

Part E – Engineering



iHFG

International Health Facility Guidelines

2025

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1 Introduction

This document hopes to provide the knowledge and understanding to existing healthcare design engineers and healthcare operators, to enable them to understand the benchmark for engineering systems in healthcare facilities.

This will also allow them to ensure that the design for any healthcare facility, is compliant, efficient and will be able to run for years to come.

This document is not meant as a replacement of international healthcare standards or codes, but the culmination of standards put into a single simplified design guide to help design engineers, maintenance engineers and hospital operators. It brings out the best and most practical design of MEPF systems for global practice.

Engineering Services in Health Facilities

Engineering services in health care facilities shall satisfy general comfort demands, health procedure and patient care relevant requirements.

An important role of engineering services is controlling specific risks characteristics within a Health Facility. Engineering services become part of the complex risk management environment which includes many other factors such as maintenance and management. The optimal solution is the structuring of risk management to suit the potential risks specifically for the facility and financial circumstances (that will vary among projects).

These guidelines cannot cover all engineering options or define the requirements of a risk management system for engineering services. These systems should be developed during the design phase of the project by specialist engineers having experience in designing health facilities.

As energy efficient solutions are becoming increasingly important, certain measures are mentioned in this guideline for the design of health facilities. Some energy efficient solutions based on good engineering and general project development approach do not necessarily increase capital costs.

The provision of most energy recovery equipment does increase capital costs of the project; therefore, life cycle cost analysis is recommended to justify additional expenditure and application of this equipment will depend on budget constraints.

It is not the intention of the Guideline to cover every aspect of public and private health facilities. Project specific issues that are expected to be covered in the project brief include:

- Involvement of affected stakeholders
- Nomination, listing of critical and sterile areas, including unacceptable risks
- Application of energy recovery systems, life cycle cost analysis and other financial requirements
- Provisions for foreseeable modifications
- Emergency power distribution
- Facility specific requirements
- Specific risks and risk management policy
- Trade wastes
- Service requirements for health care equipment
- Specific Management and Maintenance requirements
- Critical safety and performance parameters required being included into the maintenance regime.

Note: Healthcare procedure-specific equipment is excluded from the engineering services as the service contractors usually do not provide them. Engineering services shall be provided as necessary to suit equipment.

General Requirements

Engineering services shall comply with relevant, applicable legislations, municipality requirements and these guidelines.

Services, or their loss, shall not cause any unacceptable hazard. The particular risks involved with patients and healthcare procedures shall be considered. Where loss of service could cause unacceptable risk (including post disaster function), services shall be continuously available and provide reliable operation.

All services shall satisfy the facility specific healthcare procedure requirements, patients', and other occupants' needs. All services shall be designed and installed in a manner that will minimize the opportunities for patient self-harm.

All services shall satisfy comfort requirements as determined in the acceptable international guidelines.

All services shall be designed for safe usage and maintenance. Maintenance shall only cause acceptable minimal disruption to healthcare procedures and minimal disturbance to patients.

Access points are recommended to be located outside patient areas and thorough fares to avoid patient disturbance and frequent traffic.

No services shall create a hazard to or damage the environment.

Services shall be designed for minimal dust collection and easy cleaning.

All services shall be energy and cost efficient within the budgetary limits of the project.

Operation, monitoring and control of services shall suit the specific patient and healthcare procedures needs of the area serviced. Controls generally shall be tamper proof.

As-built drawings and detailed Operation and Maintenance Manuals shall be supplied at the end of a project. The drawings shall be clearly marked "AS BUILT" in large lettering and submitted to the Local Health Authority as part of the final inspection.

At the completion of the works, or section of the works, testing shall be carried out to prove the suitability and operation of the works or section of the works and that the installation complies in full with the requirements specified.

All equipment shall be suitable for the environment where they are located and operate (including temperature and pressure) and for the material they handle.

Seismic restraints in healthcare services design have become increasingly important and many jurisdictions have standards governing the same. In absence of local AHJ requirement, it is recommended to hospital services be designed to minimum requirements of international building code and relevant SDC (seismic design category) determined by the structural engineer. For higher risk categories appropriate importance factors should be assigned based on life safety, explosive nature, business continuity risks and restraints provided accordingly.

Scope of this document

Engineering systems and services design for healthcare facilities shall ensure that the healthy, clean, and hygienic environment is maintained in hospitals as per the departmental strategy by healthcare planners. Patient care, visitor safety and efficient hospital operations by the hospital operator will heavily depend on these systems.

This document shall provide an engineering design guidance for the following building services systems:

- Section 2 - Mechanical (HVAC) Systems
- Section 3 – Electrical Systems
- Section 4 – ICT & ELV Systems
- Section 5 – Water Systems
- Section 6 – Drainage Systems
- Section 7 – Medical Gas Systems
- Section 8 – Fuel Systems
- Section 9 – Pneumatic Tube Systems
- Section 10 – Fire-Fighting Systems (Special Case Areas Only)
- Section 11- Vertical Transportation Systems

The key role of above-mentioned engineering services is controlling the environmental parameters within healthcare facilities. Also, this document provides operation and maintenance for healthcare operators to ensure that the system does not encounter any major faults or incidents with the main engineering plant that shall jeopardize patient and visitor safety.

Key Objectives

The following objectives are key for a well-designed healthcare facility as well as the intent of this document:

The engineering design guide is not a replacement of other international healthcare standards, but a simple, no jargon design guide for engineers, operators, and maintenance engineers.

The engineering design within this document shall compliment requirements needed by local authorities and other relevant authorities.

The engineering design shall meet the departmental requirements set out by healthcare planners and healthcare architects.

The engineering design shall ensure that any opportunities for patient self-harm are minimized or eliminated.

The engineering design benchmark outlined within this document ensures that the loss of engineering system or failure is minimized and, in some areas, can be eliminated if the system is well maintained.

The engineering design shall ensure that any scheduled operation and maintenance procedures carried out shall keep disruptions to the operation of the healthcare facility kept at a minimum, by having these at off-peak patient/visitor traffic.

The engineering design shall ensure that any access is kept out of any clinical and patient occupied areas, but if access is required in clinical areas, then the design shall indicate that area will need to be re-treated to ensure that a safe and hygienic environment is maintained.

The engineering system design shall ensure that in the event of failure of the system, the emergency engineering system, is able to support the hospital facilities for a dictated period (usually 24-48 Hours).

All equipment shall be suitable for the environment where they are located & operated (including temperature and pressure) and for the material they handle.

Engineering Briefing

Briefing in healthcare facilities is usually provided by healthcare planners and hospital operators. This type of briefing is usually referring to the following items:

- Air Conditioning
- Ventilation Provision
- Power Outlets, (Quantity & Type – Such as General, Essential, UPS etc.)
- Sanitary and other Fixtures
- Data and Voice Points
- Medical Gas (Number of Outlets and type of service)
- CCTV and MATV (Number of outlets and type)
- Nurse Call

The type and quantity of the above outlets is not regarded as an Engineering decision, proposal or brief, these are regarded as part of Health Facility Briefing and covered in Part B.

They represent the needs of patients, staff and visitors as determined by Health Facility Planners in consultation with the facility operators.

These minimum requirements are shown in Room Layout Sheets provided under Part B.

The engineers take the above briefing requirements as a starting point and determine the Engineering Systems from there.

2 Mechanical (HVAC) Engineering Design

This HVAC design guideline written for healthcare facilities, is a consolidated document listing out the design requirements for all new construction and major renovation healthcare projects. Compliance to this document, which stipulates minimum performance design standards, ensures that facilities will be of the highest quality. This is an international guideline based on best practice.

Substantial variance from this Design Manual may be proposed by the design consultant to promote new concepts and design enhancements. Variance shall not conflict with Federal Regulations, Local Municipality Laws, Executive Orders, or the needs of the end users. Substantial variance shall be reviewed by each local authority.

This document is intended for the Architect/Engineer and others engaged in the design and renovation of healthcare facilities. Where direction described in applicable codes are in conflict, the AE shall comply with the more stringent requirement. The A/E is required to make themselves aware of all applicable codes and ordinances and assure compliance thereto.

The document should be read in conjunction with other parts of the International Health Facility Guidelines (Part A to Part F) & the typical room data sheets and typical room layout sheets.

Key Objectives

The HVAC systems should be designed to achieve the following key objectives.

Mechanical services that deliver the anticipated levels of comfort and functionality.

A zero-tolerance approach to patient safety and infection control.

Compliance with the applicable codes and standards.

Appropriate pressure differentials between adjacent spaces and departments in clinical facilities.

Adherence to air changes per hour requirements as per code.

Reliable operation at the extreme outside design temperatures.

Reducing operating and maintenance costs shall be a key component in all new constructions.

Flexibility for future modification and expansion.

Energy efficiency & appropriate local or international green building code such as LEED, BREEM, Green Star etc.

An appropriate level of consistency across facilities, recognizing the specific demands of each facility and clinical specialty.

Abbreviations & Reference Standards List

Abbreviations List

Abbreviation	Description
ΔT	Delta T
A/E	Architect Engineer
ACH	Air Changes Per Hour
AHU	Air-Handling Unit
All	Airborne Infection Isolation
BMT	Bone Marrow Transplant
BSC	Biological Safety Cabinet
C	Celsius
CAPEX	Capital Expenditure
CD	Construction Documents
CFC	Chlorofluorocarbon
cfm	Cubic Feet Per Minute

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Engineering**

Abbreviation	Description
CO2	Carbon-dioxide
CRAC	Computer Room Air Conditioner
CT	Computerized Tomography
CV	Constant Volume
DB	Dry Bulb
DD	Design Development
DOAS	Dedicated Outside Air System
DX	Direct Expansion
EEG	Electroencephalography Laboratory
EER	Energy Efficiency Ratio
EMG	Electromyography
ERCP	Endoscopic Retrograde Cholangiopancreatography
ETO	Ethylene Oxide
fpm	Feet Per Minute
fps	Feet Per Second
GE	General Exhaust
Gpm	Gallons Per Minute – US
GWP	Global Warming Potential
HCFC	Hydro chlorofluorocarbons
HEPA	High-Efficiency Particulate Arrestance
HFC	Hydrofluorocarbons
HFO	Hydrofluoro-Olefins
Hp	Horsepower
HVAC	Heating, Ventilation and Air Conditioning
HX	Heat Exchanger
ICU	Intensive Care Unit
IAQ	Indoor Air Quality
IMRT	Intensity-Modulated Radiation Therapy
I/O	Input/output
IR	Infrared Radiation
IT	Information Technology
IRMM	Infection Risk Management Mode
kg	Kilograms
kPa	Kilopascal
kWh	kilowatt hour
L/s	Liters per Second
LCC	Life Cycle Cost
LCCA	Life Cycle Cost Analysis
m/s	Meters per second
MERV	Minimum Efficiency Reporting Valve
MRI	Magnetic Resonance Imaging
NC	Noise Criteria

Abbreviation	Description
NICU	Neonatal Intensive Care Unit
OA	Outdoor Air
ODP	Ozone Depletion Potential
OPEX	Operational Expenditure
OT	Occupational Therapy
OR	Operation Room
Pa	Pascal
PACU	Post Anesthesia Care Unit
PE	Protective Environment
PET	Positron Emission Tomography
ppm	Parts Per Million
QA/QC	Quality Assurance/Quality Control
RA	Return Air
RDS	Room Data Sheets
RH	Relative Humidity
SA	Supply Air
SE	Special Exhaust
TB	Tuberculosis
TAB	Testing, Adjusting and Balancing
UPS	Uninterruptible Power Supply
VPS	Variable Primary System
VSD	Variable Speed Drive

Reference Standards List

Local/international regulations, guidelines or standards as listed below are required to be followed while designing healthcare facilities unless superseded by this document. The requirements given in these regulations or standards are not repeated generally in this document; however specific additional healthcare specific requirements emphasized in the following sections will take precedence over referenced standards. Local standards will always take precedence over international standards. The editions mentioned are current editions and latest editions of the documents, at the time of registration of the project shall apply. Since this is an international guideline, all reference standards cannot be mentioned but

Items marked with * indicate optional compliance.

Summary of Key Design Codes, Standards and Reference Documents for HVAC Design		
SUBJECT	DOCUMENT	EDITION OR LATEST
General HVAC Design	ASHRAE 170 - Ventilation of Healthcare Facilities	2021
	ASHRAE HVAC Design Manual for Hospitals and Clinics Second Edition*	2013
	ASHRAE 62.1 Ventilation for Acceptable Indoor Air Quality	2016
	ASHRAE 241 – Control of Infectious Aerosols 2023	
General Building Codes	IBC	2021
	CIBSE B0 to B4	2016
Pharmacy HVAC Design Reference	USP 795 - Pharmaceutical Compounding - Non-sterile preparations	2015
	USP 797 - Pharmaceutical Compounding - Sterile preparations	2015

Summary of Key Design Codes, Standards and Reference Documents for HVAC Design		
SUBJECT	DOCUMENT	EDITION OR LATEST
	USP 800 – Hazardous Drugs – Handling in Healthcare Settings	2014
Refrigeration Systems	ASHRAE 15- Safety standard for refrigeration systems	2013
	ASHRAE 34 Designation and safety classification of refrigerant	2013
Thermal Comfort	ASHRAE 55 Thermal environmental conditions for human occupancy	2017
Ventilation for Catering Facilities	NFPA 96- Ventilation control and fire protection of commercial cooking operation	2014
Sustainability	ASHRAE 189.3 Construction, and Operation of Sustainable High-Performance Health Care Facilities *	2017
Laboratory HVAC Design	ANSI/AIHA Z9.5 - Laboratory Ventilation*	2012
	ANSI/NSF 49 - Biosafety Cabinetry: Design, Construction, Performance and Field Verification	2014
	ASHRAE laboratory Design Guide: Planning and Operation of Laboratory HVAC Systems second edition*	2015
	Laboratory Safety Guidance – OSHA*	2011
Fire Safety	NFPA 13- Standard for the Installation of Sprinkler System	2022
	NFPA 45 - Standard on Fire Protection for Laboratories Using Chemicals	2015
	NFPA 90A - Installation of Air Conditioning and Ventilating Facilities	2018
	NFPA 90B- Standard for the Installation of Warm Air Heating and Air-Conditioning Systems	2018
	NFPA 92 - Standard on Smoke Control Systems	2018
	NFPA 99 - Health Care Facilities Code	2018
	NFPA 101 - Life Safety Code Handbook	2018
	NFPA 5000 - Building Construction and Safety Code	2018
	Civil Defense Authority	
Access and Maintenance	ASHRAE 180 - Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems*	2012
UL Standards	UL 1995 Heating and Cooling Equipment	2015
	UL 555 Fire Dampers	2013
	UL 705 Standard for Power Ventilators	2017

Infection Control & HVAC

It is important to note the below mentioned functions desired from the HVAC system serving a healthcare facility, as compared to other building types for which the HVAC system is simply designed for thermal comfort.

Infectious diseases are spread by several different routes. Tuberculosis and in some cases influenza, the common cold, and other diseases are spread by the airborne route. The spread can be decelerated or controlled by heating, ventilating, and air-conditioning (HVAC) systems. The designer must keep these aspects in mind & consider it an ethical responsibility to comply with all relevant codes and standards.

For healthcare facilities, HVAC systems play a very important role in reducing airborne infections by:

- Air Change Rates to reduce the residence time of particles in the air.
- Filtration and air cleaning to remove microbes.
- Ultraviolet Germicidal Irradiation (UVGI) to in-activate the viable agents and prevent growth.
- Pressurization of spaces to move air from clean to less clean and dirty area.

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- Temperature and humidity control to reduce propagation.
- 100% exhaust from designated high-risk spaces to remove the particles from the space. It is recommended to design the HVAC system for areas where the risk of infectious spread is high such as waiting rooms and emergency department, ensuring its capability to function in Infection Risk Management Mode (IRMM) during high-risk events like a pandemic.
- Proper air distribution to reduce the deposition of particles and provide a designed path to the exit.
- Pressurization of the entire building to reduce air infiltration from outside.
- Plasma air filtration for the return air is acceptable practice in accordance with ASHRAE 241.

Life Safety & HVAC

The HVAC systems should follow design requirements stated within the NFPA & other relevant referenced standards. Points to note are listed below.

Fire Dampers, Smoke Dampers and Combination Fire and Smoke Dampers should be provided in accordance with the local code and in line with the Fire and Life Safety Drawings. All such dampers should be clearly shown in the design drawings.

It is encouraged to utilize dampers that have the ability to be remote tested in healthcare facilities in order to routinely check and maintain the dampers. This ensures that in a critical life safety event the damper operation is ensured.

Mechanical smoke management should be provided for atriums, corridor, and open circulation spaces.

Mechanical pressurization should be provided for egress stairs, lift hoist ways & lift lobbies for fire lifts.

If the air handling units return ducting is utilized for smoke control, the system design zoning should be carefully matched with the smoke zones, which in turn should line up with fire alarm and fire sprinkler zones. All other requirements related to duct construction and fan rating should be adhered to such as fire rating for the ductwork and the extract fan etc.

It is recommended to install dedicated extract air ducts for corridor and open circulation spaces smoke management, where required by code, rather than utilizing AHU ducts which would complicate AHU control and operation sequences, especially for typical in-patient floors. Using AHU return duct would also warrant replacement of ducting, post fire incident. Makeup air can, however, be provided through the AHU supply fans.

HVAC Services Reliability, Redundancy & Resiliency Requirements

The HVAC system designed for a healthcare facility is providing mission critical filtration, cooling, humidification & dehumidification as well as pressure regime management to the various critical healthcare spaces within the hospital.

Thus, the failure of an HVAC system component can lead towards a loss of pressurization which could be life threatening to an immune-compromised patient and can also result in a spread of viral infections.

The following section will list out the key requirements for an HVAC system to meet these challenges.

Reliability

Reliability of an HVAC system is the quality of the system components, installation, commissioning, and facility maintenance.

To ensure reliable construction and operation, the International health facility guidelines aim to introduce a prequalification system for the design consultants. Part A of these guidelines provide more information on the proposed system.

It is encouraged that owners and facility operators get involved early in the design process and provide feedback on the system components and operational aspects of the design.

For future healthcare projects, HVAC equipment manufacturers that have a strong local presence and full-service support shall be selected. All applicable components should be tested at the local

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Laboratories or other equivalent facilities worldwide and test certificates provided for record. Witness testing is encouraged for all major HVAC system components.

Redundancy

In simple terms, redundancy can be thought of the amount of standby equipment that is available to cover a system or component in the event of a partial system failure.

Standby equipment requirement should always be aligned with the owner’s facility operation plan.

Key system components in healthcare facilities must be configured in N+1 configuration. A guidance is provided below

Redundancy Requirements for Healthcare Facilities		
SYSTEM COMPONENT	DESIRED OPTIMAL REDUNDANCY LEVEL	ALTERNATE ALLOWED
Water Cooled Chillers	N+1	Deviation allowed for smaller hospitals & clinics if loss of one chiller does not affect critical cooling.
Air Cooled Chillers	N+1	Deviation allowed for smaller hospitals & clinics if loss of one chiller does not affect critical cooling.
Central Steam Boilers	N+1	Deviation allowed for smaller hospitals & clinics if loss of one boiler does not affect critical cooling.
Hydronic Heat Exchangers	N+1	
Chilled Water & Hot Water Pumps	N+1	
Operation Theatre Air Handling Units	N+1	AHU’s with dual fans with each sized at 100% of the airflow or fan arrays with one additional fan are allowed as an alternate to N+1 AHU’s.
Air-Side Equipment – Hygienic Air Handling Units (Critical Care, LDR, Emergency, Diagnostic Imaging, Laboratory, Oncology, In-patient pharmacy, Radiotherapy, Renal Unit, CSSD, Surgical Suite, Isolation Rooms)	N+1 (Fans) Each sized at 100% airflow & Critical Cooling.	Fan Coil Units can be used for Emergency, Imaging, Oncology, in patient pharmacy, Radiotherapy and renal departments but their use is highly discouraged.
Server Room	N+1	N+1 Precision Control Units or single indoor unit with dual coils & dual fans backed up by independent heat rejection equipment.
Critical Rooms Dedicated Exhaust Fans (Isolation Rooms, Bronchoscopy, Nuclear Medicine Hot Labs, Emergency and Radiology Waiting Rooms, Lab Fume Hoods, CSSD Sterilizers & Washers, Pharmacy hazardous-drug exhausted enclosures)	N+1	
Fire & Life Safety / Smoke Control System / Pressurization System Fans	N	As per local Fire and Life Safety code requirements

Resiliency

For the HVAC system, resiliency can best be thought of how much of the total system continues to operate in the event of a failure of one part of the system. Resiliency is critical to business continuity which is essential for public hospitals operating under disaster management and helps mitigate revenue losses in case of system failures for private hospital operators.

Resiliency must be built into the design, during the concept design stage. The consultant must evaluate the risks associated with the failure of a system component, engage in an effective dialogue with client/owner/operator and determine ways and means to mitigate the risks.

External risks associated with climatic conditions such as Sand/Snow/Hailstorms & heavy rainfall should also be evaluated and intake and exhaust louvers should be positioned & sized so that they can handle an extreme event.

Major equipment located below grade must be evaluated for flash flood risk.

Operating weights of equipment’s should be considered for structural design. Critical weights of equipment’s such as absorption chillers should also be considered to ensure that the structure can handle the HVAC equipment loadings.

Redundant systems should be routinely operated through BMS and tested at design conditions.

Some of the major equipment risks are mitigated by the table in the previous section on redundancy, but distribution systems such as ductwork and pipework should be configured in a way that eliminates a single point of failure.

Ring mains, multiple risers, dual connections to larger AHU coils, bypass over major control valves with proper isolation, Individual VFD's per fan, bypass for VFD's, manifolded air handling unit configuration are some of the measures that can be adopted for better system resiliency.

HVAC System Zoning & Emergency Operation

HVAC System Zoning

HVAC systems for clinical buildings shall generally be zoned to match the smoke control compartments for the building. The intention is to ensure that the impact of one zone being shut down is minimized. If this approach results in an excessive quantity of air handling units, more than one zone can be combined with fire and smoke dampers to separate them. In this case designers shall consider arranging the distribution ductwork so that only part of the system has to be shut down in a fire alarm condition.

By zoning the system using smoke control compartments it is unlikely that the capacity of a single air handling unit would exceed 16,500 L/s (60,000 m³/hr.). If it does the designer should consider dividing the air volume between two air handling units. It is encouraged that consultants prepare zoning diagrams during the concept design stage to clearly demarcate HVAC zones for coordination & clarity.

HVAC Systems Emergency Operation

Emergency generators are to be provided for the buildings to supply power to the HVAC system in a loss of power supply from the grid.

As described in the Electrical section, the capacity of the generators is determined using a risk classification process. The HVAC designer shall work with the electrical designer for the building to determine which HVAC systems are to be provided with emergency power through this process. The result of this analysis should also be used to assess how systems are zoned.

As a minimum all critical areas identified in this standard SSU, CSSD, Surgical Suite, Labor & Delivery Suite/Birthing Unit, Recovery, Emergency, Intensive Care, Nursery & Inpatient Rooms) should be provided with backup cooling/heating fed from emergency power. The space ventilation and pressure relationship requirements for Isolation rooms, Operating rooms including Caesarean section, should be maintained, via backup power. Refer to the electrical section, detailing the requirements for different risk categories within the hospital.

It is encouraged that mechanical consultant table the electrical power requirements (normal power or emergency power) in the mechanical equipment schedules in order to obtain clarity for the electrical engineer.

HVAC Services Acoustic Requirements

The HVAC system shall be designed to be compliant to ANNEXURE- Acoustic A-2. Other equivalent standards are also acceptable. Specific requirements for HVAC system components should be obtained from Annexure A-2 -Acoustic Values and ASHRAE standards.

Lining of ductwork is not allowed in healthcare facilities after final filtration, as per ASHRAE 170 except in terminal units, sound attenuators and air distribution devices (plenum boxes etc.). Such lining should be provided with an impervious cover, or carry certifications citing no vapor absorption and be acceptable to local civil defence requirements. CAV/VAV boxes which cannot meet acoustic requirements, should be provided with downstream attenuators in critical areas.

Backup power generator is if installed within hospital buildings should be provided with critical hospital grade silencers.

Car park exhaust and make up air fans should be provided with sound attenuators to reduce the sound during normal mode operation.

Acoustic Ratings for plant room doors should be carefully specified with detailed coordination between trades.

HVAC Services Future Proofing & Spare Capacities

Due to the nature of medical facilities, changes to internal layouts and upgradation of the medical equipment is quite common, which results in HVAC cooling/heating load variances. The designer should engage in an effective dialogue with the owner/operator to determine the allowance to be kept for future expansion as well as retrofitting and modifications within departments.

As a strong recommendation this guide asks for 20% extra useable area allocated for mechanical shafts for additional pipework and ductwork. It is also recommended that mechanical AHU rooms for medium to large hospitals should allow for space for an additional air handling unit for every 10 air handling units. Mechanical Pump rooms should be provided with space for 1 additional pump for both primary and secondary systems

HVAC System Selection – Distribution

The intent of this section is to provide a guidance for HVAC systems selection process for healthcare facilities as well as list out acceptable and unacceptable HVAC systems. Specific Room design guidance is provided at the end of this document in a separate section, which should be read in conjunction with this section.

Acceptable HVAC Systems-Distribution

All-air systems shall be used for all new facilities and major renovations of existing facilities where above ceiling clearance is available to accommodate HVAC air distribution systems. All-air systems designs shall provide for the admittance of minimum required outdoor air in all operating conditions. The use of constant volume (CV) systems shall be carefully considered and only utilized if proven more cost effective through a Life Cycle Cost Analysis (LCCA), or if required due to the area served.

The following list of systems is acceptable for air-distribution systems within healthcare facility.

Variable Air Volume with terminal reheat

This distribution system is acceptable in all facilities and is considered as the preferred solution for general clinical areas.

VAV terminal units shall be in a pressure independent configuration to maintain airflow under fluctuating upstream duct pressures as system flow changes.

Supply air VAV terminals shall be provided with integral hot water reheat coil or electrical reheat coil for areas with permanent occupancy as deemed necessary through heat load calculations.

Supply air temperature differential to room temperature shall not exceed 10°C in heating mode to prevent stratification.

Terminal units shall be equipped with sound attenuators as necessary to meet acoustic requirements.

Supply air temperatures shall be reset based on demand to minimize cooling and reheat loads.

VAV terminal units shall be provided for both supply and return/exhaust air systems for areas where mandated pressure control is required.

Terminal humidification is discouraged expect in operating theatres.

Minimum air volumes for VAV boxes shall be in accordance with the room air change rate, as per the Table in this standard for ventilation. This will generally be higher than the typical 30% minimum for a conventional commercial VAV system. The tender drawings & specs should indicate minimum value for each VAV box.

Fan Coil Units

Chilled water-based Fan Coil Units are not recommended solution for administration and support areas as well as clinical areas as constraints in filtration requirements for recirculation by room units.

For Larger facilities, use of FCU is discouraged due to higher energy consumption, maintenance issues and the need to access clinical spaces to replace components such as filters, fan motors and control valves.

In specific cases fan coil units may also be used in circulation spaces, if there are high sensible cooling loads from heat gain through the building envelope or in spaces where there are localized heat gain from electro-mechanical equipment's; such as plant rooms, electrical and telecom rooms.

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Care must be taken to place FCU's outside of the electrical/telecom rooms to avoid chilled water piping within the room.

Fan coil units shall not be used to dehumidify the outdoor air as outdoor air has a high moisture fraction. A dehumidified outdoor air supply should be ducted to the Fan coil units through a dedicated 100% outdoor air handling unit, utilizing energy recovery.

DX or VRF based Fan coil units are also acceptable where there is no centralized source of chilled water for smaller installations.

Displacement Ventilation

Displacement ventilation is an acceptable solution for non-clinical areas only, however it is not good practice. It is not recommended in clinical areas due to the restrictions created by the fixed location of the supply diffusers. Where displacement ventilation is used, the designer shall co-ordinate locations of terminals carefully with the interior design proposals to ensure thermal comfort is achieved and future flexibility is not compromised.

Displacement ventilation can be particularly effective in spaces with lofty ceilings such as entrance areas atriums or spaces with high occupancy levels such as lecture halls.

If utilizing displacement ventilation, the designer shall avoid, due to open corridors with adjacent clinical spaces .

Natural Ventilation

Natural ventilation is not prohibited but ducted mechanical ventilation will still be required to ensure adequate number of air changes, even if natural ventilation is available.

Depending on climatic conditions, temperature, humidity, risks of natural disasters, natural ventilation constituting of operable windows is not a preferred option anymore. Furthermore, this leads to unfiltered outside air which due to increasing urbanization is under continuous degradation with major cities around the world having poor outside air quality. Thus, hospitals and healthcare facilities are encouraged to duct in outside air through mechanical ventilation.

Unacceptable HVAC Systems – Distribution

The following systems are unacceptable and should not be used in future healthcare projects.

Chilled beams or chilled ceilings due to concerns over potential condensation and associated infection control risks.

Dual duct VAV systems.

HVAC Systems Design Criteria & Relevant Applicable Codes

The following section aims to provide a general brief for the HVAC systems for new construction and major renovation healthcare projects.

External Design Criteria

The external design conditions can be obtained from <https://ashrae-meteo.info/v2.0/index.php> with this standard Climatic database or other local data sources. The design conditions should be carefully vetted, especially the wet bulb temperature for worse case air intake for outside air.

Link for climatic condition available in this standard, 20-year projected DB and WB conditions are encouraged to be used for water/air cooled chillers and cooling towers, respectively.

Design Criteria	Value to be utilized
Outside design conditions for cooling load calculation	Utilize Annual Cooling Load Conditions 0.4% Values.
Outside design conditions for fresh air	Utilize Evaporation Conditions 0.4%.
Outside design conditions for heating load	Utilize Annual Heating values 99.6%.
Outside design conditions for humidification	Utilize Humidification values 99.6%
Outside design conditions for selecting air cooled HVAC equipment (Recommended)	Projected Dry Bulb for next 20 years, Refer to link
Outside design conditions for selecting cooling towers (Recommended)	Projected Wet Bulb for next 20 years, Refer to link

Envelope Design Criteria

As a best design practice, the following values are suggested to be used for future healthcare projects following the iHFG guideline.

Component	Recommendation (U- W/m2. K)
Roof	U-0.3 (Insulation entirely above the slab) U- 0.2 (Cold Climates) Solar Reflectance Index (SRI) > 78
External Wall	U-0.4 (Mass Walls) U-0.3 (Cold Climates)
Floors	As per project requirements
Doors	U-0.74 (Swinging) U-1.45 (Non-Swinging)
Vertical Fenestration (Full Assembly)	40% max (Window to Wall Ratio) U-1.9 or lower (Thermal Transmittance) 0.25 max (Solar Heat Gain Coefficient) 0.15 min (Light Transmittance)

It is encouraged to improve upon the recommended values for medium to large healthcare facilities as they are operational round the clock and consume the most energy as compared to any other building type.

Internal Design Criteria

The internal design criteria for facilities is split up into two categories, clinical and non-clinical spaces.

The below tables would identify the performance level for internal spaces clinical and the associated ceiling with respect the heat gain from internal sources for both spaces.

Non-clinical ancillary support buildings that are part of the development shall follow the guidelines for non-clinical spaces

Non-Clinical Spaces

Criteria	Requirements
Temperature	The internal temperature requirement for non-clinical spaces shall be set at 24 °C DB.
Relative Humidity	General non-clinical spaces would not be provided with active relative humidity control, unless it is a requirement related to specialist equipment within the space. The designer to ensure that maximum relative humidity is kept within 60% by employing BMS control algorithms.
Electrical Lighting	Lighting loads shall be based on an average watts/m2 figure for each type of room based on a representative lighting layout. General guidance can be obtained from ASHRAE 90.1.2016 Lighting Power Density.
Electrical Small Power	Where there are specific equipment rooms, the heat loads shall be based on the 'worst case' values from the potential range of suppliers. Where there are no specific equipment layouts, allowances for small power loads shall be made on an average watts/m2 basis as appropriate for the space type. Refer to ASHRAE Handbook Fundamentals 2017 Chapter 18 Non-Residential Cooling and Heating Load Calculations.
Occupancy	The design shall be based on the furniture layout or ASHRAE 62.1, whichever is the more onerous.
Infiltration	The building should be designed to be at positive pressure with respect to the atmosphere, always. Infiltration load should only be considered for high rise.
Ventilation	The minimum requirements for ventilation shall be as specified in the ASHRAE Standard 62.1.2016.
Acoustic Requirements	The design for HVAC system should follow the acoustic requirements listed out in Annexure A-2

Clinical Spaces:

Criteria	Requirements
Temperature	Internal design temperatures shall generally be in accordance with ASHRAE Standard 170 & HVAC room design segment in this document. If there is an equipment specific space temperature requirement listed in the Room Data Sheets (RDS) it will supersede ASHRAE requirements.
Relative Humidity	Internal relative humidity shall generally be in accordance with ASHRAE Standard 170. If there is an equipment

Criteria	Requirements
	specific temperature requirement listed in the Room Data Sheets (RDS) it will supersede ASHRAE requirements.
Electrical Lighting	Lighting loads shall be based on an average watts/m ² figure for each type of room based on a representative lighting layout. General guidance can be obtained from ASHRAE 90.1.2016 Lighting Power Density.
Electrical Load Due to Medical Equipment	Medical equipment heat dissipation loads shall be based on the Room Data Sheets (RDS) listed values. RDS values should represent actual equipment heat dissipation values using 'worst case' manufacturer's published data from the range of potential suppliers.
Occupancy	Design occupancy for each space shall be as specified on the room data sheets. If no occupancy is provided, the design shall be based on the furniture layout or ASHRAE 62.1, whichever is the more onerous.
Infiltration	The building should be designed to be at positive pressure with respect to the atmosphere, at all times. Infiltration load should only be considered for high rise.
Ventilation	The minimum requirements for ventilation shall be as specified in the ASHRAE Standard 170.2017. For spaces not listed under ASHRAE 170, utilize ASHRAE 62.1.
Acoustic Requirements	The design for HVAC system should follow the acoustic requirements listed out in Annexure A-2

Air Intake & Exhaust

The air intake and exhaust louvers/vents positions should be carefully planned for healthcare facilities to ensure that there is no recirculation of air. Minimum separation distances mentioned in ASHRAE standards to be minimum 8m from Fresh Air and Exhaust Air termination.

Harsh climatic conditions warrant special attention to the air intake air louvers. As a minimum the intake outdoor air should be drawn into the system through sand trap louvers sized at 1m/s across the face area of the louver to provide an 80% or higher filtration efficiency at coarse sand grain size (355-425 microns).

For bigger healthcare facilities providing a central air intake to the 100% outside air energy recovery air handling unit it is recommended to utilize a self-cleaning inertial air cleaner. The air cleaner provides 99% efficiency at a sand grain size of 10 to 100 microns. Due to the high velocity intake it also overcomes the constraints regarding the large face area, which are a problem for the standard sand trap louver.

Washable aluminum filters can be provided at the rear of the sand trap louver. If provided, designer should ensure access for proper maintenance. If proper access cannot be guaranteed, enabling the removal of the filters without shutting down the AHU, the filters should not be provided for the air intake louvers as dirty filters would clog the air stream providing higher pressure drop and in turn reduced air volume.

Based on the ambient acoustic levels, determined through a survey conducted at the site by a professional acoustic consultant, if required the outdoor air intake & exhaust should be provided with a sound attenuator.

Buildings shall maintain a positive pressurization (5-10% net positive). Tighter buildings are eligible for less net pressurization. Designers should ensure enough outside air is provided for adequate pressurization. It is encouraged to undertake blower door testing for facility integrity as part of the testing and commissioning process.

Filtration

Mechanical filtration plays a very important role in ensuring that the hospital continues provide best in class care & is fit for occupancy. Mechanical filtration is one of the key elements to healthcare HVAC design and is of primary significance regarding air quality & infection control.

All air handling units directly serving the spaces & outside air handling units serving downstream terminal units, should be provided with a 1st stage filtration of no less than MERV 8/ePM₁₀ 60% rating and a final filter downstream of all wet-air cooling coils and supply fan according of no less than MERV 14/ ePM₁ 70% rating.

Majority of the spaces are highly critical departments [Critical Care, OT, NICU, Procedure rooms, Recovery Rooms, Isolation Rooms, X-Ray Rooms (surgery/critical care & catherization/angiography), Endoscopy Rooms, Autopsy Room, etc.] where cleaning difficulty and potential building of contamination has led to the requirement of no-recirculation of air. Refer to Annexure A-3 for filtration requirements.

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Ultraviolet (UV-C) disinfection (also called ultraviolet germicidal irradiation [UVGI]) is used to inactivate microorganisms. The use of UV-C is encouraged for healthcare projects specially for cooling coil surfaces to avoid fungal amplification. The peak effective wavelength range for inactivation of microorganisms is near 254 nm. Use of upper air UV for patient rooms in critical care or isolation rooms is also encouraged to deactivate the virus spread.

Alternative filtration techniques such as electronic filters and air cleaners using photocatalytic oxidation (PCO) are not encouraged to be used because of negative health effects that arise from exposure to ozone and its reaction products. Substantial technical evidence is required on the use of these techniques, validated by international agencies, test standards and standard engineering bodies, local authorities etc. If utilized, they are not considered a replacement for mechanical filtration but can be considered as aides to achieve better indoor air quality.

Materials

The table below provides basic information on reference design standards for core HVAC system components. It is highly recommended that the materials and system components carry certifications citing compliance to the following standards or approved equals for all new construction and major renovation healthcare projects. Latest versions of the following will apply at the time of the project registration.

Certification & Design Standards for All Facilities		
SUBJECT	DOCUMENT	EDITION
Ductwork	DSP DW/144 Specification for sheet metal ductwork. Third edition	2016
	DSP DW/172 Specifications for kitchen ventilation systems.	2018
	SMACNA HVAC Systems Duct Design	2006
	SMACNA HVAC Duct Construction Standards-Metal & Flexible	2005
Pipework	ASME B31.9 Building Services Piping	2014
	ASTM A53 Pipe, Steel, Black and Hot-Dipped, Zinc Coated (Galvanized), Welded and Seamless.	
	ASME B31.5 - Refrigeration Piping	2016
Filter Standards	ASHRAE 52.2-Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size	2017
	ISO Standard 16890 Air Filters for General Application	2016
HEPA Filter Standard	EN 1822 High efficiency air filters (EPA, HEPA and ULPA). Aerosol production, measuring equipment, particle counting statistics	2009
	ISO 29463 High efficiency filters and filter media for removing particles from air	2017
Fan Coil Units & Package Units	Eurovent RS 6/C/002-2017 Rating Standard for Certification of Non-Ducted Fan Coil Units	2017
	Eurovent RS 6/C/002A-2017 Rating Standard for Certification of Ducted Fan Coil Units	2017
	AHRI 340/360 Performance Rating of Commercial and Industrial Unitary Air-Conditioning and Heat Pump Equipment	2015
	AHRI 310/380 Standard for package terminal AC and Heat Pump	2017
	AHRI 410 Forced-Circulation Air-Cooling and Air-Heating Coils	2001
	AHRI 440 Performance Rating of Room Fan-Coils	2008
	ANSI/AHRI 1230 Performance Rating of VRF Multi Split AC & Heat Pump Equipment	2010
Standard Air Handling Unit Construction	Eurovent RS 6/C/005-2017 Rating Standard for Certification of Air Handling Units	2016
	AHRI 1350 Mechanical Performance Rating of Central Station Air-handling Unit Casings	2014
	AHRI 430 Performance Rating of Central Station Air-handling Unit Supply Fans	2014
Hygienic Air Handling Unit Construction	VDI 6022 - Ventilation and indoor-air quality - Hygiene requirements for ventilation and air-conditioning systems.	2011
	DIN 1946-4 - Ventilation and air conditioning - Part 4: Ventilation in buildings and rooms of health care	2008

Certification & Design Standards for All Facilities		
SUBJECT	DOCUMENT	EDITION
	Eurovent RS 6/C/011-2017 Rating Standard for Certification of Hygienic Air Handling Units	2017
Boilers & Chillers	ANSI/AHRI 1500 Performance Rating of commercial Space Heating Boilers	2015
	ARI 550/590 Performance Rating of Water Chilling Packages Using the Vapor Compression Cycle	2017
Cooling Towers	CTI (Cooling Technology Institute) STD-201 Certified	2013
Ventilation Equipment	AMCA 210 Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating	2016
	AMCA 300 Reverberant Room Methods for Sound Testing of Fans	2014
	AMCA 301 Methods for Calculating Fan Sound Ratings from Laboratory Test Data	2014

Hydronic System Design

Hydronic refers to the science of heating or cooling with water. Open systems are open to the atmosphere at least one location, such as cooling towers. Closed systems on the other hand are not open to the atmosphere.

Piping systems distribution scheme can be direct or reverse return. With the advent of Pressure Independent control valves (PICV), direct return systems outweigh the advantages offered by reverse return both in terms of cost and system simplification, so they are encouraged for new healthcare facilities.

All new facilities using hydronic cooling or heating system, should utilize pressure independent two-way control valves.

Hydronic piping distribution schemes should either be constant primary / variable secondary pumping or variable primary pumping. For Variable Primary Flow, the chillers must be provided with automatic isolation valves and the decoupler line provided with a control bypass actuated by a flow meter ensuring that the minimum flow through the chiller is guaranteed. Care must be taken in correct sizing of expansion tanks and air separators especially for heating hydronic systems.

Variable Primary Flow pumping systems are the preferred choice for future medium to large scale healthcare projects because they offer

- Low installed cost
- Reduced Mechanical room footprint
- Higher system efficiency
- Best response to Low Delta T syndrome.

Constant primary / variable secondary systems are also acceptable. Pumps should be in headered configuration and located in a controlled environment.

Refer to the Figure 2.1, 2.2, 2.3 for illustrative example of the various distribution schemes.

Pipe material should be Black Steel Schedule 40 with welded or grooved joints.

HVAC Insulation Requirements

All insulation should be rated to DIN EN 13501 A1, A2, B, C with S1 or S2 smoke performance and D0 droplet performance. ASTM E-84/UL 723 is only applicability should be checked as per material type. The system rating shall be based on insulation, jacket, adhesives, coatings, fittings, and cements. Any treatment of jackets or facings to impede flame and/or smoke shall be permanent.

Thermal performance, Vapor permeability and environmental performance should be as per local regulations. Anti-microbial requirements should be as per VDI 6022 or ASTM G21 or approved equal standard.

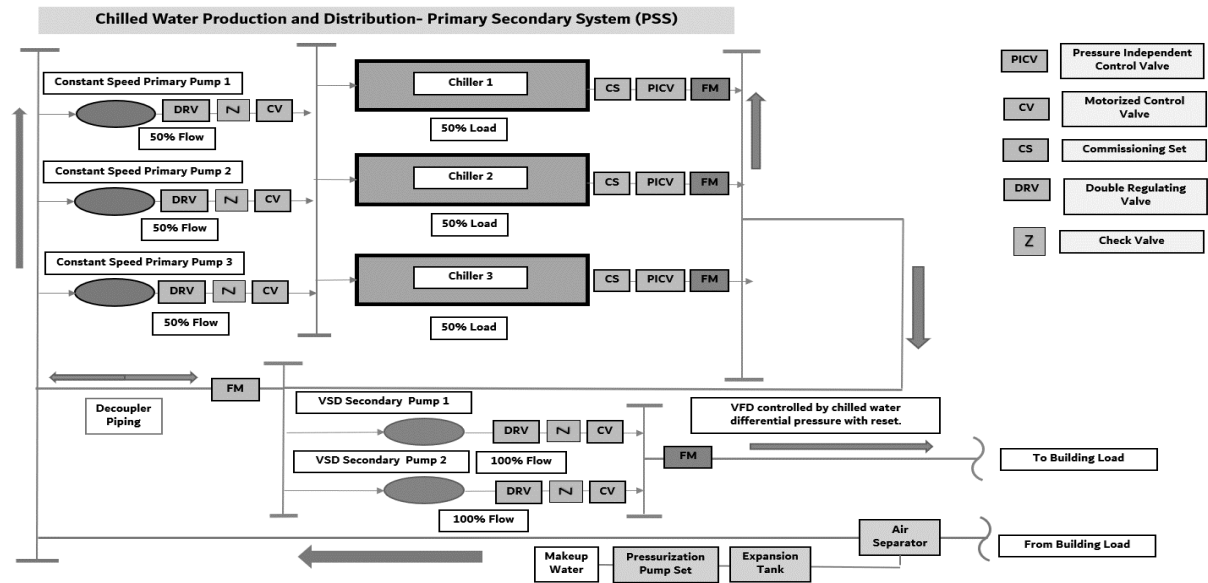


Figure 2.1

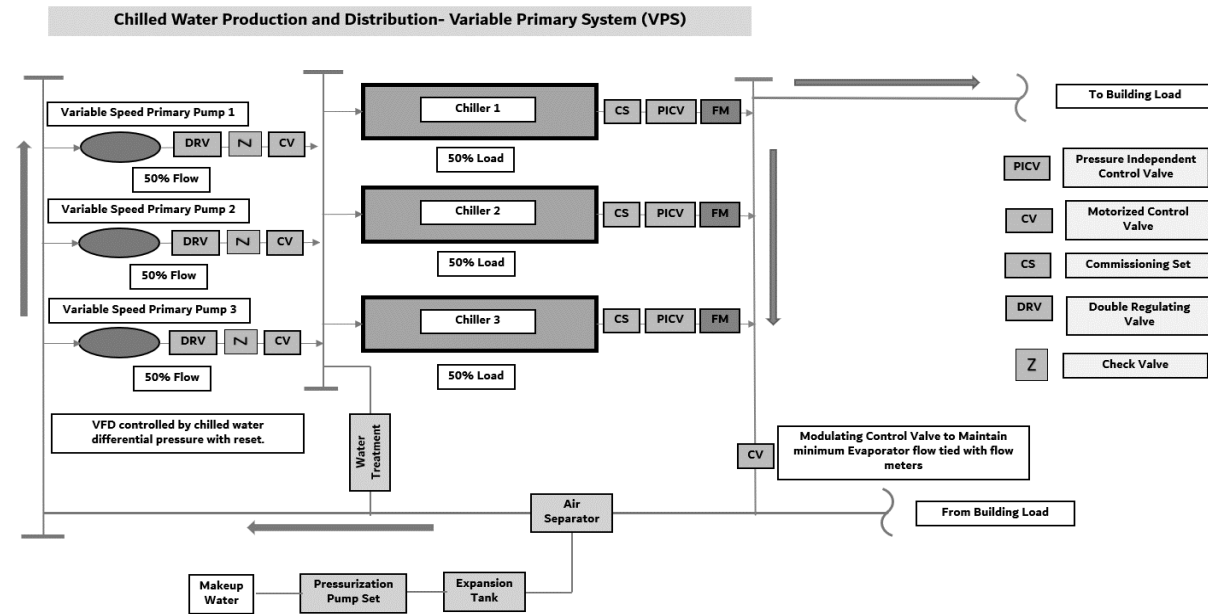


Figure 2.2

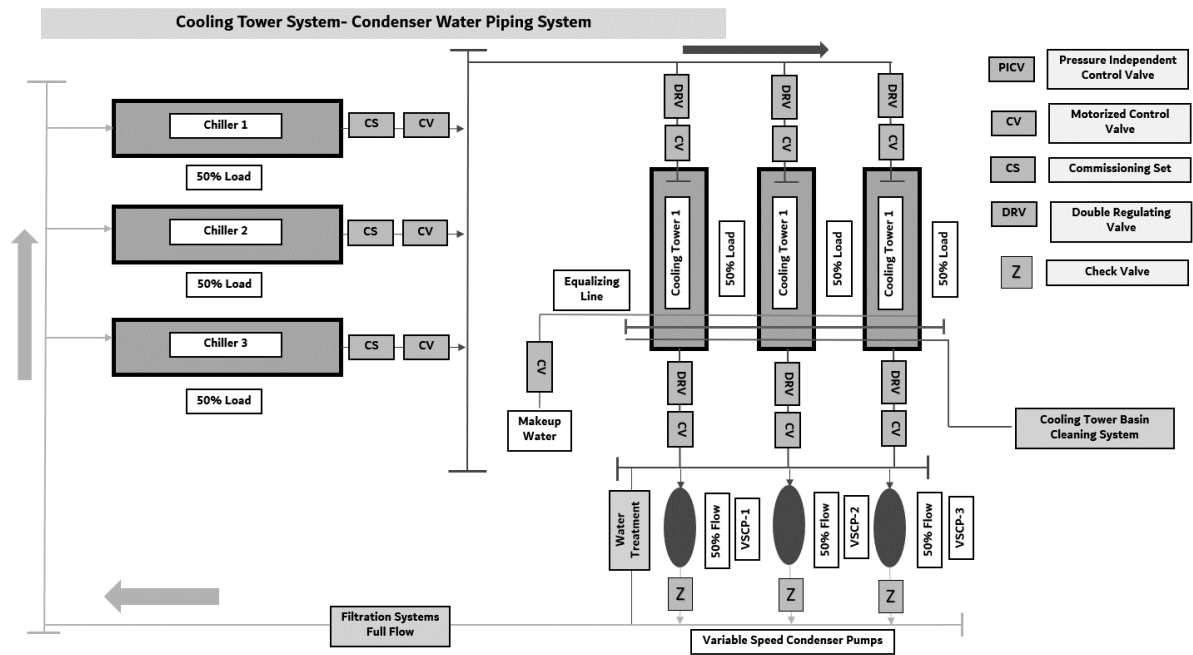


Figure 2.3

HVAC System Location Access & Maintenance

Major Equipment

Location

All significant HVAC equipment such as FAHU's, AHU's shall be located in enclosed mechanical plant rooms. The only HVAC equipment which may be located externally is the following:

- Exhaust Fans.
- Heat Rejection Equipment. (e.g. Air-cooled chillers, Air cooled condensers, Cooling Towers, etc.)
- Staircase & Lift core Pressurization Fans.
- Smoke Management Fans.

