Monday, 18 June 2018

(10.00 am)

SIR MARTIN MOORE-BICK: Well, good morning, everyone, and welcome to this week's hearings. We're going to begin the week by hearing some presentations from the various expert witnesses instructed by the inquiry.

Yes, Ms Grange.

MS GRANGE: Mr Chairman, thank you.

This is the first of three days of expert presentations. These will be given by Dr Barbara Lane, Professor Niamh Nic Daeid and Professor Luke Bisby. As Mr Millett outlined in his opening submissions, the purpose of these expert presentations is to set in context the factual evidence which will shortly be called in Phase 1.

Dr Lane will be introducing key aspects of the building and its history, and will identify the active and passive fire and safety measures which were present in the tower at the time of the fire.

Professor Nic Daeid's presentation will address three principal topics: first, the basic science of fire; second, the element of fire investigation, and in particular what evidence such as fire markings can tell us about the origin of a fire; and, third, a summary of her preliminary analysis of the cause and origin of the

initial fire within the kitchen of flat 16.

Professor Bisby will be explaining certain key scientific concepts relevant to flammability and flame spread, and will describe the material properties of certain materials present in the facade and the windows in the tower. He will also set out the preliminary evidence which assists in understanding the pattern of flame spread out of flat 16 and over the exterior of the tower on the night of the fire.

It is hoped that these expert presentations will assist in setting the framework and context to the factual evidence which will follow, including from firefighters, who will be called first, and from the bereaved and survivors of the fire who escaped from the tower and who will give evidence from September.

In terms of the substantive conclusions of the experts in their Phase 1 reports, those will be tested when they come to give detailed evidence in October, and once they have heard and taken account of the factual Phase 1 evidence. It is at that time that the experts will be questioned on the key opinions they have expressed in their reports on Phase 1 issues.

At that stage, we will also hear from other inquiry experts, and in particular Professor Jose Torero, who has considered the ignition of the facade materials, the

fire spread to and on the exterior of the tower and the fire and smoke spread within the tower.

We will also hear from Professor Purser. He will be dealing with the issues relating to the production of toxic gases, including the toxicity performance of materials present in the tower on the night of the fire.

Mr Chairman, the core participants were informed by letter last week that if they wish to suggest relevant questions for the inquiry experts when they provide their oral evidence, those should be submitted to the inquiry solicitor's mailbox by Monday, 3 September 2018. If there are any further questions which arise out of factual evidence heard after that time, then those will need to be provided no later than five clear working days before the relevant expert is due to give oral evidence.

Prior to calling Dr Lane, who will give today's presentation, I need to give some trigger warnings about the content of the forthcoming expert material.

The presentation of Dr Lane which will take place today will contain images of the tower before the fire, and also some detailed images of certain parts of the building after the fire, concentrating on the physical features of, for example, the cladding, the windows and fire doors. There will also be a simulation of a fire

in a flat with reference to how stay put is intended to operate.

I will be calling Dr Lane today.

The presentation of Professor Nic Daeid, which will take place tomorrow, will contain detailed images of the flat of origin, flat 16, after the fire, the burnt-out compartment. It will also include videos showing the early development of the fire and thermal images of the firefighting in flat 16, together with the playing of the first 999 call by Mr Kebede.

Mr Andrew Kinnier QC will call Professor Nic Daeid tomorrow.

Finally, the presentation of Professor Bisby, which will take place this Wednesday, will include a large number of images and videos depicting the external flame spread on the night of the fire. This will include the playing of his composite flame spread video, which was played by Mr Millett in his opening, and detailed consideration of that and of other flame spread material which shows the tower burning and on fire.

Some of the videos include the audio of persons witnessing the fire and their distress at the unfolding events. The presentation will also contain a number of images of the burnt-out tower after the fire and the playing of the first 999 call again.

Mr Millett will call Professor Bisby.
So I would now like to call Dr Lane.
SIR MARTIN MOORE-BICK: Yes, thank you.
DR BARBARA LANE (sworn)
SIR MARTIN MOORE-BICK: Thank you very much. Sit down if you like.
MS GRANGE: Thank you, Dr Lane.
Can you give the inquiry your full name?
DR LANE: Dr Barbara Lane.
MS GRANGE: I'm going to put to you a number of propositions which I hope will be uncontroversial.
You have provided to the inquiry a preliminary Phase 1 report which is dated 12 April 2018 and which consists of 21 chapters and 11 appendices, A to K.
DR LANE: Yes, I have.
MS GRANGE: That report addresses in particular the active and passive fire protection measures within the tower and the extent to which they failed to control the spread of fire and smoke and contributed to the speed at which the fire spread.
DR LANE: That's correct.
MS GRANGE: As you indicate in the declaration in section 21 of your report, you have provided it in the same way as you would have provided a report to a court.
DR LANE: That's correct.

MS GRANGE: In section 1.1 and appendix A to your report, you have outlined your background and experience relevant to the matters in this inquiry.
DR LANE: Yes, I have.
MS GRANGE: Now, we don't need to rehearse all of that in detail today, but I want to pick out some key points.
You are a director of Arup, which is an independent company of designers, planners, engineers, consultants and technical specialists addressing professional services in the built environment.
DR LANE: Yes, I am.
MS GRANGE: You specialise in fire safety engineering in the built environment and you have 20 years' experience in the construction industry in England and internationally.
DR LANE: That's correct.
MS GRANGE: You are a chartered fire safety engineer, having graduated from Trinity College Dublin.
DR LANE: Yes, that's correct.
MS GRANGE: You are a fellow of Arup, which is an honorary title awarded to exceptional individuals within the firm.
DR LANE: Yes, I am.
MS GRANGE: Finally, you are also a fellow of the Royal Academy of Engineering and the Royal Society of Edinburgh.

DR LANE: Yes, I am.
MS GRANGE: Thank you.
I outline that, Dr Lane, so that everyone will appreciate the expertise that you are able to bring to bear and your experience in dealing with the matters this inquiry has asked you to consider.
Are the factual matters set out in your report true to the best of your knowledge and belief?
DR LANE: Yes, they are.
MS GRANGE: Does your report accurately set out your opinions on matters relevant to this inquiry?
DR LANE: Yes, it does.
MS GRANGE: Thank you, Dr Lane.
Now, in your own time, please, would you go ahead and give your oral presentation.
DR LANE: Okay, thank you.
SIR MARTIN MOORE-BICK: If you would like to stand or sit, you do whichever is most comfortable.
DR LANE: I'll move around a bit.
SIR MARTIN MOORE-BICK: Yes, do that too.
DR LANE: Good morning.
I've arranged my opening presentation into an ordered series of subjects as follows.
First, this morning I will start by explaining the

original construction materials and the original building form and layout when Grenfell Tower was designed and built between 1967 and 1974. I will provide information on the external landscape around the tower at that time also.
I will then provide a detailed presentation on the fire safety requirements for high-rise residential buildings in England.
In part 1, I will address the Building Regulations and the requirement to provide a stay-put strategy, how it is a design condition and why it is not a Fire Brigade policy. I will address how this is the single safety condition required to be provided.
In part 2, I will explain each of the required active and passive fire protection measures that are provided for the stay-put strategy.
I will then move specifically on to Grenfell Tower. I will explain the summary time-line I have derived regarding the recorded building works to the tower since 1974, before explaining, in chronological order, each of: the replacement of the passenger lifts which took place in 2005; the replacement of the majority of the flat entrance fire doors in 2011; a description of the gas supply refurbishment works which had commenced in 2016 and were still in progress the night of the fire.

I will then dedicate the rest of the afternoon session to describing in detail the works that were undertaken on the building as part of the primary refurbishment carried out between 2012 and 2016. This includes a description of the work done to the interior of the building as well as the works done to the exterior of the building.

I will provide an overview and then explain in the following order the external works to the immediate surroundings of Grenfell Tower: the reconfiguration of ground level to level 3; the reconfiguration of the internal fire main; the refurbishment of the existing smoke control system; the provision of a new heating system and the new hot and cold water systems, before ending with a detailed explanation of the materials forming the rainscreen cladding works as I have found them in my work for the inquiry.

My colleagues working with me on my factual investigations are Susan Deeny, Peter Woodburn, Tom Parker, Alfie Chapman, Daniel Antonellis and Graeme Flint.

Dr Flint is in attendance to operate the series of photos, illustrations and animations throughout the presentation which we have provided in order to help understand the technical issues I'm focusing on today.

The original building construction and layout.

As I've explained in section 3 of my preliminary Phase 1 report, Grenfell Tower is a 25-storey building with a basement level and a ground to level 23 inclusive, plus a plant room located above level 23 at roof level. It is a residential block built in the early 1970s and is located in the Lancaster West Estate in the North Kensington area of London.

The Lancaster West Estate is located in the Royal Borough of Kensington and Chelsea. The estate was designed by Clifford Wearden & Associates in the late 1960s. Phase 1 was approved in 1970 and consisted of the tower as well as three low-rise residential blocks called finger blocks. These are Testerton Walk, Hurstway Walk and Barandon Walk. They are three- and four-storey buildings.

Construction of Grenfell Tower by contractors AE Symes of Leyton, London, commenced in 1972, with the tower completed in 1974.

To help explain the external spaces around the outside of Grenfell Tower, I have drawn on some additional information not currently in my report, using online mapping services and commercially available context models of the surrounding area.

There was a walkway at level 2 of Grenfell Tower

that allowed access from each of the finger blocks over to the tower. The finger blocks extend to the south side of Grenfell Tower and enclose two large green spaces. The area to the immediate east of Grenfell Tower is Lancaster Green and there were children's play areas to the immediate west. To the north side lies Silchester Road.

Grenfell Tower is owned by the local authority, Kensington and Chelsea London Borough Council. Grenfell Tower was part of their provision of social housing in the borough. The management of social housing in the borough was devolved in 1996 to the Kensington and Chelsea Tenant Management Organisation.

Originally, the main fire vehicle access designed for was via Grenfell Road at the south end of the tower. Based on the original design drawings, it also appears that fire vehicles could also have accessed the building via Silchester Road at the north end of the tower if that was needed.

As shown in this 3D model, fire vehicles approach the building from Grenfell Road in the south, with access to the southeast corner of the tower provided by driving under the level 2 walkway.

In this series of photographs, this southern approach route is shown, which was the state before the

last refurbishment works occurred. The height between the road surface and the underside of the walkway structure is approximately 4.8 metres.

The presence of the walkway is important in retrospect because it means that, whilst it was tall enough to allow fire vehicles to access underneath the walkway for the purposes of internal firefighting, such a walkway provides an obstacle for unplanned external firefighting, as became required during the fire. High-reach appliances would need to move out from underneath the walkway to deploy their ladder or platform and to deploy their stabilisation systems.

The areas around the east, north and west side of the building were quite open, with a mixture of grassy areas and hard landscaping. It is useful to orientate from the south side, where the three finger blocks are located.

Originally, outside and around the tower at ground level were positioned a ballgame pitch, nursery play areas and other amenity landscaping. From online mapping services, it is apparent that the amenity landscaping around the base of the tower was largely retained until around 2012.

In this image, all the areas around the building that could support vehicle access are highlighted in

red. In its original form, therefore, fire vehicles could have moved around the base of the tower as follows: three-quarters of the south side; full access to the east and north side; half of the west side.

Pedestrians and, therefore, firefighters could additionally reach all parts of the outside of the building originally at ground level as I have marked here.

Originally, there were three main pedestrian entry routes into Grenfell Tower. At ground level, firefighters could access the lifts within the central core there. Alternatively, they could climb one of the three open stairs external to the tower up to the walkway at level 2. At this level 2, access was also possible into the central core, to the protected internal stair and the original lifts. Therefore, firefighters would've been able to access the inside of the tower by the walkway. However, fire vehicle access was only provided at ground level.

Grenfell Tower is 67.3 metres tall. Originally, it contained 120 one- and two-bedroom flats. There were six dwellings per floor on 20 of the 24 storeys, with the other four storeys being used for non-residential purposes. It was originally intended to house up to 600 people. Levels ground, 1 and 3 were more flexible open

spaces which were created for uses such as a nursery, offices and a community health centre. Level 2 was left entirely open as a continuation of the walkway connecting to the adjacent blocks of the Lancaster West Estate.

Each storey in Grenfell Tower is 2.6 metres high, except for level 2, which is 4.3 metres high, and level 3, which has a height of 3.9 metres.

Grenfell Tower has a plan floor area of approximately 22 by 22 metres. It has a single central reinforced concrete core, reinforced concrete floors and with perimeter reinforced concrete columns. Reinforced concrete cross walls were provided to separate each flat at level 4 to level 23 inclusive. These walls did not extend to the basement level, nor did these walls exist at ground to level 3.

The structural stability mechanism for Grenfell Tower is that of a conventional concrete building, with a lateral stability core in the middle of the building and concrete columns around the perimeter supporting gravity loads. The floor is a flat reinforced concrete slab transferring load directly to the core. At the perimeter of the building, loads are transferred into the columns directly by the floor and via the precast perimeter beams. Additional support to

the floor is provided by the concrete cross walls between the flats.

To add further detail to the description I've currently included in my report, the floor slabs were 20 centimetres thick. The walls enclosing the protected lobbies, stairs and lift shafts on every level are collectively referred to as the core walls. The thickness of the core walls vary between 20 and 30 centimetres.

The perimeter beams are approximately 25 centimetres thick. The perimeter columns are approximately 70 centimetres square. This does not include the precast ridge facing that was used as sacrificial form work. This ridged facing, as visible today on the tower, was permanently connected to the columns through the provision of metal wires embedded in the concrete. The structural walls between flats were 20 centimetres thick.

The original external wall of Grenfell Tower consisted of exposed concrete surfaces and glazing. The perimeter beams were solid concrete. The opening between each perimeter beam was filled with a combination of sliding windows held in aluminium frames and non-structural, non-combustible infill panels. The specific material of the infill panels is currently

unknown, but I understand it to consist of asbestos-bearing cementitious material.

As you can see in this photograph and highlighted by the yellow dotted line, the windows fully filled the space vertically between the top of one perimeter beam and the underside of the next beam.

Horizontally, the metal window frames were fixed directly to the concrete structure on three sides and to the infill panel on the fourth side. The external wall of the building was, therefore, entirely non-combustible.

The external wall was a single system. This meant there was no void or space concealed within that external wall.

From here, I will refer to such spaces, concealed spaces, as cavities. Cavities are spaces enclosed by elements of a building or contained within an element of the building. I will be presenting more information on the issue of cavities and building construction later in my presentation.

I now move inside the building to describe the original construction of the window and the external wall internally.

Here is a photograph of the inside of a two-bedroom flat before the refurbishment works were undertaken.

