

Guidelines for the classification and design of isolation rooms in health care facilities

Victorian Advisory Committee on Infection Control

2007



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Disclaimer

These guidelines have been prepared following consultation with current experts in the field of engineering and infection control, and practitioners should take note of any information on these matters that may become available subsequent to this publication.

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Contents

Acknowledgements	iii
Disclaimer	iv
Summary	1
1 Introduction	3
2 Classification of isolation rooms	5
2.1 Class S–Standard pressure room	5
2.2 Class N–Negative pressure room	5
2.3 Class P–Positive pressure room	6
2.4 Class A–Alternating pressure (negative/positive pressure)	7
3 Isolation room checklist	9
4 Number of isolation rooms required	11
4.1 General principles	11
4.2 Class S rooms	12
4.3 Class N rooms	12
4.4 Class P rooms	12
5 Design recommendations and general principles of isolation space control	13
5.1 Performance-based approach	13
5.2 Pressure gradients	13
5.3 Air filter efficiencies	14
5.4 Supply air and exhaust duct design	14
5.5 Ventilation design	15
5.6 Air change rates	20
5.7 Building exhaust discharge location	22
5.8 Monitoring of room pressure	23
5.9 Methods of varying room pressure	23
5.10 Minimum outdoor air requirements	23
5.11 Minimising room air leaks	23
5.12 Isolation room interiors	24
5.13 Signs and labels	24
5.14 Doors	24

5.15	Communication system	25
5.16	Patient comfort and safety	25
5.17	Energy conservation	25
5.18	Plant back-up systems	26
5.19	Renovating or converting a room	26
5.20	Commissioning	27
5.21	Patient transport	30
5.22	Routine performance monitoring and maintenance	30
5.23	Renovation, construction, remediation, repair and demolition:	31
	Infection control risk assessment	
6	An introduction to general principles of microbial transmission	33
6.1	Contact transmission	33
6.2	Droplet transmission	33
6.3	Airborne transmission	33
6.4	Common vehicle transmission	35
6.5	Vector-borne transmission	35
6.6	Functional classification of isolation rooms	35
	References	37
	Glossary	39
	Appendix A	41
	Appendix B	43
	Appendix C	45

Summary

In many health care facilities, patients with known or suspected infectious diseases are physically isolated from other patients. These guidelines aim to provide standards for new and renovated isolation rooms in health care facilities across Victoria, and are designed as a reference document for engineers, architects and infection control personnel.

The Clinical Epidemiology & Health Service Evaluation Unit at The Royal Melbourne Hospital undertook a review and analysis of national and international standards for isolation facilities for hospitals and provided recommendations to the Department of Human Services. These guidelines have been revised to include the recommendations from this review.

Section 2 introduces a classification system, based on function, for isolation rooms:

- Class S (standard pressure): Class S rooms are for isolating patients capable of transmitting infection by contact or droplet routes.
- Class N (negative pressure): Class N rooms are for isolating patients capable of transmitting infection by airborne droplet nuclei.
- Class P (positive pressure): Class P rooms may be used to isolate immuno-compromised patients.
- Class A (alternating pressures): Class A rooms are not recommended and will not be considered in this document.

Section 5 provides guidelines for the design, construction, and maintenance of new and renovated hospital isolation facilities. The key recommendations are:

- twelve air changes per hour or 145 litres per second per patient, whichever provides the greater air flow rate;
- an anteroom associated with Class N rooms;
- differential pressure gauges outside the room and a local alarm system to monitor fan status;
- low-level exhausts;
- provision of clinical handbasins;
- good sealing of the room;
- independent supply air on negative pressure rooms;
- independent exhaust on negative pressure rooms;
- exhausts under negative pressure within the building; and,
- minimum maintenance requirements.

These guidelines form part of the Department of Human Services *Victorian Guidelines for Hospitals and Day Procedure Centres* (Part D – Infection Control, 830 Isolation Rooms), and can be found at: www.healthdesign.com.au/vic.dghdp/guidelines.htm. These guidelines can also be used to review, classify and benchmark existing isolation facilities.

1 Introduction

Health care facilities should develop, implement, assess and revise infection control policies and practices that are appropriate to their particular needs based on the patient population demography and the facility's specialties. In many health care facilities, patients who are known to or suspected of posing a risk of transmitting certain infectious micro-organisms are physically isolated from other persons. Patients requiring isolation are identified by surveillance using clinical and/or microbiological criteria. Physical isolation ceases when the patient is no longer capable of transmitting infection or an alternative diagnosis is made.

When possible, a patient known to or suspected of harbouring transmissible micro-organisms should be placed in a single room with hand-washing and ensuite facilities. A single room helps prevent direct or indirect contact transmission, or droplet transmission of infectious agents. An infected or colonised patient can contaminate the environment, or have difficulty in maintaining infection control precautions (for example, infants, children and patients with altered mental status).

A single room with appropriate air handling and negative ventilation is particularly important for reducing the risk of micro-organisms being spread by airborne transmission from a source patient to susceptible patients and other persons in hospitals.

This document describes:

- criteria that may be used to describe and identify settings that are appropriate for isolating patients known to have, or suspected of having, specified infectious conditions;
- engineering and architectural recommendations for isolation facilities, with particular regard to room ventilation, patient toilet and bathing facilities, and staff hand-washing facilities; and
- use and monitoring of the engineering components.

Certain features are described as optional. These relate to the presence of elements that, if made available, will facilitate patient comfort and nursing care while maintaining appropriate isolation. In the absence of these optional elements, similar isolation objectives may be achieved, but with greater patient discomfort and more restrictive nursing practices.

Details of triage, surveillance, infection control practices and education are not within the scope of this document, but are available in the Department of Health and Ageing's *Infection Control Guidelines for the Prevention of Transmission of Infectious Diseases in the Health Care Setting*.⁽¹⁾

These guidelines form part of the *Victorian Guidelines for Hospitals and Day Procedure Centres*, which are intended to enhance the quality of patient care by ensuring hospital facilities are designed to provide appropriate living conditions and standards of care for patients and visitors.

2 Classification of isolation rooms

2.1 Class S–Standard pressure room

Standard pressure rooms are used for patients requiring contact or droplet isolation. A standard room with normal air conditioning is appropriate.

Recommended elements

- A staff hand washbasin within the room.
- An ensuite bathroom.
- A self-closing door.

Optional elements

- Pan sanitiser near the room.
- Label to indicate standard pressure isolation room.

2.2 Class N–Negative pressure room

Negative pressure rooms are used for patients requiring airborne droplet nuclei isolation. Patients are placed in negative pressure rooms to reduce transmission of disease via the airborne route. Class N or negative pressure rooms are also known as ‘airborne infection isolation’ and ‘infectious isolation units’. Diagrams of Various Class N rooms have been included and should be used as a guide only. (*Appendix A, B and C*)

Recommended elements

- Maintain a negative pressure gradient from the room to the anteroom and the ambient air. This is accomplished via a separate exhaust system dedicated to each room that removes a quantity of air greater than that of the supply system. Exhaust air ducts should be independent of the common building exhaust air system to reduce the risk of contamination from back draught.
- Maintain an air change rate of 12 air changes per hour, or 145 litres per second per patient, whichever results in the greatest air quantity, when supply or exhaust air filters are at their maximum pressure drop. Introduce supply air through a displacement diffuser.(2,3)
- Construct an anteroom with each room with a pressure less than the adjacent ambient pressure. The pressure differential between rooms should be no less than 15 Pascals (Pa).
- Install an ensuite bathroom. The ensuite entrance should not be in the anteroom. An ensuite is not a mandatory requirement for a NPR in an emergency department. A clinical risk assessment should be conducted to determine if the ensuite can be excluded. En-suite exhaust shall not be connected to the common building toilet exhaust system.
- Provide 100% outside air ventilation.
- Duct the exhaust directly to the outside discharging vertically at 10m/s in accordance with Australian Standard (AS) 1668-2002 Part 2(4), Type A exhaust.

