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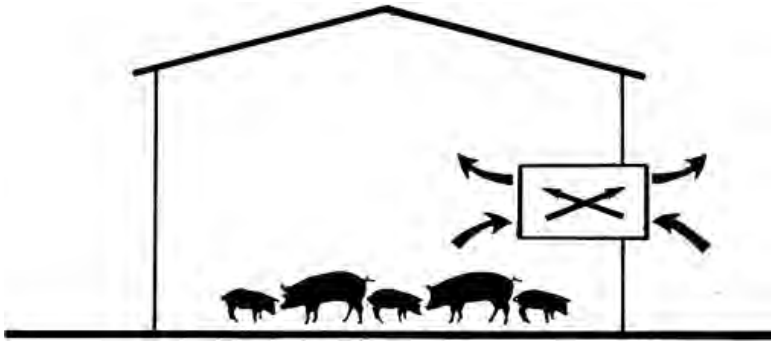

Better Air A-3000
C and J Jones
Del Air A-150
Del Air A-800
Robbco Al- 3500 - BIK
Z-Air 74-60-1

Heat Recovery Ventilators

A Co-operative Program Between
ALBERTA FARM MACHINERY RESEARCH CENTRE
PAMI
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 (i.e. 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 H RV 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

$3000.00 (May, 1989, f.o.b. Humboldt, Sask.)

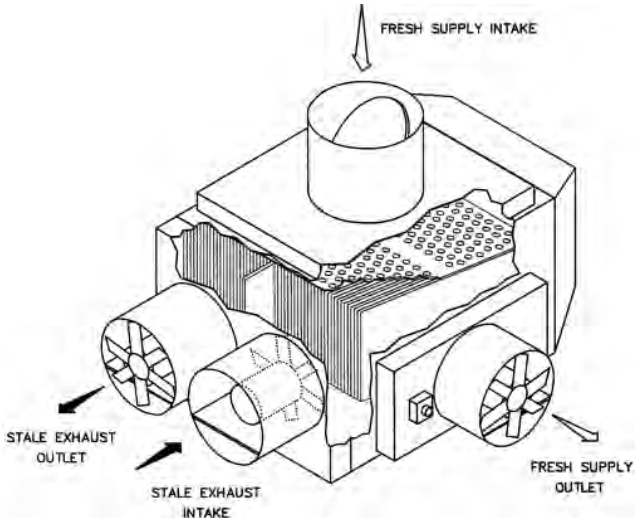

FIGURE 1. Better Air A-3000.

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 operable.
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 1800 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.

LOCATION:	Landmark, Manitoba
TYPE OF BARN:	Chicken Broiler
NUMBER OF ANIMALS:	10,000
INSIDE BARN DIMENSIONS:	250 x 40 x 8.5 ft (75 x 12 x 2,6 m)
FEEDING SYSTEM:	Commerical mash feed, augers to self-feeclers near floor,
MANURE SYSTEM:	Straw floor litter, scheduled cleanout between batches of birds.
WINTER VENTILATION SYSTEM:	
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.
AVERAGE BARN TEMPERATURE:	59°F (15°C)
AVERAGE BARN HUMIDITY:	70%
HEAT BALANCE TEMPERATURE:	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.

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		Length of Heating Season	Seasonal Heat Saved	
°F	°C	hours	MBtu	kWh
32	0	3530	103	30100
23	-5	2640	85	25000
14	-10	1890	67	19700
+5	-15	1294	50	14600
-4	-20	796	33	9600
-13	-25	367	16	4700
-22	-30	100	5	1400
-31	-35	10	0.5	155

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.

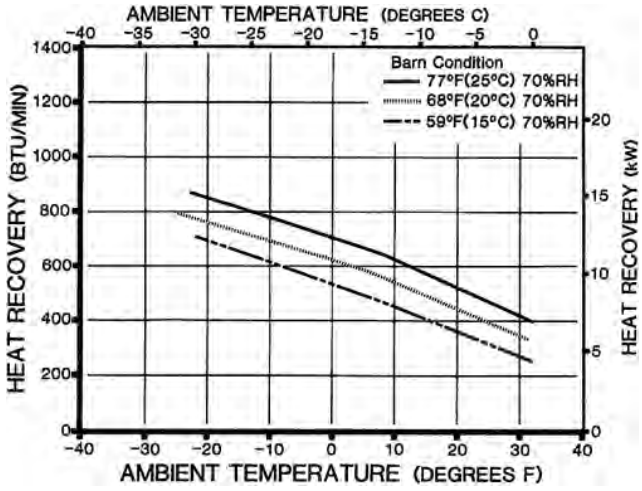

FIGURE 2. Better Air A-3000 Heat Recovery Rates at Three Barn Temperatures.

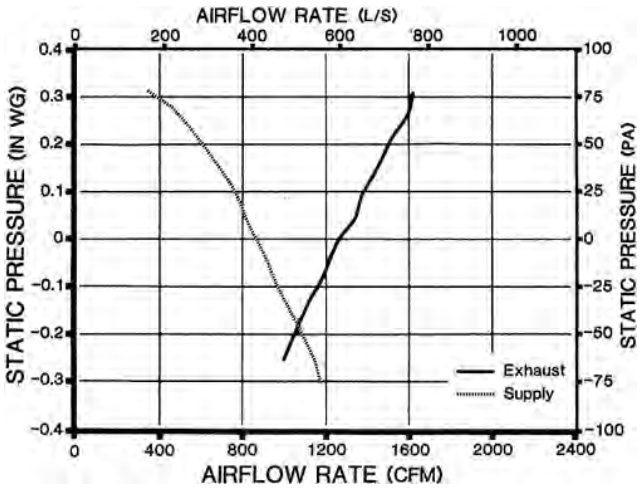

FIGURE 3. Better Air A-3000 Ventilation Rates.

