A Tale of Two Cities:
Multifamily Central Ventilation Systems

Building Energy Boston
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Presented by

Tom Holmes
Aspen Environmental Services
tholmes@woodstockenergy.com

Doug Kumph
Petersen Engineering
doug@petersenengineering.com

John Twomey
IAQ Champs
johnt@iaqchamps.com
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Central ventilation systems in multifamily buildings are a vital building system with significant energy, sustainability and occupant health & safety implications. Recent code requirements place increased emphasis on getting them right in both new construction and retrofit projects.

This session explores how these systems work and why, quite often, they don’t work. It builds on lessons learned from a number of retrofit projects and offers recommendations for designing and constructing both new and retrofit systems.
Learning Objectives

At the end of this course, participants will be able to:

1. Understand the design, equipment & field considerations that help determine how central ventilation systems actually work
2. Identify the important project design considerations that lead to reliable performance in retrofit & new construction applications
3. How to design, specify & set performance objectives that can be reliably & cost-effectively achieved
4. Understand ways to inspect, evaluate & commission projects that achieve & sustain building performance objectives
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Used Air Drainage System

<table>
<thead>
<tr>
<th>Floor</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof</td>
<td></td>
</tr>
<tr>
<td>6th</td>
<td></td>
</tr>
<tr>
<td>5th</td>
<td></td>
</tr>
<tr>
<td>4th</td>
<td></td>
</tr>
<tr>
<td>3rd</td>
<td></td>
</tr>
<tr>
<td>2nd</td>
<td></td>
</tr>
<tr>
<td>1st</td>
<td></td>
</tr>
<tr>
<td>Cellar</td>
<td>RESIN AT 50 GPM TYPICAL FOR ALL BATHROOM EXHAUST GRILLE</td>
</tr>
<tr>
<td>Sub-Cellar</td>
<td>RESIN AT 25 GPM TYPICAL FOR ALL KITCHEN EXHAUST GRILLE</td>
</tr>
</tbody>
</table>

EXHAUST RISER DIAGRAM BUILDING 2
Existing Systems: What We Expect

- Roof exhaust fan draws air from the riser
- Exhaust air flows up the riser to the fan
- Apartments exhausted through grilles to risers
- Fresh air replaces stale air
Existing Systems: What We Expect

But…
Existing Systems: What We Find

- The fan is switched off, broken, missing its belt or otherwise not functioning properly
- The riser has gaps and holes that compete with the vents or sometimes the “duct” is missing altogether
- Air flows at the vents vary wildly, sometimes flowing into the apartments or changing direction with the wind
- Shaft blockages or accumulated leaks prevent lower floors from removing any air at all or send it into apartments above
- Occupants block up their vents or neglect them to the point where no flow can get through.
Existing Systems: What We Find

Fan Not Exhausting Air

The Fans Belt Is Broken

Motor/Pulley #1 Are At Full Speed, While 2\textsuperscript{nd} Pulley Connected To Fan Blades Is Stopped
Existing Systems: What We Find

Sheetrock Exhaust Shafts
Existing Systems: What We Find

Masonry Tile Exhaust Shafts

- Mortar deteriorates over time leading to an increased amount of unintended leakage
- Often contain electrical and plumbing lines along with large unsealed penetrations
- Lateral sections composed of sheetmetal with large gaps at masonry connections
- Haphazard renovations are common leading to large unintended openings in shaft walls and blockages in the floors below
Existing Systems: What We Find

Exhaust Shaft Blockages

- Lateral Blockage
- Register Blockage
- Vertical Shaft Blockage
Existing Systems: What We Find

Obstructions And Leakage Points Found At The Unit Level
Existing Systems: What We Find
Existing Systems: What We Find
Existing Systems: What We Find
## Existing Systems: What We Find

