# FAN VENTILATION PRINCIPLES AND RATES

COMPLETE INSTRUCTIONS

NEW 87:06

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When livestock and poultry are confined in farm buildings, you take responsibility for giving the animals a satisfactory air environment, ideally within their 'comfort zone'.

The animals' comfort zone is determined by the combined effect of air temperature, humidity and airspeed. Temperature is the easiest of these to measure and control, therefore the comfort zone is usually defined as the range between the animals' upper and lower critical temperatures. Critical temperatures are then adjusted up or down depending on humidity, airspeed and animal factors such as age (size), feeding (maintenance or full-fed), health, single or group penning, bedding or no bedding and activity (active or sleeping, very important).

The ventilation svstem must remove stale air containing respired and evaporated moisture, carbon dioxide, dust, manure gases and airborne disease organisms. It then has to replace this stale air with fresh air while maintaining the air within the comfort zone of the animals. This is not a simple task.

With young, sensitive animals like baby pigs and chicks, the comfort zone is quite narrow and specific. That is, temperature must be maintained within a narrow band (such as 30-35°C), airspeed must be very low (under 0.25 mss, no drafts) and relative humidity (RH) must be low enough to keep the floor and litter dry, but not so dry that the air becomes too dusty. At the other extreme, large well-coated animals like sheep and cattle can easily tolerate cold. That is, their lower critical temperature falls considerably below freezing as long as their hair-coats are not wetted by fog, dripping condensation or dirty pens. The acceptable humidity range in animal buildings is normally 50-80% RH. You should consider first the comfort and productivity of the animals even though you may have to over-ventilate the barn to your own discomfort.

## HOW VENTILATION WORKS

First, winter ventilation. Figure 1 shows fan-powered winter ventilation in an insulated barn. Ventilation controls the barn humidity by exchanging drier outside air for moist inside air, continuously removing the water vapor. Good ventilation also removes contaminants like dust, manure gases and the disease organisms shed by sick animals.

Figure 1 shows 1 kg of cold outside air; at the conditions stated it occupies a volume of 700 L. In the worst conditions (during a snowstorm, for example) it can be saturated with water vapor (100% RH), although at -25°C it can hold only 0.4 g . This cold air is drawn into the barn through the fresh air inlets, where it mixes with the warm air inside.

Warming 1 kg of cold air (from -25°C to + 15°C, in this example) causes the air to expand (from 700 L to 820 L). More important, warming greatly increases its water vapor capacity - at 100% RH it could hold over 30 times as much as the cold air outside.

Of course, it is not acceptable to let the inside air reach 100% RH. A more practical maximum is 75-80% RH for a comfortable barn and healthy livestock. Moisture evaporates into the room air from the animals' breath and from wet floors until 1 kg of the mixed air is at 75% and holds 8 g of water vapor at 15°C. This is still 20 times the amount of moisture brought into the barn by the outside air. Exhaust fans (or with natural ventilation, the outlet vent at the top of the room) then remove this warm, moist air at a controlled rate. Restated, each kilogram of air comes in carrying 0.4 g, mixes with room air, and later goes out carrying 8 g, thus removing 8.0 - 0.4 = 7.6 g of water vapor.

Research in controlled environments has shown how fast water vapor is produced. For example, a 54 kg growing pig on a partly slotted floor produces an average of 70 g of water vapor per hour. Thus, the ventilation rate to maintain good inside air is:

Ventilation rate = 70 g/h /7.6 g/kg = 9.2 kg/(h.pig)

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Exhaust fans are rated in litres of air per second (L/s), or in cubic feet per minute (cfm), not kg/h. Therefore, we must convert the ventilation rate to fan ratings:

$$9.2 \text{ kg/h} \times \frac{820 \text{ L/kg}}{60 \times 60 \text{ s/h}} = 2.1 \text{ L/s}$$ (or, in imperial units, 2.1 x 2.12 = 4.5 cfm)

This calculation locates one point on the ventilation rate curve called 'humidity control' in Figure 2. Similar curves have been developed for various age-groups of pigs and other livestock housed under typical Canadian management and climatic conditions.

Realize at this point that you can't precisely predict the heat and moisture produced by animals. For any animal or group, short-term heat outputs can vary as much as 50% above or below the average hourly output. Animals produce two forms of heat, 'sensible' and 'latent'. The sensible part (so called because you can feel it) helps keep the barn warm. The latent part evaporates moisture, mostly from the animals' breath, but some as well from manure and wet floors. Total heat production (sensible plus latent) depends on animal activity (sleeping, versus active socializing), animal size, room temperature and a host of other factors. The latent heat part tends to decrease as the air temperature goes down. That is, lowering the room temperature makes animals produce less moisture but more sensible heat - more about this later.

WINTER HEAT BALANCE An ideal situation exists if the heat produced by the animals is greater than that lost through ventilation plus the building surfaces. The barn stays warm and dry without added heat. Unfortunately, it takes a lot of heat to warm the incoming cold air, and this is lost later when the warm air is removed by ventilation (the 'ventilation heat loss'). Some more heat is lost through the building surfaces, the ceiling, walls and foundation of the barn (the 'building heat loss'). When it gets very cold, the 'sensible' part of the livestock heat production may not be great enough to balance the ventilation plus building heat losses, even the barn is super -insulated.

