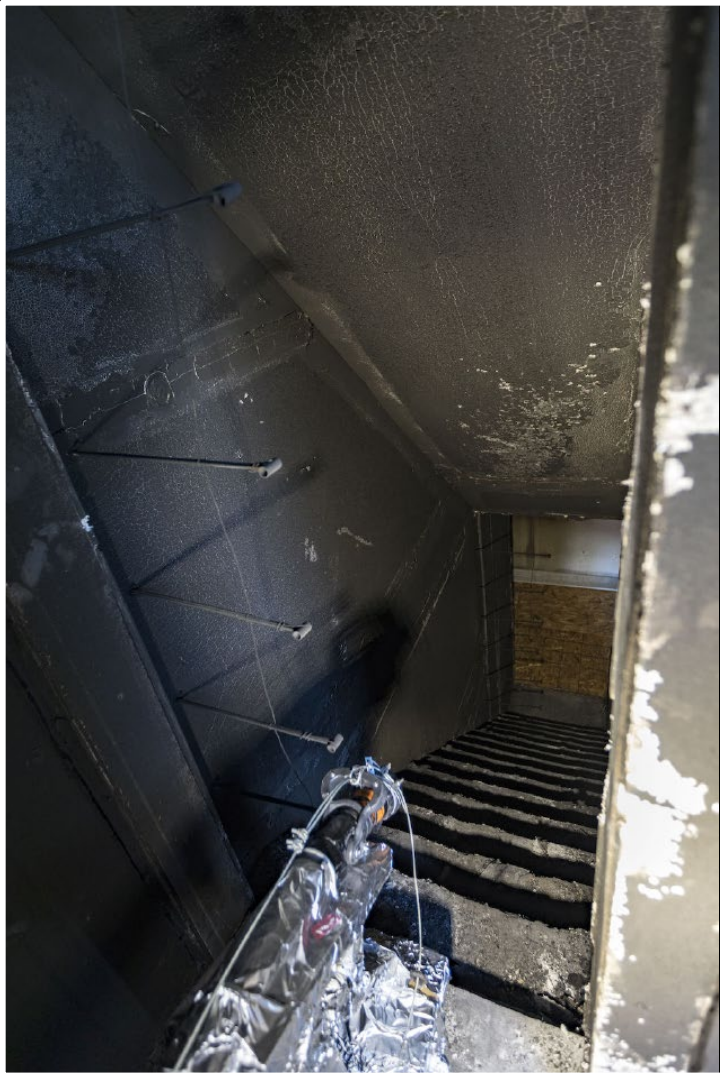
1. 150 gpm Piercing Nozzle
2. 150 gpm Straight Stream

Front door, stairwell, & four vent pipes open prior to ignition.

Ignition of fuel packages on the Delta Side of the basement



Thermal Conditions at the Top of the Stairs



Experiment	Temperature	Heat Flux
4	218° C	1.5 MW/m ²
12	200° C	1.6 MW/m ²
6	280° C	2.0 MW/m ²
11	630° C	4.5 MW/m ²
7	540° C	5.3 MW/m ²
8	898° C	8.6 MW/m ²

In NIST tests, facepiece surface temperature above 280° C and heat flux above 3.1 MW/m² resulted in degradation and failure.

Potential Confounding Variables

- Nozzles had different flow rates as well as distribution patterns.
- Multiple suppression methods in a single experiment may have influenced the results of methods later in the sequence.
- Experiments varied fuel packages, ignition location, and ventilation



Tactics Not Examined



What the Data Says

It is difficult to tease out specific suppression outcomes due to multiple variables in each experiment. However, data points to the following conclusions:

- The basement stairwell flow path is generally untenable.
- Any water in the basement is likely to improve conditions
- Cooling the gases has a positive impact
- Putting water on the burning fuel surfaces has the best effect

