Thermostat location for a naturally ventilated swine barn

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Choinière, Y., Munroe, J.A., Ménard, O. and Blais, F. 1990 **Thermostat location for a naturally ventilated swine barn.** Can. Agric. Eng. 33:169-177. A preferred location for thermostats in an automatically controlled naturally ventilated barn was determined based on the ability to establish comfort zones for the animals and to minimize the effect of wind direction and exterior temperature. Thermostats located at 0.9 m above the floor, 3.0 m from the outside walls, at midlength of the barn provided adequate environmental control under all conditions studied.

Pour une étable porcine ventileé naturellement, le système de contrôle de la ventilation doit réagir aux conditions météorologiques variables tels la direction des vents et la température extérieure. Dans le but de maintenir un interval de confort thermal pour les porcs à l'engraissement, divers emplacements des thermostats furent évaluée selon leurs aptitudes à obtenir un contrôle optimum de la température intérieure. Les résultats démontrent que l'emplacement idéal des thermostats est à la mi-longueur de la porcherie. Chaque thermostat doit être à 0.9 m au-dessus du plancher et distancé de 3.0 m des murs extérieures.

INTRODUCTION

Thermostat location can affect the performance of natural as well as mechanical ventilation systems. Many recommendations have been made regarding locations for thermostats for mechanical ventilation systems but very few recommendations exist for natural ventilation systems.

According to the Ontario Ministry of Agriculture and Food ventilation manual (Huffman 1984), the recommended thermostat location should be as close as practical to the livestock living space, but not near a warm ceiling, or a cold wall, and not exposed to sunlight. "They should be in the normal air flow of the barn, near the animals and in an area where they can be easily read, adjusted and kept clean".

The purposes of a thermostat control system are to: provide a comfort zone over the sleeping area; and to minimize temperature fluctuations in the animal space regardless of the variability of outside temperature and wind.

During the falls of 1986 and 1987, data were collected to establish the preferred thermostat locations along and across an Automatically Controlled Natural Ventilation (ACNV) building for growing-finishing hogs.

LITERATURE REVIEW

Variables involved

Several variables affect temperature control inside a naturally ventilated building. Hellickson et al. (1983), Bird (1984), and Milne (1984) classified some variables such as wind direction and speed and exterior temperature as being uncontrollable. The type of building, its orientation, interior layout, type of air inlets and outlets, and related animal management factors are controllable variables; these should be chosen to give the best possible environmental conditions in the barn.

Barrie (1986) stated that weather conditions have direct effects on the temperature zones along and across the barn. For isothermal conditions, Ogilvie and Boyd (1985) stated that wind direction is the dominant influence on interior three dimensional airflow patterns. Strom (1987), Mitchell and Ross (1977), and Choinière et al. (1988) studied isothermal two dimensional air flow patterns for a cross section of a gable roofed naturally ventilated barn. In another study Choinière et al. (1989) reported the differences in airflow patterns between isothermal and non-isothermal conditions.

Thermostat location for ACNV

Bird (1984) recommended that thermostats be located halfway along the barn, close to the sets of ventilation doors they control, and 1.5 m above the floor.

Anon (1984), Spackman et al. (1983), and Strom and Morsing (1984) reported the capability of an ACNV system to maintain indoor temperature between 15 and 20°C in cold weather. Barns studied had thermostats centrally located in the room (centre alley layout) between 1.5 and 1.8 m above the floor.

In Ontario, MacDonald et al. (1985) found 7-10°C temperature gradients across and along an ACNV barn at an outside temperature of -10°C. Here only one thermostat, located in the middle of the room, was used to control the sidewall openings. Similar temperature fluctuations were observed by Borg and Huminicki (1986) for the cold weather conditions of the Canadian Prairies.

Barrie (1986) studied an ACNV finishing barn where the thermostats were centrally located in the room at 2.6 m above the floor. He recommended adjusting the thermostats to 17°C in order to obtain a target temperature of 14°C at floor level. He also noted vertical and horizontal temperature gradients in the barn which varied with wind speed and direction.

Owen (1984) described a controller which could accommodate several temperature sensors. It was anticipated that this controller would reduce temperature gradients in the barn since its action was based on the average temperature of several locations. It should also be less affected by other factors such as empty pens. He also discussed the importance of a time delay between temperature readings by the controller in order to reduce the frequency of door adjustments.

