Thursday, 29 November 2018
(10.00 am)
SIR MARTIN MOORE-BICK: Good morning, everyone. Welcome to today's hearing.
Today we are going to hear from another of the inquiry's expert witness.
Yes, Mr Rawat
MR RAWAT: Good morning, Mr Chairman.
Our witness today is going to be Professor David Purser. But before I call Professor Purser, can I just explain what we're going to be doing today.
He will begin his evidence by giving a presentation setting out the work that has gone into his Phase 1 report, which has been circulated and published.
The presentation is in three parts, and for each part, the professor has prepared detailed slides to which he will be speaking.
If I make clear, these slides contain images, including diagrams of flame ingress and smoke production, photographs of the tower and also fire damage in other buildings.
Because of the nature of the professor's work, he will also be talking about the impact of toxic gases on people.
SIR MARTIN MOORE-BICK: Yes. So there's quite a lot that

might be distressing.
MR RAWAT: That is exactly it. So I will give a shorter warning as we go through the presentation, but I want to repeat a warning now that we have given on previous occasions that some may find the contents of the slides and, indeed, the presentation itself distressing.
SIR MARTIN MOORE-BICK: Thank you very much.
If people fear that they may be upset by what is going to be shown, they can of course leave, and they can leave at any time if they feel that is appropriate.
MR RAWAT: Thank you, sir.
Can I now call Professor David Purser.
SIR MARTIN MOORE-BICK: Yes, thank you.
PROFESSOR DAVID PURSER (sworn)
SIR MARTIN MOORE-BICK: Thank you very much, professor. You prefer to stand up to give your --
THE WITNESS: I'll start by standing up. I might perch on this stool.
SIR MARTIN MOORE-BICK: Yes, do.
Yes, Mr Rawat.
MR RAWAT: Good morning, professor.
A. Good morning.
Q. Could you confirm your full name for the record, please.
A. David Anthony Purser.
Q. Can you confirm that you have provided a preliminary

Phase 1 report to the inquiry which is dated 5 November 2018?
A. I have.
Q. Can you also confirm that you were asked in that Phase 1 report to address three matters: firstly the production of toxic gases in fires similar to that at Grenfell Tower and the consequences of inhaling toxic gases in such circumstances, both physiological and behavioural; secondly, the toxicity when exposed to fire of certain materials which were present at Grenfell Tower; and, thirdly, any recommendations arising from those two points that I've just set out, including as to any further testing which ought to be carried out which is relevant to the issues.
A. Yes.
Q. Is it also right that you were asked to set out your preliminary conclusions on, again, three matters: firstly, the production of toxic gases and consequences to occupants of different generic fire scenarios and conditions occurring in fires similar to those likely to have occurred at different stages and locations during the Grenfell Tower fire; secondly, the likely causes of incapacitation and death at Grenfell Tower, including those whose bodies were consumed by the fire; and, thirdly, the possible toxicity performance of materials

present at Grenfell Tower?
A. Yes.
Q. It is important to note before we continue that you have also been instructed to provide a further report at Phase 2, which will address the matters that I've just listed, but which will be updated and expanded as necessary.
A. Yes.
Q. You have confirmed and said in your report that it is a preliminary report and you intend to conduct a more detailed analysis in your Phase 2 report; that's right, isn't it?
A. Yes, that's an important point.
Q. So is it right, therefore, that the views which you express in your Phase 1 report are provisional?
A. Yes.
Q. Can you confirm that the statements made in that report, whilst provisional, are true to the best of your knowledge and belief?
A. To the best of my knowledge, yes.
Q. Can you also confirm that you've provided this report in the same way as you would've provided a report to a court?
A. Yes.
Q. Can I begin, then, just by dealing with your

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professional background.

Appendix C to your report sets out your background and experience relevant to matters in this inquiry.

I'm not going to rehearse all of that today, but I just want to pick out some key points.

The first of those is that you have a PhD in neurophysiology from the University of Birmingham, and you're also a diplomate member of the Royal College of Pathologists; is that right?
A. Yes.
Q. Secondly, for 17 years, from 1974 to 1991, you were in the department of inhalation toxicology at the Huntingdon Research Centre, where you conducted and directed research in environmental and inhalation toxicology.
A. Correct.
Q. That work included research into the effects of fire products on the nervous system, lung function and behaviour in order to evaluate the mechanisms whereby fire products cause incapacitation and death?
A. Yes.
Q. In 1991, you joined the Building Research Establishment, and up to 2006, you then continued to conduct and direct research on the toxicological and behavioural aspects of human fire exposures; is that right?

A. Yes, and that included a lot of work on fire chemistry and fire testing, things like that.
Q. So to develop that a little, your research included the psychology of human behaviour in fires --
A. Yes.
Q. -- the chemical yields of toxic products in fires --
A. Yes.
Q. -- and the evaluation of fire hazard development.
A. Yes.
Q. You have also lectured on toxicology, combustion chemistry and fire safety at a number of universities, both national and international.
A. Yes.
Q. You've authored and presented a total of 152 publications and conference presentations; is that right?
A. Yes.
Q. You've been a member of a number of British and international safety committees relating to fire hazards, fire toxicity, fire safety engineering and means of escape.
A. I have, yes.
Q. You've also been a member of health expert committees established to give advice to the Chief Medical Officer.
A. Yes.

Q. As a consultant, you've advised on national and international standards and on toxic and environmental standards, particularly involving combustion.
A. Yes.
Q. You've also advised on means of escape design in a number of building projects, both in the UK and abroad?
A. Yes.
Q. As a legal expert, you've been instructed in cases both in this country and internationally as an expert in fire toxicity and human behaviour in fire.
A. Yes.
Q. That included the Rosepark fire, which you will be discussing today.
A. Taking about today.
Q. Is it right that in 2013, the Institution of Fire Engineers awarded you the David Rasbash Medal for outstanding contribution to the advancement of knowledge in fire behaviour?
A. Yes, they did.
Q. Finally, is it right also that in 2015, you were made Commander of the British Empire for services to fire safety?
A. Yes.
MR RAWAT: I've explained before you came in, professor,

that the first part of today's hearing is going to involve a presentation from you on your report. It's in three parts, the first part of which is headed "Production of toxic smoke and gases and effects in generic domestic fire scenarios similar to those occurring at Grenfell".

Can I now invite you to give the first part of that presentation.

Presentation 1: Productions of toxic smoke and gases and effects in general domestic fire scenarios similar to those occurring at Grenfell

PROFESSOR PURSER: Thank you very much.

Just to reprise some of that, I just wanted to highlight the fact that initially I'm going to be talking about generic effects, and you may be wondering why I'm going to address generic effects rather than just talking specifically about Grenfell, and I will come to that later.

Also to reprise the point that my Phase 1 report is intended to be a general report that does not make reference to specific detailed evidence regarding individual Grenfell occupants.

At phase 2, the report will be update and expanded as necessary in relation to the continuing evidence, and I will be then bringing in a lot more detail from the witness statements and oral evidence, and the transcripts of emergency calls made by Grenfell occupants during the fire. I will also be reviewing the firefighter evidence.

Now, I've already been doing a lot of work on this area, and so while I'm talking to you today, although I'm not going to go into great detail about individual persons, a lot of this material is in the back of my mind as I speak to you and is informing my presentations.

My main objective and main purpose, as I see it, is to obtain a detailed understanding of the conditions to which each person inside the tower was exposed, and how their behaviour, escape capabilities and survival were affected.

Before I go a bit further into my report, I just wanted to highlight a few small points. The first one is: what do we mean in this context by toxicity or toxicology?

I think you might find it useful to think of toxicology as having two main aspects. One aspect is pathology, which is basically tissue damage, and the other is physiology, which is direct, immediate effect on people.

Pathological toxicological effects often take place

over a long period of time. Minimally, they usually take days to develop, and frequently months to years. But physiological effects, which are also part of toxicology, can happen in seconds to minutes. And it's these physiological effects of exposure to combustion products which is so important in determining whether people survive or die during a fire, and it's really on these physiological effects that I'm going to be concentrating my work today.

You'll be hearing a lot about this. These sort of compounds in smoke that have physiological effects are mainly the irritants, chemicals and smoke particles themselves, and certain gases.

That brings me on to my second point: what do we mean by smoke?

Well, smoke, strictly speaking, is the stuff that you can see during a fire, the grey and black smoke, and that is composed of very, very fine respirable carbon particles. That's the essential part of smoke. Tiny particles of soot, essentially.

Now, in its purest form, this material is relatively harmless, apart from the fact that you can't see through it. But, in reality, during a fire, the fire produces lots of other chemicals, toxic chemicals, and the main problem with these chemicals are they're highly

irritant. Some of them are organic materials and some of them are acid gases, and these compounds stick to the soot particles. So when the smoke gets in your eyes or you inhale it, these can cause an immediate painful effect, making it difficult to see and difficult to breathe. So this is an immediate physiological effect of smoke.

The smoke also contains permanent gases, and some of these permanent gases are asphyxiants, and you're going to hear me talking a lot today about asphyxiants. What these gases do is that when you inhale them, and you inhale certain doses of these gases, they reduce the amount of oxygen getting to your heart and your brain essentially. Particularly the brain. And the brain hypoxia that is caused by this results in dizziness, confusion and collapse, and ultimately death in fires. So the effects of these asphyxiant gases is extremely important.

When I talk about smoke in the next few slides, I'm really encompassing all these things, because they all move together in the fire. So when I'm talking about smoke, I'm thinking about the smoke particles, I'm thinking about the irritant compounds attached to those particles, and I'm also thinking about the irritant gases and the asphyxiant gases that are contained in

that smoke.

Okay? That's smoke.

Now, in order to understand what these are going to do to people, how people at Grenfell were affected and how it affected their ability to survive and escape, you'll understand that I've got to take into account a lot of different aspects of the way the fire developed and people were exposed at Grenfell.

For example, one thing I need to know is when various different materials burned at the different stages of the Grenfell fire, what toxic products did they produce, and how much? We're talking there about the yield of toxic products. If I burn a kilogram of this lectern here, how many kilograms of the toxic gas carbon monoxide will be released into the atmosphere, for example? So I need to know that.

That is the main subject of the third presentation I'm planning to give you today.

But another thing that's obviously very important is not just what is formed, but when it's formed and where it goes. So I really need to know how this smoke, once formed, either inside or outside the tower, has moved in and around the flats and the various spaces in the tower, with time. I'm particularly concerned about when the smoke got into the lobbies at Grenfell on the different floors, because this, I feel, was a key stage in the incident.

So in order to do that, I need a lot of very complicated information, and I am relying mainly, for that, on the work of the other experts that you've heard from, who have described and shown you images of the fire going up the outside of the tower, and shown you the damage inside the tower and these other aspects. So I need to make use of that.

But, particularly, I am making use of what was observed by the occupants, by the witnesses that you've been hearing, during the course of the fire, to help me build up a picture, if you like, of what the conditions were and how they were developing with time.

Beyond that, I also need to understand, as we were hearing earlier, about how individual people will interact with this smoke once they're confronted by it. That in itself is another quite complex area, because it's partly a physical or physiological thing, but very much it's a behavioural thing. If one person sees smoke in the exit over here, they may decide it's too dangerous to go through that smoke and they may stay here, where another person may decide they can escape and plough on through the smoke.

So this brings me to my fourth point here, which is

that a lot of the evidence you're going to hear from me today is really essentially qualitative, in that unlike the evidence from the other witnesses, where they can show you the actual picture of some part of the burnt tower or something like that, a lot of what I'm talking about is going on hidden inside the tower at different times. We don't know exactly when certain things were developed, we don't know exactly the conditions and the timing under which all the materials burned, and we certainly can't predict how each individual person would have reacted to what they were exposed to.

But by taking into account a lot of the work that I've done in previous years in the laboratory and also in fire investigation and human behaviour, taking into the context of what we do know about Grenfell and what the witnesses have told us, I hope by the end of today you'll agree with me that I'm starting to get quite a good picture, if you like, of essentially what happened to people at Grenfell.

So I hope that clarifies some of these points.

So why is my Phase 1 report based mainly on generic evidence on fire hazards rather than specifically on Grenfell evidence? Well, it's because we do have a lot more detailed information from previous incidents and investigations. Unfortunately, there are certain

limitations, as I've alluded to, on the sort of evidence that we have from Grenfell, and I'm going to talk a bit more about that in a minute.

Thirdly, and very importantly, as you heard, a lot of my work is preliminary, it's quite complex, a lot of the information is just coming in or hasn't yet come in, and so because some of these detailed aspects are still under investigation, it's better not to go into too much detail at the moment about individual occupants.

So as you heard, my presentation is in three parts, and we're going to start with the first one, which is very general, about past work, and alludes to sorts of scenarios that may have occurred at Grenfell, part 2 is more specifically dealing with what happened at Grenfell, and part 3 is about the performance of the materials.

Now, one thing that I always have at the back of my mind in these cases, and I'd like you to do the same, is that what happens in fire is very, very time-dependent. This is reflected in the performance-based design principle which underlines a lot of the fire safety engineering standards. In fact, I'm currently working on the British Standard at the moment which is being revised, I'm leading a panel on this.

So fire hazards depend essentially on two parallel

processes. There's two things going on simultaneously in fires. One of these is the time from ignition, when the fire starts, to when that fire becomes dangerous. So the fire starts very small, and it gets bigger and bigger and it spreads throughout a building, and this is happening over a period of time. The threat is increasing.

In parallel with that, you've got the behaviour of the occupants. When will they first realise or be warned that there is a fire? When will they decide to evacuate? How long will it take them to evacuate? How does that parallel with the threat, the hazard, that is facing them?

Essentially, in a design context, what we want to ensure is that the available safe escape time, the time available for escape, is greater than the time people need to escape by an appropriate safety margin.

I've kind of illustrated that in principle down in the bottom corner here (Indicates). So normally the work I do, I'm concerned with actually trying to get people to evacuate very quickly in a fire situation, so one is very interested in the time from detection to the fire alarm and the time from the fire alarm to when people start to move. Generally speaking, if people start to be alerted and warned early on, they start to move early on, there's usually a golden early period during any fire when people can make a safe escape.

The problem with fires, as illustrated by this curve here (Indicates), is that the rate at which they get worse tends to get exponentially greater. So if you delay, then you get caught by this time period when the conditions can very, very rapidly deteriorate.

A stark example of that was the Bradford stadium fire which I had some involvement with the investigation of in 1985. This was all captured on television. The match was being televised and you can probably find the video on the web if you want to look for it.

The point here was that at the early stages here, the fire was burning underneath the stand, and you see people here standing around not too concerned initially. But very rapidly then the fire went to flashover, and sadly people went running onto the pitch and the heat from the fire was igniting their hair.

So conditions can deteriorate very rapidly once things start to develop.

Now, in order to try to understand the hazards in a specific fire and when it becomes dangerous, ideally what I need is to determine the time concentration curves for the fire hazards occupants were exposed to, because I'm trying to work out how long this time

available is for escape.

The three hazards I'm mainly concerned about are the smoke, the visibility and density of the smoke, because of the way that affects people's ability and behaviour to escape; I'm interested, secondly, in the asphyxiant gases, because when people have inhaled a certain dose, as I say, they're likely to collapse; and, of course, I'm also interested in whether they will be exposed to heat and suffer burns during the fire, which in itself may incapacitate or kill them.

What I'm trying to do is determine the time during the fire at which escape capability was affected by each hazard, because they tend to occur in sequence, and when collapse and death occurred or is predicted, to find out the effects on occupants' escape behaviour and survival.

Now, on the right-hand side here, I have a set of curves from a reconstruction test of the Rosepark care home fire. I'm going to show you more of these in the next few slides. The only point I'm trying to make at the moment is because we did a reconstruction of this fire, we have the actual time concentration curves measured for the heat, the smoke and each of the toxic gases in the fire.

You'll notice here that at the beginning of this particular fire, there's a period of about 4 or

5 minutes when there's hardly any smoke or gases in the experimental rig, and during that time, if a person was standing under those conditions in that room, they would have 4 or 5 minutes of easy time for escape. But after that, the fire suddenly becomes very serious, and they would be in a lot of trouble. That's why in any fire hazard assessment situation, I'm interested in how these different hazards develop with time during the fire.

Now, in order to do a detailed analysis of the hazards in a fire, ideally when I am investigating an incident there are a number of things that one needs to have.

The first thing is a detailed fire incident investigation. This is in order to obtain in-depth information on the interactions between what is happening to the building, how the fire is developing and the effects on the occupants. This would involve the sort of things that have been done for Grenfell: examining the remains in the building, interviews with survivors, and finding their detailed experiences, all that kind of basic fire investigation work you've been hearing about from the other experts.

It would also involve toxicology and pathology studies, and this applies both to people who may have died in the fire, and also to people who have survived

the fire but had to go to hospital because they've been injured.

So in these studies, what we want to know is: to what extent were people burned? That's pretty obvious. How much smoke did they inhale? You can look at the soot in the airways, things like this, both of living and dead people. And particularly, there's one very important and powerful tool that we have and I'm going to be talking about quite a lot today, and that on this slide is labelled COHb. COHb stands for carboxyhaemoglobin.

Basically, what happens in a fire is that there's always a certain amount of a toxic gas called carbon monoxide, and as a person inhales carbon monoxide, the carbon monoxide combines with the haemoglobin in the blood to form carboxyhaemoglobin. The longer the person is exposed to that carbon monoxide and the higher the concentration of the carbon monoxide inhaled, the greater the level of carboxyhaemoglobin reached in the blood.

So this is a very important tool in assessing the extent and degree to which people have been exposed to toxic smoke, because not only the CO but all the other toxic gases in the fire are all together.

So the COHb is a very good measure of this, and it's routinely measured in both fire victims and survivors. So by looking at the carboxyhaemoglobin in the blood of decedents or fatalities or survivors tells us a lot about what they experienced in the fire.

Now, these fire investigations can give us a lot of useful information, but one thing they lack -- and this is particularly true for Grenfell -- is there's no detailed information on the conditions during the fire just from an investigation after the event, and no detailed information on the effects of the individual hazards. Unfortunately, we don't have any devices in Grenfell which measure carbon monoxide as the fire goes on. We do have, however, the fatalities, which in a way gives us a kind of measure.

Okay? That's the first part.

The next thing that we would like to do if we're doing an in-depth investigation is to set up a full-scale fire reconstruction test to duplicate what happened during the actual incident as far as we are able to do so.

If we do such a test then we can, as we did for Rosepark, as it says on the right there, we can measure those gases, the temperature and the heat and have a complete record of that.

But even this is not perfect, because the test

conditions in an experimental duplication or replication of fire are not always identical, no matter how careful you are, to those that occurred during the actual incident. And, of course, it doesn't tell us anything about the actual effects on the occupants; all we're measuring is gases and smoke.

I would like to take this point to emphasise, because it's important later on, that even if you set up a large-scale fire test and repeat it several times with the identical set-up of all the fuels and the way you ignite it, fires can be inherently variable, and so that fire test can develop in several different ways in different circumstances, even though you've done your ultimate best to try and duplicate it.

So having a combination of incident investigation, showing the damage, and a test does provide useful information, but it's not everything.

The third thing that I can do is to look at the human physiological data on exposures to individual fire gases and mixtures. So what I do is I use some physiological calculation methods, most of which I've developed personally, and they are called FED models, I'm going to explain a bit more about that in a minute, but their main purpose is to predict the timing and effects of what would happen to somebody if they were

exposed to the smoke irritants and asphyxiant gases and heat in the conditions during the experimental test fire. So we don't have people there, but I'm saying if we did have a person there, I could calculate what would happen to them.

Like any model or any method, there are certain variations and uncertainties about this, but it gives us a good way of predicting what would happen. We do need to validate it against real human exposures in actual fire incidents.

Where these methods become quite powerful is when we combine all three. Just to give you an example of this, supposing I carry out a reconstruction test, such as at Rosepark, and I measure the carbon monoxide during the test, I'm able to calculate, as part of my analysis, the amount of carbon monoxide taken up by a person who might have been standing in that rig, and calculate their carboxyhaemoglobin, say, at the time they were rescued. So let's say they have been rescued, they may have 40 per cent carboxyhaemoglobin in their blood.

What I can then do is look at the blood samples taken from the actual victims in the real incident and see if they have similar levels of carboxyhaemoglobin in their blood to those that I predict from the reconstruction test. And if we find that the two

measures are in reasonable agreement, this provides validation that the conditions in the fire reconstruction test were a good recreation of the conditions in the actual incident. It also gives us a lot of information on how and when the occupants were exposed and overcome in the fire.

So the purpose, then, is to understand how flames and smoke developed and spread through a building, how and when occupants were exposed to heat and toxic smoke, why they were unable to escape and how they died.

Now, trying to apply that to Grenfell, one way of looking at it is that Grenfell can be considered as approximately 100 separate domestic fires, fires in what we call domestic dwellings, ie fires in flats. Looking at the totality, there are four main what I'm going to call occupant exposure scenarios.

So the first one, for example, would be where occupants are alerted early during the fire, and then they evacuate, or perhaps decide to remain, but the point is that because they've decided to move or take action early, they experience no or minimal exposure to toxic smoke or heat. They may have some exposure, which may influence their behaviour. But, physiologically, they're going to be minimally affected. That's one scenario and that applies, in fact, to a lot of people who were in Grenfell Tower.

Secondly, they may be in a smoke-free flat for a while, but then open the door to the lobby and find the lobby filled with a very dense smoke. A very difficult situation because of the decision they are then faced with.

So then, depending on the conditions in that smoke and the irritants and gases in that smoke, they may then decide to shut the door and remain in the flat, which has certain consequences, or they may attempt to move through the smoke, which may or may not have other consequences regarding whether they succeed in escaping. Or they may be in their flats for an hour or more while smoke slowly builds up in the flat, perhaps leaking under the flat entrance door from the lobby, and so they have a long, slow, gradually increasing exposure to these toxic smoke and gases, rather than a sudden cliff-edge high concentration.

Then you may have another situation where at some point fire appears outside the flat and breaks in, and you've got a rapidly growing flame fire in your flat, and you then have to deal with the consequences of this rapid short-term evacuation.