Assume in Figure 1 (for discussion) that a single thermostat set at 15°C controls the ventilation. As animals warm up the room, the thermostat is 'off' until the temperature passes the 15° setpoint; at 16° it trips 'on' and the fan starts. Ventilation then cools the room down to 14° where the thermostat trips 'off'.

Temperature continues to cycle up and down within this 2° range (the thermostat 'differential'), automatically balancing the heat account but ignoring humidity. In very cold weather, ventilation 'on' periods will be short, the 'off' periods will be long and humidity will rise. A wet building and sick animals can result if the conditions are not soon corrected.

One could ask, why not use humidistats instead of thermostats? The short answer is no, because humidistats respond only to humidity, allowing the temperature to float out of control. Also, existing humidistats are quite unreliable in the damp, dusty, corrosive barn atmosphere.

Figure 2 shows theoretical ventilation rate curves for a well-insulated growing,-finishing pig barn, to illustrate the heat balance principle. At -25°C outside, the ventilation rate for humidity control is 2.1 L/s per pig. But with a thermostat balancing the ventilation to match the animal heat produced, the average ventilation rate would be only 1.7 L/s. The practical solution is to add supplemental heat, thus improving the heat balance and increasing the ventilation.

.In Figure 2, the curves for 'temperature control' and 'humidity control' cross at about - 5°C outside. That is, supplemental heating in this example is only needed below -5°C. One control strategy is to interlock the wiring of the heating and cooling (ventilation) thermostat so that heating is reduced and ventilation increased as it gets warmer outside, and vice versa.

Wherever animal heat alone can't maintain a heat balance (below the heat balance point, -5°C in the example pig barn), you have four options:

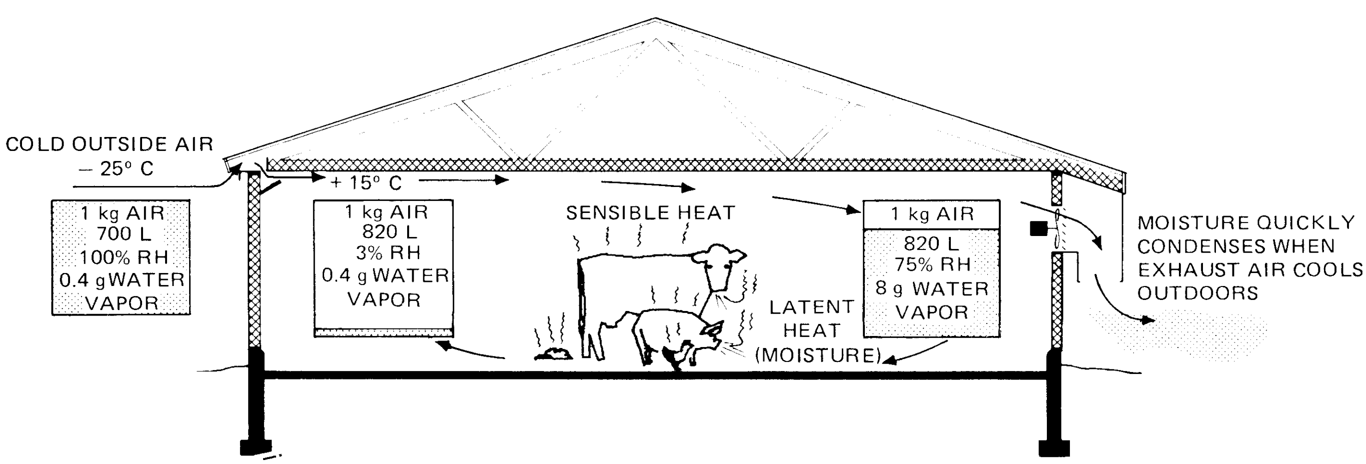



Figure 1 Winter ventilation for livestock in controlled-environment barns

1 allow the humidity to rise out of control;
2 add heat to maintain both temperature and humidity;
3 lower the barn temperature; or
4 increase the insulation.

Option 1 is quite acceptable where the outdoor temperature drops below the heat balance point for only short periods each winter. In the milder parts of Canada (southwestern Ontario, southern British Columbia, Nova Scotia), most well-insulated growing/ finishing and breeding/gestation pig barns are run this way, without supplemental heat. Ventilation quality suffers, but only for short periods.

Option 2 is recommended for all animals sensitive to extremes of humidity and temperature (including growing/finishing pigs, in the colder regions of Canada).

Option 3, reduced barn temperatures, is a good choice with larqer, cold-tolerant animals like dairy cows, breeder turkeys, horses and sheep. Lowering the room temperature (but still within the comfort zone) increases total animal heat production but reduces latent heat (moisture) production. For example, reducing the barn temperature for dairy cows to about +2°C during periods of coldest weather is much cheaper and more practical than option 1 or 2. The cows will eat more feed to produce the additional heat, but milk production and health will not suffer. Setting the thermostat below freezing is not recommended as the heat balance is not further improved and water lines will freeze unless protected.

Option 4, increasing the insulation, can also help the heat balance, if the building is not already well insulated. Walls insulated to RSI-3.5 and ceilings to RSI-5.2 are about optimum for most livestock barns in Canada. Exceptional cases are high-temperature brooding units for baby chicks and weanling pigs in the colder regions, where walls can be insulated to RSI-4.7 and ceilings to RSI-7.8 if there is enough space for the extra insulation within the framing.

