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A quality environment within a milking center requires a properly designed, installed, managed, and maintained environmental management system. The objective of a milking center environmental management system is to economically moderate the temperature, relative humidity, odors, and gas levels so a comfortable range is maintained for both the operator and the cow. Standard components of an environmental management system typically include a ventilation system, a cooling system, and a heating system.

Within the milking area, cows and milking personnel interface. Each occupant prefers different environmental conditions based on their respective thermal-neutral comfort zones. Cows are in an ideal environment from a temperature standpoint when we are cold. For this reason, the design and operational management of an environmental system for a milking center offers a unique challenge. Additionally, the environments within the holding area and milking area are vastly different from those within the milk storage room, mechanical room, basement, employee support room, office, bathroom, and storage room. Each areas need to be properly controlled. A quality design accommodates the individual needs of each room or area and integrates them when possible to enhance overall system performance.

The need for milking center environmental management typically receives minimal attention during the design process. The location of individual rooms within the milking center affects environmental management 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 an environmental management system into an existing milking center almost always results in shortcomings in effectiveness and efficiency.

The need to provide proper environmental management becomes more and more important as milking centers become larger and larger, and as they approach continuous round-the-clock operation. Operator comfort and efficiency can be improved by providing proper working conditions. A comfortable environment will enhance worker productivity and increase job satisfaction.

Temperature, humidity, odors, and gases influence the productivity, comfort, and well being of cows and operators alike.

Proper ventilation is a major component in the creation of a quality work environment for operators and cows. Proper ventilation is also important to maintain milk quality. Poor ventilation leads to stale, odorous air, which can taint milk (Cassidy *et al*., 1987). Adequate ventilation helps to prevent premature deterioration of building components 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. Also, electrical wiring and equipment will better withstand a ventilated environment.

The objective of a milking center ventilation system is to provide adequate during all seasons. is the simple process of: 1) bringing fresh outside air into a structure through planned openings, 2) thoroughly mixing fresh air with inside air to pick up heat, moisture, and air contaminants, and 3) exhausting moist, contaminated air from the building.

The rate of air exchange needed depends 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 to remove moisture during the winter, provide adequate air exchange and air movement in the summer, and work effectively to satisfy both requirements in transitional seasons.

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. The ventilation system must respond to changing indoor as well as outdoor conditions. In the milking area, 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 from one system to the other, usually done manually. But the result is a more satisfactory environment for workers and cows the majority of the time.

For milking centers the 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 a natural or a mechanical ventilation system, 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 areas of a milking center.

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 through the sidewall and up and out through a peak opening (thermal buoyancy effect). Natural ventilation works well for dairy housing applications when the building's longitudinal axis is oriented perpendicular to the prevailing winds and adequate sidewall, endwall, and ridge openings are provided.

Within the milking center, the primary area that lends itself well to natural ventilation is the holding area. Open-curtain sidewalls with a minimum height of approximately 12 ft. exposes the holding area to the outside. However, support rooms (mechanical rooms, offices, milk room, and storage areas) located adjacent to the parlor preclude natural ventilation by blocking sidewall openings from the outside (see Figure 2).

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 natural ventilation 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 system during non-summer conditions.

Mechanical ventilation is well suited for all areas of a milking center, except for the holding area. (Mechanical ventilation of the holding area may be employed to overcome shortcomings in an existing or a potentially compromised new natural ventilation system.) 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 ductwork and 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, and 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 slightly above that of outside air. Air can be disributed 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 greater than 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 is drawn into the ventilated area through well-designed and managed inlets, mixed with building air, and subsequently discharged. The room pressure with a negative pressure system is slightly less than outside. Care must be taken to ensure that contaminated air is not used as a source of inlet air. 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 not well suited for 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 its review well before construction begins.*** 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. This system is best suited for wintertime application since the doors are typically closed except for the time 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.

Required Ventilation Rates

The required rate of ventilation for each room or zone that makes up the milking center is based on two factors: 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. Higher rates of ventilation are needed as outside temperatures increase.