So those are the kinds of basic exposure scenarios, if you like, that I'm considering here.

The other thing, of course, is that there are a number of different fire development scenarios in different flats and other the locations. This refers to the way the fire actually developed, which I'm going to talk about a bit.

So I want to talk about Rosepark for two reasons. One is as an example, if you like, of a fairly ideal fire investigation with a lot of information to show how these techniques can be applied. But secondly because I believe quite a lot of the exposure scenarios occurring at Rosepark are relevant to the sorts of general exposure scenarios faced by most of the Grenfell occupants.

So this fire occurred in January 2004 and resulted in 14 deaths of the elderly residents of this care home. On behalf of the Scottish Office and the procurator fiscal, the legal authority in Scotland, the Building Research Establishment, my colleagues and I, were asked to carry out a full-scale reconstruction of the actual incident. My part in this was to advise on the set-up of the rig and to assist with the measurement and interpretation of the gases and the FED calculations.

Not only that, but, in fact, we were then asked to carry out another full-scale reconstruction, but this time with sprinklers, what would've happened if there

had been sprinklers in that care home, which we did. In fact, that has resulted in some changes in the legislation in Scotland regarding requirements for sprinklers.

Thirdly, we did another reconstruction where we replaced the ordinary doors on each of the residents' rooms which were involved in the fire with half-hour fire doors to see what influence that would've had on the way the hazards might have developed. Of course, that's quite relevant to some of the issues at Grenfell.

Finally, after that -- this is about the time I retired from BRE -- I was asked by the procurator fiscal to investigate the timeline and effects on the decedents, the fatalities and survivors to understand the hazards they were exposed to and how they were affected.

Now, this is some photographs of the rig that we built to replicate the Rosepark fire. You don't need to understand the details of this, except to realise that basically what we had here was a sort of dogleg, two corridors, and off these corridors were the individual rooms where the occupants were spending the night.

But the point I want to make to you is that in this rig, we have tried as far as we can to exactly replicate the original building. Not just the building itself and

the bedrooms, but all the original materials. So with the aid of the Glasgow police, we were able to source the actual materials identical to those that were there on the night of the fire. For example, that included, with some difficulty, getting hold of these sort of reclining chair objects, which were heavily padded and were a major source of cyanide during the course of this fire.

Now, the second set of photographs here shows you the rig after the test, and you can see there's quite a bit of fire damage there. The fire was actually in a cupboard on the left here, it started in a cupboard.

But another point I want to make to you is that although there's quite a bit of damage here, this fire was a very short, violent fire, which self-extinguished in a few minutes because it was in an enclosed space. So most of the building and the contents and everything else, although damaged, were still there for us to investigate.

This contrasts to some extent with a lot of the material at Grenfell, because Grenfell continued for about 24 hours. A lot of the material that was involved in the crucial earlier periods of the fire has been destroyed, whereas at Rosepark most of it was still there.

So I'm just going to talk you through a little bit about the Rosepark incident.

So, as I say, it started as a short, violent fire in a cupboard, which is shown on the bottom slide here. Again, we tried as far as we could to replicate what was in that cupboard.

This little graph here shows the temperature in the cupboard as the fire developed, and you can see that it was very short-lived, but it went up to about 1,000 degrees centigrade at its peak. Very, very violent, short, hot fire.

The other thing that's important in this case, if we look at this diagram on the right, this is a plan of the building, and the bit that we've replicated on our rig where the fire was is this dogleg corridor here and all the rooms off it.

There are two corridors, essentially: there's a corridor 4 set and a corridor 3. Between the two is a set of fire doors, and these fire doors closed automatically when the fire started, triggered by the detection system. This meant that these corridors and the rooms off it were to some extent protected from the smoke during the fire.

But a particular feature of this incident was that this cupboard contained a lot of aerosol cans. These

aerosol cans exploded at intervals during the fire. Each time one of these cans exploded, it caused an overpressure in this enclosed system and blew this door open, allowing smoke to flow into corridor 3 and the rooms off corridor 3.

So what we've ended up with is a whole range of different exposure scenarios, because the people, shown in black here, who were in open bedrooms off the fire corridor, with their doors open at night, were exposed to the full force of all the smoke and gases produced by this short fire. But the two people in these rooms here had their doors closed, and so instead of having a short, violent exposure, they had a long, slow exposure as the fire products gradually built up in their rooms, a bit like happened in some of the Grenfell flats when smoke was leaking in from the lobbies. Then we have the set of people off corridor 3 who had somewhat lesser exposure still. So we have different sets we can look at there.

What I was able to do, of course, with this data, as I say, is we measured the gases, and then I analysed the effects.

The next slide is a sort of blown-up simple diagram of this thing. So, basically, as a result of this fire, we had very high concentrations of asphyxiant gases in

the fire corridor: 13,000 ppm of carbon monoxide and about 800 ppm of cyanide. And it was very hot in the corridor, so anybody standing in the corridor during that period could've collapsed and died within a few minutes and possibly suffered some burns, but there was nobody in the corridor.

But then we have the people in the rooms off the corridor who essentially got the same gas exposure but, crucially, not the same heat exposure, and this is something I want to develop in regard to Grenfell. I will talk a bit more in a minute about that.

Then we have the people off corridor 3. Basically, there are various levels of exposure.

So these two people here in closed rooms (Indicates) had a slow build-up over a period of about an hour before they could be rescued by the fire service. These two people here (Indicates), where the red is shown, had their doors open, but they had some protection from the fire doors. So their exposure was somewhat similar to the two blue ones, if you like.

So those four people were alive, survived for nearly an hour in the fire, about half an hour before these two were rescued, and they were rescued alive. Two of them were comatose and never recovered consciousness; in other words, they had hypoxic brain damage from the

carbon monoxide and cyanide inhaled. Two of them recovered consciousness and were relatively well for a short period. One lady was semi-conscious and she recovered in the ambulance and was talking to the ambulance service on the way to hospital. When they got to hospital, blood samples were taken and they were treated, but sadly all four of them later died, and they died after 36 to 48 hours from bronchopneumonia.

To some extent, this may have been brought on by the irritant smoke they'd inhaled. On the other hand, elderly people going to bed rest hospital are very prone to developing bronchopneumonia, particularly if they've had smoke exposure.

So they had a lesser exposure than the ones in the open bedrooms who I predict died within a few minutes.

Then the three pink people here (Indicates) had a lower exposure still. One person was just unconscious, but recovered quickly, the other two were conscious when rescued, and they all survived the fire and made a good recovery.

Finally, the lady in this room here (Indicates) had her door shut throughout. She had two layers of protection. She was unaffected and, in fact, she was sort of joking with the fire officers as they helped her out of her room.

So you can see a sort of spectrum of different types of exposure and of different effects, all of which I think are relevant to Grenfell, because somebody who is in a flat in Grenfell when the fire breaks in from the outside, through the windows, if they're standing in the same room as the fire's broken in, could be exposed to these rapidly deteriorating conditions with a sudden high peak of both heat and toxic gases, similar to sort of conditions faced by somebody standing in that corridor, if they had been there.

If, however, somebody in a Grenfell flat were to retire to another room and take refuge in another room within their flat after the fire has broken in -- so suppose, for example, the fire's broken in through the lounge window, they may well go and take refuge in a bedroom, and this did happen at Grenfell -- but let's say in this case they left the interior doors in their flat open throughout, then they are going to be in a similar exposure scenario to the people in the open bedrooms of this Rosepark incident.

Whereas those in the closed rooms are relevant to people also in a Grenfell flat who may have shut the internal doors to take refuge, maybe some people took refuge, for example, in a bathroom or the hallway, while there may be a fire the other side of their interior

door, burning in another room within the flat.

In order to assess these effects, just a little bit of technical stuff here.

Each toxic gas in a fire at any time, we use the concept of fractional effective concentration, FEC, and fractional effective dose, FED.

FEC is used for those hazards for which the immediate concentration is important, which is the smoke density, whether you can see through the smoke, and the irritant gases in the smoke, because these affect you immediately. If they're there, it affects you; if the smoke clears, you're all right. It's an immediate concentration-related effect.

FED is for those hazards for which a certain dose level has to be acquired over a period of time before a certain effect occurs.

There's more technical explanation of all this is in my report, but in order to follow the slides I'm going to show you, the only thing you need to know is that on any of the charts that I show you, when the line for any hazard, the FEC or FED line for any hazard, crosses 1 on the left-hand axis of the graph, the Y axis of the graph, that is predicting the time during that fire when a certain hazard endpoint is reached, where the hazard has reached a level where it would have some significant

impairment of the ability of a person to escape, or possibly whether it would collapse or even whether they would die at that point.

So here is an example, which is from the Rosepark fire, and this shows, over a short timescale here of 10 minutes, the concentrations of smoke and toxic gases, asphyxiant gases, in the open bedroom off that fire corridor at bed height, because all the elderly people in the rooms were asleep at the time of the fire in bed.

The lower picture is my fractional effective analysis of the effects that the exposure would have on a person who was in that room on that bed.

So what you can see here is that the green line is the smoke, so there's a lot of smoke flowing in. The red line is the carbon dioxide, which is always produced in fires. The black line is the carbon monoxide, which, as I told you earlier, went to very high concentrations very quickly.

Also, crucially, although it looks like a small blip here, in toxicity terms, there's a high concentration of hydrogen cyanide, another asphyxiant gas.

The lower image shows my calculated predictions of what exposure to that environment would do to a person exposed. What this shows is that around about 4 minutes, this is the smoke line, it's going to get

very densely smoky in there, and this is crossing the line of 1, so about 4 minutes, a person in that room, had they been able to get up and leave, would've had some difficulty in moving through the smoke.

Now, in the actual incident, all these elderly people were more or less confined to bed, so none of them tried to move out.

But, crucially, after 6 minutes, I'm predicting that a person exposed to this cocktail of asphyxiant gases would become unconscious.

I'm also calculating the uptake of carbon monoxide, and that's predicted to reach a lethal level -- 50 per cent -- at 7.9 minutes.

Another thing I've done in my calculation is to take the cyanide away and calculate how long it would be before somebody became incapacitated if there was no cyanide in this fire. What the analysis shows is that if you didn't have the cyanide, you'd have about an extra minute available to make your escape.

Now, a minute might not sound very much, but in a minute you can move 60 metres and possibly escape from a building.

This is why I feel that in fires like this, particularly fires involving upholstered furniture and things like domestic fires, cyanide can be an important factor in limiting the time available for people to escape. It's a cause of incapacitation. Not so much a cause of death, but a cause of why people who try to escape may collapse.

But the other term I've got in here is the effects of heat, because we measure the temperature in the bedroom. I told you it was very hot in the corridor. But what's crucially important here -- and this is very, very important and relevant to Grenfell -- is that this is the FED curve for heat for somebody in that open bedroom, and you see that this curve is rising quite slowly and it never gets to 1 on this axis, which means that during this fire, it's predicted that a person in that bed, although they would receive rapidly lethal exposure to asphyxiant gases, they would never suffer from pain -- this is for pain from heat, this analysis -- they would never suffer pain from heat, and they would certainly not suffer from burns.

That was corroborated by the pathology on these victims, because the bodies weren't burned, and they all had very high carboxyhaemoglobin, as the test is predicting.

Now, this slide shows the pathology data, the toxicology data, from the actual victims. What I want to draw your attention to is the red numbers here, which

are the carboxyhaemoglobins in the blood of all the fatalities in the open bedrooms that I've said died after about 7 minutes during this fire, you can see that they're all very high.

Now, you may remember I told you that 50 per cent carboxyhaemoglobin is a lethal dose. Most people will collapse and become unconscious at about 30 per cent carboxyhaemoglobin. 50 per cent is a lethal dose. So if 50 per cent is lethal, how come -- most of these people are above 50, but we can see levels of 80, higher levels here.

The reason for that is that once you become comatose and unconscious due to exposure to carbon monoxide, you're not dead. You may have collapsed, but you are still inhaling the carbon monoxide, you're still quietly breathing. So as long as you remain alive, you continue to inhale the asphyxiant gases and your carboxyhaemoglobin continues to increase in your blood until the point where you're heart stops beating and you stop breathing.

At that point, the carboxyhaemoglobin becomes effectively frozen in the blood of that person and is very stable, so it's a very powerful tool. When the autopsy is done, maybe weeks later, those levels of carbon monoxide in the blood are essentially the same,

so they tell us the dose received during the fire.

Now, the pink numbers here are for those four people who were rescued alive but in a serious condition. You'll notice two things. One is that they are somewhat lower than for the fatalities. These were acquired over a long exposure period up to an hour. They are given two numbers there for each one. The reason for that is that for these, the blood samples are measured in survivors when they get to hospital, and on the way to hospital, they're given oxygen -- and this happened at Grenfell to some people -- which washes the carbon monoxide out of the blood, and people can often make a good recovery when that happens. But I can compensate for that, I can back-calculate from the measurement in hospital to what the dose would've been at the time of rescue.

But in order to do that, I need to know precisely when the blood sample was taken after arrival at hospital. What happened in this case was that although I had all the hospital records -- and I had tremendous access to all the hospital records, all the GP records of these people -- in some of these cases, the time the blood sample was taken, exact time, wasn't recorded. But I know approximately when it was recorded because of the procedures that were going on and the order in which

things are carried out in hospital. So I've had to give a range because of that uncertainty, and I suspect in reality some of these people were in the middle of that range.

So these are the people who have not quite had a lethal dose, they survived for a while but then died in hospital. Then the blue lines there are for the people who were either unconscious or awake, and you can see they're lower still. So you've got this range of effects.

So where this takes us is that for Rosepark, we have a detailed fire investigation, we have an examination of the fire scene, we have detailed interviews with survivors and other witnesses, so we do have some of that for Grenfell. But what we don't have for Grenfell is a full-scale reconstruction fire test of the parts of the building affected by the fire, including the same materials and contents as in the actual incident.

We had replication at Rosepark of the original fire, with measurement of the time concentration curves. We had calculation of the incapacitating effects, the FED calculations. We had all the data for carboxyhaemoglobin, both from the test and from the actual fatalities. And so by comparing the two, we're able to make a good analysis of the situation.

So when I compare that to what we have for Grenfell, we have some quite important differences, because for Grenfell we have a very large and complex fire, with differing development in individual flats, so a full-scale reconstruction would just not be feasible, and the fire burned for a very long period, as I mentioned, so the building and its contents were very different after the fire than they were during the early stages, when most of the occupants were exposed to heat, possibly, and particularly to toxic smoke. The combustible contents of many flats were completely burned out, so we can't say exactly when they burnt or what was there at the time.

Similarly, for the fatalities, many of the bodies of people whose remains were recovered from the flats were almost completely consumed during this extended fire, so it's difficult to establish the conditions they were exposed to during the fire before they died.

Also, the pattern of fire development and smoke spread into and through the tower was very complex, involving penetration into the flats of a proportion of combustion products from the exterior cladding and insulation materials, from the structural materials around the windows, and then successive involvement of fires in the contents of different flats.

So what can we do for Grenfell? Well, it is possible, as I've explained, to identify a set of different exposure scenarios for Grenfell occupants similar to those common in domestic fire incidents, fires in houses and flats, which happen in their hundreds every year and I've investigated many.

For some of these, we do have a lot of detailed information which I think we can, if you like, translate into the Grenfell situation with regard to developing conditions, and Rosepark is one example of such an investigation.

From the information we do have on the development of the Grenfell fire and its data, from previous incidents and experimental fires, I believe it is possible to estimate the likely effects on Grenfell occupants.

Also, from information on the fire performance, smoke and toxic gas yields, generic versions of the exterior and interior structural materials at Grenfell and typical house and flat contents, such as furnishings and appliances, the possible contributions to development and spread of toxic smoke into and through the tower with time can be estimated, but only very approximately.

So I've used these above sources to estimate the

likely general effects on Grenfell occupants.

But we do have some very valuable data from the actual Grenfell incident. In order to validate these estimates of these generic effects for individual Grenfell occupants, I am making a detailed examination of the witness statements and the oral evidence, and also very valuable are the transcripts of the emergency calls from the occupants during the incident.

I have been asked questions about whether I've actually listened to these calls and, mainly because of time pressure, so far I haven't done that, but I certainly plan to do so as part of my Phase 2 work.

Now, I would like to really emphasise here that I am finding these witness accounts and transcripts extremely valuable and effective in understanding the experiences of occupants during the fire, and the effects of exposure to toxic smoke, both for those who survived and for many of those who subsequently died during the fire.

So I would like to say that all of those of you who have gone through this traumatic experience and then given these detailed witness statements to the police, and those of you who have given oral evidence in court, be assured that we are taking -- I in particular am taking -- great note and studying with great care all the things that you said. Very valuable.

Also, the witness descriptions of how smoke and flames penetrated different flats, the lobbies and the stair are also providing me with a good understanding of these aspects, which I'm using to validate my generic predictions of likely smoke development, spread and composition.

Also, I mention the importance of carboxyhaemoglobin. We do have some blood toxicology data for Grenfell, blood samples are available for actually about 20 fatalities, but there was only 15 of those for which the toxicologist was able to assign a numerical value for the carboxyhaemoglobin in their blood. Some of these people died in flats, some in lobbies and some on the stair. I've also viewed photographs of the remains of these fatalities. I'm currently awaiting the full autopsy reports, which I will consider as part of Phase 2.

So this information, taken together with the witness accounts and the emergency call transcripts, considered in the context of data from previous incidents, is providing me, I feel, with a good basis for assessment of causes of incapacitation and death for Grenfell fatalities.

Now, I just want to briefly, at this point, before I go more deeply into some of this material, address one very important issue, which is: were the Grenfell fatalities affected by exposure to heat or burns before they died, or were they overcome by toxic smoke?

Now, I stress that my work is still preliminary, but from my review of the Grenfell-specific evidence so far, and taken in light of data from previous incidents, it's a strong possibility that those who died did so from smoke inhalation rather than being burned, and I'm placing particular emphasis here on the available carboxyhaemoglobin data.

I'd also want to point out that while inhalation and exposure to irritant smoke can be quite unpleasant and cause breathing difficulties and discomfort, exposure to asphyxiant gases, people are totally unaware that they're inhaling them, they have no real effect, until the point where you suddenly feel dizzy and collapse. So dying from carbon monoxide, even if there's cyanide in the mixture, is not a painful death. You basically faint then go into slowly a coma and die.

I think that might be important to the relatives.

SIR MARTIN MOORE-BICK: Would that be a good point to have a break?

PROFESSOR PURSER: Yes.

SIR MARTIN MOORE-BICK: Well, we do have a break roughly every hour. We'll take one now.

I'm going to ask you, please, not to discuss your evidence with anyone once you leave the room.

We'll come back at 11.15. If you go with the usher, she'll look after you.

PROFESSOR PURSER: Thank you.

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

Right, 11.15, please.

(11.05 am)

(A short break)

(11.15 am)

SIR MARTIN MOORE-BICK: All right, professor, happy to carry on?

PROFESSOR PURSER: Yes, if we can get the display.

SIR MARTIN MOORE-BICK: You're cut off at the moment.

PROFESSOR PURSER: I may have ended the presentation. We might have to get someone to start it again.

(Pause)

SIR MARTIN MOORE-BICK: Can you pick it up from there?

PROFESSOR PURSER: I think so, yes.

(Pause)

Right, okay.

Now, apart from the Rosepark study I mentioned earlier, some very useful work I was involved in quite a long time ago now was some full-scale reconstruction fires, looking at typical domestic fire scenarios. This

was when I was at BRE.

In those days we had an experimental house, like a typical semi-detached house at the time, in our hangar in Cardington, Bedfordshire, where we could do the experiments, and we carried out a series of fires, looking at the toxic hazards from upholstered furniture.

All these fires involved setting fire to armchairs, basically, as shown in the bottom-left there. We had them in a flat rig, with a room, corridor and a bedroom, but we also had this two-storey house where we did most of the tests.

What I want to explore with you particularly here is the hazards faced by somebody who was upstairs during such a fire.

So what happened in these fires was we'd ignite the furniture, and this is also true for anybody who is in a room with a fire downstairs, and that is initially you see the conditions are reasonably benign, you can stand here in that room and watch that fire when it's that sort of size.

But if you can just make it out, already a layer of smoke is building up under the ceiling. So any toxic products that are formed by this smoke and any heat is taken up to the ceiling. So if you were in the room down here, you're not immediately exposed to them.

That layer of smoke gradually falls down, a bit like an inverted bathtub filling with water, until -- in many of these fires, we had the room to the hallway open and some we had it closed. And when we had the room door open, when the smoke gets below the level of the top of the doorway, called the soffit, the smoke flows out into the hall, upstairs, mixes with air and fills the landing above and all open areas within the house.

Because this is an enclosed system, after 10 minutes or so, these fires self-extinguish. They went out because they used up sufficient oxygen for the fire to stop burning. But this left this house filled with a highly toxic atmosphere, evenly distributed throughout all the open spaces. Upstairs we had a closed bedroom which we measured conditions in, and we also had an open bedroom.

This is the conditions in the landing here. So you have 5,500 ppm carbon monoxide, you have 5 per cent carbon dioxide, which stimulates breathing and increases the rate of uptake of other gases. You have some decrease in oxygen, but not too worrying. But you also have a very high concentration of cyanide, which is caused by burning the foam in the furniture and the covers on the furniture.

You also have these irritant organic chemicals that sting your eyes and make it difficult to breathe. And, of course, it's hot.

But, as I told you before in relation to Rosepark, although it may be very hot in this room here, by the time the smoke has come and mixed and gone upstairs, and the structure has absorbed some of the heat, the temperature actually on the landing here is not too bad: it's 60 degrees centigrade. Now, you wouldn't want to spend all day at 60 -- I mean, it's well below the temperature of a sauna, for example, but you'd sense that it was hot.

What I would like to explore with you is the dilemma, if you like, or the conditions faced by somebody who might have been asleep in this bedroom here (Indicates).

By the way, these photographs -- this is the top of the stairs looking down, early in the fire (Indicates), and the right-hand side shows the camera view about 5 minutes later. You can see that by that time, you can't see anything either in the room where the fire is or, crucially, upstairs on the landing. You can't see the hand in front of your face, which is something that was said by many Grenfell occupants when they tried to step out of their front door into the lobby at Grenfell.

