BUILDINGENERGY BOSTON

Tales from the Trenches: Passive House Ventilation Commissioning Roadblocks

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Learning Objectives

1. Discuss **common passive house ventilation system designs**, layouts, and components pertaining to the performance and field installations.
2. Demonstrate through examples **common problem areas** related to implementing high-performance ventilation systems.
3. Recommend ways to **design for best ventilation performance** based upon lessons learned.
4. Describe the **Passive House certification criteria** and the actual performance necessary for ventilation systems to be within compliance.

Overview of Presentation

1. Passive House Basics and Relevance
2. Cx Process & Relevance in PH Buildings
3. TAB, Shop Dwg, System leakage
4. ERV/HRV Controls & Interlocks
5. Operations & Maintenance
6. Conclusion

Passive House Basics & Relevance

Passive House In the News

Passive House Required for Multi-family equal to or greater than 12,000 square feet:

- Effective Jan 1, 2023: Passive House required for buildings up to 5 stories
- Effective Jan 1, 2024: Passive House required for buildings 6 stories and above

Winthrop Center
Boston, MA

The Distillery
Boston, MA

North Commons
North Hamptons, MA

Harbor Village
Gloucester, MA

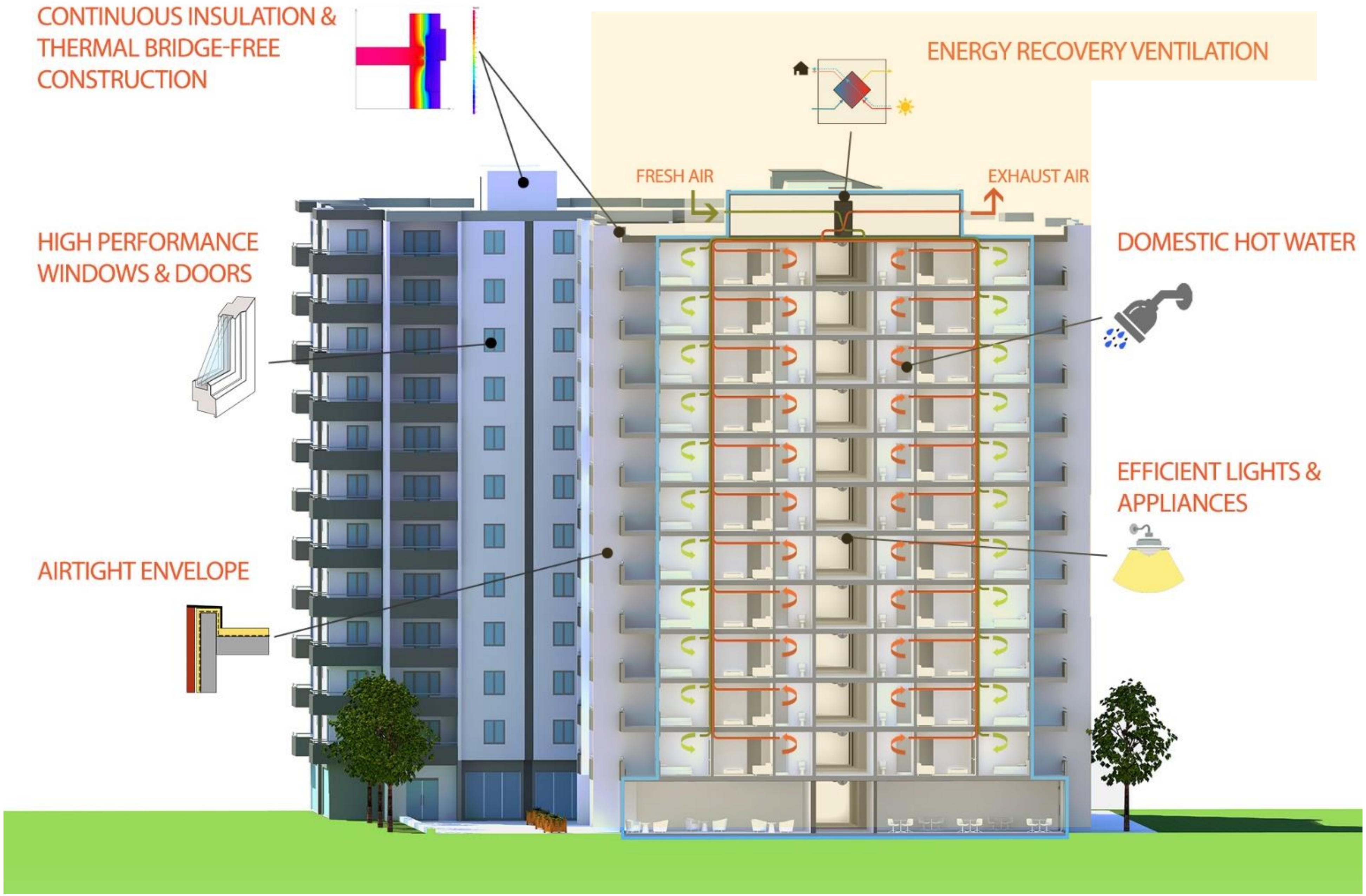
Bunker Hill
Boston, MA

Depot Village
Hanson, MA

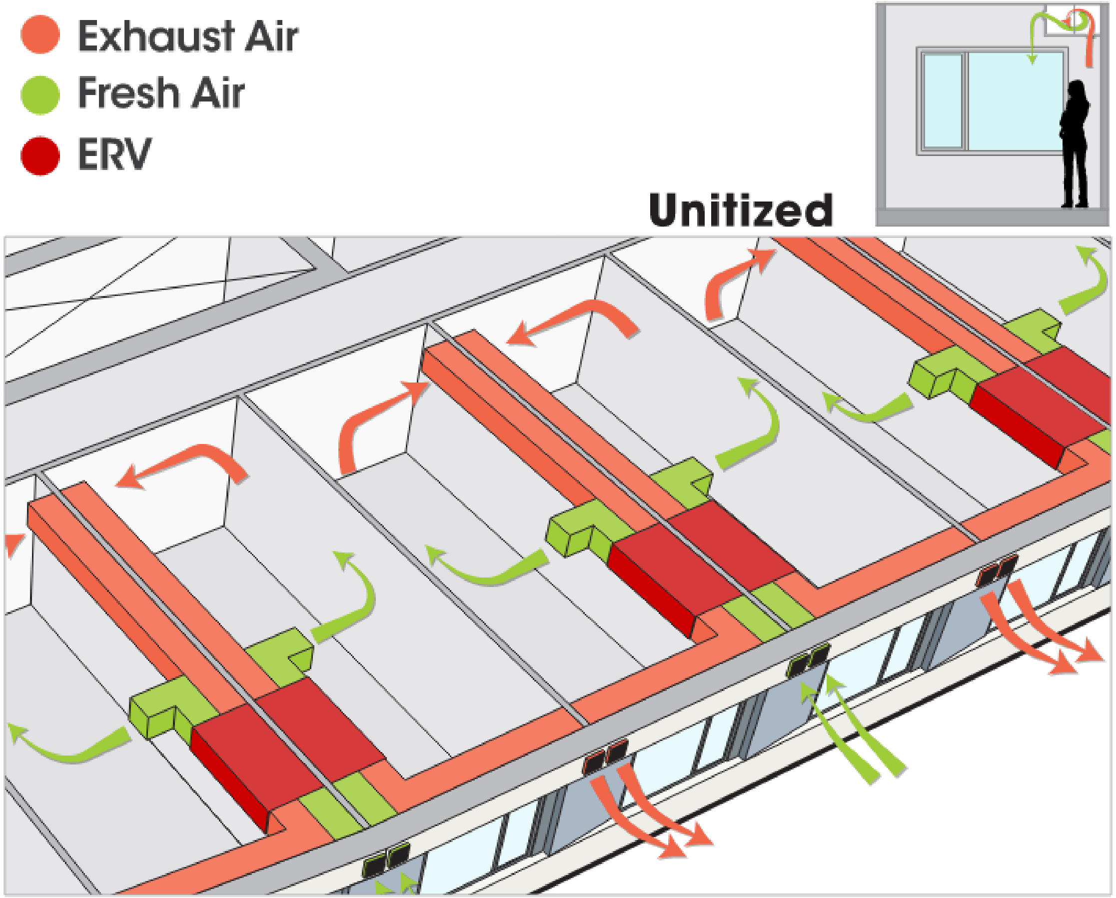
- **Over 6,500 Passive House Units in Development in MA**
- **Passive house Growth: 6+ unit multi-family currently over 6,500 units in the Mass Save® incentive program pipeline versus less than 20 in 2017.**
- **133 MA firms have Certified Passivehouse consultants, $1.7m for Mass Save training of 3,600 people in 2022-2024.**
- **Significant Mass Save incentives available for design/feasibility and construction up to $3,000 per unit.**

