Size Up & Decision Making
Wind Driven Fires

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May 19, 2022

Tall Buildings
fire safety network

Smoke Movement & Control

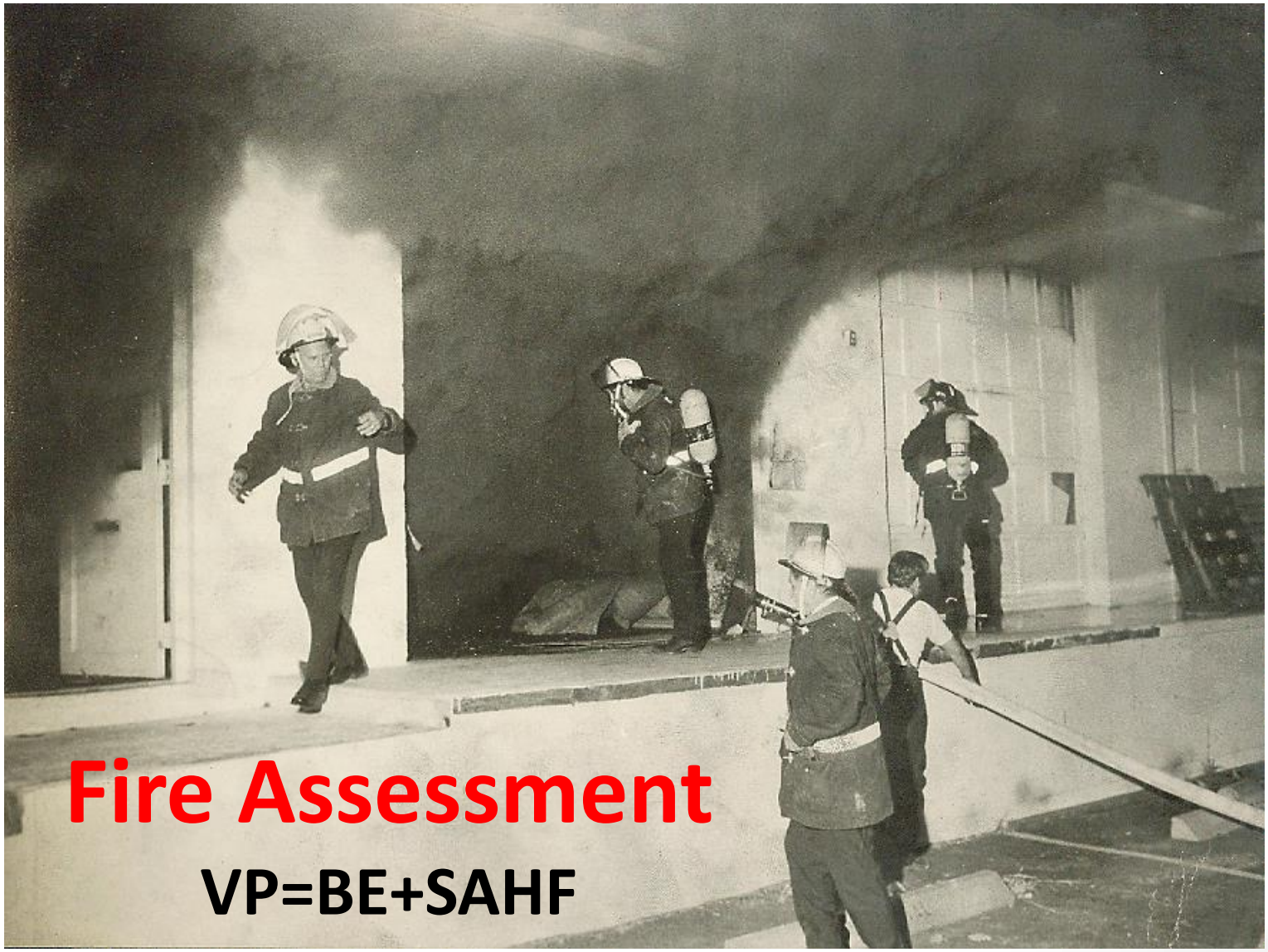
Research for High Rise Buildings

NFPA RESEARCH FOUNDATION
RESEARCH FOR THE NFPA MISSION

F.I.R.E.
FROM KNOWLEDGE TO PRACTICE

Seek Knowledge In Fire

Ottawa Fire Services



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FROM KNOWLEDGE TO PRACTICE


Shan Raffel
Reading the Fire Article 2008
13A
KME
74-D070
FROM KNOWLEDGE TO PRACTICE
FIREFIGHTING
EDUCATION
RESEARCH

Shan Raffel

Reading the Fire Article 2008

- **Around 1999, firefighters were being taught to recognize the “signs and symptoms of Flashover” and the “signs and symptoms of Backdraught”.**
- **This information provided a foundation for the skill of reading the fire. There was no mention of the indicators that could lead to a “fire gas ignition”, and I saw the need for a simple method of assisting firefighters to rapidly make a risk assessment of the fire behaviour indicators.**
- **After a lot of research, I came up with a simple mnemonic, SAHF. To be effective, it is essential that any fireground mnemonics is simple to remember and logical in order.**

VP = BE + SAHF

The integrated evaluation of fire conditions within a structure using the **V**entilation **P**rofile, **B**uilding and **E**nvironmental Factors, along with the **S**moke, **A**ir, **H**eat and **F**lame indicators, for the purpose of strategic and tactical decision making.

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Ventilation Profile:

The appearance of the <u>entire</u> fire building's ventilation openings, showing the flow paths of any air movement into the structure as well as smoke, heat or flame out of the structure. *(FKTP ➢ NFPA 1700)*

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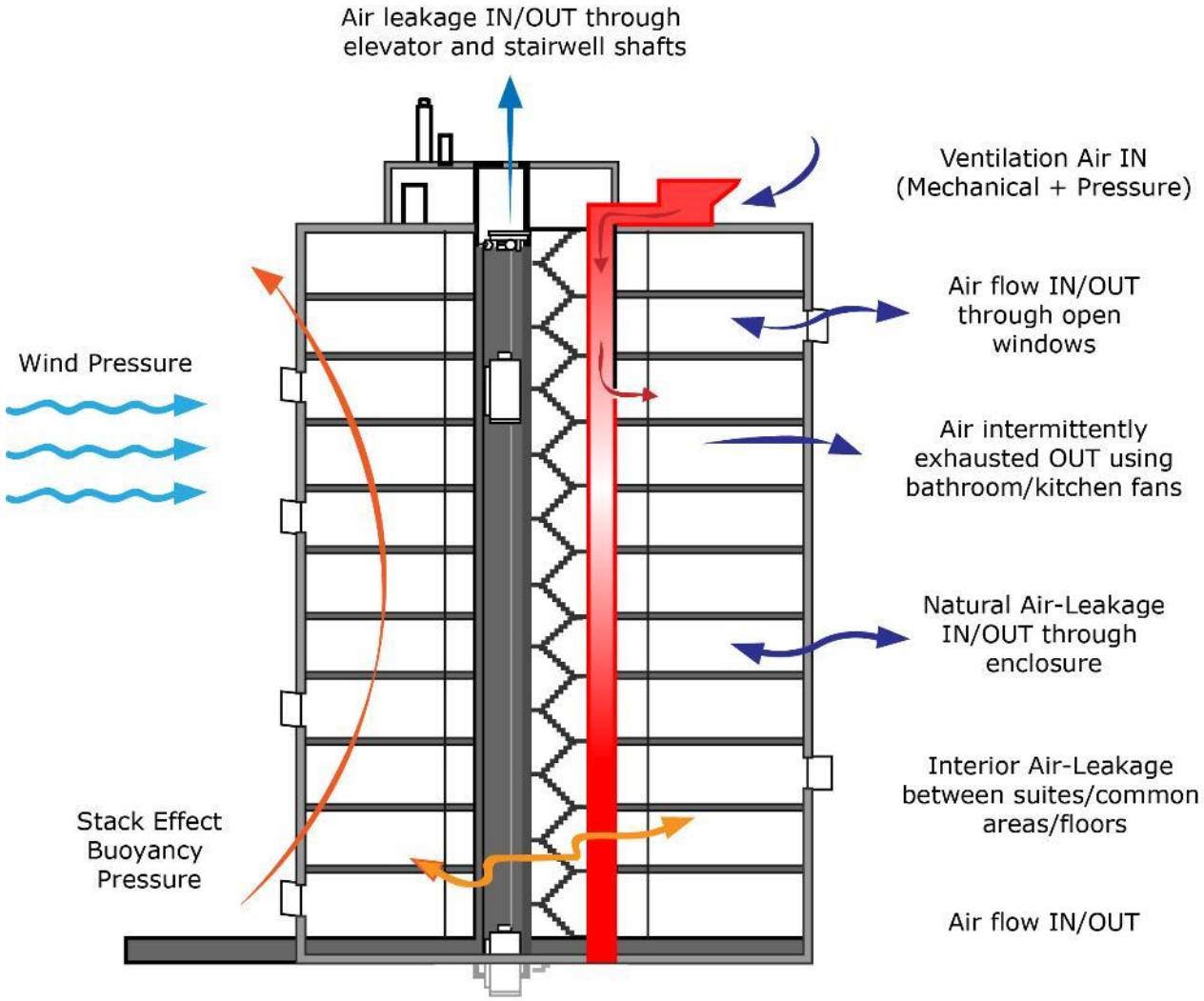

