EUROPEAN FAN EFFICIENCY STANDARD PLANS FOR REVISION INCLUDING STANDARDISED PRODUCT INFORMATION

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SUMMARY

Responding to criticism from other stakeholders, the European fan industry acknowledges a need to provide additional data describing the energy losses at partial load operation. Rarely is a fan used at its best efficiency point. Standardization is required that describes the performance characteristics at other operating points. Standardized methodology can then be used by regulators to legislate product information requirements. This would also provide users with reliable data to make better informed decisions. This paper describes proposals from European fan industry for a European standardization request (sReq).

INTRODUCTION

A standardisation request from the European Commission

The efficiency test standard FprEN17166 [1] was developed at the request of the European Commission to support regulation 327/2011 [2]. In drafting the standard, technical experts of the technical committee CEN TC156 WG17 took the opportunity to create new terms and definitions to clarify some issues that occurred with the publication of the regulation. Other issues had to follow the legally binding requirements of the regulation leaving unresolved matters.

The request for a revision, or new standard, in the European Commission annual Union work programme for European standardisation for 2021 [3] gives an opportunity to put right some of those issues. But the request in the work programme is specific in its requirement stating – '*the main objective is to define a sufficient number of operating points and an interpolation/ calculation method, but also to limit the environmental impact of fans driven by motors with an electric input power between 125 W and 500 kW and increase the market penetration of technologies that limit the life-cycle environmental impact of this type of fans*'. These are the main objectives that must be addressed in a revision or new standard.

The source of the request for '*a sufficient number of operating points and an interpolation/ calculation method*' can be found in criticism from several stakeholders, including the consultant acting on behalf of the commission. This is explained in detail in the Problem Statement published by the European Ventilation Industry Association (EVIA) [4].

The consultant stated at the consultation forum on the review of regulation327/2011 '*there have been no major developments in the metric underlying that Regulation. The 'extended product approach'* for part load testing, which is part of several other Eco-design-regulated products, has hardly been explored by the sector' [5]. The term Extended Product Approach is often confused with system efficiency and incorrectly linked to an Energy Efficiency Index (EEI), see the EVIA Problem Statement.

Other stakeholders refer to the term Extended Product Approach (EPA) defined in IEC 61800-9-1 [6] and conclude that an EEI must be used in fan standards to define the efficiency of the fan system operating at part load. The European fan industry does not consider an EEI as an appropriate metric as it does not provide sufficient data for users to make informed decisions.

An alternative approach, like that used in European regulation of motor and drives, is proposed by EVIA, European AMCA and Eurovent in their Proposal for a standardisation request [7] and is described in this paper.

IDIOSYNCRASIES OF 327/2011

Unexpected outcomes of European ecodesign regulation of fans 327/2011

The review study that formed the contents of ecodesign regulations for fans 327/2011 started in 2006 and the regulation was published in April 2011. What was not appreciated was the implications of terms being created in a legal document that conflict with those in technical standards. The effect of missing terms and definitions in fan standardization was also not realized.

Ecodesign regulations for fans 327/2011 defined a fan as – 'means a rotary bladed machine that is used to maintain a continuous flow of gas, typically air, passing through it and whose work per unit mass does not exceed 25 kJ/kg, and which:' 'may or may not be equipped with a motor when placed on the market or put into service;'

This conflicts with the term from the fan definition standard ISO 13349 [8, 9] that defines a fan as a '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'. The two key points are that this describes the fan as a machine with mechanical input, whereas the regulation omits this part. Secondly the regulation states it may or may not be equipped with a motor.

The outcome was regulation of a fan that is equipped with a motor, and a fan without a motor. However, the regulation only set limits and describes a methodology of measurement of fans equipped with motors.

The concept of fans being equipped with and without motors was commonly accepted but the distinction was not described in standardisation. Some in the industry could foresee this confusion and in parallel tried to resolve with new definitions of 'bare shaft fan' (fan not equipped with a motor) and 'driven fan' (fan equipped with a motor) being added to the revision of ISO 13349 in 2010 [9], but this was too late to influence the regulation.

Other idiosyncrasies effected Jet fans and Circulating fans. The regulation used measurement methodologies as described in ISO 5801 [10] but Jet fans are not measured with these methodologies, resulting in all failing to meet the limits.

