COVID 19 and
Why Ventilation is so Important
PART TWO

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- Registered as Chartered with the Engineering Council in the UK

- IHEEM were founded in 1943 and are an International Institute

- Republic of Ireland Branch founded in 1989

- Objectives;
- Provide Regulation of Engineering through registration
- Support to Healthcare Engineers
- Education of members on New Technology through technical seminars
- To Share experiences and common issues
- Bring Public and Private Sectors together
- Promote Communication within our Industry

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AGENDA
PART TWO
COVID 19 and
Why Ventilation is so Important

12.05 – Richard Knight CEng MCIBSE FIHEEM
Authorising Engineer HTH03 Ventilation
(Richard Knight Consultancy Ltd)

12.30 – James Reilly MIHEEM
Director Homan O'Brien Consulting Engineers

12.50 - Questions to the Speakers

13.00 – Close

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Republic of Ireland Branch

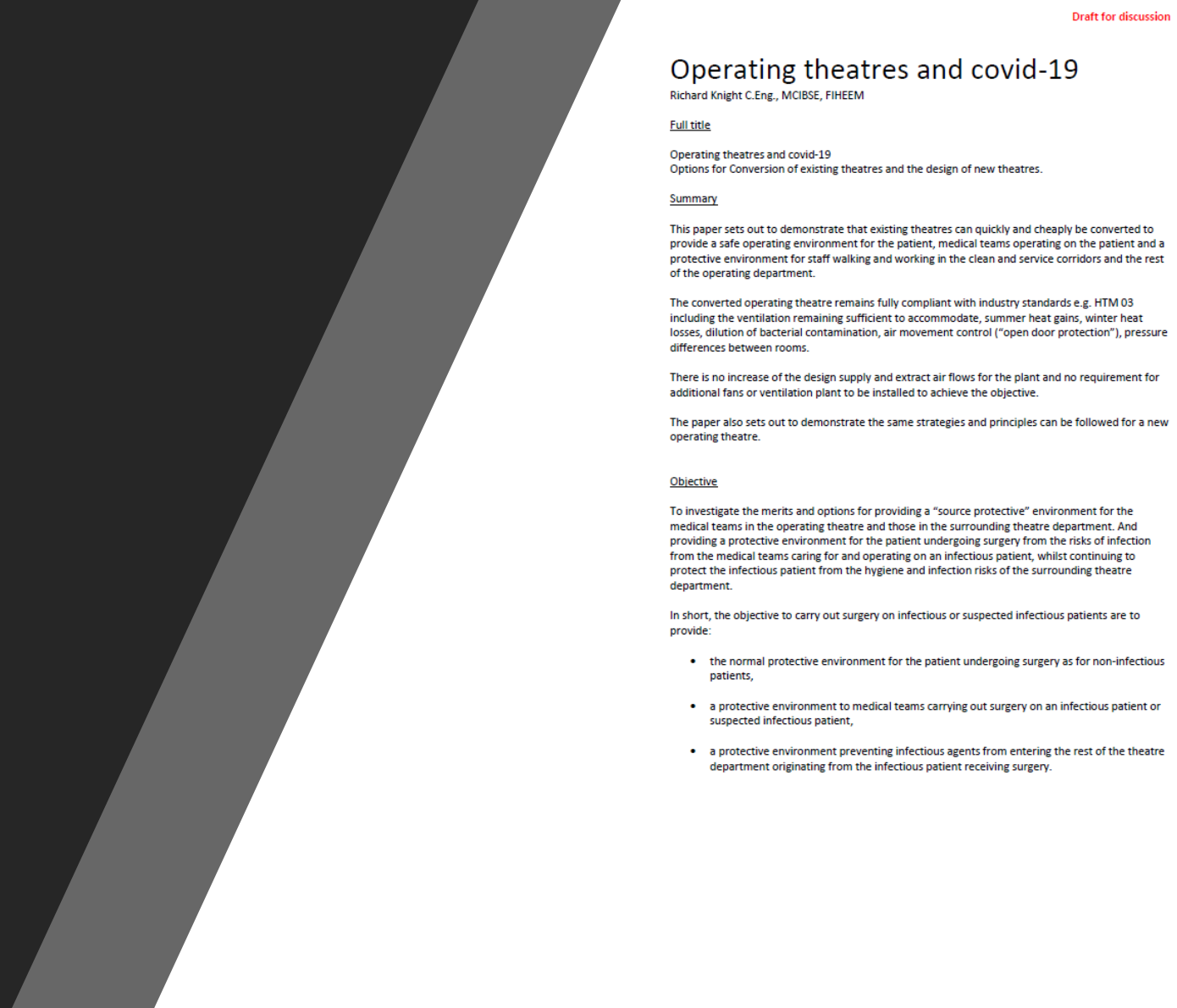
Operating Theatres and Covid-19

Options for Conversion of existing theatres and the design of new theatres

Richard Knight CEng MCIBSE FIHEEM

Richard Knight Consultancy Ltd

GoToWebinar
12noon 8th July 2021



Draft for discussion

Operating theatres and covid-19

Richard Knight C.Eng., MCIBSE, FIHEEM

Full title

Operating theatres and covid-19
Options for Conversion of existing theatres and the design of new theatres.

Summary

This paper sets out to demonstrate that existing theatres can quickly and cheaply be converted to provide a safe operating environment for the patient, medical teams operating on the patient and a protective environment for staff walking and working in the clean and service corridors and the rest of the operating department.

The converted operating theatre remains fully compliant with industry standards e.g. HTM 03 including the ventilation remaining sufficient to accommodate, summer heat gains, winter heat losses, dilution of bacterial contamination, air movement control ("open door protection"), pressure differences between rooms.

There is no increase of the design supply and extract air flows for the plant and no requirement for additional fans or ventilation plant to be installed to achieve the objective.

The paper also sets out to demonstrate the same strategies and principles can be followed for a new operating theatre.

Objective

To investigate the merits and options for providing a "source protective" environment for the medical teams in the operating theatre and those in the surrounding theatre department. And providing a protective environment for the patient undergoing surgery from the risks of infection from the medical teams caring for and operating on an infectious patient, whilst continuing to protect the infectious patient from the hygiene and infection risks of the surrounding theatre department.

In short, the objective to carry out surgery on infectious or suspected infectious patients are to provide:

- the normal protective environment for the patient undergoing surgery as for non-infectious patients,
- a protective environment to medical teams carrying out surgery on an infectious patient or suspected infectious patient,
- a protective environment preventing infectious agents from entering the rest of the theatre department originating from the infectious patient receiving surgery.

Is there a need ?

- Through out the pandemic, and no doubt ongoing, there has been a need to carry out surgical procedures on infectious patients,

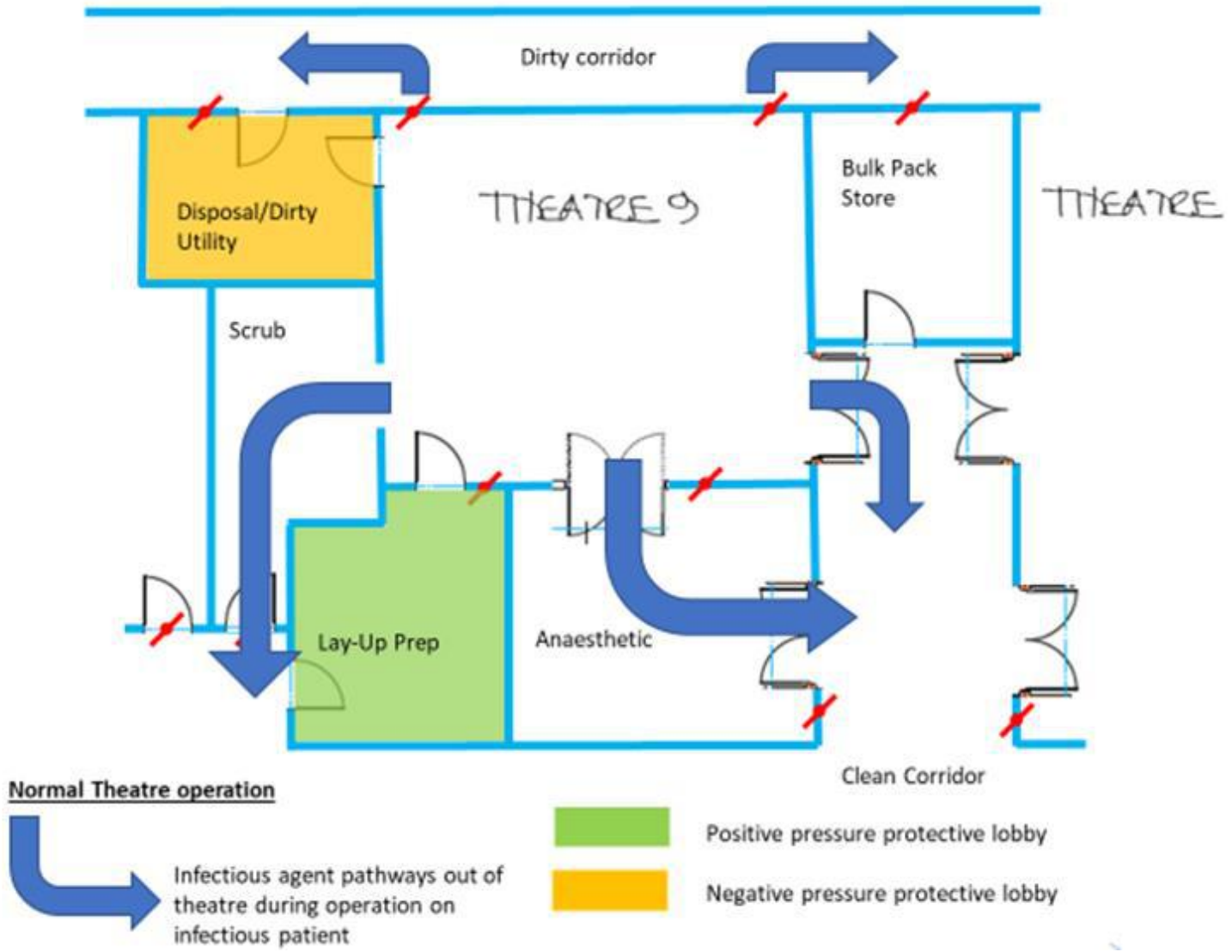
- Many operating theatres were modified for this use.

