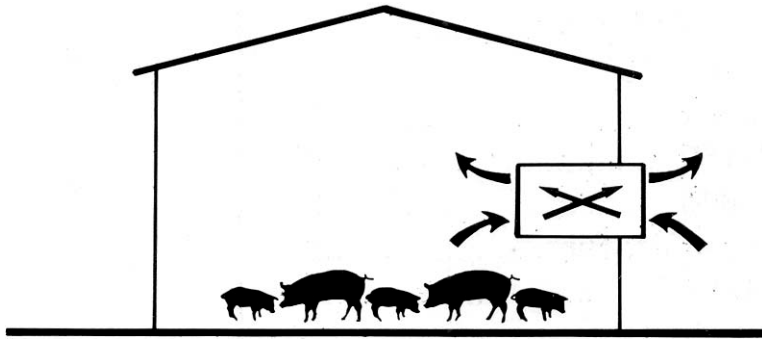


# Evaluation Report

# 619



**Better Air A-3000**  
**C and J Jones**  
**Del Air A-150**  
**Del Air A-800**  
**Robbco AI- 3500 - BIK**  
**Z-Air 74-60-1**

## Heat Recovery Ventilators

A Co-operative Program Between



ALBERTA  
FARM  
MACHINERY  
RESEARCH  
CENTRE



PRAIRIE AGRICULTURAL MACHINERY INSTITUTE

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# HEAT RECOVERY VENTILATORS

## INTRODUCTION

The following evaluations were conducted in a joint two year study by PAMI and the Manitoba Department of Agriculture under sponsorship from Energy Mines and Resources Canada, ENERDEMO program, and the Manitoba Department of Energy and Mines. The main purposes of the project were to demonstrate heat recovery as an energy conservation measure, and to evaluate the performance of commercially available HRVs.

Each heat recovery ventilator (HRV) was installed and monitored in a livestock barn. In addition, laboratory tests were conducted to measure performance under a more complete range of conditions. Nine tests were run in combinations of three barn conditions and three outdoor temperatures. Each HRV was evaluated for heat recovery rate, ventilation rate, heat recovery ratio, leakage, defrosting, power requirements, ease of installing, adjusting and cleaning, operator safety and suitability of the operator's manual. Mechanical problems and failures during normal operation were recorded.

*Senior Engineer: J.D. Wassermann*

*Project Engineer: M.E. Jorgenson*

*Project Technologist: A. R. Boyden*

## TERMINOLOGY

### HEAT RECOVERY VENTILATOR

A **heat recovery ventilator (HRV)** is designed to transfer waste heat from building exhaust air to the incoming fresh supply air while providing ventilation.

**Heat recovery** is defined as the rate of heat transferred from the exhaust air to the fresh air as it passes through the HRV. Since the rate of heat recovery fluctuates daily with outdoor temperature and several other variables, it is difficult to determine the overall benefits of an HRV over an entire winter season. Therefore in this report, a table of typical **seasonal heat savings** were calculated. It is important to realize that these values are only accurate for a specific location and barn condition. In the table, seasonal heat savings are shown for different heat balance temperatures. The **heat balance temperature**, is the outside temperature below which the heat produced by the animals is no longer enough to keep the barn warm. It is measure of total animal heat production and barn heat loss. Most farmers can estimate their heat balance temperatures by observing the outdoor temperature when they have to turn heaters on in the barn. For example, if heaters are needed when outside temperature drops below 14°F (-10°C), then that is the heat balance temperature. Heat balance temperature can significantly affect the seasonal heat savings, since a well-insulated barn requires heat for fewer days than a poorly-insulated barn. Specific calculations for an individual barn can be obtained by contacting your provincial Department of Agriculture or PAMI.

**Exhaust air heat loss** is the heat exiting from the barn in stale exhaust air and is the maximum amount of heat available to be recovered. The **heat recovery ratio (HRR)** is the portion of the available heat that was actually saved and is a measure of core efficiency. It is defined as the average heat recovery divided by the exhaust air heat loss.

### VENTILATION RATE

**Exhaust airflow** is the rate of stale barn airflow exiting from the barn through the HRV. **Supply airflow** is the rate of fresh airflow entering the barn through the HRV. **Ventilation rate** includes both of these airflows listed separately, since an HRV acts as both an inlet and an exhaust.

Ventilation rates are affected by barn static pressure. **Barn static pressure** is the difference between air pressure inside the barn and outside. Most livestock barns operate under a slightly negative static pressure, so that humid barn air is drawn out through fans rather than being pushed out through cracks or inlets. It is therefore desirable that an HRV have a higher exhaust airflow than supply airflow, under all operating conditions (ie. icing or fouling).

Ventilation rate for an HRV determines the size of barn and number of animals for which it is suited. Guidelines for determining ventilation requirements are available from most Provincial Departments of Agriculture or PAMI.

### LEAKAGE

Cracks and imperfections in the seals within the core permit some exhaust air to leak into the fresh supply air stream. **Leakage** is expressed as the actual quantity or percent of exhaust airflow rate leaking into the supply. High leakage is undesirable because the contaminants and humidity are simply recirculated back into the barn, fouling the fresh supply air.

### DEFROST

Animals in livestock barns produce large quantities of moisture as well as heat. When moist air is passed through an HRV in winter, it cools and condenses on the cooler heat transfer surfaces. Some of this moisture drains out as liquid, and some freezes to the cold parts of the core. When too much frost accumulates, the core becomes restricted, reducing airflow rates and heat recovery. While several methods of controlling ice build-up are possible, most agricultural HRVs use a defrost cycle. A **defrost cycle** consists of shutting off or reversing the supply airflow at regular intervals for a few minutes until the ice has melted. **Condensate**, or condensed water vapor and melted ice, must be drained out of the HRV.

## BETTER AIR A-3000 HEAT RECOVERY VENTILATOR

### MANUFACTURER AND DISTRIBUTOR:

Better Air Manufacturing Ltd.  
P.O. Box 490  
MacGregor, Manitoba  
R0H 0R0  
Phone: (204) 252-2333

### RETAIL PRICE

\$3,000.00 (May, 1989, f.o.b. Humboldt, Sask.).

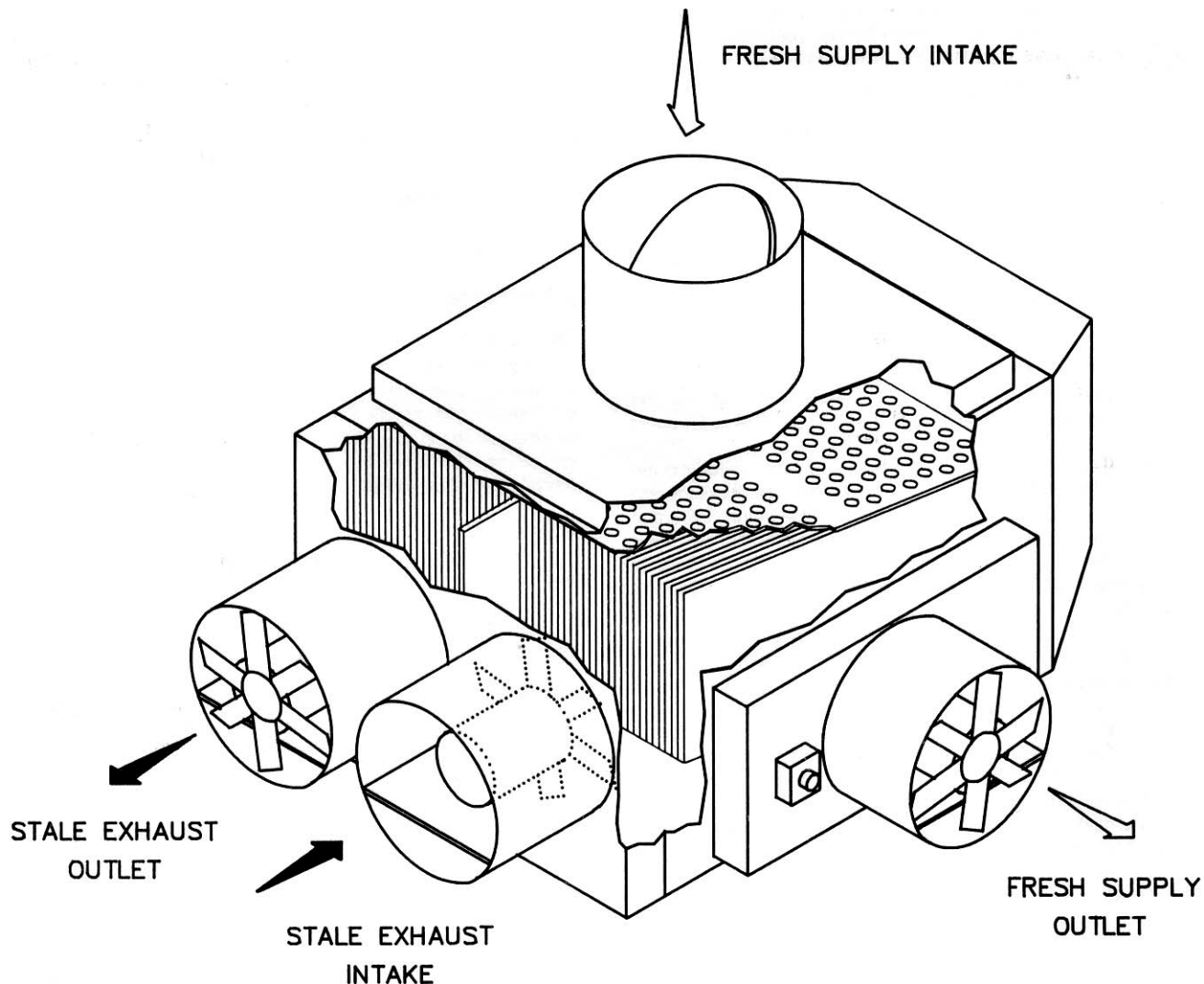


FIGURE 1. Better Air A-3000.

### SUMMARY AND CONCLUSIONS

**Rate of Work:** Maximum rate of heat recovery of the Better Air A-3000 was 860 Btu/min (15.1 kW) which occurred in a warm 77°F (25°C) barn with outdoor temperature -22°F (-30°C). In normal operating mode, ventilation was about 1260 cfm (590 L/s) exhaust and 875 cfm (410 L/s) supply.

**Quality of Work:** Heat recovery ratio ranged from 39 to 43%. Core leakage was only about 6 cfm (3 L/s) or 0.5% of exhaust airflow. Defrost control was fair. Only 3 minutes of shutdown per hour was needed in the coldest weather, but the defrost control thermostat did not cycle as intended. Cycles had to be manually activated for the test.

**Power Requirements:** The three fans drew approximately 6.5 A at 120 V AC and required about 0.8 kW of power.

**Ease of Operation:** Ease of installing was very good. It took two men 6 hours to install the unit and defrost control in the ceiling. Ease of adjusting was good. The thermostat had to be adjusted several times and did not prevent freezing. Ease of cleaning was very good. The core was easily accessible without tools and could be cleaned from either end.

**Operator Safety:** The Better Air A-3000 was not CSA certified, but no hazards were apparent.

**Operator's Manual:** None was provided. The manufacturer was consulted for installing and operating guidelines.

**Mechanical History:** No mechanical problems occurred in 30 days of operating.

## RECOMMENDATIONS

It is recommended that the manufacturer consider:

1. Modifying the defrost control to ensure complete ice removal and more stable ventilation.
2. Providing an operator's manual with each unit sold.

## THE MANUFACTURER STATES THAT

With regard to recommendation number:

1. We agree the A-3000 heat exchanger requires a better defrosting control to make it more operateable.
2. We agree the A-3000 heat exchanger should have operating instructions for the customer.

## GENERAL DESCRIPTION

The Better Air A-3000 is a cross-counter flow, plate type heat recovery unit designed to be mounted in the ceiling in connection with the barn's ventilation system. It consists of an aluminum alloy enclosure encasing an aluminum core and supporting two exhaust fans, one supply fan, a supply inlet duct with back draft damper, and an airflow diverter cap.

Stale barn air is drawn into one side of the core by the first exhaust fan, passes through half the core, turns 180° and passes through the other half, where it is drawn outside by a second exhaust fan. Fresh supply air usually enters from the attic, passes down through a diffuser and the core, and is blown into the barn by the supply fan. The supply fan may be mounted on either side of the core, and may be connected to a duct if desired. For defrosting, a Goldfan T-1 mechanical thermostat monitors supply outlet temperature and shuts off the supply fan only as required. The core is inclined for drainage, and all panels are removable for core cleaning.

## SCOPE OF TEST

For the test, the Better Air A-3000 was mounted in the ceiling and delivered fresh air directly to the barn without ducting. The unit was installed at a chicken barn near Winnipeg, Manitoba (TABLE 1) and operated during the winter of 1988/89 for a total of about 30 days.

TABLE 1. Operating Conditions.

<b>LOCATION:</b>	Landmark, Manitoba
<b>TYPE OF BARN:</b>	Chicken Broiler
<b>NUMBER OF ANIMALS:</b>	10,000
<b>INSIDE BARN DIMENSIONS:</b>	250 x 40 x 8.5 ft (75 x 12 x 2.6 m)
<b>FEEDING SYSTEM:</b>	Commercial mash feed, augers to self-feeders near floor.
<b>MANURE SYSTEM:</b>	Straw floor litter, scheduled cleanout between batches of birds.
<b>WINTER VENTILATION SYSTEM</b>	
Without HRV:	Two home made single pass heat exchange tubes into recirculation duct, one variable speed exhaust fan.
With HRV:	Better Air mounted in ceiling, fresh air from attic blown into the recirculation duct.
<b>AVERAGE BARN TEMPERATURE:</b>	59°F (15°C)
<b>AVERAGE BARN HUMIDITY:</b>	70%
<b>HEAT BALANCE TEMPERATURE:</b>	14°F (-10°C)

## RESULTS AND DISCUSSION

### RATE OF WORK

**Heat Recovery:** Heat recovery rates for the Better Air A-3000 at three barn temperatures are illustrated in FIGURE 2. The maximum rate of 863 Btu/min (15.1 kW) occurred in a 77°F (25°C) barn with an outdoor temperature of about -22°F (-30°C). The graph shows that more heat was recovered from warm barns than cool barns. Also, the rate of heat recovery decreased as outdoor temperatures increased. Thus,

the total heat savings over an entire season would vary depending on the barn temperature, outdoor temperature and the heat balance temperature.

TABLE 2 illustrates the seasonal heat saving by the Better Air A-3000 in a single season based on 20 years weather data for Winnipeg, Manitoba and a barn temperature of 68°F (20°C). If a barn at that location had a heat balance temperature of 14°F (-10°C), the Better Air A-3000-BIK would recover up to 67 MBtu (19700 kWh) of heat in one season. To fully realize the savings, the HRV must be properly matched to the ventilation requirements of the barn.

**Ventilation Rate:** FIGURE 3 illustrates the supply and exhaust airflow rates through the Better Air A-3000 versus the pressure difference inside and outside the barn. It ventilated about 1260 cfm (590 L/s) exhaust and 860 cfm (400 L/s) supply at a neutral barn pressure.

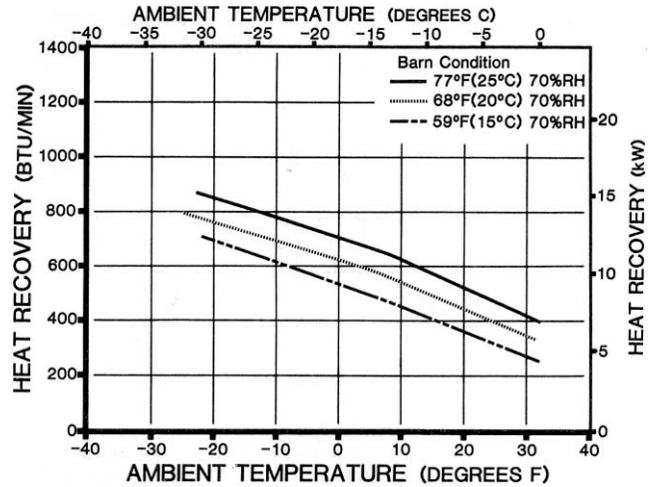


FIGURE 2. Better Air A-3000 Heat Recovery Rates at Three Barn Temperatures.

TABLE 2. Seasonal Heat Savings of the Better Air A-3000 near Winnipeg. (Barn temperature 68°F (20°C), Outdoor temperature 20 year average 1968-1987).

