Ventilation Strategies for Environmental Control of Modern Milking Centers

by

C.A. Gooch and W.G. Bickert
Senior Extension Associate, Dept. of Ag. & Bio. Eng., Cornell Univ., Ithaca, NY 14850
Professor, Dept. of Ag. Eng., Michigan State Univ., East Lansing, MI 48824

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Summary

Effective milking center ventilation is needed to provide comfortable conditions for the operator and the cows alike. Likewise, proper ventilation can help to prevent premature deterioration of building materials and equipment. Milking center designers need to be aware of the need for proper ventilation and incorporate its design into the normal design process. Natural or mechanical ventilation can be used to ventilate milking centers. Mechanical ventilation has advantages over natural ventilation for this application. Control of mechanical ventilation is more reliable and better suited to maintain a quality environment in most instances. A positive ventilation system is preferred for summer conditions and presented in this paper. To meet minimum ventilation requirements in the winter, a neutral system that is balanced between positive pressure heat transfer fans located in the mechanical room with cupola fans operating in the reverse direction seems to be working well in practice.

Key Words

Milking centers, Ventilation, Dairy Cattle, Livestock environment

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Introduction

A good environment within a milking center requires a properly designed, installed, managed, and maintained ventilation system. The objective of a milking center ventilation system is to economically moderate the temperature, relative humidity, and odor levels within a comfortable range for both the operator and the cow. Proper ventilation is also important to maintain milk quality. Improper ventilation leads to stale, odorous air, which can taint milk (Cassidy *et al*., 1987).

Within the milking area, cows and milking personnel interface with each other. Each occupant prefers different ambient conditions based on their respective thermal-neutral comfort zones. For this reason, the design of the ventilation and heating systems for a milking center offers a unique challenge. Additionally, the environments in the holding area, milk storage room, mechanical room, basement, crew lounge, office, bathroom, and storage room need to be properly controlled. A quality design accommodates the individual needs for each room or area in the milking center and integrates them when possible to enhance the overall system performance. Therefore, the design of a milking center ventilation system can incorporate the design of the heating system. In most areas of the United States and Canada, some sort of wintertime heating system is required to prevent equipment and water supply lines from freezing in addition to providing operator comfort.

Observation has shown that minimal attention is typically given to the need for milking center ventilation during the design process. The location of individual rooms within the milking center affects ventilation design and operation. Some rooms in a milking center may prove to be future design obstacles that are difficult to overcome for a retrofit system. Retrofitting a ventilation system into an existing milking center almost always is accomplished with shortcomings in either effectiveness or efficiency.

The need to provide proper ventilation becomes more and more important as milking centers become larger and larger and as they also approach continuous round-the-clock operation. Operator comfort and efficiency can be affected by providing proper working conditions. A comfortable environment will enhance worker productivity and increase job satisfaction. Temperature, humidity, and odors influence the productivity, comfort, and well being of cows and operators alike.

[1]Senior Extension Associate, Dept. of Ag. & Bio. Eng., Cornell Univ., Ithaca, NY 14850
[2] Professor, Dept. of Ag. Eng., Michigan State Univ., East Lansing, MI 48824

Besides creating a quality work environment for operators and cows and contributing to milk quality, adequate ventilation can help to prevent premature deterioration of the building and equipment. Rusting of steel members, detachment of ceramic tiles or glazed blocks from their substrate, and moisture stains on ceilings, walls, or windows can be minimized or eliminated with an adequate year-round ventilation system.

The primary purpose of this paper is to create an awareness for the need for proper milking center ventilation. Also, a different way of operating fans to effectively and efficiently ventilate, heat and cool a milking center is presented.

Basic Ventilation Considerations

In order to achieve the objective of a milking center ventilation system as described above, adequate **air exchange** must be provided. **Air exchange** is the simple process of bringing fresh outside air into a structure to dilute the contaminated inside air. The rate of air exchange that is needed is dependent on several factors including: ambient air conditions, heat and moisture production of building occupants, their respective thermo-neutral zones, the number of each occupant in the group, and heat and moisture production by mechanical equipment. For example, in the animal zones of the milking center, basic requirements for ventilation are: 1. to remove moisture during the winter, 2. provide adequate air exchange and air movement in the summer, and 3. work effectively to satisfy both requirements in transition periods.