<table>
<thead>
<tr>
<th>System</th>
<th>Sealing Event</th>
<th>Operating Pressure (Pa)</th>
<th>Design CFM</th>
<th>Starting Leakage (CFM)</th>
<th>Ending Leakage (CFM)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ERV-01 Exhaust</strong></td>
<td></td>
<td>312.5</td>
<td>3650</td>
<td>Total: 7229.0</td>
<td>Total: 220.3</td>
</tr>
<tr>
<td>1st Floor East</td>
<td></td>
<td>312.6</td>
<td>530</td>
<td>1167.4</td>
<td>6.4</td>
</tr>
<tr>
<td>1st Floor West</td>
<td></td>
<td>312.5</td>
<td>1180</td>
<td>1154.7</td>
<td>26.5</td>
</tr>
<tr>
<td>2nd Floor East</td>
<td></td>
<td>312.5</td>
<td>480</td>
<td>1102.4</td>
<td>8.2</td>
</tr>
<tr>
<td>2nd Floor West</td>
<td></td>
<td>312.5</td>
<td>410</td>
<td>1089.2</td>
<td>17.8</td>
</tr>
<tr>
<td>3rd Floor East</td>
<td></td>
<td>312.5</td>
<td>500</td>
<td>1093.7</td>
<td>70.1</td>
</tr>
<tr>
<td>3rd Floor West And Riser</td>
<td></td>
<td>312.5</td>
<td>605</td>
<td>1621.7</td>
<td>92.4</td>
</tr>
<tr>
<td><strong>ERV-01 Supply</strong></td>
<td></td>
<td>312.5</td>
<td>4170</td>
<td>Total: 2494.2</td>
<td>Total: 97.9</td>
</tr>
<tr>
<td>1st Floor East</td>
<td></td>
<td>312.5</td>
<td>525</td>
<td>431.9</td>
<td>17.8</td>
</tr>
<tr>
<td>1st Floor West</td>
<td></td>
<td>312.5</td>
<td>1010</td>
<td>438.0</td>
<td>32.8</td>
</tr>
<tr>
<td>2nd Floor East</td>
<td></td>
<td>312.5</td>
<td>480</td>
<td>350.9</td>
<td>8.6</td>
</tr>
<tr>
<td>2nd Floor West</td>
<td></td>
<td>312.5</td>
<td>410</td>
<td>350.0</td>
<td>9.6</td>
</tr>
<tr>
<td>3rd Floor East And West</td>
<td></td>
<td>312.5</td>
<td>1105</td>
<td>920.3</td>
<td>29.1</td>
</tr>
<tr>
<td><strong>ERV-02 Supply</strong></td>
<td></td>
<td>250</td>
<td>4055</td>
<td>Total: 1453.9</td>
<td>Total: 62.1</td>
</tr>
<tr>
<td>1st Floor West</td>
<td></td>
<td>250</td>
<td>260</td>
<td>87.6</td>
<td>9.6</td>
</tr>
<tr>
<td>1st Floor East-No Corridor</td>
<td></td>
<td>250</td>
<td>790</td>
<td>220.9</td>
<td>8.0</td>
</tr>
<tr>
<td>2nd Floor West</td>
<td></td>
<td>250</td>
<td>505</td>
<td>208.6</td>
<td>12.3</td>
</tr>
<tr>
<td>2nd Floor East</td>
<td></td>
<td>250</td>
<td>790</td>
<td>222.1</td>
<td>7.5</td>
</tr>
<tr>
<td>3rd Floor East and West</td>
<td></td>
<td>250</td>
<td>750</td>
<td>714.6</td>
<td>24.7</td>
</tr>
<tr>
<td><strong>ERV-02 Exhaust</strong></td>
<td></td>
<td>250</td>
<td>3480</td>
<td>Total: 6876.1</td>
<td>Total: 83.2</td>
</tr>
<tr>
<td>1st Floor West</td>
<td></td>
<td>250</td>
<td>260</td>
<td>498.0</td>
<td>18.7</td>
</tr>
<tr>
<td>1st Floor East</td>
<td></td>
<td>250</td>
<td>790</td>
<td>1149.3</td>
<td>10.7</td>
</tr>
<tr>
<td>2nd Floor West</td>
<td></td>
<td>250</td>
<td>555</td>
<td>1084.0</td>
<td>6.0</td>
</tr>
<tr>
<td>2nd Floor East</td>
<td></td>
<td>250</td>
<td>790</td>
<td>1276.7</td>
<td>15.1</td>
</tr>
<tr>
<td>3rd Floor East and West and Riser</td>
<td></td>
<td>250</td>
<td>1085</td>
<td>2868.0</td>
<td>32.6</td>
</tr>
</tbody>
</table>
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Design Objectives
### Basis of Design