Rooftop/Exposed air handling units are not recommended in high humidity/hot conditions.

Mechanical rooms shall be provided with air-conditioning & ventilation. In temperate/cold climates air handling units can be located on rooftop/exposed.

Access

Mechanical rooms and roofs with mechanical equipment shall be provided with staircase and preferably lift access to facilitate maintenance and equipment replacement. Access to mechanical rooms and roof mechanical areas shall be directly from cores or main corridors. It is not acceptable for the access to mechanical rooms to be through treatment or patient care areas.

Clear access routes through mechanical rooms and roof areas shall be provided from the staircases. Routes shall be clearly and permanently marked on the mechanical room floor. The minimum clear height for access routes shall be 2000mm or higher if dictated by the dimensions of equipment.

Steps on access routes are not acceptable. If changes of level are needed, or if services must be run at low level across an access route, a ramp must be provided.

Service Shafts

Location

Service shafts shall be strategically located to provide rational and flexible services installations and minimize the size of the distribution ductwork and pipework on each floor. It is recommended that main ductwork shafts are located away from stair cores and elevator shafts to allow ducts to enter and leave the shaft on all sides.

Pipework shafts are most suited to locations adjacent to structural cores.

In clinical facilities, shafts shall not be located inside surgery suites or critical care areas. If the designer encounters a specific situation where a shaft is needed in one these spaces it should be discussed and agreed with AHJ during the schematic designs stage, through architectural design submission.

Access

Pipework shafts shall be provided with access doors at each floor level to allow for inspection and maintenance and installation of additional pipework in the future. Removable floor gratings are recommended to be provided where clear openings exceed 450mmx450mm.

Ductwork shafts shall be provided with access doors as needed to enable cleaning. It is anticipated that installation of additional ductwork would require the removal and replacement of wall finishes.

Terminal Equipment Locations

Locating HVAC equipment in ceilings above patient, staff and public areas shall be avoided where possible. Where it is necessary, its location shall be carefully selected to minimize the disturbance during maintenance and limit the infection control measures which are required to access it.

In clinical facilities it is not acceptable under any circumstances to have HVAC equipment accessed from the space in any of the areas listed below. Terminal units should be located outside the rooms in corridor spaces or other back of house spaces.

- Surgical Suite/ Zone
- Treatment Room
- All Critical Care Areas (ICU, CCU, NICU, PACU)
- Patient Rooms (permitted over ensuite)
- Sterile Store
- Fire Escape Horizontal Exit Passageway

The only exception is room side accessible terminal HEPA filters and fan filter units (FFU), where access is obtained through special housing's allowing quick replacement. All HEPA filters should be located at terminal locations.

Maintenance Strategy

It is strongly suggested that the designer develops an access and maintenance strategy document. This document shall clearly describe the access and maintenance strategy for all mechanical systems, including HVAC, plumbing and medical gas. Document shall be made available during the 90% stage inspection stage. The document must identify the strategy for plant maintenance and replacement including the following considerations:

- Locations with Accessible ceilings for terminal units (VAV, FCU etc.)
- Access and Maintenance clearances for major equipment.
- Major plant removal routes with mechanical rooms.
- Infection control and patient safety implications.

Design Considerations - HVAC Equipment's

The following section outlines the important design considerations that should be kept in mind while selecting HVAC equipment for healthcare facilities.

Central Plants

If the project is significantly large, it is beneficial to locate all major MEP equipment at a central location. This will help optimize the cost and increase the overall efficiency of all the systems.

District cooling availability for the project should also be ascertained at an early stage and if approved by the local district cooling provider the building should be designed to be hooked up to district cooling system. The building still must provide critical cooling (SSU, CSSD, Surgical Suite, Labor & Delivery Suite/Birthing Unit, Recovery, Emergency, Intensive Care, Nursery & optionally Inpatient Rooms) in case of failure of the district cooling network, by means of local heat rejection equipment owned by the building owner.

Remotely located central plant may use directly buried piping or use trenches/tunnels to connect to hospital building. When utilizing service tunnels, a minimum of 2000mm clear depth should be considered with a 900mm access passageway in between pipes to allow for sufficient space for maintenance.

Central Chilled Water Plant Considerations

The following recommendations are for central chilled water plants.

- Select cost-effective and optimum central chilled water plants and/or small chilled water systems to meet the project-specific requirements. Each installation shall consist of multiple (minimum two) chillers.
- For central plants and small systems, it is recommended to conduct a comprehensive study to evaluate and define the lowest life-cycle cost performance of the chilled water system. The study shall address both CAPEX and OPEX.
- Chillers shall be rated and certified as per AHRI conditions.
- Where a central plant serves more than one air handling system, the capacity of the central plant shall be calculated based on the peak simultaneous load, not the sum of the individual loads. In addition, the following diversity factors are reasonable when calculating central cooling plant capacity. The actual calculated central plant capacity shall be specific to the nature and size of the system(s) however and should be determined via computer simulation.
 - Lighting 0.9
 - Equipment 0.85
 - People 0.8
- For air cooled chiller in noise-sensitive locations, include chiller manufacturer's standard acoustic options in the design.
- Imaging systems such as MRIs, PET, CT Scanners, LINAC require chilled water for equipment process cooling. Central plants should be sized to cover process loads, if use of plant central chilled water use is approved by the imaging equipment manufacturer, otherwise a dedicated chiller plant must be provided. Typically, the chiller, buffer tanks, and pumps for these applications are provided by the manufacturer of the imaging equipment for installation by others.
- Potable water cooling should be provided as per the hydraulics engineering section of this report.
- Adequate space should be provided for equipment removal and maintenance. Replacement routes should be marked on the design drawings. Design for non-disruptive access to all chillers, pumps, cooling tower, and cooling tower components without the need to disassemble or remove other equipment or systems and/or building components such as piping, doors, walls etc.
- Higher delta T should be utilized to obtain energy savings by lowering pumping costs.
- Consider VFD driven equipment for further energy savings for any pump consuming over 7.5kW.
- Arrange piping, especially piping in hydraulic decoupler to ensure that all water flow meters have ideal flow conditions for accurate measurement. Follow worst case flow meter recommendations.
- Cooling Towers should be provided with an automatic basin cleaning system, which help in mitigating risks associated with natural calamities & the risk of legionella associated with manual cleaning.
- Cleaner environment friendly refrigerants should be utilized. ODP value should be 0 and GWP value should be less than 2500. HFO's are being developed which have much lower GWP values <10 and are encouraged for use.

Central Hot Water Plant Considerations

The following recommendations are for central hot water plants.

- Select cost-effective and optimum central hot water plants and/or small hot water systems to meet the project-specific requirements. Each installation shall consist of multiple (minimum

two) Boiler/Calorifier etc.

- For central plants and small systems conduct a comprehensive study to evaluate and define the lowest life-cycle cost performance of the hot water system. The study shall address both CAPEX and OPEX.
- Adequate space should be provided for equipment removal and maintenance. Replacement routes should be marked on the design drawings.
- Higher delta T should be utilized to obtain energy savings.
- VFD driven equipment should be utilized, for further energy savings.

Energy Benchmarking

Medium to Large scale healthcare projects are encouraged to apply the principles mentioned in ASHRAE 189.3 Construction, and Operation of Sustainable High-Performance Health Care Facilities.

In addition, LEED v4 for Healthcare guiding principles are also encouraged to be utilized for a sustainable healthcare building.

HVAC Major Source Equipment's

The following section lists out the specific requirements for major HVAC source equipment's to be utilized for healthcare projects. The aim is not to create an equipment specification list but to highlight essential elements of design related to each equipment which must be considered due to the critical nature of the healthcare facilities & the challenging climatic conditions.

Water Cooled Chillers

- Water cooled chillers can be centrifugal/screw or absorption type. Most common water-cooled chillers utilized are centrifugal chillers with single compressor or dual compressors based on the tonnage.
- Chillers should be in air-conditioned environment, with adequate clearance space for maintenance.
- Consultant is encouraged to undertake an LCC study for VFD chillers vs. standards chillers & also for the type of chillers used.
- Refrigerants with 0 ODP and less than 2500 GWP should be utilized for future healthcare projects.
- Provide emergency chilled water flanged piping connections covered with blind flanges and isolation valves for emergency chilled water service where redundant chillers are not installed.
- Chillers should adhere to the performance metrics listed in ASHRAE 90.1 or equivalent.

Air Cooled Chillers

- Air cooled shall be screw type for tonnage over 100 tons. Scroll type chillers can be utilized for smaller installations. Reciprocating chillers are not allowed to be installed in future healthcare projects.
- Consultant is encouraged to undertake an LCC study for VFD chillers vs. standards chillers.
- Provide emergency chilled water flanged piping connections covered with blind flanges and isolation valves for emergency chilled water service where redundant chillers are not installed.
- Chillers should adhere to the performance metrics listed in ASHRAE 90.1 or equivalent.

Cooling Towers

- Induced draft-type, counter-flow, factory-fabricated, and factory-test cooling towers are preferred choice for new construction and major renovation projects. The cooling towers shall be certified by the Cooling Tower Institute (CTI) and shall meet OSHA safety requirements.
- It is recommended that the Cooling Tower structure should be stainless steel, with FRP removable louvers and an FRP or Stainless-Steel basin.
- Consultant is encouraged to undertake an LCC study for VFD cooling tower fan motors vs. standard motors.
- Cooling Towers should be provided with a Basin cleaning system.

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- Legionnaires Disease: When a new hospital building is constructed, place cooling tower(s) in such way that the tower drift is directed away from the hospital's air-intake system and design the cooling towers such that the volume of aerosol drift is minimized.

Heat Exchangers

- Heat exchangers used for HVAC applications for district cooling systems should comply with the regulations from the relevant district cooling provider etc.
- For potable water pre-conditioning and other applications plate and frame type heat exchangers should be utilized. It is recommended that two heat exchangers as a minimum are provided, each sized at 50% of the load.
- For low temperature hot water circuit for heating, heat exchangers can either be plate & frame type or shell & Tube type. It is recommended that two heat exchangers as a minimum are provided, each sized at 50% of the load.

HVAC Major Airside Equipment's

The following section lists out the specific requirements for major HVAC air side equipment's to be utilized for healthcare projects. The aim is not to create an equipment specification list but to highlight essential elements of design related to each equipment which must be considered due to the critical nature of the healthcare facilities.

Outside Air Energy Recovery Air Handling Units

Outside air units should employ means of energy recovery. Approved methods include

- Air to Air Plate Type Heat Exchangers. Preferred choice for areas where no cross contamination is permitted such as OR's.
- Heat Pipes. Allowed for all areas but offer lower energy savings.
- Total Energy Recovery Wheels. Allowed & encouraged for all areas except OR's. Must have a cross contamination limit of less than 0.04% by particulate count and have a purging section.
- Run around Coils. Allowed for all areas but offer lower energy savings.

Outside air energy recovery should not be employed for the following air streams. These should be directly exhaust to ambient with dedicated exhaust.

- Exhaust from all fume hoods and bio-safety cabinets.
- Kitchen Exhaust (Range hood and wet exhaust).
- Autopsy Exhaust.
- Isolation Room Exhaust.
- Wet Exhaust from cage and cart washers.
- ETO- Ethylene Oxide Sterilizers Exhaust.
- Refer to the Figure 2.4,2.5,2.6 for outside air handling unit approved configurations.
- Refer to the AHU section for other applicable notes.

Typical Healthcare Outdoor Air Handling Unit with Energy Recovery Design – Type A- Plate Type Heat Exchanger with Horse Shoe Heat Pipe

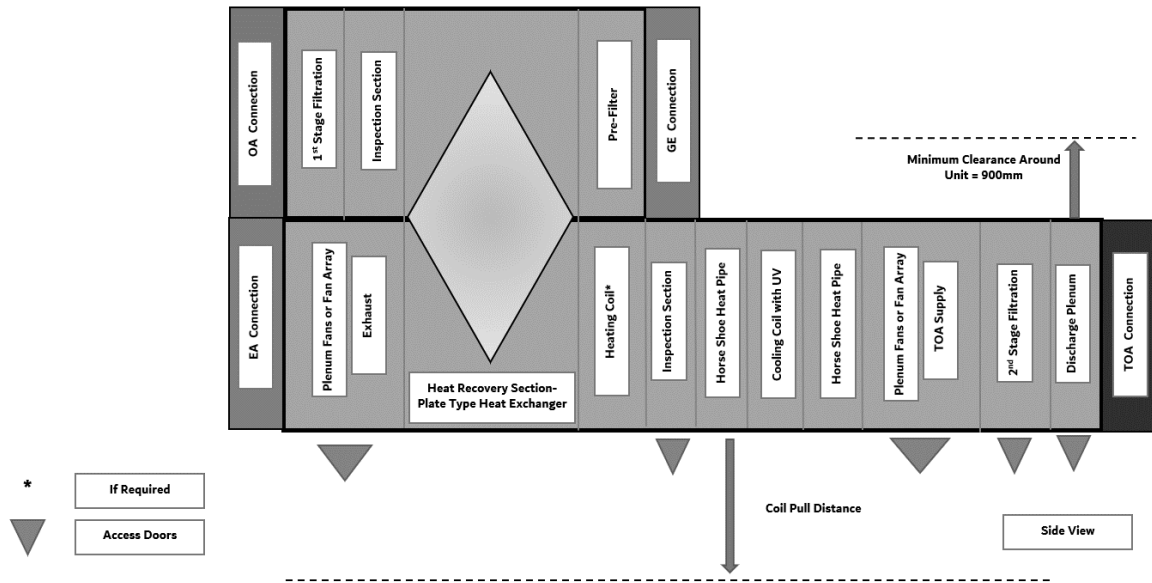


Figure 2.4

Typical Healthcare Outdoor Air Handling Unit with Energy Recovery Design – Type B – Enthalpy Wheel with Horse Shoe Heat Pipe

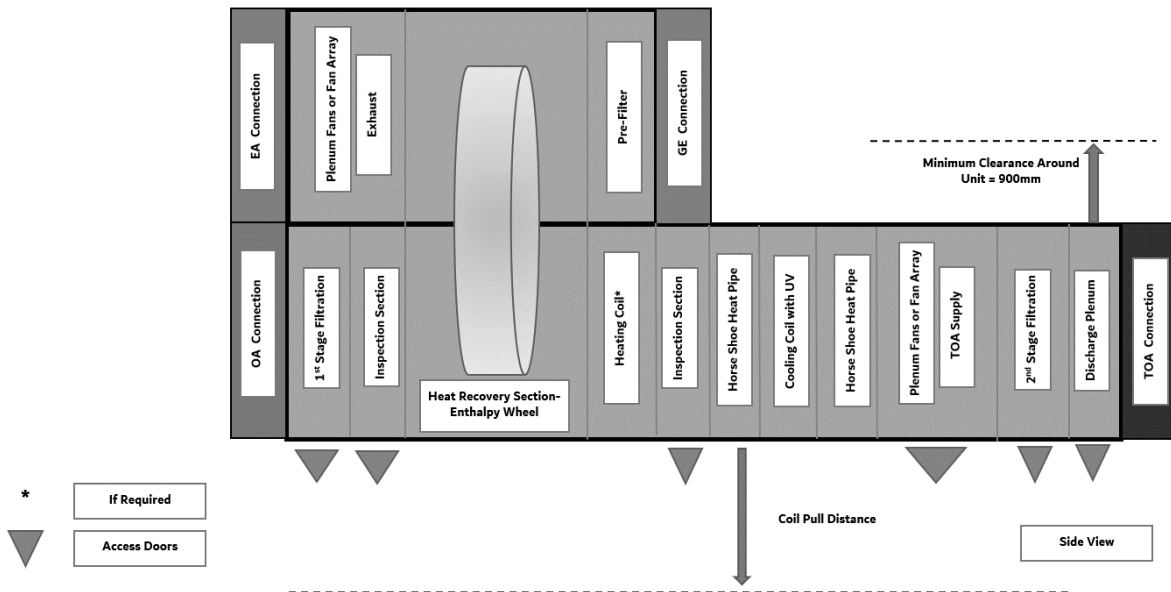


Figure 2.5

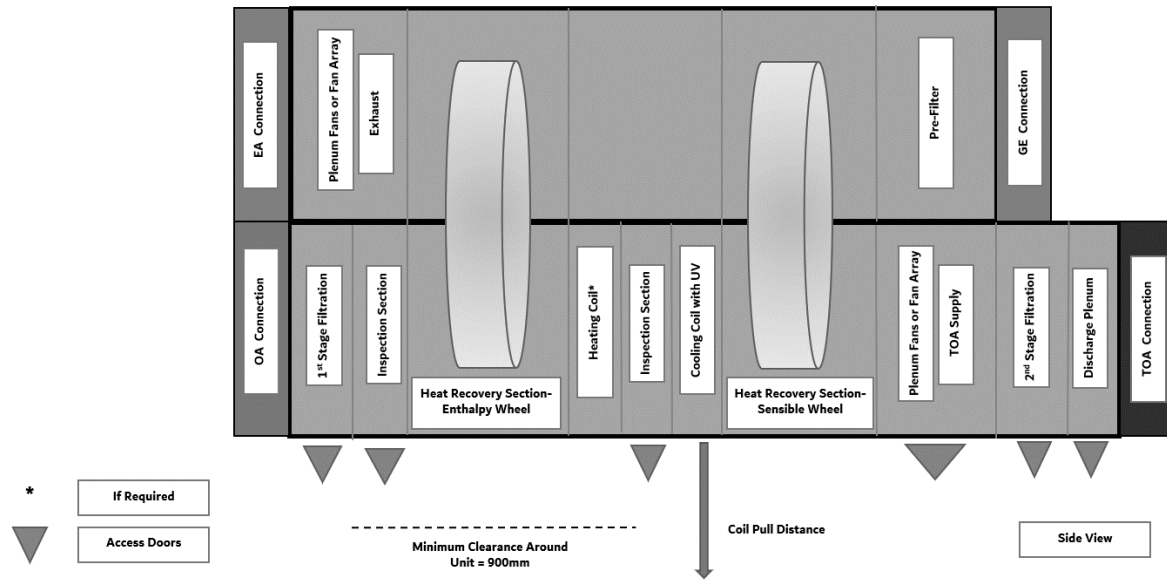


Figure 2.6

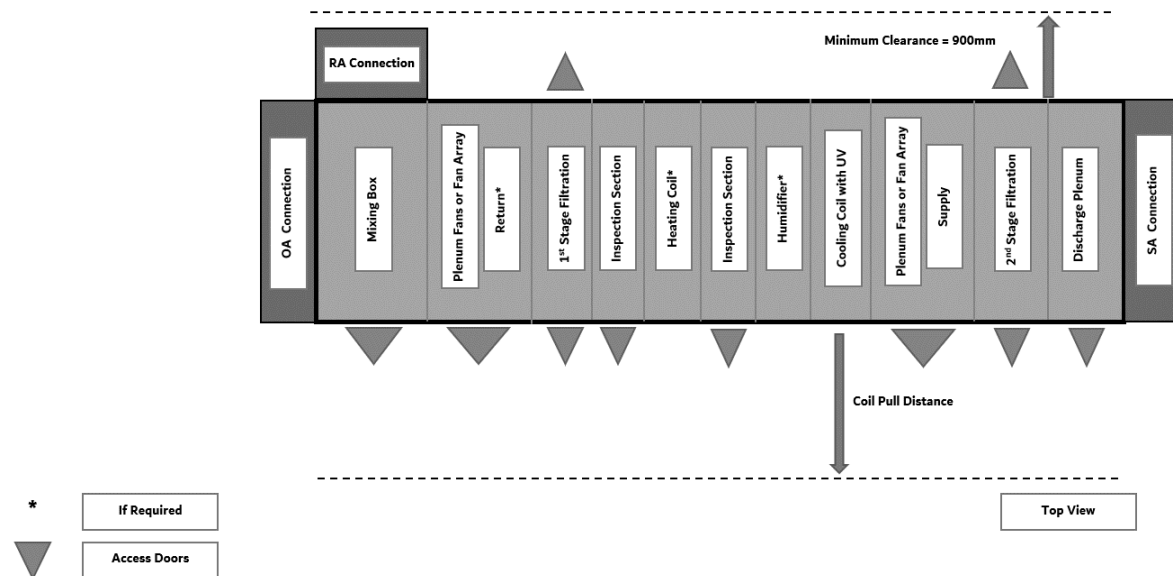
Air Handling Units

- The capacity of a single air-handling unit shall not exceed 50,000 m³/hr. [16,500 L/s].
- Air handling units shall be AHRI or Eurovent certified, factory-fabricated, and the standard product of one manufacturer. All air-handling units shall be constructed in modular and draw-through configuration. Use of blow-through air-handling units are not permitted, as fully saturated air leaving the cooling coil causes damage to the downstream filters and sound attenuators.
- Air handling units serving clinical areas should be hygienic type units. Refer to the materials section for required certifications and standards.
- To prevent cross contamination, separate AHU's should be provided as a minimum for the following spaces.
 - Operating Theatres
 - Mortuary
 - Main Kitchen
- Each air-handling unit shall be installed as a standalone entity without any physical interface with another air-handling unit. Selection of stacked (one on the top of another) air handling units is not permitted. Use of a common return air fan for two or more air-handling units is also not permitted.
- Use of a single or multiple plenum fan (fan array) is permitted & encouraged over housed, air-foil centrifugal fans. Fan motors shall be premium efficiency.
- Where room air can be returned to the system, provide a dedicated return or relief air fan for each air-handling unit to facilitate room-by-room air balance, economizer cycle, and intended volumetric air balance. Provide a direct digital control (DDC) interlock between the supply and return or relief air fans.
- Variable frequency drives (VFD) shall be utilized in all air handling units and rooftop units. Building type (e.g., hospital, outpatient facility, etc.) will determine level of redundancy required for VFDs. VFDs shall include either a bypass switch or be configured in a manner that failure of one VFD does not disable the entire unit. Fan motor shall be high efficiency.
- Each cooling coil shall not exceed six (6) rows and ten (10) fins per inch (FPI). Design two (2) coils in a series arrangement if the cooling coil capacity requirement exceeds the capability of a 6 row, 10 FPI coil. Chilled water shall be piped in series through both coils, and a 42-inch access section shall be provided between the two equally sized coils

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- Maximum cooling coil discharge face velocity shall not exceed 450 fpm. Heating coil discharge face velocity shall not exceed 800 fpm.
- Ultraviolet (UV) lamps shall be located on the leaving air side of the cooling coil.
- Access doors (or panels) on the air handling unit sections shall always open against the positive side of the door and shall not be blocked by internal filter casings or internal equipment components. Micro switches or safety switch interlocks need to be provided at access doors or panels on UV sections to protect maintenance personnel from possible injuries.
- Refer to Figure 2.7 for general AHU approved configuration.

Typical Healthcare Hygienic Air Handling Unit Design



Fan Coil Units

- All Fan Coil Units must be provided with a source of treated precooled dehumidified fresh air through the DOAS systems. Direct injection of outside air dumped over the ceiling void or ducted to units is not allowed.
- Fan coil unit systems served by chilled water with hot water or electric heating are an attractive solution for areas requiring special control or out of hours operation. Such areas include computer/communication rooms, lift machine rooms, distribution communications and electrical rooms, PABX rooms and administration areas. Fan coil units are not recommended for clinical areas where recirculation to be properly filtered.
- Fan Coil unit's usage is highly discouraged for new constructions for areas other than mentioned above, where adequate space for distribution ductwork can be provided.
- Select fan coil units that deliver the required capacity at medium speed.
- For new construction and major renovation, PICV should be provided for each FCU.
- FCU shall be located outside of patient occupied spaces/rooms for ease of maintenance.

Terminal Units (VAV, CAV)

- All terminal units shall be pressure-independent type and equipped with DDC controls. All air terminal units (constant volume or variable air volume) serving perimeter or interior spaces with permeant occupancy & mandated air change requirements as per Annexure A-1-Ventilation Rates, shall be equipped with integral reheat coils.
- The maximum and minimum air volume settings shall be factory set, but field adjustable. The minimum setting for each space should be dictated by the air change requirement, the ventilation requirement for multi zone VAV's based on ASHRAE 62.1 and the makeup air requirement for exhaust. The designer should list out minimum settings for each VAV box in the detailed design drawings.

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- All rooms requiring acoustic treatment according to Annexure A-2- Acoustics, should be provided with terminal sound attenuators.
- Variable Air Volume (VAV) boxes shall be located outside of patient occupied spaces for ease of maintenance.

Air Valve Terminals

- If VAV systems are specified, Venturi Air Terminals or Air Valves with high speed actuators are highly recommended to be utilized for all new construction and major renovation for the following space types in lieu of VAV boxes due to their higher reliability and stable airflow control.
- Operation Theatre
- Pharmacy Clean Rooms
- Isolation Rooms
- Laboratories with Fume Hoods (Should be equipped with a 3 sec or faster response actuator)
- Additional rooms as identified by the building end user that have strict pressure control requirements due to infection control issues.
- Venturi air terminal should be programmed as using the variable air volume approach with maximum energy savings. Usage based controls can also be employed at the facility owner's discretion. Each airflow control device shall be factory characterized on air stations NVLAP Accredited.
- Venturi Air Valves shall be located outside of patient occupied spaces for ease of maintenance.
- For an AHU provided with downstream venturi air terminals, it is preferable to utilize all venturis instead of a combination of venturi terminals and VAV/CAV terminals due to varying pressure drops. Low speed venturis and constant air venturis can be used for non-critical areas, for cost savings.

Humidifiers

- The need for humidification should be ascertained by psychrometric studies. If humidification is required at a large scale it can be achieved through a clean steam network utilizing steam boilers or electric steam generators.
- If active humidification is only required for critical areas such as OT, burns unit etc. it is better to be achieved by small individual package electric humidifiers.
- The humidifier should be located prior to the cooling coil and fed with clean steam (steam generated from RO or DI water and piped using stainless steel). Smaller ceiling mounted electric units should also be fed with RO or DI water.
- If duct mounted humidifiers are used 304 stainless steel ducting should be provided for a minimum of 1.5m downstream and 0.5m upstream of the humidifier. Designer Team to verify the absorption distance for each application and adjust the length of stainless steel accordingly. Duct sections downstream of steam humidifiers shall be sloped to a low point with drain valve and cap.

Diffusers, Registers and Grilles

Diffusers, Registers, and grilles should be specified as per the project requirements and in alignment with the clinical and interior design. Air Diffusion Performance Index (ADPI) shall conform to selection criteria given in ADPI table of the "Room Air Distribution" chapter of the ASHRAE Handbook – HVAC Applications 2015.

Terminal HEPA filters for all spaces other than OT's served by dedicated AHU's should be Fan powered type, catering for the entire pressure drop of the filter, allowing for the AHU supply fan to be sized for only the pressure drop of the secondary filtration.

Ductwork

- Rectangular galvanized steel has consistently been shown to be more cost effective as compared with rigid circular ductwork which is both less efficient in its space requirements and normally more expensive because of the excessive costs of fittings.

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- All clinical areas shall be provided with a fully ducted system. Use of the ceiling void, for air delivery (supply or return) is not allowed, only back of house areas and admin areas can use return air plenum but should be provided with appropriate sealing and smoke sensors.
- Duct sizing is to be based on the recommended velocity and pressure drop ranges in the project specifications, SMACNA & ASHRAE or equivalent.
- Air handling duct systems shall be designed to be accessible for duct cleaning, generally by the provision of access panels. Access panels shall be fitted at each reheat coil and fire and smoke damper to allow annual Essential Services inspection.
- It is encouraged to provide anti-microbial coating on the internal surface of the duct complying with ASTM 3152 and ASTM G21 or equivalent standard.
- Commercial dishwasher exhaust, steam sterilizer, and sterile washer exhaust shall be type 304 stainless steel with welded joints.
- Laboratory hood exhaust ductwork shall be 304 stainless steel with welded joints.
- Kitchen hood exhaust shall be 16-gauge black steel where concealed and 18-gauge, type 304 stainless steel, welded and polished to a No. 3 finish, where exposed.

HVAC Services Instrumentation and Control

HVAC Instrumentation and Control systems which are commonly part of the BMS systems are integral to the proper operation of a healthcare facility. BMS Control systems form the backbone of the operation and maintenance system for HVAC and provide the facility management team with information regarding equipment life & operational performance.

The following points should be kept in mind while designing a BMS system for healthcare applications.

- The BMS system shall be suitable, compatible, scalable, and flexible to meet the demands imposed by healthcare facilities. The system shall have spare capacity at field level to allow for departmental changes and equipment changes.
- All actuation shall be electronic.
- Specific requirements related to control actuators, control valves, control dampers, end switches, safeties and safety alarms, control wiring, air flow measuring stations, room temperature & humidity sensors, DDC control systems servers & tablet displays should be detailed within the project drawings and specifications.
- A detailed Input/output point list should be prepared by the consultant in consultation with specialist solution providers and included as part of the project tender documentation.
- BMS systems should be configured to optimize energy usage.
- Control algorithms should be programmed to utilize the data collected and allow for effective energy recovery, air-side filter diagnostics, critical alarms, and sensor calibration checks.
- Ensure system is capable of robust metering. Separate sub-meters should be allocated for lighting, HVAC plant, HVAC distribution, general power, service water heating, renewables, and whole building power & water as a minimum. Energy use should be benchmarked every month. Facility managers should be trained on continuous benchmarking.

HVAC Systems Commissioning & Handover

The HVAC systems commissioning is an important phase in the project timeline and is critical in confirming that the design parameters are met by the installed system and the system meets the minimum code requirements related to air changes, filtration effectiveness and infection control.

For medium to large scale healthcare projects an independent commissioning agent (CxA) should be employed the facility owner/client to oversee the commissioning process.

The following points should be kept in mind while preparing for commissioning of HVAC systems for healthcare facilities.

- Method Statements should be provided by the contractor during the commissioning phase for all HVAC equipment.
- Testing and Commissioning plan should be developed by the contractor in consultation with the CxA to provide a clear and concise roadmap for the implementation of the commissioning

process and to provide a record of the results of the commissioning process.

- The design consultant should engage with the owner and the facility management team and develop the Owner's Project Requirements (OPR). Furthermore, these should be formulated in a report along with the design narrative, submitted as part of the construction documentation submitted to the contractor.
- Follow ASHRAE Guideline 0-2013 and ASHRAE Guideline 1.1-2007 for HVAC&R Systems commissioning.
- It is encouraged to develop monitoring-based procedures and identify points to be measured and evaluated to assess performance of energy and water through advanced meters.
- It is encouraged to perform a building flush out for IAQ prior to occupancy or conduct testing for IAQ for particulate matter and inorganic gasses to kept under allowances mentioned in codes and standards.
- As a minimum space pressurization report is required for the following spaces:
 - Class N & Class Q -Airborne Infection Isolation Rooms
 - Class P- Protective Environment Rooms
 - Bone Marrow Transplant
 - IVF Labs and Procedure Rooms
 - Operating Rooms
 - Interventional Imaging Rooms
 - Pharmacy Clean Rooms
 - Laboratory Clean Spaces
 - Sterile Processing Rooms
 - Sterile Storage Rooms
 - Vivarium Areas
 - Operating Rooms and other clean rooms should be tested for particle counts as per international standards.
- The commissioning agent (CxA), Testing Adjusting and Balancing Contractor (TAB), MEP Contractor, Controls Contractor (BMS Contractor) should work together on the commissioning of systems and provide all reports and test results as well as arrange for witness testing for agreed systems for the owner's representative and the supervision consultant.
- Functional Testing for all critical systems should be included in the scope of works.
- O&M Manuals for all HVAC equipment should be provided by the contractor.
- Training on the systems installed should be conducted by the contractor's team for the owner's facility management team.
- FM Team should keep a record of all O&M activities on site, preferably through an electronic record keeping system.

HVAC- Room Side Design

The intent of this section is to identify key design elements related to the various spaces found within a healthcare environment and provide a checklist that must be adhered to for approval of new construction and major renovation projects.

Operating Rooms

Following requirements must be adhered too for Operating Room HVAC systems.

- Proper temperature (18-22°C), humidity (20-60% RH) and ventilation control for the comfort of surgical personnel and patients & to environmentally discourage the growth and transmission of microorganisms for general operating rooms.
- Operating-room ventilation systems should produce a minimum of about 20 ACH of MERV 17 HEPA (99.995% MPPS as per EN 1822) filtered air for thermal control, 4 ACH (20%) of which must be outside air. Air should be introduced at the ceiling and exhausted near the floor.

- Each operation theater should be provided with a dedicated air handling unit.
- Air Handling units for operation theater should be provided with VFD's to allow for variable speed to cater for HEPA filter loading.
- Air handling units should supply constant volume (20 ACH) airflow. Constant volume systems are common and should be the basis of design as complicated systems lead to operational issues during operation and maintenance.
- Variable systems are permitted for use "only if" they continue to provide a positive room pressure (normally +0.01-0.04 in. wg or +2.5-10 Pa differential) with respect to the corridors and adjacent areas and the required ACHs are maintained when the room is occupied. This can be achieved by communicating fixed offset air-valves. Active Monitoring of pressure is required through a pressure display monitor, connected to the BMS system. Space temperature, humidity and air change rate shall be displayed simultaneously. Pressure monitor should have an IP-54 rated housing, resistant to spray wash down & decontamination chemicals. Accuracy RSS of at least +/-0.25% full scale. This guide recommends an air differential of 10 Pa. Refer to figure 2.8.
- HEPA-filtered airflow should be dissipated through laminar airflow diffusers. Laminar airflow must be designed to move clean air over the aseptic operating field at a maximum face velocity (0.15–0.3 m/s), sweeping away particles in its path. All laminar flow diffuser should be room side accessible. Laminar flow array should entirely cover an area equivalent to the footprint of the surgical table plus 305mm on each side as a minimum.
- UVGI (Ultraviolet Germicidal Irradiation) should be provided as additional measure to reduce SSI (Surgical-Site Infection) risks.
- Medical plume evacuation system should be provided for OR's using lasers and other instruments generating plumes. This equipment should be part of the medical equipment package as a standalone equipment.
- Amount of reheat should be minimized, through supply air temperature reset, if humidity conditions can be met, and through reduced airflow when the operating room is not occupied.
- Special low temperature requirements related to heart and orthopedic surgery should be ascertained early in the design process and a corresponding low temperature chilled water circuit be provided to meet the surgeon's desired temperature (if required). It is to be noted that temperatures as low as 16 C DB can be required in operating rooms. Special elevated temperature requirements related to burn and pediatric units should also be ascertained, and systems designed to suit with space heating & humidification.
- Surgeons should only be allowed to set the dry bulb temperature. Humidity display should be provided.
- Humidity and temperature sensors should be provided in the return air duct for system control.
- In general, operating room air handling units should be designed at 2 m/s air velocity at the coil to allow for lower leaving air temperatures.
- In general, operating room chilled water pipes to the AHU should be designed at higher velocities in the range of 1.8 m/s to 2 m/s to allow for better heat transfer.
- Refer to Figure 2.8 for operating room airflow configuration and pressure relationship.

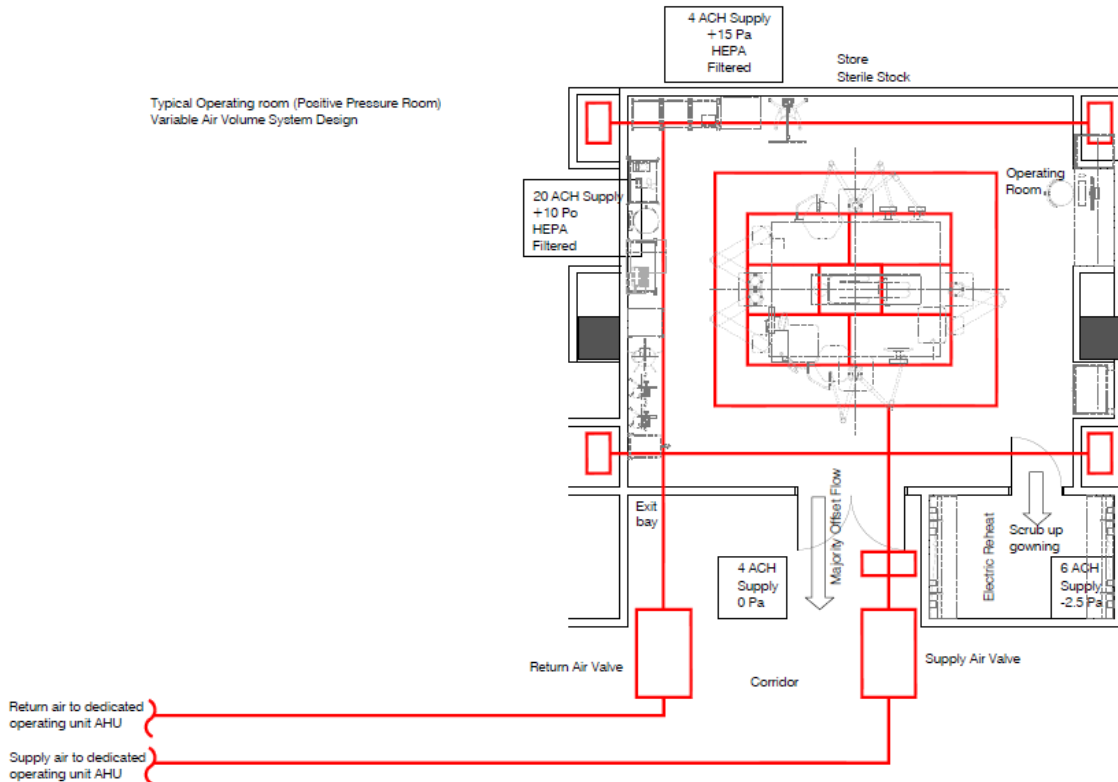


Figure 2.8

Imaging Rooms

Following requirements must be adhered too for Imaging Room HVAC systems.

- Imaging rooms can be grouped into 4 types as mentioned below, each having their respective requirements.
 - X-Ray (CT, Radiography, Fluoroscopy)
 - Ultrasound (Diagnostic Treatment)
 - Magnetic (MRI)
 - Nuclear (PET Scan, Linear Accelerator LINAC, Nuclear Camera, Gamma Knife)
- In general Imaging rooms fall under diagnostics which require 6 ACH minimum of supply air with 2 ACH of outside air & a Temperature requirement (21-24°C), humidity (<60% RH).
- Imaging rooms do not require dedicated air handling units and can be served from the same air handling unit serving the rest of the radiology suite.
- Imaging rooms designed for treatments such as fluoroscopy (e.g. vascular, cardiac catheterization, interventional lab, cystoscopy, electrophoresis(EP)) carry a prescriptive requirement for treatment rooms 15 ACH of supply air with 3 ACH of outside air but are recommended to be designed to operating rooms standard as mentioned in section 2.15 for future flexibility. All relevant clauses applicable should be adhered to.
- Data should be obtained from Room Data sheets for the control room, procedure room and equipment room heat dissipation.
- Wherever possible water-cooled medical equipment should be preferred. Process water cooling can be provided via dedicated medical grade chillers backed up by central chilled water system or with the central chilled water system backed up by chilled potable water. Discussion on the system and its criticality should be brought up by the designer to the facility owner during concept design.
- MRI rooms must be designed to cater for the heat load produced by the equipment. As a minimum 6 ACH of supply air and 2 ACH of outside air should be provided. Following key considerations should be accounted for.

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- All materials in the room should be nonferrous.
- No rotating equipment (motors, fans) should be placed within the 1 gauss field.
- Chilled water requirements as per point above.
- Provide an insulated stainless-steel quench pipe with proper thrust restraints sized as per manufacturer guidelines and vented to outside with the exclusion zone clearly marked.
- Provide an emergency exhaust fan sized at 12ACH to exhaust helium. This can also be used to purge clean agents in case of fire.
- Provide an overpressure relief grille.
- PET & SPECT Scan rooms are diagnostic rooms requiring 6 ACH SA/2 ACH OA. All air should be exhausted via the general exhaust system from the scanning rooms. Chilled water requirements as per point 6. Hot labs, Radio pharmacies provided with PET and SPECT scan rooms normally house BSC II Hoods and should be provided with dedicated hood exhaust with bag-in bag-out filtration for isotopes and general exhaust from the space.
- LINAC rooms are also diagnostic rooms with no invasive procedures being carried out. Regular requirements of 6ACH SA/ 2 ACH OA will suffice. Humidity should be kept less than 50%. Chilled water requirements as per point 6. Modern day LINAC's are often coupled with MRI's within the same suite. Care should be taken to accurately calculate the heat dissipation and cater for all requirements of MRI room as per point 7.

Laboratories

Following requirements must be adhered too for Laboratories HVAC systems.

- Proper temperature control (21-24°C), maximum 60% RH with 6 ACH SA/ 2 ACH OA should be provided for all labs.
- All Laboratory work areas should be 100% exhausted to outside through general exhaust passed through heat recovery.
- Fume hoods and Bio Safety cabinets located within the labs should be exhausted to the ambient through high plume dilution fans through proper filtration. Exhaust from BSC cabinets can be combined into a single manifold, provided they carry the same class of air and exhausted through N+1 exhaust fan. Similar approach can be adopted for Fume cupboards. Engineer should minimize the number of fans for operational efficiency and maintainability of the system.
- Labs containing Fume Hoods or BSC cabinets should be provided with laminar flow diffusers located at appropriate locations.
- Flammable cabinets should be provided with ventilation with dedicated exhaust fan and discharge.
- Variable systems are permitted for use "only if" they continue to provide a negative room pressure (normally -0.01-0.04 in. wg or -2.5-10 Pa differential) with respect to the corridors and adjacent areas and the required ACHs are maintained when the room is occupied. This can be achieved by communicating fixed offset air-valves for the supply, general exhaust, and hood exhaust (one per BSC). Active Monitoring of pressure is required through a pressure display monitor, connected to the BMS system. Space temperature, humidity and air change rate shall be displayed simultaneously. Pressure monitor should have an IP-54 rated housing, resistant to spray wash-down & decontamination chemicals. Accuracy RSS of at least +/- 0.25% full scale.
- Laboratory sterilizing areas should be provided with 10 ACH SA/ 2 ACH OA.

Pharmacy

Following requirements must be adhered too for Pharmacy HVAC systems.

- As a minimum Pharmacy spaces should be provided with temperature control (21-24°C), maximum 60% RH with a 4 ACH SA/ 2 ACH OA.
- Pharmacy should be kept at positive pressure. VAV systems are permitted without compromising on the pressure requirement.
- In-patient pharmacy providing compounding facilities should be designed according to USP

797.

- Vault, if designed for controlled substances should be provided with cooling with supply and return air.
- Pharmacy clean rooms (if required by clinical planning) should be designed to ISO Class 7 Standard according to ISO 14644, unless stated otherwise for the project by the operator, providing a minimum of 40 ACH of HEPA filtered air, with a ceiling coverage between 30%-40%, keeping the maximum face velocity under 0.15 m/s and providing low level return. These should be provided with an ISO Class 8 ante room, providing a minimum of 20 ACH of HEPA filtered air.
- HEPA filters modules should be fan filter type to reduce central fan size.
- Clean rooms should be kept at positive pressure except when used for hazardous drugs which should be negative pressure with associated ante room at positive pressure. Clean rooms should be certified to ISO 14644 standard.
- Hazardous drugs compounding clean rooms are provided with BSC cabinets. The exhaust from these cabinets should be filtered with a carbon filter and a hepa filter before being discharged through a high plume dilution fan or an exhaust stack.
- Clean room personal are wearing heavy protective clothing so lower temperature should be considered as a design requirement, 20 C.

Patient Rooms

Following requirements must be adhered too for Patient Room HVAC systems.

- As a minimum Patient rooms should be provided with temperature control (21-24°C), maximum 60% RH, with a 6 ACH SA/ 2 ACH OA.
- Each patient room should be provided with a thermostat linked with the BMS system (if available).

Intensive Care Rooms- Critical Care Rooms

Following requirements must be adhered too for Intensive Care Room HVAC systems.

- Intensive Care rooms include specialized rooms such as Surgical Intensive Care (SICU), Medical Intensive Care (MICU), Cardiac Care Unit (CCU), Pediatric Intensive Care Unit (PICU), Neonatal Intensive Care Unit (NICU), High Dependency Unit (HDU) etc. All these rooms require a minimum of 6 ACH SA/2 ACH OA with temperature range of 21- 24°C, and 30-60% RH.
- ICU areas should not be served with recirculating type units such as FCU's.
- Reheat should be provided to each ICU room/bay. Thermostat should be linked with the BMS system (if available).