During the winter of 1984-85 Choinière (1985) evaluated a non-modulated natural ventilation system where the thermostats were 2.1 m above the floor at the mid-length of the barn. Large temperature fluctuations were noted at floor level while the temperatures at 2.1 m were quite stable. Based on observations of the air flow patterns and temperature profiles, he recommended that thermostats be located on both sides of the barn 3.0 m from the wall, and that they should be located 0.9 m above the floor for outside temperatures below 0°C, and 1.5 m above the floor for outside air temperature above 0°C. These were locations experiencing large temperature fluctuations.

Prediction of air flow patterns and temperature zones

DeBruyckere and Neuckermans (1968) discussed the relation of temperature profiles to airflow velocities and patterns and stated that such information was essential for the development of a control strategy for barn ventilation.

Comfort zone for finishing pigs

According to Curtis (1983), an animal can survive and grow in a variety of temperature zones. The optimal temperature range 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 purpose of this study was to determine a preferred thermostat location in an ACNV growing-finishing hog barn in order to provide a comfort zone over the sleeping area. The effects of wind direction and outside temperature on thermostat location were also to be considered.

The performance of the temperature control system could be evaluated by assessing temperature profiles and fluctuations, while air flow patterns could be used to qualitatively indicate air velocity distributions.

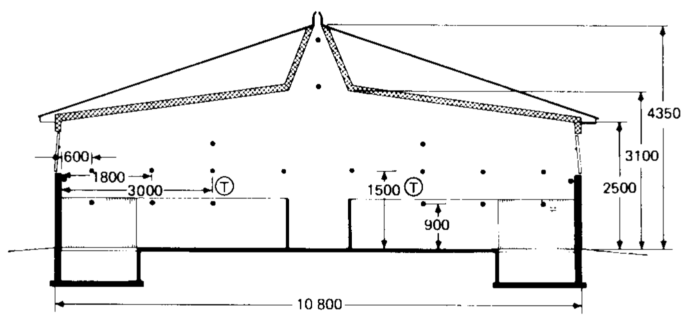
TEST PROCEDURES AND INSTRUMENTATION

The monitored barn was a 10.8 x 23.0 m naturally ventilated, growing-finishing barn (Fig. 1) owned by A. de Wit of Spencerville, Ontario.

The barn had a centre alley between two rows of 2.4 x 4.8 m pens. The pens had solid wall partitions except over the slatted area, and solid pen fronts.

The barn was oriented north-south and attached at the north end to a mechanically ventilated barn with matching roof and wall planes. A continuous ridge outlet was manually adjustable. The barn was equipped with an automatic modulated control system consisting of two thermostats, time delays, and gear motor driven actuators that opened or closed the rotating ventilation doors in the side walls.

An adjustable timer activated the control sensor, in this case the thermostats, periodically (for example, every three minutes), which in turn activated a gear motor to open or close the ventilation doors. An adjustable time delay controlled the length of time that the gear motor was energized after being activated (for example 3 seconds). This allowed the doors to move in increments of about 20 to 30 mm, thus modulating the operation of the system. The thermostats had a dead band of about 2°C. This commercially available modulated system was distributed by Faromor Inc., Waterloo, Ontario.



Length of the building .... 23 000 mm
No. of ventilation doors 17
Overall insulation .... 3.6 RSI
Scissor truss construction
Orientation .... North - South
Date of construction 1982
• Temperature sensors (T - type thermocouples)
(T) Thermostat, 0.9 or 1.5 m above floor
All dimensions are in millimetres

Fig. 1. Central cross section of barn showing thermocouple locations.

Location of the thermostats

Following the recommendation of Bird (1984) and Choinière (1985), the thermostats were located midway along the barn and 3.0 m from the outside walls. Also recommended was the use of separate thermostats to control the inlet doors on each side of the barn. Two thermostat elevations (0.9 and 1.5 m above the floor) were used for different test periods. The thermostats were carefully adjusted to the same temperature. When thermostats were located at the 0.9 m height, they were protected from the hogs by an electric shocker system similar to that used for cattle.

Wind direction

Figure 2 shows the orientation of the barn. There was no wind interference on the south and the west sides of the barn whereas some buildings were located to the north and east.

Outside temperatures

Three outside temperature ranges were selected to represent isothermal, intermediate and cold conditions. They were respectively above 18°C, between +5°C and +18°C, and between -5°C and +5°C. There were no comparative data available for colder temperatures.

During this study, wind speed and direction were continuously monitored. For comparison purposes, test periods were chosen when wind speeds were similar.

Test periods and instrumentation

The building was monitored continuously from October 1986 to January 1987 and from September 1987 to November 1987. Thermostats were installed at 0.9 m and 1.5 m heights alternatively on a weekly basis. During the experiment, the continuous ridge outlet had an opening width of 20 mm. This is equivalent to an opening area of 0.4 m^2 for the whole barn.