Calculation of required air exchange rates is relatively easy and straightforward. Ensuring uniform distribution of fresh air throughout the area can sometimes be difficult to achieve, especially with retrofit systems. Uniform air distribution is the challenge of a ventilation system designer.

Milking center ventilation can be accomplished by either natural or mechanical ventilation systems, or with a combination of both. The system chosen for a particular application depends on the location of the facility, other site-specific variables, and owner preference. However, the use of mechanical ventilation offers advantages over natural ventilation in many circumstances.

A special challenge in ventilation system design is to provide a suitable environment during weather that is between design conditions for winter and for summer which, in fact, is most of the time. The ventilation system must respond to changing indoor as well as outdoor conditions. In the milking parlor this requires a high degree of control. Furthermore, because ventilation requirements for winter and summer design conditions are vastly different, two different ventilation systems may be used. Use of two systems complicates ventilation management because, at some point, a decision must be made to change form one system to the other (changing systems is usually a manual process). But the result is a more satisfactory environment for workers and cows the majority of the time.

Natural Ventilation

The principle of natural ventilation is to use wind and thermal forces to provide air exchange and air movement through a structure. This process relies on large openings in the building to act as air inlets and air outlets. Ventilation can be either through the barn (cross ventilation) or in through the sidewall and up and out through the roof (thermal buoyancy effect). Natural ventilation works well for dairy housing applications when the building is oriented to take advantage of the prevailing winds and adequate sidewall, endwall, and ridge openings are provided.

Within the milking center, the primary area that lends itself to being naturally ventilated is the holding area. The width of the holding area is often less than the width of the remaining structure. Opening the sidewalls exposes the holding area to the outside. Support rooms (mechanical rooms, offices, milk room, and storage areas) located adjacent to the parlor increase the overall width of the structure. The presence of common walls to divide these rooms blocks the parlor sidewall opening precluding effective natural ventilation (see Figure 1).

Another shortcoming of natural ventilation in most areas of the milking center is the lack of effective control during periods of changing and cold weather. The variance and unreliability in wind speed and direction present special difficulties in maintaining a controlled environment within the parlor area during these periods. Experience has shown that milkers will override temperature based control systems in the winter to prevent unfavorable conditions in the operator's pit. Improved control systems are needed to effectively automate a naturally ventilated parlor during non-summer conditions.

Mechanical Ventilation

Mechanical ventilation is well suited for all areas of a milking center, except possibly for the holding area (mechanical ventilation of the holding area may be employed to overcome shortcomings in an existing or a potentially compromised natural ventilation system). Air circulation fans may be used in the holding area to improve cow comfort during hot weather. Mechanical ventilation is more reliable and controllable than natural ventilation, and can function effectively independent of room partitions.

Mechanical ventilation is the process of using fans or blowers in conjunction with planned air inlets or outlets to provide the desired rates of air exchange and air movement. Three types of mechanical ventilation concepts have been used for milking center ventilation and can be classified as positive, negative, or neutral pressure systems.

Positive Pressure System

A positive pressure system consists of using fans to push fresh air into a room. The fresh air becomes mixed with contaminated room air and is subsequently discharged through air outlets. The air pressure within the ventilated room is above that of outside air. Adequate air distribution can be obtained by using multiple fans for large rooms or by using a single fan that discharges into a properly designed duct with air diffusers. Because the pressure within the room is slightly above outside, room air can penetrate cracks and other imperfections in interior wall liners causing undesired moisture contamination. Therefore, it is especially important to ensure tight building construction with this type of ventilation system.

