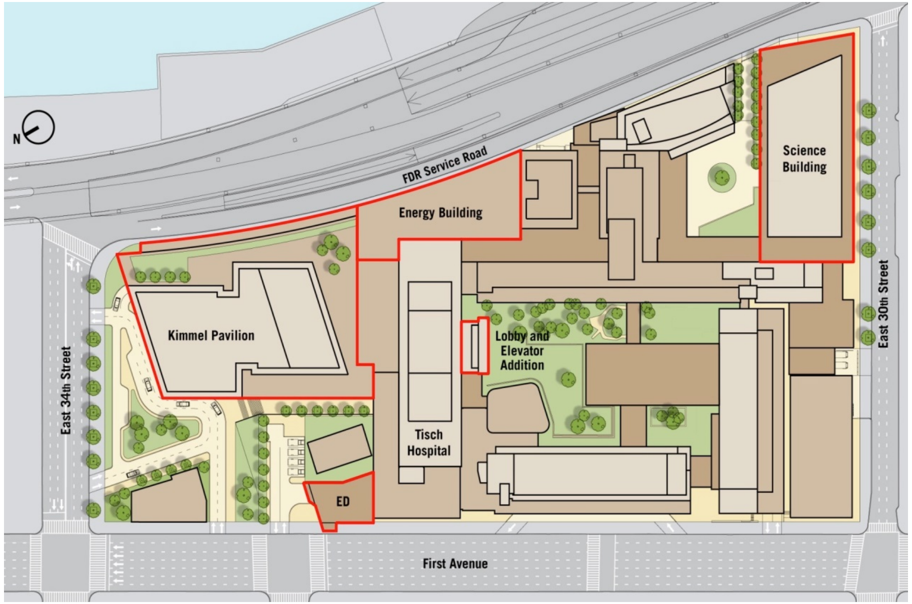
Control Strategies for Operating Rooms and Critical Spaces

John Bartlik, PE

Adam Vesterholt, PE

Introduction to NYULH

- 3.6 M SQFT Main Campus
- Centralized Steam and CHW systems
- 2 CHPs – Primary 7 MW Gas Turbine w/ 2.4 MW Steam Turbine combined cycle
- Secondary 2.9 MW reciprocating gas engine CHP
- 3 Electric + 1 Steam Turbine Chiller Plant feeding single loop
- **4 Lab Buildings, 2 Vivaria, 67 ORs**



Outline

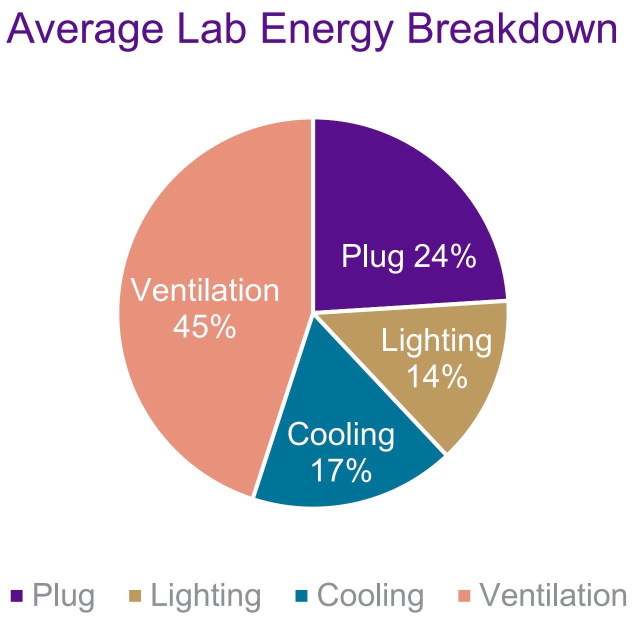
- Overview of Critical Spaces and Importance of Critical Spaces to Energy Conservation
- Pressurization and Airflow
- Temperature and Humidity Control
- Controls Strategy

Critical Room Ventilation Requirements

- **Air Change Rates (ACH)**
  - Specified minimum total and outdoor air change rates per hour
  - Operating Rooms: 20 ACH total, 4 ACH outside air
- **Pressure Relationships**
  - Specified relationship relative to all adjacent spaces
  - Operating Rooms: Positive pressure differential of at least +0.01 inWC
- **Design Space Temperature Requirements**
  - Specified temperature range for normal operation
  - Operating Rooms: 68-75 °F
- **Design Relative Humidity Requirements**
  - Specified humidity range for normal operation
  - Operating Rooms: 20-60 %RH (FGI Guidelines)

Source: ANSI/ASHRAE/ASHE Standard 170-2013

Importance of Control Optimization

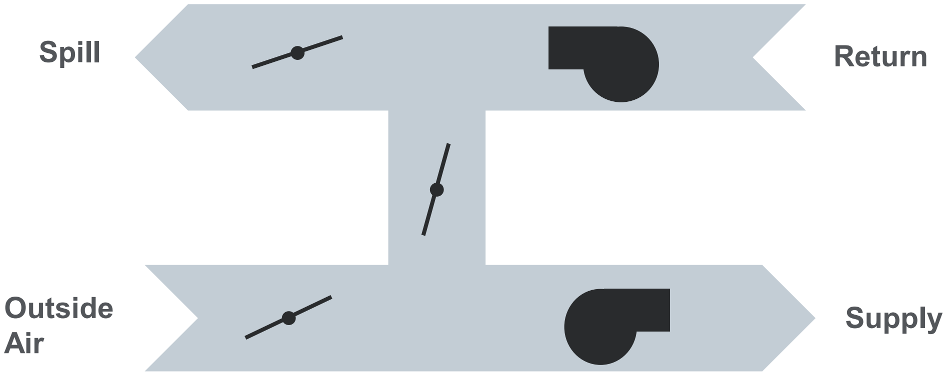


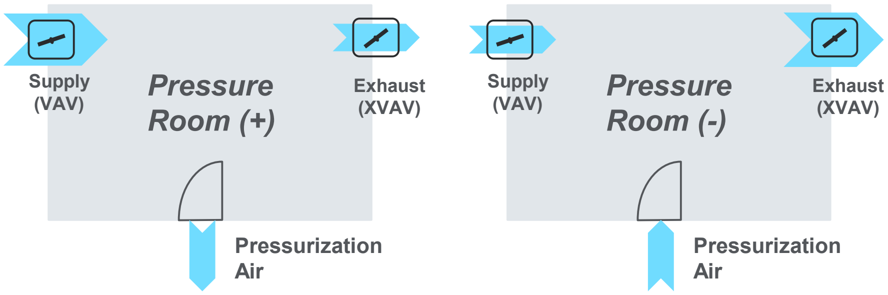
Breakdown of Average Energy Use for Measured Lab Buildings in the USA.
Labs 21 Benchmarking Tool, 2010

- Critical spaces use a tremendous amount of energy for conditioning
- Many are over ventilated above their require ACH levels to maintain pressure, temperature or humidity
- Temperature and ACH setbacks have potential to provide significant energy savings