This is taken from section 8.4 of my report. The photograph shows the original form of the interior window finishes and the windows themselves. The windows were originally side sliding metal framed windows in a wooden frame fixing system. As I have already noted, these windows and the adjacent infill panels fully filled the space between each perimeter beam from floor to floor.

The window cills, the window jambs on both sides and the head of the window appear to be lined in timber. The original infill panel also appears to have been faced with timber on the room side.

Below the windows, a plasterboard covered with a polymeric insulation, a product called purlboard, was applied directly to the concrete perimeter beams. This layer of purlboard was also applied to the concrete ceiling in a small area close to the external wall, but ran along the full perimeter of every room in every flat at ceiling level.

Therefore, in terms of combustible material, the original design contained the internal timber surrounds and timber lining of the infill panel, as well as the purlboard above and below the window on the room side. This combustible material did not extend to the outside of the building.

Levels ground, 1 and 3 contained a nursery at ground floor, community use rooms at level 1 and a health centre at level 3.

The layout of levels 4 to 23 were the same on every storey. There were six flats on each of these storeys. The flats in each corner were two-bedroom flats, and the retaining two, one on each side of the core, were one-bedroom flats. Reinforced concrete cross walls and floors separated each flat on level 4 to level 23. Therefore, each flat was enclosed in fire-resisting construction. This is known as compartmentation and I will further describe this concept later on.

Within the central core was a common lobby that provided access to each of the flats. This lobby also provided access to the residential lifts and the only means of escape, the single escape stairs. This lobby was a separate compartment to the flats and enclosed within its own fire-resisting concrete walls.

The original smoke control system used automatic vents on the north wall of the lobby to exhaust smoke into smoke exhaust shafts on the north side, with fresh air being supplied from fresh air shafts through automatic vents on the south wall of the lobby. These smoke and fresh air fans were provided for firefighters to operate if required.

The basement has been used since 1974 as a plant space for the various electrical, gas, water and heating systems in the building, with multiple services shafts rising up from the basement through every storey in the tower.

Level 24 is roof level. This level had a fully enclosed plant space in the central portion of the storey, with an open walkway around the perimeter of the roof. A ladder was also provided to the roof of this main plant enclosure. There, at the roof of the plant enclosure, was located: the outlets from the flues from the basement gas boilers; the outlets from the smoke control system; the outlets from the lift motor room and lift shaft ventilation systems; the permanently open vent provided at the top of the stairs; the output vents to the waste pipe stacks serving each of the flats on each of the floors.

This ends my explanation of Grenfell Tower and its surrounding area as it was designed and constructed between 1967 and 1974.

I will now set out the fire safety requirements for high-rise residential buildings in England and, in doing so, address specifically the design requirement to provide a stay-put strategy. I will explain how it is designed and how it is intended to operate.

After a short break in the second part of this presentation, I will then explain each of the active and passive fire protection measures required to create the safety condition, the stay-put strategy.

Building fire safety is dealt with through the requirements of the Building Regulations. The Building Regulations state that the requirements shall not require anything to be done except for the purpose of securing reasonable standards of health and safety for persons in or about buildings and any others who may be affected by buildings or matters connected with buildings.

The Building Regulations contains a series of requirements; they are all listed on this slide.

Fire safety requirements are dealt with in part B of the Building Regulations: Part B -- fire safety.

The Building Regulations make clear that Approved Document B, fire safety, is approved by the Secretary of State for the purposes of the 2000 regulations. Approved Document B is therefore what I refer to as the statutory guidance document in my report and in this presentation.

Fire safety requirements are considered by means of five specific requirements. I've reproduced each one on each of the next five slides.

B1 deals with means of warning and escape. The building shall be designed and constructed so that there are appropriate provisions for the early warning of fire, and appropriate means of escape in case of fire from the building to a place of safety outside the building capable of being safely and effectively used at all material times.

Requirement B2 deals with the requirements to inhibit internal fire spread as it relates to the internal linings of a building.

Requirement B3 deals with further requirements for internal fire spread as relates to the structural stability of the building, subdividing a building with fire-resisting construction and preventing the unseen spread of fire and smoke within concealed spaces.

Requirement B4 makes requirements regarding external fire spread and, specifically, that the external walls of the building shall adequately resist the spread of fire over the wall and from one building to another, having regard to the height, use and position of the building. It makes requirements for the fire performance of the roof of the building.

Requirement B5, the fifth and last of these building requirements, deals with the requirements for access and facilities for the fire services. Specifically, it

requires that the building shall be designed and constructed so as to provide reasonable facilities to assist firefighters in the protection of life. Further, it requires that reasonable provision shall be made within the site of the building to enable fire appliances to gain access to the building.

There are three other general requirements, but specifically relating to fire safety.

The first of these three is the requirement to provide fire safety information, regulation 38. This requires the person carrying out the building work to give fire safety information to the responsible person for that building no later than the date of completion of the work and as reproduced on this slide. The responsible person is the person who owns or controls the building.

The required fire safety information to be provided is defined in the Building Regulations as information relating to the design and construction of the building which will assist the responsible person operate and maintain the building with reasonable safety. This is for any building where the Regulatory Reform (Fire Safety) Order applies. This is the legislation that provides for fire safety duties when buildings are completed and occupied. The Building Regulations relate

to design and construction stages only.

There is a further requirement for any building to which the Regulatory Reform (Fire Safety) Order will apply once that building is occupied; that is a requirement to make a full plan submission. This means providing a description of the proposed building work and any other plans necessary to show that the work would comply with regulations.

The final requirement is the requirement of the local authority to provide a completion certificate for buildings to which the Regulatory Reform (Fire Safety) Order will apply.

I note the requirement for a local authority to ascertain, after taking all reasonable steps, that the relevant requirements specified in the certificate have been satisfied. The relevant requirements mean the requirements of regulation 38 regarding the required fire safety information being provided to the responsible person and the five requirements of part B. I note also that the Building Regulations currently state that such a certificate is not conclusive evidence that the requirements specified have been complied with.

These are the requirements under the Building Regulations.

I would like now to draw your attention to

Approved Document B for fire safety, which is approved, as I said, by the Secretary of State for the purposes of what's called practical guidance with respect to the requirements contained in the Building Regulations. Therefore, Approved Document B communicates practical guidance for the five fire safety requirements, B1 to B5 inclusive.

I note it acknowledges that there may well be alternative ways of achieving compliance with the requirements. I have no evidence that such an alternative approach was considered in matters relating to Grenfell Tower and will therefore not mention the concept of an alternative approach again. I will refer to this statutory guidance document, Approved Document B.

Just as the Building Regulations directly connect design and construction-related duties to the Regulatory Reform (Fire Safety) Order, so too does the approved document make that clear.

Approved Document B states, for blocks of flats, the Regulatory Reform (Fire Safety) Order applies to the common parts of blocks of flats only. It advises it would be useful for designers to carry out a preliminary fire risk assessment of the building as part of the design process, and how this fire risk assessment can

then be used in the Building Regulations submission and can be used to assist the fire safety enforcing authority in providing advice on any additional provisions that may be necessary in the occupied building.

However, for high-rise residential buildings the Housing Act 2005 also applies and exists in parallel with the Regulatory Reform (Fire Safety) Order. Section 3 of the Housing Act requires local housing authorities to keep housing conditions in their area under review and to investigate and take action against hazards that may be present. Fire is explicitly referenced as a relevant hazard in section 10 of the Act.

Where fire hazards are identified in the common parts of flats, the Act requires the local housing authority to consult the local fire authority, where possible, before taking action.

It is important to note that the Housing Act 2004 states the common parts of a building include the structure and the exterior of the building.

Before I explain the stay-put strategy, it's important to note that the term "stay put" is not used anywhere in Approved Document B. It states:

"a. the fire is generally in a flat;

"b. there is no reliance on external rescue ...

"c. measures in section 8 ... provide a high degree of compartmentation and therefore a low probability of fire spread beyond the flat of origin, so that simultaneous evacuation of the building is unlikely to be necessary; and

"d. although fires may occur in the common parts of the building, the materials and construction used there should prevent the fabric from being involved beyond the immediate vicinity ..."

It further states these provisions assume that, in the design of the building, reliance should not be placed on external rescue by the fire and rescue service, nor should it be based on an assumption that the fire and rescue service will attend an incident within a given time.

This approved document has been prepared on the basis that, in an emergency, the occupants of any part of a building should be able to escape safely without any external assistance.

Approved Document B refers for means of escape from flats to a British Standard, British Standard 5588 part 1, which is called "Fire precautions in the design, construction and use of buildings: code of practice for residential buildings". This is no longer current but

remains cited in the Building Regulations. It is now superseded by British Standard 9991 called, "Fire safety in the design, management and use of residential buildings".

BS 9991 does refer to the stay-put strategy and in four specific locations.

First, regarding escape, which is almost identical to the text used in Approved Document B. It goes further and refers to occasions where operational conditions are such that the fire and rescue service decide to evacuate the building. This is the only reference in the standard and no specific provisions are made in order to enable the communication of this change or the management of this change with regard to the provision of active and passive fire protection measures within the building.

Secondly, BS 9991 refers to the need for additional protection to the staircase by the provision of smoke control because of the stay-put strategy.

Thirdly, regarding an increase in fire resistance periods for structure for the occupants of other dwellings remaining in place.

Finally, it specifically references the stay-put strategy regarding the fire performance of the external face of the building. It says flame spread over or

within an external wall construction should be controlled to avoid creating a route for rapid fire spread by bypassing compartment floors of walls. This is particularly important, it says, where a stay-put strategy is in place.

I would like to conclude with a reminder from the very first British Standard code of practice for flats, referred to as CP3, where in 1962 it provided the first explanation of the stay-put strategy, where occupants, if they choose, remain safely on their own floor and occupants on the floor on which the fire occurs, and in some circumstances those floors in the immediate vicinity of the fire, should be free to reach safety in another part of the building via the staircase. Since that time, a total building evacuation has not been provided for when designing the active and passive fire protection measures.

I have set out each of the statutory guidance document, Approved Document B, and the British Standards since 1962 because they all provide the same requirement for active and passive fire protection measures in high-rise residential buildings.

I note that whilst stay put is directly referenced in the British Standards, no such mention of it nor what it relies upon is provided in Approved Document B.

I will refer to those published guidance documents at times throughout my presentation today. These published guidance documents are all matters of Building Regulations; they are not matters of Fire Brigade policy.

The stay-put strategy.

During a single flat fire, the occupants of that flat evacuate and all other occupants are safe if they remain where they are. The concept of being safe to remain where they are during a fire is the stay-put strategy.

It is the single safety condition provided for through the statutory guidance document, Approved Document B, and all versions of the British Standards for flats to date.

It is a single safety condition, but with multiple layers of protection provided. These layers of protection, or safety layers, are provided through the required active and passive fire protection measures: the building construction, including its external walls, the internal compartmentation in the building and the structural stability system of the building, or the active fire protection measures, such as smoke control to the staircase. One of the other layers of safety is something I have chosen to refer to

in my Phase 1 report as "defend in place" firefighting.

Since 1962, CP3 states the guiding principle in the recommendations which follow is safety of life. In securing this, means of escape, construction and firefighting all play a part.

Section 701 goes on to state that in high blocks of flats it is essential that provision should be made to assist the fire service in applying water to a fire as early as possible. The need to apply water early in a fire and the need for the fire being extinguished early are required of the Fire Brigade. This form of firefighting is provided for by means of the active and passive fire protection measures in the building too.

So the building construction, its active fire safety systems and the firefighting in combination provide the safety of life and are the foundation of the stay-put strategy.

Defend in place firefighting also relies on the high degree of compartmentation in a high-rise residential building, because it is this compartmentation which enables this single flat fire event upon which the stay-put strategy relies. This compartmentation is the very basis of design.

I will now narrate an explanation of how the stay-put strategy is designed to function in a fire.

This is in order to explain how the design of the active and passive fire protection measures, which includes the external wall fire response, provides the safety condition required, which is for the building residents and for the firefighters. The content of this section of my presentation is drawn from section 3.2, 3.3, 3.4 and section 18 of my report.

In the event of a fire in a flat, a fire detection and alarm system should be present in the flat and raise the alarm for occupants in that flat only. No alarm will sound anywhere else in the building. The Fire Brigade will not be alerted automatically.

Once alerted to the fire, the occupants should leave the flat with the door shut behind them. To support this first stage of evacuation from the flat itself, a protected entrance hall is required within the flat.

In a single stair building, the person from within the flat on fire must first escape through the common lobby over to the stair entrance.

A range of fire protection measures are provided to protect the occupants when travelling through the lobby: fire-resisting walls around the flat of fire origin; fire-resisting walls around the protected lobby and around the protected stairs; fire doors in the relevant fire-resisting walls; a smoke control system

extracting heat and smoke from the protected lobby, designed to prevent smoke from being able to penetrate into the stairs, but providing some local protection in the lobby too; controls on materials in the common lobby to prevent rapid fire spread through this part of the escape route in the event fire breaks out of the flat compartment.

People in adjoining dwellings on the same floor do not automatically evacuate. They have received no alarm or signal to evacuate. The design is focused, therefore, on containing a fire within the flat of fire origin, creating a single flat fire event. This is provided through the fire-resisting walls and floors in that flat.

The final side of the fire-resisting box is the external wall. In accordance with the Building Regulations, the construction of the external walls are required to adequately resist the spread of fire. Therefore, the people in adjoining flats on the same floor, who rely on the same horizontal escape route through the lobby, are protected, because the design intent is that the fire stays within this one compartment or box around the flats. Everything is invested in preventing the internal spread of fire. The required external wall fire performance based on

adequately resisting the spread of fire is intended to prevent an external fire scenario beyond the single flat on fire.

Equally, people on the floors above the floor where the flat fire has started are also to be protected from the single flat fire below them, again, by the measures provided to contain the fire in one flat; again, through the compartmentation to the flats, lobby and stairs, along with the lobby smoke control; and, again, the external wall and the requirements for the construction of that external wall should also provide protection to the people in the flats above the flat on fire.

A person requiring assistance will also need to escape from their flat to the lobby. Once they are out in the lobby, they are now separated from the immediate effects of the fire in the flat. However, protection measures for the lobby are not intended to provide indefinite protection and it may not be safe for a person to remain within the lobby.

At this stage, the choices available to a person requiring assistance to escape are: to escape using the stairs if they are able; to use an evacuation lift with assistance from building management if such assistance is available; to use the firefighting lift with assistance from the Fire Brigade; to be carried down the

stairs by firefighters, building management staff or potentially their neighbours.

There is no provision required in the statutory guidance for residential buildings, unlike other building types, to provide equipment for those persons, so there is no provision made for them to either contact building management, should they even be present in a building, nor to communicate directly with the fire service present in the building. The person can only make a personal 999 call. In other building types, refuges with communication devices are required.

