RESIDENTIAL SWIMMING POOL HEATING WITH GEOTHERMAL HEAT PUMP SYSTEMS

Andrew Chiasson, P.E.
Geo-Heat Center

ABSTRACT

The objective of this study is to examine the feasibility of swimming pool heating with geothermal heat pump (GHP) systems in residential applications. Six locations with varying climates are examined across the U.S. A contour plot is presented for use in estimating the potential reduction in ground loop size as a function of the total annual building loads and the total annual swimming pool heating load. Results show that ground loop lengths may be reduced by up to about 20% in southern U.S. climates with the addition of a swimming pool, but may be as much as double in northern U.S. climates. A simple economic analysis demonstrates that it would not be economically justifiable to heat a swimming pool with a GHP system in northern U.S. climates due to the extra ground loop required to meet additional heating demands. In contrast, immediate savings could be realized in southern U.S. climates since the pool can accept heat from the heat pump system that would be otherwise rejected to the ground.

INTRODUCTION

A frequently asked question by prospective and current residential geothermal heat pump (GHP) owners is, "Can I use it to heat my pool?" The short answer in the past has been "Yes, but it depends on the climate." The design challenge arises from the fact that GHP systems are exactly that: they are <u>systems</u>. The addition of a swimming pool to a GHP system changes the heat balance of the original system (i.e., without a pool), and the new design depends on the climate.

In northern climates, more heat is generally extracted from the ground than is rejected during the year. Therefore, a water-to-water heat pump and more ground loop would be required to heat a pool in summer months, but the amount of extra ground loop needed would depend on the length of the swimming season and on the heating/cooling loads profile for the home during the remainder of the year. In southern climates, the opposite occurs and more heat is generally rejected to the ground than is extracted during the year. In these cases, heat from the ground loop that would otherwise be rejected to the ground can be used to heat a swimming pool either directly or with a water-water heat pump. The decision to heat a pool with a GHP is an economic one, similar to the decision to heat/cool a home with a GHP. There are tradeoffs between first cost and operating cost savings.

The objective of this paper is to determine if it is economically feasible to heat an outdoor swimming pool with a GHP system. Six climatic locations across the United States are examined: Boston, MA; Charlotte, NC; Dallas, TX; Denver, CO; Los Angeles, CA and Seattle, WA. A graph is presented to estimate the relative change in overall ground loop length when swimming pool heating is incorporated into a GHP system. Finally, an economic analysis is conducted.

APPROACH

Figure 1 illustrates the system scenarios that were considered. The approach used in the analysis is summarized as follows:

- Annual heating and cooling loads were computed for a 2,000-sq ft(186-m^2) home of new, tight construction.
- A vertical-bore ground loop was sized for the house with a heat pump entering fluid temperature of 90ºF (32.2ºC) maximum and 35ºF minimum (1.7ºC) (Figure 1a). An earth thermal conductivity of 1.2 Btu/hr-ft-ºF (2.0 W/m-K) was assumed.
- Monthly swimming pool heating loads were computed based on the following assumptions:
    - A pool size of 30 ft long x 20 ft wide x 5 ft average depth (9.1m x 6.1m x 1.5m)
    - Only **outdoor, underground pools** are considered
    - An outdoor swimming season of June through August for northern climates, and mid May through mid-September for southern climates.
    - A pool setpoint temperature of 80ºF (26.7ºC), representing the average monthly pool temperature
    - Heat transfer processes considered were: *incident solar radiation gain (with 10% shading assumed), convection to the atmosphere, evaporation, thermal radiation to the sky, and conduction to the ground.* These are illustrated in Figure 2.
    - Loads were computed for cases where the pool remains uncovered at all times and where the pool is covered at night.
- The vertical-bore ground loop was re-sized for the combined loads of the house and pool (Figure 1b and 1c) and compared to the ground loop size required for the house only (Figure 1a). For southern climates, some heat rejection from the ground loop to the pool was accomplished with the configuration shown in *Figure 1c*.
- A simple economic analysis of pool heating was conducted.