NYU Langone Health

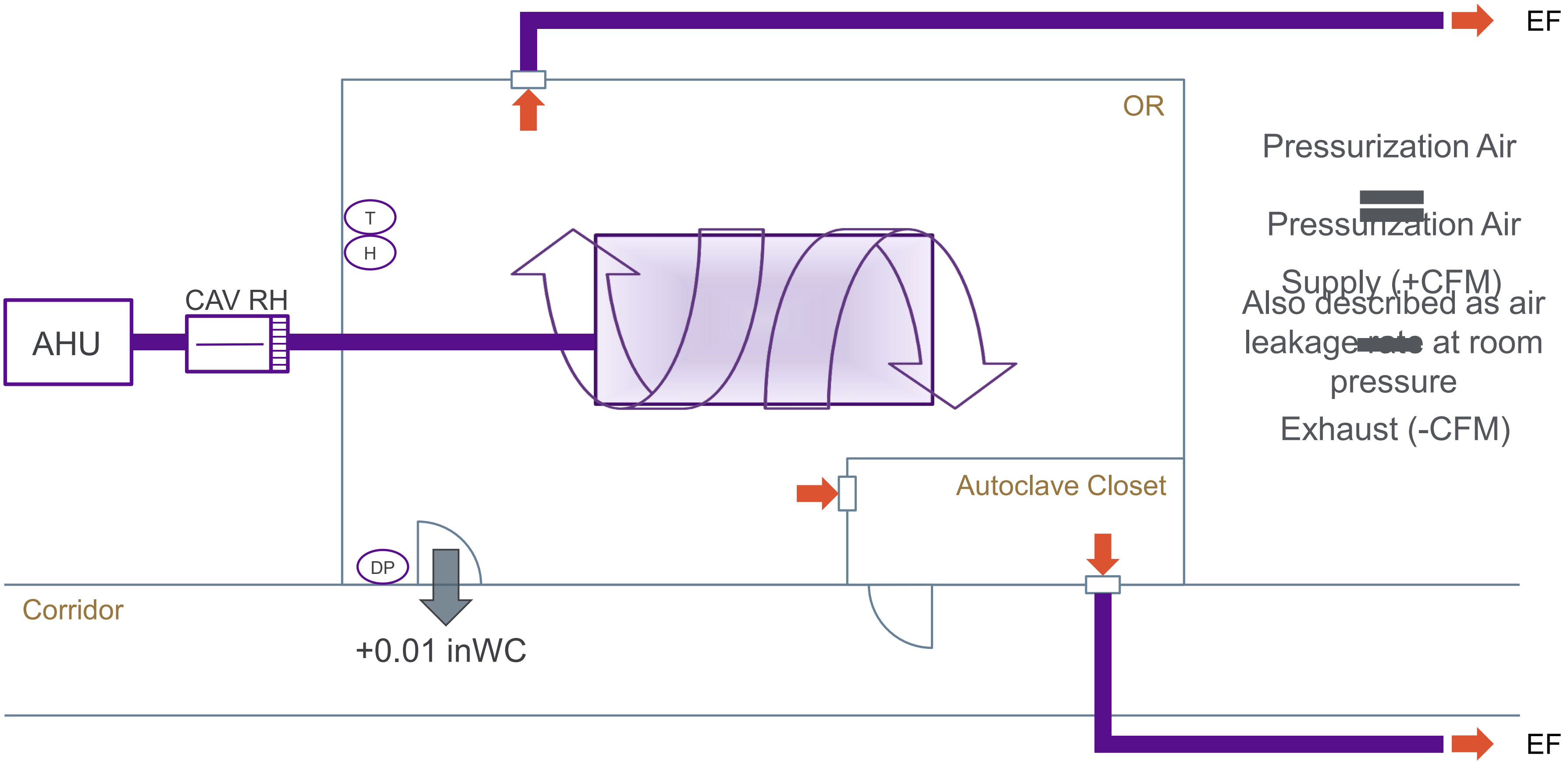
Key Concepts





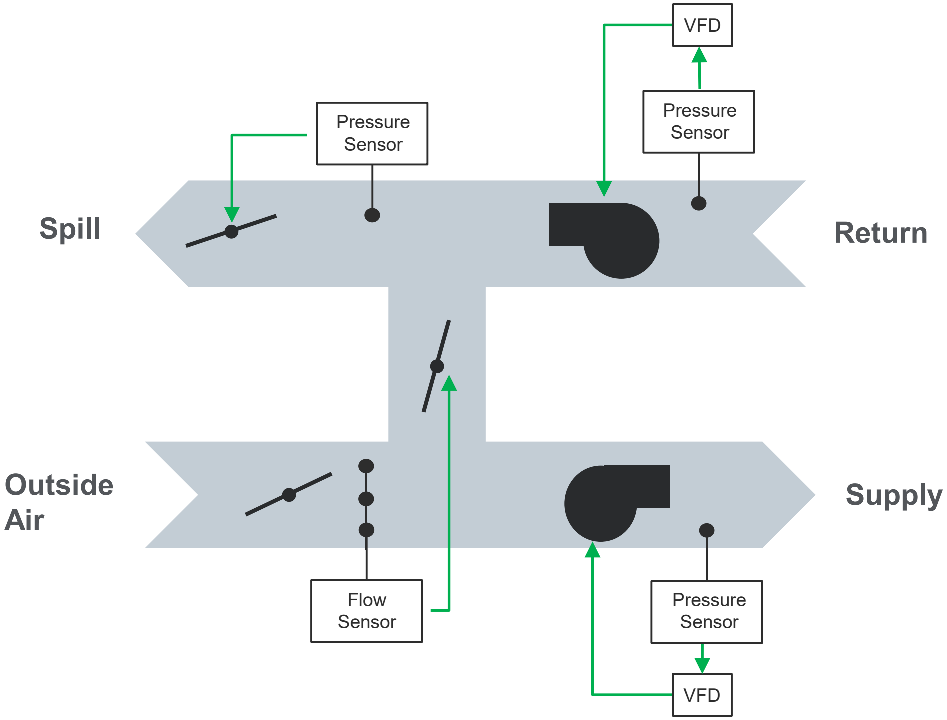
- Pressurization Air = Air In- Air Out = Supply - Return = OA – Spill
- Maintaining pressure often requires excess ACH due to leakage sources:
  - Outlets, Ceilings, Med Gas Manifolds, Access Panels
  - **Sensors/Tstats** – Can suck in air resulting in improper control
  - Seal EVERYTHING
- Reduce pressurization air = reduced OA conditioning & fan energy

