HIGH-RISE FIREFIGHTING
Evidence based Research 1990-2019

Paul Grimwood PhD, FIFireE
Kent Fire and Rescue Service
Borders onto Essex, London, Surrey, Sussex and Calais, France, Fire Service Areas
County Area
3,544 km²

23,047 Call Outs in 2018
from 56 Fire Stations

413 people/km²
67 High-rise residential buildings between 10 and 20 storeys
A German fire chief once said that the most important room in a fire building is the stairwell!

HE WAS RIGHT!

Stairwell protection is a critical strategy in a successful firefighting operation, in an occupied building involved in fire.
Human behavior related to fires in tall residential buildings

Stay Put Policy - 113 Grenfell Tower residents gave evidence
3rd October to 9th November 2018 inclusive

- 38% Would Ignore Stay Put
- 38% Unaware of Stay Put
- 24% Aware of Stay Put

Number of residents answering: 34-44
The attack stair is the worst place for residents to evacuate into unless it’s kept free of smoke

In 1995, six people died in the stairway of a burning high-rise apartment building in Ontario, Canada. In 1998, New York City, four people were killed in a smoke-filled stairway on the 27th floor during a high-rise apartment fire. In Chicago, 2003, six office workers were killed in a smoke-filled stairwell attempting to escape fire in a high-rise building.

Within eight years, 16 building occupants had died in fires in Chicago, New York City and Toronto; the victims shared one common fate with three primary factors — they were all found in the attack stair, they were well above the fire floor and all died of carbon monoxide (CO) poisoning.
Six occupants die in a Chicago fire attack stair overcome by smoke as firefighters take hose-lines from the rising main through the stair door in 2003 – but this was actually an evacuation stair!
The victims lived on the 38th floor, far above the fire. They decided to evacuate with their two dogs, and started down one of the two stairwells.

They made it as far as the 31st floor, where they were overcome by smoke.

The fire was burning in a small apartment on the 20th floor, but had not spread.

Firefighters, coming up the same stairwell the victims were using, entered the fire floor, and opened the stair doors and the apartment door, sending the smoke up as if through a chimney. One of the men and both dogs died. The residents were evacuating in the firefighting attack stair whilst the evacuation stair remained relatively smoke free.
It’s true that National Operational Guidance and GRA 3.2 require all FRSs to formulate a plan to reverse a stay put strategy, where necessary. However, there are many factors that serve as a disconnect between building design and firefighting procedure, preventing any viable means of doing so.
TWO SERIOUS HIGH-RISE FIRES IN 2001 IN KENT CHANGED HOW WE APPROACH SUCH FIRES
<table>
<thead>
<tr>
<th>What Key Factors Are Needed for an Effective High-Rise Fire-Fighting Operation?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adequate fire protection <em>(compartments/sprinklers)</em></td>
</tr>
<tr>
<td>Adequate resources, personnel and appliances</td>
</tr>
<tr>
<td>Adequate fire-fighting access and facilities</td>
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<tr>
<td>An effective pre-plan (SOP)</td>
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<td>To be familiar with all building types</td>
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**What key factors are needed for an effective high-rise firefighting operation?**
KENT FRS
HIGH-RISE
FIREFIGHTING
DEVELOPMENTS
2003-2019

1. ATTACK FROM THE FIRE FLOOR 2003
2. TRAINING 97 COMMAND OFFICERS 2010-11
3. R.I.C.E COMMAND DECISION TOOL 2010
4. STAIRWELL SEARCH TEAMS 2010
5. RE-LOCATE RISING MAIN OUTLETS 2010
6. VENTILATION OF EXTENDED CORRIDORS AND STAIRS 2011
7. ADEQUATE FIREFIGHTING WATER 2014
8. 51mm ATTACK HOSE 2014
9. 150mm TWIN-OUTLET RISING MAINS 2015
10. STAIRWELL PROTECTION TEAMS 2019
<table>
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<th>Key Factors</th>
<th>Status</th>
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<td>?</td>
</tr>
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<td>Adequate resources, personnel and appliances</td>
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• Nine two-day command seminars over two years

