Grenfell Tower Inquiry

Day 296

June 29, 2022

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Wednesday, 29 June 2022
(10.00 am)
SIR MARTIN MOORE-BICK: Good morning, everyone. Welcome to today's hearing. Today we're going to hear evidence from Professor David Purser, the expert toxicologist instructed by the Inquiry.
Yes, Mr Millett.
MR MILLETT: Yes, Mr Chairman, good morning to you. Good morning, members of the panel.
Before I call Professor Purser, I just want to mention this: he's a toxicologist. He has analysed the relevant evidence which relates to the deceased on the night at Grenfell Tower. You will recall that he provided a Phase 1 report. He has now provided a report for this phase, his Phase 2 report. His evidence does contain descriptions of facts and matters about the deceased's last movements and the immediate causes of death, which many will find distressing. I wanted to raise that at this stage so that those who are following these proceedings, both in person here in the hearing room and on the live stream, are aware of the contents of his evidence in general terms, and then they can choose whether they listen and follow or not.
SIR MARTIN MOORE-BICK: Yes.
MR MILLETT: So this is a trigger warning.

SIR MARTIN MOORE-BICK: Thank you very much.
MR MILLETT: Can I now call Professor Purser, please.
SIR MARTIN MOORE-BICK: Thank you.
PROFESSOR DAVID PURSER (sworn)
SIR MARTIN MOORE-BICK: Thank you very much indeed. Now, please sit down and make yourself comfortable.
(Pause)
THE WITNESS: Thank you.
SIR MARTIN MOORE-BICK: Yes?
Yes, Mr Millett.
Questions from COUNSEL TO THE INQUIRY
MR MILLETT: Thank you, Mr Chairman.
Professor Purser, good morning.
A. Morning.
Q. You are Professor David Purser CBE?
A. That's correct, yes.
Q. Can I ask you, please, before we start your evidence, that when giving evidence, if you could keep your voice up, so that the person who sits to your immediate right there typing away can get down everything on the transcript clearly. Also, please don't shake your head or nod your head; you have to say "No" or "Yes" as the case may be.
We will take breaks in the normal way at about 11.15 or 11.20 or so during this morning and at an equivalent

midway point during this afternoon.
Finally, if there's anything in the questions that I'm asking you which are unclear or you would like me to repeat or put a different way, or there's parts of your report you would like me to show you, then we can do that.
A. I understand, yes.
Q. All right?
A. Should there be a screen display -- oh, here it is.
Q. The screen is in front of you, yes.
A. Yes, okay.
Q. Everything that I'm going to show you will appear on the screen in front of you, and we can take it as quickly or as slowly as you like.
Now, first, can you confirm that you provided a preliminary Phase 1 report to the Inquiry dated 5 November 2018?
A. Yes.
Q. Can you confirm that that report -- and I'll just give the reference, {DAPR0000001} -- was the subject of your evidence at Phase 1 of this Inquiry?
A. It was, yes.
Q. And that you were asked questions about that on Day 84 of the Phase 1 hearings; yes?
A. Yes.

Q. And the transcript reference for that if we need it is {INQ00015183}.
You have now provided a final report entitled your Phase 2 report, I think, haven't you?
A. Yes, I have.
Q. Is it right that's now in three parts? And I'll just read those into the record.
A. Yes.
Q. Sections 1 to 4 are at {DAPR0000005}, section 5 is at {DAPR0000011}, and section 6 is at {DAPR0000006}.
A. Yes.
Q. Yes.
Now, I'm going to ask you some detailed questions about that shortly, but is it right to say that your Phase 2 work builds upon the preliminary conclusions you reached in your Phase 1 report?
A. Yes, it's a continuation, basically.
Q. Yes.
Can we go, then, to {DAPR0000005/17}. You can see there a summary of your instructions at paragraph 1 and 2. Paragraph 1 says:
"I have been asked to provide reports, for the purposes of Phases 1 & 2 of the Inquiry, which address the following issues:
"(1) The production of toxic gases in domestic fires

and the consequences of inhaling toxic gases in such circumstances, both physiological and behavioural;
"(2) The toxicity when exposed to fire of certain materials which were present at Grenfell Tower;
"(3) Any recommendations arising from points (1) to (2) above, including as to any further testing which ought to be carried out which is relevant to these issues."
Then at paragraph 2 you say:
"I was asked to provide a report for Phase 1 ..."
And you explain what that was there.
Can you confirm that you have updated and expanded on your preliminary conclusions where necessary in this Phase 2 report?
A. Yes, I have, yes.
Q. Is it also right that, as you say at paragraph 4 here, if you look down at that towards the foot of the screen, now in the middle of your screen, that you have addressed:
"... how each of the 71 persons who died were prevented from escaping, how they were overcome and the causes of their deaths."
That's what you have done, in essence.
A. Yes, I wanted to address each individual named person.
Q. Yes.

Now, just to explain, is it right that the number, 71, is the number of persons who died on or about the night of 14 June 2017 and do not include Pily Burton, who died some months later?
A. That's correct.
Q. Right.
If we turn to the bottom of page 3 {DAPR0000005/3}, please, in this document, we can see a signature on the report dated 10 May 2022. Is that your signature?
A. It is indeed, yes.
Q. Have you read this report recently?
A. Yes.
Q. Can you confirm that the statements of fact that you have made in it are true to the best of your knowledge and belief?
A. Yes, they are, yes.
Q. Can you also confirm that the opinions that you have expressed in this report represent your true and professionally held opinions?
A. They do, yes.
Q. Can you also confirm that you have provided this report in the same way as you would have done to a court?
A. Yes.
Q. Thank you.
Now, you have also provided two further documents to

the Inquiry recently, which have been disclosed to core participants, and I'm going to show you those and ask you about them.
The first is {DAPR0000012}, if we could please have that. That is entitled:
"Summary of approximate fire arrival and occupant flat exit times and outcomes from detailed accounts in Section 6 floor by floor analysis."
First, can you confirm that you prepared this document?
A. I did, yes.
Q. This is a document which serves, does it, as an aide memoire for your analysis and your conclusions in the Phase 2 report?
A. Exactly. I thought it would be helpful as, if you like, a quick reference to what was happening on each floor at each time, that we could refer to if necessary.
Q. Thank you. Can you explain in short terms what it shows?
A. Yes. So as you can see there, you've got each floor there, and the document is set out in six pages. Each page is for one column of flats. So the page you put up is all the flats -- it refers to all the flats 6 on the east side of the tower from the 23rd floor down to the 4th. There's an approximate estimate of the time that

the fire arrived outside each of those flats, approximate time that the occupants left the flat, if they did so, and then the final column is just a brief summary for me of who was in those flats. Where they're outlined in red, those are people who died during the incident. The others are those that evacuated successfully. So it's just a quick reference guide, really.
Q. Yes.
A. The detail behind all this is in section 6 of my report.
Q. Yes, thank you. Can you confirm that there's nothing new in that document and that it is simply a summary of the more detailed data found in your report?
A. Yes.
Q. Thank you.
Again, the statements of fact set out in this document are true to the best of your knowledge and belief?
A. They are, yes.
Q. Thank you.
The second document is at {DAPR0000013}, please. That is entitled, "Summary table of toxicity endpoints in each 23rd floor flat". Did you prepare this document as well?
A. I did, yes.

Q. What does it show?
A. Just scroll down to the table.
Q. Yes, can we go to the foot of the page.
A. Yes, so this was something I did prepare initially a while ago, but I felt it was quite important to demonstrate the issue of: what was the latest time that occupants of different flats around the tower, ie flat 6 to flat 1 at each level, the latest time they could have left their flat and still succeeded or had a good chance of succeeding in descending the stair without being overcome in the stair on the way down. So it's a kind of last time that you might reasonably be expected to have self-evacuated, had you had the opportunity to do so.
I prepared this originally just for the top floor. I started at the top and worked down, because most deaths were at the top of the tower. And these times, they're very approximate, but they give a picture, if you like, of that situation.
The caveat is that, as you go down the tower, there's a slight lag in the way the fire went round the tower, so these times would be increased by a few minutes on the lower floors. But they're quite close to these times for the upper half of the tower.
Q. Yes, thank you.

A. We can come back to this in discussion later if necessary.
Q. Yes, thank you.
Can you also confirm that there's nothing new in this document and that it's simply a summary of the data contained elsewhere in your report?
A. Yes, it's a summary of the data in the report, yes.
Q. Again, it would follow, would it, that you can confirm that the statements of fact set out in it are true to the best of your knowledge and belief?
A. Yes.
Q. And, similarly, the opinions expressed in it are your --
A. Yes.
Q. -- properly and professionally held opinions?
A. They are, yes.
Q. Can we then turn to your qualifications and expertise.
You have set out your background and expertise relevant to the matters we are investigating here at this Inquiry at appendix D. Can we go to that, please. That's {DAPR0000010}. There it is. I'm not going to go through all that today with you.
First, can you confirm that you have reviewed and updated this CV --
A. I have, yes.
Q. -- for the purposes of this report?

A. Sorry. Yes, I have, yes.
Q. Just picking out some key points. First, you have a PhD in neurophysiology from the University of Birmingham.
A. Yes.
Q. And a DipRCPath in 1984 from the Royal College of Pathologists.
A. Yes.
Q. I think as you say in your second report, which we'll come back to, you are a diplomate member of the Royal College of Pathologists.
A. Yes.
Q. Yes.
A. That's correct.
Q. Yes. Was that from 1984 or was that more recently?
A. No, that's continuous from 1984, yes.
Q. Right. What does diplomate member of the RCP mean?
A. Well, there's a qualification that is usually obtained by clinical medic pathologists that become members, MRCPath. I'm not an MRCPath. The College of Pathologists offered the opportunity for toxicologists to obtain a diploma in toxicology, which I took in 1984, and then you become a member of the college. But I want to make it clear I'm not an MRCPath.
Q. Right, thank you.
Do your specialisms that you have listed in your CV

include the medical effects of inhalation of toxic smoke and gases on the human body?
A. They do, as far as a toxicologist would normally deal with these matters, or a physiologist, yes.
Q. Yes.
You currently act, I think, as a consultant in relation to toxicology, environmental hazards and human behaviour in emergencies, combustion chemistry and hazard modelling.
A. Those are the areas where I'm active, yes.
Q. Yes. You are currently a visiting professor at the University of Central Lancashire --
A. That's correct, yes.
Q. -- at the centre for fire and hazards science, I think.
A. Yes.
Q. If we go to page 2 of this document {DAPR0000010/2}, we can see there, in summary, that for 17 years or so between 1974 and 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; yes?
A. That's correct, yes.
Q. Did that work include research into the effect of fire products on the nervous system, the lung function and behaviour in order to evaluate the mechanisms whereby

fire products cause incapacitation and death?
A. Yes, it did.
Q. Yes.
If we look a little bit above that, we can see that from 1991 to 2006 you worked for the Building Research Establishment, the BRE, Fire Research Station, now BRE Limited, where you continued to work on the toxicological and behavioural aspects of human fire exposures; is that right?
A. Yes, that's correct.
Q. That related to occupant behaviour in relation to means of escape, chemical yields of toxic smoke and evaluation of fire hazard development; is that right?
A. Yes, those were the areas of research I was conducting.
Q. Yes.
On page 3 {DAPR0000010/3}, if we go to that, please, you identify yourself as a member of a number of institutions, including the Royal College of Pathologists, the British Association for Lung Research to 2017, and the International Association of Fire Safety Science to 2018; yes?
A. Yes.
Q. Yes, and you were awarded a CBE for services to fire safety in the 2015 new year's honours list.
A. I was, yes.

Q. In 2013, the Institute of Fire Engineers awarded you the David Rasbash Medal for outstanding contribution to the advancement of knowledge in fire behaviour; yes?
A. They did. I'm not a member of the Institution of Fire Engineers, but they did grant me that honour, yes.
Q. If we go to page 4 {DAPR0000010/4}, you say you were a member of a number of British and international standards committees.
A. Yes, I'm still a member of some of those, yes.
Q. They include, I think -- you set them out -- hazard to life from fires.
A. Yes, that still continues, I'm a member of that still.
Q. Fire safety engineering, means of escape.
A. Yes.
Q. And the National Association of State Fire Marshals scientific advisory group?
A. That's now more or less wound up, but I was a member of that for a number of years, yes.
Q. Right. I think you have also been a member of various Department of Health expert committees, as you have set out.
A. In the past, yes.
Q. In the past. And you have lectured widely on toxicology, combustion chemistry and fire safety at universities nationally and internationally, I think.

A. Yes.
Q. At page 5 {DAPR0000010/5} you say that you have also worked as a legal expert in a number of different fora nationally and internationally on the subjects of fire toxicity and human behaviour.
A. Yes, these were various cases that came up over the years.
Q. Also on page 5 we can see that one of those appointments was as expert to the Département de Savioe in Chamberéy, France, the Tribunal de Grand Instance De Bonneville Proces de la catastrophe du tunnel du Mont-Blanc, in 2004 to 2006.
A. Yes.
Q. Yes. On page 6 {DAPR0000010/6} you have authored and presented a total, I think, of 152 -- we have counted, I think, 152 -- publications and conference presentations between 1969 and 2018; yes?
A. Yes.
Q. And one can scroll down at some length to see what they are if one wants to; yes?
A. Yes.
Q. Yes.
Now, can I then go to your Phase 2 work and start with some general principles, and we will pick up some specific instances later in your evidence.

The easiest place to start, I think, would be your contents page on {DAPR0000005/13}, please. We can see there that the report, which is a very long and complex document, to be fair, is helpfully arranged in the following sections. You have got the summary of contents here, and then you've got "Introduction", then "Methodology" is section 2, and if we turn the page {DAPR0000005/14}, please, we have section 3, which is the "Results of analysis of fire and toxic smoke spread and effects on exposed occupants".
A. Yes.
Q. Section 4, "Analysis of toxicology results", and then over the page again {DAPR0000005/15}, section 5 is the "Extent to which different materials are likely to have contributed to the effects of toxic smoke on the tower occupants". Then section 6, underneath that, "Floor-by-floor analysis of causes of incapacitation and death at Grenfell Tower". Yes?
A. Yes.
Q. Then a number of appendices. Appendix A is, "Timings and reported smoke conditions in the stair"; appendix B is "Analysis of fire spread across the tower"; and then we don't need to turn the page, but appendix C is "Common terms and abbreviations", and then the CV which I've shown you.

Now, I want to start by asking you to take us through these sections and explain, first , the purpose of each one and, secondly, how they link together.

So to begin at the beginning, as it were, how was the work that you conducted during this phase of the Inquiry different from the work that you undertook at Phase 1, in very broad terms?

A. It's more a question of depth than ... so for Phase 1 I was asked to do two sort of things, really . One was to talk in general about fires , and I talk about various past experiments and cases we'd done, how people are overcome in fires . I talked a lot about the toxicology of fires , effects of heat in fires , this sort of thing. Then the other thing I addressed in Phase 1 was, if you like , a preliminary general outline of what I felt had happened in terms of exposure to toxic smoke at Grenfell Tower.

I was just reviewing my summary of that report before we came today, and I feel it's still very much valid and stands up against what I've done in part 2.

The main thing I wanted to do and I felt needed to be done in part 2, as I said, was to address in detail what had happened to each individual person who died in the fire , and in order to do that, I carried out —— I used two sort of approaches, right? So for one

approach I found it helpful to understand what had happened to, as it were, step back and look at the tower as a system, the occupants and the tower and the fire, everything that was in it , step back and look at it as a system. I found that very helpful because, as I think we've already indicated to some extent, for example, if you look at what happened in one flat 6 on one floor, you'll find that the same sort of things, same sort of conditions, were occurring in all the flats 6 almost at the same time, and then very similarly in flats 1 all the way round. So to understand what had happened, because our information tends to be somewhat patchy —— some flats we have good information, some somewhat less so —— I found my understanding was certainly assisted by looking at them as a group.

Similarly , when you're thinking of what's going on in the lobbies, which is a crucial part of this , then on each floor the lobbies are —— to understand what's happening in the lobbies, you need to look at what all the people in all the flats on that floor are doing, and by looking at the lobbies as a set, it also helped me to understand how things were unfolding.

Obviously the stair is common to everybody, and what happens in the stair with time is so important in the outcomes of this incident. I was looking at the stair .

So, in a way, I'm pooling the data to improve my understanding.

Another way I pooled the data is with respect to the toxicology and pathology results. Now, unfortunately, as you're aware, many of the persons who died in flats at Grenfell , their bodies were essentially reduced to ashes, and so the amount of information that we're left with for toxicology/pathology is rather limited.

I think Alecto Forensics did a wonderful job in locating the bodies in the various flats , and I've made great use of their work, but fortunately we have a small number of cases where sufficient tissues were obtained from the flats to get some blood toxicology data and some pathology data. By inference, and looking at other people who were in the same flats or similar flats on different floors , I think this has given us a good understanding of how things worked out.

Similarly , I'm very grateful to 21 persons who gave me permission —— survivors who gave me permission to look at their hospital data, and by pooling that data, I feel I've learned a lot about the conditions, particularly in the stair and the flats , for those who survived, which also affected those who died. So by looking at it as a pooled dataset, that was very helpful to me. Also, by pooling that data I was able to

preserve the anonymity of those persons and just look at them as a group.

So that's all this sort of looking at things as pooled sets, and then in part 6 of my report, that's where I go floor by floor in detail, looking at the analysis for each flat , particularly those where people died, and how they were individually affected.

So that's the overall approach that I've used.

Q. Yes, thank you very much.

In the most general of terms, if you can do this —— it may not be possible —— are you able to summarise extremely pithily what you found as a result of having done that work?

A. Yes, I'll try to.

So I think it's helpful to look through it in a sequence. So the first thing that's happened, obviously, is that we have the fire going rapidly up the east side of the tower, outside basically the kitchens of each flat 6. As the fire arrived at each level going up, it very quickly broke through into those flats , and the occupants of those flats became aware very quickly that there was something wrong; in fact, many of them were aware before the fire actually got to their flats . The key actions they took was they were obviously —— they went to the kitchen, they saw the flames outside, they saw the flames starting to break through and the smoke filling their flats. They were immediately very highly motivated to evacuate.

I've read the individual witness statements and some of the evidence in some detail and studied it, and I have to say at this point all those witness statements that I spent a lot of time looking at were very, very helpful to me in understanding what had happened, so I'm very grateful to those witnesses for making all those statements.

What it showed is that they rushed very quickly, some of them ran out without -- only partially dressed, they went to maybe grab a phone and a passport and the children, as it were, and all the occupants of flats 6 evacuated the flats within very few minutes, very, very quickly. They then went out into the lobbies at an early stage in the fire, when the lobbies were still substantially clear of smoke, and then most of them then entered the stair and the stair was clear of smoke. So they were able then to move down the stair or between floors within the building, and many of them evacuated the tower at that time. Sadly some of them, as we know, took refuge in other flats higher up the building. But the key point about those flat 6 occupants was they were highly motivated by the smoke and fire coming into their

flats to immediately evacuate, and they were able to do so because the lobbies were clear and the stair was clear at that time.

That then contrasts with what happened next, because within a few minutes of them doing that, the lobbies on most floors became filled with dense smoke, and those occupants -- some occupants of other flats had already left during this early phase, but once that happened, I feel it strongly inhibited those who had remained in their flats from attempting to escape.

So the filling of the lobbies within a couple of minutes of the fire arriving outside each flat 6 on each floor, the filling of the lobbies was a key event which then inhibited occupants from escaping, led to many of them remaining in their flats and ultimately led to their being overcome by asphyxiant gases and dying in their flats. So this was a key event.

Now, some occupants, even after the lobbies filled with smoke during this early stage, were highly motivated to escape and succeeded in crossing the smoke-filled lobbies. Finding the stair had some smoke but really not very much, they were then able to descend and escape in safety.

The whole thing sort of goes in periods of time. So you've got this sort of period of time before about 1.25

to 1.30-odd, when on different floors the lobbies were relatively clear, so people were able to move around and escape relatively "easily", in quotes.

Then you have the period when the lobbies are filling with smoke. Some people are still coming out. About 50 -- more than 50 people succeeded in crossing that smoke and coming down the stair through reasonable conditions at that time -- we can go into detail later if you wish. And at the end of that period, which takes us up to about 1.41, something like that -- now, the last couple of people who came down from a high floor in the tower were Petra Doulova and her companion, and they crossed the lobby with some difficulty, leaving at about 1.36 on the floor they evacuated from. With some difficulty, they managed to make it to the stair, but they were then able to descend in safety.

Then we have a break of a period about half an hour or more when nobody comes down, and I believe what's happening then is that those people who were still in the tower had remained in their flats, so they were sort of staying put, as it were, and that was partly influenced by the fact that their flats at that time were relatively clear of smoke, for most of those flats, but they were inhibited from leaving by the smoke in the lobbies.

If I may, I would suggest it's a little bit like -- the way to look at this from the point of view of effects of irritant smoke is it's partly physiological and it's partly behavioural. So it's a little bit like if you imagine a pair of scales, and there are weights going into either pan, "Do I go or do I stay?" And I feel very sorry for these occupants who were trapped in these flats, because those who left early, after early cues that there was a fire outside -- noises of fire engines, people ringing them up, bit of smoke, smell maybe, a bit of odour -- they made this decision to leave at an early stage, they opened the door to the lobby, found the conditions clear, so they had, if you like, weights in the side of the pan that is saying, "I think we should go" or "We should go and investigate", and they had no obstacle to them doing that, so they were able to perform that task with relative confidence. Once the lobbies filled with smoke, then they had a strong incentive not to enter that lobby and they needed a very big push factor to make them do it. Do you understand how I'm looking at these various influences on people? So it's a combination of behavioural and physiological effects.

So those people that remained in their flats were able to do so initially because their flats were relatively clear of smoke. But over various -- the next hour or so, depending on which flat you were in, the external fire moved round the building and comes to each flat in turn, first to flats 1, then to flats 2 and flats 5, then to flats 4, and then to flats 3 eventually at about 3.30/4.00. And as the exterior fire came round the outside of these flats, the occupants were then faced with this difficult decision again. Now they had a very urgent situation, because they had a large fire coming round the outside and penetrating from the outside of their flats, and they also had the dense smoke in the lobbies. And so we have a second wave, if you like, of occupants who attempted, and many of whom succeeded, in evacuating at that time.

Now, from my analysis of the conditions and the timing of this, I spent a lot of effort into trying to establish the exact timelines for these events, exactly what people were exposed to at different times and how they were affected, and my overall conclusion from this is that those occupants who remained in their flats until the exterior fire arrived, if they left their flat and attempted to cross the lobby and enter the stair as soon as or within a few minutes of the arrival of the exterior fire, the exposure that they'd had to some toxic smoke via leakage from the lobby up to that point

was relatively minor; in other words, they hadn't accumulated a large dose of asphyxiants up to that time. So if they were able to cross the dense -- the lobbies were extremely hazardous, filled with very dense smoke and high concentrations of asphyxiant gases. So if you for example were in a flat 3 and you wanted to get across to the stair, you only had a very short distance to cross, and although the conditions in the lobby were really bad, you had a good chance even of holding your breath for the short period of time to cross to the stair. Once you've got into the stair, there was a lot of smoke in the stair, but, from my analysis, the concentrations were moderate, which meant that it was possible to walk down the stair and spend up to about 15 minutes walking down the stair, breathing asphyxiant gases on the way down, and this is very unpleasant, but by the time a person got to the bottom of the stair, the dose they'd accumulated was on the cusp, on the threshold, of an incapacitating dose of carbon monoxide. So if you had acquired a limited dose, as I believe these occupants had, up to the time you left the flat and you crossed the lobby efficiently, you had a good chance of succeeding in walking down and escaping the -- walking out the tower. And that continued up to about -- the last person to do this was at about

4 o'clock, from a high level of the tower, and then a couple of others came out later from lower levels of the tower.

So this shows that the conditions in the stair -- in the stair -- remained survivable, if you like, negotiable, for a long period of time during the incident, and if people were encouraged to leave before they were overcome in their flats, they had a good chance of being able to make it out alive.

Now, then you have a group of people who attempted to leave their flats but collapsed almost immediately in the lobby, or on the first flight of the stair when they got into the stair, or perhaps after a couple of floors, and when I analysed the situation for that group, that cohort, if you like, what I find is that those were mostly people who remained too long, remained longer in their flats.

Now, what happened with each flat was that obviously you've got multiple rooms in a flat, and the fire is moving round slowly in a sideways manner. So depending on which flat you're in, it starts to come to one room in your flat. So for example if you were in a flat 1, the first room affected by the fire coming from flat 6 is the living room. That meant that for the occupants of those flats, flats 1, for example, were able to

shelter in the bedroom, the next room along. If they closed the interior doors, they were able to remain in there for some time, even though there was fire coming past the living room next door. Then eventually, the fire moved past their last refuge, in whichever flat they were in. Once the fire came externally outside their -- and broke through the window in their room of refuge, where they were sheltering, then conditions deteriorated very rapidly, and occupants who tried to evacuate then had acquired too much of a dose of asphyxiants before they tried to leave, and that's why they collapsed so quickly in the lobby or the stair.

I have a couple more points, if I may continue, sir?

Q. Yes, please.

A. So those who died immediately in the lobby or almost immediately after entering the stair, often that's because they'd remained in the last refuge room, if you like, of their flat too long, in a sense, they got too big a dose before they tried to set out, and in a couple of cases I think they more or less just stepped out the door and immediately collapsed, so they only just made it out before they would have collapsed in the flat. Those who remained in the flats were then rapidly overcome and asphyxiated by asphyxiant gases, mostly carbon monoxide.

