Multifamily Central Ventilation Assessment and Retrofit Techniques

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Center for Energy and Environment

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Who is CEE

The Center for Energy and Environment (CEE) is a nonprofit organization that promotes energy efficiency to strengthen the economy while improving the environment

We conduct research and develop programs so that:

- Businesses operate more efficiently and profitably;
- Government agencies and nonprofits spend less on facilities and functions;
- Utilities achieve their energy-efficiency goals at least-cost; and
- Households save money and improve comfort.

What we do

- Design and Delivery of Energy Programs
- Engineering Services
- Public Policy
- Lending Center
- Innovation Exchange
    - Research dissemination
    - Education and Outreach

CEE multifamily experience

- Facility assessments of over 2,000 buildings in Minnesota
- Completed over 20 research projects

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Current multifamily research projects

- Condensing boiler optimization
- Multifamily ventilation optimization
- Demand Controller recirculation loop controls
- Multifamily aerosol envelope air sealing
- Indoor pool optimization

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DIVISION OF ENERGY RESOURCES

All funded through the MN Department of Commerce's Conservation Applied Research and Development grant program.

The Conservation Applied Research and Development (CARD) grant program is funded by MN ratepayers, and administered by the Minnesota Department of Commerce, Division of Energy Resources

Introductions

- Your name
- Your organization
- What you do

Housekeeping Notes

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Today's Objective

1. To provide the basic info needed to incorporate ventilation assessment into your work
2. Familiarize you with the Multifamily Ventilation Assessment and Retrofit Guide
3. Practice some skills
   - *Calculating ventilation airflow targets*
   - *Measuring airflow*
   - *Commissioning a retrofitted exhaust shaft*

Agenda

Intros, Project overview, Case studies, Determining airflow targets	9:00 -10:00
Break	15 mins
Ventilation system types	10:15 – 11:15
Break	15 mins
Airflow measurement methods	11:30 – 12:30
Lunch	12:30 – 1:00
Assessment process , retrofit work scopes, commissioning	1:00 – 2:00
Break	15 mins
Practice stations	2:15 – 4:15
Q & A	4:15 – 4:30

Acknowledgements

This project is supported in part by a grant from the Minnesota Department of Commerce, Division of Energy Resources through a Conservation Applied Research and Development (CARD) program

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Project Overview and Case Studies

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Project background

Reducing the Energy Cost of Effective Ventilation in Multifamily Buildings

- 18 buildings studied
- 6 retrofits completed
- *Multifamily Ventilation Assessment and Retrofit Guide*
  - Available for download
- Final report will be published this spring

Multifamily Ventilation Systems

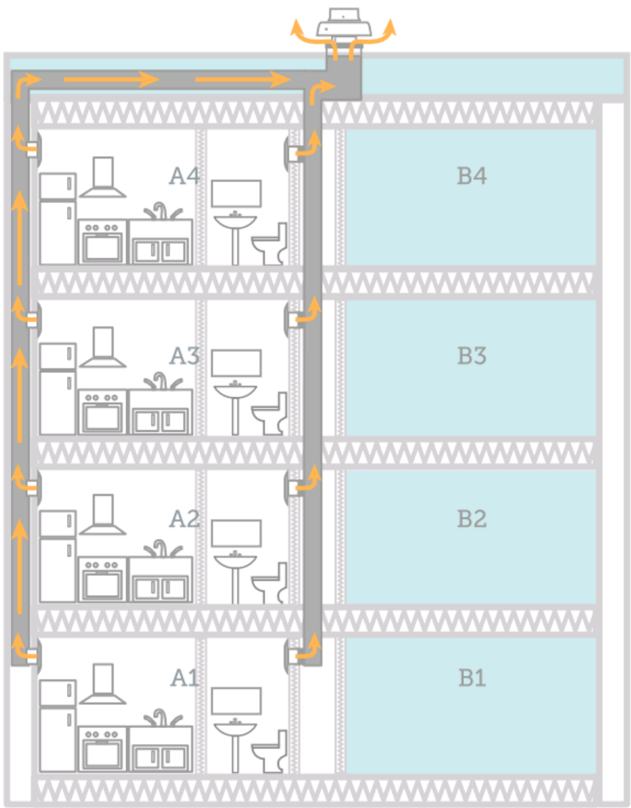
- Common Ventilation System Types
  - Corridor supply / make up air
  - Central apartment exhaust
  - Trash chutes
  - Individual apartment exhaust fans

Low energy savings potential

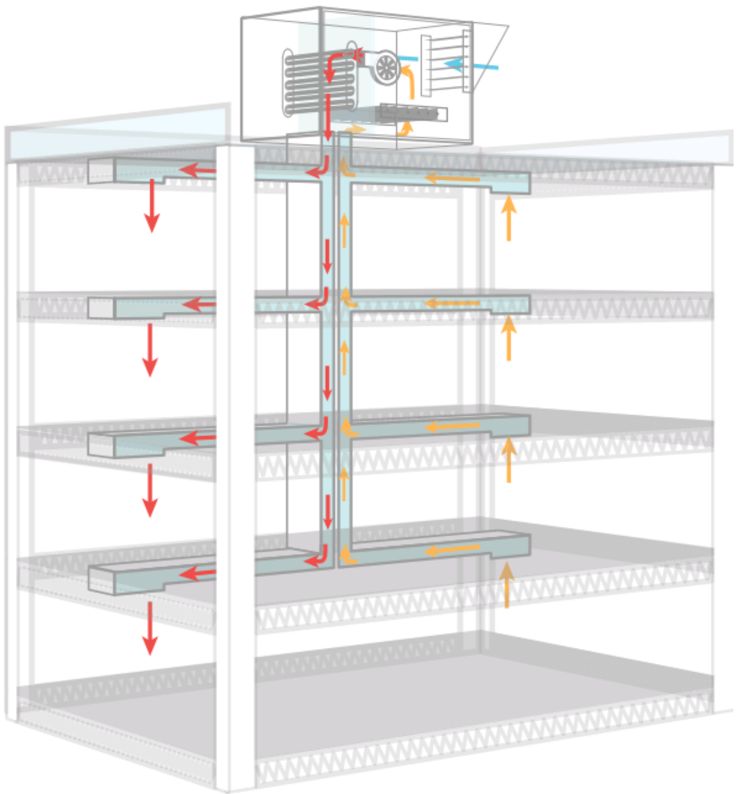
- Specialty Ventilation Systems
  - Elevator equipment rooms
  - Elevator shafts
  - Commercial kitchens
  - Pool rooms
  - Mechanical rooms

Beyond scope of project

Central ventilation systems: 2 basic types



Central apartment exhaust



Central corridor supply / make up air systems

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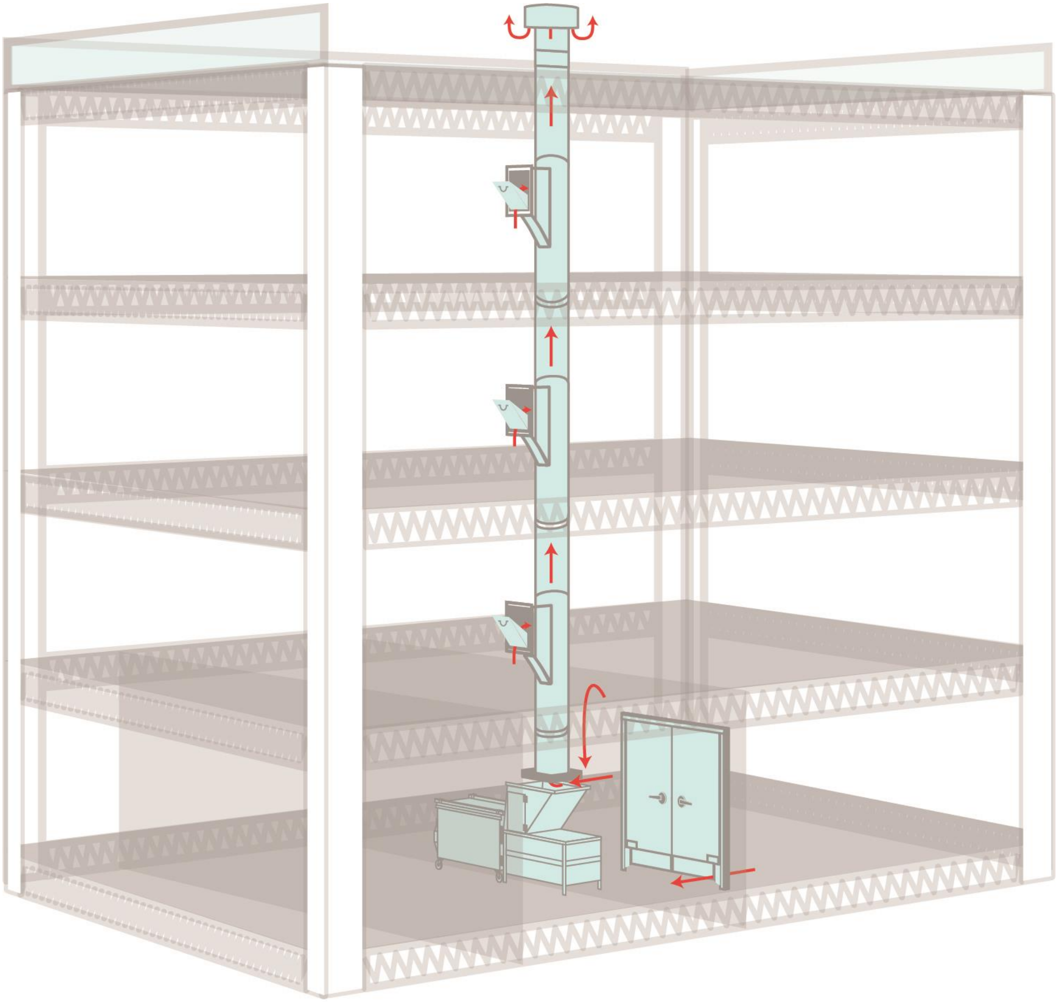
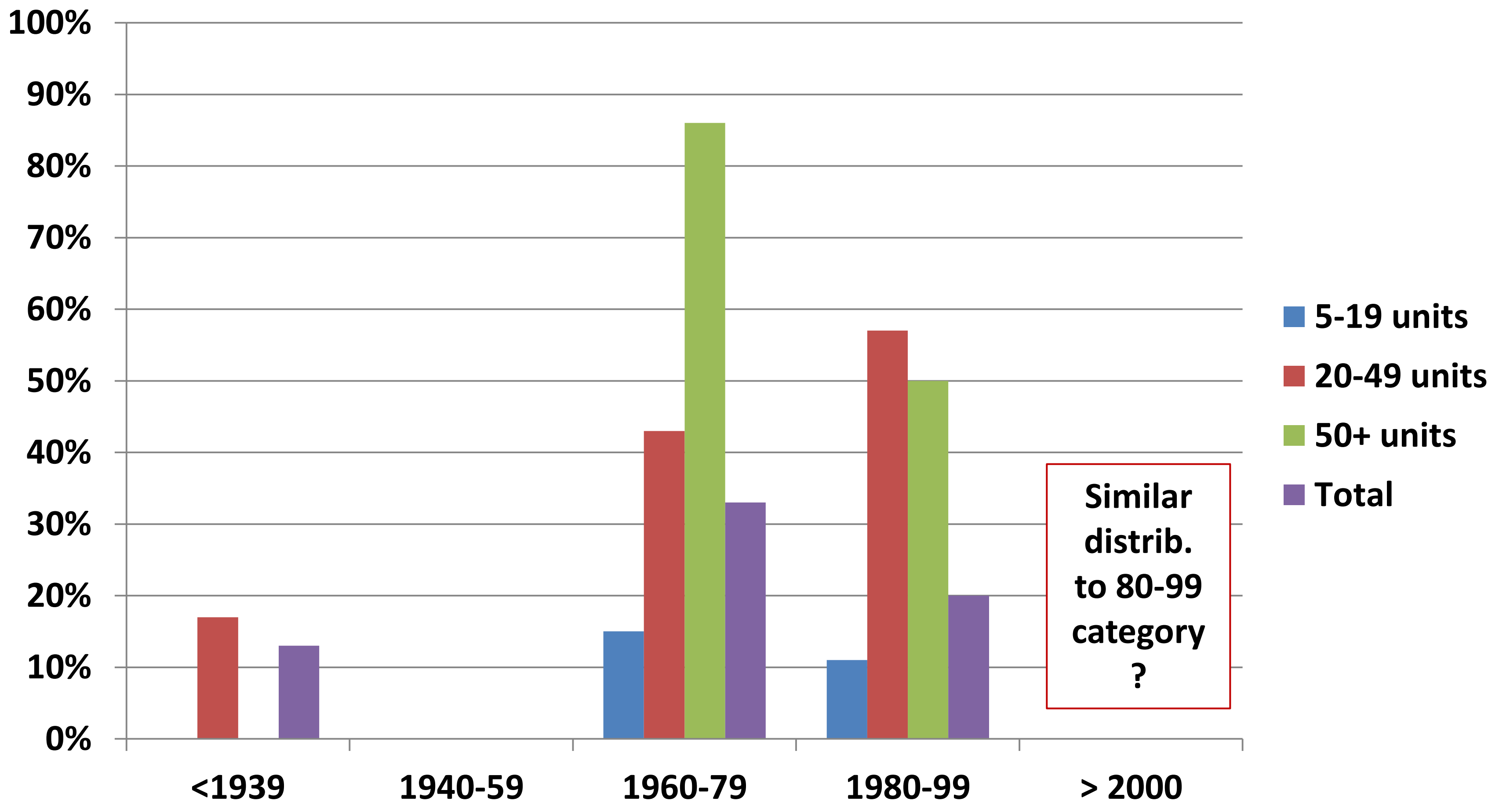
Trash Chutes affect ventilation performance



Central ventilation: What are the issues?

- Excessive ventilation flow rates
  - Cost of ventilating excessive heated or cooled air
  - Cost of electricity for motors
  - Draftiness and noise
- Lack of effective airflow distribution, clogs or imbalances
  - Odor complaints
  - Moisture problems
- Difficulty measuring airflows

Where will you encounter central ventilation?



Number of cost-effective energy savings opportunities found

- 7 of 11 with trash chutes (64%)
  - Gas savings ranged $0.60 to $12 / unit / year
- 3 of 16 with corridor supply/make up air systems (19%)
  - Gas and electric savings ranged $24-38 / unit / year
- 6 of 12 exhaust systems (50%)
  - Gas and electric savings ranged $27-188 / unit / year

Case Studies:
Solving Central Ventilation System Issues

Reducing excessive airflow
and balancing distribution flows

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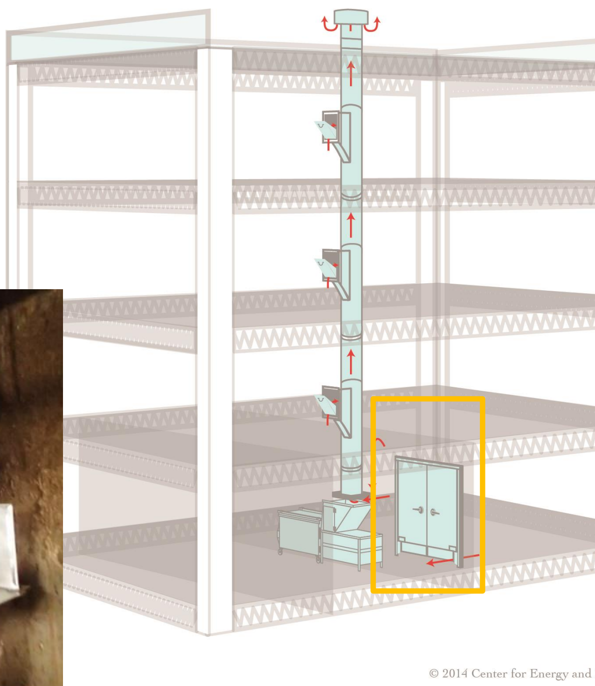
Trash Chute Retrofit in Mpls

- 20 stories
- 127 units
- Construction year 1973
- Market rate housing



$1,500 annual heating savings
Reduced odors
Estimated 1.5 year payback

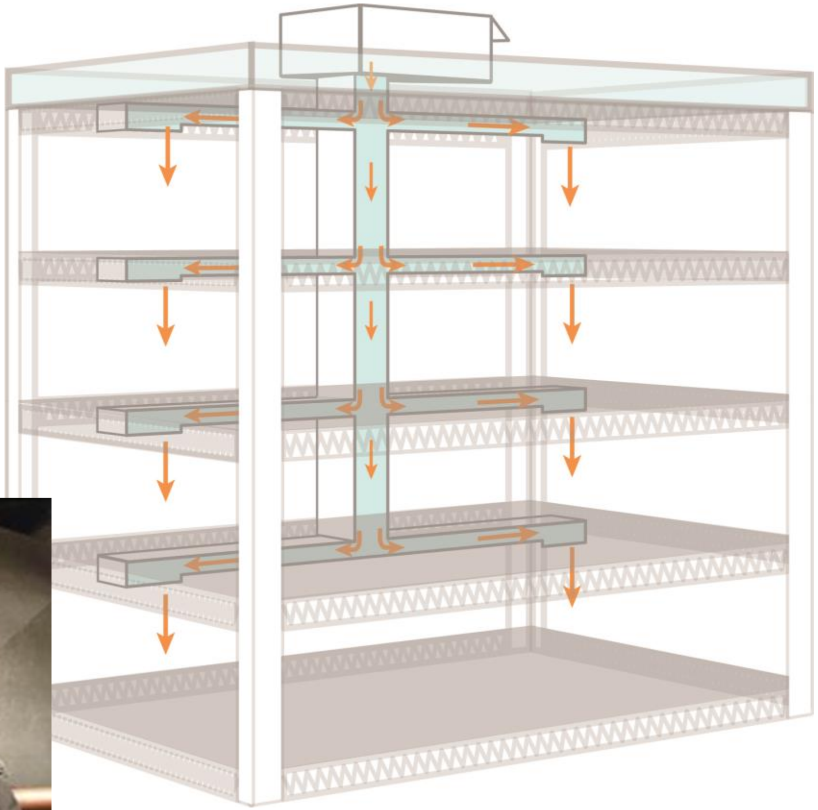
Corridor supply retrofit in Minneapolis

- 24 stories
- 193 units
- Construction year 1970
- Affordable / Senior housing

Make up air / Supply Ventilation Retrofit Mpls

Delivering 70% more than recommended ventilation level.

