Ventilating Calf Barns in Winter

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Take Home Message

- Ventilation is only one part of a complete housing system for calves
- Management of the calf environment should consider all aspects of the housing design including ventilation for excellent air quality without draft
- A positive pressure supplemental ventilation system can improve air quality in naturally ventilated calf barns

Introduction

The two environmental options for raising calves are cold housing and warm housing. In this discussion only cold naturally ventilated calf housing will be discussed. A cold housing system is typically naturally ventilated which operates a few degrees above the ambient outside temperature and is the recommended system for raising calves. Cold-housing systems should provide a dry comfortable resting space and an environment with excellent air quality, free from excessive drafts in winter. Disease organisms are less likely to thrive in the cold, dry environment. Disadvantages of cold housing are possible frostbite of calf's ears, additional feed costs to maintain body heat and growth, and poor working conditions for the caretaker in inclement weather.

The Calf Environment

Providing an environment that meets the needs of the calf with excellent air quality and without a cold draft is a key component in successfully rearing calves in cold weather. The calf environment includes the animal's resting space, feeding area and walking surface as well as the environment surrounding the calf, such as the sun, relative humidity, precipitation, air quality, air temperature and air velocity. Understanding basic concepts of a quality calf environment is critical in developing optimum calf housing systems.

Bedding provides benefits to the calf by helping the calf maintain a clean dry fluffy hair coat, providing a cushioned resting surface, providing insulation from the cold floor, and acting as a moisture adsorption media.

Ventilation is necessary for providing fresh air and removing moisture, animal heat, pathogens and air contaminants. Ventilation, which can affect air quality and thermal environment of the calf, is only one of many design and management factors of the housing system that can affect the calf environment, health, and growth.

■ The Calf Hutch Model

The calf hutch is a model for creating an excellent calf environment. It is a proven system that is successful for many calf raisers. The calf can choose its environment dependent on its needs. In cold, windy conditions the calf will choose to lie down (nest) in a deep bed of straw in the rear part of the hutch shelter. On a cold sunny calm day the calf may choose to stand at the doorway of the hutch shelter and sun itself.

The challenge of caring for animals properly and providing additional shelter for the calf and the caretaker in extreme cold climates has prompted the design of calf barns with individual or group pens. The main reason calf pen space is designed into a building is to provide additional shelter for the calf caretaker. The design of the calf barn should still focus on the needs of the calf and integrate the additional needs of the care taker without creating a poor environment, including air quality for the calf. The additional building shelter can severely compromise the calf environment if not properly designed and managed.

When the calf space is placed in a building the tendency is to also minimize the space per calf to control costs of construction. The reduced space can cause stress on the calf and increase the concentration of pathogens in the air volume of the building. The smaller the calf space the higher the concentration of disease organisms in the space and the poorer the air quality. Ventilating the calf barn in winter can be a challenge in trying to provide for competing design needs; providing protection for the caretaker versus providing an optimal physical and thermal environment for the calf including excellent air quality.

■ Individual Calf Pen Design

Any design for the calf pen space in a building should attempt to create a quality environment for the calf. Pen space should allow the calf to turn around, lie down, and access feed and water easily and without injury. Typical pen space ranges from a minimum pen space per calf of approximately 1.2 m x 1.8 m (4' x 6') or 2.2 s.m. (24 s.f) with 1.2 m x 2.4 m (4' x 8') or 2.9 s.m. (32 s.f.) recommended. Increasing pen space has been shown to improve air quality since the volume of air in a larger pen can dilute the concentration of microorganisms.

Other management decisions such as the choice of the type of bedding used can impact the calf environment. For example in cold weather, nesting in a deep bed of straw and the optional use of a calf blanket is important to protect the calf from cold temperatures. Providing air movement in the calf pen without a draft also becomes important in maintaining good air quality without chilling the calf.

Individual pens design can be as simple as wire panel partitions that confine an individual calf in its own space. The pens are typically spaced apart from each other by at least 0.3-0.5 m (12-18 inches) to prevent calf to calf contact. This pen arrangement requires additional space in the building as compared to a pen arrangement that uses common solid pen partitions. A 30 cm (12 inch) deep layer of straw bedding provides insulation between the ground /concrete and the calf. Since there are no solid partitions between calves the deep bed of straw allows the calf to nest in the straw to minimize the effect of a draft.