**Say What You Mean and Mean What You Say**

**System Description**

**Load Summary**

<table>
<thead>
<tr>
<th>Load Summary (Continued)</th>
<th>Load Summary (Continued)</th>
<th>Load Summary (Continued)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Ventilation in Apartments**

<table>
<thead>
<tr>
<th>Apartment Type</th>
<th>EIV</th>
<th>Mechanical</th>
<th>Electrical</th>
<th>Current Rate</th>
<th>Outside Air Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Legend**

- **CLIMATE**
- **CODES AND STANDARDS**
- **SYSTEM DESCRIPTION**
- **LOAD SUMMARY**
- **VENTILATION SUMMARY**
- **VENTILATION IN APARTMENTS**
Design Objectives

- Owner Requirements → Basis of Design
- Codes and Standards
- *It needs to work!*

*Planning is everything.*

*— Dwight D. Eisenhower*
Codes and Standards
Codes and Standards
Codes and Standards

Example - 900 SF 2 BR apt with 9' Ceilings = 8,100 CUFT:

- IMC 2015 (0.35 ACH) =
- 47 CFM
- IMC 2015 (OCC) =
- 45 CFM
- ASHRAE 62.2 (2007) =
- 32 CFM
- ASHRAE 62.2 (2013) =
- 50 CFM
- PHIUS (0.3 ACH) =
- 41 CFM
- PHIUS (18 CFM /OCC) =
- 54 CFM
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System Types

“Old Code” Central

Rooftop ERV

Floor by Floor

Unit Level
“Traditional” Rooftop Exhaust Only - Schematic
“Traditional” Rooftop Exhaust Only – Make it Work

Pros
• It’s What We Got

Cons
• 100% “Lost Air” Energy Penalty - $$$
• NO DIRECT MAKE UP FRESH AIR
• Ducts Leak, are Blocked or filled with Mold
• Rarely in Balance
• Rarely EVER Work!

Making them WORK
• Seal the “Big Gaps” (10%-15% leakage max)
• Set Design Flows at least 50% above minimum thresholds – “gauge” more than measure flows
• Expect that vents will need periodic cleaning/ maintenance
• Can Repair Line By Line
Central Rooftop ERV - Schematic
Central ERV – Make it Work

Pros
• Centralized Equipment
• Energy Recovery Reduces Energy Penalty $$
• *Modern Systems* Provide Unit-Level Make Up Air

Cons
• “Old Code” Systems – NO MAKE UP AIR
• Ducts Must Be Tight
• Too Many Vent Connections Hurt Performance

Making them WORK
• Really Tight Sheet Metal Ducts (3%-5% leakage max)
• Set Design Flows *at least* 20% above minimum thresholds – flows WILL fade farther from the fans
• Expect that vents will need periodic cleaning/ maintenance
Floor-by-Floor Ventilation – Schematic
Floor-by-Floor ERV – Make it Work

Pros

• Energy Recovery Reduces Energy Penalty $$
• Eliminates Stack Effect, No Riser Shafts
• Better Building Compartmentalization

Cons

• Mechanical Spaces on Every Floor (Noise)
• Requires Corridor Ceiling Space for Ducts
• More Machines that Require Maintenance

Making them WORK

• Tight Sheet Metal Ducts (5% leakage max)
• Set Design Flows at least 20% above minimum thresholds
• Expect that vents will need periodic cleaning/ maintenance
Unit Level Ventilation – Schematic
Unit Level Ventilation – Make it Work

Pros

• Ductwork minimized
• Easy to balance
• No fire smoke dampers

Cons

• Filter changes in every apartment, access
• Requires space in each unit
• Insufficient dehumidification

Making them WORK

• Access, access, access. These cannot be buried.
• Keep decoupled from heating and cooling
• Residential commissioning
## System Types: **Pros** & **Cons**

<table>
<thead>
<tr>
<th><strong>Pro</strong></th>
<th>&quot;Old Code&quot; Exhaust Only</th>
<th>Modern Code with In-Unit Make Up Air</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Central Exhaust Only</td>
<td>Central Exhaust Only ERV</td>
</tr>
<tr>
<td>Already Installed in Existing Building</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Centralized Equipment</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Mechanical Access from Common Spaces Only</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Up to 75% Energy Recovery</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Direct Make Up Air to Apartments</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>No Riser Shafts</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Easier to Balance</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Better Compartmentalization</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>No Fire/ Smoke Dampers</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Occupant Pays for Energy Use</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Occupant Controls Ventilation Directly</td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>
### System Types: Pros & Cons

