



Evaluating Mechanical Ventilation Systems Evaluating Livestock Housing Environments Part 3 of 3

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Characterizing a Mechanical Ventilation System's Performance

When people think of air quality in an animal environment, they often think of the ventilation system. This makes them eager to take measurements of fan performance and inlet characteristics. Air exchange and air distribution are the main concerns. Air speed at the fan and inlets can be measured to get the necessary information to calculate the capacity of the ventilation system. The static pressure against which the system is operating can be checked. Fan performance can be verified. Evaluate the system under typical animal density and weather conditions.

Although the ventilation system's performance is important, conditions in the area occupied by the animals are even more important. The ventilation system will influence conditions within the animals' space, so environmental measurements should be made along with observations of animal behavior. For example, in some cases the ventilation system may appear to be working correctly and within its design specifications, yet air quality in parts of the animal facility is unacceptable.

This fact sheet series also contains Part 1, Principles of Measuring Air Quality, which outlines how to take proper air quality measurements, and Part 2, Instruments for Measuring Air Quality, which describes instruments used for characterizing the environment in the animal zone.

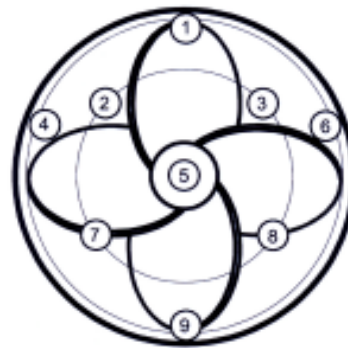
Fan Air Speed

Fast air speed at the discharge or entry into a fan



Vane Anemometer

can be measured with a vane anemometer. Many readings should be taken across the face of the fan, as shown in the figure in the upper right, to get an average air speed. Because this is a rather crude field measure-

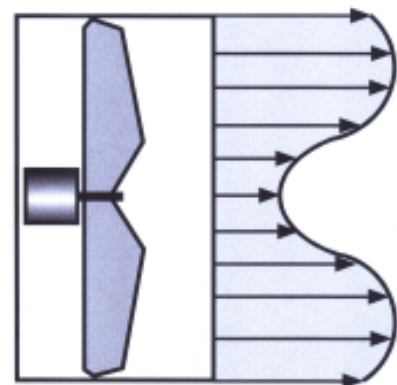


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Take air speed measurements at several locations across the fan area.

ment, include as many readings as possible in your average air speed. Use the nine readings shown in the figure as a minimum. Each measurement represents only a very small area of air flow over the fan face. Air speed varies greatly

Cross section of fan showing large variation in air speed coming off fan tips versus near fan hub.



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across the face of a fan, with highest velocities coming off the blade tips and minimal velocity near the hub. Sample velocities near the blade tip, in the middle, and at the center of the fan. Some fans will have negative air flow at the center, indicating a draft of air short-circuiting backwards through the fan. Obstructions and wind gusts cause uneven air speed distribution over the

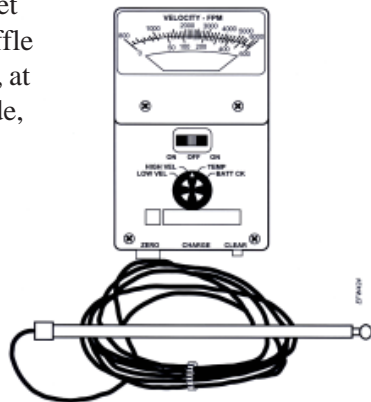
fan face. A hooded poultry house fan will exhibit lower air flow at the top quadrant of the fan due to the resistance of the external hood, which is open at the bottom. Air speeds are more accurately determined on the discharge side of the fan than on the inlet side.

It is important to minimize the amount of air flow that your body blocks as you position the anemometer. Step back out of the air flow, to the side of the fan when possible. Vanes that attach by cable to the air speed display unit offer an advantage here. Several instruments are appropriate for measuring the fast air speeds exiting a fan, including a velocity manometer, vane anemometer, hot-wire anemometer, or air speed streamer (see Part 2).

