Integration of a seasonal thermal loop into a passive ventilation system for heating, cooling, and thermal energy recovery

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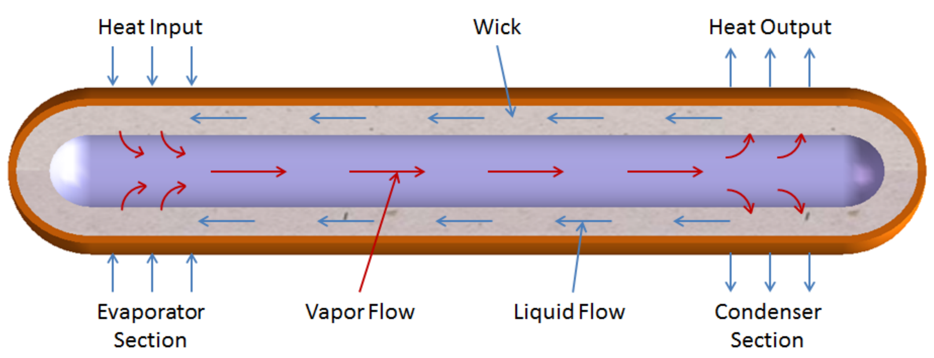
Objectives

This project aims to integrate a seasonal thermal loop into apassive ventilation system to provide a low energy alternative to conventional heating, cooling, and ventilation (HVAC) systems.

Passive ventilation generates airflow through a combination of regional pressure differences and the stack effect. Ventilation can however result in a large amount of wasted thermal energy lost to the environment. As a result, passive ventilation systems such as wind towers are often closed throughout the winter. Heat recovery devices can be used to recover waste thermal energy but must be considered carefully due to the low driving pressures through the wind tower. Initial testing focussed on using heat pipes to recover and transfer waste heat from the exhaust channels of a wind tower to the fresh air entering through the inlet. Through this the fresh air temperature is increased and the amount of energy required to warm it to room temperature is reduced.

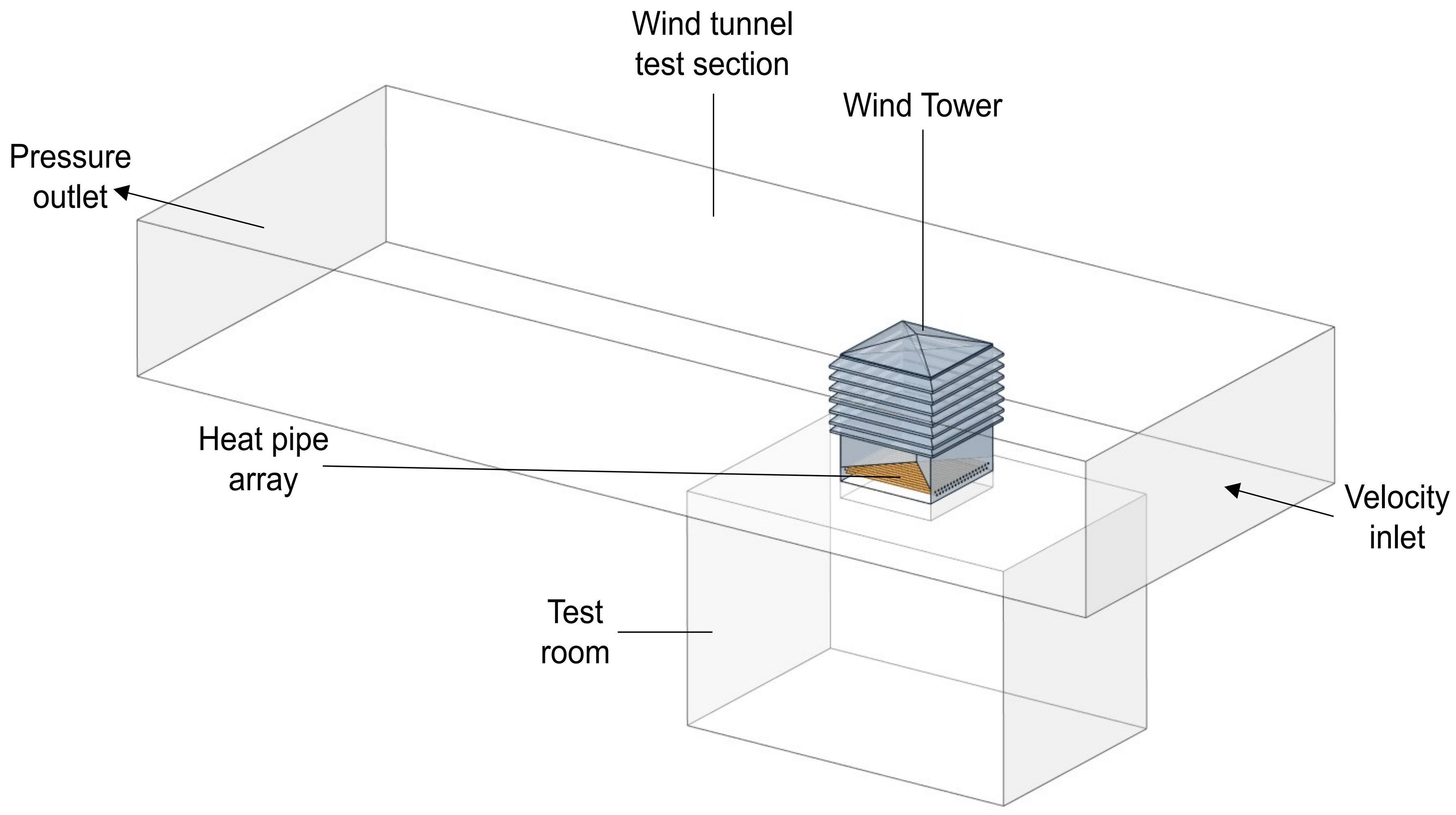
Future work will replace the heat pipe system with a water heating/cooling system capable of providing both heating and cooling whilst recovering waste thermal energy. Heat recovered during the summer will be stored using seasonal thermal energy storage for periods of up to 6 months and redelivered during the winter.