Circulating fans were not defined until the revision of ISO 13349 in 2010. They fall within the scope of 327/2011, perhaps by accident, but also they too are not measured using ISO 5801.

The conclusion is to understand that technical standards need to be full and concise with all the terms used within the industry. This gives a chance that future regulation follows convention. Where terms emerge outside of fan standardisation and they are problematic, then the industry needs to resolve.

TERMS AND DEFINITIONS

Energy Efficiency Index (EEI)

Three terms were introduced in IEC 61800-9-1 that have a significant impact on fans.

- Energy Efficiency Index (EEI) - value describing the energy efficiency of an application, resulting from the extended product approach (EPA) ;
- Extended Product (EP) **-** driven equipment together with its connected motor system (e.g a PDS) ;
- Extended Product Approach (EPA) - methodology to determine the energy efficiency index (EEI) of the extended product (EP) using the speed torque profiles of the driven equipment, the relative power losses of the motor system and the duty profile of the application.

An extended product is a fan; equipment driven by a motor. The standard states in section 4.3 that it is the responsibility of the fan committee ISO TC117 to produce an extended product approach. As the definition states such an approach is a methodology to determine an EEI, then it sets a precedence and the assumption that no other metric is appropriate.

An EEI is more appropriate for applications that use fans. The fan industry is of the view that an EEI is not always appropriate to describe the performance and efficiency of a fan itself.

IEC Guide 118 [11] introduces the phrase systems approach in section 4 and the guide refers to IEC 61800-9-1 and the terms system approach and extended product approach become entwinned into system efficiency and system efficiency metric.

The standard also refers to partial-load and part-load without describing the terms. The European industry proposes partial-load should be defined as – '*any point within the safe operating characteristics of the fan away from the optimum point on the performance curve at constant speed or at any point below with reduced speed*'.

The European industry proposal document suggests the following must be defined in fan standards to balance the effect of IEC 61800-9-1 and to add further clarity:

- Extended product,
- Extended product approach,
- System efficiency metric,
- Partial-load.

ENERGY EFFICIENCY INDEX

Is an EEI appropriate in a fan standard?

An energy efficiency index (EEI) is described in IEC 61800-9-1 as a value describing the energy efficiency of an application, resulting from the extended product approach. Where an extended product approach is defined as a methodology to determine the energy efficiency index (EEI) of the extended product (EP) using the speed torque profiles of the driven equipment, the relative power losses of the motor system and the duty profile of the application.

As described in the Terms and Definitions there is an assumption that an EEI mut be used to describe the efficiency of an application, and that an EEI should be used in fan standards. But a fan is not always an application, where application is something that is designed for a particular purpose. A fan is designed for a principle of moving a gaseous substance from one point to another, and is designed to be used for many purposes. Fans are often components that are integrated in applications, for example a refrigeration system, see figure 1.

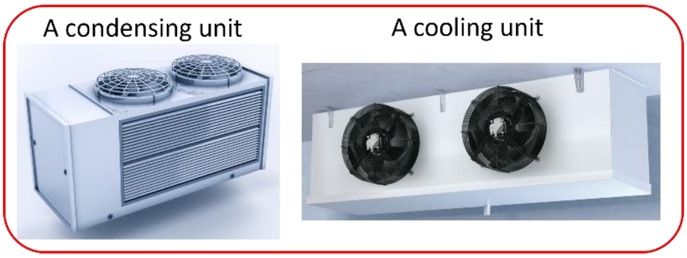


Figure 1: a refrigeration system

Fans are components of the refrigeration system. The refrigeration system is an application and is likely to have a duty profile, but the profile will be unique to where and how the system is used. Each application and installation will have a different profile. The load on the fan(s) will vary depending on the demand from the refrigeration system, and that will vary based on the load applied, and this will change depending on ambient conditions, temperature, humidity, etc. Defining a load profile in a fan standard would be challenging with such a wide variety of conditions, if not illogical.

IEC 61800-9-1 gives an example of a pump with an EEI. EN 17038-2 [12] describes the EEI as the ratio between the power input weighted by a load profile and a reference power. The load profile is based on periods of time at four defined operating points, see figure 2.