An incremental design change for draft control would be to use common individual pen solid sides that are designed to prevent calf to calf contact. In many pen designs the rear panel of the pen is also typically solid to minimize drafts but this solid panel can also reduce air quality in the microclimate of the three sided pen.

A design change to improve air quality would be to replace the solid rear panel with a partially open rear panel to allow air to move through the pen (Figure 1). The rear panel is open for the upper 0.7 m (30 inches) to provide air movement through the pen and solid on the lower 0.5 m (18 inches) of the panel to provide a solid draft barrier when the calf is resting and to help retain bedding. The front panel is designed with openings for the calf to access the feed and water pails. This allows air circulation into the pen from the front through the back.

Solid pen partition surfaces should be smooth and non porous to allow for effective washing and sanitizing. Many producers are selecting plastic materials to provide for an easily cleanable surface. Pen partitions should be removed from the building for cleaning. Cleaning pens inside the building with a pressure washer can aerosol the disease organisms into a fine mist that can spread to other calves in the building. Provide enough pen space so the individual pens can be rested at least two weeks after being cleaned and sanitized.

In many older facilities, hovers are placed over the top of the rear portion of the individual pen to prevent drafts from above. In some cases the hover covers the entire top of the pen. Hovers are not recommended especially when there are already three solid sides on the pen creating a four sided box that is likely to have minimal air exchange through the pen creating very poor air quality.

For this pen design to be successful in cold weather, a deep bed of dry fluffy material such as loose straw is necessary to allow the calf to nest into the bedding when it chooses. Other bedding materials such as coarse saw dust, or wood shavings can be used in milder temperatures.

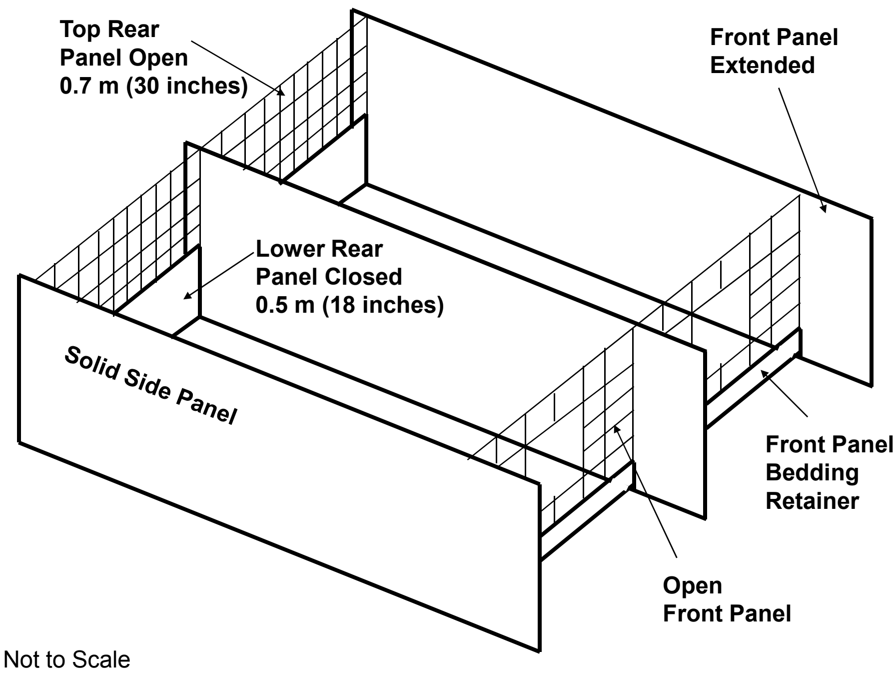

Figure 1. Individual calf pen design.

■ Ventilation Of The Calf Barn And Pen Space

The calf housing site should be upwind of the larger animals to minimize the exposure of the calf to the air borne transmission of pathogens. Avoid calf building sites where ventilation systems for older animals or manure storage exhaust contaminated air to the calf barn site.

