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Fan Application
FA/135-25

PRODUCT APPLICATION

A technical bulletin for engineers, contractors and students in the air movement and control industry

Understanding the Fan Energy Index

What is the Fan Energy Index?

The Fan Energy Index (FEI) is a metric of energy usage for fan systems that includes motors, drives, and variable frequency drives (VFDs). It compares the electrical input power of a reference fan to that of an actual fan at a specific duty point. This metric provides a standardized way to compare the energy consumption of fan systems using the same pressure basis at the same duty point, even if the fan systems differ in size or type.

This allows FEI to be a design tool for selecting the optimal fan system from an energy perspective. Manufacturers can include FEI ratings in the data they present for comparable fans so that specifiers can make informed choices about energy efficiency. Specifiers should use FEI ratings to optimize energy consumption once they have selected a fan type based on application, duty point, space constraints, and acoustical requirements.

FEI is also a mandate that is included in energy codes and efficiency regulations. FEI was adopted in ASHRAE Standard 90.1[1] in 2019, and in the International Energy Conservation Code (IECC) in 2021. IECC requires that a third party certify FEI values presented by manufacturers to assure engineers, contractors, and facility owners that the fan will efficiently perform as stated.

As for product efficiency regulations, such as those that exist for dishwashers and air conditioners, the U.S. Department of Energy (DOE) selected FEI for its fan efficiency regulation for commercial and industrial fans. Since October 30, 2023, all voluntary representations of fan energy usage have included FEI calculated using data collected in accordance with the test procedure. DOE has not yet published an energy standard that establishes minimum FEI values for fans and blowers. However, California has. Since April 29, 2024, the California Energy Commission (CEC) has required commercial and industrial fan manufacturers to test covered fans using the DOE test procedure and meet filing and labeling requirements.[2]

Calculating the Fan Energy Index

The full calculation for FEI is described in ANSI/AMCA Standard 208, which states:

“The fan energy index (FEI) is defined as a ratio of the electrical input power of a reference fan to the electrical input power of the actual fan for which the FEI is calculated, both calculated at the same duty point, *i,* which is characterized by a value of airflow (Q_i) and pressure ($P_{t,i}$ or $P_{s,i}$). FEI can be calculated for each point on a fan curve.”

$$FEI_{t,i} \text{ or } FEI_{s,i} = \frac{\text{Reference Fan Electrical Input Power}}{\text{Actual Fan Electrical Input Power}} = \frac{FEP_{ref,i}}{FEP_{act,i}}$$

Equation 1

This ratio can be simplified further:

$$FEI = \frac{\text{Reference Electrical Input Power}}{\text{Actual Electrical Input Power}}$$

Equation 2

The next three sections describe each element of Equation 2.

Reference Electrical Input Power

The reference fan is a “reasonably efficient” conceptual fan that is used to set a consistent electrical input power level for the FEI calculation. Its electrical input power is a function of airflow and fan pressure. It also has a specified shaft input power. It has a motor efficiency based on a 4-pole 60Hz IE3[3] motor, uses a v-belt drive, and does not include a speed control.

ANSI/AMCA Standard 208[4] provides formulae to assign or calculate the following parameters:

- Reference fan electrical input power
- Reference fan shaft power
- Total pressure basis for the reference fan
- Static pressure basis for the reference fan
- Reference fan transmission efficiency
- Reference fan motor efficiency

Additionally, since the reference fan is a constant-speed fan, the motor controller efficiency is 100%. Note that FEI is calculated differently for fans rated using total pressure vs. static pressure. This is because total-pressure fans are more energy-efficient.

In AMCA 208, fans calculated using total pressure have a target efficiency of 66%, while fans calculated using static pressure have a target efficiency of 60%. Because these calculations are not necessary for applying FEI in fan selection, they are not given here but are available in Standard 208 for reference.