Milking Parlor and Holding Area

Within the milking parlor and holding area, the minimum recommended ventilation rate is 100 cfm per cow for the wintertime and 1,000 cfm per cow for the summer. An alternative method of calculating minimum required rates that is sometimes suggested is to provide 15 room air exchanges per hour in the winter and 60 to 90 in the summer. The first method, based on the number of cows occupying an area, is the preferred method. The milking area can have a large volume of air relative to the number of cows in it, while the holding area may have a large number 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 excess heat generated from mechanical equipment (milk cooling equipment, vacuum pumps, boilers, etc.) operating within the room. Turner and Chastain (1995) suggest that a minimum of one room air exchange rate per minute should be used in the summer, with lower rates possible in the winter. The winter ventilation rate should be set so ample amounts of heat are removed to keep the mechanical room equipment temperature within the operating range specified by the equipment manufacturer without over-cooling the room. In the winter, heated air can be transferred to the operator’s pit to enhance milker comfort. In the summer, ventilation air should be discharged outside.

Milk Room

The ventilation rate of the milkroom should be a minimum of 800 cfm (Brugger, 1992). A positive pressure ventilation system is recommended to minimize infiltration of contaminated air from other areas. Air should come 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 adjacent areas.

Basement

Ventilation of the basement area is important and should not be overlooked. Since the basement is lower in elevation than the other rooms in the milking center, it is a natural place for free water to accumulate. Improper building design, imperfections in construction materials or faulty construction techniques can result in direct pathways for water to flow from the milking area to the basement. Without adequate ventilation, this area has significant potential for moisture accumulation and subsequent premature deterioration of building materials. 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, Employee Support Room, and Restroom

These areas should be ventilated and heated to ensure 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 use, although they typically cost more to purchase. Payback time can vary based on the number of hours per year the fans operate and the cost of electrical power in a 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.

Manufacturers' 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 (negative system only) and decreases effective fan capacity (both negative and positive systems). Positive and negative pressure air ducts are appropriately sized so that approximately one square foot of duct cross-sectional area is provided for each 600 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). Gravity or mechanically operated louvered inlets or outlets should be sized to provide a area of one square foot per 600 cfm fan capacity (MWPS-32, 1990).

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 day to day, but require scheduled preventative maintenance to ensure proper operation. For an automated system, good performance is in large part a function of properly locating the sensor providing input to the controller. Sensors should be located so they "sense" the air that represents the average condition within the room. Temperature sensors should be placed so that they are not affected by solar radiation or localized extreme conditions.

In most areas of the United States and Canada, a wintertime heating system is required to prevent equipment and water supply lines from freezing. A heating system also enhances operator comfort. The best heating system is one that is effective, reliable, responsive to changing weather conditions, cost competitive to install and operate, and is energy efficient.

An optimum energy efficient system will utilize the excess heat produced by milk harvesting and cooling equipment (located in the mechanical room) as a heat source for other areas within the milking center. Heat is produced during milk cooling. This heat comes from the electricity used to operate the compressor and the heat removed from the milk. Additionally, vacuum pumps, boilers, air compressors, and lights produce heat during operation. A good portion of the mechanical room waste heat can be transferred to other areas by either a forced air or a hot water system.

The objective of heating the operator's pit is to supplement the pit heating requirements as needed so a comfortable working temperature is provided for the operator. The operator's pit can be efficiently heated by a forced air system that relies on the waste heat from the mechanical room as the primary heat source. Air used to transfer the heat to the pit is part of the ventilation system in a well designed environmental control plan. In extreme cases, a furnace or hot water heat exchanger (hot water supplied by the boiler used for heating milking system wash water) can be used to provide supplemental heating of the forced air system. Ductwork should be located so air diffusers discharge air low in the operator's pit sidewall. This type of system is best installed as part of original construction since air ducts need to be run beneath the cow decks.

The heating of offices, bathrooms, employee support rooms, and storage areas can be provided by a heating, ventilation, and air conditioning (HVAC) system.

