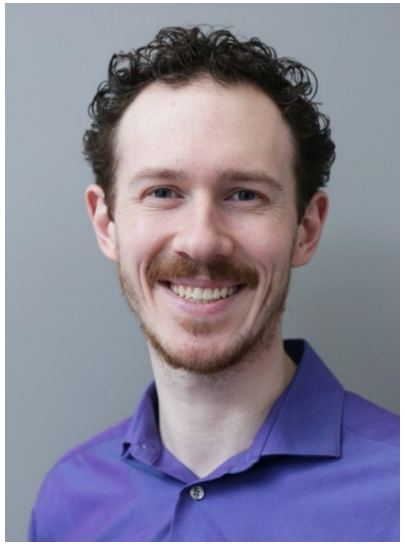
Room Pressurization Solutions for Critical Spaces



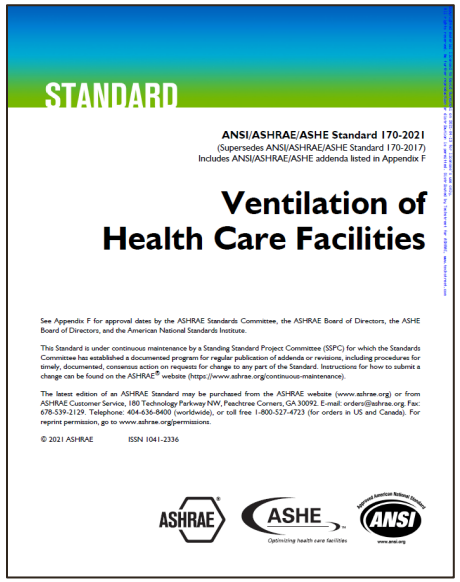
Curtis Carrick
Technical Sales Engineer

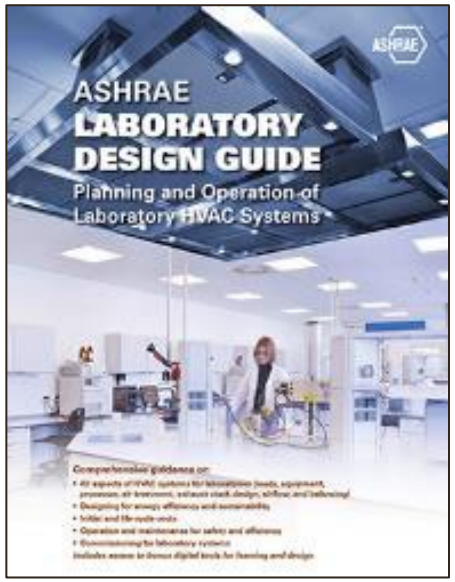
+ M.Sc. Mechanical Engineering
+ 3+ years experience designing critical spaces

Room Pressurization Controls for Critical Spaces

Agenda

+ Room pressure control
  – Creating pressurization, vs Control to a pressure setpoint
+ Critical spaces overview
+ Temperature control
+ Room pressure measurement, monitoring and control
+ Summary





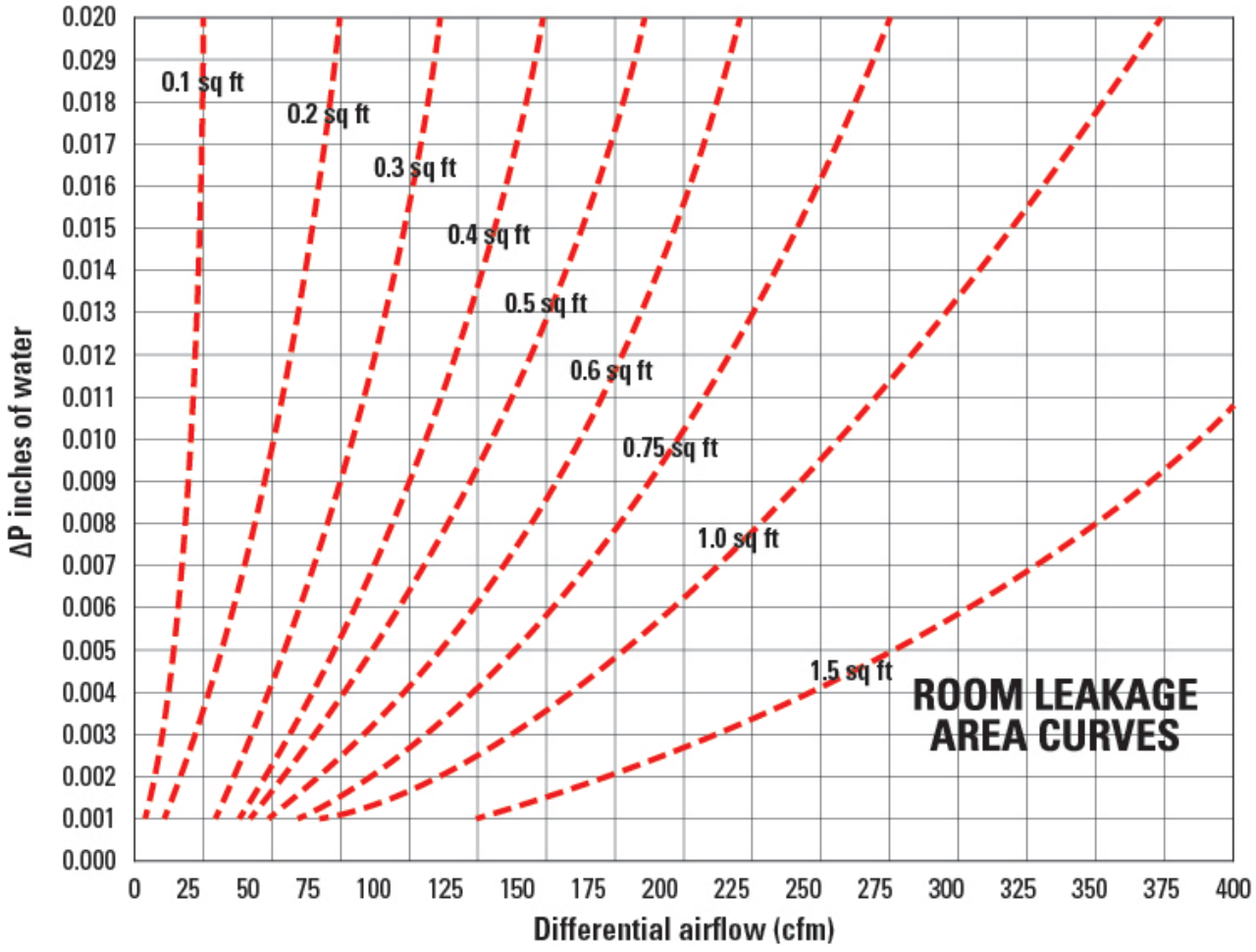
Related standards:

- *ASHRAE 170-2021: Ventilation of Health Care Facilities*
- *CAN/CSA-Z317.2-10: Special Requirements For HVAC Systems In Health Care Facilities*
- *ASHRAE Lab Design Guide, 2nd Edition – 2015*
- *ANSI Z9.5 – 2012: Laboratory Ventilation*
- *USP 795, 797, 800: Pharmaceutical Compounding (795, 797), Hazardous Drugs Handling in HC Settings (800)*

Room Pressurization Controls for Critical Spaces

Introduction

- Direction of air movement from clean to less clean spaces
  - ANSI Z9.5 (Sect 5.2.1, Page 40)
    - *"…airflow shall be from areas of low hazard to higher hazard unless the laboratory is used as a barrier facility, such as a clean room…"*
- Difference between supply and exhaust
- Air changes may be reduced when room is not in use
- Tightly sealed rooms

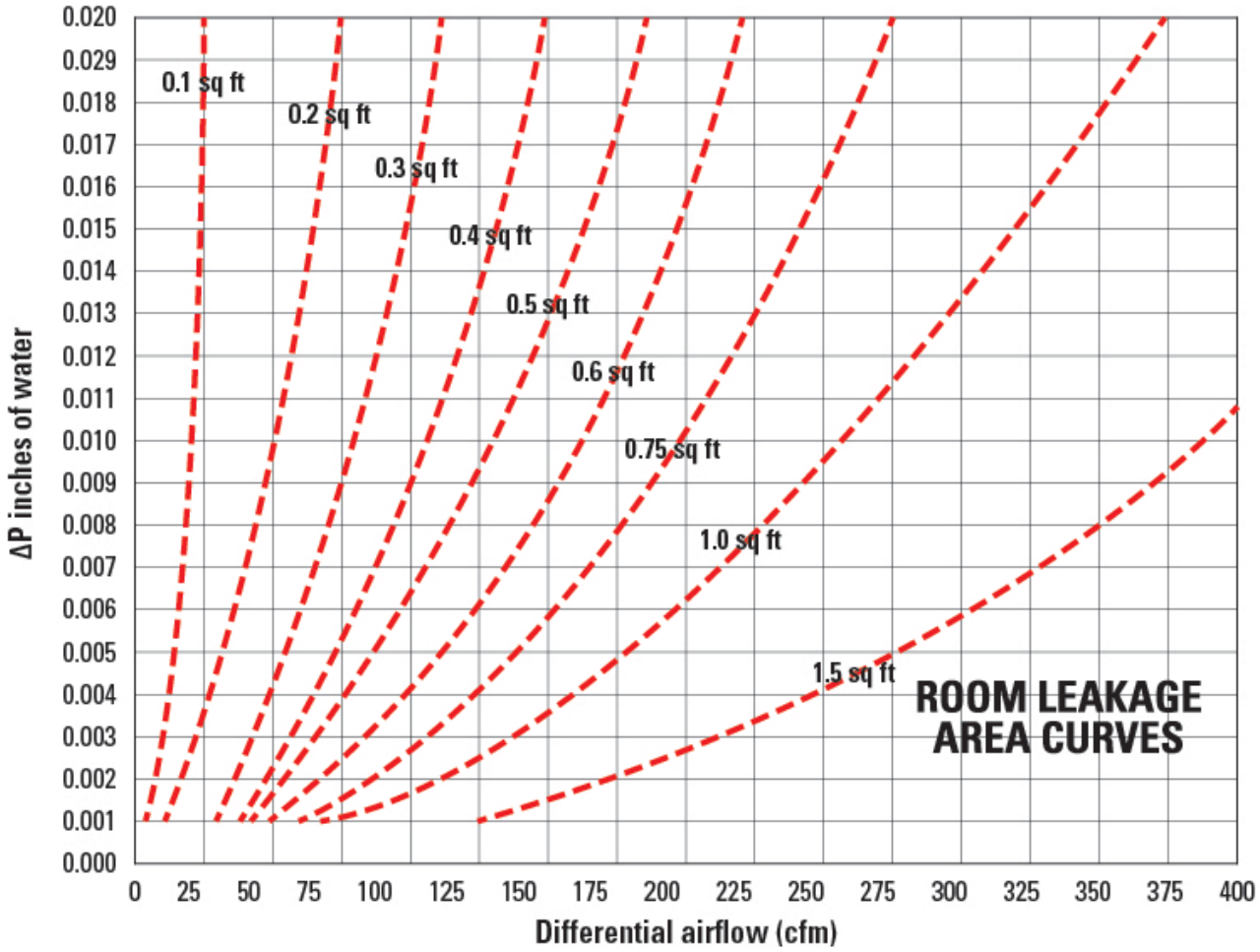


DeLuga. *"Differential airflow, pressure, have key relationship in pressurization."* Lab Design 1997(2)

Room Pressurization Controls for Critical Spaces

Introduction

- ANSI/AIHA Z9.5 (Sect. 5.2, Page 40)
  - *"The flow rate of Transfer Air depends on the differential pressure and the effective leakage area around the doors and through envelope. If the room envelope is tightly sealed, the leakage area is small, and there is very little Transfer Air flow for a given pressure. If the room is not so tight, the leakage area is larger, and more Transfer Air flows for the same differential pressure."*



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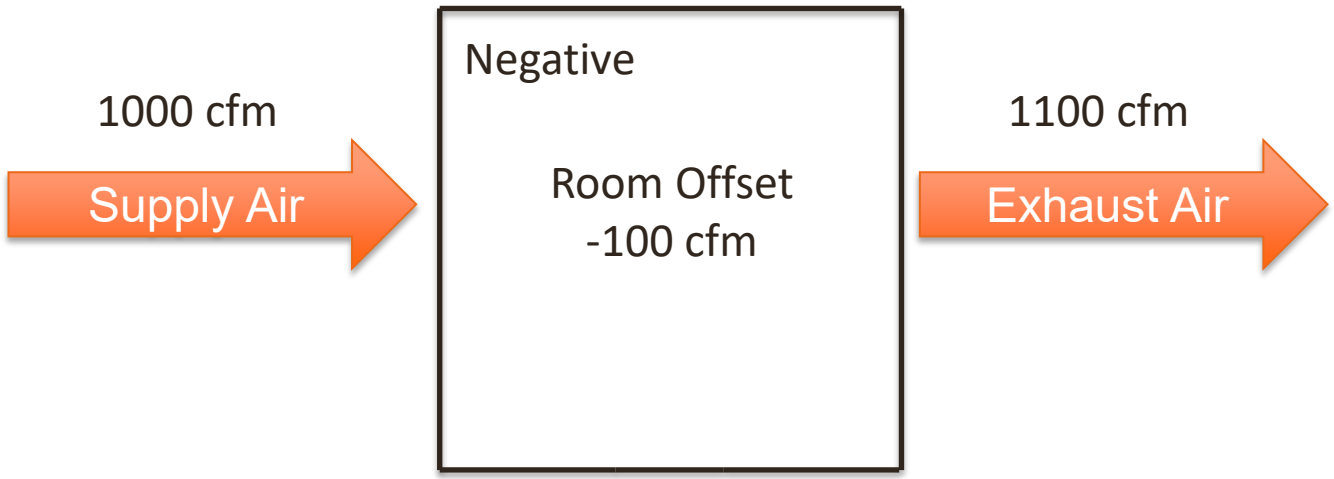
Room Pressurization Controls for Critical Spaces

Creating Pressurization

+ **Volumetric offset control (ie. Flow Offset)**
  - Open loop control
  - Maintains a constant CFM offset between supply and exhaust valves
    - Regardless of room mode: occupied, unoccupied, etc
  - Independent of room pressure
  - Most common solution (especially in laboratory applications)
  - Room pressure sensor and door contact switches can be used for **monitoring**