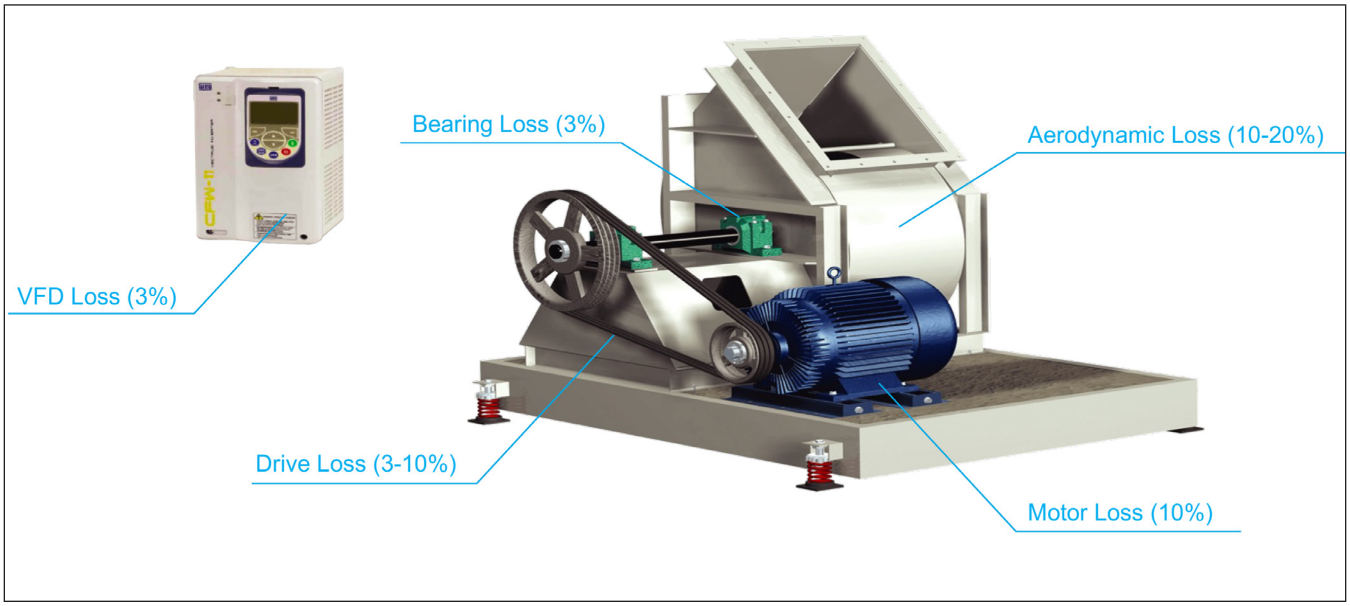
Actual Electrical Input Power

The actual electrical input power from Equation 2, rendered as FEP_{act} in Equation 1, is the actual power required to operate a fan system at a specific duty point. The duty point is defined by the airflow and pressure.

The method for determining actual electrical input power, for both a fan with a motor and a fan with a motor and speed control, is referred to by AMCA as “wire-to-air measurement.” Wire-to-Air considers all losses between the wire supplying electricity and the air output of the fan system, including efficiency losses from VFDs, motors, drives, bearings, and fan aerodynamics.

Figure 1 shows these elements measured by actual electrical input power and the approximate percentage of power loss each of them contributes.

Figure 1. Elements of a wire-to-air measurement of a fan system.



The test procedures for calculating actual electrical input power are given in a test procedure legally required in the United States for testing and rating commercial and industrial fans.[5] The central variables involved are:

- Actual fan electrical power in kW
- Actual fan shaft power in kW or HP
- Actual transmission efficiency
- Actual motor efficiency or actual combined motor/VFD efficiency, depending on whether a VFD is included

FEI Values

The FEI value is therefore the ratio of the reference electrical input power to the actual electrical input power of a fan system calculated at a specific duty point (airflow, pressure, air density). If the input electrical power of an actual fan selection is equal to the reference fan at the same duty point, the FEI is 1.00.[6] If the FEI of the actual fan selected is 1.10, it uses 10% less energy than the reference fan, and if its FEI is 0.90, it uses 10% more energy.

To illustrate FEI in action, Table 1 presents sample manufacturer data comparing FEI for multiple sizes of the same fan model for a specific design duty point.

Table 1 shows the ease of using the FEI metric in identifying efficient fans that save the most electrical input power. This example is for applying a fan with a design duty point of 10,000 cfm (4,700 l/s) at 3 in. (747 pascal) static pressure.

Observe that FEI increases as fan size increases and fan speed decreases. Larger, slower fans tend to be more energy-efficient than smaller, faster-moving fans. They also tend to have quieter sound performance. A higher FEI value is an indicator of these benefits. FEI helps identify a fan with optimized performance over a lower-performing comparable fan selection with a lower FEI (at the same duty point).