Objectives

For infectious or suspected infectious patients provide:

- the normal protective environment for the patient undergoing surgery as for non-infectious patients,
- a protective environment to medical teams carrying out surgery on an infectious patient or suspected infectious patient,
- a protective environment preventing infectious agents from entering the rest of the theatre department originating from the infectious patient receiving surgery.

The problem


Dirty corridor
Disposal/Dirty Utility
THEATRE 9
Bulk Pack Store
THEATRE
Scrub
Lay-Up Prep
Anaesthetic
Clean Corridor
Normal Theatre operation
Infectious agent pathways out of theatre during operation on infectious patient
Positive pressure protective lobby
Negative pressure protective lobby

Earlier solutions

Commonly:

Negative pressure theatres,

Neutral pressure theatres.

Common problems:

Reduced supply air or no supply air, result over heating, reduced dilution, poor air flows, likely increased risk of infection, not to evidenced standards, loss of “open door” protection.

Existing guidance

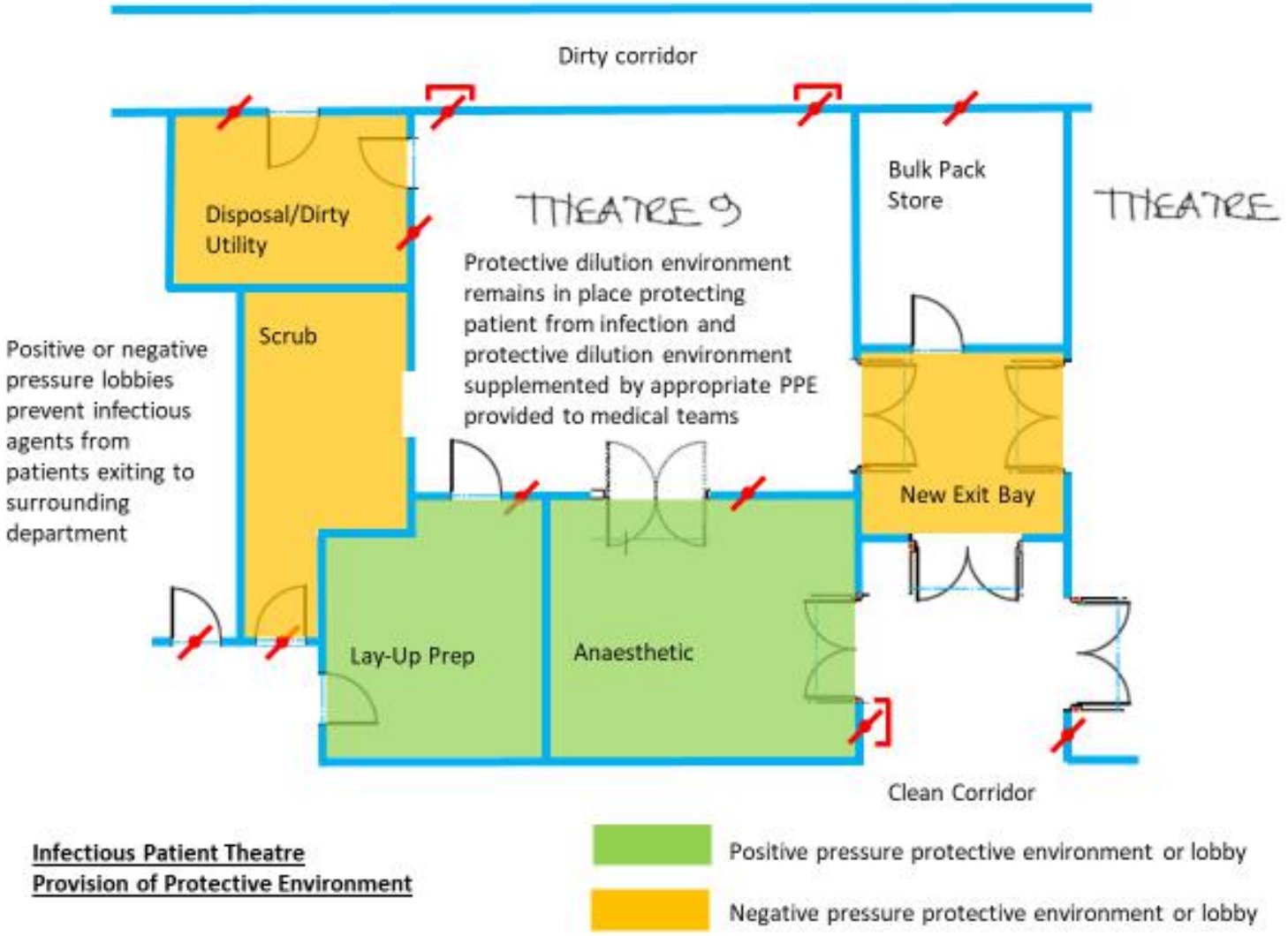
Effectively none:

- Some countries COVID-19 web guidance suggest negative pressure theatres (no discussion how to deliver),

- UK from HTM 03 “balanced flow theatres for infectious cases” then “returning to first principles”, no definition what they are,

- UK gov, use theatres as normal (dilution will reduce risk to others).

Isolation theatre (for an existing theatre)

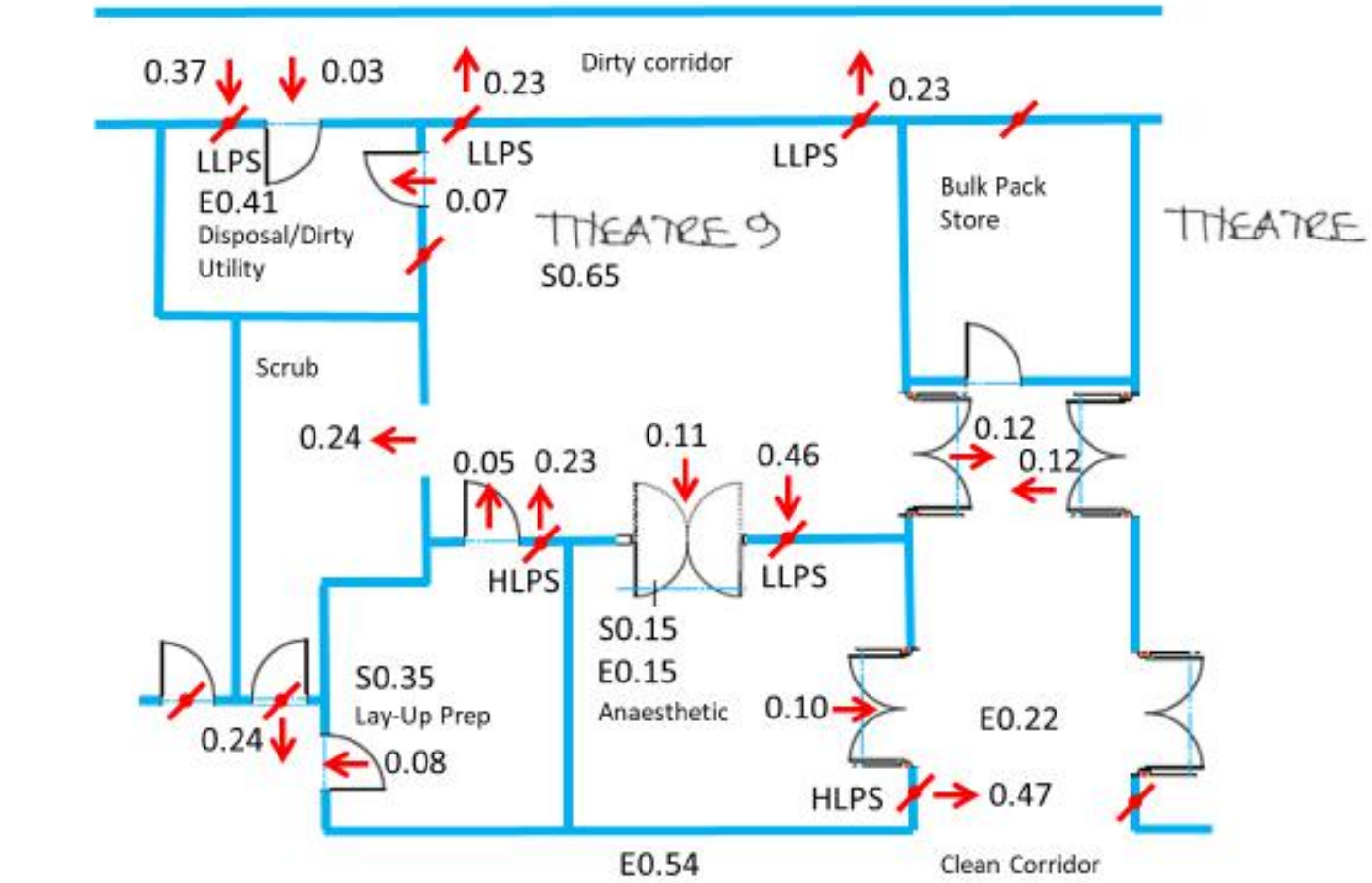


Is it a scalable solution? (Conversions)

- Typically, one theatre per district general hospital,
- Example selected is most common lay out,
- Examples worked out for other theatre layouts,
- Not EVERY THEATRE IS EASY TO CONVERT (but most are).

