Noise associated with the ground water systems serving residential geothermal heat pumps

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ABSTRACT

Geothermal heat pumps are an energy efficient option for many residences as an alternative to more conventional gas or oil fueled residential HVAC systems. This paper continues discussions about the noise and vibration issues from these residential geothermal systems that have been presented in prior papers by this author. In this paper, the noise contributions of two components of the ground water system will be discussed. First, the paper will discuss the influence of noise from the control system that regulates the ground water flow. A comparison of the noises from a simple pressure switch system versus a variable speed controller will be discussed. Second, the ground water system includes zone control valves to manage the water flow for the different systems. These valves can contribute to the noise generated by the system when it operates. Two types of valves will be discussed, which have dramatically different designs and different sound emissions. The paper concludes with recommendations for achieving a low noise ground water system to serve the geothermal heat pumps.

Keywords: Geothermal, valves, noise I-INCE Classification of Subjects Numbers: 12.4.3, 11.3.1

1. INTRODUCTION

In the past decade, geothermal heat pump systems have become a more popular choice for heating and cooling buildings. In particular, the advancements in refrigerant compressor technology, interest in sustainable living and desire to reduce heating and cooling costs have made these systems attractive for residential applications. Typically, the benefits of the geothermal systems for residents are a very economical system with environmental benefits and lower operating costs that traditional petroleum fueled systems.

As explained in previous papers (1, 2), geothermal heat pump systems can generate noise and vibration to the interior of the residential building. These systems use ground water for the source of heating and cooling and the systems are primarily installed indoors. In these conditions, there are no exterior sound emissions from the operation of the system to the environment, which might be a very useful feature for applications where exterior noise emissions are a concern. However, depending on how the systems are installed, the noise and vibration generated by these systems could adversely impact the occupied spaces within buildings they serve. Previous papers discussed the issues with noise and vibration transmission from the system via the plumbing to the building structure and the importance of compressor isolation for minimizing the noise and vibration of the system.

This paper will focus on the noise associated with the components for an open loop ground water system that supplies the water to the heat pump. These types of systems are similar to traditional artesian well systems. Different variations of these open loop ground water systems and their associated noise and vibration are discussed below.

2. OPEN LOOP GROUND WATER SYSTEM COMPONENTS

This paper will focus on the components associated with open loop ground water systems. These systems consist of numerous components; however, the components that significantly affect the noise and vibration include the submerged well pump, the well pump control system and zone control valves. Conceptually, these components are shown in Figure 1.