WINTER TO SUMMER VENTILATION Figure 2 shows that ventilation for humidity control is almost constant below - 5°C outside. But with warmer weather the solid curve for temperature control shows ventilation rapidly increasing with outdoor temperature. At 27°C, temperature control requires 30 L/s per pig - over 14 times the 2.1 L/s calculated for cold weather.

With only one fan, big enough to give the full summer ventilation rate, winter ventilation would require the fan to run onlv 1/14 of the time. Also, with each start of the big fan, a cold blast of air would chill the animals. Figure 3 shows a better way, using a series of fans ranging from small to large, controlled by a corresponding series of thermostats set in temperature steps. This shows five steps, with the step 1 fan

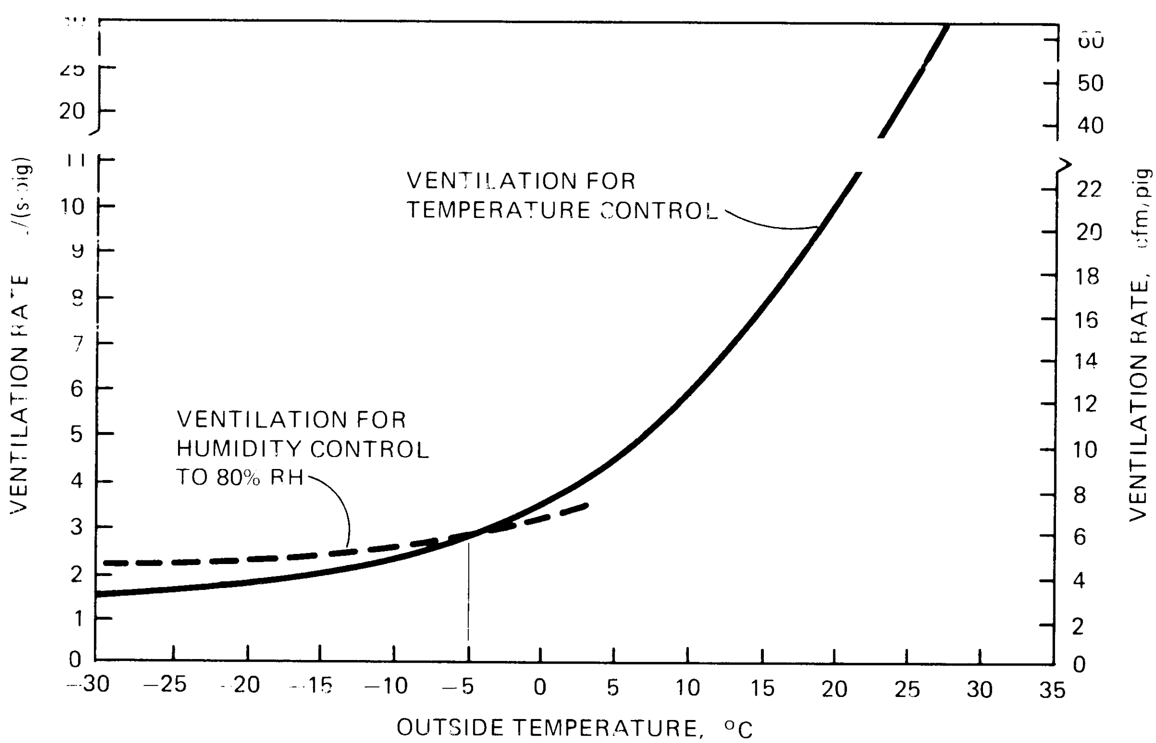



Figure 2 Ventilation rates calculated to control temperature and humidity for growing-finishing pigs weighing 20-95 kg, housed in a well-insulated barn with 30% of pen floors partly slotted

sized to ventilate continuously at 5/8 to 2/3 of the rate for humidity control, step 2 at double the step 1 rate and so on. Step 1 is set well below, but still over half of, the humidity control rate for cold weather. This is done so that the step 1 ventilating fan can maintain some ventilation even during the coldest periods. Then doubling to step 2 will slightly over-ventilate for intermittent, varying periods so that the average ventilation will control humidity. Plan M-9705 outlines this and other strategies for sizing and controlling ventilating fans.

Hot weather requires the highest ventilation. This is usually determined by the airflow needed (with all fans running) to limit the temperature rise to only 1-2°C above outdoors. When temperature outside passes the upper critical temperature of animals, it would be ideal to keep the barn temperature below that outside. However, with animals continuously adding heat, this is obviously impossible. In very hot weather it may feel cooler inside due to the building's shade and the rapid air movement, but properly-shaded thermometers will usually show some temperature rise unless refrigeration or evaporative cooling is added.

Except in very specific cases (like breeder bulls housed for artificial insemination), refrigeration is seldom economic. On the other hand, intermittent sprinkler cooling for growing and finishing pigs encourages the natural 'good housekeeping' habits of pigs in spite of hot weather. Evaporative pad cooling of the intake air is another option, but its value is marginal unless the outdoor air is initially quite dry.