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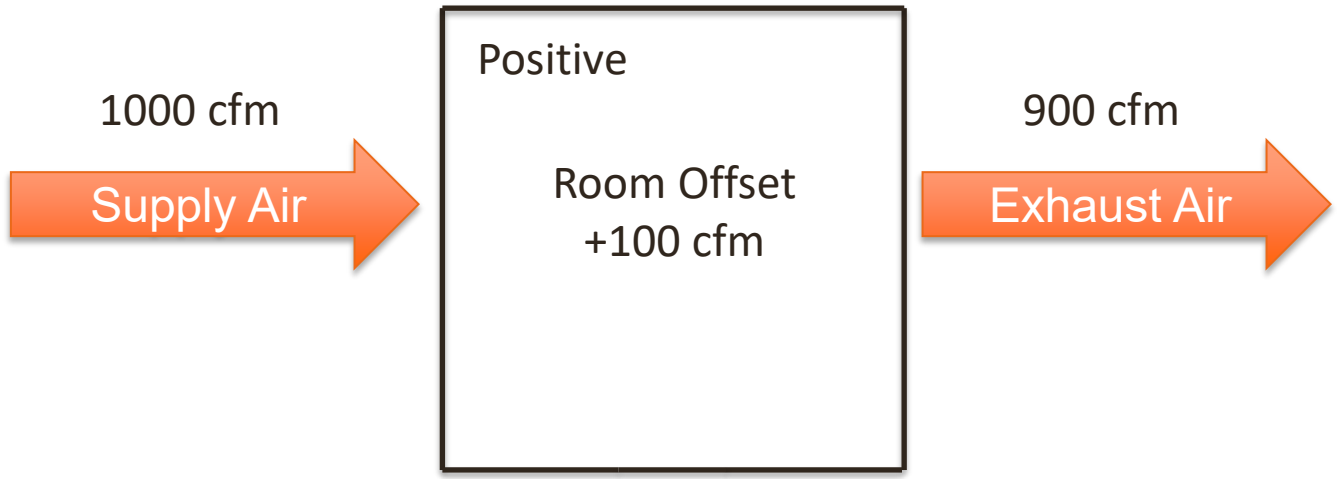
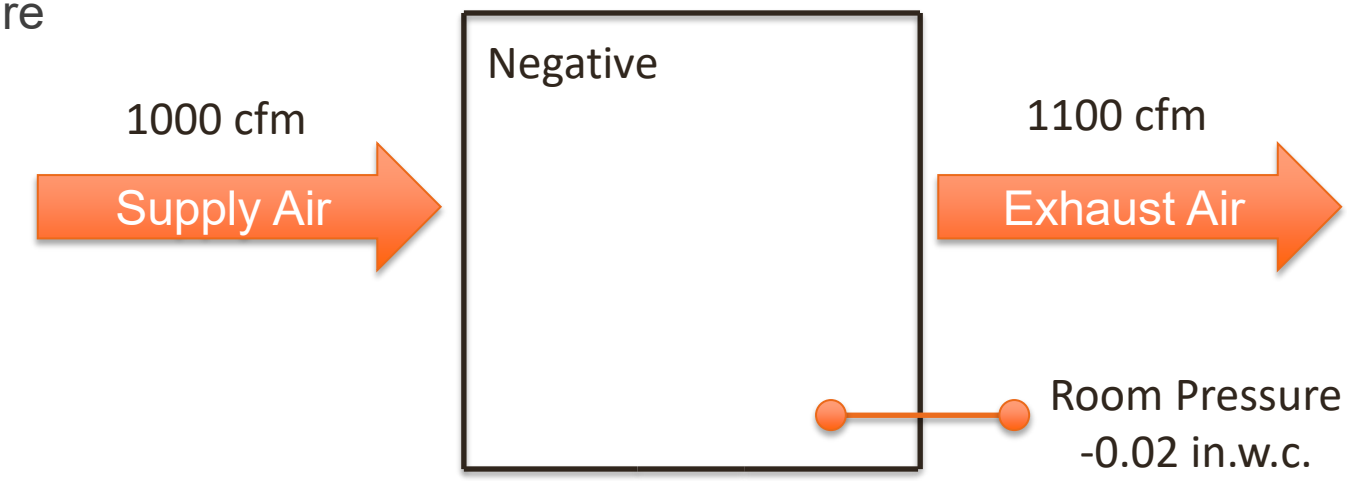


Room Pressurization Controls for Critical Spaces

Controlling to a Pressure

- **Direct pressure control**
  - Closed loop control
  - Airflow adjustment based on room pressure
    - Separate pressure targets for each room mode: occupied, unoccupied, etc
  - Independent of room offset
  - Becoming more common in pharmacy applications
  - Room pressure sensor and door contact switches can be used for **control**
  - ANSI Z9.5 (Sect 5.2.1, Page 41)
    - *"It is impractical to maintain a differential pressure across an open door."*



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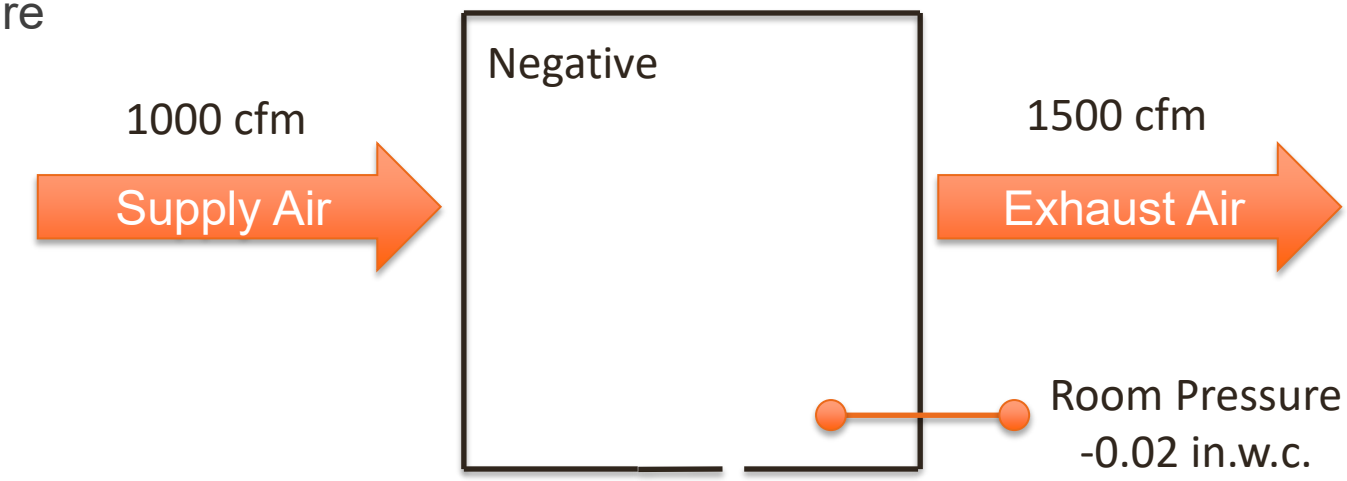

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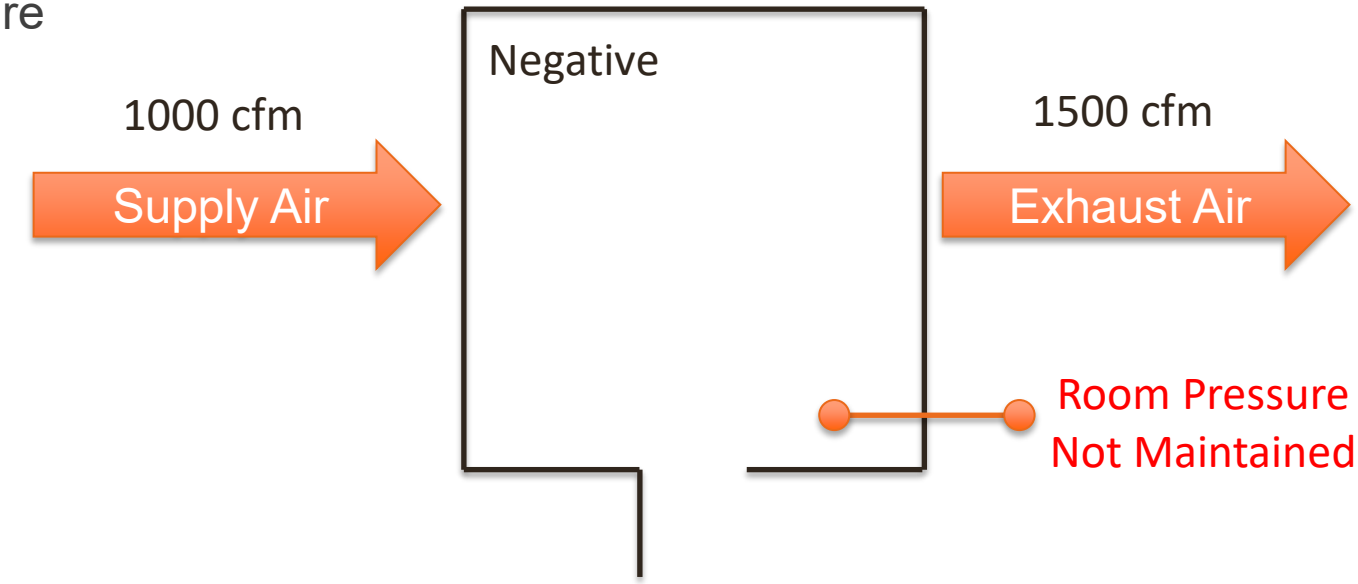
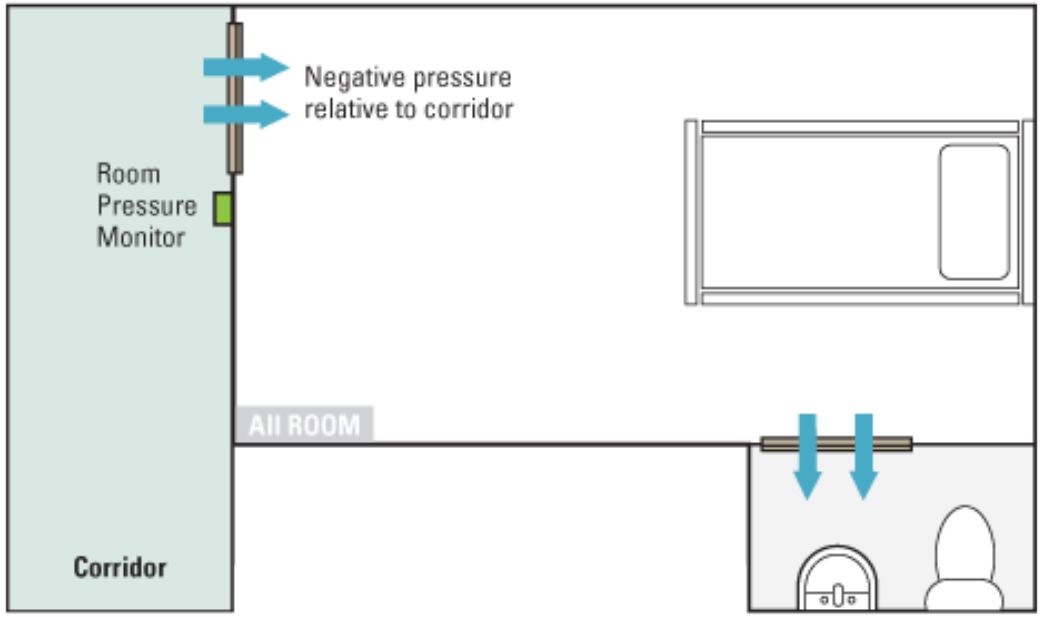


Room Pressurization Controls for Critical Spaces

Healthcare

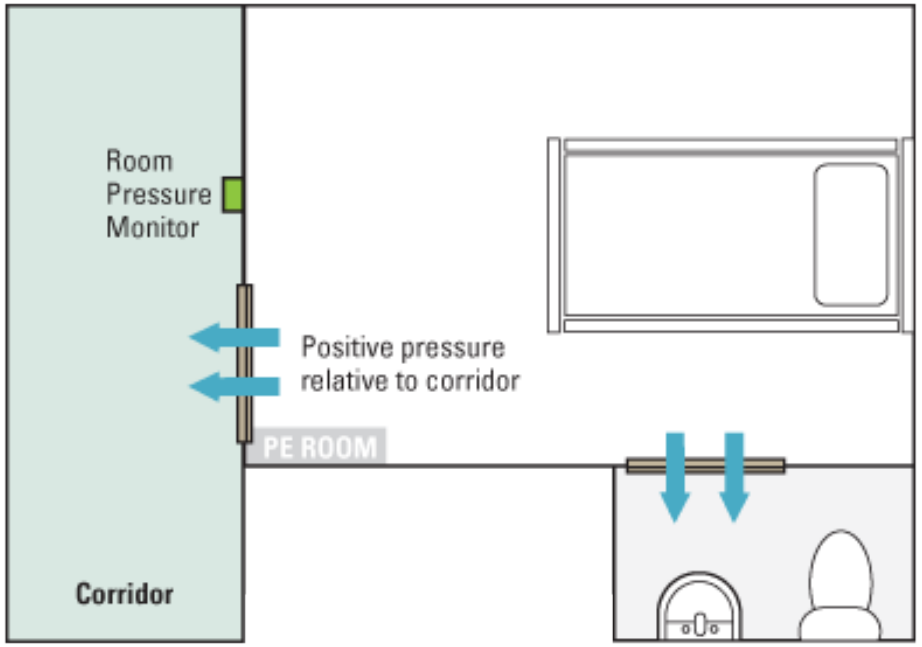
+ Airborne Infection Isolation (AII)