Once occupants of the flat on fire have made their way through the lobby, the final part of their evacuation is down the stairs. Once down the stairs, they should now phone 999 and alert the Fire Brigade to the fire.

The protection provided to stairs is intended to physically prevent the penetration of smoke and fire into the stair enclosure by provision of fire-resisting construction, including the stair door; prevent smoke from entering the stair by provision of fire-resisting lobbies, including the flat entrance fire door and smoke ventilation systems; and so also prevent the spread of fire and smoke blocking use of the protected stair for any residents above the fire floor.

The protection measures in the lobby and the stair, however, are also provided to create a safe working environment for the Fire Brigade. The Fire Brigade require this safe working environment in order to be able to access the building, travel up to the flat on fire, and suppress the fire in that flat early. They also rely on the safe working environment in the lobby and the stairs to allow them time and a protected route to travel to rescue any residents in what is expected to be the immediate vicinity of the flat on fire.

Nothing more extensive than that is provided for through the building design requirements for the stay-put strategy. The requirements of the Building Regulations to provide active and passive fire protection measures are relied on by all building occupants during a fire -- all residents and all firefighters.

Since the first code of practice for fire safety in flats was published, it states:

"Reliance on such appliances as manipulative types of escape or mobile ladders is considered unsatisfactory."

High-rise residential buildings must, therefore, be designed on the basis that firefighting does not occur from outside. This concept has been carried over into

all modern design codes, where the regulations require provisions only for internal firefighting in high-rise residential buildings.

Therefore, the Building Regulations require adequate access to buildings for firefighters and their vehicles only at the entry point to the building and nowhere else around the building.

The provisions made for firefighting are also based entirely on an internal fire occurring. By design, these provisions are made on the assumption that a single internal flat fire and contained within the compartment will occur.

The construction of the external wall to this compartment is to adequately resist the spread of fire, such that mitigating a spreading external fire is not incorporated into any of the other protection measures in the building as provided for the firefighters. The external fire scenario not happening is critical to maintaining this box around each flat. The high degree of compartmentation is also required for safe firefighting in high-rise residential buildings.

Therefore, on the basis of internal firefighting only, Approved Document B provides for suitable road access and a parking space for a single fire vehicle within 18 metres of the firefighter entrance and the

fire main inlets. It is from here the Fire Brigade will prepare for internal firefighting operations.

Once inside the building, the following is provided for firefighters: a firefighting stair; a firefighting lift, which is a lift that can be operated under sole Fire Brigade control and has safety features to permit it to be used during a fire; a firefighting main, a dedicated system for conveying firefighting water to the upper floors of a building; a protected lobby on every floor, including a smoke control system; a protected space between the firefighting stairs and all flats.

The design requirements provide for the following firefighting process. On arrival, the Fire Brigade will secure a water supply for firefighting from outside the building by means of the required water hydrant in close proximity to the building. The firefighting teams move towards the building and enter.

The statutory guidance provides them with a firefighting lift within a protected lobby. The firefighters can approach the firefighting lift and take it under their direct control. The lift is then used by fire crews to carry their equipment, such as hoses, tools and breathing apparatus, and, by design, is assumed to go to the lobby two floors below the fire.

This lobby becomes the bridgehead, which is an area used to muster firefighters and their equipment. This lobby is designed to protect the firefighters from fire and smoke on the fire floor above and maintain a safe air environment there. That is air safe to breathe without the protection of breathing apparatus.

Firefighters will be tasked with approaching the flat containing the fire and extinguishing it. From within the stair, they connect their fire hose and branch into the building fire main.

Firefighters use the protected stair to walk up to the fire floor with the charged hose. They are provided with sufficient water by means of the building fire main provisions, and this includes the provision to charge a second hose as may be required to protect those firefighters who are now in the flat on fire and suppressing that fire there.

The firefighters are now operating within what they term the fire sector. One example of this is a fire sector which includes the fire floor, the floor above and below. The active and passive fire protection measures are required to prevent a fire from significantly spreading beyond a single flat in the fire sector.

I have found it useful to understand how

compartmentation is so important when firefighters split the building into sectors.

Firefighters rely on the compartmentation and the smoke control to the lobby to also set up any search sectors needed above a fire sector. They rely on the protected stairs and lobby to move safely to any of these required search sectors.

They rely on the compartmentation and smoke control within the building to set up what they call the lobby sector, which is below the fire sector and used for co-ordination of all their required logistics. Again, they rely on the protected stairs and lobbies to move safely up and down to the lobby sector.

Finally, the firefighting lifts are provided so that they can be safely used during the fire to transport firefighters and their equipment to a floor of their choice.

Two final points.

The fire protection measures must be constructed and then maintained to ensure they are fit for purpose in the event of fire. The stay-put strategy is provided through design construction and ongoing maintenance. All building occupants, including the Fire Brigade, rely on it in the event of a fire. It is the single safety condition provided for in the design of high-rise

residential buildings in England.

The statutory guidance makes no provision within the building for anything other than a stay-put strategy. There is no means of warning nor a means to communicate the need to increase the areas to be evacuated as is currently regulated for other building uses.

As I explain in my report, I consider the building's stay-put strategy to have failed at 1.26 am, and that all events after that time occurred in the context of the total loss of the only safety condition provided for.

Thank you.

MS GRANGE: We were going to take a 15-minute break at this point.

SIR MARTIN MOORE-BICK: Yes. That would be convenient, would it, to have a break now?

DR LANE: Yes, please, thank you.

SIR MARTIN MOORE-BICK: Well, let's say resume at 11.15 sharp. All right? Thank you very much.

(11.00 am)

(A short break)

(11.15 am)

SIR MARTIN MOORE-BICK: Yes, Dr Lane, when you're ready.

DR LANE: Okay, thank you.

Okay, I'm just going to start the second part about

fire safety in a high-rise.

In table 3.1 of my Phase 1 report I have provided a full list of the active and passive fire protection measures required through the Building Regulations for high-rise blocks of flats.

A passive fire protection system is one that is an inherent part of the building construction and so does not require any further power, action or intervention to perform its intended purpose.

By contrast an active fire protection measure is one that must undertake an action of some kind, either automatically or manually, in order to perform its intended purpose. Active protection measures typically also require a power supply in order to perform their function.

I will first describe the required passive fire protection measures.

Buildings are required to be subdivided into fire-resisting compartments to prevent the spread of fire. These compartments are constructed from walls, floors and fire doors, required to have fire resistance.

Approved Document B defines fire resistance as follows:

"The ability of a component or construction of a building to satisfy for a stated period of time, some

or all of the appropriate criteria specified in the relevant standard test."

These compartments, or fire-resisting boxes, are required in multiple locations: the box enclosing each flat; the box enclosing every lobby; the box enclosing any vertical or horizontal shafts; the box enclosing the escape stair.

These internal compartment walls and floors protect the occupants of the building. This is achieved by preventing the fire from spreading to adjacent flats or to shared public spaces through the provision of fire-resisting walls and floors and protecting any openings in those walls and floors.

Compartment walls and floors are fire tested to demonstrate their ability to prevent the passage of fire and heat.

As well as the structure of the walls and floors, buildings also need to contain a variety of different services, such as cables, ducts and pipes. These services need to be able to pass through the building in order for the mechanical services to operate as intended. Openings are therefore created to allow the services to pass through. These openings need to be sealed to prevent the spread of fire through any required fire-resisting compartment enclosure.

If a fire separating element is to be effective, every joint or imperfection of fit or opening to allow services to pass through the element should be adequately protected by sealing or fire-stopping so that the fire resistance of the element is not impaired.

Approved Document B defines a fire stop as:

"A seal provided to close an imperfection of fit or design tolerance between element or components, to restrict the passage of fire and smoke."

Fire doors are also a form of protection to an opening in fire-resisting compartment enclosures. A fire door is defined in British Standard 8412 as:

"A door which, together with its frame and hardware as installed in a building, is intended (when closed) to restrict the passage of fire and/or smoke, and is capable of meeting specified performance criteria to those ends."

As with the tested performance of compartment walls and floors and fire-stopping, there are also required methods for demonstrating the specific performance criteria set for fire doors through fire testing.

Appendix I of my Phase 1 report identifies five specific types of fire door that are critical to maintaining the compartmentation required to support the stay-put strategy, as well as support the defend in

place firefighting. These are: fire doors in a protected stair enclosure; main flat entrance fire doors; protected lift shaft fire doors; the doors within the protected entrance hall in a flat; doors into any fire protected service shafts.

Moving to the external wall component of the enclosure to a flat.

This image shows the external wall forming one side of the fire-resisting box enclosing a flat. Regulation B4 requires the external walls are constructed so that the risk of ignition from an external source and the spread of fire over their surfaces is restricted by making provision for them to have a low rate of heat release. This is dealt with in section 12.5 of Approved Document B which states:

"The external envelope of a building should not provide a medium for fire spread if it is likely to be a risk to health or safety. The use of combustible materials in the cladding system and extensive cavities may present such a risk in tall buildings.

"External walls should either meet the guidance given in paragraphs 12.6 to 12.9 [of Approved Document B] or meet the performance criteria given in the [Building Research Establishment] report 'Fire performance of external thermal insulation for

walls of multi-storey buildings' ... for cladding systems using full-scale data from [British Standard] 8414 ..."

That report is referred to as BR 135.

So taking each of paragraph 12.6 to 12.9 in turn first.

Section 12.6 of Approved Document B states:

"The external surfaces of walls should meet the provisions in diagram 40."

Section 12.7 states:

"In a building with a storey 18m or more above ground level any insulation product, filler material (not including gaskets, sealants and similar) etc used in the external wall construction should be of limited combustibility ..."

Finally, section 12.8 and 12.9 relate to cavity barriers. The Approved Document B advises:

"9.2. ... The provisions necessary to restrict the spread of smoke and flames through cavities are broadly for the purpose of subdividing:

"a. cavities which could otherwise form a pathway around a fire-separating element and closing the edges of cavities; therefore reducing the potential for unseen fire spread; and ...

"b. [subdividing] extensive cavities ...

"Consideration should also be given to the construction and fixing of cavity barriers provided for these purposes and the extent to which openings in them should be protected."

Section 12.5 of Approved Document B states that, as an alternative to following that guidance in 12.6 to 12.9, as I have just set out, the fire performance of the construction of external walls can be determined instead by reference to BR 135. This describes a fire test for external cladding systems so that they can be installed as close to typical end-use conditions as possible, and subject to a specific localised fire.

So either carrying out this test or complying with the guidance set out in Approved Document B is intended to provide the required performance to the external wall of the flat.

That external wall should therefore be constructed so that the risk of ignition from an external source and the spread of fire over its surface is restricted by making provision for the external wall materials to have low rates of heat release. That is the provision made for the external portion of the box around each flat.

Another passive fire protection measure is the provision of an overall stability system for the building during a fire.

I present here the structural form of Grenfell Tower as an example. I described earlier this morning how the floors, walls, beams and columns all contributed to the designed fire stability system.

Approved Document B states that the load-bearing elements of the structure of the building must be capable of withstanding the effects of fire for an appropriate period without loss of stability. Approved Document B defines this as resistance to collapse, the ability to maintain low-bearing capacity during a fire.

For concrete buildings like Grenfell Tower, the structural fire resistance of the structure is achieved through the depth and thickness of the member, and a specific depth of concrete insulating the embedded steel reinforcing bars. This combination of concrete and the reinforcing bars provide the stability system.

Structural fire resistance is a passive fire protection measure because it requires no power to activate and, once installed, remains an intrinsic part of the building safety condition.

Approved Document B states:

"B2.i. The choice of materials for walls and ceilings can significantly affect the spread of a fire and its rate of growth, even though they are not likely

to be the materials first ignited.

"It is particularly important in circulation spaces where linings may offer the main means by which fire spreads and where rapid spread is most likely to prevent occupants from escaping."

Therefore, for a means of escape to comply with regulation B1, capable of being safely and effectively used at all material times, it is required that the surfaces of walls and ceilings within protected lobbies and stairs are materials that restrict fire spread.

Additionally, in accordance with clause 5.19, firefighting stairs must be constructed of materials of limited combustibility.

I have described the passive fire protection measures. They are considered to be materials, products and structures. Their required fire performance and how to achieve that performance is then addressed in appendix A of the Approved Document B. Appendix A describes each of the different classes of performance and each of the appropriate methods of test.

Appendix A states:

"In such cases the material, product or structure should:

"a. be in accordance with the specification or design which has been shown by tests to be capable of

meeting that performance; or.
"b. have been assessed from test evidence against appropriate standards, or by using relevant design guides, as meeting that performance; or ...
"c. where tables of notional performance are included in this document, conform with an appropriate specification given in these tables ..."
Therefore, the fire resistance of walls, floors and doors are determined using a standard furnace.
I present in this image a furnace designed to undertake standard fire-resisting resistance testing on floor systems. This image shows a modern furnace test of a door to determine its fire resistance. The gas temperatures within the furnace must follow the temperature with time profile shown here, reaching 1,000 degrees Celsius after approximately an hour and a half.
There are a multitude of reaction to fire tests as applied to the performance of the materials forming the external wall which I have explained in substantial detail in appendix F of my Phase 1 report.
Finally, I present three images replicated from the BR 135 guide, which shows how it explains the concept of fire spread through external wall cavities, and then two photos from the fire test it represents: BS 8144. These

photos are a before and after example of a cladding fire test.
It is essential that there are no fundamental differences between the tested construction and the designed for construction of an external wall. This is also true of any fire-resisting feature, such as fire doors, too. Such fundamental differences mean the test evidence can no longer be relied upon to demonstrate compliance with the provisions made in Approved Document B.
I will now move on to active protection measures.
An active fire protection measure is one that must undertake an action of some kind and typically requires a power supply, as I said earlier.
In appendix G2.3 of my Phase 1 report, I describe the requirements for residential detection and alarm systems. The design guidance in Approved Document B is to provide independent fire detection and alarm systems within each flat and for the purposes of raising the alarm in that flat only.
The minimum requirement for locations of detectors within the flats is within the protected entrance hall. This is intended to sound an alarm when smoke first starts to enter the protected entrance hall in the flat, because this is the escape route within the flat. The

intention is that occupants of that flat should have sufficient time to evacuate before the entrance hall becomes impassable due to fire or smoke.
Under certain circumstances, a detection system may need to be enhanced by installing additional detectors in the living room and the kitchen, or in all of the rooms in the flat. Where more than one detector and alarm unit is provided in a flat, they must be interlinked so that all of the units sound an alarm on activation of any one device.
Approved Document B, section 5.36, states that all escape routes should have adequate artificial lighting which illuminates the route if the main supply fails. For a high-rise block of flats, the common lobby and stair shaft require emergency lighting. Emergency lighting is connected to the main lighting circuit in the building for normal power, but it is also provided with a backup battery installed within the light fitting with the capacity to run the light for a minimum duration of three hours in case the mains supply fails. The spacing of emergency lighting is controlled to give a minimum light level over all parts of the escape route in the event of a mains power failure.
Smoke control is an important provision to protect escape routes. Approved Document B states it is

probable that some smoke will get into the common corridor or lobby from a fire in a flat, if only because the entrance door will be opened when the occupants escape the flat. Therefore, section 2.25 of Approved Document B states that there should, therefore, be some means of ventilating the common corridors or lobbies to control smoke and so protect the common stairs. This offers additional protection to that provided by the fire doors to the stair.
There are two basic types of smoke control system identified in section 2 of Approved Document B. These are natural smoke ventilation, and, as an alternative to the natural ventilation provisions, mechanical ventilation to the stair or lobby. Approved Document B refers on to other guidance available for the design of smoke control systems using pressure differentials, this guidance is BS EN 12101, part 6.
This diagram shows a simplified section through a building. A fire has started in a flat; however, the smoke has not yet passed into the common lobbies and therefore the ventilation system has not yet activated. When smoke enters the common lobby, either by leaking through the door or if the door is opened during an escape, the smoke ventilation system is activated by smoke detectors in the lobby. All types of smoke

control systems then have common activation process. The vents on the fire floor only remain open. All other vents close. The vent at the top of the stair opens. The fans, if present, in the system, start up.