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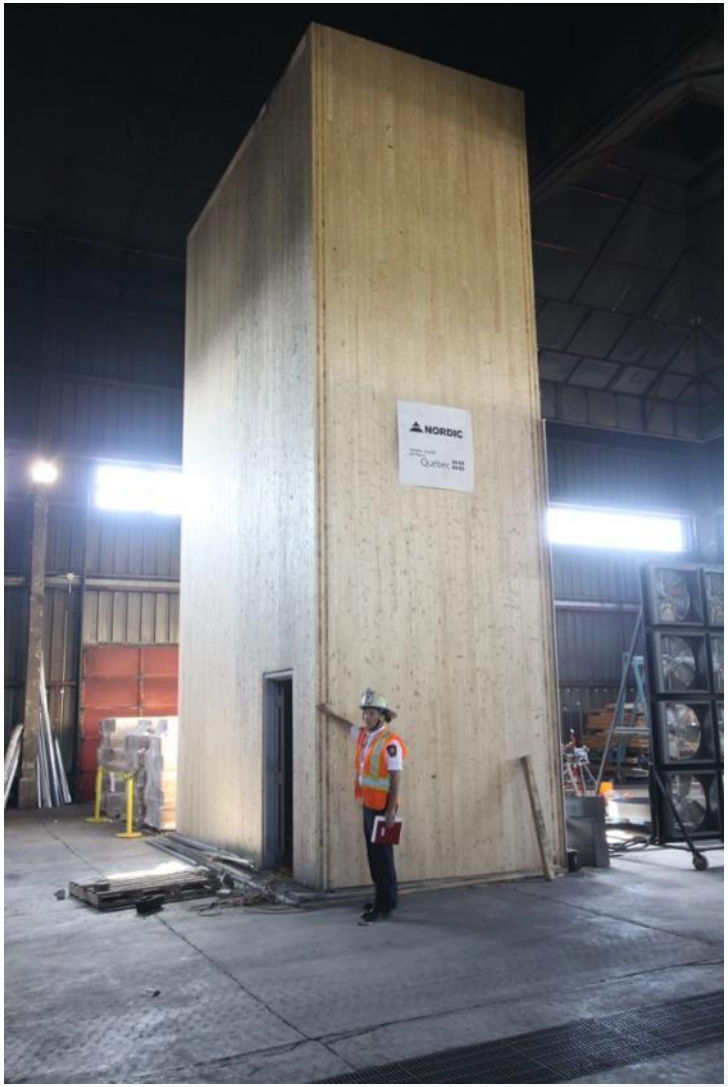
Building Factors

- Principles
  - Loads
  - Forces
  - Material characteristics
  - Structural elements
- Types of Construction
  - FR, NC, O, HT, WF, + PBD
- Math vs Mass



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Building Factors

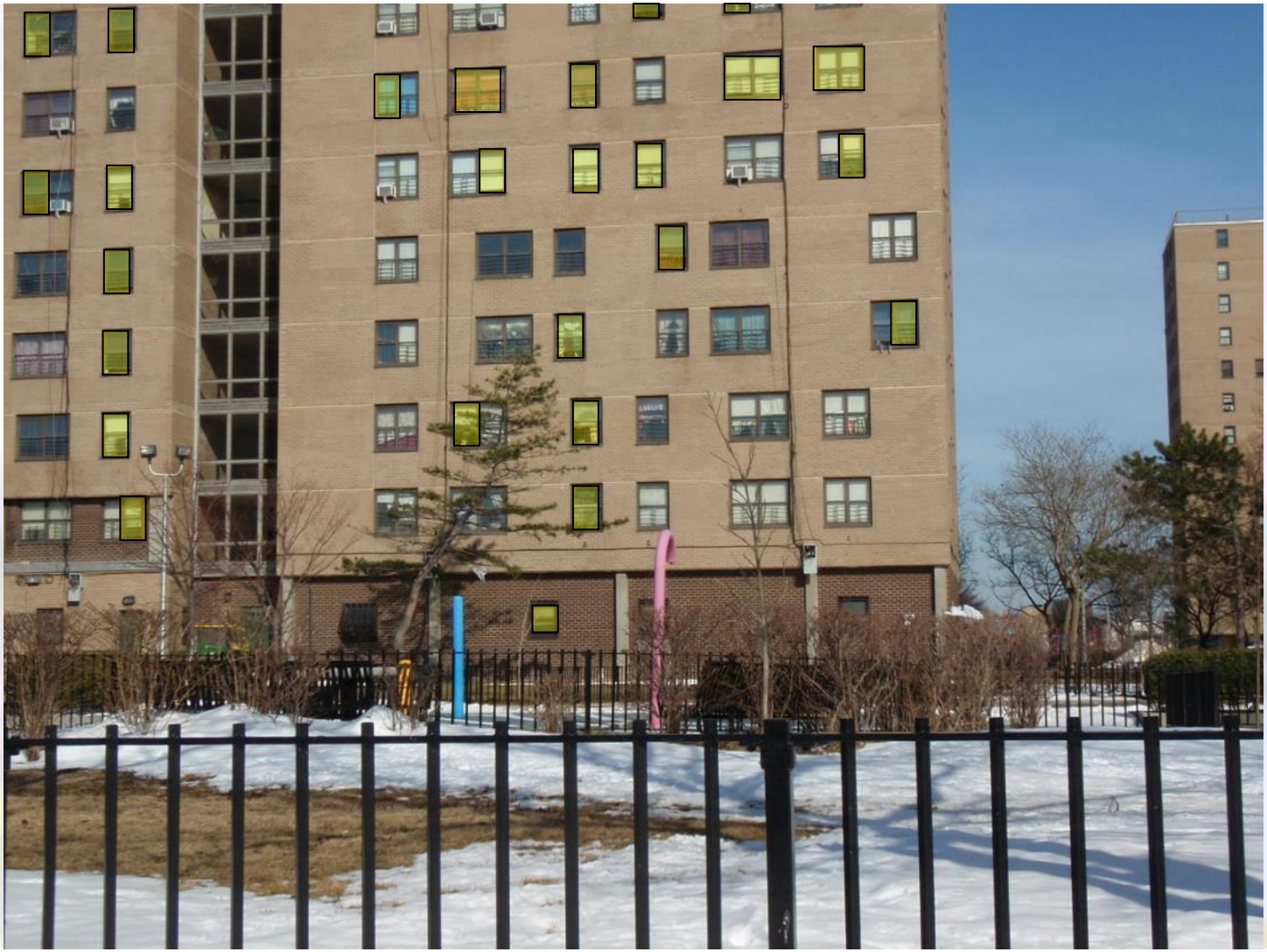
- Occupancy
- Compartmentation
  - Building envelope
    - Cladding
  - Interior wall & ceiling finishes
    - Thermally thick or thin
  - Compartment size
    - Area, height, open volume

VP = BE + SAHF

Building Factors

- Openings
  - Horizontal/vertical
  - Internal/external
  - HVAC
- OCCUPANT BEHAVIOUR!

OCCUPANT BEHAVIOUR!



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Building Factors

- Compartmentation
  - Fuels
    - State – Solid/Liquid/Gas
  - Contents vs Structure
    - Flashover as a benchmark
  - Protective Features
    - Passive Systems
      - Rated assemblies, stopping
    - Active Systems
      - Sprinklers, Pressurization

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Environmental Factors

Weather

- Wind speed & direction
  - Accelerate fire growth
  - Fire spread via forced convective heat transfer, direct flame contact or ember transport
  - O_2 supply replenished
  - Air pressure differences that drives Smoke/Air/Heat/Flame movement

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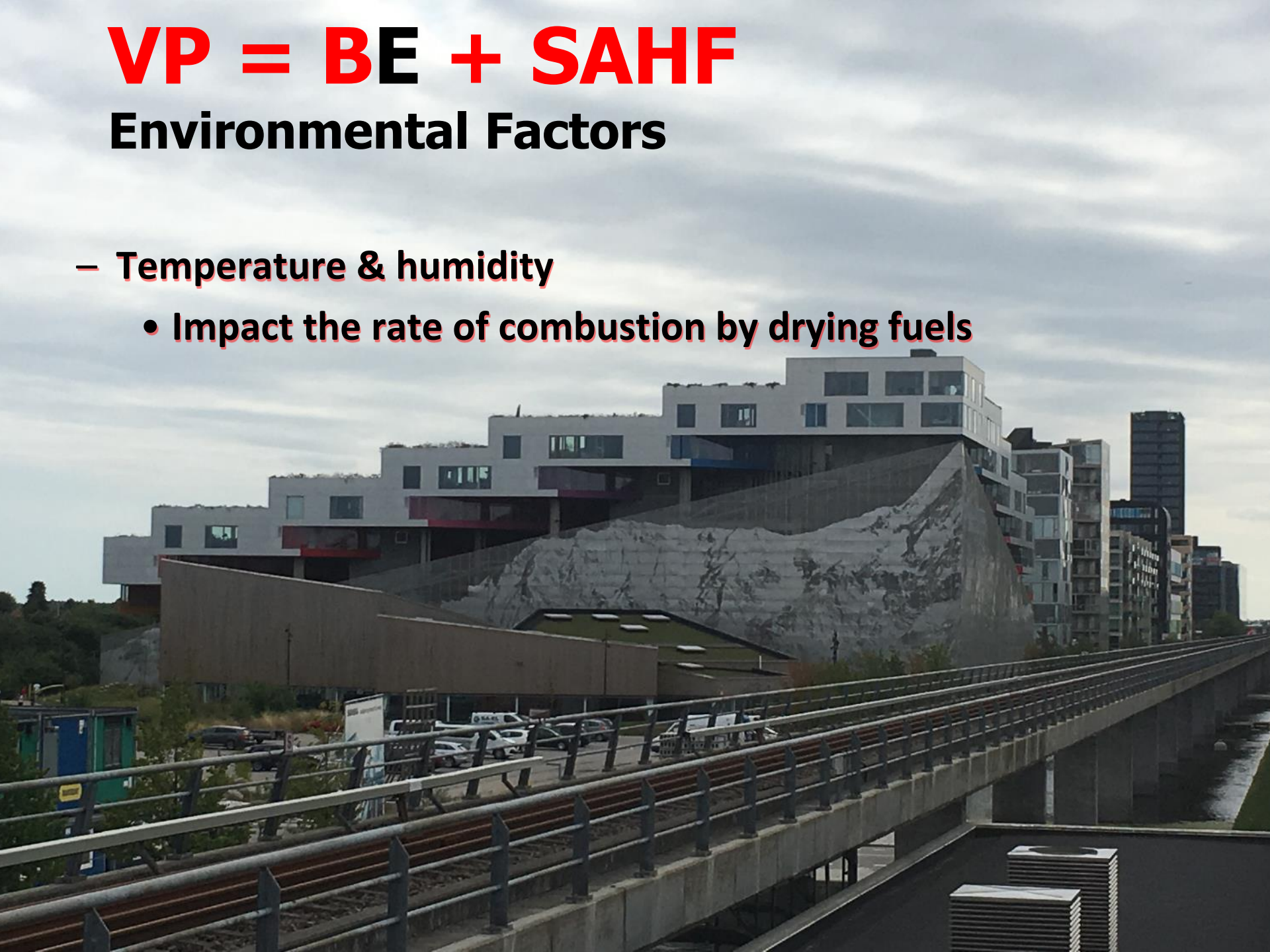
Environmental Factors

