Earth Cooling Tubes

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Abstract. The CAMTAC Linamar plant consumes large amounts of energy at a great expense. With the goal of reducing their energy costs, a design of an earth cooling tube system was proposed to cool the southern climate-controlled room. The system functions by passing ambient air through underground tubes and cooling it before passing it into the building. Final results of the analysis have shown that this would not be an effective method of supplementing the existing cooling system of the plant.

Key words: heat exhanger, earth cooling tubes, space heating, drain condensation

1 Introduction

Blue Sky Consulting Ltd, representing the Linamar Corporation, issued a request for proposals for the design of energy-related cost saving systems at the CAMTAC Linamar plant in Guelph, Ontario. A cooling tube system applicable to the southern assembly room of the plant was proposed and accepted.

Major design constraints taken into consideration include maintaining the room between 18 and 24 degrees Celcius, intaking only filtered air, maintaining a positive pressure condition in the room and lowering monthly electricity costs. Major design criteria taken into consideration include minimizing electricity use, and minimizing the return on investment.

The assembly room is currently cooled by several HVAC units, which also ensure the pressure in the room remains positive. Unfortunately, these units require large amounts of electricity, especially during hot summer days. Some alternative solutions to the temperature control problem include the use of a Trombe wall, a geothermal system, or a green roof placement. These alternatives all carry high overhead costs and require extensive modification to the plant. The proposed cooling tubes present an innovative system which is simple to construct and maintain.

2 Conceptual Design/Methodology

The detailed design consists of a series of underground tubes that use the earth as a heat sink to cool ambient air entering the south-side climate-controlled assembly room in the plant. The tube system starts with a weather protected inlet to allow for ambient air to make its way into the tube without introducing precipitation. From there, the air is cooled as it loses heat to the inner pipe wall. Any condensation collects at the lowest elevation of the pipe, dut to the 1% grade, and is processed through the condensation system. The cooled air is then forced into the room by the fan, resulting in fresh air to assist the existing HVAC units in controlling the climate of the room.

3 Detailed Design

3.1 Inlet/Fan/Filter

The inlet of the cooling tube system consists of one large pipe that descends vertically to the appropriate depth before branching out into 15 tubes. At the top of the inlet sits the fan and filter. The fan used to propel the air through the cooling tubes is a hooded propeller roof supply with a capacity slightly larger then the required flow rate. Since the flow rate of the selected fan cannot be adjusted, a looped PVC pipe that connects to both the input and the output of the fan could be used. In this way, the ow from the fan can be moderated without putting stress on the motor. A filter with MERV 8 rating was chosen for the system since it provided a good compromise between filtration capabilities and restriction of flow.

3.2 Outlet

The system outlets protrude from the ground directly along the side of the SE assembly room wall. A thin layer of insulation covers the areas exposed to the outside air and covers the pipe up to a depth of $1m$. The outlets angle themselves at 90 degress and enter the room horizontally at $50cm$ off the concrete assembly room floor, at which point they are covered with a thin grate to prevent unwanted large particulate from entering.

3.3 Cooling Tubes

A one-dimensional analytical method was used to model the underground cooling tubes, as taken from De Paepe (2003). Inlet and outlet air temperature, ground temperature at 4m below the ground surface, and mass flow rate of air were used as inputs in the model to produce a given diameter and length for a number of tubes to be installed: 15 tubes, each with a length of $23.2m$ and an inner diameter of $0.15m$.

The tubes themselves are set up in a manner in which adjacent tubes are spaced by at least $1m$ of soil so as to limit thermal interference and are laid in the ground with a 1% grade at the inlet so condensation drains out of the tubes and into a nearby manhole.

3.4 Condensation Drain

The cooling tubes are placed at a 1% grade to allow the condensate water to drain toward the inlet end of the tubes. Through a simple pipe system, the condensate drains into a maintenance hole. The capacity of the maintenance hole is $2.7m^3$, which is sufficient to store condensate from 50 hours of operation. The collected condensate water is to be pumped and disposed of weekly by a liquid waste disposal service.

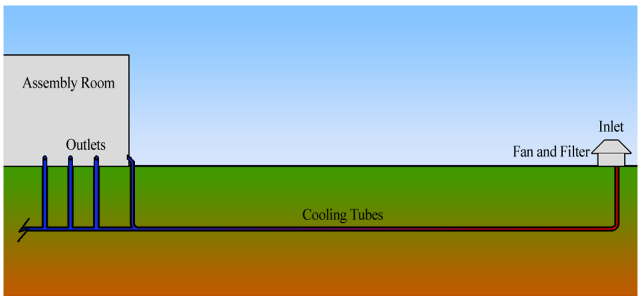

Fig. 1. Earth Cooling Tubes

4 Discussion

4.1 Financial Analysis

The capital cost of the system was determined to be approximately $220,000. Annual maintenance and operation costs amount to $3300/year and $100/year. The maintenance costs are associated with condensate drainage pumping and disposal, and the operating costs are associated with powering the fan.

The return on investment was determined to be 27.6 years, assuming the system operated full time. In terms of energy, with an electricity cost of $0.06 per kilowatt-hour, the system would be required to cool 3.66 Gwatt-hours before seeing a return on investment.

4.2 Uncertainties

There are several uncertainties and assumptions associated with the analysis that may significantly impact the results of the analysis. Primarily, the effect of friction within the cooling tubes due to irregularities in the flow path was ignored to simplify the analysis. Other uncertainties that require further analysis prior to considering the system for implementation include but are not limited to: the value of convection coefficients, the soil's thermal and physical properties, and air flow requirements within the assembly room.

5 Conclusion

As a result of the number of uncertainties in the system analysis and design, it should be acknowledged that the costs estimated for this project may not reflect the true costs involved in an underground cooling tube project. It is recommended that the system undergo several iterations of a more detailed and wholistic design methodology before being considered for implementation.

References

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