The engineering details (air flow management)

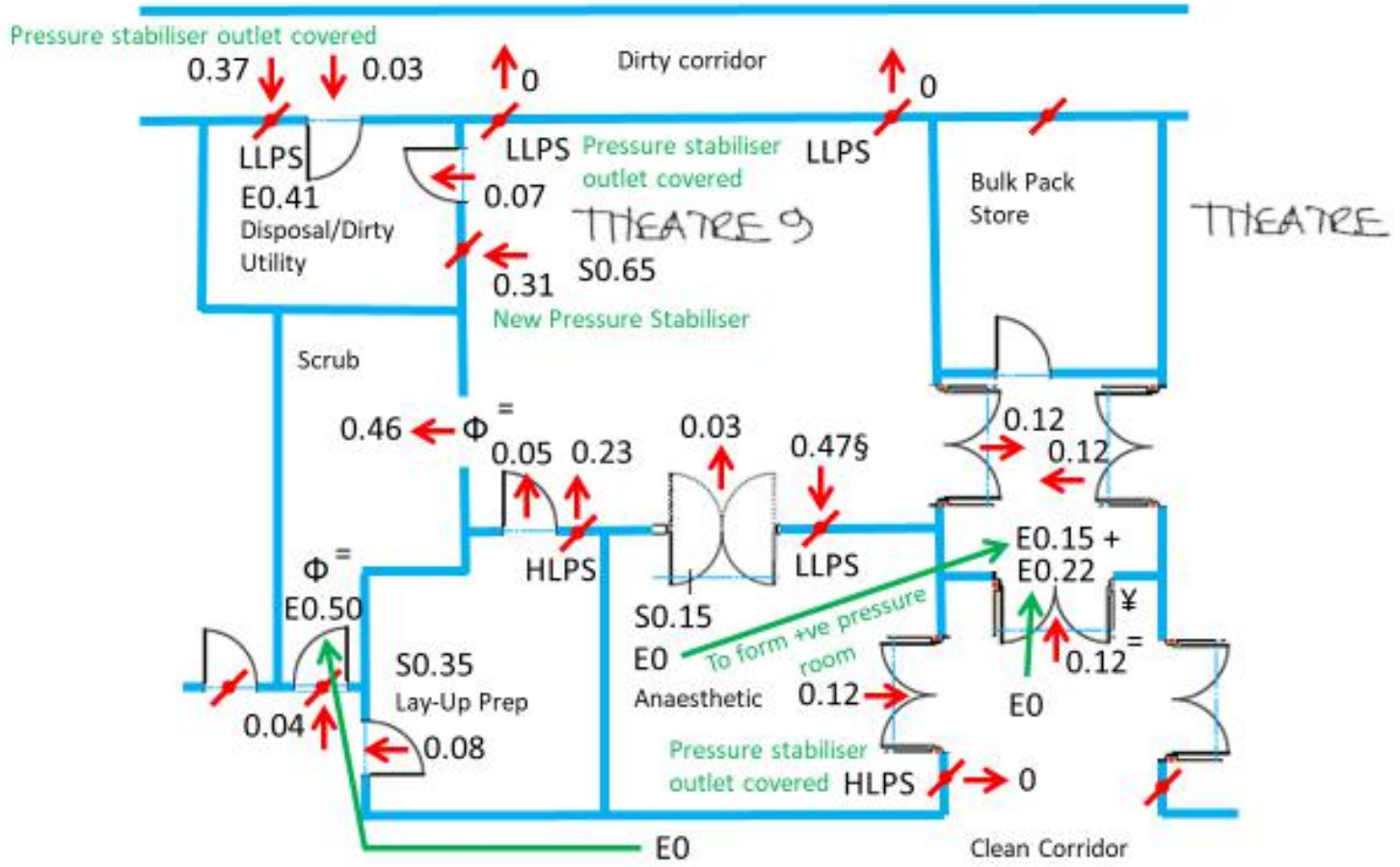
Normal operation



Normal Theatre operation

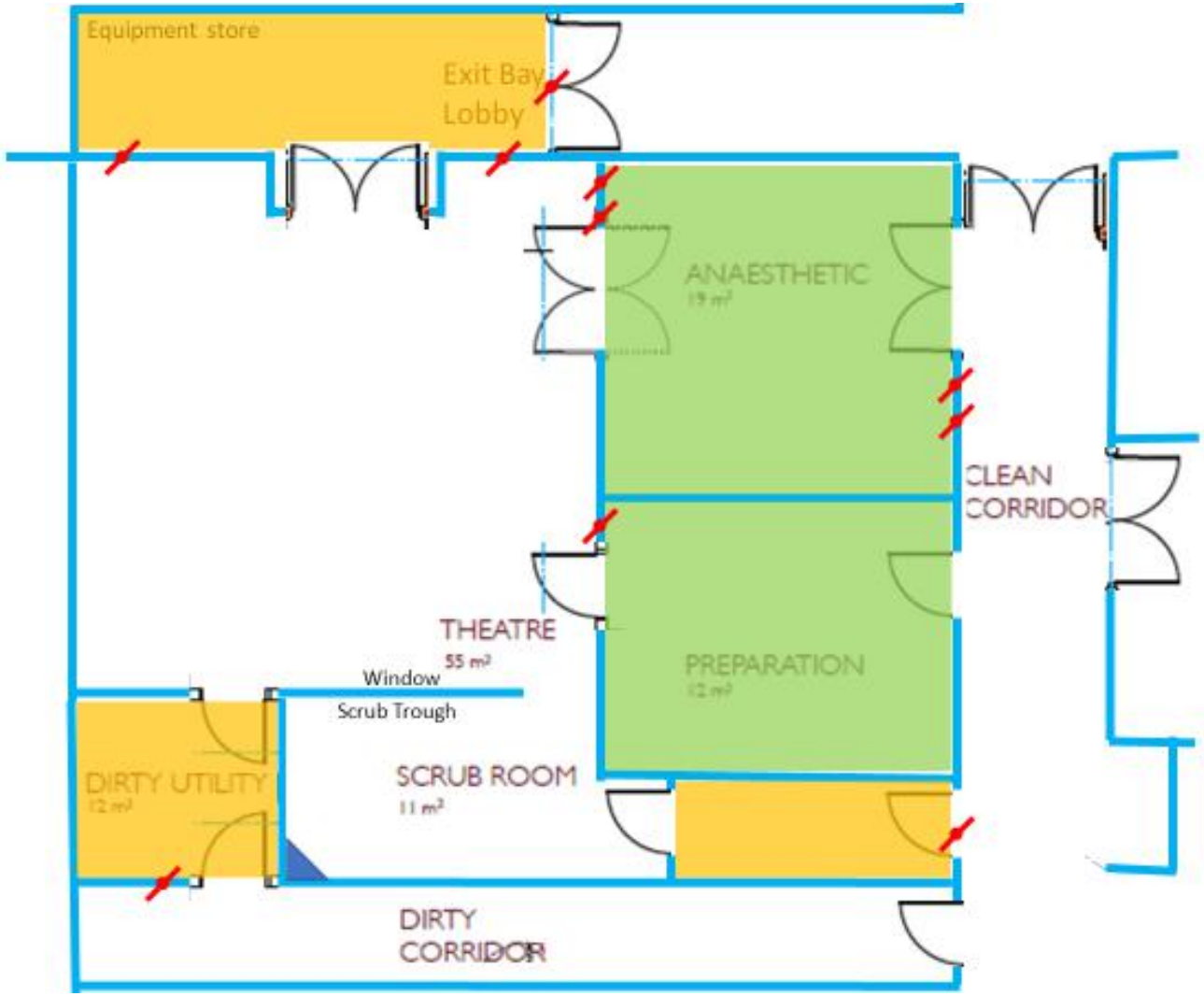
The engineering details (air flow management)

Infectious operation



Infectious Patient Theatre Changes and operation

Isolation theatre, new theatre solution



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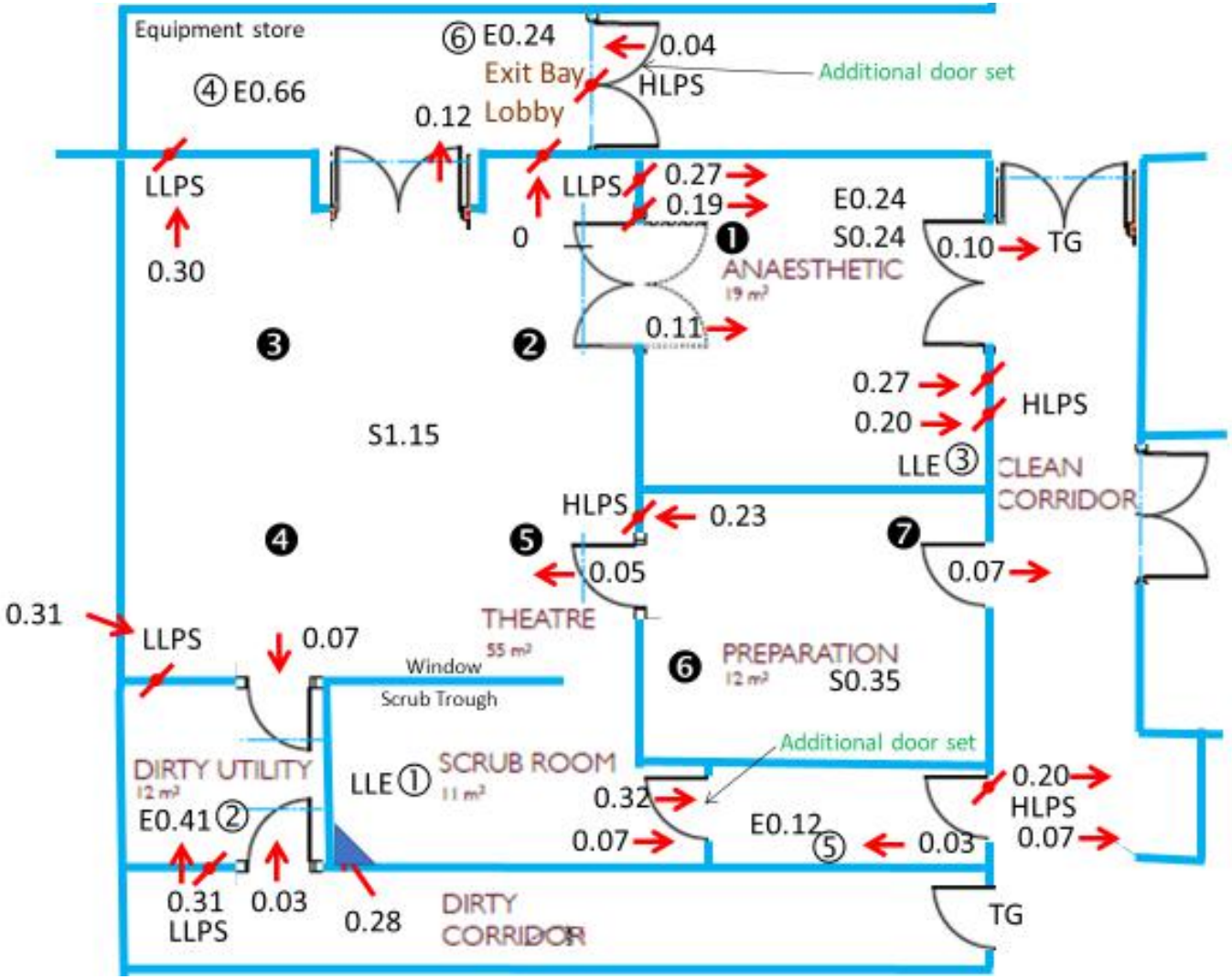

