Fan Regulation Update for DOE

October 28, 2014

Exhibit 4: Product Selection

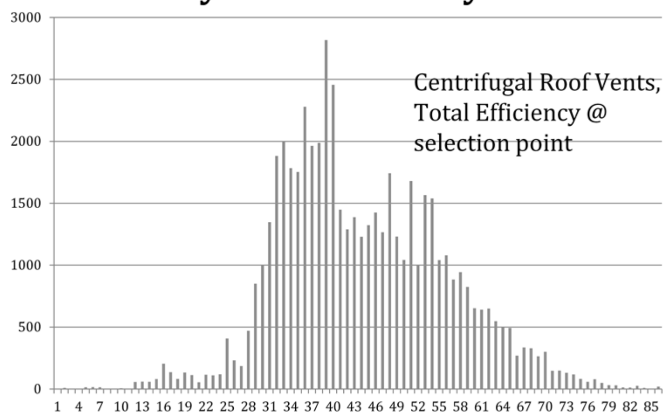
Operating Performance   Data from Cookware v6.0 (Loren Cook Company)
80,000 CFM
3.0" SP

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

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**

- Fan efficiency varies widely with selection



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

Fan Efficiency Ratio
Fan Efficiency @ design pt. / Required Efficiency

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

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

Here is what the PBER equation looks like.

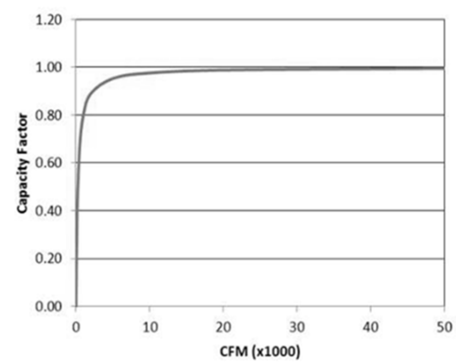
The only input variables are CFM and pressure – the two variables that engineers start with when they select a fan.

It calculates a required minimum efficiency by multiplying three factors:
- One, a Target efficiency, determined by a regulatory body
- Two, a CFM factor, which reduces the efficiency required by smaller fans, exactly the way that FEG does with the banana shaped curves
- and Three - a Pressure factor, which reduces the efficiency required for low pressure fans.

FER Capacity Factor

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

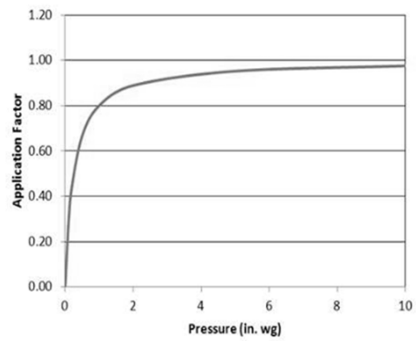
$$\text{Capacity Factor} = \left[\frac{\text{CFM}}{(\text{X}+\text{CFM})}\right]$$