So what will this person do in this situation?

Let's suppose they're asleep and the smoke alarm goes off. So they go to this door which is closed and they open it, and what are they faced by? They are faced by this dense smoke, and a bit of it is going to come in and it will sting their eyes and be very unpleasant. So obviously their first reaction is most likely to be to shut the door and stay in the bedroom.

They will then either remain there, maybe they'll call the fire service or, being a two-storey house, they may attempt to escape through the window.

Now, I've come across many examples of this in real life. I've known people who have done exactly this. They've opened the door, they've found conditions very frightening. In one particular recent case I worked on, they actually got out and came down a drainpipe to escape. Three young people.

In another one, which is quite interesting in this context, a man woke like this, he started to go down the stairs, and he said, "As I tried to go down the stairs, I felt that it was hot." Not painful, but just something wrong. And of course it was very smoky and irritant, and, of course, he didn't know what was below; it could've been a raging inferno, for all he knew. So halfway down the stairs, he turned around and went back, took refuge in the bedroom and called the Fire Brigade,

from where he was rescued.

In this case here, with these gases, if this person stepped out now onto the landing, what would happen to them? Well, the first thing would be they can't see. The second thing, within seconds, is they would be suffering from the irritants, which would affect their vision, their breathing and be very unpleasant.

If they don't turn back at that point but continue, at some point they're going to start taking some breaths and they will be inhaling these very high concentrations of asphyxiant gases. In my example here, they've gone a few steps and then, because of that, they've collapsed at the bottom of the stair.

Now, as I said before, they're still alive, but they're continuing to breathe these toxic gases. If they're rescued at that point and treated with oxygen in the ambulance, they may make a good recovery. If they've had a more severe exposure, as did my four cases at Rosepark, then they may suffer permanent brain damage, from which they'd never recover. A common finding is that people who have been poisoned by carbon monoxide, even if they don't have obvious neurological symptoms, suffer from personality changes. Or it may be they're so badly affected, they never recover consciousness.

Alternatively, they may have inhaled a dose of smoke sufficient -- and this is a fairly common occurrence -- that several hours, a few hours, three hours after the time of exposure, they may go through a crisis where they get lung oedema and inflammation. So all the irritant smoke they've inhaled causes water to build up on the lung, and that makes it very difficult to breathe. So they may actually die at that point or they may, with treatment, come through it.

So these are the kind of hazards that people will face.

On the next slide here I show the FED analysis for this case of somebody stepping out onto that landing. So we're looking for when any of these lines crosses 1 on this scale right down here (Indicates).

What this shows is that the concentration of irritant smoke is immediately about 15 times the concentration that would be predicted to give you difficulty in progressing through it and breathing it. It wouldn't kill you, but it would make things difficult.

Secondly, because of the asphyxiant gases here, I predict that the overall effect which are added to these different gases would cause, after a couple of breaths in that particular atmosphere, the person to likely collapse unconscious. When I remove the cyanide, they've got 150 seconds. So you can see here, in this case, the presence or absence of cyanide could make a significant difference to whether they're able to get down the stairs and out through the front door, which will only take 10/20 seconds or so.

So that's an example of a sort of scenario or situation that was faced by a lot of Grenfell occupants. There's two sides to this: the behavioural side and the physiological side.

So the behavioural side of it is: I've got this very difficult decision to make -- which was faced by Grenfell occupants in some cases several times during the course of the fire. Early in the fire, you open the door, you see smoke, maybe this was after about 01.30 on the morning of the fire, when there was a lot of smoke in those lobbies, and you have to make this difficult decision: do I stay put or do I decide to try and make it to the stair and go out? If I go to the stair and get out, that's over, but if I decide to stay put, I may then have to revisit this decision later on as conditions deteriorate outside the flat.

So I think that example shows you some of the issues that people were facing and the consequences of doing one thing or the other.

I just want to briefly talk a little bit about some of these different hazards.

The first one is smoke. This is some work done years ago by Professor Jin in Japan, where he got volunteers to walk down a corridor while being exposed to smoke to see how their movement, speed and ability to progress was affected.

What Professor Jin found was that when he used non-irritant smoke, which is this blue line here, people with no smoke walked at about 1 to 1.1 metre per second, that's typical walking speed, but once the smoke density got such you could only see about 2 metres, their behaviour changed from walking as if they could see to walking as if they're feeling their way in darkness. Do you understand? Feeling their way along the walls and things like that. At that point, their speed was greatly reduced to 0.3 metres per second.

But when he replaced the smoke with irritant smoke, he found the same phenomena occurred at a 5-metre optical density. The combination of optical and irritancy gave the same effect. So although theoretically you could see for 4 or 5 metres, you were still affected.

So that's the physical affect on progress.

The other affect that is more important in some

ways, or as important, is the behavioural effect. I've summed that up in one line almost here, but there were two big studies done, one actually at the BRE fire research station by Dr Wood, and one in America by Professor Bryan at the University of Maryland, where Torero is -- in fact, Torero is now the Bryan professor at Maryland, and I've taught at Maryland

What these people did was they analysed a lot of incidents, and they were looking at this kind of decision-making: when do people decide to continue, at what smoke conditions will they turn back?

They found, simplifying it, that once you get to about 4 metres' visibility, quite a large proportion of people will turn back rather than continue through the smoke. So just the density of the smoke and, to some extent, its irritancy, because these are real incidents, is having a profound effect on their escape behaviour and capability.

However, I would point out that I believe that this effect, and from the studies I've made, very much depends on the context, all right? So if you imagine somebody who is in, for example, a Grenfell flat, and the flat fills with smoke -- this could be like a flat 6, the column of flats in the flat 6 location of the tower, during the early stages of the fire. The

fire comes in and the smoke comes in from outside and fills your flat. No matter how dense that smoke is, you are going to be very highly motivated to get to your front door and out into the lobby, which at that time was relatively smoke-free. So I would say that whatever the density, you will try. I've come across lots of incidents where people have moved through very dense smoke, as indeed they did at Grenfell.

On the other hand, if you're in a reasonably smoke-free flat and you open the door and see dense smoke in the lobby, then you're much more likely to stay where you are and shut the door. So it depends on the context.

The other thing I want to talk about is the asphyxiants. Again, it's why there is a difference, really, between cyanide and carbon monoxide. In these experiments here, subjects were exposed to carbon monoxide at different concentrations. It's on the right-hand axis here. What we're looking for is the dose, which is roughly the concentration to which they're exposed multiplied by the time until they became unconscious.

So you can see here at the top left-hand there, when they were exposed to 1,000 parts per million, then collapse occurred, unconscious after 26.6 minutes. If you multiply those two figures together, you get 26,600 ppm minutes. That's the sort of measure of dose.

When they're exposed, at the bottom of that column, to 8,000 ppm, then they collapsed after about 3 minutes. Multiplying the two together gives you roughly the same number.

So there's a very clear relationship that, over these timescales at least, the effects of CO are purely dose-related.

But this contrasts with the effect of cyanide here. Now, with cyanide, when they're exposed to 87 parts per million, they were able to function for half an hour. Multiplying the two together gives you 2,610.

But at 300 ppm, they collapsed after 0.9 of a minute, very, very quickly. Multiply them together, you get 270.

What this tells us is that a long exposure to a low concentration, which in this context is less than 100 parts per million of cyanide, can be tolerated quite well. But if you're exposed to twice that concentration, say 200 to 300, then you're going to collapse within a couple of minutes. That's partly why I believe cyanide causes incapacitation in fires. Not necessarily death, but incapacitation.

This slide is about carboxyhaemoglobin in blood.

This study on the left here was done by Professor Gordon Nelson in the United States, and it's a very large forensic database of people who have died from carbon monoxide poisoning, essentially, either in fires or from CO poisoning itself.

So the green bars here are the concentrations of carboxyhaemoglobin in the blood of fatalities, of people who have died from accidental carbon monoxide exposure, either caused by faulty home heaters, faulty boilers, things like that, or in this case -- it's quite an old database -- mostly young men committing suicide by exposing themselves to exhaust fumes in the garage, before we had catalytic converters.

What this shows is there's quite a range of sensitivity in the population before people actually die, but most of these people have got at least 40 to 50 per cent or more. The mode, the most common, most frequent dose at death is between 70 and 80 per cent carboxyhaemoglobin. A few people survive until they're at nearly 100 per cent, amazingly, before they actually die.

Now, if you compare that to the red bars, which are for people who have died in fires but not burned, then you can see that it follows roughly the same pattern. That gives us some confidence that the main cause of

asphyxiant death in fires is, in fact, carbon monoxide. That's the main agent causing death, or it's consistent with that.

However, there is a bit of a left shift here, there are some people here (Indicates), and so this tells us that there's something else as well in fires that's contributing. Although CO is the main thing, there's something else, and that may well be cyanide and some other things in fires.

Now, the right-hand curve is from a Polish researcher whose name was Pach, and this is about survival as opposed to death. So in this case, these are people who have been rescued, having had carbon monoxide poisoning, and the probability that with treatment they would survive.

What this shows is up to about 30 per cent carboxyhaemoglobin here, everybody survives, but then you see the survival rate drops off very quickly, and the 50 per cent survival rate, which is what toxicologists look for, is indeed at 50 per cent carboxyhaemoglobin, whereas very few people survived having had 60 to 80 per cent carboxyhaemoglobin.

In the next slide, I've compared Pach's data to the Rosepark data. So here we have all the people who were dead in their rooms very quickly at Rosepark, and you

see they're all in this very high COHb group. They died from smoke poisoning. The reason I'm going into this in such detail is because of what we're going to see in the Grenfell victims.

These are the four ladies who were rescued alive but then died in hospital. They're in the middle, almost at this 50 per cent point. These are the ones that survived. So we have good agreement with the Polish data.

This slide is from a London Fire Brigade database of burns and carboxyhaemoglobin in fire fatalities in the London area. I think it was for one particular year, I forget the exact year. The point about this is that we have not only a record of the extent of burns -- the white bars are burns, and the grey bars are serious, possibly life-threatening burns, the black is the number of cases with different levels of carboxyhaemoglobin.

Importantly, these two pictures, one is for people who are not in the same room as the fire, and this is for people who are in the same room as the fire (Indicates). What you can see is that most people who have died in a room other than the fire room, so for example in a bedroom at Grenfell when the fire was in the lounge, all have very high carboxyhaemoglobin levels, and very little, if any, burns. These are

people dying from smoke inhalation.
Whereas in the room of fire origin, there are quite a lot of people who have very low carboxyhaemoglobin levels, less than about 20 or so, and a high incidence of burns. So these are people who basically have died from burns before they had time to inhale a high dose of carbon monoxide.
So if we find certain levels in a body of a person who has died, and that body then gets burned, but we find these very high concentrations, in most cases that tells us that they died from carbon monoxide or smoke poisoning rather from burns. If they've only 10 or 20 per cent, then we suspect that it may have been heat and burns that killed them. So what I'm telling you is that all the Grenfell cases up here somewhere (Indicates).
Very briefly, this is the effect of how we calculate time to effect from heat. There are two kinds of heat exposure in fires: one is heat radiation, which comes directly from the fire and from the hot upper layer when you have hot smoke; the other is if you're enveloped in smoke and exposed to hot air, hot atmosphere, this is human data on time of tolerance.
There is one important point I want to draw to your attention for this curve, which is at 200 degrees

centigrade in air, it's possible for volunteers to tolerate that for several minutes before they start to feel pain to their exposed skin.
This is of some relevance to Grenfell, because you may remember Dr Lane found that some of the light diffusers in the stair -- I believe it was between floors 12 and 16, around there, I went and saw these myself -- were softened by heat. So she decided that the temperature in the stair may have been in this sort of region.
I'm saying that even if it was as hot as that, especially above head height, whereas it was cooler lower down, people could still have got through those few floors without necessarily suffering severely, although in reality this may have occurred after most people had moved.
I want to talk a bit now about scenarios. We've talked about some obviously here. These are the enclosed scenarios I've described.
One important point about these which I'm going to talk about a bit later is that when a fire first starts to burn in an enclosed room, initially, if I set fire to this laptop here, we have lots of nice fresh air from the room coming in to support the flaming combustion. All right?

The result of that is that the combustion is very efficient, so that generally the products of combustion are carbon dioxide, water and heat, and anyway all that goes up to the ceiling -- so we're all safe for a while, you'll be pleased to hear -- and forms a layer under the ceiling, and it is some time before we're exposed to it.
But if the room is enclosed, this layer quickly fills down, and once the flames are burning in their own smoke, as it were, in this oxygen-depleted layer, then the combustion process becomes very inefficient. The products of inefficient combustion are a big increase in the yields of carbon monoxide from any carbon in the fuel, smoke itself, that goes up, and if there's any nitrogen in the fuel, you start to generate a lot of hydrogen cyanide. That's what's happened in these furniture fires here.
Now, briefly -- I will address this now just in passing -- this may have some relevance to the conditions when the PIR was burning on the outside of the tower, because the PIR insulation, initially at least, is encased in a cavity with the rainscreen cladding outside it. So it's in a sort of enclosed space, like a big pipe, almost.
When a fire occurs in that material, at the bottom of the area where the flaming is, it's exposed to quite

good air conditions. There's air coming up from below and there's the fuel being exposed, and the two combine to combust. Those products then continue up due to buoyancy.
Those products are now depleted in oxygen, but the heat from the fire is likely to decompose the same material higher up the pipe. That material decomposed higher up the pipe is now going to encounter, those thermal decomposition products, we call them, a hot plume which is depleted in oxygen.
What's important in this context is the fuel-air ratio at various points. So when there's excessive air for combustion, as in this case, then combustion is efficient. But when there's more fuel than air, as in this case, or possibly may have occurred for a period in some of this cladding, insulation, then you tend to get higher yields of toxic products.
The term we use for this is the equivalence ratio, which is in relation to the fuel-air ratio. So when the equivalence ratio is less than 1, that's sufficient combustion, low toxicity; when this ratio is greater than 1, you can get highly toxic products.
Going back to these room fires, though, there's another important aspect, because all the fire tests I've described to you so far were conducted in enclosed

situations where the fire grew, then became under-ventilated, then more or less went out.

Now, at Grenfell, that would be sort of equivalent to fire coming in around a closed window on the outside of Grenfell, which was described by some people. So you may have fire in your flat, but at this point the windows are still intact. That would be a sort of situation similar to these room fires. Instead of the furniture burning, it's structural materials, initially at least, around the window area, and may then spread to involve the contents. That's going to remain a relatively small fire, and it's going to become very toxic, very poisonous, very quickly.

But a very different situation occurs if the window is fully open or, in particular, as at Grenfell, if the window glazing fails and the whole window falls out.

Now, when that happens, you're in this kind of situation (Indicates), where you have continuous air coming in through the bottom of the window to feed the fire. The fire can then get bigger and hotter, and it can continue to burn until all the fuel, including all the contents, has burned away.

The consequence of this is that the fire, the upper layer, becomes very hot, and the downward thermal radiation from the hot upper layer, once it gets to the

about 600 degrees centigrade, can ignite fuels remote from where the fire has started. So you may have a fire initially burning near the windows, and the hot plume is flowing towards the back of the flat. Once those temperatures get so high, even those materials can ignite.

There is a very clear example of this from experiments we carried out at BRE many years ago. On the right here, although you can't make it out in the shot, this is a sofa we ignited. It's burning fiercely. This is the point of flashover, because this hot upper layer now is radiating down, and you can perhaps just see it's just igniting all the newspapers and various materials on this occasional table. So that is the exact point at which flashover occurred in this room.

Now, as you can see, these conditions are extreme, and certainly nobody could survive for more than a few seconds in that room. But one of the questions is: what would happen to them in the rest of the flat? Would they be able to survive any longer if they took refuge? I think conditions like this would be difficult to survive for more than a few minutes, even if you took refuge somewhere, although it's quite a complicated situation and there are many different variants we've observed in different flats at Grenfell.

Just to say that we have these different rigs. I mentioned the flat rig, and this is the open rig where we studied these more developed fires.

I'm going to go a bit quicker now. I think I've covered most of this.

This illustrates the conditions in one of these furniture fires with time, as it goes on. You can see after 5 minutes, you can't see anything if you're in that room.

But the amount of damage you can see here is quite small. I think on the slides and in my report, I mentioned a number of times that, in order to create lethal conditions in the enclosed volume of a flat or house, you really only need to burn about 5 to 7 kilograms of material, which represents in this case about a third to a half of that armchair. That was enough to make lethal conditions in the house.

This slide shows the conditions -- that's the landing again, and this the -- can't see anything after 5 minutes. Top-right shows the FED for the occupants of the open bedroom upstairs. A crucial difference here is although they are going to be overcome by the same smoke very quickly, they're not troubled by heat, because the heat has gone. There's heat downstairs, but it's been lost from this more sheltered place.

This slide compares the smoke in a situation where we've closed the lounge door and measured the smoke throughout the house. This is an ordinary door, not a fire door. And then we've measured the -- so the left-hand one is the enclosed fire, the right-hand one is the one with the door open. It's a bit hard to understand here but, basically, this is the smoke density, and these lines here are inside the closed room, and you can see they very rapidly go up to the top of the graph.

But the conditions in the hallway and landing and other rooms are much less smoky, and this demonstrated that if you're in an ordinary two-bedroom house, and you had taken the trouble to shut the lounge door before you go to bed, if you have a fire in your lounge, you have a very good chance of getting past it to the front door, if you shut the door. But if you leave the door open, as you can see just at a glance, the whole of the house rapidly gets filled with dense, toxic smoke.

This shows the condition in Rosepark for somebody taking refuge in a closed room, and you can see the contrast. Instead of having these rapidly increasing concentrations, you have a very, very slow, gradual filling-up over a period of an hour or so and uptake of carboxyhaemoglobin by the occupants.

So this shows how somebody who has taken refuge in a flat, for example, at Grenfell, which happened in many cases, the situation was that they found themselves, when they opened the front door to the landing, they couldn't see their hand in front of their face, darkness, so they were then trapped in the flat for what may be an hour or so at Grenfell. They would've been facing a situation like this with a slowly building-up dose.

Right, I think we're nearly there.

Now, for any given smoke visibility, how far can people go before they collapse from asphyxia? These examples that I've shown you, fire scenarios and effects, can be useful to estimate the likely experiences and effects on Grenfell occupants exposed in similar situations, including staying in flats with rapid smoke, slow smoke and going into lobbies. But because the time concentration occurs of smoke/gases throughout the Grenfell -- we don't have that information like I do for the tests, is there another way we can come at it? Well, one set of information we do have is descriptions by the witnesses of the smoke density and toxicity at different times and locations, from the witness statements and the 999 emergency calls, and because the ratio of smoke density to concentration

is a constant, I can use this to predict what would happen.

I'm going to speed up and show you this graph here.

Basically, this is an image of the visibility compared with time to collapse. So because the smoke visibility and the other toxic gases are tracking together in the fire, if you know the smoke is dense, you know there's a high concentrations of the gases. If the visibility is good, then you have low concentrations.

So if, for example, you had somebody in a flat in Grenfell and they could see for 3 metres, they said "Oh, there was smoke coming in the flat, I was there for half an hour, but I could see across the room", how dangerous is that smoke? Well, this graph tells me that after, say, half an hour, you're at nowhere near half a dose that would cause incapacitation.

But if that person, having been there for half an hour, then steps out onto the landing and they can't see their hand in front of their face, then according to this curve, you only have 2 or 3 minutes further before you would collapse.

So I think this can help us to see how exposure to different smoke densities correlates with the asphyxiant gas concentrations at different times and locations at

Grenfell.

So, in summary, using data from past incidents and full-scale experiments, coupled with FED physiological methods for calculating time to incapacitation and death, it's possible to identify a set of fire exposure scenarios occurring at Grenfell and the likely effects on occupants.

By expressing the FED tenability as a function of visibility, as I did in the last slide, it's possible to estimate the hazards from irritant smoke and asphyxiant gases at different times and locations at Grenfell from witness accounts of visibility and reported toxicity symptoms.

Carboxyhaemoglobin measurements in the blood of some Grenfell fatalities related to that from previous incidents can be used to determine the extent of exposure of these fatalities to toxic smoke or heat and burns.

That's the end of that presentation. Thank you.

SIR MARTIN MOORE-BICK: Thank you very much.

Now, would you like another break at this point? Have you got to load something on next?

PROFESSOR PURSER: The next presentation, yes.

SIR MARTIN MOORE-BICK: Would this be a good time to have a short break?

All right. We'll do that now.

Just for my benefit, how long is the next presentation, do you think?

PROFESSOR PURSER: Just under an hour, I'm afraid. I'm hoping we can at least get through that one before lunch.

SIR MARTIN MOORE-BICK: Well, if we came back at 12.05, you reckon you'd finish by 1 o'clock?

A. Yes. Then I have the third presentation, which is a shorter one, but I think that is going to go into the afternoon, is it? I'm happy to do it this morning. See how we go.

SIR MARTIN MOORE-BICK: We'll get on to that. We can't push people too hard. They need their lunch.

All right, we'll stop now until 12.05. Again, please don't talk to anyone about your evidence while you're out of the room.

Go with the usher, she'll look after you. All right?

PROFESSOR PURSER: Thank you.

SIR MARTIN MOORE-BICK: All right, 12.05, please. Thank you.

