WELCOME!

High MERV Filters in Central Air Handlers: Opportunities & Challenges

ROCIS PRESENTATION
HIGH MERV FILTERS WITH CENTRAL AIR HANDLERS: THE ROCIS EXPERIENCE WITH OPPORTUNITIES & CHALLENGES

National Home Performance Conference

HVAC 1  10:30 – Noon; April 24, 2018

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ROCIS (Rock-us) or (Raucous) Reducing Outdoor Contaminants in Indoor Spaces

WWW.ROCIS.ORG
WHAT IS ROCIS?

MISSION

A Southwestern Pennsylvania initiative to reduce the impact of exterior pollution in indoor spaces.
ROCIS LCMP
LOW COST MONITORING PROJECT
Low Cost Monitoring Project (LCMP) Objectives

1) Learn how low-cost air monitors empower occupants
2) Examine the impacts of outdoor pollution on indoor air
3) Explore interventions to improve indoor air quality
Making the Invisible Visible

Dylos 1700 Optical Particle Counter:
# Particles per 1/100 ft³, 1 min. resolution

2 size ranges:
> 0.5+ μm (Dylos “Total”)
> 2.5+ μm (Dylos “Large”)

Cost: $300 - 400; 1 week data storage

3 Dylos / Site

- Outside, Inside (living area) Roamer (usually bedroom)

NOTE: Scale at right is from manufacturer; not health based

Pittsburgh’s Air Quality is Poor

People Most at Risk in the U.S.
From Year-Round Particle Pollution (Annual PM$_{2.5}$)

- 8th worst city$^1$ & worst city east of the Rockies)
- Allegheny County (Pittsburgh) is 13$^{th}$ worst

1. Pittsburgh-New Castle-Weirton (PA-WV-OH)

Particles

PM₁₀: Particulate matter less than 10 µm in diameter
PM₂.₅: Particulate matter less than 2.5 µm in diameter

ROCIS LCMP Dylos: PM₀.₅+: Particulate matter is greater than 0.5 µm in diameter (1/100 of human hair!)
Indoor Median & Distribution
(Dylos Total 0.5+ µm)

15-minute avg.

More than 10 to 1 difference!
Median: ~2/3 Fair; ~1/3 Good

50% of observations are within each vertical box

Log Scale
Outdoor Median & Distribution (Dylos Total - 0.5+ µm)

15-minute avg.

~½ Poor; ½ Fair

Log Scale

50% of observations are within each vertical box
ROCIS AIR HANDLER INQUIRY
We observed that running an air handler continuously with a high MERV filter substantially dropped particle counts.

But, our question was…

Is there an easy way to determine if I can use a high MERV filter with a longer air handler run-time without causing problems (energy $, equipment durability, performance)?
ROCIS High MERV Filter – Air Handler Inquiry

We observed that running an air handler continuously with a high MERV filter substantially dropped particle counts.

But, our question was…

Is there an easy way to determine if I can use a high MERV filter with a longer air handler run-time without causing problems (energy $, equipment durability, performance)?

NO!!

Diagnostic Screen is Required
ROCIS Air Handler Inquiry:  *Context*

**SW Pennsylvania typical housing stock**

- Basements
- Mostly gas heat; central AC (oversized)
- Sheet metal ducts in basement
- Supplies & returns to each room

Implications are different w/ attic or crawlspace ducts & homes with central returns
Big Issues with 24/7 High MERV Filter

• **Air handler (AHU) energy use** can be high due to 500 to 1,500 watt-draw
  - High cost of running air handler continuously
    (360 kWh to 1080 kWh/month = ~$500 to $1500/year\(^1\))

• **Wrong blower speed**
  - Seldom set in field
  - Often defaults to high speed, not low, in continuous mode
  - Higher energy cost, less effective filtration

• **Ductwork issues** introduce additional problems
  - Static pressure too high
  - Duct leaks (energy waste & pressure-related problems)

\(^1\) $0.12/kWh
ROCIS Air Handler Inquiry

Purpose:

➢ Explore feasibility of using air handler w/ high MERV filer to reduce particle counts

➢ 1-minute resolution particle counts for 3+ weeks (0.5+ microns, 2.5+ microns)

➢ Gain experience w interventions & impact

http://rocis.org/air-handler-inquiry
Filter/AHU Inquiry: Approach

- Developed diagnostic protocol
- Over 40+ air handler systems tested to date
- Evaluate opportunity for MERV 13 plus 24/7 operation

Next up:

- Rhett Major, The Energy Doctor
  - Description of the diagnostic visit & intervention
Rhett Major
The Energy Doctor
www.energydoc.info
TheEnergyDoctor@Comcast.net
1” high MERV filters tend to be very restrictive.