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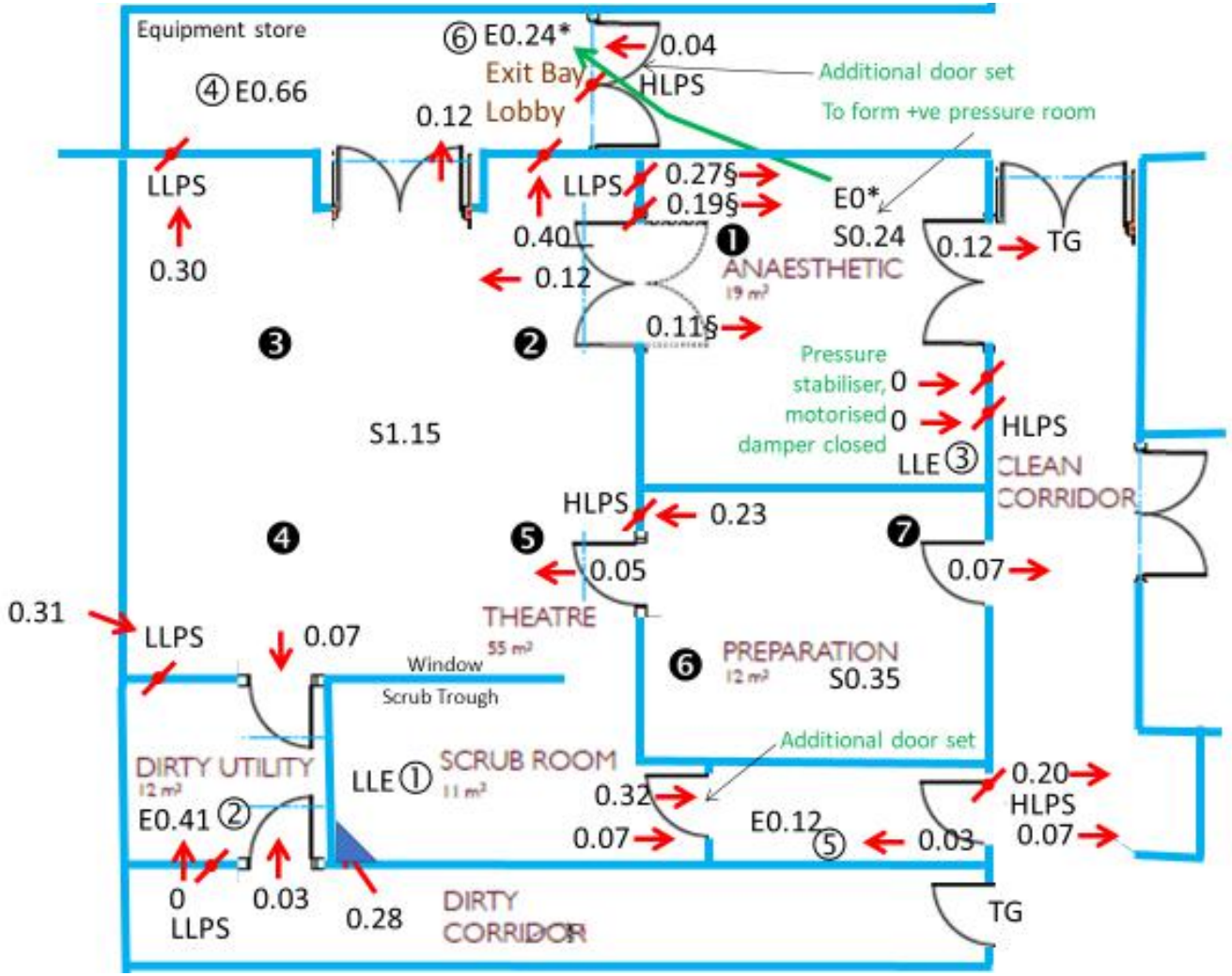

Conclusion

- A scalable solution,
- Simple conversion,
- No increase in ventilation rates,
- Compliant with UK standards,
- Compliance no exception found for other world standards,
- Meets duty of care for patients, medical teams in theatre and those in “high foot fall areas” in rest of department.

Questions & Answers

Operating Theatres and Covid-19

Options for Conversion of existing theatres and the design of new theatres

Richard Knight CEng MCIBSE FIHEEM

Chartered Engineer

CIBSE Healthcare Committee Member

CIBSE Interviewer and Mentor

BSI Expert, Member of RHE/2 and CEN TC 156 WG18

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JAMES REILLY, MIHEEM, MCIBSE

Director, Homan O'Brien Consulting Engineers

Option Appraisal on two Operating Theatre Ventilation Systems and COVID19

July 8th 2021

HOMAN O'BRIEN

IHEEM

The Institute of Healthcare Engineering and Estate Management

Republic of Ireland Branch

http://www.iheem.org.uk/Ireland

CASE STUDY HOSPITAL A

DISCUSSION ON POTENTIAL MODIFICATIONS TO VENTILATION IN AN OPERATING THEATRE TO NEUTRAL OR NEGATIVE PRESSURE

+

CASE STUDY HOSPITAL B

OPERATING THEATRE CONVERT FROM POSTIVE PRESSURE TO NEGATIVE PRESSURE

CASE STUDY HOSPITAL A

DISCUSSION ON POTENTIAL MODIFICATIONS TO VENTILATION IN AN OPERATING THEATRE TO NEUTRAL OR NEGATIVE PRESSURE

HOMAN O'BRIEN

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OPTIONS REVIEWED:

- **Option 1:**
Neutral Pressure Operating Theatre: Outline the changes which could be made to the ventilation system in Operating Theatre to convert from a positive pressure suite to a neutral pressure suite.

- **Option 2:**
Negative Pressure Operating Theatre: Outline the changes which could be made to the ventilation system in Operating Theatre to convert from a positive pressure suite to a negative pressure suite.

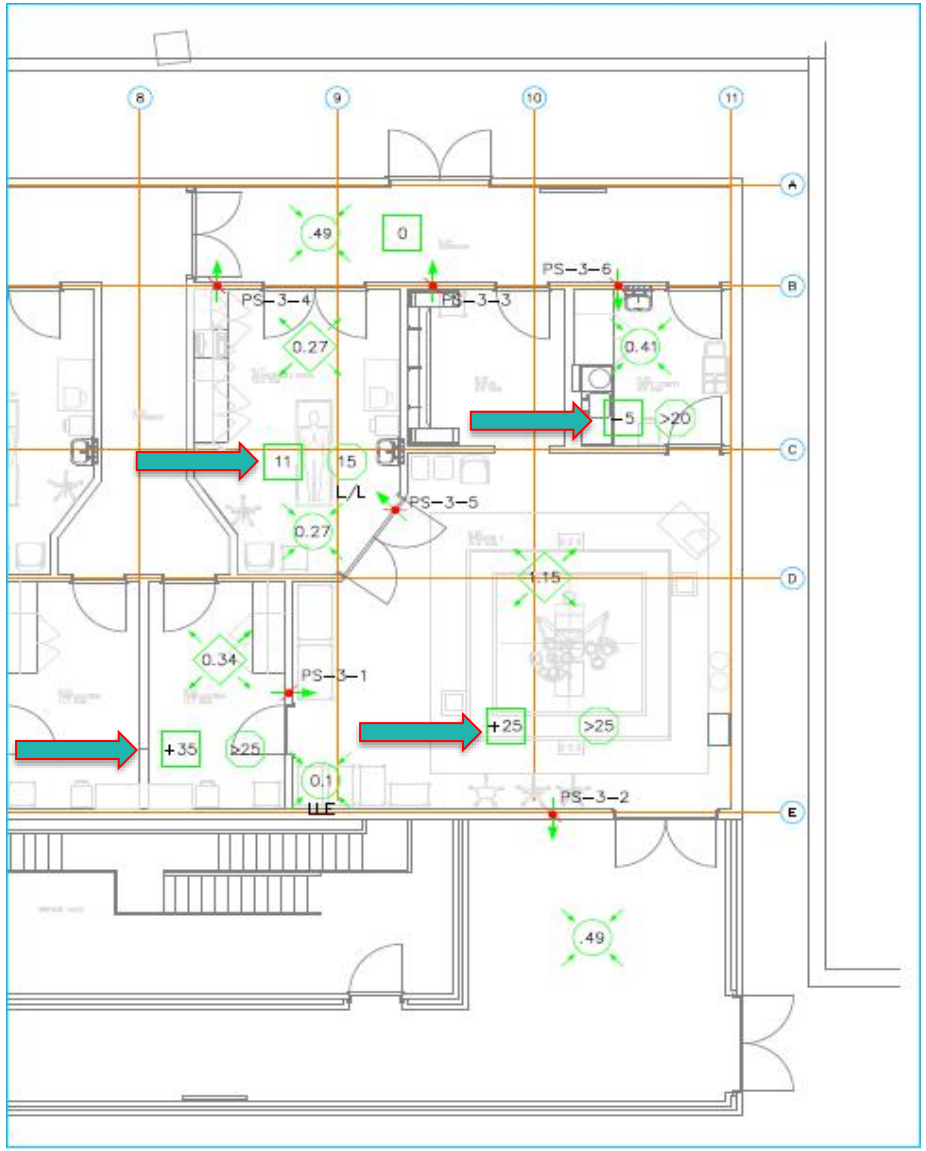
DESCRIPTION OF EXISTING VENTILATION INSTALLATIONS

The existing Operating Theatre is an ultra-clean ventilation (UCV) theatre and has a 2.8m x 2.8 m square Ultra-Clean canopy. The entire suite was designed tested, commissioned and validated in accordance with HTM 03-01 and is a positive pressure operating theatre as outlined in the next slide.

The plant and equipment serving this theatre is dedicated to the theatre suite and is located directly above the Prep Room area.

