GUIDELINE ON CONCEPTUAL DESIGN AND ENGINEERING REQUIREMENTS FOR ISOLATION ROOM

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MINISTRY OF HEALTH
MALAYSIA

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MESSAGE

THE DIRECTOR GENERAL OF HEALTH

The emergence of many new viruses has posed mounting a challenge for the health sector to handle. Being able to treat, diagnose, and contain those viruses from spreading to the whole population demand proper strategies and infrastructure. One of the critical area of concern is the need for appropriate and internationally compliance isolation room to place the patients for treatment or observation.

It is an obligation of the Ministry of Health to ensure all isolation rooms in healthcare facilities are built and operated in accordance with international practices and codes or standards. The complete cycle of building an isolation room, starting from the planning stage to the handing over of completed facility, shall emphasize the importance of blending the engineering perspective and the user's requirement to achieve the most practical, operable and maintainable room for the patient and relevant parties.

The formulation of this guideline is timely as the Ministry of Health is in pursuit of improving the existing and building new isolation rooms in order to meet the continuous demand due to increasing population and the presence of new viruses. It will set a benchmark for isolation room design in the Ministry of Health and serve as a useful guidance for all interested parties.

This guideline, hopefully, can benefit various parties within or outside the Ministry of Health to further enhance the effective planning, design, and operation of isolation rooms in hospitals.

Datuk Dr. Noor Hisham Bin Abdullah
Director General of Health
Ministry of Health Malaysia

PREFACE

THE DIRECTOR OF ENGINEERING SERVICES DIVISION

With the emergence of numerous airborne diseases that are easily transmitted from one person to the other, and the dire effects on the patient and the nation as a whole, there is a need to establish new or upgrade existing isolation rooms to cater to a safe and conducive environment for patients, visitors, and healthcare workers.

The guidelines are developed to ensure that all isolation rooms at the hospitals comply with international infection control measures and protocol requirements. The guidelines specifically cover the engineering requirements for the isolation rooms.

The information in these guidelines is intended to establish the minimum requirements for an isolation room to ensure that the new and existing isolation rooms meet the safe and conducive environment. The information in the guidelines is derived from numerous sources to reflect the design requirement, maintenance requirements, and certification.

This guideline is prepared by the Engineering Services Division of the Ministry of Health Malaysia (MOH) to be used as a guiding document in the construction of a new isolation room and upgrading or converting an existing patient room into an isolation room.

The guideline can be used by the Ministry of Health officials (the owners), the hospital administration, the healthcare workers, maintenance personnel, designers, and others concerning the isolation room in the healthcare facilities.

The guideline is applicable to all government hospitals and health facilities in Malaysia.

Haji Md. Jalal Bin Bongkik
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LIST OF ABBREVIATIONS

Organizations

AIA	American Institute of Architects
ASHRAE	American Society of Heating, Refrigerating, and Air Conditioning Engineers
CDC	Centres for Disease Control and Prevention
MOH	Ministry of Health

TERMS

ACH	Air Change per Hour	MERV	Minimum Efficiency Reporting Value
ACMV	Air Conditioning and Mechanical Ventilation	Pa	Pascal
AHU	Air Handling Unit	PE Room	Protective Environment Room
AIIR	Airborne Infection Isolation Room	PPM	Planned Preventive Maintenance
CAV	Constant Air Volume	T&C	Testing and Commissioning
CFM	Cubic Feet per Minute (ft^3/m)	SOP	Standard Operating Procedure
FCU	Fan Coil Unit	µm	Micro meter. Commonly known as micron
HEPA	High Efficiency Particulate Air	UV	Ultraviolet
HEPPM	Hospital Engineering Planned Preventive Maintenance	UVGI	Ultraviolet Germicidal Irradiation
ICU	Intensive Care Unit	VAV	Variable Air Volume
In w.c.	Inches water column	w.c.	Water column

GLOSSARY

Air Exchange Rate	Air Exchange Rate refers to the number of times that the outdoor air replaces the volume of indoor air (in a building) per unit time and is typically expressed as Air Changes per Hour (ACH); or the number of times that the ventilation replaces the air within a room or zone within the building.
Air-Conditioning	A form of air treatment whereby temperature humidity and air cleanliness are all controlled within limits determined by the requirements of the air-conditioned enclosure.
Airborne Disease	Airborne disease refers to any disease that is caused by pathogens and transmitted through the air. Such diseases include many that are of considerable importance both in human and veterinary medicine. The relevant pathogens may be viruses, bacteria, or fungi, and they may be spread through coughing, sneezing, raising of dust, spraying of liquids, or similar activities likely to generate aerosol particles or droplets. Strictly speaking, airborne diseases do not include conditions caused simply by air pollution such as dust and poisons, though their study and prevention may be related.
Air Filter	A device that filters particle matter when the air passes through it.
Air Handling Unit (AHU)	AHU is a device that is used to filter, condition, and circulate the air as part of a heating, ventilating, and air-conditioning (HVAC) system.
Airborne Infection Isolation Room (AIIR)	A single-occupancy room for patient care where environmental factors are controlled in an effort to minimize the transmission of those infectious agents usually spread from person to person by droplet nuclei associated with coughing or inhalation (Such rooms typically have specific requirements for controlled ventilation, air pressure, and air infiltration).
Air Movement Relationship	The air movement relationship is the relationship of the air movement with respect to adjacent areas.
Anteroom	A small room leading from a corridor into an isolation room. This room can act as an airlock, preventing the escape of contaminants from the isolation room into the corridor.
Bio-film	A community of bacteria and other microorganisms, embedded in a protective layer with entrained debris, attached to a surface. This is normally found on cooling coils.

Differential Pressure	A measurable difference in air pressure creates a directional airflow between adjacent spaces.
Differential Pressure relationship with adjacent spaces	The pressure difference of the patient room with respect to the surrounding. The surrounding here refers to the corridor, the toilet or the anteroom where applicable.
Evaporative cooling	A process by which the evaporation of a liquid removes the latent heat from the surface where evaporation takes place; e.g. moisture on the skin evaporates, thereby taking the required latent heat of vaporization from the body making it feel cool.
Emergency supply	Emergency supply is the second level of electricity supply. The electricity is supplied from a generator when the main electrical supply from the utility company fails. The switch socket outlets need to be colour-coded.
Essential supply	Essential supply is the third level of electricity supply. The electricity is supplied from a battery backed Uninterruptible Power Supply (UPS) when the main electrical supply from the utility company fails. The switch socket outlets need to be colour-coded.
Healthcare worker	Refers to the clinical staff such as doctors, dentists, nurses, paramedical professionals such as occupational therapists, physiotherapists, and radiographers, and laboratory staff.
HEPA filter	High Efficiency Particulate Air filters are capable of removing 99.97% of particles 0.3 µm in diameter and may assist in controlling the transmission of airborne disease agents.
Host	A host is the source of infection and can be a person, animal, or of plant origin.
Hospital Support Services (HSS)	HSS refers to the concession companies that have a contract with MOH to provide hospital support services; e.g. maintenance of isolation room and associated equipment.
Immune compromised, Immunosup-pressed	A state in which the immune system of the patient is compromised or suppressed due to infection (for example, severe cellular immunosuppressant resulting from HIV infection or immunosuppressive therapy/ chemotherapy).
Inches water column	Inches in water column (inch w.c.) is a non-SI pressure measurement unit.

Monolithic	An item that is made up of a single piece, solid and unbroken, e.g. monolithic ceiling, which refers to a single piece ceiling such as plaster boards, or monolithic flooring, which refers to single piece flooring materials such as vinyl flooring.
Negative Pressure	It is the relative pressure of one room with respect to adjacent spaces. 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 infections	Nosocomial infections are also known as Hospital-Acquired Infection (HAI), it is an infection whose development is favoured by a hospital environment, such as one acquired by a patient during a hospital visit or one developing among hospital staff.
Pascal	Pascal is a unit of pressure measurement in SI. Its abbreviation is "Pa".
Protective Environment Room	A bedded unit where severely immunosuppressed patients are cared for (e.g. bone marrow transplant units).
Plenum	A space between the structural floor and the dropped ceiling that is used to facilitate the air circulation from an air-conditioning system.
Positive Pressure	It is the relative pressure of one room with respect to adjacent spaces. A room that is at positive pressure has a higher pressure than adjacent areas, which keeps air from flowing into the room and into adjacent rooms or areas.
Room Units	Room units here refer to local air-conditioning units that are used primarily for cooling of air, and not disinfection of air.
Risk assessment	Identifying and assessing the risk of converting or upgrading the patient room so as not to affect any services or work flow to other patient rooms.
Self-closing door	A mechanical or electrical device installed at the door that closes the door to an entry or exit of patient or nursing staff.
Transmission	Transmission is the mode by which the microorganisms are transmitted in hospitals. There are five main modes of transmission: contact, droplet, airborne, common vehicle, and vector borne. The routes can be cavities or skin etc.

EXECUTIVE SUMMARY

The guidelines are prepared by the Engineering Services Division of the Ministry of Health Malaysia (MOH) and have **ten** (**10) sections**. The guidelines have been developed based on numerous established guidelines ranging from Centres for Disease Control and Prevention (CDC), American Institute of Architects (AIA), American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE), and others.

Section 1: Introduction
This section explains the importance of the isolation room.

Section 2: Modes of Transmission of Microorganisms
This section discusses the modes of transmission of microorganisms from the source of infection to the host. The source can be a person, animal or plant, while the host is the person that can potentially be infected.
There are five modes of transmission of microorganisms: contact transmission, droplet transmission, airborne transmission, common vehicle transmission, and vector borne transmission. The isolation rooms are mainly related to airborne transmission of microorganisms.

Section 3: Isolation Room
This section discusses the need for isolation rooms to control the transmission of microorganisms and the medical area where isolation rooms are required. It also classifies the isolation rooms: Airborne Infection Isolation ROOM (AIIR) (commonly known as negative isolation room) and the Protective Environment (PE) Isolation Room (commonly known as positive isolation room).

Section 4: Design Requirement for Airborne Infection Isolation (AIIR), Protective Environment (PE) and combined AIIR/PE Rooms
This section discusses the architectural, mechanical, and electrical design requirements for AIIR. The architectural requirements covered are the walls, ceiling, flooring, and the fittings in the patient room, anteroom, and en-suite bathroom of the AIIR. The mechanical requirements covered are the air conditioning and mechanical ventilation parameters, air distribution, fire safety system, and medical gas pipeline system. The electrical requirements covered are the switchboard, power supply, lighting, switch socket outlets, nurse call system, intercom system, and bed head panel. The last subsection is on other considerations that may be implemented.

Section 5: Assessment of Existing Isolation Room
This section discusses the guidance for the assessment of existing isolation rooms after some time of operation. The result of the assessment shall lead the owner to propose for upgrading or converting an existing patient room.

Section 6: Upgrading or Converting an Existing Patient Room to AIIR
This section discusses the elements to be considered when upgrading or converting an existing patient room to an AIIR.

Section 7: Signage
This section is on signage that needs to be in place so as to ensure safe operation and maintenance of the isolation room. The signage are precautionary measures to enter the AIIR and PE rooms; caution signage at duct and exhaust fans, directional flow signage, and UV light signage.

Section 8: Testing and Commissioning (T&C), Handing Over, and Warranty Management
This section briefly discusses the elements in the Testing and Commissioning (T&C). The elements are the documentation, validation of isolation room, and the activities to be carried out. The elements discussed on handing over and warranty management are the scopes of works between MOH/hospital, hospital support services, and contractor.

Section 9: Maintenance
This section discusses the type of maintenance and lists some of the maintenance requirements for the architectural, mechanical, and electrical systems of the isolation room.

Section 10: Isolation Room Validation
This section on isolation room validation discusses the types of tests to be carried out, frequency, conditions requiring validation, and elements to be reported.

1. INTRODUCTION

People have different thresholds towards infection depending on their nutritional intake, health condition, lifestyle, age, work environment, and stress levels. When a person is infected and the immune system is compromised, he or she is more susceptible to further infections.

In hospitals, Infection Control plays a very important role in minimizing the transmission of microorganisms from a patient to a susceptible host or from the host to an immunosuppressed patient. Of the five modes of transmission of microorganisms, the airborne transmission mode is of great concern as the pathogens are small, light, and easily transferred from one location of the hospital to another via the air-conditioning system.

One of the Infection Control measures taken is to isolate the patient from the surroundings and vice versa based on the protection required. There are mainly two types of protection; the first type is the isolation of the healthcare workers from the airborne infected patient using Airborne Infection Isolation Room (AIIR), and the second type is the isolation of an immunosuppressed patient from his/her surrounding using Protective Environment (PE) rooms.

In view of the emerging need for properly designed and functional isolation rooms, the guideline highlights the overall concept of isolation room evolution in healthcare ranging from the basic principles, design, maintenance, assessment of existing set-up, and the handing over requirements. The greater emphasis is placed on the engineering controls that are used to negate the transmission of microorganisms when patients are placed in the AIIR and PE rooms.

Last but not least, all isolation rooms need to maintain their status in relation to the stipulated designation, i.e. positive or negative, throughout their life span. The physical facility may deteriorate over time but the integrity of the room shall be periodically renewed through appropriate validation processes.

2. MODES OF TRANSMISSION OF MICROORGANISMS

There are three elements required for an infection to spread: source of infection, a susceptible host, and modes of transmission of the microorganisms.

There are five main modes of transmission of microorganisms:

- Contact transmission,
- Droplet transmission,
- Airborne transmission,
- Common vehicle transmission, and
- Vector borne transmission.

2.1. Contact Transmission

Contact transmission is the most important and frequent mode of transmission of nosocomial infections (Hospital-Acquired Infections [HAI]). It is sub-divided into two groups: direct-contact and indirect-contact transmissions.

2.1.1 Direct-contact transmission *involves direct body to body contact, resulting in physical transfer of microorganisms between a susceptible host and an infected person*; e.g. when a healthcare worker turns a patient, gives a patient a bath, or performs other patient-care activities. Direct-contact transmission can also occur between two patients, with one serving as the source of the infectious microorganism and the other as a susceptible host.

2.1.2 Indirect-contact transmission occurs when a susceptible host has contact with a contaminated usually inanimate, intermediate object, such as contaminated instruments, needles, or dressings, or contaminated hands that are not washed, and gloves that are not changed between handling of patients.

2.2. Droplet Transmission

Droplet transmission is a form of contact transmission. However, the mechanism of transfer of the microorganism to the host is quite different from contact transmission. Droplets are generated from the source person primarily during coughing, sneezing, and talking, and during the performance of certain procedures such as suctioning and bronchoscopy.

Transmission occurs when microorganism-filled droplets released from the infected person are dispersed through the air and are deposited on the host's conjunctivae, nasal mucosa, or mouth. Because droplets do not remain suspended

in the air, special air handling and ventilation are not required to prevent droplet transmission.
Note: droplet transmission must not be confused with airborne transmission.

