AMCA Standard 205-10

(Rev. 2011)

Energy Efficiency Classification for Fans

Approved by the AMCA Standard 205 Technical Committee on October 6, 2011

AIR MOVEMENT AND CONTROL ASSOCIATION INTERNATIONAL, INC.

The International Authority on Air System Components

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Energy Efficiency Classification for Fans

Air Movement and Control Association International
30 W. University Drive
Arlington Heights, Illinois
60004

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Air Movement and Control Association International
30 West University Drive
Arlington Heights, IL 60004-1893 U.S.A.

AMCA International, Incorporated
c/o Federation of Environmental Trade Associations
2 Waltham Court, Milley Lane, Hare Hatch
Reading, Berkshire, United Kingdom
RG10 9TH

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Translation Review

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Contents

1. Scope

This standard defines the energy efficiency classification for fans. The scope includes fans having an impeller diameter of 125 mm (5 in.) or greater, operating with a shaft power 750 W (1 hp) and above, and having a total efficiency calculated according to one of the following fan test standards: ANSI/AMCA 210, ANSI/AMCA 230, AMCA 260, or ISO 5801. All other fans are excluded. The standard only applies to the fan, not the fan drive or the fan system.

This standard can be used by legislative or regulatory bodies to define the energy efficiency requirements of fans used in specific applications.

2. Normative References

The following referenced documents shall be utilized for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ANSI/AMCA Standard 99
Standards Handbook

ANSI/AMCA Standard 210-07
Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Ratings

ANSI/AMCA Standard 230-07
Laboratory Methods of Testing Air Circulating Fans for Rating and Certification

AMCA Standard 260-07
Laboratory Methods of Testing Induced Flow Fans for Rating

IEEE 112-2004
Standard Test Procedure for Polyphase Induction Motors and Generators

IEEE 114-2001
Standard Test Procedure for Single Phase Induction Motors

ISO 5801:2007
Industrial Fans - Performance Testing Using Standardized Airways

ISO 12759:2010
Fans - Efficiency Classification for Fans

ISO 13348:2007
Industrial Fans - Tolerances, Methods of Conversion and Technical Data Presentation

ISO 13349:2008
Industrial Fans - Vocabulary and Definitions of Categories

3. Definitions / Symbols

For the purpose of this standard, the definitions, units of measure, and symbols in this section apply.

Definitions for fan pressures and efficiencies are found in the standards referenced in Section 2.

3.1 Definitions

3.1.1 Fan
A rotary machine that imparts energy to an air stream and by means of one or more impellers fitted with blades to maintain quasi continuous flow with a fan pressure rise that does not normally exceed 30 kPa (120 in. wg).

Note: The pressure limit corresponds approximately to a fan specific work of 25 kJ/kg.

3.1.2 Fan size
The design impeller diameter.

3.1.3 Fan drives (transmission, motor/control system)
Any device used to power the fan including motor, mechanical transmission (e.g. belt drive, coupling etc.), motor/control system (e.g. variable frequency controller, electronic commutator etc.).

3.1.4 Fan without drive
A fan with its impeller attached to a fan shaft supported by bearings. See Figure 1.

3.1.5 Fan with drive
A fan with drive. See Figure 2.

3.1.6 Air
Term used as abbreviation for “air or other gas”.

3.1.7 Standard air
The air with a density of 1.2 kg/m^3 (0.075 lbm/ft^3).

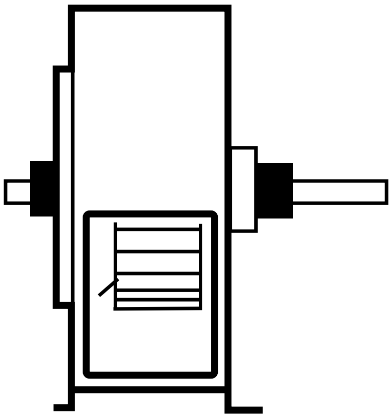
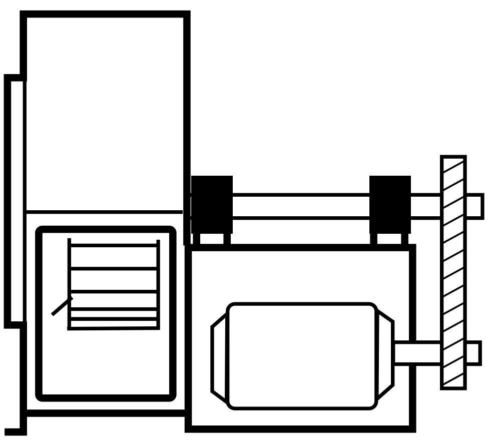


