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Janice Storebo

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Tina Smith

CD-ROM
David Brown

Logo Design
Ruth Cronje, and Jan Swanson;
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Measuring and minimizing energy consumption

Dr Mike Brumm
Brumm Swine Consultancy, Inc, North Mankato, Minnesota

The economic ripple from the current frenzy in the energy sector of the world economy is impacting pork production in a variety of ways. The impact of the US Reformulated Fuel Standard on feed grain prices as increasing amounts of corn is converted to ethanol and fat is utilized for bio-diesel is being felt as corn prices rise past $8/bu in late June. For many production systems, a secondary impact will hit during the winter of 2008-09 as propane costs to heat swine facilities soar.

In late June, 2008 with much of eastern Iowa, western Illinois and northeast Missouri under water, the prospects of a delayed corn harvest are rising. Current prospects are for a very large increase in propane usage this fall for corn drying. Combine this with projections from the US Department of Energy for a 25% increase in home heating costs this winter and the prospect of a dramatic increase in direct energy costs to swine units is in place. Many electric suppliers have increased their rates this summer or will be increasing rates soon.

Current energy costs

There are few publicly available production cost summaries. One of the best is the information from the Center for Farm Financial Management at the University of Minnesota (www.finbin.umn.edu). For the 4 year period of 2004-2007, wean-to-finish cooperators in this record program reported an average fuel and oil expense of $1.43 per pig and a utilities expense of $1.04 per pig. Fuel and oil includes both propane and any diesel and gasoline charged to the swine unit for such items as tractors, lawn mowers, power washers, generators, pickups, etc. Utilities include electricity and telephone/internet. Surprisingly, both fuel and oil and utilities varied little for the 4 year period. There was no indication in the data set of what the mix is of curtain sided versus tunnel wean-finish facilities.

Finishers of feeder pigs reported fuel and oil expenses of $0.71/pig and utility expenses of $0.62/pig. For farrow-weaning cooperators (average inventory of 950 sows), the fuel and oil expense was $0.49 per pig weaned while utilities were $1.03/pig weaned.

New construction

Energy conservation planning should be a part of every new or remodel project. Obvious considerations include the amount of insulation in ceilings and sidewalls.

Less obvious is the selection of ventilation fans. The University of Illinois Department of Agricultural and iological Engineering conducts performance tests on agricultural fans (www.bess.uiuc.edu). Included in their test results are fan efficiencies, reported as cfm/watt. For 24” fans, commonly used for pit ventilation in wean-finish facilities, at 0.05 in. of static pressure, these efficiencies range from 8.7 to 19.4 cfm/watt. The least efficient fan, rated at 6070 cfm at 0.05” static pressure, would require 698 watts of electricity for every hour of operation. Contrast this with the 392 watts per hour requirement for the most efficient fan rated at 7610 cfm. At $0.08/kWH electricity cost, this difference represents $0.024/hour. For continuously operating stage 1 pit fans, this is $0.58 per fan per day difference in operating expense per fan.

Electric utilities are encouraging installation of energy efficient ventilation equipment. Alliant Energy, a regional electric utility in Iowa, Minnesota and Wisconsin, has a rebate program to support their efforts. For example, Alliant Energy customers in Iowa and Minnesota qualify for a $75/fan rebate if they purchase and install 24” fans that have a minimum cfm/watt rating of 13.0 at 0.05 in. static pressure (www.alliantenergy.com). Rebates are also available for other size fans, circulating/stirring fans commonly used in curtain-sided wean-finish facilities, energy efficient lighting systems, replacement electric motors and electric water heaters. Other regional utilities have similar rebate programs.

Temperature selection

An obvious determinant of energy consumption is the set point temperature in the swine facility. While most producers and advisors are concerned with temperature variation in the facility, there is very good evidence that nursery and growing pigs have a preference for reduced temperatures during night time hours (Curtis and Morris, 1982; Morrison et al, 1987; Bench and Gonyou, 2007). This is supported by data which suggests that the weaned pig have a marked circadian variation in heat loss, with a maximum in late afternoon and a minimum in early morning hours (Ingram and Dauncy, 1985; Verstegen et al, 1986).

In a series of experiments in the 1980’s and early 90’s, University of Nebraska researchers demonstrated that a

10˚F reduced nocturnal temperature regimen beginning one week post weaning resulted in an increase in daily feed intake and daily gain, with no impact feed conversion. Under the conditions of the experiments, propane usage was reduced as much as 15% versus housing pigs at constant 24 hour temperatures (Brumm and Shelton, 1988; Shelton and Brumm, 1988; Brumm and Shelton, 1991; Brumm et al, 1995)

Reduced nocturnal temperatures have not been widely adopted by the swine industry because of how most ventilation controllers are programmed to function. In most controllers, if the set point is reduced 10˚F, the ventilation fans operate and immediately cool the room. In the University of Nebraska research, only the furnace set point was reduced from 7 PM to 7 AM. The set point at which fans increased ventilation for heat removal did not change.