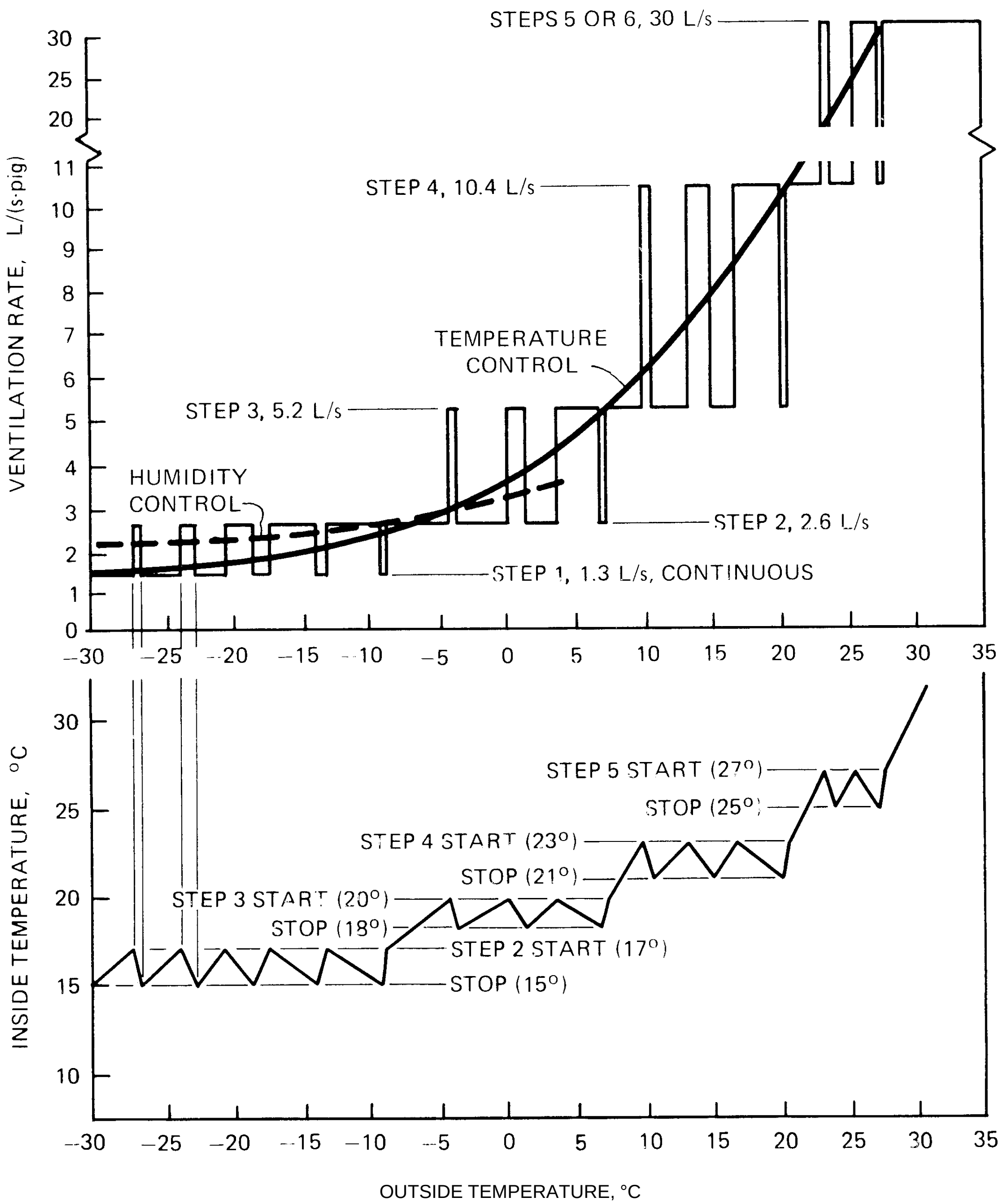
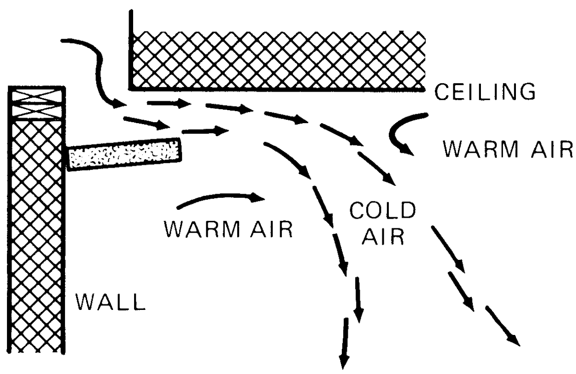



Figure 3 Stepped ventilation control diagram based on growing and finishing pigs, 20-95 kg liveweight, in a well-insulated swine barn with pen floors partly slotted

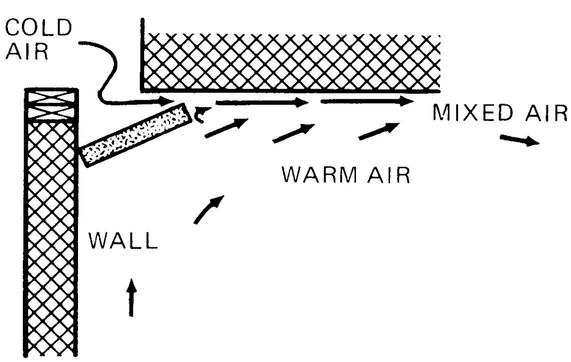
In the coastal provinces and other humid areas (Ontario and Quebec), hot weather is so often accompanied by high humidity that evaporative air cooling seldom improves animal comfort.