HEAT BALANCE TEMPERATURE °F	HEAT BALANCE TEMPERATURE °C	LENGTH OF HEATING SEASON hours	SEASONAL HEAT SAVED MBtu	SEASONAL HEAT SAVED (kWh)
32	(0)	3,530	103	(30 100)
23	(-5)	2,640	85	(25 000)
14	(-10)	1,890	67	(19 700)
+5	(-15)	1,294	50	(14 600)
-4	(-20)	796	33	(9 600)
-13	(-25)	367	16	(4 700)
-22	(-30)	100	5	(1 400)
-31	(-35)	10	0.5	(155)

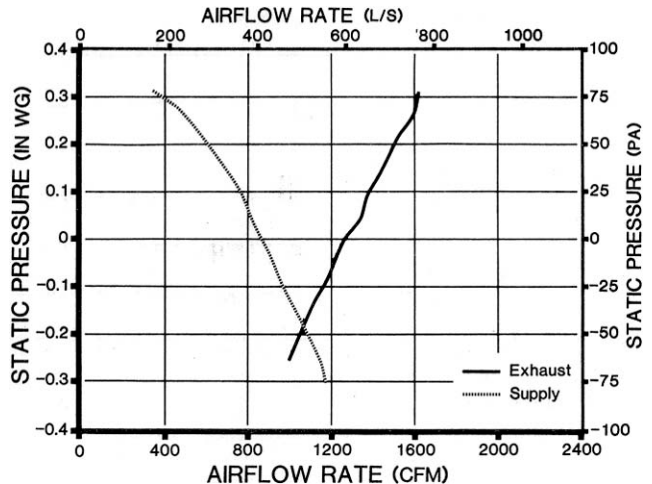


FIGURE 3. Better Air A-3000 Ventilation Rates.

Typically in winter, barns are operated under a negative pressure ranging from 0 to -0.10 in.wg (0 to -25 Pa). Under these conditions, exhaust airflow decreased by as much as 100 cfm (47 L/s) while supply airflow increased by up to 100 cfm (47 L/s).

In the test barn, dust gradually built up in the exhaust passages of the core, slightly reducing the ventilation rate. The core had to be washed about once a week with a garden nozzle or pressure washer. Frequency of cleaning may vary for other barn conditions.

In cold weather, the defrost cycle affected overall ventilation rates. The supply fan was shut off for an average 3 minutes each hour while the exhaust flow became slightly restricted with ice formation. In the worst case test run, the net ventilation rates, averaged over a complete cycle, were 1147 cfm (540 L/s) exhaust and 830 cfm (390 L/s) supply.

## QUALITY OF WORK

**Heat Recovery Ratio:** Heat recovery ratios (HRR) for the Better Air A-3000 ranged from 39 to 43% (TABLE 3). TABLE 3 lists the complete summary of results from the nine test runs. The Better Air A-3000 was slightly more efficient at colder outdoor temperatures, but efficiency was not affected by changes in barn temperature.

**Leakage:** About 6 cfm (3 L/s) of stale exhaust air leaked into the incoming fresh air with the core clean and operating at normal flow rates and pressures. This amounted to a very low cross-contamination rate of only 0.5%.

**Defrost:** The Better Air A-3000 defrost control system was fair. When operated according to the manufacturer's guidelines, it cycled sporadically, leaving some ice in the core, and making ventilation harder to control. The Goldfan T-1 thermostat was set at approximately 32°F (0°C). It shut off the supply fan as intended, but the sensor warmed up too quickly, restarting the supply fan after as little as 40 seconds. It would then continue to cycle on and off rapidly, since all ice was not removed from the core. For the tests, the supply fan was manually held off until all ice had melted from the core. TABLE 3 shows that no defrost was required for the warmest six conditions, and only 3 minutes per hour was needed at the coldest conditions. Also, the thermostat had to be set below 32°F (0°C) in very cold weather. It is recommended that the manufacturer consider modifying the defrost control to ensure complete ice removal and more stable ventilation.

Condensate drained very well from the inclined core passages.

## POWER REQUIREMENTS

The Better Air A-3000 plugged into two standard 120 V AC wall outlets. Maximum current draw was about 6.5 A for all three fans. Total power consumption of the unit was about 0.8 kW.

## EASE OF OPERATION

**Installing:** Ease of installing was very good. The Better Air A-3000 was installed by two men in about 6 hours. A hole was cut in the ceiling to admit fresh air, while stale air was ducted to an outside wall. No ducting was required, though recirculation ducts could be used to distribute the warmed fresh air through the barn. Installation instructions were not provided.

**Adjusting:** Ease of adjusting was good. The defrost control thermostat was easily adjusted, but it cycled the supply fan on and off quickly, resulting in unpredictable ventilation conditions in the barn. Modifications to improve the stability of the defrost control have been recommended.

No other adjustments were needed.

**Cleaning:** Ease of cleaning was very good. The fan panels core and shrouds hinged conveniently out of the way, without tools providing complete access to both ends of the core. Water and dust drained readily out of the inclined core and could be connected to a drain pipe for convenient disposal.

## OPERATOR SAFETY

No safety hazards were apparent. The Better Air A-3000 was not CSA certified as meeting the requirements of the Canadian Electrical Code. Some provinces require an electrical inspection of installed equipment which is not CSA certified.

Some caution was required when gaining access to the overhead core for washing or servicing, especially when the operator had to stand on penning or a slippery floor.

## OPERATOR'S MANUAL

No operator's manual was supplied. Basic installation instructions were received directly from the manufacturer, and from sales brochures. It is recommended that the manufacturer consider providing an operator's manual with each unit sold.

## MECHANICAL HISTORY

No mechanical problems occurred with Better Air A-3000 through about 30 days of normal operation.

Table 3. Test Result Summary

	Units	Test Condition Number								
		1	2	3	4	5	6	7	8	9
Barn Air Temperature (70 % Relative Humidity)	°F (°C)	76.0 (24)	65.5 (19)	59.1 (15)	77.2 (25)	68.3 (20)	60.4 (16)	77.8 (25)	69.0 (20)	60.0 (16)
Outside Air Temperature	°F (°C)	-22.8 (-30)	-24.7 (-31)	-21.9 (-30)	7.5 (-14)	6.6 (-14)	6.4 (-14)	31.9 (0)	31.5 (0)	32.3 (0)
Fresh Air In Temperature	°F (°C)	37.6 (3)	28.6 (-2)	24.9 (-4)	50.6 (10)	44.1 (7)	37.7 (3)	59.0 (15)	54.2 (12)	49.3 (10)
Exhaust Airflow Rate	cfm (L/s)	1235 (580)	1208 (570)	1147 (540)	1259 (590)	1259 (590)	1216 (570)	1270 (600)	1257 (590)	1258 (590)
Supply Air Flowrate	cfm (L/s)	884 (415)	890 (420)	883 (415)	878 (415)	876 (410)	873 (410)	874 (410)	869 (410)	870 (410)
Defrost Shutdown	min/hr	3	3	3	0	0	0	0	0	0
Exhaust Air Heat Loss	Btu/min (kW)	1996 (35.1)	1831 (32.2)	1622 (28.2)	1488 (26.2)	1352 (23.8)	1175 (20.7)	1002 (17.6)	823 (14.5)	625 (11.0)
Average Heat Recovery	Btu/min (kW)	863 (15.1)	786 (13.8)	703 (12.4)	642 (11.3)	568 (10.0)	477 (8.4)	390 (6.9)	325 (5.7)	243 (4.3)
Heat Recovery Ratio	%	43	43	43	43	42	41	39	40	39

## SPECIFICATIONS

<b>MAKE:</b>	Better Air	
<b>MODEL:</b>	A-3000	
<b>SERIAL NUMBER:</b>	N/A	
<b>MANUFACTURER:</b>	Better Air Manufacturing Ltd. P.O. Box 490 MacGregor, Manitoba R0H 0R0	
<b>OVERALL DIMENSIONS:</b>		
- length	65 in (1650 mm)	
- width	46 in (1520 mm)	
- height	40 in (1000 mm)	
- overall weight	350 lb (160 kg)	
<b>CORE DESCRIPTION:</b>	cross-counter flow plate	
<b>CORE CONSTRUCTION:</b>		
- external shell	aluminum alloy	
- internal core	aluminum alloy	
- seal	foam rubber	
	<b>EXHAUST</b>	<b>SUPPLY</b>
<b>NOMINAL AIRFLOW:</b>	1260 cfm (590 L/s)	860 cfm (400 L/s)
<b>INLET AREA:</b>	154 in <sup>2</sup> (0.10 m <sup>2</sup> )	200 in <sup>2</sup> (0.13 m <sup>2</sup> )
<b>OUTLET AREA:</b>	154 in <sup>2</sup> (0.10 m <sup>2</sup> )	154 in <sup>2</sup> (0.10 m <sup>2</sup> )
<b>SURFACE AREA OF CORE:</b>	49900 in <sup>2</sup> (32 m <sup>2</sup> )	48000 in <sup>2</sup> (31 m <sup>2</sup> )
<b>PASSAGE SIZE:</b>		
- quantity	26	50
- width	0.31 in (8 mm)	0.19 in (5 mm)
- height	15 in (380 mm)	15 in (380 mm)
- length	64 in (1630 mm)	32 in (810 mm)
<b>FANS:</b>		
- quantity	2 exhaust fans, 1 supply fan; exhaust and supply fans are identical	
- make	Better Air	
- type	axial	
- no. of blades	6	
- diameter	14 in (360 mm)	
- speed	1715 rpm	
- motor	Magnetic Century Electric model FR-K4BZ type CX 1/4 hp 115 V AC 3.4 A 60 Hz 1 phase	
<b>CONTROLS:</b>		
- defrost	Goldfan T-1 mechanical thermostat connected to supply fan.	

## C AND J JONES MC II HEAT RECOVERY VENTILATOR

### MANUFACTURER AND DISTRIBUTOR:

C and J Jones Ltd.  
55 Myrtle Street  
Winnipeg, Manitoba  
R3E 2R3  
Phone: (204) 786-3373  
FAX: (204) 772-8002

### RETAIL PRICE

\$2,695.00 (May, 1989, f.o.b. Humboldt, Sask., basic core only with no fans, mounts or ductwork).

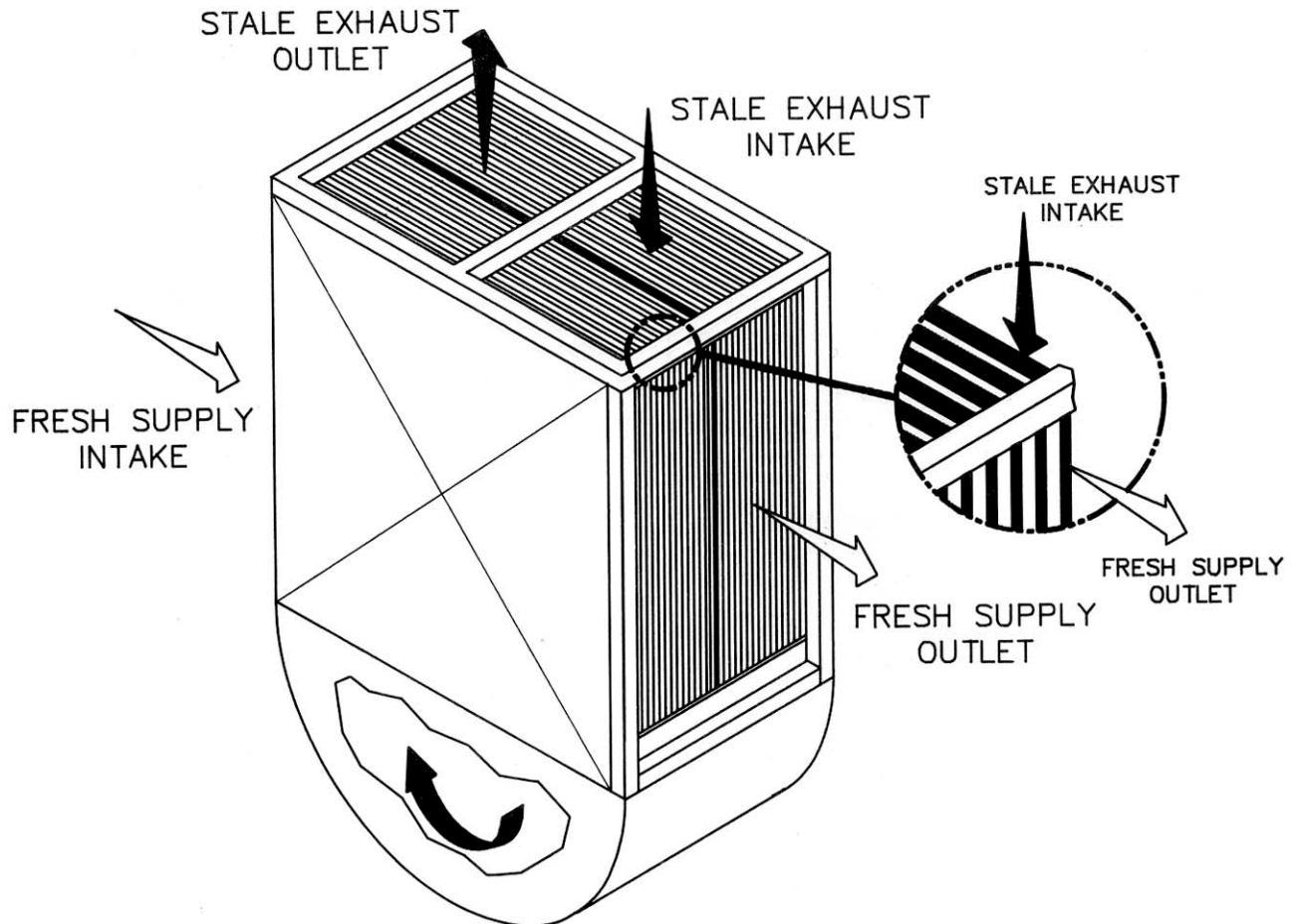


FIGURE 4. Jones MC II.

### SUMMARY AND CONCLUSIONS

**Rate of Work:** Maximum rate of heat recovery for the Jones MC II was 1350 Btu/min (23.8 kW) which occurred in a warm 77°F (25°C) barn with an outdoor temperature of -22°F (-30°C). Fans were not supplied, but the core was sized to ventilate about 1500 cfm (700 L/s) exhaust and 1500 cfm (700 L/s) supply.

**Quality of Work:** Heat recovery ratio ranged from 54 to 61%. Core leakage was only about 19 cfm (9 L/s) or 2.5% of exhaust airflow. No defrost control was supplied, so a timer was installed by PAMI. The supply fan had to be shut off for up to 7 minutes every 45 minutes to remove ice.

**Power Requirements:** The two Chicago blower 3/4 hp (0.6 kW) centrifugal blowers installed by PAMI drew about 21 A at 120 V AC and required about 2.4 kW of power.

**Ease of Operation:** Ease of installing was fair. When locating the core outside the barn, it took two men 16 hours to install the system. Ease of adjusting was very good. No routine adjustments were needed. Ease of cleaning was fair. The outside core was inconvenient to wash. The core drain line had to be insulated and heated.

**Operator Safety:** No hazards were apparent.

**Operator's Manual:** None was provided. The manufacturer provided verbal instructions and assisted with the installation, but written instructions would have helped.

**Mechanical History:** No mechanical problems occurred in 100 days of operating.



## RECOMMENDATIONS

It is recommended that the manufacturer consider:

1. Supplying a defrost controller as standard equipment.
2. Providing a convenient core washing system as standard equipment.
3. Supplying an operator's manual and detailed installation instructions to ensure proper setup and operation.

## THE MANUFACTURER STATES THAT

With regard to the above recommendations:

- 1 & 2. C and J Jones Limited has now introduced a complete heat exchanger package standard with variable speed energy efficient axial fans, timer/thermostat defrost control, digital supply air temperature readout and automatic wash system for ease of maintenance. Unit comes completely assembled for easy installation. Efficiency of unit is rated at 50% with 75% R.H. in barn.
3. A complete installation and operation manual is now being designed and will be completed prior to July 31, 1989. This will be submitted to PAMI for further comments and recommendations.

## MANUFACTURERS ADDITIONAL COMMENTS

Retail price varies from \$1.80 per CFM of ventilation for a 4500 CFM unit to \$2.80 per CFM of ventilation for a 1650 CFM unit. Retail pricing per CFM is based on supply air volume of heat exchangers. Lower cost per CFM than shown is realized if based on exhaust air volume.

## GENERAL DESCRIPTION

The Jones MC II is a cross-counter flow plate type air-to-air heat recovery core designed for mounting inside or outside a building in connection with the ventilation system. It consists of a core only, without fans, ducting, or controls. The core is constructed of aluminum alloy sheets supported in a steel tubing frame.

Stale barn air enters one-half of the core at the top, passes through the core in a U-pattern and exits through the other half of the top. Fresh air enters the side of the core adjacent to the exhaust outlet and passes horizontally straight through the core.

No defrost control or fans were supplied for the test unit. A mechanical timer clock was installed by PAMI which shut off the supply fan at regular intervals to melt ice out of the core. Two Chicago Blower model 122 fans were also installed, along with the required ducting.

## SCOPE OF TEST

For the test, the Jones MC II was mounted outside. The manufacturer supplied custom ducting to and from the barn. Fans were supplied by PAMI, since none were included. The unit was installed at a hog barn near Winnipeg, Manitoba (TABLE 4) and operated during the winters of 1987/88 and 1988/89 for a total of about 100 days.

TABLE 4. Operating Conditions.