Room Pressurization Controls for Critical Spaces

Healthcare

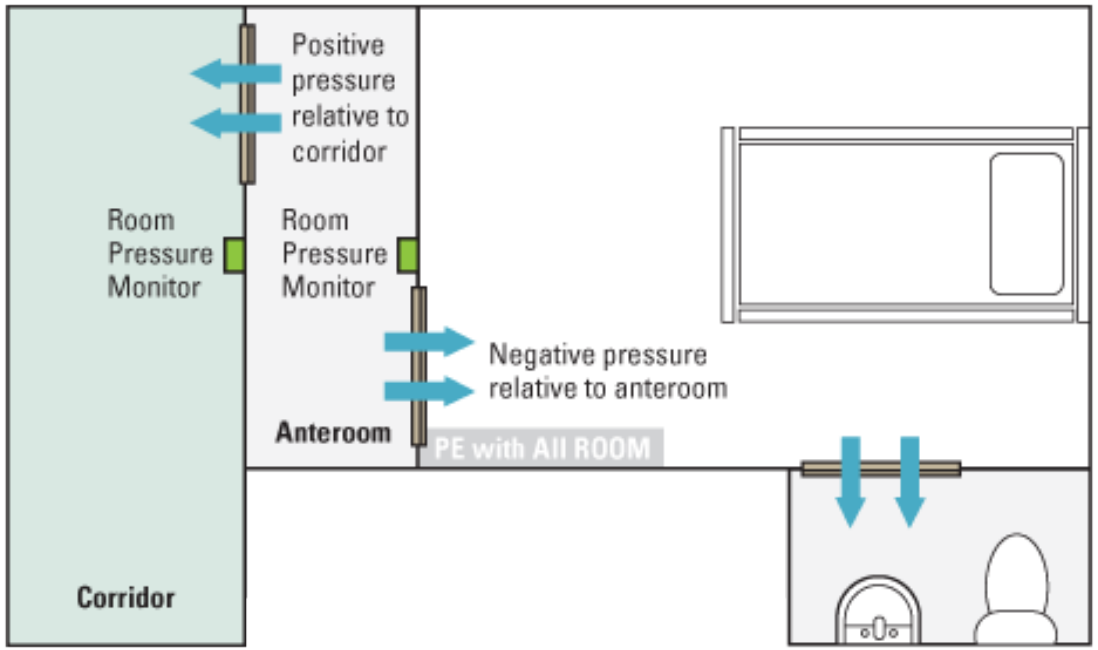
+ Protective Environment (PE)



Room Pressurization Controls for Critical Spaces

Healthcare

+ Protective Environment (PE) *with* Airborne Infection Isolation (AII)



Room Pressurization Controls for Critical Spaces

Healthcare

+ Isolation Room (AII,PE) Requirements
  - ASHRAE 170-2021
  - CAN/CSA-Z317.2-10
- Minimum room pressure differential relative to adjacent spaces
  - ASHRAE / CDC: 0.01”W.C.
  - CSA: +/- 0.03”WC (7.5 Pa)
- Rooms shall have a permanently installed device to constantly monitor the differential pressure
- A local visual means shall be provided to indicate whenever negative differential pressure is not maintained

Room Pressurization Controls for Critical Spaces

Healthcare

+ Isolation Room (AII,PE) Requirements
  - AII and PE rooms require minimum 12 ACH
  - Ante rooms require minimum 10 ACH
  - ACH may be reduced when room not in use
- Airborne infection isolation rooms shall have provisions for normal patient care when protective isolation is not required
- Room pressurization shall not be switched from positive to negative or vice versa
- Anterooms are only required for rooms occupied by immunocompromised patients also requiring airborne infection isolation

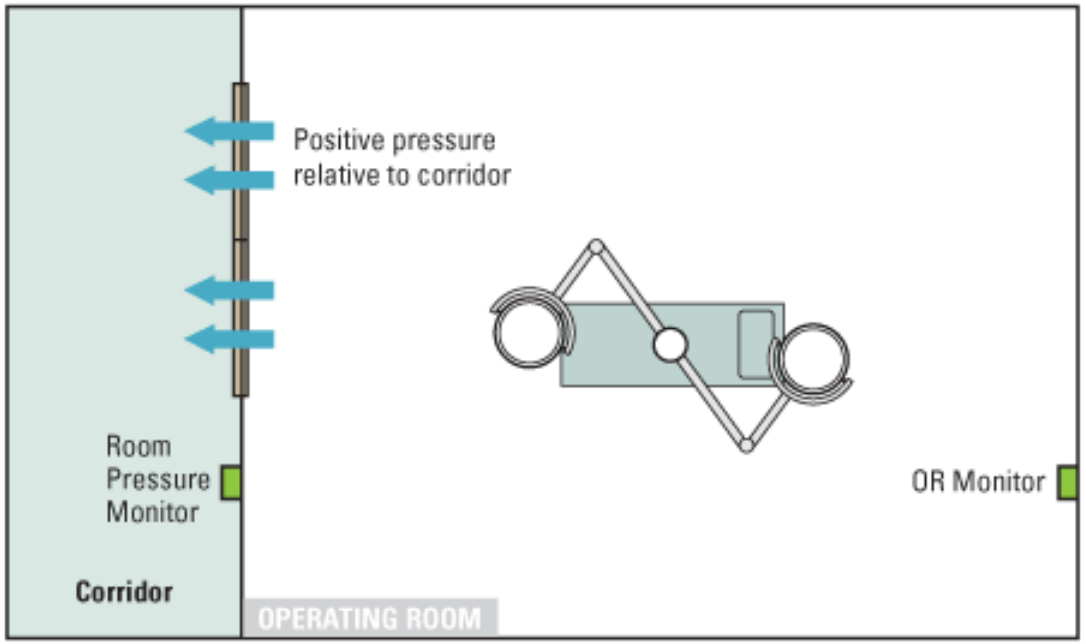
ASHRAE®

CSA Group™

Room Pressurization Controls for Critical Spaces

Healthcare

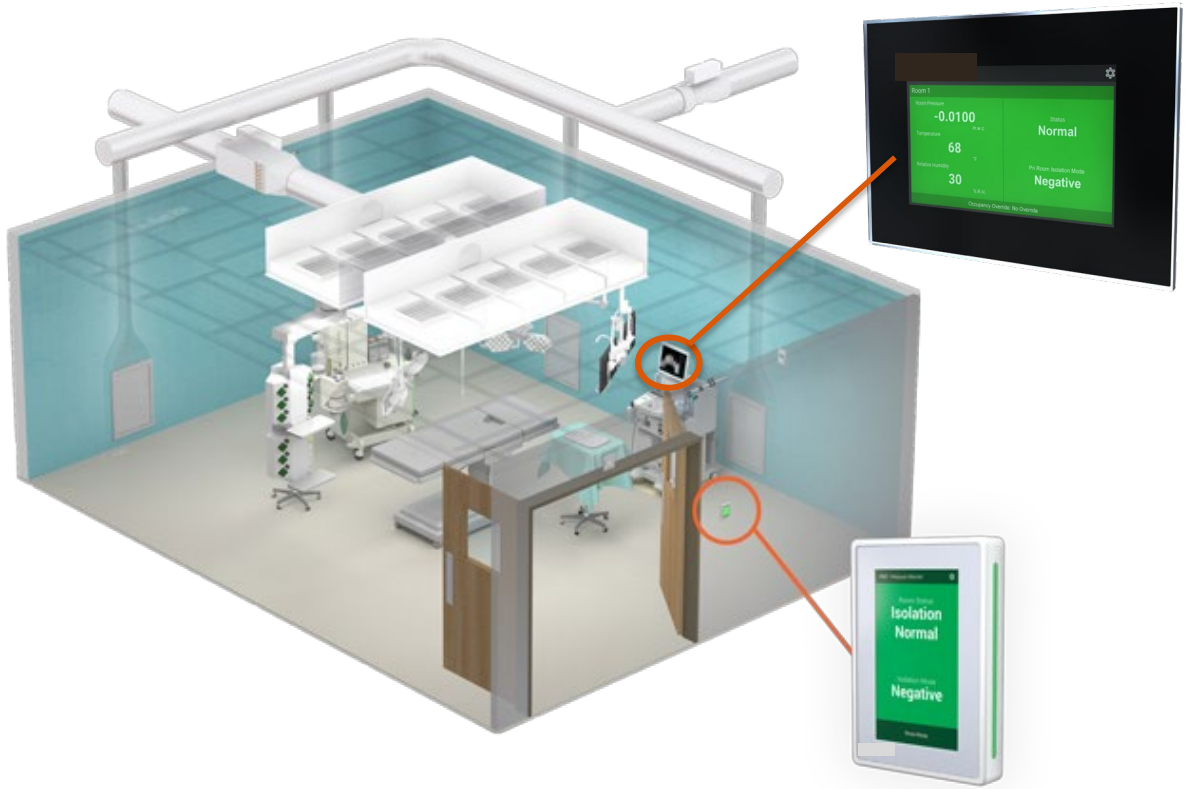
+ Operating Room



Room Pressurization Controls for Critical Spaces

Healthcare

- Operating Room
  - Positive room pressure
  - Relatively high in/out occupant traffic
  - High air change rates
  - Pressure monitor requirements



Room Pressurization Controls for Critical Spaces

Healthcare

+ Operating Room Requirements
  - ASHRAE 170-2021
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- Minimum room pressure differential relative to adjacent spaces
  - ASHRAE: 0.01”W.C.
  - CSA: +/- 0.03”WC (7.5 Pa)

Room Pressurization Controls for Critical Spaces

Healthcare

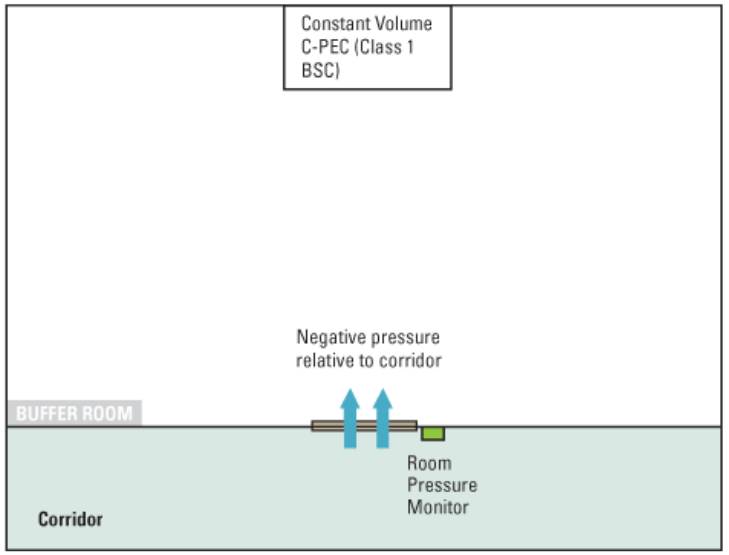
+ Operating Room Requirements
  - Minimum 20 ACH
  - ACH may be reduced when room not in use
- If pressure-monitoring device alarms are installed, allowances shall be made to prevent nuisance alarms

Room Pressurization Controls for Critical Spaces

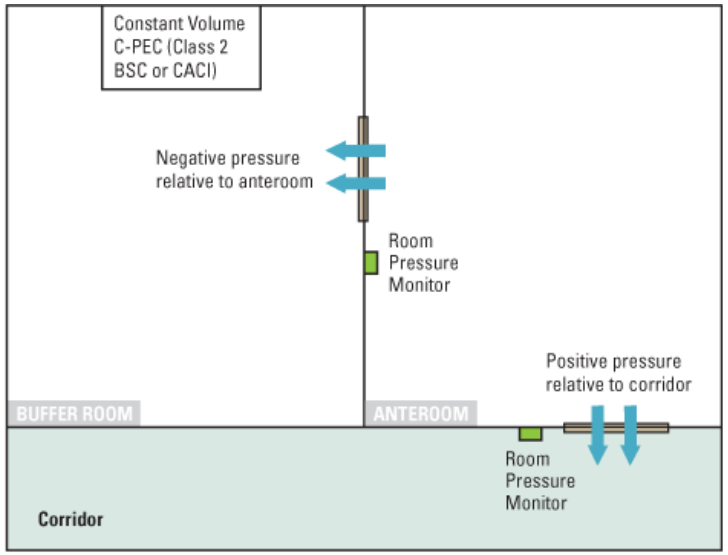
Compounding Pharmacy

- Types of isolation: buffer vs ante
- Types of compounding:
  - Sterile vs non-sterile
  - Hazardous vs non-hazardous