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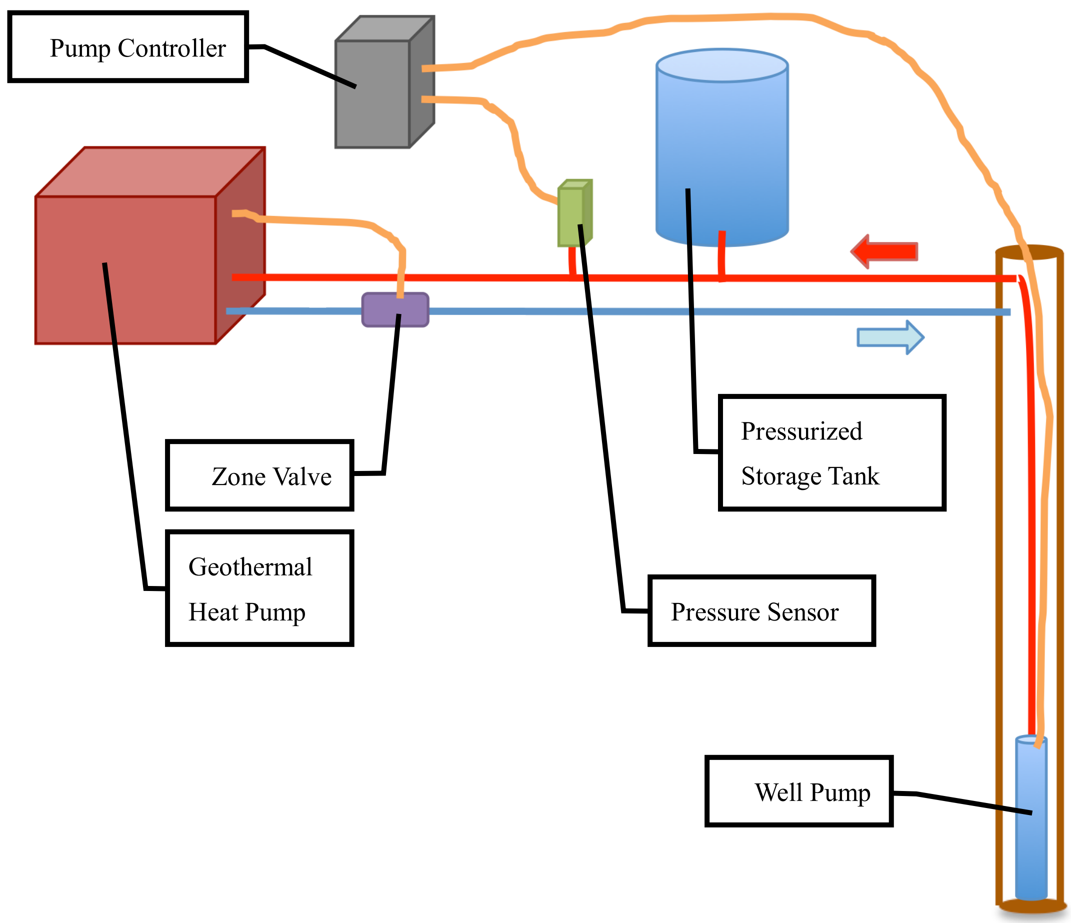


Figure 1 –Schematic diagram of the ground water system components for a geothermal heat pump system.

2.1 Well pump

After the well has been drilled and water has been found, a submersible well pump is lowered into the well. The pump is plumbed and wired vertically in the well feeding the supplied water to the building through horizontally routed unground piping. Typically, the piping enters into the building through the foundation and is routed to a pressurized water storage tank.

2.2 Well Pump Control System

There are several methods for how the operation of the well pump is controlled. This paper will discuss two options; the first being a traditional pressure switch with a single speed pump controller, while the second consists of a pressure sensor and a variable speed pump controller. The differences of these two setups are discussed below.

2.2.1 Pressure Switch and Single Speed Pump Controller

The pressure switch method has been used for many years for controlling these types of well pump systems. This type of control system is a standard diaphragm pressure switch that is connected to a single speed pump controller. The switch is used to sense the pressure in the ground water system. When the heat pump is not running, a set pressure is maintained in the pressurized water storage tank in the ground water system. After the heat pump is activated and the zone control valve opens, the pressure switch senses when the water pressure in the system drops below a set pressure, at which time the switch activates a relay that provides a signal to the single speed pump controller that the pump should operate. The pressure at which the switch activates the relay is referred to as the “cut in” pressure, which turns the pump on. After the heat pump turns off and the zone control valve closes, the well pump restores the water pressure in the system to the set pressure, which is referred to as the "cut out" pressure, which turns off the well pump. Using this control system, the pump operates under a condition of either 100% on (full capacity) or off. For example, the cut in pressure might be 2 bars (30 psi), while the cut out pressure might be 3 bars (45 psi). A hypothetical operating sequence of these parameters is shown in Figure 2.