NIOSH Death in the Line of Duty Reports

Basement Fires 22.48%

Structure Fires Trauma n=169

97-04 Residential

98-03 Residential

98F-06 Residential

98F-17 Mixed Use

99F-21 Apartment

F2000-26 Residential

F2000-43 Apartment

F2001-04 Residential

F2001-08 Residential

F2001-16 Residential

F2001-23 Commercial

F2002-06 Residential

F2002-11 Residential

F2002-49 Residential

F2004-02 Residential

F2004-05 Residential

F2004-17 Church

F2005-04 Residential

F2005-05 Residential

F2006-24 Residential

F2006-26 Residential

F2006-28 Residential

F2007-07 Residential

F2007-16 Residential

F2008-08 Residential

F2008-09 Residential

F2008-26 Residential

F2009-23 Commercial

F2010-13 Residential

F2011-13 Residential

F2013-02 Residential

F2014-09 Residential

F2014-25 Residential

F2014-76 Residential

F2015-21 Residential

F2015-20 Residential

F2015-19 Residential

F2016-18 Residential



Advancing Down a Stairwell

1655 Middleton Street
Philadelphia, PA
December 9, 2014
NIOSH F2014-25
PFD Report



This is not the training tower!

Similarities?



15 Years!

Those who do not read history are doomed to repeat it!

