Not just the cladding…
The Grenfell Tower Fire: Understanding what happened

There is an awful sameness to catastrophic events. They are not the result of a single failure. A chain of events is triggered by an active failure, such as an ignition source, and then pre-existing latent conditions combine to create a sequence of events resulting in disastrous consequences.

Here Gill Kernick offers a dispassionate summary of the chain of events leading to the deaths of 72 people in the Grenfell Tower Fire on the 14th June 2017. It is based on expert evidence presented to the Public Inquiry in November 2018.

The Public Inquiry was called by the Prime Minister on the 15th June 2017, the day after the fire. The purpose is to establish the facts about what happened in order to prevent a similar tragedy. It is chaired by Sir Martin Moore-Bick, a retired judge. Phase 1 of the Inquiry is considering what happened on the night of the fire. Hearings began on the 14th September 2017 and concluded on the 12th December 2018. The Phase 1 report is due to be released in Spring 2019.

Hearings for Phase 2, which will consider the events and decisions before and after the fire, are expected to begin toward the end of 2019 or early in 2020.

Hanan Wahabi survived the fire with her two children. Her brother Abdulaziz El Wahabi, his wife Faouzia, and children Yasin, Nur Huda and Mehdi died on the 21st floor. During her evidence she said.

> *'Sir Martin Moore-Bick 72 people died as a result of what happened. None of them had to die. This could have been prevented and should have not happened. Please make sure there is change'. Hanan Wahabi[i] (survivor and bereaved)*

WARNING: This document includes descriptions and pictures which some people may find distressing.

On 14 June 2017, the world watched in disbelief as the largest fire in London since World War II claimed 72[ii] lives.

This is a high level, non-technical account of what happened, based on the Grenfell Tower Inquiry expert witness hearings in November 2018[iii]. It considers:

- The refurbishment
- The start of the fire
- The breaking of compartmentation
- External fire spread
- Internal conditions and control failures, and
- Smoke and toxicity

It is sourced from the BBC Grenfell Inquiry Podcasts[iv] and the expert witness reports[v] available on the Inquiry's web site. Further expert evidence will be provided so this should be viewed as an emerging as opposed to a definitive picture. The Inquiry is due to publish its Phase 1 report in Spring 2019.

1 The refurbishment

Between 2012 and 2016 a major refurbishment was undertaken at Grenfell Tower. Significant changes were made to the façade of the building including the cladding system, the windows and the architectural crown. These changes turned a relatively safe building into an unsafe one.

1.1 The cladding system

> *"If a fire is ignited in a cladding system such as this made of these materials under any circumstances, we have to expect it to spread quickly and catastrophically"[vi] Prof Luke Bisby*

The rainscreen cladding system (Figure 1) that was added to the building during the refurbishment was comprised of

- two layers of polyisocyanurate (PIR) foam insulation against the original concrete walls
- a cavity separating the insulation from the
- Aluminium Composite Material (ACM) panels or cassettes which were comprised of two thin aluminium panels with a polyethylene (PE) core. (Figure)

Thermoplastics such as PE melt and drip and burn. Prof Bisby said that PE was the main cause of the fire spread and that the dangers of using such materials were well known and had been documented for decades. He would have expected any competent fire professional to be aware of these dangers.

Each cladding panel was cut and folded to hang on metal rails. This led to their being multiple routes where the PE was exposed directly to heat and flames. The metal rails enabled pooling of melted PE.

In addition, the way these panels and the windows were connected to the original façade meant that there were numerous vertical channels and extensive internal cavities. Horizontal and vertical barriers were installed in the cladding cavity, intended to isolate any fire. Some of the barriers were missing or incorrectly installed.

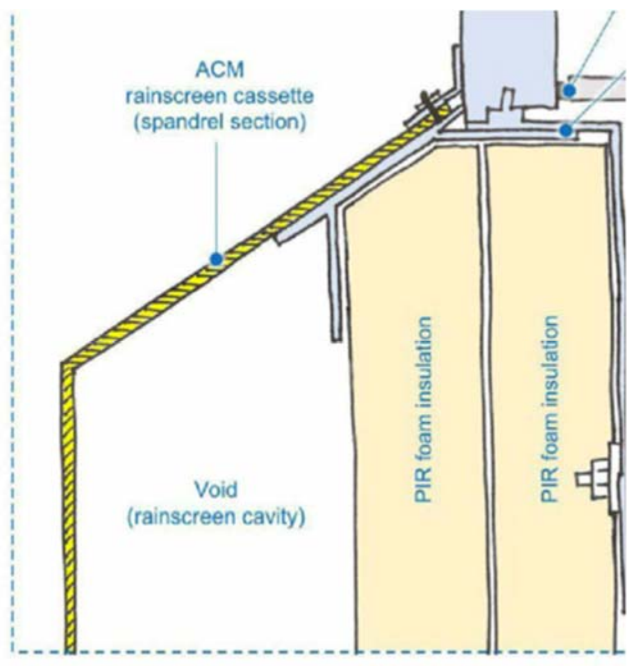

Figure 1: Cladding System[vii]

