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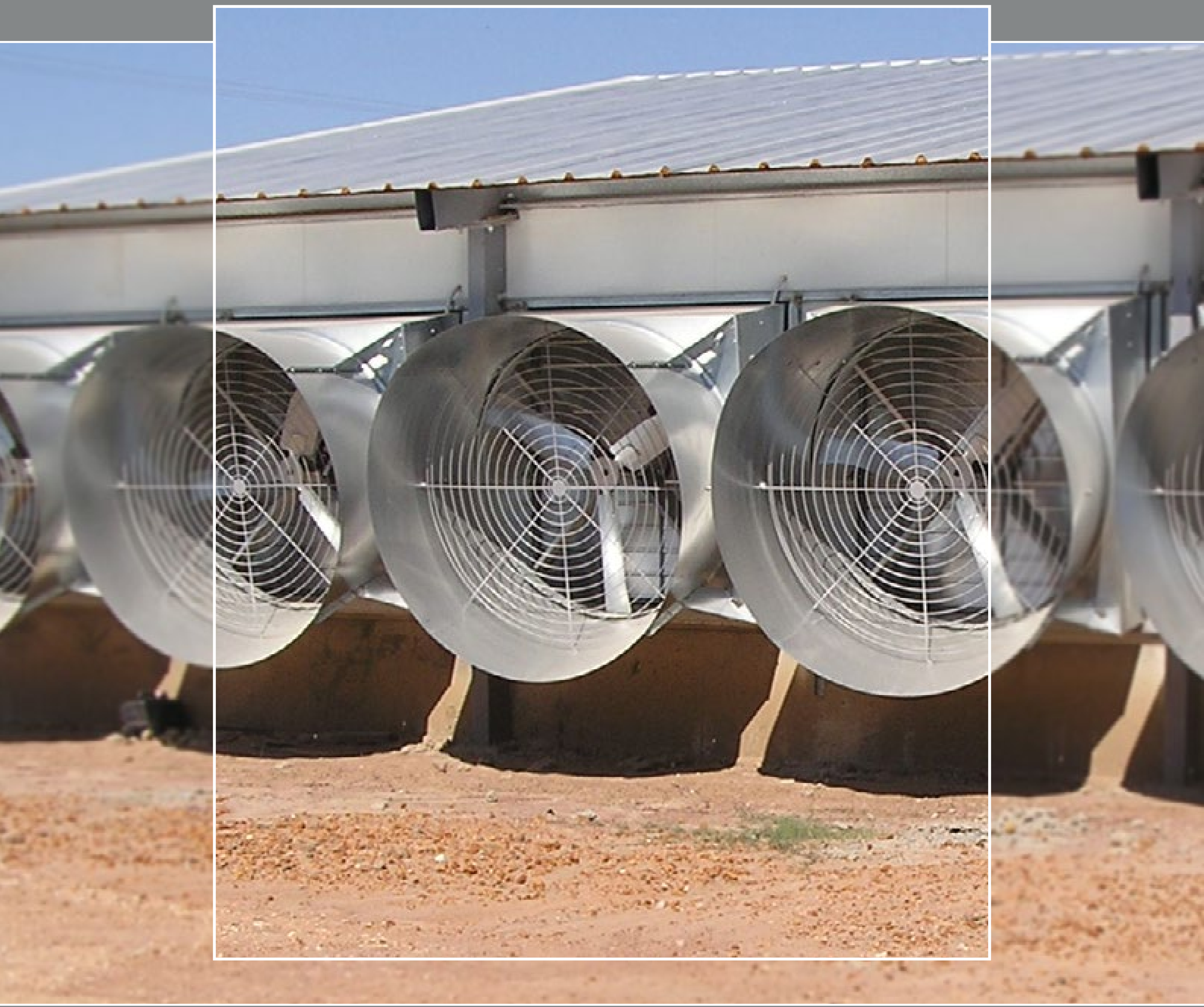
'How to' guide for measuring fan performance and efficiency in meat chicken sheds

by Mark Dunlop and Grant Brown



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Researcher Contact Details

Mark Dunlop
Department of Agriculture and Fisheries (DAF)
PO Box 102
TOOWOOMBA QLD 4350

Phone: 07 4688 1280
Fax: 07 4688 1192
Email: mark.dunlop@qld.gov.au

Grant Brown
Department of Agriculture and Fisheries (DAF)
PO Box 102
TOOWOOMBA QLD 4350

Phone: 07 4688 1521
Fax: 07 4688 1192
Email: grant.brown@qld.gov.au

In submitting this report, the researcher has agreed to RIRDC publishing this material in its edited form.

RIRDC Contact Details

Rural Industries Research and Development Corporation
Level 2, 15 National Circuit
BARTON ACT 2600

PO Box 4776
KINGSTON ACT 2604

Phone: 02 6271 4100
Fax: 02 6271 4199
Email: rirdc@rirdc.gov.au.
Web: http://www.rirdc.gov.au

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Foreword

Many Australian chicken farms depend on ventilation fans to control the in-shed environment. The performance and energy efficiency of these fans changes over time due to wear and dust accumulation. Measuring fan performance is necessary for ensuring that ventilation requirements are being met and may be useful for scheduling fan maintenance, identifying fans for replacement.

This 'how to guide' describes a series of tests to measure how well individual fans are performing under operational conditions. Many of these tests require relatively little time and can be performed by farm staff.

Additional information on fan efficiency can be found in a complementary report *'Review of fan efficiency in meat chicken sheds'* (RIRDC Publication No. 15/018). Data collected using the tests in this guide can be input into the *'Tunnel Ventilation Fan Comparison Spreadsheet'*, which is a spreadsheet that ranks fans against others in terms of performance, energy efficiency, purchase costs and operating costs. Both the report and spreadsheet are available from the RIRDC website.

This project was funded from industry revenue which was matched by funds provided by the Australian Government.

This report, an addition to RIRDC's diverse range of over 2000 research publications, forms part of the Chicken Meat R&D program, which aims to stimulate and promote R&D that will deliver a profitable, productive and sustainable Australian chicken meat industry that provides quality wholesome goods to the nation.

Craig Burns
Managing Director
Rural Industries Research and Development Corporation

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Introduction

This guide provides methods to measure ventilation fan performance while installed in meat chicken sheds. These methods can help to identify poorly performing fans that may not be moving the correct amount of air or are operating inefficiently.

This guide should be read in conjunction with a complementary report *'Review of fan efficiency in meat chicken sheds'* (RIRDC Publication No. 15/018) which is also available on the RIRDC website.

The methodology used in this guide draws heavily from *Poultry Housing Tips,* which has been published by the University of Georgia, USA, for almost 20 years to provide poultry growers with technical information. *Poultry Housing Tips* is available from http://www.poultryventilation.com.

This guide does not cover topics such as how to maximise fan performance and efficiency with good shed design or ventilation system operation. Although these are essential for good fan performance, they do not fall within the scope of this guide. Detailed, quality information on these subjects can be sourced from internet websites of Auburn University http://www.aces.edu/dept/poultryventilation and University of Georgia http://www.poultryventilation.com.