- Temperature & humidity
  - Impact the rate of combustion by drying fuels



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Environmental Factors

Weather

- Drives stack effect

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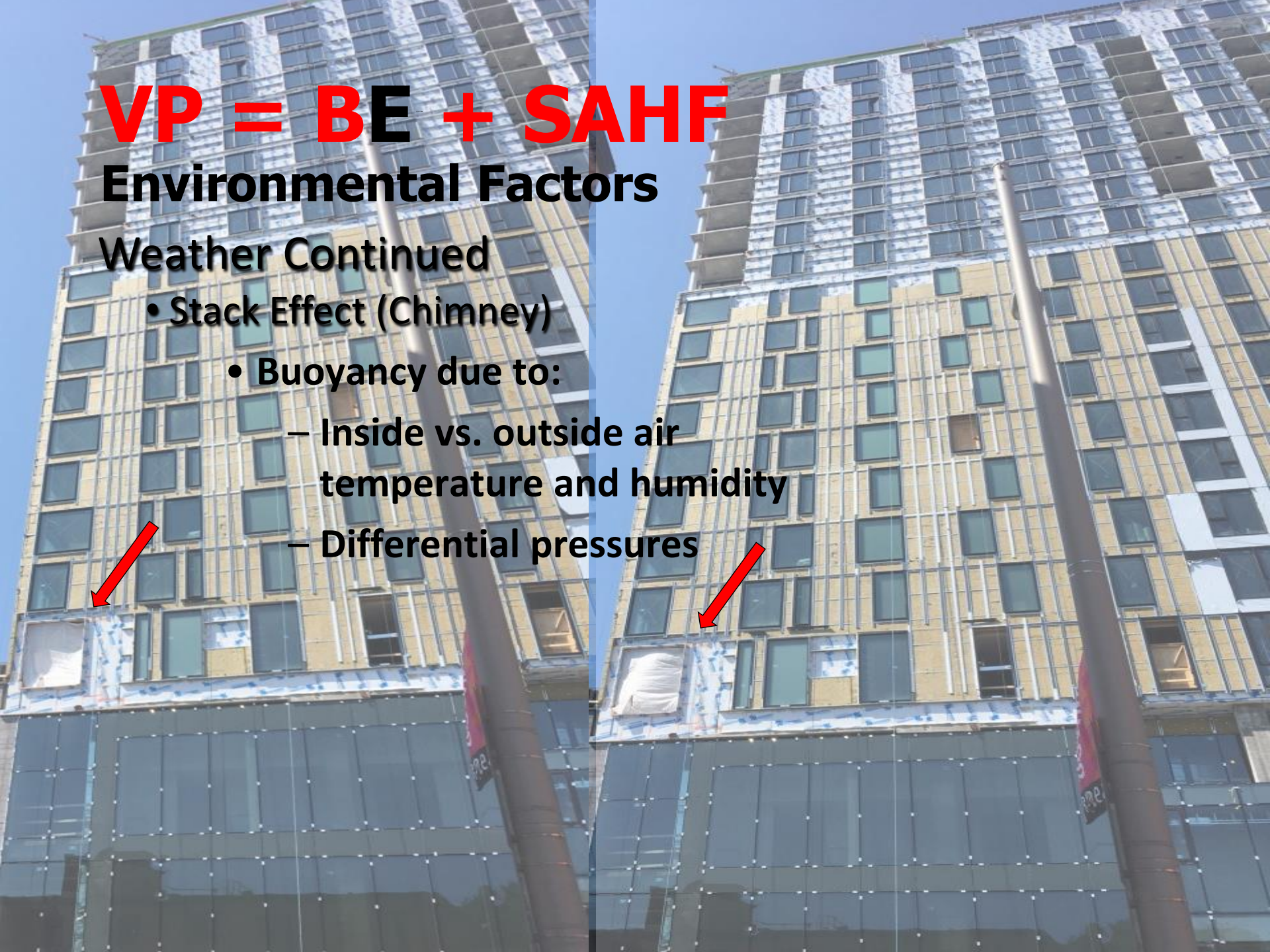
Environmental Factors

Weather Continued

- Stack Effect (Chimney)
  - Buoyancy due to:
    - Inside vs. outside air temperature and humidity
    - Differential pressures



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Environmental Factors

Differential pressures

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Environmental Factors

Weather Continued

- Stack Effect (Chimney)
  - Buoyancy due to:
    - Inside vs. outside air temperature and humidity
    - Differential pressures
    - Building leakage

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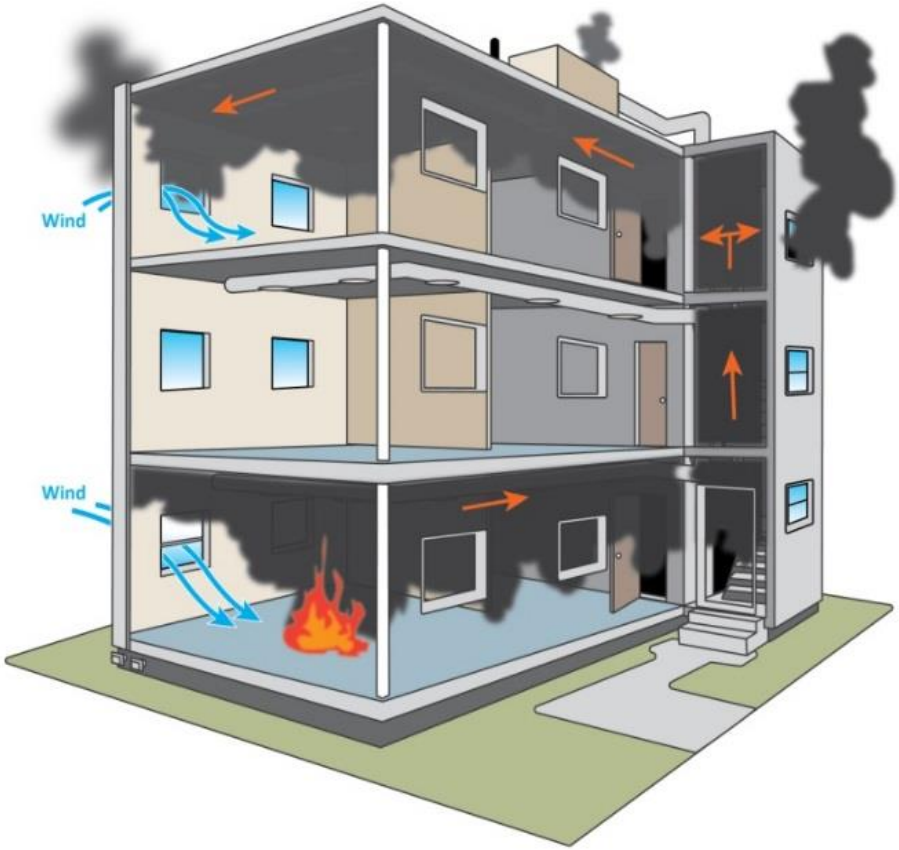
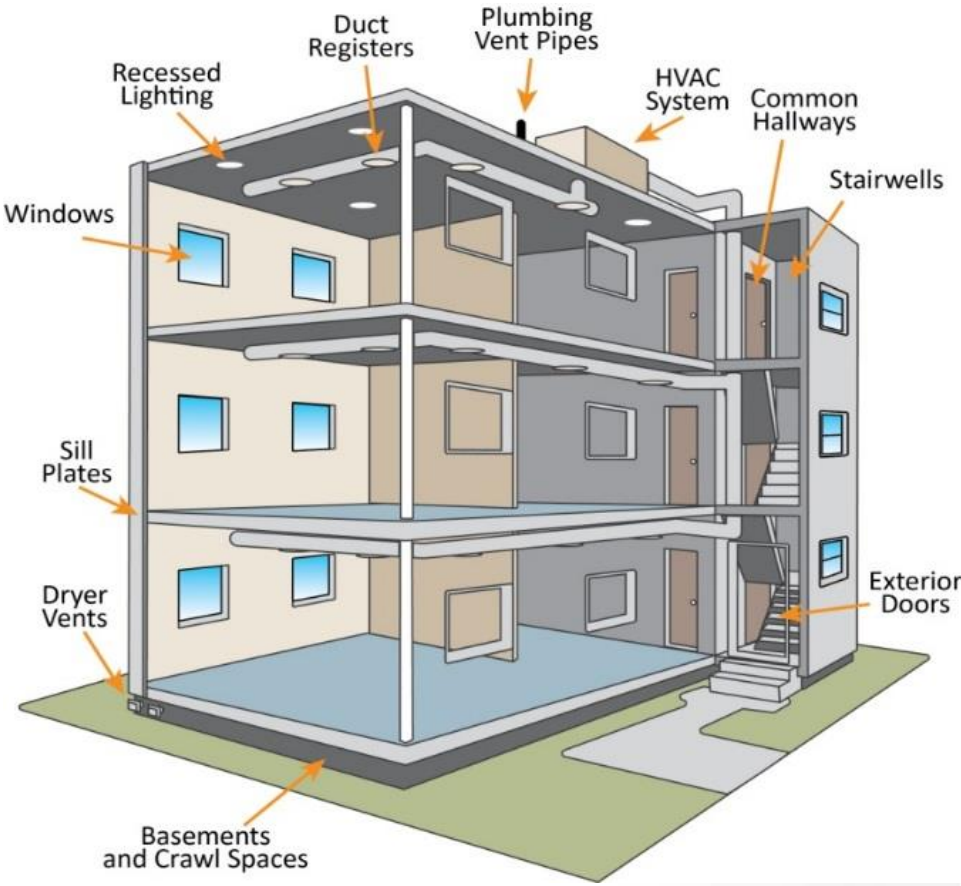
Environmental Factors