From my analysis of the pathology and toxicology data we have, all those occupants for whom we have blood data show very, very high doses of carbon monoxide in their blood, well above the lethal threshold limit. So I am convinced that they died from smoke exposure, inhalation of asphyxiant gases, not from burns, although their bodies were subsequently burned in the fire, many of them.

So that's the people who died in the flats.

Yes, the other point I wanted to make was the lobbies. The lobbies were -- from the accounts of people who tried to cross the lobbies -- and I'm talking mainly here from about 2.00 or 2.30 up to about 4.00 -- the condition -- the smoke in those lobbies was incredibly dense, and by my understanding of the composition of the smoke, that means that the concentrations of asphyxiant gases -- carbon monoxide and, to a somewhat lesser extent, hydrogen cyanide -- were of very high levels, capable of causing collapse if inhaled after three or four minutes. Very high levels indeed.

Now, as I've said, if you were in a flat 1, a flat 2 or a flat 3, the distance you had to travel in order to get from the front door of your flat to the stair door was really quite short, and so most people who attempted

to do so were able to do that without really being exposed to these extreme conditions for very long in the lobby.

Where I found a problem arising was for occupants of flats 5 and flats 4, because they had a more complicated and tortuous -- and not particularly longer, but a bit longer, but it was mainly the complexity of the route, and I've read a number of accounts of surviving witnesses who became disorientated and confused in those lobbies. A couple of them went into the rubbish chute door by accident, others tried to open the cupboard that had recently been installed, and so they were having great difficulty finding their way to where the stair door was. Some of them had to go back and try a couple of times before they succeeded in doing this. So they were in danger of inhaling -- of exposure to these extreme conditions in the lobby.

Now, in most cases they managed to negotiate and did this, but there were a couple of examples where I think people succumbed because they were exposed to those conditions, and I think I should mention at this point, I think the Belkadi family are one where we should explore this area of the lobby influence.

The second, which is a clear example, in a way, is the three persons who died on the 10th floor, because

they arrived in the lift to the 10th floor having had virtually, in my opinion, no exposure to anything up to that point, and yet having stepped out of the lift, they were unable to cross that short distance to the stair to carry on down the stair, and their bodies -- one body was found just outside the lift; the other two were found in the little blind corridor that led to flat 1. I think they became disorientated -- well, they did, they became disorientated in that lobby and, therefore, inhaled that lobby smoke for a few minutes. Now, it has to be only a few minutes, because say it had been 20 minutes, surely you would have found your way to that stair door. They had to have been overcome within a very short period of time. And this is about 1.25. This is just after the fire has come up past that floor. So this tells me that the conditions in terms of asphyxiant gas concentrations, certainly on the 11th floor and, I believe, by inference, in most of the other lobbies up the tower -- not all of them, but most of them -- were really extreme at this time, and that's why we've got those particular cases.

Just finally to round this off, from the analysis I've done, looking particularly at the survivors and those who -- the hospital data I had, the conditions in the stair were never as bad as that. The conditions in

the stair were of moderate concentrations of smoke and asphyxiant gases, such that although they were very hazardous, as I say, it was possible to inhale those conditions in that stair for maybe 15 minutes without being overcome, if you were an adult. Slightly more hazardous for children.

I think that more or less covers my points I wanted to raise at this time. Thank you.

Q. Yes, thank you very much, professor.

Now, before we turn to some detailed aspects of your approach and your methodology, I just want to highlight with you, if I can, the principal caveats in the light of which your approach and your analysis and conclusions should be viewed.

A. Yes.

Q. First, it's right, I think, that it wasn't possible to measure exact concentrations during the fire and all your analysis is based, I think, on estimations on the available evidence.

A. That's correct, yes.

Q. They're not exact measurements but approximations, doing the best you can.

A. That's correct, yes.

Q. You have used, I think, a squiggle to show that all times that you've --

A. I understand it's called a tilde.
Q. A tilde -- it's in my note and I wasn't sure whether that was a typographical error or not -- to show that the times that you have given are approximations.
A. Yes.
Q. Yes. When you have provided a time of death as approximately or with a tilde, how broad was the estimated time range?
A. Yes, I had some difficulties with this, because -- I think it might be an opportunity to explain -- may I use the flipchart?
SIR MARTIN MOORE-BICK: If you find it helpful, do, yes.
A. We're talking mainly here about carbon monoxide as the main cause of incapacitation and death in these occupants. So I'm just going to draw and then I'll come back and ...

(Pause)

I'm not the next Banksy, I'm sorry.

If we think of somebody who's exposed to carbon monoxide at, say, a thousand parts per million concentration, which is about half what there was, I believe, in the stair, and say there's somebody walking down a corridor, for example the Mont Blanc Tunnel, as you alluded to earlier, I analysed that, or down the stair at Grenfell, and if we assume for

a moment that the concentration of gas they're inhaling is constant all the time they're walking down, and on the right-hand axis here I'm looking at the percentage of carboxyhaemoglobin in their blood. If we assume that they start off with a clean sheet, that they haven't had any exposure, every time they inhale this smoke containing this toxic gas, then each lungful of carbon monoxide then combines with the haemoglobin in your blood to form carboxyhaemoglobin, COHb. Of the 100% of haemoglobin in your blood, an increasing proportion becomes converted to carboxyhaemoglobin, which means the bit left over to carry oxygen to your brain and your tissues is reduced in proportion. Not only is it reduced in proportion, but the carboxyhaemoglobin inhibits the release of the oxygen that is carried to the tissue, so it's a very serious effect on oxygen supply to the body.

So what effect does this have?

Well, initially -- so you get a steady increase where let's say this is 100% and we're starting to go up the scale. So let's say you get up to 10% carboxyhaemoglobin. What will that do to you? Well, the answer is: virtually nothing; you would be totally unaware that you are inhaling it and it will have no effect on you whatsoever. A heavy smoker can get up to

10% carboxyhaemoglobin without showing any symptoms at all.

The problem arises if you're actively walking along when the percentage rises to about 30%. So for a person -- and this is based on experiments, partly on experiments that I carried out myself -- at 30%, you're liable to get a sudden change from being normal -- walking around, good condition, if you're on the phone, you're making good contact and agreement with people -- you suddenly become dizzy and then you collapse. You go over a sort of physiological cliff. It's quite dramatic. You collapse down and you're now unconscious and more or less in a coma, and that's at 30%. As soon as that happens, your breathing drops considerably. So if you were walking down a stair, you might be breathing 20 litres of air a minute. As soon as you collapse and you're unconscious, that could drop to about 5 litres a minute. So, of course, the effect this has is that then the rate of uptake of the gases that you're inhaling is slowed down. So the increase in the level in the blood still carries on increasing, but at a slower rate.

The other problem we have with Grenfell is that, depending on where you were, the concentration you were inhaling might also be changing. But we can make

a pretty good estimate up to this point of collapse, and that's very important, of course, in the Grenfell context, because if you're anywhere in the tower and you haven't collapsed, then you still have the ability to move around and possibly escape. Once you are unconscious, you're going to just stay there. Unless somebody gets to you and carries you out immediately, you're going to stay there and carry on inhaling and eventually die, as we know many people did.

So we've got to the 30%. What then happens is you then have this slow continued uptake until you get to about 50%, and I've got some slides to show you there if you want to of data on this. 50% carboxyhaemoglobin, half your haemoglobin converted to carboxyhaemoglobin, is more or less the threshold for lethality, and what that means is if you're alive and you reach 50%, if you are rescued at that point and treated and given oxygen to breathe, your probability of recovery is very poor. So if you have got 40% in your blood and you're rescued, unconscious, and treated, you should wake up within a few minutes, and within half an hour or so all that CO is taken from your body, you should make a good recovery and there's a good chance you'll have no subsequent effects from an acute exposure like at Grenfell. You'd make a good recovery. Once you have got to about 50%, you're very unlikely to survive. You will most likely suffer brain death and never be able to recover. I mean -- but, of course, it depends a bit on the individual, but that's the general point. So 50% carboxyhaemoglobin is a very important endpoint for us to bear in mind.

Now, what happens next? So let's say the subject has got to 50% but they're still alive. So they're lying down, they're in a coma, they're totally unaware of what's going on, they're breathing very slowly, and their breathing is slowing continuously, at a rate depending upon the individual person. This process continues, with the concentration in their blood continuing to increase, until their heart circulation and their breathing cease. At that point, they die, and the concentration of carboxyhaemoglobin in their blood is, if you like, frozen at that point. If we recover pathology samples, that is the level that we will then measure, and it's very stable in the cadaver, in the blood at autopsy.

So 50% is the threshold, if you like, the point of no return for most people, but the amount that you find if you recover a sample from that person, it can be anything between 50 and even in the upper 90% at death. So a person who's got 90% in their blood at the point of

death -- and there were a couple of examples at Grenfell -- it meant they must have been technically alive and continuing to breathe until they reached that point, very, very slowly, with their respiration gradually failing. So it's very difficult for me to calculate, if you like, that time, because of the variability in the amount they're breathing and possibly in the gases they're inhaling, but I can give a very approximate window if I've got that data. If I know they died at 90%, I know they must have lived for a long time before they died. But even though they reached that high level, they would not have been -- it was not survivable. So had they been rescued -- removed at that time and treated, there's really no chance that they would have survived. So the 50% is more important in that context.

MR MILLETT: Yes, thank you.

A. Now, another level, as I mentioned earlier, that I think we also need to be very interested in is the highest level that they could reasonably achieve while in various locations in the tower and still have the headroom, if you like, to be able to take up more and not reach a collapsing dose by the time they evacuated. So I think that's why this succession of endpoints need looking at.

In some way, the final one just tells us the point at which they actually -- the system -- the vital systems packed up, if you like, stopped working, but it doesn't really relate to whether or not they could have survived.

Sorry, does that help?

Q. Yes, it does, thank you very much.

A. Just one very final point. If we don't have carboxyhaemoglobin data for that particular individual who died, we don't know whether they died at 50 or 90, so I have to give the range. It could be either of those extremes.

SIR MARTIN MOORE-BICK: Professor, would we be right in understanding -- maybe this puts it a little crudely -- that at 30% you become unconscious and comatose, and at 50% you're likely to die?

A. Yes. There's another caveat on that, though. If you're in a flat and you're just sort of sitting around or walking around the flat, or as we are in the court here now, then the threshold at which you become unconscious is round about 40% carboxyhaemoglobin. When you get up and start walking actively, as down the stair, then you obviously need more energy, more metabolic input to your breathing, and so you succumb at a lower dose when you're being physically active.

In fact, what has been observed quite a lot in fire deaths is somebody who was maybe in bed in a house with a house fire -- I remember a particular case where two children were in bunk beds, and they achieved quite high blood levels, but they were found in the act of trying to get up and get out of the beds. So the very physical act of moving was enough to make them collapse at that point.

SIR MARTIN MOORE-BICK: Thank you.

MR MILLETT: Yes, thank you.

Just in relation, then, to further caveats, I think we can take this quite quickly.

A. Sorry, yes.

Q. No, it's very helpful to have that presentation, professor, it really is. I just want to go back to the caveats just for a moment.

A. Yes.

Q. It's right that your information came from a wide range of sources and included witness statements from occupants and firefighters; yes?

A. Yes.

Q. Some of the 999 call transcripts?

A. Yes.

Q. Photographs and analysis of external fire spread?

A. Yes.

Q. And other experts' reports, such as those of Dr Lane, Professor Bisby and Professor Torero; yes?
A. Yes, and of course I relied very heavily on the Chairman's Phase 1 report appendix for the times of leaving the tower for each person.
Q. Yes. Is it right that where there's a substantial amount of evidence about a particular deceased, your findings have taken into account that evidence?
A. Yes.
Q. I think it's right also, as you have said, that in some cases there was very limited information available about particular individuals, and is it right that, in that situation, your analysis has been limited by those constraints?
A. That's correct.
Q. Yes.
Now, I just want to examine some methodology with you, just identifying where it is in the report, section 2 largely.
At paragraph 10 of your Phase 2 report, page 18 -- we don't need to go to it, I don't think -- at {DAPR0000005/18}, you have described the essential principles of the production of toxic smoke during a fire.
In summary, is it right -- and I'm just going to put

these propositions to you -- first, that burning materials produce a wide range of toxic products?
A. Yes.
Q. And some toxic products are produced from most materials.
A. Yes.
Q. Is it right that the type of toxic product produced from a material will depend upon the extent of the elemental and organic composition of the particular material?
A. Yes.
Q. They divide into, I think, gases and particulates; yes?
A. Yes. Yes, that's correct.
Q. Is it right both can be irritants?
A. Yes. So basically all materials when they burn have a high carbon content, and when that carbon in the fuel is burnt, it turns to a range of products, and one set that we're very interested in is the carbon particles, which are the actual smoke and soot particles, which obviously affect your vision, but a proportion is released as partly combusted organic materials, substances, some of which can be very highly irritant, powerful chemical irritants, which are often associated with these particles. So that's one category that we really need to consider very carefully.
Another source of these irritants is acid gases, and

these acid gases only occur if the relevant elements are present in the fuel, and the most important one is chlorine. So many, many substances have a certain amount of chlorine in the organic -- added to the organic matrix of the material. When these are burned, it produces hydrogen chloride acid gas, which is a strong irritant. So those are the irritants.
Then we have the asphyxiant gases, and really it's a very short list, and the most important are carbon monoxide, hydrogen cyanide. Carbon monoxide from all materials that burn, because they all contain carbon; hydrogen cyanide only if they have nitrogen in the organic structure of the material.
Q. Yes, thank you.
Now, we're going to come back later to your analysis of the three main fuel packages at Grenfell Tower and their relative contributions to the production of toxic gases in that incident.
In your report you have referred to some common terms which inform your analysis and your work, and you have explained those in more detail in the Phase 1 report. Could you just explain to us what a fractional effective dose is?
A. Yes.
Q. It's one of those terms.

A. I might have to go back to the board.
(Pause)
Q. If you need your Phase 1 report, I can show it to you.
A. Well, I'm just going to try and explain the principle of it.
Q. Right, do that.
A. If we think of carbon monoxide again, one way of expressing a dose of carbon monoxide that would incapacitate you is in terms of the amount available to inhale. So if, for example, we had 3,500 parts per million, and we inhaled that for ten minutes, then you could express the dose inhaled as 35,000 ppm dot minutes. So the concentration multiplied by the time is an expression of dose available.
So if we were in a particular fire, with time, as I showed you earlier, the person would have inhaled a certain dose up to that time, and the FED, the fractional effective dose, is a way of expressing that in a sort of normalised form. So what we do is very simply we have a fraction, and the denominator of that fraction is 35,000, which is the dose required to cause incapacitation, and the numerator is the dose obtained up to that period of time in the actual event. So let's say it's 1,000 ppm for ten minutes, then you would have had 10,000 ppm minutes, divide that by 35, that gives

you the FED as a fraction up to that point of time.
So we sum these fractions throughout the fire until the fraction becomes 1, until this equals that, and we say at that point the person will collapse. So FED 1 is the fractional dose predicted to cause incapacitation.
Now, that's for a single gas. But, of course, we have multiple gases, and so we have to have some way of dealing with the combination, and this also provides us with a way of doing that.
So we do a similar calculation for the fractional dose of hydrogen cyanide, for example, and from the toxicological studies that we've made, there's some complications in this, but we would treat them as essentially additive. So what we would say is at a certain point in time, if the FED, fractional dose, inhaled of carbon monoxide is 0.5, and if the fractional dose inhaled of hydrogen cyanide is also 0.5, 0.5 plus 0.5 equals 1, we've now reached a time during this exposure when we predict that person would be overcome.
Q. Yes.
A. That's the essence of it. Is that helpful?
Q. Yes, it does. Just to be clear on this, was there any significance, though, in your demonstration there of 35,000 parts per million per minute?
A. Yes. So I prefer to -- for carbon monoxide, I feel it's

more useful to express the fraction in terms of the calculated carboxyhaemoglobin, because we can then relate it to the data that we have. So another way of expressing this is to say -- perhaps I should have done this before -- 30% carboxyhaemoglobin is the dose of carbon monoxide in the blood at which you would become overcome. So if you calculate, with expressions that we've got, the dose achieved -- so let's say you've got 15% carboxyhaemoglobin after a certain point in time, then you've got half of a dose for incapacitation. So that's another way of coming at it.
Now, in international standards, we use both these methods, depending on the application, and 35,000 is the figure in the international -- the ISO standard from the committee that I serve on sometimes. Yes.
Q. Right, I see. So 35,000 --
A. 35,000 ppm minutes of carbon monoxide represents approximately the dose available to be inhaled that could overcome you.
Q. Before incapacitation?
A. Up to the point of incapacitation.
Q. Thank you.
A. Expressing it as calculated carboxyhaemoglobin is a more accurate way of doing it. It also is more useful to us, because we can then compare our findings with actual

blood measurements made on survivors and fatalities.
Q. Yes.
Now, I want to ask you some questions about the calculations to estimate exposure to and the effects of irritant smoke.
Is it right that to estimate the extent of exposure and the effect of irritant smoke, you have relied on, first -- I know there are a number of things -- the results of a BRE study of materials toxicity?
A. Sorry, I want to just explain briefly, if I may.
So over the years I've done a lot of toxicology experiments and studied human data on irritancy of various individual chemical irritants. So there is a bit of literature out there from industrial hazards and things on, for example, if a person is exposed to hydrogen chloride at about 300 parts per million, what would it do to you? And we have some information from accidents and things on this. So if you know what gases are there, you can make some sort of estimate of what it would do to somebody if they inhaled it. And by looking at, as we've discussed, the composition, and the data I obtained when I burnt these materials in tests at BRE of the gases that come off from these materials, I can confidently say that all the materials involved, the various fuel packages that we're going to discuss in

a minute, at Grenfell would have contained considerable quantities of organic and inorganic irritant gases. So that's on the supply side of the problem, if you like.
Q. Yes.
A. But to determine what effect those are actually going to have on an exposed person is somewhat more uncertain. So we have methods of doing it, but I feel we have a much better method for Grenfell because we have a wealth of witness statements on this. So for Grenfell I've relied for the severity, if you like, of the irritancy that people experienced on what they said they experienced, because I felt that was much more first-hand.
Q. Yes.
Now, I just want to see if I can identify the report that you refer to. There was a March 2003 BRE study which you refer to in this context, and I just want to see if we've identified it correctly.
Can we please go to {DAP00000002} and have that up. This is a report that you prepared for Anthony Burd on 26 March 2003, "The potential for including fire chemistry and toxicity in fire safety engineering"; do you see that?
A. Yes.
Q. Is that the report that you're referring to --

A. Right, so --
Q. -- as the 2003 report?
A. Yes, that report is results of two experiments measuring the yields and concentrations of these various gases produced when you burnt that set of materials, and so that's the dataset that I've relied on for just about all the work I've done for Grenfell.
Q. Yes, I see, thank you very much. And I think it was prepared by you and Jenny.
A. It was, indeed.
Q. Your partner.
A. Who is in the court over there, just to make sure I'm on the ball.
Q. Yes, very good.
The second thing I think you relied on -- is this right? -- was the tests carried out by Professor Anna Stec on the elemental composition of smoke particulates and toxic gas yields from samples taken from Grenfell Tower itself.
A. Yes. So just very briefly, obviously the work we did some years ago at BRE was on a generic set of materials. They were very -- some of which were the same polymers, the same general materials as there are in Grenfell, particularly the polyisocyanurate, the polyvinyl chloride, polyethylene and the polystyrene. So we

tested -- those were included in what we did at BRE, but they weren't actual samples, obviously, from Grenfell Tower, and so we felt it was important that samples from the actual tower were tested, and the Chairman supported this research, so Professor Stec carried out that research. So that work was done mainly on the sort of structural materials on samples of materials actually recovered from the tower.
Does that cover the point? Sorry.
Q. Yes, it does, thank you very much.
The third category of documents you have relied on was an assessment of witness descriptions of conditions and medical records, I think, which indicate the extent of smoke obscuration and the severity of smoke irritancy.
A. Yes.
Q. Now, let's then turn to the assessment of exposure concentrations and effects, and I just want to ask you about your calculations.
A. Yes.
Q. You have explained in the first part of your report, page 37 at section 2.6 -- let's just go to that, {DAPR0000005/37}.
A. Yes.
Q. Section 2.6, and this section is entitled:

"Using smoke density and visibility as a first approximation to estimate exposure concentrations and time to incapacitation from the effects of asphyxiant gases."
A. Yes.
Q. You have explained here in this section how you have estimated exposure concentrations and time to incapacitation on the basis of smoke density and visibility.
Now, in summary -- and just correct me if I'm wrong about this -- is it right that when a fuel material burns, it produces certain yields of particulates, carbon monoxide and hydrogen cyanide?
A. Yes.
Q. And while the actual concentrations vary as they're diluted by the air, is it right that the ratios of smoke particulates, carbon monoxide and hydrogen cyanide each remain constant?
A. Yes.
Q. Right.
A. Approximately.
Q. And you mean the relative concentration?
A. Yes.
Q. Is it right that you then took the elemental compositions, the yields and the concentration data from

the materials used for the BRE experiments --
A. Yes.
Q. -- that you and your wife, Jenny, carried out to derive the fuel mixture from the three main fuel packages at Grenfell?
A. That's correct.
Q. Was that -- let's just tick them off: exterior cladding; yes?
A. Yes.
Q. The window surrounds.
A. Yes.
Q. And then the mixed flat contents.
A. Exterior cladding and insulation.
Q. And insulation.
A. The first package --
Q. -- exterior cladding system.
A. Yes, that's right, yes.
Q. Yes, the window surrounds, and then the mixed flat contents; yes?
A. Yes.
Q. Yes. You then used those to estimate the ratios of those materials --
A. Yes.
Q. -- at Grenfell.
A. Yes.

Q. Yes.
Now, let's go, please, to page 41 of this document {DAPR0000005/41}. This is taken from your Phase 1 report, figure 1. Here it is. It's entitled:
"Concentrations of carbon monoxide ... and hydrogen cyanide ... at different smoke visibilities for a mixed fuel set (From Phase 1 report Figure 19)."
Am I right that this shows the estimated concentration of carbon monoxide and hydrogen cyanide ppm in relation to the visibility reflected in metres under both well-ventilated and under-ventilated conditions? Yes?
A. Yes.
Q. Yes.
Have you assumed here the ratio 27:1 for carbon monoxide and hydrogen cyanide, as you have calculated elsewhere, or is it some other ratio?
A. Sorry, this example here was for a particular set of fuels, a fuel package, mixed fuel package, that I worked on some years ago. It's not dissimilar from the sort of packages we have at Grenfell, but it was -- this particular diagram and the data in it weren't specifically tailored to Grenfell.
Q. Right.
A. But they illustrate the very important point that, as I've said, the ratios of smoke and hence visibility and asphyxiant gases within that smoke are linked, the ratios are constant. So for this particular fuel package, which is, I would say, fairly typical of what we would expect to see at Grenfell anyway, there's a very important point here, which is that if, for example, you can see for 5 metres at the right-hand corner of that graph, it means that the concentrations of these asphyxiant gases, carbon monoxide and cyanide, that you're inhaling are extremely low, such that you could breathe them for some hours without really suffering any ill effects. But as soon as the visibility gets down to, for example, 1 metre, then you're starting to get quite serious concentrations of these gases that could cause incapacitation after some minutes of exposure -- minutes of exposure.
So as a proxy for a very approximate estimation of the amount of carbon monoxide and cyanide that people in Grenfell were inhaling at any particular time, if I can have an approximate idea of how seriously dense the smoke was that they were exposed to at that time, I can make an estimate of that, within these broad ranges.
What I'm looking for is: are we operating in a range where these concentrations are effectively harmless, that you could be exposed for some hours without really suffering? Are they in this kind of middle range where you might be able to perform -- for example come down, spend 15 minutes walking down the stair and just about make it down? Or are we in the realm, as I believe we were in the lobby of the 10th floor, where two or three minutes or five minutes' exposure will have you unconscious? So I think it gives us a take on that.
Now, this was for one particular fuel package. For Grenfell in Phase 2, I have refined the datasets to reflect as far as I can the specific Grenfell fuel packages. So the numbers that I've used for the Phase 2 work are a recalculation of this sort of picture, but more targeted at Grenfell.
Q. Now, in the graph that we can see here, my question is really directed at the ratios of carbon monoxide to hydrogen cyanide.
A. Yes.
Q. Did they remain constant at 27:1 throughout the graph?
A. Well, I'm not sure what the ratio was, approximately that in here, but what I'm saying is that for my examination of the Grenfell fuel mixes, I found that the ratios in the cladding and insulation, when the -- from the work that we've done, we believe that essentially all the polyethylene was burnt away very quickly in the fire at any one point on the exterior of the tower, and from the residues left behind, approximately half the mass of the Celotex insulation was burned away, which means that approximately equal masses, about 50:50 mass ratio of those two fuels burned.
From my data from our BRE tests on the yields and compositions of these materials, I was able to arrive at an approximate ratio of carbon monoxide to cyanide I would expect to find in the smoke from that burning cladding and insulation mix, and I arrived at a figure of around about 26/27:1. That's important, because it means that anybody breathing that smoke of whatever concentration, the toxicity is going to be dominated by the carbon monoxide component, but that there's going to be significant contribution from hydrogen cyanide. So both are important, but it's dominated very much by carbon monoxide.
Q. Right.
A. I then did an analysis -- and it has to be very approximate -- for what I'd expect to find as the fuel load of individual materials in an individual flat. So the way I went about this was on the internet I found a local authority website of advice for removal people about what items you would expect to find in a typical flat or house, in terms of how many beds and what weight they were, how many cupboards, et cetera, et cetera. So

I was able to come up with a kind of fire load contents package for a flat, and then I related the composition of those materials to, as far as I could, the materials we'd studied in our BRE experiment, to work out the approximate elemental composition, in terms of carbon, nitrogen, hydrogen, chlorine, for flat contents, and the yields, more importantly, and yield ratios of gases that we'd expect from a typical total involvement. This is for total involvement, a fully involved compartment fire of an entire flat.