Morgue & Autopsy

Following requirements must be adhered too for Morgue & Autopsy HVAC systems.

- As a minimum Morgue & Autopsy spaces should be provided with temperature control (20-24°C), maximum 60% RH with a 12 ACH SA/ 2 ACH OA.
- Air should be supplied via unidirectional flow diffusers.
- Exhaust grilles should be located at both high level and low level.
- All air should be exhausted outside through dedicated ductwork.
- Direct exhaust connection to the autopsy table should be provided. Exhaust air should be HEPA filtered, UV treated, and carbon filtered for odors and discharged at a high velocity, preferably using a stack. Since autopsy is normally not carried out at private facilities, this requirement will not apply.
- Body Holding refrigerators should be designed by the specialist manufacturer. Designer to take the heat dissipated for the refrigerators into account while designing the HVAC system.
- Negative room pressure (normally -0.01-0.04 in. wg or -2.5-10 Pa differential) with respect to the corridors and adjacent areas is required. Active Monitoring of pressure is required through a pressure display monitor, connected to the BMS system.

Isolation Rooms

Isolation rooms can be classified into 3 categories.

- Class N- Airborne Infection Isolation Rooms (AIIR) – Negative Pressure Isolation Room
- Class Q – Quarantine Isolation – Negative Pressure Isolation Room with Clean and Dirty Utility.
- Class P- Protective Environment Isolation Rooms (PE)- Positive Pressure Isolation Room.
- Class S- Standard Isolation Room - Contact Isolation Room- Neutral Isolation Room.
- Switchable Pressure Isolation Rooms – No longer allowed by standards like FGI/ASHRAE.

Class N- Negative Isolation Room

- Proper temperature (21-24°C), humidity (<60% RH) and ventilation control, minimum 12 ACH SA/ 2 ACH OA, anteroom 10 ACH SA.
- Use of negative pressure rooms with close monitoring and control of airflow direction (normally -0.01 to -0.04 in. wg or -2.5 to -10 Pa differential). Negative pressure to be maintained during un-occupied mode by communicating Air Valves. Provide differential pressure monitor with alarm points to building automation system. Space temperature, humidity and air change rate shall be displayed simultaneously. Pressure monitor should have an IP-54 rated housing, resistant to spray wash down & decontamination chemicals. Accuracy RSS of at least +/- 0.25% full scale. This guide recommends a negative pressure of 10 Pa for the class N room. Refer to figure 2.9.
- Seal room below 0.5 ft²(465 cm²) of air leakage (called Effective Leakage Area under 4 Pa pressures differential test)
- Exhaust air grille should be placed over the patient head or at low level near the head. Air from negative pressure rooms is to be HEPA-filtered with a bag in bag out filter and exhausted directly to the outside with dedicated N+1 high plume dilution exhaust fans discharged 10 feet above roof level. Recirculation is not allowed. Air from other AIIR rooms can be mixed provided each room is providing with a VAV or Air Valves prior to connection.
- UVGI fixtures may be placed in upper room, or inside the ducts as an additional measure, but are not a mandatory requirement.
- Pressure relationship should be negative with respect to the ante room with the ante room negative with respect to the corridor.
- Refer to Figure 2.9 for AIIR room airflow configuration. Room exhaust and supply air valves should be VAV type while the remaining

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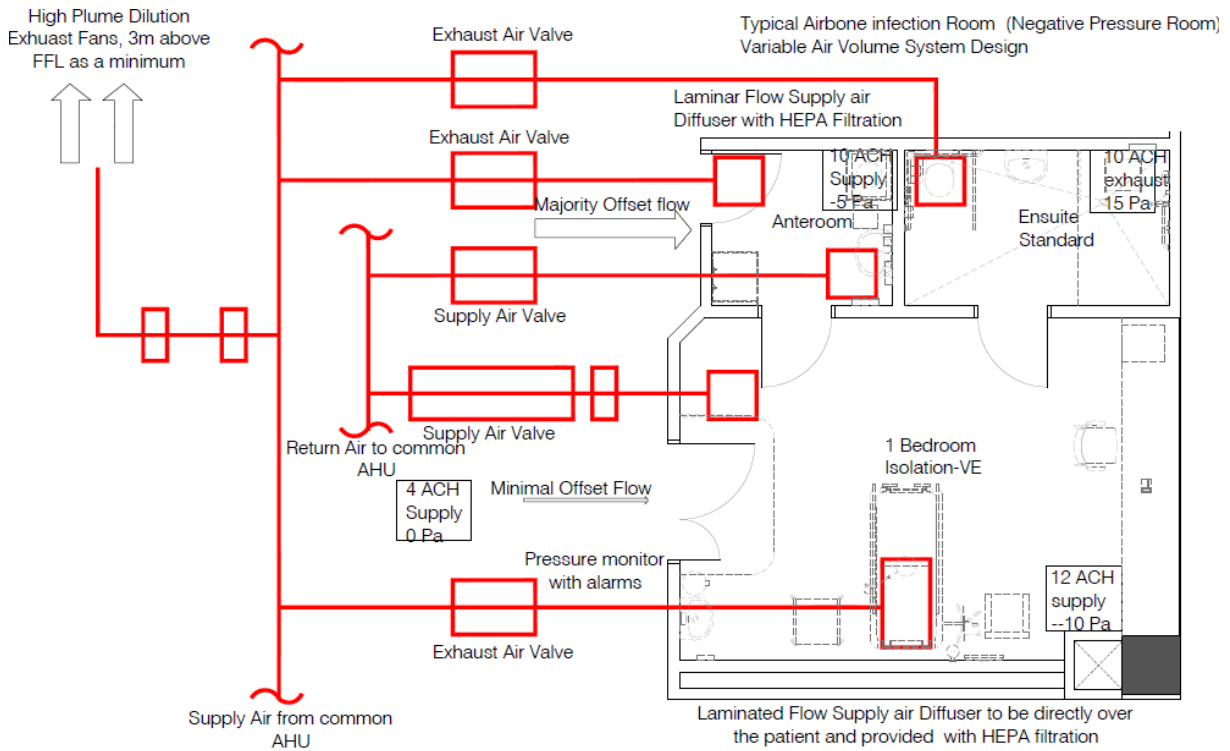


Figure 2.9

Class Q- Negative Isolation Room

- All the requirements for Class N rooms must be adhered too for Class Q rooms.
- In addition, supply should be provided with HEPA filters similar to Class P rooms.
- Class Q isolation suite will contain a dirty utility as well. That should also be exhausted to outside, similar to the bedroom, ante room and toilet.

Class P-Positive Isolation Room

- These rooms are to be designed for high-risk, immuno-compromised patients (BMT, organ transplant, leukemia, burn, late-stage HIV) and to minimize fungal spore counts in air.
- Proper temperature (21-24°C), humidity (<60% RH) and ventilation control, minimum 12 ACH SA/ 2 ACH OA, anteroom 10 ACH SA.
- Incoming air through HEPA filters or fan powered HEPA filters mounted in laminar flow diffusers, supply air on top of the patient bed and exhaust out through the opposite side of the room, preferably at low level.
- Pressure of +2.5 Pa (0.01" w.g.) relative to the corridor as a minimum. Provide differential pressure monitor with alarm points to building automation system. Space temperature, humidity and air change rate shall be displayed simultaneously. Pressure monitor should have an IP-54 rated housing, resistant to spray wash down & decontamination chemicals. Accuracy RSS of at least +/-0.25% full scale. This guide recommends a positive pressure of 10 Pa for the isolation room. Refer to figure 2.10. Room return and supply air valves should be VAV type while the remaining valves for ante room and toilet can be CAV types.
- Seal room below 0.5 ft²(465 cm²) of air leakage (called Effective Leakage Area under 4 Pa pressures differential test)
- UVGI fixtures can be placed in upper room, or inside the ducts as an additional measure.
- Pressure relationship should be positive with respect to the ante room with the ante room positive with respect to the corridor.
- Refer to Figure 2.10 for PE room airflow configuration.

Class S-Contact Isolation Room

- These isolation rooms are used to provide physical isolation for patients having a communicable disease which is not airborne as chicken pox, etc. Requirements for regular patient rooms apply.

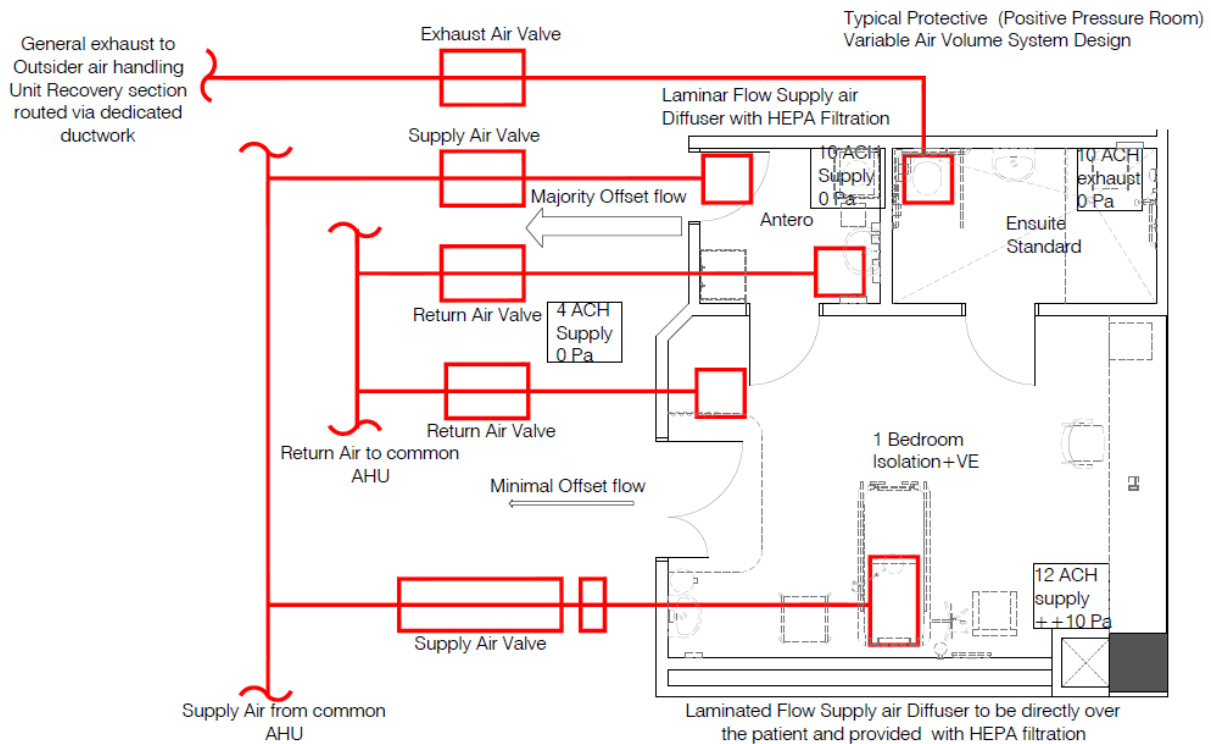


Figure 2.10

SSU (CSSD)

Following requirements must be adhered too for SSU(CSSD) HVAC systems.

- SSU(CSSD) can be broken down into 3 areas.
 - Dirty Area – 6 ACH SA/2ACH OA with 100% dedicated exhaust and negative pressure. Temperature 16-23°C
 - Clean Area- 4 ACH SA/2 ACH OA with positive pressure. Temperature 20-23°C
 - Sterile Store – 4 ACH HEPA filtered SA/ 2 ACH OA with positive pressure. Temperature 24°C
- Means of recording daily temperature and humidity should be provided via the BMS system for all spaces.
- Exhaust ductwork should be stainless steel for durability.
- Direct exhaust from washers, disinfectors and sterilizers should be provided as per the Room Data Sheets.
- Where ethylene oxide (ETO) sterilizers are used and ETO is stored system shall be designed to provide 100% dedicated exhaust to outside. Upon loss of exhaust system airflow, an audible and visual alarm shall activate in the sterilizer work area, and at a location that is continually staffed.

Renal Dialysis & Chemotherapy

Following requirements must be adhered too for Renal Dialysis Patient Bays systems.

- Room/Bay can be considered as having the same requirements as standard patient room.
- Consider radiant heating panels directly over the patient chair/bed for radiant heating as dialysis/chemo patients are frequently cold, anemic & immobile for the duration of the treatment.

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- Consider low design velocities of below 0.25 m/s at the treatment bed/chair, preferably through laminar flow diffusers.

Recovery (Post Anesthesia Care Unit)

Following requirements must be adhered too for PACU Recovery area HVAC systems.

- As a minimum PACU room should be provided with temperature control (21-24°C), 30- 60% RH, with a 6 ACH SA/ 2 ACH OA.
- Low level return should be provided with stainless steel grilles to capture the anesthetic gasses being exhaled by the patients and allow for better flushing of the space.
- Each room/bay should be provided with a thermostat linked with the BMS system (if available).

Emergency

Following requirements must be adhered too for Emergency area HVAC systems.

- Decontamination Room: Temperature control (21-24°C), with a 12 ACH SA/ 2 ACH OA, negative pressure. All air should be 100% exhaust with dedicated ducting.
- Exam/Treatment Room: Temperature control (21-24°C), maximum 60% RH, with a 6 ACH SA/ 2 ACH OA, positive pressure.
- Resuscitation (Trauma) Room: Temperature control (21-24°C), 20-60% RH, with a 15 ACH SA/ 3 ACH OA, positive pressure. If Trauma is to be utilized as emergency Operating room under the hospital's disaster management scheme, operating room requirements should be imposed.
- Triage: Temperature control (21-24°C), maximum 60% RH, with a 12 ACH SA/ 2 ACH OA, negative pressure. All air should be 100% exhaust with dedicated ducting.
- Emergency Department Public Waiting Area: Temperature control (21-24°C), maximum 60% RH, with a 6 ACH SA/ 2 ACH OA, negative pressure. All air should be 100% exhaust with dedicated ducting.

Burn Units

Following requirements must be adhered too for Burn Unit Room HVAC systems.

- As a minimum Burn Units rooms should be provided with temperature control (21-32°C), 40-60% RH, with a 6 ACH SA HEPA Filtered with laminar flow diffusers / 2 ACH OA. Room should be at positive pressure.
- Each patient room should be provided with a thermostat linked with the BMS system (if available).
- Each patient room should be provided with an individual humidifier and a humidistat to control the humidity level in the room.
- Each patient room should be provided with reheat sized to raise the temperature to 32°C inside the room.

Bone Marrow Transplant Rooms

Requirements for Protective Environment PE Isolation rooms should be applied for Bone Marrow Transplant rooms.

Hydrotherapy & Therapeutic Pools

Following requirements must be adhered too for Hydro-Therapy Pool HVAC systems.

- Should be provided with temperature control (26-28°C), with the ability to reheat up to 32°C, with a minimum of 10 ACH SA / 100% exhaust from the space. Space should be at negative pressure.
- Provide a dedicated or common wet exhaust system with welded stainless-steel ductwork. To allow for energy saving, VAV system can be employed via supply and exhaust terminal during unoccupied mode.
- The Spinal cord injury patient requires 33°C (92°F) water temperature, while the patient with

multiple sclerosis requires 28°C(84°F) water temperature. The pool equipment should be designed to accommodate rapid water temperature change, where both patient types can use the same pool on a given day based on schedule. Humidity control should be appropriately designed to cater for the water evaporation from the pool surface.

Psychiatric Rooms

Requirements for standard patient rooms apply, in addition

- Care must be taken that all grilles/diffusers and other HVAC devices must be suicide and vandal resistant.
- Use duct mounted sensors and allow for heavy-gage construction to resist damage and vandalism and reduce injury.
- Special Anti-Ligature devices should be used.

Procedure Rooms

Following requirements must be adhered too for Procedure Room HVAC systems.

- As a minimum procedure rooms should be provided with temperature control (21-24°C), 20-60% RH, with a 15 ACH SA with laminar flow diffusers / 3 ACH OA. Room should be at positive pressure.
- If aesthetic gasses are administered all requirements related to operating rooms should be applicable.

Endoscopy Procedure Rooms

Following requirements must be adhered too for Endoscopy Procedure Room HVAC systems.

- Gastrointestinal Endoscopy procedure room:
 - As a minimum should be provided with temperature control (21-23°C), 20-60% RH, with a 6 ACH SA with laminar flow diffusers / 2 ACH OA. Room shall have no mandated pressure requirement, but its preferable to be under negative pressure.
- Endoscopy/Bronchoscopy:
 - As a minimum should be provided with temperature control (20-23°C), 20-60% RH, with a 12 ACH SA with laminar flow diffusers / 2 ACH OA. Room shall be negative pressure with dedicated 100% exhaust ducting to outside.
 - This is more common scenario and endoscopy rooms should be designed as a worse case to this requirement, unless noted otherwise by the operator.
- Endoscopy ERCP procedure room:
 - If specifically designed by the clinical planning team as a dedicated ERCP (Endoscopic Retrograde Cholangiopancreatography) room the following requirements shall supersede the previous requirements.
 - As a minimum should be provided with temperature control (20-23°C), 20-60% RH, with a 15 ACH SA with laminar flow diffusers / 3 ACH OA. Room shall have positive pressure requirement.
- Endoscope Cleaning Rooms:
 - As a minimum should be provided with temperature control (21-24°C), 20-60% RH, with a 10 ACH SA / 2 ACH OA. Room shall have negative pressure requirement. All air should be exhausted to outside with dedicated ducting.

Outpatient Clinics & Support Spaces

The HVAC systems for outpatient clinics & support functions are often not designed to the same level of redundancy as in-patient facilities. It is encouraged that the consultant engages with the owner/facility manager early in the design process to figure out the requirements for the clinics and day surgery units, endoscopy & imaging procedures if present.

Any particular low temperature requirements for day surgery units should be advised by the owner's representatives and the consultant should undergo an analysis of whether the requirements are achievable by the proposed system design.

IVF Clinics/ Fertilization Centres

Following requirements must be adhered too for IVF HVAC systems.

- IVF Clinics typically contain the following spaces.
 - Procedure Room & Embryo Transfer Room: The procedure room & embryo transfer room should be treated as an OR and all requirements for operating room should be complied.
 - Recovery Room/Bays: Recovery bays should be treated as PACU rooms and all requirements should be taken for PACU rooms.
 - Laboratories (Embryology, Andrology, Cryogenics, etc.): Labs for IVF center represent ultra-clean labs. In addition to the requirement for laboratory mentioned in the previous section all air should be HEPA filtered with laminar flow diffusers. Pressure requirement should be positive pressure (+0.01-0.02 in. wg or +2.5+5 Pa differential). ISO Class 7 certification testing is highly recommended.
 - Infectious Labs: Infectious labs should be provided with the same systems as other IVF labs, but the air pressure regime should be negative. (-0.01-0.02 in. wg or -2.5-5 Pa differential)
 - Sample Collection Rooms: Sample collection rooms should be kept at negative pressure via the adjoining shower area exhaust.
- HVAC air handling units serving the laboratories, procedure and embryo transfer rooms should be provided with carbon filters, with activated alumina impregnated with potassium permanganate & HEPA filters in the air handling unit. HEPA filters can also be installed at the terminal locations instead of the air handling units if dedicated air handling units are not used.

Data Centre

Following requirements must be adhered too for Data Centre/Server Room HVAC systems.

- As a minimum Server rooms should be provided with temperature control (19-22°C), 30-60% RH, with supply air governed by the heat load for the servers but not less air required to cool 0.5 kW/m² of data hall of heat load, to cover for future expansion.
- Server Room should be cooled by precision ac units or close control ac units, providing cooling and humidity control, located within the server room with adequate clearance space or preferably adjacent to the server room in a dedicated mechanical room.
- A minimum of two close control units should be provided for each server room in N+1 arrangement, one fed from the central chilled water circuit and one fed from a dedicated DX machine for medium to large scale healthcare facilities. For smaller facilities and outpatient facilities one close control unit can be provided with dual coil arrangement and dual fans. Close control units shall be fed from emergency power.
- Server Rooms rack should be arranged in hot aisle and hot cold arrangement, where applicable.
- Server Rooms should be conditioned through raised floor arrangement, with perforated floor tiles provided for up to 6kW rack load and fan powered tiles or rack containment provided for higher heat loads.
- Use of Fan coils to provide backup cooling is not permitted.

Hyperbaric Chamber

Following requirements must be adhered to for Hyperbaric Chamber HVAC system design.

- Hyperbaric Chambers rooms fall under diagnostics which require 6 ACH minimum of supply air & with 2 ACH minimum of outside air. Due to the nature of the facility and a requirement from NFPA 99 Chapter 14, all air should be exhausted to outside. A Temperature requirement (21-24°C), humidity (<60% RH).
- Exhaust air should not be merged with other exhaust and should not be passed through any heat recovery device.
- Hyperbaric Chambers should also comply with ASME's Safety Standard for Pressure Vessels for Human Occupancy (ASME PVHO)

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- For larger multi person chambers, it is highly recommended that the chamber manufacturer provides a dedicated A/C and Ventilation system for the chamber itself. This would keep in mind the appropriate capacity and inlet angles for the air to ensure optimum thermal comfort for multiple person hyperbaric chambers.

3 Electrical Services

This document is intended for the Architect/Engineer (A/E) and others engaged in the design and renovation of healthcare facilities. Where direction described in applicable codes are in conflict, the A/E shall comply with the more stringent requirement. The A/E is required to make themselves aware of all applicable codes.

The document should be read in conjunction with other parts of the Health Facility Guidelines (Part A to Part F) & the typical room data sheets and typical room layout sheets.

Introduction

This section of health facility design guideline provides, Healthcare Planners and Designers guidance on the acceptable level of standards to be achieved for all fixed electrical wiring installation within healthcare facilities. This applies to all new installations and modifications to existing facilities within the framework of Part A of this document.

It is not the intention of this document to unnecessarily repeat national, international or industry standards. Where appropriate, these standards are referenced, and additional specific requirements are described in the following sections.

In addition, guidance is also given on ELV and ICT systems.

Abbreviations, Standards and References

Abbreviation	Description
BMS	Building Management System
CIBSE	Chartered Institute of Building Services
CCTV	Closed-Circuit Television
CE	European Conformity
CT	Current Transformer
EBB	Equipotential Bonding Bar
ELCB	Earth Leakage Circuit Breaker
ELV	Extra Low Voltage
EMC	Electromagnetic Compatibility
EMR	Electronic Medical Records
EMR	Electronic Health Record
EPS	Emergency Power Supply (Also referred as Secondary Power Supply)
FL	Full Load
HIS	Hospital Information System
ICU	Critical Care Unit
IEC	International Electrotechnical Commission
IEE	Institute of Electrical Engineering
IGBT	Insulated Gate Bipolar Transistor
IPS	Isolated Power Supply (also referred as Medical IT)
ISO	International Standards Organization
IT	Impedance Terra Earthed (Derived from an Isolated Power Supply)
ICT	Information and Communication Technology
LAN	Local Area Network
LPS	Lightning Protection System
LS0H	Low Smoke Zero Halogen
LV	Low Voltage

Abbreviation	Description
MV	Medium Voltage
NTP	Network Time Protocol
PACS	Picture Archiving and Communication System
PEC	Protective Earth Conductor
PPS	Primary Power Supply
PTZ	Pan Tilt and Zoom
RCBO	Residual Current Breaker with Overcurrent
RCD	Residual Current Device
RDS	Room Data Sheet
SPS	Secondary Power Supply (Also referred as Emergency Power Supply)
TPS	Tertiary Power Supply (Also referred as UPS Power Supply)
TRA	Telecom Regulatory Authority
UPS	Uninterruptible Power Supplies
VRLA	Valve Regulated Lead Acid Battery

Risk assessment

- Electrical power distribution systems are inherently designed to isolate power supplies to parts of the installation where an electrical fault is detected for safety and reliability of electrical distribution in general.
- In any electrical installation the power supply may fail at some point and contingency needs to be in place to mitigate the impact of the power failure by providing redundancy in power source and distribution.
- The level of redundancy to be contusive for the type of healthcare premises and level of care rendered. A power failure in an outpatient care facility may not have much detrimental effect on the patient safety while a power failure in an acute care facility could have disastrous consequences.
- Depending on the level of care provided in the healthcare facility, the stake holders should carefully consider the risks involved due to a power failure for clinical, non-clinical and engineering applications and come up with an optimum arrangement that will minimize the risk to the patient safety and healthcare facility operation in general.
- The risk assessment can be a simple or complex approach depending on size and nature of the medical services being provided in the healthcare facility. This guideline recommends the risk assessment approach described in Table E3.1, be followed for determining the risks; business continuity risks are graded from Grade 1 to Grade 4 (Grade 1 being highest risk) while clinical risks are graded from Grade A to Grade E (Grade A being highest risk).
- Specific requirements given in this guideline takes precedence any other Standard or regulation.
- Within an outpatient department in a large healthcare facility or in a clinic, it may be determined as acceptable to have single points of failure in a system, since ambulant patients are likely to be more mobile than patients in critical care areas and staff will be able to move them away from the affected area in the event of a power failure. On the other hand, in critical care areas or operating theatres, the consequence of a prolonged, or even a very short, power failure could result in serious health disabilities or, in the worst cases, fatality. In this instance, a more resilient infrastructure with additional levels of secondary and/or tertiary power supplies are appropriate. Also, the eventual stakeholder's (hospital owner/end user) vision with respect to management of business continuity risks to be considered while finalizing the risk levels (clinical and business continuity).

Design considerations

- It is important to access the requirements of a healthcare facility project in terms of power supply requirement for equipment, small power outlet, lighting etc.; it is particularly important

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to identify those areas or functions that will require special consideration, for example Group 2 Medical Locations (HD 60364-7-710:2012, IET Guidance Note 7) in healthcare facilities.

- Local/international regulations or standards as listed below are required to be considered while designing healthcare facilities.

Sl. No.	Standard/Guideline
1	Local Electricity Distribution Company Regulations as applicable.
2	Local AHJ fire code.
3	Local or International Green Building Rating System Compliance.
4	Local Telecom Company Regulations as applicable.
5	HD 60364-7-710:2012 (or later) Electrical installations of buildings - Part 7-710: Requirements for special installations or locations - Medical locations.
6	CIBSE Lighting Guide 2: Hospitals and healthcare buildings,2008, by The Society of Light and Lighting.
7	IEC 60079 - Electrical apparatus for explosive gas atmospheres.
8	IEEE 519 - IEEE Recommended practices and requirements for harmonic control in electrical power systems.
9	NFPA 99 – Health Care Facilities, Chapter 6, Section 6.4.2.2 (Edition 2012 or later).
10	Equipment and installation material standards/listing: IEC, EU Declaration of Conformity, or UL Listed.

- The requirements given in the above regulations or standards are not repeated generally in this document; however specific additional healthcare specific requirements emphasized in the following section will take precedence over the referenced standards above.
- It is important to note that, the services outlet (power, data etc.) quantities and their types provided in the various medical locations shall be based on the guidance provided as per the RDS (Room Data Sheets) included under Part B of this guideline.
- Non-medical equipment should not be used in a patient environment unless it meets the electrical safety requirements of IEC 60601-1, particularly with respect to touch and leakage currents.
- Primary Power Supply (PPS): - Primary Power Supply is the electricity supply provided by the local utility company. PPS is generally reliable in most countries, however, while power supply allocation requests are made to the local utility company, level of care provided by the proposed healthcare facility should be conveyed to the utility company so that appropriate level of redundancy could be considered by the utility supply company for power intake provisions.
- Secondary Power Supply (SPS): - Secondary Power Supply is the electricity supply provided from an on-site power source such as a Diesel Generator Set (s). The secondary power source shall be suitably supplemented by appropriate secondary distribution system to reduce the risk of single point failure. Single point of failure to be as close as practically possible to the load. Secondary power supply shall be available to the associated loads in 15 seconds or less from the PPS interruption. Power outlets fed from the SPS are also referred as Emergency Power Supply (EPS) outlets.
- In the event of a primary power supply failure the secondary power supply should be available to the associated emergency loads in 15 seconds or less.
- Providing a resilient secondary power source is only one part of the solution while providing a redundant secondary distribution network is equally important. Refer to section 3.8.
- Tertiary Power Supply (TPS): - Tertiary Power Supply (with less than 0.5 Sec break) is required to provide additional (in addition to PPS and SPS) power source in clinical risk Grade A and B areas where loss of power supply could have disastrous consequences. Static double conversion Uninterruptible Power Supplies shall be provided as TPS sources. Refer to section 3.9.
- Isolated Power Supplies (IPS): Isolated power supplies incorporating an isolation transformer, distribution arrangement and Isolation monitoring system are used to deliver power supplies to power outlets intended for relevant critical medical equipment in critical medical locations where enhanced level of resilience is required. Refer to section 3.9.
- Following clinical risk grading and associated recommendation on power supply types are

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provided based on the interpretation of HD 60364-7-710:2021 in the context of developed countries where quality and reliability of primary power supply is generally excellent. Therefore, this clinical risk grading may not be applicable for other locations where primary power is less reliable and almost 100% backup to secondary power is required.

Clinical Risk Grade	Medical Location (Interpretation of HD 60364-7-710:2015)	Area Description	Power Supply Types
Grade A	Group 2	<p>These are areas where treatment and patient safety will be compromised and endangered by any minor interruption of electrical supply; such areas include but not limited to the following.</p> <p>Operating Rooms Anesthetic Induction rooms Recovery Bays (Stage 1) Critical Care Angiography and Cath labs Emergency resuscitation bays IVF Procedure rooms High dependency units Neo-Natal Intensive Care Units Brachytherapy rooms Chemo embolization rooms</p>	<p>SPS: Required TPS: Required IPS: Required (Note: PPS is also recommended in these areas to serve power outlets intended for non-clinical applications such as cleaning. Power supply for support systems such as HVAC, hot & cold water, and medical gas alarms shall be connected to SPS)</p>
Grade B	Group 1	<p>These are areas where treatment and patient safety may be compromised (but not endangered) by any minor interruption of electrical supply; such areas include but not limited to the following areas.</p> <p>Delivery rooms Endoscopy Procedure Rooms Emergency treatment areas. Hemodialysis bays Urology treatment rooms Radiation therapy rooms Imaging equipment Procedure rooms Triage Staff stations.</p>	<p>SPS: Required TPS: Generally, not required. However, TPS may be required for specific medical equipment. IPS: Not Required (Note: A few power outlets connected from TPS is recommended at Nurse stations serving critical care areas, PPS is recommended in these areas to serve power outlets intended for non-clinical applications such as cleaning Power supply for support systems such as HVAC, hot & cold water, and medical gas alarm shall be connected to SPS) SPS backup for imaging equipment are optional depending upon the level of care provided in the facility. If the healthcare facility is having interventional procedures at least one of each type of imaging system to be connected to SPS.</p>
Grade C	Group 1	<p>These are areas where treatment and patient safety will not be immediately compromised by an interruption of electrical power; such areas include but not limited to the following areas.</p> <p>Outpatient Treatment rooms Consult/Exam rooms Pharmacy Patient bedroom Recovery – Stage II Observation bays</p>	<p>PPS: Required SPS: Required TPS: Not Required IPS: Not Required (Note: Power supply for support systems such as HVAC, hot & cold water, and medical gas alarms shall be connected to SPS)</p>
Grade D	Group 0	<p>These are areas where loss of power supply may give rise to disruption, inconvenience and a reduced environmental quality but would not directly compromise clinical treatment and safety. such areas include but not limited to the following areas.</p> <p>Consult rooms Waiting areas Sterile Supply Unit (SSU)</p>	<p>PPS: Required SPS: Optional TPS: Not Required IPS: Not Required (Note: SPS for small power outlets in these areas are optional; the designer may provide SPS to mitigate business continuity risk, if required by the end user.</p>

Clinical Risk Grade	Medical Location (Interpretation of HD 60364-7-710:2015)	Area Description	Power Supply Types
			It is recommended that 50% of lighting circuits are connected to SPS. SPS backup is highly recommended for at least one of each type of sterilizing and cleaning equipment in Sterile Supply Unit (SSU) as a minimum)
Grade E	-	These are areas where loss of the electrical supply does not have an immediate effect on the clinical treatment or safety of patients; such areas include but not limited to the following areas. General circulation areas Offices Other Non-clinical areas	PPS: Required SPS: Optional TPS: Not Required IPS: Not Required (Optional: SPS and TPS for areas such as offices are optional; the designer may provide SPS and TPS to mitigate business continuity risk, if required by the end user)

Table: E.3.1 Clinical Risk Grading

- Notwithstanding the guidance provided above, there may be situations where enhanced level of power supply resilience is required based on the specific medical treatment envisaged. The designer is required to assess the risks involved and shall include further enhancements in the design, as necessary. In addition, power supplies for building’s life safety system shall be supplied from SPS as per the local fire code.

Power quality

Electrical disturbances may affect the reliability of high-tech medical equipment. As medical equipment is often connected to vulnerable patients, such a malfunction may result in fatal consequences. To mitigate this problem careful consideration shall be made in terms of the design of the electrical distribution system as well as selection of electrical distribution equipment. The following approaches shall be considered.

- Power supply feeders for sensitive medical equipment such as X-Rays, CT, MRI and Linac. etc., shall be directly sourced from the Main Distribution Boards (MDB) rather than from shared sub-distribution panels. Alternatively, dedicated appropriately sized submain distribution board (SMDB) located in the MDB room to serve a group of imaging equipment will also suffice.
- Providing surge protection devices.
- Providing active harmonic filters: Power system harmonics of order 3rd, 5th, 7th, 9th, 11th and 15th order can create significant problems such as over current and overheating of cables, busbars, and transformers. since it is not practical to accurately estimate the rating of active harmonic filters required for any project in advance, provision such as breakers shall be made in the Main Distribution Boards to install harmonic filters when actual harmonics can be measured at the earliest. Spare breakers designated for this application shall be labels as “ For Harmonic Filter Only”.
- Harmonics to be measured once the majority of the mechanical, electrical, and medical equipment are in operation. This guideline recommends that this measurement be made within 6 months following the opening of the facility. Suitably rated harmonic filters shall be installed to limit the harmonics stipulated as per IEEE 519 (Recommended practices and requirements for harmonic control in electrical power systems).
- Power factor correction meeting LOCAL AUTHORITY requirement; Power factor correction equipment can also contribute to the harmonic generation, unless properly designed detuning reactors are incorporated into the design of the power factor correction capacitor banks. Power factor correction capacitor banks shall be with detuning reactors. Capacitor banks employing Thyristor based capacitor switching is recommended.
- Special attention is drawn to LOCAL AUTHORITY regulation clause 1.10 and 8.2 with respect to under voltage release and auto-reclosing for feeders serving air conditioning units or similar

equipment employing compressors drawing large inrush current at start-up.

- Facility to display power quality parameters such as THD is recommended to be provided in the Main Distribution Boards.

Power supply and distribution resilience

- The resilience of power supply and distribution shall be as per the type of health care facility and level of care provided in that part of the facility.
- When designing the strategy for the electrical distribution, it is important to take an all-inclusive approach.
- All Main Distribution Boards serving non-critical applications shall have temporary generator connection provision to connect temporary generator in case of any prolonged utility power supply outage.
- Refer to Fig. E.3.1 for a diagrammatic representation of a typical Hospital high-level power distribution arrangement. The number of Automatic Transfer Switches indicated in this diagram may have to be increased or decreased based on the layout of the hospital, load considerations and distribution arrangement.
- All automatic transfer switches serving critical areas shall be bypass isolation type to enable ATS maintenance or fault rectification without loss of power supply to critical services.

Primary (Normal) power supply and distribution

- Primary power supply shall be sourced from local utility provider LOCAL AUTHORITY, based on the standard procedures and approval process mandated by the local power supply authority.
- Main power supply intake rooms (RMU, Transformer and MDB) shall be provided as per LOCAL AUTHORITY regulations.
- With fast evolving advancements in the medical treatment field there is an ever-increasing need for electrical power for healthcare facilities and this trend is likely to continue. Considering this spare capacity may be allowed in the power distribution equipment such as transformers.
- Typically, in healthcare facilities, large number of small power sockets are provided at patient locations on service panels and pendants for redundancy and convenience than simultaneous use. As such, suitable diversity shall be worked out by a qualified and experienced designer to avoid ending up with an inappropriately expensive oversized electrical system.
- For critical care facilities separate, dedicated Main Distribution Board rooms shall be provided for primary and secondary power supplies to segregate primary and secondary Main Distribution Boards.
- Figure E.3.1 below indicates a typical primary and secondary distribution arrangement for a hospital. Note that this is a typical high-level arrangement and the number of different equipment and connection arrangement may vary depending upon the size of the facility, associated loads, and relative location of loads.

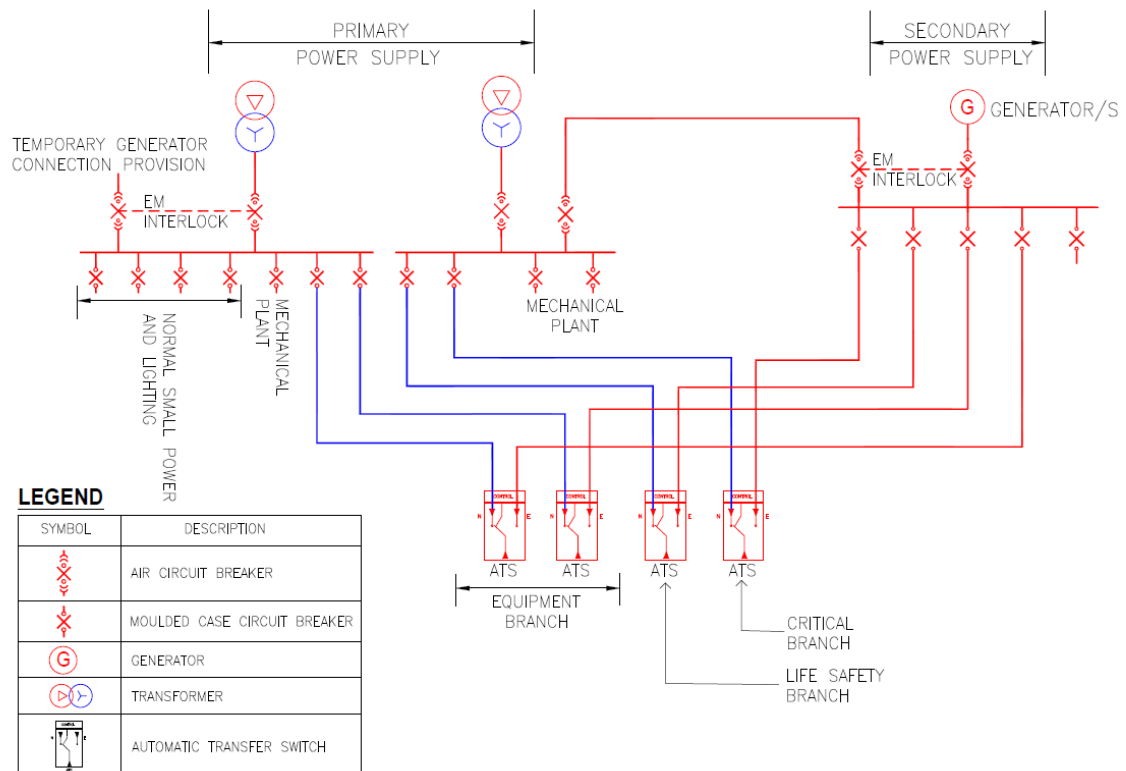


Figure E.3.1 Typical high-level power distribution arrangement schematic for a Hospital

Secondary (Emergency) power source and distribution

- Onsite secondary power supply source (Diesel Generator Set) and associated distribution shall be provided for Healthcare facilities. Coverage of the secondary power supply shall be as per the level of care provided in the facility.
- Location of the Generator Set shall optimize the secondary distribution by reducing the amount of power distribution elements between the critical load and the power levels. The location of the generator room shall also be protected from general flooding levels.
- It is recommended that Diesel Generator Sets serving healthcare facilities are not located below the grade level.
- It is recommended that Diesel Generator Sets serving healthcare facilities are prime rated (ISO 8528-1) and not standby rated. Furthermore, ISO 8528-5 defines operating limits for generators during transient and steady state conditions (see Table below). Generators in a healthcare facility shall comply to the 'G3' class as a minimum.

Equivalent Class	Steady State	Frequency Droop	Load Rejection	Load Acceptance	Recovery Band	Recovery Time	
G1	Hz	±2.5%	8%	18%	15% (25%) ⁽¹⁾	3.5%	10 s
	V	±5%	---	35%	25%	10.0%	10 s
G2	Hz	±1.5%	5%	12%	10% (20%) ⁽¹⁾	2.0%	5 s
	V	±2.5%	---	25%	20%	5.0%	6 s
G3	Hz	±0.5%	3%	10%	7% (15%) ⁽¹⁾	2.0%	3 s
	V	±1%	---	20%	15%	2.0%	4 s

- (1) Specific frequency acceptable operating limits for gas generating sets in brackets.
- Table E: 3.2 – Typical operating limit values as per ISO 8528-5.

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- Where multiple Diesel Generator Sets are forming the Secondary Power Supply source and is only supporting critical loads in Grade A, B and C medical locations, N+1 source redundancy shall be provided.
- Where the secondary power source is providing power backup for the entire facility, in addition to clinical risk grade A, B and C locations, N+1 redundancy may not be required. However, in the event of one Generator failure, the remaining arrangement shall be capable of supporting the entire Grade A, B and C medical locations.
- For healthcare facilities where, the total capacity of the Secondary Power Source requirement is within the limit of a single generator set, it is acceptable to have one diesel generator set.
- This guideline does not recognize an alternate power supply (in addition to PPS) from the local utility company or a Solar PV/Concentrated plant as a means of secondary power source.
- Special consideration shall be given to the choice of starting batteries and battery chargers for diesel generator sets. The diesel generator plant is highly dependent upon the availability of the batteries for cranking the engine when required. The batteries shall be either VRLA or Ni-Cd type; However, Ni-Cd batteries are highly recommended.
- Battery status to be monitored and alarmed through the building management system or any other separate monitoring system.
- Onsite fuel storage shall be provided for diesel generator sets. The fuel storage quantity requirements shall be carefully determined considering the level of care provided in the facility; it is recommended that healthcare facilities providing inpatient and critical care functions are provided with a minimum of 24 Hours of fuel storage at 70% average loading of the respective diesel generator sets. This can be reduced to 4 hours in case of outpatient clinics.
- The diesel fuel storage within the generator room shall not exceed 2400 liters.
- Separate, dedicated Main Distribution Board rooms shall be provided for secondary Main Distribution Boards serving emergency functions of the facility.
- Secondary power supply outlets in clinical areas shall be logically grouped in distribution branches with segregated distribution. Automatic change over between PPS and SPS shall be as close as practically possible to the point of utilization depending upon the criticality of the application.
- Feeder cables for radiology equipment incorporating high voltage generators drawing pulse currents for a short duration (not exceeding 5 Sec.) need not be sized considering the peak current as continuous current. The following general guideline may be followed while determining the demand load and associated feeder cable sizes for medical equipment drawing short duration impulse current.
- One imaging equipment: Demand load and cable size shall be designed based on 50% of the short time peak rating of such equipment or 100% of the continuous rating of the equipment; whichever is higher.

Two imaging equipment: Demand load and cable size for an upstream feeder serving two such imaging equipment shall be designed based on the sum of (50% of the short time peak rating of the first equipment or 100% of the continuous rating of the first equipment; whichever is higher) and (50% of the short time peak rating of the second equipment or 100% of the continuous rating of the second equipment; whichever is higher).

More than two imaging equipment: Demand load and cable size for an upstream feeder serving more than two such imaging equipment shall be designed based on the sum of the (demand load for largest of the two imaging equipment based on "b" above) and 20% of the sum of peak current of the all the remaining imaging equipment.

- Note that the above criteria are a general guideline for the design stage, final section of the cable shall be verified against manufacturer's certified requirement once the final selection of the equipment has been made.
- The 'momentary rating' referred above is defined as a rating based on an operating interval that does not exceed 5 seconds.
- The 'continuous rating' referred above is defined as a rating based on an operating interval of 5 minutes or longer.
- The secondary power supply distribution shall be logically organized in separate change over

(ATS) and distribution branches. Refer to table E.3.2 as example of grouping of circuits for secondary power distribution.

Secondary Power Distribution Branch	Connected Equipment/systems
Life Safety Branch	<ol style="list-style-type: none"> 1. Fire pumps 2. Emergency lighting 3. Fire detection and signaling 4. Smoke management systems 5. Firefighting lifts 6. Other fire and life safety equipment as per local fire code. 7. (Building life safety systems in general)
Critical branch	<ol style="list-style-type: none"> 1. Socket outlets in Grade A clinical risk areas 2. Socket outlets in Grade B clinical risk areas 3. Socket outlets in Grade C clinical risk areas 4. Critical medical equipment power supplies 5. Medical gas power supplies 6. Critical area illumination 7. UPSs serving ICT Systems 8. UPSs serving IPSs and medical locations
Equipment branch	<ol style="list-style-type: none"> 9. Domestic water pumps 10. Pneumatic tube system blowers 11. HVAC system equipment as applicable (part/full) as per design. 12. Lifts 13. Drainage sump pumps 14. Water treatment plants 15. Applicable loads in Kitchen 16. Laundry equipment 17. Standby lighting

Table: E.3.2 Secondary Power distribution branches

- 100% Power supply backup for chilled water generating plant or hot water generating plant for space cooling/heating is not mandatory but desirable. However, SPS shall have enough capacity to serve chilled water hot water for space cooling/heating in clinical risk grade areas A and B as a minimum. In cases where the primary cooling/heating for the healthcare facility is provided by remote district cooling/heating plant, power backup should be provided for backup cooling plant as described in Part E, section 2.12.2 of this guideline.
- SPS backup shall be provided for HVAC air plant such that loss of PPS will not compromise the pressure differential regime mandated by the HVAC section of this guideline.

Tertiary (UPS) power source and distribution

- Tertiary power supply source in the form of Uninterruptable Power supplies (UPS) shall be provided for Healthcare facilities to serve critical applications in clinical risk areas Grade A and Grade B defined in Table E.3.1. In addition, tertiary power supplies may be provided for sensitive equipment in other areas such as laboratories, pharmacy, critical care supervision stations, PACS and HIS workstations etc.
- In some cases, sensitive medical equipment is provided with individual UPS units provided adjacent to the respective equipment. In such cases, secondary power supply would suffice.
- In consideration of mitigating business continuity risks, the designer may provide UPS power outlets in non-clinical areas such as the finance department and receptions desks if required by the end user.
- The UPS units shall be static double conversion type either monolithic or modular type.
- Long life (10 Years) VRLA type batteries meeting IEC 60896 connected in dual string arrangement is recommended for UPS units. Multiple string battery connection assists in maintaining the batteries without completely eliminating the backup capacity of the UPS while in operation.
- Since the battery life is closely related to the ambient room temperature it is critical that the UPS/battery rooms temperature is maintained within a temperature range of 20 to 22°C. Alarm

systems may be considered to monitor the UPS room temperature and raise local and remote alarm when the temperature exceeds the limit.

