

Rocks Used to Salvage Heat from Exhaust Air in NDSU Dairy Barn

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Maintaining acceptable levels of relative humidity and temperature can be a problem with confinement livestock barns in areas of severe winter such as North Dakota. A ventilation rate sufficient to remove the moisture provides unsatisfactory temperature conditions.

One way to solve this problem is to add heat, but the disadvantages are cost and fire hazard. Other than adding heat, additional insulation could be added or heat from the exhaust air can be reclaimed. Adding additional insulation has limited effectiveness in maintaining satisfactory conditions in a livestock structure.

Heat exchangers have the ability to reclaim a significant amount of heat, but there are problems with maintaining the surfaces to effectively transfer the heat.

This article discusses a heat exchange method tested in a small barn and used successfully in the large (120-cow) free-stall NDSU dairy barn. The ventilation system uses field rocks to absorb the heat from the exhaust air and return it to the barn in the intake air by reversing the ventilating fan.

Preliminary Test Summary

The use of field rock for salvaging heat from ventilation air was demonstrated in a small beef unit and compared with a commercial heat exchanger installed in a swine farrowing unit. Results show that the rocks are as effective in recovering heat as the commercial heat exchangers, and the installation costs are

lower. The rocks did not require attic space or have the installation problems associated with commercial units and are more easily maintained.

The primary operational problem was the development of frost on the rocks when outside temperatures reached about -26° F. for an extended period of time. In the small barn, the problem was minimized in three different ways. First, salt or antifreeze was used on the rocks. Second, the cycle, normally five minutes in each direction, was increased to three or four hours in each direction to remove the frost. Third, larger rocks were used.

The original uncrushed rocks used were from $\frac{3}{4}$ to $1\frac{1}{2}$ inches. These were gradually increased to diameters of 3 to 4 inches. To compensate for the reduced surface area of the larger rocks, the rock bed was increased in depth to 12 inches. Frosting of the rocks in the large barn has not been a problem.

The original installation had the intake and exhaust rock beds side by side on one side of the building. This was to help minimize the effect of the wind on the system. Air passed directly from the outlet to the inlet without mixing with fresh air. This reduced the effectiveness of the system. Improved operation was obtained by installing the inlet and exhaust fans on opposite sides of the building.

Belt-driven fans with variable-speed pullies were originally installed to provide adjustments in air flow. All fans have been changed to direct drive to avoid maintenance problems.

The selection of fan blades is important. "Kidney" shaped blades were not satisfactory because they moved much more air in one direction than in the other. Cast aluminum blades performed well and move more nearly the same amount of air in both directions.

The rock heat beds are essentially self-cleaning. The rocks are supported by 3-inch expanded metal over an angle iron frame. Condensation forms on the rocks and combines with the dirt and drops to the ground. Summer-time cleaning with a power washer was beneficial.

A repeat cycle timer was used to control the fans. The timer is adjustable to provide cycles of 1, 2, 4, 5, 10 or 20 minutes. An off cycle of 30 seconds provides time for the fans to come to a complete stop. However, the fan blades may continue to turn because of the wind and the blades must be reversed electrically. Any three phase motor will normally do this. Single phase motors normally used in overhead door operators are available for this purpose and are known as "instant reverse." Phase converters with three-phase motors failed to give positive fan reversal.

The New Dairy Barn

When a new free-stall dairy unit was constructed on the NDSU campus in 1978-79 it was decided to use this rock-type of heat exchanger (see Figures 1 and 2). The unit is 84 x 152 feet and houses 120 head of dairy cows of mixed breeds. This free-stall barn is oriented with the length east and west.

Four ventilating fans were installed on the north side and four on the south side. Each was rated at 3350 cfm. The two fans on west end of the north side are paired and controlled by one set of controls. The two on the east end of the north side are paired and controlled by a second set of controls. The south side is similar. Each pair is designated as NW, NE, SW and SE. Four sets of controls operate each of the four pairs of fans (see Figures 2 and 3) but synchronized with one timer and a thermostat.



Figure 1. The 120 cow free-stall barn at NDSU.

The ventilating rate used was 13,400 cfm or 112 (4 x 3350/120) cfm for each of the 120 cows. The fans selected were 24-inch, 1750 rpm, $\frac{3}{4}$ hp., 208-volt and three-phase designed to operate at $\frac{5}{8}$ -inch SP. Motor protection and reversing were accomplished with reversing motor starters. Air leaving the fans is fed into the barn and removed from the barn through distribution pipes (Figure 2).

