ABSTRACT

ENERGY RECOVERY WHEEL[1]

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Recent emphasis on the conservation of energy led to the consideration of methods that recover the energy from air exhausted from buildings that require 100 percent air exchange. The energy recovery wheel was selected and installed in two buildings. Because there is a slight exchange of air across the wheel from the exhaust side to the intake side, the system was tested with an aerosol of T_1 E. Coli phage to evaluate the potential recirculation of biological materials within the system. The wheel, the illustration, the mode of operation, the method of testing, and the results of the test will be described. The energy recovery wheel which covers 70 to 90% of the energy (according to the manufacturer's literature), has a cross-over of less than 0.1% as determined by the biological tests.

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THE ENERGY RECOVERY WHEEL

Introduction

Recent emphasis on energy conservation led the design engineers of the Frederick Cancer Research Center to consider methods of recovering energy from the air discharged from buildings that require 100% fresh air, such as animal holding areas. The enthalpy or energy recovery wheel and the runaround coil systems were considered. Since the energy recovery wheel recovers both latent and sensible heat, it is 2.4 times more effective than is the run-around coil. The energy recovery wheel, therefore, was selected for use in portions of two buildings where animals were to be housed under strict containment and with rigid control of temperature and humidity.

The energy recovery wheel (Figure 1) is approximately 8 feet in diameter and is 14 inches thick. It is composed of lithium chloride, a desiccant that is finely dispersed throughout the microstructure of the surface of the wheel. Energy is recovered both by heat exchange from the mass of the wheel and, to a greater extent, by absorption of the latent heat that is in the moisture absorbed by-the lithium chloride. The wheel rotates at approximately 8 rpm and the air passes through the wheel at approximately 550 fpm. The lithium chloride absorbs the moisture from the humid air stream and gives it up to the dry air stream due to the difference in vapor pressure between the lithium chloride and each air stream. The latent heat is thus absorbed and released together with the moisture.

During summertime operation, as shown in Figure 2, the moist, warm, incoming supply of air passing through the bottom half of the wheel gives up moisture and heat to the wheel. As the wheel turns, surfaces are exposed to the top exhaust, air and the cool dry air from the building picks up the heat and moisture and carries it out of the building. The result is that dehumidified cool air is provided to the building, where it is further conditioned by heating, cooling and humidification to give proper control.

In our application, the outside supply air is filtered through a dust stop filter and a 60% efficient filter before going to the wheel; it is subsequently passed through 95% efficient filters as it is distributed to each animal room. The exhausted air is filtered at each room exhaust by a dust stop filter and by 90% efficient filters just before the wheel. During the biological testing, the 90% efficient filters were removed so as to provide sufficient numbers of organisms at the wheel to detect the numbers crossing over.

Growth of Phage

T_1 phage lysates were produced in double-strength nutrient broth containing 50 ppm of Dow Corning Antifoam A (Dow Corning Corp., Edgewood, Cliffs, NJ). Batches of 250ml were grown in 2-liter Erlenneyer flasks.

The seed inoculum of E. Coli strain B (No. 2710 from Edgewood Arsenal) was prepared by introducing the growth from an agar slant into 25 ml of double strength media contained in a 125 ml Erlenmeyer flask and incubated at 37^0C on a shaker for 16 hours. A 2-liter flask containing 250 ml was then inoculated with 2% by volume of inoculum and incubated at 37% on a reciprocal shaker at 120 one inch strokes per minute. After 3.5 hours of incubation, the E. Coli culture was assumed to have reached the end of the logarithmic phase of growth (approximately 3×10^9 cells per ml). Crude phage lysates were added in the ratio of 1-5 phage particles per bacterium and the flask was shaken for an additional 5 to 6 hours.

The crude phage lysate was clarified by centrifugation at 1700 x g for 30 minutes in an International Refrigerated Centrifuge to remove bacteria and large particulate debris. The resulting suspension was used for the challenge of the system.