Heat pipe heat transfer method [1]

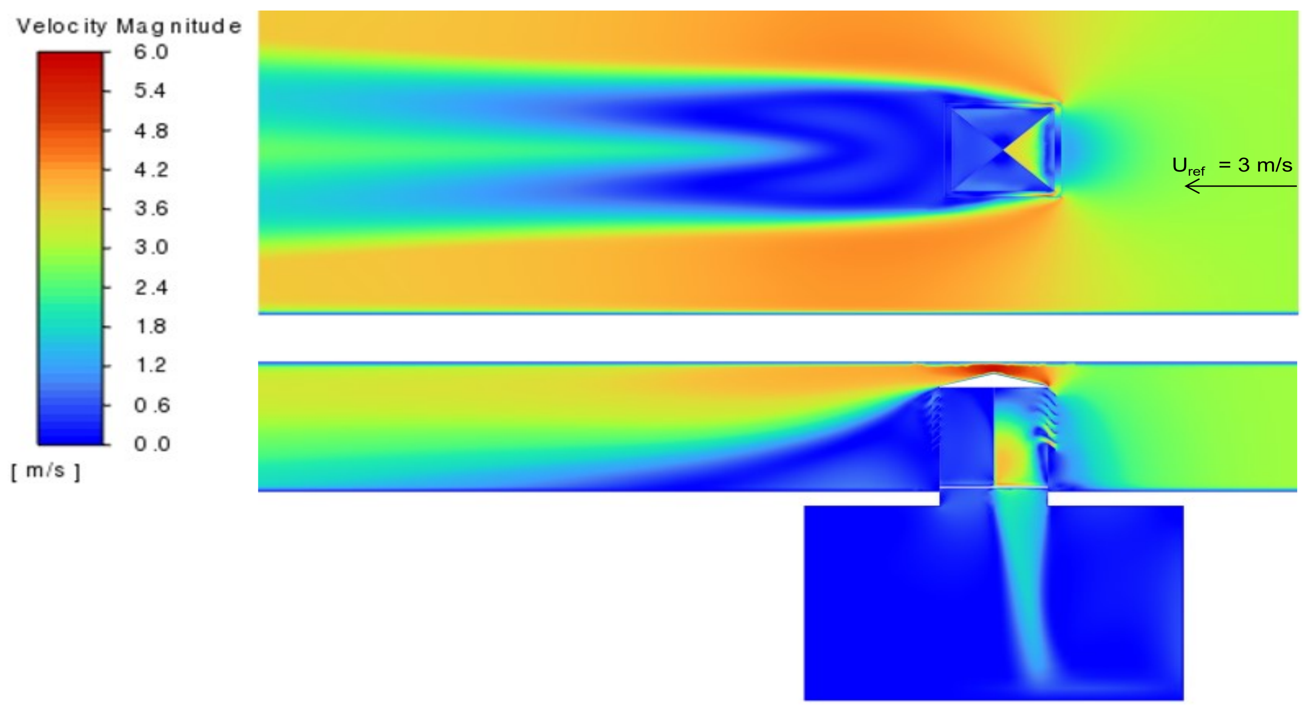
Research Methods

A full-scale wind-tunnel test of a 4-sided wind tower with heat pipes connecting each quadrant was conducted to determine the potential for pre-heating of fresh air through heat recovery as well as the impact on inlet mass flow rate. These results were used to validate a computational fluid dynamics (CFD) model in which simulations focused on the impact of inlet velocity, temperature, and the number of heat pipes.