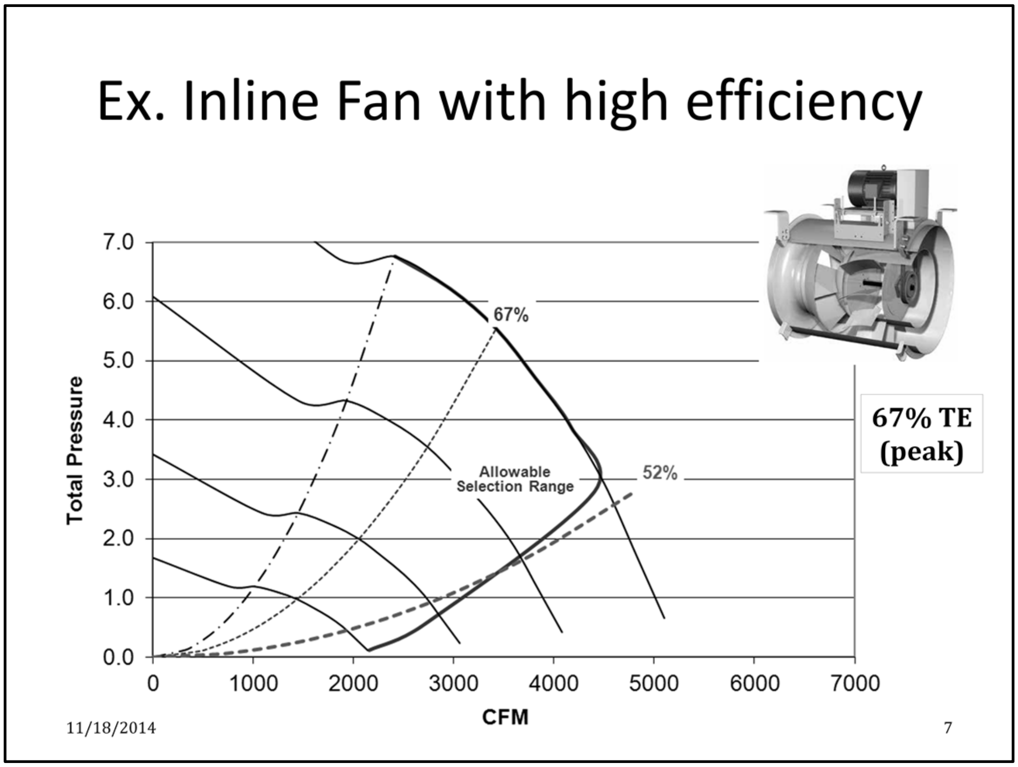


FER Application Factor

- Accounts for reduced efficiency for low pressure applications

$$\text{Application Factor} = \left[\frac{\text{Ps}}{(\text{Y}+\text{Ps})}\right]$$



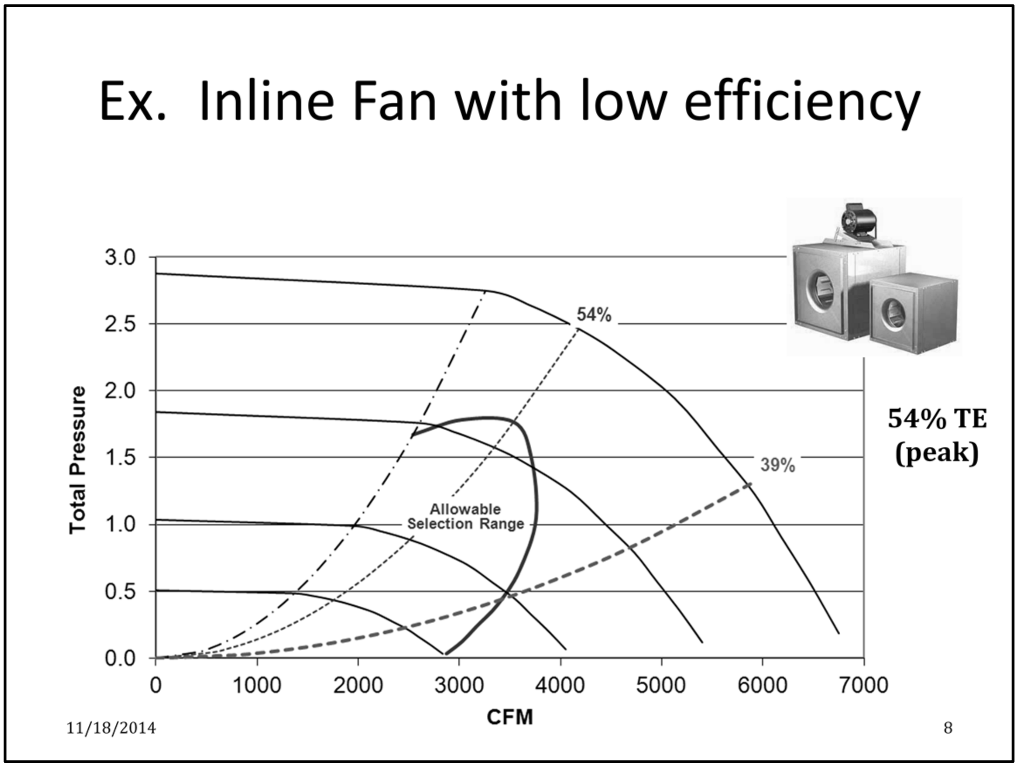


Now here is a an example of an inline fan with a high fan efficiency – a mixed flow fan.

Note that the red balloon of allowable fan selections extends all the way to the maximum fan RPM and down to about the system curve that is 15 points off the peak efficiency of 67%. If you wanted to select this inline fan for 4000 CFM at one inch of total pressure, you are outside of the red balloon and you would have to pick the next larger size.

As a fan designer, your goal would be to create as large of an area as possible within this red PBER balloon. This would give you an advantage over your competitors by being able to meet the maximum allowable horsepower with a smaller fan, and hence a lower price.

When we consider a metric based only on peak total efficiency, fan manufacturers could game the system by maximizing peak total efficiency at the expense of decreasing fan efficiency at selections points to the right of peak. The PBER equation closes this loop hole.



In this slide, I want to demonstrate the impact of applying the PBER equation onto a product.