Table 1 gives recommended step 1 (winter) and maximum (summer) ventilation rates. These rates are based on heat and moisture production research, in some cases further adjusted to reflect the practical experience of livestock and poultry producers.

MINIMUM AND MAXIMUM AIR CHANGE RATES As stated above, an average winter ventilation rate obtained by alternating between 'step 1' and 'step 2'(step 1 doubled, from Table 1) is based on control of humidity. But with disease-susceptible livestock like baby calves and young weanling pigs, this may not be enough. Other air quality factors frequently require more winter ventilation. These factors include airborne disease organisms and manure gases (especially with liquid manure stored under the pens). Four room air changes per hour is suggested as a minimum ventilation rate, regardless of humidity control requirements. With densely housed animals like growing/finishing pigs and caged laying hens, the step 1 rate usually exceeds four air changes per hour anyway.




INLET OPEN TOO WIDE; LAZY STREAM OF COLD AIR SINKS TO FLOOR, CAUSING A DRAFT AND A COOL ZONE AT FLOOR LEVEL




INLET ADJUSTED CORRECTLY; HIGH-SPEED COLD AIR SWEEPS ACROSS THE CEILING, DRAWING AND MIXING WITH WARM AIR FROM BELOW

Figure 4 How the size of an air inlet slot affects the jet of cold air

Densely housed, sensitive livestock may also suffer from over-ventilation where the summer ventilation is based only on the number and size of the animals, regardless of the room volume. A practical maximum air exchange rate is 60 changes per hour (or one air change per minute) for these sensitive animals.

INLETS, FANS AND AIR PRESSURE

Up to this point, little mention has been made of the forces that move air for ventilation. With exhaust (or 'negative pressure') ventilation, fans pull air from the building so that the inside air pressure is slightly below the atmospheric pressure outside. Outside air then slips in through any openings, large or small, to try to equalize the different pressures.

For reasons that are more fully explained in Plan M9710, internal air circulation patterns are improved if air velocities through the inlets are kept in the range of 4 to 5 m/s (800-1000 ft; min) in winter. If cold air enters much slower than this, it will not have enough energy to mix with the air mass already inside the room. Recall Figure 1; 1 kg of the cold outside air occupies 700 L, but when warmed to match the temperature of the inside air, it expands to 820 L. In other words, cold air is considerably more dense than warm air. If allowed to trickle slowly into a warm room, it will immediately sink to the floor, where it will stay as a cool layer at the animal level. To prevent this, Figure 4 shows how the adjustment of a slot air inlet can affect the velocity of the incoming cold air and its resulting trajectory or 'throw'.

To maintain 4-5 m/s velocity, the inlets must be adjustable; a good rule is to adjust for 1 m2 of inlet area for each 5000 L/s of ventilation (or 1 ft2 inlet area for each 1000 cfm of ventilation). Recognizing that this requires inlet flap adjustments every time a thermostat calls for a change of ventilation, up or down, some type of automatic inlet offers important advantages. There are two types, electromechanical inlets and counter-weighted (gravity controlled) inlets. See plans M9710 and M-9715 for details of the counterweighted types.

Automatic inlets are not foolproof. Any 'accidental inlet' (such as a door left ajar) can let all the air into the room at one point; then the automatic inlet closes and most of the barn gets no ventilation. Furthermore, all types of automatic inlets can be fooled by wind effects - more about this in Plan M-9710.

STATIC PRESSURE The airspeed at the inlet slots is related to the drop in static pressure as air accelerates through the slot (Figure 5). The static pressure change is measured as the height of a water column in a glass or plastic tube, called a 'manometer'. In metric, the manometer is calibrated in pascals (Pa); in imperial it is calibrated in inches of water (1 in. water gauge = 250 Pa.).

calibrated in inches of water (1 in. water gauge = 250 Pa). In actual practice, the simple U-tube shown in Figure 5 is not sensitive enough at typical ventilation static pressures - an inclined-tube manometer (see plan M-9703) is better.

Figure 5 shows that to obtain the critical airspeed of 5 m/s (1000 ft/min) at the inlet slot, the static pressure must drop 15 Pa (0.06 in. wg). A simple inclined-tube manometer can be used to check inlet adjustments and to indirectly indicate if the critical winter airspeed of 5 m/s is being achieved at the inlets. In practice, the 'at-mospheric' tube of the manometer should be opened to the attic, not to an outside wall as Figure 5 shows. To avoid wind effects it would also be better to use the ventilated attic as a winter air inlet plenum.