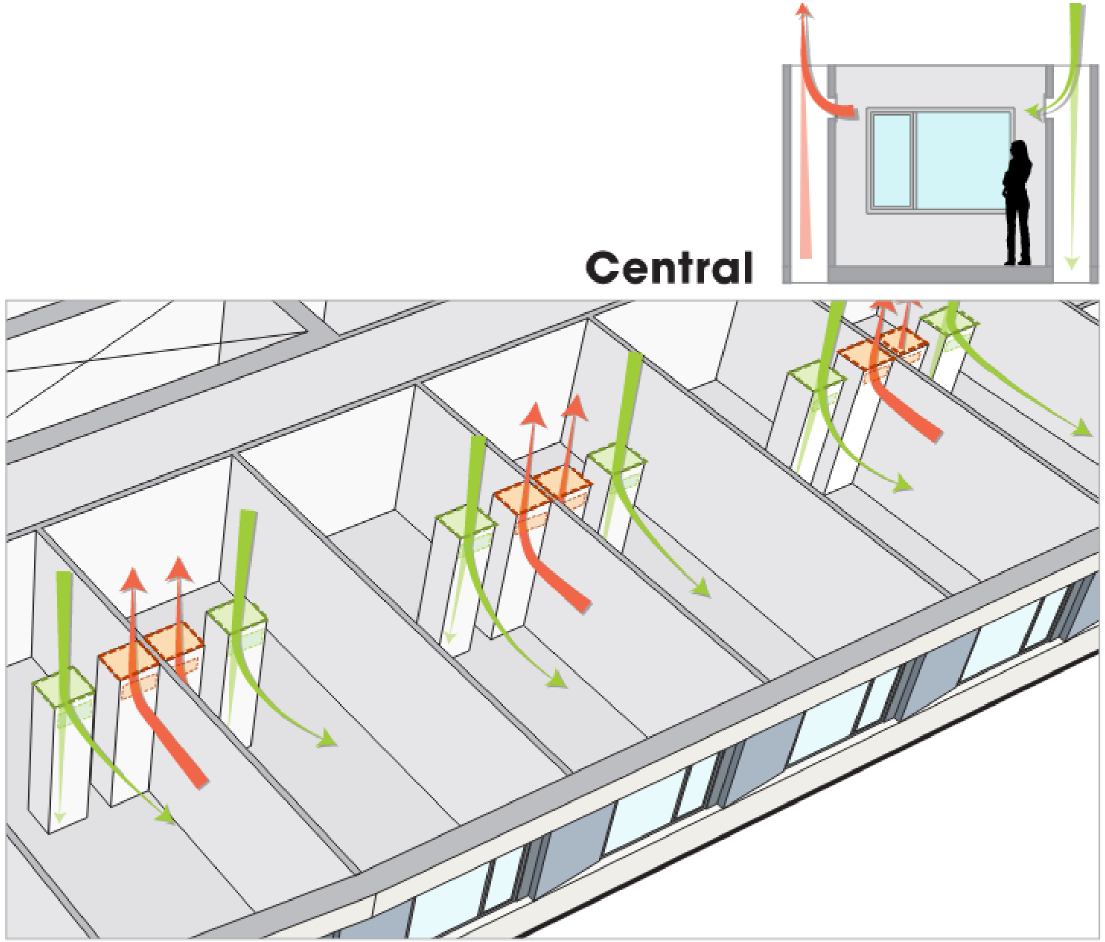
https://phmass.org/buildingcode/

ELEMENTS OF A LARGE MULTIFAMILY PASSIVE HOUSE BUILDING



Ventilation: Unitized vs. Central vs. Semi- Central





Credit: Handel Architects

Introduction – Ventilation Recommendations and Requirements

Energy Efficiency:

- Recommend ERV HRV fan motors consume 0.765 W/cfm or less at the highest power setting
  - **Verify ERV/HRV wattage at final**

Balancing Requirements:

- Supply and exhaust flows are **within 10% of each other (at the unit)**
- A targeted air change rate between 0.30 and 0.50 air changes per hour (ACH)
- Minimum **flow rates must be met** in apartments
- Supply and exhaust flows are +/- 15% or 15 CFM of design values (in apartments)
- **Third-party** (certified air balancing professional e.g. NEBB, AABC)
- Required pre-meeting with TAB contractor to discuss expectations

Cx Process & Relevance in PH Buildings

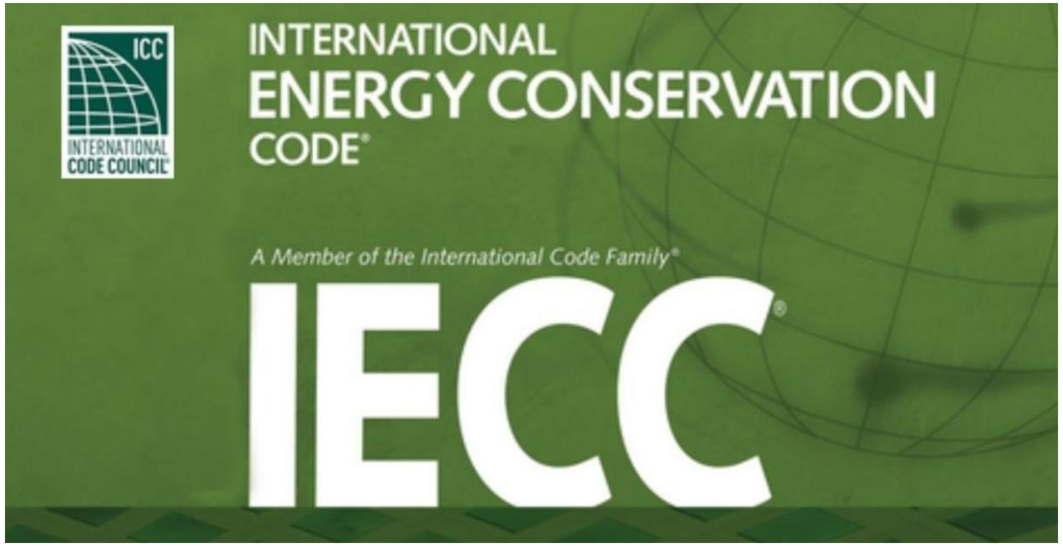
Project Flow

Modeling and Design	Project Kickoff	Review Feasibility, 100 DD, 50 CD, and 100 CD	Model performance and provide reports	Develop Cx specs, Create Cx plan
Pre-Construction	Develop construction checklists	Construction kickoff meeting with client	Define training requirements	Clarify roles & responsibilities for Cx scope
Construction Phase	Contractor Training	Ongoing site inspections	Submittal review	Interim testing
Construction Completion	Verify proper installation of MEP systems	MEP Startups & Functional Testing	Testing and Balancing (TAB)	Ventilation system readings (Post-TAB verification)
Closeout Phase	O&M & As-Built Documentation	Submission to a certifying body	Warranty review	Seasonal testing

Energy Code Commissioning (Cx)

Exceptions: The following systems are exempt:

1. Mechanical systems and service water heater systems in buildings where the total mechanical equipment capacity is less than 480,000 Btu/h (140.7 kW) cooling capacity and 600,000 Btu/h (175.8 kW) combined service water-heating and space-heating capacity.
2. Systems included in Section C403.3 that serve individual *dwelling units* and *sleeping units*.



Cx Impact

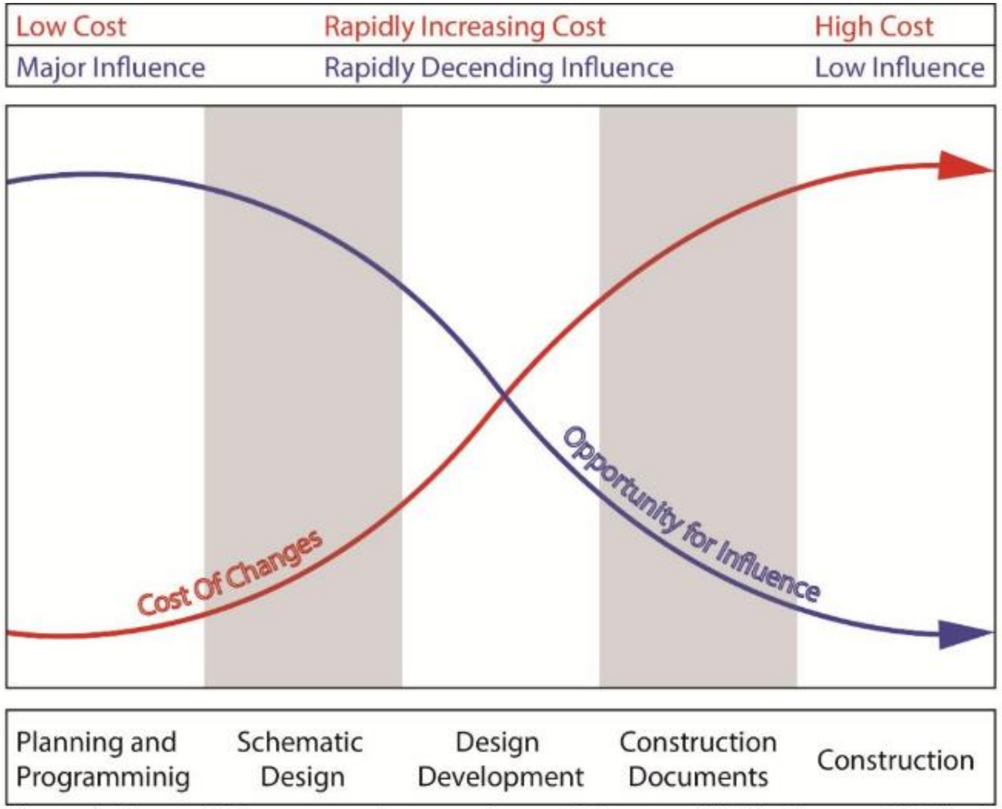
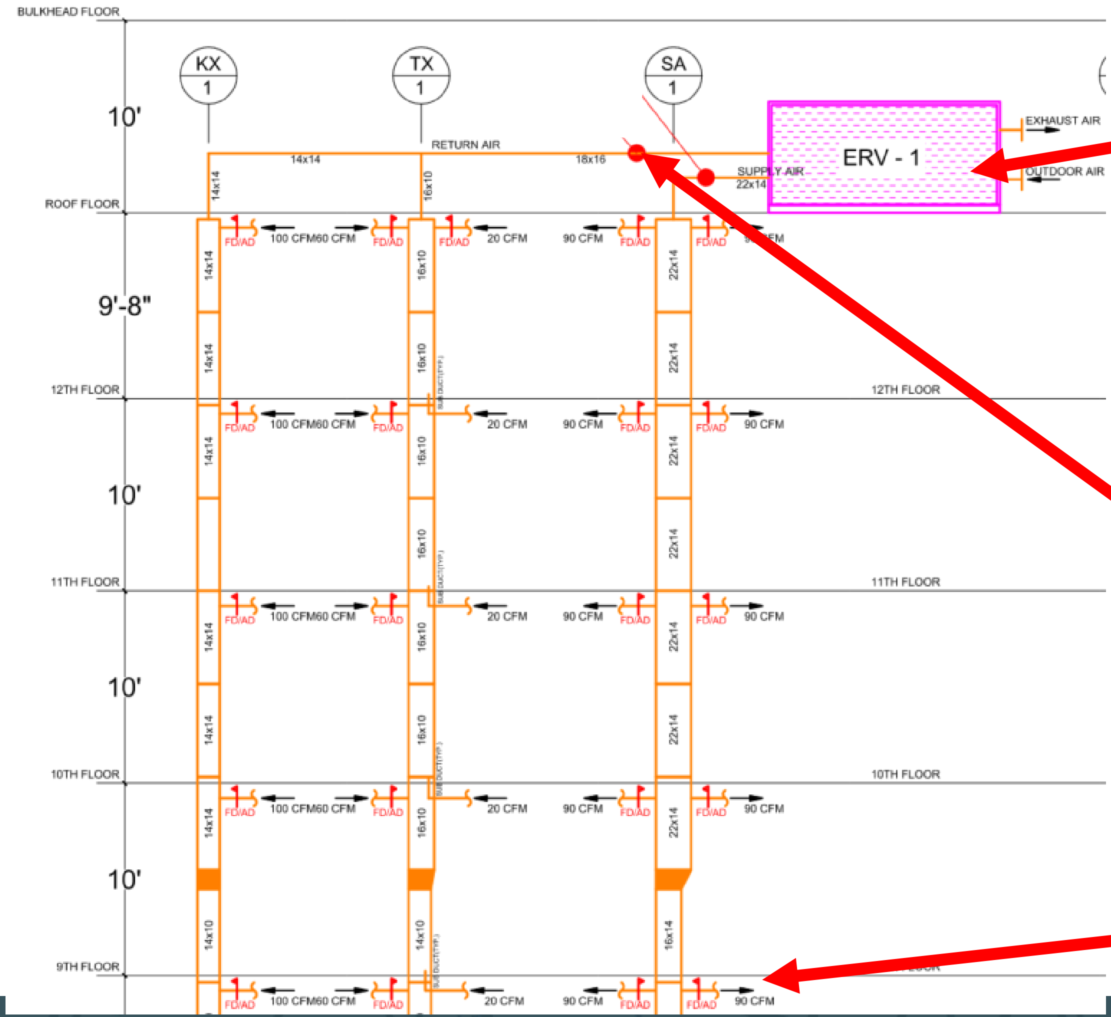