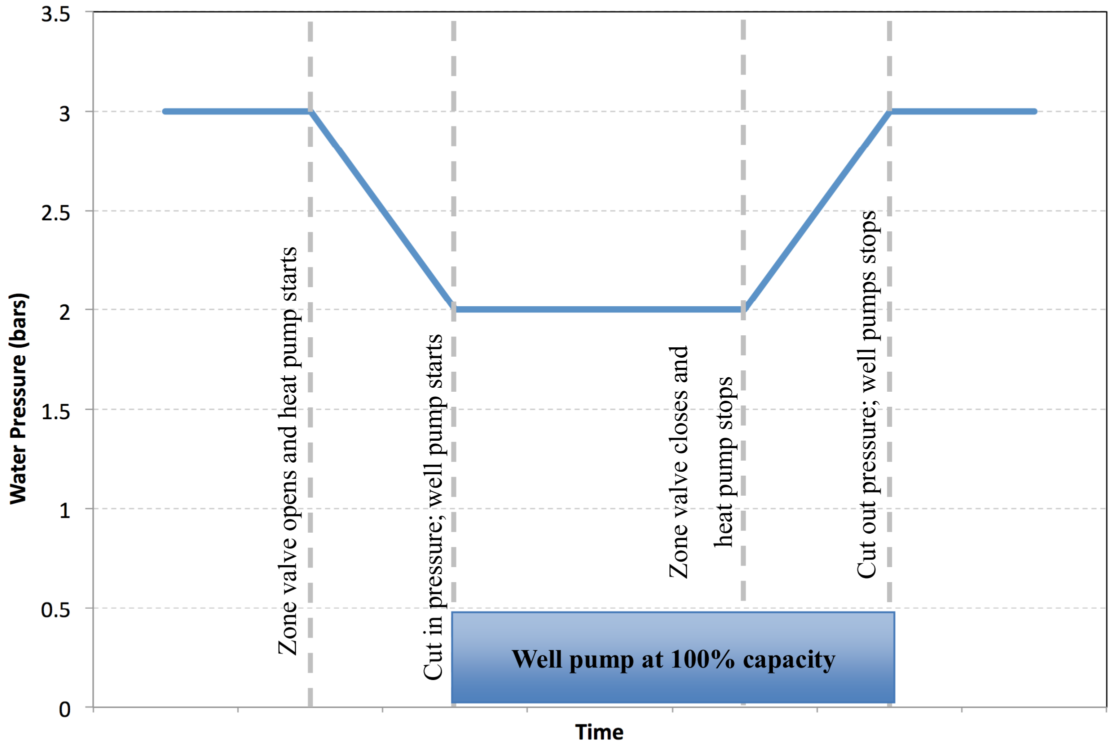


Figure 2 – Operating sequence of system with a pressure switch and single speed pump controller.

There are conditions that might cause this type of pressure switch system to cycle frequently while the geothermal heat pump system operates. For example, factors such as a small pressure/storage tank, low cut out pressure or well pump with a high capacity can cause the pressure switch and single speed controller system to cycle between the cut in and cut out pressures repeatedly during a single cycle of the geothermal heat pump system. These conditions that cause short cycling should be avoided, as the frequent and repeated sound of the well pump and control system cycling can be bothersome to residents.

2.2.2 Pressure Sensor and Variable Speed Pump Controller

More recently, it is becoming more economical and efficient to use variable speed pump controller for operating the well pumps. Variable speed controllers use a pressure sensor substituted for the pressure switch that monitors the water pressure in the system to vary the capacity of the well pump for maintaining the set pressure in the system. The pump controller increases the speed of the well pump when the system pressure drops below an allowable deviation from the set pressure; conversely, the control system decreases the speed of the pump when the system pressure exceeds the set pressure. For example, the set pressure might be 2 bars (30 psi) with an allowable deviation of 0.2 bars (3 psi) from this set pressure; see Figure 3 for an example of the operating sequence of this type of system.

2.3 Zone Control Valves

The ground water system is controlled by the geothermal heat pumps using a zone control valve installed downstream of the heat pump. Before the heat pump can be activated, the zone valve must open to allow the ground water to start flowing. By allowing the water to start flowing through the heat pump, the operation of the heat pump can be started, and the heat transfer process can begin. This paper will describe two types of zone control valves: globe valves and ball valves.