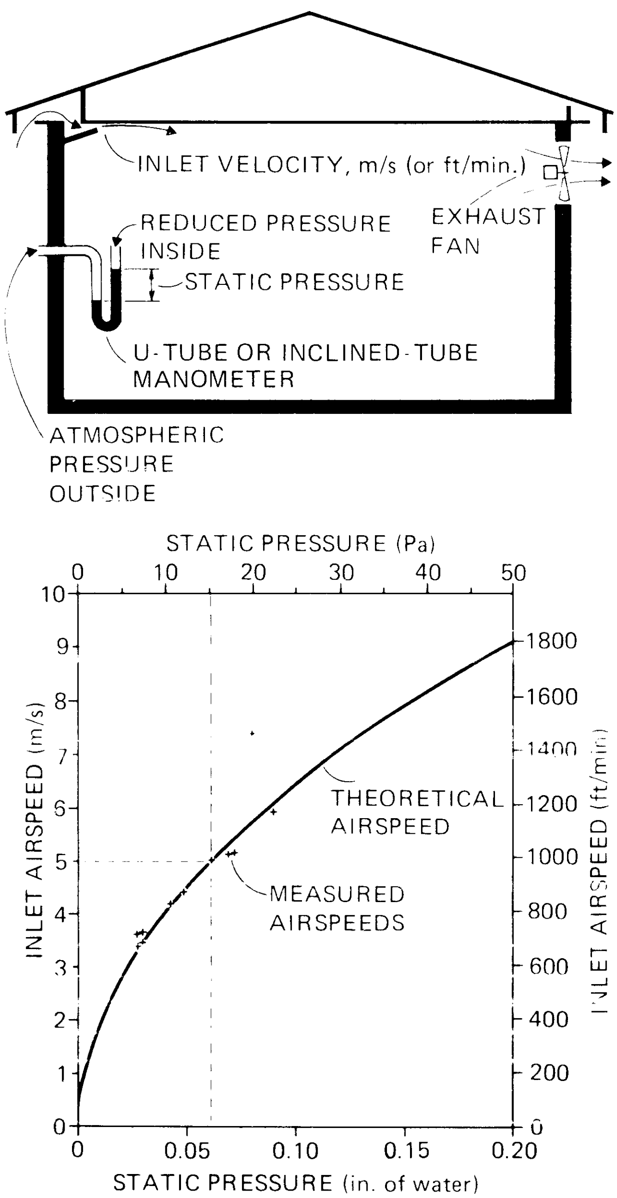



Figure 5 Static pressure and its relation to the air speed at the inlet slots

In practice it is often difficult to make a farm building tight enough to hold 15 Pa, especially at low winter ventilation rates. Another option is to 'boost' the incoming cold air jets by some forced recirculation of the room air - more about this in Plan M-9710, Fresh Air Inlets.

WIND EFFECTS Figure 6A shows the effects of a moderate 30 km/h wind, blowing against the exhaust fan side of a ventilated barn. Where this wind is stalled against the windward wall. 30 km/h converts to a static pressure of 32 Pa (0.13 in. water gauge). At the leeward wall where the inlets are, the same wind produces a suction of 22 Pa. In this example, the fan must work against a total static pressure of 22 (leeward wall) + 15 (inlet slots) + 32 (windward wall) = 69 Pa. Wind effects in this case have caused 77% of the work the fan must do to ventilate the barn. Furthermore, the wind pressure increases in proportion to windspeed squared. That is to say, if the windspeed is doubled, the pressure increases four times! Wind blowing against an unprotected wall fan can thus reduce or even stop all ventilation!

One could ask, why not put the fans in the leeward wall, away from the prevailing winds? The problem is that the leeward wall today often becomes the windward wall tomorrow.

Figure 6B shows the same barn, but the air inlet is changed to take air from the attic and the fan is protected with a wind hood. The attic is ventilated with a generous eave slot around all four sides so that the supply air static pressure is close to the average atmospheric pressure, thus almost eliminating wind effects on the inlet. These changes combine to give a big reduction of static pressure across the fan (in this case, 69 down to 25 Pa). More important, the ventilation rate and resulting barn environment will not be affected as much by the whims of wind and weather.

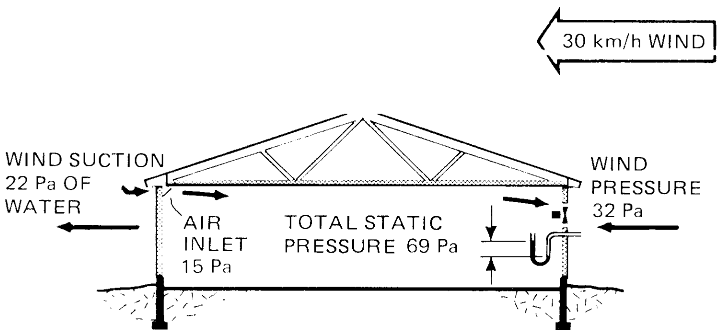
Design details for an improved fan weatherhood are given in plan M-9705.

WHY EXHAUST VENTILATION? Up to this point we have discussed only exhaust (or 'negative pressure') ventilation. Fans can be installed to either exhaust from or blow into a building. The latter is called 'positive pressure' ventilation, that is the room air pressure will be slightly above the average at-mospheric pressure outdoors. To obtain good distribution of the fresh air, the fan must connect to diffusers or an air duct that runs the length of the room. Positive pressure ventilation gives one minor advantage in that cracks under doors, etc. will not let in a cold draft. However, there are some important disadvantages:

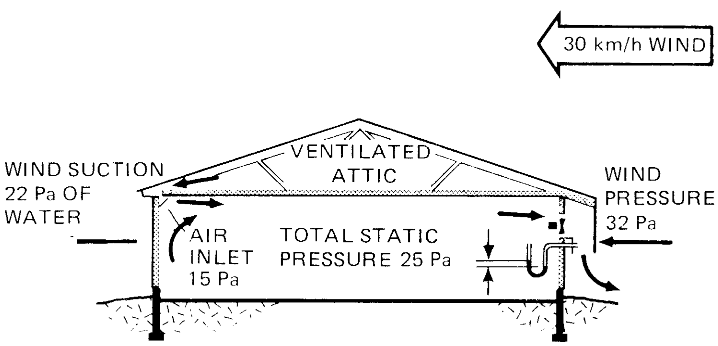
- air friction in the distribution duct requires extra fan power and uses extra electrical energy;
- distribution ducts must be large to handle the peak summer ventilation, or supplementary inlets are needed for summer;

- if the vapor barrier does not make a perfect seal, warm moist air can be forced into cracks and cold spaces in the walls and attic, causing damaging condensation
- contaminated air may be pushed into adjacent rooms making isolation of 'clean' areas difficult.