NYU Langone Health



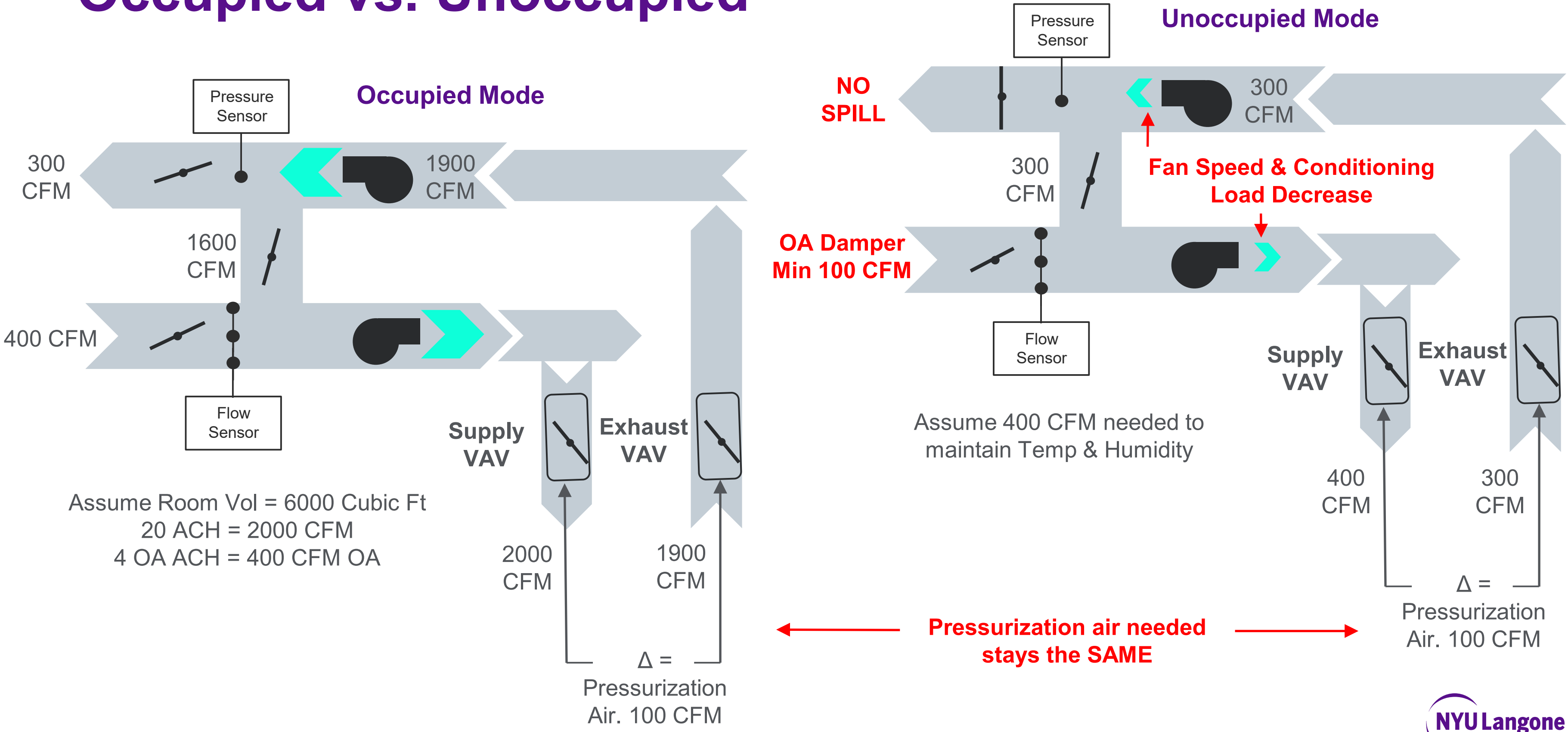
Pressurization

Key Concepts



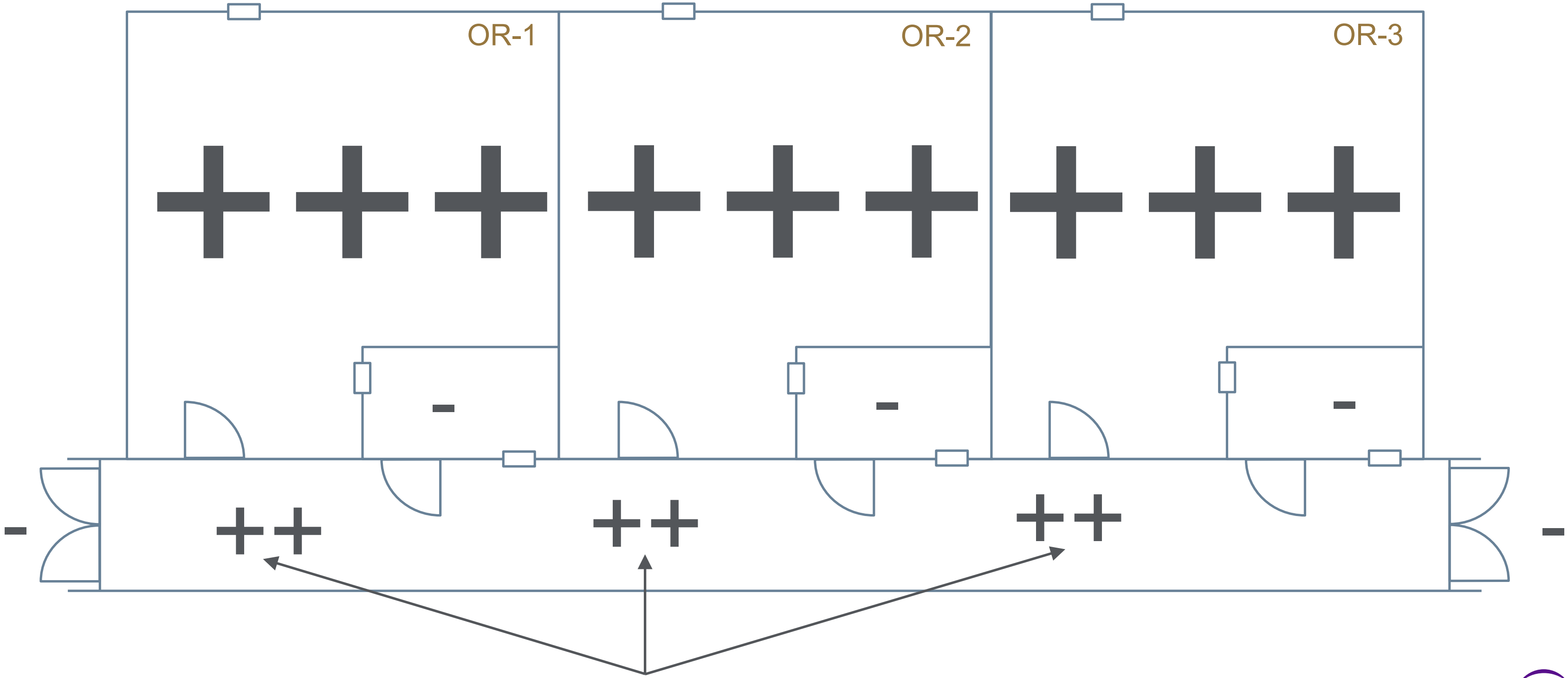
- Outdoor Air Flow Rate = Greater of OA ventilation required for code and make up air (exhaust) or Pressurization Air required
- The goal is to reduce pressurization air as much as possible to maximize return air available and reduce excess OA ventilation. This allows savings in occupied mode and expands savings in unoccupied mode.
- Flow sensor controls return damper
- Pressure sensor controls spill damper
- Spill Air only required if Pressurization Air < OA ventilation code requirement
- VFDs control room pressure & temp independently

Occupied vs. Unoccupied



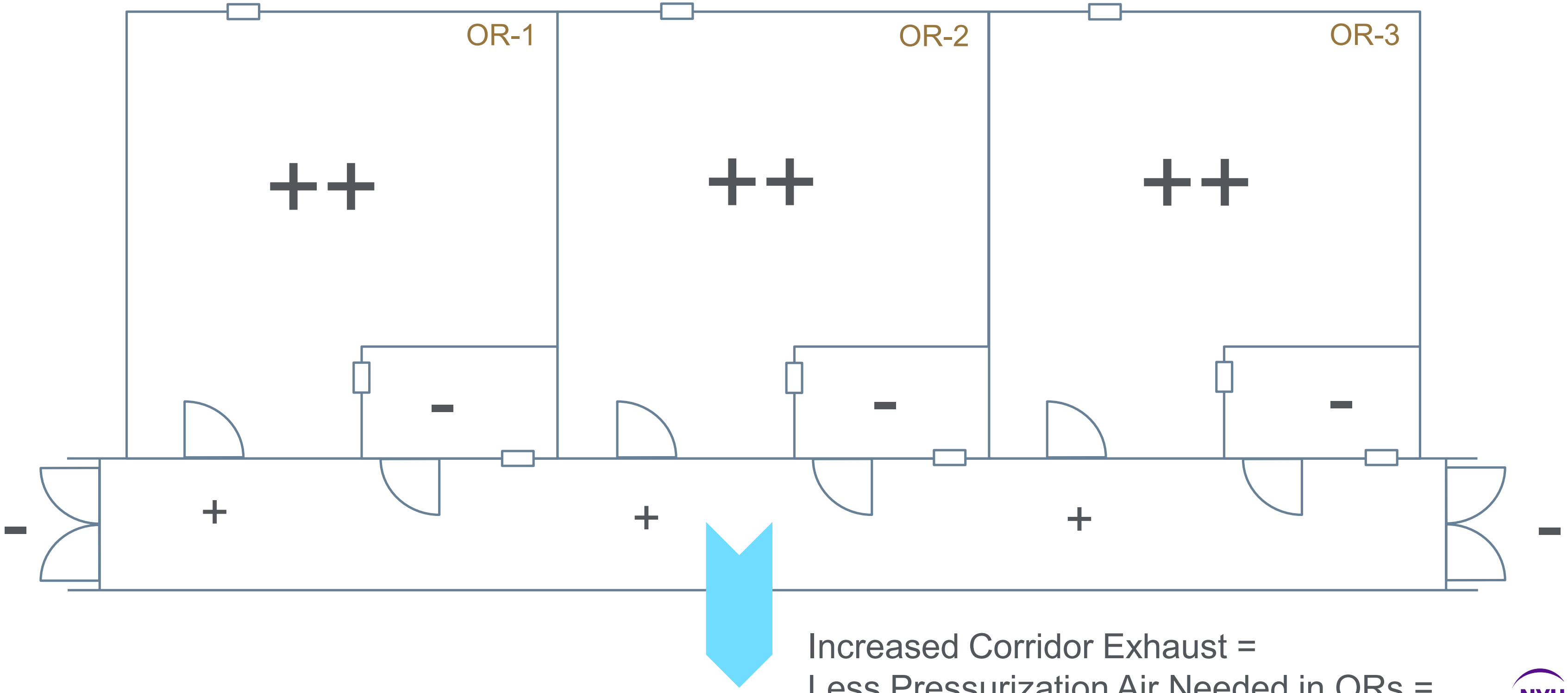
NYU Langone Health

Suite Relationship



Inadequate Corridor Exhaust -ORs “Fight” Each Other to Remain Pressurized

Suite Relationship



Increased Corridor Exhaust =
Less Pressurization Air Needed in ORs =
Less air to condition