Negative Pressure System

A negative pressure system exhausts building air to the outside through one or more fans that are usually wall or ceiling mounted or positioned within an insulated air duct. Air enters into the ventilated area through well-designed and managed inlets, mixes with building air, and is discharged. The room pressure with a negative pressure system is less than outside. Care must be taken to ensure that contaminated air is not used as a source of inlet air for a negative pressure system. Therefore, doors and windows that are not part of the designed inlet system need to be closed, especially if they are not on an exterior wall. Negative pressure systems are hard to apply to the milking area of most modern milking centers because of the lack of a wall between the holding area and the milking area. It is undesirable to draw moist holding area air into the milking area, and this may violate standards set forth by the local milking center regulatory agency (*A complete milking center ventilation plan should be provided to the local regulatory agency for their review well before construction is initiated*). However, a negative pressure system can be employed in older milking centers that have a solid wall with doors between the milking and holding areas. For this application, the system is best suited for wintertime application as the doors are typically closed except for when a group of cows is entering or exiting the parlor.

Neutral Pressure System

In a neutral pressure system, the room pressure is approximately the same as outside conditions. Pressure fans and exhaust fans are used to push air into and draw air out of the room, respectively. Well-designed neutral pressure systems can work well to ventilate the milking area of milking centers during periods when minimum ventilation rates are required.

Calculation of Required Ventilation Rates

Determining the required rate of ventilation for each room or zone that makes up the milking center is based on the desired range of conditions to be maintained within the room or zone and how adversely the conditions are impacted by the animals or equipment that occupy the space. Outside temperature is the other variable that needs to be considered in determining ventilation rates for each room or zone. Higher rates of ventilation are needed as outside temperatures increase.

Milking Parlor and Holding Area

Within the milking parlor and holding area, the minimum rate of ventilation is 100 cfm per cow for the wintertime and 1,000 cfm per cow for the summer. An alternative method of calculating minimum required ventilation rate is to provide 15 room air exchanges per hour in the winter and 60 to 90 in the summer. Preferred is to calculate the required air exchanges based on the number of cows occupying each area. The milking area can have relatively large volumes of air relative to number of cows in it while the holding area can have relatively large numbers of cows relative to the volume of air contained within (the ridge height of the holding area can be measurably lower than that of the milking parlor for milking centers that have support rooms located adjacent to the parlor).

Mechanical Room

The summer and winter ventilation rates for the mechanical room are based on the amount of air needed to remove heat generated from mechanical equipment operating within the room. Turner and Chastain (1995) suggest that a minimum of one air exchange rate per minute should be used in the summer, with lower rates possible in the winter. The winter ventilation rate should set so amble amounts of heat are removed to keep the mechanical room temperature within the range specified by the equipment manufacturer without over-cooling the room. System operation in the summer should expel ventilation air to the outside. In the winter, heated air can be transferred to the operator's pit to enhance milker comfort.

Milk Room

The rate of ventilation of the milkroom should be a minimum of 800 cfm (Brugger, 1992). A positive ventilation system is best, as the room will be slightly pressurized thus minimizing infiltration of contaminated air from other areas. Air should be drawn from a fresh air source. Air outlets should be located across the room from the fan and preferably discharge to the outside. Discharging to the outside will preclude the system from being negatively influenced by other positive pressure systems that may be operating at higher static pressures in the milking center.

Basement

Ventilation of the basement area of a milking center is important and should not be overlooked. The basement area is lower in elevation than the other rooms in the milking center. Consequently, it is a natural place for free water to accumulate. Improper building design or imperfections in construction materials and or construction techniques can result in direct pathways for water to follow from the milking area to the basement. This area has significant potential for moisture accumulation and subsequent premature deterioration of building materials without adequate ventilation. A minimum ventilation rate should produce at least 10 room air exchanges per hour. Additional ventilation may be required if high moisture levels are prevalent.

Office and Restroom

These rooms should be ventilated and heated to provide good worker comfort. The ventilation system should provide fresh or conditioned air in the summer. Heat needs to be provided in the winter in many areas and can be incorporated into a ventilation system. The bathroom should have an exhaust fan to remove odor and moisture.

Selection of Fans

Only quality, high efficiency fans should be selected for use in mechanical ventilation systems. Quality fans help ensure reliable performance. Efficient fans save on energy usage although they typically cost more to purchase initially. Payback time can vary based on the number of hours per year the fan is in operation and the cost of electrical power in the given location.