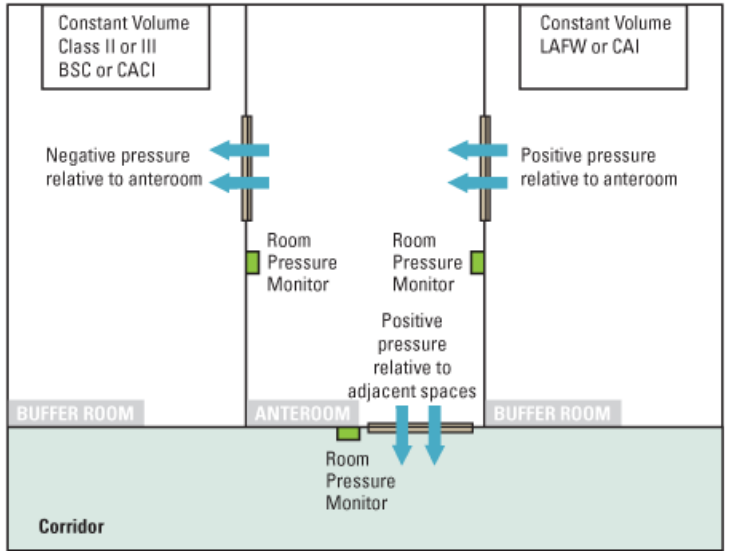
NON-STERILE



STERILE



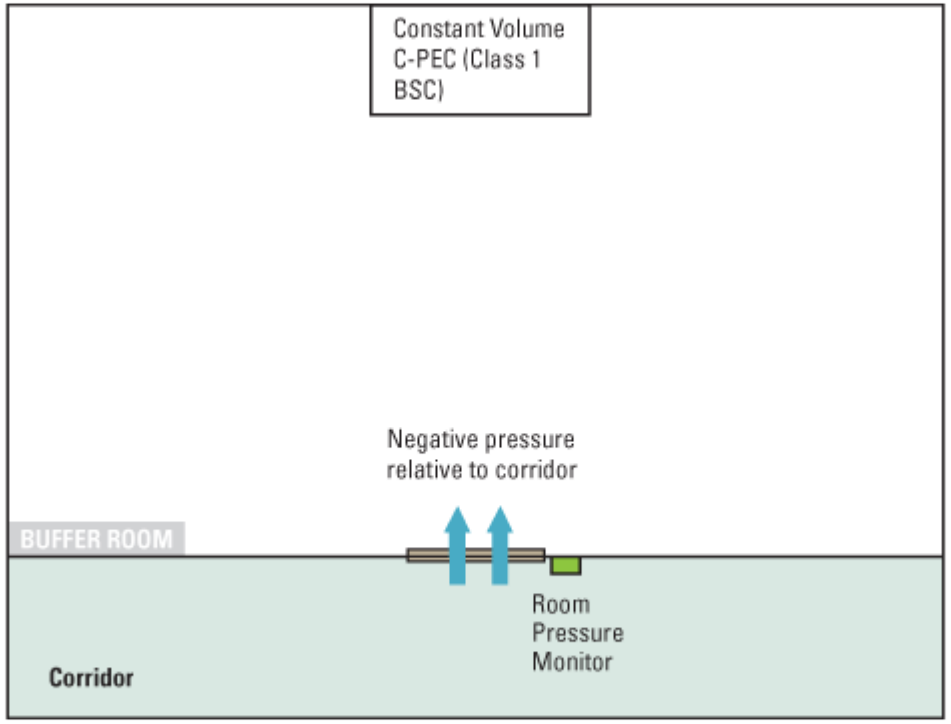
STERILE



Room Pressurization Controls for Critical Spaces

Compounding Pharmacy

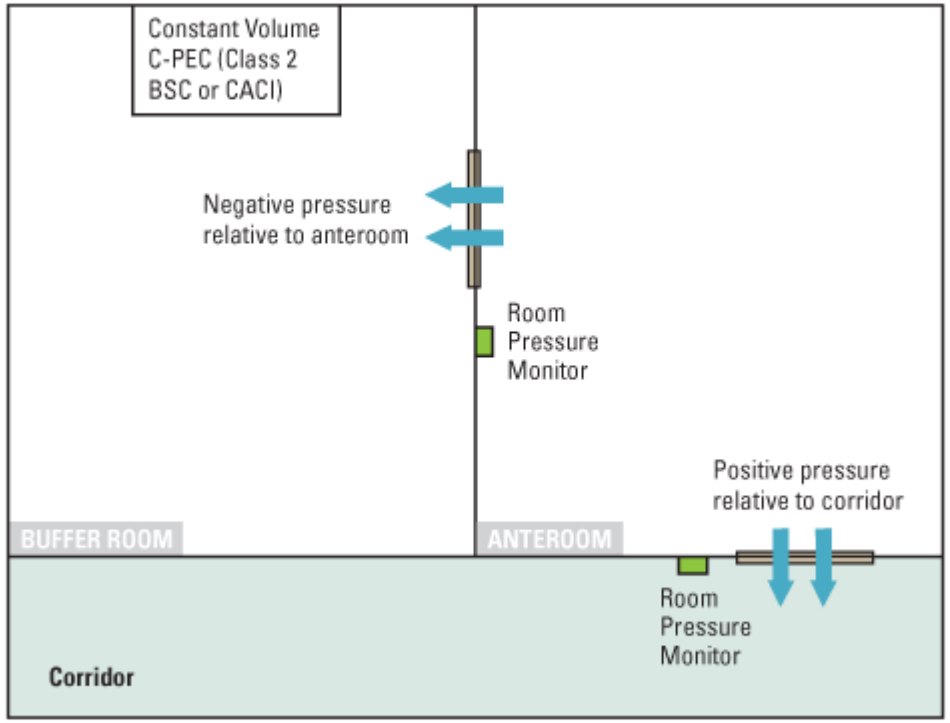
+ Non-Sterile Pharmacy



Room Pressurization Controls for Critical Spaces

Compounding Pharmacy

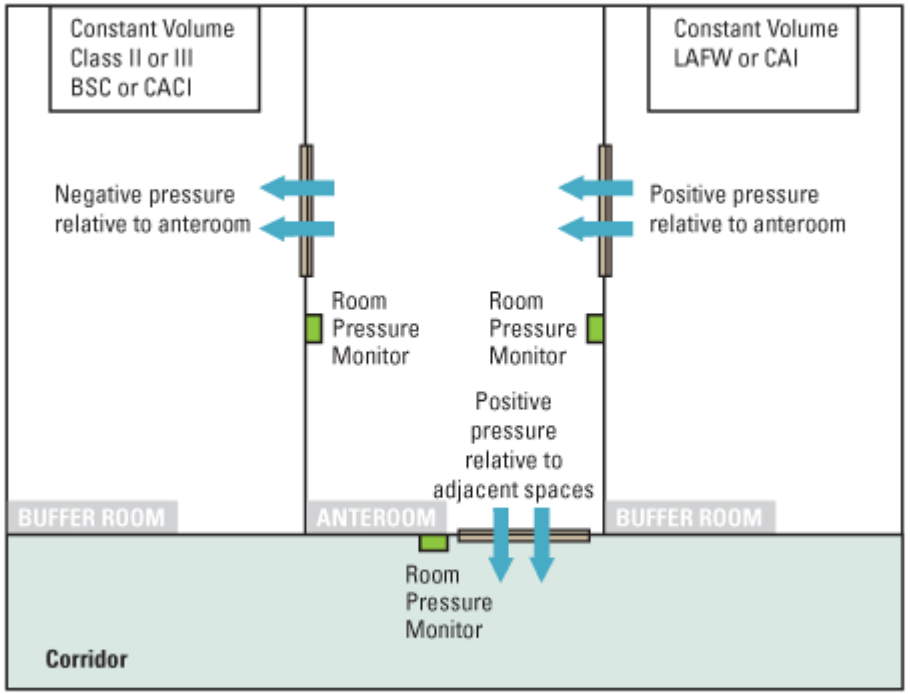
+ Sterile Pharmacy



Room Pressurization Controls for Critical Spaces

Compounding Pharmacy

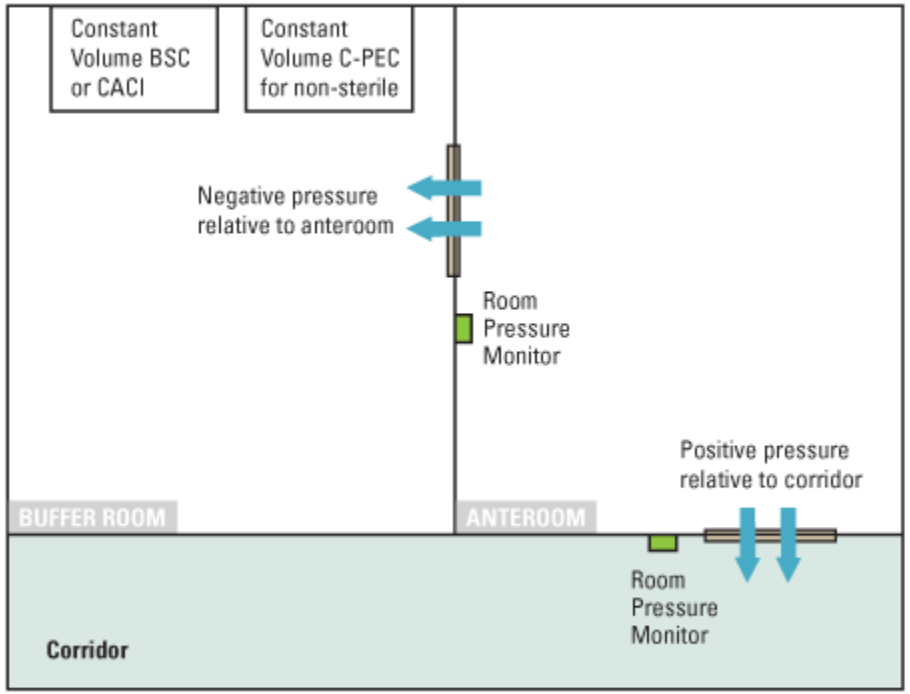
+ Sterile Pharmacy



Room Pressurization Controls for Critical Spaces

Compounding Pharmacy

+ Non – Sterile/Sterile Combo Pharmacy



Room Pressurization Controls for Critical Spaces

Compounding Pharmacy

+ Pharmacy Requirements
  - USP <797>
  - USP <800>
  - CSHP

- Rooms shall have continuous pressure monitoring
- Minimum room pressure differential relative to adjacent spaces
  - -0.01-0.03 in w.c. Buffer Rooms
  - +0.02 in w.c. Ante Rooms

USP U.S. Pharmacopeial Convention™

Canadian Society of Hospital Pharmacists
Société canadienne des pharmaciens d'hôpitaux

Room Pressurization Controls for Critical Spaces

Compounding Pharmacy – USP 795, 797, 800

+ Pressure and air change requirements

	Sterile	Non Sterile
Hazardous Drugs Room	Negative (-0.01 in.w.c. to -0.03 in.w.c.) 30 ACH	Negative (-0.01 in.w.c. to -0.03 in.w.c.) 12 ACH
Non Hazardous Drugs Room	Positive (+0.02 in.w.c. to +0.05 in.w.c.) 30 ACH	Positive 4 ACH
Hazardous Drugs Anteroom	Positive (Minimum +0.02 in.w.c.) 30 ACH	Positive (Minimum +0.02 in.w.c.) 12 ACH
Non Hazardous Drugs Anteroom	Positive (Minimum +0.02 in.w.c.) 30 ACH	N/R

+ A pressure indicator shall be installed that can be readily monitored for correct room pressurization
  - *It further states*: The results shall be renewed and documented on a log at least every work shift (minimum frequency shall be at least daily) or by a continuous recording device.

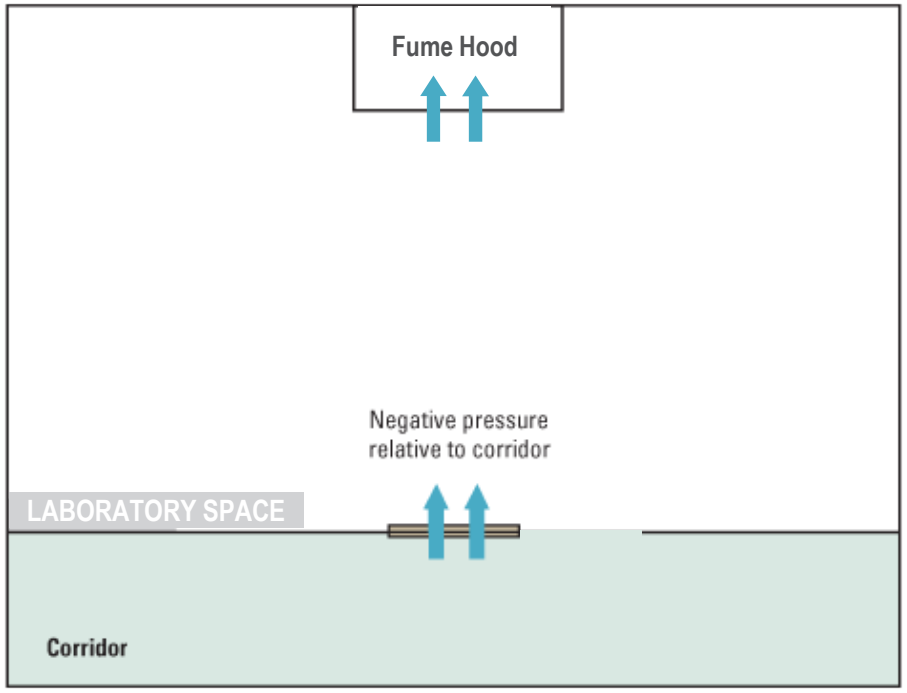
Room Pressurization Controls for Critical Spaces

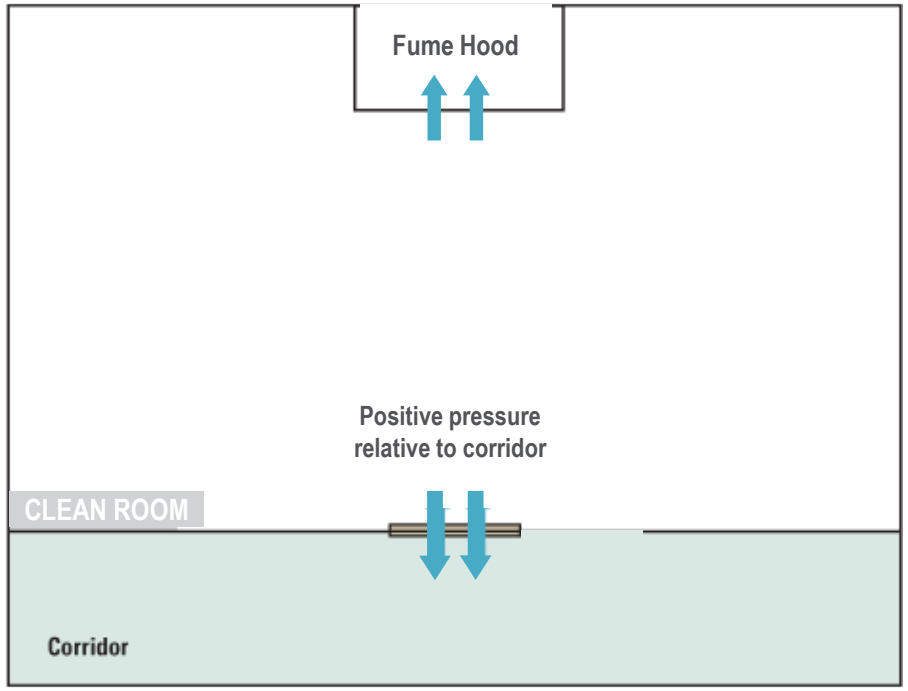
Laboratory

Room Pressurization Controls for Critical Spaces

Laboratory

- Types of laboratory spaces
  - R&D or wet labs: negatively pressurized
  - Clean rooms: positively pressurized





Room Pressurization Controls for Critical Spaces

Laboratory

- **2015 ASHRAE Handbook – HVAC Fundamentals (Ch. 16, Pages 12-13)**
  - *direct pressure control sequences function best in the presence of "slow disturbances only", whereas "fast disturbances (e.g., VAV fume hoods)" are explicitly listed as a factor that favors a flow offset control solution.*
- **ASHRAE Laboratory Design Guide 2nd Ed (Ch. 11, Page 173)**
  - *"… the HVAC system for a laboratory is often subjected to rapid disturbances or changes, such as those caused by opening doors, opening sashes on numerous fume hoods at once, or turning on large pieces of heat-generating equipment. Such disturbances require a fast response from the control system to maintain the precise conditions required in the laboratory."*
- **ANSI Z9.5 Laboratory Ventilation (Sect 5.2, Page 41)**
  - *Such factors lead to flow offset control as being "the most commonly applied approach" to room pressurization control in laboratories.*
- **ANSI Z9.5 Laboratory Ventilation (Sect. 6.3.5.2, Page 80)**
  - *"…10 seconds will be an acceptable time to achieve the desired area pressurization", subject to any applicable hazard evaluations.*

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Room Pressurization Controls for Critical Spaces