The important conclusion I came to was that the nitrogen content is about 3% by mass of both the fuel package 1, that burning on the outside of the tower, and the contents, and therefore that the ratios of CO to cyanide from any part of the contents burning at any time are going to be similar to the ratios that we would get from the outside burning materials.

Q. Right.
A. Therefore, the toxicity in that sense is going to be very similar.
Q. Yes.
A. And also for the smoke as well.
Q. Yes, thank you. That's very helpful.
A. Sorry.
MR MILLETT: No, no, that's very helpful. We may see

a little bit of that in the next figure.

Mr Chairman, I note the time, but there are one or two further questions on this very topic that I would like to finish off if we can before the break --
SIR MARTIN MOORE-BICK: Yes, all right.
MR MILLETT: -- if that's all right with the professor.

Professor, can we then turn down a page, please, to page 42 {DAPR0000005/42} to look at figure 2, and that's entitled:

"Calculated time to collapse from asphyxia at different smoke visibilities (from Phase 1 report Figure 18)."
A. Yes. So that is for the fuel package we have just been looking at, not specifically for Grenfell, but very similar kind of --
Q. That was really my question. That's the same mix, is it, of carbon monoxide and hydrogen cyanide?
A. Yes, that's the mix that I used for the illustration I put into my Phase 1 report. It's not specifically tailored to Grenfell, but it's similar, similar ratios.
Q. So taken together, these two figures, figures 1 and 2 -- is this right? -- show how you have calculated the time to collapse from asphyxia based on the visibility in metres.
A. Yes, they're an illustration of the method, yes.

Q. Exactly. So is a rough estimate that where visibility is less than 1 metre, it will take roughly 20 to 25 minutes to collapse?
A. Yes.
Q. Yes, I see. And when it's less than half a metre, it will take less than ten minutes to collapse?
A. Yes.
MR MILLETT: Yes, I see, thank you.

Mr Chairman, is that a convenient moment?
SIR MARTIN MOORE-BICK: Yes, it is, thank you very much.

Well, professor, as you were told earlier, we are going to have a break during the morning. We will take it now, so we will stop there. We'll resume, please, at 11.35.

As I'm sure you know, I think I said this to you on previous occasions: while you're out of the room, please don't talk to anyone about your evidence or anything relating to it.
THE WITNESS: I understand, yes.
SIR MARTIN MOORE-BICK: All right?
THE WITNESS: Thank you.
SIR MARTIN MOORE-BICK: Thank you very much. Would you go with the usher, please.
THE WITNESS: Thank you.

(Pause)

SIR MARTIN MOORE-BICK: Thank you very much, Mr Millett. 11.35, please. Thank you.
(11.21 am)

(A short break)
(11.35 am)
SIR MARTIN MOORE-BICK: All right, professor, are you ready to carry on?
THE WITNESS: Yes.
SIR MARTIN MOORE-BICK: Thank you very much.

Yes, Mr Millett.
MR MILLETT: Yes, thank you, Mr Chairman.

Professor, can I please show you, then, next in the same document, page 48 {DAPR0000005/48}, table 7, and at the top of the screen there's a table entitled:

"Calculated approximate CO and HCN concentrations as a function of visibility through smoke from flat contents and exterior cladding and insulation."

You have set out there the visibility, the smoke density, the flat contents divided between carbon monoxide and hydrogen cyanide, and the cladding plus insulation and the splits there as well.

Is it right that that shows you essentially what it shows you, as you've described it; yes?
A. Yes, that's right, and this is specifically for those Grenfell sets of data.

Q. Yes.
Just to pick a point up in the footnote, it says:
"Includes 100% PE cladding and 50% PIR insulation."
A. Yes.
Q. That's I think an assumption that underlies all of your work.
A. Right, no, well, actually, that was a very crude estimate based on my visits to the tower in 2018 or whenever it was, that about half the insulation had burnt away, but obviously all of the cladding was gone. But subsequent to that, Professor Stec's team have done an amazing and indeed very detailed survey of the tower to measure with some precision how much of that insulation has been burned away, and not only did they look at what remains on the tower now -- because one of the problems is things have changed a bit over the years -- they used the drone footage to validate what's there now with what appeared immediately after the fire. In fact, you can see on the drone footage the fire is still burning to some extent. So we have a pretty good picture of how much of that insulation was burned away and how much now remains.
Q. Now, can we go to the next table down, same page, table 8, which runs over to page 49. Here is the table:
"Estimated volume concentration ratios for mixed

flat contents compared with those from cladding and insulation under two ventilation conditions."
A. Yes.
Q. Can you explain how you came to your findings that the relative concentrations of carbon monoxide and hydrogen cyanide are similar regardless of the origin, whether from exterior materials or flat contents --
A. Yes, okay.
Q. -- by reference to this table?
A. I did refer to this a bit before we broke.
Q. Yes.
A. So, basically, if we take the cladding and insulation, because it's simpler in the sense that there are only two materials involved, I looked at, firstly, the elemental compositions of those fuels. So polyethylene is almost -- is entirely -- a very pure polymer, really, it's just carbon and hydrogen, so it has a very high carbon content, but nothing else, carbon and hydrogen only, whereas polyisocyanurate has ratios of -- well, has elements of carbon, oxygen, nitrogen and chlorine in it, and we measured those for our BRE work and then Professor Stec has re-measured them for the actual Grenfell materials. So those are the elemental compositions.
But what perhaps -- as important as that is what

happens when you actually burn these materials. So all these materials were burned in our BRE work on the tube furnace to measure the yields and concentrations of these gases, and hence we can look at the relative concentrations of smoke, CO and cyanide, when we burn these under controlled conditions, and for the cladding and insulation, that work has been repeated by Professor Stec on actual Grenfell materials. For the flat interior contents, that relies more on the general materials that we studied at the time of the BRE work. From that work, as I've said, we found that there were these certain ratios involved, and I've used those ratios for all my FED calculations that I've carried out for estimating the effects on occupants of flats, lobbies and the stair, and essentially the ratios -- so from what we were saying this morning earlier, if you know the concentration of one of these elements, one of these items, you can calculate the concentrations of all the others by these set of ratios.
Q. Yes, thank you. Yes, I see.
If we then turn to the next page {DAPR0000005/49}, paragraph 176, and this is at the foot of the page, underneath the heading, "Method for estimation of exposure concentrations and effects on occupants in the flats, lobbies and stair".

A. Yes.
Q. And the first is from witness evidence.
You say at 176 there:
"From the descriptions of dense irritant smoke in the lobbies, and based on the general fire conditions I estimate that with almost zero visibility in the lobbies, the concentrations of CO are likely to have been high, in the approximately 5,000-10,000 ppm CO range with HCN in the approximately 190-380 ppm range based on the ratios between smoke density and gas concentrations shown in Table 8)."
A. That's correct, yes.
Q. That's the position.
Then smoke density at that concentration -- is this right? -- would cause collapse or could cause collapse within three to five minutes for any person in the lobby?
A. So inhaling those asphyxiant gases, that amount of carbon monoxide and that amount of cyanide, for three or four minutes would cause you to collapse, yes.
Q. Yes. Three to four minutes?
A. Well, it depends on where you are on that range, and obviously it's quite a wide range. Because one of the problems is if you can see 5 metres and then it goes down to 2 metres, you're conscious of that difference,

but the difference between being able to see 10 centimetres and 5, you can't really judge. So all we can say is it's very high.
Q. Yes, I see.
Can we please go, then, to page 50 {DAPR0000005/50}, the next page, and the next paragraph, where you say this. This is paragraph 177:
"The main exposure to asphyxiant gases for the majority of occupants escaping down the stair (having left their flats before or very soon after the arrival of the exterior fire) occurred while they were descending the stair over periods of approximately 5-12 minutes depending on which floor they descended from and their descent speed."
A. Yes.
Q. "Based on the descriptions of the smoke conditions, and the fact that most of these occupants were able to descend and walk from the Tower, the average CO concentrations in the stair during these descents were at moderate concentrations (in the range approximately 1000-2000 ppm CO and approximately 35-75 ppm HCN. This first approximation estimate of the stair conditions is based on the descriptions of the smoke conditions by descending occupants. Evacuating occupants described very dense smoke in the lobbies with no visibility. The

majority of those evacuating successfully after approximately 02:00 also described severe smoke conditions in the stair with also with [sic] very poor visibility. Some occupants could see nothing in the stair but others reported being able to see lights in the stair or their knees or a person in front of them. Others described the visibility improving at lower floor levels below approximately the 10th floor (see Appendix A). Based on these accounts, on the developing conditions and that occupants succeeded in walking down I have made a preliminary estimate that this indicates visibility approximately in the 0.4 to 1 metre range so moderate concentrations of asphyxiant gases averaged over the stair column shown in Table 7, enabling them sufficient time to descend without inhaling a dose causing collapse as indicated by Figures 1 and 2."
Now, first, can you explain how you estimated visibility at between 0.4 metres and 1 metre in the stairs?
A. So obviously this is very -- I mean, the word "approximately" should perhaps be in heavy type. These are very, very approximate. This is the first approximation that I'm making here. So all I'm asking myself is: how bad was that smoke? Was it not too bad at all, really quite bad or -- is there any chink of

light, if you like, in there? And so simply based upon what these witnesses are saying, I'm estimating we're operating in this approximate range. It's pretty bad, you almost can't see -- in fact, you can't really see ahead of you, but because smoke tends to be layered, even in a stair -- and some witnesses did actually refer to this, sometimes they could see their knees or their feet or, you know, the stair rail. So that to me means we're operating in approximately this range of visibility.
Q. And the variables in that range would be you've got to take into account the differentials in concentrations in the smoke layer, where you are in the staircase and the time?
A. Yes.
Q. Yes.
Now, using that range, 1,000 to 2,000, how long would it take, on your estimate, to cause collapse?
A. Yes, so one --
Q. Sorry, I should just add: assuming you start from a base of no carbon monoxide or hydrogen cyanide uptake.
A. Yes, I think there's more of a worked example later on, but, I mean, we're talking very approximately, especially if we went back to that other figure. A thousand parts per million you can walk through for

about half an hour, and -- what was it you said? -- 2,000 would be about half that time. That's very, very approximate and, of course, it various on the individual and what they're doing.
Q. And that's walking?
A. That's walking, yes.
Q. Right. And static?
A. Static, the ratio is 40% to 30% -- oh, hang on a minute. Static is quite a bit longer because you're breathing less, so your uptake is about half that, so roughly twice as long.
Q. Right. So you could, before incapacitation, spend an hour in the stairs, or between 30 minutes and an hour, depending on where you were on the range?
A. It might be helpful to go back to that diagram with the smoke density. But, yes, something like that, yes.
Q. So can we go back to table 7, I think, page 48 {DAPR0000005/48}. Let's go to that. Table 7 at the top. Is that the one --
A. No, I meant the figure with the curved graph on it.
Q. Ah. Well, perhaps we can do that shortly.
Can we then go to page 50 of your report {DAPR0000005/50} and look at paragraph 178. There you have derived more accurate estimations of exposure and uptake of asphyxiant gases and effects on carbon

monoxide, and you cover that, I think, in some ten paragraphs between 178 and 188. You have done that, I think, through an analysis of individual experiences; is that right?
A. Yes. So here I'm looking at the condition of the people when they got to the bottom of the tower. So, for example, one of the first two people I looked at was Naomi Li and Lydia Liao, and they both walked down from the 22nd floor. It took them -- we have a fairly accurate understanding of when they entered the stair, just after they finished their 999 call, so they're one of the few examples where we have some actual objective time data, and they know the time they left the bottom of the stair, and so I estimate it took them 11.5 minutes to walk down. So all the time they're walking down, they're inhaling carbon monoxide and a little bit of cyanide. So the state they're in, the condition they're in when they reach the bottom of the stair, gives me an indication of how much they've inhaled.
Now, from the witness statements, Naomi said -- I think she met some firefighters very close to the bottom of the tower, in the lower floors, and she felt that she would have been able to continue, walked out unaided, but they insisted on helping her, whereas her

companion had sort of semi-collapsed, more or less collapsed, and had to be carried out. So you can see they were both on this cusp of collapse, which means that they were at about 30% carboxyhaemoglobin.
So knowing that they were at 30% carboxyhaemoglobin and knowing how long they were exposed, I can calculate what the concentration of CO they were exposed to was, with some reasonable accuracy, plus or minus about 20% uncertainty.
Q. Yes.
Now, we'll come, I think, to that worked example shortly, but that's very helpful indeed as an introduction.
Can I just explore with you the indicators that you have used to inform the more accurate estimates that you do in these paragraphs from individuals.
Can we go first, please, to page 145 in this report {DAPR0000005/145}, or this part of your report, table 18, and that's entitled:
"Blood [carboxyhaemoglobin] ranges with effects of increasing severity on exposed subjects and likely associated extent of post-exposure lung injury resulting from inhalation of irritant smoke soot particulates."
Just to summarise that, am I right that it goes like this, if you start at the bottom of the table: roughly

20 to 25% are occupants who were alert and active with no signs of dizziness, weakness or impending collapse, and they had accumulated blood concentrations of carboxyhaemoglobin of less than 20% to 25%?
A. Sorry, I can't see where you're reading that from.
Q. It's the last entry in the table?
A. "Minor signs even in active subjects"?
Q. Yes.
A. Yes.
Q. Yes. Then moving up -- I'm just walking you through this --
A. Yes.
Q. -- the next one up is occupants who were able to walk, but reported symptoms of dizziness, weakness or collapse, especially where one person is able to walk while a companion collapses, and requires assistance to evacuate. Those people had accumulated a blood concentration of carboxyhaemoglobin in the range of approximately 25% to 35%.
A. So you're reading from the text but you're looking at the table, is that what --
Q. I'm summarising the --
A. Yes. So essentially if you're in that range, around about 25% to 35%, that's the sort of concentration where we're seeing people collapse if they're physically

active, yes.
Q. Yes. Then the next one up, 40 to 45%, there's an increasing incidence of collapse and loss of consciousness in resting subjects.
A. Yes.
Q. Yes, and the lung injury effects are also identified.
A. Yes.
Q. And at 45 to 50% roughly, you have got collapse, coma and death.
A. Yes.
Q. Then above 45% to 90%, unconscious and comatose until death, decreasing breathing. So this, I think, summarises what you told us before.
At what level of blood concentration of carboxyhaemoglobin would an individual be likely to lose consciousness? I think you told us earlier it was 30%?
A. So 30% for somebody who is --
Q. Moving.
A. -- walking quite actively along, and about 40% for somebody who is sitting at rest.
Q. Yes.
A. Or just walking slowly round a flat.
Q. Yes, and you gave us the lethal threshold here, really, which is about 45%.
A. Well --

Q. Depending.
A. Yes, I mean, I would normally say 50, but 45/50 you start to get -- I have got a diagram to show this from actual data, but the survivability -- very quickly. So if you look at survivability against dose, it sort of does that (indicated), where this is about 45 to 50%. There's a huge drop-off. These are people who have been rescued and survive, these are people who have been rescued alive but then go on to die, and the survivability percentage drops precipitously in this middle range here.
Q. Right.
Now, where an individual is known from the evidence that you've studied to have had limited exposure to asphyxiant gases in the flat before they left the flat, is it the case that any accumulated exposure to carbon monoxide can be attributed to uptake in the lobby and the stair?
A. Yes. So the way to think of it is that it's a continuous process. As soon as you start to be exposed to carbon monoxide, inhale it, you're building up a dose in your body, as I mentioned earlier, and for the Grenfell occupants, that starts with them in the flats.
Now, one of the -- sorry, if I may just say --

important aspects of the Grenfell incident was that after the lobbies filled with smoke, some people were then trapped in their flats for up to two hours, and during that period they nearly all -- well, they all except one I can think of, I think, reported smoke leakage around their front doors, flat entrance doors, into their flats from the lobby. So this very bad lobby smoke is leaking into the flats, all right? So I was at pains to try to understand and estimate: how serious was that exposure during that period before the external fire's come round to their flat?
My conclusion, having looked at all this data, is that they were able to limit their exposure quite successfully by sheltering in various rooms, opening windows on sides of the tower away from the fire, so that the dose they accumulated while in the flat was actually quite low, but it's all building up.
Then they go into the lobby. If they hold their breath, they don't take any in, but if they inhale any of that bad lobby smoke, then they get a bit more of a spike, but it's such a short period, it's probably quite trivial, if they efficiently get across the lobby, and then the major exposure continues as they descend the stair. So it's the cumulative total by the time they've reached the bottom of the stair that we need to

consider and where that's been acquired.
Q. So one can break it up, I think, but is it right also -- it follows from what you have said -- that where an individual is known to have had some or perhaps significant smoke exposure before evacuating their flats, then the difference between their calculated uptake in the stair and the total uptake -- is this right? -- is going to represent the difference in the extent of their exposure while in the flat before entering the stair?
A. Let me just clarify that, because it's quite important. So, basically, by looking at quite a lot of different people and doing these calculations, I was able to establish that the average concentration, which is the important figure, in the stair during this period -- and we're talk mainly about the period between about 2.30 and 4.00, the 50-odd people who came down during that period. So during that period, the concentration of carbon monoxide in the stair was of a moderate level, and by looking at the -- lots of -- a number of individuals, I was able to home in on a figure of 1,800 parts per million as my best estimate of the average concentration of carbon monoxide in the stair during that period. Right?
Now, that concentration means that by the time

you -- if you walk from an upper floor, you're going to be at sort of 20%-odd carboxyhaemoglobin just acquired in the stair by the time you reach the bottom. If you've reached 30 at the time you reach the bottom, then the difference is 10. Where did you get that 10? You had to get it while you were in the flat.
Does that clear things?
Q. Yes.
A. So by being very -- looking very closely at the acquired dose in the stair, which in itself was important, I was also able to deduce what the pre-exposure was in the flat up to that time.
Q. In doing that, did you take account of uptake in the lobby?
A. Yes. Now, for some of these calculations, I assumed that they took a few breaths in the lobby during this transition period as they crossed the lobby, and as I've said, I think the concentration in the lobbies were really high. But because it's still only -- we're only talking about a couple of breaths or 10, 20 seconds at the most, the amount of dose acquired during this period in the lobby is very, very small in the context of the entire exposure. So if you came out of, say, a flat 3 again and you went straight across, holding your breath, and got into the stair door of the stair, then you have

inhaled nothing in the lobby. If, however, you took a few involuntary breaths while crossing the lobby, even though the conditions are really bad, because that period is so short, it doesn't significantly add to your dose. If, however, for some reason you become disorientated and stay there for a few minutes, then it's very serious.
Another point I would make is that there is a reflex physiological response to inhaling smoke, which is that you get involuntary breath-holding for a few seconds. It's a physiological reflex. So if you walked out into that lobby and took a breath, you would hold your breath. You can't not do that. You can only do that for a short period of time, but it would be long enough for you to get across the lobby if you were taking a direct, simple movement.
Q. Holding your breath, would that have a physiological effect?
A. Well, anybody could hold their breath for a few seconds and not collapse, if you like, yes. No. Sorry, I don't understand the question.
Q. Well, if you're holding your breath, is there therefore less oxygen in your system?
A. Yes, but we can all, you know, dive or hold our breath for maybe a minute, so that's not a problem.

Q. So it's immaterial? That's not --
A. Not for a few seconds, no.
Q. Was it also the case that you took into account the variability presented by the fact that people coming out of flats on different levels would have to travel down the stairs for a greater or lesser distance?
A. Yes, and that showed up when I looked at this hospital data.
Q. Yes.
A. Yes.
Q. I see.
Let's then turn to the applied example. If we go, please, to page 51 -- I'm so sorry, before we do that, can I take you back, please, to page 42 {DAPR0000005/42}. You wanted to be shown the graph on page 42, I think, in relation to my question about distances.
A. Yes. So can you repeat the question?
Q. Well, I think my question was can you tell from this chart how much --
A. You have to look at the previous -- the two charts, the one before that.
Q. Yes, let's go back a page to the top of page 41 {DAPR0000005/41}.
A. We really need them on the same page, which I've got ...

Q. They're not. Page 41, figure 1.
A. If you go to page 6 of the document I prepared of my graphs and things, they're both on the same page, so we can see them.
Q. Oh, right.
A. Don't worry.
So all I'm saying is if you are exposed to -- well, I did do some calculations on people walking down the stair, and at about 2,000 ppm you could -- I think I -- I haven't got the figures in my head, but you could walk for about 15 minutes. Now, I think the question you were asking me was: if you were sitting, would you be able to go longer, and you certainly would.
Q. Yes.
A. And because you are breathing about twice as much when you're walking as when you're sitting, it should double the time before you would collapse, approximately.
Q. Yes, thank you.
A. Does that cover it?
Q. It does.
A. I mean, I'd have to do some calculations to really address it.
Q. That was the question and that's the answer. That's very helpful.
Can I then turn, please, to page 51 of this document

{DAPR0000005/51}, paragraph 189 and following. This picks up on something you mentioned a few minutes ago in your evidence.
Here you have explained your methodology through an applied example.
A. Yes.
Q. I think this is right: there are two individuals who you used who successfully evacuated from flat 193 on floor 22. They entered the stair at 3.10 --
A. Yes.
Q. -- and left the tower at 3.21.
A. Yes.
Q. So took 11 minutes to descend the stair from floor 22.
A. Yes.
Q. I think you have then estimated their exposure in three scenarios.
A. Yes.
Q. And you have set those out --
A. Yes.
Q. -- in sections 3.3.1, 3.3.2 and 3.3.3 of your report; yes?
A. Yes.
Q. We can scroll through that. The assumptions in each scenario are -- let's have them up. Scenario 1, top of page 52 {DAPR0000005/52}, is "Assumed free from exposure

in the flat". Scenario 2 is "Inclusion of exposure", which is the foot of page 53 {DAPR0000005/53} -- yes? "Inclusion of exposure" --
A. Yes.
Q. -- "in the flat and lobby in addition to the stair". And then 3, assumption or scenario 3, I think you find at the top of page 57 {DAPR0000005/57} --
A. I have included the other gases.
Q. -- is the other gases, the asphyxiant gases, and you have provided a figure for each scenario, and I want to take each in turn.
If we go back, please, to page 52 {DAPR0000005/52}, and look at figure 3 --
A. Shall I just talk you through this?
Q. I was going to ask you to do that.
A. So this is, if you like, well, a quasi-theoretical example. It does represent these two individuals who actually did perform this task, and it uses their actual exposure time, but for this particular scenario, as you can see from the beginning of that graph, the dots along the bottom are at 0. So I've assumed, which wasn't actually the case, for the purpose of this worked example that they had no exposure up to the time they left the flat. So they're in a completely smoke-free flat, and then they step out into the lobby, they cross

the lobby, taking perhaps a couple of breaths, but the effects of that are trivial, as I explained, and then they enter the stair, and over 11.5 minutes they walk down the stair, and that's their main exposure. By the time they get to the bottom of the stair, they've reached about 30% carboxyhaemoglobin, they're in a state of near collapse; one's collapsed and one hasn't, in reality.
So from my CO uptake calculation methods, I can calculate what carboxyhaemoglobin they would have acquired if the average concentration during that descent was at various levels. This is completely arbitrary, I just put a figure into my spreadsheet and I calculate their uptake for that particular scenario.
Let's say I've guessed very accurately that they would be inhaling 2,100 ppm of carbon monoxide. So when I run that through the analysis, that then equates to the exactly correct, as it were, dose of 30% at the time they get to the tower (sic). So I would say if they had no exposure before entering the stair, and they still got to 30% at the bottom, then the average concentration would have to be somewhere around 2,100 parts per million in the stair.
If we repeat the calculation for a similar but somewhat higher figure of 2,600, then we predict that

they would have got to 40% carboxyhaemoglobin, and would have in fact collapsed quite a few floors up in the tower when they were at 30, about two-thirds of the way down, which they didn't do, so that can't be correct.
Similarly, if you look at the pink curve, which is for 1,600 ppm, then they only get to 20% by the time they exit the tower and they would have been uninjured, unaffected, so we know it can't have been as low as 1,600.
So I think this gives you two things: it shows you the method I'm using, but it also gives you some indication that it's really quite accurate, you know, that we're not going to double or treble these gas concentrations, it's got to be somewhere in this range for it to be true.
Now, this is assuming no prior exposure. Then the next example, I deal with the flat.
Q. Yes. Let's go to that, which I think is scenario 2, page 54 {DAPR0000005/54}. That's what you're --
A. Yes, if you blow that up a bit.
Now, as I have said, by looking at a number of these cases -- and, in fact, in at least one of them, the occupants -- I've forgotten the name now. Was it Burton? One of these occupants, he stated in his witness evidence that their flat was totally clear of

smoke up to the time they left. I think it's Pilar's husband I'm thinking of.
Q. That'd be Nicholas Burton?
A. Yes, Nicholas Burton. So Nicholas Burton said that their flat wasn't penetrated by smoke up to the time they left, so his only exposure was in the stair, and yet, by the time they reached the bottom, they were in this kind of almost collapsed condition.
So by looking at a number of examples like this, I have honed in on the actual average figure for the CO in the stair as 1,800 parts per million. Right?
So in this worked example you have in front of you now, this shows the concentration profile I've used for Li and Liao, taking into account their exposure in the flat.
Now, I just need to explain what this shows.
So the right-hand end of that chart, if we look at the CO concentration there, where the label says "2 escaping in stair" --
Q. Just so people can follow this, that's the little black bar in the middle.
A. Yes, so this represents the concentration with time of carbon monoxide that I've used for this analysis, right? So, as you can see, I have set that at 1,800 ppm. That covers the time period, the 11.5 minutes, during which

they were actually descending the stair. From a number of people, I've estimated that they were exposed to 1,800 ppm while descending the stair in reality in that case.