1655 Middleton Street
Philadelphia, PA
December 9, 2014

NIOSH F2014-25

3146 Cherry Road NE
Washington, DC
May 30, 1999

NIOSH 99F-21
NIST IR6510



Tactical Considerations

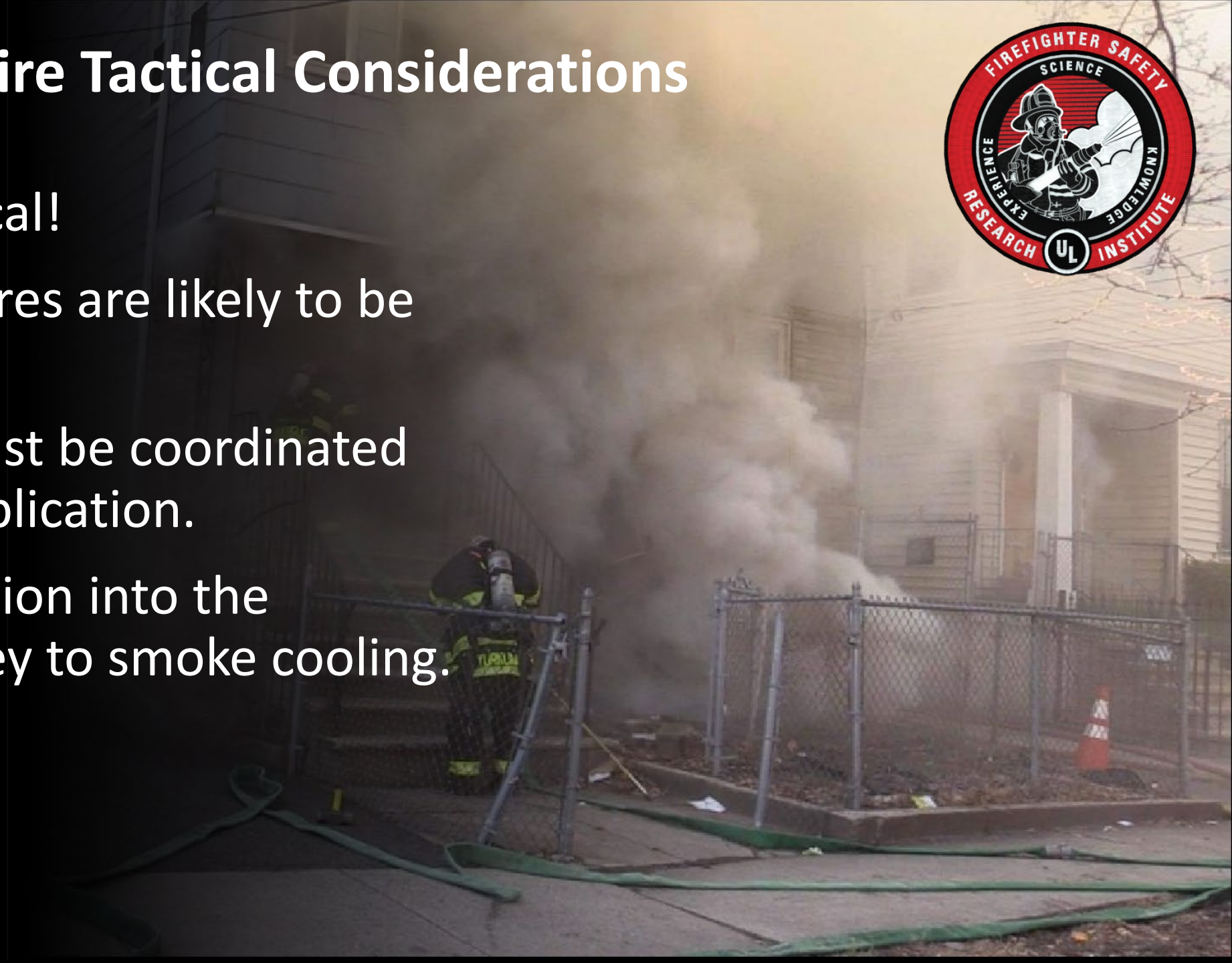


Tactical considerations are concepts to consider. These considerations increase knowledge of the fire service and should be