Report from New York 2019

Fire Department of New York's High-rise Stair Search Strategy

and other firefighting research topics

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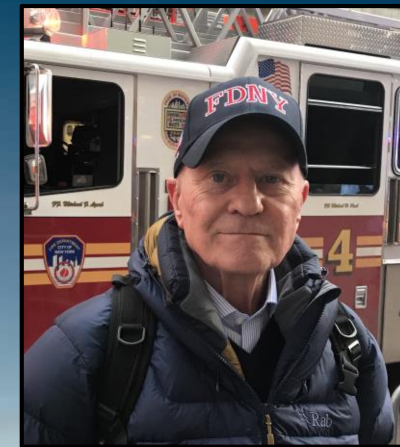


With thanks to FDNY Special Operations Chief John Esposito and Captain John Ceriello (Rescue 1) for their hospitality, assistance and organisation

Report from New York 2019

Fire Department New York

Stair Search & Protection Concepts

In December 2019 I was fortunate enough to be hosted by the Fire Department of New York (FDNY) where I presented the two EuroFirefighter books (1 & 2) to Chief of Department John Sudnik for the Department's Library. I also presented the Kent FRS stair protection strategy to the corporate board of FDNY Staff Chiefs and debated high-rise *stair search* and *egress route protection* strategies in New York City.

I welcomed this opportunity to meet the FDNY Commissioner Daniel A. Nigro, Chief of Department John Sudnik and Chief of Operations Tom Richardson, thanking them for a 44 year collaboration with FDNY dating back to 1975. This relationship has served as a catalyst for a range of developments and amendments to UK regulatory guidance and firefighting procedures.

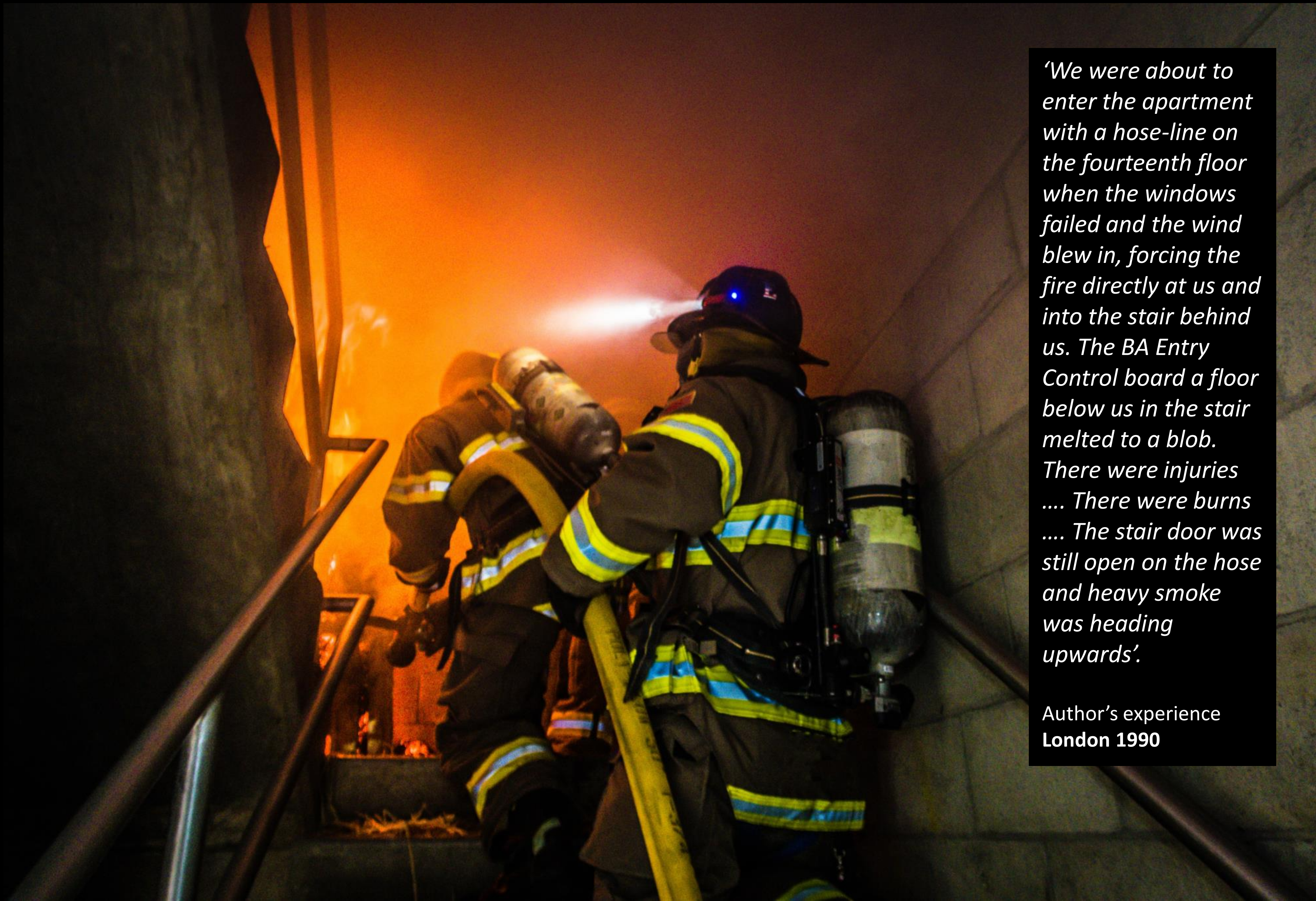
FDNY have operated strategically with dedicated high-rise stair search teams since the 1980s. Since 1992, my books have incorporated FDNY stair search guidance and other high-rise firefighting strategies and tactics as used by NYC Firefighters.

This presentation will discuss key learning points in relation to Stair Search and Stair Protection strategy and also demonstrate much of the research undertaken by Kent Fire and Rescue Service over the past decade, including how building fire damage was reduced in Kent and Medway through targeting a higher primary water flow-rate from 2015 and how changes to smoke control design was influenced in 2011.

FIRE DEPARTMENT CITY OF NEW YORK

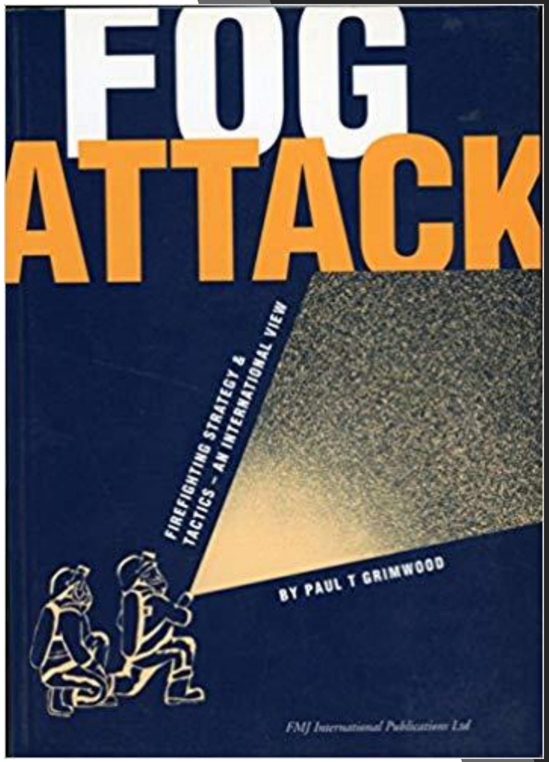
INVICTA

Leaving the stairs unprotected and failing to search the stairs early on will inevitably lead to failure and life loss



'We were about to enter the apartment with a hose-line on the fourteenth floor when the windows failed and the wind blew in, forcing the fire directly at us and into the stair behind us. The BA Entry Control board a floor below us in the stair melted to a blob. There were injuries …. There were burns …. The stair door was still open on the hose and heavy smoke was heading upwards'.

Author's experience
London 1990

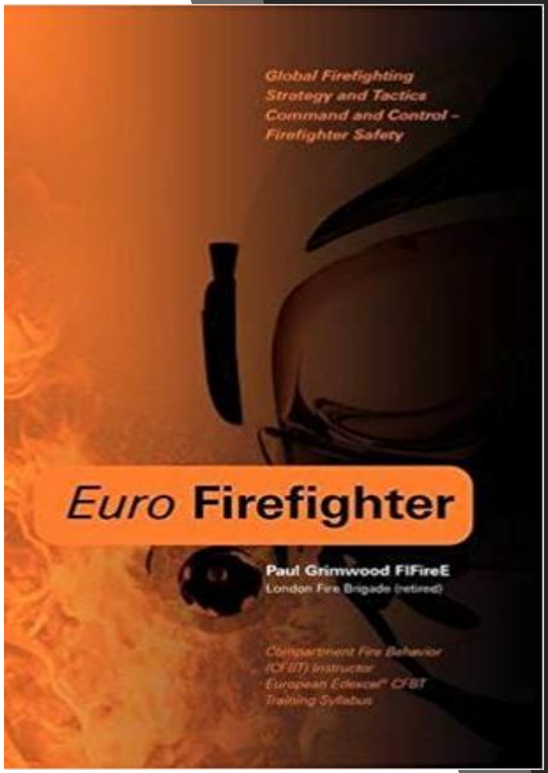


“Battalion Chief Glenn Dinger of the Los Angeles Fire Department felt strongly that any pre-plan should account for a team of firefighters to be dispatched into the [*high-rise protected*] stairs above the fire floor on the initial response, but it was surprising to find that few fire departments actually do this [1990].

However, FDNY do deploy a two-man scout and search team above the fire floor on arrival. They will search stairs, lifts shafts and report smoke conditions in egress routes. The FDNY stair protection procedure is coordinated by a designated Search and Rescue Commander”

Fog Attack p276

1992



"A prompt fire suppression action may save lives. However stair-shaft integrity should be maintained as far as possible. Whilst it is recognised that building design may, in some situations, place the rising main outlets in the stair-shaft, every effort should be made to keep the stair doors closed as much as possible.

Prior to opening a door into the stairs from the fire floor, a check should be made for occupants in the stair for at least five floors above the fire. Any stair-shaft contaminated by smoke should be prioritised for secondary search undertaken by the second arriving response firefighters".

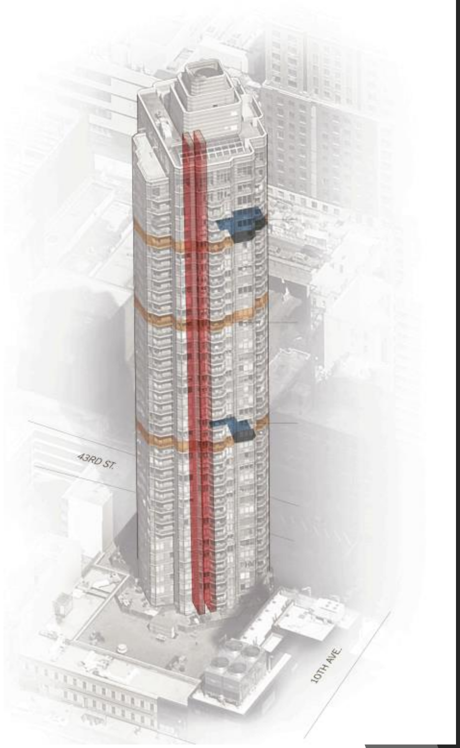
EuroFirefighter 2008
p331

CP3 ‘Stay or Go’ UK Designs

The design of CP3 (1960-70) high-rise buildings in the UK suggested that occupants may still evacuate at any stage should they wish to do so, despite the stay-put (defend in place) intentions. These buildings were designed to prevent smoke infiltrating into the stair with riser outlets located in ventilated lobbies. Since that design objective was established, we now allow smoke into the stair due to building design and firefighting procedural conflicts, but still indicate that people can leave at any time whether affected by smoke or not. This is a clear disconnect in design and evacuation strategy.

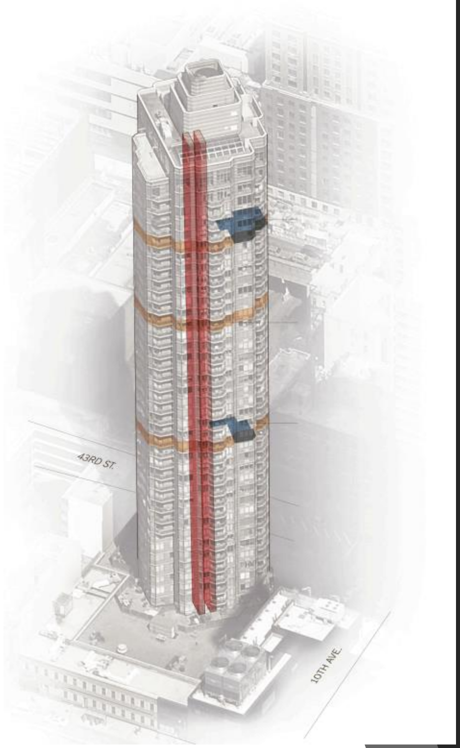
The increasing popularity of taking the first hose-line from the fire floor is based on risk assessment. It isn’t a major training burden and firefighters are just as safe when approaching from the access corridor/lobby **unless it has become the fire compartment.** Kent FRS firefighters have done this effectively and safely for the past 16 years.

Human Behaviour at Residential High-rise Fires



The prediction of human behaviour during a fire emergency is one of the most challenging areas of fire safety engineering. In recent years we have witnessed clear patterns emerging in how human behaviour impacts on firefighting operations and occupant evacuation, particularly in tall residential buildings with single stairs. Past fire experience around the world has received much media coverage and this has been reflected in how people now respond to fires where they are far more likely to make early decisions to self-evacuate themselves and their families.

Human Behaviour at Residential High-rise Fires



Since 1962 it is the case in most tall residential buildings in the UK that a **'stay put'** strategy is generally dictated by 60-minute compartment design, whereby simultaneous evacuation of all residents together is likely to be problematic due to limited stair escape capacity, building height and lack of general fire alarm provisions. Many of the buildings still around today, constructed in the 1960s and 1970s, originally incorporated a **'stay or go'** approach, stating that '*the possibility that individuals may seek to leave the building cannot be overlooked and provision should therefore be made for the occupant of any dwelling to do so by his own unaided efforts, using adequately protected escape routes within the building without outside assistance*'.

Kent Fire and Rescue Service have raised concerns nationally over the past decade in relation to the clear disconnect between operational firefighting objectives, regulatory building design and human behaviour.

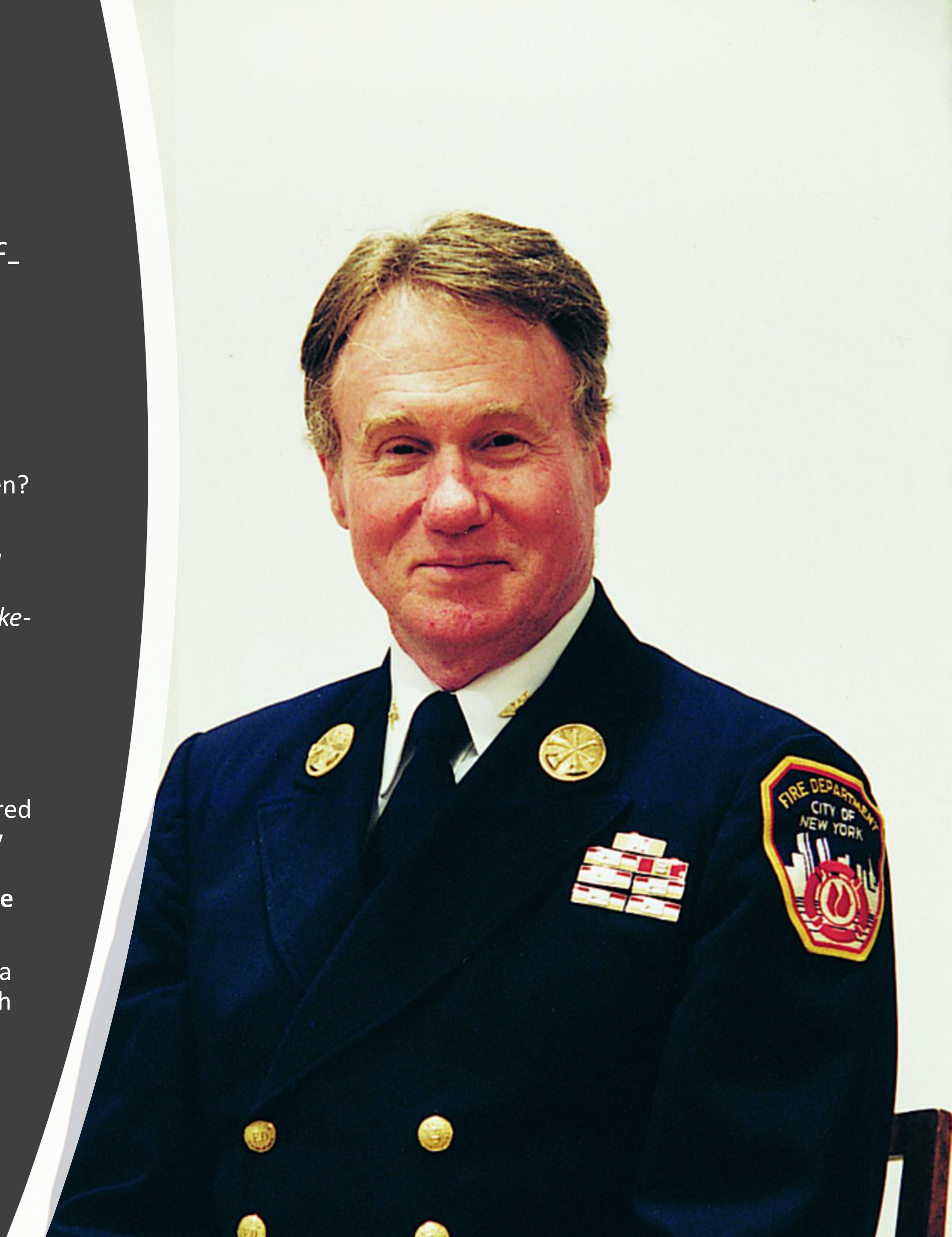
The Problem of Smoke Infiltration into Stairwells where residents decide to self-evacuate

In 2005 New York City Deputy Fire Chief Vince Dunn made it very clear for us that we should protect the stairwells at building fires. Did we learn anything then? Is it relevant now?

"In 1995, six people died in the stairway of a burning high-rise apartment building in Ontario, Canada. In l998, New York City, four people were killed in a smoke-filled stairway on the 27th floor during a high-rise apartment fire. In Chicago, 2004, six office workers were killed in a smoke-filled stairwell attempting to escape fire in a high-rise building".

Within nine years, 16 civilians 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.**

A new 2008 Law in NYC following the loss of lives in a stairway saw new residential buildings over 40m high to have fire service-controlled voice alarms.