Trade and brand names referred to in this guide are for information purposes only. ***The Queensland Department of Agriculture and Fisheries (DAF) and the Rural Industries Research and Development Corporation do not endorse any product mentioned, nor imply preference of one product over another. Anyone purchasing or using instruments/equipment to assess fan performance should undertake their own due diligence checks regarding safety, accuracy, reliability and cost effectiveness.***

Assessing fan performance could be DANGEROUS due to close proximity to moving parts, mechanical objects and live electricity. Anyone assessing fan performance must undertake risk assessments to identify any potential hazards.

This guide covers—

- Measuring air flow through the fans (including measuring static pressure)
- Measuring and recording fan rotational speed (rpm)
- Measuring power consumption
- General maintenance tips for upkeep of fans

Equipment Needed

- Air speed meter (anemometer)
- Differential pressure gauge
- Laser tachometer
- 3 phase electrical clamp-on power meter*
- Infrared thermometer
- V-belt and sheave gauges

*must only be used by a licensed electrician

Why is fan performance and energy efficiency important?

Fan performance and air flow rate

As all meat chicken farmers know, good ventilation is required to grow healthy birds and achieve good feed conversion. It is therefore important to check that each fan is delivering the amount of air that it is supposed to, ensuring that the ventilation system is working properly. Worn, damaged, dirty or poorly adjusted fan belts, sheaves (pulleys), bearings, blades, shutters, motors, and grills will reduce the amount of air flow that a fan will deliver. **Poorly performing fans will cost you more** because they will be working harder; and other fans will also be working harder to compensate for underperforming fans. Also, bird growth and feed conversion may be compromised if optimal growing conditions can't be achieved.

The techniques described in this guide will help you to identify fans that aren't performing the way they should and allow you to schedule maintenance for those fans.

Fan efficiency

Fan efficiency is all about how much air a fan will move for the amount of power it is using and is directly related to how many dollars it is costing you to ventilate your sheds. Fans with worn, dirty, damaged or poorly adjusted bearings, blades, shutters, motors, and grills will likely be running less efficiently and will be costing you more money to operate. Other factors, such as excessive static pressure caused by air flow obstructions (i.e. building trusses, baffles, dirty cool pads, insufficient inlet area) or excessive in-shed air speed will make fans work harder and therefore less efficiently.

So what are the most important things to do to ensure fans are working efficiently? The first and most important thing is to **make sure you are using energy efficient fans to begin with.** Fans with poor energy efficiency to start with will **never** be energy efficient. The electricity cost for using inefficient fans could be as much as $3,000–3,500 per shed per year compared to $1,500–2,000 for a more efficient type of fan. So if purchasing fans for a new shed, it is well worth investigating the efficiency of the fans being considered. The only way to compare fans for your specific situation is to get fan performance and efficiency data from your fan supplier and use a spreadsheet for ranking fans against others in terms of performance, energy efficiency, purchase costs and operating costs such as *'Tunnel Ventilation Fan Comparison Spreadsheet'*, which is available from the RIRDC website. This spreadsheet is based on the *'Tunnel Ventilated Broiler House Fan Comparison Spreadsheet'* available from the University of Georgia's website http://www.poultryventilation.com/spreadsheets.

Once you have fans installed in your shed, and they're still working, it is unlikely that it will be cost effective to replace them with a more efficient fan (based on a 10 year payback period). So it is important to pick an efficient fan the first time if you want to minimise your operating costs.

What to look for in a new fan

A rating system for fan performance and efficiency has been developed by extension staff at the University of Georgia (see Table 1 (Czarick, 2008)) to enable fans to be assessed for energy efficiency at 25 Pa static pressure as well as air flow ratio. Air flow ratio quantifies the loss of fan air flow capacity as the static pressure increases from 12.5 Pa to 50 Pa. An air flow ratio of 0.8 indicates that air flow capacity will reduce by 20% as the static pressure increases from 12.5 Pa to 50 Pa.

Table 1 Rating system used for energy efficiency and air flow ratio (Czarick, 2008)

Rating	Energy Efficiency @ 25 Pa (m^3/h/W)	Air flow ratio
Poor !	Less than 32.3	Less than 0.70
Minimum acceptable *	32.3 - 33.8	0.70 - 0.72
Good * *	34.0 - 35.6	0.73 - 0.77
Excellent * * *	35.7 - 37.3	0.78 - 0.82
Outstanding * * * *	37.4 +	0.83 +

When selecting new fans, try to choose a fan with an energy efficiency of at least 32.3 m^3/h/W and air flow ratio no less than 0.70. Ideally, choose a fan with the highest possible efficiency and air flow ratio that is available to you at the time.

Because some energy efficient fans may have lower air flow capacity than other fans, which means that more fans will be required for your sheds, it is a good idea to use the *'Tunnel Ventilation Fan Comparison Spreadsheet'* to estimate the likely costs of purchasing and operating different types of fans in your sheds. However, you will likely find that total costs over a 10 year period is closely related to energy efficiency, with more efficient fans being cheaper.

Other factors such as quality of construction, local dealer reputation, parts availability, after sales support and warranty also need to be considered prior to making a final selection (Czarick, 2012).

Techniques to measure fan performance and efficiency

Shed setup and other preparations

Before undertaking any kind of assessment on tunnel ventilation fans, it is important to firstly consider a few factors that may influence the measurement, such as static pressure, temperature, barometric pressure and strong winds.

Static pressure is perhaps the most important of these and is one that can be controlled. It is important that static pressure remains constant during testing and 25 Pa is likely to be a good static pressure to use because it is typical of normal shed operation. You may wish to choose an alternative pressure if it is more relevant for your situation. More information about measuring static pressure is included in the next section, but ideal placement for the sensor is about 6 m from the tunnel fans when assessing fan performance.

Fans should be 'warmed-up' prior to any testing to allow motors, bearings and drive belts to reach normal operating temperatures. Running fans for at least 20 minutes should be sufficient.

Fan assessments should be avoided on windy days if possible, because fluctuating winds will affect the shed static pressure especially if blowing against the fans.

Fans (especially the blades, grills and shutters) should be cleaned and operating smoothly before any testing.

Preparation is the key….

- Regulate the static pressure
- Warm up the fans
- Avoid windy days
- Clean fans and adjust drive belts

Static pressure measurement

Static pressure affects fan performance and efficiency, so it needs to be measured and regulated during any testing. Static pressure will vary throughout a meat chicken shed due to resistance to air movement (friction) along the walls, floor and ceiling, baffles and other obstructions. More information about this can be obtained from *Poultry Housing Tips Vol.22 No.9—Measuring static pressure in tunnel-ventilated houses,* http://www.poultryventilation.com/sites/default/files/tips/2010/vol22n9.pdf (Czarick and Fairchild, 2010).

Ventilation controllers measure static pressure inside a shed, but usually only in the middle of the shed halfway between the evaporative cooling pad and the tunnel fans. It is important to realise that the static pressure in the middle of the shed is likely to be lower than at the fans. It may be possible to use the static pressure sensor that's already installed in the shed by temporarily extending the sensor tube that's already in the shed to a position approximately 6 m from the fans.

