INDIVIDUAL ANALYSIS: FAN SIZING

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Introduction

The Red Feather capstone team is currently developing a prototype solar furnace for the Red Feather nonprofit group. Red Feather currently installs commercial solar furnaces in homes on the reservation of Northern Arizona to help disadvantaged families heat their homes in a safe and renewable way. The team's goal is to create a cheaper alternative to the commercial options that Red Feather can manufacture themselves to save money and be able to install more solar furnaces.

The solar furnace is a box that will let light in through a front panel made of plexiglass. The light then hits black metal fins on the inside of the box which absorb the lights energy and release heat within the box. The heat is then forced into the home with a small fan. To optimize the heating process the flow rate of the air must be considered. If the air moves to fast through the furnace it will not collect enough heat while inside and if it moves to slowly valuable heat may be lost.

Calculations

Some assumptions will be made to simplify the calculations for the fan sizing. First, the heat production will be considered uniform across the inside of the solar furnace. Second, the heat produced will be considered constant. Finally, the interior of the home and ambient conditions outside it will be considered constant. This analysis only details the optimal air flow rate through the solar furnace and not heating efficiency or sizing as it relates to the home. Third, an outside temperature of 30 degrees Fahrenheit will be used to calculate the heating energy needed for the home. This is not the lowest daytime temperature in Flagstaff but would allow the solar furnace to be the main heating source during the day for most of the year. Last, the current commercial solar furnace used by Red Feather will be used as a baseline for heat production capability as the team's goal is to meet the same production capability as it.

To find the flow rate for the furnace, the heat production and therefore difference in temperature from inlet to outlet must be considered. Most solar furnaces aim for a temperature increase of between 50 and 60-degrees Fahrenheit [1]. This is not because of efficiency, but what owners feel satisfied with. Air that is 50 degrees hotter than ambient feels hot to the touch and resembles the output of a space heater. Essentially it reassures the owner that the system is working. [1]. For this analysis the temperature difference will be 50 degrees Fahrenheit or about 28 degrees C or K. At these temperatures, the SOLARSHEAT 1500 GS outputs about 20,400 BTU/day to heat 750 square feet [2]. The model is about 3.5 ft by 7.2 ft to make about 25 square feet.

Equation 1 can be used to find heat rate where: $\dot{Q}$ is the heat rate
$\dot{m}$ is the mass flow rate
Cp is the specific heat of air
ΔT is the difference in inlet and outlet temp

$$\dot{Q} = \dot{m}\ Cp\ \Delta T \quad (1)\ [3]$$

Equation 1 can be rearranged to solve for the mass flow rate as shown in equation 2.

$$\dot{m} = \frac{\dot{Q}}{Cp\,\Delta T} \quad (2)$$

The flow rate can then be found using equation 3. Where: Q is the flow
ρ is density

$$Q = \frac{\dot{m}}{\rho} \quad (3)$$

The current prototype for the team is expected to be about 4 ft by 6 ft for 24 square feet (0.96 the size of the SOLARSHEAT). With the assumption that the team has met the SOLARSHEAT'S capability this would generate 19,584 BTU/day. Assuming 12 hours of sunlight per day:

$$19{,}584\frac{BTU}{day} * \frac{1\ day}{12\ hr} = 1632\frac{BTU}{hr} = 0.478\ kW$$

Then using equation 2 the mass flow rate can be calculated as 0.058 kg/s. And equation 3 can be used to find the flow rate to be 0.0477 m^3/s which is about 101 ft^3/min. These numbers are like those of found commercial models which should allow for and ideal flow rate of heat through the system. The fan does not need to be perfectly rated for 101 cubic feet per minute as a slightly faster flow rate will still conduct the same heat energy into the home, just at lower temperature.

Fan Selection and Installation.