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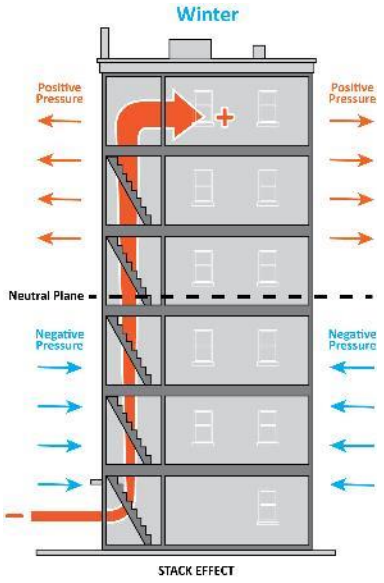
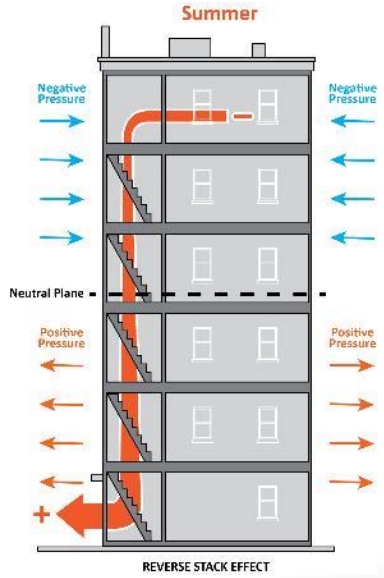
Environmental Factors

Weather Continued

- Height
  - Note: Stack effects in winter are significant even in a one or two storey house and very significant in tall buildings.
  - Reverse stack effects are possible in warm climates within air condition buildings.

- **Significant stack effect can produce the same forced combustion and vent characteristics as a wind impacted fire, without the presence of a wind condition.**





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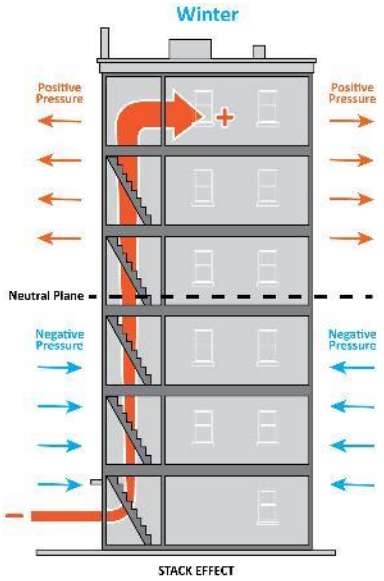
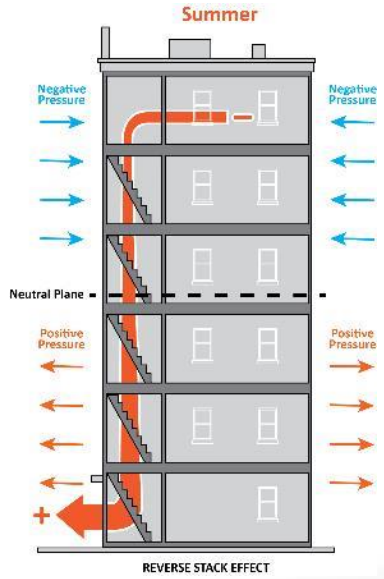
Environmental Factors

- Large pressure differences are possible, and may be compounded by opening and/or failing to close doors by firefighters or occupants.

- The failure to manage the resultant flow path(s) dominated by stack effect has resulted in serious injury and death.





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Environmental Factors

Weather Continued

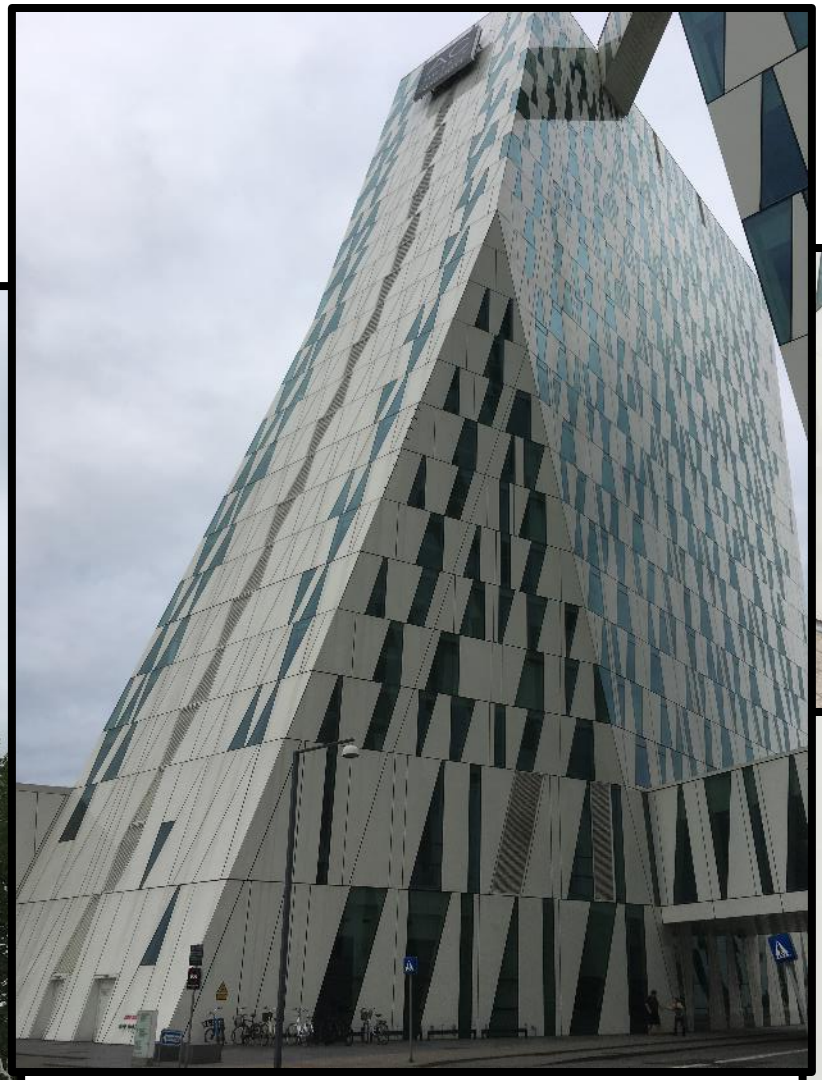
- Low Temperatures
  - Rapid cooling results in loss of buoyancy
  - Entrained water condenses & larger particles precipitated out producing dense white smoke
  - Smoke characteristics may conceal intensity of fire
  - Possibility of inversion layer

VP = BE + SAHF

Building and Environmental Factors

Topography


AC




CAUTION STRONG
WIND BLOWING !
PAS PÅ
KRAFTIG VIND !

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Building and Environmental Factors

Topography

- Effects caused by variations in elevation of land and/or buildings and building geometry.
- Can generate significant aerodynamic effects even in low to moderate wind conditions such as:
  - Pressure zones
  - Buffeting
  - Rip currents
  - Vortices

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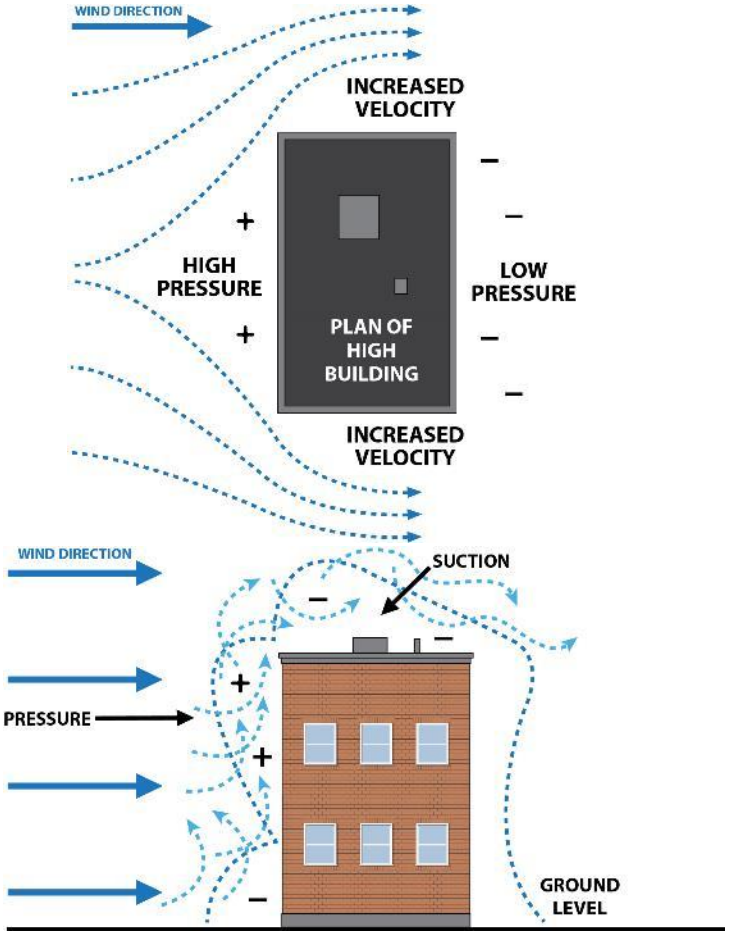
Building and Environmental Factors



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Smoke, Air, Heat and Flame Indicators

- Indicators
- May be assessed individually
- Don’t focus on one indicator
- Assess in context of Building and Environmental factors
- Use to establish the VP

VP = BE + SAHF

Smoke, Air, Heat and Flame Indicators

Smoke Movement & Control

- Of critical importance in assessing & managing effects of fire
- Driven by:
  - Stack effect & HVAC
  - Buoyancy
  - Expansion
  - Wind