We want cleaner air, but can our systems take the extra restrictions presented by the filter?
Total External Static Pressure

• TESP - AKA - External Static Pressure

• Combined highest Positive and Negative pressure External to the air handler created by the total resistance in the entire furnace/AC/duct system.

• The greater the TESP, the less the airflow.
Test Holes

Greatest Positive Pressure

Greatest Negative Pressure

Drill test holes very carefully!
Static Pressure Probe for measurement
Digital Manometer reading in Pascals

DG-700 Pressure & Flow Gauge

Device: -162.3 00
Mode: Time Avg
Heating Performance worksheet

Air Handler/furnace ____________________________
Rated Input BTU ______ Output BTU__________
Temperature Rise range ____________________________

1) Drill test holes - 3/8” (carefully located to avoid drilling into components) Check filter for cleanliness - replace if dirty

2) Start up furnace system - set to 85° - Measure spillage stop time _________ seconds
   Allow system to run for 5 - 10 minutes - remember to open interior doors after spillage test.
   As the system warms up, take static pressure measurements - IWC or Pascals

   a. Before filter ____________ (Return system)
   b. After filter ____________
   c. Before coil ____________
   d. After coil ____________ (Supply system)

3) Allowable TESP - from manufacturers nameplate ____________ (IWC x 250 = pascals)
   Measured TESP = Absolute value of [b] + [c]. ____________

   High TESP pressures indicate many possible problems - isolate where the restrictions are:

4) Ideal Return pressure - 20% of TESP ________ Measured return pressure is = a. ________

I record the static pressure measurements here, & start doing the calculations
Every furnace or air handler has the maximum static pressure on the manufacturers label. I transfer this number to my static pressure test sheets.
High Static pressure values indicate problems

Air Handler/ furnace Trane TUD120R9V5H6 2 Stage
Rated Input BTU 120,000, 78,000
Output BTU 95,000, 62,400
Temperature Rise range 35° - 65°
Filter - Carrier Electronic air cleaner

1) Static pressures: AC speed
   a. Before filter -44
   b. After filter -68
   c. Before coil +188
   d. After coil +46
   e. Wattage 630
   f. CFM 1100
Lo Heating speed
   Before filter -39
   After filter -60
   Before coil +182
   After coil +43
   Wattage 500
   CFM 870
High speed
   Before filter -48
   Before coil +189
   After filter -61
   After coil +50
   Wattage 610
   CFM NM
   constant speed
   Before filter -31
   After coil +49
   Before coil +137
   After coil +35
   Wattage 400
   CFM 740

3) Allowable TESP - from manufacturers nameplate  125
   Measured TESP  256
   242
   250
   186

   High TESP pressures indicate many possible problems - isolate where the restrictions are:

4) Ideal Return pressure - 20% of TESP
   Measured return pressure
   -44
   -39
   -48
   -31

   High values indicate return restrictions, lower values indicate duct leaks or low fan speed

5) Ideal max filter pressure drop = 20% x TESP
   Pressure drop across Filter
   24
   21
   13
   18

   High value indicates problems: Clogged or restrictive of filter - decreases airflow capacity
Measuring Watt Draw

• Clamp-on style Current Sensors (CT)
• Converts to Wattage
• Wireless monitor display
Clamp-on style Current Sensors
The wireless monitor shows the instantaneous wattage draw for the fan.

(This wattage is high, as it's capturing electric backup heat also.)
What can increase TESP?

- **Wrong fan speed**
- **Dirt** - primarily in the filter &/or coil
- **Restrictions** in the ductwork system or filter

- The greater the TESP, the less the airflow with PSC motors, or the higher the wattage draw (with ECM)
Wrong fan speed
Power Draw versus Air Flow for Tested Air Handler

Slide credit: Building Science Corporation
I check Heat-rise - to evaluate appropriateness of fan speed.
Heat Rise/Temp Rise Basics

