RESEARCH ABSTRACT

ANIMAL SCIENCE

Title: Ventilation improvements for controlling swine production systems**, NPB # 13-213**

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Introduction: Mechanical ventilation systems are used extensively in swine production facilities to control the inside environment. Good quality indoor air is a necessity for animal health and for maximizing productivity. Continuous release of sensible and latent heat, CO_2 from animals, and NH_3 and H_2S released from manure, are some of the major sources of inside air contamination. Ventilation forces outside air through the barn, which dilutes and removes indoor air contaminates (ASHRAE, 2013). In the mechanical ventilation process, air enters into the barn simultaneously through planned openings and unplanned leakage points. Unplanned air entry into a room (i.e., infiltration) is an integral part of any ventilation process. Zhang and Barber (1995b) summarized infiltration air entering a barn in three categories: 1) Interflow - "contaminated" air from an adjacent interior room leaks into the building, 2) Inflow – outside fresh air leaks into the barn, and 3) Short-circuiting – outside fresh air leaks into the barn from the envelope openings around the exhaust fans and exits through fan without mixing with inside air.

Infiltration negatively affects ventilation control and effectiveness. High infiltration rates reduce the effectiveness of the ventilation air and is an indicator of potentially poor design and/or construction (Jadhav et al., 2015). Zhang and Barber (1995b) highlighted the negative effects of air leakage; 'interflow' reduces air quality; 'inflow' may be the common source of drafts and increase winter heating costs, and 'short-circuiting' causes a reduction in ventilation effectiveness. All three types of infiltration potentially affect the controllability and performance of planned inlets as infiltration reduces the quantity of air coming into the barn through designed and planned inlets. Infiltration develops pockets of non-uniform and undesired environments in a barn (Masse et al., 1994b) and in winter can develop cold drafts around/nearby cracks. Albright (1990) highlighted that air infiltration directly affects air mixing and its distribution. More infiltration from one section of the building compared to low infiltration from another affects the uniform distribution of fresh air in the barn. ASAE standard EP270.5 also cautions that negative pressure ventilation systems may get affected easily due to wind effects and air leaks and may not provide acceptable air distribution at low air flow rates. Air leakage has also been identified as one of the important reasons for the deterioration of building components (Zhang and Barber, 1995a) especially for positive pressure ventilation systems. Water condensation on interior claddings and water accumulation in the ceiling and walls are other ill-effects of infiltration. Water condensation can affect animal comfort and health; whereas, water accumulation can reduce the building durability and energy efficiency.

Masse et al. (1994a) summarized the available methods and tests to determine building air leakage. Along with pressurization methods, tracer gas, acoustic, and thermographic surveys are methods used to determine the leakage rate. The ASHRAE "crack method" has also been used for leakage prediction (ASHRAE, 2013). Albright (1990) questioned ASHRAE's crack method of infiltration quantification and stated that this method has not proved accurate for agricultural structures and suggested the development of methods specific for agricultural structures. During minimum cold-weather ventilation, Munroe (1988) recommended a pressure difference of 15 Pa (0.06 inches water column; in wc) or greater across the planned inlet system to ensure proper fresh air distribution. Zhang and Barber (1995a) stated that ventilation systems for animal barns are operated at a low pressure difference, usually less than 25 Pa (0.10 in wc) and animal barn leakage characteristics at low pressures are more important in ventilation system design than those at high pressure differences. Therefore, precise data on infiltration is very important in the design of animal barn ventilation systems. To increase the effectiveness of a ventilation system, Zhang and Barber (1995a) recommended using air infiltration at 20 Pa (0.08 in wc) when designing ventilation systems for animal barns.

Many researchers commented on the lack of sufficient data on infiltration of agricultural barns (Albright, 1990; Zhang and Barber 1995a, 1995b). Using the pressurization method, Zhang and Barber (1995a) measured and modeled the leakage rates of five new grow/finish swine rooms built for research purposes. Data on the infiltration rate of commonly constructed swine finishing rooms as affected by their age, construction layout, and construction material are missing. A general data set on infiltration of swine finishing rooms that could readily be used in the design of ventilation systems is needed. In the present study, 19 swine finishing rooms were tested for their leakage potential using the pressurization method – an alternate to ASHRAE's crack method. Numerous methods are available for quantification of air infiltration into a building including pressurization, tracer gas, acoustic, and thermographic survey (Masse et al., 1994a). Among all tests, the tracer gas and pressurization methods are most common (Masse et al., 1994b). The pressurization method is relatively easy, quick, inexpensive, and less weather dependent as compared to the tracer gas method (ASHRAE, 2013). The most common method uses pressurization testing (ASHRAE, 2013 and Masse et al., 1994b). Shaw and Tamura (1980), Kronvall (1978), and Hunt (1978) all adopted the pressurization method to measure leakage through buildings.

For a ventilation system to function properly, the major system components, including fans, planned inlets, controllers, and the building itself, must work in harmony. This research project focused on the path fresh-air must take from outside to inside the building. Our swine production ventilation systems, unless filtered for virus control, are negative pressure where fans pull air out of the barn, creating a slight vacuum inside the barn relative to outside thus allowing fresh outside air to enter the barn *through any opening, planned or otherwise*. Ideally, all of the fresh-air that gets pulled into a building should travel to and through planned inlets. The reality however is that a significant amount of this fresh-air is being pulled through unwanted cracks and leakage points throughout the building shell. Curtains, for example, have been installed and used in their current configuration for decades with little or no regard to the seal-ability of this potentially high-leakage area, especially with the low static pressure differences associated with wean-to-finish buildings. Back-draft shutters have been used for years but over time these components warp and crack, losing the ability to reduce back-drafting into the animal occupied zone. Ventilation engineers need to account for infiltration but currently the very best available information for barn leakage rates is from a study conducted over 60 years ago from *two dairy barns* (Millier, 1950). These leakage rates in turn can drastically affect the performance of any ventilation system during the heating season where air distribution suffers from excessive leakage area compromising the performance of the designed and planned fresh-air inlet system. The end result is that fans require a given amount of air and this same amount of air must enter into the barn. If significant enough, unplanned leakage locations can satisfy most all of the inlet area required, rendering the planned inlet system inoperable. This can cause drafts on pigs which impacts effective temperature and acts as a stressor which may create opportunities for disease. It may also impact propane usage and dunging patterns within pens, potentially creating a wet environment which can also act as a stressor. This research project was intended to quantify the extent of infiltration through careful in-field evaluation of barn leakage rates and locations, with follow-up construction techniques to significantly reduce these rates in new and existing barns.

The PI and Co-PI for this research have been involved in swine production system design for a combined 50 years. Problems that existed 25 years ago are still prevalent today requiring a dedicated and focused effort to resolve these building design and climate control flaws and provide recommendations for retrofitting existing buildings. The PI studied (Hoff, 2001) curtain material properties and leakage rates of curtains in a controlled laboratory setting. This research concluded that, assuming no obvious curtain tears, the vast majority of curtain leakage air was entering through improper sealing and overlap at the opening and not through the curtain material itself (unless the curtain was designed and marketed as breathable). From this research, recommendations have been made for specific curtain overlaps and maintenance there-of. These changes are simple and cost effective and more importantly allow the designed fresh-air inlet system to function closer to intended design conditions. Significantly more effort however needs to be placed on in-field whole barn