(11.55 am)

(A short break)

(12.05 pm)

MR RAWAT: Mr Chairman, I hope Professor Purser's second presentation has been loaded. It should start.
Before he begins, can I just repeat the trigger warning that we gave this morning, just because I think --
SIR MARTIN MOORE-BICK: We are going to see more potentially disturbing material.
MR RAWAT: Yes, and the nature of the presentation may be distressing in itself.
SIR MARTIN MOORE-BICK: Thank you for making that clear.
Right, ready to go on, professor?
PROFESSOR PURSER: Yes.
SIR MARTIN MOORE-BICK: Thank you.
Presentation 2: Fire hazard scenario development and effects on occupants during the Grenfell incident
PROFESSOR PURSER: Okay. So for this second presentation, I want to address some of the effects believed to actually be happening in the Grenfell incident.
Before I get into the detail of this, I just want to remind you of some information that Dr Lane put up about the fire requirements and the Building Regulations. The one I want to focus on particularly -- you remember she told us that there has to be adequate means of escape, and essentially each flat should be a fire-resisting box and that the fire should not be able to get out of the

flat, the lining should not propagate the fire, and there shouldn't be external fire spread.
But the one I want to focus on is the 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."
So that's a fundamental requirement of the Building Regulations.
Now, at Grenfell, the design attempted to achieve that partly, as I said, by the fire-resisting construction. But we do have a mean of escape. We had detection in each flat, there were detectors in the flats. And then you have corridors, hallways, in each flat to enable a person to escape away from a fire in their flat in safety into the lobby. The flat entrance door is a fire-resisting door, which should resist both fire and smoke contamination of the lobby, so once you're in the lobby, you should be in a smoke-free environment. And then we have an extra layer of protection before we come to the concrete protected shaft of the stair, a fire door on the stair itself. So

we have these provisions at Grenfell.
But we also have a stay-put policy, and a stay-put policy means that people are encouraged, basically, to remain in their flats most of the time. There's a lot of statistics on this. Many times when there are fires in a flat in a tower block, it's restricted to that single dwelling, and so there is no need, in many cases, for people to evacuate.
However, the important point is that should things change so that they become uncomfortable because of the situation, or because, say, smoke or fire comes to another flat in the block, there should still be this preserved escape route out that should be free of smoke and fire at all times.
Now, clearly these requirements were failed, all of them, at some time at Grenfell. For my investigation, then, I'm trying to decide how and when smoke and flames penetrated individual flats, at the beginning, particularly on the east side of the tower. So we have a column of flats, basically flat 6 on each floor, that are first affected by penetration from the exterior fire moving up the structure. When and how did that happen?
How, then, did dense smoke penetrate into the lobbies? How did this affect the behaviour, escape capability and survival of the occupants? When did it

get into stair and have effects in the stair? When, later, other flats were penetrated by fire, how did that happen and what did it do?
Now, I just want to briefly talk a bit about the stair at Grenfell.
Why do I want to do that? Well --
MR RAWAT: I'm sorry to interrupt, I just wanted to be clear, because Professor Purser's slides are not coming up on the system.
PROFESSOR PURSER: Oh, I beg your pardon.
SIR MARTIN MOORE-BICK: Well, I was waiting to see one.
PROFESSOR PURSER: I was ploughing on with great gusto then, and you can't see anything ...
MR RAWAT: I understand it's being looked into. It might be a technical --
SIR MARTIN MOORE-BICK: How many slides have we missed, professor?
PROFESSOR PURSER: I won't talk to them, I'll just flash them up when it comes back on to remind people.
SIR MARTIN MOORE-BICK: Are we talking about three or four?
PROFESSOR PURSER: Yes, only three or 4.
(Pause)
We're away, thank you.
SIR MARTIN MOORE-BICK: This reflects the --
PROFESSOR PURSER: Building Regulations.

SIR MARTIN MOORE-BICK: Yes, and this is what you've just been telling us. So we can probably go on from here.
PROFESSOR PURSER: Yes, that's the one about means of escape. This is the diagram of the layout showing the various points I mentioned.
SIR MARTIN MOORE-BICK: Mm-hm.
PROFESSOR PURSER: And this is what I'm saying, these are what I'm trying to determine.
I'll now talk a bit about the stair.
The reason I'm interested in the stair is because my mission, if you like, is to consider the effects of exposure to toxic smoke. One place you can be exposed to toxic smoke is in the stair. Whether or not you are able to get down the stair without collapsing depends partly how long it takes you to get down the stair.
So if, for example, we assume that there are approximately 293 persons in Grenfell Tower on the night of the fire, let's suppose that around about 1 o'clock they'd all simultaneously attempted to get into the stair and come down the building. How long would it have taken them to do so? If that would've taken an hour, and that smoke filled the stair, then that's a long time to be exposed.
So how long would it have taken? Well, I've done a lot of work on evacuations and drills and things like

that.
So for a building designed for simultaneous evacuation, Approved Document B assumes in its calculations, which are hidden within the document, a standing density on the stair of four persons per metre squared. So the idea is that the population could move into the stair of such a building, stand on the steps and landings in the stair and be in a protected space. But that would be very dense packing and you wouldn't be able to move; you'd have to wait for the building to clear from below you.
Now, in practice, when I've carried out experiments of this kind, I found that people will not pack to that level of density, and typically will crowd, if you like, to the extent of two persons per square metre.
Now, that density, you would still have to be moving quite slowly as you came down in a group, but you would be able to move reasonably well.
At the packing density of two persons per square metre, there would be room for about 460 persons in the Grenfell stair. We've got 290, so you can see that that would be 20 persons per floor. If the 293 at Grenfell went in, that's 13 per floor, which is one person, roughly, per metre.
So even in the extreme case, where everybody went in

at once, there would be plenty of space and free movement available physically in the Grenfell stair.
Now, my colleague, Professor Galea, who we haven't heard from yet but is working for Phase 2, will be doing an in-depth analysis of this, but I'm just pointing these basic things out.
So even in the extreme case, there would be plenty of room for people in the stair to move freely.
How long does it take to come down?
Well, when I was at Grenfell, I timed myself coming down the stair. I was wearing protective clothing, heavy boots, a respirator, very restrictive clothing. At the time, I was 73 years old. I found I was able to descend at a rate of 9.3 seconds per floor, which represents time to get to the bottom nominally of 23 floors from the very top of 3.5 minutes. That's a person on their own in an empty stair, descending on their own.
Evacuation time of a crowd in a building. We have a 1-metre wide stair. The maximum flow rate of people down the stair is calculated according to a fairly standard formula. For a 1-metre wide stair, that would be about 42 persons per minute could flow down and out of the bottom of that stair.
So if there was 293 people in the building, that

would represent, if you like, an ideal nominal evacuation time of the whole population to the lobby in 7 minutes, if they all suddenly went into the stair. Quite a short period of time.
Of course, in practice, we have children, elderly people, some of them disabled, and they may be slower, and also may block the stair to some extent. But I confirmed I was able to pass somebody on the Grenfell stair and, indeed, many occupants report, especially the slower ones, people coming past them on the stair. So it was possible to overtake. They also reported going past fire officers in the stairwell with equipment.
So although the single stair at Grenfell was quite narrow, there was a good handrail and the physical capacity was sufficient for all occupants to have evacuated safely within minutes if there had been some means of alerting them to evacuate, such as, for example, a general tower alarm system, which of course we didn't have.
So what did people do in practice?
Well, despite the lack of a general simultaneous alarm in the tower, the majority of tower occupants became aware of the fire at a very early stage. I get this from my studies of the witness statements. And they picked it up from a variety of cues, which I've

listed here, but I won't read them all out. Things like noises, fire engines, smelling smoke, in some cases detectors going off, and many, many people on all floors, even right to the very top, realised at a very early stage that there was something serious going on, and many of them decided to evacuate at that point. Some of them decided they would go down just to investigate, because they were worried about what might be happening below; others made the decision it was serious and to get out.

I've tried to summarise this and depict it in this slide here on the right.

Now, one thing I realised when I started to read these statements and study the evacuation times that were recorded, was that there was a very different set of behaviours on the top 6 floors of the tower, floors 18 to 23.

There was a lot of interaction between people within and between those floors, so it makes a kind of group, a little community, if you like, that were doing certain things.

So on this graph here, I've plotted the number of people who are on those top -- that's the red line here -- six floors and their evacuation from the tower.

Because I had done the top six floors, I then went

down the tower in groups of six floors. So the next chunk, if you like, the next group, is floors 12 to 17 which is the black line, and then floors 6 to 11, which is the brown line. That left me with two floors towards the bottom, the fire floor, floor 4, and the floor above that, floor 5, which is the blue line.

These two vertical lines here are quite important, because the red line is the point in time when, from studying the witness statements, I believe that most lobbies became filled with dense smoke that people couldn't see through.

Now, obviously this is not a point in time, it's a process, but this provides a good sort of anchor point for when smoke conditions became serious in the lobbies.

The times on here are not the times people exited the building; they're the times I've estimated from those times that they started, so when they entered the stair wherever they were. I've done that using a very simple calculation -- so it's only an estimate -- where I've assumed you descend at a rate of 12 seconds per floor. So from the exit time, allowing 12 seconds per floor, I can calculate the slightly earlier time at which the person entered the stair on whatever floor they were on. Okay? That's what's depicted here.

What this shows is that many, many people started to

evacuate very early on. Indeed, nearly all these people here on these floors started to evacuate before there was significant smoke in the lobbies. They were able to make an effective and safe descent because there was virtually no smoke in the stair at that time either.

But after that time, the stair is still relatively clear of smoke, but the lobbies are full of dense smoke. So now we have a period where people are opening their flat doors and either deciding to brave going through the smoke, or they say, "It's too dangerous, I'm going to stay put."

People who did venture out into the lobby had great difficulty finding their way to the stair, and a bit like Professor Jin's work, they were feeling their way, as they describe, along the walls. Some of them had several attempts, had to go back to their flats, maybe have some fresh air from a window, and then they'd try again. Eventually they found their way to the door leading to the stair, opened it, got into the stair, and this is this period here (Indicates). When they got into the stair, they found there was some smoke in the stair, but they could see several metres and it wasn't too onerous. They were also able to descend safely.

But on the top floors here, there was a different kind of pattern of behaviour that emerged, which is

something I need to get into in a lot more detail to understand what was going on. But, basically, a lot of these people did decide at a very early stage to evacuate the tower.

I believe what's actually happened here is that crucial in this was the behaviour of people on floors 18 and 19. Quite a lot of those people decided to evacuate, they started to come down the stair, and then for some reason they turned back and went back up, and they went back up to the 23rd floor in most cases. So instead of coming out of the tower, they took refuge in other flats within the tower.

Also affected were other people, particularly on floors 20 to 23, who had made a decision very early on -- I'm talking about before 01.30 -- things were getting bad, they'd been alerted by people probably from flat 6s who had fire coming into their flats, and they decided "We ought to get out."

But when they went to the door to the stair to decide to come down, they were confronted by this knot of people ascending, and I've got some statements here, they were saying, "Oh, I was going to go down the stair, but these people were coming up saying it's not possible to go down, and anyway they were blocking the stair, so I was unable to do so."

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So quite a lot of those people also ended up staying either on their own floor or a different floor, taking refuge in flats, who otherwise probably would've descended at that time.

This is just a summary of some accounts from different witnesses who describe the conditions in the stair, how they were able to overtake and various things like that. I won't read these out.

This question of why people turned back and didn't come down is so crucial, I think, that we need to spend a little time thinking about it.

If you forgive me, I'd like to read out a couple of statements. This is from Meron Mekonnen's statement [IWS00000912]. She was in flat 163 on the 19th floor.

She left her flat, I estimate, at approximately 01.27, when conditions in both the lobby and the stair were reasonably good, but she ended up going back and then tried again a few minutes later.

So I'll just read this out:

"17. Amal's relative had remained on the landing and started to follow me and my children down the stairs. We had not gone far down the stairs, though I do not remember which floor we had reached, when we met a group of approximately 10 people on the stairwell (they all seemed to be other residents of the Tower).

Someone below us shouted out, 'Go back, go back!'. The group, including me, my two girls, and Amal's relative, all started moving back up the stairs ie up the Tower.

"18. I got to the top of the stairs on my floor. I did not want to go back into my flat, so I decided to ignore the advice that had been shouted in the stairwell, to go back up, and I headed back down the stairs with my daughters."

The next bit is also very important:

"There was no one on the stairwell at this point."

So this knot of people had gone and the stair was now empty or relatively empty:

"As we were walking down the stairs, the smoke was becoming thicker and thicker."

So this may be a factor:

"It was dense and dark grey but I could see through it. I was able to breathe without any difficulty."

Now, there may be a number of reasons why this group of people turned back, and of course, especially if you're near the top of the tower, and you're coming down towards the fire, it's a very frightening situation. You don't really know what's going to be happening below you. This may be why, particularly art the upper part, people were more reluctant to come down.

But it could also be that they were starting to

encounter a little bit of smoke in the stair and thinking it's going to be a lot worse lower down. But for whatever reason, this was a crucial event in the incident.

This is the statement of Dr Naomi Li [IWS00000515]. This is again at 01.27:

"45. We immediately went to the staircase and opened the emergency door. At that point we intended to walk down the stairs and leave the building.

"46. We saw a lot of people walking up the stairs. I can't remember how many people were walking up It was a lot, enough to mean we could not go downstairs. It was people constantly walking up. There was hazy smoke in the staircase at that point. They looked normal walking upstairs, not screaming, running or anything unusual. We didn't talk to anyone. I was a bit stunned at that point, people walking upstairs wasn't something I expected to see."

At this point, a lady comes out of flat 193 and invites her and I think it's her cousin to take refuge with them in flat 193, which of course was smoke-free at that time. They wait there for some time and then eventually she and her cousin came down a long time later.

So this is a period before 01.30, but from 01.30,

most lobbies are filling with dense smoke, but much less in the stair. The stairs, it was increasing, but people were still able to descend safely if they were able to reach the stair, but they had to go through the lobby first, which was very badly smoke-logged.

From 01.30 to 01.47, a further 31 persons entered the stair and evacuated from different floors up to the 20th up to about 01.49. The last person to come out from that height at this point was Petra Doulova, so her statement is quite important in this respect.

Then there was a period of about 29 minutes -- I am going to go back to my previous ... there, right.

This period here. So everybody is coming down, suddenly there's a period when nobody is leaving for about 29 minutes, straddling the 2 o'clock point. Then people come down in ones and twos at intervals over the rest of the period, up to actually 8 o'clock, when the last person came out.

So 31 people came down in small numbers, and although there was smoke in the stair, they were able to come down safely.

But the smoke in the stair is increasing all the time, and there's one very useful account where somebody describes at some point coming into the stair, which was relatively smoke-free, and seeing people coming into the stair at floors above and below, and as they were opening the door from the lobby, the smoke is coming in to the stair at all levels from the lobbies.

So after this period -- so we're now past 2 o'clock, and I sort of put a line on my graph of 2 o'clock, and I'm saying basically that up to somewhere just before or around 2 o'clock, the stair itself was reasonably safe to come down, there was smoke in it but it wasn't too bad, and people quite successfully came down during that time.

Sometime after 2 o'clock, when the next people start to come down, by this time the stair is really quite hazardous, and it has much denser smoke but also high concentrations of asphyxiant gases. So from about 2 o'clock, the stair is now much more hazardous as well as the lobbies.

So Grenfell occupants descending in dense smoke after 2 o'clock, they were able to progress rapidly by holding the handrail. For a few people -- yes, so this slide I'm addressing -- I've talked about speed of descent in the stair when it's clear. But one of the problems, going back to Professor Jin, is that if the stair gets full of smoke, we'd expect people to slow down a lot. That was certainly the case when people are trying to find their way through the lobbies.

But in the stair itself, we found in experiments that if you have a guide, like a handrail, you can still progress quite rapidly, even if you can see hardly anything. People reported that. Indeed, for some of these people, we can make an estimate of how long it took them to descend where we have the end of their last 999 call, timed, and we have the time they got to the lobby, so we know the time between the two. This tells me that at least for a few of these people, where we have those two bits of information, they were descending generally quite rapidly in the stair at this time.

So that's the situation with the stair: all right up to 01.30, both the lobbies and stair reasonably clear and navigable; between 01.30 and 02.00, very bad conditions in lobbies but reasonable conditions in the stair; after 02.00, you've got hazardous conditions both in the stair and in the lobbies.

I now want to go back to what's happening in the flats.

Just as a sort of brief example, I am looking at flat 16. I don't think I'll read all this, but basically flat 16 is just an example of a simple, basic domestic fire scenario typical of the sort I described to my previous lecture.

So Mr Kebede realised early there was a fire.

I think his smoke alarm went off. He got people out, he closed the door, he warned the neighbours, everybody evacuated and called the Fire Brigade. Everything was all right.

But what happened next?

Well, you've then got this big plume of smoke coming out of his flat and flowing up the side of the tower. Here I've got some pictures from Professor Bisby's presentation showing all this smoke.

Now, this smoke is important or is interesting because as smoke flows up the outside in a plume, as you can see there, it entrains air, air mixes with it, it becomes extremely diluted. So although it looks a bit unpleasant, if you like, it's not particularly hazardous.

Some of that smoke coming from fires low in the tower is going to find its way through gaps, penetrations, open windows, whatever, into flats higher up in the stair. So people were reporting smelling smoke, some smoke alarms were going off, and people were being warned, if you like, or becoming aware of the fire partly because of this. But at this point, it may be causing a slight haze in your flat, but nothing terribly dangerous.

Apart from flowing up the outside, there may be some

smoke coming in inside. Some of it may be coming from flat 16 into the lobby and then into the stair, but it may have been moving through other kinds of penetrations between floors, and I think other experts are going to be talking about those in more detail. So there are a number of routes for smoke spread.

But I believe that in most of the lobbies at this early stage, the main source of smoke was coming from flat 6 on each floor, finding its way into the lobby.

Now we get to the point where flames ignite the exterior cladding and insulation outside flat 16. So this at about 01.15 hours. As Professor Bisby has described, it goes rapidly up the side, reaching the 23rd floor at 01.24.

The exterior fire then penetrates mostly the kitchens of flat 6 on each floor in sequence. This spreading plume is shown in Professor Bisby's photographs here.

So what then happened at each flat as the fire rose up the side to it?

The first thing that's happened is that smoke that is generated immediately outside the flat is not thin smoke, as I described; because it's near the source, it's dense and undiluted. So its thick, dense smoke and it will have contained significant amounts of toxic asphyxiant gases.

There are two possible main routes of smoke dense entry and flame penetration into flats as the exterior reaches each floor from below. One is from the exterior fire plume involving the cladding and insulation, and smoke from that, and flames, coming through open windows, the kitchen ventilator openings which were mentioned by a number of witnesses, and through sort of gaps and holes in windows, especially where you get early partial glazing failure. That's reported by number of people. They say, "The flames came up outside and then part of my window fell out", or in one case they said the whole window fell out.

Secondly, from an insulation fire burning in the void behind the columns, as I mentioned earlier, and spandrel cladding, entering the flat through penetrations around the window flames. You'll remember Dr Lane describing that. This is a diagram from her report showing the routes by which this happened. This is dense smoke with highly toxic gases.

The next stage is dense smoke from combustible materials -- structural materials still, not the contents of the flat -- of the window surround adding to the flame and smoke development inside the flats around the windows, especially the flat 6 kitchen and possibly

the east side lounge windows.

This picture here (Indicates) from Dr Lane's report shows how the fire has come in around the window and started to involve the PVC and other materials of the window around the window frame.

That's going to be a source generating more toxic gases and smoke into the enclosed flat.

Finally, the fire may spread to involve the flat contents, starting with combustible contents close to the window, such as blinds and curtains -- and that was reported by a number of people -- and then spreading -- this is where it gets really serious -- to involve things like upholstered furniture and other items. I haven't seen that particularly described by people.

So once you get to this point, you will have the danger of having a serious fire in the room that's being penetrated. What happens next depends a lot on what happens to the glazing and whether the windows fall out or whether they remain intact.

Particularly where the windows fall out, there is a danger that this fire will progress rapidly to flashover or at least a very serious fire. I think I've captured this on this -- this is an image 3 from Professor Bisby's presentation, and you can see here this is taken between 01.56 and 02.23 -- closer to

02.23, according to his slide -- and it's taken looking at the east face of the tower. So at this point, the fire has already gone all the way up the flat 6 column here, and it's now moved laterally to more like the flat 1 location.

So these bright flames here and here (Indicates) are basically the cladding and insulation burning outside those flats. But here, most of that has stopped burning, it's gone -- you can see these dark marks here (Indicates), then you have these bright outlines of windows. So this looks to me very much like we have serious fires inside these flats, involving the flat contents, by this time in the fire.

This is something that the other experts are going to be very knowledgeable and interested in, and we will be looking into it in much more detail in Phase 2 of the inquiry.

So, again, from first becoming aware of a fire, the flat occupants were repeatedly faced with this difficult decision, stay or go, and they were affected by different considerations and experiences. But the extent of exposure to smoke or flames would be an important factor, in some cases encouraging people to get out, in other cases preventing it.

So if we think of what is happening in flat 6, at

the early stages of development, as fire penetrates flat 6 on any floor, it's still going to be similar to these domestic growing fire scenarios I've already said to you, except that instead of a fire starting in an armchair or appliance, it's now starting in the window surround and external materials.

So the flat 6 occupants were alerted by a variety of cues. In some cases, their smoke alarms went off. So the fire has just started to penetrate, and most people in flat 6s became aware quite quickly there was something very bad going on if you read their accounts.

There was a lot of variation between different flats in fire development, and this shows up in the witness reports. Some people describe flames appearing at the window as their first thing that happened when they came into the kitchen to look and see what was going on. Other people woke up to find the flat full of smoke before there was any fire penetration from outside. There's a variety of different experiences, and it partly depended upon what happened to this ventilator assembly, whether or not they had their windows open -- it was warm weather -- and various other factors.

But the general pattern is of rapid smoke-filling of flat 6, people being aware of it from an early stage, and realising, all the way up the tower, they were in a very serious situation.

And so what did they do? Well, they all evacuated, sometimes with no shoes on and partially dressed. They got out very quickly, and they were able to do so.

Now, the important thing here is the flat 6 occupants left their flats before there was any significant smoke in the lobbies. A large number of them just carried on and evacuated the tower, but others, as we heard, didn't come down the tower; they took refuge elsewhere in the tower, in other flats, sometimes on other floors.

Some flat 6 occupants stated they left their flat 6 doors open, and an open door would be a route for smoke flow into the lobbies. I'm looking to find out when and how all those lobbies became filled with dense smoke at about 01.30, which prevented other people from evacuating, and so I believe that flat 6 was probably the main source.