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 d raw 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.

Table 3. Test Result Summary

		TEST CONDITION NUMBER								
	Units	**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 Heat Loss	Btu/min kW	1996 35.1	1931 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

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 drainpipe 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.

SPECIFICATIONS

MAKE:	Better Air	
MODEL:	A-3000	
SERIAL NUMBER:	N/A	
MANUFACTURER:	Better Air Manufacturing Ltd. P.O. Box 490 MacGregor, Manitoba R0H 0R0	
OVERALL DIMENSIONS:		
-- length	65 in (1650 mm)	
-- width	46 in (1520 mm)	
-- height	40 in (1000 mm)	
-- overall weight	350 lb (160 kg)	
CORE DESCRIPTION:	cross-counter flow plate	
CORE CONSTRUCTION:		
-- external shell	aluminum alloy	
-- internal core	aluminum alloy	
-- seal	foam rubber	
	Exhaust	**Supply**
NOMINAL AIRFLOW:	1260 cfm (590 L/s)	860 cfm (400 L/s)
INLET AREA:	154 in² (0.10 m²)	200 in² (0.13 m²)
OUTLET AREA:	154 in² (0.10 m²)	154 in² (0.10 m²)
SURFACE AREA OF CORE:	49900 in² (32 m²)	48000 in² (31 m²)
PASSAGE SIZE:		
-- 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)
FANS:		
-- quantity	2 exhaust fans, 1 supply fan; exhaust and supply fans are identical	
-- make	Better Air	
-- type	axial	
-- number 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	
CONTROLS:		
-- defrost connected to supply fan.	Goldfan T-1 mechanical thermostat	

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

$2695.00 (May, 1989, f.o.b. Humboldt, Sask., basic core only with no fans, mounts or ductwork).

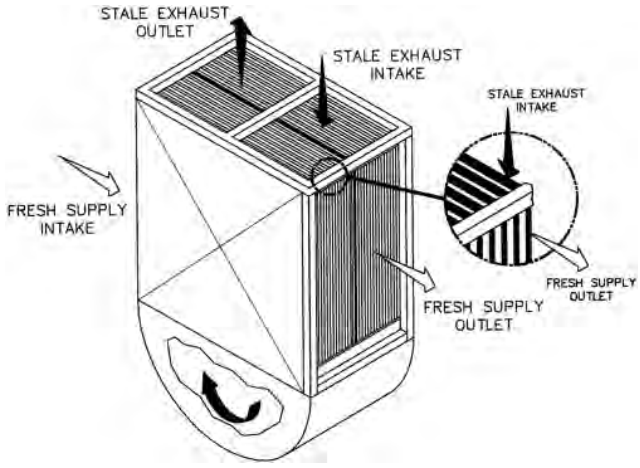

FIGURE 4. Jones MC II.

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.

LOCATION:	Stony Mountain, Manitoba
TYPE OF BARN:	Swine Finisher
NUMBER OF ANIMALS:	1500
INSIDE BARN DIMENSIONS:	300 x 40 x 24 ft (90 x 12 x 7 m)
FEEDING SYSTEM:	Overhead auger to self-feeders, on-farm milled. Also some wet/dry feeders.
MANURE SYSTEM:	Open flush gutter at the center.
WINTER VENTILATION SYSTEM:	
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.
AVERAGE BARN TEMPERATURE:	59°F (15°C)
AVERAGE BARN HUMIDITY:	70%
HEAT BALANCE TEMPERATURE:	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 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.

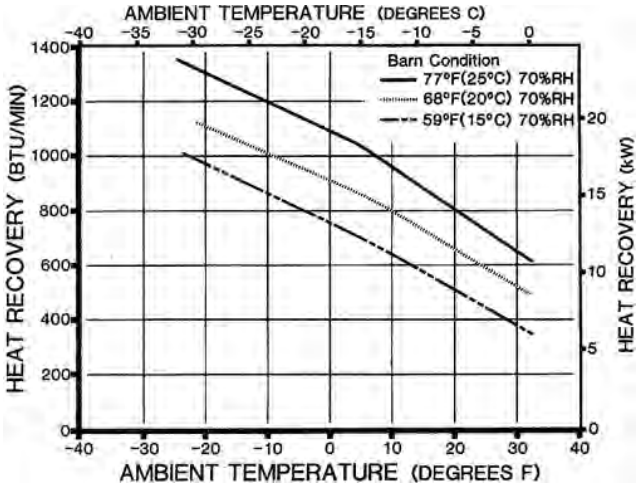

FIGURE 5. Jones MC II Heat Recovery Rate at Three Barn Temperatures.

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		Length of Heating Season	Seasonal Heat Saved	
°F	°C	hours	MBtu	kWh
32	0	3530	151	44400
23	-5	2640	125	36700
14	-10	1890	98	28700
+5	-15	1294	72	21100
-4	-20	796	47	13800
-13	-25	367	23	6790
-22	-30	100	7	1980
-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.