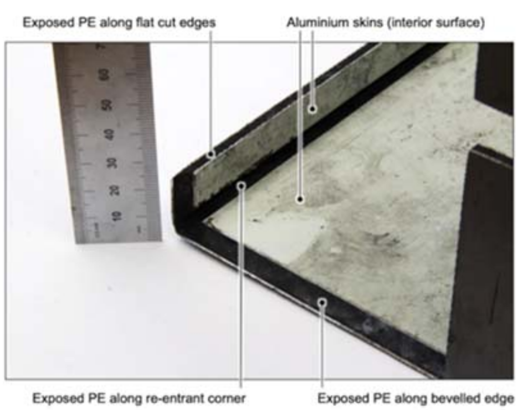

Figure 2: ACM panels or cassettes[viii]

European Standards for Fire Testing rate materials from A1 – non-combustible - through to F – which are 'really burny' (to use the words of Ms Grange (QC)). Current Regulations require cladding systems to be at a minimum of limited combustibility - A2. According to Dr Lane the PIR insulation was European Class D and the ACM panels European Class E.

1.2 The windows

Windows (Figure 3) were reduced in size during the refurbishment and moved to sit flush with the new cladding system. The old wooden window frames, sills and other materials were left in-situ. The new window frames and the extractor fans [set into the windows] were made of unplasticised polyvinyl chloride (uPVC) and were glued rather than fixed into position. uPVC melts at low temperatures.

Extruded polystyrene (XPS) was shaped and covered in aluminium foil to fill gaps around the extractor fans and was used in the infill panels placed between the windows. XPS melts rapidly forming burning droplets.

Phenolate Foam (PF) and spray foam was used in small quantities near the windows to fill drafts and gaps. PF is flammable, and it is possible that the foam was the first material to ignite.

An ethylene propylene diene monomer (EPDM) rubber membrane was used to cover the gap between the window and the wall. It too is flammable and once alight would allow a fire access to the cavity. Dr Lane said you could cut a hole into the EPDM and put your hand into the cavity.

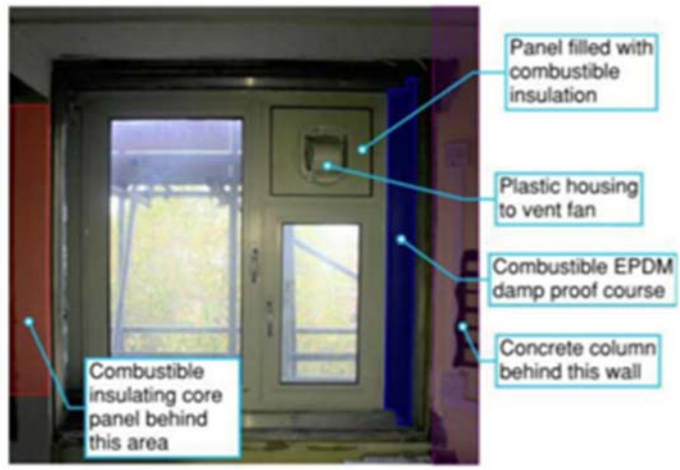

Figure 3: Windows[ix]

The materials around the windows were glued together and led directly into the cladding system on the outside of the building. Dr Lane said that building regulations require that cavity barriers should be placed around the windows to stop the spread of fire. None were present at Grenfell either in the design drawings or the building itself.

Dr Lane confirmed that:

> *Once there was a localised fire near the window the majority of the materials around the window had no potential fire resisting performance. No part of the construction had the ability to prevent fire spread from inside the building to the external cavity. And once there was a fire anywhere near a window there was very high likelihood it would break out the window into the cladding."* [x]

1.3 The architectural crown

A crown (Figure 4) was installed at the top of the building comprised of 'folded' ACM cladding. Its purpose was purely architectural. Exposed edges of PE were found everywhere in the crown.

Figure 4: Architectural Crown[xi]

2 The start of the fire …

The fire began in the kitchen of Behailu Kebede’s flat; number 16 on the 4^{th} floor.

Mr Kabede turned the main ‘fuse box’ off as he left the flat which Dr Glover said meant that investigators had a helpful ‘frozen moment’ in time from which to determine what had happened. At this point one of the electric circuits had already tripped which pointed to the area where the fire started and thus limited the number of appliances where the fire could have started.

Through investigating the electrics, the fire patterns and statements from witnesses and firefighters, the consensus is that the fire started in the Whirlpool Hotpoint Fridge/Freezer. Dr Glover suggests that the initial source of ignition could have been a poorly crimped wire in the relay compartment near the compressor. Prof Nic Daeid agreed that the fire started at the base of the fridge freezer and that it was electrical but suggested more testing was needed to pinpoint the component that started the fire. There have been two previous events of this model of Fridge/Freezer being potentially linked to a fire.

UK and EU regulations allow plastic covers at the rear of these appliances whereas the USA requires steel covers. A steel cover would likely have slowed the spread of the fire which may have enabled firefighters to extinguish the flames before they reached the cladding.

