Winter performance of different air inlets in a warm naturally ventilated swine barn

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Choinière, Y., Blais, F., Munroe, J. A. and Leclerc, J.-M. 1989. **Winter performance of different air inlets in a warm naturally ventilated swine barn.** Can. Agric. Eng. **31**: 51–54. Air flow patterns and temperature distributions were determined under winter conditions in eastern Ontario in a warm naturally ventilated swine barn fitted with different types of sidewall openings. The building was originally built with rotating panels in the side walls. Material was then added in various configurations to these wall openings to simulate the vertical panel system, as well as windbreak panels. The vertical panel, as compared to the rotating doors, resulted in less temperature fluctuation in the animal area for both leeward and windward ventilation. The added windbreak improved performance in minimizing temperature fluctuations.

INTRODUCTION

Many types of air inlets and control systems are used for naturally ventilated warm buildings; however, their performances with regard to temperature control have not been evaluated. Jedele (1979) reported a gable roof, naturally ventilated barn for finishing hogs which had a manual adjustment for the ridge and an automatic and manual adjustment for solid vertical panels on both sidewalls. Inside temperatures ranging from 0°C to 18°C were noted during winter conditions (Illinois, U.S.A.). Large temperature fluctuations were also noted in swine finishing barns by Bird and De Brabandere (1981), MacDonald et al. (1985) and Choinière (1985). Choinière noted that the major portion of the air was entering at the lowest part of the inlet which was only 1.2 m above the floor. This may have had an effect on the low temperatures observed at pig level.

Milne (1983) emphasized the effect of the wind on the ventilation patterns and the necessity of opening only the leeward doors during cold weather. The concept of partial windbreaks observed by Turnbull (1984) was presented as a possible solution to wind direction changes and temperature regulation problems.

For naturally ventilated warm swine buildings, Choinière (1985) recommended a study of different air inlet configurations to visualize the air flow patterns and temperature regulation in relation to changing weather conditions. He recommended studying the above-center-pivot rotating doors and a simulation of vertical panels with and without an added windbreak.

For warm naturally ventilated barns, the rotating door is the most popular inlet structure. It is insulated, weather resistant, has a clean appearance, and is easy to adjust by manual or thermostatic control. An adjustable vertical panel such as a plastic curtain may be suitable for beef, dairy cattle, sheep and goats. The associated greater inlet height above floor level could be advantageous for winter conditions but still provide a large total opening for warm weather. Simple windbreaks in front of these openings may help to control drafts during winter caused by strong winds and changing wind directions.

Comfort zone for finishing pigs

According to Curtis (1983), an animal could survive and grow in a variety of temperature zones. The optimal range of temperature for animal growth is called the "thermal comfort zone". This zone is somewhat above the lower critical temperature (LCT), but below the upper critical temperature (UCT). For this study the "optimal" zone for 40-kg finishing hogs was considered to be between 17 and 19°C, the "warm" zone to be between 19 and 25°C, the "cool" zone to be between 15 and 17°C, and the "cold" or discomfort zone to be below 15°C. These considerations were based on work by De La Farge (1981), Yousef (1985), and Curtis (1983).

Curtis (1983) also stated the importance of ventilation patterns and temperature control in relation to animal activities such as eating, drinking, dunging and sleeping. A natural ventilation system should be able to establish comfort zones where pigs could sleep without excessive temperature fluctuations.

OBJECTIVES

The objective of this study was to monitor a naturally ventilated hog barn and compare the performance of various types of inlets under winter conditions. Inlet types included the following:

1. Above-center-pivot rotating doors;
2. Simulated adjustable vertical panel;
3. Simulated adjustable vertical panel with the addition of a simple windbreak.

Evaluation of performance was based on:

1. Visualization of interior airflow patterns;
2. Determination of comfort zones based on isothermal contours;
3. Comparison of the effect of windward and leeward openings on temperature profiles.

METHODS AND PROCEDURES

Barn description

Tests were performed during the winter of 1985–1986 in a naturally ventilated hog barn owned by Albert de Wit, R.R. no. 4, Spencerville, Ontario. This barn was an addition to a mechanically ventilated barn. The facility was 23.0 m long, 10.8 m wide and 4.35 m high at the ridge with a north-south orientation. Use of scissor trusses provided a sloping ceiling. Adjacent buildings were mainly to the north of this barn; thus, there was minimum interference from the prevailing westerly winds. Each side of the barn had nine 900 × 2100-mm above-center-pivot rotating doors. These doors were controlled by a modulated automatic control system based on thermostats as described by Choinière et al. (1987). A total of 315 finishing hogs averaging 80 kg were in this barn during the tests.