An alternative approach is to use a portable differential pressure gauge/meter and to measure the static pressure. A Magnehelic® differential pressure gauge (Dwyer Instruments, model 2000-60Pa, see Figure 1), or similar, can be purchased for about $200 for this task.

Differential pressure gauges use two tubes: one will be marked as 'HIGH' or '+' and is placed outside the shed as the reference pressure; and the other one marked as 'LOW' or '–' is positioned about *6m from the tunnel fans.* (Alternatively, one tube may be used to go to one of these locations, either reference or near the fans, but the gauge will need to be situated in the second position). The tubes should be put on the ground to reduce the effects of wind or in-shed airspeed and turbulence.

Figure 1 Dwyer Instruments Magnehelic® differential pressure gauge

TIP: Using a portable pressure gauge to measure shed pressure

1. Connect a length of tube to the "HIGH +" port on the pressure sensor and run the tube outside the shed.
2. Connect a second length of tube to the "LOW –" port on the pressure sensor and place it 6 m upwind from the fans. (Alternatively, don't use the second tube and place the pressure gauge in this position.)
3. Place the tubes along the ground if possible to minimise air moving over the tube.
4. Care should also be taken not to kink or twist the tube.
5. Ensure the tunnel or mini-vent inlets are sufficiently open to safely operate the number of fans you require.
6. Turn on the required fans.
7. Read the gauge and adjust the static pressure using tunnel curtains/inlets and mini-vent inlets.

   Suggestion—Thick walled, flexible 4 mm irrigation tubing (4 mm internal diameter with 1.5 mm walls) is a suitable and economical tube to use for this purpose.

Measuring fan rotational speed (rpm)

Fan air flow capacity and rotational speed (measured in revolutions per minute, rpm) are directly related. Fans that are running around 10% slower than normal can result in a reduction in air flow of about 10–15% (Czarick and Fairchild, 2004).

A handheld non-contact tachometer (i.e. laser or optical tachometer, see Figure 2) is a tool used to measure rotational speed (for more information refer to *Poultry Housing Tips Vol.16 No.7—Electronic Tachometers,* *http://www.poultryventilation.com/sites/default/files/tips/2004/vol16n7.pdf* (Czarick and Fairchild, 2004)). Measuring ventilation fan rotational speed is a quick way to identify fans that may be underperforming. The tachometer counts the number of blades going past it every minute. Fan rotational speed (rpm) is the number of blade counts divided by the number of blades on the fan (see the example below). The value that is returned can be used to compare individual fans against each other, or calculated into actual rpm and compared against the manufacturer's published data for that fan.

Non-contact tachometers may occasionally have trouble detecting the blades, especially when used in direct sunlight or if the fan blades are dirty. This may be overcome by using the tachometer inside the shed, cleaning the fan blades or attaching a strip of reflective tape to a blade or belt sheave to help achieve a reading.

TIP: Using a laser tachometer to measure fan rotational speed (rpm)

1. Clean fan blades and, if necessary, attach a strip of reflective tape.

2. Allow fans to warm up to full operating speed and temperature (for 15–20 minutes) and set the static pressure to 25 Pa.

3. Hold tachometer about 10–20 cm from blades and take a reading, ensuring that nothing is impeding the beam e.g. safety guarding.

   Caution — Do not stand directly in front of the fan being measured as this will interfere with the air flow and affect the rotational speed reading. Stand to the side of the fan and reach out with the tachometer to get the reading.

4. To calculate the actual rotational speed (rpm), take the tachometer reading (blade counts) and divide it by the number of blades on the fan. E.g. if the tacho is reading 2928 and the fan has 6 blades:

$$Rotational\ speed\ (rpm) = \frac{blade\ counts\ per\ minute}{number\ of\ \ fan\ blades} = \frac{2928}{6} = 488\ rpm$$

It is highly recommended that the rotational speed (rpm; or blade counts) of each individual fans be recorded as a reference value for future measurements. This will allow for rotational speed of fans to be tracked over time and compared to previous readings to help identify a trend in lost performance. As a general rule, a fan operating more than 5–10 % slower than its normal speed should be inspected to identify the cause and schedule appropriate maintenance.

A sample '*Fan rotational speed (rpm) or blade count record sheet*' is included at the back of this guide.

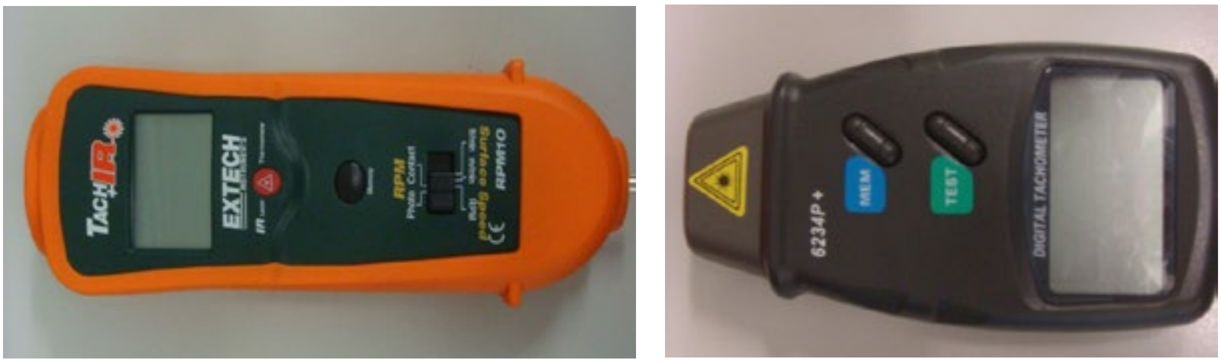


Figure 2 Two types of electronic laser tachometers that are suitable for rotational speed (rpm) measurements of axial fans

Measuring air flow rate

Note: **Air speed** is measured in units of **meters per second (m/s);** and **Air flow rate** is measured in **cubic meters per hour (m³/h)**—Conversion to cubic feet per minute is provided in the '*Conversion factors'* section at the back of this guide.

Air flow rate is a critical part of fan performance and is estimated by multiplying the **air speed** through the fan by the fan's cross-sectional area. Measurement of air speed is one of the most challenging tasks of assessing fan performance. One of the reasons for this is that air speed is not uniform across the fan face. Figure 3 shows an example of how air speed varied across the face of this fan—air speed near the middle of the fan was about 4.1 m/s, maximum air speed was 5.7 m/s and the average air speed across the whole fan was 4.3 m/s. Because air speed is not uniform across the front of the fan, it is not recommended to randomly take a single air speed reading; otherwise the reading may be very inaccurate.

