Ventilation in Multifamily Buildings

Welcome to the Webinar! We will start at 2:00 PM Eastern Time

Be sure that you are also dialed into the telephone conference call:

Dial-in number: 888-324-9601; Pass code: 5551971

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Date: November 1, 2011

Building America U.S. Department of Energy

Building America: Introduction

November 1, 2011

Cheryn Engebrecht
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Building AMERICA U.S. Department of Energy

- Reduce energy use in new and existing residential buildings
- Promote building science and systems engineering / integration approach
- "Do no harm": Ensure safety, health and durability are maintained or improved
- Accelerate adoption of high performance technologies

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15 Industry Research Teams

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

CARB – Consortium for Advanced Residential Buildings

Alliance for Residential Building Innovation (ARBI)

BA-PIRC

IBACOS | Home Quality + Performance |

NAHB Research Center

NorthernSTAR Building America Partnership

BIRA – Building Industry Research Alliance ...a catalyst for change

Building America Retrofit Alliance (BARA)

bsc Building Science Corporation

Fraunhofer USA

ARIES Collaborative

Dow Building Solutions

Habitat Cost Effective Energy Retrofit Program

PARR – The Partnership for Advanced Residential Retrofit

N.E.L.C. The National Energy Leadership Corps

Building Energy Efficient Homes for America (BeeHa)

Today's Speakers

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Maureen Mahle is an engineer with Steven Winter Associates, Inc. where she manages the firm's work with projects seeking certification under LEED® for Homes, Green Communities, the National Green Building Standard, and ENERGY STAR® for both single family homes and multifamily buildings. Much of her work focuses on balancing objectives for indoor air quality and energy efficiency.

Sean Maxwell is a Senior Energy Consultant with Steven Winter Associates, Inc. where he provides energy audits for large and small residential buildings. He has extensive experience in performance testing of ventilation and other building systems. He also participates in research activities on emerging high-performance building strategies.

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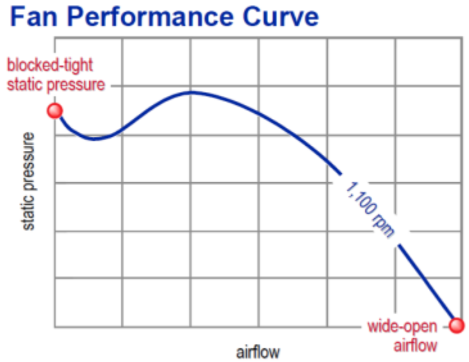
Multifamily Ventilation

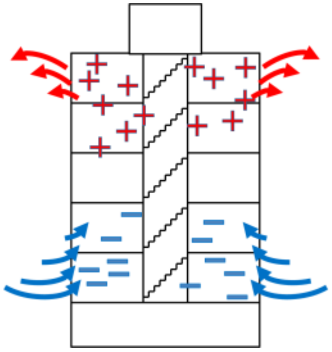
Maureen Mahle and Sean Maxwell

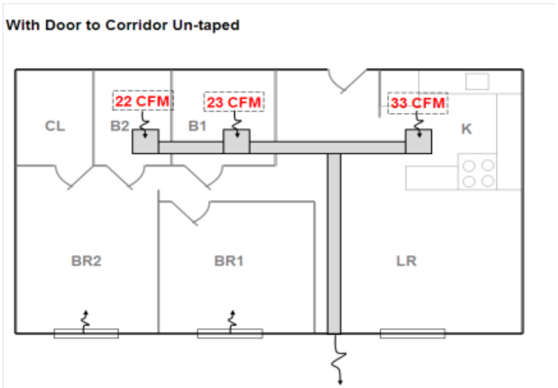
November 1, 2011

Today's Discussion

- Part I: Multifamily Ventilation Design







- Part II: Multifamily Ventilation Implementation

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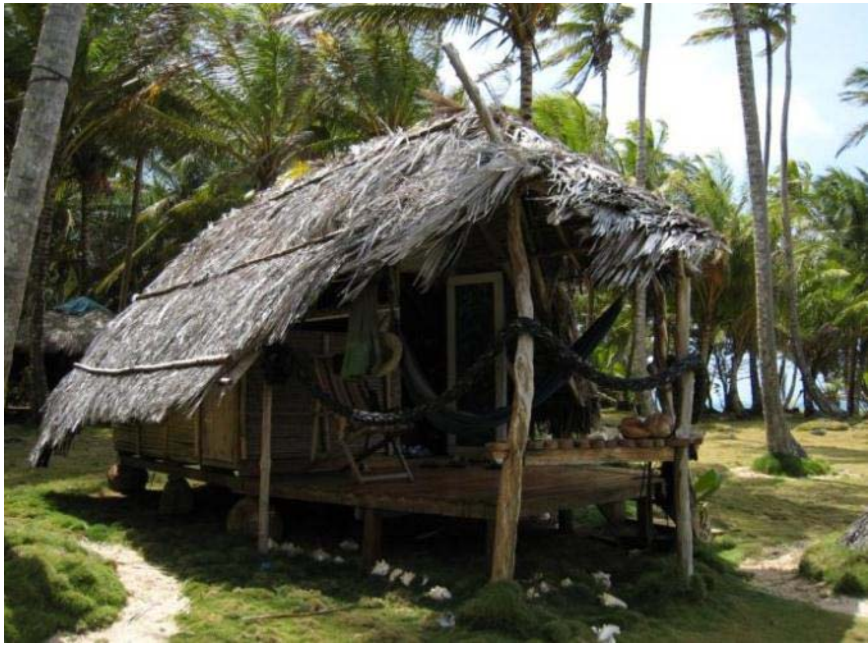
Part I: Ventilation Design

- Ventilation Requirements
- Air Movement in Multifamily Buildings
- Fresh Air Ventilation Strategies
- Local Exhaust Strategies
- Energy Impacts of Ventilation

Why Ventilate?

- Materials have changed
- Siting has changed
- Tightness has changed
- Codes and standards



Build-tight-ventilate-right saves more energy than building naturally leaky buildings, and air quality is better, too

Two Primary Objectives

1) Providing Fresh Air - *Whole-House*

2) Removing Pollutants - *Local Exhaust*

Our goal is to find the simplest solution that satisfies both objectives while minimizing cost and energy impacts.

ASHRAE 62.2 Ventilation & IAQ

- Low-Rise Residential
- Fresh Air (Section 4)

  *Q = .01*S.F. + 7.5*(#BR+1)*
- Local exhaust (Section 5)

  K = 100cfm int /5ACH cont

  B = 50 cfm int / 20 cfm cont
- Windows do not count
- <u>Best for Multifamily in-unit spaces</u> regardless of building height

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ASHRAE 62.1 Ventilation for IAQ

- MF 4+ stories
- Fresh Air (Table 6-1)

  5cfm/person + 0.6cfm/SF
- Local exhaust (Table 6-4)

  K = 100cfm int /50 cfm cont

  B = 50 cfm int / 25 cfm cont
- Kitchen exhaust not req'd for MF
- Windows count for 25' deep units
- <u>Best for MF common areas</u> regardless of height

Venting Challenges in Multifamily

- Forces acting on building (wind, stack effect) are much greater in multifamily buildings than other residential buildings
- Control of air movement is crucial!
  - Defining air barriers (pressure boundaries)
  - Tightening up mechanical systems to control flow of air

Fans as System Components

Question:

How much air does a one horsepower fan move?

Answer:

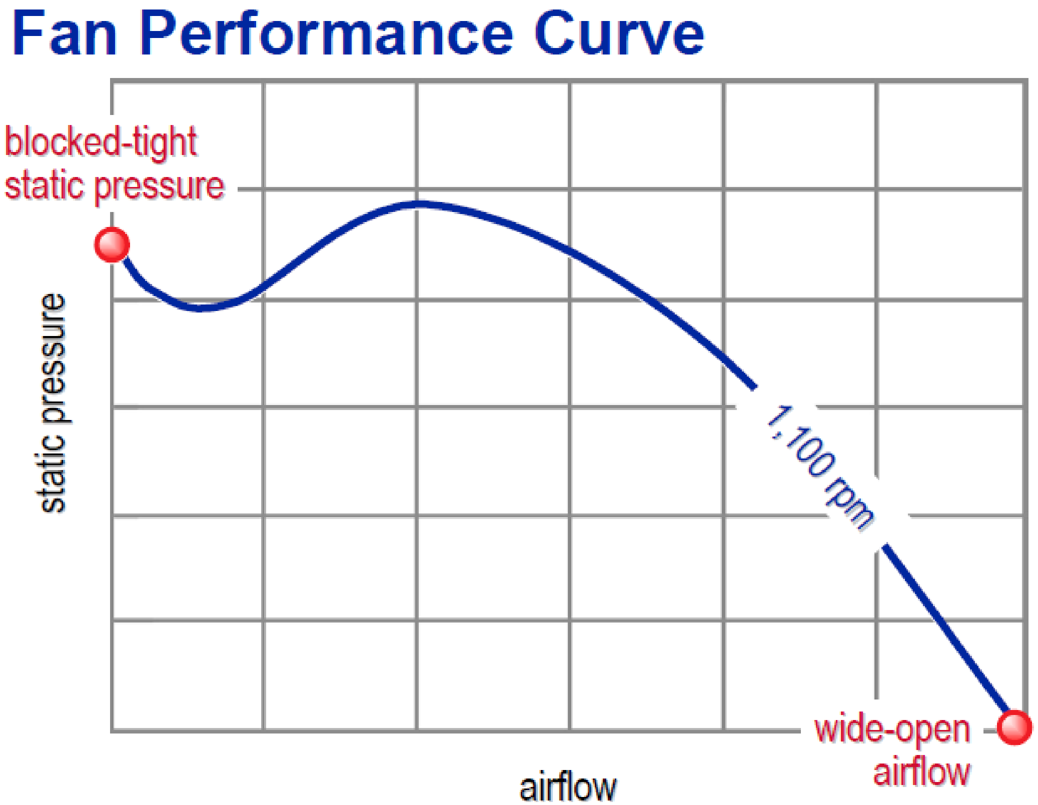
It depends!

Fans as System Components

- Fan performance dependent on rest of system

- Higher static pressure = lower flow

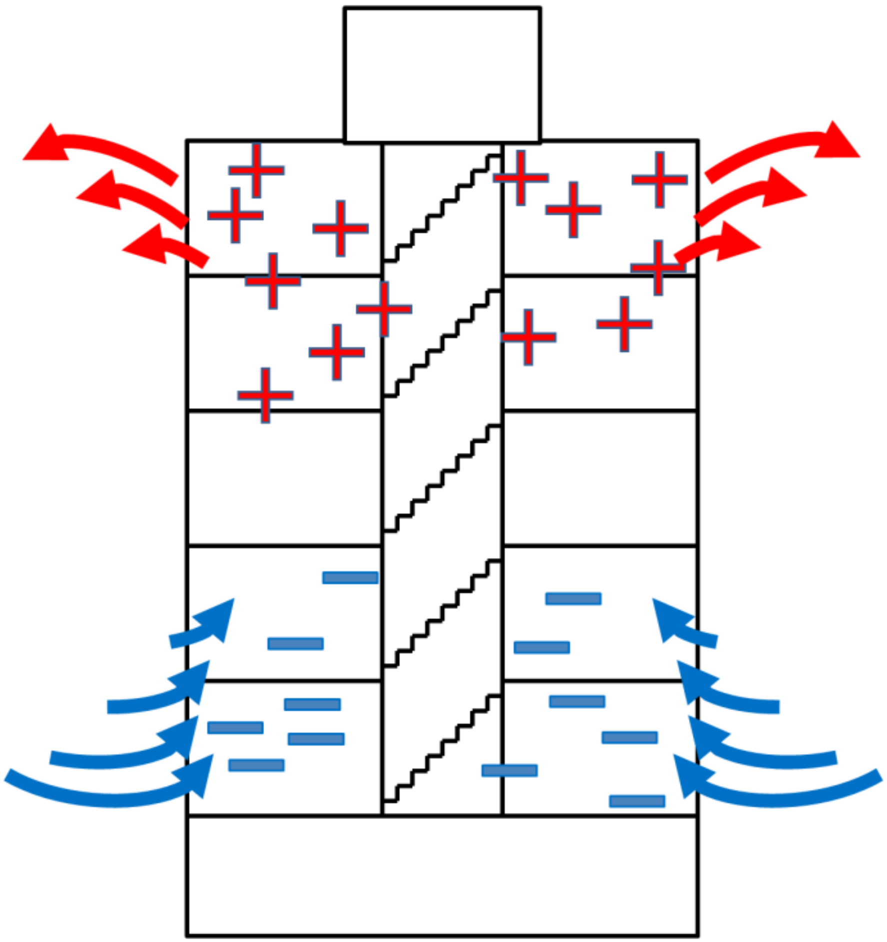
- Fans = “pressure inducers”



Graphic courtesy of Trane

Forces at Play

- Other forces at play:
  - Wind
  - Stack effect
- Pressure difference due to stack effect can be large
  - >5 Pascals per floor on cold days
  - 10 story building = 50 Pa total



