SCOTTISH HOSPITALS INQUIRY

Hearings Commencing
9 May 2022

Day 1
Monday 9 May
Morning Session

CONTENTS

10:00

THE CHAIR: Good morning. That is a good morning to those who are here in the Inquiry suite and those who are following proceedings on YouTube. We have around the table John MacGregor QC, who will be leading evidence this morning, the Deputy Counsel to the Inquiry. He is assisted by Ross McClelland, Counsel to the Inquiry, and instructed by Ms Rore, who is on his right. I am being helped by Ms MacNeil, who is the assistant solicitor to the Inquiry, and we have a member of the document management team, I think probably principally to assist the witnesses.

We have done what we can to make the proceedings as accessible to everyone. This hearing is being livestreamed, transcripts of oral evidence will be uploaded onto the website, and indeed at present, by accessing the website, people can find witness statements, the documents that we will be referring to in this session of the hearing and the expert reports.

The plan is to take oral evidence today and Tuesday; we are not sitting on Wednesday of this week. On Thursday we will be hearing evidence, I think using a remote link, and we will be sitting again to hear evidence on

Friday. We will try and begin promptly at 10.00 a.m. We will, I would anticipate, take a break during the course of the morning and sit again at 2.00 p.m. and aim to finish about 4.00 p.m., but that may depend on how the evidence goes.

Now, we are no longer in a statutory regime of Covid regulations, but, as people will be well aware, Covid risk remains and I would encourage people when moving around the Inquiry area or the outside area to be conscious of that, wear masks and be aware of social distancing.

Our topics for these two weeks, which we will be hearing evidence in this session, are, first of all, the general theory of ventilation in the context of hospitals and that, broadly speaking, is our topic for this week. Our topic for next week will be to look at the background to the plans for the construction of The Royal Hospital for Children and Young Persons at Edinburgh. No fire alarm tests are scheduled this morning so should you hear a fire alarm then it should be taken seriously and the building evacuated. I think that covers all the preliminary matters which I need to draw to your attention.

I would conclude by explaining to

those in our audience, questioning will be by Mr MacGregor, Counsel to the Inquiry. Core participants have had the opportunity – or their legal representatives have had the opportunity – to discuss possible lines of questioning with Mr MacGregor and I understand that he is taking account of what he has been asked to do in his planned questioning. Should the matter arise, if core participants feel that, for whatever reason, a question which they would wish to be asked has not been asked, the opportunity will arise, or begin with an informal discussion with Mr MacGregor. If that does not resolve matters – and I would hope it would – we may need to proceed to something more formal, having regard to the terms of Rule 9 of the Inquiry rules. I think that covers everything I need to say and, accordingly, I will turn to Mr MacGregor to lead his first witness.

MR MACGREGOR: Thank you, Lord Brodie. The first witness would be Dr Shaun Fitzgerald.

THE CHAIR: Good morning, Dr Fitzgerald. As I think you understand, you are about to be asked questions by Mr MacGregor. First of all, can I ask you to take the oath?

Dr Shaun Fitzgerald

Sworn

THE CHAIR: Thank you very much, Dr Fitzgerald. As I have already explained, I would plan that we take a break in the middle of the morning at some point decided on by Mr MacGregor, but if for any reason you want to break, feel free to just draw that to my attention and we can always take a break. Mr MacGregor.

Questioned by Mr MacGregor

Q Thank you. You are Dr Shaun Fitzgerald?

A I am.

Q You have provided a report to the Inquiry dated 22 March 2022?

A I have.

Q Just for the benefit of core participants, that will be found at pages 29 to 44 of bundle 6 of the Inquiry bundles. Does that report set out your opinion on various principles regarding ventilation design?

A It does.

Q The content of the report will form part of your evidence to the Inquiry, but you are also going to be asked some questions today. If you do want to refer to your report at any

point today, please let me know. I want to begin by asking you, Dr Fitzgerald, about your qualifications and experience. Am I right in thinking that you are an engineer?

A I am an engineer.

Q Qualifying as a Chartered Engineer in 1997?

A Yes.

Q You became a fellow of the Chartered Institute of Building Services Engineers in 2005?

A Yes.

Q You became a fellow of the Royal Academy of Engineers in 2014?

A That is correct.

Q You are currently a fellow of Girton College, Cambridge?

A I am.

Q How long have you been a fellow at Girton College, Cambridge?

A I have been a fellow at Girton College, I think, about 20 years. I can't remember exactly when.

Q Within the University of Cambridge, you are the director of the Centre for Climate Repair at the department of engineering?

A My formal position of employment at the university is a position called the Director of Research, but I do direct the Centre for Climate Repair, which is a multidisciplinary group at the University of Cambridge. So I am the director of that.

Q What does that involve?

A That involves firstly liaising with academics across the university on issues and research interests in the topic of climate repair, liaising with them and crafting research projects, and then working with potential fundraisers to raise funds for those particular groups.

Q Within your report, you explain that you spent time in academia but also time in industry as well. Is that correct?

A That is correct.

Q How long, in total, have you spent working in the field of ventilation in relation to buildings?

A I started my research in buildings in about the year 2001. I joined a, then, relatively new research project at the University of Cambridge on a part-time basis and then I moved to a full-time basis in about 2004, I think it was, and I've maintained a very active interest in the area of ventilation of buildings since then.

Q Thank you. If I could ask you to have your report in front of you and if we could look to your curriculum vitae at page 45 of the bundle, please. Thank you.

Do we see there at the top your professional experience you set out from 2020 to present that you have been with the University of Cambridge, but towards the bottom we see that you have been with Girton College, Cambridge from 2002 until the present day?

A Correct.

Q Then if we look over the page, to page 46 of the bundle, you see that you spent a period of time as the director of the Royal Institution of Great Britain.

A That's correct.

Q What did that involve?

A So, the Royal Institution of Great Britain is an organisation set out, now, to enhance the public understanding of science. So it's a public engagement of science organisation. It doesn't do research; it is a public engagement organisation and I was director of that.

Q Then before that, we see that from 2015 to 2020 that you were a visiting professor with the Royal Academy of Engineering.

A That's correct and that was in a part-time capacity whilst I was a) at Breathing Buildings and then, b) still with the Royal Institution, so I was in a part-time role. Mainly that role was mainly doing teaching of

ventilation and other aspects of low energy building design.

Q So, in addition to your academic research and teaching, you also mentioned that you spent time in industry. Is that correct?

A That's correct.

Q So, we see on page 46, from 2006 until 2018 you were involved with a company called Breathing Buildings Ltd. What was Breathing Buildings?

A So, the company was set up in 2006. I was a co-founder and it was funded by BP, who had funded research at the University of Cambridge, and that generated some intellectual property. As a result of that, we then formed the company with BP's blessing. They provided some seed funding. I then left the full employment of the university in order to be the chief executive of the company. It was originally called E Stack Ltd, and then we rebranded that in around 2009 when we then started taking on venture capital backing to grow the company. The main venture capitalist was MMC Ventures. Then I took it through, I think, two rounds of venture capital, growing it and then eventually selling it in 2016 to Volution Holdings.

Volution Holdings are probably

better known for some of their brand names. One of those is Vent-Axia Ltd, so they are a more mechanical ventilation company and we were moving towards hybrid ventilation, so they were a natural home for the company in order to further its growth thereafter into hybrid ventilation and to support Volution Holdings in the whole area of mechanical and natural ventilation.

Q As you have explained in your report, within Breathing Buildings, the focus was on ventilation in buildings.

A Absolutely.

Q Was one project that Breathing Buildings undertook concerning the ventilation strategy at Houghton-le-Spring Primary Care Centre?

A Houghton-le-Spring Primary Care Centre, near Durham.

Q Thank you. Can you just explain what you mean by a “primary care centre”?