Dissemination

A spray device (all glass nebulizer) operating at 25 psig, spraying 100 ml of suspension per minute was used to generate the aerosol of phage particles. The aerosol was generated simultaneously with sampling and continued throughout a 2.5 minute period. The aerosol was introduced into the exhaust system of the building approximately 8 feet from the energy recovery wheel. With a circulating air volume of 18,000 cfm, an assumed phage count of 2×10^9 particles per milliliter, and a spray rate of 100 mil per minute, the exhaust air should contain 1×10^7 phage particles per cubic foot of air as it enters the wheel. Accepting a 0.04% return due to the cross-over within the wheel and a diluting effect of 18,000 cfm of incoming air, the detectable amount of phage present for an impinger operating at 0.45 cfm for 2.5 minutes is 26 organisms/ml of impinger fluid.

Sampling for Phage

The all-glass impinger (AGI-4) (Ace Glass Co., Vineland, NJ) was used to sample the phage aerosol concentrations before, during, and after challenging the ventilation system. The AGI-4 was filled with 22 ml of nutrient broth (Difco) containing 50 ppm of Dow Corning Antifoam A and was operated at the maximum flow rate of 0.45 cfm.

Sampling - stations

The ventilation system was challenged with a phage aerosol introduced into the exhaust duct approximately 8 feet from the energy recovery wheel on the building side of the wheel.

The amount of phage circulating in the air of the duct was measured at three stations (A, B, and C) as described below. (Figure 3) Each station consists of a 4-foot length of 3/8" steel tubing inserted into the duct so as to be approximately 8 inches from the wheel, 8 inches from the bottom of the duct and 3 feet from the nearest wall.

Station A - In the air exhaust duct on the building side of the energy recovery wheel.
Station B - In the air exhaust duct after the energy recovery wheel.
Station C - In the air supply duct on the downstream (after) side of the energy recovery wheel.

The aerosol was drawn through the sampling tube to the AGI-4 sampler by the vacuum produced by a rotary-vaned pump drawing 25 inches of mercury negative to atmospheric pressure.

Assay for Phage

Phage suspensions were assayed by making serial dilutions in nutrient broth and plating 1 ml samples of the dilutions in triplicate by use of a soft agar overlay method. Fresh nutrient broth cultures of E. Coli incubated on a shaker at 37^0C for 4-6 hours were used as the seed cultures. Test tubes containing 3-1/2 ml of melted dilute Difco nutrient agar (11 g per liter of water) were inoculated with 0.5 - 1 ml of the seed E. Coli culture and 1 ml of the phage dilution. The mixture was swirled briefly, poured over the surface of a solid sterile nutrient agar plate and

allowed to harden. The melted dilute agar tubes were held at 46^0C in a water bath prior to seeding with the E. Coli culture. The plates were incubated for 10-12 hours at 25^0C to eliminate the spreading or running of plaques that often occurs with incubation at 37^0C.

Number of Tests

The test was repeated three times on each of two days.

Calculations

The design of the system calls for 20,000 cfm of supply air. Of this, 2000 cfrn is used to purge the wheel and 18,000 cfm enters and leaves the animal holding area of the building. Thus, the aerosol is generated into 18,000 cfm of exhaust air. A small portion (to be determined) is passed across the wheel and is mixed with 18,000 cfm of supply air. Since the samplers are operated at 0.45 cfm for 2.5 minutes, they collect the phage from 1.125 cfm of air. In actual usage, the ratio of the number of phage particles recovered from the Supply air versus those generated and recovered from the exhaust air give the percentage of cross-over, since all the factors of time and volume remain constant.

(i.e) $$\frac{\text{number of phage recovered from supply air}}{\text{number of phage recovered from exhaust air}} = \text{Percent Cross-over}$$

Results

The results are shown by building. The first results are on the system installed in Building 539. Table 1 shows the numbers of phage particles per cubic foot of air recovered at each of the sampling stations on each of two tests. The percentage of particles crossing from Station A to C is also shown. From these data it is concluded that the number of particles crossing from Station A to C is substantially in agreement with that as described by the manufacturer.