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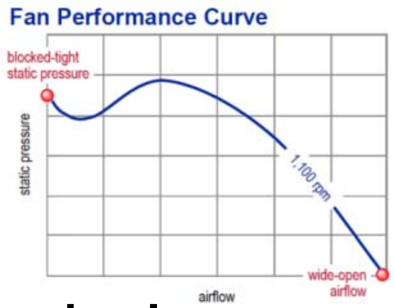
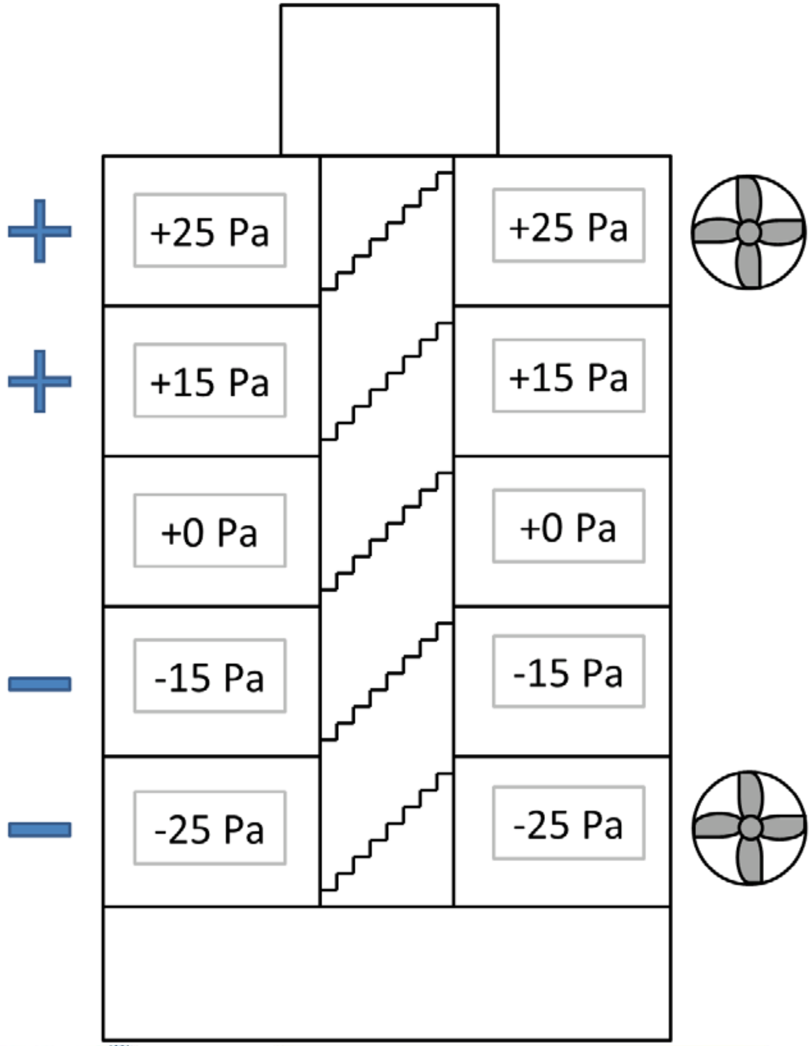
Stack Effect

- Different fan locations = different flows



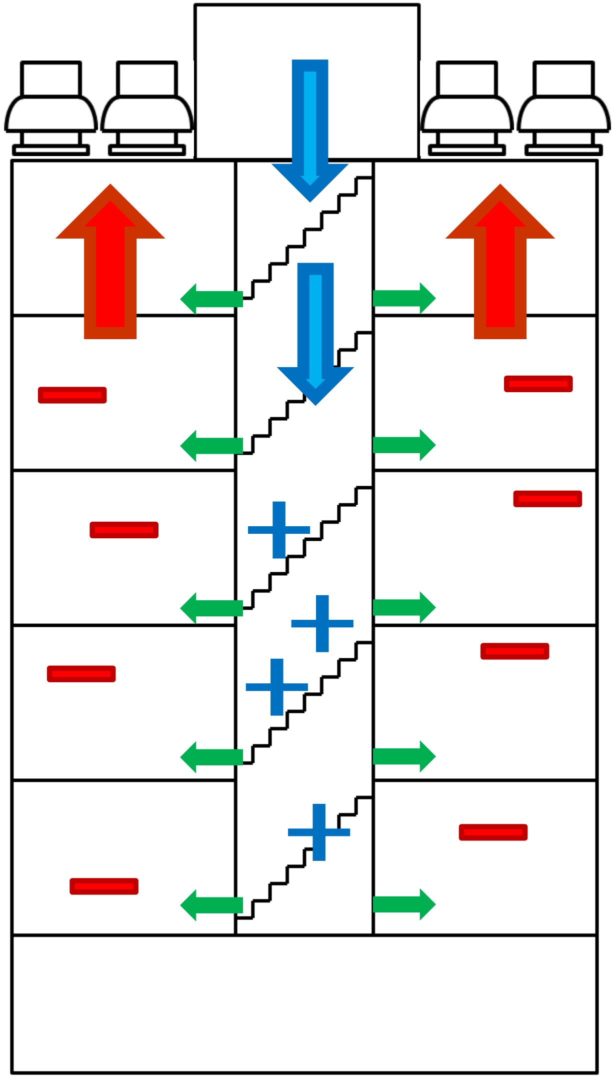
- Large fans for whole building must overcome stack effect
- Small fans for individual units must each overcome local pressure differences



Systems View of Ventilation

- Systems interact with each other: *Positive and negative pressure zones produce inter-zonal flows*

- Systems interact with air barriers: *Good ventilation systems take advantage of good air barriers*



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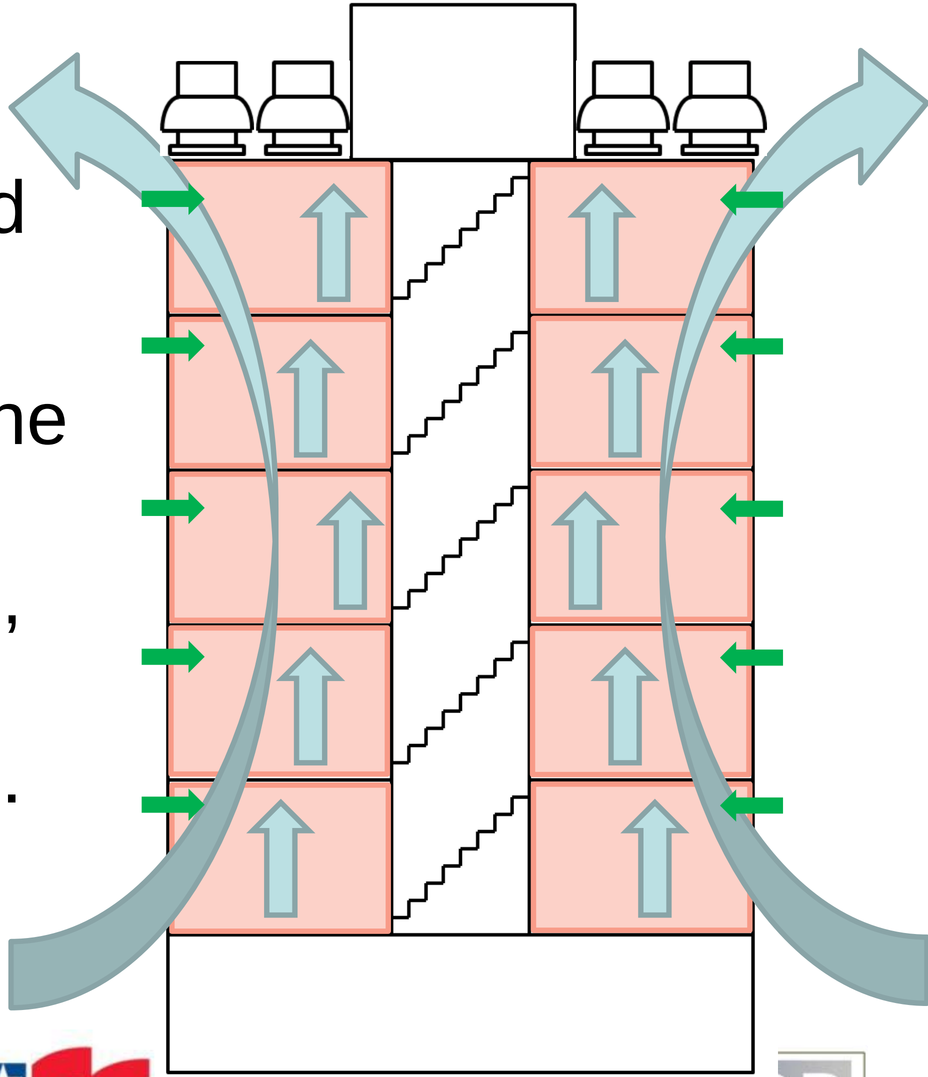
Systems View of Ventilation

- Tight construction both requires and allows good ventilation
- Compartmentalization, the construction of airtight individual compartments, breaks big forces (stack, wind) into smaller forces. It's also important for unitized ventilation.

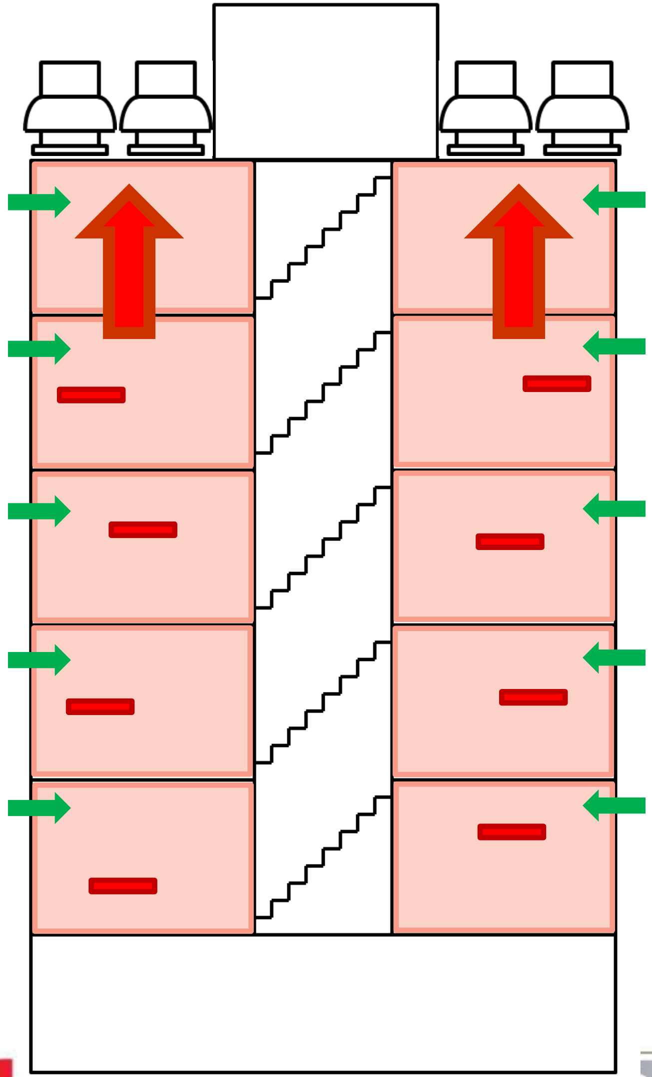


Fresh Air Strategies

- **Exhaust-driven** fresh air ventilation, with or without makeup air
- **Supply-driven** fresh air
- Balanced fresh air and exhaust with **heat or energy recovery**

Exhaust-Driven Fresh Air Design

- Exhaust slightly depressurizes the units
- Outside air enters through leaks, cracks, or planned inlets (trickle vent, not undercut)
- Widely used in the North



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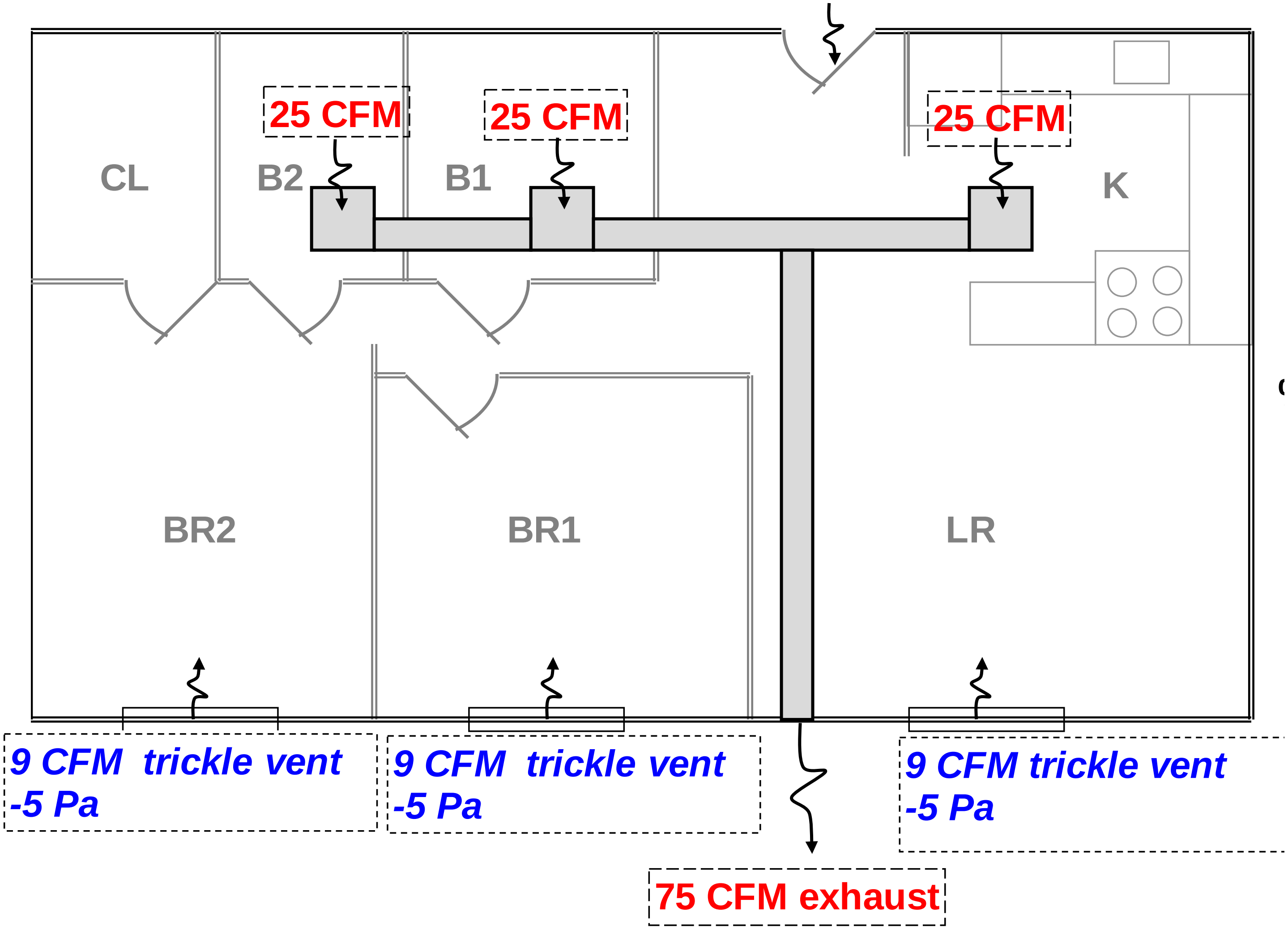
Exhaust-Driven Fresh Air Design