Naturally ventilated barns are designed to provide shade in the summer and draft control in the winter. Well-ventilated naturally ventilated barns will operate at temperatures of only one to three degrees centigrade above the outside air temperature. The majority of newly-designed calf facilities use natural ventilation where wind is the primary motive force in providing air exchange (ventilation) of the building and calf space. Thermal buoyancy (i.e., warm air rises) provides minimal motive force since there is very little temperature difference between the inside and outside conditions. Air enters through the curtain sidewall and windward eave inlets and exits through the open ridge and leeward eave inlets and downwind curtain sidewalls. (Figure 4)

The curtain sidewalls of the calf barn should be designed to be easily adjusted according to the outside weather conditions. Some building designs use a two piece sidewall curtain which allows the bottom curtain to remain closed in cold weather to provide draft protection and the top curtain is used to manage the ventilation of the building. The sidewall curtain(s) can also be equipped with automatic ventilation controls. The building curtain and inlet system design should prevent these openings from being closed completely. Even in the worst weather, air must be allowed to move through the building to ventilate it properly. It also is recognized that rain and snow blowing in can cause problems of wet bedding affecting the calf environment.

Newborn calves have little resistance to disease challenges so it is important to have excellent air quality in the pen space to minimize respiratory problems. One of the biggest challenges with any calf housing system is management of the calf's environment. Since the individual pen space for the calf is usually minimal, the calf has no choice in choosing its environment by moving into a different part of the pen like it does in a hutch system. The manager must make the decisions to control the building ventilation management providing the proper calf environment year round.

Excellent air quality in the calf pen space should be the primary goal for the ventilation management of the barn. Air quality problems for the calf arise when the caretaker bases ventilation system management on human needs rather than the calf needs. The calf is in the microclimate of the pen 24 hours a day. The caretaker is in the barn for only a short time in the personal space to feed and care for the calves.

■ Positive Pressure Ventilation Design for Improving Calf Barn Air Quality

Recent work on air quality in calf buildings has shown that in many calf barn designs the air quality can be very good in the personal alleys but may be inadequate and often very poor in the individual calf pen space. (Nordlund, 2007). In general the more space provided for the calf the better the air quality of the calf space. Also the more open the pen partitions the better chance for air movement to exchange air in the pen. The challenge and art of design is to provide the necessary air exchange to provide good air quality in the calf space without creating a draft and chilling the calf in cold weather.

Individual pens inside the barn and calf hutches provide a microenvironment for the calf that is not necessarily representative of the environment in the alley space or overall building space. Three solid sides that are typically used to prevent draft also impede air movement through the calf space and may not allow proper ventilation and removal of the microorganisms generated in the calf space.

A positive pressure ventilation system can be used to control the distribution of the fresh air without creating a draft. The system is similar to those used in veal barns where air is recirculated through a duct that has spaced holes to evenly distribute air down the length of the building. In this case, the system does not recirculate air but provides a continuous supply of fresh air from outside. The air duct is positioned along the length of the barn to provide fresh air uniformly distributed along the length of the building. A fan placed in the sidewall and connected to the duct is used to deliver the required volume of fresh air.

Table 1 shows the air flow recommendations from Midwest Plan Service. Calculations for ventilation can be made with both recommendations and compared to determine the design need for a particular situation. The amount of air required at this cold weather condition is small and it is hard to control the distribution adequately with a negative pressure ventilation system.

The fan and duct system creates a positive pressure differential between the inside of the barn relative to the outside of the barn. The fan is sized to provide the recommended ventilation rate at a positive pressure differential of 25 mm (0.1 inch) of water or 25 Pa. The total air flow required for a calf barn is calculated based on the number of animals in the barn or air volume of the building space depending on the recommendations from Table 1.