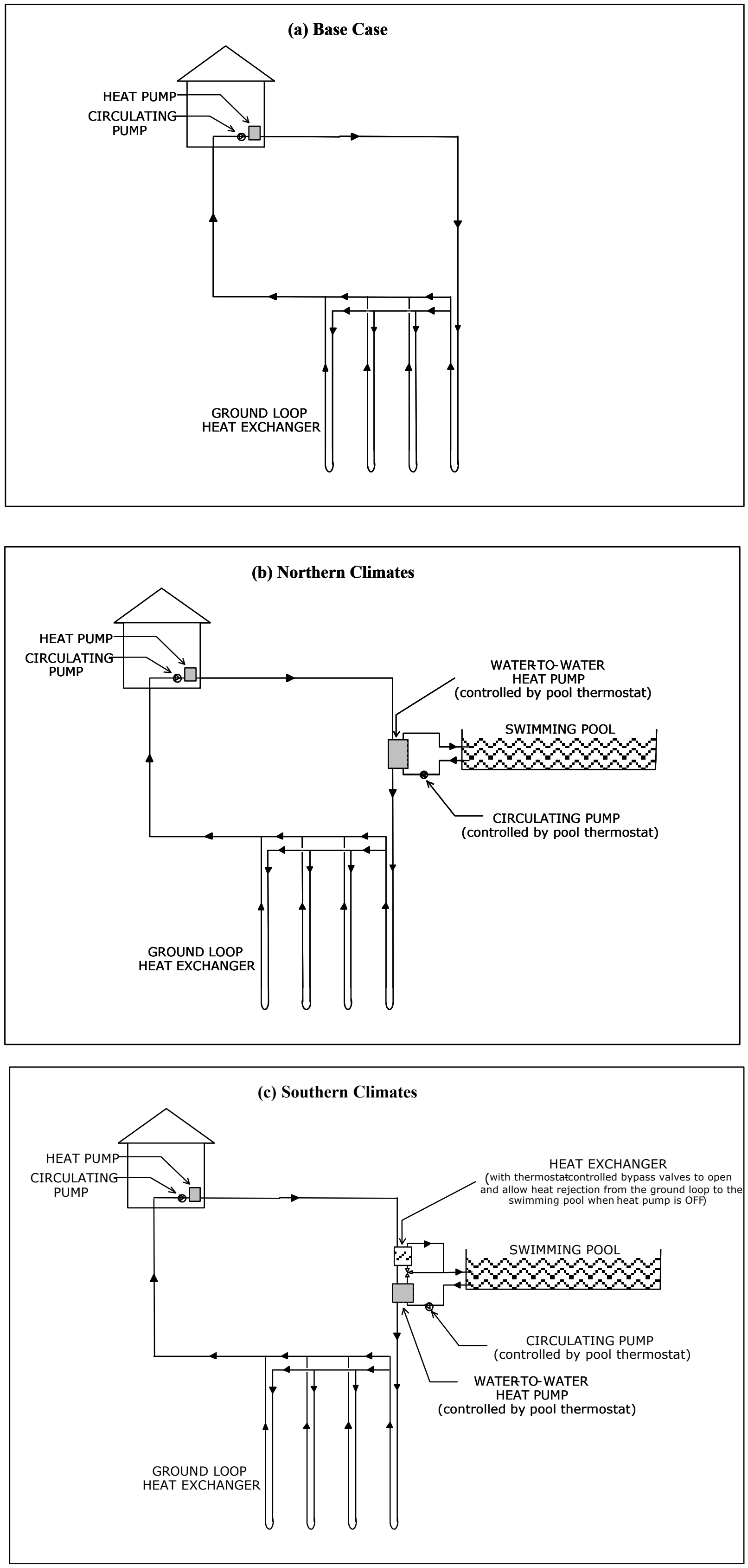

Figure 1. Schematic diagrams of the pool heating scenarios examined.

