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Fans — Efficiency classification for fans

Ventilateurs — Classification du rendement des ventilateurs

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 12759 was prepared by Technical Committee ISO/TC 117, *Fans*.

Introduction

The last decade has seen not only an escalation in the price, but also an increasing recognition of the finite life of many of the fossil fuels in use. There is also a belief that climatic change is due to an increase in the levels of carbon dioxide in the atmosphere. This has lead to many nations reviewing methods of energy generation and usage.

Therefore, there is a need to promote energy efficiency in order to maintain economic growth. This requires better selection of equipment by users and better design of this equipment by manufacturers.

Fans of all types are used for ventilation and air conditioning, process engineering (drying, pneumatic conveying), combustion air supply and agriculture, etc. Indeed, the energy usage by fans has been calculated as nearly 20 % of worldwide demand.

The fan industry is of a global nature, with a considerable degree of exporting and licensing. To ensure that defined fan performance characteristics are common throughout the world, a series of International Standards has been developed. It is the belief of the industry that there is a need for the recognition of minimum efficiency standards. To encourage their implementation, a classification system is proposed which incorporates a series of efficiency bands. With improvements in technology and manufacturing processes, the minimum efficiency levels can be reviewed and increased over time.

This International Standard can be used by legislators or regulatory bodies for defining future energy saving targets.

Fans — Efficiency classification for fans

1 Scope

This International Standard establishes a classification of fan efficiency for all fan types driven by motors with an electrical input power range from 0,125 kW to 500 kW. This International Standard is applicable to bare shaft and driven fans, as well as fans integrated into products. Fans integrated into products are measured as stand-alone fans.

This International Standard is not applicable to:

a) fans for smoke and emergency smoke extraction;

b) fans for industrial processes;

c) fans for automotive application, trains and planes;

d) fans for potentially explosive atmospheres;

e) box fans, powered roof ventilators and air curtains;

f) jet fans for use in car parks and tunnel ventilation.

2 Normative references

The following referenced documents are indispensable 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.

ISO 5801:2007, *Industrial fans — Performance testing using standardized airways*

ISO 13348:2007, *Industrial fans — Tolerances, methods of conversion and technical data presentation*

ISO 13349:2010, *Fans — Vocabulary and definitions of categories*

IEC 60034-2-1, *Rotating electrical machines — Part 2-1: Standard methods for determining losses and efficiency from tests (excluding machines for traction vehicles)*

IEC 60034-30, *Rotating electrical machines — Part 30: Efficiency classes of single-speed, three-phase, cage-induction motors*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 13349 and the following apply.

NOTE See, in particular, ISO 13349:2010, Tables 4 and 5, as well as the associated equations in Clause 5 of this International Standard and ISO 5801.

3.1 Fans — General

3.1.1
fan
rotary bladed machine which receives mechanical energy and utilizes it by means of one or more impellers fitted with blades to maintain a continuous flow of air or other gas passing through it and whose work per unit mass does not normally exceed 25 kJ/kg

NOTE 1 Fans are defined according to their installation category, function, fluid path and operating conditions.

NOTE 2 Adapted from ISO 13349:2010, definition 3.1.1.

3.1.2
fan size
maximum impeller tip diameter, D, on which the design of the fan is based

3.1.3
drive
⟨transmission and motor/control system⟩ device used to power the fan, including motor, mechanical transmission and motor/control system

NOTE 1 Examples of mechanical transmission are belt drive and couplings.

NOTE 2 Examples of a motor or control system are variable frequency controller and electronic commutator.

3.1.4
bare shaft fan
fan without drives, attachments or accessories (appurtenance)

See Figure 1.

NOTE Adapted from ISO 13349:2010, definition 3.1.2.

3.1.5
driven fan
one or more impellers fitted to or connected to a motor, with or without a drive mechanism, a housing and a means of variable speed drive

See Figure 2.

NOTE Adapted from ISO 13349:2010, definition 3.1.3.

3.1.6
air
abbreviated term for the expression “air or other gas”

[ISO 13349:2010, definition 3.2]

3.1.7
standard air
atmospheric air having a density of exactly 1,2 kg/m^3

NOTE 1 Atmospheric air at a temperature of 16 °C, a pressure of 100 000 Pa and a relative humidity of 65 %, has a density of 1,2 kg/m^3, but these conditions do not form part of the definition.

NOTE 2 Adapted from ISO 13349:2010, definition 3.3.

3.2 Fan or test installation categories according to the arrangement of ducting

See Figure 3 and ISO 13349.

3.2.1
installation category A
installation with free inlet and free outlet

3.2.2
installation category B
installation with free inlet and ducted outlet

3.2.3
installation category C
installation with ducted inlet and free outlet

3.2.4
installation category D
installation with ducted inlet and ducted outlet

3.3 Fans — Definitions relating to calculations

3.3.1
average density at fan inlet
ρ_1
fluid density calculated from the absolute pressure and the static temperature

3.3.2
atmospheric pressure
p_a
pressure, measured with respect to absolute zero pressure, which is exerted at a point at rest relative to the air around it

3.3.3
fan pressure
p_f
difference between the stagnation pressure at the fan outlet and the stagnation pressure at the fan inlet

3.3.4
fan static pressure
p_{sf}
conventional quantity defined as the fan pressure minus the fan dynamic pressure at the fan outlet corrected by the Mach factor

3.3.5
absolute stagnation pressure at a point
p_{sg}
absolute pressure which would be measured at a point in a flowing gas, if it were brought to rest via an isentropic process

3.3.6
conventional dynamic pressure at a point
p_d
pressure calculated from the velocity and the density of the air at the point

3.3.7
fan dynamic pressure at the fan outlet
p_{d2}
conventional dynamic pressure at the fan outlet calculated from the mass flow rate, the average gas density at the outlet and the outlet area

3.3.8
mass flow rate
q_m
mean value, over time, of the mass of air which passes through the specified airway cross-section per unit of time

3.3.9
inlet volume flow rate
q_{V1}
mass flow rate at the inlet divided by the corresponding mean value, over time, of the average density at the inlet

3.3.10
fan work per unit mass
W_m
increase in mechanical energy per unit mass of fluid passing through the fan

3.3.11
compressibility coefficient
k_p
ratio of the mechanical work done by the fan on the air to the work that would be done on an incompressible fluid with the same mass flow, inlet density and pressure ratio

3.3.12
fan air power
P_u
conventional output power which is the product of the mass flow rate and the fan work per unit mass, or the product of the inlet volume flow rate, the compressibility coefficient and the fan pressure

3.3.13
fan static air power
P_{us}
conventional output power which is the product of the mass flow rate and the fan static work per unit mass, or the product of the inlet volume flow rate, the compressibility coefficient and the fan static pressure

3.3.14
impeller power
P_r
mechanical power supplied to the fan impeller

NOTE This is applicable to direct driven impellers which are open (as in, for example, a plenum fan) or enclosed in a housing.

3.3.15
nominal motor power
P_N
rated output power of an electric motor

3.3.16
fan shaft power
P_a
mechanical power supplied to the fan shaft

3.3.17
motor output power
P_o
shaft power output of the motor or other prime mover

3.3.18
motor input power
P_e
electrical power supplied to the fan's motor

3.3.19
drive/control electrical input power
P_{ed}
electrical power supplied to the motor's drive or control

3.4 Definitions relating to fan efficiency

3.4.1
fan impeller efficiency
η_r
fan air power divided by the impeller power, P_r

3.4.2
fan shaft efficiency
η_a
fan air power divided by the fan shaft power, P_a

3.4.3
overall efficiency
η_e
fan air power divided by the input power for the fan and motor

3.4.4
overall static efficiency
η_{es}
fan static air power divided by the input power for the fan and motor

3.4.5
overall efficiency drive
η_{ed}
⟨transmission and motor/control system⟩ fan air power divided by the input power for the fan and motor combination which include transmission or variable speed controls to take account of all losses within the fan assembly

3.4.6
overall static efficiency drive
η_{esd}
⟨transmission and motor/control system⟩ fan static air power divided by the input power for the fan and motor combination which include transmission or variable speed controls to take account of all losses within the fan assembly

NOTE 1 The efficiency can be referred to the installation category (see Figure 3 and ISO 13349).

NOTE 2 Efficiency can be expressed as a proportion of unity. To obtain a per cent value, multiply the efficiency result by 100.

3.4.7
optimum efficiency
η_{opt}
maximum efficiency achieved on the fan air characteristic with all operational parameters, except the air system resistance, being fixed

3.4.8
compensation factor
C_c
factor, used in the determination of efficiencies for fans incorporating or fitted with variable speed drives

See Figure 5.

3.5 Fan efficiency grades

3.5.1
fan efficiency grade
FEG
efficiency grade for a bare shaft fan

NOTE The definitions given in 3.4.1 and 3.4.2 can apply.

3.5.2
fan motor efficiency grade
FMEG
efficiency grade for a driven fan

NOTE The definitions given in 3.4.3, 3.4.4, 3.4.5 and 3.4.6 can apply.

3.5.3
grade number
N_G
integer of the FMEG

4 Symbols and units

For the purposes of this document, the symbols and primary units in Table 1 for the parameters listed apply.

Table 1 — Symbols and units

Symbol	Description	Unit
C_c	Compensation factor to account for energy savings at part load	—
C_m	Compensation factor to account for suboptimal matching of components	—
D	Maximum impeller tip diameter (fan size)	mm
k_p	Compressibility coefficient	—
N_G	Grade number (integer) of the FMEG	—
P_a	Fan shaft power	W
P_b	Power loss in bearings	W
P_e	Motor input power	W
P_{ed}	Drive/control electrical input power	W
P_N	Nominal motor power	W
P_o	Motor output power	W

Table 1 (*continued*)

Symbol	Description	Unit
P_r	Impeller power	W
P_{sf}	Specific fan power	kW/(m^3/s) or W/(l/s)
P_u	Fan air power	W
P_{us}	Fan static air power	W
p_a	Atmospheric pressure	Pa
p_d	Conventional dynamic pressure at a point	Pa
p_{d2}	Fan dynamic pressure at the fan outlet	Pa
p_f	Fan pressure	Pa
p_{sf}	Fan static pressure	Pa
p_{sg}	Absolute stagnation pressure at a point	Pa
q_m	Mass flow rate	kg/s
q_{v1}	Inlet volume flow rate	m^3/s
W_m	Fan work per unit mass	J/kg
η_a	Fan shaft efficiency	Expressed as a decimal
η_b	Fan bearing efficiency	Expressed as a decimal
η_c	Variable speed drive efficiency	Expressed as a decimal
η_e	Overall efficiency for fans without drives	Expressed as a decimal
η_{ed}	Overall efficiency for fans with drives	Expressed as a decimal
η_{es}	Overall static efficiency for fans without drives	Expressed as a decimal
η_{esd}	Overall static efficiency for fans with drives	Expressed as a decimal
η_m	Motor efficiency	Expressed as a decimal
η_{opt}	Optimum efficiency	Expressed as a decimal
η_r	Fan impeller efficiency	Expressed as a decimal
η_T	Drive mechanism (transmission efficiency)	Expressed as a decimal
ρ_1	Average density at fan inlet	kg/m^3
NOTE	Efficiency in per cent (%) divided by 100 equals the efficiency, expressed as a decimal.	

5 Fan installation, efficiency and tolerance

5.1 General

Fans range from the purpose-built single fan to the series-produced certified ranges, which are manufactured in large quantities. A fan can be an impeller on a shaft with no drive mechanism attached (i.e. bare shaft fan) (see Figure 1), or a motor attached to a drive system attached to an impeller within an impeller housing. In that case, it can be supplemented by a volume control, such as a variable speed control or guide vanes (i.e. driven fan) (see Figure 2).