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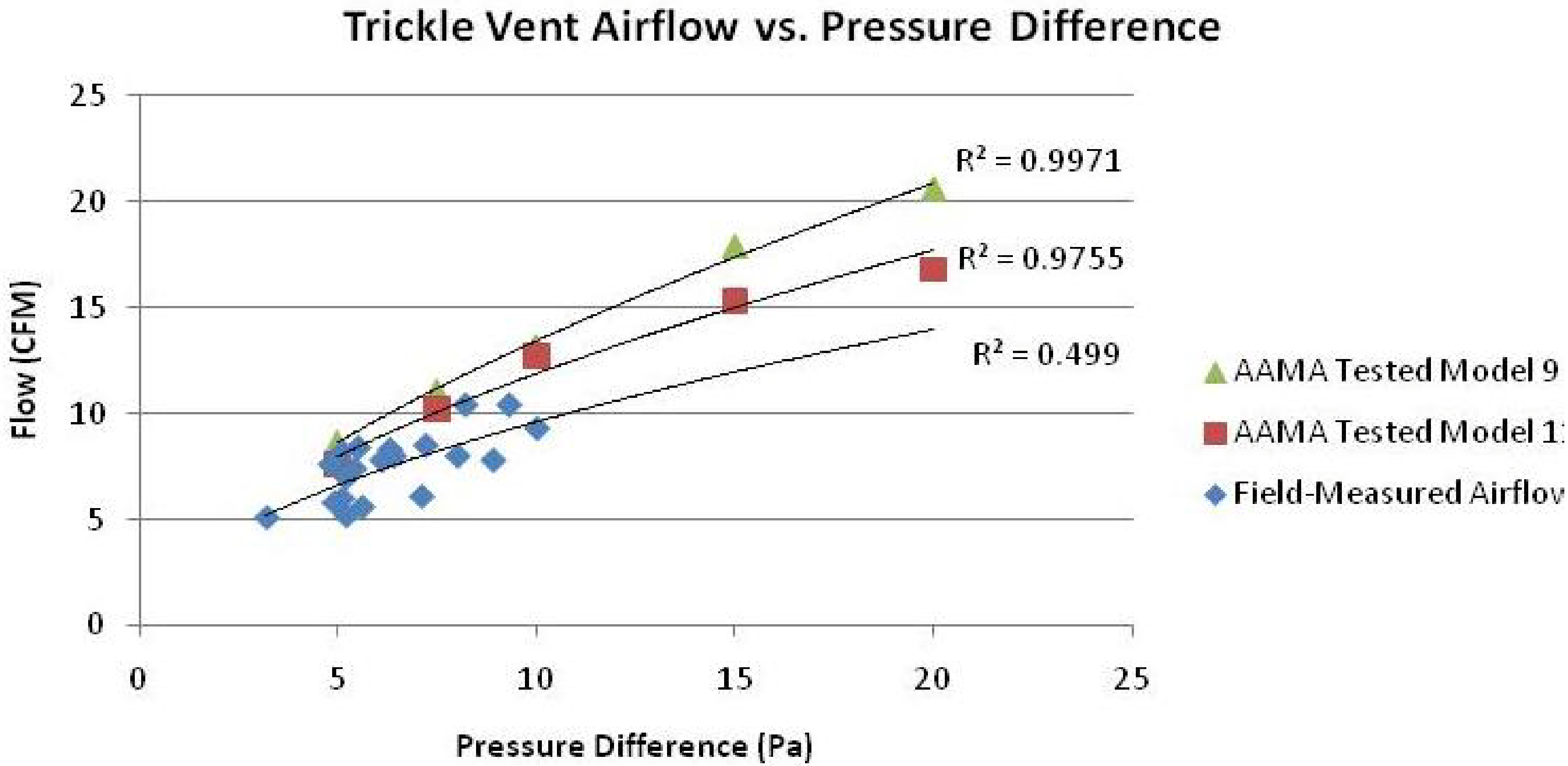
Designed Inlets for Exhaust-Driven

- Intentional openings in building envelope that allow a trickle of air into buildings in response to pressure differential
- Trickle Vents often built into window frames (AL,FG)
- Comfortable and effective when located high
- Good practice for 4+ stories

Trickle Vents

A real-world application of 4 in ^{2} trickle vents



AAMA = American Architectural Manufacturers Association

Energy Impacts from Exhaust-Driven

- Align Local Exhaust with Fresh Air requirements for best efficiency *(Ex: 25 Bath + 25 Kitchen)*
- Continuous OR timer
- Adjustable fans rated for continuous use are best
- Quiet fans <= 1 sone
- ENERGY STAR fans 40-60 cfm, 6-10 watts

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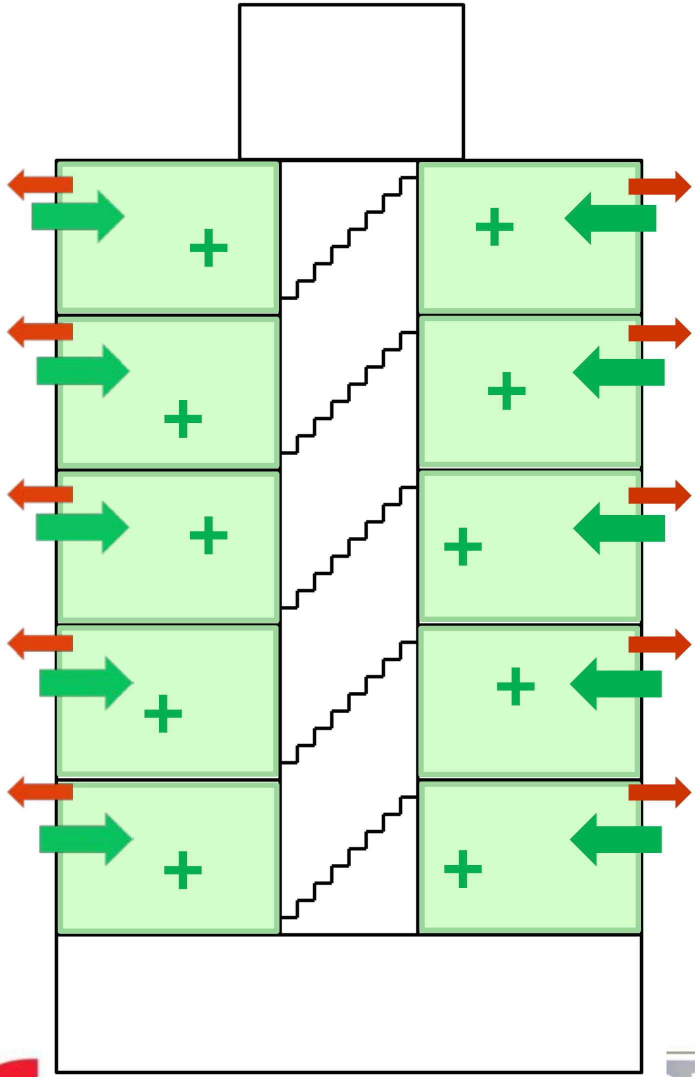
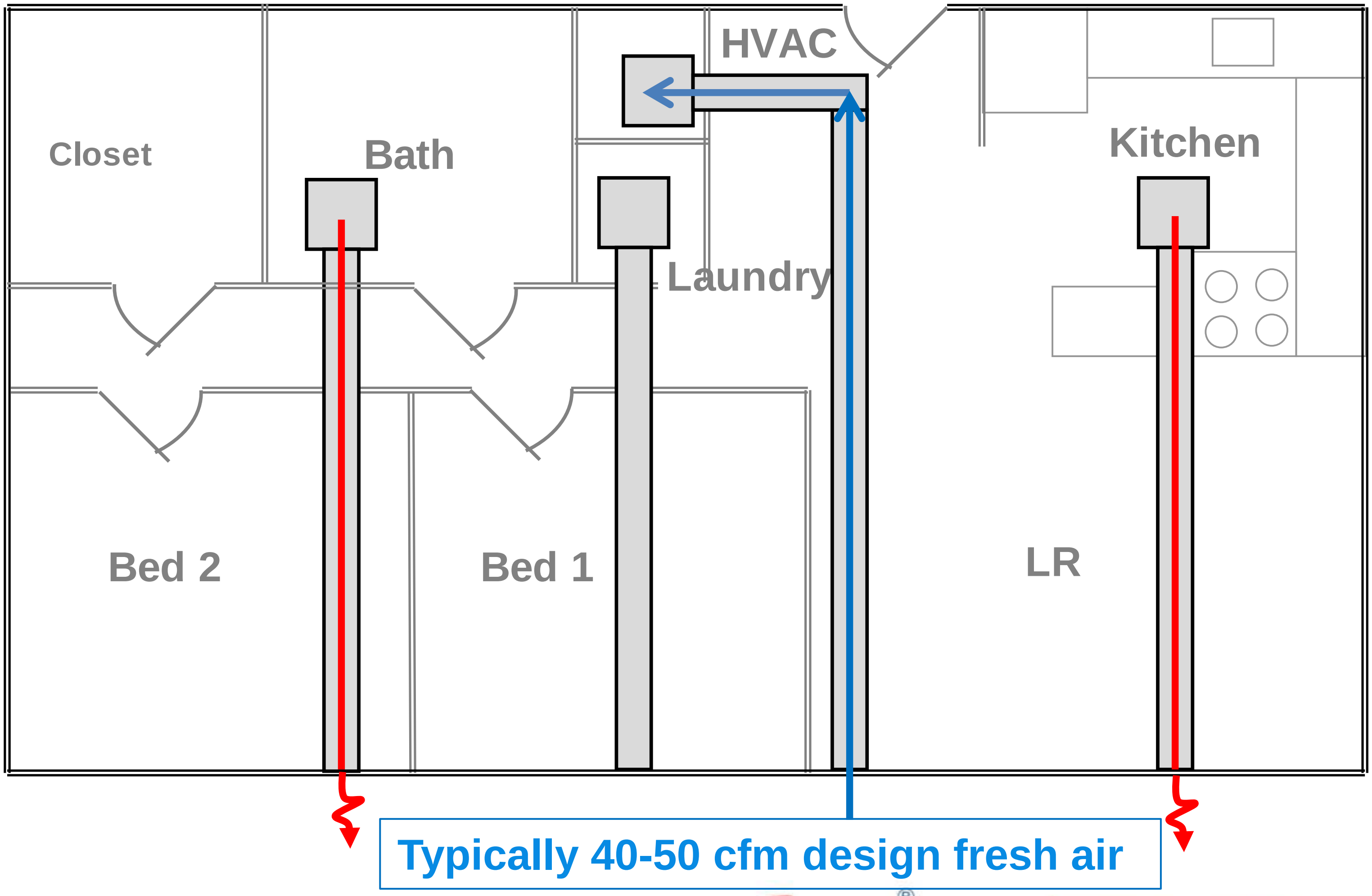
Supply-Driven Fresh Air Design

- Mechanically supplied fresh air slightly positively pressurizes the units
- Forces stale air out through leaks and cracks
- Typically a 4-6” fresh air duct to return ductwork
- Used in Moderate and Southern climate



Supply-Driven Fresh Air Design



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Energy Impacts from Supply-Driven

- Draws fresh air when air handler runs; add a control with timer + damper to trigger fresh intake periodically
- Air handler fans are large, so need efficient VFD to avoid energy penalty with this strategy