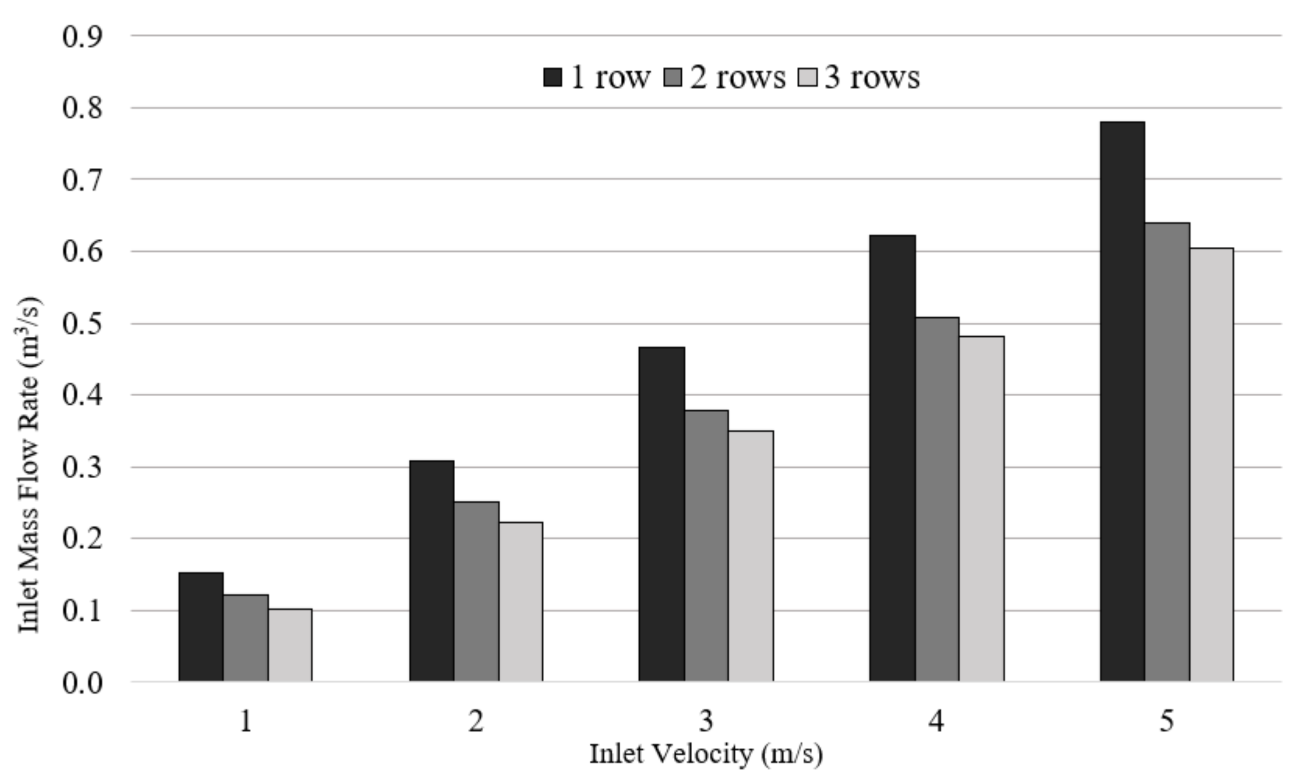


Results

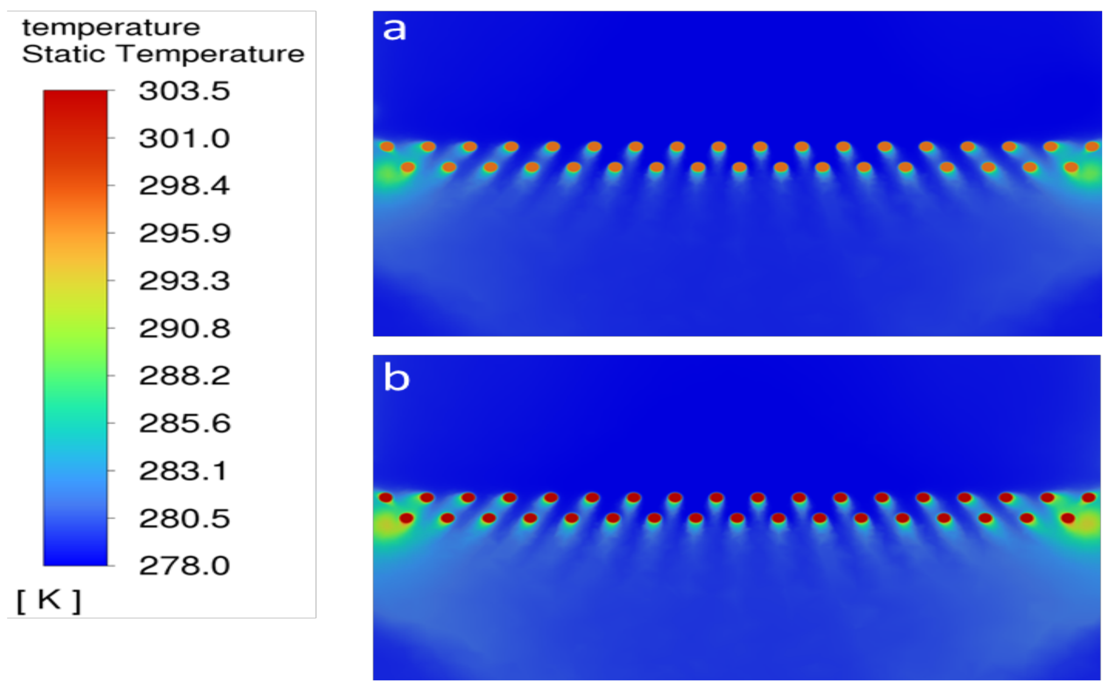
The image below shows the contours of velocity through the wind tunnel test section, wind tower, and adjoining test room. Due to the orientation of the wind tower, one quadrant acts as an inlet and the remaining three as outlets. Fresh air enters through the inlet hitting the internal dividing x-frame and travelling down to the floor before spreading out throughout the room. Diffusers can be used below the inlet to better distribute the fresh air throughout the room.



