Filter/AHU Inquiry: *Approach*

- Developed diagnostic protocol
- Over 60+ 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
We want cleaner air, but can our systems take the extra restrictions presented by the filter?
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
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.
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 more restricted the airflow.
Drill test holes very carefully!
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

-162.3 Pa
<table>
<thead>
<tr>
<th>OUTPUT</th>
<th>SORTIE</th>
</tr>
</thead>
<tbody>
<tr>
<td>78,000</td>
<td>31,000</td>
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<table>
<thead>
<tr>
<th>AIR TEMPERATURE RISE</th>
<th>AUGMENTATION DE LA TEMPERATURE DE L'AIR</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEG. F</td>
<td>40 - 70</td>
</tr>
<tr>
<td>DEG. C</td>
<td>22 - 39</td>
</tr>
</tbody>
</table>

| DESIGN MAX. OUTLET AIR TEMPERATURE CONCU POUR UNE TEMPERATURE MAX. D'AIR DE SORTIE DE |
|------------------------------------------|-------------------------------|
| DEG. F | 185 | 195 | 195 |
| DEG. C | 91 | 91 | |

**FOR PURPOSE OF INPUT ADJUSTMENT**

<table>
<thead>
<tr>
<th>ALTITUDE</th>
<th>MANIFOLD PRESSURE/PRESSION TUBULURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 4,500 FT.</td>
<td>IN. W.C. / PO C.E.</td>
</tr>
<tr>
<td></td>
<td>3.2 - 3.8</td>
</tr>
<tr>
<td>0 - 1,372 m</td>
<td>KPa</td>
</tr>
<tr>
<td>4,500 - 10,000 FT.</td>
<td>13,72 - 3,050 m</td>
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<tr>
<td>REFER TO INSTALLATION MANUAL</td>
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<td>RESPECT LES INSTRUCTION D'INSTALLATION</td>
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<td>KPa</td>
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<td>0.5</td>
<td>3.39</td>
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<tr>
<td>0.125</td>
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**MAX. HEATING EXT. STATIC PRESS.**

**PRESS. STATIQUE EXT. MAX. EN MODE DE CHAUFFAGE**

**MAX. INLET GAS PRESSURE**

**PRESS. MAX D'ADMISSION DE GAZ**

**MIN. INLET GAS PRESSURE**

**PRESS. MIN D'ADMISSION DE GAZ**

For installation in alcove or closet at Min. clearance from combustible material as shown here.
<table>
<thead>
<tr>
<th>OUTPUT</th>
<th>76,000</th>
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<tbody>
<tr>
<td>AIR TEMPERATURE RISE</td>
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<td>DESIGN MAX. OUTLET AIR TEMPERATURE</td>
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<td>185</td>
</tr>
<tr>
<td>CONCU POUR UNE TEMPERATURE MAX. D'AIR DE SORTIE DE</td>
<td>DEG. C</td>
<td>85</td>
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<tr>
<td>0 - 1372 m</td>
<td>KPa</td>
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<td>4,500 - 10,000 FT.</td>
<td>1372 - 3050 m</td>
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**MANIFOLD PRESSURE/PRESSION TUBULURE**

| 0 - 4,500 FT. | IN. W.C. / PO C.E. |
| 0 - 1372 m | KPa |
| 4,500 - 10,000 FT. | 1372 - 3050 m |

**MAX. HEATING EXT. STATIC PRESS.**

- Press. statique ext. max. en mode de chauffage: 0.5
- Press. min. d'admission de gaz: 0.125

**MAX. INLET GAS PRESSURE**

- Press. max. d'admission de gaz: 13.6

**MIN. INLET GAS PRESSURE**

- Press. min. d'admission de gaz: 4.5

For installation in alcove or closet at Min. clearance from combustible material as shown here.
Every furnace or air handler has the maximum static pressure on the manufacturers label. I transfer this number to my static pressure test sheets.
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. ________
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
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   ____________

