Wide-Body Dairy Housing Barns

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For the last several decades, common freestall barn configurations have been two, three, four, and six rows of stalls. As herd sizes have grown, these barns have become much longer while the widths have remained essentially the same other than a few additional feet added here and there base on improving cow stall use and feed access. Experience has shown that many naturally ventilated barns experience shortcomings, especially if they are located on a site that is not well exposed to consistent summertime air movement. As a result, the concept of tunnel-ventilating barns was adopted from the swine and poultry industries over 10 years ago and adjusted to meet the needs of dairy facilities.

Tunnel-ventilated barns that provide 1,000 cfm per cow of air exchange in the summer months provide excellent barn air quality in the northeast. However, as I have noted in the past, providing high air speeds at cow stall level is difficult to achieve with tunnel ventilation. Lateral baffles suspended from the ceiling have little effect on airflow at cow stall level. A tunnel ventilation system designed to provide 600 fpm of average air speed results in 250 to 350 fpm of air speed at cow level, short of what is recommend by about 300 fpm.

The factors that influence barn size and layout of the past are ever so present today. Cow housing systems need to be affordably priced, comfortable and healthy for cows to live in, efficient for operators and caretakers to work in, durable, and overall provide a favorable return on investment.

A few upper Midwest dairy producers have looked to maximize all these factors and in doing so decided that building wider, and comparatively shorter cow housing systems should be tried. Most are 8-row wide configurations, as shown in Figure 1, but we visited one under construction that was 22-rows and over 500 ft. wide! Barns with more than 6 rows of freestalls I'm calling wide-body barns.

Wide-body barns utilize pre-engineered steel structural systems with a 0.5:12 roof slope. They are mechanically ventilated year-round using the same type of fans as employed in tunnel-ventilated barns. Fans are located along one longitudinal sidewall as shown in Figure 2. The ventilation air inlet is located on the opposite sidewall. Some wide-body barns use evaporative cooling pads to cool ventilation air as it enters the barn. The under side of the roof cladding is covered with spray-on insulation.

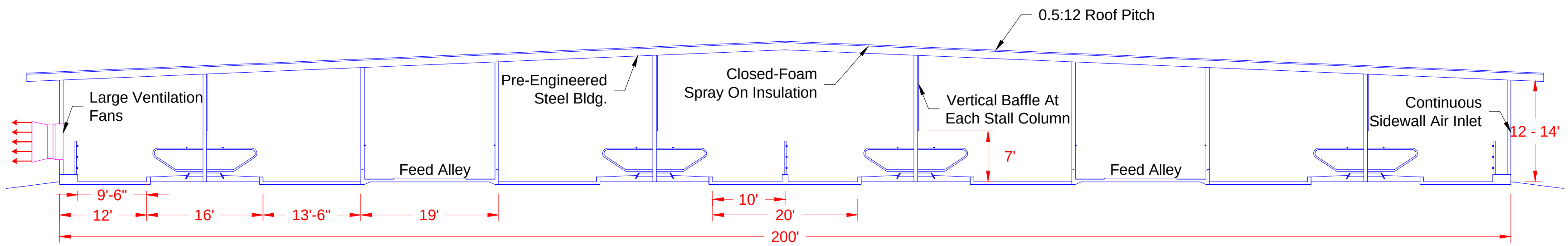

Figure 1. Head-to-head 8-row wide-span freestall barn.


Figure 2. Exhaust fans for a wide-span freestall barn.

Let's explore some of the key and unique factors of wide-body barns.

Ventilation

The goal of any dairy cow barn's ventilation system is to provide ample amounts of fresh air and evenly distribute it through the barn year-round without causing a drafty condition during cold temperatures. Mechanically cross ventilating a 200-wide barn during the summer presents no concern from a technical standpoint. Data collected from a 620-ft long tunnel-ventilated freestall barn during hot weather shows that summer air quality is excellent when 1,000 cfm of in-place fan capacity per cow is provided. Spot data taken during a visit to two wide-body barns on a 90F plus degree day reinforced the position that summertime ventilation is not a problem.

