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Saving Energy With Ventilation Heat Recovery in Poultry Barns

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Ventilation is used to maintain a healthy environment for birds by exhausting poor-quality indoor air and replacing it with fresh outdoor air. Farmers adjust ventilation rates to attain acceptable levels of humidity, odor and ammonia inside the houses. Ventilation also helps to maintain a healthy balance between oxygen (needed for bird respiration) and carbon dioxide (produced by bird respiration and heater combustion). Farmers are aware that higher ventilation rates promote better air quality at the expense of increased fuel (propane or natural gas) and electricity consumption. When outside air is cold, proper ventilation can be costly.

A large amount of energy is lost in the air exhausted in cold weather. For every cubic foot of warm, moist air (heated to 80 °F to 90 °F when birds are young) that is exhausted, the same volume of cold air must enter and be heated to the indoor temperature setting. The exhausted air, for which the farmer has already paid, has the desired temperature. The question is: How do you remove moisture and pollutants while retaining the heat embodied in the exhaust air? A **ventilation heat recovery system** is one option to reclaim the wasted heat to pre-heat cold, fresh air. These systems reduce seasonal heating energy consumption and the annual heating bill.

An air-to-air heat recovery ventilator brings two airstreams of different temperatures – (1) incoming fresh, cold air and (2) exhausted moist, warm air – into thermal contact, transferring heat from the exhaust air to incoming air during heating season (see Figure 1). The fuel spent in attaining the warm air can be reclaimed in this way. The heat recovery technology is a logical step to take before considering other renewable energy technologies. Because poultry barns are ventilated day and night, heat recovery systems can be operated and provide savings around the clock as needed.

Figure 1. A heat recovery ventilator evaluated in a broiler house at the Applied Broiler Research Farm of the University of Arkansas. Picture shows the heat exchanger core, house air intake (with filter attached to duct) and fresh air intake duct from attic space (adapted from Liang et al., 2011).

An additional benefit of using a heat recovery system lies in a potential improvement of indoor air quality associated with reduced heater operating hours and reduced release of combustion products into the house. Water vapor and carbon dioxide, the primary products of combustion, are released from unvented gas heaters typically used in poultry housing. Lower fuel consumption as a result of heat recovery means less combustion-related byproducts, translating into improved air quality and potentially drier litter.

Technology of Heat Recovery Systems

Heat recovery ventilators, also known as **air-to-air heat exchangers** extract heat from one airstream and deliver it to another. The heat from the stale air (warm indoor air) is conducted through the solid material (core) of the heat exchanger to the fresh (cold, incoming) air. The solid material keeps the two airstreams separate so that no contamination (i.e., moisture or pollutants) of the incoming air occurs.

It is easy to measure the beneficial heating of the incoming air by simply using a thermometer to show the rise in temperature of the outdoor air entering the heat exchanger compared to exiting the heat exchanger and entering the building. This temperature rise represents free heating to the farmer. Interestingly, there is a further benefit due to water condensation occurring inside the heat exchanger. Room air typically contains 0.5 to 2 percent (by weight) of water vapor. This seemingly small amount of water vapor contains a large amount of so-called **latent heat**, which has already been paid for due to water evaporation inside the house. On very cold days, condensation of water occurs inside the heat exchanger when the humid exhaust air is sufficiently cooled by the incoming fresh air. Some of the latent heat of condensation in the stale airstream is then picked up as **sensible heat** by the incoming airstream, providing a further reduction in heating system operating hours, fuel consumption and cost.

The heart of a heat recovery ventilator is a core (Figure 2) that consists of a set of solid members that keep the warm and cold airstreams separate and exchange heat from one to the other. The exchanger core can be built with a variety of materials; i.e., polypropylene plate, aluminum with special coating, high conductive polyethylene pipes, etc., to protect the material from corrosion by moisture and gases in a poultry house to ensure a long service life. The airstreams are driven through the heat exchanger by fans or blowers, causing some additional electricity usage. In addition, the ventilator may include insulation and defrost controls to prevent moisture from freezing on the core or fans in cold weather. A pre-filter or dust separator may be included to intercept dust that otherwise might be trapped in the narrow passages of the core. Air-to-air heat recovery equipment includes cross-flow or counter-flow heat exchangers (Figure 2). These two common types differ in construction, with a tradeoff of performance, efficiency, footprint (size) and purchase cost.

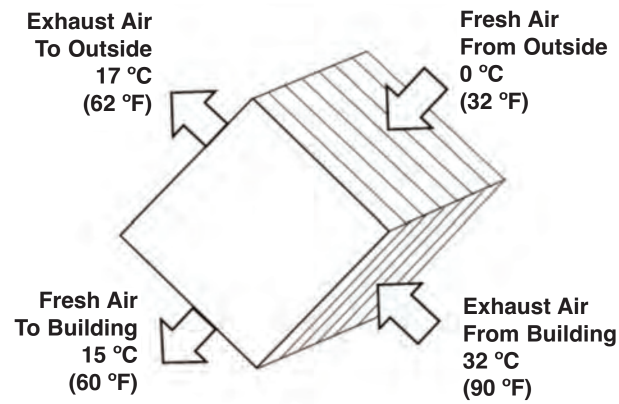

Figure 2. A cross-flow heat recovery ventilator (with typical temperatures). Arrows indicate the directions of airflows.