<u>Other Methods</u>

Radiant heating can be used to warm the operator in a parlor without maintaining a high air temperature in the area. Radiant heaters are available in electric or gas-fired models. The required heater size and configuration will vary according to specific parlor layout and the spatial characteristics of the milking stalls. Radiant heaters should be sized to provide approximately 85-120 Btu/hr per ft^2 of pit area (Turner and Chastain, 1995). Radiant heaters generally are best located over the pit area so that heat is directed towards the hands of the operator when milking units are attached and detached. Adequate clearance between the heater unit and people, cows, and combustibles must be ensured. Check with the manufacturer for the minimum distance requirements for their product.

Gas-fired radiant heaters can be either vented to the outside or non-vented. Non-vented models rely on room air ventilation to remove combustion gases. A minimum rate of room air ventilation based on heat output is usually specified. In most cases, if the minimum air exchange rate per cow is provided in the winter, sufficient room ventilation will exist for non-vented heaters. Again, be sure to follow the information provided by the manufacturer.

In-floor heating is sometimes used to heat the operator's pit. Though floor heat is one of the most costly forms of heat both in terms of capital and operating costs (Turner and Chastain, 1995), it is attractive to many because cold feet is a major complaint of operators who have worked in a poorly heated parlor. To warm the floor, high resistance electrical wiring or hot water pipes are located within the concrete cross section. Floor heat systems are slow to respond to control adjustments due to the heat-sink-like properties of concrete. A timer wired in series with a thermostat can be used to start warming the floor prior to the onset of milking. Turner and Chastain (1995) and MWPS-34 *Heating, Cooling and Tempering Air for Livestock Housing* provide design information for in-floor heating systems.

Summer heat can present an uncomfortable working environment for cows and operators alike in a milking center. Air temperature, moisture, and velocity coupled with solar radiation are variables that act together to determine the net level of heat stress experienced.

Steps can be taken in each area of the milking center to provide various degrees of relief. Air conditioning is one option to consider for offices, bathrooms, and employee support areas. Producers interested in exploring this option are advised to work with a reputable designer, supplier, and installer of air conditioning systems to determine the size and layout that best suit their particular situation.

This section of the paper will focus on measures to provide heat stress relief in the holding area and milking area. Air conditioning of these areas is not practical due to the cost to purchase and operate an appropriately sized system. The severity of heat stress can be decreased by providing air movement past the cow and further by coupling air movement with evaporative cooling.

Research has shown that heat stress can be decreased or sometimes even alleviated by directing airflow past cows' bodies at a speed between 400 to 600 feet per minute, if adequate air exchange already takes place (Shearer *et al*., 1991). Thus, positioning of fans is critical to ensure the target air velocity is achieved over each cow's body.