2.3. Airborne Transmission

This type of transmission occurs through dispersion *of either infectious airborne droplet nuclei or dust particles*. Small-particle residues (5 µm or smaller in size) of evaporated and concentrated droplets (known as droplet nuclei) containing microorganisms, remain suspended in the air for long periods of time and can be dispersed by air currents within the patient room or travel over long distance assisted by mechanical ventilation. Some of these microorganisms can be infectious depending on the origin of the droplets.

Dust particles may carry microorganisms that can be dispersed widely by air currents and may be inhaled by a susceptible host within the same room or over a longer distance from the source patient. Therefore, special air handling and ventilation are required to prevent airborne transmission.

2.4. Common Vehicle Transmission

This occurs when *microorganisms are transmitted by contaminated items such as food, water, medications, devices, and equipment*.

2.5. Vector Borne Transmission

Vector Borne Transmission occurs when *vectors such as mosquitoes, flies, rats, birds, and other vermins transmit microorganisms.*

This guidelines deal with the airborne transmission of microorganisms.

3. ISOLATION ROOM

3.1. General

Isolation refers to measures taken to prevent pathogens from spreading from a patient to other patients, healthcare workers, and visitors, or from others to an immunosuppressed (*immunocompromised*) patient. The patient can be immunosuppressed due to diseases (such as AIDS) or due to medical treatment (such as chemotherapy, bone marrow or organ transplant, and burns).

There are three main lines of defence in infection control, namely:

- the infection control measures or techniques also known as contact procedures (hand washing technique and personnel protective equipment such as gowns, masks and gloves),
- the isolation (*segregation*) of the susceptible host and patient with airborne infection, and
- the engineering control to mitigate transmission of microorganisms.

Where a patient is suspected or has airborne infectious disease that is transmitted by droplet or airborne, this patient is placed in a dedicated room to interrupt the transmission of microorganisms from the patient to a susceptible host and vice versa. The patient is isolated as it is easier to control the transmission of pathogens when compared to the movement of the patient.

These dedicated rooms are referred to as isolation rooms. The environment of these isolation rooms needs to be conducive as well as able to isolate the source patient from other patients, healthcare workers, and visitors, or from others to a patient.

The room needs to have a dedicated ventilation system that is not shared with other rooms or areas so as to disrupt the transmission and spread of microorganisms. In addition to the dedicated ventilation system, the airflow direction and room pressurization needs to be controlled so that both the patients as well as the surroundings are safe.

The isolation rooms can be part of a department or a ward or can be grouped into a dedicated ward or building.

3.2. Medical Areas with Isolation Rooms

Isolation rooms are required in a number of areas in the healthcare facilities and these are listed below:

- critical care units,
- paediatric units,

- new born intensive care unit,
- emergency services unit,
- nurseries,
- surgical and medical units, and
- renal dialysis unit

The number, type, and location of the isolation rooms shall be determined by the Infection Control Risk Assessment under the jurisdiction of Medical Development Division, Ministry of Health based on the needs of the community and the patient population.

The planning of areas and dedicated sizes for each area in the isolation room shall follow the latest version of medical brief and schedule of accommodation requirements stipulated by the Planning Division, Ministry of Health.

3.3. Classification of Isolation rooms

The isolation rooms are classified based on the basic principle of pressure controls of the isolation room. The isolation rooms are classified into two main categories: Airborne Infection Isolation Room (AIIR) and Protective Environment (PE) Room. The other less common categories are combination AII/PE and contact isolation rooms.

3.3.1. Airborne Infection Isolation Room (AIIR) (Negative Pressure Room)

The Airborne Infection Isolation Room is commonly known as Negative Isolation Room as it refers to the negative pressure relationship between the patient room and the corridor; i.e. the air pressure in the patient room is more negative than the corridor.

In an AIIR, air shall flow from the corridor to the patient room so as to protect the environment. This isolation room is used to house patients who are suspected or infected with airborne microorganisms (pathogens).

AIIR is a suite made up of a patient room and en-suite bathroom. AIIR preferably may have an anteroom; however, prudence dictates that patients with viral haemorrhagic fever shall be placed in an AIIR, preferably with an anteroom. Anterooms shall be provided in ICU, emergency department, infectious disease unit, and inpatient units accommodating respiratory patients and others as decided by MOH. En-suite bathrooms are not required at specialized areas; e.g. intensive care unit, neonatal care unit, cardiac care unit etc., as the patients are immobile and are assisted by healthcare workers.

These isolation room ventilation systems shall be specifically designed to ensure negative pressure gradient between the patient room and the corridor so as to ensure a safe external environment. The system shall contain patient generated infectious microbial within the room and to prevent the spread of infection to other patients and healthcare workers.

3.3.2. Protective Environment Room (PE) (Positive Pressure Room)

The Protective Environment (PE) Room is commonly known as Positive Pressure Isolation Room. The term "positive pressure room" refers to the positive pressure relationship between the patient room and the corridor; i.e. the air pressure in the patient room is more positive than the corridor.

In a PE room, air shall flow from the patient room to the corridor so as to protect the patient. These isolation rooms shall be used to house suspected or infected patients that are immune compromised/suppressed.

The PE room is a suite made up of a patient room and en-suite bathroom. The PE room preferably may have an anteroom. En-suite bathrooms are not required at specialized areas; e.g. intensive care unit, neonatal care unit, cardiac care unit etc., as the patients are immobile and are assisted by healthcare workers.

These isolation room ventilation systems shall be specifically designed to ensure positive pressure gradient between the patient room and the corridor so as to protect the patient against infectious microbial that would normally not pose infection risks to healthy humans.

3.3.3. Combine AII/PE Room

This room shall be provided for patients who are suffering from a weaken immune system as well as having an airborne communicable disease. The patient shall be put in the protective environment for his or her own health, but also shall be isolated to protect others from the communicable disease.

The possible arrangement for this situation shall be the placement of patients in the positive pressure environment with an anteroom that is under negative pressure in relation to the corridor and the positive pressure environment.

3.3.4. Contact Isolation Room

This type of room is for normal patients suffering from communicable diseases such as Methicillin Resistant Staphylococcus Aureus (MRSA). This

room does not require special design measures for the air-conditioning and ventilation systems.

The tables below summarize the basic differences between the most common isolation rooms in hospitals, i.e. an AIIR and a PE Room.

Table 1: Functional Classification of Isolation Room		
	Airborne Infection Isolation Room (AIIR)-(Negative Isolation Room)	**Protective Environment (PE Room) - (Positive Isolation Room)**
Key Ventilation Criteria	Lower air pressure in the room than in the adjacent corridor.	Greater air pressure in the room than in the adjacent corridor.
Transmission based precaution	To prevent transmission of pathogens from AIIR to the outside environment.	To prevent transmission of pathogens from the outside environment to immunosuppressed patients.

Table 2: Functional Classification of Isolation Room		
	Airborne Infection Isolation Room (AIIR)-(Negative Isolation Room)	**Protective Environment (PE Room) - (Positive Isolation Room)**
Examples of pathogens/ immunosuppressed patients	Pathogens-Mycobacterium Tuberculosis (TB), Varicella-zoster (Chickenpox), Avian Flu (H5N1), Severe Acute Respiratory Syndrome (SARS), measles etc.	Immunosuppressed patients-Bone marrow or organ transplant recipients, patients with AIDS, leukaemia, burns, cancer, Allogeneic Hematopoietic Stem Cell Transplant etc.

3.4. Special Safety Design and Operational Consideration

The isolation rooms shall be basically dedicated patient en-suite rooms with controlled ventilation strategies to eliminate the transmission of airborne pathogens both to the patient and healthcare worker.

The stringent monitoring of room pressurization via appropriate devices or verification mechanism(s) shall be strictly adhered to eliminate any possibilities of pressure scheme changes in the dedicated isolation room.

The basic principle of cascading airflows from the cleanest area to the relatively contaminated area shall be maintained at all times.

It is imperative that the isolation room's functional integrity be regularly verified by the technical personnel to ensure that each feature and system is working in accordance with the design intent.

Combined alternating pressure rooms (rooms with reversible airflow provisions for the purpose of switching between AIIR to PE functions and vice versa) shall not be permitted.

The isolation rooms shall be designed to accommodate safe patient and staff evacuation path in the event of fire or any other emergency incidents. The escape route or fire exit shall be integrated with the other departments in the building.

4. DESIGN REQUIREMENT FOR AIRBORNE INFECTION ISOLATION (AII), PROTECTIVE ENVIRONMENT (PE) AND COMBINED AII/PE ROOMS

The section describes the basic requirements of isolation rooms (AIIR and PE) with respect to architecture, mechanical, and electrical requirements. Where AIIRs or PE rooms are in specialized areas, e.g. intensive care unit, neonatal intensive care unit, the basic room requirements remain the same, except that the number of switch socket outlets may increase to cater the need for additional medical equipment.

4.1. Architectural Requirements[1]

4.1.1. Architectural Details

The AIIR or PE room is a suite made up of three rooms; the patient room, anteroom and en-suite bathroom. However, some of these rooms may or may not have anteroom. The patient room of an AIIR/PE shall meet all the requirements for a single-patient room with specialized ventilation requirements as described in Section 4.2.

The anteroom (highly recommended to maintain pressurization and the air pattern) shall be required for staff and visitors to change and dispose of personal protective gear used upon entering and leaving these rooms when caring for infectious patients. Anterooms shall not be shared between rooms.

Anterooms also increase the effectiveness of AIIR by minimizing the potential escape of airborne nuclei into the corridor when the door is open. For the PE room, the anteroom shall minimize the entry of airborne nuclei from the corridor when the door is open and to mitigate the transmission of airborne pathogens to immunocompromised patients.

The bathroom is en-suite and shall not be shared. It shall be used by patients so as to minimize any outside contact, thereby preventing any potential infections being transmitted to other patients or staff.

4.1.1.1. The size of the room shall be approximately 15m^2 excluding bathroom, anteroom, closet or locker. The space shall accommodate the patient bed and some furniture for family/ carers without blocking the access of healthcare workers to the patients.

1 Engineering Services and Sustainable Development Guidelines TS11, NSW Health Asset and Contract Services, 2007

4.1.1.2. The room's perimeter walls, ceiling, and floors shall be sealed tightly so that air does not freely move in or out to the environment from the room except through the allowable gap under the door. Windows shall be provided for AIIR so that each patient may be cognizant of the outdoor environment. All windows shall be fixed and sealed to eliminate infiltration.

4.1.1.3. All isolation rooms shall have self-closing devices on all room exit doors.

4.1.1.4. Viewing panels/windows shall be provided in doors or walls with privacy blinds to allow nursing staff observation without entering the isolation room. The viewing panel shall be of safety glass, wire glass or tempered clear plastic to reduce hazard from accidental breakage.

4.1.1.5. Rooms shall be well-sealed for better maintenance of pressure gradients that will also eventually reduce load on the air handling plant. The air tightness shall be assured by:

- Properly constructing windows, doors, and intake and exhaust ports
- Maintaining plasterboard ceilings that are smooth and free of fissures, open joints, and crevices
- Sealing all penetrations on the walls above and below the ceiling
- Monitoring for leakage and making any necessary repairs

4.1.1.6. The isolation room wall, floor or roof that is in contact with any 24 hour air-conditioned facility shall be adequately insulated (double wall, PU panel, etc.) so as to prevent the surface from condensation build-up.

4.1.1.7. Gaskets shall be provided at the sides and top of the door, and the ceiling and wall penetrations such as those around medical and electrical outlets.

4.1.1.8. Sufficient and appropriate storage space shall be provided for linen and waste receptacles inside the patient room, and for gowns, gloves, and masks in the anteroom.

4.1.1.9. Multiple isolation rooms shall be clustered and located away from the main entrance of the departments or units, and if possible, avoid areas prone to strong drafts, such as doorways or near elevators.

2 Engineering Services and Sustainable Development Guidelines TS11, NSW Health Asset and Contract Services, 2007

4.1.2. Architectural Finishes and Surfaces[2]

4.1.2.1. General

All surfaces in the isolation rooms shall be smooth, impervious, and easily cleaned.

Avoid using horizontal, textured, moisture-retaining surfaces or inaccessible areas where moisture or soil can accumulate.

All fixtures and fittings shall be easily cleaned to discourage the accumulation of dust.

Blinds or flame-retardant curtains shall be provided to cover windows and viewing panels.

Bed screens shall be washable, easily hanged and removed, and easily pulled around the bed.

4.1.2.2. Ceilings

Ceilings shall be monolithic from wall to wall without fissures; i.e. open joints that may retain or permit passage of dirt particles or supporting microbial growth.

Ceilings shall be cleanable, continuous, impervious, and of durable finishes. Cracks or perforations are not allowed. The ceiling shall be able to withstand disinfecting and cleaning agents without deterioration.

Light fittings shall be recessed, flush fitted, and sealed to prevent dust ingress.

Where required to support ceiling mounted equipment with ceiling hoists provided, set plasterboard ceiling from wall to wall without fissures shall be provided.

Acoustic and/or lay-in ceiling shall not be used. Where appropriate, the ceiling shall be provided with manhole for maintenance purpose and access.

4.1.2.3. Floors

Floor coverings shall be easy to clean and resistant to disinfection procedures.

Floors materials shall not be physically affected by germicidal cleaning solution.

Floors penetrated by pipes, ducts, and conducts shall be tightly sealed.

In bath areas, the floor finishes shall be of nonslip surface homogeneous tiles.

In the patient room, vinyl sheet flooring shall be used with all joints to be hot welded, and the skirting shall be backed by a coving and bent up to a height of 100mm high.

4.1.2.4. Walls

Wall finishes shall be smooth, scrubable, and washable.

Wall finishes shall be free of fissures, open joints, or crevices that may retain or permit passage of dirt particles.

Walls penetrated by pipes, ducts, and conducts shall be tightly sealed.

Joints of structural elements shall be sealed.

Wall surfaces shall be impervious and not liable to be damaged by disinfectants, chemicals, and scrubbing.

Walls shall be plastered with acrylic plaster and painted with anti-bacterial epoxy or equivalent type of paint.

4.1.2.5. Gaps

Gaps between surfaces; e.g. wall and ceiling, wall and floor, or two walls or two sections of utility benches shall not be permitted and shall be properly sealed.

Gaps in the following area are not allowed:
- between skirting and floor
- between utility benches and walls
- between cupboards and wall or floor
- between fixtures attached to floors and walls.

The only gap that shall be planned and allowable is a half inch gap at the bottom of the door.

4.1.2.6. Skirting

Skirting, floor, and wall joints shall be made integral with the floor, tightly sealed against the wall, and constructed without voids.

4.1.2.7. Doors

Door openings shall have a minimum of 1.2 meter clear opening with proper clearance for beds, wheelchairs, and mobile medical equipment.

Room exit doors shall have self-closing devices.

Doors shall have edge seals.

All doors shall be of the swing type.

Doors shall have viewing panels made of safety glass, wire glass or tempered clear plastic to reduce hazard from accidental breakage.

All doors shall be provided with antirust heavy duty ironmongery appropriate for their function, complete with fixing screws of the same material and finishes.