- Clean screen and coil
- Re-sheave unit for reduced flow



Annual Savings Details

Whole Building	
Flow reduction	4,695 cfm
Gas savings (NG)	9,611 therms
Electric savings	7,244 kWh
Cost savings*	$6,899
Payback	2 mos.

Per unit savings	(193 units)
Gas savings (NG)	31 therms
Electric savings	36 kWh
Cost savings*	$30/unit

*Based upon $0.65/therm and $0.09/kWh

Central exhaust retrofit in Minneapolis

Ventilation airflow measured at 48% above recommended rates. Reported odor and moisture issues.

- 14 stories
- 81 units
- Construction year 1972
- Market rate housing

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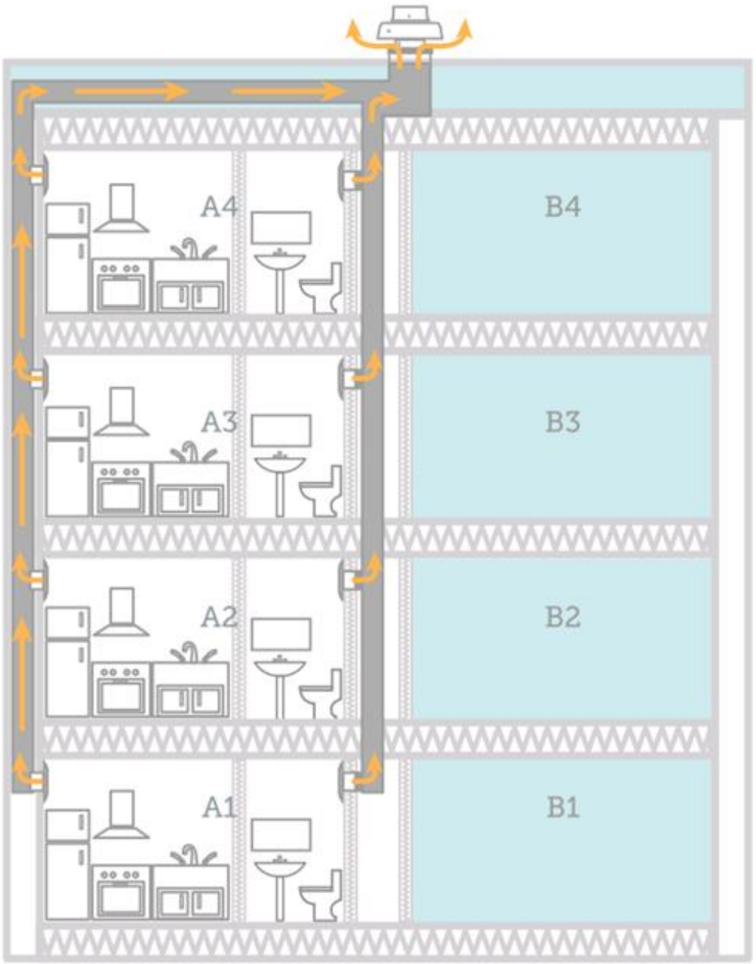
Central Exhaust Retrofit in Mpls

1. Replace balancing louvers with fixed orifices
2. Replace rooftop belt drive exhaust fans with high-efficiency type
3. Verify airflow



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Replacing fans with EC motors w/ speed controls allows for turndown

Air seal at curb below fan

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Fixed balancing orifices balance inlet flow at low cost

1. Remove balancing devices prone to clogging or tampering

2. Seal duct leakage at inlet

3.Install fixed orifice sized for correct flow

Post retrofit: Kitchen shaft savings dominated

Pre – retrofit >	Post– retrofit >
x05	x05
4	4
63	34
	32
56	34
147	31
161	30
171	33
	34
30	34
50	31
26	35
15	35
100	34
190	30
NA	NA

Pre – retrofit	Post– retrofit
84	33

		Pre – retrofit	Post– retrofit
Very High	> 45	67%	0
High	> 36	67%	0
Good	+/- 20%	17%	100%
Low	< 24	17%	0%
Very Low	< 15	17%	0%

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Post retrofit: Improved distribution in baths

Pre – retrofit >

Shaft	x05	
RTV#	3	3
Floor	Full	Half
14	5	19
13		
12	41	5
11	43	5
10	18	41
9	32	46
8		
7	29	26
6	26	20
5	5	
4	27	35
3	5	20
2	25	33
1	11	NA
Avg	22	25

Post– retrofit >

Shaft	x05	
RTV#	3	3
Floor	Full	Half
14	0	28
13	29	23
12	34	25
11	24	26
10	21	21
9	24	23
8	23	28
7	26	26
6	22	23
5	22	26
4	22	22
3	21	22
2	21	25
1	11	NA
Avg	21	24

Category	Range	Pre Full	Pre Half	Post Full	Post Half
Very High	> 37.5	17%	20%	0%	0%
High	> 30	25%	40%	7%	0%
Good	+/- 20%	33%	30%	79%	100%
Low	< 20	42%	30%	0%	0%
Very Low	< 12.5	33%	20%	14%	0%

Annual Savings Details

Whole building	
CFM savings	2,299 cfm
Gas savings (NG)	4,706 therms
Fan power savings	21,979 kWh
Cooling savings	5,539 kWh
Energy Cost savings*	$5,535
Payback	6.2 yrs

Per unit annual savings	
Gas savings (NG)	58 therms
Electric savings	339 kWh
Energy Cost savings*	$67/unit

*Based upon $0.65/therm and $0.09/kWh

How do you find and address energy savings potential?

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Multifamily Ventilation Assessment and Retrofit Guide

Conservation Applied Research & Development (CARD) Report

Prepared for: Minnesota Department of Commerce, Division of Energy Resources

Prepared by: Center for Energy and Environment

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COMM-03192012-55802 | January 2016

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Topics

- Determining target airflow rates
- Ventilation system types
- Solving common ventilation issues
- Airflow measurement methods
- Assessment process
- Retrofit commissioning and verification

Determining target ventilation rates

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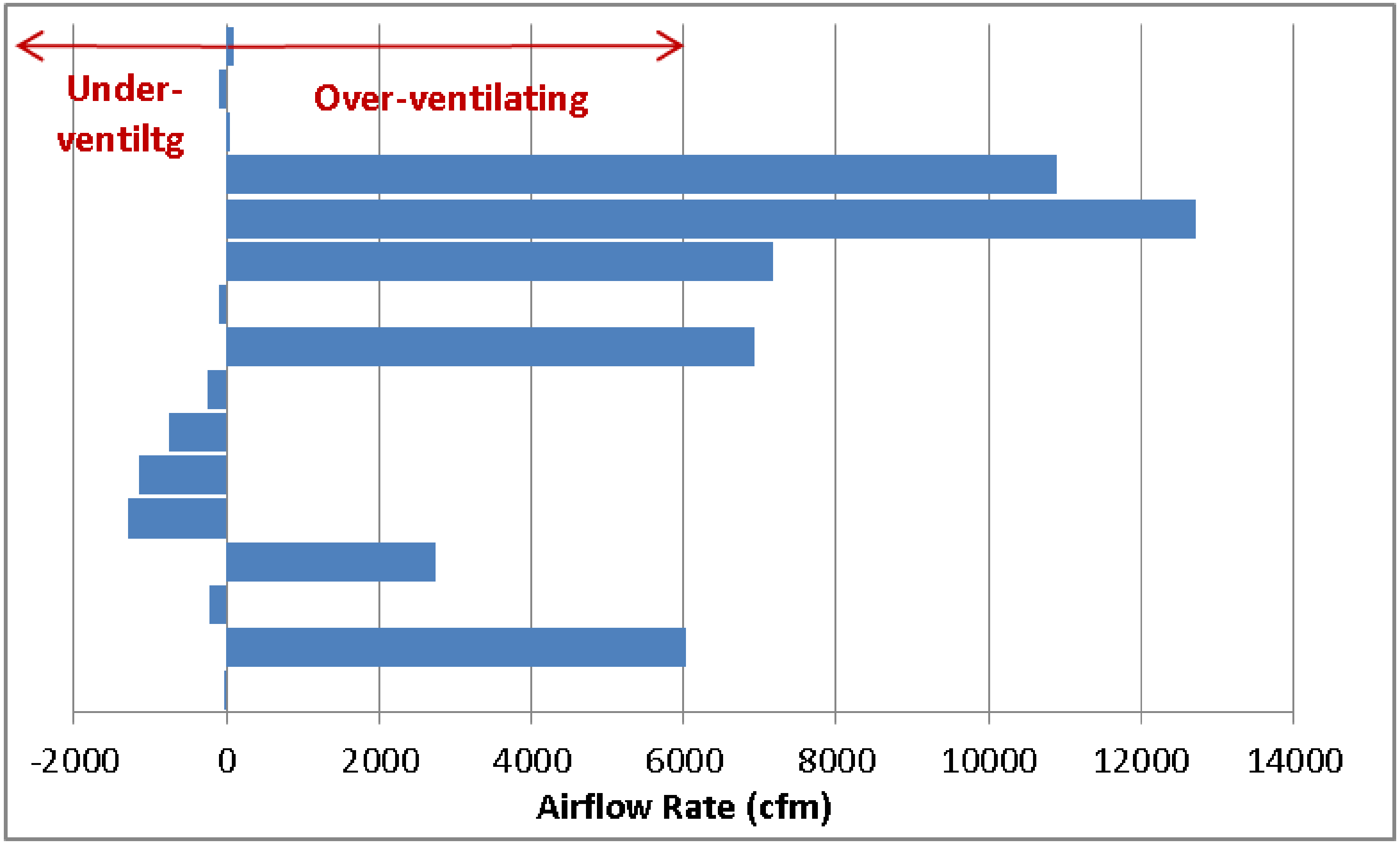
Building supply ventilation status when targetting code minimums (0.06cfm/ft² of hallway area)



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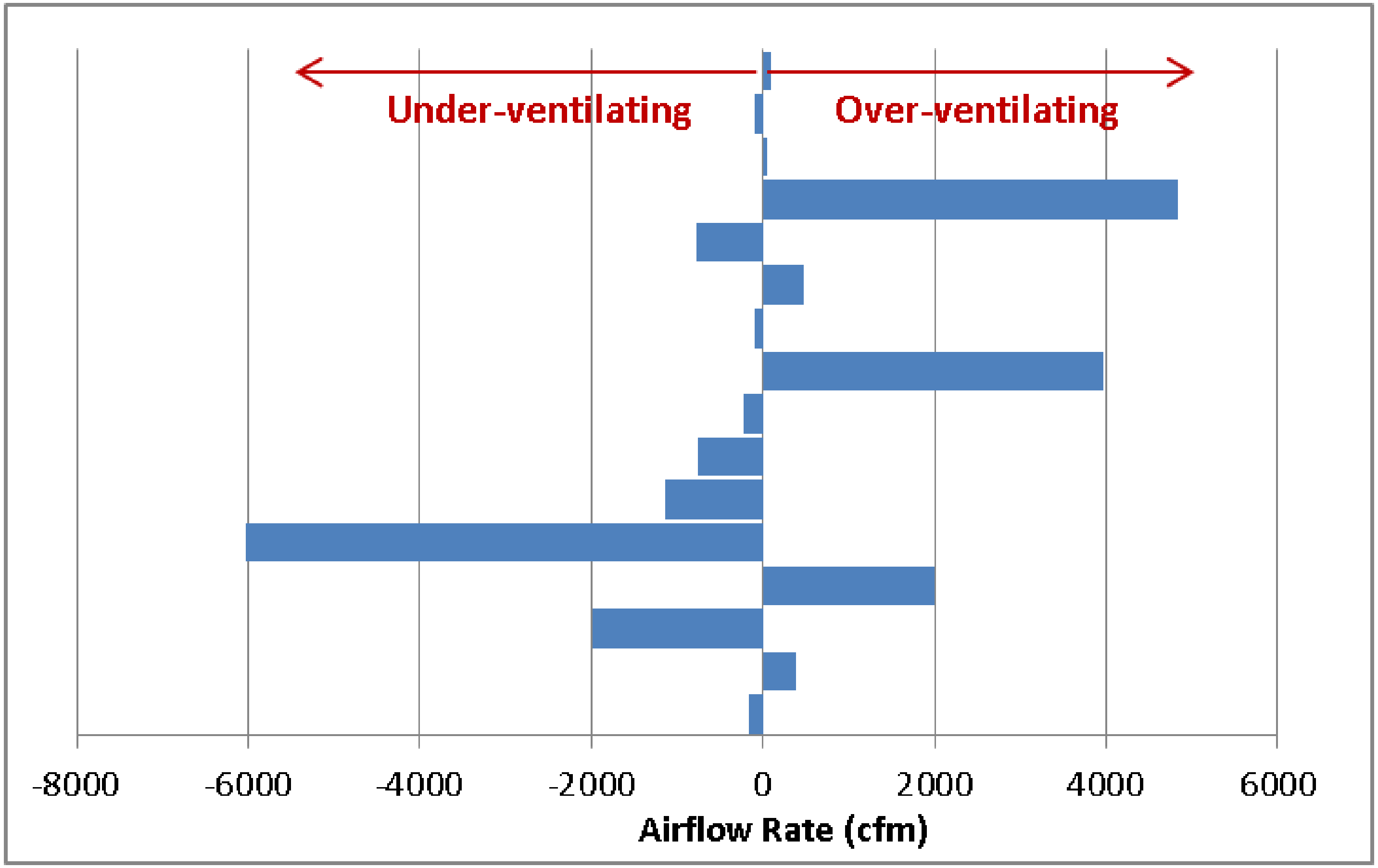
Building supply ventilation status when targeting 1:1 exhaust make up air
(balanced supply and exhaust)



Determining target airflow

- What does current code require (new code in 2015)?
- What does the building official require?
- What does the building owner want for their building?
- What is a reasonable approach for most existing buildings?

Code : 2016 Multifamily ventilation requirements

“High Rise” buildings (≥ 4 stories), or any multifamily with shared conditioned space

- 2015 MN Mechanical Code dictates ventilation requirements (2012 IMC and MN Amendments)

“Low rise” buildings (≤ 3 stories), no shared conditioned space

- 2015 Residential Energy Code

High rise ventilation required by 2015 code (Pg 4)

From 2015 MN Mechanical Code (2012 IMC and MN Amendments)

Area type	Ventilation requirement	Notes
Bathroom	20 cfm continuous exhaust (50 cfm intermittent)	Do not use the "Toilets-private" value of 25 cfm in Hotels, motels, resorts, dormitories section
Kitchen	25 cfm continuous exhaust (100 intermittent)	
Living Areas	0.35 ACH but not less than 15cfm/person*	Can be natural (e.g. infiltration and/or open windows) or mechanical. Must be mechanical when apartment is tighter than 5 ACH@50Pa*
Corridors, community rooms	0.06 cfm/sq ft continuous supply	Main entry not required
Public toilets	50 cfm continuous exhaust	Per toilet or urinal
Trash room	1 cfm/sq ft continuous exhaust	Not in 2015 Mechanical code, taken from ASHRAE 62.1-2010

*Existing buildings will most likely be assumed to be >5ACH and be allowed to provide the living area ventilation requirement naturally instead of mechanically

Low Rise Ventilation Required:

Alterations to existing systems exempt from requirements

Area type	Code Ventilation requirement	Notes
General ventilation	$\frac{(0.02x\ ft2\ of\ conditioned\ space\ ) + (15\ cfm\ x\ \ (\#\ of\ bedrooms + 1)}{2}$	Balanced -both supply and exhaust system provide this flow rate
Bathroom	20 cfm continuous exhaust (50 cfm intermittent)	
Kitchen	25 cfm continuous exhaust (100 cfm intermittent)	

Flow rate minimum for all dwellings = 40 cfm

Code enforcement interpretation for ventilation modifications

- Adjustments or modifications of existing equipment: Code not enforced, building permit not required.
- Replacement of equipment: Code at time of construction enforced.
  - **Exception: Current code enforced if tightness standard is being enforced**
- Minneapolis commercial code official requires supply ventilation air to match exhaust.

Enterprise Green Communities Criteria (MHFA required for rehabs/new construction)

Area type	Code Ventilation requirement	Notes
Bathroom	20 cfm continuous exhaust (50 cfm intermittent)	Optional with moderate rehabs
Kitchen	5 ACH (based on kitchen volume) or (100 cfm intermittent)	Optional with moderate rehabs
Apartment general ventilation	[7.5 cfm x (# of bedrooms + 1)] + [1 cfm per 100 ft^2 of floor area]	(ASHRAE 62.2-2010)
Corridors, meeting rooms, community rooms	0.06 cfm/sq ft + [25 cfm / 1000 ft2] continuous ventilation	(ASHRAE 62.1-2010)
Public toilets	50 cfm continuous exhaust (70 cfm intermittent)	Rates are per toilet or urinal
Trash room	1 cfm/ft continuous exhaust from ASHRAE 62.2-2010	Includes janitor closets, trash and recycling rooms

Also requires restoration, replacement, repair or recommissioning of abandoned ventilation systems.

CEE ventilation flow recommendations

Pertaining to buildings where an existing ventilation system is modified/retrofitted

- Provide the larger of the two exhaust flow rates to apartments:
  - **0.35 ACH general ventilation, not less that 15 cfm/person**
  - **20cfm bathroom + 25cfm kitchen**

  (works for all 2 bedroom apartments that are ~1,000 ft^2 in area)

- Where possible, match the exhaust airflow provided to the apartments (above) with equal supply airflow

Summary Quiz

- What is the code minimum airflow rate that works in most apartments with ~1000ft² area?
  - ______ cfm for kitchen
  - ______ cfm for bathroom

- What does CEE recommend for supply/make up air whenever it is possible?