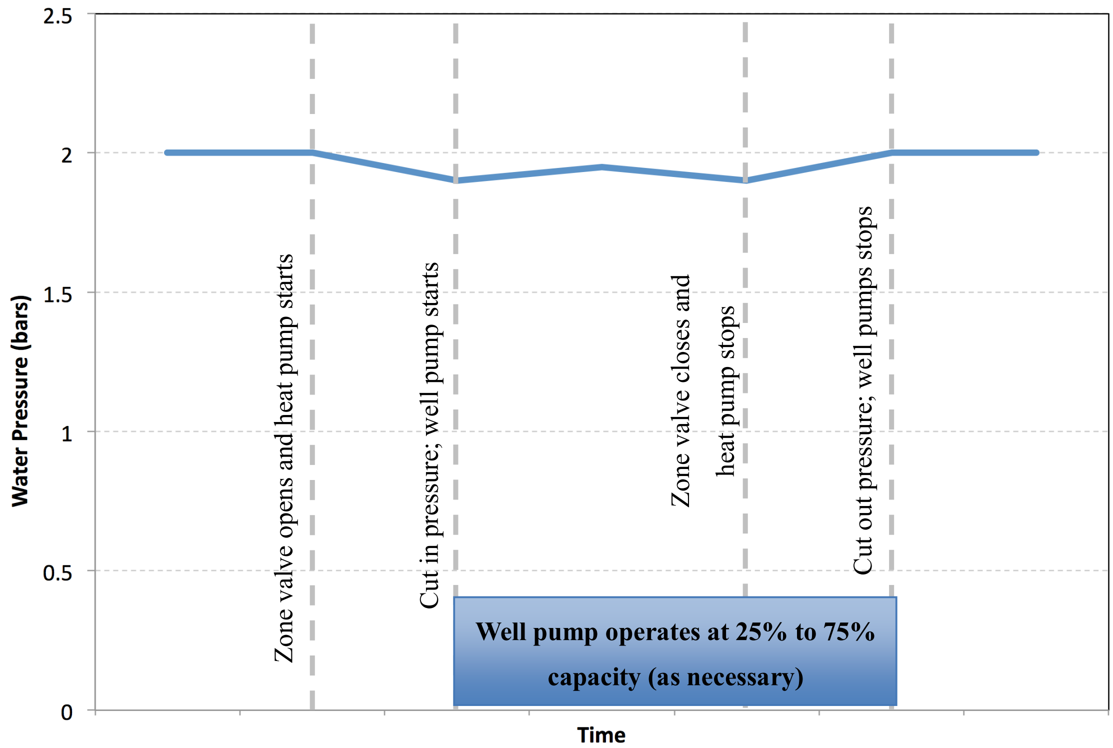
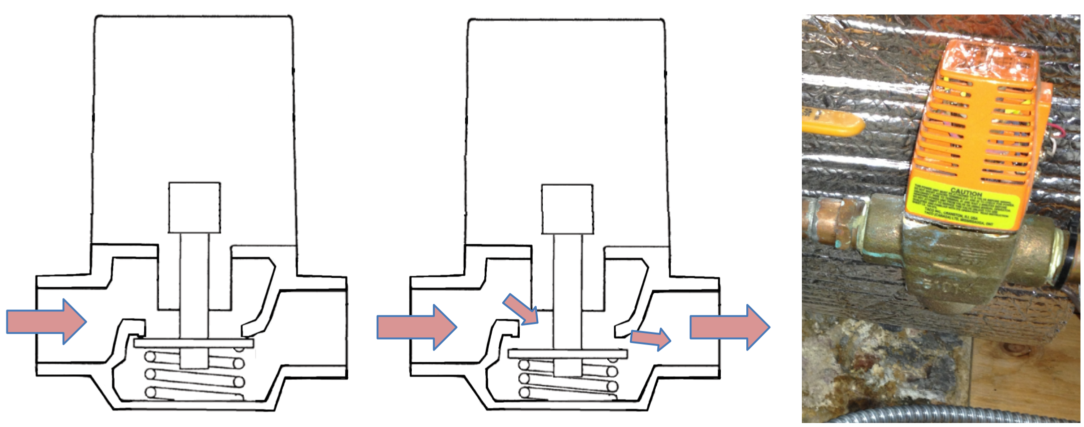


Figure 3 –Operating sequence of a system with a pressure sensor and variable speed pump controller.