Locks shall be provided at doors and shall be master suited with each department.

Bathroom doors shall be fitted with indicator locks, and push and pull handles; i.e. the doors can be opened from the outside.

Kick plates and push plates shall be provided at the doors as patient beds and trolleys will be moving in and out.

4.1.2.8. Windows

Each isolation room shall be provided with natural light by means of a window to the outside.

The height of window sills shall be level with or lower than the sight line of patients in their beds or in a chair to allow a view of the outside environment.

All windows shall be double glazing type.

All windows shall be locked shut and sealed to eliminate infiltration.

Privacy or shading shall be provided. Window treatments shall be selected for ease of cleaning. Smooth wipeable, non-pleated window treatment shall be used.

4.1.2.9. Sanitary Fittings

Handwashing stations shall be provided in the anteroom and the bathroom.

Sinks shall be of deep basin type to prevent splashing, and shall be made of porcelain, stainless steel or equivalent material.

Sinks shall be well-fitted and sealed to the backsplash to prevent water leaks onto the wall space.

Sink height shall be appropriate and shall be 850-900mm from the floor level.

Waterproof backsplash minimum of 500mm shall be required behind all basins. The backsplash area shall be large enough to contain splashes and prevent moisture seeping behind the splash back.

Suitable taps shall be used, which can be operated without hands. Taps with single levers or wrist blade handles shall be used.

All basins shall be provided with liquid, neutral pH soap dispensers. Soap dispensers are to be of the non-refillable types, and mounted on the backsplash.

Paper hand towels shall be provided at all hand wash basins.

Dispensers for disposable gloves shall be provided at the hand basin area. The dispenser shall allow restocking without the need to touch new gloves.

Waste receptacles shall be provided at hand basins for the disposal of single use towels and clinical waste. The bins shall be of adequate size, of non-touch design, and easy to clean.

Mirrors shall be installed in the bathrooms.

Pedestal WCs shall be provided in bathrooms. Push button type WCs shall be used. All WCs shall be provided with a complete set of hand spray controlled bidets with holders and toilet roll holders.

Bathrooms shall be provided with proper grab bars on the wall and at the door. Grab bars shall have a finish colour that has a value that contrasts with the adjacent wall surface.

Hooks shall be provided at the back of shower doors for hanging of towels, etc.

4.1.2.10. Other requirements

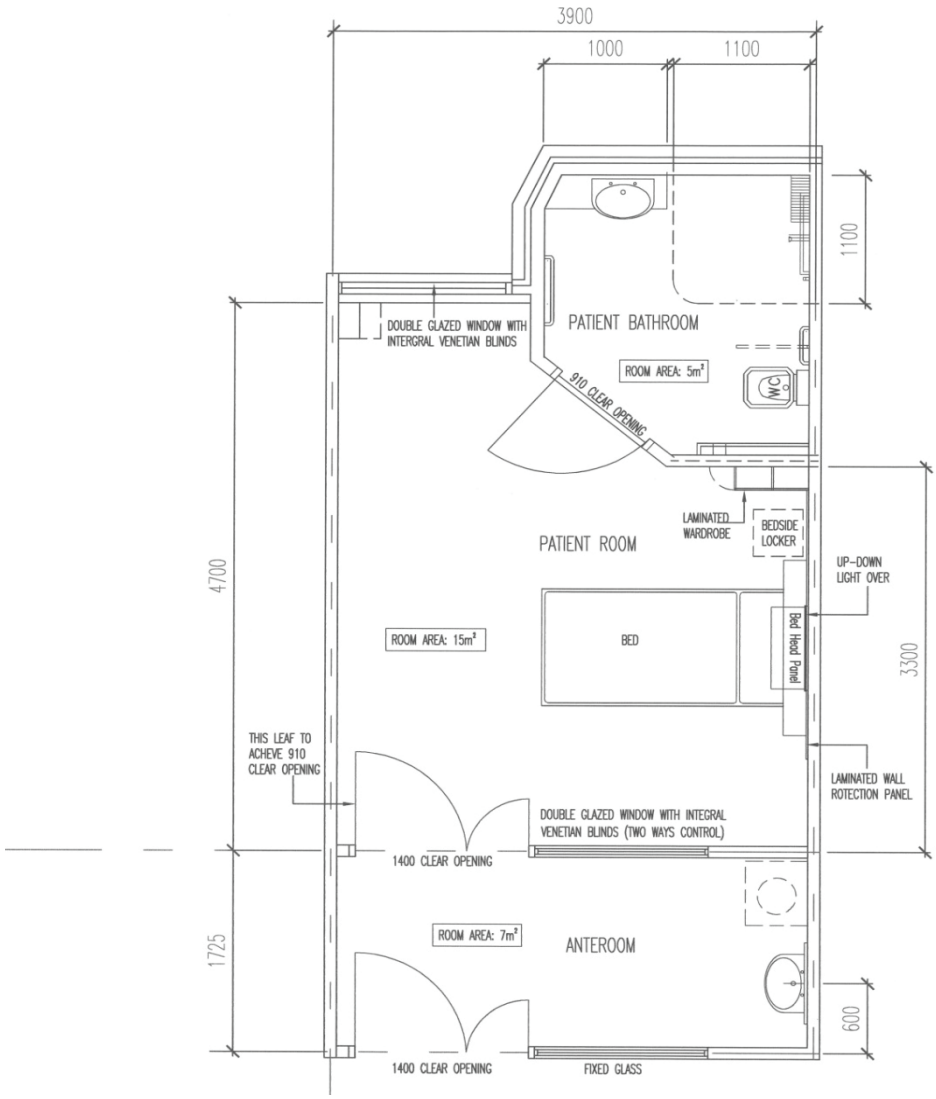
Bathrooms shall be designed to allow entry of portable/mobile mechanical lifts and shower gurney devices. This shall be for specific areas; e.g. burn unit.

Floors shall be designed to facilitate use and prevent tripping of wheelchairs and other portable wheeled equipment used by patients and staff.

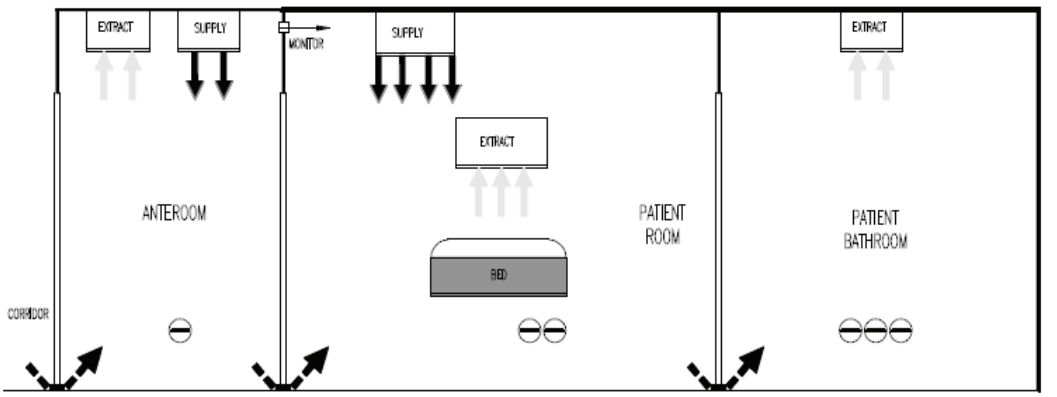
Each patient shall be provided with a wardrobe, locker or closet suitable for hanging full length garments and storage of personal items.

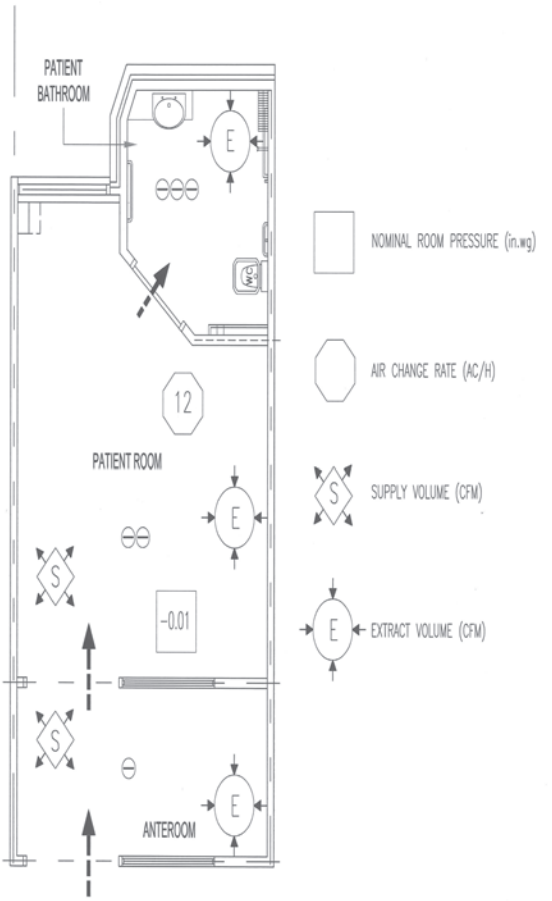
Appropriate and sufficient storage space shall be provided for linen and waste containers inside the room and for gowns, gloves, and masks in the anteroom.

The figures below show propose layout of the AIIR and PE rooms. Other room layouts shall be accepted as long as the pressurisation scheme & air flow pattern are strictly complied and do not posed any risks of cross contamination between areas in Isolation Room.

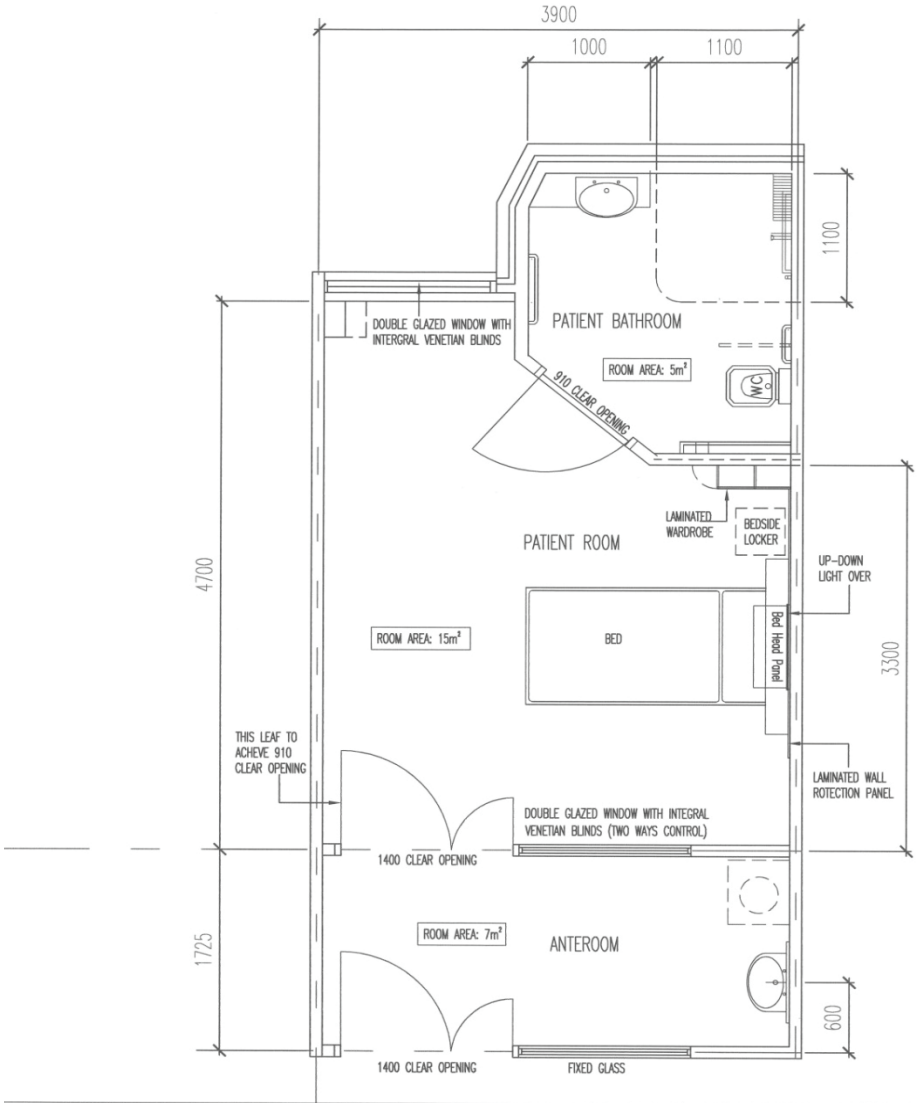


PROPOSE LAYOUT OF AIRBORNE INFECTION ISOLATION ROOM (AIIR)

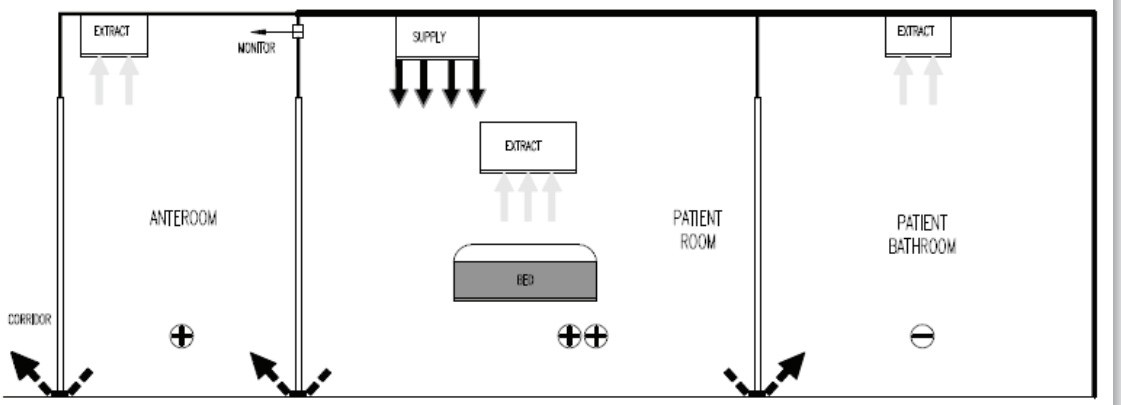


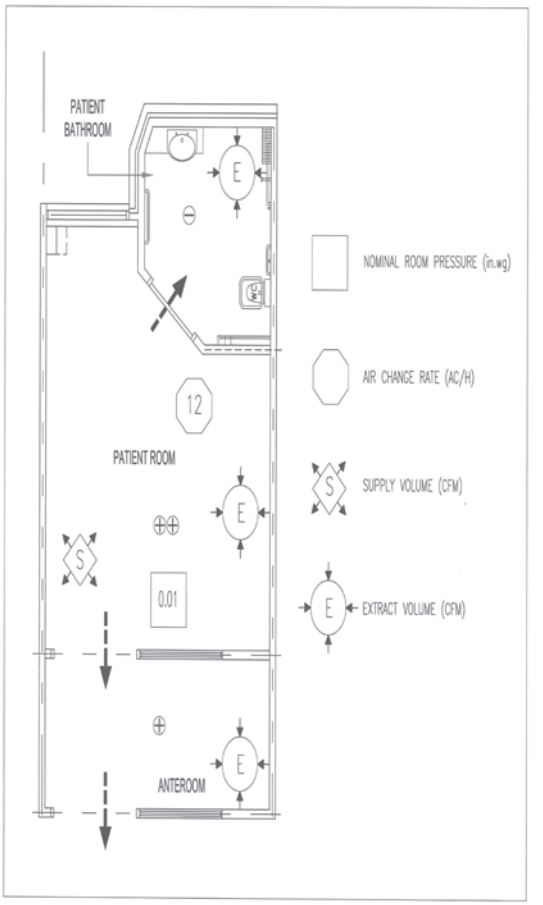


AIR FLOW MOVEMENT IN AN AIRBORNE INFECTION ISOLATION ROOM (AIIR)



PROPOSE LAYOUT OF PROTECTIVE ENVIRONMENT ROOM (PE ROOM)





AIR FLOW MOVEMENT IN A PROTECTIVE ENVIRONMENT ROOM (PE ROOM)

4.2. Mechanical Requirements

Mechanical systems in an isolation room shall include air conditioning and mechanical ventilation, the medical gases, and the fire protection system.

