Ventilation for Healthcare Facilities

Presented to

Wisconsin Healthcare Engineering Association

November 13, 2014

Topics to be Covered

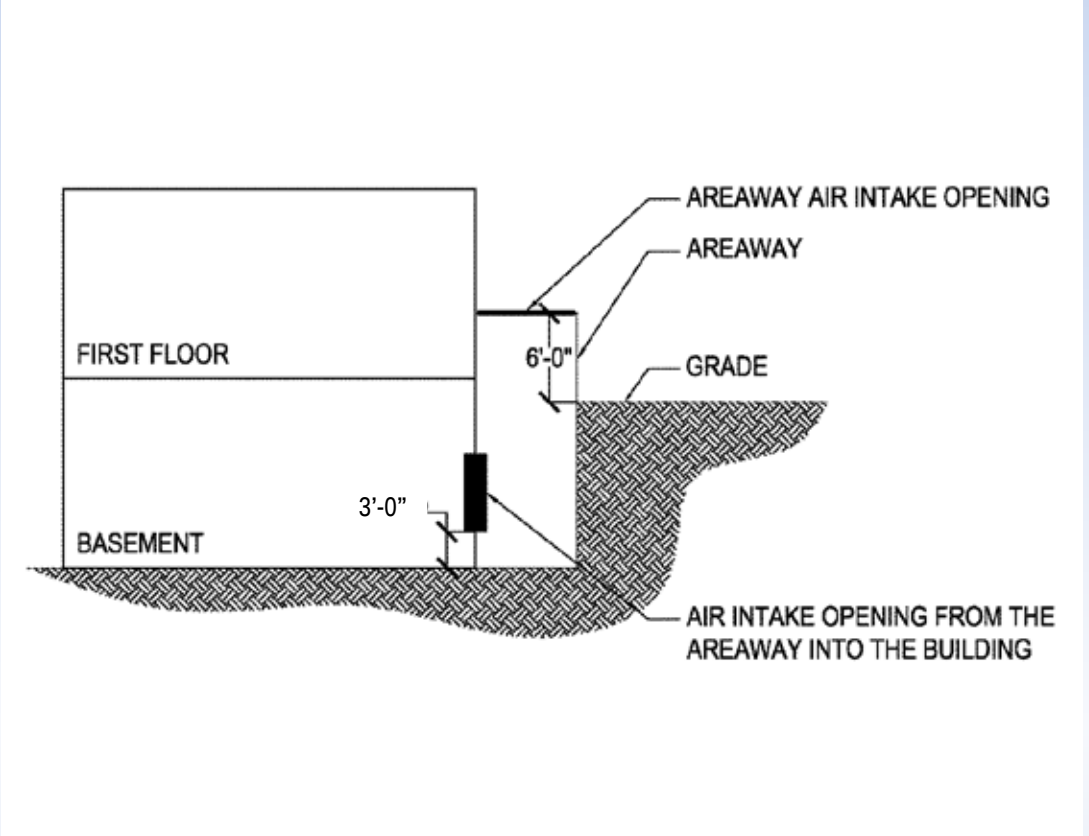
- Relevant codes and standards
- Air handling units
- Space ventilation requirements
- HVAC distribution systems
- Real world examples of spaces focusing on challenges, particularly pressure relationships and pressure control
  - Patient rooms
  - Operating rooms
  - Airborne infectious isolation (AII) rooms
  - Pharmacies

Relevant Codes and Standards

Wisconsin Department of Health Service:	• AIA 2006 Healthcare Guidelines which references: • ASHRAE 170B – Ventilation of Healthcare Facilities
Joint Commission on Accreditation of Healthcare Organizations (JCAHO)	• FGI Guidelines for Design and Construction of Hospitals and Outpatient Facilities 2010 which references: • American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 170 Ventilation of Healthcare Facilities 2008
ASHRAE Standard 170	• 2013 is most recent version

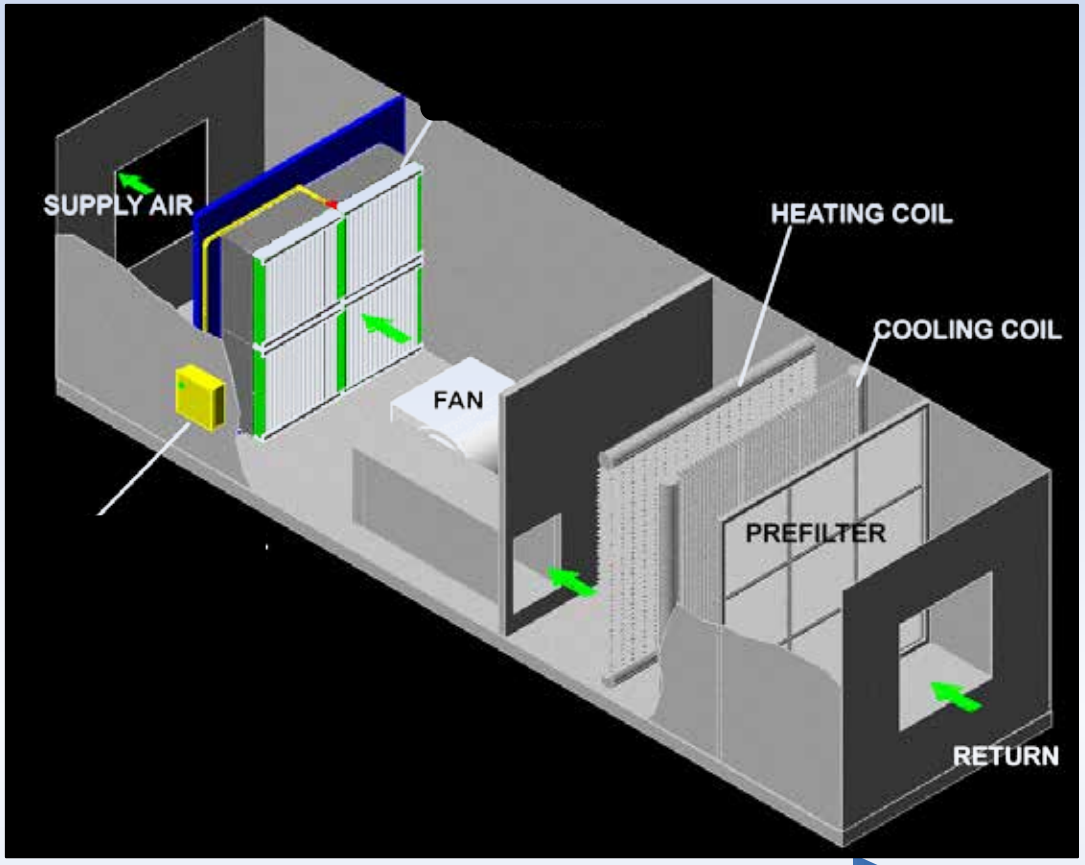
ASHRAE Standard 170
AHUs - Outside Air Intakes

- 25 ft from cooling towers, exhausts, vents
- 6 ft above grade
- 3 ft above roof
- ASHRAE 170 for Areaways: Bottom of the air intake 6’ above grade, intake at bottom of areaway 3’ above bottom of areaway.



ASHRAE Standard 170
AHUs - Filters

- Filter Bank 1 shall be upstream of coils
- Filter Bank 2 shall be downstream of coils and supply fan. Bank 2 must be sealed and airtight



ASHRAE Standard 170 Minimum Filter Efficiencies

Space Function	Filter Bank 1 ASHRAE/AIA (MERV)	Filter Bank 2 ASHRAE/AIA (MERV)	Comments
Operating Rooms	7/7	14/14	
Inpatient Care	8/7	14/14	Includes patient rooms
Protective Environment Rooms	7/8	HEPA/17	
Laboratories	13/13	NR/NR	
Administrative	8/7	NR/NR	
Nursing Facilities	13/7	NR/13	Nursing homes
Psychiatric Hospitals	7/8	NR/14	

Types of MERV 14 Final Filters

Bag filters

Supported media filters

Low pressure drop “green” filters

Electronic filters

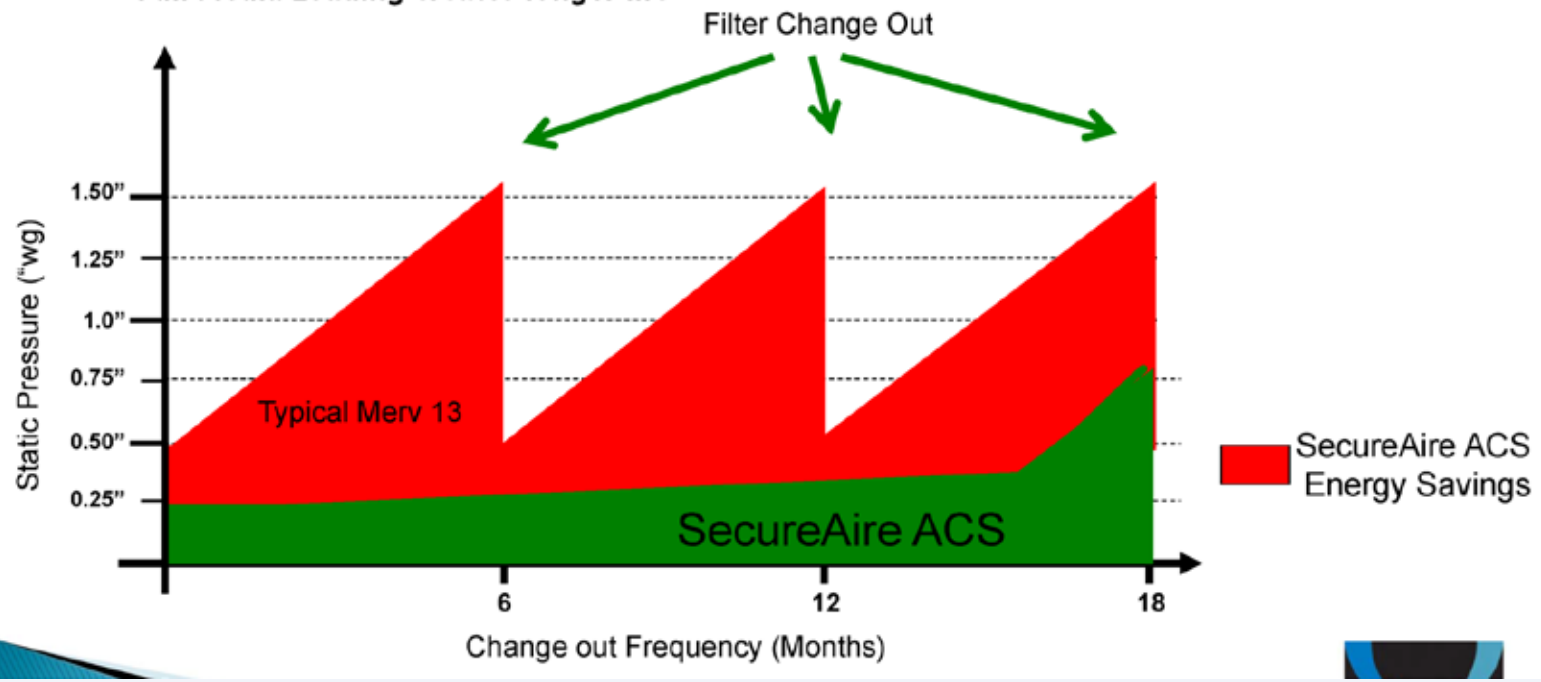
MERV 14 Final Filters
Examples of Pressure Drops