OPERATING THEATRE

Existing Airflow Diagram



PROPOSED VENTILATION INSTALLATIONS

Option 1: Neutral Pressure Operating Theatre

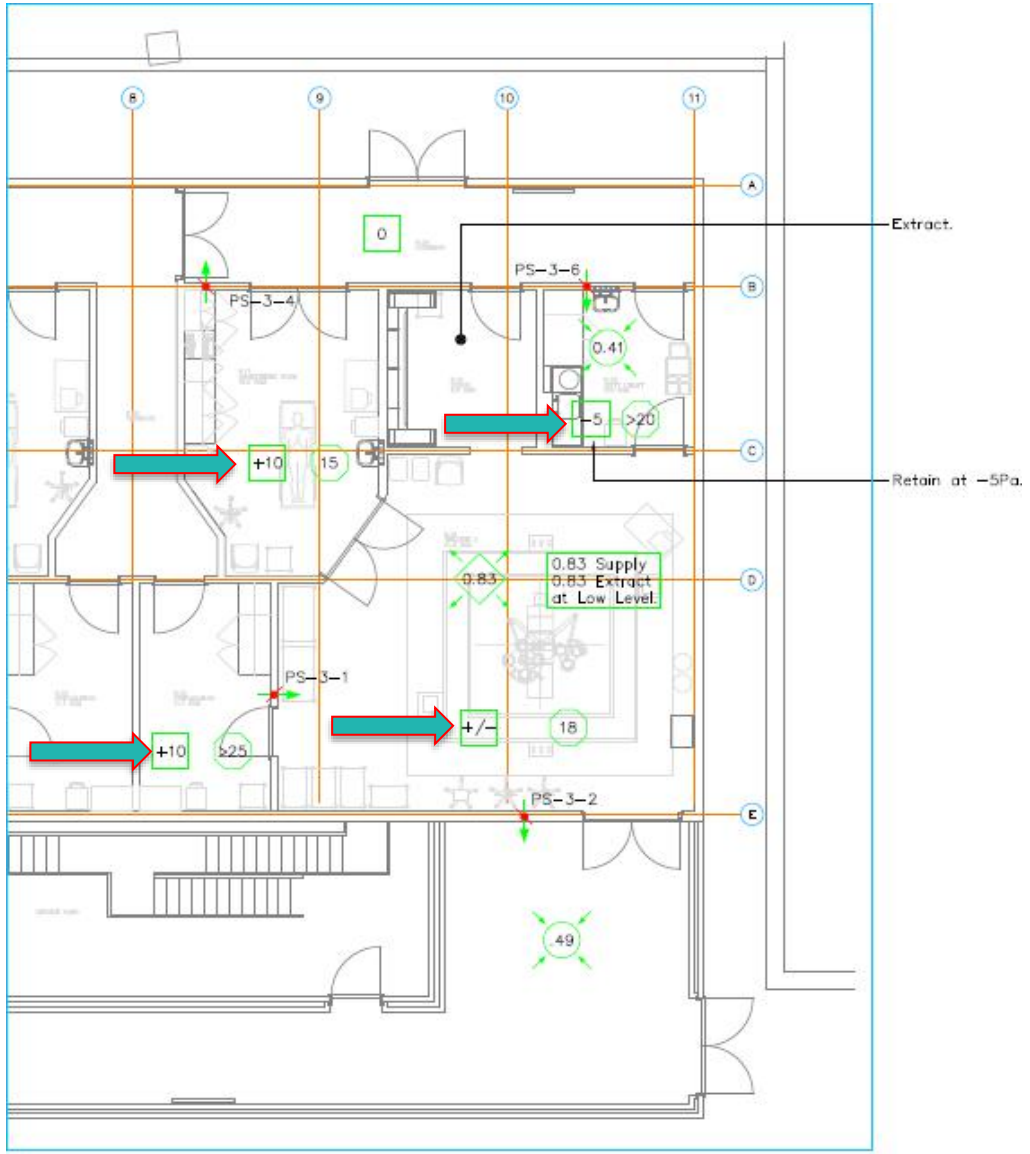
The principle is based on a Positive Pressure Ventilated (PPVL) Lobby Isolation room as set out in Health Building Note 04-01: Supplement 1: '*Isolation facilities for infectious patients in acute settings'.* The Operating Theatre would be converted to a neutral pressure room by adding in low level extract in the space. The overall air change rate in the room would be reduced to 18 air changes per hour. The Anaesthetic and Preparation rooms would act as a positive pressure buffer. An extract air point would be required in the Scrub room. Note that this approach is endorsed by specialist bodies in the UK such as the Specialist Ventilation for Healthcare Society(SVHSoc) document '*Updated Briefing & Guidance on Considerations for the Ventilation Aspects of Healthcare Facilities for Coronavirus'* – Updated 24th March 2020. However, the local infection control team and clinicians should sign off on the principle and the operation of the suite and each individual space for the proposed non-standard solution.

Outline Summary of Scope of Works

1. Install a new in-line extract fan in the plantroom above.
2. Install an in-line HEPA filter in a safe change housing on the intake side of the new fan,
3. Install a low level extract grille within the Operating Theatre.
4. Install Gas tight dampers on all ductwork entering or exiting the OT suite, existing and new to all for the facility and ductwork to be sealed and decontaminated.
5. Interlock doors from Corridor entry and Anaesthetic room.
6. Seal off the door to the Preparation room and review its use in this configuration
7. Recommission and re-validate the ventilation system to the new parameters.

OPTION 1-

Neutral Pressure



Neutral Pressure – Operating Theatre No. 7 – Air–Flow Diagram Option 1

Proposed Ventilation Installations

Option 2: Negative Pressure Operating Theatre

The principle is based on a Negative Pressure Isolation room as set out in Health Building Note 04-01: Supplement 1: '*Isolation facilities for infectious patients in acute settings'* and reference to the solution undertaken by a hospital in Hong Kong during the 2008 SARS Epidemic, reference article published in the *Journal of Hospital Infection (2006) 64, 371e378'.*

The Operating Theatre would be converted to a negative pressure room by adding in low level extract in the space. The overall air change rate in the room would remain at 25 air changes per hour. The Corridor would act as a positive pressure buffer and the doors into the Anaesthetic Room would be interlocked with the Corridor doors and the door to the Preparation room from the Corridor sealed. The local infection control team and clinicians should sign off on the principle and the operation of the suite and each individual space for the proposed non-standard solution.

Outline Summary of Scope of Works

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Journal of Hospital Infection (2006) 64, 371e378

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Conversion of operating theatre from positive to negative pressure environment

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[b] *Department of Anaesthesiology, United Christian Hospital, Hong Kong SAR, China*

Received 24 November 2005; accepted 7 July 2006
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KEYWORDS
Operating theatre;
Airflow performance;
Airborne infection

Summary The severe acute respiratory syndrome (SARS) crisis led to the construction of a negative pressure operating theatre at a hospital in Hong Kong. It is currently used for treatment of suspected or confirmed airborne infection cases, and was built in anticipation of a return of SARS, an out- break of avian influenza or other respiratory epidemics. This article de- scribes the physical conversion of a standard positive pressure operating theatre into a negative pressure environment, problems encountered, air- flow design, and evaluation of performance. Since entering regular service, routine measurements and observations have indicated that the airflow performance has been satisfactory. This has also been confirmed by regular air sampling checks. Computational fluid dynamics, a computer modelling technique, was used to compare the distribution of room air before and after the design changes from positive to negative pressure. The simulation results show that the physical environment and the dispersion pattern of bacteria in the negative pressure theatre were as good as, if not better than, those in the original positive pressure design.

Introduction

The severe acute respiratory syndrome (SARS) crisis in Hong Kong from March to June 2003 resulted in extreme stresses and strains on the general running of hospitals. Generally, SARS patients were accommodated in negative pressure isolation rooms on the ward. When these pa- tients required operative procedures, a negative

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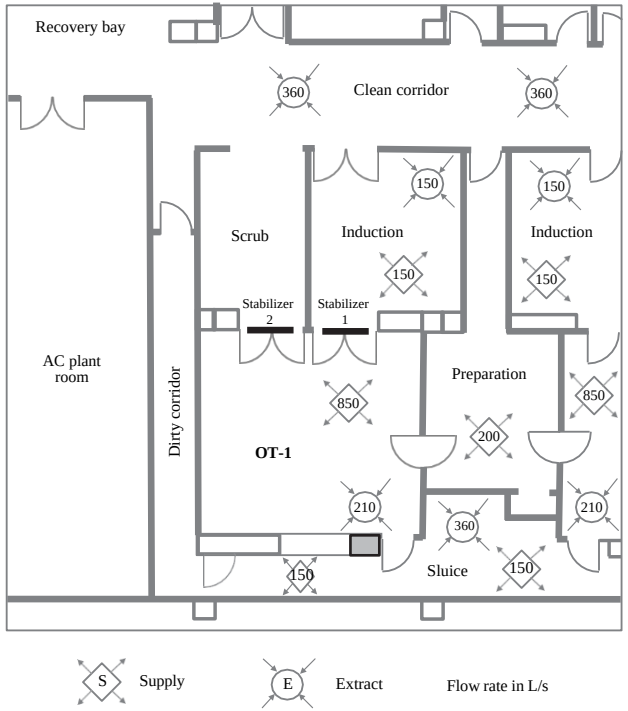


Figure 1 Floor plan of operating theatre suite before pressure conversion. E.D., exhaust duct; OT-1, Operating Theatre 1; AC, air conditioning.

design, compared with the positive pressure design, was the incorporation of a much stronger low-level exhaust system. The exhaust air passed through a two-stage filtration system (prefilter plus High Efficiency Particulate Air (HEPA) filter) before its final disposal via an exhaust air fan. In order to achieve the designated airflow criteria, an ante- room was constructed at the front end of the scrub and induction rooms leading to OT-1. All doors leading to these negative pressure rooms were made airtight and interlocking. The physical layout and the airflow specification of the negative pres- sure operating theatre suite are shown in Figure 2. As OT-1 and OT-2 originally shared the same air con- ditioning system, a separate air conditioning system had to be built for OT-2 before the necessary changes were made to OT-1.

Static pressure heads in OT-1 and in the adjacent rooms were monitored by differential pressure gauge measurements. Correct airflow velocities at the supply diffuser and exhaust grilles were checked by vane anemometer measurements. The airflow pattern was examined carefully using smoke tests. In order to gather more technical information for assessing the effectiveness of the present airflow system, the room air distribution before and after the conversion was examined through computer analysis.