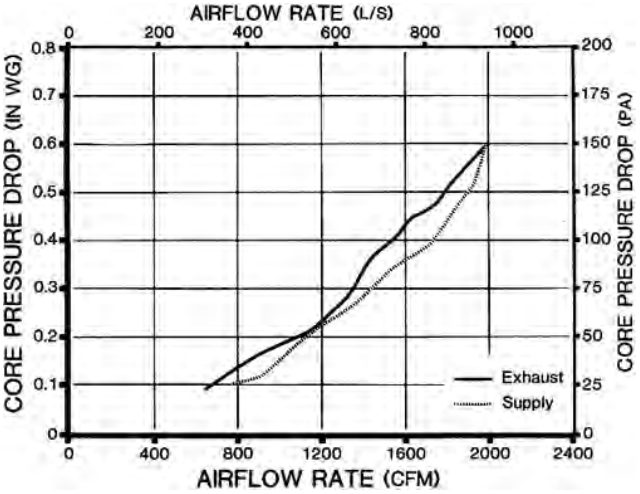

FIGURE 6. Jones MC II Airflow Resistance Curve.

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 (HRR) for the

Table 6. Test Result Summary

		TEST CONDITION NUMBER								
	Units	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Barn Air Temperature (70% Relative Humidity)	°F °C	77.2 25	67.7 20	58.1 15	76.9 25	68.7 20	57.4 14	76.8 25	68.7 20	57.9 14
Outside Air Temperature	°F °C	-25.0 -32	-21.7 -30	-23.8 -31	5.2 -15	6.4 -14	7.1 -14	32.6 0	32.0 0	32.6 0
Fresh Air in Temperature	°F °C	32.3 0	25.9 -3	19.4 -7	45.8 8	40.9 5	3401 1	57.2 14	51.7 11	46.1 8
Exhaust Airflow Rate	cfm L/s	1334 625	1330 625	1341 630	1451 680	1426 670	1433 675	1514 710	1516 710	1506 710
Supply Air Flowrate	cfm L/s	1499 705	1500 705	1496 705	1501 705	1501 705	1510 710	1520 715	1522 715	1507 710
Defrost Shutdown	min hour	5 0.75	6 0.75	7 0.75	0	5 2	5 2	0	0	0
Exhaust Heat Loss	Btu/min kW	2225 39.1	1986 34.9	1867 32.8	1685 29.6	1442 25.4	1194 21.0	1070 18.8	906 15.9	635 11.2
Average Heat Recovery	Btu/min kW	1353 23.8	1121 19.7	1006 17.7	1024 18.1	836 14.7	670 11.8	607 10.7	489 8.6	340 6.0
Heat Recovery Ratio	%	61	56	57	61	58	56	57	54	54

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.

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 freeze-up. 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	
	Exhaust	**Supply**
NOMINAL AIRFLOW:	1500 cfm (700 L/s)	1500 cfm (700 L/s)
INLET AREA:	300 in² (0.19 m²)	650 in² (0.42 m²)
OUTLET AREA:	300 in 2(0.19 m²)	650 in² (0.42 m²)
SURFACE AREA OF CORE:	69,120 in² (44.6 m²)	72,540 in² (46.8 m²)
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

$1095.00 (May, 1989, f.o.b. Humboldt, Sask.)

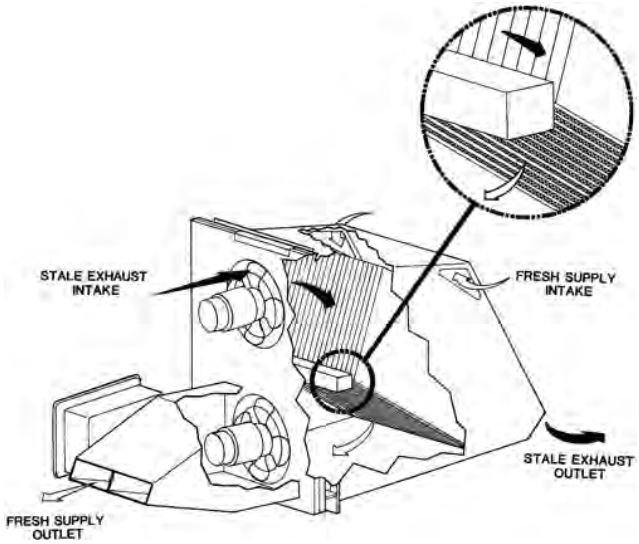

FIGURE 7. Del-Air A-150.

SUMMARY AND CONCLUSIONS

Rate of Work: Maximum rate of heat recovery for the Del-Air A150 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 propeller 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

LOCATION:	Beausejour, Manitoba
TYPE OF BARN:	Dairy calf
NUMBER OF ANIMALS:	10
INSIDE BARN DIMENSIONS:	14 x 12 x 8 ft (4.3 x 3.6 x 2.4 m)
FEEDING SYSTEM:	Milk, hay, and grain; pail-fed.
MANURE SYSTEM:	Straw bedding, manually scraped.
WINTER VENTILATION SYSTEM:	
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.
AVERAGE BARN TEMPERATURE:	59°F (15°C)
AVERAGE BARN HUMIDITY:	70%
HEAT BALANCE TEMPERATURE:	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.

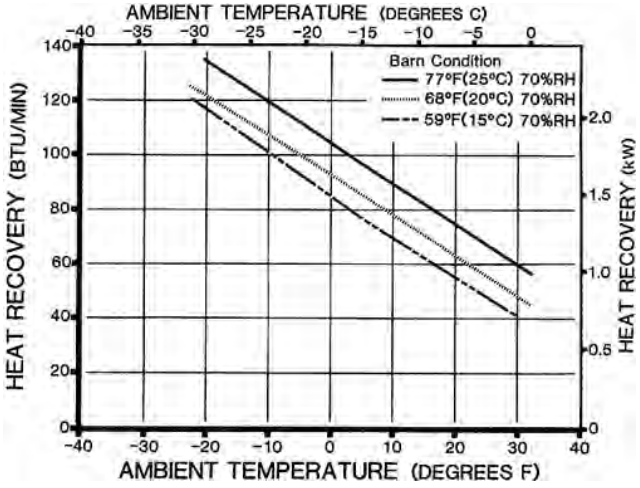

FIGURE 8. Del-Air A-150 Heat Recovery Rate at Three Barn Temperatures.