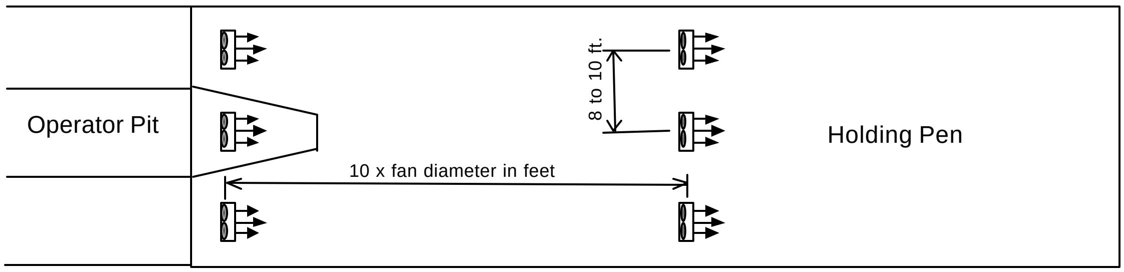
Holding Area

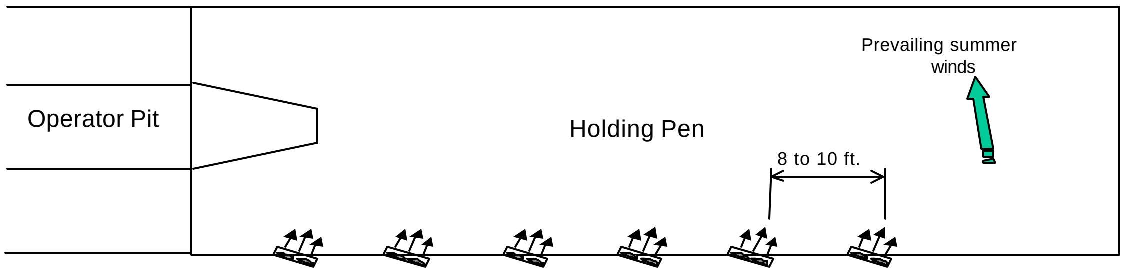
When reviewing all of the cow-frequented areas on the farm where fans are required as part of an overall heat stress management plan, it is generally recommended that the holding area be outfitted with cooling fans first.

Cooling fans should ideally be positioned in a holding area to direct air away from the parlor, as shown in Figure 1a. When limited vertical space does not allow for placement of fans over the cows, locate fans along the sidewall to blow laterally across the pen in the direction of prevailing summer wind, as shown in Figure 1b. Do not blow air from the holding area into the parlor since this can be unsanitary and moves hot, humid air into the milking area.

Milking Area

The primary objective in the milking area is to keep the operator comfortable and working efficiently. Operator cooling fans should be located to provide reasonably uniform air movement over the entire pit area. Fans can be mounted to the ceiling or to milking stalls. In long pits, more smaller fans are preferred over less larger fans.





In geographic regions were many heat stress days are present every year, it is advantageous to locate cow cooling fans above the milking stalls. These fans should be oriented to blow air parallel to the operator's pit over the cows' backs. Fans should be spaced in a row, with the spacing no more than 10 times their blade diameter. Stalls that have a lot of support framework may require significantly more fans since the effective air throw from fans may be decreased.

Providing substantial air movement over a cow's body does not always offer her complete heat stress relief. Additional relief can take place by evaporative cooling. Evaporative cooling is the process of using heat to change water from a liquid phase to a vapor phase. The heat consumed during the state change results in a temperature reduction.

Evaporative cooling can be employed to cool a cow in two distinctly different ways. The first method cools the air that surrounds the cow and in turn offers her relief by removing heat via convective heat transfer. Both misting and fogging systems are examples of this method. Misters and foggers require high water pressure so introduced moisture is effectively evaporated. Mister or fogger nozzles are generally attached to the fan in a ring orientation to evaporate the pressurized water discharge into the air stream and cool the air.

Alternatively, the cow is cooled directly by saturating the hair coat on her back and upper flanks with water and subsequently allowing it to evaporate. Sprinkler systems used in conjunction with cooling fans are an example of direct cooling.

The best method of evaporative cooling depends on several factors. Local climatic conditions, the design of the facility, the availability of water, and the time and willingness of the manager to ensure that system adjustment and maintenance are performed as scheduled are all variables that need to considered.

Ambient Air Conditions Effect Cooling

The major factor that generally determines which method of evaporative cooling to use is geographic location. Location influences the predominate condition or state of the ambient air that is present during the summer months.

In the Southwest, where summer conditions are hot and dry, evaporative cooling of the air is used successfully to cool cows. Significant air temperature reductions have been reported with well-designed systems.

However, in the Northeast, summer conditions are typically hot and humid. Humid conditions make it hard to cool the air by evaporative cooling because the air already has relatively high levels of moisture vapor (high humidity). Primarily for this reason, the application of sprinkler systems used in conjunction with fans to direct cool cows offers an advantage. Ambient humidity has little effect on cooling by this method because fans force large volumes of air past the cows.

Sprinkling and Fan Cooling

Sprinkler systems can provide effective heat stress relief when an effective ventilation system is in place. The extra moisture generated by the evaporative system must be removed by in order to maintain a quality environment. Additionally, the holding area must be appropriately outfitted with fans as described above for a sprinkling system to be effective. In hot, humid conditions, sprinklers alone will not effectively cool cows.