- Draw exhaust air from low-level exhaust ducts approximately 150 mm above the floor in the room.
- Locate duplex exhaust fans at a point in the duct system that will ensure the duct is under negative pressure throughout its run within the building.
- Ensure supply air ducts are independent of the common building supply air system.
- Supply air and exhaust systems to be of a constant volume system.⁽⁵⁾
- Fit differential purpose built low-pressure instrumentation in a prominent location outside the room.
- Fit a local audible alarm in case of fan failure. Interlock supply and exhaust fans to shut down supply fan in the event of exhaust fan failure. Install fan run status on fan using CT's or equivalent.
- Ensure the room is as airtight as possible, with monolithic ceilings, well-sealed penetrations, tight fitting doors and windows, and a door grille designed for a controlled air path.⁽²⁾ Efficient sealing of the room will result in better maintenance of pressure gradients with less load on the air handling plant.
- Fit a Non-hand operated clinical handbasin within the room and anteroom.
- Install a self-closing door, with well fitting, durable door seals taking into consideration the direction of door swing in relation to room pressure. Doors can be interlocked.
- All mechanical, electrical and building systems shall be designed and constructed to be easily accessible for maintenance. All mechanical plant shall be outside the patient room.
- Label as a negative pressure isolation room.

2.3 Class P–Positive pressure room

Rooms with a positive pressure relative to the ambient pressure are used in some facilities to isolate profoundly immuno-compromised patients, such as certain transplant and oncology patients. The aim is to reduce the risk of transmission of infection to a susceptible patient via the airborne route. Evidence for a protective effect from positive pressure is largely limited to studies of patients at high risk of nosocomial aspergillosis where laminar airflow at ultra-high airflow rates was used to create a positive pressure.⁽⁶⁾ The evidence for the use of such rooms for other purposes is currently lacking. Furthermore, difficulties arise when the patient requiring protective isolation is also infectious to others, particularly with infections spread by the airborne route; for example, a renal transplant patient with varicella zoster. Class P or positive pressure rooms are also known as 'protective environment' and 'protective isolation units'.

Recommended elements

- Maintain a positive pressure gradient from the room to ambient air via an exhaust system that removes a quantity of air less than that of the supply system.
- Maintain an air change rate of 12 air changes per hour, or 145 litres per second per patient, whichever results in the greatest air quantity, when the supply air filter is at the maximum pressure drop.⁽³⁾ Introduce supply air through a displacement diffuser.
- Install an ensuite bathroom.
- As positive pressure rooms may share common supply air systems, ensure minimum outdoor air requirements comply with AS 1668-1991 Part 2.⁽⁴⁾
- Fit a terminal HEPA filter on the supply air inlet.
- Fit differential low-pressure instrumentation in a prominent location outside the room.
- Fit a local audible alarm in case of fan failure. Ensure interlock supply and exhaust fans shut down the exhaust fan in the event of supply fan failure.
- Ensure the room is as airtight as possible, with plaster board ceilings, well-sealed penetrations, tight fitting doors and windows, and a door grille designed for a controlled air path.⁽²⁾ Efficient sealing of the room will result in better maintenance of pressure gradients with less load on the air handling plant.
- Fit a non-hand operated clinical hand basin inside the room and anteroom.
- Install a self-closing door, taking into consideration the direction of door swing in relation to room pressure.
- Label it as a positive pressure isolation room.

Optional elements

To prevent the airborne spread of infections (such as open pulmonary tuberculosis or chicken pox) from an infected immuno-compromised patient, the positive pressure room requires an anteroom at negative pressure relative to the ambient pressure. Alternatively, the infectious patient may be placed in a 'non-protective' environment in a Class N room.

2.4 Class A–Alternating pressure (negative/positive pressure)

Rooms with reversible airflow mechanisms enabling the room to be either negative or positive pressure are not recommended.⁽⁷⁾ Problems with such rooms include the difficulty of configuring appropriate airflow for two fundamentally different purposes (see section 5.4), the risk of operator error, complex engineering and fail safe mechanisms. The clinical role of a Class P room is unresolved (see section 2.3).

3 Isolation room checklist

Table 1: Isolation room checklist

Features	S Standard	N Negative	A Alternating	P Positive
Non-hand operated handbasin in room and anteroom	Yes	Yes	This isolation room type is not recommended	Yes
Ensuite bathroom (shower, toilet & hand washbasin) ^(1,2)	Yes	Yes		Yes
Pan sanitiser (near room)	Optional	Optional		Optional
Door on room with door closer	Yes	Yes		Yes
Anteroom		Yes		
Sealed room, door grille for controlled air flow		Yes		Yes
12 ACHR or 145 litres per patient		Yes		Yes
100% outside air ventilation		Yes		
Local differential pressure monitoring		Yes		Yes
Independent supply air ⁽⁴⁾		Yes		
HEPA filters on supply air				Yes
Low-level exhaust 150 mm above floor		Yes		Yes
Independent exhaust discharging vertically at 10 m/s according to AS 1668.2 Type A exhaust ⁽⁴⁾		Yes		
Exhaust duct under negative pressure within building with duplex fans		Yes		Optional
HEPA filters on exhaust for retrofit ⁽³⁾		Optional		

Optional elements

Certain features are described as optional in this table. These options relate to the presence of elements that, if made available, will facilitate patient comfort or nursing care while maintaining appropriate isolation requirements. In the absence of these optional elements similar isolation objectives may be achieved, but with greater patient discomfort and more restrictive nursing practices.

Notes

- 1 An ensuite is not a mandatory requirement for a NPR in an emergency department. A clinical risk assessment should be conducted to determine if the ensuite can be excluded.
- 2 Consideration should be given to incorporating a decontamination facility into a new NPR in an emergency department. If this option is adopted, provide access from the ambulance bay.
- 3 HEPA filters should be installed on exhausts only if the requirements of AS 1668.2 cannot be met due to physical limitations of an existing building. If HEPA filters are installed, high efficiency deep bed filters shall be installed to protect the HEPA.
- 4 The above requirements are for new installations only. When renovating or retrofitting a room in an existing building physical limitations may be present that restrict full compliance with the stated requirements. In these situations it is essential the intent of the requirement is fulfilled. A multi-disciplinary risk assessment may be required to determine the most suitable means of achieving the required intent. See 5.20 – Renovating or Converting a room for more details.

4 Number of isolation rooms required

4.1 General principles

Health care facilities should use available data on patients known to or suspected of having infectious agents requiring isolation facilities to help estimate the number of isolation rooms required.

In existing facilities, data should be collected prospectively to assess the actual demand for, and use of, facilities to isolate patients known or suspected to have infectious agents requiring isolation.

The assessment of such cases should include:

- the number of patient admissions with infections known or suspected to require isolation;
- the duration of isolation required for each patient;
- clustering of cases that may be influenced by seasonal and other trends; and
- the type of unit where patient isolation may be necessary.

Data collected over a year or more provide more reliable estimates of isolation room requirements. These estimates help determine peak needs for diseases with marked seasonal variation (for example, RSV, rotavirus and influenza). Retrospective data in relation to cyclic epidemics of diseases (for example, measles and influenza) may help determine 'worst-case scenarios', although it may not be cost-effective for individual facilities to provide sufficient isolation rooms for extreme circumstances.

Other factors that should be considered when estimating isolation room needs are:

- the state and national trends in disease in the general population and the particular population served by the facility;
- the demographic trends in the population served by the facility; and,
- the specialties of the health care facility, and projected changes in the facility's activities.

For planned new facilities, retrospective data will be unavailable but such data from similar facilities serving comparable populations may be available.

Retrospective data (based on discharge diagnoses) should be used with caution as persons suspected (but not confirmed) of certain infections requiring isolation may not be included, thereby causing an underestimation of requirements.

The final assessment of isolation room requirements should be made in consultation with involved clinical specialists, engineers, architects and the infection control committee.

4.2 Class S rooms

The isolation room requirements for persons known or suspected to have infections requiring contact or droplet precautions will determine the need for Class S rooms.

