Schneider Electric

Application Note

AN-HC-001

Isolation Rooms

with EcoStruxure™ for Healthcare

March 2019

Schneider Electric

About this Document

This paper explains the different types of Isolation Rooms in healthcare and the recommended solution from Schneider Electric

EcoStruxure for Healthcare™

EcoStruxure™ for Healthcare is Schneider Electric's IoT enabled platform for digital hospitals, designed to deliver improved safety, patients' satisfaction, and operational efficiency. EcoStruxure™ represents the infrastructure holistic architecture for smart, connected hospitals and it brings the digital transformation in healthcare beyond the EMR, by connecting smart devices with big data analytics and artificial intelligence to ensure that critical infrastructure is smart, fast, efficient and patient-focused.

For more information pelase visit: https://www.schneider-electric.com/en/work/solutions/for-business/healthcare/

Application Notes

Application Notes describe the design considerations for engineers who are involved in the planning, design, installation, commissioning or operation of applications within healthcare facilities. The documents are intended as guidance only and will reference recognized standards and regulations and industry equipment.

The document will provide indicative illustrations for the application and its configuration.

About the Author

Robert Heinlein is a senior Solution Architect and brings over 45 years of experience in the controls industry. Robert has led the design of many complex projects in the healthcare and pharmaceutical industry and has applied this knowledge to the development of innovative solutions and engineering standards for Schneider Electric's healthcare offer. Robert is also a Life Member of ASHRAE and is an active member of the ASHRAE 170 Ventilation for Healthcare Committee. He also participates on ASHRAE Technical Committee 9.6 Healthcare

Disclaimer

This document does not attempt to describe the proposed solution in its entirety. Users are solely responsible for compliance with national and international safety laws and regulations. This document does not replace any specific project documentation.

Please note that there are many references to ASHRAE Standard 170 Ventilation for Healthcare Facilities in this document. ASHRAE 170 Ventilation for Healthcare Facilities is an ASHRAE Standard used in the United States in the building code for healthcare facilities. The Standard gives the minimum design criteria for various spaces in a healthcare facility. Consulting engineers can design in excess of these requirements.

Due to advances in healthcare and continuing research, ASHRAE Standard 170 Ventilation for Healthcare Facilities is continually being revised. All references made to ASHRAE 170 should be verified. ASHRAE 170- 2013 was used in writing this document.

Table of Contents

1 Introduction

Healthcare facilities are designed to provide a comfortable healing environment for both patients and staff. Many of the patients who are cared for in these facilities are combating contagious diseases or have weak immune systems. Therefore, it is critical that the infrastructure of patient areas is designed and maintained correctly to ensure that patients and staff are protected from airborne diseases and infections.

Healthcare facilities often contain specialist rooms; rooms designed specifically to protect patients and staff from airborne contaminants. These rooms have unique design requirements such as negative or positive room pressures or high air change rates. Specialist or precision airflow control systems are often installed to aid in meeting these needs.

Listed below are some common examples of these specialized rooms:

- Airborne Infection Isolation (AII) rooms (Negative Pressure)
- Protective Environment (PE) rooms (Positive Pressure)
- Operating rooms (Positive Pressure)
- Compounding Rooms (Positive Pressure)
- Newborn Intensive Care (Positive Pressure)
- Laboratory (Negative Pressure)

Isolation rooms are designed to protect the patient and others in the hospital. This document considers the design requirements for isolation rooms, both AII and PE, and provides an overview of the solutions available.

1.1 Airborne Infection Isolation (AII) Rooms

Airborne Infection Isolation (AII) rooms are designed and operated to ensure room pressure is kept at a negative pressure. The purpose of these rooms is to protect clinical staff, other patients and visitors from exposure to airborne infectious agents. The rooms are intended for patients who can spread communicable diseases through the air, such as tuberculosis, Severe Actuate Respiratory Syndrome (SARS), influenza and other respiratory diseases. Design guidelines such as ASHRAE 170 require that AII rooms are maintained to a negative pressure of -0.01 Inches of Water Column (-2.5Pa). The design guidelines ensure that movement of airflow is maintained.

