Ventilation in Dairy Production

Alberta
Government

Introduction

On average, 15% of the electricity consumption in a dairy operation is attributed to ventilation (Figure 1). This equates to 16,650 kWh for a 100 cow dairy.

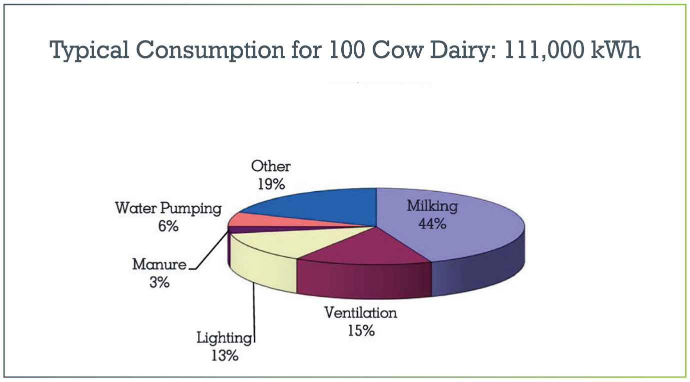

Figure 1. Electricity Usage and Distribution

Assuming the cost of electricity is $0.10 per kWh, this equates to $1,665 per year. Electricity prices over the last five years have been unpredictable ranging from $0.06 to $0.15 per kWh (Figure 2). This equates to a range of $999 to $2,498 per year for a 100 cow dairy.

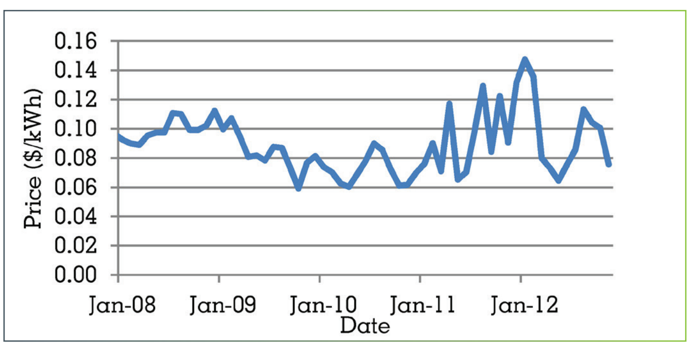

Figure 2. Alberta Price for Electricity from 2008 to 2012
Source: Alberta Agriculture and Rural Development

Ventilation systems for confined dairy facilities are used to maintain desirable environmental conditions inside the barns. There are usually two types of ventilation, natural and mechanical. As dairy cattle can withstand high temperature fluctuations without affecting their performance, many dairy barns use natural ventilation systems. However, mechanical ventilation systems (Figure 3) can be used in these facilities as well.

Unlike natural ventilation systems, mechanical ventilation systems consume energy. Based on the techniques used, a number of different mechanical ventilation systems are commercially available. In barn settings, proper design, sizing, control selections, locations, modifications and maintenance can make a significance difference in energy consumption and reduce the operating costs.

Figure 3. Mechanical Ventilation on Livestock Barn
Source: www.jdmfg.com

Animal Requirements

Proper sizing of fans is important to meet the optimal environmental requirements. Summer and winter design temperatures are usually considered in sizing the fans. Winter ventilation rates are considerably lower than the summer ventilation rates. Winter design temperatures are used to determine the minimum ventilation requirements while summer design temperatures are used to determine maximum ventilation requirements. Moisture removal is the primary function of ventilation in winter and heat removal is the primary function of ventilation in summer.

Table 1 shows the parameters and their recommended minimum and maximum ventilation levels for a dairy operation. In general, mature dairy cows do not show significant reduction in the performance when there are wide fluctuations in the environmental conditions. A small loss in milk yield occurs when the temperature and humidity range are between 2 - 24°C and 40 - 80%. Increase in feed consumption occurs when the temperature drops below 10°C to compensate for the heat losses.

Table 1. Minimum and Maximum Ventilation for Dairy Barns

Cattle Type	Winter (ft^3/min per Animal)	Mild Weather (ft^3/min per Animal)	Summer (ft^3/min per Animal)
Calves (0 - 2 months)	15	50	100
Heifers (2 - 12 months)	20	60	130
(12 - 24 months)	30	80	180
Cows (1,400 lb)	50	170	470

Source: Midwest Plan Service

Applicable Technology

There are a number of industrial ventilation systems available commercially. Figure 4 shows exhaust fans typically used in livestock barn ventilation systems. They are categorized based on the pressure, speed and frequency. Choosing a suitable type of ventilation systems for a particular application is very important in saving energy costs.

Positive pressure systems force air into the building. This type of system needs to have a filter to make sure the incoming air is of good quality. Twenty to 30% of the energy used by fans is rejected as heat into the building which is advantageous during winter and disadvantageous during summer. If the air is humid, moisture may condense on walls and equipment.

Negative pressure systems force air outside from the building. Negative pressure systems need to have allowances for reduced fan efficiency as dust accumulation on fan blades is unavoidable. These fans may also get exposed to ammonia, corrosive gases, dust, high humidity etc. At low air flow rates, negative pressure systems will not provide uniform air distribution. There are systems available to capture heat from the air that is being exhausted to the atmosphere. These heat recovery systems are mostly used in modern commercial type and big residential buildings.

Multi speed fans are usually equipped to have two speeds. The lower speed is 60% of the full speed. Small fans can be equipped to have 5 different speeds.

Intermittent fans are controlled by a timer or a thermostat so that they operate at certain times during a period. Fans should be sized to operate at least 50% of the time with frequent cycles.