A So, as I understand it, an expanded general practice. My experience of medicine as a patient is that small general practices-- and this was a large facility involving a number of doctors with more treatment rooms than I had been experiencing before as a patient in my own small general

practices, but it was not a full hospital by any stretch of the imagination, so it didn't have operating theatres and things like that.

Q So a treatment facility, but it certainly wasn't an acute hospital?

A It was not an acute hospital, indeed.

Q Presumably you would agree that the patient groups and the ventilation requirements for primary care would be different to an acute hospital setting?

A They are different.

Q Can I just clarify? Do you have any direct industry experience in relation to acute care ventilation systems in terms of the design?

A I don’t.

Q Do you have practical experience in using Health Technical Memorandums and the associated Scottish Health Technical Memorandums?

A When we designed the Houghton-le-Spring Primary Care Facility, yes, we were introduced to the HTMs and there was a further project with which I was involved called Breathing Space in Rotherham. In that particular project, I was not involved in the provision of equipment; it was merely as a design consulting project

on behalf of the ultimate client – that was Rotherham Council – and then the design was progressed and implemented and that was a mainly natural ventilation system.

Q So, if we can just go back to Houghton-le-Spring, what did your work with Breathing Buildings at that facility involve?

A There were two major areas. The first involved assisting with the design of the overall strategy for ventilation in the building, and in particular identifying areas where we were able to consider it, and allow for more mixed air throughout the space, but being really clear that there were certain rooms that had to be effectively divorced from the overall space and some of those were in the middle of the building, which is quite challenging for a natural ventilation system when you're normally using opening windows and things like that.

So, in that particular instance, we created a spine along the building with dedicated shafts and some of those shafts then fed individual consulting and treatment rooms without any interaction with air in the rest of the building. Whereas some of the more common spaces we were able to use those shafts and the air moved from one area of a space – a large space –

to others.

So the first was design, and then the second area was-- in terms of when the contractor was then appointed, it was Willmott Dixon. We then provided ventilation equipment to the contractor, which they then installed. We then went and helped with the commissioning of that in terms of making sure that our equipment was then operating as it was intended.

Q Would it be fair to say that it was a healthcare facility and it had some natural ventilation within it?

A Indeed.

Q Now, you also mentioned a separate project that you had worked on dealing with the Health Technical Memorandums. You mentioned Breathing Space. Could you just explain to the Inquiry what your involvement was in that project?

A It was purely design and it was a respite facility where people with breathing difficulties – hence the name Breathing Space – I think mainly derived from the mining area, historical in that area, and it was a building that was constructed for patients to come and have a residential offering of a few weeks at a time before they then went home. So they had bedrooms around the perimeter on a multistorey building with a central core, which we then

naturally ventilated in the design, but we weren't involved in the provision of any equipment.

Q Again, just so I am understanding you, you were involved in the design and checking that against Health Technical Memoranda?

A We were looking at the areas, in particular how we would be able to provide airflow and doing the sizing of the vents in order for that to happen.

Q Just to cover off your industry experience, in addition to working within the healthcare sector, am I right in thinking that you have also worked on other large projects, including on the Apple headquarter buildings in California----

A That's correct.

Q -- and the Bloomberg European Headquarters building in London?

A That's correct.

Q Looking towards your CV, you mentioned that you have been actively involved in work concerning the Covid-19 pandemic, including work for the UK government. Is that correct?

A That's correct.

Q That includes sitting as a member of the Scientific Advisory Group for Emergencies, commonly

referred to as SAGE?

A No, I was on the SAGE Environmental Modelling Group, so as part of that overall infrastructure, there were a number of subgroups and I was a member of the SAGE Environmental Modelling Group then fed into SAGE.

Q What was the SAGE Environmental Modelling Group and what was your involvement?

A It was looking at the modelling side, in terms of trying to understand the physical aspects of how the virus might be transmitted and in particular looking at the different routes, which were identified as aerosol droplet and the indirect route through contact. My involvement in that was because of my experience in ventilation and therefore looking at the sorts of measures we might be able to undertake in order to intersect the airborne transmission route.

Q Thank you. Were you also a member of the World Health Organisation's High-Level Expert Group on COVID-19?

A Yes, and still am on both of these.

Q In terms of your work with the World Health Organization, what did that involve?

A That has been quite recent and has, again, involved looking

at the-- commenting on ventilation strategies for helping reduce the risk of transmission of COVID.

Q Thank you. I now want to turn to the substance of your report and begin with the section whereby you introduce building ventilation, so that is page 33 of the bundle. Can you just please explain for the Inquiry, what is the primary purpose of ventilation?

A The primary purpose of ventilation is-- Do you mean in a healthcare context or more broadly?

Q I think let us just begin generally and then we will move on to the healthcare context.

A So it is ensuring that you're providing enough fresh air to manage the internal environment. The sorts of things that you need to worry about are control of odour levels within the space, as well as reducing the build-up of contaminants, and one of those contaminants is literally carbon dioxide which we emit to make sure that therefore it's sufficiently well ventilated. So that's the primary function. The secondary function is therefore also looking at thermal comfort.

Q So, just at a very basic level, if we are talking about ventilation, are we really talking about getting fresh air into a space?

A We are.

Q Thank you. Can you just explain to the Inquiry what is the difference between ventilation on the one hand and air conditioning on the other?

A So ventilation is the provision of fresh air to the space and removal of contaminants. Conditioning of air is about managing the conditions of that air within the space. So, in extremis, it would be quite possible to have a space that isn't too hot and where the humidity levels are managed with a recirculating air system in the ceiling, where you-- it takes the heat out of the air that we're generating in the space and actually, by doing so, with the way that they're designed, would also take up moisture, but you wouldn't control the air quality with contaminants being released by ourselves, for example. So that would be a conditioner, but it wouldn't actually sort out the air quality within the space and, in particular, contaminants, and that's why ventilation is needed.

Q So, just to make sure I am understanding you, ventilation is about getting fresh air into space, whereas air conditioning is really about the condition of the air in the space and possibly heating and cooling?

A That is my understanding.

Q Would I be right in thinking that you could have an air conditioning system within a ventilation system?

A That is correct.

Q Now, within your report, you introduce a number of concepts, particularly natural, mechanical and hybrid ventilation. So, if we could just take each of those in turn, what do you mean by natural ventilation?

A So, by natural ventilation, I mean the provision of fresh air to a space where the driving forces governing the rate of provision of fresh air are natural, and the two that we have at our disposal are wind and buoyancy.

Q So would one example be opening a window to let fresh air into a space?

A Yes, it would, but if you have a space with just one window and there are-- and it's a completely sealed space, that window will not only be the provision of fresh air, it's also the exit pathway as well. So you have bidirectional flow through that window.

Q You mentioned two forces, wind, but you also mention buoyancy. Can you just explain, what do you mean by buoyancy?

A So, by buoyancy, I mean the effect of a column of air relative to a column of air through-- to which it is linked and where they have different densities. So hot air rises because hot air is less dense than cold air, and therefore if they are linked, and it could be linked, for example, in a building where you have windows at the top and windows at the bottom, if the building is linked and those openings are of comparable size, the airflow pattern that one should observe is that cooler air will be drawn in through the bottom windows, it then gets heated up and will be exhausted through the upper windows, and what drives the rate of flow of air is the density difference between the two columns of air – so a column of air literally being outside – and the height of the building and indeed the size of the openings.

Q Thank you. Now, within your report at page 34 of the bundle, you introduce a number of concepts – single-sided ventilation, cross ventilation and stack ventilation. I think you have touched on some of those, but if we could just take each in turn, could you just confirm what do you mean by single-sided ventilation?

A So, by single-sided ventilation, I mean where we have a room in a building and the only

openings that are available for air exchange between the interior and the exterior are on the same façade. That's what I mean by single-sided ventilation. By cross ventilation, I mean, where there's more than one façade that is available to a given occupied space, and therefore when the wind is blowing, then in addition to whatever help you might get through air coming in through bottom parts of windows and top parts of windows, when the wind is blowing, you have a positive pressure on the upwind side and a negative pressure on the downwind side, and therefore that can drive more air through the building. That's what I mean by cross ventilation.