Cow sprinkling systems are designed to operate at low water pressures, about 10 psi. Low water pressure results in large water droplets that will effectively soak a cow's hair coat to the skin. After the hair coat is soaked, the water is allowed to evaporate until such time application of water is again required. Fans located throughout the sprinkling area help in the evaporation process by quickly removing water just evaporated off of the cow's skin.

Caution should be used to ensure that the hair coat is soaked and not merely covered with a light mist. Application of a light mist results in the outer portion of the hair coat only covered, creating an insulating layer which will impede heat loss from the cow. Conversely, over application is a waste of water and can possibly be counter effective if the udder becomes wet. Target rates of application are to apply 0.05 inches of water in 0.5- to 3-minute time intervals during a 15-minute cycle. Additional design information is available from Bray et al., 1994.

Direct solar radiation is not significant in most milking centers because materials used for construction provide protection from the summer sun. Solar heat gain is generally negligible in well-ventilated structures that have reflective roof material. Significant solar heat gain can happen when transparent materials are used as cladding. Measures are needed ensure that cows and operators are kept comfortable in these structures.

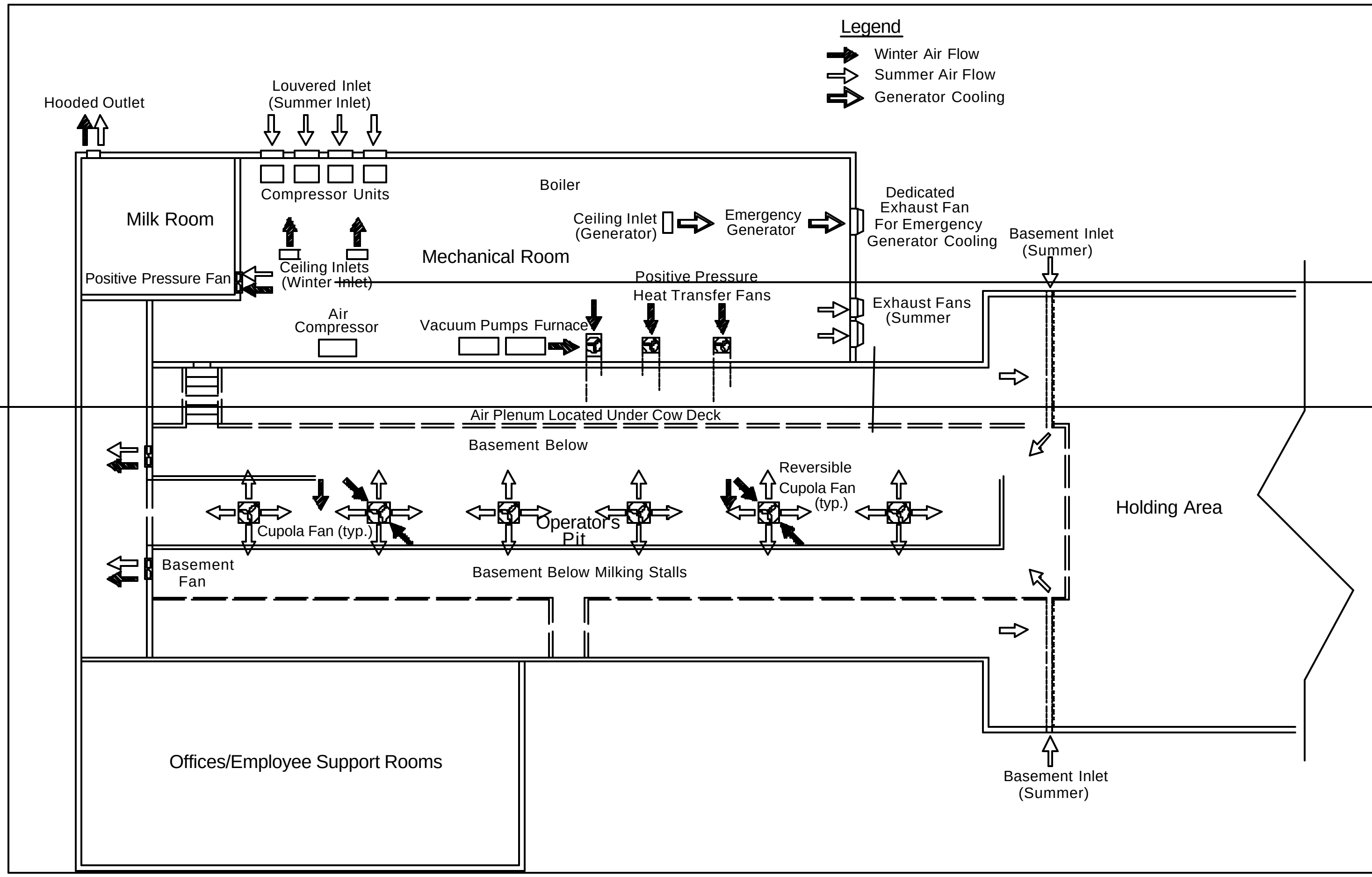
As discussed above, a neutral pressure ventilation system can be effectively used for milking area ventilation during winter conditions. For this ventilation concept to work well, a balance between inlet air and outlet air needs to be maintained. This balance will minimize the flow of contaminated air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