• 97 Level 1 & 2 command officers trained

• Supporting self-evacuation was a key learning objective

• Six different external wall fire types were discussed at length

• A 90 minute Fire Studio exercise featured an external wall fire across eight storeys
SHANGHAI CHINA 2010
58 LIVES LOST
Potentially 6,000 existing UK buildings with combustible walls

The Fire Studio simulation pitched KFRS Command Teams against a fast developing external wall fire. The prime objectives were to **save life and save property**. The teams were split into radio linked sectors including Lobby, Bridgehead, Exterior etc. It was a real-time exercise lasting 90 minutes. **There was a 100% failure rate in the first two seminars**.
‘ICE’ was originally developed whilst training high-rise firefighters in the city of Kuala Lumpur in 2008

As reported in the Journal - Gulf Fire 12/2015
Initially called ‘ICE’ where RESCUE was a branch off the INTERVENTION header.

- **INTERVENTION** (Firefighting Compartment Entry)
- **CONTAINMENT** (Actions to limit internal and external fire development & spread)
- **EVACUATION** (Primary OR Secondary)

**RESCUE** (Life Safety Intervention)
The primary objective of RICE is to simplify initial decision making but also to make **EVACUATION** and **CONTAINMENT** part of the critical decision making process, and not just an afterthought.
External Observations and Internal Reconnaissance

**NO BRIDGEHEAD YET**

- **RESCUE**
  (Life Safety Intervention)
  - Life Safety Intervention
  - Single hose-line attack based on clearly defined ‘TRIGGERS’ or Credible Evidence

- **INTERVENTION**
  (Firefighting Compartment Entry)

- **EVACUATION**
  (Primary OR Secondary)

- **CONTAINMENT**
  (Actions to limit internal and external fire development & spread)
External Observations and Internal Reconnaissance

**BRIDGEHEAD**

- **RESCUE** (Life Safety Intervention)
  - Life Safety Intervention
    - Single hose-line attack based on clearly defined ‘TRIGGERS’ or Credible Evidence

- **INTERVENTION** (Firefighting Compartment Entry)
  - Firefighting Intervention
    - Attack hose-line and support hose-line with Bridgehead established

- **EVACUATION** (Primary OR Secondary)

- **CONTAINMENT** (Actions to limit internal and external fire development & spread)
External Observations and Internal Reconnaissance

BRIDGEHEAD

RESCUE (Life Safety Intervention)
- Life Safety Intervention
  - Single hose-line attack based on clearly defined ‘TRIGGERS’ or Credible Evidence

INTERVENTION (Firefighting Compartment Entry)
- Firefighting Intervention
  - Attack hose-line and support hose-line with Bridgehead established

EVACUATION (Primary OR Secondary)
- LOBBY-CORRIDOR Evacuation

CONTAINMENT (Actions to limit internal and external fire development & spread)
Evacuation (Primary OR Secondary)

Containment (Actions to limit internal and external fire development & spread)

Rescue (Life Safety Intervention)

Firefighting Intervention

Lobby-Corridor Evacuation

Stairshaft/S Evacuation

Partial OR Total Building Evacuation

Life Safety Intervention

Single hose-line attack based on clearly defined ‘TRIGGERS’ or Credible Evidence

Attack hose-line and support hose-line with Bridgehead established and crews working above fire floor protected by compartmentation

External Observations and Internal Reconnaissance
BRIDGEHEAD

**RESCUE**
(Life Safety Intervention)
- Life Safety Intervention
  - Single hose-line attack based on clearly defined ‘TRIGGERS’ or Credible Evidence

**INTERVENTION**
(Firefighting Compartment Entry)
- Firefighting Intervention
  - Attack hose-line and support hose-line with Bridgehead established and crews working above fire floor protected by compartmentation

**EVACUATION**
(Primary OR Secondary)
- LOBBY-CORRIDOR Evacuation
  - STAIRSHAFT/S Evacuation
    - PARTIAL OR TOTAL BUILDING Evacuation

**CONTAINMENT**
(Actions to limit internal and external fire development & spread)
- External Observer

External Observations and Internal Reconnaissance
External Observations and Internal Reconnaissance

**BRIDGEHEAD**

- **RESCUE** (Life Safety Intervention)
  - Life Safety Intervention
  - Single hose-line attack based on clearly defined ‘TRIGGERS’ or *Credible Evidence*