- In general, it is recommended that UPS units are not shared between building services (IT, Security system etc.) and clinical applications. However, in case of healthcare facilities such as outpatient clinics it may be more feasible to have combined UPS units to serve clinical and nonclinical applications.
- Careful consideration shall be given to the UPS connection arrangement and redundancy. An appropriate number of central UPS systems connected in N+1 redundancy, closer to the critical loads, are recommended, rather than one single large UPS plant serving the entire facility. On one hand the single large UPS plant increases the risk of single point failure while on the other hand having large number of UPS units to monitor and maintain would become an operational challenge; thus, careful consideration shall be made by the designer to have an optimum number of UPS units based on the nature of the healthcare facility. Refer to figure below as an example of recommended secondary power source and distribution arrangement for a group 2 medical location.
- A parallel synchronous redundant UPS arrangement is recommended for serving non-clinical applications such as building IT systems. Refer to below figure as an example. N+1 modular UPS arrangement is also acceptable.

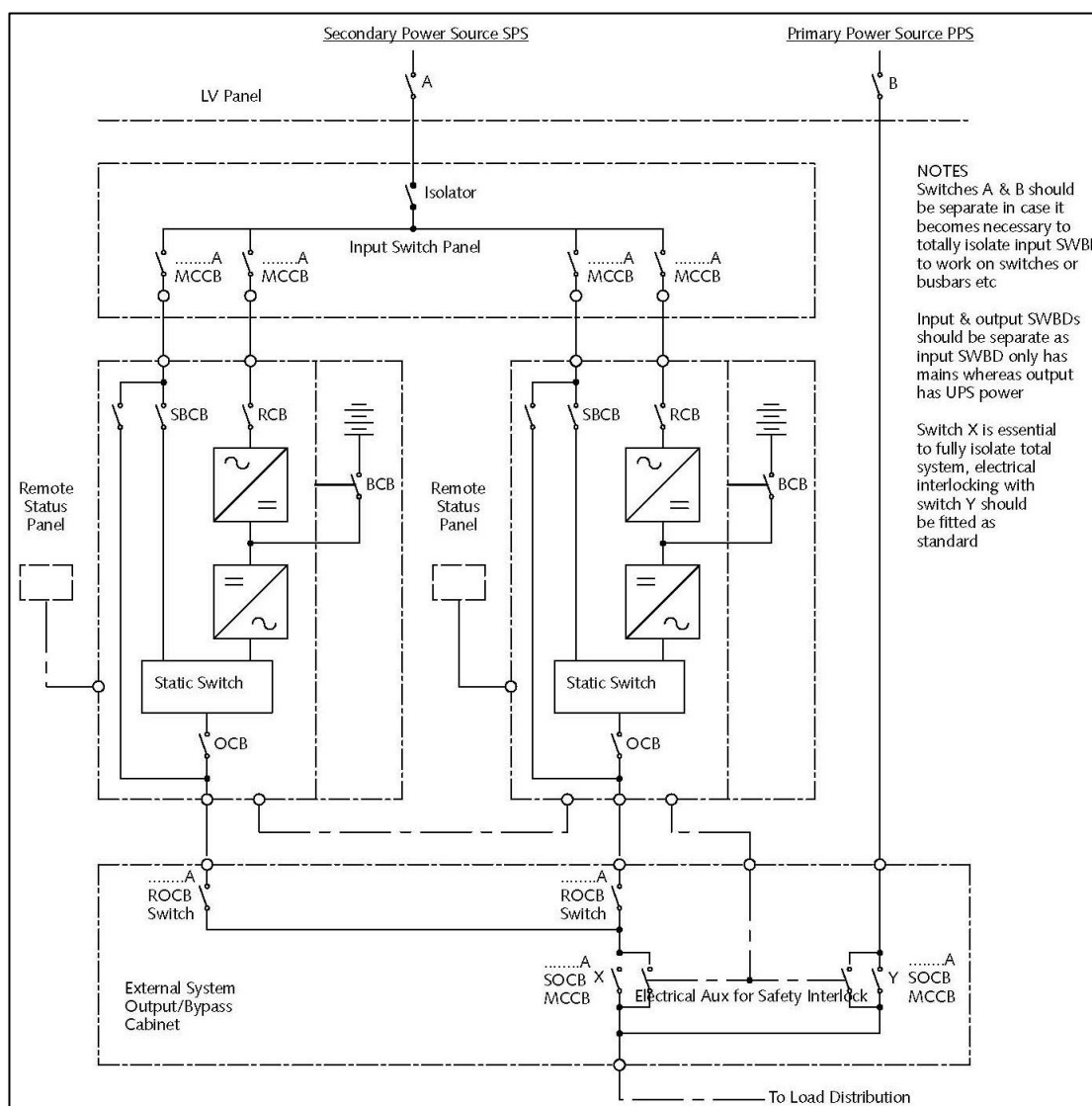


Figure: Synchronous / Parallel Redundant UPS Arrangement

- An autonomy time of 60 minutes shall be provided for UPS units serving clinical services in critical care areas while the input power to the UPS units are sourced from secondary power supply.
- This guideline does not recognize rotary UPS units as tertiary power source (TPS) for

Healthcare facilities due to the following reasons.

- Autonomy time provided by the Rotary UPS systems are not comparable to autonomy times that can be achieved with Static UPS systems.
- Rotary UPS units are normally installed together with Diesel Generator Sets, making it not suitable for installation closer to sensitive medical locations such as Operating Theatres.
- UPS units of 20kVA and larger or serving clinical risk grade A areas shall be provided with external bypass panel. Ability to by-pass the UPS unit in the event of a total failure of the UPS unit is a critical last option that should be available to the operator to maintain the power supply.
- Separate UPS rooms are recommended for UPS units larger than 20kVA, than housing the UPS units in sub-electrical rooms.
- UPS status and alarms shall be available in the Operating Theatres through the Surgeons' control panels or other annunciator units.
- In general imaging equipment such as X-Rays, CTSs, MRI do not require power backup for the entire equipment from a central UPS, but a smaller local UPS to power the respective control console (not x-ray generator and magnet) would be sufficient.
- If the imaging equipment is forming part of an interventional operating theatre suite, UPS unit serving such imaging equipment shall be specially designed to power the entire imaging equipment including x-ray generator or magnet to avoid the UPS units switching to bypass in case of transient overload and to ensure power quality.
- If the designer opts for backing up the entire imaging equipment such as CT including the X-Ray generator, individual UPS units specially designed to handle transient currents should be provided. It is recommended that this UPS is not shared to serve other medical locations. Autonomy time for UPS serving noninterventional imaging only and fed from SPS can be limited to 10 Minutes.
- Power outlets intended for connecting critical medical equipment in clinical risk grade A locations shall be fed from propitiatory Isolated Power Supply (IPS) panel meeting relevant IEC standard or UL listed.
- It is recommended that IPS panels serving operating theatres are provided with integral automatic transfer switch for additional resilience. Power sources for the ATS shall be primarily from the tertiary power source while alternate power supply can be from the secondary power source.
- Isolated power panels shall be located closer (within 30m) to the area of application to minimize the leakage currents due to conductor capacitance.
- Maximum capacity of the IPS panels shall be limited to 10kVA, with single phase input.
- It is recommended that at least two IPS circuits are provided for each patient care location in clinical risk grade A. Locations where critical medical equipment are likely to be connected to the patient.
- Where multiple IPS panels are provided to serve multiple Operating Theatres or critical care areas it is recommended that the IPS final circuits are interleaved between the different rooms so that failure of one IPS unit will not render all IPS outlets in any given patient location without power simultaneously.
- IPS panels are not recommended to be located within operating theatres; rather these shall be located in suitably designed ventilated spaces to facilitate cooling and maintenance access.
- This guideline recommends that a maximum of 4 Nos. 13A sockets outlets are connected to any given IPS final circuit. No ring circuits are not permitted for IPS final circuits.
- IPS final circuits shall not be protected with RCD or RCBOs.
- Due to the inherent nature of isolated power supply final circuits, both conductors of the final circuit will be live and will be at a higher potential with respect to the ground; considering this both conductors of IPS final circuits shall be wired with same phase colour as that of primary power supply input to the IPS and should be ferruled as L1 and L2.
- The IPS sockets shall be double pole unswitched, with blue colour face plate with engraving "For Medical Equipment Only".

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- Luminaires including operating theatre surgical lights are not required to be connected to IPS panels
- Remote Alarm Annunciator Unit for the IPS panel shall be located in the respective Operating Theatre and associated nurse stations.
- In case of IPS panels serving critical care areas other than operating theatres, the Remote Alarm Annunciator unit shall be located at the respective supervision (nurse) station.
- It is recommended that the IPS Remote Alarm Annunciator Unit in the operating theatres have the following parameters displayed.
- IPS insulation status/Leakage current
- IPS load information
- IPS temperature
- Input ATS status (if applicable)
- UPS Alarm
- Isolated circuit fault locator system in conjunction with IPS leakage monitoring system is desirable but not mandatory.
- Socket outlets supplied from IPS panels are also referred as “Cardiac Protected” outlets elsewhere in these guidelines.

Protection and switchgear

- Since it is critical to ensure availability of critical healthcare facilities during any natural calamities it is important that the main intake switchgear (both LV and MV) are not placed below grade level. Potential flooding risks are to be assessed carefully before finalizing the location of main electrical intake rooms.
- Main Medium voltage / 11kV intake switchgear and its arrangement shall be as per LOCAL AUTHORITY code compliance.
- Main intake and distribution MV switchgear shall be rated with an internal arc classification (IAC) of ‘A-FL’ (arc containment from front and lateral of the panel) as a minimum or recommended to be ‘A-FLR’ (arc containment from front, lateral and rear of the panel) as per IEC 62217-200.
- Main Intake LV switchgear (MDB) serving the critical care facility shall be a minimum of Form 4b assembly meeting IEC 61439-2 and relevant sections of LOCAL AUTHORITY regulations.
- All Motor Control Centres (MCC) shall be a minimum of Form 4a or 4b type tested assembly meeting IEC 61439-2 and relevant sections LOCAL AUTHORITY regulations.
- Final circuit distribution boards shall be factory-built assemblies meeting IEC 61439. To reduce the impact of cumulative natural earth leakages of medical equipment on the protective device, that may cause nuisance tripping, it is recommended that final circuits serving clinical areas are protected with RCBOs, rather than RCDs covering multiple MCB circuits.
- RCBOs and RCDs serving small power circuits in Group 0, Group1 and Group 2 (as per HD 60364-7-710) medical locations shall have a tripping characteristic of Type A or Type B with a maximum tripping current of 30mA: Type AC, RCBOs or RCDs shall not be used in Group1 and Group 2 medical locations.
- Socket outlets protected for earth leakage is also referred as “Body Protection” elsewhere in these guidelines.

Electromagnetic Compatibility

- In general, all electrical and electronic equipment used in healthcare facilities shall be CE (or Equivalent) marked or certified. Careful consideration shall be given to power distribution induced electromagnetic interferences on sensitive medical equipment.
- Where non-CE marked or equivalent non-certified, equipment has to be used in the facility the original equipment manufacturer shall confirm that the proposed equipment use in the facility will not have any adverse effect on other sensitive equipment in the facility.
- The following are recommended for healthcare facilities for EMC.

- Cable containment (conduits and cable trays) used shall be metallic rather than plastic. Conduits recessed in concrete, masonry or cement plaster can be plastic.
 - Cable trays with slots longitudinal to the length of the cable trays are recommended for carrying communication cables rather than caged or basket type cable containment.
 - Where screened or armored cables are used the screen shall be earthed at both ends of the cable.
 - Follow IEC 61000-5-2 with respect to electromagnetic compatibility.
 - Follow IEC 60364-5-54 with respect to earthing and bonding.
 - Follow EN 50310:2016 Application of equipotential bonding and earthing in buildings with information technology equipment.
 - Follow IEC 60364-5-52 with respect to segregation of cables at various voltages from one another.
- Total harmonic distortion shall be limited below 5%.
 - Single core power cables emanating from the secondary side of the transformers shall be armored and armoring to be earthed at both ends to reduce magnetic coupling of the cables with structural steel reinforcement of the building.
 - Communication or Extra-Low voltage system cable shall not be run in the same cable tray or trunking as power cables

Earthing and bonding

- High voltage and Low Voltage system earthing to be as per LOCAL AUTHORITY practice. In addition, safety requirements given below shall be met.
- Equipotential bonding to be provided for all Group 1 and Group 2 Medical locations by providing equipotential bonding to all fixed medical equipment including service panels, pendants and bedhead units by bonding the metal frames or metal bodies of these equipment with the Earth Bonding bar (EBB). Refer to LOCAL AUTHORITY regulation Appendix 9 for the applicable conductor sizes for supplementary bonding.
- Critical medical locations such as Operating Theatres shall have dedicated EBBs located near the Operating Theatre. For other areas EBB shall be in the respective sub-electrical rooms, where the final distribution boards are located.
- For Hyperbaric Chambers, NFPA 99 Chapter 14 codes stipulate that if the oxygen inside a chamber is in excess of 23.5 percent, the patient as well as the chamber must be electrically grounded because a static charge could increase the risk of fire. The installation of additional electrical equipment should be limited only for devices which comply with hyperbaric conditions
- Medical imaging and treatment locations requiring multiple supplementary bonding such as CT Room, MRI Room and Radio Therapy Bunkers shall be provided with dedicated EBB.
- Connections to the EBBs shall be carefully labelled and easy to inspect.
- When earth mats are provided in Operating Theatres, the mat to be made continuous and should be connected to EBB.
- Dedicated earthing jacks may be provided in critical care areas such as Operating Theatres, however these are not mandatory. (IEEE Std. 241)
- IPS panels shall have a dedicated earthing as illustrated in the typical operating theatre earthing as illustrated in diagram E.3.2

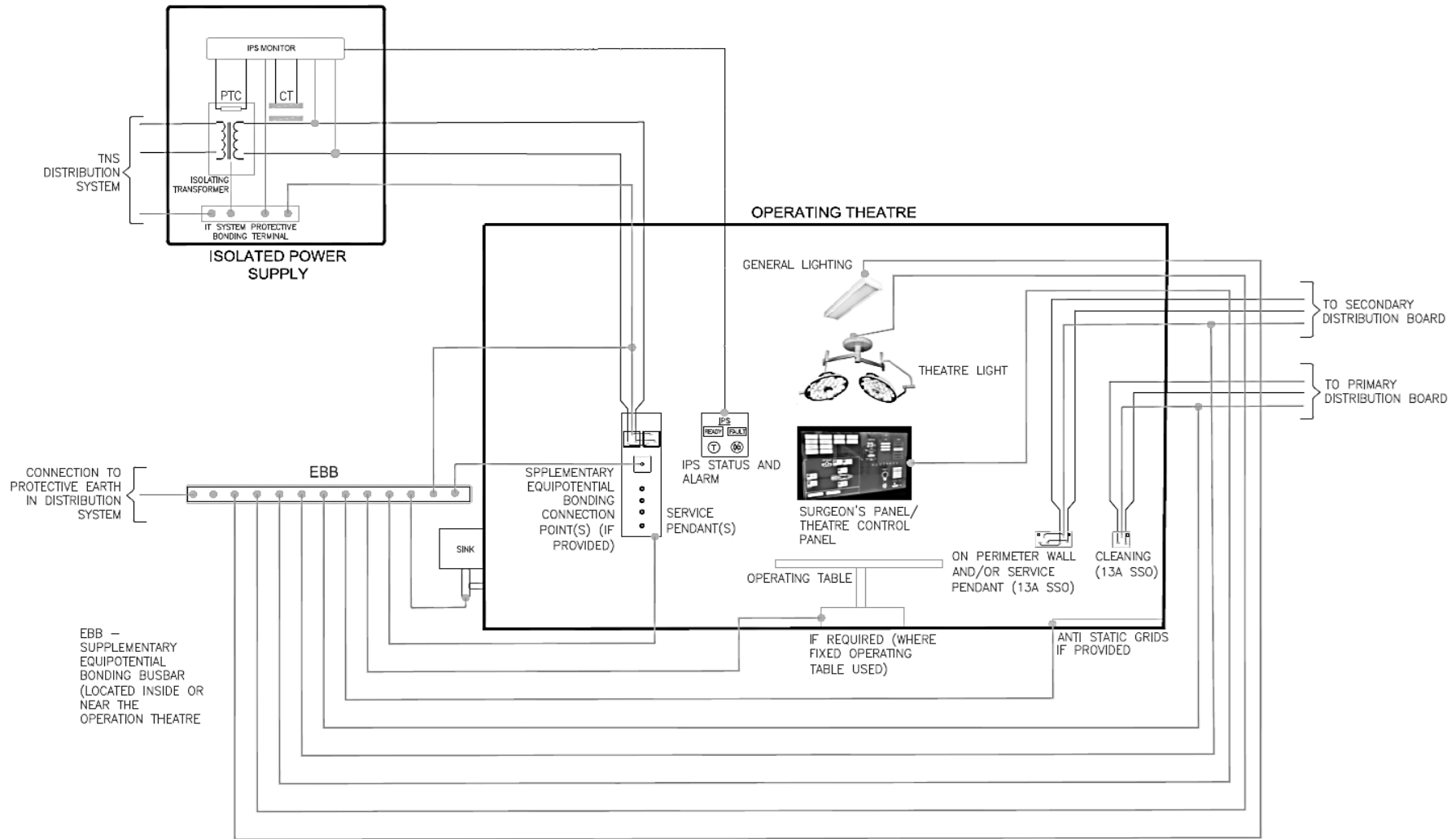


Figure E.3.2 Typical earthing arrangement for an operating theatre

Lightning protection

- Lighting protection system for healthcare facilities to be designed based on IEC 62305 series.
- The class of lightning protection required for the facility to be determined by the designer based on IEC 62305 Part 2.
- Type 1 or 1+2 Surge protection devices (SPDs) to be provided at the incomer of each main distribution boards (MDB)
- Special consideration to be given for protection of electronic devices and medical equipment within healthcare facilities for damages from lightning strike. Surge protection devices (SPDs) shall be provided for submain electrical branch circuits serving critical medical and communication equipment. The surge protection device to be carefully selected based on the surge protection environment (defined in IEC 62305) in which it is located.

Containment and cables

- Power supply distribution cables serving life safety equipment such as fire pumps, firefighting lifts and smoke management systems shall be fire proof as per local civil defense requirement, while SPS cables serving medical equipment other than life safety systems shall be same type of cables as used for PPS.
- Wiring cables and power cables used in healthcare facilities shall be with Low-smoke Zero Halogen (LS0H) insulation. Armored power cables installed outdoor or buried underground shall be with PVC outer sheath.
- Separate cable containment for PPS, SPS and TPS distribution is required for clinical risk grade A and B areas.
- Isolated power supply (IPS) final circuits shall be provided with separate cable trunking and conduits.
- Conduits used in clinical risk grade A and B areas are highly recommended to be of galvanized steel, while galvanized steel conduits are desirable in clinical grade areas C, D and E.
- Separate containment to be provided for emergency lighting circuits.
- Containment to be labelled suitably for ease of identification of services it carries.
- Final circuits
- Using of floor power outlet boxes in healthcare facilities shall be minimized due to housekeeping considerations. Where floor boxes are used in open public spaces, it shall be with stainless steel lid and suitable for wet mopping with lid in closed position.
- Use of multi-plug extension cords are not permitted in healthcare facilities, as extension cords are prime cause for overloading of circuits and safety risks associated with it.
- Primary (Normal) power supply sockets (13A) shall be identified with white rocker switches. Faceplate shall be either plastic or metal. Plastic faceplates shall be white coloured with white rocker switch. Where metal face plates are used, the rocker switch to be of similar colour as that of faceplate.
- Secondary (Emergency) power supply sockets (13A) shall be identified with red rocker switches. Faceplate shall be either plastic or metal. Plastic faceplate shall be white coloured with red rocker switch. Where metal face plates are used, the rocker switch to be red.
- UPS power supply sockets (13A) shall be identified with blue rocker switches. Faceplate shall be either plastic or metal. Plastic faceplate shall be white coloured with blue rocker switch. Where metal face plates are used the rocker switch to be blue.
- Edges of Light switches and socket outlets shall be suitably spaced away from the medical gas outlets at any location so that medical gas outlet accessories do not obstruct the socket outlets.
- USB charging sockets integrated with 13A socket outlets shall not be used in healthcare facilities. Where USB charging points are to be provided in public areas it shall be separate charging stations plugged into standard 13A sockets.
- 13A Socket outlets indented for mobile x-ray machines in operating theatre shall not be fed

from IPS, but from the primary or secondary power supply branch.

- UPS backup shall be provided for operating theatre surgical lights.
- UPS backup shall be provided for Operating Theatre IT equipment and Theatre Control Panel.
- Socket outlets intended for highly sensitive medical equipment such as automated medication cabinets shall be provided with dedicated circuits.
- All power outlets to be clearly labelled with respective final circuit reference.

Lighting

- While designing healthcare lighting, follow detailed recommendations given in CIBSE Lighting Guide 2: Hospitals and healthcare buildings, 2008 or later version, by The Society of Light and Lighting.
- Lighting circuits shall not be connected to IPS circuits.
- Nighttime orientation lights, mounted low level on wall, are recommended in patient bedrooms. These lights should be operable from patient location and from main door to the patient bedroom.
- In many clinical locations varying levels of lighting is required. Careful consideration shall be given to proposed clinical function of the area while determining the lighting control approach and design of the switching circuits. It is always advisable to employ two switching circuits in any rooms having more than two light fixtures.
- For sterile areas, the light fixtures used shall have a degree of protection not less than IP54 and the luminaires should be sealed onto or into the ceiling or building fabric to an equivalent standard. It should be noted that only parts of the areas designated 'clean' will require this level of cleanliness. Reference should also be made to BS EN 14644(21) with regard to general requirements for clean rooms.
- Refer to Table 3.3 (reproduced from CIBSE LG2) for recommendations on lighting levels, colour rendering index, lighting control and standby lighting requirement.
- Standby lighting (normal lighting backed up by SPS) shall be provided for all clinical risk grade areas A, B and C.
- Clinical risk area Grade A shall be provided with Grade A standby lighting. (100% Luminaires supplied from SPS branch)
- Clinical risk area Grade B and C shall be provided with Grade B standby lighting. (Around 50% Luminaires supplied from SPS branch)
- Luminaire selections to be complementing the ceiling integrity in relation to infection control; detailed recommendations given under CIBSE Lighting Guide 2 to be adhered with.
- Life safety emergency lighting to be provided based on local fire code.
- Recommended illumination levels, colour rendering index, method of lighting control and grade of backup lighting is summarized in table

Room/Function	Illuminance (Lux)	Colour Rendering Index (%)	Recommended Lighting Control Method*	Lighting Grade (Section 3.16.8,9)
Emergency Unit				
Admissions/Reception	300	80	N	B
Stores	300	80	N/AL	A
Treatment Area	500	80	N	B
Minor Operation	500(15000 / 30000 Local)	90	N	B
Triage	500	90	N	A
Plaster Room	500	80	N	B
Procedure Room	500 (15000 / 30000)	90	N	A

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Room/Function	Illuminance (Lux)	Colour Rendering Index (%)	Recommended Lighting Control Method*	Lighting Grade (Section 3.16.8,9)
	Local)			
Resuscitation Room/Bay	500	80	N	B
Common and Circulation Areas				
Corridors (General)	200	80	S/AL	B
Entrance Canopy	50 (Min)	80	S/AL	B
Entrance Lobby	200 (Min)	80	S/AL	B
Library	300	80	S/AL	—
Lift Car	150	80	-	—
Lift Lobby	200 (Min)	80	S/AL	B
Loading Bay	100	80	S/AL	—
Reception Area	300	80	S/AL	B
Overnight Stay	150	80	S/AL	—
Lounge	150	80	S/AL	—
Shop/Kiosk	300	80	S/AL	—
Storage (General)	200	80	N/AL	—
Toilets	200	80	N/AL	—
Changing Room, Lockers	100–150	80	N/AL	—
Prayer Rooms	75-100	80	N/AL	—
Tutorial Room	300	80	N/AL	—
Consult/Exam Room	300	80	N	B
Disposal (Clinical, Domestic Waste)	200	80	N/AL	—
Doctor's Office	500	80	N/AL	B
Medication Room	500	80	N/AL	B
General Office	300	80	N/AL	B
Seminar Room	300	80	S/AL	B
Staff Change	100	80	N/AL	—
Staff Room	50/200	90	N/AL	—
Clean Utility	150	80	N	B
Dirty Utility	200	80	N	B
Critical Care				
Critical Care (Night)	5 (Max)	80	N/S	B
Observation/Night Watch	20	80	N/S	B
High Dependency Unit (HDU)	100	80	N/S	A
Intensive Care Unit (ICU)	100	80	N/S	A
Night Light	5 To 10	80	N	A
Simple Observation /Examination	300	80	N/S	A
Examination	1000 (Local)	90	N	A
Sterile Supply Unit (SSU)				
Decontamination and loading	500 (Local)	80	N	A/B
Maintenance (Including Rear of	200	80	N	—

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Room/Function	Illuminance (Lux)	Colour Rendering Index (%)	Recommended Lighting Control Method*	Lighting Grade (Section 3.16.8,9)
Cleaning Units)				
Sterile Storage	150	80	N	—
Packing Area	500	80	N	B
Dental Unit				
Laboratories	500	80	N	B
Reception/Administration Areas	300	80	N/S	B
Dental Surgeries	8000 To 20000	90	N/S	A
White Teeth Matching	5000	90	N	B
Laboratory				
Aseptic Laboratory	300	80	N	B
Blood Bank	300	80	N	A
Colour Inspection	1000 (Local)	90	N/V	A
Cold Rooms	200	80	N	B
Inspection	500 (Local)	80	N	A/B
Laboratories	500	80	N	A/B
Relatives' Waiting Room	300	80	N/S	B
Seminar Room	300	80	N/S/V	B
General Treatment Areas				
Dialysis	500	80	N/V	B
General Storage Areas	200	80	N/AL	—
Teaching Areas	300	80	N	—
Administration (Medical Records)	500	80	N	—
Pharmacy	500	80	N	A/B
Morgue				
Autopsy Table	5000	90	N	—
Autopsy Rooms General	500	90	N	—
Body Holding Room	200	80	N	B
General	300	80	Sp	—
Staff Change	100 To 150	80	N	B
Storeroom	150	80	N	—
Viewing Room	50/100	80	S/V	B
Waiting Room	200 (Min)	80	N/S	B
Linen Holding Unit				
Linen Store (Linen Department)	100	80	N	—
Pack and Dispatch	300	80	N	A
Pressing	300	80	N	A
Sewing Room	500 (Local)	80	N	A
Laundry	300	80	N	A
Delivery Unit				
Applying Sutures	1000 (Local)	90	N	A

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Room/Function	Illuminance (Lux)	Colour Rendering Index (%)	Recommended Lighting Control Method*	Lighting Grade (Section 3.16.8,9)
Circulation Space (Day)	100	80	N	B
Delivery	500	80	N/S	A
Circulation Space (Day)	100	80	N	B
Day	50 To 100	80	N	A
Night	5	80	N	A
Nurseries (Day)	100	80	N	B
Nurseries (Night)	5	80	N	B
Formula Room	300	80	N	B
Special Care Baby Unit	1000 Local	80	N	A
Staff Station				
Day	300	80	N/S	A
Night	30/200	80	N/S	A
Interview	300	80	N	B
Operating Rooms				
Anesthesia Induction Room	1000 (Local)	80	N	A
Anesthesia Induction Room	500	80	S	A
Angiography Procedure Room	500	80	S/V	A
Endoscopy Procedure Room	300	80	S/V	B
Operating Room	1000	90	S/V	A
Operating Table/Cavity	10000 to 100000	90	S/V	A
Recovery – Stage 1	500	90	N/S	A
Scrub	500	80	N	B
Clean Utility	100 To 150	80	N	B
Dirty Utility	100 To 150	80	N	B
Allied Health				
Gymnasium	300	80	N/S	—
Hydrotherapy Pool	200	80	N	A
Physiotherapy	200	80	N/S	—
Rehabilitation	200	80	N/S	B
Ophthalmology				
Consult Room	300	80	S/V	B
Examination of Outer Eye	1000 Local	80	N	—
Reading/Colour Vision Test Screen	300	90	N	—
Vision Test Area	100 (Max)	80	S	—
Outpatient Unit				
Consult/Exam Room	300	80	N	B
Treatment Room	500	80	N	B
Medical Imaging / Interventional Cardiology / Nuclear Medicine				
Angiography	300	80	N/V	A
CT/MRI Scanning Rooms	300	80	N/V	A

Room/Function	Illuminance (Lux)	Colour Rendering Index (%)	Recommended Lighting Control Method*	Lighting Grade (Section 3.16.8,9)
ECG	300	80	N/S	A
Electro-Medical	300	80	N/S	A
Screening - Fluoroscopy	300	80	N/S	A
Isotope Store	300	80	N/S	B
Radiotherapy	100	80	N/V	A
Ultrasound	300	80	N/S	A
Mammography	500	80	N/V	A
X-Ray	300	80	N/S	B
Inpatient Unit				
Children's Play Area	300	80	N/AL	B
Circulation Space	100	80	N/S	B
Circulation Space (Night)	5	80	N/S	B
Treatment Room	1000 (Local)	90	S/V	A
Treatment Room	500 (General)	80	N/S	B
Staff Station				
Day	300	80	N/S	A
Night	30/200	80	N/S	A
Observation/Night Watch	20	80	N/S	B
Observation/Night	1 To 5	80	N/S	B
Mental Health Units	200	80	N/S	B
Patient Bed	300	80	N	B
Corridors (Day)	200	80	N/S/AL	B
Corridors (Night)	50	80	N/S/AL	B
<p>* LIGHTING CONTROL</p> <p>N – Conventional On/Off Switching</p> <p>S – Multilevel switching with ability to control the lighting level in the room by selective on / Off switching of groups of luminaires</p> <p>V – Variable lighting output from luminaires</p> <p>AL – Automatic lighting control for energy saving</p>				

Table E.3.3 Recommended Illumination Levels

System Testing, Commissioning and Operation

Equipment commissioning is an important phase in the project timeline and is critical in confirming that the design parameters are met by the installed system and the system meets the minimum code requirements and commissioned as per manufacturer recommendations.

For medium to large scale healthcare facilities an independent commissioning agent should be employed by the facility owner/client to oversee and integrate the commissioning process.

The following points should be kept in mind while preparing for commissioning of the systems for healthcare facilities.

- Method Statements
- Testing and Commissioning plan
- Testing and commission shall be carried out by respective system manufacture's trained and authorized represented.
- All testing and commissioning records to be included in the O&M documents. It is highly

recommended that an online solution is deployed for O&M documentation for ease of retrieval and reference.

- Routine testing of backup generators and UPS to be conducted at every 30 days or recommended by the manufacturer (whichever is shorter), and results recorded for verification during facility inspections.
- Training on the equipment installed should be conducted by the authorized representatives of original equipment manufacturer.
- Routine maintained activities shall be carried out as per the respective system manufacturer's recommendation and easily retrievable records are maintained in the facility. Deployment of online software-based facility management solutions incorporating necessary maintenance modules are highly recommended, depending upon the nature of the facility.
- Refer to LOCAL AUTHORITY regulation section 1.13 with respect to detailed requirement on routine inspection and maintenance of electrical distribution equipment. These requirements to be strictly adhered to and records shall be available in the facility for routine verification.
- All critical system malfunctions to be monitored and all such events to be recorded and archived.

4 ELV and ICT systems

This document is intended for the Architect/Engineer (A/E) and others engaged in the design and renovation of Healthcare facilities. Where direction described in applicable codes are in conflict, the A/E shall comply with the more stringent requirement. The A/E is required to make themselves aware of all applicable codes.

The document should be read in conjunction with other parts of the Health Facility Guidelines (Part A to Part F) & the typical room data sheets and typical room layout sheets.

Introduction

ELV and ICT systems play a key role in efficient and safe operation of any Healthcare facility. With the advent of multitude of systems and approaches and fast evolving technologies it is not prudent to mandate specific design criteria in this guideline for ELV and ICT systems. The following section provides general guidance to the designer during the design of various ELV and ICT system in healthcare facilities from a functional point of view.

The LAN Infrastructure shall provide IP connectivity for several services, which may require being isolated from one another from an application point of view while sharing the same physical network. The applications include but not limited to Voice, Data, CCTV, Video, Public Address, Digital Signage, Nurse call, Central Clock, queuing systems, HIS, PACS and others. The IT infrastructure shall be flexible high capacity network capable of providing virtualized services to IP unicast and multicast applications. The IT network must be highly dependable and provide sub-second recovery in the event of any component, node, or link failure.

ICT Network

The following key objectives to be considered for the Medical Grade Network (MGN) design and its implementation for healthcare facilities. Follow standard ISO/IEC 11801 – “Information technology, Generic cabling for customer premises”, with respect to structured cabling.

- **High Availability & Resiliency:** Due to the mission critical nature of many of the systems that will run on the IT network, fault tolerance and resiliency are mandatory requirements in all aspects of Design. The solution must be designed with No Single Points of Failure: link redundancy, power redundancy and core switch redundancy are essential. The network should be available at all times and should not be severely affected in the cases of component failures. LAN switches must support state of the art and latest LAN technologies.
- **Security:** The network design shall have capability for virtualizing and segregating users and services in isolated zones over the same physical network. In addition, the proposed solution should be capable of protecting network from traditional IP hacking and IP exposure. IT security to be considered during the design and implementation and to be verified as part of completion sign-off.
- **High Performance:** The Network should be able to support latency sensitive applications by using low latency switches that can support optimal topologies to reduce number of hops through the network. In addition, the proposed network should be fully active-active load sharing with no idle hardware or links.
- **Convergence:** It is recommended that a highly resilient converged Network Infrastructure is planned for healthcare facilities than several individual semi-resilient networks. Each virtual network shall have own firewalls to avoid hopping from one virtual network to another.
- **Scalability:** The network shall be designed in a way that allows for smooth future growth and scalability. Scalability is required to guarantee the support for future applications, users, traffic, technologies, etc. without the need for major upgrades, or restructuring. Future technologies such as 40G & 100G may be considered.
- **Simplicity:** The network design solution shall provide automated end to end configuration of services with minimal human intervention. SDN (Software Defined Networking) and configuration automation technologies shall be capable to expand to the campus and remote sites where users and network devices exist.
- **Manageability:** Manageability is an essential requirement. All aspects of the solution should provide a method of Centralized Control via SNMP Management as well as the normal switches management features through console interface, web-interface. All management features should be integrated in the switches whether on the backbone or the edge switches.

Simplicity of the design is an important advantage. Intelligent patch panels are recommended for large facilities with over 3000 network points.

- **Open Standards:** The network design and technology shall be based on open Standards and only use IEEE or IETF certified protocols to allow interoperability with other vendors supporting the same standards such as HL7 and DICOM. Proprietary protocols and mechanisms are not desirable.
- **Product & Technology Reliability and Maturity** is a critical factor that should be considered during the implementation. Vendor's technologies and approaches must be proven in live implementations prior to their deployment in any healthcare facilities.
- **Multicast Enabled Architecture:** The IT network shall support multiple virtual IP multicast routed domains with complete traffic separation between them.
- **Medical Devices security and tracking:** The network shall be capable of providing security and ease of mobility and tracking for expensive medical equipment that may need to be relocated across the healthcare facility, and to provide automated SDN based deployment to centrally manage, configure, and secure those devices.
- **Bandwidth requirements** to be carefully considered when determining the topology of the network and data storage requirements. Bandwidth and data storage requirement to be calculated based on the systems and number of modalities anticipated in the facility. Systems such as PACS require high amount of bandwidth requirement while systems such as Laboratory Information Systems or Central Clocks may require only limited bandwidth.
- **Fully redundant and resilient converged network** is preferred over a number of individual networks supporting different systems. However, high bandwidth systems such as CCTV together with access control may be in a separate network.
- **All ICT and ELV equipment** located in the clinical areas shall be specifically designed for the intended application especially with respect to safety and infection control.
- **Data storage capacity** shall be planned for a minimum of 6 years operation of the facility during the initial build. Additional off-site storage is also recommended.
- **The main data storage and server room** for the facility shall not be located below grade level.
- **A typical network topology** that will provide enhanced level of availability and network redundancy is illustrated below.
- **When public WIFI access** is provided in the facility, this should be implemented through Captive Portals.
- **Where cloud storage** is considered it should be compliant to TRA information security policies.

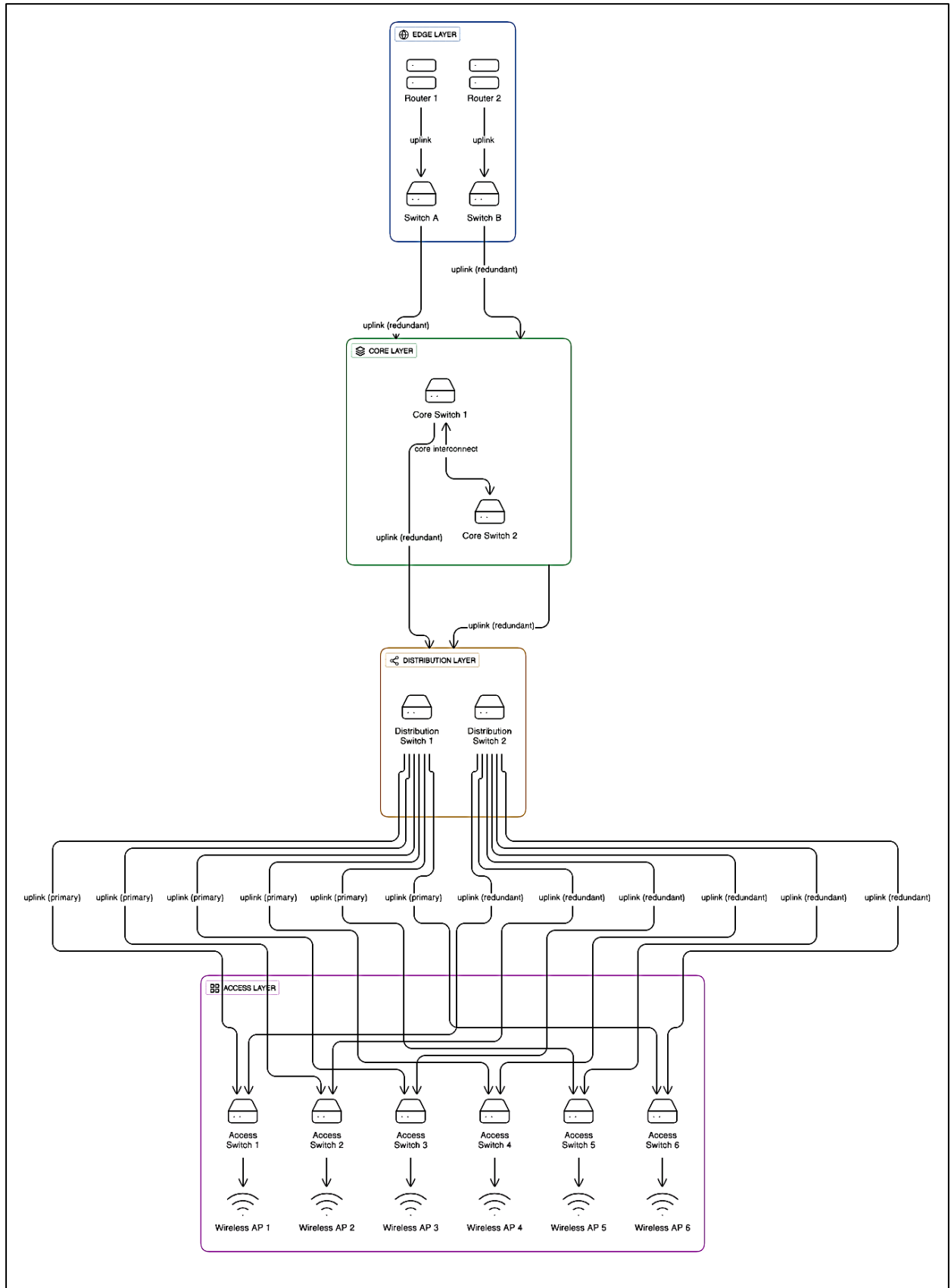


Figure E.4.1 - Typical IT Network Topology

Nurse Call Systems

- Nurse call system shall be provided in all healthcare facilities to suite the level of care provided in the facility. This guideline recommend that the component terminologies and its basic functions are standardized as follows.
- Annunciator - Desktop Console (AN-DC): This unit is intended to be located at the nurse stations for receiving calls and alarms from different patient and staff locations. This unit is recommended to have bi-direction speech capability with patient privacy in mind.
- Annunciator - Room Lights (AN-RL): These are colour coded lights above or beside each main entrance to the area/room where the Nurse Calling devise is located, to assist the responder to reach the originator of the call quickly and efficiently.
- Annunciator - Corridor Display (AN-CD): Corridor displays, alphanumerically indicating the origin and nature of a call from the patient or other staff member greatly help in efficiently responding to an emergency call. Depending up on the specific configuration of the clinical department corridor displays may be required. This can be either dedicated linear LED displays or can be integrated into strategically positioned IPTV screens if seamless integration of the two systems are implemented.
- Patient call with handset (PC-H): These devices shall be located in in all patient locations where the patients are likely not attended by a staff member continuously. This unit shall comprise of a fixed unit at the bed head with Staff Assist button, Speaker, Microphone and Emergency Call buttons in addition to the jack for plugging the patient handset. The patient handset shall have a minimum of easily identifiable nurse call button to originate a call to the associate nurse station, speaker, and microphone for bi-direction communication with nurse and reading light control. The handset to be durable, simple, and easy to use and disinfect.
- Patient call without handset (PC): These units shall be used in areas where all functioning of PC-H (above) is desired other than the function of the handset. This will be a wall mounted unit.
- Patient call – En-suite [Toilet] (PC-E): These units are used to initiate an emergency alarm call from the patient toilets to the associated nurse station. These call buttons are to be easily visible and recommended to be located at low level in the patient toilets reachable from shower area as well as from WC. One or two buttons shall be provided depending up on the configuration of the toilet. These units shall be waterproof and designed to be located at wet locations. Ceiling mounted call units with pull cords are not recommended.
- Staff Assist Call (SAC): These devices are intended for staff at a patient location to seek additional help from other staff members. This button may be integrated with a common face plate providing other functions or can be on a separate face plate depending up on the product design by the manufacturer.
- Staff Presence (SP): This is an optional device that can be provided at the entrance to a patient bedroom for activation by a staff member to indicate someone is already attending to the patient. The annunciator room light above the door shall indicate the nurse presence. This module can be either an independent button or can be integrated to other modules forming part of any workflow solution the end user may optionally include for efficient functioning of the facility.
- Emergency Call (EC): Emergency Call buttons are intended for clinical staff to escalate an emergency by alerting other relevant staff members for additional help. Activation of the emergency call (EC) button shall generate an audible tone-based alarm, at the associated staff station and other designated mobile devises, along with alphanumeric display indicating the nature and location of the call. The emergency call button can be a separate unit or integrated into a console including buttons for other nurse call system functions. Emergency calls should only be cancellable from the patient location where the call was originated.
- Wireless Handset (WH): Wireless handsets to receive nurse call system audio calls and alert text messages are recommended for use of staff members on the move within departments. A minimum of two wireless units are recommended at each supervision station; this quantity to be increased based on the number of anticipated staff members on the move within the department.
- Refer to the RDS (Room Data Sheets) included under Part B of this guideline for the recommended Nurse Call System devices for various clinical locations.

Part E: Health Facility Briefing & Design Engineering

- Additional optional functions to facilitate workflows and patient monitoring may be provided as part of the nurse call systems.
- There shall be interface between the fire alarm system and nurse call system to discretely alert the respective Nurse Stations of any fire detection events.
- Where IP based communication is used by the Nurse Call system, the Nurse Call System may share the facilities' hospital grade IT backbone network.
- It is recommended that the nurse call system has the capability to relay alarm text messages from the Nurse Call system to mobile devices such as IP Phones in the facility or over mobile phone data networks and over facility WIFI network.

Central Clock Systems

- Central Clock Systems are recommended in critical care and relevant public areas of the hospital for unified time referencing. The system comprises the following components in general.
- Master Clock Unit: The function of this unit to accept time references inputs over GPS and NTP and relay time reference signals to time display clocks located at various locations in the facility.
- Clock Displays: These devices will display the unified time based on the input received from the master clock unit. The clock display can be either analogue or numerical. This guideline recommends clocks with numerical displays where medical procedures takes place, while analogue displays in public areas (where provided).
- Due to reliability considerations it is recommended that clocks are wired type powered using POE. Where POE facility is not available local power supplies or battery cells may be considered.
- Clocks with additional functions such as elapsed time displays are required in operating theatres. The reset button for these elapsed clock function to be located at an accessible height.
- Refer to the RDS (Room Data Sheets) included under Part B of this guideline for the recommended locations of clock displays.

CCTV and Access Control

Healthcare premises pose unique changes to ensure security due to the presence of people under mental stress, high value equipment and sensitivity of medical data. To mitigate this risk a carefully designed and implemented CCTV and Access Control system to be provided for healthcare facilities. The coverage and complexity of the system will depend up on the type of facility. The following section provides a brief on general considerations to be made while designing CCTV and Access Control Systems for healthcare facilities.

- CCTV system design and installations shall meet the requirements of local law enforcement agencies with respect to equipment standards, coverage, monitoring and data storage requirements. In addition, the requirements given hereunder shall be considered during the design.
- Patient privacy to be considered while deciding the location of CCTV cameras. Cameras shall not be installed in areas where patient privacy may be compromised.
- CCTV coverage shall include the following areas but not limited to.
 - Inside medication rooms.
 - Outside medication rooms covering entrance door.
 - Inside laboratories
 - Inside blood storage rooms
 - Common corridors
 - All entry and exits
 - Emergency Room waiting areas and reception
 - Pharmacy, medication dispensing areas

- Loading dock and receiving areas
 - Cash counters
 - Waiting areas
 - Nursery
 - Body storage areas
 - Individual department main entrance doors
 - Staff/Nurse stations
 - Staff rooms
 - Inside enclosed fire exit stairs
 - Outside public toilet main entrances
 - Inside Hot Labs
 - Nursery
 - Entrance to technical rooms
 - Inside main MEP plant rooms
 - In lift lobbies and inside lifts
 - Sterile Supply Unit
 - Also refer to RDSs provided under Part B of this HFG.
- In addition to the CCTV system cameras provided for the general security surveillance, there may be CCTV real time monitoring required in imaging and radiotherapy areas from the respective treatment control rooms. Such monitoring systems are not required to be connected to the central CCTV system. These monitoring systems are recommended to be provided as part of medical equipment scope of supply and be positioned as per respective medical equipment manufacturer's recommendation.
 - All security system equipment including cameras shall be provided with UPS backup. CCTV cameras may be powered using POE. Associated network switches shall be provided with UPS power backup.
 - Primary CCTV surveillance for any required area shall be provided by means of fixed cameras, where additional secondary means of surveillance is required, such as main entrance hall, shall utilize PTZ cameras.
 - Electronically access controlled doors in the fire escape route shall be interlocked with the fire alarm system through normally closed contacts in the fire alarm interface units.
 - It is recommended that the security management system software have the capability for real time integration of the CCTV, access control, asset management and infant protection systems.
 - It is advisable that the CCTV system covering outpatient waiting areas have the capability to display live video from the waiting areas on the consultant's computer workstation in a web browser to provide the Consultant Doctor a visual reference to the waiting areas when required.
 - Access control system employing RFID cards/tags and readers that use encrypted message transfer are recommended. Fingerprint biometric readers requiring touch to scan the fingerprints are not recommended in healthcare facilities due to infection control reasons.
 - The access card reader or door open switch for electrically operated swing doors located in the circulation corridors shall be placed 2400mm before the door to facilitate ease of operation while transferring patients on stretchers or beds.
 - Separate IT network may be considered for the IP CCTV network and access control due to operational and security authority requirements.
 - Where RFID based or RTLS asset management systems are provided, it is recommended that asset management system is interfaced with access control system to avoid items moving out of designated areas.