Fan efficiency is determined by comparing the volumetric output (cfm of air) to the electrical input (watts) and is expressed as cfm/watt. For smaller fans (24 inches in diameter or less), efficient fans will have a rating of about 12 cfm/watt when operating against 0.10 inch of static pressure. Larger fans (36 and 48 inches) will have a rating of approximately 17 cfm/watt at 0.10 inch of static pressure (Turner and Chastain, 1995). Selecting a fan that provides the required airflow at 0.10 inches of pressure assures the required air exchange is met. Well-designed systems should operate at less static pressure.

Manufacturer's charts can be used to determine fan efficiency. Also, a summary of fan performance ratings for many fans based on unbiased tests can be obtained from *Agricultural Ventilation Fans, Performance and Efficiencies* (Ford *et al*., undated).

Sizing Air Inlets, Outlets, and Ducts

As air moves past inlets, outlets, and through ducts it meets resistance to flow due to friction and turbulence. A properly designed ventilation system will provide adequate space for air to move past or through with minimal resistance. Higher resistance creates increased static pressure conditions within the area ventilated and decreases effective fan capacities. Positive pressure air ducts are appropriately sized so that one square foot of duct cross-sectional area is provided for each 1,000 cfm of fan capacity. Positive pressure duct discharge air diffusers should have a total area slightly less than the duct cross-sectional area (MWPS-7, 1997). Negative pressure air ducts should be sized to provide one square foot of cross sectional area per 600 cfm fan capacity. Gravity or mechanically operated louvered inlets or outlets should be sized to provide a **net** area of one square foot per 600 cfm fan capacity (MWPS-32, 1990).

Controls

Successful operation of a ventilation system is fully dependent on proper control. Controls can be either manual or automatic. Manual controls require attention by a designated individual(s). System performance can be significantly compromised by the lack of human attention or human error. Automatic controls are more reliable from a day-to-day perspective, but require periodic maintenance to ensure proper operation. For an automated system, good performance is a function of properly locating the sensor providing input to the controller. Sensors should be located in such a manner that they “sense” the air that represents the average condition within the room. Location of temperature sensors should be placed so that they are not effected by solar radiation or intense localized extreme conditions as a result of heat generated by operating equipment.

Neutral Pressure Ventilation

As discussed above, a neutral pressure ventilation system can be effectively used for milking area ventilation during winter conditions. For this ventilation concept to work well, a balance of inlet air and outlet air needs to be provided in order to minimize the flow of contaminated air from the holding area to the milking area. Flow of warm, moist air from the parlor into the holding area is undesirable also. Condensation and fog will be a problem when this air meets the colder air in the holding area.

Figures 1 and 2 show a plan view and cross-sectional view, respectively of a ventilation system for a large milking center with 60 milking stalls. Within the milking area, neutral pressure ventilation is used for winter conditions while a positive pressure system is used for the other times of the year. The following paragraphs describe the design and operation of the system.

Summer Operation

Milking Area and Breezeway

Based on the required summer air exchange rates of 1,000 cfm per stall, a minimum of 60,000 cfm needs to be provided for this area. This is accomplished by placing six 3-foot fans in cupolas located directly above the operator’s pit. The capacity of each fan is approximately 11,000 cfm with a combined capacity of 66,000 cfm. These fans draw outside air through the cupola inlet to pressurize the room forcing heat and moisture out through the holding area. The capacity for each fan can be decreased by adjusting a variable speed controller manually. A decision needs to be made during the design process as to where the controllers are located. They can either be located in the mechanical room, breezeway, or operator’s pit. Locating the controllers in the mechanical room minimizes wiring and makes them less apt to be adjusted; locating them in the breezeway risks that employees that don’t understand how the system is intended to operate will adjust them.

Mechanical Room

The mechanical room is ventilated in the summer by a negative pressure system. Wall mounted exhaust fans are located at one end of the mechanical room and louvered wall inlets are mounted at the far end of an adjacent sidewall. This layout provides airflow longitudinally through the room. Outside air is drawn past the compressor units and other mechanical equipment to remove excess heat and is subsequently discharged. A centrally mounted thermostat is used in conjunction with a stage controller to control the exhaust fans.