Filter Type	Initial Pressure Drop* (inches w.g.)	Final Pressure Drop* (inches w.g.)	Comments
Bag	0.60	1.0	24”x24”x30”
Rigid Media	0.60	1.0	24”x24”x12”
Low Pressure Drop “Green”	0.41	1.0	24”x24”x30”
Electronic	0.25	0.75	SecureAire ACS

*Based on 500 fpm face velocity

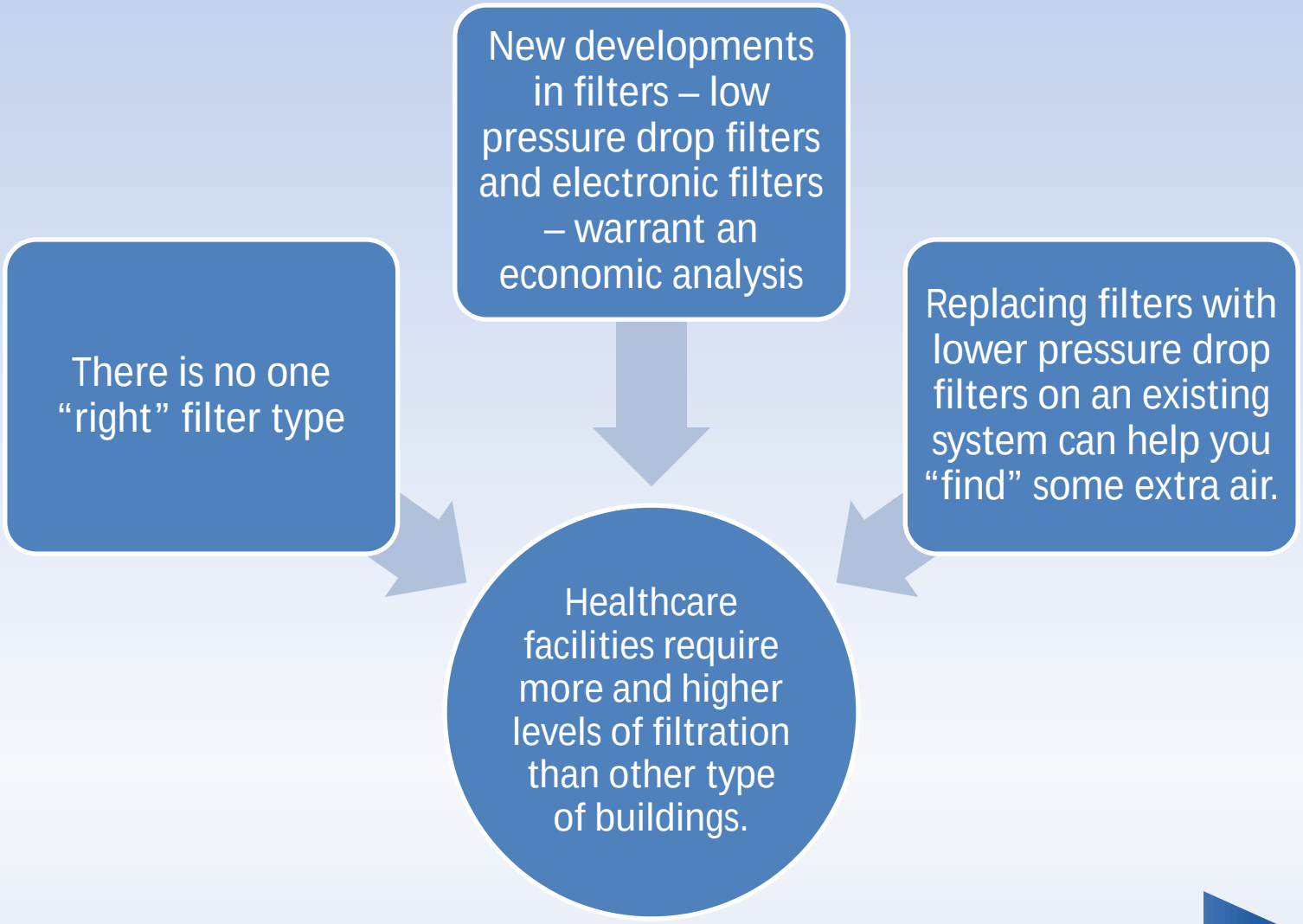
MERV 14 Standard versus Electronic Filter Loading (1)

- ✓ Low Initial and Continuous Pressure Drop = Energy Savings
  - ✓ Full Media Loading due to Electrical Enhancement
- ✓ Long Filter Life (Typical Increase 2x) = Maintenance Cost Savings
  - ✓ Full Media Loading creates longer life



(1) Slide Courtesy of Temperature Equipment Corporation and SecureAire

Filter Type Summary



ASHRAE Standard 170 Humidifiers

Steam humidifiers must be used; no reservoir type or evaporative pan, etc.

Chemical additives for humidifier steam shall comply with FDA requirements.

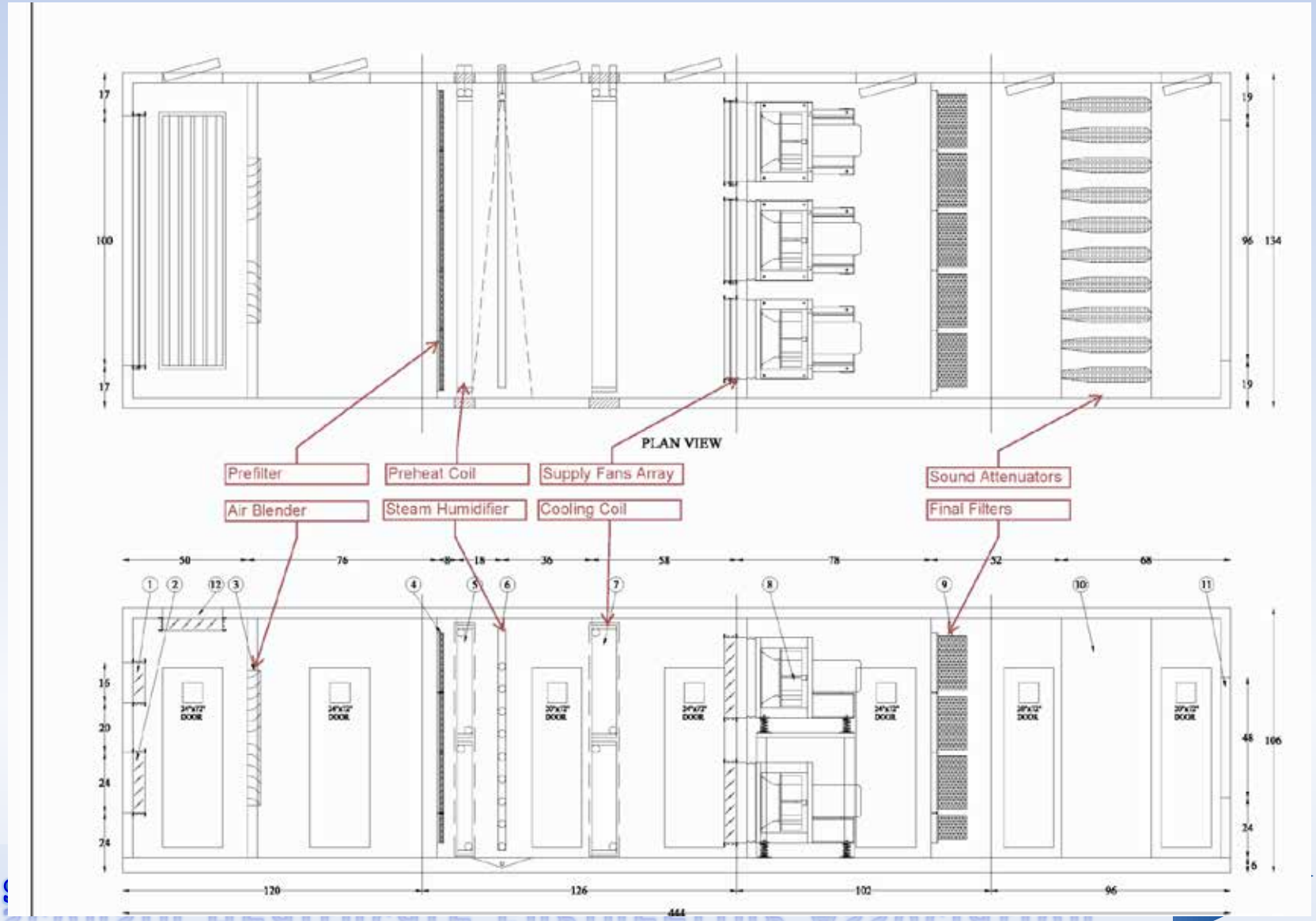
- Direct boiler steam is acceptable with good chemical treatment.
- RO system on boiler make-up will reduce chemical usage

If unable to use boiler steam need steam-to-steam clean steam humidifier.

Location of humidifier?

- Before cooling coil – reduces risk of wetting final filters
- Can do after cooling coil if careful with absorption distance.