The results of the second series of tests In Building 522 are shown in Table 2. The data are first expressed as the number of phage particles per cubic foot of air sampled. Under test conditions, the percentage of particles recovered is approximately one log lower than would

have been expected from information given in the manufacturer's literature. This is probably the result of an increase in the amount of air being purged. In both tests and systems, the number of organisms crossing over the wheel from the air exhaust to the air supply is quite low.

Discussion

The energy exchange wheel, as installed in our facility, functions much as should be expected from the manufacturer's literature. Generally, less than 0.1 percent of the particles carried in the exhaust air at the wheel are recovered on the air supply side.

If we assume 1000 organisms per cubic foot of animal room air (a figure at least 10-fold above that routinely experienced), the number of organisms would be reduced by 90 percent by the exhaust air filter, at least by 99.9 percent by the energy exchange wheel and by 95 percent by the supply air filter. Thus, 0.0005 percent of the organisms in the original animal room air would return to the room. Thus a room 8' x 12' x 10' with 15 air exchanges per minute would receive back to the work area only 0.5 organisms per minute. When biological decay is considered as well as the actual numbers of airborne contaminants, the level of risk is very small. Therefore, the system can be used safely in any area with the possible exception of one where biological agents of the Class III or higher classification are handled.

When high-risk agents are to be used and the conservation of energy is important, the less efficient tube type energy exchange system should be used, since there is no cross-over of exhaust to supply air in this system.

To determine a rough estimate of size distributions, the phage aerosol was collected by a six-plate Anderson Sampler just prior to the wheel on the building side of the exhaust duct. The Anderson Sampler was operated at 1 cfm for one minute. The deposition of phage particles peaked on plates 3 and 4, which corresponds to particle sizes 3 to 6 and 2 to 4 microns, respectively. This indicates that most of the particles were in the 2 to 6 micron range.

Table 2 notes the large reduction in the number of phage particles as the exhaust air stream passed through the wheel. This reduction is shown by comparing the phage count obtained at Station A versus Station B that are located in the air exhaust on either side of the wheel. The most obvious reason for this reduction in count appears to be impingement on the surface of the wheel. To minimize the effect of this deposition, the surfaces of the wheel must be periodically vacuumed. A design that includes high efficient filters immediately before the wheel on the exhaust will reduce greatly the potential problem.

The literature on the wheel mentioned that it can be damaged by liquid water. In the design of the system, this only can occur if the preheat element fails mechanically. The design of the system can preclude this by providing interlocks between the supply fan and the preheat coil such that if the preheat coil fails, the supply fan will cut-off and minimize the damage.

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Table 1.

NUMBER AND PERCENT OF PHAGE PARTICLES PASSING ACROSS THE ENERGY RECOVERY WHEEL IN BUILDING 539

Station	Test 1	Test 2	Average
	Numbers of Phage Particles per Cubic Foot of Air		
A- 1/	7.2×10^6	2.6×10^6	4.9×10^6
B- 2/	7.8×10^6	1.0×10^6	4.4×10^6
C- 3/	13518	533	7025
Percent Crossover From A to C	0.19	0.02	0.14
Suspension used for Challenge Phage/ml	10.0×10^9	18.2×10^9	14.2×10^9

1 Station A - Located in exhaust duct building side of wheel.

2 Station B - Located in exhaust duct outer side of wheel.

3 Station C - Located in intake duct building side of wheel.

Table 2.

NUMBER AND PERCENT OF PHAGE PARTICLES PASSING ACROSS THE ENERGY RECOVERY WHEEL IN BUILDING 522

	Test		
Station	**1**	**2**	**Average**
	Numbers of Phage Particles per Cubic Foot of Air		
A- 1/	6.8×10^{6}	14.1×10^{6}	10.4×10^{6}
B- 2/	3.0×10^{6}	6.4×10^{6}	4.7×10^{6}
C- 3/	488	370	429
Percent Crossover From A to C	0.007	0.003	0.005
Culture used as Challenge Phage/ml	25.3×10^{9}	17.6×10^{9}	14.3×10^{9}

