HVAC&R Skills Workshop

MODULE 113

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FAN PERFORMANCE

Skills summary

What?
A guide to fan test configurations, fan performance (including performance curves), and manufacturers' selection aids.

Who?
Relevant for anyone involved in the design, selection, installation, operation, maintenance and assessment of fans and fan systems.

This Skills Workshop discusses the performance rating of fans, the tests used to rate performance, how test data is turned into performance information, the limitations of the test methods and the data produced.

It also discusses fan and system efficiency and the overall impact of fans on system energy use.

PULLOUT

INTRODUCTION

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FAN TEST STANDARDS

In order that the performance of various products can be compared, fan manufacturers must rate the performance of their equipment in accordance with a recognised code or standard. The following are the main fan test methods and standards used by fan manufacturers:

AS ISO 5801 deals with the determination of the performance of fans of all types except those designed solely for air circulation e.g. ceiling fans and table fans. Estimates of uncertainty of measurement are provided and rules for the conversion, within specified limits, of test results for changes in speed, gas handled and, in the case of model tests, size, are given. This standard allows the use of a star type straightener for ducted tests. AS ISO 5801 superseded AS 2936.

AS 4429 classifies smoke-spill fans and describes laboratory test methods and procedures used to rate their performance (and that of their motors). Fans are rated in terms of their suitability to operate continuously without significant loss of performance for a specified time at a specified air temperature. This standard deals only with laboratory type testing and does not consider the testing of smoke-spill fans after they have been installed in a building. Performance ratings are specified in AS/NZS 1668.1.

ANSI/AMCA 210 / ANSI/ASHRAE 51 Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating defines uniform methods for conducting laboratory tests on housed fans to determine airflow rate, pressure, power and efficiency, at a given speed of rotation. The standard also includes requirements for checking effectiveness of the airflow settling means and testing for chamber leakage. This standard and test method(s) is equivalent to but not identical with AS ISO 5801.

AS/NZS ISO 12759 specifies requirements for classification of fan efficiency for all fan types driven by motors with an electrical input power range from 0.125kW to 500kW. It 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. It is not applicable to fans for smoke extraction; fans for industrial processes; fans for non-stationary applications (e.g., trains, aircraft, automotive), fans for explosive atmospheres; box fans, powered roof ventilators and air curtains or jet fans for use in carparks and tunnel ventilation.

ISO 5802 deals with the determination of the performance of fans as they are installed within a system, i.e., an in-situ performance test method.

ISO 13347 deals with the determination of the acoustic performance of industrial fans. It may be used to determine the acoustic performance of fans combined with an ancillary device such as a roof cowl or damper or, where the fan is fitted with a silencer, the sound power resulting from the fan and silencer combination.

ISO 13350 deals with the determination of the performance of jet fans.

ISO 14695 describes a method of measuring the vibration characteristics of fans and ISO 14694 gives specifications for vibration and balance limits of fans of all types except those designed solely for air circulation.

ISO 1940 specifies balance tolerances, the necessary number of correction planes, and methods for verifying the residual unbalance for rotors in a constant (rigid) state.

Recommendations are given concerning the balance quality requirements for rotors in a constant rigid state according to their machinery type and maximum service speed. A balance quality grade of G6.3 is appropriate to most fans and a grade of less than G2.5 is usually only achievable on very special equipment. ISO 1940.1 states acceptance criteria for the verification of residual unbalances. Detailed consideration of errors associated with balancing and verification of residual unbalance are given in ISO 1940.2.

TEST CONFIGURATIONS

Fan performance curves are produced by the manufacturer by testing a fan in standardised conditions as prescribed by the relevant standard such as AS ISO 5801.

There are four standard test configurations that attempt to represent the range of basic fan applications as shown in Figure 1. Roof ventilator fans are represented by Category A, roof discharge fans by Category C. Centrifugal fans in air handling units or plenums are likely to be represented by manufacturers as Category B. Category D is the one most likely to be closest to the representation of both axial and centrifugal fans in many ducted ventilation and air conditioning applications. Many heat rejection fan applications in refrigeration are represented by Category A.

Centrifugal fan performances have usually been derived from measurements for fans with free inlets and ducted outlets (category B), but this depends on the size and type of fan. For axial fans, ducted inlets and ducted outlets have usually been used. These methods have been adopted for convenience since, for double-width centrifugal fans, flow measurement at the inlets would be difficult and for axial fans the presence of swirl at the outlet causes complications. Flow straighteners are used to remove the swirl in AS ISO 5801.

