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Practical Considerations for Ventilating Calf Barns in Winter

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Introduction

Both natural ventilation and mechanical ventilation using negative pressure systems are widely and successfully used for adult cattle. However, both methods have been shown to be problematic for calf barns in our clinical investigations of problem herds and in field research trials. Our recent research trial showed that while air exchange rates may be excellent in naturally ventilated calf barns, the ventilation of the pens is independent of the barn ventilation[1]. Indeed, most calf pens within these barns are badly polluted microenvironments within well-ventilated barns. Mechanically ventilated barns that use negative pressure have their own set of problems. The overall air exchange rate in winter is usually quite low and it is very difficult to distribute small volumes of air to each calf pen using negative pressure systems. In contrast, positive-pressure ventilation systems to supplement natural or negative-pressure ventilation systems have been shown to be effective and easy to maintain. This paper will review some of these issues, present the calculations used to design a supplemental positive-pressure ventilation system, and describe some practical techniques for installing the systems.

Individual Calf Pens in Naturally Ventilated Barns

While single-calf hutches have proven to be an excellent method to house young calves, workers who provide care to calves find working with calves in hutches in rain and snow to be miserable. As herds expand, so does the number of milk-fed calves. To avoid outdoor calf work, many expanded dairies have constructed naturally ventilated barns with individual calf pens inside. Our clinical investigations of problem herds have shown that endemic calf pneumonia is common in these new barns. The ventilation deficits seem to have evolved from inappropriate steps to minimize cold stress in very young calves. Rather than provide supplemental heat or sufficient bedding to allow young calves to nest, pens were constructed to prevent drafts. The “draft-free” pens with solid panels on three and sometimes four sides are difficult to ventilate. When placed in naturally ventilated barns, calves do not produce sufficient heat to create ventilation from thermal buoyancy in cold weather, and the solid panels effectively minimize ventilation from prevailing winds when the sidewalls are opened in warm weather. The poorly ventilated “draft-free” pens inadvertently create highly polluted microenvironments of airborne bacteria associated with respiratory disease[1].

Experiences with Negative Pressure Ventilation in Winter Calf Barns

Negative pressure systems are commonly recommended for livestock buildings because passive inlet systems are usually cheaper to construct than ductwork associated with positive pressure systems. The problem is that recommended ventilation rates for calf barns in winter result in very small capacity systems with very small inlet areas. For example, it is not uncommon to exchange 1,200 cubic feet of air per minute (cfm) from a moderate sized barn for 40-50 calves. Inlets sized so that the incoming air would enter at a speed of 600 feet per minute (fpm) would yield a total of 2 square feet (1,200 cfm / 600 fpm = 2 ft^2) a very small area.

The challenges of designing and maintaining a small inlet area come from many factors. For starters, it is estimated that the average house in the US will have more than 2 square feet of inlet area around windows, doors, etc. It is hard to imagine our calf barns have less. If the total inlet area is more than expected, the excess inlet area will cause air to enter too slowly, reducing mixing within the barn. Similarly, if any window or trapdoor is left open by accident, the planned inlet system becomes essentially non-functional. And if the additional inlet area is not evenly distributed, it will create areas of colder, fresh air near the excess openings and insufficient fresh air in the areas without openings. Low-volume negative pressure systems for winter calf-barn use are not reliable enough to be recommended.

Positive Pressure Systems to Supplement Other Ventilation Systems

In contrast, I have found positive pressure systems to be very dependable and consistent for low capacity situations. The advantage is that they can be a self-contained system of a fan forcing air into a distribution duct. It will not be affected by unseen cracks in the walls and windows or doors left ajar. They can complement naturally ventilated calf barns as shown in Figure 1 and deliver minimal volumes of fresh air to dilute polluted air within the

Figure 1. *A positive pressure distribution duct installed in a naturally ventilated calf barn. The fan the powers the system is installed in an outside wall and forces air into the tube. Holes are punched at 4:00 and 8:00 o'clock positions in this barn and sized so that air exits the holes at about 800 feet per minute. The very small volumes of air are driven into the pens between the solid panels. In this barn, the airborne bacterial counts dropped from above 170,000 cfu/m^3 to approximately 40,000 and the number of calves treated for respiratory disease was reduced by approximately 75%.*

pens. As weather warms, the sidewall curtains are lowered and the positive pressure system continues to operate.

Positive pressure systems can also be used to complement negative pressure systems, i.e., the positive pressure system can be used at low ventilation winter situations and then be supplemented with larger capacity negative pressure systems that engage as the temperature increases.