- **INTERVENTION** (Firefighting Compartment Entry)
  - Firefighting Intervention
  - Attack hose-line and support hose-line with Bridgehead established and crews working above fire floor protected by compartmentation

- **EVACUATION** (Primary OR Secondary)
  - LOBBY-CORRIDOR Evacuation
  - STAIRSHAFT/S Evacuation
  - PARTIAL OR TOTAL BUILDING Evacuation

- **CONTAINMENT** (Actions to limit internal and external fire development & spread)
  - Exterior Observer
  - Exterior Streams

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**ATTACK HOSE LINE**

- Attack hose-line to compartment immediately above fire

**BRIDGEHEAD**

- Exterior Streams

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**PARTIAL OR TOTAL BUILDING Evacuation**

- Transition to evacuation based on clearly defined 'TRIGGERS' or credible evidence

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**EXTERNAL OBSERVER**

- External observer provides real-time feedback

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**EVACUATION**

- Life Safety Intervention
  - Single hose-line attack based on clearly defined ‘TRIGGERS’ or *Credible Evidence*

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**FIREFIGHTING INTERVENTION**

- Attack hose-line to compartment immediately above fire

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**RESCUE**

- Life Safety Intervention
  - Single hose-line attack based on clearly defined ‘TRIGGERS’ or *Credible Evidence*
External Observations and Internal Reconnaissance

**Bridgehead**

**Rescue** (Life Safety Intervention)
- Life Safety Intervention
  - Single hose-line attack based on clearly defined ‘TRIGGERS’ or Credible Evidence

**Intervention** (Firefighting Compartment Entry)
- Firefighting Intervention
  - Attack hose-line and support hose-line with Bridgehead established and crews working above fire floor protected by compartmentation

**Evacuation** (Primary OR Secondary)
- LOBBY-CORRIDOR Evacuation
- STAIRSHAFT/S Evacuation
  - PARTIAL OR TOTAL BUILDING Evacuation

**Containment** (Actions to limit internal and external fire development & spread)
- Exterior Streams
  - Hose-line deployed to compartment DOOR immediately above fire compartment
  - Hose-line deployed INTO compartment immediately above fire compartment

External Observer

Hose-line deployed directly to the compartment DOOR immediately above the fire floor protected by compartmentation.
External Observations and Internal Reconnaissance

**NO BRIDGEHEAD YET**

- **RESCUE**
  - (Life Safety Intervention)
  - Life Safety Intervention
  - Single hose-line attack based on clearly defined ‘TRIGGERS’ or Credible Evidence

- **INTERVENTION**
  - (Firefighting Compartment Entry)
  - Firefighting Intervention
  - Attack hose-line and support hose-line with Bridgehead established and crews working above fire floor protected by compartmentation

- **EVACUATION**
  - (Primary OR Secondary)
  - LOBBY-CORRIDOR Evacuation
  - STAIRSHAFT/S Evacuation
  - PARTIAL OR TOTAL BUILDING Evacuation

- **CONTAINMENT**
  - (Actions to limit internal and external fire development & spread)
  - External Observer

**BRIDGEHEAD**

- Exterior Streams
  - Exterior Streams
  - Exterior Streams

- **Hose-line**
  - Hose-line deployed to compartment DOOR immediately above fire compartment
  - Hose-line deployed INTO compartment immediately above fire compartment

- **Aerial water tower**
  - Aerial water tower replaces interior crews
External Observations and Internal Reconnaissance

NO BRIDGEHEAD YET

- RESCUE (Life Safety Intervention)
  - Life Safety Intervention
  - DOOR CURTAIN
    - Single hose-line attack based on clearly defined ‘TRIGGERS’ or Credible Evidence

BRIDGEHEAD

- INTERVENTION (Firefighting Compartment Entry)
  - Firefighting Intervention
  - ATTACK hose-line and support hose-line with Bridgehead established and crews working above fire floor protected by compartmentation

- EVACUATION (Primary OR Secondary)
  - LOBBY-CORRIDOR Evacuation
  - STAIRSHAFT/S Evacuation
    - PARTIAL OR TOTAL BUILDING Evacuation
    - STAIRWELL PROTECTION TEAMS
      - DOOR CURTAIN