Table 1. Ventilation recommendations for calf barns (Midwest Plan Service)

Temperature	Air flow per calf	Building Air Volume Changes
Cold - 23 °C to -7 °C,(-10 °F to +20 °F)	7 l/s (15 cfm)	4 air changes per hour
Mild - 7 °C to 10 °C (+20 °F to +50 °F)	24 l/s (50 cfm)	15 air changes per hour
Warm > 10 °C (+50 °F)	56 l/s (120 cfm)	60 air changes per hour

It is recommended to select fans based on air flow capacity at a static pressure of 25 mm (0.1 inches) water or 25 Pa. The challenge for smaller buildings is finding a fan small enough to deliver the desired ventilation rate and not be oversized. Figure 2 shows the fan capacity air flow for several different manufactures of fans on the market. Note there is a large variation of fan air flow capacity for a specific fan diameter which is dependent on the fan motor horsepower and fan blade design. For example a 30 cm (12 inch) fan diameter can deliver between 250-1100 l/s (500-2200 cfm). Use manufacturer's literature and fan testing agency data (BESS) to get accurate fan air flow information.

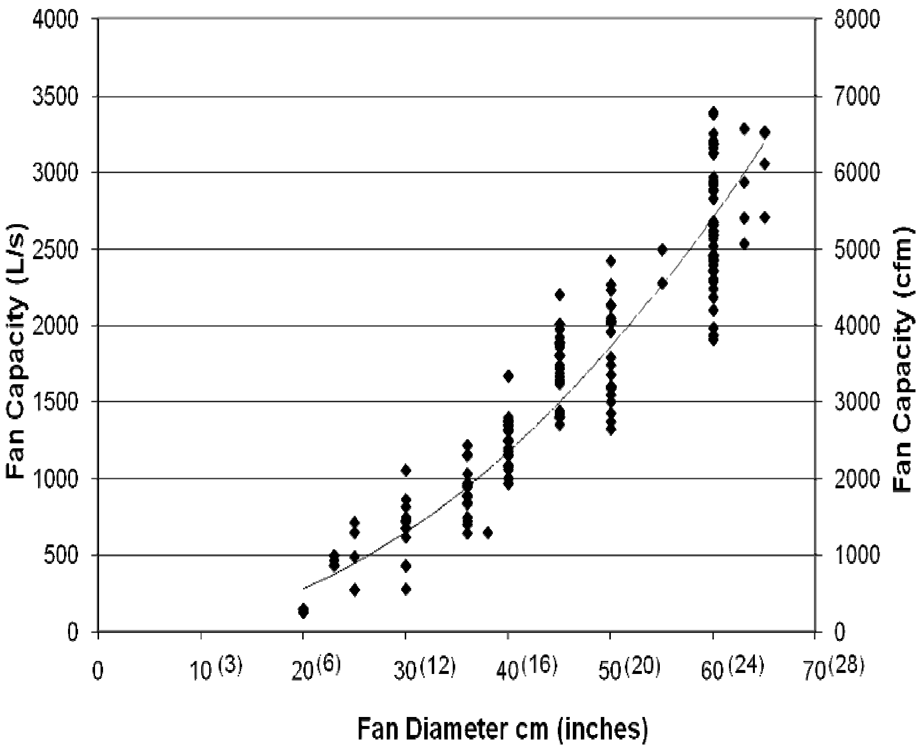

Figure 2. Fan capacity at 25 mm (0.1 inches) water 25 Pa.

A flexible or rigid polyethylene plastic duct is connected to the fan and distributes air along the length of the duct through a series of holes. The recommendation is to select a duct that is 1.3-1.5 x larger diameter than the fan diameter. For example a duct of up to 45 cm (18 inches) in diameter would be recommended for a 30 cm (12 inch) diameter fan. The duct diameters available in the market vary from 15-75 cm (6 - 30 inches). The duct air velocity is recommended to be in a range from 2-5 m/s (400-1000 fpm) to minimize static pressure and frictional loss in the duct.

Table 2 shows the air flow capacity of manufactured ducts in terms of total air flow delivered at several different duct velocities and in terms of the number of calves that could be served by the duct at a rate of 7 l/s (15 cfm) per calf. The duct is supported by clips connecting the duct to a cable along the length of the duct to prevent the duct from sagging. The duct is mounted at a height of between 2.4-3.0 meters (8-10 feet) to allow clearance of equipment for cleaning.