Part E: Health Facility Briefing & Design Engineering

- Infant Protection System employing trackable tags shall be implemented for maternity wards and nursery. Such system shall be interfaced with access control system to lock down in case of any security breach.
- Electronic access control is recommended for the following areas. However, the exact provisioning of the access control to be based on the specific security strategy and workflow employed for the project based on the proposed layout of the facility. The following list act only as a general guide.
 - Fire exist doors leading to fire exit staircases.
 - Medication rooms
 - Clean utility
 - Dirty utility
 - Electrical, mechanical and ICT rooms
 - IT server room/data center
 - Imaging rooms
 - Department entrances
 - Staff only corridors
 - All entries and exits to outside
 - Pharmacy
 - Cash counters
 - Entrances to back offices, insurance offices
 - MRI Zones
 - Radiotherapy areas
 - Entrances to staff only areas
 - Medical records
 - Isolation rooms
 - Nursery
 - Air lock area between dirty and clean areas in Sterile Supply Unit (SSU) (with interlock so that only one door can be opened at a time)
- Discrete Panic Alarms to be considered, as a minimum, at cash counters, emergency department reception and main reception. Expanse of the panic alarm coverage should be reviewed based on the security assessment for the facility and further alarms to be provided based on the assessment.
- Where electronic access control is provided in fire escape routes suitable failsafe interlock to be provided to ensure the locks are released or lock overriding facility is available in case of any emergency. Such doors to me alarmed and monitored from the main security room.

Patient/Medical Equipment Monitoring

Many of medical equipment used these days are having the facility to transmit alarms and monitoring data over IP networks for clinical use and for equipment maintenance purposes. For safe and efficient operation of healthcare facilities such monitoring information should be efficiently managed and should be readily retrievable. To facilitate this, data outlets to be provided throughout the facility near to all locations where such medical equipment are intended to be used. In addition, wireless LAN coverage to be available throughout the facility for connecting mobile monitoring equipment likely to be hooked to patients. Refer to the RDS (Room Data Sheets) included under Part B of this guideline for the recommended number of Data Outlets at various locations.

- It is recommended that medical equipment requiring monitoring including fridges and freezers are provided with wired data appoints for connection to centralized medical fridge/freezer monitoring system than a wireless monitoring system.
- It is highly recommended that patient tagging system employing trackable tags (RFID / RTLS)

are implemented for psychiatry and geriatric wards. Such system shall be interfaced with access control system to lock down in case of any security breach.

Intercom Systems

Audio or Audio/Video intercom system to be provided as required to suite the workflow and security strategy employed by the designer. IP based solutions are recommended for better operational flexibility. The intercoms functioning in conjunction with the access control system shall have facility to unlock the associated doors.

Intercoms are recommended for.

- Entry doors normally locked by electronic access control system and required to be occasionally accessible for persons without valid access cards. (Between unsecure side and designated door operator)
- Radio therapy rooms. (Between control room and patient in treatment position)
- Computed Tomography (CT), rooms (Between control room and patient in imaging position)
- Magnetic Resonance Imaging (MRI) rooms (Between control room and patient in imaging position)
- Isolation rooms (Between outside the entry door and patient position)
- Loading docks
- SSU (Sterile Supply Unit), between dirty and sterile area

Patient Infotainment Systems

Suitable patient entertainment facilities are recommended in patient bedrooms and at locations patients are likely to be stationed for extended period.

- The patient infotainment provisions may include but not limited to facility to view mainstream television channels, video on demand, patient education videos, hospital department information, dietary menus, Audio/Video Communication etc., based on the type of the facility.
- The interface to access the infotainment information can be suitably positioned medical grade Smart Television Screen connected to IPTV network. In addition, optional medical grade PDA, networked over wireless LAN, of suitable size may be provided. When portable PDAs are provided appropriate docking, station incorporating changer and security lock is recommended. The docking station to be fixed adjacent to the patient location. The PDAs may be tagged with asset management system for additional asset tracking. When PDAs are provided it should not be shared with staff for accessing clinical data due to infection control reasons. Where wireless PDAs are opted for patient infotainment, the wireless access coverage and bandwidth requirements to be carefully coordinated to ensure a seamless user experience. A suitable mounting mechanism to be provided, preferably mounted on the bedside table.
- Use of mobile phones to be carefully regulated in healthcare environment. A total ban on mobile phone throughout the entire healthcare facility may not be practical nor required. However, use of mobile phones should not be allowed near critical life support medical equipment and critical care areas. Healthcare facilities shall develop their own mobile phone usage policies considering the above and display necessary signages at mobile phone restricted areas.

Queue Management System

Queue management systems are recommended be provided in areas such as outpatient waiting, pharmacy and other areas where visitors / patients are having to wait for their turn. The queue management system shall be a consolidated solution integrating different waiting areas of the hospital so that tokens can be transferred from one system to other. The proposed solution may have the following components and functions.

- Token dispensing station shall be either standalone or at suitable location attended by the staff members for better efficient utilization of the system and workflow.
- Waiting area display: This can be a suitably sized LED panel screens to display the token number along with associated counter or room number. These screens are recommended to be integrated with IPTV system of the facility to play television or patient education content.

Sufficient number of waiting area displays shall be provided for ease of viewing. Auditable automatic token number announcements could be avoided for maintaining a quieter ambiance.

- Counter/room number display: This can be suitably sized displays conveniently placed near the individual locations such as pharmacy counters to display the counter number and attending token number. Individual electronic counter displays may be provided for areas such as pharmacy or registration counters, however electronic counter displays may not be suitable for areas such as consulting rooms; in such cases normal (passive) alpha-numeric room number signage can be provided near the entry doors.
- It is recommended that the calling station used by the staff are software based, and can be operated from computer workstation screens, rather than dedicated hardware with keypad. Standalone calling station units shall be used at locations where computer workstations are not used.
- The system management software should have capabilities such as real time monitoring dashboards, overall performance reports, individual employee performance reports, service quality levels, SMS alerts etc.
- It is recommended that the Queue management system also have the facility to accept and record customer experience feedbacks by incorporating suitable hardware and software.

Asset Management Systems

- Depending up on the Enterprise Resource Planning (ERP) for the healthcare facility electronic means for tagging assets are highly recommended. The asset management system may employ any combination of the following technologies.
 - Real Time Location System (RTLS)
 - Radio Frequency Identification (RFID) - Active and/or Passive
 - Bluetooth Low Energy (BLE)
- The choice of technology employed largely depended on the type and size of healthcare facility. The choice of asset tracking technology to be decided during the early stage the facility design, so that appropriate infrastructure is made available. Whilst, designers are encouraged to embrace modern innovative technologies for improved patient care delivery it is important to ensure that the selected solution is proven and reliable. Designs shall pay special attention to ensure only healthcare grade tested solutions are deployed in healthcare environments.
- Healthcare facilities having maternity and neo-natal departments shall be provided with infant protection system. This system shall be interfaced with the access control system to set off alarms and activate selected door locks.

Health Information System (HIS)

- All Health Information System (HIS) software deployed in the healthcare facilities shall follow the Health Information Interoperability Standard issued by the local health authority. .
- The objectives of the Interoperability Standard are generally as follows.
 - To serve and establish a cooperative partnership between the public and private sectors to achieve a widely accepted and useful set of standards that will enable and support widespread interoperability among healthcare software applications in a city-wide eHealth Information Network.
 - To harmonize relevant standards in the healthcare industry to enable and advance interoperability of healthcare applications, and the interchange of healthcare data, to assure accurate use, access, privacy, and security, both for supporting the delivery of care and public health.
 - Interoperability contributes to enhanced healthcare delivery facilitating continuity of care and better decision making while delivering cost savings. Refer to the Health interoperability standard for further details on standardization of coding.
 - Compiling population health data for research, analysis, and improvement measures to enhance the health level of the population.

- The HIS system provided for the healthcare facilities shall be HL7 and DICOM compliant.
- The basic de-identified information that will have be shared with Health Authority , will include but not limited to services provided, lab reports, radiology reports, admission and discharge and other information updated from time to time. Certain information may remain confidential at each facility as informed from time to time. As a minimum the HIS must have the above-mentioned capabilities. The health information record sharing with other health facilities is subjected to the consent from the patient with option to opt-in or opt-out anytime.
- HIS Coding and terminology employed by the healthcare facilities to describe specific items and services for delivery of healthcare shall be in standardized in accordance with latest version of Health Information Interoperability standard.
- Whilst EMR system increase the safety and efficiency of healthcare delivery, concerns related to patient data privacy to be carefully addressed. In additional to data encryption the key to preserving confidentiality is to allow only authorized individuals to have access to the information.
- Authorization levels and accountability to be clearly defined in healthcare facility HIS manuals and thoroughly implemented. Assigning user access privileges is a major aspect of medical record security. Strong privacy and security policies are essential to secure patient's information.
- Cloud service provider for the healthcare facility shall have the following.
- Cloud based data storage must be local and within the boundaries of the country. Any exceptions have to be approved by the relevant Healthcare Authority.
- Cloud service provider must be classified as Tier 3 or above.
 - It is recommended that the Cloud service provider has HIPAA (Health Insurance Portability and Accountability Act) - compliant business associate agreement (BAA). This is optional for the first two years and it will become compulsory afterwards.
- Information Governance and Risk Management Framework shall include third party auditing for.
 - Implementation plan for ISO 270001 with a grace period of 2 years.
 - Data sharing agreements.
- Electronic Medical records of the healthcare facilities shall have.
 - Government's data submission requirements shall be fulfilled.
 - Audit trail and Role-based access is required.
 - PHI encryption to be employed.
 - Third party review
- Data Breach Reporting procedure shall be implemented based on the following.
 - Healthcare facilities shall report any healthcare data breach incidents that are caused by theft, loss of computers of devices, cyber-attacks, negligence, etc.
 - Patients can also report suspected data breach incidents or miss-use of their protected healthcare data.
- All healthcare facilities existing as well as newly proposed are required to enhance the HIS system of their facilities.

Fire detection and signalling

Fire detection and signaling to be provided as per local civil defense requirement. This include fire detection and alarm systems comprising detectors, sounders, alarm speaker and strobes. In addition, the following healthcare specific design recommendation to be considered during the design.

- Critical care areas where patients are not normally mobile and likely to be connected to medical equipment are not required be provided with audible means of alarm sounders or speakers to avoid panic. Such areas shall be provided with discrete means of fire alarm notification at the corresponding nurse stations, by providing fire alarm repeater stations at the

nurse/supervision stations. In addition, interface shall be provided between Nurse Call System and Fire detection system to alert staff of any fire alarm incidents.

- Alarm speakers or strobes are not required in operating theatres. Associated nurse station to be alerted of a fire condition through discrete means.
- Fire alarm and signalling system cables used in the health care facilities shall be “enhanced” grade not standard grade.

Public Address System

Public address System is recommended in healthcare facilities for broadcasting call for prayer, background audio, announcements etc. in areas such as waiting areas and circulation corridors. Staff paging over public address system is not encouraged. Discrete staff paging over wireless network is recommended.

- Acoustics characteristics of the built environment shall be taken into consideration while designing public address systems to ensure audio intelligibility. Zone wise volume control shall be provided so that different volume levels can be set depending on the areas. Volume control knobs shall be placed near respective supervision stations. IP based solutions are recommended over conventional analogue systems.
- The public-address system to be zoned to suite the operational requirements of the facility. Such zoning to be agreed with the stake holders during the initial phase of the design to ensure cabling is designed to suite.

System Testing, Commissioning and Operation

- Method Statements
- Testing and Commissioning plan
- Testing and commission shall be carried out by respective system manufacturer’s trained and authorized represented.
- All testing and commissioning records to be included in the O&M documents. It is highly recommended that an online solution is deployed for O&M documentation for ease of retrieval and reference.
- Training on the systems installed should be conducted by the authorized representatives of original equipment/system manufacturer.

Routine maintained activities shall be carried out as per the respective system manufacturer’s recommendation and easily retrievable records are maintained in the facility. Deployment of online software-based facility management solutions incorporating necessary maintenance modules are highly recommended depending upon the nature of the facility.

5 Public Health – Water Systems Design (WS)

This PH-WS design guideline written for healthcare facilities, is a consolidated document listing out the design requirements for all new construction and major renovation healthcare projects.

In healthcare facilities, the importance of clean hygienic, and a good quality of water are critical. This has an impact on infection control parameters, equipment, staff, and patients.

The requirements outlined in these guidelines are not intended to conflict with Federal Regulations, Local Municipality Laws, Executive Orders, or the needs of the end users.

This document is intended for the Architect/Engineer (A/E) and others engaged in the design and renovation of health facilities. Where direction described in applicable codes are in conflict, the A/E shall comply with the more stringent requirement. The A/E is required to make themselves aware of all applicable codes.

The document should be read in conjunction with other parts of the Health Facility Guidelines (Part A to Part F) & the typical room data sheets and typical room layout sheets.

Aim & Objectives

The Aim of this section of the guidelines is to promote the correct design of water systems for healthcare facilities.

The scope of the Water Systems design will include the following:

- Potable Cold-Water System
- Potable Cooled-Cold Water Systems
- Water Treatment System
- Hot Water Systems
- Healthcare Sanitary Fittings
- Irrigation Systems
- Grey-Water Systems
- Steam Systems

General

- The design, installation and commissioning of the potable water systems is very critical for healthcare facilities. Many systems and operations in healthcare facilities are dependent upon clean, treated water being provided for patient and staff as well as for the use of medical equipment.
- Reliability and resiliency of water system is also crucial. Thus, it is important to ensure that disruption in water supply from the network or via main storage tanks is eliminated or reduced to the lowest risk possible. The engineer needs to ensure that the requirement of additional water storage does not lead to stagnation of water in the tanks.

Design Codes & Standards

The water system will be designed in accordance with the latest edition and requirements of the relevant standards, codes and guidelines issued by Authorities having jurisdiction and internationally recognized institutions including but not limited to the entities listed below.

International Standards	
Code Reference	Description
BS EN 805	Water Supply System
BS 6700	Design, Installation, testing and maintenance of services supplying water for domestic use within buildings.

International Standards	
Code Reference	Description
BS EN 12201	Polyethylene Specification for Water Systems
BS EN 1057	Copper Specification
ASTM IPC	International Plumbing Code
HBN-13	Sterile Services Department (SSD or CSSD)
HBN-07-01 & 02	Satellite Dialysis Unit & Main Renal Unit
IoP	Institute of Plumbing – Plumbing Engineering Services Design Guide
IPC	International Plumbing Code
UPC	Uniform Plumbing Code
ASPE	American Society of Plumbing Engineers
CIBSE Guide G	Chartered Institute of Building Services Engineers Guide - Public Health & Plumbing Engineering Guide
ASHRAE Applications	American Society of Heating & Refrigeration Air Conditioning Engineers Applications, Chapter 50
HSE – L8	The control of legionella bacteria in water systems.
WSR – 1999	Water Supply Regulations (Water Fittings) 1999 (U.K)
Laboratory Safety Guidance – OSHA	Laboratory Safety Guidance – OSHA
NRC	Nuclear Regulatory Commission (NRC)
WHO-1	WHO - Guidelines for Drinking Water Quality
WHO-2	WHO - Guidelines for Safe Recreational- Water Environments Vol 2 - Chapter 5 - Managing Water & Air Quality
EU Regulations 528	European Union Biocides Regulation 528 (2012),

Glossary & Abbreviations

Above Ground Installation – System installations that are not buried, i.e. within the basement space and floors above.

Backflow – Flow upstream, that is in a direction contrary to the intended normal direction of flow, within or from a water fitting.

Biofilm – a complex layer of microorganisms that have attached and grown on a surface. This form of growth provides a niche environment for a wide range of microorganisms to interact and where the secretion of exopolysaccharides by bacteria will form an extracellular matrix for both bacteria and other unicellular organisms such as amoebae and flagellates to remain in a protected state.

COSHH – Control of Substances Hazardous to Health [Regulations]

CQC – Care Quality Commission

Dead-leg – a length of water system pipework leading to a fitting through which water only passes infrequently when there is draw off from the fitting, providing the potential for stagnation.

DWI – Drinking Water Inspectorate

Healthcare-associated infections (HCAI) – encompasses any infection by any infectious agent acquired as a consequence of a person's treatment or which is acquired by a healthcare worker in the course of their duties.

Healthcare facility/building – all buildings, infrastructure, equipment, plant, embedded systems, and related items that support the delivery of healthcare and services of all types, irrespective of their ownership or operation by third parties.

Healthcare Operator: organizations that provide or intend to provide healthcare services.

HSG274 Part 2 – The Health & Safety Executive's technical guidance on the control of Legionnaires' disease in hot and cold-water systems

Point-of-use (POU) filter – a filter with a maximal pore size of 0.2 µm applied at the outlet, which removes bacteria from the water flow.

Redundant pipework (also known as blind end): a length of pipe closed at one end through which no water passes.

Thermostatic mixing valve: valve with one outlet, which mixes hot and cold water and automatically controls the mixed water to a user-selected or pre-set temperature.

Waterborne pathogen: microorganism capable of causing disease that may be transmitted via water and acquired through ingestion, bathing, or by other means.

Water outlet: (In this document) refers mainly to taps and showerheads, but other outlets, as indicated by risk assessments, may be considered important.

Water supply [to the healthcare facility]: The water supplied can be via:

- the mains water supply from the local water company.
- a borehole (operated by the healthcare organization as a private water supply).
- a combination of mains water and borehole supply.
- emergency water provision (bulk tankered water or bottled drinking water).

WRAS – Water Regulations Advisory Scheme

Design Criteria

- The system components will need to comply with water regulating bodies such as WRAS, AWWA and LOCAL AUTHORITY requirements. Where there is a clash the international recognized requirements and local standards, the local standards shall take precedence.
- One of the most important factors regarding water quality is the concern of legionnaires disease. The control and elimination of legionella is very crucial, and measure must be provided. The United Kingdom's Health and Safety Executive (HSE)274 & L8, provides one of the best Approved Code of Practice and guidance on regulations 'Legionnaires' disease: The control of legionella bacteria in water systems.
- Metals in contact with water will also influence the quality of potable wholesome water. Therefore, for any material that is contact with water used for wholesome purposes shall all conform to BS 6920: 2000 Part 1 & 2 and Part 3 (Hot Water Service) for non-metallic materials or equivalent international standards i.e. WRAS approved fitting.
- The healthcare facility owner is obligated to preserve the quality of water according to the outline highlighted within these guidelines.
- It is recommended that plumbing installation contractors and companies have the appropriate qualifications and the industry knowledge and competence of installing the correct system suitable for healthcare facilities.

Source of Water Supply

- Depending on the water source the incoming TDS/PPM can vary from 2000 PPM to 80PPM. Water must be treated to reach water quality levels of 0 – 150PPM.
- The following water sources are acceptable for healthcare facilities:
 - Connection from the Potable Water Network Supplier
 - Service Connection for Potable Water Trucks
 - Underground Water Wells
 - Bore Hole
- Healthcare facilities shall ensure that they have secondary water supply to the facility, from one of the sources mentioned above.
- The Incoming water supply from the sources mentioned above must be checked via a water quality report.
- The Water report is to be used to provide the correct water quality design to the healthcare facility.
- The water sources to the healthcare facility must be spilt into two systems for resiliency, redundancy and to avoid having a concern of inadequate water supply to the system. One supply will be an emergency supply to the system.
- Both the main incoming supply as well as the emergency water supply will need to have components to protect the healthcare facility from infection. This is provided through backflow prevention valves or Double Check Valves. The valve detail below provides an example of one of the acceptable configurations.

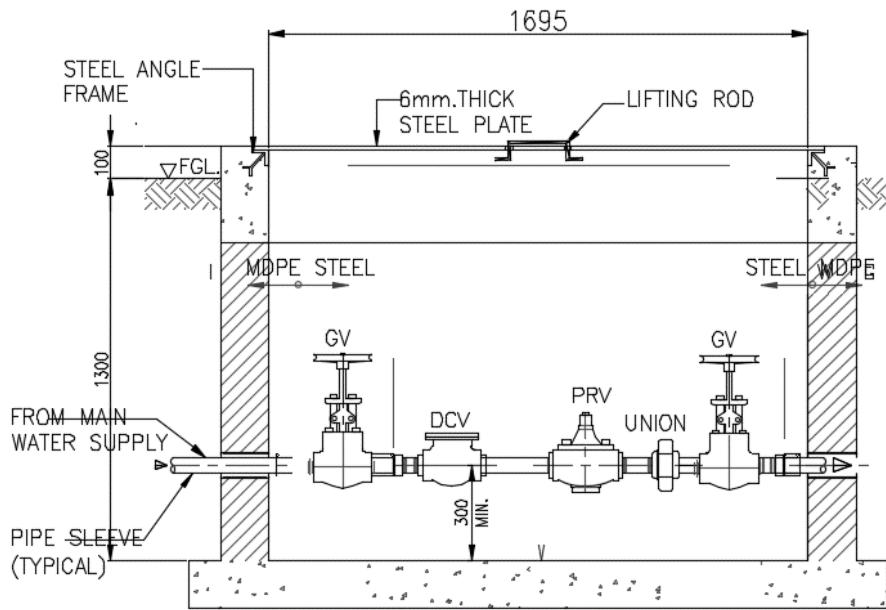


Diagram 5.1A – Incoming Mains Water Valve Detail Buried at the Ground Floor

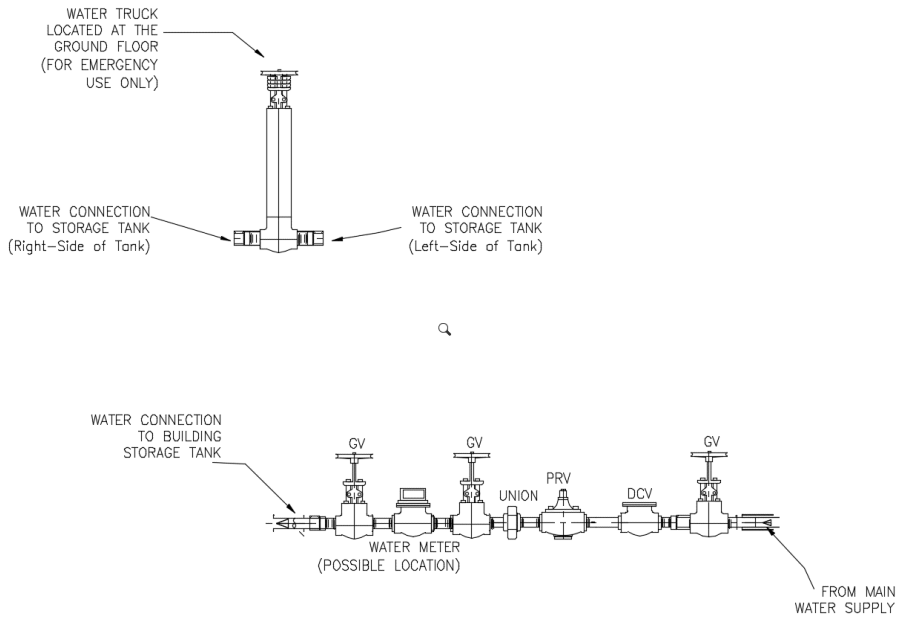


Diagram 5.1B– Incoming Mains Water Valve Detail at High Level Ground Floor or Basement (Water Meter Shown)

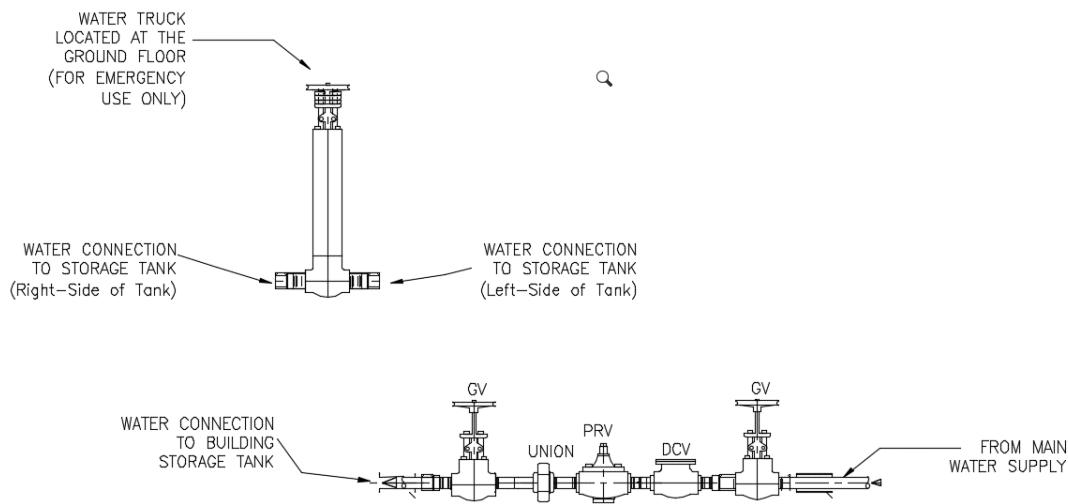


Diagram 5.1C– Incoming Mains Water Valve Detail at High Level Ground Floor or Basement (Without Water Meter Shown)

- Diagrams 5.1A, 5.1B and 5.1C show an emergency water truck connection allowance as a redundancy measure in situations where the main water network will fail or in areas where the water network has not been established or a provision from the network has not been provided by the local authority.
- To provide the most efficient water quality with the correct water treatment system installed, the following information must be known from the incoming water quality report:
 - Details of the elements and organisms in the source water supply such as the amount of metals, micro-biological etc.
 - The process or method of water purification used by the network provider chemical, a Reverse Osmosis treatment etc.
 - The design must take into consideration the maximum foreseeable water consumption and average flows as well as peak loads and pressure required from the LOCAL AUTHORITY water network.
 - During the stages of design, the design engineer must inform LOCAL AUTHORITY of the hospital water consumption as outlined in Part A of these guidelines.
 - The water design for the healthcare facility must obtain approval from LOCAL AUTHORITY before any installation is carried out. The engineer must ensure that the following information is submitted:
 - Service Connection Details
 - Access to Valve Assemblies and Water Meters
 - Flushing By-Pass
 - Provisions for Fire & Rescue Service (If applicable)

Quality of Water Supply

- In certain situations, there may be times in the year when the water supply from the network supplying the healthcare facility is interrupted and the network provider may provide the water supply from a different source to maintain the supply for the required demand. The change in water supply will most likely have different quality of water such as water hardness, metallurgy etc. This change in water supply may cause issues such as scaling. Water hardness may increase by almost 50% when the services changes.
- The design engineer will need to provide a strategy to ensure that water treatment is provided from the point of supply up until its use. Below is a table that consists of internationally recognized levels of potable water requirements.

Please note: For renal dialysis areas, certain elements such as copper & silver need to be controlled. Also, chemical water treatment has to be avoided.

Table 5.1 – Water Quality Table

- The design engineer should consider the type of water treatment used by the water network

Factor	Standard	Factor	Standard
Temperature	20°C	Calcium	250 mg/l
pH	5.5-9.5	Potassium	12mg/l
Colour	20 Hazen Units	Sodium	150 mg/l
Turbidity	4 Formazin Units	Copper	3000 µg/l
Qualitative Odor	All Odor Investigations	Zinc	5000 µg/l
Qualitative Taste	All Taste Investigations	Lead	50 µg/l
Dilution Odor & Dilution Taste	Dilution No. 3 at 20°C	Silver	10 µg/l
Conductivity	1500 µs/cm at 20°C	Antimony	10 µg/l
Total Hardness – Alkalinity	Applies Only if Water is Softened	Barium	1000 µg/l
Free Chlorine & Total Chlorine	Comparison Against Average	Boron	2000 µg/l
Fecal Coliforms	0 / 100 ml	Cyanide	50 µg/l
Clostridia	1 / 20 ml	Cadmium	5 µg/g
Fecal Streptococci	0 / 100 ml	Chromium	50 µg/l
Total Coliforms	0 / 100 ml (95%)	Mercury	1 µg/l
Colony Count: 2-Day & Colony Count: 3-Day	Comparison Against Average	Nickel	50 µg/l
Oxidisability	5 mg/l	Selenium	10 µg/l
Ammonia	0.5 mg/l	Total Organic Carbon	Comparisons
Nitrite	0.1 mg/l	Trihalomethanes	100 µg/l
Nitrate	50 mg/l	Tetrachloromethane	3 µg/l
Chloride	400 mg/l	Trichloroethene	30 µg/l
Fluoride	1500 µg/l	Tetrachloroethene	10 µg/l
Phosphorus	2200 µg/l	Fluoranthene 3, 4-Benzofluoranthene 11, 12-Benzofluoranthene 1, 12-Benzoperylene Indeno (1, 2, 3-cd) Pyrene	Individual Testing of these Substances to Provide Total
Sulphate	250 mg/l	Total Polycyclic Aromatic Hydrocarbons (PAHS)	0.2 µg/l
Magnesium	50 mg/l	Anionic Detergents	200 µg/l
Aluminum	200 µg/l	Pesticides and Compounds	5 µg/l total

supplier to ascertain what type of water treatment should be used. In some supplies, the water may have residual chemical treatment used during extreme hot climates and cool weather at different times of the year. This will affect certain immunodeficient patients in the healthcare facility.

- The design of the healthcare facility must also consider any possible concerns that will affect the quality of water in the facility such as “dead leg” or “stagnate water areas”. The design must eliminate these areas.

Potable Cold-Water (Cooled-Water) System

- Incoming water as well as the water stored can go up to 40°C or higher in extremely hot climates. This then becomes an area for bacterial growth, water contamination becomes a high risk. Many of the most dangerous types of bacteria such as pseudomonas legionella thrives in such an environment. Therefore, potable water cooling must be provided if incoming water temperature cannot be ensured.
- The design should ensure that water temperature is between 15-20Deg C. This should be done via plate heat exchanger arranged in an N+1 provision.
- Cooled water is to be used for wash hand basins, sinks, baths, showers, and hand-held bidet.

Normal Temperature Potable Cold-Water System

- Water that shall not be cooled, shall still be treated to ensure water quality & legionella protection.
- Potable normal temperature water service shall only be used in the following:
 - WC flushing System.
 - Maintenance areas, Work Shops, Back of house areas for services areas.
 - Cleaners Sinks
 - Bib Tap Points
 - Cooling Tower Makeup Water

Water Storage

- The purpose of water storage is to act as a safety net for when the main incoming water supply is interrupted, ensuring continuous supply.
- Many healthcare guidelines limit the amount of water storage to be kept at 12 hours storage. This will ensure that the prevention of bacterial contamination is kept at a minimum via continuous emptying and top up of water within the tank.
- For Healthcare Facilities, the following strategy is preferable:
 - 3 days of Potable Water Storage
 - Out of the 3 days, 2 Days are actual Raw Water Storage.
 - The remaining 1 day shall be divided in 2 No. tanks.
 - 1 No. Tank will be treated cold-water (cooled)
 - 1 No. Tank will be treated Cold water serve non-clinical areas
- The main 2-day storage tank shall be concrete, buried or GRP tank(s). The treated water storage tanks must be insulated GRP tanks. Treated water tanks water quality shall be as per Table 5.1. Diagram 5.2 flow diagram shows a more detailed design provision of the water system but provides the design strategy behind the water storage.
- Potable water supply to the network, must be after the valve assembly shown in Figure 6.1. In some facilities, the valve assembly may be part of an existing building or include a water meter requirement.
- To avoid the risk of deterioration of water quality, Low level chemical treatment as well as circulation pumps must be provided.
- Water storage calculation should be based on the peak demand and the rate of water supply make up from the main external water source.
- For potable water sizing, water demand or loading units are used for calculations. These contain an inherent diversity factor.
- There is no diversity factor to be considered for special departments such as SSU's, Laboratories, Renal Dialysis etc. This will be sized with full provision.

**Part E: Health Facility Briefing & Design
Engineering**

As mentioned in Part A of these guidelines, there are many different types of healthcare facilities using the RDL 1-6 designation. Tables 5.2 (below) provides the water demand based on a KPU (bed numbers) for hospitals as benchmark requirement, this is only to be used in the early stages of design calculations

General Hospital – RDL 4-5 (Acute Healthcare Facilities)	
Number of Beds	Average Water Consumption (Liters Per Day Per Bed)
0-50	299
51-100	398
101-200	490
201-400	590
401-600	599
Over 600	978

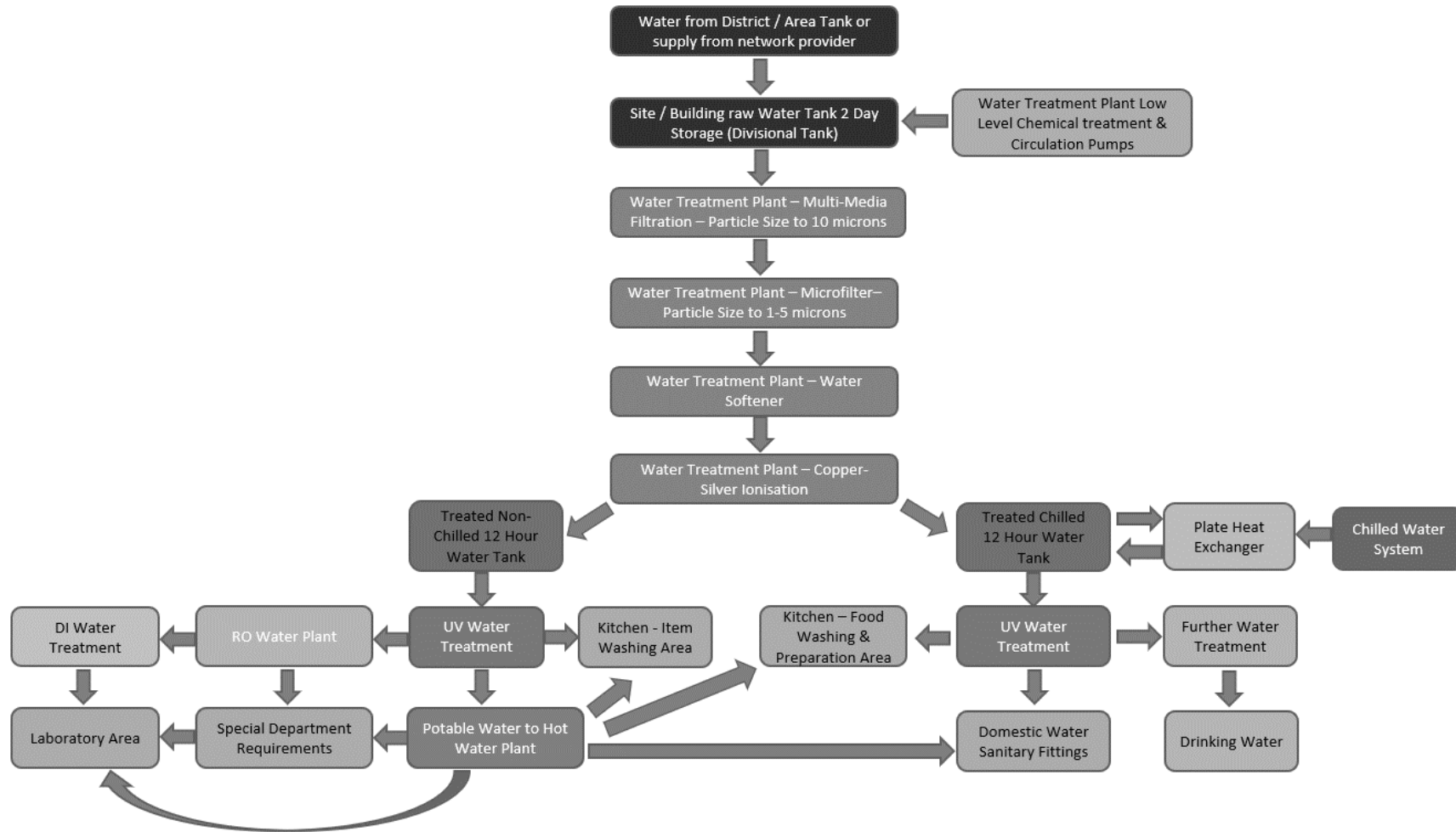


Diagram 5.2 – Water System for Healthcare Facilities

Centre of Excellence – RDL 5-6 (Specialist Acute Healthcare Facility)	
Number of Beds	Average Water Consumption (Liters Per Day Per Bed)
0-25	319
26-50	347
51-100	362
101-200	479
Over 199	530
LTC – (Long Term Care)	
Number of Beds	Average Water Consumption (Liters Per Day Per Bed)
0-50	180
51-100	269
101-200	247
201-300	217
Over 300	306
Recovery and Convalescent Facilities	
Number of Beds	Average Water Consumption (Liters Per Day Per Bed)
0-25	216
26-50	206
51-100	185
Over 100	181
Geriatric & Chronic illness Facilities	
Number of Beds	Average Water Consumption (Liters Per Day Per Bed)
0-50	246
51-100	203
101-200	164
Over 200	127
Psychiatric Facilities	
Number of Beds	Average Water Consumption (Liters Per Day Per Bed)
0-100	180
101-200	269
201-400	247
Over 400	350
Teaching Facilities	
Number of Beds	Average Water Consumption (Liters Per Day Per Bed)
0-100	680
101-200	866
201-300	830
301-500	904
Over 500	1228

Table 5.2 – Water Consumption Data for Healthcare Facility types in relation to number of beds

- A number of healthcare facilities may include residences for doctors and nurses being served from the main hospital potable water system. The designer is to take the data based on the healthcare definitions mentioned in Table 5.2.
- The water consumption figures provided in Table 5.2, are overall figures which consider special departments. In later stages of design, detailed calculations should be conducted for accurately sizing the storage requirements.

Water Storage Tank Locations

- The strategy in the past was to provide two sets of potable water storage tanks (not including fire). 1 No. tank at the incoming main (basement or ground floor) and 1 No. at the roof of the healthcare facility. This strategy may continue to be used for healthcare facilities due to the site space restrictions, flood risks which could contaminate the potable water source for the facility.
- A flood risk assessment must be carried out to determine the best location of the potable water tanks.
- If there is a risk of flooding the potable water tanks must not be placed in areas of flooding risk such as the basement, ground floor etc.
- If there is no risk of flooding. Its preferable to locate portable water tank at the lower levels of any healthcare facility (basement, ground floor etc.).
- To ensure resiliency in the system and not to solely depend on gravity roof water tank approach, the booster pumps will need to be connected to emergency power. This ensures that the potable water supply will be available to all sanitary fittings within the facility.
- The risk assessment must consider the following concerns for possible potable water contamination:
 - Location in relation foul & wastewater drainage
 - Ingress of insects, rodents, dust, sand, debris etc.
 - Danger of oil or fuel seepage (if installed below a car park or other fuel vessels)
- Tanks should be installed with a watertight bund allowing sufficient space all around and beneath the storage vessel to permit inspection and maintenance. For buried underground tanks the construction may not allow for risk elimination of the tank being contaminated.
- The tank chamber should include provision for a sump to collect drainage water and any piping necessary to pump out tanks to the site drainage
- During the healthcare design process, the healthcare facility may be required to constructed in phases. Phases may last months, years and sometimes maybe decades. The design engineer shall ensure that the actual size of the water tank is to be designed for the completed facility. The reason for this is for the following:
 - Risk of cross water contamination of providing multiple sources and risk to patient, visitor, and operational staff safety.
 - Space planning restrictions
 - Equipment costs of providing separate systems

Future Water Considerations

- Many healthcare operators expand their services. This expansion of services will require extra system capacity to be provided. The design engineer must provide a 15% spare water capacity to the system to allow for future expansion of the facility. This means that 15% must be added when submitting requirements to the utility company for water demand approval (Please note that this 15% is on top of the water consumption requirements provide in Table 6.2A & 5.2B).

Material Tank Construction

- As per international standards, the construction of the water of the tanks shall be Glass-reinforced plastic (GRP) as per BS EN 13280 if above ground. Tanks must be in a conditioned space in hot climates.
- There shall 1m provision around all sides of the GRP tanks for equipment maintenance.
- Raw Water Tanks can be concrete tanks buried or within a conditioned space.

Divisional Tanks

- Buildings operate in a very extreme climate and thus critical equipment such as the healthcare facilities water tanks need to be maintained even during operating hours.

Part E: Health Facility Briefing & Design Engineering

- The water tanks support with the tank must not retain water within the supports as this increases the risk for water stagnation.
- The water storage tanks must always be divided into two compartments. These parts should be the total tank capacity divided into two (50/50 configuration).
- This type of arrangement allows for one part of the tank to be cleaned, disinfected, serviced, repaired, inspected etc. while the other is in operation.
- To ensure that the water flow is provided when required and that each tank is provided with equal volume of flow a water meter should be installed as well as a solenoid valve linked to the ball float or chain valve.
- In each section of the divisional tank the following needs to be provided:
 - An Isolation Valve at the inlet and outlet of the tank division.
 - A Valve Strainer at the outlet of each tank division.
 - Drain Connection at the bottom of each tank. The invert of the drain should be located to fully drain that division of the tank.
 - Overflow pipe from each division of the tank. Overflow connection to be connected directly to drainage
 - Overflow warning pipe with insect protection screen (0.65mm mesh – design needs to ensure that the screen area will pass the same amount of water as the overflow or warning pipe)
 - An External and Internal Access ladder of the tank division.
 - A vent pipe with an air inlet corrosion resistant mesh.
- In certain circumstances, it may be difficult to install an overflow or a warning pipe directly to a drain line. In this instance, the design must include an audible warning alarm to inform the facility team of overflow scenario.
- A Sectional GRP Tank should not be installed directly on a concrete plinth that is protected by an asphalt membrane. This is because irregular settlement into the asphalt may lead the tank leak.

Pressure Vessels

- Pressure (Expansion) vessels are designed to deal with the thermal (natural, not heated) expansion of the system.
- The most recognized certificate is the KTW (Germany & Netherlands/Holland) approved certificate. KTW provides guidelines for organic materials in contact with water. KTW also provides the concentration of substances that are permitted. The installed pressure vessels must have certification and should be installed as per manufactures specifications. This ensures that they are operated in a manner that prevents the accumulation of debris, water stagnation and increase of water temperature within the vessel.
- The design of the pressure vessel must have water entering the vessel at low level and exiting at high level. Some manufactures use special valves which encourage water flow or pressure movement within the pressure vessels, this is an acceptable alternative.
- For general pressure vessels for medium to large systems, there must be drain connections for flushing at the top and bottom of the vessel. If a diaphragm/bladder type expansion vessel is used, then a connection only at the bottom of the vessel is sufficient.
- Pressure vessels must be provided on the cold potable water side of the system and the pipes to the vessel should be insulated to minimize heat gain.

Water Treatment Systems

- In healthcare facilities the treatment of water and the control of microbiological safety of water is an important functionality to ensure a safe, hygienic clean water provision.
- The extent of water treatment will vary for each application depending on water quality, intended usage etc. But the source of water supply is also important to identify the type of water treatment to be used. Source of water supplies such as Wells, Reservoirs, Rivers and Lakes may contain organic matter, higher TDS/PPM and will require water treatment prior to

active facility use.

- Generally, to control microbiological growth within water systems, temperature, chemical and mechanical control methods will be enforced to reduce the risk of water contamination. The methods that can be used are the following:
 - Pasteurization
 - Chemical Treatment (Biocides, Chlorine etc.)
 - Silver-Copper Ionization
 - Filtration
- Depending on the type of healthcare facility the water treatment strategy needs to be considered for current hospital design and possible future expansion. For example, of hemodialysis department, a separate mains water supply must be considered so that other areas of the healthcare facility may be dosed without affecting the RO plants.

Pasteurization Treatment

- Pasteurization or water heat treatment flashing of the system is a method used in some healthcare facilities by raising the water temperature of the hot water system to 70-75°C for at least 60mins and running each sanitary fitting within the facility for 5mins. A well-insulated system is required so that heat is maintained to all sanitary fixtures. This is a temporary solution and does not prevent re-infection of the system. This method must not be used for new facilities.
- Existing facilities may only use this method as a temporary solution but will need to install a permanent water treatment method. This method is costly and huge waste of electricity and water as well as it will require complete shutdown of all sanitary fixtures for 5mins, which will be very difficult for medium to large for facilities, but for smaller facilities it may be possible.
- In relation with this method and biocide water treatment, the effectiveness of biocides concentration is difficult to achieve in hot water systems due to gassing off.

Biocidal treatment

- Biocide treatment concentration should be as per international requirements for healthcare facilities. UK COSHH regulations 2002 , provide a good reference.
- Since Legionella and other water contamination organisms play a huge part of water quality, there are occasions where biocide water treatment will be used to maintain the water quality.
- It is important that biocides system must not be drawn for bathing, food preparation or drinking until the treatment chemical has been completely flushed from the system. The hospital operator must ensure that that measures are taken to protect vulnerable patients such as those in renal dialysis units.
- As per international standards, biocides used for water treatment must have the following:
 - Contain an active substance approved for that use
 - Be suitable for drinking-water use.
- For effective biocide water treatment, there must be an implementation of a very rigorous water monitoring regime with a fail-safe system to ensure the safety of the system as well as ensure the correct dosing of biocide concentration is applied which reduces risk of water contamination.
- Local monitoring will still be required by healthcare operational staff.
- The equipment supplying biocide water treatment shall be provided with a leak detection system.
- As described by the European Union Biocides Regulation 528 (2012), biocides are used to control harmful unwanted organisms within water systems. The regulations also require supplies of biocide to be registered.

Chlorine dioxide

- Chlorine dioxide water treatment is an oxidizing biocide that is capable of reacting with a wide range of organic substances within the water. As per BS EN 12671, the treatment method has

been shown to be effective to control organisms within the water. Chlorine-dioxide water treatment equipment is a dispersive water treatment method and the equipment needs to generate a product efficacy greater than 90% to provide the optimum performance. Hence, since it is a dispersive treatment method, bacteria in the water continue to be killed.

- As per international legionella control requirements, Chlorine Dioxide is an approved method of control for legionella bacteria in water systems for PPM values greater than 0.1 and for DWI requirements of less than 0.5 PPM for total oxidants. But as mentioned for biocide treatment, it will require rigorous control and monitoring.
- Chlorine Dioxide is also a very powerful disinfectant that kills both planktonic and sessile organisms. This is important as the majority of organisms live in sessile bacteria.