incorporated into training and procedures, if deemed applicable.

Basement Fire Tactical Considerations



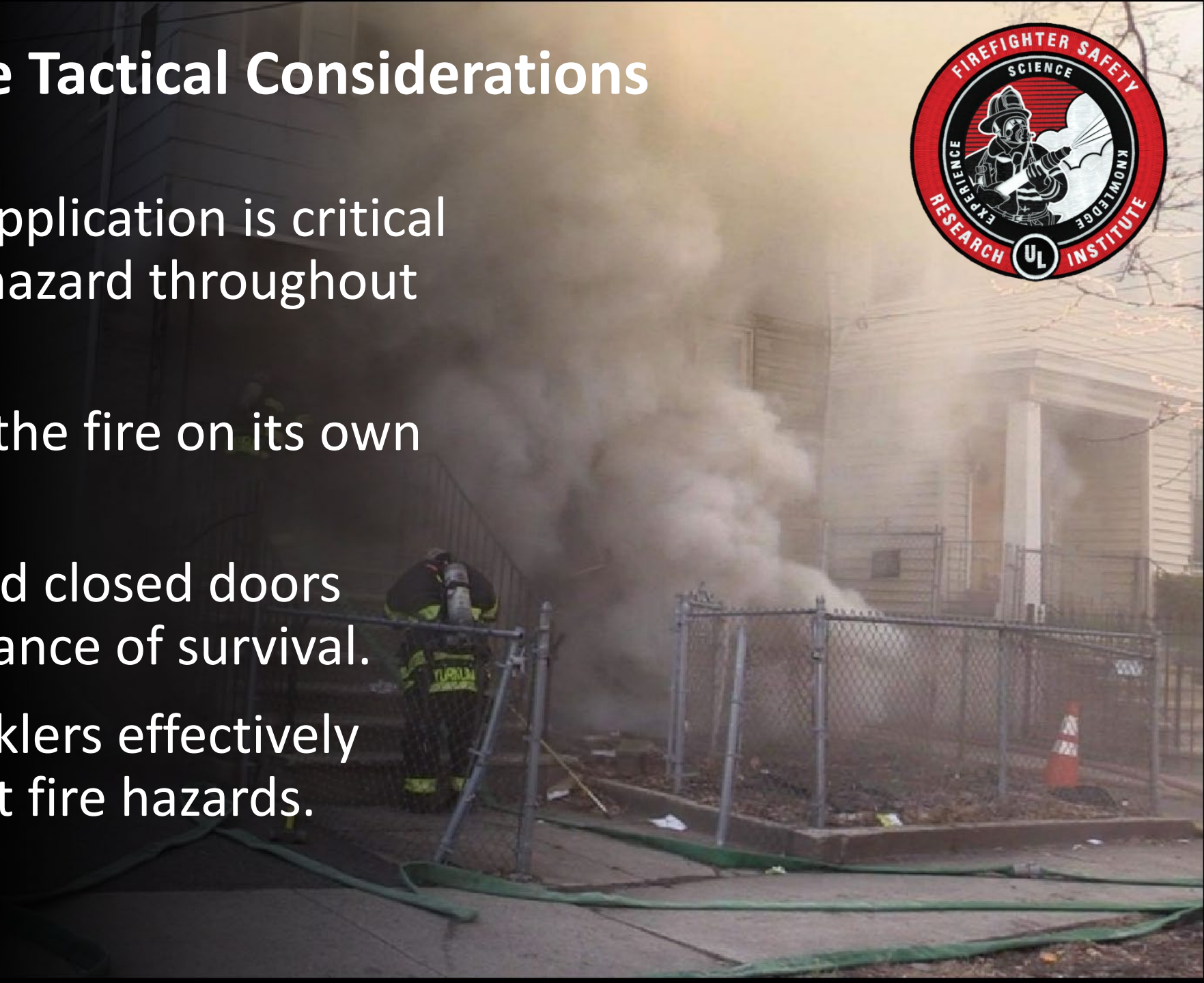
- Size-up is critical!
- Below grade fires are likely to be vent limited.
- Ventilation must be coordinated with water application.
- Water application into the basement is key to smoke cooling.