- CONTAINMENT (Actions to limit internal and external fire development & spread)
  - Exterior Observer
  - Exterior Streams
    - DOOR CURTAIN
    - Hose-line deployed to compartment DOOR immediately above fire compartment
    - Hose-line deployed INTO compartment immediately above fire compartment
    - Aerial water tower replaces interior crews
• Simple mnemonic for primary command
• Rapid decision making on-scene
• Supports analytical thought process
• Assists when in ‘Information Overload’
• Intervention may not be the first option

This tool was seen to increase situational awareness amongst 97 KFRS officers by 33% in exercises.
R.I.C.E. AS AN ANALYTICAL COMMAND MNEMONIC
A proposal to reposition rising main outlets by design to protect stairwells

See para 17.1

a. Any building

b. Shafts serving flats

Diagram 52
A proposal to reposition rising main outlets by design to protect stairwells

See para 17.1

a. Any building

b. Shafts serving flats
150mm Rising mains with twin outlets at each floor level, located away from the stairwell.

Within one metre of the stair door.
150mm Rising mains with twin outlets at each floor level, located away from the stairwell.

**Advantages of Rising Main outlets sited away from the stair** -

- Hose-lays are reduced in length and are easier to manage.
- Firefighters are exposed to less stress and breathing apparatus will last longer.
- The stair door in residential buildings remains closed and smoke infiltration into the stair is dramatically reduced.
- Where occupants are self-evacuating, particularly but not solely in single stair buildings, the vertical escape routes are relatively clear of smoke and tenable throughout firefighting operations.
DUBLIN FIRE BRIGADE HIGH-RISE OPS
‘Floor below Nozzle’
(Wind Driven Fires)
‘In circumstances where teams need to work in an area above the bridgehead which is not affected by fire or smoke and the Incident Commander has confirmed that the building’s construction and any fire engineered solutions have not been compromised, teams can be committed without respiratory protective equipment.

These teams must maintain communication and a Safety Officer must be deployed in the stairwell and be in contact with other Safety Officers and the Incident Commander outside the building’.
STAIRWELL PROTECTION TEAMS 2019

ROLES AND OBJECTIVES

- **Patrol** stairwells continuously from top-to-bottom to ensure that egress routes are safe and free of obstructions; **monitor gas levels**
- **Search** stairwells, corridors, lobbies and lifts for building occupants who may be trapped or are entering an untenable environment
- **Report** information about conditions at each floor to the incident commander
- Ensure the stairs are **clear of smoke**
- **Deploy to FSG calls** where required
- **Manage occupant evacuation** where required
Prior to taking hose-lines from a rising main located in the stair, a check should be made for occupants at least five floors above the fire floor.

As soon as possible, on arrival of the third pump where viable, a stair protection team should be deployed above the fire floor where considered safe to do so.

Before allowing smoke to enter the stair, every effort must be made to prevent or reduce this by deploying door smoke curtains where possible.
Initial Stairwell Protection Team deployment
Secondary Stairwell Protection Team deployment

Stairwell Protection Team 1
Stairwell Protection Team 2
Stairwell Protection Team 3

SafetyOfficer
Fire Floor
Bridgehead
External Observer

KENT FRS STAIRWELL PROTECTION TEAMS 2019
### Carbon Monoxide

<table>
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<th>Concentration (ppm)</th>
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<tbody>
<tr>
<td></td>
<td>10 min</td>
</tr>
<tr>
<td>AEGL-1*</td>
<td>NR</td>
</tr>
<tr>
<td>AEGL-2†</td>
<td>420</td>
</tr>
<tr>
<td>AEGL-3‡</td>
<td>1,700</td>
</tr>
</tbody>
</table>

### Hydrogen Cyanide

<table>
<thead>
<tr>
<th></th>
<th>Concentration (ppm)</th>
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<tbody>
<tr>
<td></td>
<td>10 min</td>
</tr>
<tr>
<td>AEGL-1*</td>
<td>2.5</td>
</tr>
<tr>
<td>AEGL-2†</td>
<td>17</td>
</tr>
<tr>
<td>AEGL-3‡</td>
<td>27</td>
</tr>
</tbody>
</table>
Star Protection as a strategy – Evacuation v. Rescue

