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Cooperative Extension South Dakota State University

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Energy Use in Livestock Buildings

Cooperative Extension Service
South Dakota State University
U.S. Department of Agriculture

and

SOUTH DAKOTA
OFFICE OF ENERGY POLICY
ENERGY INFORMATION
Confinement housing for livestock and related facilities is spreading across South Dakota. There is economic justification for this:

**Reduced labor.** Labor has become a serious problem because of higher wage rates and unavailability of reliable labor for livestock feeding and handling. Managerial time is more valuable, so a higher degree of mechanization to reduce labor is justified. Confinement operations are easier to mechanize.

**Increased volume.** With confinement it is possible to increase volume without increasing the amount of labor.

**Environmental control.** Maintaining optimum temperatures, dry buildings, freedom from drafts, and suitable air quality results in higher survival rates of young animals, healthier livestock, faster gains, and better feed efficiency. More non-dietary energy is used to produce feed crops than livestock, so good feed efficiencies are important in saving energy.

**Land productivity.** Confinement of livestock allows more land to be used for field crops.

**Waste disposal.** Manure quality is better and handling is more efficient. Conversion into fertilizer helps reduce energy requirements for commercial fertilizer.

**Operator comfort and convenience.** This has become increasingly important in attracting young farmers to the livestock business.

The key to energy conservation in confinement buildings is good planning and management.

Whether it be a swine, dairy, beef, poultry, or sheep operation, some guidelines should be followed for energy and cost savings without impairing the efficiency of the operation. Several areas that should be considered are adequate insulation, controlling ventilation rates, natural ventilation of livestock buildings, and taking advantage of natural influences such as wind and sunlight, solar energy, and heat exchangers.

**Insulating livestock buildings**

There are optimum temperatures at which livestock and poultry produce most efficiently. What is optimum depends on the size and species.

Laying hens, for example, produce most efficiently at 55 degrees F. Growing pigs (weaned at 50 lbs) seem to peak in performance at around 70 degrees F, while heavier hogs perform best at around 60 degrees F. Dairy cows adjust to a wide range of temperatures and perform well between 15 degrees F and 75 degrees F, depending somewhat on the breed. Beef cattle also can adjust to a wide range of temperatures, 6 degrees F being considered the low critical temperature. At this point more feed is required to maintain body temperatures.

You need to know the optimum temperatures for the livestock, the outdoor temperatures, and the heat and moisture produced by the animals. Then you can design the insulation and ventilation required. Insulation conserves body heat. In small animal buildings such as farrowing houses, pig nurseries, calf barns, lambing barns and nurseries, supplemental heat must be added to maintain desirable temperatures.

Table 1 shows recommended minimum insulation resistances for these types of buildings.

<table>
<thead>
<tr>
<th>Building component</th>
<th>Resistance (R)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sidewalls</td>
<td>13.0-14.0</td>
</tr>
<tr>
<td>Ceilings</td>
<td>21.0-23.0</td>
</tr>
<tr>
<td>Foundation (perimeter)</td>
<td>7.0-9.0</td>
</tr>
</tbody>
</table>

In some livestock buildings such as dairy free-stall barns, sheep feeding and ewe housing, beef confinement feeding barns and horse barns, only enough insulation is provided to prevent condensation, reduce radiative heat gain in summer, and improve ventilation performance. Table 2 can be used to determine insulation levels for cold housing.

All insulation must be adequately protected from moisture condensation by a suitable vapor barrier on the "warm" side. It should also be protected from mechanical damage, rodents, fire, etc., by
covering it with a suitable lining.

**Ventilation**

If a livestock building is well insulated, the ventilation system usually represents the greatest heat loss.

Cold weather ventilation rates are based on moisture removal, while summer ventilation rates are based on heat removal.

Fortunately, if the heat is conserved by insulating, ventilation rates can be reduced because warm air can hold more moisture vapor than the same volume of cold air. Thus, a controlled ventilation system is modulated in air removal capacity according to the temperature of the air.

Modulating rates can be obtained by controlling the fans (which force the moisture-laden air out of the building) by percentage timers, thermostats, or variable speed controllers. Table 3 provides guidelines for the modulating rates needed for fan capacities for different livestock and temperatures.

Bringing the fresh air into the building in the right amounts and velocity and distributing it properly so that it blends and mixes thoroughly with the warm inside air is essential. Tempering the incoming air by bringing it into the building through ceiling intakes, which allow it to absorb heat by solar gain from the roof and heat loss through the ceiling, is a way to conserve energy without extra cost (Fig. 1).