The variation in design has led to efficiency being defined in a number of ways to suit the demands of the fan type and the market.

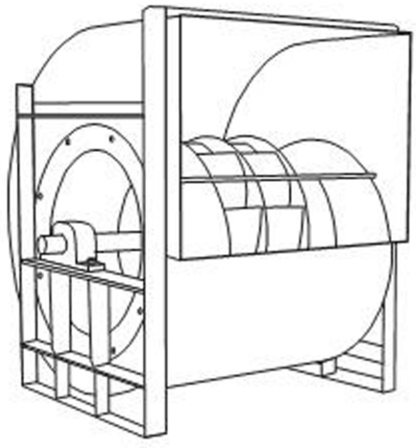
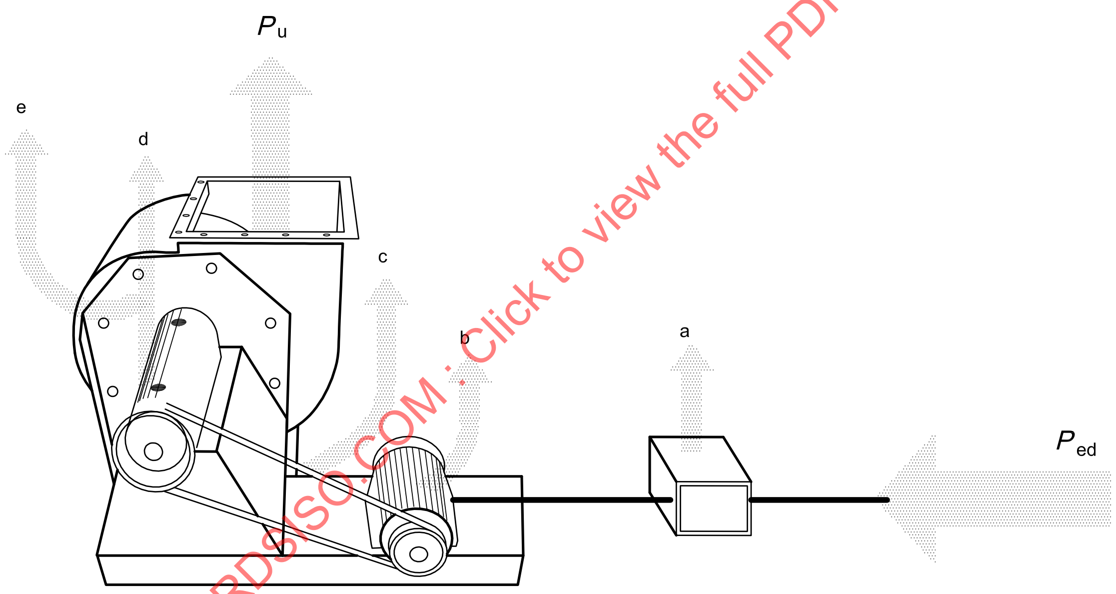


Figure 1 — Example of a bare shaft centrifugal fan



Key

P_u fan air power

P_{ed} drive/control electrical input power

a Variable speed device loss (heat). [The variable speed device can be fitted or not (see Clause 6).]

b Motor losses (heat).

c Belt losses (heat).

d Bearing losses (heat).

e Impeller and casing aerodynamic losses (heat).

Figure 2 — Example of a driven fan showing power losses

5.2 Use of installation categories

Fan efficiency ratings are frequently specific for each standardized test installation category.

If a fan is designed for a single installation category, its rated efficiency grade shall refer to that particular test installation category, and this shall be clearly identified.

If a fan is suitable for use with different installation categories, the fan efficiency grade shall be based on the efficiency ratings referring to the most suitable category, and this shall be clearly identified.

To determine the operating point of the fan, four installation categories shall be considered (see Figure 3). For details of test methods, see the following clauses of ISO 5801:2007:

a) category A installations — Clause 30;

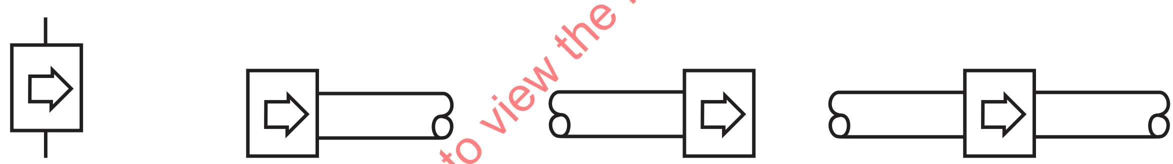
b) category B installations — Clause 31;

c) category C installations — Clause 32;

d) category D installations — Clause 33.

The standardized installation category used for rating the fan shall be clearly stated (see Annex C).

The motor input power and motor output power may be measured or determined using the methods given in ISO 5801. Installation category E is not included in this International Standard.



a) Category A   b) Category B   c) Category C   d) Category D

Figure 3 — Installation categories

5.3 Calculation of efficiency

5.3.1 The fan air power and efficiency are calculated from fan work per unit mass in accordance with ISO 5801:2007, 14.8.1.

5.3.2 For a bare shaft fan where bearing losses are excluded, the efficiency is given by Equation (1):

$$\eta_r = P_u / P_r \quad (1)$$

5.3.3 For a bare shaft fan where bearing losses are included, the efficiency is given by Equation (2):

$$\eta_a = P_u / P_a \quad (2)$$

5.3.4 For a driven fan that does not include a variable speed drive, where the input power can be determined, the overall efficiency is given by Equation (3) or (4):

$$\eta_e = P_u / P_e \quad (3)$$

$$\eta_{es} = P_{us} / P_e \quad (4)$$

5.3.5 For a driven fan that includes a variable speed drive, where the input power can be determined, the overall efficiency is given by Equation (5) or (6):

$$\eta_{ed} = C_c \times P_u / P_{ed} \quad (5)$$

$$\eta_{esd} = C_c \times \frac{P_{us}}{P_{ed}} \quad (6)$$

NOTE The use of fan pressure or fan static pressure determines the appropriate efficiency grade according to the installation category.

5.4 Tolerances

At each stage of the fan design and manufacturing cycle, including conversion from prototype performance data or calculation, fabrication and testing of a purpose-designed fan, finite uncertainties prevail and acceptance tolerances shall be applied.

Any test for fan performance is subject to error, and the range within which these testing errors can be expected to lie is defined numerically as the uncertainty of measurement. In addition, the true performance of the fan (if it can be ascertained) would be found to differ from that of another nominally identical fan, owing to inevitable variations in manufacture. The expected range of this manufacturing variation shall be added to the uncertainty of measurement to determine the minimum tolerance required for a performance specification.

The tolerances given in ISO 13348:2007, Clause 5 (performance tolerances for purpose-designed fans and series-produced non-certified fans), and ISO 13348:2007, Clause 6 (performance tolerances for series-produced fans in certified ratings programmes), shall apply.

6 Ratings

6.1 General

The variation of fan type and drive option leads to efficiency being derived in different ways. For grading purposes, the efficiency has been defined as a function of the size for bare shaft fans and as a function of input power for driven fans. Direct comparison shall not be made between driven fans rating (FMEG) and bare shaft fans rating (FEG).

If the efficiency of the bare shaft fan is required on a driven unit (see 6.2), Figure 4 remains applicable. In this case, the motor efficiency shall be obtained from a dynamometer test or by calibrated motor performance curves, conforming to IEC 60034-2-1.

This clause gives guidance on the optimum efficiency (best efficiency point) levels which are achievable by the fan types addressed in this International Standard. The minimum levels of acceptability are dependent on consultation between regulator and manufacturer's representatives or local legislation, where this exists.

The efficiency grade for a fan is based on its performance characteristics at a speed not higher than the maximum safe operating speed to obtain its best efficiency point.

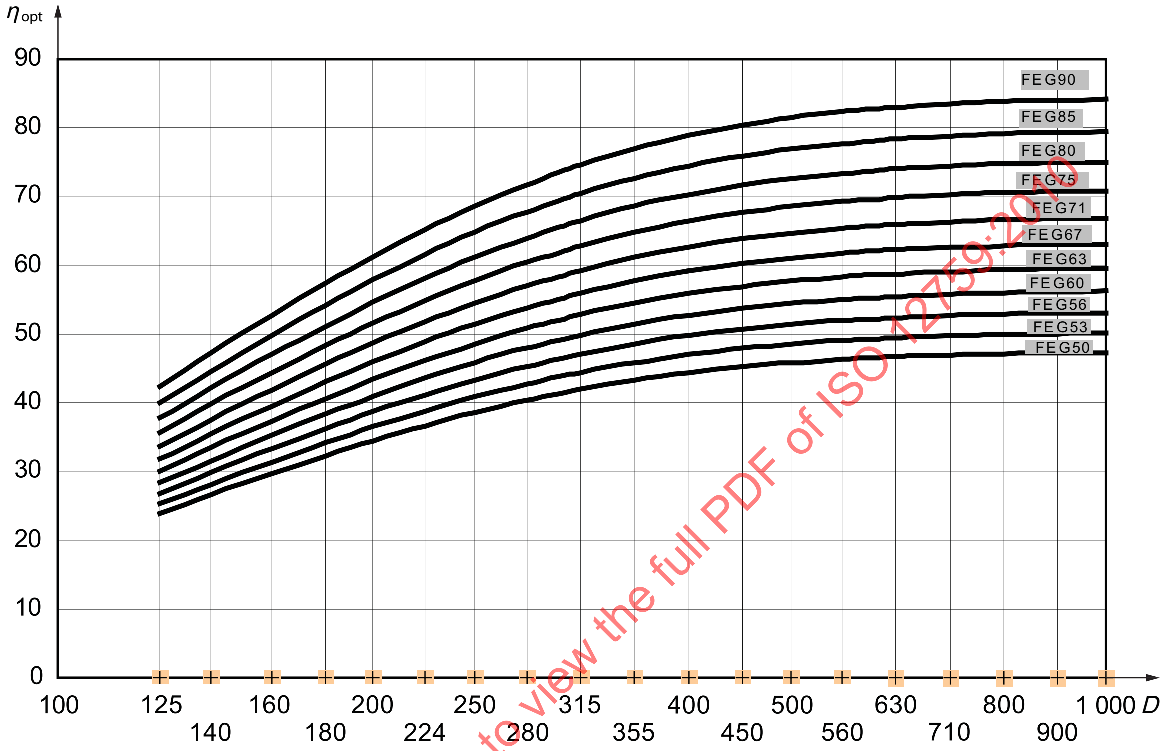
6.2 Bare shaft fans

The relationship between the FEG and fan size is shown in Figure 4. While the fan efficiency is a function of the operating point of the fan, the efficiency grades are based on the optimum (peak) efficiency of the fan as the characteristic of fan energy efficiency.

A fan belongs to an FEG grade (e.g. FEG85), if its efficiency, at best efficiency duty and maximum speed, is higher than the calculated value, at the impeller diameter, along the boundary, calculated in accordance with

Annex A from the level of the immediately lower efficiency grade (e.g. 80 from FEG80), and equal to or lower than the value on the boundary calculated for the nominal efficiency grade (e.g. FEG85).

In simple terms, a fan belongs to an FEG grade (e.g. FEG85) if its efficiency, at best efficiency duty and maximum speed, is below the curve according to its designation, but above the next curve beneath (e.g. FEG80).



Key

D fan size (mm)

η_{opt} optimum (peak) fan efficiency (%)

Figure 4 — FEG for bare shaft fans

The incremental efficiency grades for bare shaft fans are given in Table 2. An explanation of how to determine the FEG is given in the notes to Table 2. The FEG grade for a given fan size is assigned when the fan optimum (peak) efficiency is equal or lower than the value of efficiency in the row for that label and higher than the value of efficiency in the next row down.