‘An advantage in strategically and tactically supporting any ‘self-evacuation’ that may already be occurring, is to enhance any later decision to reverse a ‘stay-put strategy’, as the natural command and stair deployment structure will already be in place and less resources will be required’.
ADEQUATE FIREFIGHTING WATER
280 Sq. METRES OF FIRE

IS THE MAXIMUM SIZED OFICE FIRE WE CAN DEAL WITH!
900 Square Metres – 1,500 L/min

1.66 L/min/m²

60 Metres hose-line
900 Square Metres – 1,500 L/min

5.36 L/min/m²

60 Metres hose-line
900 Square Metres – 1,500 L/min

60 Metres hose-line

2.5 L/min/m²
Open floor space in office fires – Fire Spread Rates – Paul Grimwood IFP (IFE) Journal August 2018

London 2004
- 24 m²/min
- 29 mm/second

Chicago 2003
- 15 m²/min
- 27 mm/second

Los Angeles 1988
- 25 m²/min
- 36 mm/second
The research demonstrated that commercial office fires and industrial storage fires are likely to spread beyond any practical firefighting capability within the 8-12 minutes, where a fire growth curve is established.

The provision of automatic fire suppression systems or effective compartment size reductions by design in such premises may be critical.
THE HAZARDS OF SMOKE SHAFTS & AUTOMATED VENT OPENINGS TO FIREFIGHTERS
WHERE IS IT OK TO VENTILATE AN ACTIVE FIRE BUILDING?
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As there was a smoke shaft located immediately behind the advancing firefighters protecting an evacuation stairway, the flow path exacerbated the heat and smoke conditions being driven directly at the firefighters. Despite two 65mm hose-lines being advanced towards the fire the firefighters were unable to make little headway against the flames.

A change in strategy saw firefighters successfully redeploy using an alternative corridor, avoiding the negative flow-path created by a smoke shaft behind their advance.
If the pressure differential is reduced behind the firefighters advance, either through the opening of a smoke shaft or a stair door, the fire will head towards the lowest pressure.
The July/August 2011 issue of FRM Journal (IFE) presented CFAST modelling research undertaken by Kent Fire and Rescue Service into the existing conflict between smoke shaft locations and a firefighter’s approaches from a firefighting shaft in single stair buildings.

This research was later presented at the international ‘EuroFire’ fire engineering conference in Paris in 2011 and led to changes in smoke shaft location design in the subsequent publication of the SCA Guide in 2015. This placed extracting smoke shafts away from the stair and this one change increased firefighter safety dramatically.

<table>
<thead>
<tr>
<th>Exposure Condition</th>
<th>Maximum exposure time (minutes)</th>
<th>Maximum air temperature (°C)**</th>
<th>Maximum radiated heat flux (kW/m²)</th>
<th>Remarks</th>
<th>Recommended distance from apartment door*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Routine</td>
<td>25</td>
<td>100</td>
<td>1</td>
<td>General firefighting</td>
<td>15-30m</td>
</tr>
<tr>
<td>Hazardous</td>
<td>10</td>
<td>120</td>
<td>3</td>
<td>Short exposure with thermal radiation</td>
<td>4-15m</td>
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<tr>
<td>Extreme</td>
<td>1</td>
<td>160</td>
<td>4 – 4.5</td>
<td>For example, snatch rescue scenario</td>
<td>2-4m</td>
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<tr>
<td>Critical</td>
<td>&lt;1</td>
<td>&gt;235</td>
<td>&gt;10</td>
<td>Considered life threatening</td>
<td>0-2m</td>
</tr>
</tbody>
</table>

The design guidance produced by the Smoke Control Association in 2015 for extended corridor MSVS took into account the 2011 research and demonstrated how placing the extracting shaft away from the stairs will improve firefighter safety and reduce exposure to unnecessary heat and smoke during firefighting.
“Experience is what you get five minutes after you needed it”

‘Don’t let us look back tomorrow and say what we did today, we could have done better’ . . . . . . .

PLAN – PREPARE – EQUIP – TRAIN for it