Sniffer dogs and laboratory tests found no traces of hydrocarbons or fire accelerants. Prof Nic Daied said that she was certain that the cause of the fire was accidental.

The initial size was equivalent to a waste paper basket or half an armchair being on fire. Fires of this size are not uncommon. Prof Torero said you would expect a building to respond appropriately to such a fire.

However, due to the nature of the refurbishments and the materials on the building Prof Torero confirmed that ...

> *In the event of any fire starting near a window at Grenfell Tower there was a disproportionately high probability of fire spread into the cladding system.* [xii] *Any kitchen fire within 3 m of the windows could have started the events of the night.*[xiii]

3 The breaking of compartmentation

Compartmentation refers to a design by which fire is contained within a single unit or a single floor. Prof Torero explained that it is the primary robust defence mechanism and the basis for the fire-fighting strategy. Compartmentation should not be viewed as the first layer of protection, but rather the only one that brings robustness. Once it was broken, no secondary defence (such as fire doors) could have been expected to withstand the fire.

The entire Grenfell fire-fighting strategy assumed compartmentation would work. “Stay put” (where residents remain in flats) relies on compartmentation working. Once the fire was in the external cladding at Grenfell compartmentation was breached.

Grenfell had a stay put policy that was reversed at 2:47, nearly 2 hours after the fire started.

Prof Torero believes compartmentation was breached by 1:05 (11 minutes after the fire started at 00:54) as at that point you can see dripping PE so you know that external propagation is happening. At this point you know that the fire is progressing in an unexpected manner and there is a flame creeping into the external components of the building. Stay Put was no longer appropriate at this point.

At the stage that compartmentation was breached the ignition of other components of the façade and the external flame spread was inevitable. At the stage that compartmentation is breached it invalidates the stay put policy. Egress or rescue is the preferred option once compartmentation is breached.[xiv] *Prof Torero*

Prof Bisby said that at 1:09 PE was burning in the cladding and this meant you had a fire that you expect to propagate left to its own devices. He said it is difficult to know if external firefighting prior to 1:16 could have made a difference. His view was that Stay Put was not a viable strategy as soon as the cladding was put on the building.

The cladding at Grenfell failed to meet the requirements of building regulations – which say that external walls must adequately resist the spread of fire. Because the cladding failed to do this the stay put advice should have been changed after the refurbishment. Once the refurb cladding was installed at Grenfell it follows logically that the stay put policy was also not a credible component of any fire safety strategy.

The fundamental assertion is that if a fire is ignited in a cladding system such as this made of these materials under any circumstances, we have to expect it to spread quickly and catastrophically because of the nature of the materials involved. On that basis it is unreasonable to expect compartmentation to be maintained and, on that basis, it is unreasonable to have a stay put policy in place[xv]*. Prof Bisby*

Dr Lane says compartmentation was breached at 1:13 but Stay Put failed at 1:26. At 1:21, 8 flats were affected and at 1:26, 20 flats were affected. Her view is that up until this point it was still a localised fire and it is unreasonable to have expected back then, on the night, that everyone should have known the minute the flame was in the cavity on the fourth floor that we knew what was going to happen. And, up until 1:26, while it was still within a few stories it was an event that could have been mitigated.

When asked if the nature of the materials within the cladding were known would that affect this view of what could have been inferred from seeing the fire breaking out of floor 4 Dr Lane said ‘

Well I’d go further – I think that if those materials had been known the building shouldn’t have been occupied because then the London Fire Brigade (LFB) would have then also known what was facing them’[xvi]

4 External fire spread

The fire at Grenfell acted differently to other cladding fires in that once it egressed into the cladding it spread and engulfed the entire building.

4.1 Egress: entering the cladding

There are two routes by which the fire could have entered the cladding – either directly through the windows frames and/or the extractor fan and surrounding materials, or externally by flames escaping through the windows and igniting the external ACM panels.

uPVC loses mechanical strength at relatively low temperatures. It melts at around 50°C. Ordinary glass, by comparison, melts or breaks at around 550 °C. The heat from the smoke of the relatively small fire was capable of causing the uPVC to fail, thus opening a path for the flames to any of the combustible materials outside. This would have happened 5 to 11 minutes after the fire started. The fact that the uPVC was glued rather than mechanically fixed in place would have contributed to the speed of the failure.

Prof Torero thinks the most likely path was flames spreading across the ceiling and reaching the inside of the window igniting any of the components exposed by the melted uPVC such as the PIR window insulation or the rubber damp proof membrane. A small fire was able to ignite any of these materials.

> *If you are relying on materials to provide any protection in a fire you ought to be in my opinion deeply suspicious of uPVC to provide it. Prof. Bisby* [xvii]

Flames could also have escaped through one of the windows and ignited the cladding outside. The PE core would have melted and dripped, so feeding the fire.

Prof Bisby suggests that it was probably a combination of both routes.

4.2 Engulfing the building: Vertical, horizontal, lateral fire spread and ingress

In 12 to 15 minutes, the fire spread vertically up 19 floors to the top of the east face of the tower. The fire accelerated as it rose and was similar to flame spread up a solid fuel surface.