Important Features of the FDNY High-rise Strategy

- Two stairwells in most residential apartment towers
- Standpipes are generally located in the stairwells
- Stairwell Identification Markings
- Attack stair and evacuation stair designated by Commanders on-scene
- A Fire Tower is an enclosed stairway built between 1938 and 1968. These generally incorporate a lobbied smoke shaft or are ventilated in other ways to protect the evacuation stair
- The smoke shaft protecting the stair will draw smoke towards its location and therefore should not normally be used as the attack stair
- Voice alarms under fire department control to reassure residents to stay-put, or direct evacuation towards the appropriate ‘safe’ stairwell
- Portable smoke-stop apartment/stair door curtains under trial now
- Wind control devices (External Window Curtains)
- Floor below nozzles and high water flow-rates.
- Dedicated Stair search teams since the 1980s

FDNY High-rise Firefighting Tactics CLASS "A" HIGH RISE FIREPROOF MULTIPLE DWELLING FIRES (75’ (23m) or more in height)

All extinguishment efforts shall proceed initially from the one attack stairway. If a second stairwell is required for attack and extinguishment, it should not be the stairwell designated as **the evacuation stair**. When the fire apartment door is left open; it will allow smoke and/or fire to vent out into the public hallway. If a window in the fire apartment fails, and wind is blowing into the fire apartment, an extreme condition may be created on that floor. This may negate the standard attack strategy; which is a direct frontal attack with a hose line from a stairwell, down the public hall and through the apartment door. Prior to advancing to the reported fire floor, members must gather information from the floor below, or two floors below if scissor stairs are present.

Determine the location, letter or number designation and number of stairways serving the fire floor. Prior to the designation of the attack stairway, all members must access the fire floor from the same stairway. If the door to the fire apartment has been left open and size-up indicates that wind may impact fire conditions, the air flow paths must be controlled on the fire floor. Uncoordinated opening of apartment and stairway doors may cause fire conditions to dramatically increase with little or no warning.

Initial hose lines stretched from a standpipe shall be from an outlet on **a floor below the fire. The second hose line is usually stretched from** two floors below the fire. Search attack stairway for **five floors above the fire** after searching the hallway on the fire floor.

FDNY High-rise Firefighting Tactics CLASS "A" HIGH RISE FIREPROOF MULTIPLE DWELLING FIRES DISCUSSION

Discussion –

I was able to debate with senior FDNY Staff Officers, Battalion Chiefs and Captains on station to determine how their tactics might change if they approached fires in tall single stair residential UK buildings with 2-hour firefighting shafts but without alternative evacuation stairs or fire service-controlled voice alarms, as are currently requirements in NYC Building Codes.

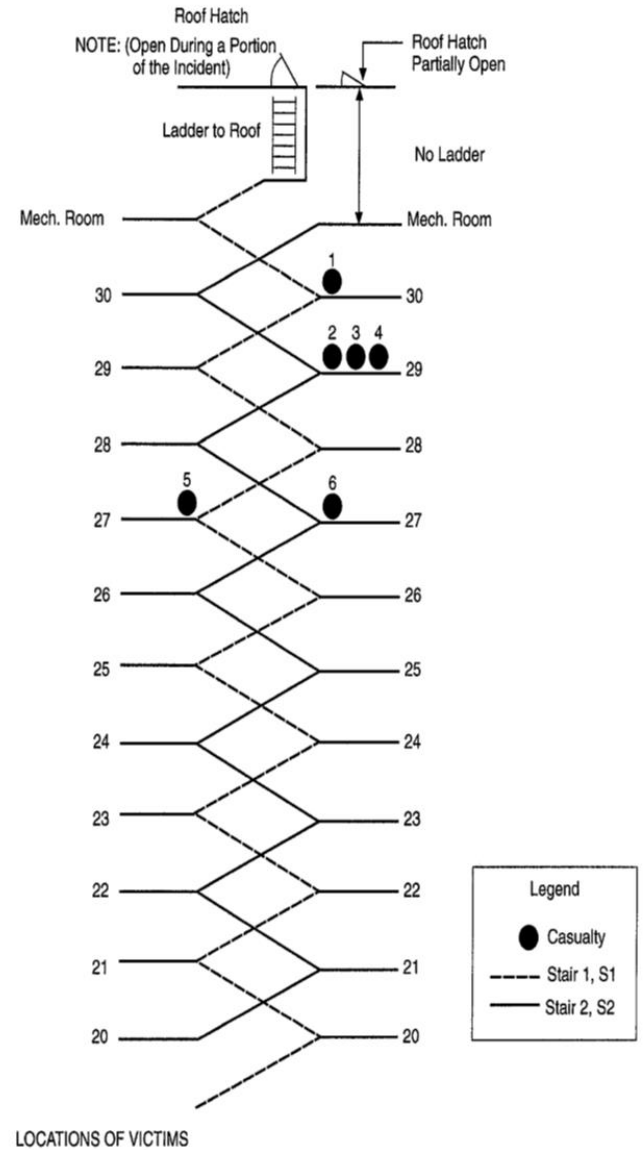
Their overriding view is that rising fire main (standpipe) outlets should remain in the stair and not be brought into the accommodation for fear of being caught by rapid fire development outside of the protected stair. However, it was acknowledged that as with UK reconnaissance teams approaching to initially locate the fire, FDNY Ladder Company firefighters will also enter the hallway/corridor/access lobby on the reported fire floor to locate the fire apartment. An argument could therefore be made that this is the same as a crew laying and charging hose within the same space. The difference is that the hose attack team will be under air, whereas the reconnaissance teams are likely not. There have been instances where firefighters have been unable to retreat to the safety of the stair in time as rapid-fire development reduced visibility to zero. However, this would almost certainly have been the case wherever hose was deployed from. Wayfinding in heavy smoke is generally the same, even when the hose comes from the floor below or at the fire floor. Where corridors are significantly extended in distance, or form T-junctions or 'racetrack' (circular) layouts, wayfinding becomes even more difficult. Before UK firefighters lay in from the fire floor outlet a **dynamic risk assessment** must determine if it is a safe area to enter and hose should be laid with careful consideration that it may provide a guide-line back to the stair.

The Vandalia Avenue fire (as an example) was discussed at length where three Ladder Company firefighters lost their lives as a wind driven fire pushed flaming combustion into the corridor. In this instance, there was no water deployed on the fire floor at this time and later efforts required two hose-lines flowing high amounts of water from the floors below to deal.

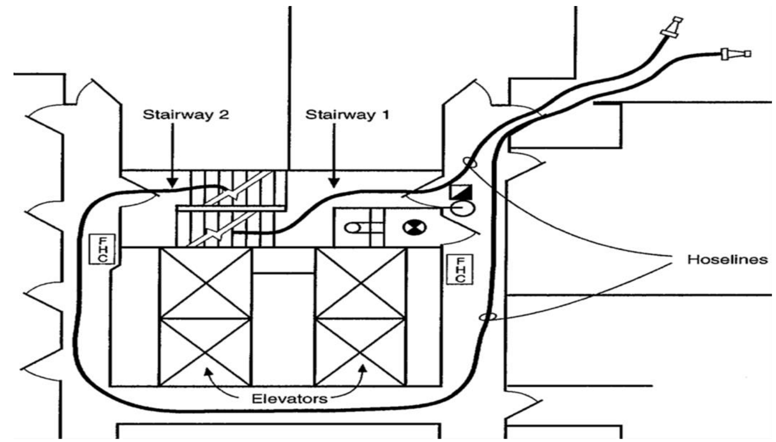
Residential High-rise Fire Ontario 1995

Six fatalities found in stairwells

Stack effect and firefighting Hose-lines breach stair doors



The fire that was strongly impacted by stack effect on a very cold night forced stair doors to swing open at the fire floor and push smoke into the stairs even before firefighters were on-scene. The subsequent laying of hose-lines through stair doors may have worsened smoke levels at upper floors.



The stack effect was made worse by stair doors opened below the fire and the stair roof vent opened by a resident.

Casualties

Six residents died in this fire. All were found in the exit stairways and all died from smoke inhalation. The following table provides basic information regarding the six victims.

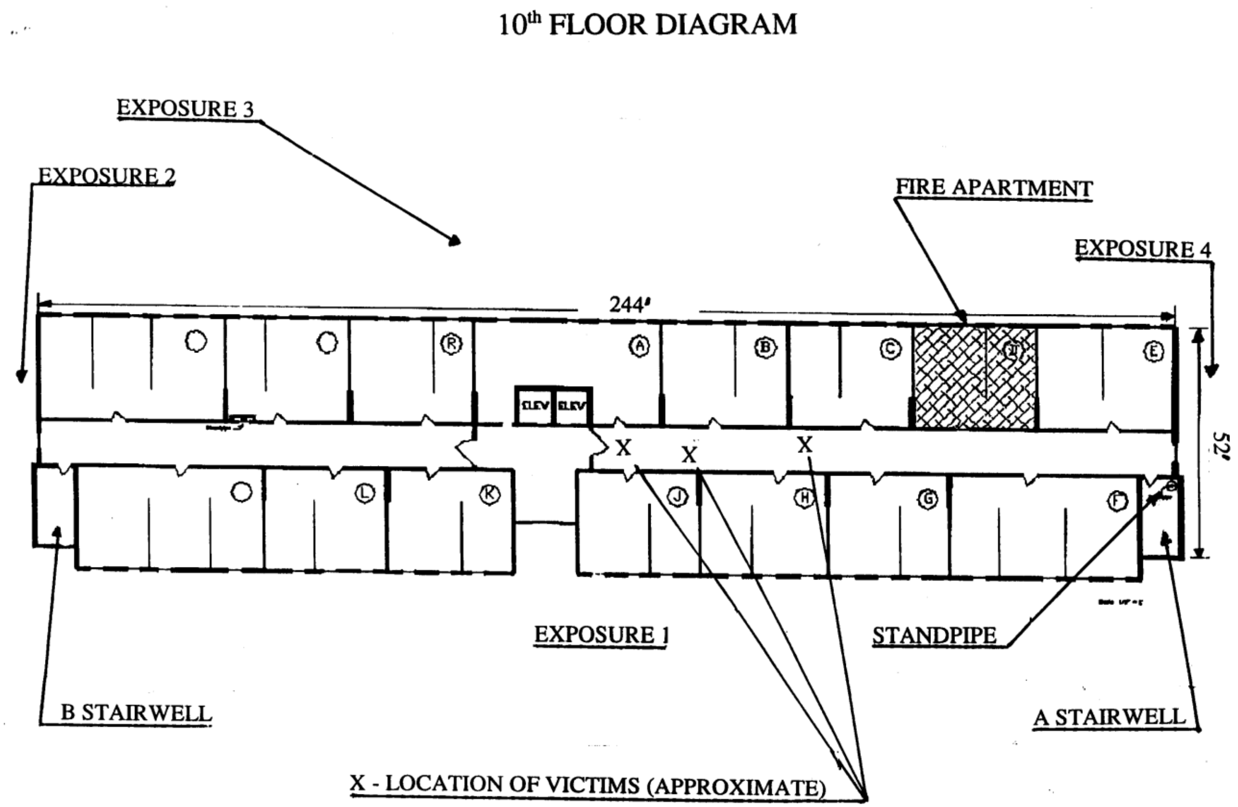
Victim Information

Victim #	Apt. #	Sex	Age	COHb[13] Level	Stairway #	Location
1	3008	M	35	0.67%	1	30th fl, east landing
2	2911	F	16	0.65%	2	29th fl, east landing
3	2902	F	29	0.69%	2	29th fl, east landing
4	2902	M	33	0.56%	2	29th fl, east landing
5	1601	M	29	0.41%	1	27th fl, west landing
6	2711	F	35	0.79%	2	27th fl, east landing

Vandalia Avenue Fire New York City 1998

3 Ladder Company Firefighters caught and killed in a fatal corridor Flow-path

https://www.cdc.gov/niosh/fire/reports/face9901.html



Vandalia Avenue Fire New York City 1998
3 Ladder Company Firefighters caught and killed in a fatal corridor Flow-path

https://www.cdc.gov/niosh/fire/reports/face9901.html

The Captain and two fire fighters on Ladder 103 were responding to the report that a woman was trapped in Apartment 10E. They took the A-stairwell to the tenth floor, which is the closest stairs to Apartment 10E. The Captain and one of the fire fighters on Ladder 103 removed the resident from Apartment 10E, and carried her with the assistance of the driver on Ladder 170, to the ninth floor.

During this same time period, the Lieutenant and 2 fire fighters (victims) from Ladder 170 entered the lobby with the Lieutenant, nozzleman, and controlman from Engine 290 and took the elevator to the ninth floor. Two fire fighters from Engine 290 took the B-stairway (see diagram) to the ninth floor where they met up with their Lieutenant and the victims. The victims along with the Lieutenant from Engine 290 took the B-stairs to the tenth floor, whereby, they entered the hallway on the tenth floor and observed only a light haze, and no fire. The four fire fighters from Engine 290 remained on the ninth floor, B-side landing, were flaking-out three, 50-foot lengths of 2 ½-inch hose lines in preparation for hooking up to the ninth floor standpipe outlet. At 0503 hours, the Lieutenant on Engine 290 radioed the driver of Engine 290 from the tenth floor B-side hallway, and asked, "Where is the fire?" The driver radioed back, "The fire is in the rear, towards exposure 4." The Lieutenant on Engine 290 relayed this information to Victim #1 who was near the center smoke doors attempting to locate the fire. The Lieutenant on Engine 290 then left the tenth floor, went down the B-stairs to the ninth floor, and along with four of the fire fighters from Engine 290, pulled the hose line to the A-stairwell to hook up and advance the line to the tenth floor.

It is recommended that when fire fighters are fighting a fire in high-rise buildings, they make connection to the standpipe on the floor below the fire floor. Although there were specific problems with the insulation on the standpipe, tenth floor, A-stairwell, the fire fighter also encountered problems due to the intense heat and smoke that was introduced in the stairwell every time the stairwell door was open.

Vandalia Avenue Fire New York City 1998
3 Ladder Company Firefighters caught and killed in a fatal corridor Flow-path

https://www.cdc.gov/niosh/fire/reports/face9901.html

Engine 257 fire fighters were on the tenth floor, A-stairwell, attempting to make a hookup, which was not successful because of the insulation on the standpipe, difficulty with the valve, lack of a control wheel, and the high heat and heavy smoke pushing from the public hallway. Engine 290 had connected on the ninth floor, A-stairwell. The Lieutenant on 257 requested assistance from Engine 290 at the door on the tenth floor stairwell. Fire fighters on Engine 257 and Engine 290 with a charged line, opened the door to the tenth floor hallway and were driven back by intense heat.

At 0513 hours, on a third attempt, fire fighters from Engines 290, 257, and 283, with two charged lines (2 1/2-inch and 1 3/4-inch), in full open position, entered the tenth floor A-hallway door, and moving very slowly because of the extreme heat and zero visibility, proceeded towards the fire apartment, 10D (approximately 40 feet inside the stairwell door). Fire fighters on Engines 290 and 283 were running low on air and were replaced by fire fighters on Rescue 2. As they were approaching the fire apartment, they observed flames leaping out across the hall. The Lieutenant on Rescue 2 heard a Personal Alert Safety System (PASS) alarm sounding beyond the fire apartment (all PASS devices used by this fire department are integrated with the self-contained breathing apparatus [SCBA], i.e, when a fire fighter turns on his air, the PASS device is activated) He went to investigate, and within 20 feet from the fire apartment found Victim #1 (Lieutenant on Ladder Company 170) down and unresponsive. The Lieutenant on Rescue 2 discovered Victim #1 at 0528 hours, moved him toward the A-stairwell, left him, went for help, and completed the removal toward the B-stairway.

At 0518 hours, the Captain on Squad 252 and a fire fighter on Rescue 2 were proceeding down the tenth floor hallway, from the B-side towards the fire doors, when they opened the doors (see diagram) and found a helmet just inside the doors, then they found Victim #3 (first victim to be removed from the tenth floor), who was unresponsive. Victim #3 was removed from the tenth floor and taken to the ninth floor where he was given CPR and then transported to a local hospital where he was pronounced dead by the attending physician.

Vandalia Avenue Fire New York City 1998
3 Ladder Company Firefighters caught and killed in a fatal corridor Flow-path

https://www.cdc.gov/niosh/fire/reports/face9901.html

Recommendation #4: Fire departments should ensure that the standpipe hookup is on the floor below the fire. [2]

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Discussion by author with FDNY Commanders –

It is clear that a 'light haze' of smoke with low heat in the corridor very quickly turned into a wind driven flow path as openings were created almost at the same moment at fire floor level by (a) the fire on the windward side and (b) a resident on the downwind side of the building. This created untenable conditions for three firefighters caught in its path. These firefighters were undertaking further reconnaissance to locate the fire involved apartment and search for victims. This type of rapid fire event was mirrored at a high-rise fire in Kent in 2001.

The connection of hose-lines at fire floor level to the 'A' stairwell rising main (standpipe) failed due to intense heat existing at the stair door. This high heat would have occurred even if this line had been advanced from the floor below. However, a third attempt to enter the corridor and control heavy fire succeeded using a 65mm hose-line and a 45mm hose-line deployed in unison, connected to outlets at floors below. The author's view was given that it was not that connecting at the fire floor was the problem but that such a very severe fire required two hose-lines flowing and large amounts of water. In effect, it was the only logical approach in order to achieve control of the extreme fire event occurring.

