

# **ROLE OF FACILITY DESIGN AND VENTILATION ON CALF HEALTH<sup>1</sup>**

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## **Introduction**

A pre-weaned dairy calf has several basic needs that must be met in order for her to be healthy and achieve target weight gains. Generally speaking these needs are: 1. optimal nutrition (quality and quantity), 2. free access to clean water, 3. a clean, dry, and comfortable resting area, and 4. adequate, draft-free ventilation with fresh air. Ensuring each calf is provided the proper environment is vitally important; the design and management of a calf housing facility directly affects the environment she experiences.

The housing facility's initial capital, operating, and maintenance and repair costs are all important considerations also. Less permanent confined housing units like greenhouses and fabric-covered structures, collectively defined as alternative housing structures, generally have lower initial cost but higher maintenance and repair costs. Due to the variations in material and structural life between housing systems, it is best to determine the total annual cost for each housing option being considered. Difficulty can exist in calculating the exact total annual cost since some of the alternative housing systems available are relatively new and the life of the systems are not well established. However, it is well known that plastic cladding only lasts a few years while corrugated aluminum cladding will last 30 years or more.

Labor efficiency for pre-weaned calf housing facilities must also be evaluated. Raising dairy replacements represents between 15 and 20 percent of the total farm costs and labor expense is the second largest expense for the overall heifer enterprise (Karszes, 1996). Housing facilities for pre-weaned calves need to be as labor efficient as possible without any sacrifice to animal health or performance.

Many dairy producers who rear a large number of pre-weaned calves and custom calf rearing operators alike are interested in facilities that provide a quality, healthy environment for each calf and that are profitable and labor friendly and efficient. In other words, they want a successful housing system!

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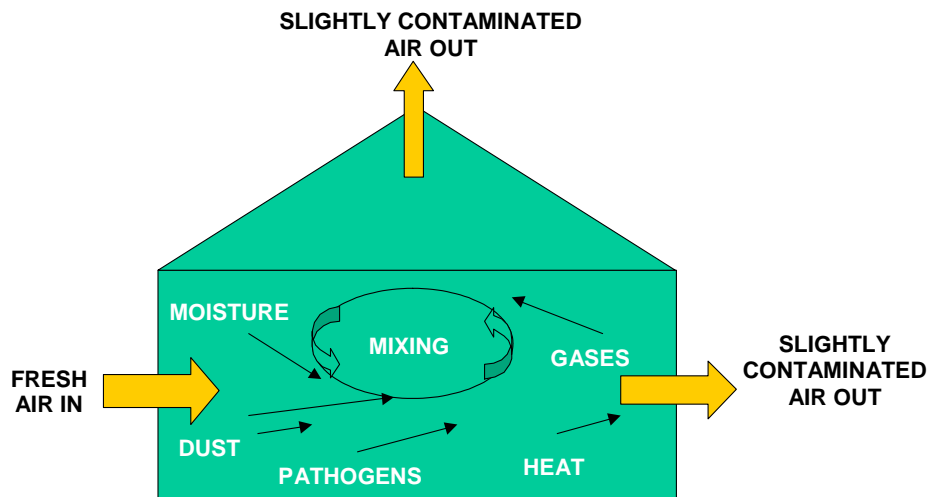
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This paper focuses mainly on the ventilation aspect of facility design and its affect on pre-weaned calf health. Specifically, the discussion will be on facilities designed to house many pre-weaned calves under one roof. Although rearing pre-weaned calves in calf hutches is very successful and popular, ventilation and other housing considerations for calf hutches will not be discussed herein. For information on this topic, the reader is referred to Van Horn and Wilcox (1992), McFarland (1996), Davis and Drackley (1998), and Gooch (2005).

Other facility design aspects that also can affect calf health will be briefly discussed.

### Ventilation Basics

Whether using mechanical or natural ventilation, the goal is to provide fresh air uniformly at calf level throughout the housing facility so all calves receive an adequate quantity of draft-free fresh air. A calf housing facility's fresh air source is the ambient outside air. Therefore, proper ventilation means taking outside air and evenly distributing it throughout the barn. Incoming air mixes with in-barn air contaminants (moisture, dust, pathogens, manure gases, and heat) and is exhausted as shown in Figure 1.