<table>
<thead>
<tr>
<th>Con</th>
<th>&quot;Old Code&quot; Exhaust Only</th>
<th>Modern Code with In-Unit Make Up Air</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Central Exhaust Only</td>
<td>Central with ERV</td>
</tr>
<tr>
<td>100% Lost Air</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Duct Risers Penetrate Floors</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Make-up Air Equipment Outside Envelope</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Stack Effect</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Fire/ Smoke Dampers</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Uses Corridor Ceiling Space</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Uses Corridor Ceiling Space</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Multiple Inside Mechanical Spaces</td>
<td></td>
<td></td>
</tr>
<tr>
<td>In Unit Mechanical Service</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unit-Level Thru-Wall Penetrations</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Equipment, Parts & Pieces
Equipment, Parts & Pieces

Hands On Discussion
Equipment, Parts & Pieces
The Vents

Wind Pressure on a Building

Beaufort Wind Scale

<table>
<thead>
<tr>
<th>Beaufort No.</th>
<th>Description of wind</th>
<th>Observation</th>
<th>Wind speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Calm</td>
<td>Smoke rises vertically. The sea is mirror smooth.</td>
<td>0 - 0.15</td>
</tr>
<tr>
<td>1</td>
<td>Light Air</td>
<td>Direction of wind shown by smoke drift but not by vanes. Scale-like ripples on sea, no foam on wave crests.</td>
<td>0.15 - 2.7</td>
</tr>
<tr>
<td>2</td>
<td>Light Breeze</td>
<td>Wind felt on face, leaves rustle, ordinary vanes moved by wind. Shorts, thermal waves, glassy wave crests.</td>
<td>2.7 - 6.3</td>
</tr>
<tr>
<td>3</td>
<td>Gentle Breeze</td>
<td>Leaves and small twigs in constant motion, wind makes slight sighing.</td>
<td>3.6 - 5.4</td>
</tr>
<tr>
<td>4</td>
<td>Moderate Breeze</td>
<td>Raising dust and loose paper, small branches moved. Fairy frequent whitecaps occur.</td>
<td>7.2 - 8.9</td>
</tr>
<tr>
<td>5</td>
<td>Fresh Breeze</td>
<td>Small trees in leaf branches in sway. Moderate waves, many white foam crests.</td>
<td>8.5 - 12.5</td>
</tr>
<tr>
<td>6</td>
<td>Strong Breeze</td>
<td>Large branches in motion, whistling heard in telegraph wires. Some spray on the sea surface.</td>
<td>12.5 - 14.5</td>
</tr>
<tr>
<td>7</td>
<td>Moderate gale</td>
<td>Whole trees in motion, inconvenience felt when walking into wind. Foam on waves blows on streaks.</td>
<td>14.5 - 20</td>
</tr>
<tr>
<td>8</td>
<td>Gale</td>
<td>Twigs broken of trees, generally impeded progress. Long streaks of foam appear on sea.</td>
<td>20 - 22</td>
</tr>
<tr>
<td>9</td>
<td>Strong gale</td>
<td>Straight structural damage, e.g. slates and chimney pots removed from the roofs. High waves, crest start to roll over.</td>
<td>22 - 28</td>
</tr>
<tr>
<td>10</td>
<td>Storm</td>
<td>Trees uprooted, considerable structural damage. Exceptionally high waves, visibility affected.</td>
<td>28 - 31</td>
</tr>
<tr>
<td>11</td>
<td>Violent Storm</td>
<td>Widespread damage</td>
<td>31 - 37</td>
</tr>
<tr>
<td>12</td>
<td>Hurricane</td>
<td>Air is filled with spray and foam.</td>
<td>&gt;37</td>
</tr>
</tbody>
</table>

20MPH breeze can shift operating range by 1/3!
Exhaust Only Ventilation:
Older Buildings

CAR Dampers vs. Variable Orifice Plates
Car Damper Issues Observed

This image is from a four year old 20 story building located in Long Island City.
The Vents

- Manual Vent Damper
- SEO/ VOP Vent Damper
- Self-Regulating Vent Damper (CAR)
The Vents