The mechanical system design in an isolation room shall fulfil the intended function and meet all local statutory, building safety, fire, infection control and occupational safety requirements.

4.2.1. Air Conditioning & Mechanical Ventilation (ACMV)

4.2.1.1 General

The installed Air Conditioning & Mechanical Ventilation (ACMV) system shall be designed to provide comfort environment (temperature, relative humidity, and air speed) to the patient and reduce the risk of infection to other patients or healthcare workers.

The ACMV system shall be designed so that it is capable of maintaining a consistent and intended air delivery volume, within the specified range of temperature and humidity at any point during normal operations.

Temperature control thermostats shall be secured or have “stops” so that patients do not have access or cannot change the setting below an agreed range.

The correct proportion of supply and exhaust air quantity shall be duly calculated to create the intended pressurization in the room. The comfort parameter monitoring devices shall be placed at suitable locations to indicate actual readings of the room.

Appropriate pressure and airflow control devices shall be installed to facilitate monitoring of the isolation room integrity.

The exhaust fan for the AII rooms and the supply fan for the PE rooms shall be connected to the emergency power supply to prevent potential contamination exposure.

The bathroom shall be at a negative pressure with respect to the patient room. The recommended air change per hour for the bathroom shall be 10ACH.

Efficient air filtration type and rating shall be installed at the supply and exhaust air to promote healthy indoor environment.

The introduction of effective and proven in duct and at the AHU's UVGI mechanism to further enhance the indoor air cleanliness shall be recommended.

The diffuser neck shall be carefully designed to allow enough air travel distance and minimize noise.

A monitoring system shall be provided to signal any malfunction of the supply/exhaust air system. Consider differential low pressure instrumentation in a prominent location outside the room along with a local audible alarm in case of supply/exhaust failure.

The makeup air intakes shall be located so that no contaminated air from nearby exhaust stacks or any sources of air contaminants are drawn into the makeup air system.

The room units' air conditioning shall not be used as the primary air-conditioning system as they are difficult to clean and can be a source for potential contaminant build-up.

Rooms with a through-the-wall ventilation unit shall not be used as an isolation room unless it can be demonstrated that all required engineering controls are met.

All rooms shall be properly labelled whether the areas are a negative or positive pressure isolation room.

4.2.1.2 Ventilation Requirement for AII Rooms

The AII rooms shall be designed to maintain negative pressure in relation to the surrounding areas. The movement of air shall be from the less contaminated area to the more contaminated area. The air shall flow from the anteroom/corridor into the isolation room to prevent the spread of airborne contaminants to other areas. The main purpose shall be to reduce exposure of uninfected staff or visitors in the space.

The design of the supply air and exhaust systems shall be of a constant volume system, where the volume of air delivered is constant with a volumetric difference between supply air and

exhaust air when the system is balanced. Variable air volume (VAV) systems shall NOT be recommended.

The preferred design approach shall be air mixing effectiveness and dilution ventilation.

All airborne infectious isolation rooms shall be designed to maintain negative pressure at all times. The air pressure shall be monitored periodically with audible manometer or smoke tubes at the door (for existing AII rooms), or with permanently installed visual monitoring devices.

Continuous negative air pressure in the room shall be maintained no less than -2.5Pa (-0.01 inch water gauge) in relation to the surrounding areas.

The minimum air changes per hour of not less than 12ACH for new or renovated AII rooms, and >6ACH for existing AII rooms.

The air travel from the patient to outside shall be at the shortest distance possible. The supply air shall be located such that clean air is first passed over the staff/other occupants and then to the patients. Air distribution shall reduce the staff's exposure to potential airborne droplet nuclei from infectious patients, accounting for the positions of the staff and the patients, and the procedures undertaken in the isolation room.

The air filtration shall be minimum MERV 14 rating air filter (90% dust spot filters) on the supply side and HEPA filter at the exhaust that shall be able to arrest 99.97% @ 0.3µm particles or a MERV value of 17 and above.

The ventilation system shall be able to remove (exhaust out) not less than 10-15% more than that of the supply system.

Recirculation of exhausted air shall be discouraged. The exhaust air shall be directed to outside, away from air-intakes and populated area. In case the room is retrofitted from a standard patient room and where it is deemed not practical to exhaust air from AII directly to the outside, the air shall be returned through HEPA filters.

For the isolation rooms located at the highest floor, the air shall be exhausted directly to the outside using the ductworks at least

10ft (3m) above roof level and shall be located not less than 10ft horizontally from any air intakes.

For the intermediate floor isolation rooms, the air shall be exhausted directly to the outside through HEPA filter.

Ultraviolet germicidal irradiation (UVGI) shall be used as a supplemental engineering control in conjunction with HEPA filters at the exhaust to further enhance the cleanliness of outgoing air.

Supply air ducts shall be independent of the building's common supply air system. If sharing of supply ducts with other isolation rooms is unavoidable, the ducts with terminal HEPA filters shall be provided (or other failsafe back draught prevention system). A high efficiency bag filter as a pre-filter shall be installed to protect the HEPA filter.

Appropriate self-closing devices on all 'AII' room exit doors shall be installed considering the direction of door swing in relation to room pressure.

A handwash basin shall be provided in the anterooms. Personal respiratory protection for persons entering these rooms and for staff who lack immunity to airborne viral diseases (e.g., measles or varicella zoster virus [VZV] infection) shall be provided.

The disposal of effluents from the room shall not create any potential hazard to persons outside or the staff operating and maintaining these systems.

The practice of maintaining backup ventilation equipment (e.g. portable units for fans or filters) for emergency provision of ventilation requirements for AII rooms shall be encouraged.

Supply and exhaust

There are two approaches on where the air diffuser and exhaust/ return air grille for the AIIR shall be located.

- The first approach is that the ceiling mounted air diffuser shall be located at centre of the room or slightly towards the entrance, *while the return/exhaust grille is to wall mounted at a low level above the patient bed head*. This arrangement maximizes the room air mixing and contaminant removal. However the supply diffuser shall be carefully selected and located such that the air throw does not induce bedroom air to enter the anteroom.
- The second approach is that the ceiling mounted air diffuser shall be located at centre of the room or slightly towards the entrance, while the return/exhaust grille is to be ceiling mounted over the patient bed head.

The first approach shall be the better arrangement.

The above arrangement of the air diffuser and grille shall ensure that the air is moving downward from the air diffuser to a clean area where health workers and visitors are likely to be and across to the infected patient into the exhaust grille.

The air diffuser shall be of the louvered blade type that directs air to all parts of the room, so as to ensure good mixing and minimize stagnant air; and shall be located where it is not obstructed by suspended television or surfaced light fixtures. These diffusers shall be of the plenum type and flush mounted to the ceiling. The diffuser shall be of Group A (outlet mounted in or near the ceiling that discharges horizontally) or Group E (outlet mounted in or near the ceiling that projects primary air vertically).

The air shall be exhausted through a grille that is located at the ceiling above the patient's head or wall mounted at a low level above the patient bed head or above the patient bed. The grille shall have a neck that is sufficiently large so as to easily draw in the required exhaust quantity.

Summary on AIIR Parameters

The table below provides a summary on the AIIR parameters.

Table 3: Summary on AIIR Parameters		
Parameter	**Airborne Infection Isolation Room (AIIR)**	**Isolation alcove or anteroom**
Minimum total air changes per hour.	12 (new) 6 (existing)	10
All air exhausted directly to outdoors.	Yes	Yes
Minimum air changes of outdoor air per hour.	2	N/R
Recirculated by means of room units*.	No	No
Air movement relationship to adjacent areas.	In	In/Out
Differential pressure between AIIR and adjoining areas.	-0.01 inch wg	-
Design temperature (degrees F/C)	78°F/24°C (22-26°C)	N/R
Relative humidity (%)	Max 60	max 60

N/R: No requirement

*Note *: Portable or fixed recirculating devices shall not be used for heating or cooling air in AIIR. Air may be recirculated within individual isolation rooms if recirculating devices with HEPA filters are used as an interim or supplement environmental controls. The supply and exhaust locations should direct clean air to areas where the healthcare workers are likely to work, across the infection source, and then to the exhaust, so that the healthcare workers are not in position between the infectious source and the exhaust location. The design of such systems should also allow for easy access for schedule preventive maintenance and cleaning.*

4.2.1.3 Ventilation Requirement for PE Rooms

The protective environment (PE) room shall be designed to maintain positive pressure in relation to the surrounding areas. The air movement shall be from a clean area to a less clean area. The protection of the patient shall be the most favourable and important.

A unidirectional approach shall be recommended in which air is introduced from the ceiling mounted, nonaspirating flow diffusers.

The clean air supply flow vertically downward through the breathing zone of a patient, washing away contaminants as the air passes through the lower portion of the room and out through the exhaust registers.

The design of the supply air and exhaust systems shall be of a constant volume system where the volume of air delivered is constant with a volumetric difference between supply air and exhaust air when the system is balanced. Variable air volume (VAV) systems are NOT recommended.

The positive room air pressure of (≥2.5 Pa [0.01-inch water gauge]) in relation to the corridor shall be maintained.

The ventilation system in the room shall be able to maintain more than 12 ACH 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.

The exhaust air shall be directed to outside. It shall be recirculated to less clean areas or exhausted to other apparatus for energy recovery mechanism.

The rooms shall be either 100% fresh air or can use recirculated air, which is usually a 60/40 mix of outdoor air/recirculated air. Air pressure shall be maintained positive with respect to any adjoining rooms by supplying 10% to 15% excess air.

The recommended air filtration for the protective rooms shall be HEPA (99.97% @ 0.3µm DOP) on the supply side and NO filtration shall be needed on the exhaust side. The HEPA filter shall be centrally located at the air handling unit or point-to-use HEPA filters may be used. A terminal HEPA filter at the point of use shall be preferred.

Ultraviolet germicidal irradiation (UVGI) shall be used as a supplemental engineering control in conjunction with HEPA filters at the supply air to further enhance the incoming air. The installation of the same mechanism at the exhaust shall not be mandatory.

Positive pressure rooms shall share common supply air systems.

Differential pressure indication device shall be installed to permit air pressure readings in the rooms and provide a local audible alarm in case of fan failure.

Airflow patterns shall be maintained and monitored on a daily basis by using permanently installed visual means of detecting airflow in new or renovated construction, or by using other visual methods (e.g., flutter strips or smoke tubes) in existing PE units.

Self-closing devices on all room exit doors shall be installed in PE rooms. All emergency exits (e.g., fire escapes, emergency doors) in the PE wards shall be kept closed (except during emergencies) and equipped with alarms.

Supply and exhaust

The ceiling mounted air diffuser shall be located at centre of the room, at the bed head, while the return/exhaust grille shall be at the floor level slightly towards/near the entrance. This arrangement shall maximize the room air mixing and removal of contaminants. Do not use laminar airflow system.

The arrangement of air diffuser and exhaust register shall ensure the downward flow of air towards the patient and lower portion of the room and out through the exhaust register.

The air diffuser shall be of the louvered blade type that directs air to all parts of the room, so as to minimize stagnant air and shall be located where it is not obstructed by suspended television or surfaced light fixtures. These diffusers shall be of the plenum type flush mounted to the ceiling.

The diffuser shall be of Group A (outlet mounted in or near the ceiling that discharges horizontally) or Group E (outlet mounted in or near the ceiling that projects primary air vertically).

Summary on PE Room Parameters

The table below provides a summary on the PE Room parameters.

Table 4: Summary on PE Room Parameters		
Parameter	**Protective Environment Room (PE Room)**	**Isolation alcove or anteroom**
Minimum total air changes per hour.	12 (new) 6 (existing)	10
All air exhausted directly to outdoors.	No	Yes/No
Minimum air changes of outdoor air per hour.	2	N/R
Recirculated by means of room units*.	No	No
Air movement relationship to adjacent areas.	Out	In/Out
Differential Pressure between PE Room and adjoining areas.	+0.01 inch w.c	-
Design temperature (degrees F/C)	75°F/24°C (22-26°C)	N/R
Relative humidity (%)	(max 60)	(max 60)

N/R: No requirement
*Note *: Portable or fixed recirculating devices shall not be used for heating or cooling air in PE Room. Air may be recirculated within individual isolation rooms if recirculating devices with HEPA filters are used as an interim or supplement environmental controls. The supply and exhaust locations should direct clean air to areas where the healthcare workers are likely to work, across the infection source, and then to the exhaust, so that the healthcare workers are not in position between the infectious source and the exhaust location. The design of such systems should also allow for easy access for schedule preventive maintenance and cleaning.*

4.2.1.4 Ventilation Requirement for combined AII/PE and PE/AII Rooms

There are cases where a patient is concurrently immunosuppressed and infected with airborne infection. This patient shall be placed in dedicated, specially designed combined isolations; AII/PE room and PE/AII room.

a) **Combined AII/PE room (anteroom at positive pressure to both patient and corridor)**

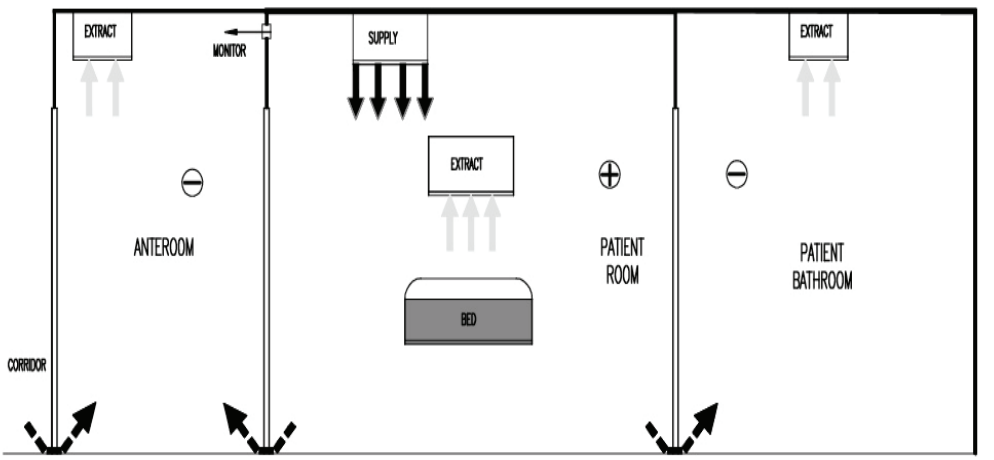
This isolation room is a typical AIIR with anteroom; having all the architectural, mechanical and electrical requirements except for the air flow movement at the anteroom.