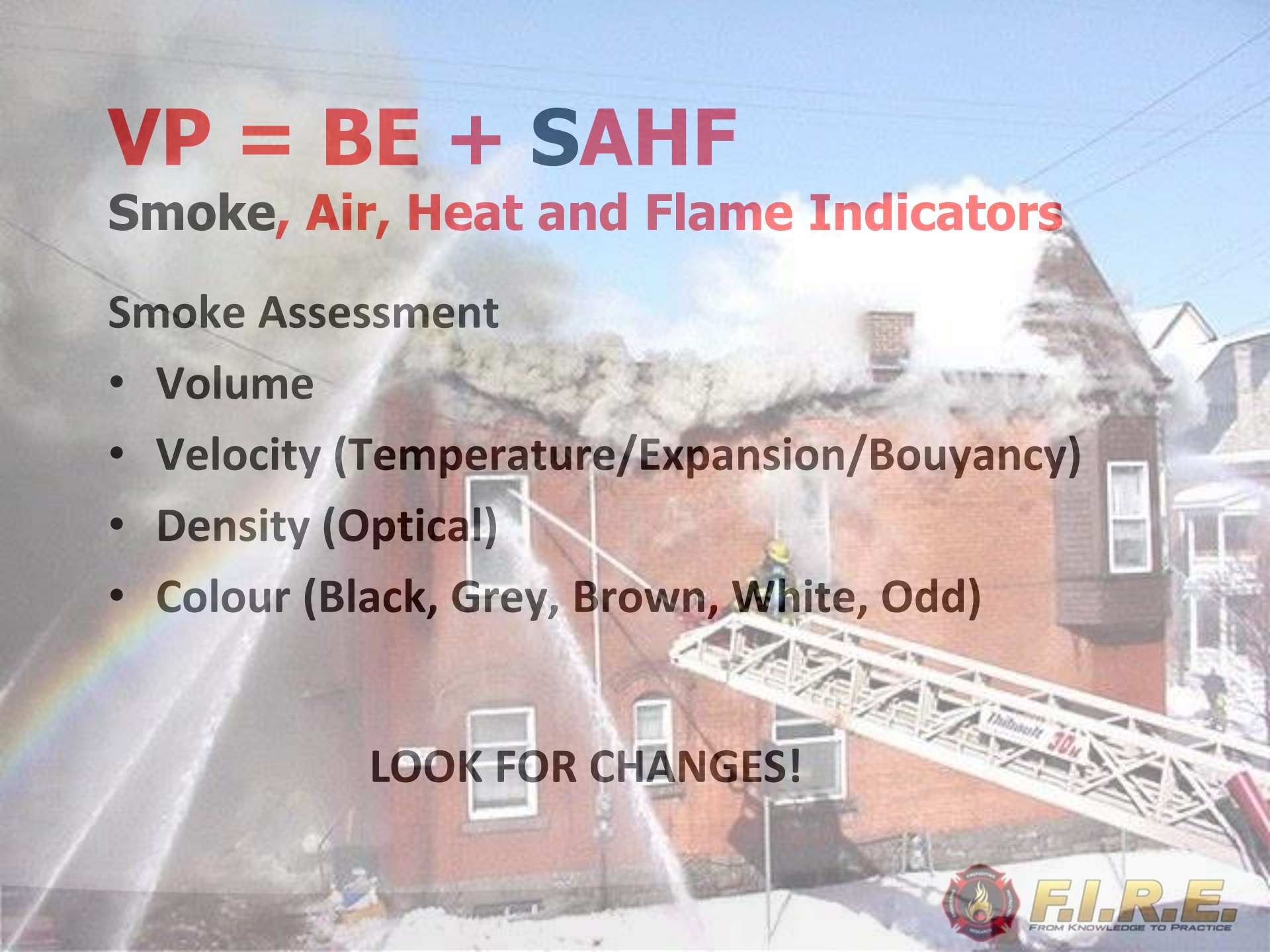
VP = BE + SAHF

Smoke, Air, Heat and Flame Indicators

Smoke Assessment

- Volume
- Velocity (Temperature/Expansion/Bouyancy)
- Density (Optical)
- Colour (Black, Grey, Brown, White, Odd)

LOOK FOR CHANGES!



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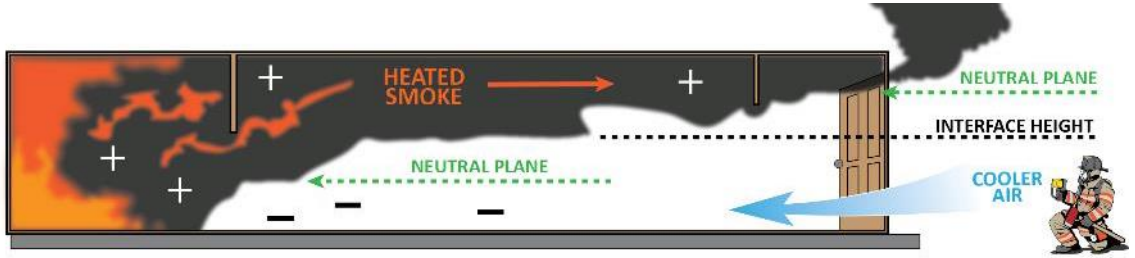
Smoke, Air, Heat and Flame Indicators



Air

- **Invisible**
- **Indicated by the movement of contrasting Smoke and its:**
  - **Stratification within the boundaries of a compartment or opening**
  - **Degree of turbulence**
  - **Direction, velocity and shape**
  - **Height of interface height & neutral plane**
- **The single most important factor in fire growth and decay!**

VP = BE + SAHF

Smoke/Air Flow, Heat and Flame Indicators

Smoke/Air Flow

- Layering a function of the gravity current
- Read together to quickly establish the:
  - Burning regime
  - Flow path(s)
  - Ventilation profile (Vent profile)

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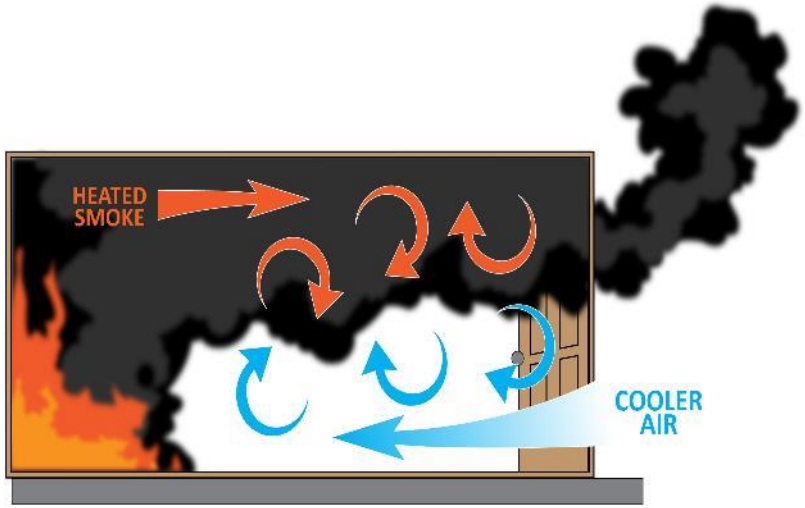
Smoke/Air Flow, Heat and Flame Indicators

Gravity Current

- A gravity current occurs because the density of fresh air is higher than the density of the hot smoke inside the compartment
- Gravity current layering can be disrupted by wind or the combustion cycle and create an irregular or dynamic flow(s) and indicate extreme or unstable fire conditions



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Smoke/Air Flow, Heat and Flame Indicators

Burning Regimes

- **Fuel Controlled**
  - **Fire growth is limited by the available fuel supply**
- **Ventilation Controlled**
  - **Fire growth is limited by the available air/oxygen supply**

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Smoke/Air Flow, Heat and Flame Indicators

Flow path *is the route followed by smoke, air, heat or flame toward or away from an opening; typically, a window, door or other leakage points due to pressure differences.* *(FKTP ➢ NFPA 1700)*

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Smoke/Air Flow, Heat and Flame Indicators

The flow is caused by pressure differences that result from temperature differences, buoyancy, expansion, wind impact and HVAC systems.

- Stack effect & HVAC
- Buoyancy
- Expansion
- Wind

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Smoke/Air Flow, Heat and Flame Indicators

Flow characteristics include stratification within the boundaries of a compartment or at an opening, degree of turbulence, its direction, velocity and shape.

These characteristics can often be identified by evaluating the smoke/air flow.

VP = BE + SAHF

Smoke/Air Flow, Heat and Flame Indicators

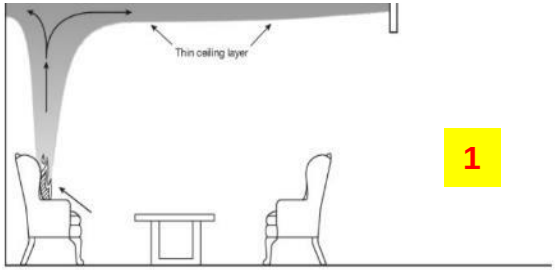


FIGURE 6.4.2.1.1.4 Early Compartment Fire Development.

1

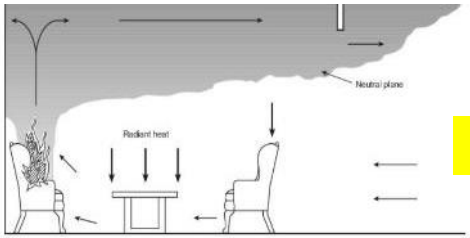


FIGURE 6.4.2.1.1.6(c) Neutral Plane — Upper Layer Development and Airflow.