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).

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		Length of Heating Season	Seasonal Heat Saved	
°F	°C	hours	MBtu	kWh
32	0	3530	15.3	4480
23	-5	2640	12.8	3770
14	-10	1890	10.2	3000
+5	-15	1294	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

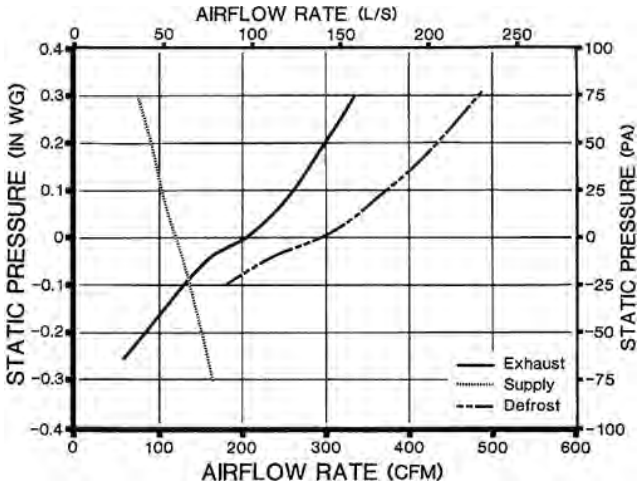

FIGURE 9. Del-Air A-150 Ventilation Rates.

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.

QUALITY OF WORK

Heat Recovery Ratio: Heat recovery ratios (HRR) for the Del-Air A150 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 build-up 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

Table 9. Test Result Summary

		TEST CONDITION NUMBER								
	Units	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Barn Air Temperature (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
Outside Air Temperature	°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
Fresh Air in Temperature	°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
Exhaust Airflow Rate	cfm L/s	190 90	190 90	190 90	190 90	190 90	190 90	190 90	190 90	190 90
Supply Air Flowrate	cfm L/s	125 60	125 60	123 60	126 60	126 60	125 60	127 60	126 60	126 60
Defrost Shutdown	min/hr	8	8	8	8	8	8	8	8	8
Exhaust Heat Loss	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
Average Heat Recovery	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
Heat Recovery Ratio	%	42	40	42	41	40	40	37	37	39

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.

SPECIFICATIONS

MAKE:	Del-Air	
MODEL:	A-150	
SERIAL NUMBER:	HC-3164-A	
MANUFACTURER:	Del-Air Systems Ltd. P.O. Box 2500 Humboldt, Saskatchewan S0K 2A0	
OVERALL DIMENSIONS:		
-- length	36 in (910 mm)	
-- width	16 in (410 mm)	
-- height	19.5 in (500 mm)	
-- overall weight	27 lb (12 kg)	
CORE DESCRIPTION:	cross-flow plate	
CORE CONSTRUCTION:		
-- external shell	moulded polyethylene	
-- internal core	corrugated polypropylene sheets	
-- seal	plastic cement	
	Exhaust	**Supply**
NOMINAL AIRFLOW:	180 cfm (85 L/s)	170 cfm (70 L/s)
INLET AREA:	33 in² (0.021 m²)	20 in² (0.013 m²)
OUTLET AREA:	28 in² (0.018 m²)	12 in² (0.008 m²)
SURFACE AREA OF CORE:	40,000 in² (25.8 m²)	40,000 in² (25.8 m²)
PASSAGE SIZE:		
-- 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)
FANS:	exhaust and supply fans are identical	
-- make	Del-Air	
-- type	axial	
-- number of blades	4	
-- diameter	6 in (150 mm)	
-- speed	3450 rpm	
-- motor	FASCO Industries Inc. Eldon Motor Division Type U62 0.3 A 120 V AC60 HZ 1 Phase No. 7162-2517	
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	

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

$1950.00 (May, 1989, f.o.b. Humboldt, Sask., with supply air diffuser and filter adapter kit).

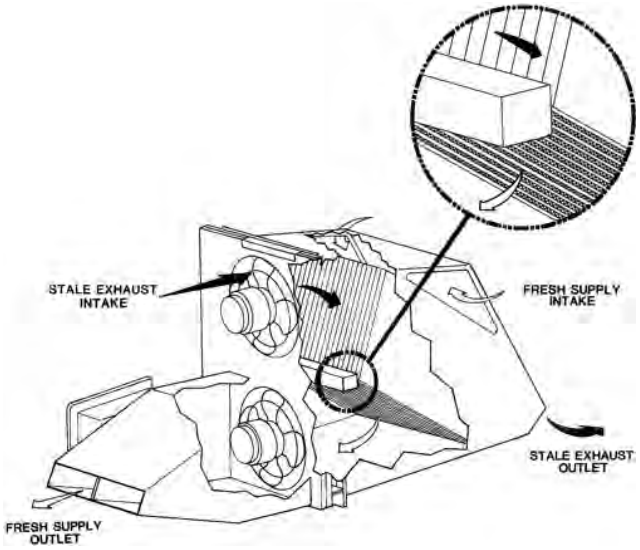

FIGURE 10. Del-Air A-800.

SUMMARY AND CONCLUSIONS

Rate of Work: Maximum rate of heat recovery for the Del-Air A800 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 welt 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 propeller 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 adapter kit and the optional fresh air diffuser.