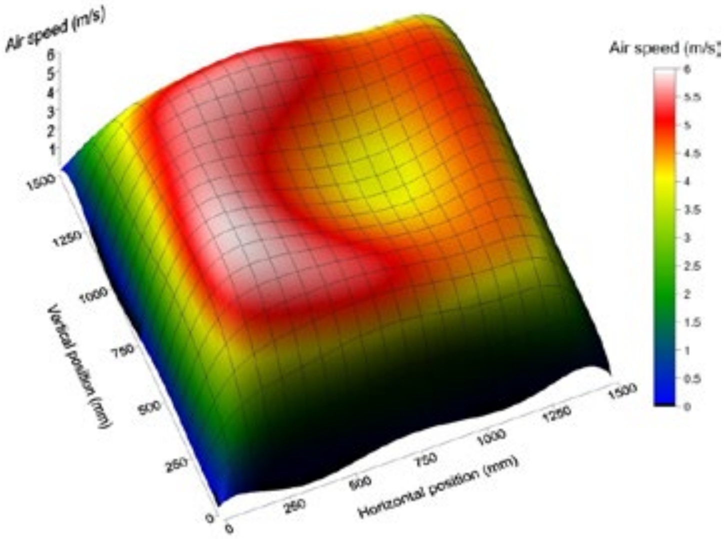


Figure 3 *LEFT*—Inlet side of a fan with temporary cowling attached. *RIGHT*— air speed distribution across the inlet side of the fan

(Air speed was assumed to be 0 m/s around the edges in this diagram.)

Air speed is measured with an air speed meter, also called an anemometer (see Figure 4 for examples). Air speed meters are available in two styles: hot-wire or vane (impeller). Hot-wire air speed meters cost $1,000–2,000 whereas vane air speed meters can be purchased for $25–300, but it should be noted that cheap, low quality air speed meters may lack the accuracy of higher quality products. More information about air speed meters is available in *Poultry Housing Tips Vol.11 No.11—Tools for Poultry Producers,* http://www.poultryventilation.com/sites/default/files/tips/1999/vol11n11.pdf (Czarick and Lacy, 1999). If purchasing an air speed meter, it is worth considering models that can also measure temperature and relative humidity.

Figure 4 Different types of anemometer that are available: *left*—Hot-wire anemometer; *middle and right*—vane anemometers

Ideally, air speed should be measured using a sampling strategy in accordance with Australian Standard 4323.1—1995, *Stationary Source Emissions: Selection of sampling positions* (Standards Australia, 1995); however, application of this standard requires the construction of substantial inlet ducting that is about 10–15 m long to define the sampling area as well as to improve uniformity of the air flow, especially around the edges. It is unlikely that construction or use of such a duct will be justifiable, so using a much smaller temporary cowling, such as that shown in Figure 3 would still be considered better than not using any inlet ducting at all.

An evenly spaced grid of 36 sampling points (six by six grid pattern) as shown in Figure 5 is then applied on the inlet side of the fan. Air speed is measured in the middle of each grid position and the average is calculated from all of these air speed readings. This average air speed is multiplied by the cross sectional area to get the air flow rate. The drawback to using this method is that it can be time consuming (15–20 minutes per fan); requires a temporary duct to be manufactured and installed on the fan; and requires post-calculation of the air flow rate.

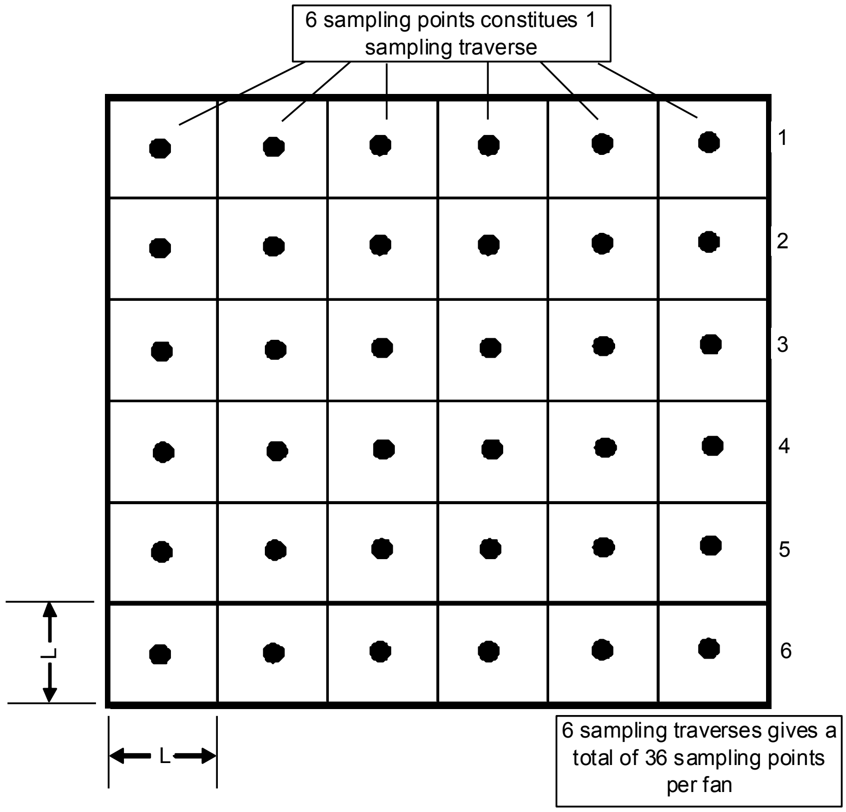


Figure 5 Sampling points across the face of the fan

Each sampling point represents an equal area segment of the sampling plane. Air speed is measured in the middle of each segment (represented by the black dots)

A simplified but much less reliable method to estimate air speed is to use an air speed meter and measure the air speed in a location on the fan that is not in the middle, not near the edge, but also not where air speed is at maximum. This will hopefully give a reasonable estimation of the average air speed. If repeat measurements are required on separate occasions, it may be worth marking the position on the grill to allow the air speed meter to be repositioned in the same spot at a later date. It is possible that the air speed distribution (as shown in Figure 3) will be similar for fans of the same type and model. Therefore, when measuring air speed for multiple fans of the same type, it is important to measure the air speed in EXACTLY the same spot. Measuring air speed in this manner is unlikely to provide an accurate measurement of air speed, but may be useful for identifying fans with much lower air flow relative to others of the same type.

Static pressure needs to be well controlled during air speed measurement because it will have a considerable effect on air flow rate. It is vital to maintain consistent static pressure when comparing fans. Static pressure of 25 Pa is a reasonable value to represent normal operating conditions. It is also advisable that if possible, air flow measurements should be carried out on days when the air temperature is about 20°C, relative humidity is 40% and barometric pressure is about 1013 hPa. Air speed measurements will vary slightly when conditions are substantially different to these ‘normal’ conditions. It is also important to avoid windy days, as gusty winds will cause fan performance to fluctuate.

TIP Using an air speed meter to measure air speed and calculate air flow rate

1. Ideally pick a day when conditions are mild (air temperature 20°C, relative humidity 40% and barometric pressure is about 1013 hPa) or at least 'normal' for your location. Avoid windy days.

2. Allow fans to warm up to full operation speed and temperature (for 15–20 minutes) and set the static pressure to 25 Pa.

3. Set the air speed meter to measure airspeed and ensure the correct units are selected (this guide uses m/s).

4. Hold the air speed meter approximately 10–15 cm from the safety guarding, taking measurements from inside the shed on the inlet side of the fans. Ideally measure air speed using a grid pattern or at least find a spot on the fan away from the centre and edges but avoiding spots where the air speed is noticeably faster. If repeating measurements on the same or different fans (of the same type), ensure you return to EXACTLY the same spot each time.