Fan Energy Index vs. Brake Horsepower

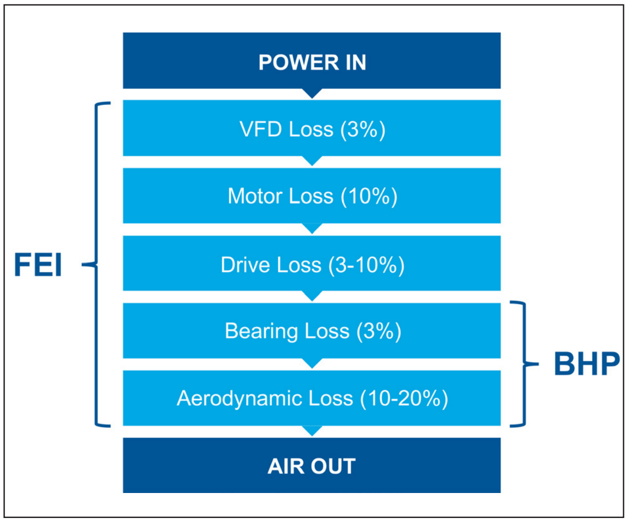
Brake horsepower (BHP) has been the main metric for fan power used in the industry for many years. BHP is, however, a limited metric. It does not measure the power of a fan system, but only the power needed to brake or stop the fan's motor, which represents the *minimum* amount of power needed to operate the fan. It is useful in sizing the motor, but it does not indicate the motor's efficiency, nor the impact of the drive, belts, pulleys, or electrical components on fan energy consumption.

Table 1

Fan Size in. (mm)	Fan Speed	Fan Power bhp (kW)	Baseline Power (kW)	FEI
18 (460)	3,238	11.8 (8.8)	7.96	0.67
20 (510)	2,561	9.6 (7.2)	7.96	0.83
22 (560)	1,983	8.0 (6.0)	7.96	0.99
24 (610)	1,579	6.8 (5.0)	7.96	1.16
27 (685)	1,289	6.2 (4.6)	7.96	1.28
30 (770)	1,033	5.7 (4.3)	7.96	1.39
36 (920)	778	6.0 (4.5)	7.96	1.32

FEI includes the efficiency of those auxiliary components to the fan. It provides a standardized method in the form of a ratio to compare the "wire-to-air" electrical usage of the whole fan system. Figure 2 below shows that brake horsepower captures bearing and aerodynamic losses, while FEI includes those as well as losses from VFDs and other controllers, motors, and drives.

Figure 2. Wire-to-Air losses in a fan with approximate "normal" losses for each component. Note that brake horsepower only accounts for 13–23% of losses.

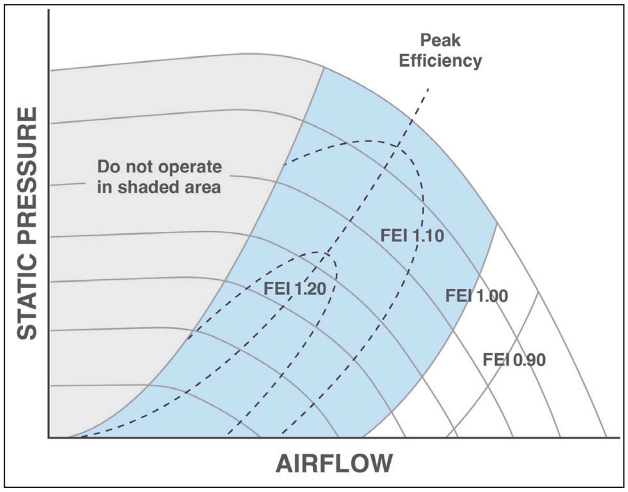


FEI and Fan Curves

Fan performance represented by the FEI metric can also be illustrated in fan curves. Figure 3 (below right) uses a series of fan curves to show a fan system that can operate at multiple speeds using a VFD. This allows for comparing how fan pressure, airflow, and FEI rating change as speed varies.

The solid lines show airflow and pressure at various speeds. The dotted lines show the operating conditions under which a fan can meet or exceed a desired FEI rating, such as 1.1 or 1.2. The blue-colored area is the "FEI bubble" that shows the compliant range at which the fan achieves peak energy efficiency at each speed. For a given fan, a higher FEI value means that the fan runs more efficiently at a central point on the fan curve. This area of the curve is also less sensitive to small changes in static pressure than points closer to either end. A selection that is more central in the fan curve provides more forgiveness against unforeseen static pressure conditions in installed air systems, which is a common concern among design engineers.[7] In essence, the higher the FEI rating, the more utility the fan can provide across a larger range of operating points, and at higher efficiencies.

Figure 3. FEI values for different operating regimes defined by airflow and static pressure for a fan controlled by a VFD. The blue shaded area shows where the fan is compliant if the minimum FEI value is set at 1.00.



