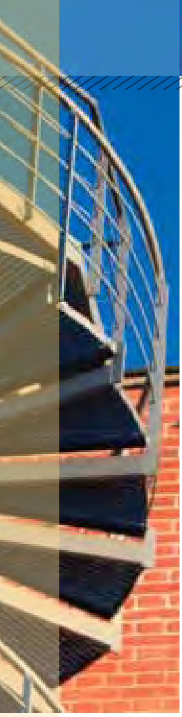

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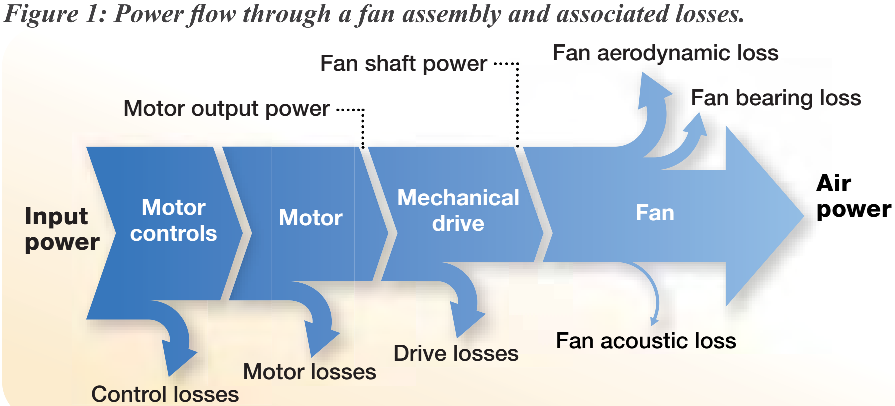
Fan Motor Efficiency Grades in the European Market

While the United States is only beginning to regulate fan efficiencies in codes, standards, and federal regulations, the European Union (EU) has fan-efficiency regulations taking effect on January 1, 2013.

The European approach is based on a metric called Fan Motor Efficiency Grade, and is very different from the direction that America is heading, which is based on a metric called Fan Efficiency Grade. This article outlines the International Standards Organization (ISO) standard that defines fan motor efficiency grades, and briefly describes how the European regulation will be applied in fan selection. Because this topic involves many definitions and calculations, a spreadsheet with sample calculations and other material has been posted online at the AMCA website at www.amca.org/feg/fmeg.aspx.

Figure 1: Power flow through a fan assembly and associated losses.



FEG refreshed

Several previous articles in AMCA's *inmotion* magazine editions have explained and discussed the efficiency classification for fans per ANSI/AMCA Standard 205-12, *Energy Efficiency Classification for Fans*. AMCA 205 defines Fan Efficiency Grades (FEG) for fans with 5 in. impeller diameters or larger and operating with a shaft power of 1 hp and above. FEG ratings represent the aerodynamic quality of a fan without the impact of the fan motor drive system. The FEG classification uses fan total pressure and consequently the total efficiency.

Fan total efficiency relates to the bare-shaft fan alone and should not be confused with overall efficiency of the complete driven fan assembly. Fan total efficiency is the product of airflow times fan total pressure divided by the fan shaft power requirement. An FEG is determined for the fan's peak total efficiency point (η_{pk}). The FEG bands embrace increasing fan total efficiency values with increasing impeller diameters. (Visit www.amca.org/feg/best-practices.aspx for previous technical articles on AMCA 205, FEGs, and fan total efficiency.)

AMCA Standard 205 is harmonized with Section 6.2 *Bare Shaft Fans* of ISO standard 12759:2010, *Fans—Efficiency classification for fans*. ISO uses the term bare-shaft fans to distinguish those from complete fan assemblies that include electric motors and, as applicable, mechanical drive systems or variable speed drives (VSDs). The remainder of ISO 12759 is devoted to Fan Motor Efficiency Grades (FMEG).