The patient room shall be at negative pressure, while the anteroom shall be at positive pressure with respect to patient room and corridor. The air flow movement shall be from anteroom to patient room and the corridor. This design is NOT recommended.

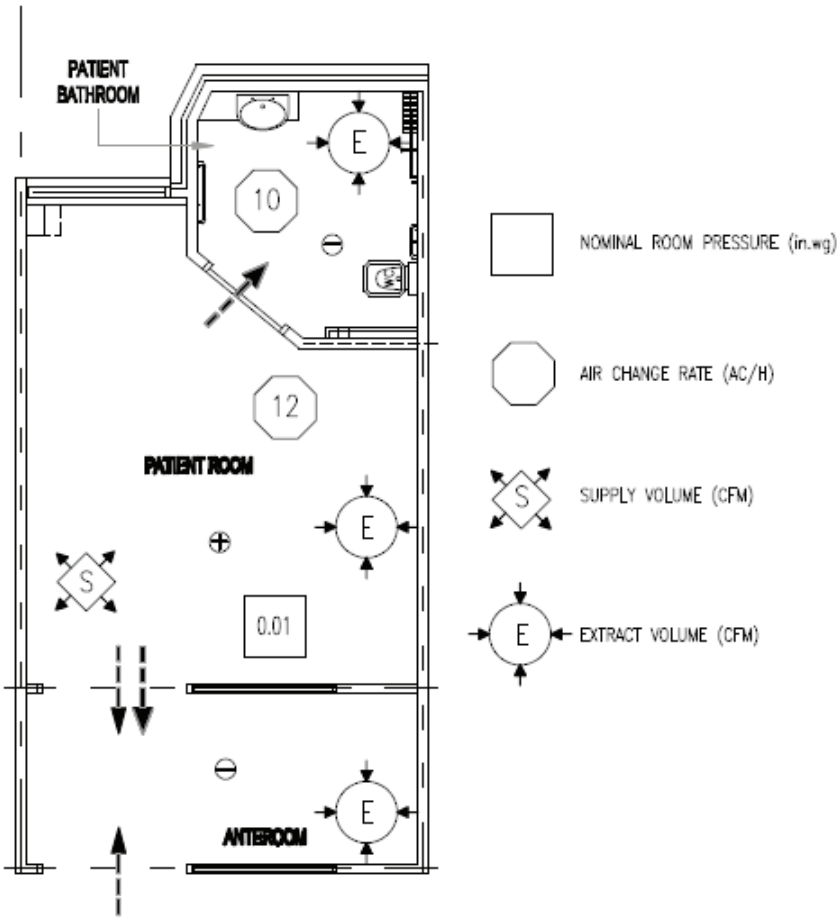
b) **Combined PE/AII room (anteroom at negative pressure to both patient and corridor)**

This isolation room is a typical PE room with anteroom; having all the architectural, mechanical and electrical requirements except for the air flow movement at the anteroom.

The patient room shall be at positive pressure, while the anteroom shall be at negative pressure with respect to patient room and corridor. The air flow movement shall be from the patient room and corridor into the anteroom.



PROTECTIVE ENVIRONMENT ROOM (PE ROOM) WITH NEGATIVE PRESSURE ANTEROOM



PROPOSE LAYOUT OF PROTECTIVE ENVIRONMENT ROOM (PE ROOM)
WITH NEGATIVE PRESSURE ANTEROOM

The advantage with this design is that there is no need to supply air to the anteroom. **This design is more reliable**.

4.2.1.5 Air Distribution

Air Handler

The air handling unit (AHU) shall be preferred over fan coil unit (FCU) due to the availability of environmental parameters controlled features, easy installation, and ease of maintenance. AHU shall be properly sized to deliver the required air change with the desired temperature and humidity requirement.

Each isolation suite shall have its own dedicated supply and extraction system with its own AHU[3].

Where space is not permitted and FCU is used, the unit shall be placed outside the suite, easily accessible with sufficient space for maintenance and repairs. The unit shall have appropriate fan controls are needed to ensure air volumes and static pressure are achievable and maintained via correcting the fan speed for loading of filters.

Duct Construction

These ducts shall be rigid and made from metal. Flexible ducts shall be limited to 1.5 meter length. These ductworks shall be installed in a manner that will minimize any vibration from being transmitted along the duct route.

Duct Labelling

The ducts shall be labelled to indicate the intended purpose so that the maintenance personnel are aware when carrying out maintenance. This is more so for the exhaust air duct as it is ducting contaminated air.

Dampers

The air intake, supply, exhaust/return air ducts shall have control dampers to adjust the airflow quantity. These dampers are usually manually operated, but may be automatic.

These damper handles shall be accessible for air balancing. If dampers are installed at the isolation rooms, the handles for the dampers shall not be above the AIIR ceiling, but accessible from the corridor ceiling.

Outside Air Intakes

The outdoor air intakes (supply air) for the Air Handling Units (AHU) to the isolation rooms shall be located at a minimum of 25ft (7.6m) from combustion stack exhaust outlets, ventilation exhaust outlets, medical gases (AGSS and Vacuum) outlets, cooling towers, plumbing stacks, smoke control exhaust outlets, and areas that may collect vehicular exhaust and other noxious fumes.

3 Health Building Note 04-01 Supplement 1 – Isolation facilities for infectious patients in acute settings, 2013, p. 6.

Outdoor air intake shall be located as high as practical, but not less than 6ft (1.8m) above ground. Air intake on the top of the building shall be located at a minimum of 3ft (0.9m) above the roof level. The area around the air intake shall be free from vegetation, waste products, or any other possible source of contamination.

All intakes shall be designed to prevent the entrainment entrapment of wind-driven rain and shall contain features for draining away precipitation. The air intakes shall be equipped with a bird-screen of mesh no smaller than 0.5in (13mm).

For new facilities, the air intakes shall be located away from public access to prevent unauthorized access as well undesirable exposure to terrorist attacks.

Exhaust Air Outlets

The exhaust discharge outlets from the isolation rooms shall be discharged in a vertical direction at least 10ft (3m) above ground and away from doors, occupied areas, and operable windows or areas that are normally accessible to the public or maintenance personnel. The preferred location is above the roof level projecting upwards or horizontally away from outside air intakes.

The exhaust duct of both types of isolation rooms shall be labelled to identify its intended purpose. The label shall read “Caution-AIIR Exhaust Duct” or “Caution-PE Room Exhaust Duct” and the label shall be bilingual; in Bahasa Malaysia and English.

To ensure the pressure at AIIR is negative, the exhaust fan shall extract more air than the delivered air. For the PE room, the delivered air shall be more than the exhaust air. Both types of exhaust fans shall be labelled “Caution-AIIR Exhaust Fan” or “Caution-PE Room Exhaust Fan” and the label shall be bilingual; in Bahasa Malaysia and English.

The dedicated exhaust ductwork shall be used to exhaust air from the various sub-rooms; i.e. patient room, anteroom, and bathroom at the isolation rooms. This ductwork shall neither be shared with other exhaust ducts from other isolation room nor shared with other mechanical ventilation ducts; e.g. centralized or general toilet exhaust duct. If the combined

exhausts with others become unavoidable, HEPA filtration shall be installed before merging airflows.

Air Filtration System and Minimum Efficiency Reporting Value (MERV) Ratings

Air filters shall be designed to remove air particles. The design performance shall be based on two requirements; i.e. the range of air particle size to be removed and the efficiency of the filter to remove the range of particle size.

Filters shall be installed in such a manner that there is no leakage at the filters edges, and between the filters and the supporting frame. Any air bypass increases the likelihood of airborne pathogens being distributed into the facility.

The air filtration system at the air handling units is to be made up of two filter banks. The first bank (Filter Bank No. 1) shall be placed upstream of the cooling coils so that air intake is filtered. The second filtration bank (Filter Bank No. 2) shall be placed downstream of the cooling coils and the supply fan.

In the air handling unit for the AII application, Bank No. 1 shall be fitted with a filter of a MERV 7 rating, while Bank No. 2 shall be fitted with a filter of a minimum MERV 14 rating.

As for the PE room, air supplied shall be filtered through a HEPA filter that removes at least 99.97% of 0.3µm sized particles or having a MERV value of 17 and above.

Filter Bank No. 1 shall have a MERV rating of 7, while Filter Bank No. 2 shall be a HEPA filter. Alternatively, Filter Bank No. 2 shall be a filter with a minimum MERV rating of 14, if a tertiary terminal HEPA filter is provided.

The pressure drop across the filter is a direct function of the filtration efficiency. A differential pressure measuring device shall be installed to determine the filter efficiency.

Room Pressure Monitoring System – Permanent

All isolation rooms shall have permanently installed visual mechanisms to constantly monitor the pressure status of the room when occupied by a patient.

The pressure monitoring system shall be installed to continuously monitor and display the differential pressure between the isolation room and the adjacent spaces of the room.

There are two common types of pressure monitoring systems; i.e. the direct room pressure monitoring system and the indirect pressure monitoring system. Both of these monitors are made up of wall-mounted display panels and sensors. The display panel shall be mounted at eye level at the corridor wall just outside AIIR and displays the pressure difference in the water gauge.

The direct room pressure monitor measures the pressure directly, while the indirect pressure monitoring system is an electrical device that measures the air velocity and direction, which is then converted to pressure readout. An indirect pressure monitoring system shall be preferable to a direct monitoring system.

The Room Pressure Monitoring System shall be effective only when the room is fully sealed and the filters are not clogged.

Direct Room Pressure Monitor

The direct room pressure monitoring system is made up of two sensor ports and a display unit. The sensor ports are the room sensor port and the reference sensor port (at corridor).

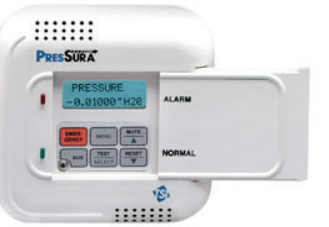
The room sensor port shall be installed at the wall or ceiling inside the patient room (preferably above the door or next to the door, but away from the influence of air drafts), and the reference sensor port is installed at the corridor wall outside the rooms whether or not there is an anteroom. The difference between these two sensor pressure ports will provide the differential pressure that is then displayed on the panel.

For optimal monitoring, an additional system can be installed to measure the pressure difference between the anteroom and the corridor. The display unit shall be installed at eye level, on the wall along the corridor adjacent to the entry door.

The system accuracy will depend on the distance between the sensors. They become less accurate and slow to respond when the distance between the sensors increases.

An example of the direct room pressure monitor is the Magnehelic Pressure Gauge. The gauge installed shall be of reasonable size (approx.5" Ø) and have a range between 0 to -1 inch w.c.

Indirect Pressure Monitor



This consists of air tubes with velocity sensing elements. The tubes shall be installed at the wall of the patient room and anteroom room if available, otherwise, the corridor. The device measures the velocity and direction of the air, and the signal is sent to the panel where it is translated to a pressure reading and displayed on the air monitoring panel.

This device not only provides a visual display of the pressure of the room, but also has an inbuilt alarm that will be triggered when the predetermined reference pressure setting (-0.001wc) is breached.

The device shall be connected to an alarm system located at the nurse's station. It shall also be linked to the building's automation system. The alarm from these monitors shall be set to ensure nuisance alarms caused by routine entry of healthcare workers into the airborne isolation are minimized. The nuisance alarms shall be minimized by programming the inbuilt time delay between the pressure loss and alarm activation (Typical alarm delay is around 45sec).

This device shall have a key switch input to change the room pressure difference from negative to no isolation mode so that AIIR can be used for non-infectious patients.

Verifying Negative Pressure

The negative pressure in the isolation room shall be verified on a daily basis using mechanical devices to ensure that the systems are functioning as desired. These devices are used to verify the system performance. Some of these devices are the smoke tube, tissue paper or flutter strip, and manometer.

Smoke Tube

Smoke tube is a tube that generates white, non-corrosive smoke that is used to create a white trail of the airflow. This tube is also known as smoke generator. This smoke tube shall be held parallel to the door, about 2 inches in front of the gap under the closed door outside the room. Once the tube is squeezed, white smoke will be generated. The smoke will travel in the direction of airflow. If the room is at a negative pressure, the smoke will travel under the door and into the room (from higher to lower pressure). If the room is at a positive pressure, the smoke will travel away from the door and into the corridor.

Smoke Tube Kit

This test shall be performed while the door is closed. If room air cleaners are being used in the room, they shall be running. A smoke test is the most reliable method of testing, but is only a qualitative method, which is a snapshot in time, and is labour intensive. If smoke tubes are not available, an incense stick can be used.

Tissue paper or flutter strip

Tissue paper or flutter strips shall also be used and shall be placed two inches in front of the gap under the door, similar to the smoke tube. The direction of the movement of the strip indicates the direction of the flow.

Manometer

Manometer can also be used, where one of the tubes will be placed under the door into the room and the other in the reference corridor. A display of the manometer indicates that the room is at a negative or positive pressure.

UVGI (Ultraviolet Germicidal Irradiation)[4]

Ultraviolet light (UV) is an electromagnetic radiation with wavelengths ranging from 400nm to 100nm. The electromagnetic spectrum of the ultraviolet light is further categorized based on

4 Guidelines for Environmental Infection Control in Health-Care Facilities, Recommendations of CDC and Healthcare Infection Practices Advisory Committee (HICPAC), 2003, p. 16

solar irradiance. UVGI or Ultraviolet C (UV-C) light of the range 280-100nm is known to have germicidal effect. The commercially available UVGI lamp is the low pressure mercury vapour lamp that emits radiant energy at predominantly 253.7nm.

Ultraviolet Germicidal Irradiation (UVGI), commonly known as UV-C light, has shown to inactivate airborne droplet nuclei. UV-C wavelength breaks the molecular bonds within the microorganisms' DNA, thereby destroying them, rendering them harmless or prohibiting growth, and prevents microorganisms from replicating. This then avoids having living microorganisms being trapped at the filter. The UVGI lamp has been mooted in three main applications; i.e. in-duct UVGI, at the AHU and Upper Room UVGI.

In-duct UVGI

In-duct UVGI lamp is installed in the return or exhaust duct to kill airborne droplet nuclei. In-duct UVGI lamp may be used to augment HEPA filters, but cannot be used in place of HEPA filters, as the effectiveness on the air stream is limited.