ALDES  RUSKIN  E FLOW
The Vents

CAR Regulators - Limitations

☑ Rated flows +/- 15%: a 30CFM “spec” = 25-35CFM design.
☑ Requires minimum 50pa (0.2” wg) to operate properly
☑ Smaller opening “competes” more with system leakage –

*Requires Tighter Ducts*
Lessons Learned

CAR Regulators – Will work well when…

✓ Overall duct systems are tight enough to hold negative pressures along the entire riser (3%-5%)
✓ Fans have sufficient power to maintain static pressures along entire riser
✓ Regulators are not “competing” with large gaps, especially at fan curbs & at the boots
✓ Open windows, windy conditions will influence performance of even very good systems!
Manual/ SEO/ VOP - Limitations

✓ Manually Set Flows Vary with Building Pressure Dynamics
✓ Tolerance +/- 30%: a 35CFM “spec” = 25-45CFM design.
✓ Smaller opening “competes” more with system leakage –

**STILL Need to Fix Ducts**
The Vents

ALDES FEA II
New Construction

Custom Assembly
Retrofit
Fans
Energy Performance: Reduce Fan Energy

Fan Savings

- 25 Rooftop Fans
- Average Measured Fan Power: 300W/ Fan
- New Measured Fan Power: 140W/ Fan
- Savings: 1,400 kWh/ fan = $300/ year savings
- 25 Fans = 4kW off Demand Load
- Typically Direct Drive, 15 – 20 year life
- Installed Cost: $1,800/ Fan

Pro Tip – Know Your Building! Is there enough of the RIGHT power for the fans you specify?
The Risers

Rooftop Curbs/ Tops of Risers

✓ Blockages, restrictions through the roof deck
✓ Failed joints or visible holes in risers
✓ Gaps inside the curb or between the deck and duct
✓ Are there even any ducts at all?
Energy Recovery Ventilators (ERV)
Horizontal Buildings
Vertical Buildings
Floor-by-Floor & In Unit – Equipment
Floor-by-Floor Buildings
In Unit
In Unit
IAQ Issues Associated With Improper Fan Installations

Fans that are not sealed at the roof level become significant sources of wasted energy. These end up ventilating the roof prior to the intended locations, leading to low airflow rates at the unit level.
IAQ Issues Associated With Masonry Shafts

Upper East Side Condo and Co-op Buildings

- Co-op Building With 153 Units Constructed In 1962
- Ventilation Assessment Performed Due To Constant Odor And Airflow Complaints Throughout Building
- Masonry Risers In Terrible Shape Having Never Been Maintained.
- 40% Of The Units In This Building Consist Of Reckless Renovations
IAQ Issues Associated With Masonry Shafts

Careless and Unsupervised Remodels Spur Much Larger Issues
IAQ Issues Associated With Sheetrock Shafts

- Water damage and staining caused by discontinuous shafts have caused several of the bottom caps to rot out and significantly increase stack effect.
- Mold growth in several lower portions of the shafts.
- Uncontrolled Air flowing from the exhaust shafts back INTO the units, often contains mold spores, friable asbestos fibers, bacteria, viruses, and other unsafe contaminants.
IAQ Issues Associated With Sheetrock Shafts

If not addressed in a timely manor, these shafts will continue to deteriorate until they become unsalvageable and remain wet to the touch.
IAQ Issues Associated With Sheetrock Shafts

Everything may appear in working order, but an investigation of the exhaust shaft must be performed.
Pandemic

- ASHRAE Keep ventilation systems running
- ASHRAE Don’t change system settings
- ASHRAE Systems must be well maintained and working correctly
- Wash your hands, cough into your elbow, PPE, face coverings
- Building Humidity? Refer to previous item
Energy Code

90.1-2007
90.1-2010
90.1-2013
90.1-2016
If you CAN’T Control the AIR
You CAN’T Control the ENERGY
Codes and Standards

Example - 900 SF 2 BR apt with 9’ Ceilings = 8,100 CUFT:

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- PHIUS (18 CFM /OCC) = 54 CFM
Energy Performance: Cost of Lost Air

- $1 \text{ft}^3 \text{ of air} = 1.08 \text{ BTU/hr/degree F}$
- Average Northern Winter $\Delta T = 30^0 - 40^0 \text{ F} \approx 40 \text{ BTU/hr}$
- Each CFM of air flow $\times 4,350 \text{ hrs/ heating season}$
  = $170,000 \text{ BTU}$ per heating season
  - 1.7 therms of natural gas
  - 50 kWh of electricity
  - 1.2 gallons of heating oil
Energy Performance: Cost of Lost Air

Annual Energy Cost per CFM of Lost Air

Building Heating System is...