<b>LOCATION:</b>	Stony Mountain, Manitoba
<b>TYPE OF BARN:</b>	Swine Finisher
<b>NUMBER OF ANIMALS:</b>	1500
<b>INSIDE BARN DIMENSIONS:</b>	300 x 40 x 24 ft (90 x 12 x 7 m)
<b>FEEDING SYSTEM:</b>	Overhead auger to self-feeders, on-farm milled. Also some wet/dry feeders.
<b>MANURE SYSTEM:</b>	Open flush gutter at the center.
<b>WINTER VENTILATION SYSTEM</b>	
Without HRV:	Naturally ventilated with center ridge inlet and outlet. No heat.
With HRV:	Exhaust through wall to exterior HRV, fresh air from HRV ducted into recirculation duct.
<b>AVERAGE BARN TEMPERATURE:</b>	59°F (15°C)
<b>AVERAGE BARN HUMIDITY:</b>	70%
<b>HEAT BALANCE TEMPERATURE:</b>	32°F (0°C)

## RESULTS AND DISCUSSION

### RATE OF WORK

**Heat Recovery:** Heat recovery rates for the Jones MC II at three barn temperatures are illustrated in FIGURE 5. The maximum rate of heat recovery was 1353 Btu/min (23.8 kW), which occurred in a 77°F (25°C) barn with an outdoor temperature of -22°F (-30°C). The graph shows that more heat was recovered from warm barns than cool barns. Also, the rate of heat recovery decreased as outdoor temperatures increased. Thus, the total heat savings over an entire season would vary depending on the barn temperature, outside temperature and the heat

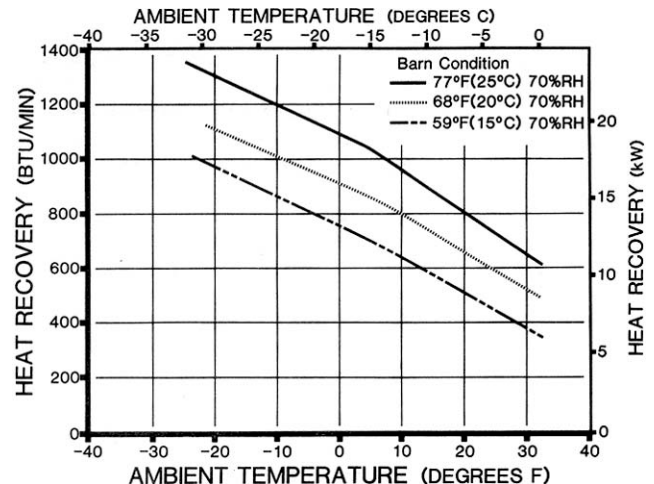


FIGURE 5. Jones MC II Heat Recovery Rate at Three Barn Temperatures.

balance temperature.

TABLE 5 illustrates the seasonal heat savings for the Jones MC II in a single season based on 20 years weather data for Winnipeg, Manitoba and a barn temperature of 68°F (20°C). For example, if a barn at that location had a heat balance temperature of 14°F (-10°C), the Jones MC II would potentially save up to 98 MBtu (28,700 kWh) of heat in one season. To fully realize these savings, the HRV must be properly matched to the ventilation requirements of the barn.

TABLE 5. Seasonal Heat Savings of the Jones MC II near Winnipeg. (Barn temperature 68°F (20°C), Outdoor temperature 20 year average 1968-1987).

HEAT BALANCE TEMPERATURE °F	HEAT BALANCE TEMPERATURE (°C)	LENGTH OF HEATING SEASON hours	SEASONAL HEAT SAVED MBtu	SEASONAL HEAT SAVED (kWh)
32	(0)	3,530	151	(44 400)
23	(-5)	2,640	125	(36 700)
14	(-10)	1,890	98	(28 700)
+5	(-15)	1,294	72	(21 100)
-4	(-20)	796	47	(13 800)
-13	(-25)	367	23	(6 790)
-22	(-30)	100	7	(1 980)
-31	(-35)	10	0.75	(220)

**Ventilation Rate:** No fans were supplied by the manufacturer. The manufacturer had requested that the Jones MC II be operated at about 1500 cfm (700 L/s) balanced exhaust and supply airflows. The core was calibrated to determine airflow resistance (FIGURE 6). PAMI equipped the Jones MC II with two Chicago Blower Model 122 belt driven centrifugal fans with 3/4 hp (1.0 kW) motors, which were adjusted to produce the desired airflow.

In the test barn, dust gradually built up in the exhaust passages of the core, reducing the ventilation rate. The dust had to be removed about once a day with a garden nozzle or pressure washer. Frequency of cleaning would vary depending on the severity of barn dust.

Ice build-up in the core further restricted the exhaust passages. In the coldest test run, the core had to be defrosted for 7 min every 45 min, and exhaust airflow dropped to an average of 1330 cfm (625 L/s).

**QUALITY OF WORK**

**Heat Recovery Ratio:** TABLE 6 lists the complete summary of results from the nine test runs. Heat recovery ratios (HR R) for the Jones MC II ranged from 54% to 61% (TABLE 6). The Jones MC II became slightly more efficient as barn temperature increased, and was slightly more efficient in colder weather.

**Leakage:** About 19 cfm (9 L/s) of stale exhaust air leaked into the incoming fresh air with the core clean and operating at normal flow rates and pressures. This amounted to a low cross-contamination rate of about 2.5%.

**Defrost:** The Jones MC II was not equipped with a defrost control system. Laboratory tests showed that in cold weather, defrosting was required to remove ice from the core. Therefore, a mechanical defrost timer was installed and adjusted by PAMI to determine the optimum defrost cycles. TABLE 3 shows that this varied from 5 minutes every 2 hours at 5°F (-15°C) to 7 minutes every 45 minutes at -22°F (-30°C). No defrosting was required at 32°F (0°C), and a warm barn required less defrosting than a cool barn. It is recommended that the manufacturer consider supplying a defrost controller as standard equipment.

**POWER REQUIREMENTS**

The Jones MC II was not equipped with fans. Two 3/4 hp (1.0 kW) centrifugal fans were selected by PAMI to deliver the manufacturer's specified airflows. The two fans drew a maximum current of about 21 A when connected to 120 V AC. Maximum power required was about 2.4 kW.

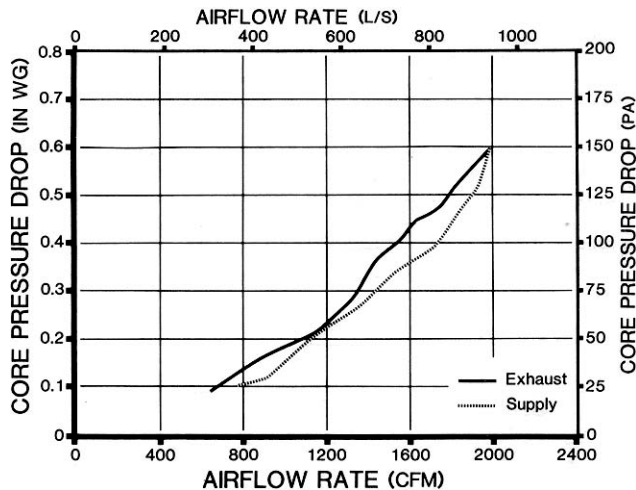


FIGURE 6. Jones MC II Airflow Resistance Curve.

Table 6. Test Result Summary

	Units	Test Condition Number								
		1	2	3	4	5	6	7	8	9
Barn Air Temperature	°F	77.2	67.7	58.1	76.9	68.7	57.4	76.8	68.7	57.9
(70 % Relative Humidity)	(°C)	(25)	(20)	(15)	(25)	(20)	(14)	(25)	(20)	(14)
Outside Air Temperature	°F	-25.0	-21.7	-23.8	5.2	6.4	7.1	32.6	32.0	32.6
	(°C)	(-32)	(-30)	(-31)	(-15)	(-14)	(-14)	(0)	(0)	(0)
Fresh Air In Temperature	°F	32.3	25.9	19.4	45.8	40.9	34.1	57.2	51.7	46.1
	(°C)	(0)	(-3)	(-7)	(8)	(5)	(1)	(14)	(11)	(8)
Exhaust Airflow Rate	cfm	1334	1330	1341	1451	1426	1433	1514	1516	1506
	(L/s)	(625)	(625)	(630)	(680)	(670)	(675)	(710)	(710)	(710)
Supply Air Flowrate	cfm	1499	1500	1496	1501	1501	1510	1520	1522	1507
	(L/s)	(705)	(705)	(705)	(705)	(705)	(710)	(715)	(715)	(710)
Defrost Shutdown	min	5 min	6 min	7 min	0	5 min	5 min	0	0	0
	hour	45 min	45 min	45 min		2 hrs	2 hrs			
Exhaust Air Heat Loss	Btu/min	2225	1986	1867	1685	1442	1194	1070	906	635
	(kW)	(39.1)	(34.9)	(32.8)	(29.6)	(25.4)	(21.0)	(18.8)	(15.9)	(11.2)
Average Heat Recovery	Btu/min	1353	1121	1006	1024	838	670	607	489	340
	(kW)	(23.8)	(19.7)	(17.7)	(18.1)	(14.7)	(11.8)	(10.7)	(8.6)	(6.0)
Heat Recovery Ratio	%	61	56	54	61	58	56	57	54	54

**EASE OF OPERATION AND ADJUSTMENT**

**Installing:** Ease of installing was fair. The Jones MC II was installed by two men in about 16 hours. Most of this time was spent designing and installing the duct work required to direct air to and from the outside of the barn where the core was located. Additional time was also spent selecting and placing the fans and defrost timer, since these were not supplied by the manufacturer. Two holes had to be cut in the barn wall for exhaust and supply ducting. Exhaust air exited the barn at the wall. The fresh supply air was ducted to a recirculation tube extending along the center of the barn.

**Adjusting:** Ease of adjusting was very good. No routine adjusting was necessary. The mechanical defrost timer installed by PAMI was easily adjusted for any length of cycle, but the manufacturer did not provide any guidelines with the unit. Similarly, since fans were not supplied, the correct fans had to be selected and adjusted for desired airflow rate.

**Cleaning:** Ease of cleaning was fair. Access panels had to be installed on the test unit, but because the core was outside the barn, some provision for washing outside was needed. Since the core needed washing at least twice weekly, this was inconvenient. The manufacturer indicated that an optional built-in washing system was available, but this was not tested. It is recommended that the manufacturer consider providing a convenient washing system as standard equipment.

The core drained back into the barn through a PVC pipe. The drain had to be insulated and wrapped with an electric heat tape to prevent freezeup. The core drained well in all conditions.

**OPERATOR SAFETY**

No safety hazards were apparent with the Jones MC II. Since the Jones MC II did not contain fans or any other electrical connections, it was not subject to CSA Approval. However, fans and controls connected to the unit had to be CSA approved. Some provinces require an electrical inspection of installed equipment which is not CSA certified.

**OPERATOR'S MANUAL**

No operator's manual was supplied. A sketch of the core and related duct work was drawn up by the manufacturer for the particular installation. The defrost cycle timer and fans were selected and installed by PAMI. The manufacturer assisted directly in the installation, so no major problems arose. However, it is recommended that the manufacturer consider supplying an operator's manual and detailed installation instructions to ensure proper setup and operation.

**MECHANICAL HISTORY**

No mechanical problems occurred with Jones MC II through 100 days of normal operation.

**SPECIFICATIONS**

**MAKE:** C & J Jones

**MODEL:** MC-2

**SERIAL NUMBER:** MC-2-1001

**MANUFACTURER:** C & J Jones Limited  
55 Myrtle Street  
Winnipeg, Manitoba  
R3E 2R3

**OVERALL DIMENSIONS:**  
- length 40 in (1020 mm)  
- width 23 in (584 mm)  
- height 38 in (965 mm)  
- overall weight (fans not included) 285 lb (129 kg)

**CORE DESCRIPTION:** cross-counter flow

**CORE CONSTRUCTION:**  
- external shell 304 stainless steel, modular frame  
- internal core 3003 aluminum alloy  
- seal stainless steel flat springs and neoprene gaskets

	<u>EXHAUST</u>	<u>SUPPLY</u>
<b>NOMINAL AIRFLOW:</b>	1500 cfm (700 L/s)	1500 cfm (700 L/s)
<b>INLET AREA:</b>	300 in <sup>2</sup> (0.19 m <sup>2</sup> )	650 in <sup>2</sup> (0.42 m <sup>2</sup> )
<b>OUTLET AREA:</b>	300 in <sup>2</sup> (0.19 m <sup>2</sup> )	650 in <sup>2</sup> (0.42 m <sup>2</sup> )
<b>SURFACE AREA OF CORE:</b>	69,120 in <sup>2</sup> (44.6 m <sup>2</sup> )	72,540 in <sup>2</sup> (46.8 m <sup>2</sup> )

**PASSAGE SIZE:**

- quantity	32	31
- width	0.313 in (8.0 mm)	0.188 in (4.8 mm)
- height	72 in (1839 mm)	32.5 in (830 mm)
- length	15 in (380 mm)	36 in (910 mm)

**FANS:** not supplied

**OPTIONS AND ATTACHMENTS:** multiple core models, custom installations, washing system

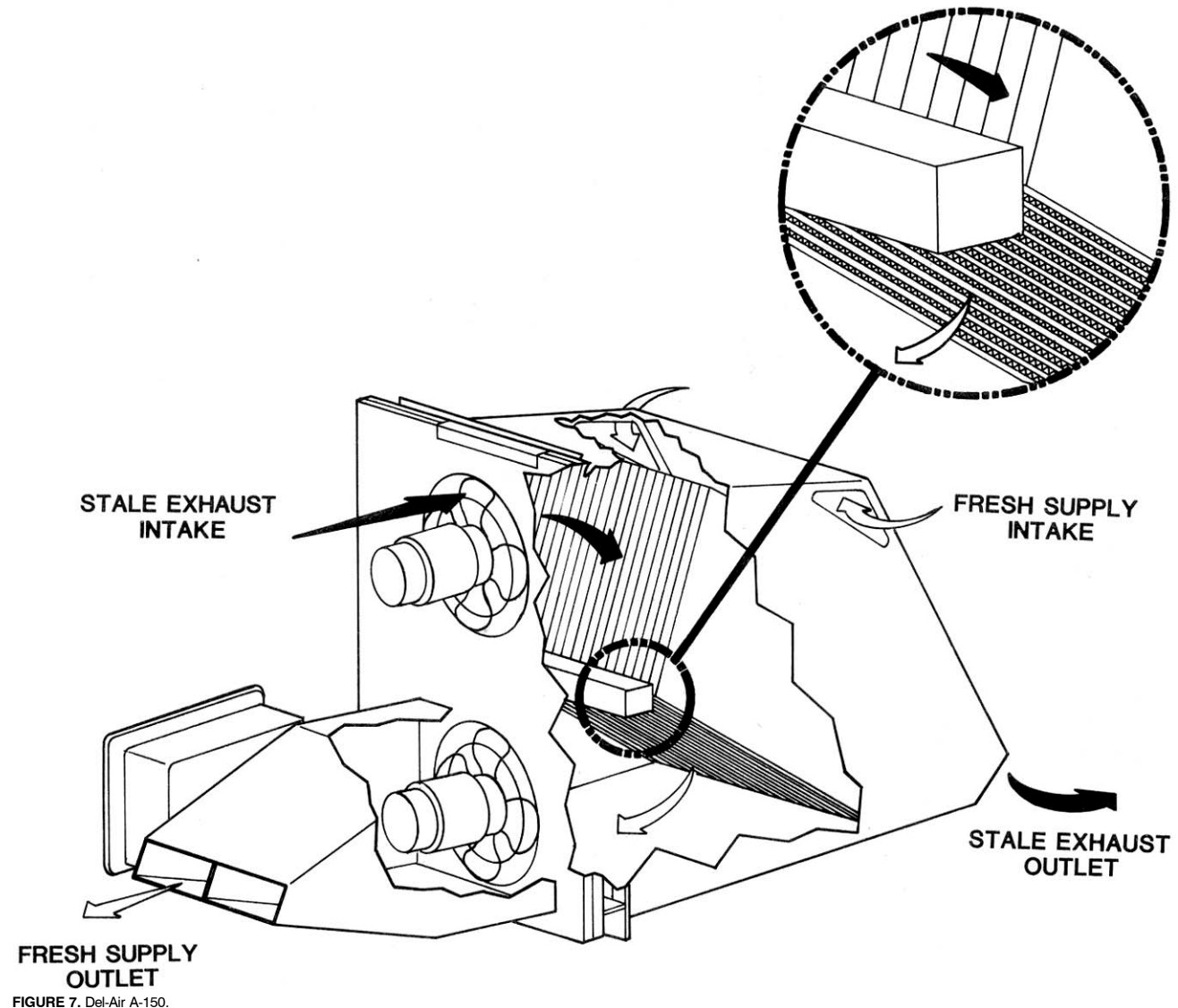
## DEL-AIR A-150 HEAT RECOVERY VENTILATOR

### MANUFACTURER AND DISTRIBUTOR:

Del-Air Systems Ltd.  
P.O. Box 2500  
1704 - 4th Avenue  
Humboldt, Saskatchewan  
S0K 2A0  
Phone: (306) 682-5011

### RETAIL PRICE

\$1,095.00 (May, 1989, f.o.b. Humboldt, Sask.)