In-duct UVGI lamp when placed in the return or exhaust duct shall be of higher intensity compared to Upper Room UVGI as it is not exposed to the persons in the room.

An access door with a viewing window shall be provided so that lamps can be checked, cleaned, and replaced. The access door shall be electrically linked to switch off the power supply to the lamp when the access door is opened. A warning sign alerting the staff of the danger of UV light exposure to skin and eyes shall be posted on or adjacent to the viewing window.

Upper Room UVGI

Upper Room UVGI lamp is installed directly in the room. It is installed high on the walls or suspended from the ceiling, and its radiation is directed at the upper portion of the room.

The air in the upper portion will be disinfected and when mixed with the air from the lower part of the room will result in diluted contaminated air.

This UVGI lamp shall be shielded and shall never be viewable to the naked eye. The lamp is to be placed in fixtures that will direct the irradiation upwards.

This unit is to be placed below the air diffuser so that the air will pass in front of the unit to be sterilized.

A warning sign alerting the staff of the danger of UV light exposure to skin and eyes shall be posted on the unit.

UVGI at AHU

UVGI can also be placed upstream of the cooling coil in an AHU to prevent or limit the growth of microorganisms. The AHU compartment door shall be electrically linked to switch off the power supply to the UVGI lamp when the door is opened.

A warning sign alerting the staff of the danger of UV light exposure to skin and eyes shall be posted on the compartment door.

The application of UVGI lamp as a complimentary to further enhancing indoor air quality of the isolation rooms shall be encouraged. Due the availability of so many application of UVGI lamp in the market, the choice of lamp for the isolation rooms shall be carefully selected based on the correct length of exposure time and intensity.

The recommended installation of UVGI lamp for the isolation rooms shall be in-duct and at the AHU application. The installation protocols of UVGI lamp shall be adhered to and post installation result shall be verified to ensure effectiveness of the mechanism.

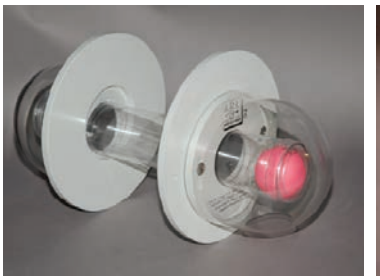
Other Considerations

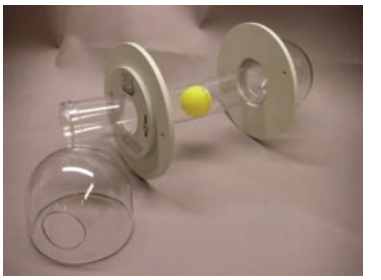
Other considerations that are not discussed above but may improve the monitoring of the isolation rooms are ball in tube installation and proximity switch installation.

Ball in tube

The ball-in-tube (Baulin Tube) is a mechanical device that is used to show the airflow relationship. This device is made up of a number of components that are assembled and installed at the wall. This device visually displays the direction of the airflow between the patient room and the anteroom or between the anteroom and the corridor.

This device can be easily installed and does not work on electricity.





Proximity door switch at the patient room door of isolation room

A proximity door switch with delayed alarm system shall be installed at the patient room door. In case the patient door is not fully closed or left open for long periods of time, the proximity switch can activate a lamp or sound an alarm at the nursing station.

4.2.2. Fire Safety

The fire suppression system at AIIR & PE Room shall comply with the latest version of Uniform Building by Laws and the requirements established by the Fire and Rescue Department.

All piping and sprinkler outlets shall be sealed to ensure no air leakages.

All ventilation ductworks that pass a fire compartment or fire wall shall be fitted with fire or smoke damper.

All gaps between service penetration; e.g. ventilation ductworks, electrical cable tray, medical gas pipeline system, etc., into the fire wall or fire compartment shall be sealed with fire stops.

Proper route of evacuation for patient and staff out of the room shall be established and integrated as part of the whole floor/building evacuation plan.

4.2.3. Medical Gas Pipeline System

The Medical Gas Pipeline Systems (MGPS) shall be preferably installed in an isolation room(s) to supply the required medical gases to the patient. The design of the system shall comply with the latest requirement and applied standard by the Ministry of Health.

There shall be mainly two types of medical gases commonly used in AIIR & PE Room; i.e. oxygen (O_2), and medical air (MA4). The vacuum pipeline shall be used to create a negative pressure for fluids to be sucked into vacuum containers.

Table 5: Quantity and type of Terminal Unit (TU)[5]				
Type of Terminal Unit	**O_2**	**MA4**	**Vacuum**	**Alarm**
AIIR/PE Room	1/bed		1/bed	1
AIIR/PE Room at critical care unit*	3/bed	1/bed	3/bed	

Note * AIIR & PE Room at Critical Care Unit refers to and is not limited to Coronary Care Unit (CCU), Paediatric Critical Care Unit and Neonatal Intensive Care Unit (NICU).

The arrangement of the medical gas terminal units shall comply with the Ministry of Health's requirements, i.e. a horizontal array, and when viewed from left to right, shall begin with terminal units for oxygen, medical air, and vacuum.

These terminal units shall be installed in a dedicated compartment within the bed head panel/trucking as the bed head panel is compartmentalized to accommodate electrical service, nurse call system, audio services, night light services, etc.

In the case of AIIR or PE Room in critical care units, terminal units shall be installed on pendants and they may either be installed in the vertical or circular array as per acceptable international practice.

Where there is a dedicated ward that houses numerous single-bed isolation rooms or multi-bed isolation rooms, the Area Valve Servicing Unit (AVSU) shall be installed at the ward/department street.

The local alarm system shall be placed at the main staff base (nurses' station) for easy viewing.

4.3. Electrical Requirements

4.3.1. Electrical Installations

All electrical material and equipment, including conductors, controls, and signalling devices shall be installed in compliance with available or established standards where such standards are required.

5 Guidelines for Design and Construction of Hospital and Health Care Facilities, The American Institute of Architects Academy, 2001, p. 83

The electrical installations, including alarm, nurses call, and communication systems, shall be tested to demonstrate that equipment installations and operation are appropriate and functional.

A written record of performance tests on special electrical systems shall show compliance with applicable codes and standards. These test records will be utilized to compare with routine maintenance tests so that the equipment or system is deemed to be safe for operation.

4.3.2. Services and Switchboards

Main switchboards shall be located in an area separate from plumbing and mechanical equipment, and shall be accessible to authorized persons only. Switchboards shall be convenient for use, readily accessible for maintenance, away from traffic lanes, and located in a dry, ventilated space free of corrosive or explosive fumes, gases, or any flammable material.

Overload protective devices shall operate properly in ambient room temperatures. The main switchboard shall have normal and essential supply backup by generators.

Distribution Boards (DBs) serving lighting and appliance circuits shall be located on the same floor of the isolation room, preferably in the anteroom. The essential supply DB shall be similarly installed, and possibly in the same DB for normal supply, provided it is labelled clearly or in a different compartment of the normal DB.

4.3.3. Power Supply

The room exhaust for AII rooms shall be on emergency power. The supply fan for PE room shall be on emergency power. For the combined AII/PE, both supply and exhaust shall be on emergency power.

The electrical circuit for lighting, nurse calls and communication shall be from the emergency power supply distribution board.

The power supply to the isolation room at specific units; e.g. critical care unit, shall comply with the requirements for the specific units.

4.3.4. Lighting

Lighting fixtures shall have the minimum area of horizontal or near horizontal surfaces on which dust may settle, and such dust shall be easily removed by simple cleaning methods.

Recess type of lighting fixtures shall be used in the ceiling with good sealing facilities. Provision shall be made for easy cleaning of the interior of enclosed light fittings without the risk of electrical shock.

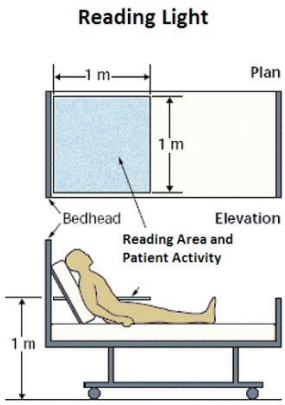
The construction of the light fittings shall be robust and can be securely mounted so that there is no rattling noise due to normal building vibrations or draughts. The isolation room shall have general lighting, reading light, and night light.

General Lighting

Suitable light fittings shall be provided over the hand basins, the bathroom, and the anteroom. The illuminance for these areas shall be around 300lux.

Reading Light

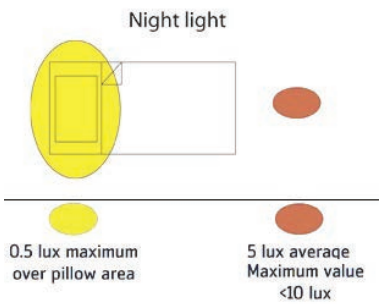
A reading light shall be provided for the patient with an illuminance of 300 lux. The light shall be located over a horizontal area of 1m x 1m centred at the patient bed head directed downwards.



The reading light controls shall be located at the bed head panel so as to prevent the patient from getting out of bed. Incandescent and halogen light sources that produce heat shall be avoided to prevent burns to the patient and/or bed linen. The light source shall be covered by a diffuser that can be easily cleaned.

Night Light

Night lighting shall fulfil three functions; i.e. to provide enough light for safe movement during the night, to allow the nursing staff to see facial features and the patient's general condition, and to allow the patient to sleep.



The average luminance at the centre of the room shall be 5 lux, with a maximum illuminance measured on the pillow of 0.5 lux.

All lighting requirements shall comply with the latest version of the Illuminating Engineering Society (IES) handbook.

Lighting levels for the isolation room shall be as follows[6]:

General lighting	300 lux
Reading light	300 lux
Night light	5 to 10 lux

4.3.5. Switch Socket Outlets (SSO)

Each patient room shall have two twin 13A SSOs; one twin SSO on each side of the bed head panel. Electrical supply to one set of the twin SSOs is from the normal power supply circuit and the electrical supply to the second twin SSO is from the essential power supply circuit.

Each wall shall have at least one 13A SSO at suitable low level locations for equipment, small refrigerator, floor cleaning machines, and the bed. An additional one SSO at a high level opposite the patient's bed shall be provided for a suspended TV.

All socket outlets need to be properly grounded. The SSOs shall be colour-coded to reflect the source/circuit of the power supply.

The number of SSOs at the isolation room at a specialized unit; e.g. the intensive care unit, shall comply with the schedule of accommodation by the Ministry of Health.

4.3.6. Nurse Call System

The wireless nurse call system shall be preferred.

The patient call station shall either be a normal call cord or a device having a call reassurance light, call/cancel button, and a nurse assist button. This device shall be located at the patient bed.

The staff registration and emergency call system shall be equipped with speech facilities and are located at the patient bed.

Toilet and bath stations shall have a water resistance membrane call point that include a pull cord or membrane call point with reassurance lamp and reset button.

Door and zone lights shall be installed along the corridor. Lamps shall be clearly visible from a distance of 30m.

6 Lighting Guide 2: Hospitals and health care buildings, The Society of Light and Lighting, UK,2008, p. 25

The nurse call system shall be operated at Extra Low Voltage (24V DC) from a conversion unit fixed to a 240V AC source from the essential supply.

When the nurse call is activated at the patient call station, the system shall initiate a visible and audible signal that can be turned off at the patient calling station. The signal shall activate an annunciator panel at the nurse station and a visible indicator door light in the corridor at the patients' door.

4.3.7. Intercom System

The intercom system shall be a two way communication tool between the patient and those outside the room. The intercom system is useful as it prevents visitors from coming into contact with the patient.

The system shall consist of two hands-free intercom stations; one at the bed head panel, and the other at the corridor next to the entrance door.

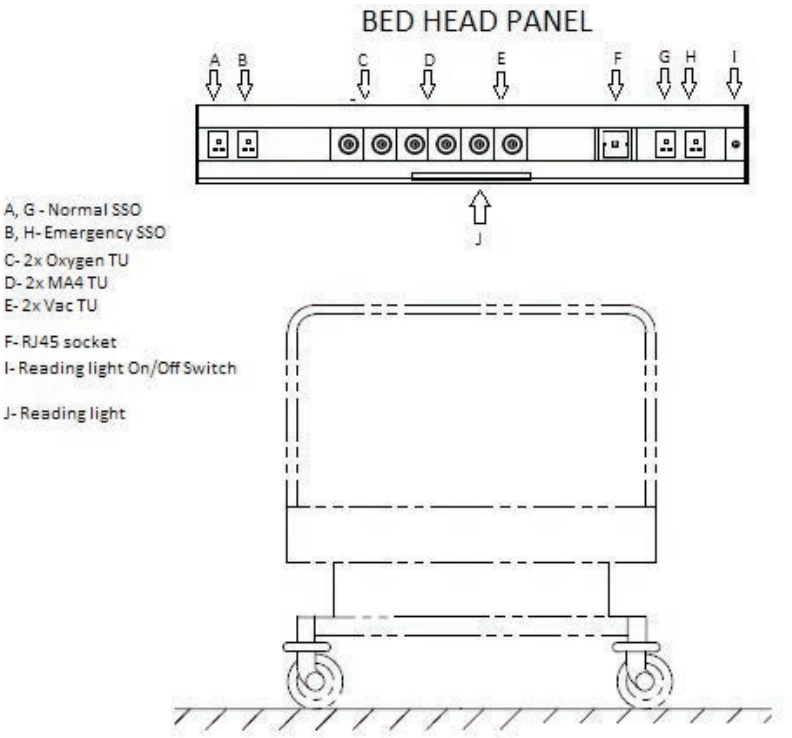
4.3.8. Bed Head Panel

The bed head panel shall be a versatile panel that incorporates all the fixed utilities and communication devices that are required by the patient, and shall be installed on the wall above the bed head. All devices mounted in the bed head panel shall be flushed-mounted.

A typical bed head panel has the following;

- medical gas outlets
- electrical sockets
- night light
- nurse call system
- intercom system
- telephone socket outlet

A typical bed head panel schematics is shown below.



5. ASSESSMENT OF EXISTING ISOLATION ROOMS

The installation of the isolation room in hospitals shall be operated at the intended design parameters and specification. In order to ensure the integrity of the isolation room is continuously intact, the steps shall be taken by the owner to ensure its effectiveness for operation. In the event, any non-compliances are found or the operation of the room is no longer as per design requirements, measures to upgrade or refurbish the room shall be initiated.

The assessment shall cover at least the listed major aspects of installation and operation of an isolation room. This shall include mechanical ventilation, electrical, civil and structure as well as the architectural aspects of the room. This section shall provide a simple guide for room assessment that will help prevent common failures in engineering controls that perhaps lead to the unexpected outbreak.

As the principle and operational of the isolation room is mainly a manipulation of the ventilation system, this section shall put heavy emphasis on the matter and make the assessment criteria as simple as possible for anyone. This type of assessment shall be done on a regular basis as part of ensuring the isolation room is still effective to be used or in need for upgrading or replacement.