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

4) Ideal Return pressure - 20% of TESP __________ Measured return pressure is = a. __________
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
   a. Before filter -39  
   b. After filter -60  
   c. Before coil +182  
   d. After coil +43  
   e. wattage 500  
   f. CFM 870

High speed
   a. Before filter -48  
   b. After filter -61  
   c. Before coil +189  
   d. After coil +50  
   e. wattage 610  
   f. CFM NM

Constant speed
   a. Before filter -31  
   b. After filter -49  
   c. Before coil +137  
   d. After coil +35  
   e. wattage 400  
   f. 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 -25
   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 25
   Pressure drop across Filter 24  
   21  
   13  
   18

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

High Static pressure values indicate problems
Temperature Rise range 35° - 65°
Filter - Carrier Electronic air cleaner

1) Static pressures: AC speed
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<th>High speed</th>
<th>constant speed</th>
</tr>
</thead>
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   b. After filter   | -68         | -60          | -61           | -49          |
   c. Before coil    | +188        | +182         | +189          | +137         |
   d. After coil     | -46         | +43          | -50           | +35          |
   e. Wattage        | 630         | 500          | 610           | 400          |
   f. CFM            | 1100        | 870          | 710           | 740          |

3) Allowable TESP - from manufacturers nameplate: 125
   Measured TESP: 256, 242
   High TESP pressures indicate many possible problems.
   Isolate where the restrictions are:

4) Ideal Return pressure - 20% of TESP: 25
   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: 25
   Pressure drop across Filter: 24, 21, 13, 18
   High value indicates problems: Clogged or restrictive of filter - decreases airflow capacity.
High Static pressure values indicate problems

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

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 _-25_

| 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 _25_

| 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 Transformer (CT) (OWL, Energy Detective, Sense)
Measuring Watt Draw

• Clamp-on style Current Transformer (CT) (OWL, Energy Detective, Sense)

• Converts magnetic field to Wattage
Measuring Watt Draw

- Clamp-on style Current Transformer (CT) (OWL, Energy Detective, Sense)
- Converts magnetic field to Wattage
- Wireless monitor display
Clamp-on style Current Sensor (CT)
The wireless monitor shows the instantaneous wattage draw for the fan.
The wireless monitor shows the instantaneous wattage draw for the fan.

(This wattage is high, as it's capturing electric backup heat also.)
Total External Static Pressure

- What can increase TESP?
Total External Static Pressure

• What can increase TESP?

• Wrong fan speed
Total External Static Pressure

• What can increase TESP?
  • Wrong fan speed
  • Dirt - primarily in the filter &/or coil
Total External Static Pressure

- What can increase TESP?
  - Wrong fan speed
  - Dirt - primarily in the filter &/or coil
  - Restrictions in the ductwork system or filter
Total External Static Pressure

• 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 - PSC
Wrong fan speed - PSC
Wrong fan speed - PSC
Wrong fan speed - PSC
Wrong fan speed