Another feature of this barn was the raised ceiling section through the middle of the barn (Figure 5). The purpose of this section was to provide an observation room at the west end. It appears that this raised ceiling has done much to improve the ventilating system by giving greater volume and more height.

An additional two fans were installed in the peak at the middle of the barn with distribution ducts running east and west (see Figures 2 and 5). These fans are reversible and two speed, although they have been used only at the high speed. The rating on these 20-inch fans is 2400/4370 cfm at $\frac{1}{4}$ -inch SP, 1150/1750 rpm, $\frac{1}{2}$ hp., 208-volt, and three-phase. These fans provide an additional 73 cfm (4370 x 2/120) per animal. The fans are used in the summer for removal of air from the building and for recirculation of air in the winter.

The repeat cycle timer set at 10 minutes is variable from 1 to 20 minutes with a 30-second delay between cycles as previously described (see Figure 3). A similar three-hour timer is also in the circuit. This three-hour timer intended to defrost the rocks under severe conditions has not been needed. A thermostat controls the room temperature at 45° F.

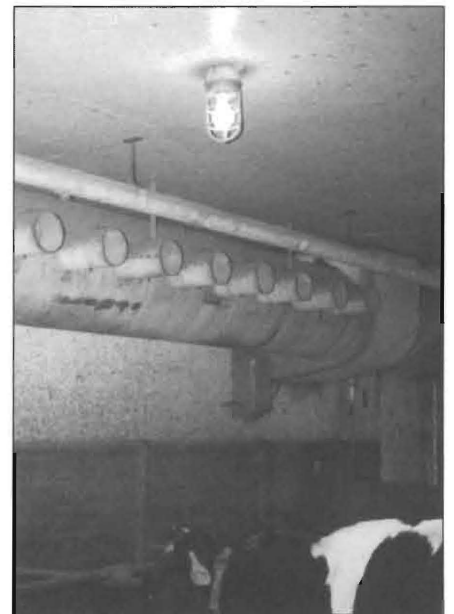


Figure 2. The inside distribution ducts.