If the system uses natural ventilation then fans are not required. In this type of system, hot smoke rises up a smoke shaft under the effects of natural buoyancy and vents to outside above the roof of the building. A chimney effect is created, pulling air and smoke out of the lobby.

An alternative to the natural system is a mechanical ventilation system. This type of system can be designed to use the same kind of shaft as the natural system; however, it relies on an extract fan at the top of the shaft, pulling smoke into the lobby and up into the shaft. The extract fan is signalled to start at the same time as the lobby vents are signalled to open from activation of a smoke detector in the lobby being protected.

There is an alternative to this mechanical ventilation system too. This is called a pressurisation system. The difference is rather than pulling the smoke out from the lobby, the fan instead pushes air down and into the stair enclosure. The intention is this air prevents the smoke in the lobby entering the stairs.

The smoke in the lobby is then either pushed up a shaft provided for that purpose, or is pushed out of the building through some other opening, such as open windows.

Regardless of the type, all smoke control systems are designed to operate for a fire on one floor only. This floor is normally selected automatically by the smoke control system programming, which relies on the location of the detector that has first activated. In addition, a manual override for use by the Fire Brigade may also be provided on each floor to manually select the floor to be extracted from.

The Fire Brigade may also change where the system is running by using controls directly on the main control panel. These panels are typically located at the ground floor, where the Fire Brigade entered the building.

As well as the building requirement to provide a safe air environment for the Fire Brigade using smoke control, the brigade have their own equipment too: protective clothing and breathing apparatus. Breathing apparatus is required for firefighters to pass beyond the safe air environment of the bridgehead and into the fire sector. The Building Regulations require buildings to incorporate adequate smoke protection to the stairs and lobbies such that this equipment is not

required until the firefighting teams are advancing into the fire floor.

Firefighting lifts are lifts with specific protection and control mechanisms to permit them to be used safely by the Fire Brigade during a fire.

This figure identifies the key features of a modern firefighting lift. The protection measures for firefighting lifts I will be describing in more detail later on.

But it is because of these protection measures to firefighting lifts that Approved Document B also states:

"Where a firefighting lift has been provided to satisfy requirement B5, this can be utilised as part of a management plan for evacuating disabled people. Any such plan should include a contingency for when the Fire and Rescue Service arrive."

I will discuss this again later.

Fire mains are installed in a building and equipped with valves, et cetera, so that the Fire Brigade may connect hoses for water to fight fires inside the building. Fire mains may be of the dry type, which are normally empty and are supplied with water through a hose from a Fire Brigade pumping appliance outside the building. Alternatively, they may be of the wet type, where they are kept full of water and supplied from

tanks and pumps from inside the building. There should be a facility to allow a wet system to be replenished from a pumping appliance in an emergency also.

Regarding a dry main, there are two limiting factors in this system: the ability of the fire engine pump to raise water up the building, and the amount of pressure that the pipe being used can withstand. With a dry rising main, the further up the building the firefighters are, the lower the water pressure available at the outlet. This is because water pressure is required to push the water up the pipe against gravity. The amount of water pressure that can be introduced into the pipe is limited by the strength of the pipe.

Therefore, eventually a height is reached where the water pressure that can be delivered by a dry main cannot effectively operate a fire hose. For this reason, the statutory design guidance limits the use of dry mains to buildings less than 50 metres in height. In a building which is 50 metres or more in height, there is a requirement to provide a wet fire main.

The key differences in a wet fire main are:

A tank of water is provided within the building as a water supply for the system. It does not require the fire service to connect the system to an external hydrant.

A pump or set of pumps is provided within the building to pump water through the vertical pipe. It does not need a fire service pump appliance.

The pumps are automatically controlled to keep the fire main filled and pressurised with water at all times. Therefore, water can be drawn at any floor by the fire service immediately. There is no delay as occurs in a dry riser, where the fire service must manually charge the fire main when they arrive at the fire.

The pumps and the pipes are designed to deliver the minimum pressure deemed required for effective firefighting at the highest floors of the building. So a wet rising main reduces the time required for the fire service to secure firefighting water and, more importantly, is designed specifically to ensure adequate flow and pressure of water on every floor of the building. Performance of this main type does not worsen on the highest floors.

The standard for the fire main design, British Standard 9990, states in section 6.3.1 that wet fire mains systems are intended to supply two outlets at any one time. Therefore, if any more than two hoses are used, the water flow and pressure from any one outlet will be reduced. The standard does not make any

specific statements on the number of firefighting jets a dry main is intended to support.

However, as I have described, the maximum pressure in the main is limited by the ability of the pipe to withstand the pressure being introduced by the fire pump appliance. As more hoses draw water off the main, the pressure and flow to each hose will drop. Fire mains are also designed for a single internal fire event.

Whether the main is a dry or wet main, the design guidance for the location of landing valves where the Fire Brigade plug in to obtain water from is that they should be sited and their outlets directed such that access to them is unobstructed; personnel can safely lay out and charge hose lines before entering the fire compartment; there is minimal risk of any discharge of water from the outlets coming into contact with lift controls and lift communications equipment or of flowing into the lift well; there is minimal risk of exposure to fire from the accommodation if a door is open; hoses can be connected, charged and advanced into the accommodation without excessive kinking of the hose line or obstruction to fire doors and exit routes.

In addition, the location of the outlets presented in the design guidance has changed over time. When Grenfell Tower was built, the guidance for high-rise

blocks of flats was to place the rising main outlet in the common lobby. The current guidance is for the rising main outlet to be positioned in the protected stair.

The firefighting hoses for the fire mains are not provided in the building nor through design, but are the Fire Brigade's own equipment.

This ends my description of the active fire protection measures.

Finally, the presence of these active and passive fire protection measures are intended to create a layered safety approach. They provide the means for early internal defend in place firefighting. They provide the means to limit the fire and smoke spread from a flat fire out to the lobby and help prevent fire and smoke spread to the escape stair. They create the high degree of compartmentation to support the stay-put strategy in high-rise residential buildings.

Those layers of safety are required to prevent reliance on the fire and rescue services for safe evacuation, as so clearly stated in the statutory guidance document. The terms of reference for those layers of protection are to mitigate the effects of a single flat fire, with minor fire and smoke spread into the adjacent lobby.

Those layers of safety are not designed to protect from a multi-storey building envelope fire, nor are they designed to protect from a series of internal flat fires occurring on multiple storeys in a building. Such events are not considered as relevant design events in the current terms of reference for those layers of safety.

That ends my more general presentation and I'm now going to specifically speak about Grenfell Tower for the rest of the day.

SIR MARTIN MOORE-BICK: Yes, thank you very much.

DR LANE: In this next part of my opening presentation, I will provide a summary of works undertaken at Grenfell Tower since the building was originally completed in 1974.

I have provided a chronology in appendix D4 of my report of the design and construction of Grenfell Tower, as well as the timing of any significant modifications.

The items in this chronology as relate to refurbishment works on the tower have been identified using records made available to me and specifically from planning applications, Building Regulations applications, fire risk assessments and other contract documents, including, for example, the health and safety file from the 2005 lift replacement works.

I carried out a detailed review of works to Grenfell Tower since 1974 for two specific reasons: first, because I wanted to understand if any significant change to the original fire safety features have been made; second, to understand the dates of any such changes. This was for the purposes of understanding the appropriate legislation and regulations as may have applied at the time of that change. This was important when analysing the compliance requirements, and so the performance requirements, for the active and passive fire protection measures in Grenfell Tower on the night of the fire. It also helped me understand the range of legislation and regulation as applied to Grenfell Tower, and helped me conclude on what, if any, difference in requirements that range created.

As I stated in section 3.4 of my preliminary Phase 1 report, in respect of all the fire safety measures I have investigated, I have explained my understanding of what was required by the regulations and the relevant statutory guidance at the time of construction of Grenfell Tower. I have also then explained what is required under the current Building Regulations and its statutory guidance.

In this image, I have produced a time-line with the

dates of the key changes made to Grenfell Tower since the first recorded works in 1979. I have derived this time-line presented on this slide here from the information contained in a chronology of works submitted by the Royal Borough of Kensington and Chelsea, and through inspection of various contract documents provided to me.

The first recorded works on Grenfell Tower was a Building Regulations application for improvement to the ground floor community rooms in 1979. Between 1979 and 2017, there is evidence of a total of 19 different sets of works undertaken to various parts of the building, including the final refurbishment from 2012 to 2016.

For the purposes of this presentation, works include alterations or modifications or even replacement of existing elements of the building or its services. I have identified different types of refurbishment work with different colours on the time-line I have provided in this slide.

I will now explain those works, separated into types.

Nine of the 19 recorded changes to the building relate to its internal layout. Three of those nine dealt with the residential floors of the building,

highlighted in yellow. Specifically, these were the refurbishment of lobbies on all floors in 1985, the refurbishment of levels 3 and 4 in 1986 and, finally, the works in the primary refurbishment.

Five of the nine sets of internal layout works dealt only with the non-residential floors. One set of internal works undertaken in 1980 was not specific on location.

Whilst I have substantial detail on the most recent primary refurbishment, there is little detail available on the specifics of the other eight sets of internal works that occurred.

Four of the 19 recorded refurbishments included work to the lifts in Grenfell Tower. In 2005, all three lifts in the building were fully replaced. This consisted of the two main lifts serving all floors and a smaller hydraulic lift that was provided to access level 2 and 3 from ground. To enable these works, additional preparatory work was also needed separately in 2004. These were works to build a new brick enclosure at ground level to contain the new hydraulic lift equipment for one of the three lifts.

The other two sets of work on lifts in Grenfell Tower were undertaken as part of the primary refurbishment. First, in 2013, the low-level access

lift between ground and level 3 was removed as part of the demolish works for the tower. Then, later, in the primary refurbishment, the lift shafts were modified to permit the lifts to also serve levels 1 and 3, where previously they did not.

Three of the 19 recorded refurbishments included work to fire doors within Grenfell Tower. Fire door replacements were carried out within the tower in 1985, 2011, and finally during the final primary refurbishment. The 1985 works replaced an undetermined number of flat entrance fire doors in unknown locations in the building. The Building Regulations application provided to me and associated with the works did not define the exact number of doors.

In 2011, a programme of flat entrance door replacements was undertaken. This involved fitting 106 replacement flat entrance doors to tenanted flats. No works were done to 12 leaseholder flats or two tenanted flats.

Finally, in the last primary refurbishment, new stair doors, new flat entrance fire doors and fire doors to other rooms were provided on levels ground, 1, 2 and 3 only.

Two of the 19 refurbishments since 1974 were to the external construction of the building. Specifically, in

2008, the flat roof coverings at roof level on top of the building were replaced. Then the overcladding of the whole building which took place from 2012 to 2016.

In 2016, one gas supply riser running vertically up the building was decommissioned and replaced with a new gas supply pipe. The appointed gas expert, Rodney Hancox, is investigating all aspects of the gas supply to Grenfell Tower and will cover these matters in detail, including the history of gas supply-related works for the tower. I have incorporated the most recent works in 2016 only for the purposes of my fire safety-related work as they relate to compartmentation.

As a result of my understanding of the works carried out to Grenfell Tower since 1974, I provided in section 4 of my report the specific refurbishment works that I considered to be relevant to my investigation of the active and passive systems that existed in Grenfell Tower. This is due to their direct influence on the eventual performance of the fire safety measures on the night of the fire. These are: the lift replacement works in 2005; the tenant flat entrance door replacement in 2011; the refurbishment works between 2012 and 2016; and the new tenant gas supply, which was incomplete the night of the fire.

I will deal with each of these in turn in the next

series of presentations.

SIR MARTIN MOORE-BICK: Right.

DR LANE: The first of the relevant works is in relation to the lifts provided in Grenfell Tower and so the status of that lift provision the night of the fire.

Works were undertaken in 2005, as I said, with further works undertaken during the primary refurbishment. Both works are relevant to the fire safety status of the lifts the night of the fire. I will, therefore, describe the works during both time-frames here.

The original plan drawings for Grenfell Tower indicate three lifts were installed. As this image shows, this included a small lift connecting ground level to level 3. This small lift was located in the southeast corner of the building. It was ultimately removed as part of the primary refurbishment works and so I have not considered it any further.

The remaining two lifts, as you can see, were located centrally in the building, opening out into the lobby between each flat and the single protected escape stair. Access to the two main original passenger lifts was provided from the original ground level lobby and at level 2. Access to these two lifts on upper floors was provided on every floor between level 4 and level 23.

These central lifts did not serve level 1 and level 3. Therefore, these passenger lifts were for the purposes of accessing the floors in the tower with flats only.

Before describing the works undertaken to the lifts in Grenfell Tower, I want to first describe the two types of lift for firefighting. There are two types in the context of Grenfell Tower because, since the tower was built, the requirements for lifts for firefighting has changed. This occurred in 1992. Therefore, understanding the lift requirements for firefighting before and after 1992 is relevant.

For lifts to be suitable for firefighting, they require special features to allow the Fire Brigade to access them during a fire and for the lifts to be robust enough to continue operating in a fire scenario.

Since 1971, prior to the construction of Grenfell Tower, there has been a requirement for the provision of a lift which may be used by the Fire Brigade within high-rise residential buildings. At that time, lifts with specific firefighting provisions were referred to as fire lifts.

In 1992, the name used to describe these lifts changed to firefighting lifts, and the required safety provisions to enable lifts to be safely used by firefighters in a fire was changed also. This term,

firefighting lift, and the associated requirements for such lifts are in general still in force today.