Prof Bisby said this is what you would expect, and that the rate it spread to the top of Grenfell Tower was in fact slower than in a previous cladding fire in Dubai. He thought this was likely due to the fact that fires started on the ground from the dripping PE were extinguished at Grenfell whereas in Dubai, which started on a 20th floor terrace, the PE pooled and kept the heat release at the base of the fire strong.

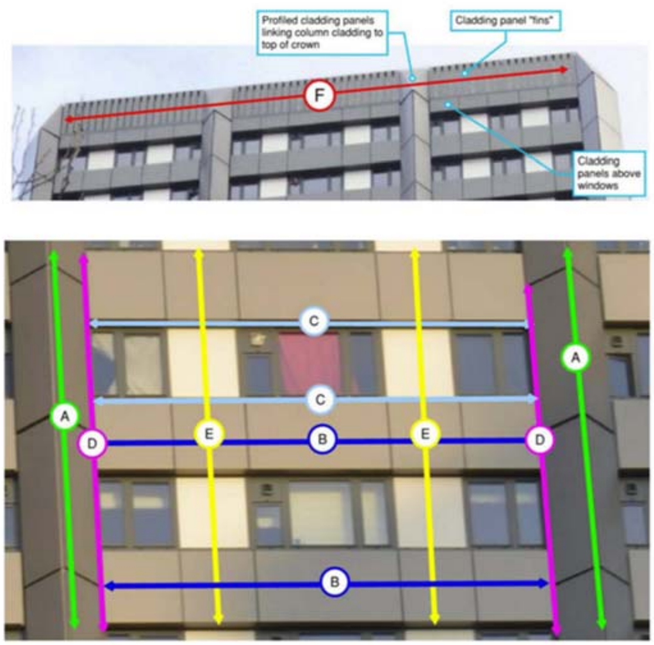

Figure 5: The 6 routes of fire spread[xix]

The materials on the tower were the most important factor in the rapid spread of the fire up the tower.

PE was the main contributor to the vertical spread but the PIR insulation also played a role heating the cavity behind the rainscreen. The materials would have fed off one other further fuelling the fire.

The materials, numerous cavities and metal railings created routes for the fire to spread vertically and horizontally. Dr Lane identified 6 routes that the fire took, she wanted to show that *'at every turn there is something there that can participate in a combustion process, so all the time the flame front had something that would allow it to carry on'.*[xviii]

The exterior of the building was meant to adequately resist the spread of fires and there were cavity barriers between the PIR insulation and the ACM panels. Cavity barriers are meant to stop the flames from exiting one compartment to the next. But they cannot stop a flame in a cavity if the wall itself is burning. The very founding principle is that the wall is not burning. Dr Lane said the use of a cavity barrier with a Rainscreen cladding system formed with an ACM panel is 'entirely problematic'.

> *If you put combustible materials outside the cavity barrier then the cavity barrier has no meaning as the burning can happen around the cavity barrier.*[xx] *Prof Torero.*

Cavity barriers were often shown to be missing or incorrectly installed but Dr Lane said this was likely not material, as soon as the fire was in the cladding there was nothing to stop it spreading around the building.

Prof Bisby said that in other cladding fires you tend not to see entire buildings engulfed. The distinguishing feature in this seems to have been the architectural crown which, as described earlier, was made of ACM panels with multiple folds exposing the PE. The flames appear to have been able to travel horizontally in both directions through the crown. The crown was almost acting as a fuse.