Now, obviously if the flat 6 door is open, it's an easy route for smoke to flow from the flat into the lobby, and so there are questions then about how those doors performed and the self-closers, whether those doors were shut after people had just come out and left them. But there are a lot of accounts of these doors remaining open and smoke flowing out and quickly filling

the lobby from the ceiling down with dense smoke.

Now, some people actually stated that they did in fact close their flat doors before they left, and we would hope that that would reduce the speed of filling of the lobbies with smoke.

I'm in the process of trying to analyse these statements, but my impression is that even where the flat doors were shut, there was still significant leakage of smoke that filled those lobbies with quite dense smoke quite quickly. So it would be necessary in Phase 2 to look more closely into this.

Of course, after they left the flats, the fire was continuing to develop in each flat, and so some of these flats were completely burned out.

Now, of course, during the later parts of this fire, as we come more towards 2 o'clock, these interior fires are getting very serious, and most of the smoke and toxic gases are generated in those flat fires and finding their way partly out through the windows, through the open window plume, but partly into the lobby are coming from the flat contents burning, an increasing proportion, and some of these are going to reach very high temperatures and to flashover.

So when we look at the pattern -- so this table 6 in my report shows the number of fatalities in each flat,

and the way I've kind of organised this is that this is the sort of west side of the tower, and this is the east side of the tower (Indicates). And the thing that really leaps out at you is that nobody died or no remains were recovered from any flat 6.

So all these people were confronted with fire coming in through the windows all the way up the tower, rapidly deteriorating conditions in their flat, but they were able to evacuate the flat -- not necessarily the tower, but they evacuated the flat -- into a relatively smoke-free lobby. In many cases, they came down.

The fire also spread quite rapidly to flat 1 and, in general, most people left flat 1, apart from flat 201, which is a case where a lot of people were for some time.

What also shows in this analysis is that, ironically, it's the least affected flats that's then become the most dangerous, because when people took refuge, typically in flat 3, which is in the south-west corner of the block, was the last place to be affected by fire spread around the tower. So they remained there often for an hour or so before they were forced to evacuate or before the fire got to them. So they were in a situation where they stayed and then got exposed.

So up to 01.30, most flats other than flat 6 on each

floor, and possibly flat 1, were generally smoke-free. From 01.30 to 01.35, we have lobbies on various floors filling with dense irritant smoke, reports of almost zero visibility, could not see hand in front of face, difficulty breathing and irritant smoke.

Some people then tried to go through this smoke, feeling their way around the walls, as I mentioned. This is likely to have had high concentrations of -- in the lobbies of high concentrations, but not in the stair. Fortunately, it doesn't take very long to get across the lobby. Even so, some people did report feeling dizzy when they were in the lobby around about this time.

Occupants who then entered the stair between 01.30 and 01.49 found much clearer conditions in the lobby, not totally smoke-free, and were able to descend safely without collapsing.

I put a few examples in here, but one person in particular I want to talk about is Abraham Abebe and his wife, because this is an example of a couple who came down -- this is from the 7th floor, exited at 01.48 eventually. But in his statement, he recounts coming down the stair at a fairly early stage in reasonable conditions, but then finding thick, black smoke in the stair between the 4th and 5th floor, and an open door to the stair with a hose going through it. So smoke is flowing out from firefighting activities from a flat, into the lobby and then into a stair.

He saw this big cloud of thick, black smoke in this area, and he said something along the lines of he was frightened to continue down the stair. But he was kind of preparing himself to go through, because he knew he only had a couple of floors to go down. But his wife, who was a little bit higher up, called him back. So he and his wife then ascended back up to their flat until firefighters came up and encouraged them to leave, and so they came down again.

The second time they came down, the stair has now got more smoke in it, but they were kind of more confident because the firefighters had told them they could come down, so they came down. But he does say that by the time he got to the 4th floor, this smoke he had encountered before had now cleared somewhat. So it may be at this point the firefighting operation there had ceased and the door had been closed.

Branislav Lukic, who was one of the last people in this group to come down with his flatmate at 01.49, thick smoke in the lobby, relieved to find less smoke in the stairwell -- so this is 01.49.20 -- could see through it, more grey than black. He was more or less

carrying Clarita Ghavimi, which requires a lot of physiological effort, yet he was able to do it through the conditions at that time. This demonstrates to me that although there was some smoke in the stair at this time, you could still descend in reasonable safety.

After 01.30, many occupants stayed put. Least affected flats are those in the 3 position. Mostly smoke-free conditions at first, but then gradually filling. The flat occupants then took various measures to try and limit smoke entry.

It seems at this time that most of the slow smoke-filling is coming from the lobby. So, again, we have this issue of smoke penetrating possibly partly around the flat entrance doors.

So at one stage you've got smoke coming from flat 6, around the flat 6 entrance door, even if it's closed -- and this was described by somebody -- into the lobby; now we have the lobby filled with thick smoke, clear conditions in a flat, but smoke coming in the opposite direction, from the lobby into the flat. So obviously there was some leakage going on.

Also, some people describe smoke coming through pipe penetrations between their flat and lobby and various other routes. But anybody trying to leave now is in difficulty.

So this is now a scenario where they're stuck in the flat and they have something very like the people in the closed rooms at Rosepark, slowly taking up carbon monoxide over a period of an hour or two.

Because the concentrations are very low, I don't believe that cyanide would have been a significant factor in the slow build-up of the CO.

Now, after 2 o'clock, if occupants had attempted to evacuate into the lobby, they were exposed to very high concentrations of smoke, CO and possibly cyanide in the lobby and stair, also capable of causing collapse within minutes. The outcome for these people I believe depended on the dose accumulated while in the flat.

So if you were in a flat that had low smoke or you left within a short period, you would be able to descend the stair within a few minutes without collapsing, and some people certainly described being trapped in a flat but being able to open the exterior windows and keep some of the smoke out of the flat, because it was before the fire has come round to them.

So the conditions in the lobby were definitely hazardous. The escaping occupants, some of them experienced zero visibility, breathing difficulties and pain, and as they descended, they reported being affected by the asphyxiant gases, feeling weak and

dizzy, in some cases collapsing on the stair.

But as the descent of people at various times shows, it was not impossible to descend the stair, so far as I could see, at any time, since some occupants succeeded in doing so at intervals from all floors up to almost 8 o'clock.

I want to talk now about the blood toxicology.

This image on the right here is not in my Phase 1 report, but these are objective data from the toxicologist that will not change, so I feel we can have a look at it now. I haven't identified any individual people here.

Again, I think this is very useful because it confirms again that people were being overcome by smoke and toxic gases rather than by heat, because as you can see, all these numbers are in the very high range, apart from this one (Indicates), who is in this very low range. But that was an individual who was rescued alive and taken to hospital, and of course would've been given oxygen on the way to hospital, which washed out CO from his blood. Also, there was a problem with the sample. The toxicologist reported uncertainty about whether that is a true reading.

Then you have two people who may have fallen from the tower, but they had a significant dose. So we can tell that these two people had been exposed to quite significant smoke, not enough to make them incapacitated, but they were exposed for some time before they fell.

And then, crucially, the purple bars here, are from bodies in flats. You can see that these are all in this high range where death is occurring due to inhalation of toxic smoke -- one exceptionally high, nearly 90 per cent carboxyhaemoglobin before that person died from the smoke.

The black bars are from fatalities in the lobby or stair, and you can see they also are all well up into this death from carbon monoxide essentially group. So they've died from collapsed and died from exposure to asphyxiant gases in the smoke.

If these persons found inside the flats had been overcome by heat and burns before they had time to collapse from asphyxiant gases, I would've expected to see much lower blood levels than we actually are seeing.

Right. I think, in view of the time, I'll stop at that point.

SIR MARTIN MOORE-BICK: That's a convenient point for you, is it?

PROFESSOR PURSER: Yes.

SIR MARTIN MOORE-BICK: Right. But there is still further

to go on this part of the presentation?

PROFESSOR PURSER: I think we can leave that and move on to the third one when you are ready.

SIR MARTIN MOORE-BICK: Yes.

Shall we stop now then and take time for lunch? And I am going to say we'll resume at 2 o'clock.

PROFESSOR PURSER: Right.

SIR MARTIN MOORE-BICK: Which gives you just over the hour.

Again, please don't talk to anyone about your evidence over the break.

If you go with the usher, she'll look after you.

PROFESSOR PURSER: Okay, thank you.

SIR MARTIN MOORE-BICK: All right? Thank you very much. Thank you, 2 o'clock, then, please.

(1.00 pm)

(The short adjournment)

(2.00 pm)

SIR MARTIN MOORE-BICK: All right, professor, ready to carry on?

PROFESSOR PURSER: Yes.

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

PROFESSOR PURSER: Okay?

SIR MARTIN MOORE-BICK: Yes, thank you.

Presentation 3: Possible toxicity performance of materials present at Grenfell Tower

PROFESSOR PURSER: Right, I know you have some questions to put to me, so I will try and keep this as brief as I can. I would like to reassure you this is a somewhat shorter presentation than some of the ones this morning.

SIR MARTIN MOORE-BICK: Thank you.

PROFESSOR PURSER: So in this one I want to address the possible toxicity performance of materials present at the Grenfell Tower.

In doing this, I want to emphasise that the statements and calculations and things and the numbers I'm presenting you are intended to be purely indicative of the possible conditions that could be produced.

Really what I'm trying to address here is essentially a sort of qualitative question, which is: taking in all these different individual materials, including the cladding, the insulation, the window structural materials and the contents, each of these individually or in combination, had they become involved in fire outside, if you like, a typical or an example two-bedroom flat, could they have produced hazardous conditions in the flat and the lobby beyond?

In particular here, I'm looking at a snapshot in time early in the fire, when the fire is breaking into flat 6 on every floor, and then the smoke is going beyond into the lobby.

It's this sort of period up to around 01.30 hours, when the lobbies filled with a dense, irritant smoke, that was so important in affecting the potential of escape for people who remained in their flats at that time. So it's this kind of 01.30ish period in the back of my mind.

So what is the contribution of any burning material to toxic hazards at Grenfell? This would depend on obviously the extent to which their combustion products form part of the time concentration curve of the toxic smoke and gases inhaled by each occupant at various locations and times in the tower.

This depends upon the mass burning rate, how many kilograms of any particular fuel are consumed each second, and then it depends on the yields of smoke and toxic products from those fuels when they burn. For example, how many kilograms of carbon monoxide is produced when each kilogram of material is burned? And then it depends on the volume into which those products are dispersed, such as the interior volume of an enclosed flat.

That gives us a term mass loss concentration, kilograms per metre cubed, it's the number of products from that material dispersed, say, into the volume of this room.

Now, what can determine the yields of smoke and toxic gases from any burning material? Well, firstly, it depends upon the elemental composition of that material, how much carbon, hydrogen, oxygen, nitrogen, chlorine, bromine, phosphorus and possibly inert fillers this material is composed of.

Secondly, it depends to some extent on the organic composition, what kind of polymer is it? Something like polystyrene, for example, or polyisocyanurate, they behave differently in the way they behave. Polystyrene, for example, because of its aromatic composition, produces very high yields of smoke particulates when it burns.

Flame retardant additives can also have a large effect on the type of combustion and the products that you get.

Thirdly, and very importantly, it depends on the combustion conditions, as I explained this morning. For flaming fires, it's the fuel-to-air equivalence ratio, whether it's well ventilated or under-ventilated, that can have a big effect on the yields of toxic products.

For developing hazards in a Grenfell flat, I have identified three main what I call fuel packages of interest.

The first one is the combustible parts of the

rainscreen cladding and the insulation basically outside the flat. So that's the Reynobond, the Celotex panels on the spandrels and the panels on the columns.

Secondly, you've got the combustible parts in the window surround and between the windows. So you've got the exterior infill panels, which were expanded polystyrene, and you have the window surround consisting of these 9.5-millimetre thick uPVC sills and exterior bits. Quite a large amount of material in that.

Then there are lots of other smaller components that Dr Lane, for example, and Professor Bisby have set out in their reports. So far I haven't considered the contribution from any of those because they're fairly minor ones; so far, I've concentrate on the major fuel packages. But I could do so.

Then, of course, once the fire has moved beyond the windows into the flat, you have a very large fuel mass consisting of the contents of any particular flat.

So just to remind you, this is from Professor Bisby's report. These are some of the structural materials.

This is the 3-millimetre PE in the cladding (Indicates).

This is the PIR insulation (Indicates), which is two forms, 100-millimetre thick single layer on the columns,

and two 80-millimetre thick layers on the spandrels.

This is the polystyrene (Indicates), which is quite thick but it's a very light density foam.

And then you have the very dense, very heavy material, which is the PVC, which is about 9.5 millimetres thick. But they were quite deep seals.

So these are the main materials I considered other than the contents of the flat.

Just to remind you where they are, then, these are these XPS panels between the windows, and here is the cladding and, of course, the insulation is behind it. This is a lower part of the tower where there's been limited damage.

But the top of the tower there -- these are from Professor Bisby's report -- you can see that there's been considerable loss of these materials. They've been burnt away. So pretty well all the rainscreen cladding has gone, and a considerable amount of the PIR insulation.

However, as you can see here, there's quite a bit of charred PIR still left on some of these flats, particularly the spandrels, although the columns are pretty well bare.

Now, I'm not sure when this photograph was taken, but of course I'm aware that I, certainly when I went to

see the tower about a year on, was seeing it at that time, and so I can't say exactly what was there immediately after the fire. But there may be photographic evidence of that which I haven't yet been shown.

Inside the flat, we have the PVC window surround. This illustration is from Dr Lane's report showing how the fire has come in around the window frame and has started to decompose this PVC.

This is a fairly small amount involved. This was actually in flat 15. I'm afraid you can't see it terribly well, but this is from I think Professor Bisby's report -- or maybe it's Professor Torero's, I forget now -- and it shows over there where some of the PVC had much more destruction.

Now, in order to estimate the potential hazard from these, the first thing I needed to know is how much material is there. I had to work out the area for all these panels on the exterior, and I took the dimensions from Professor Bisby's report to calculate the area. Then from the thickness I could work out the volume, and by using figures for the density of the material, I could work out the mass.

So what I'm trying to work out here: is what is the mass of these various components, in this case the exterior materials, outside a typical one- or two-bedroom flat?

For the flat contents, it's much more difficult, because every flat is going to have different contents. We don't know what was in the contents of each individual flat. So I haven't detailed how I've done this, but basically I had to come up with a figure for the typical fuel load in a flat and it's sort of average composition.

So I went through an exercise of assessing the typical amount of furniture you would have in a typical flat in terms of mass or different items -- cupboards, doors, wardrobes, beds, everything I could think of, even appliances -- to come up with an overall total combustible fuel load for a flat.

From my knowledge of the composition of those materials from work we've done at BRE and the approximate composition of these materials -- for example, if you have a wooden cupboard, it's made of wood; if you have a composite one, it's probably MDF or something like that, which I know the composition of -- so I can work out the mass of carbon in these various items and sum it to find the total proportion and mass of carbon in a typical fuel load, and the same for nitrogen, and I've also done that for chlorine.

Having gone through that exercise -- and I will try to detail how I arrived at these figures more comprehensively in my Phase 2 report -- this is what I've come up with. What I'm looking for here is not the exact figures; it's the sort of relative amounts. Have we got a large amount of something or a small amount that might be trivial, in comparison, for example, with the combustible fuel load in the flat?

I'm going to focus here on two-bedroom flats because most people who took refuge were in two-bedroom flats.

So for a two-bedroom flat, then, according to my calculations, which are very preliminary and subject to me checking them and looking for more information, I'm estimating that there's about 158 kilograms of PIR in the insulation outside each two-bedroom flat, quite a large area.

The LDPE, although it's only 3 millimetres thick, is much denser than the PIR, and so actually quite a large mass of LDPE.

The XPS, though, is quite a small amount, so we would expect that not to contribute too much.

The PVC -- and somebody's queried this, and I must admit I'm a little bit surprised -- according to my calculations -- and there was a lot of it there, and it's very heavy, very dense material -- there's about

184 kilos of PVC in the window surrounds, all the windows of a typical two-bedroom flat in the tower.

When we come to flat contents, this, of course, is by far the largest total item. So I would say that the flat contents is going to be about 660 kilos of contents.

But what this shows is that the PIR and the LDPE and the PVC are quite large, significant amounts in the context of, for example, a total flat fire load. I keep going back to my 5 to 7 kilograms burning in a flat is enough to cause a hazardous atmosphere. All right? And we're talking about hundreds of kilos here.

So having got the total masses of materials, I then need to know what they're made of, and I've taken data from our work and this is all in the report. But, essentially, I've identified some individual materials here that we're interested in, and then you see I have a row for the mixed flat contents.

I also, for comparison, put in plywood and polyurethane foam, which is in upholstered furniture.

What you can see immediately, of course, is that all these materials have a high carbon content, the lowest being PVC, and so that means when they burn, they will all produce a certain amount of smoke, particulates which are carbon based, and they will all produce

a certain amount of carbon monoxide and carbon dioxide, but the carbon monoxide would depend a bit on the conditions under which they are combusted.

With regard to fuel nitrogen, PIR stands out as having quite a high nitrogen content. The other main item with nitrogen in is the upholstered furniture, the polyurethane foam, and to some extent some fabrics and things in upholstered furniture.

In plywood and MDF, things like that, it's not pure wood, you have certain resins and things in, but you also have a little bit of nitrogen, as you can see there.

So for the mixed flat contents, taking all the sorts of things you'd find in a flat, my estimate is overall about 50 per cent of the mass being carbon, and about 3.7 per cent nitrogen and a little bit of chlorine.

Now, the next thing we have to consider is the combustion conditions, because I've said that will affect the yield of toxic products.

Well, the LDPE cladding and the XPS panels are burning mainly in open air on the building exterior, so I've estimated that they will be combusting under reasonably well-ventilated combustion conditions.

The PIR insulation burning in the cavity is more complicated, as I explained this morning, and I believe as long as it's in the cavity, there's a probability that it will be burning under a somewhat under-ventilated combustion condition. But when the cladding falls away and exposes the PIR, then, of course, it's open to the air and will transition to a well-ventilated combustion condition.

At the moment, we don't know what the overall combustion condition was for most of the combustion of the PIR. This could be resolved potentially by some form of testing strategy if we feel it was appropriate to do so.

But for the purposes of my indicative assessment here, because we don't know, I've used both cases. So I put in data for if it all was well ventilated and if it was all under-ventilated, and it should be somewhere between the two.

The PVC window surround was initially well ventilated, but the thing about PVC is that, unlike other materials where the yield goes up like that (Indicates) with the vitiation, PVC has a fairly flat yield across the whole of its range. So because of the halogens in PVC, when it burns, it produces high yields of carbon monoxide, even under well-ventilated air conditions. When it's vitiated, it doesn't really make any difference; it's more or less the same throughout

the range. So I've assumed a fairly well-ventilated combustion condition, but it doesn't matter.

When the flat contents become involved, by then I've estimated the conditions would be already under-ventilated. So I treated all the flat contents that I've used as being under this under-ventilated condition.

The smoke and toxic gases are derived from data produced at BRE years ago.

These are for generic materials, by the way. None of these numbers are for the actual Grenfell materials, but they're for the same general type of polymer, so they should be substantially similar. But so far we haven't done any testing on actual Grenfell material.

From all this, I then produced this table, which I'm going to talk you through, but to start with, just go back to the scenario.

So the first stage, of course, as I said this morning, is you have this diluted smoke plume flowing up the side of the tower, which is not particularly hazardous. When things become potentially hazardous is when the fire arrives at the level of your flat.

Two-bedroom flats, I believe, are the most vulnerable because they have a much greater mass of cladding insulation and window surround materials, and

of course they go around the corner of the tower.

So the time to untenable conditions, then, depends on the area of the flat exterior and the windows involved, and the timing and extent of fire involvement of the contents.

Now, this table shows potential contributions from materials to toxic hazards in a two-bedroom flat and potentially the lobby beyond if the door is open or it's leaking.

Now we have to consider the order in which these things get involved.

So the first burning materials generating toxic smoke into the flat are likely to be the LDPE rainscreen cladding and the PIR insulation, because the fire is coming up the outside of the building, involving these materials first.

You will remember I was talking this morning about the various routes of ingress, of penetration of flame and smoke around the windows and things that Dr Lane has explained to us.

So the next thing we need to consider is, of this burning material on the outside of the tower, what proportion of the products, from what proportion of the mass, comes into the flat, and how much goes up the outside of the tower and blows away over London?

We don't know. I don't know whether anybody could model this, but it's a question.

The extremes, of course, are we could assume none of it goes into the flat. But that's patently not the case because we've lots of descriptions from occupants of smoke actually coming in and we have Dr Lane's analysis.

The other extreme we could make is that all of it goes in the flat. Well, that's obviously also ridiculous because we know a lot of smoke has gone up the outside, so it's somewhere between the two.

I've used quite a conservative estimate for these materials, and I've assumed that, of the mass that's burning, the products from only 5 per cent, a 20th of that mass, find their way into the flat. 95 per cent of the smoke is going to go up and away, not be involved.

I've also, though, looked at the effects of a case where only 1 per cent goes in, and I'll talk a bit about that in a minute.

But for the moment, for the purposes of these calculations, I've estimated about 5 per cent, and I don't think that's unreasonable.

Now, the other thing is how much of the material is burned during the fire, particularly at this early stage.

From what I've seen from the other experts and looking at the tower now, most of the rainscreen cladding has gone. So for the purposes of this calculation, I've assumed that 100 per cent of the polyethylene has been burned.

Now, of course, some of it fell away, some of it dripped away, so in reality it might be slightly less than I'm saying. But that's what I've done for the purposes of these calculations.

However, because it's all burning on the outside of the tower, it's going to produce low yields of CO.

When you look at the PIR insulation, as I showed you on the photograph, most of the PIR insulation on the columns has gone. This is a year on, of course, but it's not there now.

We've got two layers of PIR on the spandrels. From what I've seen, particularly when I've been to the tower and some of these flats, at least the outer layer has gone, representing about 50 per cent of the spandrel PIR mass. So for the purposes of these calculations, I've assumed or estimated that 50 per cent of the PIR has been burned during this stage of the fire.