2.3.1 Globe Valve

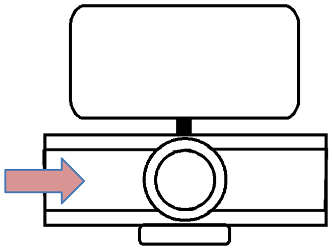
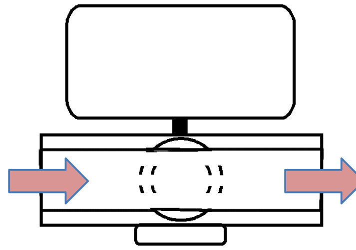
The original zone control valve used with geothermal systems was a globe valve. The globe valve uses a spring-loaded piston with a flat plate, referred to as a valve disc that covers an opening within the valve, referred to as the seat. To allow the water to flow, the valve disc is pushed away from the seat opening the valve. Section drawings through closed and open globe valves are shown in Figure 4 & 5. One example of such a geothermal zone control valve is model 557G by Taco Inc. (Figure 6).



Figures 4 & 5 – Globe valve sketches closed (left) and open (center). Figure 6 – Taco Inc. model 557G.

2.3.2 Ball Valve

A new option of zone control valves for geothermal systems consists of a ball valve. The ball valve uses a smooth ball with a hole through the middle that is rotated to control the water flow (see Figures 7 & 8). The valve simplifies installation, since it can be installed in either direction. The ball valve provides effective shut off of the water flow when closed. An example of this is the Geo-Sentry Zone Valve model by Taco (see Figure 9).


Figures 7 & 8 – Ball valve closed (left) and open (center). Figure 9 – Taco Inc. model Zone Sentry.

3. NOISE ASSOCIATED WITH GROUND WATER SYSTEM COMPONENTS

3.1 Well pumps

For these open loop ground water systems, submersible well pumps are typically located at the bottom of the well. Despite the long distance from the interior of the residence, the well pump serving the systems studied here was audible when it ran at full capacity. It was not clear whether the pump noise was transmitted via the piping, which originally consisted of 6.1 m (20-foot) sections of threaded PVC, or through the water. Either way, the sound was audible within the basement next to the equipment and had a low frequency tonal character (a hum).

3.2 Pressure Sensor and Control Systems

3.2.1 Pressure Switch

The pressure switch (model Square D Pumptrol 9013FSQ2) used originally in the ground water system functioned for approximately 10 years. This switch generated an impulsive noise resulting from the engagement of the electric relay when the switch reached the preset “cut in” or “cut out” pressure. The clicking sound was not overly loud, but was very abrupt and distinct from quiet background noise.

The single speed controller did not make any sound. However, when the pressure switch activated the relay and the well pump was turned on, the tonal sound of the pump was audible adjacent to the equipment.

The abrupt start up of the well pump by the single speed controller generated significant torque and caused the piping from the pump to jostle within the well shaft. After 10 years of operation, the electrical wiring routed from the pump controller down the well to the pump had failed due to repeated impacts between the piping and the well casing. As a result, the electrical wiring needed to be replaced.

3.2.2 Pressure Sensor

The pressure switch and single speed controller were replaced with a pressure sensor and variable speed drive to reduce the torque generated by the well pump at start up and improve the energy efficiency of the system. A new pressure sensor replaced the former pressure switch, while the variable speed drive replaced the single speed pump controller.

The new pressure sensor does not produce noise as it merely sense the water pressure in the system and does not have any moving components.

3.2.3 Variable Speed Pump Controller

The variable speed pump controller generally consists of electronic and computer components. In the process of controlling the well pump capacity, the electrical components generate relatively high frequency sounds in the third octave band frequencies between 5,600 Hz and 8,000, as shown in Figure 10. The sound pressure levels are relatively quiet, but are clearly discernable in a quiet environment.