Table 2 — Fan efficiency grades (FEG) for bare shaft fans

FEG grade[b,c]	Optimum (peak) fan efficiency[a] %												
	for fan size, D_r[d,e] (mm) of:												
	125	132	**140**	150	**160**	170	**180**	190	**200**	212	**224**	236	**250**
FEG90	Optimum (peak) fan efficiency above the FEG85 grade												
FEG85	42,5	44,8	47,2	50,1	52,7	55,2	57,4	59,4	61,3	63,3	65,2	66,9	68,6
FEG80	40,1	42,3	44,6	47,3	49,8	52,1	54,2	56,1	57,9	59,8	61,6	63,1	64,8
FEG75	37,8	39,9	42,1	44,7	47,0	49,2	51,1	53,0	54,6	56,5	58,1	59,6	61,2
FEG71	35,7	37,7	39,8	42,2	44,4	46,4	48,3	50,0	51,6	53,3	54,9	56,3	57,8
FEG67	33,7	35,6	37,5	39,8	41,9	43,8	45,6	47,2	48,7	50,3	51,8	53,1	54,5
FEG63	31,8	33,6	35,4	37,6	39,5	41,4	43,0	44,6	46,0	47,5	48,9	50,2	51,5
FEG60	30,1	31,7	33,4	35,5	37,3	39,0	40,6	42,1	43,4	44,8	46,2	47,3	48,6
FEG56	28,4	29,9	31,6	33,5	35,2	36,9	38,3	39,7	41,0	42,3	43,6	44,7	45,9
FEG53	26,8	28,2	29,8	31,6	33,3	34,8	36,2	37,5	38,7	40,0	41,1	42,2	43,3
FEG50	25,3	26,7	28,1	29,8	31,4	32,9	34,2	35,4	36,5	37,7	38,8	39,8	40,9
	23,9	25,2	26,6	28,2	29,7	31,0	32,3	33,4	34,5	35,6	36,7	37,6	38,6
FEG grade[b,c]	**for fan size, D_r[d,e] (mm) of:**												
	265	**280**	300	**315**	335	**355**	375	400	425	**450**	475	**500**	530
FEG90	Optimum (peak) fan efficiency above the FEG85 grade												
FEG85	70,3	71,8	73,5	74,6	75,9	77,0	77,9	78,9	79,7	80,4	81,0	81,5	81,9
FEG80	66,4	67,8	69,4	70,4	71,7	72,7	73,6	74,5	75,3	75,9	76,5	76,9	77,4
FEG75	62,7	64,0	65,5	66,5	67,6	68,6	69,5	70,3	71,1	71,7	72,2	72,6	73,0
FEG71	59,2	60,4	61,8	62,8	63,9	64,8	65,6	66,4	67,1	67,7	68,1	68,5	68,9
FEG67	55,9	57,0	58,4	59,3	60,3	61,2	61,9	62,7	63,3	63,9	64,3	64,7	65,1
FEG63	52,7	53,8	55,1	55,9	56,9	57,7	58,4	59,2	59,8	60,3	60,7	61,1	61,4
FEG60	49,8	50,8	52,0	52,8	53,7	54,5	55,2	55,9	56,5	56,9	57,3	57,7	58,0
FEG56	47,0	48,0	49,1	49,9	50,7	51,5	52,1	52,8	53,3	53,8	54,1	54,5	54,8
FEG53	44,4	45,3	46,4	47,1	47,9	48,6	49,2	49,8	50,3	50,7	51,1	51,4	51,7
FEG50	41,9	42,8	43,8	44,4	45,2	45,9	46,4	47,0	47,5	47,9	48,2	48,5	48,8
	39,5	40,4	41,3	42,0	42,7	43,3	43,8	44,4	44,8	45,2	45,5	45,8	46,1
FEG grade[b,c]	**for fan size, D_r[d,e] (mm) of:**												
	560	600	**630**	670	**710**	750	**800**	850	**900**	950	**1 000**		
FEG90	Optimum (peak) fan efficiency above the FEG85 grade												
FEG85	82,3	82,7	83,0	83,3	83,5	83,7	83,8	84,0	84,1	84,1	84,1		
FEG80	77,7	78,1	78,4	78,6	78,8	79,0	79,1	79,3	79,3	79,4	79,4		
FEG75	73,4	73,8	74,0	74,2	74,4	74,6	74,7	74,8	74,9	75,0	75,0		
FEG71	69,3	69,6	69,8	70,1	70,3	70,4	70,5	70,6	70,7	70,8	70,8		
FEG67	65,4	65,7	65,9	66,1	66,3	66,5	66,6	66,7	66,8	66,8	66,8		
FEG63	61,7	62,1	62,2	62,4	62,6	62,7	62,9	63,0	63,0	63,1	63,1		
FEG60	58,3	58,6	58,8	59,0	59,1	59,2	59,4	59,4	59,5	59,5	59,6		
FEG56	55,0	55,3	55,5	55,7	55,8	55,9	56,0	56,1	56,2	56,2	56,2		
FEG53	51,9	52,2	52,4	52,5	52,7	52,8	52,9	53,0	53,0	53,1	53,1		
FEG50	49,0	49,3	49,4	49,6	49,7	49,8	49,9	50,0	50,1	50,1	50,1		
	46,3	46,5	46,7	46,8	47,0	47,0	47,1	47,2	47,3	47,3	47,3		

The fan sizes in bold print in this table are in the R20 Series of preferred numbers (see ISO 13351). The values of efficiencies are calculated for fan sizes in the preferred numbers in the R40 Series. If this method is used for a direct driven fan not having the shaft and bearings integral to the fan, the fan efficiency is the impeller efficiency.

[a] The optimum (peak) fan efficiency may be calculated from the fan total pressure (see ISO 5801:2007, Annex A).

[b] The FEG grade for a given fan size is assigned when the fan optimum (peak) efficiency is equal to or lower than the value of efficiency in the row for that grade and higher than the value of efficiency in the next row down.

[c] No grade shall be considered for fans with optimum (peak) efficiency below FEG50.

[d] The fan size is the maximum impeller tip diameter, D, in millimetres.

[e] For any fan size larger than 1 000 mm, the values in the column for the size 1 000 mm apply.

To evaluate the efficiency of a bare shaft fan combined with or fitted to a drive system, the method given in Annex B shall be used. As previously stated, no direct comparison shall be made between this method and that stated in 6.3.

6.3 Driven fans

6.3.1 General

The efficiency grades for driven fans are shown in Figures 6, 7 and 8; the variation of optimum efficiency and FMEG grade is shown as a function of input power and design.

A fan belongs to a given FMEG grade (e.g. FMEG55) if its best (optimum) efficiency at full speed is equal to or greater than the value calculated according to Annex F (see 6.3.2, 6.3.3 and 6.3.4), for the nominal efficiency grade level, e.g. FMEG55, and relevant input power. Any efficiency line can be interpolated from those shown in Figures 6, 7 and 8.

In cases where a volume control device is necessary, a variable speed drive is the best option, as it is the most efficient method for adjustment to different operating points. Other options for volume control, such as guide vanes and control valves, are less efficient.

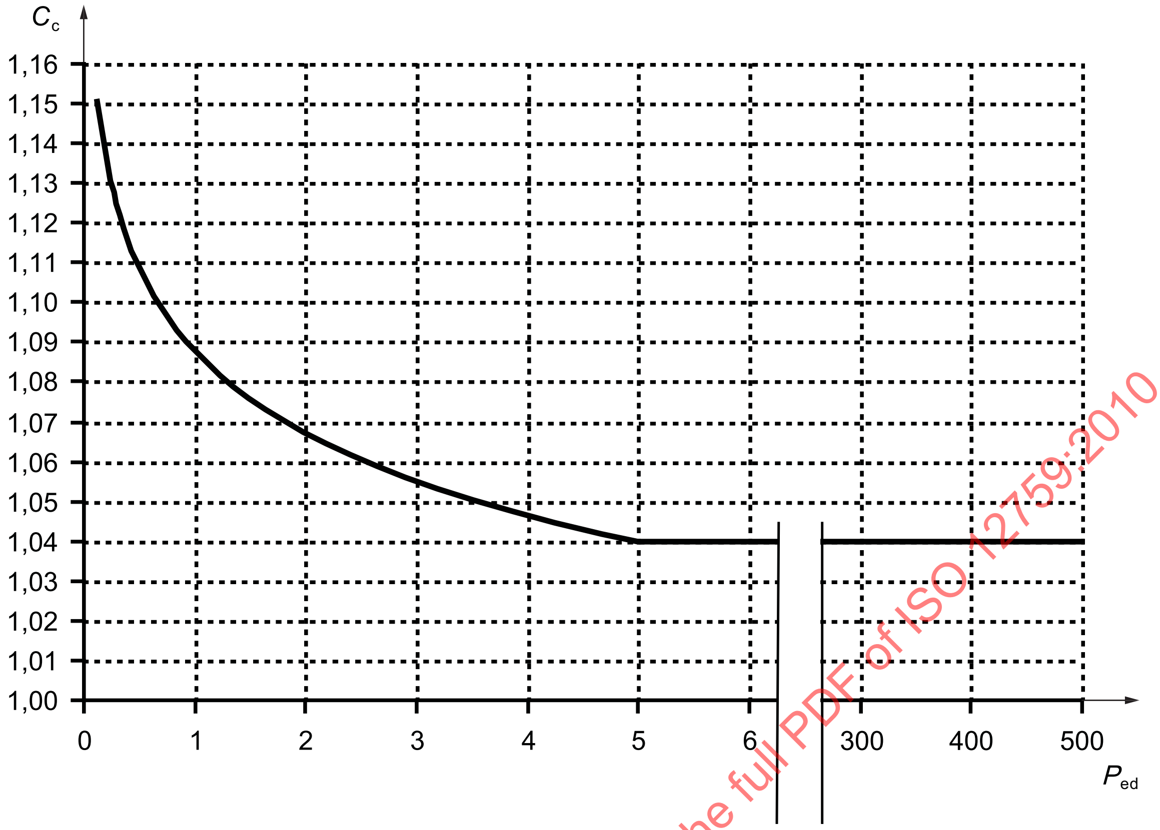
Many fans are required for duties less than their maximum. The most efficient way of achieving this, dependent on the system characteristic, is by speed reduction.

The curves of FMEGs are based on impeller and motor combinations. If a control device is used, the efficiency data can be revised by the correction values, compensation factor, for controls given in Table 3 and Figure 5. This is intended to put systems with variable speed drives on the same level as fixed speed systems because it recognizes that there are energy-saving opportunities.

NOTE Built-in means constructed as a non-detachable part of a larger unit and also being an essential and permanent part of the unit.