As indicated in Fig. 1, 20 thermocouples were used to sense temperatures over the central cross section of the barn. This profile indicates the general thermal behavior of the barn. An additional 22 thermocouples were located along the barn at 0.9 m above the floor (Fig. 2). A weather station next to the barn monitored exterior temperature, relative humidity, wind speed and direction. While testing, all readings were taken at intervals of 10 seconds, but averaged over a 10-minute period. A land drainage program, Macdrain (Kok and Tremblay 1988), was used to plot isothermal contours from the data.

Air flow patterns were observed using air current smoke tubes.

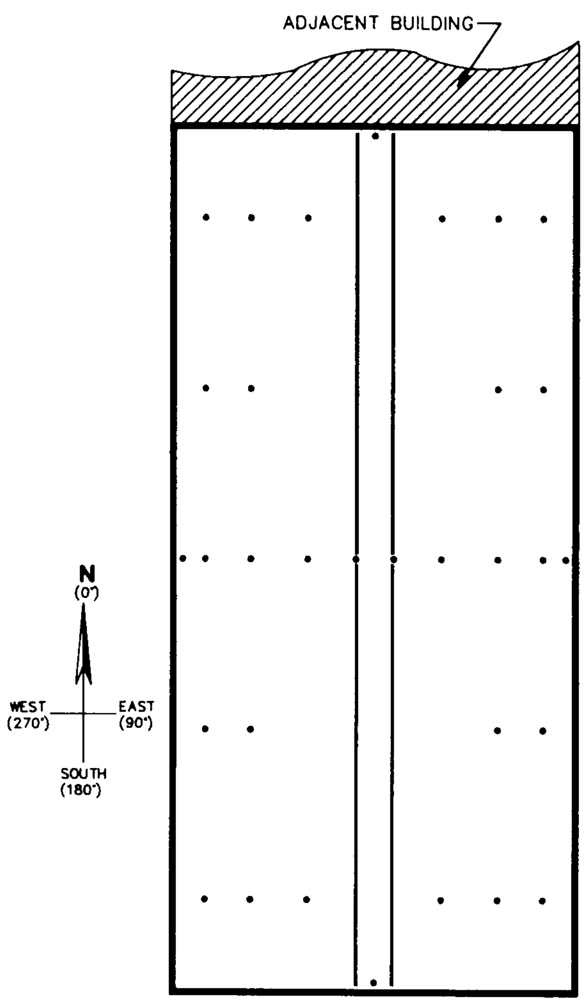


Fig. 2. Plan view of barn showing thermocouple locations and building orientation.

RESULTS AND DISCUSSION

Thermostat adjustment

Thermostats on both sides of the barn were adjusted to within ± 0.5°C of each other. Inspection of Figs. 3 to 7 shows that the fluctuation of temperature at either thermostat was small. As well, the small difference in temperature between thermostat locations indicates that quite precise adjustment of the thermostats was achieved.

Previous observations by the authors had shown that unequal adjustment of the thermostats caused the doors on one side of the barn to open more than on the other; this in turn aggravated temperature gradients and fluctuations.

Effect of outside temperatures

Isothermal conditions ($T_o > 18^oC$). These conditions occur during warm weather when outside temperatures approach inside temperature. For these conditions, the thermostat location had no influence on the temperature control but rather the quality of the ventilation relied on the adequacy of the air inlet and outlet design. The inside temperature was never more than 2°C above the outside temperature for the three isothermal tests. The temperature was fairly uniform across the building. Slightly warmer zones were sometimes observed close to the walls and close to the alley partitions. These zones have been previously identified as stagnant zones by Choinière et al. (1988).

Intermediate conditions ($5^o < T_o < 18^o$). With cooler outside temperatures, the required ventilation rates decreased, causing the air inlet doors to partially close. Also, the incoming air jets tended to fall rather than to complete a totally developed isothermal airflow pattern. Barber et al. (1982), Randall (1975), Timmons et al. (1986), and Leonard and McQuitty (1986) described these phenomena by considering the differences in relative densities and the lack of momentum of the air jets. Close to the main incoming air streams temperature fluctuations were greater at the ceiling than at the floor.

A distance 3 to 4 meters from the outside walls corresponded to where the air jets were falling from the ceiling. The highest temperature fluctuations occurred along the outside walls, diminishing toward the centre of the barn. The present locations of the thermostats, at 3.0 m from the walls were adequate to maintain desired temperatures over the sleeping area.

Cold conditions ($-5^o < T_o < 5^o C$). As shown by Choinière et al. (1989), for outside temperatures below 0 to 5°C, the airflow patterns indicated that the incoming air fell close to the outside walls. The ridge opening acted as the main outlet. Thermostats as located were able to provide adequate environmental conditions over the sleeping area of the pens.