To understand the fire safety features for a lift, it is useful to understand the basic components of a lift system and the terms used to describe it. These are illustrated in this image.

People or goods are transported within the lift car, which is suspended by cables directly affixed to the lift car. A lift machine, typically located in a machine room at the top of the lift, drives and stops the lifts. A counterweight is used for traction. The lift is housed within a vertical shaft. Openings in these shafts at each floor of the building allow people to access the lift. The lift landing doors positioned in each of these openings allow controlled access to the lift car and to the shaft itself.

The original code of practice for fire safety as applied at the time of construction of Grenfell Tower is, again, CP3, dated 1971, and it describes the provisions to be made for a fire lift.

I have illustrated the key features required for a fire lift at the time of construction of Grenfell Tower on this image. The requirements are that the fire lift should serve every residential floor, a fire switch should be provided whereby firefighters

can obtain and control the use of a lift without interference from other persons, and the requirement of a maximum distance between the stair and lift of no more than 10 metres. The lift car should have a platform area of not less than 1.5 metres squared, a capacity of 550 kilograms and reach the top floor from ground level within one minute. Finally, the requirement that the electrical supply to any fire lift should be provided by a sub-main circuit exclusive to the lift, with the cable supplying current passing through routes of negligible fire risk.

If we now consider the fire safety requirements for a firefighting lift, there is a clear difference in standard. As I have illustrated in this image, the number of features required in a firefighting lift as required from 1992 onwards is substantially greater.

Of the 15 features required for the new firefighting lift, three of those provisions were also required for the historic fire lift shown here in blue. They relate to the size of the lift car, the minimum travel time for the lift to reach the top floor and the provision of a fire switch for the Fire Brigade.

Four of the 15 required features for a firefighting lift were also required for a fire lift, but a higher standard is now required. I have shown those features

in orange. For example, the lift is required to serve every floor, not just residential floors. The power supply is required to be fire protected, not routed through areas of negligible fire risk. The minimum capacity of the lift car has increased to 630 kilograms.

Finally, there are eight additional fire safety features required for a firefighting lift compared to a fire lift, which I've shown in blue/grey here. These are more substantial features. For example, two independent power supplies for the lift in case of power failure to the main supply; water protection to the lift; the provision of an escape hatch to the lift car; fire-resisting landing doors; a two-way intercom communication device between access level, the lift car and the machinery room. This was the standard required for lifts used at the time of the lift replacement work in 2005 and, subsequently, in 2012 to 2016.

The standard of lift for firefighting is also relevant to the use of lifts for evacuation. The current version of Approved Document B which was applicable at the time of the primary refurbishment permits the use of lifts which meet the standard of a firefighting lift to be used as an evacuation lift. This provision applies to firefighting lifts only and not to historic fire lifts. In general, this is because

of the higher standard of protection now provided to firefighting lifts.

I will now explain the lift replacement works.

A complete replacement of the central lift system was undertaken in 2005. From reviewing the specification within the health and safety file prepared for the works, the standard of lifts specified then was consistent with the historic fire lift standard and not the firefighting standard applicable in 2005.

Further modification works were also undertaken during the primary refurbishment. The scope of this modification was to increase the number of floors served by the two central lifts. During these works, the lifts were not upgraded either to the applicable firefighting standard.

The scope of the lift refurbishment works in 2005 was substantial. It included replacing all associated equipment and machinery. New lift cars were installed, new lift landing doors were installed, call points and controls. The openings in the lift shaft were also increased in width. The lift was not at this time upgraded to serve level 1 and 3 and, therefore, continued not to serve every floor of the building, as is required for a firefighting lift.

Later during the primary refurbishment, new openings

in the lift shaft were created on levels 1 and 3 as a way to access the new residential flats on these levels. Therefore, after the primary refurbishment, both lifts could be used to access every floor, as is required for the firefighting lift standard.

During 2005, the two lift cars were increased in size and capacity. The plan drawing on the left indicates the smaller, original lift car and, on the right, the larger, replacement lift car. The openings in the lift shaft on every floor were widened to increase the clear entrance of the doors from 800 to 880 millimetres. The new capacity of 900 kilograms did meet the minimum standard for a firefighting lift.

The specification for the 2005 works also required a firefighter control switch to be installed. A firefighter control switch is required for both a fire lift and a firefighting lift.

I observed two firefighter control switches in Grenfell Tower, photographs of which you can see here, one at ground level, where it is required, as this is the firefighter entry point to the building. I observed a second switch at level 2. This is not the firefighter entry point to the building.

The 2016 fire risk assessment states that the control switch should then be changed from level 2 to

ground level, indicating that, prior to 2016, the fire control switch at level 2 was operational. The 2005 specification also included an emergency intercom system which is required for a firefighting lift only; however, I've not yet been able to observe whether this system was installed on site.

Therefore, following the 2005 and 2012 to 2016 works, the lifts specified for Grenfell Tower contained a number of fire safety features which I have highlighted in green in this illustration. These provisions satisfied the requirements for a historic fire lift; they did not satisfy all of the requirements for a firefighting lift as existed at the time of the 2005 and the 2012 to 2016 refurbishment works.

Key features that were required to meet the standard but which were not specified are: a secondary power supply was not specified; electrical schematics showed it had an independent power supply, the exact cable routing is not known; the lift landing doors were not specified as requiring any fire resistance when they were required to have 60 minutes' fire resistance; no water protection measures were specified for electrical equipment within the lift car and well; an escape hatch was not specified for the replacement lift car.

As the lifts were not specified to meet the standard

of a firefighting lift, they could not, therefore, also be relied upon for evacuation because, as it states in Approved Document B, where a firefighting lift has been provided to satisfy requirement B5, this can be utilised as part of a management plan for evacuating disabled people. Any such plan should include a contingency for when the fire and rescue services arrive.

That ends my lift talk.

SIR MARTIN MOORE-BICK: Thank you very much.

DR LANE: Will I keep going?

SIR MARTIN MOORE-BICK: Well, what is your next topic and how long --

DR LANE: I can move on to doors now or have a break and do doors later.

SIR MARTIN MOORE-BICK: How long do you think doors might keep us going for?

MS GRANGE: 15 minutes.

DR LANE: About 12 to 15 minutes.

MS GRANGE: We can do the 15 minutes now and then break for lunch, if that's convenient.

SIR MARTIN MOORE-BICK: Shall we do the doors?

DR LANE: Yes, I'll just do the doors.

SIR MARTIN MOORE-BICK: Thank you.

DR LANE: I will now describe the works that were undertaken to fire doors in Grenfell Tower in 2011.

I've described the role of fire doors in protecting door openings in compartments. Compartmentation is the primary fire protection measure for the single safety condition, the stay-put strategy.

Where doors are required within walls requiring fire resistance, those doors must be self-closing or lockable fire doors according to the statutory guidance.

There are various performance requirements that they need to achieve and must be subjected to fire testing to confirm these performance requirements.

These requirements have changed over time since 1974, when the tower was built. Fire doors are tested as a whole assembly, which is in the state it is installed in a building. Importantly, this includes the hardware, glazing, seals around the door and several other components. These components are shown in the next slide.

But before I move on, to show that a door assembly meets the required standard, the door assembly should be in accordance with the specification or design which has been shown by test to be capable of meeting that performance, or have been assessed from test evidence against appropriate standards or by using relevant design guides as meeting that performance.

These are the components of a fire door assembly.

In appendix I2.2 of my report, I listed out 44 features that form a fire door. Of these, the principal components are: the door leaf; the doorframe; the architrave, which is a trim that serves to mask the joint between a doorframe and the surrounding structure; a self-closing device; an intumescent fire seal; and a smoke seal, which is for the purposes of restricting the flow of cold smoke.

Fitted to the door leaf is various ironmongery, which includes latches, locks, letter plates and handles. As indicated in this diagram, everything together is known as the door assembly and every component is relevant to the fire performance of the system.

I will now describe the location of the specific doors in Grenfell Tower which were required to be fire doors. These are the fire doors required to maintain the compartmentation to all flats, the stairs and the openings on to all the lobbies and to other risers.

Within the core of Grenfell Tower, on levels 4 to 23, all of the fire doors were installed in the partitions forming the core of the tower. To indicate each of these, a diagram of the protected lobby and stairs is shown.

First, flat entrance fire doors. The front door of

every flat should be a fire door as it separates the flat from the protected lobby. There are six of these doors per floor on levels 4 to 23 and they are indicated in yellow.

The lift shafts must also be a separate fire compartment and should be separated from the protected lobby as the lift doors open on to the protected lobby. The two doors to the lifts of each lobby, therefore, should achieve a specified fire resistance, as shown in yellow here.

The refuse chute room is also required to be a separate fire compartment, and so the single door to the refuse chute room on every level is required to be a fire-resisting door, and that is located at the yellow marking there.

Finally, the single door to the protected stair at each level. The protected stair is another separate fire compartment and so was also required to be provided with a fire door.

In 2011, a programme of fire door replacements at Grenfell Tower was undertaken. This 3D image of Grenfell Tower indicates in the model the flat entrance doors on a typical level. Zooming out to the extent of the full screen, you can see the doors that were replaced in the tower and the doors that were not

replaced as part of these works. That's their locations.

The programme of work was undertaken by the TMO to replace the front door of dwellings occupied by Royal Borough of Kensington and Chelsea tenants. 106 fire doors appear to have been supplied and installed by Manse Masterdor to replace the main flat entrance doors. This is based on their door replacement schedule, which included 104 tenanted flats and two leaseholder flats. Therefore, 14 fire doors that were not replaced consisted 12 leaseholder flats and two tenant flats. These works did not specify new doors for the lifts, stairs, refuse chute room or any other riser in the tower, nor any of the doors on levels ground to 3.

The standard for the fire safety performance for the flat entrance fire doors at the time of installation is described in Approved Document B. The key requirements are: integrity fire resistance of 30 minutes when tested to the fire resistance test, British Standard 476, part 22; the doors should be fitted with smoke seals restricting air leakage around head and jambs; no glazing is permitted unless that glazing has been demonstrated to achieve an insulation performance that is equivalent to the integrity performance of the door; a self-closing device is required; the fire door should

only be fitted with locks readily openable from the inside without a key.

Regarding glazing, any door containing glazing should have been tested with the glazing in place, or an assessment have been made to show that it would meet the required performance. The glazing must have insulation fire resistance in addition to integrity fire resistance, because table A4, "Limitations on the use of uninsulated glazed elements on escape routes", as presented in Approved Document B states no part of the wall or door leaf between residential sleeping accommodation and a common escape route of a single stairway building can contain uninsulated glazing.

The fire door product to replace the flat entrance doors in Grenfell Tower was Suredor GRP, as manufactured by Manse Masterdor limited. The brochure for Suredor GRP doors describes the doors as a fibre glass composite door which was successfully tested for the integrity and stability criteria for 30 minutes. The brochure does not state that the doors have been tested for cold smoke leakage as required, nor for the insulation component of fire resistance.

The photograph on the left shows the exact single test specimen that was used to achieve those test results. It does not feature any glazing or a number or

nameplate, for example. It does feature a specific latch, lock, letter box, handle and spyhole. The self-closer on the tested specimen was externally mounted on the door.

In Grenfell Tower, the Manse Masterdor specification sheet specified 58 unglazed Suredor fire doors were installed, an example I observed as shown on the left. 48 glazed Suredor fire doors were installed, an example I observed is shown on the right.

Sorry, I got a little bit mixed up there. On the right.

With regard to the ironmongery, the Manse Masterdor specification sheet specified different locks, different letter boxes, different self-closing devices and hinge types to that provided for within the fire test.

Regarding the 14 flat entrance doors which were not replaced, there is little evidence available regarding those doors as they have mostly been destroyed by the fire. In considering if those doors were the originals as installed in 1974, it is now useful to note that the requirements were different at that time.

The main differences for a flat entrance door at that time were:

Self-closing devices were different. This could be achieved using what's called rising butt hinges, which

are the wedged-shaped hinges shown in this photograph. These are no longer acceptable.

Integrity rating of 20 minutes. This is 10 minutes less than the 2011 standard.

A 12-millimetre rebate was also required to prevent smoke spread, which I will now explain.

In both 2011 and in 1974, fire doors have incorporated measures to stop the spread of smoke. In 1974, this was in the form of an overlap between the door and the frame known as a rebate. In the picture on the left, the door would swing into the frame away from the viewer and be stopped from swinging any further once in the frame by the rebate. The depth of rebate required was specified rather than a limit on the rate of air passing through the door.

In 2011, preventing the spread of smoke was and still is usually accomplished by smoke seals, which could be brush-like or rubber-like strips around all sides of a door that are designed specifically to seal airflow around the edge of a door.

Regarding the stair fire doors, I have no records of replacement works to the stair doors. Therefore, I have assumed that the stair doors were the original doors as fitted In 1974. Again, comparing the requirements for stair doors in 1974 as opposed to the requirements set

out now in Approved Document B.

In both 1974 and 2011, stair doors were required to be self-closing. In 1974, an integrity fire resistance rating of 30 minutes was required; current standards would be for a 60-minute integrity rating. In 1974 a 25-millimetre rebate was required; the current standard would require smoke seals with prescribed limits on airflow. I observed in Grenfell Tower that the rebate was 12 millimetres, not 25, on the stair fire doors. A 12-millimetre rebate would indicate that this is a 20-minute fire door.

To summarise the fire door provision within Grenfell Tower on 14 June 2017, 106 of the 120 flat entrance doors were replaced which Suredor GRP doors. The remaining 14 doors comprised of leaseholder flats and two tenanted flats. They are assumed to be original doors; however, few remain to be investigated. The lift landing doors were replaced in the 2005 lift works with no specified fire resistance. The stair fire doors have no documentation or records defining any replacement, so it is assumed they are the original doors as installed and appear to have fire resistance of 20 minutes.

For the refuse chute room doors, currently no documentation or records of the replacements are available and so it is assumed they are the original

doors as installed in 1974.

Fire doors are a crucial element of the stay-put strategy as they represent an opportunity for weak spots to form in the fire-resisting partitions that separate a flat fire from occupants either on that floor where the fire has started or occupants in flats above the floor the fire has started. Fire doors are, therefore, a Building Regulations requirement as a passive fire protection measure. Faulty fire doors mean faulty compartmentation and compartmentation is the primary basis of the stay-put strategy.

Thank you.

SIR MARTIN MOORE-BICK: Thank you very much.

Now, you've been speaking almost non-stop for quite a long time. Would you like a break now?

DR LANE: Yes, I would.

SIR MARTIN MOORE-BICK: Well, I'm not surprised.

Thank you very much, you've given us a lot to think about.

We will break then in a moment. It's a little earlier than usual. If we resume at 2 o'clock, is that going to give you enough time to finish?

DR LANE: Absolutely fine.