Typical Hospital Air Handling Unit



Typical Hospital Air Handling Unit

Space Design Criteria Ventilation Requirements

Function of Space	Pressure [1]	AIA 2006 ACH	ASHRAE 170 ACH	Comments
Patient room	NR [2]	6	4 or 6	6 for single-bed patient room service by aspirating diffusers
Protective isolation	Positive	12	12	
Airborne infectious isolation (AII)	Negative	12	12	All air exhausted to outside
Operating room (OR)	Positive	15	20	
Caesarian delivery room	Positive		20	
Procedure (minor surgery)	Positive	15	15	
Emergency room waiting	Negative	12	12	All air exhausted to outside
Radiology room waiting	Negative	-	12	All air exhausted to outside

1. Pressure Relationship to Adjacent Areas
2. NR = No Requirement

Space Design Criteria Ventilation Requirements

Function of Space	Pressure (1)	AIA 2006 ACH	ASHRAE 170 ACH	Comments
X-Ray (treatment/ diagnosis)	NR	6	6	
X-Ray (surgery/catheterization)	Positive	-	15	
Lab (general, cytology, histology, and other types)	Negative	6	6	
Labs (sterilization and glass washing)	Negative	10	10	
Bronchoscopy, sputum collection	Negative	12	12	All air exhausted to the outside
Pharmacy	Positive	4	4	USP <797> governs, if applicable

1. Pressure Relationship to Adjacent Areas

Space Design Criteria
Nursing Facility Ventilation Requirements

Function of Space	Pressure [1]	AIA 2006 ACH	ASHRAE 170 ACH	Comments
Resident room	NR	2	2	
Resident gathering/dining	NR	4	4	
Physical therapy	Negative	6	6	
Occupational therapy	Negative/NR [2]	6	6	

1. Pressure Relationship to Adjacent Areas
2. NR = No Requirement

Space Design Criteria Humidity Levels

- Recently ASHRAE has lowered the winter humidity level requirements in some spaces, including ORs from 30% RH to 20% RH:

Function of Space	AIA 2006 % RH	ASHRAE 170 % RH
Patient room	NR	Max 60%
Newborn nursery	30-60	30-60
Operating room (OR)	30-60	20-60
Procedure room	30-60	20-60
Critical and intensive care	30-60	30-60

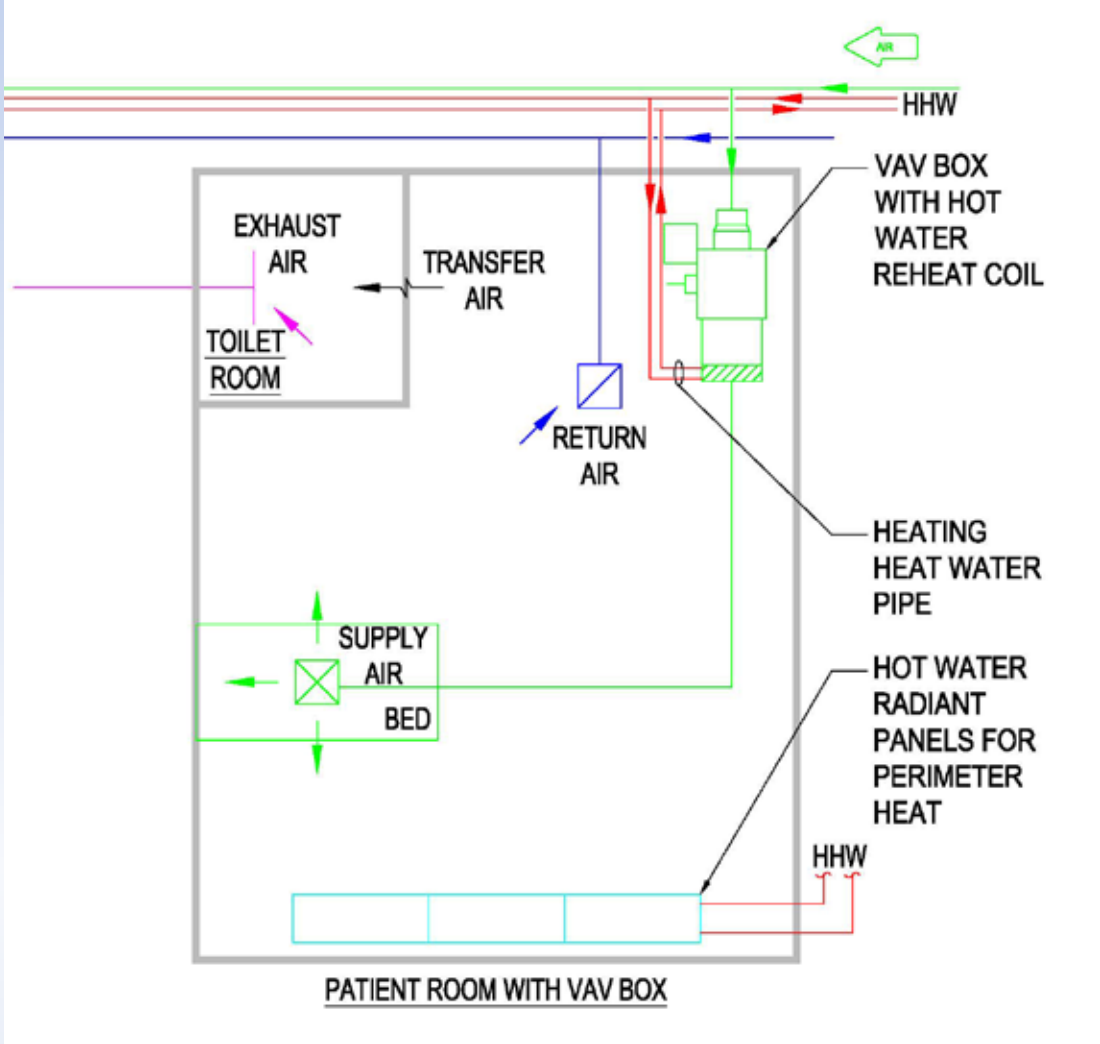
Space Design Criteria Implementing 20% RH in ORs:

CMS is allowing a waiver – organization must declare waiver at the beginning of a CMS-conducted survey.

Must check humidity requirements of equipment used in ORs. AAMI, the Association for the Advancement of Medical Instrumentation, has issued caution:

- Supplies and medical devices used in the ORs may be sensitive to lower humidity levels. Electrodes, for example, are sensitive to humidity, as are other devices with sensors.
- Legacy medical devices still are in use and have not been tested in the lower humidity range. Devices with temperature controls or electronics are particularly sensitive to humidity.

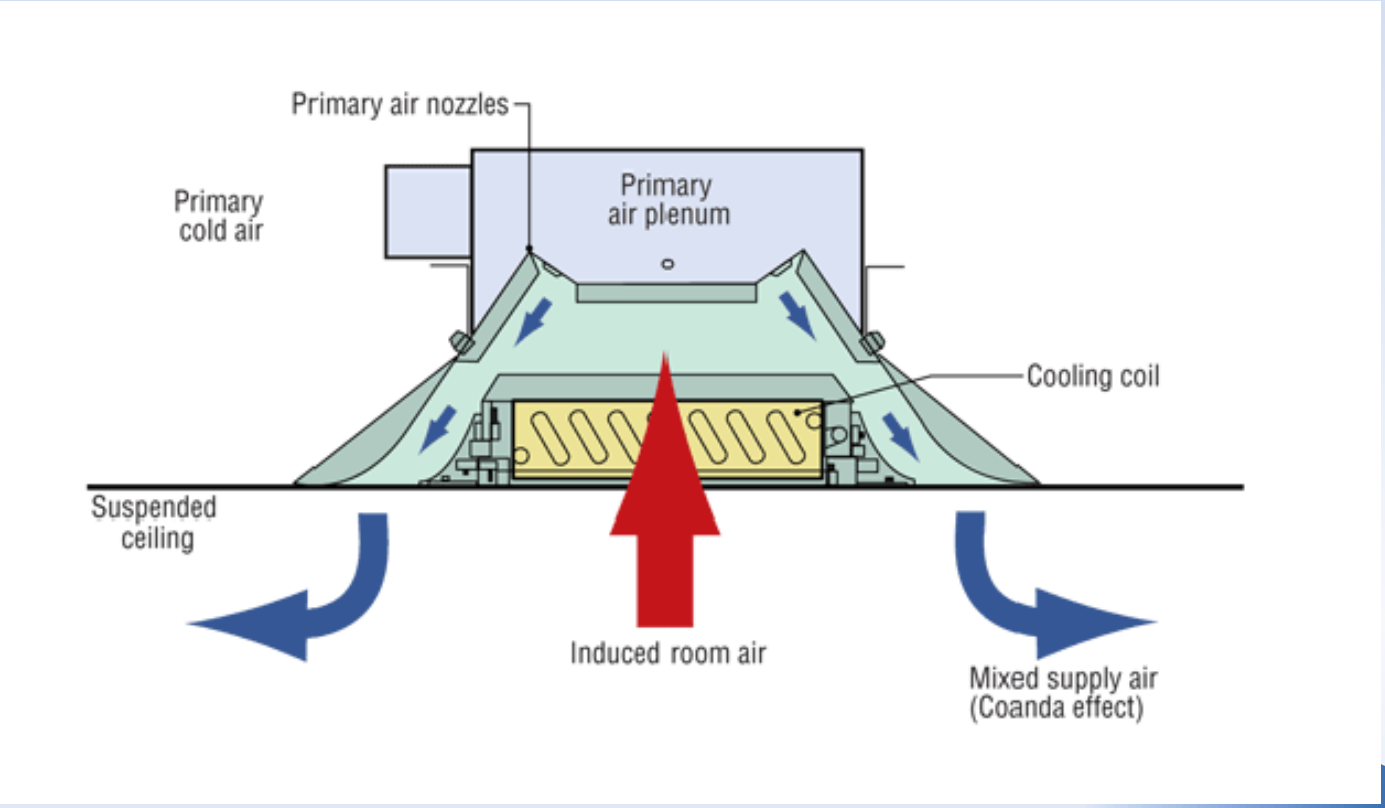
Patient Room HVAC Plan



A common patient room HVAC layout – VAV with reheat supply and radiant panel perimeter heat

Patient Rooms and Chilled Beams

- Active chilled beams are induction units in the ceiling.