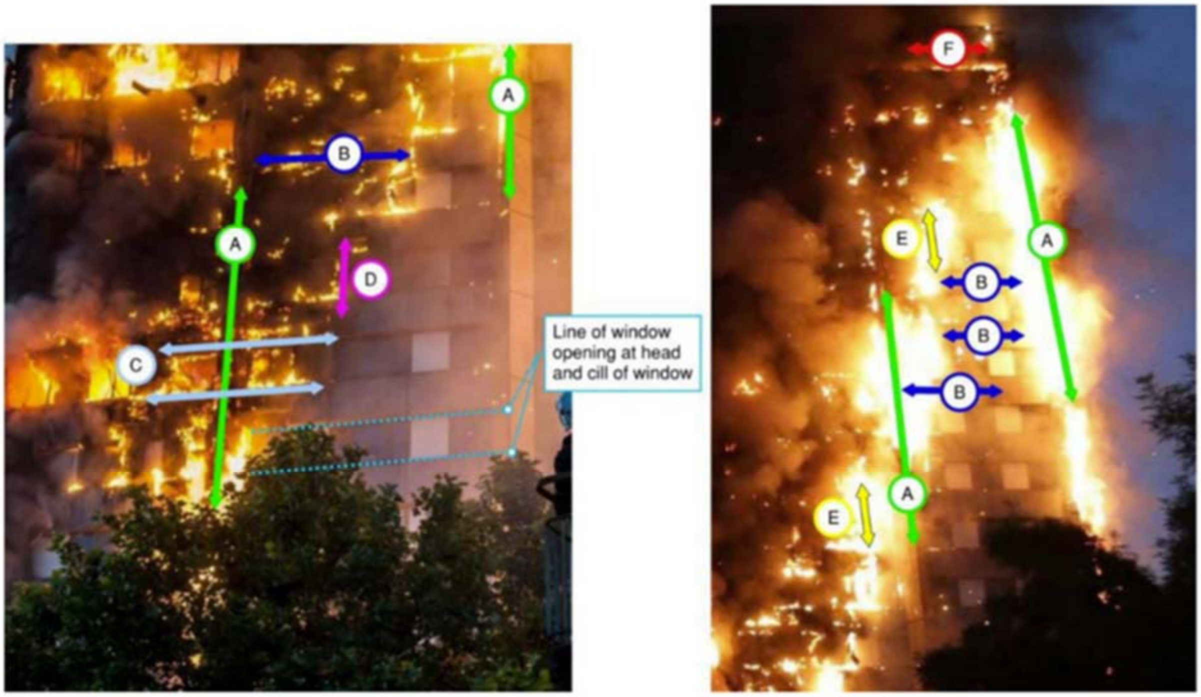

Figure 6: Photographic evidence of the 6 routes of fire spread[xxi]

The helicopter footing (Figure 6) shows the flame front progressing and causing extensive pools of burning PE which could then flow down the spandrels and columns. This pooling and dripping of the PE together with burning debris enabled the fire to spread down below the upper floors.

The fire spread rapidly laterally around the crown and engulfed the building as the PE melted and dripped and the lower fires made their way up the building.

The crown appears to have had no purpose other than architectural and when asked if there was anything that could have been done to stop the spread of fire in the crown Dr Lane said

> *'the only way to stop the crown from being a flame front on its own is to not clad it in combustive material'*[xxii]

The rapid internal penetration (ingress) of the fire above Level 20 (where most people died) can be attributed to the progression in the crown according to Prof Torero. Smoke and flames started making their way into the building. Glass smashed, extractor fans broke, the uPVC frames melted, and the smoke and fire would have travelled through open windows. Smoke may well have entered through gaps around the windows.

5 Internal conditions and control failures

In the event of a fire, the lobbies and stairs should have provided an environment that was safe for escape.

The central enclosed stairwell was designed to be a protected escape route in the event of a fire. The last place to which smoke and fire could spread. That's why it's built within the thick concrete core of the building. Lobbies likewise should have been protected from smoke and fire to enable access to the stairwell.

We know from evidence from both residents and firefighters that conditions in both the lobbies and stairwell inhibited evacuation, rescue and the ability to fight the fire. The systems to control flames and smoke in the lobbies and stairs failed.

Dr Lane reports very different behaviours from residents above the 17th floor.

- No-one residing on the 10th floor or below died.
- 16 people who originally resided between floors 11 and 17 died. 13 in the flats that they resided in and 3 whose bodies were recovered outside the tower.
- 54 who originally resided between floors 18 and 23 died. There was significant internal movement amongst this last group.
    - 47 bodies were recovered between floors 18 and 23. 24 people died on floor 23, 9 of whom resided there and 15 of whom had moved up the building to floor 23. 4 of these 47 were recovered from the stairwell above floor 18.
    - The 7 remaining bodies were recovered in the stairwell below floor 18 or outside the tower.
- 8 bodies in total were recovered in the protected lobbies or stairwells.

5.1 Internal Conditions

There was heavy damage to the lobbies and symptoms of high temperatures in the stairwell. Thick black smoke in the lobbies and stairs created a barrier (both physical and psychological) to residents and their ability to move from their flats. Poor visibility and irritants when they opened doors were a significant deterrent to escape. [xxiii]

Figure 7: Conditions inside[xxiv]

These internal conditions lowered the speed and ability of the firefighters to conduct rescues as it hampered their ability to ascend stairs, inhibited orientation and the heat impacted their ability to reach higher floors.

Figure 7 provides a link to a video from Marcio Gomez's flat on the 21st floor. As they open the door, it shows thick black smoke with zero visibility. A white wall was approximately 1 meter away. Mr Gomez, his wife and two daughters escaped the building. Their unborn son Logan Isaac was the youngest victim of the fire.

Prof Purser says there is a golden early period in a fire when people can make an easy escape. Fires tend to get worse at an exponential rate. So, if you delay escape you can get caught by rapidly deteriorating conditions. Half of the people between floor 6 and 11 had started to escape by 1:30 (36 minutes after the first 999 call). The rate of escape decreased rapidly thereafter.

Prof Purser said that if there had been a way to ask all residents to evacuate at the same time, they could have left within 7 minutes.

At some points it was safe for people to escape and at others not. Thick black smoke was reported in lobbies on floor 12, 14, 16, 18 and 21 between 1:30 and 2:00. A ‘hot zone’ was reported between floors 13 and 16 reaching 150°C. This temporarily stopped residents evacuating – between 1:45 and 2:25 nobody exited the tower from above that zone. Dr Lane reported some melted plastic lights in the stairwell and significant damage to the lobbies and stair doors on these levels. Prof Purser said that people can withstand quite high temperatures and that people could have gotten through those floors without having suffered severely.