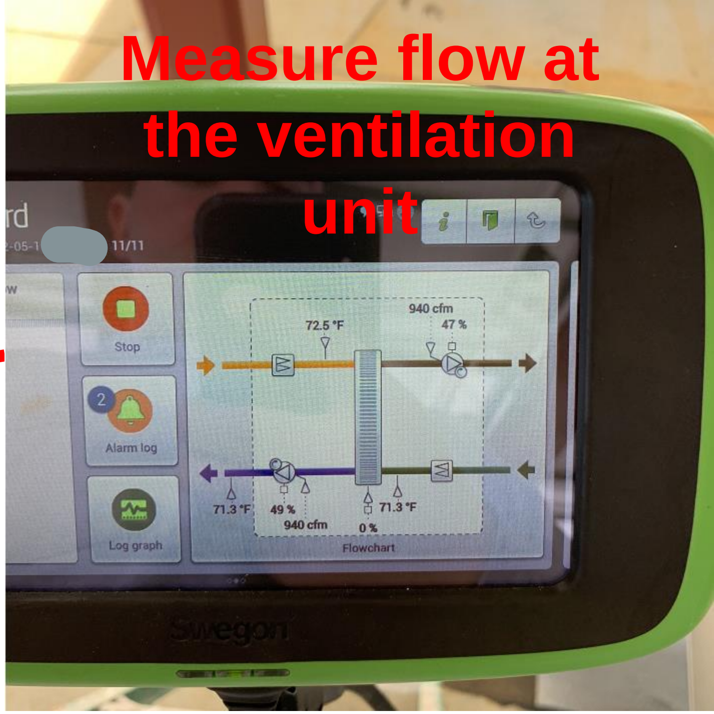
Figure 1. Cost of Change vs. Opportunity to Influence, Edith Cherry, FAIA, ASLA a

TAB, Shop Drawings and System Leakage

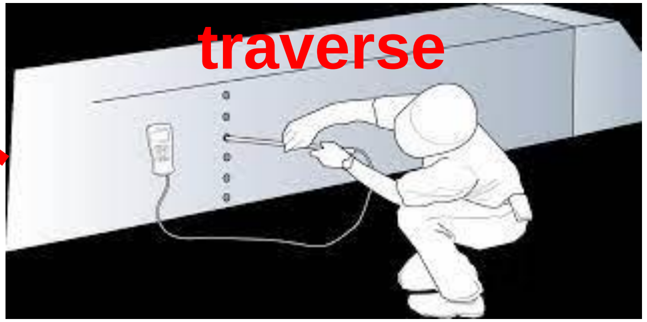
Testing and Balancing - Process



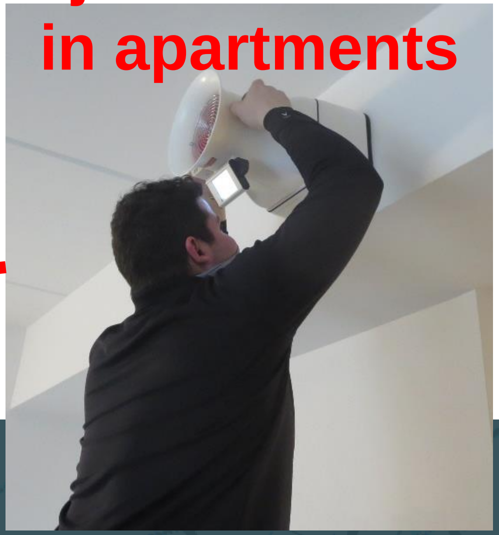
Measure flow at the ventilation unit



Pitot tube traverse



Measure and adjust flow rates in apartments



Testing and Balancing – Comparing Flow Hoods

Key Findings of LBNL Report - 47382

"Extensive laboratory tests and several field tests show…Their RMS errors are typically in the 20% to 30% range compared to accuracies of 10% or better required for most distribution system diagnostics. *In particular, they are inadequate for use in estimating duct leakage, air handler flow and individual register flows for room load and comfort."*

"The laboratory results for the reference active flow hood show an RMS error of only 2%."

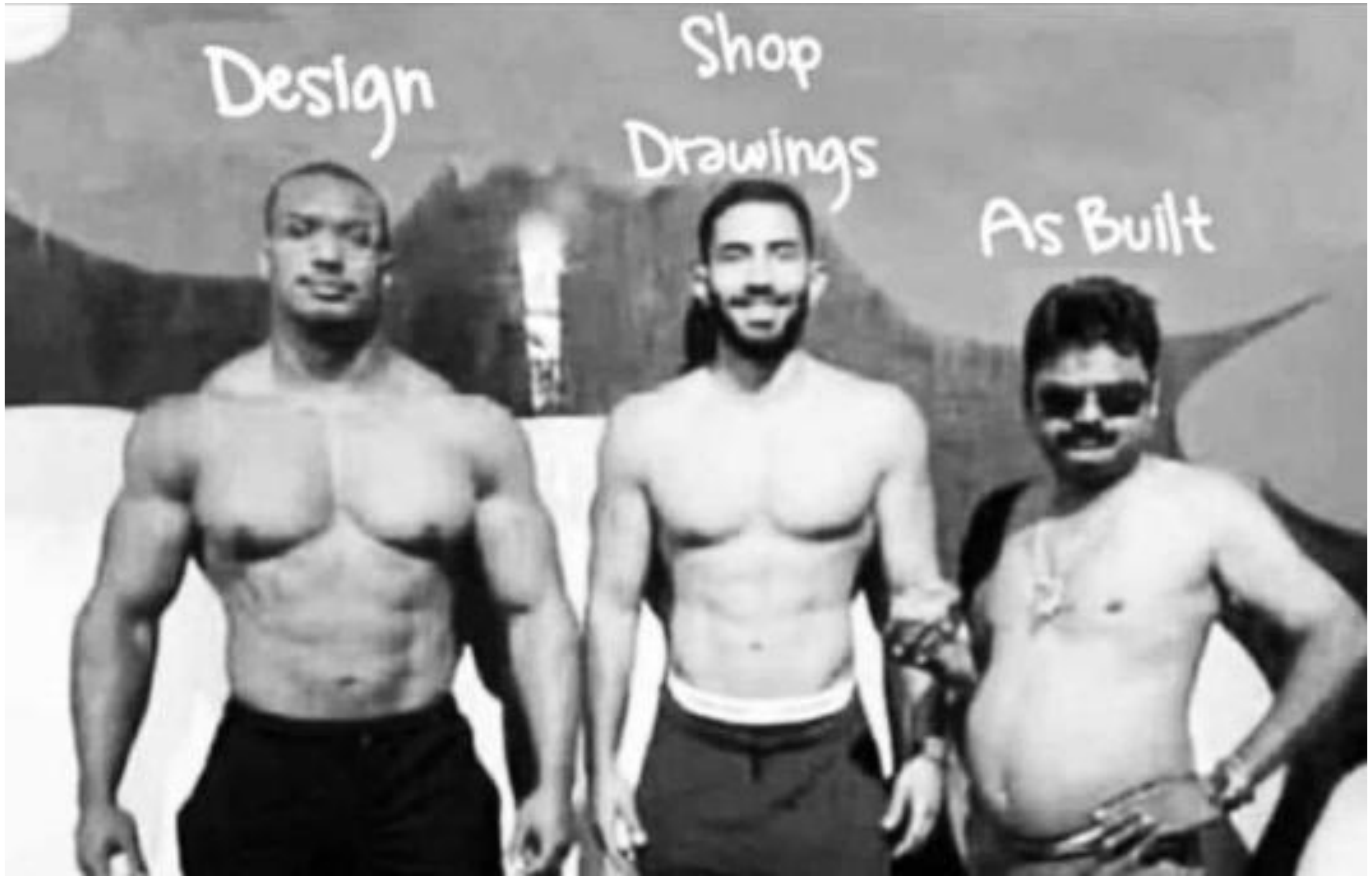
Testing and Balancing - Reporting

Manufacturer: [redacted]
Model:

Location: Apt 6C Closet

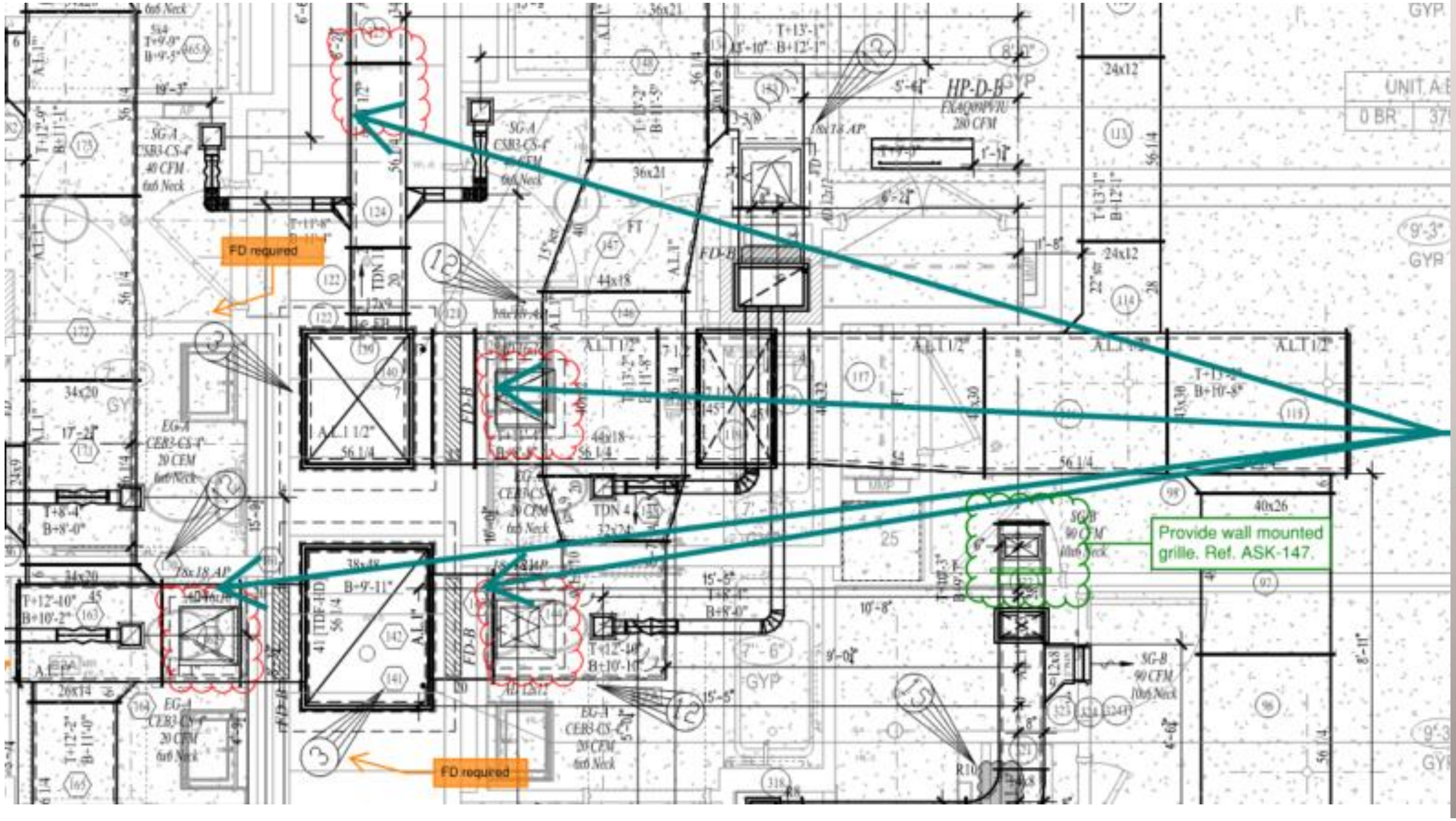
			Grille		CFM	
Drawing	Area Served	Supply/ Return	Type	Size	Design	Actual
27	Apt 6C	ERV Supply	SWR	6x4	15	15
28	Apt 6C	ERV Supply	SWR	6x4	15	15
30	Apt 6C	ERV Supply	SWR	6x4	15	15
32	Apt 6C	KX	SWG	6x6	25	25
33	Apt 6C	TX	CG	6x6	20	20