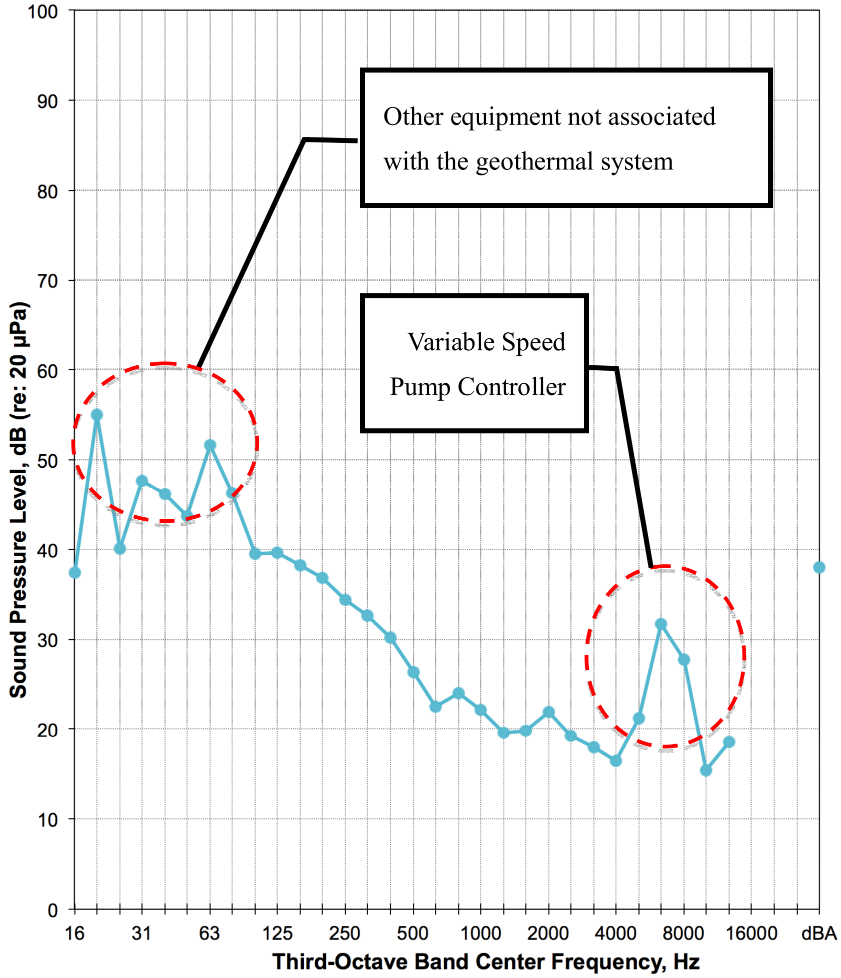


Figure 10 –Variable speed controller after the heat pump is shut down and the system water pressure was approaching the cut out pressure; measured approximately 1 meter (3 feet) from the controller.

The operation of the variable speed pump controller generally varies between 30-60% of the well pump capacity. Within this range of operation, it is noted that the noise of the well pump is no longer audible. However, it is not entirely clear whether this reduction in the well pump noise is due to the new variable speed controller and the slower speed of the pump operating or the replacement of the threaded PVC piping with new poly (HDPE) pipe between the pump and the indoor equipment.

3.3 Zone Control Valves

The noise from the zone control valves varies in several ways described below.

3.3.1 Globe Valve

The system originally operated with the globe valves for zone control of the geothermal systems. Quantitative sound levels of these valves were not measured for this paper. Qualitatively, the valve produced increased noise levels as the valve opened and closed. The valve also generated a significant amount of noise when the valve was open with water flowing at a constant rate. The noise was generated from the turbulence resulting from the water flowing around the globe valve, which has a relatively circuitous flow path. The flow-generated noise was audible along the length of the piping, indicating that it carried either in the wall of the copper pipes or in the water. The loudness of this noise varied based on the quantity of water flow through the valve.

The globe valves recently failed from corrosion and needed to be replaced.

3.3.2 Ball Valve

For a replacement valve, a newer Taco Zone Sentry ball valve was chosen. The new valve was marketed as requiring less power to operate and it offered provided a manual override.