Right fan speed - PSC
Right fan speed - PSC
<table>
<thead>
<tr>
<th></th>
<th>DIP SWITCH SETTING</th>
<th>EXTERNAL STATIC PRESSURE</th>
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<tr>
<td></td>
<td>SW 7</td>
<td>SW 8</td>
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<tr>
<td><strong>HEATING 1ST STAGE</strong></td>
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<td>ON</td>
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<tr>
<td>MEDIUM LOW</td>
<td>OFF</td>
<td>ON</td>
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<tr>
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<td>ON</td>
<td>OFF</td>
</tr>
<tr>
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<td>HIGH</td>
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<tr>
<td>MEDIUM LOW</td>
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<td>ON</td>
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<td></td>
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<tr>
<td>NORMAL **</td>
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<tr>
<td>HIGH</td>
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**NOTES:**
* First letter may be "A" or "T"
** Factory setting
<table>
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<tr>
<th>Static Pressure - effect on ECM</th>
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<tr>
<td><strong>EXTERNAL STATIC PRESSURE</strong></td>
</tr>
<tr>
<td>CFM</td>
</tr>
<tr>
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<tr>
<td>Temp. Rise</td>
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<tr>
<td>Watts</td>
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<table>
<thead>
<tr>
<th>CFM</th>
<th>0.1</th>
<th>0.3</th>
<th>0.5</th>
<th>0.7</th>
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<tr>
<td>Temp. Rise</td>
<td>52</td>
<td>51</td>
<td>50</td>
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<td>Watts</td>
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<td>165</td>
<td>215</td>
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<td>41</td>
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<td>40</td>
<td>41</td>
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<tr>
<td>Watts</td>
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<td><strong>CFM</strong></td>
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<tr>
<td><strong>CFM</strong></td>
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<td>1120</td>
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<td>1080</td>
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I Check Heat-rise - to evaluate appropriateness of fan speed.
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<td>MAX. INLET GAS PRESSURE</td>
<td>PRESS. MAX D'ADMISSION DE GAZ</td>
<td>13.6</td>
<td>3.39</td>
</tr>
<tr>
<td>MIN. INLET GAS PRESSURE</td>
<td>PRESS. MIN D'ADMISSION DE GAZ</td>
<td>4.5</td>
<td>1.12</td>
</tr>
<tr>
<td>For installation in alcove or closet at a distance from combustible material as shown here</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOP SIDES</td>
<td>BACK</td>
<td>FRONT</td>
<td>EVENT</td>
</tr>
<tr>
<td>DESSUS</td>
<td>COTES</td>
<td>AVANT</td>
<td>AVENT</td>
</tr>
<tr>
<td>25.4</td>
<td>0</td>
<td>0</td>
<td>25</td>
</tr>
<tr>
<td>DOWFLOW W/O COIL USE SUB-BASE</td>
<td>TYPE FSP CATEGORY IV DIRECT VENT FORCED AIR FURNACE</td>
<td>KGASBG201ALL</td>
<td></td>
</tr>
<tr>
<td>DEBIT DESCENDANT SANS SERPENTIN, UTILISER LA BASE</td>
<td>TYPE FSP CATÉGORIE IV, GÉNÉRATEUR D'AIR CHAUD A ÉVACUATION DIRECTE ET A AIR FORCE</td>
<td>KGAP5201VSP</td>
<td></td>
</tr>
<tr>
<td>FACTORY AUTHORIZED GAS CONVERSION KITS</td>
<td>ENSEMBLES DE CONVERSION AU GAZ AUTORIES PAR L'USINE</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Heat Rise/Temp Rise Basics

- The slower the airflow (thru the heat exchanger) the greater the heat rise.
Heat Rise/Temp Rise Basics

• The slower the airflow (thru the heat exchanger) the greater the heat rise.

• The faster the airflow, the lower the heat rise.
Heat Rise/Temp Rise Basics

- The slower the airflow (thru the heat exchanger) the greater the heat rise.
- The faster the airflow, the lower the heat rise.
- Compare this heat-rise to Manufacture’s spec on furnace.
Adjust Fan Speeds as needed
Adjust Fan Speeds as needed

Not as hard as you think!
Adjusting Fan Speeds

**THERMOSTAT HEAT ANTICIPATION SETTINGS**

<table>
<thead>
<tr>
<th>SS AMP HONEYWELL VALVE</th>
<th>50 AMP WHITE-RODGERS VALVE</th>
</tr>
</thead>
</table>

**JACKPLUG CHART**

| J20 | JACK/PLUG GAS |
| J1  | JACK/PLUG BURNER CONTROL |
| J2  | JACK/PLUG BLOWER DECK |
| J3  | JACK/PLUG COND. AIR BLOWER |
| J4  | JACK/PLUG IND. BLOWER |
| J5  | JACK/PLUG IGNITION |