- Electric Resistance: $0.225/ kWh = $10.77 PER YEAR/ CFM reduced
- Electric ASHP (COP 2.5): $4.38 PER YEAR/ CFM reduced
- Oil: $3.28/ gallon = $3.90 PER YEAR/ CFM reduced
- Natural Gas: $1.58/ Therm = $2.84 PER YEAR/ CFM reduced

Summer Cooling adds an extra 20% savings (by fuel type)

- Buildings with chillers or with common area central AC
- Buildings with PTAC units
- ASHP

Depending on fuels, cooling may offer the greater cost savings!

Note – These savings estimates are for “post production” energy that doesn’t include system losses (boiler/ chiller efficiency, condensate temps, etc.)
### Energy Performance: Reduced Ventilation Rates

“Old Code” Buildings built before 2008 have higher ventilation rates:

<table>
<thead>
<tr>
<th></th>
<th>Kitchens</th>
<th>Bathrooms</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pre-2008 Building Code</strong></td>
<td>100 CFM</td>
<td>50 CFM</td>
</tr>
<tr>
<td><strong>Revised Ventilation Rate</strong></td>
<td>50 CFM</td>
<td>35 CFM</td>
</tr>
<tr>
<td><strong>Net Reduction for Continuous Ventilation</strong></td>
<td>(50 CFM)</td>
<td>(15 CFM)</td>
</tr>
</tbody>
</table>
### Energy Performance: Reduce Ventilation Rates

#### ANNUAL Heating Savings Opportunity Per Apartment…

<table>
<thead>
<tr>
<th></th>
<th>Kitchens</th>
<th>Bathrooms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas @ $1.58/ Therm</td>
<td>$142</td>
<td>$43</td>
</tr>
<tr>
<td>#2 Heating Oil @ $3.28/ Gal.</td>
<td>$195</td>
<td>$59</td>
</tr>
<tr>
<td>Electricity @ $0.225/ kWh</td>
<td>$539</td>
<td>$162</td>
</tr>
</tbody>
</table>
Learning Objectives

At the end of this course, participants will be able to:

1. Understand the design, equipment & field considerations that help determine how central ventilation systems actually work
2. Identify the important project design considerations that lead to reliable performance in retrofit & new construction applications
3. How to design, specify & set performance objectives that can be reliably & cost-effectively achieved
4. Understand ways to inspect, evaluate & commission projects that achieve & sustain building performance objectives
Commissioning: The Ducts

Was it Built to Design?

- **Multi-unit systems are COMMERCIAL**
  - Fans designed for operating flow/ SP
  - Ducts designed for a known leakage
  - Tolerances should reflect project parameters
  - Put it in the specs

- **In-unit systems are RESIDENTIAL**
  - RESNET, PHIUS – put it in the specs
Commissioning: SMACNA Method

- Seal & Leakage Class Well Defined
- X CFM per 100SF of DUCT @ YSP
  - Duct Only - Excludes curbs, vent boxes, etc.
  - Done as sampling only throughout construction (when engineers stay on it)
- Lower volume systems with lots of ducts pass at higher leakage percentages
Commissioning: Percent of Flow Method

- Specified % of Design Flow
- Measures entire system
  - Curb to Vent
  - Test at OP – 1.5 OP
- Can test sections, but subsequent tests should include prior tests until the whole system is measured.
- Can be riskier if they wait till the system is complete
Compare Allowable Leakage

- Size: 8”
- Len: 2,500 ft
- Area: (5,236 SF)
- OP: 1” WG
- Vents: 25 @ 35CFM
- Sys Flow: 835 CFM

### SMACNA

#### 1” WG
- Class 2: 105 CFM
- Class 4: 209 CFM
- Class 8: 419 CFM

#### 1.5” WG
- Class 2: 136 CFM
- Class 4: 272 CFM
- Class 8: 545 CFM

### Percent of Flow

#### 1” WG
- 10%: 84 CFM
- 5%: 42 CFM
- 3%: 26 CFM

#### 1.5” WG
- 10%: 84 CFM
- 5%: 42 CFM
- 3%: 26 CFM
“Open Book” Commissioning

100% Testing and Verification

✓ Test system at operating pressure (up to 2 ½” WG)

✓ You can test to SMACNA Standards using identical protocol.