Inlet Air Speed

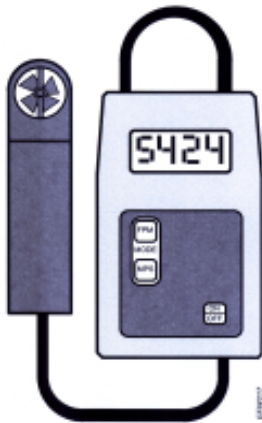
Air speed from inlets should be quite fast, between 700 and 1000 ft/min, in a properly operated mechanical ventilation system.

Unfortunately, the inlet gap of a slotted or baffle inlet is often so small, at 1/4 inch to 1 inch wide, that the large 3-inch diameter head of a typical vane anemometer cannot determine a meaningful air speed. The small probe head of a hot wire anemometer is most appropriate for measuring air speed out of slotted inlets.

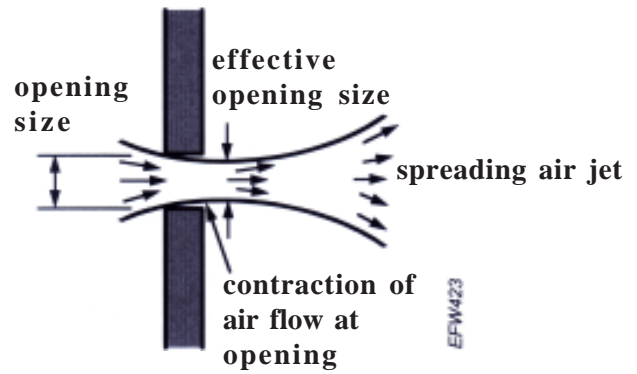


Hot Wire Anemometer

A vane anemometer can be used to measure air speed out of some duct holes (rigid or polytube ducts) or other inlets with large openings. The key is to make sure the vane anemometer head is no larger than the airstream being measured. Small-headed vane anemometers can measure smaller diameter airstreams. The low-cost air velocity manometer may be used with these fast inlet air speeds.



Small-headed Vane Anemometer



Correction of edge effect for air flowing through holes involves reeduced effective opening area.

Air speed from slotted inlets is not uniform over the vertical cross section of the inlet. The air speed will be zero at the edges of the inlet and will typically increase to its maximum near the middle of the inlet opening. Take air speed measurements across the vertical opening of the inlet until you get a maximum air speed reading, then correct for the edge effects by using a concept called the “coefficient of discharge.” This has been empirically determined to be about 0.6 for sharp-edged openings such as ventilation slots, holes or windows. The real inlet air speed is the maximum measured air speed multiplied by the coefficient of discharge of 0.6. In other words, the average air speed over the face of the entire inlet opening is 60 percent of the maximum speed you measured.

Capacity of Ventilation System

To calculate the air volume being moved by a ventilation system, you will need a measured air speed and an estimate of cross-sectional area through which that air is moving. Air speed involves measurements at the fan and/or inlets. To determine cross-sectional area, measure the fan wall opening(s) or the sum of inlet areas. It is easier and better to determine ventilation capacity by taking measurements at the fan. Inlet air speeds may seem easy to measure, but the effective inlet area and average air speed are not as easy to determine. Particularly with long slotted inlets, construction irregularities will mean that small openings such as 1/4 inch cannot be maintained along the length of the slot. In polytube or other ducted inlets, air velocity in the duct and at the holes will vary with the distance along the duct, so many measurements will be needed. Even tightly con-

structed buildings have some “unplanned” inlets for air exchange, and these are very hard to account for.