5. Care should be taken to not to stand in front of the fan being measured as this will compromise the air flow and therefore the air flow reading. Standing to the side of the fan with one arm outstretched with the air speed meter is the best technique.

It is important to remember that the values reported by the air speed meter are in m/s, but the units for air flow rate is m^3/h, therefore the data must be converted into the correct units when comparing to manufacturer data.

TIP: Converting airspeed (m/s) into air flow rate (m^3/h)

Example: Calculate the air flow rate for a fan that has an inlet opening 1.32 m wide and 1.35 m tall with an average air speed of 4.8 m/s.

- Take the measured ***air speed*** value/s for the fan, in m/s (*from example, 4.8 m/s)*

- Calculate the cross sectional area of the fan using the units of square meters (m^2). The area will either be the fan inlet opening or the inside of a temporary cowling (if used, see Figure 3). Measure the width and height of the measurement area on the face of the fan in metres (m) and apply the following formula.

$$\text{Fan cross sectional area } (m^2) = \text{width } (m) \times \text{height } (m) = 1.32 \times 1.35 = 1.78\ m^2$$

- Calculate the ***air flow rate*** (m^3/h) by multiplying the air speed (m/s) by the fan cross sectional area (m^2) and then multiplying by the number of seconds in an hour.

$$\text{Air flow rate } (m^3/h) = \text{air speed } (m/s) \times \text{area } (m^2) \times 3600 \text{ seconds} = \mathbf{30{,}758\ m^3/h}$$

Measuring electrical consumption to calculate energy efficiency

NOTE: Measuring the electrical consumption of ventilation fans requires access to live conductors and must only be attempted by a licensed electrician.

Measuring and calculating power consumption of individual tunnel ventilation fans can be quite complicated because an electrician is required to access the wires going to each fan and three phase power is complex, requiring specialised measurement equipment. All three phases must be analysed simultaneously because voltage and current can be unbalanced between phases. There are multiple dimensions to electrical power (described below) and the most important one, known as active power, cannot be measured directly without considering the power factor of the whole system.

Accurately measuring instantaneous electricity usage for individual fans will seldom be required under normal circumstances. However, there is value in understanding the different dimensions of electrical power as described below. Farmers may find it useful to track their electricity usage from their power bills (comparing similar months over many years) because an increase in power consumption may be an indication of reduced fan efficiency.

It should be mentioned that most electric motors have a nameplate located somewhere on the motor that lists values such as rated power, amps, current, service factor and power factor. It is not enough to simply read off these values on the nameplate, as they are not an accurate indication of how much power the motor may be using. For example, a motor may be stamped as having a power factor of 0.84, however this number indicates the maximum power factor while under full load—the power factor is often less than the name plate indicates.

There are three dimensions of power to consider: *active power*, *reactive power* and *apparent power* (see the diagram of the power triangle in Figure 6).

Specifically relating to ventilation fans:

- *Active power* is the electrical power that is converted by an electric motor into mechanical power, i.e. drives the fan blades. Active power is also the power recorded by conventional power meters and is what electricity bills are usually based on. Active power uses units 'watts' (W) and is calculated using the equation: *Active power* = *VI cosØ* (where *V* is voltage, *I* is current in a circuit and Ø is the phase angle).
- *Reactive power* could be viewed as power 'lost' in the windings of an electric motor. Power users currently are not charged for reactive power (unless under specific arrangements by power supply companies). Reactive power uses units 'reactive volt-amperes' (VAR) and is calculated using the equation: *Reactive power* = *VI sinØ* (where *V* is voltage, *I* is current in a circuit and Ø is the phase angle).
- *Apparent power* is the total 'complex' or 'vector' sum of the active and reactive power components. Apparent power uses units 'volt-amperes' (VA) and is calculated using the equation:
  Apparent power = *VI* (where *V* is voltage and *I* is the current in a circuit)

Phase angle (Ø) and *power factor* are terms related by the equation: *power factor* = cosØ.

At the time of publication, the majority of power supply companies use conventional power meters to measure the *active power* being consumed. The *reactive power*, or loss in the motor (determined by the phase angle or 'power factor') is not taken into account. New generation 'Smart' power meters are being introduced by some power companies and have the ability to measure the total or *apparent power* and it is possible that meat chicken farms may one day be charged for their active and reactive power usage in the future. Until then, electricity bills will only be based on active power.

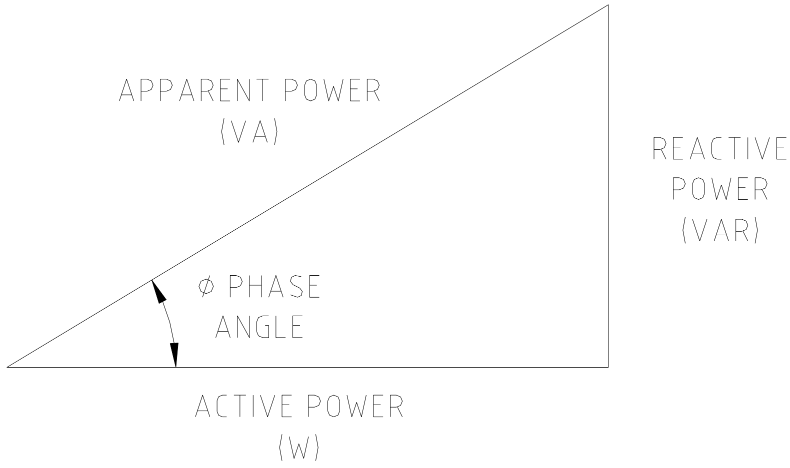


Figure 6 The power relationship triangle for AC electricity, showing active, reactive and apparent power

Power factor (cosØ) is the ratio between active power and apparent power

With all this in mind, it is possible to gain a reasonable understanding of how much active power a fan is consuming by using a three phase clamp-on power meter, such as the one in Figure 7 (Testrite® T350, Test Equipment, Queensland). These three phase power meters have the ability to simultaneously measure voltage and current and calculate the active power used by the fan motor. To operate the power meter, test leads need to be wired into each phase and then the clamp is put around each active phase wire in turn to sum the power in each of the three phases. The meter then reports the power (active, reactive and apparent) being used by the fan motor as well as the power factor.

Many electricians *will not* have a suitable power meter with the capacity to measure instantaneous electrical power, especially for three phase systems. Electricians will usually have a 'clamp meter' that is able to measure current and a multimeter that is able to measure voltage. Measuring the current and voltage will enable calculation of apparent power but without accurate measurement of power factor (which will be measured by a specially designed three phase power meter), there is no way to accurately measure the active power, which is the dimension of power of greatest interest when measuring fan efficiency. The power meter mentioned previously can be purchased for approximately $350.

Figure 7 Three phase power meter and test leads

The 3 phase clamp meter can be used in conjunction with test leads that can be wired into a fan's isolation switch to read the power in each phase and provide the total power consumption for the fan.