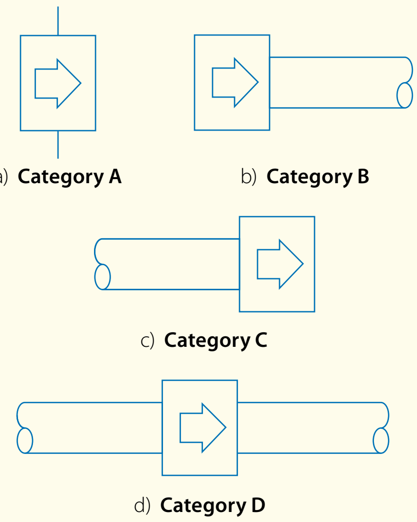

Figure 1: Fan test configuration categories.

Open inlet measurements (categories A or B) may be taken with or without an inlet cone fitted. The fan performance without an inlet cone is likely to be less than that with a cone. Restricted space around the inlet of a category A or B fan, or around the outlet of a category A or C fan, will affect the performance. For optimum performance there should be no restriction within two fan diameters. This is of major importance wherever the fan is contained within a machine or a box, such as an air handling unit or a dust collection unit.

Fans mounted in a manner that does not reflect any of the standard categories (such as roof extract fans, or in air handling units) will have altered performance characteristics.

With good duct design, most fans (except plate-mounted fans) give their highest performance under category D conditions. Reference to manufacturer catalogues should show which installation category has been used in the test, but where there is doubt, the manufacturer should be contacted for clarification.

FAN PERFORMANCE

Performance data may be presented either graphically in a fan curve, or in tabular form in a rating table. Performance data is either listed for standard air temperature and pressure, or the air temperature, density and pressure at which the tests were carried out are listed so that appropriate adjustments to expected performance can be made.

Note: Standard temperature and pressure (STP) air is defined as clean, dry air with a density of 1.2 kg/m^3, a sea level barometric pressure of 101.325kPa and a temperature of 20°C.

It should be remembered that catalogued fan performance data is the result of testing generally without any obstructions in the fan inlet or outlet and without any optional accessories in place. Unless careful design of inlets, outlets and ductwork has been undertaken a fan will not perform in practice as per the catalogued performance data. Appropriate pressure drop corrections should be applied when obstructions and accessories exist and to account for the effect of the system connections.

Fans are also commonly packaged into products such as air handling units, rooftop units, ducted split air conditioners and other HVAC&R systems and products. It is important to consider the performance of these products, as a fan in a packaged unit, rather than as a fan connected to a ductwork system. Individual product manufacturers should be able to provide product performance data which accounts for casing losses and internal components. Designers should rely on this information instead of using stand-alone fan performance data for such equipment.

FAN PERFORMANCE CURVES

The fan performance or characteristic curve is a graphical representation of fan performance and is one of the most useful tools for optimising fan selections. A series of performance curves for a particular fan type is usually presented as a graph of flow versus pressure and flow versus power with a separate curve for each particular fan speed.

Fan performance curves are developed based on standard tests measuring the output of a fan, its volume flow rate, and pressure for a range of conditions. This concept is shown in Figure 2, with tests ranging from the flow being fully closed off to when the air path is completely open, all measured at a constant fan speed (although fan speeds do vary when tested). Back pressure fans are typically used to change the duty of the fan under test. At the same time the power input to the motor is recorded and operating noise levels are established.

The fan performance graph is generally composed of a series of separate performance curves including:

Static pressure Vs Volume curve – Called the fan performance or fan characteristic curve, this is a plot of static pressure against volume at a constant speed and gas density.

Fan total pressure (pt) and velocity pressures (pv) are also plotted against volume.

Note: pt = ps + pv, therefore pt can never be less than pv, so the fan performance curve doesn't reach zero pressure, but rather pv. When volume flow is zero pt = ps and pv = 0

Power Vs Volume curve – plot of the fan power drawn for any point on the performance curve.

Efficiency Vs Volume curve – plot of fan efficiency for any point on the performance curve.

The efficiency curve is produced by dividing air power (air power = pressure in Pa × volume flow rate in m^3/s) by the power input to the fan unit. This can be static efficiency (using p_s) or total efficiency (using p_t). See equation 1.

Note: ISO12759 requires the use of motor input power.

Using the test data, a complete set of fan performance curves is produced as illustrated in Figure 3.

Fan performance curves offer a convenient method of fan selection as well as additional information such as the amount of reserve pressure that exists between the design pressure and peak available pressure, the maximum power the fan may draw and the likely efficiency of operation.

Typical "generic" fan performance curves for common fan types are shown in Figure 4.