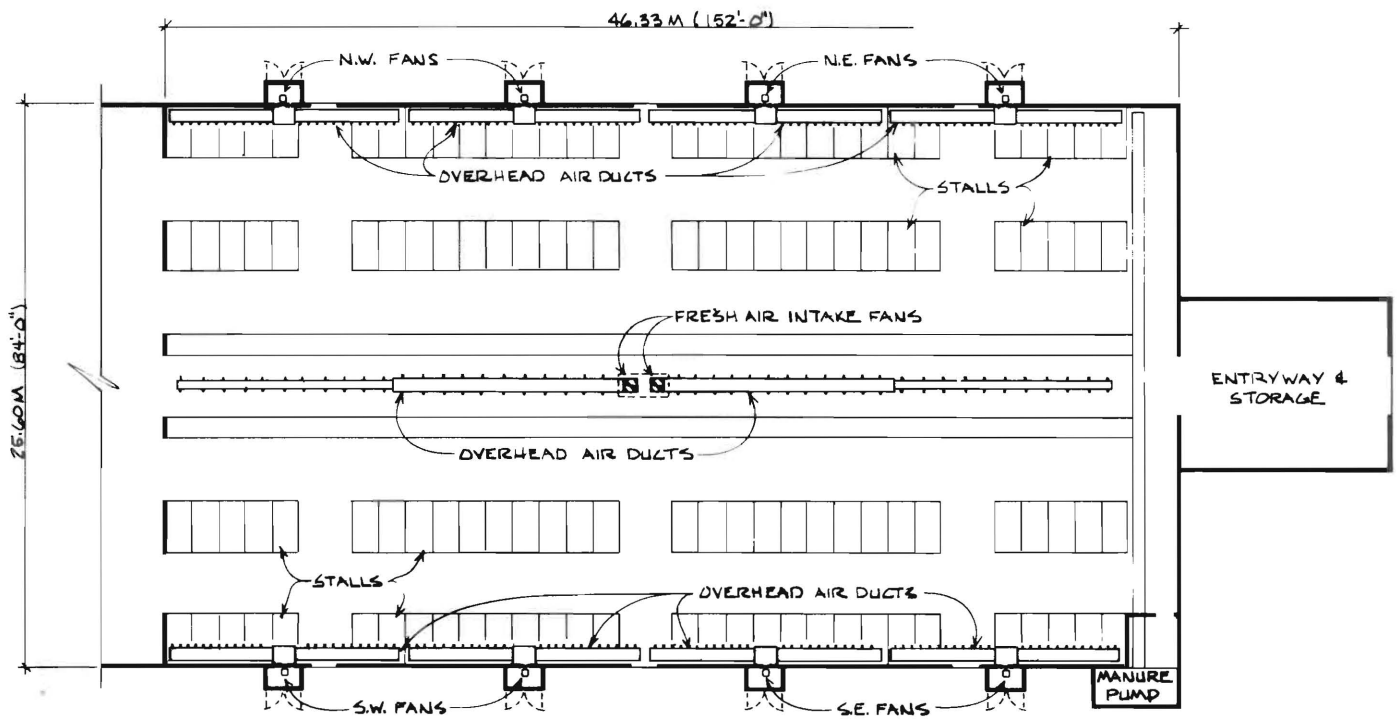


Figure 3. Floor plan showing fan locations.

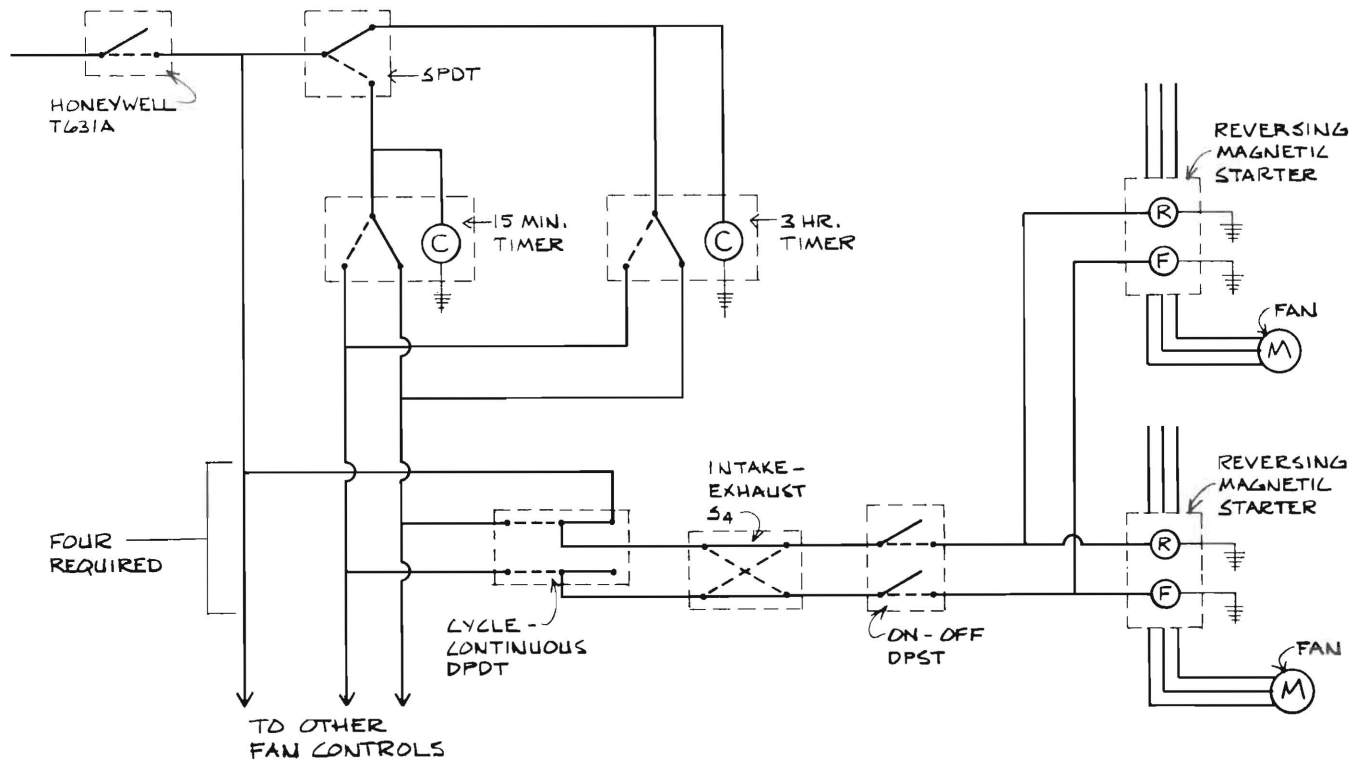


Figure 4. Wiring diagram controlling each pair of fans on lower level.