BREAK

Come back in 10 mins

Next up:

Multifamily Ventilation System types

Multifamily ventilation systems

Components,

Performance issues,

Retrofit methods

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Corridor supply
or
"Make Up Air" systems

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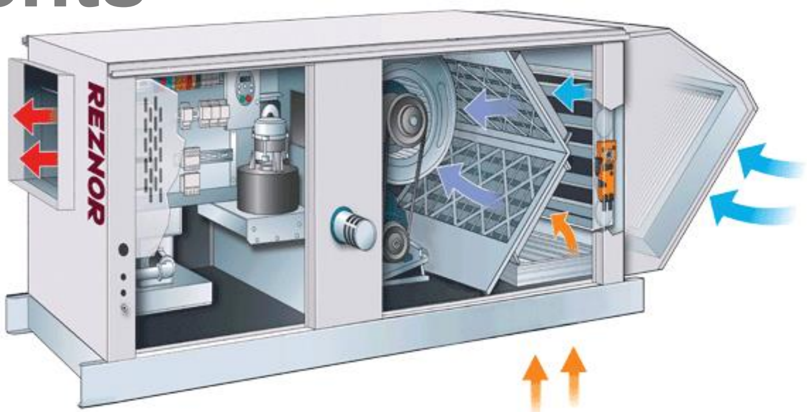
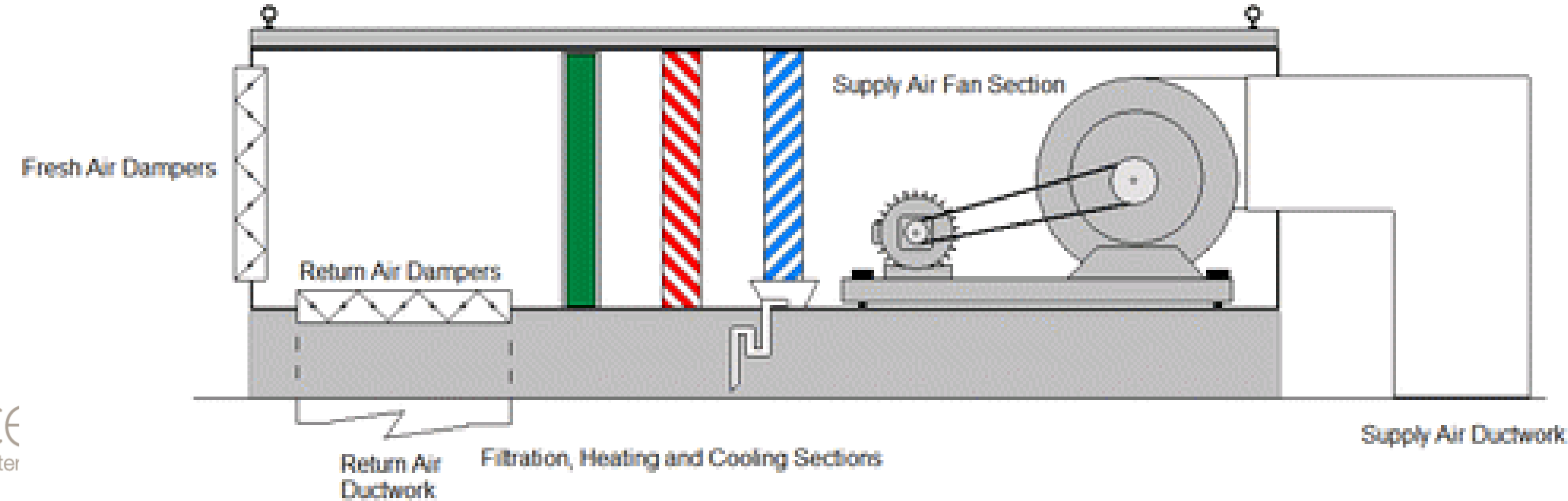
Air handler Components

- Outdoor air intake
- Air filters
- Air dampers
- Fan
- Heating/cooling coil
- Thermostat/control



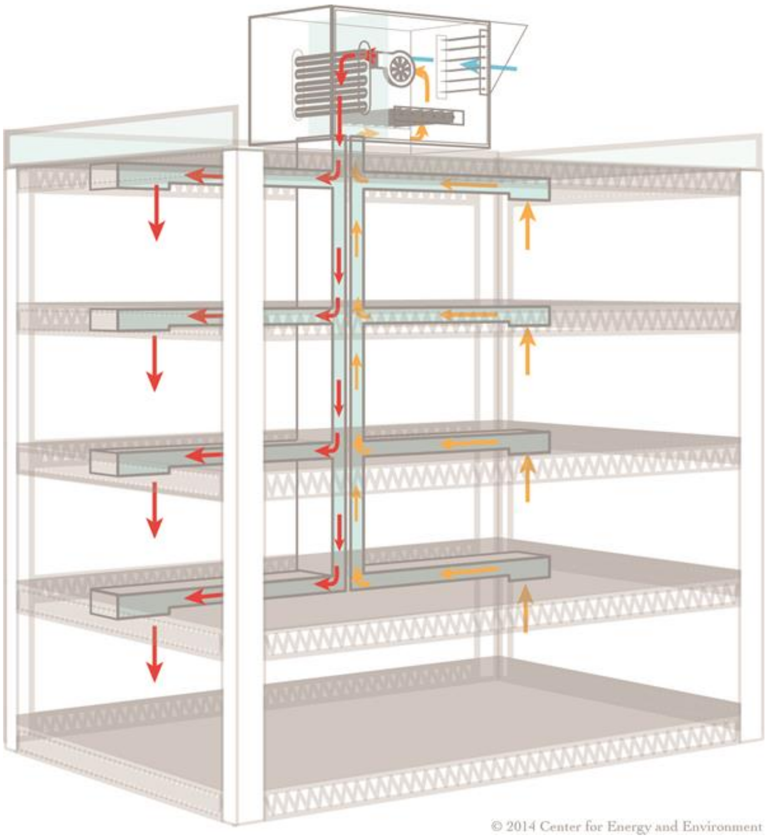
www.reznorhvac.com



www.stewartanthony.co.uk

Distribution components

- OA duct
- Supply duct
- (Return duct)
- Register grilles
- Balancing dampers



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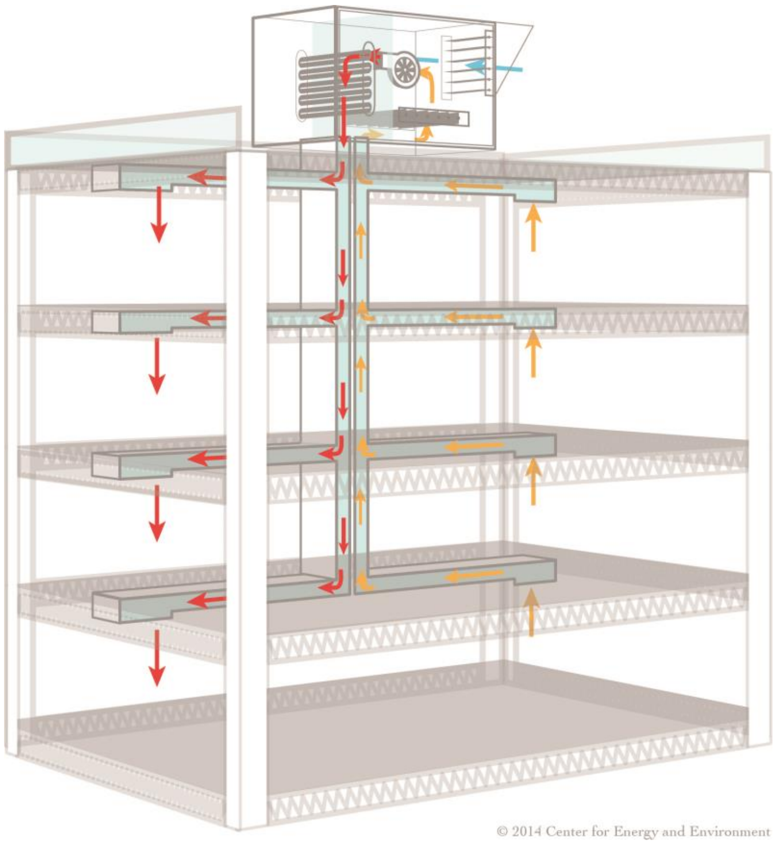
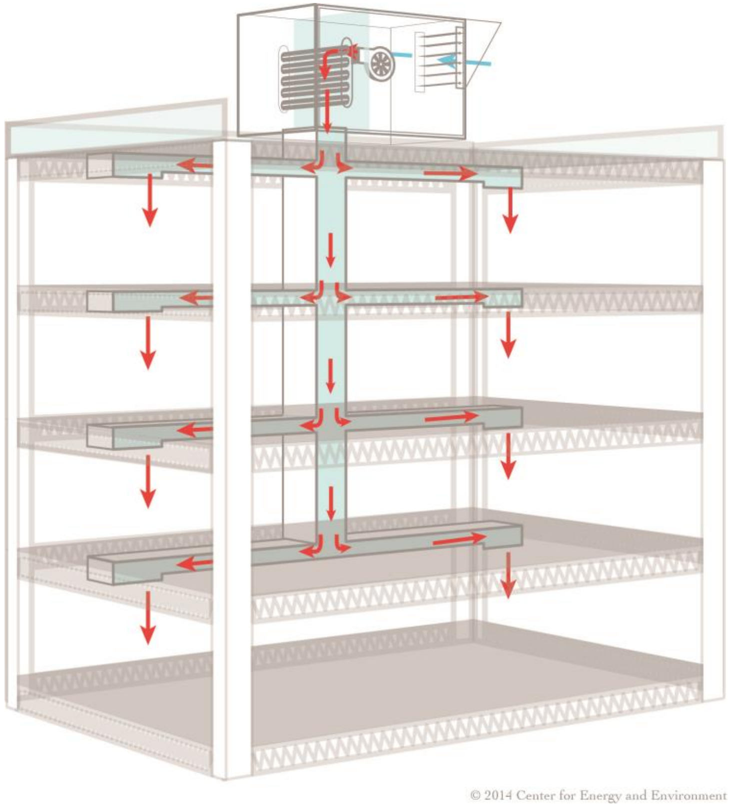
Two System Types

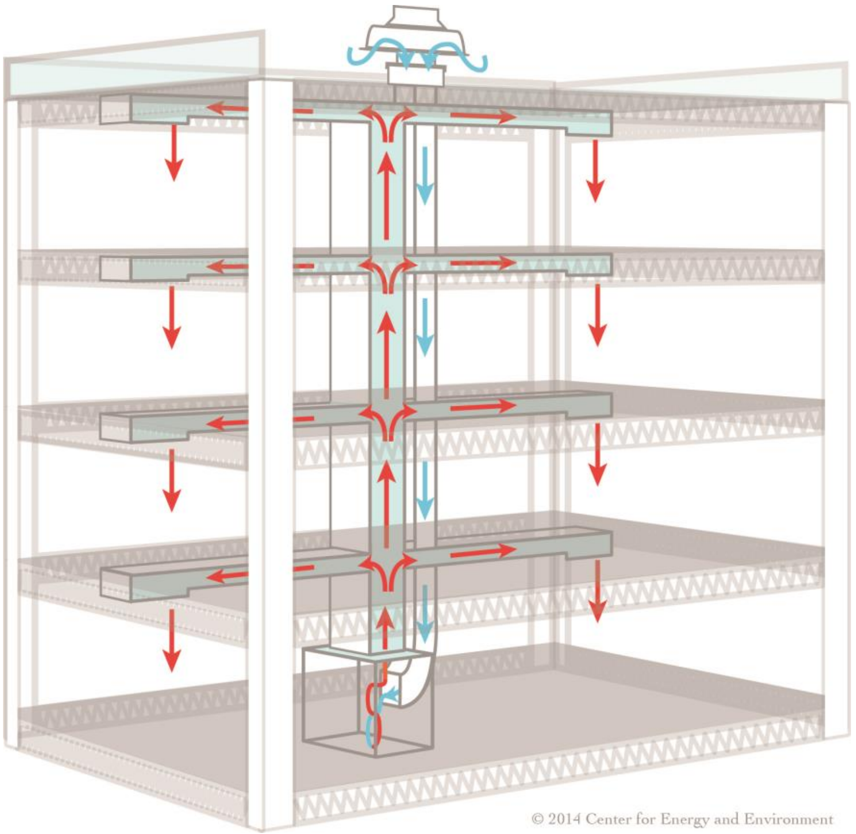


Supply and Return



Supply Only

1st Floor Air Handler & Roof Intake



Supply Only

Functional Purpose

- Fresh air. Provides fresh outdoor air to the hallways
- Make up air? Replaces or balances some ⟺ all apartment exhaust ventilation
- Pressurize? Reduce apartment air/odor transfer through hallways
- Conditioning. At least 40°F and may be the sole source of hallway heating/cooling

Performance Improvement Opportunities

- Reduced Space Heating (& Cooling) costs. Reduced outdoor air flow reduces air handler heating/cooling loads
- Reduced motor operation costs. Reduced air flow reduces fan motor energy use
- Reduced drafts. Excessively ventilated hallways can feel drafty

Assessment of central supply ventilation

Measure the outdoor air intake flow rate

- **Too high?** Reduce and rebalance to design requirement for energy savings
- **Too low?** Increase and rebalance to design requirement for better ventilation

Common reasons for high OA Flow on supply systems

Maladjusted

- Excessive design flow
- Target airflow never commissioned/verified
- System turned up because of odor or overheating

Malfunctioning

- Broken or malfunctioning damper actuator or linkage
- Clogged filters, bird screens and/or coils
- Control or sensor failure

Limits of air handler

- Minimum air flow rate required over HX/DX

Air handlers

Supply air handler intakes

Clogged intakes

Clean clogged intakes and coils before adjusting flow

System Variations

- Location of air handler – roof, penthouse, or mechanical room
- Run Time – 24/7, or intermittent (timer, thermostat)
- Recirculated air / outdoor air mix – 100% OA, or mix
- OA Location – roof, exterior wall on any floor
- OA Flow Control – dampers, fan speed, or both
- Conditioning type – hydronic/steam coil, direct fire, heat pump

Retrofitting supply systems

Adjusting the air handler for reduced airflow

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Reducing OA Flow Rate

Method 1. Re-sheave : adjust/replace the fan pulley and /or motor pulley for different flow rate.

- Permanent
- Typically done by TAB crew
- Tiered adjustment (larger range of error)
- Cost range $2,000-$3,000

Reducing OA Flow Rate

Method 2. Change VFD control setting (or add VFD fan control)

- Easily adjustable
- Flow rate adjustment close to desired
- More expensive if VFD not already present
- New - not compatible with all motors

Reducing OA Flow Rate

Method 3. Adjust damper positions

- Recirculated air systems
- Changes ratio of recirculated to outdoor air
- Manual damper adjustment or a control adjustment for damper actuator (or both)
- Consider return air duct flow capacity limits

Balance Distribution

Adjust balancing damper position to achieve target flows at register

Source: freshair.ro

Short-Circuited Air Flow

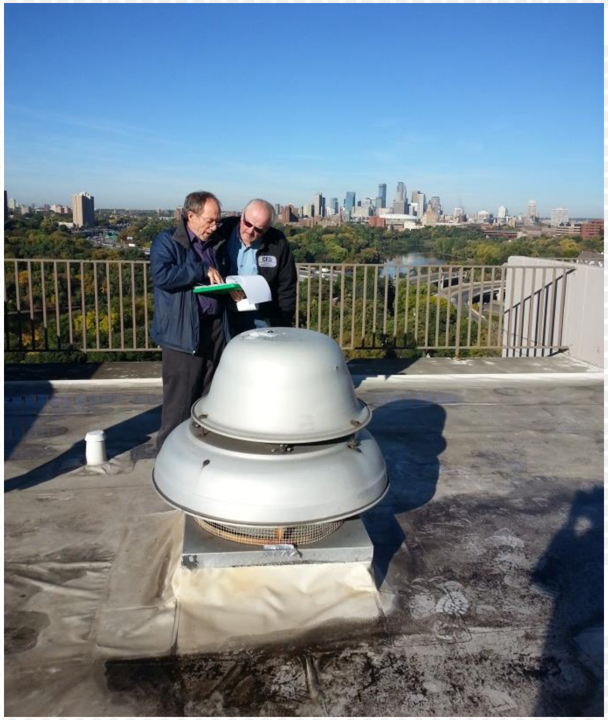
A design flaw that is expensive to remedy

Supply and return registers too close in proximity will inhibit air distribution and reduce system performance

Summary Quiz: Central Supply Ventilation

- What is the primary energy cost of supply or make up air ventilation?
- What are 2 common performance issues you might find with supply / make up air systems?
- What are 2 methods to reduce the outdoor airflow on a supply / make up air ventilation system?