Laboratory

- **ASHRAE Laboratory Design Guide (Chapter 11)**
  - *Fixed minimum airflow rates in the range of 6 to 12 air changes per hour (ach) when the space is occupied have been used in the past. However, recent university research (Klein et al. 2009) showed a significant increase in dilution and clearing performance when the ventilation rate was increased from 6 to 8 ach, with diminishing returns above 12 ach.*
  - *Minimum ventilation rates should be established on a room-by-room basis considering the hazard levels of the materials expected to be used in the room and the operations and procedures to be performed*
- **ANSI Z9.5**
  - *The specific room ventilation rate shall be established or agreed upon by the owner or his or her designee.*
  - **Further:** *An air exchange rate cannot be specified that will meet all conditions. Furthermore, air changes per hour is not the appropriate concept for designing contaminant control system*

Room Pressurization Controls for Critical Spaces

Thermal Considerations for Air Changes

- Requirement to ensure space is properly conditioned based on thermal loads
- Affected by occupancy, equipment and external loads
- Calculated values based on formulas in Chapter 16 of the ASHRAE HVAC Applications Handbook

$$Q = \frac{q}{\rho c_p \Delta T}$$

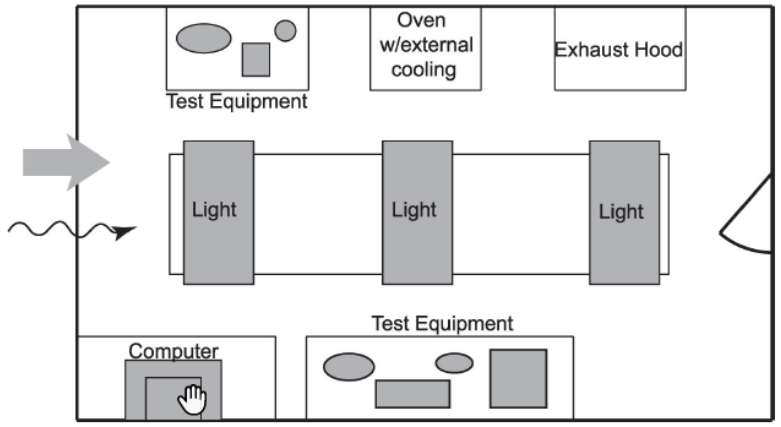
where Q = airflow rate, CFM

q = sensible heat load, Btu/h

ρ = air density (around 0.075 lb/ft^3 at/near sea level)

c_p = specific heat of air (around 0.24 Btu/lb°F)

ΔT = temperature difference between indoor and outdoor air, °F



Room Pressurization Controls for Critical Spaces

Temperature Control

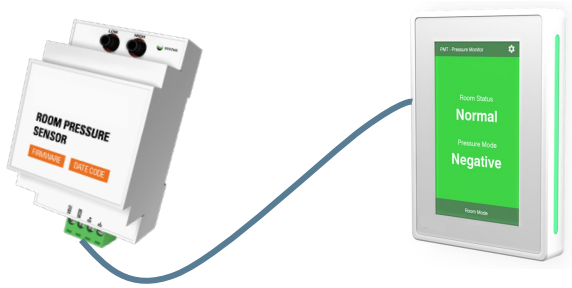
+ **Staged temperature control**
  - Reheat or cooling coil will be staged to operate from 0-100% **before** adding airflow to the room
    - Typically more efficient since water is less expensive compared to air
  - More stable because only one device is performing majority of temperature control, but can be slow
+ **Synchronous temperature control**
  - Reheat or cooling coil will operate from 0-100% at the **same time** airflow is added to the room
  - May require more PID loop tuning during commissioning
  - Can be faster to reach since more hot or cold airflow is supplied sooner in the control loop
+ **Room temperature control with DAT limits**
  - Modulating reheat or cooling coil to maintain DAT target
  - Room temperature tells DAT target to increase or decrease based on demand
  - High and low DAT limits are defined to prevent overshoot
  - Extremely stable response and therefore, may be slower to react

Room Pressurization Controls for Critical Spaces

Measurement vs Monitoring vs Control

+ Measurement
  - Device dedicated to the measurement of a physical quantity

+ Monitoring
  - Device used to display or report what is measured by another device



+ Control
  - Device using a measurement to enact change on a system
  - Monitoring device is optional

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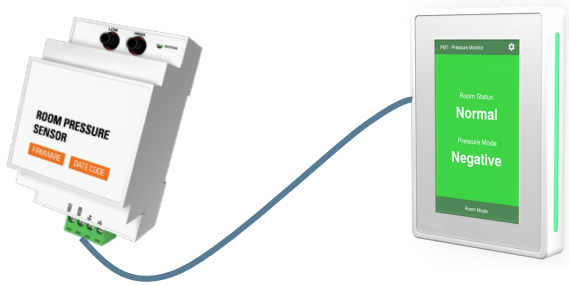

+ Control
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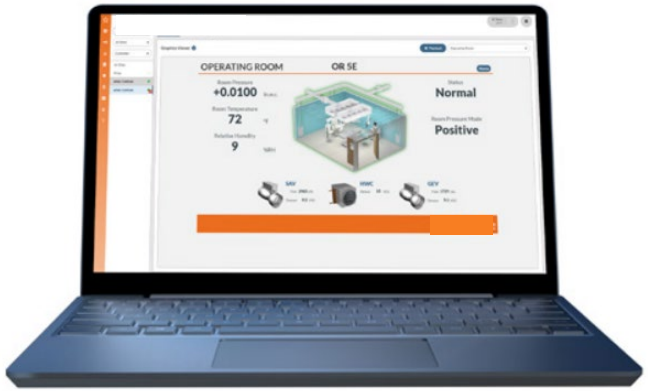
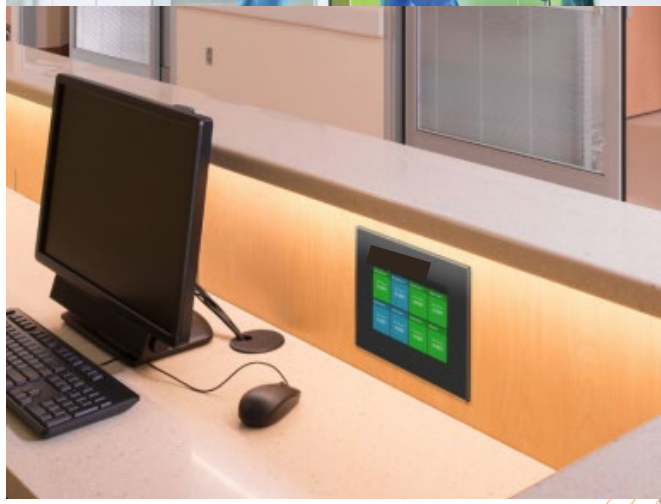
Room Pressurization Controls for Critical Spaces

Monitoring Devices



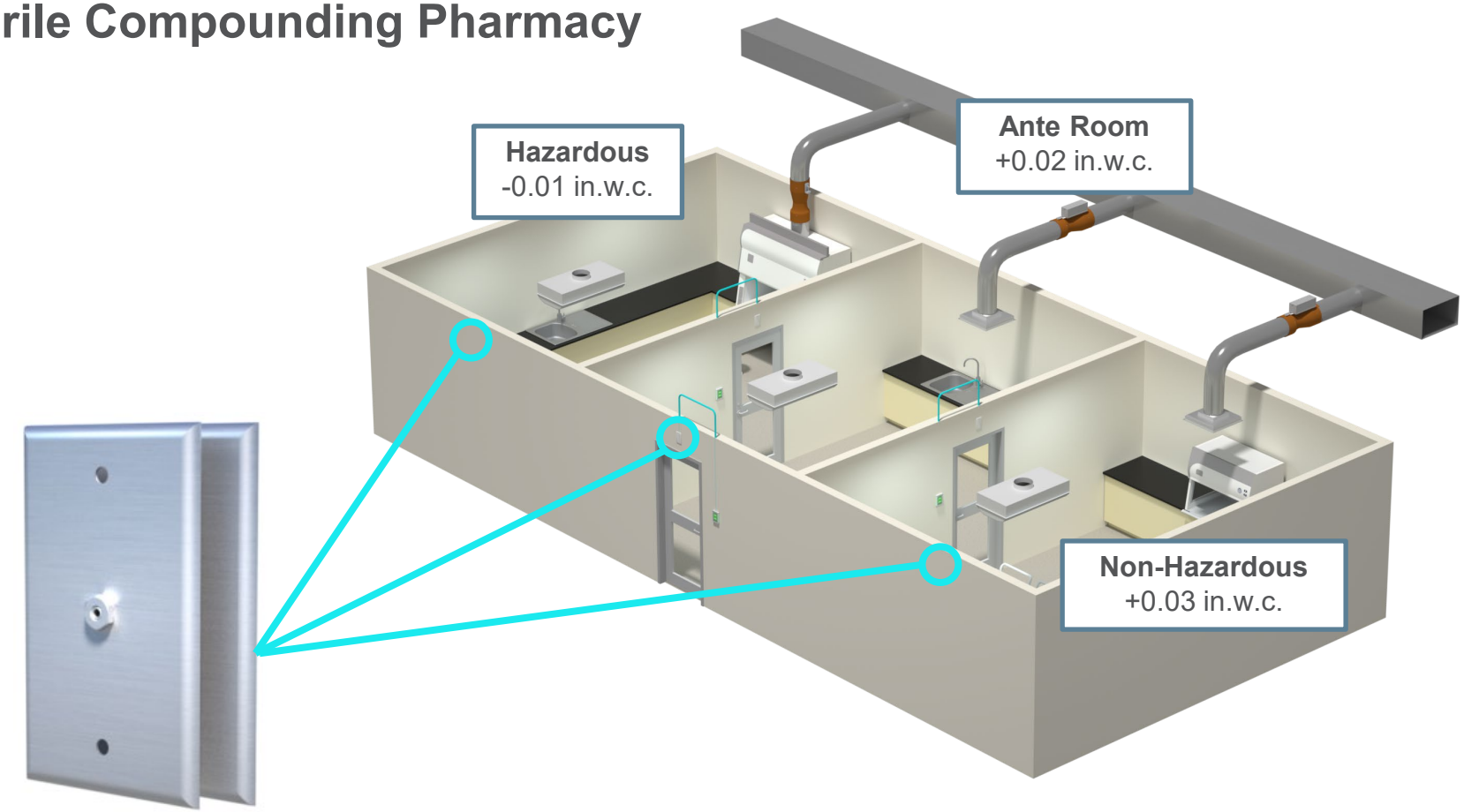
- Purpose
  - Visual indication of room pressure
- Monitor types
  - Ball-in-tube vs digital
  - Local vs remote vs off-site
  - Options: Audible alarm, integration with BAS, custom graphics, etc
- ANSI Z9.5 (Sect 5.2.1.2, Page 43)
  - *"If the direction of airflow between adjacent spaces is deemed critical, provision shall be made to locally indicate and annunciate inadequate airflow and improper airflow direction."*
- ASHRAE Laboratory Design Guide 2nd Ed (Ch. 11, Page 192)
  - *"A room pressure monitor with an alarm can be provided to verify room pressure is being maintained."*