A dedicated exhaust fan moves exhaust from both the ensuite and above the patient bed directly outdoors. The Health Building Note 04-01 from the National Health Service in the UK requires exhaust from the ensuite only. Input from the infection control team is critical during the design phase when determining the provision of the systems.

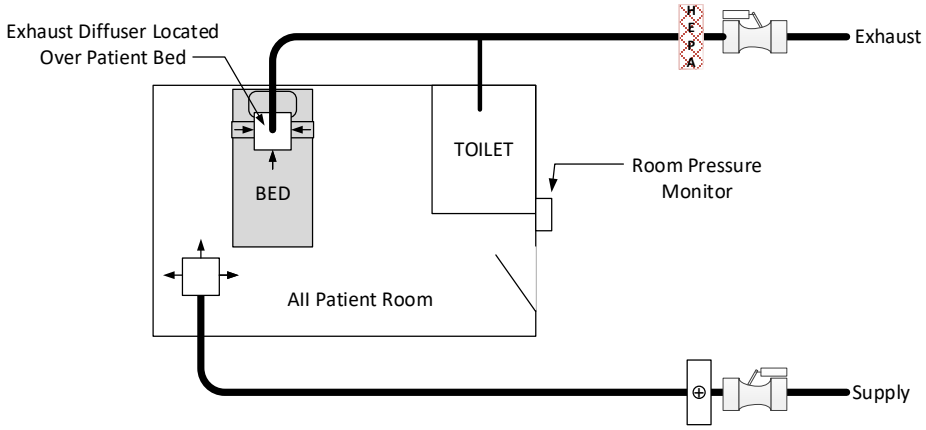

Figure_1: Typical Airborne Infection Isolation (AII) Room

The ventilation ductwork leading from an AII room is also a potential route for airborne agents. HEPA filters are typically installed at the room exhaust or at the inlet of dedicated exhaust fans.

Sometimes an AII room has an Ante Room provideing an airlock lobby as an additional barrier against loss of pressurization. These rooms are used for gowning of protective clothing. The Ante room has a negative pressure to the corridor and a positive pressure to the patient. Interlocking of the doors may be required to avoid impacting pressure control. If the isolation is also used for quarantine, interlocking and controlled access is required.

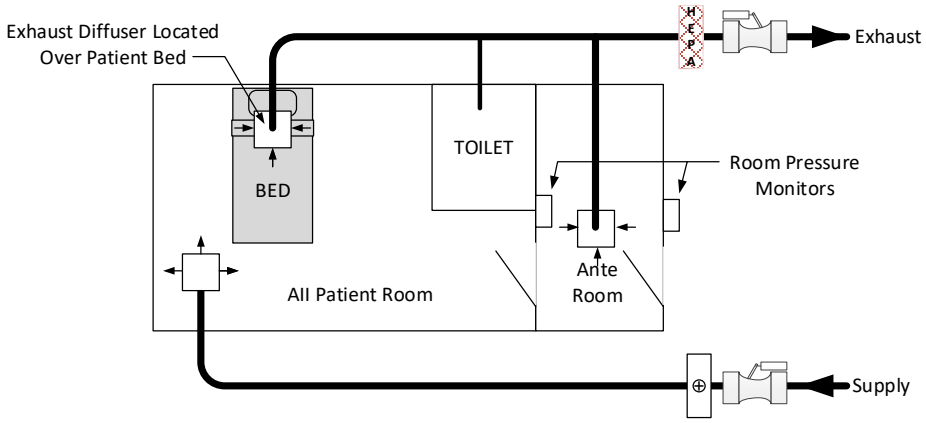

Figure_2: Typical Airborne Infection Isolation (AII) Room with Ante Room

1.2 Protective Environment (PE) Isolation Room

A dedicated exhaust fan moves exhaust from both the ensuite and above the patient bed directly outdoors. Input from the infection control team is critical during the design phase when determining the provision of the systems.