Before that, they had a very short exposure to a very high concentration in the lobby, which is why the black chart -- those figures go right up to the top of the graph, but it's very short, so the dose they've inhaled is very small. Before that, we've got the concentrations of smoke and gases that I've estimated very approximately that they could have been exposed to while they were in the flat.

You can see that they were in the flat for -- how long? Well, about 1.30 to nearly 3 o'clock. Over a long period of time they were in that flat, and they were exposed to an increasing -- we don't know the exact shape of that profile of increasing, but it would have been a gradual increasing profile of smoke and gases. The smoke -- this is shown in terms of visibility, so the red graph is coming down, because the lower the visibility, the higher the concentration of smoke, so it goes in the opposite direction to the curves for gas concentrations. I hope that's not too confusing.

Q. And that's, just to be clear, the mauve --
A. The red colour, the red --

Q. The red is the visibility in metres.
A. Yes, so the red is the visibility. That's coming down because there's more smoke.
Q. Yes.
A. In fact, yes, I've got -- sorry, I've got -- the pink is the optical density per metre, which is the smoke concentration.
Q. OD is optical density?
A. Yes, that's right.
Q. Right.
A. So you've got smoke concentration, cyanide concentration and carbon monoxide concentration.

Now, those are arrived at by me just putting in rough estimate numbers into my spreadsheet based upon their description of the conditions at that time, and by putting in that curve and running it right the way through the analysis, I end up with a calculation, which we'll look at in a minute, but I end up at a calculation of the dose they've acquired from breathing all those gases by the time they reached the bottom of the stair.

Now, these concentrations are constrained by the dose they eventually reach. So if I put in a profile like this and calculate the outcome, and I find that it predicts they collapse at the top of the stair, then obviously I put too much smoke and gases in the flat, so

I have to re-run with a lower curve. If, on the other hand, they haven't acquired enough, then I need to do more. So it's a kind of iterative process that I use to arrive at these numbers.
Q. Yes, I see.
A. So perhaps if we go on to the next graph.
Q. Yes, figure 5, page 56 {DAPR0000005/56}, please.
A. So this, then, from that gas profile I've just shown you, this is their calculated FED uptake, and this is just -- I've just plotted the carboxyhaemoglobin on this chart.
Q. 8.
A. So this is predicting the carboxyhaemoglobin in their blood with time from the time they first took refuge in flat 193 up to the time they walk out the bottom of the tower, or stagger out the bottom of the tower is perhaps a better way of putting it.

So the sharply rising part is the bit they've acquired in the stair, which is constrained by all the other people I've analysed on this figure of 1,800 ppm. The bit before that is the dose they must have acquired while in the flat in order for us to arrive at 30% at the bottom. By constraining it by that outcome -- and I feel this is quite robust, quite strong -- it means that -- and it's to some extent a surprising result to

me -- they cannot have inhaled more than about 9 or 10% carboxyhaemoglobin over that entire period they were sheltering in that flat from the smoke that had been leaking in from the lobby. So they were able, by taking various precautionary measures, to avoid a serious exposure.

Now, I just briefly will say why this is very significant, because when I worked for the Rose Park Care Home Fire Inquiry in Scotland, and we reproduced the actual incident there, one of the features of that incident was that there was a very large fire in a corridor which filled the corridor with about 10,000 parts per million of carbon monoxide, very similar to what I believe was in the lobbies at Grenfell, and there were a number of people who were in their rooms, behind closed doors and in closed rooms, occupants, during that incident. So they were in a similar situation. They were in juxtaposition to these very high concentrations in the lobby, but they were in their closed bedrooms, and they were there for up to 50 minutes before they were rescued. Those occupants, when they were rescued, were comatose and in fact subsequently died. So even though they were not in the same compartment, the same room as the fire, over that period of time, sufficient smoke and asphyxiant gases had leaked into their room,

about 1,000 to 2,000 ppm concentration over a period of an hour or so, to result in them ultimately dying.
So it could quite easily have been the case that something very similar could have happened at Grenfell, but it didn't, and this is my calculation demonstrating that fact.
Q. Does it also give you an indication of the last or a point in time at which one could exit the flat on that floor at that time and survive?
A. Yes. So I think it does show, in fact, quite -- that the time they left, just after about -- perhaps within -- just to go back to that particular case, then. So Naomi and Lydia were in the flat with the Choucair family, wasn't it? And they said in their witness statement that there was smoke in the flat building up over that period to some extent, and then as it got closer to the point that they left at about 3.10 -- so quite late leavers from that very high floor -- they saw that the fire was coming round, hadn't quite reached -- the external fire was juxtaposed to their flat.
Let me think. We're in flat 3. Oh, I was going to have a diagram, wasn't I? What happened to the diagram of Grenfell floor plan I was promised?
Q. We can find that for you, professor.
A. Hang on. If we go to page 13 of my --

Q. We can have it up. Let's just show it on the screen, {BLAR00000009/12}.
A. Yes, we want floors 4 to 23. We want that bit blown up really.
Right. So we are in a flat 3, aren't we?
Q. Just to say, this is from Barbara Lane's report.
A. Barbara Lane's report, yes.
Q. Phase 1 report.
A. It's just a general floor plan.
Q. Yes.
A. So -- that's right. Forgive me, I'm just trying to orientate myself here.
So in this particular case, the spread of fire to first reach that flat was coming along the south side of the tower, wasn't it?
Q. Yes.
A. So the first room to be affected was the first bedroom in this particular flat, or this column of flats. So what Naomi and Lydia saw was that the fire was about to come past the pillar in the middle there and was starting to -- was just about to attack that bedroom when they evacuated, and so the first room in that flat to be affected by the fire would be that bedroom. What they actually -- and the others were all sheltering, I think, in the living room, so they were able to avoid

initially that exposure. But what Lydia and Naomi said -- or Naomi, I think, I'm thinking of her statement -- was that by this time, the hallway of that flat was filled with very, very dense smoke, and they -- after their final 999 call just before about 3.09, they went to the bathroom to try to wet towels to cover their faces, and had quite some difficulty negotiating it to cross that hallway because of the density of the smoke, and they spent, I don't know, maybe 20 seconds or so getting these wet towels, and then they prepared -- they took one last breath -- that's right. They said, "We took one last breath from the only window" -- this would have been a west-facing window in the living room, where they could still get fresh air. They took a final breath of fresh air, and then they plunged through the smoke in the hallway of the flat, across the lobby and made it to the stair.
So you can see that the conditions were quite -- there was quite a lot of bad conditions in certain places, at least, in that flat at that time, and yet my calculations show that by sheltering in that living room and having access to an open window on the clear side, they were able to minimise their exposure up to that point in time, so that, unlike the occupants at Rose Park, they were in quite a good condition to be

able to still walk all the way down the stair.
Q. Yes, thank you.
Can we then go back to your report at {DAPR0000005/57} and go to paragraph 219. There you have, "Scenario 3: Inclusion of other asphyxiant gases in the analysis", and at figure 6, a little lower down the screen, if we can have a look at that, scroll down to figure 6, this is the "Full FED analysis for Flat 193 case", and you there set it out, taking into account all asphyxiant gases in addition to or including carbon monoxide.
Could you just talk us through that slide, please?
A. Allow me just ...
(Pause)
Yes, so this is for the -- yes, sorry.
Q. This is the --
A. I'm getting my head round this again. So this is just the third in the set, isn't it?
Q. That's right.
A. Yes, sorry. So this is still just for Naomi and Lydia, but this time I've included the full analysis, which includes the uptake of hydrogen cyanide, which you can see is the blue curve there, and -- what else have I got? Oh, yes, right. So as I mentioned earlier, the fractional effective dose calculation that we used for

a mixed gas set includes individual terms for each individual gas and the summed terms assuming simple additivity for the fractions of the various gases. I think I explained that earlier. So in this curve here I've got the fractional effective dose for carbon monoxide on its own, that's the red curve; I've got the summed fractional effective dose for cyanide alone, that's the blue curve; and then I've got the FED in sum, which is the black curve, which is for those two gases added together, and also includes some consideration of the influence of carbon dioxide on their breathing, and also of reductions in oxygen from the fire, which in this case is trivial, so it doesn't really affect the calculation.

What this illustrates is that they were overcome essentially by carbon monoxide, that's the biggest term in this analysis, but you can see that, based upon the ratios that we talked about earlier, I have estimated that there would certainly have been some contribution from hydrogen cyanide from these burning materials. And just to remind you, to the extent that that may have come from the cladding and insulation, the only material in the insulation producing the cyanide is the insulation. The PIR Celotex insulation is the source of cyanide. But to the extent that some of this smoke may

be derived from burning flat contents, we're talking about things like upholstered furniture, which also have a high nitrogen content.

So it just illustrates here that the dominant gas here that's causing incapacitation is carbon monoxide. When I later went on to look at the hospital data, the doses of carboxyhaemoglobin that people are acquiring and being affected by is almost exactly what you'd expect to see from carbon monoxide alone. So the influence of cyanide is relatively minor, in my opinion, in this case.

Q. You say it was relatively minor, but you also say it was significant.
A. Yes.
Q. You say that in paragraph 225 on the next page {DAPR0000005/58}.
A. All right.
Q. Explain how it is significant, if you can.
A. Yes, okay. It's there, it's having an effect, and we shouldn't ignore it. Now, I might be getting into some complexities here. There is quite a difference between the way people are affected by cyanide and carbon monoxide. They're both asphyxiant gases. It's possible that they have a fractionally additive effect, although there's still some uncertainty about that. But one of

the key features —— and I've got a figure that —— I might look it up in a minute —— I prepared that illustrates it —— is that if you're exposed to a low concentration of carbon monoxide and a very low concentration of cyanide, the cyanide has almost no effect. So, for example, if I expose you to less than 100 parts per million of cyanide, then you can function inhaling that gas for about 30 minutes at 100 ppm. But if I double that to 200 ppm, you're going to be unconscious within three minutes. So the effects of cyanide are partly dose-related but partly concentration-related.

Now, because we're dealing here —— because of the ratio that I established earlier, and because we're dealing here with moderate concentrations of carbon monoxide, it means that the concentrations of cyanide are low enough that it doesn't have —— it's not really driving the outcome, but it is contributing to some extent.

However, and this is where I suspect it may have had more influence on the occupants of the 10th lobby, because whereas here we're talking about 1,800 ppm of CO, in the lobby we might be talking about 10,000 ppm of CO, and the cyanide is going up proportionately. At those ratios and those concentrations, cyanide becomes

a more significant actor in collapse. Not so much in cause of death, but in cause of collapse.

Quite a lot of my work has been directed at looking at the relative influences of cyanide and CO in fires, and from fires containing relatively high concentrations of cyanide, like furniture, upholstered furniture fires —— funnily enough —— well, not funnily enough —— there has been in the last two days a press report of a prison fire in I think it was Ecuador or something, where the prisoners set fire to their mattresses, which are high nitrogen content materials, and I think there were 48 deaths. It happened in the last couple of days. So under certain circumstances, cyanide can be a very important driver of outcome. But in this particular case, because of the ratios, I believe it's having a —— it's there, but it's having a relatively limited effect.

Q. Can you just explain why, when it comes to the lobby on floor 10, you say the cyanide is going up proportionately there?
A. I need to try and find this —— excuse me a moment.
Q. I may be able to help you with that. Is it at {DAPR0000003/24}?
A. That's the one, thank you. Thank you very much. Yes.

So these are the results of some experiments I conducted at Huntingdon. So this shows the relationship between exposure concentration and time of consciousness for exposed subjects. These were in fact primates. The blue curve is for carbon monoxide, and the little table there shows you the relationship between inhaled concentration and time to incapacitation and CT product, which is the exposure dose to concentration.

So you can see that for these small animals, the concentration of dose, the dose of carbon monoxide at which they collapsed, became unconscious, was about 27,000 parts per million minutes, CT, for the first figure there. So at 1,000 ppm carbon monoxide, the concentration was 1,000, and after 26.6 minutes, the subjects became unconscious, and multiply those two figures together gives you 26,600, and it's just under 27,000.

When the experiment was repeated at 2,000, 4,000, and 8,000 ppm, the calculated dose at which they collapsed was always the same, as you can see there, it's a constant, it's just under 27,000 ppm minutes. So that's for carbon monoxide.

So dose and time are absolutely -- and concentration are equivalent. If you're exposed to half -- twice the amount for half the time, it has exactly the same effect as half the amount for twice the time.

Sorry, I've begun --
Q. Yes, I see. And do these two lines, the red and blue lines, interact?
A. Yes. So the blue one is the CO. But in contrast to that, if you look at the cyanide curve, it doesn't follow that pattern.
Q. No.
A. And if you look at the little table on the top right, I've calculated the two figures together. So if I get exposed to 87 ppm of cyanide, then I've got 30 minutes before I collapse, and you multiple those two figures together you get 2,610. But if I'm exposed to 300 ppm, I collapse after 0.9 of a minute, giving a figure of 270. So it's ten times more toxic, if you like, when it's at that higher concentration.
Q. Yes. I mean, would you have -- let me try this slightly differently.
A. Yes.
Q. If you were to eliminate the carbon monoxide from this, therefore take the blue line out altogether, would the line for HCN still look the same?
A. Oh, yes, so these are independent. They're not -- these were different experiments.
Q. Right.
A. One set of experiments is on CO, one was done -- I just

plotted them on the same chart.
Q. That's very helpful.
A. Yes, sorry about that.
Q. Now, can we then go back to your report, please, at {DAPR0000005/58}, and this is your calculation now part 4, paragraphs 229 to 233, where you've got the "Forward calculation of carbon monoxide uptake for flat occupants".

Is it right that you were able to use a number of markers to inform your analysis for individuals in different locations?
A. Yes.
Q. Yes. Did that include -- and let's just run through the pointers here -- is this right: that where some occupants in a flat successfully escaped and others were unable to, you were able to measure the exposure and uptake for all individuals in the flat as similar up until the time that the individuals successfully escaped?
A. Yes.
Q. Yes. Where you have 999 transcripts available for those individuals or those present, you have relied on the condition of the individual to estimate their level of asphyxiant intoxication; yes?
A. Yes.

Q. For example, if an individual was semi-conscious then they're estimated to have had an accumulated dose of about 40% carboxy?
A. Yes.
Q. For individuals who fell from the tower, their blood carboxyhaemoglobin was fixed, I think, at the time they fell?
A. Yes. So this is very sad, but actually it gives an exact point in time and an exact dose at that point in time.
Q. Yes, and you were able to use those levels, I think, to calculate their exposure and the exposure of those who were left in the flat at that time?
A. Yes.
Q. Yes. For those individuals who died in the flats, I think you have used their post-mortem blood carboxyhaemoglobin levels --
A. Where that was --
Q. -- where they were available --
A. Yes, yes.
Q. -- to estimate their exposure in the flat?
A. Yes, and then correlated, obviously, with any 999 call transcripts, yes.
Q. Yes, thank you.

Now, you have also explained, on the next page

{DAPR0000005/59} in section 4, that you have applied the "washout method" to evacuating occupants from the tower. Now, let's see if we can just have a bit more clarity on that --
A. Yes.
Q. -- for those who have never heard of the expression "the washout method".
You have described it at paragraph 234 at page 59, "Overview of method", but are you able to summarise that for us and just explain it in very simple terms?
A. Yes. So if you have inhaled a certain dose of carbon monoxide after a point in time anywhere, and then you are taken out of that exposure and you're exposed to air, as soon as you're exposed to air, every breath you exhale contains some carbon monoxide that you're excreting from your body. You're washing it out of your blood by breathing it out. So the concentration remaining attached to your haemoglobin, the carboxyhaemoglobin, decays with time. The longer -- as you breathe, it gradually gets washed out until it's all gone.
Now, the rate at which it's washed out depends upon the partial pressure of oxygen you're inhaling, because it's the oxygen that's driving it off your blood, and so we express this in terms of the half-life, the time it

takes to get rid of half of the dose that's in your body at any point in time. So the half-life of carbon monoxide in the blood of a person breathing air is very long, it's about four and a half hours. So if you walk out of a tower with 30% in your blood, it's going to take four and a half hours to get down to 15% left, okay? Long time. But if somebody gives you oxygen to breathe from a face mask when you walk out the tower, which is 100% oxygen, then the half-life is about 74 minutes, just over an hour. It varies a little bit with individuals, and I have obtained that figure from published studies on -- you know, in the literature, and if you look at the literature, you get various estimates. This was one recent publication looking at quite a large number of individuals, and they're all fairly close, but that's the figure I've used. So 74 minutes half-life of somebody breathing oxygen from a face mask.
Q. If we look at figure 8 on page 63 of this same part of your report {DAPR0000005/63}, there is a set of carbon monoxide washout curves for four persons evacuating from flat 183.
A. Would it be helpful just to look at -- there were a couple of diagrams I put in just illustrating the basic calculation first, and then --

Q. We can do that. I think that's at page 60 {DAPR0000005/60}. If we go to that.
A. Here we are. So this was just to illustrate what I've just said, really.
Q. Yes.
A. So the upper example is sort of semi-theoretical, but it's based on actual data. So imagine there's somebody in the tower, they walk out and they've got 30% carboxyhaemoglobin in their blood. They stand outside for 20 minutes before anybody gives them oxygen, so that's the little red bit at the top of the curve, and they're washing out the CO, but very slowly. They're then given oxygen to breathe and the curve then becomes steep. After about 70 minutes, they arrive at hospital and somebody takes a blood sample, and that's the first red diamond on the curve, and then various samples are all taken at intervals. So I can fit a curve to those samples -- this is what I've actually done for these actual hospital figures --
Q. Right.
A. -- and then I can back extrapolate that curve to the time they were first given oxygen, if I know what that is. So in this particular case, suppose I know they started at 20 minutes, then I can calculate that they had about 28/29% carboxyhaemoglobin at the time they

started breathing oxygen.
Q. Right, but --
A. Now, the lower curve is exactly the same thing, but in this case I've made a different assumption. So I've assumed that they came out of the tower from a lower floor, they had about 20% carboxyhaemoglobin, they weren't semi-unconscious or anything, so they weren't given any oxygen, but eventually they didn't -- they looked unwell, so they were taken to hospital. When they got to hospital, the same blood sample was taken and they were started on oxygen. So now my back extrapolation goes along that blue curve, because all the time before they got to hospital, they were only breathing air, and that means they could only have had about 20% carboxyhaemoglobin at the time they walked out of the tower. So that's just to illustrate the approach.
Q. Yes, I see.
A. So if we can -- do you want to move on to the next lot?
Q. Yes.
A. Sorry.
Q. No, that's very helpful.
The next lot is at figure 8 on page --
A. You were just going to ask about --
Q. Yes, page 63 {DAPR0000005/63}, and I think --

A. So this is for a set of actual Grenfell occupants --
Q. Yes.
A. -- from flat 183.
Q. Yes.
A. I have anonymised them, so I can't remember who they were, but basically for these individuals, I have a number of blood measurements taken at hospital, which are shown by the enlarged dots on those graphs, so those are actual readings, and from those readings I've fitted curves to their individual washouts for those set of individuals, so it gives you some idea of the variability of this method.
Now, the dashed line in there is the average 74-minute half-life curve, if you can see that little dashed line. So you can see that some of the occupants -- in the legend, I've put the calculated half-lives for these ones. So the dotted line is the published dataset curve factor.
Q. That's the 74 --
A. 74.
Q. Yes.
A. But 183, this individual, 183, you see their washout was to -- fitted to their actual data shows a slightly more rapid half-life of just under an hour, 59.8 minutes. So back calculating their figure, it gives a figure of

about 35% when they left the tower -- well, when they were first given oxygen.
And also 183B also had quite a rapid washout time. You'll notice that she had quite a high figure at the time she left the tower, but that individual was a heavy smoker. If you smoke cigarettes, you get quite a bit of carbon monoxide in your blood even before you're in the fire, so I think that's why her figure is a bit higher.
But the green curve was actually for a child, if I remember rightly, or a young person, and you can see it's quite shallow. They've got quite a long half-life, a longer half-life. That person was asthmatic, and when they got to hospital they were in some distress. The hospital tried to put them on a ventilator, put them in an induced coma and put them on a ventilator, and the hospital records show that they had great difficulty ventilating this person because of their bronchoconstriction, and they had to use a particular special method of ventilation called CPAP, which is a sort of pulsed air method, and by doing that, they were able to overcome this problem and ventilate this person so they made a good recovery.
But I think this curve shows that it's picking up the fact that this person was in an asthmatic state, and that's partly why the washout curve was shallower than

it was for the other individuals. So it gives some idea of the individual variation.
Q. Yes. Let's turn, then, on that topic, to individual characteristics and the effect of particular characteristics of the individual on the rate of uptake of asphyxiants.
Let's start with children, but when I ask these questions and you answer them, please don't name any of the children if you can avoid it.
A. I understand.
Q. Now, you have explained, I think, that the rate of uptake of asphyxiant gases by infants and young children is about twice the rate of that of an adult, which would then hasten the time to collapse and death; yes?
A. Yes.
Q. You have given us a number of examples.
First, does the increased rate of uptake for children apply equally between those who were sheltering in flats and those who were descending the stairs?
A. In a word, yes. Let me just go through that.
So, basically, for all animals, from mice to elephants, the amount of air you breathe each minute depends on the ratio of your body surface area to volume ratio. So the bigger you are, the less you need to breathe per unit body weight. That applies equally to

humans. So the smaller the child, the more it breathes per minute per unit body weight. I mean, in theory, I could do more accurate calculations of this, but because of all the unknowns that were involved here, it didn't seem appropriate.
As an approximation, a small child is going to -- who is sitting in a flat -- this is your question, sorry -- breathing carbon monoxide, their uptake rate will be approximately twice that of an adult sitting next to them. When they walk -- and this is quite important -- down the stair, both will increase by a factor of two or so. So an adult sitting in a flat is breathing 10 litres a minute, 8 to 10 litres a minute, we're all doing that here now. If we start to walk down a stair fairly vigorously, that doubles to 20 or so, and the same would apply to the child, from their -- double whatever they started at. Right?
If, however, the child was carried, so say it was an infant and was carried down, then of course they continue to breathe at their resting rate, because they're not exercising, and therefore a small child, say a three or four-year-old child, who is walking down the stair through the smoke is at much greater risk than the same child were they being carried, say, by a firefighter or a parent.

Q. Yes, that's very helpful.
Is it likely in all cases where infants or young children were sheltering in flats with their parents that they would have lost consciousness and died before their parents?
A. Yes. I mean, I think they certainly would have lost consciousness before the parents and almost certainly would have died before the parents, yes.
Q. What about young teenagers, slightly older children?
A. Well, it's in proportion, so still sort of say a 12-year-old, I would expect to see some evidence for that as well, but obviously it's in proportion.
Q. Yes.
A. I mean, it also applies to adults. So an adult with a large, heavy body mass would go for longer than one with a smaller body mass.
Q. Let's then turn to the relevance of asthma. You have touched on that a moment ago.
A. Yes.
Q. Can I just show you first an article that you co-authored in 2016. That's at {DAP00000003}. Let's have a look at the first page first. It's entitled "Assessment of Hazards to Occupants from Smoke, Toxic Gases, and Heat".
A. This is our chapter in the SFPE handbook, yes.

Q. Yes, indeed. If we go to the foot of page 1, you can see, I think, an indication of that. It's the copyright of the Society of Fire Protection Engineers 2016.
If we go, please, to page 27 {DAP00000003/27}, if we look at the second paragraph down on the left-hand column, in the penultimate paragraph break, you say:
"Asthmatics and sufferers of other lung conditions, such as chronic bronchitis and reactive airways dysfunction syndrome, are particularly susceptible to bronchoconstriction on even brief exposure to very low concentrations of irritants, with distress, severely reduced aerobic work capacity, collapse, and death resulting, depending on the sensitivity of the individual and the severity of the exposure.
"It is the objective of fire safety engineering to ensure that essentially all occupants, including sensitive subpopulations, should be able to escape safely without experiencing or developing serious health effects. Thus, safe levels for exposure of the human population to fire effluent toxicants must be significantly lower than those determined from experiments with uniformly healthy animal or even human surrogates."
Now, are you able to elaborate on how asthma might have affected occupants of the tower during the fire?

