Data Drives Efficiency Regulation

November 14, 2014

Fan Efficiency – DOE Rule

- Fans consume 30% of commercial HVAC energy
- DOE initiates Fan efficiency regulation 6-28-11
- AMCA has been negotiating ever since
  - To develop a consensus among fan manufacturers (done)
  - To convince Efficiency Advocates & DOE
  - To sell consensus to others (AHRI, engineers, contractors, owners)
Exhibit 4: Product Selection

Operating Performance

Data from Cookware v6.0 (Loren Cook Company)

<table>
<thead>
<tr>
<th>Model</th>
<th>FEG</th>
<th>Total Efficiency</th>
<th>Operating Power (HP)</th>
<th>Budget Price</th>
<th>Operating Cost/Yr</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>365CADWDI</td>
<td>85</td>
<td>56%</td>
<td>114</td>
<td>$21,100</td>
<td>$37,797</td>
<td>2330</td>
</tr>
<tr>
<td>402CADWDI</td>
<td>85</td>
<td>62%</td>
<td>90</td>
<td>$16,100</td>
<td>$29,939</td>
<td>2850</td>
</tr>
<tr>
<td>445CADWDI</td>
<td>85</td>
<td>68%</td>
<td>74</td>
<td>$16,900</td>
<td>$24,402</td>
<td>3570</td>
</tr>
<tr>
<td>490CADWDI</td>
<td>85</td>
<td>77%</td>
<td>60</td>
<td>$17,800</td>
<td>$19,926</td>
<td>4170</td>
</tr>
<tr>
<td>540CADWDI</td>
<td>85</td>
<td>78%</td>
<td>56</td>
<td>$20,300</td>
<td>$18,401</td>
<td>5200</td>
</tr>
<tr>
<td>600CADWDI</td>
<td>85</td>
<td>81%</td>
<td>51</td>
<td>$23,800</td>
<td>$16,976</td>
<td>6310</td>
</tr>
<tr>
<td>660CADWDI</td>
<td>85</td>
<td>81%</td>
<td>50</td>
<td>$27,400</td>
<td>$16,478</td>
<td>7490</td>
</tr>
</tbody>
</table>

Operating cost based on 16 hrs/day, 250 days/year and $0.10/kw-hr

- **All sizes are FEG85** (represents the energy efficiency potential)
- **Actual efficiency at the operating point varies greatly** (larger sizes are operating close to peak efficiency)
- **This illustrates the impact proper selection has on energy efficiency**
Data Base

• 22 manufacturers – 46% of the American market

• 1.3 million fans (one line per fan, 18 columns)

• 4.4 million horsepower (85% ≥ 1 motor hp) in 2012

• Flow, Press. Power, Efficiency, Price, Size, Type

---

Initial Recommendation

• ASHRAE 90.1 – FEG 67, select within 15 pts of peak

• What are the savings?

• How do you select a fan at “0” pressure?

• Will the market respond w adverse selections?
• Fan efficiency varies widely with selection

Based on AMCA data base of 1.3 million fan selections, 45% of USA market

New Metric: Fan Efficiency Ratio

• One formula for all fans – two target efficiencies

• Accommodates low flows & pressures (like FEG)

• Tied to:
  – Total efficiency on ducted fans (flow and total pressure)
  – Static efficiency on non-ducted (flow and static pressure)
  – Regulation focused on efficiency @ design point – not an arbitrary test point or points.
Fan Efficiency Ratio (FER)
Fan Efficiency @ design pt. / Required Efficiency

\[
\text{Required Efficiency} = \left[ \frac{\text{Target Efficiency}}{\text{CFM Factor}} \right] \times \left[ \frac{\text{Pressure Factor}}{\text{CFM Factor}} \right]
\]

FER calculates a minimum required efficiency based on CFM and pressure at the design point of operation.