Table 3 — Compensation factor for fans fitted with variable speed drives

Drive/control electrical input power P_{ed}	Compensation factor C_c
< 5 kW	$-0{,}03 \times \ln(P_{ed}) + 1{,}088$
⩾ 5 kW	1,04



Key

P_{ed} drive/control electrical input power (kW)

C_c compensation factor

Figure 5 — Compensation factor for fans fitted with variable speed drives

6.3.2 Axial, forward curved or radial-bladed centrifugal driven fans

The graph in Figure 6 and Table 4 are generated by Equations (7), (8), (9) and (10).

a) For input power of less than or equal to 10 kW:

1) fan and motor

$$\eta_{opt} = 2{,}74 \times \ln(P_e) - 6{,}33 + N_G \tag{7}$$

2) fan, motor and drives

$$\eta_{opt} = 2{,}74 \times \ln(P_{ed}) - 6{,}33 + N_G \tag{8}$$

b) For input power greater than 10 kW:

1) fan and motor

$$\eta_{opt} = 0{,}78 \times \ln(P_e) - 1{,}88 + N_G \tag{9}$$

2) fan, motor and drives

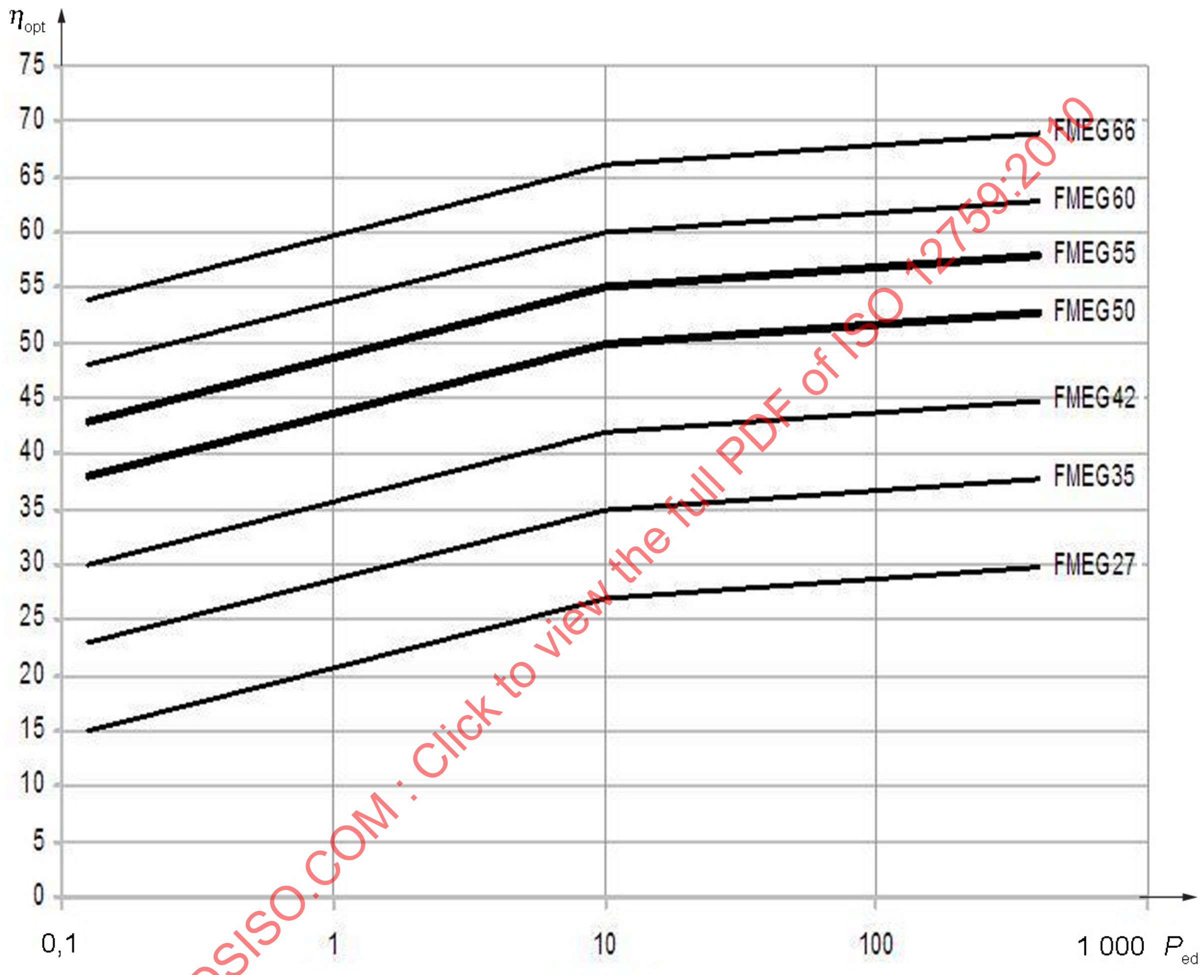
$$\eta_{opt} = 0{,}78 \times \ln(P_{ed}) - 1{,}88 + N_G \tag{10}$$

where

P_e is the input power, in kilowatts;

P_{ed} is the drive/control electrical input power, in kilowatts;

N_G is the grade number (integer) of the FMEG, e.g. $N_G = 40$ for FMEG40.



Key

P_{ed} defined input power (kW)

η_{opt} optimum efficiency (best efficiency point) (%)

Figure 6 — Efficiency grades for axial, forward curved or radial-bladed centrifugal driven fans

Table 4 — Efficiency grades for axial, forward curved or radial-bladed centrifugal driven fans

Input power kW	0,125	0,3	1,0	2,5	5	8	10	20	60	160	300	375	500
Efficiency grade	**Optimum efficiency (best efficiency point)** %												
FMEG27	15,0	17,4	20,7	23,2	25,1	26,4	27,0	27,5	28,3	29,1	29,6	29,7	30,0
FMEG31	19,0	21,4	24,7	27,2	29,1	30,4	31,0	31,5	32,3	33,1	33,6	33,7	34,0
FMEG35	23,0	25,4	28,7	31,2	33,1	34,4	35,0	35,5	36,3	37,1	37,6	37,7	38,0
FMEG39	27,0	29,4	32,7	35,2	37,1	38,4	39,0	39,5	40,3	41,1	41,6	41,7	42,0
FMEG42	30,0	32,4	35,7	38,2	40,1	41,4	42,0	42,5	43,3	44,1	44,6	44,7	45,0
FMEG46	34,0	36,4	39,7	42,2	44,1	45,4	46,0	46,5	47,3	48,1	48,6	48,7	49,0
FMEG50	38,0	40,4	43,7	46,2	48,1	49,4	50,0	50,5	51,3	52,1	52,6	52,7	53,0
FMEG53	41,0	43,4	46,7	49,2	51,1	52,4	53,0	53,5	54,3	55,1	55,6	55,7	56,0
FMEG55	43,0	45,4	48,7	51,2	53,1	54,4	55,0	55,5	56,3	57,1	57,6	57,7	58,0
FMEG58	46,0	48,4	51,7	54,2	56,1	57,4	58,0	58,5	59,3	60,1	60,6	60,7	61,0
FMEG60	48,0	50,4	53,7	56,2	58,1	59,4	60,0	60,5	61,3	62,1	62,6	62,7	63,0
FMEG62	50,0	52,4	55,7	58,2	60,1	61,4	62,0	62,5	63,3	64,1	64,6	64,7	65,0
FMEG64	52,0	54,4	57,7	60,2	62,1	63,4	64,0	64,5	65,3	66,1	66,6	66,7	67,0
FMEG66	54,0	56,4	59,7	62,2	64,1	65,4	66,0	66,5	67,3	68,1	68,6	68,7	69,0

6.3.3 Centrifugal backward-bladed fans (with and without housing) and mixed-flow driven fans

The graph in Figure 7 and Table 5 are generated by Equations (11), (12), (13) and (14):

a) For input power of less than or equal to 10 kW:

1) fan and motor

$$\eta_{opt} = 4{,}56 \times \ln(P_e) - 10{,}5 + N_G \quad (11)$$

2) fan, motor and drives

$$\eta_{opt} = 4{,}56 \times \ln(P_{ed}) - 10{,}5 + N_G \quad (12)$$

b) For input power greater than 10 kW:

1) fan and motor

$$\eta_{opt} = 1{,}1 \times \ln(P_e) - 2{,}6 + N_G \quad (13)$$

2) fan, motor and drives

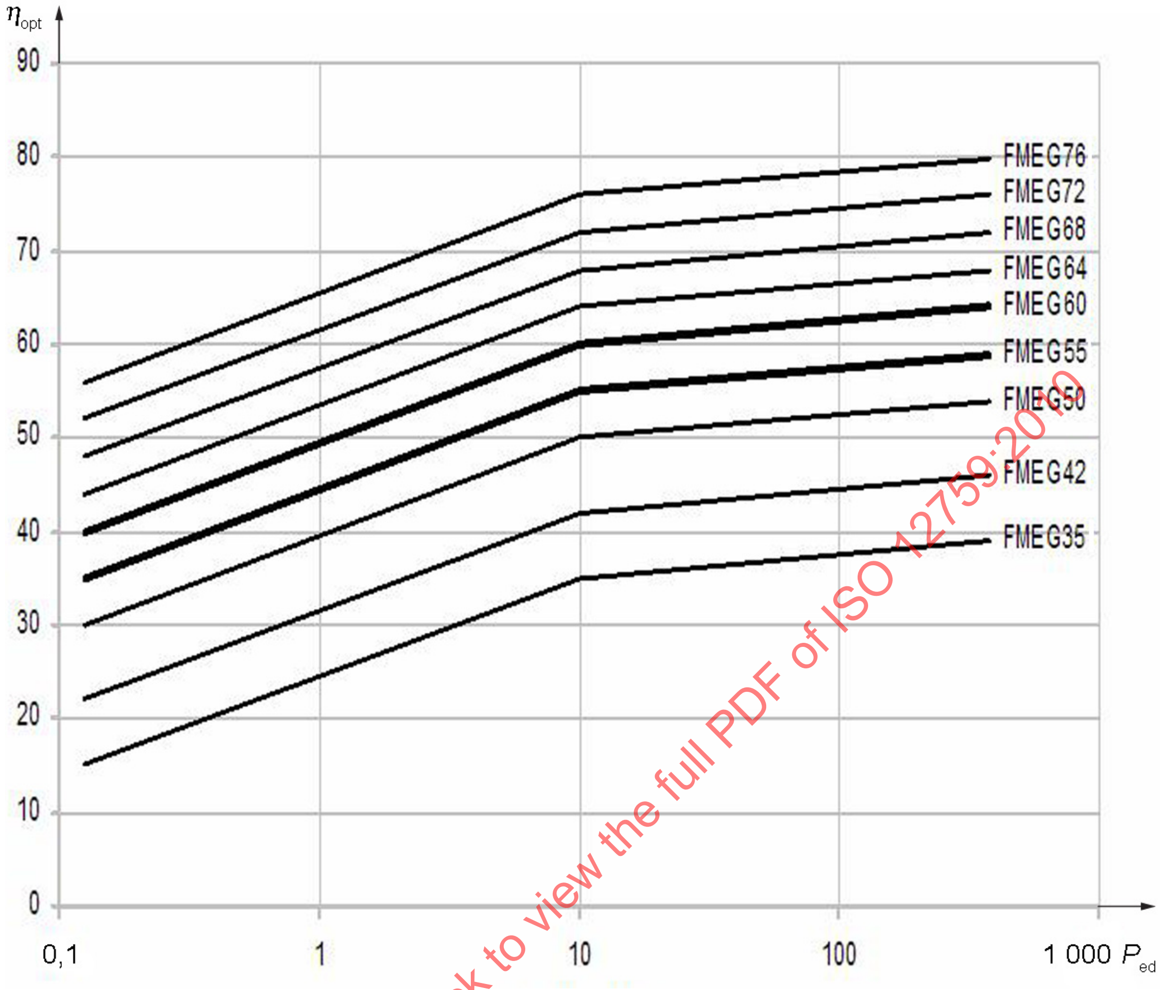
$$\eta_{opt} = 1{,}1 \times \ln(P_{ed}) - 2{,}6 + N_G \quad (14)$$

where

P_e is the input power, in kilowatts;

P_{ed} is the drive/control electrical input power, in kilowatts;

N_G is the grade number (integer) of the FMEG, e.g. $N_G = 40$ for FMEG40.



