Proposal for a Standardisation Request (sReq)

Fan System Efficiency

Regulation and Standardisation

A recommendation by the European Fan Industry

European Air Movement and Control Association

European Ventilation Industry Association

Eurovent

Summary

This document is a proposal for a European Commission standardisation request (sReq) on a future energy efficiency measure to reduce the impact of fans and increase the efficient use of fans.

Recommendations

The Fan Industry recommend providing clarity on a number of definitions and a standardised approach for providing product information.

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Introduction

Since 2011 the European Union has had an ecodesign regulation for fans, Regulation (EU) 327/2011, that has had a positive impact. It has transformed the market, removing inefficient fans, stimulating innovation, increased the use of higher efficient fans, and between 2012 and 2017 saved an estimated 46,800 GWh of electricity consumption. The next step in the journey is to further reduce energy consumption by providing additional, reliable standardised data to improve the application of the fan.

Regulation of minimum efficiency has been proven to transform the market and reduce energy consumption. The next step is to improve how fans are used to further reduce energy consumption.

Responding to criticism from other stakeholders the 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. Standardisation is required that describes the performance characteristics at other operating points. Those standards can then be used by regulators and by market surveillance to provide users with reliable standardised data to make informed decisions. It gives the fan industry a level platform from which to innovate and develop new solutions.

The EVIA Problem Statement on 'Fan System Efficiency – Regulation and Standardisation' defines the problem of today and identifies the elements that need to be resolved to provide a standardised methodology. A methodology of precisely and reliably describing the energy losses at multiple operating points throughout the characteristics of the fan.

This provides data where integrators and users can make better informed decisions of the applications, installation and use of fans. It provides a foundation where regulators and industry can be creative with protocols and marketing tools. The energy losses could be described in terms of power loss, efficiency, specific fan power or energy ratios. The energy losses could be shown in selection programs and confidently compared across suppliers giving better informed choice.

This document is a proposal for a European Commission standardisation request (sReq) on a future energy efficiency measure to reduce the impact of fans and increase the efficient use of fans. It sets out a pathway towards terms and definitions, and to the provision of additional reliable standardised data to meet future improved efficiencies in applications.

Chapter 1 – terms and definitions

The following are new or existing terms and definitions that have been produced or revised by the Fan Industry.

1.1 Extended Product (EP)

The term Extended Product (EP) is understood to have been first defined in standard IEC 61800-9-1 (1) as driven equipment together with its connected motor system (e.g a PDS). The Fan Industry proposes an alternative definition.

Extended Product

Is a combination of parts that are combined to form a new item. For example, a Fan can be as simple as an impeller, stator and motor (EN17166 definition 3.1 and note 1 to entry), or can be combination of impeller, stator, motor, mechanical drive, variable speed drive, starter, and aerodynamic elements. The skill and knowledge of the manufacturer combines those elements to obtain the optimum performance for the required application and becomes responsible for providing the technical data. Air treatment elements are excluded, e.g. air filters.

An extended product can be a combination of products and components leading to a new set of performance parameters. Therefore, a fan can become a component in a higher system.

1.2 Extended Product Approach (EPA)

IEC 61800-9-1 also includes a term Extended Product Approach (EPA) that defines it as a method to determine the Energy Efficiency Index (EEI) of the extended Product (EP).

The Fan industry does not agree with a strict extended product approach directly linked to an Energy Efficiency Index. We believe it is important to provide reliable data so that others can make informed decisions for the application where the extended product is used.

The problem is to understand the point of context when considering the term Extended Product Approach. Is it considering the fan (fan driven by a motor) as the Extended Product of the combination of impeller, stator and motor? Or is it considering the system into which the fan (fan driven by motor) is installed or integrated?

The principle of a system approach is to understand that it is not sufficient to improve the energy efficiency of a single product without considering its application. Taking the fan (fan driven by a motor) then a system approach is improving the efficiency of each product (impeller, stator and motor) and then considering the application of each product in the fan, that is considering how each product interacts with the other products.