The key features of Class S isolation rooms (door, staff hand wash basin and ensuite bathroom) facilitate good infection control practice, and should be considered for all rooms of any new or redeveloped health care facility.

Rooms designated as Class S rooms (and rooms that may be required for such a purpose in the event of an outbreak) should be designed with reference to Section 2 of this guideline, which details the required and optional structural features of such rooms.

4.3 Class N rooms

The isolation room requirements for persons known or suspected to have infections requiring airborne precautions (such as chicken pox, measles and infectious pulmonary and laryngeal tuberculosis) will determine the need for Class N rooms.

It is important to consider cases suspected of such infections in these calculations. Patients suspected of having open tuberculosis or laryngeal tuberculosis require such isolation until either the diagnosis is excluded or they are rendered non-infectious by treatment.

In larger health care facilities there are nursing, economic and engineering benefits for co-locating class N rooms.

Special areas which require either one or more Class N rooms or an area with air-handling to Class N standard include:^(2,7)

- emergency departments;
- intensive care units—adult, paediatric, newborn; and,
- procedure areas such as bronchoscopy suites or sputum induction rooms.

4.4 Class P rooms

The unresolved role of Class P rooms is discussed above. Health care facilities should determine their need for such rooms by using their own data on local threats from pathogens such as *Aspergillus*, as well as evidence from within and beyond the facility on the role of particular environments in protecting vulnerable patients.

5 Design recommendations and general principles of isolation space control

Environmental control in an isolation facility aims to control the airflow and so reduce the number of airborne infectious particles to a level that ensures infection of another person within the health care facility is unlikely. This is achieved by:

- controlling the quality and quantity of intake and exhaust air;
- diluting infectious particles in large volumes of air;
- maintaining differential air pressures between adjacent areas; and,
- designing patterns of airflow for particular clinical purposes.

5.1 Performance-based approach

Provided the intent of these guidelines is met, a performance-based approach to the ventilation system is acceptable where a recognised methodology, such as computational fluid dynamics, is used.

5.2 Pressure gradients

The minimum differential pressure between the isolation room and adjacent ambient pressure areas should be 30 Pa if the room has an anteroom, and 15 Pa if the room does not have an anteroom. The gradient between successive pressure areas should not be less than 15 Pa.⁽⁹⁾ It is recommended that the ensuite entrance is not located in the anteroom.

Table 2: Recommended isolation room pressures

Room type	Room	Ensuite	Anteroom
Class N	-ve 30 Pa	-ve 30 Pa	-ve 15 Pa
Class P	+ve 30 Pa	+ve 30 Pa	+ve 15 Pa
Class P room with negative pressure anteroom	+ve 15 Pa	+ve 30 Pa	-ve 15 Pa

Anteroom or airlock function

Anterooms have three functions.⁽⁹⁾ They provide:

- a barrier against loss of pressurisation and entry or exit of contaminated air into or out of the isolation room when the door to the anteroom is opened;
- a controlled environment in which protective garments can be donned without contamination prior to entry and exit of the isolation room; and,
- a controlled environment in which equipment and supplies can be transferred from the isolation room without contaminating the surrounding areas.

5.3 Air filter efficiencies

Air filtration should comply with the requirements as documented in the Department of Human Services, Design Guidelines for Hospitals and Day Procedure Centres.⁽⁹⁾

Class N:

- Optional terminal HEPA filter on exhaust only to prevent back draught.
- High-efficiency pre-filters before HEPA filters.

Note:

HEPA filters should be installed on exhausts only if the requirements of AS 1668.2 cannot be met due to physical limitations of an existing building. If HEPA filters are installed high-efficiency deep-bed filters shall be installed to protect the HEPA. HEPA filter installations shall be fitted, tested and certified in accordance with AS 1807.6.

Class P:

- Terminal HEPA filter on supply air. Integrated fan assisted terminal HEPA units are not recommended due to potentially high noise levels. Use of a separate inline centrifugal fan in the ductwork should be considered.
- Optional terminal HEPA filter on exhaust only to prevent back draught.
- High-efficiency pre-filters before HEPA filters.

5.4 Supply air and exhaust duct design

Negative pressure isolation room ductwork must not connect to, or discharge into, any other ductwork from the rest of the health care facility. Each NPR room must be ducted individually.

Ductwork should be designed to reduce the possibility of cross-contamination in the event of fan failure. As a minimum this can be accomplished by ducting each negative pressure isolation room separately from the air-handling unit. Separate long ductwork runs from the air-handling unit to increase static pressure and reduce the contaminated airflow in the event of a failure. Back-draught dampers may provide similar protection but the problems associated with damper failure must be considered.

Supply and exhaust systems should be designed as fail safe and duplex fans used to prevent contamination of any area within the facility in the event of fan failure. Fans should be interlocked to provide automatic shutdown in the event of failure; for example, the NPR supply fan should shutdown in the event of exhaust fan failure.

The exhaust fan should be located at a point in the duct system that will ensure the entire duct is under negative pressure within the building.

5.5 Ventilation design

Design considerations for isolation rooms

All patient rooms in health care facilities should provide an acceptable environment for patients to recover, and a good working environment for attending health care professionals. The purpose of an isolation room is to protect health care workers, other patients and visitors within a facility, from exposure to any airborne infectious agents.

A principal design goal for an isolation room should be to achieve and maintain an adequate level of airborne infection protection in the environment surrounding an infectious patient; in other words, to contain the airborne infectious material in such a way that the threat of exposure to health care personnel within the isolation room and others outside of the room is minimised. Ventilation is a key component of aerosol containment in isolation rooms. The following section discusses the ventilation strategy, design parameters and other important factors that need to be considered in the design of isolation rooms.

Ventilation strategy

The ventilation design strategy for an isolation room suite should be to achieve the best containment possible while maintaining acceptable thermal comfort for the patient. In theory, the contribution of ventilation to containment can be maximised within an isolation room through source removal, a high dilution rate and a directional airflow from health care personnel to the patient. It is also important that there are no stagnant, under-ventilated areas in the room where infectious aerosols might be concentrated.

Typically, an isolation room suite consists of a patient room, attached en-suite and an anteroom between the patient room and corridor. In principle, containment can be maximised within an isolation suite by:

- maximising containment within the patient room;
- maintaining a directional airflow from the anteroom to the patient room at all times;
- maintaining a high dilution rate in the anteroom; and,
- maintaining a directional flow from the corridor to the anteroom at all times.

Ventilation parameters

As containment within the patient room and isolation suite is dependent on so many factors, containment itself cannot be completely described by any single design parameter. The following is an overview of design parameters that can be used to characterise and specify isolation room performance in terms of containment and thermal comfort for the patient.

Pressure differential between rooms (door closed)

A properly functioning isolation room should be maintained at a negative pressure with respect to its surroundings in general, and with respect to the anteroom in particular, when the door between the room and anteroom is closed. Similarly, the anteroom should maintain a negative pressure with respect to the corridor when the anteroom corridor door is closed. Therefore, a negative pressure differential should exist between the patient room and anteroom, and the anteroom and corridor when the doors are closed. When the anteroom door is open air should flow from the corridor to the anteroom. When the patient room door is open air should flow from the anteroom to the patient room. The pressure differential when the doors are closed is often used as a surrogate measure of containment performance in isolation rooms and is expressed in Pascals (Pa).

Ventilation supply air volume (outside air)

In this context, ventilation supply air to the patient room is filtered, conditioned outside air supplied directly to the patient room, and does not include outside air that has first been supplied to the corridor or anteroom before being transferred to the patient room. Similarly, ventilation supply air to the anteroom is filtered outside air supplied directly to the anteroom and does not include outside air that has first been supplied to the corridor before passing into the anteroom. Some level of outside supply air will be necessary in a patient room that may be permanently occupied and can have a substantial heating load. This is not necessarily the case in an anteroom that does not have as large a heat load as the patient room, and is meant to be occupied only for short periods of time while people are travelling into and out of an isolation room.