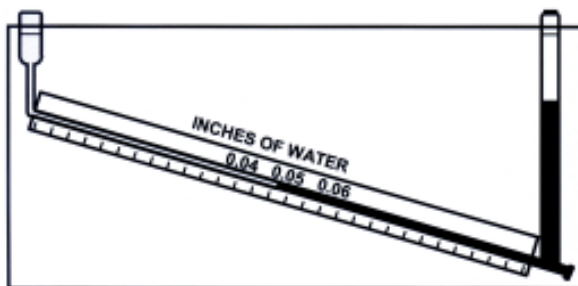
Use this very simplified method to calculate air flow capacity of a fan in cubic feet per minute (cfm): multiply the average air speed you measured in feet/minute (fpm) by the area of the fan face in square feet. (Area of circle = $\pi d^2/4$; where d = diameter in feet). Example: you calculated an 800 ft/min average air speed across the face of a 48 inch (4 foot) diameter fan. Air flow (cfm) = speed (fpm) * area (sq ft) = 800 fpm * $\pi(4)^2/4$ sq ft = 10,048 cfm.

The ventilation system capacity equals the sum of all fan capacities. For each type of fan in a staged ventilation system, one set of representative data may be used. For example, in a poultry house with banks of 36-inch and 48-inch fans, determine an average velocity reading from one (or two or three) of the 36-inch fans and one (or two or three) of the 48-inch fans. Total ventilation capacity at any stage would be estimated as the measured average air flow capacity of a 36-inch fan times the number of 36-inch fans operating plus the average air flow capacity of a 48-inch fan times the number of 48-inch fans operating.

When there are differences in fan types due to manufacturer, motor, blades, maintenance, or suspected reliability, air speed measurements will need to be taken for each different type of fan. Fans in locations where obstructions or wind effects are dominant features also will need to be evaluated separately. There is no need to measure air flow at each and every fan unless an unusual air flow imbalance is suspected.

Static Pressure

Static pressure is very important to a mechanical ventilation system since it is the driving force for air movement. Air enters or leaves the building because the interior static pressure is different than the outside pressure. Static pressure is measured with a manometer, which determines the pressure difference



Inclined manometer

between the ventilated space and the building exterior. The exterior is anywhere outside the mechanically ventilated livestock confinement that is exposed to outside air conditions. The manometer has one port open to the building interior. The second port is connected to a flexible hose which has its open end positioned outside the ventilated space. The manometer then measures the static pressure difference that influences air entering the inlets.

Inclined manometers are the most accurate manometers for agricultural ventilation situations. A colored fluid in a thin tube equilibrates to a position representing the pressure difference between the two measuring ports. Units are in fractions of an inch of water. Static pressure differences in agricultural ventilation are so small, on the order of 0.02-inches to 0.10-inches water, that an inclined rather than upright manometer is needed to accurately determine a scale reading.

Care must be taken in positioning the tubes connected to the measuring ports. Be sure they are not exposed to any moving air. The objective is to measure a “static” pressure of air and not the “velocity” pressure of moving air. The exterior measuring port often is placed in the building attic, which represents an outside condition without wind effects. The interior port should be kept away from high air velocity areas such as near the fans or inlets.

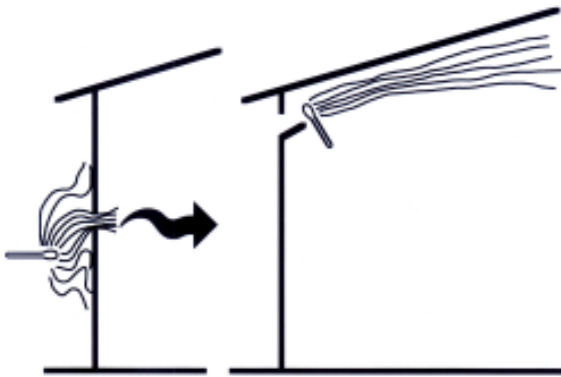
Ventilation system controls often operate by measuring the static pressure difference across the inlets. This measurement can be verified as discussed above. Ventilation fans actually operate against more pressure drop than that associated with just the inlets. They also have a pressure drop in exhausting air through the fan enclosure restrictions, including the fan housing, guard and any louvers. (This pressure change is almost impossible to measure under field conditions.) Fans are chosen for operating performance at 0.10-inch to 0.125-inch (1/10 inch to 1/8 inch) water pressure to account for fan enclosure and inlet restrictions.