Protective Environment (PE) rooms are designed to protect patients with weak immune systems, making them susceptible to infectious agents. Patients will typically have had bone marrow or organ transplants, cancer, and other immunosuppressive diseases or drug therapies. Design guidelines such as ASHRAE 170 require that PE rooms are maintained to a positive pressure +0.01 Inches of Water Column (2.5 Pa). The design guidelines ensure the movement of airflow is maintained.

The supply ventilation to PE rooms typically shares the air system with other rooms in the department. However, a HEPA filter must be installed on the inlet duct to individual PE rooms.

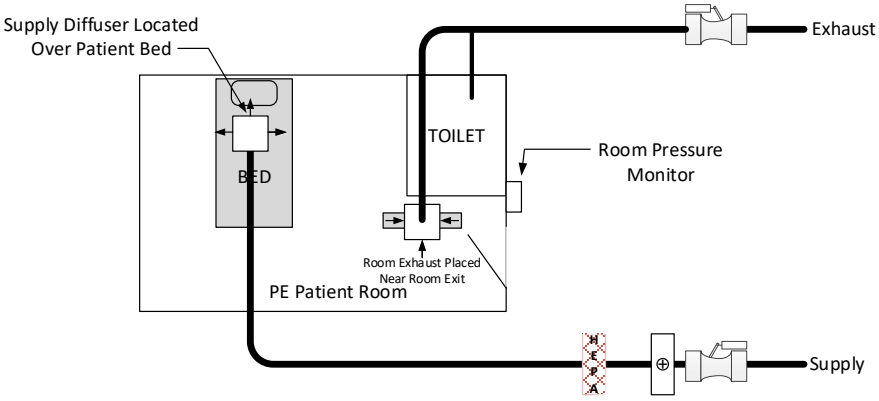

Figure_3: Typical Protective Environment (PE) Room

Sometimes a PE room has an Ante Room provideing an airlock lobby as an additional barrier against loss of pressurization. These rooms are used for gowning of protective clothing. The Ante room has a positive pressure to the corridor and a negative pressure to the patient. Interlocking of the doors maybe required to avoide impacting the pressure control.

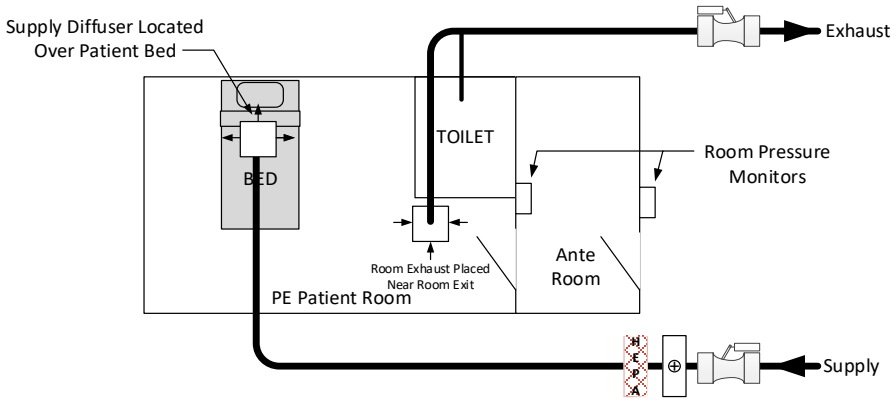

Figure_4: Typical Protective Environment (PE) Room with Ante Room

1.3 Convertible Isolation Room

Reversible airflow mechanisms are **not** recommended in any guidelines. There are many difficulties with balancing the airflow and the risk of error and engineering complexity is high.

1.4 Combined AII/PE Room

When a patient becomes infectious to others, a PE room must provide isolation. To prevent the airborne spread of infections, the positive pressure room must have an Ante Room with either of the following.

- The Ante Room must have a positive pressure with respect to both the AII/PE room and the corridor or common space, OR
- The Ante Room must have a negative pressure with respect to both the AII/PE room and the corridor or common space.

For this application, it is important that the infection control team is closely involved with all aspects of planning, designing and operating. ASHRAE170 allows both options but some standards will only allow a negative pressure configuration.