Central Apartment Exhaust



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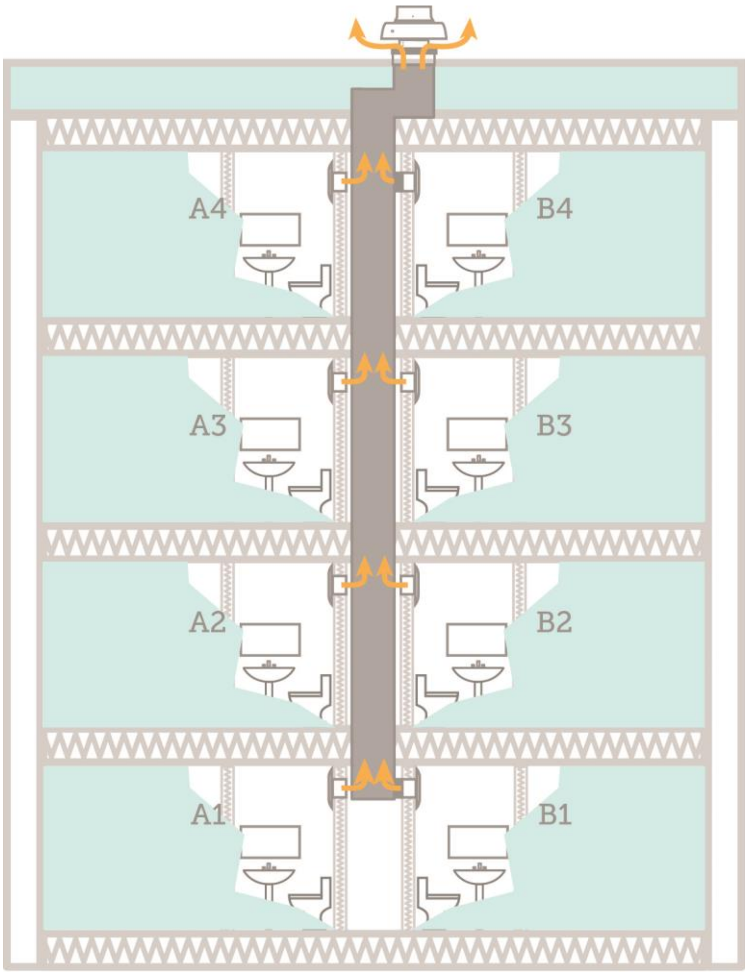
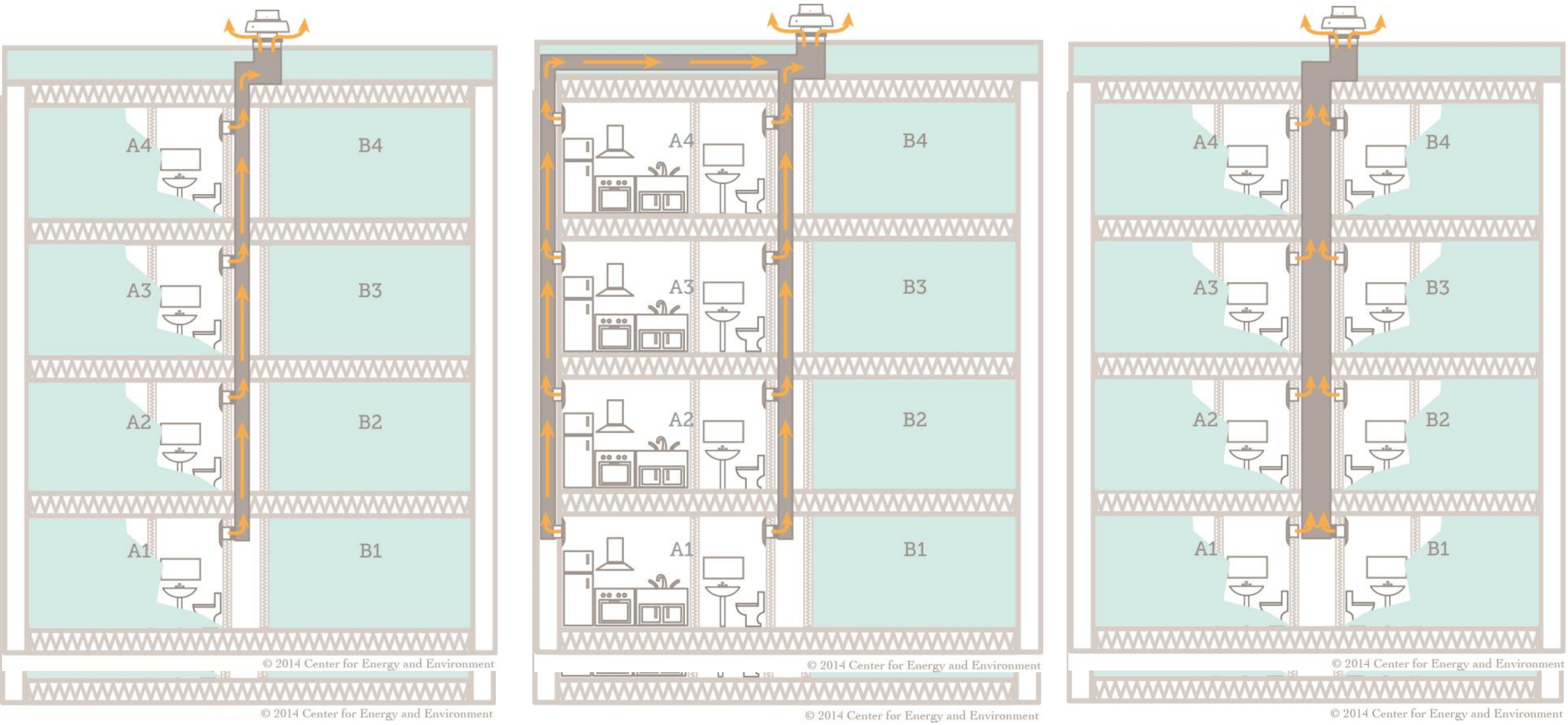
Basic Components

- Fan
  - Central air hander OR
  - Packaged rooftop ventilator
- Distribution
  - Exhaust inlet grille
    - (apartment kitchen or bath)
  - Balancing louver or CAR
  - Fire damper or subduct
  - Branch duct
  - Shaft



Shaft Variations



Functional Purpose

- **Reduce Odors / Humidity.**
- **General IAQ.** Reduce general concentrations of indoor air pollutants within dwelling units

Replacement air may come from hallway transfer air, infiltration, designated supply make up air, or other apartments (not by design)

Performance Improvement Opportunities

- Reduced Space Heating (& Cooling)Costs
- Reduced motor energy use
- Reduced resident odor complaints
- Reduced turnover repairs
- Reduced fan noise (typically)

Common Exhaust System Issues

- Design flow rate is excessive
- Flow rates never commissioned/verified
- Fans oversized
- Inlet balancing devices adjusted or clogged/defective
- Fan flow increased due to duct leakage and/or restriction

Assessment of Central Exhaust Ventilation

Measure the exhaust flow

- **Too high?** Reduce and rebalance to desired level for energy savings
- **Too low?** Increase and rebalance to desired level for better ventilation
- **Are there major duct leaks/disconnects?** May have to address duct leakage before reducing flow.

Fan types: PRVs, Central utility fans

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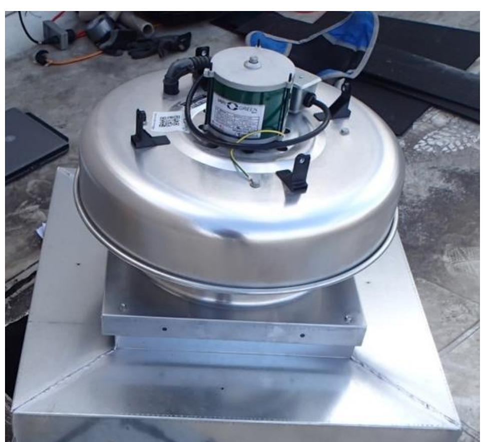
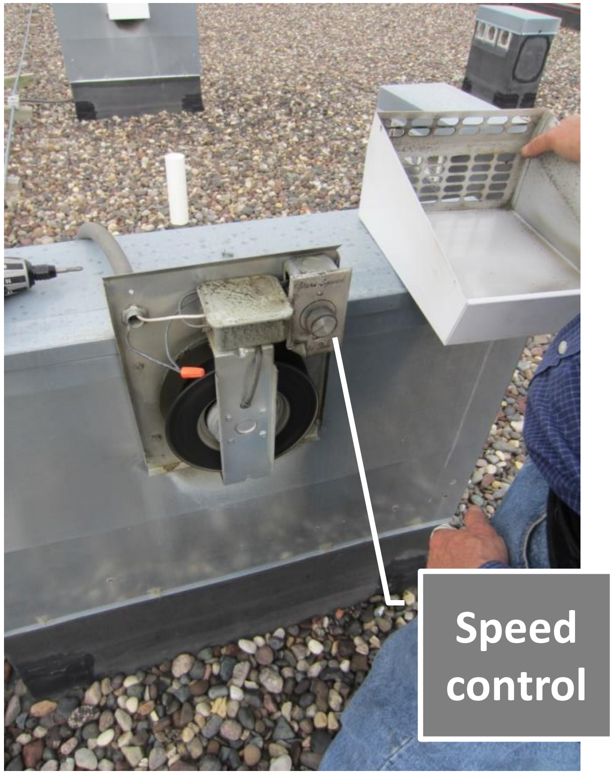
Powered Roof Ventilators (PRV)

Direct drive motor



Belt-driven motor

More PRVs



PRV Retrofit: ECM motors with speed controls

Air seal at curb below fan

Central Utility Fan

Dampers balance flow at each shaft

Utility fan retrofit

- Resheave motor
- Balance airflow

Inlet flow balancing

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Adjustable Louvers

- Can be integrated with register grille or a separate piece
- May have adjustment lever
- Clogs over time w/o cleaning
- Prone to tampering

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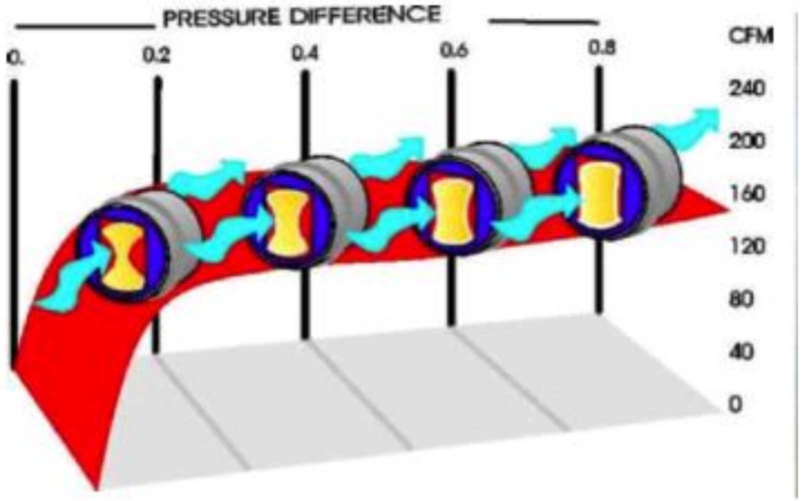
CARs
(Constant Airflow Regulators)

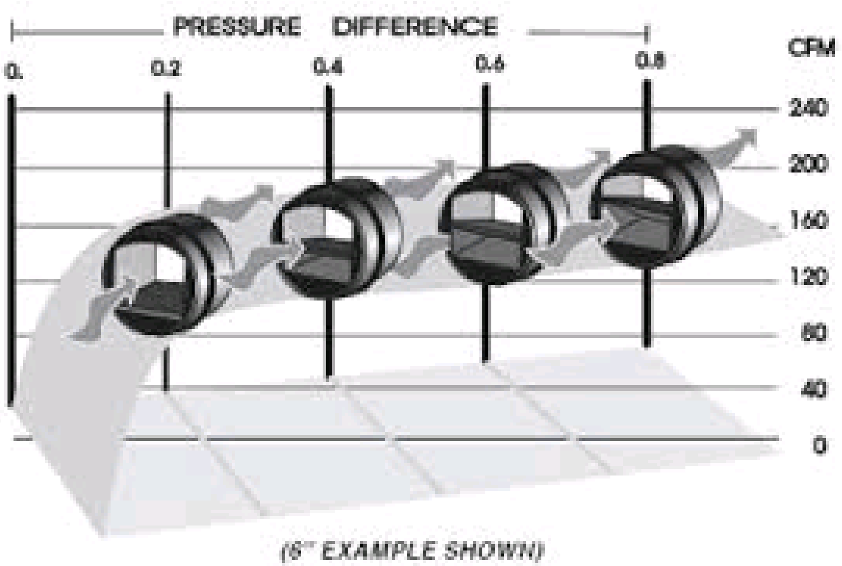
- Self-balancing
  - Some require 60Pa or more of duct pressure for self-balancing
  - Clog over time
  - Cost $35-50



CAR-II

- Functional at lower duct pressure (CAR-II-LP)
- Non-clogging?
- $40-50

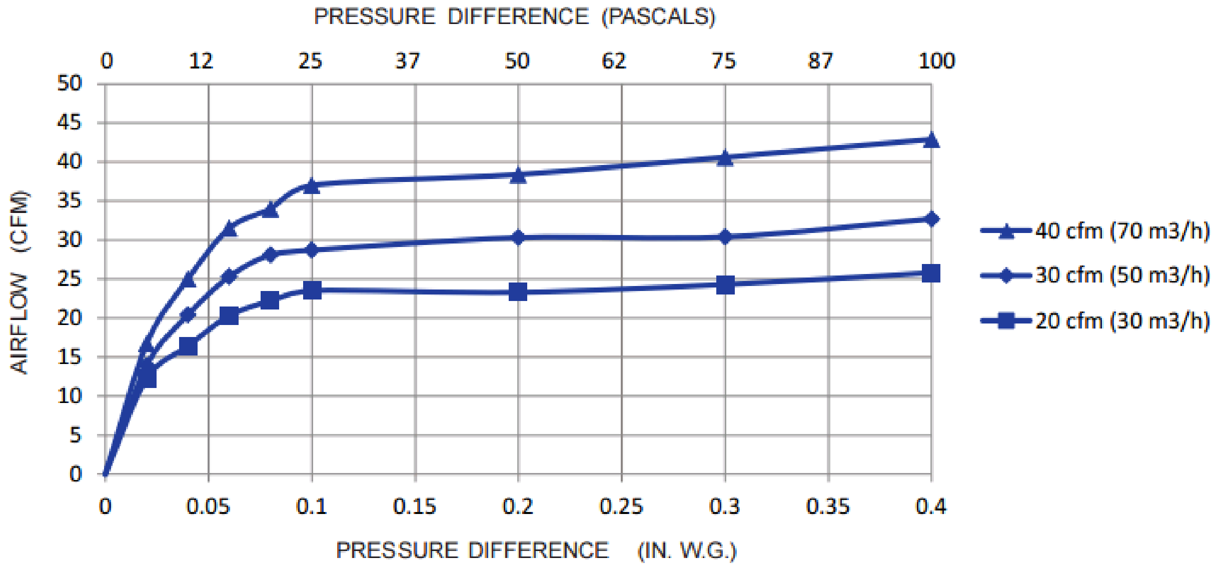
CAR II



CAR-II-LP Airflow Performance Data

Performance charts reflect airflow measurements taken at 68°F (20°C) at 1 atmosphere pressure. The CAR-II-LP is designed for system pressures between 0.1 and 0.42 in. w.g. Models are also available for applications with system pressures between 0.2 and 0.8 in. w.g (CAR-II) and above 0.8 in. w.g. (CAR-II-HP).

4" DIAMETER (100 mm) REGULATING ELEMENT



PART NUMBER	AIRFLOW
17 411	20 CFM (30 m³/h)
17 412	30 CFM (50 m³/h)
17 413	40 CFM (70 m³/h)

Fixed Orifice -"Sheet Metal With a Hole"

- Hole is sized for correct flow at design shaft pressure
- Non-clogging
- Tamper proof
- Least cost ($5-7)
- Sealed to ceiling

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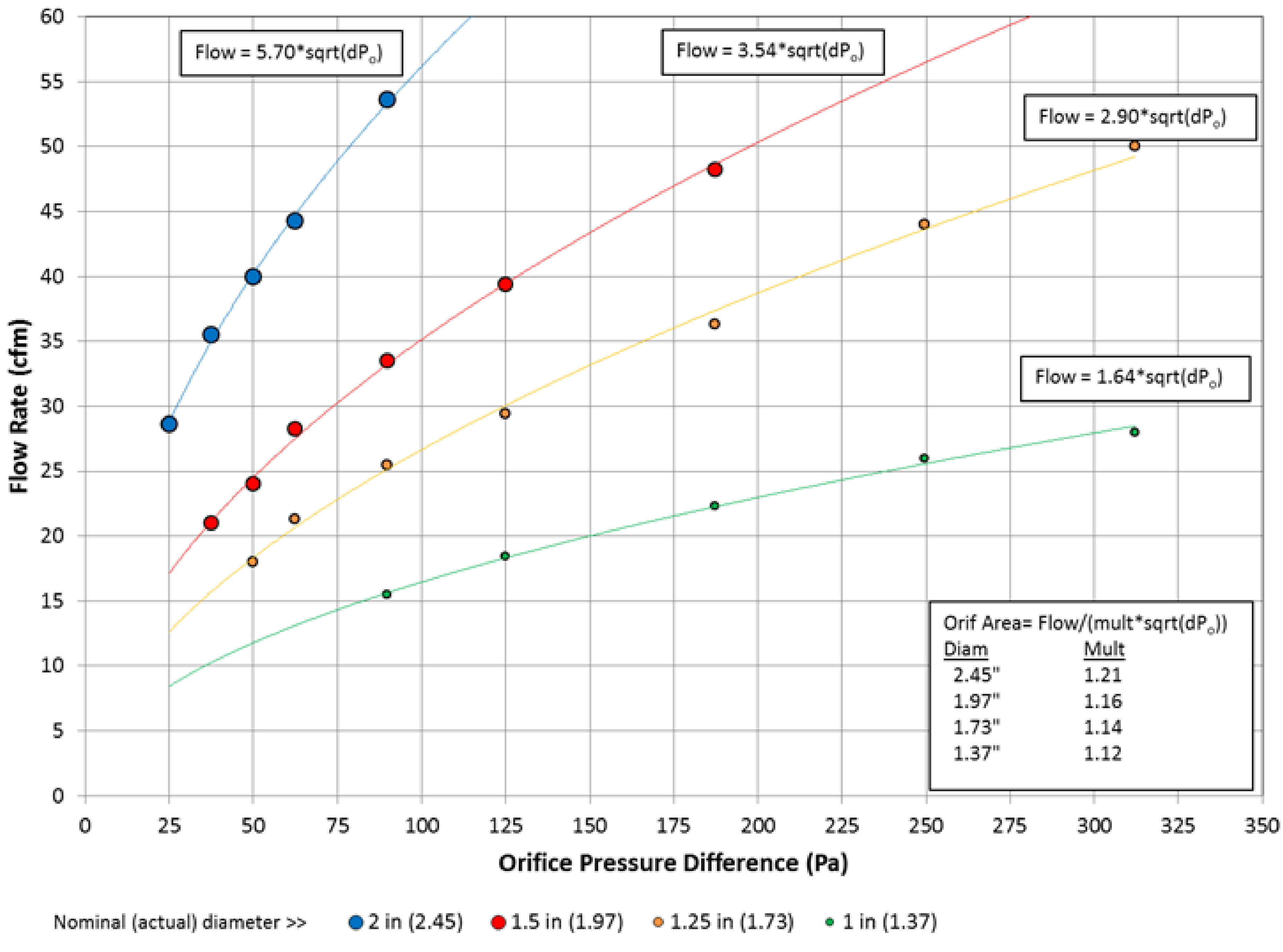

Flow = 5.70*sqrt(dP$_o$)
Flow = 3.54*sqrt(dP$_o$)
Flow = 2.90*sqrt(dP$_o$)
Flow = 1.64*sqrt(dP$_o$)
Orif Area= Flow/(mult*sqrt(dP$_o$))
Diam Mult
2.45" 1.21
1.97" 1.16
1.73" 1.14
1.37" 1.12
Flow Rate (cfm)
0
5
10
15
20
25
30
35
40
45
50
55
60
0 25 50 75 100 125 150 175 200 225 250 275 300 325 350
Orifice Pressure Difference (Pa)
Nominal (actual) diameter >>
2 in (2.45)
1.5 in (1.97)
1.25 in (1.73)
1 in (1.37)

Duct leakage at inlets

Exhaust shaft / Duct work

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Shaft / Duct Types

- Gypsum shaft
- Metal shaft
- Lined metal (as insulation in roof cavity)
- Combo / Retrofitted shaft