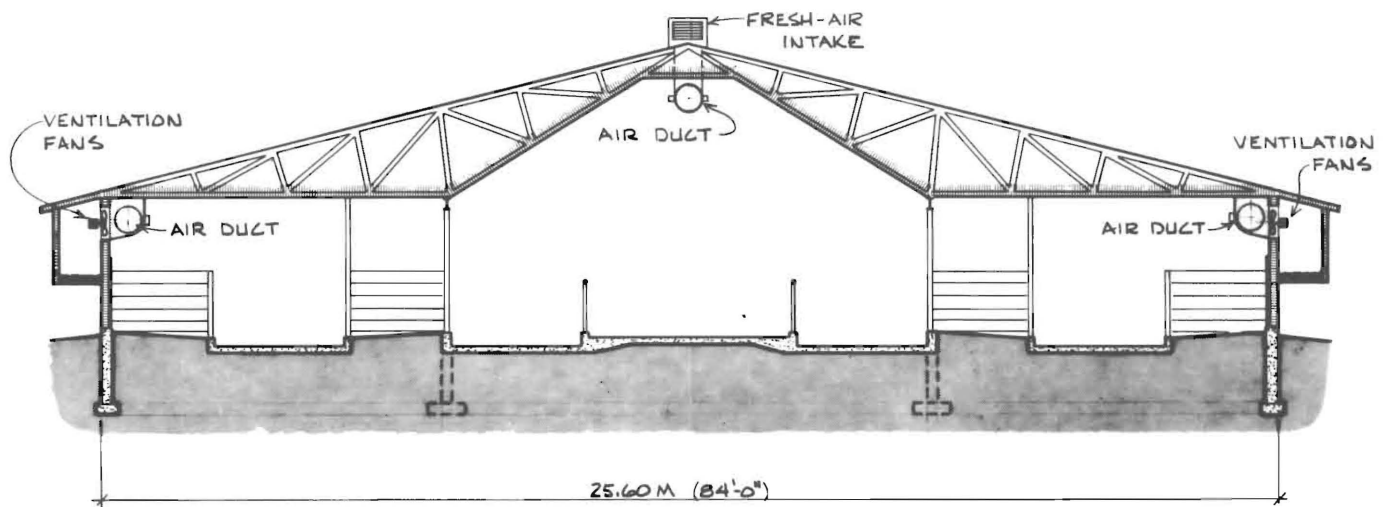


Figure 5. Cross section of 120 cow free-stall barn.

Management

This dairy barn is much larger than the experimental unit used to develop this system. The larger barn required a longer cycle time of 10 minutes as compared with five minutes in the experimental barn. Controls have been slightly modified and incorporated in the wiring diagram shown in Figure 3. Management is an important factor in putting this dairy barn system into operation as well as the continued success of the system. It does require adjustments to meet changing weather conditions.

Summer Operation

Summer operation was geared to provide a maximum of fresh air as well as air circulation. Normal operation would be to have the NW and SE fans blowing air into the barn and the NE and SW fans exhausting air. This tends to give the air a circular motion in the barn. During summer temperatures of 90° F and warmer, all side fans are adjusted to bring outside air into the barn. The overhead fans operate with continuous exhaust from April through October. Air that is not exhausted through the overhead fans is exhausted through the large doors on the east and west ends of the barn. The doors on the fan and rock enclosures are open

during the summer (see Figure 7) giving a significant increase in air volume because of reduced static pressure as the air does not pass through the rocks.

Winter Operation

The fans normally operate using a 10-minute cycle with the north units (NE and NW) intaking air and the south units (SE and SW) exhausting air and then reversing. This works well down to about 0° F. When the temperature falls lower than this, the intake cycle on one or two units is shut down.