Instrumentation

The airflow patterns were visualized using Dräger air current tubes (smoke), and recorded on video tape.

As shown in Fig. 1, 20 type T thermocouples were used to determine the temperature distribution of a cross-section at the center of the barn. A weather station outside the barn provided exterior temperature, relative humidity, wind speed (at 10 m height) and direction. All sensors were read every 10 s over a 1-h period and recorded using a Kaye Digistrip II data logger connected to an IBM-PC. The data were then transferred to "Lotus 1-2-3" (commercial computer software) to compute the average temperature and standard deviation for each thermocouple location. These data were then processed by "MacDrain", a commercial computer software program described by Tremblay (1987), that prepares contour lines from drainage survey data. In this case, the results were isothermal lines and lines of equal standard deviation.

A hot wire anemometer was used to measure air speeds inside the barn.

Air inlets

Since the barn was already equipped with above-center-pivot rotating doors, it was possible to simulate vertical panels by adding a plastic curtain over the outside of the rotating doors to effectively close off the bottom opening. Finally, 300-mm windbreaks were suspended from the eaves 150 mm out from the wall. A 100-mm space was left between the top of the windbreak and the eave to allow fresh air circulation to the attic. These inlet configurations are shown in Fig. 2.

For all tests, the ridge opening was manually adjusted to 20–30 mm wide.

Testing procedure

For leeward ventilation, tests for each air inlet configuration were carried out on each of three different days, one at −5°C and two at −15°C. Test duration was 1 h for each inlet followed by approximately 1 h to change the inlet configuration and allow the barn conditions to stabilize. Thus, a total of 6 h was needed to complete one series of tests. For windward ventilation, tests were carried out on two different days, one at −5°C and the other at −10°C. Tests with the added windbreak were not performed at the −5°C temperature because of problems on site. In all cases, days were selected when wind direction was perpendicular to building length and wind speed (10-m height) was in the 3–5 m/s range.

RESULTS AND DISCUSSION

Airflow patterns

Figure 3 shows the airflow patterns observed for the different types of air inlet. Each air inlet had somewhat different effects on the airflow pattern on the inlet half of the barn, while the patterns in the other half of the barn remained essentially the same. The patterns for any given inlet were quite similar for both leeward and windward ventilation, as well as for the different outside temperatures tested.

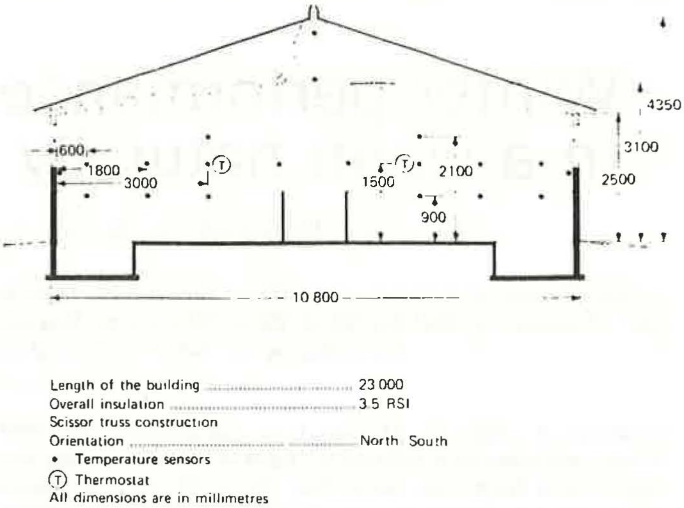

Figure 1. Cross-section of barn showing temperature sensor locations.

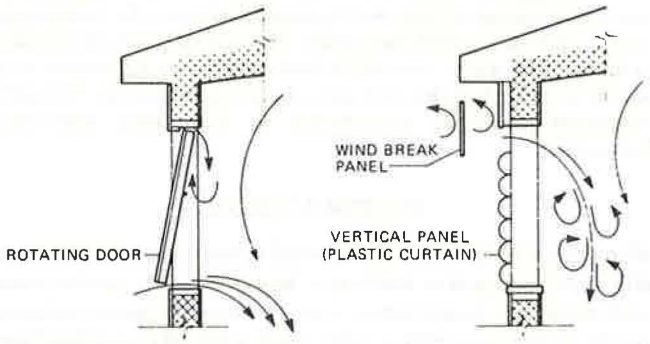

Figure 2. Air inlet configurations.

The incoming air spread over the slotted floor, warmed up, and started to rise about 3 m from the sidewall before reaching the solid pen fronts. Some air rotated back to the inlet, and some crossed the solid pen front to reach the opposite side. Finally, all the air exhausted at the ridge opening. Air movement was generally slow. No air speeds over 0.2 m/s were recorded inside the barn except near the inlets.