Milk Room

A small 9 or 14 inch positive pressure fan is sufficient to meet the 800 cfm minimum ventilation requirement. The fan is located on the common wall between the mechanical room and milk room with mechanical room air used as inlet air. A hooded outlet should be mounted on the exterior wall to minimize the effects of wind pressure.

Basement

Ventilation in the basement area during the summer is accomplished by placing two 14-inch negative pressure fans that discharge into the breezeway at the head of the basement. With an approximate capacity of 1,750 cfm for each fan, the total capacity is about 3,500 cfm. Outside air is used as a supply source and is drawn into the basement at the opposite end from the fans via two buried ducts. Each duct is sized to handle 1,750 cfm of air. Based on providing a minimum of one sq. ft. for each 600 cfm of fan capacity for a negative system, the minimum duct cross-sectional area should be 3 sq. ft.

<u>Winter Operation</u>

Milking Area and Breezeway

Recommendations for winter air exchange rates for this combined area is to provide a minimum of 100 cfm fan capacity per stall. For 60 stalls, a capacity of 6,000 cfm is needed. By reversing the rotational direction of two of the three-foot cupola fans, a neutral pressure system is approached. Tests performed by University of Illinois, Department of Agricultural Engineering, Bioenvironmental and Structural Systems Lab show that the fan capacity of one particular manufacturer’s 3 foot fan is approximately 43 percent of the normal capacity when operating in the reversed direction against 0.05 inch static pressure (unpublished data, 1997). Two fans operating in this fashion provide a total capacity of about 9,460 cfm. Positive pressure heat transfer fans are used to supply air in order to assist with balancing the system and are located in the mechanical room. The two 16” fans with individual capacities of 2,800 cfm each are chosen to transfer heated air directly to the operator’s pit via a duct located under the cow deck. Another fan located inside a forced-air furnace, supplies heated air at about the same rate to the basement. Basement air discharges through the same louvers used for summer ventilation and contributes to system equilibrium. Adding the total positive pressure fan capacities for these three fans provides approximately 8,400 cfm of air to the milking area. From a theoretical standpoint, the system is slightly out of balance. However, given the inherent variance present with such a system and the need to select from fan sizes available on the market, the system can be considered to be neutrally balanced. The control for the burner component of the furnace can be located in the operator’s pit so additional heat can be delivered during extreme outside temperatures. Controls for the heat transfer fans should be located in the mechanical room.

Mechanical Room

As in the summer, the mechanical room is ventilated in the winter by a negative system. However, in the winter, ceiling mounted counter balance inlets provides a source of air from the attic. Vented soffit material with sufficient effective opening is required to allow air to enter the attic space for the ceiling inlets to function properly. The number of ceiling inlets required is based on providing sufficient air to satisfy the requirements of the heat transfer and furnace fans (which in turn are sized as discussed above based on heat generated by equipment operating). Inlet air needs to mix well with room air before it is subsequently transferred to the operator's pit. The ducts to transfer air to the operator's pit need to be at least 2.8 sq. ft. based on providing one sq. ft. per 1,000 cfm capacity.

Milk Room

Ventilation of the milk room in the winter is the same as in the summer.

Basement

Winter ventilation in the basement is no more than using it as an air plenum to transfer heated air from the mechanical room furnace fan to the breezeway. Under normal winter conditions, the furnace burner will not be needed and its fan will be used to assist with heat transfer from the mechanical room. Discharging this air in the breezeway helps to minimize condensation of the architectural windows that are becoming more and more prevalent in new milking centers. The air ducts that supply summer air to the basement are capped during the winter to prevent entrance of cold air.

Summary

Effective milking center ventilation is needed to provide comfortable conditions for the operator and the cows alike. Likewise, proper ventilation can help to prevent premature deterioration of building materials and equipment. Milking center designers need to be aware of the need for proper ventilation and incorporate its design into the overall design process. Natural or mechanical ventilation can be used to ventilate milking centers. Mechanical ventilation has advantages over natural ventilation for this application. Control of mechanical ventilation is more reliable and better suited to maintain a quality environment within a milking center. A positive ventilation system is preferred for summer conditions and was presented in this paper. To meet minimum ventilation requirements in the winter, a neutral system that is balanced between positive pressure heat transfer fans located in the mechanical room with reversed cupola fans was discussed. This system seems to be working well in practice.