Room Pressurization Controls for Critical Spaces

Measurement vs Monitoring Devices

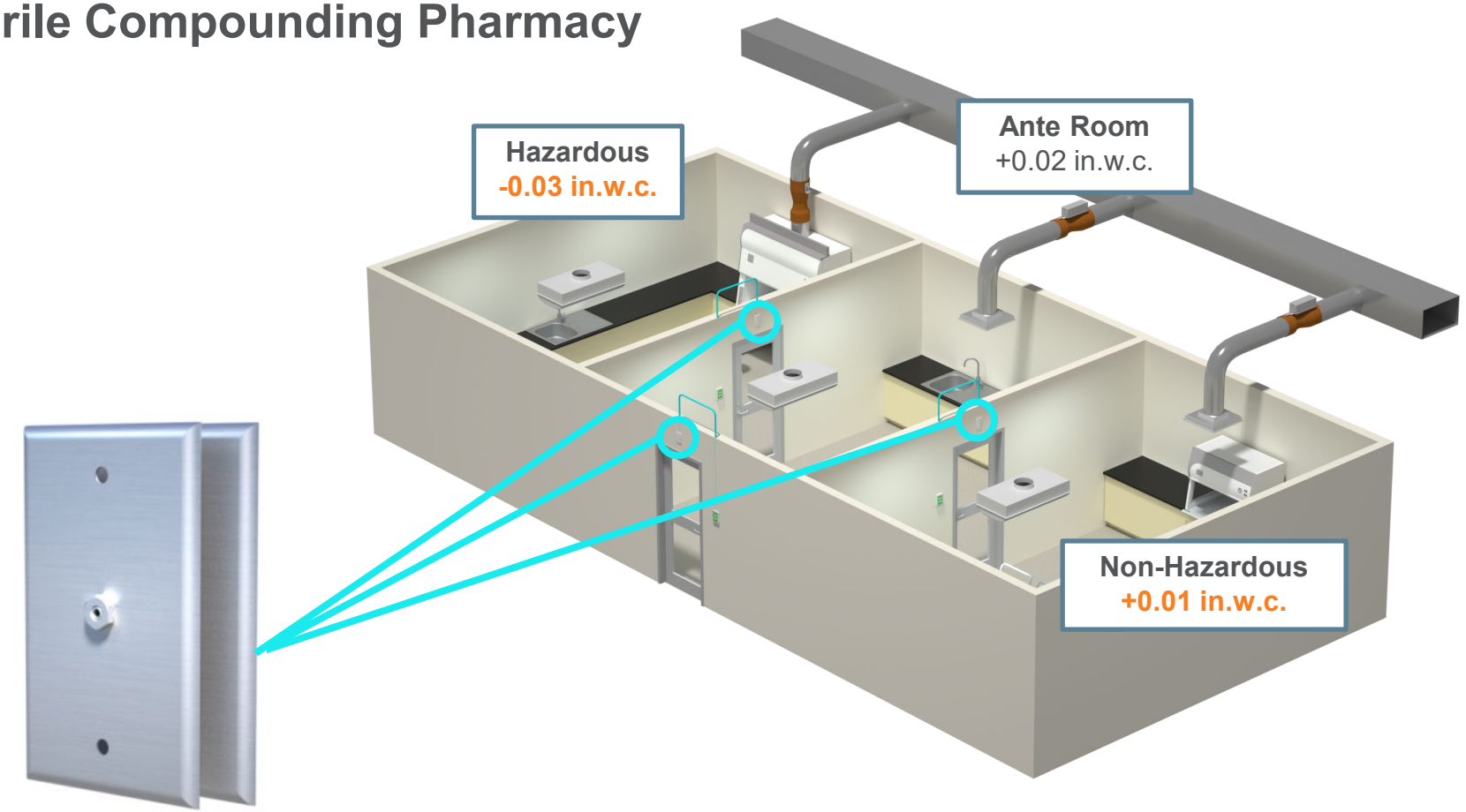
Sterile Compounding Pharmacy



Room Pressurization Controls for Critical Spaces

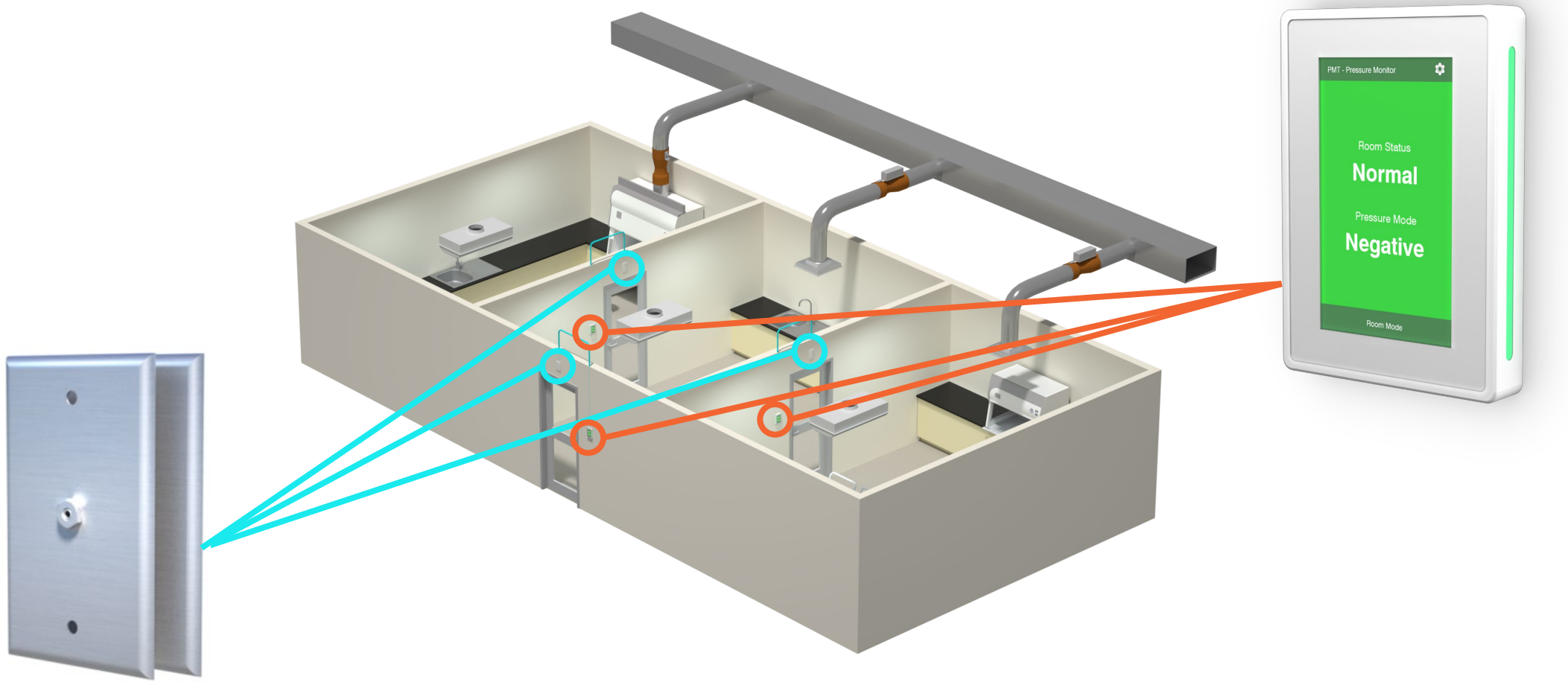
Measurement vs Monitoring Devices

Sterile Compounding Pharmacy



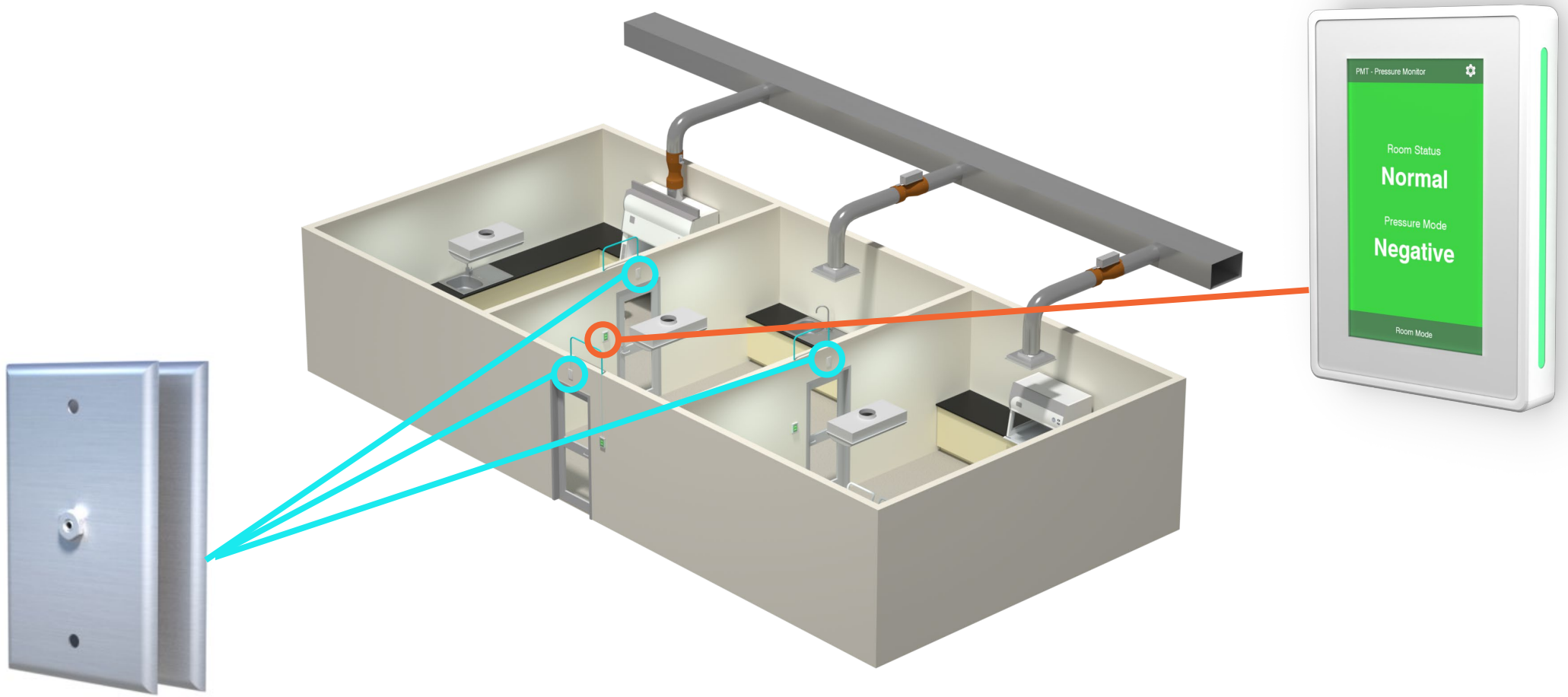
Room Pressurization Controls for Critical Spaces

Measurement vs Monitoring Devices



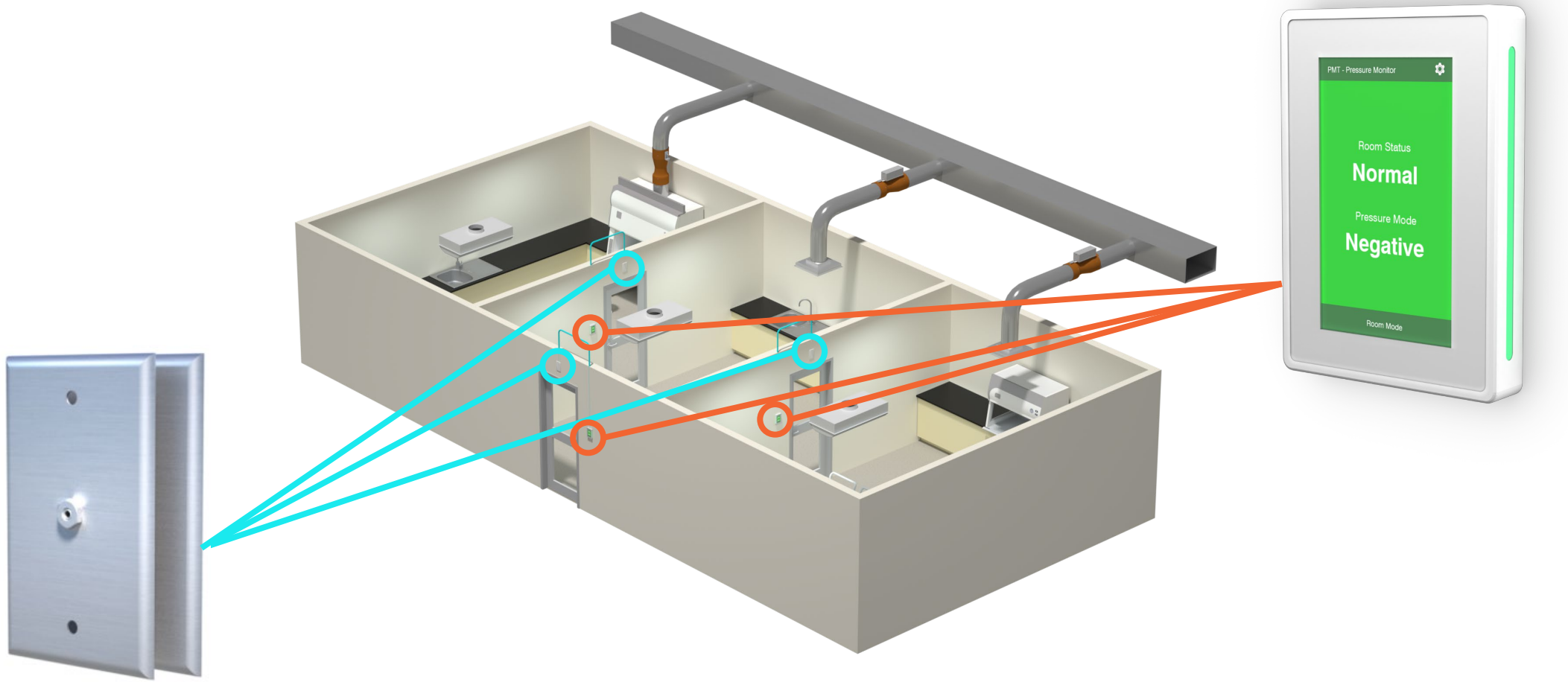
Room Pressurization Controls for Critical Spaces

Measurement vs Monitoring Devices



Room Pressurization Controls for Critical Spaces

Measurement vs Monitoring Devices



Room Pressurization Controls for Critical Spaces

Measurement vs Monitoring vs Control

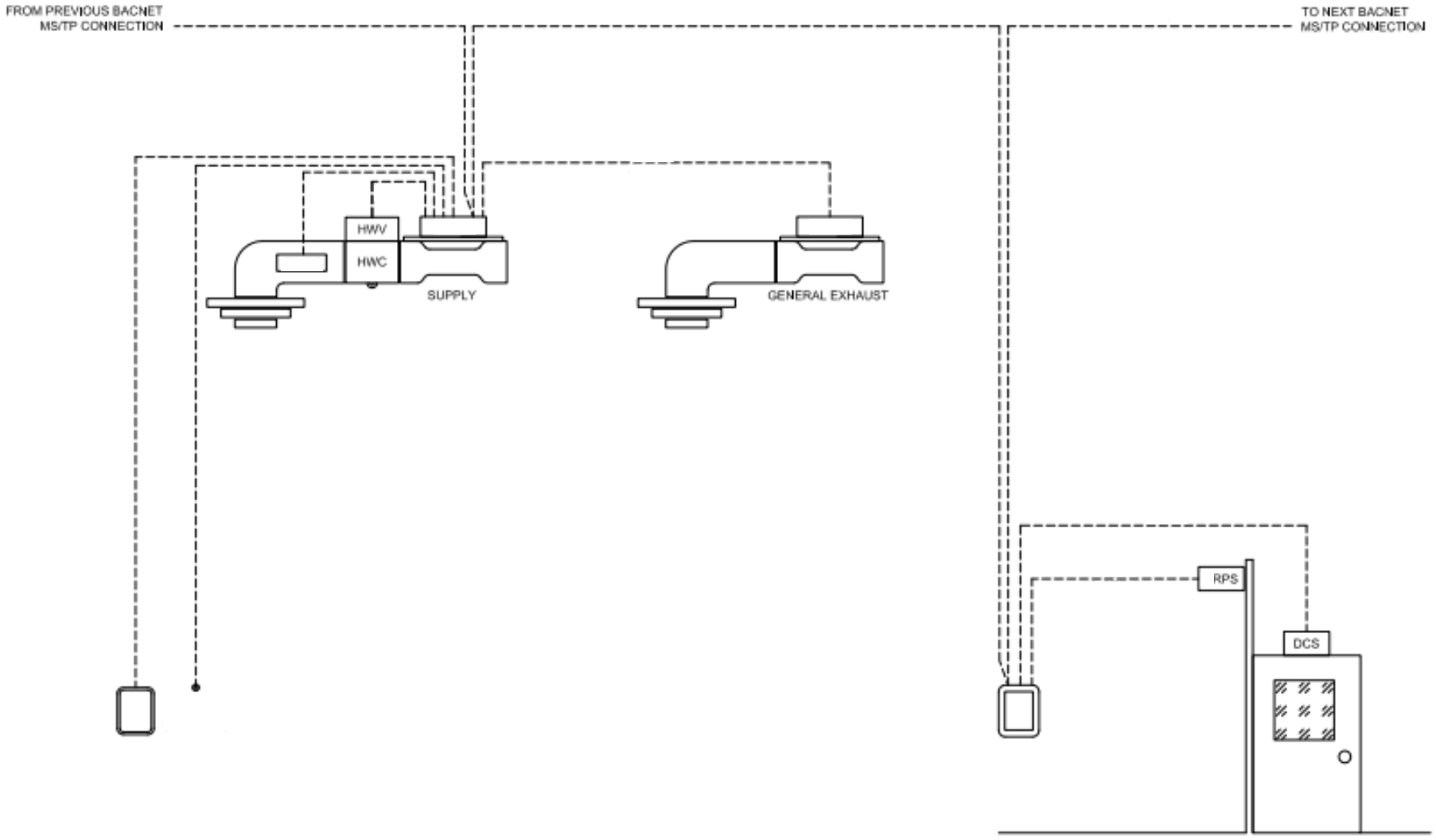
+ Measurement
  - Device dedicated to the measurement of a physical quantity