SIR MARTIN MOORE-BICK: Thank you very much. In that case, we'll rise now and resume at 2 o'clock, please.

(12.25 pm)

(The short adjournment)

(2.00 pm)

SIR MARTIN MOORE-BICK: Thank you.

MS GRANGE: Thank you. Dr Lane is going to continue with the second half of your presentation.

DR LANE: Thank you.

Okay, I am just going to finish on works before the primary refurbishment and so discuss the gas supply replacement works that were underway the night of the fire.

SIR MARTIN MOORE-BICK: Yes.

DR LANE: Regarding Grenfell Tower, I'm interested in gas supplies for two specific fire safety-related issues only.

First, the supply of gas through Grenfell Tower penetrated multiple compartments. How those penetrations were protected to maintain compartmentation is therefore relevant to the stay-put strategy.

The second issue of interest is the provision made with respect to shutting off the gas supplies during a fire. This is important when considering gas as a fuel source in a room or a flat during a fire.

Gas safety matters are the subject of investigation by the gas expert appointed to the inquiry,

Rodney Hancox, and his work will include gas shut-off issues. The inquiry will then need to understand any additional fire scenarios where caused by gas supply when his work is completed.

I investigated the gas service installations at Grenfell Tower by reviewing design and construction documentation and by observing evidence on site.

I relied on two services specialists I work with at Arup, Mr Joe Wade and Mr Conor Hoey, in particular when trying to decipher the gas supply routes throughout the tower. During our site inspections on 7, 8 and 9 November 2017, my team located the gas supplies and traced the pipework to understand how the systems were distributed throughout Grenfell Tower. This was a complex process, particularly within the basement.

My findings as a result, and as they relate to fire safety compartmentation requirements only, are summarised in the following presentation.

There were two original gas supplies in Grenfell Tower.

The first gas supply I refer as to the landlord supply. This served boilers that provided communal heating and hot water for Grenfell Tower, as well as the three finger blocks located south of Grenfell Tower. The landlord gas supply entered Grenfell Tower through

the east building elevation.

It entered at a high level within the basement level, nearly 5 metres above finished floor level. The landlord gas supply was then routed horizontally along the basement level where it served the original boilers.

During the primary refurbishment, new boilers were installed to provide a new central heating system for Grenfell Tower. The original landlord gas supply was therefore extended to serve these new boilers.

The original boilers were retained and they continued to serve the three finger blocks south of Grenfell Tower. The landlord gas supply doesn't leave the basement and does not therefore apparently breach any compartmentation. Therefore, I will not discuss the landlord supply any further at this stage.

The second gas supply, which I refer to as the residential supply, provided gas for domestic appliances, such as cookers, for residential flats on levels 4 to 23. I understand that just over 70 per cent of the flats had a live gas supply.

The original residential gas supply entered Grenfell Tower through the east building elevation at basement level also. This residential gas supply was then routed horizontally long the basement level, where it then split into four gas pipes and these were routed

vertically up four shafts in the building core. The term used for a vertical pipe that distributes upwards through a building is "riser".

These four gas risers continued up the building and, at some point between the basement level and level 4, the four risers were split into six. This split and its location requires further investigation.

However, what is clear is these six risers continued up the building to level 23. One of each of these six risers passed through each flat. These original gas risers connected every floor of Grenfell Tower from basement level to level 23.

The gas risers passed through each compartment floor, connecting all the compartments they passed through. Therefore, these risers are also required to be protected to maintain compartmentation.

Approved Document B requires that pipes which penetrate a compartment are to be protected in one of two ways: the pipe should be fire-stopped at every compartment wall or floor that it penetrates, or the pipe should be enclosed, with the protected shaft formed with fire-resisting construction. Where gas pipes are enclosed in protected shafts, they also require ventilation at the top and bottom of the shaft for safety reasons.

It is important to note that Approved Document B states that gas service and installation pipes should not be incorporated within a protected stairway unless the gas installation is in accordance with the requirements for installation and connection set out in the Pipelines Safety Regulations and the Gas Safety (Installation and Use) Regulations.

These specific requirements are not provided within Approved Document B for fire safety and they require other safety measures to be installed, for example for emergency control of the gas supply to the building. These provisions made for compliance with the separate regulations are being dealt with by the other expert.

Gasworks commenced in 2016, which led to a third main gas supply being installed at Grenfell Tower.

During an inspection by Cadent Gas on 30 September 2016, a small gas leak was identified in one of the six risers supplying gas to the original flats on levels 4 to 23. The gas riser with the gas leak was disconnected. It was capped at ground level.

This disconnected gas riser supplied flat 2. This image shows the location of flat 2, which is the flat located on the southeast corner of Grenfell Tower. As I said, just over 70 per cent of the original flats in Grenfell Tower were supplied with gas. 13 of these

flats were in this flat 2 location on the southeast corner. Therefore, 13 flats were affected by the gas leak and subsequent decommissioning of the flat 2 related gas riser in 2016.

The other five risers supplying gas to flats in location 1, 3, 4, 5, and 6 on each floor between levels 4 and 23 remained in service. The condition of these five other original gas risers that remained in operation and were present the night of the fire is also being investigated by the other expert.

However, an entirely new residential gas supply was installed to replace the decommissioned riser that served flats in location 2.

This new residential gas supply entered Grenfell Tower through the east building elevation also. It entered the tower at basement level. The gas supply pipe was then routed from the east elevation of the building to the southeast service shaft in the core of the building, where it was then routed vertically up the tower.

A new vertical route was chosen through the protected stair from levels 2 to 21, rather than directly through the flat 2 locations, as had previously occurred. Horizontal pipes were installed leading out from that vertical riser in the stair, exiting into each

lobby outside the stair and over to serve flat 2. These horizontal pipes penetrated the protected stair compartment wall and the flat compartment wall on each relevant storey within the tower. These horizontal pipes ran under the false ceiling in each lobby and so were visible from within the lobby. This was to be the case at every level requiring a residential gas supply in the southeast corner.

Approved Document B for fire safety advises a pipe is not considered to be contained within a protected stair shaft if that pipe is completely separated from that protected stair shaft by fire-resisting construction.

I observed the vertical pipe within the stair to have been enclosed by construction, as shown in this image in the stair at level 2. I currently have no information available to me as to the fire performance possible from that construction.

Where a gas pipe is enclosed, Approved Document B states:

"8.41. A protected shaft conveying piped flammable gas should be adequately ventilated direct to the outside air by ventilation openings at high and low level in the shaft."

This condition is being explored by the inquiry's

appointed gas expert at this time.

The horizontal pipes that supplied gas to flats in location 2 therefore left this vertical riser in the stair, penetrated the protected stair compartment wall and then penetrated the flat compartment wall. The pipe should be fire-stopped at each compartment wall it penetrates or enclosed with a protected shaft.

I understand that these works to the horizontal pipes were planned for June 2017, although I have seen no evidence that any of those works had commenced by 14 June 2017.

On 14 June 2017 there were three gas supplies in Grenfell Tower: a landlord gas supply with no impact on compartmentation; an original residential gas supply, the condition of which is currently being investigated; and a new residential gas supply, which had incomplete compartmentation works and incomplete ventilation works the night of the fire.

Thank you.

Okay, for the remainder of the afternoon, I'm going to talk about the primary refurbishment.

SIR MARTIN MOORE-BICK: Thank you.

DR LANE: With an overview of the whole thing first.

Between 2012 and 2016, the TMO commissioned a major refurbishment of Grenfell Tower. I refer to this as the

primary refurbishment.

The refurbishment was funded by the Royal Borough of Kensington and Chelsea and the funds for the refurbishment were released in 2012.

The primary refurbishment was substantial and I would like to read the Rydon general scope of the project as follows:

Adaption of two lifts to include two new doors.

Recladding of the facade.

Reconfiguration of the podium levels to provide additional residential accommodation (nine new flats).

Relocated and refurbishment of the nursery.

Relocation and refurbishment of the boxing club.

Provision of new community room.

Decorations to the existing lobbies.

Construction of a new entrance lobby (previously an undercroft).

Modifications to the MEP systems as follows:

New heating system to all areas.

New boosted cold water distribution system to all areas.

Refurbishment and extension of the smoke and environmental ventilation systems.

Alterations to the dry riser system.

Alterations to the door entry system.

External hard and soft landscaping.
The project scope included external works. The image on screen shows the contract boundary for the works as defined in 2012. External works included: demolition of an existing circular ramp connecting the level 2 walkway to the play area to the west of Grenfell Tower; demolition of an existing walkway that connected level 2 to the grass area to the north of the tower; and new hard and soft landscaping within the contract boundary on the north, south, east and west sides of the tower.
According to the sustainability and energy statement for the primary refurbishment, improving the insulation levels of the walls, roof and windows was the top priority of this refurbishment. The chosen strategy is to wrap the building in a thick layer of insulation and then over-clad with a rainscreen to protect the insulation from the weather and from physical damage.
The resulting works can be summarised as follows:
The overcladding of the building envelope at ground comprised a glass reinforced concrete cladding to the columns and the installation of glazed curtain walls to the new entrance lobby on the southeast corner.
From levels 1 to 23, it consisted of the addition of a drained and ventilated rainscreen cladding system,

which comprised of a backing wall by means of the existing tower external wall and a cavity containing thermal insulation, and an outer layer formed with rainscreen cladding panels.
Two different types of rainscreen cladding panels were used at first and second floor, a product called CGL wall plank, and then from levels 3 to 23, a Reynobond 55 PE aluminium composite panel in two colours: pure white for the horizontal panels at third floor only, and smoke silver colour provided on all columns and all horizontal panels on levels 4 to 23 and the crown of the building. New double glazed windows and insulating core panels between them were installed.
I have focused my analysis in my Phase 1 report on the external wall construction of the original residential floors. The cladding on the lower floors was not involved in the fire.
There were many changes made to the internal layouts of ground level to level 3. A new, tall entrance lobby was created, with a new open staircase within it. A new community room was provided at ground level. The nursery was moved from the first floor down to ground. At the first floor, a second community room and four new flats were provided. A new flat was provided at level 2 and the boxing club was moved from ground level up to

level 2. At the third floor, four new flats were provided, resulting in a total of nine.
Reconfiguring these internal spaces caused the need to reconfigure the lift and stair access and so make them fully available at those levels also.
As I have already explained this morning, the small lift that originally served ground level to level 3 was demolished. Access to the main lifts was then modified so that these two lifts could now be accessed from levels 1 and 3, as originally they were not. I have explained the modifications to the lift and will not explain them any further.
With regard to the existing stairs, modifications were made to stairs between ground level and level 3. No modifications were made to the central stair from level 4 to roof. Three small internal stairs were demolished between ground and level 3. The location of these stairs is highlighted in red in the left-hand image.
New balconies were constructed, highlighted green in the right-hand image, to connect a new open stair in the new multi-storey entrance lobby located in the southeast corner, highlighted in blue, over to the central and closed lobby at levels 1 and 2. From level 3, access via the main central protected stair and lobby was

provided.
The internal changes from ground to level 3 also required modifications to the existing internal fire main so that it became accessible at these levels. The existing smoke control system was also modified to incorporate the new lobbies at ground, level 1, 2 and 3. The operation of the system was changed and new power supplies and controls were also provided during the refurbishment.
A new heating system and booster cold water system were provided in the building. This required works in all lobbies, all flats and all non-residential spaces.
Inside every existing flat, work was required to install a new heat interface unit for individual control of heating and hot water, and new low temperature hot water pipes to supply that heat interface unit and new cold water pipes. A total of 440 radiators were installed.
The primary refurbishment therefore included: substantial work inside the building on all levels; the overcladding on all levels of the exterior of the building; it included works done externally, demolition of ramps and walkways and hard and soft landscaping within the contract boundary.
I will focus in detail on the rainscreen cladding

component of the primary refurbishment works later, but first I would like to provide more information about some of the other works done to Grenfell Tower during the primary refurbishment, and so I will provide more information on each of the external works, the reconfiguration of lower floors, the fire main works, the refurbishment of the existing smoke control system, the new heating and hot water system and the new cold water system. This is in order to provide greater clarity on how those works impacted the fire safety features in Grenfell Tower.

The contract boundary for the primary refurbishment is outlined in red. According to the primary refurbishment design documentation, external hard and soft landscaping was provided within this boundary.

There were changes to external pedestrian access to Grenfell Tower. The external walkway that connected the north side of level 2 to the grass area was demolished. The external walkway that connected Grenfell Tower to the finger blocks at level 2 was closed at the south building envelope, and the circular ramp, as I said, that connected this walkway to the play area west of the tower was demolished.

As a result of the circular ramp demolition, the pedestrian path between the area south of

Grenfell Tower, where the main building entrance is located, and the area west of Grenfell Tower became an at-level direct pedestrian path.

New hardstandings were provided on the north, south, east and west sides of Grenfell Tower, immediately around the tower, within the contract boundary.

As I explained earlier, the primary fire vehicle access to Grenfell Tower was via Grenfell Road on the south side. During my site visits, I observed that the fire access to the south and east elevations was maintained after the primary refurbishment.

The photograph on the left shows the fire vehicle access route leading to the south side of Grenfell Tower. The area underneath the elevated concrete walkway was within the contract boundary of the primary refurbishment. The photograph on the right shows the hardstanding on the east side of Grenfell Tower. A new hardstanding was provided to this area during the primary refurbishment.

Regarding the reconfiguration of the lower levels, these levels were reconfigured to provide nine additional flats and reconfigured non-residential accommodation. A tall, multi-storey entrance foyer was created with an open stair within it, and the balconies created at levels 2 and levels 1. Additionally, six new

fire doors were provided to the modified protected stair enclosure at those lower levels.

Some of the existing fire safety systems in the residential areas at level 4 and above were then extended down to serve these reconfigured levels. These fire safety systems included the firefighting lifts, dry rising main and the smoke control system.

According to the design guidance referenced at the time of the original construction, buildings over 60 metres required a wet fire main. According to the wording in the design guidance, the building height was to be measured to any floor of the building. The plant room was 65.5 metres above ground in Grenfell Tower. Therefore, a wet fire main was required when the tower was originally constructed. However, a dry main was provided.

Works were carried out to this existing dry main during the primary refurbishment. The inlet valve which is used by the Fire Brigade to charge the fire main with water was relocated from the central core of the building at ground level to the exterior of the building, next to the main entrance on the south elevation.

New piping connected this new inlet to the existing main. Vertical and horizontal piping was installed as

part of these works. I do not know the exact route or length of piping added; however, the new inlet is approximately 8.5 metres from the location of the original dry rising main.

New connections for firefighting hoses were installed at the first, second and third floor, so that the dry rising main served every floor above ground level.

At the time of the primary refurbishment, the existing smoke control system was reaching the end of its serviceable life. The smoke control system was refurbished to improve performance and reliability, as I understand matters.