Tisch Hospital – OR Ventilation Project

- **Background:**
  - Original system designed for 48 F constant volume supply 24/7
  - Rooms were not tight and air distribution issues, resulting in excessive ACH rates to maintain pressure
  - Existing OR suite served by 100% outside air HVAC systems in variety of combinations, including dedicated or shared supply/exhaust, and no individual exhaust control
  - Airside systems operate at occupied settings 24/7 although occupancy generally follows a daytime schedule (except emergency surgery)
- **Project Goals:**
  - Improve operating room environment through precise control of air flow and performance monitoring
  - Reduce energy consumption and costs
  - Improve Infection Prevention & Control (IPC) strategies related to mechanical systems and failure scenarios

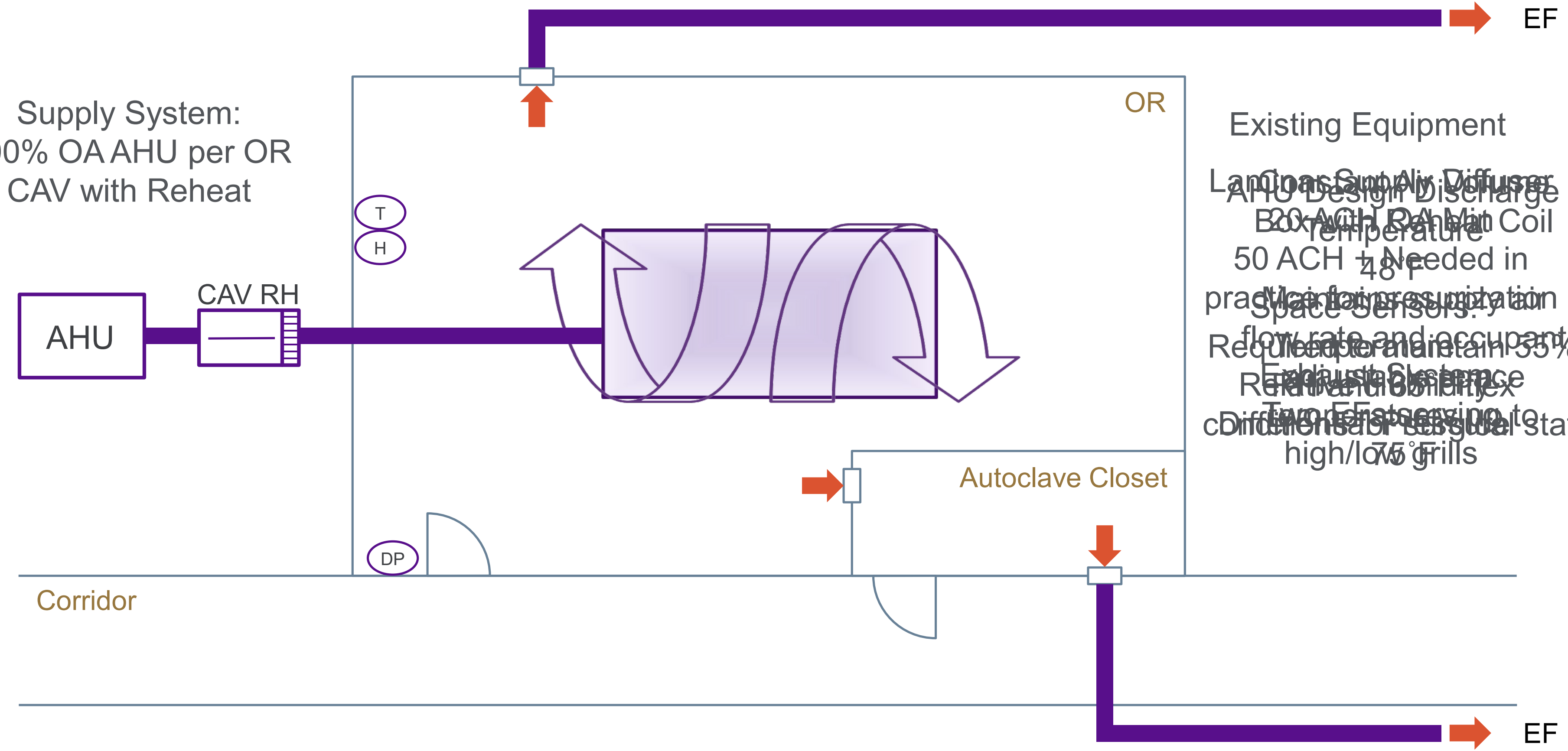
NYU Langone Health

Tisch Hospital – OR Ventilation Project

- **Interventions:**
  - Designed and installed new distributed air volume control systems that can precisely control air flow in and out of individual operating rooms
  - Installed corridor exhaust to lower pressure and allow ORs to maintain pressure with fewer ACH
  - Installed and integrated new controls, including occupant control panels, temperature/humidity/differential pressure sensors, and door DP monitors for each OR
  - Added door contacts to sense and log when operating room doors are open to reduce nuisance pressure alarms, prevent VAV boxes from responding to pressure loss
  - Implemented HVAC setback strategies to 6 ACH during unoccupied periods
  - Developed new OR Dashboard to monitor compliance conditions
  - Introduced the Flex Range to temperature/humidity ranges, which refers to a zone outside of FGI requirements that is deemed acceptable by the IPC board for a temporary period
  - Reduce IPC risk present in case of fan failure

NYU Langone Health

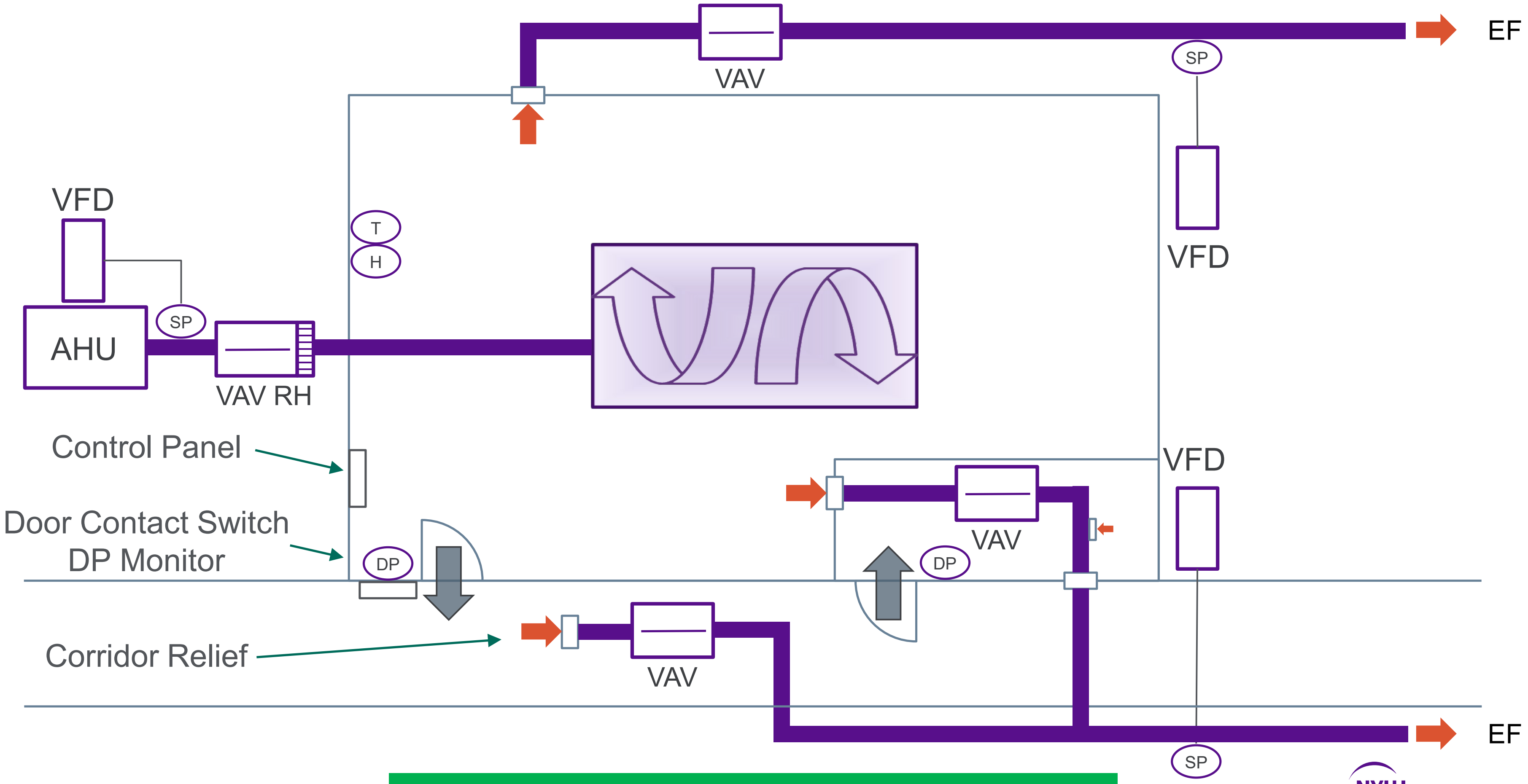
Supply System:
100% OA AHU per OR
CAV with Reheat