Figures 2 and 3 show a plan view and cross-sectional view, respectively, of a ventilation system for a double-30 milking center. Within the milking area, neutral pressure ventilation is used for winter conditions. A positive pressure system is used for the other times of the year. The following paragraphs describe the design and operation of the system. Refer to Figures 2 and 3 for each area discussed below to locate positioning of fans, ducts, inlets, and outlets.

<u>Summer Operation</u>

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 (1,000 cfm per stall x 60 stalls). This is accomplished by placing six 3-ft. fans in cupolas located directly above the operator's pit. The capacity of each fan is approximately 11,000 cfm at 1/8 in. static pressure 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. (All doors to other areas are kept closed.) Manual adjustment of a variable speed controller is used to decrease the capacity of each fan as needed during milder conditions. A


Legend
Winter Air Flow
Summer Air Flow
Generator Cooling
Hooded Outlet
Louvered Inlet
(Summer Inlet)
Compressor Units
Boiler
Milk Room
Ceiling Inlet
(Generator)
Emergency
Generator
Dedicated
Exhaust Fan
For Emergency
Generator Cooling
Basement Inlet
(Summer)
Mechanical Room
Ceiling Inlets
(Winter Inlet)
Positive Pressure Fan
Positive Pressure
Heat Transfer Fans
Exhaust Fans
(Summer
Air
Compressor
Vacuum Pumps
Furnace
Air Plenum Located Under Cow Deck
Basement Below
Reversible
Cupola Fan
(typ.)
Holding Area
Cupola Fan (typ.)
Operator's
Pit
Basement
Fan
Basement Below Milking Stalls
Offices/Employee Support Rooms
Basement Inlet
(Summer)