Designing a Positive-Pressure System for Winter Use

The general approach to designing a positive-pressure supplemental system for winter is to 1) determine the total minimal winter ventilation rate for the building, 2) decide how many distribution ducts are required, 3) calculate the minimal cross-sectional area of the duct(s) so that it can carry the required volume of air, 4) specify the area required for air to leave the duct at high speeds, and 5) distribute that air inlet area along the entire length of the duct.

In the subsequent section, calculations for an example barn will be shown in italicized sans serif type in indented paragraphs.

Minimal Ventilation Rate for Cold Calf Barns

Current recommendations for a minimal winter ventilation rate in calf barns range from 15 cfm/calf to 4 air changes per hour of the building. If the number of calves varies from time to time, the ventilation rate should be based upon the maximal number of calves. It is often practical to calculate the ventilation capacity using both approaches and then purchase a fan to move a volume of air somewhere intermediate to the two rates.

For example, consider a 160' x 26' barn with an average interior height of 12 ft (10' eave and 14 ft ridge). The barn could house 80 calves in two rows of individual 4' x 8' pens. The cfm recommendation could range from 1,200 cfm (80 calves x 15 cfm/calf) to 3,328 cfm (volume in cubic feet x (4 changes per hour/60 minutes per hour)). A catalogue from a distributor offers fans in 1,000, 2,000, and 4,000 cfm options. The 2,000 cfm fan is the best choice. This would usually be a 15-inch diameter fan, but would vary with motor size and other factors.

Figure 2. A fan and hood that are very close to the roofline and which sometimes catches snow as it drifts off the roof and propels it into the tube inside the barn.

Ventilating at these rates will produce freezing temperatures in very cold weather. It is critical that the calves have deep straw in which to "nest" and that they are fed adequately to meet energy needs of cold weather. Consider using the simple, but very effective, calf ration analysis program provided in the last version of Nutrient Requirements of Dairy Cattle[2].

The fan should be mounted in an exterior wall and the distribution tube attached directly to the fan. The tube should carry ONLY exterior air. Many people will recall these same systems used as recirculation systems about 30 years ago. In those installations, the fan was installed a foot or two inside the barn relatively close to a louvered inlet.

If the fan is mounted on an exterior wall, it will need a hood to keep snow and rain from entering the system. In some situations where the fan is close to the roofline as shown in Figure 2, snow can drift off the roof and get picked up in the flow of air entering the hood to the fan. To reduce the likelihood of this happening, install an oversized hood and extend it further away from the roofline. The larger the cross-sectional area of the hood entrance, the slower the velocity of the entering air and the less likely it will be that snow will accumulate within the tube.

There are situations where there are rooms for other purposes between the outside wall and the calf room, usually utility or feed storage sites. In some cases, ducts need to be constructed from the sidewall into the room and the fan and tube attached to the duct. An example is shown in Figure 3. The cross-sectional area of the supply duct to the side should be approximately double the cross-sectional area of the distribution tube.

Figure 3. Because of a utility room on the left, a passive air supply duct was constructed to side wall. The fan and tube were mounted in the supply duct.

Number of distribution ducts

In still conditions, air exiting a duct at 700-800 fpm will produce some mixing with the existing air for a distance of perhaps 10-15 feet. With air exiting from two sides of a centrally located duct, one duct will suffice for a 26-28 foot wide building. If the building is more than 28 ft wide, additional distribution ducts should be installed.

> *In the example barn, a single duct will suffice for the 26 ft wide building.*

Cross-sectional area of the duct

The cross-sectional area of the duct should be large enough to carry the desired volume of air at moderate speeds. For common flexible tube ducts, the cross-sectional area of the duct should be sized so that the calculated air speed through the duct nearest the fan is within a range of approximately 700-1,200 fpm. This usually required that the diameter of the tube is 1.25 to 1.5 times the diameter of the fan. Sometimes the sales representatives of the fan and tube suppliers recommend that the tube and the fan be the same diameter. If the fan and tube are the same diameter, the air speed in the proximal end of the tube is so fast that very little air exits the tube through the first 15-30 feet. In many barns, this results in no ventilation benefits to as many as 8-14 calf pens.