Office High-rise Fire Chicago 2003

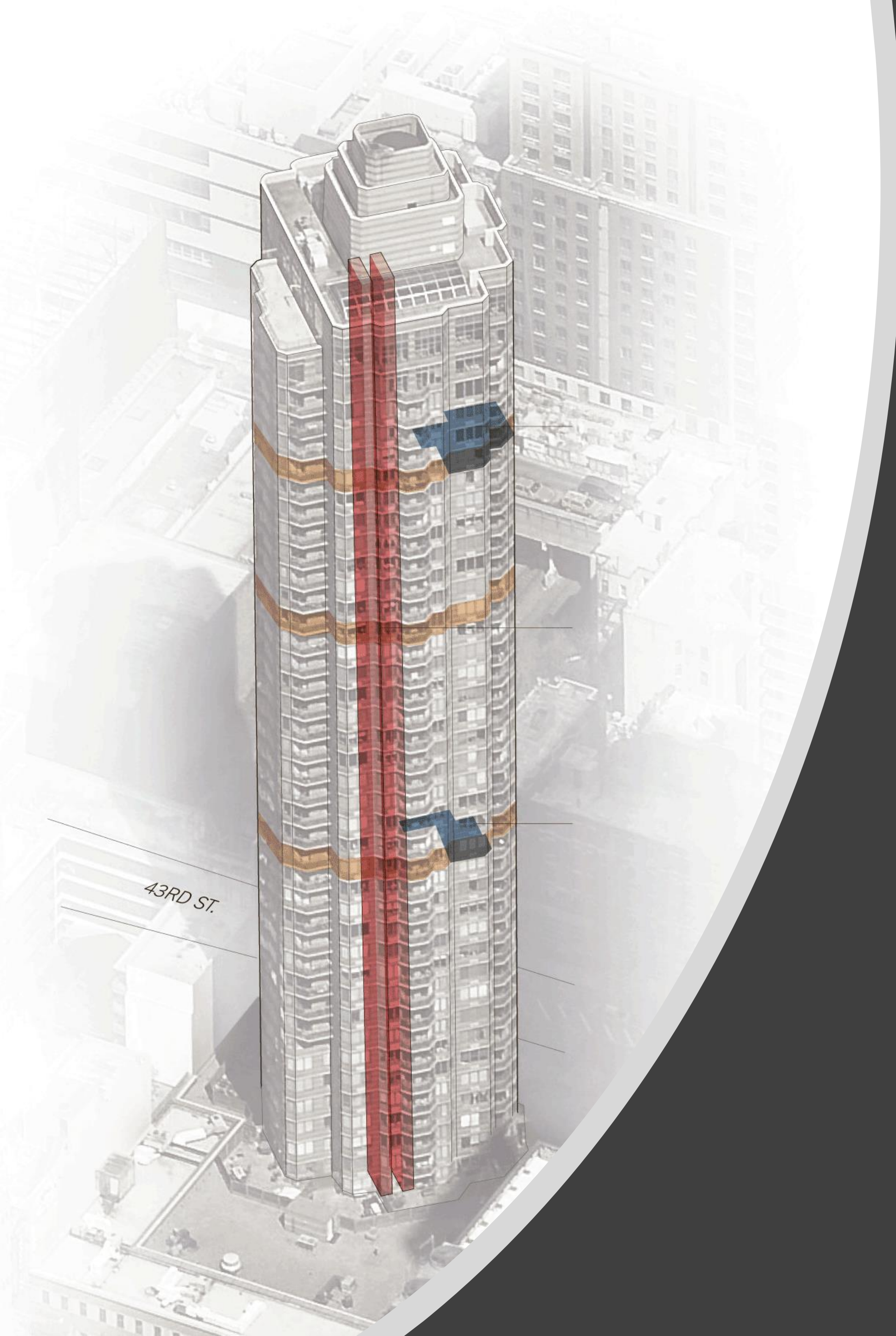
Six fatalities found in stairwells after fire extinguished

Chicago Fire Department and other organisations considered culpable during inquiry after firefighting hose-lines breach stair doors

In October of 2003, a fire broke out around 1700 hours in the Cook County Administration Building (CCAB) in the city of Chicago. The building comprised of 37 floor levels of fully occupied modern office space. The fire originated in a stationery storage closet on the 12th floor. Six occupants died trapped in the evacuation stairwell after firefighters laid hose in through open stair doors and reportedly sent people back up the stair.

It was reported in the inquiry that there had been a failure of Chicago Fire Department to maintain the integrity of a means of egress from the building that at the time, was in use by building occupants. There was also a failure by CFD to effectively respond to Fire Survival Guidance calls being made by those trapped in the stair.

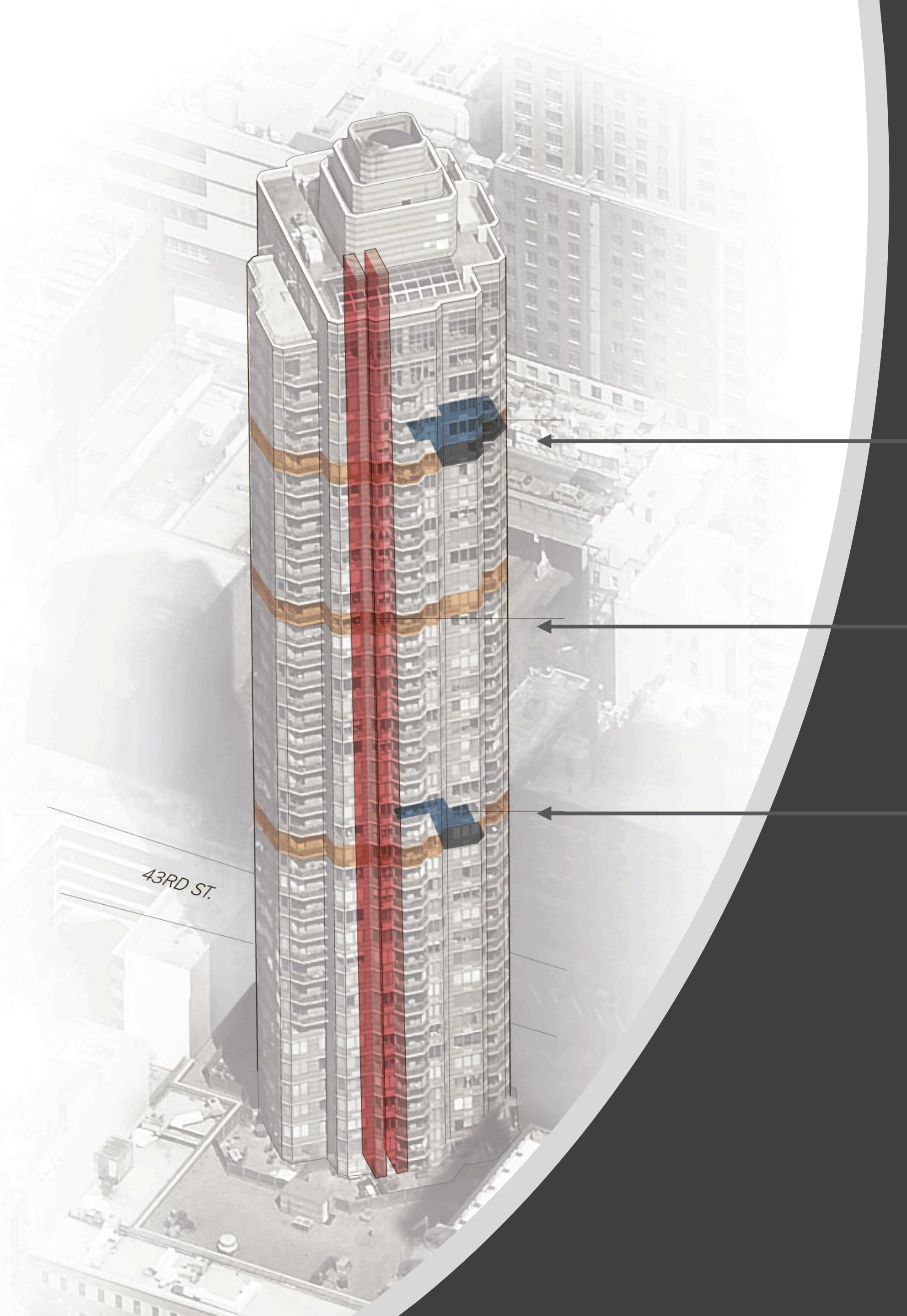
Since this fire, CFD now utilise Rapid Ascent Teams to undertake immediate stairwell searches.



10th Avenue NYC fatality 2014 as hose-lines breach the stair door

However, when people are entering the attack stair some eighteen storeys above the fire floor, it still presents a time-lag problem for firefighters. This conflict with rising main outlets in the stair and self-evacuating occupants entering the stair above becomes even more relevant at great height.

Sprinkler protected apartments, tactically deployed stair curtains by firefighters, stair search teams, fire service-controlled voice alarms and smoke free alternative stairs specifically for evacuation may go some way in preventing this.



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 stair whilst the evacuation stair remained relatively smoke free.

High-rise Firefighter Fatality in Wind Driven Houston Fire 2001

Houston Fire Department were dispatched to a report of a fire in a 40-story residential high-rise. Upon their arrival, Captain Jahnke reported a working fire on the fifth floor of the building and requested a second alarm. While Captain Jahnke's driver attached lines to the building's fire department connection, Captain Jahnke and his firefighter climbed the stairs to the fire floor. Upon their arrival on the fire floor, Captain Jahnke and his firefighter were joined by the captain and firefighter from a ladder company. The four firefighters entered the fire occupancy and began to apply water to the fire. The two firefighters ran low on air and exited to change their cylinders, leaving the two captains to fight the fire. When the firefighters opened the stairway door to exit, conditions in the fire occupancy worsened dramatically. The captains decided to leave the apartment by following their hose-line but soon became separated. Captain Jahnke became separated from the line and disoriented. The other captain was found in the stairwell by other firefighters and removed from the building. Captain Jahnke called for help on his portable radio. Firefighters responding to his request were guided to his location by the sound of his PASS device. Despite their efforts, Captain Jahnke died of asphyxiation due to smoke inhalation.

Figure 13-Fifth floor layout. Locations of civilian victim, Captain Jahnke, and fire hoseline are approximate and based on firefighter interviews.

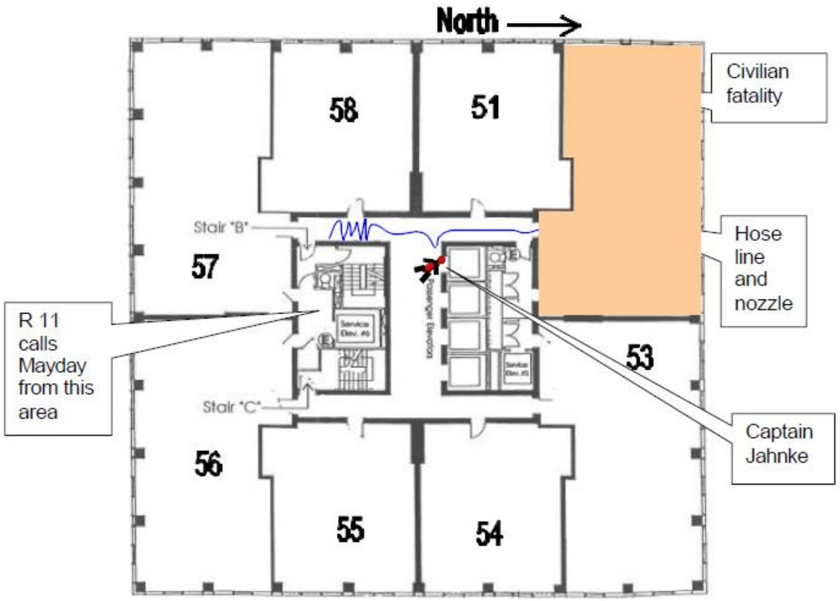


Figure 13-Fifth floor layout. Locations of civilian victim, Captain Jahnke, and fire hoseline are approximate and based on firefighter interviews.

High-rise Firefighter Fatality in Wind Driven Houston Fire 2001

This tragic fire is often referred to as a reason for deploying hose-lines from the floor/s below the fire. The attack hose-line here came from an outlet located in the corridor, which caused flaking hose to accumulate in folds that were confusing for the firefighters to follow back to the stair door. Several firefighters described the tangle of hose as a "spaghetti bowl." This was a wind driven fire and the corridor layout was in an 'H' shape. There is no doubt a hose-line laid without confusing folds in the corridor would have been easier to follow, although one firefighter was still able to find his way out. The smoke here was forced into the stair as firefighters opened stair doors and experienced a combination of exterior wind and internal stack effect, driving heat directly at them in their attempts to rescue the downed firefighter. Hose-laying technique is critical on high-rise floors and in corridors.

BDAG Research 2004 Firefighter Physiology

In 2004 the Building Disaster Advisory Group (BDAG) developed a predictive model to estimate the combination of maximum vertical and horizontal distances that firefighters could achieve, while remaining within a core temperature limit of 39ºC. Assuming 95% confidence in the outcomes, the model suggested that 34m is the maximum distance firefighters should penetrate horizontally in a heated environment to rescue a casualty or undertake firefighting, where no stair climbing is required to access the point of entry.

Having to climb stairs beforehand or undertake other activities reduces the maximum penetration distances proportionally. The BDAG research concluded that the physiological load associated with climbing stairs when carrying BA and hose took approximately 30 seconds per floor and core temperature rose by approximately 0.02ºC, per floor. When climbing unloaded it took approximately 15 seconds per floor and average core temperature rose by approximately 0.01ºC, per floor.

Maximum heart rates and other physiological impacts under heat and duress also need consideration here.

Disadvantages of Laying Hose-lines from below the fire floor

- To reach the end of extended corridors at 30m from the stair door will require at least two lengths of hose.
- To lay from 1-2 floors below the fire floor will require at least one additional length, increasing firefighter body core temperatures and raising heart rates further before they reach the fire.
- At the Shirley Towers fire in 2010 a secondary support hose-line laid from two floors below the fire failed to reach the fire involved apartment due to inadequate length. This left the attack crew without any back-up hose-line.
- Breaching stair doors with hose-lines may allow smoke to infiltrate the stair and cut off escape routes.
- Even where adequate mechanical pressure differentials are configured and functioning to effect, stack impact or external wind velocity may drive smoke, heat and possibly fire into the stairwell.

The Reality of Stair Protection

A partially open door held open by hose-lines causes the 120-minute smoke and fire resistance protective fire-fighting shaft to fail. The concept of stair protection has to be balanced on risk versus gain.

Such a door partially held open will not protect firefighters retreating into the stair if pressure differentials caused by stack effect, external wind or rapid-fire development force smoke, heat or flame to follow them, as has occurred in several fires. At one fire in Kent, smoke and heat travelled down the stair for ten storeys to the street.

Protecting the stair from smoke infiltration must be a primary objective of any fire service who are responsible for residents who may be entering the stairwell to self-evacuate.

Protecting the stairwell and maintaining tenable escape routes may be critical in any situation where a reversal of the 'stay put' defend in place strategy becomes necessary.

In allowing stairwells to remain tenable and not preventing residents from leaving if they so wish but recording their egress, any later 'stay put' reversal becomes far less demanding on resources.

Its important to recognise that mechanical smoke control creating a pressure differential between the open stairwell door and the corridor/lobby will not be able to overcome high stack effects or flow from a wind driven fire.

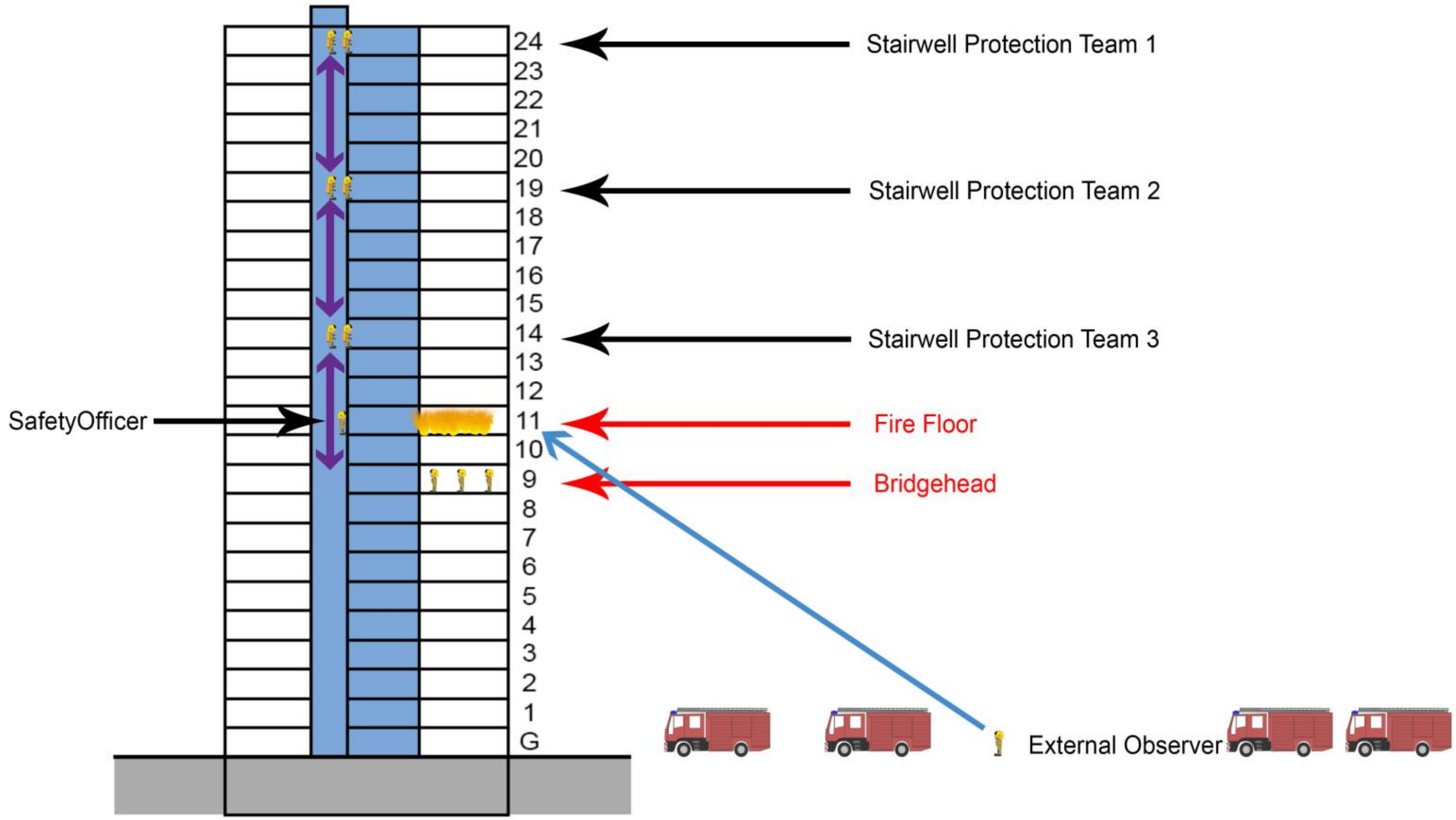
National High-rise GRA 3.2

‘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’.

The Kent FRS stairwell protection strategy follows this guidance.

Kent FRS Stairwell Protection Strategy



Roles of 'Stairway Protection Teams'

- **Patrol** stairwells continuously from top-to-bottom to ensure that egress routes are safe and free of obstructions; monitor gas levels
- **Search** floors, stairwells, hallways, and lifts for building occupants who may be trapped or are entering an untenable environment
- **Report** information about tenability conditions at each floor to the incident commander.
- Ensure the stairs are **clear of smoke**
- **Deploy directly from the stair to FSG calls** where required
- **Manage occupant evacuation** where required

When controlling stair evacuation, at what gas levels do you issue smoke hoods? Can you continue to support unaided self-evacuation both with or without smoke hoods for large numbers of people? At what gas levels may this be safe to do whilst optimising the use of a limited amounts of available smoke hoods?

Communication is KEY!