It's a very general question.
A. Yes, right.
Q. But focusing on how it might have affected their prospects of escape.
A. With pre-existing conditions?
Q. Yes. With asthmatics and other lung conditions.
A. Yes. So we've got -- it's quite a complicated question. We've got various things -- two things happening here: one is a sensitivity to asphyxiants like carbon monoxide as a gas, and the other is the effects of irritants.
Now, this material in this chapter here derived from a lot of discussions that we've had over the years in the ISO committee, where we're trying to produce standards in this area, and nearly all the work that's been done both on animals and human studies are based on otherwise sort of healthy individuals, and we have been trying to come up with the sort of numbers we've been discussing up until now on what sort of levels represent a danger of collapse for the average person and what might be a reasonable safety margin to put on a design constraint, which is partly what this chapter is aimed at.
It becomes difficult, because the objective data available for challenged individuals is rather limited, and so there have been a lot of discussions on where

this safety level should be put. I'm trying to address here the principle of it, and so what I'm saying here is that -- and I have some feeling for this, because I'm a severe asthmatic myself -- the irritants could precipitate an asthma attack. Irritant smoke could be inhaled and cause a severe bronchoconstriction, as in that example I showed you of the green curve earlier, which could, in itself, lead to some degree of incapacitation and collapse, even if there's no carbon monoxide present. So that's one issue that we have to think about.
The other is susceptibility to carbon monoxide. If you're asthmatic and you inhale a certain dose of carbon monoxide, would you be more susceptible? Now, I would think all the risk is on the downside, that you probably would be, but for the Rose Park Inquiry, I had quite a lot of access to medical data for the deceased in that case, and I published a paper where I looked at the relationship between carboxyhaemoglobin at death and pre-existing health condition. These were all elderly persons, as I am myself now, who had quite a lot of pre-existing conditions. What I found was a very clear relationship, negative relationship, between the carboxyhaemoglobin in the blood at death and pre-existing heart condition. So if you had a severe

heart or circulatory condition, then at death you had a lower carboxyhaemoglobin than one person who had a healthy heart. But when I did the same relationship for pre-existing lung disease, I didn't find any significant relationship. Quite surprisingly.
So some of these individuals had quite severe pre-existing respiratory disease, and yet the carboxyhaemoglobin at death was not particularly different from those who did not have those conditions.
So it's quite a complicated area, but I think a precautionary principle would say that you would expect to be somewhat more sensitive if you were pre-existing asthmatic or had some other condition.
Q. Right.
A. Does that help?
Q. Yes. So just working this through, then, when it comes to carbon monoxide as an asphyxiant, your opinion, based on your research from Rose Park, was that, when it came to lung disorders, it had no effect on the --
A. Limited effect, if any, yes.
Q. What about hydrogen cyanide?
A. Hydrogen cyanide? I think the true answer to that is we don't have any data --
Q. Don't have any data.
A. -- really, no.

Q. When it comes to irritants, even in the absence of carbon monoxide, my question is, going back to the green curve --
A. Yes.
Q. -- does the presence of an irritant which constricts the airways and therefore --
A. Slow the uptake?
Q. -- slow the uptake?
A. Yes, I've thought about this, and if it did anything, we would expect it to do so to some extent, but I would say it was going to have -- it would make a minimal difference.
If we're breathing carbon monoxide as a pure gas and one person is asthmatic and one person isn't, during that uptake phase, I wouldn't really expect to see any difference. If we're breathing smoke with CO in it, and one is asthmatic and one isn't, then we might see some difference, but I don't think it would be a big factor.
Q. Right.
A. In the rate of uptake.
Q. Why would the rate of uptake be different from the rate of washout in an asthmatic person?
A. Good question. Oh, yes, well, because they're not -- yes. So, right, let me just recap this and think through it.

If you're breathing the pure gas during the uptake phase, and one is asthmatic and one isn't, I would expect no real difference. But if you're breathing it with smoke, then there might be a difference.
Q. Right, I see.
A. I'm not sure I've got the answer to this, but we do seem to be observing that that person -- that's right, sorry, yes. So if you had essentially an asthma attack while you were inhaling this smoke and CO, then it might slow it up, I think. And what we're seeing with that green curve is somebody who is washing out during an asthma attack, and it's the fact that, in inverted commas, they've got bronchoconstriction which is impairing their breathing and gas exchange outside the tower in that green curve. So, by inference, you might expect to see a similar phenomenon on the way up, if you were there to measure it.
Q. Yes, thank you.
A. I'm struggling a bit here. You're getting a little bit outside my experience of what's actually happened in these cases.
Q. Fair enough.
Now, coming back to the question of irritants, is HCN, hydrogen cyanide, an irritant as well as an asphyxiant?

A. Not really, no. I mean, I think -- some people can smell it. I can smell it. Some people can't. It might have a very minor effect. But one of the reasons for the difference I showed you earlier in those two curves -- and there is a big difference -- is that carbon monoxide does not stimulate respiration. So if you're sitting here breathing, you'd breathe exactly the same whether there was carbon monoxide in the room or not. But cyanide is a very powerful respiratory stimulant, and in experiments I've performed on this, I found that if I exposed animals to, say, 150 parts per million of hydrogen cyanide, then their breathing went up by a factor of three within a couple of minutes.
Q. Right.
A. So that greatly enhanced the rate of uptake, and that's why they became unconscious so quickly. That's why there's a difference between --
Q. That's very interesting.
A. Sorry, I should have mentioned that earlier.
Q. No, that's very interesting, because when I asked you about the two curves, the blue and the --
A. Yes, that's the reason for the difference, yes.
Q. So does that tell us this: if you have the proportions of hydrogen cyanide to carbon monoxide here that we had at Grenfell --

A. Yes.
Q. -- the uptake of carbon monoxide was greater because of the presence of hydrogen cyanide than it would have been had hydrogen cyanide not been present?
A. Right. So if you're breathing hydrogen cyanide at something around 50 to 60 parts per million, then the respiratory stimulus effect of that is really quite mild, so the effect it would have on CO uptake would be quite minimal. But if you're inhaling cyanide at, say, 150 parts per million, then you get this massive increase in breathing and, as you say, if carbon monoxide is also present, it would enhance that.
So if you have, for example, a person who is otherwise at rest, breathing about 10 litres of air a minute, and they start to inhale 150 ppm of hydrogen cyanide, then within a couple of minutes they might be breathing 30 litres of air a minute, and so if they're breathing carbon monoxide as well, you'll triple the rate of uptake, even though you're not walking or doing anything else. And that may indeed be why we think we're observing some degree of additivity between these two gases in terms of toxicity. The additivity may be as a result not of any particular systemic toxic effect, which is quite complicated; it may simply be a reflection of the fact that the cyanide is stimulating

breathing and therefore the rate of uptake of the carbon monoxide.
Q. Right.
A. But it's quite a complicated area.
Q. Yes, I was going to ask you, have you done any analysis on your outcomes based on carbon monoxide subtracting the presence of hydrogen cyanide?
A. Well, what I'm saying is that for the stair cases that we've examined, where we've got the back-calculated hospital data, the relationship between the condition they're in and the carboxyhaemoglobin estimates in their blood, you can explain the outcomes for them pretty well entirely in terms of carbon monoxide.
The other thing I would say about the cyanide story is that it's very -- in certain circumstances, it can be quite serious in terms of time to collapse. As soon as you do collapse, your breathing drops right down, so that effect no longer occurs. I've measured this. And the uptake of cyanide tends, for that reason, to be somewhat self-limiting. It's quite a complicated story.
So what we're seeing is that it probably does not contribute greatly to death. The main seriousness of inhaled cyanide in fires is in this rapid knockdown, rapid collapse, which then leaves you in the situation where you continue to inhale all these gases and then

die.
Sorry, what was the question again?
Q. Well, the question was --
A. I haven't quite answered it, have I?
Q. The question was whether or not you had taken into account the stimulus --
A. Oh, yes, sorry, so that was the point I was coming to. I would say for the stair occupants, we would seem to be able to explain all that we observe, and for the flat occupants, really, in terms of carbon monoxide, perhaps with a minor contribution from the fact the cyanide was there. For the 10th lobby, I feel it may have, for the reasons I've explained, had a bit more -- some more of a significant contribution. But, still, CO is still a very important -- the major driver, I think.
Q. Right. So would you say that the stimulus effect of hydrogen cyanide on breathing was essentially negligible when it came to calculating the uptake of carbon monoxide, or did it have a material effect?
A. I would say for the stair cases, for the moderate levels of CO and therefore low levels of cyanide, it had a limited effect, plus also you've got to remember that, in the stair cases, they're walking anyway, so they're already exercising, so it's getting quite complicated.
As I say, where the lobby ones are concerned,

I think it may have had some influence, and to some extent taken ...
Q. What about the flats themselves before the time when the flame front attacked the outside of the particular --
A. Negligible.
Q. Can I just, in the few minutes before the break, turn to the impact of physical impairments on the prospects of escape.
A. Yes.
Q. Now, you have I think confirmed that your analysis of the potential for escape through the staircase would depend upon the occupants being able to descend the stairs and to do so in a time period shorter than would be required to accumulate the total threshold to collapse.
A. Yes.
Q. 30% or so.
A. Yes.
Q. If an occupant was impaired by a health condition from coming down the stairs at all or impaired from descending within the window of time before accumulating that incapacitating dose, would it follow that their prospects of escape were negated or reduced?
A. Yes. It's quite complicated, this, isn't it? Because from the examples that I put in there, and from my own

experience of trying to run down the tower, if you remember, I managed to -- I couldn't do it now. I achieved 9 seconds per floor, when I did it in anger. So if you're coming down the tower in smoke-free conditions as a reasonably fit adult, you can obviously travel down at quite a speed. The standard number that we use is 1 metre per second coming down a stair, linear travel.

If the stair is full of smoke, then you slow down, and you'll notice that although they said that they came -- they thought they travelled quite rapidly, I calculated that Naomi and Lydia were travelling at about 30 seconds per storey compared to my 9, so they were about a third the speed, and that fits in with what we know about travel in poor visibility conditions and smoke. There has been quite a bit of experimental work on this, particularly in Japan.

So if you're travelling in dense smoke, you're going to travel more slowly, and I've allowed for that, and so for each individual I've looked at who survived, I've looked quite carefully at how they describe their descent, in terms of some said they ran down, some said they came slowly, and I've tried to allow for that.

So if you have a disability but you can still walk -- and there were a number of examples of this in

Grenfell, one particular individual I remember who was assisted by another person to walk down -- then if you're walking through smoke, you may not be travelling that much different speed than an able-bodied person would, because you're all equally slowed down by the dense smoke. Are you with me?

Q. Yes.

A. If, of course, you're unable to come down at all, then obviously you're forced to remain in your flat.

Now, there was one particular case that struck me in reading through the Grenfell witness statements -- can I remember the name? I'm afraid I can't -- of a couple where the lady was quite severely disabled, physically disabled, and knowing that she would have no chance of coming down the stair, as soon as she became aware of the fire, she immediately, with her companion, got in the lift and came down at a very early stage, and therefore came down during smoke-free conditions and survived. So she had a game plan, she had a plan B of how to get out, if you like, which was extremely effective.

Q. But dependent on the lift?

A. Dependent on the lift, yes, in her case, yes.

Q. Yes.

Now, working back a little, then, what was the

maximum level of carboxyhaemoglobin blood saturation that an average healthy individual could safely reach while in the flat in order to exit the tower, assuming 30% or less carbon monoxide uptake and assuming your reference point of 1,800 parts per million of carbon monoxide in the stair column?

A. So we're talking really about this period after about 2.30 to about 4.00, when we had these conditions, so I would say, you know, about 9 or 10% preloading before you set off, yes, is about the -- above that, you're in trouble.

So, for example, in flat 205, Mr Neda fell from the tower with 20% in his blood at the time he fell. If he waited until that point and then decided to walk down, following his son and his wife, there was a good chance he would have not been able to walk all the way down, he would have collapsed on the way down, because he's preloaded 20. By the time he was halfway down the stair, he probably would have reached the point of collapse. You understand the point I'm getting at.

Q. Yes, I do, and the case you're referring to is Mr Mohamed Saber Neda.

A. Yes.

MR MILLETT: Yes, thank you. Thank you very much.

Mr Chairman, is now a convenient moment for the

lunch break?

SIR MARTIN MOORE-BICK: Yes, it is. Thank you very much.

We'll stop there, professor, for some lunch.

THE WITNESS: Thank you.

SIR MARTIN MOORE-BICK: We'll resume at 2 o'clock, please, and again, please don't talk to anyone about your evidence while you're out of the room. All right?

THE WITNESS: I understand.

SIR MARTIN MOORE-BICK: Thank you very much. Would you go with the usher, please.

(Pause)

Thank you very much. 2 o'clock, please. Thank you.

(1.03 pm)

(The short adjournment)

(2.00 pm)

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

THE WITNESS: Yes.

SIR MARTIN MOORE-BICK: Good, thank you.

Yes, Mr Millett.

MR MILLETT: Yes, thank you, Mr Chairman.

Professor, I would like to turn next, please, to an analysis of smoke and fire spread and the effects on the occupants, and look particularly at the occupants in the flat 6 group or column, and then the flats 1 to 5 group.

Can we start, please, with {DAPR0000005/64}, your report, at paragraphs 269a to g. Just summarising it there, is it fair to say that you examined the circumstances of the flat 6 occupants' awareness of the fire and their actions in the context of the conditions and the circumstances?
A. Yes.
Q. Why did you distinguish the flat 6 occupants' circumstances and experiences from those in flats 1 to 5?
A. I suppose there were two reasons, really. One is because obviously the flat 6 is where it all starts. But having looked at flat 6 and then looked at what happened subsequently in the other flats, I could see a clear pattern of distinction, if you like, between these two sets. The obvious point was that, as I said this morning, as the fire came up the tower in the first instance and arrived at each flat 6, and floors in succession, the flat 6 occupants became aware of the problem very, very quickly, often before the fire arrived, often their smoke alarms went off in many cases -- I documented the different ways in which they became aware in my report, I think -- and they reacted very quickly. Their first instinct was to go to the kitchen to see what was happening, and they saw the fire

arriving outside, by which time some of the flats were already filled with smoke. They then essentially grabbed a few very vital belongings or children or whatever and rushed out the flat, and they were able to do so because, when they opened the flat entrance door to the lobby, they found the conditions in the lobby relatively benign; there was either no smoke in the lobby or, in most cases, quite thin smoke.

There were a couple of cases where the filling of flat 6 was so rapid and severe that the occupants had some difficulty in escaping, even in that very short time. Quang Van Ho, was it, he and his wife got caught in dense smoke in the lobby, and in his witness statement, I read that he found himself trying to get his wife to the front door so they could escape from their flat, and having some difficulty opening the front door, finding the latch and things to get out.

So it wasn't that simple, but he and all the other flat 6 occupants all made it out reasonably well into the lobby and then into the stair, and they were able to do so because the conditions in the lobby and the stair were smoke-free at that time. That's the point.
Q. Yes.
A. And that differs -- now, of course, some of the occupants of the other flats were coming out at the same

time and followed the same pattern in the early stages, but after the lobbies became filled with smoke, you see that the pattern of response in the other flats is quite different, in that people were staying there. Some of them made multiple attempts to try and enter and cross the lobbies but were repulsed each time, before they either remained in their flat or finally got out.
Q. Yes.

If we could turn to the foot of the page {DAPR0000005/64}, please, paragraph 272, you say this:

"From the times at which the occupants of each Flat 6 left the Tower and other witness information I have estimated the time at which they left their flat to enter the lobby and stair. For the purposes of this assessment I have estimated a descent time of 12 seconds per floor, 10 seconds to reach the lobby from the flat and 60 seconds collecting clothing and other belongings once a decision to leave the flat has been made. (Elsewhere in my report I have made more accurate estimates of descent rates for individual occupants)."

Is it correct to say that your standard method -- which is my phrase, not yours, I think -- for estimating flat evacuation times has been to allow 60 seconds for collecting belongings and children, perhaps, and other things after deciding to leave, plus 10 seconds to reach

the lobby from the flat, plus 12 seconds per floor of time spent descending the stairs?
A. I did for that particular tabulation exercise I was performing at that time.
Q. Thank you.
A. Obviously what I'm trying to do here is to use the time of tower exit as one indicator to back calculate the time that they entered the stair and hence left the flat, but that's taken in the context of any other information that's available, such as 999 calls, other people or meeting other people. You know, it's quite a complex exercise to estimate these times.
Q. Yes, and you go on to note that you have made more accurate estimates of descent rates in particular cases.
A. Yes.
Q. Let's look, then, at page 66 {DAPR0000005/66}, please, two pages on, figure 9.
A. Yes.
Q. You have "Estimated Flat 6 exit time in relation to time of exterior fire arrival outside kitchen windows".
A. That's right.
Q. You say, if you go on to paragraph 279, just below that --
A. Yes, at the bottom, yes.
Q. -- if we could have that paragraph fully on the screen,

this is what you say. You say:
"An important finding is that many of the Flats 6 occupants were able to move away from the fire at the kitchen and living room windows and to evacuate the flat into the lobby without experiencing significant or prolonged exposure to toxic smoke and without significant exposure to asphyxiant gases."
A. Yes.
Q. Now, in general terms, is your opinion that that meant that they had relatively low exposure --
A. Yes.
Q. -- to toxic smoke and gases in their motivations?
A. Right. So, yes, what I'm saying is that, firstly, because they were moving away from the smoke towards -- into a clear area, they were able to do so. Because they did it so quickly, obviously their exposure to anything else was very limited.
Q. Yes. Does that contrast markedly with the situation in the flats 1 to 5, where the occupants were moving towards the smoke?
A. Yes.
Q. And felt unable to leave because of the dense lobby smoke?
A. Exactly.
Q. Yes.

Now, if we go, then, please, to page 69 of this same part of your report {DAPR0000005/69}, paragraph 291, you say there:
"My general finding is that smoke in Flats 6 preceding arrival of the fire originated from the burning exterior materials on lower floors, was mainly associated with open kitchen or living room windows, was generally light (but sufficient to activate smoke alarms), and generally occurred shortly before the arrival of the exterior fire. The exception was Floor 9 where smoke penetration was more significant and occurred well before the arrival of the exterior fire."
Now, do you know why floor 9 was an exception?
A. Not offhand, sorry.
Q. Right.
A. Just an observation that it was. I'd have to look at my notes to see what I'd said about that particular floor.
Q. Let's then turn to the conditions in the lobbies. I think there were three stages of smoke development.
Can we start, please, at page 73 of this self-same report {DAPR0000005/73}, paragraph 306. You say there:
"The development of smoke in the lobbies was a continuous process, becoming progressively worse over a period of several minutes, then maintained for several hours during the fire."

Then if you would go down the same page, please, to paragraph 308, you break up the development of smoke into three phases, three segments, and you say this:
"a) Early development of a burning smell and thin general smoke haze (before approximately 01:10-01:25), resulting from slow infiltration and permeation through the building of smoke originating from the burning building exterior.
"b) General smoke filling and poor visibility in the lobby:
"i. On some floors a period over which the general smoke density increased over a period of a few minutes, the smoke colour darkened from grey to black, became more irritant and difficult to breathe, and the visibility decreased progressively to a few metres or less.
"ii. On other floors a period over which a layer of dense black smoke was observed spreading over the lobby ceiling, then filling the lobby from the ceiling level downwards within approximately 1-2 minutes.
"c) On most floors a time from which the lobby was filled with dense black smoke, which leaked into the adjoining flats around the entrance doors (and possibly via other penetration routes). When flat doors were opened occupants then reported zero visibility in the

lobbies (for example 'could not see anything' [and that's a footnote to Branislav Lukic's statement] or 'couldn't see ... a hand in front of my face' [and that's a reference to Oluwaseun Talabi's witness statement])."
Now, those are the three stages.
Are you able to divide those up into timing, do you think, to time slices?
A. Can we just go back to the --
Q. Go back a page to page 73.
A. Yes.
Right, so we've got the early period up to about 1.25, depending on which floor you're on, I suppose, you know, because it's sequential with the floors.
Q. Yes.
A. So this is the period when, for example, on the top floor, the Neda family were becoming aware that there was something going on, that there was noise and there was smell and various things like that, and of course, as I think I talked about in my Phase 1 report, all buildings have to have an air exchange rate, you know, in order to keep the air fresh. So all buildings are to some extent leaky, and the fact that there's smoke flowing about, you're bound to get some degree of slow smoke penetration throughout a building in these kinds

of circumstances, so this isn't particularly hazardous, but that's the first thing that certain people became aware of at various times.

Then you've got the period after the fire has broken into flat 6 on each floor when it starts to come out from flat 6 into the lobby, and I think what I'm describing here was, I remember, two ways in which that might happen: one is that if the flat 6 door is open, then you get a fairly energetic plume, ceiling jet of smoke flowing out that's reasonably hot, or higher temperature, which comes out across the ceiling. So people who would observe that would say, "I saw a thick layer of smoke just under the ceiling". But underneath that, the conditions are clear. That layer then rapidly fills down as the smoke flows into the lobby, and, in fact, that was observed by a number of people, who saw this layer, went back into the flat, came back a minute layer and then saw it was much deeper. So that's a sort of fairly energetic way in which the smoke is filling.

Another scenario is where the flat 6 entrance door is closed for most of the time, and it's coming in through leakage, and then you get a more mixed darkening of the whole layer.

And this is this period when this —— on floors where

rapid filling occurred, from my examination of the timing evidence, I would say that from nothing serious to quite serious dense smoke, we're talking about a period of a few minutes after the fire reaches the flat 6 on each floor.

So on any particular floor, the fire gets to flat 6, flat 6 fills with smoke, the occupants leave. As they leave and open the door, and especially if the door doesn't close behind them, as happened in many cases, you then have rapid filling of that lobby with pretty dense smoke within a few minutes. So that would be —— so the time period during which this is happening is the time of arrival of the exterior fire between about 1.15 and 1.27 outside each flat 6, plus sort of three to five minutes on each floor.

Q. What was the principal cause of the ——

A. Well, from the evidence that I've examined, which I'm talking about mainly witness statements, I would say this smoke is coming from the exterior, it's flowing into and through flat 6, and then out through the flat 6 entrance doors and other leakage paths and filling the lobby from there. So I would say the main source of that smoke —— in the early —— in the initial stages, this is the point.

Q. Yes.

A. So if we're talking about within, say, five minutes or so of the arrival of the exterior fire outside each floor, that smoke is coming from the exterior fuel packages 1 and 2, which is the exterior burning materials and the window surround materials and window ledges, the PVC window ledges.

After, say, 1.49/2.00ish, then we start to see evidence from the outside of the building of large interior contents fires in certain flats on certain floors. So there appears to be quite a lag between the initial energetic exterior fire and when we're seeing considerable involvement of the flat contents.

Q. Yes.

A. And then when what happens, of course, the flat contents are substantially adding to that smoke.

Q. Now, let's then turn on to page 78 {DAPR0000005/78}. I want to ask you about the status and effect of the flat entrance doors being opened or closed or unknown, and you have covered each of those.

A. Yes.

Q. If we start on page 78 with section 3:

"Floors on which the Flat 6 door was stated to have been left open when occupants evacuated."

A. Yes.

Q. You say there at paragraph 316, just above that, so

you're dealing with the last part of the last section:

"After Flats 6 occupants evacuated their flats the rate of smoke filling of the lobbies and time to developments of dense smoke conditions was highly dependent on whether or not the Flats 6 occupants left their flat entrance doors open as [they] left or whether they closed them. In the following I have summarised the timing and extent of smoke filling in three groups: those for which the occupants stated that they left the Flats 6 entrance doors when they left ..."

A. That should be "open".

Q. That should be "open", I was going to ask you. That should say "open".

A. Yes.

Q. "... those who reported that they closed their flat entrance doors; and those floors for which the status of the entrance door was not reported."

A. Yes.

Q. Now, if a flat 6 door was opened or left open, how did that affect the conditions in the lobbies?

A. So if the flat 6 door was left open and if it remained open, obviously, then there was a clear path for smoke to flow out, particularly under the ceiling, as I've described, from flat 6 into the lobby.