Basement Fire Tactical Considerations



- Effective water application is critical to reducing the hazard throughout the structure.
- If possible, fight the fire on its own level.
- Occupants behind closed doors have the best chance of survival.
- Residential sprinklers effectively reduce basement fire hazards.



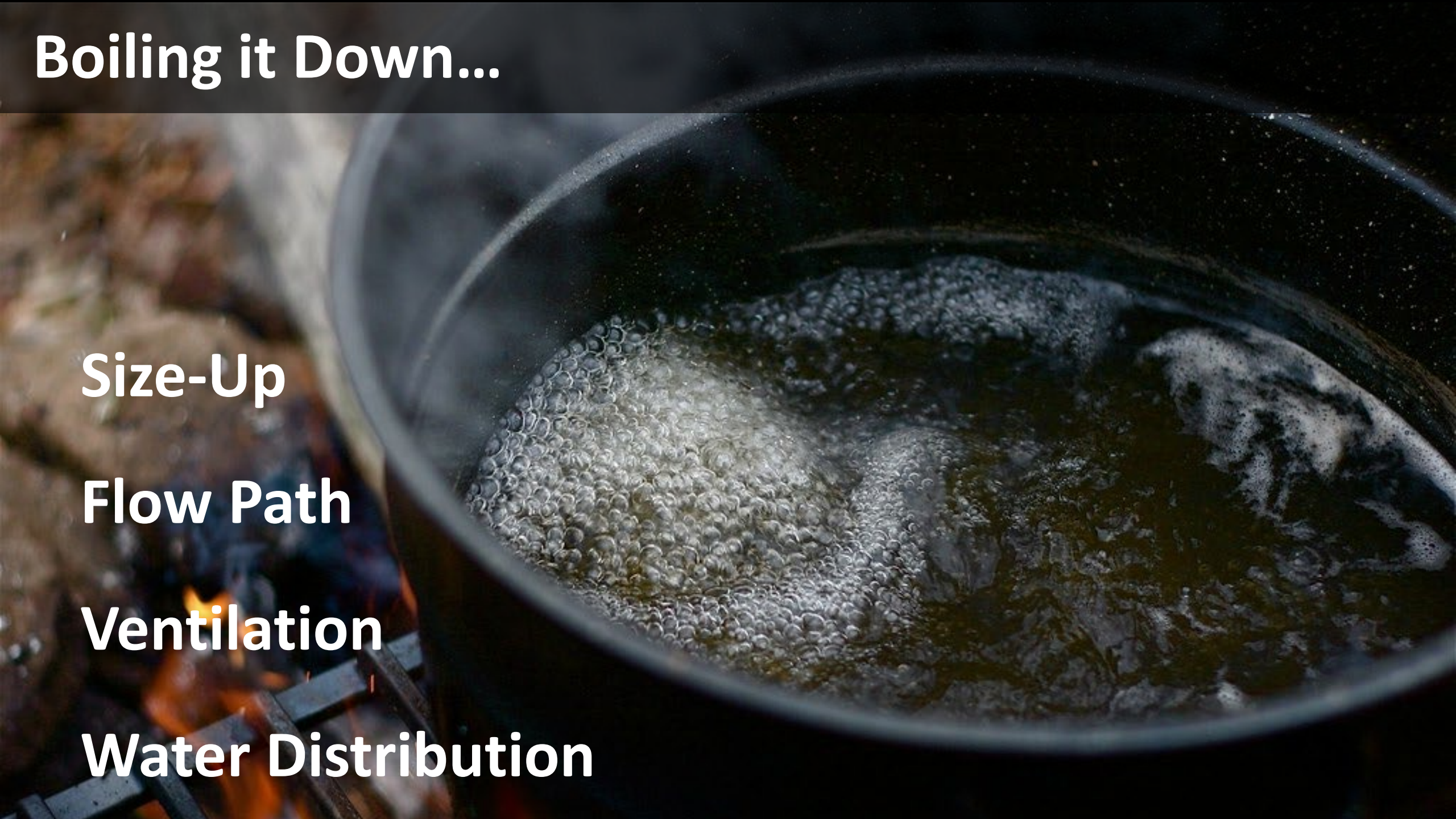
Boiling it Down...