Wind direction and building orientation

Ogilvie and Boyd (1985) reported that the wind effect dominates over the stack effect for wind speed over 2.0 m/s and a 10°C inside-outside temperature difference. Figure 3 demonstrates that the wind direction was a significant factor

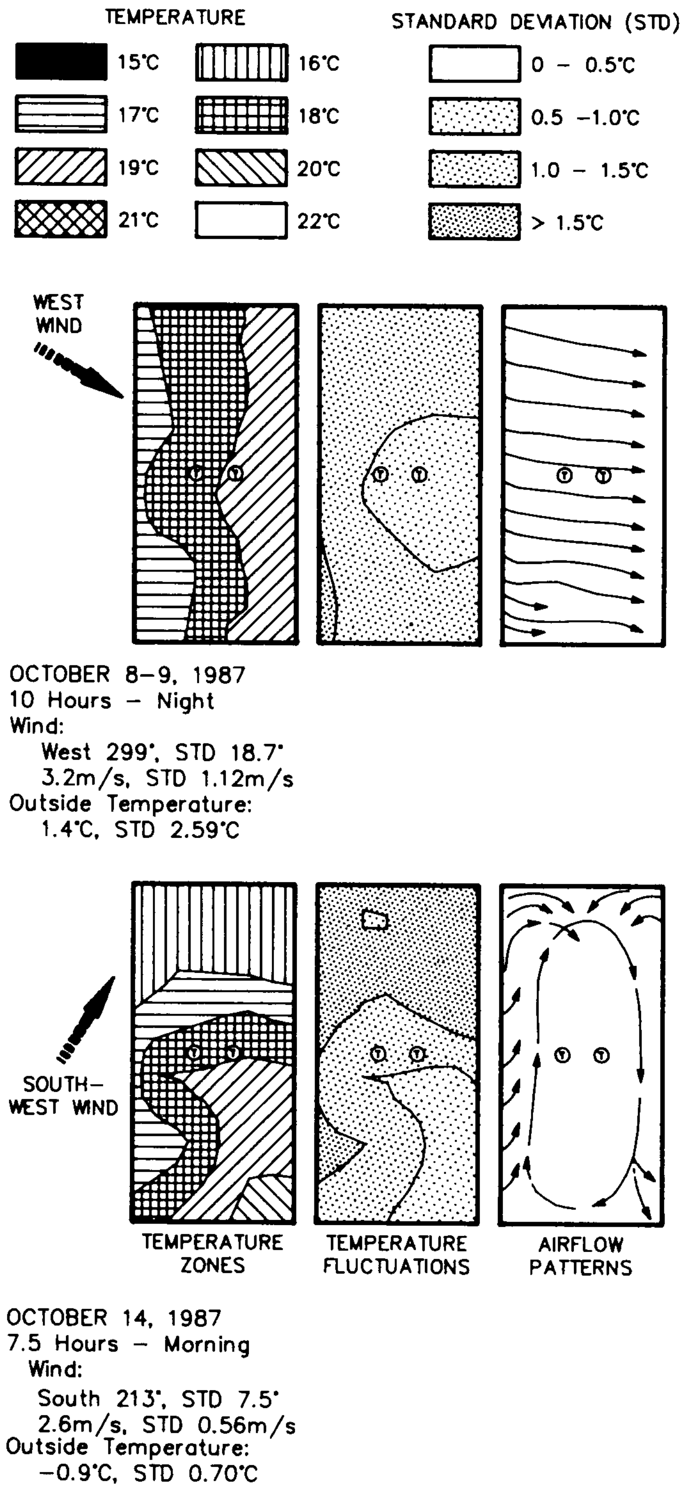


Fig. 3. Plan view of temperature fluctuations and air flow patterns: thermostats at 0.9 m height.

influencing the temperature distribution along a naturally ventilated building. For wind perpendicular to the building length, temperature profiles across the barn would be expected to remain uniform along the building length, but for other wind directions, these profiles could vary.

Wind from the southwest created a high external negative pressure zone on the ventilation doors in the southeast part of the barn. The ridge outlet was also influenced by wind direction. The south end of the ridge (high negative pressure) was the main outlet. Hellickson et al. (1983) reported that winds perpendicular to the building length exerted a rather uniform pressure along the windward side of the building.

For westerly winds, the location of the thermostat along the building was not critical. With southerly winds, the central location of the thermostats was satisfactory even though the temperature fluctuations at the north end were greater compared to those obtained with west winds (Fig. 3). No data are presently available for the combination of colder temperatures and south winds (a rare combination at this site).