Evaporative cooling pads or other air restricting devices (heat exchangers, earth tubes, ducts) will offer additional resistance to air flow. Additional manometer readings should be taken when each source of air flow resistance is being used. This “total” static pressure is used for comparing actual versus expected fan performance. For example, a ventilation system may be set to operate at 0.04-inch static pressure for part of the year. This control setting represents the static pressure difference across the inlets. The pressure difference with an evapora-

tive cooling pad in place will be higher. A new measurement may find the static pressure the fan is operating against is 0.08-inch water. Fan capacity, as shown on a fan characteristic curve, would have to be evaluated around 0.14-inch water to account for inlets, evaporative pad and fan restrictions.

Air Flow Visualization

Sometimes it is helpful to see where air mixing or unusual leaks are occurring in a ventilation system. It may be surprising, but not uncommon, to learn that a good portion of air flow in the enclosure is coming through unplanned inlets. These may include leaks around the fan installation, broken window panes, leaks around door and window frames, broken siding materials, and any other location of loose construction detail. These significant leaks are very detrimental to performance of the ventilation system. Unplanned inlets are not controllable and probably provide uneven air flow patterns, in turn creating uncontrolled and uneven air quality conditions around the building interior.



Air flow visualization by positioning smoke devices

An improperly operated ventilation system will have adequate air flow in volume as measured at the fan, but not in distribution throughout the enclosure. It is the inlets and their resultant air flow distribution that create desirable air conditions within the animal area. Fans provide a motive force (the pressure difference) to keep a volume of air moving through a building at a certain rate, but it is the inlet system that distributes fresh air. Air flow visualization will provide information about whether fresh air is being distributed to the animal areas where it belongs.

Visualizing air flow patterns in livestock buildings has a few limitations, but several methods have worked. Thermal or chemical smoke can be used, but anything which produces abundant smoke can quickly obscure air flow patterns. Very small, neutrally

buoyant soap bubbles, generated with helium, can last long enough to show airstreams within an enclosure. Threads of material can be calibrated to blow horizontally at a particular air speed and positioned inexpensively in many locations as indicators of minimum desired air flow. Air flow visualization instruments and their use are covered in Part 2, *Instruments for Measuring Air Quality*.

A certain amount of creative license is allowed in using air flow visualization. A visualization tool such as a smoke candle can be placed just outside (or just inside) an inlet to see how far the air jet is penetrating into the animal enclosure. Similarly, a smoker can be positioned around close to the exterior of a building to see where smoke is drawn through building leaks. Smoke sticks can be held down into an animal pen to look for drafts or dead air zones. Using common sense to identify where leaks and trouble spots may be occurring will lead to appropriate positioning of the air visualization equipment. Pure curiosity is allowed! Move around with the instruments and look for unusual air flow patterns. Sudden, dropping drafts of air may be caused by temperature and/or velocity changes. Look for obstructions and use other instruments to help determine causes for the air flow observations.

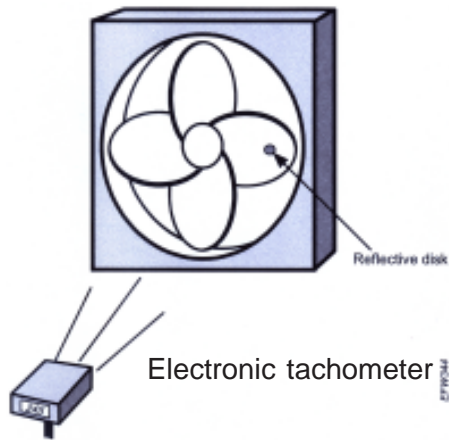
Fan Speed (rpm)

Fan operation can also be checked by measuring the fan blade rotational speed in revolutions per minute, or rpm. Because the amount of air a fan moves is directly proportional to its rotational speed, a fan running at 75 percent of its rated speed will move only 75 percent of its rated or intended air flow.