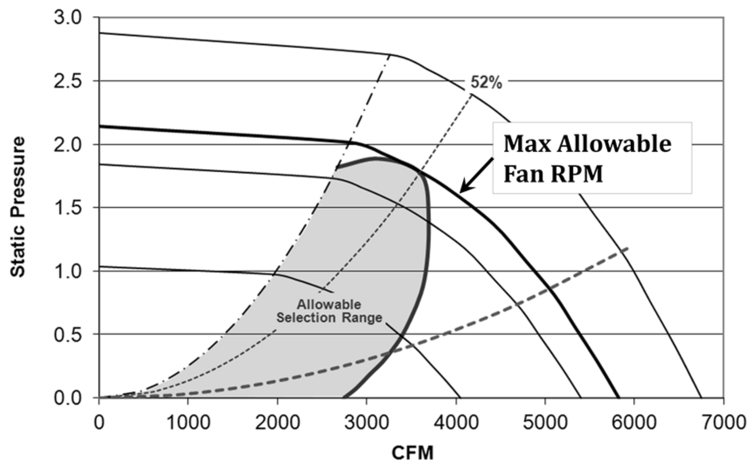
Here is a fan map of a typical square inline fan, which is a very popular low cost fan in the marketplace that unfortunately has a low fan efficiency. The solid black lines represent pressure versus CFM from the lowest cataloged fan RPM to the maximum cataloged fan RPM.

The black parabolic curve is the surge line (no fan selections are allowed to the left of that curve), the red parabolic curve is the peak total efficiency (54%) and the green parabolic curve is 15 points off peak total efficiency (39%).

Note that a regulation that required fan selections within 15 points of peak total efficiency, you could select anywhere on this fan map from the surge line to the green 39% efficiency line, bounded of course by the minimum and maximum fan RPMs.

The solid red balloon represents only that part of the fan map that selections would meet the PBER requirement. For this inefficient fan, this is a very small portion of the overall fan map. For fans over about 3600 CFM, you would be forced to a larger fan size. For fans over about an inch and three-quarters of total pressure, you would need a more efficient fan model.

PBER – Application Independent



DOE would control the maximum allowable fan RPM!

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Here again is a fan map of a relatively inefficient fan similar to the one that I showed earlier. Through an iterative process traveling along the Best Efficiency Point system curve of 52%, you would have to reduce the maximum allowable fan RPM until you just satisfied the minimum required efficiency as required by the PBER equation.

Now, instead of the maximum allowable fan RPM being controlled by the fan manufacturer, it would now be controlled and labeled on the product and in the catalog by the DOE. The DOE could not stop a customer from selecting this fan at 5000 CFM at a half an inch, but it would eliminate all fan selections on the fan map between the heavy black line labelled “Max Allowable Fan RPM” and the original maximum fan RPM.

Because our fans have efficiency curves that vary widely over their allowable selection range, any independent metric enforced by the DOE will have a small impact on energy savings. But the DOE’s acceptance of the PBER metric would set the stage for the application dependent regulations – energy codes, building codes and utility rebates – and they could save significant amounts of fan energy.

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)

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So, to summarize, there will be two important drivers for fan manufacturers to develop more efficient fans if the PBER methodology were imposed through regulation:

Number one - Natural market pressure. The more efficient of a fan you make, the smaller the size, and hence the lower first cost you will have in the market place.

Number two – over time, regulators will be raising the bar on efficiency and we will have to increase fan efficiency towards "max tech".

FAN EFFICIENCY RATIO - SIMPLE

How could FER be used?

Body	FER Requirement
DOE	FER ≥ 1.0 at Peak & Design Point
ASHRAE 90.1	FER ≥ 1.0 at Design Point
ASHRAE 189.1	FER ≥ 1.1 at Design Point
Rebates	FER = Savings over Baseline

FER = 1.10 means 10% energy savings over baseline

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Now here is how the Fan Efficiency Ratio could be used by various regulators.

The DOE could require the FER be greater than or equal to one at the Best Efficiency Point at the Maximum Fan RPM. This would be labeled on the product with an FER number greater than or equal to one on the nameplate or on a separate label. A purchaser could compare different fans – the one with the higher FER would be more efficient and most likely use less energy when applied.

ASHRAE 90.1 could demand that FER be greater or equal to one at the actual design point of operation. In this case, the fan with the higher FER would definitely use less energy. The ratio of FERs between two different fan selections would be inversely proportional to the amount of energy actually consumed.

ASRHAE 189.1, the green energy code, could demand an FER greater than or equal to 1.1, which would save exactly 10% more energy than the base code – ASHRAE 90.1.

Utility rebates could specify any level of FER and could actually calculate kw-hours per year savings over baseline based on the actual FER, actual input kW and an assumed or measured duty cycle.

Thank you.

Questions?