Note: None of these curves would "hunt" as the system resistance curve would need to intersect the fan curve at two points. However, a steeper vane axial fan curve to the left of peak pressure, would lead to instability for certain specific system curves, hence the warning "Possibly Unstable".

Note: Some designers prefer to select at 10–15% below peak pressure.

These typical curves are exaggerated and idealised indicative performance curves. Individual fans will perform differently from this although the attributes will be similar. This includes the areas of instability shown where the fan can flip between two possible flow rates at the same pressure, called hunting, or instability as a consequence of the fan stalling (refer to Section 7). Some axial flow fans have adjustable pitch blades of which the first 10–20 degrees have a non-stalling characteristic. Manufacturers will generally identify recommended working ranges for their products within their technical literature.

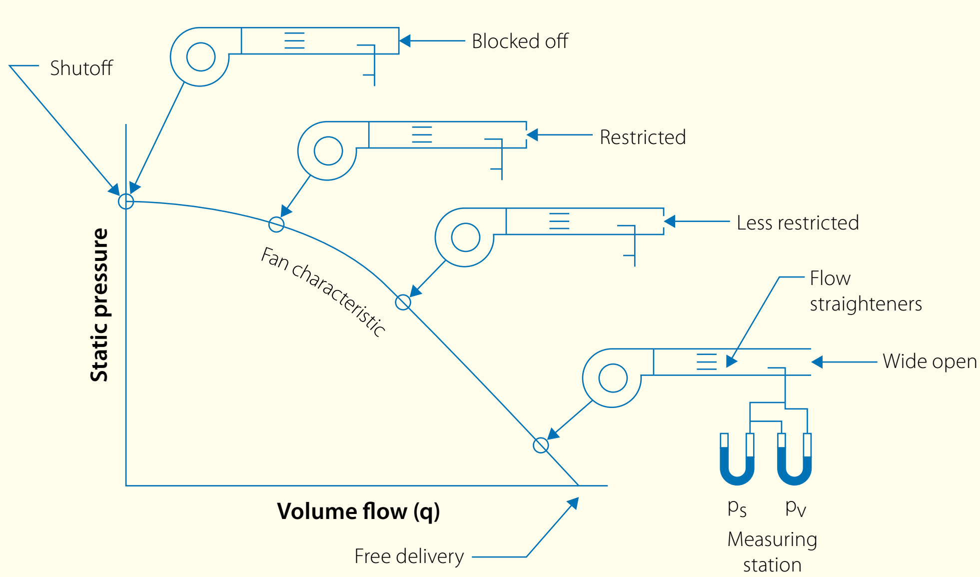

Figure 2: The creation of a fan performance characteristic.

$$\text{Total efficiency \%} = \frac{\text{airflow } (m^3/s) \times \text{Total pressure (Pa)} \times 100}{\text{Power input, in W}}$$

$$\text{Static efficiency \%} = \frac{\text{airflow } (m^3/s) \times \text{Static pressure (Pa)} \times 100}{\text{Power input, in W}}$$

Equation 1

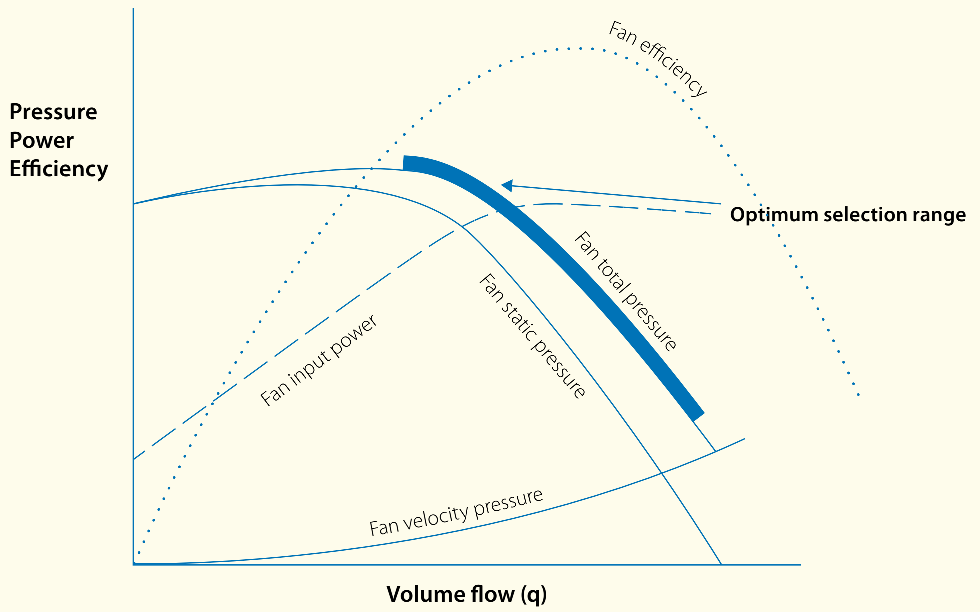

Figure 3: Fan performance curves showing recommended selection range.