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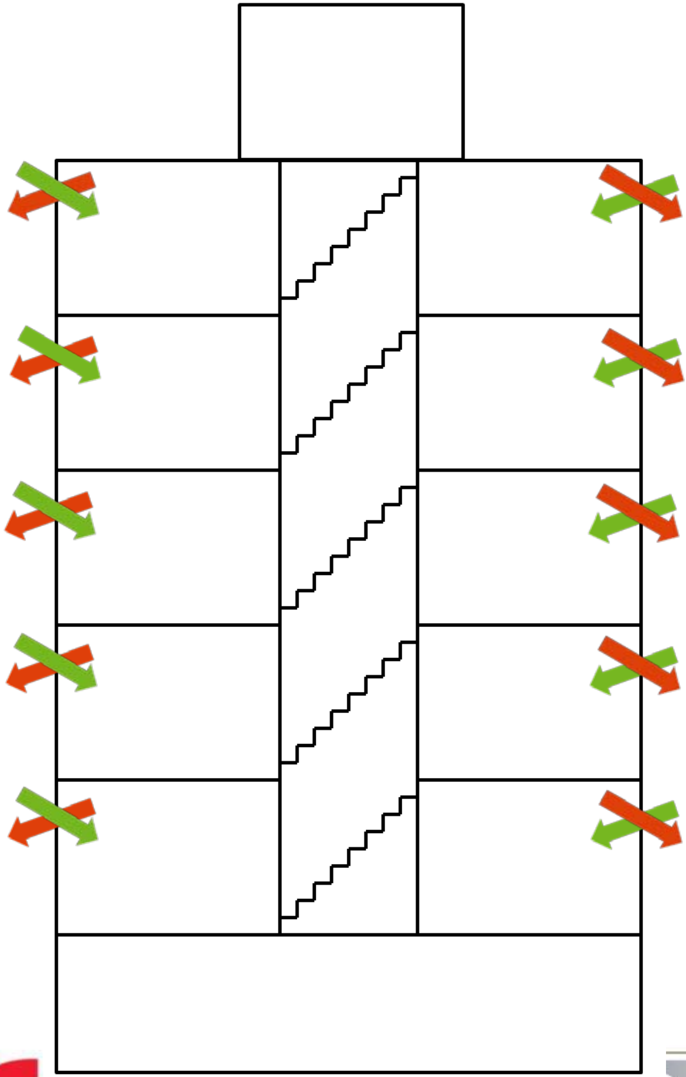
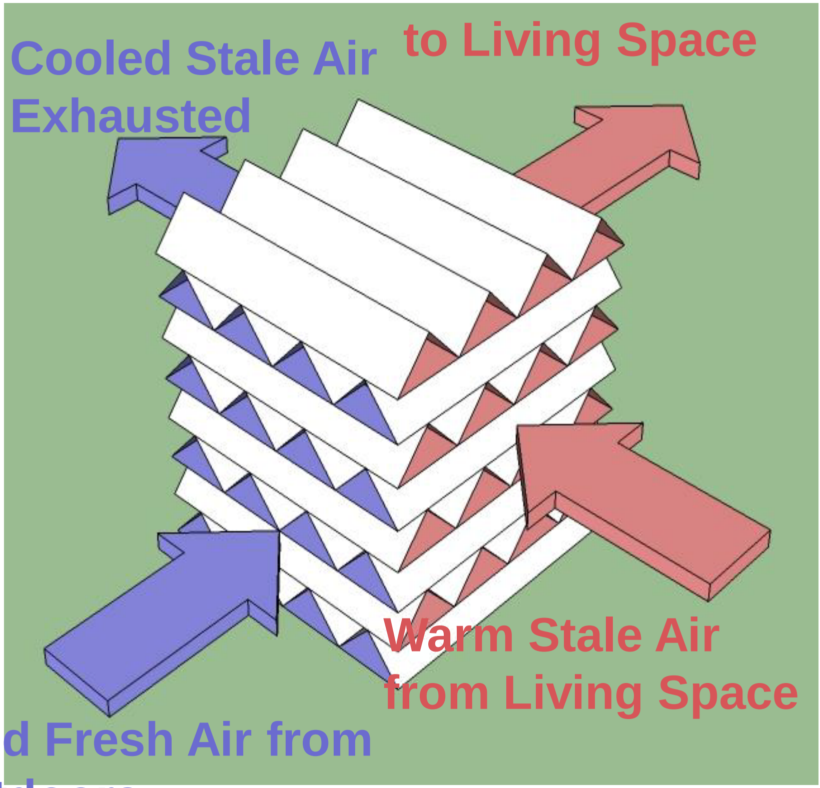
Balanced Fresh Air Ventilation

- Transfer heat between indoor and outdoor air
- Neither pressurizes nor depressurizes
- Potential solutions for many climate zones



Heat Recovery Ventilation

- Warms incoming winter air (or the reverse)
- Good to remove humidity
- Good for favorable humidity levels in & out



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Energy Recovery Ventilation

- Transfers heat **and moisture** between indoor and outdoor air
- Moisture moves from more moist air to less
- Latent energy transfer adds 30%+ efficiency
- Good for cold dry AND hot humid conditions

Energy Impacts of Balanced Design

- For best IAQ, avoid using bath exhaust
- Most efficient with small, separate ducts
- Central ERV systems serving multiple units are challenging to isolate
- Costly, so correct design and install is crucial

Local Exhaust

- Remove pollutants and moisture
- Kitchens and bathrooms vented to outdoors
- Continuous exhaust
- Intermittent exhaust
- MF Central Systems
- MF Unitized Approach

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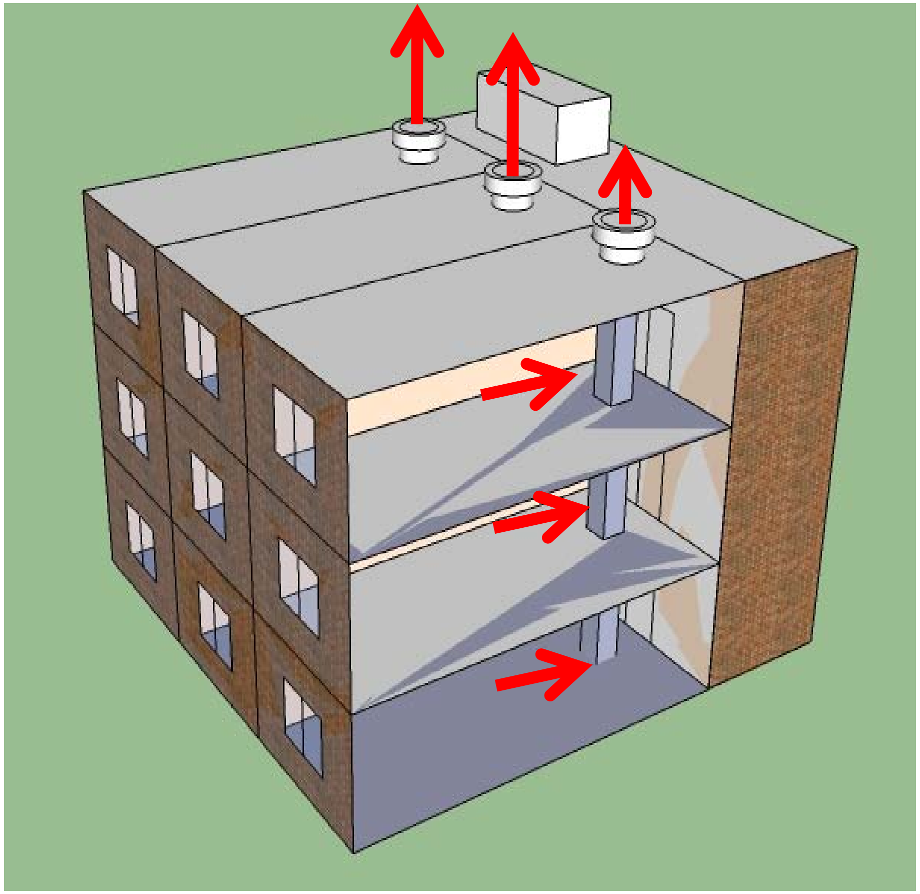
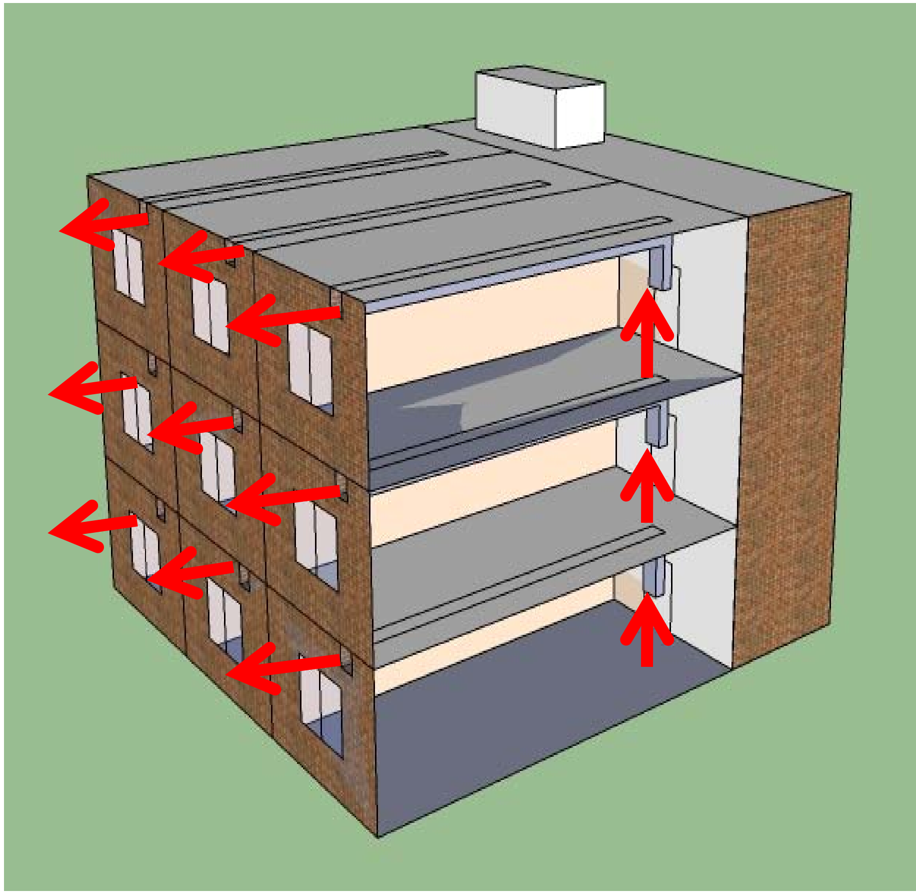
Exhaust: Central or Unitized?

Central Exhaust



Unitized Exhaust



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Exhaust System Design Parameters

<u>Central Systems</u>

- Constant Air Regulating (CAR) dampers to balance flows
- Airtight ductwork, including fan and grille connections
- Tightly compartmentalized units

<u>Unitized Systems</u>

- ENERGY STAR fans with variable speed where appropriate
- Short straight duct runs
- Tightly sealed ducts
- Tightly compartmentalized units

Continuous vs. Intermittent Exhaust

Continuous

- Bathrooms 20-30 cfm
- Kitchens 5 ACH
- Match whole-house flow rates for Exhaust Only
- Boost flow for localized humidity or pollutants
- Timed options acceptable

Intermittent

- User demand controlled
- Bathrooms 50-80 cfm
- Kitchens 100cfm
- Vented range hood removes pollutants closer to source
- Distinct from whole-house

Energy Impacts of Ventilation

Ventilation means additional air must be conditioned.

Specific heat of air (constant)

Yearly heating degree-days

$$Cost = CFM \times 1.08 \times HDD \times 24\ hr \times \frac{1}{\text{heating system eff.}} \times \text{infiltration factor} \times \frac{cost}{Btu}$$

Seasonal heating system efficiency (%)

Approximate change in infiltration due to exhaust (use 0.7 for central exhaust systems)

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Sample Calculation

Annual Cost of Ventilation

$$Cost = 23{,}000\ CFM \times 1.08 \times 4500 \times 24 \times \frac{1}{0.70} \times 0.7 \times \frac{\$1.30}{100{,}00\ Btu}$$

23,000 CFM = $34,390/yr

(heating cost only)

+ Electricity savings from reduced fan energy and reduced cooling

Specify & Verify Performance

- Write performance-based specifications for apartment tightness and duct tightness, based on ASHRAE, LEED, ENERGY STAR, etc.
  - *Total duct leakage <6 cfm25 per 100 SF floor area*
  - *Total unit infiltration leakage <0.30 cfm50/SF enclosure*
  - *Exhaust fan flows within +/- 15% of ASHRAE 62 design*
- Measure performance for to identify potential problems and to advance industry knowledge

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Educate End Users

- Ventilation is often misunderstood!
- Provide manuals and training
- Educate both building maintenance pros and apartment occupants
- Label switches and components

Summary: Successful MF Ventilation

- Step 1: Understand ventilation requirements
- Step 2: Select the simplest design that can achieve both air quality and energy objectives
- Step 3: Build a tight building
- Step 4: Pay attention to installation quality
- Step 5: Check to make sure ventilation works
- Step 6: Educate users

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Section Break

Part II: Implementation Discussion

Doing it right the first time

- Design
- Construction
- Common problems
- Retrofit

MF Ventilation Design Essentials

- Focus on IAQ goals, not technologies
- Choose appropriate technologies to fit goals
- Design for durability
- Do basic duct design, and do it well
- Include performance specifications for leakage and flow

Is this appropriate design?

- 2 ERVs
  - 27,000 CFM supply to corridors
  - 30,600 CFM exhaust from apts
- Code requires:
  - 900 CFM to corridors (IMC)
  - 12,000 CFM from apts (ASHRAE 90.1)

Is this appropriate design?