**Figure 1. Basic principle of ventilation; fresh air mixes with barn air contaminants and is exhausted.**

Newborn calves have little resistance to disease challenge so it is vitally important that the source of air used to ventilate the housing unit be clean, fresh, and draft-free. A pre-weaned calf housing barn is best located on the windward side of the overall farmstead to minimize passage of airborne pathogens from older heifers and cows. This is especially important on farms that are expanding via purchase of outside cattle or on custom grower operations that rear calves and heifers from many source farms. Some airborne pathogens, like micro plasma, can be carried by air currents several hundred yards (Welcome, 2000)

making it also important to provide substantial separation between pre-weaned and more mature animal housing units.

Given that there is clean air outside the housing structure, a goal is to have air quality within the microenvironment surrounding the calf to be very similar to the air outside the housing structure. A naturally ventilated calf barn that has adequate ventilation will have relative humidity levels nearly the same in the calf zone as it is outside levels. In a warm calf barn (supplemental heat provided) that is mechanically ventilated, the relative humidity levels at calf level will be lower than the ambient. For all cases, the concentration of manure gases, dust, and pathogens should be very low, particularly at calf level. Again, air exchange is required in order to meet these air quality goals.

Improper ventilation can cause respiratory problems, reduced feed intake and conversion rates, and have long-term affects. A number of years ago a practicing veterinarian returned to her home farm in Michigan to be the replacement herd manager. During a discussion with her, she commented that calves raised on their farm in inadequately ventilated facilities did not cope with summer heat stress during ensuing lactations as well as cows raised as calves off-farm in well-ventilated environments.

One of the biggest challenges with any housing system is management of the calf's environment. Unlike calf hutches, pre-weaned calves reared in housing barns cannot make a choice as to where they are most comfortable. It is incumbent on the calf caretaker to make adjustments to the housing unit's ventilation system in order to manage the microenvironment experienced by the calves. Research has shown that a New York State's naturally ventilated calf barn's curtains needed to be repositioned as many as 7 to 10 times per day during transition weather periods in order to maintain a quality environment (Gooch and Inglis, 2001). This level of adjustment takes a dedicated employee that is trained in the field of ventilation principles and system management. In most cases an automatic control system that continuously monitors the barn environment and makes appropriate system adjustments is best.

Problems arise when the ventilation system is managed based on human needs and not that of the calf. Remember, calves are in the barn 24/7 and the caretaker only a comparatively small portion of time.

### **Natural Ventilated Cold Barns**

Naturally ventilated calf housing barns rely on natural air movement along with large sidewall, endwall, and roof peak air inlets and air outlets to be successful. Barns with large aspect ratios are best oriented with their ridge perpendicular to the summer prevailing winds. This orientation provides better exposure to naturally moving air and also positively benefits the performance of an open peak. Other factors, such as topography, other buildings, manure flow, feed flow, traffic patterns, and expansion also need to be evaluated when determining the

location and orientation of a naturally ventilated calf housing barn.

Experience has shown that difficulty can exist when a natural ventilation system is used to ventilate pre-weaned calf barns with more than two parallel rows of pens. Specifically, the calves in the two inner pen rows of a 4-row barn can suffer from a poor microenvironment due to insufficient air exchange at calf level. This can occur mainly under four scenarios: 1) in cold conditions when the curtain sidewalls are closed or inadequately opened due to the calf caretaker's goal to temper the temperature in the calf barn, 2) during hot weather when little natural air flow exists, 3) during cool conditions when the curtain opening is reduced to help prevent a draft on calves in the rows adjacent to the sidewalls, and 4) when solid partitions are used to form the calf pen.

#### Naturally Ventilated Drive-Through Feed Delivery Calf Barn with Individual Pens

A simple gable truss post-frame construction system can be used to construct a central drive-through calf barn as shown in Figure 2. Specific attributes of this design include:

1. Thirty-two feet wide; this width provides sufficient space to centrally locate an individual pen on a nominally 11-ft. wide raised concrete platform. This central position provides more protection to the calves and bedding from driving rains when the curtain sidewall is not fully closed. At the front end of the pen, protection is provided for the feed and water pails from equipment using the center alley.
2. Two rows of pens; as previously mentioned, experience has shown that a naturally ventilated 2-row pre-weaned calf barn has a better chance of achieving adequate ventilation than a 4-row configuration.
3. Hog wire panels for pen partitions; hog panels do not block air exchange at calf level whereas solid panels can, especially in naturally ventilated shelters when the wind is perpendicular to the solid panels. Solid panels are generally thought to help minimize the spread of disease however ventilation trumps disease spread control since all calves will be compromised when ventilation is not adequate.
4. A natural ventilation system; features of the natural ventilation system are:
  - a. Adjustable sidewall curtains that meet in the middle when the 10-foot sidewall is fully opened.
  - b. Continuous eave openings that are sized based on providing an opening of 1" per every 10' of building width.
  - c. An open peak with upstands (The peak opening is 2" per

10' of building width or 12" (minimum)). Upstand height should be at least as high as the ridge is open and up to twice the opening.