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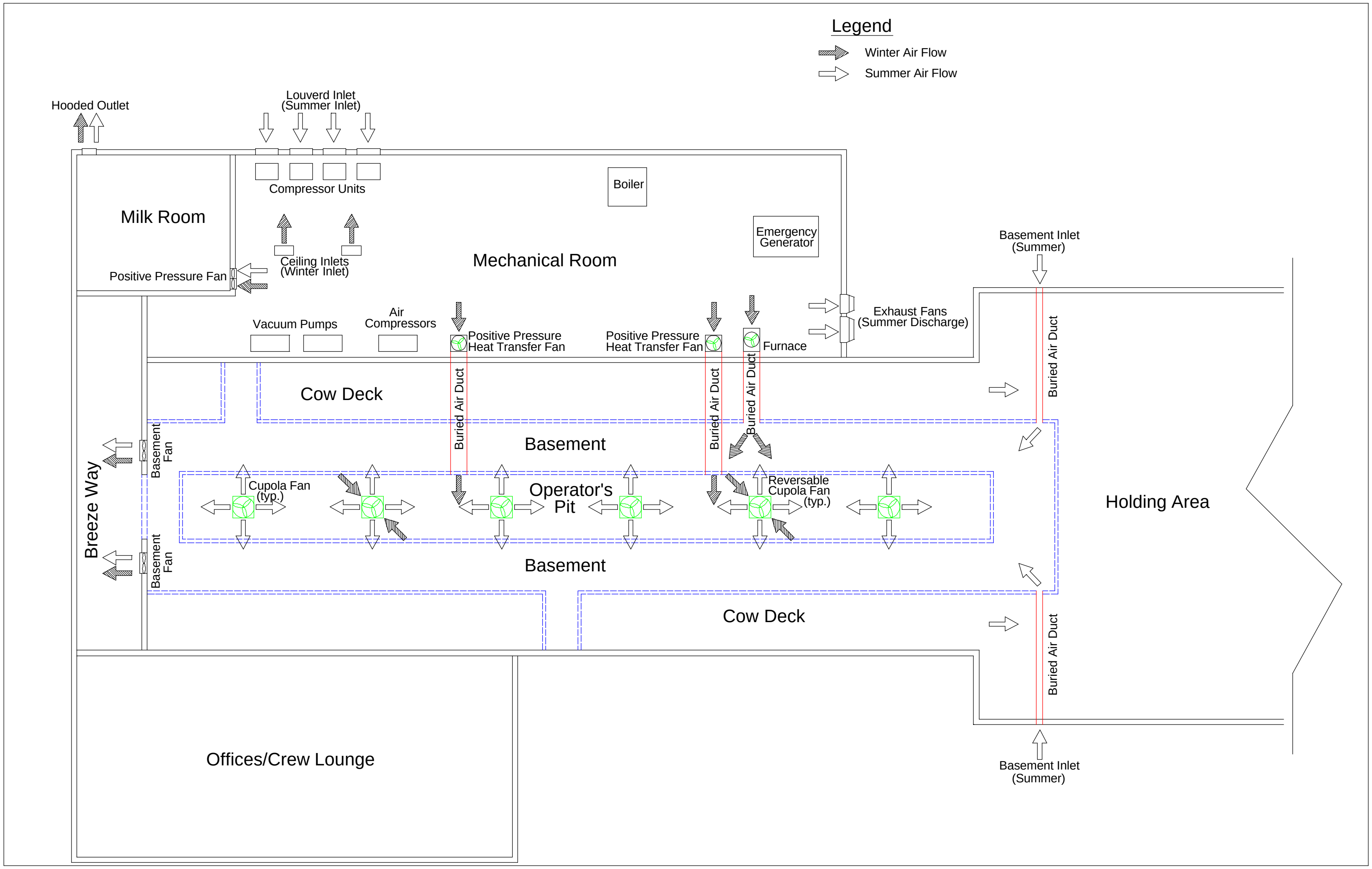

Figure 1. Plan View of Positive Pressure Summer and Neutral Pressure Winter Ventilation Systems for a Modern Milking Center.

