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Performance of Ground Source Heat Pumps in Manitoba[1]

Introduction

Manitoba Hydro has been promoting geothermal heat pump systems through the Residential Earth Power Program since April of 2002. Since program launch, over 950 customers have applied for the Residential Earth Power Loan. Manitoba Hydro has worked with industry and other partners to determine the actual geothermal system performance over an entire heating and cooling season. The performance levels reported by various manufacturers are based on an instantaneous test and do not consider all of the losses that occur in an actual system. The performance values reported in this study reflect measured performance values monitored at "as installed" working systems.

In two previous case studies in Manitoba, where actual field performance was measured it was found that the seasonal coefficient of performance (SCOP) over an entire heating season for five homes ranged from 1.4 to 2.9. The case study that included four homes indicated that two of the homes produced SCOP's of 1.4 and 1.6 but lack of maintenance and improper use of the system was found to be the cause of their poor performance. The other two homes in that study had no operational issues and produced SCOP's of 2.5 and 2.8. The second previous case study was of a single home, measured a SCOP of 2.9 for one heating season, and an SCOP of only 2.2 in a subsequent heating season. The reduction in performance in the second year was caused by a control failure which caused the auxiliary heat to operate excessively.

Based on the two previous case studies and analysis of heat pump customer billing data, Manitoba Hydro uses an average ground source heat pump SCOP of 2.5 and an EER of 14 for calculating the energy savings claimed by the Manitoba Hydro Earth Power Program. Manitoba Hydro wanted to study more residential ground source heat pump installations to provide a larger and more varied sample. A larger sample was expected to more accurately represent heat pump SCOP's of reasonably installed systems and therefore ensure that the energy savings claimed by the program would be fair and realistic.

It was felt that more extensive research needed to be completed to clarify the circumstances under which a desuperheater is beneficial in a heating dominated climate such as Manitoba. This is important because the high cost of a desuperheater increases the initial cost of the system and the high cost barrier of geothermal systems has been identified as one of three main barriers to widespread adoption of the technology. Removing the desuperheater from this initial cost may reduce the simple payback period. Conversely, when circumstances make the desuperheater a worthwhile investment, the payback period on the overall system may actually be reduced. Actual desuperheater field performance needed to be measured.

Since Manitoba is a heating dominated climate there are concerns regarding the long term thermal performance of the ground loop. This study will estimate the annual energy imbalance that is placed on the ground loop due to heating, cooling, and hot water (desuperheater). The annual energy imbalance is calculated by subtracting the quantity of heat rejected to the ground from the quantity of heat removed from the ground loop in a one year period.

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1. This article is an abstract from a comprehensive study released by Manitoba Hydro in June 2009. The monitoring project was co-funded by Manitoba Hydro and the Canadian GeoExchange Coalition (CGC) through a three year contribution agreement with Natural Resources Canada (2003-2006).

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Study Objectives

The objectives of the study were to determine:

1. an average annual Seasonal Coeffi cient of Performance (SCOP – heating season), and an average Seasonal Energy Efficiency Ratio (SEER- cooling season),
2. the average annual water heating electric energy reduction due to the desuperheater, and
3. the average annual heating savings provided by a reasonably well installed ground source heat pump system in Manitoba.

The ten homes monitored are a biased sample since most of the homes were volunteered for the project by experienced and established heat pump contractors and /or distributors that were contacted and nine of the systems were relatively new (less than three years old). The one older system in the study was the only open loop (well to well system) in the study. This system was re-commissioned when it was discovered at the preliminary site visit that it was performing poorly (COP of 1.5) due to water supply issues.

Results

Manufacturers of geothermal heat pumps have traditionally reported coefficients of performance (COP) of 3.1-to-4.0 and energy efficiency ratio (EER) of 14-to-21. These efficiency levels are based on instantaneous tests conducted under controlled conditions and do not consider all of the losses that may occur in an installed system operating in varying conditions.

This study monitored ten homes over an extended period during all heating, cooling and shoulder months to determine the average Seasonal Coefficient of Performance (SCOP) and Seasonal Energy Efficiency Ratio (SEER) of typical heat pump systems operating in an "as-installed" environment.

Test data for ten Manitoba homes shows that the SCOP of the monitored ground source heat pump systems range from 1.8 to 3.5 with an average of 2.8 for a one year period. SCOP is defined as the total energy (kWh) delivered by the system divided by the total energy input (kWh) to the system over one heating season. The average annual electric energy saved was 15,842 kWh when compared to conventional electric resistance heat. The systems operated for an average of 2041 equivalent full load hours in heating mode.

The average SEER of the ten monitored homes during the cooling season was 13.3. The estimated average annual energy saved was 17 kWh compared to a split central air conditioning system with a SEER of 13. The cooling savings with a ground source heat pump were minimal but this may not be a fair comparison since the SEER 13 assumed for the central air conditioner is based on controlled test conditions and is not based on actual monitored field data. The systems operated for an average of 218 equivalent full load hours in the cooling mode.

The desuperheater option reduced the average domestic hot water electric energy usage by 610 kWh (18%). It was found that 86% of the savings were produced during the heating season. Therefore, the heat pump had to operate longer to transfer this additional energy requirement. This additional energy requirement during the heating season only increased seasonal imbalance on the ground. Most of the systems operated with water heater temperatures lower than the 60 o Celsius (140 o Fahrenheit) that is the minimum temperature setting requirement of the National Plumbing Code for electric storage water heaters. One of the desuperheater pumps was replaced prior to the study period due to motor failure. Another pump failed during the study period. Considering all of these factors, the desuperheater option does not appear to provide the same benefit in a heating dominated climate as it would in a cooling dominated climate.

Conclusion

The results of this study indicate that there are potentially significant energy savings in a Manitoba climate when utilizing a ground source heat pump compared to electric resistance heat. It also shows that these savings can be estimated for a properly functioning system, based on the manufacturer's rating and the system design.

The cooling season savings when compared to a new central air conditioner does not appear to be significant. The major benefit for a ground source heat pump compared to a central air conditioner is that the unit itself is indoors and not exposed to the outdoor elements.

Domestic water heating savings from the desuperheater in a heating dominated climate may not justify the capital cost and maintenance costs connected to the desuperheater. There may also be a health and safety issue with respect to the water heater storage temperatures being set lower than the National Plumbing Code requirement to increase the effectiveness of the desuperheater.

Entering fluid temperature data collected during the study period were within reasonable design parameters. However, the closed loop systems being monitored were still relatively new, between one and three years old. This study does not provide enough data to determine the sustainability of long term loop and system performance.

The systems operated for an average of 2041 equivalent full load hours in heating mode and only 218 hours in cooling mode. This causes an imbalance to the ground of approximately 5 to 1 for heat being extracted from the ground versus heat that is being rejected to the ground. This thermal imbalance could cause significant issues with a heat pump's long term sustainable performance if it is not properly considered at the design phase.

The significant in-rush currents and the high numbers of starts associated with the compressors have the potential to cause a momentary dimming of lights (flicker) or other power quality issues. Ensuring that the electrical system supplying power to the heat pump is robust and utilizing lights that are less susceptible to flicker could help reduce the effects of flicker.