Ventilation exhaust-supply differential volume

For a negative pressure to be achieved and maintained in an isolation room with respect to the surroundings, there must be more ventilation air extracted from the room than is supplied to it. The patient room ventilation differential volume is given by the exhaust air volume from the room minus the supply air volume to the room. The pressure differential between a room and its surroundings that can be achieved by a given ventilation volume differential depends on the tightness of the room.

At steady state, when the pressure differential is constant, the total amount of air going into the room has to be the same as the total amount of air going out. In this case, the total amount of air going out is given by the exhaust air volume (plus the exhaust air volume from the attached ensuite, if the bathroom is at a lower absolute pressure than the patient room). The total amount of air going in is given by the ventilation supply air volume plus leakage, or infiltration, driven by the pressure differential between the room and its surroundings.

If the room is very tightly sealed (when the door is closed), the pressure differential will have to be relatively large to obtain a given air leakage rate. If the room is not well sealed, the pressure differential to obtain the same leakage rate will be much smaller. In an extremely tight room, a small exhaust-supply differential volume can produce

a relatively large pressure differential. Conversely, in a very leaky room, a large exhaust-supply differential volume may not be capable of producing the desired pressure differential. Optimally, the exhaust-supply air differential volume should be large enough so the doors are not difficult to open, and the ventilation system is stable in operation when doors are opened. This requires an intentional, controlled leakage path into the room (see below).

Air exchange rate

Air exchange rate is commonly used as a measure of how quickly contaminants released in a well-mixed zone are removed from the zone. Dilution time is also used to describe contaminant removal rate (see below). In an isolation room, where infiltration from adjoining spaces can represent a substantial total of the airflow into the room, a distinction must be made between the outside air exchange rate and the total air exchange rate, as these rates can be markedly different. The total air exchange rate is given by the ventilation exhaust flow from the room (plus ex-filtration from the patient room to the bathroom if the bathroom is at lower absolute pressure than the patient room) divided by the room volume.

The outside air exchange rate, on the other hand, is given approximately by the ventilation supply airflow divided by the room volume (direct infiltration of outside air is expected to be minimal in a properly sealed isolation room). The air exchange rate is typically expressed as the number of air exchanges per hour (ACH) in a defined volume. It is commonly used as a parameter describing ventilation in a room as whole, and assumes complete mixing of supply air throughout the entire volume.

Dilution time, on other hand, is expressed as the time necessary for a pollutant concentration to drop to a fractional value of the original concentration at a point in a volume. As such, the dilution time can vary at different points in a room with a given air exchange rate, depending on the actual local ventilation effectiveness (which again depends on the degree of mixing of ventilation air) at these points.

Air distribution systems should be designed to provide a high effective ventilation rate. It is important to consider the types, locations and entrainment characteristics of the supply and exhaust registers. These air distribution principles should be taken into account in the initial design stages. It may be difficult to achieve consistent mixing throughout the room.⁽¹⁾

Effective air change rate can be achieved in a number of ways but the most desirable one is to purpose-design the air conditioning to achieve the appropriate air change rate. When an existing system will not accommodate this, various other approaches have been used. The efficacy of these approaches is unproven, and the details of such alternative methods are beyond the scope of this document. For a further discussion, see Centres for Disease Control's *Guidelines for Preventing the Transmission of Mycobacterium tuberculosis in Health-Care Facilities*.⁽²⁾

Planned leakage (controlled air path)

Planned leakage provides a controlled air path from the corridor to anteroom, and from the anteroom to the patient room in an isolation suite. The planned air leakage into a properly sealed isolation suite normally occurs through or around the doors between these spaces. When a door is closed, the planned leakage will typically be designed to occur through the gap under the door and the unsealed sides and top of the door, or through a grille in the door where a door is sealed around all edges. Alternatively, in the case where a door and door edges are completely sealed, a dedicated duct between rooms can be installed to provide a controlled air path when the door is closed.

Unplanned envelope leakage

Unplanned envelope leakage refers to airflow into an isolation suite or room that occurs because of insufficient tightness in joints and penetrations through the suite or room envelope. Common unplanned leakage points include electrical and plumbing outlets, and wall-ceiling and floor-wall joints. The sum of the planned and unplanned leakage rates into the isolation room while the room is at the design under pressure should equal the exhaust-supply airflow differential.

To ensure the ventilation system is not overly sensitive to changes in the unplanned leakage over time, the unplanned leakage rate upon commissioning should be a small fraction of the planned leakage providing the controlled air path. The leakage rate can be conveniently expressed in this application as a fraction of the exhaust-supply airflow differential or as an air change rate per hour (ACH) at a specified pressure. Unplanned envelope leakage can be measured by first appropriately and sufficiently sealing the planned leakage paths in an isolation room.

Thermal comfort

Isolation rooms have relatively high air exchange rates in relation to other patient rooms. This implies high ventilation air supply and exhaust rates as well. Potentially uncomfortable air velocities (draughts) within the patient room can result, and therefore special attention must be given to thermal comfort, particularly for the patient, as a design issue. Draught risk, as defined in EN ISO 7730⁽¹⁾, depends not only on local air velocity, but also on air temperature and relative humidity, and the clothing and activity levels of people in the room. Consideration should be given to the installation of individual thermostats in each room to allow nursing staff to adjust the room temperature.

Related considerations

Several other important design considerations for isolation room suites fall within the scope of this document and they are discussed below.

Use of HEPA filters on ventilation exhaust and supply air

As ventilation ducts leading to and from an isolation room suite can potentially be routes of transfer of airborne infectious aerosols out of an isolation room, the use of HEPA filters can be considered in the design of the ventilation system. This includes consideration of how the filters will be safely replaced as well as periodically performance-checked. While use of HEPA filters is not directly related to ventilation and containment performance within an isolation room suite and between the suite and the corridor, HEPA filtration in isolation room ductwork can have a substantial impact on the investment and operational cost and complexity of the ventilation system. To maintain the ventilation system's integrity and ensure consistent pressure control, HEPA filters must be fitted with deep-bed pre-filters.

Control strategy

The ventilation system of an isolation suite should be designed to achieve and maintain (within agreed acceptance limits) the desired values of the design parameters discussed above. An isolation room suite in service will be subjected to disturbances that can affect the ventilation system, most notably when doors are opened and people enter and leave the suite. However, an isolation room suite is generally an integral part of a hospital building that contains other complexly ventilated spaces, and the building and its individual rooms and spaces will be subjected to changing stack and wind pressure effects over time.

To maintain the desired containment function in an isolation suite in the presence of these disturbances and changes in the external environment, the ventilation system must be designed with a control strategy in mind. A primary control requirement is an interlocking system between doors that ensures the corridor-anteroom and anteroom-patient room doors cannot be opened at the same time.

In addition, there are two fundamental control strategies that reflect the basic ventilation strategy discussed above of achieving containment between the patient room and anteroom, and the anteroom room and corridor. One strategy is to maintain constant exhaust-supply flow differentials under changing conditions and accept that the pressure differentials between the patient room and anteroom and the anteroom and corridor will vary. The second strategy is to maintain constant pressure differentials under changing conditions by varying the exhaust-supply flow differentials. Alternatively, a combination of the two approaches can be used. The choice of ventilation control strategy can have a profound impact on the cost and complexity of isolation room ventilation.

5.6 Air change rates

For Class N and Class P rooms, air change rates 12 air changes per hour (ACHR) or 145 litres per second per patient⁽³⁾, whichever calculation results in the greater air quantity^(1,2,3,11), should be achievable when the filters have reached their maximum pressure drop.

The selection of 12 ACHR is largely a matter of convention. Air change rates of 12 ACHR may cause stratification, whereas higher air change rates (20 ACHR) may cause turbulence. An air change rate of 15 ACHR may be a desirable compromise, taking into account dilution of airborne agents and air distribution.

Table 3 has been adapted from a formula used to estimate the rate of removal of airborne contaminants.⁽²⁾ The times given assume perfect mixing of the air within the space (that is, mixing factor = 1). However, perfect mixing usually does not occur, and the mixing factor could be as high as 10 if air distribution is very poor. In such circumstances, the time required to achieve a particular removal efficiency is increased.