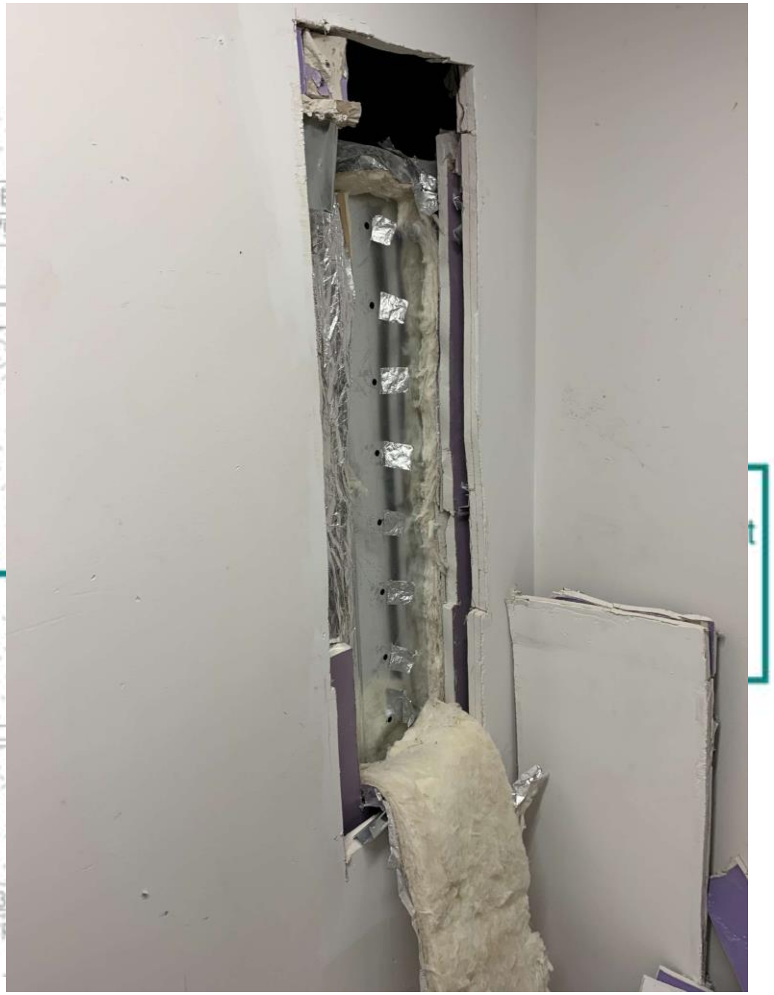
Let’s talk about shops…

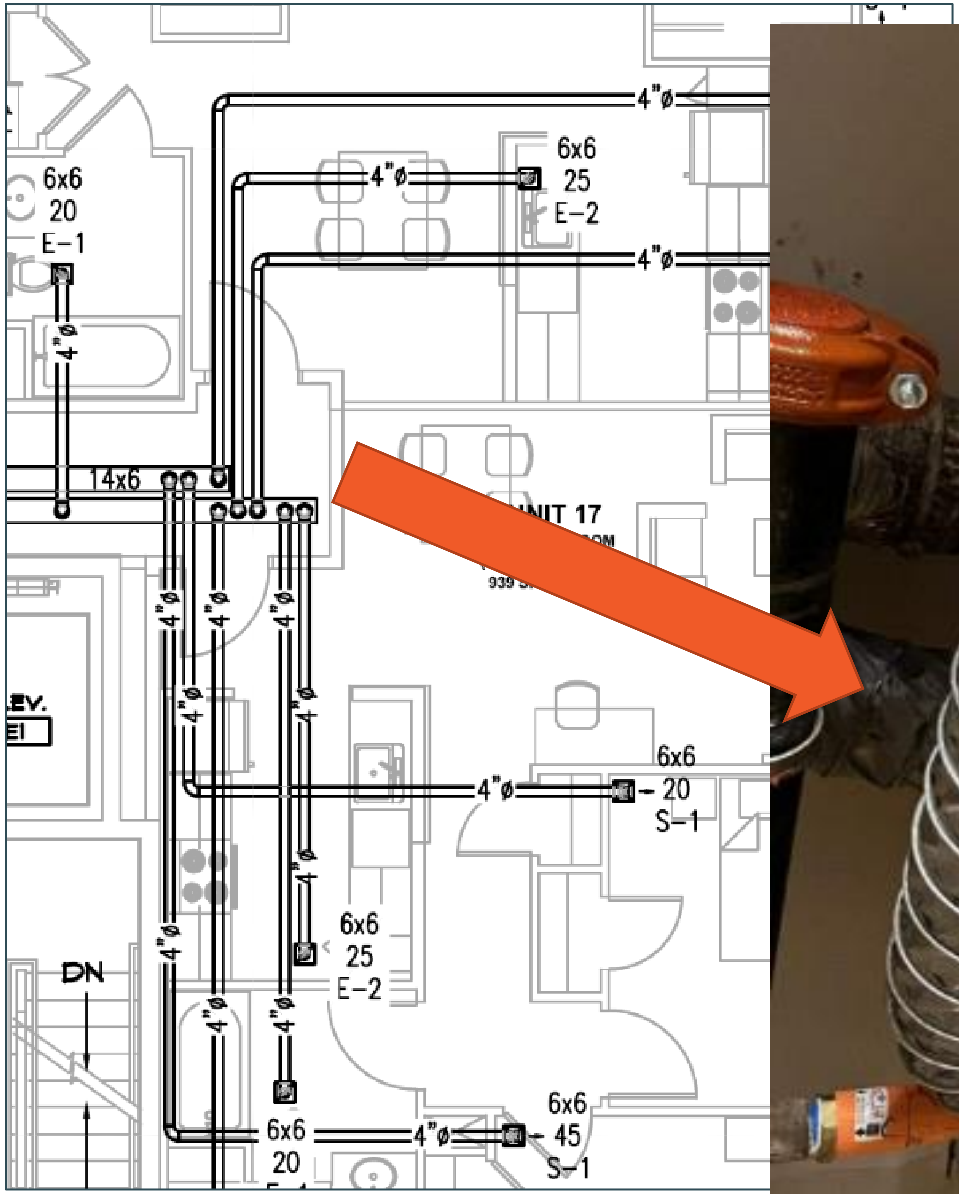


Shop Drawings – Review Physical Access

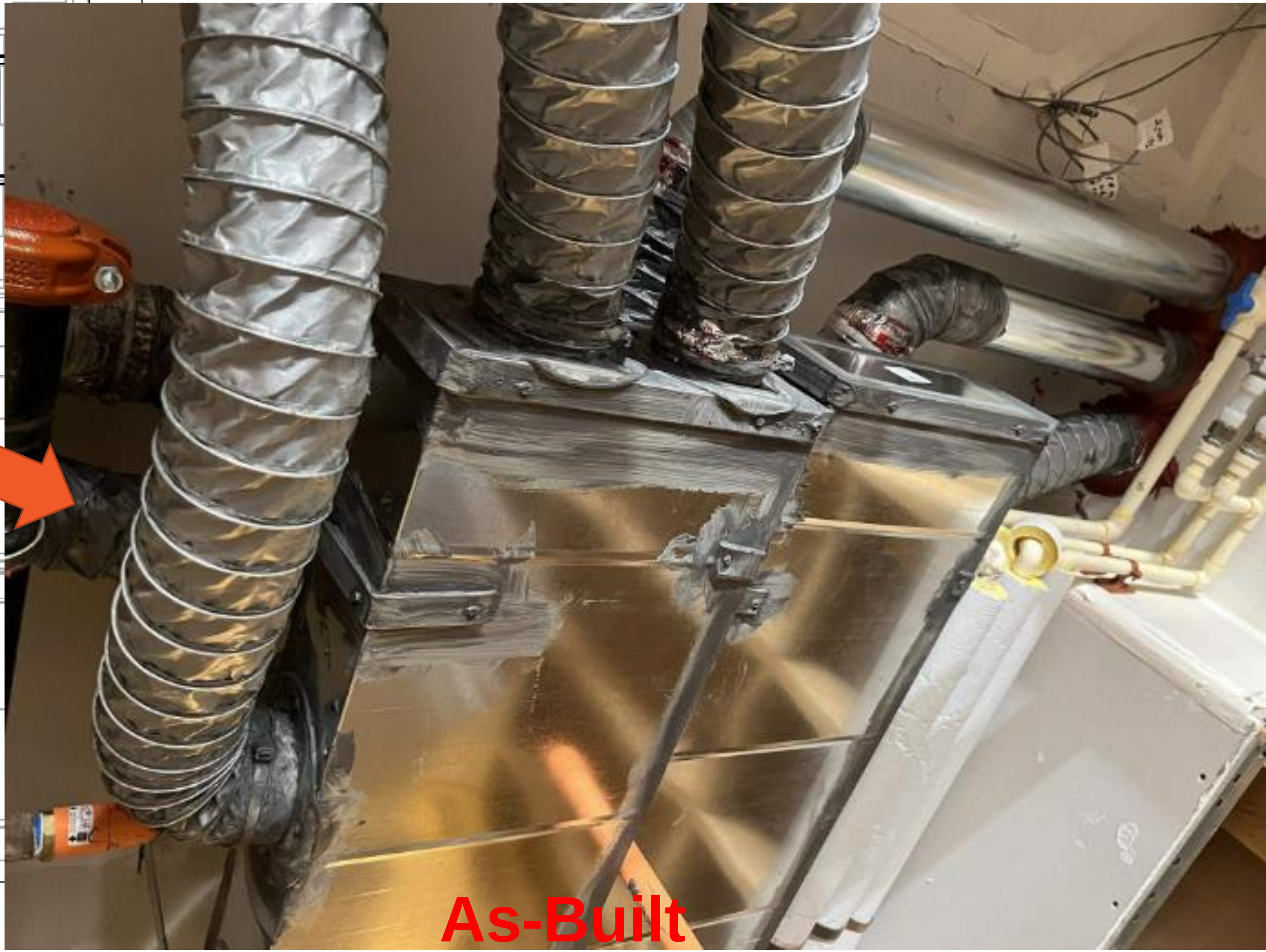
- For flow traverses, sometimes the space is there and sometimes not







Design

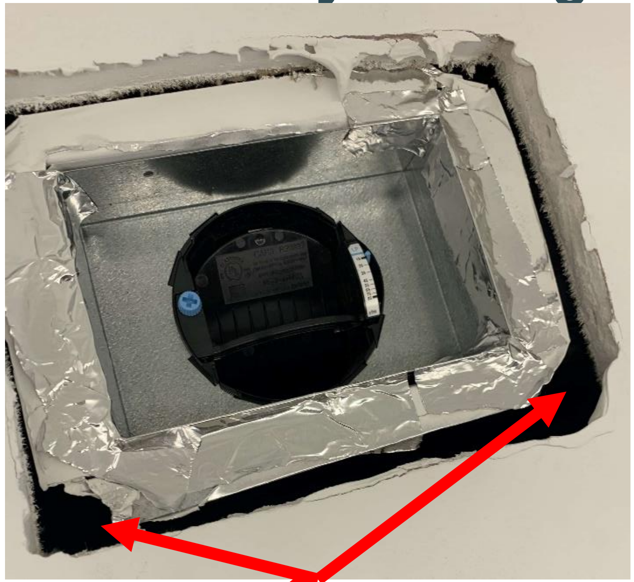


As-Built

System Leakage Examples

Duct Leakage

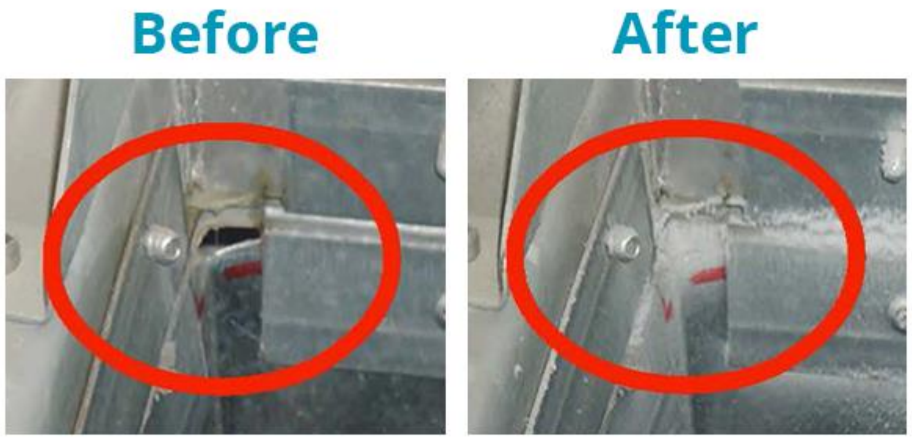
Accessory Leakage



Equipment Leakage

Duct Sealing using Aerosolized Sealant

- Seals ducts from the inside
- Pressurized aerosolized particles are forced through the duct systems and build up at leak locations.
- Can seal leaks up to ½” size

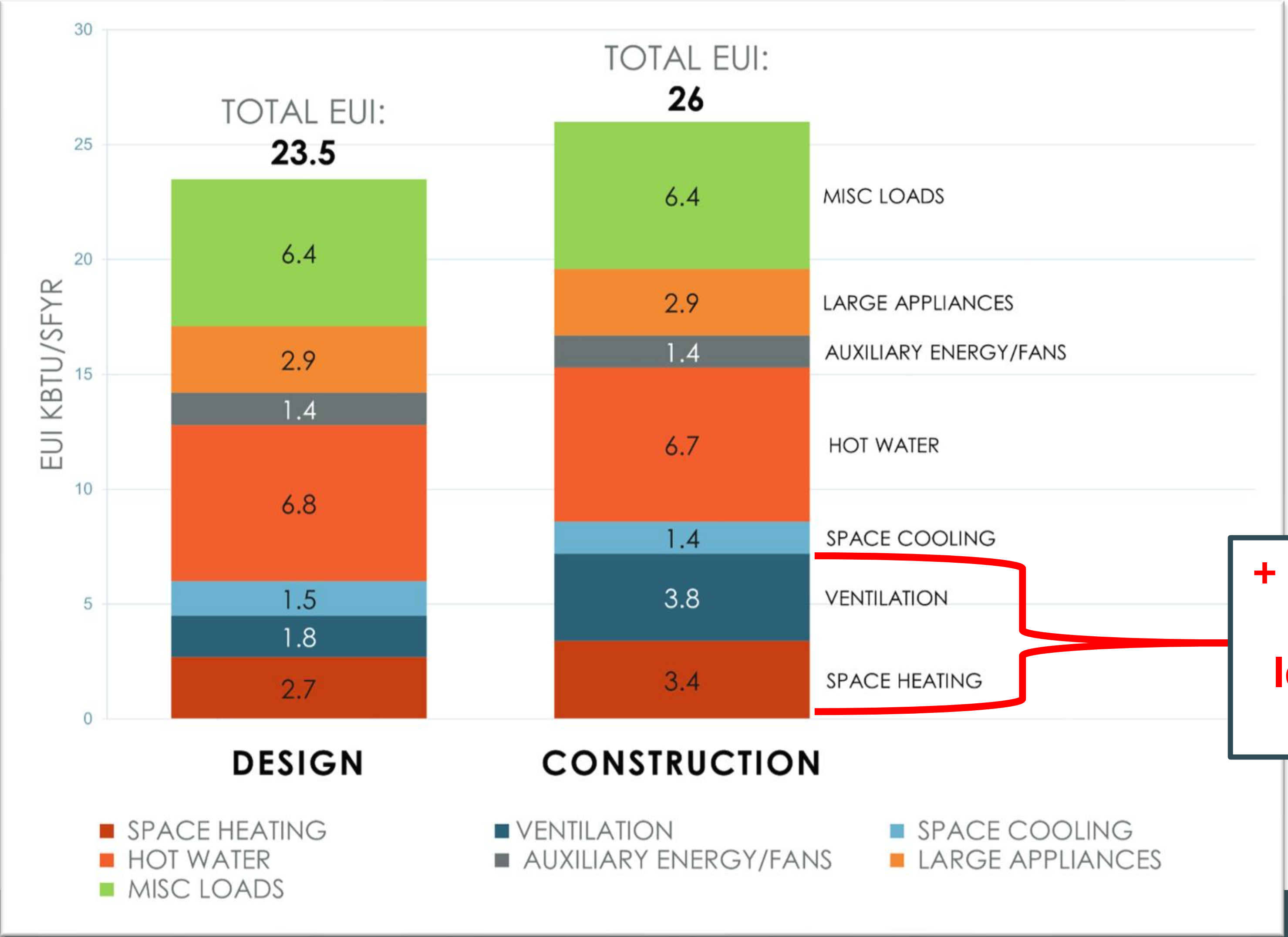


Aerosolized Sealant – Volumetric VS SMACNA Duct leakage Standard

Recommended 3% Fractional Leakage Method

	ERV-Unit 1		ERV-Unit 2	
	Supply	Exhaust	Supply	Exhaust
Design Flow Rate (CFM):	450	450	465	465
3% Volumetric Leakage %	3%	3%	3%	3%
(SMACNA CL 8) % Leakage of design flow	32%	19%	18%	31%
(SMACNA CL 2) % Leakage of design flow	8%	5%	4%	8%