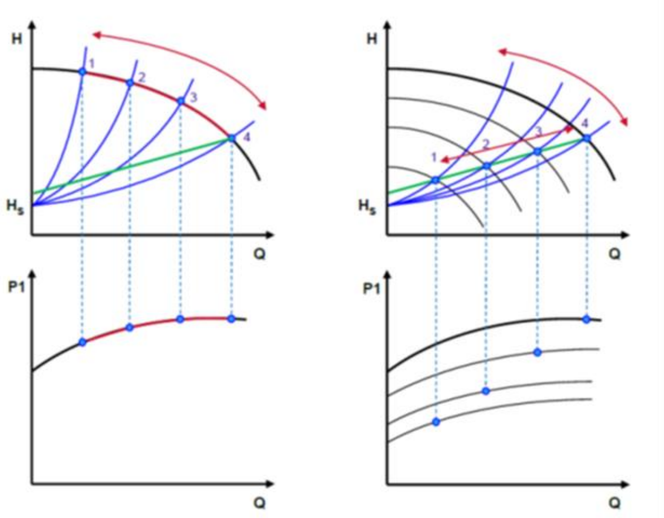


Figure 2: load points for variable flow operation. Source EN 17038-2 figure 2

This approach is appropriate for pumps where it is assumed from the standard that pumps are applications that follow similar duty profiles. Fans are different, the fans used on the refrigeration application shown in figure 1 can also be used on other applications having different duty profiles. Figure 3 is an example of one fan that is used in many ventilation applications.

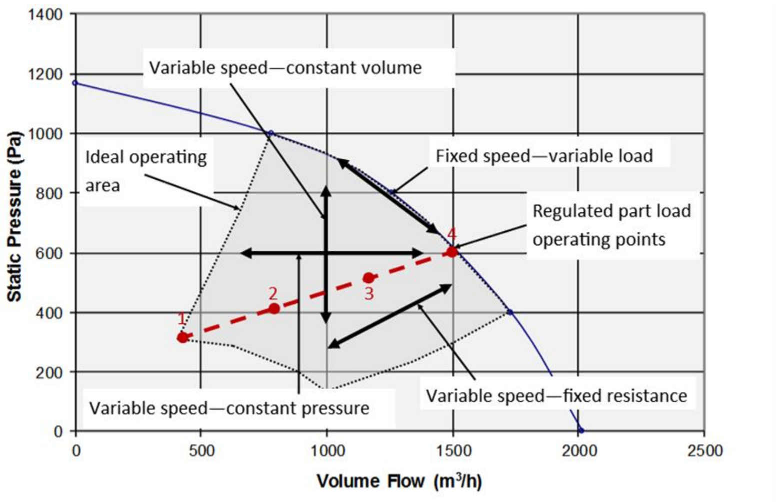


Figure 3: performance characteristics of a fan used in many ventilation applications

The different ventilation applications could operate over many different profiles; a fixed fan speed with variable load, variable fan speed to maintain a constant volume, a variable fan speed to maintain a constant pressure, a variable fan speed operating against a fixed system resistance, etc. focusing on four defined operating points in a standard does not describe the performance and energy efficiency of the fan. A concern of a duty profile defined in a standard would be that fan development engineers focus on the performance at these points to the detriment of the whole operating characteristic.

A SUFFICIENT NUMBER OF OPERATING POINTS

A sufficient number of operating points and an interpolation/ calculation method

As an alternative to an EEI, EVIA, European AMCA and Eurovent proposes that additional data should be provided at partial load operation to enable system designers and users of fans to make better informed decisions. Many fan manufacturers already provide this additional data, but it is not formerly described in standards.

Motor standards describe the performance across the operating characteristic of an electric motor by publishing data at 7 defined points, see figure 4. IEC 60034-2-3 [13] includes interpolation methodology to determine the losses at any point on the characteristic using these 7 standardised operating points.