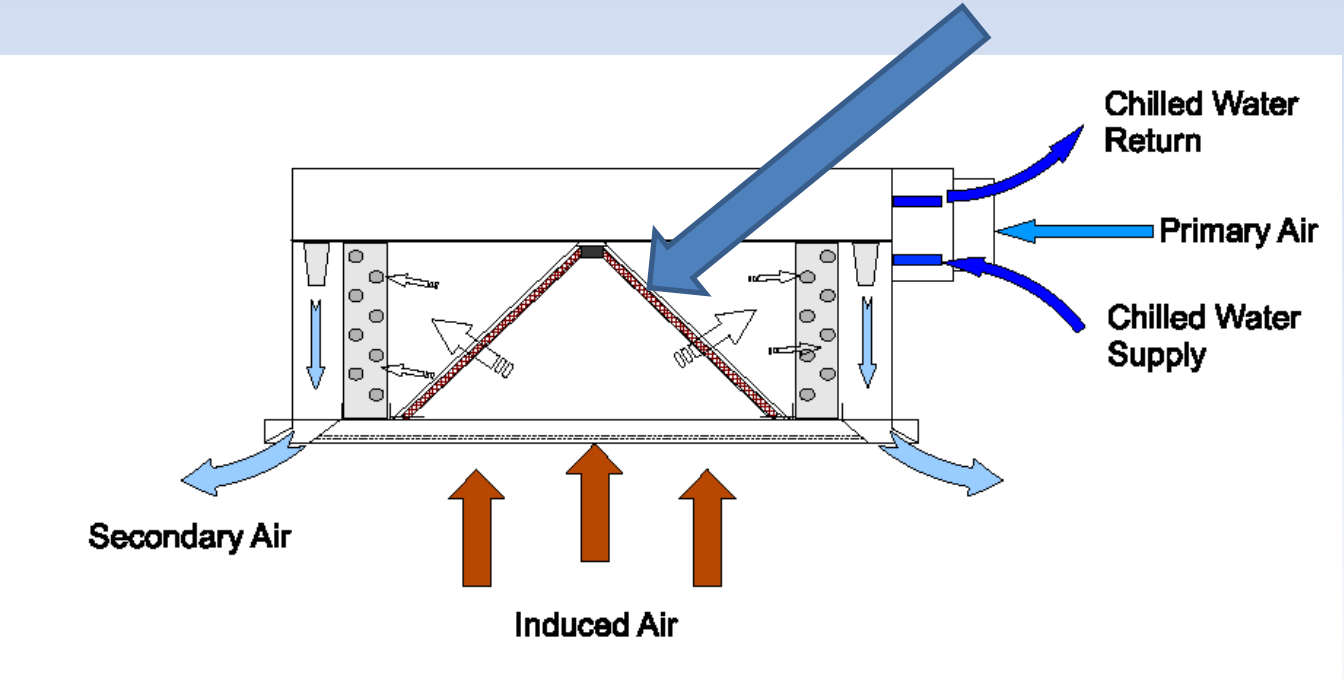
Patient Rooms and Chilled Beams

- Active chilled beams can and have been used in patient rooms
- Question has been the need for filters at the chilled beams – some jurisdictions required/others did not
- ASHRAE Standard 170 – 2012 has clarified:

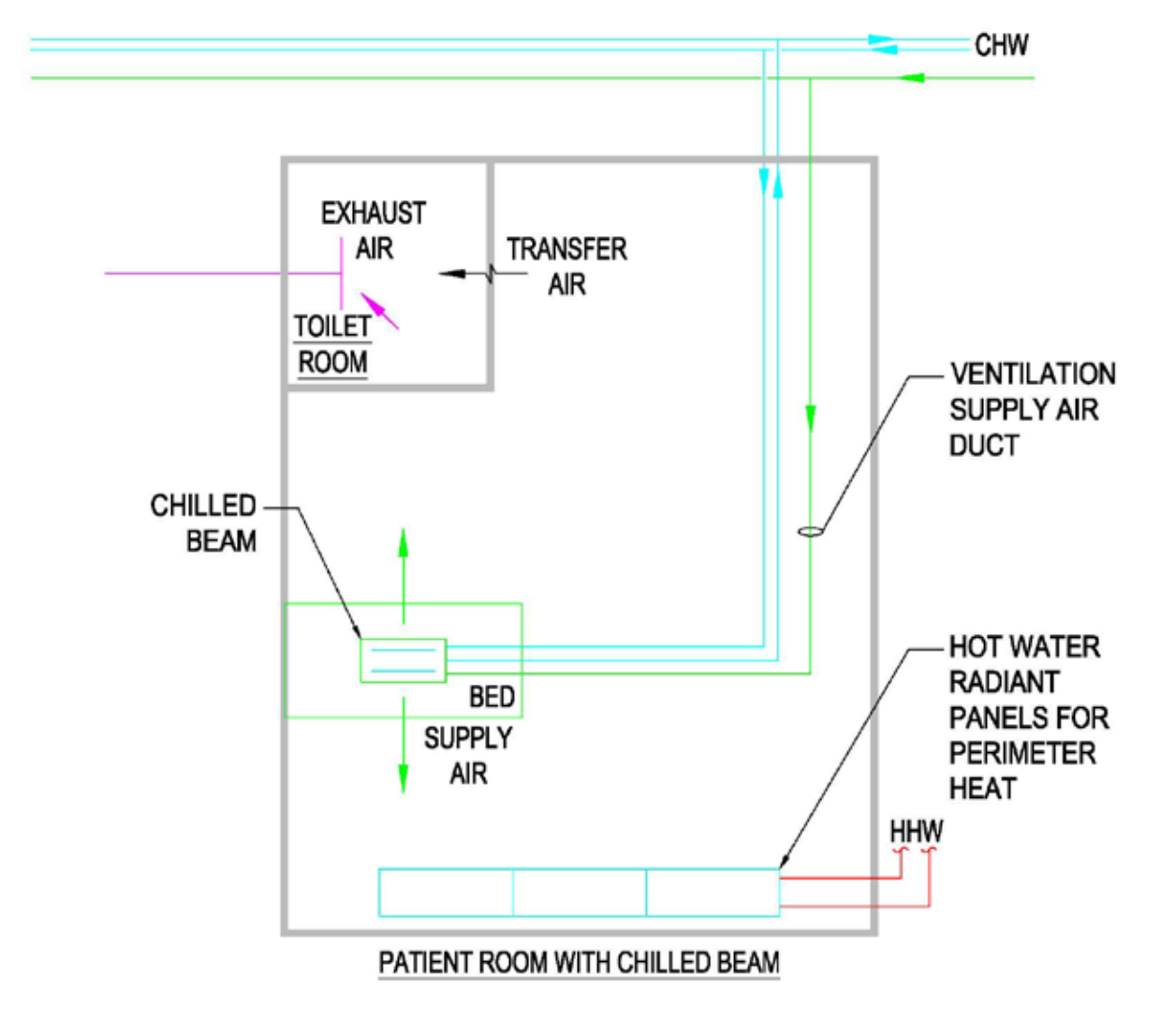
"Provide a minimum MERV 6 filter for airflow passing over any surface that is designed to condense water. This filter shall be located upstream of any such cold surface, so that all of the air passing over the cold surfaces is filtered."

Patient Rooms and Chilled Beams

– One manufacturer with filters:



Patient Room HVAC Plan with Chilled Beam



Patient Rooms and Chilled Beams

Advantages:

- Thermal comfort
- Can have low sound levels
- Need less ceiling height than all air VAV system
- Possible energy savings:
  - moving only minimum ventilation air with AHU – lower fan energy
  - Dedicated OA unit with heat recovery

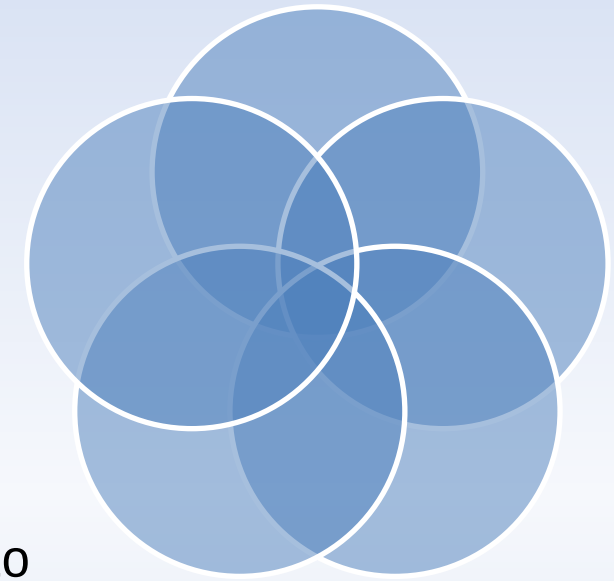
Disadvantages:

- Must change filters in patient rooms/over bed
- Risk of condensation
- A 2nd piping system to room, CHW
- Possible energy adds
  - Limited airside economizer
  - Possible increase in pumping energy

Operating Rooms Design Criteria

20 ach with
4 ach OA

Recently low end reduced for 30% RH

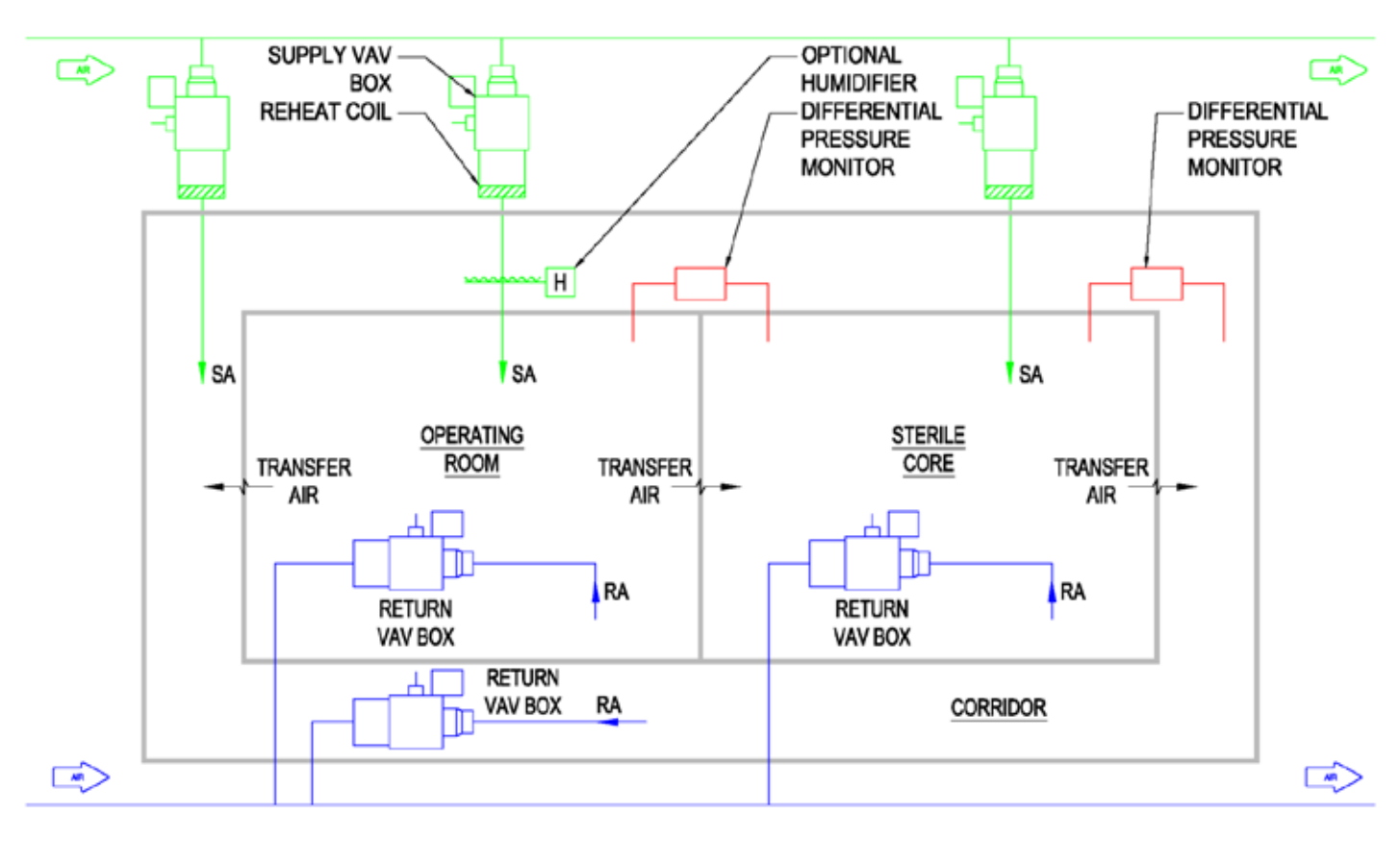


68F to 75F by code (lower as required by procedure/doctor)