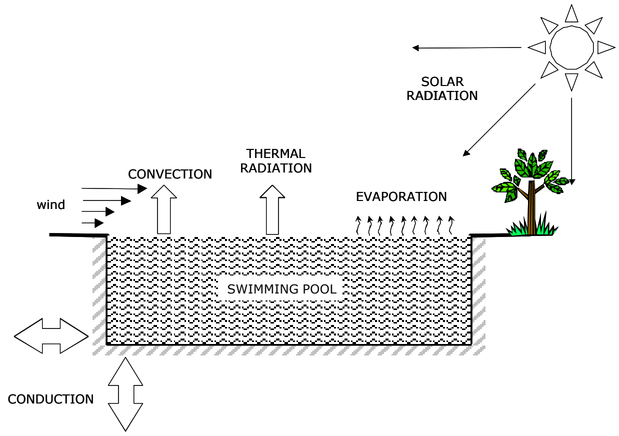

Figure 2. ***Environmental heat transfer processes in swimming pools.***

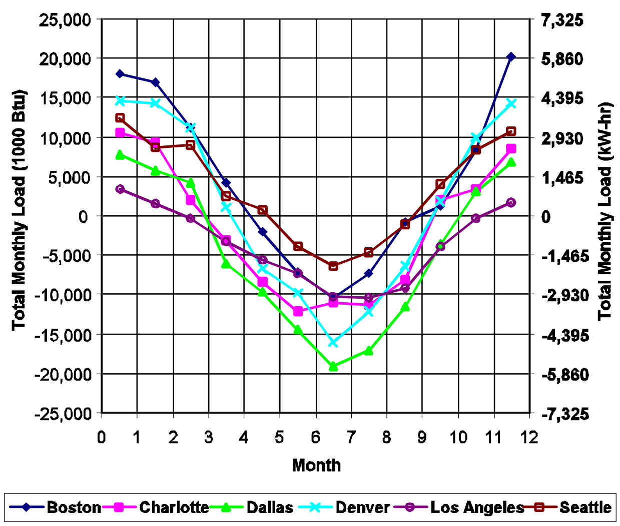

Figure 3. ***Total monthly heating and cooling loads for the cities examined (note, heating loads are positive and cooling loads are negative).***

RESIDENTIAL HEATING & COOLING LOADS

The residential heating and cooling loads for the six locations are shown graphically in Figure 3 and summarized in Table 1. The EFLH for heating (for example) is defined as the total annual heating requirement divided by the peak heating load. An important value shown in Table 1 (to be used later in this study) is the ratio of total annual cooling to total annual heating. It provides a measure of the heating or cooling dominance of a building. When this value is near unity the building is approximately balanced with regard to annual loads.

SWIMMING POOL HEATING LOADS

The monthly heating loads are summarized in Figure 4. A review of Figure 4 shows that covering the pool at night can save significantly on pool heating energy consumption. Covering the pool eliminates evaporation losses and nearly eliminates convection losses. However, it may be advantageous to leave the pool uncovered in southern climates for a portion of the summer season. In these cases, more heat may be rejected from the ground loop to the pool, and the pool would act like a *supplemental heat rejecter.* This concept of supplemental heat rejection is receiving considerable attention in commercial building applications to prevent heat build-up in the ground.

GROUND LOOP SIZING

The results of the ground loop sizing are presented as a useful contour plot in Figure 5. The contours represent the relative change of the ground loop as a function of x and y. The x-variable is the ratio of total annual cooling load to total annual heating load (see Table 1) for the house. The y-variable is similar to the x-variable, except the denominator is the total annual house heating load plus the total annual pool heating load. The "1" contour line means no change in relative ground loop length. Above and to the right of this line, ground loop savings can be realized with the addition of a swimming pool. Below and to the left of this line, additional ground loop is needed to heat a swimming pool. The gray