2

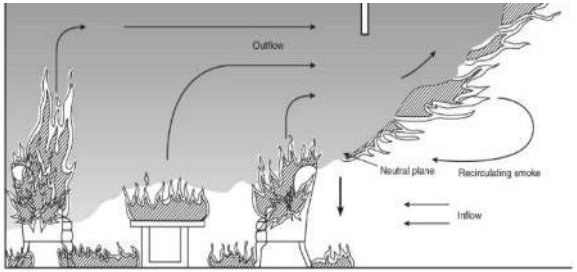
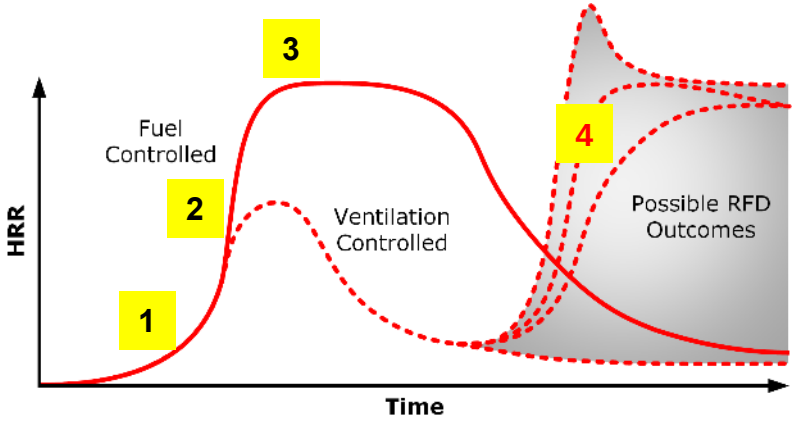


FIGURE 6.4.2.1.2 Flashover Conditions in Compartment Fire.

3



4

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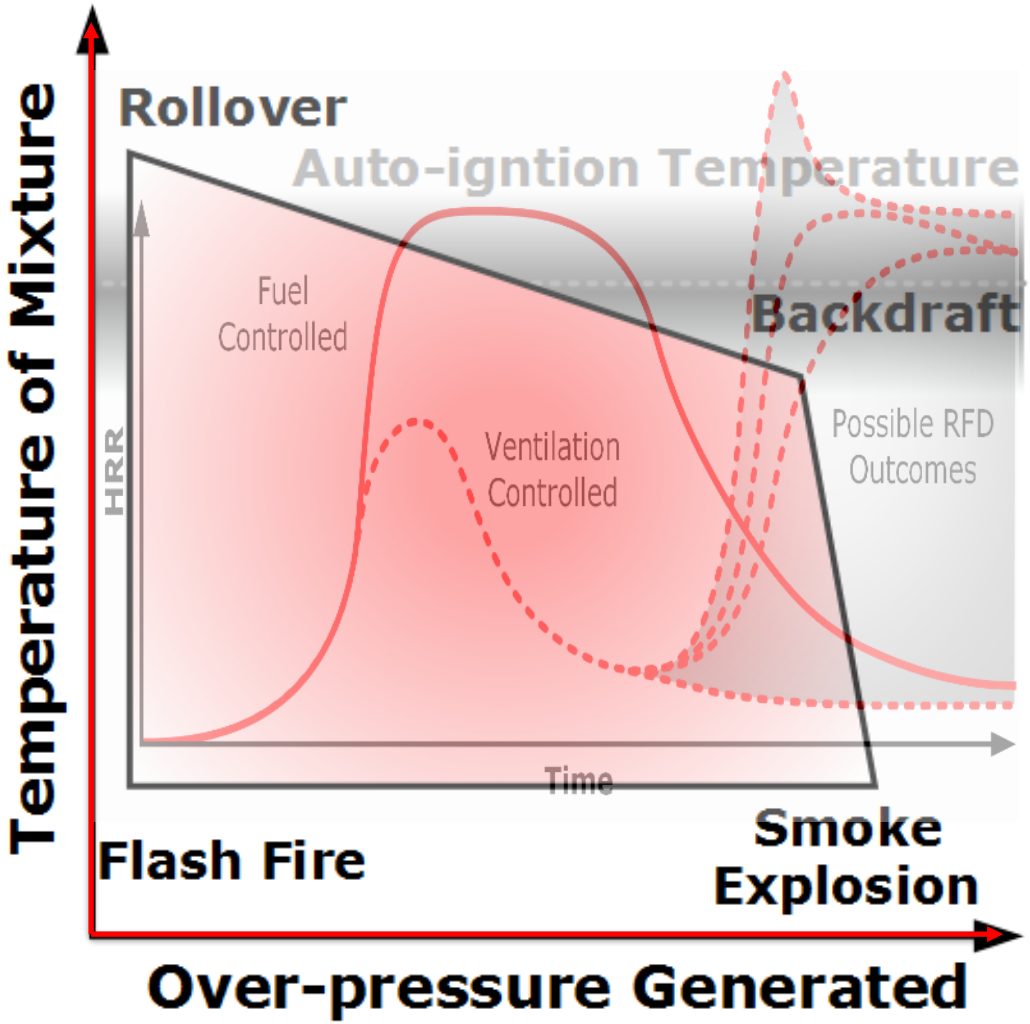
Rapid Fire Development

SAHF Assessment

- Flashover
- Smoke Ignition
  - Smoke Explosion
  - Backdraft
  - Flash Fire
    - Rollover
    - Pockets of Flame
    - Vent Ignition

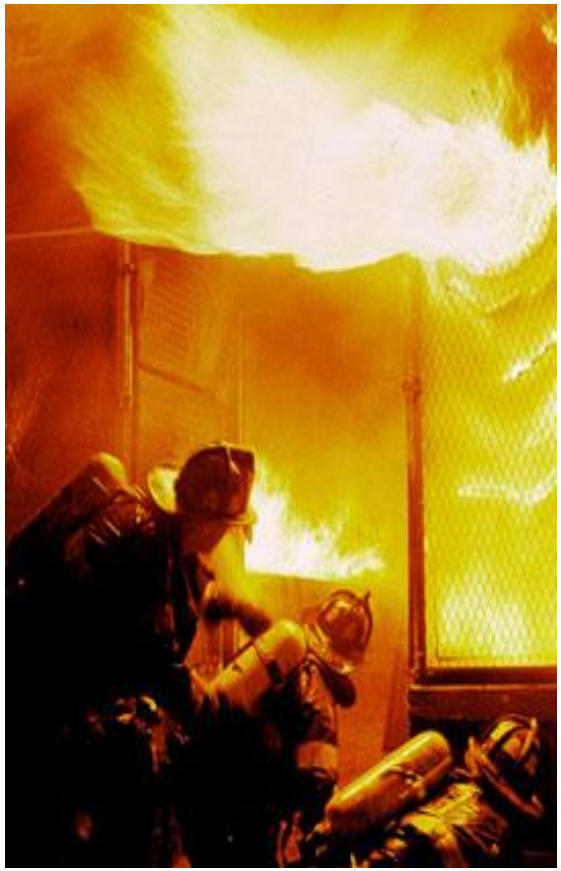
Rapid Fire Development



Impending Flashover Indicators

SAHF Assessment

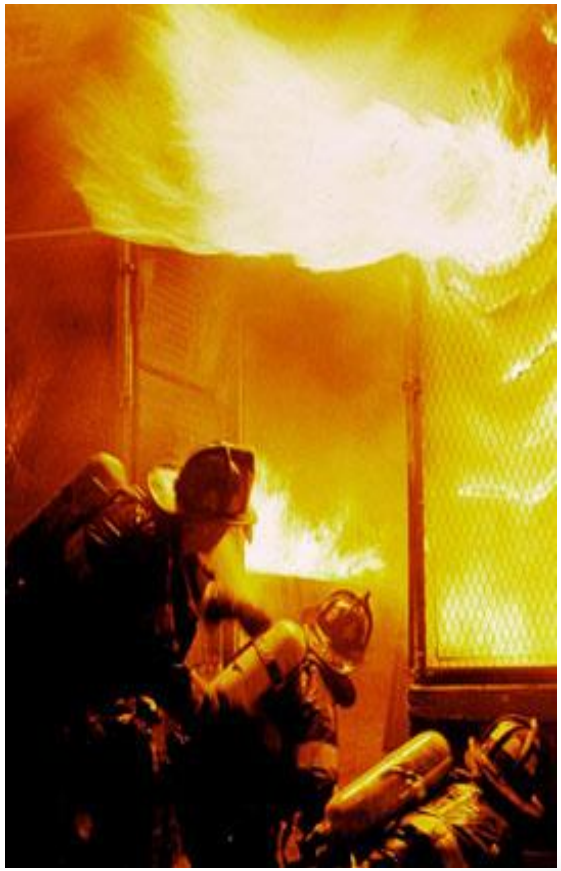
- Smoke/Air Flow:
  - Neutral Plane Height - Descending
  - Stratification/Shape – Wedge to Conical
  - Air Velocity - High
  - Flow – Turbulent



Impending Flashover Indicators

SAHF Assessment

- **H**eat
  - Melting/ Pyrolysis Upholstery
  - Pyrolysis at floor
- **F**lame (Flash Fire)
  - Pockets of flame or rollover
  - Auto Ignition outside



VP = BE + SAHF

Smoke/Air Flow, Heat and Flame Indicators

- At openings, or within rooms, the smoke/air flow flow(s) may be classified as:

  - ❖Unidirectional flow
  - ❖Bidirectional flow
  - ❖Dynamic flow

VP = BE + SAHF

Smoke/Air Flow, Heat and Flame Indicators

- Multiple flow paths are possible within a structure fire, there may be multiple combinations of inlets and/or outlets
- Flow paths can be altered by firefighting tactics.

Vent Profiles of a wind-driven fire

- **Eccentric** - showing from corners of a window, but not from the centre of the window.
- **Projected** - exiting horizontally from the vent opening.
- **Inverted** - exiting the vent over the bottom of the window sill.
- **Hollowed** - flames and smoke in an open window, but the opening is not venting flames or smoke.
- **Pulsations**
  - **Puffing -** pushing and puffing from an open vent in a pulsating pattern.
  - **Star Fire** - issuing from the building and being flattened against the building's surface.