With the rotating doors, cold air entered mostly at the bottom. A small quantity of air moved in or out at the top of the doors according to wind changes.

With the vertical panel, air entered at a greater height resulting in a narrower turbulent region along the wall surface. Although not measured, use of smoke indicated lower velocities along the floor as compared to results with the rotating doors. The addition of the windbreak created more turbulence close to the outside wall and, based on smoke tests, appeared to produce lower velocities at floor level especially for windward ventilation.

Temperature profiles — leeward inlets

Figure 4 shows the different temperature zones and fluctuations produced using leeward inlets. As temperature and temperature fluctuation patterns were similar for the different outside temperatures tested, only the results for $T_0 = -5°C$ are shown.

There were few differences in temperature profiles resulting from the three types of inlets tested. All exhibited a cool zone over the floor on the leeward side, while the windward side of the building was in the optimal and warm temperature ranges.

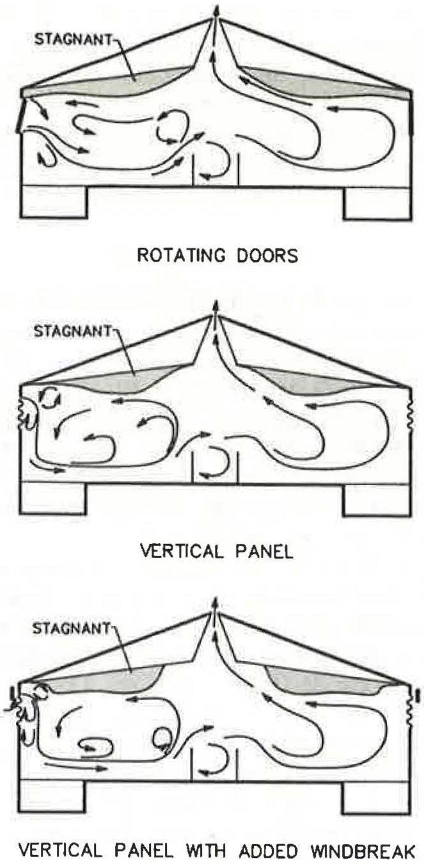

Figure 3. Air flow patterns for different inlets open on only one side of the barn.

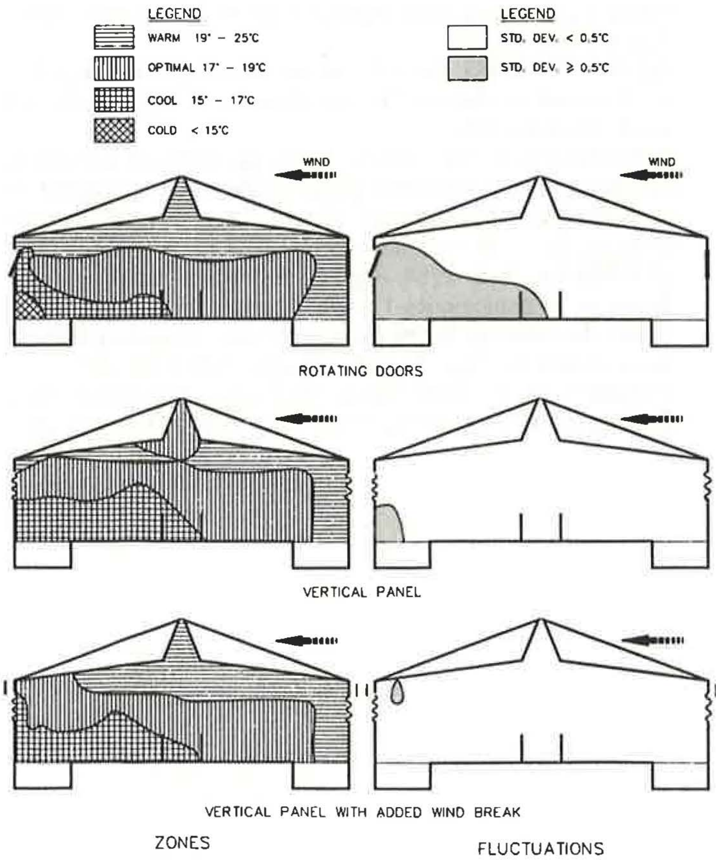

Figure 4. Temperature zones and fluctuations for leeward ventilation ($T_o = -5°C$).

The height of the air inlet above the floor appeared to have a large effect on temperature regulation.