2 Control and Monitoring

2.1 Ventilation Strategy

The ventilation supply to the isolation rooms is filtered outside air (please refer to relevant design guidelines for requirement of air changes from outside air) supplied directly into the patient room. The ventilation system provides a constant volume to achieve the air change rates on the supply and exhaust ducts.

The ventilation uses air flow tracking to ensure the pressue remains either negative or positive. Air flow tracking maintains an offset between the suppy and exhaust to achieve the required pressure. For negative pressure rooms, more air is exhausted than supplied and air flow offset is maintained. For positive pressure rooms, more air is supplied than exhausted. It is important to always achieve the correct directional flow of air in these applications.

Figure_5: Neagtively pressured room

There should be an interlock between the supply and exhaust systems to avoid a positive pressure in the event of exhaust fan failure. To maintain room pressures, it is critical that the perimeter of the room is sealed to the building structure and the undercut of the room door is not excessive. Wall penetrations also should be sealed. Planned and unplanned leakage should be addressed during the commissioning stage of the project.

2.2 Thermal Comfort

Isolation rooms require a higher air change rate than normal patient rooms, creating a risk of potentially uncomfortable air velocities. Local temperature control should be provided in the isolation room to allow the clinical staff to make adjustments based on the patient's preference.

2.3 Pressure Monitoring

Room pressure measurement is critical in isolation rooms. Design guidelines such as ASHRAE 170 require that AII and PE rooms "*shall have a permanently installed device and/or mechanism to constantly monitor the differential air pressure between the room (when occupied by patients with a suspected airborne infectious disease) and the corridor, whether or not there is an anteroom. A local visual means shall be provided to indicate whenever negative differential pressure is not maintained*."

2.3.1 Ball-in-tube

A ball-in-tube device is the simplest measurement instrument. This will only indicate which area is pressurized and does not provide an actual pressure reading.

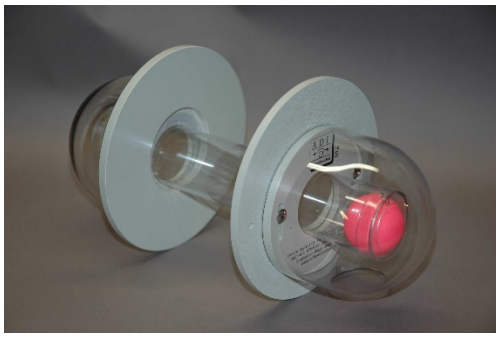

Figure_6: Image from AirFlow Direction

2.3.1 Hot Wire Anemometer

This specially manufactured tube with a built-in hot wire anemometer calculates very low air velocities due to the pressure difference between one room and another. It gives very accurate room pressure readings when the device is new.

After a period, lint builds up on the hot wire anemometer, causing artificiallylow pressure readings and unnecessary energy usage. Semiannual maintenance is required to clean the flow element and maintain the system. These sensors provide data back to a Building Management System to display pressure and provide alarming.

2.3.2 Room Monitors

A final technology for room pressure monitoring is to use room monitors utilizing a capacitive sensor with a thin diaphragm. These sensors provide very low differential pressure readings and have a high accuracy (±0.5% or ±0.25%). They are also “dead-ended” which avoids the potential of cross contamination and misreading caused by dirty build up. The room pressure monitor typically has a display indicating the actual room pressure locally and remotely to the BMS though a BACnet interface (MSTP or IP), as well as other room parameters such as temperature, humidity and air changes.

Please note the accuracy of these devices is much higher than commercial grade DP gages. When testing or commissioning these devices, make sure the testing instrument has an accuracy that is higher or equal to the DP transmitter.

These sensors have no requirement for routine maintenance, but a periodic check of system calibration is recommended.

Note: Most Pressure monitors require an input from the door contacts. If the door is the sliding type, they often swing out, as well requiring two contacts wired in series.

Figure_7: Images from Setra

2.4 HEPA Filter Monitoring

The HEPA filters must be correctly maintained and monitored for both PE and AII rooms. The location of the HEPA filter should be considered during the design stage to ensure that it can be safely replaced and inspected during maintenance.