It was also changed from a stand-alone smoke control system to a combined smoke control system and environmental system. The environmental system was installed to mitigate the heat gains from the new communal heating system.

The original smoke control system in Grenfell Tower included a fresh air shaft and a smoke extract shaft serving all of the residential lobbies. It had no environmental air purpose. Each lobby had a fresh air inlet on one side of the lobby and a smoke exhaust vent on the opposite wall of the lobby. A manual so-called fireman's override was located at ground level.

All lobbies contained four vents: two high-level vents on the north wall and two low-level vents on the south wall. These vents were mechanical, so they could open and close to allow airflow in and out of the lobby.

Originally, the low-level vents connected directly into two fresh air shafts on the south side of the lobby. A fresh air supply fan was installed at the bottom of the south shafts on level 3.

The high-level vents connected directly into two smoke exhaust shafts on the north side of the lobby. A smoke extract fan was installed at the top of the north shaft at the roof.

There was a smoke detector in each lobby. If smoke was detected in the lobby, the vents in that particular lobby were intended to open. The vents on other floors were intended to remain closed.

The south low-level vents were to supply fresh air to the lobby. The north high-level vents were to extract smoke from the lobby.

This existing smoke control system was refurbished and extended during the primary refurbishment and to work as both an environmental ventilation system and a smoke control system. The original vent openings in levels 4 to 23 lobbies were retained during the refurbishment. This meant, again, each lobby had

low-level and high-level vents. The vertical shafts were extended downwards to serve the newly created residential lobbies on the first, second and third floors and the existing lift lobby at ground.

At level 2, the existing connection to the outside of the building was replaced, including new fan sets. These new fans at level 2 were connected to the south shaft by horizontal ducts. These photographs show smoke exhaust fans at level 2. The smoke extract fan set at level 2 had dual power supplies, a primary power supply and a backup power supply in case primary power was lost. The ducts connect to the outside of the building by a vent above the entrance on the south elevation.

This photograph shows the ductwork used to connect the fans to the south shaft and on to the external face of the building. The ducts were positioned in the new stair enclosure, directly above the escape route from the internal protected stair at level 2.

Just like the original vents, the new vents were mechanical. In environmental mode, they were intended to open and close to allow air in and out of the lobby in day-to-day use. In smoke mode, they were intended to open and close to allow smoke into the shaft from a single lobby.

A new combined environmental and smoke extract fan

set was installed in the rooftop plant room and connected to the two north shafts. Both fans had dual power supplies consisting of a primary power and backup power supply. A weather housing was provided over the top of the shaft.

In the event of a fire and were smoke to enter a lobby, smoke detectors within the lobbies were intended to trigger the control system to fire mode. This is a photograph of one of the smoke detectors in the level 3 lobby for smoke control activation.

The sequence of events in smoke mode was intended to be as follows. Firstly, the vents on all other floors should shut and all the vents on the floor where smoke has been detected open. This is to isolate the non-fire floors from the floor where the fire is located, and to direct the full capacity of the smoke control system to the fire floor only.

The roof smoke exhaust fan should turn on and pull air and smoke out of the lobby vents, up the north shaft, where it vents from the building at roof level.

The environmental fan at level 2 should shut down. The separate smoke extract fan should then turn on and pull air and smoke out of the lobby vents, down the south shafts and vent from the building through the second floor external wall.

As air and smoke is extracted from the lobby by all the vents within it, air is drawn into the lobby from the stair. A permanently open vent was also located at the roof of the stair. Fresh air was intended to be drawn down through the stair and into the lobby. The flow of fresh air through the open stair door or through the gaps around the stair door, if the stair door was closed, is intended to prevent smoke entering the stair from the lobby. This is the design intent, to maintain the protected stair as a safe space for escape and fire fighting.

According to design documentation, the refurbished smoke control system was also designed to allow firefighters to change the floor of operation of the smoke control system, so change it from the current floor of operation to any other floor. The smoke control system was to be designed to operate on a single floor at any one time.

Within the entrance foyer, a control panel was provided. This was to enable the Fire Brigade to close all vents on all floors in a single operation. I have requested further information on this system.

According to design documentation, the smoke control system was also provided with override switches on each floor. I observed those switches in my site inspection.

Operation of the switch should allow the Fire Brigade to open the vents on that floor only and lock the switches on all other floors so that those vents could not be accidentally opened at the same time.

Returning this mechanical switch to its original position should close the vents on that floor and unlock the switches on every other floor. This is intended to enable the Fire Brigade to operate the smoke control system on any chosen floor using that respective key switch.

A new heating and hot water system and cold water system was installed, and these systems served every floor and every flat in Grenfell Tower. Pipes were routed throughout the tower, from the basement level through to the roof level, and into each and every flat and non-residential accommodation. Each pipe penetration through a compartment wall and floor was therefore required to be protected. New boilers were installed in the basement to serve this new system, and the landlord gas supply, as I've explained, was extended to supply those boilers. The original boilers were retained and they continued to serve the three finger blocks.

In addition to the new boilers in the basement, the new heating and hot water system included a heat

interface unit in each of the flats. The intention was it was to provide space heating and instantaneous hot water for that respective space. A pair of flow and return pipes connected each heat interface unit to the new boilers in the basement. I am going to refer to each pair as a riser to simplify my explanation of the pipe routing throughout the building.

Five risers connected the basement to level 2, serving all flats and non-residential accommodation on these levels. A sixth riser connected the basement to level 23, serving all flats on levels 3 to 23. This riser entered the protected stairway between levels 3 and 4 only. This riser then continued up the building through each protected lobby from levels 4 to 23, but within a riser cupboard in the lobbies.

The pipes appear to have been fire-stopped at each floor level, but I currently have no information available to me as to the fire performance possible from that construction.

A pair of pipes then routed out of this riser cupboard latterly across the ceiling, passing in through the compartment wall to each flat. The pipes appear to have been fire-stopped at that compartment wall also, but, again, I have no information available as to the fire performance possible from that construction.

Cold water pipes were run from water tanks on the roof down through the protected lobbies also. One pipe was run from the 23rd floor down to the 14th floor. A second pipe was run from the 23rd floor down to the third floor. This pipe then continued down to the basement level and fed risers to residential flats and non-residential accommodation areas on ground floor to level 2. Cold water pipes were routed across the ceiling of each lobby to each of the flats.

In every lobby between the 4th and 23rd level, a new partition and doors were constructed around the vertical pipes. A new ceiling was also installed in every lobby below the new pipes.

This ends my description of some of the works within the primary refurbishment.

I will next provide an explanation of the cladding, but we might take a short break.

SIR MARTIN MOORE-BICK: Would you like to do that now?

DR LANE: Yes, I would, please.

SIR MARTIN MOORE-BICK: All right, we'll break for a short time now. I suggest we resume at 2.55.

Thank you very much.

(2.40 pm)

(A short break)

(2.55 pm)

SIR MARTIN MOORE-BICK: Yes, Dr Lane, when you're ready.

DR LANE: Thank you.

Okay, the final part of my presentation today is about the external wall refurbishment.

During the 2012 to 2016 primary refurbishment, a comprehensive recladding of the external wall of the existing building was undertaken. To do this, the existing external wall construction was over-clad with a ventilated rainscreen system. New windows were installed and new linings to those windows were installed internally.

I will first describe the multiple components of a ventilated rainscreen system and the fire safety provisions required for external wall construction, before describing in detail the materials and arrangement of materials as I have found them at this stage.

Today I am only describing materials; I'm not presenting my Phase 1 report opinions on fire performance, testing or compliance status.

The rainscreen cladding system was a drained and ventilated system. I have referred to the British Standard code of practice for stone-based rainscreen cladding in describing the key components of a ventilated rainscreen system.

This image is a correction through a ventilated rainscreen system. The highlighted portion is the outer layer, also referred to as the rainscreen. This outer layer is intended to shelter the building from the majority of direct rainfall. Some joints between panels or at the edges of the rainscreen should be left open.

The second key part now highlighted is a cavity behind this outer layer, a cavity which can include insulation and which is intended to collect any water which passes through the joints in the rainscreen layer, and to permit such water to flow down to a point where it can be collected and drained from the cavity. The insulation layer should not completely fill the cavity.

A cavity is also defined in Approved Document B as a space enclosed by elements of a building or contained within an element. It can also be referred to as a concealed space.

Where insulation is provided within the cavity, it should not completely fill the cavity so as it does indeed ensure water can flow down to a point where it is collected and drained.

The third key component of a rainscreen system is the backing wall which sits behind the cavity and the outer layer. The backing wall is intended to provide a barrier to air infiltration and water ingress into the

building.

Regarding the fire safety requirements, requirement B4 makes requirements regarding external fire spread and, specifically, part 1 of B4 requires the external walls of the building shall adequately resist the spread of fire over the wall.

Approved Document B also states that the provisions are made in section 12 for the fire resistance of external walls and to limit the susceptibility of the external surfaces of walls to ignition and to fire spread.

I will now explain section 12.

In paragraph 12.5, as I explained this morning, it describes two methods to meet the regulation: that either the construction of the external wall should meet the specific guidance within paragraphs 12.6 to 12.9, or meet the performance criteria given in BR 135. The test described in BR 135 is the British Standard 8414 test.

I will explain first the method provided for in each of the paragraphs 12.6 to 12.9 inclusive.

I consider the outer layer, the rainscreen layer, to be an external surface. Paragraph 12.6 states:

"The external surfaces of walls should meet the provisions in diagram 40."

The section of diagram 40 of Approved Document B

which is relevant to Grenfell Tower is shown on the left-hand side of the screen now. For clarity, I have changed the original Approved Document B marked dark grey to a blue colour.

The image on the right is how diagram 40 would apply to Grenfell Tower. Ground to level 5 are less than 18 metres above ground. Level 6 to roof level are more than 18 metres above ground. A building height of 18 metres or more means any external wall surface above 18 metres must achieve either class 0, national class, or class B-S3, D2, the European class, or better.

I have based my opinion on the fire performance of the rainscreen panels installed on Grenfell Tower on the basis of diagram 40.

Paragraph 12.7 requires any insulation product, filler material -- not including gaskets, sealants and similar -- et cetera used in the external wall of buildings greater than 18 metres to be of limited combustibility.

The classification "limited combustibility" is defined in appendix A in Approved Document B, and I refer you to all the detail in appendix F of my Phase 1 report. But in the very simplest of meanings, a material of limited combustibility is either a non-combustible material or a material which produces

very little flame under heating. All of this must be determined using either British or European reaction to fire tests.

I have made the basis of my opinion clear and in detail in appendix F in my Phase 1 report, that Approved Document B provides no definition of filler material, nor why that excludes gaskets, sealants and similar, et cetera.

I have explained why I apply paragraph 12.7, insulation materials and products, to insulation products only.

Finally, paragraphs 12.8 and 12.9, relate to the provision of cavity barriers within the external wall construction. Cavity barriers are a construction provided to close a concealed space against penetration of smoke or flame, or they are provided to restrict the movement of smoke or flame within such a space.

Using diagram 33 from Approved Document B, cavity barriers are therefore required around the openings created by the windows; at the head of the rainscreen cladding system to close the top of the external wall cavity; at the junctions of every compartment floor and the rainscreen cladding system; at the junctions with compartment walls separating flats and the external rainscreen cladding system.

In this image, I have indicated where vertical and horizontal cavity barriers are required around openings created by windows in a rainscreen cladding system.

In this image, I have shown where horizontal cavity barriers are required at the junction of the internal compartment floor and the external rainscreen cladding system.

In this image, I have shown where vertical cavity barriers are required at the junction of the internal compartment wall and the external rainscreen cavity, which would result in the cavity behind the rainscreen cladding to be subdivided like this.

Finally, in this image, I have shown where horizontal cavity barriers are required at the head of the rainscreen cladding to close the top of the cavity. This is the crown at Grenfell Tower.

The statutory guidance document, Approved Document B, also makes provisions for the construction of cavity barriers. They are required to achieve at least 30 minutes integrity and 15 minutes insulation fire resistance. Specifically around openings, cavity barriers may instead be formed of specified materials of a minimum thickness. In addition, cavity barriers must be tightly fitted to rigid construction. Where it is not possible to tightly fit the cavity barrier,

a different protection method, called fire-stopping, must be used in those locations instead.

Fire-stopping has a different purpose to a cavity barrier. It has a higher standard of fire resistance. The required fire resistance of fire-stopping for a residential building greater than 30 metres is two hours' integrity and insulation at the junction between the compartment floors. It is one-hour integrity and insulation at the junction of the internal compartment walls with the external wall.

Therefore, if a rainscreen outer layer was not interpreted by the designer as rigid construction, then fire-stopping would be required instead of cavity barriers. Approved Document B does not state either way if rainscreen systems are considered rigid construction.

Now I will describe the second method referred to in the Approved Document B. The second method is to meet the performance criteria which are given in BRE report 135 using full-scale test data from British Standard 8414. I will be producing a separate report on this matter and will not go into detail at this stage, only to show this image on the left of a ventilated rainscreen system installed on the test apparatus for conducting a British Standard 8414 fire test.

The test standard specifies the size and orientation

of the system for testing. It requires the complete cladding assembly to be tested. The complete assembly is defined within as complete cladding assembly, including sheeting rails, fixings, cavities, insulation and membranes, coatings, flashings or joints, and these are to be specified by the test sponsor and affixed to the masonry test walls using their proprietary system fixing.

The performance criteria that Approved Document B, paragraph 12.5, refers to is defined in annex A of BR 135. It states performance of the system is to be evaluated against three criteria: external fire spread, described as fire spread up the building envelope by way of the surface of the external cladding system; internal fire spread, described as fire which spreads unseen through the external cladding system; and, finally, mechanical performance. Whilst failure criteria are defined for external fire spread and internal fire spread, no failure criteria are defined for mechanical performance. I will be considering these matters separately.

I have taken two main actions to confirm the materials and their arrangement used in the overcladding and internal lining of the external wall of Grenfell Tower. I carried out detailed on-site

inspections on 6 October, 1 November and every day between 7 and 9 November. I have carried out a detailed review of evidence from the relevant parties provided to me by the inquiry. I will update my Phase 1 work if any additional evidence becomes available. I have focused my analysis on the external wall construction of the original residential floors.

The image on the left illustrates the existing construction of the external wall of Grenfell Tower, the existing solid concrete perimeter beams, concrete columns with decorative concrete cladding, both were retained. The aluminium frame sliding windows were removed. These windows were replaced with new window frames containing glazed panels and insulating polystyrene core panels, and a small window to accommodate the kitchen extract fan.

The external overcladding of the existing wall was to create a ventilated rainscreen cladding system and so resulted in: the original building external wall used as the backing wall; a new weatherproof membrane between the new windows and the existing concrete structure; new thermal insulation applied directly to the backing wall; a rainscreen cavity drained to the exterior; and rainscreen cladding panels as the outer layer.