However, this seems to have impacted the behaviour of people on floor 17 and above. With people trying to evacuate and then turning around and going back up, mostly to the 23rd floor. Meron Mekonnen's who left her flat on the 19th floor during the early stages of the fire when on the stairs those around her suddenly came back. She said

> *‘it changed everything once we heard ‘go back’ – we were panicked but on our way down – when we heard go back I assumed something terrible, something worse was happening below us – I assumed maybe it was another resident – probably seeing flames in the stairways – who could say go back – you know in a fire who could possibly say go back unless there was something worse – it changed everything … ‘*[xxv]

5.2 Control failures[xxvi] in lobbies

Front doors were replaced in 106 homes between 2011 and 2012. The vast majority of doors did not close automatically, as they should have done. Tests on the doors resisted fire for 15 minutes as opposed to the recommended 30 minutes.

Guidance since the 1970’s has been clear about the role of the self-closers on these lobby fire doors and their importance – to ensure that doors shut, in the case of a fire thus protecting the lobby from fire and smoke. Residents gave evidence about faulty and missing closing mechanisms and doors not closing. The Local Government Association, the department for Communities and Local government and the Tenant Management Organisation (TMO) which managed the building at the time of the fire all suggested regular inspections of doors.

It is thought that the initial density of smoke in lobbies was caused by front doors being left open. Either as people escaped or were rescued. The fire spread quickly up the east column of the tower setting fire to flats on this side of the building (Flat 6’s on each level). No-one died in these flats, they all managed to escape their flats (if not the tower). Many would have left their doors open as they fled and with missing or ineffective self-closers this would have opened a path for rapid spread of smoke.

Whilst the front doors are intended as a secondary protection against fire and smoke spread – it is inevitable that they will fail at some point - for people waiting in flats the protection that they provide is very important. Dr Lane confirmed that the doors resisted fire for only half of the 30 minutes recommended by regulations in Approved Document B. She also noted that she had been surprised that there was not stricter guidance regarding resistance to protection from smoke (in addition to fire)

The **smoke ventilation system** was designed to extract smoke from lobbies. But it only operated on one floor at a time. Dampeners were fitted to the vents on each floor to block the vents on all the levels apart from the one on which it was operating enabling smoke to leave the buildings. These dampeners were meant to stop smoke for 60 minutes. Dr Lane found that the dampeners were not tested to the relevant standards and they failed smoke leakage tests. Evidence from some residents’ points to smoke leaking from the ventilation system into the lobbies. Dr Lane says there is more work to do to understand if the dampeners were the only cause of the leaking smoke.

In addition, the **protected shafts** from the smoke ventilation system could have contributed to the spread of smoke as there was an opening between the lobby and shafts on every level. The protected ventilation shaft had not been lined or rendered as required by relevant guidance. The automatic opening vent (AOV) was of a lower standard than required and could have allowed more smoke to enter lobbies. Dr Lane could find no evidence of fire resistance or smoke leakage tests having been conducted. The performance of the ventilation system is not yet fully understood and will be reported on further in Phase 2 as will it's compliance with regulation.

The **distance from front doors** to the stairwell varied greatly, in some cases exceeding 10m, which impacted the hazards experienced in specific locations. Whilst non-compliant with current building guidance this would have been compliant at the time Grenfell was build.

The lift had been replaced but not upgraded to a firefighting lift as per current specifications and TMO policy. Firefighting lifts carry more people and have their own power source and escape hatch. Even though it had not been upgraded, firefighters should have been able to take control of the lift to carry equipment and conduct rescues. However, the override mechanism did not work on the night of the fire. Dr Lane said that there was a duty to test the override switches. There is a duty to maintain lifesaving equipment at all times in any building.

The failure of the lift meant that the only means of escape for people of limited mobility was to make their way down the stairwell in very hazardous situation. She said that there is currently no design guidance regarding how people of limited mobility get out in a fire which she finds very concerning.

In addition, the inability to take control of the lift meant residents were able to use it, they gave evidence that the lift quickly filled with smoke.

There was no evidence that the lift shaft itself was protected as the lifts did not have fire resisting doors.

Grenfell had a **dry riser** not **a wet riser**. High rise buildings are required to have what is known as a 'wet riser'. This was regulation at the time Grenfell was built. A wet riser means that water is available in the pipes in the building that are connected directly to the mains – they should be able to allow 2 pipes to operate at full pressure at the top of the building. Dry risers require the LFB to connect water to the mains which takes time and it is more difficult to get pressure to use hoses on higher floors. Dr Lane said that a wet riser may have increased the chances of extinguishing the original fire in Flat 16.

5.3 Control failures in the stairwell

In addition to doors of flats being left open, fire fighters left **stairwell doors** from the lobbies into the stairs open as they propped them open to rescue people or run fire-fighting hoses into lobbies and flats. In one instance a body propped a door open. This was the primary cause of smoke and heat entering the stairwell according to Dr Lane. The doors were non-compliant with fire standards.