So 50 per cent of it is burnt, and of that 50 per cent, 5 per cent of the products find their way into the flat over this short period.

The next materials to be involved, more or less at

the same time, actually, is the XPS panel. But, again, that's burning under well-ventilated conditions and it's a small mass. But, again, I've assumed 5 per cent of those products also find their way into the flat.

The PVC is all going to be generated into the flat when it burns because it's inside the flat now, but for the purposes of the calculation, I've taken a point in time where the destruction of these sills has burnt 5 per cent of the PVC, so the sort of early stage of penetration.

The next stage is going to be to involve the flat contents, and at this early stage, I've assumed that 0.5 per cent of the flat contents, a small amount, at this point in time, this snapshot of time I'm analysing, has been burned. So that's a quarter of an armchair's worth has got involved maybe near the window at this stage.

That's what I have used to create the numbers in the table.

Let me just talk you through this table a little bit.

So the first row in the table represents the LDPE. So I'm assuming it's burning under a well-ventilated condition, and then the mass that's burned outside each flat is 90 kilograms. 5 per cent of that is

4.7 kilograms, so it's the product from this 4.7 that we're worried about. Dispersing that into the volume of the flat gives us that mass loss concentration, and from the yield data, I can then calculate what the concentration of carbon dioxide would be in that flat. The number I'm coming up with is 3.5 per cent, which is not hazardous.

There's also some carbon monoxide, but it's quite a low concentration, and there's no cyanide because there's no nitrogen in PE. But the bit that is important is I've couched the smoke in terms of visibility, and I'm estimating that the visibility in the flat at a time when you've burnt 5 kilograms, 4.7 kilograms of LDPE, is 0.25 of a metre, hand in front of your face. So the LDPE on its own could produce dense smoke in the flat and, by inference, the lobby beyond the flat.

Time to asphyxia is calculated using my FED equations for these gases, and you see it's a long time, 160 minutes. So the main hazard we're getting from the LDPE is the smoke, the irritant visible smoke.

Moving on to the PIR, you'll see I have two rows here, and the upper row is assuming all the PIR -- sorry, I'll take you through it again.

So we have 79 kilograms of PIR, so that's the

50 per cent I'm starting with, and then 5 per cent of that is coming into the flat, a similar concentration as the PE. Then you have two rows of gases. The upper row is for the well-ventilated case. So this is all burning under well-ventilated conditions.

Because the PIR has a significant halogen content, it means that it always burns in a somewhat inefficient manner. As you can see here, we're getting quite high concentrations of CO and cyanide in the flat, even under the well-ventilated case, and also quite a lot of smoke, such that if that mass was dispersed into the volume of the flat, I am calculating that somebody would become unconscious after 23 minutes.

If it was all burning in the under-ventilated case, we have more asphyxiant gases and that time comes down to only a couple of minutes.

Of course, if we're thinking of this as a flat 6, we know that nobody died in a flat 6 or collapsed in a flat 6. That's because they all had time to get out before these conditions developed.

So what we know for flat 6 is that although these gases were generating into the flat, particularly after people had left, these gases had no effect on their ability to escape because they all escaped into the lobby, at least.

Taking the polystyrene, not much coming off that but a bit of smoke.

PVC window, on the other hand, is quite a significant hazard, because it produces very high concentrations of carbon monoxide. It doesn't produce any cyanide, but it does produce a high concentration of very, very irritant hydrogen chloride gas and a lot of smoke, and on its own could produce incapacitation within about 13 minutes.

Then you have the small bit of flat contents I've assumed has been decomposed up to this point. Because of the furniture in that, quite a lot of CO and cyanide, typical domestic furniture fire, essentially, a lot of smoke. You could survive that for about 10 minutes if you stayed and breathed it, before you're incapacitated.

So the breakdown is that the toxic product from each material considered alone, the LDPE on its own will produce dense smoke but low concentrations of carbon monoxide; PIR on its own, dense smoke, CO and cyanide; polystyrene, a little bit of smoke; PVC a lot of smoke, hydrogen chloride and carbon monoxide; and the flat contents, smoke, carbon monoxide and cyanide.

Of course, these things aren't decomposing individually; they're all decomposing together. So all these effects are summed.

Because of that, I feel quite strongly that all these structural materials which are being involved in the early stages -- thinking again, in my mind, of a flat 6 situation -- are capable of producing rapidly high concentrations of smoke inside a flat 6, and the lobby beyond.

If we think of the sort of scenario at 01.30, when that lobby is filling with smoke, my feeling is that most of that smoke at that time is coming mainly from these structural materials burning outside the flats, particularly flat 6. This is predicted even if there's no involvement up to that time of the flat contents.

That's the end of my presentation.

Yes. Thank you.

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

Yes, Mr Rawat.

Questions by MR RAWAT

MR RAWAT: Thank you, sir.

Professor, would you like to take a seat?

A. I can sit here, that's all right.

Q. Thank you.

Could we start with the last part of your presentation, part 3. Can I ask you just to pick up on the last point you were saying.

You talk about the contribution from structural components which would happen irrespective of flat contents.

A. Yes.

Q. In your report -- I can take you to the paragraph if you want it -- you've mentioned that at some point in this process, flat contents will become a predominant source of toxic gases.

A. Yes. Sorry, may I just -- you've reminded me of something I should've said.

Moving on from the point I got up to in my presentation, subsequently to that, particularly after around about 2 o'clock, the smoke being generated in the flats and coming into the lobbies is going to be dominated by the contribution from the flat contents.

Subsequently, most of the smoke in the lobbies, throughout the fire, is going to be dominated in origin by the burning flat contents, with some contribution from the cladding and things. So the situation has moved on.

Sorry to interrupt you.

Q. That prompts my question, because in the answer you've just given, you said sometime after 2 o'clock.

A. Yes.

Q. What's the basis for you giving that time?

A. I suppose I'm referring back to my situation this morning. There are a couple of things going on here.

The main thing is because we have photographs from the outside of the tower around about that time -- I thought I had one to show you somewhere, maybe I showed it this morning, I think I showed you one this morning -- where --

Q. Was that the --

A. -- you can see the outline of the windows, bright with flame inside, indicating serious fires inside those flats. If there's a serious fire like that inside the room, that must be the burning contents.

Q. That was the Luke Bisby photograph you showed in the second part of your presentation marked with a time as closer to 02.23 am?

A. That's the one, yes.

Q. But in terms of flat contents playing a role, what's the basis for saying that 2 o'clock applies to all flats?

A. No, it doesn't, sorry. One thing that's really starting to show up more as we look into this is there's quite a variation between the extent and timing of penetration of fire to involve the contents of different flats up and around the tower. So there's a variation.

But some flats at around this time -- quite a lot, if you look at the pictures, and I think Professor Torero has given us a breakdown of this -- had

gone to full involvement. But others hadn't, you know.
Does that answer your question?
Q. But applying it logically, and if you take a flat 6 as an example, and you've spoken about flat 6 today and let's take the example of flame coming in through the kitchen window.
A. Yes.
Q. If you have flat contents on the kitchen counter, for example, or in the area of the kitchen, would flat contents not immediately begin to play a role?
A. Yes. I mean, I'm going back to flat 6 at the moment because I've looked at this a bit more in detail because I'm interested in this early development. If you read the witness statements from various occupants of, for example, the flat 6s all the way up the tower, you'll see that there's quite a variety -- I thought I said this, but anyway I'm going to say it now -- of ways in which smoke and/or flame first breaks into those flats.
So typically, these people were alerted at quite an early stage and they went into, say, their kitchen, and then they describe what they saw. Some people said "I saw flames coming around the windows or through the windows", some people said there was a crack and the window fell out, some people had a window open.
Some people's, however -- quite a lot of people --

first experience was of smoke. Two people I remember reading describe the early stages of involvement of the curtains and blinds around the window. One person -- I forget who it was -- said that they actually pulled these things down and stamped them out.
Another person had some kind of curtain up between the kitchen and the sliding doors to the lounge, and this curtain caught fire.
So there were certainly some instances of some materials in the vicinity of the windows in some cases being involved at quite an early stage.
So I think we're going to see a variety.
Q. Would it be fair to say what we have got to remember is the point you've made from your BRE experience, that you just need 5 to 7 kilograms of a material to be --
A. Yes.
Q. -- combusted to be getting gases which are hazardous?
A. Yes.
Q. Obviously the kind of gases generated would depend on the material.
A. Of course.
Q. But I think you described it in your first presentation as a third of half an armchair, so it's --
A. A third to a half.
Q. A third to a half of an armchair is what would be --

A. Yes, in the enclosed volume of a house or flat.
Q. I follow.
Can I take you back -- again, we're sticking with what you were just discussing recently, but just to again ask you a few more details about the process you've outlined in that presentation.
It might help if we just look at your report. Can we have, please, DAPR0000001, page 63. Could we expand paragraphs 204 to 206, please.
In these paragraphs, professor, this is where you're setting out your analysis of what you described as three fuel packages of interest. We see that in each of them, you've given an estimated density.
A. Yes.
Q. Can you explain how you come to estimate these densities.
A. Yes, I can. I slightly apologise for not having really had time yet to set all this out in my report. I will put all the sources of all this information -- well, I'm hoping to find better information. This is all very preliminary.
But basically the main information -- or the areas and volumes come from the other expert reports. But in order to work out the mass, I needed to determine the density, and I came across a datasheet for Celotex which

told me the density of the 100 and the 80-millimetre thick foam, 3.8 kilograms per metre squared or something like that for those panels. That's the source of my density data for those. Okay?
That has been provided to me. I think it's a Met document which has been provided to me with that information in.
Q. For the Reynobond rainscreen cladding, how did you --
A. I don't have a figure for that. I think I got it from the BPF website, but I can't remember exactly. But I looked up typical figures for the density of PE. It's about a density of 1, because it more or less floats. I've worked with it a lot myself. I've used that. So that's an estimated figure.
If necessary, what we can do, of course, now we have samples from the tower, we can measure the exact density of all these materials, but I don't have that information as yet, so I've had to estimate the figure.
Q. So is this something you could consider doing for Phase 2?
A. Yes.
Q. Could I ask you to pick up one thing in paragraph 206. Can you explain how you come up with a mass of 26.26 kilograms per window?
A. Yes. A lot, isn't it? Yes. Well, what I've done is

I've worked out the -- I found a figure -- and I must admit, I've forgotten where I got it from now, I think I measured it off one of the plans -- for the depth of the sills. From memory, it's something like 36 centimetres or something. Anyway, so I've got a figure for the depth. I know the perimeter distance, so from depth times perimeter distance, that's the area of PVC panelling around each window. I know that it's 9.5 millimetres thick from Bisby. Then I needed a density.

So, again, I've looked up to find out what I can, and I've used a figure, I think, of 1.5 grams per centimetre cubed. That's what I've used so far. It could be slightly less, but I think that's a reasonable figure. It's very heavy stuff, PVC, because of all the chlorine in it.

When I multiply that up by the number of windows and the area, that's the mass that I'm getting. I did try and check it last night. At the moment, I'm still sticking to that figure, but arithmetic can always be a weakness in people. I will be thoroughly checking all this obviously for Phase 2.

Q. Could we go two pages ahead in your report, please, to page 65, and look at table 2.

As we can see, it's headed, "Composition of test

materials".

You've explained in your report --

A. Oh, yes.

Q. And if you --

A. Oh, yes, yes.

Q. The explanation you've given is at paragraph 213, which is on the previous page, professor.

A. Yes.

Q. You explain:

"213. Table 2 shows the measured net heat of chemical combustion, stoichiometric oxygen demand and elemental composition for each of 14 common polymeric materials used in furnishings and building products."

I think what you've done is taken materials that would have appeared or been in use at the tower, and also would appear in flat contents.

A. Well, actually -- yes. I've selected from that list, but that list is the list of materials we tested at BRE where we had these measured.

Q. Can you explain the term stoichiometric oxygen demand?

A. It's the amount of oxygen you need to burn each gram of material to completion.

Q. Why is that important to the calculation that you were doing here?

A. It's not. It just happened to be in the table and it's

used for other purposes in our calculations.

Q. If we could have the whole page, and I draw your attention to what you've said in paragraph 215, you're speaking there to the two most important combustible polymers.

A. On the exterior.

Q. The two you give are the low density polyethylene and the polyisocyanurate.

Why are they the most important combustible polymers in terms of smoke toxicity?

A. They're the most important because there's so much of them. There's a large mass. They're most important as an input to the toxicity calculation because there's so much to consider, as I've described. In other words, the XPS, for example, as I said, is a small amount of material, therefore less significant.

Q. What you've said in your report is that the main relevance of the data that you've set out in table 2 is firstly -- you've touched on this in your presentation -- carbon content?

A. Yes.

Q. Because that affects generation of smoke particulates and carbon oxides, including carbon monoxide, during combustion.

A. Yes.

Q. The second thing is nitrogen content, which affects generation of hydrogen cyanide. Then halogen content, which is chlorine and bromine, which determines the potential to generate irritant acidic gases.

A. And affect the combustion of the other part.

Q. What you've done, if we look at table 3 on the next page --

A. Yes.

Q. -- is you've summarised --

A. I think that's just extracted from the other table.

Q. Yes, you've summarised the percentages of these elements, carbon, nitrogen and chlorine, here, in the materials found, and this relates to materials found at Grenfell but also mixed flat contents.

A. Yes.

Q. Does it follow that the percentages you give here are the percentages of these elements that will be produced when a sample of that combustible material is burnt completely?

A. Yes, so basically what that means is that these are the percentages in the pedigree material before it's burned, right? If it's all burnt and 100 per cent is burned, then all of those masses of elements or percentages of elements per unit mass will come off as combustion products.

I think that was a yes.
SIR MARTIN MOORE-BICK: Presumably the proportions will remain constant for any part of it that is burnt; is that right?
A. Good point. Not necessarily. So if 100 per cent is burned, of course it all goes. But if there's any char remaining or partial decomposition, then the proportions can change. So in char-forming materials, for example, it locks up some of the carbon, which means that the carbon that then goes up into the atmosphere is somewhat less than if you had 100 per cent combustion.
SIR MARTIN MOORE-BICK: Yes.
A. And the same for the other -- it's the carbon mainly. Yes.
MR RAWAT: Can I come back to the question of charring in due course.
A. Yes, of course.
Q. One of the points you make, and it's a point you've reiterated here, you've used the term "indicative analysis" for the work that you've done and set out in part 3 of your presentation, but you also explain in your report that estimates of the contributions of combustion products from specific materials to the concentrations of toxic smoke products in any particular locations within the tower at different times is likely

to be possible only within quite wide ranges of uncertainty.
A. Absolutely, yes.
Q. If we look at table 4, which is where you're looking at --
A. Table 4, yes, these are the yields of all the products that we measured in our BRE experiments using our tube furnace method.
Q. The first question was going to be: can you explain the reference to a tube furnace?
A. Yes, okay.
As I've explained, the yields of toxic products are very dependent upon the combustion conditions, this fuel-air ratio.
For this project that we were doing, we were particularly concerned to try and produce some data for engineers to use on the yields they might expect over a range of conditions.
Now, I've put in this table a snapshot of well ventilated and under-ventilated, and I did actually at one point have some slides to show you -- I've spared you -- but in fact you get a sort of sigmoid curve of yield in relation to equivalent ratio.
So in order to measure these amounts, I developed this tube furnace method, which involves putting a strip

of material into a tube furnace under a stream of air. Because it's designed in that way, you can dial up, if you like, tubes, specific fuel-air ratios, and ensure that the material burns under a defined condition and then measure the yield that you get.
Now, one thing you have to be aware of with any bench scale test is that you have to be careful that the results you're getting in your small-scale test -- this applies to a whole range of standard and quasi-standard tests -- to what extent they're representing fundamental properties of the material that you're testing and to what extent they're a kind of byproduct of the apparatus you're using. This apparatus was designed specifically to have complete knowledge and control of the exact combustion as far as is possible to do so in a practical apparatus, but when we were developing this and getting data for it, we're very anxious to validate it against a large-scale compartment fire, which is what we're talking about here.
Now, of course, large-scale fires are very expensive to do, so we can only do a limited number, but we conducted a number of large-scale fires using the same materials to look at the yields we got in these more realistic large volumes, to compare with the yields we're getting in our small-scale apparatus, and we found

good agreement. In fact, I recently published a paper on this in 2016, addressing this very issue.
So I am fairly confident that the results that we've got are predictive of the kind of yields you might get if and when these are produced in a compartment fire.
Q. If we go, then, to the next page in your report, page 70, please.
Could we expand paragraphs 230 and 231, please. This is where you're touching on ventilated and under-ventilated conditions, professor, because you say at paragraph 230:
"230. The LDPE cannot burn while encased in its aluminium skin, but does so when it melts and drips out from the aluminium outer layers and also when they start to delaminate and expose the LDPE core. Since these processes occurred in the open air on the outer surface of the Tower, it is likely that most of the flaming LDPE combustion occurred under well-ventilated flaming combustion conditions ..."
So as you've explained in your presentation, well-ventilated conditions will result in low yields of irritant and toxic smoke?
A. Yes. There would be some smoke, but not quite as much, yes.
Q. If we look at paragraph 231, you say:

"231. The combustion conditions for the PIR insulation are more complex, because at least initially, it is believed to have been burning in the enclosed cavity behind the rainscreen cladding on the columns and spandrels, and also in cavities associated with the window surrounds."

Can I just be clear there, are you making a distinction between PIR insulation that's in either three or two places, either PIR insulation behind the cladding on the columns, behind the cladding on the spandrels, and also in the cavities associated with the window surrounds?

A. Right, let me think and talk through that.

Basically, the two main locations are on the columns and on the spandrels, where the bulk of the PIR is. There are also some smaller inserts and things in the window surround, but I'm not considering those at the moment.

What I think I'm really getting at here -- and this goes back to Dr Lane's kind of analysis -- is that when you have the PIR burning on the columns, particularly next to a kitchen window, the gasified thermal decomposition products are finding their way through these gaps, particularly where the EDPM strip is or has been lost, into the area around the windows, and so some

of the combustion from the column PIR products, the gases produced, is occurring in these kind of areas.

I'm saying that where it's burning in the cavity actually on the column, and where the column-generated material is burning in these kind of gaps and cavities and things around the windows, under both those situations, it's likely to have an element of under-ventilated combustion. I think that's really what I'm saying.

But, I mean, there is a bit of PIR there as well, in its own right.

Q. When you were reaching this view about the degree of ventilation of the PIR insulation, did you take into account the fact that the rainscreen facade at Grenfell Tower was a ventilated rainscreen cladding system?

A. Right, I'm not quite sure exactly what is meant by that, but obviously the way I'm looking at this is that you have the PIR on the concrete, and then you've got a cavity going up, which is stopped, of course, in places -- or that's another matter of dispute, of course.

SIR MARTIN MOORE-BICK: Quite.

A. But there's a column going up, which at least allows air to flow initially. And then you've got the rainscreen

cladding.

So the basic sort of situation is that the PIR is in an enclosure, a pipe almost, all right? And as I described this morning, once you get a fire in there, it's likely for that to become under-ventilated.

Now, if there are various locations where there are gaps to let a bit more air in, if that's what's meant by this question, then if there was any air that gets in, it is going to assist combustion and may shift that fire value in one direction or the other.

If, however, some of that PE, which I said is well ventilated, because I'm envisaging it pouring down the outside, is actually dripping on the inside of the cavity, burning in the inside of the cavity, that is adding fuel and making conditions even more vitiated, under-ventilated.

So I didn't specifically consider -- other than the fact that air goes up inside the column, I didn't think of any other --

SIR MARTIN MOORE-BICK: I think maybe the point that you are being asked to consider is this: we know that the rainscreen cladding had gaps designedly -- probably not very large, perhaps an inch, perhaps two inches --

A. Between the segments?

SIR MARTIN MOORE-BICK: Between the segments.

A. I didn't consider that, but I did consider there would be some airflow available.

As I said, we don't know what the condition actually was and that's why I put in both cases.

MR RAWAT: Well, just to break that down a little bit more, firstly, in terms of your conclusion that the LDPE was well ventilated, the assumption you made was that it would seep out on the outside?

A. Yes.

Q. In terms of PIR insulation being under-ventilated, you've not taken into account the gaps in the cladding.

A. No, I haven't, no.

Q. Did you take into account the gaps that would've existed between the insulation panels and the cladding itself?

A. That's the cavity, yes.

Q. That's the cavity, so that you did take into account?

A. Yes. To the extent that it's there.

Q. Did you take into account that there would've been air present --

A. Of course.

Q. -- in that cavity?

A. Because that's what supports the initial combustion.

Q. You've I think responded to this already, in that you have said that there would've been airflow up.

A. Yes.

Q. In looking at the ventilation of the cladding system, did you consider that the response to heat might be the creation of an updraught?
A. I mean, I haven't gone to this level of detail, but I'm assuming that there is air flowing up and that there was a flame, an elongated flame, in fact. You remember, you've seen the diagrams. So I'm assuming an airflow up, yes.
But I don't have any figures for any of these flows or loss rates. I haven't done anything like that. All I've done is addressed the mass and estimated a mass that's been burned, and then assumed either one or other condition.
Yes.
Q. Are factors like that, that you might get flow up or that there are gaps in the cladding, matters that you could take into account if you were to review these calculations?
A. At present, I mean, this is something we might be able to go into further in Phase 2, but really to settle these kind of issues, the only way that I would know to do that is to build a rig with these features and have a fire in it and measure these phenomena.
So I don't have any way of calculating this, other than to say the product you're going to get would depend

on this fuel-air ratio you end up with in practice. I don't have any way of calculating that for this particular situation.
Q. Professor Bisby has noted that in terms of the LDPE, it was exposed at the edges.
A. Yes. I think he talked about drips and things, didn't he?
Q. Are you able to say what impact that would have on the process of combustion?
A. Well, I was a little bit puzzled by this question. So, I mean, my picture of this is that if you do have an edge and there's a flame impinging on that edge, this is the 3-millimetre gap between the two sheets of aluminium, then being a thermoplastic material, that LDPE is going to melt and drip and you'll have this burning stream of droplets dropping from below this. You're talking about a vertical panel, so it's flowing out, dripping down and burning. That's what I would anticipate happening.
So to the extent that those drips are on the outside and in air, I would expect them to burn quite efficiently.
Then at some point, one would expect the whole thing to delaminate as it loses its structural integrity. Then, of course, all the PE is exposed to the air.