Continuous monitoring of the HEPA filter should be provided at the BMS to monitor the dirty status and then documented. Dirty filters contribute to higher airflows and lead to increased energy use of the systems.

In most applications, a differential pressure switch or sensor (accuracy +/-2%) is used to determine the pressure drop across the filter. The dirty filter values are typically listed on equipment schedules and mechanical drawings and set up during commissioning. The pressure sensor provides more accurate readings of filter conditions and can help with planning of maiteneance.

Figure_8: EP Series Differential Pressure / Air Velocity Transducer – Schneider Electric

2.5 Door Interlocking

Door interlocks are another consideration when designing isolation rooms. Interlocks between doors are a control requirement to ensure the corridor-Ante Room and Ante Room-patient room do not open at the same time. This is achieved through an access control system or local door lock mechanism.

When an interlock is provided, an emergency release is installed to override.

Once the door is open, the door contacts are wired to the room pressure monitor to inhibit alarms from the local pressure monitoring device. Should the door remain open for longer than one minute, the alarm is enabled.

The airflow is maintained at the last known offset value.

2.6 Redundancy and Power Backup

The isolation room systems should be part of the essential power systems to ensure fans, alarms and monitoring systems do not fail if there is a loss of power to the building. For infectious isolation rooms a duty/standby, fan arrangements may be needed on the exhaust system to provide reliability and the ability to carry out maintenance without impacting the room pressure. Temporary exhaust systems may also also be needed

The IEC standards specify the following

“IEC-710.313.1.102 Power supply for medical locations of group 2

In case of a single fault in the power supply, a total loss of power shall be prevented. This may be achived by:

- *Provision of two independent supplu lines, and/or*
- *A UPS system within the same fire section for supplying the medical IT system, or*
- *A UPS system which supplies a number of group 2 locations”*

3 Solution Overview

Schneider Electric's offer is dependent on how the mechanical systems are designed and installed. The ventilation application will require precise control of the airlow to mainatin the requried volume. The ventilation system will be a variable air volume (VAV) box supplied with either a venturi valve or a single damper balde type.

3.1 Venturi Valve

The venturi valves are pressure independent control devices that have a curved body that functions as a value seat. The value has a cone that moves in and out by an internal spring to mechanically compensate for pressure changes in the system. The movement of this cone restricts airflow into the space.

These units are calibrated at the factory to provide a contstant output of airflow. The accuracy depends on the flow versus the position of cone.

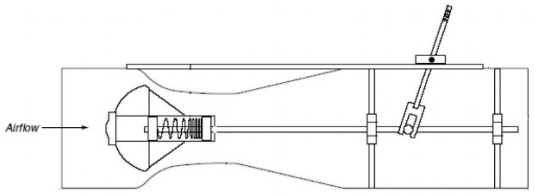

Figure_9: Venturi valve diagram

When venturi values are in place, the BMS provides a local DDC controller for monitoring of the effective airflow from both the suppy and exhaust values. The airflow offset is achived mechanically when the system is desiged and commissionied. A position feedback of the actuating shaft is monitored and logged in the BMS, but is not an air flow measurement. The differential pressure sensor provides alarming should the system fail to maintain the correct pressure.

A MP-C is used to provide control of the heating coil on the supply systems and monitoring of the HEPA filter on the exhaust.

Note: if an electric heating element is used, an interlock is needed to ensure air flow is present before enabling the heating element.