Humidity levels: 20% to 60% RH

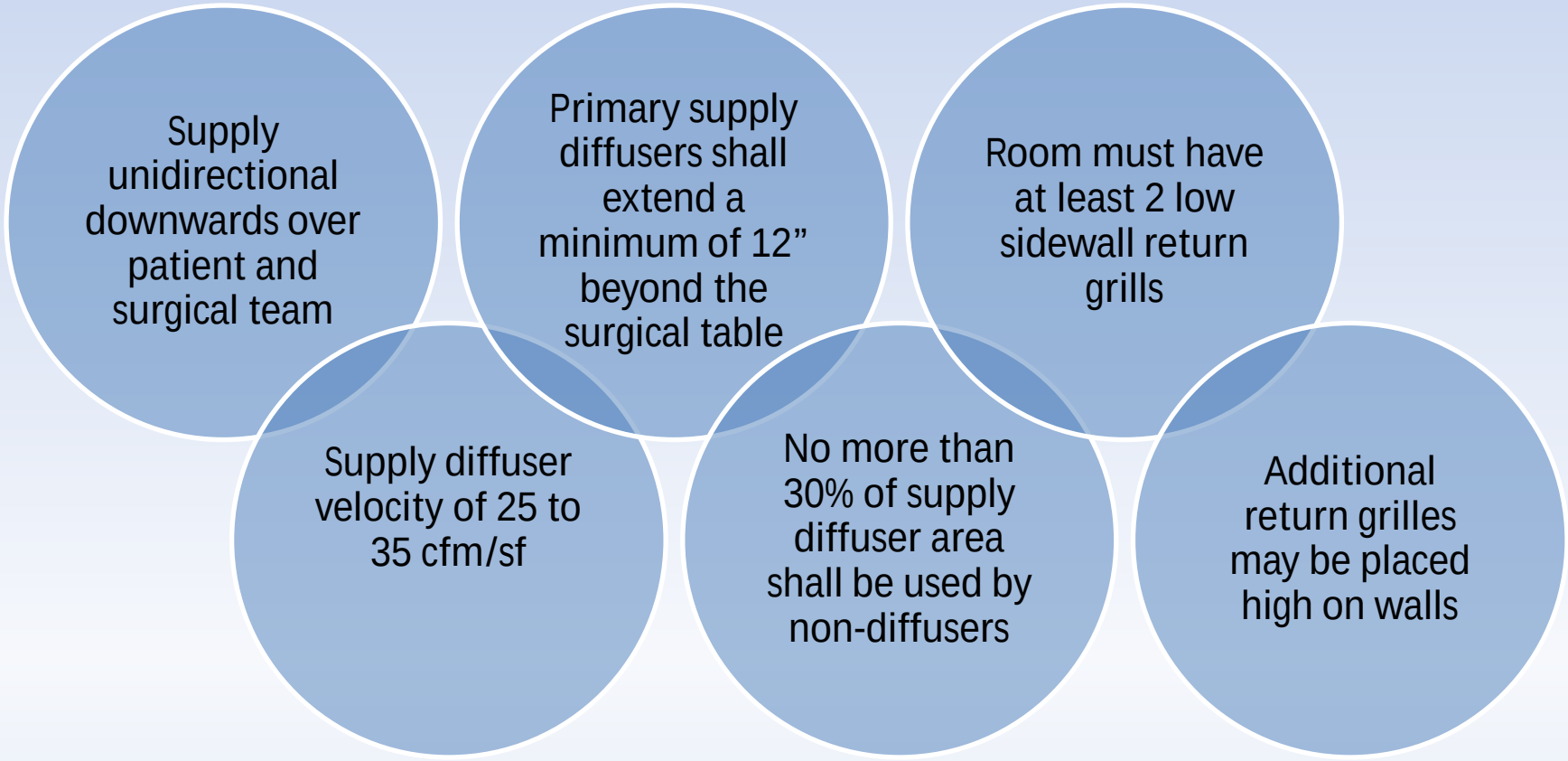
Positive pressure to adjacent areas

Operating Rooms
Typical Ventilation System



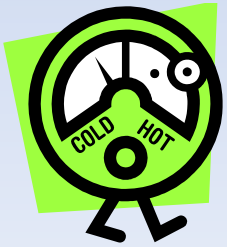
Operating Rooms Air Distribution

AIA 2006 and ASHRAE 170-2012 Agree



Operating Rooms Air Distribution

OR System Challenge #1
Low Temp OR & Humidity Level



- If all ORs at 72F and 35%
  - One OR temp lowered to 65F → 57%RH
  - One OR temp lowered to 63F → 64% RH
  - One OR temp lowered to 60F → 75% RH
- If all ORs at 72F and 20%
  - One OR temp lowered to 65F → 37%RH
  - One OR temp lowered to 63F → 43% RH
  - One OR temp lowered to 60F → 54% RH

OR System Challenge #2
Low Temp OR & Humidity Level

Lesson Learned

If implementing a new low temperature OR, analyze the psychometrics of the specific situation.

If controlling to 30% rh, consider 20% rh – or lower to 20% rh when high humidity levels occur in low temp OR

May need booster humidifiers at all ORs

- Control AHU humidifier to the room that needs the least amount of humidity (low temp OR).
- Boosters will trim other rooms required rh

Operating Room Challenge #2
Unoccupied Airflow Setback and Pressurization

Why unoccupied shut-back of airflow?

- Energy savings
- Reduction of facility's carbon footprint

For more information, ASHE has a booklet available online entitled "Operating Room HVAC Setback Strategies"

Operating Room Challenge #2
Unoccupied Airflow Setback and Pressurization

Estimated annual energy dollars saved for one OR

		Occupied ACH		
		30	20	15
Unoccupied ACH	20	$2,023	-	-
	15	$2,846	$2,027	-
	6	$3,260	$2,597	$2,378

Savings based on Chicago weather; $0.11/kWh for electricity and $0.65/therm for gas,13 unoccupied hours per day

10 ORs – annual savings is $20,000 to $32,000

Operating Room Challenge #2
Unoccupied Airflow Setback and Pressurization

- Per AHSRAE Standard 170:
  - OR's must be positive, at least +0.01 at all times
  - ACH can be reduced when unoccupied provided the pressurization is maintained

Operating Room Challenge #2
Unoccupied Airflow Setback and Pressurization

Occupancy sensor or time schedule indicates unoccupied conditions

Supply VAV box closes and return damper or VAV box closes

If supply VAV box closes faster than return damper or VAV box, the OR may go negative

Operating Room Challenge #2
Unoccupied Airflow Setback and Pressurization

Example:
Occupied Mode: OR at +0.023” to +0.014”

Unoccupied Mode Initiated

OR was negatively pressurized for 17 minutes
and less than +0.01 for 25 minutes

Operating Room Challenge #2
Unoccupied Airflow Setback and Pressurization

Lesson Learned

If implementing an unoccupied airflow setback in an operating room

Recommend the same control device on supply and return – either VAV boxes or air valves

Speed of response of air control devices must be commissioned and adjusted so room remains positive when switching from occupied to unoccupied mode and back

Airborne Infection Isolation Rooms

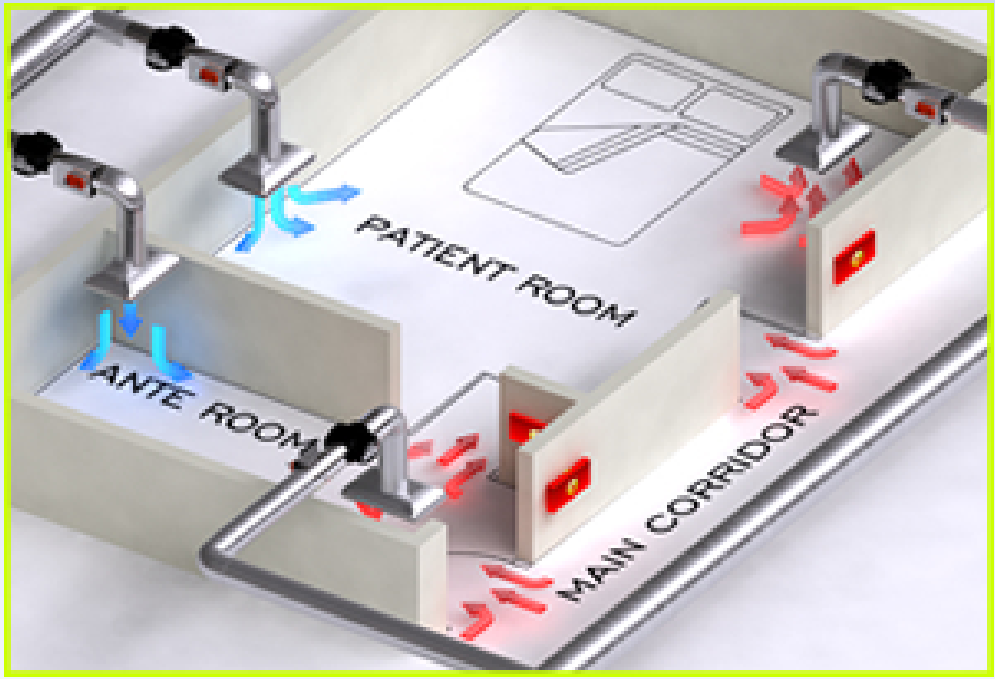
- Used to reduce the spread of airborne infectious diseases (TB) from the patient in the AII Room to the rest of the hospital.
- In addition to ASHRAE Standard 170 and AIA Guidelines:
  - "Guidelines for Environmental Infection Control in Healthcare Facilities", Recommendations of CDC and the Healthcare Infection Control Practices Advisory Committee (HICPAC), 2003