Table 2. Polyethylene duct air flow capacity

Duct Diameter	Duct Velocity					
	2 m/s (400 fpm)		4 m/s (800 fpm)		5 m/s (1000 fpm)	
cm (inches)	Air flow l/s (cfm)	Number Calves	Air Flow l/s (cfm)	Number Calves	Air Flow l/s (cfm)	Number Calves
	Duct Air Flow Capacity					
15 (6)	37 (79)	5	74 (157)	10	93 (196)	13
20 (8)	66 (140)	9	132 (279)	19	165 (349)	23
25 (10)	103 (218)	15	206 (436)	29	257 (545)	36
30 (12)	148 (314)	21	296 (628)	42	370 (785)	52
40 (16)	263 (559)	37	527 (1117)	74	659 (1396)	93
45 (18)	333 (707)	47	667 (1414)	94	834 (1767)	118
50 (20)	412 (873)	58	823 (1745)	116	1029 (2182)	145
60 (24)	593 (1257)	84	1186 (2513)	168	1482 (3142)	209
75 (30)	926 (1963)	131	1852 (3927)	262	2315 (4909)	327

m/s = meter per second, fpm = feet per minute, l/s = liter per second,
cfm = cubic feet per minute, Number Calves based on 7 l/s (15 cfm) per calf.

The duct has holes spaced evenly along the length of the duct to provide a series of uniform air streams directed to the calf level without creating a draft. Depending on the arrangement of the pens or rows of pens this may require one or two rows of holes to distribute the air evenly. Table 3 shows the air flow capacity of an individual round hole. For example a 50mm (2 inch) diameter hole with an exit velocity of 4 m/s (800 fpm) will deliver 8.2 l/s (17 cfm). The spacing of the holes will be dependent on the length of the duct and the number of holes needed.

Manufacturers place the holes on the circumference of the duct according to clock positions. Depending on the geometry of the pen arrangement, the distance to the calf level, and the height of the duct the holes are placed at either the 4 and 8 o'clock positions or 5 and 7 o'clock positions on the circumference of the duct.

Table 3. Round hole air flow capacity.

Hole Diameter	Air Velocity		
	3 m/s (600 fpm)	4 m/s (800 fpm)	5 m/s (1000 fpm)
	Hole Air Flow Capacity		
mm (inches)	l/s (cfm)	l/s (cfm)	l/s (cfm)
12 (0.5)	0.4 (1)	0.5 (1)	0.6 (1)
25 (1.0)	1.5 (3)	2.0 (4)	2.5 (5)
38 (1.5)	3.4 (7)	4.6 (10)	5.7 (12)
50 (2.0)	6.1 (13)	8.2 (17)	10.2 (22)
63 (2.5)	9.6 (20)	12.7 (27)	15.9 (34)
75 (3.0)	13.8 (29)	18.4 (39)	22.9 (49)

m/s = meter per second, fpm = feet per minute, l/s = liter per second, cfm = cubic feet per minute.

The spacing of the ducts is dependent on the geometry of the pen space and the throw distance of the air jets from the duct holes. The throw distance of the air stream from the exit holes of the duct is dependent on the hole size and the velocity of the air exiting the hole. The exit air velocity through a hole is recommended to be between 3-5 m/s (800-1000 feet per minute). The air jet from an individual hole has a spread of approximately 22 degrees creating a fan shaped air stream with a decreasing velocity the further the distance from the hole. The velocity of the air stream at the calf level is recommended to be less than 0.3 m/s (50 fpm) to prevent a cold draft. This is considered by some definitions to be still air. Table 4 and Figure 3 shows the throw distance and spread for several common hole sizes and air exit velocities.

Table 4. Throw distance to still air.