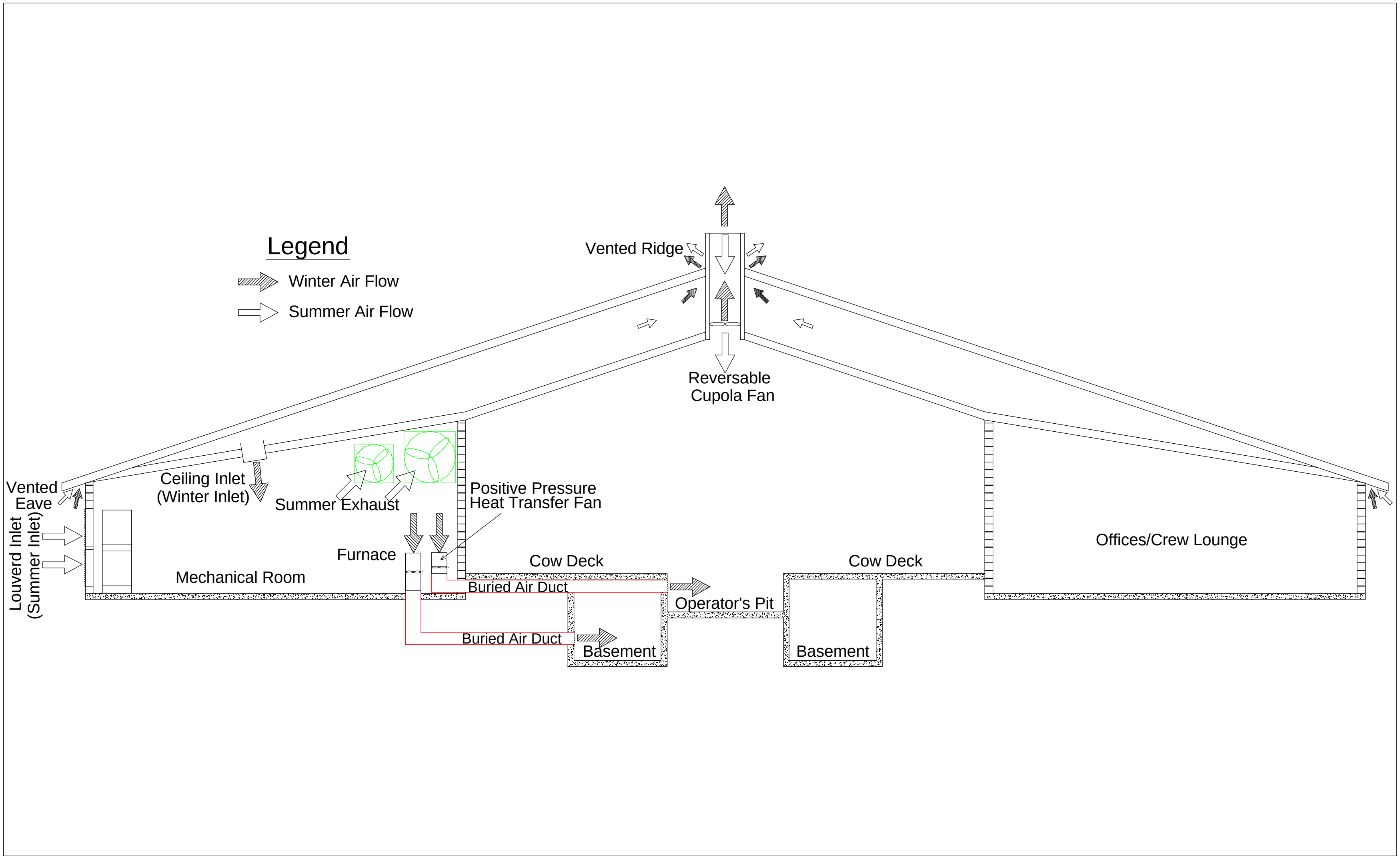

Figure 2. Cross-Sectional View of Positive Pressure Summer and Neutral Pressure Winter Ventilation Systems for a Modern Milking Center.