However, at this point, concern does exist for the non-summer weather conditions. Ventilation needs are less in the fall, winter, and spring so fewer fans need to operate. The lower air exchange rates may result in poor air quality across wide-body barns; continuous barn air quality monitoring is needed to better understand the ventilation system performance during non-summer periods. One Midwest producer indicated that he turns fans on and off (during non-summer months) based the odor level present in the barn and was happy with this management approach after one winter.

Like with tunnel-ventilated barns, the ventilation system for cross-ventilated wide-body barns can included a cow cooling component by providing significant air speed at cow level. Research has shown that an air speed of 500 to 600 fpm is an effective component of an overall heat stress mitigation system. The upper Midwest wide-body barns have baffles installed on some of the intermediate structural columns so a 7-ft high opening is created at strategic locations. Baffles are best located above each row of head-to-head stalls as shown in Figure 1.

As a working example of a cross-the-barn ventilation system, let's consider an 8-row wide-body barn for 1,500 cows with dimensions of 200-ft wide, 750-ft long and a 14-ft high eave. The minimum in-place fan capacity from a ventilation standpoint is 1.5M cfm (Vent 1) while the in-place fan capacity to create 600 fpm of air speed under the baffle (Vent 2) is 3.135M as shown in Table 1.

Insulation

As previously mentioned, spray-on foam insulation is continuously applied to the bottom side of the metal roof. The type and composition of the spray on material can vary. It appears that some of the materials used may be sufficiently combustible that either insurance companies will not insure buildings were it has been applied or insurance premiums are increased accordingly. One New York State insulation contractor indicated the retail price for a closed-foam sprayed-on insulation applied to a contractor prepared surface is $1.10 per board foot of material applied; he also added that volume discounts would apply for jobs as large as a wide-body barn.

For our working example barn, the application surface covered is 149,375 sq. ft. and without volume discounts, the capital cost for a 2" thick application is $328,625, and the estimated total annual cost is $55,162 based on a 7-year useful life (actual life may be longer).

Table 1. Barn ventilation system (Vent 1 = providing 1,000 cfm per cow and Vent 2 = providing an air speed of 600 fpm under a 7 ft. high baffle opening) and associated estimated annual electrical costs for various weather conditions and total annual economic costs for a 8-row wide-body barn with 1,500 cows.

<table>
<tr><th></th><th></th><th colspan="2">Barn Air Exchange, cfm (No. Fans Operating[2])</th><th colspan="2">Estimated Electrical Cost[3] ,$</th><th colspan="2">Est. Total Annual Cost[4], $</th></tr>
<tr><th>Ambient Temp.</th><th>No. Days per Year[1]</th><th>Vent 1</th><th>Vent 2</th><th>Vent 1</th><th>Vent 2</th><th>Vent 1</th><th>Vent 2</th></tr>
<tr><td>Hot</td><td>150</td><td>1,500,000 (45)</td><td>3,135,000 (95)</td><td>32,890</td><td>69,436</td><td>48,485</td><td>102,360</td></tr>
<tr><td>Mild</td><td>80</td><td>1,188,000 (36)</td><td>1,188,000 (36)</td><td>14,033</td><td>14,033</td><td rowspan="3">70,850</td><td rowspan="3">124,725</td></tr>
<tr><td>Transition</td><td>90</td><td>495,000 (15)</td><td>495,000 (15)</td><td>6,578</td><td>6,578</td></tr>
<tr><td>Cold</td><td>45</td><td>264,000 (8)</td><td>264,000 (8)</td><td>1,754</td><td>1,754</td></tr>
</table>

[1]For Central New York State
[2]Based on 33,000 cfm per fan
[3]Based on a fan efficiency = 16.5 cfm per Watt and electric cost = $0.10/kWh
[4]For fan system only

Costs
We were told that wide-body barns built in the upper Midwest are $250 per stall cheaper than traditional 4- or 6-row barns representing a cost savings of $250,000 per 1,000 cows. Reduced site grading and building shell costs were the two major items noted to contribute towards the substantial savings. This level of cost savings has not been able to be duplicated New York State to date based on estimates performed.