Figure 1
Fan without Drive



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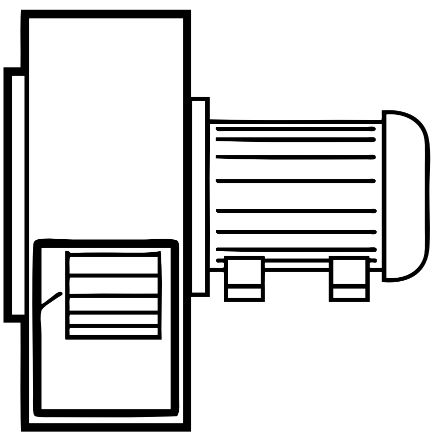

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Figure 2
Fan with Drive

3.1.8 Fan pressures

3.1.8.1 Fan total pressure, P_t

The difference between the total pressure at the fan outlet and the total pressure at the fan inlet.

3.1.8.2 Fan velocity pressure, P_v

The velocity pressure corresponding to the average velocity at the fan outlet.

3.1.8.3 Fan static pressure, P_s

The difference between the fan total pressure and the fan velocity pressure. Therefore, it is the difference between static pressure at the fan outlet and total pressure at the fan inlet.

3.1.9 Fan air power, H_o

Fan output power, which is the product of the inlet flow rate, fan total pressure, and compressibility coefficient.

Note: For incompressible flow, the compressibility coefficient is equal to 1.

3.1.10 Fan shaft power, H_{sh}

Mechanical power supplied to the fan shaft.

Note: The power loss in the fan shaft bearings is considered as a fan internal loss.

3.1.11 Fan impeller power, H_i

Motor output power supplied to the impeller of a direct driven fan where the impeller is attached to the motor shaft.

3.1.12 Fan peak efficiency, η_{pk}

Maximum fan total efficiency with the fan speed and air density being fixed.

Note: Peak efficiency can be also called optimum efficiency.

3.1.13 Fan Efficiency Grade, FEG

The efficiency grade of a fan without consideration of the drives.

3.2 Symbols

See Table 1.

4. General

4.1 Use of test installation categories

The fan test application category (test configuration) may have an impact on the determination of the fan peak efficiency. The category distinguishes arrangement of ducting to the inlet and outlet of the fan (see Table 2).

4.2 Fan energy efficiency calculations

For the purpose of this standard, the fan energy efficiency is calculated from the formulas in Sections 4.2.1 and 4.2.2.

4.2.1 Fan efficiency of a fan without drives

$$\eta_{\text{sh}} = \frac{H_o}{H_{\text{sh}}}$$

4.2.2 Fan efficiency of a direct driven fan without consideration of the drives

$$\eta_{\text{i}} = \frac{H_{\text{o}}}{H_{\text{i}}}$$

5. Efficiency classifications for fans

5.1 General

The fans within the scope of this standard shall be classified for their fan efficiency using the Fan Efficiency Grades (FEG). The FEG is an indicator of the fan's aerodynamic ability to convert shaft power, or impeller power in the case of a direct driven fan, to air power. The FEG will be most useful in evaluating the aerodynamic quality of the fan and will be the only metric useful when the fan is evaluated independently of the motor/control. This classification is a distinct metric that serves a specific purpose and allows comparison of any number of fans using this same metric. This classification shall not be used simultaneously, or interchangeably, with any other fan energy classification.

While the fan efficiency is a function of the operating point on the fan performance curve, the efficiency grades are based on the peak (optimum) efficiency. The efficiency grade is the characteristic that defines the energy usage quality of a fan and indicates the potential for minimizing the energy usage of the fan.