### SUMMARY AND CONCLUSIONS

**Rate of Work:** Maximum rate of heat recovery for the Del-Air A-150 was 135 Btu/min (2.4 kW) which occurred in a warm 77°F (25°C) barn with outdoor temperature -22°F (-30°C). In normal operating mode, ventilation was about 190 cfm (90 L/s) exhaust and 125 cfm (60 L/s) supply.

**Quality of Work:** Heat recovery ratio ranged from 37 to 42%. Core leakage was only about 4 cfm (2 L/s) or 2.0% of exhaust airflow. The defrost control was very good. The supply fan was automatically reversed for 8 minutes each hour, which prevented any ice buildup.

**Power Requirements:** The two fans drew approximately 0.7 A at 120 V AC and required about 0.1 kW of power.

**Ease of Operation:** Ease of installing was very good. It took one man 2 hours to install the unit. Ease of adjusting was very good. No routine adjustments were needed. Ease of cleaning was very good. The core hinged open conveniently for washing. An optional filter was available.

**Operator Safety:** The Del-Air A-150 was CSA certified. No hazards were apparent.

**Operator's Manual:** The operator's manual was very good. It was thorough and well illustrated.

**Mechanical History:** No mechanical problems occurred in 150 days of operating.

## RECOMMENDATIONS

No recommendations were apparent during the test.

## GENERAL DESCRIPTION

The Del-Air A-150 is a cross-flow plate type air-to-air heat recovery unit designed for mounting in an exterior barn wall to provide complete self-contained ventilation. It consists of a two-piece moulded plastic shell enclosing the plastic core and supporting two axial propellor fans in a hinged door. The core is constructed from corrugated plastic sheets sealed with plastic cement.

Stale barn air is drawn in by the exhaust fan, passes through the core at a downward angle and exits through a nozzle on the housing outside the barn. Fresh air is drawn in through the outside housing, passes through the core perpendicular to the exhaust passages, and is blown into the barn through a high velocity nozzle by the supply fan. Defrost is controlled with a mechanical timer clock which shuts off and reverses the supply fan for 8 minutes each hour to melt ice out of the core.

## SCOPE OF TEST

For the test, the Del-Air A-150 was installed in a dairy calf barn near Winnipeg, Manitoba (TABLE 7). An electronic fan speed controller was installed by PAMI to permit reducing the ventilation when fewer animals occupied the small room. All performance measurements were taken at full speed.

TABLE 7. Operating Conditions.

<b>LOCATION:</b>	Beausejour, Manitoba
<b>TYPE OF BARN:</b>	Dairy calf
<b>NUMBER OF ANIMALS:</b>	10
<b>INSIDE BARN DIMENSIONS:</b>	14 x 12 x 8 ft (4.3 x 3.6 x 2.4 m)
<b>FEEDING SYSTEM:</b>	Milk, hay, and grain; pail-fed.
<b>MANURE SYSTEM:</b>	Straw bedding, manually scraped.
<b>WINTER VENTILATION SYSTEM</b>	
Without HRV:	Small air pipe drawing exhaust to a fan in another room. Inlet at floor level.
With HRV:	Self-contained Del-Air A-150 with variable speed control. A heater was added when too few animals were present.
<b>AVERAGE BARN TEMPERATURE:</b>	59°F (15°C)
<b>AVERAGE BARN HUMIDITY:</b>	70%
<b>HEAT BALANCE TEMPERATURE:</b>	32°F (0°C)

## RESULTS AND DISCUSSION

### RATE OF WORK

**Heat Recovery:** Heat recovery rates for the Del-Air A-150 at three barn temperatures are illustrated in FIGURE 8. The maximum rate of 135 Btu/min (2.4 kW) occurred in a 77°F (25°C) barn with outdoor temperature -22°F (-30°C). The graph shows that more heat was recovered from warm barns than cool barns. Also, the rate of heat recovery decreased as outdoor temperatures increased. Thus, the total heat savings over an entire season would vary depending on the barn temperature, outside temperature and the heat balance temperature.

TABLE 8 illustrates the seasonal heat savings for the Del-Air A-150 in a single season based on 20 years' weather data for Winnipeg, Manitoba and a barn temperature of 68°F (20°C). For example, if a barn at that location had a heat balance temperature of 14°F (-10°C), the Del-Air A-150 would recover up to 10.2 MBtu (3000 kWh) of heat in one season. To fully realize these savings, the HRV must be properly matched to the ventilation requirements of the barn.

**Ventilation Rate:** FIGURE 9 illustrates the supply and exhaust airflow rates through the Del-Air A-150 versus the pressure difference inside and outside the barn. The Del-Air A-150 ventilated about 190 cfm (90 L/s) exhaust and 125 cfm (60 L/s) supply at a neutral barn pressure. Typically in winter, barns are operated under a negative pressure ranging from 0 to -0.10 in.wg (0 to -25 Pa). Under these conditions, exhaust airflow decreased by as much as 70 cfm (33 L/s) while supply airflow increased by up to 15 cfm (7 L/s).

In the test barn, dust gradually built up in the exhaust passages of the core, slightly reducing the ventilation rate. Normally, the dust had to be removed from the core once or twice a month with a garden nozzle or pressure washer. Frequency of cleaning would vary for other barn conditions. An optional filter adaptor was available, but was not tried. Filters generally prevent most dust from entering the core. They need to be cleaned or changed more often than cores but usually take less time.

The defrost cycle affected overall ventilation rates. For 8 minutes each hour, the supply fan was reversed, increasing the exhaust to about 275 cfm (140 L/s). When averaged over a complete cycle, the net ventilation rates were 205 cfm (95 L/s) exhaust and 108 cfm (50 L/s) supply.

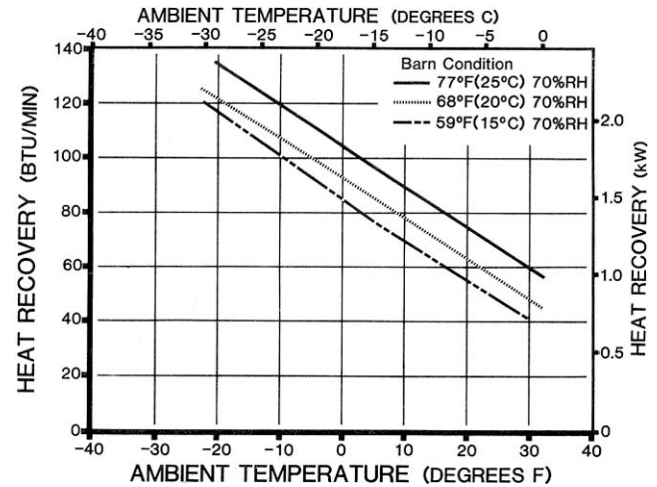


FIGURE 8. Del-Air A-150 Heat Recovery Rate at Three Barn Temperatures.

TABLE 8. Seasonal Heat Savings of the Del-Air A-150 near Winnipeg. (Barn temperature 68°F (20°C), Outdoor temperature 20 year average 1968-1987).

HEAT BALANCE TEMPERATURE °F	HEAT BALANCE TEMPERATURE (°C)	LENGTH OF HEATING SEASON hours	SEASONAL HEAT SAVED MBtu	SEASONAL HEAT SAVED (kWh)
32	(0)	3,530	15.3	(4480)
23	(-5)	2,640	12.8	(3770)
14	(-10)	1,890	10.2	(3000)
+5	(-15)	1,294	7.6	(2240)
-4	(-20)	796	5.1	(1490)
-13	(-25)	367	2.5	(750)
-22	(-30)	100	0.8	(220)
-31	(-35)	10	0.1	(25)

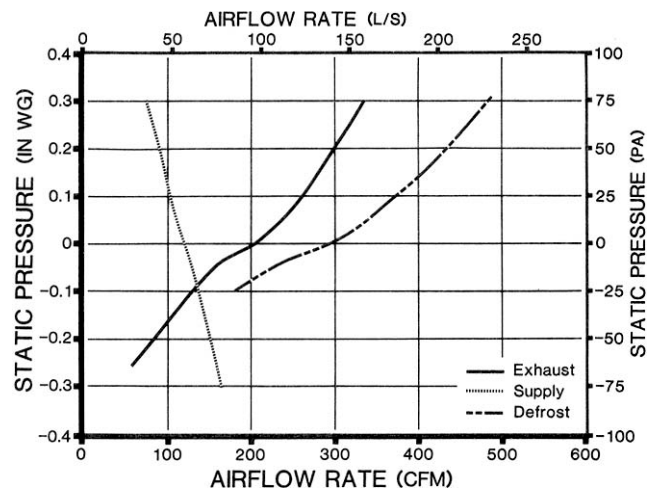


FIGURE 9. Del-Air A-150 Ventilation Rates.

## QUALITY OF WORK

**Heat Recovery Ratio:** Heat recovery ratios (HRR) for the Del-Air A-150 ranged from 37 to 42% (TABLE 9). TABLE 9 lists the complete summary of results from the nine test runs. The Del-Air A-150 was slightly more efficient at colder outdoor temperatures, but efficiency was not significantly affected by barn temperature.

**Leakage:** About 4 cfm (2 L/s) of stale exhaust air leaked into the incoming fresh air with the core clean and operating at normal flow rates and pressures. This amounted to a low cross-contamination rate of about 2.0%.

**Defrost:** The Del-Air A-150 defrost control system was very good. The mechanical timer circuit successfully prevented ice buildup in the core even through extended periods of cold weather. A manual switch was provided to allow the operator to defrost for longer periods if required, or to shut off the defrost cycle in warmer weather. Condensate was drained outside the barn through the exhaust outlet of the core. A pile of ice built up, which had to be periodically cleared away from the outlet and the barn wall.

## POWER REQUIREMENTS

The Del-Air A-150 plugged into one standard 120 V AC wall outlet. Maximum current draw was about 0.7 A for both fans. Total power consumption of the unit was about 0.1 kW.

## EASE OF OPERATION AND ADJUSTMENT

**Installing:** Ease of installing was very good. The Del-Air A-150 was installed by one man in about 2 hours. A 14 x 17.5 in (355 x 440 mm) hole was cut in the barn wall and the unit was inserted. Some framing in the hole was needed. No ducting was required. An electrical outlet had to be located with 3.5 ft (1.1 m) of the Del-Air A-150 to meet CSA regulations.

**Adjusting:** Ease of adjusting was very good. The mechanical defrost timer could be set for extended defrosting in very cold weather, or shut off during mild weather. No other routine adjusting was necessary.

**Cleaning:** Ease of cleaning was very good. The front panel of the Del-Air A-150 hinged open, completely exposing the core for washing. Wash water drained outside of the barn, and had to be cleared away occasionally as the condensate pile built up. An optional filter adapter was available to reduce the amount of dust entering the core. Dust conditions in the test barn were minimal so the filter was not used.

## OPERATOR SAFETY

No safety hazards were apparent. The Del-Air A-150 was CSA certified as meeting the requirements of the Canadian Electrical Code.

Some caution was required when gaining access to the core for washing or servicing, especially if the operator had to stand on penning or a slippery floor.

## OPERATOR'S MANUAL

The operator's manual was very good. It was accurate, clearly written and well illustrated. It contained useful information on installing, operating and troubleshooting, and provided some guidelines for sizing and positioning the unit for proper ventilation. The step-by-step installation instructions and numbered photographs were very easy to follow.

## MECHANICAL HISTORY

No mechanical problems occurred with Del-Air A-150 through 150 days of normal operation.

Table 9. Test Result Summary

	Units	Test Condition Number								
		1	2	3	4	5	6	7	8	9
<b>Barn Air Temperature</b> (70 % Relative Humidity)	°F (°C)	77.1 (25)	67.7 (20)	59.8 (15)	77.2 (25)	68.1 (20)	59.3 (15)	78.1 (26)	67.9 (20)	59.1 (15)
<b>Outside Air Temperature</b>	°F (°C)	-20.7 (-29)	-22.7 (-30)	-22.5 (-30)	4.4 (-15)	4.2 (-15)	5.0 (-15)	32.2 (0)	31.7 (0)	30.1 (-1)
<b>Fresh Air In Temperature</b>	°F (°C)	57.1 (14)	46.8 (8)	43.4 (6)	60.8 (16)	53.5 (12)	47.5 (9)	65.3 (19)	58.1 (15)	53.2 (12)
<b>Exhaust Airflow Rate</b>	cfm (L/s)	190 (90)	190 (90)	190 (90)	190 (90)	190 (90)	190 (90)	190 (90)	190 (90)	190 (90)
<b>Supply Air Flowrate</b>	cfm (L/s)	125 (60)	125 (60)	123 (60)	126 (60)	126 (60)	125 (60)	127 (60)	126 (60)	126 (60)
<b>Defrost Shutdown</b>	min/hr	8	8	8	8	8	8	8	8	8
<b>Exhaust Air Heat Loss</b>	Btu/min (kW)	323 (5.7)	309 (5.4)	288 (5.1)	239 (4.2)	215 (3.8)	189 (3.3)	152 (2.7)	124 (2.2)	102 (1.8)
<b>Average Heat Recovery</b>	Btu/min (kW)	135 (2.4)	125 (2.2)	120 (2.1)	97 (1.7)	86 (1.5)	76 (1.3)	56 (1.0)	45 (0.8)	40 (0.7)
<b>Heat Recovery Ratio</b>	%	42	40	42	41	40	40	37	37	39

## SPECIFICATIONS

<b>MAKE:</b>	Del-Air	
<b>MODEL:</b>	A-150	
<b>SERIAL NUMBER:</b>	HC-3164-A	
<b>MANUFACTURER:</b>	Del-Air Systems Ltd. P.O. Box 2500 Humboldt, Saskatchewan CANADA S0K 2A0	
<b>OVERALL DIMENSIONS:</b>		
- length	36 in (910 mm)	
- width	16 in (410 mm)	
- height	19.5 in (500 mm)	
- overall weight	27 lb (12 kg)	
<b>CORE DESCRIPTION:</b>	cross-flow plate	
<b>CORE CONSTRUCTION:</b>		
- external shell	moulded polyethylene	
- internal core	corrugated polypropylene sheets	
- seal	plastic cement	
	<b>EXHAUST</b>	<b>SUPPLY</b>
<b>NOMINAL AIRFLOW:</b>	180 cfm (85 L/s)	170 cfm (70 L/s)
<b>INLET AREA:</b>	33 in <sup>2</sup> (0.021 m <sup>2</sup> )	20 in <sup>2</sup> (0.013 m <sup>2</sup> )
<b>OUTLET AREA:</b>	28 in <sup>2</sup> (0.018 m <sup>2</sup> )	12 in <sup>2</sup> (0.008 m <sup>2</sup> )
<b>SURFACE AREA OF CORE:</b>	40,000 in <sup>2</sup> (25.8 m <sup>2</sup> )	40,000 in <sup>2</sup> (25.8 m <sup>2</sup> )
<b>PASSAGE SIZE:</b>		
- quantity	27	1890
- width	0.31 in (8 mm)	0.19 in (5 mm)
- height	8 in (200 mm)	0.19 in (5 mm)
- length	13.8 in (350 mm)	8 in (200 mm)
<b>FANS:</b>	exhaust and supply fans are identical	
- make	Del-Air	
- type	axial	
- no. of blades	4	
- diameter	6 in (150 mm)	
- motor	3450 rpm FASCO Industries Inc. Eldon Motor Division Type U62 0.3 A 120 V AC 60 HZ 1 Phase No. 7162-2517	
- defrost timer	Paragon Electric Inc. sequence timer model CPA-11-00-01	
<b>OPTIONS AND ATTACHMENTS:</b>	filter adaptor kit, supply air diffuser, duct work adaptors, filter cleaner, manual speed control	

## DEL-AIR A-800 HEAT RECOVERY VENTILATOR

### MANUFACTURER AND DISTRIBUTOR:

Del-Air Systems Ltd.  
P.O. Box 2500  
1704 - 4th Avenue  
Humboldt, Saskatchewan  
S0K 2A0  
Phone: (306) 682-5011

### RETAIL PRICE

\$1,950.00 (May, 1989, f.o.b. Humboldt, Sask., with supply air diffuser and filter adapter kit).