Now, of course, these had —— well, were designed to

have self—closers on them, and so when people left, even if they left them open, they were supposed to automatically close, but there seems to have been a problem with this.
Q. Right.
You say at 317:
"When flat doors were held open or left open, (Floors 10, 11, 14, 16, 17, 20) and Flat 6 occupants left after their flats filled with smoke, the flow of smoke and filling of the lobby was rapid."
A. Yes.
Q. Those are the floors, I think, where you've identified doors being held open or left open.
A. Yes.
Q. When you say held open, do you mean held open permanently or held open ——
A. No, there were a couple of cases, or at least one I can think of, where, for a period of time, the occupant held the door open. There was one case where the occupant held the door open while he was waiting for his father to come out, and he described the smoke flowing from flat 6 out into the lobby with some force, such that he found it difficult to hold the door open while he waited for his father to come out. After his father came out, he managed to shut the door, and then the flow of

smoke —— temporarily, at least —— ceased.
Q. If the flat 6 door was closed, how did that, in turn, affect the conditions in the lobbies?
A. Well, on some of the floors where the occupants said that they closed the flat doors —— perhaps we should look at my diagram in a minute ——
Q. Yes.
A. —— there was a clear considerable delay in smoke filling the lobby, particularly on the —— these are mainly on the lower floors, but not all of them. The 18th floor, for example, was one where there was a good 20 minutes or so before the lobby became filled with smoke.
Q. Yes.
Now, let's just do the comparison. You referred to a diagram. I think we need to look at page 86 {DAPR0000005/86} —— tell me if this is wrong, professor —— figure 11.
A. Yes, so this is a plot I made.
Q. Yes.
A. So, as I say, there was a lot of work involved in this. I spent a lot of time looking at all the witness statements and trying to put time markers for all the statements they made to find the best estimate of the times at which people first reported either a thick layer under the ceiling or dense smoke according to the

key I've got there. I've plotted those times in relation to the time of arrival of the fire outside each flat, which is the blue spots there, so that comes mainly from Professor Bisby's analysis of the time of spread up the tower, but I've also examined the photographs myself and, you know ...
So the first line is the time at which the exterior fire arrives outside flat 6 on each floor, and the two dotted lines fitted after that are for two minutes after that and for five minutes after that, and for taking the right—hand side there, the sort of purple filled squares are the times when a witness reported dense smoke—filling of the lobby.
Now, obviously, these are the latest times at which dense filling occurred, because you only can make the comparison if a person was there to observe it. So the fact that they observed it at a certain time but weren't there before it, it could have already preceded that, but it can't have been later, if you understand me.
Q. Yes. So is an example of that floor 9 here, where you've got a differential in timing ——
A. Right, so ——
Q. —— from the time at which the exterior fire ——
A. Yes, so there's ——
Q. —— spread on the exterior cladding of 1.19 ——

A. —— 40 minutes or so there, so ——
Q. Exactly.
A. So that was one example. I think that's one where the door was closed and the lobby remained relatively smoke—free for quite an extended period.
Q. Yes. That wasn't a floor on which you found an open ——
A. No, I think it was closed, that one, yes.
Q. Yes. But otherwise, the correlations are fairly closely grouped around about the five—minute mark, aren't they?
A. They are, aren't they? Yes.
Q. If we go, please, to paragraph 315 on page 78 {DAPR0000005/78}, you say this, in the last four lines:
"Critically, although most of the flat doors had been fitted with self—closing devices, many occupants reported that these did not work or had been removed, so that they had to manually close the doors to ensure they were shut."
And you attribute a number of occupants' witness statements as the basis of your evidence there.
My question is: how did the presence or absence of self—closing devices on the flat 6 entrance doors affect the conditions in the lobbies?
A. The reason I have highlighted particularly flat 6, of course, is it's the first one to be affected, so it's the one that if —— were the first flats to be filled

with smoke, and therefore, if the doors were open, the first ones to allow smoke to flow in quantity out into the lobbies. So that's why flat 6 is critical in this regard. But, of course, it would also apply to all the other flats later on.
Q. Yes.
If we go to the next page, page 79 {DAPR0000005/79}, table 11, just picking that point up a bit, this is a table labelled:
"Arrival times of exterior fire outside Flats 6, timings of lobby smoke filling after Flat 6 entrance door stated left open."
A. Yes.
Q. We have floors 10, 11, 14 and 16 there.
A. Yes.
Q. Then we can go over the page -- I'm sorry, this is not the end of the table -- scroll down to page 80 {DAPR0000005/80}, you can see you have also got floors 17 and 20.
If you go to page 82 {DAPR0000005/82}, you have got table 12, which I think is the flat 6s where --
A. The occupants stated that they closed the doors, yes.
Q. Exactly, so they're known, and that leaves, I think, five floors where the status of the flat 6 front doors was unknown.

A. Yes.
Q. I have counted them as 12, 15, 19, 22 and 23, those floors.
A. Yes.
Q. Yes? I think you have got that on page 84 {DAPR0000005/84}, table 13, if we just go to that, which I think shows three of those floors, but you've also got others too; yes?
A. Yes.
Q. So you have got 12, 15 and 19 there, but there's also 22 and 23, because we know that those doors were unknown.
Are you able to form any view about whether the preponderance of the smoke in the relevant lobbies on those floors came from flat front doors being left open as opposed to being open briefly while the occupants went through them?
A. On these ones where we don't know, do you mean?
Q. On the ones where we do know. Well, on any of them, in fact.
A. Okay. When -- as people -- there were some observations. As people actually --
Q. Let me rephrase.
A. Yes, carry on.
Q. I think I have muddled you.
In the cases where there was dense smoke in the

lobbies, can you tell whether the preponderance of smoke on those floors was because the flat front doors were opened and left open as opposed to being opened to allow access and then shut again?
A. I think we can to some extent, yes. So there were descriptions from the witnesses of smoke flowing out with them, as it were, as they left the flats, who then closed the doors, and some people quite clearly stated, you know, that they did this. The extreme example I just gave you was one where they felt this pressure of smoke forcing its way out into the lobby, but then succeeded in closing the door, and quite clearly stated that after they closed the door, the smoke flow ceased, and that at this point, although there was a bit of smoke in the lobby, it wasn't severe, and other people coming out of that floor at those times were able to move around without too much difficulty. So --
SIR MARTIN MOORE-BICK: Forgive my interrupting you --
A. Yes, sorry.
SIR MARTIN MOORE-BICK: -- but this is all very much your assessment of the original evidence, is it?
A. My assessment of the witness evidence, yes.
SIR MARTIN MOORE-BICK: Yes.
A. Yes.
SIR MARTIN MOORE-BICK: I don't know how far you have taken

into account what was said in the Phase 1 report about --
A. Well, I have --
SIR MARTIN MOORE-BICK: -- which reflects an analysis of quite a lot of the evidence.
A. Yes. Well, I have, obviously, studied the Phase 1 report as well.
SIR MARTIN MOORE-BICK: Yes.
A. But this -- I mean, I basically went to the original source for most of my --
SIR MARTIN MOORE-BICK: All right, thank you.
MR MILLETT: Let me see if I can just illustrate this differently, and then we can move on from this point.
Can we please have up at the same time tables 11 and 12. Now, table 11 is on page 79 and runs to 80 {DAPR0000005/79-80}, that's the open door table, and if we have table 12 as well on the right-hand side of the screen, which is on page 82 to 83 {DAPR0000005/82-83}. They just about fit together. Those are the closed doors.
A. Yes.
Q. Just working through those, it's right, I think, that the time for the lobbies on the floors to fill with smoke from the time the exterior fire arrived at the relevant level was longer than on the floors where the

doors were left open, except floors 8 and 21, where the smoke-logging of the lobbies occurred within two to four minutes of the flame front attacking the exterior on those floors.

A. Yes. So from what I remember of this, there were -- the general picture was if people said they left the doors open, all those floors filled quite quickly. If people said that they closed the doors, on most of those floors, there was some delay. But there were a couple of floors where even though the doors were supposed to have been closed, we still got quite rapid smoke-filling of the lobbies, even though the doors were stated to have been closed.

Q. And what was the explanation for that?

A. Well, the only explanation I can suggest is that it was other leakage paths around those doors or through other penetrations between flats 6 and the lobbies --

SIR MARTIN MOORE-BICK: Isn't one of the difficulties here that witnesses may say "I left the door open" or "I closed the door", and one tends to draw from that a conclusion that the door was either fully closed or fully open, whereas in fact it may have been somewhere between the two?

A. That's possible, yes.

SIR MARTIN MOORE-BICK: I mean, this is quite highly

conjectural, isn't it?

A. Yes, I'm only basing this on what the observations were of the outcome and what the occupants said they observed, but whatever else between those is, as you say, a speculation, yes.

SIR MARTIN MOORE-BICK: Yes. Thank you.

MR MILLETT: Against that caveat, what, in your opinion, was the source of the smoke in lobbies where the flat 6 door-closers did work?

A. Even where they were closed but it still filled up?

Q. So let me give you an example. Page 83 {DAPR0000005/83}, top of the page -- if we scroll down on the right-hand side, please, to the next page, page 83 -- you've got floor 8 with doors closed, and a time of filling up of three to four minutes.

In your words, could you identify a reason for that behaviour in comparison with the other floors, where you've got 11 minutes or 12 to 24 minutes, as you can see?

A. This was the flat, I think, where the occupant found, as I said, the smoke pushing and he had difficulty holding the door. He was holding a door waiting for his father to come. That's the one, I think.

Q. Yes.

A. So that may be some of the -- so that one. But, I mean,

it's difficult to summarise this in a table, but from what I remember of reading the witness statements for all the witnesses on that floor, and I think from Patel himself and his father, their statements were that once they -- this allowed quite a bit of smoke to flow out during that period, but once they then closed the door, they observed the smoke flow to cease, at least temporarily, although that floor did subsequently fill up in time. So closing the door did dramatically reduce that smoke flow, once they did it.

Q. Yes.

Now, can we then turn to the question of the impact of lobby conditions on escape attempts, and you cover this at page 88 {DAPR0000005/88}, the same part of your report, paragraph 335. You say this:

"On floors where there was rapid smoke filling of the lobbies, many occupants from other flats became trapped in their flats (or moved to other flats at an early stage and then became trapped)."

We will come back to the question of evacuation through the lobbies in due course, but in brief terms, can you tell us: how did the differing smoke levels in the lobbies affect, first, the decisions of occupants trying to escape? And there are other things as well, but first of all the decision.

A. Yes, I think we addressed some of this this morning. If you remember, I was raising this idea that we're sort of weighing influences on people, and it's a combination of physiological effects and effects of smoke, which is why I'm clearly concerned with this, is it's an effect of smoke, and the situation that those occupants found themselves in and their motivations as to how strongly they were motivated to want to escape or felt able to escape. And as I've explained, it's not a simple physical thing; it's the outcome of the balance of all these influences on the individual persons.

But I read many accounts where, once people had initially stayed in their flats and then come and tried to open the entrance door to their flat with the intention of leaving, they were confronted by dense smoke and therefore closed the door and went back into the flat, and quite a lot of people -- and I actually prepared a table for this, which I have got with me I think somewhere -- they tried on multiple occasions, they made multiple attempts to try to get out and cross that lobby and go into that stair, and some of them three or four times were driven back by the conditions that they were facing.

I think the term used in the Chairman's Phase 1 report was "felt unable to", which is true, but I don't

think it really quite conveys the enormity of the situation these people were facing. Not only did they have the immediate problem of the horrible conditions they were facing in the lobby, but they also had the question of: if I were to make it through this lobby to the stair, what's it going to be like in the stair, and what's it going to be like, if I'm on the 18th floor or something, lower down? It could be much worse. There could be a raging inferno in the stair, for all I know. So all these things are going through one's mind, obviously, and influencing activity.
In fact, a number of occupants said, having taken that risk and got across and got into the stair, they said, "If only I'd known, if only somebody had told me that the conditions in the stair were nothing like as bad as they are in this lobby, I would have left a long time ago, you know, earlier in the fire".
Q. How did the differing smoke levels in the lobbies affect the experiences of occupants in making attempts to escape?
A. So, as I say, they open the door, they either didn't go out or they went out, some of them went out and came back, and they were then exposed to this difficulty in seeing, obviously the fear of the situation, and the irritancy of the smoke, the difficulty -- effects on

their breathing, choking, these kinds of symptoms that were very distressing and made it very difficult for them to proceed, basically.
Q. Would you also take account, in assessing the balance that you've identified, of particular individual characteristics of the occupants of the flat, and I'll give you a short list: so, first, physical impairments such as asthma or mobility problems?
A. Yes.
Q. Cognitive impairment, such as a mental health difficulty?
A. Yes.
Q. Age?
A. Yes, yes, it did affect some of them, yes.
Q. Pregnancy?
A. Well, a number of pregnant ladies did in fact go, but it caused them problems, yes.
Q. Previous unsuccessful attempts?
A. Oh, yes. Well, I didn't actually categorise these, but those are the sorts of things, yes, that could have influenced their decisions, yes.
SIR MARTIN MOORE-BICK: These are all factual matters which we investigated on a previous occasion, surely.
MR MILLETT: They are, Mr Chairman, but they're also --
SIR MARTIN MOORE-BICK: So what are you asking the professor

to help us with that's a matter of his expertise?
MR MILLETT: Yes, the professor has given expert evidence based on his expertise of not only the physical and toxicological effects of smoke, but also the behavioural, and these are simply aspects of --
SIR MARTIN MOORE-BICK: But they're all going to be manifest in conduct or people's description of what they saw or felt or did, which we've largely covered, I think.
MR MILLETT: Yes, but what I'm seeking to elicit is the expectations of somebody confronted with thick smoke.
Would it make a difference to the way they reacted and thought about or weighed the decision whether to cross the lobby that they were old or pregnant or had made previous unsuccessful attempts or, coming to my last one, had children in the group?
A. Yes. Of course, the other factors I mentioned earlier this morning is: is the exterior fire coming in through the window at this time or not? Another big --
Q. Yes, which would be a propulsive thing.
A. Yes, exactly.
Q. Yes.
Now, let's turn to the stair. Page 92 {DAPR0000005/92}, paragraph 352, which continues over on to 93. On page 92, you have a long paragraph here, 352, which I'm not going to read in its entirety to you, but

I think you identify four stages of toxic smoke development in the stairs, and I just want to run through them, just to get you to confirm it.
The first is (a), the period before there was any smoke in the lobbies or stair or any light smoke or a burning smell; yes?
A. Yes.
Q. And then the second one at (b), a period where the stair was clear or had only some smoke in it, but where the lobbies were filling with smoke.
A. Yes.
Q. Third, I think, at (c) is where there was obvious smoke in the stair with visibility still approximately a few metres. Smoke was irritant but escapees could escape without experiencing dizziness or collapse, but that the smoke in many of the lobbies was dense.
Then the last one, over on page 93 {DAPR0000005/93}, 352(d), dense smoke in the stair, limited or zero visibility, smoke highly irritant, escapees might have felt dizzy, weak or lightheaded, and, in the event, some collapsed and were rescued or died in the lobbies or the stair. But you go on, I think, to say in the middle of that paragraph:
"During this stage escape via the stair from all floors was hazardous, but still possible."

Are you able to -- and I think you have -- summarise for us the time slices into which each of these four descriptions --
A. I'll try, yes. Let's go back a page.
Q. Let's go back to page 92 {DAPR0000005/92}.
A. Yes. So the period before there was any smoke in the lobbies or stair or only light smoke. So we're talking about the time before the lobbies were filling with smoke, and at that time the stair was also clear of smoke. Then you've got the stage -- so that would take you -- well, it depends on the floor you're in, but it's taking you up to the period between about 1.20 to 1.30 kind of thing, depending on the floor level. So during this early period, before there was smoke in the lobbies and the stair, obviously it was relatively -- there was no obstacle to getting out.
Then you've got a period when, as I described a minute ago, the lobbies were filling with smoke. So this is after 1.25 to 1.30, when the lobbies are filling with smoke, but the stair is still pretty well smoke -- there's only light smoke in it. So some people were having difficulty crossing the lobbies, but once they got into the stair, things were not too bad. I suppose that period sort of ends when -- I'm trying to think what (c) is going to be, but we're moving up towards the

sort of Petra Doulova point, where the last people who were able -- who went through dense lobby smoke to get into the stair, but once they were in the stair they were facing reasonably benign conditions and were able to escape.
What was (c)?
Q. (c) is, if we go to 92, a period when the smoke in many lobbies was dense. Go back to (c).
(Pause)
A. Yes, I think this is, from memory, around about the time leading up to about 01.40 to 01.50ish, the last few people to come down. Now, I paid particular -- and it's all detailed in my stair appendix. But the point I'm trying to get at is there was a period when people were able -- although there was some smoke in the stair, people were able to descend without much difficulty and continued down and came out.
Then there was a period when there was starting to become significant smoke in the stair, and there's some quite good descriptions. There's one particular description, for example, of somebody who came into the stair and said he observed people coming in, opening the lobby doors above and below, and smoke flowing into the stair, and how the stair was starting to darken.
There was one particular case which I found

instructive of a couple -- and, again, this is this mixture of behaviour and physiology. So you've got a couple, I think they had a child with them as well, who -- this is at a relatively early stage -- came down the stair, and they found a lot of smoke coming into the stair around about the 4th floor level, where the firefighters had got the doors open for firefighting purposes, and so there was a -- so the stair was reasonably clear of smoke for the first few floors they descended, and then they came across this dense patch. The husband was willing to carry on, walk through this smoke, he wasn't repelled by it, but the wife was concerned and was too frightened to go through it, wouldn't go through it and called him back. So they both went back up to their flat. I'm using this as an example of, again, this complicated interaction between the toxicity, the physiology of the smoke, how it interacts with other aspects.
SIR MARTIN MOORE-BICK: Just so we understand clearly, are you saying that the smoke had an effect on people's cognitive ability, or are you just saying --
A. No, no, no.
SIR MARTIN MOORE-BICK: -- people recognised that there were pros and cons -- I mean, we might all see that people might see there were risks of staying and risks of going

and they had to balance them up, but I'm not sure whether you're saying as a toxicologist that the existence of certain levels of smoke actually affects their reasoning?
A. I'm with you. I understand the question. No, I'm not saying it affects their reasoning ability; I'm saying it affects their decision-making processes based upon the physical symptoms they're suffering or experiencing. So the fact that the smoke is irritant, for example, may be more of a deterrent for them continuing than if it was non-irritant, or if this was thin or thick.
SIR MARTIN MOORE-BICK: But that's just a matter of the facts of the situation, isn't it? I mean, people are put in an impossible situation, there are strong factors --
A. Yes.
SIR MARTIN MOORE-BICK: -- inducing them to try and escape, and there are other quite strong factors -- perhaps overwhelming factors -- telling them that they shouldn't try and go through dense smoke, and this is one of the dilemmas that unfortunately they were facing.
A. I think, yes, but part of, if you like, my dilemma as a toxicologist looking at this is to say: what is the relationship between the visibility, the density of the smoke and its other chemical toxicological attributes,

and people's willingness or ability to move.

Now, one of the things that we can measure fairly objectively is walking speed in smoke as a function of -- and people have done this in volunteer studies -- the smoke density and irritancy. So there was a famous body of work by Professor Jin, a Japanese professor, who got volunteers to walk down a smoke-filled corridor and measured their walking speed as a function of smoke density and came up with a nice relationship. He then repeated the experiment with smoke -- and this was sort of theatrical smoke, so it was non-irritant. He then repeated the experiment with smoke from a bee smoker, actually, he used, which is very irritant wood smoke, and he found that, at a given physical density, optical density, people were much more inhibited, you know, at a much lower density for the irritant smoke than they were for the non-irritant smoke.

So that's a sort of -- now, that's something that's fairly easy to measure, in the sense that you're measuring a physical property of movement speed, but my point here is that even more serious in its effect on the outcome is the effect of these phenomena on people's behavioural response, and it's not a simple -- it's a serious question: what's the relationship between whether somebody will -- or of a population of people,

how many of them will be able to get out and how many won't as a function of the properties of the smoke is a serious toxicological question. But unfortunately the answer, as I'm trying to explain, is a mixture of behavioural and physical phenomena and so, therefore, quite difficult for us to address, in a way, but it's nevertheless a real problem, a real issue.

In the case of this particular couple, just to finish the story, having gone back to their flat, the firefighters then came to assist them to evacuate, which then gave them the confidence to come down, by which time also some of this smoke had partially cleared and they were able to carry on.

So I'm just raising this -- I mean, I think it has very serious consequences for the outcome of any design or any, you know, situation like this, and we have to understand that these factors are having a profound effect on the outcome. That's my point, really.

Does that help? Sorry.

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

MR MILLETT: Yes, thank you.

Now, can I then turn, please, to -- well, first of all, was it your finding, or your conclusion, rather, on the basis of the material you studied, that the risk of collapse was highest from 2.00 am, in other words the

fourth stage, stage (d)?

A. Well, obviously we went through a lot of things this morning. I think a key time point where -- I keep coming back to Petra Doulova, don't I? The time that she came out and her companion was the end of the period when the conditions in the stair could be described as almost benign, in the sense that her uptake of asphyxiant gases was absolutely negligible, so there was no real hazard of collapse in the smoke up to that time. But after -- then we have this gap where nobody comes out. When we return to the situation where people are now starting to come down the stair again, and Fadumo Ahmed is the first one that comes down after this period, we're now in a situation where the stair is definitely hazardous, we have something like 1,800 ppm of CO in the stair, and so if you spend too long in there, then you will collapse from the effects of the stair, and, as we discussed, if you have already preloaded with quite a bit of carbon monoxide, you're also going to be in danger of collapse.

Does that answer your question?

Q. Yes, I think it does.

If we go to paragraph 375 {DAPR0000005/96}, I think that covers it, although it doesn't refer to Ms Doulova.

A. Branislav Lukic --

Q. Is that her partner? No.

A. Doulova was the last one to come down from a high floor level. Was it 20th? I can't remember exactly, but it was a high floor level.

Lukic, they came down from the 11th floor, so they were coming down from -- starting from a lower point in the stair, but they experienced very severe conditions in the lobbies --

Q. Yes.

A. -- at that time, but they still had relatively benign conditions in the stair up to that point.

Q. Right. I think if we go to the foot of 95 {DAPR0000005/95}, though, paragraph 371 you say there:

"The last two occupants to descend in the stair from an upper floor ..."

A. Yes, there we go, yes.

Q. "... before dense smoke filled the stair were Petra Doulova and Leroy Augustus (20th Floor, Flat 174). They entered the stair approximately 01.36."

So is that the key point in time?

A. Well, yes, they were the last people to come down, as it was, it was the 20th floor, before this hiatus of a good half hour when people stopped coming down.

Q. Yes, thank you.

Let's then turn to toxicology, and I want to ask you

about the impact of irritant smoke on behaviour.
Now, some of this, I think, you're discovered in your exchange with the Chairman in the last five or ten minutes or so, but let's see if we can just pin this back to your report a little bit more closely.
If we go to your Phase 1 report, you have a table in annex A, and that's at {DAPR0000001/102}.
A. Yes, and this table appears in various, if you like, standard or semi-standard documents. So it's a guide, really, to -- and it's intended for designers to look at the relationship between, in this case, the experiments and the work I was referring to about smoke visibility and walking speed. And then there were two very -- what's the word? -- important studies that were made a long time ago, one in England and one in the United States, of the relationship between smoke density during fire incidents and, again, occupant behaviour, as to whether people would be willing to continue walking through the smoke in order to escape or whether they would turn back. Summarising quite a lot of information -- I would refer you to the original work, but to illustrate this, the statistic I picked out was that once the density of smoke in an average fire gets down to about 3 metres visibility, at least a third of the population will -- about a third of the population

will turn back, rather than try to continue through it. And this is important in a design context. If you're planning to design for means of escape, that's an important piece of information to know: what level of smoke can you tolerate before your design fails, you know?
Q. Yes.
Just so that we can pin this right back to the evidence, just help me -- well, let's have it up, {HOM00046371}. This is an article called "Smoke control - a short review and discussion of some current issues" by Stewart Miles, Martin Shipp and you. Is that the article you're referring to? Well, let's go to --
A. No, I don't recall this.
Q. Let's go to page 6.
A. Ah, yes, that's the -- and this diagram I put together from Professor Jin's work --
Q. Right.
A. -- and you will find it appears in quite a few, including the SFPE handbook.
I mean, the latest document to pull all this together is a British Standard fire engineers guidance document which was published in 2019 by the fire engineering committee of BSI, of a group that I was leading that produced this guidance document.

Q. Very good.
Now, let's come back, then, to the Phase 2 report. Coming out of the depths, perhaps, if we can, back to your report, page 103 {DAPR000005/103}, section 4, and you have set out there your analysis of the toxicology results and, within it, your findings of the effects of irritant smoke on the occupants of the tower. You find that at the foot of the page at 415; yes? You say there:
"Although the accounts of occupants demonstrate the physical difficulties they experienced due to lack of visibility and irritancy when they attempted to move through smoke, they also demonstrate that it was rarely if ever physically impossible to move through the smoke. So that in many cases occupants attempted on several occasions to enter and move through the smoke, but felt unable to proceed and went back into their flats, until eventually they made a decision to leave and were then able to cross the lobby and enter the stair."
Your conclusion, I think, is at the foot of page 104 {DAPR0000005/104}, if we go down to that, please, paragraph 418, and I've read you 417 already:
"These findings show that while dense, irritant smoke did not physically prevent occupants from evacuating their flats, the combination of the

behavioural and physiological effects was a major factor preventing many flat occupants from evacuating their flats when they needed to do so."
A. Yes, I think that sums it up.
Q. That sums it up, does it?
A. Yes.
Q. Now, against that background, which I think you say sums it up, let's then go to the toxicology results themselves.
Now, before we do that, I think we've covered this already, but can we tick these off: first of all, blood carboxyhaemoglobin is effectively the measurement of carbon dioxide in the blood; yes?
A. Yes, carbon monoxide in the blood.
Q. Carbon monoxide in the blood.
A. Yes.
Q. And the inhaled dose of carbon monoxide measured in percentage carboxyhaemoglobin gives you an indication of the extent of exposure to toxic smoke.
A. Yes.
Q. Carboxyhaemoglobin, as you have told us, is relatively stable in blood samples.
A. Yes.
Q. And easily measured in deceased individuals.
A. Yes.

Q. Yes, and regularly tested on survivors on admission to hospital.
A. Yes, that's right.
Q. And, therefore, a reliable data point.
A. Yes.
Q. Now, then, let's, against that happy background, go to page 109 of your Phase 2 report {DAPR0000005/109}, same part of it, paragraph 439 there, and you set out some general key principles on the fatality of --
A. Ah, yes.
Q. -- a fire derived from studies that you've referred to, and you've got five of them really there. I don't want to spend time reading them out to you, but perhaps we can tick them off.
First, a finding of severe burns with a low percentage of carboxyhaemoglobin tells you that a subject died quickly in the fire as a result of exposure to heat or burns before they had time to inhale a significant dose of smoke or carbon monoxide?
A. Yes.
Q. Correct, yes.
Is it correct also that a finding of severe burns with more than 20% of carboxyhaemoglobin but less than 40% of carboxyhaemoglobin indicates that the subject may have died as a result of burns, but almost certainly

inhaled smoke and carbon monoxide for long enough to be unconscious at the time of death?
A. Yes.
Q. Yes. Is it also right that a finding of more than 40% carboxyhaemoglobin indicates that the subject almost certainly died from smoke inhalation, and if serious burns are present, then they are most likely to have occurred after death?
A. Yes.
Q. Finally, a finding of less than 40% carboxyhaemoglobin and no burns indicates death most likely to have occurred as a result of inhalation of toxic smoke but with a contribution from other gases, such as hydrogen cyanide?
A. Yes.
Q. Yes. That is because, is it, they died from the combined effects of asphyxiants plus a sub-lethal dose of carbon monoxide?
A. Yes. So if you can't account for them solely in terms of carbon monoxide, we've got to look for some other factor coming into the picture.
Q. Yes.
A. Yes.
Q. Now, are you able to explain the mechanism of death as a result of exposure to asphyxiant gases?