Key

P_{ed} defined input power (kW)

η_{opt} optimum efficiency (best efficiency point) (%)

Figure 7 — Efficiency grades for centrifugal backward-bladed fans (with and without housing) and mixed-flow driven fans

Table 5 — Efficiency grades for centrifugal backward-bladed fans (with and without housing) and mixed-flow driven fans

Input power kW	0,125	0,3	1,0	2,5	5	8	10	20	60	160	300	375	500
Efficiency grade	**Optimum efficiency (best efficiency point) %**												
FMEG35	15,0	19,0	24,5	28,7	31,8	34,0	35,0	35,7	36,9	38,0	38,7	38,9	39,2
FMEG39	19,0	23,0	28,5	32,7	35,8	38,0	39,0	39,7	40,9	42,0	42,7	42,9	43,2
FMEG42	22,0	26,0	31,5	35,7	38,8	41,0	42,0	42,7	43,9	45,0	45,7	45,9	46,2
FMEG46	26,0	30,0	35,5	39,7	42,8	45,0	46,0	46,7	47,9	49,0	49,7	49,9	50,2
FMEG50	30,0	34,0	39,5	43,7	46,8	49,0	50,0	50,7	51,9	53,0	53,7	53,9	54,2
FMEG53	33,0	37,0	42,5	46,7	49,8	52,0	53,0	53,7	54,9	56,0	56,7	56,9	57,2
FMEG55	35,0	39,0	44,5	48,7	51,8	54,0	55,0	55,7	56,9	58,0	58,7	58,9	59,2
FMEG58	38,0	42,0	47,5	51,7	54,8	57,0	58,0	58,7	59,9	61,0	61,7	61,9	62,2
FMEG60	40,0	44,0	49,5	53,7	56,8	59,0	60,0	60,7	61,9	63,0	63,7	63,9	64,2
FMEG62	42,0	46,0	51,5	55,7	58,8	61,0	62,0	62,7	63,9	65,0	65,7	65,9	66,2
FMEG64	44,0	48,0	53,5	57,7	60,8	63,0	64,0	64,7	65,9	67,0	67,7	67,9	68,2
FMEG66	46,0	50,0	55,5	59,7	62,8	65,0	66,0	66,7	67,9	69,0	69,7	69,9	70,2
FMEG68	48,0	52,0	57,5	61,7	64,8	67,0	68,0	68,7	69,9	71,0	71,7	71,9	72,2
FMEG70	50,0	54,0	59,5	63,7	66,8	69,0	70,0	70,7	71,9	73,0	73,7	73,9	74,2
FMEG72	52,0	56,0	61,5	65,7	68,8	71,0	72,0	72,7	73,9	75,0	75,7	75,9	76,2
FMEG74	54,0	58,0	63,5	67,7	70,8	73,0	74,0	74,7	75,9	77,0	77,7	77,9	78,2
FMEG76	56,0	60,0	65,5	69,7	72,8	75,0	76,0	76,7	77,9	79,0	79,7	79,9	80,2

6.3.4 Cross-flow driven fans

The graph in Figure 8 and Table 6 are generated by Equations (15), (16) and (17).

a) For input power of less than or equal to 10 kW:

1) fan and motor

$$\eta_{opt} = 1{,}14 \times \ln(P_e) - 2{,}6 + N_G \qquad (15)$$

2) fan, motor and drives

$$\eta_{opt} = 1{,}14 \times \ln(P_{ed}) - 2{,}6 + N_G \qquad (16)$$

b) For input power greater than 10 kW: fan and motor, and fan, motor and drives

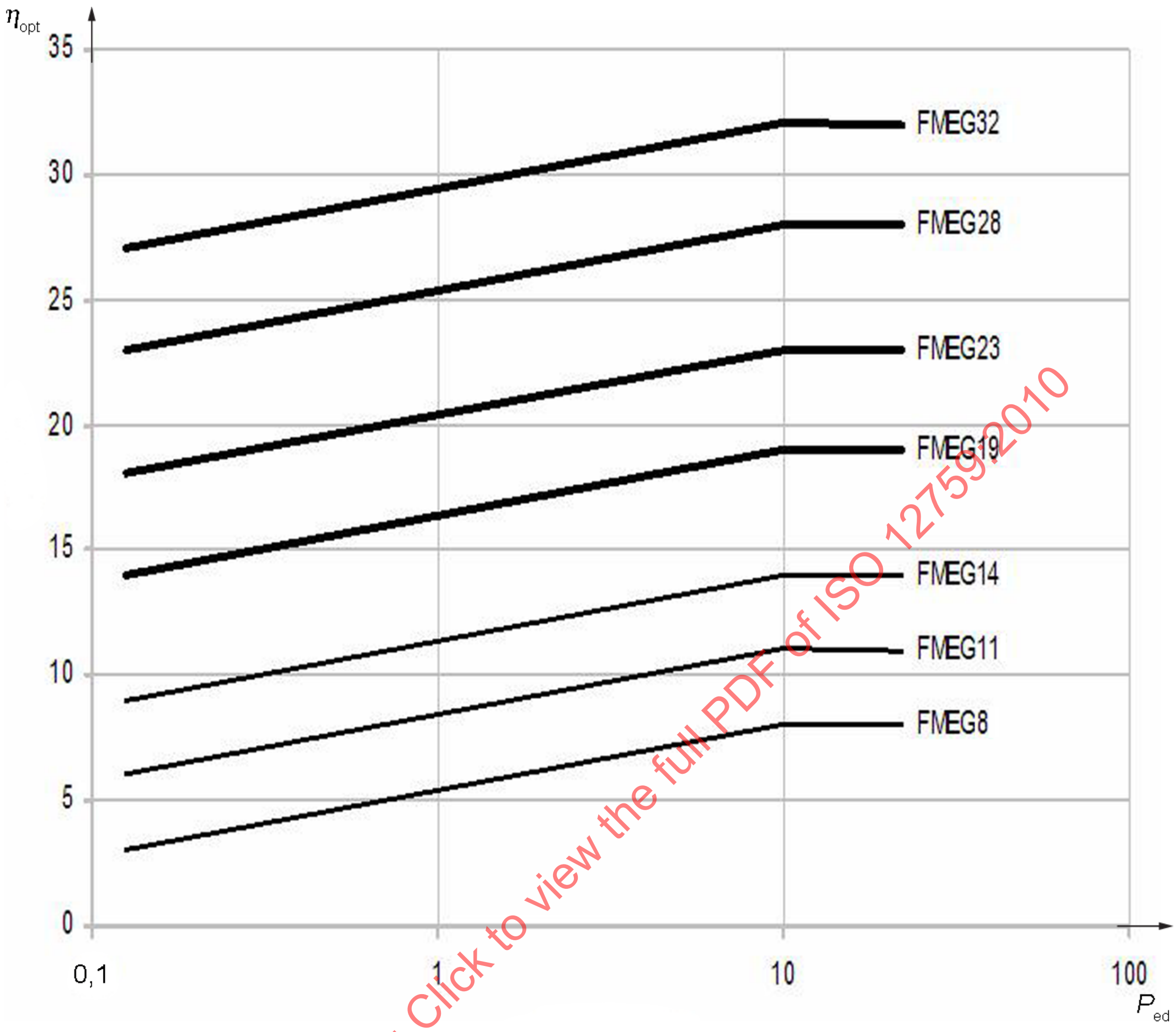
$$\eta_{opt} = N_G \qquad (17)$$

where

P_e is the motor input power, in kilowatts;

P_{ed} is the drive/control electrical input power, in kilowatts;

N_G is the integer of the FMEG, e.g. $N_G = 10$ for FMEG10.



Key

P_{ed} defined input power (kW)

η_{opt} optimum efficiency (best efficiency point) (%)

Figure 8 — Cross-flow driven fan efficiency grades

Table 6 — Cross-flow driven fan efficiency grades

Input power kW	0,125	0,3	0,50	0,8	1,0	2,0	3,0	4,0	5,0	8,0	10	16	22
Efficiency grade	**Optimum efficiency (best efficiency point)** %												
FMEG08	3,0	4,0	4,6	5,1	5,4	6,2	6,7	7,0	7,2	7,8	8,0	8,0	8,0
FMEG11	6,0	7,0	7,6	8,1	8,4	9,2	9,7	10,0	10,2	10,8	11,0	11,0	11,0
FMEG14	9,0	10,0	10,6	11,1	11,4	12,2	12,7	13,0	13,2	13,8	14,0	14,0	14,0
FMEG19	14,0	15,0	15,6	16,1	16,4	17,2	17,7	18,0	18,2	18,8	19,0	19,0	19,0
FMEG23	18,0	19,0	19,6	20,1	20,4	21,2	21,7	22,0	22,2	22,8	23,0	23,0	23,0
FMEG28	23,0	24,0	24,6	25,1	25,4	26,2	26,7	27,0	27,2	27,8	28,0	28,0	28,0
FMEG32	27,0	28,0	28,6	29,1	29,4	30,2	30,7	31,0	31,2	31,8	32,0	32,0	32,0

Annex A
(normative)

Energy efficiency grades for bare shaft fans

Equation (A.1) is used for calculation of the upper limit efficiencies of the grade FEG85 using the fan size, D_r, as the independent variable:

$$\eta_{opt}85_D^{upp} = k_0 + \left[81 + \frac{D}{k_1} - \left(\frac{D}{k_2}\right)^2\right]^{0,5} - 112 \exp\left(-\frac{D}{k_3}\right) \quad \text{(A.1)}$$

where

$\eta_{opt}85_D^{upp}$	is the efficiency value at the upper limit of FEG85 for a given fan size;
D	is the fan size (impeller diameter), in millimetres;
k_0, k_1, k_2, k_3	are constants (see Table A.1).

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

Constant	Constant definition
D_0	1 016 (exactly)
k_0	$10^{\left[1+\left(\frac{37}{40}\right)\right]} - 15 + 112 \exp\left(-\frac{D_0}{k_3}\right)$ where D_0 is the base fan size (impeller diameter), 1 016 mm
k_1	$\frac{793,75}{15^2} = 3,52\overline{77}$
k_2	$\frac{1\,270}{15} = 84,\overline{66}$
k_3	113,92 (exactly)

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

For a given fan size, D_r, the FEG$_d$ upper limits are calculated from the FEG85D_r upper limit [use Equation (A.1)] as numbers in a geometrical series with a quotient of q.

$$q = 10^{\left(-\frac{1}{40}\right)} = 10^{-0,025} = 0,944\,060\,88 \text{ (rounded)} \quad \text{(A.2)}$$

For example, the FEG85 upper limit for size 1 000 mm is 84,136 06 and the upper limit of the grade next down, i.e. FEG80, is calculated as 84,136 06 × q = 79,429 56. The next grade down is FEG75 and its upper limit is calculated as 79,429 56 × q = 74,986 34, etc.

Annex B
(normative)

Calculation method to determine efficiency of component parts

B.1 General

The efficiency of the drive end components, which are not included in the scope of delivery, can only be estimated.

The estimated efficiency values can either be those certified by the manufacturers of suitable and commercially available components or be the default values listed in this annex.

To encourage the improvement of the efficiency of the components offered as a complement to bare shaft fans, actual efficiency values provided by component manufacturers shall preferably be used instead of default values.

If the fan is supplied without a motor that drives it, the fan efficiency shall be calculated at the impeller's optimum efficiency point, η_{opt}, using Equation (B.1):

$$\eta_e = \eta_r \times \eta_m \times \eta_T \times \eta_c \times C_m \times C_c \tag{B.1}$$

where

η_e is the overall efficiency;

η_r is the optimal fan impeller efficiency according to $P_{u(s)}/P_a$, as given in ISO 5801;

η_m is the motor efficiency;

η_T is the drive mechanism (transmission efficiency);

η_c is the variable speed drive efficiency;

C_m is the compensation factor to account for matching of components = 0,9;

C_c is part load compensation factor.