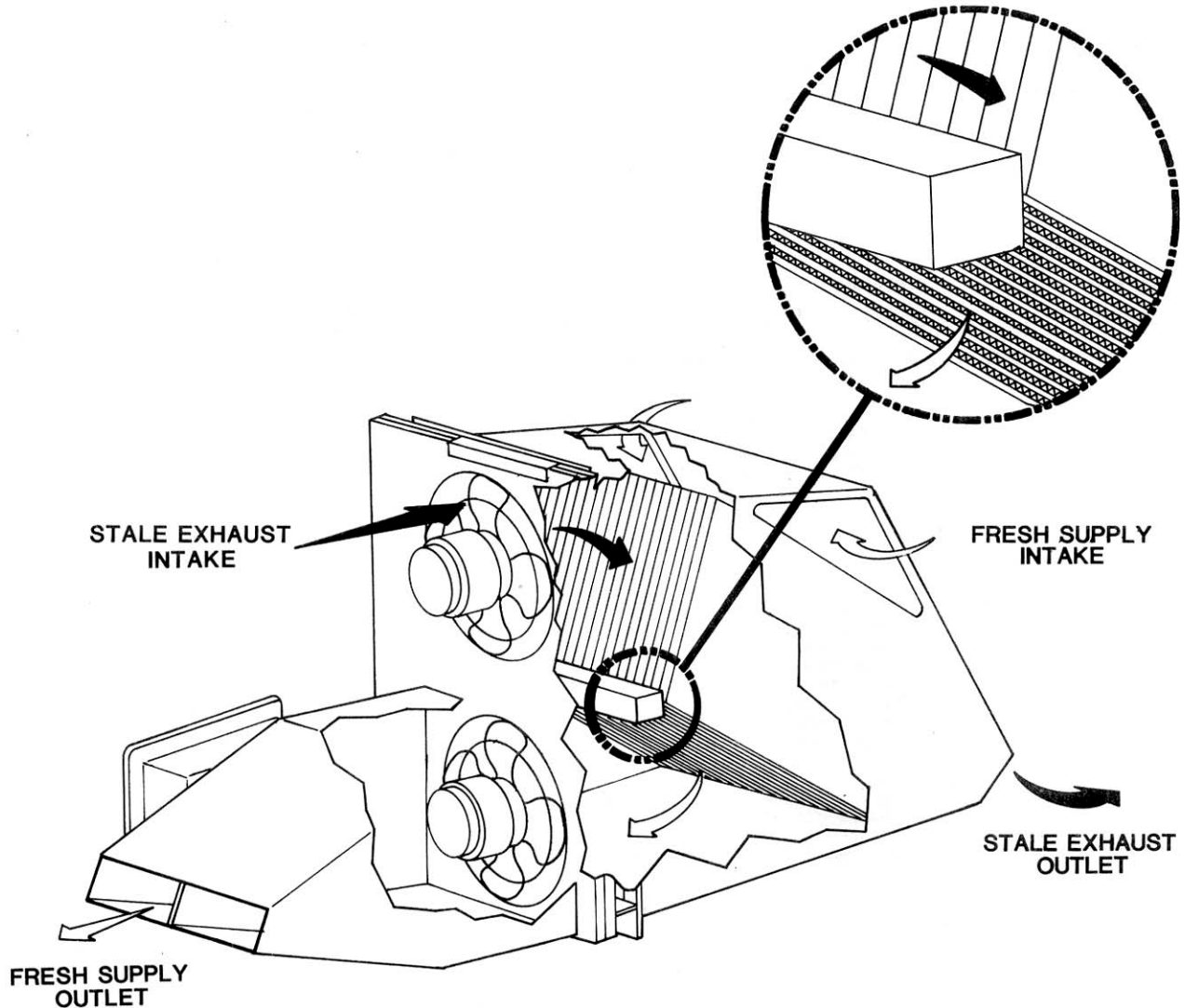


FIGURE 10. Del-Air A-800.

### SUMMARY AND CONCLUSIONS

**Rate of Work:** Maximum rate of heat recovery for the Del-Air A-800 was 608 Btu/min (10.7 kW) which occurred in a warm 77°F (25°C) barn with outdoor temperature -22°F (-30°C). In normal operating mode, ventilation was about 980 cfm (460 L/s) exhaust and 590 cfm (276 L/s) supply.

**Quality of Work:** Heat recovery ratio ranged from 32 to 36%. Core leakage was only about 10 cfm (5 L/s) or 1.0% of exhaust airflow. The defrost control was very good. The supply fan was automatically reversed for 8 minutes each hour, which prevented any ice buildup.

**Power Requirements:** The two fans drew approximately 3.6 A at 120 V AC and required about 0.4 kW of power.

**Ease of Operation:** Ease of installing was very good. It took one man 2 hours to install the unit. Ease of adjusting was very good. No routine adjustments were needed. Ease of cleaning was very good. The core hinged open conveniently for washing. The optional filter was easy to clean or change.

**Operator Safety:** The Del-Air A-800 was CSA certified. No hazards were apparent.

**Operator's Manual:** The operator's manual was very good. It was thorough and well illustrated.

**Mechanical History:** No mechanical problems occurred in 280 days of operating.



## RECOMMENDATIONS

No recommendations were apparent during the test.

## GENERAL DESCRIPTION

The Del-Air A-800 is a cross-flow plate type air-to-air heat recovery unit designed for mounting in an exterior barn wall to provide complete self-contained ventilation. It consists of a two-piece moulded plastic shell enclosing the plastic core and supporting two axial propellor fans in a hinged door. The core is constructed from corrugated plastic sheets sealed with plastic cement.

Stale barn air is drawn in by the exhaust fan, passes through the core at a downward angle and exits through a nozzle on the housing outside the barn. Fresh air is drawn in through the outside housing, passes through the core perpendicular to the exhaust passages, and is blown into the barn through a high velocity nozzle by the supply fan. Defrost is controlled with a mechanical timer clock which shuts off and reverses the supply fan for 8 minutes each hour to melt ice out of the core.

## SCOPE OF TEST

For the test, the Del-Air A-800 was installed at a hog barn near Winnipeg, Manitoba (TABLE 10). It was equipped with the optional filter adaptor kit and the optional fresh air diffuser.

TABLE 10. Operating Conditions.

<b>LOCATION:</b>	Headingley, Manitoba
<b>TYPE OF BARN:</b>	Swine Grower/Finisher
<b>NUMBER OF ANIMALS:</b>	250
<b>INSIDE BARN DIMENSIONS:</b>	64 x 36 x 8 ft (20 x 11 x 2.4 m)
<b>FEEDING SYSTEM:</b>	Mash feed, manually filled self-feeders.
<b>MANURE SYSTEM:</b>	Side wall pits with concrete slats.
<b>WINTER VENTILATION SYSTEM</b>	
Without HRV:	Continuous inlet on north wall, fresh air from attic, two exhaust fans on south wall.
With HRV:	Del-Air A-800 and one exhaust fan on south wall. Nozzle diffuser used to distribute fresh warmed air.
<b>AVERAGE BARN TEMPERATURE:</b>	68°F (20°C)
<b>AVERAGE BARN HUMIDITY:</b>	70%
<b>HEAT BALANCE TEMPERATURE:</b>	14°F (-10°C)

## RESULTS AND DISCUSSION

### RATE OF WORK

**Heat Recovery:** Heat recovery rates for the Del-Air A-800 at three barn temperatures are illustrated in FIGURE 11. The maximum rate of 608 Btu/min (10.7 kW) occurred in a 77°F (25°C) barn with outdoor temperature -22°F (-30°C). The graph shows that more heat was recovered from warm barns than cool barns. Also, the rate of heat recovery decreased as outdoor temperatures increased. Thus, the total heat savings over an entire season would vary depending on the barn temperature, outside temperature and the heat balance temperature.

TABLE 11 illustrates the seasonal heat savings for the Del-Air A-800 in a single season based on 20 years weather data for Winnipeg, Manitoba and a barn temperature of 68°F (20°C). For example, if a barn at that location had a heat balance temperature of 14°F (-10°C), the Del-Air A-800 would recover up to 44 MBtu (13000 kWh) of heat in one season. To fully realize these savings, the HRV must be properly matched to the ventilation requirements of the barn.

**Ventilation Rate:** FIGURE 12 illustrates the supply and exhaust airflow rates through the Del-Air A-800 versus the pressure difference inside and outside the barn. The Del-Air A-800 ventilated about 980 cfm (460 L/s) exhaust and 590 cfm (276 L/s) supply at a neutral barn pressure. Typically in winter, barns are operated under a negative pressure ranging from 0 to -0.10 in.wg (0 to -25 Pa). Under these conditions, exhaust airflow decreased by as much as 80 cfm (40 L/s) while supply airflow increased by up to 100 cfm (47 L/s).

In the test barn, dust gradually built up in the exhaust passages of the core, reducing the ventilation rate. Normally, the dust had to be removed from the core once or twice a week with a garden nozzle or pressure washer. The optional filter adaptor kept the core cleaner, but the filter element clogged very quickly and had to be cleaned once or twice each day. Frequency of cleaning would vary for other barn conditions.

The defrost cycle affected overall ventilation rates. For 8 minutes each hour, the supply fan was reversed, increasing the exhaust to about 1500 cfm (700 L/s). When averaged over a complete cycle, the net ventilation rates were 1050 cfm (490 L/s) exhaust and 510 cfm (240 L/s) supply.

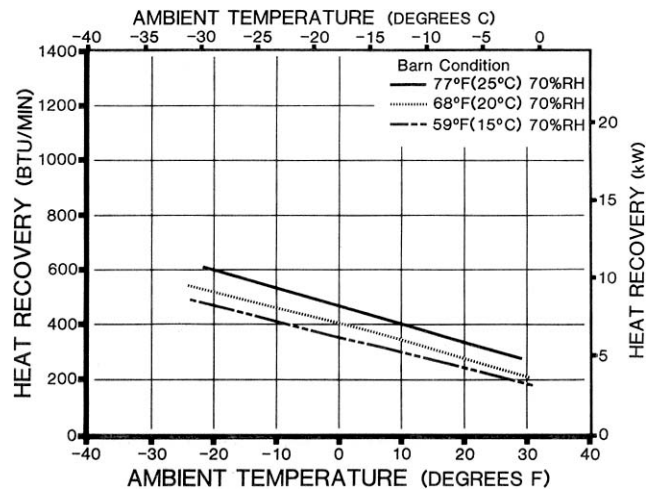


FIGURE 11. Del-Air A-800 Heat Recovery Rate at Three Barn Temperatures.

TABLE 11. Seasonal Heat Savings of the Del-Air A-800 near Winnipeg. (Barn temperature 68°F (20°C), Outdoor temperature 20 year average 1968-1987).

HEAT BALANCE TEMPERATURE °F	HEAT BALANCE TEMPERATURE (°C)	LENGTH OF HEATING SEASON hours	SEASONAL HEAT SAVED MBtu	SEASONAL HEAT SAVED (kWh)
32	(0)	3,530	67	(19 600)
23	(-5)	2,640	56	(16 400)
14	(-10)	1,890	44	(13 000)
+5	(-15)	1,294	33	(9 700)
-4	(-20)	796	22	(6 400)
-13	(-25)	367	11	(3 200)
-22	(-30)	100	3	(960)
-31	(-35)	10	0.4	(108)

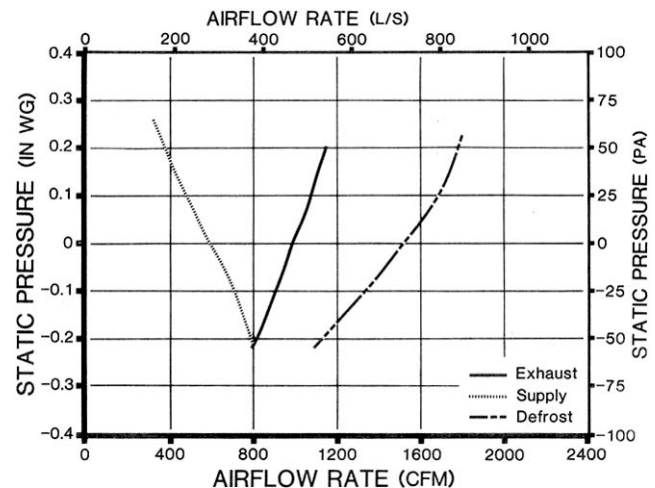


FIGURE 12. Del-Air A-800 Ventilation Rates.

**QUALITY OF WORK**

**Heat Recovery Ratio:** Heat recovery ratios (HRR) for the Del-Air-A-800 ranged from 32 to 36% (TABLE 12). TABLE 12 lists the complete summary of results from the nine test runs. The Del-Air A-800 was slightly more efficient at colder outdoor temperatures, but efficiency was not affected much by barn temperature.

**Leakage:** About 10 cfm (5 L/s) of stale exhaust air leaked into the incoming fresh air with the core clean and operating at normal flow rates and pressures. This amounted to a low cross-contamination rate of about 1.0%.

Although the quantity could not be measured, some stale air moisture and dust from the exhaust outlet was observed in the fresh supply inlet.

**Defrost:** The Del-Air A-800 defrost control system was very good. The mechanical timer circuit, successfully prevented ice buildup in the core even through extended periods of cold weather. A manual switch was provided to allow the operator to defrost for longer periods if required, or to shut off the defrost cycle in warmer weather. Condensate was drained outside the barn through the exhaust outlet of the core. A pile of ice built up, which had to be periodically cleared away from the outlet and the barn wall.

**POWER REQUIREMENTS**

The Del-Air A-800 plugged into one standard 120 V AC wall outlet. Maximum current draw was about 3.6 A for both fans. Total power consumption of the unit was about 0.4 kW.

**EASE OF OPERATION AND ADJUSTMENT**

**Installing:** Ease of installing was very good. The Del-Air A-800 was installed by one man in about 2 hours. A 22 x 29.5 in (560 x 750 mm) hole was cut in the barn wall and the unit was inserted. Some framing in the hole was needed. No ducting was required. An electrical outlet had to be located within 3.5 ft (1.1 m) of the Del-Air A- 800 to meet CSA regulations. The optional supply air diffuser and filter adapter kit were easily attached to the core with the supplied hardware.

**Adjusting:** Ease of adjusting was very good. The mechanical defrost timer could be set for extended defrosting in very cold weather, or shut off during mild weather. No other routine adjusting was necessary.

**Cleaning:** Ease of cleaning was very good. The front panel of the Del-Air A-800 hinged open, completely exposing the core for washing. The plastic retaining strip was sometimes hard to reinstall. Wash water drained outside of the barn, and had to be cleared away occasionally as the condensate pile built up. The optional filter adapter was very easy and quick to clean by tapping the dust off or washing the element. Because the filter had to be cleaned as often as twice daily, a second filter was exchanged with the fouled filter during routine chores. The dirty filter could then be cleaned at any convenient time.

**OPERATOR SAFETY**

No safety hazards were apparent. The Del-Air A-800 was CSA certified as meeting the requirements of the Canadian Electrical Code.

Some caution was required when gaining access to the core for washing or servicing, especially if the operator had to stand on penning or a slippery floor.

**OPERATOR'S MANUAL**

The operator's manual was very good. It was accurate, clearly written and well illustrated. It contained useful information on installing, operating and troubleshooting, and provided some guidelines for sizing and positioning the unit for proper ventilation. The step-by-step installation instructions and numbered photographs were very easy to follow.

**MECHANICAL HISTORY**

No mechanical problems occurred with Del-Air A-800 through 280 days of normal operation.