Size-Up

Flow Path

Ventilation

Water Distribution



Basement Fire or Attic Fire

240 Fairhaven Hill Road
Concord, MA
December 27, 2019

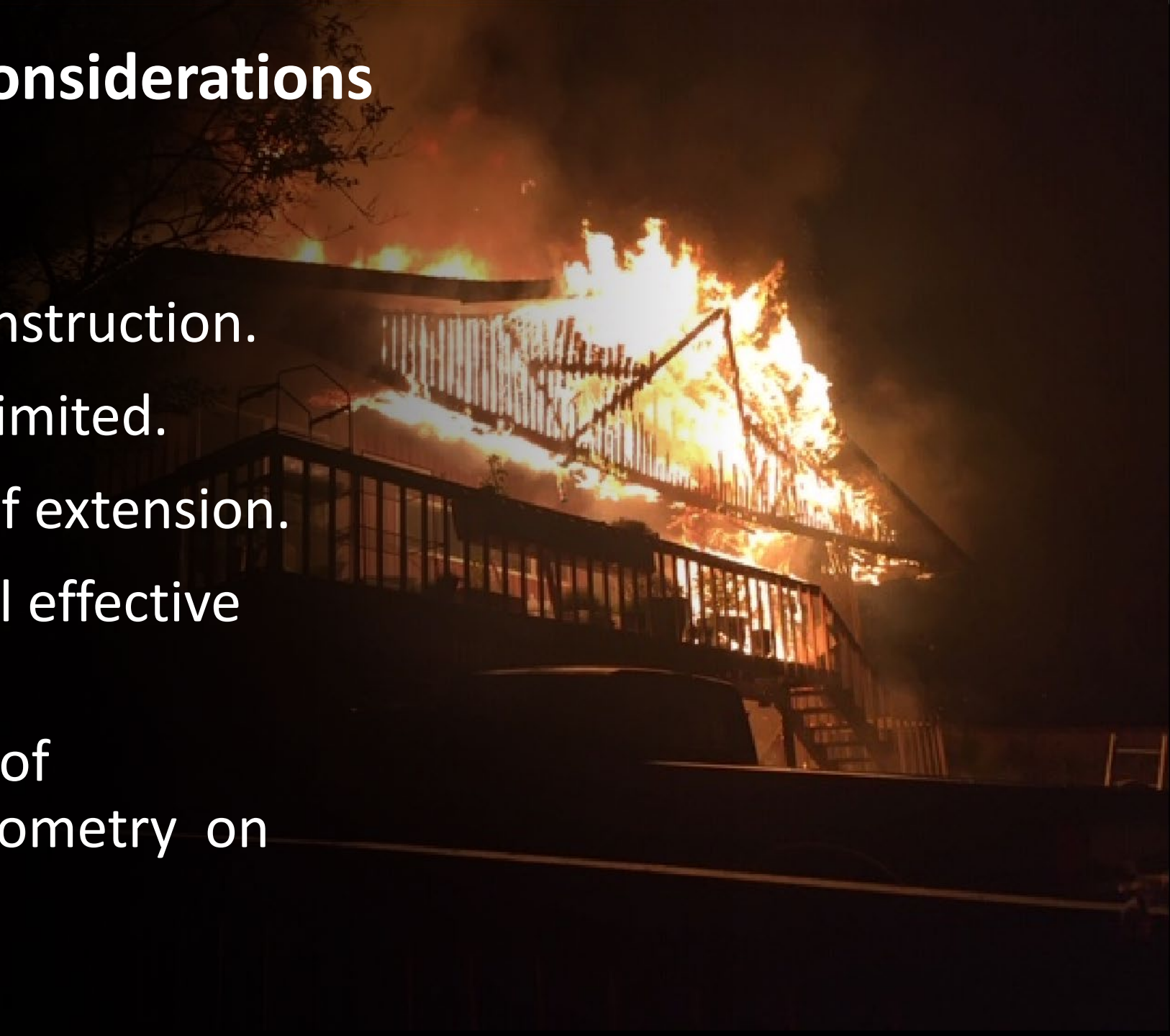
Date of Construction 1897



What are the commonalities between basement and attic fires?