During a recent training seminar series involving over sixty UK fire officers, a single key learning point was communicated and emphasised through a lone sentence, prior to a table-top exercise taking place. However, in effect, only five percent of students utilised that key piece of information and this negatively impacted on exercise outcomes.

Communication amongst professionals is as critical as human behaviour is at fires. Yet emergency workers under stress repeatedly experience failings in information transfer on the incident ground that may affect the outcome in some dramatic way. Add to this the time lag between message transfer and receipt so commonly experienced in high-rise firefighting and a sound tactical solution may be compromised by unwanted delays.

Furthermore, impacting positive and proactive amendments to established procedure can be time consuming and difficult to achieve. It has been suggested that “to make the most out of research evidence and to reach policy makers, you must give them something in a paragraph to get their attention; better still if you can give one sentence that can become a slogan” .... such as:

‘Protect the Stairwells at All Times’

The Kent FRS stair protection strategy requires 2-person search teams to be deployed into the stair at every five floors above the fire floor, in accordance with GRA 3.2. guidance. These firefighters are issued with fire gas detectors and smoke hoods. They monitor and report on resident tenability in the stairs and use Public Health England Acute Exposure Guide Lines (AEGLs) to determine safe limits for residents to self-evacuate in the stairwells, unless smoke hoods or safe refuge are needed above pre-determined levels.

Acute exposure guideline levels (AEGLs)

	Concentration (ppm)				
	10 min	30 min	60 min	4 hours	8 hours
AEGL-1*	NR	NR	NR	NR	NR
AEGL-2†	420	150	83	33	27
AEGL-3‡	1,700	600	330	150	130

Carbon Monoxide

Acute exposure guideline levels (AEGLs)

	Concentration (ppm)				
	10 min	30 min	60 min	4 hours	8 hours
AEGL-1*	2.5	2.5	2.0	1.3	1.0
AEGL-2†	17	10	7.1	3.5	2.5
AEGL-3‡	27	21	15	8.6	6.6

Hydrogen Cyanide

Acute exposure guideline levels (AEGLs)

	Concentration (ppm)				
	10 min	30 min	60 min	4 hours	8 hours
AEGL-1*	NR	NR	NR	NR	NR
AEGL-2†	420	150	83	33	27
AEGL-3‡	1,700	600	330	150	130

Carbon Monoxide

Acute exposure guideline levels (AEGLs)

	Concentration (ppm)				
	10 min	30 min	60 min	4 hours	8 hours
AEGL-1*	2.5	2.5	2.0	1.3	1.0
AEGL-2†	17	10	7.1	3.5	2.5
AEGL-3‡	27	21	15	8.6	6.6

Hydrogen Cyanide

Design tenability at 0.3 FED for exposure to concentrations of Carbon Monoxide		
Category	**Maximum asphyxiant concentration as CO 5 minute exposure**	**Maximum asphyxiant concentration as CO 30 minute exposure**
Fuel contains nitrogen (>2% by mass) such as fires in residences or retail premises	800 ppm	125 ppm
Fuel contains nitrogen (<2% by mass) such as office fires	1,200 ppm	275 ppm

Reference: BS 7974-6

The 2018 changes to Carbon Monoxide and Hydrogen Cyanide are as follows:

Carbon Monoxide

Current LTEL/TWA (8hrs) = 30 ppm — **New LTEL/TWA (8hrs) = 20 ppm**

Current STEL (15mins) = 200 ppm — **New STEL (15mins) = 100 ppm**

Hydrogen Cyanide

Current LTEL/TWA (8hrs) = N/A — **New LTEL/TWA (8hrs) = 0.9 ppm**

Current STEL (15mins) = 10 ppm — **New STEL (15mins) = 4.5 ppm**

Protection at the Stair Door

- Where the rising fire main outlet is located in the stair it becomes necessary to protect the stair as best as possible from smoke infiltration using portable smoke-stopper door curtains. FDNY currently have a pilot programme running to explore the viability of this tactical option.

Protection of Horizontal Egress Routes

- It has been demonstrated that mechanical smoke control systems cannot maintain tenable conditions for residents if the apartment door remains open during a post flashover scenario. Again, FDNY are exploring the protection of horizontal egress routes should this become necessary.

FDNY's Stair Protection Strategy

- Prior to advancing to the reported fire floor, members must gather information from the floor below, or two floors below if scissor stairs are present.
- **Determine the location, letter or number designation and number of stairways serving the fire floor**. Prior to the designation of the attack stairway, all members must access the fire floor from the same stairway.
- All extinguishment efforts shall proceed initially from the one attack stairway. If a second stairwell is required for attack and extinguishment, it should not be the stairwell designated as **the evacuation stair**.
- If the door to the fire apartment has been left open and size-up indicates that wind may impact fire conditions, the air flow paths must be controlled on the fire floor. Uncoordinated opening of apartment and stairway doors may cause fire conditions to dramatically increase with little or no warning.
- Initial hose lines stretched from a standpipe shall be from an outlet on **a floor below the fire. The second hose line is usually stretched from** two floors below the fire.
- Search attack stairway for **five floors above the fire** after searching the hallway on the fire floor. If people are coming down the stairway, ensure they are safely refuged prior to opening the stair door.

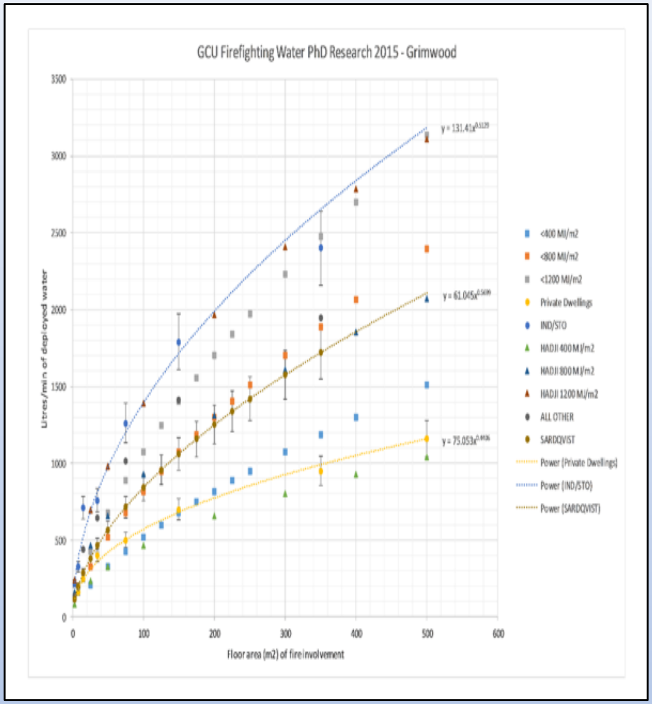
‘Adequate’ Firefighting Water

There is a legal requirement placed on the UK fire service to ensure that the water flow-rates used for fire suppression are of an *‘adequate’ amount*. As there was no actual definition for what was meant by ‘adequate’, my 2012 PhD research (*that technically began in 1989*) demonstrates what were considered (a) *critical*; (b) *minimum and (c) optimum* (adequate) amounts of firefighting water in a range of occupancies.

An important factor in this research was the decrease in heat exposure and positive impacts on firefighter physiology as the length of time on the hose-line was reduced due to applications of adequate flow-rate. As fire loads and compartment sizes increase, a greater quantity (L/min) should be deployed at the earliest opportunity and building designs should support this need. This work was also linked to the decreasing amounts of building fire damage observed as a result of adequate firefighting water deployment.

This research by Kent FRS in association with Glasgow Caledonian University (Fire Engineering)was to form the basis of firefighting water design codes (BS PD 7974-5-2015 [Rev.2020]) and National Operational Guidance (Optimum Firefighting Flow-rate)

The author's PhD research included analysis of the quantities of firefighting water used for suppression at 5,401 'working' building fires in the UK between 2009 and 2012. The lower line represents private dwellings and apartments with an upper line representing industrial units and warehouse fires. All other fires fall between these two lines, as represented by a median line of data provided by the Sardqvist research into non-residential premises. It should be noted that construction styles during this research in the UK is widely solid masonry and structure fires are in general, only tactically ventilated at the point when fire is under control, or at least is 'surrounded'. However, lightweight building construction is now becoming more widely predominant in both the UK and Europe in general.



More information -

https://img1.wsimg.com/blobby/go/877d587b-6900-4f7f-b1451-e75cc02aff97/downloads/1cvvecu5i_859848.pdf?ver=155518608307

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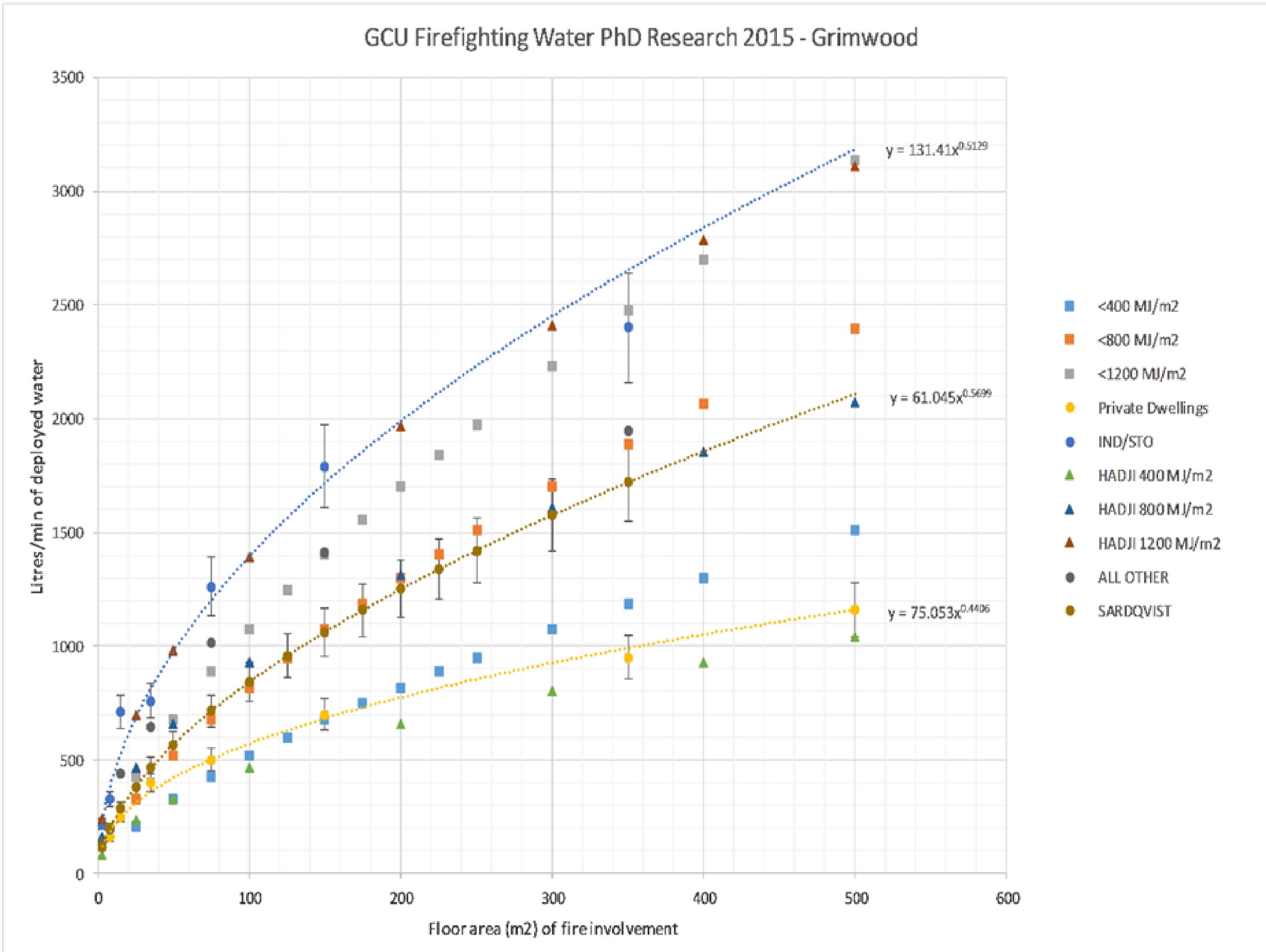
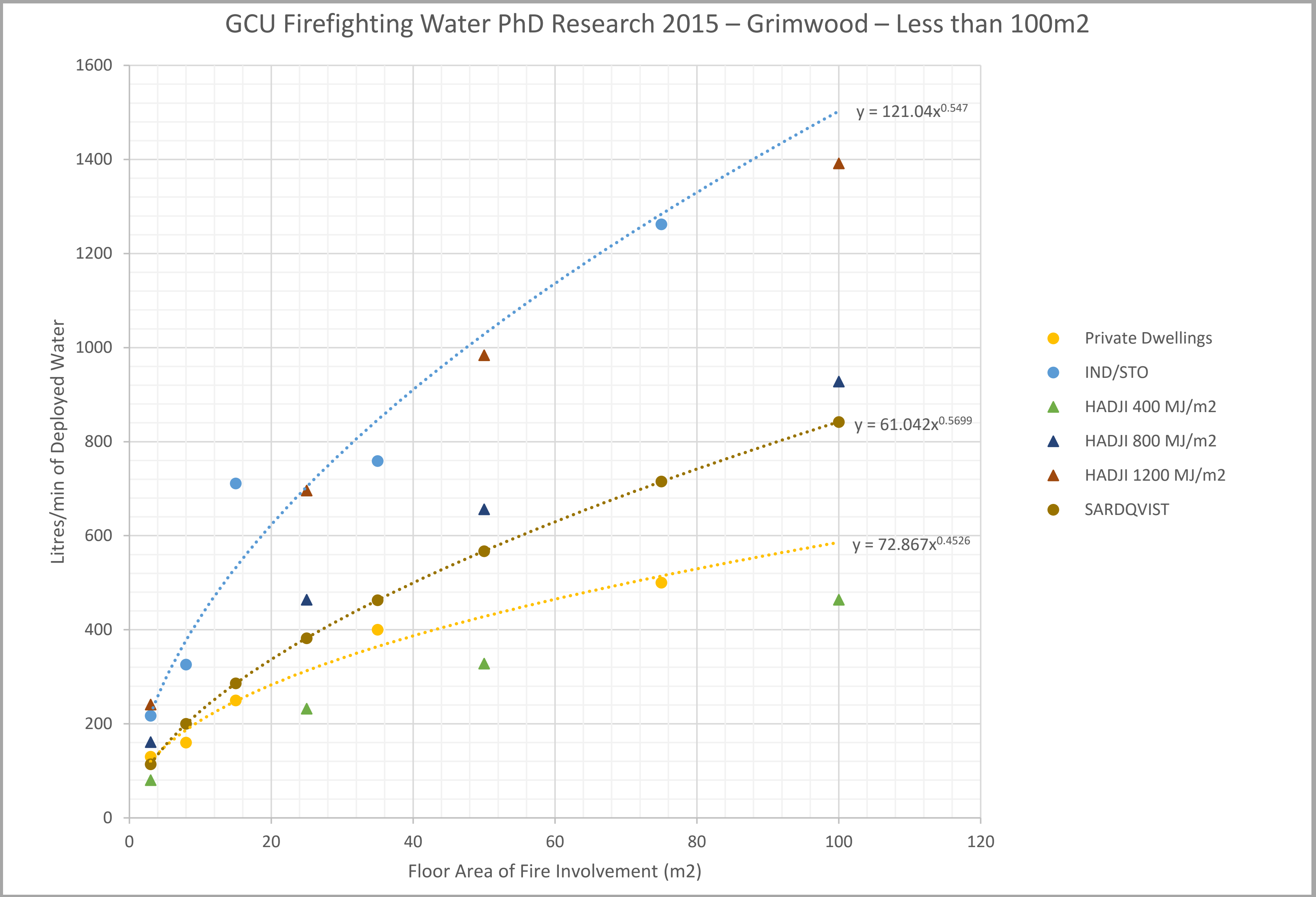


GCU Firefighting Water PhD Research 2015 - Grimwood
Litres/min of deployed water
Floor area (m2) of fire involvement
0
500
1000
1500
2000
2500
3000
3500
0
100
200
300
400
500
600
y = 131.41x^0.5129
y = 61.045x^0.5699
y = 75.053x^0.4406
<400 MJ/m2
<800 MJ/m2
<1200 MJ/m2
Private Dwellings
IND/STO
HADJI 400 MJ/m2
HADJI 800 MJ/m2
HADJI 1200 MJ/m2
ALL OTHER
SARDQVIST


GCU Firefighting Water PhD Research 2015 – Grimwood – Less than 100m2
Litres/min of Deployed Water
Floor Area of Fire Involvement (m2)
0
200
400
600
800
1000
1200
1400
1600
0
20
40
60
80
100
120
y = 121.04x^0.547
y = 61.042x^0.5699
y = 72.867x^0.4526
Private Dwellings
IND/STO
HADJI 400 MJ/m2
HADJI 800 MJ/m2
HADJI 1200 MJ/m2
SARDQVIST

National Operational Guidance Firefighting Flow-rate

At its simplest, the flow rate is the amount of extinguishing media being applied to a fire at any one time, referred to in litres per minute (L/min).

Required flow rate may be simply viewed as the amount of firefighting media required to control and ultimately extinguish a fire. This introduces many variables; more precisely two flow rates need to be considered:

- **Critical flow-rate** (CFR): typically this would be the absolute minimum amount of firefighting media flow needed to fully suppress a fire at any given level of involvement.
- **Optimum (Tactical) Flow-rate** is the target flow for a primary attack hose line or lines

The actual critical flow rate is dynamic; it is directly related to the phase of the fire and this may be unknown. It also has no built-in safety factor. More relevant is the tactical flow rate, which more accurately represents the flow rates required by firefighters to deal with a given fire in a known compartment or occupancy type.

The concept of firefighting flow rate requirements can be based theoretically in matching the flow of firefighting media against known rates of heat release in compartment fires (measured in megawatts or MW).

It can also be empirically based on fire loads, in established floor space, against the flow of firefighting media needed to suppress fires during their growth or decay stages. The latter is generally a defensive application.

It is recognised that flow rate i.e. the amount of firefighting media, extinguishes fire, not pressure.

Relying on pressure alone as the basis to deliver firefighting media does not provide information on the litres per minute being delivered and may be insufficient to prevent fire growth and spread.