As new generations of ventilation controllers become available, the ability to program a reduced nocturnal regimen into the controller is an option. For now, producers that wish to experiment with reduced nocturnal temperatures are advised to not apply the reduction in temperature until at least 1 week after the pigs are weaned. It is important that all pigs be in a positive energy balance that is associated with rapid increases in daily feed intake.

For producers with the TC-5 controller from Airstream, reduced nocturnal temperatures can be accomplished by manually lowering the furnace 'offset' at 7 PM and returning the set point at 7 AM. For most other controllers, producers will have to manually lower the 'on and 'off' temperature set points for the furnace evening and morning. In both instances, the set point at which stage 1 fans increase ventilation does not change, only the temperature at which the furnace is set to operate. Many producers who have tried using reduced nocturnal temperatures begin with a 5˚F reduction in furnace set point temperatures until they become comfortable with the result.

Common ventilation management mistakes that increase energy expenses

The ventilation needs for a wean-to-finish facility range from 2 cfm/pig at weaning in winter to 120 cfm/pig at market weight in summer. Designing and managing facilities to accomplish this range of needs continues to be a challenge. Ventilation mistakes are common in production facilities and these mistakes often equate to elevated and unnecessary energy expenses.

Many of the wean-finish facilities built in the past 5-10 years have 1200 pig spaces per room. Commonly constructed with deep pits, the facilities often have two 24" variable speed pit fans as the stage 1 ventilation. While 24" fans have a range in ventilation capacity when operated at 0.05 in. static pressure, many have an installed capacity of approximately 6000 cfm (www.bess.uiuc.edu). With 1200 pigs in the facility, this means each 24" fan has 5 cfm/pig capacity. When there are 2 fans installed as the first stage of ventilation, this means the capacity of this stage when operated at 100% is 10 cfm per pig, which is 500% of the 2 cfm/pig requirement for moisture removal within the facility for the newly weaned pig.

The most common method used to reduce the ventilation rate for weaned pigs is to install the fans with a variable speed ventilation controller. At 50% of capacity (not necessarily 50% of fan speed or 50% as stated on the controller) each 24" fan provides 2.5 cfm/pig. When pigs are single stocked into a facility, a common mistake is to operate both stage 1 fans which equates to 5 cfm/pig as the minimum ventilation rate.

Brown-Brandl et al (2004) have summarized recent research on pig heat production. When this data is combined with heat loss estimates for the building shell and the ventilation system (MWPS, 1977), it is possible to model the impact of varying ventilation rates on the heat flows within a wean-finish facility. For example, if one combines the heat production of a 25 pound pig with the heat loss estimates from a curtain-sided wean-finish barn when the room temperature is 78˚F, at 5 cfm/pig the balance point temperature is estimated to be approximately 45˚F. That is, heat production by the pig equals heat loss from the building shell and ventilation system when the incoming air temperature is 45˚F. At incoming air temperatures lower than this, additional heat must be provided or the room will gradually lower temperature. At incoming air temperatures higher than this, the ventilation system must gradually increase the rate of heat removal or the facility will gradually increase in temperature.

Contrast this 45˚F estimate with the estimate of 22˚F when the ventilation rate is lowered to 2.5 cfm/pig. Thus, when stage 1 fans are over-sized, the result is a significant increase in propane usage as a result of over ventilation.

Three common methods often used to correct this over-ventilation are: 1) turn the minimum ventilation speed to 20 or 30%; 2) unplug or otherwise disable one of the pit fans; 3) install a single speed 18" fan (often 3500-4000 cfm rated). When the minimum ventilation speed is set very low for a variable speed fan (option 1), the fan's ability to maintain static pressure is usually compromised. This means that wind effects, either when blowing into the fan, or into the attic, causes the ventilation rate to fluctuate rapidly, ranging from severe under to severe over ventilation.

In the case of turning off one of the pit fans (option 2), if the facility has ceiling inlets linked to the controller (often called powered inlets), operators must turn off the ceiling inlet control device or make other temporary adjustments. The controller will react as though both pit fans are operating and open the inlets accordingly which means there will be too much inlet capacity into the pig space, resulting in lowered inlet velocities and reduced air blending and cold air dropping into the pig zone in the wrong areas.

A second common ventilation mistake made in wean-finish facilities with variable speed fans is to assume that the 50% setting for minimum speed on the controller equates to 50% of the rated capacity of the fan. Most often this isn't what happens.

The following discussion of variable speed fans applies to facilities using ventilation controllers such as those supplied by Airstream and Aerotech, the most commonly installed controllers in swine facilities in the upper Midwest. Both of these companies use electronic control circuitry manufactured by Thevco Electronics, a Quebec, Canada based company. These controllers control the speed of variable speed fans by varying the voltage sent to the fan. While the ventilation output of a fan (cfm) is directly related to the speed of the fan (rpm), the rpm of a given fan motor is most often not directly proportional to the voltage. Every type and brand of motor reacts to voltage with a differing rpm, and the smaller the motor (fan), the more variation between motors (fans) in speed for the same voltage (Table 1).