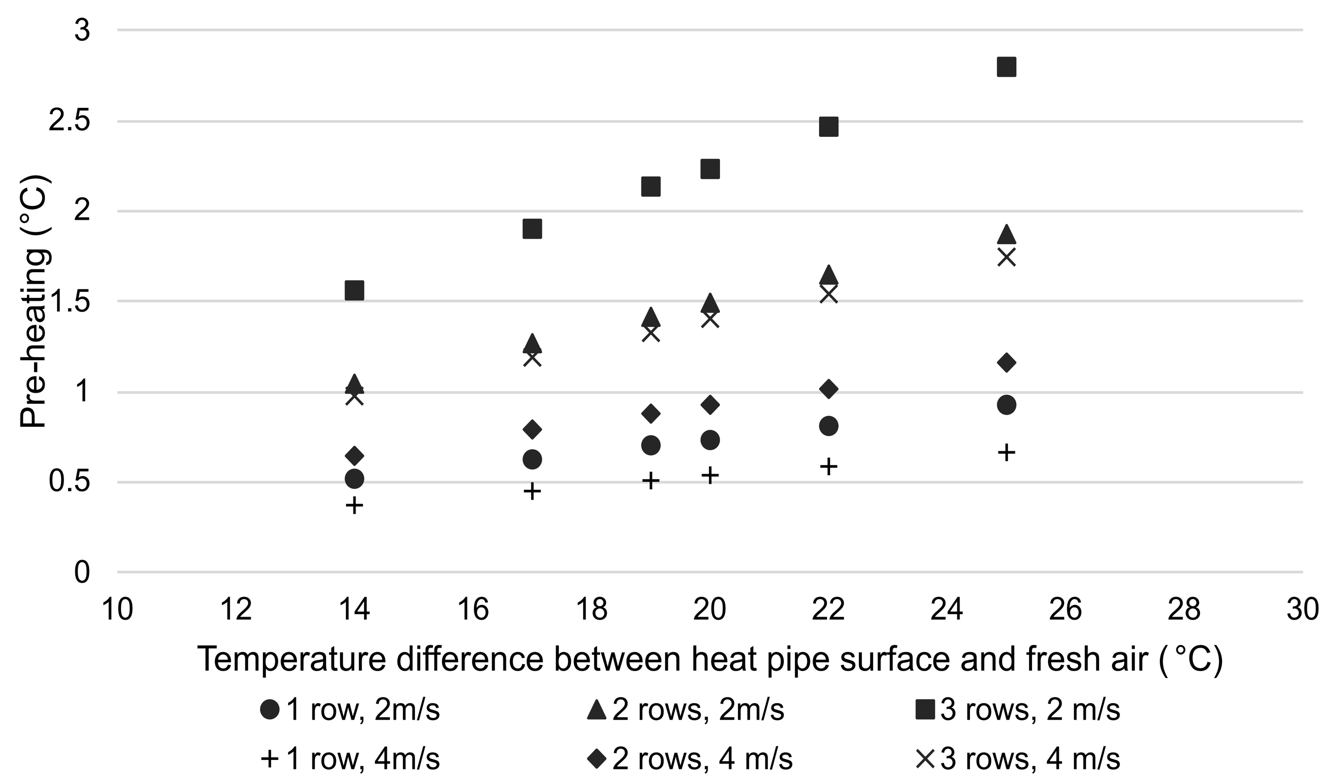
Due to the staggered arrangment of the heat pipes, the inlet mass flow rate decreases non-linearly with an increasing number of rows. A mass flow rate of 0.1 meters-cubed per second, or 100 L/s is maintained at inlet velocities as low as 1 m/s with 3 rows of pipes. To give this some context a UK classroom is recommended to have a minimum ventilation rate of 8 L/s per occupant.



Due to the complexity of the internal evaporation-condensation cycle within the heat pipes and the limitations of the CFD software, they are modelled as solid bodies with a surface temperature equivalent to the air temperature through the outlets to estimate the rate of heat transfer to the fresh air. The image below shows the contours of temperature through the wind tower inlet when the inlet temperature is a) 297 K and b) 303 K.



The amount of pre-heating is directly proportional to the difference in temperature between the fresh air and the exhaust air/heat pipe surface. Adding additional rows of heat pipes also serves to reduce the velocity of the fresh air through the inlet, allowing more time for heat transfer but reducing the ventilation rate.



Future Work

Having evaluated the system under steady state conditions, the following steps will be taken:

- Integrate a seasonal thermal loop with water heating and cooling system to enable links with seasonal thermal energy storage. Establish water return temperatures to determine best STES match.
- Conduct a full scale field test to evaluate performance under real world conditions. Establish water return temperatur to match with seasonal thermal storage.
- Develop a numerical model using ANSYS and validate it against the field trial results to conduct simulations under a range of boundary conditions and optimise the system

[1] https://myheatsinks.com/heat-pipe-solutions/standard-heat-pipes/

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