By stack ventilation, it is where you have a space, and it isn't just a window now, you have an access to either the roof or another high-level part of the building, and one has created a pathway – often a shaft – so that air can then come in through the perimeter and out through the shaft or indeed, as I alluded to regarding the Houghton-le-Spring, it's quite possible to not even have any façade openings and all of your ventilation is through the shaft, through the stack. When you have a stack, it is quite common to put a divider in the stack because that

is how you can then get more ventilation as a result of just one opening through the roof.

Q Moving on then to mechanical ventilation, what do you mean by mechanical ventilation?

A By mechanical ventilation, I mean where the driving force for the ventilation is a mechanical device, namely a fan.

Q Just to be clear, how is the rate of fresh air supply to the space governed?

A It is governed by the rate at which the blades are going to spin on the fan, and therefore these things called fan curves. So, for a given rotation and configuration of blades, you can get a-- they can create a pressure difference across the fan unit and a volume flow rate.

Q So, just to make sure that I am understanding this, in very simple terms, when we are talking about a fan in a mechanical ventilation system, are we talking about the fan drawing fresh air into a space and then a separate fan drawing air out of a space?

A Normally, but you are-- there are a number of instances where you can have an extract fan and the supply is then through opening windows, and that will be one form of a

hybrid.

Q If you are using a fan, how would one determine the specification of the fan that is required?

A One would need to look at the ventilation flow rate requirement that you are trying to meet within a space, and then also the resistance that you are going to calculate will be needed to be overcome as a result of the duct, the duct size, the duct length and the duct-- how tortuous the flow is – in other words, what the resistance is – because the fan has got to not only provide a given flow rate, it needs to provide enough pressure to drive the air through that resistive pathway, namely the duct.

Q What consequences could arise if the fan is not correctly specified?

A If it is not correctly specified, it's either over-specified or under-specified, all right? So, if it's under-specified, then one will have less than the rate of-- a rate of provision of fresh air lower than that which was intended by the design. If it's over-specified, then you can actually have more air than was intended. That actually also isn't necessarily great news because if you're providing more fresh air to a

space than actually you're intending, that can lead to higher energy bills in terms of heating in the winter.

Q You also mention hybrid ventilation, or in your report you refer to it as “mixed-mode ventilation”. Can you please explain what those concepts are?

A So there are a number of different permutations, manifestations of hybrid ventilation. One, which I have mentioned already, is where you have fans providing the extract and windows providing the-- therefore the inflow, so that's one form of hybrid ventilation. Another form of hybrid ventilation would be where the building is intended to be mechanically ventilated for periods of the year when the weather outside is actually either too hot or too cold, and yet when the weather is more temperate, you shut down the mechanical ventilation system and then you open up the natural ventilation vents, and it's then a naturally-ventilated building. So you're availing yourself of the benefits of being more connected to the outside, but also the energy-saving benefits by not running the fans to provide the fresh air when it's pleasant to do so.

Q Thank you. Just working through your report, at paragraph 3.1 of your report, you obviously address

natural ventilation, mechanical ventilation and mixed-mode ventilation. Can it be acceptable in some clinical areas to achieve a flow rate by means of using natural ventilation or using both mechanical ventilation and natural ventilation acting together?

A So, there are different areas in a clinical setting. So, certainly when I've read the HTMs or the SHTMs, there is a suggestion that it will be possible to naturally ventilate, for example, general ward areas, certainly the office areas. So there are areas within a clinical setting in the broadest sense where natural ventilation and/or hybrid ventilation is going to be possible, and in other areas where a close control of ventilation rates and pressures, for example, and if you need control when there is somebody there at specific times, it can be very difficult to do that just with a natural ventilation system because you can't dial up, for example, the wind speed on a given day. You have a crossflow ventilation strategy, for example, in the old Nightingale wards, with windows open on both sides of a ward, you can't necessarily dial up the wind at every time-- if you're having a more-- in an operating theatre or something like that. You need to use mechanical ventilation.

Q So am I right in thinking you are saying for some areas of the hospital it would have to be mechanical ventilation?

A I believe so because I can't-- I personally can't see how you can meet the requirements with a natural ventilation system, especially if you're going to introduce air where the requirements are for an air quality with a filter system, in other words removing all of the particulates. You can't do that with a natural ventilation system.

Q But there could potentially be some areas within a healthcare setting that could use either natural ventilation or mixed mode ventilation?

A Indeed, which is what we did at the Houghton-le-Spring Primary Care Centre, so the general waiting areas, for example, were naturally ventilated.

Q Yes. So, perhaps just to follow up, you mentioned some references to that within the Health Technical Memoranda. If we could just look, please, to the Scottish Health Technical Memoranda 03-01, "Ventilation for healthcare premises, Part A – design and validation, February 2014." That will be found in In Bundle 1. The document begins at

page 618, just to make sure we are looking at the right document.

A Yes.

Q Whenever you are referring to the SHTM, is this the document you are referring to, the Scottish Health Technical Memoranda---

A It is.

Q -- from February 2014?

A It is indeed.

Q Thank you. Then, within that document, if we could please go to page 639 of the bundle, which should be "Section 2: Provision of ventilation in healthcare buildings".

A Yes.

Q If we could look to paragraph 2.2, it says:

> "Natural ventilation is usually created by the effects of wind pressure. It will also occur if there is a temperature difference between the inside and the outside of the building. The thermo-convective effect frequently predominates when the wind speed is low and will be enhanced if there is a difference in height between inlet and outlet openings. Ventilation induced by wind pressures can induce high air change rates through a building provided air is allowed to move freely within the space from the windward to the leeward side.
>
> 2.3 As the motivating influences of natural ventilation are variable, it is almost impossible to maintain consistent flow rates and ensure that minimum ventilation rates will be achieved at all times. This variability is normally acceptable for general areas including office accommodation, general wards, staff areas, libraries rooms, dining rooms and similar areas which should, where possible, be provided with opening windows of a design that facilitates natural ventilation."

Do you agree with what is stated within that document?

A I do.

Q If we could just look on over the page, please, to page 640 of the bundle, which is paragraph 2.8, "Supply only ventilation", it states:

> "Mechanical supply ventilation will be required in areas where it is important to maintain a positive pressure in order to prevent the ingress of less clean air, e.g. in pharmacy aseptic suites, sterile supply packing rooms, operating theatres and their preparation

rooms (air change rates are given in Table A1)."

Do you see that?

A I do.

Q Do you agree with the statement that is set out there?

A I do.

Q Can you just explain really, in simple terms, what is being said at paragraph 2.8?

A What we're really saying is, as a result of fluid moving from high-pressure zones to low-pressure zones, if you wish to therefore control a space and ensure that it is being supplied only with, for example, air that's been passed through a HEPA filter, so it's really high-quality air and not being affected by ingress of air through other means, then what you would need to do is to ensure that (a), that that requisite flow rate is being provided by the ventilation system and, (b), that the pressure then maintained within that space is sufficiently high to reduce the risk of ingress of air, for example through an opening door and a movement through that door, reducing the risk to a satisfactory level, so to reduce the risk of ingress of contaminated air.

Q You mentioned earlier that there were some areas within a hospital that would have to have mechanical ventilation. Is this one example of an area that would really have to have mechanical ventilation?

A It is.

Q Thank you. If I could also ask you to please have in front of you, within Bundle 1, page 802, please. This is a document from February 2022 entitled "Scottish Health Technical Memorandum 03-01 (Interim Version – Additional guidance related to COVID 19 to be added in an update in 2022), Specialised ventilation for healthcare premises, Part A: The concept, design, specification, installation and acceptance testing of healthcare ventilation systems". So this is some interim guidance that has been issued since the version of SHTM 03-01 that I have just taken you to, Dr Fitzgerald.