way

B r e e z e -

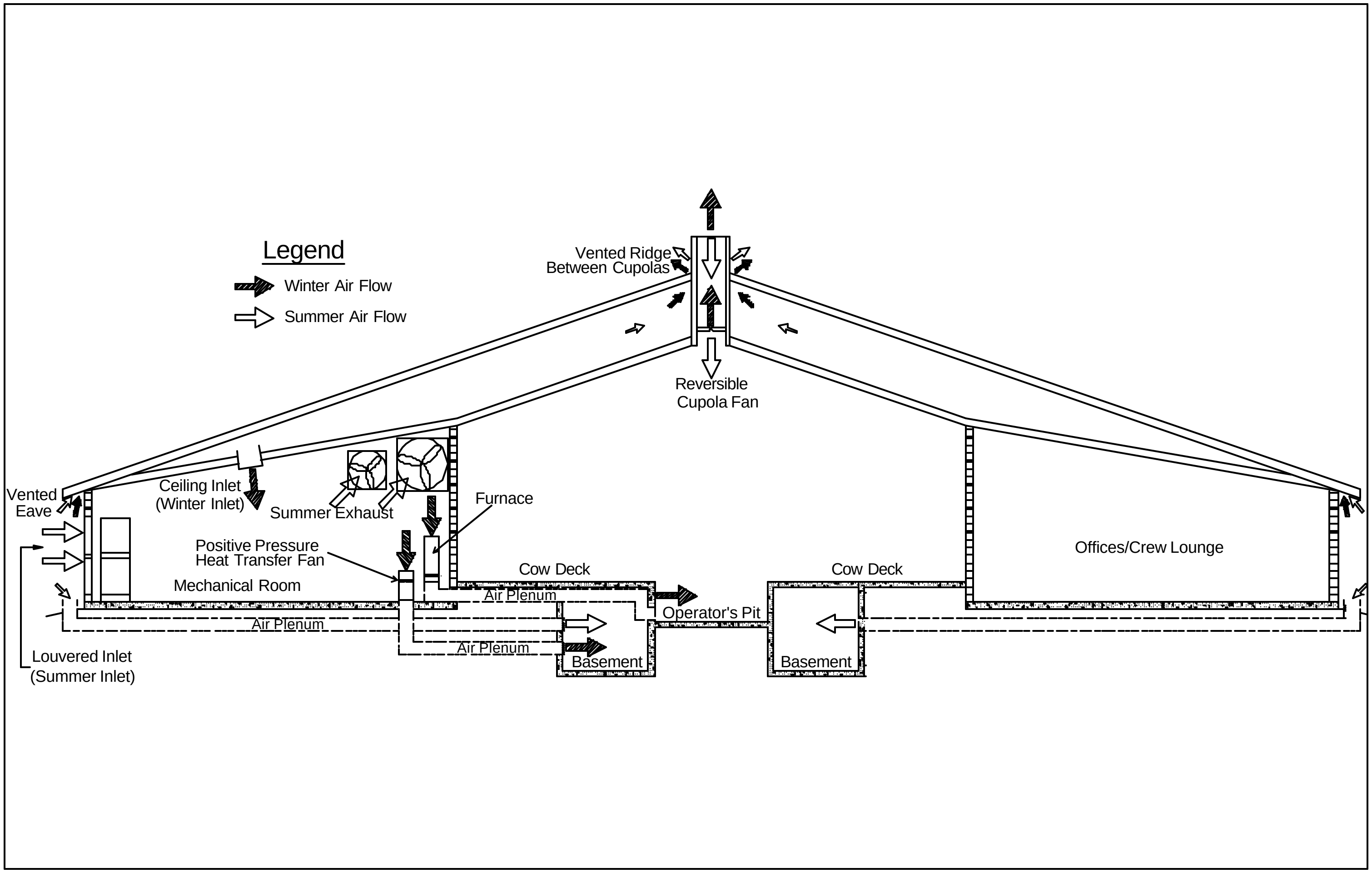


Figure 3. Cross-sectional view of positive pressure (Summer) and neutral pressure (Winter) ventilation systems for a modern milking center.

decision needs to be made during the design process on where to locate the controllers. 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 or operator's pit makes them more accessible, but risks incorrect adjustment by employees who do not understand or have not been educated on the system’s operation.

Holding Area

The holding area is ideally ventilated utilizing natural ventilation throughout the year. High curtain sidewalls that allow for maximum opening are recommended. Curtains should open from the top down so cold air does not cause a drafty condition during periods of minimum ventilation. Large ridge openings are recommended to allow for the escape of warm, moist air. Provide a minimum of 2 inches of clear opening per 10 feet of building width with 3 inches preferred. Orient the ridge of the holding area so it is perpendicular to the prevailing summer winds. This orientation will provide the best air exchange potential by maximizing inlet area, minimizing the distance air has to travel to leave the holding area, and enhances ventilation at the ridge. Siting the milking center on high ground without obstruction provides the best exposure to winds needed for proper ventilation.

