Insulation in Low Profile Cross Ventilated Freestall Facilities

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TAKE HOME MESSAGES

- A minimum R-6 insulation should be installed beneath the roof and inside sidewalls and end walls of low profile cross ventilated freestall buildings.
- All seams and holes must be property sealed to prevent moisture from condensing between the insulation and roof.
- Based on author's observations, it appears the close-cell spray-in-place or foam-in-place insulation is preferred over the flexible batt or rigid board insulation.

INTRODUCTION

Differences in temperature cause heat to transfer from warm areas to cooler areas within a building. In order to effectively control interior temperature and limit heat transfer in low profile cross ventilated freestall dairy facilities, insulation must be installed along the roof and exterior walls. Any material that reduces heat transfer from one area to another is considered insulation. Its main functions are to conserve heat, maintain and stabilize warm interior temperatures, prevent heat loss from in or out of the building, and reduce condensation.

HEAT TRANSFER

Heat transfer is caused by conduction, convection, or radiation. Conduction occurs when two objects of different temperatures come into contact with each other. Two types of convective heat loss result when air moves over a surface. Natural convection occurs when rising hot air displaces cold air, pushing it down. Mechanical, or force convection, happens when air is moved passed an animal.

Naturally ventilated freestall buildings, which are not typically insulated, have 4/12 roof slopes that allow warm air to rise and escape the ridge opening, resulting in convective heat loss. On the other hand, the heat in an LPCV building has to be ventilated through the fans. The air exchange rate in these buildings should be high enough during the summer that no noticeable temperature rise occurs inside the building, even though radiant heat may still be transferred into the cow housing area. Radiant heat loss occurs when heat transfers from one object to another by electromagnetic waves separated in space.

The sun is an example of radiant heat transfer because it radiates traveling heat waves that are either absorbed or reflected by a surface. Increased solar radiation raises the temperature of the roof surface which, as a result, increases the temperature inside a building. A typical LPCV building allows for approximately 100 square feet of space per cow, meaning that over 200,000 British Thermal Units (BTU) of energy per cow per day may strike the roof surface during the summer months. Therefore, insulation is necessary to minimize temperature increase in the building from the sun's conductive and radiant heat. Table 1 shows the average solar radiation on horizontal surfaces at different locations in North America.

Table 1: Average Total of Solar Radiation (BTU/square foot) Per Day at Various Locations (MWPS-23)

Time of Year	**Location**			
	Albuquerque, NM 35.03 N Latitude	Davis, CA 38.33 N Latitude	Lincoln, NE 40.51 N Latitude	Boise, ID 43.34 N Latitude
January	1134	581	699	522
February	1436	942	939	858
March	1885	1480	1277	1248
April	2319	1944	1561	1789
May	2533	2342	1826	2161
June	2721	2585	2006	2353
July	2540	2540	1977	2463
August	2342	2249	1870	2095
September	2084	1833	1517	1679
October	1646	1281	1196	1156
November	1244	795	762	666
December	1034	544	633	452

CONDENSATION

Condensation occurs when warm, moist air comes in contact with the exterior shell of a metal building, such as the post, purlins, roof, or exterior walls. Condensation problems normally occur when outside temperatures are 35°F or less, and there is a combination of humid air and cool surface temperatures below the dew point. Insulation helps prevent condensation during the winter months when warm, moist air remains longer inside the building due to lower ventilation.

Relative humidity is defined as the ratio of water vapor in the air to the maximum amount of water the air can hold. A humidity level of 50% means the air is carrying only one-half of the total moisture that it could contain at that particular temperature. Because relative humidity is a function of the temperature, cold air holds less moisture than warm air even though the humidity level may be the same. Inside an LPCV, the humidity is typically 70% or greater throughout the entire year. Since the air is warmer and at a higher relative humidity inside the building, there is a greater potential for condensation problems when compared to most naturally ventilated freestalls.

In LPCV buildings, visible condensation occurs on exposed surfaces below dew point temperatures. Visible condensation control requires proper insulation or reduction of cold surface areas where condensation may take place. Increasing the ventilation rate also helps reduce the moisture content inside the building, but it may lead to the freezing of alleys and water pipes. Simply increasing the ventilation does not typically reduce visible condensation in LPCV buildings.

Concealed condensation occurs when moisture passes through the vapor retarder, or seam, and into interior roof and/or wall cavities, resulting in condensation on surfaces below the dew point temperature. Concealed condensation is very difficult to deal with and can be extremely damaging to any structure because the problems often are not discovered until they already require costly repairs.

If moisture is in vapor form, insulation performance is not seriously affected. However, the presence of water seriously hinders insulation performance, and condensed moisture can impair or destroy the insulation value.

INSULATION

Insulation is necessary in LPCV buildings year-round. In the summer months it reduces the increased temperature from the sun's heat, and during winter months it minimizes condensation problems. Three common types of insulation used are flexible batt-insulation, rigid board, and foam-in-place (spray-in-place). The least expensive insulation is the flexible fiberglass, or rolled insulation, that is commonly used in metal buildings.