5.1. Mechanical

5.1.1. Ventilation

The primary concern of the ventilation system in the isolation room shall be the amount of air changes per hour, which shall meet the required figure. The airflow measurement shall be carried out by the certified testing and balancing personnel or by in-house engineering staff.

The airflow of a room shall be measured at the individual registers or diffusers using a balometer. This device shall consist of a hood, a velocity sensor, and a microprocessor that shall indicate the value of airflow, normally in feet per minute, through those particular air entrances.

In case of insufficient space for the placement of a balometer, the airflow shall be measured by a pitot traverse in the duct that serves the outlet where air velocity is measured at various locations in the duct. All these readings and the cross-sectional area of the duct shall constitute the amount of airflow.

5.1.2. Air Mixing and Directional Airflow

The effectiveness of air mixing and direction of air in the room shall be established through a smoke test. Such method shall indicate poor mixing

or undesirable airflow patterns, thus identifying the ventilation problem of the room. Optimum air mixing shall be demonstrated by the absence of short-circuiting or stagnation of air.

The effective air mixing shall be determined by the rapid dissipation of the smoke test in all parts of the room, whereas the quick removal of particles generated in the room indicates the right directional of airflow.

5.1.3. Exhaust Ductwork and Discharge

The exhaust ductwork and fan shall be checked for optimum performance to justify corrective work due to an excess of leakage at duct joints, damaged ductwork, incorrect dampers adjustment, and fan in need of servicing.

If the AII rooms share the same exhaust system, the filtration system shall be inspected to ensure HEPAs are in place and individual rooms shall have dedicated filtration before the main exhaust line to prevent cross infection. The correct labelling on the ductwork shall also be inspected.

5.1.4. Pressure Verification

There shall be a few methods for assessing the pressure in the isolation room. For an ideally operating isolation room, there shall be an air current moving under the door.

The type of verification shall be based on the smoke trail test, tissue test, manometer reading, and velometer reading. All tests shall be conducted at least three times until the results are consistent.

The integrity of the permanent room pressure monitor (if available) shall be validated through one of the above methods.

5.1.5. Pressure measurement

If the type of pressure (positive or negative) for the room is confirmed, the measurement of the pressure shall be carried out to determine the readings, whether they are within the intended design limit or not. The readings shall be repeated for at least three times for consistency assurance.

5.2. Civil, Structural, and Architectural

5.2.1. General

After years of operation, the isolation room is normally subjected to various building issues such as worn finishes, crack, and some extent of structural-related problems. These problems shall be paid serious attention by the owner because the amount of airflow into/out of the room and the pressurization scheme of the room can be affected if not addressed in time.

5.3. Electrical

5.3.1. General

As part of the requirement by the authority, all electrical installations shall be fully inspected after a number of years in operation. It is to ensure the safety and the integrity of the system is intact. This assessment shall also serve as an indicator for the need of upgrading power voltage in view of changing medical requirement, particularly the increase of medical equipment used to treat the patients.

6. CONVERTING OR UPGRADING AN EXISTING PATIENT ROOM TO AN ISOLATION ROOM

If there is a need for additional isolation rooms, existing patient rooms can be converted or upgraded. There are numerous steps to be taken to convert or upgrade an existing patient room. The first step shall be to carry out a risk assessment and identify the differences or shortfalls in the requirements between the existing patient room and the isolation room as provided in this guidelines, depending on the type of isolation required.

Once the shortfalls have been identified, the process of establishing what needs to be done shall be listed out; e.g. availability of space area for the room, an anteroom, en-suite bathroom and so on, the suitability of location in relation to the other departments, budget and construction planning, etc.

In addition to the above, the existing facilities, especially all engineering systems or installations above the proposed isolation room ceiling shall need to be identified and possibly rerouted if required, so as to eliminate the risk of leakage, especially the piping, and to minimize any maintenance works related to these facilities during the operational phase.

Upgrading an existing patient room to an isolation room shall be done similar to constructing a new isolation room with all requirements mentioned in the guidelines. It shall involve a large financial layout and substantial time as well as departmental service continuity planning.

Converting an existing patient room to an isolation room shall involve a short time span and financial layout, but it is a retrofit. Retrofitting may not fulfil all the design requirements and may not be aesthetically designed due to space constraint; e.g. there may not be a sufficiently-sized anteroom, or the air change requirement may not be fulfilled.

During converting or upgrading an existing patient room to an isolation room, some of the basic precautionary measures that shall be taken to minimize disruption to hospital activities are as follows[7]:

- Having a multidisciplinary team incorporating infection control personnel as part of the team.
- Conducting a risk assessment and establishing contingency plans in place for service disruptions.

7 Guidelines for Environmental Infection Control in Health-Care Facilities, Recommendations of CDC and Healthcare Infection Practices Advisory Committee (HICPAC), 2003, p. 32–34

- Educating healthcare workers and construction workers on the project and establishing communication protocol.
- Establishing alternative traffic routes for healthcare workers, patients, visitors, and construction workers.
- Confirming affected areas and installing boarding/barriers. Installing proper safety and directional signage.
- Sealing off or blocking return air registers.
- Installing dust control measures to minimize airborne particulate movement.
- Having proper storage area and designated routes for raw material, finished products, and disposal of debris. Having water damage management plan and replacing water damage products that cannot be dried out within 72 hours, e.g. porous building material.
- Having a proper housekeeping system in place.
- Replacing primary filters more frequently to control dust in the air and surfaces to avoid build-up of dust particulates.

One of the main differences between an existing patient room and isolation room shall be the provision of a more specific ventilation system. Some of the elements shall be properly examined before and after upgrading or converting normal room into an isolation room. Items like the exhaust air, room leakages, rebalancing the ventilation system, and installing recirculating the HEPA Filter Unit shall be relooked.

6.1. Exhaust Air

In a normal patient room, the air shall be circulated and returned to AHU. In the case of AIIR, the air shall be exhausted to the outside. In case it cannot be exhausted to the outside, the exhaust air shall be filtered using the HEPA filter and returned to the Air Handling Unit (AHU) that is dedicated for AIIR. If the existing exhaust system is connected to a recirculating system, it shall be disconnected from the system.

To ensure that AIIR is in a negative pressure in relation to the surrounding, the exhaust fan shall be sized accordingly to exhaust more air than that supplied so as to create a negative pressure.

The exhaust fan shall preferably be located outside the building so that ductworks within the building are under a negative pressure.

6.2. Room Leakages

To consistently maintain the room at a negative/positive pressure, the room shall be sealed so that there is no air leaking into/out from the isolation room. Some of the areas where air can leak into the room are through the door, window, ceiling, gaps between wall and ceiling, service penetrations, lighting fixture, etc.

The top and sides of the door shall be gasketted, and windows caulked at and around the window.

The ceiling and walls are to be of monolithic material. The space between the ceiling and the wall shall be sealed.

All recessed light fixtures shall be replaced with surface-mounted fixtures. All lighting and electrical fixtures shall be sealed.

6.3. Rebalancing the Ventilation System

Rebalancing the ventilation supply is required as there are changes in the airflow requirements, the supply and exhaust requirements, and the placement of the air registers.

In the case of AIIR, the ventilation system shall be adjusted to exhaust more air. The air supply and exhaust shall be rebalanced using dampers. In the case of the PE room, the ventilation system shall be adjusted to exhaust less air. The air supply and exhaust shall be rebalanced using dampers.

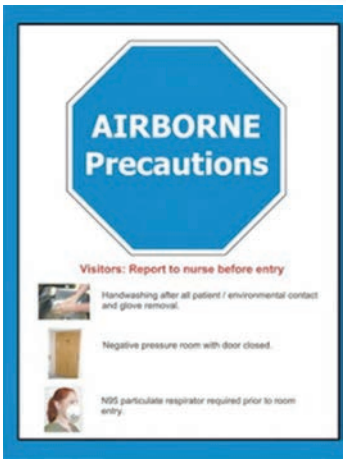
6.4. Recirculating HEPA Filter Unit

The recirculating of the HEPA Filter Unit shall be used to increase the ventilation rate without affecting the room pressurization. It is normally used to supplement the room airflow rate, where there is insufficient air change. This device shall have a HEPA filter with a MERV value of 17 and above.

In addition to the mechanical ventilation system, there are other architectural elements that shall be considered, but not limited to that mentioned below:

a) En-suite bathroom and anteroom.
b) All suspended ceilings to be replaced with monolithic ceilings.
c) All service penetrations are to be sealed; e.g. switch socket outlets.
d) All light fittings to be flushed with ceiling and gasket.
e) Doors to have door closer with observation window.

7. SIGNAGE



Signage shall play an important role as it provides visual graphics to display information to healthcare workers, visitors, and maintenance staff. Some of the common signages for AIIR and PE shall be:

7.1. AIIR signage and PE signage

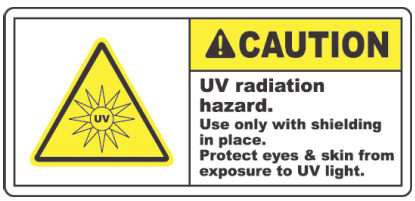
This signage shall be placed in a holder installed at the door when the room is occupied with a patient with an airborne infection. This signage shall inform all parties on the type of isolation room and the precautions to be taken.

7.2. Caution Signage on the Duct

This is a safety signage and informs the maintenance staff on the type of duct; e.g. supply, return or exhaust duct, and the area served; i.e. AIIR or PE room. This signage shall be placed along the ductwork at a distance of 10ft apart.

The signage shall provide instructions on actions to be taken before carrying out any work on the duct; e.g. inform the healthcare staff before carrying out the works, PPE to be worn, precautionary measures to be taken, etc.

7.3. Caution Signage on the Fan



This signage shall inform the maintenance staff on the type of fan; e.g. supply, return or exhaust fan, and the area served; i.e. AIIR or PE room. This signage shall be placed at the fan compartment and may have instructions on actions to be taken before shutting down the fan.

7.4. Direction Flow Signage

This signage shall be placed on ductworks to show the direction of the airflow.

7.5. Warning Signage at the In-Duct UVGI Lamp, Upper Room UVGI, and UVGI at AHU

This signage shall alert the staff on the dangers of UV light exposure to skin and eyes.

8. TESTING AND COMMISSIONING (T&C), HANDING OVER, AND WARRANTY MANAGEMENT

8.1. Testing and commissioning (T&C) is a process used to achieve, validate, and document that the isolation room systems are constructed, installed, tested, and are capable of being operated and maintained in conformity with the design intent or performance expectations.

The process shall be appropriately planned and executed in the presence of all interested parties in the hospitals.

8.1.1. Validation

During T&C, the isolation room shall be validated to establish the value of the parameters after it has been constructed. If the results of the validation do not comply with the design values, the system can be adjusted to achieve the design requirements. The following tests shall be carried out to validate the isolation room:

8.1.1.1. Differential Pressure between Rooms

The differential pressure test shall be carried out between the patient room and the corridor, and between the anteroom and the corridor. The test shall be carried out with the doors closed.

Differential pressure is an important measurement to show the containment between the rooms.

The test shall be carried out using a calibrated direct reading pressure gauge that measures the pressure of the room against the pressure at the corridor (reference point).

8.1.1.2. Airflow Direction between Rooms

The test shall be carried out between the patient room and the corridor, and between the anteroom and the corridor.

Airflow direction is an important measurement to show the containment between the rooms.

8.1.1.3. Airflow Pattern within Rooms

The airflow pattern verification shall be carried out to ensure that there is no stagnant or short-circuiting of air.

Airflow pattern within the patient room is important to ensure that air is flowing from the clean area to a lesser clean area. This test shall be carried out using a smoke tube.

8.1.1.4. Air Exchange Rate

The air exchange rate shall be measured to determine the total volume of air delivered to the patient room, anteroom room, and bathroom.

Air exchange rate is an important measure to determine the dilution of contaminants in the air.

The air exchange rate shall be measured directly using a tracer release.

8.1.1.5. Supply and Exhaust Air Volume from Registers

The supply and exhaust airflow rates shall be checked at all the registers at the patient room, anteroom, and bathroom.

This test shall be carried out to ensure that the airflows are as per the intended design. The test method shall be similar to that as in the air exchange rate; i.e. using tracer release.

8.1.1.6. Tightness (Leakage Rate)

The tightness of the patient room shall be checked to ensure that there are no air leakages into the room.

The test shall be carried out using a smoke tube or by tracer release with room pressurization.

Smoke tube with room pressurized
The patient room shall be pressurized by sealing the air supply and the planned leakage at the door. Pressure shall be built up by shutting off the supply or exhaust fan. The room shall be under or over pressurized and the smoke is released using a smoke tube. The smoke will show the leaks.

Tracer release method
The room shall be pressurized by sealing the supply grilles and doors. The exhaust air shall be adjusted to create a negative pressure of around -50Pa. The exchange rate is measured using

the tracer release and the concentration decay over time is measured as well.

8.1.1.7. HEPA Filter Integrity Leak Testing

This test shall be carried out to ensure that there is no leak through or around the HEPA filter. It shall be done by using the Disperse Oil Particle (DOP) or Poly Alpha Olefin (PAO) aerosol generator and scanned to detect leaks.

8.1.1.8. Airborne Particulate Test

The airborne particulate test shall be carried out to confirm the level of nonviable airborne particulates within the isolation room.

The above tests shall also be used for certification or recertification, and this is discussed in the Isolation Room Certification and Recertification section. Note that most of these tests shall require personnel with expertise to carry them out.

All test procedures and results shall be documented so as to establish a baseline or benchmark for evaluating the system performance over time.

8.1.2. Documentation

A commissioning document for the isolation room shall be prepared and submitted to MOH. The document must contain the following information, but is not limited to those stated below:

a) Methodology for carrying out T&C
b) Schedule for T&C
c) Architectural, Electrical, and Mechanical as-built drawings
d) Room identification and information
e) List of equipment and manuals
f) Schedule, test criteria, and calibration test results
g) Test, criteria, and certificates for air-conditioning system and mechanical equipment
h) Ductwork pressure testing
i) Electrical acceptance testing
j) Medical gases acceptance testing
k) AHU decontamination
l) List of calibrated tools used, and copy of calibration certificate
m) Records on training

Test records shall be verified by the designer and documented as part of T&C.

8.1.3. Activities carried out

The following activities shall be carried out, but not limited to, during T&C:

a) MOH and Hospital Support Services (HSS) provider to witness the T&C,
b) MOH and HSS provider to identify any noncompliance, and
c) MOH to request the contractor to rectify the noncompliance.

Once the non-compliances have been rectified, the above activities a) and b) shall be repeated.

Some specific test tools that shall be used during T&C are rotating vane anemometer, balometer, hygrometer, lux meter, and UV radiometer and manometer. All these tools shall be provided, duly calibrated and valid, and functional during the process.

A typical checklist for onsite Testing and Commissioning of AIIR (Negative Isolation Room) is shown below:

Date	
Hospital Name	
Location	
Department/ Ward Name	
Room No.	