A Okay.

Q If I could ask you to have in front of you, please, page 837 of that bundle.

A Yes.

Q This is headed up, "Section 5: Ventilation Strategies." Then if we could look, please, to paragraph 5.6 at the bottom of that page, which states:

"With natural ventilation, it is almost impossible to maintain consistent flow rates and ensure

that minimum ventilation rates will be achieved at all times. However, this variability is normally acceptable in non-clinical spaces, such as office accommodation, staff areas, library/seminar rooms and dining rooms …"

Now, if we pause there, that is broadly the same as what we saw in the previous version. But it continues:

" … and some clinical areas, such as level 0 and 1 air spaces and waiting and consulting rooms where risk of airborne infection is likely to be low. The design must still aim to achieve agreed limits for room temperatures and, for clinical areas, achieve the desired room air change rate with "thermo-convective" effect (at peak room temperature coincident with summer external design temperature). Where it is essential to achieve a minimum ventilation rate at all times, mixed mode or mechanical methods will be needed."

Do you see that?

A I do.

Q So, again, would you agree with that in terms of the mixture of areas stated there that could have natural ventilation and the areas that would require either mixed-mode or mechanical ventilation?

A I would, but my level of knowledge is that I would need to interrogate what we mean by "level 0 and 1 care spaces", so modulo(?) that, yes.

Q Is it as simple as saying you'd potentially have natural ventilation for a clinical space but you would need to know exactly what that space was and what patients were going to be in it?

A Yes. ,

Q If I could just check if the purpose of a room or a ward is not to control the spread of infection from an infectious person or towards a particularly vulnerable person, then is the flow rate not clinically important?

A I would be guided by what it says in the SHTMs, so-- in terms of that might be the principle, but it's absolutely clear in terms of the different flow rates and different pressures for different settings that have been looked at to say these are the guidelines that are needed, that should be followed.

Q Thank you. Returning to your report – I'm at section 3.2 of your report which is within bundle 6 at p.34 – you set out the components of a

natural ventilation system, so there would have to be some opening of the space to allow air in. I want to ask you about a mechanical ventilation system, and if I could ask you to have, within bundle 1, p.968 in front of you, please. I think there should be a hard copy large diagram.

A Yes, thank you.

Q Do you have that?

A I do.

Q So, in the top right-hand corner, it should have p.968, and do we see there really a diagram for an operating theatre?

A Yes.

Q If I just ask you to take us through, please. From the top left-hand corner we see "intake", is that really referring to the intake of fresh air into the mechanical ventilation system?

A It is.

Q Then if we move through there, moving through on the right-hand side, the air would come from the intake into the attenuator – what's an attenuator?

A An attenuator is a device to basically eliminate noise and to prevent noise ingress or passing through that device. It's not necessarily eliminating all the noise, it's reducing the amount of noise that comes through that device. The noise itself is made up of different frequencies, therefore the attenuator will be designed to tackle whatever the source is in terms of the high frequencies, low frequencies, and how the mix of those are deemed noise source.

Q The fresh air comes in in the noise reduction process. There's a "fog coil" next. What's a fog coil?

A I'm not familiar with a fog coil.

Q We then see that we've got the "supply fan". So what's the-- Well, we've got the filter first. What's the filter doing?

A So the filter is taking out particulates in large part.

Q Thank you. Then the fan, I think you've already explained that, but just in simple terms, what's the fan doing within the system?

A So the fan is creating a pressure difference at that point to then draw air in from the intake and putting it out through-- into the duct.

Q Thank you. So the air is still moving from the left-hand side of the page to the right-hand side----

A It is.

Q -- of the page through the system. After the fan, we then have something called a "run-around coil",

what's that?

A So a run-around coil is one of the devices whereby the heat or the enthalpy from the air that is being exhausted in another part of the system to provide that enthalpy to the incoming air. So there's a heat exchanger on the extract as well as a heat exchanger on the intake, and it's passing the enthalpy so that we don't have to provide as much heating – for example in winter – to the incoming air if we're able to raid some of that excess enthalpy, the heat energy, from the air that's being exhausted; this is what the run-around coil does.

Q So is this essentially about energy efficiency of the system?

A It is.

Q Next to that, there's a cooling coil. What's the purpose of a cooling coil?

A So that will be for use in summer if the air coming in is warmer than we would like to provide to the system. It's then having a refrigerant or something like that within the coil, which is cold, to then have the incoming air pass over that and therefore for the enthalpy of the incoming air to be reduced. You'll notice that there's a drainage system drawn underneath that; the reason is because, when you reduce the

temperature of the air, you are reducing its capacity to hold moisture and you can often get therefore condensation occurring on the cooling coil itself, and therefore the drainage system is taking away that moisture.

Q Thank you. Then next to that we've got a secondary filter again, is that filtering particulate just like the primary filter but just in a slightly different way?

A Before we get there, there's a heater battery which is----

Q Thank you.

A -- which is another-- basically adding more heat beyond the run-around coil if you then need to top it up with yet more heat. That's what that device is for. The secondary filter is indeed yet another filter to make the air even cleaner.

Q Then we see an attenuator. Is that performing the same function as the attenuator we've already considered?

A The same function but the noise source that was being tackled by the second attenuator is likely the noise being generated by the air moving through all the bits that we've just been discussing.

Q Thank you. Then towards the right-hand side, are we really then seeing what you referred to

as the “duct work” previously taking the air down towards the space?

A That’s correct.

Q Then we see that the air would go into the operating theatre on the bottom, both in the left and the right-hand side, we see an extract. Can you just explain what would be happening with the extract?

A Sorry, which bit of the diagram were you looking----

Q If you look to the diagram both on the bottom left and the bottom right, there’s what looks like a grill with “extract” written on it.

A Sorry, yes, okay.

Q What would be happening there?

A So the extract grill is where the air that’s come into the room from high level is now being extracted at low level.

Q How would that extraction be taking place?

A As a result of creating a negative pressure at that point and therefore drawing air into the grill.

Q Would that possibly involve an extract fan?

A It will involve an extract fan.

Q There are a number of other concepts related to mechanical ventilation systems that you mention in your report that I’d like to discuss with you, Dr Fitzgerald. The first is the concept of thermal wheels. What are thermal wheels?

A So thermal wheels are-- they’re rotary heat exchangers where the air passing-- air passes through. Half of the thermal wheel, you have an air supply, and through the other half of the thermal wheel, you have the air exhaust. The device itself rotates slowly, and the concept is that the air itself is separated so that the air itself doesn’t move but, in order to improve the energy efficiency of the building, that if you imagine you have warm, moist air leaving the space, the intention is to condense some of the water vapour from the outflowing air onto surfaces which then get introduced to the incoming cold, dry air, and then are-- that moisture is then evaporated and therefore what you are doing is doing a moisture reclamation and, in large part, that’s an enthalpy reclamation to reduce the heating bills of the building. So it’s a heat recovery device.

Q In terms of the purpose of a thermal wheel again, is that about energy efficiency?

A It is.

Q And just within the diagram on page 968 I’ve already

taken you to, at the bottom we see there's a reference to double-stacked supply and extract air handling unit and, within that, there's a thermal wheel. Can you just talk us through what we see in that diagram and how the thermal wheel would operate?

A So we'll start at the top, if you don't mind, which-- therefore the extract air-- So the top right where it says "extract", that will be the air that's being extracted from the room, and that's related to the upper figure where it says "extract" just below the grille. So that's the air that's come from the room, and it's moving from the right to the left. It passes through a return air filter. The reason why it will go through a filter is to protect the thermal wheel itself – we don't want the thermal wheel to get dirty.