Existing Equipment

Existing Operating Room

NYU Langone Health



After Retrofit

NYU Langone Health

Tisch Hospital – OR Ventilation Project

Occupied Operation

Supply and exhaust systems will operate to maintain:

Air flow	20 ACH
Pressure	> 0.02 inWC
Humidity	20-60%
Temperature	Control to SP

CRC Panel will read **OCCUPIED**

Unoccupied Operation

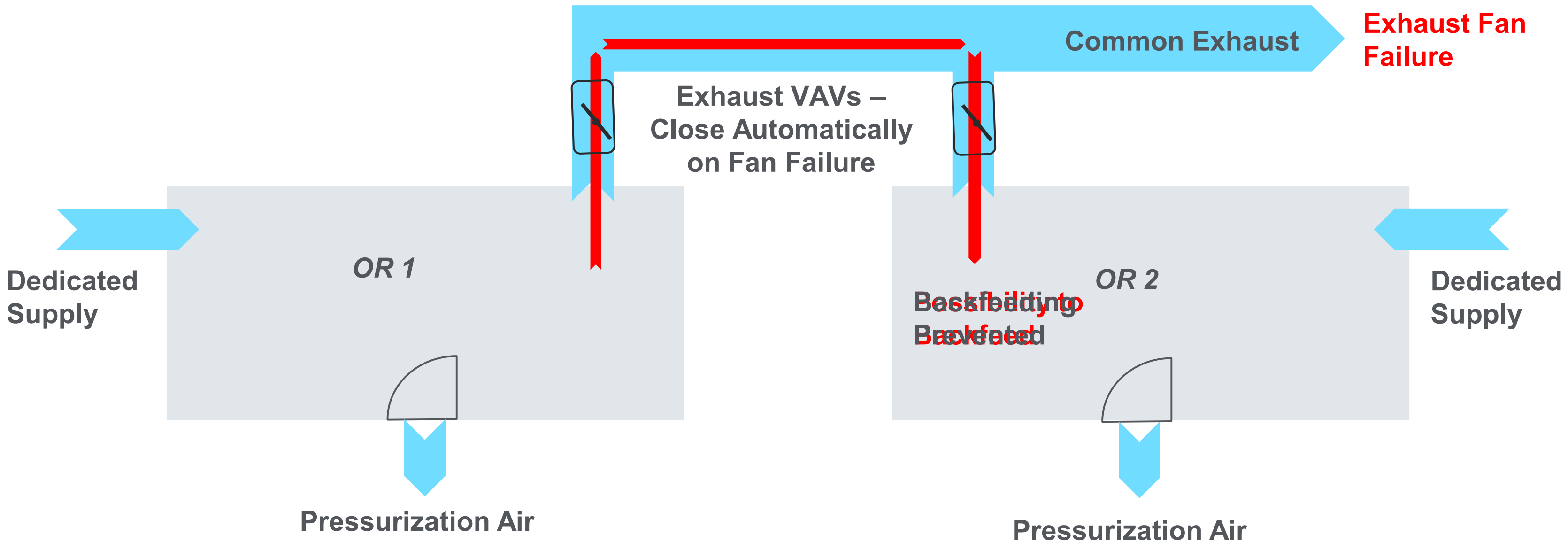
Supply and exhaust systems will operate to maintain:

Air flow	Min 6 ACH
Pressure	0.013 inWC
Humidity	20-60%
Temperature	Control to 68-75°F Range

CRC Panel will read **UNOCCUPIED**

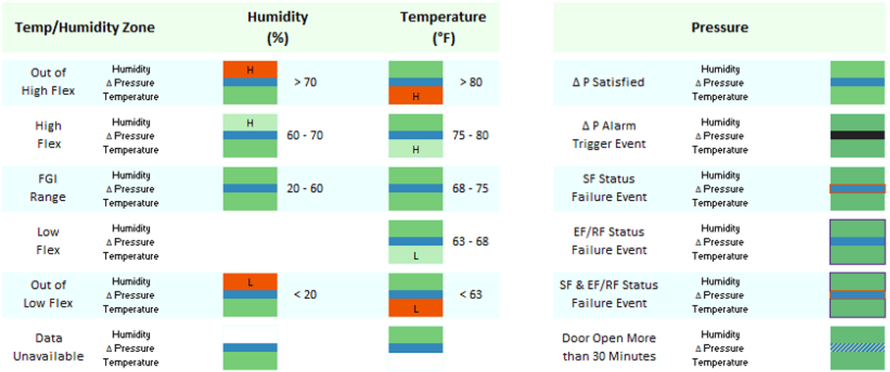
NYU Langone Health

Tisch Hospital – Infection Risk Reduction

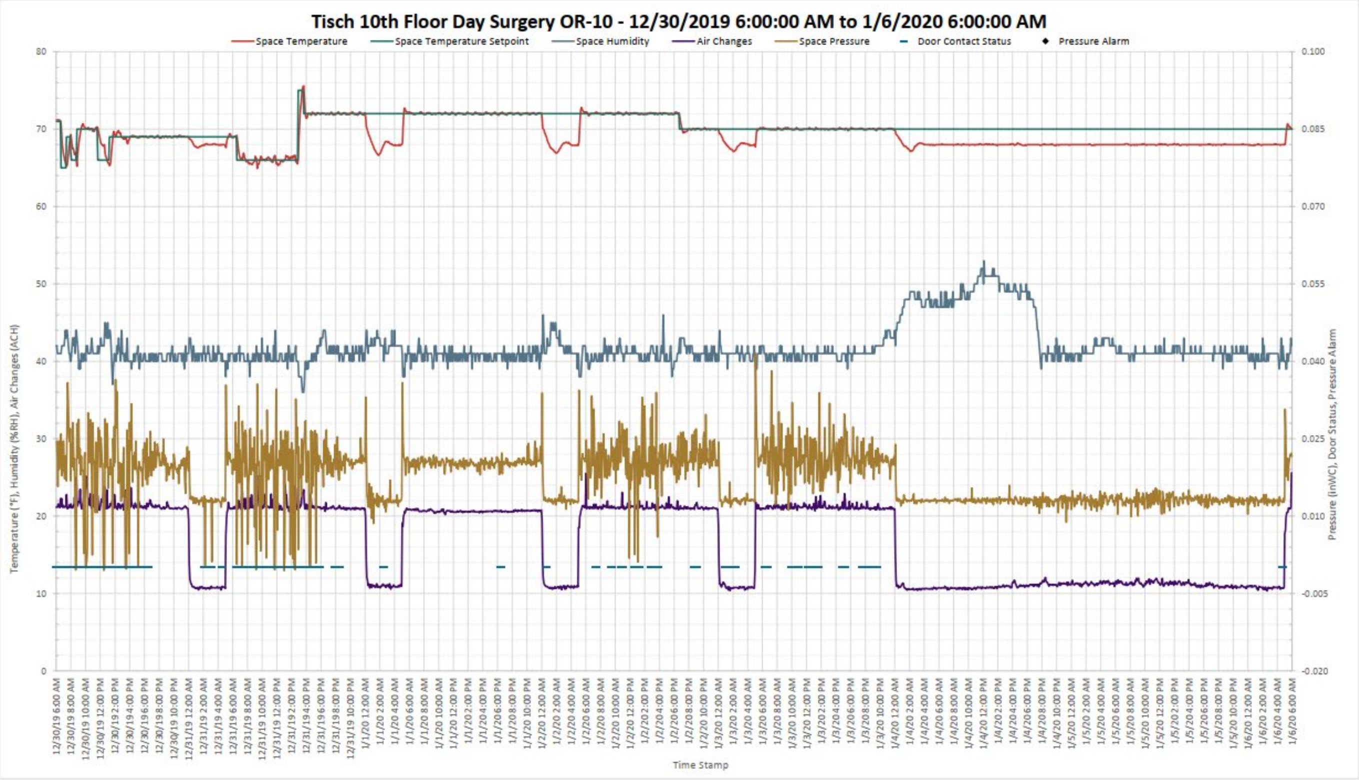


OR Performance Monitoring and Reporting

- **Automated Daily Performance Review**
  - Provides comparison of OR space conditions and system performance with NYULH policy and OR Occupancy Program
  - Color-coded blocks illustrate hourly performance profile with accompanying tabular summary
  - Includes performance metrics to gauge historical performance and encourage continual improvement