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FMEGs

The European Commission has issued several "ecodesign" codes for "Energy-Related Products." One of these codes is regulation (EU) No. 327/2011, which covers fans that are driven by motors with an electric input power between 125 W and 500 kW. This code takes effect with one set of minimum efficiency levels on January 1, 2013, and higher levels effective on January 1, 2015. This directive led to the creation of the present version of ISO 12759:2010 with FMEG.

The FMEG designation addresses the overall efficiency of an entire assembled fan system. An FMEG therefore accounts for losses in the belt drive system, in the electric motor, in the variable speed drive, and for losses from suboptimal combinations of those components (Figure 1).

FMEG ratings are based on a reference efficiency η_{ref} of the driven fan. The η_{ref} values for the FMEG limits in ISO 12759 are independent from impeller diameter but increase steadily with increasing electric input power P_e or P_{ed}.

Two methods exist to arrive at η_{ref} for the driven fan overall:

1. If the drive components are not included in the measured fan assembly, their efficiencies must be estimated. η_{ref} is the overall product of all component efficiencies multiplied, including any applicable compensation factors:

$$\eta_{overall} = \eta_{component1} \times \eta_{component2} \times \eta_{component3} \times \eta_{component4}$$

This standardized estimation method applies when the proposed driven fan has not been measured as a complete assembly. The FMEG result is based on measured fan shaft power, adjusted for loss assumptions of the motor and of the other drive system components.

2. If air performance test data and input power test data for the completely assembled driven fan are available – including electric motor, variable speed drive and mechanical transmission where applicable – then η_{ref} is the ratio of measured fan output power adjusted with the part load compensation factor C_c over the electrical input power measured during a lab test at the point of peak operating efficiency of the fan.

Fan Output Power and Installation Categories

The closer the fan test method for catalog data matches a fan's eventual application, the better its operational data will correlate with the catalog information.

The definition of a fan's discharge area influences the calculated average discharge velocity and therefore the calculated velocity pressure. The size of the discharge area for a fan tested with ducted discharge, which is installation category B or D, is self-evident. The velocity component of the fan output can be determined with certainty. Consequently, the fan air power P_u is simply the product of fan total pressure times flow rate. **Note:** The AMCA symbol for fan air power is H_o; however, the convention in ISO 12759 is the symbol P_u. Refer to www.amca.org/feg/fmeg.aspx for a table of symbol definitions and AMCA/ISO cross-references.

Fan tests per installation categories A or C use no duct on the fan discharge. Then the fan static pressure and fan static efficiency must be used. The velocity pressure is often lost in these configurations and may not contribute useful air power. As shown in Table 1, the European Commission regulation requires that the fan static air power P_{us} is used in the equations whenever the fan data are from installation category A or C tests. P_{us} is always lower than P_u and two different sets of performance minimums in the European Commission regulations compensate for it.

Point of Rating

FEG ratings are always determined at the peak fan total efficiency. However, FMEG ratings are determined either at the peak fan total efficiency or at the peak fan static efficiency, depending on the fan test installation category. Manufacturers declare the FMEG based on full fan speed and they list the chosen efficiency category: static or total.

Actual Fan Operating Point

AMCA 205 recommends that the fan be selected in the system close to the peak of the fan total efficiency η_{pk}. A proposed addendum to ANSI/ASHRAE/IES 90.1-2010 requires an FEG of 67 or greater, and selection within 15 points of peak total efficiency. A number of exceptions are also proposed in the addendum. The 2012 International Green Construction Code (IgCC) requires an FEG of 71 and selection within 10 points of peak total or peak static efficiency. (Note: Visit www.amca.org/feg/codes-and-standards.aspx for detailed information about the 90.1 addendum and the IgCC requirements.)

The European regulation, however, does not directly limit the fan selection point. Instead, an indirect mechanism discourages a poor fan selection: The higher the electrical input power, the greater the required η_{ref} to stay within a given FMEG band, and the greater the associated costs. An inefficient fan operating point would demand a needlessly more powerful and more costly motor with a larger transmission belt drive or VSD. Even the electrical panel powering this fan may require components with higher ratings.

Table 1: EU-327 Fan Air Power Assignments for Different Installation Categories.