A. Yes.
Q. Would you please --
A. Yes, okay. Well, obviously -- yes, basically what happens is that the two organs, if you like, that are most sensitive are the brain and the heart, and of the two, it's probably the brain that's the most significant. So whereas many tissues like the muscles can still operate for quite a while without an oxygen supply, for example in sprinters, where you build up an oxygen debt, but you can still run, if you're Sebastian Coe or somebody, the brain has no such reserves at all. So if you cut off the blood supply to the brain or the oxygen in that blood for more than a few seconds, you collapse almost immediately.
So what happens is that when you inhale carbon monoxide, as I explained this morning, and it converts the haemoglobin to carboxyhaemoglobin, the delivery of oxygen to the tissues is heavily impaired by that process, and although one compensates up to a point, a critical point is reached where things deteriorate very rapidly. When I've observed this happening, as I've said, the transition is from a normal state, through a brief period of intoxication-like behaviour of a few seconds, to collapse. In fact, one of the symptoms of oxygen starvation can be a brief period of

euphoria, and at least one of the Grenfell survivors described that as he walked down the stairs, having this temporary feeling of euphoria, which was a warning that he was about to reach this point of collapse.
So then the oxygen supply to the brain is impaired and this results in permanent brain damage from which you often cannot recover.
Sorry, does that cover the point?
Q. Yes, thank you. And what about the heart?
A. Yes, so the other thing is obviously the heart needs blood and oxygen for the heart muscle to keep working. If you interrupt that, you start to get arrhythmias, heart attacks and problems like that, which is probably why -- so if you have a pre-existing atherosclerosis, coronary atherosclerosis, as many of us have in middle age and going on, you have already got an impaired blood and oxygen supply to the heart muscle. If that is then further reduced by the presence of carboxyhaemoglobin, you can reach this sort of tipping point where you go into heart attack, heart failure -- well, heart attack, basically.
SIR MARTIN MOORE-BICK: So would it be right to understand it in this way: the effect of the creation of carboxyhaemoglobin is to reduce the amount of haemoglobin that can carry oxygen to the vital organs?

A. Well, its twofold: it reduces proportionally the amount that can be carried, so if you have 50% carboxyhaemoglobin, you're only left with half to carry oxygen.
SIR MARTIN MOORE-BICK: Yes.
A. But, more seriously, due to the chemistry of it, it impairs the -- the bit that's left can no longer give up its oxygen to the tissues. So it's a kind of double effect. That's why it's very serious.
Now, cyanide, on the other hand, doesn't do that. Cyanide prevents the oxygen being used in the tissues. It blocks tissue metabolism, so it has a different mechanism. But the end result is the same: that the tissues can no longer metabolise, basically.
SIR MARTIN MOORE-BICK: Thank you.
MR MILLETT: And are those two effects cumulative?
A. Right. If we can take carboxyhaemoglobin, for example, the dose is building up cumulatively as long as you're inhaling the thing, but at a particular level, the effect is the effect of that level. So if you then wash out, you know, the carbon monoxide, and providing you haven't got to a point where you've got permanent tissue damage, you should make a very rapid and hopefully complete recovery.
Q. Right.

A. I'm not sure that's answered your question.
SIR MARTIN MOORE-BICK: Well, I think Mr Millett's question was, if I can presume to rephrase it, does the effect of the hydrogen cyanide act, as it were, in combination with carboxyhaemoglobin, so that that oxygen which does get to the tissues isn't used by the tissues?
A. Yes, that's a very good question that I partly addressed this morning. Because one is affecting delivery and the other one is affecting use when it gets there, you would think that they wouldn't be additive, and in fact when you look at the blood of somebody who's poisoned with cyanide, it looks like arterial blood, because it's full of oxygen, it's just that the oxygen is not being used when it gets to the end of the line. So you wouldn't obviously expect them to be additive. But there are lots of other complications which mean that they might well be, one of which we mentioned this morning is this effect on the uptake rate. So it's quite a complicated --
SIR MARTIN MOORE-BICK: I think one would expect them to be additive, because I had assumed from what you told us earlier that although the haemoglobin which is not affected by the carbon monoxide can still carry oxygen, it doesn't give it up very readily, and therefore one would have thought that that which is given up would

then be affected by the presence of the cyanide to prevent it being used by the tissues, so they would have a cumulative effect. But that's not --
A. It's possible. It's possible. I mean, it's quite a complex situation, and there's even more to it than that.
SIR MARTIN MOORE-BICK: Right.
A. I mean, the default that we tend to use is to really assume, if you like, at least for design purposes, the worst possible case, which is that they are directly additive in a dose sense. But, in practice, it may not be as simple as that, I think is the answer.
SIR MARTIN MOORE-BICK: All right. Thank you.
MR MILLETT: Right.
Would it be right to describe the effect of carbon monoxide in combination with hydrogen cyanide as the cause of death as asphyxia from asphyxiant gases?
A. Yes.
Q. Now, I want to ask you about hypoxia.
You have covered this in your report at page 107 {DAPR0000005/107}, if we can go to that, back two pages, at paragraph 435. I think we have probably also again touched on this just now in the exchanges, but in the last four lines of that paragraph you say:
"Carbon monoxide causes hypoxia mainly by limiting

the carriage of oxygen in the blood and delivery of oxygen to the tissues. Hydrogen cyanide causes tissue hypoxia by inhibiting the availability of oxygen for tissue respiration and low oxygen concentrations limit the oxygen available for inhalation from the air."
A. Yes, those are three mechanisms of causing hypoxia at the tissue level.
Q. Yes.
Now, again, we have covered this a little bit, and it may be that the answer is the same, that it's all very complicated, but are you able to explain the correlation between hypoxia and asphyxia and its role as a mechanism for death in the case of the Grenfell Tower victims?
A. Yes, I can see this can be a bit of confusion here. We're really talking about the same sort of thing. Hypoxia obviously means lack of oxygen and, strictly speaking, with cyanide poisoning, you're not lacking the oxygen; the oxygen is there but you can't use it. I think that's the reason we use the global term asphyxiant.
It all ends up with the same thing: that these three mechanisms, the presence of carbon monoxide, the presence of cyanide or low oxygen in the air you're inhaling, all end up with the body tissues, and

particularly the brain tissues, either not receiving or not being able to use sufficient oxygen to metabolise. So that is the end result.
Q. Right. Is hypoxia really just another word for the extent of --
A. Asphyxiant effect, yes.
Q. Well, the extent of carboxyhaemoglobin, or rather the effect of --
A. The end result of carbon monoxide poisoning is a form of hypoxia, yes.
Q. Which is asphyxiating in its --
A. Which is asphyxiating in its effect.
Q. -- effect.
A. Yes.
Q. Yes, I see. Right, thank you.
A. Sorry if that's not very clear.
Q. The rate of hypoxia is essentially the rate of uptake of carbon monoxide and --
A. The extent to which it's developed depends upon the dose of uptake up to that point, yes.
Q. Right.
Now, can I ask you, then, one or two questions about metabolic acidosis.
Can we go, please, to page 155 of this part of the report {DAPR0000005/155} and look at paragraph 677.

This is also in the context of hypoxia.
A. Yes.
Q. You say:
"Hypoxia from inhalation of asphyxiant gases, especially when combined with the physical stress and exercise involved in escaping down the Tower, can result in a transient metabolic acidosis. This showed in the blood of several persons, with serious consequences in one case."
I think we know what the case is, but could you just explain, what is the process of metabolic acidosis?
A. Right. So the simplest explanation is if you think of what happens in sprinters. A sprinter uses their muscles very actively over a very short period, and they build up what's known as an oxygen debt, in that they develop energy by glycolysis, the end product of which is lactic acid, and lactic acid then builds up in the blood and, as it says, is an acid, so acidifies the blood. So if you prevent the body from obtaining energy by oxygen metabolism, then it will use anaerobic methods to obtain that energy. These anaerobic methods result in acid in the blood, acidosis due to, for example, lactic acid.
So if you inhale carbon monoxide or hydrogen cyanide -- especially hydrogen cyanide -- a sign of the

intoxication is that you will end up with a more acidic blood. So that's a metabolic acidosis.
Respiratory acidosis occurs when you get a build-up of carbon monoxide in your body. So if you're unable to -- again, this happens in exercise as part of normal life. If you exercise and use a lot of energy, you generate a lot of carbon dioxide in your body and your blood from the exercise, from the metabolism of your exercise, because CO2 is the end product of metabolism, and you have to excrete it through your lungs by breathing it out, and if you can't get rid of it quickly enough, then the carbon dioxide increases in your blood, you get a respiratory acidosis, which is an increase in carbon dioxide concentration in the blood.
And both of these are going on here, because you've got the metabolic acidosis from the inhaled asphyxiant gases, the carbon monoxide, the hydrogen cyanide, and you've got the respiratory acidosis partly from the fact that people are hurrying down the tower, particularly if they're overweight or pregnant or whatever, you know, it's a physical problem. And also, don't forget, we're talking about fire here, so the fire is generating carbon dioxide. So one of the gases present is carbon dioxide. So whereas in normal life there's hardly any carbon dioxide, fortunately, at the moment, in our

ambient air, in a fire, it can go as high as 17%, and so -- and the exhaled breath is -- sorry to the stenographer. Exhaled breath is about 5% carbon dioxide. That's your normal exhaled breath. So if the air you're inhaling has no carbon dioxide, then you're winning, because you get rid of 5%, inhaling none. If, as can easily happen in a fire, the concentration in the inhaled gas is 5%, then you can't excrete any, which means that your body has to then go above 5% in your blood by sheer physics, you know. So that's another cause of acidosis, through retention of carbon monoxide.
Another mechanism is that if you get bronchoconstriction or blockage of your airways through to smoke inhalation, and you're not breathing, you're not exchanging air efficiently, and so you're not excreting carbon monoxide as well as you should, again you get this build-up.
So all these factors are coalescing on people trying to come down that tower.
Q. What effect does acidosis, either respiratory or metabolic, have or did it have in this case on the outcomes of victims who came down the stairs?
A. Well, yes, okay, you're starting to move more into the medical area now, but essentially it can be distressing, and there are a number of people who, once they got to

hospital, were noted as having -- perhaps, for the reasons I've stated, not that surprisingly -- some degree of acidosis when they first arrived at hospital. Some received some treatment for that, you can give buffers in the blood and bicarbonate and things like that, and some just naturally, over a period of an hour or two, especially as they washed out their carbon monoxide, made a natural recovery.

But I'm sort of now passing over to what -- I'm accepting the medical and pathologists' findings. They claimed that this particular case, the death resulted from acidosis. So all I'm talking about is the potential source of that acidosis, not the consequences of it.

Q. Very good, thank you for making that distinction clear.

Now, you were provided with toxicology tests for those who died in Grenfell Tower where they could be carried out, weren't you?

A. Yes.

Q. I think you have analysed those results in your report, and we can see that at page 123 {DAPR0000005/123}, if we go back, please, to page 123 and look at paragraph 484.

A. Are we talking about the fatalities now?

Q. We are talking about fatalities.

A. Yes, yes.

Q. And the heading is, "Significance of findings of Carboxyhaemoglobin concentrations in fatalities at Grenfell Tower", and you say in paragraph 484 as follows:

"In this section I have considered the measured values for the blood %COHb concentrations, their distribution and the condition of the bodies of the deceased to establish their significance in evaluating the cause of death for Grenfell occupants. In Section 4 (Figure 13) I discussed the distribution of post-mortem blood COHb measured in a large United States database of fatalities from non-fire carbon monoxide poisoning and for unburned fire fatalities. It is therefore relevant to compare this distribution to the distribution of the Grenfell fatalities to assist in establishing whether Grenfell fatalities are likely to have died from carbon monoxide asphyxia before their bodies were burned."

Now, the United States database, I think, is the Nelson database.

A. Yes.

Q. Yes.

Now, if we go, please, down to figure 17, if we can have that fully on the screen, please, there it is, it says:

"Comparison of percentage distribution of percentage

COHb [carboxyhaemoglobin] levels of Grenfell deaths with Nelson unburned fire death database."

You have illustrated the range of tests there, test results, in the Grenfell deaths.

Is there a correlation between the two contained in that figure?

A. Yes, so we can see that quite a few of the -- I think it'll be a bit clearer with some of the later pictures, but quite a lot of the Grenfell deaths have got very high concentrations of carboxyhaemoglobin in their bodies, and they're in this -- I mean, in the Nelson distribution, the most common amount at death was about 75%. Sorry, that was for non-fire deaths. The other graph of his compares carbon monoxide gas poisoning incidents with fires.

Sorry, let me start again.

What this shows is that most of the Grenfell deaths were at high levels, above about 40% to 50% carboxyhaemoglobin. They were all in this range where Nelson is finding in non-burn deaths. So in other words, it correlates with his. The ones that don't at the left there I think are the ones who fell from the tower. We'll see them better in another figure.

MR MILLETT: We do, and let's go to that straight away.

Mr Chairman, I'm going to cover this quickly, if

I can, before the break.

SIR MARTIN MOORE-BICK: Yes, very well.

MR MILLETT: If we go, please, to figure 18, which we will find on the next page, page 124 {DAPR0000005/124} --

A. Yes, I think this is quite telling, so if we could blow that up a bit.

Q. Could you just talk us through this chart?

A. Yes.

If we look at the -- perhaps start with the ones who died in the lobbies or stair, you can see that that's the black bars. Most of those are well up in above -- bearing in mind that 50% is the lethal threshold for most people. So these are up in the 60 to 70, 70 to 80, even up into the 80 to 90, extremely high levels of carbon monoxide in the blood of people who collapsed and died in the lobbies or stair.

If we look at the purple distribution, those are people who died in the flat, and the same applies in general to them. Most of them are in this very high range and, therefore, clearly inhaled a large amount of carbon monoxide before they died, well up above the lethal threshold.

There are a few examples -- there was one -- the person in red who died in hospital had a high level, and I think there was a problem with the blood sample, so it

may have been even somewhat higher at the time of death.
Then you've got the three blue bars, which are for people who died having fallen from the tower. Now, two of those were at 20% carboxyhaemoglobin. Now, that obviously is a sub−lethal level, it's also a sub−incapacitating level. It's a level at which you probably got a −− you start to get a throbbing headache, would be the normal symptom people would respond at that level, and you would still be able to walk around the flat and be fairly lucid, but it shows that those −− but it's a substantial dose, because we've only got to get to 30 to 40 when you would collapse unconscious. So the fact that those people at the time they fell from the tower had these sub−incapacitating but very high −− you know, rising levels to quite high doses gives us a strong indication that those who then remained in those two flats subsequently were on this very steeply rising curve and hadn't got much further to go before they too would have collapsed from asphyxiant gases.
Then we have one person that I have mentioned already who fell from their flat with an incredibly high dose of 50% carboxyhaemoglobin, a young man.
Q. I think it's Ali Yawar Jafari.
A. Yes. So he had 50% carboxyhaemoglobin, which, as I've said, is normally regarded as a sort of lethal

threshold, but he was still able to move sufficiently to fall from the tower. He was obviously a young man. But, I mean, that indicates that the occupants of that flat were facing lethal concentrations at that time.
I think that just about covers it.
I think one of the lower ones also, I've made some notes in the text below, was known to have suffered −− I think a couple of these people were known to suffer from heart disease and, as I've already mentioned, that's a risk factor for lower level deaths.
Q. Yes. Just to correct what I just said, it wasn't Ali Yawar Jafari, he was found in the lobby on floor 10. I was thinking, I am afraid, of Mohammad Alhajali.
A. Alhajali, that's it, yes, I beg your pardon.
Q. And it's right, I think, that two of the individuals found in flats with less than 50% carboxyhaemoglobin had factors which may have explained their results.
A. Heart disease, yes.
Q. Heart disease, yes.
Is it right that for eight of those who died in the lobbies or the stair, which is the black column, all but one had very high blood carboxyhaemoglobin concentrations above the lethal threshold?
A. Yes, and the other point, of course, was that none of them had significant burns. None of them had

significant burns.
Q. Yes.
A. And, in particular, the person with 50% who fell from the tower had no burns on his body at that time, even though he had inhaled a potentially lethal dose of asphyxiant gases.
Q. Yes, and that was Mohammad Alhajali.
A. Yes.
Q. Yes. Mr Ali Yawar Jafari, I think, was the exception, and he had blood carboxyhaemoglobin at 47% −−
A. Ah, yes. He was in the 10th lobby, wasn't he?
Q. He was in the 10th floor lobby.
A. So he had a pre−existing heart condition. In fact, his daughter mentioned something about his medication as he left the flat −− concerned about his medication for heart disease. So, yes.
Q. Yes.
To bring us to a conclusion on this, can we go, please, to page 137 {DAPR0000005/137}, where you set out your conclusions, and at paragraph 576 you start with the exterior fire reaching the outside room, but if we go, please, to 584 on page 138 {DAPR0000005/138}, you say:
"From these findings it is likely that most if not all flat occupants were comatose and in most cases dead

before exposure to significant heat or burns. I cannot exclude the possibility of some heat exposure in some flat occupants while still breathing (and therefore before the point of death), since the autopsies of Vincent Chiejina from flat 144 and Steven Power from Flat 122 show some signs of possible minor heat damage to the airways consistent with inhalation of hot fumes before death. The severe burning of bodies of flat occupants resulting in charred remains is likely to have occurred in all cases sometime after death when the flat interiors developed prolonged, fully involved compartment fires which effectively consumed all the combustible flat contents."
That's your conclusion.
A. Yes.
MR MILLETT: Yes, thank you.
Mr Chairman, is that a convenient moment?
SIR MARTIN MOORE−BICK: Well, it is, but there is one thing I would just like to clarify.
Can we just go back up to the bottom of 584 on the previous page, please. You say there that you think it likely that most if not all the occupants were comatose before being exposed to significant heat.
A. Yes.
SIR MARTIN MOORE−BICK: You can't exclude the possibility,

you then say, of some heat exposure to some occupants, but do you think it more likely or not that those who were exposed to heat were at that stage comatose?
A. Yes, I think it's more likely than not that those -- if some were alive, they were most likely to have been comatose or almost comatose -- comatose at that time, yes.
SIR MARTIN MOORE-BICK: All right. That's really what I wanted to clarify.
A. Yes, I do believe that's the case, yes.
SIR MARTIN MOORE-BICK: Right. Thank you very much.
Well, we'll take the afternoon break at that point, so we'll stop there. We will resume at 3.40, please, and the usual restrictions apply. Thank you very much.
THE WITNESS: Yes. Thank you.
SIR MARTIN MOORE-BICK: Would you go with the usher, please. Thank you.
(Pause)
Thank you. 3.40, please.
(3.23 pm)
(A short break)
(3.40 pm)
SIR MARTIN MOORE-BICK: All right, professor, ready to carry on?
THE WITNESS: Yes.

SIR MARTIN MOORE-BICK: Thank you very much.
Yes, Mr Millett.
MR MILLETT: Mr Chairman, thank you.
Now, can I turn to the question of hydrogen cyanide exposure and post-mortem blood tests for cyanide.
Can we go, please, to page 111 of the same section of your report, {DAPR0000005/111}, and you say there, section 2.2 at the top:
"Hydrogen cyanide exposure and post-mortem blood tests for cyanide."
Now, if we can break this up into simple steps, is it right, first, all burning fuels contain carbon?
A. Yes.
Q. Yes. So a fire survivor will also show the presence of carboxyhaemoglobin concentrations proportionate to their exposure?
A. Yes.
Q. Yes. But not all fuels contain nitrogen?
A. That's correct.
Q. You say, I think, that it's possible for a fire survivor to present with high blood carboxyhaemoglobin concentrations but low blood cyanide.
A. Yes, if there have been no nitrogen-containing fuels in the fuel load that they were exposed to.
Q. Yes. You've explained before this morning, and just to

repeat the point, that hydrogen cyanide inhalation causes rapid incapacitation.
A. Yes.
Q. And it's considered more significant for rapid incapacitation than as a primary cause of death.
A. Yes.
Q. Yes.
Now, let's go, then, to page 112 {DAPR0000005/112}, paragraph 447 at the top of the page. There is a long paragraph, I'm not going to read it all out to you, but let me see if I can summarise it and see if you can agree with my summary.
Is it right that, unlike carboxyhaemoglobin concentrations in blood, testing the concentration of cyanide in blood is difficult for a number of reasons: first, that there is a low natural background concentration of cyanide in blood?
A. Yes.
Q. And, secondly, the natural background concentration of cyanide is elevated for smokers; yes?
A. Yes.
Q. And also after the ingestion of certain foods, such as bitter almonds?
A. Yes.
Q. And a short exposure to high concentrations of cyanide

causing collapse may cause incapacitation, but then the levels of blood cyanide may reduce, is this right --
A. Yes.
Q. -- so that when they're finally measured, they can be lower than at the --
A. Yes.
Q. -- critical stages of the fire?
A. There can be a peak, yes.
Q. Yes.
Also, cyanide is unstable in blood and there will be a decrease in the cyanide levels in blood between the death and the date of measurement.
A. Quite marked, yes.
Q. Quite marked. And they continue to decrease in blood stored after removal.
A. Yes.
Q. I think you also say that cyanide concentration levels change in frozen blood samples between freezing and thawing.
A. Small changes have been observed, yes.
Q. And in that, you also say more significantly in smokers.
A. I don't recall particularly about that, no. You mean frozen blood from smokers?
Q. Yes, I picked that up at the top of page 113 {DAPR0000005/113}.

A. Okay.
Q. Let's just go to that. You look doubtful. You say at the top there that the freeze/thaw is:
"... due to the re-conversion of small amounts of thiocyanate to cyanide."
A. Yes. That was in any of these samples, yes.
Q. Right. You say:
"This effect is considered likely to be significant only when examining low concentrations of cyanide such as is found in the blood of smokers ..."
A. Ah, yes, sorry. Yes, I think that's slightly misleading.
So what I'm saying is that when you are basically looking at background levels, very low levels, in either normal non-smokers or in smokers, where there is a bit of cyanide in the blood, then because it's so low, the difference between frozen and non-frozen can be quite a large percentage of the original very low level. So it looks like a big change in percentage terms, but it's actually a very small change in real terms.
If you have a much higher blood level, such as from a fire or something, then this tiny change doesn't really show up as any great significance.
Q. Yes.
Now, you have explained at paragraph 595, if we can

go, please, to page 140 {DAPR0000005/140}, at the foot of the page, that there were significant amounts of nitrogen in both the exterior cladding and in the flat contents; yes?
A. Yes.
Q. And that meant that the Grenfell occupants would have been exposed to hydrogen cyanide during the fire come what may.
A. Yes.
Q. You asked for blood samples from Grenfell to be tested for cyanide, and that was done some two years or so after the fire.
A. It was eventually done then, yes.
Q. Yes.
A. It was about a year after when I requested it.
Q. Yes. We can pick that up -- we don't need to go to it.
A. No, no. There was a long time before the analysis was done, yes.
Q. Due to the passage of time, could any meaningful analysis be made of the blood tests taken after this time, so far as cyanide is concerned?
A. Yes, so my reason for doing this, partly, was obviously that we knew it was there, so we felt we should look into it. Also, it was picked up -- at the time, it was suggested that certain people had been exposed to

cyanide during Grenfell, so we ought to look for it. And although any measurement we made on these post-mortem samples now was subject to all these caveats, it still might be possible to show a signal, if you like. If there was a sign of elevation there, then it would be evidence to corroborate the fact that they had inhaled cyanide. On the other hand, if the samples were so deteriorated that we couldn't really say anything, that couldn't rule out the fact they may have inhaled cyanide. Is that clear? Do you understand? Yes.
Q. Yes.
A. Make sense?
Q. It does make sense, and it probably makes sense to show you how you put it in your report.
Can we pick it up at paragraph 601 {DAPR0000005/141}, please.
A. Yes, that sort of sums it up.
Q. You say -- yes, exactly, thank you:
"While the absence of measurable cyanide in these samples does not provide evidence that the subjects were not exposed to cyanide, where cyanide is detected in any samples above threshold levels this may be an indication of exposure during the incident."
Yes?