Results (Figs. 4 to 7) show that the wind direction (west versus south) actually had limited influence on the temperature profiles across the midlength of the barn. For both wind directions and the three outside temperatures studied, the thermostat controller was able to maintain a comfort zone over the sleeping area. But generally higher temperature fluctuations occurred with south winds as compared to with west winds. During cold weather, temperature fluctuations over the sleeping area in the order of 2.6°C occurred with south winds compared to 1.4°C with west winds. No data were obtained for such a comparison during very cold outside temperatures.

To optimize cold weather performance, it is recommended that a naturally ventilated building be oriented perpendicular to prevailing winds, if they can be identified for the site. No data are presently available to verify if these recommendations also hold for warm weather conditions.

Comparison of Figs. 4 to 7 show that both thermostat eleva-

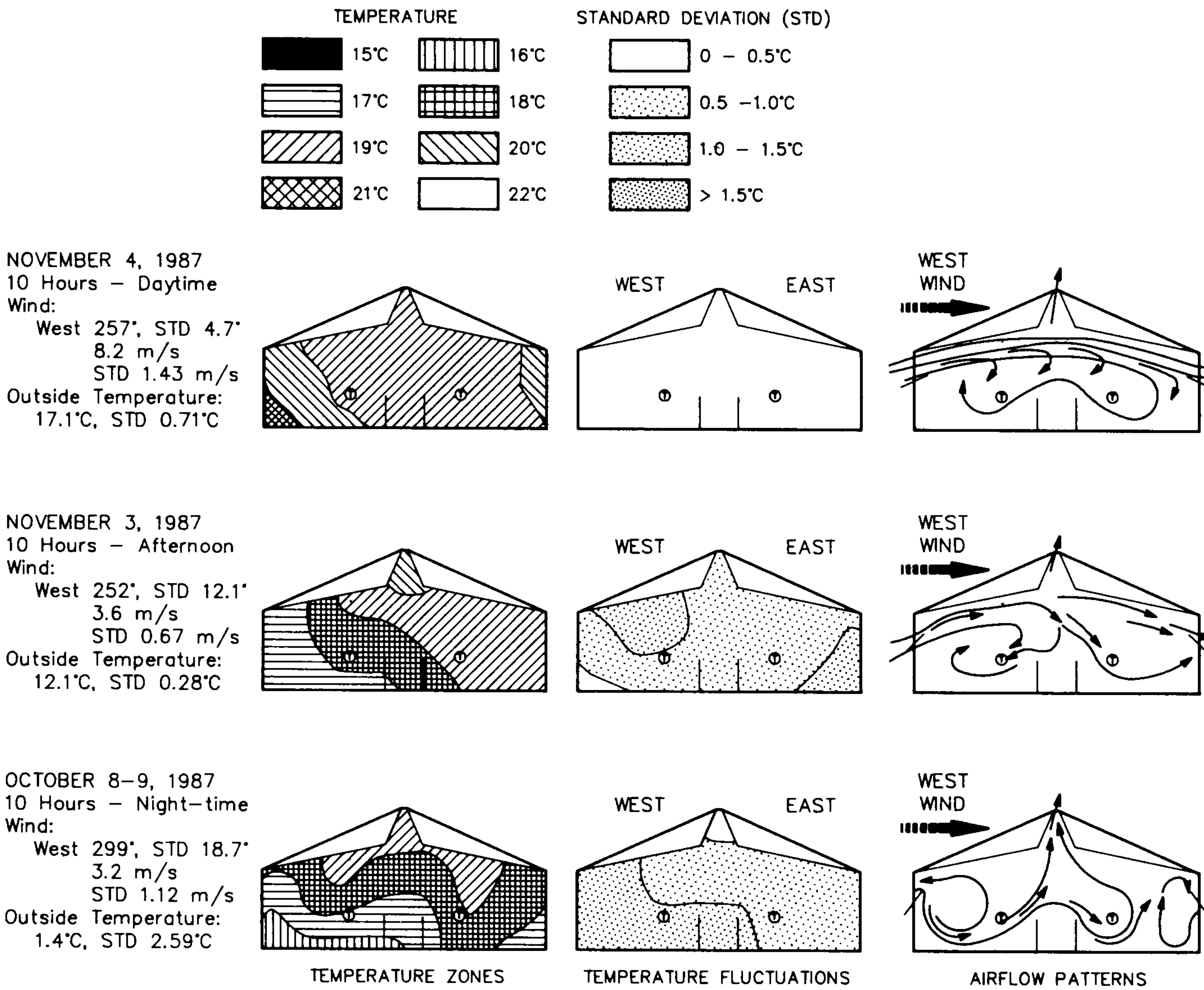


Fig. 4. Temperature zones, temperature fluctuations and air flow patterns: west wind, thermostats at 0.9 m height.