There are several commercial recirculating systems using fans on both intake and exhaust. Examples are Fristamat, Axis-Air and Aston. Some produce a neutral or slightly negative pressure while others produce a slightly positive pressure.




A No weatherhood on fan, air inlets exposed to wind




B Fan with weatherhood, winter air inlets from ventilated attic

Figure 6 Wind effects on a powered ventilation system

**TABLE 1 POWERED VENTILATION RATES FOR LIVESTOCK AND POULTRY (METRIC)**

| Type of livestock or poultry | Minimum temp., °C | Type of housing | Minimum (step 1) winter rate, L/ s per unit | Maximum summer rate, L/s per unit |
|---|---|---|---|---|
| DAIRY CATTLE | | | | |
| 450 kg cow | 2° | Conventional fall to spring stabling. Ventilation by windows or doors during summer. Walls insulated less than RSI 0.9 | 10-animal | 160/animal |
| 450 kg cow | 2° | Year-round housing. Windowless or non opening windows. Walls and ceilings insulated to at least RSI 1.8 | 12/animal | 190/animal |
| 450 kg cow | 5° | Milking parlor | 12/stall | 190/stall |
| | 5° | Milk room | - | 280/room |
| CALVES | | | | |
| Dairy replacements | 7° | | | |
| White veal | 20° | | | |
| Continuous housing: | | | | |
| 50 kg (1 mo.) average calf | | Year-round housing in well-insulated barn | [1]5/calf | 40/calf |
| 65 kg (2 mo.) average calf | | | [1]7.5/calf | 60/calf |
| All-in, all-out housing: 45 kg at start | | Year-round housing in well-insulated barn | [1]5/calf | 40/calf |
| 135 kg at finish | | | [1]10/calf | 80/calf |
| BEEF 450 kg cow | 2° | Ventilation by windows and doors during summer. Walls insulated less than RSI 0.9 | 10/animal | 160/animal |
| CHICKENS | | | | |
| Laying hens | 16° | Cages, high density | [2]0.14/hen | 2.9/hen |
| | 16° | Litter, up to 0.14 m2/bird | 0.19/hen | 3.3/hen |
| Heavy breeder hens | 16° | Litter or mesh floor | 0.19/hen | 3.6/hen |
| Replacement pullets | [3]32°-21° | 1 or 2 deck cages | 0.02-0.19/pullet | 2.4/pullet |
| Chicken broilers | [3]32°-21° | Litter, up to 0.09 m2/bird | 0.02-0.14/bird | 2.4/bird |

**TABLE 1 (CONT'D)**

| Type of livestock or poultry | Minimum temp., °C | Type of housing | Minimum (step 1) winter rate, L/s per unit | Maximum summer rate, L/s per unit |
|---|---|---|---|---|
| TURKEYS | | | | |
| Broilers, 0-14 wks | [3]35°-16° | Litter | 0.05-0.3/bird | 6.4/bird |
| Heavy broilers, 18-22 wks, 7-9 kg max. | 16° | Litter | 0.05-1.0/bird | 9-15/bird |
| Breeders (light to heavy breeds) | 16° | Litter | 0.5-1.0/bird | 8-14//bird |
| SWINE | | | | |
| Dry sow, 180 kg | 13° | Group pens | 3.0/sow | 96/sow |
| | 18° | Individual pens | 2.4/sow | 96/sow |
| Farrowing sow and litter | [4]18° | Farrowing pens | 7.0/sow | [5]144/sow |
| Weanling pig 7-25 kg | [3]27°-21° | All-in/all out housing | 0.4/pig | [5]16/pig |
| | 24° | Continuous housing | 0.7/pig | [5]12/pig |
| Grower, 25-60 kg | 21° | Partly slotted floor | 1.3/pig | [5]32/pig |
| Finisher, 60-100 kg | 15° | Partly slotted floor | 2.0/pig | [5]40/pig |
| Combined, 25-100 kg | 18° | Partly slotted floor | 1.6/pig | [5]35/pig |
| HORSES | | | | |
| 450 kg horse | 2° | Year-round insulated stabling, ventilated by windows and doors during summer | 10/horse | 80/horse |
| SHEEP | | | | |
| 45 kg ewe | 2° | Ventilated by windows and doors during summer. Walls insulated less than RSI 0.9 | 1.0/ewe | 8/ewe |
| RABBITS | | | | |
| Doe and litter | 12° | Cage housing, 14 kg liveweight/cage | 0.08/kg | 1.3/kg |
| | | Lower density | 0.06/kg | 0.96/kg |
| CHINCHILLAS | | Mature animals. Year-round, insulated housing, in cages | 0.05/animal | 1.6/animal |

1 This ventilation rate is considerably greater than that required to control humidity. It may have to be further increased if it does not give at least four room air changes per hour.