**BLOWER SPEED CHART**

<table>
<thead>
<tr>
<th>UNIT</th>
<th>COOL</th>
<th>HEAT</th>
<th>FACTORY CONNECTED SPEED TAPS</th>
<th>MOTOR SPEEDS AVAILABLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>02</td>
<td>BLACK</td>
<td>YELLOW</td>
<td>RED</td>
<td>BROWN</td>
</tr>
<tr>
<td>02/4</td>
<td>BLACK</td>
<td>YELLOW</td>
<td>BROWN</td>
<td>4</td>
</tr>
<tr>
<td>02/7</td>
<td>BLACK</td>
<td>YELLOW</td>
<td>BROWN</td>
<td>5</td>
</tr>
<tr>
<td>02/10</td>
<td>BLACK</td>
<td>YELLOW</td>
<td>BROWN</td>
<td>BLUE</td>
</tr>
<tr>
<td>02/14</td>
<td>BLACK</td>
<td>YELLOW</td>
<td>BROWN</td>
<td>BLUE</td>
</tr>
<tr>
<td>02/16</td>
<td>BLACK</td>
<td>YELLOW</td>
<td>BROWN</td>
<td>BLUE</td>
</tr>
<tr>
<td>02/18</td>
<td>BLACK</td>
<td>YELLOW</td>
<td>BROWN</td>
<td>BLUE</td>
</tr>
</tbody>
</table>

**BLOWER SPEED SELECTION**

- LOW
- MEDIUM
- HIGH

**SPEED TAPS**

- BLACK
- BROWN
- BLUE
- YELLOW
Adjusting Fan Speeds

The furnace installation manual usually has a color chart to tell you which colors represent which speed.
Adjusting Fan Speeds

The furnace installation manual usually has a color chart to tell you which colors represent 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 or mode</th>
<th>AC/ Circulation Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Before filter</td>
<td>a. Before filter</td>
</tr>
<tr>
<td>b. After filter</td>
<td>b. After filter</td>
</tr>
<tr>
<td>c. Before coil</td>
<td>c. Before coil</td>
</tr>
<tr>
<td>d. After blower</td>
<td>d. After blower</td>
</tr>
<tr>
<td>e. wattage</td>
<td>e. wattage</td>
</tr>
</tbody>
</table>

- a. Before filter: -64 (Return system)  
- b. After filter: -176  
- c. Before coil: +62  
- d. After blower: N/A  
- e. wattage: 680  
- a. Before filter: -71  
- b. After filter: -188  
- c. Before coil: +62  
- d. After blower: N/A  
- e. wattage: 840

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

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

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

- 238

**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
- b. -71

*High values indicate restrictions in return system, lower values may indicate duct leakage or low fan speed*
Example 1

4) Ideal max filter pressure drop = 20% x TESP
   Pressure drop across Filter = \([b] - [a]\)
   \[\begin{array}{c}
   25 \\
   112 \\
   \end{array}\] = \[\begin{array}{c}
   25 \\
   117 \\
   \end{array}\]

   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 = \(c - b\)
   \[\begin{array}{c}
   50 \\
   \text{N/A} \\
   \end{array}\] = \[\begin{array}{c}
   50 \\
   \text{N/A} \\
   \end{array}\]

   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 = \(d.\)
   \[\begin{array}{c}
   25 \\
   62 \\
   \end{array}\] = \[\begin{array}{c}
   25 \\
   62 \\
   \end{array}\]

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

7) Dry bulb temperature from return hole
   \(72.5\)°
   Dry bulb temp from supply hole
   \(127°\)
   Heat rise = \(54.5\)