Airborne Infection Isolation Rooms Codes and Standards

CDC	AIA 2006	ASHRAE Standard 170-2013 (incorporates CDC)
• Temp/humidity – not addressed • Min 12 ach exhaust for rooms constructed since 2001 • Min 0.01"H_2O pressure differential to achieve airflow into room • All air exhausted to outside away from air intakes and traffic or exhausted after HEPA filtration	• 75F • 30%-60% rh • 12 ach minimum total airflow/2 ach outside air • All air exhausted to outside • Min 0.01"H_2O pressure differential to achieve airflow into room	• 70F-75F – ability to maintain at all times • 60%rh (no minimum) • 12 ach minimum total airflow/2 ach outside air • All air exhausted to outside • Negative pressure relative to adjacent spaces

Airborne Infectious Isolation Room Architectural Design Considerations

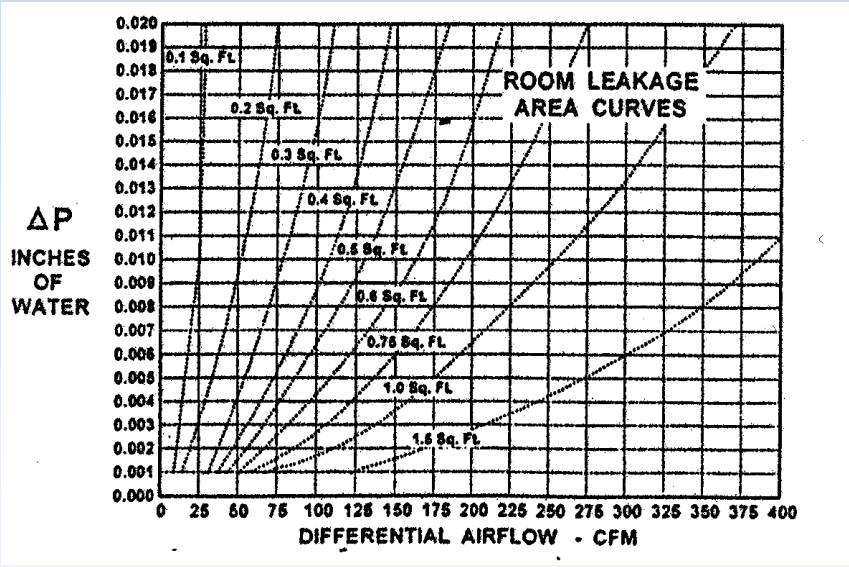
- Ante room not required but per AIA “Each room shall have an area for hand-washing, gowning, and storage of clean and soiled materials located directly outside or immediately inside the entry door to the room.
- Ante room with hand wash sink satisfied these requirements



Airborne Infectious Isolation Room Architectural Design Considerations

- AII room constructed to minimize leakage areas
  - Walls – slab-to-slab
  - Ceilings – plaster or drywall
  - Self-closing doors with door sweeps
  - Sliding doors preferred
  - Finishes should be smooth and cleanable
  - Seal all penetrations
- Room will not remain pressurized or will need a lot of air to stay pressurized if room is leaky.

Lesson Learned



Airborne Infectious Isolation Room Pressurization Design Considerations

AII room negative to ante room/ante room negative to corridor (ASHRAE)

→

Min ΔP between AII room and adjacent rooms/corridor -0.01" wg (ASHRAE)

↓

Min of 10% more EA than SA but no less than 50 cfm

- New tight construction – 200 cfm to 300 cfm differential
- Poorly constructed - 300 cfm to 500 cfm

→

Permanently installed ΔP monitoring device (ASHRAE)

Airborne Infectious Isolation Room Room Supply & Exhaust Design Considerations

Location of supply diffusers and exhaust grilles - CDC 2003 and ASHRAE Standard 170 disagree

- CDC 2003: Supply above patient, exhaust low on wall
- ASHRAE Standard 170 2008/2013: "Exhaust grilles or registers … shall be located directly above the patient bed on the ceiling or on the wall near the head of the bed…"

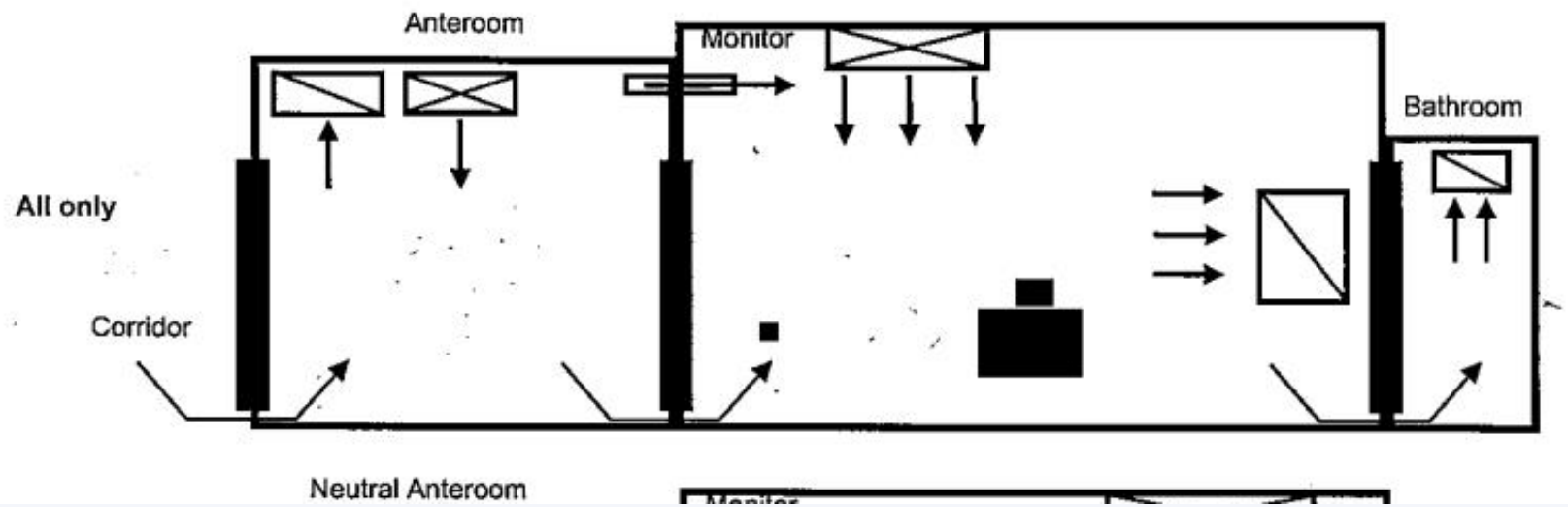
Designer may consider discussing discrepancy with hospital infection control

If chose to supply above patient, use non-aspirating laminar flow type diffusers

Airborne Infectious Isolation Room Airflow Diagram

Diagram from CDC Guidelines

Figure 4. Example of airborne infection isolation (AII) room with anteroom and neutral anteroom* + §



Airborne Infectious Isolation Room Room HVAC Design Example

Exhaust system:

- EA from AHII to maintain 12 ach: 1,400 cfm
- Toilet exhaust: 100 cfm
- EA from ante room to maintain 10 ach: 250 cfm
- Constant volume exhaust box to maintain EA / Total EA = 1,400 cfm + 100 cfm + 250 cfm = 1,750 cfm

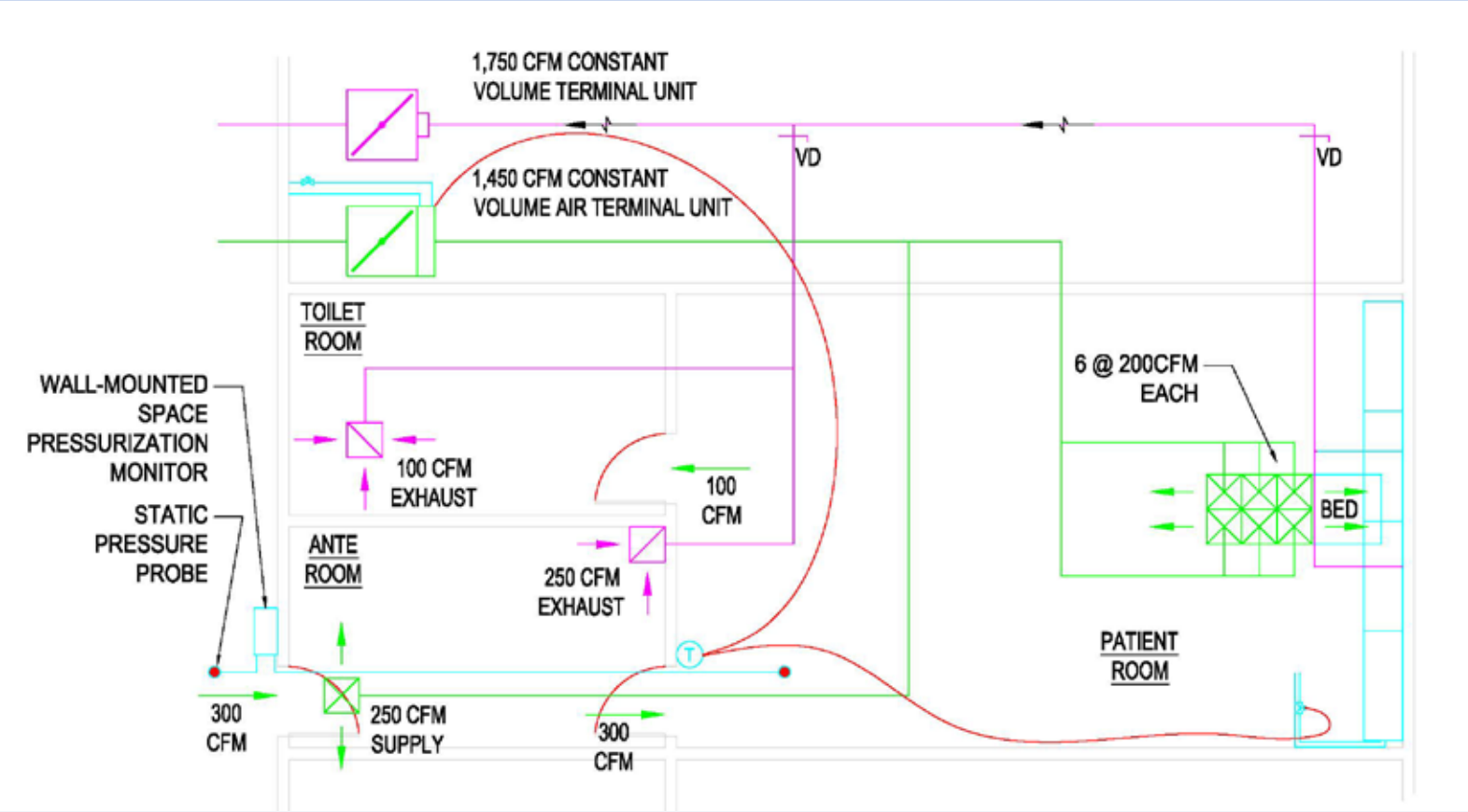
Transfer air from corridor to ante room and ante room to AII room