Efficiency Category	Installation Category	Relevant Output Power
Total	B or D Ducted discharge	Fan air power P_u
Static	A or C Unducted discharge	Fan static air power P_{us}

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Table 2: Effect of Part Load Compensation Factor and Efficiency Category on the Symbols for Air Power Outputs and Electrical Inputs.

Reference Efficiency For a Driven Fan Based On Actual Test Data	Efficiency Category Total	Efficiency Category Static
Variable speed drive was installed during the test	$\eta_{ref} = \frac{P_u}{P_{ed}} \times C_c$	$\eta_{ref} = \frac{P_{us}}{P_{ed}} \times C_c$
No variable speed drive was installed during the test	$\eta_{ref} = \frac{P_u}{P_e}$	$\eta_{ref} = \frac{P_{us}}{P_e}$
Note: Estimation of the drive-end components that were not measured as one assembly are necessary in lieu of actual measurements of the complete fan assembly. In such cases, the standardized equations in Table 3 apply. Note that the calculated electric input power is used for FMEG verification.		

Fan Selection Process

FMEG considerations do not affect the initial selection method for a driven fan. The proposal for the driven fan and necessary peripherals is established first.

Either the fan air power P_u or the fan static air power P_{us} (depending on the efficiency category) is then calculated at the peak efficiency point of the fan and at full fan speed. Fan power is the product of flow rate at optimum efficiency and the fan total pressure or fan static pressure respectively.

The application dictates whether the fan will operate at a fixed speed or it will use a variable speed drive for load matching. The flow chart of Figure B.3 in ISO 12759 illustrates the FMEG verification process and the necessary inputs. The flow chart is too complex to reproduce for this article.

FMEG Verification

The EU directive allows FMEGs to be determined in different ways, depending on whether some parameters are measured or estimated.

For driven fans with available airflow and electrical input tests for the complete system, the overall efficiency of a driven fan is the ratio of the fan output power divided by its electrical input power P_e.

If the driven fan includes a variable speed drive, then the symbol for electrical input power will change from P_e to P_{ed}, which indicates that the variable speed drive losses are included in the electrical measurement, even though these are relatively small at 100% output. In return, high-efficiency electronic drives such as EC motors and all variable frequency drives with induction motors receive a credit for their energy-savings at part load operation of the fans. It is in the form of the compensation factor C_c. The value of C_c is not measured but assumed and it will increase the reference efficiency η_{ref}. Variable voltage

Table 3: Standardized Estimation Method for the Reference Efficiency from Component Efficiencies and Compensation Factors.

Reference Efficiency	$\eta_{ref} = \eta_r \times \eta_m \times \eta_T \times \eta_c \times C_c \times C_m$			
Electrical Input Power	$P_e = \frac{P_u}{\eta_{ref}}$	$P_e = \frac{P_{us}}{\eta_{ref}}$	$P_{ed} = \frac{P_u}{\eta_{ref}}$	$P_{ed} = \frac{P_u}{\eta_{ref}}$
Where:				
η_r and η_{pk} or η_{rs}	Manufacturer's catalogs indicate the optimal efficiency of bare-shaft fans either based on the static or the total efficiency category. Symbols are from ISO 12759 and AMCA 205.			
η_m	The motor efficiency is estimated with the equation B.2 in ISO 12759 unless a valid regulation minimum exists.			
η_T	The transmission efficiency is calculated with the equations in ISO 12759 table B.1 from the nominal motor output power. The actual fan shaft power is not relevant here.			
η_c	The VSD efficiency is declared by the VSD manufacturer. If no VSD is supplied with the fan system or if the VSD is only of the variable voltage type, then this factor is 1.			
C_c	The part load compensation factor is calculated based on the VSD input power at full speed of the fan assembly according to table 3 in ISO 12759.			
C_m=0.9	The compensation factor C_m is applied if the proposed fan has not been measured as a complete assembly. It reflects the anticipated losses associated with suboptimal matching of components.			