The holding area can also be mechanically ventilated if needed due to the lack of poor natural ventilation. Cupola and/or sidewall fans that transfer outside air to the holding area can be used to provide ventilation air. Tunnel ventilation can also be used if adequate endwall opening can be made available (see Gooch and Timmons for information on tunnel ventilation).

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 then discharged. A centrally mounted thermostat is used in conjunction with a stage controller to control the exhaust fans.

Milk Room

A small 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 an air supply. 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 air ducts. (The basement access door must be closed to prevent short-circuiting of the system.) 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, the minimum duct cross-sectional area should be 3 sq. ft for each duct.

Office, Employee Support Room, and Restrooms

These areas are all environmentally controlled with a HVAC system during all seasons. The air conditioning system can be used as needed to provide cooling in some or all of the rooms.

<u>Winter Operation</u>

Milking Area, Breezeway, and Basement

A minimum wintertime air exchange rate for the milking area and breezeway is 100 cfm of fan capacity per milking stall. For 60 stalls, a capacity of 6,000 cfm at 1/8 in. static pressure is needed. By reversing the rotational direction of two of the 3-ft. diameter cupola fans (so they become exhaust fans) and supplying forced air from other sources, a neutral pressure system can be established. Tests performed by University of Illinois, Department of Agricultural Engineering, Bioenvironmental and Structural Systems Lab found 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 cupola fans operating in this fashion provide a total capacity of about 9,460 cfm, exceeding the minimum ventilation requirement.

Fans used to transfer waste and supplemental heat from the mechanical room to the operator's pit and basement are used to balance the system. A positive pressure waste heat transfer fan (capacity of 2,800 cfm at 1/8 in. static pressure) is located in the mechanical room to provide heated air and ventilation to the basement. Basement air is discharged into the breezeway by the same set of fans used for summer ventilation and contributes to system equilibrium. Discharging this air in the breezeway helps to minimize condensation of architectural windows that are becoming more prevalent in many new milking centers. The air ducts that supply summer air to the basement are capped during the winter to prevent entrance of cold air.

A second positive pressure waste heat transfer fan of equal capacity is used to provide heat and ventilating air to the operator's pit via an air duct system located under the cow deck. A third fan of similar capacity is located inside a forced-air furnace to supply waste heat and supplemental heat (when needed) to the operator's pit. Under normal winter conditions in much of the United States, the furnace's heating unit will not be needed in facilities where milking is performed around the clock.

These three fans supply a total of approximately 8,400 cfm of air to the milking area. From a theoretical standpoint, the system is slightly out of balance (8,400 cfm to 9,460 cfm). However, given the inherent variance present with such a system and the need to select from fan sizes available on the market, the system is considered to be neutrally balanced. Fine system adjustment can be achieved by manipulating the speed of the reversed cupola fans.

The control for the heater component of the furnace can be located in the operator's pit so supplemental heat can be delivered on operator demand 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 inlet air from the attic. Vented soffit material with sufficient effective opening is required to allow outside air to enter the attic space in order 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. These are, in turn, sized as discussed above based on heat generated by operating equipment. Inlet air needs to mix well with room air before it is transferred to the operator's pit. The ducts to transfer air to the operator's pit need to be at least 9.3 sq. ft. based on providing 1 sq. ft. per 600 cfm capacity (5,600 cfm/600 cfm per sq. ft.).

Milk Room

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

An effective milking center environmental management system is needed to provide comfortable conditions for the operator and the cows alike. Proper ventilation can also help to prevent premature deterioration of building materials and equipment. Milking center designers should be aware of the need for proper environmental management and incorporate its design into the overall design process.

Natural or mechanical ventilation can be used to ventilate areas within the milking centers. Mechanical ventilation of the milking area has advantages over natural ventilation as it can be more readily controlled and interfaced with a heating system. Control of mechanical ventilation is more reliable and better suited to maintain a quality environment. 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 is reported to work well in practice.

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