In the case of a complete fan driven by motor that has been design, built, and placed on the market by the manufacturer then an Extended Product Approach has been undertaken.

When the fan driven by motor is then applied or integrated in a system, for example a Ventilation Unit, then an Extended Product Approach is where the application of the fan into the equipment is considered; what is the space envelope for the fan, the required duty and resistance to flow, what is the power consumption at the various operating conditions, what are the acoustic considerations? An EEI does not meet this requirement. The Fan Industry proposes the following definition.

Extended Product Approach

The Extended Product Approach understands that it is not sufficient to improve the energy efficiency of a single product (or system component) without considering its application. Where the application is the system that the product subsequently attaches to, or the appliance where the product is subsequently integrated within.

The consideration of the application includes the work required by the product, and additionally may consider, physical constraints, the application's duty cycle and acoustic requirements.

1.3 Partial-Load

Part-Load is described in EN 17038-2 (3), a European Standard describing methods of qualification and verification of the Energy Efficiency Index for Rotor Dynamic Pump Units. A pump is a similar fluid flow machine to a fan.

The term Part-Load is not defined within the standard but is used in the title of the standard, the first paragraph of the Introduction, in section 5.2.3 and in section 5.3.

As the term is not defined it is open to interpretation and would indicate Part-Load is any point other than the maximum 100% operating point. The standard determines the Best Efficiency Point of the unit to be 100% flow and 100% head pressure.

An analogy can be applied to show that the Best Efficiency Point of a fan is its maximum or peak efficiency and therefore operation at any other point is at a point of Part-Load.

Extract from EN 17038-2

Introduction

This part of the European standard is the second part of a series of standards describing a methodology to evaluate energy efficiency performance of single pump units, comprising the pump, the motor with or without frequency converter, based on a non-dimensional numerical value called Energy Efficiency Index (EEI). An EEI allows the comparison of different pump sizes and types with one common indicator. Physical influences such as pump size, specific speed, pump unit part-load operation, motor-efficiency characteristic and frequency converter influence are implemented into this metric.

5.2.3 Determination of part load and over load points and reference control curve

The reference flow points of the flow rate Q_i shall be calculated by the following formula:

$$Q_i = \left(\frac{Q}{100}\right)_i \cdot Q_{100\%} \qquad (2)$$

5.3 Calculation of $P_{1,avg}$

5.3.1 General

Measure the values Q_i, H_i and $P_{1,i}$ at each reference part load/over load point.

The term Partial-Load is used in the discussion of energy efficiency metrics for fans, but a definition does not exist in any fan standard or regulation. The Fan Industry agrees the following definition.

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.

Note Partial Load is not Part-Load. Part-Load is defined in the motor industry to show the real motor efficiency compared to defined load points (75%, 50%, 25%) of the full load efficiency at a constant speed. Different load profiles at reduced speed are not covered by this definition.

Separate definitions (Part-Load versus Partial-Load) are important to avoid possible misunderstandings between motor efficiency values and system efficiency values (like a fan), between a component and a system regulation.

For fans and other systems with not only constant speed, the term "Partial Load" should be used.

1.4 System Efficiency Metric

The term System Efficiency Metric is used in the discussion of energy efficiency metrics of fans, but a definition does not exist in any fan standard or regulation.

There is not one metric that is appropriate for all conditions. Many fans are embedded within many applications. One metric cannot define the fan operation in all applications as they each have different requirements of the fan. For embedded fans it is important that the metric provides reliable data so that the developer of the application can make informed decisions. For embedded fans partial load data is essential.

Industrial fans are often designed and manufactured for a specific contract requiring a defined duty to be met. In such circumstances the above is superfluous, unnecessary, and not appropriate.

For standalone fans, a defined metric can be beneficial and provide a comparison to other options to the system integrator. The Fan Industry proposes the following definition.