- d. An automated control system and/or dedicated calf caretakers to reposition the curtains as needed.
5. Sloped concrete floors; the concrete slab-on-grade for each row of calf pens is sloped towards the center of the shelter. This facilitates drainage of wash and sanitization water during cleanup operations. The concrete between the outside edge of the pens and the building sidewall is sloped towards the sidewall to drain precipitation away from the bedding. The central alley is counter sloped towards the center of the building again with the goal to facilitate drainage of wash down water and precipitation. The shelter is also ideally sloped 2 to 3 percent longitudinally to allow liquids to gravity flow to a well-designed floor drain gutter.
6. A large eave; the eave extends horizontally 2.5 feet from the building sidewall to assist in minimizing entry of precipitation. The eave also provides moisture protection for the curtain sidewall system and some shade to the calf.
7. End wall doors; these doors allow easy access to both the drive through alley and each pen deck. Opening of these doors facilitates easy cleanout of soiled bedding.

Alternative structural systems can also serve as calf confinement shelters. These structural systems should have the same attributes as listed above so a suitable calf environment is provided. Well-managed sidewall, endwall, and peak openings are especially needed to maintain air quality within structures that have transparent or translucent cladding. Basic heat transfer theory and data shows that transmission of radiant energy from the sun through the plastic will quickly warm the air within the structure (Gooch and Inglis, 2001). The degree of warming is highly dependent on the amount of energy transmitted; clear plastic coverings transmit about 87 percent of incident light while white plastic coverings transmit approximately 30 percent. Warming of the interior air results in:

1. Additional evaporation of free moisture
2. Increased production of manure gases
3. Increased air moisture from animal respiration

Consequently, confined housing systems that have transparent or translucent cladding will require more ventilation on any given day compared to systems with opaque cladding.