TIP: Using a 3 phase clamp meter to measure power consumption

(ONLY TO BE DONE BY A LICENCED ELECTRICIAN)

1. Allow fans to warm up to full operation speed and temperature (for 15–20 minutes) and set the static pressure to 25 Pa.
2. Isolate power running to the shed.
3. Gain access to the active wiring of the fan at the isolation switch or sub-board.
4. Identify all three phases running to the electric motor.
5. Wire in the insulated test leads, and plug them into the clamp meter, ensuring they are in the correct phase order.
6. Turn the fans back on and check that the static pressure is still 25 Pa.
7. Once the fan is running the clamp-on power meter will return a power reading (in watts) for each phase. The clamp must be moved to each of the three phases sequentially. Follow the power meter's instruction manual to sum the power for all three phases— this number is the total amount of power the fan is consuming. Record the apparent power, reactive power and power factor if necessary.

It is possible to calculate the overall efficiency of a fan, expressed in units of cubic meters per hour per watt ($m^3/h/W$) once the power consumption and air flow rate are known. Energy efficiency is what determines how much air your fans can move per watt of power (or per dollar on your electricity bill).

TIP: Calculating energy efficiency ($m^3/h/W$)

Example: Calculate the energy efficiency of a fan with air flow rate 30,758 m^3/h that is using 880 watts of power.

- Divide the measured air flow rate (from example, 30,758 m^3/h) by the power consumption (880 W).

$$Energy\ efficiency\,(m^3/h/W) = \frac{air\ flow\ rate\,(m^3/h)}{power\ consumption\,(W)} = \frac{30{,}758}{880} = 35.0\ m^3/h/W$$

Energy efficiency data is usually provided by fan manufacturers based on laboratory testing. This reported efficiency can be compared against the measured energy efficiency to see how fans are performing compared to test data. However, it should be noted that some fan manufacturers, particularly those from North America, test their fans with 60 Hz AC frequency compared to 50 Hz used in Australia. This means direct comparisons between the two may not be accurate. Additionally, test results from a laboratory situation are expected to be slightly different from the in-shed situation.

General tips for identifying maintenance issues

Cleaning and shutter maintenance

Shutters are essential equipment on any broiler shed exhaust fan. They are necessary to conserve house tightness and prevent backflow through inactive fans. However, they do inherently hinder air flow, and this hindrance can become worse as a result of poor maintenance and cleaning of shutters. Studies have shown that 42 days into a batch, a 91 cm (36 inch) fan can accumulate over 400 g of dust and dirt—which resulted in a reduction in air flow of 23.5% and presumably energy efficiency as well (Simmons and Lott, 1997). Proper and regular shutter maintenance and cleaning is crucial to maintain air speeds in broiler sheds and keep power consumption to a minimum.

Belt and sheave gauges

Fan belt and sheave (otherwise known as a pulley) maintenance is essential to maintain good air flow. Belt and sheave condition are directly related to the fan rotational speed (rpm) and air flow capacity. As a fan belt begins to wear it starts riding deeper in the sheave, and as a result fan rotational speed will decrease. With most sheaves, the belt should sit just proud of the sheave when the belt is new and sheave is in good condition.

V-belt and sheave gauges (eg Carlisle Power Transmission part # 102495, Kansas, USA) such as those in Figure 8 are an excellent way of quantifying the wear on belts and sheaves, which may help schedule replacement.

The technique for using belt gauges is simple—**Firstly turn off the fan and isolate the power to prevent it accidently turning on.** Slide the gauge over the belt as shown in Figure 8 and see if the belt lines up with marks. In this figure, the ‘A’ section belt lines up nicely with the ‘A’ mark on the gauge, indicating that the belt is not very worn. If the belt sat below the line marked ‘A’, it would indicate that the belt was worn.

The technique for using sheave gauges is also simple—**Firstly turn off the fan and isolate the power to prevent it accidently turning on.** Insert the sheave gauge into the groove in the sheave as shown in Figure 8 ensuring that the correct gauge and groove angles are being used. In this case, use the ‘A’ gauge in an ‘A’ section sheave. V-belt sheaves have different groove angles depending on the diameter of the sheave. The gauge specifies which side of the gauge to use for any given sheave diameter. Wear in the sheave will appear like the inset diagram in Figure 8. If more than 0.8 mm (1/32”) of wear is evident on each side wall, the sheave should be replaced.

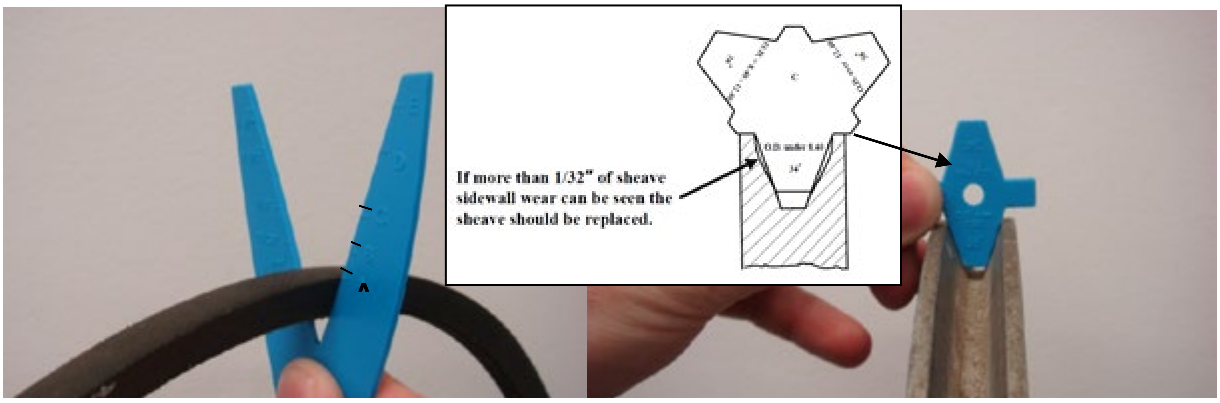


Figure 8 ***Left*****—V-belt gauge and** ***right*****—sheave gauge**

These gauges can be used to quantify the wear on belts and sheaves, which may lead to reduced fan performance (Inset diagram from Carlisle Power Transmission)

Non-contact thermometers—laser thermometer and thermal imaging cameras

Assessing the operating temperatures of fan belts, sheaves, bearings and motors can yield important information about how they are performing, and identify components that may soon fail. If a belt sheave is running at a high temperature relative to other fans, it may be a sign that the belt is worn or poorly adjusted, and may indicate that the performance or efficiency may be reduced.

A handheld laser thermometer, such as that shown in Figure 9, can help identify fan components that are running hot. These laser thermometers can be purchased for about $40-100. The advantage of the laser thermometer is that it can be used at a distance 20-30 cm away from the source, and does not require safety guards to be removed from the fan before using. When selecting a laser thermometer, take note of the distance to spot ratio (D:S), which defines the width of the detection area. A D:S ratio of 12:1 means that when the thermometer is 12 cm from the hot object, the spot it is measuring on the source is 1 cm in diameter. A minimum D:S ratio of at least 10:1 is recommended.