For the desired flowrate the Orion OD-1238 creates a flow rate of 105 ft^3/min which is around the range expected. It can withstand 170 ˚F and has a noise level of only 43 dB which is within an acceptable range specified by Red Feather. It runs on 12 V DC and draws 0.5 amps to create 2800 RPM. [4]

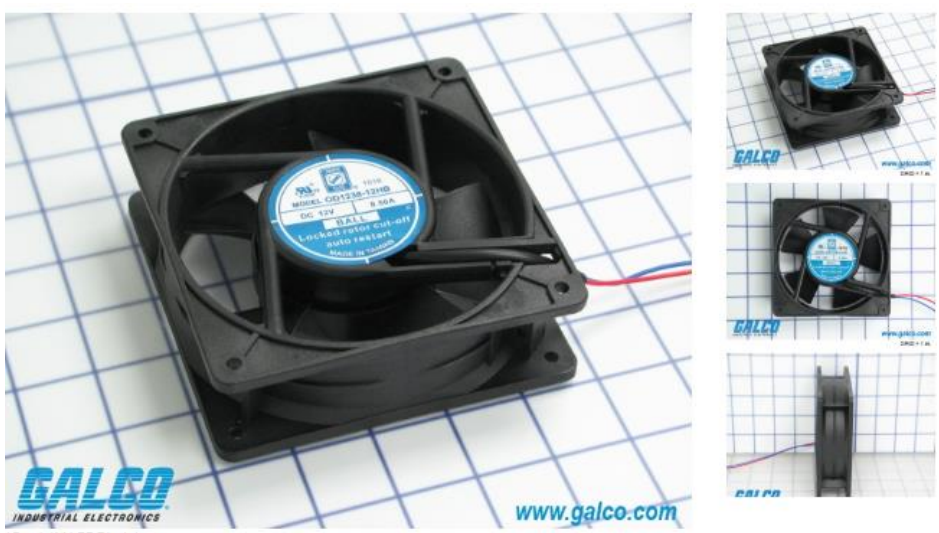

Figure 1. Orion OD-1238 Fan

The fan is just under 1.5 inches wide meaning it could easily be installed in the back of the panel before the outlet pipe.

The fan would then be powered by a small solar panel like that in figure 2.

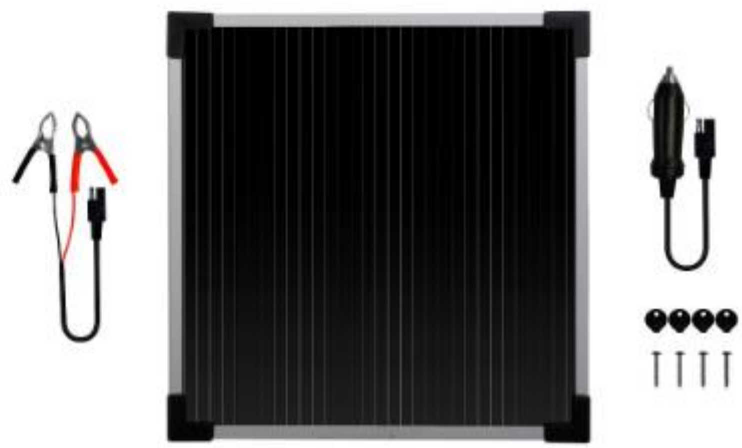

Figure 2. Coleman 6-Watt 12 Volt Solar Battery Maintainer

The Coleman solar panel shown in figure 2 produces 6 Watts of power which equates to a max amp output of 0.5 amps [5], which would run the Orion fan at full speed. A weatherproof outdoor panel like this would be ideal to pair with the solar furnace to run the fan.

Conclusion

Based on the analysis conducted, the optimal flow rate to best achieve the desired panel is about 101 cubic feet per minute. This was found assuming similar heat generation to one of the commercial models that the team is trying to compete with. Luckily, the flow rate of the fan is not critical within a reasonable range and the desired temperature of the output air is based solely on user preference rather than heating capability, so the team has room to alter the fan selection as they see fit.

References

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