System Efficiency Metric

A System Efficiency Metric is one where not just the efficiency of the product is considered, but also of the application of the product. There is more than energy consumption to consider when bearing in mind its application. The product may have other impacts on the environment and its performance may be affected by its environment.

A System Efficiency Metric is one that defines the minimum energy efficiency of the product and also 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.

Chapter 2 – Position statements

The following are the view of the Fan Industry on specific topics within the general discussion of fan system efficiency.

2.1 Energy Efficiency Index (EEI)

IEC 61800-9-1 states in section 4 that a number of elements are required to determine an energy efficiency standard and concludes with table 1 that an EEI is required to complete the EP and it is the responsibility of ISO TC117 – fans.

The Fan Industry is of the opinion that an EEI is not appropriate for the fan industry and states the following.

Energy Efficiency Index (EEI)

An EEI is not appropriate for the fan industry. An EEI describes a unique operation condition, including weighted average times and loads, for a single application. Fans are used in hundreds of different applications requiring a large variety of different indexes. One index would be completely misleading for all other applications. It will also restrict innovation of fans to this one index.

2.2 Measured versus calculated data

The Fan Industry has requested that the performance of a fan is only determined by direct measurement. It is understood that the revised regulation 327/2011 will remove the 'not-final-assembly' calculation method. The Fan Industry is of view that reliable calculation methods are not available in current standards. The Fan Industry position is described as follows.

Measured vs calculated

A measured value is more accurate than a calculated value of fan performance data. A calculation approach does not always consider the tolerance of the motor, VSD and combination. Further is does not consider aerodynamic losses of component parts, such as the effect of the motor and mechanical drive in the airstream.

An explanation

A Driven Fan (definition 3.1.3 of ISO 13349:2010) is at least an impeller, stator and motor and the term for the electrical input power at the motor terminals is P_e. The Driven Fan may also include a Variable Speed Drive (VSD), in which case the term for the electrical input power at the motor terminals is P_{ed}.

The performance of fans is determined using the testing methodology described in ISO 5801:2017. The efficiency of the fan is determined from the *fan air power* divided by the *electrical input power*. The following equations are examples for the methodology using total pressure (term and definition 3.53 and 3.54 respectively):

Overall efficiency for a fan without variable speed drive; $\eta_e = \frac{P_u}{P_e}$

Overall efficiency for a fan with variable speed drive; $\eta_{ed} = \frac{P_u}{P_{ed}}$

The following diagram shows the inputs and outputs of a fan:

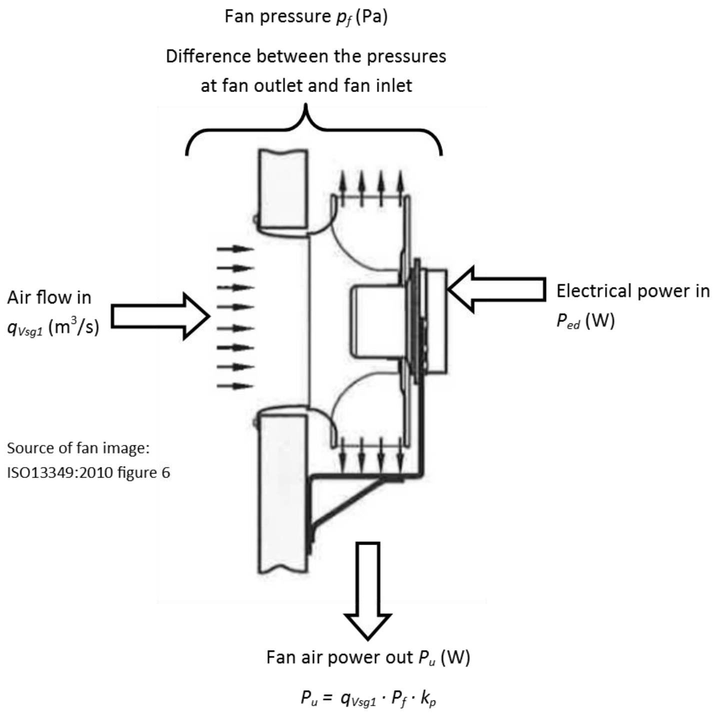


Figure 1 - diagram showing the inputs and outputs of an example of a Driven Fan

The standard ISO 5801:2017 describes the determination of the performance of fans by direct measurement of the input power and the output power. A calculated approach is discussed in an informative Annex E.