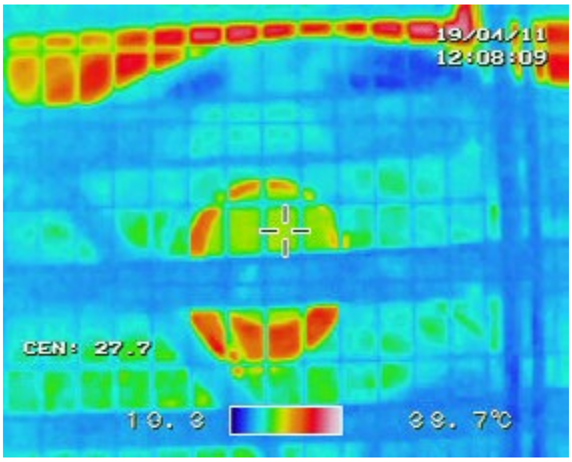
One shortcoming of laser thermometers to be aware of is they can be ‘tricked’ by shiny metallic surfaces reflecting the heat signature from other objects instead of indicating their own temperature. For example, a shiny object may have a temperature of 70°C but the thermometer may only detect a temperature of 40°C (which may be a reflection off the ceiling, fan housing or other cool object). While not ideal, sensible measurements can usually still be made.

Figure 9 An example of an infrared laser thermometer that can be used to measure the surface temperature of fan belts, sheaves, bearings or motors to measure if they are running hot

An even better instrument for identifying hot fan components is a thermal imaging camera. These can be purchased for $300–10,000 depending on the quality and resolution of the image. Thermal imaging cameras can still be ‘tricked’ in the same manner as laser thermometers by reflected heat on shiny surfaces. Nonetheless, they are still very useful for identifying hot objects. Figure 9 shows a series of photographs and corresponding thermal images. The images at the top are of a fan motor sheave with a normally adjusted belt. The temperature of the sheave is about 27.7°C, which is relatively cool. The images at the bottom are of a motor sheave with a loose belt (in this case **visibly** loose). The temperature of the sheave is about 68.6°C, which is much hotter than the other one. The rotational speed and air flow rate (at 12.5 Pa static pressure) of the fan with the properly adjusted belt were 625 rpm and 41,050 m^3/h whereas the fan with the loose belt were 505 rpm and 26,300 m^3/h—**a 35% reduction in air flow rate.**

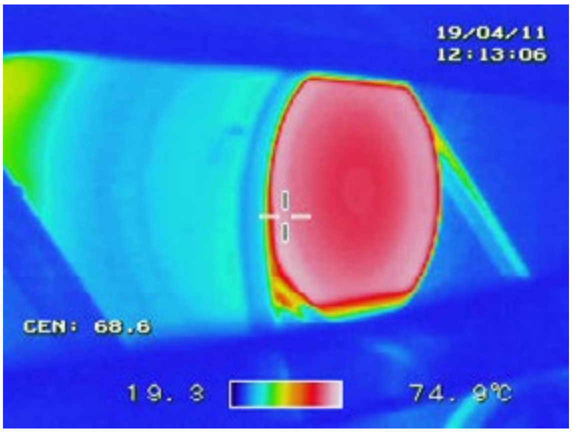
In this case, the poorly adjusted belt was identifiable with both the non-contact thermometer and tachometer.

Belt sheave with properly tensioned belt



Thermal view of belt sheave with properly tensioned belt showing an operating temperature of 27.7°C

Belt sheave with a loose belt



Thermal view of a belt sheave with a loose belt showing an operational temperature of 68.6°C

Figure 10 Series of photos taken with a thermal camera to demonstrate how temperature can be used to identify poorly adjusted or worn fan components

The top fan has a correctly adjusted belt and the lower fan has a loose belt. Temperature of the sheave with the loose belt was 68.6°C whereas the sheave with the properly adjusted belt was 27.7°C

Last words

By taking the time to perform some or all of the above mentioned fan tests, problems with fans can be identified quickly, easily and with confidence. These tests can help to discover fans that are starting to drop off in performance due to wear or poor adjustment. Some of these tests may help to identify worn fan components before they fail completely. This will help to minimise downtime due to malfunctioning fans and ensure optimal performance and ventilation rate is maintained.

For more information about fan maintenance and measuring in-shed conditions or fan performance, refer to the *Poultry Housing Tips* at http://www.poultryventilation.com.

sheet

SHED:____________

Fan Descriptions		DATE:								
(example)			2875	2865						
FAN 1:										
FAN 2:										
FAN 3:										
FAN 4:										
FAN 5:										
FAN 6:										
FAN 7:										
FAN 8:										
FAN 9:										
FAN 10:										
FAN 11:										
FAN 12:										
FAN 13:										
FAN 14:										
FAN 15:										
FAN 16:										
FAN 17:										
FAN 18:										

Conversion factors—metric to imperial

Temperature

Degrees Celsius	Degrees Fahrenheit
0	32
1	34
2	36
3	37
4	39
5	41
6	43
7	45
8	46
9	48
10	50
11	52
12	54
13	55
14	57
15	59
16	61
17	63
18	64
19	66
20	68
21	70
22	72
23	73
24	75
25	77
26	79
27	81
28	82
29	84
30	86
31	88
32	90
33	91
34	93
35	95
36	97
37	99
38	100
39	102
40	104
41	106
42	108

Flow Rate

m^3/h	m^3/s	CFM	L/s
1	0.00028	0.589	0.278
1000	0.28	589	278
5000	1.39	2,943	1,389
10000	2.78	5,886	2,778
11000	3.06	6,474	3,056
12000	3.33	7,063	3,333
13000	3.61	7,651	3,611
14000	3.89	8,240	3,889
15000	4.17	8,829	4,167
16000	4.44	9,417	4,444
17000	4.72	10,006	4,722
18000	5.00	10,594	5,000
19000	5.28	11,183	5,278
20000	5.56	11,771	5,556
21000	5.83	12,360	5,833
22000	6.11	12,949	6,111
23000	6.39	13,537	6,389
24000	6.67	14,126	6,667
25000	6.94	14,714	6,944
26000	7.22	15,303	7,222
27000	7.50	15,892	7,500
28000	7.78	16,480	7,778
29000	8.06	17,069	8,056
30000	8.33	17,657	8,333
31000	8.61	18,246	8,611
32000	8.89	18,834	8,889
33000	9.17	19,423	9,167
34000	9.44	20,012	9,444
35000	9.72	20,600	9,722
36000	10.00	21,189	10,000
37000	10.28	21,777	10,278
38000	10.56	22,366	10,556
39000	10.83	22,954	10,833
40000	11.11	23,543	11,111
50000	13.89	29,429	13,889
100000	27.78	58,857	27,778
150000	41.67	88,286	41,667
200000	55.56	117,715	55,556
250000	69.44	147,144	69,444
300000	83.33	176,572	83,333
350000	97.22	206,001	97,222
400000	111.11	235,430	111,111
450000	125.00	264,858	125,000
500000	138.89	294,287	138,889

Speed

m/s	feet/min
1	196.850
0.25	49
0.5	98
0.75	148
1	197
1.25	246
1.5	295
1.75	344
2	394
2.25	443
2.5	492
2.75	541
3	591
3.25	640
3.5	689
3.75	738
4	787
4.25	837
4.5	886
4.75	935

Distance

m	ft
1	3.28083
5	16.4
6	19.7
7	23.0
8	26.2
9	29.5
10	32.8
11	36.1
12	39.4
13	42.7
14	45.9
15	49.2
16	52.5
17	55.8
18	59.1
19	62.3
20	65.6
100	328
110	361
120	394
130	427
140	459
150	492
160	525

