Space Heating in Poultry Production

Alberta Government

Introduction

On average, 98% of the natural gas consumption in a poultry operation is attributed to space heating (Figure 1). This equates to 2279 Gigajoules (GJ) for a 50,000 head broiler operation.

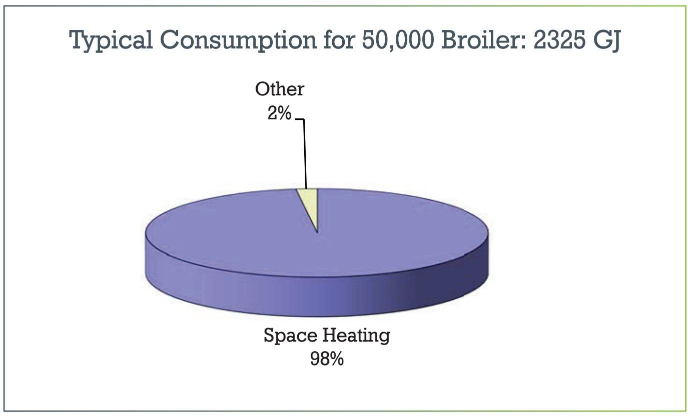

Figure 1. Natural Gas Usage and Distribution

Assuming the cost of natural gas is $5.50 per GJ, this equates to $12,535 per year. Natural gas prices over the last five years have been unpredictable ranging from $1.40 to $10.50 per GJ (Figure 2). This equates to a range of $3,191 to $23,930 per year for a 50,000 head broiler operation.

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

Animal Requirements

Birds are homeothermic which means they maintain a nearly constant internal body temperature despite environmental temperature changes. Cold-stressed birds eat more to increase the production of body heat. If a bird converts much of its feed to heat, it will put on less weight, produce fewer eggs, and generally be less productive. Depending on the bird's weight, age, and species, the effects of cold on productivity can be considerable.

Heat in the barn comes from three different sources: the birds themselves, the heating system, and the lights and motors. Birds produce significant amounts of sensible heat that is used to help maintain barn temperature in cold weather. The birds also release latent heat, mainly in the form of respiration. Newly hatched chicks and poults suffer from cold. The Code of Practice from the Canadian Agri-Food Research Council states that depending on the type of housing used, brooding temperature on the first day of life should range from 30 to 32°C at the eye level of the chicks. Thereafter, the temperature should be lowered by 2 to 3°C each week, down to approximately 21 to 23°C at the age of 6 weeks, and thereafter preferably maintained relatively steady within the range of 10 to 27°C.

Various strains of chickens can vary in their optimum temperature requirements. For this reason, the behavior of chickens in a pen or brooding cage can be used as a reliable indicator of thermal comfort. The crowding of young chickens outside the perimeter of the heating zone usually indicates too high a temperature and, conversely, the gathering of chickens in close proximity to the heat source usually indicate too low an environmental temperature. A temperature close to optimal is present when the chickens are evenly distributed throughout the whole brooder area. Most adult birds can tolerate a considerable range of temperature so long as average environmental temperature is appropriate. Environmental temperatures from 10 to 25°C are well-tolerated by layers. The optimal environmental temperature for layers depends largely on the diet used. Temperature cycles for layers are acceptable because there is no evidence that a constant temperature increases productivity.

Turkeys require slightly higher temperatures during the first two weeks of life. The turkey production handbook from the United States Department of Agriculture states that the temperature 8 cm above the floor should be 35°C for dark poults and 38°C for white. Temperature near the floor of the room outside the brooding area should be 21°C.

Terminology

Homeothermic - warm-blooded or homeothermic animal species is one whose members maintain thermal homeostasis; that is, they keep their body temperature at a roughly constant level, regardless of the ambient temperature. This involves the ability to cool down or produce more body heat. Warm-blooded animals mainly control their body temperature by regulating their metabolic rates, such as increasing their metabolic rates as the ambient temperature begins to decrease.

Sensible heat - Refers to the amount of energy released or absorbed by a chemical substance during a change of temperature.

Latent heat - Refers to the amount of energy released or absorbed by a chemical substance during a change of state that occurs without changing its temperature, meaning a phase transition such as the melting of ice.

Annual fuel utilization efficiency (AFUE): The percentage of fuel the furnace converts to usable energy with the rest of the energy exhausted outside.