Table 3: Air changes per hour (ACHR) and time in minutes required for various airborne contaminant removal efficiencies

ACHR	Minutes required for a removal efficiency of		
	90 per cent	99 per cent	99.9 per cent
1	138	276	414
2	69	138	207
3	46	92	138
4	35	69	104
5	28	55	83
6	23	46	69
7	20	39	59
8	17	35	52
9	15	31	46
10	14	28	41
11	13	25	38
12	12	23	35
13	11	21	32
14	10	20	30
15	9	18	28
16	9	17	26
17	8	16	24
18	8	15	23
19	7	15	22
20	7	14	21
25	6	11	17
30	5	9	14
35	4	8	12
40	3	7	10
45	3	6	9
50	3	6	8

The concept of litres/sec per patient as an alternative to ACHR was put forward by Marshall⁽³⁾, who challenged traditional thinking on contamination dilution.

When the ventilation design is based on ACHR, as the volume of the room decreases, the concentration of airborne contaminants increases. The decrease in air volume is due to the decrease in room volume, while the release of airborne contaminants from the patient remains the same. These considerations are particularly important in smaller rooms, as the following example illustrates.

Consider two isolation rooms of different dimensions, but with the same contamination source. As it is impossible to determine an average contamination rate, assume a patient is expiring a steady rate of airborne contaminants of one particle per second.

Room 1: 4m x 4m x 2.7m = 43.2 m³ (an average sized room)
 12 ACHR = 144 litres/sec.
 Contamination rate = 1 particle/sec.

Then steady state concentration = 1/144 = 0.0069 particles/l or 6.9 particles/m³.

Room 2: 3m x 4m x 2.7m = 32.4 m³ (a slightly smaller room)
 12 ACHR = 108 litres/sec.
 Contamination rate = 1 particle/sec.

Then steady state concentration = 1/108 = 0.0092 particles/l or 9.2 particles/m³.

Although the air change rate is the same for both rooms, the steady state concentration of contaminants in room 2 is 33 per cent greater than room 1.

If, instead, ventilation design is based on a litres per second per patient basis, using a minimum of 145 litre per second, then the ventilation of room 2 will achieve a particle concentration equivalent to room 1, independent of room volume. In effect, an ACHR of approximately 16 is required in the smaller room to achieve comparable dilution.

5.7 Building exhaust discharge location

Exhaust from infectious isolation rooms shall be mechanically exhausted to atmosphere as a Type A (objectionable) exhaust under clause 5.3 of AS 1668.2 and should meet the following requirements:

- discharge vertically at a velocity of at least 5 metres per second;
- be at least three metres above the roof at point of discharge
- above any part of the building (or adjacent building) that is within 15 metres (horizontally) or the discharge point;
- be at least three metres above a thoroughfare or roof subject to regular traffic, but within 15 metres of the discharge point;
- be a minimum distance of 10 metres from an air intake, or natural ventilation point, window or door and outside of the re-circulation range of the building; and
- in the case of a pitched roof, be at least one metre above the ridge.

In some situations the exhaust discharge plume may need to be modelled to determine an appropriate discharge location.

5.8 Monitoring of room pressure

It is important to monitor pressure locally using reliable digital or analogue instrumentation. Purpose built electronic isolation room monitors are available and are preferable to analogue gauges. Gauges or readouts should be located in a prominent location outside the room. In addition to local monitoring, the rooms can be connected to the building automation system for remote monitoring. An instrument should be selected with an appropriate scale; that is, the maximum pressure being approximately 80 per cent of full-scale deflection. The actual airflow should be monitored with a flow-switch, and a local audible alarm fitted in case of fan failure.

Airflow alarms must not depend on the output from the fan contactor. A building automation system (BAS) should only be used for secondary monitoring of room pressure. Temperature control via a BAS system is acceptable. When a room is occupied, smoke tests should be carried out monthly in addition to continuous electronic monitoring of room pressure, and daily monitoring and documentation of room and anteroom pressures by nursing staff. When a room is not occupied, room pressure should be checked monthly. As part of planned maintenance, electronic monitoring devices should be calibrated annually.

5.9 Methods of varying room pressure

It is important to ensure the room is well sealed (see section 5.10). An alarm system (visual/audible) should be installed to warn of pressurisation failure. Such a system should incorporate a delay to minimise nuisance alarms caused by routine entry to the room.

Constant airflow and pressure should be maintained within the room, and the control system should include a method of maintaining a constant room pressure. Air quantities need to be adjusted as filters become clogged. Only maintenance personnel should operate these controls.

Variable speed fans may be used to control room pressure. This may be operated by a BAS provided alarms are installed. The exhaust duct should be maintained at a constant negative pressure within the building.

5.10 Minimum outdoor air requirements

The minimum outdoor airflow rate delivered to an isolation room shall be 100% outside air.

Air shall not be recirculated from an infectious diseases isolation room to any other enclosure and must be discharged outdoors.

5.11 Minimising room air leaks

Rooms should be inspected for air leakage points during and after construction. Pressures within the room will be easier to maintain and there will be less load on the air handling plant if the rooms have monolithic plaster ceilings and tight fitting doors, and if windows and access panels and service penetrations into the room are sealed.⁽²⁾

5.12 Isolation room interiors

The design, materials and construction of the interior surfaces of an isolation room are critical to the performance of the room in containing infections.

The aims are to:

- facilitate cleaning;
- minimise dust collecting areas;
- minimise areas that may remain contaminated between patients; and,
- facilitate patient care and comfort.

Preferred features include:

- continuous impervious surfaces such as welded vinyl, epoxy coatings or similar durable surfaces;
- welded vinyl floors covered up the walls, and wall finishes that are durable and easy to clean; for example, welded vinyl.⁽¹⁴⁾ The use of carpet is discouraged because it is difficult to clean;
- minimisation of horizontal surfaces;
- guard rails to protect the walls from damage by beds and mobile equipment;
- epoxy-coated or stainless steel joinery that is easier to clean than uncoated timber;
- windows designed to avoid pelmets and dust collection areas;
- washable curtains; and,
- wall-hung toilet pan and basin with non-hand operated taps.

5.13 Signs and labels

All isolation room ductwork systems should be labelled with appropriate warning signs.⁽⁸⁾ Appropriate signage should be prominently placed outside the door of isolation rooms. The bedside and other charts should also be labelled once isolation has been ordered for a patient. Educational information on necessary precautions and procedures should be readily available and accessible (for example, in the form of information pamphlets, folders or posters, located adjacent to the isolation room) for staff, patients and visitors, while ensuring there is no breach of medical confidentiality.

5.14 Doors

Sliding doors are not recommended but if space is an issue, sliding doors should only be used as a last resort due to difficulties with maintenance and maintaining a seal. The pressure differential should force swing doors into the seal; that is, doors should open out of a NPR or open into a PPR.⁽¹⁾ Each entry door to the room should be sealed on its top and sides (including astragal vertical joint seal for leaf or double doors) and include an adjustable bottom seal. Self-closing doors can help control room pressure. An alternative arrangement can be to have both doors swing into the anteroom. If doors have an interlocks mechanism fitted, an emergency breakout system must be provided.

5.15 Communication system

A nurse call system with the capacity for direct communication between the nurse and patient should be available in each room.⁽⁸⁾ Design considerations should allow for adequate visual observation of the patient without health care personnel having to enter the room. This can be achieved by fitting the door of the anteroom and patient room with a window.⁽⁸⁾

5.16 Patient comfort and safety

The majority of isolated patients do not need high-level care but, to cater for those that do, high dependency units (HDU) and intensive care units (ICU) should include at least one isolation room that is located within view of the nurses' station.

In clinical units containing isolation rooms protocols should be established that ensure patients and their families are provided with verbal and written information about what to expect in isolation and so assist them to cope with the experience.

Privacy blinds, which can be controlled by staff and patients, should be installed on observation windows. Design considerations should allow for adequate view of the isolated patient, without health care personnel having to enter the room (for example, a window in the entry door).