Efficiencies (fraction of available energy that is actually captured) usually range from 40 to as high as 80 percent, depending on the design and quality of waste energy sources. Typical efficiency values claimed by manufacturers are in the range of 60 to 80 percent. Efficiency values alone mean little unless the ventilator has the needed capacity for adequate airflow rates. Reduced airflow rates, for example, due to air resistance may increase efficiency but provide little overall benefit. Hence, the heat exchanger design and installation should consider the resistance to airflow and blower electricity requirements. Furthermore, any imbalance of flow rates of the two airstreams can affect efficiency. So, there is room for manufacturers to develop systems with a wide variety of performance and savings potential for the poultry farmer.

How Much Energy to Recover?

Commercial heat recovery systems used for confined livestock and poultry houses operate as stand-alone units with independent fans and ductwork to provide first-stage ventilation compatible to the desired minimum ventilation rates. They come in various sizes, ranging from 1,200 cubic feet per minute (cfm) to 15,000 cfm per unit. Some systems employ variable frequency control on the motors so that lower airflow rates can be used with younger birds for better efficiency while still meeting the higher ventilation needs of the older flock. Multiple units of smaller sizes or a single unit with a larger size can be installed. Multiple units (i.e., three to five) installed in different control zones make it easier to distribute air to the whole building rather than using a single unit. A subset of the units can be operated during half-house brooding during grow-outs.

The amount of heat recovery depends not only on the capacity and efficiency of the system but also on the building characteristics, stocking density and the ventilation management. Partial-house brooding is practiced on most broiler farms, while whole-house brooding is used to raise poults in turkey brood barns. The influence of building insulation and system efficiency upon annual recovered heat and savings due to the installation of the heat recovery system is calculated (Table 1) using an energy-use spreadsheet model (Berry and Miller, 1989). Two insulation levels are represented, namely curtain-sided (referred to as **low insulation**) or solid-sidewalls (referred to as **high insulation**). More solid-sidewall broiler or turkey brood barns have been constructed in the last two decades, but there is still a significant stock of houses with relatively poor insulation in the southern region. Minimum ventilation rates and heat and moisture production of broilers and poults in published literature were used in the calculation (Czarick and Fairchild, 2007; Xin et al., 1998). The size of the heat recovery system installed is to deliver 70 to 80 percent of the minimum ventilation required for market-size birds. Values calculated in Table 1 are based on an installed ventilation capacity of 0.5 cfm/bird for the heat recovery system. The decision to install larger capacity may incur high capital investment costs with limited return.

The potential recoverable heat is first calculated by multiplying the ventilated heat loss and the heat exchanger efficiency. Then, the potential recoverable heat is compared to the supplemental heat calculated based on the building conductive heat loss and ventilation requirements. The smaller of the two quantities is the actual recovered heat. As birds grow older, less heat is progressively required for the building, until heat recovery ventilation has to be deactivated in warmer seasons.

As shown in Table 1, heat recovery systems with a thermal efficiency between 0.5 and 0.8 will save 40 to 60 percent of the original supplemental heating costs. With similar heat recovery system capacity installed, higher efficiency units will recover more heat through ventilation.

Economic Feasibility

Heat recovery systems are most attractive for livestock and poultry that are not sufficient in heat production and for buildings that have some combination of (a) high room temperature, (b) high ventilation rates, (c) low winter temperature and (d) high energy cost. Low energy costs of earlier years (< $0.60 per gallon of propane seen before year 2000) made heat recovery systems uneconomical. In recent years, however, escalating fuel prices have encouraged producers to undertake major efforts to improve energy efficiency. Propane fuel costs continue to fluctuate, and heating a typical 16,000 square foot broiler house could costs $8,000 to $10,000 annually in northwest Arkansas.

While heating costs have increased over the past decade, heat recovery ventilator technology has greatly improved over the years through better design, higher efficiency and lower capital investment. One of the technologies recently evaluated on the commercial-scale broiler research farm at the University of Arkansas showed that use of a heat recovery system of 4,000 cfm capacity (peak heat recovery around 100,000 Btu/hr) could reduce fuel consumption by 20 to 25 percent (Liang et al., 2011). While heat recovery ventilators incurred an additional 1,000 kWh of electrical consumption per winter flock, this represented a small fraction of total energy expenditures.

Table 1. Projected annual recovered heat (MMBtu, Million Btu), reduced heat demand with heat recovery and percentage savings under low or high building insulation levels and low or high heat exchanger efficiencies in poultry housing in northwest Arkansas.