Applicable Technology

Ventilation is used to balance temperature, humidity and gas and dust concentration. Space heating systems must work in coordination with ventilation systems to provide a good environment for poultry. The systems for adding heat to the poultry environment may be categorized into three main types: convective, radiant, and conductive heaters. Convective heaters discharge warmed air into the room to raise the room air temperature directly. Radiant heaters do not directly heat or circulate air, but rather warm surfaces that are in view of the heating element. With a conductive heater, heat is supplied to a material internally and then transferred by conduction to the exposed surface. Heating technology is usually categorized by the heat source or conduction liquid.

Electric - Electric heaters are expensive to operate but have many advantages such as instantaneous response, no required venting, clean and quiet equipment, and localized heating.

Hydronic - Hot water heating is a common and effective method for heating poultry barns. Main components of the basic system are a boiler, circulating pump, distribution piping and radiators in the space to be heated. Radiators can be suspended on either the walls or ceiling under air inlets, or above floor or in-floor. Zone brooding with a hot water heating system should be used to conserve fuel in the brooding period. This can be achieved by having the radiators adjustably suspended from the ceiling to heat smaller areas during brooding. Another method is to install crossovers and valves to direct heat to one-half of the barn and use a plastic curtain or fold-down panel to reduce barn heat loss. Regular cleaning of the radiators is required due to dust accumulation.

Forced Air - Forced air heating systems (Figure 3) fired by natural gas or propane are economical but have to overcome potential high maintenance due to re-circulated dust and moisture. Some of the newer units are flueless and draw fresh air from outside. Uniform heat distribution may be a problem but it can be solved by using a recirculation system. Conventional forced air heaters are usually mid-efficiency with AFUE's in the range of 78 to 82%. New generation high efficiency forced air heaters use condensing and have AFUE's between 89 and 97%. They include a secondary heat exchanger to extract most of the heat remaining in the combustion by-products.

Figure 3. Typical Forced Air Heating System
Source: Prairie Swine Centre

Case Study
Most forced air furnaces installed prior to 1992 have an AFUE of 65%. Retrofitting this furnace with a high efficiency furnace could increase the AFUE to 97%. For a 50,000 broiler poultry operation, this would reduce annual natural gas use by 767 GJ. Assuming the cost of natural gas is $5.50 per GJ, this equates to a savings of $4,219 per year.

Gas-fired hooded brooders - Gas-fired hooded brooders are practical and low cost but have a greater fire hazard because of the open-flame combustion. They can be easily lowered during the brooding period.

Infrared Radiant - Infrared radiant tube heaters (Figure 4) use the heat of combustion from several flame units to heat a length of pipe which then radiate the heat onto the birds. The system only provides heat to the birds and does not provide heat to warm air except for some re-radiation from the warmer surfaces. The air temperature can be kept lower resulting in lower heating costs. The heaters are normally flueless so heat is exhausted via the flue gases. A two-stage burner can further increase efficiencies. Material used for the heat reflector affects the performance of radiant heaters. Infra-red radiant heaters are also available in a brooder style similar to the gas-fired hooded brooders.

Figure 4. Typical Infrared Heater
Source: Prairie Swine Centre

Research at the Prairie Swine Centre (PSC) observed infrared radiant heating consumed 60% less natural gas than a forced air convection heater in a grow-finish room. The infrared heating also provided more uniform heat distribution and had no adverse impact on the growth performance of the pigs. Results in a poultry barn would be similar.

Energy Recovery

Air-to-air energy recovery systems used in poultry barns are heat recovery devices that use warm exhaust air from barns to pre-warm incoming fresh air, thus recovering some heat from the exhaust air. Frost buildup is an issue that must be addressed with energy recovery systems operated in cold weather. Frost controls include reducing capacity to raise surface temperature, use defrost mode by reversing flow or preheating the outdoor air. The main types of heat exchangers are parallel flow, counter flow, cross flow and multiple-pass. The heat recovery efficiency is around 40%. Research by the PSC found a reduction in energy use of 54% when using an air-to-air energy recovery device with a forced air convection heater. The initial installed overall heating system cost is often lower when using air-to-air energy recovery devices because fuel-fired heating equipment can be reduced in capacity. Heat exchangers require regular maintenance due to the presence of humid, corrosive and dusty exhaust air. One manufacturer recommends washing once per week.

Energy Sources

Conventional - Natural gas is by far the most common fuel source used for space heating of poultry barns. Other fuel sources to consider if natural gas is not available are propane and biomass. Coal is not a preferred fuel source due to the higher emission of greenhouse gases. Sources of biomass can be wood and crop residues. The wood biomass industry is developed and wood pellets are available in Alberta.