OR Performance Monitoring and Reporting



NYU Langone Health

OR Performance Monitoring and Reporting

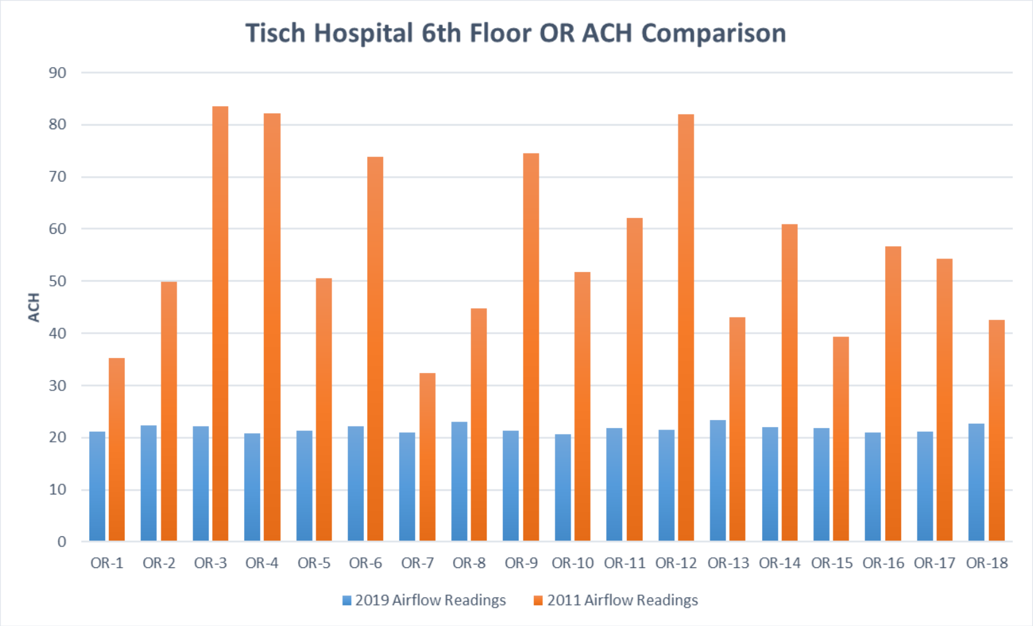
OR #	Trend	6:00 AM	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM	4:00 PM	5:00 PM	6:00 PM	7:00 PM	8:00 PM	9:00 PM	10:00 PM	11:00 PM	12:00 AM	1:00 AM	2:00 AM	3:00 AM	4:00 AM	5:00 AM
OR-1	Humidity ΔPressure Temperature	68.6	65.0	L	L	L	L	L	L	65.3	69.0														
OR-2	Humidity ΔPressure Temperature	65.0	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L
OR-3	Humidity ΔPressure Temperature	72.0																							
OR-4	Humidity ΔPressure Temperature	69.0																							
OR-5	Humidity ΔPressure Temperature	67.0	L	L	L	L	L	L	L	L	L	L	L	L	L	L	65.5	65.0	L	L	L	L	L	L	L
OR-6	Humidity ΔPressure Temperature	69.0			68.5	68.0	68.6	69.0				68.7	68.0		L	L	L	L					L	L	L
OR-7	Humidity ΔPressure Temperature	70.0	67.3	65.3	65.0		L		L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L
OR-8	Humidity ΔPressure Temperature	68.0				L				L		L		L			L	L					L	L	L
OR-9	Humidity ΔPressure Temperature	72.0	66.0	L	L	68.3	69.5	72.0																	
OR-10	Humidity ΔPressure Temperature	69.0				69.8	70.3	71.0	69.3	69.5	69.0						67.5	67.0	L	L	L	L	L	L	L
OR-11	Humidity ΔPressure Temperature	70.0	67.8	67.0				L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L
OR-12	Humidity ΔPressure Temperature	68.0		L		L	L	69.0	69.8	68.0	68.5	68.3	72.0	70.3	69.0										
OR-13	Humidity ΔPressure Temperature	71.0											67.5	65.0	L	L	L	L	L	L	L	L	L	L	L
OR-14	Humidity ΔPressure Temperature	69.0								69.4	70.0														
OR-15	Humidity ΔPressure Temperature	65.0	L	L	66.3	68.0		68.5	69.0					67.0	65.0	L	L	L	L	L	L	L	L	L	L
OR-16	Humidity ΔPressure Temperature	68.3	65.0		65.8	65.0	L	65.3	65.0	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L
OR-17	Humidity ΔPressure Temperature	66.0	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L
OR-18	Humidity ΔPressure Temperature	71.7	68.0		68.8	70.4	70.0																		
OR-19	Humidity ΔPressure Temperature	72.0	66.0	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L

NYU Langone Health

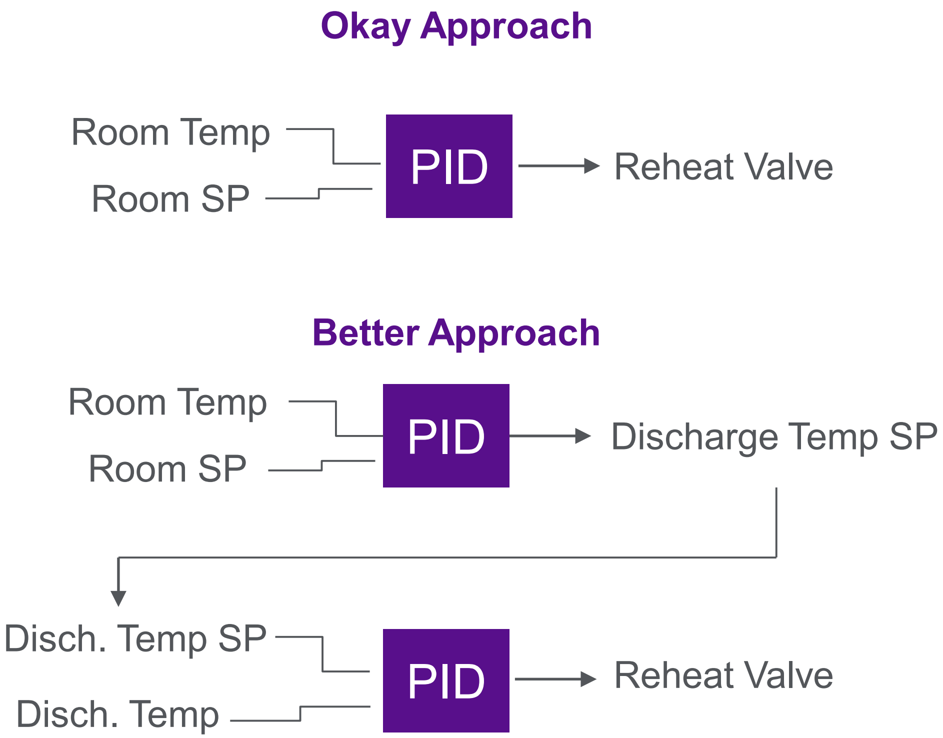
OR Performance Monitoring and Reporting

Tisch Hospital has achieved:

- Drastically reduced occupied ACH rates
- 99.9% humidity compliance
- 98.9% temperature compliance
- 99.6% pressure compliance
- 99.8% AHU runtime
- $500k in estimated energy savings