So at the moment I'm basing this on a model that it's all well ventilated, but I'm not totally wedded to this, should other information appear.
Q. Can I show you a page from Dr Lane's report. Could I have, please, BLAS0000010_0020.
Could we expand just the top diagram, please.
A. I'm going to come out and look at this. I can't see it.
SIR MARTIN MOORE-BICK: Make sure you can see it all right.
A. I'll stand there, is that all right?
SIR MARTIN MOORE-BICK: Of course.
MR RAWAT: If you see, Professor Purser, there's a sort of red and yellow arrow going up.
A. Yes.
Q. That I think represents the LDPE --
A. Core.
Q. -- core.
A. Yes.
Q. So you have a polyethylene core with two aluminium faces.
A. Yes.
Q. Could you get flaming up this 3-millimetre --
A. In that space.
Q. -- PE core with no delamination of the aluminium sides?
A. You could do for a period but, I mean, this is getting a bit out of my expertise.

SIR MARTIN MOORE-BICK: This is not quite your area, is it? No.
A. No. But let's assume for the moment you do, if that helps to answer the question. What we would have is a situation where initially the flame is impinging upon this edge and is dripping down and burning below, as I described. If that starts to flow out, say up to this sort of level here (Indicates), then you're going to have the sort of melting PE sort of running inside this space.
But, of course, if it's going to burn, it's got to get air up there as well, which isn't going to be that easy. So there could be a bit of combustion in there which may assist the delamination process, of course, but it's getting a bit out of my --
Q. Well, I won't press it.
SIR MARTIN MOORE-BICK: You can take your seat again, yes.
MR RAWAT: Let's go back to the same page in your report and paragraph 231 again, please.
You refer to rainscreen cladding falling away.
A. Yes.
Q. Would you agree that there would've been variability as to the time when this occurred?
A. Of course, yes.
Q. Would that then have a consequence for the combustion

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conditions for the cladding?
A. Yes, yes.
Q. And for the PIR as insulation?
A. Yes, it would.
Q. In relation to the analysis you've done -- I think I know the answer to this -- is this something that could be taken into account and, if so, how?
A. Right. Well, assuming at the moment the same mass has decomposed, in the one case with the cladding intact and the other case with it having fallen away, something like that, then of course, if it remained intact, then it preserves this cavity which tends to lead or is more likely to lead to under-ventilated combustion. So if the rainscreen cladding remains in place for a longer period, you would theoretically prolong the period of under-ventilated combustion of the PIR.
If the cladding falls away at a very early stage, then you move to the more well-ventilated regime at an earlier stage for the PIR, I would say. We could do example calculations of this should it be relevant, but --
SIR MARTIN MOORE-BICK: As far as we're concerned, at least at the moment, are your calculations based on what you would consider to be a reasonable average condition?
A. Exactly.

SIR MARTIN MOORE-BICK: Or have you gone for one extreme or the other?
A. Yes. I mean, the most extreme thing in this table is that I've assumed that all the cladding around the flat in question is equally affected. All right? So if, for example, you had a two-bedroom flat, and the fire came up only in a column near the kitchen, say flat 6, and never spread laterally to involve any other cladding or insulation, then of course my figures come down in proportion to the area that's been -- I think I did say this -- it all depends on the area that's been attacked and destroyed by the fire, which varies somewhat between flats. I'm taking a case here, one of these typical flats high up in the tower, where most of it has gone apart from the charry bit that is left behind.
MR RAWAT: So we're clear, I'm asking you about table 5, which you put up in your presentation.
A. Yes.
Q. What you're not doing is trying to represent varying conditions throughout the tower --
A. No.
Q. -- throughout the progress of the incident.
A. Right. Now, as I said earlier, this sort of analysis, I'm kind of looking at a snapshot of a few minutes during the early stages of fire penetration, for example

into a flat 6. Well, of course, the same would apply to all the other flats later on that were penetrated.
In this particular set of calculations, I'm estimating that all the PIR and all the rainscreen has been affected on both sides of the flat, because they're in a corner location, it's all gone, and that it's all gone in this short period of time as well. I mean, it would be possible to do a varied set of calculations with various assumptions to look how they might spread, but that's essentially what I'm doing, yes.
SIR MARTIN MOORE-BICK: Can I ask, you proceeded on the basis that only 5 per cent of the smoke generated by 100 per cent combustion gets into the flat.
A. Yes.
SIR MARTIN MOORE-BICK: To what extent would a departure from your assumption be likely to affect the proportion or the volume of smoke getting into the flat?
A. Yes, well, it would be in proportion, for these two materials on the outside.
SIR MARTIN MOORE-BICK: So a 20 per cent difference would only result in a 1 per cent difference in smoke. Is that 1 per cent difference in smoke volume?
A. Well, I've assumed 5 per cent going in, and then I also had a look at the case for only 1 per cent going in. What I found with the 1 per cent case for these two

materials was that it lowers the concentration, obviously, of the asphyxiant gases, so it prolongs the predicted time to collapse, not that that happened in any flat 6.
But there's so much smoke there that even when you do this, you still end up with hand in front of the face smoke. That's just from each material, and the total thing has got to be summed for the --
SIR MARTIN MOORE-BICK: Just so I've understood you correctly --
A. Yes.
SIR MARTIN MOORE-BICK: -- I think what you're saying is that even if you reduce the quantity of materials consumed by 20 per cent --
A. Yes, it wouldn't make much difference.
SIR MARTIN MOORE-BICK: Well, I was going to say, because you're reducing the smoke into the flat by 1 per cent, as it were, and it doesn't make much difference.
A. No, because there are kind of two things here. One is the smoke density and a change like that, because it's so dense, it won't really affect the visibility.
SIR MARTIN MOORE-BICK: All right.
A. But it does reduce the proportion, the concentrations of asphyxiant gases, and prolongs in proportion the tolerance time for that, approximately.

SIR MARTIN MOORE-BICK: Thank you.
MR RAWAT: One of the points you make in your report -- and it's at paragraph 210, I won't ask for it to be brought up -- is that the components that you've been discussing, if they were involved in a fire, they would be involved in an order, and you put it as running from left to right. So then you state:
"... the first smoke to which flat occupants were exposed came from the PIR, and LDPE then the PS [polystyrene], PVC and other minor window components and finally the flat contents. For occupants taking refuge in flats remote from the fire for an hour or more, but exposed to smoke infiltration from the outside and the lobbies, or in the lobbies or stair, the source was derived from a mixture of all these sources in varying proportions at different times."
A. Including the contents, yes.
Q. So can you clarify or help us further with what factors you had in mind when you state that any mixture from these sources would vary in proportion and at different times?
A. Well, yes. So, I mean, this is not terribly quantitative, but what I'm saying is it's a progression. So you start off, thinking of flat 6 again, with the exterior and structural materials as the main source

during these early minutes up to about 01.30, 01.35, something like that, and that's going into the lobbies and giving you dense smoke in the lobbies, and then most of that is derived from the structural materials because the fire hasn't yet started to growing the flats.
After that, as time goes on, we can expect and we can observe fire development inside the flats, and we're getting an increasing involvement of the contents which, as I said earlier, are a much bigger fire load. This is variable, of course, between floors and flats and times.
But once we start to approach 02.00 hours, we can see that a lot of these flat contents are on fire and they're going to dominate the combustion products that are being formed. Most of it may go out through the window if the windows have failed, but, of course, a proportion is going to find its way into the lobby.
So if you were in another flat taking refuge and you tried to open your lobby door at 2 o'clock, the smoke that confronts you in the lobby is now starting to be more dominated, I would say, by combustion products from contents of other burning flats than from the cladding and other materials.
Does that make sense?
SIR MARTIN MOORE-BICK: Mm.
MR RAWAT: Again, just picking up on that last -- if we need

to take you to the paragraph, we will, but what you say -- it's paragraph 248 -- is that during actual fires, the fuel burning rates and concentrations of smoke and toxic products are not constant and increase continuously as long as the fire is burning.
A. Yes.
Q. So does that mean that the concentration of gases --
A. Changes.
Q. -- would vary throughout the building, depending on the progress of the fire?
A. Well, this is where it starts to get very complicated. So you can consider the situation in an individual flat, and of course that's all varying with time. These calculations here are for a kind of snapshot in that time, and they would have been preceded by some kind of growth curve and followed by a further growth curve, all right? But once you get beyond the burning flat into other parts of the tower, you are starting to get into more complex questions about smoke leakage through various doors and shafts and other things like that.
I've forgotten what your question was, but essentially you've got a large generator in all the burning flats, and the fire on the exterior, producing smoke. Some of the exterior smoke is finding its way into the building, and all the building smoke is being

produced in the building. Some is going out, some is going out and up and coming in at higher levels. There's a whole lot of things going on. Then that smoke is migrating through the various interior spaces of the building.
Does that answer your question?
Q. Thank you.
One of the slides you put up when you were setting out the materials that you considered for the analysis that you set out in this part of your report, you made the point that what you did not bring into play was other material. So you specifically list the purlboard and the EDPM.
A. Yes.
Q. When you were presenting, you said that these are minor.
Can you just expand on why you did not include such combustible materials in your analysis?
A. Yes, I can. The short answer is because I was trying to do a preliminary figure, so I picked the things I thought were most significant in terms of mass. But I'm aware that these other materials are there.
Also, it's quite hard from the information I have to quantify them. I don't know necessarily from Barbara exactly what the dimensions are of all these things. But I can go on to include them in further work.

The EDPM is quite a small piece -- I mean, it's quite important whether or not it was a barrier, but in terms of its contribution by mass, it's quite a small amount.
The purlboard might have some significance, and I think there's some wood underneath all this somewhere as well.
So the short answer is I probably will go on to kind of expand these elements I'm considering, but because they're relatively small in comparison to these, I don't -- they will make some contribution, yes.
Q. There's a foil facia to the PIR insulation.
A. Yes.
Q. Is that a material that you would want to consider if you reviewed this analysis?
A. Foil face?
Q. Facia to the PIR insulation.
A. You mean the aluminium foil? That's on all the PIR, yes.
Q. If the PIR were burning, would that be significant --
A. I haven't considered the aluminium itself. I don't think that will produce anything very much. Its main significance is the extent to which it protects the PIR from combustion and, to some extent, it does quite a good job on that, up to a point.

Q. Is that something you could take into consideration, that protective mechanism of the aluminium?
A. No, not really.
SIR MARTIN MOORE-BICK: Would it be relevant to the sort of calculations you're doing?
A. No, no. I mean, it's relevant to the extent whether or not the PIR burned. So I'm basing that on what we observed --
SIR MARTIN MOORE-BICK: You are assuming it is going to burn.
A. Well, I tell you, I did a series of experiments where I lined a standard room, it's called an ISO room, with aluminium-faced PIR, and the purpose was to study the combustion of those materials when they are used as wall linings. Because I wanted to have the same material only in the room, I made what's called a crib, which is a standard ignition fire source that experimenters use, whereby you saw -- usually it's wood, but you saw them into sticks and build a boy scout crib and set fire to that, and depending on the crib, you can have a standard flaming heat source.
So we did some experiments. We sawed up PIR and made it into cribs, ignited it and it burned quite fiercely under those artificial conditions.
We calibrated that to get the right heat output and

put it into this ISO room, which is now lined with PIR aluminium-faced panelling.
What happened in these experiments is that the standard flame in the corner of this room never penetrated the aluminium and never involved the PIR.
So in that particular case, it performed very well.
SIR MARTIN MOORE-BICK: Right.
Mr Rawat, I'm just wondering whether we should have a break at some point.
MR RAWAT: We can stop now.
SIR MARTIN MOORE-BICK: Does it suit you?
MR RAWAT: Yes. I mean, I've got a few more questions on this topic, but it's a good enough time. Thank you.
SIR MARTIN MOORE-BICK: Professor, I think we'll have a short break now.
THE WITNESS: Thank you very much.
SIR MARTIN MOORE-BICK: Ten minutes, let's say, 3.25. Don't talk to anyone about your evidence, please, as before.
You go with the usher and she'll look after you.
All right? Thank you very much.
All right, 3.25, then, please, thank you.
(3.15 pm)
(A short break)
(3.25 pm)
SIR MARTIN MOORE-BICK: Ready to carry on, professor?

THE WITNESS: Yes.
SIR MARTIN MOORE-BICK: Good, thank you very much.
Yes, Mr Rawat.
MR RAWAT: Could we have table 5 up on the screen. That's at page 74 of the report, please.
Professor, one of the assumptions you made in this, as you describe it, indicative analysis, was that 0.5 per cent of the flat contents would burn.
A. Yes, a very small amount.
Q. Why did you choose that percentage?
A. Yes, that's an important question. Basically because I'm addressing these conditions at a moment in time, as I said, when the fire has just broken in -- I'm thinking again of flat 6 mainly here -- and coming in around the windows, and it's either still around the windows and hasn't involved the contents at all, or it's just started, say, to ignite a chair or something close to the window, so we're getting some involvement of the content. So this is a sort of snapshot of a situation possibly around 01.40, 01.50, 2 o'clock, I don't know, something like that, depending on the flat.
But, I mean, you know, obviously after this, if we did another snapshot later on, I would expect that bottom line to become much, much bigger and significant.
Q. So as one moves through the incident in time --

A. Time, yes.
Q. -- the estimate of different components that burn would change.
A. Vary a lot, yes. Absolutely, yes.
Q. Because, for example, if the cladding had fallen away outside a particular flat and the flat contents were --
A. Increasing.
Q. -- increasing --
A. One is going down in significance, the other is going up.
Q. I follow.
In terms of when you made this calculation -- and you've touched on this in your presentation -- you gave a figure of 50 per cent for the total mass of PIR.
A. Oh, yes.
Q. This is something you say in your report. But you estimate, following a visit to the tower, that approximately 50 per cent of the PIR may have burned.
A. On particular parts, yes. I'm not taking into account the -- I mean, half the bottom of the tower is still intact, so I'm not including that at all in this. I'm thinking of a sort of stereotypical flat towards the top of the tower sort of thing, yes.
Q. Was this assumption based purely on the observations that you made, visual observations, during your visits?

A. One of the problems when I went there is that the whole tower is clad in a sort of membrane, so you can't do a survey from the outside without climbing out onto the scaffolding. So what I did personally was I went into various flats and went to the window and looked at the state on the columns and spandrels around various flats.
But I'm also looking at some of the photographs that you can see, so many of them, taken after the fire, which I showed in one of my slides, where you can see that, for example, the columns have got no PIR on, most of them, but you definitely can see -- I mean, there are substantial amounts of PIR still there, even near the top of the tower on some of these spandrels. Most of the column stuff has gone though.
Q. So is it right to say that, in making your estimates, you didn't take any account of the volume of PIR that may have fallen off during the fire?
A. No.
Q. Or been removed by firefighting effort?
A. I'm obviously aware that that may have happened to some extent, but I'm purely basing it on what I can observe, you know.
Q. As I understand your analysis here, you're assuming that -- let's take the PIR insulation as the example -- a percentage of it burns and a percentage of that burnt

material then enters the flat?
A. Yes.
Q. Is it possible that some of the PIR insulation may have been burned as a result of fire break-out from compartment fires after the cladding had burnt out?
A. Yes, I saw that question. That's an interesting point.
So I think basically what we seem to be seeing is the fire during the early stages moving rapidly up the tower, and the very bright flames that we can see -- I mean, the other experts could comment, but I think a lot of that is the LDPE, but it's also burning some of the PIR behind it.
Once the fire has moved on, the photo I showed you where the fire is burning to the left of the original, and you can see the fire inside, there's obviously still some PIR left on those, and it's stopped burning. It's stopped burning.
But if you had the fire in the flat then going to flashover, and you had the windows falling out -- and I haven't seen any pictures that show this, but you had a big flame plume coming out, which should happen, and that flame plume then goes up the outside towards the next level, if that's impinging on a spandrel above the window level, one would expect that to be attacked.
So I've not taken that into account. So my

assumption is that the mass I'm saying has gone during this fairly short window of time that I'm addressing. If, in fact, it was going over a longer period of time, that would reduce the amount during that window of time, as it were.
Q. I follow.
One of the points you mentioned earlier was the idea of charring.
A. Yes.
Q. As I understand it, PIR on its own, when burned, will char and self-extinguish; is that right?
A. Yes.
Q. When you were coming to your approximation of 50 per cent of PIR burning, did you assume that any charred insulation had been consumed in the fire?
A. Mm. What I looked at was the thickness, for this kind of indicative calculation, and I'm thinking mainly of the spandrels here, but the same logic I've applied for the other, is that you have two aluminium-faced layers, so if one of those layers has gone -- and that's what I observed appeared to have happened -- then that's 50 per cent of your PIR gone. So I've assumed all that has combusted. All right?
Behind that is the layer that the windows are set in, which is still attached in places to the concrete of

the building. That is all blackened and charred and sort of bulbous.

In fact, we took some specimens of this and sawed through them, and if you look at a cross-section of one of these charred pieces, it looks a bit like a loaf of bread that's been burnt in the oven, you know. So you have this kind of charred exterior of a certain thickness, which is the way it's designed to happen, and then behind that you have some creamy-looking, apparently intact PIR that's not been decomposed at all.

But from the bit that is charred, although there is significant carbon still left, which is the char, that will have lost a considerable part of its mass.

So if, for example, you had a case where 50 per cent had burned and gone, that's your 50 per cent, if you had 50 per cent left of which 50 per cent of the mass content had gone, leaving the charred bit, then you would end up with 75 per cent of the total mass decomposed, which would be 50 per cent more than I've assumed. So it can kind of go in either direction, depending on what you say.

I mean, one of our plans is to look at the density of this charred material and estimate how much actually has gone from the specimens removed from the tower.

Q. If we look at table 5, you give a figure of 552 parts --

A. Hydrogen chloride.

Q. -- for hydrogen chloride, and that's from the uPVC window surround.

A. Yes.

Q. Would that hydrogen chloride, as produced by the PVC window, have an impact on the efficiency of combustion conditions for other materials?

A. Absolutely, and I've stated that in my report.

Q. Can you explain how it has that impact?

A. Yes. So I mention it as a phenomenon, but I've only factored it into my calculations here insofar as it affects the PVC itself, all right? So PVC, when you burn it, even when you burn it with a flame, which is quite hard to do, it produces, as I said, a very high yield of carbon monoxide. That is because the chlorine content is 50 per cent by mass roughly chlorine. It is all released as hydrogen chloride. This is a free radical scavenger, which means that it prevents or limits oxidation and flame reactions in the flame zone above it, and so instead of all the carbon gases being burnt to completion, you get a high yield of partial combustion, which is the carbon monoxide. So that's why we get such a high yield of CO from PVC itself, okay?

But if you burn something like wood, in a well-ventilated condition, all the carbon goes to

carbon dioxide. If you burn the wood next to a piece of PVC so that the products mix in the flame, then the CO yield from the wood is increased by the hydrogen chloride in the flame on that wood. With me?

So in this context, what would happen would depend on where we are in the system, right?

So imagine you have some polyethylene, the LDPE. I said that's burning under well-ventilated conditions on the exterior. That means most of the products that are finding their way into the flat, as I've described, are mixing with the flames and smoke from the PVC. I've already gone more or less to completion, CO^2. So I wouldn't necessarily expect them to be changed very much.

But if you had another material which had not been fully burned and been under-ventilated combustion, so you've got partially burned gases coming in through the window, mixing with the flame from the PVC, then the yield of CO and cyanide from those materials would then be increased by the presence of the PVC.

To quantify it is quite challenging, but the phenomenon would be there.

Q. Could we look, please, at page 72 of your report.

I just draw your attention first to paragraph 245 at the bottom, where you say:

"245. With regard to smoke and fire penetration into individual flats, the two-bedroom flats were most vulnerable because the aggregate areas of the windows and of the cladding and insulation outside them was greater than that for single bedroom flats."

If we go and look at paragraph 242, what you say there is that:

"From witness accounts, although some smoke was reported as entering the flats from outside around the windows, the main source of smoke entering the flats before fire reached the flats from outside was likely to have been from the lobbies."

A. The lobbies, yes.

Q. So what you have is a statement that a two-bedroom flat is more vulnerable because it's got a greater area exposed to the outside.

A. Yes.

Q. But at paragraph 242, a statement that certainly until the fire reaches the flat --

A. I don't think there's a contradiction there at all.

Q. Could you explain why you don't think that?

A. So in the one case we're talking about the vulnerability to exterior fire penetration. In fact, I think the two-bedroom flats are even more vulnerable because of their corner situation. If you have a fire breaking in

through one corner -- I think somebody described this -- it can then break out through the next corner. You then have two openings, and that's a nice condition, if you like, to develop quite a big fire in that flat, whereas the one-bedroom flats are somewhat more protected, which may partly explain the slower fire growth in flat 201, which is a one-bedroom flat, for example.

This is all to do with the fire breaking in from outside.

But this other aspect of smoke penetration is smoke penetration from the inside, from the lobby. And there, in fact, you could argue in that situation, because they all only have one front door, that with respect to smoke penetration from the lobby, slow smoke infiltration from the lobby, the one-bedroom flat, because the volume is less, would actually be more vulnerable in that context than a two-bedroom flat, because you're dispersing the same amount of smoke and gases into a smaller or larger volume.

But they're talking about two totally different things: one is smoke coming from the lobby, one is smoke and fire coming from the outside.

Q. Thank you.

Have you, for the purpose of this Phase 1 report, considered the potential impact of the smoke ventilation

system to the passage of smoke around the building on the night?

A. Yes. Only in very general terms.

So as I've said, there are a number of ways in which smoke could be spread around the building. Having read the witness statements, at the moment I'm coming to the view that the main source of the early dense smoke in the lobbies was via basically flat 6 on each floor at about 01.30.

Sorry, I've forgotten what the question was.