Where possible, isolation rooms should be constructed to have a view to the outside.

Isolating patients in 'side rooms' within general wards, rather than constructing separate isolation wards, may also lessen the negative effects of isolation. Therefore, it is recommended that isolation rooms should be collocated within general wards.

Research suggests that isolation can adversely affect patient safety and quality of care because it inevitably puts barriers between patients and clinicians. One study reported that isolated patients were twice as likely as control patients to experience adverse events during hospitalisation. Another study of isolated patients in an intensive care unit found that health care workers entered the rooms of patients in contact isolation half as often as other patients' rooms.

5.17 Energy conservation

The use of 100 per cent outside air in Class N isolation rooms is relatively energy intensive but essential to control potentially infectious aerosols. Energy conservation measures must not interfere with best isolation practice. Use of heat wheels or similar principles for heat recovery is not recommended. Transmission of infectious particles can occur by entrapment of air within the wheel and release on the clean side. If energy conservation measures were to be used, devices such as run-around tubes may be more appropriate. Run-around coil piped systems and air-to-air plate type reclaim equipment is difficult to clean and decontaminate. Consultation with appropriate infection control professionals is essential when incorporating energy conservation measures into the design of isolation rooms.

5.18 Plant back-up systems

A back-up emergency power supply should be available to ensure fans, alarms and monitoring systems do not fail in the event of disruption to the main power supply.⁽¹¹⁾

Duplicate supply and exhaust fans should be installed to provide uninterrupted air flows in the event of fan failure or maintenance. A reliable mechanism for preventing backflow from one fan to another should be installed for maintenance staff safety. Positive pressure room design should include extract fans that automatically switch off if the supply air fan fails.

5.19 Renovating or converting a room

When an isolation room is being incorporated into an existing facility, it is rarely possible to create the ideal room. Physical and financial factors often constrain the construction. It is critical to create a room that is fit for its purpose; therefore, the design intent of section 2 should be adhered to as closely as possible.

When converting existing accommodation into Class N rooms, the easiest and least expensive option is to adapt existing single rooms with ensuite facilities. The following requirements should be met in any conversion:

- furnishing and fittings:
 - clinical handwash basin with non-touch, fixed temperature mixer tap
 - wall-mounted soap dispensers
 - disinfectant hand rub dispensers
 - disposable towel holders
 - glove dispensers
 - storage for clean personal protective equipment
 - clean waste bins
- observation window in corridor wall with integral privacy blinds
- investigate the use of a pressure stabiliser above the bedroom door
- compliant exhaust system
- compliant air supply (see below)
- sliding transfer grille in room door
- sealed, monolithic ceiling with sealed access panels
- windows to the exterior to be locked shut and sealed
- provision of two-way intercommunication system between the patient's room and the nurses' station.

The ventilation characteristics of an existing patient room must be considered when converting it into NPR. The following issues should be considered:

- Disconnection of re-circulating air system.
- Upgrade/conversion method.

- Preferred option is to adjust the building ventilation system to create a permanent NPR.

or

- A temporary solution is to add HEPA filter unit to supplement, or even replace, the building ventilation system.
- Room must be adequately sealed (as tightly as possible).
- Ventilation system should be modified and new exhaust system added to rebalance existing mechanical system. Dampers should be adjusted.
- When the installation of a separate air handling unit for each room is not practical, and providing the existing supply air quantities are adequate, an alternative arrangement is the installation of a fan boosted terminal HEPA filter with a pre-filter plenum for each room. It is essential that pre-filters are installed prior to the HEPA filter. It is recommended a variable frequency drive be fitted to the fan. This arrangement must be subject to a multi-disciplinary risk assessment.
- When the installation of a duct for each exhaust is not practical an alternative arrangement is the installation of a fan boosted HEPA filter with a pre-filter plenum for each room. It is essential that pre-filters are installed prior to the HEPA filter. It is recommended a variable frequency drive be fitted to the fan. This arrangement must be subject to a multi-disciplinary risk assessment.

Air leakage points should be checked after construction and prior to operation. All room penetrations above and below the ceiling and the ductwork should be sealed effectively.

5.20 Commissioning

Testing at start-up sets a benchmark against which performance can be tested in later performance monitoring checks. A 'failure of room pressures' contingency plan should be established as part of room commissioning. A list of commissioning tests from the Nordic guidelines is provided below.

Pressure differential between rooms

The pressure differential (door closed) between corridor and anteroom, and anteroom and patient room, should be checked on the permanent monitors and recorded.

Airflow direction between rooms (door open)

The airflow direction between the corridor and anteroom and anteroom and patient room should be checked, with one door open at a time, and the results documented.

Use smoke tube: release smoke and observe movement patterns.

Airflow patterns within the room

The airflow pattern within the patient room should be tested to ensure there are no stagnant areas and that air supply is not being short-circuited.

Use smoke tube: release smoke and observe movement patterns.

Air-exchange rate

Air exchange rate can be calculated by dividing the ventilation exhaust rate by the room volume. It can also be measured directly by using a tracer release.

Method 1: Tracer decay rate. A tracer is instantaneously released into a room and the concentration decay over time is observed. This method can also be used to measure the dilution rate at a point or points in the room.

Method 2: Tracer constant release method. A tracer gas is released at a known rate into the volume. Measurement of the steady state tracer gas concentration yields a quantitative measure of air exchange rate in the volume.

Tracer methods require trained personnel and specialised equipment not usually available from most ventilation contractors.

Supply and exhaust air volumes from registers

Supply and exhaust airflow rates should be checked in all registers in the anteroom, patient room and bathroom, and the results documented.

There are a number of ways of measuring supply and exhaust air volumes from ventilation register in isolation suites but the most common are either a flow hood or vane anemometer. In some situations, measurement of these rates can also be used a substitute for the measurement of air exchange rate directly with a tracer gas (see above).

Leakage rate

The tightness of the patient room should be checked and documented. There are a number of ways of measuring the leakage rate quantitatively and qualitatively.

Smoke visualisation combined with pressurisation

This method can be used to check for leakage visually by releasing smoke at suspected leakage locations while the isolation room is at under or over pressure with respect to the surroundings. The room should be pressurised by closing and sealing appropriate ventilation registers and other envelope openings (such as doors) and shutting off supply or exhaust fan. Under or over pressure should be measured, and leaks with a smoke source sought.

Fan pressurisation method

This method quantifies leakage rate in m^3/hr by measuring airflow rate in or out of the room at a specified pressure differential. It is commonly done with commercially available 'blower door' apparatus.

In most cases, use of 'blower door' apparatus means the planned leakage path through the door is sealed during the test. Alternatively, a sufficient pressure differential can possibly be obtained in an isolation room by turning off the supply fan and sealing (for example, using tape and plastic sheeting) supply registers and planned leakage paths. Measurement of the airflow rate through the exhaust register can then yield a leakage rate directly.

Both methods yield an upper limit to the unplanned leakage that is limited by the extent to which the planned leakage paths, or unfinished openings (in the case where the test is performed before the isolation room is complete) can be blocked during the test.

Tracer method: measure air exchange rate during pressurisation

This method quantifies leakage rate in ACH by measuring the tracer concentration decay rate while the room is pressurised. The room should be pressurised by closing and sealing supply vents and other envelope openings (such as doors) and shutting off the supply fan. The exhaust air should be adjusted so a pressure of -50Pa is achieved in the room. The air exchange rate should be measured using a tracer method (see above).

Containment

The containment of the isolation suite should be checked and the results documented. Containment with regard to the isolation suite refers to the ability of the suite to withhold airborne infectious substances, particularly when persons exit the room and suite. In itself, containment is not a currently established design parameter.

Point release tracer method

The tracer is instantaneously released at the position of the patient bed in the patient room. Tracer concentrations are measured in the anteroom and corridor outside the patient room after a person exits the room and anteroom.

Constant release tracer method

The procedure is as above except that a constant release of tracer gas is used in the patient room and results in a steady-state constant concentration of tracer gas in the patient room.