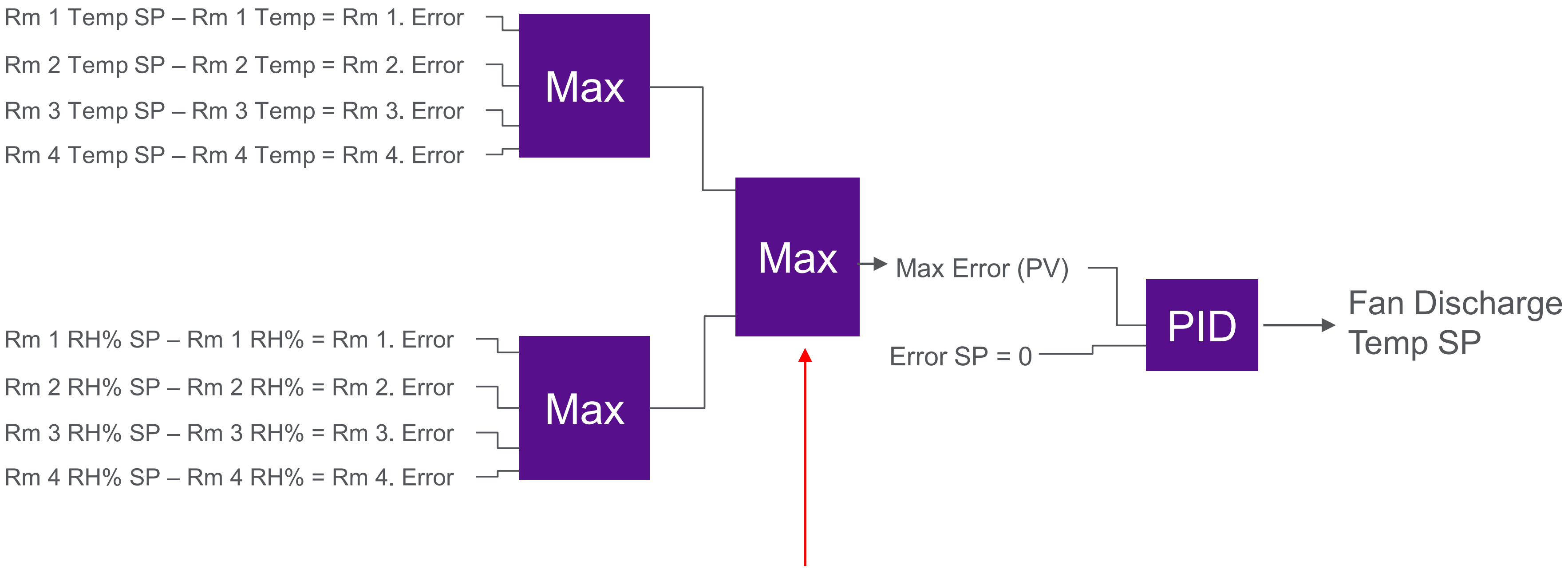
Cascaded PID Loops



Other Applications

- Room temp vs RmTmpSp to AHU discharge temp SP for room temperature control
- Room %RH vs RmDeHumSP to AHU discharge temp SP for room dehumidification control
- Room %RH vs RmHumSp to AHU discharge HumSp (or Dewpoint) for room humidity control.
- Differential pressure vs DpSp to GPM setpoint for pump speed control. For parallel pumping of multiple plants.
- Return CO2 vs RCO2Sp to AHU discharge CO2.
- Room temp vs RmTmpSP to VAV box CFMSp

Worst Case Error Control



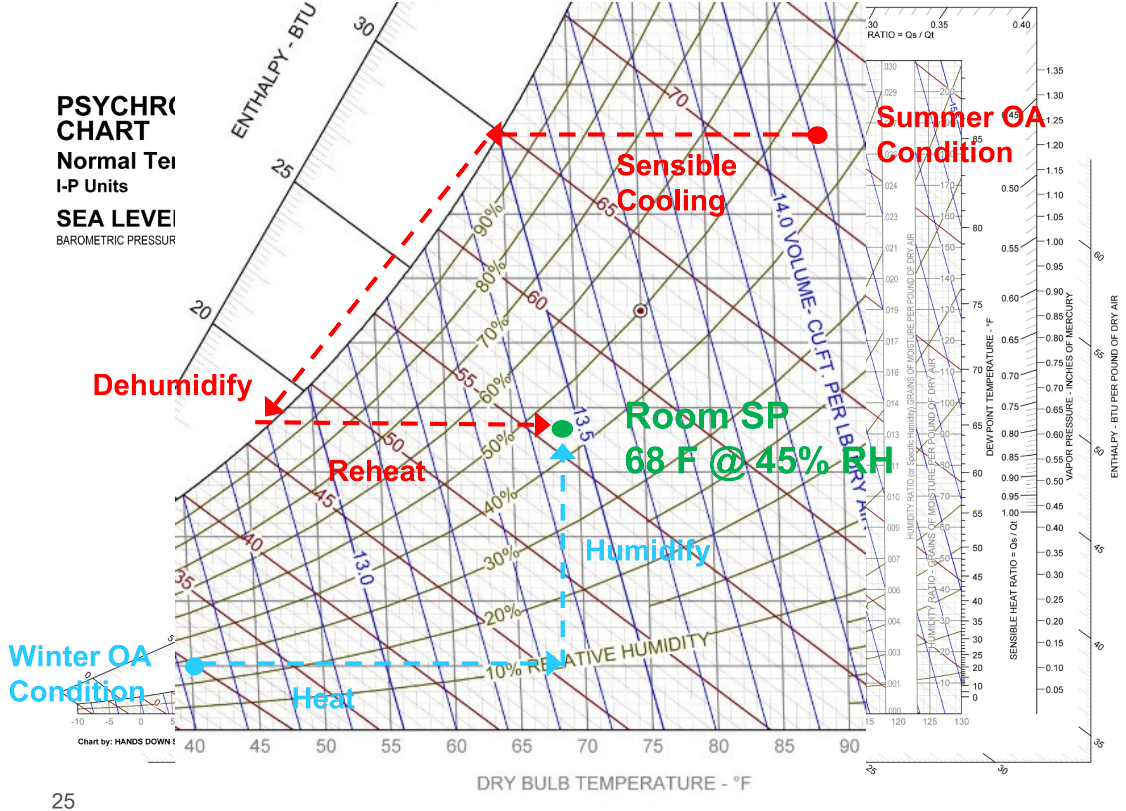
Temp and RH error are close enough for tuning purposes

Example - VAV Control Optimization

- Open lab spaces often are designed with multiple Tstats controlling boxes in different zones
- Mixing of air in the space results in divergence. One set of boxes will go to full cooling, one will go to full heating and will swing wildly
- Mitigate by averaging Tstat readouts and controlling to average or controlling to single Tstat.