Different application (test) categories (test configurations) may yield different peak efficiencies. If a fan can be used in more than one of the categories, the highest peak efficiency of all the categories may be used for the classification. The test application category used for determination of the peak efficiency shall be indicated with the classification grade.

5.2 FEG Classification of fan efficiency

This classification is based on fan peak (optimum) total efficiency for a given fan speed, fan size, and application (test) category (test configuration). For the purpose of energy classification, the peak efficiency shall be determined at a speed that is lower than the maximum design speed of the

Table 1
Symbols and Subscripts

Symbol	Description	SI Unit	IP Unit
D	Impeller diameter	mm	in.
D_0	Impeller diameter for a base fan size	mm	in.
E_{year}	Annual Energy Consumption	kWh	kWh
H_i	Fan impeller power	W	hp
H_o	Fan air power	W	hp
H_{sh}	Fan shaft power	W	hp
P_s	Fan static pressure	Pa	in. wg
P_t	Fan total pressure	Pa	in. wg
P_v	Fan velocity pressure	Pa	in. wg
$\eta 85_D{}^{upp}$	Upper limit efficiency of the grade FEG85	%	%
$\eta 85_{D0}{}^{upp}$	Upper limit efficiency of the grade FEG85 of the base fan	%	%
η_i	Efficiency of direct driven fans without drives	dimensionless or %	
η_{pk}	Fan peak efficiency	dimensionless or %	
η_{sh}	Efficiency of fans without drives	dimensionless or %	
η_t	Fan total efficiency	dimensionless or %	

Table 2
Application (Test) Categories for Fans

Category	Configuration of Ducts
A	No ducts attached to the fan inlet or outlet
B	No duct attached to the fan inlet; duct attached to the fan outlet
C	Duct attached to the fan inlet; no duct attached to the fan outlet
D	Ducts attached to the fan inlet and outlet

fan. In the case of variable geometry fans, it is advisable that the FEG be determined at the physically achievable blade angle that produces maximum efficiency. The relationship between the FEG and the fan sizes is shown in Figures 3a and 3b.

A fan belongs to an FEG if, for the fan impeller diameter, the fan peak efficiency is equal to or lower than the calculated efficiency grade upper limit and higher than the calculated efficiency grade lower limit for the grade.The FEG for a given fan size and peak efficiency shall be calculated using the formulas indicated in Annex A.

For example, a fan with an impeller diameter of 500 mm (19.7 in.), at a speed of 1800 rpm, in application category C has a peak efficiency of 79%. The fan belongs in FEG85 because for the fan impeller diameter the fan efficiency is below the grade upper efficiency limit of 81.5% and higher than the grade efficiency lower limit of 76.9%.