TABLE 10. Operating Conditions

LOCATION:	Headingly, Manitoba
TYPE OF BARN:	Swine Grower/Finisher
NUMBER OF ANIMALS:	250
INSIDE BARN DIMENSIONS:	64 x 36 x 8 ft (20 x 11 x 2.4 m)
FEEDING SYSTEM:	Mash feed, manually filled self-feeders.
MANURE SYSTEM:	Side wall pits with concrete slats.
WINTER VENTILATION SYSTEM:	
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.
AVERAGE BARN TEMPERATURE:	68°F (20°C)
AVERAGE BARN HUMIDITY:	70%
HEAT BALANCE TEMPERATURE:	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.

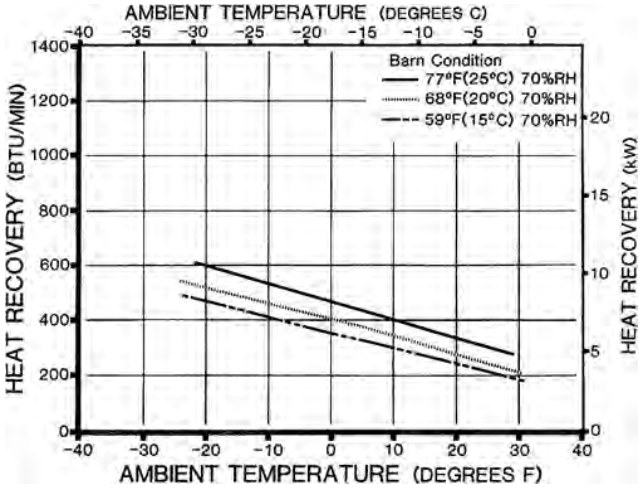

FIGURE 11. Del-Air A-800 Heat Recovery Rate at Three Barn Temperatures.

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).

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		Length of Heating Season	Seasonal Heat Saved	
°F	°C	hours	MBtu	kWh
32	0	3530	67	19600
23	-5	2640	56	16400
14	-10	1890	44	13000
+5	-15	1294	33	9700
-4	-20	796	22	6400
-13	-25	367	11	3200
-22	-30	100	3	960
-31	-35	10	0.4	108

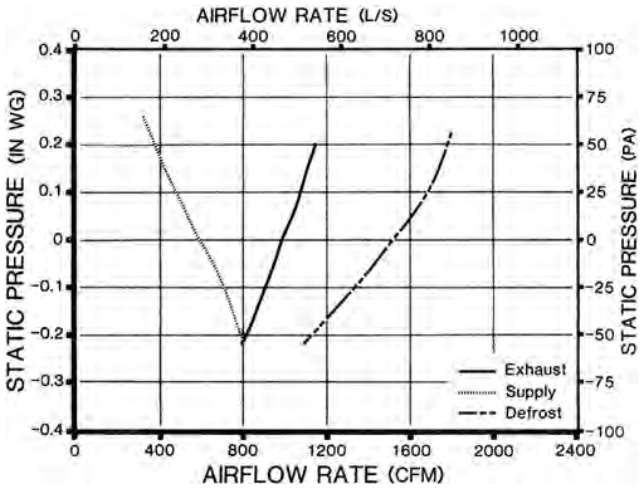

FIGURE 12. Del-Air A-800 Ventilation Rates.

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.

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-

Table 12. Test Result Summary

		TEST CONDITION NUMBER								
	Units	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Barn Air Temperature (70% Relative Humidity)	°F °C	76.8 25	67.4 20	57.6 14	76.7 25	67.8 20	56.5 14	77.2 25	67.1 20	61.3 16
Outside Air Temperature	°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
Fresh Air in Temperature	°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
Exhaust Airflow Rate	cfm L/s	965 455	961 450	947 445	984 460	983 460	997 465	992 465	995 465	969 455
Supply Air Flowrate	cfm L/s	597 280	594 280	563 265	610 285	607 285	591 275	611 285	613 290	597 280
Defrost Shutdown	min/hr	8	8	8	8	8	8	8	8	8
Exhaust Heat Loss	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
Average Heat Recovery	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
Heat Recovery Ratio	%	36	34	35	35	34	33	33	32	33

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.

SPECIFICATIONS

MAKE:	Del-Air	
MODEL:	A-800	
SERIAL NUMBER:	GY-2612-C	
MANUFACTURER:	Del-Air Systems Ltd. P.O. Box 2500 Humboldt, Saskatchewan S0K 2A0	
OVERALL DIMENSIONS:		
-- length	61 in (1550 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	
	Exhaust	**Supply**
NOMINAL AIRFLOW:	800 cfm (375 L/s)	700 cfm (330 L/s)
INLET AREA:	144 in² (0.09 m²)	138 in² (0.09 m²)
OUTLET AREA:	89 in² (0.06 m²)	66 in² (0.04 m²)
SURFACE AREA OF CORE:	40000 in² (25.8 m²)	40000 in² (25.8 m²)
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	
-- number 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:

$3286.00 (May, 1989, f.o.b. Humboldt, Sask.).