2 0.14 L/s applies where manure is removed weekly With deep pit manure storage, increase to 0.24 L/s and increase supplemental heating accordingly.

3 Start day-old chicks, poults and weanling pigs at the first temperature and gradually decrease temperature as they grow.

4 18"C is a comfortable room temperature for the sow, but newborn piglets need 29-30°C min. Provide a heated creep and gradually decrease creep temperature to 24°C as piglets grow.

5 Not over one air change per minute for sensitive stock

**TABLE 1 POWERED VENTILATION RATES FOR LIVESTOCK AND POULTRY (IMPERIAL)**

| Type of livestock or poultry | Minimum temp., °F | Type of housing | Minimum (step 1) winter rate, cfm per unit | Maximum summer rate, cfm per unit |
|---|---|---|---|---|
| DAIRY CATTLE | | | | |
| 1000 lb cow | 36° | Conventional fall to spring stabling. Ventilation by windows or doors during summer. Walls insulated less than R5 | 21/animal | 340/animal |
| 1000 lb cow | 36° | Year-round housing. Windowless or non opening windows. Walls and ceilings insulated to at least R 10 | 25/animal | 400/animal |
| 1000 lb cow | 36° | Milking parlor | 25/stall | 400/stall |
| | 41° | Milk room | - | 600/room |
| CALVES | | | | |
| Dairy replacements | 45° | | | |
| White veal | 68° | | | |
| Continuous housing: 110 lb (1 mo.) average calf | | Year-round housing in well-insulated barn | [1]10/calf | 85/calf |
| 140 lb (2 mo.) average calf | | | [1]16-calf | 127/calf |
| All-in, all-out housing: 95 lb at start | | Year-round housing in well-insulated barn | [1]10/calf | 85/calf |
| 300 lb at finish | | | [1]20/calf | 170/calf |
| BEEF | | | | |
| 1000 lb cow | | Ventilation by windows and doors during summer. Walls insulated less than R5 | 20/animal | 340/animal |
| CHICKENS | | | | |
| Laying hens | 64° | Cages, high density | 20.3/hen | 6/hen |
| | 60° | Litter, up to 1.5 ft2/bird | 0.4/hen | 7/hen |
| Heavy breeder hens | 60° | Litter or mesh floor | 0.4/hen | 7.6/hen |
| Replacement pullets | [3]90°-64° | 1 or 2 deck cages | 0.04-0.4/pullet | 5/pullet |
| Chicken broilers | [3]90°-64° | Litter, up to 1 ft2/bird | 0.04-0.3/bird | 5/bird |

**TABLE 1 (CONT'D)**

| Type of livestock or poultry | Minimum temp., °F | Type of housing | Minimum (step 1) winter rate, cfm per unit | Maximum summer rate, cfm per unit |
|---|---|---|---|---|
| TURKEYS | | | | |
| Broilers, 0-14 wks | [3]95°-60° | Litter | 0.1-0.6/bird | 14/bird |
| Heavy broilers, 18-22 wks, 7-9 kg max. | 60° | Litter | 1-2/bird | 19-32/bird |
| Breeders (light to heavy breeds) | 60° | Litter | 1-2/bird | 17-30/bird |
| SWINE | | | | |
| Dry sow | 55° | Group pens | 6.3/sow | 200/sow |
| | 65° | Individual pens | 5.1/sow | 200/sow |
| Farrowing sow and litter | [4]65° | Farrowing pens | 15/sow | [5]300/sow |
| Weanling pig 7-25 kg | [3]75°-65° | All-in/all out housing | 0.9/pig | [5]34/pig |
| | 75° | Continuous housing | 1.5/pig | 25/pig |
| Grower, 55-130 lb | 65° | Partly slotted floor | 2.7/pig | [5]68/pig |
| Finisher, 130-220 lb | 60° | Partly slotted floor | 4.2/pig | [5]85/pig |
| Combined, 55-2201b | 65° | Partly slotted floor | 3.4/pig | [5]74/pig |
| HORSES | | | | |
| 1000 lb horse | 35° | Year-round insulated stabling, ventilated by windows and doors during summer | 20/horse | 170/horse |
| SHEEP | | | | |
| 100 lb ewe | 35° | Ventilated by windows and doors during summer. Walls insulated less than R5 | 2/ewe | 171/ewe |
| RABBITS | | | | |
| Doe and litter | 54° | Cage housing, 30 lb liveweight/cage | 0.08/lb | 1.25/lb |
| | | Lower density | 0.06/lb | 0.9/lb |
| CHINCHILLAS | | Mature animals. Year-round, insulated housing, in cages | 0.1/animal | 3.4/animal |

1 This ventilation rate is considerably greater than that required to control humidity. It may have to be further increased if it does not give at least four room air changes per hour.

2 0.3 applies where manure is removed weekly. With deep it manure storage, increase to 0.5 and increase supplemental heating accordingly.

3 Start day-old chicks, poults and weanling pigs at the first temperature and gradually decrease temperature as they grow.

4 65°F is a comfortable room temperature for the sow, but newborn piglets need 84-86°F min. Provide a heated creep and gradually decrease creep temperature to 75°F as piglets grow.

5 Not over one air change per minute for sensitive stock