Low heat rise
Adjust Fan Speed down
2/8/17 - adjusted
Air Handler/ furnace NUGE100BG01 1/2 HP
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>AC/ Circulation Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Before filter  62.5 (Return system)</td>
<td>a. Before filter  63</td>
</tr>
<tr>
<td>b. After filter  165</td>
<td>b. After filter  165</td>
</tr>
<tr>
<td>c. Before coil  65</td>
<td>c. Before coil  55</td>
</tr>
<tr>
<td>d. After blower N/A (Supply system)</td>
<td>d. After blower N/A</td>
</tr>
<tr>
<td>e. wattage  550</td>
<td>e. wattage  480</td>
</tr>
</tbody>
</table>

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

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

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

<table>
<thead>
<tr>
<th>Measured return pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 (25 - 62.5 - 63)</td>
</tr>
</tbody>
</table>

High values indicate restrictions in return system, lower values may indicate duct leakage or low fan speed.
Lower speed = higher heat rise, and lower static pressures

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 =
What else can increase TESP?

- Dirt - primarily in the filter &/or coil
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
Example 2
Pre-retrofit
What else can increase TESP?

- Dirt - primarily in the filter &/or coil
- Restrictions in the ductwork system or filter
**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 <em><strong><strong>-60.8</strong></strong></em> (Return system)</td>
<td>a. Before filter <em><strong><strong>-47</strong></strong></em></td>
</tr>
<tr>
<td>b. After filter <em><strong><strong>-148</strong></strong></em></td>
<td>b. After filter <em><strong><strong>-143</strong></strong></em></td>
</tr>
<tr>
<td>c. Before coil <em><strong><strong>+115</strong></strong></em></td>
<td>c. Before coil <em><strong><strong>+101</strong></strong></em></td>
</tr>
<tr>
<td>d. After blower <em><strong><strong>+19</strong></strong></em> (Supply system)</td>
<td>d. After blower <em><strong><strong>+18</strong></strong></em></td>
</tr>
<tr>
<td>e. wattage <em><strong><strong>750</strong></strong></em></td>
<td>e. wattage <em><strong><strong>730</strong></strong></em></td>
</tr>
<tr>
<td>f. CFM <em><strong><strong>1050</strong></strong></em></td>
<td>f. CFM <em><strong><strong>1000</strong></strong></em></td>
</tr>
</tbody>
</table>

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

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>IWC x 250 = pascals</td>
<td></td>
</tr>
<tr>
<td>125</td>
<td>125</td>
</tr>
<tr>
<td>263</td>
<td>244</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:**  
25  
**25**  

*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]**  
25  
25  
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.

| 5) Ideal coil pressure drop = 40% of TESP | 50 | 50 |
| Pressure drop across coil = c - b | 97 | 83 |

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

| 6) Ideal supply duct pressure = 20% of TESP | 25 | 25 |
| Measured supply duct pressure = d. | 19 | 18 |

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

| 7) Dry bulb temperature from return hole | NO AC |
| Dry bulb temp from supply hole | 85° |
| Heat rise = | 160°+ |
| | 75°+ |

Low speed Wattage 750 Cost per hour $0.0975 per year $ 854.1

1050 CFM measured w/ TruFlow CFM/watt 1.4

Heating speed Wattage 730 Cost per hour $0.0949

1000 CFM measured w/ TruFlow CFM/watt 1.37
Total External Static Pressure

- What else can increase TESP?
- Restrictions in the ductwork system (harder to fix)
Dirty Coils are a bigger problem
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 replacement 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
Example 2

- post retrofit
- TESP nearly cut in half

Air Handler/ furnace GMUH150-E5A 3/4 HP ECM
Rated Capacity 150,000 INPUT 120,000 Output
HEAT RISE - 50°-80°
Filter - New MERV 13 Horizontal, with pre-filter.