Energy Efficiency

m^3/h per watt	CFM per watt	L/s/Watt
1	0.589	0.278
10	5.9	2.8
11	6.5	3.1
12	7.1	3.3
13	7.7	3.6
14	8.2	3.9
15	8.8	4.2
16	9.4	4.4
17	10.0	4.7
18	10.6	5.0
19	11.2	5.3
20	11.8	5.6
21	12.4	5.8
22	12.9	6.1
23	13.5	6.4
24	14.1	6.7
25	14.7	6.9
26	15.3	7.2
27	15.9	7.5
28	16.5	7.8
29	17.1	8.1
30	17.7	8.3
31	18.2	8.6
32	18.8	8.9
33	19.4	9.2
34	20.0	9.4
35	20.6	9.7
36	21.2	10.0
37	21.8	10.3
38	22.4	10.6
39	23.0	10.8
40	23.5	11.1
41	24.1	11.4
42	24.7	11.7
43	25.3	11.9
44	25.9	12.2
45	26.5	12.5
46	27.1	12.8
47	27.7	13.1
48	28.3	13.3
49	28.8	13.6
50	29.4	13.9
51	30.0	14.2
52	30.6	14.4
53	31.2	14.7

Energy Efficiency

Watts per m^3/h	Watts per CFM	Watts per L/s
1	1.699	3.597
0.100	0.170	0.357
0.091	0.154	0.323
0.083	0.142	0.303
0.077	0.131	0.278
0.071	0.121	0.256
0.067	0.113	0.238
0.063	0.106	0.227
0.059	0.100	0.213
0.056	0.094	0.200
0.053	0.089	0.189
0.050	0.085	0.179
0.048	0.081	0.172
0.045	0.077	0.164
0.043	0.074	0.156
0.042	0.071	0.149
0.040	0.068	0.145
0.038	0.065	0.139
0.037	0.063	0.133
0.036	0.061	0.128
0.034	0.059	0.123
0.033	0.057	0.120
0.032	0.055	0.116
0.031	0.053	0.112
0.030	0.051	0.109
0.029	0.050	0.106
0.029	0.049	0.103
0.028	0.047	0.100
0.027	0.046	0.097
0.026	0.045	0.094
0.026	0.044	0.093
0.025	0.042	0.090

Pressure

Pa	inch H_2O
1	0.00402
2	0.01
4	0.02
6	0.02
8	0.03
10	0.04
12	0.05
14	0.06
16	0.06
18	0.07
20	0.08
22	0.09
24	0.10
26	0.10
28	0.11
30	0.12
32	0.13
34	0.14
36	0.14
38	0.15
40	0.16
42	0.17
44	0.18
46	0.18
48	0.19
50	0.20
52	0.21
54	0.22
56	0.22
58	0.23
60	0.24
62	0.25
64	0.26
66	0.27
68	0.27
70	0.28

Conversion factors—imperial to metric

Temperature

Degrees Fahrenheit	Degrees Celsius
32	0.0
34	1.1
36	2.2
38	3.3
40	4.4
42	5.6
44	6.7
46	7.8
48	8.9
50	10.0
52	11.1
54	12.2
56	13.3
58	14.4
60	15.6
62	16.7
64	17.8
66	18.9
68	20.0
70	21.1
72	22.2
74	23.3
76	24.4
78	25.6
80	26.7
82	27.8
84	28.9
86	30.0
88	31.1
90	32.2
92	33.3
94	34.4
96	35.6
98	36.7
100	37.8
102	38.9
104	40.0
106	41.1
108	42.2

Flow rate

CFM	m^3/h	m^3/s
1	1.699	0.000472
2000	3,398	0.94
2500	4,248	1.18
3000	5,097	1.42
3500	5,947	1.65
4000	6,796	1.89
4500	7,646	2.12
5000	8,495	2.36
5500	9,345	2.60
6000	10,194	2.83
6500	11,044	3.07
7000	11,893	3.30
7500	12,743	3.54
8000	13,592	3.78
8500	14,442	4.01
9000	15,291	4.25
9500	16,141	4.48
10000	16,990	4.72
10500	17,840	4.96
11000	18,689	5.19
11500	19,539	5.43
12000	20,388	5.66
12500	21,238	5.90
13000	22,087	6.14
13500	22,937	6.37
14000	23,786	6.61
14500	24,636	6.84
15000	25,485	7.08
15500	26,335	7.32
16000	27,184	7.55
16500	28,034	7.79
17000	28,883	8.02
17500	29,733	8.26
18000	30,582	8.50
18500	31,432	8.73
19000	32,281	8.97
19500	33,131	9.20
20000	33,980	9.44
20500	34,830	9.67
21000	35,679	9.91
50000	84,951	23.60
100000	169,902	47.20
150000	254,853	70.79
200000	339,804	94.39
250000	424,755	117.99
300000	509,706	141.59

Speed

feet/min	m/s
1	0.00508
50	0.25
100	0.51
150	0.76
200	1.02
250	1.27
300	1.52
350	1.78
400	2.03
450	2.29
500	2.54
550	2.79
600	3.05
650	3.30
700	3.56
750	3.81
800	4.06
850	4.32
900	4.57

Distance

ft	m
1	0.30480
10	3.0
15	4.6
20	6.1
25	7.6
30	9.1
35	10.7
40	12.2
45	13.7
50	15.2
55	16.8
60	18.3
65	19.8
300	91.4
350	106.7
400	121.9
450	137.2
500	152.4
550	167.6
600	182.9
650	198.1
700	213.4
750	228.6

Energy Efficiency

CFM per watt	m^3/h per watt
1	1.699
10	17.0
11	18.7
12	20.4
13	22.1
14	23.8
15	25.5
16	27.2
17	28.9
18	30.6
19	32.3
20	34.0
21	35.7
22	37.4
23	39.1
24	40.8
25	42.5
26	44.2
27	45.9
28	47.6
29	49.3
30	51.0

Energy Efficiency

Watts per CFM	Watts per m^3/h
1	0.589
0.100	0.059
0.091	0.054
0.083	0.049
0.077	0.045
0.071	0.042
0.067	0.039
0.063	0.037
0.059	0.035
0.056	0.033
0.053	0.031
0.050	0.029
0.048	0.028
0.045	0.027
0.043	0.026
0.042	0.025
0.040	0.024
0.038	0.023
0.037	0.022
0.036	0.021
0.034	0.020
0.033	0.020

Pressure

inch H_2O	Pa
1	249
0.01	2
0.02	5
0.03	7
0.04	10
0.05	12
0.06	15
0.07	17
0.08	20
0.09	22
0.10	25
0.11	27
0.12	30
0.13	32
0.14	35
0.15	37
0.16	40
0.17	42
0.18	45
0.19	47
0.20	50
0.21	52
0.22	55
0.23	57
0.24	60
0.25	62
0.26	65
0.27	67
0.28	70
0.29	72
0.30	75

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‘How to’ guide for measuring fan performance and efficiency in meat chicken sheds

by Mark Dunlop and Grant Brown

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