**How insulation and ventilation can save energy**

Adequate insulation in the sidewalls, ceiling (or roof), doors, and floor reduces the heat loss from the building housing the livestock. This conserves energy that might have to be added to maintain suitable temperatures to enable the warm air to absorb and remove the moisture produced by animal respiration and evaporation from the floor and/or litter.

For every 20 degrees F temperature increase, the moisture-holding ability of air is approximately doubled. Therefore, by conserving the internal heat energy inside the building, ventilation rates for moisture removal in winter can be reduced, conserving even more energy.

Winter ventilation rates should be controlled carefully, especially in livestock buildings where supplemental heat is required, such as swine farrowing and nursery buildings, small calf barns, poultry brooding buildings, milking parlors and milkrooms. Excessive ventilation rates waste heat energy.

Table 4 pointedly illustrates that controlling ventilation rates as well as using recommended thermal insulation quantities can dramatically reduce supplemental heating needs. For example, at -10 degrees F
Table 3. Ventilation rate guidelines for determining fan capacity.

<table>
<thead>
<tr>
<th> </th>
<th>Winter minimum ventilation rate</th>
<th>Winter maximum ventilation rate</th>
<th>Summer ventilation rate</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Poultry</strong></td>
<td><strong>Chicks</strong></td>
<td>cfm</td>
<td>0.1/bird</td>
</tr>
<tr>
<td></td>
<td>Layers, pullets, breeders, broilers</td>
<td>cfm/bird</td>
<td>1/2</td>
</tr>
<tr>
<td><strong>Swine</strong></td>
<td>Sow &amp; litter</td>
<td>cfm/sow &amp; litter</td>
<td>20*</td>
</tr>
<tr>
<td></td>
<td>Growing pigs:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>20-40 lb</td>
<td>cfm/pig</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>40-100 lb</td>
<td>cfm/pig</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>100-150 lb</td>
<td>cfm/pig</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>150-210 lb</td>
<td>cfm/pig</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Gilt, sow or boar, 200-250 lb</td>
<td>cfm/hog</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>250-300 lb</td>
<td>cfm/hog</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>300-500 lb</td>
<td>cfm/hog</td>
<td>15</td>
</tr>
<tr>
<td><strong>Dairy</strong></td>
<td>Cows in warm barns (stanchion or free stall)</td>
<td>cfm/1000 lb</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Calves in warm barns</td>
<td>cfm/100 lb</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Milk rooms</td>
<td>cfm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Milking parlors</td>
<td>cfm/stall</td>
<td>100</td>
</tr>
<tr>
<td><strong>Beef</strong></td>
<td>Cattle in warm confinement</td>
<td>cfm/1000 lb</td>
<td>15</td>
</tr>
</tbody>
</table>

10 cfm continuous, and 10 cfm manual switch to control odor and humidity.

outside temperature and +70 degrees F inside temperature, only 3.6 cubic feet per minute (cfm) per 50-pound pig are needed to remove moisture.

Many times, producers will purchase an exhaust fan with excessive capacity with the philosophy that “more is better.” The example of 11 cfm per pig is based on a recent experience of a swine producer in South Dakota. This over-capacity represents a waste of approximately one gallon of L.P. gas (or equivalent) per hour when such temperature conditions exist.

Table 4. Supplemental heat requirements to maintain 70 degrees F. in a 150-pig nursery at various insulation and ventilation rates (To = 10 F).

<table>
<thead>
<tr>
<th>Bldg. heat loss, BTU/hr</th>
<th>Vent. rate cfm/pig</th>
<th>Vent. heat loss, BTU/hr</th>
<th>Heat avail. BTU/hr (+)</th>
<th>Supp. heat reqd., BTU/hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>11,794 (1)</td>
<td>3.6*</td>
<td>46,656</td>
<td>22,500</td>
<td>35,950</td>
</tr>
<tr>
<td>11,794 (1)</td>
<td>5.0**</td>
<td>64,800</td>
<td>22,500</td>
<td>54,094</td>
</tr>
<tr>
<td>11,794(1)</td>
<td>11.0***</td>
<td>142,560</td>
<td>22,500</td>
<td>131,854</td>
</tr>
<tr>
<td>58,037(2)</td>
<td>3.6*</td>
<td>46,656</td>
<td>22,500</td>
<td>63,657</td>
</tr>
<tr>
<td>58,037(2)</td>
<td>5.0*</td>
<td>64,800</td>
<td>22,500</td>
<td>99,067</td>
</tr>
<tr>
<td>58,037(2)</td>
<td>11.0***</td>
<td>142,560</td>
<td>22,500</td>
<td>173,607</td>
</tr>
</tbody>
</table>