Airflow evaluation by CFD technique

Computational fluid dynamics (CFD) analysis pro- vides comprehensive data on airflows within a room. It demonstrates any deficiencies in air distribution and in contaminant removal. It has been applied to the study of airflows and contam- inant distribution patterns in various operating theatre applications.[6–10]

In this study, the computation models of Cases A and B, i.e. before and after the pressure

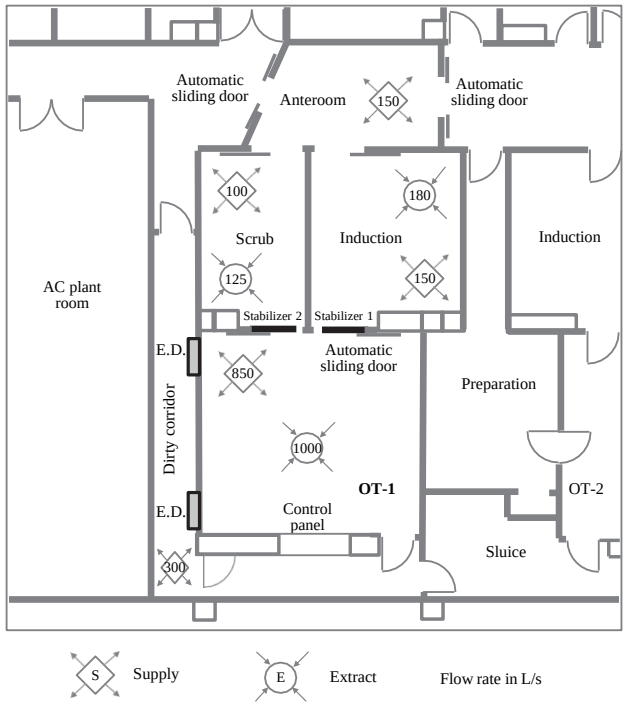


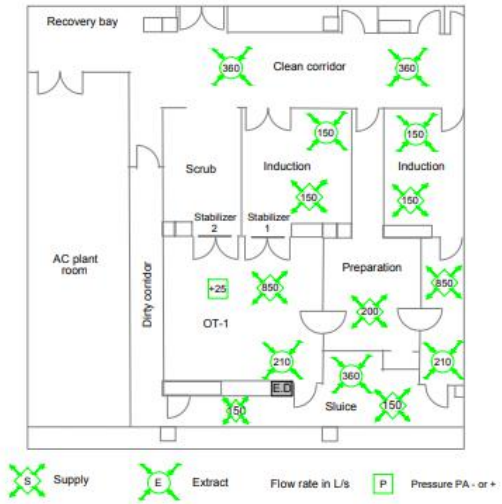
Figure 2 Floor plan of operating theatre suite after pressure conversion. E.D., exhaust duct; OT-1, Operating Theatre 1; OT-2, Operating Theatre 2; AC, air conditioning.

conversion, are shown in Figure 3 (a) and (b), respectively. The room dimensions were 6.3 m (length) 5.9 m (width) 3.1 m (height). In the computer model, the seven surgical staff standing upright and the patient lying on the operating table were represented as rectangular solid boxes. In the analysis, it was assumed that each staff member released infectious particles at a rate of 100 CFU/min from the body surface that faced the patient. Also, an assumption was made that an infectious particle release rate of 400 CFU/ min occurred from the surgical incision site at the waist position and from the patient's upper surfaces. The main and satellite medical lamps were 350 W and 200 W, respectively, and produced heat fluxes from their downward surfaces. Each of the eight fluorescent lighting panels surrounding the perforated supply diffuser released a heat flux of 70 W. The flow of fresh air was 0.85 m^3/s.

For Case A (positive pressure), the exhaust airflow at the exhaust grille was 0.21 m^3/s and the balance airflow of 0.64 m^3/s was a combination of discharge from the two pressure stabilizers and the gaps between the doors and the floor. For Case B (negative pressure), the total air extraction rate through the two exhaust grilles was 1 m^3/s. The balance airflow of 0.15 m^3/s entered the room through the two pressure stabilizers. A deflector plate was positioned 0.15 m in front of Stabilizer 2 to divert the incoming flow upwards. These constituted the only differences between the two cases, and hence the simulation results can be readily compared.

Numerical simulations were performed with the commercial CFD software FLUENT.[11] The standard empirical model was adopted to simulate the flow turbulence. Only steady-state conditions were considered.

Conversion of operating theatre from positive to negative pressure environment at Hospital in Hong Kong



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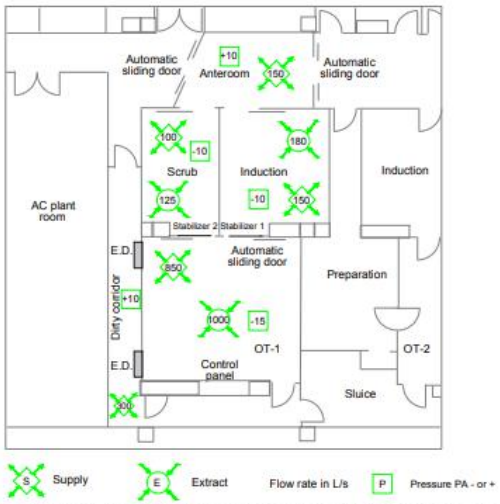

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Table I Pressure (in Pascals) recorded in a routine check of the negative pressure theatre

Location	Intended pressure	Differential pressure (all doors closed)	Differential pressure (anteroom with one door opened)
Anteroom	+10	+6.1	0
Scrub room	-10	-1.9	-4.3
Induction room	-10	-6.2	-8.6
Operating Theatre 1	-15	-11.3	-14.3
Dirty corridor	+10	+3.0	-1.6

FOR REFERENCE

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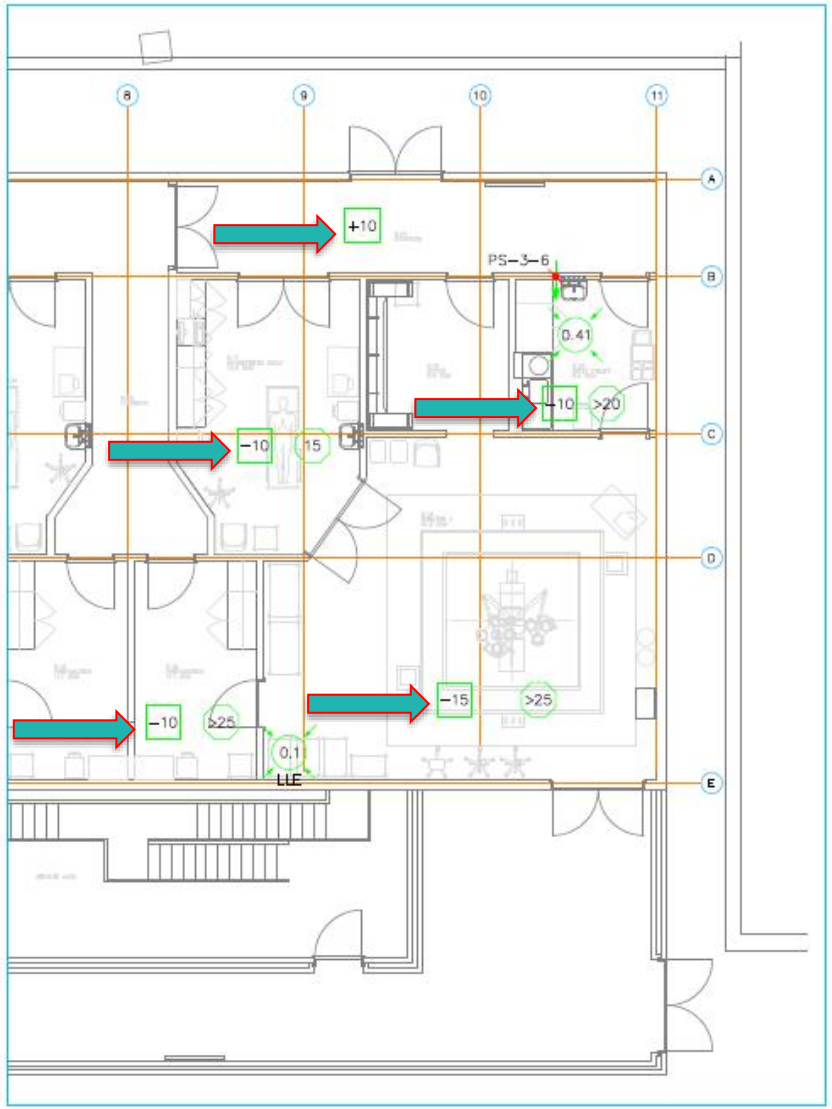
OPTION 2-

Negative Pressure



CONCLUSIONS AND RECOMMENDATIONS

1. The ventilation installation can be adjusted to suit either a Neutral or Negative pressure configuration.

2. The requirement to modify one of the Operating Theatres to operate on infectious patients infected with Covid-19 particularly, considering the current pandemic, should be a multi- disciplinary decision taking into account the following non-exhaustive considerations.

    2.1. Transfer of the patient to the Operating Theatre. The Operating Theatre was chosen as a practical potential Operating Theatre to be converted as it is the most remote and has separate external access.

    2.2. Recovery of the patient following the operation and route to the recovery location.

    2.3. Use of the Prep Room as a pack store of for opening packs. Consideration should be given to the impact of changing the pressure profiles in the suite and the impact on infection control.

    2.4. Overall Operational Policy to be developed for use of the Operating Theatre in non-standard mode.

    2.5. Procedure to convert the Operating Theatre from non-standard mode back to a positive pressure Operating Theatre to be developed. This is technically possible but will require re-commissioning and re-validation as well as ductwork cleaning, sealing off systems, full decontamination of the suite and replacement of the HEPA filters in the UCV canopy.

    2.6 A risk assessment should be carried out at the outset to account for local conditions.

3. In conclusion, the report commissioned focuses on the ventilation requirements only and in that regard the Operating Theatre ventilation can be modified to convert the chosen Operating Theatre to either a neutral pressure or negative pressure configuration. It should also be noted that a third option of utilising the ventilation in its current configuration and dealing with the infection issue with PPE is being considered and recommended by Public Health England.

4. We recommend that should the neutral pressure or negative pressure options be pursued that a design team be appointed to detail the implications and provide budget costs for the modifications required.