The mathematical calculations for the amount of water required to extinguish a given fire are relatively complex. However, as a fire ground **rule of thumb for fires between 100 to 600m^2**, the following calculation could be considered:

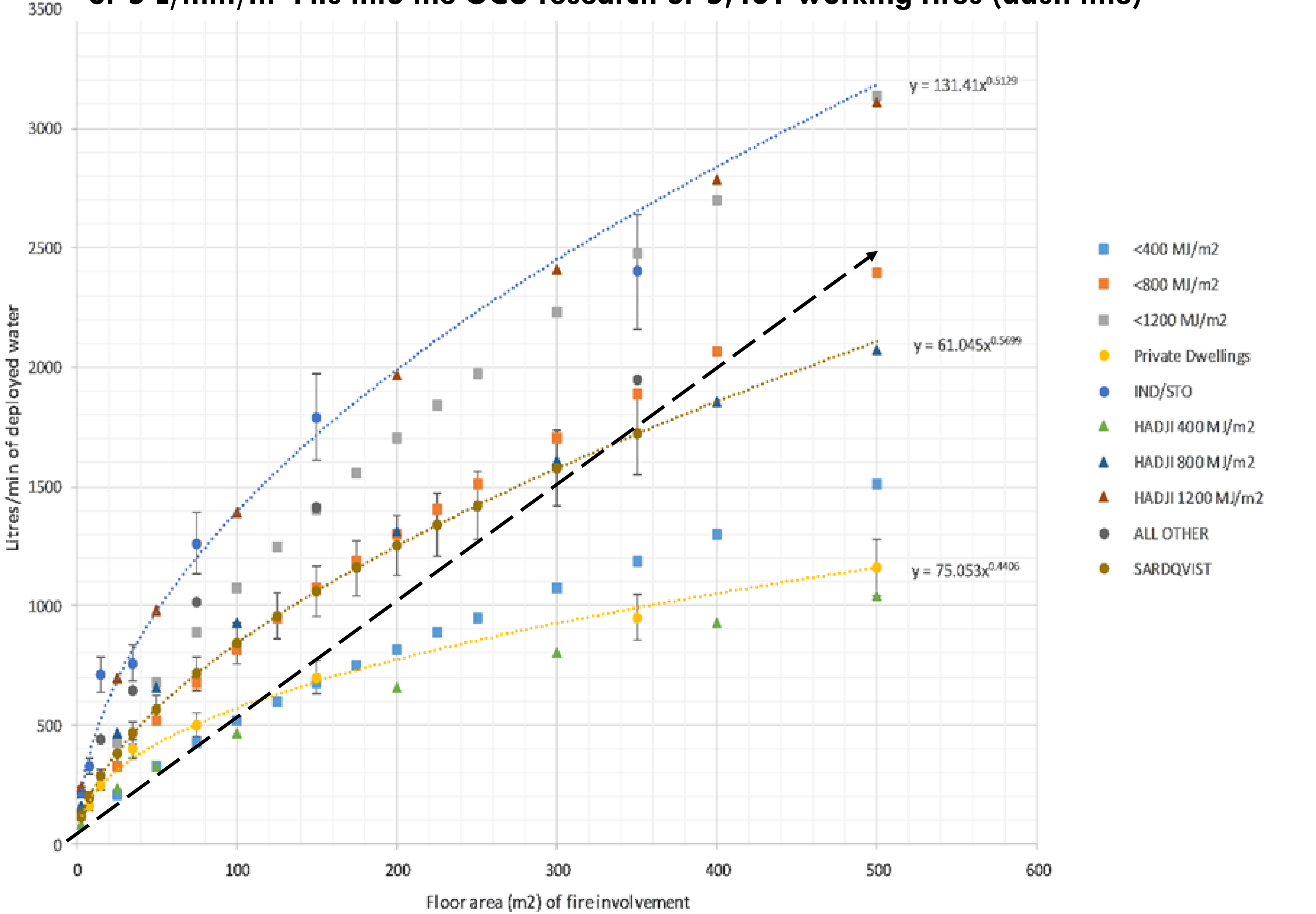
Optimum flow rate (L/min) = fire area (m^2) x 5

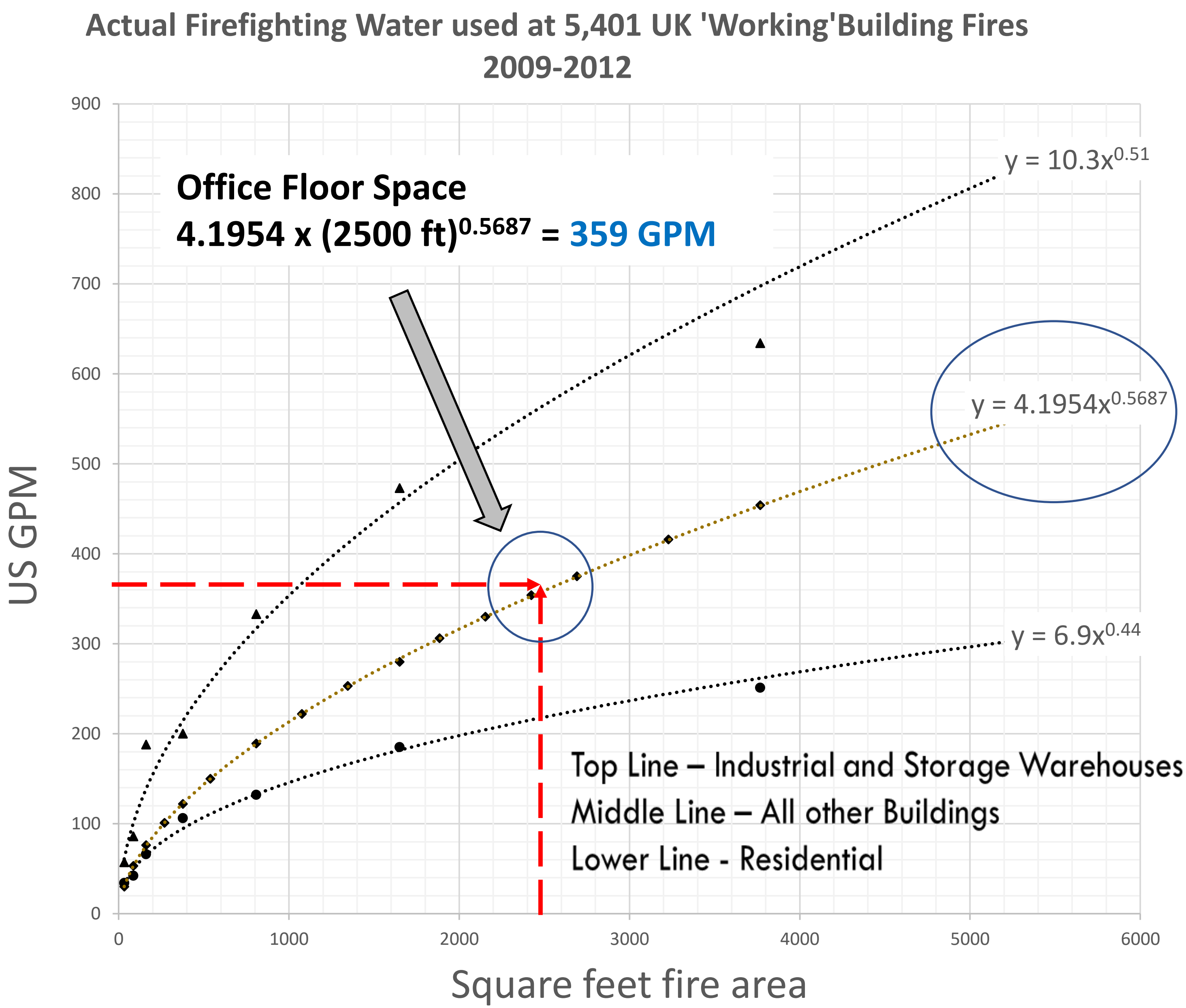
For example, in a situation with a fire in an open plan flat measuring 90 m2

Optimum flow = 90m^2 x 5 = 450 L/min

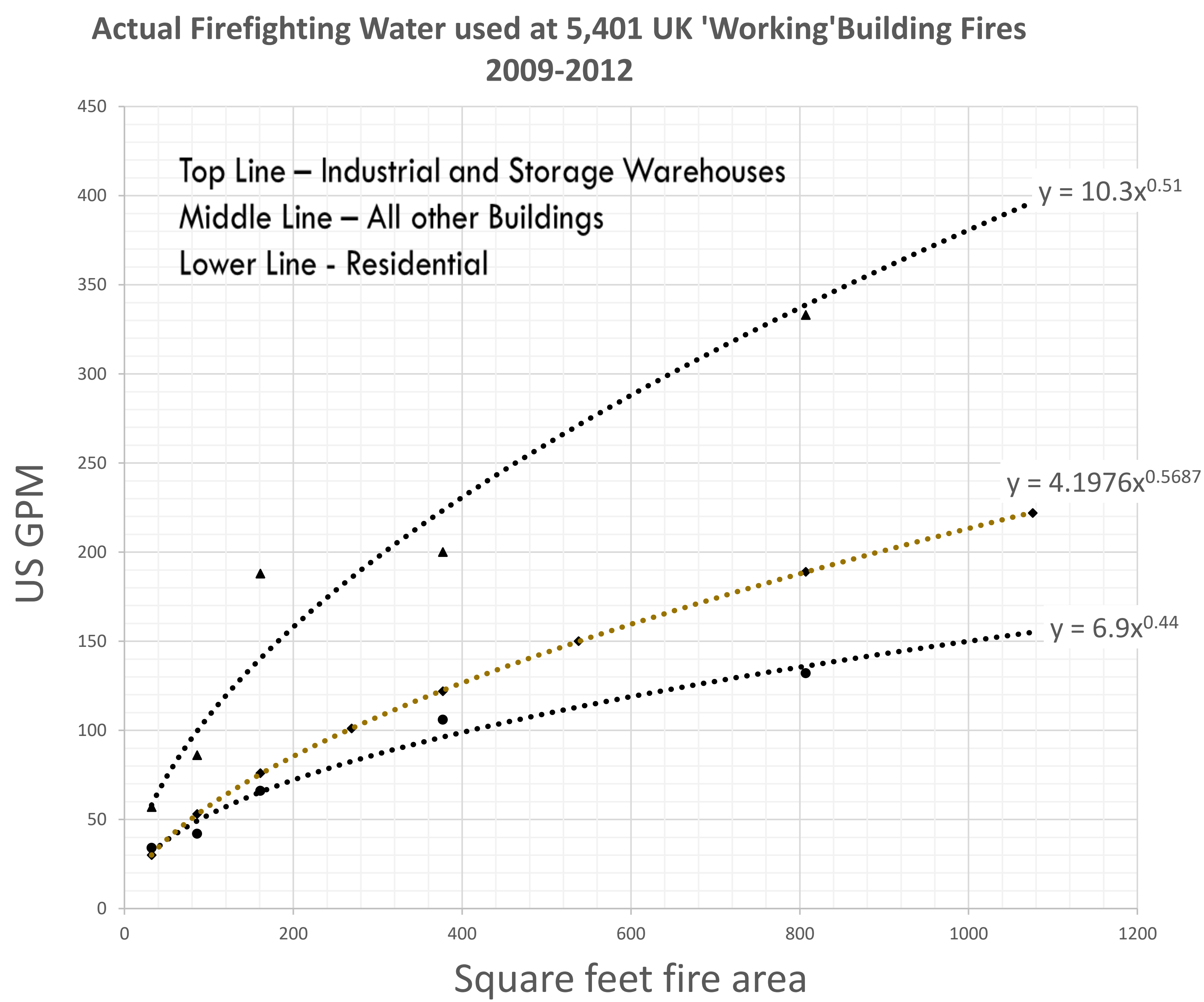
This shows that an estimated flow rate of at least 450 L/min would be required as a minimum to extinguish the fire safely and effectively by lessening the amount of heat exposure firefighters may be subjected to, over time on the hose-line.

How the National Operational [Fireground] Guidance Optimum Flow-rate of 5 L/min/m² Fits into the GCU research of 5,401 working fires (dash line)





Actual Firefighting Water used at 5,401 UK 'Working'Building Fires
2009-2012
Office Floor Space
4.1954 x (2500 ft)^0.5687 = 359 GPM
y = 10.3x^0.51
y = 4.1954x^0.5687
y = 6.9x^0.44
Top Line – Industrial and Storage Warehouses
Middle Line – All other Buildings
Lower Line - Residential
US GPM
Square feet fire area
900
800
700
600
500
400
300
200
100
0
0
1000
2000
3000
4000
5000
6000


Actual Firefighting Water used at 5,401 UK 'Working'Building Fires
2009-2012
Top Line – Industrial and Storage Warehouses
Middle Line – All other Buildings
Lower Line - Residential
y = 10.3x0.51
y = 4.1976x0.5687
y = 6.9x0.44
US GPM
Square feet fire area
450
400
350
300
250
200
150
100
50
0
0
200
400
600
800
1000
1200

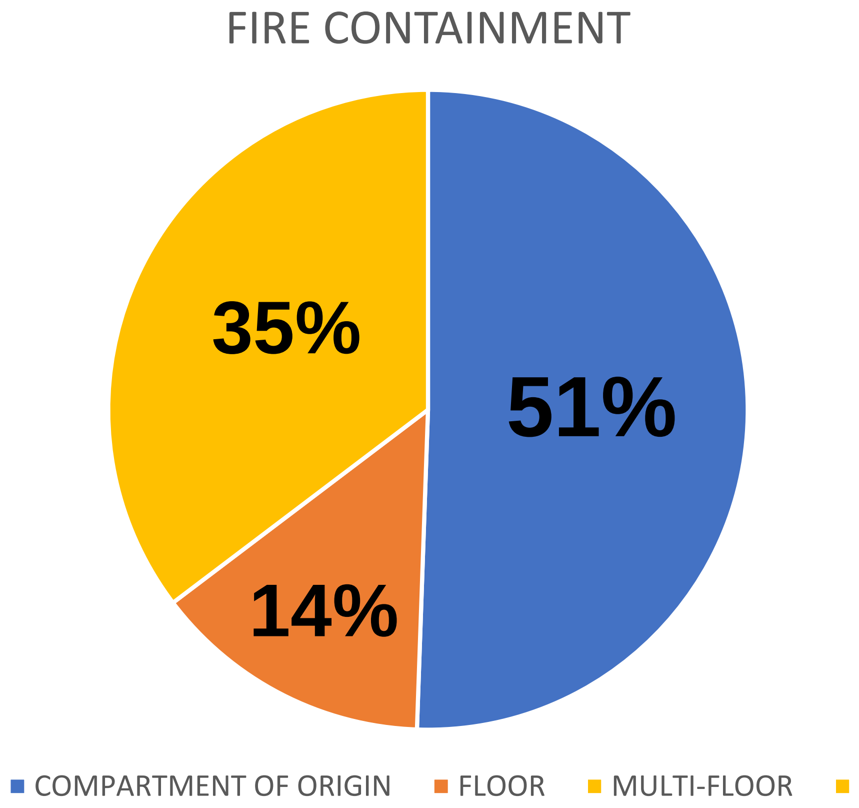
‘Adequate’ Firefighting Water

The Kent Fire and Rescue Service responded to their own internal capability review in 2012 in several ways to optimize response and service delivery further. It was noted in the firefighting water flow-rate research that due to demographics; they were seeing greater building fire damage than a Metropolitan Fire and Rescue Service who responded with greater weight of attack and more closely spaced fire stations and reduced response times.

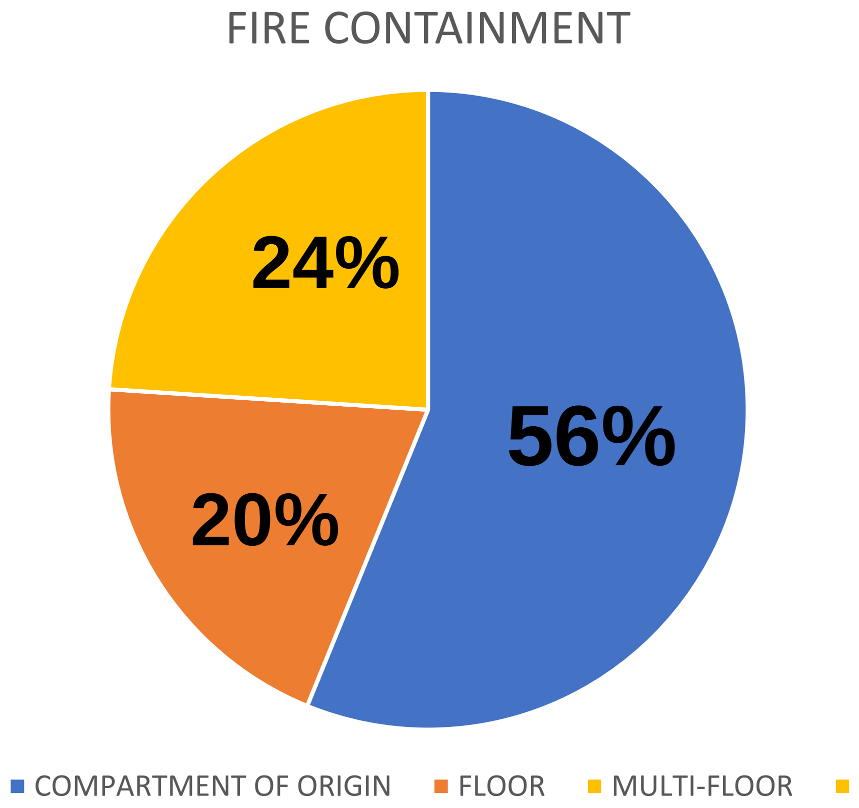
The KFRS firefighting water flow model was adapted by 2015 to deliver the same quantity of water as delivered previously but in a more rapid way. This was achieved through 22mm Hose-reels (replacing 19mm) and 22mm smooth-bore branches (augmenting some automatic branches).

The reductions seen in building fire damage were dramatic and inline with the Metropolitan FRS.