Leakage Impacts on PHIUS WUFI Energy Model



+ 2.5 Site EUI Due to high duct leakage and fan power

Duct Leakage – Cx Example

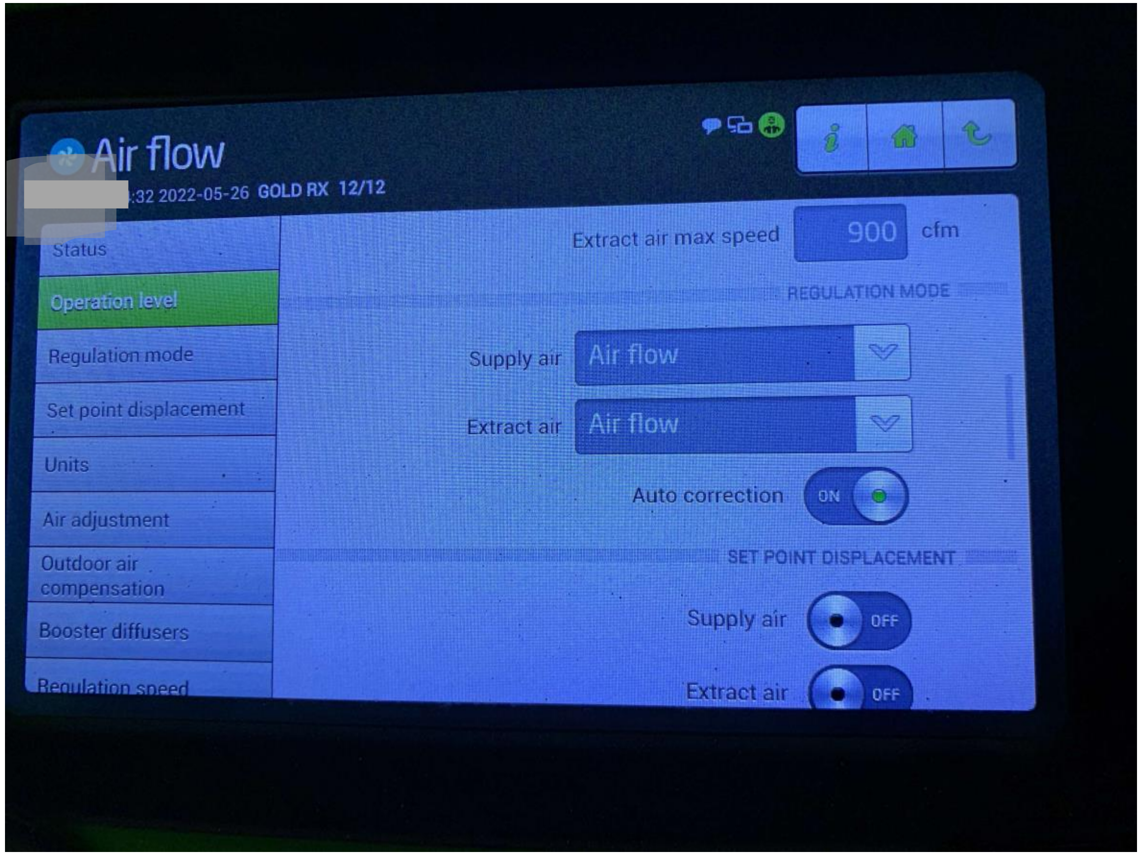
Table 2. Airflow Data from Five ERV Units Before and After Cx										
	ERV-1		ERV-2		ERV-3		ERV-4		ERV-5	
	Supply	Exhaust	Supply	Exhaust	Supply	Exhaust	Supply	Exhaust	Supply	Exhaust
Design Flow Rate (CFM):	795	795	450	450	465	465	2240	2240	1470	1470
Round 1 T&B % System Leakage:	12%	15%	3%	3%	12%	32%	12%	12%	11%	23%
Average System Leakage Before Cx:	**14%**									
Final Commissioned TAB % System Leakage:	15%	15%	3%	3%	0%	0%	0.4%	9%	1%	1%
Average System Leakage After Cx:	**5%**									

9% Leakage reduction from early Cx engagement

ERV/HRV Controls & Interlocks

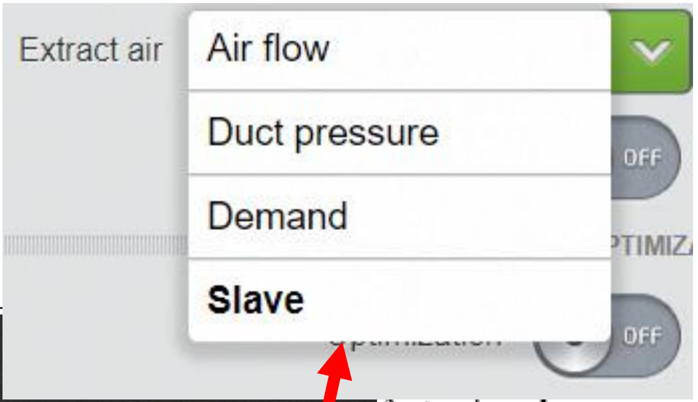
ERV Sequences & Controls

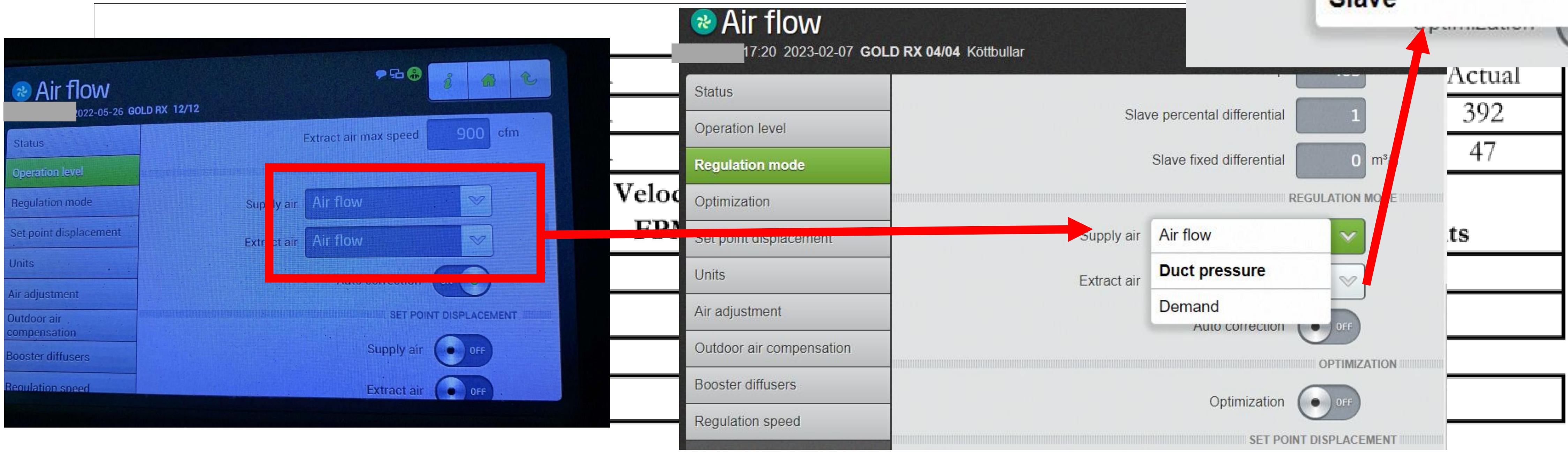
- Constant Flow vs Variable Flow
- Key Setpoints:
  - Airflow
  - Static pressure
  - Supply Air Temperature
- Other Setpoints:
  - CO2 concentration
  - Schedules



Example 1 – Fictitious TAB reports

- Is the relevant sensor installed?
- Is the controller setup correctly?





Example 1 (cont.) – Proper reporting

Design airflow in the system data sheets reflect the sum of all diffuser design ratings. These ratings were provided in the mechanical drawings.

Static pressure setpoint: 0.51"

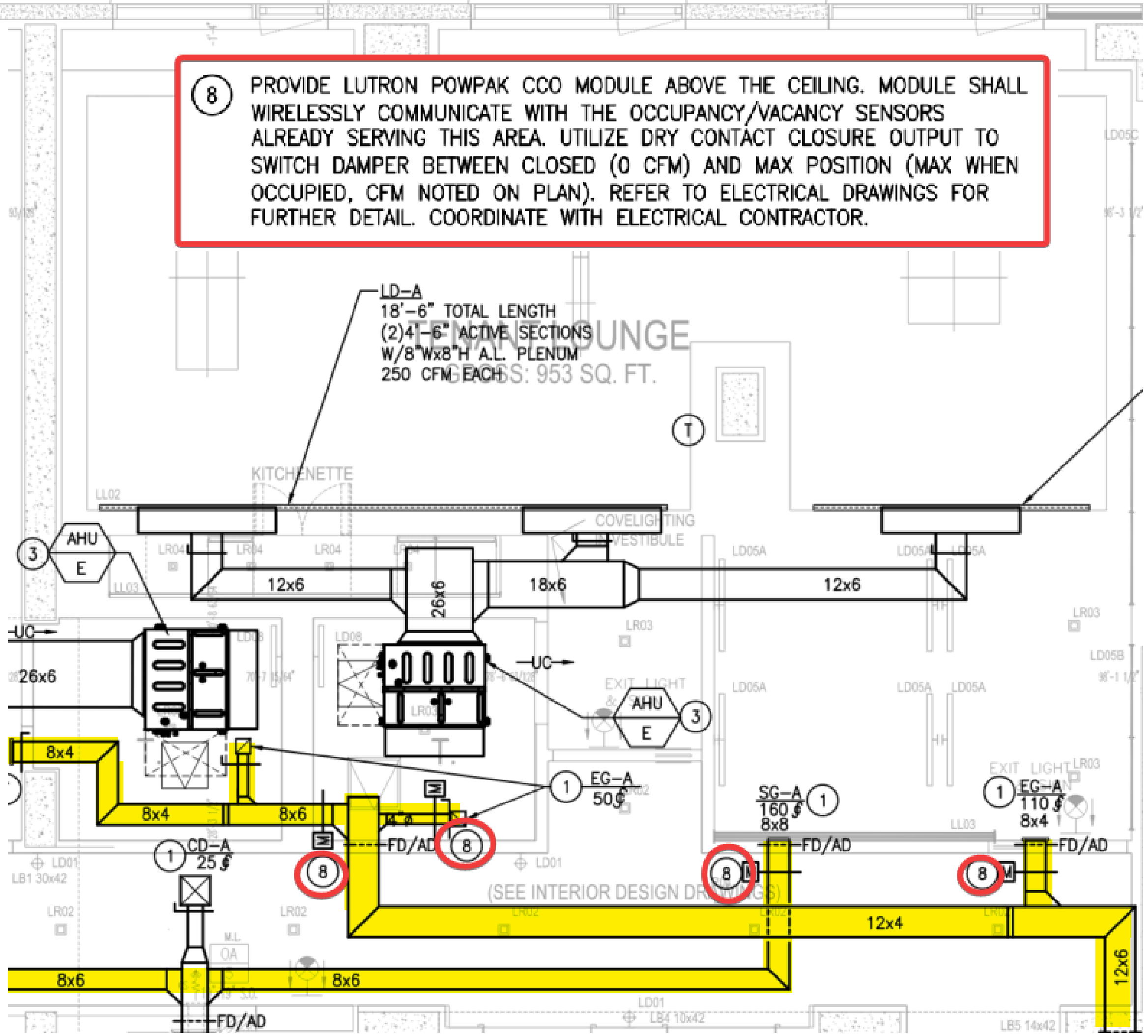
Example 2 – Lighting ctrls. & Ventilation ctrls.