So the air, it's not just got-- the extract air just doesn't just have moisture, it might have some other particulates that have been generated within the space itself. We're trying to remove those so that we don't contaminate the thermal wheel. So, at that point, the thermal wheel is rotating and the air moving from right to left. As the moist, warm extract air hits the thermal wheel, it sees relatively cold surfaces; these are veins or a honeycomb matrix that it's seeing.

The moisture then condenses on that, and then the extract fan is what is pulling the air from the extract grille all the way out. So it's pulling it through the thermal wheel and then it pushes it out to the discharge.

Now, that honeycomb that I mentioned from the thermal wheel has now rotated, and it's now going to come into the incoming fresh air stream. That fresh air stream is indicated in the lower half of Figure A2. The bottom-- the left-hand side is the intake louvre, so that's air from the outside coming in through a louvre. The reason why we often have a louvres is so that we don't get rain ingress into the system itself. The air is then going through a filter, the supply fan is what's drawing it in. Now we've got-- In winter, it will be relatively cold but relatively dry air. In particular it's cold, and therefore, even if you thought it was raining outside, because it's cold we're about to warm it up, and it will therefore be able to take on more moisture as a result of the temperature rising. So the thermal wheel is therefore able to pass the moisture that's been collected from the thermal wheel on the exhaust side, is able to pass that moisture back or put it into the incoming air stream, and that will reduce the heating bills for the building

in operation.

Q Thank you. Can the installation of a thermal wheel impact on air cleanliness?

A So there are tests that are done which look at the potential migration of aerosols, air from the exhaust pathway to the incoming pathway. I was written to only very recently with some data being provided by one of the manufacturers of thermal wheels, and they're claiming that it's very, very low.

Q You mentioned tests, so are those general tests?

A No, these are tests in their facility, so it's very early thinking at the moment, but the idea is that these systems are designed to try and really keep the passage of air from the exhaust pathway to the incoming pathway to an absolute minimum. The claims that I have heard are that the rate at which air might pass from the exhaust pathway of a thermal wheel to the inflowing pathway are less than the amount of air that you could possibly get even with a plate heat exchanger. So a plate heat exchanger is where the incoming air is separated from the exhaust air by a metal plate; but engineering systems are such that, even with a metal plate, you can sometimes get leaks. The

manufacturers of the thermal wheels have compared that with the leakage rates that you can sometimes get even with plate heat exchanges, and they are-- they're claiming are comparable or even better; so it's that no system is absolutely bulletproof.

Q If I just want to be clear that I'm understanding what you're saying, is there the potential for the thermal wheel to impact on air cleanliness but the----

A There is if the system hasn't been configured correctly; that is a greater risk. So, in my discussions with manufacturers of thermal wheels, that is something that concerns them. If they've been installed incorrectly then the pressure difference between the outflowing air and the incoming air can increase the risks. So it's really important that they're configured correctly.

Q What could happen if they weren't configured correctly?

A Then you could get a certain degree of passage of air from the exhaust pathway to the inflowing pathway. That's what I have been told.

Q What particular risks would that give rise to in a healthcare setting?

A In a healthcare setting,

that would mean that the air-- the air that's-- if it's being exhausted, if it's contaminated, then you're getting a certain recirculation pathway there and entering other spaces that were unintended.

Q Could that potentially be significant if one was dealing with vulnerable patients such as immunosuppressed patients?

A Theoretically, I believe it could be, but it would depend therefore, in large part, what other measures you might have in your system. So, for example, in this figure we have a final filter, and if that final filter has been introduced to the incoming air stream at the latter part of this diagram and that is well designed, then that will be potentially reducing the risks to an acceptable level.

Q In your opinion, would it be appropriate to install a ventilation system with a thermal wheel when the intended use would be in relation to space for immunocompromised patients?

A I'm not--theoretically, I would need to assess it, but I've not got experience of designing healthcare settings in this area, so I'm not sure I can answer that question.

Q Thank you. If I could then move on and ask you about

chilled beams.

A Yes.

Q What are chilled beams?

A The chilled beams are-- there are two types, active and passive. So the active type is where they are constructed as part-- or they're integral to the ventilation system, so the air that is being delivered to a number of rooms. For example, you may have different requirements in those spaces in terms of temperature and things like this, therefore introducing a local device such as an active chilled beam could be quite a convenient way of having a centralised supply system but with different conditioned air being delivered to those spaces. So that's part of a-- that's an active system. A passive chilled beam is where you're relying on just the convective patterns within the space itself, drive the airflow over, for example, the cooling coils.

Q So just so I'm absolutely clear, can you just explain what the purpose of a chilled beam would be within a hospital in particular?

A The purpose of a chilled beam is to help control the temperature and possibly the humidity, but certainly the temperature.

Q Thank you. In your opinion, are there any particular risks

associated with the use of chilled-beam technology in areas of a hospital where mechanical ventilation would be required?

A Not that I'm aware of but it's outwith my area of expertise.

Q Thank you. The Inquiry may hear evidence in relation to a company called Swegon that manufactures a product called a comfort module. Have you ever heard of that?

A I have heard of it.

Q What is a comfort module?

A So, I don't know the details of the Swegon product.

Q I now want to move on and ask you some questions about filters. What is a high efficiency particulate filter?

A It's a filter designed to remove the smallest of particles that are possible to remove with a filter – very, very high-grade filter.

Q Would that be used in a healthcare setting to try to reduce the risk of infection?

A I believe so, yes. They're also used on, for example, aircraft.

Q Thank you. And are they commonly referred to as a HEPA filter?

A They are. High efficiency particulate air filter.

Q Can you have a portable HEPA filtration system?

A Believe so.

Q In your opinion, should a portable HEPA filtration system be required in a space that already has a fixed HEPA filter?

A There's potentially a bigger question at stake in terms of the role of just HEPA filters, these standalone devices. We have been thinking quite hard about their use in the current context of the last two years and Covid, the role of ,standalone HEPA filters. They have greater value, much greater value when another system – and it could be a ventilation system, for example – is not delivering the amount of fresh air and therefore the role of dilution, potentially, that some people use in those spaces. Therefore, in answer to the question you posed, is that a standalone HEPA filter in conjunction with, for example, a HEPA filter that's already been provided within a space? I would first of all query why it is being suggested. Why is it necessary if the system itself, not the standalone device, had been designed correctly? So I would first of all look at whether the first system has been installed

correctly in delivering the requirements.

Q Thank you. Moving on within your report, at section 3.3 you address the concept of thermal comfort. What do you mean by "thermal comfort"?

A As hot bodies, 37 degrees centigrade, we generate moisture as well as carbon dioxide. We need to be in an environment where our temperature is regulated and we do that by sweating, for example, and radiating heat to the surfaces and convecting heat away from ourselves as well. So the environment that we are in is really important to how efficient we are at regulating our own internal temperature. Therefore, thermal comfort, in terms of the way that the ventilation system and a heating and cooling system is constructed, as well as indeed the surfaces of the environment to which we are exposed, will determine how well our bodies can therefore help us keep thermally comfortable.

Q In very simple terms is it about comfort of patients and staff within a facility?

A Yes.

Q Moving on then to section 4 of your report on page 36, which specifically addresses ventilation in a healthcare setting, can you please explain to the Inquiry, what would you say that the primary function of ventilation is in a hospital?

A So, as it says in the SHTMs-- have you got section 1 of the SHTMs, of the first one?

Q It begins at page 618 of bundle 1. The index is at page 618.

A So, I'll just comment on clause 1.4:

> "'Ventilation' is … provided in healthcare premises for the comfort of the occupants of buildings [so, yes it is]. More specialised ventilation will also provide comfort but its prime function will be to closely control the environment and air movement in the space that it serves in order to contain, control and reduce hazards to patients and staff from airborne contaminants, dust and harmful micro-organisms."

I think that's quite clear.

Q Is that your view as well?

A Yes.

Q Just to be clear, we are looking here at page 627 of that bundle----

A We are, sorry, yes.

Q -- paragraph 1.4 in

particular. Is that correct?