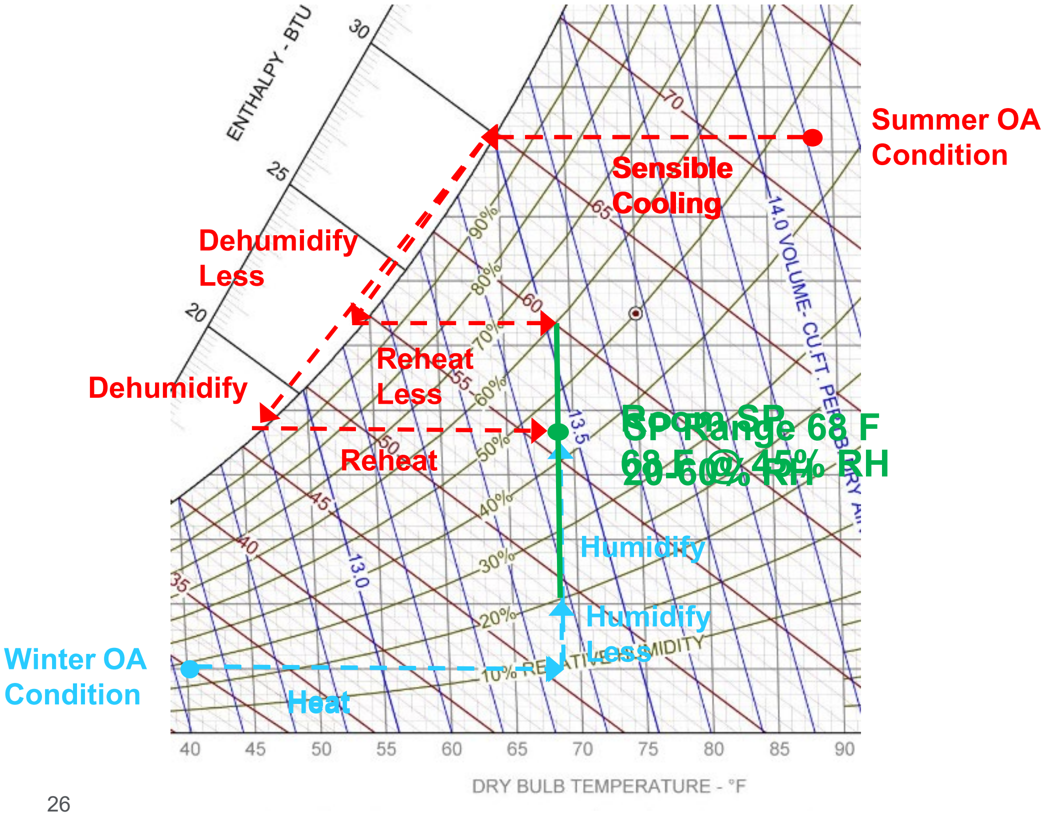
NYU Langone Health

Humidity and Temperature Control – Base Case



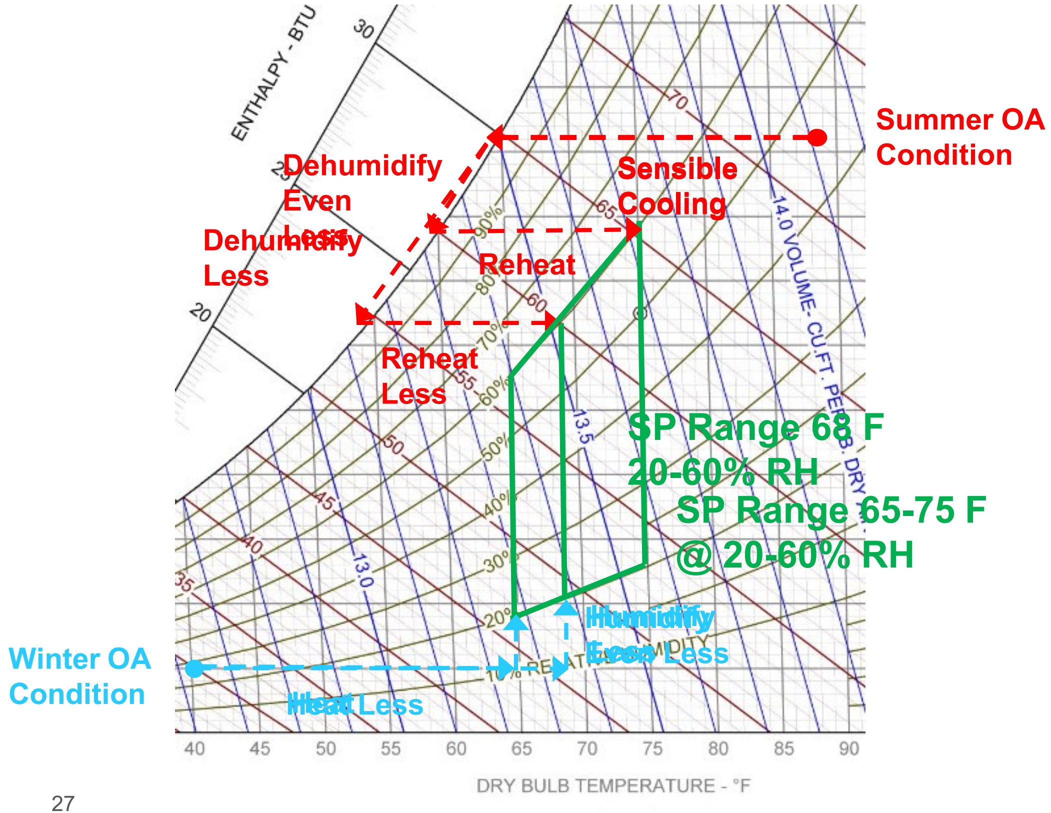
- Typical controls control to a temp and humidity set point
- Often requires both latent and sensible heat changes

Humidity and Temperature Control – Variable RH



- Occupied Mode: Temperature is set, but humidity operates on a range.
- Reduces latent cooling and reheating and humidification for various temperature and humidity ranges.

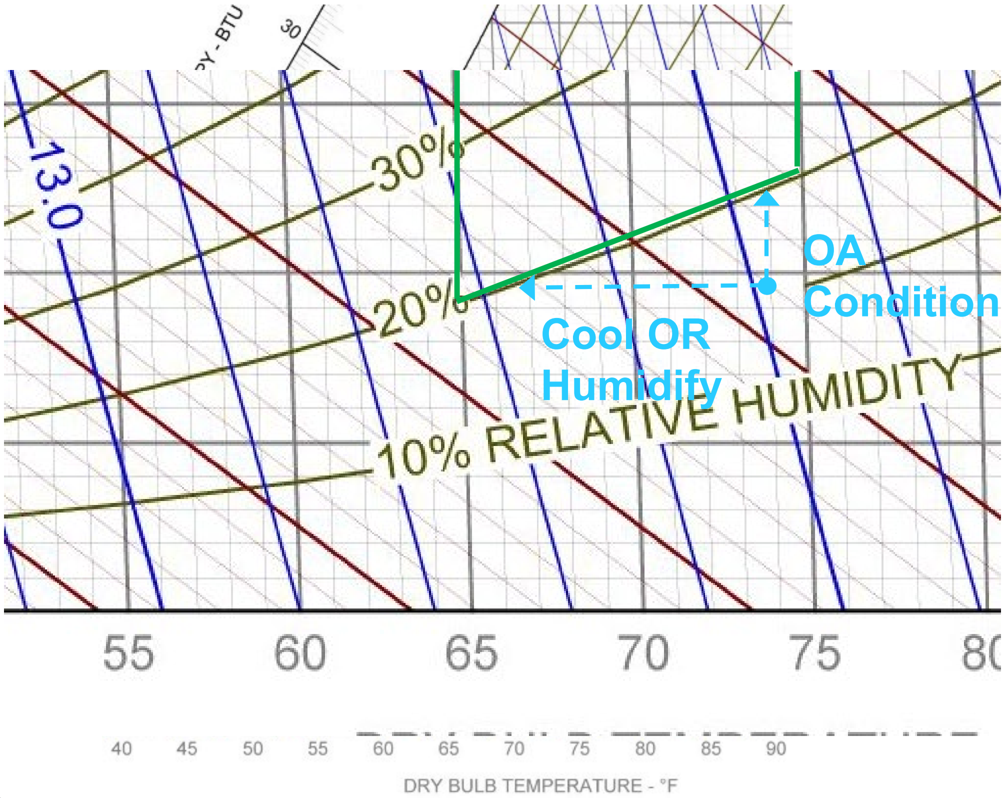
Humidity and Temperature Control - Unoccupied



- In unoccupied mode, temperature becomes a range as well
- Control to zone instead of point
- Allow for elimination of unnecessary conditioning under many circumstances

NYU Langone Health

Humidity and Temperature Control – Fuel Choice



- Certain temperature ranges allow for a choice between sensible cooling or humidification
- Can optimize based on fuel costs
- In our case, always maximizing sensible cooling (i.e. cooling to minimum flex temp) and minimizing humidification results in lowest cost

Next Step – Statistical Management of VAVs

- VAVs modulate and enter reheat depending on AHU discharge temp
- If all VAVs are reheating, discharge temp is too low = Energy Waste
- What if some or no VAVs are reheating? Lowering discharge temp will cause modulating VAVs to close.
  - More reheat on some units, higher CHW consumption
  - AHU fans will slow down, saving fan energy
  - Raising discharge temp will reduce reheating but boxes open, increasing fan energy
- Key is to find balance for optimum cost reduction
- Challenging because controls have to know real time marginal cost of steam and CHW.
- Single starved VAV on a system can force many VAVs to reheat. Add supplemental cooling.

Thank You