- The slower the airflow, the greater the heat rise
- The faster the airflow, the lower the heat rise.
- Compare to Manufacture’s chart
<table>
<thead>
<tr>
<th></th>
<th>See Note Below</th>
<th>BTU/HR</th>
<th>OUTPUT SORTIE</th>
<th>Voir la Note ci-dessous</th>
<th>BTU par HRE</th>
<th>78,000</th>
<th>91,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIR TEMPERATURE RISE</td>
<td>DEG. F.</td>
<td></td>
<td>40 – 70</td>
<td>DEG. C.</td>
<td>50 – 80</td>
<td>35 – 65</td>
<td></td>
</tr>
<tr>
<td>AUGMENTATION DE LA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TEMPERATURE DE L'AIR</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>DESIGN MAX. OUTLET</td>
<td></td>
<td></td>
<td>22 – 39</td>
<td></td>
<td>28 – 44</td>
<td>19 – 36</td>
<td></td>
</tr>
<tr>
<td>AIR TEMPERATURE</td>
<td></td>
<td></td>
<td>185</td>
<td></td>
<td>195</td>
<td>195</td>
<td></td>
</tr>
<tr>
<td>MAX. D' AIR DE SORTIE</td>
<td></td>
<td></td>
<td>85</td>
<td></td>
<td>91</td>
<td>91</td>
<td></td>
</tr>
<tr>
<td>(FOR PURPOSE OF INPUT ADJUSTMENT)</td>
<td>(POUR L'ADJUSTMENT D'ENTREE)</td>
<td>MANIFOLD PRESSURE/PRESSION TUBULURE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ALTITUDE</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>0 – 4,500 FT.</td>
<td></td>
<td></td>
<td>IN. W.C. / PO C.E.</td>
<td>3.2 – 3.8</td>
<td>1.3 – 1.8</td>
<td>0.50 – 0.65</td>
<td></td>
</tr>
<tr>
<td>0 – 1372 m</td>
<td></td>
<td></td>
<td>KPa</td>
<td>0.80 – 0.95</td>
<td>0.32 – 0.42</td>
<td>0.125 – 0.162</td>
<td></td>
</tr>
<tr>
<td>4,500 – 10,000 FT.</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>1372 – 3050 m</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>MAX. HEATING EXT. STATIC PRESS. PRESS. STATIQUE EXT. MAX. EN MODE DE CHAUFFAGE</td>
<td></td>
<td></td>
<td>0.5</td>
<td></td>
<td>0.125</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MAX. INLET GAS PRESSURE</td>
<td>PRESS. MAX D'ADMISSION DE GAZ</td>
<td></td>
<td>13.6</td>
<td></td>
<td>3.39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MIN. INLET GAS PRESSURE</td>
<td>PRESS. MIN D'ADMISSION DE GAZ</td>
<td></td>
<td>4.5</td>
<td></td>
<td>1.12</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For installation in alcove or closet at Min. clearance from combustible material as shown here:

<table>
<thead>
<tr>
<th>TOP DESSUS</th>
<th>SIDES COTES</th>
<th>BACK ARRIERE</th>
<th>FRONT AVANT</th>
<th>VENT EVENT</th>
<th>FRONT SERVICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm</td>
<td>mm</td>
<td>mm</td>
<td>mm</td>
<td>mm</td>
<td>mm</td>
</tr>
<tr>
<td>25.4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>25</td>
<td>0</td>
</tr>
</tbody>
</table>

Refer to Installation Manual
Respecter les Instruction d'Installation

For installation in alcove or closet at Min. clearance from combustible material as shown here:

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<td>mm</td>
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<td>mm</td>
<td>mm</td>
<td>mm</td>
</tr>
<tr>
<td>25.4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>25</td>
<td>0</td>
</tr>
</tbody>
</table>
Adjust Fan Speeds as needed