B.2 Motor

Motor efficiency, η_m, shall be estimated if the motor is not included in the fan product.

The estimated efficiency for three-phase motors shall be the minimum specified by valid legal regulations or if not in existence, the minimum specified for class IE1 in accordance with IEC 60034-30.

The estimated efficiency for all other induction motors, rated below 0,75 kW, shall be calculated using Equation (B.2):

$$\eta_m = 0{,}146\ 2 \times \ln(P_N) + 0{,}838\ 1 \tag{B.2}$$

where P_N is the nominal motor power, in kilowatts.

Key

P_N nominal motor power (kW)

η_m motor efficiency (%)

Figure B.1 — Default efficiency values for motors below 0,75 kW

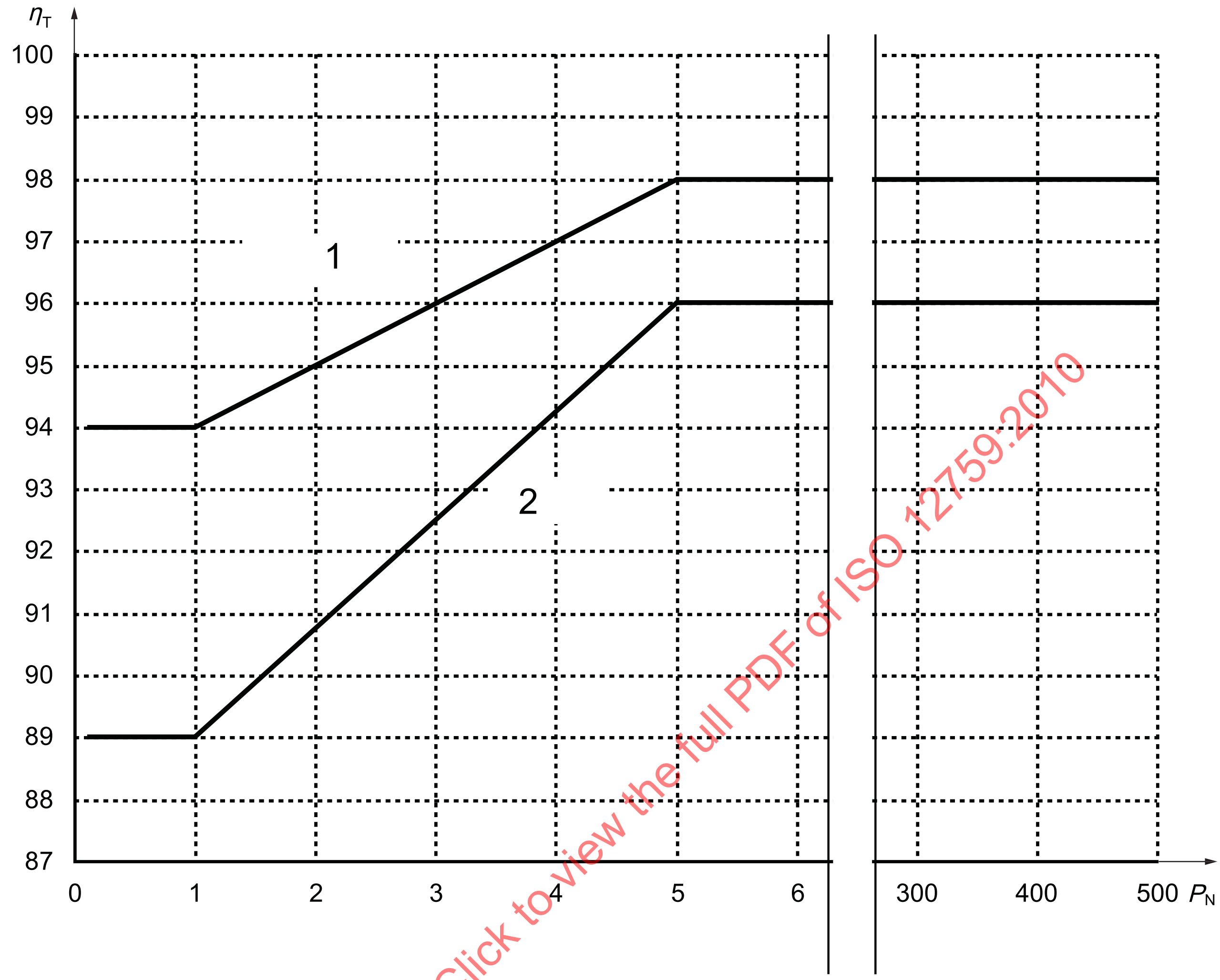
B.3 Transmission

If the fan has a direct drive, i.e. the impeller is mounted directly on the motor shaft, a transmission efficiency, η_T, of 100 % shall be assumed. An allowance shall be made for bearing losses, flexible coupling, etc., if these form part of the transmission system; these may be determined using ISO 5801.

If the fan has a belt drive, the default values are given in Table B.1.

Table B.1 — Default values for belt drive efficiency

Nominal motor power	η_T (V-belts)	η_T (flat belts)
$P_N < 1$ kW	0,89	0,94
1 kW $< P_N <$ 5 kW	$0{,}017\,5 \times P_N + 0{,}872\,5$	$0{,}01 \times P_N + 0{,}93$
$P_N > 5$ kW	0,96	0,98



Key

P_N nominal motor power (kW)

η_T drive mechanism (transmission efficiency) (%)

1 flat belt

2 V-belt

Figure B.2 — Default efficiency values for belt drives

B.4 Controls

Variable speed drive (VSD) efficiency, η_c, shall be that declared by the manufacturer. The compensation factor shall only be those given in 6.3. If a VSD is not used, η_c and C_c shall be removed from Equation (B.1).

B.5 Worked example for a forward curved centrifugal fan

Legislation could require a fan to exceed a driven fan efficiency line, for a centrifugal forward curved fan, of FMEG35. The proposed fan has not been measured as a complete assembly and comprises of fan, motor and V-belt drive mechanism. The impeller efficiency, η_r, is 60 %, the fan air power, P_u, at point of optimum efficiency is 1,125 kW, and has been measured using installation category D. The motor used is a 2,2 kW

4-pole motor of efficiency classification IE2, in accordance with IEC 60034-30. A variable speed drive, with an efficiency of 95 %, is part of the fan.

Using Equation (B.1), $\eta_e = \eta_r \times \eta_m \times \eta_T \times \eta_c \times C_m \times C_c$

where

η_r is 0,60 (60 %);

η_m is 0,843 (see B.2, IE2, 84,3 %);

η_T is 0,911 (see B.3);

η_c is 0,95 (see B.4);

C_m is 0,90 (see B.1);

C_c is 1,064 (see 6.3);

then $\eta_e = 0{,}60 \times 0{,}843 \times 0{,}911 \times 0{,}90 \times 0{,}95 \times 1{,}064 = 0{,}418$ (41,8 %)

Using equation $\eta_e = P_u/P_e$, then $P_e = P_u/\eta_e$. Therefore $P_e = 1{,}125/0{,}418 = 2{,}69$ kW.

Using the graph in Figure 6 or Table 4, it is found that the optimum efficiency should be 31,4 % or greater for a power input of 2,69 kW. Therefore, the proposed fan meets the minimum criteria for efficiency line FMEG35.

$$\text{FMEG35} = 2{,}74 \times \ln(P_e) - 6{,}33 + N_G \quad \text{(B.3)}$$

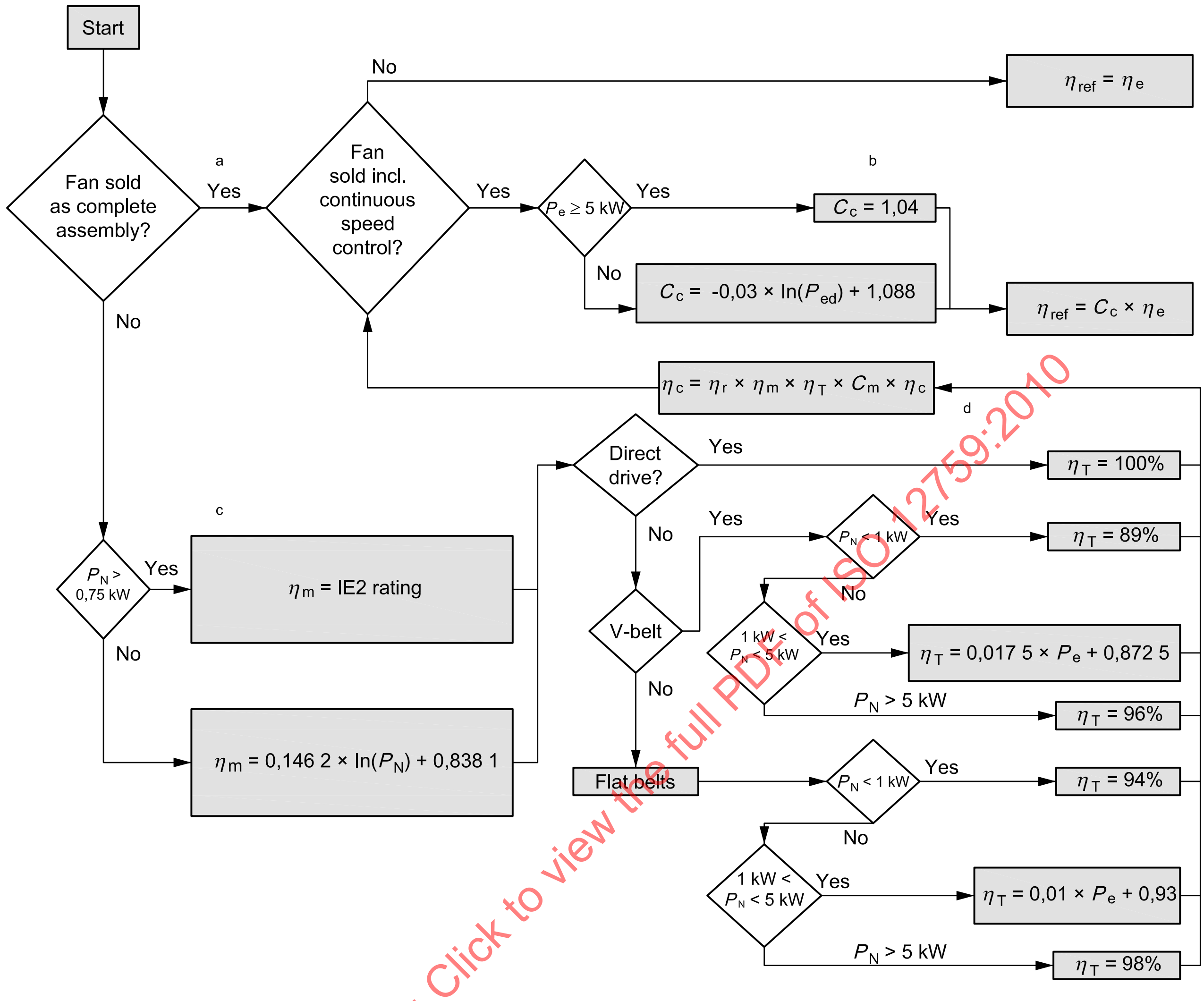
where

$N_G = 35$

$P_e = 2{,}69$ kW

then

$$\text{FMEG35} = 2{,}74 \times \ln(2{,}69) - 6{,}33 + 35 = 31{,}4\ \%$$



Key

C_c compensation factor to account for energy savings at part load, if using speed control

C_m compensation factor to account for suboptimal matching of components, 0,9

P_e input power to the fan product (kW)

P_N nominal motor power (kW)

η_c efficiency of the VSD only (if not integrated within a motor)

η_e efficiency of the complete product, including fan wheel, motor and transmission

η_m efficiency of the motor only (including losses of VSD, if integrated within the motor)

η_r efficiency of the fan wheel only

η_{ref} reference efficiency of the fan product that should be applied in the context of Directive 2009/125/EC

η_T efficiency of the transmission only

a If a fan is sold as a complete assembly, efficiency, η_e, shall be assessed by direct measurement of P_e or P_{ed} and P_u.

b To account for energy savings at part load, a compensation factor shall be used.

c Default values shall be used for calculation, if the fan is not supplied as a complete assembly.

d To account for the mismatching of components, a compensation factor, C_m, of 0,9 shall be applied.