With the simulated vertical panel the unstable zone (temperature standard deviation >0.5°C) was restricted to the region above the leeward slotted floor. With the addition of the windbreak, no cold zones were evident. Also, there were no unstable zones in the solid floor (sleeping) areas of the pens.

Temperature profiles — windward inlets

Tests with inlets on the windward side of the barn were not carried out on the same day as those for leeward inlets; however, we attempted to select a time that had similar weather conditions (outside temperature, windspeed). Figure 5 shows temperature profiles obtained with the rotating door and vertical panel inlets. Due to the wind pressure, it was difficult to control drafts and restrict incoming air. With the rotating door inlet, much of the windward pen area was in the cold zone and unstable. With the vertical panel, the size of the unstable zone was considerably reduced. This could be due to the increased height of the inlet above the floor. Due to weather conditions, complete tests for windward inlets using a vertical panel with added windbreak were not carried out; however, we did note that the addition of the windbreak appeared to improve temperature regulation significantly. The windbreak appeared to reduce the throw of the incoming air jet by increasing the turbulence immediately inside the barn.

Air flow patterns versus temperature profiles

The airflow patterns observed serve to corroborate the temperature profiles.

In general, the temperature gradients followed the flow of air from the inlet to the exhaust. In comparing the airflow patterns and the temperature profiles, the zones of turbulence coincide with the unstable temperature zones. The zones of slow recirculation, generally result in stable temperatures.

Animal behavior versus temperature profiles

Leonard and McQuitty (1985) reported that the "air flow pattern may promote a cool area for dunging and a warmer area for sleeping". From Figs. 4 and 5 it is noted that the dunging area below the air inlet was the coolest area in the barn, but on the opposite side the dunging area was always warmer than the sleeping area. Pigs throughout the barn appeared very clean, thus the statement of De La Farge (1981) may be more appropriate: "a pig is able to become acclimatized to very different climatological conditions as long as these conditions are permanent". Animals would develop good manuring habits as long as the ventilation system could provide reasonably stable temperatures over the sleeping area.

SUMMARY AND CONCLUSIONS

Airflow patterns and temperature profiles were observed to evaluate the performance of three different types of air inlets during cold weather. Temperature profiles of windward and leeward ventilation are presented. The tested air inlet designs were:

- above-center-pivot rotating doors;
- simulation of a vertical panel (plastic curtain); and
- simulation of a vertical panel with the addition of a simple windbreak.

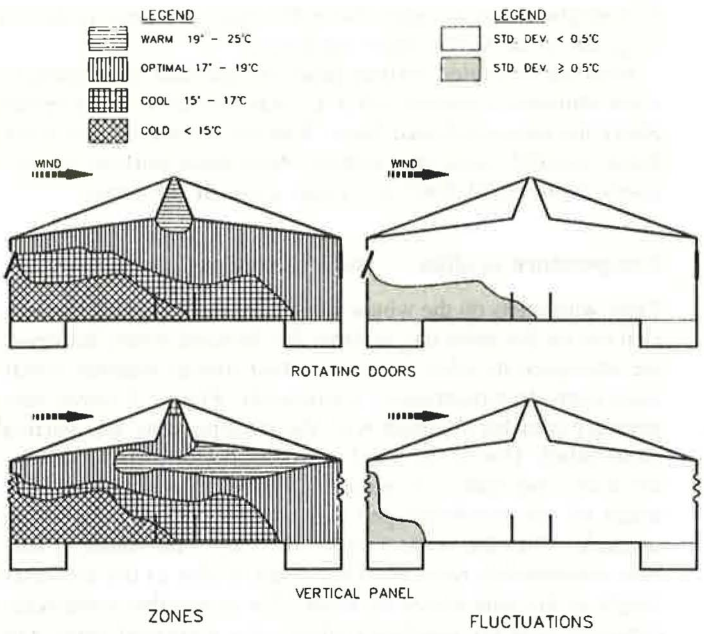

Figure 5. Temperature zones for windward ventilation ($T_0 = -5°C$).

The results showed the following:

1. The rotating door design produced the largest unstable temperature zone (standard deviation > 0.5°C). It also produced the largest cool and cold zones for leeward and windward ventilation. The air speed at pig level was higher than with the other types of inlets.
2. The vertical panel reduced the unstable temperature zone for both the leeward and windward ventilation more than the rotating door inlet.
3. The addition of windbreaks further reduced the size of the unstable temperature zones and also reduced air speed at animal level.

The natural ventilation systems tested provided a reasonably stable temperature control over the sleeping area as indicated by the cleanliness of the pigs even though the slotted dunging area might be cooler or warmer than the comfort zone.

Turbulent zones noted in the air pattern tests coincided with zones of greater temperature fluctuation.

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