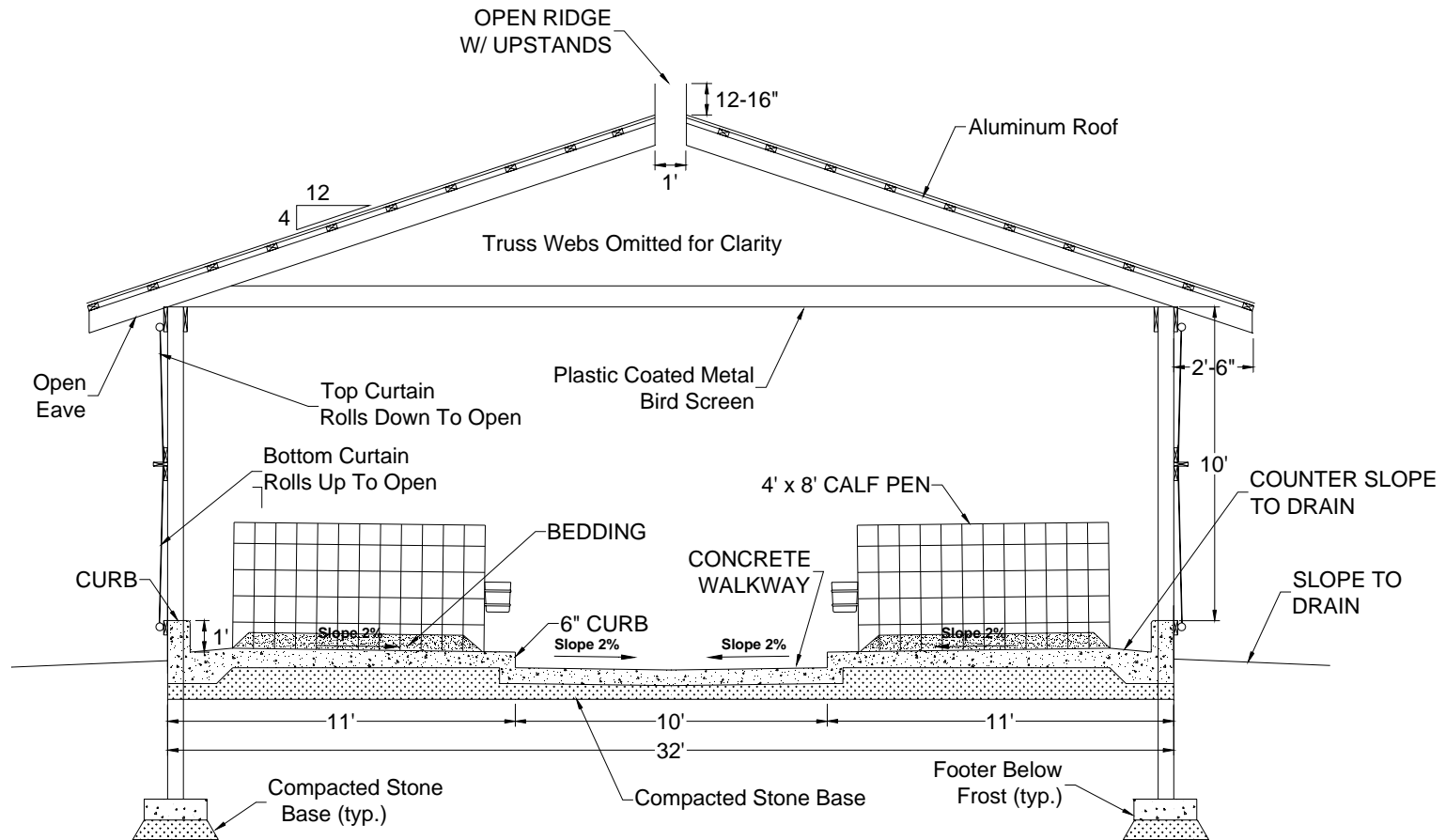


Figure 2. Naturally ventilated cold drive through calf barn with 2-rows of individual pens.

## Mechanical Ventilation

Most mechanical ventilation systems for pre-weaned calf barns incorporate the use of a negative ventilation system; this system employs exhaust fans and planned air inlets. Other ventilation system approaches include positive pressure systems and neutral pressure systems but they are usually not as well suited as a negative pressure system.

Mechanical ventilation systems are appropriate when any one or more of the following exists.

1. The calf housing barn is poorly exposed to prevailing summer winds
2. Summer winds are not consistent
3. The number of pen rows is four or greater
4. It is desired to operate the barn as a warm barn
5. If the barn owner prefers mechanical ventilation over natural ventilation

Mechanical ventilation systems for newborn calf facilities are designed by following one of two methods: 1) the room volume air exchange method or 2) the per animal head method. The room design method is based on providing 1, ½, 1/5, and 1/10 room volumes of air exchange per minute for summer, warm, mild, and cold conditions, respectively. Design information for both methods is summarized in Table 1. It is recommended that a ventilation system designer investigate both design methods and employ the one that results in the higher air exchange rates.

**Table 1. Suggested minimum ventilation rates for a mechanically ventilated pre-weaned calf barn.**

| Weather Condition <sup>(1)</sup> | Room Volume Design Method<br>(room volume air exchanges per hour) | Per Animal Design Method<br>(cfm/hd) |
|----------------------------------|---|--------------------------------------|
| Summer                           | 60  | 100                                  |
| Warm                             | 30  | 65                                   |
| Mild                             | 12  | 30                                   |
| Cold                             | 6   | 15                                   |

<sup>(1)</sup>A four tiered weather condition design approach is recommended by McFarland (2001).

The ventilation system designer uses the overall required air exchange rate for each weather condition along with the barn layout to size and locate air inlets and exhaust fans. Sizing of an inlet is largely based on providing an air inlet speed of 500 to 1,000 fpm depending on inlet location and ventilation condition (MWPS-32, 1990). Higher air inlet speeds are targeted for ceiling inlets that discharge air horizontally; the high air speed helps ensure adequate inlet air distribution and mixing with barn air. Lower inlet air speeds are targeted for winter conditions when ceiling inlets are located adjacent to walls and discharge their air vertically down.

Inlet location depends on the width of the barn and the location of the exhaust fans. Inlets should be located no further than 75 feet from a discharge fan (MWPS-32, 1990). Barns up to 18 feet wide normally have one row of inlets, from 18 to 38 feet wide two rows of inlets, from 38 to 48 feet wide three rows of inlets and over 48 feet wide a minimum of four rows of inlets with no more than 24 feet between inlet rows. All rows mentioned above are parallel to the longitudinal sidewalls.