1. **Target Efficiency** – establishes the “upper” limit of efficiency
2. **CFM Factor** – reduces efficiency at low CFM
3. **Pressure Factor** – reduces the efficiency at low pressures

FER Capacity Factor

- Reduces efficiency requirements for small diameter fans, just like the banana curves in AMCA 205

\[
\text{Capacity Factor} = \left[ \frac{\text{CFM}}{\text{X} + \text{CFM}} \right]
\]
FER Application Factor

- Accounts for reduced efficiency for low pressure applications

Application Factor = \[ \frac{P_s}{(Y+Ps)} \]
New Metric: **Fan Efficiency Ratio**

Fan Efficiency = \( \text{flow} \times \Delta \text{pressure} / \text{power} \)

Minimum Efficiency = \( \text{flow} \times \Delta P / \text{max power} \)

Maximum Power = \( \text{flow} \times \Delta P / \text{min. efficiency} \)

**Fan Efficiency Ratio (FER)**

Maximum Power / Actual Power @ design pt.

\[
\text{Maximum Power} = \left[ \frac{\text{cfm}}{250} \right] \times \left[ \frac{\Delta \text{pressure}}{+ 0.4} \right] / \left[ \frac{\text{Target Efficiency}}{x 6343} \right]
\]

FER calculates a minimum required efficiency based only on CFM and pressure at the design point of operation.

1. **Target Efficiency** – establishes the “upper” limit of efficiency
2. **CFM Factor** – reduces efficiency at low CFM
3. **Pressure Factor** – reduces the efficiency at low pressures
Using FER for Extended Products (wire-to-air)

\[
\text{Required Overall Efficiency} = \text{Target Efficiency} \times \text{CFM Factor} \times \text{Pressure Factor} \times \text{Drive Factor}
\]

\[
\text{Maximum Allowable BHP} = \frac{(X+\text{CFM}) \times (Y+\text{Pressure})}{6343 \times \text{Target Effic.} \%}
\]

\[
kW_{\text{max}} = \frac{\text{BHP}_{\text{max}} \times 0.746}{\text{Motor, Drive, Control Efficiency}}
\]

FAN EFFICIENCY RATIO - SIMPLE

How could FER be used?

<table>
<thead>
<tr>
<th>Body</th>
<th>FER Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Federal Regulation</td>
<td>FER ≥ 1.0 at Peak &amp; Design Point</td>
</tr>
<tr>
<td>ASHRAE 90.1</td>
<td>FER ≥ 1.0 at Design Point</td>
</tr>
<tr>
<td>ASHRAE 189.1</td>
<td>FER ≥ 1.1 at Design Point</td>
</tr>
<tr>
<td>Rebates</td>
<td>FER = Savings over Baseline</td>
</tr>
</tbody>
</table>

FER = 1.10 means 10% energy savings over baseline
What does this mean to the Fan Manufacturers?

XX% of fan selections in 2012 do not meet the regulation target

- XX --- subject to negotiation (5% to 55%)
- Data reveals the relationship between
  - Target efficiency
  - Non-compliance rate
  - Reduction in connected load
  - Price impact on customer
- Most non-compliant selections can become compliant
  - With a larger fan diameter
  - With a different, more aerodynamic fan

What does this mean to the Fan Manufacturers?

American Department of Energy will

- Require Manufacturer to certify compliant range
- Require catalog data to identify compliant range
- Require Distributors/Reps to Inform Buyers
- Check Test Fans that are not third party certified
What does this mean to Fan Selections?

### Fan Performance Selection Table based on Static Pressure

<table>
<thead>
<tr>
<th>Fan Size (in.)</th>
<th>Fan Speed (rpm)</th>
<th>Fan Class</th>
<th>Fan Power (bhp)</th>
<th>Actual Total Efficiency</th>
<th>Baseline Power (bhp)</th>
<th>FER_H</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>3238</td>
<td>III</td>
<td>11.8</td>
<td>40%</td>
<td>7.96</td>
<td>0.67</td>
</tr>
<tr>
<td>20</td>
<td>2561</td>
<td>II</td>
<td>9.56</td>
<td>49%</td>
<td>7.96</td>
<td>0.83</td>
</tr>
<tr>
<td>22</td>
<td>1983</td>
<td>II</td>
<td>8.02</td>
<td>59%</td>
<td>7.96</td>
<td>0.99</td>
</tr>
<tr>
<td>24</td>
<td>1579</td>
<td>I</td>
<td>6.84</td>
<td>69%</td>
<td>7.96</td>
<td>1.16</td>
</tr>
<tr>
<td>27</td>
<td>1289</td>
<td>I</td>
<td>6.24</td>
<td>76%</td>
<td>7.96</td>
<td>1.28</td>
</tr>
<tr>
<td>30</td>
<td>1033</td>
<td>I</td>
<td>5.73</td>
<td>82%</td>
<td>7.96</td>
<td>1.39</td>
</tr>
<tr>
<td>33</td>
<td>887</td>
<td>I</td>
<td>5.67</td>
<td>83%</td>
<td>7.96</td>
<td>1.40</td>
</tr>
<tr>
<td>36</td>
<td>778</td>
<td>I</td>
<td>6.01</td>
<td>79%</td>
<td>7.96</td>
<td>1.32</td>
</tr>
</tbody>
</table>