1. Building construction:
   - Walls - 3½-inch batt + steel + ½-inch ply.
   - Ceiling - 6-inch batt + aluminum
   - Foundation - 6-inch concrete + 2-inch styrofoam
   - Doors - 1 3/8-inch ply. + 1½-inch styrofoam

2. Building construction:
   - Walls - steel + 1-inch polyurethane
   - Ceiling - steel + 1-inch polyurethane
   - Foundation - 6-inch concrete
   - Doors - ½-inch plywood

* Amount needed for moisture removal at (-10 degrees, 80 pct + 70 degrees, 75 pct).
** Minimum continuous recommended by MWPS.
*** Typical lower output of 2-speed, 20-inch ½ hp fan (1650).
(+): 150 BTU/hr sensible heat produced at 70 degrees F by 50-lb pig.

Table 3: Ventilation rate guidelines for determining fan capacity.

Heat exchangers

The heat lost through ventilation represents a sizable quantity of energy. Heat exchangers are an attempt to transfer heat from the exhaust air to the incoming fresh air. In some cases, a heat pump will reclaim heat from the exhaust air of the ventilating system.

In practically all test cases, unsatisfactory results were obtained largely due to ice and dirt accumulations on fins and tubes, and high initial and maintenance costs.

An experimental heat exchanger using a rock heat sink was operated for 3 years at North Dakota State University (Fig. 2). The rock sink heat exchanger did provide heat reclamation from the exhaust air at an estimated 33 per cent efficiency. Some problems of controlling icing in the bed of rocks were encountered which had to be overcome with sodium chloride. Corrosion problems from the effect of salt were not evaluated.

Natural ventilation

Some livestock buildings housing heavier, more mature animals such as swine finishing buildings, free-stall dairy barns, sheep feeding sheds, and horse barns, often perform as well with natural ventilation as controlled environment buildings. This represents a considerable saving in energy costs.

The building is completely insulated (walls and roof) to conserve the heat produced by the hogs. The exhaust of moisture laden air is accomplished by an open ridge in the roof.

As the air in the building is warmed by the heat from the hogs, it expands and...
its density is less than outside air coming into the building. This creates a “chimney” effect at the ridge, exhausting the warm air out and creating enough negative pressure in the building to pull fresh air in through controlled openings in the insulated, hinged sidewall doors (Fig. 3).

Much of the technology is known; however, the economics of such investments have not proven entirely feasible when fixed and operating costs are considered. A solar collector-storage system with the south wall of a farrowing house as a collector is being used at Kansas State University to preheat ventilating air. During cold winter months, when the demand for heat is the greatest, the sun’s path is low, so the south wall of a building receives much solar radiation. Black painted concrete blocks without mortar and with gaps in the vertical joints, provide heat storage and air movement through the wall.

During a typical winter in Manhattan, it is estimated that 1¼ to 1½ gallons of L.P. gas...
PER SQUARE FOOT OF COLLECTOR CAN BE SAVED WHERE THE INSIDE TEMPERATURE IS MAINTAINED AT 65 DEGREES F; THE SAVINGS COULD INCREASE TO ABOUT 2 GALLONS FOR BUILDINGS MAINTAINED AT 80 DEGREES F. THESE ESTIMATES ASSUME CERTAIN CONDITIONS ARE MET INCLUDING ESSENTIALLY FULL-TIME USE OF THE BUILDINGS. IN ADDITION, THIS SYSTEM WILL RESTRICT THE CHANGE IN VENTILATION AIR TEMPERATURE CAUSED BY A SUDDEN DIP IN OUTSIDE TEMPERATURE. OTHER SYSTEMS USE ROOF COLLECTORS OR PORTABLE REMOTE COLLECTORS.

IF WELL DESIGNED, THE BASIC CONCEPT OF SOLAR ENERGY COLLECTOR-STORAGE FOR PREHEATING VENTILATION AIR FOR LIVESTOCK BUILDINGS IS SOUND (FIG. 4). IT SHOULD BE AN ALTERNATIVE TO CONSIDER AS ENERGY BECOMES LESS AVAILABLE AND MORE EXPENSIVE.

BASED ON CURRENT ENERGY COSTS, IT WOULD BE DIFFICULT TO JUSTIFY ON A STRICT ECONOMIC BASIS, UNLESS TAX CREDITS OR OTHER INCENTIVES ARE PROVIDED. HOWEVER, RESEARCH AND EDUCATION MUST BE CONTINUED TO DEVELOP SOLAR APPLICATIONS SO THAT FUNCTIONAL AND RELIABLE UNITS CAN BE CONSTRUCTED WHEN DEMANDED BY FUTURE ENERGY SITUATIONS.