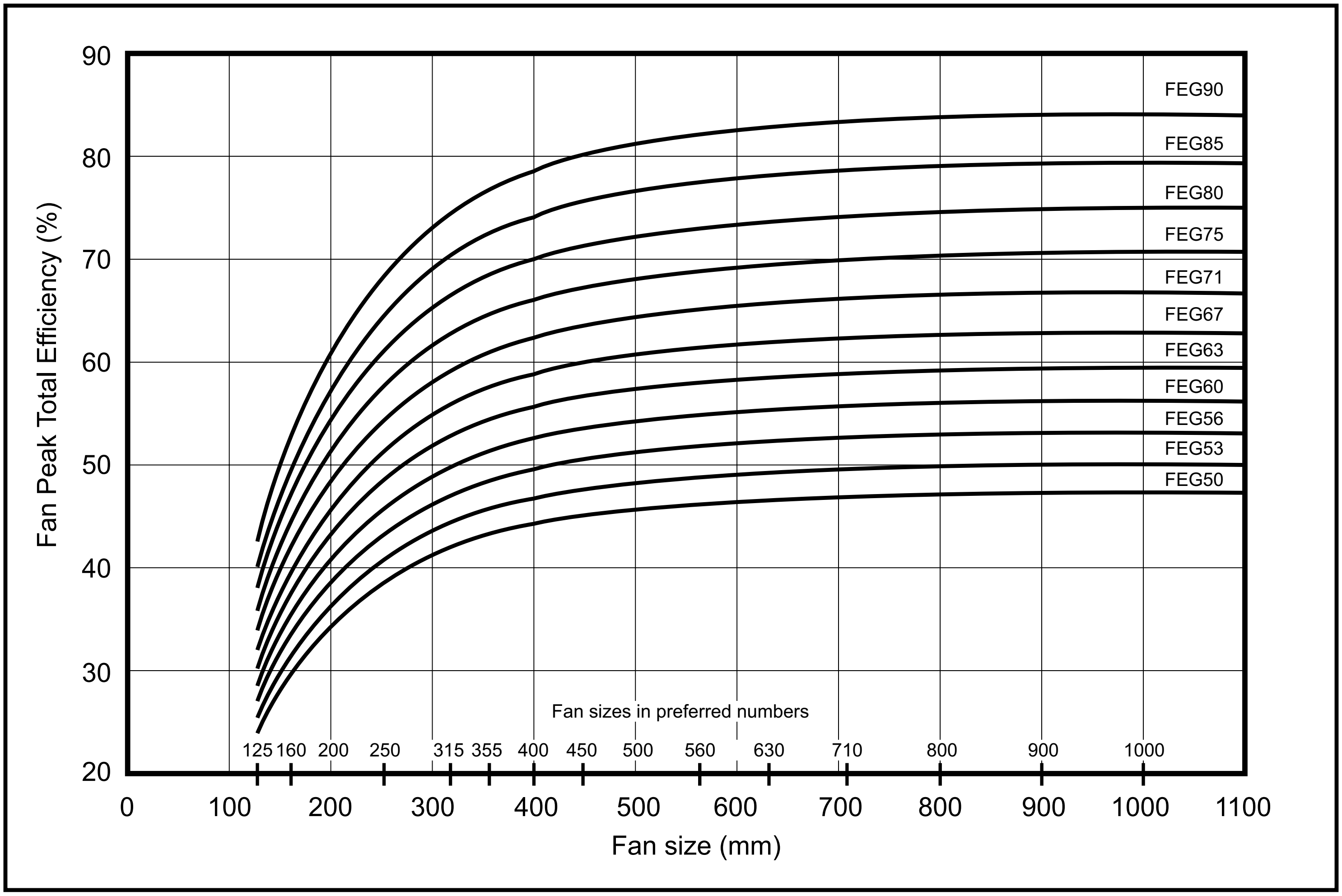
When the fan has been tested integrally with the motor, the shaft power shall be determined by measuring the input electrical power and motor efficiency, which must be determined by calibration per IEEE 112-2004 or IEEE 114-2001.

Estimation by other methods (e.g., using ratios of amperage to full load amperage, etc.) shall not be acceptable.