> *For example, a duct sized to carry 2,000 cfm should large enough to keep the air speed in end nearest the fan below 1,200 ft per minute, which would require a cross-sectional area of at least 1.67 square feet. (2,000 cfm / 1,200 fpm = 1.67 sq ft.) If a round tube-type duct is used, the area formula, $A = \pi r^2$ is used. The desired cross-sectional area of 1.67sq ft is converted into sq. inches by multiplying by 144 in^2/ft^2, yielding 240 sq inches. Divide 240 sq in by π (or 3.14) to get the r^2 of 76. Find the square root of 76 which is 8.7 inches. The minimal diameter tube should have a radius of 8.7 inches or a minimal diameter of about 18 inches.*

Total area of inlet holes in the duct

The air forced into the distribution duct should exit the holes at a speed of 700-800 fpm so that it travels some distance toward the pens and mixes well with the existing interior air.

> *In our example using a system of 2,000 cfm, I would divide 2,000 by 800 fpm to get 2.5 square feet. This total area needs to be distributed among inlet holes along the length of the distribution duct.*

For every cfm of air being forced into the building, an equal quantity of air must leave the building. In naturally ventilated buildings, this air will exit through the open ridge and eaves. In mechanically ventilated buildings, make sure that there are openings from the building at least equal in area to the calculated inlet area.

Uniform distribution of the incoming air

The goal of these systems is to deliver a small volume of fresh air to the microenvironment of the calf without creating a draft. Technically, a draft is defined as air movement at a speed greater than 50 feet per minute[3]. Do not expect to squat in the calf pen and feel a cooling breeze; the air movement will and should be imperceptible except that it should not feel stale.

The openings from the distribution duct should distribute the air evenly throughout the area in which calves are housed. With the polyethylene tubes, this is done by punching holes along the length of the tube. The holes are usually custom punched and you must specify the diameter of the holes, the intervals between holes, and the location on the tube in terms of clock positions, i.e., 5:00 and 7:00 o'clock.

If air exits two holes of different diameters at precisely the same speed, the air emerging from the larger diameter hole will have the greater "throw" distance. In general, hole diameter options range from about 1 to 3 inches. For typical installations in calf barns, the holes should be 2 to 3 inches in diameter.

The total number of punched holes is determined by dividing the total area needed to achieve an air exit speed of about 800 fpm by the area of the chosen diameter hole.

Hole diameter, in	Area per hole, in^2
1.5	1.77
2.0	3.14
2.5	4.91
3.0	7.07

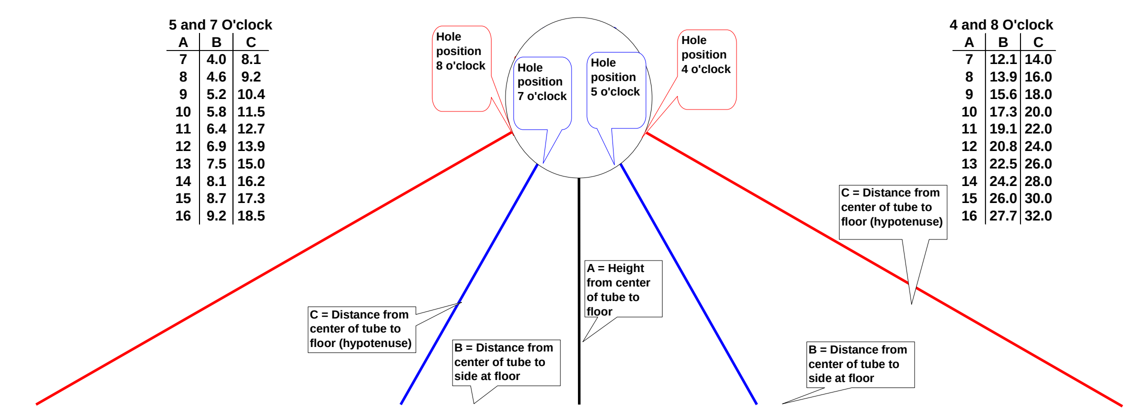
The spacing between holes is determined by the length of the tube. The custom punched holes are normally done in pairs as the punch goes through two layers of the tube. The total length of the tube is then divided by half the total number of holes to yield the interval between each pair of holes.

> *In the example above, we might decide to provide an intermediate total area of 2.5 square feet or 360 square inches. If we choose to work with 3" diameter holes, this would require a total of 51 holes (360 in^2 / 7.07 in^2) in the tube. Assuming that the duct is centrally located down the barn and that there are two rows of holes along the tube, there should be 25 or 26 holes evenly spaced along each side of the duct.*
>
> *In this example, the barn was 120 feet long. If the tube is 120 feet, each pair of holes would be about 4.6 feet or 55 inches apart.*

There is no need to have a hole punched for each stall. As the air exits the tube, it begins to slow and disperse wider and more slowly. However, the holes can become too widely spaced and the holes should be spaced no wider than the width of two pens.