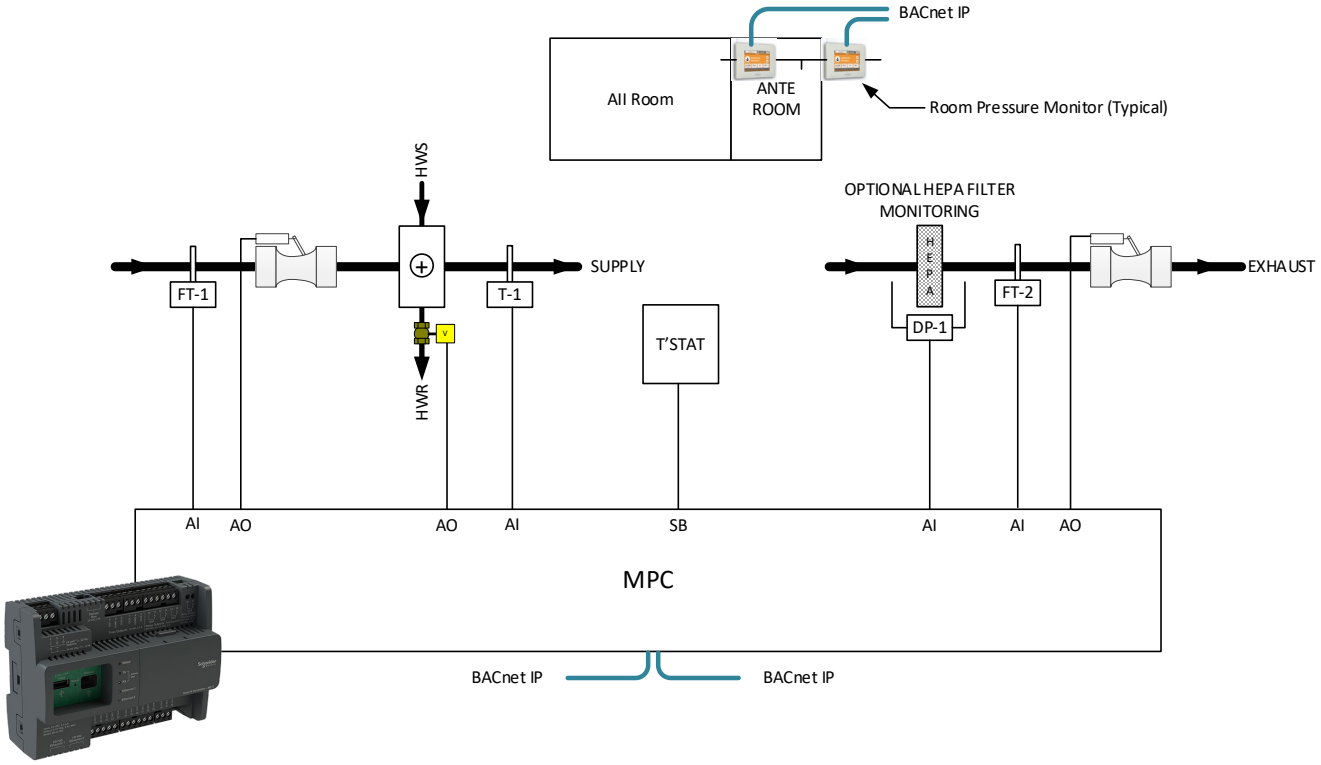

Figure_10: Controller configuration for Schneider Electric MP-C

3.2 Single Blade Damper

A single blade damper functions by rotating the damper blade to adjust the air flow, from almost fully open to fully blocked. They are pressure-depenedant and require an actuating device to control the damper position and an air flow sensor. The air flow sensor provides closed-loop control to adjust the damper position based on the actual air flow reading. The air flow sensor detects the change in pressure in the system and commands the actuator to adjust the damper blade until the setpoint is satisfied.

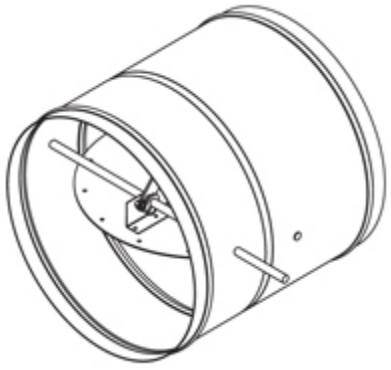

Figure_11: Single-blade damper diagram

Single blade dampers are typically part of Variable Air Volume (VAV) boxes, and MP-V controllers and installed on both the supply and exhaust. A 2-10V signal is recommended between the primary box and the slave box to ensure the air flow offset is maintained. In a negative pressure room, the exhaust box is the primary unit. In a

positive pressure room, the supply box is the primary unit. The 2-10V signal is calibrated during the commissioning stage so that an alarm is generated if the signal is at or below 2V.