Not as hard as you think!
Adjusting Fan Speeds

The furnace installation manual usually has a color chart to tell you which colors represents which speed.
Some models are a little more complex, they have tiny dip switches that need to be adjusted according to the desired settings.
Re-Check Heat-rise/Temp-drop
Example 1

```
Air Handler/ furnace _NUGE100BG01
Rated Capacity _100,000 / 82,000_____  
Heat Rise _40° - 70°_  
4" Merv 13 filter (4 months old)  
Ecobee thermostat - _1/2 HP PSC motor

1) Take static pressure measurements - IWC or Pascals

<table>
<thead>
<tr>
<th>Heat mode</th>
<th>mode</th>
<th>AC/ Circulation Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Before filter</td>
<td>---64---</td>
<td>a. Before filter</td>
</tr>
<tr>
<td>b. After filter</td>
<td>---176---</td>
<td>b. After filter</td>
</tr>
<tr>
<td>c. Before coil</td>
<td>---62---</td>
<td>c. Before coil</td>
</tr>
<tr>
<td>d. After blower</td>
<td>N/A</td>
<td>d. After blower</td>
</tr>
<tr>
<td>e. wattage</td>
<td>680</td>
<td>e. wattage</td>
</tr>
</tbody>
</table>

2) Allowable Total External Static Pressure - TESP - from manufacturers nameplate

---125--- (IWC x 250 = pascals) 

Measured TESP = Absolute value of [c] + [d]. 

---238---

---250---

High TESP pressures indicate many possible problems - isolate where the restrictions are:

3) Ideal Return pressures = 20% of TES 

---25---

Measured return pressure is = a 

---64---

---71---

High values indicate restrictions in return system, lower values may indicate duct leakage or low fan speed.
```
<table>
<thead>
<tr>
<th>Example 1</th>
</tr>
</thead>
</table>

4) Ideal max filter pressure drop = 20% x TESP  
Pressure drop across Filter = [b] - [a]  
| 25 | 25 |
| 112 | 117 |

High value indicates problems such as: Clogged filter or Too restrictive of filter - decreases airflow & cooling capacity

5) Ideal coil pressure drop = 40% of TESP  
Pressure drop across coil = c - b  
| 50 | 50 |
| N/A | N/A |

High values may indicate Dirty coil - inspect if possible - decreases airflow & cooling capacity

6) Ideal supply duct pressure = 20% of TESP  
Measured supply duct pressure = d.  
| 25 | 25 |
| 62 | 62 |

High values indicate restrictions in supply system. Lower values could indicate duct leakage or low fan speed

7) Dry bulb temperature from return hole  
Dry bulb temp from supply hole  
Heat rise =  
| 72.5 |  |
| 127° |  |
| 54.5 |  |
Adjust Fan Speed down
Example 1

Air Handler Rated 1/2 HP
Heat Rise 40° - 70°
4" Merv 13 filter (4 months old)
Ecobee thermostat - 1/2 HP PSC motor

1) Take static pressure measurements - IWC or Pascals

<table>
<thead>
<tr>
<th>Heat mode mode</th>
<th>AC/ Circulation Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Before filter <strong><strong>-62.5</strong></strong> (Return system)</td>
<td>a. Before filter <strong><strong>-63</strong></strong></td>
</tr>
<tr>
<td>b. After filter <strong><strong>-165</strong></strong></td>
<td>b. After filter <strong><strong>-165</strong></strong></td>
</tr>
<tr>
<td>c. Before coil <strong><strong>+56</strong></strong></td>
<td>c. Before coil <strong><strong>+55</strong></strong></td>
</tr>
<tr>
<td>d. After blower <strong><strong>N/A</strong></strong> (Supply system)</td>
<td>d. After blower <strong><strong>N/A</strong></strong></td>
</tr>
<tr>
<td>e. wattage <strong><strong>550</strong></strong></td>
<td>e. wattage <strong><strong>480</strong></strong></td>
</tr>
</tbody>
</table>

2) Allowable Total External Static Pressure - TESP - from manufacturers nameplate

—-125———
(IWC x 250 = pascals) —-125———

Measured TESP = Absolute value of [c] + [d].

—-221———

High TESP pressures indicate many possible problems - isolate where the restrictions are:

3) Ideal Return pressures = 20% of TES

—-25———
Measured return pressure is = a

—-62.5———
—-63———

High values indicate restrictions in return system, lower values may indicate duct leakage or low fan speed

Lower TESP
Example 1

Retest

4) Ideal max filter pressure drop = 20% x TESP
   Pressure drop across Filter = [b] - [a]
   
   High value indicates problems such as: Clogged filter or Too restrictive of filter - decreases airflow & cooling capacity

5) Ideal coil pressure drop = 40% of TESP
   Pressure drop across coil = c - b
   
   High values may indicate Dirty coil - inspect if possible - decreases airflow & cooling capacity

6) Ideal supply duct pressure = 20% of TESP
   Measured supply duct pressure = d.
   
   High values indicate restrictions in supply system. Lower values could indicate duct leakage or low fan speed.

7) Dry bulb temperature from return hole
   Dry bulb temp from supply hole
   Heat rise =

Lower speed = higher heat rise, and lower static pressures
What else can increase TESP?

- Dirt - primarily in the filter &/or coil
- Restrictions in the ductwork system or filter
A wider filter (4") has about four times the surface area as the 1" filter, and offers less restriction to the system.