Temperature is controlled by the amount of ventilation air allowed into the barn. Exhaust cycles run at their normal 10-minute cycle. During severe temperature conditions of -26° F and below, fans facing the wind run only on exhaust cycle and fans opposite the wind run a normal exhaust/intake 10-minute cycle. The overhead fans continuously pick up air from near the

ceiling at the middle of the building and distribute it back in the barn. The rock beds do not freeze up with this type of operation. A thermostat turns off the side

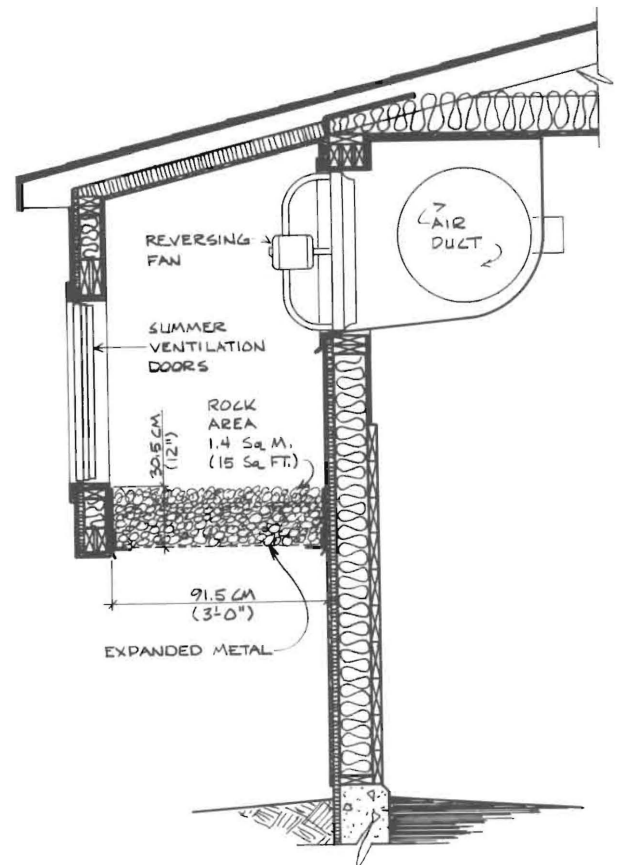


Figure 6. Cross section of the rock-bed and fan.

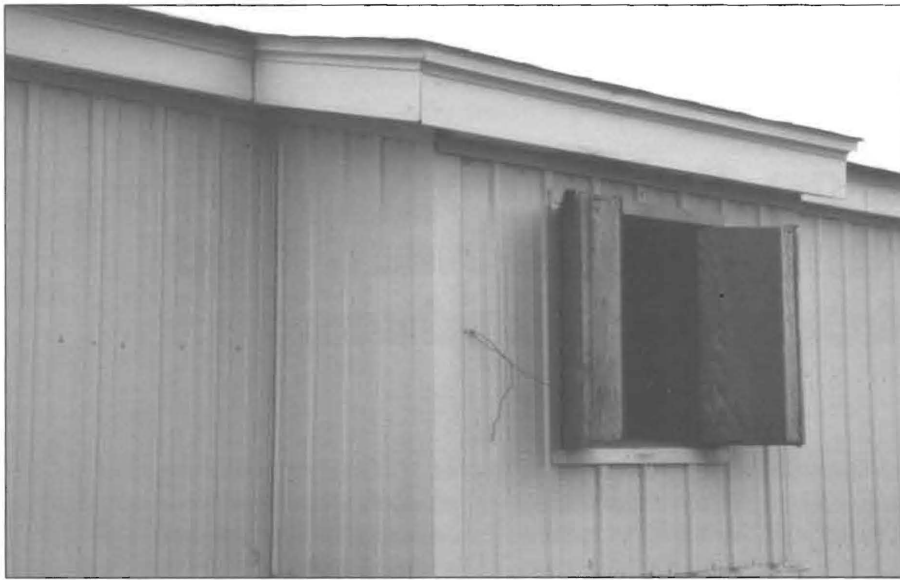


Figure 7. The doors are open on the rock units for summer ventilation.

fans at a few degrees above freezing but does not normally operate. The barn needs to be filled to capacity to provide the maximum heat.

The rocks are cleaned once a year by removing them and washing with a hose and cold water. Washing them in place does not appear to be successful. The doors on the fan housing as shown in Figures 6 and 7 are closed during the winter and open for summer ventilation.

Summary

With good management, the system has operated very well. There is never any fog or rain in this barn. Milk production does not vary because of flies or outside temperature fluctuations. The circular flow of air gives good circulation of insecticides for the control of flies. The electrical cost obviously is higher than a conventionally ventilated barn due to the energy required to push air through the rocks. During the summer all fans are used for air intake, more than doubling the quantity of ventilation used on common livestock ventilation systems.

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