- Single ERV takes exhaust from 2 risers; supplies air to corridors
- Simple HX core, low maintenance
- All other apt exhausts are at code levels
  - simple design
  - great construction quality
  - Testing for leakage and flow

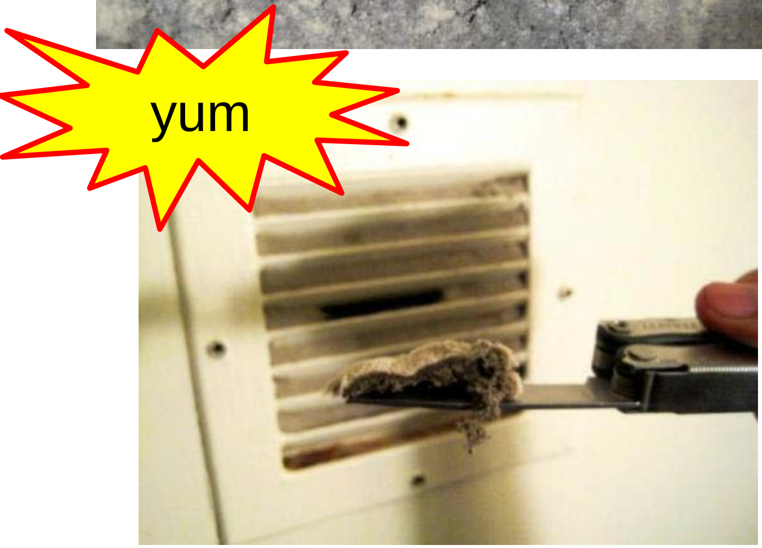
Tips for Long-Term Performance

- Don’t rely on timers
  - Choose constant, adequate ventilation instead
- Don’t rely on belts
  - Choose direct-drive, variable speed instead
  - Ex: Greenheck Vari-Green
    - Efficient DC motors (up to 3 HP soon)
    - Variable speed for field adjust

Design for Durability

All New Buildings become Existing Buildings

- Fire dampers
- Balancing dampers
- Roof fan belts
- Registers



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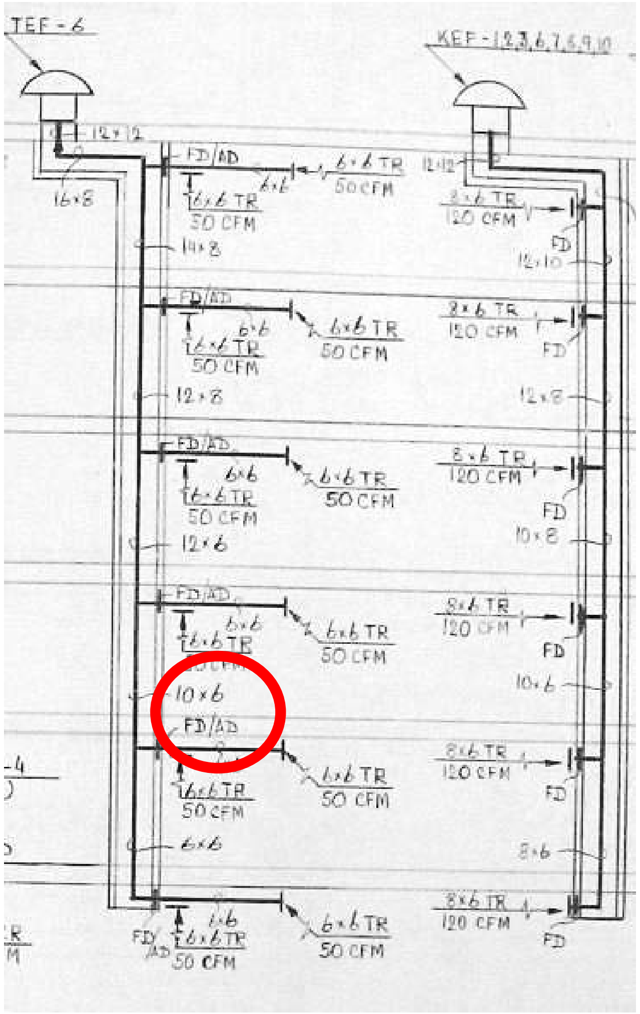
Mechanical Designers' World View

- Balancing damper → transferring responsibility to balancing contractor
- Many grilles, many floors, relatively low flow targets, plus wind and weather on balancing day = balancing is difficult
- Building inspectors are more worried about cranes falling down
- Many TAB contractors don't have the right gauges



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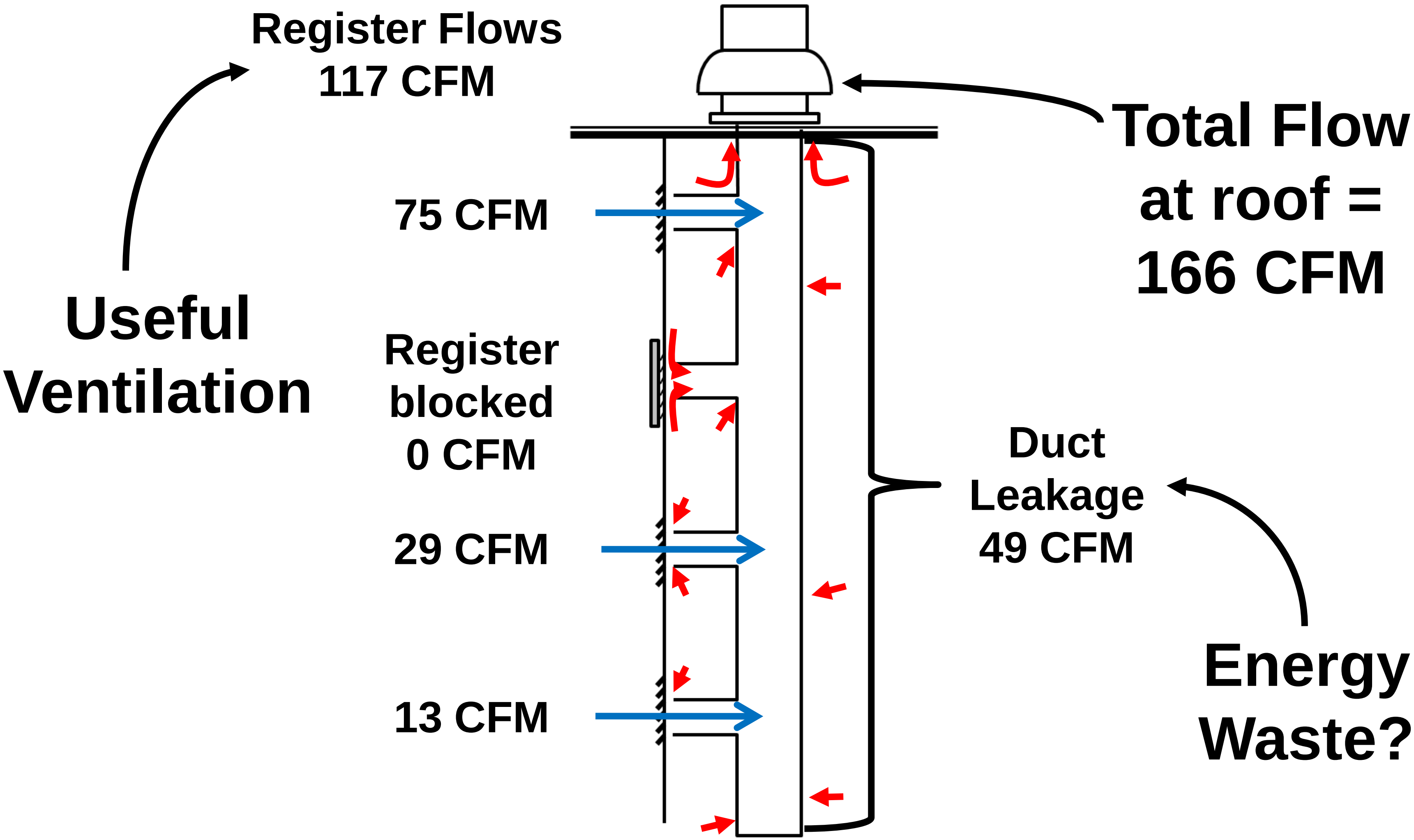
Construction Quality Control

- Duct leakage
- Register leakage
- Balancing

- Whole-building systems
- In-unit ventilation

Duct Leakage



Where Do Ducts Leak the Most?

Roof curb?

Takeoffs?

Transverse (sectional) joints?

Longitudinal (lengthwise) joints?

Register connections can be the largest set of leaks

Could be any of them, OR…

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Tips for High Performance

- Include performance specifications for duct tightness in construction documents
- Call out specific details to be sealed: all joints, takeoffs, connections, registers, etc., etc.

Then test for leakage:

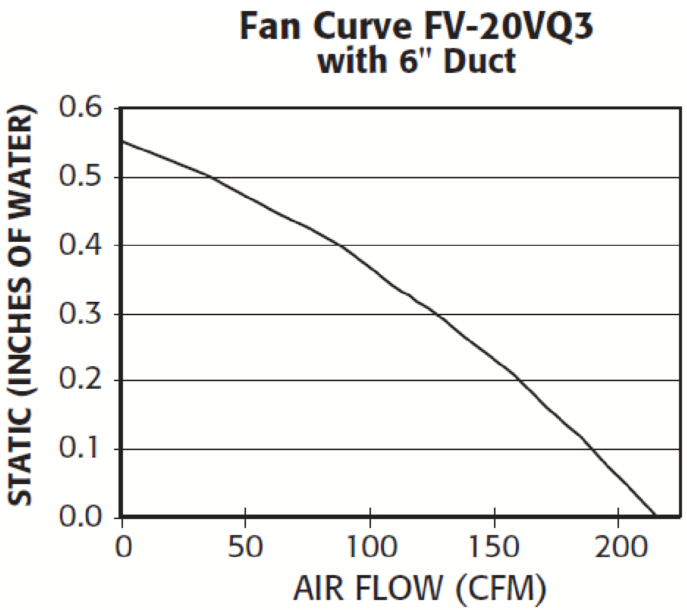
- Good =
  10 CFM50/register
- Better =
  5 CFM50/register

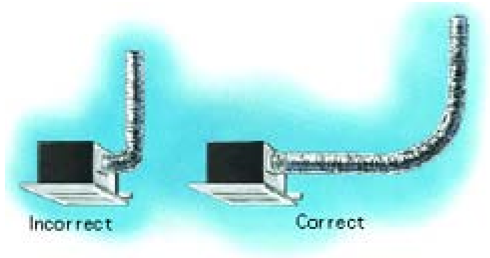
In-Unit Exhaust Systems

Small fans, relatively low flow (50-100 CFM), low power consumption, easier to balance floor to floor

In-Unit Ventilation Quality Control

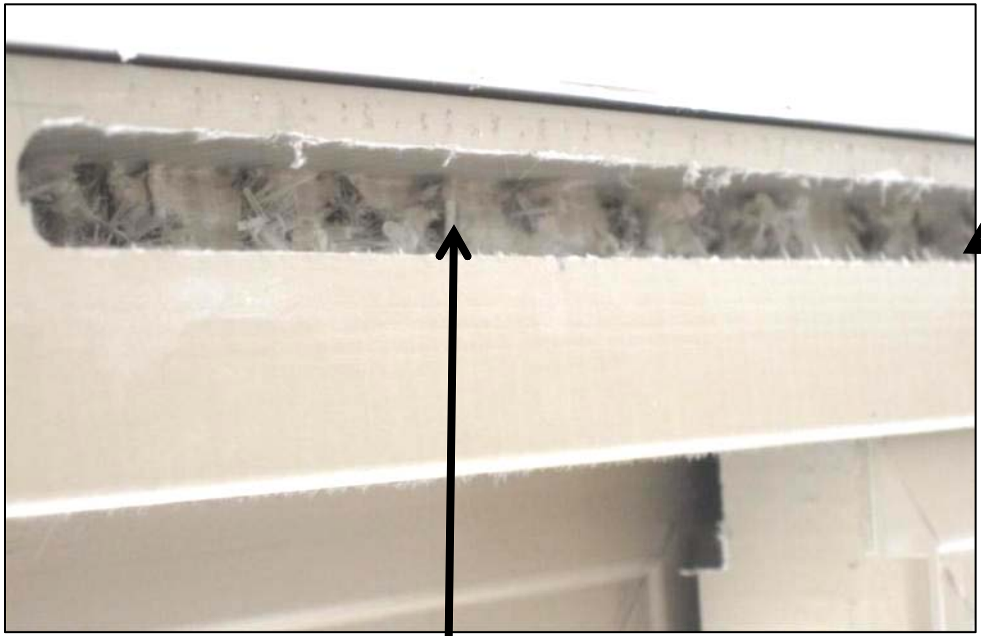
- Duct sealing
- Avoid kinks, long duct runs; use rigid duct
- Test for leakage early
- Can also test for flow with static pressure probes