Figure B.3 — Calculation procedure, control compensation factor and components

Annex C
(informative)

Variation of fan performance between installation categories

There can be a significant difference in results of performance measurements between the installation categories. It is, therefore, important for the person selecting the fan, the end user or legislator to understand which installation category is being considered. In addition to the installation category, it should be stated whether the FMEG considered is based on overall efficiency or overall static efficiency (see ISO 5801).

The installation categories are devised to give a good indication of how the fan can perform in a particular application. For example, an axial fan on a refrigeration condenser operates in a condition close to free inlet and free outlet conditions and, therefore, installation category A would be appropriate. Installation category D is for applications where there is a duct fitted on the inlet and outlet. This gives an incorrect indication of performance if the fan is applied to a refrigeration condenser.

Another example is a radial (plenum) fan used in an air handling unit (AHU). This operates in close to free inlet and outlet conditions, and measurements taken according to installation category A would be appropriate. If a duct is connected to the inlet inside the AHU, installation category C would be more appropriate.

An axial fan tested according to installation category D gives a higher efficiency value than one measured to installation category A. A plenum fan measured according to category C gives a higher efficiency value than according to category A.

Legislators should use this International Standard by clearly stating the installation category when setting the minimum efficiency levels, for example:

a) axial fan according to installation category A — minimum efficiency level FMEGxx;

b) axial fan according to installation category B — minimum efficiency level FMEGxx;

c) axial fan according to installation category C — minimum efficiency level FMEGxx;

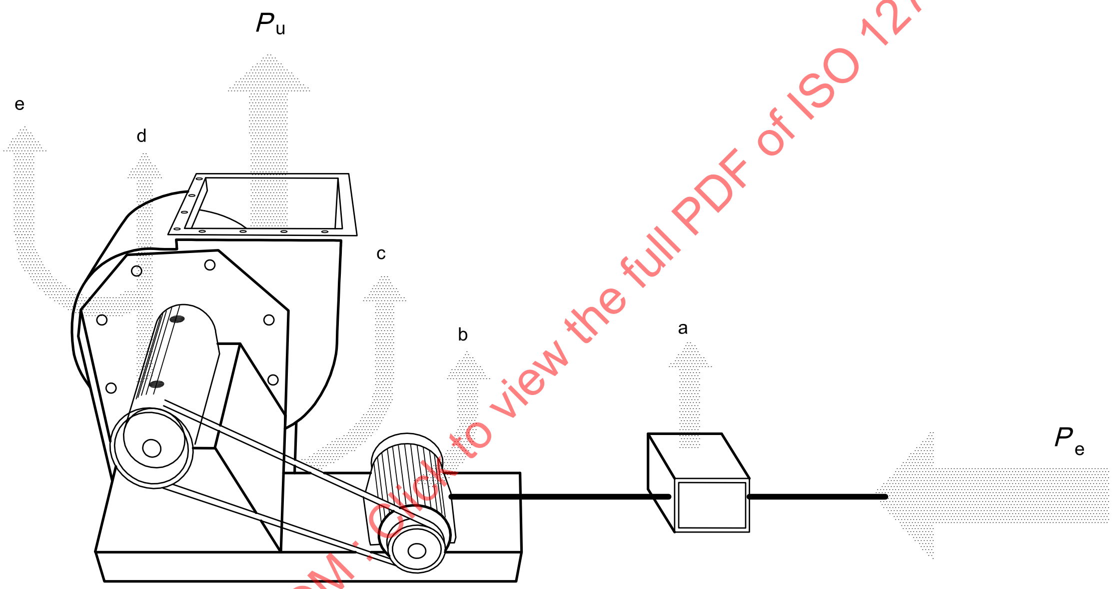
d) axial fan according to installation category D — minimum efficiency level FMEGxx.

Annex D
(informative)

Input power calculation for driven fans at design point

D.1 General

Economic or environmental concerns have resulted in renewed attention being given by many countries to the need for increasing the energy efficiency of all types of fan installations. There is, therefore, a need for an agreed approach to the calculation of the electrical input power, P_e. Figure D.1 shows a typical V-belt driven fan and the various losses that occur, as shown in Figure 2.



Key

P_e electrical input power

P_u volume flow and pressure (air power)

a Variable speed device loss (heat).

b Motor losses (heat).

c Belt losses (heat).

d Bearing losses (heat).

e Impeller and casing aerodynamic losses (heat).

Figure D.1 — Typical belt driven fan showing power losses

D.2 Power consumption calculations

D.2.1 General

The electrical input power consumed by a fan installation is made up of a number of elements. These may be summarized as follows in D.2.2 to D.2.4.

D.2.2 Impeller power is the mechanical power supplied to the fan impeller in a cased fan. This is denoted as P_r, and is expressed in watts or kilowatts. P_u is the fan air power and fan impeller efficiency is:

$$\eta_r = \frac{P_u}{P_r} \tag{D.1}$$

expressed as a decimal.

This is directly applicable to fan arrangements 4, 5, 15 and 16 (see ISO 13349).

D.2.3 Fan shaft power is the mechanical power supplied to the fan shaft. This is denoted as P_a, and is expressed in watts or kilowatts. P_u is the fan air power and fan shaft efficiency is:

$$\eta_a = \frac{P_u}{P_a} \tag{D.2}$$

expressed as a decimal.

This is directly applicable to all other fan arrangements, i.e. 1 to 3, 6 to 14 and 17 to 19 (see ISO 13349).

It differs from the impeller power by the addition of power losses in the fan bearings as a result of friction.

D.2.4 Bearing frictional power: these losses can be obtained from Equation (D.3):

$$P_b = 1{,}05 \times 10^{-4} \times M \times N \tag{D.3}$$

where

P_b is the power loss in bearings, in watts;

M is the total frictional moment of the bearings, in newton metres;

N is the impeller/shaft rotational speed, in reciprocal minutes.

The frictional moment for a good quality, correctly lubricated, bearing can be estimated with sufficient accuracy in most cases taking a coefficient of friction, μ, as constant, and using Equation (D.4):

$$M = 0{,}5 \mu C_d \tag{D.4}$$

where

M is the total frictional moment of the bearing, in newton metres;

μ is the coefficient of friction as a constant for the bearings (see Table D.1);

C_d is the equivalent dynamic bearing load, in newtons;

d is the bearing(s) bore diameter(s), in metres.

Table D.1 — Approximate constant coefficients of friction for different bearing types — Unsealed

Type of bearing	Coefficient of friction μ
Deep groove ball	0,001 5
Angular contact ball	
— Single row	0,002
— Double row	0,002 4
Four-point contact ball	0,002 4
Self-aligning ball	0,001 0
Cylindrical roller	
— with cage	0,001 1
— full complement	0,002 0
Needle roller	0,002 5
Taper roller	0,001 8
Spherical roller	0,001 8
Thrust ball	0,001 3
Cylindrical roller thrust	0,005 0
Needle roller thrust	0,005 0
Spherical roller thrust	0,001 8
NOTE For all other types of bearing, see the information supplied by the manufacturer.	

The total resistance to rotation of a bearing comprises the rolling and sliding friction in the rolling contacts, in the contact areas between rolling elements and the cage, the guiding surfaces of the rolling elements or the cage, the friction in the lubricant and the sliding friction of contact seals, if fitted.

If bearings are fitted with contact seals, the frictional losses in these may exceed those generated in the bearings. The frictional moment of seals for bearings that have seals on both sides may be estimated from the empirical Equation (D.5):

$$M_{\text{seal}} = k_1 d_{\text{s}}^{a} + k_2 \tag{D.5}$$

where

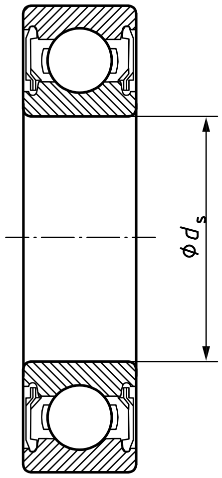
M_{seal} is frictional moment of seals, in newton metres;

k_1 is a constant dependent on bearing type;

k_2 is a constant, in newton metres, dependent on bearing type and seal type;

d_{s} is the shoulder diameter of bearing, in metres (see Figure D.2);

a is a multiplicand dependent on bearing and seal type.



Key

d_s shoulder diameter of bearing

Figure D.2 — Section through a sealed rolling element bearing

In Equation (D.5), a can vary between 0 and 2,3; k_1 can vary between 0 and 0,06 and k_2 can vary between 0 and 50. For confirmation of these values, see the information supplied by the bearing manufacturer, if necessary, noting that different symbols can be used.

As:

$$P_b = P_a - P_r \tag{D.6}$$

the efficiency may be defined as fan bearing efficiency, given in Equation (D.7):

$$\eta_b = \frac{P_r}{P_a} = 1 - \frac{P_b}{P_a} \tag{D.7}$$

and

$$\eta_r \times \eta_b = \eta_a \tag{D.8}$$

In all cases, it is probably better to test the same fan design in arrangements such as 1 and 4 (see ISO 13349), obtaining the bearing losses by subtraction.

NOTE The total moment of the fan bearings is the numerical sum of the individual moments ignoring the sign (the direction of the moments is immaterial).

D.2.5 Transmission power

Many fans, especially in the heating, ventilation, air conditioning and refrigeration (HVACR) sector, are driven through pulleys and V-belts. This gives flexibility to fan manufacturers, who can cover a wide duty range with a limited number of models. The system designer can take comfort in the thought that if his or her system resistance calculations prove to be wrong, a simple pulley change can rectify the situation, provided there is sufficient motor capacity.

Care should be taken to neither over, nor under provide in the design of the belt drive. In either case, its efficiency suffers. Whereas a well-designed drive can exceed 95 % in its efficiency, the provision of additional belts for a direct-on-line start can often reduce this considerably. A “soft” start can be part of a better solution.

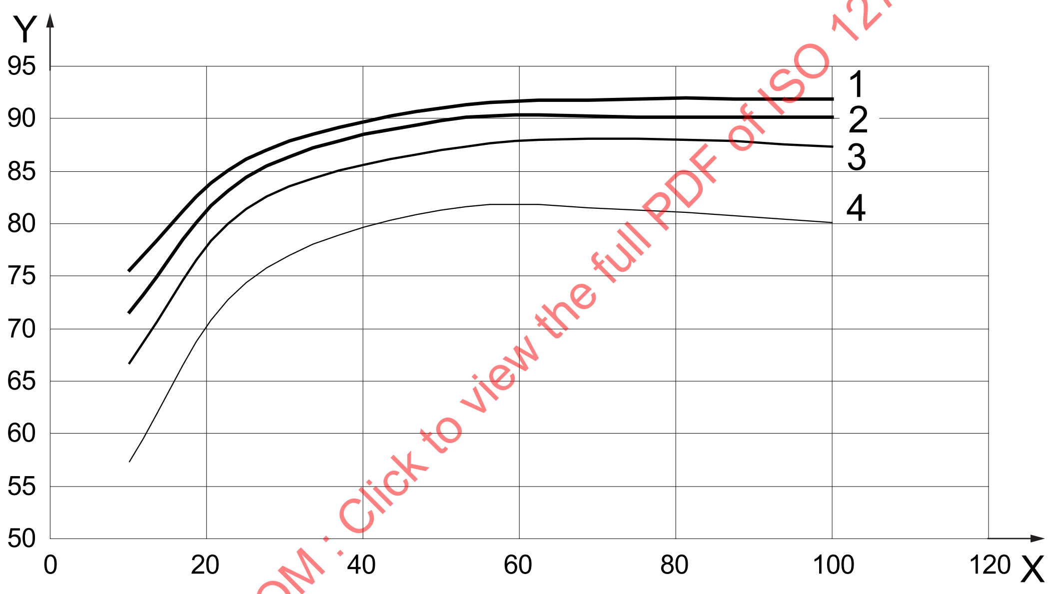
If fans are driven through flexible couplings (see arrangements 7, 8, 9 and 17 in ISO 13349), these are normally assumed to have an efficiency of 97 % unless figures are available from the coupling supplier.