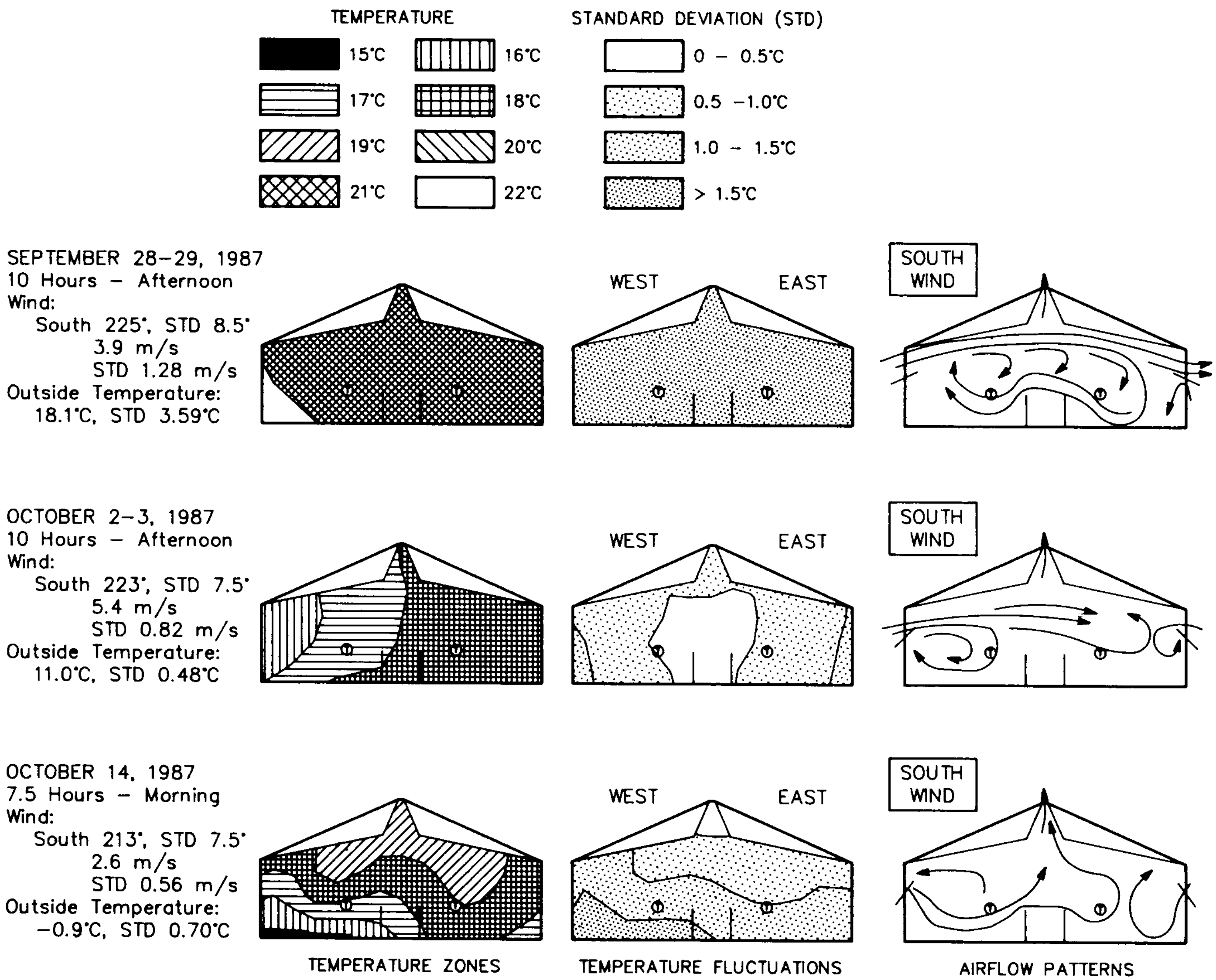


Fig. 5 . Temperature zones, temperature fluctuations and air flow patterns: south wind, thermostats at 0.9 m height.

tions, 0.9 and 1.5 m, maintain adequate temperature levels over the sleeping area. For intermediate and especially cold conditions, temperature fluctuations in this area were generally greater when the thermostat was at the 1.5 m height.

On this basis the 0.9 m height would be preferred over the 1.5 m height; however at this location, it must be protected from physical damage by the hogs.