Chloramine Water Treatment

- Healthcare operators and healthcare engineering designers must take note that municipality distribution company may have introduced chloramine as a disinfecting agent in potable water supply network as alternative to chlorine. This is because chloramine is able to provide a more stable approach of providing a residual antibacterial activity with lower chlorine levels. In systems, where free chlorine is rapidly lost, such as typical hot and cold-water service systems, chloramines can remain for much longer, which is of grave concern for dialysis patients.
- Chloramines and to a lesser extent chlorine in dialysis water can cause haemolysis – a condition whereby red blood cells are ruptured. In addition, all renal patients suffer from anaemia to some extent because they are lacking in erythropoietin. This natural hormone, which stimulates bone marrow to produce red blood cells, is not available in sufficient quantities in patients with damaged or diseased kidneys. Synthetic erythropoietin is administered to dialysis patients but, apart from its high cost, can have unpleasant side-effects. Where chlorine or chloramines are present, the need for erythropoietin escalates, and therefore it is imperative to eliminate chlorine and chloramines from water supplies to dialysis equipment to minimize the dosage of erythropoietin. Dialysis requires a water supply that has the minimum of chemical and bacterial impurities. Hence, special water treatment is required, such as reverse osmosis (RO), which removes chloramines or chlorine from the water.
- For Water Supply using Chloramines a Reverse Osmosis water treatment will need to be used, along with non-chemical water treatment (Copper-Silver Ionization and Ultraviolet Water Treatment).
- The use of deionization should not be used for a water treatment method for the entire facility or as the sole water treatment method. This is because of the following:
 - There is some reduction of chloramines (not all)
 - The quality of water degrades at a fast rate.
 - The water quality shall be as detailed in table 5.5 below.

Water Softener

- Water Softening is used in areas where the quality of water is not suitable for its intended use. For example, hard water areas where the Calcium and Magnesium salts in the water are high, means that scale deposits in the systems equipment and pipework become a concern as they reduce the flow of the system, efficiency and increase the surface area of biofilm.
- In healthcare facilities water softening is used in water to serve the following equipment within a facility:
 - Copper-Silver Ionization Water Treatment
 - Steam Boilers
 - Laundry Area
 - Hot Water Systems
 - CSSD Sterilizers
- International Studies have shown some concern with cardiovascular disease tends to be higher in areas with soft water supplies than in areas with hard water supplies. The association is clearest where the soft water supplies contain hardness below about 150 mg/L (as CaCO₃). Therefore, the correct water softening regime is necessary to remove any risk to

patient within those healthcare facilities, especially in areas where the water supply will be used for drinking water (including LDR Nurseries for baby bottle feeding) and kitchen washing facilities.

Recommendation: If it is considered essential to provide water softening to drinking water and kitchen areas, then the softening must be maintained to a minimum and the manufacturer must be informed to provide the correct disinfection regime of the water softener.

Copper-Silver ionization

- Copper-Silver Ionization is a water disinfection system used for Legionella and other organisms that exist in contaminated water supply and storage. The system works by passing a current through a copper-silver plate and thus forcing the plate to release ions of Copper-Silver. The ions are used to control planktonic and sessile bacteria and area effective against the formation of biofilm.
- The concentration of Copper-Silver ratio must be as per the table below:

Healthcare Facility Size	Copper-Silver Ratio
Small to Medium Facilities (RDL: 1-4)	10% Silver& 90% Copper
Large Facilities (RDL: 5-6)	30% Silver & 70% Copper

Table 5.4 – Copper-Silver Ratio in Relation to Healthcare Facility Size

Important Note: Ratio percentages does not mean an amalgam of the elements. It refers to the ratio of the elements to each other i.e. if 90 % of Copper is 1 kg then 10% of silver is 0.1kg etc.

Reverse Osmosis Water Treatment

- Reverse Osmosis (RO) is one of the most widely used treatment process in healthcare facilities. It is the water treatment technology that removes majority of contaminants within the water by applying pressure through a semi-permeable membrane.
- In healthcare facilities, RO water is required to be served to Renal Dialysis Units/Departments, SSU’s, Dirty Utilities (for washer sterilizers) and Laboratories.
- The RO water requirements for healthcare facilities as well as the concentration of copper-silver ions in the water system must be as detailed in Table 5.1, except for dialysis units. For dialysis units, the quality of water shall be as per Table 5.5 below. The table is based on ANSI/AAMI 13959 requirements.

Contaminant	Maximum Allowable Level (mg/l)
Contaminants with Documented Toxicity to Hemodialysis	
Fluoride	0.2
Chloramines	0.1
Copper	0.1
Aluminium	0.01
Lead	0.005
Total Chlorine	0.1
Nitrate (as N)	2
Sulfate	100
Sulfate	100
Zinc	0.1
Total Dissolved Solids	5-1000

Contaminant	Maximum Allowable Level (mg/l)
Trace Elements	
Antimony	0.006
Arsenic	0.005
Barium	0.1
Beryllium	0.0004
Cadmium	0.001
Chromium	0.014
Mercury	0.0002
Selenium	0.09
Silver	0.005
Thallium	0.002
Microbiological Standards	
Colony Forming Units	<100 CFU/mL (Standards) And ≥50 CFU/ML (Action Level)
Endotoxin Units	<0.25 CFU/mL (Standards) And ≥0.125 CFU/ML (Action Level)

Table 5.5 –Water Quality Requirements for Dialysis Use

Important Note: For Microbiological Standards, the term standard refers to the acceptable microbiological level. The term Action Level refers to the testing protocol used to determine the bacteria level.

- As can be seen from Table 5.5 above the concentration level of Copper & Silver is much lower than the standard mentioned in Table 5.1.
- Copper-Silver Water treatment needs to be installed prior to the main treatment. This solution allows the treatment process to work best as well as encourage the water to remain at a high quality for a longer period.
- Copper-Silver Ionization also requires the water feeding it to be treated with softened water. This method prevents scaling.

Ultraviolet treatment

- Chemical Water Treatment methods are used mainly as a dispersive treatment method. But non-chemical water treatment methods are used a final point of water treatment in healthcare facilities.
- The function of the ultraviolet (UV) water treatment is to kill or deactivate the bacteria in the water. This is done by the UV light disrupting the natural make organic makeup of the bacteria. This technique is in sharp contrast to techniques such as high temperatures and chlorine dioxide which ‘burn’ the outside of the cell wall. For this technique to successfully work the correct UV wavelength must be selected. This is because different wave lengths of light are absorbed in different proportions and for this method to be successful, the UV light must be absorbed to cause the necessary disruption within the bacteria. Optimum wavelength for the destruction of biological matter occurs close to 254nm, and therefore it is important that the lamps used to provide UV light which is close to this ideal value. The process of killing bacteria, via this technique is often referred to as ‘inactivation’.
- Ultraviolet (UV) disinfection will be provided at the distribution side. System shall incorporate system sensor to monitor the effectiveness of the disinfection. For typical potable water

applications, the target exposure dose is 400j/m² for a wavelength of 254nm (as mentioned above).

- Hydrotherapy pools in healthcare facilities will have an exposure target of 400 j/m² for a wavelength of approx. 313nm.
- All biological species require different levels of UV light to inactivate/kill them. For example, legionella pneumophilla, will die at relatively low exposures and others like pseudomonas, which can also cause problems, are more robust and do require a higher dose of UV light to inactivate them.
- The UV water treatment plant shall be connected after the packaged cold-water tank and pumps. It shall incorporate a UV photo sensor to monitor the effectiveness of the disinfection. The output of every lamp will drop with time, typically lamps last between 11 months – 24 months (dependent on the lamp) for 24 hours of lamp operation.
- It should be remembered that all water borne bacteria, undesirable or benign, will enter the system via the incoming main, and despite the water suppliers care and diligence it is simply not possible to deliver water across the network in total sterility, thus the job of protecting the system starts with treatment of the incoming main. This treatment adds considerable value and security to the water handling process.

Ozone Water Treatment

- Ozone is a method of treatment that uses an unstable gas made up of 3 oxygen atoms and the active gas usually lasts only for a few milliseconds.
- Ozone Water Treatment usually provides a good disinfection effectiveness of any odor and taste from the water by reducing the concentration of elements such as iron and manganese.
- An Ozone system consists of passing dry, clean air through a high voltage electric discharge, thus creating an ozone concentration. The raw water is then passed through a venturi throat which creates a vacuum and pulls the ozone gas into the water or the air is then bubbled up through the water being treated. The following are important part of ozone water treatment:
 - It rapidly reacts with the bacteria in the water and is effective on a wide range of PH values.
 - The Treatment process does not require to add chemicals to the water
 - It is unable to prevent or inhibit bacterial growth.
 - The system will require pre-treatment water plant to be installed before the unit.
 - There is a potential hazard of the system being fire risk as well as toxicity issues, which may raise approval concerns with Civil Defense.
- In healthcare facilities, ozone water treatment needs to be used with a combination of other water treatment means to compliment the weaknesses in the system.
- Many designers and hospital operators in the region are not familiar with ozone water treatment for healthcare facilities, but rehabilitation clinics that use hydrotherapy pools use this approach instead of the chemical cleaning system.
- Ozone water treatment should not be used as the only source of water treatment for healthcare facilities but with a combination of other water treatment methods.
- Oxygen Gas to this type of water treatment can be from the healthcare facility medical oxygen bulk supply (VIE Tanks or PSA Generation).
- Pipe Material for this system shall be Stainless-Steel (316L).

Point-of-use filtration

- Many small clinics may use small point of use filtration systems to provide water treatment for pathogenic waterborne organisms including multi-drug-resistant strains, at a minimum.
- If small clinics wish to proceed with this approach a risk assessment strategy must be conducted for the water treatment strategy. This strategy should be made to determine the sterilizing grade of the filters installed with the filter by determining the bacteria retention and have a management strategy based upon that.

Multi-Media Filtration & Microfiltration

- Multi-Media filtration (MMF) is the most common type of filtration system used generally in healthcare facilities, they ensure particles are removed as well as odor and taste from the water system used. Whereas, microfiltration removes small particles from the water post MMF use.
- In healthcare the design of MMF should be as follows:
 - Sand Filtration – Removing Particles down to 10microns (this includes turbidity/suspended solids as per WHO definitions)
 - Carbon Filtration – Removing Odor & Taste from the Water
- MMF suppliers and manufactures shall provide this approach in a two-vessel system, one for Sand Filtration and one for Carbon Filtration.
- Microfiltration uses a bag & cartridge filtration method that removes particles of less than 10microns. This type of water treatment method needs to be maintained by the healthcare facility staff and bags need to be checked on a monthly basis. If the system is maintained correctly, bags should be changed between 6-12 months strategy.
- Both water treatment methods are unable to prevent or inhibit bacterial growth. Therefore, this water strategy method must be used with other water treatment methods.

Distilled Water

- Distilled water is the condensed purified water from condensed steam. Distilled water is provided for laboratory use in healthcare facilities.
- Distilled water requires a RO water connection from the plant or DI water connection (depending on the requirements of the laboratory functions).

Due to the amount of distilled water used, this will be a local bench top unit and not a major plant or a centralized system

Drinking Water

- Some healthcare facilities may provide a separate water supply for drinking water fountains (as shown in Diagram 5.2). The quality of drinking water with Chemical treatment must be as per the requirements highlighted in Table 5.1 or as per local municipality requirements.
- The chemicals used for water treatment for drinking water need to ensure that there have no adverse effects for human consumption. Chemical products used have been provided in an approved list by the Drinking Water Inspectorate (DWI).
- To prevent the drinking water system from stagnation and from the likelihood of temperatures exceeding 20°C (thus affecting the quality of water) the drinking water will need to be provided from a central chilled water storage tank and pump made for drinking water purposes only.
- Drinking water without a storage requirement must not be installed.
- If a central drinking water system has not been provided, then a bottled water drinking water system shall be provided via a water cooler.
- Bottled water coolers shall be provided with chilled and hot water capability but shall only be supplied with a dedicated single water supply (1 No.) designated for drinking purposes only.
- In healthcare facilities pantry areas, there is a requirement for above bench or below bench hot water boiler/chiller unit (as per Part B of these Guidelines). These will be required to be supplied with a normal potable water supply (these units will have internal low-level water treatment).

Specialist Water Systems Provisions

- For healthcare facilities that are expanding their departmental services or providing new FPU's as part of the expansion, local water treatment solution shall be provided if the potable water supply is not treated. An example of this requirement is a new Dialysis unit or Endoscopy clean-up area etc.
- For locally installed water treatment system, the connect from the main supply line to the treatment plant must be provided with a valve assembly set (DCV/BFP, PRV & IV's).

Hydrotherapy Pools

- Water treatment for Hydrotherapy pools shall be via a combined water treatment system.
- The intent of the water treatment system is to control the water mineral concentration. The combined water treatment system will be a combination of MMF and chemical water treatment or Ozone water treatment.
- The treatment system shall be a backwash system that reuses the water within the pool.
- Plant equipment must be installed according to manufacturer's specifications and shall be located in close proximity to the Hydrotherapy Pool with easy access for staff to monitor and service the water treatment systems.
- The water temperature of the pool needs to range between 28 to 35°C as per healthcare requirements. For most conditions being treated the optimum temperature is between 33-35°C.

Cold-Water & Cooled Cold-Water Distribution System

- In healthcare facilities, the water system design relies heavily on the installation practices in any region. The installation practices determine the type of contingencies the water distribution should be designed with.
- The water design and installation should be as per Water Supply (Water Fittings) Regulations 1999 and relevant parts of BS EN 806-2 and BS 8558 or as mentioned by local regulations.
- To maintain the chilled water conditions of the system for healthcare facilities and reduce the risk of heat gain, the pipework should be insulated. The installation should be a vapor seal type to avoid any condensation as per BS 5970.
- Water Hammer Arrestors or Surge Water Arrestors should be connected to discharge to waste via appropriate type AA air gap as per BS EN 1717.

Cold Water & Cooled Cold-Water Booster Pumps

- As part of the World Health Organization Infection Control Strategy high flows are essential for hygienic hand washing. Healthcare facilities depend on high flows and constant pressure to ensure hygienic clean infection control strategy is maintained. Clinical fixtures need to be provided with the following:
- The cold-water pressure range at fixtures shall be between the following:
 - Minimum: 1.38 Bar (gauge)
 - Maximum: 5.52 Bar (gauge)
- The cold water piping maximum flow velocity shall be the following:
 - Piping to 50mm: 1.5 meters per second (m/s)
 - Piping 65mm and larger: 1.8 meters per second (m/s)
- A pumped water system ensures that an adequate water supply is provided throughout the healthcare facility. The potable water booster pumps must be variable driven speed pump system.
- The booster pumps should be a multi-stage pumping system rather than duty-standby single pumps. This approach provides a longer system life with higher energy efficiencies as well as a wider range of flow rates for the facility.
- As part of the healthcare facility resiliency strategy and to continue to provide the healthcare facility with clean, hygienic water, the booster pumps must be connected to the emergency power supply.
- All booster pumps should have automatic control to prevent stagnation.
- Many healthcare facilities may have higher occupant loads on upper floors, thus the pumping amount to these levels will be higher. This amount of pumped water should be controlled by transmitting sensors within the tanks at high level.
- A low-level water alarm should also be provided so that the pump does not run dry.
- The water pump and water storage plant room must be installed with a waterproof and non-

dusting floor as well as and non-dusting walls and ceilings. The floors must fall to the dedicated floor drainage locations provided. The drainage floor gully should be provided with a trap. The trapped gully should incorporate provisions to either avoid or replenish any trap-water seal loss. In hot climates, traps are usually susceptible to evaporation, thus a to Primer valve must be installed (refer to Drainage (section 6) for more details).

Hot Water Strategy

- Hot water is to be provided by 2 types of systems to healthcare facilities:
 - Warm Water to Clinical Hand Wash Basins (Including Scrub Sinks) & General Hand Wash Basins
 - Hot Water to Clinical Sterile Areas, Kitchens, Maintenance Areas and Cleaners Sinks.
- The Hot water system in healthcare facilities should be designed as outlined by BS 6700 (with respect to the Water Supply (Water Fittings) Regulations 1999, BS EN 806 (Parts 1–5), BS 8558 and BS EN 6700.
- The potable water serving the hot water plant shall be treated via Ultraviolet, before connecting to the hot water system.
- In Healthcare facilities hot water system can be vented or unvented systems.
- Vented hot water systems were adopted in older healthcare facilities. This approach consists of a cold-water storage (open to atmosphere) provided above sanitary fixtures which feeds a hot water storage vessel. This approach is no longer accepted in new facilities.
- Unvented hot water systems are connected to a boosted main line (network or internal water system) via a valve assembly set. This strategy maintains the efficiency of the system by maintaining the water quality.

Types of Hot Water Generating Systems

- There are four main type of hot water systems that are acceptable in healthcare facilities (they include direct and indirect heating methods) the following:
 - Electrical Hot Water Generation (Direct)
 - Fuel Burning Hot Water Generation (Indirect, Including Boiler/Steam)
 - Solar Hot Water Generation with a combination of one or both of the above (Direct & Indirect)
 - Heat Pump System
- In healthcare facilities, the design of the system must be provided with a backup water heating strategy along with the above-mentioned hot water systems. Generally, the electrical heating element is the back-up to the other two systems, but it may also be the primary source of hot water generation.
- Solar water system to be provided with a duty and standby system setup.

Hot Water Storage & System

- The water storage temperature must be kept at minimum of 60 - 65°C to any prevent bacterial growth within the stagnant water.
- Energy conservation is achieved with an integral thermostat set between 60- 65°C and return water temperature is to be from 50 – 55°C.
- The domestic hot water pressure range at fixtures shall be between the following:
 - Minimum: 1.38 Bar (gauge)
 - Maximum: 5.52 Bar (gauge).
- Many healthcare facilities use instantaneous hot water system approach by having an electrical hot water generation locally to the department or sometimes to each wash hand basin. This approach not only has huge capital costs on purchasing the units but on the operational costs also.
- Having local small hot water generators does have its advantages over a large central storage system. They are easier to maintain and provide a quicker hot water temperature provision.

Furthermore, balancing the hot water system becomes much easier and less of a problem. But this approach also wastes a lot of energy and moves away from sustainable design. Most of hot water generated is heated but not used as the basin is only used for approximately 30 seconds.

- A central hot water system is the best approach for healthcare facilities.
- A hot water return should always be provided to the central hot water system, unless provided with electrical trace heating tape.
- A central hot water system encourages a low risk of infection concerns for healthcare facilities.

Hot water Return Approach

- Hot water return systems are used to ensure that water temperatures to each of the sanitary fixtures are provided with the appropriate temperature and it ensures that the initial heat generated from the hot water flow is used once again as part of the main hot water system.
- A balancing valve is to be provided on the hot water return system.
- The hot water return is to ensure hot water is provided almost instantly when needed, keeps water consumption low and prevents bacterial growth within the hot water system.
- All hot water supply pipes shall be insulated with flame-safe molded pipe insulation, having a factory-applied jacket suitable for temperature increase.
- The hot water return connection shall be as close to the sanitary fixture as possible. This allows for hot water to be achieved between 10-20 Seconds.

Direct Hot Water Approach

- Direct hot water system approach can be used. This may be provided in RDL5-6 facilities where the return system may take longer to return to the central hot water plant.
- The direct approach will require a hot water system pumps and the pipes to be trace heated to maintain the hot water temperature of the system.
- The trace heating ensures that the hot water is maintained at a minimum temperature of 50°C.
- All hot water supply pipes shall be insulated with flame-safe molded pipe insulation, having a factory-applied jacket suitable for temperature increase.

Hot water temperatures

- In healthcare facilities, the provision of a hot water is required for several healthcare operational needs and systems, Such as the following:
 - Main Facility Kitchen
 - Food Preparation Areas
 - Facility Laundry
 - Clinical Service Areas
- The remaining areas outside these areas will depend on the operational policy of the healthcare facility provider.
- For above areas mentioned to be provided with hot water for a single hot water supply to a fixture, the draw-off water temperature must be a minimum of 50°C and maximum of 55°C.
- Hot water temperatures must be achieved within a certain time frame as per BS 6700.
- This requirement is to ensure that appropriate control of microbial elements in hot water systems are in place. For 50°C, this water temperature must be achieved within 30 Seconds and for 55°C, this temperature must be achieved within 60 Seconds.

Hot Water Plant Safety Blow Down (Air Vent)

As part of the healthcare facility infection control strategy, it is important to preserve the quality of the stored water. The previous practice was to provide a vent pipe to terminate back into the hot water storage vessel. This approach is no longer permitted. The vent should be arranged to discharge over a separate air-break-to-drain (tundish) and then to a floor drain as per BS EN 1717.

Instantaneous Water Heaters

- Generally Instantaneous hot water heaters are susceptible to scale formation, where they will require frequent maintenance. If the design engineer wants to specify such a system, they must ascertain the water quality being provided to the healthcare facility. Furthermore, if the system is to be used for shower areas the system should be thermostatically controlled and provided with a BEAB mark of approval.
- Instantaneous hot water heaters may only be used for RDL 1-3 healthcare facilities.

Hot Water Storage Calorifiers

- Storage calorifiers are usually cylindrical vessels mounted either vertically or horizontally; the base of the vessel usually where the heating element is located or where there is an indirect heat exchange. Sometimes areas below the element can have a lower water temperature than the heated water above. This area can provide an ideal breeding ground for bacteria.
- Galvanized type cylinders are particularly susceptible to scale formation, which can also provide a source of nutrition and shelter for bacteria. Therefore, galvanized cylinders are not allowed in healthcare facilities.
- The storage water cylinder lining should be resistant to bacterial growth.
- Storage requirement for hot water should be based on the peak water usage with a 24-hour usage. As mentioned earlier in these guidelines, there may be multiple peak demand areas. Therefore, it is important that the issue of vessel stratification is dealt with.
- Many storage vessels suffer from stratification. The lower levels provide a breeding ground for legionella bacterial growth since they are not heated properly. Therefore, destratification pumps attached/mounted in the cylinder are to be provided in larger vessels.

Hot water circulating pump

- For all healthcare facilities, the hot water circulating pumps have been installed on the hot water flow side or the hot water return side. When installed on the flow or return the connection is provided with a valve assembly set along with a bypass and where the pump is mounted or connected.
- In healthcare facilities, the type of pump installed is important. For example, duplex pumps should not be installed as the purpose of the system is to keep circulating to maintain water temperature. But rather a clean dry standby pump should be provided or a permanently installed standby pump should be made available.

Water System Isolation Valves

- In healthcare facilities, it is important that the design provides a strategy for future maintenance as well as system durability. Isolation valves are to be fitted before entering main sanitary fixtures in toilets, clinical departments etc. Please note that for the design or maintenance of the design, these isolation valves should not be used for balancing the system flow rates.
- Thermostatic Mixing Valves
- In healthcare facilities there is a risk of scalding (water burning) for vulnerable patients and ensuring that that scalding does not affect them, the hot water service needs to be blended down to warm conditions with a use of a thermostatic mixing valves (TMV). There are three main types of TMVs: TMV-01, TMV-02 and TMV-03. TMV-03 is the type of valve that must be installed in healthcare facilities. While the other two are for a more domestic type of installation and operate at a lower operating pressure than TMV-03.
- In healthcare facilities wash hand basins and scrub sinks will be provided with a TMV that allows outlet temperature control. This limits the maximum temperature of water delivered from the basin taps. Diagram 5.3 below provides a brief detail on the installation of a TMV to a basin.
- Not all sanitary fixtures will require TMV's. Some sanitary fixtures such as stainless-steel sinks in dirty utilities, clean up rooms, kitchens need a higher temperature requirement. All areas not used for hand washing facilities i.e. any tap outlet to other fixtures other than a wash hand basin (such as dirty utility, clean utility, pantry, and kitchen etc.) shall not have TMV's installed. Diagram 5.3 below provides a brief detail of the installation without a TMV.

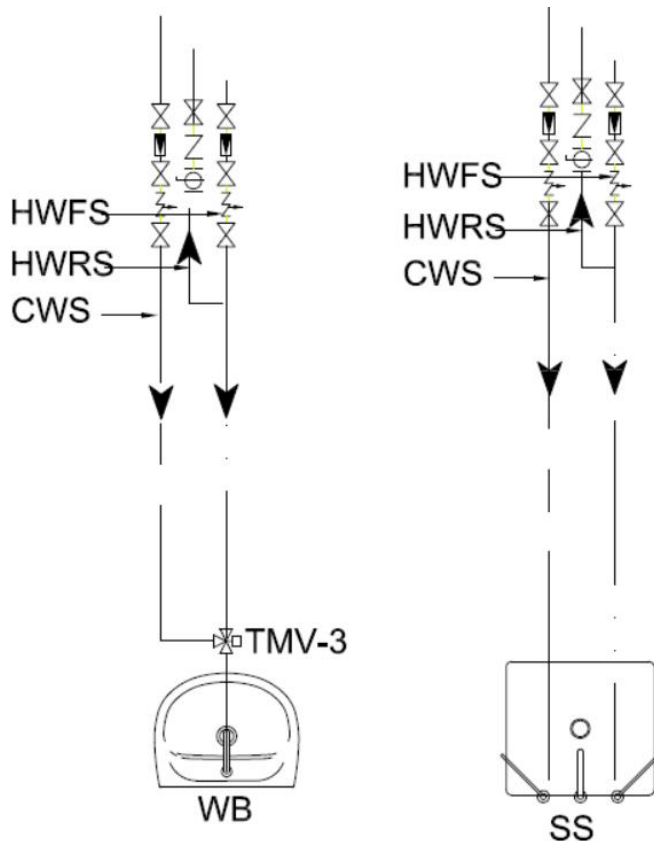


Diagram 5.3 – Location of TMV in relation to Sanitary Fixture

- In recent years, sanitary ware manufacturers have provided a combined TMV and sanitary tap into a single fitting. Some of these are as per healthcare requirement and some are not. The fittings that in contact with the water being discharged must be WRAS approved or equivalent.
- TMV's, along with the hot water return should always be installed as close as to the sanitary fixture as possible to remove any dead leg concerns as many of facilities have high ceilings and long runs (maximum 3m from the basin).
- Close location of the TMV to the sanitary fitting ensures ease of maintenance.
- Table 5.5 below provides the water temperatures required for sanitary fittings required to be installed with a TMV-03 (this must have an enhanced performance testing certificate).

Healthcare Areas & Fixtures	Maximum Recommended Temperature °C
Showers & Hair Washing Facilities	41
Unassisted Baths	44
Baths for Assisted Bathing	46
Bidets and Hand-Held Shatafs	38
Any Basin	38-41

Table 5.5 – TMV location and Maximum Temperatures

- For assisted baths and areas, water temperature is to be monitored and checked by hospital operational staff (Medical or Non-Medical Staff)
- Some facilities may wish to provide higher temperatures than the above recommended maximum temperature value. If healthcare operators wish to do so, then a safe means must be provided to prevent access to these areas by vulnerable patients.

Healthcare Sanitary Fittings

- Healthcare requirements for sanitary fittings differ from other commercial facilities. The goal is always an infection free, safe, hygienic environment for all users (vulnerable users in particular).

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- International Water Supply Regulations places limits on water draw of and requirements to prohibit basin or sink waste plugs (blocker), therefore no drainage waste plugs shall be provided for all sinks and basins.
- Providing an overflow or a waste plug provides an environment for bacterial growth and infection infringement concern. No overflow hole shall be provided for all sinks and basins.
- In healthcare facilities sensor taps should be used for basin washing facilities or as per Part B of these Guidelines.
- The sensor tap solenoid valve is to be checked at least once a month.
- Since legionella is most dangerous in its spray form and can live in the system at any time, spray-type mixer taps are prohibited in healthcare facilities.
- Water flow from the mixer tap should fall in such a way that it forms a shape around the basin discharge area.
- The basin spout should not discharge directly over the waste drain or in an area that causes splashing.
- Some sanitary mixing taps have flow restrictors and aerators at the point of discharge. Flow restrictors or aerators shall not be provided for basins or sinks in healthcare facilities. These tend to be locations where bacterial growth can occur as well as restrict high flows required for healthcare washing requirements.
- Showers in healthcare facilities are generally provided with an integral TMV along with the shower mixing valve.
- Shower heads should not be installed with adjustable spray option around the shower head. This type of issue leads to water stagnation issues.
- Moveable flexible hose type systems should be provided with a back-flow prevention valve and should be selected on ease of descaling and disinfection.
- The purpose of having a back-flow prevention on hose type fixtures such as ‘Shatafs’ handheld bidets and hose showers is to ensure that submersion of the units into a WC or floor drains does not contaminate the supply system.
- Handheld Bidets or ‘Shatafs’ should be served from the same water supply serving wash hand basins. They must not be served from water supply lines serving WC’s (unless this is the same line serving the basins).

Irrigation Water Supply

- For healthcare facilities, the irrigation system needs to be split into two different systems.
- Internal and external landscape areas where patients, staff and visitor will be loitering.
- Internal and external landscape areas where there will not be any patient, staff, and visitor loitering
- Water used for irrigation shall be served from a dedicated irrigation water tanks for each area mentioned above.
- The internal irrigation system is prohibited to be served with a TSE water supply to areas described in section 5.19-1(a) above.
- Irrigation to areas described in section 5.19-1(a) can only be served with clean potable water supply (Non-Cooled).
- Irrigation to areas described in section 5.19(b) can be served with TSE water from STP plant or treated condensate water supply (or both).

Grey Water (WC Flushing Only) & WC Flushing Systems (Non-Chilled Systems)

- Grey water strategies are generally avoided for healthcare facilities, due to the level of water treatment is sometimes not sufficient to be used with the healthcare facilities. But they may be times where Due to the local water requirements and local water shortages, strategies have been provided within this design to allow for water to be re-used. Green Building Code requirements encourage the use of a grey water system, therefore grey water systems are allowed but only for the following systems:

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- Non-loitering Irrigation Areas
- WC Flushing Systems
- Maintenance Bib Tabs
- All other areas except for the areas mentioned above (5.20-1) shall not be provided with grey water service.
- The following sources can be used for grey water systems:
- Water from Basins, Showers, Floor drains that have been treated (Waste-Water Drainage) and RO Water Rejection Water

Steam System

- There are three types of steam services provided for any healthcare facility and they are the following:
 - Plant Steam – A steam supply service used for Healthcare facilities Laundry and food and beverages area
 - Clean Steam – A steam supply service used for healthcare laboratories and sterile store units (SSU)
 - Pure Steam – A steam supply used for high grade healthcare facilities or biotech or pharmaceutical laboratories.
- In healthcare facilities, the quality of steam will depend upon the application it will be used for and this will be known for the healthcare briefing provided by the healthcare facility operator. The water quality serving the steam system must be treated (including softened water in some cases to reduce the mineral deposits in the system).
- Plant Steam and Clean Steam are main type of services that will be used in healthcare facilities.

Source of Steam System

- There will be two types of sources for the steam system used for healthcare sterile services and they are the following:
 - Central Steam Boiler System
 - Local or Central Electric Generation Steam Boiler
- Both systems will provide any healthcare facility with the quality of steam they require, depending on the water quality supply into the system.

Plant Steam

- Plant steam is based on having central local plant serving the healthcare facility. This system then serves multiple applications.
- The steam system must have chemical additives added to control the pH level of the steam as well as the foaming of the water.

Clean Steam

- Clean steam requires a supply of specialized treated water such as RO or DI water.
- The production of clean steam contains no dissolved minerals on surfaces of cleaned items.
- Where medical equipment requires steam supply, it shall be clean steam.
- Medical Equipment with integrated steam generators shall be provided with RO or DI water service to generate clean steam.

Steam System Pipe Materials

- Piping must be stainless-steel due to the quality of the water and its contents.
- Stainless-Steel is a non-reactive metal and is able to resist corrosion as well as being a hard metal.
- Other types of metal such as copper are more active metals and they can leach.

- Plastic Pipes or FRP are not allowed for steam service pipes.

Central Steam Generation vs Local Steam Generation

- While the option is the most economical to operate a central steam generation plant it is not the most efficient type of system for healthcare facilities. Having a local generation makes the system resilient against any failures as the local generation is intended for a single unit and purpose. If unit fails, the parts are easily repaired or replaced, whereas failure of the central steam plant system will have devastating impact on healthcare facility operation.
- Some healthcare operators may use a combination of both systems. A combination of both systems should only be used for the following reasons:
 - Redundancy – Having the local steam generators be a backup set of steam generation
 - Sterilization Speed – Increase the Sterilization speed by having the incoming steam at a lower temperature and the integral unit being the second stage of steam (this will require advance control strategy)
- Both steam generation methods can be used for healthcare facilities, but proper maintenance must be provided to the units.
- Steam equipment serving SSU areas to be provided with equipment backup.

Public Health Maintenance

- In healthcare facilities, it is crucial to have a maintenance strategy to maintain the quality of the system along with a fully qualified team.
- Water tanks are to be cleaned on a weekly basis. The water tank must be a divided water tank that allows the system to operate for least 12 hours without incoming water. All cleaning within the tank must be completed within that time.
- Post treatment tanks cleaned after the water treatment process (except UV water treatment) must be cleaned to a level where large particles have been removed as reasonably as possible.
- After the tanks or water treatment systems have been cleaned, the healthcare operator will need to observe the water system for 24 hours to ensure for the system is fully clean, safe, and hygienic for the healthcare facility.
- For hot water systems, the maintenance team must have a strategy in place to check the hot water heating element being used. This can usually be done monthly via the access manhole provided by the element.
- For steam, correct healthcare design and maintenance of the system is needed. This will allow for a successful steam sterilization outcome to the required healthcare areas. Maintenance tasks should ensure that wet packs are minimized, equipment staining, and chamber scale is minimized in the system.
- The maintenance team for the facility must be familiar with water maintenance strategy as well the equipment installed within the facility.

6 Public Health - Sanitary Drainage System Design (DS)

This PH-DS design guideline written for healthcare facilities, is a consolidated document listing out the design requirements for all new construction and major renovation healthcare projects.

The requirements outlined in these guidelines are not intended to conflict with Federal Regulations, Local Municipality Laws, Executive Orders, or the needs of the end users.

This document is intended for the Architect/Engineer (A/E) and others engaged in the design and renovation of healthcare facilities. Where direction described in applicable codes are in conflict, the A/E shall comply with the more stringent requirement. The A/E is required to make themselves aware of all applicable codes.

The document should be read in conjunction with other parts of the Health Facility Guidelines (Part A to Part F) & the typical room data sheets and typical room layout sheets.

Introduction

- The drainage system design needs to deal with amount of effluent delivered in the system. The standard drainage principles shall apply as per municipality requirements unless specially stated otherwise within these guidelines.
- For drainage design of healthcare facilities, the following details are important:
 - Healthcare facility geographical location
 - The ground surface level of where the healthcare facility is located
 - The locations of existing drainage network main holes and main connection points (if any)
 - The healthcare facility operational hours and times of peak load (if known)
 - Type of special drainage that will be discharged from the healthcare facility (radiation, chemical, grease etc.)
- The drainage connection points for the external network must be as per municipality requirements.

Drainage Strategy

- The drainage system that must be a gravity drainage system for general drainage systems.
- Pressure drainage system shall only be used externally to the building or within the basement areas via a sump pump connection.
- Pressure drainage systems within buildings lead to a number of design failures and add to the risk of leakages in the system.
- The drainage design of the system needs to ensure the following:
 - Prevent any odors emerging from the drainage system via dried traps.
 - Minimize the frequency of blockages.
 - Provide sufficient drainage gradient to discharge waste into main sewer network (or central plant)
 - Drainage discharge to be connected from sanitary fixtures to the main drainage runs and not via a floor trap or any other fixture.
- The healthcare drainage design guidelines for healthcare facilities shall only concentrate on drainage systems within healthcare facilities i.e. above ground installations.

Types of Drainage Systems

- In healthcare facilities, there are several different types of drainage systems. It is imperative that these systems are kept separate in healthcare facilities, so that the infection control strategy is not jeopardized, and the system maintenance is optimized.
- The drainage systems are the following:

- Wastewater Drainage – Generally drainage from Wash Hand Basins, Showers, Baths, Sinks, Scrub Sinks and Floor Drains. Drainage that does not contain human waste or contaminated water discharge.
 - Soil Water Drainage – Drainage from systems that contain human waste. Such as WC's, Urinals, Dirty Utility Flushing Rims (Slope Hopper) and Baby Washing Rooms.
 - Storm Water Drainage – This is drainage from water precipitation from external conditions such as rain, sprinkler water discharge or bib tap discharge.
 - Chemical Drainage – Drainage from dedicated laboratory areas where systems will need to be neutralized before connecting to the main system.
 - Radiation Drainage – This is drainage from the healthcare facility oncology areas, hot labs, and toilet areas. This only applies to low level of radiation and not industrial radiation uses.
- Some of the above systems maybe combined with other systems to ensure the system operation and function, such as including designing for grease / oil interceptors.

Vent Pipes

- All the above systems will be required to be vented to atmosphere via a vent pipe connection to the drainage runs. The vent pipe can be provided at high level or just above the point of discharge of the sanitary fixture units.
- For very small facilities, where there are local toilet facilities made up of a WC and WHB, then the system is not required to be vented at high level via vent pipes, but a stub stack shall sufficient for a system to be vented via the drainage system connection.
- For low rise and small floor area healthcare facilities, an automatic air vent or air admittance valve can be provided at the top of a sanitary drainage system. This scenario is sometimes existing when a facility in a high-rise building is being refurbished on a single floor of a building and a separate drainage system needs to be installed.

Drainage System Design Types

- A number of international drainage systems from different countries around the world use their local drainage system requirement (System 1, System 2, System 3, System 4 etc.). The drainage design will be based upon the requirements of BS EN 12056 unless required otherwise by the local municipality.

Wastewater Drainage

- The drainage from sanitary fixture units in the drainage system must be directly connected to the main drainage line (vertical or horizontal main drainage lines).
- Clean outs must be located behind the sanitary fixture unit or above ceilings or floor access in service areas.

Floor Drains

- Floor drains are required as per Part B briefing requirements for areas such as in dirty utilities, SSU, clean-up areas.
- Floor drain and clean out shall be a combined fitting with trap to prevent odors in areas requiring floor drains
- Floor drains located in an environment that will dry out will need to be connected to a primer valve that is connected to the potable water system to ensure that the trap refills with water if the trap dries up due to evaporation.
- A special floor drains with a special seal can be used in place of a combined trap and primer valve.

Soil Water Drainage

- Soil drainage shall be the drainage discharge from Toilets (WC's), dirty utilities and baby washing facilities.
- These can be S-Trap or P-Trap discharge systems.

- The type of discharge will depend on the local some parameters limiting the designing of the drainage system. Ceiling space may be restricted, structure may prevent core drilling through below or shaft space may be limited.
- It is highly recommended to install a P-trap system. It is easier to maintain and replace parts of fittings to the WC. Furthermore, it provides the shortest possible drainage route and eliminates any drainage runs over healthcare sensitive areas.
- The WC drainage connection must be a minimum of 150mm (160mm) if more than 1 No. WC is connected to the system.
- Bends of 90° must not be installed on soil drainage lines as these are the points of the system that blockage is likely to occur.
- All bends must be provided with a Rodding Eye (RE) access door for unblocking the soil system if it suffers from blockage.
- The RE should be located in service areas or behind WC's, never in clinical areas.

Soil & Wastewater Drainage Over Critical Areas

- The opportunity of having a clear drainage route over non-sensitive areas may not always be possible. There are some instances where the drainage will need to be taken over Grade A and B areas.
- Where health planning briefing design does not allow for such leisure the drainage design shall be sleeved or double walled completely through the critical area that the pipe is routed through. The end of the pipe sleeve is to be open on both ends to the external areas (that are not critical). This strategy allows for any leaks to be taken out if the critical zones completely.
- If a double wall pipe solution is not used, then a double ceiling system over the clinical areas must be provided.
- For Dialysis areas, there should be a dedicated drainage point for each proposed dialysis station. The drainage connection shall be provided below the water supply point and shall be a clean drainage connection with no air gaps. The drainage pipe shall be easy to disconnect between machine and station.

Rainwater Drainage System

- Complete rainwater drainage system needs to be provided to any healthcare facility.
- Rainwater Drainage at healthcare facility roof (s) will be collected via a network of horizontal pipes and transferred to a level to connect to the external storm water network or within the facility holding tanks or in some cases into soak ways used to increase the water table level. Municipality requirements shall be the design that is followed for connection requirements.

Siphonic Rainwater systems

- It is highly recommended that these items should only be used in areas where there is limited ceiling space for services and thus several bends will be used, or a water seal has been provided at the rainwater floor gullies/drains to ensure that the symphonic process is enabled.

Pipe Materials for Drainage Systems

- The drainage system pipe materials shall be as per BS EN 12056 or municipality requirements. These requirements shall be as follows:
 - Sanitary Sewer, Storm water and Vent, Above Grade: uPVC (un-plasticized polyvinyl chloride) as per BS EN 1329. Gravity Drainage to UPVC for local to the sanitary fixtures.
 - Force Main Below & Above Grade as well as gravity drainage: HDPE (High Density Polyethylene) as per 12201. Gravity drainage for min stacks to be HDPE.
 - Kitchen Waste: HDPE (High Density Polyethylene)

Special Drainage Systems

- Special drainage systems are used in laboratory and in special healthcare departmental areas such as morgues, incinerators etc.

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- Special drainage systems are the following:
 - Acid Waste Drainage
 - Infectious Contaminated Drainage

Acid Waste Drainage

- An acid waste drainage system deals with drainage liquid discharge of liquids with a PH level lower than 7. Generally, this type of drainage system is provided at high level fully operational teaching healthcare facilities where pharmaceutical drugs are prepared and manufactured.
- All the drainage from the acid waste drainage must be neutralized to a pH of 4 as minimum before being connected to the external drainage network.
- Floor drains should be avoided in laboratory areas.
- Where floor drains are provided in laboratory areas, the floor drain shall be covered with a special odor type seal and the floor drain must have a disinfection capability.
- Any spillage should be wiped away with a cloth and that cloth used for wiping be placed in hazardous waste bins.
- Clean out in lab area to be floor clean out type.

Acid Waste Drainage Health and Safety Concerns

- Concentrations of Acid drainage can cause a number of severe damage (eyes, skin etc.) to healthcare operators. Emergency showers, eye wash units, drench system shall be provided by exit doors as per Part B healthcare briefing.
- A floor drain be needed to prevent the flooding of the area where the emergency is being provided.
- The floor drain shall be connected to a neutralization plant. If gaseous or fog acid is generated in a facility, fog water nozzles are to be used to prevent the gas from spreading.

Acid Waste Drainage Design Considerations

- Each sanitary fixture will need to be individually trapped and each unit to be provided with a vent pipe to atmosphere.
- Drainage from laboratory systems shall be connected to a single acid neutralization plant unless mixing of the chemicals causes a hazardous or a catalytic reaction, then another drainage system along with another neutralization plant will need to be provided.

Acid Waste Drainage Pipe Material

- The following pipes materials are required for acid waste drainage systems:
 - Polypropylene with Electrofusion welding joints
 - Glass with Compression Joints (encased in plastic for protection) – But not Vent pipes.
 - High Silicon Cast Iron with Compression Gasket Joints
- Other materials such as PVC or UPVC or CPVC may be considered but should be avoided as they have a lower chemical compellability and lower temperature rating.
- Polytetrafluoroethylene (PTFE) seal is the only material that is resistive to a wide range of chemicals as well as having the highest temperature rating.
- The pipe for the acid waste drainage systems should be supported through the system to prevent drainage spots in the drainage system that could lead to leaks.

Acid Waste Drainage Treatment

- Acid waste drainage pH levels from healthcare laboratories require to be neutralized to a pH between 4 and 7 before being connected to the main external drainage network. Local municipality may have a more stringent requirement and that does not allow any discharge to the network from the laboratory.
- Probes will be required after the neutralization process to ensure that the pH level is correct when connecting to the external drainage network.

Part E: Health Facility Briefing & Design Engineering

- If drainage cannot be connected to the municipality from laboratory waste, then a storage/holding tank system shall be provided for a number of days.
- The storage/holding tank can only be emptied by a licensed contractor.
- The type of neutralized system used is the drainage laboratory discharge to be in contact with limestone chips or a limestone gel/liquid or chemical feces or equivalent.
- The design of the treatment system should be designed for the maximum flow rate foreseen from the laboratory area.
- In smaller health facilities or clinics, a central neutralization plant or equipment may be too costly. If this is the case, then single isolated sink(s) should be provided.
- These sinks will need to have an acid neutralizing trap as part of the unit. These should be used for discharging acid waste drainage only.

Infectious Contaminated Drainage

- Drainage that will consist of biohazardous material carrying suspended living organisms which is risk of causing infection to patients, visitors and healthcare operational staff is considered infectious contaminated drainage.
- The drainage will be from type Q isolation rooms.
- These systems need to be disposed of correctly and safely to ensure the continuity of the facility clean and safe environmental conditions via discharge to a holding tank.
- The holding tank will be connected to all the areas of concern where there is a biohazardous material being discharged.
- The containment is divided into the following parameters:
 - Primary Measures – Particular equipment such as the biological safety cabinet, glove boxes etc.
 - Secondary Measures – Measures used to support primary measures.

Types of Biological Safety Levels

- CDC/NIH Guidelines for Biosafety in Microbiological and Biomedical Laboratories have provided biosafety level of contaminants for facilities. The range from Biosafety Level (BL) BL1 – BL4. In the majority of healthcare facilities, the safety level is between BL1 and BL2, (BL3 is very rare).

Infectious Contaminated Drainage Treatment

- The holding which is also known as a 'Kill Tank', is the when the tank is injected with a chemical that attacks the hazardous organisms.
- Please note that the decontamination process is not an instantaneous process, but the 'Kill Tank' works in stages for the drainage to be neutralized before connecting to the system.

Infectious Contaminated Drainage System Components

- For healthcare facilities, the drainage system must be closed system and the floor drains (if provided) are to be sealed.
- Floor drains will need to have valve connections when the system is not in use.
- In many of these areas the HVAC areas (as discussed in section 2 of these guidelines) will have negative air requirement, therefore the floor trap will need to be 90-100mm deep.
- The floor trap seal will need to be filled with a disinfectant solution that can prevent the spread of organisms.
- The pipe system will be a double wall pipe system with leak detection.

Infectious Contaminated Drainage System Pipe Material

- The proposed drainage materials for such systems are the following:
 - Stainless steel
 - PTFE – For higher temperature systems

- PVC, CPVC, PP, or lined FRP pipe – For lower temperature systems.

Infectious Contaminated Drainage System Vent

- Vents from pipe, fixtures, sealed sump pits, and kill tanks must be filter-sterilized prior to leaving the system using an HEPA (EP1) filter (connected to HVAC system exhaust).

Radiation Drainage

- As per international standards, there is no need for radiation (Contaminated Drainage) holding tanks for drainage from toilets coming from patients who have just used iodine-131 or other low-level radioactive isotopes.
- If a healthcare facility would like to provide a radiation tank, they will need to provide the tank external to the building in a location where there is limited to radiation exposure. The level acceptable radiation levels will be determined by the radiation safety officer.
- Local municipality may not allow for radiation drainage to be diluted and connected to the external drainage network; therefore, a holding tank shall be provided.