Thermal comfort

Thermal comfort should be checked at the patient bed and documented. The draft rating should be measured at the position of the head of the bed.

HEPA filter leakage

HEPA filter leakage should be checked for all HEPA filters in the isolation room ventilation system according to AS1807.6 and the results documented. This refers to the leakage of aerosol through or around an installed HEPA filter when an aerosol challenge is presented upstream of the filter.

HEPA filter pressure drop

Pressure drop should be checked across all HEPA filters in the isolation room ventilation system by observing pressure readings on permanently installed monitors, or by using a portable pressure gauge. The results should be documented.

5.21 Patient transport

Provision of appropriate patient transport to and from isolation rooms is an important component of infection control, and the following precautions are recommended:

- Limit the movement and transport of patients who require respiratory isolation precautions to medically necessary purposes.
- If transport or movement outside a negative pressure room is necessary, use a personal respirator on the patient (valveless filtered facemasks, such as N95 particulate respirator mask) during transportation.
- Notify the department where the patient is being transferred to in advance, so they may take steps to prevent the possible spread of infection.

5.22 Routine performance monitoring and maintenance

Performance protocols should be established before rooms are brought into service. It is important to define persons responsible for the operation, monitoring and maintenance of rooms. Regular in-service training should be provided for staff using the facility to ensure they understand the functions of the room, and how to read and interpret the monitoring instrumentation. The nursing care plan of the isolated patient must include daily monitoring and documentation of room and anteroom pressures. Nosocomial outbreaks have occurred when deterioration of system performance has not been recognised due to a lack of routine monitoring.⁽¹²⁾

Established protocols and details of unit/persons responsible for the operation, monitoring and maintenance of rooms, and the results of such activities, should be made available to staff (for example, via the hospital intranet). All staff members using the facilities should receive training at orientation and at least annually thereafter on the functions of the room, and how to read and interpret monitoring instrumentation. A record of training should be documented for nursing staff who are responsible for checking and recording room pressures via external monitoring equipment, including an assessment of competency in the use of such equipment.

System performance monitoring by engineering staff should be undertaken via a planned maintenance system. Training in monitoring techniques of maintenance staff is advisable. This should be arranged during the design phase and included in the mechanical specification so the mechanical contractor can train maintenance staff before the facility is operational. If monitoring equipment is required, this can be included in the specification to be supplied to the maintenance staff by the mechanical contractor as part of the contract.

Planned maintenance⁽⁷³⁾ should be scheduled at an interval not greater than 13 weeks and the following items checked:

- air change rate;
- supply air and exhaust quantities;
- terminal HEPA filters;
- exhaust registers;
- room pressure gauges;
- damage to the room interior;
- supply and exhaust fans;
- room seals and door closer;
- BAS system connections where fitted;
- handbasin and ensuite plumbing; and
- room signage.

All HEPA filters should be tested and certified according to AS1807.6 at least annually. Each filter should have a test label fixed in a prominent position.

Record keeping

The engineering department should keep a logbook for each isolation room containing a minimum of:

- a schematic layout of the room and its serving ventilation system serving;
- information on the ventilation design parameters;
- a record of the actual ventilation performance at initial validation;
- a record of annual validations;
- a record of any routine service and maintenance activities;
- a record of any repairs or modifications; and
- a method statement for disinfecting the system.

The logbook should be retained for at least five years after the room is taken out of use. An annual 'fit for service' authorisation for each isolation room should be conducted.

5.23 Renovation, construction, remediation, repair and demolition: Infection control risk assessment

Any construction activity carries an infection control risk; therefore, the following points are considered essential for construction, renovation, maintenance, demolition and repair:

- Establish a multidisciplinary team that includes infection-control staff to coordinate demolition, construction, and renovation projects, consider proactive preventive measures at inception, and produce and maintain summary statements of team activities.

- Educate construction team and health care staff regarding infection control.
- Incorporate mandatory adherence agreements for infection control into construction contracts, and ensure there are penalties for non-compliance and mechanisms to ensure timely correction of problems.
- Implement infection control measures relevant to construction, renovation, maintenance, demolition and repair. These include:
 - Performing an infection control risk-assessment prior to the commencement of the project to define the scope of the activity and the need for barrier measures;
 - Implementing infection control measures for external and internal demolition and construction activities; and
 - Avoidance of damaging all water systems, particularly underground water systems, to prevent soil and dust contamination of the water.
- Perform engineering and work-related infection control measures as needed for internal construction, repairs and renovation:
 - Ensure proper air handling system in the affected area.
 - Create and maintain negative pressure in work zones adjacent to patient-care areas, and ensure required engineering controls are maintained.
 - Monitor barriers for integrity.
 - Seal windows and leaks.
 - Wear protective clothing in the designated entrance, corridors and anteroom.
 - Create a clean work zone.
 - When working in a patient area, use a negative pressure system within this enclosure to remove dust and pass the air through an industrial-grade, portable HEPA filter capable of filtration rates of 500 litres/second, or exhaust air directly to the outside.
 - Upon completion, restore appropriate ACH, humidity, and pressure differential.
 - Clean or replace air filters and dispose of used filters.
- Establish and maintain surveillance for airborne environmental disease, as appropriate, during construction, renovation, repair and demolition activities.
- Evaluate the integrity of the isolation room barrier after any construction work.
- Commission the HVAC system for newly constructed health care facilities and renovated spaces before occupancy and use.

6 An introduction to general principles of microbial transmission

This section briefly introduces the modes by which infectious micro-organisms may be transmitted from a source of infection to a person, and emphasises the routes by which health care acquired infections are commonly transmitted.

The five main routes of transmission are contact, droplet, airborne, common vehicle, and vector borne. The same micro-organism may be transmitted by more than one route. Common vehicle and vector borne transmission are only discussed briefly, as these are uncommon routes of transmission of nosocomial infections, and are less affected by room design and construction factors.

6.1 Contact transmission

The most important and frequent mode of transmission of hospital-acquired infections is contact transmission, which may be subdivided into direct-contact transmission and indirect-contact transmission.

Direct-contact transmission involves direct body-surface to body-surface contact and physical transfer of micro-organisms from an infected or colonised person to a susceptible host. This may occur between patient and carer in the course of patient-care activities involving direct personal contact, or between any two persons (patients, carers, others) in the health care setting.

Indirect-contact transmission involves the contamination of an inanimate object (such as instruments) by an infected or colonised person. Infection may then be transmitted by contact between the contaminated item or the environment and a susceptible host.

6.2 Droplet transmission

Droplets are generated when a person coughs, sneezes, and talks, and during procedures such as suctioning and bronchoscopy. Transmission occurs when droplets containing micro-organisms are generated from an infected or colonised person, propelled a short distance (usually less than one metre) through the air, and deposited on the conjunctivae, nasal mucosa or mouth of a host, or land on surfaces where they can be a source of contamination to mucous membranes via hands or objects. Droplets do not remain suspended in the air; therefore, special air handling and ventilation are not required to prevent droplet transmission. It is important to not confuse droplet transmission with airborne transmission.

6.3 Airborne transmission

Airborne transmission occurs by dissemination of either airborne droplet nuclei or dust particles containing the infectious agent.

Droplet nuclei

Droplets have large surface areas and therefore evaporate rapidly in the air. The droplet size and the difference between the pressure of the water vapour in the air and at the surface of the droplet determine the rate of evaporation.

In low relative humidity, droplets evaporate rapidly. As the droplet evaporates, the concentration of dissolved substances increases. The droplet shrinks until the concentration of dissolved substances is such that the vapour pressure the droplet exerts is equal to the atmospheric pressure. If the saturation pressure of the droplet at equilibrium is greater than the saturation pressure of the atmospheric water vapour, with the evaporation of the remaining water, the contents of the droplet will crystallise. The residue of the droplet after evaporation, which contains any organism originally present, is called a droplet nucleus and is typically 5 µm or smaller in size. As the water evaporates, the weight of the droplet decreases, and therefore the droplet-settling rate decreases. In occupied spaces, droplet nuclei settle so slowly that they remain airborne and circulate on air currents until mechanically removed by the ventilation system.