C. BASE BUILDING/AMENITY ENERGY RECOVERY VENTILATOR (ERV) SEQUENCE:

1) ENERGY RECOVERY VENTILATOR SHALL RUN CONTINUOUSLY.

2) VARIABLE FREQUENCY DRIVE ON SUPPLY AND EXHAUST FAN SHALL MODULATE TO MAINTAIN A CONSTANT PRESSURE AS SENSED BY DUCT MOUNTED PRESSURE SENSORS.

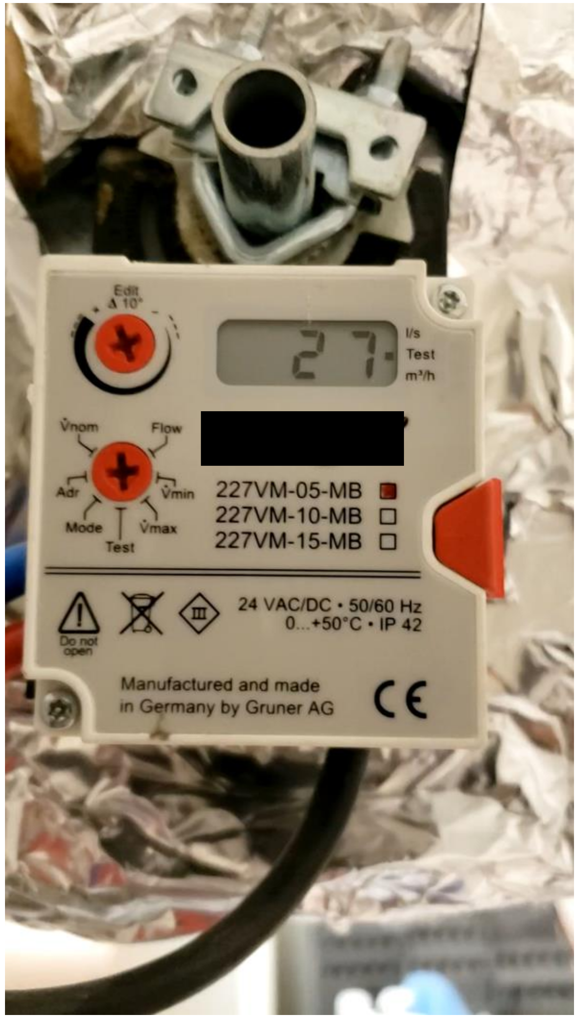
3) DURING A FIRE EMERGENCY CONDITION, THE SUPPLY FAN SHALL SHUT OFF, THE SUPPLY SIDE MOTORIZED DAMPER SHALL CLOSE, AND THE EXHAUST FAN SHALL RUN CONTINUOUSLY.



Example 1 (cont.) – The way it should go

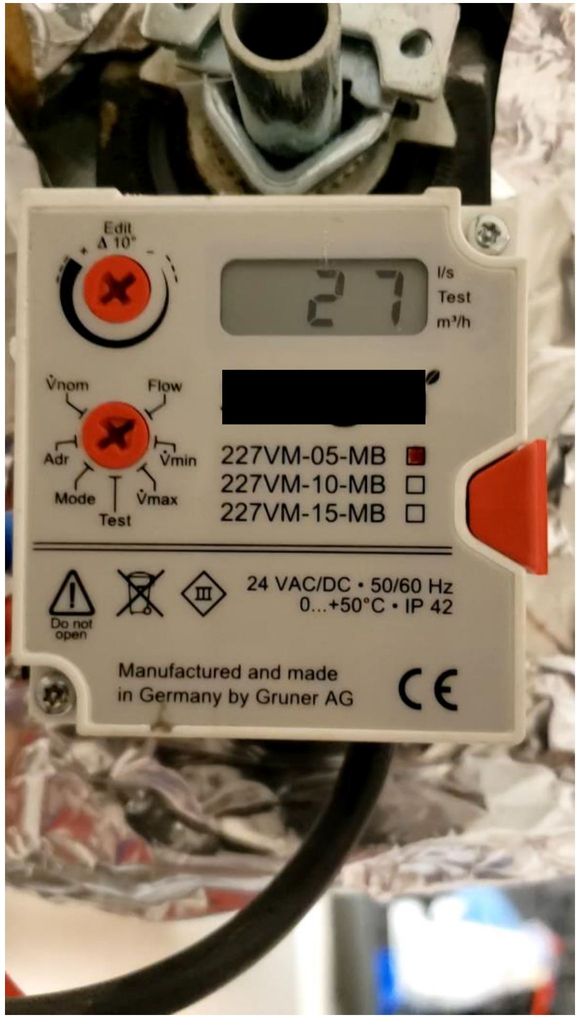
Minimum

Damper closes



Maximum

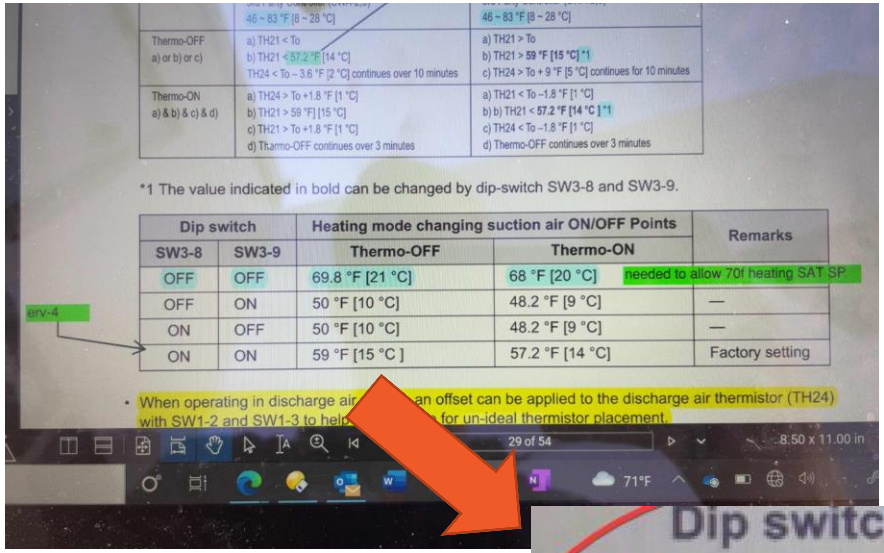
Damper opens



Example 3 – Complicated controls?

ERV Controls – Heat Pump Interlocks

- Who is responsible for setting these up?