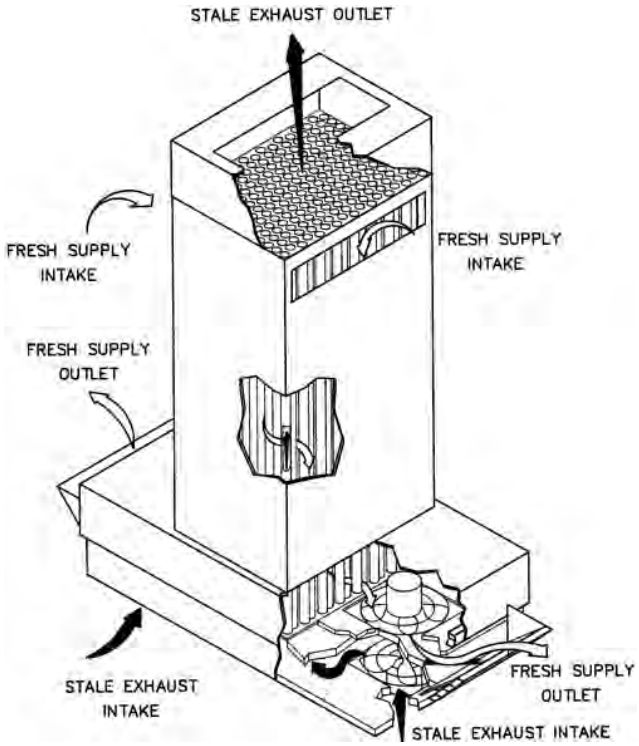

FIGURE 13. Robbco A1-3500-BIK.

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 sheeted 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

LOCATION:	Steinbach, Manitoba
TYPE OF BARN:	Swine Finisher
NUMBER OF ANIMALS:	1100
INSIDE BARN DIMENSIONS:	200 x 36 x 8 ft (60 x 11 x 2.4 m)
FEEDING SYSTEM:	Home milled feed. Automatic chain drag conveyor to self feeders.
MANURE SYSTEM:	Open flush gutter on side walls.
WINTER VENTILATION SYSTEM:	
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.
AVERAGE BARN TEMPERATURE:	64°F (18°C)
AVERAGE BARN HUMIDITY:	90%
HEAT BALANCE TEMPERATURE:	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.

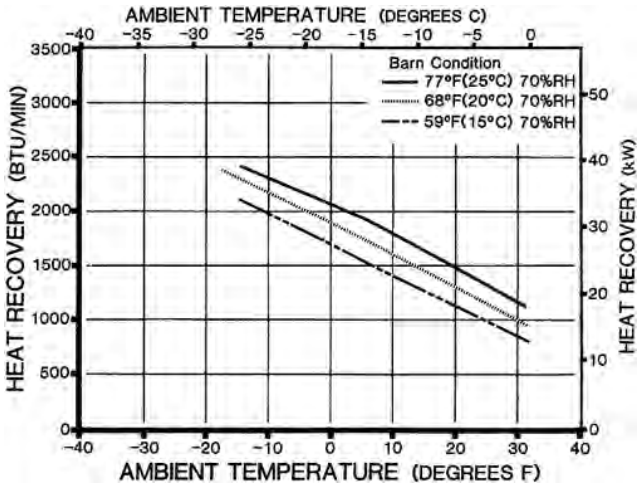

FIGURE 14. Robbco A1-3500-BIK Heat Recovery Rate at Three Barn Temperatures.

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	Seasonal Heat Saved	
°F	°C	hours	MBtu	kWh
32	0	3530	300	88900
23	-5	2640	250	73900
14	-10	1890	200	58200
+5	-15	1294	150	43200
-4	-20	796	98	28600
-13	-25	367	50	14200
-22	-30	100	14	4200
-31	-35	10	1.6	500

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).

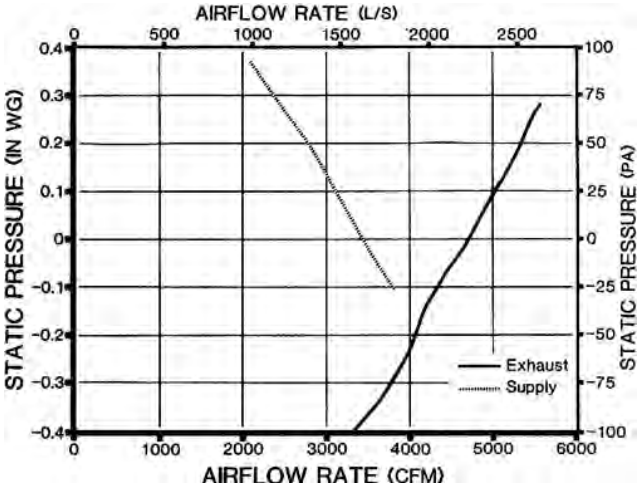

FIGURE 15. Robbco A1-3500-BIK Ventilation Rates.

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 drainpipe.

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 drainpipe 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 alleyway 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.

Table 15. Test Result Summary

		TEST CONDITION NUMBER								
	Units	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Barn Air Temperature (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
Outside Air Temperature	°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
Fresh Air in Temperature	°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
Exhaust Airflow Rate	cfm L/s	4626 2170	4510 2120	4488 2110	4588 2155	4607 2165	4613 2170	4616 2170	46663 2190	4656 2190
Supply Air Flowrate	cfm L/s	2898 1360	3078 1445	3121 1465	3174 1491	3156 1485	3142 1475	3255 1530	3234 1520	3189 1500
Defrost Shutdown	min/hr	8	8	8	8	8	8	8	8	8
Exhaust Heat Loss	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
Average Heat Recovery	Btu/min kW	2407 42.2	2370 41.7	2090 36.7	1911 33.6	1669 29.3	1495 26.3	1115 19.6	956 16.8	796 14.0
Heat Recovery Ratio	%	36	38	38	37	38	38	35	36	39