+ Monitoring
  - Device used to display or report what is measured by another device

+ **Control**
  - Device using a measurement to enact change on a system
  - Monitoring device is optional

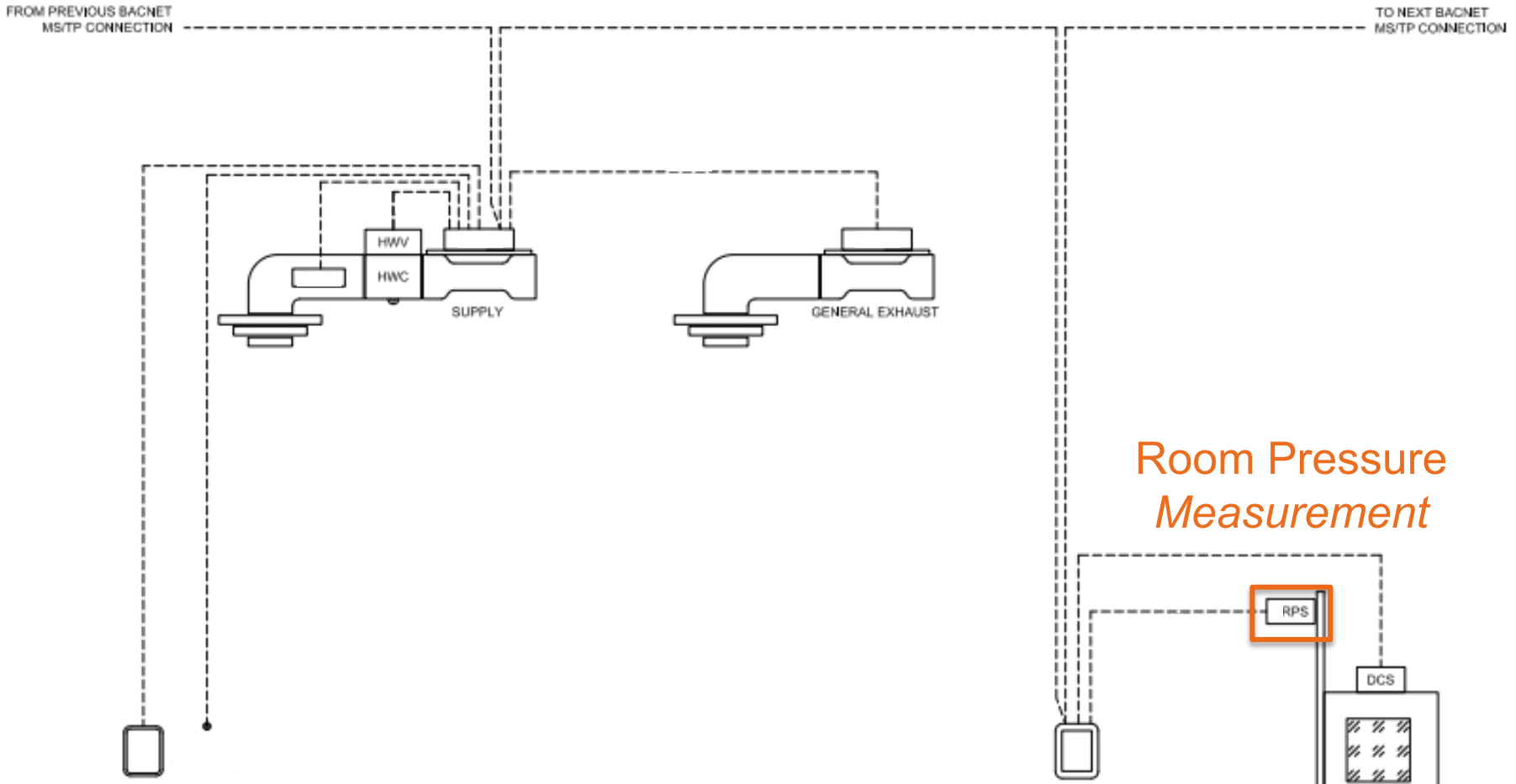
Room Pressurization Controls for Critical Spaces

Measurement vs Monitoring vs Control



Room Pressurization Controls for Critical Spaces

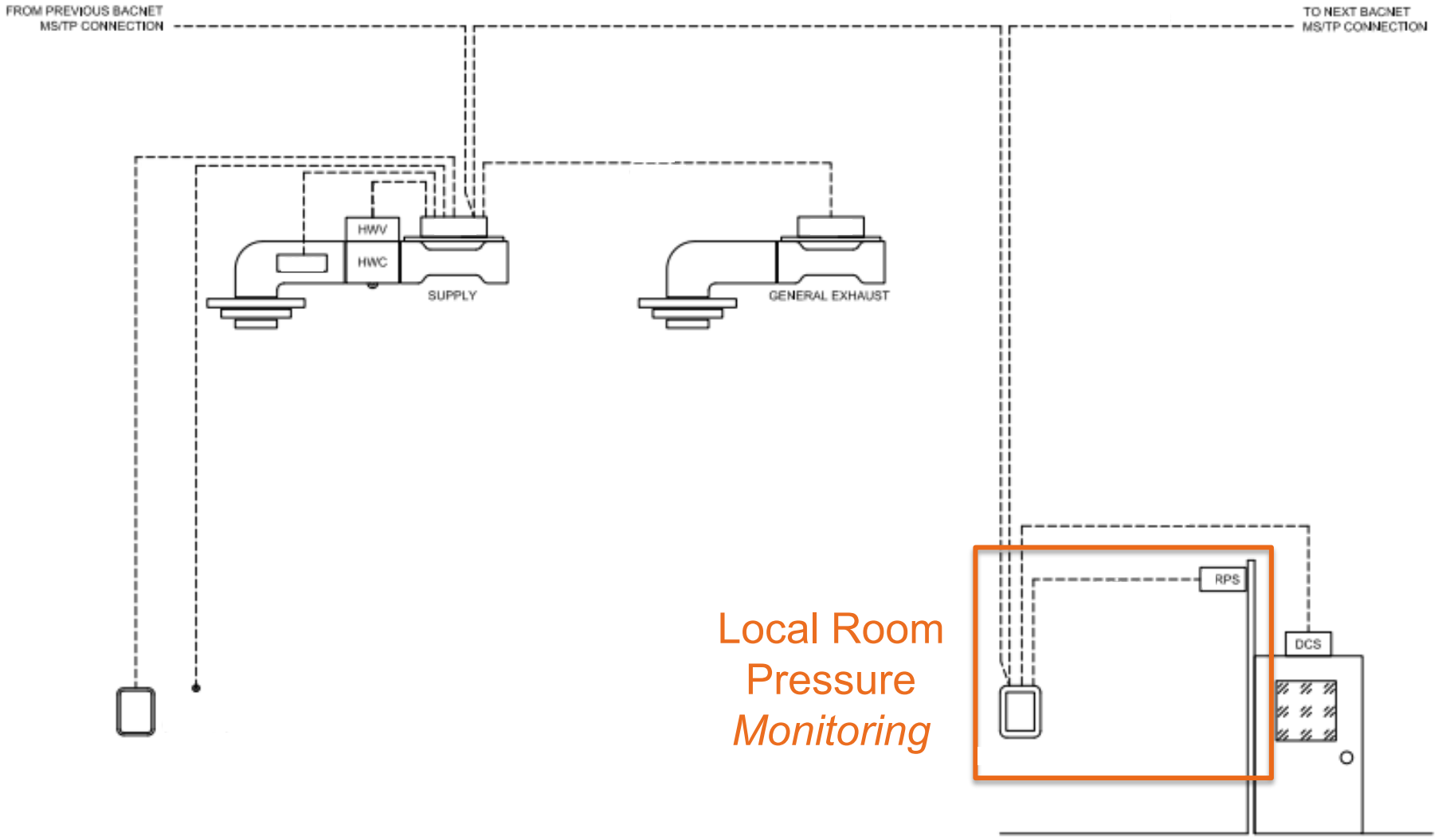
Measurement vs Monitoring vs Control



Room Pressure
Measurement

Room Pressurization Controls for Critical Spaces

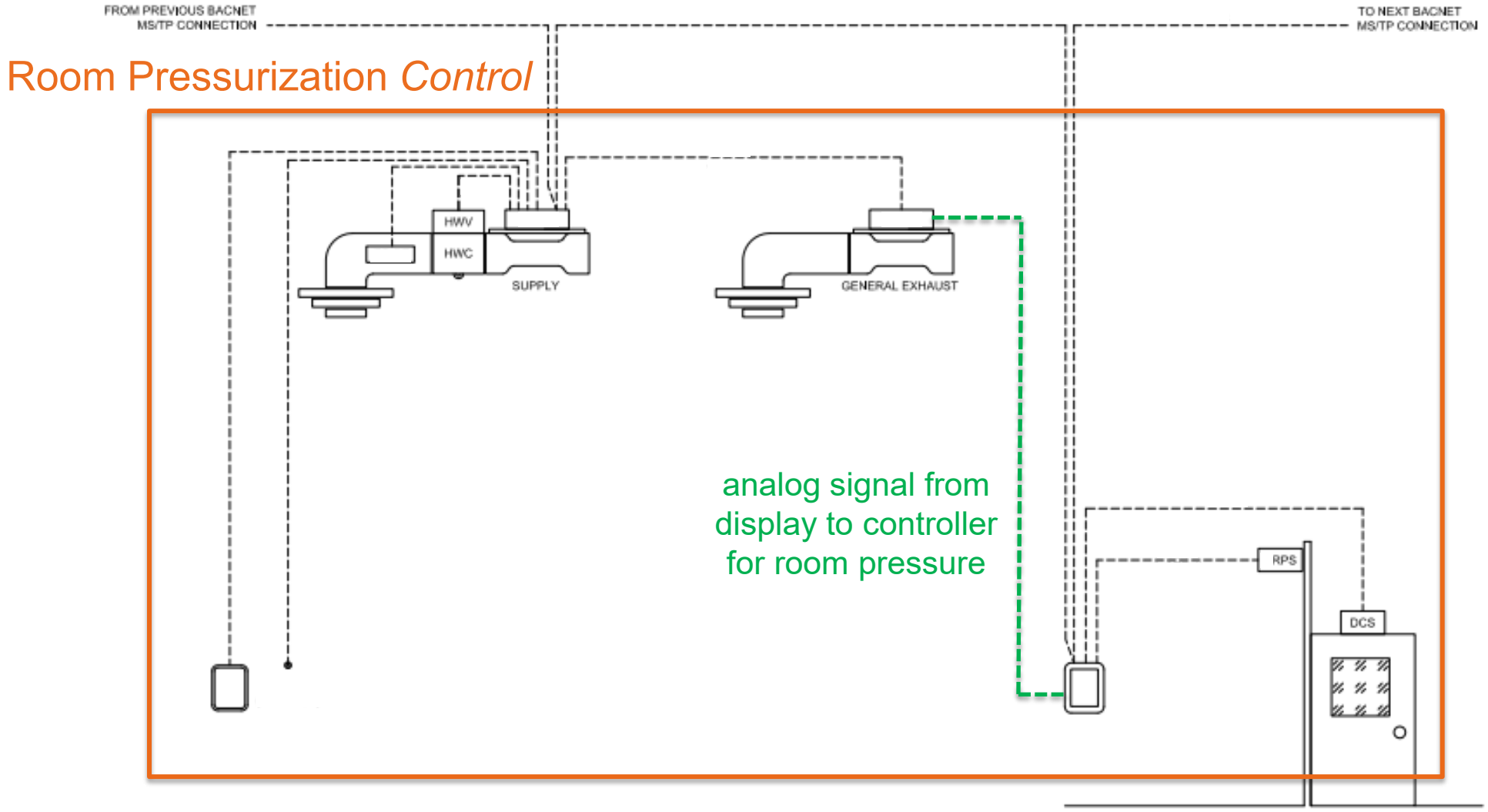
Measurement vs Monitoring vs Control



Local Room Pressure *Monitoring*

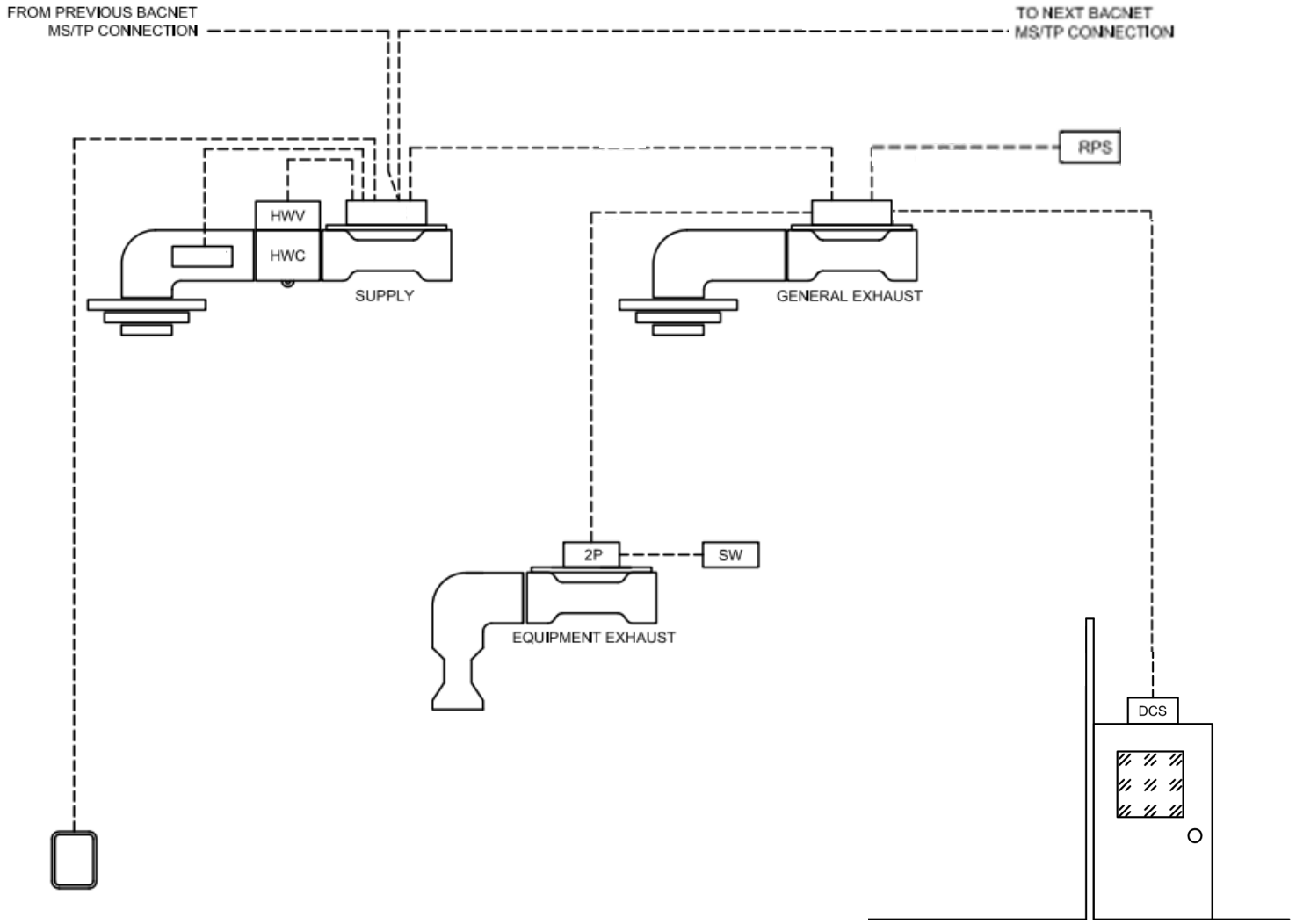
Room Pressurization Controls for Critical Spaces