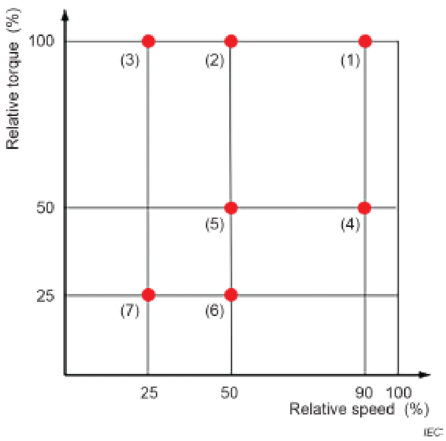


Figure 4; standardized operating points of a converter-fed motor. Source figure 1 of IEC 60034-2-3[1]

[1] IEC 60034-2-3 ed 1.0 “Copyright © 2020 IEC Geneva, Switzerland. www.iec.ch”

A similar approach can be applied to fans. But instead of 7 operating points, three characteristic curves could be provided to describe the performance across is entire operating characteristic. This is based on a driven fan with a variable speed drive. One at the stated inherent speed, one at the minimum recommended speed and one between the two, see figure 5.

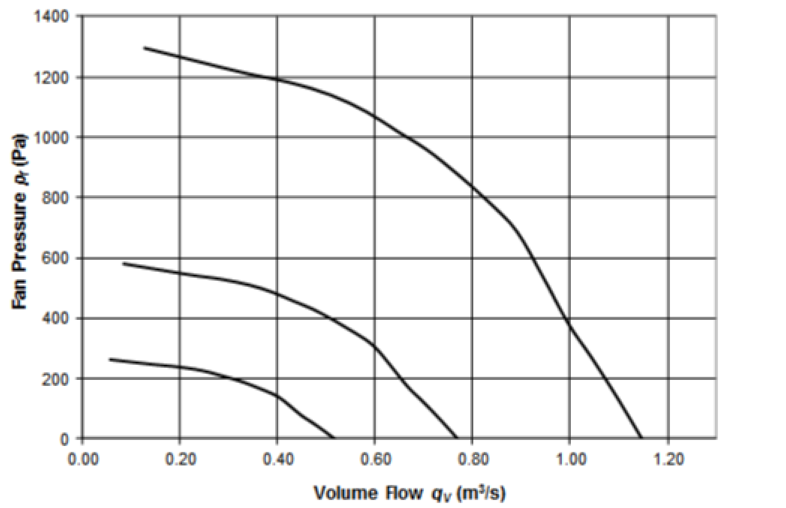


Figure 5; a proposal of partial-load operational performance described by three fan curves

Test points for determining fan characteristics curves would comprise a sufficient number of plotted test points to permit the characteristic curve to be plotted over the normal operating range, reference section 7.7 of ISO 5801:2017.

A method to determine the losses at any point between these curves needs to be defined. For a non-driven fan (fan without an electric motor), a method is already described using the laws on fan similarity, reference section 14 of ISO 5801 and section 7.1 of ISO 13348 [14]. Can this methodology be adapted for driven fans?

In the case of non-driven fan, the laws on fan similarity can be used to determine the fan shaft power (P_a) at a specific point on the fan characteristic between these curves. If the motor is directly coupled to the non-driven fan, then P_a will be the same as the required motor output power (P_o).

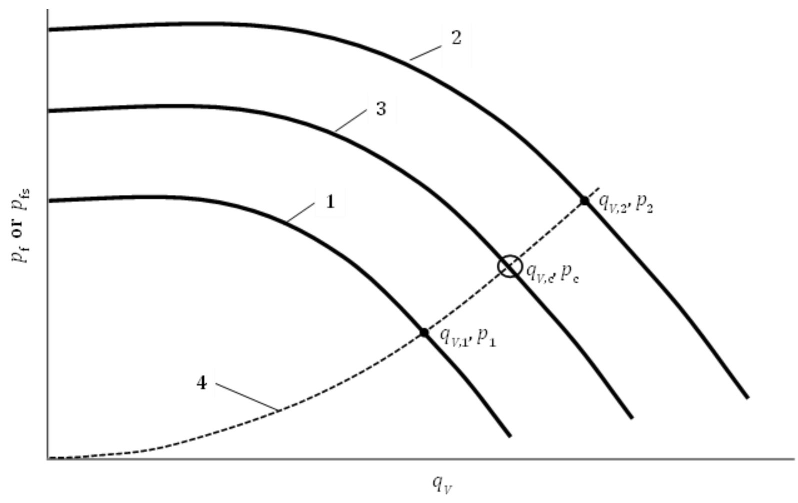
The losses of the motor can be can be added to the non-driven fan loss to establish the overall efficiency and the electrical power input to the motor at the chosen duty point.