Firefighting on the 10th floor with the door being left open is thought to have contributed to the 'hot zone' between floor 13 and 16.

The failure of ventilation in the common corridors and **lobby smoke** coupled with doors being propped open failed to protect the common stairs from smoke.

Services were run through the stairwell. During the refurbishment **gas pipes** had been run up the stairwell and from the stairwell to lobbies through newly drilled holes on 13 floors of the tower. Dr Lane said this created a link from lobby to lobby and enabled smoke to travel from one lobby to another. More research is needed to understand the impact. **Water pipes** were installed on lower floors. This was against regulation, but it is unclear if it had any impact on the fire.

It is unclear if the **lighting in the stairwell** failed or was ineffective due to the smoke. There was an issue with the **floor numbering** not being clearly visible, and perhaps not accurate as floor numbers had been changed during the refurbishment. This would have contributed to orientation difficulties both for residents and firefighters.

The **stair width** was less than current regulation, but Dr Lane said the width did not impede evacuation or firefighters attempts to fight the fire or conduct rescues.

6 Smoke and Toxicity

Prof Purser looked at the causes of incapacitation and death. The way the smoke moved around the fire and when the smoke got into the different lobbies was key to the incident. He explained the significance of the thick black smoke that was present in the tower.

If smoke is dense then there is a high concentration of toxic gases. There were two key toxic gases. carbon monoxide and hydrogen cyanide. Exposure to these can be deadly and people are unaware they are inhaling them, they have no real effect until you suddenly become dizzy and collapse.

The two gases act both cumulatively and additively. Perhaps surprisingly, cyanide fires tend not to be fatal. Hydrogen cyanide is initially incapacitating rather than deadly. If people die in fires, they usually have a lethal dose of carbon monoxide in their blood. If you're exposed to cyanide, it will make you collapse before you can escape rather than die.

Prof Purser identified the following as sources of gases at Grenfell. The **PIR insulation** produces high quantities of carbon monoxide. As it was enclosed in a cavity between the wall and the ACM cladding it was likely to have burned ineffectively thus increasing the amount of gas released. **PVC** produces high yields of carbon monoxide, but it also affects how surrounding materials burn as you've got partially burned gases (due it being under-ventilated) coming through the windows which increases the yield of both carbon monoxide and cyanide.

The outcomes for people depended on their exposure in the flats. Conditions in the lobbies were hazardous with occupants experiencing zero visibility, breathing difficulty and pain. It was not impossible at any time to descend the stairs. Essentially whether or not you are able to get down the stairs without collapsing depends on how long it takes you.

Ironically it was the least affected flats that become the most dangerous because when people took refuge in the South West corner of the block which was the last place to be affected by fire spread – they remained there for an hour or more before they were forced to evacuate or the fire got to them – and so – they were they were the most exposed to toxic gases.

Most people who died in Grenfell even those whose bodies were burned in flat fired died from Carbon Monoxide inhalation. Prof Purser said*…*

> *…dying from carbon monoxide, even if there's cyanide in the mixture, is not a painful death. You basically faint then go into slowly a coma and die.* [xxvii]

About me…

I partner senior executives in high hazard industries to develop the culture and leadership to prevent low probability, high consequence (catastrophic) events. I believe a systemic cause of Grenfell is the failure to understand or mitigate such events.

Key to this is understand the complexity of what happened. Catastrophic events are never the result of one failure, but rather an active failure (in this case a small kitchen fire) kick starts a process where existing latent conditions and failures combine to produce devastating consequences.

I wanted to understand how this had happened at Grenfell and this paper is my attempt to articulate the nature of the event. I hope it is valuable and informs debate and more importantly learning.

Between 2011 and 2014 I lived in a beautiful apartment on the 21st Floor of Grenfell Tower. I now live in a nearby tower-block. 7 of my former neighbours died.

As I watched the tower burn, I vowed to ensure we learn. This is written in honour of those that lost their lives, their loved ones and the Grenfell community who inspire and give me hope every day.