Insulation Level*	Heat Exchanger Efficiency	Broiler**			Turkey Brooder***		
		Recovered Heat	Heat Needed (with Heat Recovery)	Saving	Recovered Heat	Heat Needed (with Heat Recovery)	Saving
		MMBtu	MMBtu	%	MMBtu	MMBtu	%
Low	0.5	260	370	41%	310	530	37%
	0.8	370	260	59%	450	390	54%
High	0.5	200	270	43%	220	280	44%
	0.8	290	180	62%	310	190	62%

* Low insulation level consists of wall R-value of 7 $ft^2 \times °F \times hr/Btu$, ceiling R-value of 11 $ft^2 \times °F \times hr/Btu$, while high insulation level consists of wall R-value of 11 $ft^2 \times °F \times hr/Btu$, ceiling R-value of 19 $ft^2 \times °F \times hr/Btu$.

** With 20,000-bird capacity using partial-house brooding; 5½ grow-out cycles each year with 6.5 weeks each.

*** With 18,000-poult capacity using whole-house brooding; 4 brood cycles each year with 5.5 weeks each.

Table 2. Total present value (8 percent interest) of the cost saving occurring over a period of three years as a function of propane costs and annual projected fuel savings in gallons.

Annual Projected Propane Saving (gallon)	Propane Cost ($/gallon)						
	$1.00	$1.50	$2.00	$2.50	$3.00	$3.50	$4.00
	Net Present Value of Projected Fuel Savings Over the Period						
500	$1,289	$1,933	$2,577	$3,221	$3,866	$4,510	$5,154
1,000	$2,577	$3,866	$5,154	$6,443	$7,731	$9,020	$10,308
1,500	$3,866	$5,798	$7,731	$9,664	$11,597	$13,530	$15,463
2,000	$5,154	$7,731	$10,308	$12,885	$15,463	$18,040	$20,617
2,500	$6,443	$9,664	**$12,885**	$16,107	$19,328	$22,550	$25,771
3,000	$7,731	$11,597	$15,463	$19,328	$23,194	$27,060	$30,925
4,000	$10,308	$15,463	$20,617	$25,771	$30,925	$36,079	$41,234
5,000	$12,885	$19,328	$25,771	$32,214	$38,656	$45,099	$51,542
6,000	$15,463	$23,194	$30,925	$38,656	$46,388	$54,119	$61,850
7,000	$18,040	$27,060	$36,079	$45,099	$54,119	$63,139	$72,159
8,000	$20,617	$30,925	$41,234	$51,542	$61,850	$72,159	$82,467

Table 2 shows the total present value of projected fuel savings over a selected planning period. For example, if propane costs $2.00 per gallon and the HRV is capable of recovering 2,500 gallons of fuel, then the total present worth value of the fuel saving is $13,000, based on an interest rate of 8 percent and a three-year period. Under this scenario, the grower could afford to invest (or borrow) as much as $13,000 for the system and expect the fuel savings to pay the note.

Payback periods can be computed to estimate the time required for capital cost investment in the equipment to be recovered in fuel cost savings. Payback periods for different scenarios are given in Table 3 for two initial costs, two fuel costs, two interest rates and 11 levels of annual recovered heat. Obviously, the payback period is sensitive to the cost of fuel. Additionally, the amount of annual targeted propane saving not only depends on the size of the system selected but also the efficiency of the system. With the same installed cost, for example $10,000, an increased performance due to higher efficiency (from 2,100 to 3,160 gallon of annual saving) could reduce system payback periods from three to two years, assuming $2.00 per gallon of propane gas. Therefore, it is important to obtain a reliable estimate of projected fuel savings for the system you have in mind

Table 3. Payback periods (in years) for different initial equipment costs, propane fuel costs, interest rates and annual heat recovered (in gallons of propane).*

Cost of HRV System	$10,000				$20,000			
Fuel Cost ($/gal)	1.0		2.0		1.0		2.0	
Interest Rate (%)	8	12	8	12	8	12	8	12
	Payback in Years							
500	> 10	> 10	> 10	> 10	> 10	> 10	> 10	> 10
1,000	> 10	> 10	7	8	> 10	> 10	> 10	> 10
1,500	> 10	> 10	5	5	> 10	> 10	10	> 10
2,000	7	9	3	4	> 10	> 10	7	9
2,500	6	6	3	3	> 10	> 10	5	6
3,000	5	5	2	2	10	> 10	4	5
4,000	3	4	2	2	7	8	3	4
5,000	3	3	2	2	5	6	3	3
6,000	2	2	1	1	4	5	2	2
7,000	2	2	1	1	4	4	2	2
8,000	2	2	1	1	3	4	2	2

***Btu content of fuel used in calculation: liquid propane – 95,000 Btu/gallon, natural gas – 100,000 Btu/CCF.**

(as affected by both system efficiency and airflow capacity) to make an informed financial decision.

Issues and Challenges

The biggest challenge facing heat exchanger application in a poultry house is the amount of dust encountered in the air. Dust in the exhaust airstream, if not handled properly, will degrade the performance of any heat recovery system. Proper handling of dust is critical to the success of a heat recovery system application. Traditional flat-plate heat exchangers require upstream filtration systems on the warm exhaust air side to intercept the dust (from indoor air) before it enters the heat exchangers. After a grow-out, exchanger cores need be cleaned using compressed air or water, depending on the equipment designs. Regular cleaning effectively removes dust and rejuvenates the cores.

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