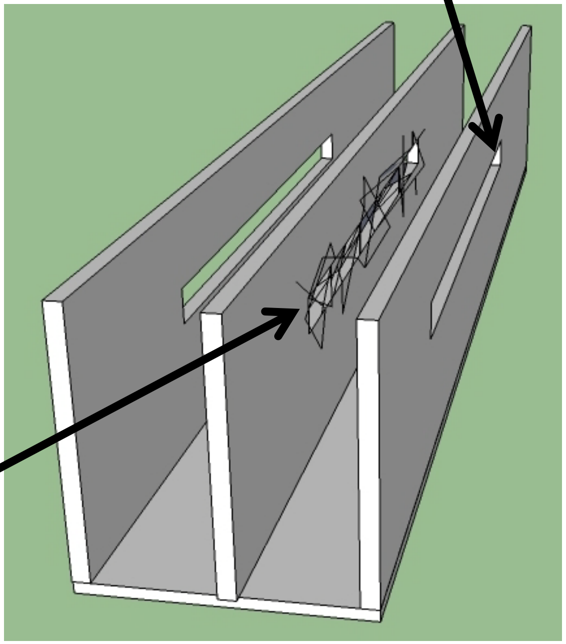




From Panasonic

Trickle Vents – Quality Control

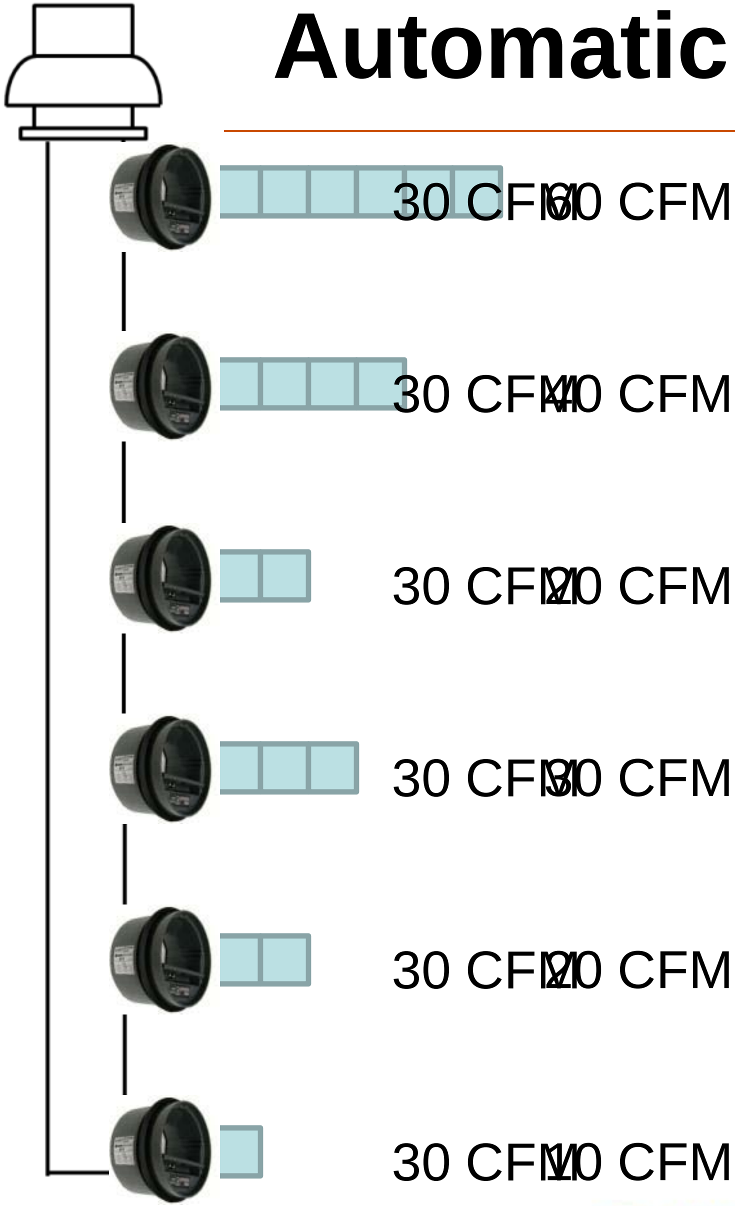




Clean holes

Improperly cut orifice
Restricts flow

Automatic Balancing Dampers

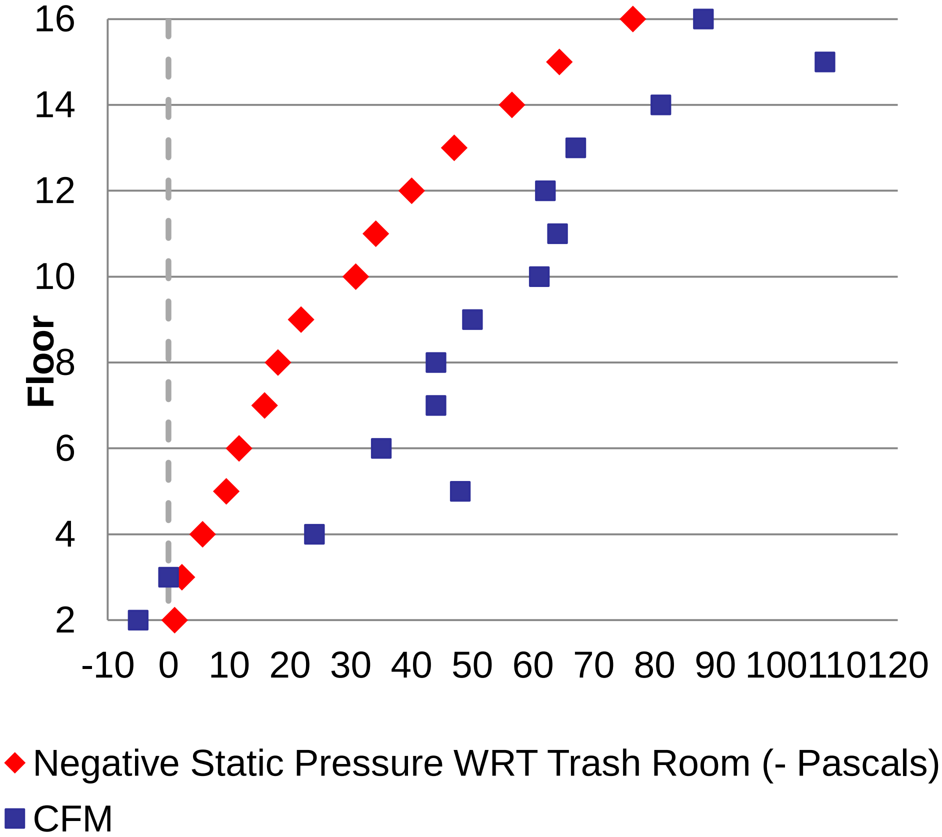


Balance in two ways:

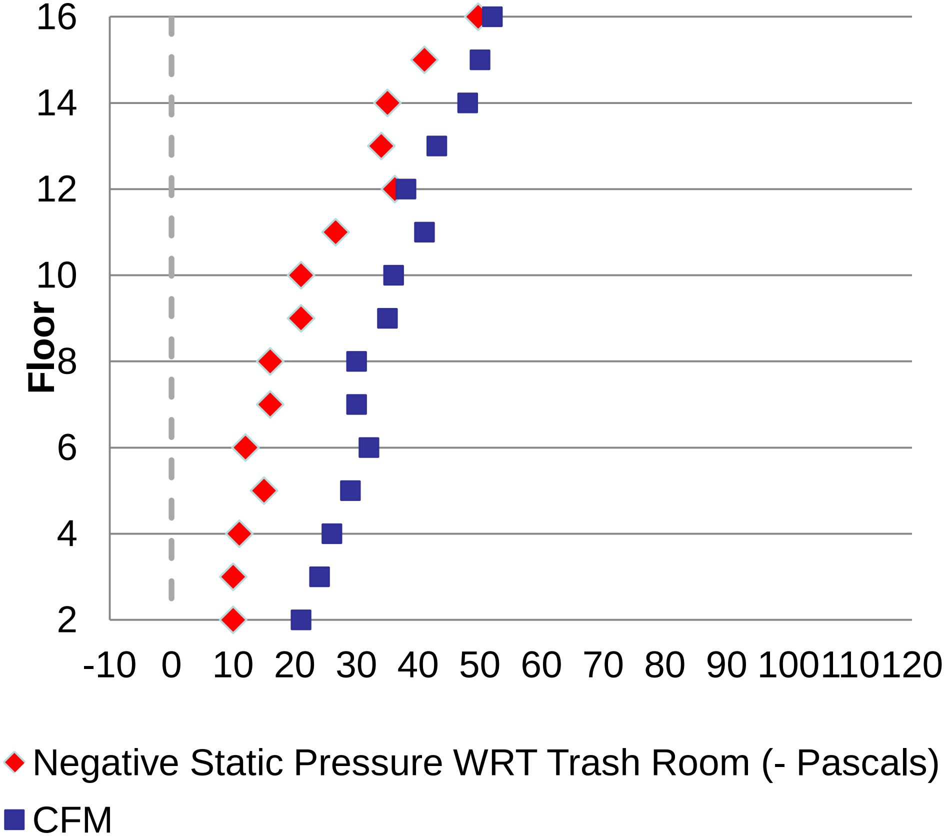
- Provide restriction in size of opening (increase static pressure)
- Dynamically self-adjust to changes in the system (automatic balancing)

Effects of Balancing on Performance

Pre-retrofit



Post-retrofit



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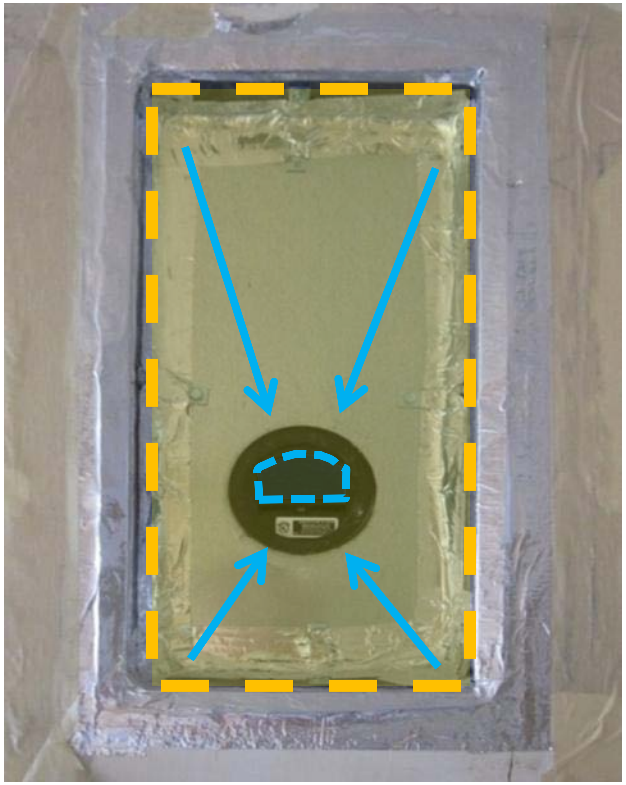
Takeaways – Construction Quality

- Duct sealing is easy and critical to success
- Test early, test often
- Restriction created by CAR dampers or fixed orifices raises static pressure and helps balance system

97% reduction in free area



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Retrofit Process – Video Inspection

Dirty ducts

Blocked ducts

Beer in ducts

Retrofit Process – Register Inspection

- Large gaps at takeoff are very common
- Often the largest “duct leak” in the system
- Fixing requires entry into every apartment

Retrofit Process – CAR Insert Install

- Balancing damper at every register
- Excellent sealing required (can be significant)
- Very labor-intensive; tenant education required

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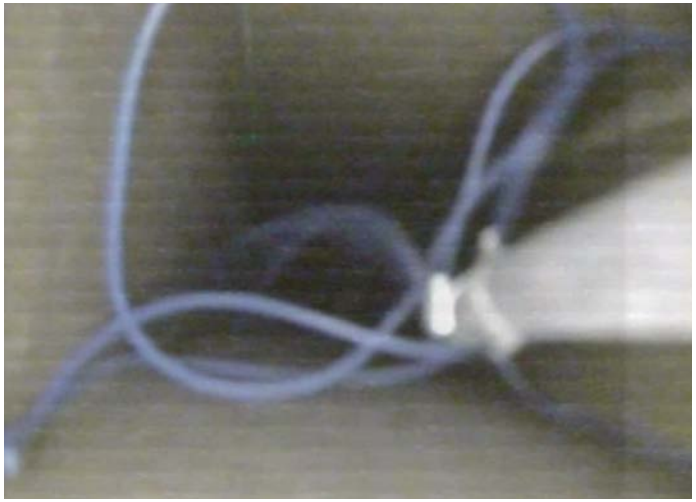
Retrofit Process – Cleaning Ducts

Cleaning tips using compressed air



Vacuum to ensure dust removal

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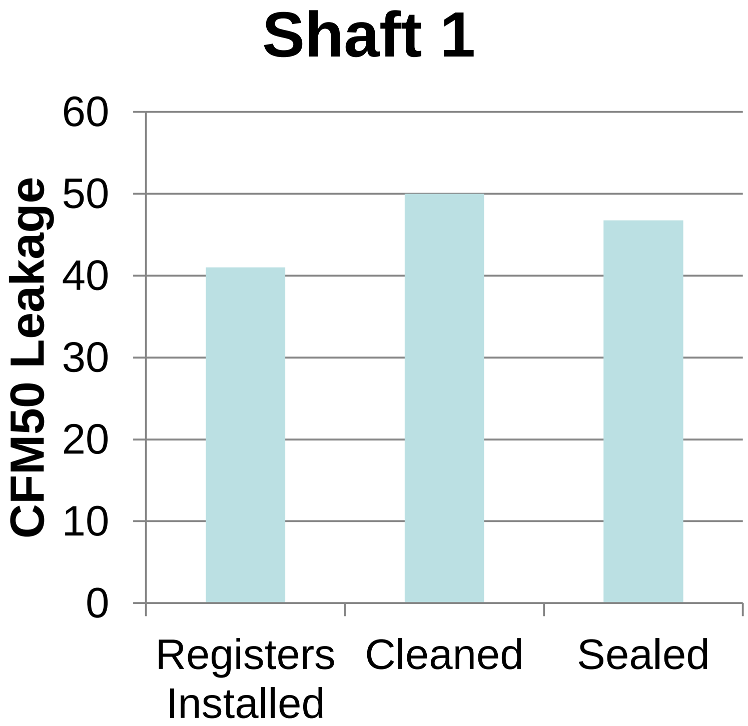
Retrofit Process – Sealing Ducts