1 Station A - Located in exhaust duct building side of wheel.

2 Station B - Located in exhaust duct outer side of wheel.

3 Station C - Located in intake duct building side of wheel.

FIGURE 1

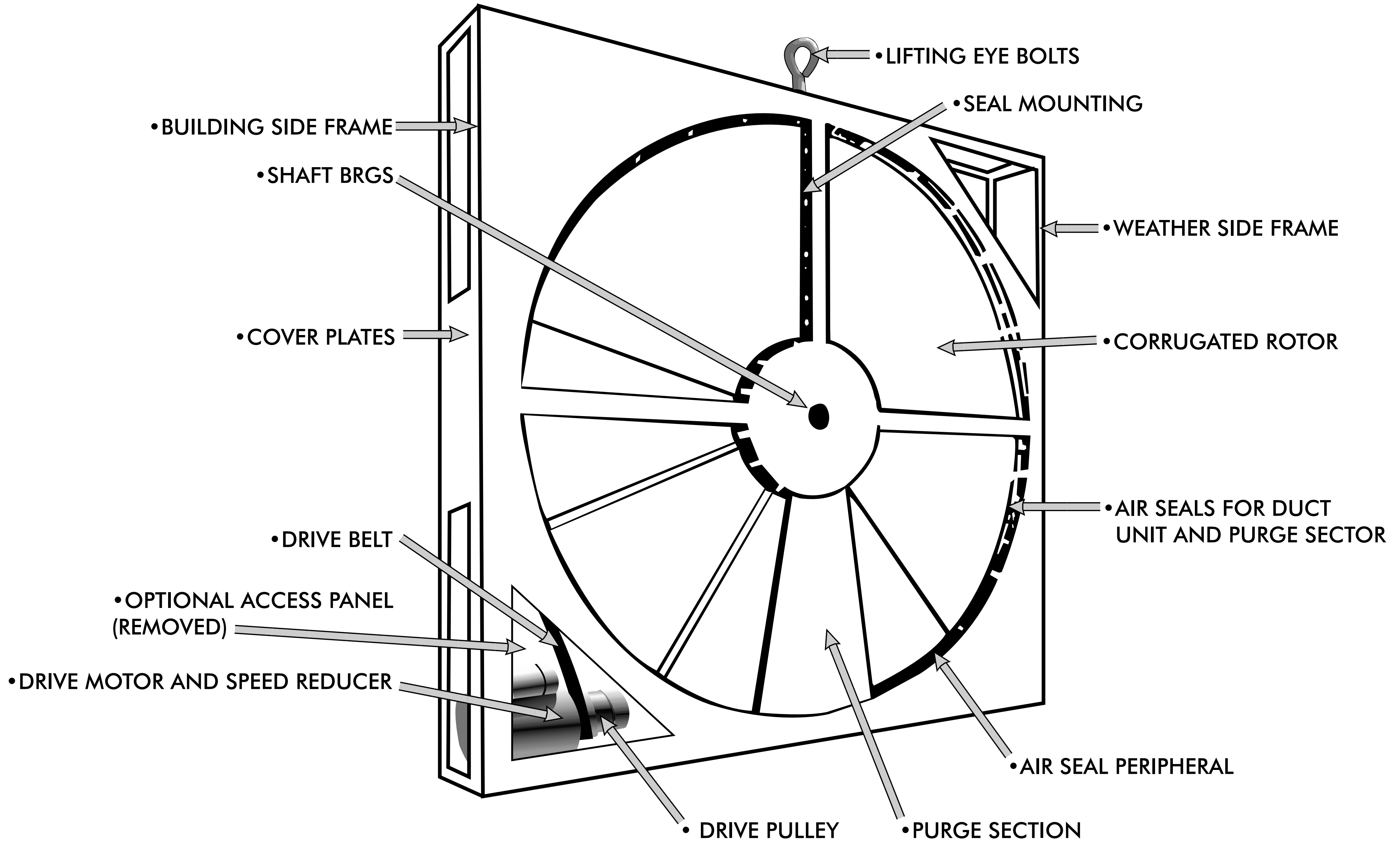

FIGURE 2

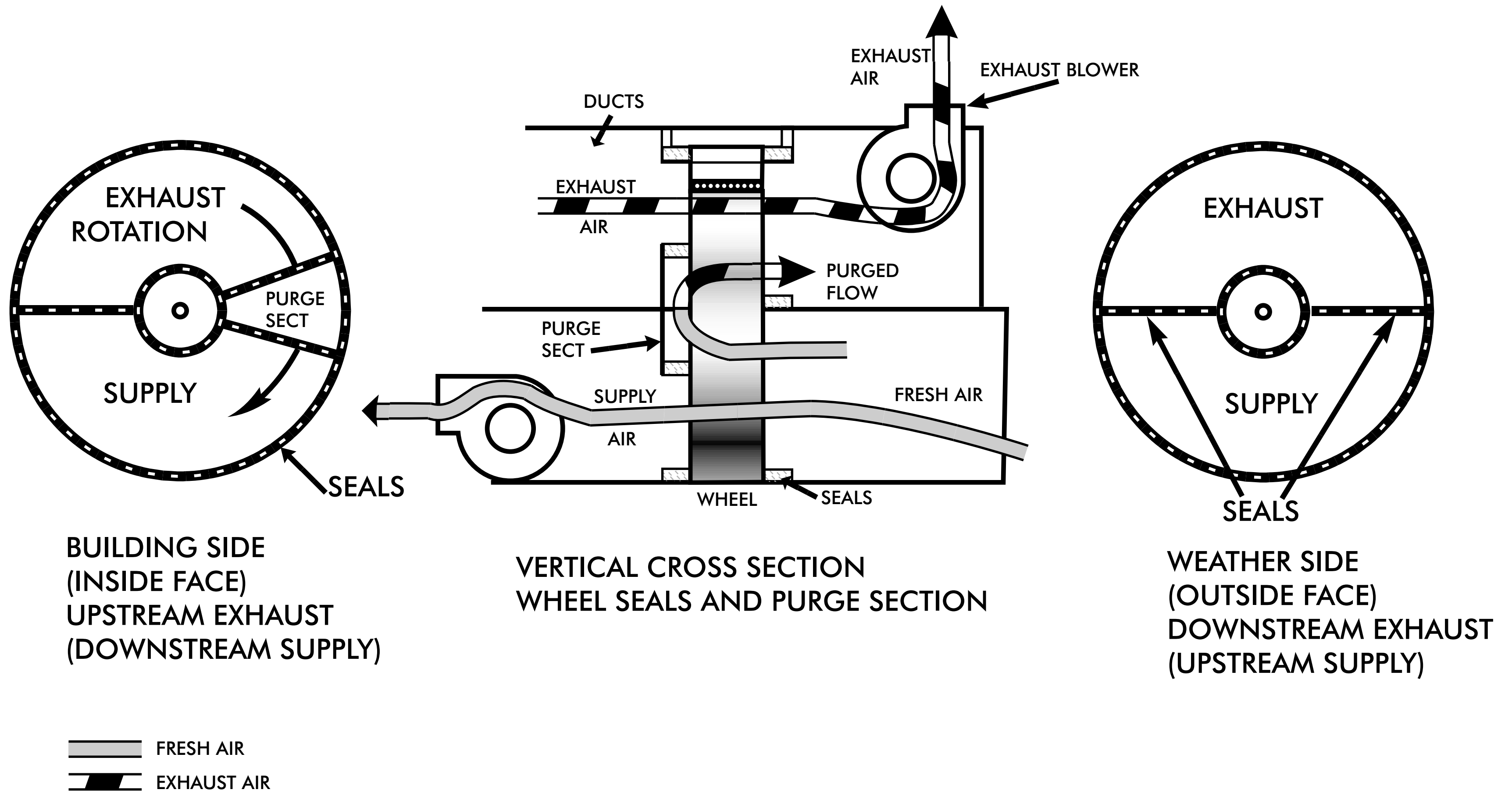

FIGURE 3