The MP-V is also used to provide control of the heating coil on the supply systems and monitoring of the HEPA filter on the exhaust.

Note: if an electric heating element is used, an interlock is needed to ensure flow is present before enabling.

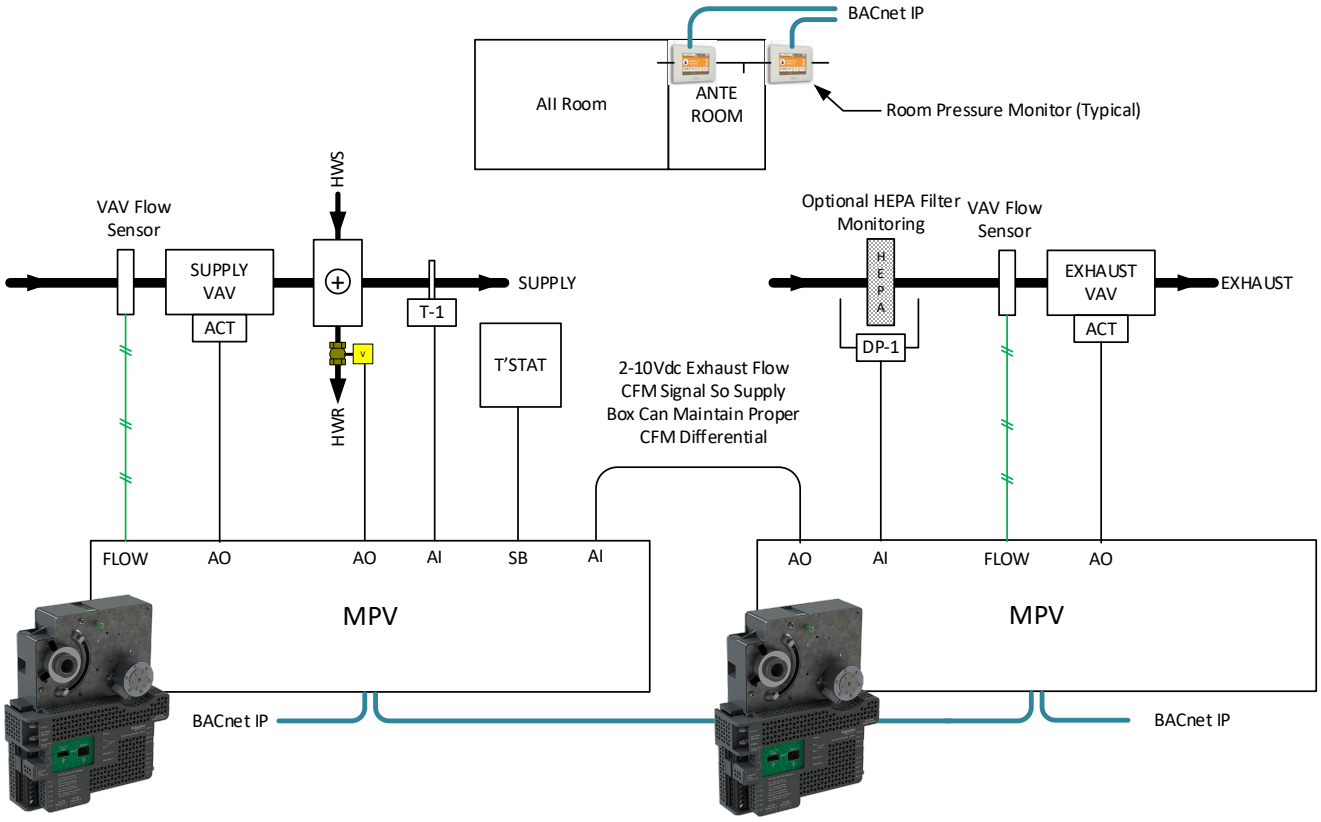

Figure_10: Controller configuration for Schneider Electric MP-V

4 Design Guidelines

4.1 ASHRAE 170

ASHRAE 170 Minimum Requirements						
Space	Pressure Relationship to Adjacent Spaces	Min Outdoor ACH	Min Total ACH	All Room Air Exhausted Directly to Outdoors	Design %RH	Design Temp
AII Ante Room	-0.01"WC -2.5Pa	NR	10	Yes	NR	NR
AII Room	-0.01"WC -2.5Pa	2	12	Yes	Max 60%	70-75°F 21-24°C
PE Ante Room	+0.01"WC +2.5Pa	NR	10	NR	NR	NR
PE Room	+0.01"WC +2.5Pa	2	12	NR	Max 60%	70-75°F 21-24°C
Combination AII/PE Ante Room	***	NR	10	Yes	NR	NR
Combination AII/PE Room	+0.01"WC +2.5Pa	2	12	Yes	Max 60%	70-75°F 21-24°C
ACH = Air Changes per Hour NR = No Requirement						

***

An isolation room cannot set up to be an AII room one day and a PE room the next, per ASHRAE 170. However, ASHRAE 170 allows a combination AII/PE room provided an Ante Room is also provided. The pressure relationship to adjacent areas for the required anteroom shall be one of the following:

1. The anteroom shall be at a positive pressure with respect to both the AII/PE room and the corridor or common space.
2. The anteroom shall be at a negative pressure with respect to both the AII/PE room and the corridor or common space.

4.2 UK: Health Building Note 04-01- Supplement 1

Table 1. Isolation suite – ventilation parameters		
Room	Parameter	Nominal design values
Lobby	Room volume Bed access lobby (5 m2 × 2.7 m) Personnel access lobby (4 m2 × 2.7 m)	 13.5 m^3 10.8 m^3
	Pressure differential to corridor Nominally 10 pascals	Nominally 10 pascals
	Supply air flow (see Note 3)	Bed access lobby – 238 L/s Personnel access lobby – 208 L/s
	Air change rate	Bed access lobby – 63 per hour lobby – 69 per hour