SPECIFICATIONS

MAKE:	Robbco	
MODEL:	A1-3500-BIK	
SERIAL NUMBER:	N/A	
MANUFACTURER:	Robbco Ltd. 62 Thatcher Drive Winnipeg, Manitoba R3T 2L3	
OVERALL DIMENSIONS:		
-- 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)	
CORE DESCRIPTION:	counter-flow, shell-and-tube	
CORE CONSTRUCTION:		
-- external shell	plywood and framing	
-- internal core	extruded 6 mil polyethylene tubes	
-- seal	foam gaskets and caulking	
	Exhaust	**Supply**
NOMINAL AIRFLOW:	4600 cfm (2200 L/s)	3200 cfm (1500 L/s)
INLET AREA:	510 in² (0.3 m²)	670 in² (0.4 m²)
OUTLET AREA:	760 in² (0.5 m²)	650 in² (0.4 m²)
SURFACE AREA OF CORE: 1	16,420 in² (75 m²)	116,420 in² (75 m²)
TUBE SIZE:		
-- quantity	225	N/A
-- diameter	1.83 in (46 mm)	N/A
-- length	90 in (2290 mm)	N/A
FANS:		
-- number	2	2
-- make	Hurst	Hurst
-- type	axial	axial
-- number 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:

$3196.64 (May, 1989, f.o.b. Humboldt, Sask.)

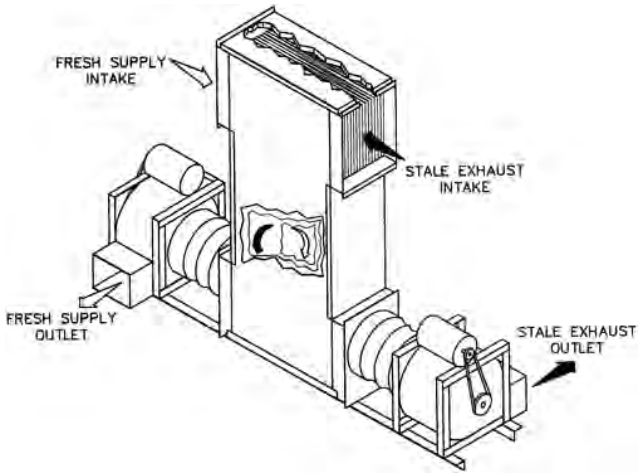

FIGURE 16. Z-Air Model 74-60-1.

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 p lace 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

LOCATION:	Landmark, Manitoba
TYPE OF BARN:	Chicken Broiler
NUMBER OF ANIMALS:	10,000
INSIDE BARN DIMENSIONS:	250 x 40 x 8.5 ft (75 x 12 x 2.6 m)
FEEDING SYSTEM:	Commercial mash feed, augers to self-feeders near floor.
MANURE SYSTEM:	Straw floor litter, scheduled cleanout between batches of birds.
WINTER VENTILATION SYSTEM:	
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.
AVERAGE BARN TEMPERATURE:	59°F (15°C)
AVERAGE BARN HUMIDITY:	70%
HEAT BALANCE TEMPERATURE:	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).

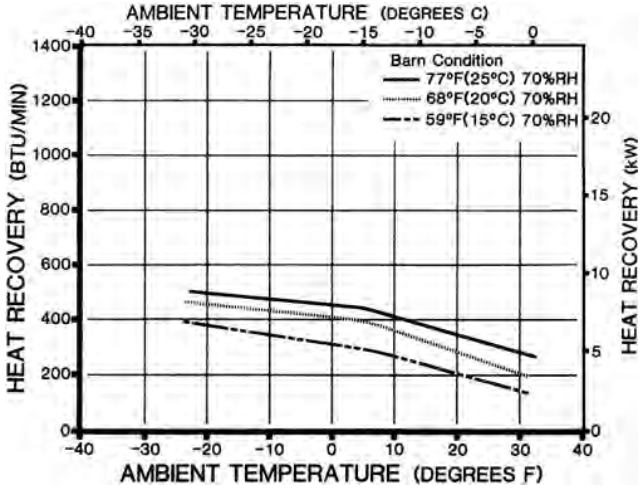

FIGURE 17. Z-Air Model 74-60-1 Heat Recovery Rate at Three Barn Temperatures.

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		Length of Heating Season	Seasonal Heat Saved	
°F	°C	hours	MBtu	kWh
32	0	3530	65	19200
23	-5	2640	55	16100
14	-10	1890	43	12700
+5	-15	1294	32	9400
-4	-20	796	20	6000
-13	-25	367	10	2900
-22	-30	100	3	800
-31	-35	10	0.3	90

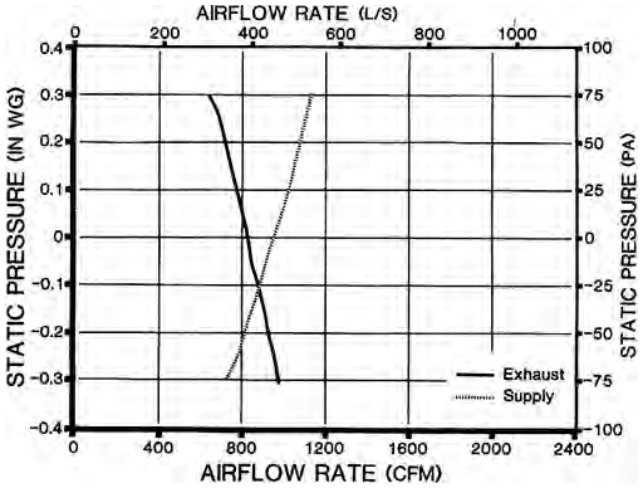

FIGURE 18. Z-Air Model 74-60-1 Ventilation Rates.

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 preheat 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.