Gypsum, intact

Metal shaft

Gypsum shaft , looks discontinuous

Shaft & Duct Types

Lined duct in roof cavity

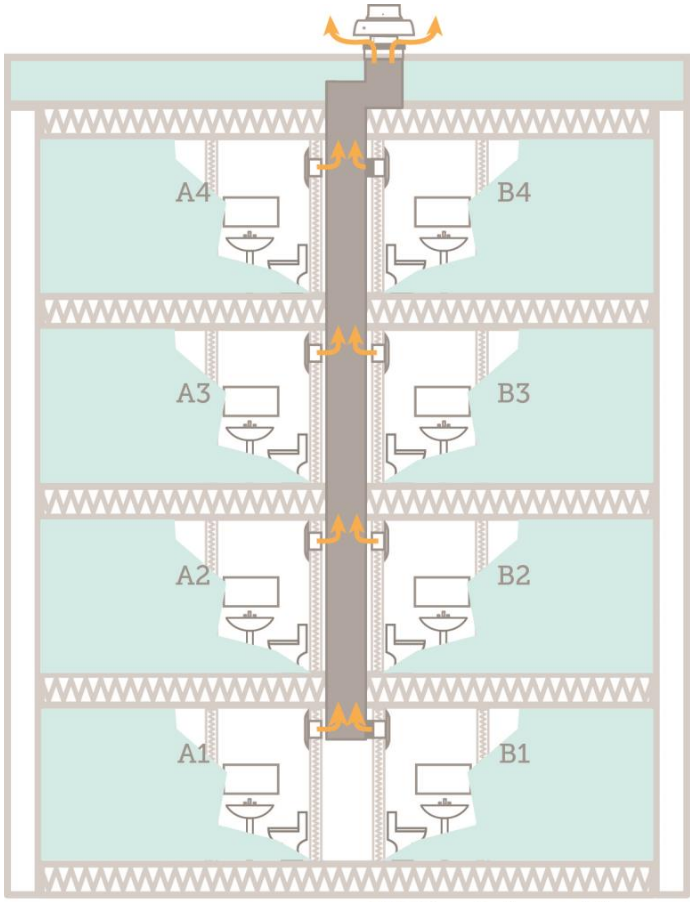
Retrofitted shaft is discontinuous—planks/floor slab was drilled for shaft to pass though

Duct leakage below fan at curb

After leaks are sealed

Effects of duct leakage on exhaust ventilation

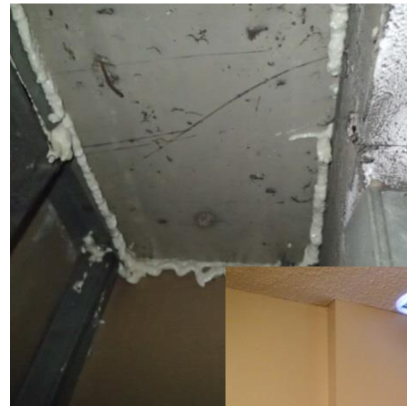
- May have to increase exhaust fans to achieve inlet target flows
- May not be able to achieve inlet flow targets without duct sealing
- May have to increase the orifice size to achieve flow target at inlets furthest from fan



Duct sealing opportunities are limited

Aeroseal injected aerosol sealant can seal up to 1/2” gap

Accessible manual duct sealing



Exhaust Ventilation Summary Quiz

- How can you reduce the energy cost of an exhaust ventilation system?
- What do Constant Air Regulators (CARs) and balancing louvers do?
- What are the advantages of a fixed orifice over CARs and balancing louvers?
- Why are large duct leaks a concern when reducing exhaust ventilation?

Trash Chutes

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Basic Components

Chute

- 2’ wide shaft for trash deposits
- Terminates into dumpster
- Capped opening at roof allows exhaust

Trash Room

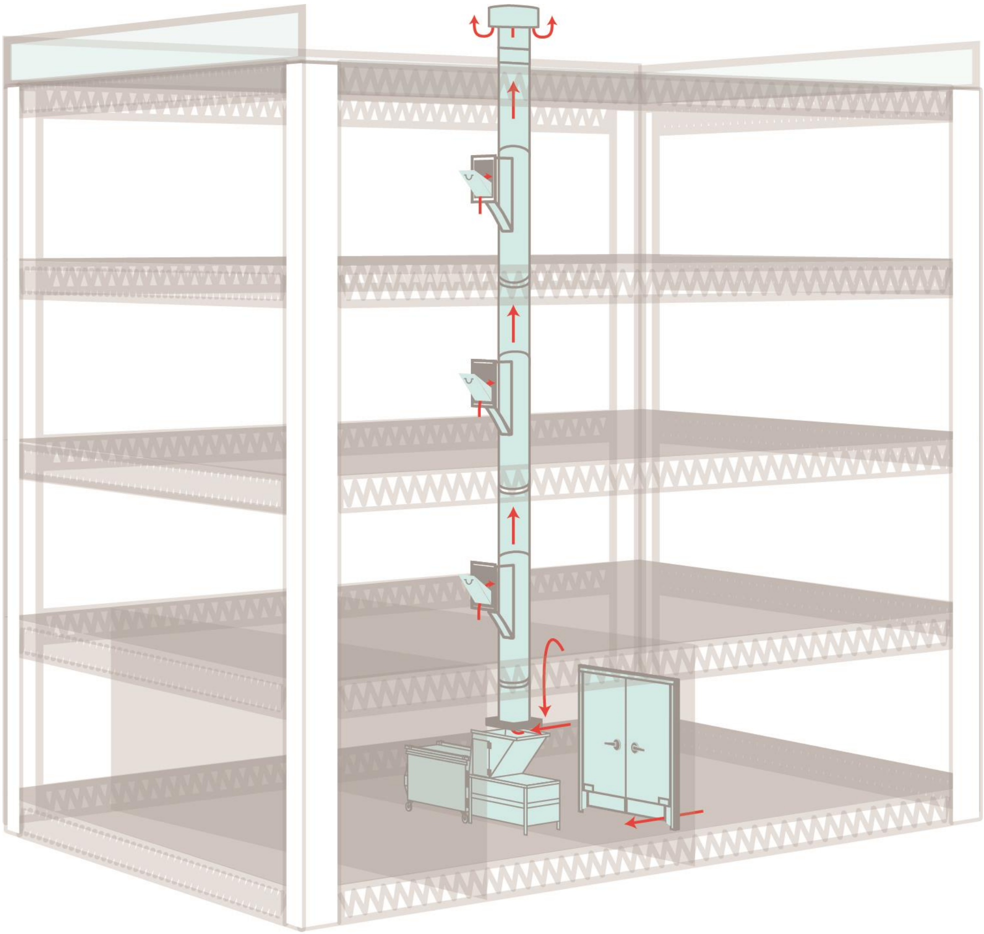
- Exhaust ventilation
- Fire door
- Air seal / fire barrier to rest of building

Rooftop Exhaust Termination

- Open area determines stack effect air flow

Typical Trash Chute Configuration

- Convenient Trash Deposit
- No Trash Odors in Building



Energy / O&M saving opportunities

- Space Heating (& Cooling) savings. Reduced air flow out of chute reduces building air heating/cooling loads.
- Reduce odor complaints.

Assessment and Solutions for Trash Chutes

- **Rooftop Termination excessive open area?**
  - Lower cap to reduce stack flow
- **Air leaks connecting building air to trash room?**
  - Seal air leaks to prevent odor transfer
  - Close trash room doors
- **Trash room exhaust fan exhausting too much or too little air?**
  - Reduce / increase fan flow

System Variations

- **Type of Exhaust Fan:** PRVs or individual continuous fans
- **Dumpster/chute Outlet:** Isolated room or connected to building occupant air
- **Rooftop Termination:** Amount of open area at cap
- **Chute Trash Disposal Access:** room or access door

Trash Room Exhaust Fans

Individual fan in dumpster room

PRV serving trash rooms (on each floor) and dumpster room

Trash Room Dumpster / Chute Outlet

Trash Chute Access

Trash room with access door and dedicated exhaust ventilation

Fire door with access door, no room

Trash Chute Roof Terminations

Trash Chute Summary Quiz

- Name 2 ways that a trash chute can have excessive energy cost?
- Why should the trash chute be isolated from the building air?
- What are 2 solutions for improving trash chute performance?

BREAK

Come back in 10 mins

Next up:
Airflow Measurement

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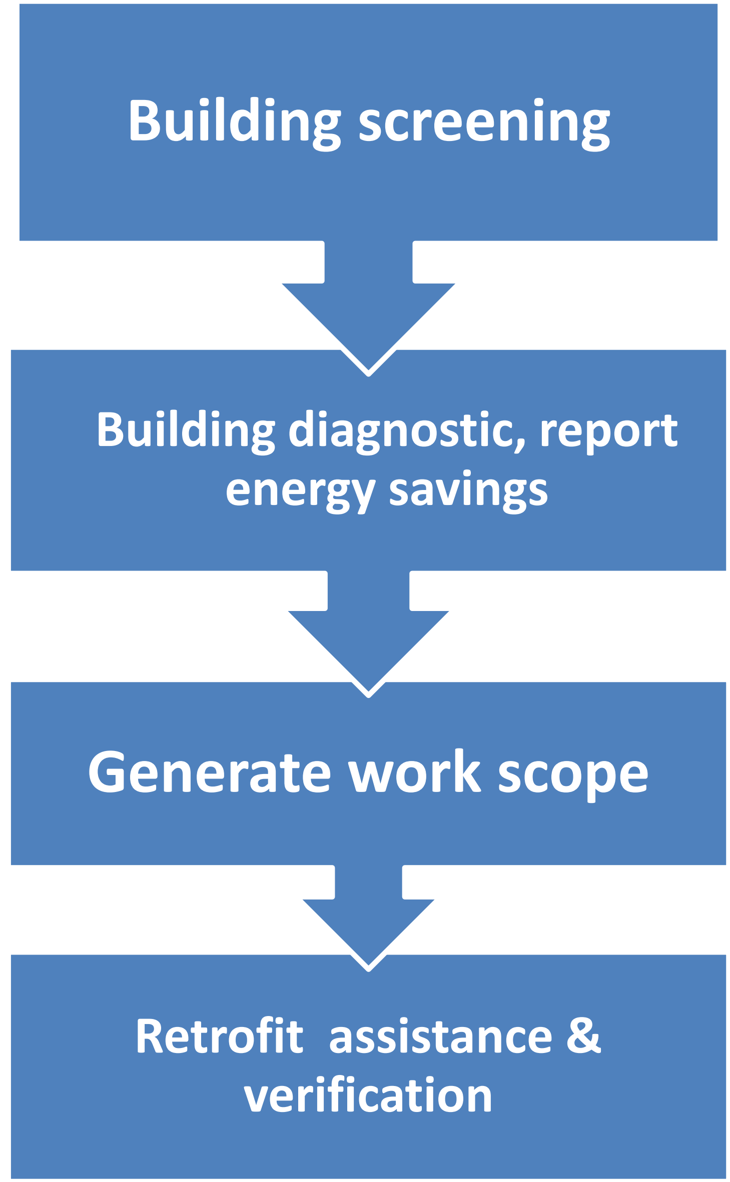
Assessing multifamily ventilation systems

- General process flow
- Air flow measurement methods
- Building screening visit
- Building diagnostic visit

Process Flow
Ventilation Assessment & Retrofit

- **Phone survey- optional**
  - Ventilation system?
  - Issues with ventilation?
- **Building screening-**
  - Significant energy savings?
- **Building diagnostic-**
  - How much energy savings?
  - Solution?



Assessment Goals

- **"Building Screening"**

  Characterize building ventilation energy savings potential at lowest cost possible

- **"Building Diagnostic"**

  Provide accurate energy savings and payback estimates

Airflow measurement methods

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Airflow measurement for building screening vs. diagnostics pg.20

Table 2. Recommended airflow measurement methods.

Measurement Type	Purpose	
	Building Screening	**Diagnostics**
Exhaust inlet	Exhaust fan flow meter box	FlowBlaster
Rooftop exhaust fan	(1) TrueFlow capture box	(1) TrueFlow capture box (2) TrueFlow Meter below frame (3) DuctBlaster capture box
Rooftop or makeup unit outdoor air intake	(1)Vane anemometer duct traverse (2) Customized TrueFlow Meter frame	(1) Thermal anemometer duct traverse (2) Customized TrueFlow Meter frame (3) Temperature method

Measuring exhaust inlets

TEC flow meter box for screening

- Measures flow through orifice
- Lightweight
- Fits most inlets
- $175

Considerations

- Pressure drop through box may alter low flows

FlowBlaster for diagnostics

- Compensates for pressure drop through device

Considerations

- Heavier/bulkier
- Requires 16x16 flat surface
- 29” vertical clearance
- $1,100

Adapter for 30” kitchen hood

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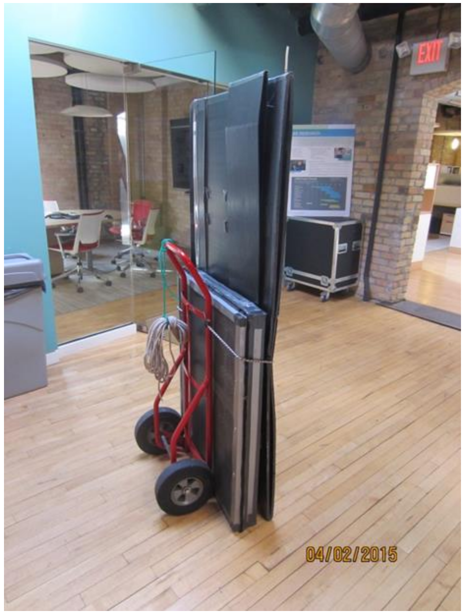
Measuring rooftop ventilators

TrueFlow capture box for screening & diagnostics

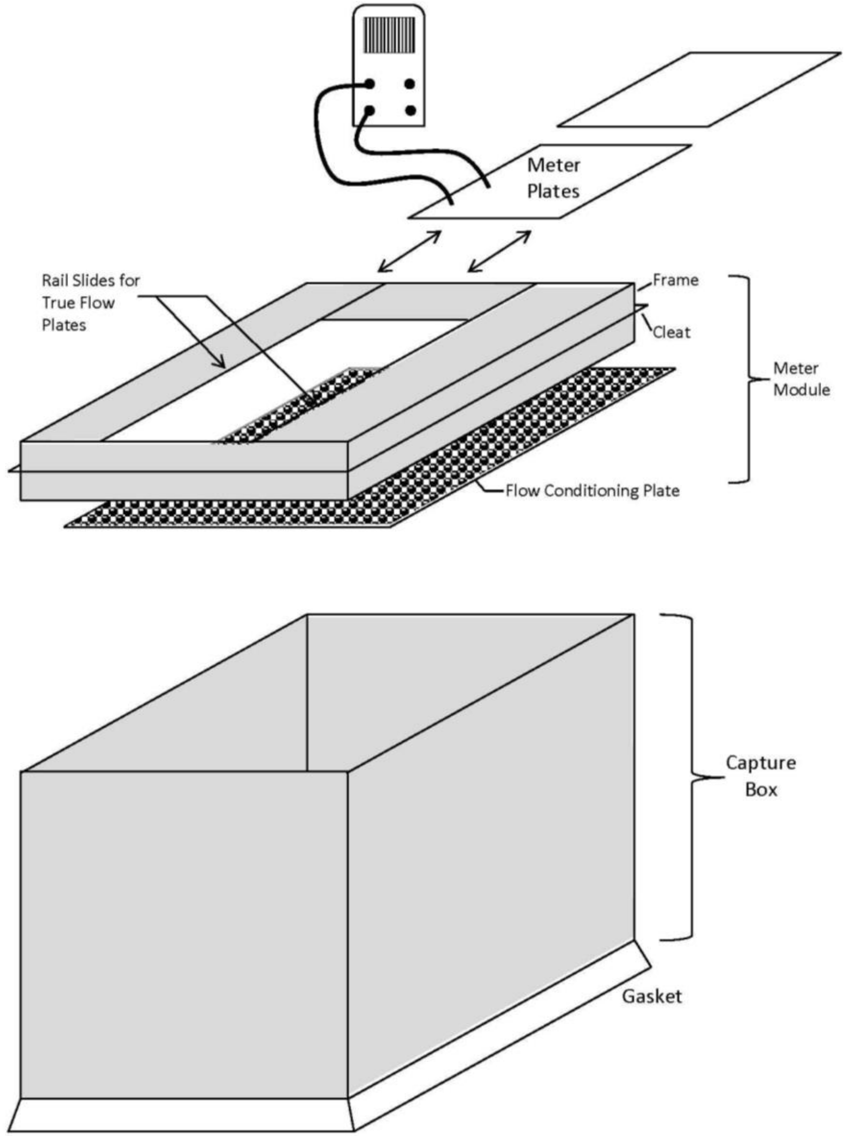
- No power required
- Collapsible
- Scalable
- Quick, easy measurements
- $500-$1,000

Considerations

- **Minimize box pressure**
- **Size for anticipated flow**



Main Components



Process

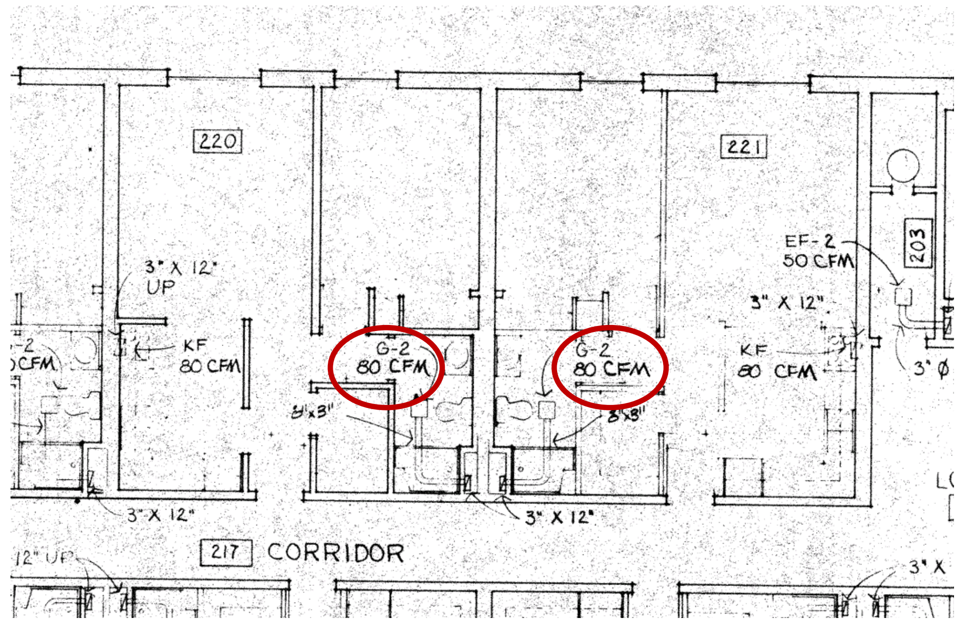
Step 1. Determine box size

- Measure PRV height and width
- Make sure the box will fit completely over the fan and seal to the roof

Process

Step 2. Determine # of TrueFlow plates needed

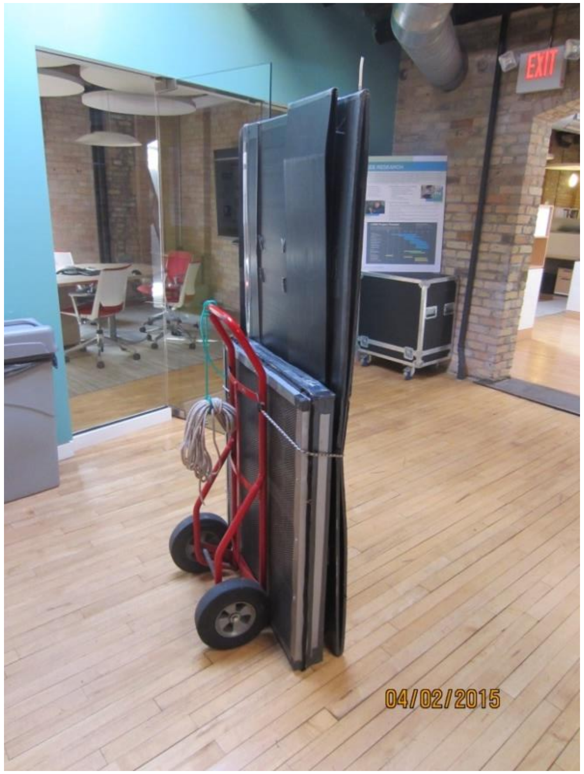
- **Rule of thumb:** Use enough TrueFlow plates to be at or below the low end of the TrueFlow flow range per plate
- Example
  - 6 story building
  - 80 cfm/inlet, 2 inlets per floor
  - 6x80x2=960 cfm anticipated



Flow Range:	#14 Metering Plate:	365 cfm to 1,565 cfm.
	#20 Metering Plate:	485 cfm to 2,100 cfm.