A Yes.

Q Controlling the air movement and containing, controlling and reducing hazards to patients----

A Is the prime function.

Q In relation to that primary function, does the importance of close control of ventilation systems apply to all areas or simply to some clinical areas?

A As is laid out in the document, the level of the rate of fresh air, pressure differences and whether they can be maintained at all times, does depend on the particular environment. So we've already learnt this morning that, for example, general ward areas can be afforded more tolerance than other areas of a hospital.

Q I suppose it would potentially depend on the patients that are being treated and their individual requirements?

A As laid out in the SHTMs.

Q So, if that is the primary function of ventilation in a healthcare setting, what are some of the potential risks associated with errors related to design, installation or operation of a ventilation system in a hospital?

A So if you don't provide the necessary flow rates or the

pressure differences between spaces, then one can increase the risks of transmission of infection from one person to another.

Q Just while we are on this topic of healthcare ventilation, would you agree that over-provision, over-engineering of a ventilation system, is undesirable, particularly in publicly funded projects?

A (After a pause) Let me explain why I'm pausing. Over-designing, in other words, increasing--there are two avenues: one is increasing the capital cost of a project, and some people might think that that is therefore over-designing. However, if by increasing the capital cost of a ventilation system you are, a) not only providing mechanical ventilation, but in some spaces also providing the facility to have natural ventilation, which is then going to be possible to use at certain times of the year, so a hybrid system or like this can indeed cost more than a just a mechanical ventilation system.

In that particular instance, over-designing from a ventilation system point of view could actually be the right answer for the long-term benefit of certainly energy costs, but also health and wellbeing. If you're able to create more airflow in summer or when it's

pleasant outside with natural ventilation in a general ward area, then that would be something to consider, but if it's just over-ventilating, for example, a lot of the time, then one is going to lead to, a) potentially having a greater capital cost upfront and then greater energy bills through the operation thereof and that wouldn't be desirable.

Q Thank you. Moving on then, within section 5 of your report on page----

A Sorry, can I just add though, over-designing-- there is a section in the SHTMs which makes it clear in terms of what the tolerance levels that you should be designing to. So, you shouldn't be designing to the wire because it's very difficult sometimes to calculate the resistance through ducts and things like this. Therefore, the tolerance levels are laid out, for example, in the SHTM. Sorry, let me just bring this up. Where is this? I can't remember which table it was, counsel, I apologise. There's a table in the-- it was something like 5 per cent or 10 per cent additional allowance after one's calculations to try and ensure that you are going to be complying with the design guidelines.

Q For example, if we could look to page 653----

A 653?

Q In bundle 1.

A That's it, exactly, section 3.53. Thank you very much.

Q If you could just explain, what do you mean by “not designing to the wire” and “having a tolerance”?

A As an engineering principle, you do your calculations and it can be very difficult to calculate, for example, the pressure resistances for a given flow rate down a duct, taking into account, a) all of the bends of the design, but also potentially some changes that inevitably happen on-site when one is when is putting ducts within a within a ceiling void or something like that.

There may be small changes that the contractor makes for practical reasons, and it's just important that you have enough in reserve in terms of the power of the fan to be able to accommodate those small changes. That's what this table, in large part I believe, is drawing at. So therefore that is part of over-design, but it's sensible over-design. It's not by factors of three, but it is over-design in terms of beyond the theoretical calculations that you might be able to achieve.

Q The tolerance, essentially, taking what should work in

theory, but trying to make sure it works in practice?

A Correct.

Q If we could then move on to section 5 of your report, that is at page 36 of bundle 6. You outline a number of critical parameters that require to be controlled by ventilation systems in hospitals and you introduce a number of concepts such as pressure, flow rate, temperature and humidity. Now, in terms of pressure, what do you mean by “pressure”?

A Specifically, the pressure in a space relative to the spaces to which it could be connected, through an opening door, or indeed any other openings. That's what I mean by pressure.

Q So, if we're talking about positive pressure and negative pressure or balanced pressure, what do those mean?

A So a positive pressure, as I understand it, is positive relative to ambient external pressure and negative being where the pressure is lower than the outdoor air pressure.

Q So why is that important in relation to ventilation systems in a hospital?

A It is important because air moves from high pressure to low pressure and therefore it is governing

the movement of air and the quality of that air from where it's come from to do with, therefore, managing risk of transmission, or risk of illness, which might not be transmission as such, but for example, just as a result of dirt.

Q So, if we could return to the Scottish Health Technical Memorandum 03-01 and if we could look to page 756 of bundle 1, you will see appendix 1----

A Yes.

Q -- which has got air changes----

A Air changes per hour.

Q Indeed, so if we see there, there is the “Application”, “Ventilation”, “Air changes”, “Pressure [in Pascals]” and “Supply Filter”. If we look, for example, to “critical care areas”, we see that for the pressure, or the Pascals, it has got “+10”. What is that table telling us?

A That is telling us, with a +10 Pascal pressure level relative to the exterior, it's telling us that the air that is coming into that critical air area is being provided by the mechanical system and not being provided by air from other sources. This is to try and ensure the quality of the air in that space. For example, if it's come through a HEPA filter, then it is HEPA filter quality air that is being delivered

to that space rather than anything else.

Q In terms of setting that, the pressure is a positive or negative, in terms of how you are trying to move the air, what is it----?

A So, the +10 is telling us that it's air being provided by the fan to stop air coming in from other sources. This is what the +10 is telling us, that it's to try and reduce the ingress of air from other sources.

Q Just to be clear, how does that potentially link into infection prevention and control issues within a hospital?

A So, the intention is to reduce the risk of infection of those patients as a result of air from other sources around the perimeter being either dirty or with some contaminants from infectious persons. It's to try and reduce the risk of those being admitted to the space.

Q Again, if we just think back to within appendix A1 that the critical care area, if, rather than being at the positive end pressure Pascals, that was set to the wrong levels, it was set to a negative pressure regime, what could the potential consequences be?

A Increased risk of illness for the-- increased risk of acquiring an infection by persons in that space if

they were vulnerable and there was air around the perimeter, therefore from other spaces that could lead-- which they shouldn't be exposed to.

Q On page 37 of your report, you introduce the concept of a flow rate. What do you mean by “a flow rate”?

A By a flow rate I mean the amount of fresh air being provided to a given space as a function of time. So, for example, 10 litres of fresh air per second being provided to a space and sometimes expressed as 10 litres per second per person, depending upon the number of people in the space, more fresh air being provided.

Q And why is that important?

A That is important because we all generate contaminants, carbon dioxide, odours, moisture – as I mentioned at the beginning – and the rate of fresh air being provided helps ensure that the amount of material that we are generating is then taken out of the room. Therefore, the level of contaminants within the space is kept to a reasonable level.

Q And is that the same, or is that different, to an air change per hour?

A Right. So, there are two

concepts which are important to recognise. The first is that the concentration level of contaminants in a space is a function of two things, in steady state: the function at the rate at which they are generated in the space and the rate at which they are taken out. The rate at which they are taken out is equal to the rate of supply of fresh air to the space. So that will determine the steady state concentration of contaminants in a space. The air change rate happens to be that rate divided by the volume of the room.

Where the air change rate becomes important is that if we're not just interested in the steady state value of contaminants in a space, but rather also the rate at which the contaminant level will build up in a space then that is a function of the air change rate. So the air change rate tells us how quickly, for a given generation rate of contaminants, how quickly the steady state level will be achieved in a space. Conversely, it also tells us how quickly that that concentration level will also decay once we've removed the source of contaminants in the space.

Q Thank you. So in page 37 and page 38 of your report there's a couple of sentences I want to pick up with you, Dr Fitzgerald. The first is at

page 37, you say that, “Flow rate is important because the rate of removal of a contaminant is directly proportional to the rate of supply… and rate of extraction…”, and then at page 38, you go and say that, “Flow rates…are important because they help manage the build-up and decay of contaminants in a space.” Can you just expand and explain what you mean by those statements?