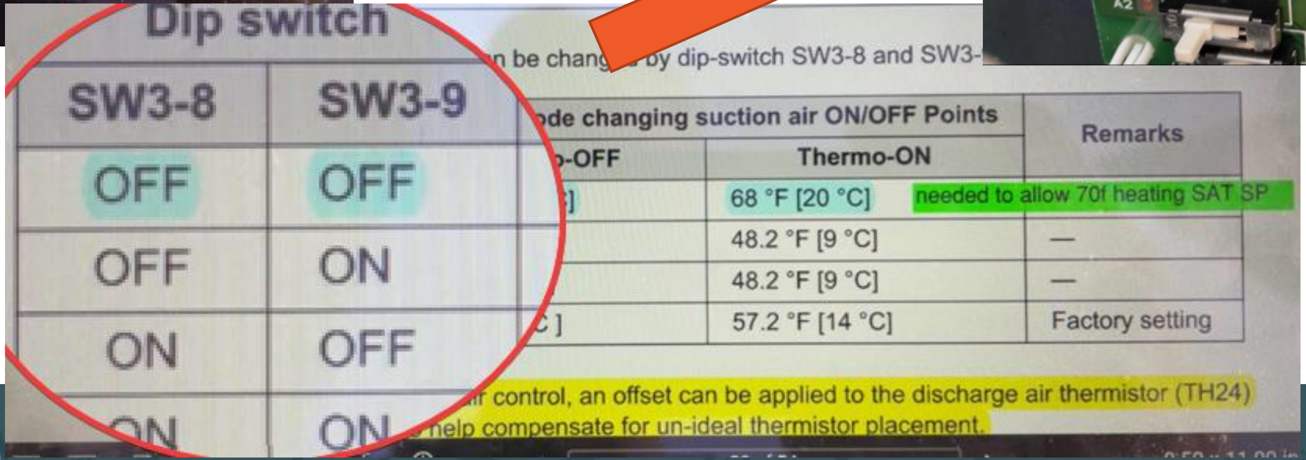


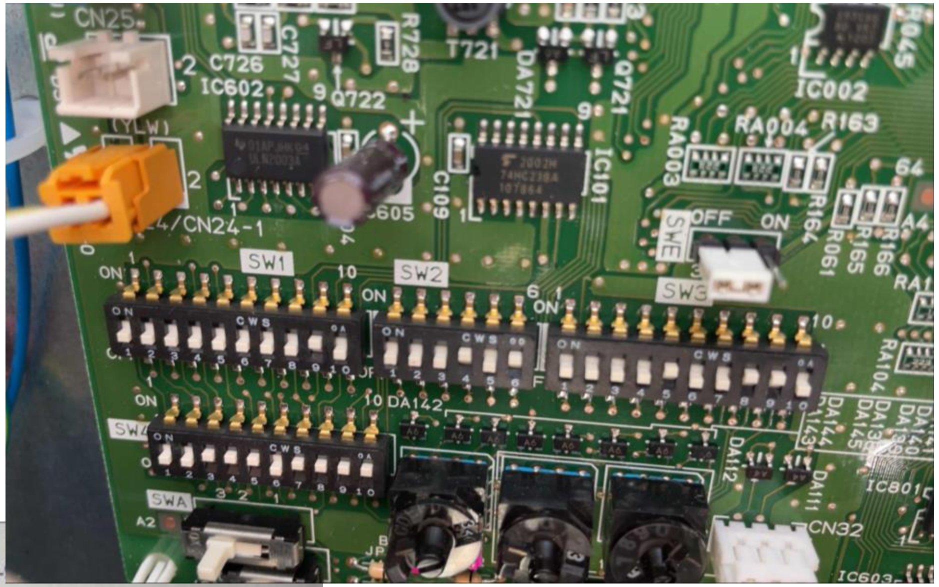
	46 ~ 83 °F [8 ~ 28 °C]	46 ~ 83 °F [8 ~ 28 °C]
Thermo-OFF a) or b) or c)	a) TH21 < To b) TH21 < 57.2 °F [14 °C] TH24 < To – 3.6 °F [2 °C] continues over 10 minutes	a) TH21 > To b) TH21 > 59 °F [15 °C] *1 c) TH24 > To + 9 °F [5 °C] continues for 10 minutes
Thermo-ON a) & b) & c) & d)	a) TH24 > To +1.8 °F [1 °C] b) TH21 > 59 °F [15 °C] c) TH21 > To +1.8 °F [1 °C] d) Thermo-OFF continues over 3 minutes	a) TH21 < To –1.8 °F [1 °C] b) b) TH21 < 57.2 °F [14 °C] *1 c) TH24 < To –1.8 °F [1 °C] d) Thermo-OFF continues over 3 minutes

*1 The value indicated in bold can be changed by dip-switch SW3-8 and SW3-9.

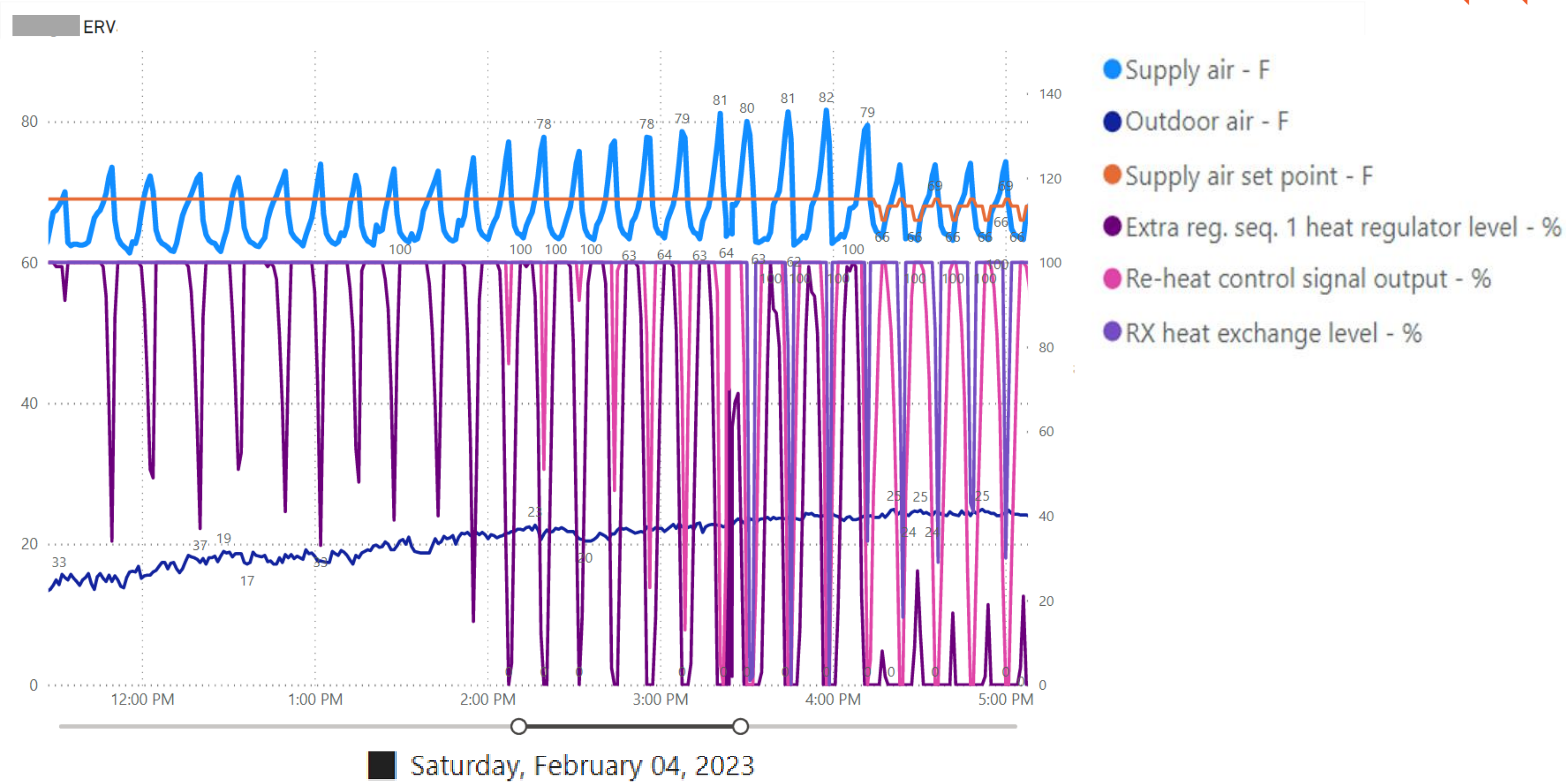
Dip switch		Heating mode changing suction air ON/OFF Points		Remarks
SW3-8	SW3-9	Thermo-OFF	Thermo-ON	
OFF	OFF	69.8 °F [21 °C]	68 °F [20 °C]	needed to allow 70f heating SAT SP
OFF	ON	50 °F [10 °C]	48.2 °F [9 °C]	—
ON	OFF	50 °F [10 °C]	48.2 °F [9 °C]	—
ON	ON	59 °F [15 °C]	57.2 °F [14 °C]	Factory setting

- When operating in discharge air ... an offset can be applied to the discharge air thermistor (TH24) with SW1-2 and SW1-3 to help ... for un-ideal thermistor placement.





ERV Controls – Heat Pump Interlocks



How could we avoid these issues?

- Clear & realistic sequences of operation
  - Early Design Reviews.
- Clearly defined roles
  - Installer + Supplier + Manufacturer + CxA
- Clear expectations
  - The job is done when…
  - Warranty periods

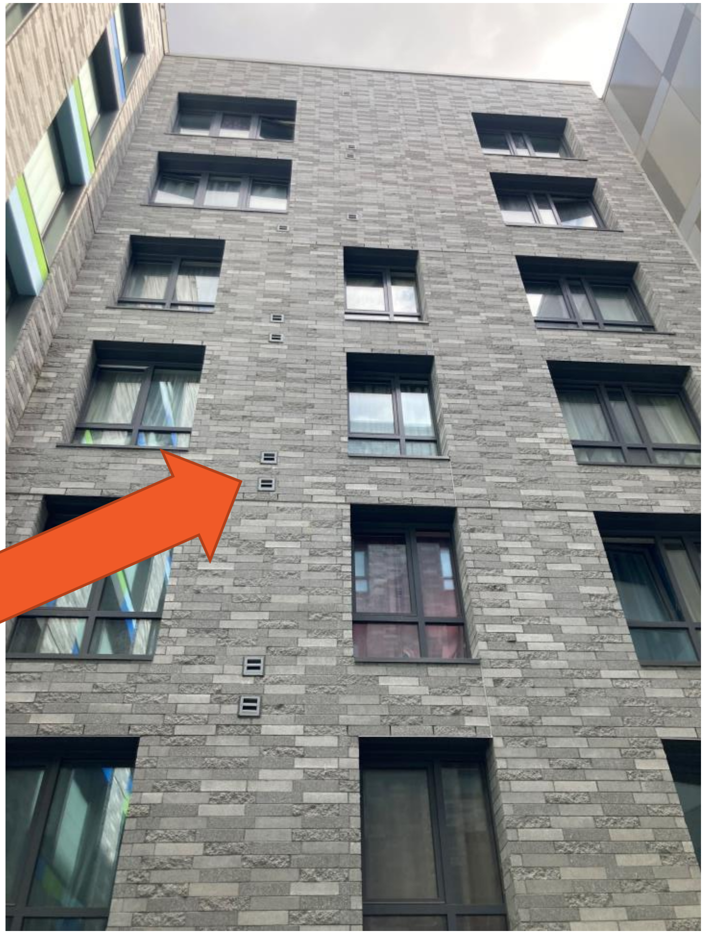
Operations & Maintenance

O&M and Ongoing Cx

- Proper training
  - Training requirements come from the spec
- Ongoing Cx
  - Test plans templates
- Central ERVs w/ DX
  - 3 or more days for tuning

Live-in Building Superintendent

Operations and Maintenance



Operations and Maintenance

Conclusion

Conclusion

- Traditional and **typical specifications for duct leakage may not be enough** for high-performance buildings
- Communicate **design AND construction expectations** through specifications **reinforced with on-site training**
- **Communicate project nuances** and PH requirements early and often
- **Engage CxA early** in the design phase
- Push for **clear and realistic sequences** of operation
- Consider **operations and operators** during the design phase

Trust but Verify

Bridging the Gap - Design - Construction - Operation

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