Informative Annex E of ISO 5801:2017 notes that 'there is, therefore, a need for an agreed approach to the calculation to the electrical input power, P_e'. The annex provides a calculation, equation E.8, that includes losses for impeller, bearings, mechanical transmission, motor and VSD, but is does not consider matching the load of each element and does not include all the possible elements that add losses to the fan and that should be included.

The following table lists all possible elements that are a loss within a Driven Fan and highlights where equation E.8 and other approaches falls short and shows how a calculated approach can give a false optimistic overall efficiency.

Element	**Efficiency term**	**Included in a direct measurement of a fan?**	**Included in a calculated measurement of a fan?**	**Comments**
Impeller	η_r	yes	yes	The performance can only be determined by direct measurement and shall be measured with its stator; ISO 5801:2017
Bearing, impeller shaft	η_b	yes	Can only be estimated	Determined by direct measurement or estimated;

				ISO8501:2017
Mounting arm	none	yes	no	Note 1
Protection guard	none	yes	no	Note 1
Mechanical drive – belt & pulley	η_T	yes	no	Note 1. η_T is a generic term for all mechanical drives
Mechanical drive – flexi-coupling	ditto	yes	no	Note 1
Mechanical drive – gear box	ditto	yes	no	Note 1
Mechanical drive – aerodynamic loss	none	yes	no	Note 1
Motor, AC induction	η_{mot}	yes	yes	Standard methods for determining the losses and efficiency from test of rotating electrical machines: IEC60034-2-1 Specific test methods for determining the losses and efficiency of converter-fed AC induction motors: IEC60034-2-3
Motor, Other than AC induction	η_{mot}	yes	no	No known standard
Motor – aerodynamic loss	none	yes	no	Note 2
Motor terminal box – aerodynamic loss	none	yes	no	Note 2
VSD	η_c	yes	yes	IEC61800-9-2
VSD – aerodynamic loss	none	yes	no	Note 2
EMC filter	none	yes	no	No known standard
Line harmonic filter	none	yes	no	No known standard
Motor starter	none	yes	no	No known standard

		All losses are included	Not all losses are included	Not an equal comparison

Table 1 - direct versus calculated - list of elements of a fan

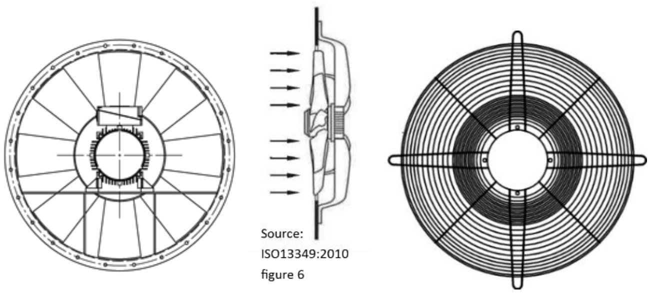
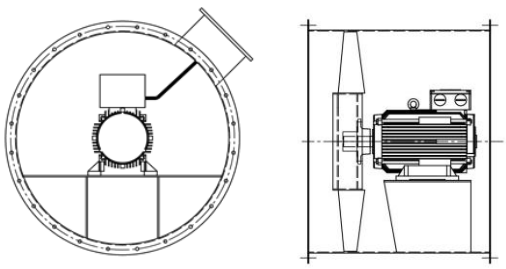
Note	Comment	examples
1	Obstructions at the inlet and outlet of the fan add losses due to restriction and due to adverse aerodynamic effect to the impeller & stator. No known method to calculate losses. Examples are; • Mounting arm • Protective guard • Belts & pulley • Flexible couplings • Gearboxes	 
2	An element located in the airstream can add losses due to adverse aerodynamic effect to the impeller & stator. No known method to calculate losses. Examples are: • Motor • Terminal box • VSD • EMC filters • Line harmonic filter	

Table 2 - notes supplementing Table 1

In some circumstances, product performance can be established through calculation. For example, in the case of a simple arrangement where the motor does not adversely affect aerodynamic performance. In such cases the calculation of the combined components needs to be to the same level of uncertainty as a direct measurement of a complete fan.