No data were available for thermostat elevations less than 0.9 m. A lower location might provide some benefit in control of temperature fluctuations but could also be subject to misleading readings due to the proximity of the hogs.

Multi-zone control systems

The use of a multi-temperature sensor system as proposed by Owen (1984) would not solve the problem of the longitudinal temperature gradient associated with wind not perpendicular to the building, but might help to reduce the temperature fluctuations at the downwind end.

CONCLUSIONS

The longitudinal location of the thermostats should be at the midlength of the building in order to minimize temperature variations along the building. This was true for all exterior temperatures and all wind directions measured. For the weather conditions studied, thermostats located 3.0 m from the outside walls provided comfort zones over most of the sleeping area. Temperature fluctuations were less for a thermostat elevation of 0.9 m as compared to 1.5 m.

CONCLUSION

Pour toutes les températures extérieures et directions du vents considérées, les thermostats doivent être situés à la mi-longueur du bâtiment pour réduire les variations de

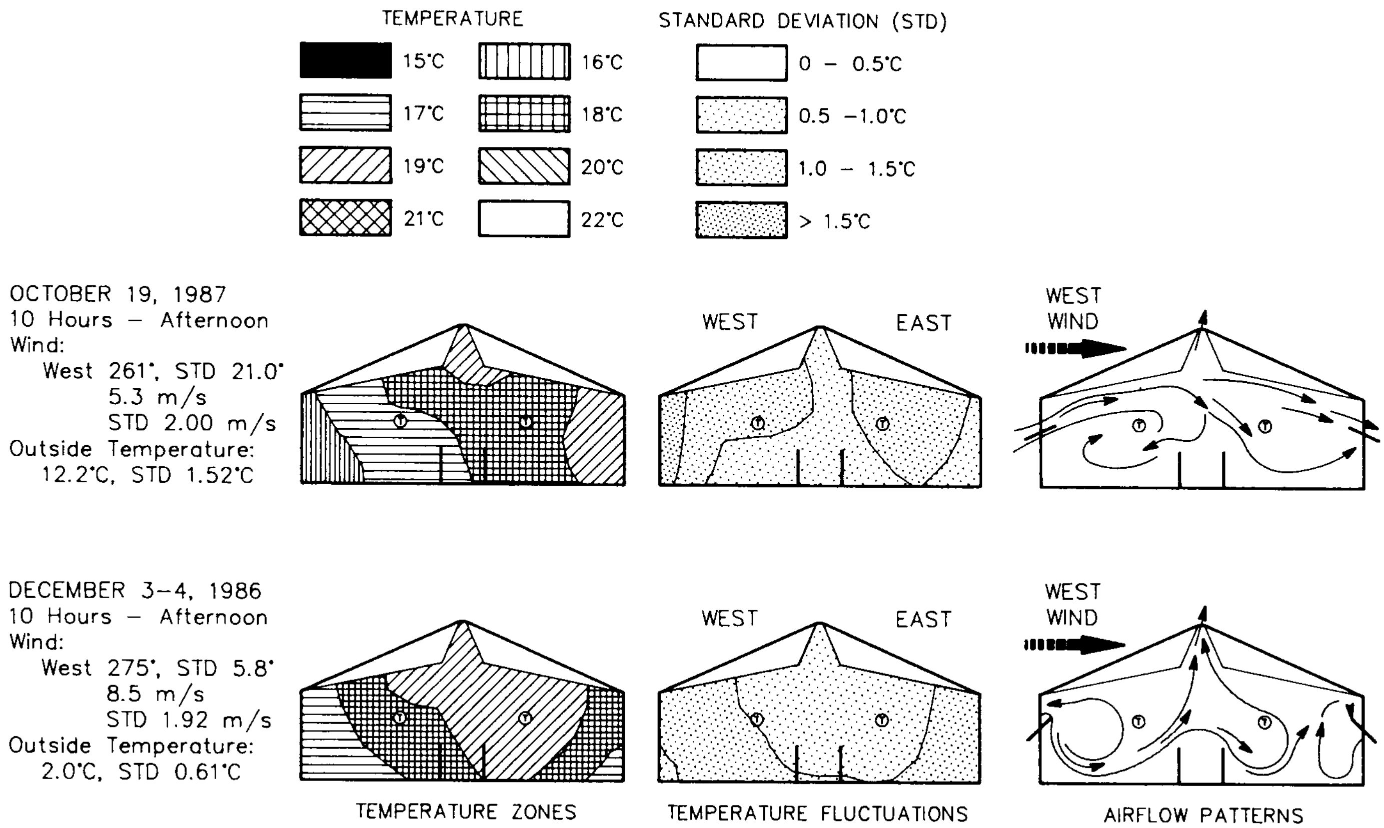


Fig. 6 . Temperature zones, temperature fluctuations and air flow patterns: west wind, thermostats at 1.5 m height.

températures d'un bout à l'autre du bâtiment. Pour les conditions météorologiques considérées, les thermostats situé à 3.0 m des murs extérieurs ont maintenu des zones de confort thermal au-dessus de la plus grande partie des régions-dortoirs dans les enclos. Les fluctuations de température furent moindres pour une élévation du thermostat de 0.9 m comparativement à 1.5 m.