Measurement vs Monitoring vs Control



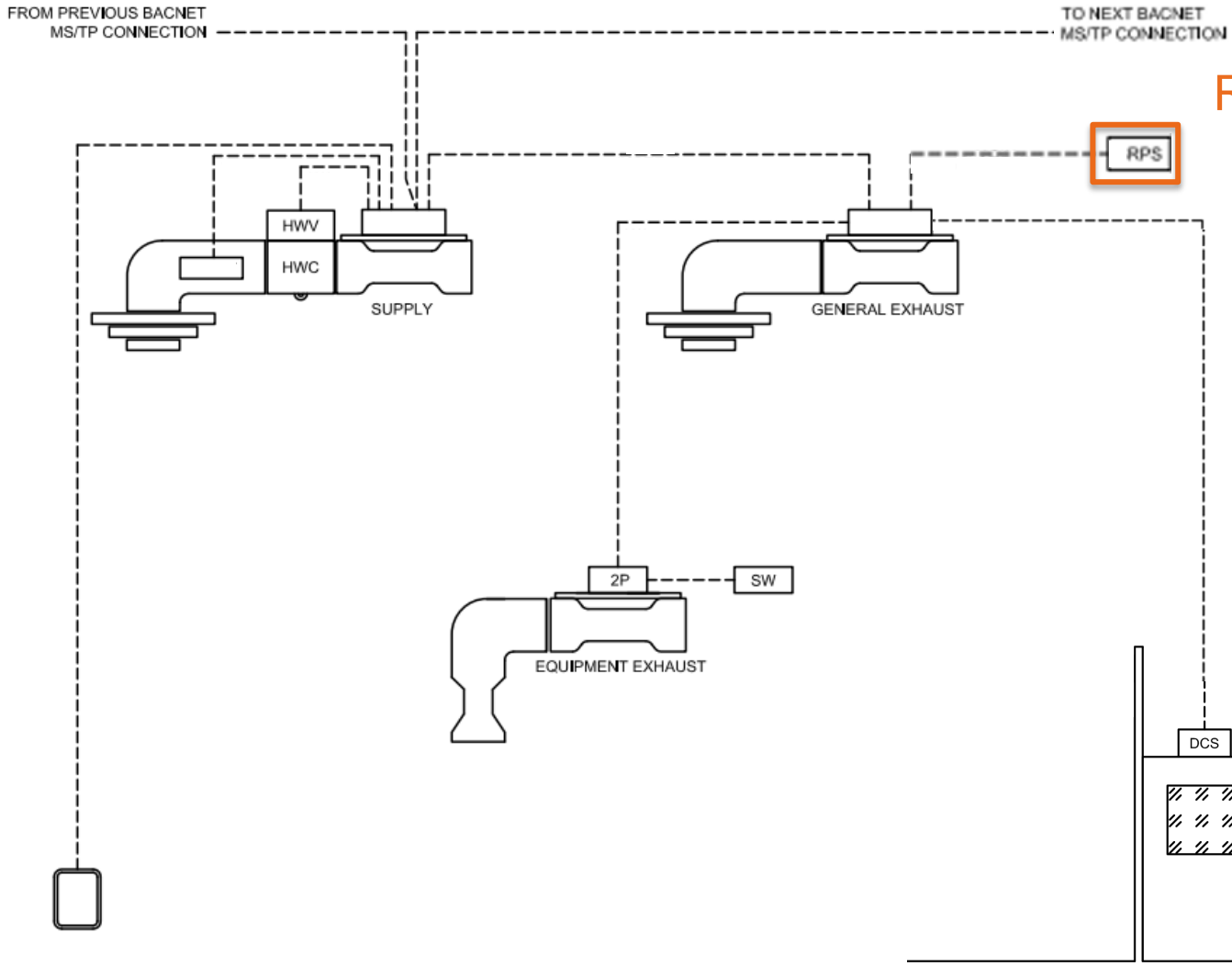
Room Pressurization Controls for Critical Spaces

Measurement vs Monitoring vs Control



Room Pressurization Controls for Critical Spaces

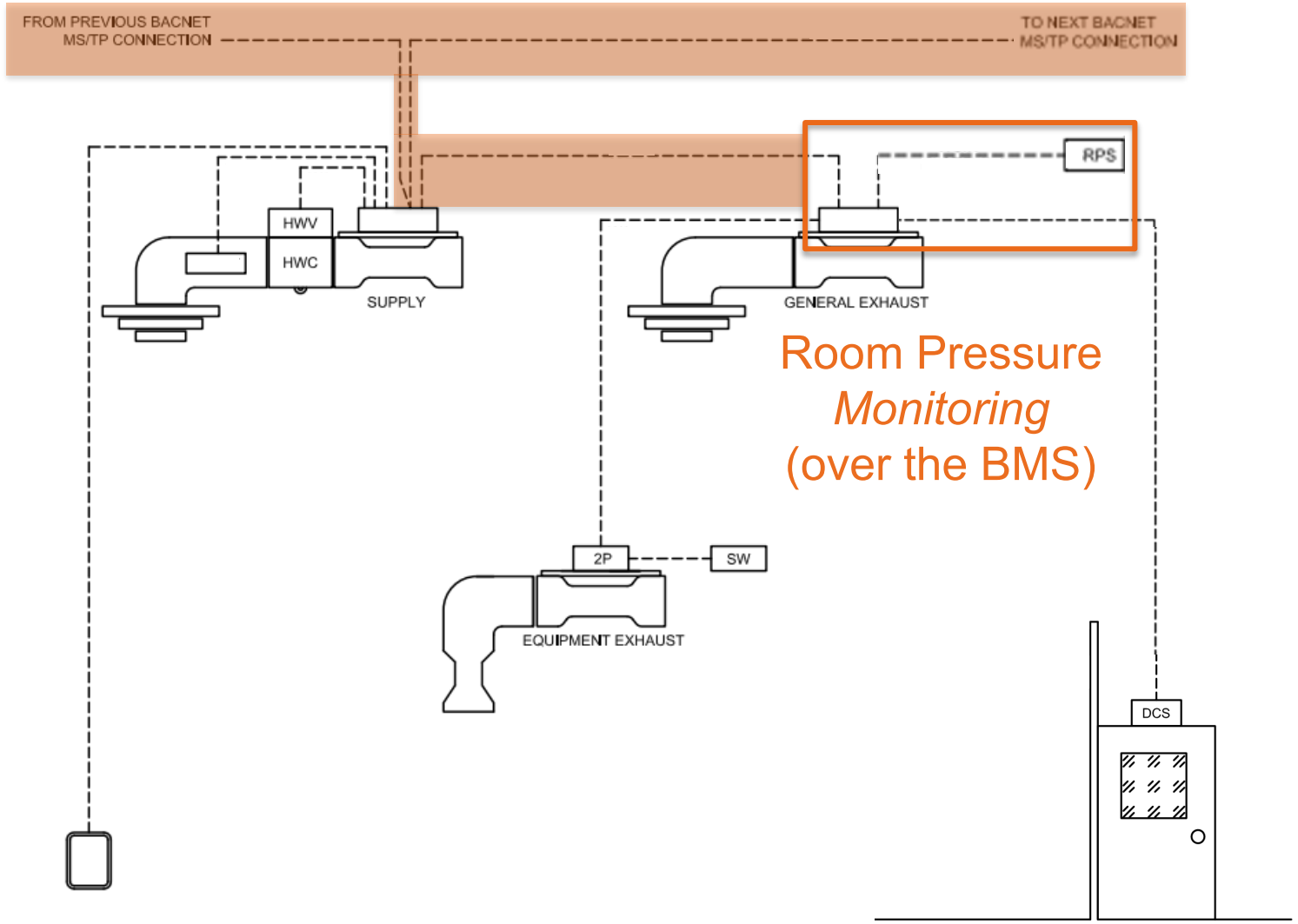
Measurement vs Monitoring vs Control



Room Pressure
Measurement

Room Pressurization Controls for Critical Spaces

Measurement vs Monitoring vs Control

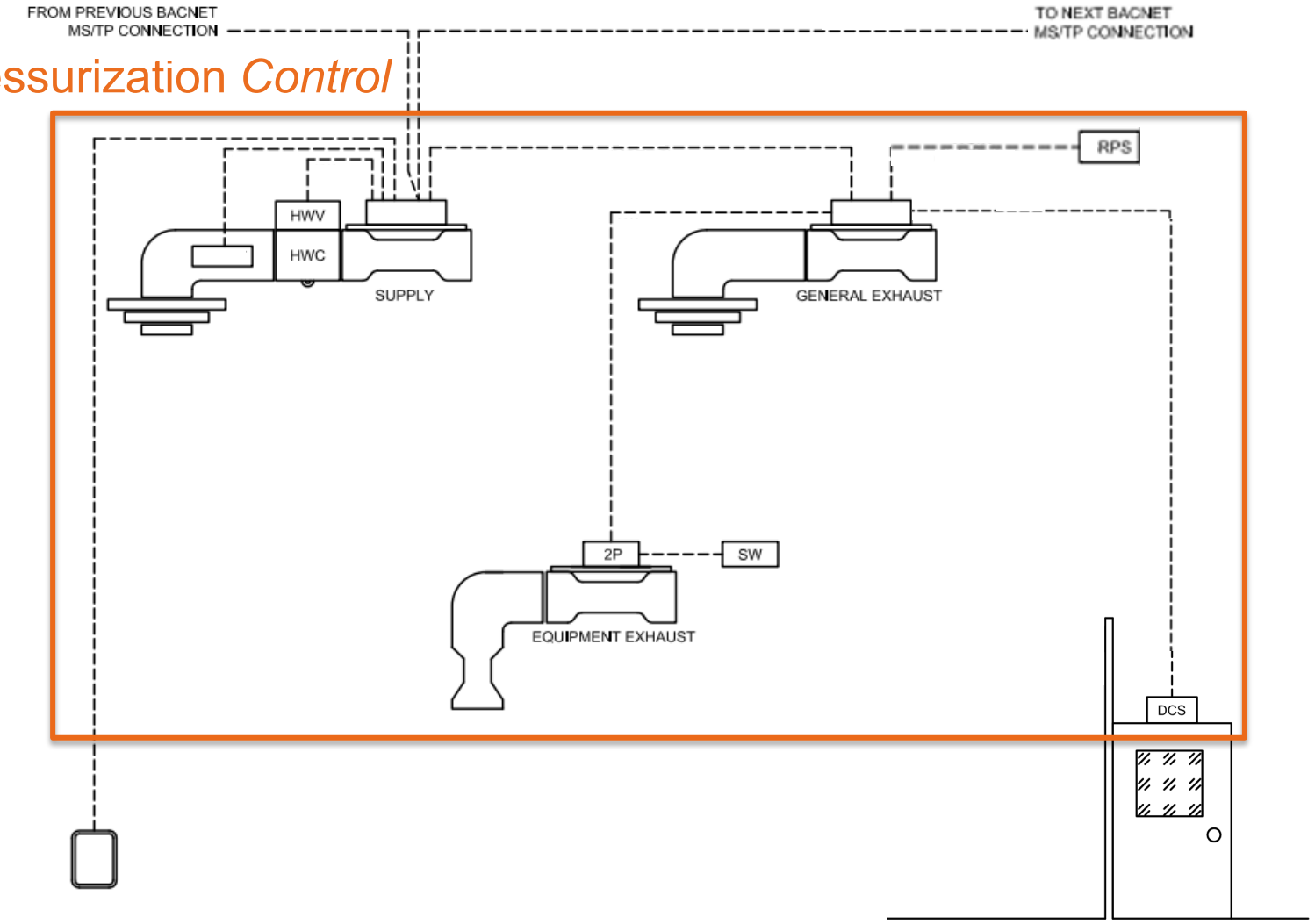


Room Pressure
Monitoring
(over the BMS)

Room Pressurization Controls for Critical Spaces

Measurement vs Monitoring vs Control

Room Pressurization *Control*



Room Pressurization Controls for Critical Spaces

Summary and Typical Recommendations

	Laboratory	Compounding Pharmacies	Healthcare	
			Isolation	Operating
Airflow Control Devices	Venturi Valve	High Accuracy TU *or* Venturi Valve (with BSC)	High Accuracy TU *or* Venturi Valve	
Room Pressurization Control	Volumetric Offset Control	Volumetric Offset or Direct Pressure Control	Volumetric Offset or Direct Pressure Control	
Room Pressure Measurement and Monitoring	Optional	Required	Required	Optional
Actuator Speed	High Speed	Standard Speed	Standard Speed	
Additional Considerations	-Fume hood sash type -Chemicals used in fume hoods	-Location of room pressure monitors vs room pressure measurements	-Reduced ACH in Patient room mode	-Condition monitoring for surgical staff

Questions?

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