Variable speed fans can be adjusted down to 10% of the full fan speed. Speed is regulated by varying the root mean square (RMS) voltage or frequency to the motor by a variable transformer or a solid state control. A variable speed fan can be more efficient than the ones with either on/off or multi speed control (Teitel 2008). Typically the speed is varied as a function of barn moisture and temperature. Variable speed ventilation systems adjust their speed as needed and maintain the desirable barn conditions more accurately with optimal energy consumption.

Figure 4. Typical Fans Used in Livestock Barns

Factors Affecting Ventilation Efficiency

Factors affecting ventilation efficiency are motor type; construction material; fan drive (direct coupled or belt driven); fan housing; using shutters, guards, cones and deflectors; inlet and exhaust location and size; thermostat location and maintenance. Installing discharge cones or wind hood deflectors can increase the efficiency up to 15%. Exhausting against the prevailing wind situation is not desirable. The recommended location of the thermostat is near the exhaust fan, especially when the operating temperature is equal or below the thermostat's final settings. Keeping the fan in good condition through maintenance is very important for reducing energy costs. Poor maintenance can reduce the fan efficiency by 50% or more. Ventilation fans should be inspected periodically to remove the dust built up on the fan and motors should be serviced regularly.

Ventilation rates can affect the temperature and humidity levels in the barn. Therefore, using appropriate monitors and controllers may optimize the ventilation rates, increase animal performance and reduce energy consumption. Related items such as timers, thermostats, variable speed drive controls, humidity controllers, etc. are commercially available. Installing such monitoring and controlling equipment will help maintain desirable barn conditions.

Table 2 has performance targets for different fan sizes with and without cones. VER 10 is the ventilating efficiency expressed in ft^3/min/W at 0.10 inch water column (w.c.) static pressure. Exhaust fans in barns usually operate at negative 0.10 inch w.c. static pressure. This can change depending on the design of the facility as well as the maintenance issues such as dirt build-up and damaged fan blades along with wind pressure affecting the exhaust. Airflow ratio is the ratio of airflow 0.2 inch to 0.05 inch w.c static pressure. In Table 2, it is evident that larger fans have higher efficiency. It is also evident from the same table that larger fans with cones are more efficient.

The number of fans and sizes of the fans will depend on the minimum and maximum ventilation requirement given in Table 1. As mentioned previously, proper sizing of fans will save energy costs.

Table 2. Recommended Energy Performance Efficiency

Fan Size (in)	Cone	Performance Targets	
		VER 10	Airflow ratio
10 & 12	N	8.0	0.75
14 & 16	N	8.0	0.75
18 & 20	Y N	10.5 11.0	0.75 0.75
24	Y N	15.0 12.0	0.70 0.70
36	Y N	17.0 16.5	0.70 0.65
48	Y N	18.0 17.0	0.75 0.65

Source: ASABE (2008)

Calculating Operating Cost and Savings

Operating cost savings from using energy efficient ventilation fans can be estimated using the following equation (ASABE 2008):

Eq-1 EOCS = $(AFR_1/FE_1 - AFR_2/FE_2)$ x AOH x ER x 0.001

AFR_1 – air flow rate (ft^3/min) of fan No.1 at the selected static pressure

FE_1 – fan efficiency (ft^3/min/W) of fan No.1 at the selected static pressure

AFR_2 – air flow rate (ft^3/min) of fan No.2 at the selected static pressure

FE_2 – fan efficiency (ft^3/min/W) of fan No.2 at the selected static pressure

AOH – average operating hours per year (h/yr) for the fan

ER – the electric rate (dollars/kWh) charged by electric power supplier

EOCS – electric operating cost savings per year (dollars/yr) in energy costs between the two

The following is a case study using Eq-1 to calculate the cost savings from energy efficient ventilation fans.

Case Study	
Fan 1	Fan 2
AFR_1 – 15,340 ft^3/min at 0.1 inch Static Pressure	AFR_2 – 15,500 ft^3/min at 0.1 inch Static Pressure
FE_1 – 15.6 ft^3/min/W at 0.1 inch Static Pressure	FE_2 – 12.9 ft^3/min/W at 0.1 inch Static Pressure

AOH – 8,760 hours per year (h/yr) for the fan
ER – $0.10 kWh charged by electric power supplier

Substituting the above values in Eq-1 (shown below)

Fan 1: EOCS = (AFR_1/FE_1) x AOH x ER x 0.001
= (15,340/15.6) x 8,760 hr/yr x 0.10 x 0.001
= $861.40

Fan 2: EOCS = (AFR_2/FE_2) x AOH x ER x 0.001
= (15,500/12.9) x 8,760 hr/yr x 0.10 x 0.001
= $1,052.56

This means savings of $191 per year. Payback period may be estimated using EOCS and considering average servicing or motor replacement costs.

Summary

Ventilation systems are important for maintaining the optimum performance in confined feeding operations (CFO). Dairy barns use natural as well as mechanical ventilation systems. Mechanical ventilations systems consume considerable energy to operate. Energy efficiency of the ventilation fans depend on a number of factors. Summer and winter design temperatures as well as number of animals and type of operation determines the maximum and minimum ventilation rates required for a CFO. Sizes and number of fans for the facility will in turn depend on the building size, configuration as well as minimum and maximum ventilations rates. Different types of ventilation systems are commercially available. Multi-speed, intermittent, variable speeds, belt driven and direct coupled are some of the examples. Choosing a suitable type of ventilation system can reduce the operating costs. Motor type, construction materials and modifications such as installing cone, housing, hoods and wind deflectors can affect the efficiency. In addition, periodic maintenance including dusting off can improve the energy efficiency of the fans. Installing controllers such as thermostat, moisture control and variable speed drive can optimize energy consumption. Replacing existing inefficient fans with the newer, more efficient fans using the energy efficiency guidelines can conserve energy.

References

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