Regulation of Commercial/Industrial Fan Efficiency by the US Department of Energy

Fans consume 18% of the electricity purchased by industrial and commercial buildings (Figure 1). Yet, fan efficiency has escaped the attention of most who endeavor to design efficiency into the air systems they specify. That is about to change. The U.S. Department of Energy (DOE) will publish their proposed rule this year covering fans from 1 to 200 horsepower.

If you follow ASHRAE 90.1 or model energy codes, you may have discovered requirements for fan efficiency based on the metric Fan Efficiency Grade (FEG), which is tied to the fan's peak efficiency. Unfortunately, FEG has been proven inadequate to the task of lowering fan energy use. That is because the fan's performance at its peak efficiency is poorly correlated with the fan efficiency and power use at its design operating point.

The operating efficiency of every fan varies dramatically from single digits to peak levels that are over 90%. Unfortunately, a fan with a 90% peak efficiency will generally operate at lower efficiency; how low depends on where the fan is selected. The DOE will now embrace a new fan efficiency metric called the "Fan Efficiency Index" (FEI). The proposed DOE standard will establish a maximum power input that will vary by a formula tied to the design point flow and pressure.
(http://www.regulations.gov/#!documentDetail;D=EERE-2013-BT-STD-0006-0179)

FEI is the ratio of the DOE standard's maximum allowable watts into the fan motor, over the actual fan electrical power at the design point. An FEI of 1.0 or greater meets the proposed DOE regulation. An FEI of 1.1 will use 10% less energy than the DOE standard. That makes FEI especially helpful. It informs the public immediately of the percentage savings relative to a fixed benchmark of DOE regulation ---- at design conditions. FEI is deterministically linked to the fan's relative operating efficiency at design conditions.

If one were to plot the compliant operating range (Figure 2) of a fan where FEI is greater than 1.0, several interesting observations can be made that impact design practice.

1. Every fan has a compliant range. The proposed DOE regulation will not arbitrarily force any fan off the market. Instead, the proposed regulation will constrain fan applications to a compliant range.
2. Every fan has a non-compliant range. That means that manufacturers are rewarded for improving the efficiency of every fan they sell to expand the compliant range.
3. A non-compliant selection is resolved with a larger diameter fan, or one which is more aerodynamically designed. Which is a better fit with jobsite and air system requirements? Which is less expensive? Answers to these questions will change the competitive dynamic in the fan industry.

4. Since the proposed DOE standard will be “wire-to-air”, improvements in motor, transmission and variable speed drive efficiency expand the fan’s compliance envelope, making it possible to satisfy design requirements with a smaller diameter fan.
5. Owners are more likely to compare actual design conditions (and actual FEI) recorded during commissioning to those specified. Clients will have a clearer expectation of the power use of their fan, thanks to DOE regulation and the FEI metric. Getting the air system design right will become equally important.

There is much to understand in this new DOE rulemaking, and many implications to engineers’ design practices in wastewater and water treatment. This FEI metric compares the DOE determined maximum fan input power (numerator) to the actual fan power at the system design point (denominator). The DOE maximum input power requirement (DOE calls this the Fan Electrical Power standard, or FEP_{std}) is determined by a formula:

$$Maximum\ Fan\ Power = \frac{(cfm + 250) * (pressure\ rise + .4)}{(6343 * target\ efficiency)}$$

For fans that have an unducted discharge, the formula uses static pressure rise and a target static efficiency equal to 62%. For fan categories that are normally ducted, the formula will use total pressure rise and a total efficiency of 68%.

Fan power varies with the cube of any change in airflow. So, for a given air system and fan, if the flow is reduced by half, the energy draw will drop to one-eighth. Most fan systems are either on or off, but the loads they serve are continuously variable. In the case of the fan, varying the speed to match the load pays great dividends. (Essentially, the fan is oversized when running at partial speed – oversized fans are more efficient.) So, variable speed is an attractive option to improve system efficiency.

All fans offered for sale at operating conditions that require 1 bhp to nominally 200 bhp will be covered by the rule, unless they are on an exclusion list. The terms sheet recommends a long list of exclusions, either because fan energy is already part of another DOE regulation, the fan application requires a design that compromises efficiency, or because the fan type is so rarely used that its aggregate energy use was trivial.

The DOE standard will establish a maximum input power (called FEP, or Fan Electrical-input Power) that varies with flow and pressure at the fan design point. That means that the regulation applies at an infinite set of conditions, which define the particular design/selection point flows and pressure rises that are offered for sale. The maximum fan shaft power allowed at operating point i allowed by DOE will be calculated in accordance the following equation:

Where: $$FEP_{STD,i} = \frac{(Q_i+Q_0)(P_i+P_0)}{6346 * \eta_{target}}$$

$FEP_{STD,i}$ = maximum fan power at operating point i ;

Q_i = flow (cfm) at operating point i;

P_i = pressure differential at operating point i (total pressure for fans that are normally ducted, and static pressure for fans that free discharge);

Q_o = flow constant of 250 cfm;

P_o = pressure constant of 0.4" of pressure;

η_{target} = target efficiency levels to be set by DOE.

There are many impacts of the new DOE rule to system designers. The fans may shift to larger diameters, better aerodynamic efficiencies, direct driven, and/or partial widths designs to become compliant. These shifts are targeted to use less fan energy thereby less system energy.

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