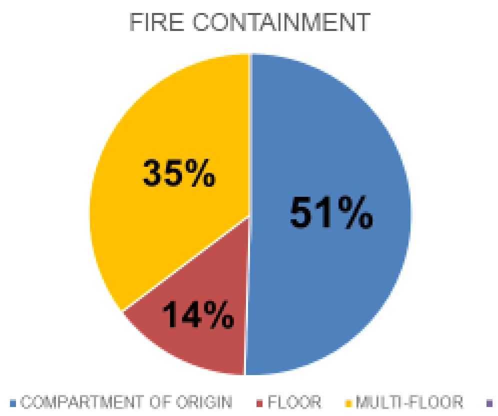
COUNTY FIRE CONTAINMENT 2012-15



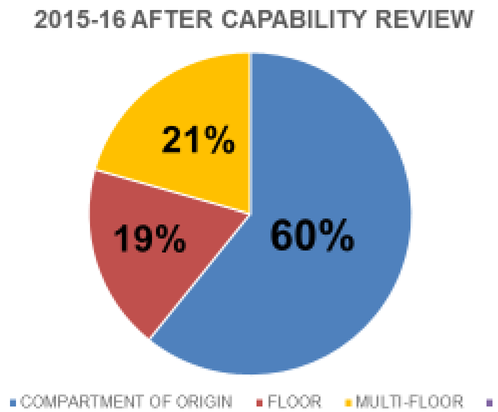
METRO FIRE CONTAINMENT 2012-15



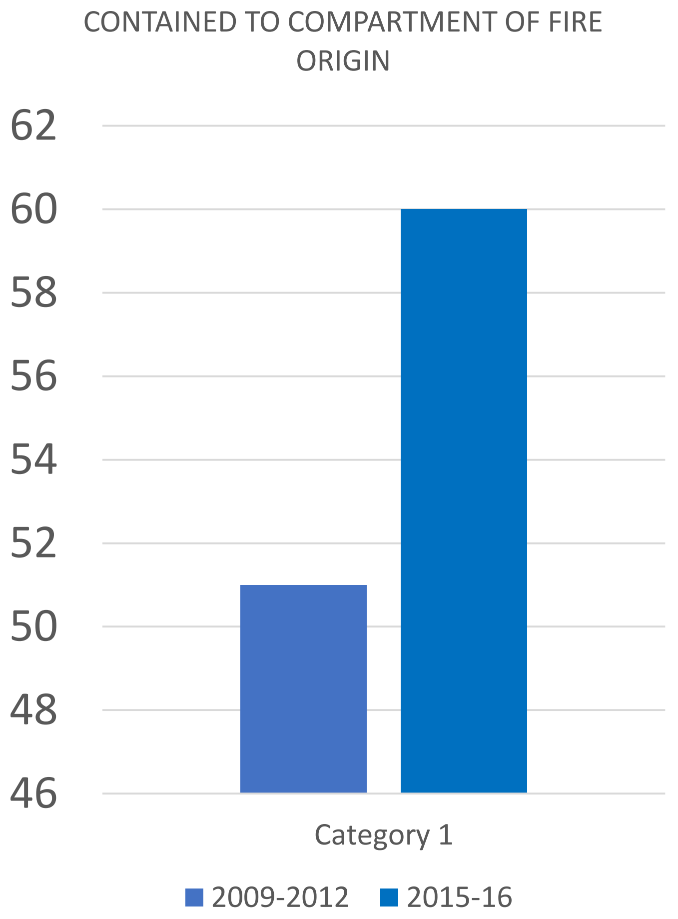
COUNTY FIRE CONTAINMENT



COUNTY FIRE CONTAINMENT



The link between flow-rate and fire damaged area was shown when the County increased their primary flow-rates by approximately 50% in 2015-16 (22mm hose-reels and smooth-bore main nozzles)

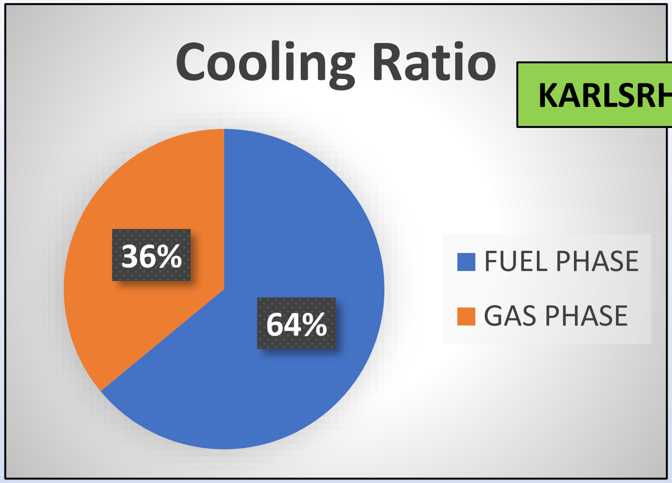


Cooling Ratios and Mechanisms of Extinguishment

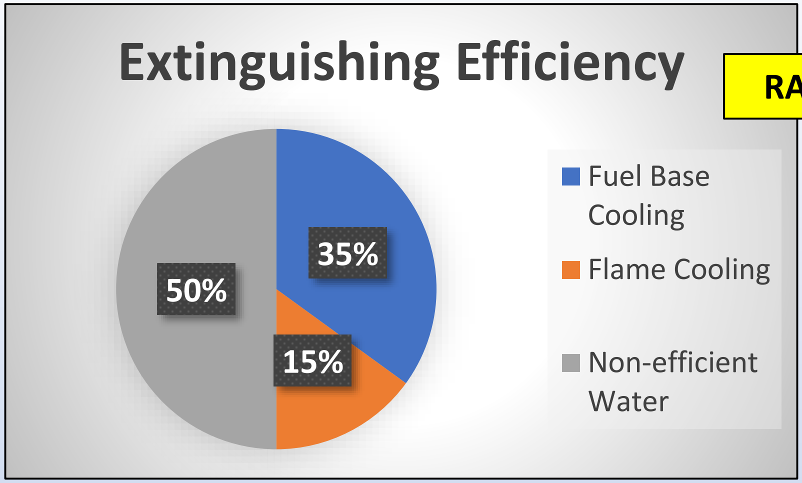
Research (reported in 1979-1984) from several full-scale ventilation-controlled fire tests at Karlsruhe University (Fire Research Station) in Germany revealed some commonality during the overall extinguishing process, where 36 percent of applied water was seen to suppress active (flaming) combustion, with the remaining 64 percent cooling the fuel base surface fire. This was noted in the live fire tests and then validated using a complex mathematical model developed to support the test process.

So too is there generally some major water run-off when firefighting water is delivered directly onto a burning fuel base. Estimates in research have placed this efficiency of applied firefighting water at around 30-50 percent. That is, for every 100 litres applied, only 30-50 will take part in the suppressive and cooling phase, with the remainder possibly finding its way onto the floor and out of the structure. Researchers have broken this down to 35 percent efficiency when applied into the fuel base and 15 percent efficiency when applied into the gas-phase (total 50 percent). Research by *Rasbash* suggested primary efficiency factors that conform to later work by Barnett in producing a cooling efficiency factor.

EuroFirefighter 2 – 2017 (p239 on)



KARLSRHUE



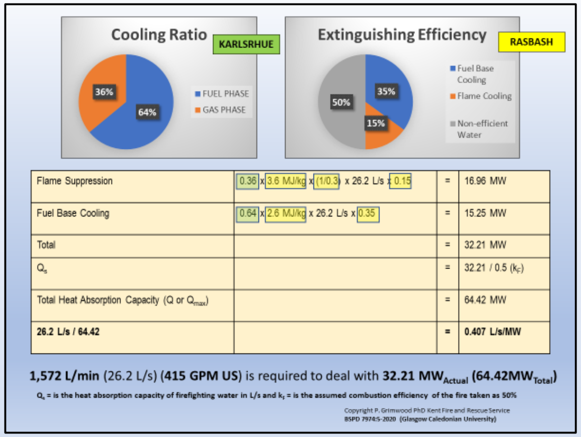
RASBASH

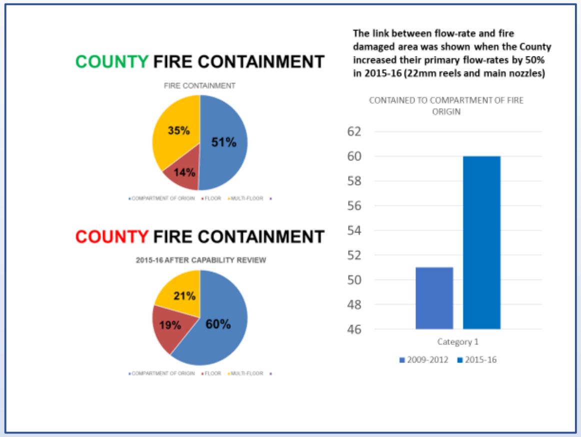
Flame Suppression	0.36 x 3.6 MJ/kg x (1/0.3) x 26.2 L/s x 0.15	=	16.96 MW
Fuel Base Cooling	0.64 x 2.6 MJ/kg x 26.2 L/s x 0.35	=	15.25 MW
Total		=	32.21 MW
Q_s		=	32.21 / 0.5 (k_F)
Total Heat Absorption Capacity (Q or Q_{max})		=	64.42 MW
26.2 L/s / 64.42		**=**	**0.407 L/s/MW**

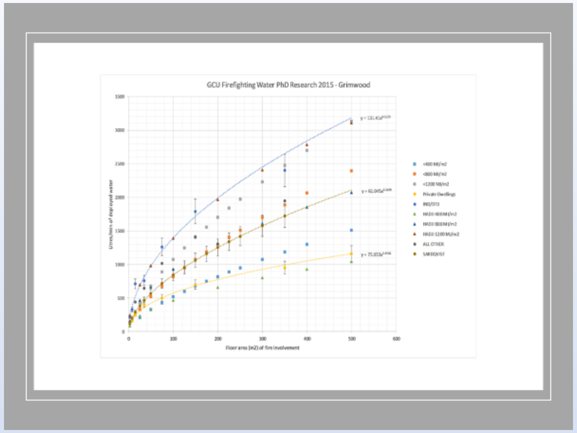
1,572 L/min (26.2 L/s) (**415 GPM US**) is required to deal with **32.21 MW$_{Actual}$ (64.42MW$_{Total}$)**

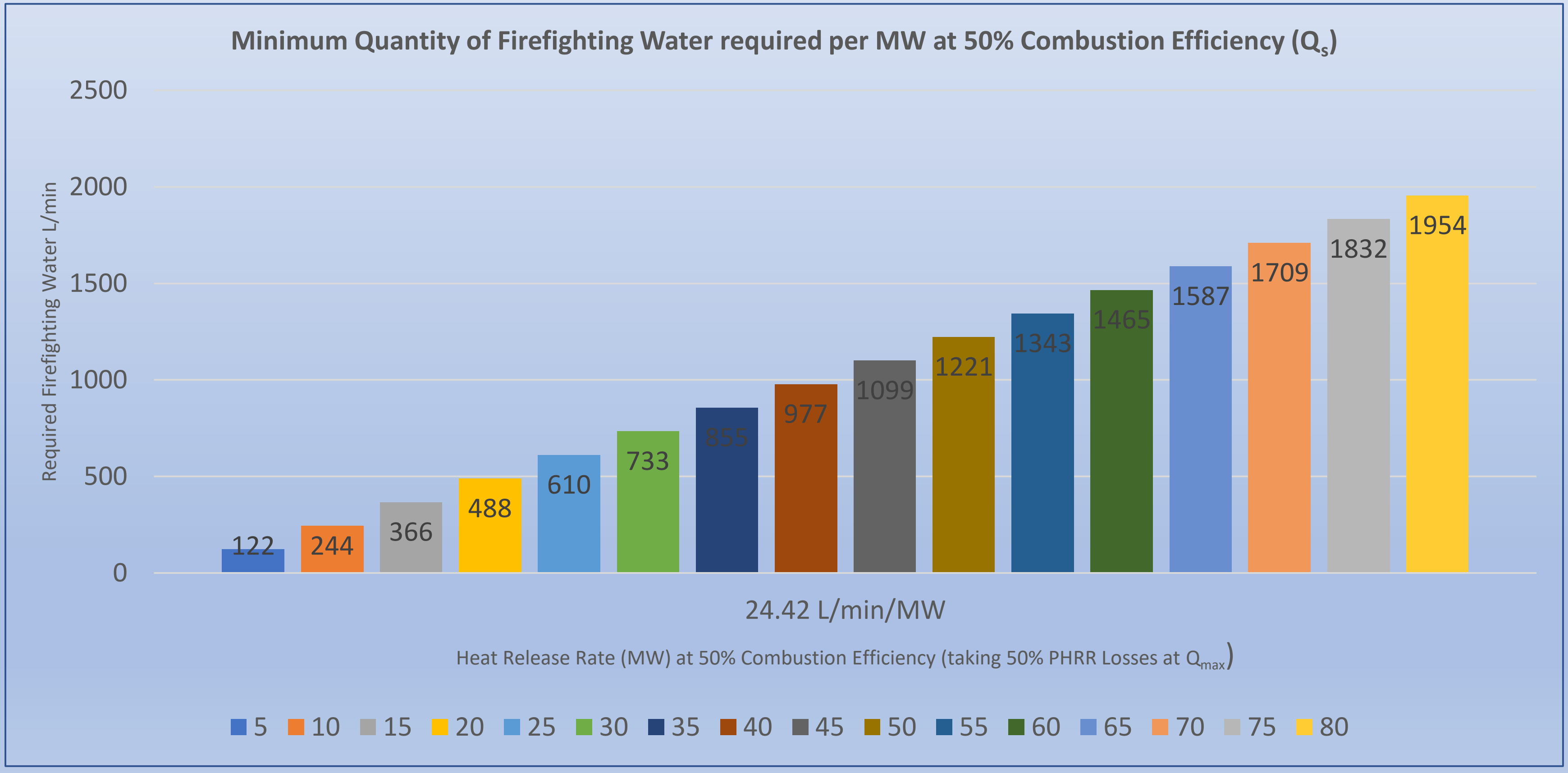
Q_s = is the heat absorption capacity of firefighting water in L/s and k_F = is the assumed combustion efficiency of the fire taken as 50%

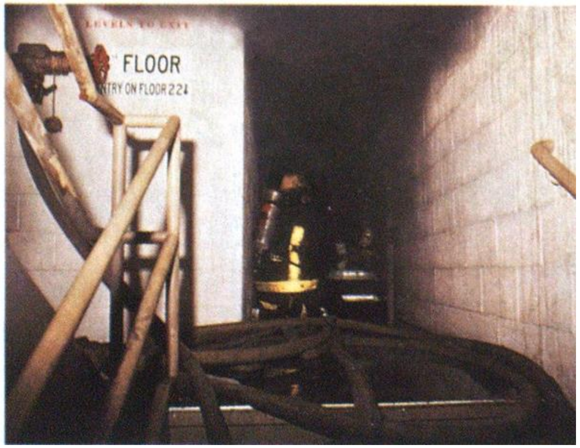
BSPD 7974:5-2020 (Glasgow Caledonian University)


Cooling Ratio
KARLSRHUE
36%
64%
FUEL PHASE
GAS PHASE
Extinguishing Efficiency
RASBASH
50%
35%
15%
Fuel Base Cooling
Flame Cooling
Non-efficient Water
Flame Suppression | 0.36 x 3.6 MJ/kg x (1/0.3) x 26.2 L/s x 0.15 | = | 16.96 MW
Fuel Base Cooling | 0.64 x 2.6 MJ/kg x 26.2 L/s x 0.35 | = | 15.25 MW
Total | = | 32.21 MW
Q_s | = | 32.21 / 0.5 (k_F)
Total Heat Absorption Capacity (Q or Q_max) | = | 64.42 MW
26.2 L/s / 64.42 | = | 0.407 L/s/MW
1,572 L/min (26.2 L/s) (415 GPM US) is required to deal with 32.21 MW_Actual (64.42MW_Total)
Q_s = is the heat absorption capacity of firefighting water in L/s and k_F = is the assumed combustion efficiency of the fire taken as 50%
Copyright P. Grimwood PhD Kent Fire and Rescue Service
BSPD 7974:5-2020 (Glasgow Caledonian University)


COUNTY FIRE CONTAINMENT
FIRE CONTAINMENT
35%
51%
14%
COMPARTMENT OF ORIGIN
FLOOR
MULTI-FLOOR
COUNTY FIRE CONTAINMENT
2015-16 AFTER CAPABILITY REVIEW
21%
19%
60%
COMPARTMENT OF ORIGIN
FLOOR
MULTI-FLOOR
The link between flow-rate and fire damaged area was shown when the County increased their primary flow-rates by 50% in 2015-16 (22mm reels and main nozzles)
CONTAINED TO COMPARTMENT OF FIRE ORIGIN
62
60
58
56
54
52
50
48
46
Category 1
2009-2012
2015-16




Minimum Quantity of Firefighting Water required per MW at 50% Combustion Efficiency (Q_s)
2500
2000
1500
1000
500
0
Required Firefighting Water L/min
122
244
366
488
610
733
855
977
1099
1221
1343
1465
1587
1709
1832
1954
24.42 L/min/MW
Heat Release Rate (MW) at 50% Combustion Efficiency (taking 50% PHRR Losses at Q_max)
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80



100mm v 150mm Rising Fire Mains

The advantage of 150mm rising mains over 100mm mains are that they enable higher flows with less pressure losses. However, they also enhance the provision of twin floor outlets and four inlets at the base.

This enables an attack hose-line and a support safety hose-line to be laid from the same floor level. If the risers are located off the stair and into the lobby/corridor, the stair remains protected from any smoke infiltration.

The provision of four inlets at the base offers additional opportunity to augment the supply, especially if a low flowing hydrant was selected on first arrival.

In 1972 as a firefighter I attended one of the first commissioning tests of a wet rising main in the UK at the 91 metre Metropole Hotel in Paddington, London. High-rise buildings were now prominent on the capital's skyline and the growth of the vertical city phenomenon in the UK was becoming truly established.

Over the following decades UK firefighters were to experience a range of challenging and sometimes terrible and tragic fires in high-rise buildings, both in residential and commercial settings. This led to a range of building design amendments and firefighting procedural updates. It is interesting to go back over some of these changes to consider why and where we are today.

Compliance?...

BS 5306-1 : 1976 Wet or Dry rising mains should have a nominal bore of 100mm where only one outlet is provided on each floor level on each riser. If two outlets are permitted on any level on any one riser the main should have a nominal bore of 150mm.

A 150mm main should be fitted with a four-way inlet breeching.

Compliance?...

BS 5588-5 : 1991 – 'Landing valves ought to be sited where personnel can safely lay out and charge hose lines before entering the fire compartment, and ease of access; exposure to fire from the accommodation if a door is open; obstruction of fire doors by the hose line and the risk of unintentional discharge of water hitting the lift doors or controls; [all] need to be considered when siting landing valves'.

Compliance?...

BS9990:2006 - Each landing valve should be sited:

a) Within a ventilated lobby of a lobby approach stairway, where this is provided; or

b) In a stairway enclosure; or

c) **In any other position as agreed with the appropriate authority.**

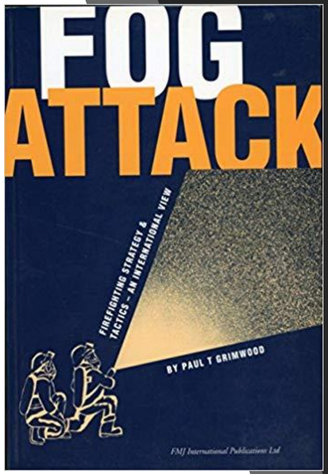
BS9990:2015 added - **NOTE 1**: For residential blocks of flats, where fire mains are proposed to be provided it is expected that the landing valves are located within the staircase enclosure on the full landings.

Compliance?...

Compliance from 2020?