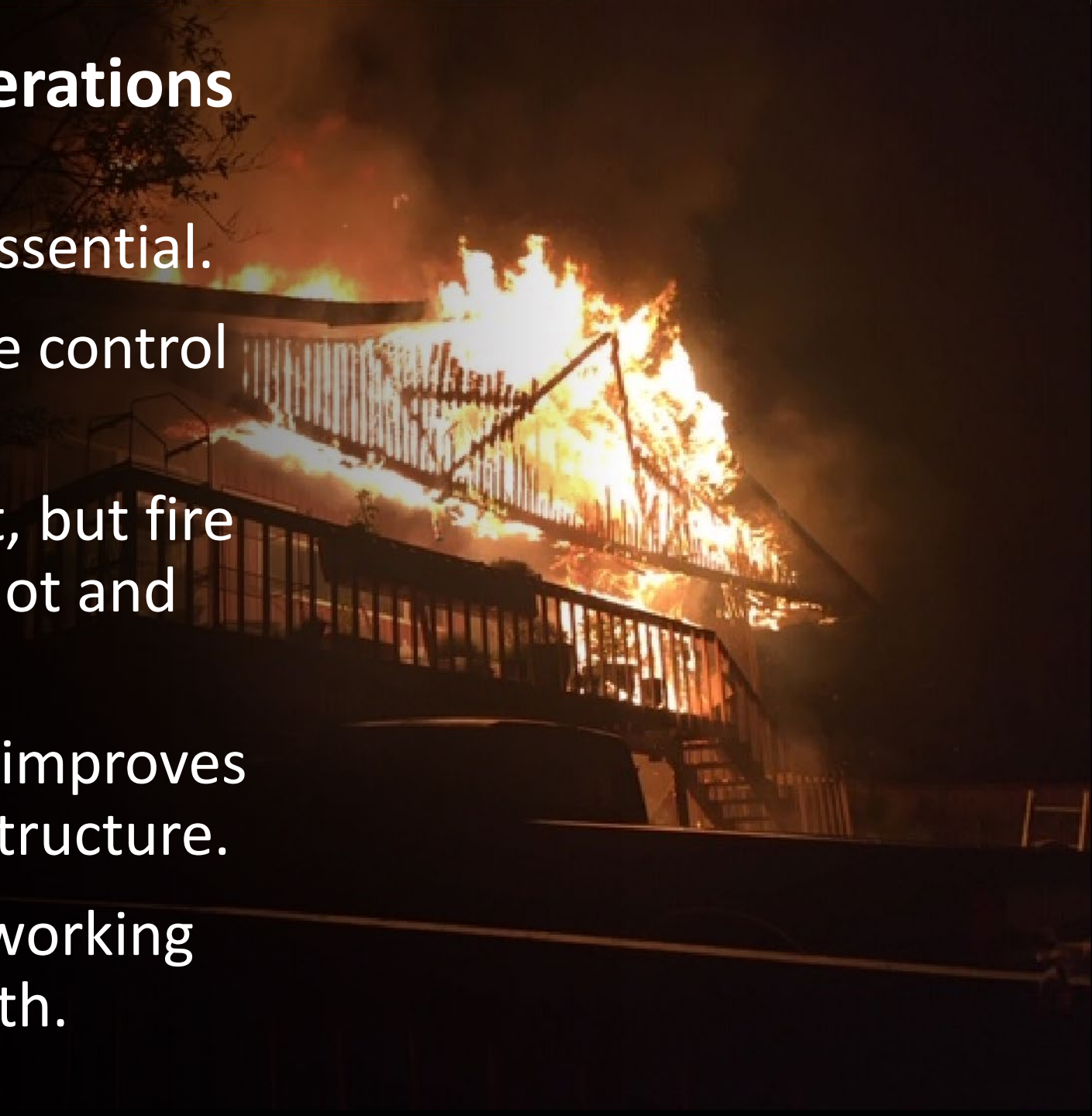
Tactical Considerations

- Size-up is critical!
- Consider building construction.
- Fires are often vent limited.
- Anticipate avenues of extension.
- Limit ventilation until effective water is on the fire.
- Consider the impact of configuration and geometry on water distribution.



Tactical Considerations

- Quick water on the fire is essential.
- With exterior fires, start fire control from the exterior.
- Cooling smoke is important, but fire control requires water on hot and burning surfaces!
- Effective water application improves tenability throughout the structure.
- Whenever possible, avoid working in the downstream flow path.



Look Up, Look Down, Look All Around



Importance of the 360



8960 Steinebrey Ridge Road NW
Sugar Creek, OH
June 27, 2020 at 00:10

Importance of the 360



Importance of the 360



Importance of the 360



Importance of the 360



Attic Fire – Fire Control Tactics

1. Eave attack (soffits)
2. Interior attack with large opening
3. Fog nails exterior (roof surface or soffits)
4. Fog nails interior
5. Gable attack (less effective)
6. Master stream or other exterior attack (defense)

Basement Fire – Fire Control Tactics

1. Exterior attack at the level of the fire
2. Exterior attack through look out or window well windows
3. Attack through the floor at an entry point
4. Attack down the interior stairs



Attic & Basement Fires— Ventilation Tactics

1. Tactical Anti-Ventilation

- Door Control
- Door Curtain

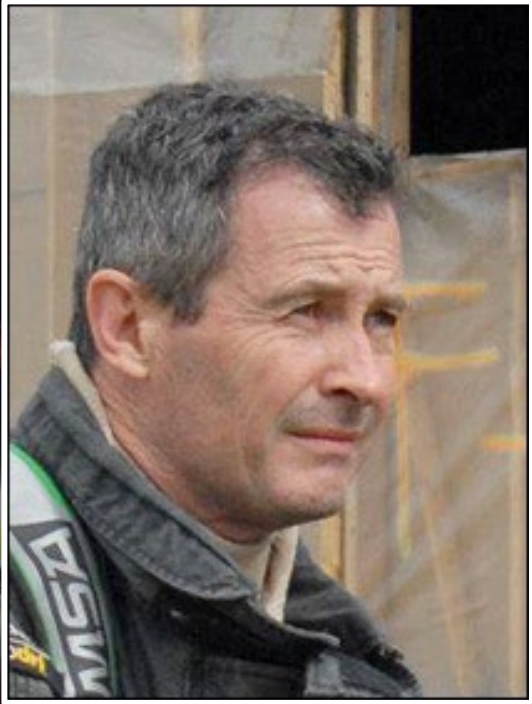
2. Tactical Ventilation

- Direction- Horizontal/Vertical
- Method-Natural, Hydraulic, PPV

Coordination



Which Comes First?



- Strategy
- Tactics
- Tasks



Inspector John McDonough



Real life presents the initial IC with diverse and dynamic challenges!
Some say it is better to be lucky than good, but chance favors the prepared mind!



How do we make sense of what has, is, and will happen?



Reading the Fire • Size-Up • Situational Awareness



Questions?

Ed Hartin

Command Competence, CFBT-US LLC

ed.hartin@cftb-us.com

+01 (503) 793-1296 (Cell/WhatsApp)

<https://commandcompetence.com>



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