Table 1. Summary of Heating and Cooling Load Data

City	Heating Peak Load 1000 Btu/hr (kW)	Heating EFLH*	Cooling Peak Load 1000 Btu/hr (kW)	Cooling EFLH*	Total Annual Cooling to Total Annual Heating Ratio
Boston, MA	38.0 (11.1)	2,453	31.2 (9.1)	1,305	0.44
Charlotte, NC	29.7 (8.7)	1,697	37.8 (11.1)	1,818	1.37
Dallas, TX	25.6 (7.5)	1,522	47.4 (13.9)	1,955	2.38
Denver, CO	38.9 (11.4)	2,261	52.4 (15.4)	1,360	0.81
Los Angeles, CA	16.7 (4.9)	1,637	41.1 (12.0)	1,734	2.61
Seattle, WA	26.3 (7.7)	2,734	30.5 (8.9)	1,040	0.44

* EFLH = Annual equivalent full load hours

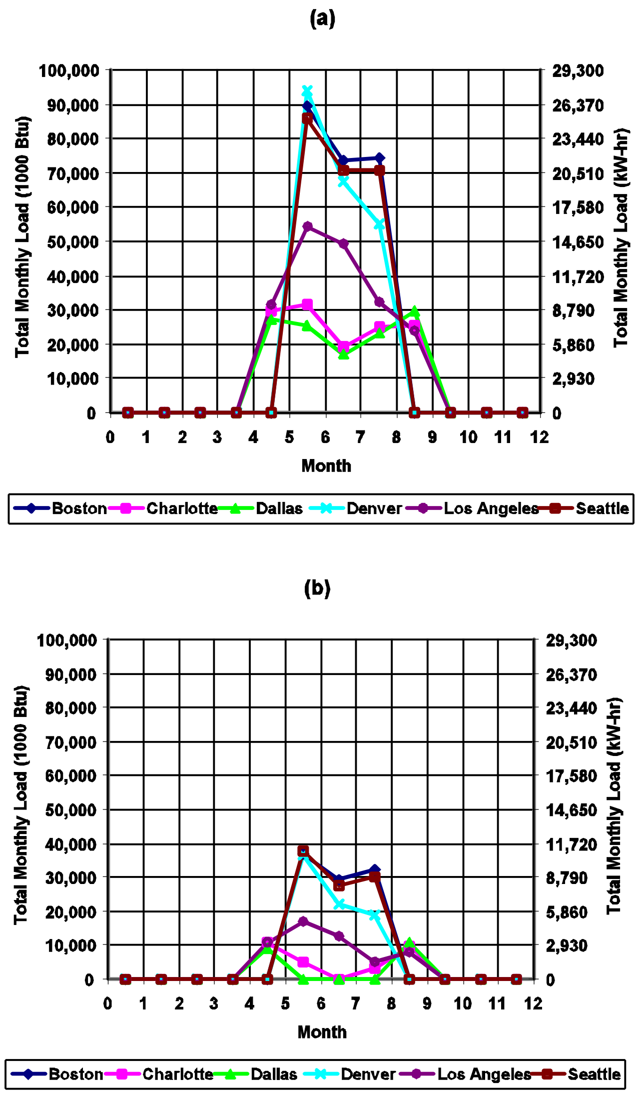

Figure 4. ***Swimming pool heating loads for an outdoor pool kept at 80°F (26.7°C);, where, the pool is (a) uncovered and (b) covered at night. Note, the pool seasons described in the text.***

region is not applicable since it would represent pool cooling, not heating.

Some interesting conclusions can be made from observation of Figure 5. For the cases examined, ground loop length reduction is not possible until the ratio of total annual house cooling to total annual house heating exceeds about 1.25 to 1.30. For the Boston and Seattle cases, about double the amount of ground loop would be required to handle the swimming pool heating loads. For the cooling-dominated cases (Charlotte, Dallas, and Los Angeles), up to about 15% ground loop reduction was possible for covered pools. However, there appears to be an optimum balance point of pool heating load and ground loop length reduction as seen by the uncovered pool cases. For the Dallas case, an uncovered pool resulted in an additional 5% ground loop length reduction but no significant change was observed for the Los Angeles and Charlotte cases. For the Los Angeles and Charlotte cases, the additional heat to the pool began driving these cases to become heating-dominated. Therefore, the optimal situation for pool heating in warm climates would involve some schedule of covering and uncovering the pool.