- Assume mid range in tightness – use 300 cfm transfer air (TA)

Supply system:

- AII SA = EA–TA from ante room + TA to toilet /AII SA = 1,400 cfm – 300 cfm + 100 cfm = 1,200 cfm
- Constant volume box to maintain total SA / Total SA = 1,200 cfm + 250 cfm = 1,450 cfm
- SA to ante room: 250 cfm (Ante room neutral)
- Reheat coil to provide space temperature control

Airborne Infectious Isolation Room
Room HVAC Design Example



Airborne Infectious Isolation Room Room Pressure Monitors

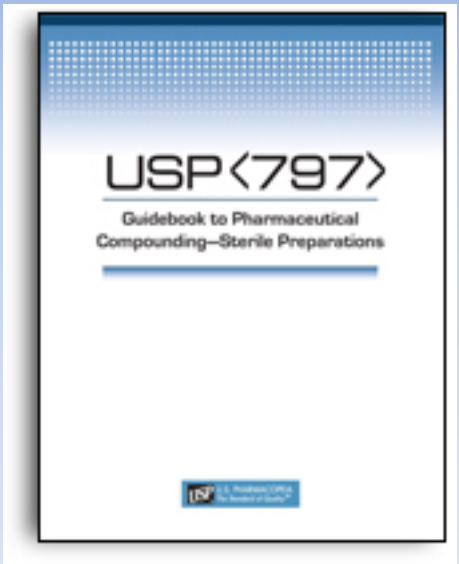
- Locate outside of ante room door in corridor
- Alarms visually and audibly if negative pressure is not maintained
- Tie-in alarm to building automation system
- Lesson Learned:
  - To avoid nuisance alarms, control to a higher ΔP than to the ΔP at which the alarm is set
  - Control to 0.03” and alarm at 0.01”.

Airborne Infectious Isolation Room HVAC Design Example

Example simplified AII room sequence of operation

- Modulate supply CAV air terminal unit damper to maintain supply airflow setpoint.
- Modulate exhaust air terminal unit damper to maintain exhaust airflow setpoint.
- Modulate reheat valve and radiation valve to maintain temperature setpoint.
- Coordinate with users to setup time delay to allow entrance/exit to the pressurized space without audible alarm.
- If an exhaust fan failure alarm is received at the front end, close the supply air terminal damper operator.

Pharmacies



- US Pharmacopeial Convention (USP) <797> Pharmaceutical Compounding – Sterile Preparations applies to:
  - Facilities in which sterile products are prepared manipulations are performed during the compounding of sterile products which increase the potential for microbial contamination of the end product.
  - Facilities where products are compounded using devices or ingredients which are not sterile to prepare products which must be sterilized prior to use.
- Many hospitals have upgraded - upgrades and renovations typically exceed of $1M.

Pharmacies and <USP 797> Requirements

A positive or negative pressure cleanroom with ISO Class 7 air quality	An ISO Class 7 Anteroom for entry from the outside areas	An ISO Class 7 Buffer Zone (and Compounding Rooms)
Airlocks or pass-throughs for material movement	Hand-washing facilities	Laminar Air Flow Workbench(es), Biological Safety Cabinet(s), or Barrier Isolator(s) in which sterile compounding takes place

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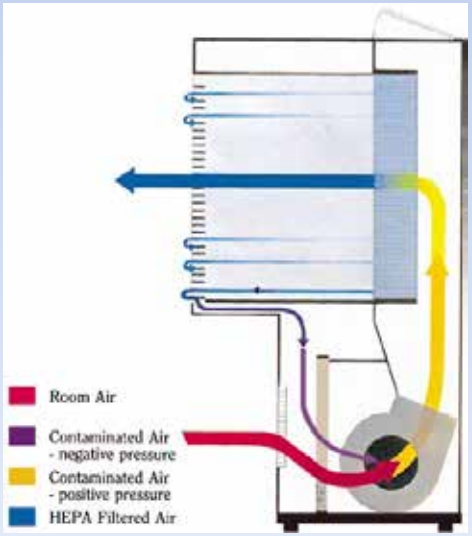
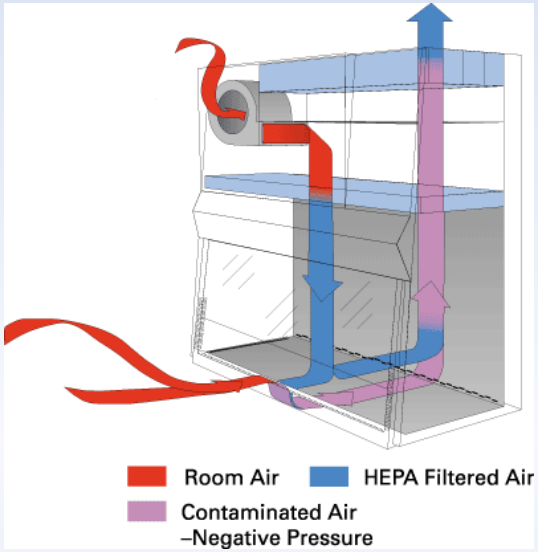
Pharmacy Compounding Equipment



- Laminar Airflow Work Benches (LAFWs)
  - ISO Class 5 (Class 100) cleanliness.
  - Provides laminar airflow across the work surface
  - HEPA supply filter with 99.99% minimum efficiency in capturing 0.3 micrometer particulates
- Applications:
  - IV admixture preparation
  - Drug compounding
  - Media preparation
  - Pharmaceutical procedures
  - Electronic assembly
- Used in clean workroom and does not require ducted exhaust air

Pharmacy Compounding Equipment

- Biological Safety Cabinet(s), (BSC's)
  - Down flow of air and HEPA treatment of re-circulated air
  - Depending on type, some or all air is exhausted
  - Inflows and downflows certified at sash velocities (90-105 fpm), per ASHRAE
- Types: A1, A2, B1, B2
  - A1 & A2 – exhaust 30% of air
  - B1 – exhaust 40% of air
  - B2 – exhaust 100% of air
- Use type B2 for chemo compounding unless glove box used
  - Caution – requires about 1,000 cfm at -2.0" at inlet



Pharmacy Compounding Equipment

- Barrier Isolators (Glove Boxes)
  - Leak tight negative pressure work area
  - HEPA filtered air better than ISO 5
  - Exhaust volumes typically 300-500 cfm at -2.0” w.g. (50% of type B2 BSC)

Pharmacies and USP <797>
ISO Classes

Table 1. ISO Classification of Particulate Matter in Room Air (limits are in particles of 0.5 µm and larger per cubic meter [current ISO] and cubic feet [former Federal Standard No. 209E, FS 209E])*

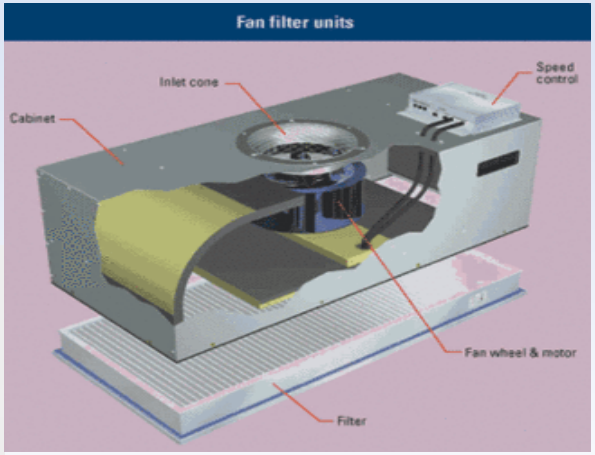
Class Name		Particle Count	
ISO Class	U.S. FS 209E	ISO, m^3	FS 209E, ft^3
3	Class 1	35.2	1
4	Class 10	352	10
5	Class 100	3,520	100
6	Class 1,000	35,200	1,000
7	Class 10,000	352,000	10,000
8	Class 100,000	3,520,000	100,000

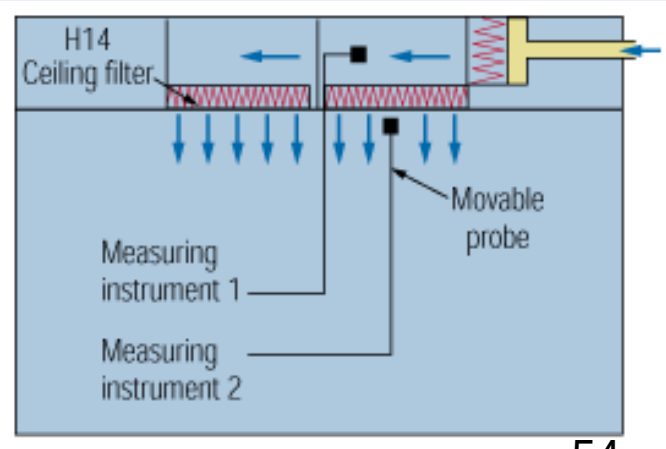
*Adapted from former Federal Standard No. 209E, General Services Administration, Washington, DC, 20407 (September 11, 1992) and ISO 14644-1 : 1999, Cleanrooms and associated controlled environments—Part 1: Classification of air cleanliness. For example, 3,520 particles of 0.5 µm per m^3 or larger (ISO Class 5) is equivalent to 100 particles per ft^3 (Class 100) (1 m^3 = 35.2 ft^3).