The problem is they are expensive, so people don't want to change them as often as they ought to be changed.
Dirty Filters are a big problem
Dirty Coils are a bigger problem
Example 2

Air Handler/ furnace__GMUH150-E5A__3/4 HP
Rated Capacity _150,000 INPUT 120,000 Output__
HEAT RISE - 50°-80°
Filter - FPR -10 (MERV 12) 1" dirty

1) Take static pressure measurements - IWC or Pascals

<table>
<thead>
<tr>
<th>Fan On - Circulation Mode</th>
<th>Heat Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Before filter <strong><strong>50.8</strong></strong>_ (Return system)</td>
<td>a. Before filter <strong><strong>-47</strong></strong></td>
</tr>
<tr>
<td>b. After filter <strong><strong>-148</strong></strong>_</td>
<td>b. After filter <strong><strong>-143</strong></strong>_</td>
</tr>
<tr>
<td>c. Before coil <strong><strong>+115</strong></strong>_</td>
<td>c. Before coil <strong><strong>+101</strong></strong>_</td>
</tr>
<tr>
<td>d. After blower <strong><strong>+19</strong></strong> (Supply system)</td>
<td>d. After blower <strong><strong>+18</strong></strong>_</td>
</tr>
<tr>
<td>e. wattage <strong><strong>750</strong></strong>_</td>
<td>e. wattage <strong><strong>730</strong></strong>_</td>
</tr>
<tr>
<td>f. CFM <strong><strong>1050</strong></strong>_</td>
<td>f. CFM <strong><strong>1000</strong></strong>_</td>
</tr>
</tbody>
</table>

2) Allowable Total External Static Pressure - TESP - from manufacturers nameplate

<table>
<thead>
<tr>
<th></th>
<th>TESP (IWC x 250 = pascals)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>125</td>
</tr>
<tr>
<td></td>
<td>263</td>
</tr>
</tbody>
</table>

High TESP pressures indicate many possible problems - isolate where the restrictions are:

3) Ideal Return pressures = 20% of TES
   Measured return pressure is a
   ____50.8____  ____-47____

   High values indicate restrictions in return system, lower values may indicate duct leakage or low fan speed

4) Ideal max filter pressure drop = 20% x TESP
   Pressure drop across Filter = [b] - [a]
   ____97.2____

High value indicates problems such as: Clogged filter or Too restrictive of filter - decreases airflow & cooling capacity

Very High TESP
Example 2

This fan speed is too low & should be adjusted up – furnace shut down on high limit
But restrictions in the ductwork prevented proper airflow.
Total External Static Pressure

- What else can increase TESP?
- **Restrictions** in the ductwork system (harder to fix)
Example 2
Pre-retrofit

HVAC tech removed the dirty coil first
Example 2
Pre-retrofit
Example 2
Post-retrofit

New ductwork & filters
About $500.00
(parts and labor)
The new filter system - 4” Honeywell MERV 13 with a 1” fiberglass pre-filter

**Much** less restrictive than a clean 1” filter.
The pre-filter is there to catch the largest “boulders”, and should be changed monthly.

This enables the larger filter to last 6 months or longer.
After Improving air flow, we are able to change out the inefficient permanent split capacitor motor (PSC) with an ECM. The drop in wattage (same airflow) is often very significant.

This model also allows us to set up a very low continuous movement of air for filtration, ~400 - 700 CFM, @120 - 180 Watts of power.
Example 2

New ECM motor install - an additional $500.00 parts and labor
1) Take static pressure measurements - IWC or Pascals

<table>
<thead>
<tr>
<th>Fan On - Circulation Mode</th>
<th>Heat Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Before filter -16 (Return system)</td>
<td>a. Before filter -40</td>
</tr>
<tr>
<td>b. After filter -38</td>
<td>b. After filter -88</td>
</tr>
<tr>
<td>c. Before coil +15</td>
<td>c. Before coil +51</td>
</tr>
<tr>
<td>d. After blower +9 (Supply system)</td>
<td>d. After blower +20</td>
</tr>
<tr>
<td>e. wattage 177</td>
<td>e. wattage 644</td>
</tr>
<tr>
<td>f. CFM 720</td>
<td>f. CFM 1230</td>
</tr>
</tbody>
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2) Allowable Total External Static Pressure - TESP - from manufacturers nameplate

<table>
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<td>125</td>
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High TESP pressures indicate many possible problems - isolate where the restrictions are:

3) Ideal Return pressures = 20% of TES

<table>
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<tr>
<th>Measured return pressure is</th>
<th>-16</th>
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<tbody>
<tr>
<td>-40</td>
<td>25</td>
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High values indicate restrictions in return system, lower values may indicate duct leakage or low fan speed

4) Ideal max filter pressure drop = 20% x TESP

<table>
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<th>Pressure drop across Filter</th>
<th>22</th>
</tr>
</thead>
<tbody>
<tr>
<td>-48</td>
<td>25</td>
</tr>
</tbody>
</table>

High value indicates problems such as: Clogged filter or Too restrictive of filter - decreases airflow & cooling capacity

Example 2 - post retrofit - TESP nearly cut in half
<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>5) Ideal coil pressure drop = 40% of TESP</td>
<td>50</td>
</tr>
<tr>
<td>Pressure drop across coil = c - b</td>
<td>6</td>
</tr>
<tr>
<td>High values may indicate Dirty coil - inspect if possible - decreases airflow &amp; cooling capacity</td>
<td></td>
</tr>
<tr>
<td>6) Ideal supply duct pressure = 20% of TESP</td>
<td>25</td>
</tr>
<tr>
<td>Measured supply duct pressure = d.</td>
<td>9</td>
</tr>
<tr>
<td>High values indicate restrictions in supply system. Lower values could indicate duct leakage or low fan speed)</td>
<td></td>
</tr>
<tr>
<td>7) Dry bulb temperature from return hole</td>
<td>NO AC</td>
</tr>
<tr>
<td>Dry bulb temp from supply hole</td>
<td>71°</td>
</tr>
<tr>
<td>Heat rise =</td>
<td>147°</td>
</tr>
<tr>
<td></td>
<td>76°</td>
</tr>
<tr>
<td>Low speed Wattage <em>177</em> Cost per hour <em>$0.022</em> per year <em>$193.81</em></td>
<td></td>
</tr>
<tr>
<td><em>720</em> CFM measured w/ TruFlow CFM/ watt <em>4.07</em></td>
<td></td>
</tr>
<tr>
<td>Heating speed Wattage <em>644</em> Cost per hour <em>$0.0805</em></td>
<td></td>
</tr>
<tr>
<td><em>1230</em> CFM measured w/ TruFlow CFM/ watt <em>1.9</em></td>
<td></td>
</tr>
</tbody>
</table>

Example 2 - post retrofit

24/7 Filtration for less than $200 a year (instead of $854.00 pre-retrofit)
Example 3

What the heck?
Example 3

Air Handler/ furnace N9SE0601714A1
Rated Input BTU 60,000 Output BTU 58,000
Temperature Rise range 40-70
Filter Used High Merv 1" filter Filtrete 2200 Medium High speed

1) Take static pressure measurements - IWC or Pascals
   Continuous mode
   a. Before filter -28
   b. After filter -92
   c. Before coil +46
   d. After coil +27
   AC mode
   a. Before filter -36 (Return System)
   b. After filter -115
   c. Before coil +59
   d. After coil +28 (Supply system)

2) Allowable TESP - 125 pa (IWC x 250 = pascals)
   Measured TESP = Absolute value of [b] + [c].
   138
   174
   High TESP pressures indicate many possible problems - isolate where the restrictions are:

3) Ideal Return pressure - 20% of TESP 25
   Measured return pressure is a.
   23
   36
   High values indicate return restrictions, lower values indicate duct leaks or low fan speed

4) Ideal max filter pressure drop = 20% x TESP 25
   Pressure drop across Filter = [b] - [a]
   64
   79
   High value indicates problems: Clogged or restrictive of filter - decreases airflow capacity
Example 3

5) Ideal coil pressure drop = 40% of TESP
   Pressure drop across coil = c - d
   \[ \frac{25}{31} \]
   High values may indicate Dirty coil - inspect if possible

6) Ideal supply duct pressure = 20% of TESP
   Measured supply duct pressure = d.
   \[ \frac{21}{28} \]
   High values indicate restrictions in supply system. Lower values could indicate duct leakage or low fan speed.