Figure 5 could be used during the planning stages of choosing a swimming pool heating system. **It should not be used to replace a detailed design and analysis**. As an example use of Figure 5, consider a home where the ratio of total annual cooling to total annual heating is 2. Enter Figure 5 at $(x,y) = (2,2)$ (i.e., no pool heating). The pool heating loads would be computed separately, but values in Figure 4 could provide estimates scaled for various pool sizes. The annual pool heating loads are then added to the total house heating loads to compute a new ratio on the *y-axis*. A reduction in ground loop length could then be estimated.

ECONOMIC ANALYSIS

A simple economic analysis was conducted to evaluate the feasibility of incorporating swimming pool heating into a GHP system. The following cost assumptions were used in the analysis:

- Ground loop installation costs are widely variable across the U.S. An average cost of $8/ft ($26/m) of vertical bore was assumed.
- Water-to-water heat pump costs were estimated at $1000/ton ($3516/kW) of nominal capacity
- Electricity cost rate was $0.10 per kWh.
- The alternative pool heating mechanism was assumed to be a natural gas-fired pool heater. Costs were taken from R.S. Means Mechanical Cost Data. Natural gas prices were taken as $0.85/therm ($0.30/m^3).

Results of the economic analysis are presented in Figure 6 in the form of simple cumulative annual cash flows. For the “Geothermal Heat Pump” cases, first costs include the differential cost of the ground loop (either positive or negative) with respect to the base case and the heat pump and heat exchanger equipment. For the “Natural Gas” cases, first costs include the cost of the gas-fired heater. Annual costs include the fuel costs only.

A review of Figure 6a (for the Denver case) clearly shows that it is not economically justifiable to use a GHP system for pool heating in heating-dominated climates. With the additional cost of the ground loop and heat pump, the simple payback period is unacceptably long, on the order of 30+ years. For a more balanced climate such as the Charlotte case, the payback period is more acceptable, on the order of 5 years. For the cooling-dominated cases (Dallas and Los Angeles) the ground loop cost savings more than pays for the water-to-water heat pump and the payback period is immediate.

CONCLUDING SUMMARY

This study has examined the feasibility of swimming pool heating with geothermal heat pump systems in residential applications. Space heating, cooling, and outdoor swimming

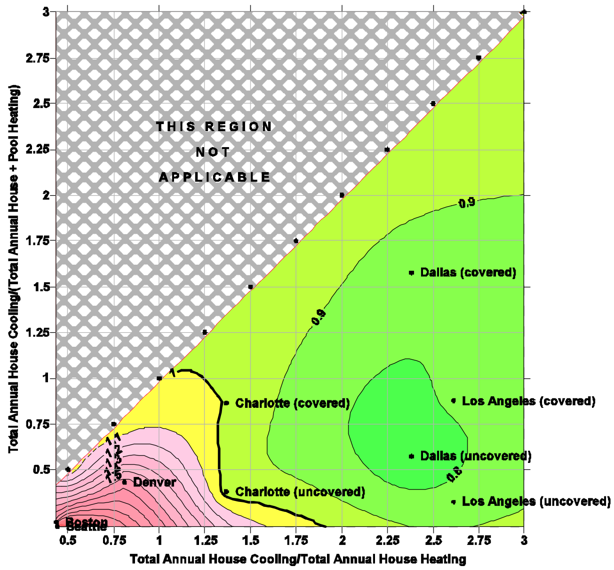

Figure 5. ***Contour plot showing relative changes in ground loop size as a function of total annual building loads and total annual pool heating loads. "Uncovered" refers to an uncovered pool. Boston, Denver and Seattle pools are covered.***

pool heating loads were computed for a residential building in six varying climates across the U.S. A vertical-bore ground-loop field was sized for each case with and without the pool.