The clock position of the holes on the tube controls the direction of the air flow toward the pens. In general, the further the tube is mounted above the floor, the more vertical the hole position should be. For example, if the bottom of the tube is more than 10 feet high, 5:00 and

Figure 4. *Illustration and tables showing the effect of hole position on the direction of airflow and the resulting distance from the tube to the floor.*



5 and 7 O'clock

A	B	C
7	4.0	8.1
8	4.6	9.2
9	5.2	10.4
10	5.8	11.5
11	6.4	12.7
12	6.9	13.9
13	7.5	15.0
14	8.1	16.2
15	8.7	17.3
16	9.2	18.5

4 and 8 O'clock

A	B	C
7	12.1	14.0
8	13.9	16.0
9	15.6	18.0
10	17.3	20.0
11	19.1	22.0
12	20.8	24.0
13	22.5	26.0
14	24.2	28.0
15	26.0	30.0
16	27.7	32.0

7:00 o'clock sites may be preferred. If the bottom of the tube is 8 feet above the floor, perhaps 4:00 and 8:00 o'clock locations would be preferred.

In Figure 4, "throw" locations can be estimated. If the center of a tube is 12 feet above the floor (A), the center of the air stream would theoretically be directed toward a spot on the floor 6.9 feet to the side if the holes are punched at 5:00 and 7:00 o'clock. However, if punched at 4:00 and 8:00, the air stream would be directed at a location on the floor 21 feet to each side.

Figure 5. The support cable runs the length of the barn and is supported by the building ties. The tube is attached to cable with clips.

There are a number of suppliers of tubes and fans and you should consider contacting builders in your area. Two common catalogue suppliers of these materials are FarmTek at 1-800-327-6835 and QC Supply at 800-433-6340.

These positive pressure systems are complementary to natural and negative pressure systems that may become active as the temperature increases. Curtains should be opened normally or if negative pressure systems are present, the fans should be activated with thermostats and additional inlets opened as normal.

Figure 6. Plastic freezer strips used to provide additional support for a flexible air distribution duct.

Some Comments on Installation of the Tubes

The tubes are usually clipped to a cable stretched between the end walls of the building as shown in Figure 5.

The tubes sometimes are sometimes buffeted by winds in the summer when sidewall curtains are down. Three techniques have been used to minimize the exposure to wind damage. First, supplemental support can be provided with "freezer strips" or bands of heavy plastic used to cradle the plastic tube as shown in Figure 6.

Second, the ducts can be installed within the truss structure, as shown in Figure 7, which removes the tube from the direct force of prevailing winds. We do not have long-term experience to indicate whether friction between the tube and the truss will cause premature wear or tear on the tube.

Figure 7. Air tube installed within truss structure to reduce impact of wind.

Finally, some installations of larger diameter PVC pipe and "flume" pipe have been completed. While these materials are frequently ten times as expensive as the flexible polyethylene tubing, they will clearly withstand wind forces. In these installations, the holes need to be drilled manually into the pipe and this allows the builder to install either single or multiple rows of holes. One installation using flume piping is shown in Figure 8.

Connecting the larger diameter tube to a smaller diameter fan requires some improvisation. In some installations, the larger diameter tube is mounted on various pieces of plastic cut from barrels or pails. One such adaptation is shown in Figure 9.

Figure 8. The air distribution duct in this barn is a firm "flume" pipe usually used for drainage and other heavy duty purposes. It can withstand wind in relatively open situations.

Figure 9. A section of a plastic barrel has been used to mount the air distribution duct to the wall. A smaller diameter fan is mounted on the plywood panel on the end wall.

Photo courtesy of Dr. Dan Smith, Montrose, SD.

Summary

The last several years of research and clinical experience in calf barns have suggested that traditional systems of ventilation, both natural and negative-pressure mechanical systems, are problematic in cold weather. Individual pen designs should have two solid sides, but the front and rear should be as open as possible. Thermal stress should be managed by providing deep, long straw bedding and not by enclosing the pen. Air hygiene can be improved in most situations by supplemental positive pressure ventilation systems to deliver very small amounts of air to each pen in volumes of about 15 cfm per calf. Implementation of these recommendations can produce calf barns that appear to equal calf hutches in terms of minimizing disease and provide better working conditions for the caregivers.

References

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