The Fan Industry considers this acceptable according to the criteria that is defined in related standards or if not is considered according to the below.

Due consideration needs to be given to the possibility of determining fan performance via methods other that direct measurement. For example, through the use of computational fluid dynamics simulations. The challenge is establishing a standardised approach with acceptable levels of uncertainty.

The Fan Industry proposes to commission an independent research institute to conduct an assessment of the difference between declared and measured values. Using the Eurovent 'Expected tolerances of embedded fans' document as a basis for a concept note. Note that this will not address aerodynamic aspects.

The Fan Industry proposes to explore the technical difference between a measured and a calculated approach by looking at the level of uncertainties.

Chapter 3 – Product Information

Future ecodesign regulation should continue with a minimum efficiency requirement based on the optimum energy efficiency point at the stated inherent speed ('inherent speed' see 7.2 and 16.3 of ISO 5801:2017) (There may be a need to define the term). To assist integrators or users to make better informed decisions additional product information shall be provided:

1. For series produced fans that have integrated variable speed drives or are designed to be used with a variable frequency drive the additional information shall describe the partial-load operational performance of the fan. This shall be described by a minimum of three performance curves; one at the stated inherent speed, one at the minimum recommended speed, plus an additional one between the other two, see figure 12. More than three curves can be provided.
2. For series produced fans that are fixed speed and are not to be used with variable speed drives the additional product information shall be the performance curve characteristic at the inherent speed.
3. For industrial fans that have been designed to meet a specific duty, or a range of duties, the additional information provide shall be the performance at the specified duty or range of duties.

3.1 Series produced fans

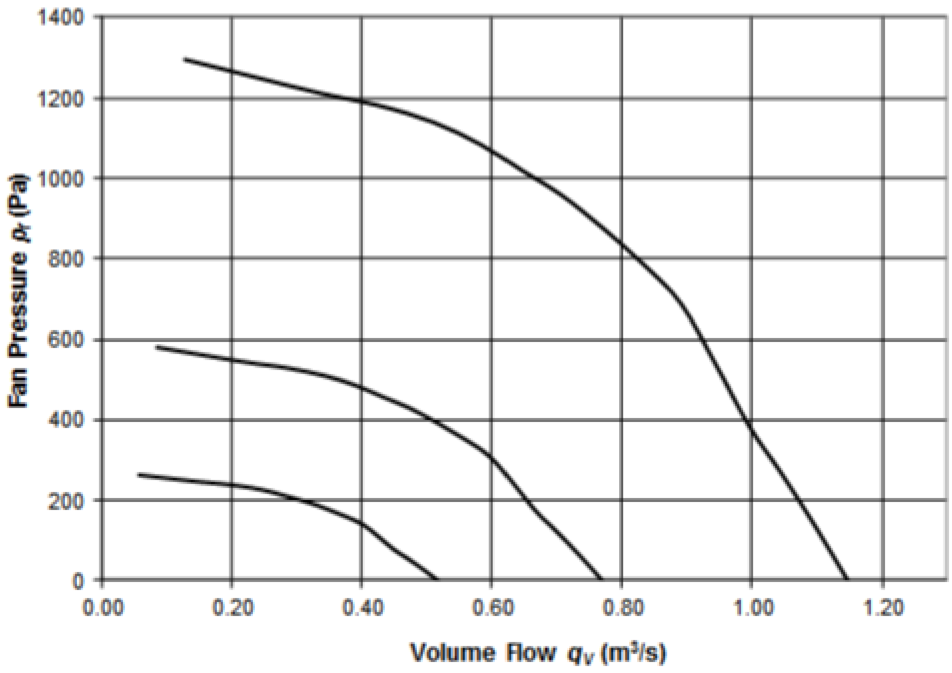


Figure 2 - an example of partial-load operational performance described by three fan curves

Test points for determining fan characteristics curves shall comprise a sufficient number of plotted test points to permit the characteristic curve to be plotted over the normal operating range (source 7.7 of ISO 5801:2017).