One method to determine the motor losses is detailed in IEC 60034-2-3. This calculates for a motor without a variable speed drive.

An alternative calculated approach is described in ISO 12759-2 [15]. Section 4 describes how the efficiency of the motor at the load equivalent to P_a can be determined together with a method to calculate the electrical input power to the driven fan arrangement, p_e.

In addition, the methodology in ISO 12795-2 can determine the efficiency of other components of the fan system; variable speed drive and mechanical transmission.

Currently an interpolation or extrapolation method for driven fans is not fully defined. One is proposed in an informative annex of the draft FDIS 12759-6 [16].



Key:

1	Fan curve at known speed N1 and standard density ρref
2	Fan curve at known speed N2 and standard density ρref
3	Fan curve at desired speed Nc and standard density ρref
4	System curve at standard air density, $p/(\rho_{\text{ref}} \times q_v^2) = \text{constant}$

Figure 6; source FDIS 12759-6 Figure E.1 — Specific case at standard air density

FDIS 12759-6 proposes that with two known points from measured fan characteristic points a third desired point can be calculated, see q_{vc} p_c on curve 3 of figure 6. The methodology uses the laws on fan similarity to derive a final equation to determine the power input at the desired operating point, equation (1) is equation [E.6] from FDIS 12759-6,

$$P_{ed} = P_{ed,c} = P_{ed,1} + \left(\frac{q_{v,c} \times p_c - q_{v,1} \times p_1}{q_{v,2} \times p_2 - q_{v,1} \times p_1}\right) \times \left(P_{ed,2} - P_{ed,1}\right) \quad (1)$$

The equation does not account for the non-linear relationship of the motor, and variable speed drive if fitted. But how significant are these losses? The industry needs to identify this and decide if it is significant and if so, adapt this equation to take it into consideration.

The above is for a driven fan with a variable speed drive (VSD). The proposal for a standardization request from the European fan industry includes methods for fans without VSD, for Jet fans and Circulating fans.

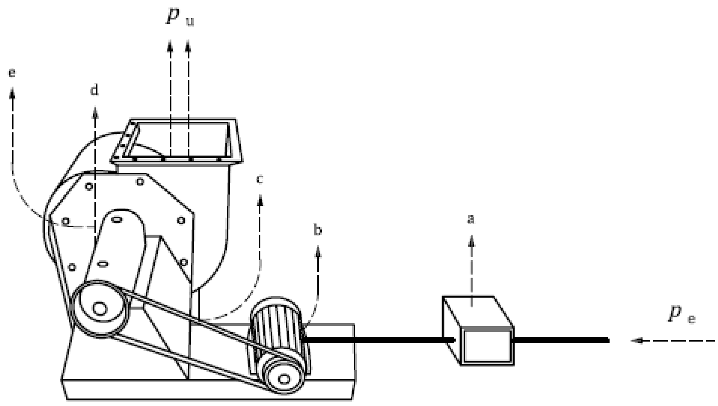
MEASURED VERSUS CALCULATED DATA

Does a calculated approach consider all the losses in a fan system?

The performance of a driven fan can be directly measured using the methodology in ISO 5801. The efficiency at any operating point can be determined from the direct measurement of the fan air power P_u (output power) and the motor input power, P_e, or drive control electrical input power P_{ed}. Equation (2) is the overall efficiency for a driven fan with variable speed drive, source – term 3.54 of ISO 5801. All losses between the measured input an the measured output are taken into consideration.

$$\eta_{ed} = \frac{P_u}{P_{ed}} \quad (2)$$

Informative Annex E of ISO 5801 describes a calculation method to determine the input power for driven fans at a design point. Figure 7 is figure E.1 of ISO 5801 and shows the various elements and losses of a belt driven fan, a driven fan with belt & pulley mechanical transmission and with a variable speed drive



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 7; an example of a driven fan – source ISO 5801 figure E.1

The fan air power can only be measured. The electrical power input from the mains may be calculated using Formula (E.8) of ISO 5801, see equation 3. The Annex states it is important to use the efficiency at the actual absorbed power of the various components of the fan, impeller, bearings, transmission, motor.

$$P_e = \frac{q_{Vsg1} \times p_f \times k_P}{\eta_r \times \eta_b \times \eta_T \times \eta_{mot}} \quad (3)$$

Chapter 4 of ISO 12759-2 describes the calculations required to estimate the extended fan system input power and overall extended fan system efficiency. Calculations start with the fan performance and then progress to each fan system component; V-belt transmission, synchronous belt transmission, coupling, direct drive, motor and variable speed drive.