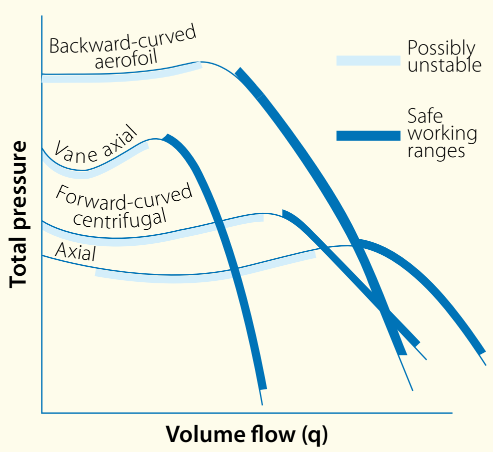

Figure 4: Typical 'generic' fan performance curves.

PUBLISHED AND CERTIFIED PERFORMANCE CURVES

The fan performance curves generated under test become the basis of the catalogue curves and selection tables used by manufacturers to market their products. The manufacturing process and associated tolerances are designed to ensure that a fan will match the catalogued performance.

When purchasing or specifying a fan, designers can request its certified performance curve to ensure compliance with the published data. Unlike the published curve, which represents a general curve or set of curves for a fan model and size, the certified performance curve reflects the actual test results for a particular fan.

Note: A certified performance curve should require a works test be performed on the specific fan being supplied. In the HVAC&R market, a works test is not often specified or allowed for within project budgets.

MANUFACTURER FAN SELECTION AIDS

Selection charts

A selection chart shows the performance map for a family of similar fans. They are often formatted on semi-log or log-log scales to display a wide range of flow and pressure on a single chart. The chart shows the various fan sizes and designs available and a selection is made by evaluating the fans with a best efficiency point near the specified operating points.

Once the fan size has been selected the individual fan performance curve should be consulted for full details of the fan performance, capability and characteristics.

Fan rating tables

Similar to fan selection charts, multi-rating tables have traditionally been used for selecting centrifugal fans. Usually airflow, pressure, fan speed and power are tabulated, for equal increments of outlet velocity for a given size of fan.

These tables can be used for fan selection although some interpolation may be required.

Computer selection programs

More frequently used than traditional charts or tables, computerised data selection allows for the rapid selection of many possible fans and selection optimisation at the click of a button.

Many fan manufacturers have web-based selection programs available. The most appropriate choice will still depend on many factors. Specifiers and designers should review choices in detail rather than rely on a choice made from a brief comparison summary table.

The most important issue with computer selection programs is to input the correct information about the fan application. This includes an accurately calculated fan duty and the other specific conditions of service such as air temperature and density. Most fan curves are only valid for standard temperature and pressure ranges.

INTERPRETING FAN MANUFACTURER DATA

With a basic understanding of the fan performance curve, designers can predict the way the fan performance would change if the fan characteristics were changed or if combinations of fans, in series or in parallel, are used in a system. Designers need to be aware of the following uses when interpreting performance curves:

Fan performance curves are developed under controlled test conditions with the fan installed with favourable inlet and discharge connections. These connection conditions are often not able to be replicated in the field.

Fan performance curves are developed under a specified air condition (temperature, pressure, density), the air conditions prevalent during the test. Check the actual conditions the fans have been tested at. Do not rely on the term "Standard" to identify this as this varies between fan test centre locations.

Fan performance curves are generally developed without any of the optional accessories that may be available. Some accessories may alter the aerodynamic performance of the fan and hence will vary from the standard performance curve.

Fan noise is a function of the fan design, volume flow rate, total pressure and efficiency. The sound power generation of a given fan performing a given duty is best obtained from the fan manufacturer's actual test data taken under standardised test conditions. However, test conditions vary and some manufacturers display actual measured data without manipulation while others manipulate data to provide example in-duct noise levels which changes for each different installation. The true measured sound power data is the only way to compare how each fan will perform in the specific installation. Manufacturers generally have available descriptions of how the fans are tested and how the data is presented. ■

This month's Skills Workshop has been taken from AIRAH Application Manual DA13 – Fans.

Next month: Applied psychrometrics