Some fan motors have the majority of increase in rpm's occur over a range of only 10-20V when wired into a 230-240V system (App-12F fan in Table 1), while others respond over a 100+V range (Aerotech AT Series 24" fan in Table 1). To compensate for this variation in fan motor response to voltage, Thevco has created 10 'motor curves' in their controllers. The curves vary the voltage signal to the fan motor for a given percentage setting on the controller. For example, when the minimum speed is set to 50% in the Airstream Expert Series of controllers, the voltage sent to the variable speed fan circuit (240V input) ranges from 170 volts with motor curve 5 to 96 volts with motor curve 10.

At the time of installation of fans and controllers, most equipment installers and electricians select a motor curve for the fans installed, and in my experience, the selection is most often correct. However, when fan motors are replaced, unless an original equipment motor is selected, the replacement motor may respond to voltage differently.

Table 1: Response of different variable speed fan motors to voltage.

Aerotech AT Series Fans							
Installed with hoods and shutters							
14"		%		24"		%	
RPM	Voltage	Full RPM	240V	RPM	Voltage	Full RPM	240V
1620	208	100%	87%	1040	240	100%	100%
1450	155	90%	65%	1000	214	96%	89%
1340	148	83%	62%	920	182	92%	76%
1240	141	77%	59%	840	164	84%	68%
1160	135	72%	56%	710	142	71%	59%
1090	129	67%	54%	610	131	61%	55%
1020	124	63%	52%	510	117	51%	49%
950	119	59%	50%				
820	112	51%	47%				
Airstream APP Series							
APP-12F		%		APP-24F		%	
RPM	Volts	Full RPM	230V	RPM	Volts	Full RPM	230V
1765	230	100%	100%	1040	230	100%	100%
1665	125	94%	54%	940	194	90%	84%
1575	119	89%	52%	840	176	81%	77%
1475	115	84%	50%	740	157	71%	68%
1375	112	78%	49%	640	143	62%	62%
1275	111	72%	48%	540	130	52%	57%
1175	109	67%	47%				
1075	107	61%	47%				

Another common finding is that someone has changed the motor curve selection in the controller for the fans installed. A common mistake I often have to correct is 24" variable speed pit fans operating with motor curve 8 (163V at 90% minimum speed with the Airstream Expert controller in a 240V system) when the correct curve is number 4 (217V at 90% in a 240V system).

Furnaces are often oversized in swine facilities. As a consequence, when the furnaces operate, air temperatures rapidly increase. Because temperature probes for ventilation controllers are often suspended some distance from furnaces, rapid increases in air temperatures results in 'overshoot' of the temperature setting in the controller that turns off the furnace. In general, furnaces should be set to turn off 2˚F below the temperature at which the ventilation system either increases the speed of variable speed fans or turns on additional fans.

Most ventilation controllers capture hi/low temperatures. An effective tool to monitor for 'overshoot' is to record the daily high temperature logged by the controller. If this high temperature reaches the temperature at which the ventilation system begins increasing output when the facility is operating in heating mode, 'overshoot' has occurred and propane expense is increased.

Another method of monitoring 'overshoot' that will begin appearing in future generations of ventilation controllers and data logging systems will be a reporting of the voltage signal to stage 1 variable speed fans. When operating at minimum speed, the voltage signal to the stage 1 variable speed fan should be constant. If the voltage sent to the stage 1 fan circuit increases, the controller is telling the fan to increase speed. In the future, data capture system will display stage 1 voltage along with furnace 'on' times. If the stage 1 voltage increases every time the furnace shuts off, 'overshoot' is occurring and energy expense is excessive.

Other causes of high energy expense

Swine facilities are being located in remote areas with no residences nearby. In at least one instance that I was involved in, excessive propane usage was traced to theft of propane from storage tanks. Investigation by the local sheriff's office suggested 'meth' producers were identifying remote storage tanks and stealing propane for use in their drug manufacture activities. The local propane supplier cooperated with the facility owner by furnishing locks for the propane tank, and propane usage at the site was immediately reduced.

Monitoring energy consumption

Brumm (2007) discussed the current technology for both on-site and remote monitoring of energy consumption in swine facilities. Currently, these systems only capture temperature, fan run time, propane usage, etc. They do not relate the consumption of energy to a predictive model that is unique for the facility as sited and constructed and for the specific pig numbers and growth status of the pigs in the facility.

Many of the ventilation controllers now being installed in swine facilities log daily hours of run time for furnaces. The challenge producers and their many advisors face is comparing the logged run times to an estimate of what is 'normal' for that facility. Future data capture technology will include an internal model of pig heat production, facility heat loss and energy expenditures to maintain set point conditions. The reporting from the data capture system will include process control charts documenting energy (both electric and propane) usage versus predicted.

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