But do the calculation methodologies of ISO 5801 and ISO 12759-2 take into consideration all the potential losses of a driven fan? The study into a potential ecodesign regulation for fans commissioned by the European Commission did not think so. In the final regulation 327/2011 a compensation factor to account for mismatching of components, C_m, is included, see Annex II, 3.2 of the regulation.

In addition, aerodynamic losses due to disturbances of the airflow through the impeller are not considered. In a calculated approach the performance of a non-driven fan is determined in ideal conditions. Obstructions at the inlet, such as from the pulley of a mechanical transmission, figure 8a, or the turbulence caused by the motor mounting and terminal box, figure 8b and 8c, are not taken into consideration.

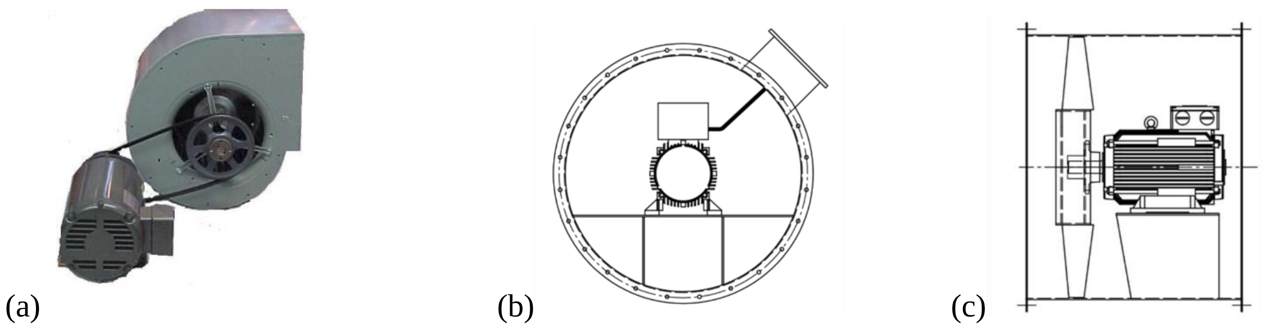


Figure 8: examples of obstructions and aerodynamic losses in the fan system

ISO/TR 16219[17] estimates that cartridge and pillow bearing blocks at the fan inlet can adversely affect the volume flow by as much as 5 %, see table 11 of the technical report. As the air power is a product of volume flow then the efficiency of any calculation is adversely affected unless this loss is taken into account.

Figure 9 shows direct measurement fan characteristics of a 560 mm backward curved centrifugal fan with and without an obstruction at the fan inlet of the fan system.