	Air Velocity								
	3 m/s (600 fpm)			4 m/s (800 fpm)			5 m/s (1000 fpm)		
Hole diameter	25mm 1 inch	50mm 2 inch	75mm 3 inch	25mm 1 inch	50mm 2 inch	75mm 3 inch	25mm 1 inch	50mm 2 inch	75mm 3 inch
Throw distance to still air	1.1 m 3.4 ft	2.1 m 6.9 ft	3.2 m 10.3 ft	1.4 m 4.6 ft	2.8 m 9.2 ft	4.2 m 13.7 ft	1.8 m 5.7 ft	3.5 m 11.5 ft	5.3 m 7 ft

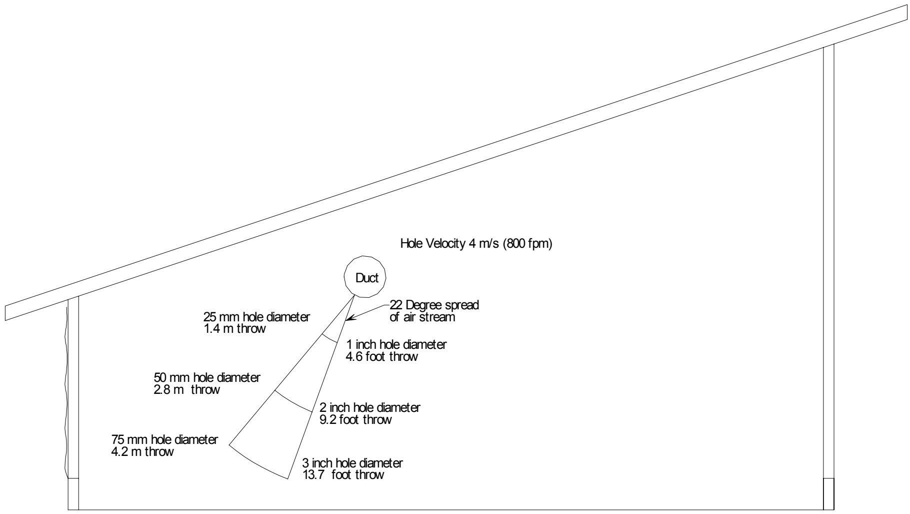

Figure 3. Throw distance of air stream from duct holes. Example shows 4 m/s (800 fpm) hole exit velocity. See Table 4 for other hole exit velocities.

Calf Barn with individual Pens

The positive pressure ventilation system design for a calf barn with two rows of individual pens with a central working alley will be shown below. The calf barn layout is shown in Figure 4. The total air flow for the building is calculated by multiplying the air flow per calf from Table 1 by the number of calves in the building.

Total air flow rate = 7 l/s (15 cfm)/calf x 50 calves = 350 l/s (750 cfm)

The fan selected must be able to deliver at least 350 l/s (750 cfm). Reading from Figure 2, a fan diameter of 35 cm (14 inch) diameter will supply the required air flow rate of 350 l/s (750 cfm).

The duct area is calculated by dividing the air flow rate by the velocity of the air in the duct. In this case the air velocity is assumed to be 4 m/s (800 fpm).

$$\text{Duct area} = \frac{350 \text{ l/s} \times 1 \text{ cubic meter/1000 l}}{4 \text{ m/s}} = 0.0875 \text{ square meter duct area}$$

$$\left(\text{Duct area} = \frac{750 \text{ cfm}}{800 \text{ fpm}} = 0.9375 \text{ square feet duct area}\right)$$

For a round duct the diameter is 0.33 m (13.1 inches). Reading from Table 2 the closest duct available from the manufacturer is a duct diameter of 30 cm

(12 inch) with a velocity of 5 m/s (1000 fpm) which could supply the air flow 370 l/s (785 cfm) for 52 calves.

The number of holes to deliver the air uniformly will depend on the air velocity exiting the hole and the hole diameter. Choosing a 50 mm (2 inch) hole diameter and a velocity of 4 m/s (800 fpm) from Table 3 each hole will deliver 8.2 l/s (17cfm) per hole. The number of holes is calculated by dividing the total air flow needed by the air flow capacity per hole.

$$\text{Number of holes} = \frac{350 \text{ l/s}}{8.2 \text{ l/s/hole}} = 43 \text{ holes @ 50 mm diameter}$$

$$(\text{Number of holes} = \frac{750 \text{ cfm}}{17 \text{ cfm/hole}} = 44 \text{ holes @ 2 inch diameter})$$

Assuming the duct has two rows of holes each row would have approximately 22 evenly spaced holes. The spacing of the holes will be:

Hole spacing = 31 m / 22 holes = 1.4 m spacing

(Hole spacing = 100 ft/ 22 holes = 55 inch spacing)

According to Table 4 the throw distance to still air for a 50 mm (2 inch) hole at the 4 m/s (800 fpm) air exit velocity is approximately 2.8 m (9.2 feet). This is less than the throw distance from the duct to the calf level in the pen which is approximately 3.5 m (11.3 feet). The air velocity at that distance will be below the threshold considered to be a draft. Two rows of holes would be positioned at 4 and 8 o'clock on the circumference of the duct to distribute the air to the two rows of pens.

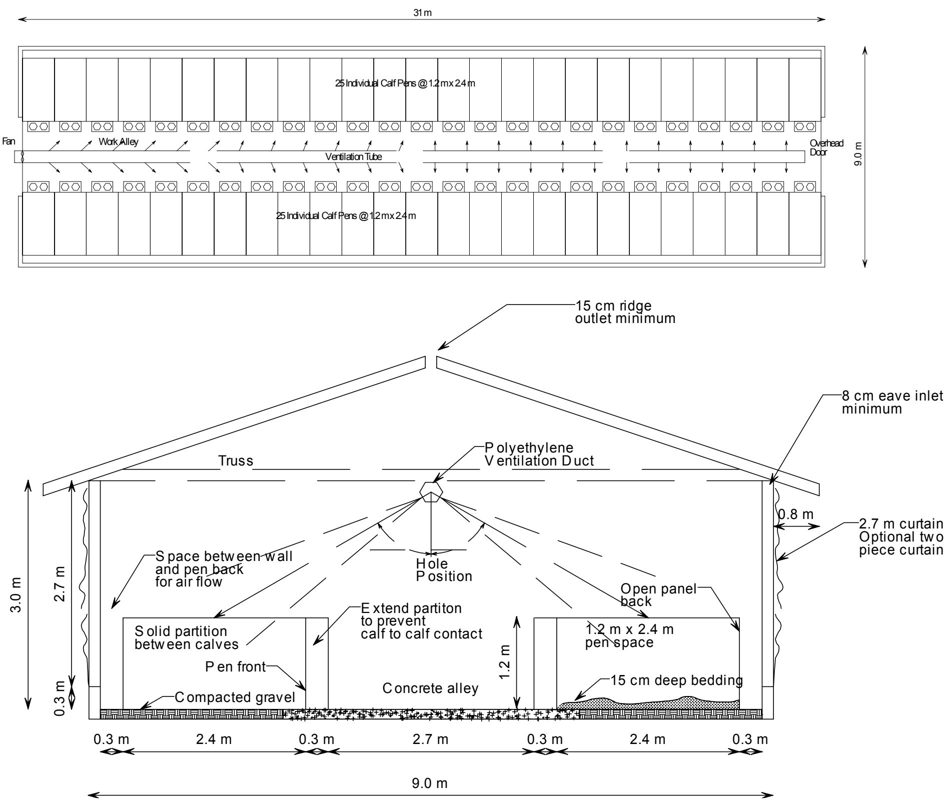

Figure 4. Naturally ventilated calf barn with 2-rows of individual pens.

▪ Calf Barn with Group Bedded Pens

Some producers raise in group pens in a calf barn as shown in Figure 5. A concrete alley adjacent to the bedded pens is used for access to feed and water. Solid panels on the fence or gates between pens can help to limit drafts. Each bedded pen houses 12 calves.

In this example the total air flow recommended for the calf barn is:

Total air flow rate = 7 l/s (15 cfm)/calf x 72 calves = 504 l/s (1080 cfm)

Reading from Figure 2 a fan diameter of 35 cm (14 inch) diameter will supply this air flow rate.

Reading from Table 2 a duct diameter of 40 cm (16 inch) with a velocity of 4 m/s would supply an air flow of 527 l/s (1117 cfm) for 74 calves.