Table 18. Test Result Summary

		TEST CONDITION NUMBER								
	Units	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Barn Air Temperature (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
Outside Air Temperature	°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
Fresh Air in Temperature	°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
Exhaust Airflow Rate	cfm L/s	903 425	851 400	877 415	941 445	922 435	946 445	947 445	945 445	953 450
Supply Air Flowrate	cfm L/s	814 385	810 380	810 380	808 380	807 380	805 380	801 380	795 375	794 375
Defrost Shutdown	min/hr	8	8	8	8	8	8	8	8	8
Exhaust Heat Loss	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
Average Heat Recovery	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
Heat Recovery Ratio	%	33	33	33	39	33	33	36	31	27

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.

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	
	Exhaust	**Supply**
NOMINAL AIRFLOW:	1000 cfm (470 L/s)	1000 cfm (470 L/s)
INLET AREA: (on core)	184 in² (0.12 m²)	184 in² (0.12 m²)
OUTLET AREA: (on fan)	63 in² (0.04 m²)	63 in² (0.04- r²)
SURFACE AREA OF CORE:	51,800 in² (33.4 m²)	51,800 in² (33.4 m²)
PASSAGE SIZE:		
-- quantity	18	19
-- 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 4-10 Eisenheiss	
-- type	centrifugal blower, belt driven	
-- diameter	10 in (250 mm)	
-- width	7.25 in (180 mm)	
-- speed	variable, maximum 1 100 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	$3000.00 (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 therrrostat 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 rren 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	$2695.00 (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 4-5 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

DEL-AIR A-150

RETAIL PRICE	$1095.00 (May, 1989, f.o.b. Humboldt, Sask.)
RATE OF WORK	
-heat recovery	maximum 135 Btu/min (2.4 kW)
-ventilation rate	190 cfm (90 L/s) exhaust, 125 cfm (60 L/s) supply
QUALITY OF WORK	
-heat recovery ratio	37 to 42%
-leakage	4 cfm (2 L/s), 2.0% of exhaust flow
-defrost	**Very Good;** supply fan reversed for 8 minutes per hour automatically
POWER REQUIREMENTS	Approximately 0.7 A at 120 V AC, 0.1 kW
EASE OF OPERATION:	
-installing	**Very Good;** took one man 2 hours, core installed in barn wall
-adjusting	**Very Good;** no routine adjustments needed
-cleaning	**Very Good;** core hinged open for washing, optional filter was available
OPERATOR SAFETY:	CSA certified, no hazards apparent
OPERATOR'S MANUAL:	**Very Good;** thorough and well illustrated
MECHANICAL HISTORY:	No mechanical problems

DEL-AIR A-800

RETAIL PRICE	$1950.00 (May, 1989, f.o.b. Humboldt, Sask.)
RATE OF WORK	
-heat recovery	maximum 608 Btu/min (10.7 kW)
-ventilation rate	980 cfm (460 L/s) exhaust, 590 cfm (276 L/s) supply
QUALITY OF WORK	
-heat recovery ratio	32 to 36%
-leakage	10 cfm (5 L/s), 1.0% of exhaust flow
-defrost	**Very Good;** supply fan reversed for 8 minutes per hour automatically
POWER REQUIREMENTS	Approximately 3.6 A at 120 V AC, 0.4 kW
EASE OF OPERATION:	
-installing	**Very Good;** took one man 2 hours, core installed in barn wall
-adjusting	**Very Good;** no routine adjustments needed
-cleaning	**Very Good;** core hinged open for washing, optional filter was available
OPERATOR SAFETY:	CSA certified, no hazards apparent
OPERATOR'S MANUAL:	**Very Good;** thorough and well illustrated
MECHANICAL HISTORY:	No mechanical problems

ROBBCO A1-3500-BIK

RETAIL PRICE	$3286.00 (May, 1989, f.o.b. Humboldt, Sask.)
RATE OF WORK	
-heat recovery	maximum2400 Btu/min (42.3 kW)
-ventilation rate	4600 cfm (2160 L/s) exhaust, 3200 cfm (1500 L/s) supply
QUALITY OF WORK	
-heat recovery ratio	35 to 39%
-leakage	170 cfm (80 L/s), 3.8% of exhaust flow
-defrost	**Very Good;** supply fan shut off for 8 minutes per hour automatically
POWER REQUIREMENTS	Approximate 10 A at 230 V AC, 1.6 kW
EASE OF OPERATION:	
-installing	**Fair;** took two men 16 hours, core installed through barn roof
-adjusting	**Very Good;** no routine adjustments needed
-cleaning	**Excellent;** the core was completely self-cleaning
OPERATOR SAFETY:	Exposed fan blades, outlet serviced on roof, not CSA certified

Z-AIRMODEL 74-60-1

RETAIL PRICE	$3196.64 (May, 1989, f.o.b. Humboldt, Sask.)
RATE OF WORK	
-heat recovery	maximum 497 Btu/min (6.7 kW)
-ventilation rate	950 cfm (450 L/s) exhaust, 820 cfm (385 L/s) supply
QUALITY OF WORK	
-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
POWER REQUIREMENTS	Approximate 8 A at 120 V AC, 0.9 kW
EASE OF OPERATION:	
-installing	**Good;** took one man 1 to 12 hours, depending on ducting requirements
-adjusting	**Good;** defrost timer had to be added and adjusted
-cleaning	**Fair;** core was awkward to access, a filter element was added
OPERATOR SAFETY:	CSA certified, no hazards apparent
OPERATOR'S MANUAL:	**Good;** thorough and well illustrated, but no agricultural information
MECHANICAL HISTORY:	No mechanical problems

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