Radiation Drainage Strategy

- Radiation drainage shall be discharged to its own dedicated system. The system may be a diluted type of system or a holding tank system for a licensed contractor to remove the tanks contents.
- A sample access to the system is to be provided for the radiation safety officer to take periodic samples of the system.
- Many facilities may wish to hold radiation drainage confined to glove boxes or protected hoods. Radiation drainage in these areas should be shielded.

Radiation Drainage Holding & Decontamination

- External radiation storage tank shall be a divisional storage tanks to allow for operation and maintenance of the radiation storage tank.
- Depending on the level radiation used, the tank storage volume can be for 30 to 90 days storage capacity (it may sometimes be less for an oncology dedicated facility).
- It is highly recommended a second set of holding tanks should be provided to reduce the risk of healthcare operations. This provision should be based on a risk assessment carried outlining the availability of the licensed contractor as well as the operational parameters of the facility and oncology department.

Radiation Pipe Material

- The pipes used for radiation drainage will depend on the level of radiation being discharged or carried in the drainage system. As per the NRC requirements, the pipe material will need to have the following properties:
 - Pipe to be nonporous.
 - Pipe must be easy to clean and decontaminate.
 - Pipe must be acid resistant.
 - Pipe to be non-oxidizing as the oxides of the pipe can become radioactive
 - The pipe joints should not form a crud trap for drainage discharge
 - The pipe joints should not be by radiation exposure such the weakening of gaskets.
- For healthcare facilities with low levels of radiation drainage levels some materials such as plastic are not acceptable since there is possibility for certain plastics to react to different types of radiation drainage.
- Stainless Steel pipes (typical 316L) with welded joints is the only pipe that covers the above requirements as well as not allowing crud trap on the pipe joints.
- Stainless-Steel press fitting pipe fittings with smooth surfaces may also be used instead of welded joints.
- In bunker areas, where thick concrete is used, the drainage pipe shall be pipe-in-pipe, the

pipe, with a Duplex Stainless-Steel pipe to be the exterior pipe that is in contact with concrete.

- Pipe joints are to be outside the concrete cast (unless its unavoidable).

Condensate Drainage

- All condensate drainage from local air conditioning, HVAC main equipment and plant to be collected or discharged to foul drainage via a trap (i.e. HepvO trap).
- For water re-use efficiency, condensate should be collected in a single tank and treated prior to use.
- In line with majority of the green building codes, condensate collected shall be used as irrigation purposes (please refer to irrigation water system in these guidelines).

Kitchen Grease Drainage

- Where there is a facility for hot food to be cooked then a grease interceptor is to be provided for all the drainage in that area to be connected to before being discharged to the external drainage network.
- If the healthcare facility is a small clinic (RDL 1-2), then a local below the kitchen sink grease interceptor is to be provided.
- In larger facilities (RDL 3-6) the grease interceptor should be provided in an area that is readily accessible by the healthcare maintenance staff.

Oil or Fuel Drainage

- Many healthcare facilities may have main electrical equipment that relies on a fuel source. Any drainage around this area is to be provided with an Oil Interceptor as per BS EN 858.
- Oil Interceptor as per BS EN 858 to be provided car park areas where care washing takes place.
- For generator areas where a foam extinguishing system has been activated, the drainage from the discharge shall not be directly discharged into the sewer network.
- Foam systems have a high BOD and therefore will need a storage drainage tank stored below the generator and treated before discharging to the external drainage network via Oil Interceptor as per BS EN 858.

7 Public Health - Medical Gas System Design (MGS)

This PH-MGS design guideline written for healthcare facilities, is a consolidated document listing out the design requirements for all new construction and major renovation healthcare projects.

The Medical Gas System security, resilience and storage capability must be designed to ensure that patient safety as well hospital operations are not at risk.

The requirements outlined in these guidelines are not intended to conflict with Federal Regulations, Local Municipality Laws, Executive Orders, or the needs of the end users.

This document is intended for the Architect/Engineer (A/E) and others engaged in the design and renovation of health facilities. Where direction described in applicable codes are in conflict, the A/E shall comply with the more stringent requirement. The A/E is required to make themselves aware of all applicable codes.

The document should be read in conjunction with other parts of the Health Facility Guidelines (Part A to Part F) & the typical room data sheets and typical room layout sheets.

Introduction

- The aim of this section of the guidelines is to promote the correct design of Medical Gas Systems for healthcare facilities.
- The design will discuss storage requirements, type of system proposed as system locations for the following Medical Gas Services:
 - Oxygen
 - Medical Air (MA4)
 - Surgical Air (SA7-SurgicalTool Air 7Bar)
 - Vacuum/Suction Air
 - Nitrous Oxide (N2O)
 - Helium/Oxygen (Heliox)
 - Nitrogen (N2)
 - Carbon Dioxide (CO2)
 - Nitrous Oxide/Oxygen (Gas Mixture – Entonox)
 - Gas Scavenging Systems (AGSS)
- These design guidelines are to be used in new healthcare facilities as well as facilities that will refurbished under the process as mentioned in Part A of these Guidelines.
- The guidelines for pipe sizing and other associated works can be based on ISO 7396.
- NFPA 99 guidelines should be applied for zoning, materials, hazard determination, alarms & equipment's.

Design Criteria

- The Medical Gas Service is designed to provide a safe and effective method of delivering quality medical gas service to the terminals within FPU's in healthcare facilities.
- In addition to Medical Gas Services being supplied to the department, some areas will require gas scavenging disposal systems to control the exposure to nitrous oxide.
- Medical gas services shall only be supplied to clinical areas as per the healthcare briefing requirements shown in Part B of these guidelines.
- Medical gas service should not be provided for non-clinical areas such as workshops (not biomedical workshops) and pathology departments. These areas shall be provided by 11Bar Compressed Air.
- For sensitive patient areas such as patients having infectious diseases, portable suction devices should be used in order to not contaminant the medical gas system.
- The Medical Gas System should be providing a number of sources to serve the facilities. Within these guidelines the sources shall be stated primary, secondary, and

reserve/emergency systems.

- The piping distribution systems according to the RDL level of the facility as well as number of beds can be very simple as a single riser, more resilient with a looped riser and even more with a double riser or a ladder riser. Designer has to make a conscious choice based on project criticality and area served.
- The purity of the medical gases shall be as the European Pharmacopoeia requirements table as shown in table 7.1 below
- Particulate level tests are to be provided with medical gas purity requirements.
- To maintain the sterile services of the medical gas service throughout the healthcare facility, the quality in terms of particulate content, dryness and concentration of impurities should comply with the requirements for maximum concentrations given in Table 7.1 below.
- Bacteria filter are to be included in medical and surgical compressor systems to reduce the risk of delivering spores of infectious material to vulnerable patients.
- The medical gas service connected to the bacteria filter must be a dry service. This is to ensure that any micro-organisms are prevented from bypassing the bacteria filter.
- Micro-organisms can penetrate a bacteria filter if the material is wet. The filter is to be checked every 12 weeks of hospital operation.
- For Medical Gas purity tests these are to be checked by the healthcare operator every 6 months for new builds and refurbished/retrofit facilities.

Gas & Source	Oil	Water	CO (Carbon Monoxide)	CO ₂ (Carbon Dioxide)	NO (Nitric Oxide) & NO ₂ (Nitrogen Oxide)	SO ₂ (Sulphur Dioxide)	Odor/Taste
Oxygen from Bulk Liquid Storage	-	≤67 vpm ≤0.05 mg/l, atmosphere dew point of -46°C)	≤ 5 mg/m ³ , ≤ ppm v/v	≤ 300 ppm v/v	-	-	None
Oxygen from PSA Plant (Oxygen Generation)	0.1mg/m ³	≤67 vpm ≤0.05 mg/l, atmosphere dew point of -46°C)	≤ 5 mg/m ³ , ≤ ppm v/v	≤ 300 ppm v/v	≤ 2ppm v/v	&	None
Nitrous Oxide	-	≤67 vpm ≤0.05 mg/l, atmosphere dew point of -46°C)	≤ 5 mg/m ³ , ≤ ppm v/v	≤ 300 ppm v/v	≤ 2ppm v/v		N/A
Nitrous Oxide/Oxygen Mixture	-	≤67 vpm ≤0.05 mg/l, atmosphere dew point of -46°C)	≤ 5 mg/m ³ , ≤ ppm v/v	≤ 300 ppm v/v	≤ 2ppm v/v		N/A
Medical & Surgical Air	0.1mg/m ³	≤67 vpm ≤0.05 mg/l, atmosphere dew point of -46°C)	≤ 5 mg/m ³ , ≤ ppm v/v	≤ 900 mg/m ³ ≤ 500 ppm v/v	≤ 2ppm v/v		None
Synthetic Air	-	≤67 vpm ≤0.05 mg/l, atmosphere dew point of -46°C)	-	-	-	-	None
Helium/Oxygen O ₂ < 30%	-	≤67 vpm ≤0.05 mg/l, atmosphere dew point of -46°C)	≤ 5 mg/m ³ , ≤ ppm v/v	≤ 300 ppm v/v	≤ 2ppm v/v	-	None

Table 7.1 – Quality of Medical Gases

- For all healthcare facilities and to maintain the operation of the system, the medical gas supply throughout should be designed to achieve continuity of supply to the terminal units in normal condition and in a single fault condition. Loss of supply due to maintenance of a supply source (or a component within it) is not considered a single fault condition.

- The medical gas design provided will need to ensure that both system design parameters and the need for supply security of the service haven been identified. This will need to be carried out via a system/healthcare operator requirements risk assessment.
- As mentioned via the sources of supply section of these guidelines, security of medical air supplies must be given a high priority and electrical failure must not be allowed to jeopardize supplies (as mentioned in the electrical sections of these guidelines, all medical gas system is to be connected to Primary, secondary and tertiary power supplies).
- Gas Scavenging system (AGSS) shall only be provided to areas being serviced with Nitrous Oxide.

Sources of supply

Medical Gas services within the medical system in healthcare facility operate based on a redundancy and resiliency provision of the service to ensure patient safety and maintain the operation of the healthcare facilities.

Liquid Oxygen Cylinder Systems

- Primary Supply – Liquid Cylinder Manifold System (No Change over panel, all cylinders are on at the same time)
- Secondary Supply – Automatic Cylinder Manifold System. Activated when Primary Supply fails or there is a shortage of primary supply.
- Reserve Supply – Automatic Cylinder Manifold System to Grade A areas.

Oxygen Generation Plant (PSA)

- Primary Supply – Multiplex Compression Unit
- Secondary Supply – Automatic Cylinder Manifold System. Activated when Primary Supply fails or there is a shortage of primary supply. The number of cylinders should be based on a 4-hour operation storage provision.
- Recommendation: The secondary supply should be filled from the primary supply. This will provide an indication to the hospital operator when the primary supply fails and ensures that the secondary supply serving the healthcare departments are always filled.
- Reserve Supply – This type of supply will depend on the risk assessment carried out by the design consultant. The conclusion may lead to the use of an Automatic Cylinder Manifold System, a manual Cylinder Manifold system or another Oxygen generated plant located at a different location on site or local bottles to departments to serve Grade A areas.

Medical Air Supply (MA4)

- Duplex Compressor Set-Up:
 - Primary Supply – Duplex Compressor System
 - Secondary Supply – Automatic Cylinder Manifold System. Activated when Primary Supply fails or there is a shortage of primary supply. The number of cylinders should be based on a 4-hour operation storage provision.
 - Reserve Supply - Automatic Cylinder Manifold System. Activated when Primary Supply fails or there is a shortage of primary supply. This type of manifold system may only be located locally near Grade A areas.
- Triplex Compressor Set-Up:
 - Primary Supply – Two Compressor of a Triplex Compressor System.
 - Secondary Supply – Third Compressor of a Triplex Compressor System.
 - Reserve Supply – Automatic Cylinder Manifold System to support the entire healthcare facility.
- Quadruplex Compressor Set-Up:
 - Primary Supply – Two Compressor of a Quadruplex Compressor System.
 - Secondary Supply – The Other Two Compressor of a Quadruplex Compressor System.
 - Reserve Supply – Automatic Cylinder Manifold System to support the entire healthcare facility.

- Recommendation: Each compressor/pump is sized to cope with half the system design flow

Surgical Medical Air (SA7 /Tool Air-7Bar)

- Simplex Unit Set-Up:
- Primary Supply – Simplex Compressor Unit.
- Secondary Supply - Automatic Cylinder Manifold System. Cylinder system shall be Activated when Primary Supply fails or there is a shortage of primary supply. The number of cylinders should be based on a 4-hour operation storage provision.
- Reserve Supply – Departmentally localized valve Cylinders with flow regulators and meters. This will be located in a small plant room near Grade A areas such Operating Theatres.
- Duplex Unit Set-Up:
 - Primary Supply – One Compressor of Duplex System.
 - Secondary Supply – Second Compressor of Duplex System.
- Reserve Supply - Automatic Cylinder Manifold System. Cylinder system shall be Activated when Primary Supply and Secondary fails or there is a shortage of the supply. The number of cylinders should be based on a 4-hour operation storage provision of the specific department.

Combined Medical Air & Surgical Air Plant

- Duplex Compressor Set-Up:
 - Primary Supply – Duplex Compressor System.
 - Secondary Supply – 2 No. Automatic Cylinder Manifold System (1 No. for Medical Air and 1 No. for Surgical Air). Cylinder system shall be Activated when Primary Supply fails or there is a shortage of primary supply. The cylinders may be filled by the primary source or already filled cylinders provided by a local supplier. The number of cylinders should be based on a 4-hour operation storage provision.
 - Reserve Supply - Automatic Cylinder Manifold System. Activated when Primary Supply fails or there is a shortage of primary supply. This type of manifold system may only be located locally near Grade A areas.
- Triplex Compressor Set-Up:
 - Primary Supply – Two Compressor of a Triplex Compressor System.
 - Secondary Supply – Third Compressor of a Triplex Compressor System.
 - Reserve Supply – Automatic Cylinder Manifold System to support the entire healthcare facility.
- Quadruplex Compressor Set-Up:
 - Primary Supply – Two Compressor of a Quadruplex Compressor System.
 - Secondary Supply – The Other two Compressor of a Quadruplex Compressor System.
 - Reserve Supply – Automatic Cylinder Manifold System to support the entire healthcare facility.
- Recommendation: Each compressor/pump is sized to cope with half the system design flow.

Liquid Gas Mixture (Oxygen & Nitrous Oxide)

- Primary Supply – Liquid Oxygen and Liquid Nitrogen Vessels with Mixer Unit.
- Secondary Supply – Secondary Liquid Oxygen and Liquid Nitrogen Vessels with Mixer Unit.
- Recommendation: The for Primary and secondary unit, depending on the specialty and size of the facility a cylinder system may be sufficient, but this will need to be confirmed by a risk assessment.
- Reserve Supply – This type of supply will depend on the risk assessment carried out by the design consultant. The conclusion may an Automatic Cylinder Manifold System, a manual Cylinder Manifold system or another Oxygen generated plant located at a different location on site or local bottles to departments to serve Grade A areas.

Medical Vacuum System

- Triplex Pump Set-Up:
 - Primary Supply – Two Pump of a Triplex Pump System.
 - Secondary Supply – Third Pump of a Triplex Pump System.
 - Reserve Supply – Portable Suction Equipment.
- Quadruplex Compressor Set-Up:
 - Primary Supply – Two Pump of a Quadruplex Pump System.
 - Secondary Supply – The Other two Pump of a Quadruplex Pump System.
 - Reserve Supply – Portable Suction Equipment.
- Recommendation: Each pump is sized to cope with half the system design flow.
- Important Note: In the event of power failure, cylinder- or medical-gas-system-powered vacuum generators can be used, but the use of venturi-type vacuum generators is recommended only for emergency use, as these units are generally driven from the medical oxygen system and use large amounts of gas. This can lead to oxygen enrichment and present a potential fire hazard and may result in the emission of pathological material.

Gas Cylinder Manifold System

- Primary Supply – Automatic Cylinder Manifold System and the number of cylinders based on the system design. Number of hours of operation as well as the availability of the cylinder supplier needs to be considered through a risk assessment to determine the number of operating hours, which will provide the exact number of cylinders.
- Secondary Supply – Manual Emergency Reserve manifold. System to come in line via a non - return valve. Number of cylinders based on 4 hours of system operation.
- Reserve Supply – Automatic Cylinder or Manual Emergency Reserve manifold supplying the system via a non-interchangeable screw threads connecter.

OR

- Local gas cylinder bottles or cylinders within departments with flow regulators.
- Important Note: For Carbon Dioxide Gas or Carbon Dioxide Mixture Gas, depending on the number of beds as well as the type of facility, gas bottles shall be provided local to the departments as per Part B requirements. But for larger facilities they shall follow the cylinder manifold arrangement as mentioned above (Primary, Secondary and Reserve Supply).

Vacuum Insulated Evaporator System (VIE)

- Simplex Unit Set-Up:
 - Primary Supply – A Simplex VIE Vessel System.
 - Secondary Supply – Automatic Cylinder Manifold System. Activated when Primary Supply fails or there is a shortage of primary supply.
 - Reserve Supply – Automatic Cylinder Manifold System. Activated when Primary Supply fails or there is a shortage of primary supply. This type of manifold system may only be located near Grade A areas.

OR

- Automatic Cylinder or Manual Emergency Reserve manifold supplying the system via a non-interchangeable screw threads connecter.
- Please Note: Medical vacuum is provided by means of a central vacuum plant. The vacuum system should always be used in conjunction with vacuum control units that include vacuum jars. In the event of inadvertent contamination of the pipeline systems resulting from vacuum jars overflowing, immediate action is required to clean the system before any fluids etc. dry out.
- Duplex Unit Set-Up:
 - Primary Supply – One Vessel of a Duplex VIE Vessel on plinth.

- Secondary Supply – Second Vessel of a duplex VIE System on the same plinth as Primary Supply.
- Reserve Supply – Automatic Cylinder Manifold System. Activated when Primary Supply fails or there is a shortage of primary supply. Reserve to be used to serve the entire healthcare facility.
- Separate VIE Vessel Set-Up:
 - Primary Supply – One Vessel of a Duplex VIE Vessel on plinth.
 - Secondary Supply – Second Vessel of a duplex VIE System on a separate plinth as Primary Supply. Location of supply is carried out through a risk assessment as it determines that there is a risk of the primary supply in that location being a failure and therefore the secondary supply needs to be located in a different location. Secondary supply to be installed with a non-return or double check valve to prevent gas loss in the event of one vessel leak or failure.
 - Reserve Supply – This type of supply will depend on the risk assessment carried out by the design consultant. The conclusion may be an Automatic Cylinder Manifold System, a manual Cylinder Manifold system etc. The risk assessment may also determine that a reserve supply is not required as there is a dual supply or ring main approach has been provided by the secondary supply system.

Important Note: For all compressor systems with a design flow greater than 500 L/min, two receivers, each able to be isolated individually.

Gas Scavenging System (AGSS)

For operating theatres and other critical clinical spaces (Grade A), the number of AGSS plant depends on the number of Air Handling Units to those areas. For example, for each operating theatre having its own dedicated Air Handling Unit then a Simplex AGSS plant is to be provided for each operating theatre. The reserve provision shall be a Simplex AGSS unit that can serve up to 6 No. Areas. If there are 12 areas then 2 No. simplex units shall be spare if all 12 areas are being served by 12 No. Simplex AGSS Units.

- Simplex Unit Set-Up:
 - Primary Exhaust – Simplex Pump Unit.
 - Reserve Exhaust – Simplex Pump Unit in Manual Change Over.
 - Important Note: For operating theatres and other critical clinical spaces (Grade A), where more than two areas are being served by a single Air Handling Unit, then a Duplex AGSS plant is to be provided with an automatic change over to the spare pump.
- Duplex Unit Set-Up:
 - Primary Exhaust – Duplex Pump System (one Pump).
 - Reserve Exhaust – Second Pump from Duplex AGSS Unit.

Basic Sizing of Medical Gas Cylinder Sources

- The sizing of the cylinders and major systems such as VIE system, will need to be carried out via risk assessment based on the following parameters:
 - Healthcare operating Hours
 - Distance from Supplier
 - Traffic Data
 - Supplier operating Hours
 - Supplier Response time in Peak working hours of the day
 - Supplier Response time in slow night operating hours.
 - Cylinder Delivery and Restocking History (if Known)
- The objective of the risk assessment is to ensure that the risk to patient safety is eliminated or reduced to as low as possible as well as ensure that hospital operation is undisturbed.
- Cylinder manifold and storage capacities should be determined in line with NFPA 99, Chapter

5 (Gas and Vacuum Systems) requirements.

Number of Medical Gas Outlets and Locations

- As per the part B of these guidelines, the number of medical gas outlets as well as the type of medical gas service to FPU's shall be provided via the use of Room Layout Sheets (RLS) and Room Data Sheets (RDS).
- International guidelines can also be used for briefing based on project team's decision, which then have to be implemented in project specific RDS and RLS.

AVSU and LVA

- Area Valve Service Units (AVSU's) and Medical Gas Zone Valves (LVA) are the main isolation valve terminal units used to isolate the medical gas services serving the clinical departments.
- The AVSU's & LVA must be located by a nurse station that is continuously occupied during the healthcare facility operating hours.
- The panel is to be a combined panel with valves as well as alarm panel. This is not a separate alarm panel in one location and service isolation valve in another.
- The installation height requirements of the panel for healthcare facilities, shall be around 1000-1500mm. This height is based on the comfortable average heights for nurses.
- The installation height of the panel ensures that the healthcare operational staff can operate the panel if needed (alarm mute, valve isolation in emergencies).
- The panel needs to be provided with access requirements to operate the valves if need be.
- Access to the panel must be provided via a dedicated key or a break glass hammer. These shall only be provided for hospital operational staff (Nurses, Doctors and Maintenance staff).
- The minimum height for AVSU installation shall be 1m for dual circuits.
- Dual circuits shall only be arranged (in two columns) if the height from the top to bottom of the unit exceeds 1m.
- To avoid using an excessive number of Panels, this can be increased to 1.2m.
- The panels located on a wall will need to ensure that there is a minimum clearance of 100mm behind the unit for Medical Gas pipework (175mm for back to back pipes serving the AVSU's).
- The panels are to be labelled with permanent naming templates and not adhesive labels.
- A key is to be provided at the fire command center for Civil Defense Access.

Medical Gas Plant Rooms

- Table 7.2 below provides a safety distance compliance for location of Bulk Liquid Oxygen Tank from buildings, vehicles etc. (based on the volume of gas liquid stored).

Safety Distances from Exposure to Vessel/Point Where Oxygen Leakage or Spillage Can May Occur	Up to 20 tons (Distance in m)	Over 20 tons (Distance in m)
Areas where open flames / smoking are permitted	5	8
Places of Public Assembly	10	15
Offices, Canteens, and areas of Occupancy	5	8
Pits, Ducts, surface water drains (un-trapped)	5	8
Openings to underground systems	5	8
Building Footprint	5	8
Public Roads	5	8
Railways	10	15
Vehicle Parking Areas (other than authorized)	5	8
Large Wooden Structures	15	15
Small Stocks of combustible materials, site huts etc.	5	8

Safety Distances from Exposure to Vessel/Point Where Oxygen Leakage or Spillage Can May Occur	Up to 20 tons (Distance in m)	Over 20 tons (Distance in m)
Process Equipment (not part of installation)	5	8
Continuous Sections of Flammable Gas Pipelines	3	3
Flanges in Flammable Gas Pipelines (Over 50mm)	15	15
Fuel Gas Vent Pipes	5	8
Compressor / Ventilator Air Intakes	5	8
Fuel Gas Cylinders (up to 70m ³)	5	5
LPG Storage Vessels (up to 4 tons)	7.5	7.5
LPG Storage Vessels (up to 60 tons)	15	15
Bulk Flammable Liquid Storage Vessels (up to 7.8m ³)	7.5	7.5
Bulk Flammable Liquid Storage Vessels (up to 117m ³)	15	15
MV or HV Electrical Sub-Station	5	8

Table 7.2 – Safety Distance Compliance for Medical Gas Plants

- The Medical Gas Cylinder plant room must be located on the ground floor of any healthcare facility.
- The Medical Gas Compressor and Vacuum may be located in the basement of a facility as long as that area is ventilated but is highly recommended for the plant room to be located on the ground floor for maintenance.
- In hot climates, the Medical gas plant rooms (including the cylinder rooms) need to be air-conditioned to provide an air temperature of less than 40°C.
- Medical Gas Cylinder Store Rooms should be well ventilated and that cylinders of this gases (especially Mixture gases) are kept above 10°C for 24 hours before use, and arrangements should be in place to ensure that cylinders collected from a cold store are not used immediately for patient treatment.
- Medical Gas Cylinders should not be subjected to extremes temperature. Cylinders should be kept away from sources of heat (this includes hot water service pipes, steam pipes, hot air emitters and direct sun exposure).
- No other chemicals, flammable material, or rubbish to be stored within the medical gas plant room.

Medical Gas Plant Rooms – For Hyperbaric Chambers

- Special Gas cylinder room should be provided for the hyperbaric chambers
- Gas cylinder room should be large enough able to store enough (H) cylinders and manifolds for the reserve breathing gases required for chamber operations. Cylinders quantity should be decided by the vendor. Liquid O2 tank with vaporizer is also permitted as source of oxygen. If central gas / compressed air is available, it can be utilized provided it complies with NFPA 99 Chapter 14 requirements.
- Have explosion proof electrical fittings.
- Have an automatic gas manifold monitored by alarm. Maintain an alarm that monitors the high and low gas pressure.
- Provide a door to the room with door vents for O2 to pass in case of leakage from cylinders
- Provide access for a truck to refill the O2 in case the facility uses liquid O2 for the treatment.

8 Public Health - Fuel Systems Design (FS)

This PH-FS design guideline written for healthcare facilities, is a consolidated document listing out the design requirements for all new construction and major renovation healthcare projects.

The requirements outlined in these guidelines are not intended to conflict with Federal Regulations, Local Municipality Laws, Executive Orders, or the needs of the end users.

This document is intended for the Architect/Engineer (A/E) and others engaged in the design and renovation of health facilities. Where direction described in applicable codes are in conflict, the A/E shall comply with the more stringent requirement. The A/E is required to make themselves aware of all applicable codes.

The document should be read in conjunction with other parts of the Health Facility Guidelines (Part A to Part F) & the typical room data sheets and typical room layout sheets.

General

The aim of the fuel system guidelines is to promote the correct provision of Fuel Systems for healthcare facilities. The design will be based on the requirements, but there will be parts of the design that will be tailored for healthcare facilities.

Design Criteria

- The design will discuss which systems in healthcare facilities requires Fuel and they are the following:
 - Hot Catering Kitchens
 - Hot Catering Commercial Kiosks
 - Electrical Generators
 - Hot Water Generators
 - Fuel Run Fire-Fighting Pumps
- These design guidelines are to be used in new healthcare facilities as well as facilities that will refurbished.
- The fire and life safety requirements for installing these systems must be as per Civil Defense requirements. The design guidelines will not change this strategy in any form.
- When designing the fuel requirements for healthcare facilities, a risk assessment needs to be carried out to understand the requirements of the facility.
- Requirements such as distance from supplier of medical (if applicable), the geopolitical understanding, traffic, workdays, peak times, particular times of year where workload is affected (Public Holidays etc.) as well as patient safety.

The objective of the risk assessment is to ensure that the risk to patient safety eliminated or reduced to as low

9 Public Health - Pneumatic Tube System Design (PTS)

This PH-PTS design guideline written for healthcare facilities, is a consolidated document listing out the design requirements for all new construction and major renovation healthcare projects.

The PTS must not jeopardize the continued operation of a healthcare facility and incur any huge capital costs due to equipment replacement.

The requirements outlined in these guidelines are not intended to conflict with Federal Regulations, Local Municipality Laws, Executive Orders, or the needs of the end users.

This document is intended for the Architect/Engineer (A/E) and others engaged in the design and renovation of health facilities. Where direction described in applicable codes are in conflict, the A/E shall comply with the more stringent requirement. The A/E is required to make themselves aware of all applicable codes.

The document should be read in conjunction with other parts of the Health Facility Guidelines (Part A to Part F) & the typical room data sheets and typical room layout sheets.

General

- Pneumatic Tube Systems (PTS) are internal logistics and transport solutions used to transport small items or documents, placed in a container or carrier, from one point to another, through an air pressurized network of tubes.
- In healthcare facilities, Pneumatic Tube Systems (PTS) transport small materials, documents, laboratory samples etc. to and from pharmacies, laboratories, blood banks, surgery centres, emergency departments and nursing stations, as well as other locations throughout healthcare facilities.
- The PTS can be constructed as a single-zone-system or as a multi-zone-system. The major components of such a system include the blower, tubes, stations, diverters, carriers, and the central control unit that forms the command centre of such a system. Figure 9.1 shows a single zone operation with 4 stations (two stations on the Ground Floor, two stations on the First Floor and the blower and diverter in the basement area).
- Each healthcare facility PTS is designed for its respective facility. Figure 9.1 below shows an example of PTS.

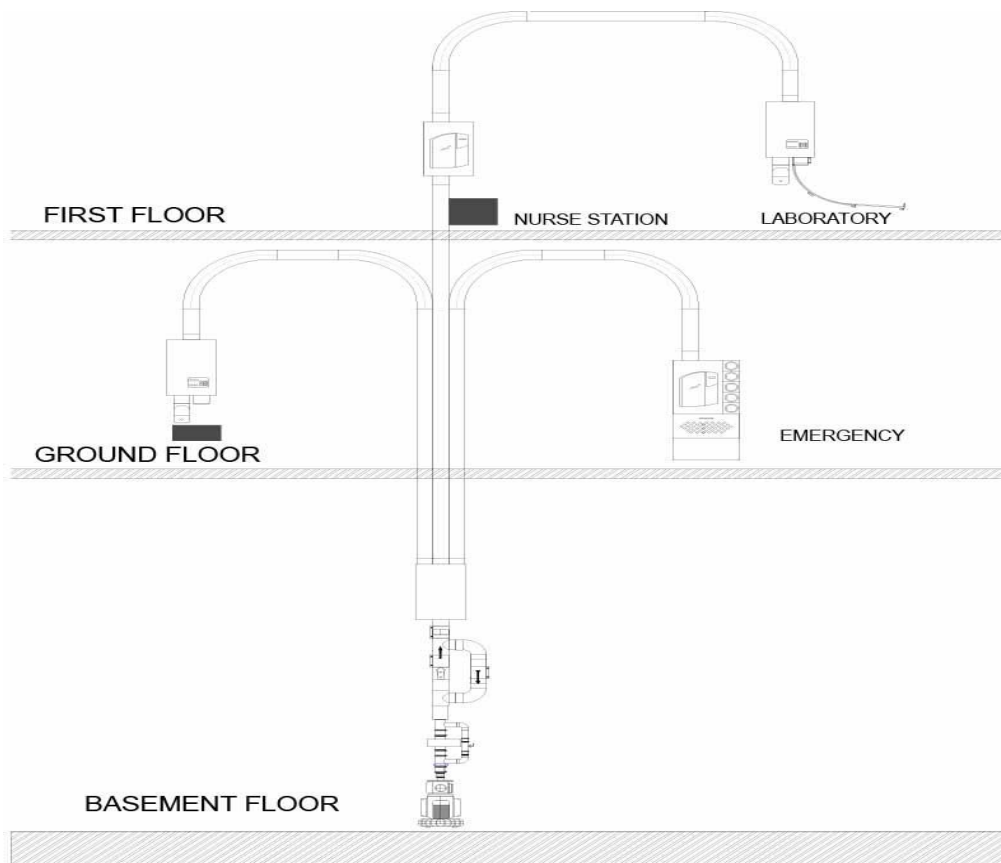


Figure 9.1 – Typical Pneumatic Tube System Layout – Single Zone System

- Multi-zone systems, as seen in Fig. 9.2, are connected together by a transfer system. Each zone has its independent air supply (blower) so transmission can take place at the same time. Dividing a system into multi-zones increases the number of carriers that can be transported as each zone can operate independently. Productivity is improved, efficiency is increased while NPA (non-productive activities) and staffing requirements are decreased.

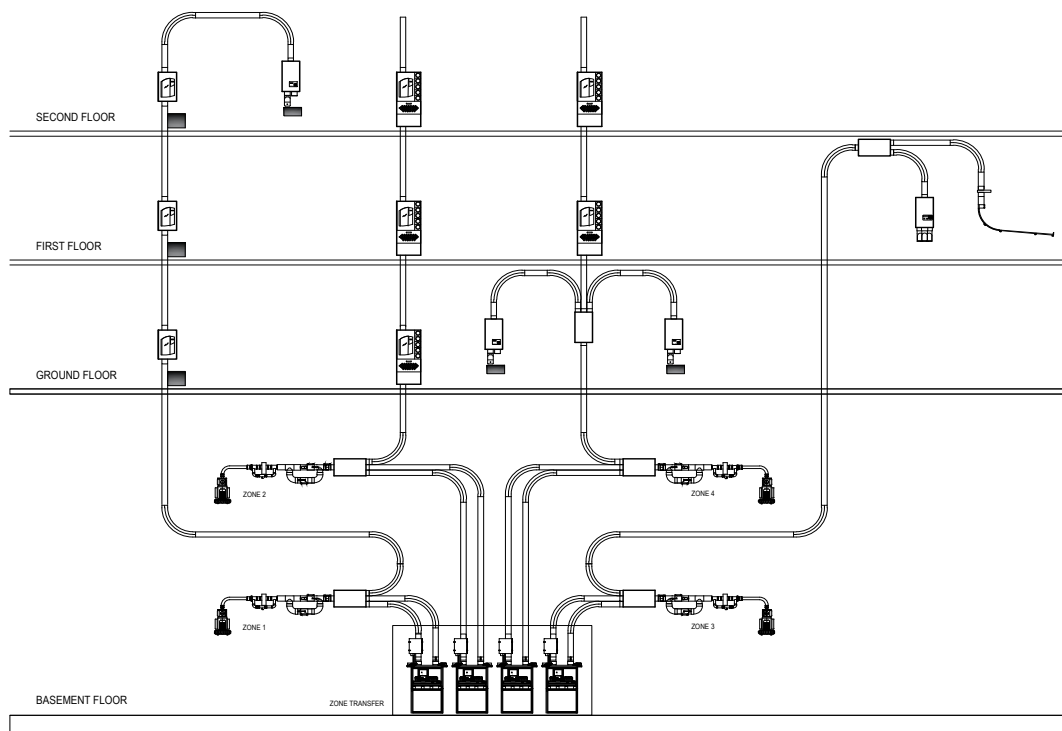


Figure 9.2 – Typical Pneumatic Tube System Layout – Multi-Zone System

Design Criteria

- The PTS shall be provided in accordance with the requirements of NFPA 99 (Health Care Facilities Code), the manufacturer's recommendations, and the healthcare facility's planning brief as defined in Part B of these guidelines .
- The contents of the items within the PTS delivery casing transports material between different sending and receiving modules called PTS Stations.
- The locations of these stations are determined by the health planner and briefing requirements as mentioned in Part B of these guidelines.
- The briefing will also state the details of the station operation i.e. the station is sending or receiving or both or a multiple sending and receiving station.
- The PTS carrier, carries the following critical specimens through the system between departments:
 - Blood Specimens for Chemistry and Hematology
 - Arterial Blood for Blood Gas Analysis
 - Urine Specimens for routine analysis and culture
 - Cerebral Spinal Fluid
 - Tissues for Biopsy and other Body Fluids
- By simply placing the carrier in the station, the user can send it to a predetermined destination. Some key features are:
 - A carrier can be stored at a station of a single-zone-system, independent of the stage of operation.
 - After a carrier is inserted into the station, it will be transported directly to its destination.
 - After one sending process, the system can automatically start the next.
- Speed simulation study with expert/manufacturer software to be made part of the construction plan to assess the delivery time to respective stations.

Pneumatic Tube System Components

- The system consists of many components that make the system as well as allow the system to be designed and operated correctly. The system components are the following:
 - Blower & Air Reverse Valve –The Blower (PTS compressor system) generates the air that moves the PTS carriers throughout the healthcare facility via pressure or vacuum suction. The location of the blower will be in the healthcare facility plant room as per coordination with the healthcare operator and health planning briefing. As soon as all pending processes are finished, the blower disconnects automatically
 - Recommendation: Blowers should come fitted as standard with energy efficient IE2/NEMA motors (acc. to destination country) conformant to the IEC 60034-30 standard. Blowers to be installed in the plant room along with the system control unit and inter zone/linear coupler if applicable.
- Blower Group – This a group of PTS blowers that are interconnected that include sending and receiving drivers allowing any single blower to handle the carrier delivery from sending and receiving as well as vice versa. These are usually installed in large healthcare facilities such as a tier 4-6 delineation healthcare level.
- Carrier – A PTS Reusable plastic container that hold and protect contents (lab specimens, pharmaceuticals, blood products, etc.) sent through a pneumatic tube system. The carriers come in different sizes to cater for the function or requirement of the facility. The carriers used in healthcare facilities include:
 - Standard carriers: for medications or solid particles and small instruments
 - Leak-proof carriers: for the transport of liquids or sensitive samples used in the PTS
 - Special carriers: these designed and developed for very specific uses such as carriers lined with lead or cooling carriers

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- All carriers are equipped with an RFID sensor for easy distribution of carriers to departments by programming 'Home' station and 'Destination', which will automatically be guided by the scanner mode or dialled destination. The carrier's movement can be tracked.
- Control Centre – The PTS software that controls the communication between the stations, devices, and user requirements. This also locates the current location of the carrier via a user interface.
- Database – A repository of information for each of the PTS carrier movements including a date and time as well as station operability.
- Interzone Connection – A section of tubing that connects one zone to another zone.
- Station – The user interface unit that may include an interactive touch screen system, a mechanical dialling system and or an RFID scanner, for the sending or receiving of the carrier.
- Diverter – A PTS route switching device used at branching points within a tube network to allow a carrier to move from one path to another. In many healthcare facilities, this is usually located within riser shafts or above the ceilings.
- Tubing – Tubing or system piping is generally provided for 110mm or 160mm. The tubes are available in PVC (Grey), PVC (Transparent), GI and Stainless Steel, depending on the environmental conditions of the site. Healthcare operators may request a pipe greater than 160mm to be provided for bulk pharmacy items or multiple samples or documents being carried from one location to another.
- Zone – A collection of stations with direct tubing connections. Zones are interconnected with inter zone connections. A traditional zone includes approximately 10 stations, while a Blower Group Zone can support up to approximately 60 stations.
- Slow Speed Device – This device used especially in hospitals where certain sensitive goods such as laboratory tests and blood samples require transport with a reduced speed.

Pneumatic Tube System Pipe Material

- Typically for Existing and New building piping material used for PTS is as under;
 - PVC (160mm Diameter Piping)

10 Fire Protection (FP) – Special Areas Design

This FP design guideline written for healthcare facilities, is a consolidated document listing out the design requirements for all new construction and major renovation healthcare projects.

For FP Systems, the protection of the healthcare facilities and its occupancies are of prime importance when discussing fire and life safety. But more so in healthcare facilities, the continued operation is also as important.

The FP must not jeopardize the continued operation of a healthcare facility and incur any huge capital costs due to equipment replacement.

The impact of FP strategy on major imaging equipment in healthcare facility is very huge if not assessed correctly.

The requirements outlined in these guidelines are not intended to conflict with Federal Regulations, Local Municipality Laws, Executive Orders, or the needs of the end users.

This document is intended for the Architect/Engineer (A/E) and others engaged in the design and renovation of health facilities. Where direction described in applicable codes are in conflict, the A/E shall comply with the more stringent requirement. The A/E is required to make themselves aware of all applicable codes.

The document should be read in conjunction with other parts of the Health Facility Guidelines (Part A to Part F) & the typical room data sheets and typical room layout sheets.

General

- The aim of this section of the guidelines is to promote the correct design of fire-fighting systems for healthcare facilities for the following areas:
 - Burn Units
 - Imaging Department
 - Operating Theatres
 - Endoscopy Procedure Rooms
 - Day Surgery Rooms
 - Dental Procedure Rooms
- The systems below are the systems that are to be used in healthcare facilities, but not only limited to these systems.
- As per NFPA Code (depending on the complexity/level of the healthcare facility departmental functions), the following fire protection system shall be used (but not limited to):
 - Sprinkler System (Active & Dry)
 - Standpipe System
 - Hose Reels System
 - Clean Agent System
 - Deluge System
 - Foam System
- Healthcare facilities rely heavily on a continued operation of the facility and its equipment post controlled fire extinguishing scenarios. Therefore, the correct fire protection system should be used with this objective in mind.

Design Criteria

- The design, installation and commissioning of the fire-fighting protection system shall be as per NFPA or local AHJ requirements. Wherever there is a conflict between international and local codes, the local codes shall take precedence.

Sprinkler Systems

- As per FF strategy, all areas within a facility need to be fire protected.

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- Certain areas will require certain fire extinguishing systems that will work best for safety of inhabitants and the hospital operator costing concerns.
- Rooms with huge capital cost equipment, such as medical imaging units, Bunker areas etc., should not be provided with a wet pipe sprinkler system for fire protection. Gas suppression system should be used in these areas or pre-action system.
- Both pre-action and Gas suppression can be provided in the same room, with the gas suppression system extinguishing first completely before the pre-action system starts its extinguishing process (if the fire is still active)

Pre-Action Systems

- In healthcare facilities, pre-action sprinkler systems are used for areas that a fire scenario event will be very disruptive to the operation of the healthcare facility. In cases disruption to these areas via an automatic sprinkler system may be hazardous or in some cases life threatening.
- The system is usually installed in the following areas in healthcare facilities:
 - Operating Theatres
 - Endoscopy Procedure Rooms
 - Day Surgery Rooms
 - Dental Procedure Rooms
 - Burn Units
 - Imaging Rooms
- Pre-action systems should be a double interlocking system. This means that the system will have both a preceding and supervised event such as heat or smoke detectors as well as an automatic sprinkler activation. Figure 10.1 below shows a pre-action valve arrangement with an addressable panel. Generally, these types of systems operate faster and reduce fire and damage compared to the standard automatic sprinkler systems.

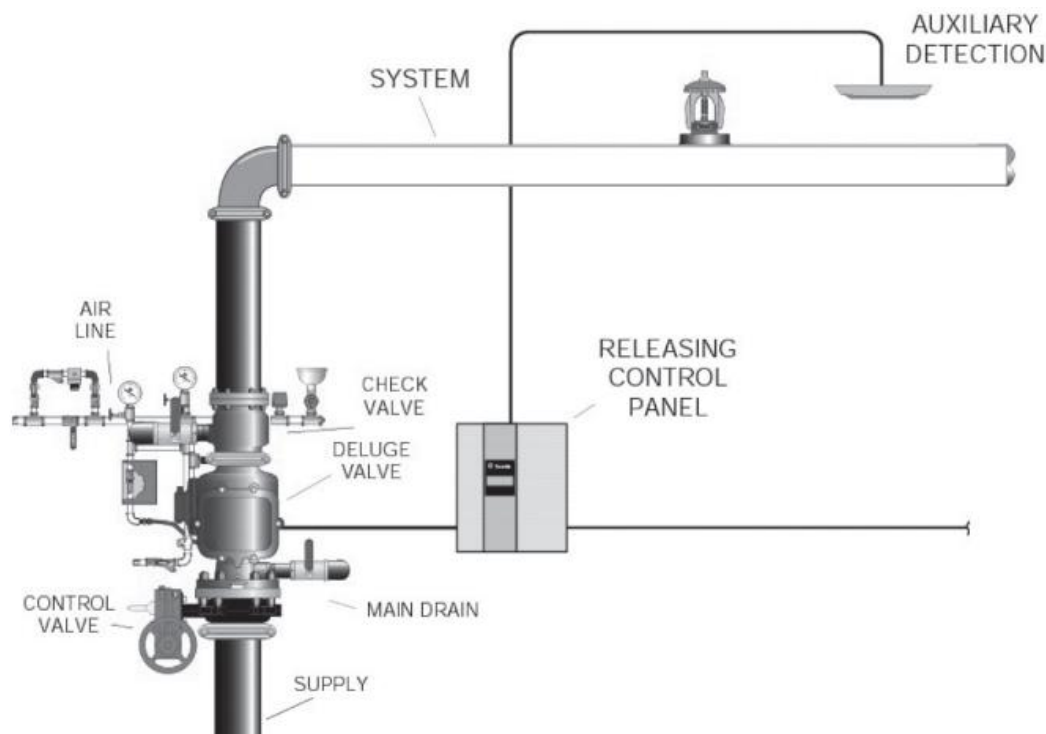


Figure 10.1 – Pre-Action Valve Setup

- In operating theatres, audio alarms and strobe lighting shall be removed and replaced with light indication alarm fitting (non-audible) as part of the surgical panel

Clean Agent System

- Clean agent systems are designed to be chemical inhibitors that react with the transient products of combustion. They are made to eliminate the chain reaction of combustible elements by reducing the oxygen content in a room, attacking one of the elements of the fire triangle. Oxygen levels are reduced below the point of a reaction for combustion to be maintained. This is done with use of an inert gases.
- Inert gases have a low level of toxicity and in the healthcare facilities they are used for fire-fighting services in patient and healthcare operator staff occupied major medical equipment rooms. Therefore, it is important to ensure that the inert gas concentration does not exceed the limits of No Observed Adverse Effect Level (NOAL) as per the limits set out in NFPA-2001, which is 43%.
- As per NFPA 2001, the maximum exposure limit should only be 5 minutes. Any personnel in the area where clean agent system is to be used will be required to evacuate in the count down time between the fire and the release of the clean agent.
- A clean agent system does allow for an emergency push button cancellation in case of a false alarm or if the fire within the space has been contained.
- The system can also be designed for time delay to give patients, staff, and visitors to evacuate the area prior to the system being extinguished.
- In healthcare facilities the following rooms will require a clean agent system.
 - Server Room
 - UPS Room
 - CT Scan Room
 - CT Scan Room
 - CT Scan Equip Room
 - MRI Equipment Room
 - Chemo-Emboli Station Room
 - Computer Equip Room
 - SPECT Scanning Room
 - PET Scanning Room
 - Computer Equipment Room
 - Main Electrical Room
 - MRI-LINAC
 - Medical Records
 - Burns Unit (If water will cause more damage to the patient)
- Burn Unit patients are at risk of infection if water is discharged from sprinkler system while they are in the space (not all patients, critical patients only)
- Clean agent cylinders should not be located in the same room, where clean agent ceiling nozzles will be discharged. If the cylinders are to be located in the same room, they shall be in a fire rated enclosure.
- A clean agent system can be used with a pre-action sprinkler system.

Deluge Water Systems

- In healthcare facilities, deluge systems are used on external liquid oxygen and LPG storage systems. The pipes are installed to surround the storage vessel containing hazardous flammable liquids.
- Deluge systems sprinkler systems provide high flow and high volume of discharge over the hazardous area in a fire scenario in the quickest time possible.