6. Use of Fan Efficiency Grades in Codes and Specifications

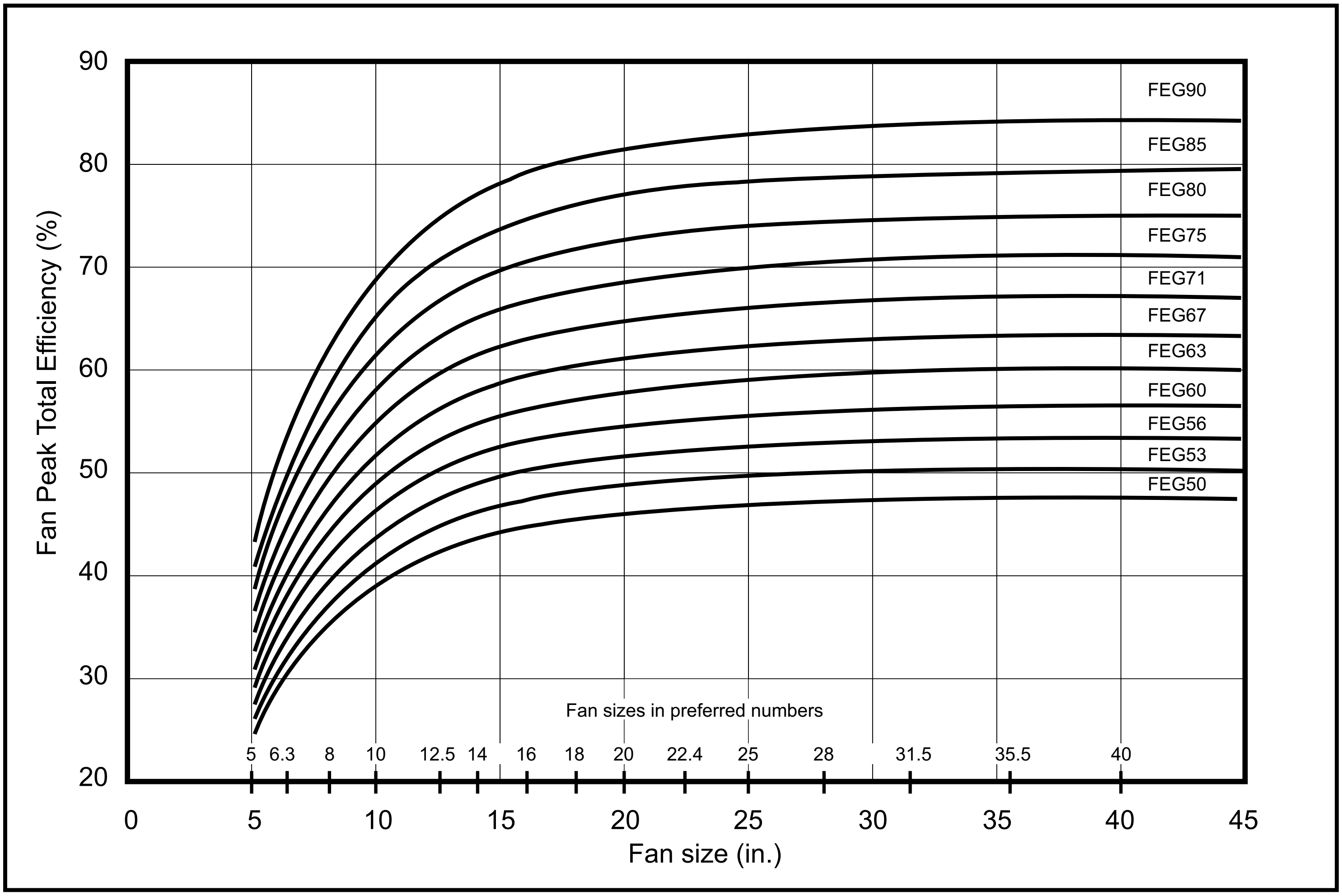
Any code or specification that requires an FEG shall also require that the fan total efficiency, at all intended operating point(s), be within a required number of points of the fan peak total efficiency. That number shall not be greater than 15 points. The restriction imposed by this limitation is explained in Annex B.

Note: For example, a certain regulation specifies a fan efficiency grade of FEG67 and also that the operational fan total efficiency shall not be more than 12 points from the fan peak total efficiency. If the fan considered for use has a peak total efficiency of 65%, then the operational fan total efficiency of that fan under this regulation shall not be below 53%.



Notes:
1. Fan size is the impeller diameter in mm.
2. The fan peak efficiency shall be calculated from the fan total pressure.
3. If this method is used for a direct driven fan, the fan efficiency is the impeller efficiency.
4. The FEG label for a given fan size is assigned when the fan peak efficiency is equal or lower than the efficiency at the grade upper limit and higher than efficiency at the grade upper limit of the next lower grade for the fan size.
5. For any fan sizes larger than 1016 mm, the values of the grade upper limits are the same as for a size of 1016 mm.
6. No labels are considered for the fans with the fan peak total efficiency below FEG50.
7. The values of efficiencies are calculated for fan sizes in the preferred R40 Series.
8. Not all fan sizes in preferred numbers shown.