Table 12. Test Result Summary

	Units	Test Condition Number								
		1	2	3	4	5	6	7	8	9
<b>Barn Air Temperature</b> (70 % Relative Humidity)	°F (°C)	76.8 (25)	67.4 (20)	57.6 (14)	76.7 (25)	67.8 (20)	56.6 (14)	77.2 (25)	67.1 (20)	61.3 (16)
<b>Outside Air Temperature</b>	°F (°C)	-21.8 (-30)	-24.1 (-31)	-24.0 (-31)	5.7 (-15)	5.4 (-15)	3.3 (-16)	29.2 (-2)	30.3 (-1)	31.2 (0)
<b>Fresh Air In Temperature</b>	°F (°C)	48.9 (9)	37.7 (3)	31.5 (0)	55.5 (13)	48.1 (9)	41.9 (6)	62.3 (17)	54.6 (12)	52.5 (11)
<b>Exhaust Airflow Rate</b>	cfm (L/s)	965 (455)	961 (450)	947 (445)	984 (460)	983 (460)	997 (465)	992 (465)	995 (465)	969 (455)
<b>Supply Air Flowrate</b>	cfm (L/s)	597 (280)	594 (280)	563 (265)	610 (285)	607 (285)	591 (275)	611 (285)	613 (290)	597 (280)
<b>Defrost Shutdown</b>	min/hr	8	8	8	8	8	8	8	8	8
<b>Exhaust Air Heat Loss</b>	Btu/min (kW)	1678 (29.5)	1577 (27.7)	1378 (24.2)	1229 (21.6)	1100 (19.3)	1000 (17.6)	828 (14.6)	652 (11.5)	537 (9.4)
<b>Average Heat Recovery</b>	Btu/min (kW)	608 (10.7)	538 (9.5)	487 (8.6)	426 (7.5)	369 (6.5)	331 (5.8)	271 (4.8)	205 (3.6)	175 (3.1)
<b>Heat Recovery Ratio</b>	%	36	34	35	35	34	33	33	32	33

**SPECIFICATIONS**

**MAKE:** Del-Air

**MODEL:** A-800

**SERIAL NUMBER:** GY-2612-C

**MANUFACTURER:** Del-Air Systems Ltd.  
P.O. Box 2500  
Humboldt, Saskatchewan,  
CANADA  
S0K 2A0

**OVERALL DIMENSIONS:**  
- length 61 in (1 550 mm)  
- width 24 in (610 mm)  
- height 32 in (810 mm)  
- overall weight 109 lb (49kg)

**CORE DESCRIPTION:** cross-flow plate

**CORE CONSTRUCTION:**  
- external shell moulded polyethylene  
- internal core corrugated polypropylene sheets  
- seal plastic cement

	<u>EXHAUST</u>	<u>SUPPLY</u>
<b>NOMINAL AIRFLOW:</b>	800 cfm (375 L/s)	700 cfm (330 L/s)
<b>INLET AREA:</b>	144 in <sup>2</sup> (0.09 m <sup>2</sup> )	138 in <sup>2</sup> (0.09 m <sup>2</sup> )
<b>OUTLET AREA:</b>	89 in <sup>2</sup> (0.06 m <sup>2</sup> )	66 in <sup>2</sup> (0.04 m <sup>2</sup> )
<b>SURFACE AREA OF CORE:</b>	40000 in <sup>2</sup> (25.8 m <sup>2</sup> )	40000 in <sup>2</sup> (25.8 m <sup>2</sup> )

**PASSAGE SIZE:**

- quantity	45	6750
- width	0.31 in (8 mm)	0.19 in (5 mm)
- height	15 in (380 mm)	0.19 in (5 mm)
- length	29.75 in (750 mm)	15 in (380 mm)

**FANS:** exhaust and supply fans are identical

- make Del-Air
- type axial
- no. of blades 4
- diameter 12 in (305 mm)
- speed 1550 rpm
- motors FASCO Industries Inc.  
Eldon Motor Division  
Type U24  
1/6hp 115VAC  
1.8 A 60 HZ 1 Phase  
No. 7124-0431

**CONTROLS:**  
- defrost timer Paragon Electric Inc. sequence timer model CPA-11-00-01

**OPTIONS AND ATTACHMENTS:** filter adaptor kit, supply air diffuser, duct work adaptors, filter cleaner, manual speed control

# ROBBCO A1-3500-BIK HEAT RECOVERY VENTILATOR

## MANUFACTURER AND DISTRIBUTOR:

Robbco Ltd.  
62 Thatcher Dr.  
Winnipeg, Manitoba  
R3T 2L3  
Phone: (204) 269-5881

## RETAIL PRICE

\$3,286.00 (May, 1989, f.o.b. Humboldt, Sask.).

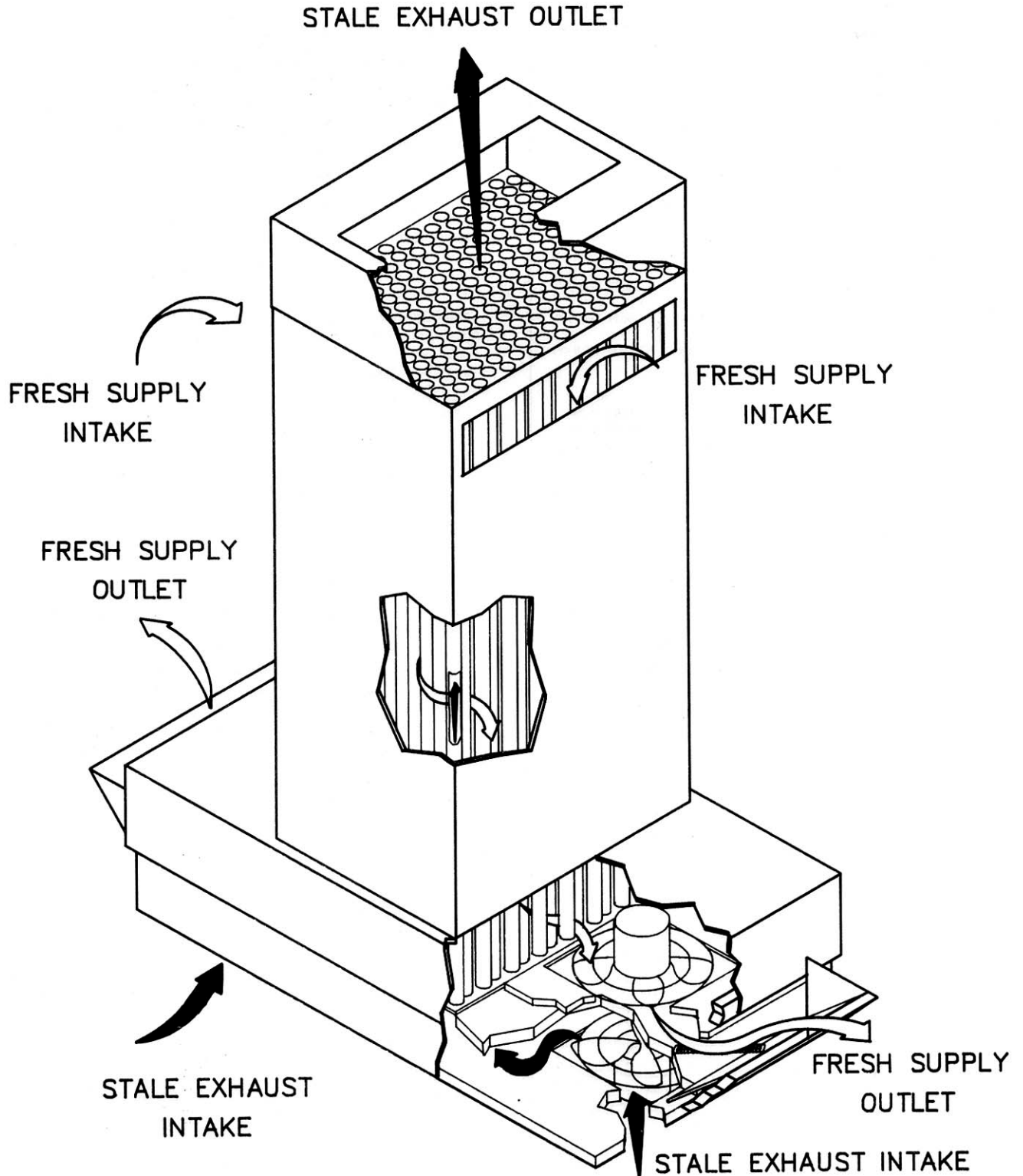


FIGURE 13. Robbco A1-3500-BIK.

## SUMMARY AND CONCLUSIONS

**Rate of Work:** Maximum rate of heat recovery for the Robbco A1-3500-BIK was 2400 Btu/min (42.3 kW) which occurred in a warm 77°F (25°C) barn with outdoor temperature -22°F (-30°C). In normal operating mode, the ventilation was about 4600 cfm (2160 L/s) exhaust and 3200 cfm (1500 L/s) supply.

**Quality of Work:** Heat recovery ratio ranged from 35 to 39%. Core leakage was about 170 cfm (80 L/s) or 3.8% of exhaust airflow. Defrost control was very good. The supply fan automatically shut off for 8 minutes every hour to remove ice. The defrost timer could be manually adjusted to optimize heat recovery.

**Power Requirements:** The four fans drew approximately 10 A at 230 V AC, and required about 1.6 kW of power.

**Ease Of Operation:** Ease of installing was fair. It took two men 16 hours to install the unit through the ceiling. Ease of adjusting was very good. The variable speed thermostat and defrost timer were easy to set. Ease of cleaning was excellent. The core was completely self cleaning.

**Operator Safety:** Although individual electric components were CSA certified, the Robbco A1-3500-BIK was not CSA certified. No hazards were apparent.

**Operator's Manual:** The operator's manual was good. It contained thorough installation guidelines, but no operating information.

**Mechanical History:** No mechanical problems occurred in 300 days of operating.

## RECOMMENDATIONS

It is recommended that the manufacturer consider:

1. Including information on operating, adjusting, and servicing in the operators manual.

## THE MANUFACTURER STATES THAT

With regard to recommendation number:

1. All present owners have received operating instructions. Written instructions will be provided in the future.

## GENERAL DESCRIPTION

The Robbco A1-3500-BIK is a counter-flow, shell-and-tube type heat recovery unit designed to be mounted through the barn roof for self-contained ventilation or supplementing of a recirculation system. The core is constructed of thin wall extruded polyethylene tubes held vertically in place by steel plates. The core is housed in a wood frame sheathed with plywood and rigid foam insulation. The two exhaust fans and two supply fans are housed in a rigid styrofoam enclosure attached to the ceiling of the barn at the base of the core.

Stale barn air is drawn into the bottom of the unit, passes up through the tubes, and exhausts out the chimney-like roof duct. Fresh air enters from the attic, passes downward around the tubes, and is blown into the barn along the ceiling. Exhaust and supply airflows are automatically adjusted with an electronic thermostat controller. The supply fan is connected to a manually adjustable shut-off timer for core defrosting. The core is drained through the exhaust intake housing inside the barn.

## SCOPE OF TEST

For the test, the Robbco A1-3500-BIK was mounted near the center of a long narrow room, and recirculation ducts were used to help distribute the fresh air. The unit was installed at a hog barn near Winnipeg, Manitoba (TABLE 13) and operated during the winters of 1987/88 and 1988/89 for a total of about 300 days.

TABLE 13. Operating Conditions.

<b>LOCATION:</b>	Steinbach, Manitoba
<b>TYPE OF BARN:</b>	Swine Finisher
<b>NUMBER OF ANIMALS:</b>	1100
<b>INSIDE BARN DIMENSIONS:</b>	200 x 36 x 8 ft (60 x 11 x 2.4 m)
<b>FEEDING SYSTEM:</b>	Home milled feed. Automatic chain drag conveyor to self feeders.
<b>MANURE SYSTEM:</b>	Open flush gutter on side walls.
<b>WINTER VENTILATION SYSTEM</b>	
Without HRV:	Recirculation duct and attic inlets at center, exhaust fans on side walls.
With HRV:	Robbco A1-3500 in center of room with direct exhaust, fresh air jetted into recirculation duct.
<b>AVERAGE BARN TEMPERATURE:</b>	64°F (18°C)
<b>AVERAGE BARN HUMIDITY:</b>	90%
<b>HEAT BALANCE TEMPERATURE:</b>	32°F (0°C)

## RESULTS AND DISCUSSION

### RATE OF WORK

**Heat Recovery:** Heat recovery rates for the Robbco A1-3500-BIK at three barn temperatures are illustrated in FIGURE 14. The maximum rate of 2407 Btu/min (42.3 kW) occurred in a 77°F (25°C) barn with outdoor temperature about -22°F (-30°C). The graph shows that more heat was recovered from warm barns than cool barns. Also, the rate of heat recovery decreased as outdoor temperatures increased. Thus, the total heat savings over an entire season would vary depending on the barn temperature, outside temperature and the heat balance temperature. Although not tested, airflow rates and heat recovery could also be regulated with the electronic variable speed thermostat connected to the fans.

TABLE 14 illustrates the seasonal heat savings by the Robbco A1-3500-BIK in a single season based on 20 years' weather data for Winnipeg, Manitoba and a barn temperature of 68°F (20°C). For example, if a barn at that location had a heat balance temperature of 14°F (-10°C), the Robbco A1-3500-BIK would recover up to 200 MBtu (58200 kWh) of heat in one season. To fully realize these savings, the HRV must be properly matched to the ventilation system of the barn.

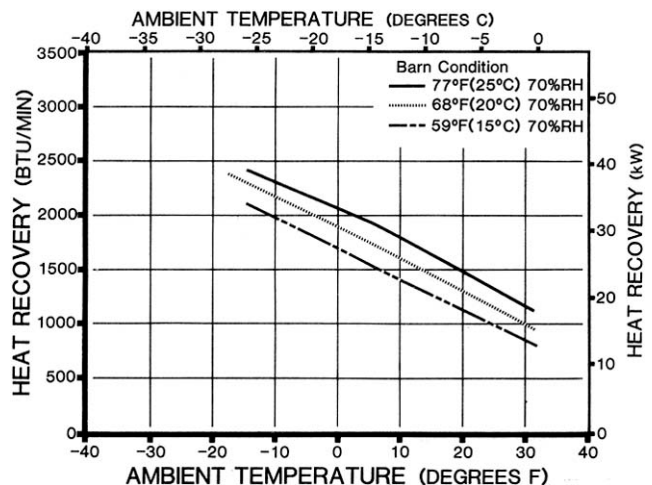


FIGURE 14. Robbco A1-3500-BIK Heat Recovery Rate at Three Barn Temperatures.

**Ventilation Rate:** FIGURE 15 illustrates the supply and exhaust airflow rates through the Robbco A1-3500-BIK versus the pressure difference inside and outside the barn. The Robbco A1-3500-BIK was equipped with a variable speed electronic thermostat which simultaneously adjusted both supply and exhaust airflows. At the maximum fan speed setting, the Robbco A1-3500-BIK ventilated about 4600 cfm (2160 L/s) through two exhaust fans and 3200 cfm (1500 L/s) through two supply fans at a neutral barn pressure. Typically in winter, barns are operated under a negative pressure ranging from 0 to -0.10 in.wg (0 to -25 Pa). Under these conditions, exhaust airflow decreased by as much as 380 cfm (180 L/s) while supply airflow increased by up to 340 cfm (160 L/s).

TABLE 14. Seasonal Heat Savings of the Robbco A1-3500-BIK near Winnipeg. (Barn temperature 68°F (20°C), Outdoor temperature 20 year average 1968-1987).

HEAT BALANCE TEMPERATURE		LENGTH OF HEATING SEASON hours	SEASONAL HEAT SAVED	
°F	(°C)		MBtu	(kWh)
32	(0)	3,530	300	(88 900)
23	(-5)	2,640	250	(73 900)
14	(-10)	1,890	200	(58 200)
+5	(-15)	1,294	150	(43 200)
-4	(-20)	796	98	(28 600)
-13	(-25)	367	50	(14 200)
-22	(-30)	100	14	(4 200)
-31	(-35)	10	1.6	(500)

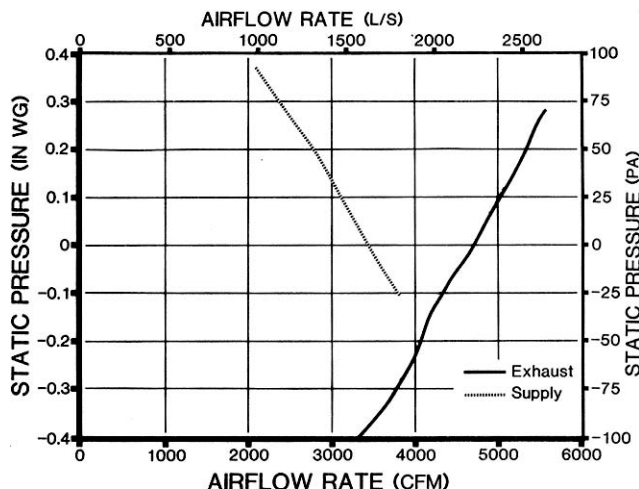


FIGURE 15. Robbco A1-3500-BIK Ventilation Rates.

Table 15. Test Result Summary

	Units	Test Condition Number								
		1	2	3	4	5	6	7	8	9
<b>Barn Air Temperature</b> (70 % Relative Humidity)	°F (°C)	76.5 (25)	67.9 (20)	59.2 (15)	77.5 (25)	67.5 (20)	59.4 (15)	76.8 (25)	68 (20)	58 (15)
<b>Outside Air Temperature</b>	°F (°C)	-14.8 (-26)	-17.6 (-28)	-14.5 (-26)	5.9 (-15)	7.5 (-14)	6.6 (-14)	31.4 (0)	31.3 (0)	31.9 (0)
<b>Fresh Air In Temperature</b>	°F (°C)	39.5 (4)	32.2 (0)	29.1 (-2)	47.8 (9)	44.6 (7)	40 (4)	57.6 (14)	53.9 (12)	50.2 (10)
<b>Exhaust Airflow Rate</b>	cfm (L/s)	4626 (2170)	4510 (2120)	4488 (2110)	4588 (2155)	4607 (2165)	4613 (2170)	4616 (2170)	4663 (2190)	4656 (2190)
<b>Supply Air Flowrate</b>	cfm (L/s)	2898 (1360)	3078 (1445)	3121 (1465)	3174 (1491)	3156 (1485)	3142 (1475)	3255 (1530)	3234 (1520)	3189 (1500)
<b>Defrost Shutdown</b>	min/hr	8	8	8	8	8	8	8	8	8
<b>Exhaust Air Heat Loss</b>	Btu/min (kW)	6750 (118.7)	6288 (110.5)	5499 (96.7)	5134 (90.3)	4392 (77.2)	3948 (69.4)	3222 (56.6)	2691 (47.3)	2025 (35.6)
<b>Average Heat Recovery</b>	Btu/min (kW)	2407 (42.3)	2370 (41.7)	2090 (36.7)	1911 (33.6)	1669 (29.3)	1495 (26.3)	1115 (19.6)	956 (16.8)	796 (14.0)
<b>Heat Recovery Ratio</b>	%	36	38	38	37	38	38	35	36	39

In the test barn, dust gradually built up in the exhaust passages of the core, slightly reducing the ventilation rate. However, water condensing on the tubes of the core washed most of the dust down and out the drain. Thus, the core had to be washed only once or twice in a season. Frequency of cleaning may vary for other barn conditions.