Conclusion

Electric motors that power fan systems are one of the biggest energy consumers in commercial buildings, according to ASHRAE.[8] In the U.S., HVAC/R applications account for nearly 46% of electricity consumed in commercial buildings, which in turn account for 35% of energy consumption nationwide. Thus, a metric that helps to identify motor losses in fan systems can provide significant savings to the energy grid.

To ensure the energy performance of a wire-to-air fan system, document FEI values on your equipment schedule and hold them. Schedule the FEI value at the actual duty point for each fan selection. A sample schedule with an FEI column is given in Table 2.

Also, specify AMCA-certified fans that have FEI ratings. Most FEI ratings come from manufacturer selection software because FEI is calculated during the selection process to capture the variety of fan types, sizes, configurations, and motor/drive combinations. You can find the complete database of fan models with FEI certifications at https://www.amca.org/find-FEI.

Finally, FEI continues to be adopted in codes and standards across the U.S. Even if your state has not yet adopted the current code, update your specifications and schedules to include FEI for optimal performance and energy efficiency.

Table 2. Example of a typical fan schedule.

TAG	QTY	TYPE	MAKE & MODEL	CFM	" W.C.	BHP	SONES	ELECTRICAL DATA		FEI	WEIGHT (LBS)	NOTES
								V/C/P	HP			
EF 1	1	D.D. UPBLAST CENTRIFUGAL	MANUFACTURER A MODEL XX	4,300	1.50	1.69	17.3	460/60/3	3	1.53	236	1, 2, 3
EF 2	1	INLINE CENTRIFUGAL	MANUFACTURER B MODEL XX	3,600	1.25	1.44	15.5	460/60/3	2	1.47	119	1, 3
EF 3	2	D.D. CENTRIFUGAL	MANUFACTURER C MODEL XX	2,000	1.25	0.81	15.2	460/60/3	1	1.38	69	1, 2, 3
EF 4	1	D.D. CENTRIFUGAL	MANUFACTURER D MODEL XX	1,700	1.00	0.48	13.9	208/60/1	1/2	-	53	1, 2

NOTES:

1. MOTORS SHALL BE HIGH EFFICIENCY EC TYPE
2. PROVIDE WITH 12" HIGH ROOF CURB
3. FANS SHALL MEET OR EXCEED SCHEDULED FEI VALUE AND BE LICENSED TO BEAR THE AMCA CRP SEAL FOR FEI

Endnotes and References

1) *ANSI/ASHRAE/IES Standard 90.1-2022: Energy Standard For Sites And Buildings Except Low-Rise Residential Buildings - I-P Edition.* American National Standards Institute. 2022. https://webstore.ansi.org/standards/ashrae/ansiashraeies902022?source=blog&_gl=1*1brzl8b*_gcl_au*MTkyNzgzOTYzMi4xNzMzMjU0MjE3.

2) For more information on the California Title 20 regulation, visit www.energycodeace.com.

3) IE3 motors are the "premium efficiency" classification of motors and are the required minimum efficiency motor class in many countries. Characteristics include:
Output: 0.75 kW to 355 kW
Poles: 2, 4, 6, 8
Speed range: 750rpm to 3600 rpm
RPM frequency: 50Hz to 60 Hz

4) *ANSI/AMCA Standard 208-18: Calculation of the Fan Energy Index.* Air Movement and Control Association International, Inc. January 24, 2018. Accessed November 15, 2024. https://ashraemadison.org/images/meeting/101419/Presentation/amca_208_18.pdf

5) The U.S. Code of Federal Regulations established a legally required test and rating procedure for commercial and industrial fans in 10 CFR 431 Appendix A to Subpart J. The requirements apply to "voluntary" representations of an energy usage and other parameters that are linked to the test procedure, including brake horsepower, static efficiency, total efficiency, Fan Energy Index, and Fan Electrical Power. Voluntary representations include fan data required for projects and documentation for compliance with energy code requirements.

6) Note that FEI is always expressed using two decimal places, including where the trailing digit is a zero. Hence, 1.00, 1.15, and 1.99 are valid FEI representations while 1.0 and 1 are not valid.

7) Installed systems can have higher-than-anticipated static because of improper fan inlet and/or outlet conditions, additional bends and elevation changes in ductwork, more air-system leakage than planned, or a combination of any of these factors.

8) B. Rajavel, Tom Bise, and Paul Bauch: "Key Factors of Fan System Wire-to-Air Efficiency." *ASHRAE Journal,* Vol. 63, No. 12, December 2021. Accessed November 19, 2024. https://www.ashrae.org/technical-resources/ashrae-journal/featured-articles/december-2021-key-factors-of-fan-system-wire-to-air-efficiency

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