BSPD 7974-5:2019 DPC - 'The minimum package of measures provided through regulatory guidance and standards to facilitate firefighters in accessing or entering the building surrounds and transporting firefighting water and equipment to upper floors in large or tall buildings, form a critical part of the buildings overall design. Where fire engineering principles are used to meet functional requirements, it may be necessary to enhance the provisions and performance of firefighting access and facilities. It is equally important to ensure firefighters are able to enter and remain in the safest of firefighting environments to undertake intervention, evacuation and rescue activities, as necessary.

Where agreed by all relevant parties including the fire service at QDR stages, simple measures may be taken that further enhance firefighting access and facilities. In some cases, the fire service may demonstrate a preference for specific facilities, such as rising fire mains, to be located away from the stair, within a protected lobby/corridor. According to an on-scene risk assessment, this may enable firefighters to lay initial attack hose-lines from the fire floor itself, reducing the likelihood of smoke infiltrating into the firefighting stairwell. This preference is particularly important in single stair residential buildings but may also feature in multi-stair buildings. However, any such deviation in this respect, where firefighting main design is not specifically according to normally prescribed regulatory guidance or standards, should take place at the QDR stage and local fire service agreement is essential'.



"The two 100mm rising mains were unable to provide adequate amounts of firefighting water to upper levels to deal with the amount of fire. Rising fire mains should be at least 150mm diameter with dividing connections to allow two hose-lines at each floor level"

Fog Attack p269 – Churchill Plaza Fire, UK
1992

"Two fire main outlets per level assists the laying of an attack hose-line additional to a safety hose-line in support, from the same floor (preferably the fire floor, to reduce hose-lay distances and also to protect the stairs from smoke infiltration)"

EuroFirefighter 2
p264 February 2017

Kent FRS 150mm Rising Mains in New Single Stair Residential Buildings

- Kent Fire and Rescue Service have been requesting rising fire mains to be 150mm with twin outlets at each floor level since 2010. In residential buildings the outlets have been taken away from the stair and placed in a lobby/corridor.
- 150mm mains are code compliant and outlet location was also compliant (by fire service choice) up until 2015 (BS 9990) and may again be compliant in fire engineered buildings when the updated BS 7974:5 DPC (2019) is published. In effect, an extended corridor beyond 7.5m denotes a fire engineered building.

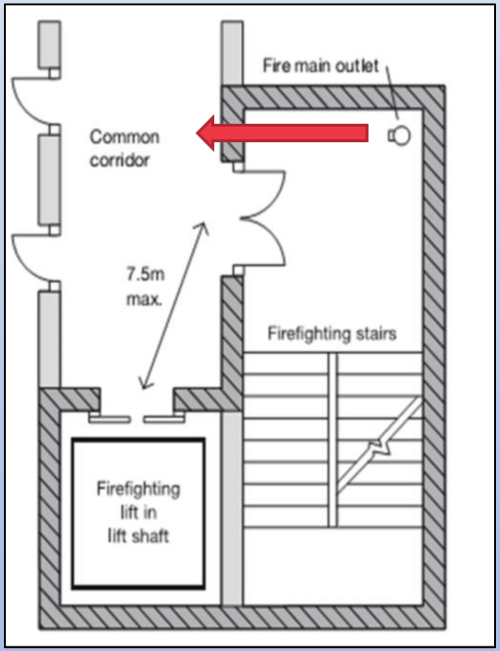
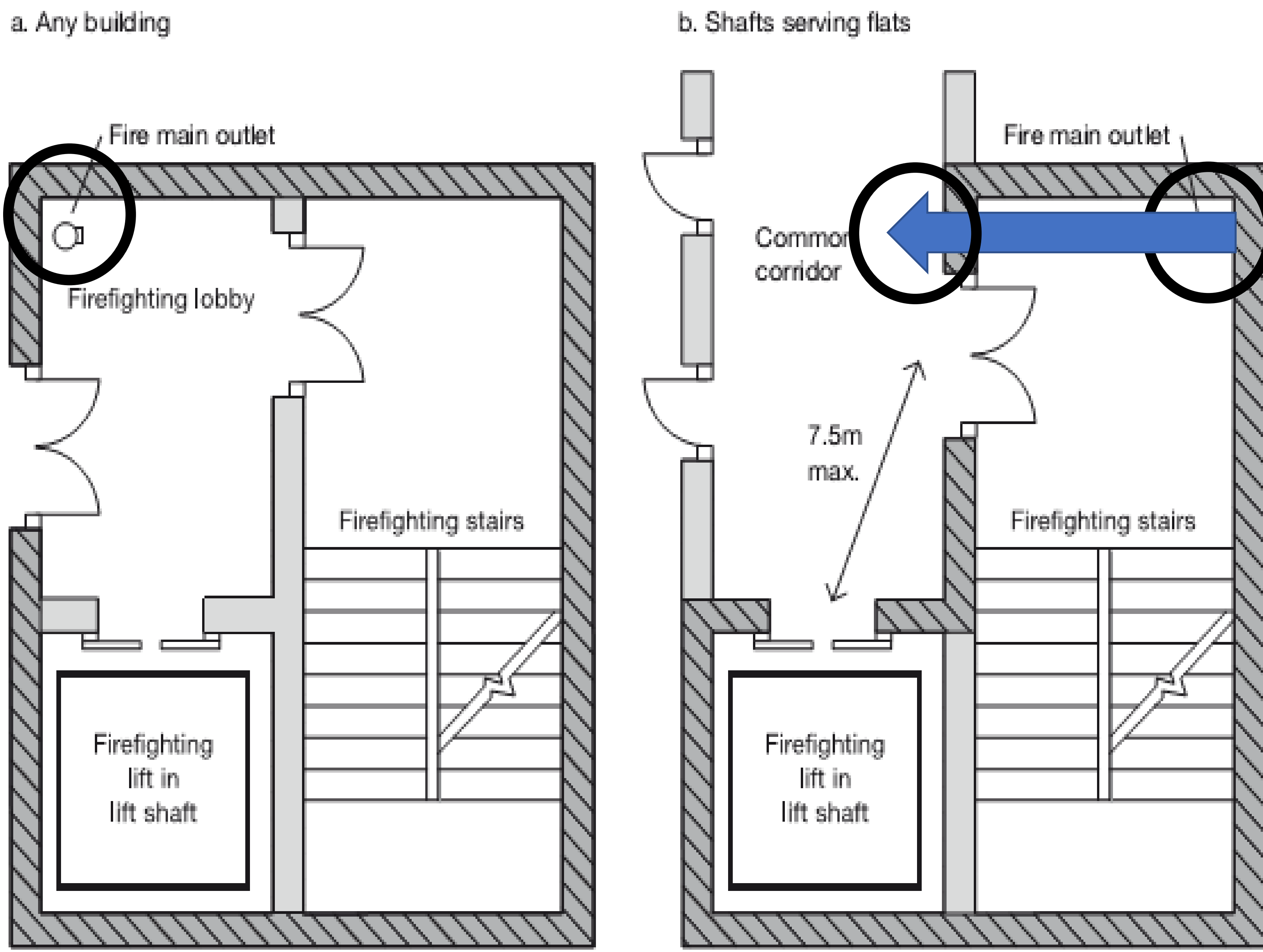


Diagram 52 A proposal to reposition rising main outlets by design to protect stairwells

See para 17.1



Kent FRS 150mm Rising Mains in New Single Stair Residential Buildings

Kent Fire and Rescue Service have hydraulically calculated and flow tested the new 150mm twin outlet rising fire mains. These have demonstrated a single 750 L/min jet or two jets of 650 L/min each at 50 metres high are achievable using 51mm hose.

Pressure loss per unit length of 100mm rising main at 1500 L/min	**9.3mbar/m**	**BS 5306 part 2 (1990) Table 64**
Pressure loss per unit length of 150mm rising main at 1500 L/min	1.4mbar/m	BS 5306 part 2 (1990) Table 64
Velocity at 1500 L/min in 100mm pipe	2.98 m/s	CIBSE Pipe sizing tables V2.2
Velocity at 1500 L/min in 150mm pipe	1.34 m/s	CIBSE Pipe sizing tables V2.2
50m high 100mm riser with 6m horizontal run, allowing for 90º bends	71m total length Pressure loss (71 x 9.3mbar) + 5000 m/bar static head loss = 5660 mbar (5.6 bar)	Estimated time to fill riser 56m at 2.98m/s = 19 seconds
50m high 150mm riser with 6m horizontal run, allowing for 90º bends	71m total length Pressure loss (71 x 1.4mbar) + 5000 m/bar static head loss = 5099 mbar (5.0 bar)	Estimated time to fill riser 56m at 1.34m/s = 42 seconds

100mm v 150mm Rising Fire Mains

- In practical terms, a 150mm rising main will take around 800 – 1000 litres to fill from an appliance tank and may take up to a minute to get water to the highest level. Rising mains should be laid dry on arrival and charged wet as soon as a fire is confirmed.

Risk Assessing the Corridor Hose Connection at the Fire Floor

It is generally necessary to first enter the fire floor corridor or lobby in order to primarily locate the involved fire apartment prior to laying a hose-line. GRA 3.2 terms this as reconnaissance.

If the corridor or access lobby is compromised by smoke and is now considered an extension of the fire compartment, the primary hose-line/s should be laid from a floor below the fire.

Incident Commanders should understand when a partial or full evacuation strategy might become the priority over firefighting in a residential building where a “Stay Put” policy is normally in place

Stack Effect in High-rise Fires

On a cold night (or a very warm day) the impact of stack effect in tall buildings can play havoc with fire floor pressure differentials and create effects similar to wind driven conditions sending searing heat directly at advancing firefighters, depending on whether the fire is above or below the Neutral Pressure Plane (NPP).

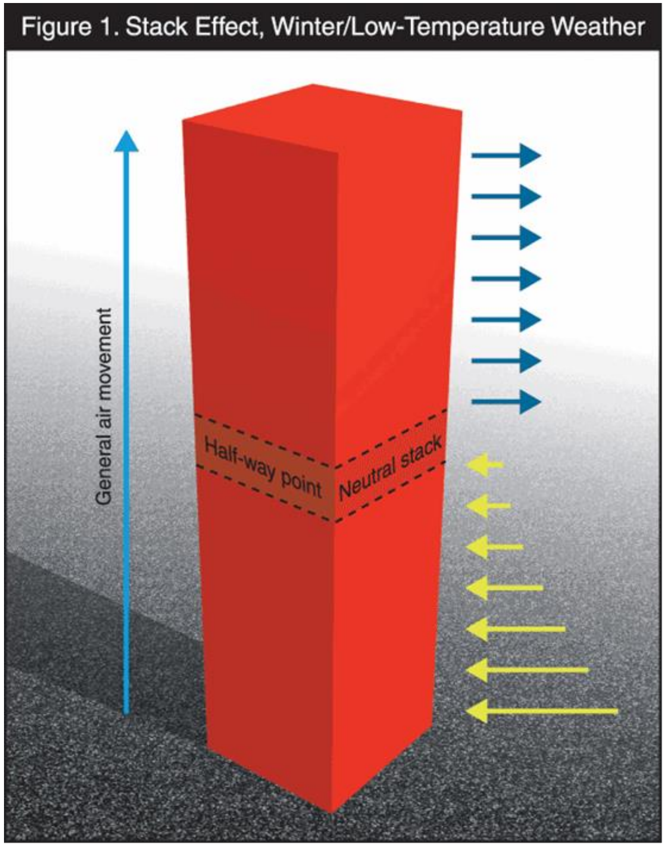
Trying to pull open an outward opening street door in a New York City high-rise on a cold day demonstrates the draw of air into the building that is created by the difference in temperature between the inside and outside. It is extremely hard to open this door as the positive pressure differential is far greater on the outside, hence the need for air tight revolving doors. Note the Ontario fire conditions discussed earlier where stack effect caused smoke and heat to push into the stairs.

Stack Effect in High-rise Fires

In side the building on a cold night with sub zero temperatures outside, expect interior wind velocity caused by these outside to inside pressure differentials to create intense fire, heat and smoke to head directly at firefighters advancing along a corridor and into a fire involved area. As you get closer to the top of the building this effect will reduce. Therefore a post flashover or ventilation controlled fire on the lower floors on such a cold night will create the worst firefighting conditions.

Opening roof vents and stair doors below the fire floor may increase the stack impact and worsen conditions. In an extended corridor scenario without sprinkler protection, the fire conditions could be very dangerous indeed.

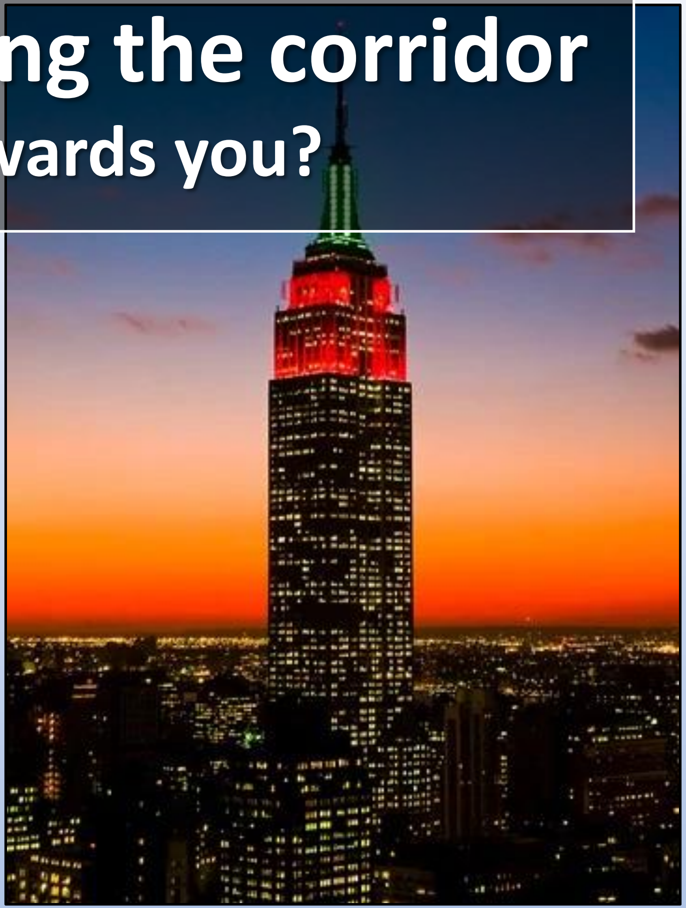
Stack Effect in High-rise Fires



The taller the building and the colder the outside temperature, the greater the impact that stack effect may have on fire development and smoke spread. The very hot summer day may reverse the direction of smoke and heat flow.

The calculations used to demonstrate stack effect can be complex and need to accommodate a wide range of variables. **From a firefighter's view, be very aware of the hazard for it may unleash a very severe form of internal fire spread.**

Advancing a hose-line along the corridor
WHY does the fire turn towards you?



EMPIRE STATE BUILDING FIRE NYC 1990

A fire on the 51st floor in the 102 storey building led FDNY firefighters into an intense battle to save the building. Exterior winds, coupled with interior stack driven pressure differentials, had fully involved an 85 sq. Metre (916 sq. Feet) office suite and firefighters were forced to crawl as a 60 mph wind entered the floor as windows failed. Six firefighters were badly burned at this point. At this time there were also multiple calls from trapped occupants on the upper floors and firefighters immediately initiated their stair search and evacuation plan, deploying ten teams to upper levels.

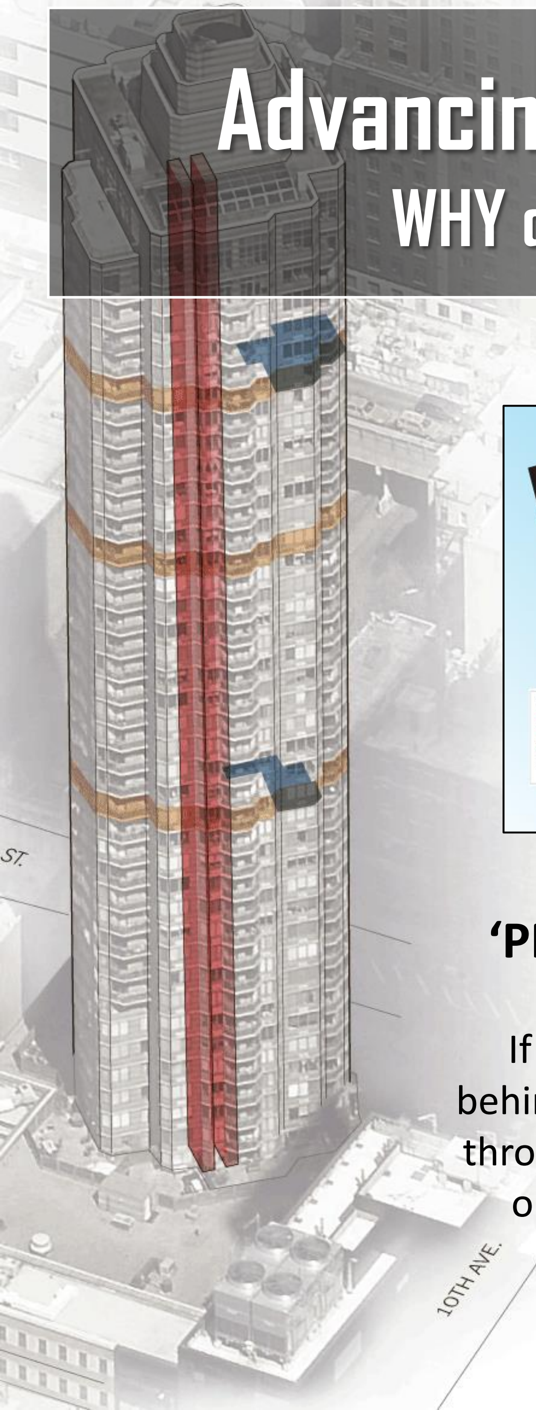
As there was a **smoke shaft located immediately behind** the advancing firefighters protecting an evacuation stairway, the flow path exacerbated the heat and smoke conditions being driven directly at the firefighters. Despite two 65mm hose-lines being advanced towards the fire the firefighters were unable to make little headway against the flames.

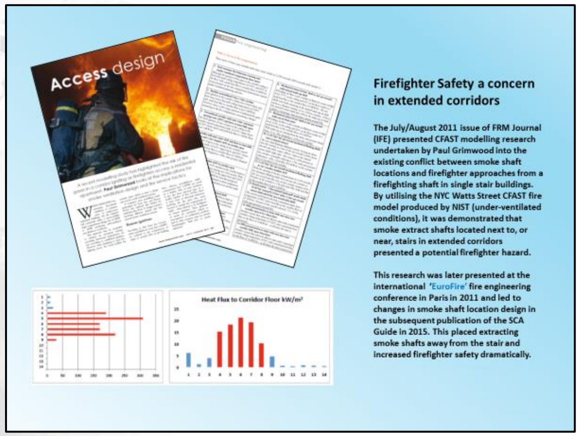
A change in strategy saw firefighters successfully redeploy using an alternative corridor, avoiding the negative flow-path created by a smoke shaft behind their advance.