Foam System

- In healthcare facilities foam fire extinguishing systems are used for special hazard areas. They should not be used for medical gas plant/systems or electrical rooms.
- Foam, mostly a mass of air- or gas-filled bubbles formed by chemical or mechanical means, is most useful in controlling fires involving flammable liquids with a low flash point and specific gravity that are lighter than water. The mass of bubbles forms a cohesive blanket that extinguishes the fire by excluding air and cooling the surface and by separating the fuel from the fire. This strategy is used for Oil fueled Generators.

Spray Fog/Mist System

- For Multi person Hyperbaric Chambers where there is a risk for fast spread of the fire, due to higher partial oxygen pressure in the chamber atmosphere and other associated risks to patients its recommended to utilize a spray fog system.
- The system allows for effective firefighting control with a low water consumption and workability at a higher pressure of the chamber. The size of the water tank should be ideally selected by the chamber supplier corresponding to the chamber size. The room should be served by standard sprinklers.

11 Vertical Transportation System

General

Healthcare facilities are greatly depended on lifts to provide a reliable and efficient vertical transport system for the movement of patients, staff, visitors, medical equipment, and associated support services. They are also dependent on lifts to provide firefighting and evacuation facilities.

All lifts shall meet the statutory regulations from Municipality and Civil Defense authorities.

Lift Categories

The lifts in healthcare buildings shall be categorized and provisioned based on the function as below:

- General Passenger Lifts
 - These lifts supporting general passenger traffic including wheelchair users. The clear internal dimension of a general passenger lift serving clinical areas should not be less than 2000mm wide by 1700mm deep with a minimum loading capacity of 1250kg with a minimum clear door opening width of 1100mm and clear height of 2100mm. This is to enable proper circulation space for patients on wheelchair and accompanying persons. The lifts intended for housekeeping services may be part of a group of general passenger lifts. However, housekeeping activities should be scheduled not to coincide with general peak passenger demands. As far as practically possible, care should be taken so that public passenger lifts are separated from the Bed, Service and Goods lifts with access to separate lifts lobbies.
- Bed Lifts
 - These lifts are intended for the carrying of a patient on patient beds or stretchers together with the necessary staff and support equipment. The bed lifts should have a minimum rated load capacity of 2500 kg, with a minimum clear car dimension of 1800mm wide by 2700 mm deep. Clear door-opening width must be no less than 1400mm and 2200mm high. Lift car internal height should not be less than 2500mm.
- Service/Goods Lift/s
 - These lifts are intended for the movement of items such as furniture, equipment, building materials, equipment maintenance supplies, waste etc. The service/goods lifts should have a minimum rated load capacity of 2500 kg, with a minimum clear car dimension of 1600mm wide by 2200 mm deep. Clear door-opening width must be not be less than 1200mm and 2200mm high. Lift car internal height should not be less than 2500 mm. For smaller healthcare facilities (less than 50 beds) smaller sized goods lifts may be considered based on proper due diligence. However, in facilities where heavier equipment is anticipated to be transported, larger goods/service lift with wider door opening size to be provided.

Design Considerations

Below is key recommendations and requirements to be adhered with while designing vertical transportation solution for healthcare facilities.

- Selecting the appropriate lift operational speed and drive system is important in order to optimize the operation, comfort, and efficiency of the system.
- Lifts to be located away from sensitive areas in consideration of vibration and acoustics, and with respect to magnetic distortion for MRIs.
- Depending upon the nature of the facility firefighting lift/s to be provided where called for as per Civil Defense requirements.
- In large facilities with numerous lifts, Passenger Lifts may be categorized based on different usage such as VIP Lifts, OPD Lifts and Visitor's Lift etc., Such designation, however, is not mandatory.
- It is recommended that as far as possible the Bed Lifts and Service Lifts to be identical in design and specifications. This will give the operator maximum flexibility allocate the lift types for different use as the need arises and the operation of the facility changes over time.

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- The Service Lifts need to be categorized for different types of use. As a minimum there should be two groups, Dirty Lifts and Clean Lift.

Dirty Lifts may be used for: Transport waste bins, Dirty Linen, Diseased patients, Infected Patients, Dirty SSU goods, Returned food trolleys and similar goods as well as staff.

Clean Lifts may be used for: Transportation of items from the central stores, clean food trolleys, Clean SSU goods, medication and occasionally a patient bed (when the bed lift is under maintenance) and staff.

- In large facilities, with numerous lifts, the operator should consider designating specific tasks to the service lifts such as: Food Safe Lift, Waste Lift, Clean Goods, Etc. Apart from Clean/Dirty, the above subdivisions are not mandatory.
- Firefighting lift can also be used for regular passenger/patient use during normal operation of the healthcare facility. However, it is recommended that the designated firefighters lift is not used for moving waste, goods, equipment etc. in order to prevent the risk of the lift being occupied or its entrance being obstructed when the lift is required for firefighting.
- In healthcare buildings, choosing the appropriate number, capacity and operational speed and drive system is important in order to minimize any adverse effects, particularly on patients and care providers. The criteria to consider while determining the vertical transportation solution include but not limited to:
 - Anticipated number of patients
 - Anticipated number of staff
 - Operation and visiting hours
 - Nature of the departments
 - Location of Imaging equipment such as MRI's
 - Food deliveries
 - Waste disposal
 - Emergency evacuation
 - Clinical workflows
 - Configuration of the building
- Because a healthcare environment has a higher percentage of sick and vulnerable people, special consideration needs to be given during the traffic analysis.
- The selection of an appropriate speed is dependent on building height. Table below indicates suggested values. However, speed has very little effect on the handling capacity of lifts in healthcare facilities due to the longer loading and unloading times; therefore, rated speeds could be lower than would normally be required in office buildings. The average interval of the lift (the time between successive lift arrivals at the main entrance floor) can be longer than that is recommended for office building. Interval time of 30s to 50s is generally acceptable for healthcare buildings.

Travel Height (m)	Rated Speed (m/s)
18	0.63
30	1.0
48	1.6
75	2.5
100	3.5
120	4.0
150	5.0

- Centre opening doors provide better traffic performance as compared to side opening doors; in consideration of this, only center opening doors shall be provided for lifts serving patient and clinical staff. Side opening lifts may be acceptable for goods lifts not intended for clinical staff or patients. The center opening doors shall be in two leaves or four leaves configuration to

suite the available lift shaft.

- In order to reduce the stress imposed on vulnerable patients the acceleration of the lift cars used to serve surgical and clinical areas shall not exceed 0.6 m/s², while rate of change of acceleration or deceleration shall not exceed 1.0m/s³.
- During vertical transportation traffic analysis for healthcare buildings, lift car occupancy to be considered lower than the normal 80% of rated capacity used in commercial building traffic calculations to account for the space requirement for wheel chair, stretchers, equipment etc.; 25% of the rated capacity will be more appropriate for healthcare buildings.
- Diffused soothing illumination of 100 Lux to be provided in lift cars at floor level. The car should not be widely over lit or under lit due to patient safety and comfort considerations.
- Emergency lighting to be provided in lift cars as part the lift car design with 3hr local battery back up to provide a minimum illumination of 10 Lux.
- Lift shafts generally penetrate all floors of a healthcare building and therefore pose a risk for the transmission of infection across the floors. To reduce this risk, lift shaft wall and ceiling should be sealed and painted.
- Lift car doors should be fitted with contact free passenger/obstruction detection to minimize the risk of car/landing door collisions with persons, beds, or equipment, working in conjunction with the automatic door operator.
- Lift cars and all landing shall indicate the floor number and direction of travel of the lift car.
- When function of the lifts physically located as a group are similar, such cars shall be grouped and controlled in “collective” method, while the function of each lift in the group are different (such as dirty, clean, staff etc.) the cars may have to be controlled individually (simplex).
- Depending upon operational workflows and security strategy, electronic card access systems to be implemented, along with emergency bed services function. Emergency bed services facilitate priority lift car call option for patients in critical care and associated staff.
- At least one elevator in a bank of lifts to be fed from the emergency (secondary) branch of power distribution.

Power supply for lifts to be sourced directly (grouped or individually) from the main distribution board (MDB) of the healthcare building.

12 Annexures

A-1 Ventilation Rate

Standards For Pressurization Of Spaces

Design Parameters—Inpatient Spaces

Function of Space (ee)	Pressure Relationship Adjacent to Areas (n)	Minium Outdoor ach	Minimum Total ach	All Room Air Exhausted Directly to Outdoors (j)	Air Recirculated by Means of Room Units (a)	Unoccupied Turndown	Minimum Filter Efficiencies (cc)	Design Relative Humidity (k), %	Design Temperature (l), °F/°C
Nursing Units And Oth & Er Patient Care Areas									
All anteroom (FGI 2.1-2.4.2.3) (u)	(e)	NR	10	Yes	No	Yes	MERV-8	NR	NR
All room (FGI 2.1-2.4.2) (u)	Negative	2	12	Yes	No	Yes	MERV-14	Max 60	70-75/21-24
Cesarean Delivery room (FGI 2.2-2.9.11.1) (m), (o)	Positive	4	20	NR	No	Yes	MERV-16	20-60	68-75/20-24
Combination All/PE anteroom (FGI 2.2-2.2.4.5)	(e)	NR	10	Yes	No	No	HEPA	NR	NR
Combination All/PE room (FGI 2.2-2.2.4.5)	Positive	2	12	Yes	No	No	HEPA	Max 60	70-75/21-24
Continued care nursery (FGI 2.2-2.10.3.2)	N/R	2	6	N/R	No	Yes	MERV-14	30-60	72-78/22-26
Critical care patient care station (FGI 2.2-2.6.2)	NR	2	6	NR	No	Yes	MERV-14	30-60	70-75/21-24
Emergency department exam/treatment room (FGI 2.2-3.1.2.6 & 2.2-3.1.3.6) (p)	NR	2	6	NR	NR	Yes (ff)	MERV-14	Max 60	70-75/21-24
Emergency department human decontamination (FGI 2.2-3.1.3.6(8))	Negative	2	12	Yes	No	Yes (ff)	MERV-14	NR	NR
Emergency department public waiting area (FGI 2.2-3.1.2.4 & 2.2-3.1.3.4)	Negative	2	12	Yes (q)	NR	Yes (ff)	MERV-8	Max 65	70-75/21-24
Emergency department trauma/resuscitation room (FGI 2.2-3.1.3.6(4)) (c)	Positive	3	15	NR	No	Yes	MERV-14	20-60	70-75/21-24
Emergency service triage area (FGI 2.2-3.1.3.3)	Negative	2	12	Yes (q)	NR	Yes (ff)	MERV-8	Max 60	70-75/21-24
Intermediate care patient room (FGI 2.2-2.5) (s)	NR	2	6	NR	NR	Yes	MERV-14	Max 60	70-75/21-24
Labor/delivery/recovery (LDR) (FGI 2.2-2.9.3) (s)	NR	2	6	NR	NR	Yes	MERV-14	Max 60	70-75/21-24
Labor/delivery/recovery/postpartum (LDRP) (FGI 2.2-2.9.3) (s)	NR	2	6	NR	NR	Yes	MERV-14	Max 60	70-75/21-24
Laser eye room (FGI Table T2.2-1)	Positive	3	15	NR	No	Yes	MERV-14	20-60	70-75/21-24
Neonatal intensive care (FGI 2.2-2.8)	Positive	2	6	NR	No	Yes	MERV-14	30-60	72-78/22-26
Newborn nursery (FGI 2.2-2.10.3.1)	NR	2	6	NR	No	Yes	MERV-14	30-60	72-78/22-26
Nourishment area or room (FGI 2.1-2.8.9)	NR	NR	2	NR	NR	Yes	MERV-8	NR	NR
Nursery workroom (FGI 2.2-2.10.8.5)	NR	2	6	NR	No	Yes	MERV-8	Max 60	72-78/22-26
Operating room (FGI 2.2-3.3.3) (m), (o)	Positive	4	20	NR	No	Yes	MERV-16 (hh)	20-60	68-75/20-24
Operating/surgical cystoscopic rooms (FGI 2.2-3.4 & Table T2.2-2; also see Class 3 Imaging) (m), (o)	Positive	4	20	NR	No	Yes	MERV-16	20-60	68-75/20-24
Patient care area corridor	NR	NR	2	NR	NR	Yes	MERV-14	NR	NR
Patient room (FGI 2.1-2.3.2)	NR	2	4 (y)	NR	NR	Yes	MERV-14	Max 60	70-75/21-24
Patient toilet room (FGI 2.1-2.3.5 & 2.1-2.3.6)	Negative	NR	10	Yes	No	Yes (ff)	MERV-8	NR	NR
PE anteroom (FGI 2.2-2.2.4.4) (t)	(e)	NR	10	NR	No	No	HEPA	NR	NR
Phase I PACU and Phase II recovery (FGI 2.1-3.4.4 & 2.1-3.4.5)	NR	2	6	NR	No	Yes	MERV-14	20-60	70-75/21-24
Procedure room (Table T2.2-1) (o), (d)	Positive	3	15	NR	No	Yes	MERV-14	20-60	70-75/21-24
Protective environment room (FGI 2.2-2.2.4.4) (t)	Positive	2	12	NR	No	No	HEPA	Max 60	70-75/21-24
Radiology waiting rooms (FGI 2.2-3.4.10.1)	Negative	2	12	Yes (q), (w)	NR	Yes (ff)	MERV-8	Max 60	70-75/21-24
Seclusion room (FGI 2.1-2.4.3)	NR	2	4 (y)	NR	NR	Yes	MERV-14	Max 60	70-75/21-24
Sterile processing room (FGI 2.2-3.3.6.15)	NR	2	6	NR	No	Yes	MERV-8 (gg)	NR	NR
Treatment room (FGI 2.2-3.1.2.6) (p)	NR	2	6	NR	NR	Yes	MERV-8	20-60	70-75/21-24
Wound intensive care (burn unit)	Positive	2	6	NR	No	Yes	HEPA	40-60	70-75/21-24
Behavioral And Mental Health Facilities (K)									
Patient bedroom, resident room (FGI 2.2-2.12.2 & 2.5-2.2.2)	NR	2	2	NR	NR	Yes	MERV-8	NR	NR
Seclusion room (FGI 2.1-2.4.3 & 2.2-2.12.4.3)	NR	4	2	NR	NR	Yes	MERV-8	NR	NR
Diagnostic And Treatment									
Bronchoscopy, sputum collection, and pentamidine administration (FGI 2.2-3.9.2) (n), (x)	Negative	2	12	Yes	No	Yes	MERV-14	NR	68-73/20-23
Class 1 imaging room (FGI 2.2-3.4.1.2 & Table 2.2-2)	NR (jj)	2	6	NR	NR	Yes	MERV-8	Max 60	72-78/22-26
Class 2 imaging room (FGI 2.2-3.4.1.2 & Table 2.2-2) (d), (p)	Positive	3	15	NR	No	Yes	MERV-14	Max 60	70-75/21-24
Class 3 imaging room (FGI 2.2-3.4.1.2 & Table 2.2-2) (m), (o)	Positive	4	20	NR	No	Yes	MERV-16 (hh)	20-60	68-75/21-24
Dialysis treatment area (FGI 2.2-3.10.2)	NR	2	6	NR	NR	Yes	MERV-8	NR	72-78/22-26
Dialyzer reprocessing room (FGI 2.2-3.10.8.16)	Negative	NR	10 (bb)	Yes	No	Yes (ff)	MERV-8	NR	NR
ECT procedure room (FGI 2.2-2.12.4.1 & 2.5-3.4)	NR	2	4	NR	NR	Yes	MERV-8	Max 60	72-78/22-26

Standards For Pressurization Of Spaces

Design Parameters—Inpatient Spaces

Function of Space (ee)	Pressure Relationship Adjacent to Areas (n)	Minium Outdoor ach	Minimum Total ach	All Room Air Exhausted Directly to Outdoors (j)	Air Recirculated by Means of Room Units (a)	Unoccupied Turndown	Minimum Filter Efficiencies (cc)	Design Relative Humidity (k), %	Design Temperature (l), °F/°C
Gastrointestinal endoscopy procedure room (FGI 2.2–3.11.2 & Table 2.2-1) (x)	NR	2	6	NR	No	Yes	MERV-8	20–60	68–73/20–23
General examination room (FGI 2.1–3.2)	NR	2	4	NR	NR	Yes	MERV-8	Max 60	70–75/21–24
Hydrotherapy (FGI 2.1–8.4.3.9)	Negative	2	6	NR	NR	Yes	MERV-8	NR	72–80/22–27
Instrument processing room (FGI 2.2–3.11.4)	Negative	2	10	Yes	No	No	MERV-8 (gg)	NR	NR
Medication room (FGI 2.1–2.8.8.2[1])	NR	2	4	NR	NR	Yes	MERV-8	Max 60	70–75/21–24
Nuclear medicine hot lab (FGI 2.2–3.4.8.22)	Negative	NR	6	Yes	No	Yes (ff)	MERV-8	NR	70–75/21–24
Physical therapy (FGI 2.2–2.13.8.16 & 2.6–3.1)	Negative	2	6	NR	NR	Yes	MERV-8	Max 65	72–80/22–27
Special examination room (aa)	NR	2	6	NR	NR	Yes	MERV-14 (ii)	Max 60	70–75/21–24
Treatment room (FGI 2.2–3.1.2.4)	NR	2	6	NR	NR	Yes	MERV-8	Max 60	70–75/21–24
Patient Support Facilities									
Bedpan room (FGI 2.1–2.8.12.2 & 2.1–5.1.3.3)	Negative	NR	10	Yes	No	No	MERV-8	NR	NR
Environmental services room (FGI 2.1–2.8.14)	Negative	NR	10	Yes	No	No	MERV-8	NR	NR
Food and supply storage (FGI 2.1–4.3.8.13)	NR	NR	2	NR	No	No	MERV-8	NR	72–78/22–26
Food preparation areas (FGI 2.1–4.3.2) (i)	NR	2	10	NR	No	Yes	MERV-8	NR	72–78/22–26
Laboratory work area, bacteriology (FGI 2.1–4.1.2) (f), (v)	Negative	2	6	Yes	NR	Yes	MERV-8	NR	70–75/21–24
Laboratory work area, biochemistry (FGI 2.1–4.1.2) (f), (v)	Negative	2	6	Yes	NR	Yes	MERV-8	NR	70–75/21–24
Laboratory work area, cytology (FGI 2.1–4.1.2) (f), (v)	Negative	2	6	Yes	NR	Yes	MERV-8	NR	70–75/21–24
Laboratory work area, general (FGI 2.1–4.1.2) (f), (v)	Negative	2	6	NR	NR	Yes	MERV-8	NR	70–75/21–24
Laboratory work area, glasswashing (FGI 2.1–4.1.2) (f)	Negative	2	10	Yes	NR	Yes	MERV-8	NR	NR
Laboratory work area, histology (FGI 2.1–4.1.2) (f), (v)	Negative	2	6	Yes	NR	Yes	MERV-8	NR	70–75/21–24
Laboratory work area, media transfer (FGI 2.1–4.1.2) (f), (v)	Positive	2	4	NR	NR	Yes	MERV-8	NR	70–75/21–24
Laboratory work area, microbiology (FGI 2.1–4.1.2) (f), (v)	Negative	2	6	Yes	NR	Yes	MERV-8	NR	70–75/21–24
Laboratory work area, nuclear medicine (FGI 2.1–4.1.2) (f), (v)	Negative	2	6	Yes	NR	Yes	MERV-8	NR	70–75/21–24
Laboratory work area, pathology (FGI 2.1–4.1.2) (f), (v)	Negative	2	6	Yes	NR	No	MERV-8	NR	70–75/21–24
Laboratory work area, serology (FGI 2.1–4.1.2) (f), (v)	Negative	2	6	Yes	NR	Yes	MERV-8	NR	70–75/21–24
Laboratory work area, sterilizing (FGI 2.1–4.1.2) (f)	Negative	2	10	Yes	NR	Yes	MERV-8	NR	70–75/21–24
Pharmacy Services: Pharmacy Areas (FGI 2.1–4.2.2) (b)	Positive	2	4	NR	NR	Yes	MERV-8	Max 60	70–75/21–24
Toilet room (FGI 2.1–2.9.2)	Negative	NR	10	Yes	No	Yes	MERV-8	NR	72–78/22–26
Warewashing (FGI 2.1–4.3.4) (r)	Negative	NR	NR	Yes	No	Yes	MERV-8	NR	NR
General Support Facilities: Sterile Processing									
Clean assembly/workroom (FGI 2.1–5.1.2.2[3]) (z)	Positive	2	4	NR	No	No	MERV-8 (gg)	Max 60	68–73/20–23
Soiled workroom/decontamination room (FGI 2.1–5.1.2.2[2]) (z)	Negative	2	6	Yes	No	No	MERV-8	NR	60–73/16–23
Sterile storage room (clean/sterile medical/ surgical supplies) (FGI 2.1–5.1.2.2[4]) (z)	Positive	2	4	NR	NR	No	MERV-8 (gg)	Max 60	Max 75/24
Other General Support Facilities									
Autopsy room (FGI 2.1–5.7.2.2)	Negative	2	12	Yes	No	No	MERV-8	NR	68–75/20–24
Clean linen storage room (FGI 2.1–2.8.13.1 & 2.1–5.2.2.1[3])	Positive	NR	2	NR	NR	Yes	MERV-8	NR	72–78/22–26
Hazardous material storage (FGI 2.1–5.4)	Negative	2	10	Yes	No	No	MERV-8	NR	NR
Laundry, processing room (FGI 2.1–5.2.2.1)	Negative	2	10	Yes	No	No	MERV-8	NR	NR
Linen and refuse chute room (FGI 2.1–5.2.8.1[2] & 2.1–5.4.1.4)	Negative	NR	10	Yes	No	No	MERV-8	NR	NR
Nonrefrigerated body holding room (FGI 2.1–5.7.3) (h)	Negative	NR	10	Yes	No	No	MERV-8	NR	70–75/21–24
Regulated waste holding spaces (FGI 2.1–5.4.1.3)	Negative	NR	10	Yes	No	No	MERV-8	NR	NR
Toilet (FGI 2.1–2.9.2)	Negative	NR	10	Yes	No	Yes	MERV-8	NR	NR
Support Areas For Nursing Units And Other Patient Care Areas									
Clean supply room (FGI 2.1–2.8.11.3)	Positive	NR	NR	NR	NR	Yes	MERV-8	NR	NR
Clean workroom (FGI 2.1–2.8.11.2)	Positive	2	NR	NR	NR	Yes	MERV-8	NR	NR
Soiled workroom or soiled holding (FGI 2.1–2.8.12)	Negative	2	10	Yes	No	No	MERV-8	NR	NR

Standards For Pressurization Of Spaces

Design Parameters—Specialized Outpatient Space

Function of Space (f)	Pressure Relationship Adjacent to Areas (n)	Minium Outdoor ach	Minimum Total ach	All Room Air Exhausted Directly to Outdoors (j)	Air Recirculated by Means of Room Units (a)	Minimum Filter Efficiencies (cc)	Design Relative Humidity (k), %	Design Temperature (l), °F/°C
Surgery And Emergency Department (Ed)								
Delivery (Caesarean) (FGI 2.1–3.2.3) (m), (o), (v), (gg)	Positive	4	20	NR	No	MERV-16 (dd)	20–60	68–75/20–24
ED humandecontamination (FGI 2.8–3.4.8)	Negative	2	12	Yes	No	MERV-14 (cc)	NR	NR
ED exam/treatment room (FGI 2.8–3.4.2) (p)	NR	2	6	NR	NR	MERV-14 (cc)	Max 60	70–75/21–24
ED public waiting area (FGI 2.8–6.2.3)	Negative	2	12	Yes (q)	NR	MERV-8	Max 65	70–75/21–24
Operating room (FGI 2.1–3.2.3) (m), (o), (v), (gg)	Positive	4	20	NR	No	MERV-16 (dd)	20–60	68–75/20–24
Procedure room (FGI 2.1–3.2.2) (d), (o), (p)	Positive	3	15	NR	No	MERV-14	20–60	70–75/21–24
Phase I recovery (PACU) (FGI 2.1–3.7.4)	NR	2	6	NR	No	MERV-8	Max 60	70–75/21–24
Phase II recovery (FGI 2.1–3.7.5) (u)	NR	2	2	NR	NR	MERV-8	Max 60	70–75/21–24
Pre-procedure patient care (FGI 2.1–3.7.3) (t)	NR	2	2	NR	NR	MERV-8	Max 60	70–75/21–24
Trauma room (crisis or shock) (FGI 2.8–3.4.4) (bb)	Positive	3	15	NR	No	MERV-14	20–60	70–75/21–24
Triage (FGI 2.8–6.2.2.2 & 6.2.2.3)	Negative	2	12	Yes (q)	NR	MERV-8	Max 60	70–75/21–24
Diagnostic And Treatment								
Class 1 imaging room (FGI 2.1–3.5.2.4[1][b][i]) (ff)	NR	2	6	NR	NR	MERV-8	Max 60	72–78/22–26
Class 2 imaging room (FGI 2.1–3.5.2.4[1][b][ii]) (d), (p), (ff)	Positive	3	15	NR	No	MERV-14	20–60	70–75/21–24
Class 3 imaging room (FGI 2.1–3.5.2.4[1][b][iii]) (m), (o), (ff)	Positive	4	20	NR	No	MERV-16 (dd)	20–60	68–75/20–24
Diagnostic imaging waiting (FGI 2.1–3.5.10.4) (g)	Negative	2	12	Yes (q), (r)	NR	MERV-8	Max 60	70–75/21–24
All anteroom (FGI 2.1–3.3.2.3) (i)	(e)	NR	10	Yes	No	MERV-8	NR	NR
All room (FGI 2.1–3.3.2) (i)	Negative	2	12	Yes	No	MERV-8	Max 60	70–75/21–24
PE anteroom (FGI 1.2–4.2.2.1[1]) (n) (w)	(e)	NR	10	NR	No	HEPA	NR	NR
Protective environment room (FGI 1.2–4.2.2.1[1]) (n) (w)	Positive	2	12	NR	No	HEPA	Max 60	70–75/21–24
Cancer treatment area (FGI 2.6–3.1)	NR	2	6	NR	NR	MERV-8	Max 60	70–75/21–24
Dialysis treatment area (FGI 2.10–3.2)	NR	2	6	NR	NR	MERV-8	NR	72–78/22–26
Dialyzer reprocessing room (FGI 2.10–3.8.12)	Negative	NR	10	Yes	No	MERV-8	NR	NR
Bronchoscopy (FGI 2.1–3.2.2.1) (n) (x)	Negative	2	12	Yes	No	MERV-14	NR	68–73/20–23
Instrument processing room (FGI 2.1–4.3.2.3)	Negative	2	10	Yes	No	MERV-8 (s)	NR	NR
Endoscopy procedure room (FGI 2.9–3.2) (h)	NR	2	6	NR	No	MERV-8	Max 60	68–73/20–23
Examination/observation (FGI 2.1–3.2.1)	NR	2	4	NR	NR	MERV-8	Max 60	70–75/21–24
Specialty IC exam room (FGI 2.1–3.2.1.3) (y)	Negative	2	6	Yes	NR	MERV-8	Max 60	70–75/21–24
Laboratory work room (FGI 2.1–4.1.2.1) (z)	Negative	2	6	Yes	NR	MERV-8	NR	70–75/21–24
Pharmacy/med prep (FGI 2.1–3.8.8.2 & 2.1–4.2.2) (b)	Positive	2	4	NR	NR	MERV-8	NR	NR
Laser eye room (FGI 2.1–3.2.2)	NR	2	6	NR	No	MERV-8	Max 60	68–73/20–23
Nuclear medicine (see Section 8.7) (FGI 2.1–3.5.7)	Negative	2	6	Yes	No	MERV-8	NR	70–75/21–24
Toilet or Toilet/Shower room (FGI 2.1–3.10.2)	Negative	NR	10	Yes	No	MERV-8	NR	NR
STERILE PROCESSING (Aa)								
One-room sterile processing (FGI 2.1–4.3.2.3)	NR	2	6	NR	No	MERV-14 (ee)	NR	NR
Sterilizer equipment room (FGI 2.1–4.3.2.2)	Negative	NR	10	Yes	No	MERV-8	NR	NR
Clean workroom (FGI 2.1–4.3.2.2.3)	Positive	2	4	NR	No	MERV-14 (ee)	Max 60	60–73/16–23
Clean supply storage (FGI 2.1–4.3.2.2.4)	Positive	2	4	NR	NR	MERV-14 (ee)	Max 60	72–78/22–26
Supply receiving (FGI 2.1–4.3.2.4)	Negative	NR	10	Yes	No	MERV-8	NR	NR
Decontamination room (FGI 2.1–4.3.2.2)	Negative	2	6	Yes	No	MERV-8	NR	60–73/16–23
Service/Support Space								

Standards For Pressurization Of Spaces

Design Parameters—Specialized Outpatient Space

Function of Space (f)	Pressure Relationship Adjacent to Areas (n)	Minium Outdoor ach	Minimum Total ach	All Room Air Exhausted Directly to Outdoors (j)	Air Recirculated by Means of Room Units (a)	Minimum Filter Efficiencies (cc)	Design Relative Humidity (k), %	Design Temperature (l), °F/°C
Environmental services room (FGI 2.1–5.3.1)	Negative	NR	10	Yes	No	MERV-8	NR	NR
Laundry/linen processing (FGI 2.1–4.4.2.1)	Negative	2	10	Yes	No	MERV-8	NR	NR
Clean workroom or clean supply (FGI 2.1–3.8.11)	Positive	2	4	NR	NR	MERV-8	NR	NR
Regulated waste holding (FGI 2.1–5.2.1.3)	Negative	2	10	Yes	No	MERV-8	NR	NR
Soiled workroom or soiled holding (FGI 2.1–3.8.12)	Negative	2	6	Yes	No	MERV-8	NR	72–78/22–26

Standards For Pressurization Of Spaces

Design Parameters—General Outpatient Spaces (q)

Function of Space (f)	Pressure Relationship to Adjacent Areas (d)	ach Design Option		All Room Exhausts Directly to Outdoors	Air Recirculated by Means of Room Units (a)	Min. Filter Efficiencies (c)	Design RH% (i)	Design Temperature °F/°C (k)	R _p -R _a Air-Class Design Option		
		Min. Outdoor ach (q)	Min. Total ach (q)						Air Class (q)	R _p cfm/(L·s)/ person and Min. Space Population (q)	R _a cfm/ft/(L·s/m) (q)
Birth room (FGI 2.4-2.2)	NR	2	3	NR (h)	NR	MERV-14	Max 60	70–75/21–24	2	10 (5) / 4	0.18 / (0.9)
Urgent care exam (FGI 2.5-3.2.1) (e)	NR	2	3	NR	NR	MERV-8	NR	70–75/21–24	2	7.5 (3.8) / 3	0.12 / (0.6)
Urgent care treatment (FGI 2.5-3.2.2) (e)	NR	2	3	NR	NR	MERV-8	NR	70–75/21–24	2	7.5 (3.8) / 3	0.18 / (0.9)
Urgent care triage (FGI 2.5-3.2.3)	Negative	2	3	Yes	NR	MERV-8	Max 60	70–75/21–24	3	10 (5) / 3	0.18 / (0.9)
Urgent care observation (FGI 2.5-3.3)	NR	2	2	NR	NR	MERV-8	NR	70–75/21–24	2	5 (2.5) / 2	0.12 / (0.6)
General examination room (FGI 2.1-3.2.1)	NR	2	2	NR	NR	MERV-8	NR	70–75/21–24	1	7.5 (3.8) / 3	0.12 / (0.6)
Specialty IC exam room (FGI 2.5-3.2.3) (b)	Negative	2	3	Yes	NR	MERV-8	Max 60	70–75/21–24	3	10 (5) / 3	0.18 / (0.9)
Laboratory work room (FGI 2.1-4.1.2.1) (l)	NR	2	3	NR (h)	NR	MERV-8	NR	70–75/21–24	2	7.5 (3.8) / 2	0.12 / (0.6)
Medication room (FGI 2.1-3.8.8.2)	NR	2	2	NR	NR	MERV-8	Max 60	70–75/21–24	1	5 (2.5) / 2	0.18 / (0.9)
Class 1 Imaging rooms (FGI 2.1-3.5) (g)	NR	2	3	NR	NR	MERV-8	Max 60	72–78/22–26	1	7.5 (3.8) / 2	0.12 / (0.6)
Psychiatric examination room (FGI 2.11-3.2.2)	NR	2	3	NR	NR	MERV-8	NR	70–75/21–24	1	5 (2.5) / 2	0.06 / (0.3)
Psychiatric consultation room (FGI 2.11-3.2.4)	NR	2	3	NR	NR	MERV-8	NR	70–75/21–24	1	5 (2.5) / 2	0.06 / (0.3)
Psychiatric group room (FGI 2.11-3.2.5)	NR	2	3	NR	NR	MERV-8	NR	70–75/21–24	1	5 (2.5) / 2	0.06 / (0.3)
Psychiatric seclusion room (FGI 2.11-3.2.7)	NR	2	2	NR	NR	MERV-8	NR	70–75/21–24	2	10 (5) / 3	0.12 / (0.6)
ECT procedure room (FGI 2.11-3.2.9.2)	NR	2	2	NR	NR	MERV-8	NR	70–75/21–24	1	7.5 (3.8) / 3	0.12 / (0.6)
Physical therapy individual room (FGI 2.12-3.2.2.1)	NR	2	3	NR (h)	NR	MERV-8	NR	70–75/21–24	2	10 (5) / 3	0.12 / (0.6)
Physical therapy exercise area (FGI 2.12-3.2.3)	NR	2	3	NR (h)	NR	MERV-8	NR	70–75/21–24	2	20 (10) / 2	0.18 / (0.9)
Hydrotherapy (FGI 2.12-3.2.4)	Negative	2	3	Yes	NR	MERV-8	NR	72–80/22–27	3	20 (10) / 2	0.12 / (0.6)
Physical therapeutic pool (FGI 2.12-3.2.4)	Negative	2	10	Yes	NR	MERV-8	NR	72–80/22–27	3	—	0.48 / (2.4)
Speech therapy room (FGI 2.12-3.3.2)	NR	2	2	NR	NR	MERV-8	NR	70–75/21–24	1	5 (2.5) / 2	0.06 / (0.3)
Occupational therapy (FGI 2.12-3.3)	NR	2	3	NR	NR	MERV-8	NR	70–75/21–24	1	5 (2.5) / 2	0.06 / (0.3)
Prosthetics and orthotics room (FGI 2.12-3.3.1)	NR	2	3	NR	NR	MERV-8	NR	70–75/21–24	2	10 (5) / 3	0.18 / (0.9)
Dental treatment (FGI 2.14-3.1.1)	NR	2	3	NR	NR	MERV-8	NR	70–75/21–24	1	10 (5) / 3	0.18 / (0.9)
Other dental treatment areas (FGI 2.14-3.2)	NR	2	3	NR	NR	MERV-8	NR	70–75/21–24	1	5 (2.5) / 2	0.06 / (0.3)
Toilet room (FGI 2.1-3.10.2)	Negative	NR	4	Yes	No	MERV-8	NR	NR	3	—	—
SERVICE /SUPPORT SPACE											
Environmental services room (FGI 2.1-5.3.1)	Negative	NR	6	Yes	No	MERV-8	NR	NR	3	—	—
Clean supply (FGI 2.1-3.8.11) (m) (n)	NR	2	2	NR	NR	MERV-8	NR	NR	1	5 (2.5) / 2	0.12 / (0.6)
Soiled holding (FGI 2.1-3.8.12) (m) (o) (p)	Negative	NR	6	Yes	No	MERV-8	NR	NR	3	5 (2.5) / 2	0.12 / (0.6)

Standards For Pressurization Of Spaces

Standards For Pressurization Of Spaces									
Design Parameters for Residential Health, Care, and Support-Specific Spaces									
Function of Space (l)	Pressure Relationship to Adjacent Areas (d)	Minimum Outdoor ach	Minimum Total ach	All Room Air Exhausted Directly to Outdoors (f)	Air Recirculated by Means of Room Units (a)	Unoccupied Turndown	Minimum Filter Efficiencies (i)	Design Relative Humidity (g), %	Design Temperature (h), °F/°C
Residential Health									
Nursing Homes									
All room (FGI 3.1–2.2.4.1) (b)	Negative	2	12	Yes	No	Yes	MERV-14	Max 60	70–78/21–29
All anteroom (FGI 3.1–2.2.4.1) (b)	Negative	NR	10	Yes	No	Yes	MERV-14	Max 60	70–78/21–29
Occupational therapy (FGI 3.1–3.3.3)	NR	2	6	NR	NR	Yes	MERV-14	NR	70–78/21–29
Physical therapy (FGI 3.1–3.3.2)	Negative	2	6	NR	NR	Yes	MERV-14	NR	70–78/21–29
Resident living/activity/dining (FGI 3.1–2.3.3)	NR	4	4	NR	NR	Yes	MERV-14	Max 60	70–78/21–29
Resident room (FGI 3.1–2.2.2)	NR	2	2	NR	NR	Yes	MERV-14	Max 60	70–78/21–29
Resident corridor (FGI 2.4–2.2.2)	NR	NR	4	NR	NR	Yes	MERV-14	NR	70–78/21–29
Toilet/bathing room (FGI 3.1–2.2.2.6)	Negative	NR	10	Yes	No	No	MERV-14	NR	70–78/21–29
Hospice Facilities									
All room (FGI 3.2–2.2.3.1) (c)	Negative	2	12	Yes	No	Yes	MERV-14	Max 60	70–75/21–24
All anteroom (FGI 3.2–2.2.3.1) (c)	(e)	NR	10	Yes	No	Yes	MERV-8	Max 60	NR
Resident room (FGI 3.2–2.2.2)	NR	2	2	NR	NR	Yes	MERV-8	Max 60	70–75/21–24
Resident corridor (FGI 2.4–2.2.2)	NR	NR	4	NR	NR	Yes	MERV-8	NR	NR
Toilet/bathing room (FGI 3.2–2.2.2.6)	Negative	NR	10	Yes	No	Yes	MERV-8	NR	70–75/21–24
Residential Care And Support Assisted Living Facilities									
Resident living/activity/dining (FGI 4.1–2.3.3)	NR	NR	NR	NR	NR	Yes	MERV-8	NR	NR
Resident room (FGI 4.1–2.2.2)	NR	NR	NR	NR	NR	Yes	MERV-8	NR	70–78/21–29
Resident corridor (FGI 2.4–2.2.2)	NR	NR	NR	NR	NR	Yes	MERV-8	NR	NR
Toilet/bathing room (FGI 4.1–2.2.2.7)	NR	NR	NR	NR	NR	Yes	MERV-8	NR	NR
Service									
Clean linen storage (FGI 2.3–4.6)	Positive	NR	2	NR	NR	No	MERV-8	NR	72–78/22–26
Dietary storage (FGI 2.3–4.5)	NR	NR	2	NR	No	No	MERV-8	NR	72–78/22–26
Food preparation center (FGI 2.3–4.5.3.3) (e)	NR	2	10	NR	No	Yes	MERV-8	NR	72–78/22–26
Hair salon (FGI 2.3–2.3.5 & 4.1–2.3.5)	Negative	NR	10	Yes	NR	Yes	MERV-8	NR	70–78/21–29
Laundry, central and personal (FGI 2.3–4.2.7)	Negative	2	10	Yes	No	No	MERV-8	NR	NR
Linen and trash chute room (FGI 2.3–4.6 & 2.3–4.9)	Negative	NR	10	Yes	No	No	MERV-8	NR	NR
Medication room (FGI 2.3–4.2.2.2)	NR	2	4	NR	NR	Yes	MERV-8	Max 60	70–75/21–24
Soiled linen sorting and storage (FGI 2.3–4.6)	Negative	NR	10	Yes	No	No	MERV-8	NR	NR
Warewashing (FGI 2.3–4.5.3.6)	Negative	NR	10	Yes	No	Yes	MERV-8	NR	NR
Clean utility (FGI 2.3–4.2.5)	Positive	2	4	NR	NR	No	MERV-8 (k)	NR	NR
Environmental services room (FGI 2.3–4.9) (j)	Negative	NR	10	Yes	NR	No	MERV-8	NR	NR
Hazardous waste storage (FGI 2.3–4.8)	Negative	2	10	Yes	No	No	MERV-8	NR	NR
Soiled utility or soiled holding (FGI 2.3–4.2.6)	Negative	2	10	Yes	No	No	MERV-8	NR	NR

A-2 Acoustic

Source room	Receiving room																																																
	Clinical areas																Public areas										Staff areas																						
	Single-bed/on-call room	Multi-bed room	Children & older people (single bed)	Children & older people (multi-bed)	Consulting room	Examination room	Treatment room	Counselling/bereavement room	Interview room	Operating theatre suite	Nurseries	Birth room	Laboratories	Dirty utility/slucie	Clean utility	Speech and language therapy	Snoezelen/multi-sensory room	Multi-faith/chapel	Corridor (no door)	Atrium	Dining	Toilets (not cubicles)	Waiting (large >20 people)	Waiting (small ≤ 20 people)	Toilets (not cubicles)	Main kitchen	Ward kitchen, pantry	Storeroom	Restroom	Locker/changing room	Large training/seminar (>35m ²)	Small training/seminar (≤ 35m ²)	Lecture theatre	Library/archiving room	Single-person office	Multi-person office (2-4 people)	Open-plan office (≤ 5 people)	Boardroom	Large meeting room (>35m ²)	Small meeting room (≤ 35m ²)									
Clinical areas																																																	
Single-bed/on-call room	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47				
Multi-bed room	37	37	37	37	37	37	37	37	42	42	37	37	37	37	37	37	37	42	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	42	42	37	37	37	37	37	37	37	37	37	37			
Children & older people (single bed)	47	47	47	47	47	47	47	47	52	47	47	47	42	42	52	52	52	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42		
Children & older people (multi-bed)	42	42	42	42	42	42	42	42	47	42	42	42	37	37	47	47	47	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37		
Consulting room	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47		
Examination room	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47		
Treatment room	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47		
Counselling/bereavement room	47	47	47	47	47	47	47	47	52	47	47	47	47	47	52	52	52	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	52	52	47	47	47	47	47	47	47	47	47	47	47	47		
Interview room	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	
Operating theatre suite	42	42	42	42	42	42	42	42	47	42	42	42	42	42	47	47	47	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	
Nurseries	52	52	52	52	52	52	52	52	∅	52	52	52	47	47	∅	∅	∅	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47		
Birth room	52	52	52	52	52	52	52	52	∅	52	52	52	47	47	∅	∅	∅	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47		
Laboratories	37	37	37	37	37	37	37	37	42	37	37	37	37	37	42	42	42	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37		
Dirty utility/slucie	42	42	42	42	42	42	42	42	47	42	42	42	n/a	n/a	47	47	47	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
Clean utility	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	37	n/a	n/a	n/a	n/a	n/a	37	37	37	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
Speech and language therapy	47	47	47	47	47	47	47	47	52	47	47	47	47	47	52	52	52	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	
Snoezelen/multi-sensory room	47	47	47	47	47	47	47	47	52	47	47	47	47	47	52	52	52	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	
Public areas																																																	
Multi-faith/chapel	47	47	47	47	47	47	47	47	52	47	47	47	42	42	52	52	52	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	
Corridor (no door)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	42	n/a	n/a	n/a	n/a	n/a	42	42	42	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
Atrium	42	42	42	42	42	42	42	42	47	42	42	42	n/a	n/a	47	47	47	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Dining	42	42	42	42	42	42	42	42	47	42	42	42	n/a	n/a	47	47	47	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Toilets (not cubicles)	37	37	37	37	37	37	37	37	42	37	37	37	37	37	42	42	42	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37		
Waiting (large >20 people)	42	42	42	42	42	42	42	42	47	42	42	42	n/a	n/a	47	47	47	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Waiting (small ≤20 people)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	42	42	42	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
Staff areas																																																	
Toilets (not cubicles)	37	37	37	37	37	37	37	37	42	37	37	37	37	37	42	42	42	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37		
Main kitchen	52	52	52	52	52	52	52	52	∅	52	52	52	47	47	∅	∅	∅	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47		
Ward kitchen, pantry	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	42	n/a	n/a	n/a	n/a	n/a	42	42	42	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
Storeroom	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	37	n/a	n/a	n/a	n/a	n/a	37	37	37	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
Restroom	42	42	42	42	42	42	42	42	47	42	42	42	37	37	47	47	47	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37		
Locker/changing room	37	37	37	37	37	37	37	37	42	37	37	37	37	37	42	42	42	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	
Large training/seminar (>35m ²)	47	47	47	47	47	47	47	47	52	47	47	47	42	42	52	52	52	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	
Small training/seminar (≤35m ²)	42	42	42	42	42	42	42	42	47	42	42	42	42	42	47	47	47	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	
Lecture theatre	47	47	47	47	47	47	47	47	52	47	47	47	42	42	52	52	52	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	

Part E: Health Facility Briefing & Design Engineering

Library/archiving room	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	37	n/a	n/a	n/a	n/a	n/a	37	37	37	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	37	37	n/a	n/a	n/a	n/a	n/a	n/a
Single-person office	42	42	42	42	42	42	42	42	42	47	42	42	42	42	42	47	47	47	42	42	42	42	42	42	42	42	42	42	42	42	42	47	47	42	42	42	42	42	42
Multi-person office (2–4 people)	37	37	37	37	37	37	37	37	37	42	37	37	37	37	37	42	42	42	37	37	37	37	37	37	37	37	37	37	37	37	42	42	37	37	37	37	37	37	
Open-plan office (15 people)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	42	n/a	n/a	n/a	n/a	n/a	42	42	42	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Boardroom	47	47	47	47	47	47	47	47	47	52	47	47	47	47	47	52	52	52	47	47	47	47	47	47	47	47	47	47	47	47	52	52	47	47	47	47	47	47	
Large meeting room (>35 m ²)	47	47	47	47	47	47	47	47	47	52	47	47	47	42	42	52	52	52	42	42	42	42	42	42	42	42	42	47	42	47	47	52	52	47	47	47	47	47	47
Small meeting room (135 m ²)	42	42	42	42	42	42	42	42	42	47	42	42	42	42	42	47	47	47	42	42	42	42	42	42	42	42	42	42	42	42	47	47	42	42	42	42	42	42	

A-3 Filtration Requirement

FILTRATION REQUIREMENT		
Space Designation (According to Function)	Filter Bank No. 1 (MERV) ^a	Filter Bank No. 2 (MERV) ^a
Operating rooms (ORs); inpatient and ambulatory diagnostic and therapeutic radiology; inpatient delivery and recovery spaces	7	14
Inpatient care, treatment, and diagnosis, and those spaces providing direct service or clean supplies and clean processing (except as noted below); All (rooms)	7	14
Protective environment (PE) rooms	7	HEPA ^{c,d}
Laboratory work areas, procedure rooms, and associated semirestricted spaces	13 ^b	NR
Administrative; bulk storage; soiled holding spaces; food preparation spaces; and laundries	7	NR
All other outpatient spaces	7	NR
Nursing facilities	13	NR
Psychiatric hospitals	7	NR
Resident care, treatment, and support areas in inpatient hospice facilities	13	NR
Resident care, treatment, and support areas in assisted living facilities	7	NR