Because of excess moisture from cow urine, respiratory activity, and tractor exhaust, all insulating joints and seams in LPCV buildings, including sidewalls, must be sealed. Unsealed or broken seams allow moisture to become trapped between the roof and insulation, causing the material to sag and the insulation to pull away from the roof. As a result, warm, moist air comes into contact with the cold metal roof and causes condensation. The problem continues until the insulation fails. However, seams are difficult to reseal once the tape pulls away from the insulation since the surface becomes dusty. Because seam and moisture problems are extremely common with the flexible fiberglass insulation, owners must have clear communication with the contractor about the importance of sealing the seams to extend the life of the building.

Close-cell and open cell insulations are the two basic types of spray-on insulations. Spray-on insulation has the ability to seal cracks and conform to odd shapes. Close-cell insulation weighs 1.5 to 2 pounds per cubic foot (pcf) and has an R-value (value of resistance to heat flow) of around 6 per 1-inch of thickness. This material expands 35 to 50 times its original volume. The open cell insulation has a final weight of 0.4 to 0.6 pcf when fully cured and expands approximately 150 times its original volume. The R-value is 3.5 per inch thickness. The open cell material allows moisture to enter the foam, while the close cell insulation resists water absorption. One disadvantage of the close cell material is the maximum thickness applied per application pass is generally limited to 0.5 to 1.5 inches, as compared to the open cell insulation which may be applied in one application pass. The close cell insulation has a flammability rating of 800 ^{o}F and the open cell between 300 and 400 ^{o}F. Additional flame retardants are available to spray over the surface.

Another possible insulation option is rigid board insulation. Typically, this insulating board has a white surface which enhances light reflectivity and is washable with a high-pressure system. Thickness ranges from ½ to 3 inches with an R-value of 6 per 1-inch of thickness. The end rigid board is supplied in 4 ft widths, but a manufacturer may cut the boards to match the lengths of the purlin spacing. The joints overlap on top of a purlin, so placement of the proper boards and spacing between purlins is essential during installation. As with the flexible insulation, sealing of the joints is critical to prevent condensation.

INSULATION RECOMMENDATIONS

Low profile cross ventilated freestall buildings are cold environments. The building temperature is not maintained at a set temperature using a supplemental heater or solely by heat from animals. In LPCV buildings, the temperature varies depending on the outside air temperature. Cold buildings (i.e. minimal warmth inside the building) require minimum insulating values of R-6 in walls and roofs (MWPS-34). Increasing the R-value to 9 or 12 in cold climates provides additional benefits. According to observations of winter data from LPCV buildings, insulation design should account for a maximum 30 degree F temperature difference between the outdoor and indoor air temperatures.

Radiant barrier insulation is not a good substitute for the conductive insulation needed in an LPCV facility, but radiant heat or reflective roof coatings will reduce the radiant heat load. More information on radiant heat barriers can be obtained from the US Department of Energy website (http://www.eere.energy.gov/).

VAPOR BARRIERS

Liquid water from condensation has a thermal conductivity approximately fifteen times greater than most commercial thermal insulations, and the thermal conductivity of ice is almost four times greater than water. This high conductivity requires vapor facings with very low moisture vapor transmission rate properties in circumstances where condensation may occur. The North American Insulation Manufacturing Association recommends that metal building insulation be faced with a vapor retarder with a maximum 0.10 US permeance. Even the best vapor retarder becomes inadequate if leaky seams are present, so all punctures, penetrations, and holes must be repaired with tape to maintain continuity of the vapor retarder.

Vapor retarder facings are available in a wide variety of styles and performance properties. Styles range from plain white vinyl film to laminated composites. Facings differ in strength, color, light reflectivity, and their ability to prevent moisture from entering the insulation.

A 6-mil polyethylene film is often used in other livestock buildings as a vapor barrier. Screw holes and joints may create many openings for moisture to pass through but, overall, significant reductions in moisture absorption occur when compared to the liner feet of seams in blanket or foam-in place insulation.

SUMMARY

The roof, sidewalls and end walls of LPCV buildings should be insulated to reduce summer heat loads, winter heat loss and condensation. The insulating material selected should have a minimum R-6 value. Condensation is a problem inside an LPCV building if the warm moist air contacts cold exterior metal surfaces. Non spray-on insulation material requires sealing of all seams or joints.

RESOURCES UTILIZED

Anon. 2003. Insulation. http://metalbuildingdepot.com/aspx/menuinsulation.aspx

Hoke, J.R. editor. 1988. Ramsey/Sleeper Architectural Graphic Standards. John Wiley and Sons. New York, NY.

MWPS-23. 1983. Solar Livestock Housing Handbook. Midwest Plan Service, Iowa State University, Ames,. IA 88 pp.

MWPS-34. 1990. Heating, Cooling and Tempering Air for Livestock Housing. Midwest Plan Service, Iowa State University, Ames,. IA 48 pp.