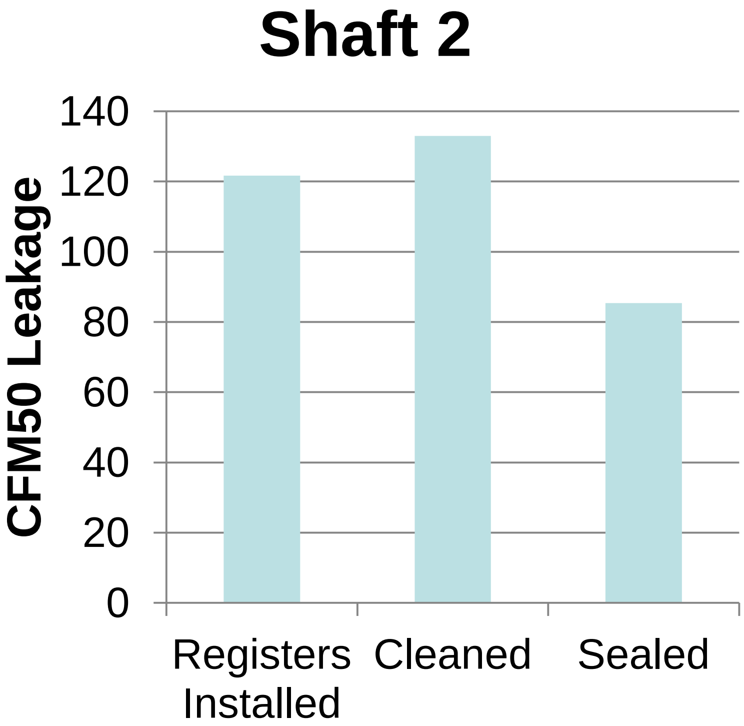
Rotating spray head applies mastic directly to leaks identified by camera

-Simple concept

-Very effective on straight shafts

Sealing Results – Spray Mastic





Cleaning made leakier (by avg. 10 CFM50)

Sealing made tighter (by avg. 17 CFM50)

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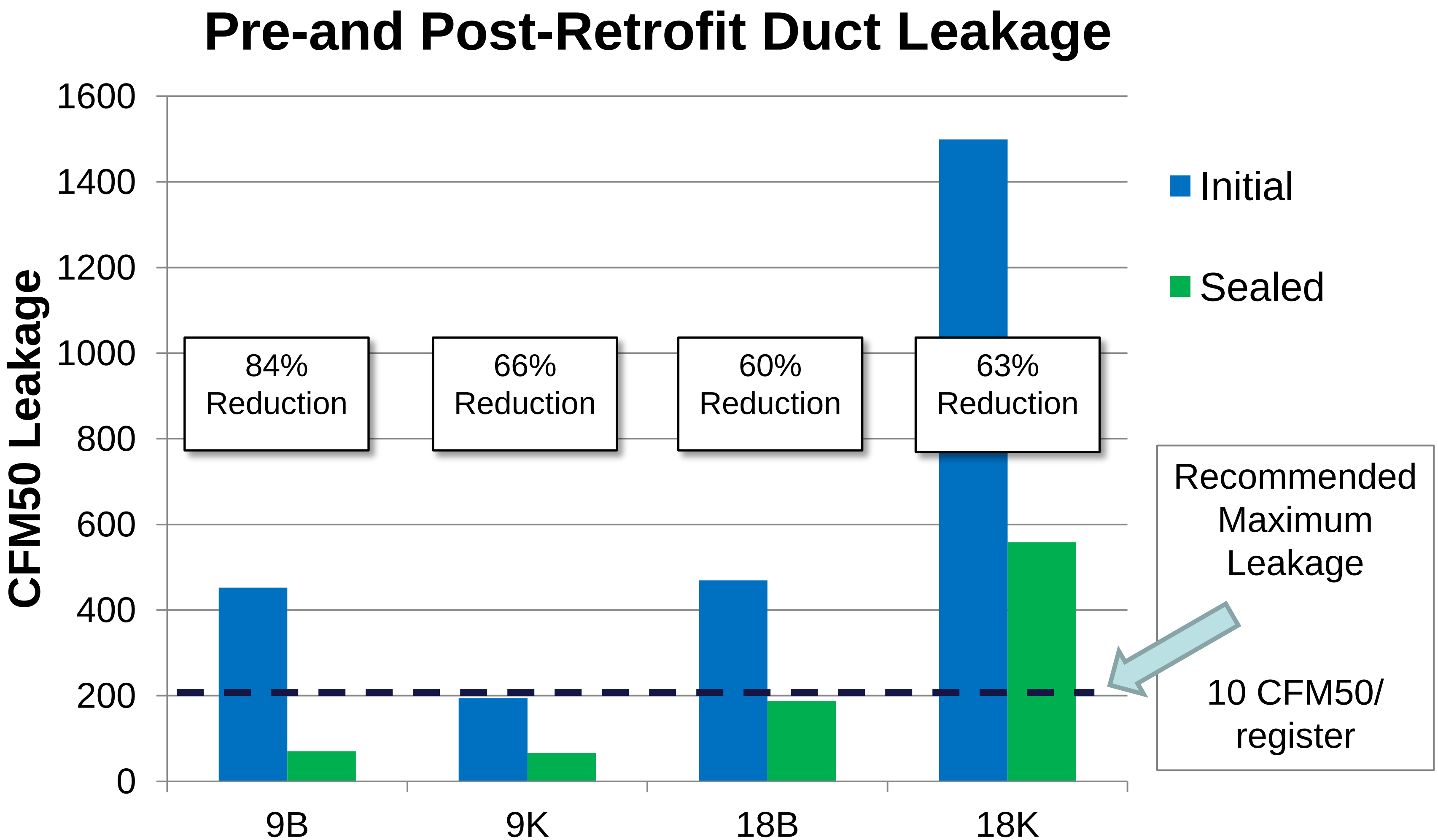
Retrofit Results – Spray Mastic



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Retrofit Process – Sealing Ducts

Aeroseal® aerosol duct sealant sticks to holes in ductwork and seals them

- Measures leakage as part of process
- Can work in more complicated shafts
- Achieves very tight shafts

Roof Fan Replacement After Duct Fix

25 Fans on Rooftop

Avg. Existing Fan Power

= 300 W per fan (measured)

New Fan Power

= 140 W per fan (measured)

Annual Electric Savings => $280 per fan ($7,000 for 25 fans)

Installed cost = $500 per fan

(with building staff installing)

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Takeaways – Retrofits

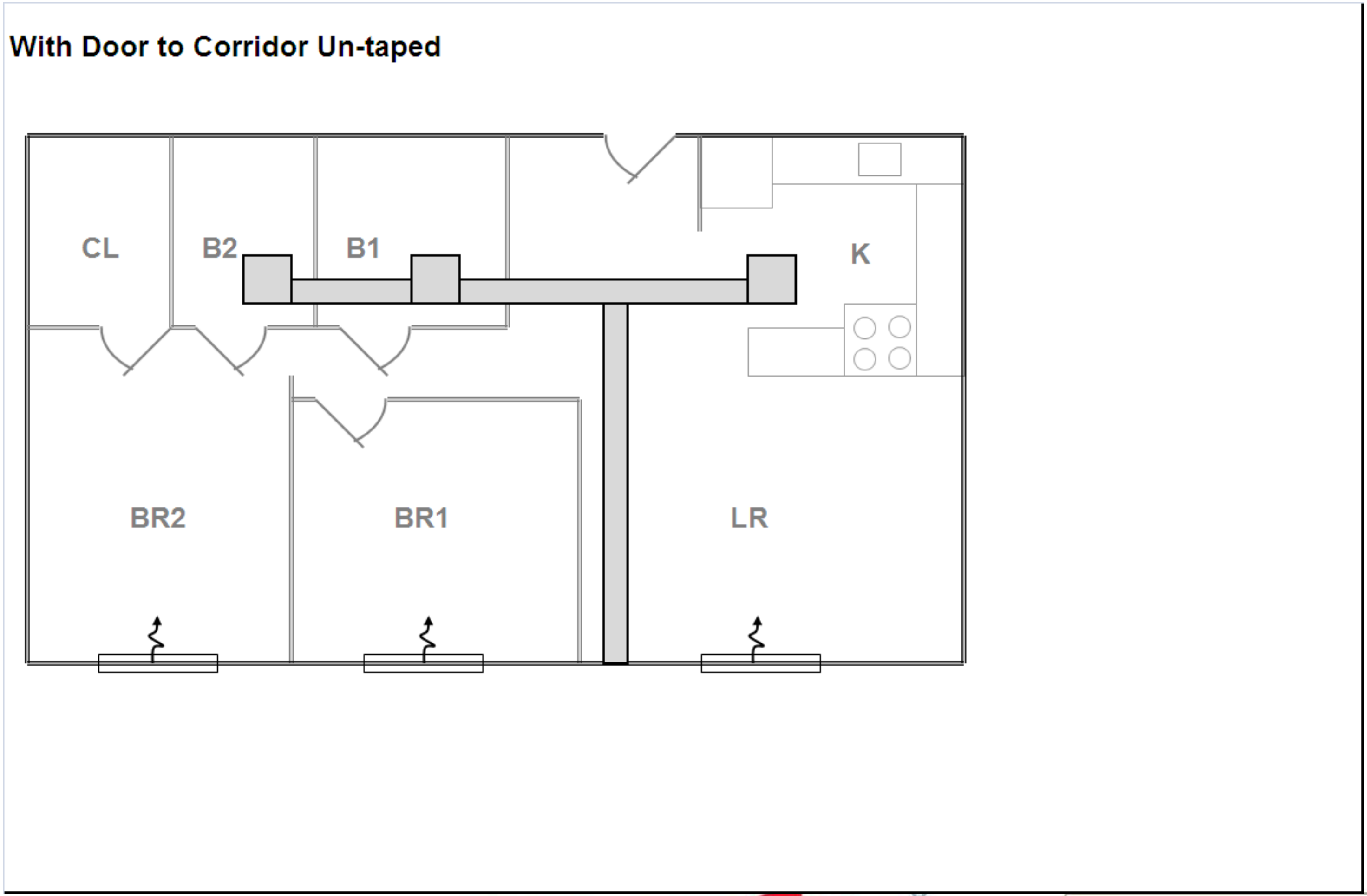
- Several sealing technologies exist
  - Spray mastic, Aeroseal
- Largest improvements can come from gaps at register connections
- Apartment access is critical obstacle in occupied buildings
- Possibility that building is over-ventilated; opportunity for energy savings

Putting the Pieces Together

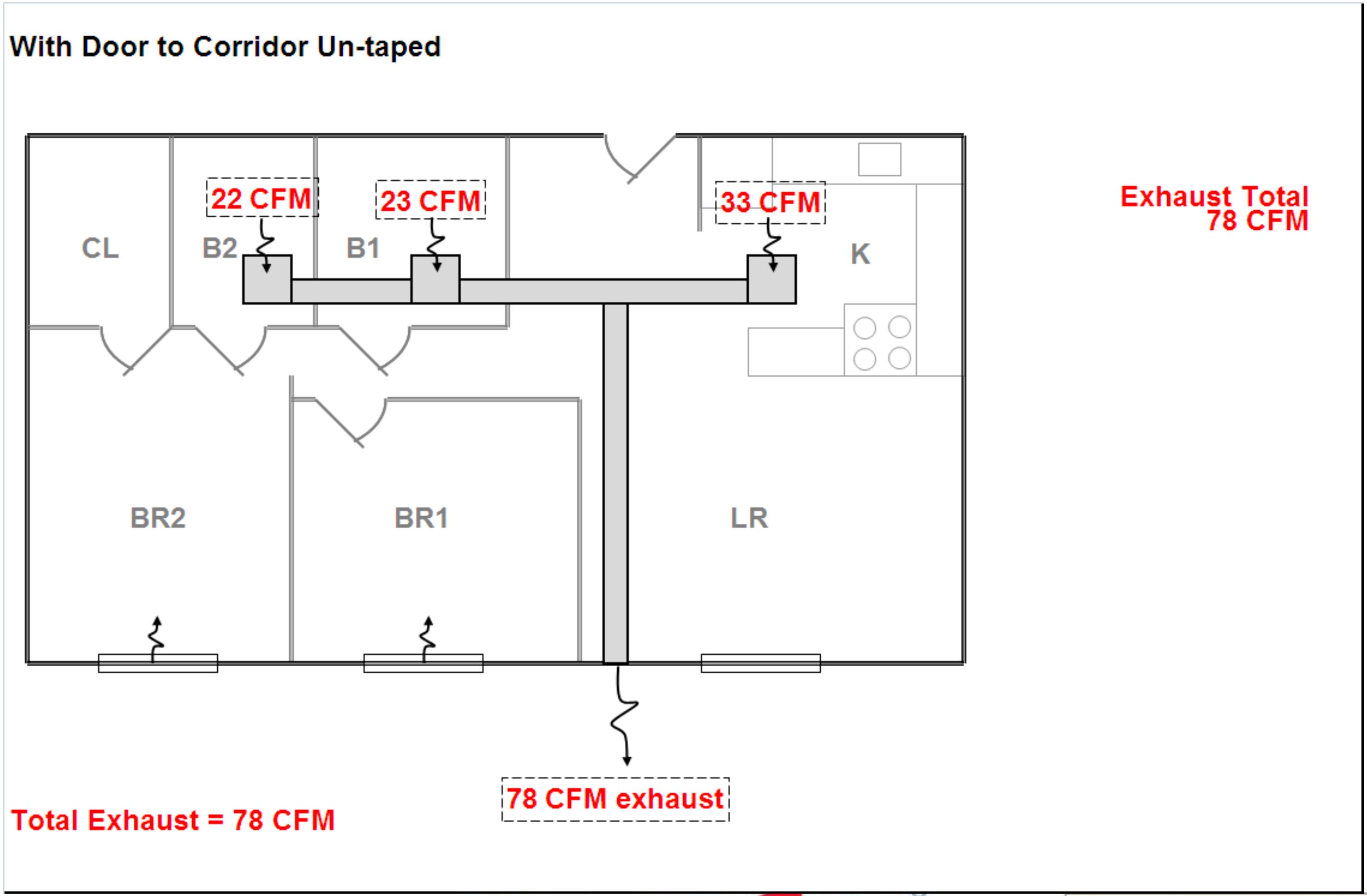
- In-unit exhausts
- CAR dampers to balance flow between rooms
- Excellent apartment air sealing (2.5 ACH50)
- Appropriate corridor supply