The defrost cycle affected overall ventilation rates. For 8 minutes each hour, the supply fan was shut off, while the exhaust flow became slightly restricted with ice formation. When averaged over a complete cycle, the net ventilation rates were 4490 cfm (2100 L/s) exhaust and 2770 cfm (1300 L/s) supply.

#### QUALITY OF WORK

**Heat Recovery Ratio:** Heat recovery ratios (HRR) for the Robbco A1-3500-BIK ranged from 35 to 39% (TABLE 15). TABLE 15 lists the complete summary of results from the nine test runs. The Robbco A1 - 3500-BIK was slightly more efficient in a cooler barn, but efficiency was not affected much by outdoor temperature.

**Leakage:** About 170 cfm (80 L/s) of stale exhaust air leaked into the incoming fresh air with the core clean and operating at normal flow rates and pressures. This amounted to a cross-contamination rate of about 3.8%.

**Defrost:** The Robbco A1-3500-BIK defrost control system was very good. The mechanical timer circuit prevented nearly all ice build-up in the core even through extended periods of cold weather, though a few tubes near the outer edge of the core did block with frost. The controller was manually adjustable to allow the operator to defrost for longer periods if required, or even to shut off the defrost cycle in warmer weather. Condensate drained down the tubes into the barn where it could be connected to a drain pipe.

#### POWER REQUIREMENTS

The Robbco A1-3500-BIK plugged into one standard 230 V AC wall outlet. Maximum current draw was about 10 A for all four fans. Total power consumption of the unit was about 1600 W.

#### EASE OF OPERATION AND ADJUSTMENT

**Installing:** Ease of installing was fair. The Robbco A1-3500-BIK was installed by two men in about 16 hours. The large core had to be lifted into the ceiling, and extreme care had to be exercised in handling the delicate core. A hole had to be cut through the ceiling and the exterior roof, and some framing changes were made to the rafters. No ducting was required, though in the test barn, recirculation ducts were used to distribute the warmed fresh air through the long narrow barn. Installation instructions were very helpful.

**Adjusting:** Ease of adjusting was very good. The mechanical defrost timer could be set for any duration of cycle, or turned off during mild weather. The electronic variable speed thermostat allowed for some adjustment to suit desired barn temperature.

**Cleaning:** Ease of cleaning was excellent. The self-cleaning action of the vertical polyethylene tubes eliminated the need for washing. Water drained down the tubes into the barn, and could be connected to a drain pipe for convenient disposal.

**OPERATOR SAFETY**

Although, individual electrical components were certified, the Robbco A1-3500-BIK was not CSA certified as meeting the requirements of the Canadian Electrical Code. Some provinces require an electrical inspection of installed equipment which is not CSA certified.

An operator could accidentally get fingers caught in the exposed exhaust fan blades which were located along the alley way at about head level.

Some caution was required when gaining access to the core from the top of the barn roof for end of season servicing.

**OPERATOR'S MANUAL**

The operator's manual was good. It contained useful, well illustrated installation instructions on the unit, but did not contain any information on general operating. It is recommended that the manufacturer consider including information on operating, adjusting, and servicing in the operator's manual.

**MECHANICAL HISTORY**

No mechanical problems occurred with the Robbco A1-3500-BIK through about 300 days of normal operation.

<b>SPECIFICATIONS</b>		
<b>MAKE:</b>	Robbco	
<b>MODEL:</b>	A1-3500-BIK	
<b>SERIAL NUMBER:</b>	N/A	
<b>MANUFACTURER:</b>	Robbco Ltd. 62 Thatcher Drive Winnipeg, Manitoba R3T 2L3	
<b>OVERALL DIMENSIONS:</b>		
- length	10.0 ft (3.0 m)	
- width	4.3 ft (1.3 m)	
- height	10.4 ft (3.2 m)	
- overall weight	479 lb (217 kg)	
<b>CORE DESCRIPTION:</b>	counter-flow, shell-and-tube	
<b>CORE CONSTRUCTION:</b>		
- external shell	plywood and framing	
- internal core	extruded 6 mil polyethylene tubes	
- seal	foam gaskets and caulking	
	<u><b>EXHAUST</b></u>	<u><b>SUPPLY</b></u>
<b>NOMINAL AIRFLOW:</b>	4600 cfm (2200 L/s)	3200 cfm (1500 L/s)
<b>INLET AREA:</b>	510 in <sup>2</sup> (0.3 m <sup>2</sup> )	670 in <sup>2</sup> (0.4 m <sup>2</sup> )
<b>OUTLET AREA:</b>	760 in <sup>2</sup> (0.5 m <sup>2</sup> )	650 in <sup>2</sup> (0.4 m <sup>2</sup> )
<b>SURFACE AREA OF CORE:</b>	116420 in <sup>2</sup> (75 m <sup>2</sup> )	116420 in <sup>2</sup> (75 m <sup>2</sup> )
<b>TUBE SIZE:</b>		
- quantity	225	N/A
- diameter	1.83 in (46 mm)	N/A
- length	90 in (2290 mm)	N/A
<b>FANS:</b>		
- number	2	2
- make	Hurst	Hurst
- type	axial	axial
- no. of blades	4	4
- diameter	18 in	16 in
- speed	1625 rpm	1625 rpm
- motor	Leeson model A4P17NB8D 1/3 hp 115/230 V AC 3.8/1.9 A 60 Hz 1 phase	Leeson model A4P17NB7C 1/4 hp 115/230 V AC 3.2/1.6 A 60 Hz 1 phase

## Z-AIR MODEL 74-60-1 HEAT RECOVERY VENTILATOR

### MANUFACTURER:

Z-Air Fabrication inc.  
7115 Laurette  
St. Damien, Quebec  
J0K 2E0

### DISTRIBUTOR:

Airmaster Sales Ltd.  
400 Keewatin Street  
Winnipeg, Manitoba  
R2X 2R9  
Phone: (204) 633-5756

### RETAIL PRICE

\$3,196.64 (May, 1989, f.o.b. Humboldt, Sask.)

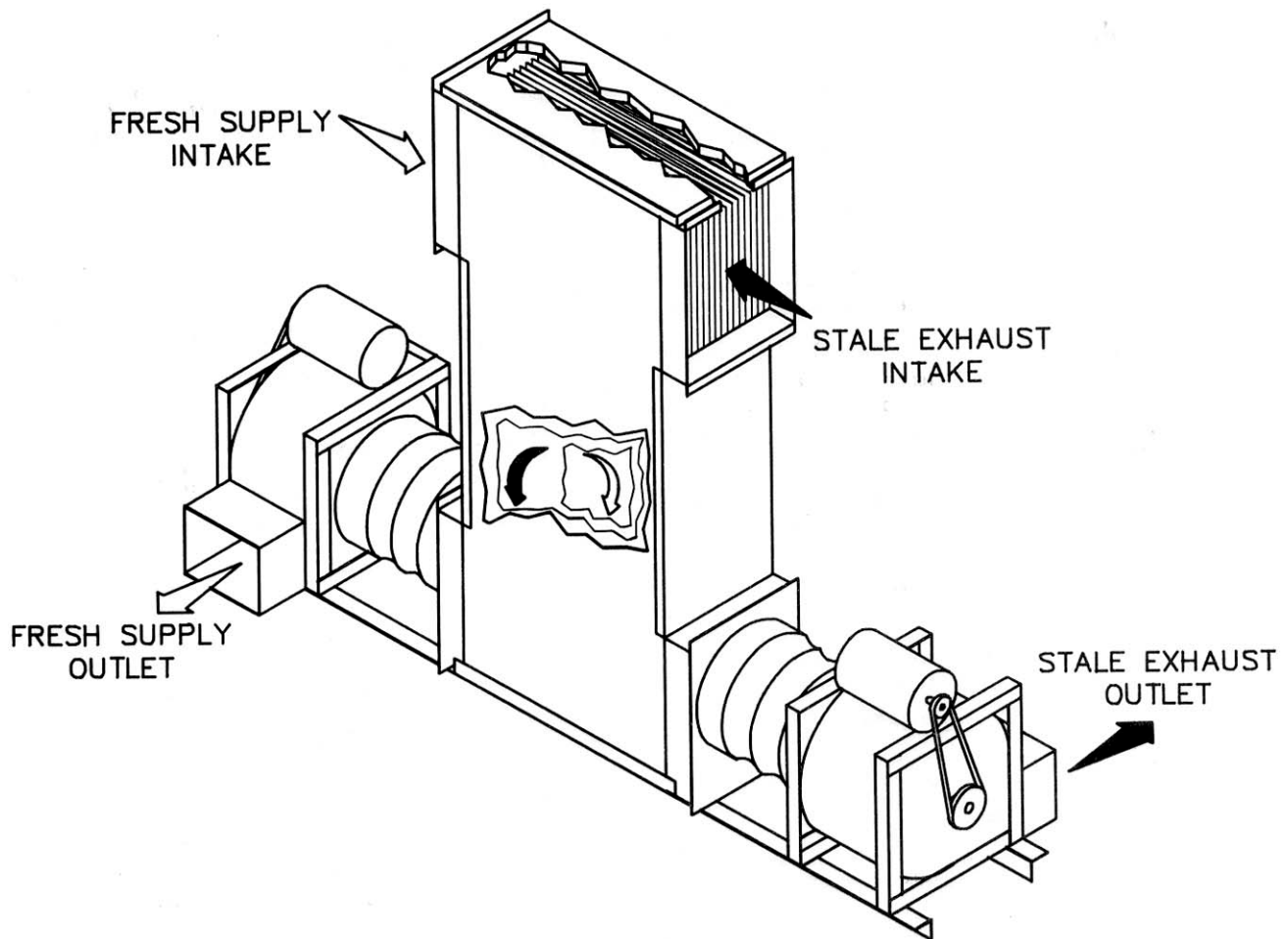


FIGURE 16. Z-Air Model 74-60-1.

### SUMMARY AND CONCLUSIONS

**Rate of Work:** Maximum rate of heat recovery of the Z-Air Model 74-60-1 was 497 Btu/min (8.7 kW) which occurred in a warm 77°F (25°C) barn with outdoor temperature -22°F (-30°C). In normal operating mode, ventilation was about 950 cfm (450 L/s) exhaust and 820 cfm (385 L/s) supply

**Quality of Work:** Heat recovery ratio ranged from 27 to 39%. No measurable core leakage occurred. No defrost control was supplied. A mechanical timer was installed by PAMI, and the supply fan had to be shut off for up to 8 minutes per hour.

**Power Requirements:** The two fans drew approximately 8 A at 120 V AC and required about 0.9 kW of power,

**Ease of Operation:** Ease of installing was good. It took one man 1 to 12 hours to install the unit depending on ducting requirements.

Ease of adjusting was good. A defrost timer had to be installed and adjusted. Ease of cleaning was fair. The core was awkward to access for thorough washing, so a filter element was installed by PAMI.

**Operator Safety:** The Z-Air Model 74-60-t was CSA certified. No hazards were apparent.

**Operator's Manual:** The operator's manual was good. It was thorough and well illustrated, but did not contain specific information for handling the dust and humidity commonly encountered in agriculture.

**Mechanical History:** No mechanical problems occurred in 30 days of operating.



## RECOMMENDATIONS

- It is recommended that the manufacturer consider:
1. Supplying a defrost controller as standard equipment.
  2. Shielding the fan drives.

## THE MANUFACTURER STATES THAT

- With regard to recommendation number:
1. The heat exchangers shall be supplied with an exhaust air thermostat positioned in the leaving air stream that will actuate a time clock whenever the leaving exhaust temperature drops below 35°F (2°C) (adjustable). The time clock shall switch off the supply fan for 5 minutes every hour to allow the heat of the exhaust air to defrost ice formation.
  2. Belt guards shall be supplied with all units.

## GENERAL DESCRIPTION

The Z-Air Model 74-60-1 is a parallel flow plate type air-to-air heat recovery unit designed for mounting on the barn floor in connection with the ventilation system. It consists of an aluminium body containing the core and supporting two belt driven centrifugal fans on an angle iron stand. The core is constructed from a continuously folded aluminum material sealed in place with steel reinforced refractory cement.

Stale barn air is drawn into the top of the unit, passes vertically down through the core and is blown into an exhaust duct by the exhaust fan. Fresh air enters the other side of the unit at the top, passes vertically down through the core, and is blown into the barn by the supply fan. No defrost control was provided. The two fans are designed to plug into two 120 V AC outlets.

## SCOPE OF TEST

For the PAMI test, the Z-Air Model 74-60-1 was installed in a chicken barn near Winnipeg, Manitoba (TABLE 16). A mechanical timer was installed by PAMI to provide defrost control.

TABLE 16. Operating Conditions.

<b>LOCATION:</b>	Landmark, Manitoba
<b>TYPE OF BARN:</b>	Chicken Broiler
<b>NUMBER OF ANIMALS:</b>	10,000
<b>INSIDE BARN DIMENSIONS:</b>	250 x 40 x 8.5 ft (75 x 12 x 2.6 m)
<b>FEEDING SYSTEM:</b>	Commercial mash feed, augers to self-feeders near floor.
<b>MANURE SYSTEM:</b>	Straw floor litter, scheduled cleanout between batches of birds.
<b>WINTER VENTILATION SYSTEM</b>	
Without HRV:	Two homemade single pass heat exchange tubes into a recirculation duct, one variable speed exhaust fan.
With HRV:	Z-Air placed in adjacent hallway with ducting to recirculation duct.
<b>AVERAGE BARN TEMPERATURE:</b>	59°F (15°C)
<b>AVERAGE BARN HUMIDITY:</b>	70%
<b>HEAT BALANCE TEMPERATURE:</b>	14°F (-10°C)

## RESULTS AND DISCUSSION

### RATE OF WORK

**Heat Recovery:** Heat recovery rates for the Z-Air Model 74-60-1 at three barn temperatures are illustrated in FIGURE 17. The maximum rate of 497 Btu/min (8.7 kW) occurred in a 77°F (25°C) barn with an outdoor temperature of -22°F (-30°C). The graph shows that more heat was recovered from warm barns than cool barns. Also, the rate of heat recovery decreased as outdoor temperatures. Thus, the total heat savings over an entire season would vary depending on the barn temperature, outdoor temperature and the heat balance temperature.

TABLE 17 illustrates the seasonal heat savings by the Z-Air Model 74-60-1 in a single season based on 20 years weather data for Winnipeg, Manitoba and a barn temperature of 68°F (20°C). If a barn at that location had a heat balance temperature of 14°F (-10°C), the Z-Air

Model 74-60-1 would potentially recover up to 43 MBtu (12 700 kWh) of heat in one season. To fully realize the savings, the HRV must be properly matched to the ventilation requirements of the barn.

**Ventilation Rate:** FIGURE 18 illustrates the supply and exhaust airflow rates through the Z-Air Model 74-60-1 versus the pressure difference inside and outside the barn. The Z-Air Model 74-60-1 ventilated about 950 cfm (450 L/s) exhaust and 820 cfm (385 L/s) supply at a neutral barn pressure. Typically in winter, barns are operated under a negative pressure ranging from 0 to -0.10 in.wg (0 to -25 Pa). Under these conditions, exhaust airflow decreased by as much as 65 cfm (30 L/s) while supply airflow increased by up to 55 cfm (25 L/s).

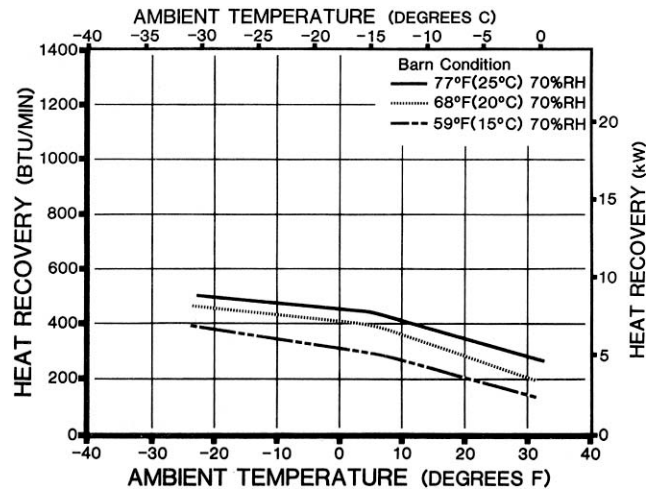


FIGURE 17. Z-Air Model 74-60-1 Heat Recovery Rate at Three Barn Temperatures.

TABLE 17. Seasonal Heat Savings of the Z-Air Model 74-60-1 near Winnipeg. (Barn temperature 68°F (20°C), Outdoor temperature 20 year average 1968-1987).