We're going to show an animation of all the layers

now before I go through each one in turn.
(Pause)
First, I would like to talk specifically about the new window frames with glazing and insulating polystyrene core panels.
This image shows the assembly of the windows, including glazing panels, larger insulating core panels and smaller insulating core panels with a small fan mounted in the centre.
The new window frames marked in blue were system 5-20Hi+ tilt and turn windows, which were manufactured by Metal Technology Systems. The frames were made from polyester powder coated aluminium alloy. Aluminium is not a combustible material unless it is ground into a powder.
The glazing in the window frames is highlighted in dashed red. The glazing used was a double glazing system with a 6-millimetre toughened glass pane either side of a 16-millimetre argon-filled cavity. Glass is not a combustible material.
The white panel, indicated in a dashed pink, is an insulating core panel. This infill panel was a product called Aluglaze manufactured by Panel Systems Limited. The panels installed were 1.2 metres high and 1 metre wide. Aluglaze is described by its suppliers as

comprising aluminium bonded to an insulating core. A 25-millimetre Styrofoam core was specified for these panels. Styrofoam is extruded polystyrene and extruded polystyrene is combustible.
I have highlighted the smaller window insert insulating core panels in dashed yellow. These panels were 530 millimetres by 500. This panel was specified to be a core of 25-millimetre Kingspan TP10 insulation. TP10 is a polyisocyanurate, which is a combustible material.
However, I did not find Kingspan in those locations where I inspected them; I found more Aluglaze-type panels with a polystyrene core. The foam insulation observed on site was light blue, which is consistent with the Styrofoam, which is extruded polystyrene, and as specified for the main infill panels.
This whole window assembly, including the glazing and the insulation core panels, was then fixed to the outside face of the existing horizontal concrete perimeter beams, as illustrated here.
I remind you the horizontal concrete above and below the windows are beams which support the internal floor.
The window frame is bolted onto the outside of the existing external wall using metal brackets at the top and bottom of the window frame. Therefore, the new

position of the window is 185 millimetres further out relative to the original windows.
Additionally, the new position of the window frames relative to the existing external wall structure also introduced a gap around the edges of the new windows. The design anticipated this gap to vary between 35 and 90 millimetres as the existing columns were not perfectly straight. The gaps that I was able to observe on site varied between 30 and 120 millimetres.
To close the gap introduced by the alterations to the size and position of the new windows, a damp proof course, also called a membrane of ethylene propylene diene monomer rubber, referred to as EPDM, was used as a weatherproof seal. EPDM is a synthetic rubber and is a combustible material.
The photograph on screen now was taken during my site investigation, viewing the new window frames where they meet the columns. Highlighted with the dashed line, visible in the gap once the external cladding panel is removed from view, is the damp proof course.
In this image highlighted with the dashed line, visible in the gap once the internal linings were removed from view, is the black EPDM.
The new thermal insulation was directly fixed to the perimeter beams and the vertical concrete columns.

Two layers of thermal insulation were fixed directly to the face of the building above and below the windows. A single layer of thermal insulation was fixed directly to the face of the columns. Each were fixed using a 180-millimetre stake screwed into the face of the existing concrete perimeter beam or column. The 180-millimetre stakes pierced the insulation, therefore mechanically fixing it to the existing structure.
On the columns, this was a single layer of 100-millimetre thick polymeric foam insulation with an aluminium foil outer facing. The designation shows that it was manufactured by Celotex. The product used was Celotex RS5000, which is made from polyisocyanurate foam. This is commonly shortened to PIR. PIR is a combustible material.
On the perimeter beams, the same insulation material, Celotex RS5000 PIR, was affixed in two separate layers of 80 millimetres directly to the wall. This photograph shows the perimeter beam area after one of the two insulation boards has been removed, revealing the second layer of insulation behind it. An expanding foam was used as joint filler to partly fill joint gaps associated with the insulation throughout the rainscreen system.
The Harley material data sheets show this was

a polyurethane foam.
Purchase orders show that, due to supply issues with Celotex RS5000, 276 metres squared of a Kingspan product, Kooltherm K15 rainscreen board of 80-millimetre thickness, was ordered as a substitute. These Kingspan boards were applied to the horizontal perimeter beam, as can be seen in the image on screen.
The final material I will explain is the rainscreen outer layer. At Grenfell Tower, these were Reynobond 55 PE aluminium composite panels. They were installed on the vertical length of the columns and in horizontal runs above and below the windows of each floor meeting the columns. I have highlighted the location of the panels below a window in the photograph on screen. These panels were typically 1.3 by 1.2 metres wide below the windows.
I have also highlighted the location of the panels that were installed on the columns of the building. These panels were typically 2.5 metres high and 0.55 metres wide.
Arconic Reynobond 55 PE aluminium composite panels consist of 0.5-millimetre aluminium sheets either side of a 3-millimetre thick polyethylene core. Polyethylene is a combustible material.
Arconic Reynobond 55 PE panels are manufactured as

flat panels. These flat panels can either be screwed or riveted into the support frame as shown on the left-hand image on screen.
Alternatively, the edges of the panels can be bent, making a 3D shape. Slots are cut in the edges of the panels so they can be hung on a support rail behind. Therefore, the support is then hidden behind the front face of the panel. These are called modular cassettes. This modular cassette method was the method of supporting the rainscreen cladding at Grenfell Tower.
Vertical metal channels were attached to the building exterior at approximately 1.15-metre centres, as measured on site. These vertical channels were bolted to the underside of the metal brackets supporting the new window frames.
These cladding rails were in turn fixed back onto the new window brackets.
These photographs from my site investigation show the vertical cladding rails in place below a window. The cladding rails are highlighted in orange and the steel brackets to which they are affixed in green.
My understanding is that both these brackets were manufactured by Trifab. The vertical cladding rail is bolted to the steel bracket. It therefore sits in front of the thermal insulation, but no fixings go through the

insulation itself to support it.
The photograph on the right-hand side is a close-up image of the rail. It is a U shape with metal bolts connecting the two sides. The Arconic Reynobond 55 PE panels were hung on these bolts.
This photograph shows one of the rainscreen panels being removed from the building as I witnessed it. It shows the 3D shape of the panel and the slots cut into the edge to hang on the bolts within the cladding rails.
This animation illustrates the application of the rainscreen cladding panels to the horizontal perimeter beam and the vertical columns.
As shown on screen now, gaps were left between aluminium composite panels in their installed position. On site in the areas I inspected, I noted that the panel gaps range between 15 and 30 millimetres. At the edge of the panels in these gaps the polyethylene core is clearly visible, and polyethylene is combustible, as I said.
The installation of a rainscreen cladding system to the outside of the existing building created cavities between the existing concrete wall and the new rainscreen outer layer. The cavity formed between the original concrete structure and the rainscreen cladding above and below the windows is illustrated on screen.

This cavity contained two layers of 80-millimetre either Celotex or Kingspan insulation on the perimeter beams. Therefore, the depth of cavity between the insulation and the rear face of the aluminium composite panel is 156 millimetres.
The cavity was also formed between the concrete structure and the rear face of the aluminium composite panel attached to the columns. The column cavity contained 100-millimetre thick insulation. Therefore, the depth of cavity between the insulation and the rear face of the ACP here is 139 millimetres.
Horizontal cavity barriers were installed on both the columns and horizontal perimeter beams at Grenfell Tower. The photograph on screen now shows a horizontal cavity barrier fixed to the front face of a column on Grenfell Tower. The cavity barrier is mechanically fixed in place using metal support brackets, which pierce the full depth of the cavity barrier. A split protruding end of the bracket should be counter-folded to retain the cavity barrier in position.
In this picture, the split end has not been counter-folded and, instead, has been bent in a single direction.
The cavity barriers I observed were SIDERISE RH25

open state horizontal cavity barriers. They come with instructions to be installed with a 25-millimetre gap between the front face of the cavity barrier and the rear face of the rainscreen outer layer, allowing drainage of any moisture within the rainscreen cladding system as required and for the purposes of maintaining the required airflow.

This horizontal cavity barrier consists of non-combustible stone wool core with reinforced aluminium foil faces. The front face, highlighted in orange, is a reactive intumescent strip which is bonded to the barrier. In the event of exposure to fire, the intumescent strip expounds outwards and is intended to close the gap between the cavity barrier as installed and the rear face of the rainscreen panel.

These two photographs show the horizontal ventilated cavity barrier installed below a window at Grenfell Tower. Several notches were cut in the cavity barrier to allow the cladding rail for the rainscreen panels to pass through. The picture on the right-hand of the screen then shows how the cladding rail passes through the horizontal ventilated cavity barrier. The photograph on the left-hand side of the screen shows the same cavity barrier with the cladding rail removed, showing the gap that was cut in the cavity barrier.

Vertical cavity barriers were installed on 10 of the 14 columns of the tower. For the vertical cavity barriers, the Harley design drawings specified SIDERISE RVG full fill cavity barriers. The image on the right is taken from SIDERISE product literature. It shows the SIDERISE RVG full fill cavity barriers are to be installed over the full depth of the cavity, leaving no gap. It is a mineral wool product which is non-combustible.

On site I observed instead that the horizontal cavity barrier product, SIDERISE RH25 open state cavity barrier, had been rotated and installed vertically. It had also been installed with the intumescent strip facing into the existing concrete structure.

This photo shows the SIDERISE RH25 cavity barrier rotated and installed in the vertical position. A gap was observed between the roughly cut mineral wool barrier and the rainscreen panel.

I observed some required cavity barriers not to have been installed at Grenfell Tower. This image illustrates the cavity barriers present in the external wall cavity. It can be seen there are no cavity barrier products installed around the openings made by the windows.

The installed internal material linings to the

windows in the refurbishment, which I will describe shortly, are also not considered to meet the performance of a cavity barrier as defined in Approved Document B.

No cavity barriers were specified at the head of the external wall cavity up by the so-called crown. I have yet to carry out an inspection of that area to check if they were anyway.

I will now move to the materials on the interior of the tower.

This photo from prior to the refurbishment illustrates the original windows and material lining the window reveals on the left. When the original windows were removed, the highlighted lying materials were also removed. New materials were then installed internally around each of the windows. The materials highlighted here are the final finished linings. As you can see, the location of the new materials installed was limited to the top, bottom and both sides of every window opening.

The materials applied internally included:

Existing timber, part of the original window linings. This solid timber material is highlighted in blue in the image of the original construction which is on the left.

New uPVC linings around the window opening. UPVC,

plasticised polyvinyl chloride, is a solid plastic combustible material. This is highlighted in orange in the right-hand side image.

Pieces of insulation placed between the existing concrete construction and this uPVC lining. This is highlighted in yellow in the right-hand image, as well as other larger pieces of thermal insulation underneath all four sides of the uPVC linings, which I will also explain.

Firstly, timber batons and, in places, timber board, which formed part of the original linings to the window reveals, were left directly affixed to the concrete construction. I have shown the position of these materials in the images on the screen here.

The timber materials themselves can be seen in this image, which shows the condition when all the newly installed linings have been removed. Where the original timber lining was retained, this was approximately 195 millimetres wide and, as can be seen in the image on the left, does not extend out to the new window position; a gap exists.

While inspecting the external wall of Grenfell Tower, I observed foam-type filler materials placed in these gaps. This image on the right is a view looking up to the top of the window at the right-hand

corner. In the gap above, between the window frame and the existing concrete face of the building, an orange foam filler material can be seen.

I also observed insulation material underneath the uPVC lining directly, 25-millimetre thick insulation foam beneath the uPVC, filling the gap between the original timber window linings and the new window frame location. I have found no evidence of a specific insulation product or material specified for this location. In this image, I have illustrated the locations that it was observed; that is around all four sides.

This image shows a polymeric insulation foam with foil facing installed at the head of the window between the new window frame and original timber lining. The final window material has been removed by others. There are no identifying logos or labels on this sample.

The pictures on screen now were taken during my site investigation, looking right at the opening between the original infill panel between windows and the new Aluglaze insulating core panel. In this location, I found 25-millimetre thick polymeric foam sealing the edge of the void created between the old and the new infill panel. The markings on the aluminium foil facing of the insulation appears to indicate that it was

Celotex TB4000, noting the Celotex logo highlighted with the orange dashed box. TB4000 is a PIR insulation. This requires formal identification via testing, however, as the design drawings do not show insulation in this location.

Further samples of insulation removed from the underside of the uPVC show a different product logo. The green logo, highlighted with the orange dashed circle here, is consistent with the Kingspan Therma range of PIR which, as I have explained, is combustible. This, too, requires formal identification via testing.

Now turning to the uPVC lining itself.

I observed the uPVC lining to all four sides of each window. The material is a rigid combustible plastic used for a variety of construction purposes.

Where the uPVC lining had been removed by others, I was able to observe its thickness as 10 millimetres. The zigzag pattern I observed on the underside of the uPVC lining was replicated on the original timber linings from which they had been removed, indicating the uPVC lining was glued in position.

These images illustrate the final finished surface of the uPVC lining to the window openings.

I have earlier explained that no cavity barriers were installed within the external cavity of the

rainscreen overcladding around the openings. Approved Document B, however, does permit cavity barriers around openings to be formed of specific materials of a minimum thickness. These include: steel, at least 0.5 millimetres thick; timber, at least 38 millimetres thick; polyethylene sleeved mineral wool or mineral wool slab under compression; calcium silicate, cement-based or gypsum-based boards, at least 12 millimetres thick.

The materials as I have just described them installed internally at Grenfell Tower around the openings created by the new windows do not meet these requirements. As the internal materials cannot be considered as cavity barriers either, no cavity barriers of any kind were present around the window openings within Grenfell Tower.

Finally, whilst inspecting the external wall of the tower, I observed a soft material above each window. Specifically, I observed a strip of board adjacent to the head of the window. The top-right image shows it was an 8-millimetre hardboard and a 12-millimetre foam. I observed a portion of the board which had been removed by others in flat 23. The board was labelled ICI purlboard, which is a polyurethane foam and plasterboard composite product, and polyurethane is also

a combustible plastic material.

This concludes my description of the materials used and how they were arranged and fixed for the external and internal refurbishment of the external wall of Grenfell Tower.

Thank you.

SIR MARTIN MOORE-BICK: Thank you very much indeed.

Thank you.

MS GRANGE: Thank you, sir. That concludes Dr Lane's presentation today and we will commence again tomorrow at 10 am with the presentation of Professor Niamh Nic Daeid.

SIR MARTIN MOORE-BICK: Yes, thank you.

MS GRANGE: Thank you.

SIR MARTIN MOORE-BICK: So we'll finish there and we'll be back here at 10 o'clock tomorrow morning.

Thank you all very much.

(3.40 pm)

(The hearing adjourned until Tuesday, 19 June 2018 at 10.00 am)

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