The concentration of infectious particles in a volume of air (and the risk to persons breathing that air) depends on the rate at which infectious particles are added to the air, and the rate they are removed by settling or ventilation. The high velocity with which droplets are expelled from the respiratory tract during coughing and sneezing results in large numbers of bacteria or viruses entering the air in smaller droplets than those produced by quiet breathing and speech. Experiments by Duguid⁽¹⁵⁾ in 1945 showed normal speech liberated up to 200 bacteria-bearing droplets less than 100 microns in diameter. Various coughs liberated up to 3500, and sneezing liberated between 4500 and 1 million bacteria bearing droplets less than 10 microns in diameter. Velocities of up to 300 metres per second in sneezing and coughing result in considerable reductions in particle size compared to those liberated during speech. Relatively frequent air changes are needed to remove infectious droplet nuclei from the air of a room.

Micro-organisms carried in this manner can be dispersed widely by air currents and then inhaled by a susceptible host near or quite far from the source patient. Control of environmental factors (such as special air handling and ventilation) is necessary to prevent hospital-acquired airborne transmission of micro-organisms such as measles, chicken pox and *Mycobacterium tuberculosis*.

Dust

The control of dust-borne particles is often overlooked. Dust contaminated by viable infectious agents may build up as a reservoir that is capable of causing an outbreak of infection, even after the departure of the infectious patient from whom the pathogens originated. Dust may become contaminated when dried sputum and other infectious secretions suspended in the air as dust particles are then mixed with environmental dust.

Ordinary house dust settles much faster than droplet nuclei, but industrial dusts, pollens and spores may have very small particle sizes that can settle slowly. These dusts may be inhaled and deposited into the lungs in a similar manner to droplet nuclei.

Particles contaminated with organisms may enter the air from the respiratory tract (sneezing and coughing) and from skin, clothing, dressings and body fluids. Larger droplets and particles settle rapidly to the ground, close to their point of origin, where they desiccate. Some organisms may survive for extended periods in the environment and may be re-suspended when contaminated dust is disturbed.

6.4 Common vehicle transmission

Common vehicle transmission applies to micro-organisms transmitted by contaminated items such as food, water, medications, devices and equipment. These items are referred to as fomites.

6.5 Vector-borne transmission

Vector-borne transmission occurs when vectors such as insects (mosquitoes, flies) or vermin (rats, mice) transmit micro-organisms; this route of transmission is rarely of significance in hospitals in Australia.

6.6 Functional classification of isolation rooms

Table 4: A functional classification of isolation rooms

	S Standard	N Negative	A Alternating	P Positive
Key ventilation criteria	No air pressure difference between the room and the adjacent corridor	Air pressure in the room is less than in the adjacent corridor	Ventilation may be configured to achieve either positive or negative pressure in the room	Air pressure in the room is greater than in the adjacent corridor
Transmission-based precautions	Contact or droplet	Airborne	Not recommended (see section 2.4)	Prevention of transmission of pathogens from the outside environment to profoundly immunosuppressed persons
Examples	<ul style="list-style-type: none"> • VRE • Gastroenteritis • Cutaneous anthrax • Hepatitis A • meningococcal disease 	<ul style="list-style-type: none"> • Measles • Chicken pox • Suspected or proven pulmonary or laryngeal tuberculosis 	Not recommended (see section 2.4)	Prevention of aspergillosis in bone-marrow transplant recipients

References

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Glossary

This glossary contains many terms used in the guidelines, as well as others encountered frequently by persons who implement infection control programs. The definitions here are not dictionary definitions, but rather those most applicable to usage when communicating with health professionals.

ACHR: Air changes per hour.

Aerosol: The droplet nuclei that are expelled by an infectious person (for example by coughing or sneezing). These droplet nuclei can remain suspended in the air and can transmit an infection to other persons.

Air changes: The ratio of the volume of air flowing through a space in a certain period of time (that is, the airflow rate) to the volume of that space (that is, the room volume). This ratio is usually expressed as the number of air changes per hour (ACHR).

Air conditioning: Artificial altering of the environment to provide comfortable conditions within an enclosed space.

Air diffuser: An air outlet discharging supply air in various directions and planes.

Air mixing: The degree to which air supplied to a room mixes with the air already in the room, usually expressed as a mixing factor. This factor varies from 1 (for perfect mixing) to 10 (for poor mixing), and it is used as a multiplier to determine the actual airflow required (the recommended ACHR multiplied by the mixing factor equals the actual ACHR).

Anteroom: A small room leading from a corridor into an isolation room. This room can act as an anteroom and prevent the escape of contaminants from the isolation room into the corridor.

ASHRAE: The American Society of Heating, Refrigerating and Air-Conditioning Engineers Inc. A professional body that develops standards for building ventilation.

Bronchoscopy: A procedure for examining the respiratory tract that requires inserting an instrument (a bronchoscope) through the mouth or nose and into the trachea. The procedure can be used to obtain diagnostic specimens.

Computational fluid dynamics: Computer-aided fluid flow modelling. Airflow analysis of flow patterns and air streams are calculated by solving fundamental fluid mechanics equations of laminar and turbulent flow, such as the flow pattern and distribution of wind blowing over a building.

Differential pressure gauge: A pressure gauge that will display the difference in pressure between one port on the gauge and the other. Normally placed to measure the difference in pressure between two rooms.

Dilution by ventilation: An engineering control technique to dilute and remove airborne contaminants by the flow of air into and out of an area. Air that contains droplet nuclei is removed and replaced by contaminant-free air. If the flow is sufficient, droplet nuclei become dispersed and their concentration in the air is diminished.

Displacement diffusion: A directional airflow pattern that provides a single pass air stream. The air should flow from the source over the designed target area and then to exhaust with the least mixing, and therefore creating as little turbulence as possible.

Displacement diffuser: Air outlet grill that creates displacement diffusion.

Droplet nuclei: Microscopic particles (1–5 µm in diameter) produced when a person coughs, sneezes, shouts, or sings. The droplets produced by an infectious TB patient can carry tubercle bacilli and can remain suspended in the air for prolonged periods of time and carried on normal air currents in the room.

Ensuite: A patient bathroom with shower, toilet and hand washbasin.

Fomites: Linen, books, dishes or other objects that are used or touched by a patient.

HCW: Health care worker.

High efficiency particulate air (HEPA) filter: A filter that is capable of removing 99.97 per cent of particles 0.3 µm in diameter. Filters may be used in ventilation systems to remove particles from the air, or in personal respirators to filter air before it is inhaled by the person wearing the respirator. The use of HEPA filters in ventilation systems requires expertise in installation and maintenance.

Immuno-suppressed, immuno-compromised: A state in which the immune system is not functioning normally (for example, severe cellular immunosuppression resulting from HIV infection or immunosuppressive therapy).

Infection: The condition in which organisms capable of causing disease (for example, M. tuberculosis) enter the body and elicit a response from the host's immune defences. TB infection may or may not lead to clinical disease.

Infectious: Capable of transmitting infection.

Negative pressure: The relative air pressure difference between two areas in a health care facility. A room that is at negative pressure has a lower pressure than adjacent areas, which keeps air from flowing out of the room and into adjacent rooms or areas.

Nosocomial infection: A hospital-acquired infection.

Recirculation: Ventilation in which all or most of the air that is exhausted from an area is returned to the same area or other areas of the facility.

RSV: Respiratory syncytial virus.

Self-closing door: A door with a self-closer.

Sputum induction: A method used to obtain sputum from a patient who is unable to cough up a specimen spontaneously. The patient inhales a saline mist that stimulates a cough from deep within the lungs.

Transmission: The spread of an infectious agent from one person to another. The likelihood of transmission is directly related to the duration and intensity of exposure to the pathogen.

Virulence: The capacity of a micro-organism to cause disease.

VRE: Vancomycin-resistant enterococci. Enterococci that are resistant to the antibiotic vancomycin.