Q. It was about the potential impact of the smoke ventilation system on the passage of smoke around --

A. Ah, yes, okay. So that's horizontal smoke. All right?

But there is this question of whether, if you had smoke filling one lobby on one floor, could any of that get up to a lobby on another floor? And the answer is, of course, yes, and there are various routes by which that might happen through gaps and penetrations and missing seals and things like that.

There's also the lift shaft, and I noted that -- this is at the very early stages of the fire -- some people mentioned seeing smoke emerging from the lift area, on I think it was the 23rd floor, very high up, and another person talked about smoke emerging from the utility cupboard on the landing that was built as part

of the renovation. I think there are a lot of pipes going vertically through there, so that would imply some migration through there.

There's also the question, which is still somewhat unresolved, about how exactly the smoke ventilation was performing and what it was doing on the night of the fire. I know Dr Lane is trying to look into that in some detail.

Indeed, I did read an account from somebody that suggested they thought they saw smoke coming from one of those grilles.

So there are a number of routes for vertical spread, and of course the stair shaft is the most obvious one.

Now, from my analysis of what I've seen so far, in every case I have read of anybody trying to escape, they've always said the smoke in the lobby was far worse than the smoke in the stair, which means that I don't believe that vertical migration of smoke up the stair was a cause of smoke in a lobby anywhere. I think it's the other way.

Although some of the smoke in the stair -- most of it I think is coming from lobbies as people open doors and things, but some of it is undoubtedly coming from down below where the firefighting and things are going on. That's another issue.

Q. Is this question, the potential contribution of the smoke ventilation system, something that you want to give further consideration to for your phrase 2 report?

A. I would like to. I don't know how far we're going to get with that, but its obviously a consideration, yes.

Don't forget, that was only designed to clear smoke from one floor. So the operation, as I understand it from Dr Lane's report, is that it was designed to be triggered by smoke on a certain floor, which should've been where a fire was, and then the dampers are supposed to shut on all the other floors, then that smoke is extracted.

There is a bit of an indication that some of those lower floors don't look as smoke-stained as others, but I don't think we quite know what happened there.

One thing I did on my second visit to the tower was to look closely at the smoke deposits with Professor Stec in the ventilation and in the shafts of those louvres on the various. So we are looking into this a bit, but how far we'll get, I don't know.

Q. Whatever the outcome of that, you can consider that in your Phase 2 report.

A. Yes, if we find anything out.

Q. Can I take you to page 8 of your statement, please, and paragraph 21.

What you've done here is to set out what might be described as a sort of model of the events of the night, and you identify three stages.

For your second stage, which is at the bottom there, at (e), you give that a time period of 01.27 to, at the outside, 02.00 am. Do you see that?

A. Yes, it's the dense smoke filling the lobbies, yes.

Q. What you're identifying -- and we see it there -- is that the main source of smoke entering the lobbies at this time was from flat 6 on each floor?

A. That's my current feeling, but, you know.

Q. Well, what's the evidential basis for that current feeling?

A. Because I looked quite closely at what people said they did in flat 6 and how they described the conditions. Basically they're saying, "Fire came in, I ran around, left the flat in a hurry", in some cases leaving the door open. I can't remember the names off hand now, but there were some quite graphic descriptions of this.

One person left, went down a few floors, then came back up again and went back to his flat and noticed how, having left his door open, he found there was a lot more smoke in the lobby.

Other people from other flats looked towards the open door of flat 6 when people came out and saw the

plume of smoke coming out and filling the lobbies.

There are quite a lot of descriptions like that, and there were other floors lower down where people deliberately left the doors open for the firefighters to go into the flats and deal with them, but these doors were open for some period of time.

Other people, we don't know what they did.

So it's based on that kind of evidence, yes.

Q. I want to put to you a proposition, and it's that during that second stage that you've identified, there were internal fires in flats.

A. Yes.

Q. To do that, I need to show you a number of pieces of evidence.

A. Yes.

Q. The first is from Dr Lane's initial report. Could we have BLAR00000002, page 19, please.

We see there a photograph.

A. Yes.

Q. It's timed at 01.36.

We can see that there are a number of lit flats.

A. Yes, yes.

Q. Would that support the conclusion that there were developed internal fires at this time between floors 12 and 15?

A. Yes, I mean, just to clarify, I'm basically identifying a period during which these lobbies are filling with smoke. Now, this is a continuous process, so it's hard -- it's varying in different places, it's hard to get hard numbers in, but mostly around about 01.30 that these lobbies are filling with smoke. All right?

Then round about 2 o'clockish, I'm suggesting that we're now moving to a regime where we may have internal fires.

Now, this particular picture here, the main fires are on the east face, which we can't see, and we're seeing the fire coming around the corner onto the north face of the building. This brightness here I believe is mostly the burning cladding and insulation coming around the corner, as it were, as the fire spreads.

But I don't see any evidence that there are fires in any of these flats. These look like ordinary neon lights, so I don't see any fires in there.

Q. Well, can I show you the second piece of evidence --

A. This is timed at 01.36, so this is sort of after the period when I'm saying the lobbies were filled with smoke, really, or towards the very end of it.

Q. Could we have LSBS0000001, page 254, please.

If you go to the bottom there, we start at paragraph 1182.

A. Yes.

Q. What it is, this is --

A. This is one of the witnesses in flat 6, I think.

Q. If we take it in stages, the first thing I need to explain is this is an extract from Professor Bisby's report, and what he's done in this part -- this is his supplementary report -- he has summarised evidence from a number of BSR witnesses.

A. Yes.

Q. So the first person we see is Jose Vieiro, flat 46, who stated, "The first thing I saw burning was the extractor".

If we go to the next page, please.

A. I think he may have been the man whose curtains caught fire, but I can't be sure.

Q. That's the one, the curtains on fire.

A. Yes, it is.

Q. He states flames came through the fan holes where the fan was. It gave and it was hanging by the electric wire that supported it.

A. Yes, I mentioned him earlier. I mentioned this phenomenon earlier.

Q. So you're familiar with his evidence?

A. Yes.

Q. If we look at the others. Professor, perhaps if I try

and take it shortly and summarise the evidence. If you're not familiar with it and you want to read it, let me know, but if we look at the whole page, please.
What this is, in effect, is summaries of evidence from people who were in flat 6s.
A. Yes.
Q. So you have, after Mr Vieiro, a resident in flat 56, then you have flat 66 at paragraph 1184, which we know is Mrs Wahabi, who gave evidence some time ago. You then have flat 76, then flat 86, and the person who gave evidence for flat 86 is referred to at paragraph 1187, which is Nadia Jafari.
A. Yes.
Q. Then at the bottom you then go to flat 146 and then flat 186.
A. Yes.
Q. I think --
A. I understand.
Q. -- the work you've done so far, you have paid attention to evidence of the flat 6s.
A. Yes, I created a table which is in my longer draft report, which summarises all the witnesses for every flat 6, as far as I can -- and I am paying particular attention in that section of my longer report to what they observed about the penetration of fire and its

development in their flats.
What I found with that -- I mentioned it earlier -- I did actually have originally a slide with these names on in various categories, but what you find is that, as I said this morning, some people had smoke coming in first, before the fire came into their flats, more than saw flames. So more people said their first experience was the flat filling with smoke.
Others people found the fire coming through the ventilator, as described here. Other people said they had a window open and flames and smoke came through. And two people I recollect said that they had glazing failure very rapidly after the fire first appeared outside the window.
But, of course, all these are still exterior and structural fires outside and around and involving the window, with the two exceptions, which I did mention earlier, and this is one of them, Vieiro is one of them, where there were some curtains that caught fire, which he then stamped on and put out, and somebody else, as I said earlier, had a curtain between the kitchen window and the double door leading to the lounge, and that curtain caught fire. So there's a variety. But other people are only mentioning smoke at that stage. But it's not a contents fire this a structural fire.

Q. To conclude on it, there is nothing in the witness evidence that you have read in relation to a flat 6 that leads you to conclude that, in the time period for your second stage, there was an internal flat fire?
A. I mean, the numbers -- in that particular paragraph you showed me, I put up to 01.47, that might be getting a bit late. It also depends on height in the tower, because it's progression, but basically you still have these two stages, and it's hard, because there's so much variation, to put a sharp time on any of these phenomena. But basically you've got a period up to somewhere around 01.35, I think I'd probably now say, where there's dense smoke building from about 01.25 to 01.35ish in the lobby, which precedes any involvement of the contents.
SIR MARTIN MOORE-BICK: Is that right? Looking at your paragraph 21, your first period -- oh, yes, you're right, they were filling to about 01.30. Your second assumes that they were filled as from about 01.30; is that right?
A. Yes.
SIR MARTIN MOORE-BICK: Thank you.
A. Once you start to get closer to 2 o'clock, and this is a continuous process operating differently at different places, then you have the potential for these interior

fires to start to develop and form a greater part of the issue.
One of my slides I think shows that quite clearly, which was taken at about 02.20 by Professor Bisby -- well, in his report.
In that one you can clearly see fires in the windows, but that's 02.20, I think, nearer to 02.20.
MR RAWAT: Can I show you just a final piece of evidence in relation to this point, and it is again from Professor Bisby's report. It's from page 207 of the same document.
What we have there is a photograph taken at 01.44, an image taken at 01.44, and --
A. Do you know which angle this is? Which face? The east face, isn't it, I think?
Q. Yes. Does that help you to decide whether there are developed internal fires?
A. This is 01.44. We can see this brightness here (Indicates) is where the fire has moved left to start to involve the 201, flat 1 column. This here (Indicates) is where it's moving around onto the north face and involving the other face of flat 6 all the way up.
But this brightness here (Indicates) do look as if they could well be internal fires. There may be more of them lower down, as you might expect, because that's

affected first. So there could be some internal fires here, although some other shots I showed on my presentation don't seem to really show that.
But these do look like internal fires, yes.
Q. So taking that time period --
A. This is long after 01.30.
Q. Your time period ends at 2 o'clock for your second stage. I mean, to be fair to you, you give it as 01.45/02.00.
A. Yes, it's all a bit -- yes. But by that time I'm expecting to start to see interior fires, yes.
Q. So would a fair summary be that towards the end of your second stage is when you would expect to see internal fires?
A. Possibly, but this needs a lot more work, really. I'm looking forward to collaborating or looking more deeply into the exterior time shots from the other experts, combined with the observations of people who were in these flats, trying to pin down some of these aspects.
Although I don't recall much description in the witness statements of large burning furniture fires in flats. So ...
Q. As we have shown in paragraph 21 of your report, where you identified these three stages, are the time ranges that you've given based on your consideration of witness

evidence?
A. Yes.
Q. That's the --
A. Primary source.
Q. -- source of it? I follow.
Can I just take you back to flat 6.
A. Yes.
Q. If we can take that image off and go back to the professor's report.
Have you conducted an analysis thus far of whether the doors to each flat 6 had a closer, when the flat 6 was vacated and whether the door was left open, or is this something that you may consider undertaking for Phase 2?
A. I haven't done a systematic study. I'm not sure it would be my place to do that. But, of course, I am extremely interested in the timing and extent of any smoke migration and cause of it through these doors.
One of the complications, of course, is Dr Lane has given a breakdown of the different types of doors that were on all the different flats, the numbers that there were, so there's a variety there.
So far what I've done is to look at the witness statements, and without categorising exactly, the witnesses were asked this question and many of them

said -- some of them said they had had to remove the self-closer mechanisms, some of them said, "We had them but they didn't really work", including quite a few escaping from flat 6 said you had to physically close the door if you wanted to make sure it closed, you had to make sure you did it.
So where people fled and left the door open, and some of them then went back and confirmed this, there was smoke coming out. They weren't necessarily shutting properly. I'm not sure -- some of them may have done, I don't know, but there's a variety of things going on there and a variety of door types.
I'm not at the moment planning myself to do a systematic study, but I'm very interested in this kind of information, yes.
Q. Thank you.
Can I move on to a different topic, and that is just about the differences or similarities between hydrogen cyanide and carbon monoxide.
A. Yes, I'm sorry, I had two more slides on it this morning which I cut out for time reasons.
Q. Firstly, is it right that hydrogen cyanide would be more potent than carbon monoxide?
A. Yes.
Q. But what you've also said in your report is that they

are additive in combination.
A. Yes, that's based on experimental --
Q. Can you explain how that works given hydrogen cyanide is more potent than carbon monoxide?
A. Oh, yes, because we do it in terms of FED. So if you have an atmosphere and you expose an animal to it, in fact, with half the concentration of cyanide that would cause incapacitation in a certain time, and that alone, after that sort of time, they're not going to be incapacitated. If in the same mixture you put half an incapacitating dose of carbon monoxide -- it could be a much greater amount, but half the amount required, half plus a half equals one, they tend to become incapacitated in that additive way.
It's a fairly rough estimate, but that's the way we've treated it and that seems to be the case.
Q. Again, does hydrogen cyanide have a more rapid effect than carbon monoxide?
A. Yes, and as I said this morning, I really see cyanide much more in times of incapacitating effects than death. I think in most cases -- there are cases where cyanide fires have killed people. There's some recent papers, some fires in prisons where the prison mattresses produced a lot of cyanide, and there was not a lot of carbon monoxide in the blood of these victims. But

that's rare. Normally you find that when people are dead in a fire, they have a lethal dose of carbon monoxide in their blood, as I mentioned earlier.
So if they have been exposed to cyanide, and many of them are, I think this is more significant in terms of collapse before you escape rather than whether or not you die.
Q. One of the points you make in your report is that blood cyanide levels are not routinely measured following a fire.
A. **Yes.**
Q. Do you know why that is?
A. **No. Cost, I think. I mean, basically they always measure carbon monoxide, and it's fairly straightforward to measure, it's very stable, as I said, it's a very good marker of the extent to which somebody can be explained as a smoke death. And, of course, not all fires produce cyanide.**
In contrast, cyanide is very unstable in blood, particularly in the blood of fatalities. It can lose half of it within 24 hours in a body. So if it's three days before you take the blood sample in autopsy, you've lost most of the information.
Then once you've got the blood sample, whereas the CO samples are pretty stable, the cyanide will gradually

be lost on storage.
Also, the interpretation of what the significance of a particular cyanide level is in terms of what happened to the people is very complicated. I've been developing some models to try and deal with this, which I've published. So it's not an easy thing to deal with, but it would be very valuable if we did it.
There was a particular study in France by a Professor Bode, who went out with a French fire service and he took blood samples from fire victims in dwellings as they were pulled out of a building, so very fresh samples -- they were alive -- and he found very high levels of cyanide in those fresh blood samples, whereas when it's done at post-mortem, they're often much lower. So it is a bit of a problem, yes.
But it would be good. I'm disappointed it's not measured because it would give us more information.
Q. In the context of the tower, is it at all possible that someone could have been exposed to hydrogen cyanide but not carbon monoxide?
A. **No, you always have both but, of course, the proportions depend on the situation.**
Q. And to turn to carbon monoxide, if someone was exposed to a level of carbon monoxide sufficient to cause an increase in carboxyhaemoglobin levels, and that

person were then able to take shelter somewhere where there was a lower level of carbon monoxide or where they could get air, oxygen, into their system, would that mean the carboxyhaemoglobin would reduce?
A. **Decrease, yes. So if you, for example, came down the stair and you were breathing CO, and then you went and stood outside and breathed ordinary air, over a period of an hour or two, you'd get a decay curve and you'd flush it out. If you breathe oxygen at the same time, you flush it out much more quickly because the two things compete in the blood, yes.**
So yes is the answer to that. It gradually is lost, yes.
Q. What about hydrogen cyanide, if you were able to remove yourself from a source of hydrogen cyanide to somewhere safer, would the levels of hydrogen cyanide in the blood then decrease?
A. **From my studies, the level of cyanide, it does decrease, but it's over quite a long time. It's comparable to the CO though. Yes, it does decrease, yes.**
Q. Just one final matter before I ask for a short adjournment. You've set out in your report at the end -- and we don't need to go to it -- the further work that you are considering --
A. **Yes.**

Q. -- for the purpose of your Phase 2 report, and that includes, doesn't it, a review of the evidence of firefighters; is that right?
A. **Oh, yes, I haven't really had a chance to do that yet. I glanced at some of it, but I haven't done a systematic study.**
MR RAWAT: Thank you.
Mr Chairman, I've reached the end, I think, of my questions, but if I could ask for a short 5-minute break to see if there is anything else I need to canvass?
A. **Can I briefly say something on this topic? Partly because I missed off on those slides.**
I'm asking myself the role cyanide may have played, or made a difference anywhere at Grenfell, and I've talked a bit about the cyanide and the CO coming into flat 6 from the outside.
As I said this morning, nobody was incapacitated in a flat 6, they all had time to get away, so neither CO nor cyanide had any significant effect on anybody in a flat 6. All right?
Then you have the later phase when people are trapped in other flats and trying to get into the lobby. That lobby will have high concentrations of both CO and probably cyanide, but a lot of that cyanide will now have been -- particularly after 2 o'clock -- generated

from the contents as much as the cladding.
Then when the fire gets round to any flat and breaks in, it's a bit like the original flat 6 situation.
So the only situation I can see where the presence of cyanide may have affected the outcome for people at Grenfell -- if you're trapped in the flat and die there, it doesn't make any difference. Where it just could conceivably have an influence is if you stay in any flat up to, say, 3.00 am, and then you come out into the very smoke-filled lobby and the smoke-filled stair, which will contain high concentrations of cyanide, and if your flat is on fire and that has some cyanide in, then it's conceivable that whether or not you make it to the bottom of the stair or not, or collapse on the stair, might partially be affected by cyanide.
But the source of that cyanide that you're breathing in the lobby and stair is going to be mainly from the burning contents that's getting into the lobbies.
I don't know if that helps.
SIR MARTIN MOORE-BICK: All right, thank you.
Well, we'll have a short break now so that counsel can consider whether there are any further questions, so I'm going to say 4.15.
Same as before: no talking about your evidence, please, while you're out of the room.

If you go with the usher, she'll look after you.
You could leave all those there, if you would like to.
THE WITNESS: I think that will be all right.
SIR MARTIN MOORE-BICK: They will be quite safe, don't worry.
THE WITNESS: It's just if I need to look anything up, but I think I'll be all right. Okay, I'll leave it there.
SIR MARTIN MOORE-BICK: Have a cup of tea instead.
All right, thank you very much.
All right, 4.15, please, thank you.
(4.07 pm)
(A short break)
(4.15 pm)
SIR MARTIN MOORE-BICK: Thank you, professor. I gather there's one matter counsel needs to raise.
THE WITNESS: Okay.
SIR MARTIN MOORE-BICK: Yes, Mr Rawat.
MR RAWAT: Thank you, sir.
Professor Purser, can I ask you this: in both your report and in the evidence you've given today, you've explained, in terms of the toxic matters that you are concerned with, first, there is smoke as a toxic product, then you've spoken about asphyxiant gases and then you've also spoken about the irritant acidic gases.

So those, in terms of product, were what somebody in the tower risked being exposed to.
A. Sorry, it's very noisy over here. Carry on.
Q. If a person, either in a flat or making their way through a lobby or down the stairs, used a face-covering, a towel over the mouth, would that offer any protection against the toxins that you've spoken of?
A. Yes, it would, and of course many people did do this.
So the main barriers to progress initially through the lobbies and down the stair are obviously the optical effects, which you can't deal with, and the irritancy. So it's the pain to the eyes, the pain to the nose and the mouth and the difficulty in breathing. This is partly due to the smoke particles themselves and, as I mentioned this morning, to the organic irritants and acid gases attached to these particles which get down into the airways and cause distress, and partly due to the free acid gases you are breathing.
By having a towel or a wet towel, you can filter those. You can't stop the asphyxiant gases, though. Certainly there's carbon monoxide by that method. But you can get some relief from the irritants. And people did.
Q. What's the benefit of the towel being wet?
A. Well, whether it's wet or dry, it's a filter. But

I think if it's wet -- certainly if it's wet it will absorb the acid gases like hydrogen chloride to some extent. It's just a slightly better filter. But whether it's wet or dry, anything would help, you know.
MR RAWAT: Thank you.
That's all I have. Can you thank you, professor, for coming and giving your evidence today.
THE WITNESS: Thank you.
SIR MARTIN MOORE-BICK: Well, professor, thank you very much indeed. You've given a lot of time and effort to the investigation of this tragedy and you've put your undoubted expertise at our disposal, for which we are very grateful indeed.
THE WITNESS: Thank you.
SIR MARTIN MOORE-BICK: Thank you very much, and thank you for coming along today to give us your evidence and explain what it's all about.
Good. Well, now, if you would like to go with the usher.
THE WITNESS: Yes.
SIR MARTIN MOORE-BICK: Thank you very much.
(The witness withdrew)
SIR MARTIN MOORE-BICK: Yes, Mr Rawat.
MR RAWAT: Sir, before we finish for the day there is one short matter that I need to deal with.

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Could I please have on the screen INQ00000534, please.

If I could explain that this is a schedule which has already been disclosed to all core participants. It lists witness evidence of firefighters, senior fire officers, firefighters and control room operators. We would ask that the statements listed there are taken as read into the record today.

The statements themselves will be published at some point on the inquiry website and everyone has been notified of the plan.

SIR MARTIN MOORE-BICK: Yes.

Well, thank you very much. I think it's right that we record our gratitude to all those who have made statements. Even if they haven't been called as witnesses in person, their evidence is very valuable and the statements will form part of the overall evidence before the inquiry and will be taken into account accordingly.

MR RAWAT: Thank you.

SIR MARTIN MOORE-BICK: Very good.

Good, thank you very much. So that's all for today.

MR RAWAT: It is.

SIR MARTIN MOORE-BICK: Now, we're not sitting tomorrow.

MR RAWAT: No.

SIR MARTIN MOORE-BICK: But we are sitting on Monday.

MR RAWAT: We are sitting on Monday just to deal with some evidence from the bereaved, residents and survivors --

SIR MARTIN MOORE-BICK: Yes.

MR RAWAT: -- which is going to be read, admitted evidence.

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

So we will obviously break now and we'll resume at 10 o'clock on Monday morning.

Good, thank you very much.

(4.25 pm)

(The hearing adjourned until Monday, 3 December 2018 at 10.00 am)

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