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Smoke/Air Flow, Heat and Flame Indicators

❖**Unidirectional Flow:**

A flow of smoke or air moving in a single direction. *(FKTP ➢ NFPA 1700)*

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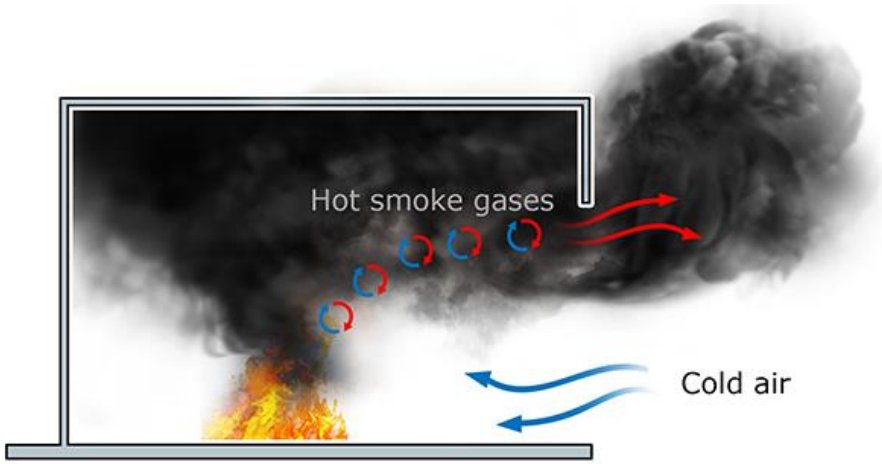
Smoke/Air Flow, Heat and Flame Indicators

- **Bidirectional Flow:**
  A smoke/air flow moving in opposing directions. *(FKTP ➢ NFPA 1700)*



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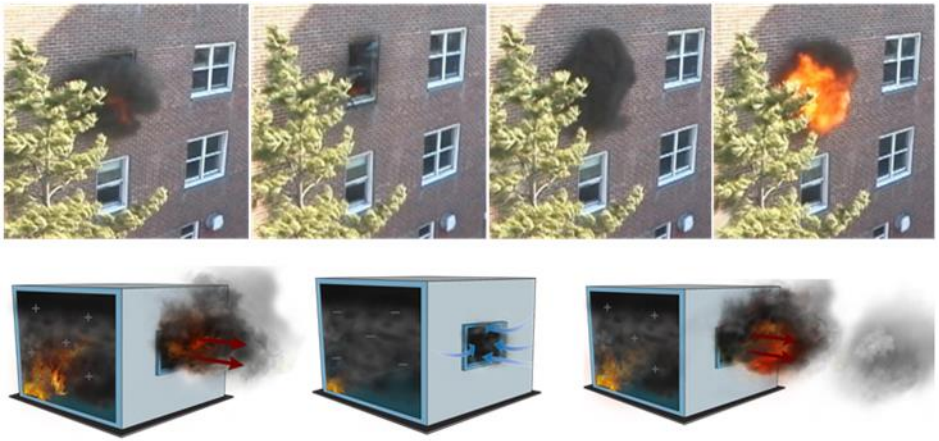
Smoke/Air Flow, Heat and Flame Indicators



- **Dynamic Flow:**

  A unidirectional or bidirectional flow of smoke/air that presents irregular stratification and shape or alternates in direction (pulsations). *(FKTP ➢ NFPA 1700)*

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Smoke/Air Flow, Heat and Flame Indicators

Dynamic Flow

- **Eccentric**

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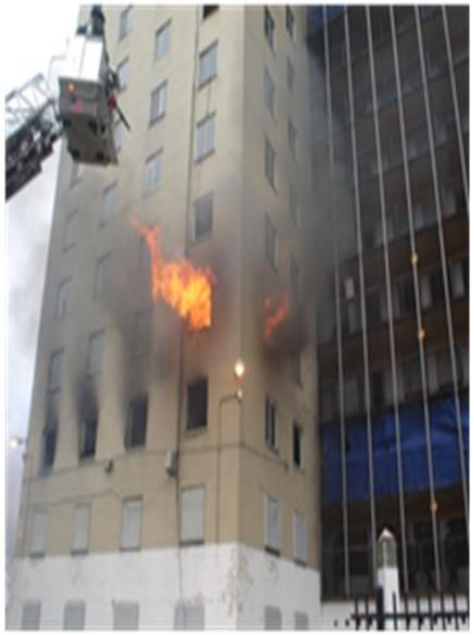
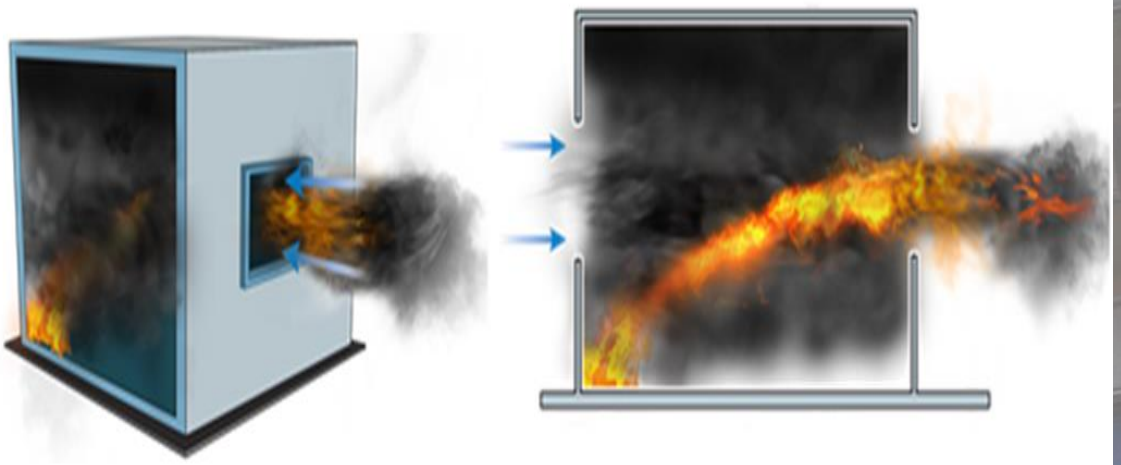
Smoke/Air Flow, Heat and Flame Indicators





Dynamic Flow

– Projected

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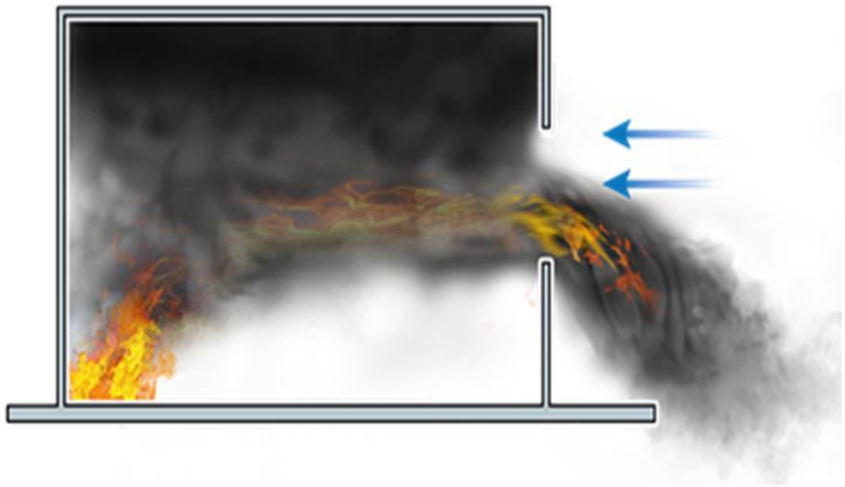
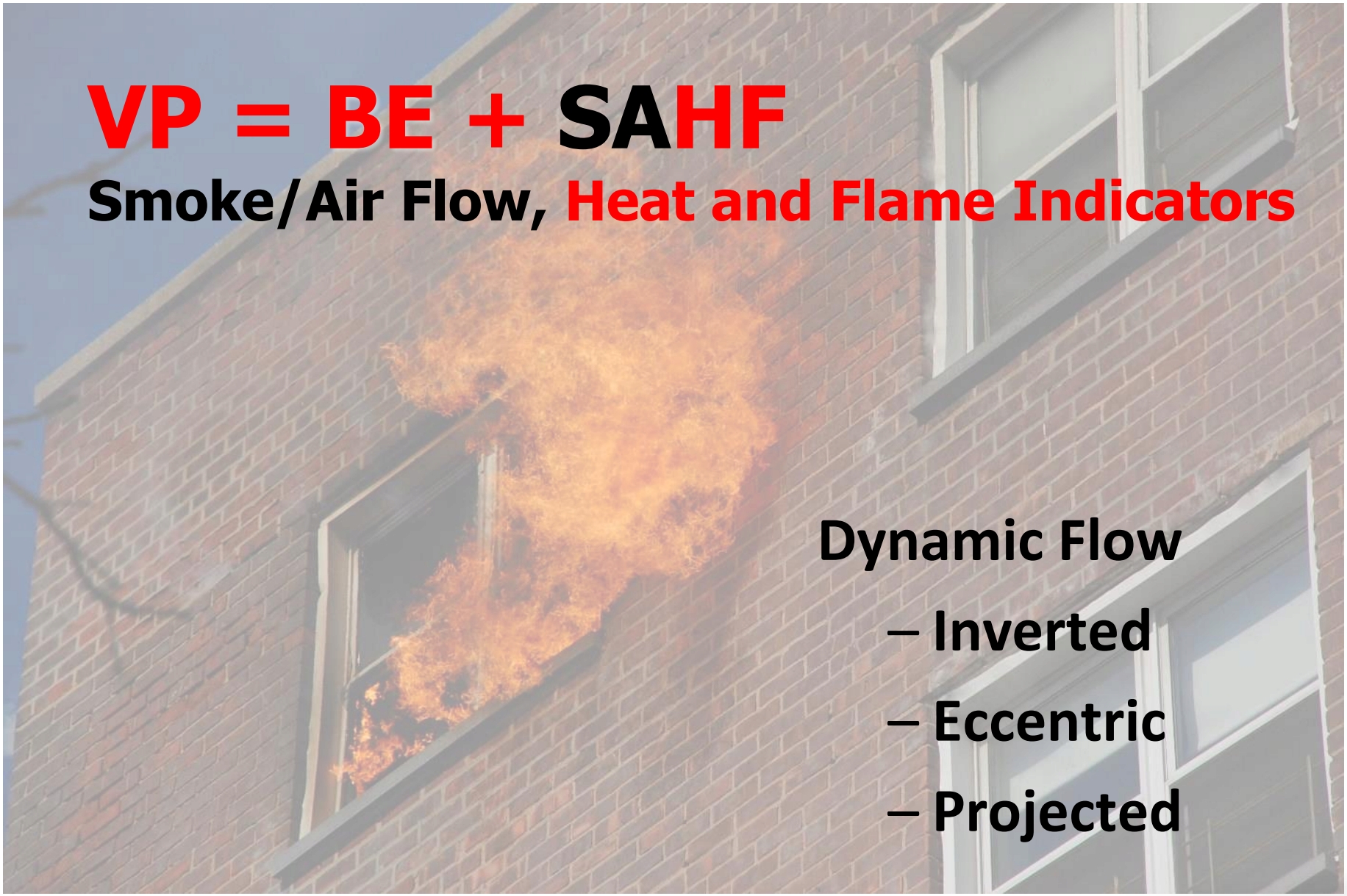
Smoke/Air Flow, Heat and Flame Indicators