The results of this study show that ground loop lengths may be reduced by up to about 20% in southern U.S. climates with the addition of a pool. However, required ground loop length may need to be doubled in northern U.S. climates. A contour plot was presented showing the potential reduction in ground loop size as a function of the total annual heating load for the building, total annual cooling load for the building, and total annual heating load for the swimming pool. A simple economic analysis showed that it would not be feasible to incorporate a swimming pool into a GHP system in northern U.S. climates due to the extra ground loop required. On the contrary, immediate savings could be realized in southern U.S. climates.

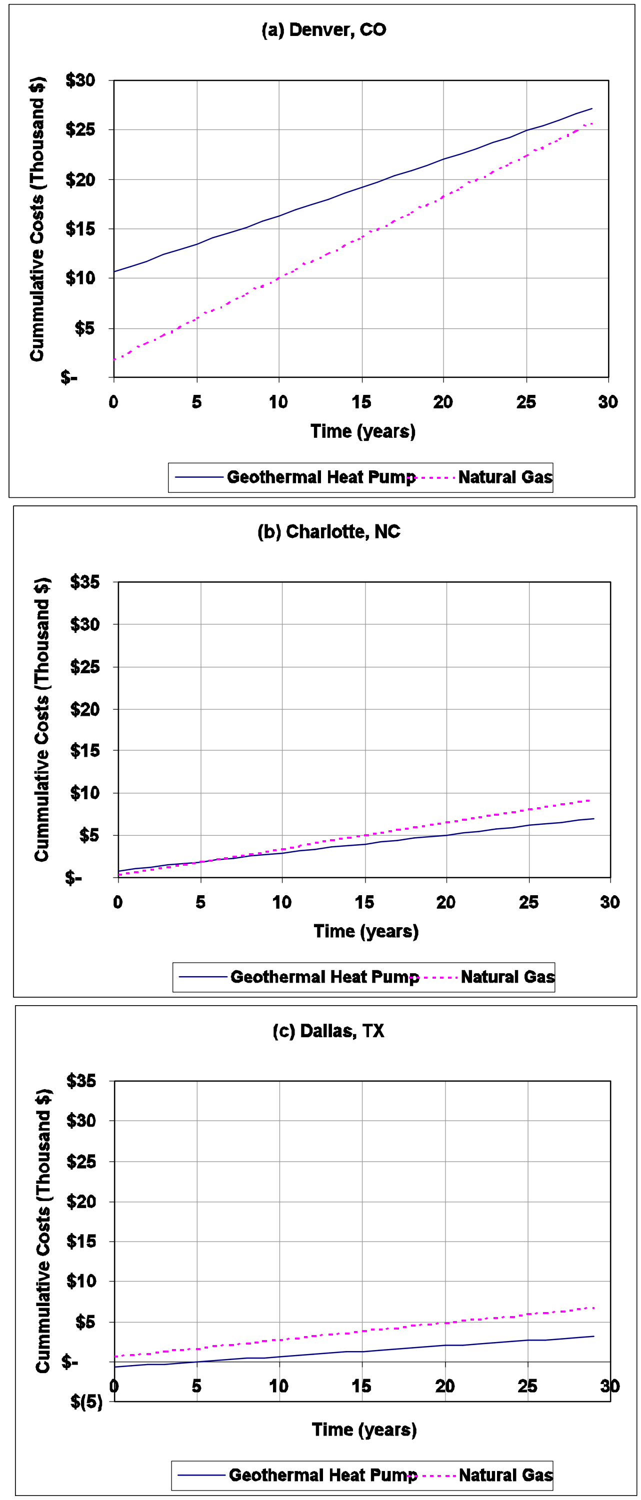

Figure 6. ***Cumulative annual cash flow for three example cases.***