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-</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</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>
</table>

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

<table>
<thead>
<tr>
<th>IWC x 250 = pascals</th>
</tr>
</thead>
<tbody>
<tr>
<td>125</td>
</tr>
<tr>
<td>139</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

<table>
<thead>
<tr>
<th>25</th>
<th>-16</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>-40</td>
</tr>
</tbody>
</table>

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]

<table>
<thead>
<tr>
<th>25</th>
<th>22</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>48</td>
</tr>
</tbody>
</table>

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 =
   
   Low speed Wattage _177_  Cost per hour _$0.022_  per year _$193.81_
   _720_ CFM measured w/ TruFlow  CFM/watt _4.07_
   Heating speed Wattage _644_ Cost per hour _$0.0805_
   _1230_ CFM measured w/ TruFlow  CFM/watt _1.9_

Example 2 - post retrofit

24/7 Filtration for less than $200 a year (instead of $854.00 pre-retrofit)
Example 3
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_______  a. Before filter _____-36_______ (Return System)
   b. After filter _____-92_______
   c. Before coil _____+46_______  c. Before coil _____+59_______
   d. After coil _____+27_______

   AC mode
   a. Before filter _____-36_______
   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_______

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

   174

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

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

Cooling speed Wattage \[ 590 \]
Cost per hour \[ $0.0755 \]
Cost per year \[ 661.65 \]

Circulation speed Wattage \[ 520 \]
Cost per hour \[ $0.0665 \]
Cost per year \[ $583.07 \]

Cooling Measured / calculated CFM \[ 1110 \] 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”
Best Practices
Horizontal Filter Box
MERV 13

Horizontal Filter Box

Inside Radius

Outside Radius

Or Turning Vanes
- Horizontal Filter Box

Flexible Duct Connection

Inside Radius

Outside Radius

OR Turning Vanes
Custom Made Transition

- Horizontal Filter Box

Flexible Duct Connector

Inside Radius

Outside Radius

OR Turning Vanes
90 degree transition designed for better airflow; lower static (with turning vanes)
2-part filter rack
(20” x 25”)
Horizontal
(4” MERV 13 +
2” pre or post filter)

Larger return drop
Fan speed adjusted to optimize heating, cooling, & continuous performance.
Much Better Performance!

Example 3
RESULTS:
5 yr. old home
Significant comfort improvement!

About $1000 investment
RESULTS:
5 yr. old home
Significant comfort improvement!

About $1000 investment

In continuous mode:
- 3.38 CFM/watt
- TESP Pre: 138, Post: 52
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)
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)
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)
➢ $441/yr savings
Example 4: Air Handler Retrofit 2.0

RESULTS:
In continuous mode:
➢ 4.27 CFM/watt
➢ 120 Watts
➢ Pressure drop across filter
  Pre: 93 Pa, Post: 16 Pa
➢ Allowable TESP: 125 Pa
  (total system)

Fan speed adjusted to optimize heating, cooling, & continuous performance.

Larger return drop

2-part filter rack
(20” x 25”)
Horizontal
(4” MERV 13 +
2” pre or post filter)

90 degree transition
designed for better air flow (heel & throat); lower static

ECM replacement
Opportunities at Changeout time
Opportunities at Changeout time

New Furnace
Opportunities at Changeout time

New Furnace

Adding AC
Opportunities at Changeout time

Downsize Furnace
Opportunities at Changeout time
Downsize Furnace
Change Return Drop & Filter
Example 4

1) Static pressures: AC speed  Heating speed  Fan only speed  Adjusted fan speed
   b. After filter  -160_  After filter  -115_  After filter  -160_  After filter  -117_
   c. Before coil  +66_  Before coil  +57.5_  Before coil  +66_  Before coil  +58_
   d. After coil  +38_  After coil  +37_  After coil  +38_  After coil  +32_
   e. Wattage  _340_  wattage  _223_  wattage  _340_  wattage  _189_
   f. CFM  1300  CFM  925  CFM  1300  CFM  920

3) Allowable TESP - from manufacturers nameplate  _125_
   Measured TESP  _226_  _172.5_  _226_  _175_
   High TESP pressures indicate many possible problems - isolate where the restrictions are:

4) Ideal Return pressure - 20% of TESP  _-25_
   Measured return pressure  _-61_  _-56_  _-61_  _-52_
   High values indicate return restrictions, lower values indicate duct leaks or low fan speed

5) Ideal max filter pressure drop = 20% x TESP  _-25_
   Pressure drop across Filter  _99_  _59_  _99_  _65_
   High value indicates problems: Clogged or restrictive of filter - decreases airflow capacity

6) Ideal coil pressure drop = 40% of TESP  _-50_
   Pressure drop across coil  _28_  _19.5_  _28_  _26_
   High values may indicate  Dirty coil - inspect if possible

7) High dust conditions - remove  80% of TESP pressure  _-25_
Example 4

1) Static pressures: AC speed
   a. Before filter _-61_
   b. After filter _-160_
   c. Before coil __+66_
   d. After coil __+38_
   e. Wattage __340_
   f. CFM _1300_

   Heating speed
   a. Before filter _-61_
   b. After filter _-115_
   c. Before coil __+57.5_
   d. After coil __+37_
   e. Wattage __223_
   f. CFM _925_

   Fan only speed
   a. Before filter _-61_
   b. After filter _-160_
   c. Before coil __+66_
   d. After coil __+38_
   e. Wattage __340_
   f. CFM _1300_

   Adjusted fan speed
   a. Before filter _-52_
   b. After filter _-117_
   c. Before coil __+58_
   d. After coil __+32_
   e. Wattage __189_
   f. CFM _920_

3) Allowable TESP - from manufacturers nameplate __125__
   Measured TESP __226__ __172.5__ __226__ __175__
   High TESP pressures indicate many possible problems - isolate where the restrictions are:

4) Ideal Return pressure - 20% of TESP __-25__
   Measured return pressure __-61__ __-56__ __-61__ __-52__
   High values indicate return restrictions, lower values indicate duct leaks or low fan speed

5) Ideal max filter pressure drop = 20% x TESP __25__
   Pressure drop across Filter __99__ __59__ __99__ __65__
   High value indicates problems: Clogged or restrictive of filter - decreases airflow capacity

6) Ideal coil pressure drop = 40% of TESP __50__
   Pressure drop across coil __28__ __19.5__ __28__ __26__
   High values may indicate Dirty coil - inspect if possible

7) Ideal return duct static pressure 30% of TESP - __25__
Example 4

1) Static pressures: AC speed
   a. Before filter -61
   b. After filter -160
   c. Before coil +66
   d. After coil +38
   e. Wattage 340
   f. CFM 1300

2) Heating speed
   a. Before filter -61
   b. After filter -115
   c. Before coil +57.5
   d. After coil +37
   e. Wattage 223
   f. CFM 925

3) Fan only speed
   a. Before filter -160
   b. After filter -117
   c. Before coil +66
   d. After coil +38
   e. Wattage 340
   f. CFM 1300

4) Adjusted fan speed
   a. Before filter -52
   b. After filter -52
   c. Before coil 58
   d. After coil 32
   e. Wattage 189
   f. CFM 920

3) Allowable TESP - from manufacturers nameplate
   Measured TESP
   High TESP pressures indicate many possible problems - isolate where the restrictions are:
   -25
   -61
   -56
   -61
   -52

4) Ideal Return pressure - 20% of TESP
   Measured return pressure
   High values indicate return restrictions, lower values indicate duct leaks or low fan speed
   -25
   -61
   -56
   -61
   -52

5) Ideal max filter pressure drop = 20% x TESP
   Pressure drop across Filter
   High value indicates problems: Clogged or restrictive of filter - decreases airflow capacity
   25
   59
   59
   99
   65

6) Ideal coil pressure drop = 40% of TESP
   Pressure drop across coil
   High values may indicate Dirty coil - inspect if possible
   50
   19.5
   28
   26