Isolation	Room volume (19 m2 × 3 m)	57 m^3
	Pressure differential to corridor	Nominally zero
	Room air flow	158 L/s
	Air change rate	10 per hour
En-suite	En-suite Room volume (6 m2 × 2.7 m)	16.2 m^3
	Pressure differential to isolation room	Negative
	Extract air flow	158 L/s (if extract is fitted in the isolation room this reduces to approximately 100 L/s in the ensuite with approximately 58 L/s extract in the isolation room)
	Air change rate	At least 10 per hour

Notes

1. In this example, the design parameters are based on Health Building Note 04-01 – 'Adult in-patient accommodation'. The en-suite is sized to comply with BS 8300 accessibility requirements.

2. The air flow rates quoted do not include any allowance for construction leakage. Airtightness specifications are given in Approved Document L of the Building Regulations (2010). See also the Air Tightness Testing & Measurement Association's (ATTMA) 'Technical Standard L2: Measuring air permeability of building envelopes (non-dwellings)' (see Appendix 2).

3. These are typical values based on standard room sizes. The actual volume of air required will be the sum of the air required to provide 10 air changes per hour in the patient's room + the air leakage through the door between the lobby and corridor at a differential pressure of 10 pascals.

Reference: https://www.gov.uk/government/publications/adult-in-patient-facilities

4.3 Australia: Victorian Advisory Committee on Infection Control

Guidelines for the classification and design of isolation rooms in health care facilities, 2007.			
Type of Pressurization	**Isolation Room**	**Anteroom**	**Ensuite**
Class S (Standard Pressure)	NR	NR	NR
Class N (Negative Pressure)	-30 Pa	-15 Pa	-30 Pa
Class P (Positive Pressure)	+30 Pa	+15 Pa	+30 Pa
Class P with negative pressure Anteroom	+15 Pa	-15 Pa	+30 Pa

Reference: http://www.eunid.eu/public/Australia_isolation_rooms_2007.pdf