The inlet opening is normally positioned to maintain proper air discharge velocity by a control device that senses the static pressure difference between the barn and the outside. An in-barn temperature sensor is used to control the number of exhaust fans operating and as more fans come on (when temperature increases) the static pressure sensor senses an increase in barn static pressure and consequently opens the air inlets until the static pressure drops back to the target set point, usually about 0.05-in. of water column.

#### *Mechanically Ventilated Drive-Through Feed Delivery Calf Barn with Individual Pens*

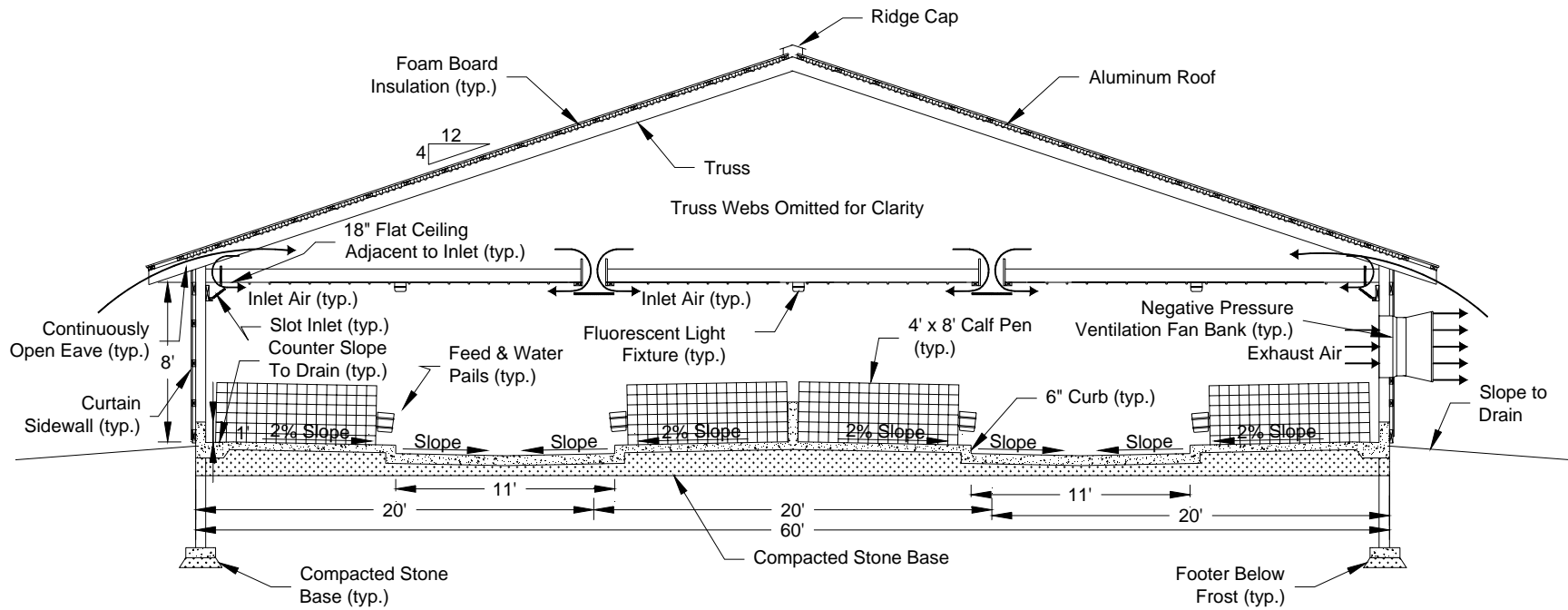
A simple gable truss post-frame construction system can also be used to construct a 4-row drive-through calf barn as shown in Figure 3. Specific attributes of this design include:

1. Sixty feet wide; this width provides sufficient space to centrally locate the outside rows of pens on a nominally 11-ft. wide raised concrete platform. This central position provides more protection to the calves and bedding from driving rains if the barn is operated in a natural ventilation mode. At the front end of the pen, protection is provided for the feed and water pails from equipment using the drive through feed alley.
2. Hog wire panels for pen partitions; hog panels do not block air exchange at calf level whereas solid panels can, especially in naturally ventilated shelters when the wind is perpendicular to the solid panels. Solid panels are generally thought to help minimize the spread of disease however ventilation trumps disease spreading control since all calves will be compromised when ventilation is not adequate. Note: solid pen partition panels can be used if the ventilation inlets are sized and located appropriately to ensure air flow through the calf zone of each pen.
3. A mechanical ventilation system; features of the mechanical ventilation system are:
  - a. Continuous open eaves that allow ambient air to enter the attic space for use as barn ventilation air.
  - b. Louvered openings in the gable endwalls to also allow ventilation air to enter into the attic space.
  - c. Insulation under the roof cladding to minimize the solar heat gain in the attic space.
  - d. Four rows of appropriately sized air inlets to ensure adequate distribution of inlet air.