Result = 30+ % savings over ASHRAE 90.1-2004

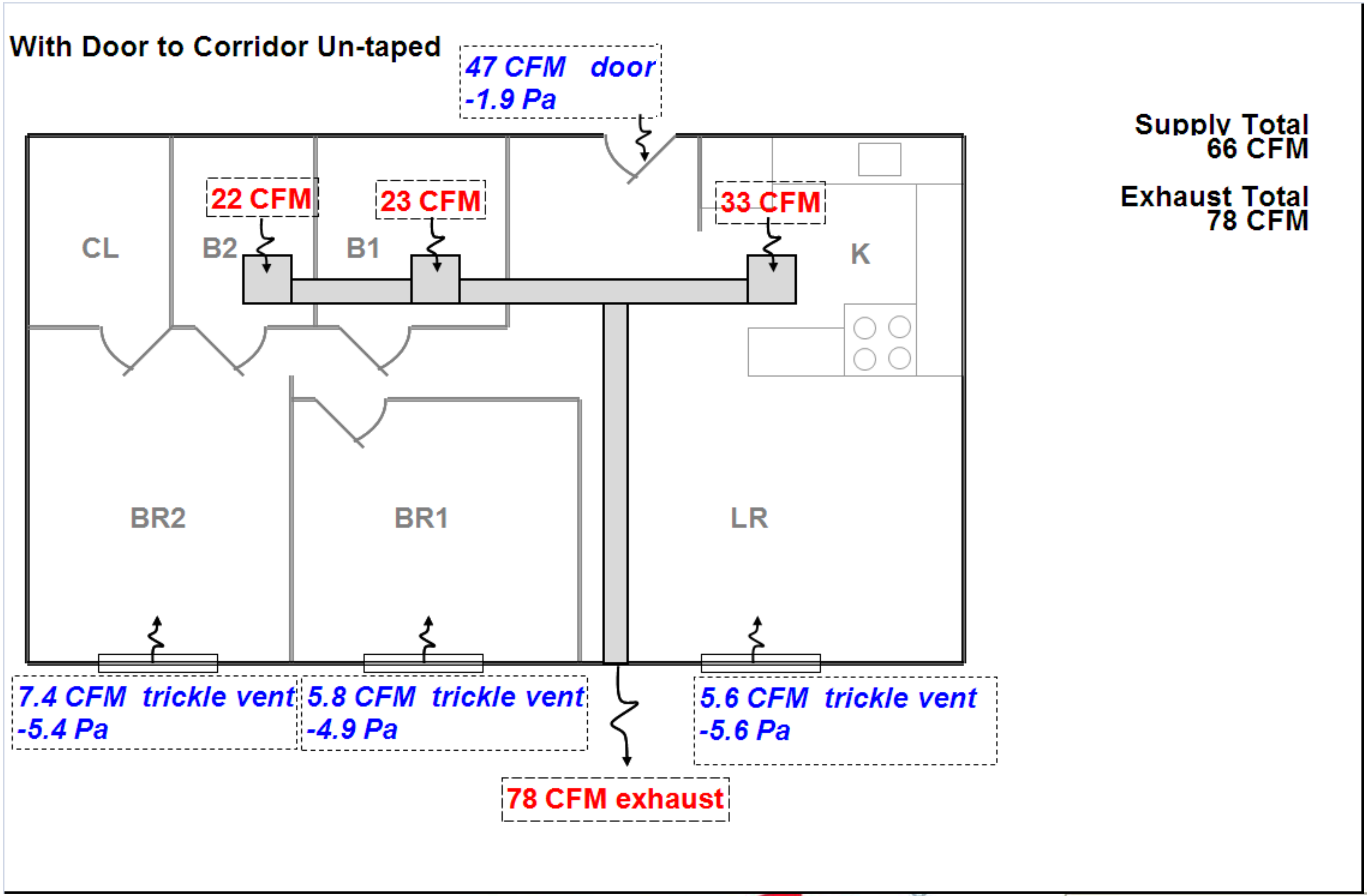
Airflow patterns in a tight unit with trickle vents



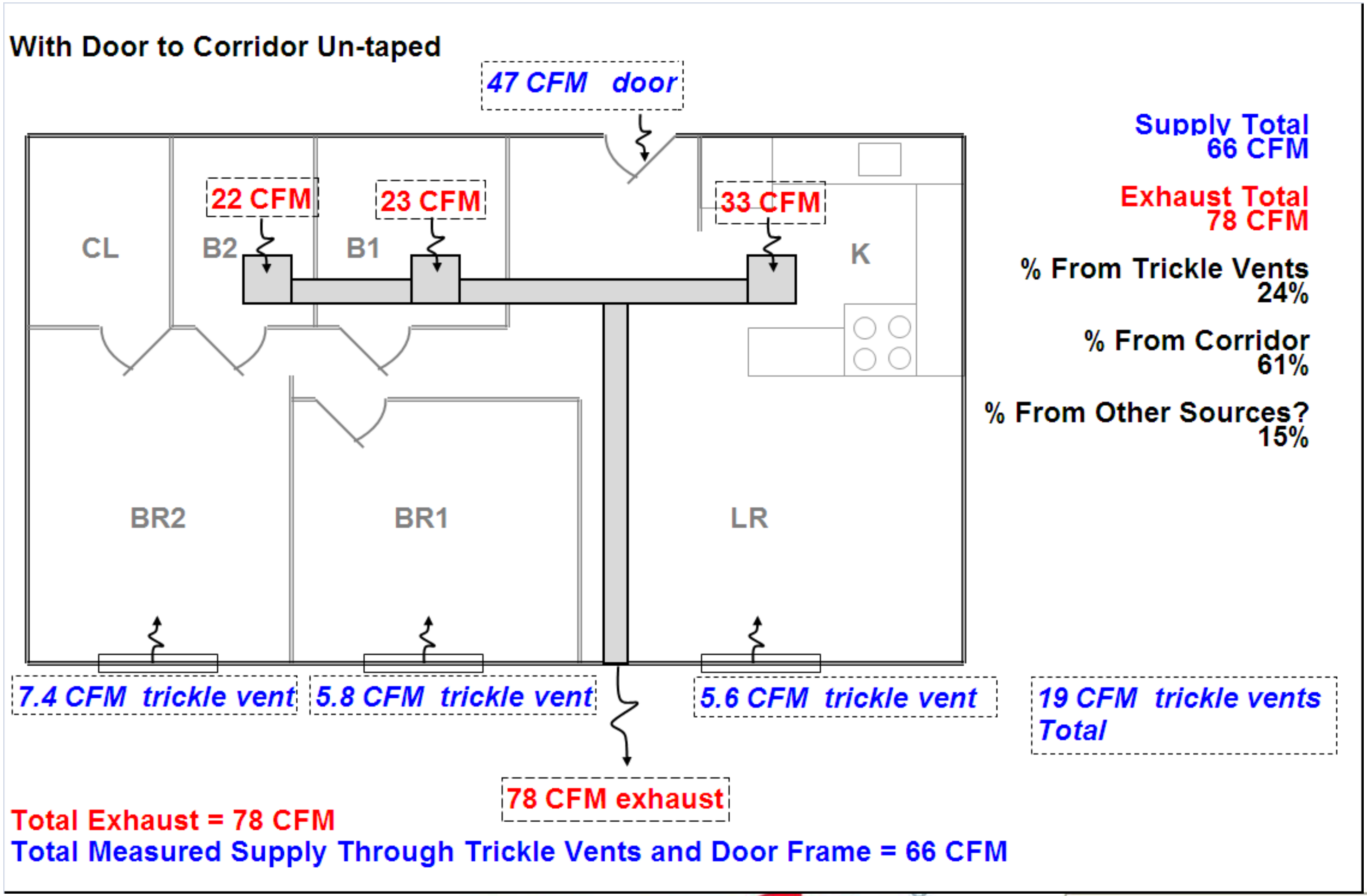
Airflow patterns in a tight unit with trickle vents



Airflow patterns in a tight unit with trickle vents

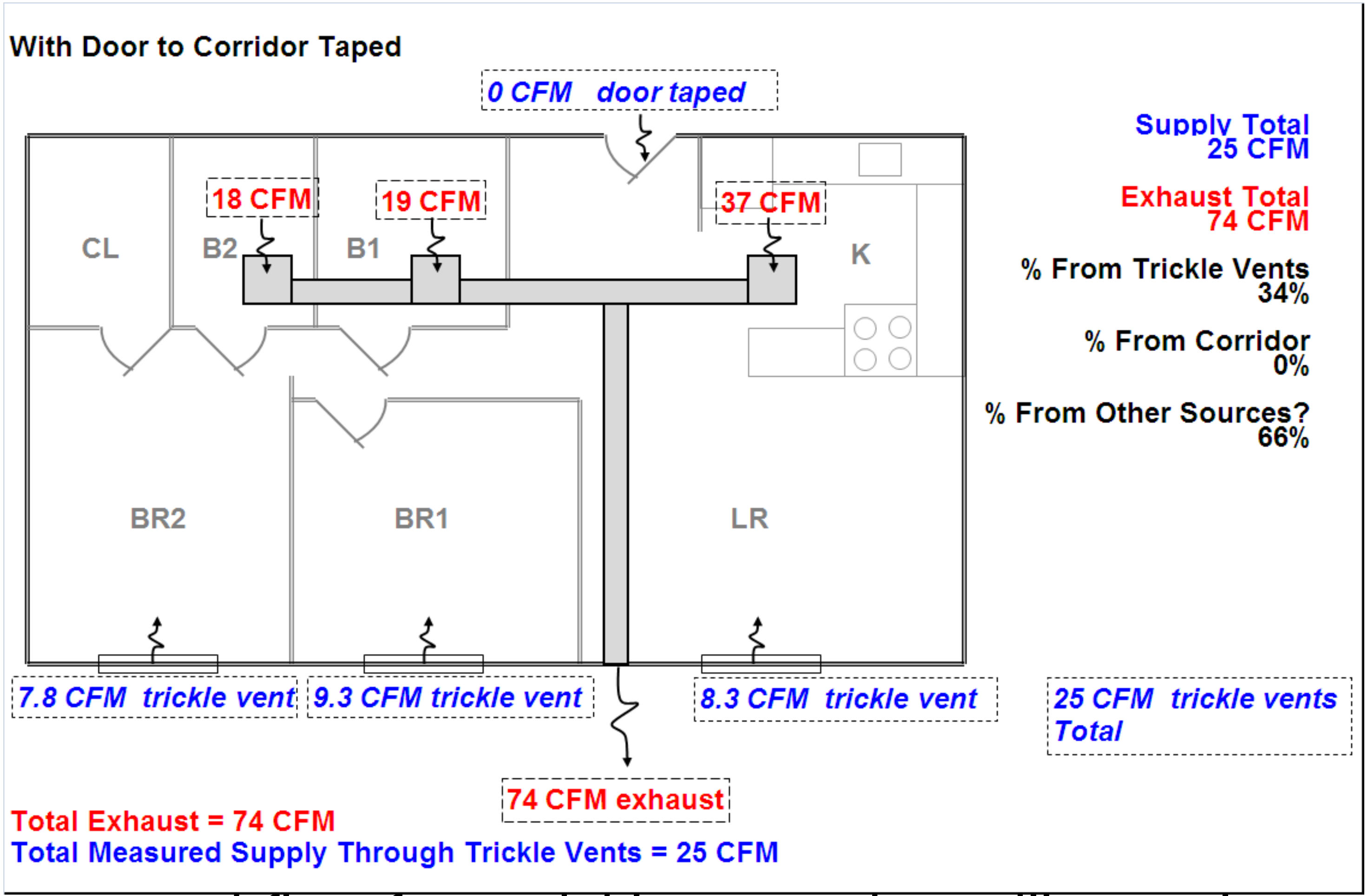


Airflow patterns in a tight unit with trickle vents



Airflow patterns in a tight unit with trickle vents

Taping apartment-corridor doors



More airflow from trickle vents, but still not a lot

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Field Assessment – Balance

- Tools
  - Static pressure box
  - Balometer
  - Vane anemometer
  - Orifice flow box
- What this tells you:
  - Balance
  - Performance at registers
- What it doesn't tell:
  - Total system flow (duct leakage?)

Field Assessment – Total Flow

- Velocity traverse on straight sections of duct
  - Hot wire anemometer or pitot tube
- Duct blaster on roof curb (up to ~700 CFM)
  - Measure SP with roof fan on
  - Replace w/ duct blaster
  - Match SP; record flow

Summary

- Step 1: Understand ventilation requirements
- Step 2: Select the simplest design that can achieve both air quality and energy objectives
- Step 3: Build a tight building
- Step 4: Pay attention to installation quality
- Step 5: Check to make sure ventilation works
- Step 6: Educate users

Thank you for attending the webinar

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Thank You

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