Item	Description	Status (Yes/ No)	Remarks
1.0 Architectural			
1.1	**Patient Room**		
	Monolithic ceiling		
	Monolithic and seamless floor with skirting.		
	Room is sealed (window, ceiling, floor, electrical switch socket outlet, pressure sensor face plates etc.).		
	One-and-half leaf door with heavy duty hinges.		
	Door has door closer.		
	Sink with splashback.		
1.2	**En-suite bathroom (shower, toilet, bathroom)**		
	Monolithic ceiling		
	Monolithic and seamless floor		
	Room is sealed (window, ceiling, floor, electrical switch socket outlet, pressure sensor face plates etc.)		
	Bath shower		
	Sink with splashback		
	Toilet bowl		
	Safety railing		
1.3	**Anteroom**		
	Monolithic ceiling		
	Monolithic and seamless floor with skirting.		
	Room is sealed (window, ceiling, floor, electrical switch socket outlet, pressure sensor face plates etc.)		
	One-and-half leaf door with heavy duty hinges.		
	Door has door closer		
	Sink with splashback		

Item	Description	Status (Yes/ No)	Remarks
2.0 Mechanical			
2.1	**Air Handling Unit**		
	Primary filter		
	Secondary filter		
	Manometer pressure gauge across filters		
	Pressure drop across filters are within manufacturer's recommendation.		
	Status of UVGI at cooling coils (if available).		
	No biofilm at drain pan and cooling coils.		
	No water stagnation at drain pan.		
	Condensate discharge pipe – insulated and properly discharging.		
	Control panel indicator lights functioning.		
	Control panel indication high pressure across filter functioning (if available).		
	AHU room and unit are clean and dry.		
2.2	**Ventilation**		
	Room size (Length x Width x Height)		
	Room volume		
	Air exchange rate		
	Air Change		
	Air diffuser located at the centre of the room or slightly towards the entrance.		
	Air grille (exhaust) located at the ceiling above bed head or at wall above bed head.		
	Exhaust duct to the roof.		
	Exhaust duct, with HEPA filter to the outside.		
	Airflow direction from anteroom towards patient room (negative differential pressure)		
	Airflow direction from corridor towards anteroom (negative differential pressure).		
	Negative pressure differential at bathroom		
	Exhaust fan status and labelled		
	Temperature at patient room		
	Humidity at patient room		
2.3	**Pressure Monitoring System**		
	Status of Direct Pressure System – Magnehelic Gauge (if available).		
	Status of Indirect Pressure Monitoring System (if available).		
	Check time for alarm to activate Indirect Pressure Monitoring system (if available).		

Item	Description	Status (Yes/ No)	Remarks
	Availability and status of remote alarm system at nurses counter.		
2.4	**UVGI**		
	Status of In-duct UVGI (if available).		
	Status of Upper Room UVGI (if available)		
2.5	**Medical Gases**		
	Oxygen TU - Qty and status		
	Vacuum TU – Qty and status		
	Medical Air TU – Qty and status		
2.6	**Fire System**		
	Ductworks passing fire compartment have smoke/ fire damper		
	Service penetrations have fire stop.		
3.0 Electrical			
3.1	**Lighting Levels**		
	Patient room		
	Reading Light		
	Night Lighting		
3.2	**Switch Socket Outlet**		
	Availability & functioning		
3.3	**Nurse Call System**		
	Availability and status – Nurse call (bed side)		
	Availability and status – Nurse call – (toilet WC)		
	Availability and status – Nurse call (shower area)		
	Availability and status – Visual indicator at the door		
	Availability and status – Audio and Visual Indicator at Nurses' station		
3.4	**Intercom**		
3.5	**Bed Head Panel**		

8.2. Handing Over

Once T&C has been carried out and accepted, there shall be an official handing over of the isolation room to the hospital.

The following activities shall be carried out during this handover.

a) HSS provider shall identify any shortcoming and report the findings to MOH and the contractor. The contractor shall be required to ensure that the isolation room is handed over in good condition.

b) MOH shall receive all relevant documents, tools, and certificates from the contractor and hand them over to the Hospital Support Services. The

relevant documents are the as-built drawings, operation and maintenance manuals, spare part list, etc. The tools and test equipment received (if any) shall be based on the provisions in the contract. The test certificates shall be the test reports of the isolation room; e.g. airflow velocity test, airborne particle count test, colony forming unit test, and room pressurization test.

All prevailing guidelines adopted by MOH shall be used.

8.3. Warranty Management

If there is a warranty management requirement in the contract between the hospital and the contractor, then the warranty management activities shall be carried out. Note that all warranty management scope of works shall be established during the procurement process.

The hospital shall identify the following:

a) Duration of warranty period.
b) Role of MOH, Hospital Support Services, and the contractor with respect to the scope of work; e.g. Response Person, Breakdown Maintenance, and Planned Preventive Maintenance, etc.
c) The spare parts and type of services provided by the contractor.
d) The frequency of the services and the calibration of components of the isolation room.

For more details on warranty management, please refer to the Guidelines on Warranty Management by MOH.

9. MAINTENANCE

Maintenance shall be carried out to ensure that the installed engineering system and its components are in good working condition. There are numerous maintenance strategies; e.g. user maintenance, breakdown maintenance, corrective maintenance, and planned preventive maintenance.

User maintenance shall be the works carried out by the user to ensure that the equipment is functioning as required. One such element of maintenance is the daily monitoring and validation of airflow.

Breakdown maintenance shall be the maintenance works carried out when the equipment fails. Meanwhile, the corrective maintenance shall be carried out on the equipment when a fault has been identified but before the equipment fails. The maintenance work shall be scheduled for repairing or replacing the faulty component.

Planned Preventive Maintenance (PPM) activities shall be carried out on a schedule, based on the service requirement of the equipment. PPM shall ensure that the equipment or system is serviced as per the manufacturer's recommendation and meet the performance standards.

9.1. Isolation Room

To ensure that the systems in the isolation room perform as required, a well-planned preventive maintenance programme shall be in place and implemented.

An isolation room is a special room having numerous systems; e.g. air-conditioning and mechanical ventilation system, medical gases, fire systems, electrical systems, nurse call systems, etc. Each system plays a distinctive role, and has its own planned preventive maintenance activities. As an isolation room is a critical facility, the planned preventive maintenance of an isolation room shall be taken as a whole and not maintained based on an individual system.

The planned preventive maintenance for the systems in the isolation rooms shall comply with the manufacturer's recommendation with respect to the type of activities to be carried out and the frequency of the activities. Where the manufacturer's recommendations are not available, good engineering practice needs to be employed. A generic Hospital Engineering Planned Preventive Maintenance (HEPPM) checklist shall be developed to ensure that the isolation room is seen (and certified) as a system. The HEPPM developed shall be agreeable by MOH.

A standard operating procedure (SOP) shall be developed when carrying out maintenance works on an isolation room. The SOP shall include elements on

potential hazards and safety measures to be taken; communication protocol between the healthcare workers and the maintenance staff before, during, and after maintenance is carried out.

Maintenance staff shall wear appropriate Personal Protective Equipment (PPE) when performing maintenance activities. Appropriate tools shall be used to carry out maintenance. Some of these tools shall be calibrated and certified at the time of use; e.g. airflow metre.

The clear communication protocol between the healthcare workers and the maintenance staff before, during, and after the maintenance shall be carried out and documented.

A summary of the elements to be maintained is listed below, but is not limited to these:

9.2. Architectural

9.2.1. Room Tightness/Leak

All the gaps in the room shall be sealed. All gaps at service penetration and light fittings shall be sealed to ensure that there is no air infiltration from the outside.

The service penetrations area such as switch socket outlets and medical gas pipeline shall be minimized.

Windows, socket outlets, light fitting, and ceiling shall be sealed.

The gap between the door and the floor shall be maintained at 0.5 inch. There shall not be any gap between the door and their frame when they are closed.

The door closer shall be functioning. Where a magnetic proximity door contact with alarm is in place, the unit shall be functioning and the time taken to close the door shall be checked against the agreed time span.

9.3. Mechanical

9.3.1. Air Handling Unit Room

The room floor shall be clean and dry.

The room shall be secured and locked at all times.

Air Handling Unit (AHU)

The fan belting shall in good condition and under proper tension.

The condensate coils shall be free from biofilm and clean.

The condensation in the drip pan shall be well-drained to an open drain via a drain pipe. The drain pipe shall be insulated, adequately sloped, and has a “P” trap.

The primary and secondary filters shall not be clogged, and the pressure drop across the filters is within the manufacturer’s recommendation. All HEPA filters are to be leak-free, not clogged, and sealed within its housing. The pressure differential gauges across the filters shall be functioning.

The dampers at the outdoor air intake opening shall be set as per design. All UVGI lamps shall be functioning effectively.

9.3.2. Control Panel

All the indicator lights and switches shall be labelled and functioning.

The temperature and humidity display panels shall be functioning, and their readings shall fall within the design requirement.

The indicators for pressure drop across both the primary and secondary filters shall be functioning.

9.3.3. Ducting

The supply and return/exhaust ducting shall be free from damages and air leaks.

Outdoor air intake openings shall be free from obstruction and clean.

The ductworks shall be secured and free from vibration.

The dampers are correctly adjusted, and fans shall be clean and well-serviced.

The ducts shall be properly labelled to indicate the intended purpose.

9.3.4. Room Pressure Monitoring System

The room monitoring system shall be functioning and working within the set limits.

In the case of the Indirect Pressure Monitoring System, the alarm system shall be tested. The time taken to eliminate the nuisance alarm shall be checked and verified against the agreed set time.

9.3.5. Grilles

The air supply diffuser and return/exhaust grilles shall be clean/sanitized, and clear of obstructions.

9.3.6. Ultra Violet Germicidal Irradiation (UVGI) Lamp

The UVGI light shall be cleaned on a regular basis as per the manufacturer's requirement. The manufacturer's maintenance safety protocol shall be adhered to when cleaning or replacing the UGVI lamp.

As the commercially available UVGI lamp is of the low pressure mercury vapour type, it shall be safely handled and disposed of. The person handling this lamp shall be properly attired with the right PPE; e.g. gloves, face mask, etc.

9.4. Electrical

9.4.1. Electrical Installation

All the electrical installations, which include the wiring and switch socket outlets, shall be inspected to ensure that they are in good working condition.

9.4.2. Switchboards

All overload protective devices and wiring shall be checked to ensure they are in good condition; i.e. without any burn marks or failed overload devices.

9.4.3. Lightning

All general room lightings, reading lights, and night lights shall be functioning with the appropriate brightness. The light fittings shall be clean and well-sealed when flushed with the ceiling.

9.4.4. Nurse Call System

All nurse call pull-cords at the room and toilet shall be available and functioning. When activated, the audio and visual display at the nurses' station and indicator light at the door shall be functioning.

9.4.5. Intercom System

The intercom system shall be functioning and the two-way communication shall be audible.

Some of the system faults can be easily identified by the healthcare workers during day-to-day operations, and shall be reported to the maintenance service provider to rectify the faults.

9.5. Calibration

To ensure that the systems are functioning as required, some of the components shall be fine-tuned during maintenance to ensure that they are functioning within the desired limits. Most mechanical components shall be adjusted to achieve the desired results; e.g. damper setting, door realignment, etc. However, electrical and electronic components used in the system; e.g. room pressure monitoring system and door open alarm system, shall be calibrated to ensure that the systems are functioning as required.

The room pressure monitoring system is a sensitive device and shall be calibrated by a certified authorized personnel or organisation.

10. ISOLATION ROOM CERTIFICATION AND RECERTIFICATION

10.1. General

Currently, there is no specific or mandatory requirement for isolation room certification. However, it is a good engineering practice to have the isolation room certified and its implementation shall be encouraged.

Certification or recertification protocols shall be established to address the following:

a) The type of tests to be performed, its methodology, the test instruments to be used, and acceptance criteria
b) Frequency of recertification
c) Selecting a certified agency to carry out recertification
d) Format of recertification report

10.2. Type of Test to be Performed

Majority of tests to be performed for room certification are adopted from the ISO 14644 Standard. They shall serve as a basis for in-house verification.

10.2.1. Particle Count Test

The purpose of the particle count test is to determine and verify the cleanliness classification of the isolation room. The isolation room shall be tested based on the Class 100K.

This test shall either be performed when the isolation room is in use (operational state) or at a state of rest, in accordance with the standard.

10.2.2. Airflow Test

The airflow test shall be carried to evaluate airflow velocity and supply air volume. The supply volume shall be used to determine the air change rate.

10.2.3. Differential Pressure Test

The differential pressure test shall be carried out to verify the capability of the isolation room to maintain a specified pressure difference between the patient room and the reference point (corridor). The test shall also be carried out between the anteroom room and the corridor.

10.2.4. Installed Filter Leakage Test

The HEPA filter integrity shall be checked by carrying out the Filter Leakage Test. This test is to ensure that there is no leakage at the HEPA filter or through its housing so that no microorganisms are passing through it. This test shall be carried out on the downstream of the HEPA filter.

10.2.5. Flow Visualization

The flow visualization test shall be carried out with the intention to demonstrate the airflow characteristics in the installation.

10.2.6. Airflow Direction Test

The airflow directional test shall demonstrate the airflow directional characteristics.

10.2.7. Temperature Test and Humidity Test

This test shall measure the air temperature and humidity supplied by the air handling unit.

10.2.8. Containment Leak Test

The containment leak test shall be carried out to evaluate the intrusion of contaminated air from the surroundings.

In addition to the above, the Colony Forming Unit (CFU) Test shall be carried out, but there is no established baseline. This test shall be carried out as and when the isolation room is suspected to contribute towards high numbers of infection cases or when required.

10.3. Frequency of Test

All the above mentioned tests shall be carried out during certification or during recertification to ensure that the isolation room meets the design requirements. Testing shall be carried out by a certified third party.

The Particle Count Test shall be done at a maximum interval of not more than 6 months. The remaining tests shall be carried out at a maximum interval of not more than 12 months. The report shall be prepared and a copy of the report submitted to the Hospital Director.

All test tools used for the above tests shall be calibrated and valid at the time of test. The test standard, methods, procedures, and test tools used shall be stated in the report.

In case of noncompliance, the maintenance service provider shall take immediate remedial actions. Once the noncompliance has been rectified, recertification shall be carried out.

10.4. Test Results

The test results shall include the following, but not limited to:

a) Name and address of the testing company.
b) Person's name and date when tests are carried out.
c) Clear identification of the physical location of the isolation room and sampling locations.
d) Date and type of tests carried out.
e) Measuring instruments used and proof of calibration.
f) Test results, including particle concentration data for all sampling locations.
g) Date of next test to prove continued compliance.
h) Letter or certificate with details on why the isolation room passed or failed certification. This document shall have recommendations to repair/rectify fault.
i) Certificate awarded for successful inspection.

10.5. Conditions when Isolation Room is to be Recertified

Recertification shall be carried out under the following conditions:

a) Significant change in operational use
b) Significant change in the air movement that affects the delivery of service
c) After the change of final/HEPA filters

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