Fog Attack p263-265
1992

Advancing a hose-line along the corridor,

WHY does the fire turn right towards you?





'PRESSURE DIFFERENTIALS'

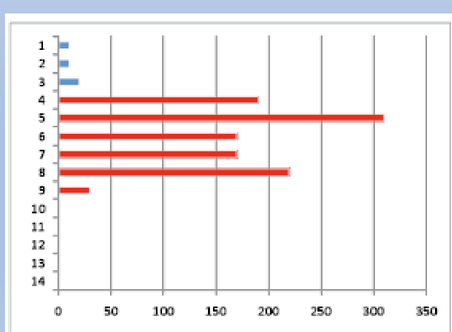
If the pressure differential is less behind the firefighters advance, either through the opening of a smoke shaft or a stair door, the fire will head towards the lowest pressure.

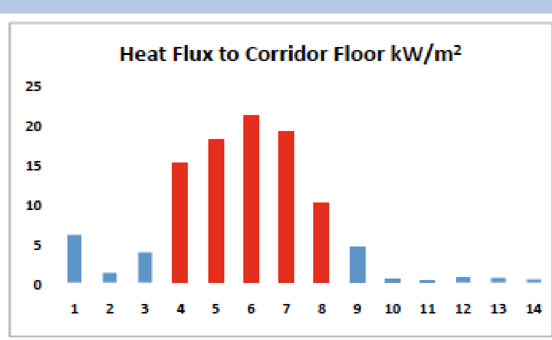
In 2015 The Smoke Control Association Guidance for residential buildings acknowledged extensive work undertaken by Kent Fire and Rescue Service in 2011 and established guidance to ensure mechanical extract smoke shafts are located at the end away from the firefighting access stair rather than at the stair, in support of firefighter tenability. This was also included in **BS 7346:8-2013** (6.4.9 c)

Firefighter Safety a major concern in extended corridors

The July/August 2011 issue of FRM Journal (IFE) presented CFAST modelling research undertaken by Paul Grimwood into the existing conflict between smoke shaft locations and firefighter approaches from a firefighting shaft in single stair buildings. By utilising the NYC Watts Street CFAST fire model produced by NIST (under-ventilated conditions), it was demonstrated that smoke extract shafts located next to, or near, stairs in extended corridors presented a potential firefighter hazard.

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.

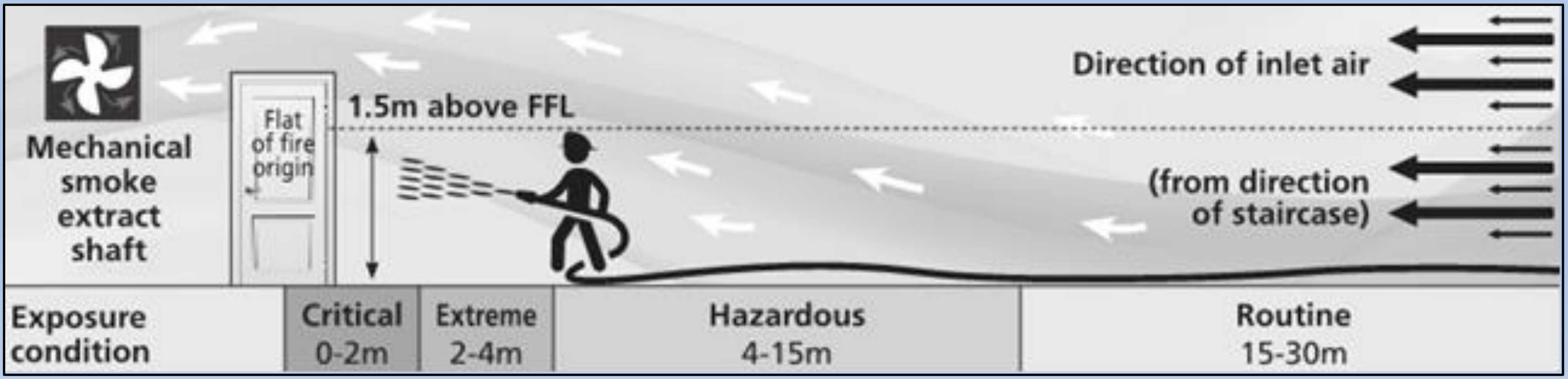




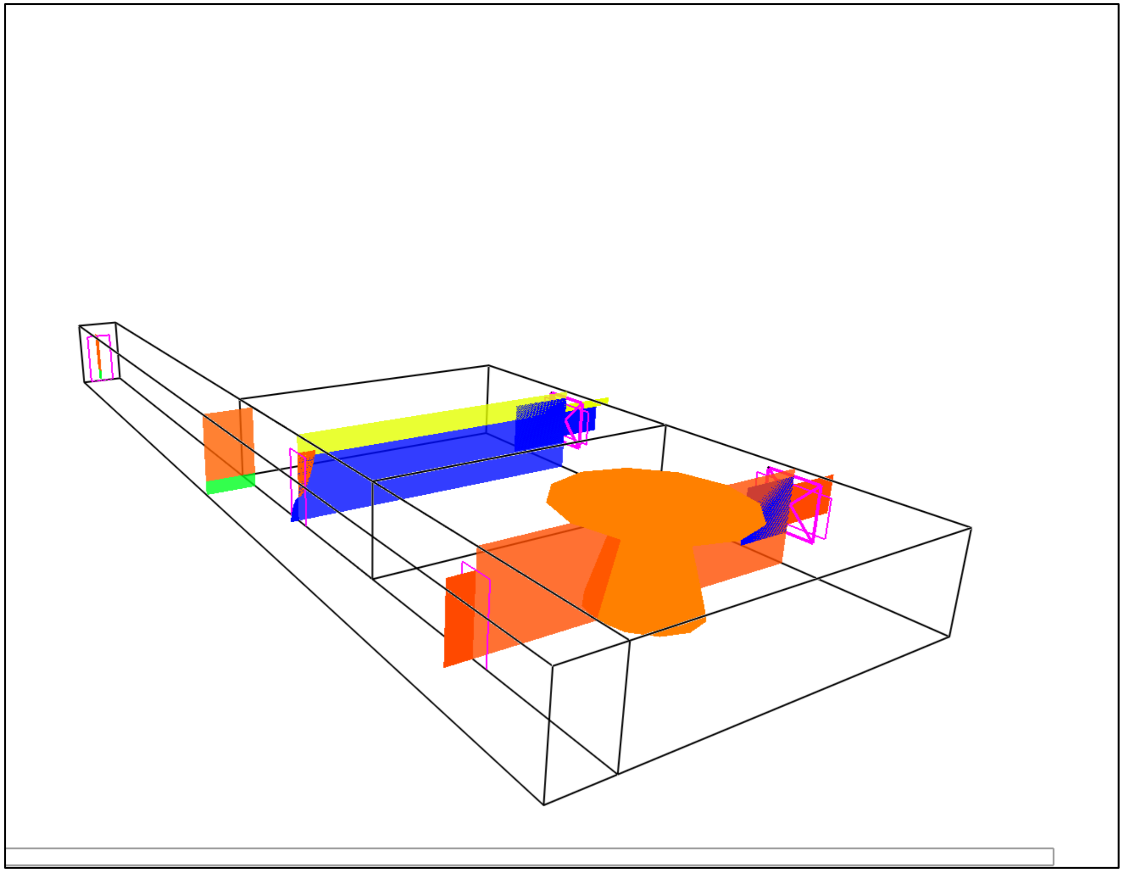
Mechanical Smoke Ventilation Systems (MSVS) (SCA Guidance 2015)

Exposure Condition	Maximum exposure time (minutes)	Maximum air temperature (^{0}C)**	Maximum radiated heat flux (kW/m^2)	Remarks	Recommended distance from apartment door*
Routine	25	100	1	General fire-fighting	15-30m
Hazardous	10	120	3	Short exposure with thermal radiation	4-15m
Extreme	1	160	4 – 4.5	For example, snatch rescue scenario	2-4m
Critical	<1	>235	>10	Considered life threatening	0-2m

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.



How pressure differentials caused by incorrectly configured mechanical smoke control systems, or stack effect, or external wind can compromise significantly extended corridors and create untenable conditions for firefighters. Several corridor flashovers had previously resulted in the deaths of multiple firefighters in St. Petersburg, Russia (9 firefighters) 1991; Vandalia Avenue, New York (3 firefighters) 1998; followed by *Neuilly*-sur-*Seine,* just north of Paris 2002 (5 firefighters). There are many other recorded fatal incidents where firefighters (not in multiples) have been overcome by fire, heat and smoke whilst attempting to reach the stair in long corridors.



Emergency Refuge Rooms in Significantly Extended (30m) Corridor Scenarios

Kent Fire and Rescue Service have undertaken two-zone computer modelling into the tactical concept of creating an emergency refuge room (zone) in the stair-side adjacent apartment to the fire apartment, prior to making entry. In effect, this may provide emergency refuge to firefighters in significantly extended corridors (30m), particularly in wind driven situations. FDNY showed great interest in this idea. More work is underway.

COMMERCIAL OFFICE HIGH-RISE FIRES

The FDNY recognise the need for greater flow-rates and weight of attack in open-plan office environments based on much experience of these types of fires

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 2004	• **15 m²/min** • **27 mm/second**
Los Angeles 1988	• **25 m²/min** • **36 mm/second**

https://img1.wsimg.com/blobby/go/877d587b-6900-4f7f-b145-e75cc02aff97/downloads/1cm2g3kb7_663897.pdf?ver=1555186108307

Technical Perspectives

Structural fire engineering: realistic 'travelling fires' in large office compartments

Paul Grimwood PhD FIFireE Principal Fire Engineer, Kent Fire and Rescue Service, reports

Estimated Building Fire Spread Rates (Grimwood)
According to on-scene command reports, videos, CCTV and fire timed messages

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, once a fire growth curve is established.

This means that firefighters must prepare, **plan, train and equip** to **rapidly deploy** higher flow-rates on the primary hose-lines – (500 L/min in residential buildings compared to **750 L/min** in commercial and industrial premises).


Technical Perspectives

All technical perspectives articles and features are sense check reviewed before publication. To submit your articles for IFP Journal publication please email Stephanie.morris@ife.org.uk

Structural fire engineering: realistic 'travelling fires' in large office compartments

Paul Grimwood PhD FIFireE Principal Fire Engineer, Kent Fire and Rescue Service, reports

The speed a fire develops in large open-plan office compartments >150m2 is reasonably well understood by experienced firefighters. Such fires will not conform to typical flashover fire spread rates commonly observed in smaller compartments, but will be seen to travel at a far slower pace across open-plan office floors. It has recently been suggested that this reduced rate of fire spread may have some alternative impacts on structural heat transfer to those provided in the Eurocode and as such, is now beginning to have greater influence on modern design parameters. We already have some very tall buildings on our skylines where fire resistance provisions have been analysed in a way to account for travelling fire methodology, but it is perhaps both prudent and relevant that previous real fire experience is also researched more closely by design engineers in order to establish some wider validation and provide more confidence in such an approach.

Under the expert guidance of Professor Guillermo Rein and Dr Adam Sadowski (Imperial College) and guest speaker Dr Panos Kotsovinos (Arup), I was fortunate enough to take part in the 2018 MSc Module on Structural Fire Engineering based at Imperial College London, where serving fire safety and senior operational officers are more than encouraged to gain some invaluable experience.

The nine-week module begins with an introduction to fire dynamics and fire spread followed by an investigation into the heat transfer mechanisms of conduction, convection and radiation. The mechanical and thermal properties of steel and concrete at elevated temperatures are described, as are the effect of thermal strains on simple structural systems. The MSc module introduces students to both prescriptive and performance-based design according to the Eurocode, concluding with an advanced computational design project using ABAQUS.

The relevance of this teaching is to develop a greater awareness and understanding amongst structural engineers in how fire may spread horizontally in various ways throughout enclosures and by vertical extension to involve multi-floor levels. Then, most importantly, detailing how heat transfer analyses into key structural elements are undertaken across the building frame so that buildings involved in fire can be most effectively protected from disproportionate collapse whilst under fire attack. That is protected for a reasonable period of time to enable occupants to escape and/or firefighters to undertake effective firefighting intervention and rescue. This creates a speciality role for the structural fire engineer, where prescriptive design codes might be considered inapplicable for the design of large, complex or tall structures.

As an introductory 'taster' session to the MSc module, Professor Rein introduced some of the most recent academic research undertaken by Rein and his students[1] (based on their earlier research published in 2011[2]) describing travelling fire spread in large open-plan office buildings. Other research into travelling fires undertaken by the University of Edinburgh has also been recently published[3]. It has long been known by the fire service, but more recently acknowledged by academics, that fires in large office compartments (>150 m^2) take a much longer period of time than an instantaneous fully developed flashover fire before flaming combustion reaches the furthest wall or area. In effect the fire 'travels' across the surfaces of the fuel load at a specific rate of spread, determined by various fuel configurations, compartment geometry/layout and ventilation factors. This specific form of fire development has been noted by Rein's students to form two distinct zones:

(a) the near field and, (b) the far field. The far field model represents smoke temperatures, which decrease with distance from the near field (steady-state fire zone) due to mixing with air. Most importantly from a structural engineer's viewpoint, this has quantitative impacts on the amount and

40 International Fire Professional August 2018 Issue No 25 www.ife.org.uk

The provision of automatic fire suppression systems or effective compartment size reductions by design in such premises may be critical.

EXTERNAL WALL FIRES

GRENFELL 2017
1 FLOOR/MINUTE

SHANGHAI 2010
3 FLOORS/MINUTE

ADDRESS DUBAI 2015
5 FLOORS/MINUTE

Potentially 6,000 existing UK buildings with combustible walls

- This includes buildings with rainscreen (or ventilated) façades clad with HPL etc., and External Thermal Insulation Composite Systems (ETICS) type façades, where a lightweight cement render covers the combustible insulation.
- Compared to the least flammable panels, **polyethylene-aluminium composites** showed 55 x greater peak heat release rates (pHRR) and 70 x greater total heat release (THR)
- widely-used **high-pressure laminate (HPL)** panels showed 25 x greater pHRR and 115 x greater THR.
- Compared to the least combustible **insulation products**, **polyisocyanurate foam** showed 16 x greater pHRR and 35 x greater THR
- **phenolic foam** showed 9 x greater pHRR and 48 x greater THR.
- A few burning drips of polyethylene from the panelling are enough to ignite the foam insulation
- **Smoke** from polyisocyanurates was 15 x, and phenolics 5 x more toxic than from mineral wool insulation.
- 1 kg of burning **polyisocyanurate** insulation is sufficient to fill a 50m3 room with an incapacitating and ultimately lethal effluent.

SIX TYPES OF EXTERNAL WALL FIRE

There are typically six types of external wall fire that may spread rapidly and with great intensity up and across the face of the building, in some cases leading to re-entry into the accommodation.

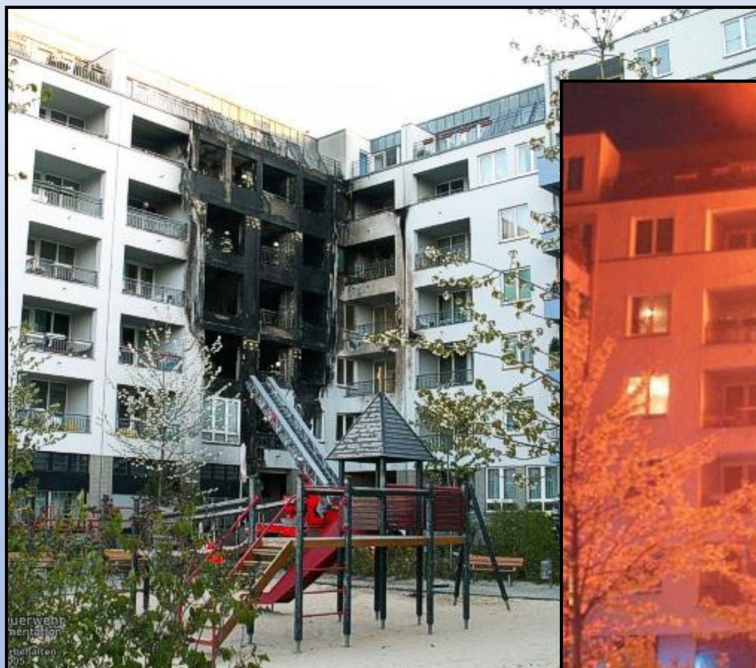
In recent years there have been several fires in the UK of this nature, although none have come close to equalling the tragic scale of a fire such as Grenfell Tower in London (2017). However, it is clear to see that each fire type may present varying levels of risk and challenges, including external wall fire and multiple floor fires, but all will place demands on firefighters and incident commanders to utilise the most effective tactical options in achieving the best outcomes.

SIX TYPES OF EXTERNAL WALL FIRE

1) Typical window to window limited vertical fire spread
2) Combustible window sets ground to roof
3) External ACM or MCM wall cladding rainscreens over combustible insulation
4) External rendered wall systems or High Pressure Laminates (HPL) over combustible insulation
5) Glass curtain walls
6) Combustible Balconies with high hazard storage included in some cases

The Garnock Court fire occurred on 11 June 1999, involving a 14-storey block of flats in Scotland and resulting in one fatality. The fire had spread via the external window cladding, reaching the 12th floor within ten minutes of the start of the fire and destroying flats on nine floors.

Several other serious external wall fires have since occurred both in the UK and around the world and all have raised international concerns from a regulatory fire safety and tactical firefighting stance.



Far from being a new phenomenon. The hazards associated with this type of fire were brought home to us in 2009 when combustible cladding exacerbated the Lakanal House fire in London causing the deaths of six people.

In 2010 an external wall cladding fire in Dijon, France caused re-entry into multiples of apartments and led to the deaths of seven occupants and caused multiple injuries, including some firefighters.

UK Government statistics show that 8,025 fires have occurred in buildings over 4 storeys since 2016/17. Of these 156 affected at least two floor levels with 72 spreading beyond two levels.

Where a fire in traditional construction spreads beyond three floors, or in lightweight construction beyond two floors, serious consideration might place evacuation as a priority where egress routes remain clear of smoke and tenable for residents of all vulnerabilities.

SHANGHAI CHINA 2010

58 LIVES LOST

Presenting the two Euro Firefighter Books along with the Kent FRS Stair Protection Strategies to FDNY Chief of Department John Sudnik

The Eurofirefighter books 1 and 2 can now be downloaded FREE from https://eurofirefighter.com/downloads

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

PLAN – PREPARE – EQUIP – TRAIN for it