Gill Kernick
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References

[i] Hanan Wahabi evidence https://www.grenfelltowerinquiry.org.uk/hearings/evidence-bsrs-16, p.188
[ii] The official figures list 71 deaths. Maria del Pilar Burton, known as Pily, died in January 2018 and is counted as the 72nd victim although not included in the official deaths.
[iii] **The Expert Witnesses who gave evidence between 20th and 29th November 2018**
Prof. Luke Bisby on the ignition of the façade materials and the fire spread over the building's external façade.
https://www.grenfelltowerinquiry.org.uk/hearings/expert-evidence-professor-bisby
Dr. J. Duncan Glover on the assessment of the electrical fire origin in Flat 16
https://www.grenfelltowerinquiry.org.uk/hearings/expert-evidence-dr-glover
Prof. Jose Torero reporting on the fire spread throughout the building.
https://www.grenfelltowerinquiry.org.uk/hearings/expert-evidence-professor-torero
Dr. Barbara Lane reporting on the fire protection measures within the building
https://www.grenfelltowerinquiry.org.uk/hearings/expert-evidence-dr-lane-0
https://www.grenfelltowerinquiry.org.uk/hearings/expert-evidence-dr-lane
Prof. Niamh Nic Daeid on the cause and spread of the fire in the flat of origin and the spread of fire within and out of that compartment.
https://www.grenfelltowerinquiry.org.uk/hearings/expert-evidence-professor-nic-daeid
Prof. David Purser on the production of toxic gases and the consequences of inhaling toxic gases in such circumstances; the likely causes of incapacitation and death at Grenfell Tower
https://www.grenfelltowerinquiry.org.uk/hearings/expert-evidence-professor-purser
List of all expert witnesses
https://www.grenfelltowerinquiry.org.uk/about/expert-witnesses
[iv] Links to the **BBC Grenfell Inquiry Podcasts** for the expert witnesses:
https://www.bbc.co.uk/programmes/p06t3ky4, 28th November 2018 Professor Nic Daeid
https://www.bbc.co.uk/programmes/p06t0d31, 27th November 2018 Dr Glover
https://www.bbc.co.uk/programmes/p06sxj4q, 26th November Part 2 2018 Dr Lane
https://www.bbc.co.uk/programmes/p06sljjv, 22nd November Part 1 2018 Dr Lane
https://www.bbc.co.uk/programmes/p06sh22m, 21st November 2018 Prof Bisby
https://www.bbc.co.uk/programmes/p06scmjq, 20th November 2018 Prof Torero
[v] Link to the Grenfell Tower Inquiry Hearing https://www.grenfelltowerinquiry.org.uk
[vi] https://www.grenfelltowerinquiry.org.uk/hearings/expert-evidence-professor-bisby, 21st November transcript, p 159
[vii] Figure 1: Cladding detail Prof Bisby Phase 1 supplemental report, https://www.grenfelltowerinquiry.org.uk/evidence/professor-luke-bisbys-expert-report-supplemental, page 4
[viii] Figure 2: ACM Panel, Prof. Bisby Phase 1 supplemental report, https://www.grenfelltowerinquiry.org.uk/evidence/professor-luke-bisbys-expert-report-supplemental, page 101
[ix] Figure 3: Windows, Dr Barbara Lane Report - Section 9, https://www.grenfelltowerinquiry.org.uk/evidence/dr-barbara-lanes-expert-report-supplemental, page 27
[x] https://www.grenfelltowerinquiry.org.uk/hearings/expert-evidence-dr-lane, 22nd November transcript, p. 50
[xi] Figure 4: Architectural Crown, Prof. Bisby Presentation Part 2, https://www.grenfelltowerinquiry.org.uk/evidence/professor-luke-bisbys-presentation, p.99
[xii] https://www.grenfelltowerinquiry.org.uk/hearings/expert-evidence-professor-torero, 20th November transcript, p97
[xiii] https://www.grenfelltowerinquiry.org.uk/hearings/expert-evidence-professor-torero, 20th November transcript, p76
[xiv] https://www.grenfelltowerinquiry.org.uk/hearings/expert-evidence-professor-torero, 20th November transcript, p101
[xv] https://www.grenfelltowerinquiry.org.uk/hearings/expert-evidence-professor-bisby, 21st November transcript pp 158, 159
[xvi] https://www.grenfelltowerinquiry.org.uk/hearings/expert-evidence-dr-lane, 22nd November transcript, p. 170
[xvi] https://www.grenfelltowerinquiry.org.uk/hearings/expert-evidence-dr-lane, 22nd November transcript, p. 50
[xvii] https://www.grenfelltowerinquiry.org.uk/hearings/expert-evidence-professor-bisby, 21st November transcript, p 56
[xviii] https://www.grenfelltowerinquiry.org.uk/hearings/expert-evidence-dr-lane, 22nd November transcript, p. 84
[xix] Figure 4: Barbara Lane Section 10 (Phase 1 supplemental) page 55
[xx] https://www.grenfelltowerinquiry.org.uk/hearings/expert-evidence-professor-torero, 20th November transcript, p. 139
[xxi] Figure 5: Barbara Lane Section 10 (phase 1 supplemental page 8)
[xxii] https://www.grenfelltowerinquiry.org.uk/hearings/expert-evidence-dr-lane, 22nd November transcript, pp. 92. 93
[xxiii] https://www.grenfelltowerinquiry.org.uk/evidence/dr-barbara-lanes-expert-report-supplemental, Section 19, p 5, 13
[xxiv] https://www.grenfelltowerinquiry.org.uk/evidence/exhibit-marcio-gomes, still from video
[xxv] https://www.grenfelltowerinquiry.org.uk/hearings/expert-evidence-professor-purser, 29 November transcript, pp. 85, 86
[xxvi] Control failures in lobbies and stairs draws heavily on pp. 21 – 36 of Section 2 of Dr Lane supplemental evidence https://www.grenfelltowerinquiry.org.uk/evidence/dr-barbara-lanes-expert-report-supplemental
[xxvii] https://www.grenfelltowerinquiry.org.uk/hearings/expert-evidence-professor-purser, 29 November transcript, pp. 85, 45

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