Cooling speed Wattage \( \frac{590}{661.65} \) Cost per hour \( \frac{.0755}{.0665} \) Cost per year \( \frac{661.65}{583.07} \)

Circulation speed Wattage \( \frac{520}{583.07} \) Cost per hour \( \frac{.0665}{.0755} \) Cost per year \( \frac{583.07}{661.65} \)

Cooling Measured / calculated CFM \( \frac{1110}{\text{method Static pressure charts}} \)
Removing Mastic from old ductwork
Learning as I go
Replaced PSC motor with ECM
Lessons Learned: An Early Change-out

In search of an easy fix.... Don’t do this!!

Not Effective!
1) Return drop restricted due to size (8” x 25”)
2) Poor design at throat w hard 90 degree angle
2) Filter still only 16” x 25”
90 degree transition designed for better air flow; lower static (with turning vanes)
Larger return drop

2-part filter rack
(20” x 25”)
Horizontal
(4” MERV 13 + 2” pre or post filter)
Fan speed adjusted to optimize heating, cooling, & continuous performance.
RESULTS:
5 yr. old home
Significant comfort improvement!

About $1000 investment

In continuous mode:
- 3.38 CFM/watt
- TESP Pre: 138, Post: 52
- 360 Watts (reduction)
- $142/ yr. elec. use
  ($583.00 Pre)

Much Better Performance!

Example 3
BACK TO LINDA...

ROCIS AIR HANDLER INQUIRY

Results & Implications
Pre & Post – Air Handler Retrofit

### Week ending 5-24-2017 (windows open) vs. 7-31-2017, poorer outdoor counts

### INTERVENTION:
- ECM blower (lower air flow & energy cost on continuous setting)
- New return (larger 20” x 25” MERV 13 filter & pre-filter)

**Cost – labor & materials:** $1,000

### RESULTS:
- Lower CO$_2$ in bedroom
- **24/7 annual operating cost:** $131.40
Selected ROCIS Intervention Homes
Pre-Post Median Particle Count

85% Reduction in Particles!!

Pre (~) 480
Post (~) 65

Use above code (w2i9) to view data on ROCIS LMCP Data Explorer
http://rocis.org/rocis-data-explorer
Reduction due to 1) adjusting speed of existing ECM (2 cases); 2) ECM change-out (9 cases).

PSC motors & ECMs are ½ HP w/ nameplate limit of 125 Pascal's.
Air Handler Interventions
Pre-Post Continuous Watt-Draw

Use these codes (w2i9) to view particle data on ROCIS LMCP Data Explorer
http://rocis.org/rocis-data-explorer

Even lower post Watt-draws should be possible with a different ECM

71% Reduction
24/7 Filtration/AHU + Portable Air Cleaner

Pre & post: Used portable air cleaners

2,240 CFM_{50}

**Intervention 07-12-17:** ECM, new return drop w horizontal 20”x25” MERV 13 filter w/pre-filter

**Results:** Continuous Watt Draw: pre: 495, post:150; 2.71 CFM/Watt
Pressure drop over filter: 52 PA to 17.5 PA

**24/7 annual operating cost:** $164.25

**Recommendations:** increase supply-side ductwork; downsize AC when replaced
Air Handler Interventions
Pre-Post TESP (Continuous Mode)

Reduction due to 1) adjusting speed of existing ECM (2 cases); 2) ECM change-out (9 cases).

PSC motors & ECMs are ½ HP w/ nameplate limit of 125 Pascal's.
Air Handler Interventions

Pre-Post Continuous Watt-Draw

Even lower post Watt-draws should be possible with a different ECM

70% Reduction

Use these codes (e6v1) to view particle data on ROCIS LMCP Data Explorer
http://rocis.org/rocis-data-explorer
Night-time Air Handler Use

Intervention (Dec. 16-Mar. 17): ECM, return drop w/ horizontal MERV 12 filter & pre-filter

Results: Continuous Watt-draw: pre 750; post:126; 3.57 CFM/Watt

System much quieter

Annual operating cost (8 hr./day): $44/yr.

This family (b8z3) uses natural ventilation (no AHU/filter) 5+ months/year

# 0.5+ μm particles per 1/100 ft³; 15-minute avg.
What Factors Should Be Considered to Choose Longer Run Time with Higher MERV Filter?
What Factors Should Be Considered Prior to Longer Run Time with Higher MERV Filter?

1) Fan operating cost
2) TESP within name plate
3) Duct system issues, such as leaks, ducts outside conditioned space
4) Face velocity for effective filtration
5) Filter maintenance (when operated 24/7 high MERV 1” filters clog very quickly)
Filter / AHU Inquiry: Questions

- ECM selection for better energy performance
- Filter replacement issues
  ($ & performance, occupant feedback, persistence)
- Selection of appropriate filter(s) (pre/post/larger)
- Bypass (leakage) around filter
- Control strategies
  - Such as EcoBee or Nest thermostat cycling options
  - Integration w/ IAQ sensor(s) - How good is good enough?
    (How important is <1 micron particle sensitivity?)
Are ECMs the Solution?