- e. A mechanical actuator to open and close the inlets appropriately to maintain target inlet air speed.
  - f. One or more banks of exhaust fans (several fans per bank) appropriately sized to provide the air exchange required during the various temperature conditions.
  - g. In-barn sensors to measure dry bulb temperature and static pressure.
  - h. An integrated control system that adjusts the fans and inlets based on the input received from the in-barn sensors and target set points inputted by the barn manager.
4. Sloped concrete floors; the concrete slab-on-grade for each row of calf pens is sloped towards the adjacent feed alley. This facilitates drainage of spilled liquid feed and free choice water and wash down and sanitization water. The concrete between the outside edge of the pens and the building sidewall is sloped towards the sidewall to drain precipitation away from the bedding. The feed alleys are counter sloped towards the center again to facilitate drainage. The shelter is also ideally sloped 2 to 3 percent longitudinally to allow liquids to gravity flow to a well-designed floor drain gutter.
  5. A large eave; the eave extends horizontally 2.5 feet from the building sidewall to assist in minimizing entry of precipitation when the barn is operated in a natural ventilation mode. The eave also provides moisture protection for the curtain sidewall system.
  6. End wall doors that are normally closed when the mechanical ventilation system is operating. These doors allow easy access to both the drive through alley and each pen deck. Opening of these doors facilitate easy cleanout of soiled bedding.

### **Warm Barns**

Cold winter weather in Pennsylvania, New York State, New England, and the upper Midwest can cause uncomfortable conditions that are not tolerable for some calf caretakers and reduce calf caretaker labor efficiency for most others as well. Because of this, some producers and many custom calf growers alike express interest in a warm barn to raise pre-weaned calves. The use of warm barns to house pre-weaned calves has been tried in the past with generally less than favorable results. Failure of such systems is generally for two reasons: 1) improper design and/or management of the mechanical ventilation system, and/or 2) insufficient opportunistic pathogen control.



**Figure 2. Mechanically ventilated drive through calf barn with four rows of individual pens.**

Ventilation systems need to be managed to provide the air exchange rates shown in Table 1 to be successful. These air exchange rates require large amounts of supplemental heat to substantially maintain room temperatures higher than ambient during cold conditions since heated air is not recirculated as part of the heating process.

An engineer can perform calculations to predict the amount of heat needed for a warm barn and the operational costs.

### **Other Consideration for Pre-weaned Calf Housing Systems**

In addition to proper ventilation a few other considerations should be given to the role a pre-weaned calf housing facility has on calf health and well being. They are:

1. Ease of observation; Pre-weaned calves have special needs that sometimes need to be met immediately and/or frequently by the caretaker making ease of observation important.
2. Opportunistic pathogen control; Pre-weaned calves have an incomplete immune system making them highly susceptible to disease challenge. Materials used for pen construction should allow for easy cleaning and sanitization and not readily support the growth of pathogens. Concrete slabs-on-grade used as pen bases should be hard-trowled (glossy finish) and properly cured and constructed from high strength concrete with a low water to cement ratio (slump less than 4 inches).

Organic matter that accumulates on the pen floor and partitions should be removed by the elbow grease method as apposed to the using high pressure washers. The high impact velocity of high pressure washwater can cause pathogens to become airborne resulting in easy spreading to neighboring pens or housing units. Stubborn dried organic matter can be removed with high pressure washing as needed after dosing with sanitizing chemicals.

3. Extra space; Extra space is needed to handle surges that inevitably take place in calving frequency. Stone (2000) showed that facilities designed based on uniform calving frequency would be significantly over crowded two to three months of a year based on data collected from 170 northeast dairies. Extra space is also suggested to provide a dormant time between stockings to enhance pathogen control in individual calf pens (Morrill, 1992). Providing 25 percent more space for pre-weaned calves than the maximum number of anticipated calves allows for a dormant period between pen stockings thus helping to break the cycle of opportunistic pathogens.

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