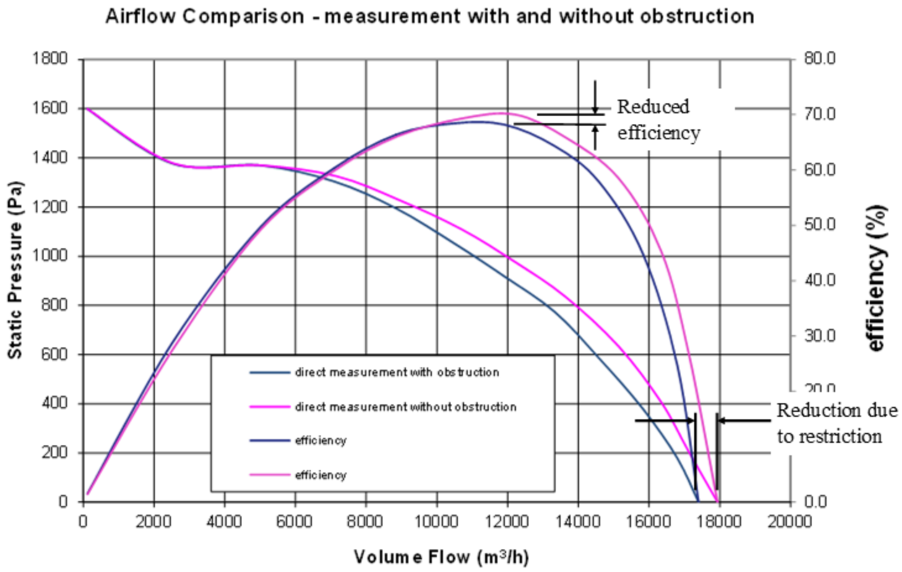


Figure 9: direct measurement fan characteristics with and without obstruction

CONCLUSION

Regulation 327/2011 has shown that if the fan industry has not ensured that all definitions, terms, and methods are in standards then regulators can introduce ones that can cause problems. Further if the industry has strong opinions that a methodology, such as an Energy Efficiency Index, is not appropriate then it must introduce alternatives for regulators to use.

The European fan industry is of the opinion that regulation requiring the publication of additional data at partial-load would provide integrators and users of fans with sufficient information to make better decisions and ensure optimum application.

A standardized format is required to describe the sufficient number of operating points for each fan arrangement; driven fan with and without a variable speed drive, Jet fan and Circulating fan.

Currently the fan similarity law does not consider motor losses, whether it needs to has to be decided and methodology adapted or new methodology added.

Calculation methods to determine fan performance already exists, but they do not always consider all the losses in a fan system. A direct measurement does take into consideration all the losses between the input and output of the fan. Calculation methods must incorporate these losses for a reasonable comparison. Alternatively, it must be stated where calculation methods can be used and where a direct measurement method can only be used. This is important if a calculation method is to be included in a regulation, to ensure an equal comparison between a direct measurement and calculated method.

With these measures in place legislators are more likely to include regulation for product information describing the efficiency and losses across the complete operating characteristics of the fan. That can be applied to any application, that is of value to integrators and users, that encourage better selection and application of fans and that can be used in calculation of the overall system losses.

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GLOSSARY

- Fan – *means a rotary bladed machine that is used to maintain a continuous flow of gas, typically air, passing through it and whose work per unit mass does not exceed 25 kJ/kg, and which:' 'may or may not be equipped with a motor when placed on the market or put into service*. Source ISO 5801 [10].
- Driven fan – *impeller fitted to or connected to a motor, with or without a drive mechanism, a housing or a means of variable speed drive*. Source ISO 13349 [9].
- Bare shaft fan – *fan without drives, attachments or apperturbances*. Source ISO 13349 [9].
- Non-driven fan – *a fan without motors, drives, attachments, or accessories*. Source DIS 13349 [18].
- Jet fan – *fan used for producing a jet of air in a space and unconnected to any ducting*. Source ISO 13349 [9].
- Circulating fan – *fan used for moving air within a space which is unconnected to any ducting and is usually without a housing*. Source ISO 13349 [9]
- Extended product (EP) – *driven equipment together with its connected motor system (e.g a PDS).* Source IEC 61800-9-1 [6].
- Extended product approach (EPA) – *methodology to determine the energy efficiency index (EEI) of the extended product (EP) using the speed torque profiles of the driven equipment, the relative power losses of the motor system and the duty profile of the application*. Source IEC 61800-9-1 [6].
- Energy efficiency index (EEI) – *value describing the energy efficiency of an application, resulting from the extended product approach (EPA).* Source IEC 61600-9-1 [6]
- System efficiency metric – *defines the minimum energy efficiency of the product and provides a requirement for concise data across its operating characteristic, with methodology to interpolate data for any operating point, thus providing data for integrators and users to make better informed decisions.* Source Proposal for a Standardisation Request (sReq) [7]
- Partial-load – *is any point within the safe operating characteristics of the fan away from the optimum point on the performance curve at constant speed or at any point below with reduced speed*. Source Proposal for a Standardisation Request (sReq) [7]
- C_m – *is the compensation factor to account for matching of components*. Source Commission regulation 327/2011 [2].

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