- Dynamic Flow
  - Inverted
  - Projected



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Smoke/Air Flow, Heat and Flame Indicators

Dynamic Flow

- Inverted
- Eccentric
- Projected

VP = BE + SAHF

Smoke/Air Flow, Heat and Flame Indicators

Dynamic Flow

- **Hollowed**

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Smoke/Air Flow, Heat and Flame Indicators

Dynamic Flow

– Pulsations - Puffing

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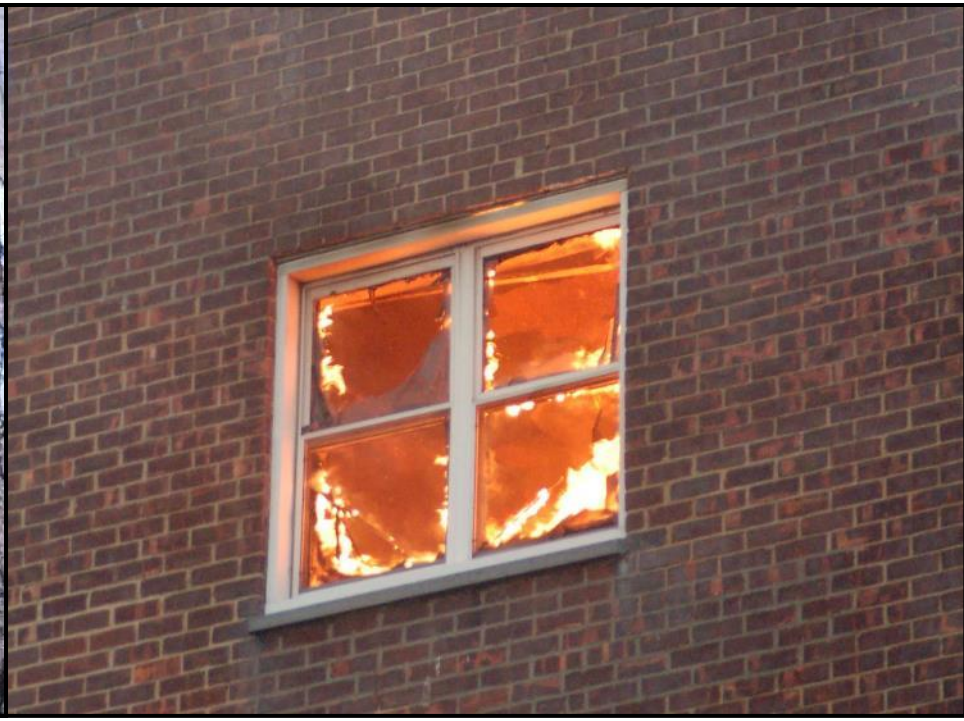
Smoke/Air Flow, Heat and Flame Indicators

Dynamic Flow

– Pulsations - Starfire

Air Geometry



Observe the Difference !

Decision Making
Tactical Bricks

- Provide guidance to firefighters on how to implement the Incident Commander's Strategic Objectives.
- Allow firefighters to choose and combine methods or techniques based on assessment and evaluation of the fire condition.
- Describe the use of extinguishing media and the movement and control of smoke, air, heat and flame.

Action slide guide

- Tactical Objective – What the commander wants
- How It Works – Fire dynamics principles
- Tactical Considerations – How we do it: Company officer
- Preferred Technique – How we do it: Task level
- Alternative Technique – Have a Plan B
- Safety Considerations – Keeping out of trouble

Action: Water Application

Tactic: Exterior Control

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FROM KNOWLEDGE TO PRACTICE

Exterior Control

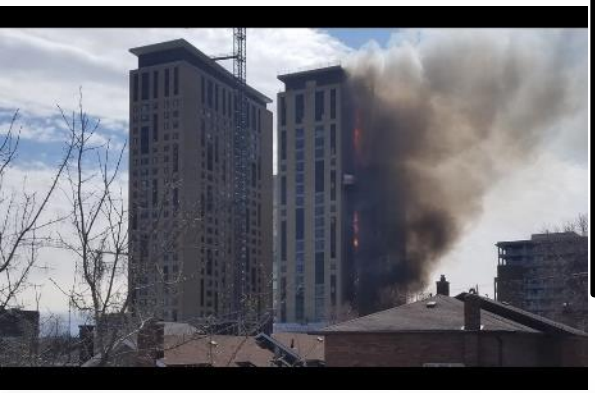
- **Tactical Objective**
  - Improve occupant tenability and interior conditions for fire attack.

How It Works

- Compartment linings and burning fuel surfaces are cooled, interfering with pyrolysis, which halts flaming combustion and in turn reduces HRR
- Reduces surface temperature of unignited fuels & stops pyrolysis.
- Flame is displaced from the surface of burning fuels.
- Steam production absorbs energy from the environment.
- *Water Map Model

Exterior Control

- Fire control using an elevating device



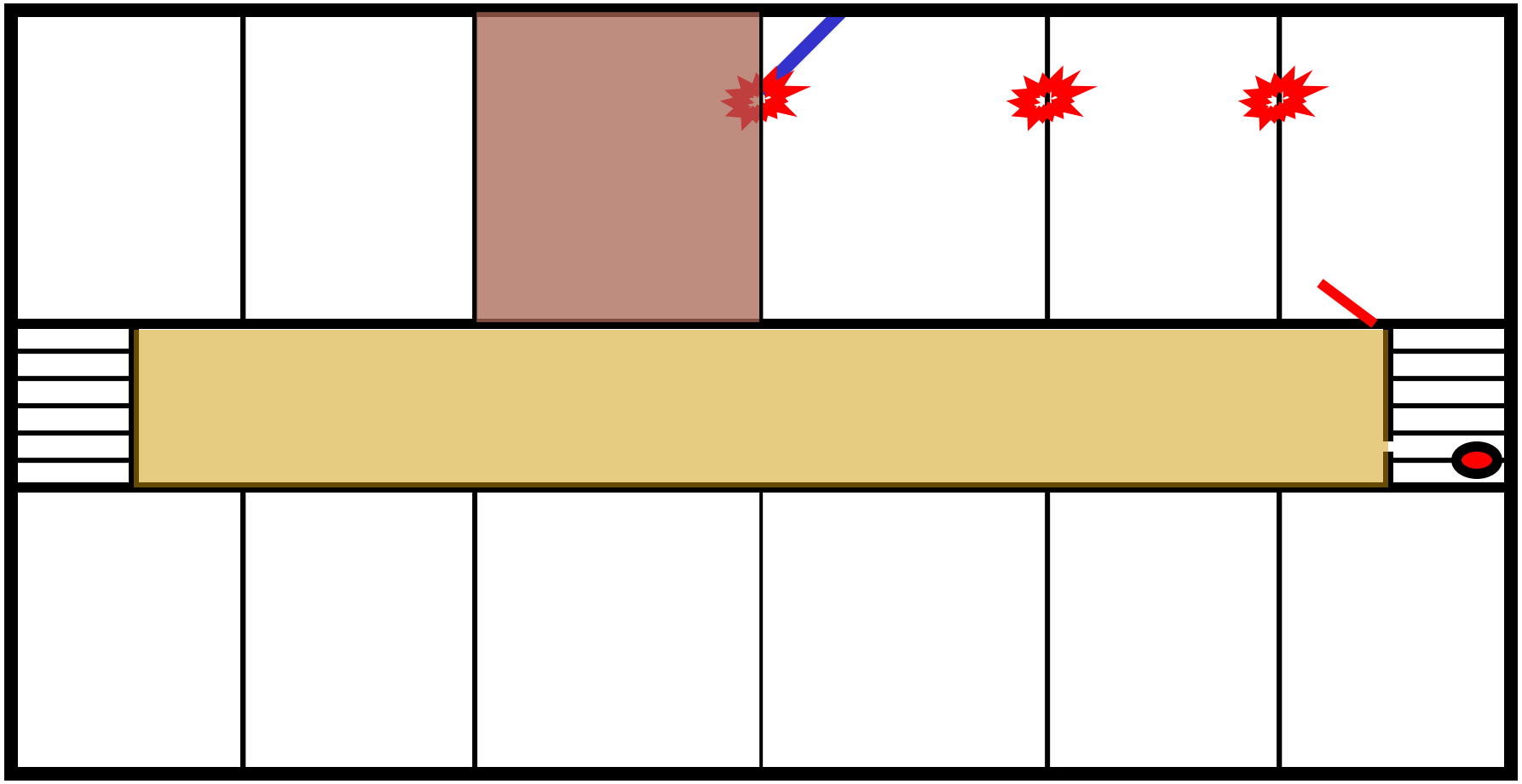
Exterior Control

- Fire control using a adjoining Balconey

Exterior Control

- Fire control by flanking

Flanking Attack



Exterior Control

- **Fire control using a cellar nozzle**

Exterior Control

- Indirect fire attack using a floor below nozzle or nozzle and curtain

Fire Dynamics

Fire and Wind

Governors Island 2008

Boston Beacon Street

March 26th, 2014

VP = BE + SAHF

The VP=BE+SAHF assessment should be a continuous exercise until such time as the fire is fully extinguished and any other incident risks are resolved.

Remember to Evaluate the Ventilation Profile and BE+SAHF

F.I.R.E.
FROM KNOWLEDGE TO PRACTICE

Thank You

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May 19, 2022

Tall Buildings
fire safety network