✓ Test In/ Seal/ Test Out – Can be witnessed by engineer or owner’s rep.
Commissioning: The Fans

ECM fans allow “tuning” of the system.

✓ Our method:
  Tachometer for fan speed
  Manometer for SP reading
  Plot on the fan curve

✓ Quick, easy, repeatable
Energy Recovery Ventilators (ERV)
Commissioning: The Vents

Establish Performance Parameters

✓ Place unit under operating conditions
  Close windows, doors
  Note overall building conditions
  Make sure the fans are operating properly

✓ Get a good seal/ get reliable readings

✓ YMMV, depending on...
  Time of year – summer VS winter conditions
  High winds – open windows, even in adjacent units!
**Commissioning: The Vents**

**Wind Pressure on a Building**

- **Typical Set Point for Rooftop Fan**
- **Operating Range of CARs**
- **20MPH breeze can shift operating range by 1/3!**

---

**Beaufort Wind Scale**

<table>
<thead>
<tr>
<th>Beaufort No.</th>
<th>Description of Wind</th>
<th>Observation</th>
<th>Wind Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Calm</td>
<td>Smoke rises vertically. The sea is mirror smooth.</td>
<td>m/s</td>
</tr>
<tr>
<td>1</td>
<td>Light Air</td>
<td>Direction of wind shown by smoke drift but not by vane. Scale-like ripples on sea, no foam on wave crests.</td>
<td>0.5 - 1.5</td>
</tr>
<tr>
<td>2</td>
<td>Light Breeze</td>
<td>Wind felt on face, leaves rustle, ordinary vanes moved by wind. Short wavelets, glassy wave crests.</td>
<td>4.0 - 5.5</td>
</tr>
<tr>
<td>3</td>
<td>Gentle Breeze</td>
<td>Leaves and small twigs in constant motion, wind extends light flag</td>
<td>5.5 - 6.5</td>
</tr>
<tr>
<td>4</td>
<td>Moderate Breeze</td>
<td>Raiser dust and loose paper, small branches moved. Fairy frequent whitecaps occur.</td>
<td>10.0 - 11.5</td>
</tr>
<tr>
<td>5</td>
<td>Fresh Breeze</td>
<td>Small trees in leaf begin to sway. Moderate waves, many white foam crests.</td>
<td>11.5 - 13.0</td>
</tr>
<tr>
<td>6</td>
<td>Strong Breeze</td>
<td>Large branches in motion, whistling heard in telegraph wires. Some spray on the sea surface.</td>
<td>13.0 - 14.5</td>
</tr>
<tr>
<td>8</td>
<td>Gale</td>
<td>Twigs broken of trees, generally impeded progress. Long streaks on foam appear on sea.</td>
<td>15.0 - 16.5</td>
</tr>
<tr>
<td>9</td>
<td>Strong gale</td>
<td>Straight structural damage, e.g., slates and chimney pots removed from the roofs. High waves, crest start to roll over.</td>
<td>16.0 - 18.0</td>
</tr>
<tr>
<td>10</td>
<td>Storm</td>
<td>Trees uprooted, considerable structural damage. Exceptionally high waves, visibility affected.</td>
<td>18.0 - 20.0</td>
</tr>
<tr>
<td>11</td>
<td>Violent Storm</td>
<td>Widespread damage</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Hurricane</td>
<td>Air is filled with spray and foam.</td>
<td></td>
</tr>
</tbody>
</table>
Car Damper Issues Observed

A four year old 20 story building located in Long Island City, with clogged CAR dampers unable to modulate.
It needs to work

• This didn’t work
It needs to work. This probably never worked well.
Built as designed

This probably never worked well.
It needs to work

Large 3'x3' hole in exhaust shaft.
Fan sizing

It needs to work

Large 3'x3' hole in exhaust shaft.
Fan sizing
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Thank You
Tom Holmes
tholmes@woodstockenergy.com

Doug Kumph
doug@petersenengineering.com

John Twomey
johnt@iaqchamps.com