Selections highlighted in green indicate FER_H ≥ 1.0

---

What does this mean?

### Electronic Fan Selection Software based on Total Pressure

10,000 CFM at 3.0" Pt

<table>
<thead>
<tr>
<th>Fan Size (in.)</th>
<th>Fan Speed (rpm)</th>
<th>Fan Class</th>
<th>Fan Power (bhp)</th>
<th>Actual Total Efficiency</th>
<th>Baseline Power (bhp)</th>
<th>FER_H</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>3238</td>
<td>III</td>
<td>11.8</td>
<td>40%</td>
<td>7.96</td>
<td>0.67</td>
</tr>
<tr>
<td>20</td>
<td>2561</td>
<td>II</td>
<td>9.56</td>
<td>49%</td>
<td>7.96</td>
<td>0.83</td>
</tr>
<tr>
<td>22</td>
<td>1983</td>
<td>II</td>
<td>8.02</td>
<td>59%</td>
<td>7.96</td>
<td>0.99</td>
</tr>
<tr>
<td>24</td>
<td>1579</td>
<td>I</td>
<td>6.84</td>
<td>69%</td>
<td>7.96</td>
<td>1.16</td>
</tr>
<tr>
<td>27</td>
<td>1289</td>
<td>I</td>
<td>6.24</td>
<td>76%</td>
<td>7.96</td>
<td>1.28</td>
</tr>
<tr>
<td>30</td>
<td>1033</td>
<td>I</td>
<td>5.73</td>
<td>82%</td>
<td>7.96</td>
<td>1.39</td>
</tr>
<tr>
<td>33</td>
<td>887</td>
<td>I</td>
<td>5.67</td>
<td>83%</td>
<td>7.96</td>
<td>1.40</td>
</tr>
<tr>
<td>36</td>
<td>778</td>
<td>I</td>
<td>6.01</td>
<td>79%</td>
<td>7.96</td>
<td>1.32</td>
</tr>
</tbody>
</table>
Ex. Inline Fan with high efficiency

Multiple Speed Fan Performance Curves
"Relatively High Efficiency Fan" = Large selection area

Static Pressure

Airflow

67% TE (peak)

Ex. Inline Fan with high efficiency

CFM

Total Pressure

67%

Allowable Selection Range

52%

67% TE (peak)
Ex. Inline Fan with low efficiency

Multiple Speed Fan Performance Curves
"Relatively low (Efficiency) fan" - Small selection area

Static Pressure

Airflow

54% TE (peak)

Ex. Inline Fan with low efficiency

Total Pressure

CFM

54% TE (peak)

Allowable Selection Range

39%
FER – Application Independent

DOE would control the maximum allowable fan RPM!

FER – Axial Fan

Constant Speed Adjustable Pitch Axial Fan Performance

Airflow
What does this mean to the Fan Manufacturers?

EVERY Fan is compliant in some range

EVERY Fan has a compliance window that limits it market

EVERY Fan is a candidate for design improvement
  • To increase its compliant selection range
  • To expand market access

Better Motor and Drive Efficiency Expands Compliant Range
  More so if motor enhances aerodynamics of fan

What are the drivers to redesign for more efficient fans, motors and drives?

1. Natural market pressure!
   – More aerodynamic fans will have a larger “compliance bubble” –
   – EVERY fan/motor is impacted, not just marginal fans at one test point or points.
   – More aerodynamic fan designs will be compliant using a smaller diameter, and be more cost competitive

2. Over time, regulators and building codes will increase “Fan Efficiency Ratios” (identical to raising target efficiency values)
Potential for Air System Savings

- Fan Efficiency
- Drive Efficiency
- Fan Selection
- System Effects & System Leakage
- System Design

Thank you.

Questions?