A Sorry, could you just say the question again? I thought we had just covered something along these lines.

Q Page 37 of the bundle----

A Yes.

Q -- you say that “Flow rate is important because the rate of removal of a contaminant is directly proportional to the rate of supply…and rate of extraction…”

A Yes.

Q So what do you mean by that?

A For a given space, the rate of supply of fresh air is equal to the rate of exhaust of air. Even if, for example, the fan rates are set to be different for some reason, they will be the same because you'll get-- the difference will be met by air coming in or out under the doors and things like this. You can't have-- We can't

create, over time, just build-up of air and, you know-- so we will have the supply rate being equal to the extract rate. The rate of removal of a contaminant is-- sorry, the concentration level in a space is dependent just on two things, as I mentioned: there's the rate at which it's being generated and then the rate at which it is being removed by the fans, and therefore the steady state concentration is just-- it's dependent on only those two things, and it's the generation rate divided by the extraction rate.

Q Is that what you are talking about in terms of managing the build-up and decay of contaminants within a space?

A The timescale involved in the build-up and the decay is a function of the room size as well, but the steady state value is just a function of the rate of generation and the rate of supply.

Q In relation to flow rates, would you accept that the importance of flow rate, once comfort levels are achieved, would depend on the specific clinical context?

A I would be guided by the SHTMs in terms of, therefore, just how much fresh air should be provided to a space, and we've seen that those flow

rates do vary depending on the kind of setting within an overall hospital.

Q Is the principal use of flow rates in general wards or non-isolation rooms to achieve the comfort of the patient?

A I'll be guided by what it says in the SHTMs, is that the primary function in a hospital care setting is indeed the contaminant build-up. The reason I make that point is that it is possible if all you cared about was thermal comfort, as I mentioned right at the very beginning, is to isolate the room, no fresh air at all, and to have a device that removes moisture and removes heat. So I might be thermally comfortable, but the air quality will be absolutely terrible if I put people-- So I come back to the SHTMs: the primary function of ventilation is about the management of the quality of the air. Thermal comfort is also important, but we have assistance for that in other ways, if necessary.

Q Thank you. Would you agree that the need or otherwise for a particular relative pressure environment would depend on the clinical context?

A I would be guided by the appendices in SHTM, which lays out quite clearly the kinds of spaces which have certain pressure differences.

Q Are the principal situations in which relative pressure environments are required either to prevent the spread of infection from a room that contains an infected person or to protect a particularly vulnerable patient from airborne infection?

A That is my understanding, given the pressure differences that are laid out in the SHTMs and the kinds of spaces to which they are applied, but I would be guided by – that's an interpretation, my interpretation, but others are able to interpret, too – by the appendices from the SHTMs.

Q Thank you. If the purpose of a room or a ward is not to control the spread of infection from an infectious person or towards a particularly vulnerable person, then is flow rate not clinically important?

A Flow rate is important, as is laid out in the SHTMs, for all of the spaces which are referred to. Most spaces in a hospital will be occupied at some point by somebody, even if it's a member of staff, and we need to be thinking about-- The reason they're written as they are is that we're looking at all people who are in a healthcare setting.

Q Are there any scientific studies demonstrating the effectiveness of different flow rates for the control or spread of infection?

A So there are some studies. So there is a-- I'm aware of, as a result of my experience on the SAGE Environment Modelling Group, of a model, which is what we call the dose-response threshold, for the likelihood of acquiring an infection as a function of the cumulative exposure to a virus, for example, within a space, and one can use that model, as well as, therefore, the understanding that I referred to a short while ago regarding what determines the level of concentration of viruses within a space as a function of ventilation rate, counsel(?), and therefore combining those two, one can say that it is likely, therefore, that there is a function of-- in terms of addressing the question you've just posed, that there is a relationship. But that's-- that was from a modelling point of view that I've just referred to.

Q So, in relation to the SAGE modelling, is that a relatively recent study that you are talking about?

A It's an academic paper that I have published, with others, in the last 12 months. I think there's another one out for review at the moment.

Q So you mentioned the SAGE modelling and the academic paper, and then you were going on to talk about effectively your understanding in relation to levels of contamination. Where does that understanding come from? Are there specific scientific studies that underpin it?

A So the level of understanding-- So there's some work back several decades ago by-- It was called the Wells-Riley Model for Infection, but I'm not a virologist and I would need to defer to others, but there is clinical work that's been done in that regard.

Q Thank you. Are you aware of research that was conducted by Dr Lidwell and others in the 1970s concerning ventilation in operating theatres?

A I'm not.

Q If we could go back within bundle 1, still within the Scottish Health Technical Memorandum, to Appendix 1 on page 756, please. We have looked at this before, but there is a table setting out a whole host of applications, from general wards to critical care areas, and there are various air changes per hour and various flow rates set out there. Are you aware of any science or scientific studies which inform the particular figures for air changes and/or flow rates that are set out for the different rooms?

A I'm not.

Q Are you aware of the basis upon which these particular figures were chosen?

A I'm not. But I would just refer to my experience in helping with the drafting of ventilation regulations for educational settings, which is called Building Bulletin 101, that was a large exercise undertaken by the Education and Skills Funding Agency on behalf of the Department for Education in the UK and, in terms of just the range of expertise that was brought in to help inform the changes to those guidelines, was quite considerable and involved multiple stakeholders – industry, academics, obviously educationalists as well. So I wasn't responsible for that, but I saw it, I was part of it, but it was-- what impressed me was that there were lots of different people with different expertises being drawn upon to help inform regulations.

Q That was regulations, but for educational establishments----

A It was, it was.

Q -- as opposed to healthcare settings?

A It was, but I'm referring to

it that I would-- that was my experience, that it wasn't just an academic doing this.

Q Again, whenever you mention various stakeholders, was it just engineers that were involved in setting those ranges or what other disciplines were involved?

A Contractors were there, mechanical contractors, architects, engineers and people from the DFE.

Q People from the?

A Department for Education.

Q Department for Education.

A And they had quality-- sorry, quantity surveyors there as well.

Q Thank you. (To the Judge) Lord Brodie, I am conscious that that is just after half past 11. That might be an opportune moment for a break, if your Lordship is minded to take one.

THE CHAIR: All right. Well, as I indicated, generally speaking, I would look to take a break in the morning. I think the clock indicates we are just after half past, so if we could try and sit again just after quarter to 12.

(Short break)

THE CHAIR: Mr MacGregor.

MR MACGREGOR: Thank you. Dr Fitzgerald, within your report in section 6 on page 36, you make reference to Table A2 from the Scottish Health Technical Memoranda 03-01. If we could look at that, it is within bundle 1, page 758. You can see “Appendix 2: Hierarchy of cleanliness”. Do you have that?

A Yes.

Q Can you see that there are various classes of room, sterile, clean transitional and dirty? Then over the page, on page 759, there's a note:

> “a. Nominal room pressures are given to facilitate setting up pressure relief dampers, the calculation process, and the sizing of transfer devices. In practice, the resultant pressures are not critical, provided the desired airflow rates movement are achieved.”

Do you see that? Do you agree with that statement?

A I do agree with the principles, yes.

Q Can you just explain the principle in relation to why the resultant air pressures are not critical, provided that the desired airflow rates and movement are achieved?

A My understanding is that, fundamentally, this is about the

principles of ventilation being the control of the internal environment. That requires desired airflow rates and movement, so that's what it's drawing at, in my-- is my understanding. That's the underlying critical factor.

Q So would that mean that, in relation to a room or a ward in which the pressure differential is not achieved, but the air movement was achieved, would that be acceptable in practice?

A That's what this says. I would be interested to know if somebody were to not therefore comply with the pressure difference, how they would demonstrate that the air flow rates and the air movement under the various guises were in fact going to be achieved.