Not by themselves…

- Even with ECMs, 24/7 operation of central AHU can have a huge adverse impact on energy use & CO₂ emissions
- Correct blower speed, TESP, & good ducts are essential
- Must avoid clogged filters & inappropriate filters
- Two of our systems with the highest watt-draw (over 1000) were ¾ HP ECMs with restricted ductwork
Items to Explore
Keep PSC vs ECM change-out?

- PSC motor set for 15 minutes/hour at higher flow or continuous at night?
- Same CADR (clean air delivery rate?)
- If so, reduction in particles may be achieved with some PSC motors, at half the intervention cost (just return drop & deeper/larger MERV 13 filter)
- **Question:** Same reduction in smaller particles or will higher face velocity affect filter performance?
When Do Filters Need to Be Replaced?

Occupant feedback tools to measure pressure drop over filter
Install when feasible & train occupants
Jury is out on effectiveness; clear labeling & reminders could increase impact
With our multi-speed ECM no impact on energy use, just air flow & TESP
What are Implications for WAP / HP / Healthy Homes?

- Integrate diagnostic w/ inspection?
- Integrate as part of healthy home intervention?
- Integrate intervention w/ HVAC upgrade?
- Or at a minimum screen for referral for full diagnostic
Big Opportunity at HVAC replacement

- Downsize HVAC to reduce TESP
- Incorporate return drop modification & option for larger, deeper filter
- Set blower speeds for optimal performance
- Address duct system shortcomings

To ponder…

- Could potential filtration health & comfort benefits add impetus to getting HVAC systems designed & installed correctly?
What are options to reach higher CFM/Watt in retrofits?

We welcome your suggestions & feedback!

A participant’s new geothermal system weighed it at 19 CFM/watt! (not our work)

This changes our perspective of what is possible … with attention to all aspects of an HVAC system design.
Intervention Summary

• These interventions can be effective; but household & HVAC screening is essential

• The **tighter** the house/building, the **greater** the **impact** of filtration…

• But, the tighter the building, the more critical it is to **control indoor sources**

• One option - shift focus from building exposure to **human exposure**, e.g., air quality in bedrooms **while people are sleeping**
Bottom Line!

Integrated solutions are needed to enhance health, resilience, energy efficiency, comfort, & durability (engagement, building tightness, source control, O&M)

Ideally, improve outdoor air quality!
Thanks to Phil Johnson & The Heinz Endowments for supporting the ROCIS initiative (Reducing Outdoor Contaminants in Indoor Spaces) and Our 180+ Project Participants!
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Range Hood Brief
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Questions?

http://ROCIS.org/

- White papers & presentations
- Access to resources & research results
  - LCMP  http://rocis.org/rocis-low-cost-monitoring-project
  - ROCIS Brief - Ducted Range Hood (Tom Phillips)  
    - http://rocis.org/kitchen-range-hoods
  - Air Handler Inquiry  http://rocis.org/air-handler-inquiry
  - ROCIS Data  http://rocis.org/rocis-data

Stay Tuned…

ROCIS Brief - Portable Air Cleaners
Video Shorts - Telling the Story

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Infiltration of Outdoor Pollutants

Examining the interface…


Illinois Institute of Technology (For PDF: Scroll down to "other publications“): http://built-envi.com/pubs/
Resources: Filtration & Air Cleaners

Available from:
U.S. EPA's web site
http://www.epa.gov/iaq/pubs/residair.html

Residential Air Cleaners
TOPICS
✓ Building Ventilation
✓ Indoor Dampness
✓ Indoor Volatile Organic Compounds
✓ Human Performance and Productivity
✓ Benefits of Improving Indoor Environmental Quality
✓ Air Cleaning Effects on Health and Perceived Air Quality
✓ Climate Change, Indoor Environmental Quality, & Health

https://iaqscience.lbl.gov/
Current Trends: Outdoor & Indoor AQ

- Worse outdoor air quality
- More frequent and larger wildfires
- More and a longer pollen season
- Hotter, longer, and more frequent heat waves
- More exposure time indoors
- Increasing population density and proximity to traffic & industrial emissions