Process

Step 3. Assemble box



Process

4. Measure NSOP : "Normal System Operating Pressure"

- Drill hole for static probe
- One minute averages
  - Calm: 1
  - Windy: 2 to 5
- Reference indoors if cold or windy
- Leave probe / hose in place

(after all measurements are done, seal hole with silicone caulk or flashing cement)

Process

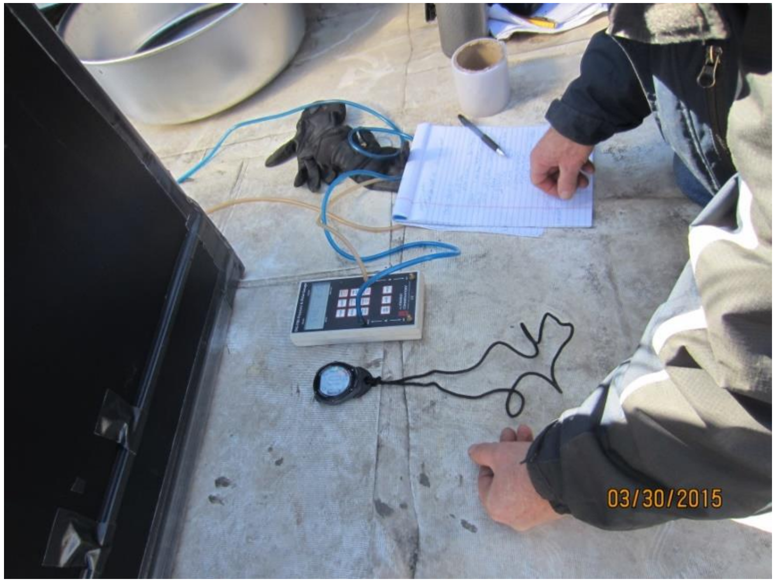
Step 5. Set box over fan

- Tie off box for safety
- Make sure box seals over fan at rooftop
- Add duct mask if box is leaking air

Process

Step 6. Measure TFSOP & TrueFlow plate pressures

- TrueFlow System Operating Pressure (TFSOP) –measure pressure change in shaft from box
- Measure pressure at each TrueFlow plate
- One minute averages
  - Calm: 1
  - Windy: 2 to 5
- Stay consistent with reference location (outside or in building)



Process

Step 7. Calculate flow resistance correction factor

(Corrects for change in operating pressure after box is placed over fan)

$$\sqrt{(NSOP/TFSOP)} = Flow\ Resistance\ Correction\ Factor$$

Step 8. Convert to cfm

$$Metering\ plate\ \#14: Flow\ (CFM) = 115 \times (TrueFlow\ Plate\ Pressure\ in\ Pascals)^{0.5}$$

$$Metering\ plate\ \#20: Flow\ (CFM) = 154 \times (TrueFlow\ Plate\ Pressure\ in\ Pascals)^{0.5}$$

Step 9. Calculate total flow in cfm

$$Total\ exhaust\ flow\ (CFM) = Sum\ of\ all\ TrueFlow\ plate\ flows\ (cfm) \times Flow\ Resistance\ Correction\ Factor$$

As instructed in TrueFlow Operation Manual

Process

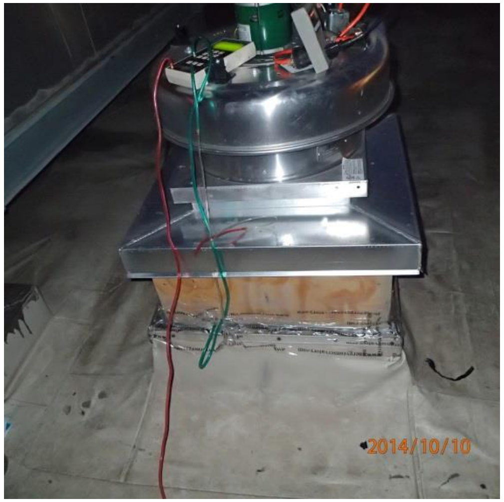
Step 10. Move box to next fan

Flow correction option: adjust speed control

Using TrueFlow plates under the fan

Considerations

- Requires 12” clearance below, 2-3” above
- Often requires customization
- Curb size must be ≥TrueFlow plate dimension
- Ability to lift PRV



Duct Blaster capture box for diagnostics

- Matches flow, zero to low box pressure
- Collapsible
- Scalable

Considerations

- Heavy
- Time intensive
- Power cords
- 2 people to maneuver
- More expensive equipment
- Fan flow capacity limits

Process

1. Determine box size, # of fans needed
2. Assemble box
3. Measure NSOP : “Normal System Operating Pressure”
4. Set box over fan
5. Adjust fans to match NSOP (measured in step 2)
6. Record flow at matched pressure
7. Move equipment to next fan

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Measuring central intakes/exhausts

Building screening

Building diagnostic

Vane anemometer grille/louver traverse for screening

- Quick, easy measurements
- Lightweight, non-bulky
- $50-$300

Considerations

- Less accurate
  - Cannot measure <80 fpm
  - Turbulence can have significant impact on measurement (>30%)
  - Less reliable on supply flows

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Thermal anemometer duct traverse for diagnostics

- More accurate than vane

Considerations

- Needs area of fairly uniform velocity
  - Straight duct run (3+ diameters from elbow, branch, transitions)
- $600-$1,000

Conducting a duct traverse

- Average of multiple measurements across duct cross-section

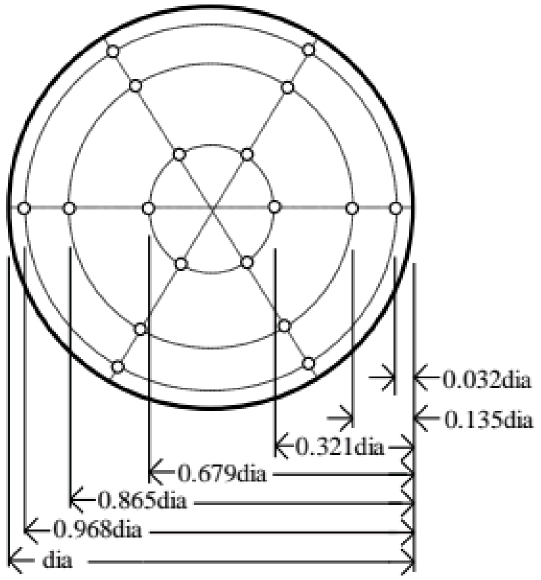


Figure 1: Location of measuring points when traversing a round duct using log-Tchebycheff method

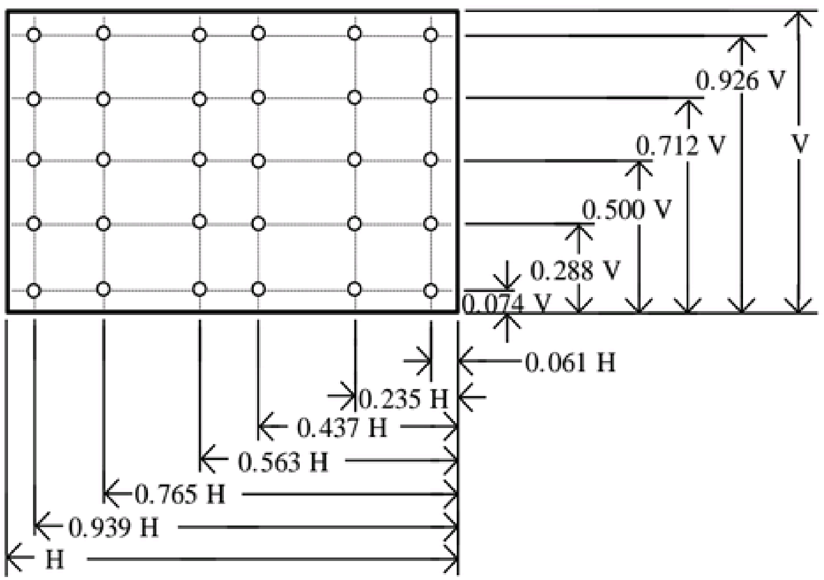


Figure 2: Location of measuring points for traversing a rectangular duct using log-Tchebycheff method

TrueFlow Meter in OA duct

- Less susceptible to turbulent air

Considerations

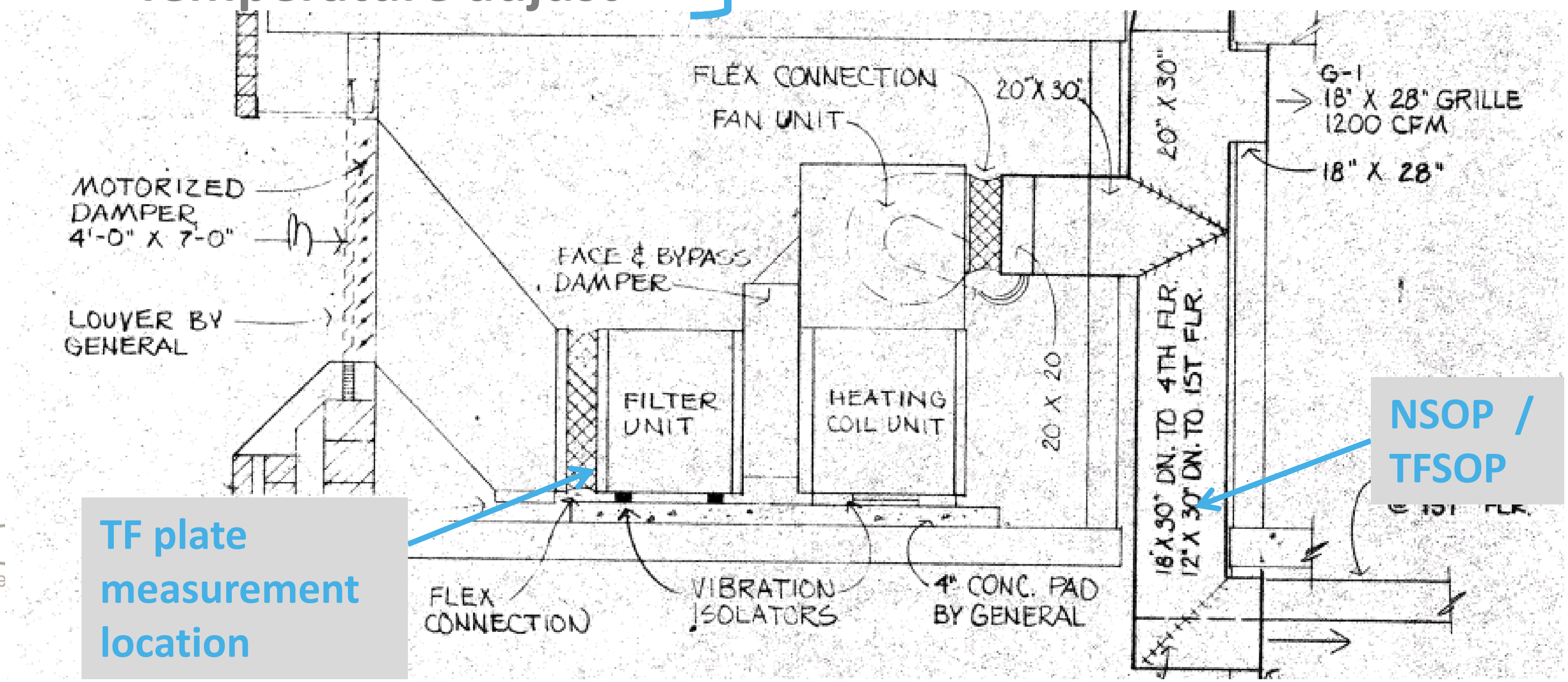
- Cardboard frame must be custom fit and taped into OA duct
- Flow capacity limits of TrueFlow plates

Flow Range:	#14 Metering Plate:	365 cfm to 1,565 cfm.
	#20 Metering Plate:	485 cfm to 2,100 cfm.

Process

- Construct frame
- NSOP
- TFSOP
- Plate pressures
- Convert to cfm
- Temperature adjust

Same process with all TrueFlow measurements
Directly from Operation Manual



Calibrated fan with pressure matching

- Match system airflow through blower door
- High measurement confidence

Considerations

- Equipment and time intensive
- Requires customization

Process

1. Determine # of fans needed
2. Measure NSOP
3. Install fan(s) over grille and seal around it
4. Adjust fan(s) to match NSOP (measured in step 2)
5. Record flow at matched pressure
6. Temperature adjust

Similar to "Measuring Total System Airflow" in Chapter 13.1 of Duct Blaster manual

Flow hood on supply registers

- Measures register flow, for balancing (cfm per floor)
- Sum of register flow may be only method to get total

Considerations

- Non-uniform flow is a problem
- Pressure change from hood can effect flow

Summary

- What methods can be used to measure supply / make up airflow?
- Where is the best location for measuring supply or make up airflow?
- Why is it less ideal to measure airflow with a vane at the supply registers?
- What should you do if, when measuring airflow, you get an odd or unexpected result?
- What is the most accurate way to measure exhaust ventilation airflow?

LUNCH

Come back in 30 mins

Next up:

Ventilation Assessment Process

Cumulative Summary Quiz

- What is the minimum MN multifamily ventilation requirement for most apartments under 1,000 ft^2 according to code?
- What are 2 common performance issues you might find with supply / make up air systems?
- What can be done to reduce outdoor airflow on a supply ventilation system?
- How can you improve the performance of a trash chute?
- What do Constant Air Regulators (CARs) and balancing louvers do?
- What are the advantages of a fixed orifice over CARs and balancing louvers?

Assessment process

A method for incorporating ventilation assessment into your work

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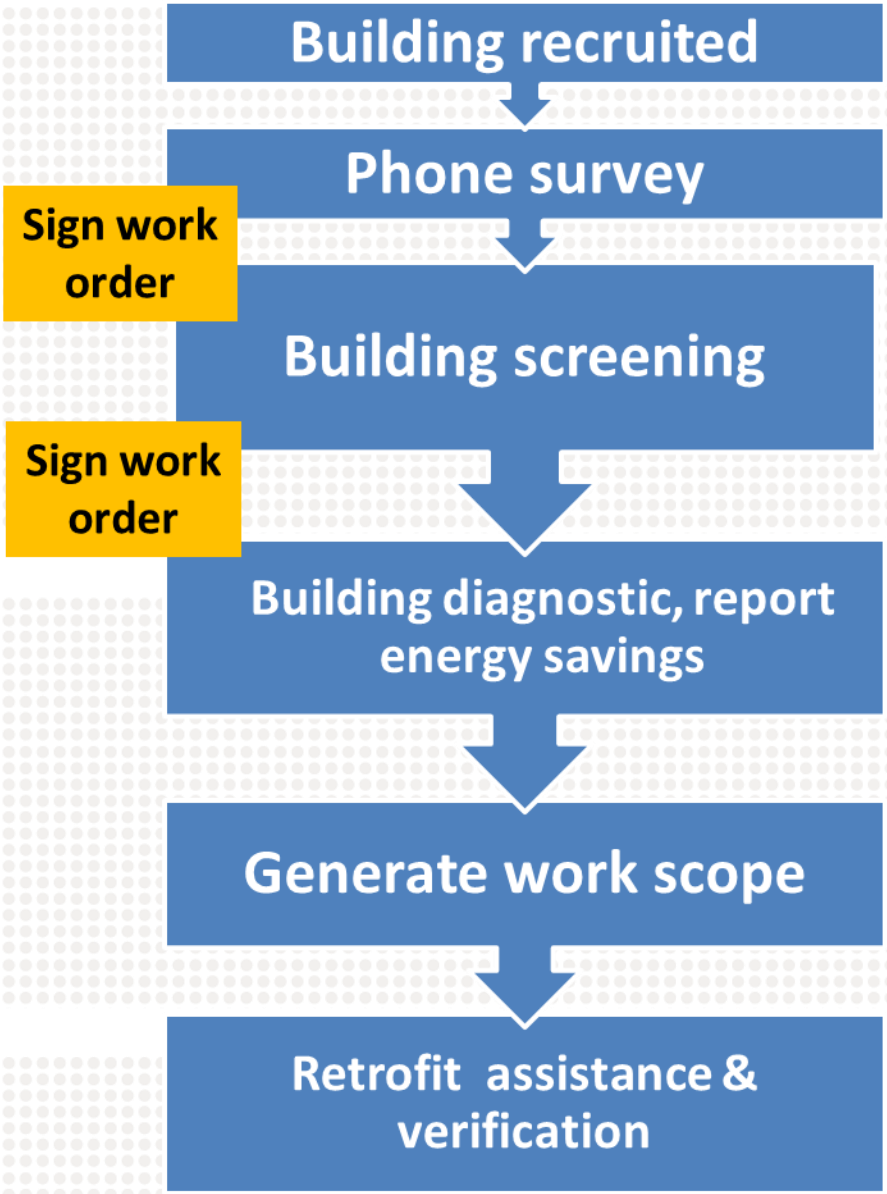
Process overview



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Phone Survey (optional)

- Determine if building is good candidate for assessment
- Keep it simple

I.E.