CASE STUDY HOSPITAL B

OPERATING THEATRE CONVERT FROM POSTIVE PRESSURE TO NEGATIVE PRESSURE

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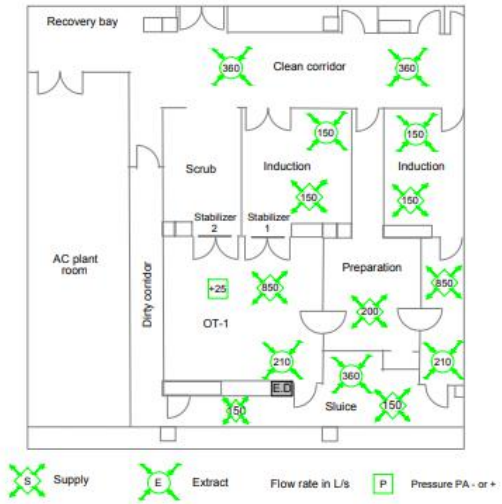

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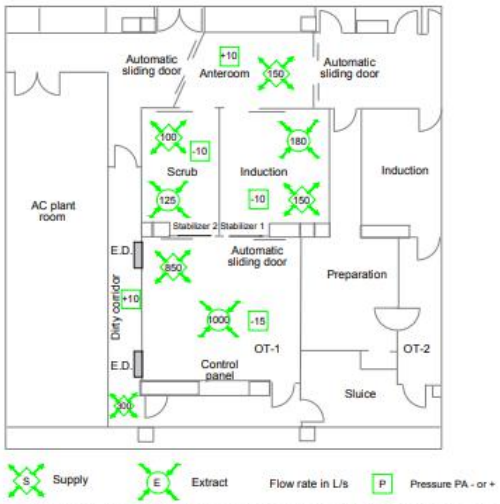

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Web: www.homanobrien.ie

Drawing Number	Date	Scale	Drawn	Checked	Issue
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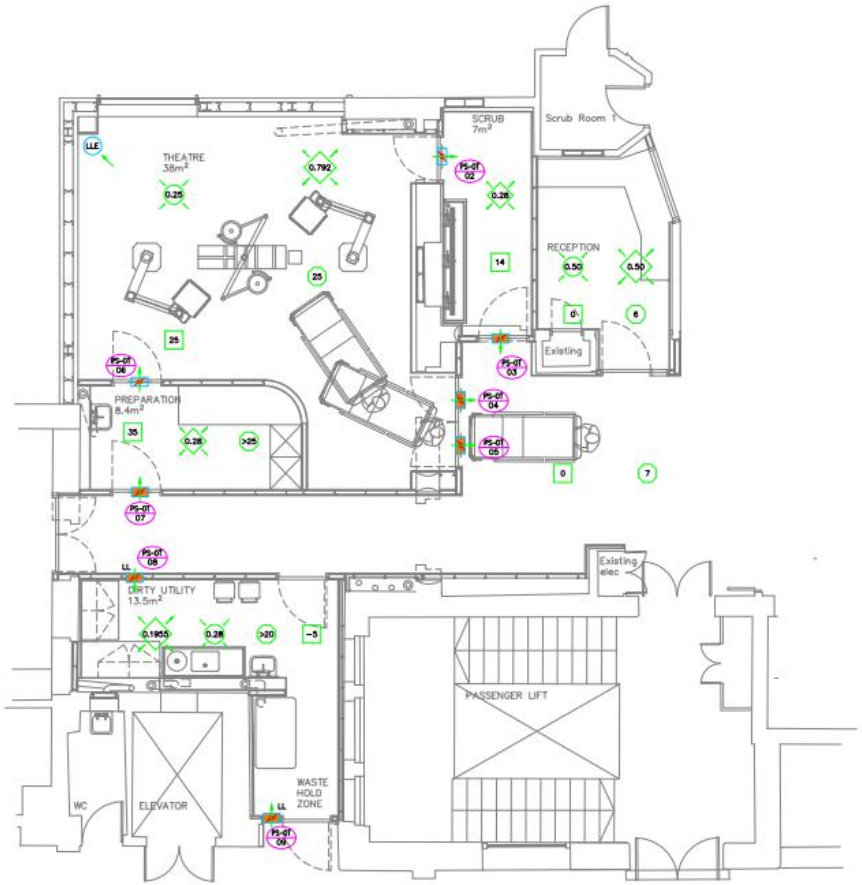
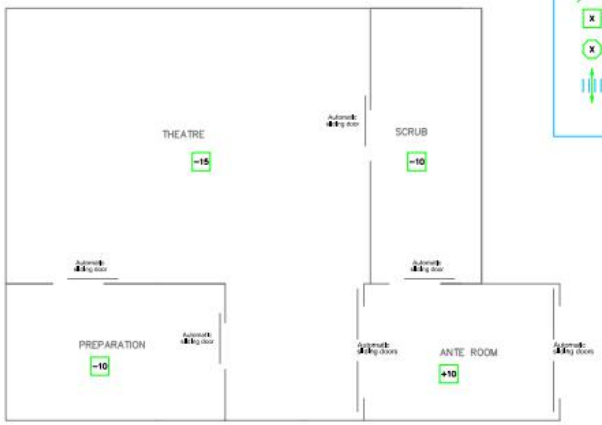
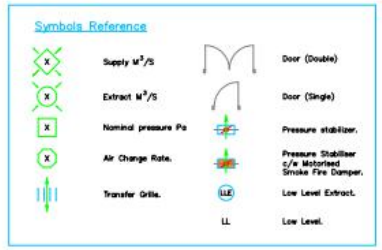


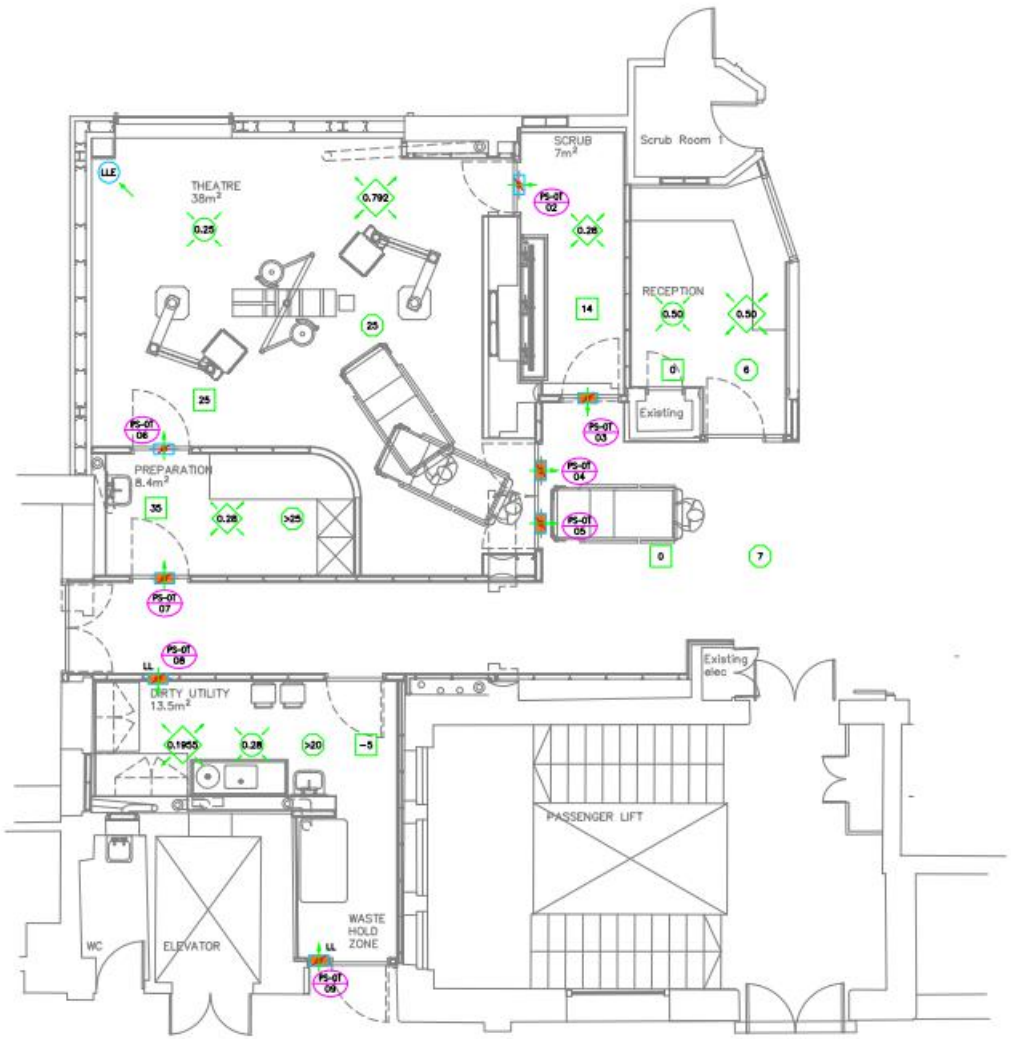
Current



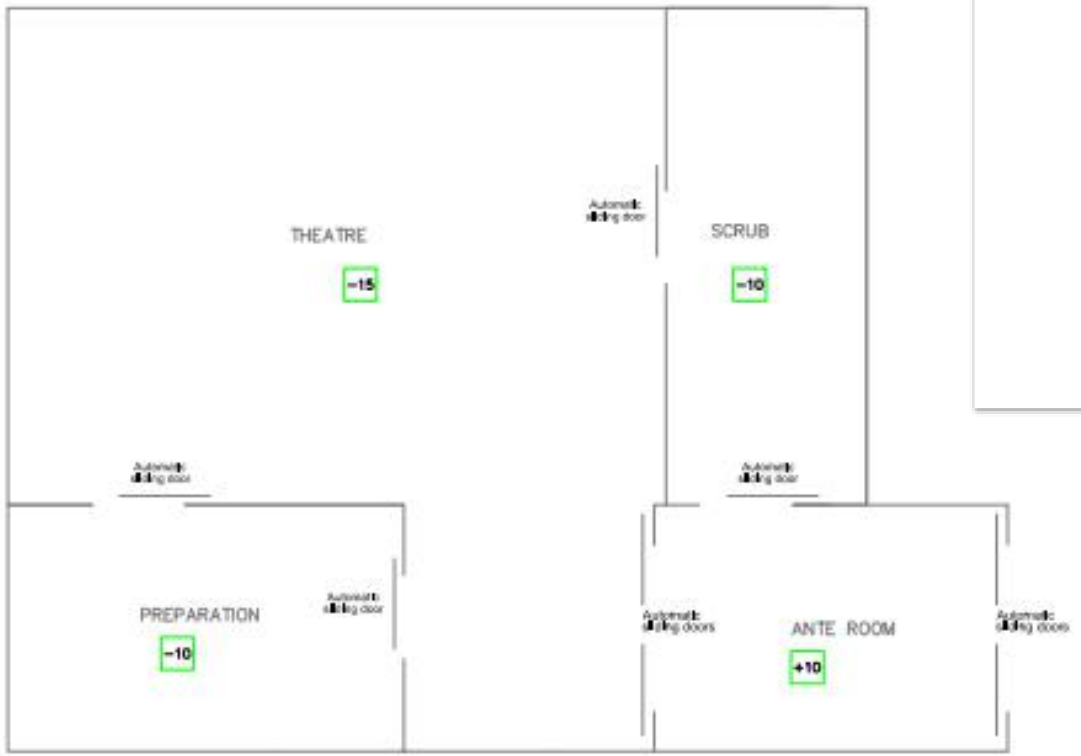
Proposed



FOR INFORMATION


THEATRE
38m²
SCRUB
7m²
Scrub Room 1
RECEPTION
Existing
PREPARATION
8.4m²
DIRTY UTILITY
13.5m²
Existing elec
PASSENGER LIFT
WASTE HOLD ZONE
WC
ELEVATOR

Current



Proposed

HTM 03-01 2021

HOMAN O'BRIEN

IHEEM
Republic of Ireland Branch

The Institute of Healthcare Engineering and Estate Management

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EXCERPT HTM 03-01 :2021

Neutral pressure theatres for infectious patients

8.124 The client may have a requirement for an operating suite for surgery on infectious patients. This may be a dedicated neutral-pressure operating suite or a standard operating suite that is designed to be easily convertible to a neutral-pressure suite. If airborne microorganisms liberated from a patient during a surgical procedure are allowed to cascade out into the adjacent corridors, they could infect other patients or the staff in the operating department.