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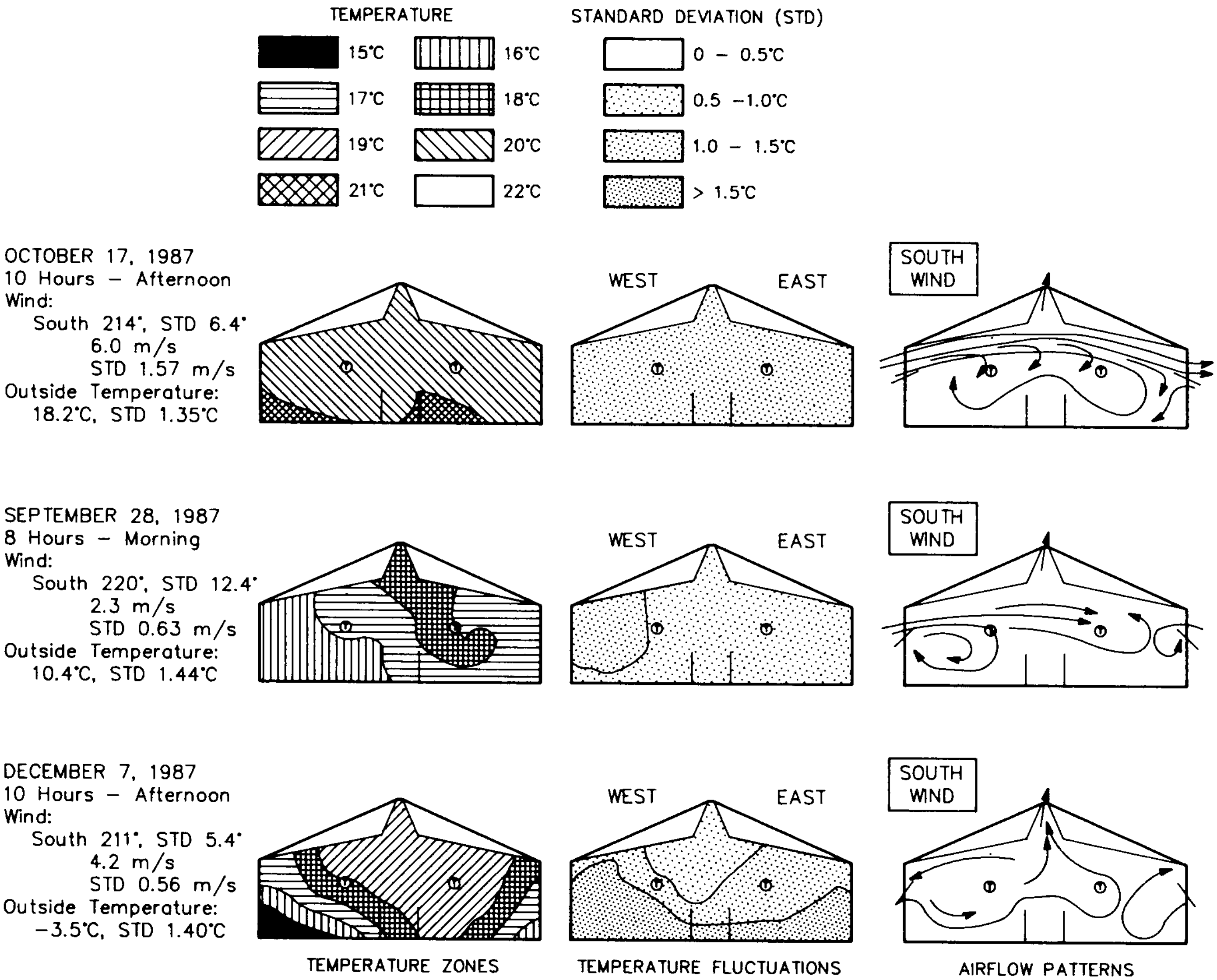

Fig. 7. Temperature zones, temperature fluctuations and air flow patterns: south wind, thermostats at 1.5 m height.

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