D.2.5 Motor power

Perhaps the most common type of motor used in fan installations (certainly above an output of 1 kW) is the squirrel cage a.c. induction design. It is robust, reliable, requires minimum maintenance and is relatively inexpensive. There has been a gradual improvement in its efficiency at both full and partial loads. This has been achieved by the inclusion of greater amounts of active material. Three efficiency levels are standardized in IEC 60034-30. The efficiency for actual motors at partial loads (around 75 % of nameplate rating) can sometimes be greater than that at full load. This is contrary to earlier designs. It is important to use the efficiency at the actual absorbed power, which may be calculated using any of the methods described in IEC 60034-2-1.

D.2.6 Controls/power loss

This is often ignored, especially with inverters. The efficiency of controls at high turn-down ratios can be much less than 100 %, although, of course, powers absorbed by the fan are also small. Figures D.3 to D.6 are typical examples of a 30 kW motor.



Key

X nominal torque (%)

Y efficiency (%)

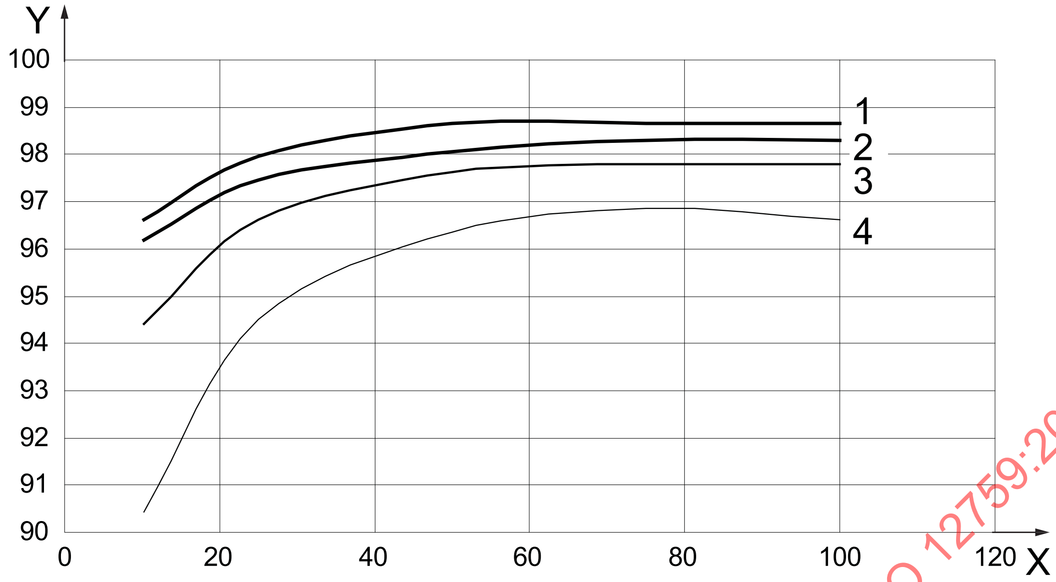
1 100 % speed

2 75 % speed

3 50 % speed

4 25 % speed

Figure D.3 — Efficiency of a typical motor at various loads



Key

X nominal torque (%)

Y efficiency (%)

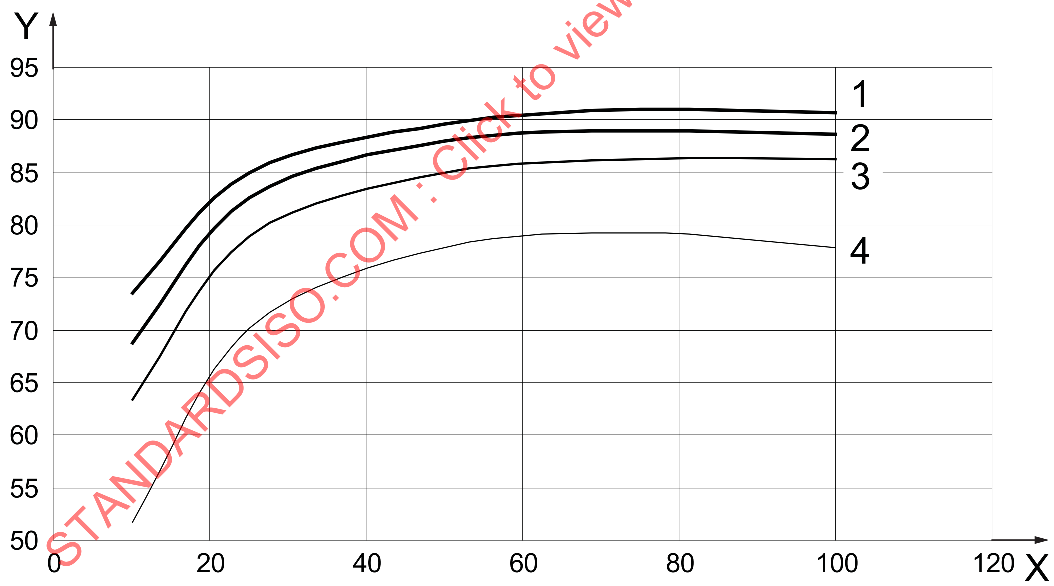
1 100 % speed

2 75 % speed

3 50 % speed

4 25 % speed

Figure D.4 — Efficiency of a typical variable frequency drive



Key

X nominal torque (%)

Y efficiency (%)

1 100 % speed

2 75 % speed

3 50 % speed

4 25 % speed

Figure D.5 — Efficiency of a typical motor and variable frequency drive

D.3 Mains power required

The electrical power input abstracted from the mains may be calculated using Equation (D.9):

$$P_e = \frac{q_{vsg1} \times p_f}{\eta_r \times \eta_b \times \eta_T \times \eta_m \times \eta_c} \quad \text{(D.9)}$$

where

P_e is the electrical input power, in kilowatts, alternatively in watts;

q_{vsg1} is the flow rate, in cubic metres per second or litres per second (m^3/s or l/s);

p_f is the fan pressure, in kilopascals or Pascals;

η_r is the fan impeller efficiency, expressed as a decimal;

η_b is the fan bearing efficiency, expressed as a decimal;

η_T is the transmission efficiency, expressed as a decimal;

η_m is the motor efficiency, expressed as a decimal;

η_c is the control efficiency, expressed as a decimal.

NOTE 1 If fan pressure is expressed in Pascals, P_e is in watts, if fan pressure is expressed in kilopascals, P_e is in kilowatts.

NOTE 2 $\eta_r \times \eta_b = \eta_a$, where η_a is the fan shaft efficiency.

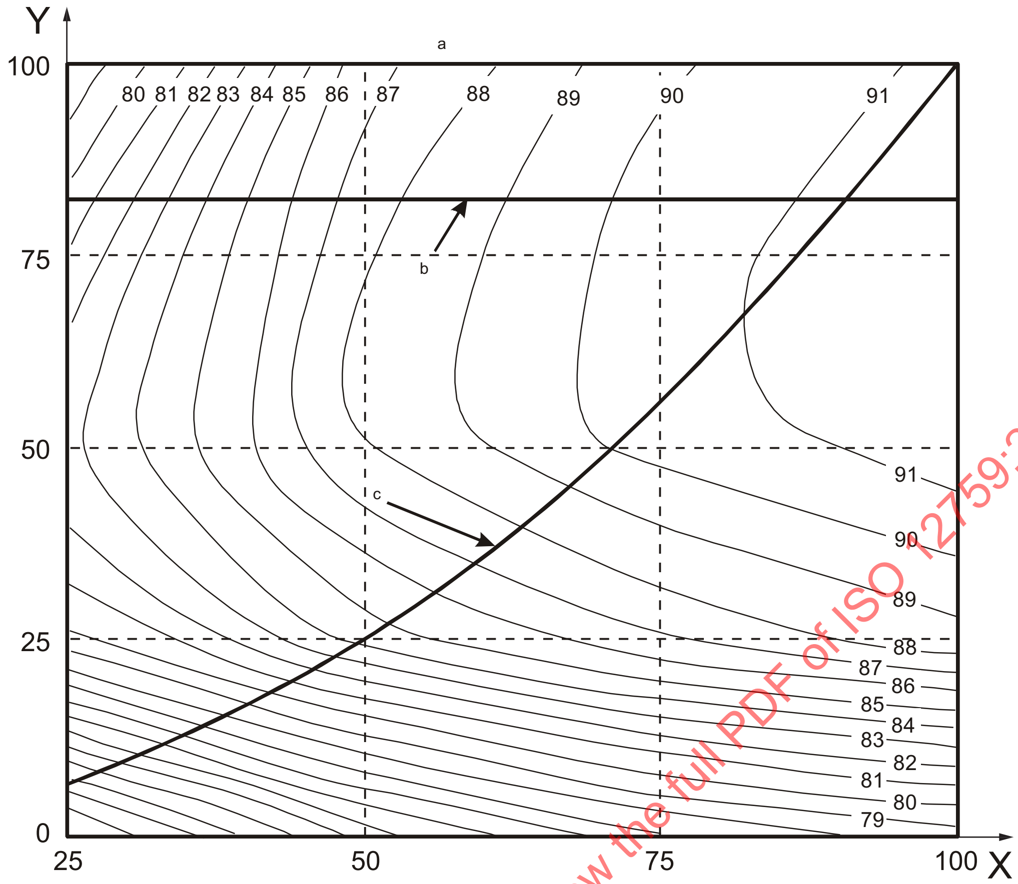
NOTE 3 Fan pressure can also be defined on a static basis provided η_r is also calculated on the same basis. Fan static efficiency is not theoretically correct as it can never be 100 % or 1.

NOTE 4 These calculations are usually conducted at the enquiry stage before an audit can be carried out.

All duties and values should be for the appropriate installation category.

D.4 Presenting results of a typical induction motor and VFD while driving a fan

The combined efficiency of an induction motor and VFD while driving a fan depends on how the fan pressure varies with flow rate. For many systems $p_f \propto q_{vsg}^2$ (see Figure D.6). By plotting the torque, t_m, required from the motor against speed, it is possible to deduce that torque $t_m \propto$ speed n^2 or N^2. There are, however, other possibilities, e.g. torque required can be virtually constant, whilst viscosity effects can reduce the speed index to less than 2. It is also possible that there are fixed resistance elements. Provided the variation of motor torque with speed can be deduced, it is possible to calculate how the efficiency varies.



Key

X speed (% nominal)

Y torque (% nominal)

a System efficiency.

b Fixed resistance.

c $t_m \propto n^2$.

Figure D.6 — Typical efficiency of motor and VFD if applied to a fan (Adapted from Reference [10].)