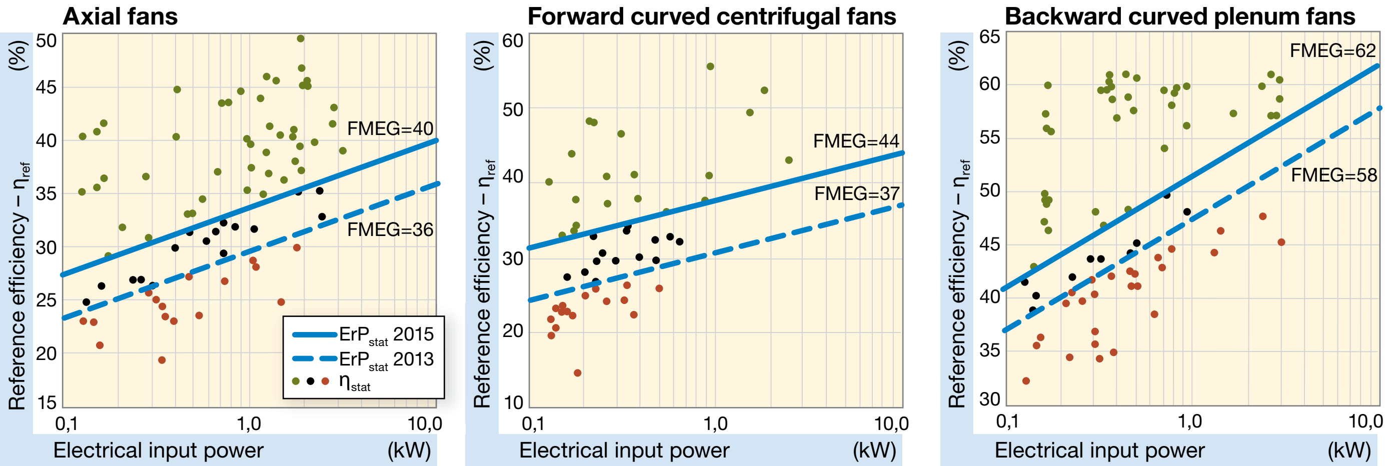

Figure 2: Reference efficiencies based on static pressure for common populations of fan assemblies in the industry today displayed against the 2-tier efficiency limits in regulation (EU) No. 327/2011.

motor speed controllers do not provide similar savings at part load and can therefore not claim this credit. These conditions are summarized in Table 2.

FMEG Lookup

ISO 12759 includes graphs for most fan types backed by equations to look up the FMEG of the proposed driven fan. The applicable reference efficiency and electrical input power values from above scenarios for the driven fan at full fan speed are inserted there.

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If the resulting FMEG does not comply with the valid legal regulation, a more efficient fan may be required.

Effect of FMEG

The impact of implementing FMEGs in EU 327/2011 is that a significant fraction of inefficient driven fans will be eliminated from the market. A random study of driven fans presently used in the European market indicated that approximately 13% will violate the first-tier requirements that become effective in January 2013. The second-tier requirements will force another 18% to disappear in 2015, for a total of 31% (Figure 2).

Conclusion:

FMEGs per ISO 12759 provide a classification of motorized fans that account for either measured or assumed losses in the motor and drive system.

Fans with inseparable motors and optional peripherals have their measured air power output compared to their measured electrical input power.

An assembly consisting of an electrical motor and a separate fan, with or without a mechanical transmission system or a variable speed device may be measured in the same way. When this test method is used, assumptions of component efficiencies become irrelevant. When only the fan shaft power is measured, a standardized equation exists to estimate the efficiency of the assembly based on assumptions of motor and drive losses.
The FMEG classification is based on full speed operation at the optimum duty point and it includes a small credit for the use of certain high-efficiency variable speed drive types.

ISO 12759 was developed to support the European Commission directive that sets forth mandatory efficiency goals and becomes effective for 27 European Union countries on January 1, 2013. The directive applies to fans sold within or imported into Europe. Even subassemblies of fans integrated in equipment will fall under this energy performance standard.