Alternative Heat

Active solar heating systems use solar energy collectors and additional electricity to power pumps or fans to distribute the solar energy. The heart of a solar collector is a black absorber which converts the sun's energy into heat. The heat is then transferred to another location for immediate heating or for storage for later use. The heat is transferred by circulating water, antifreeze or sometimes air. A recent test in Alberta on a poultry barn where the incoming ventilation air was heated using a dark colored south wall resulted in an average temperature rise for the incoming air of 6 to 8°C with an air temperature increase during daylight hours of as much as 30°C.

Geothermal heating systems use the moderate heat from the earth to heat a transfer liquid which carries the heat to the building. A heat pump is used to transfer and upgrade the heat from the liquid to the heating system in the building. Loop systems used to gather the heat from the earth can be vertical, horizontal or slinky coil ground-coupled. Each type of loop system has various advantages and disadvantages. Heat pumps are usually electric powered. For every unit of electricity the heat pump uses, it provides 3 to 4 units of heating energy. This gives a geothermal system up to 400% efficiency rating on average. Geothermal systems have a high initial cost but the underground loop systems will last up to 50 years. The price of electricity used to operate the heat pump greatly affects the economic return of a geothermal heating system. Research at the PSC found a reduction in energy use of 45% when using a geothermal heating system with a heat pump compared to a forced-air convection heater.

Case Study

An active solar heating system currently suitable for heating a poultry barn is a solar air heater. The incoming ventilation air is heated using the dark colored south wall or roof of the barn. The air is pulled through tiny perforations in the outer cladding of the building by fans. A SolarWall solar air heating system was installed on two 18m x 30m swine nursery barns in Sherbrooke, Quebec. Use of the system displaced 30% of the propane usage on the farm. This translated into annual savings of over $4,000 (based on 2007 propane prices) and a payback of five years. Results in a poultry barn would be similar.

Summary

On average, 98% of the natural gas consumption in a poultry operation is attributed to space heating. Efficiencies of forced air heaters have increased over the years. The AFUE of a furnace prior to 1992 was 65% compared new furnaces which have AFUE's as high as 97%. Retrofitting from low efficiency furnaces to ones with an AFUE of 97% in a 50,000 broiler poultry operation would result in a 767 GJ annual reduction of natural gas use. Infra-red radiant tube heaters only provide heat to the birds and don't provide heat to warm air except for some re-radiation from the warmer surfaces. The air temperature can be kept lower resulting in lower heating costs. An alternative heat source with good potential is an active solar heating system. The incoming ventilation air is heated using the dark colored south wall or roof of the barn. Recent tests have shown an average temperature rise for the incoming air of 6 to 8°C in normal sunlight with an air temperature increase during daylight hours of as much as 30°C.

References

Charles, D. R. (1981). Physical Ventilation and Temperature Control for Poultry. Environmental Aspects of Housing for Animal Production. J. A. Clark. London, Butterworths: 183 - 195.

Curtis, S. E. (1983). Environmental management in animal agriculture, Iowa State University Press.

Donald, J., M. Czarick. (2003). The Poultry Engineering, Economics & Management Newsletter. Auburn University. Issue No. 26, November 2003.

Marsden, S. J. (1971). Turkey Production, Agriculture Handbook No. 393, Agriculture Research Service, United States Department of Agriculture.

Predicala, B., A. Alvarado, and L. Dominguez. 2012. Comparison of performance of radiant and forced-convection heating systems in swine grow-finish rooms - Part 2. Final Report to Alberta Agriculture & Rural Development, 29 pp.

Stowell, R., T. Mader, and J. Gaughan. (2009). Livestock Energetics and Thermal Environmental Management, Chapter 8: Environmental Management. St. Joseph, Michigan, American Society of Agricultural and Biological Engineers.

Zhang, X., Huiqing Guo, (2010). Literature Review on Heating Alternatives for Poultry Barns. University of Saskatchewan, Saskatoon, Saskatchewan, Canada, 20 pp.

Zipperian, C. The Efficiency Rating Conundrum.

AgTech Centre. (2010). Energizing Tomorrow's Agriculture. AgTech Centre Innovator. 10:2.

Alberta Agriculture and Rural Development. (2007). OnFarm Audit Reports.

Canadian Agri-Food Research Council. (2003). Recommended Code of Practice for the care and handling of farm animals. Chickens, Turkeys and Breeders from Hatchery to Processing Plant.

Research Branch Agriculture Canada. (1988). Candian Farm Buildings Handbook.

Trane Company. Trane Engineers Newsletter – Vol. 29, No. 5.

Types of Indoor Heating Systems from http://www.uniongas.com/index.asp.