The estimated electrical cost to run the ventilation system for each weather condition is shown in Table 1 for designs based on air exchange per cow (Vent 1) and for 600 fpm of air velocity under the baffles (Vent 2). The annual estimated electrical cost for each system is $55,255 and $91,801, respectively.

The estimated total annual cost (all cost associated with owning and operating the ventilation system except interest on barrowed money) is $70,850 and $124,725 for Vent 1 and Vent 2, respectively. The table's gray shaded box values can be used to compare the total annual cost for this system (hot weather component) to a tunnel ventilation system for 1,500 cows. Assuming, for comparative purposes, two 4-row tunnel-ventilated barns are used to house a total of 1,500 cows, the estimated total annual cost for the two tunnel-ventilation systems would be $49,560 (Vent 1) and $53,872 (Vent 2). This analysis shows one historical reason cross ventilating barns at high air speeds received little attention.

The estimated total annual costs for the two wide-body across-the-barn ventilation design schemes and the spray-on foam insulation is $126,012 (Vent 1) and $179,8887 (Vent 2) or $84 and $120 per cow, respectively.

Evaporative Cooling
Evaporative cooling is the process of using a heat source to evaporate applied water consequently reducing the temperature of the heat source. In the northeast, an average temperature drop of 8 to 10F can be expected during the heat-of-the-day and less during morning and evening hours. Evaporative pads are generally turned off from mid evening to early morning hours.

Evaporative pads are widely used to cool ventilation inlet air for swine and poultry facilities but less so at this time for dairy barns. The comparatively high summertime air exchange rates for dairy cows require more evaporative pad space than needed for other species. This has been a drawback to extensive use of evaporative cooling pads located on the inlet endwall of tunnel-ventilated barns.

Mr. Nevin Wagner, a sales engineer for AeroTech, A Munters Company, suggests the target air speed through their evaporative pad be about 375 fpm in order to keep the static pressure differential across the pad at 0.05 inches of water. The retail cost for their evaporative pad system is $12 to $14 per sq. ft., depending on the height of the system. For our wide-body example barn, the evaporative pad surface area needed is 4,000 sq. ft. (Vent 1) and 8,360 sq. ft. (Vent 2) resulting in an initial capital cost of $52,000 and 108,680, respectively (based on using an average unit cost of $13 per sq. ft. for the evaporative pad). If the pad covers the full length of the barn, the theoretical required height is 5.3 ft and 11.1 ft, respectively. The actual height will depend on the pad sizes available from the manufacturer.

A temperature drop of 13F was measured across one of the North Dakota wide-body barn's evaporative cooling pads. Evaporative cooling does result in increased ventilation air humidity; over a 20 point rise across the pad was measured at the same barn.

Labor Efficiency

Just like long 6-row freestall barns over multiple smaller barns, a wide-body barn provides opportunity for increased labor efficiency over multiple smaller barns.

Closing Thoughts

Wide-body freestall barns are yet another option to consider when building facilities for a large number of cows. Like all other structures constructed on the farm, the appropriate snow and wind loading needs to be taken into account by the engineer of record during the design process; low roof slopes will hold more snow than steeper slopes.

Comprehensive fall, winter, and spring barn air quality data is needed before the concern with this aspect of the ventilation system can be fully addressed.

Total annual cost economic analysis shows that cross ventilating a 200 ft. wide, 1,500-cow wide-body freestall barn is 30 percent (Vent 1) and 57 percent (Vent 2) more expensive on a per cow basis than two 4-row tunnel-ventilated 750-cow barns. However, the 7 ft. high opening created by the baffles results in higher air speeds at cow stall level than is found in tunnel-ventilated barns. Increased speed at cow stall level can result in increase cow lying time during hot weather periods and subsequently increased milk production. Dr. Rick Grant, President of Miner Institute in Chazy, New York presented research results stating that cows produce four more pounds of milk daily per additional hour of stall lying time. It is easy to see the economic return on a system that keeps cows lying down one more hour per day during hot weather.