- Do they have central ventilation systems?
- Are they on?

Phone Survey –Multifamily Ventilation Assessment

Building Name and Address: ____________________

Date: __________ **Time:** __________ **Technician:** ____________________

BUILDING GENERAL	
General	Year built: ______ (Year of major rehab. (if any): ________) # Stories: ______ # Total units: ______
Apartment floor plan available? (Framing plans) Mechanical system plans available?	☐ Will email ☐ Provided hardcopy ☐ Not avail. ☐ DK ☐ Will email ☐ Provided hardcopy ☐ Not avail. ☐ DK
Building staff	Name: Title: Email: Phone:
HALLWAY VENTILATION SYSTEM	
Is there a hallway ventilation system?	☐Yes ☐No ☐DK (If NO or DK, skip rest of section)
Does system run continuous (24/7) or intermittent?	☐DK
Location of hallway/corridor air handler	☐ Rooftop ☐ Wall ☐ Indoors: ____________________ ☐DK
Outdoor air intake location	☐ Rooftop ☐ Penthouse ☐ Exterior wall (ladder access?) ☐DK
Recent maintenance or repair?	☐No ☐DK ☐ Yes:
Any problems, concerns or complaints about hallway ventilation?	☐No ☐ Yes:
APARTMENT EXHAUST	
Is there an apartment central exhaust ventilation system? (i.e. Fans on roof or in a penthouse pulling air out of apartments?)	☐Yes ☐No ☐DK (If NO or DK, skip rest of section)
How many total exhaust fans?	
Exhaust fan location	☐ Rooftop ☐ Penthouse ☐ Attic ☐DK ☐Other:
Apartment central exhaust inlet location:	☐ Kitchen exhaust hood ☐ Kitchen wall or ceiling inlet ☐ Bathroom ☐ DK ☐ Other:
Occupant odor or moisture complaints?	☐No ☐ Yes:
Recent maintenance or repair?	☐No ☐DK ☐ Yes:
Other concerns or complaints?	☐No ☐ Yes:
TRASH CHUTE	
Is there a trash chute?	☐Yes ☐No ☐DK (If NO or DK, skip next question)
Odor or other complaints?	☐No ☐DK ☐ Yes: ____________________
OPERATOR QUESTIONS	
Adjustments or modifications to system in past?	
Moisture, humidity or odor problems?	
Any other problems with ventilation? Resident complaints?	

field form_Phone Survey.docx Last printed 4/13/2015 4:41:00 PM

Screening goal

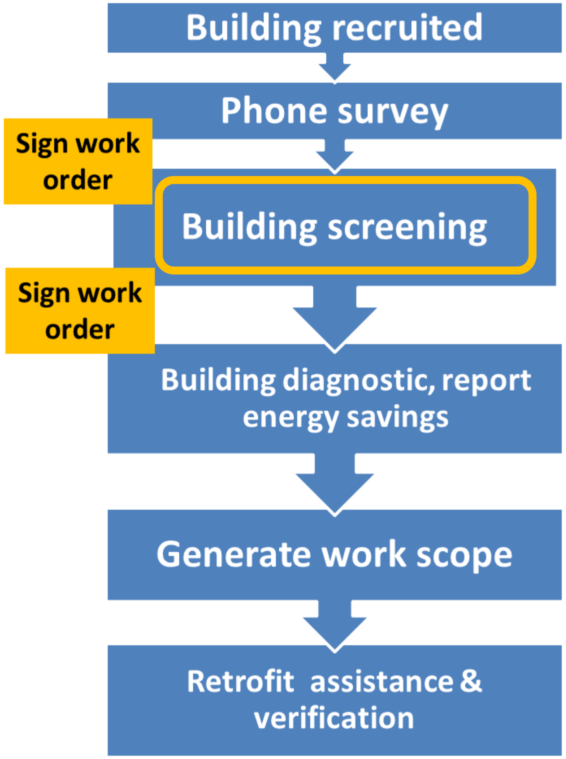
"Determine (roughly) if investing in a ventilation retrofit is going to lead to a desirable energy saving outcome."

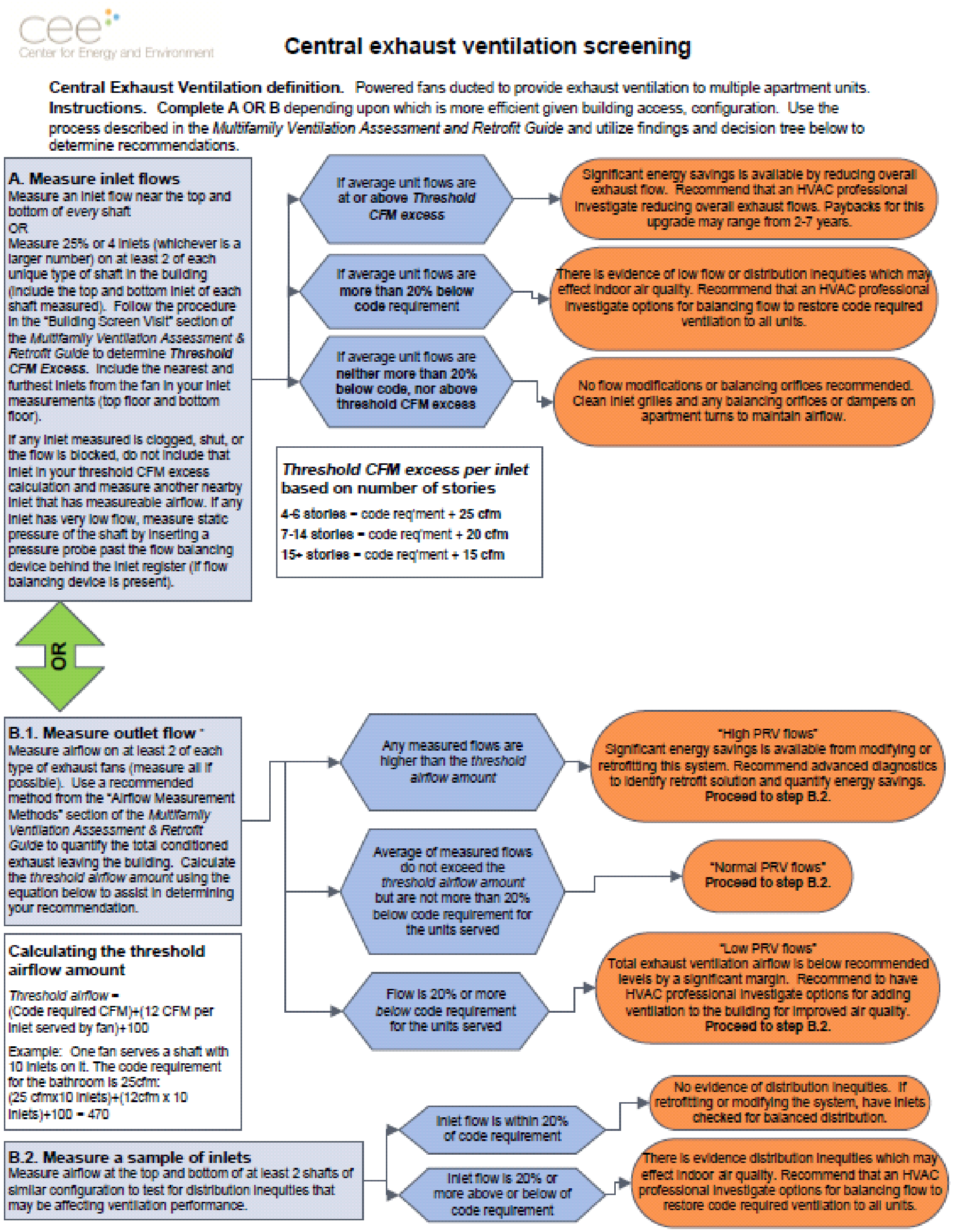
Don't waste time with *any* measurements if:

- Utility bills are already very low
- Ventilation equipment is not on and will never be turned on

Building screen

- **Exhaust system**: 2 options
- **Supply system:** Measure air intake
  - Option: Sum of register flows for 100% OA systems
- **Trash Chute:** Check roof cap, air leakage from trash room to building
- **1-2 hours**





Recommendations based on 3-8 year paybacks from assumed retrofit costs:

Orifice installation:

$100/inlet

PRV replacement:

$1,500/fan

MUA re-sheave:

$3,000 per re-sheave

Use method A or B depending on access

Screening example: 6 story building

SUPPLY

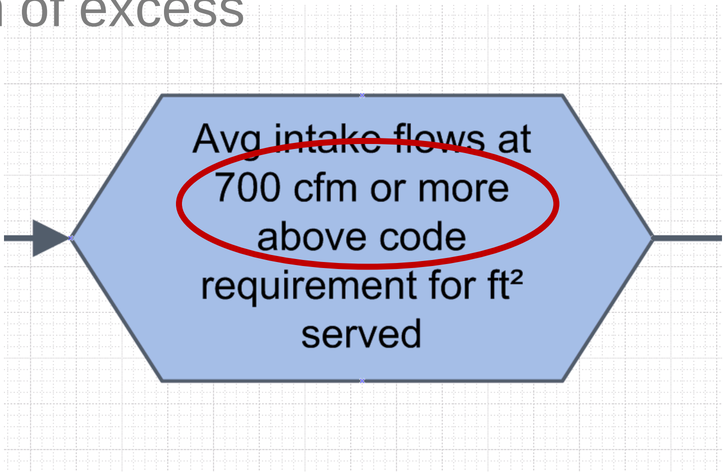
- 2 air handlers,
- 100% OA/MUA
- Ducted to hallways

EXHAUST

- 18 PRVs on rooftop
- Serve baths or kitchen inlets
  - **20 cfm bath, 25 cfm kitchen**

Example Supply screening process

1. Determine supply ventilation flow requirement
    - Matching exhaust flow per floor
        - 11 units per floor (x6 floors)
        - (20+25)* 66= 2,970 cfm required
2. Anemometer flow measurement
    - Measured flow ≈3,000 cfm per air handler = 6,000 cfm total
    - 6,000-2,970 ≈ 3,030 cfm of excess
3. Decision tree



Exhaust Ventilation Screening

Method A or Method B?

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Exhaust Screening: Method A.

“Measure inlets”

Measure inlet flow

- Measure upper floor and bottom floor flows
- Calculate average of all flows

Compare

- Does flow exceed threshold excess on decision tree?

Recommend

- “Significant energy savings available”

Exhaust Screening: Method B.

"Measure outlets"

Measure PRV flow	• Measure PRVs on roof (all or a sample of each type)
Compare	• Does flow exceed threshold airflow on decision tree?
Recommend	• "Significant energy savings available"

Exhaust screening process, Mtd. A

- Measure inlets on a sample of shafts
  - 6 bath inlets, 6 kitchen inlets
- **Check Decision Tree (Appendix 5)**

Threshold CFM excess per inlet
based on number of stories

4-6 stories = code req'ment + **25 cfm**

7-14 stories = code req'ment + **20 cfm**

15+ stories = code req'ment + **15 cfm**

	Flows	AVG	**Excess**
Bath shaft 1	30,44	37	**17**
Bath shaft 2	74, 29	52	**32**
Bath shaft 3	48, 65	57	**37**

	Flows	AVG	**Excess**
Kitchen shaft 1	16, 62	39	**14**
Kitchen shaft 2	23, 57	40	**15**
Kitchen shaft 3	44,74	59	**34**

Exhaust screen, Mtd. B

- Calculate threshold airflow
- Measure PRVs
- **Check Decision Tree (Appendix 5)**

Calculating the threshold airflow amount

Threshold airflow =
(Code required CFM)+(12 CFM per inlet served by fan)+100

Example: One fan serves a shaft with 10 inlets on it. The code requirement for the bathroom is 25cfm:
(25 cfmx10 inlets)+(12cfm x 10 inlets)+100 = 470

	# Ins	Threshd	**Meas'd**
Bath shaft 1	10	420	**809**
Bath shaft 2	10	420	**799**
Bath shaft 3	12	484	**729**

	# Ins	Threshd	**Meas'd**
Kitchen shaft 1	6	322	**325**
Kitchen shaft 2	5	285	**211**
Kitchen shaft 3	5	285	**238**

Screening disclaimer

- Recommendations are based on assumption of retrofit costs, but retrofit costs will fluctuate!

E.g.

- PRVs already have speed controls, just need flow adjustment
- VFD on make up air system just needs adjustment and flow check
- Etc.

Solution: Rough ventilation savings calculator

1 cfm reduced ≈ $1 annual energy savings

EXAMPLE

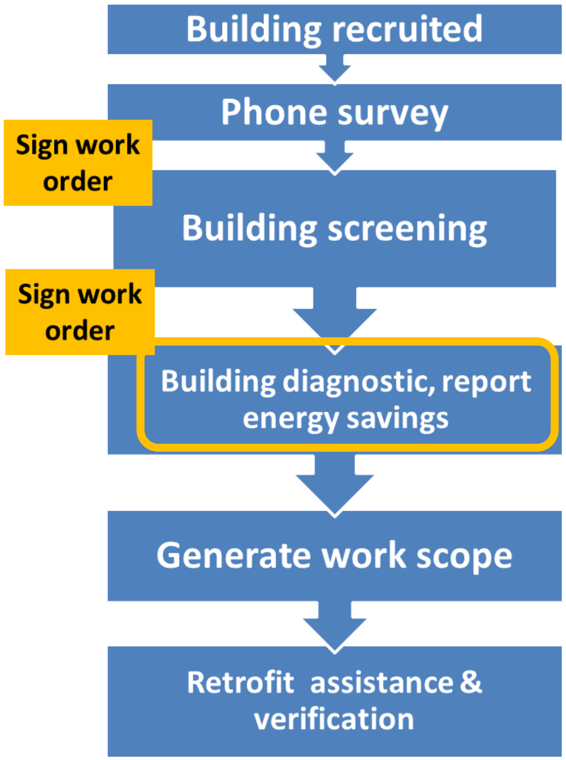
At building screen you measure approximately 1,000 cfm of savings.

- Conservative energy savings estimate is $1,000 / year
- If retrofit costs $5,000, investment yields 5 year payback

Building Diagnostics

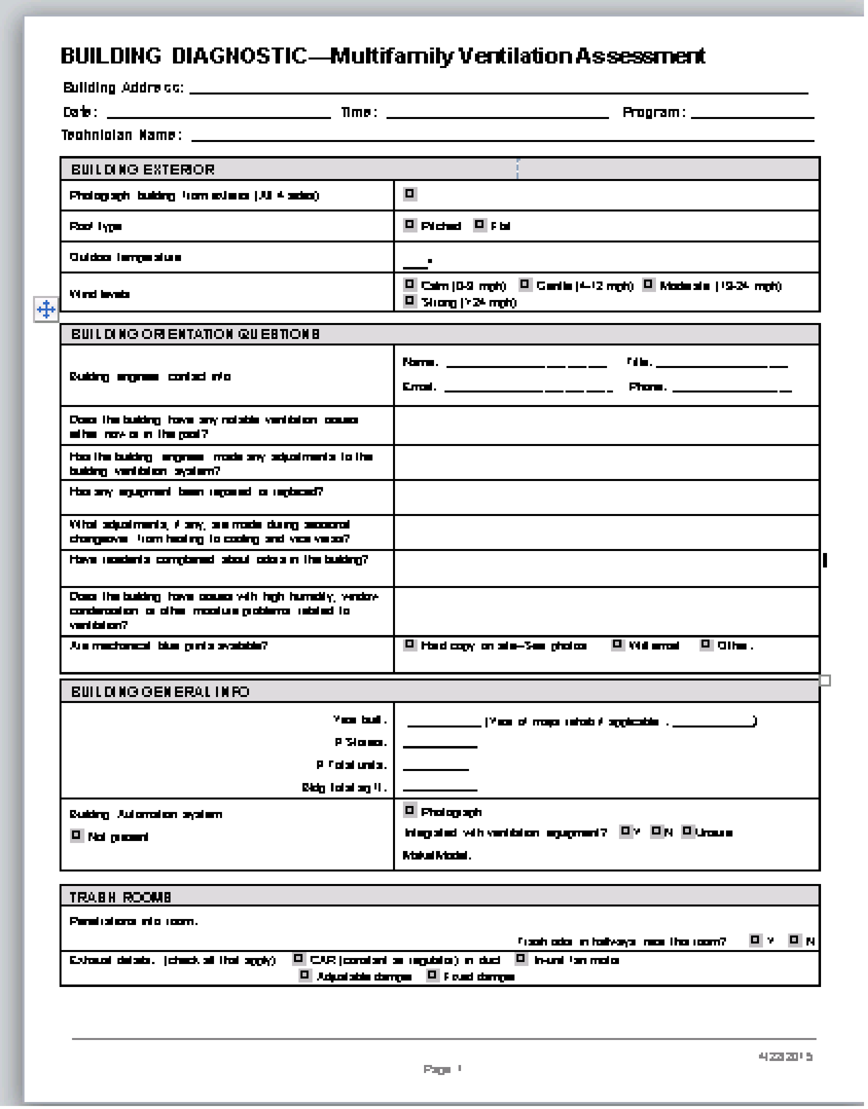
Quantifying energy savings and payback

- Determine modifications needed
- Identify any complicating factors
  - **Duct leakage**
  - **Air handler limitations**
- Generate report
- **~16 hours field, 16 hours office**