Fan speed measurement can quickly indicate if belts are loose or worn, or if the voltage level is too low. Inadequate wiring can lead to substantial voltage drops along the building length, causing fans to run slowly. Measuring fan speed is as important as other performance indicators, particularly for belt-driven fans, which can slip with worn or poorly-adjusted belts.

Fan rotational speed can be measured using a tachometer or strobe light. **Tachometers** can be either mechanical or electronic. With mechanical tachometers, the tachometer shaft is rotated by pressing it against the center of the fan shaft so that both the tachometer shaft and fan shaft have the same speed. Mechanical tachometers should be used carefully so that no personnel or equipment damage occurs if the tachometer shaft slips off the fan shaft.

Electronic tachometers (like the one in the figure) send light to a shiny, rotating object, such as a silver sticker attached to a fan blade or shaft, and the reflected light is measured by the tachometer and converted to an rpm measurement.



A **strobe light** produces flashes of bright light at an adjustable frequency (flashes per minute). As the frequency approaches the fan rpm,

the blades appear to slow down, stop, and may even appear to reverse direction. The fan rpm is determined by adjusting the flash rate until a rotating part (blade, shaft, or pulley) appears to be stopped.

It is important to note that simply adjusting the flash rate until the fan blades appear to be stopped does not ensure an accurate reading because the same blade may not be in the same position at each flash. For example, with a four blade fan, running the strobe at 3/4 or 1 1/4 times the correct flash rate will appear to stop the blades, but a given blade will not be in the same position with each flash. The correct strobe flash rate and rpm can be obtained by stopping a unique rotating part, such as an oil fitting, bolt, or key shaft on the shaft, or a shiny sticker that is half black and half shiny placed on the fan shaft.

Summary

Evaluation of a mechanical ventilation system emphasizes measurements of air exchange capacity (fan air speed) and air distribution (inlet air speed and air flow visualization). Ventilation system capacity is best measured at the discharge side of fan(s) by determining an average air speed over the face of the fan. Multiply average air speed (ft/min) by the area (square feet) of the fan face to determine capacity in cfm. Fast inlet air speed encourages good air mixing and distribution.

When environmental problems are suspected, techniques such as air flow visualization can help

identify trouble spots. Static pressure and fan speed (rpm) measurements can help pinpoint causes of poor performance.

The environmental conditions under which animals are housed are very important to their comfort and productivity. With the tools and methods outlined in this fact sheet series, one can better understand and characterize the environment to which the animals are exposed. Part 1, Principles of Measuring Air Quality, emphasized how reliable measurements are obtained. Instruments needed to make appropriate measurements in agricultural environments are described in Part 2, Instruments for Measuring Air Quality. Proper techniques for using each instrument have been emphasized. Once good measurements are taken, comparisons can be made to desirable environmental characteristics. Part 3, Evaluating Mechanical Ventilation Systems, highlights how to use instruments and observations to evaluate air exchange capacity and air distribution.

Additional Resources

Environmental problems are much easier to solve once you have good background information about where the major problem is located. Changes in management, ventilation system operation, or equipment then can be made. Environmental improvements can then be quantified and compared to previous conditions. Several publications can help solve environmental problems you may find. They include:

Pork Industry Handbook *Troubleshooting Swine Ventilation Systems*.

The above publication is available from:

Media Distribution Center, Purdue University, 301 S. 2nd St., Lafayette, IN 47901-1232

MWPS-32, *Mechanical Ventilating Systems for Livestock Housing*

MWPS-33, *Natural Ventilating Systems for Livestock Housing*

MWPS-34, *Heating, Cooling and Tempering Air for Livestock Housing*

The above publications are available from:

MidWest Plan Service <http://www.mwpsdq.org/>

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