Solar Air Heating System Designed for Energy Conservation in Manufacturing Applications

Amanda Robinson, Elisa Cooper, and Kristin Lutes

Abstract. The following paper outlines a solar air heating (SAH) system for the CAMTAC plant in Guelph Ontario. The purpose of the system is to reduce natural gas consumption costs related to the continuous heating of ventilation air during the winter months. The design consists of an acrylic plastic wall that stands approximately 11 cm from the south-east building wall. Fresh air is heated by incoming solar radiation and drawn up through the air space by existing make up air units (MUA) and distributed into the current buildings ventilation system. The SAH system will increase incoming ventilation air by 1°C which results in annual savings of $14,000 by decreasing the amount of natural gas consumed. Capital costs are estimated at $95,900 with operating and maintenance costs of $1,400 annually. This results in a return on investment (ROI) of 6.6 -7.2 years depending on climatic variables.

Key words: energy conservation, solar air heating, solar radiation, active solar technology

1 Introduction

A need was identified to reduce heating related energy costs for the CAMTAC manufacturing facility, a division of Linamar Inc. located in Guelph Ontario. Currently, a significant amount of natural gas is being consumed due to the pre-heating of ventilation air. In order to meet this objective Blue Sky Consulting (BSC) recommends that a solar air heating (SAH) system be installed to pre-heat ventilation air. The constraints placed on the design include that it must i) reduce consumption of natural gas, and ii) have a financial return within the lifespan of the current plant. BSCs design offers an efficient means to capture solar radiation by use of acrylic plastic for the solar collector material.

2 Design Process and Analysis

A solar analysis was performed to determine the amount of solar radiation incident on the wall, taking into consideration orientation, angle of the collector and shading of the wall. A heat transfer analysis determined the amount of heat that would be transferred to the ventilation air from the building wall. After accounting for losses to the environment, the temperature difference was determined for various climatic situations. Finally, the system designed was validated using RET Screen modeling tool.

Various parameters were compared in order to determine the optimal balance between performance and cost. Four materials were analyzed and include: thin acrylic panels, thick acrylic panels, polycarbonate and low iron glass. The performance of a single pane was also compared to that of a double pane for each material. Insolation estimates were taken from Natural Resources Canada (NRC) and adjusted according to the specific orientation of the wall. Best and worst case scenarios for the amount of insolation the wall would receive was determined based on error estimations related to data generation by NRC. The ROI for each design was determined for both the best and worst case scenarios.

Materials for the collector and accompanying structural supports were determined based on transmissivity, durability, thermal conductivity, strength and cost. These included absorbance, transmissivity and cost for the collector.

3 Final Design

The resulting design, Figure 1, consists of a collector composed of acrylic plastic plates, and is attached to the existing South-East wall at the CAMTAC site.

Fig. 1. Overview of Solar Air Heating System.
The design proposes to force ventilation air in-between the acrylic plates and the existing wall by the use of the fan units on the existing MUAs. The acrylic wall will allow solar radiation to be transmitted to the existing building wall which is painted black. The energy absorbed by the black wall will be converted to thermal energy. The acrylic plates will prevent this thermal energy from escaping to the environment. Cool ambient air will pass through the air space while being heated by this trapped thermal energy. The heated air from the SAH system will be ducted to the current air heating system and distributed throughout the plant. Additional required air heating will be done with natural gas using the MUA units. The system is expected to result in an air temperature increase of approximately 1°C during the day. This results in an annual energy cost reduction of approximately $14,000 per year with an ROI of 6.6 - 7.2 years, depending on weather conditions.

Dampers will be used to shut down and isolate the wall from the existing plant during the summer months when heating the ventilation air is unnecessary. The system will be required to provide heat from September to June. The system collector consists of 240, 1.25m x 2.5m acrylic plastic panels, which are secured by a steel framework. The panels are sealed in by epoxy strips. This framework is supported by structural steel supports that are anchored in the ground with concrete. No load is placed on the existing building wall by the SAH system.

4 Discussion

For all materials, double panes resulted in high capital costs leading to prohibitive ROIs. The single pane polycarbonate resulted in an ROI of 6.1 years for the best case and 6.7 years for the worst case scenarios. This was the lowest ROI for all of the materials. The acrylic glass, however, had a comparable ROI of 6.6 years in the best case 7.2 years in the worst case. Polycarbonate has a shorter lifespan than acrylic glass, meaning that it would need to be replaced sooner. Therefore it was decided that acrylic glass was the best option for the design.

Given the material selected and the structural design, capital costs are estimated to be $95,900 with operating and maintenance set at $1,400 annually. The estimated annual cost savings associated with the single pane acrylic SAH system is $14,000.

The system will also reduce greenhouse gas emissions, thus decreasing the impact of the plant on the environment. The SAH system results in a payback period that fits within the constraints and also has positive environmental implications. As a result of these factors stated above, BSC’s design is deemed to be a suitable solution to the problem of reducing energy consumption and costs for the CAMTAC facility.

5 Conclusion

A cost saving energy solution has been designed to reduce the amount of natural gas used at the CAMTAC plant. A SAH design consisting of an acrylic plastic collector and structural steel has been proposed to increase the air temperature of the incoming ventilation air. The retrofit will save the CAMTAC facility approximately $14,000 per year. Given $95,900 for capital and $1,400 for maintenance costs, this will result in a payback period of 6.6-7.2 years.

6 Acknowledgements

Special thanks is given to those individuals who helped in the analysis and guidance of the project. In particular special thanks to Dr. Lubitz, Dr. Otten and Amanda Farquharson. BSC would also like to thank Mike Minogue for all of his patience and knowledge.