8.125 The room provision and layout will be as for a conventional operating suite with the following variation to the ventilation scheme:

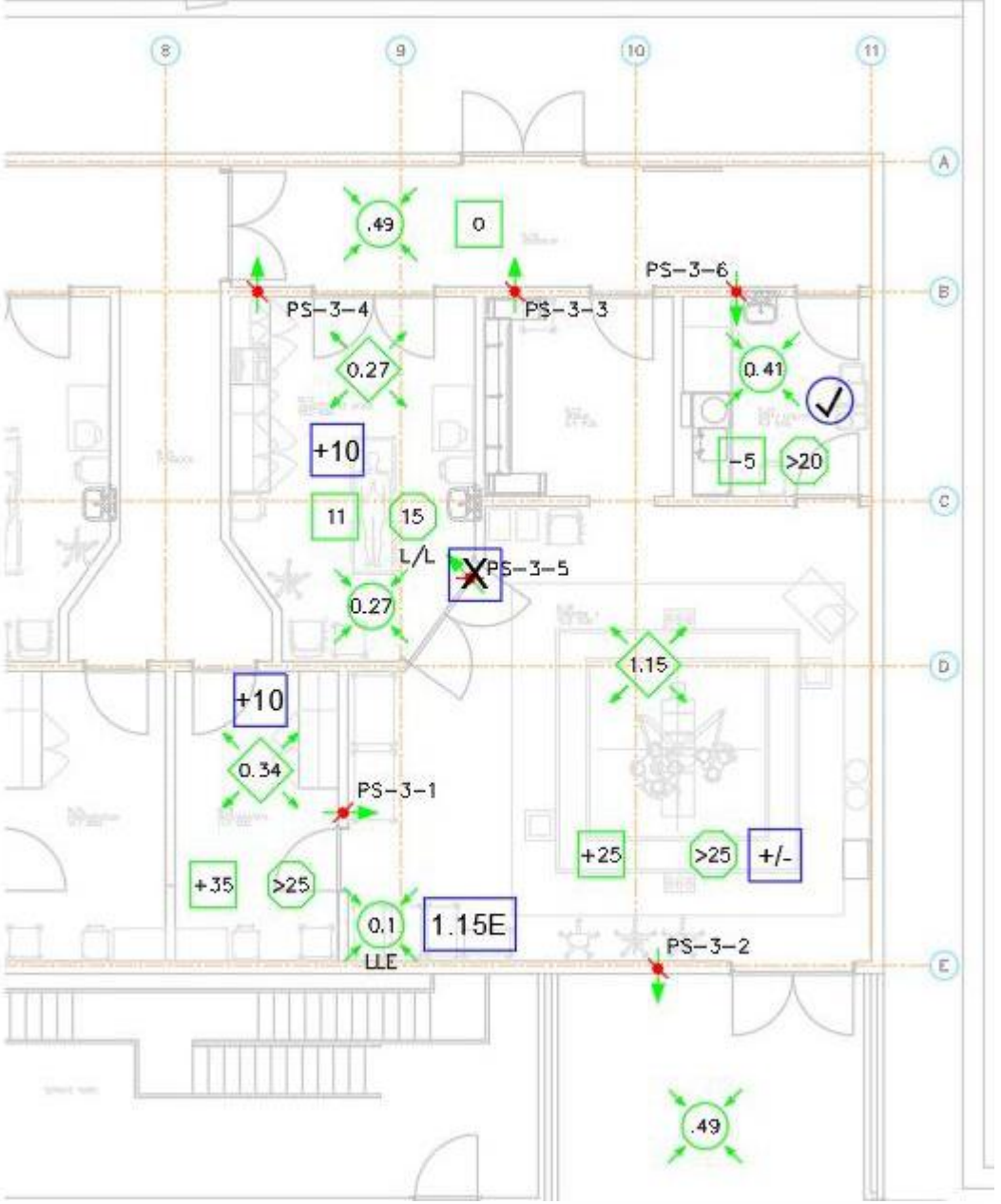
- The operating theatre will have a balanced supply and extract so that it is at the same pressure as the corridor.
- Air should not cascade from the theatre to the surrounding rooms, so pressure stabilisers and/or transfer grilles should not be fitted. In the case of a convertible operating suite, permanently fitted hinge-down blanking plates with clamps should be provided to close the pressure stabiliser/transfer grille openings when required.
- The preparation room may be dispensed with to avoid having stock that could become pre-contaminated. Sterile packs, instruments and consumables would be delivered to the theatre on a case by case basis. If a preparation room is required, it should be maintained at 10 Pa to both the theatre and corridor.
- The anaesthetic room should have a supply in excess of extract so that is maintained at 10 Pa above both the corridor and the theatre. There should be a pressure stabiliser between the anaesthetic room and the corridor but no transfer device between the anaesthetic room and the theatre.
- The scrub should have an active extract as for a conventional operating suite but no pressure stabiliser between it and the corridor.
- The utility should be at negative pressure of not less than –5 Pa to the theatre and its corridor.
- The corridor extract will be sized to cater for the air leakage from the preparation and anaesthetic rooms.

Overall, the ventilation scheme should ensure that all air supplied to the operating theatre is removed in the theatre. The theatre should be neutral (at the same pressure) to the corridor so that when the theatre exit door is open there is effectively no interchange of air between them. When the preparation or anaesthetic doors are opened, air flows from them into the theatre and not the other way.

8.126 The theatre control panel, automatic control strategy and air handling unit will be as for a conventional operating suite.

HTM 03-01:2021

Neutral Pressure



Who should use this guidance?

This document is aimed at specifiers, designers, suppliers, installers, estates and facilities managers and operations. Elements of the document will also be relevant to managers concerned with the day-to-day management of healthcare facilities and senior healthcare management.

Main changes since the 2007 edition

- Design information for specific healthcare applications has been revised and information on the reason for ventilation given. For example, endoscopy rooms are now negative pressure to contain and remove odours and manage airborne risks to staff. These endoscopy-specific risks (i.e. waste anaesthetic gases and pathogenic material (for example, multi-drug-resistant tuberculosis) discharged by the patient during the procedure being undertaken) were identified prior to the SARS-CoV-2 pandemic. As with other elements in Part A, the application of this change is not retrospective but applies to new installations and major refurbishments (see Preamble above).
- The client's needs and legal requirements are more clearly explained.
- This edition of Health Technical Memorandum 03-01 introduces the concept of the Ventilation Safety Group in healthcare organisations (similar to the Water Safety Group in Health Technical Memorandum 04-01 and the Electrical Safety Group in Health Technical Memorandum 06-01). This is a multidisciplinary group whose remit will be to assess all aspects of ventilation safety and resilience required for the safe development and operation of
- The HTM introduces a standard method of identifying and labelling ventilation systems and the creation of an inventory of installed systems.
- The issues of resilience and diversity are addressed.
- Guidance is provided on refurbishments or when changing the use of an existing installation.
- Guidance is given on lifecycle and the updating of mid-life plant.
- Design information for specific healthcare application has been extensively revised.
- Issues around rooms where anaesthetic agents are used are addressed.
- Airflow rates are more tailored to the applications to take advantage of new fan and control technology and so reduce energy consumption.
- Revised air quality and filter standards are given.
- New and emerging technologies are catered for.
- Advice is given on installation standards and the appointment of an independent validator.
- More detailed information is given on the commissioning process.
- Validation acceptance standards and methodology has been completely revised.
- Routine inspection and maintenance guidance has been revised and updated.

Net zero carbon

Health Technical Memorandum 03-01 supports UK legislation to bring all greenhouse gas emissions to net zero by 2050, and promotes sustainable methods of

HTM's core principle is that the default method of ventilation should as far as possible be natural ventilation followed by mixed mode (natural with mechanical ventilation), with mechanical ventilation being the last option.

The energy consumption of ventilation systems should be further minimised by specifying solutions with the lowest lifecycle environmental cost. The basic objective of energy-saving strategies in this HTM is to provide the required ventilation service using the minimum energy. To this end, Health Technical Memorandum 03-01 recommends switching a system "off" when not required to be the most energy-efficient policy. If the system is needed to maintain a minimum background condition, reducing its output by "setting back" to the minimum necessary to achieve and maintain the desired condition is the next best option.

Fans represent an enormous potential for energy savings to reduce carbon emissions, as they are among the largest single users of energy (they use approximately 40% of all electricity in ventilation systems). The European Regulation 1253/2014, implementing the Energy-related Products (ErP) Directive, has significantly reduced the power to drive fans. Accordingly, Health Technical Memorandum 03-01 recommends using electronically commutated fans, as these have been proven to be the most energy-efficient, while also advising that belt-driven fans should no longer be installed.

There have been many legislative changes aimed at reducing energy consumption and technical advances that have increased operational efficiency. This revised HTM incorporates those changes and has amended many of the design parameters for healthcare ventilation. Designs that are simply repeated from previous installations designed to superseded standards and guidance will not meet the revised energy or operational standards and will not produce a compliant result.

THANK YOU

QUESTIONS

IHEEM
Institute of Healthcare Engineering and Estate Management

Republic of Ireland Branch

THANK YOU

- for your participation

- To Our Speakers
  Mr. Richard Knight
  Mr. James Reilly

- To the IHEEM Committee
  Stephen Walshe, James Reilly, Brendan Redington, Damien Clarke and Pearse Douglas.

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