7) Low coil pressure drop - < 20% of TESP
Flue gas
Nat. Gas
3069 ppm
20.4
0.0% ExAir
0.00
Rheem Classic Plus® Series Two-Stage Multi-position Gas Furnaces

R96T- Series
96% A.F.U.E.†
Input Rates from 40 to 115 kBTU
[11.72 to 33.71 kW]

†A.F.U.E. (Annual Fuel Utilization Efficiency) calculated in accordance with Department of Energy test procedures.
†Up to 96% A.F.U.E.
High TESP pressures indicate many possible problems - isolate where the restrictions are:

4) Ideal Return pressure - 20% of TESP
   Measured return pressure  -16  -21  -25  -16
   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  _16  _22 _27 _16
   High value indicates problems: Clogged or restrictive of filter - decreases airflow capacity

6) Ideal coil pressure drop = 40% of TESP
   Pressure drop across coil  _NA  _50  _16
   High values may indicate Dirty coil - inspect if possible

7) Ideal supply duct pressure = 20% of TESP
   Measured supply duct pressure  +20  +25  +33  +19
   High values indicate restrictions in supply system.

8) Dry bulb temperature from return hole  _68  _68
    Dry bulb temp from supply hole  _104  _98
    Heat rise  _42°  _30°

AC speed Wattage 260  Cost per hour  $0.0286
    770 CFM measured w/ TruFlow  CFM/watt 2.96
Low fire Wattage 352  Cost per hour  $0.038
    870 CFM measured w/ TruFlow  CFM/watt 2.47
High Heating Wattage 495  Cost per hour  $0.054
   1080 CFM measured w/ TruFlow  CFM/watt 2.18
High TESP pressures indicate many possible problems - isolate where the restrictions are:

4) Ideal Return pressure - 20% of TESP
   Measured return pressure
   
   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
   
   High value indicates problems: Clogged or restrictive of filter - decreases airflow capacity

6) Ideal coil pressure drop = 40% of TESP
   Pressure drop across coil
   
   High values may indicate Dirty coil - inspect if possible

7) Ideal supply duct pressure = 20% of TESP
   Measured supply duct pressure
   
   High values indicate restrictions in supply system.

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

AC speed Wattage _260_ Cost per hour $0.0286
  ______770____ CFM measured w/ TruFlow CFM/watt __2.96__
Low fire Wattage _352_ Cost per hour $0.038
  ______870____ CFM measured w/ TruFlow CFM/watt __2.47__
Hi - Heating Wattage _495_ Cost per hour $0.054
  ______1080____ CFM measured w/ TruFlow CFM/watt __2.18__
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: __16___ __22___ __27___ __16___

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

6) Ideal coil pressure drop = 40% of TESP
   Pressure drop across coil: __NA___ __NA___ __NA___ __NA___

   High values may indicate Dirty coil - inspect if possible

7) Ideal supply duct pressure = 20% of TESP
   Measured supply duct pressure: __+20___ __+25___ __+33___ __+19___

   High values indicate restrictions in supply system.

8) Dry bulb temperature from return hole: __68___ __68___
    Dry bulb temp from supply hole: __104___ __98___
    Heat rise: __42°___ __30°___

AC speed Wattage: __260__ Cost per hour: $0.0286
   CFM: __770___ CFM measured w/ TruFlow  CFM/ watt: __2.96___

Low fire Wattage: __352__ Cost per hour: $0.038
   CFM: __870___ CFM measured w/ TruFlow  CFM/ watt: __2.47___

Hi - Heating Wattage: __495__ Cost per hour: $0.054
   CFM: __1080___ CFM measured w/ TruFlow  CFM/ watt: __2.18___

Constant speed Wattage: __260__ Cost per hour: $0.0286
   Cost per Year 24/7/365: __$250.54__
   Cost at 30 min/hr: __$125.26__
   CFM: __770___ CFM measured w/ TruFlow  CFM/ watt: __2.96___
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