Only test points and characteristic curve within the operating range are to be provided. For clarity and to assist market surveillance the volume flow, pressure, energy consumption and efficiency of the test points shall be displayed in technical documentation and published via free access websites of the manufacturer. The documentation can be in digital form such as selection software or online catalogue.

3.2 Industrial fans

Where only one operating point has been specified in the contract that point is the test point and is the additional product information.

Where a range of operation has been specified the additional product information shall be a sufficient number to describe the range.

If the Industrial Fan is placed on the market for general use, then the requirements described for series produced fans shall be provided.

3.3 Market Surveillance

The additional data can be verified by checking a minimum of two declared test points of any of the characteristic curves.

Chapter 4 – Jet fans

Jet fan performance is determined by measuring thrust according to ISO 13350 and AMCA 250. It is anticipated that minimum energy performance requirements calculated on the basis of thrust will be included in the revision of Regulation (EU) 327/2011 that is pending as of July 2020.

In the next revision of Regulation (EU) 327/2011 consideration should be given to the impact of the installation of the product and of the presence of a control system on the operating efficiency of the product, and also to the acoustic performance of the installed product.

Figure 3 - examples of Jet Fans

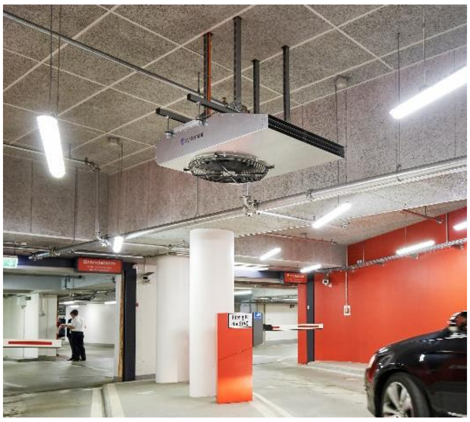


Figure 4 - example of a radial Jet Fan for enclosed car park ventilation

Figure 5 - example of the use of Jet Fans for tunnel ventilation

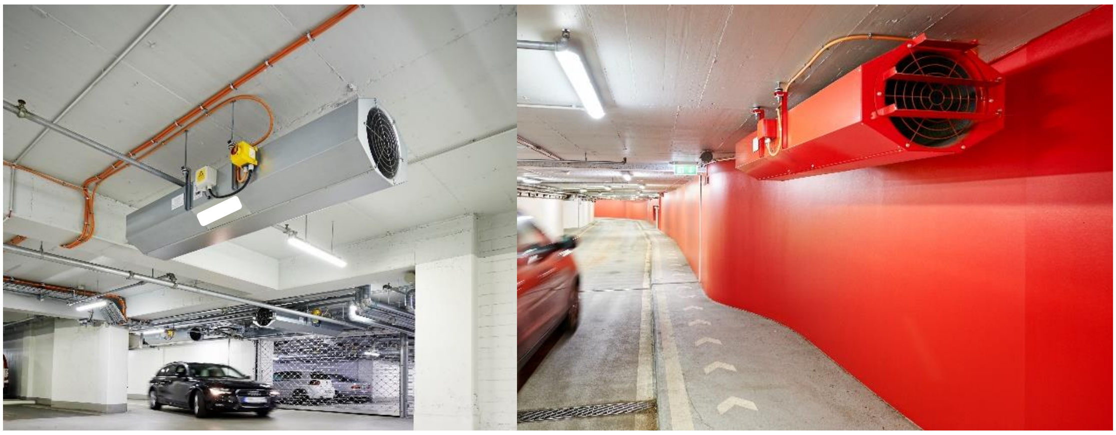


Figure 6 - example of the use of Jet Fans for enclosed car park ventilation

Chapter 5 – Circulating fans, including large comfort fans

For circulating and large comfort fans it will be necessary to establish a new method for determining the performance on the basis of thrust, similar to the approach used for Jet Fans although the limits would not be identical.