HEAT BALANCE TEMPERATURE °F (°C)	LENGTH OF HEATING SEASON hours	SEASONAL HEAT SAVED	
		MBtu	(kWh)
32 (0)	3,530	65	(19 200)
23 (-5)	2,640	55	(16 100)
14 (-10)	1,890	43	(12 700)
+5 (-15)	1,294	32	(9 400)
-4 (-20)	796	20	(6 000)
-13 (-25)	367	10	(2 900)
-22 (-30)	100	3	(800)
-31 (-35)	10	0.3	(90)

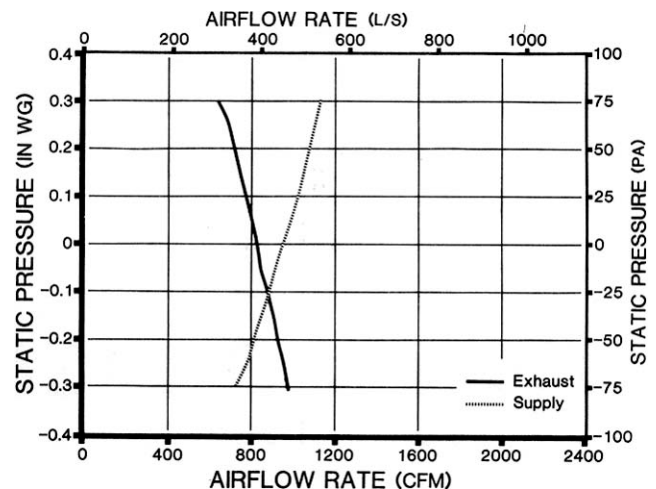


FIGURE 18. Z-Air Model 74-60-1 Ventilation Rates.

After several hours, in the test barn, dust built up in the exhaust passages of the core, significantly reducing the ventilation rate. It could be cleaned by removing the panel between the exhaust inlet and outlet, and spraying the core with a pressure washer. Because dust collected in the core quickly, a filter system of some type should help improve the ease of cleaning. Filters generally prevent most dust from entering the core, but they needed to be cleaned or changed daily or more often. Frequency of cleaning would vary for other barn conditions.

The frost buildup affected overall ventilation rates. In the cold outdoor conditions, exhaust airflows diminished, indicating the presence of frost in the core. No defrost system was supplied. The mechanical timer installed by PAMI, was set to defrost for 8 minutes each hour at -22°F (-30°C). When averaged over a complete cycle during cold weather the net ventilation rates were 851 cfm (400 L/s) exhaust and 700 cfm (330 L/s) supply.

#### QUALITY OF WORK

**Heat Recovery Ratio:** TABLE 18 lists the complete summary of results from the nine test runs. Heat recovery ratios (HRR) for the Z-Air Model 74-60-1 ranged from 27 to 39%. The Z-Air Model 74-60-1 was slightly more efficient in a warmer barn than a cool one but efficiency was randomly determined to some extent by the defrost requirements at each test condition.

**Leakage:** No measurable leakage occurred, indicating that the supply and exhaust passages were very well sealed. Thus the cross-contamination rate was 0%.

**Defrost:** The Z-Air Model 74-60-1 was not equipped with a defrost control system. Laboratory tests showed that in cold weather, defrosting was required to remove ice from the core. Therefore, a mechanical defrost timer was installed and adjusted by PAMI to determine the optimum defrost cycles. TABLE 18 shows that this varied from 4 minutes per hour at 5°F (-15°C) to 8 minutes per hour at -22°F (-30°C). No defrosting was required at 32°F (0°C). It is recommended that the manufacturer consider supplying a defrost controller as standard equipment.

#### POWER REQUIREMENTS

The Z-Air Model 74-60-1 plugged into two standard 120 V AC wall outlets. Maximum current draw was about 8 A for both fans. Total power consumption of the unit was about 0.9 kW.

#### EASE OF OPERATION

**Installing:** Ease of installing was good. The Z-Air Model 74-60-1 could be set up by one man in less than 1 hour. In the test barn, however, additional ducting, a defrost timer and an exhaust air filter had to be installed increasing the installation time to about 12 hours. The unit was conveniently placed on the floor in a pre-heat hallway with ducts carrying air to and from adjacent rooms. Installation instructions were provided, though the manual was written mainly for commercial or industrial applications where dust and humidity problems are less severe.

**Adjusting:** Ease of adjusting was good. The mechanical defrost timer installed by PAMI could be adjusted for extended defrosting in very cold weather, or to run continuously during mild weather. The fan speed was adjustable with variable sheaves. No other routine adjusting was necessary.

**Cleaning:** Ease of cleaning fair. The Z-Air Model 74-60-1 needed cleaning frequently. A panel between the exhaust inlet and outlet could be removed to inject wash water into the core, but the panel was not intended for quick removal. A filter element was installed ahead of the exhaust core, but the filter had to be changed three times a day in the very dusty test barn. A different type of filter may have made cleaning more practical. Ease of cleaning would vary depending on the individual setup and dust load.

#### OPERATOR SAFETY

The fan drive belts and sheaves were not shielded, presenting a potential hazard. It is recommended that the manufacturer consider shielding the fan drives.

The Z-Air Model 74-60-1 was CSA certified as meeting the requirements of the Canadian Electrical Code.

#### OPERATOR'S MANUAL

The operator's manual was very good. It was accurate, clearly written and well illustrated. It contained useful information on installing, operating and troubleshooting, and provided some guidelines for sizing and positioning the unit for proper ventilation. However, the manual was intended for commercial or industrial application, and did not reflect the special needs of an agricultural installation such as excess dust and humidity.

#### MECHANICAL HISTORY

No mechanical problems occurred with Z-Air Model 74-60-1 through 30 days of normal operation.

Table 18. Test Result Summary

	Units	Test Condition Number								
		1	2	3	4	5	6	7	8	9
<b>Barn Air Temperature</b> (70 % Relative Humidity)	°F (°C)	76.5 (25)	67.2 (20)	59.3 (15)	76.8 (25)	67.6 (20)	58.2 (15)	77.2 (25)	68.8 (20)	59.3 (15)
<b>Outside Air Temperature</b>	°F (°C)	-22.9 (-31)	-23.6 (-31)	-23.3 (-31)	4.6 (-15)	5.7 (-15)	7.1 (-14)	32.9 (1)	31.3 (0)	31.5 (0)
<b>Fresh Air In Temperature</b>	°F (°C)	17.8 (-8)	13.7 (-10)	7.7 (-14)	37.9 (3)	35.5 (2)	29.6 (-1)	53.6 (12)	46.7 (8)	42.6 (6)
<b>Exhaust Airflow Rate</b>	cfm (L/s)	903 (425)	851 (400)	877 (415)	941 (445)	922 (435)	946 (445)	947 (445)	945 (445)	953 (450)
<b>Supply Air Flowrate</b>	cfm (L/s)	814 (385)	810 (380)	810 (380)	808 (380)	807 (380)	805 (380)	801 (380)	795 (375)	794 (375)
<b>Defrost Shutdown</b>	min/hr	8	8	8	0	0	4	0	0	0
<b>Exhaust Air Heat Loss</b>	Btu/min (kW)	1501 (26.4)	1390 (24.4)	1255 (22.1)	1129 (19.8)	993 (17.5)	843 (14.8)	710 (12.5)	610 (10.7)	471 (8.3)
<b>Average Heat Recovery</b>	Btu/min (kW)	497 (8.7)	458 (8.1)	385 (6.8)	439 (7.7)	387 (6.8)	278 (4.9)	257 (4.5)	192 (3.4)	129 (2.3)
<b>Heat Recovery Ratio</b>	%	33	33	33	39	33	33	36	31	27

### SPECIFICATIONS

**MAKE:** Z-Air

**MODEL:** Z-Duct 74-60-1

**SERIAL NUMBER:** N/A

**MANUFACTURER:** Z-Air Fabrication Inc.  
7115 Laurette  
St. Damien, Quebec  
J0K 2E0

**OVERALL DIMENSIONS: (including fans)**

- length 77 in (1950 mm)
- width 17 in (430 mm)
- height 63 in (1600 mm)
- overall weight 297 lb (135 kg)

**CORE DESCRIPTION:** parallel flow plate

**CORE CONSTRUCTION:**

- external shell 1100 series aluminum
- internal core formed and folded 1100 aluminum sheet
- seal steel reinforced factory cement

	<u>EXHAUST</u>	<u>SUPPLY</u>
<b>NOMINAL AIRFLOW:</b>	1000 cfm (470 L/s)	1000 cfm (470 L/s)
<b>INLET AREA: (on core)</b>	184 in <sup>2</sup> (0.12 m <sup>2</sup> )	184 in <sup>2</sup> (0.12 m <sup>2</sup> )
<b>OUTLET AREA: (on fan)</b>	63 in <sup>2</sup> (0.04 m <sup>2</sup> )	63 in <sup>2</sup> (0.04 m <sup>2</sup> )
<b>SURFACE AREA OF CORE:</b>	51800 in <sup>2</sup> (33.4 m <sup>2</sup> )	51800 in <sup>2</sup> (33.4 m <sup>2</sup> )

**PASSAGE SIZE:**

	18	19
- quantity		
- width	0.625 in (16 mm)	0.5 in (12.5 mm)
- height	60 in (1520 mm)	60 in (1520 mm)
- length	24 in (610 mm)	24 in (610 mm)

**FANS:** exhaust and supply fans are identical

- make Delhi 410 Eisenheiss
- type centrifugal blower, belt driven
- diameter 10 in (250 mm)
- width 7.25 in (180 mm)
- speed variable, maximum 1100 rpm
- motor Marathon Electric Model SWL56S17T2002B P 1/2 hp 115 V AC 6.6 A 60 Hz 1 phase Type SS Code L

**CONTROLS:** none supplied

**OPTIONS:** N/A

### APPENDIX I

#### MACHINE RATINGS

The following rating scale is used in PAMI Evaluation Reports:

Excellent	Fair
Very Good	Poor
Good	Unsatisfactory

## SUMMARY CHART

### BETTER AIR A-3000

**RETAIL PRICE** \$3,000.00 (May, 1989, f.o.b. Humboldt, Sask.)

**RATE OF WORK**

- heat recovery maximum 860 Btu/min (15.1 kW)
- ventilation rate 1260 cfm (590 L/s) exhaust, 875 cfm (410 L/s) supply

**QUALITY OF WORK**

- heat recovery ratio 39 to 43%
- leakage 6 cfm (3 L/s), 0.5% of exhaust flow
- defrost **Fair**; automatic thermostat controller did not cycle as intended

**POWER REQUIREMENTS** Approximate 6.5 A at 120 V AC, 0.8 kW

**EASE OF OPERATION:**

- installing **Very Good**; took two men 6 hours, core installed in ceiling
- adjusting **Good**; defrost control was inconsistent
- cleaning **Very Good**; access panels were easy to remove

**OPERATOR SAFETY:** Not CSA certified, no hazards apparent

**OPERATOR'S MANUAL:** None supplied

**MECHANICAL HISTORY:** No mechanical problems

### C AND J JONES MC II

**RETAIL PRICE** \$2,695.00 (May, 1989, f.o.b. Humboldt, Sask.)

**RATE OF WORK**

- heat recovery maximum 1350 Btu/min (23.8 kW)
- ventilation rate 1500 cfm (700 L/s) exhaust, 1500 cfm (700 L/s) supply, fans supplied by PAMI

**QUALITY OF WORK**

- heat recovery ratio 54 to 61%
- leakage 19 cfm (9 L/s), 2.5% of exhaust flow
- defrost **Very Good**; supply fan shut off for 0 to 7 minutes per 45 minute running time

**POWER REQUIREMENTS** Approximate 21 A at 120 V AC, 2.4 kW, with two Chicago Blower model 122 fans

**EASE OF OPERATION:**

- installing **Fair**; took two men 16 hours, core installed outside of barn
- adjusting **Very Good**; no routine adjustments needed
- cleaning **Fair**; outside core was inconvenient to wash, core drain had to be insulated and heated

**OPERATOR SAFETY:** No hazards apparent

**OPERATOR'S MANUAL:** None provided

**MECHANICAL HISTORY:** No mechanical problems

# SUMMARY CHART

Continued From Page 27

DEL-AIR A-150	
<b>RETAIL PRICE</b>	\$1,095.00 (May, 1989, f.o.b. Humboldt, Sask.)
<b>RATE OF WORK</b>	
- heat recovery	maximum 135 Btu/min (2.4 kW)
- ventilation rate	190 cfm (90 L/s) exhaust, 125 cfm (60 L/s) supply
<b>QUALITY OF WORK</b>	
- heat recovery ratio	37 to 42%
- leakage	4 cfm (2 L/s), 2.0% of exhaust flow
- defrost	<b>Very Good</b> ; supply fan reversed for 8 minutes per hour automatically
<b>POWER REQUIREMENTS</b>	Approximately 0.7 A at 120 V AC, 0.1 kW
<b>EASE OF OPERATION:</b>	
- installing	<b>Very Good</b> ; took one man 2 hours, core installed in barn wall
adjusting	<b>Very Good</b> ; no routine adjustments needed
cleaning	<b>Very Good</b> ; core hinged open for washing, optional filter was available
<b>OPERATOR SAFETY:</b>	CSA certified, no hazards apparent
<b>OPERATOR'S MANUAL:</b>	<b>Very Good</b> ; thorough and well illustrated
<b>MECHANICAL HISTORY:</b>	No mechanical problems

ROBICO A1-3500-BIK	
<b>RETAIL PRICE</b>	\$3,286.00 (May, 1989, f.o.b. Humboldt, Sask.)
<b>RATE OF WORK</b>	
- heat recovery	maximum 2400 Btu/min (42.3 kW)
- ventilation rate	4600 cfm (2160 L/s) exhaust, 3200 cfm (1500 L/s) supply
<b>QUALITY OF WORK</b>	
- heat recovery ratio	35 to 39%
- leakage	170 cfm (80 L/s), 3.8% of exhaust flow
- defrost	<b>Very Good</b> ; supply fan shut off for 8 minutes per hour automatically
<b>POWER REQUIREMENTS</b>	Approximate 10 A at 230 V AC, 1.6 kW
<b>EASE OF OPERATION:</b>	
- installing	<b>Fair</b> ; took two men 16 hours, core installed through barn roof
adjusting	<b>Very Good</b> ; no routine adjustments needed
cleaning	<b>Excellent</b> ; the core was completely self-cleaning
<b>OPERATOR SAFETY:</b>	Exposed fan blades, outlet serviced on roof, not CSA certified

DEL-AIR A-800	
<b>RETAIL PRICE</b>	\$1,950.00 (May, 1989, f.o.b. Humboldt, Sask.)
<b>RATE OF WORK</b>	
- heat recovery	maximum 608 Btu/min (10.7 kW)
- ventilation rate	980 cfm (460 L/s) exhaust, 590 cfm (276 L/s) supply
<b>QUALITY OF WORK</b>	
- heat recovery ratio	32 to 36%
- leakage	10 cfm (5 L/s), 1.0% of exhaust flow
- defrost	<b>Very Good</b> ; supply fan reversed for 8 minutes per hour automatically
<b>POWER REQUIREMENTS</b>	Approximately 3.6 A at 120 V AC, 0.4 kW
<b>EASE OF OPERATION:</b>	
- installing	<b>Very Good</b> ; took one man 2 hours, core installed in barn wall
adjusting	<b>Very Good</b> ; no routine adjustments needed
cleaning	<b>Very Good</b> ; core hinged open for washing, optional filter was available
<b>OPERATOR SAFETY:</b>	CSA certified, no hazards apparent
<b>OPERATOR'S MANUAL:</b>	<b>Very Good</b> ; thorough and well illustrated
<b>MECHANICAL HISTORY:</b>	No mechanical problems

Z-AIR MODEL 74-60-1	
<b>RETAIL PRICE</b>	\$3,196.64 (May, 1989, f.o.b. Humboldt, Sask.)
<b>RATE OF WORK</b>	
- heat recovery	maximum 497 Btu/min (8.7 kW)
- ventilation rate	950 cfm (450 L/s) exhaust, 820 cfm (385 L/s) supply
<b>QUALITY OF WORK</b>	
- heat recovery ratio	27 to 39%
- leakage	none measurable
- defrost	none supplied, supply fan had to be shut off for up to 8 minutes per hour
<b>POWER REQUIREMENTS</b>	Approximate 8 A at 120 V AC, 0.9 kW
<b>EASE OF OPERATION:</b>	
- installing	<b>Good</b> ; took one man 1 to 12 hours, depending on ducting requirements
adjusting	<b>Good</b> ; defrost timer had to be added and adjusted
cleaning	<b>Fair</b> ; core was awkward to access, a filter element was added
<b>OPERATOR SAFETY:</b>	CSA certified, no hazards apparent
<b>OPERATOR'S MANUAL:</b>	<b>Good</b> ; thorough and well illustrated, but no agricultural information
<b>MECHANICAL HISTORY:</b>	No mechanical problems



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