Figure 3a
Fan Efficiency Grades (FEG) for Fans Without Drives (SI)



Notes:

1. Fan size is the impeller diameter in inches.
2. The fan peak efficiency shall be calculated from the fan total pressure.
3. If this method is used for a direct driven fan, the fan efficiency is the impeller efficiency.
4. The FEG label for a given fan size is assigned when the fan peak efficiency is equal or lower than the efficiency at the grade upper limit and higher than efficiency at the grade upper limit of the next lower grade for the fan size.
5. For any fan sizes larger than 40 in., the values of the grade upper limits are the same as for a size of 40 in.
6. No labels are considered for the fans with the fan peak total efficiency below FEG50.
7. The values of efficiencies are calculated for fan sizes in the preferred R40 Series.
8. Not all fan sizes in preferred numbers shown.

Figure 3b
Fan Efficiency Grades (FEG) for Fans Without Drives (IP)

The formula for calculation of the upper limit efficiencies of the grade FEG85 using the fan size as the independent variable is:

$$\eta 85_D{}^{upp} = k_0 + \left[81 + \frac{D}{k_1} - \left(\frac{D}{k_2} \right)^2 \right]^{0.5} - 112 \exp\left(-\frac{D}{k_3} \right)$$

Where:

$\eta 85_D{}^{upp}$	Efficiency value at the upper limit of FEG85 for a given fan size
D	Fan size (impeller diameter) in mm (in.)
D_0	Base fan size (impeller diameter) 1016 mm (40 in.)
k_0, k_1, k_2, k_3	Constants

The fan size, D, in the SI system of units is in millimeters (mm) and in IP system of units is in inches (in.). The constants have to be then used from Table A.1 accordingly.

It is advisable to use the constants as they are defined rather than using their rounded values.

For a given fan size, D, the FEGD upper limits are calculated from the FEG85D upper limit (use formula above) as numbers in a geometrical series with a quotient of:

$$q = 10^{\left(-\frac{1}{40}\right)} = 10^{-0.025} = 0.94406088 \text{ (rounded)}$$

For example, the FEG85 upper limit for size 1016 mm (40 in.) is 84.1395 and the upper limit of the grade next down, e.g. FEG80, is calculated as 84.1395 × q = 79.4328. The next grade down is FEG75 and its upper limit is calculated as 79.4328 × q = 74.9894 etc.

Shown in Table A.2 are the upper limits for all FEG for a fan size 1016 mm (40 in.). The multipliers are fan size independent and shall be used for calculating of the upper limits of all FEG from the FEG85.

Table A.1
Constants for defining the upper efficiency limit of FEG85

Constant	SI	IP
D_0	1016 (exactly)	40 (exactly)
k_0	$10^{\left(1+\left(\frac{37}{40}\right)\right)} - 15 + 112\exp\left(-\frac{D_0}{k_3}\right)$	$10^{\left(1+\left(\frac{37}{40}\right)\right)} - 15 + 112\exp\left(-\frac{D_0}{k_3}\right)$
k_1	$\frac{793.75}{15^2} = 3.52\overline{77}$	$\frac{31.25}{15^2} = 0.13\overline{88}$
k_2	$\frac{1270}{15} = 84.\overline{66}$	$\frac{50}{15} = 3.\overline{33}$
k_3	113.92 (exactly)	$\frac{113.92}{25.4} = 4.48503937$

Table A.2
FEG upper limits for a fan size of 1016 mm (40 in.) and multipliers for calculating of upper limits of all FEG from FEG85