Additional measures to improve the application of circulating and large comfort fans should include data or information to determine the local environmental parameters, depending on the application. Applications non-exhaustively include destratification, human thermal comfort and indoor air quality, agricultural odour removal, indoor air quality and thermal comfort, and industrial applications including wood drying and kiln drying.

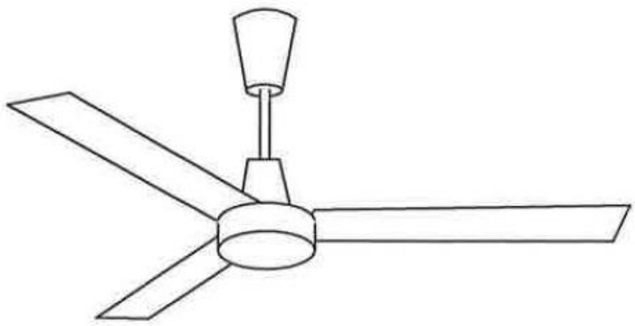


Figure 7 - image of a large ceiling fan - source figure 8.b of ISO13349:2010

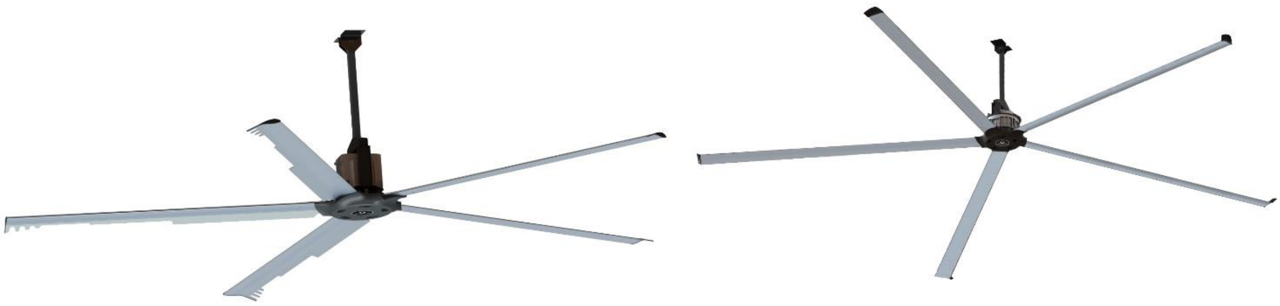


Figure 8 - two images of large ceiling fans

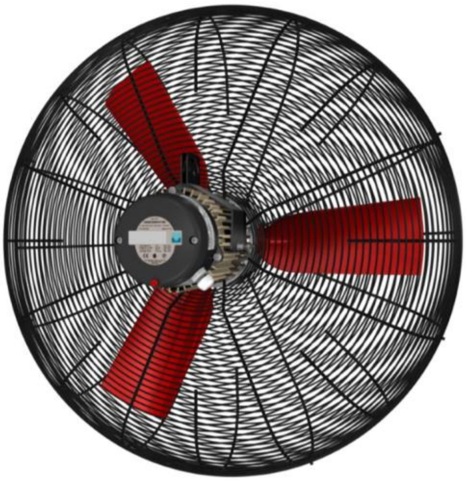


Figure 9 - example of a large circulating fan without a stator

Figure 10 - example of the use of a large circulating fam with a stator in a horticultural application

Figure 11 - image of a large comfort circulating fan - source figure 8.a of ISO 13349:2010

Figure 12 - example of a large comfort fan