Diagnostic measurements

- Characterize duct leakage
- Airflows determine heat/cooling savings
- Estimate or measure fan power
- Identify work scope items



BUILDING DIAGNOSTIC—Multifamily Ventilation Assessment

Building Address: __________

Date: __________ Time: __________ Program: __________

Technician Name: __________

BUILDING EXTERIOR

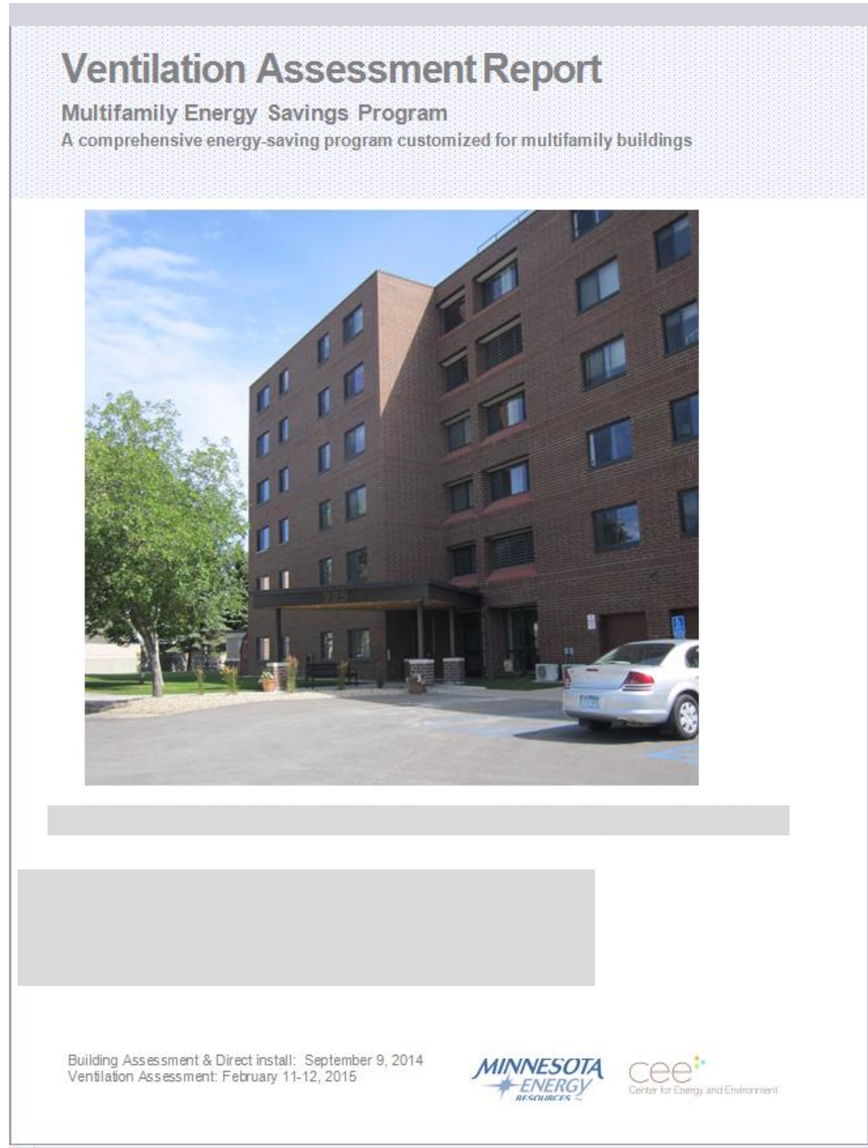
BUILDING ORIENTATION QUESTIONS

BUILDING GENERAL INFO

TRASH ROOMS

Assessment Report

- Quantifies energy savings in dollars
- Identifies which systems are over-ventilating and why
- Estimates cost of retrofit, payback


Ventilation Assessment Report

Multifamily Energy Savings Program

A comprehensive energy-saving program customized for multifamily buildings

Building Assessment & Direct install: September 9, 2014
Ventilation Assessment: February 11-12, 2015

MINNESOTA ENERGY RESOURCES

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Retrofit work scope

Goal: *Clear description of project details*

- Specifies target flow rates, shaft pressures
- Replacement fan size
- Orifice size for exhaust inlets
- Duct sealing of any accessible joints (at curb and inlet)
- Verification measures

Calculating target flow rate

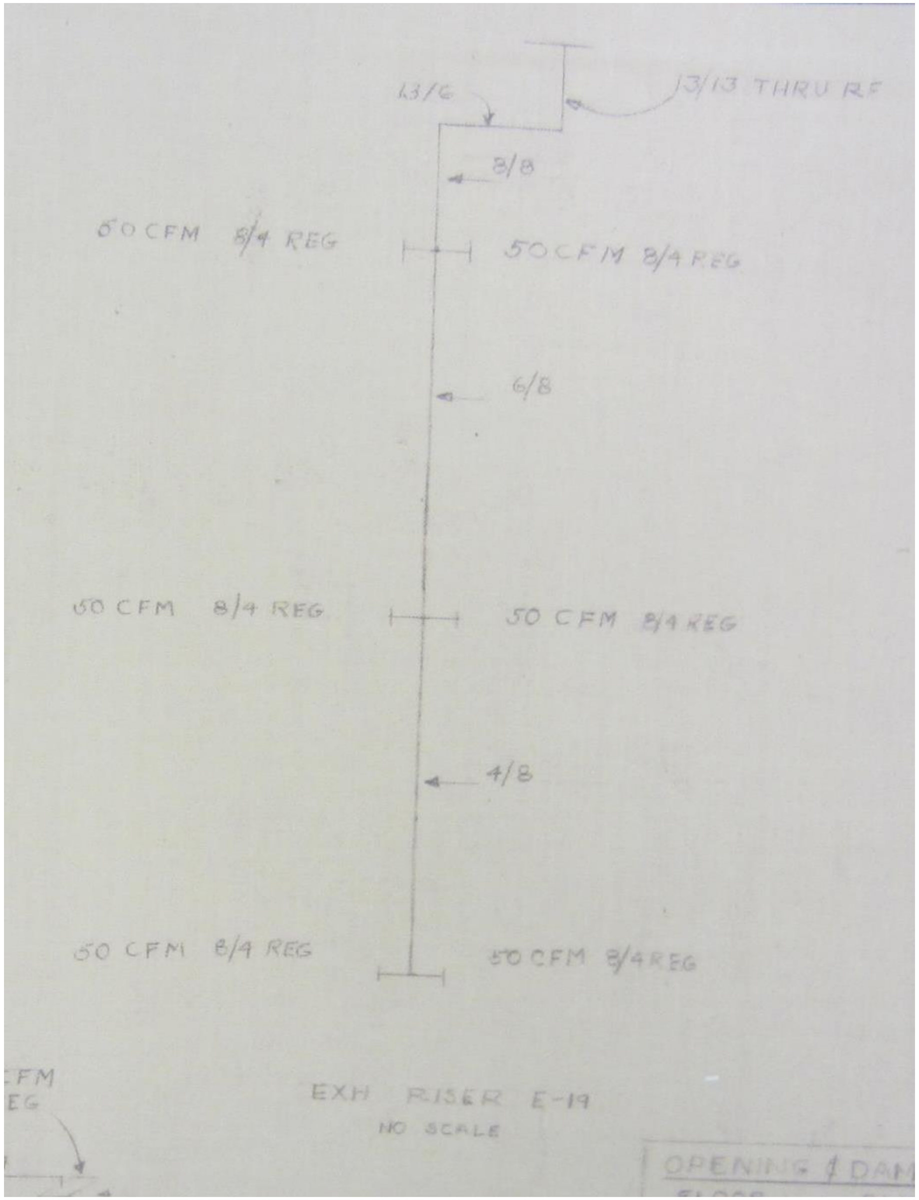
EXHAUST

- What is the flow requirement for each inlet?
- How many inlets are on each shaft?

SUPPLY

- Match exhaust
- May have to address specific areas with designated flow (e.g. trash rooms, hair stylist, community rooms)
  - What is the area type the system serves?
  - How many square feet of each area type?

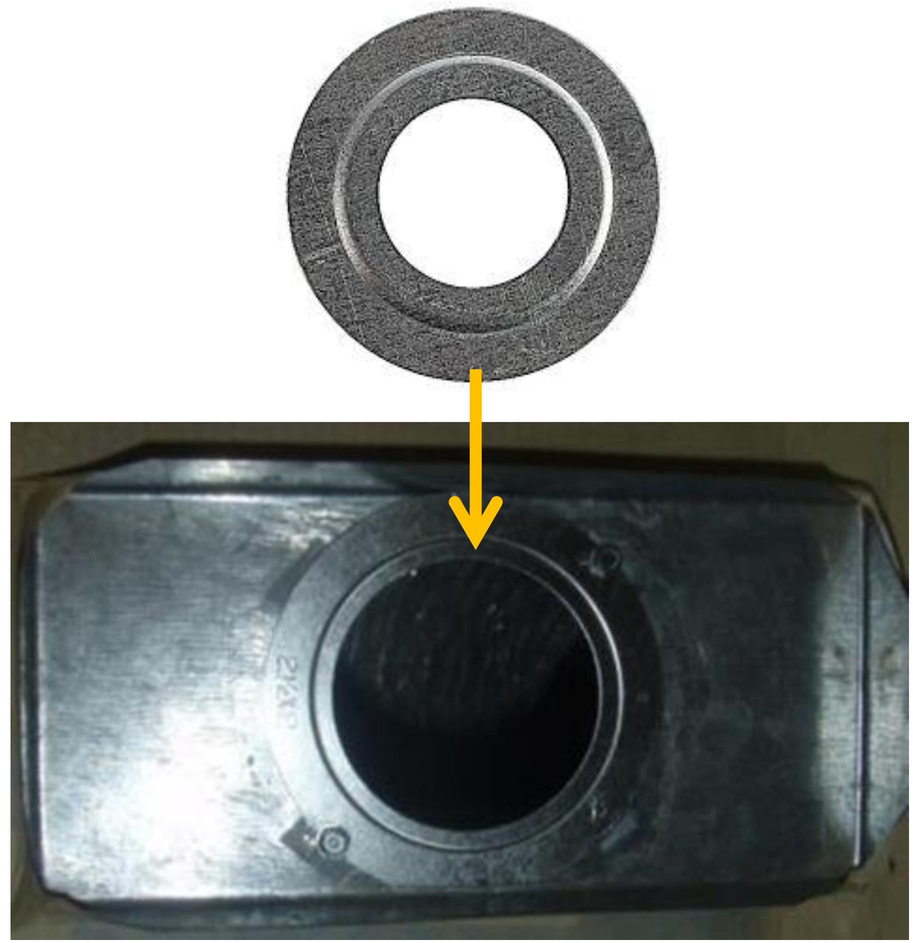
Shaft configuration and square footage on blue prints



Determining orifice size

- What are the number of stories the building has?
- What is your target inlet airflow rate?
- Custom stamped or pre-fabricated washers?

Orifices: Custom stamped or pre-fab washers



Orifice size chart – custom stamped orifice

Pg. 52-53

Table 6. Custom orifice sizes for common apartment inlet flows

# Stories	Shaft Pressure	Orifice Area (sq in)			Round Orifice Diameter (in)		
	(Pa)	Bath (20cfm)	Kitchen (25cfm)	35cfm	Bath (20cfm)	Kitchen (25cfm)	35cfm
1 to 5	25	3.33	4.17	5.83	2.06	2.30	2.73
6 to 10	35	2.97	3.52	4.93	1.94	2.12	2.51
10+	45	2.62	3.27	4.35	1.82	2.04	2.35

Orifice size chart if using pre-fabricated nominal washer sizes Pg. 52-53

# Stories	Bathroom (20 cfm)		Kitchen (25 cfm)		35 cfm	
	Orifice*	Shaft Press (Pa)	Orifice	Shaft Press (Pa)	Orifice	Shaft Press (Pa)
1 to 5	1.5"	32	2"	20	2"	38
6 to 10	1.5"	32	1.5"	50	2"	38
10+	1.25"	48	1.5"	50	2"	38

Example: 6 story building

- 20 cfm bath, 25 cfm kitchen

# Stories	Bathroom (20 cfm)		Kitchen (25 cfm)		35 cfm	
	Orifice*	Shaft Press (Pa)	Orifice	Shaft Press (Pa)	Orifice	Shaft Press (Pa)
1 to 5	1.5"	32	2"	20	2"	38
6 to 10	1.5"	32	1.5"	50	2"	38
10+	1.25"	48	1.5"	50	2"	38

Sizing the replacement fan

- PRV specs

Direct Drive	Motor HP	Fan RPM		Static Pressure in Inches wg									
				0	0.05	0.1	0.125	0.15	0.2	0.25	0.3	0.375	0.4
070													
VG-1/6 VARI GREEN	E-1/100	1050	CFM	253	226	195	179	152					
			BHP	0.01	0.01	0.01	0.01	0.01					
			Sones	2.7	2.1	1.7	1.5	1.2					
	G-1/60	1300	CFM	314	292	269	257	244	214	171			
			BHP	0.01	0.01	0.02	0.02	0.02	0.02	0.02			
			Sones	4.1	3.7	3.4	3.3	3.2	2.9	2.6			
	D-1/30	1550	CFM	374	356	337	327	317	297	274	244	190	
			BHP	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	
			Sones	5.6	5.4	5.2	5.1	5.1	4.9	4.7	4.5	4.1	
		1725	CFM	416	400	383	375	366	348	329	309	270	253
			BHP	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04
			Sones	6.8	6.7	6.7	6.6	6.6	6.5	6.3	6.2	5.9	5.7
075													
VG-1/6 VARI GREEN	E-1/80	1050	CFM	297	260	222	200	176					
			BHP	0.01	0.01	0.01	0.01	0.01					
			Sones	3.6	3.1	2.9	2.8	2.6					
	G-1/50	1300	CFM	367	338	309	293	277	241	195			
			BHP	0.02	0.02	0.02	0.02	0.02	0.02	0.02			
			Sones	4.1	3.9	3.7	3.7	3.7	3.6	3.5			
	D-1/25	1550	CFM	438	413	389	377	364	337	309	277	214	
			BHP	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.03	
			Sones	6.1	5.8	5.6	5.4	5.3	5.1	4.9	4.9	4.8	
		1725	CFM	487	465	443	432	421	399	374	349	306	292
			BHP	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
			Sones	8.0	7.5	7.2	7.1	6.8	6.5	6.2	6.1	6.0	6.0

Work scope examples in *Ventilation Assessment & Retrofit Guide* Appendix

Scope to include the following:

Reduce airflow on make up air handling unit

- Adjust the pulley of MAU as necessary to achieve the flow rate listed below for MAU.

MAU Information	
Motor Size	7.5hp [Fig 1], Motor plate is adjustable [Fig 2]
Motor Power (measured)	2.2kW
Driver Pulley [Fig 3]	Ø 5.75in., 1.375in. shaft, 1771 RPM
Driven Pulley [Fig 4]	Ø 15in., 2.125in. shaft, 562 RPM
Belt	2 Belts, V-Belt B85 (5L880)
Current Flow	11,745 cfm
Proposed Flow	**6,909 cfm**

Locale information
The MAU is located in the mechanical room in the basement of the building. The OA intake is 7ft by 9ft and located in the outdoor stairwell from grade to basement. The unit is suspended from the ceiling, but accessible with the use of a ladder.

Access Information
The facility is open for the contractor between 8am and 4pm Monday through Friday. All access should be scheduled with the owner. All work can be done during normal business hours.

Other retrofit assistance measures

- Provide contractor referrals
- Conduct contractor walk-throughs
- Assist with custom rebate submission
- Provide clear descriptions of process to building owner
- Commission one exhaust shaft before work proceeds on remaining shafts

Commissioning & Verification

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Supply system commissioning / verification

- Verify airflow is within +/- 20% of target
  - Test and Balance contractor responsible for retrofit can conduct these measurements
  - Commissioning report should be provided to building owner

Exhaust retrofit commissioning / verification

- Verify correct fan model
- Check for proper orifice install on sample of inlets
- Commission airflow on 2 of each type of shaft
  1. Adjust shaft to target pressure
  2. Check inlet flow at near/far inlets to confirm within +/-15%
  3. Adjust fan as necessary
  4. Measure PRV flow after adjustment
     - If >120% of flow target, recommend investigating duct sealing opportunities

Duct sealing opportunities

Other verification / commissioning measures

- Check trash chute
  - Air seal to rest of building?
  - Trash room doors shut?
  - Cap restricting flow?
- Document flow changes and communicate project outcomes to all parties
  - Maintenance / management staff
  - Building owner

Summary Quiz

- When determining the orifice size to install at exhaust inlets, what are the 3 details you will need to specify the correct orifice size?
- What is a very basic rule of thumb for the energy cost of ventilation per cfm?
- What guide can be used to determine whether a ventilation system is over-ventilating enough to make retrofitting the system cost-effective?
- What are 2 methods of addressing duct leakage?
- Commissioned airflow should be within ______% of target flow rates.

PRACTICE

- Determining airflow target
- Measuring airflow
- Post-retrofit airflow commissioning

STATION 1: Measuring airflow

- Determine target airflow
- Practice measuring airflow
  - **Supply OA intake**
  - **Exhaust PRV**
- Screening decision tree

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STATION 2: Commissioning

- Set shaft target pressure
- Adjust until inlet airflow target is met but not exceeded
  - Bath 20cfm +/-15%

  = 17-23 cfm

# Stories	Bathroom (20 cfm)		Kitchen (25 cfm)		35 cfm	
	Orifice*	Shaft Press (Pa)	Orifice	Shaft Press (Pa)	Orifice	Shaft Press (Pa)
1 to 5	1.5"	32	2"	20	2"	38
6 to 10	1.5"	32	1.5"	50	2"	38
10+	1.25"	48	1.5"	50	2"	38

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PRACTICE STATIONS

Exhaust Retrofit Commissioning

- Fixed Orifices VS. CAR II
- Effects of duct leakage

Screening Airflow Measurements

- Supply and exhaust airflow measurements
- Calculating design flow and threshold flow

Final Quiz

- Ventilation requirement for most apartment units under 1,000ft²?
- Why is airflow commissioning important?
- What is the most efficient and accurate method for measuring exhaust PRV airflow?
- Where can you find all of the information presented today (in written form)?
- What is one method for reducing PRV exhaust ventilation flow?
- What is one method for reducing supply ventilation flow?

THANK *you!*

Questions?

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