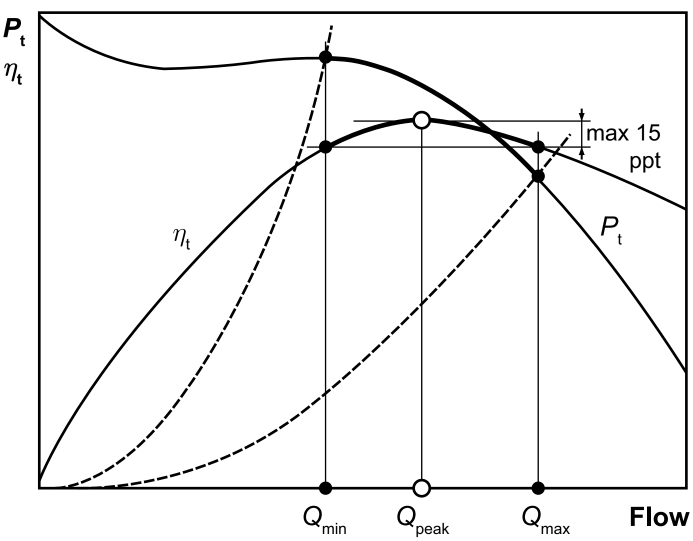
Fan Efficiency Grade	Grade upper limit (exact values from Renard formula)	Grade upper limit (rounded)	Multiplier from FEG85 (exact values)	Multiplier from FEG85 (rounded)
FEG85	$10^{\left(1+\left(\frac{37}{40}\right)\right)}$	84.1395	1	1
FEG80	$10^{\left(1+\left(\frac{36}{40}\right)\right)}$	79.4328	$10^{\left(\left(\frac{39}{40}\right)-1\right)}$	0.94406088
FEG75	$10^{\left(1+\left(\frac{35}{40}\right)\right)}$	74.9894	$10^{\left(\left(\frac{38}{40}\right)-1\right)}$	0.89125094
FEG71	$10^{\left(1+\left(\frac{34}{40}\right)\right)}$	70.7946	$10^{\left(\left(\frac{37}{40}\right)-1\right)}$	0.84139514
FEG67	$10^{\left(1+\left(\frac{33}{40}\right)\right)}$	66.8344	$10^{\left(\left(\frac{36}{40}\right)-1\right)}$	0.79432823
FEG63	$10^{\left(1+\left(\frac{32}{40}\right)\right)}$	63.0958	$10^{\left(\left(\frac{35}{40}\right)-1\right)}$	0.74989421
FEG60	$10^{\left(1+\left(\frac{31}{40}\right)\right)}$	59.5663	$10^{\left(\left(\frac{34}{40}\right)-1\right)}$	0.70794578
FEG57	$10^{\left(1+\left(\frac{30}{40}\right)\right)}$	56.2342	$10^{\left(\left(\frac{33}{40}\right)-1\right)}$	0.66834392
FEG53	$10^{\left(1+\left(\frac{29}{40}\right)\right)}$	53.0885	$10^{\left(\left(\frac{32}{40}\right)-1\right)}$	0.63095734
FEG50	$10^{\left(1+\left(\frac{28}{40}\right)\right)}$	50.1188	$10^{\left(\left(\frac{31}{40}\right)-1\right)}$	0.59566214

Table A.3
FEG50 lower limit and multiplier for a fan size of 1016 mm (40 in.) and multipliers for calculating the lower limit of the grade from the upper limit of FEG85

Fan Efficiency Grade	**Grade lower limit (exact values from Renard formula)**	**Grade lower limit (rounded)**	**Multiplier from FEG85 (exact values)**	**Multiplier from FEG85 (rounded)**
FEG50	$10^{\left(1+\left(\frac{27}{40}\right)\right)}$	47.3151	$10^{\left(\left(\frac{30}{40}\right)-1\right)}$	0.56234133

Annex B
Range of Fan Efficiency for Selection of the Fan in the System (Normative)

In order to achieve the goals in energy savings by operating fans it is important that the fan is selected in the system close to the peak of the fan efficiency. The fan operating efficiency at all intended operating point(s) shall not be less than 15 percentage points below the fan peak total efficiency (see portions of the fan curves with heavy lines in Figure B.1).



P_t	Fan total pressure
η_t	Fan total (energy) efficiency
Q	Flow
Q_{min}, Q_{max}	Flow range for the allowable fan efficiency range

Figure B.1
Allowable Fan Energy Efficiency and Flow Range for the Fan Selection for an Application

AIR MOVEMENT AND CONTROL ASSOCIATION INTERNATIONAL, INC.

30 West University Drive
Arlington Heights, IL 60004-1893 U.S.A.

Tel: (847) 394-0150 ▪ Fax: (847) 253-0088
E-Mail : info@amca.org ▪ Web: www.amca.org

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