Q How could that potentially be demonstrated?

A I think that's quite hard. So visualisation, techniques with modelling, as well as experimental observations in terms of doing tracking, but it's-- to prove that point from a fluid mechanical point of view is quite a lot of work.

Q Is filtration also important to the removal of contaminants?

A Sorry, can you explain the context of the question?

Q I was just asking if

filtration is also important to remove any contaminant from a space.

A If that filtration is being used so that the air itself is then readmitted to the space, then I can understand why-- So if it's a standalone HEPA filter in a room, then that degree of filtration is therefore being used to remove contaminants from a space, but if a filter is being used on the inlet supply that's not removing contaminants from the space and then you're applying a filter to the exhaust air, that's not removing contaminants from the space as we saw in the thermal wheel. You might want a filter on the exhaust airstream in order to stop any contaminants from the space being emitted somewhere else or passing into the inflow stream from the thermal wheel, but it’s not removing-- the filter is not removing contaminants from the space other than if it’s a recirculating system.

Q Thank you. If I could just move on and ask some questions about the design phase for a ventilation system: is it important to understand at the design stage how a range of external factors – doors, windows, lifts and the like – will all interact in order to design the ventilation system?

A I believe so.

Q After a system has been installed, how should the airflow or air change rates be monitored to ensure that the system is operating as intended?

A Well, the first thing after installation is then to ensure that the system is commissioned appropriately because the initial effect-- Effectively, the initial testing of the system, after you've assembled all of the components, that needs to be checked, and the reason it needs to be checked is, as I mentioned earlier, it can sometimes be a little difficult to exactly determine the linkages from one part of the system to another if there have been any changes on site as a result of an increased bend in the duct to accommodate something else that hadn't been foreseen, so therefore a difference in resistance. So you've got to commission it, and that requires measuring pressures and measuring flow rates with things like ventilation hoods, so a device that would be used to link up to a supply grille in a ceiling, therefore taking the measurements from that, and doing that across the system to make sure that it's been commissioned properly.

Q So you have got the design stage, you then have the system that is installed, and you are

now talking about commissioning.

A Yes.

Q Who does the commissioning?

A There are companies that have the equipment for that and then have to go and lay out certificates. So, in my work over the last two years, I was asked to review the certification-- the certificates from, actually, it was a school to see whether their system had indeed been appropriately commissioned. I offered this as a service gratis to help the school and deemed(?) that in fact the certificates looked as if the system had indeed been appropriately commissioned, but there are companies that do that.

Q Is that engineers that are going in to do that testing?

A Commissioning engineers normally, yes.

Q Is there a stage after that referred to as validation?

A That, I'm not familiar with.

Q You mentioned at the commissioning stage that things can perhaps be slightly different in practice to the theory when the system was being designed. What happens if there are differences identified at the commissioning stage?

A So this is where you can have what we call balancing dampers in duct arrangement. So, if we find that one supply duct is providing more air than is absolutely-- than is necessary at the expense of another duct, another supply grille supplying less, then you can adjust the resistances within the system then equalise the flow so you can--this is what part of the commissioning can be used to help with.

Q I'd like to ask you some brief questions about ductwork. In your experience, would you expect to find ductwork utilised to service rooms of different levels of cleanliness?

A It's outwith my experience.

Q Thank you. If I could move on to section 7 of your report, please, which addresses guidance and accepted standards. At paragraph 7.1, you refer to risk because of a higher steady state levels of contaminants. See that? 7.1, approximately just below halfway down that paragraph.

A Yes.

Q Would you agree that the distance or extent of any risk is going to depend on the clinical context?

A I would just be guided by the SHTMs in terms of the flow rates being asked for in different settings,

which can be different.

Q Are you aware of whether there's any scientific evidence of the actual risk posed by a higher steady state level of contaminants?

A So this is very similar to a question that we tackled in the earlier session regarding the modelling, looking at the risk of likelihood of infection being a function of the accumulative dose threshold, and then that itself being a function (a) of the rate of generation of a virus, for example, in a space, and the rate of exhaust of air from the space and it was a function of the two.

Q So, in terms of quantifying risk, would it depend entirely in the individual circumstances?

A It's relative risk, so in terms of-- the rate of generation of a contaminant in a space varies greatly from one infectious person to another.

Q Thank you. In relation to ventilation systems in a hospital, particularly in mechanical ventilation, we've talked this morning about a whole range of things: air change rates, pressure, temperature, you mentioned humidity, comfort of occupants, patient safety; do these all really need to be considered holistically at the design stage?

A I believe so.

Q We've looked at the standards that are set out within Health Technical Memorandum and the Scottish Health Technical Memorandum. To what extent is derogation or deviation from that guidance permitted, in your opinion?

A The projects with which I've been involved on design of buildings, we have never sought to deviate from the ventilation regulations.

Q Is it permitted to derogate from standards?

A It's something I don't know the exact answer to. As a professional, in the projects I've been involved with, trying to do what I think is right and therefore to offer good quality answers, we've never even-- we've not sought to deviate from the ventilation (inaudible).

Q Okay. So do you have any experience or knowledge in relation to derogations or procedures for derogation from such guidance?

A I have no experience.

Q Can I just ask you about one passage from page 43 of the bundle within your report? You mention that:

"The reason for this standard is that cleanliness of ventilation systems is considered important for human comfort and health, energy consumption, system service life, and for cleanliness of operations or processes carried out in the ventilated area."

So you're referring to----

A I do, yes.

Q -- the issue of cleanliness. How would the cleaning regime for a ventilation (inaudible) be determined?

A That would need-- I would need to refer to the British Standards Council(?) on that.

Q So there's British standards that----

A I believe so. I----

Q -- relate to that issue.

A -- refer to the British standards.

Q On page 44, you talk about design guides typically being written in collaboration, and you've given us your experience in relation to educational facilities.

A Yes.

Q In relation to design guides, would you expect either clinical microbiologists or infection prevention control specialists to be involved in such design guides?

A As aforementioned

regarding the education guides, I would expect to list the inputs and experience and expertise of the relevant people, and they would include people who understand infection control in this setting.

Q Can I just ask for one point of clarification arising from some of the answers that you've given? If we could look back within the Scottish Health Technical Memorandum 03-01 to page 627, please, and to paragraph 1.4 which we've looked at before.

A Yes.

Q Do you see that it says – and we've been through this before: "'Ventilation' is also provided in healthcare premises for the comfort of the occupants of buildings." Do you see that? It then goes on to say: "More specialised ventilation will also provide comfort but its prime function will be to control closely the environment and air movement..." I really just want to make sure I'm understanding you; is all ventilation in a healthcare setting about closely controlling the environment or is it only about specialist ventilation?

A (After a pause) That's a good question. I had interpreted 1.4 as its prime function being ventilation applied generally.

Q What was your view?

A My view is that the ventilation is there first and foremost to provide control of the air quality within an environment, and that in turn is therefore helping control risk of infection, contamination.

Q Thank you, Dr Fitzgerald. Lord Brodie, that deals with all the questions I would wish to raise, and I've sought to take on board issues and lines that were raised by core participants but your Lordship may wish to check that core participants feel that I've dealt fully and fairly with the issues and lines that I agreed to raise.

THE CHAIR: Well, just having heard counsel, does anything arise from this evidence so far? I take that as a "no". Thank you very much, Dr Fitzgerald. That's the end of your evidence. Thank you very much indeed.

THE WITNESS: Thank you.

(The witness withdrew)

THE CHAIR: Now, Mr MacGregor, I understand that your next witness is available. I also understand, though I may need the detail explained to me, that in order to provide a suitable gap in the transmission, we may need to pause

for-- it's just a few minutes rather than anything else.

MR MACGREGOR: Yes, my Lord.

THE CHAIR: Right. Well, if everyone is content just to wait, and I'll get a heads up when we can move to the next witness.

12:15

(Short break)