A. Yes. So it was worth looking, that's all I'm saying, for completeness, really.
Q. Let's then go to the next page, page 142 {DAPR0000005/142}.
A. That summarises what we found.
Q. Figure 19.
A. Yes.
Q. That summarises, you say, what you found. Just to summarise that, this is a plot of the results of the cyanide tests for Grenfell in relation to the background cyanide levels in both smokers and non-smokers, I think.
A. Yes.
Q. Is it right that, from the 12 samples that were available to you for testing, five showed no cyanide detected?
A. Yes.
Q. Those are the black squares along the bottom.
A. Yes.
Q. But six had some measurable levels.
A. Yes.
Q. And you can see those, they're the open -- is this right? -- white and red circles.
A. Seven we've got there, I think.
Q. Seven.
A. Yes, those are the open circles -- well, they're the

circles , the circles , had something in them.
Q. Yes. What do the red circles indicate?
A. I picked those two out because they were somewhat elevated above these sort of background levels. The other reason for plotting it the way I have is that while it's possible to have a fire with lots of carbon monoxide in but no cyanide, it's really more or less impossible to have a fire with lots of cyanide and no CO, and in previous pathology studies, particularly one big study that was done in the Strathclyde region of Scotland some years ago, there is an obvious correlation between high blood cyanide and high carboxyhaemoglobin. So if you've got high cyanide, it's always in the presence of high carboxyhaemoglobin.
Q. Why is that?
A. Because the carboxyhaemoglobin is a measure of the extent to which people have inhaled smoke. So if they've got a very low carboxyhaemoglobin, it means they've hardly inhaled any toxic products at all. So you would always expect to have quite a bit of CO present if you've got cyanide. The two correlate. They go together.
Q. Yes, and we discussed this a little bit before the break at lunch today ——
A. If you have a fuel that produces both carbon monoxide

and cyanide, then you'd expect some correlation between the elevation of those two toxins.
Q. Yes.
Now, just going to the chart ——
A. And that's the dotted line in the chart.
Q. That's the purple dotted line in the chart.
A. Little dotted line —— no, no, the tiny dots —— shows that there is a slight positive slope, which is a sort of suggestion that what I've just said is showing up slightly as a signal at Grenfell. It's all very approximate, you know.
Q. What's the difference between the red dot and the white dot so far as Mohamednur Tuccu is concerned, who is given a red dot, and Abdeslam Sebbar, who is given a white dot?
A. Ah, yes, I think it's because they were both in the same place, weren't they? Those two were in the lobby, the 10th lobby, where I think there was a severe exposure. Sebbar was in a flat on his own. I think that's why I coloured those two red. It probably tells you in the text.
Q. Well, I'm not entirely sure it does.
A. Doesn't it? Okay. Well, just to talk about these, the four black ones, obviously they couldn't —— the fact they couldn't detect anything could be related to the

state of the sample, so that's those four black squares. Then we've got the white open circles which they have reported a level, the analysts, but when I compare those levels with the sorts of background levels we might find in smokers and non—smokers, they're very, very close to these kind of threshold levels, though it doesn't really tell us a great deal. But particularly if we look at Khalloufi, and to some extent Tuccu, possibly also Sebbar, this is sort of showing its head above the waterline a little bit.
I mean, I'm not making great claims for this, I'm just pointing out these correlations, or lack of them.
Q. I understand.
Just to correct something I think you said before, Mohamednur Tuccu was recovered from the 10th floor lobby, but Abdeslam Sebbar was recovered from his flat on floor 11.
A. Yes. Mohamednur Tuccu was in the lobby as well. I think that might be where I ... anyway, that's the situation. So those two were together, and certainly Khalloufi —— well, that sample is quite elevated, but if you look at the line across the top at 1, that's a kind of threshold for a toxic cyanide level in stored blood, you know, so we're well below where we would start to make great claims for all this.

The other thing I draw your attention to is the three diamonds to the left of the picture there.
Q. Survivors.
A. They were blood levels measured in survivors at hospital. So I found three —— in the survivors' hospital data I examined, I found three references to blood measurements of cyanide in survivors, and you can see that these are also very, very low. I mean, they may be slightly —— but possibly slightly elevated about what you might expect to find if they were non—smoke —— well, if they had not been exposed at all.
So it's a kind of hint that there is some sort of signal coming through here, but it's not, you know, that significant, if you like.
Q. What are we to make of the fact that certainly for one if not two of the survivors, the blue diamonds, they are at very slightly higher levels of cyanide concentration at the date of the measurement than those you have measured for Mohamednur Tuccu or Abdeslam Sebbar?
A. Well, of course, these samples are fresh samples. They weren't stored for several years. On the other hand, they were in living persons, and in living persons the cyanide isn't washed out as it is with CO, but it's metabolised by the liver, so it decreases, and as you can see, these three diamonds, the carboxyhaemoglobin

levels were pretty low at the time, which reflects the fact that their CO had already been washed out. So there had been some time for the cyanide in their blood to some extent to have been metabolised. So to the extent that that may be slightly elevated, it was -- in all these samples, almost certainly the levels in their blood would have been significantly higher at the time they exited the tower.
Q. Yes.
A. But really the point I'm looking at with this is, if you like: does this dataset give us any kind of signal that corroborates what we'd expect to see, which is some sign of elevated blood cyanide in people who had been exposed at Grenfell to correlate with the fact that we know cyanide must have been present in the smoke they were inhaling? And I would say it is giving us some kind of weak signal in that direction, but it's not something we can really state as objective proof or anything like that. But it's an indication, that's all we can claim. And the point is we've done it, we've looked, and that's what we've found.
Q. From your results, I think it is the case -- and tell me if this is wrong -- that you were unable to conclude whether there was a sufficient hydrogen cyanide quantity inhaled during the fire to have made a significant

contribution to incapacitation and death?
A. Yes. I mean, I think these sort of levels do to some extent correlate with my earlier calculations and predictions from the conditions at the time and the ratios we talked about earlier, that we would expect to see some sign of some cyanide in the blood of these persons, but we would not expect it to be up in the 2 or 3 milligrams per litre, which is way off the top of this chart, where we would say: ah, this is the cause of incapacitation and death of these persons. So I'm afraid it doesn't give us a great deal, but it's been done for completeness. It does show some indication that helps to corroborate the fact that they were exposed to some extent. It also to some extent corroborates the idea that the extent to which they were exposed was not that extreme. But, you know, I don't think we can make great claims for all this.
Q. Now, I want to turn back to a topic that we touched on before the break, a little bit earlier than the break, if we can just do that, and that's the question of uptake of carbon monoxide and washout rates, particularly in respect of children or asthmatic people or elderly people or people who are physically compromised.
Now, can I ask you about pregnancy: would carrying

a foetus increase the uptake rate?
A. Of the adult?
Q. Of the adult, of the mother.
A. I couldn't really say either way, I don't ... not particularly, except that obviously there is more exertion involved if they're near term, sort of thing, heavily pregnant.
Q. Yes. I mean, I'm addressing you really to a mid-term pregnancy, 20 to 21 weeks.
A. Yes. It could have a minor effect, but I don't see why that would be a big effect.
Q. What about the washout rate, would that be --
A. Of the mother?
Q. Of the mother.
A. Right. Well, I don't think it would particularly affect the washout rate of the mother, but, of course, an important issue is the extent to which any CO in the mother's blood is transferred to the foetus, and I don't know quite where you're going with this.
Q. Well, would the fact that the mother was mid-term affect the rate at which the carbon monoxide was washed out of her blood?
A. Not particularly that I can think of, no.
Q. So the next question is: would washout of her blood similarly wash out the foetus' blood?

A. Right. I did try to look into this issue. It had always been my understanding that foetal blood was somewhat -- foetal haemoglobin would more readily take up carbon monoxide than adult haemoglobin, it's slightly different. But when I looked into this in relation to the Grenfell cases, the main point I discovered in the literature was that there's a considerable time lag between uptake of carbon monoxide in the mother's blood and it appearing in the foetal blood, and because the time course and washout sequence at Grenfell was relatively short, and there's this sort of one hour or so delay, the conclusion was that you would not expect to see high carboxyhaemoglobin in the foetal blood for this case, basically. Indeed, when the baby's blood was analysed, there was virtually no carbon monoxide in the baby's blood.
Q. Would any effect of pregnancy be exacerbated by asthma or other respiratory difficulties?
A. Well, I mean, obviously the concern here -- my main concern here about the pregnancy would be the hypoxic effects on the mother affecting the oxygenation and any acidosis of the foetal -- of the foetus.
Q. Indeed.
A. So that's something very serious to consider, but that's not quite what you asked.

Q. Yes. Thinking about the mother, would the effect on the mother be exacerbated if she happened to be asthmatic as well, or had other ‐‐
A. Oh, I see.
Q. ‐‐ respiratory problems?
A. It could do, yes. It could do, for the reasons we've discussed, yes.
Q. Turning to children, who have got smaller lung capacity, would the uptake rate of a young child be greater than a child who was older?
A. Right. So the uptake rate of carbon monoxide, as I said this morning, is proportional to body size. So the smaller you are, the greater the rate of uptake. So it's a question of body size. And activity level, of course.
Q. And activity level. And would the washout rate be similarly ‐‐
A. The washout rate ‐‐
Q. Would be quicker?
A. I think it probably would be, yes. I don't know I have any data for that particularly, but yes.
Q. Right.
Now, let's then turn to the analysis of the survivor records, because I think you obtained some medical records from survivors ‐‐

A. Yes.
Q. ‐‐ and I just want to ask you in general terms, first, your findings from your analysis of those records.
Can we please go to {DAPR0000005/148}, figure 20, the next figure on. Here I think you have plotted the carboxyhaemoglobin concentrations from 21 Grenfell Tower survivors relative to the time that elapsed after exiting the building.
A. Yes.
Q. Now, could you explain, in brief terms if you can, what the graph tells us?
A. Right. So this is a ‐‐ these are the washout curves, and I pooled the data from all the samples taken from all the people, partly, as I say, to preserve anonymity, but partly because it makes it more powerful as a combined dataset, and then I've fitted a curve to that dataset to see what it indicates as the percentage carboxyhaemoglobin at the time they left the tower, or at least at the time they started to receive oxygen treatment outside the tower.
I've divided the dataset into two sets, as you can see there: those who descended from the upper floors of the tower and therefore had a longer exposure in the stair, and those who descended from the lower floors of the tower ‐‐ it's actually just floors 10 to 12 that

I had data for ‐‐ where they obviously spent a shorter period descending because they're coming from lower floors.
So for those who descended from the upper floors, just fitting a curve to that dataset back extrapolating gives us a figure of just around 30% carboxyhaemoglobin at the time of exiting the tower, or just slightly lower at the time of starting oxygen, if that was ten minutes later, for example, that's the solid blue line is a ten‐minute line, I think.
Q. Right.
A. Yes.
Q. Just for those of us who don't know, and perhaps including me in that, what is a washout curve?
A. Right. I think we touched on this earlier. So, basically, as I said this morning, if you've got, say, 30% carboxyhaemoglobin in your blood, you walk out of the tower and you start to breathe air. As you breathe air, every time you exhale you excrete, get rid of, some of that carbon monoxide, you wash it out of your blood. So it's kind of washing the blood clean, in a simple sense. And the rate at which that happens is very slow if you're breathing air and it would take you four and a half hours or so to get down to the half the level you started with, to get from 30 to 15. But if you breathe

oxygen, then it takes about 74 minutes, and indeed the dotted line there, black dotted line, is the 74‐minute half‐life curve, which I got from literature as we spoke about this morning. You can see that the slope of that 74‐minute published washout curve is really very close to the fitted curve for the actual dataset from Grenfell. So that gives me a lot of confidence that this is making sense here.
Q. Just to break that up a little bit, is it right that the blue dashed line shows the fitted carbon monoxide washout curve ‐‐
A. To the actual dataset.
Q. ‐‐ back calculated to the time of actual exit?
A. Yes.
Q. Yes, and the blue vertical line gives you ten minutes after the tower exit?
A. Yes, in case you just breathed air before anybody gave you an oxygen set.
Q. Exactly. So it's to account for a delay between leaving the tower and starting to be given oxygen.
A. Yes, exactly. And obviously I've been studying the LA4 ambulance forms and the accounts of occupants to see what accounts they gave of when and what oxygen they were given.
Q. Yes, and I think at paragraph 644 at the foot of the

page, if we just can see that on the screen, you calculated or concluded that if oxygen treatment was provided immediately, survivors had at least 32% of carboxyhaemoglobin concentrations on exit.
A. Yes.
Q. Yes? And if oxygen treatment was provided after ten minutes, then survivors had at least 30% of carboxy --
A. Yes, which is more realistic. I mean, they weren't given it as they stepped out the door, sort of thing.
Q. Yes. I think you also find that the back calculated estimate of 30% to 32% carboxyhaemoglobin concentrations in survivors is consistent with survivors' descriptions of --
A. Of their state they were in.
Q. -- of the state they were in.
A. Yes.
Q. Which is the experiencing weakness --
A. Yes.
Q. -- and collapsing at the foot of the stairs.
A. Exactly.
Q. Is it right you have also explored the relationship between the carboxyhaemoglobin concentrations and exit time and floor level?
A. Yes, I have, yes.

Q. Let's see if we can just get into that a little bit.
Can we please turn to page 150 {DAPR0000005/150}, two pages on, which is the next figure, figure 21, and that's the relationship between carboxyhaemoglobin and exit time.
A. Yes. So one of the questions obviously that arises here is all this is predicated on -- or I'm kind of working towards an idea that the carbon monoxide concentration -- the average carbon monoxide concentration in the stair was around about 1,800 ppm for most of this period, and that although it may have varied somewhat at individual floor levels, on average throughout the stair column it remained at approximately the same level.
Now, this particular graph is -- I plotted the percentage COHb against time, and what I'm trying to illustrate here is if there had been a dramatic change in the average concentration of CO in the stair during that period, then we would expect to see a slope across here, you know, a trend. So, for example, if the carbon monoxide in the stair at 3 o'clock had been twice as much as it had been at 2 o'clock, then we would expect a steep upward slope if we fitted a line to these dots. But what we in fact see is it's more or less flat, and there are ones who are a little bit higher at the end

there, but I have given individual reasons why that is the case.
So, in other words, what I have concluded from this is that this evidence supports my assertion that the average carbon monoxide concentration in the stair column was more or less, within some averaging, the same over that period from about 2.30 to about 4 o'clock.
Q. And that was about 1,800 parts per minute?
A. About 1,800, yes.
Q. So this, you say, supports your thesis that it was a constant, or more or less constant --
A. The average was, yes.
Q. Yes.
A. Yes.
Q. If we go, please, to page 151 {DAPR0000005/151}, the next figure, figure 22, you have plotted, I think, carboxyhaemoglobin concentrations with flat evacuation floor levels.
A. Yes, so floor level here is a sort of proxy for the time you spend descending the stair, in the stair. So if you're coming from a high floor, you're breathing that 1,800 ppm for a much longer period, and so if the main determinant of the level you end up with is the time you spend descending the stair, then we would expect a positive slope in this dataset, which is the dotted

blue line there, and, as you can see, there is quite a strong positive relationship between the two.
Q. Yes.
A. So I think this is -- and there's various caveats in individual cases that I've detailed on there and explained in the text, but the overall position is: floor number is a strong indicator of how much you're going to inhale in the end and, therefore, it's the time that you spend descending the stair that's important.
Q. Yes, so a general relationship between the percentage carboxyhaemoglobin at tower exit time and where you have come down from.
A. Yes.
Q. The floor you have come down from.
A. Yes.
Q. Now, the next one on is figure 23, page 152 {DAPR0000005/152}, please.
A. So the alternative to that explanation could be that it's not the time you spent in the stair that's important, it's the time you spent in your flat that's important, and if it was the time you spent in your flat that's important, we'd expect to see a strong positive line in this. But, in fact, there's no relation at all, the time spent in the flat and the amount of carbon monoxide in your blood, which again supports my

interpretation that we spoke of earlier today, that providing you left -- of course, these are all people who evacuated before the external fire was outside their flat for an extended period.
Q. That was my question.
A. That was the point. So I'm saying they all -- it was not due to the time they spent in the flat, it was the time they spent in the stair that was the main correlate for their eventual total dose, and they had a low dose at the time.
Q. Right. And these are all survivors.
A. These are all survivors, yes.
Q. So people had accumulated up to some 42% of carboxy in the --
A. Yes, but it wasn't correlated with the time they spent there.
Q. Yes.
A. That's all, yes.
Q. Yes.
You have, I think, also plotted similar graphs marking the relationship between inhalation injury --
A. Yes, so this is something we haven't spoken about as yet. So --
Q. Can I just --
A. Yes, go on.

Q. Before you go on, let me just plot it out for you.
If we go, please, to page 161 -- I think we have two figures, actually, here. Page 160 {DAPR0000005/160}, first of all, which is figure 25.
A. Right, yes, so this is --
Q. And 26 on page 161 {DAPR0000005/161}.
A. So this is, again, the relationship between evacuation floor, which is a proxy for time in the stair, and severity of inhalation injury, and you can see there is a strong positive slope again. So what's happening here is that if you inhale -- if you were exposed to irritant smoke, we discussed at length the effects on your ability to escape and your behaviour, but the other effect of inhaling irritant smoke is it damages your lungs, and so there should be a correlation between the amount of smoke you inhale and the extent of lung damage, and the longer you spend in the stair descending the greater your dose and, therefore, the greater the lung damage you would expect to see, and that is demonstrated in this chart.
There is one exception there for one individual who spent seven hours in his flat before he was assisted, so in his case it's his exposure in the flat that's important.
Q. Right.

First on this chart you've got a metric for inhalation injury severity grade from 0 to 3.5.
A. Yes.
Q. What is that? What is that metric?
A. I think there is a little chart, isn't there, a little table somewhere there, that will just explain it.
I used a medical scoring system that I saw on the internet, and -- possibly we could find that, could we? Here we are. So you assign a score for severity of injury.
Q. Just pause, that's page 158 {DAPR0000005/158}, table 19, is it?
A. Yes. So on a scale of 0 to 4, based upon the reported medical signs and symptoms. So no injury, you know -- well, you can see what it is there.
Q. Yes, and --
A. So I used that scoring system and I read the notes of each individual, and then I assigned them a score from this scale, and then that's the basis of those plots that you see in the diagram we were just looking at.
Q. Right. Is there any correlation between this chart and which floor they came --
A. Yes. Yes. So the further they descended in the stair, the longer they were in the stair, the higher the carboxyhaemoglobin and the higher the probability of

having severe injury. And if you look at the chart, there is one where I plot this injury against carboxyhaemoglobin, which I think is a good one to look at.
Q. So do we take it from this chart -- can we go back to it, please, at page 160 {DAPR0000005/160} -- that the higher the floor you came down from --
A. The more likely you were to have a severe injury, yes.
Q. And that's because of uptake in the stair?
A. A longer time in the stair breathing the smoke, and I think the next one I related to carboxyhaemoglobin, which is another proxy for the same thing, essentially.
Q. And that's 26, if we can go to page 161 {DAPR0000005/161}.
A. I think this is ... Oh, no, this is the same picture again. It doesn't relate to how long you were in the flat.
Q. No.
A. No, the next one, please. I think it might be 27. I know it's there somewhere.
Q. Well, there isn't a 27.
A. Okay. There is a chart there which shows the injury level plotted against carboxyhaemoglobin, and that's quite telling, because it shows that if you've got more than about 20% -- if you've got less than about 20%

carboxyhaemoglobin in your blood, you are unlikely to have a significant inhalation injury, because you haven't inhaled that much smoke.
Q. It's 24, I think, page 159 {DAPR0000005/159}.
A. It would be good if we can find it.
Q. Yes, I think that's the one. That measures injury ——
A. There we are. That's a better one, yes.
So this is a plot of the percentage carboxyhaemoglobin at tower exit time against inhalation injury severity grade. Right? And the sort of thesis is the more smoke you inhale, the higher your carboxyhaemoglobin, and also the higher the probability you have of severe lung injury. You see this very strong positive correlation between the two, which demonstrates this point. Not only that, but in experiments we found —— animal experiments —— that there's a sort of threshold, that you seem to be able to survive having a certain amount of —— and this is smoke particulates with irritant chemicals attached, essentially, that we're inhaling, into the airways and deep lung. You can inhale a certain amount which would just give you a bit of cough the next day and then you recover quite easily, you know.
If you go above this kind of tipping point, then you seem to get really quite severe injury, and I think this

is to some extent showing up here. So the people who got less than about 20% carboxyhaemoglobin, and therefore had a relatively low smoke exposure, also had a very low instance of lung injury. But once you get up to about 30% carboxyhaemoglobin, quite a lot of these people are really in quite a bad state, and these are people who were put into induced comas, sometimes for several days, had a lot of lavage and cleaning of the lungs for secretions and were in a really quite serious state.
But I have to say, remarkably, the outcome for Grenfell, which differed considerably from the Rose Park case, was that they all survived, whereas at Rose Park they had quite a lot of deaths. So maybe things have moved on, you know. That's an encouraging sign, I think.
Q. Now, we have looked at quite a lot of this material, but just to see if we can draw some threads together, is it right that from the three graphs, 24, 25 and 26, and your analysis from the evidence in the survivors' witness statements, you have concluded that the time required to descend the stair was a significant factor in carboxyhaemoglobin levels at point and time of exit.
A. Yes. So what I'm saying is this particular cohort of people, all of whom are survivors, the thing they had in

common was that they tended to have got out of their flats without inhaling very much of a dose. The dose they did get was mostly acquired whilst descending the stair.
Q. What account have you taken so far as they are concerned of the exposure while crossing the lobby?
A. I'm estimating that, in most cases, that was quite small, that they crossed it quite quickly and that wasn't —— they didn't get much of a dose in the lobby.
Q. Right. I mean, have you left it out of account altogether in your mathematics, or have you ——
A. What we're doing here —— no, I mean, this is just correlating the back calculated carboxyhaemoglobins from the hospital data or the injury score against these factors of time in the flat or ——
Q. I see.
A. That's all I've looked at.
Q. Is it because you're working on the basis of a constant assumption of 1,800 ppm ——
A. In the stair column, yes.
Q. —— in the stair column ——
A. Yes.
Q. —— that you're able essentially to treat any uptake of carboxyhaemoglobin ——
A. As primarily in the stair ——

Q. —— (inaudible) in the lobbies as ——
SIR MARTIN MOORE—BICK: One at a time. I'm sorry, we can't have two people talking at once ——
A. Sorry, I beg your pardon.
SIR MARTIN MOORE—BICK: —— or the stenographer is going to find it impossible.
MR MILLETT: No. Can I put my question, professor.
A. Yes, sorry.
Q. Is it the case that because you're working at a basic constant assumption of 1,800 ppm in the stair column, and you can see from the washout curves what the total carboxyhaemoglobin percentage was at exit point, you're able to say that whatever was taken up in the lobbies was essentially negligible ——
A. Yes.
Q. —— so far as they're concerned?
A. Yes.
Q. Thank you, that's very helpful.
Now, if we then turn, please, to page 153 {DAPR0000005/153}, you say this at paragraph 667, and I'll read it to you, because it's a conclusion:
"The importance of these findings in relation to those who died in the Tower is that there has to have been other major contributory exposure to asphyxiant gases for their incapacitation and death in the flats,

lobbies or stair. As described in my detailed flat by flat analysis in Section 6, one important difference between those who survived and those who died is that those who survived left their flats before the exterior fire spread outside their flat, or at least before it spread outside the room they were sheltering in. Where occupants left their flats, another important difference is that those who survived are believed to have had limited exposure while crossing the lobby, whereas some who died in the lobbies or just after entering the stair are believed to have become disorientated and experienced significant exposure to the lobby smoke."
A. Yes.
Q. Just breaking that down into six propositions, if we can, just to make it crystal clear, is it right that you found, first, that the main exposure to asphyxiant gases was in the stairs?
A. Yes.
Q. Second, that the stairs were always passable or survivable, assuming minimal uptake of carbon monoxide in the flat or lobby?
A. Yes.
Q. Third, that those who were unable to survive the stairs had inhaled significant doses of asphyxiant gases in the flats before entering the stairs?

A. Yes.
Q. Fourth, that occupants in the tower would have been inhaling an increasing dose of asphyxiant gases while in their flats?
A. Yes.
Q. Fifth, but occupants would only have inhaled a significant dose of asphyxiant gases in the flat such as to impede escape when the external fire reached the flat?
A. Yes.
Q. And last, sixth, that in some cases, occupants were also disorientated in the lobby and inhaled an incapacitating dose due to prolonged exposure to asphyxiant gases in the lobby?
A. In the lobby, yes, there were a small number of cases in that category.
Q. In the lobby.
A. Yes.
Q. And that overall in certain cases, in individual cases, they were affected by individual characteristics such as age, the presence of small children, vulnerabilities and other matters?
A. Yes.
MR MILLETT: Yes, thank you.
Mr Chairman, I'm now going to turn to a different

topic, which is specific questions about section 6, which is the analysis of causes of incapacitation and death in individual cases. I'm reluctant to start on that at 4.25.
SIR MARTIN MOORE-BICK: It doesn't seem sensible to me that you should do so.
MR MILLETT: And we are making good progress.
SIR MARTIN MOORE-BICK: Well, that's good to know as well. Well, in that case, we will stop at this point.
It's slightly earlier than usual, professor, but we're going to stop at this point for the reasons that Mr Millett has explained.
THE WITNESS: Yes, thank you.
SIR MARTIN MOORE-BICK: We're going to have to ask you to come back for more questions tomorrow, but I think you were expecting that, weren't you?
THE WITNESS: Yes, I was, yes.
SIR MARTIN MOORE-BICK: Good. All right. Well, then, we will stop there. We will resume, please, at 10 o'clock tomorrow morning.
THE WITNESS: Yes.
SIR MARTIN MOORE-BICK: And the usual request applies: please don't talk to anyone about your evidence or anything to do with it over the break.
THE WITNESS: I understand.

SIR MARTIN MOORE-BICK: All right?
THE WITNESS: Okay.
SIR MARTIN MOORE-BICK: Good, thank you very much. We will see you tomorrow then. Thank you.
(Pause)
Thank you, Mr Millett. 10 o'clock tomorrow morning, please.
Thank you.
(4.25 pm)
(The hearing adjourned until 10 am on Thursday, 30 June 2022)

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