Reading from Table 3 and choosing a 63 mm (2.5 inch) diameter hole each hole could supply 12.7 l/s (27 cfm). The number of holes is calculated below.

$$\text{Number of holes} = \frac{504\ \text{l/s}}{12.7\ \text{l/s/hole}} = 40\ \text{holes @ 63 mm (2.5 inch) diameter}$$

The spacing of the holes is calculated by dividing the length of the duct by the number of holes needed to distribute the air uniformly.

30 meters/ 40 holes = 0.75 meter (30 inch) spacing

One row of holes would be spaced 0.75 m (30 inches) apart and positioned at 7 o'clock on the circumference of the duct. According Table 4 the throw distance to still air for a 63 mm (2.5 inch) hole is between 2.8 m (50 mm hole) and 4.2 m (75 mm hole). The throw distance to the calf level from the duct is approximately 3.2 m which is close to the distance above.

■ Summary

Design and management of a healthy productive calf environment should consider all aspects of the housing design including ventilation. Ventilation should provide excellent air quality without draft. In some calf barn housing systems, a supplemental positive pressure ventilation system can be designed and implemented to improve air quality. The examples in this paper demonstrate how to calculate the ventilation needs and design a positive pressure system for a specific barn.

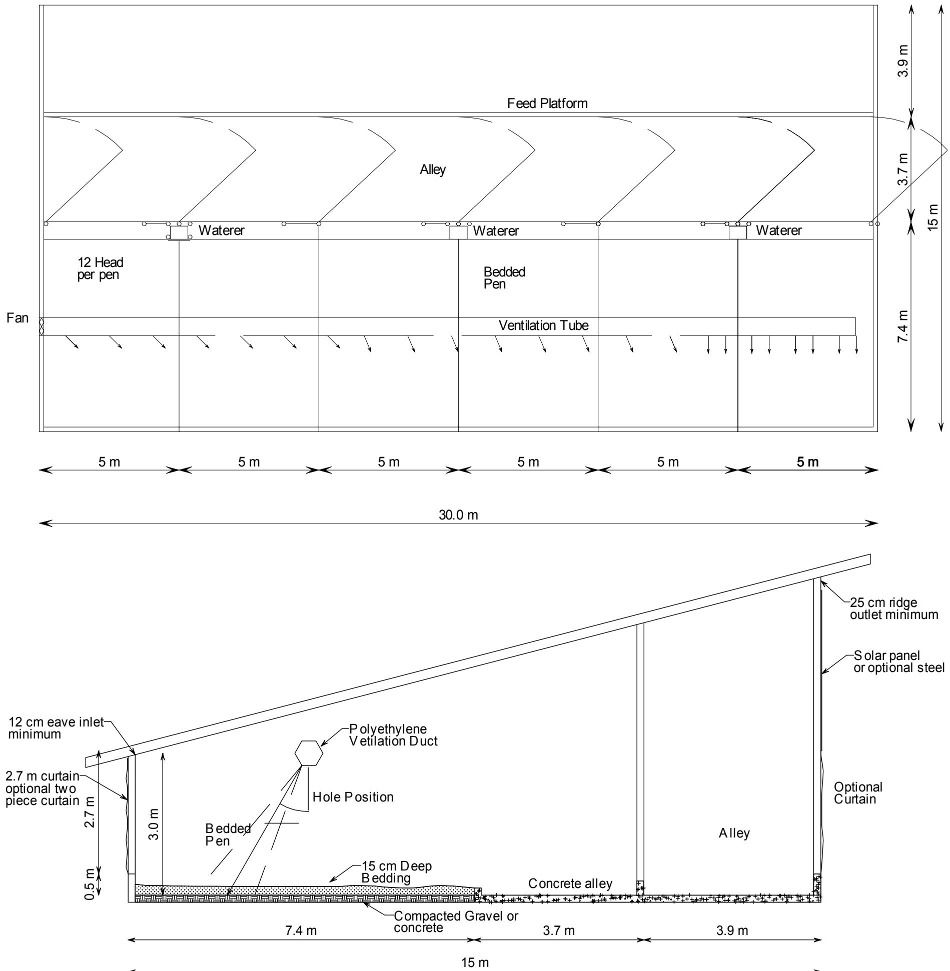

Figure 5. Naturally ventilated calf barn with group bedded pens.

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