EXAMPLE 8.10-1: An Energy Recovery Wheel

A building at the local zoo in Madison, Wisconsin houses primates, large cats, visitors and staff in four separate zones. The focus of this problem is on the zone that houses the primates. The total volume of the zone is V_{zone} = 2500 m^3. In order to maintain the health of the animals, as well as to control odors so that the zoo is a pleasant place for visitors, it is necessary to ventilate the zone at a minimum rate of ac = 2.5 air changes per hour all of the time (i.e., 24 hours per day, 7 days a week). The outdoor air that replaces the ventilated air must be conditioned to T_b = 20°C. (Internal generation from lights and equipment provides the remaining heating needs). The system is shown in Figure 1(a).

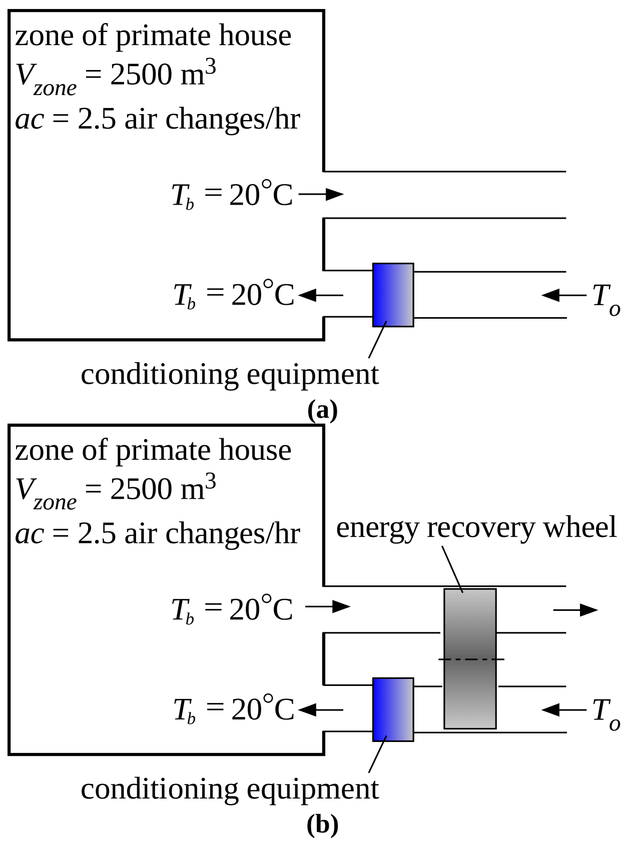

Figure 1: Ventilation and conditioning system (a) without energy recovery wheel, and (b) with energy recovery wheel.

Zoo personnel have found that the costs of heating (in the winter heating season) and cooling (in the summer cooling season) the outdoor air are substantial. Therefore, you have been asked to look at alternatives for cost savings. One possibility is the use of a rotary regenerator for recovering energy from the exhaust air and transferring it to the outside, ventilation air (an energy recovery wheel, see **Error! Reference source not found.**); such a system is shown schematically in Figure 1(b).

During the heating system, the energy recovery wheel accepts heat from the warm building air leaving the zone and transfers it to the outside air, pre-heating the air in order to reduce the heating that must be provided by the building conditioning equipment. During the cooling season the opposite happens; the energy recovery wheel rejects heat to the (relatively) cool air leaving the building and accepts heat from the warm outdoor air, reducing the cooling that must be provided by the conditioning equipment. Therefore, the energy recovery wheel provides year-round savings and is particularly attractive in applications where large ventilation rates are required.

The energy recovery wheel being considered for this application is made of aluminum with density ρ_r = 2700 kg/m^3 and c_r = 900 J/kg-K. The packing is made up of triangular channels, as shown in Figure 2. The thickness of the aluminum separating adjacent rows of channels is th_b = 0.3 mm and the thickness of the aluminum struts that separate adjacent passages is th_s = 0.1 mm. The channels themselves are H_p = 2.5 mm high and have a half-width of W_p = 1.5 mm. The diameter of the wheel is D_r = 0.828 m and the length of the wheel is L = 0.203 m. The wheel rotates at N = 30 rev/min and the matrix spends half of its time exposed to outside air and the other half exposed to building exhaust air.

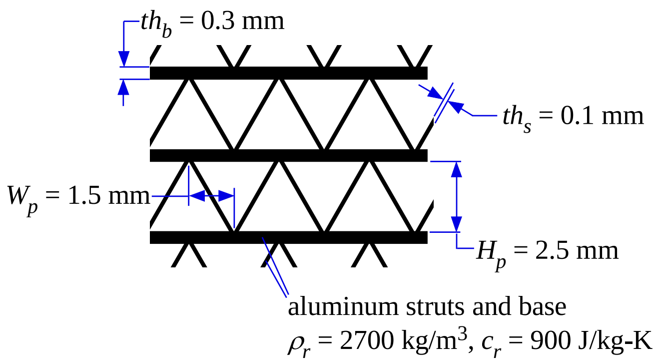

Figure 2: Structure of the energy recovery wheel.

The average outdoor temperature (T_o) for each month in Madison, WI is provided in Table 1.

Table 1: Monthly-average ambient temperatures in Madison, WI

Month	Temperature (°C)
Jan	-8
Feb	-7
Mar	-1
Apr	7
May	13
Jun	19
Jul	21
Aug	20
Sep	15
Oct	10
Nov.	2
Dec	-6

Notice that the cooling load in Madison, WI is not substantial because the monthly average ambient temperature barely exceeds the building temperature in the warmest month. Therefore, the energy recovery wheel in this climate will primarily result in a savings in the heating energy required. The cost of providing heating is hc = \$10/GJ; neglect any cost savings associated with cooling. There is an operating cost associated with the additional fan power required to force the air through the rotary regenerator. Assume that the fan efficiency is η_{fan} = 0.5 and that the cost of electricity is ec = $0.105/kW-hr.

a.) Estimate the annual cost savings that would result from installation of the rotary regenerator wheel.

b) Determine the rotation speed that will result in melting the ice in January.