- Maintaining ISO Class 7 and 8 requires HEPA filters and the following air changes per hour:
  - ISO Class 7: 30 to 60

Pharmacy Plan
Fan Filter Units for Clean Rooms

- HEPA filter and small fan in ceiling tile
- ECM Speed Control
- Filters changeable from room-side





Pharmacy Plan
Separate Clean Room for Chemo

- How are high airflows and static pressures for terminal HEPA diffusers cleanrooms achieved?
  - Can use central AHU but frequently existing AHU does not have adequate capacity
  - Additional recirculation only fan coil units
  - Ceiling mounted fan filter units

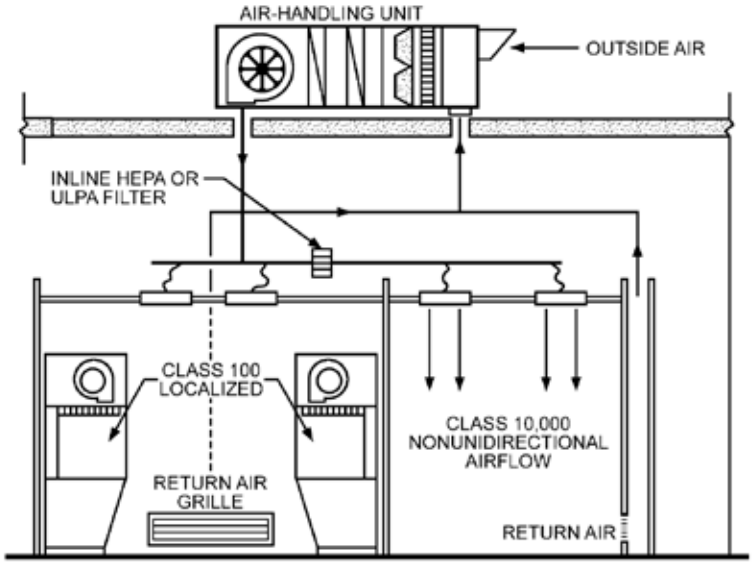
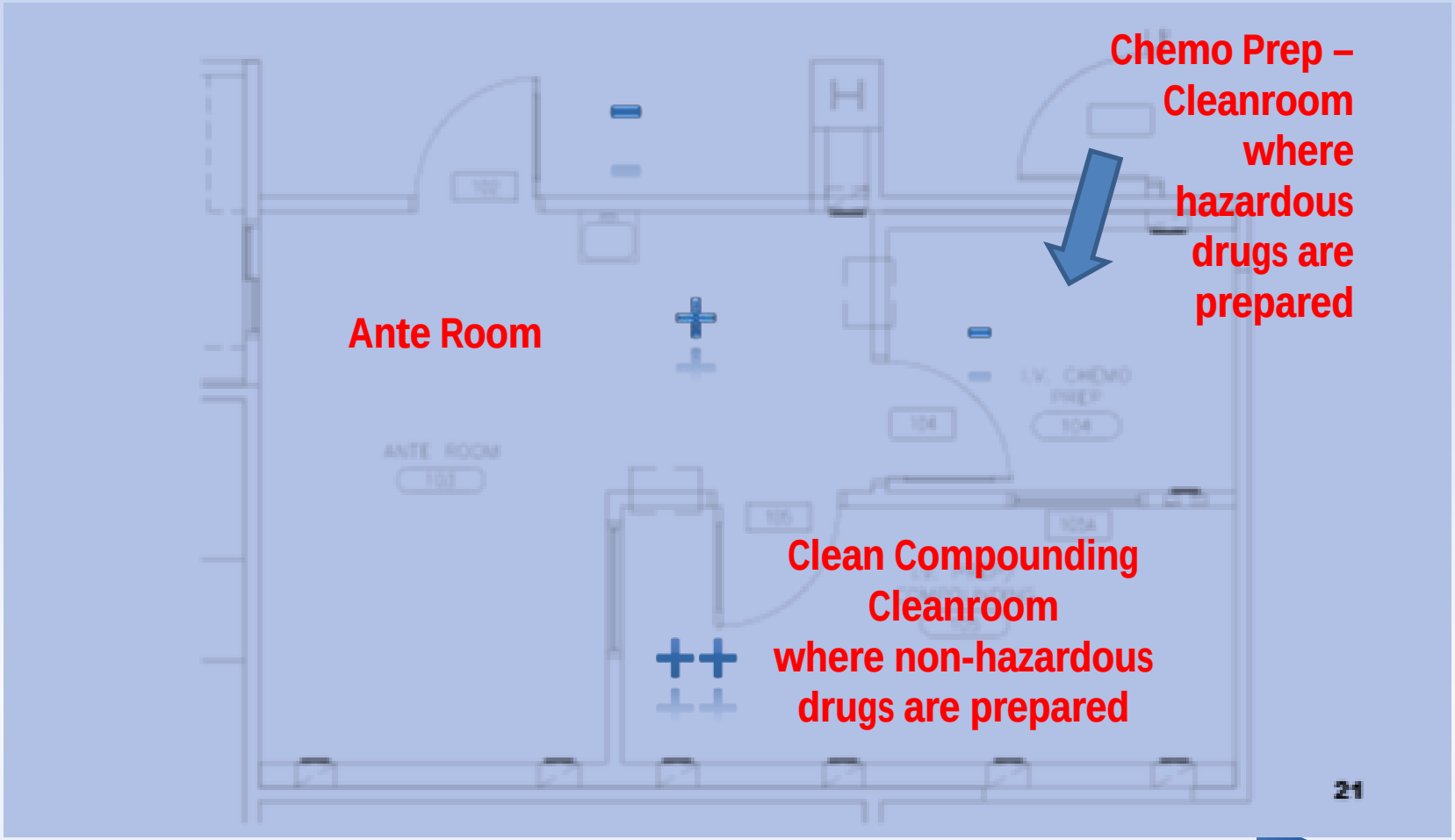
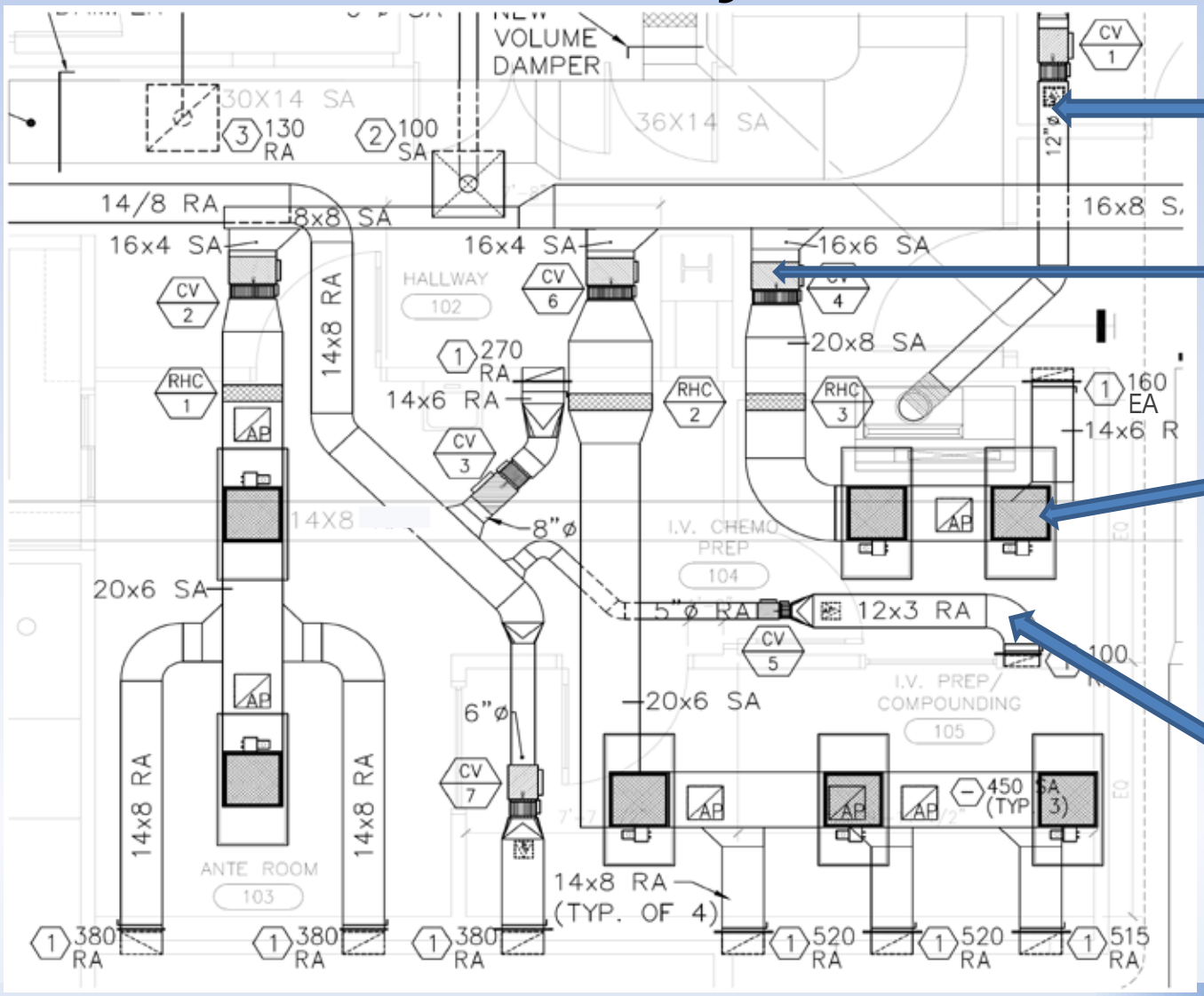


Fig. 3 Class 10,000 Nonunidirectional Cleanroom with HEPA Filters Located in Supply Duct and Class 100 Local Workstations

Pharmacy Plan
Separate Clean Room for Chemo



Pharmacy HVAC Plan



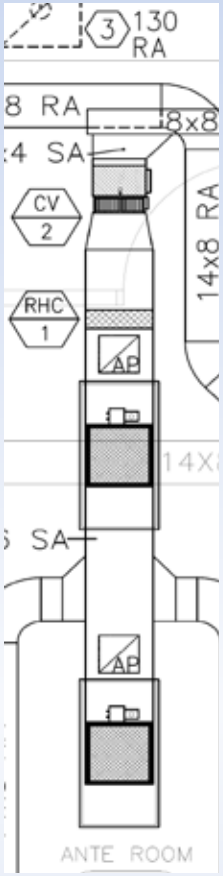
Chemo Hood Exhaust Duct

Constant Volume VAV Box

Fan Filter Unit

Low Exhaust or Return

Pharmacy HVAC System Challenge



- Fan filter units are in line with the CV boxes
- CV boxes' dampers will modulate in response to a change in pressure in the duct
- Fan filter units' ECM motors modulate as the filters load up
- Two modulating devices in series fight each other and leads to hunting
- One device must be fixed – ECM motors can be set fixed

Thank you for you time

Questions?