The new valve opens and closes relatively rapidly when allowing the water to flow. Quantitatively, a time history of the sound level of the new ball valve opening and closing is shown in Figure 11. Qualitatively, the sound of the water flow when the valve is opening and closing is significantly louder than the globe valve. Compared with the heat pump sound, the valve sound was measured to be roughly 20 dBA louder. However, the sound level when the valve is open, allowing constant water floor, the water flow noise through the valve is relatively quiet. The quiet sound level is attributed to the valve having very little flow restriction when the valve is open. Given the change to the pump control system, it is also possible that the ball valve noise is lower due to the reduced water flow velocities in the system.

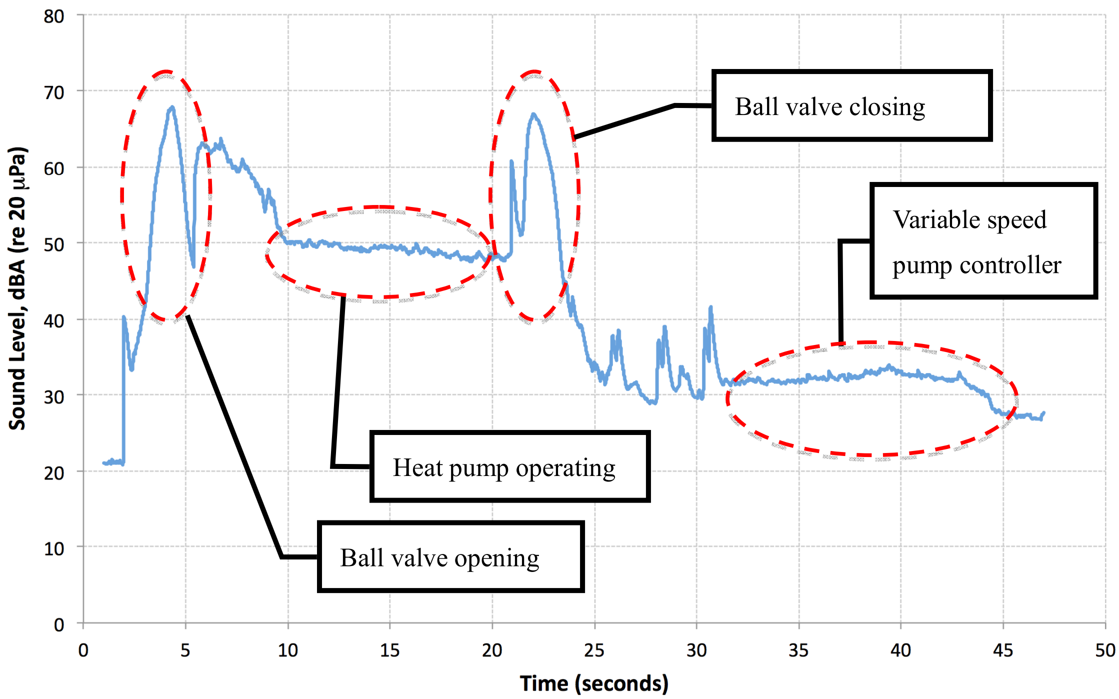


Figure 11 – One cycle of the ball valve opening, heat pump operating and ball valve closing.

4. NOISE AND VIBRATION MITIGATION

The sounds of the geothermal system are relatively quiet in comparison to traditional petroleum based furnaces that include a blower or burner. Despite this quieter sound level, the geothermal system tends to introduce more structureborne noise through the ground water piping that may be fastened to the building structure. This raises the potential concern for mitigation of the airborne and structureborne noise and vibration of the water flow noise.

4.1 Control Systems

4.1.1 Pressure Switch and Single Speed Pump Controller

The impulsive sound of the electrical relay in the pressure switch is common with many HVAC systems. Fortunately, this sound is reasonably well attenuated by most residential demising constructions and therefore this sound should not introduce adverse acoustical impacts to adjacent occupied spaces or require mitigation.

With this pressure switch, the well pump operates at full capacity. The sound of the well pump operating may be audible using threaded sections of PVC piping; poly (HDPE) piping may contribute to lower sound levels from the well pump.

4.1.2 Pressure Sensor and Variable Speed Pump Controller

The sound generated by the variable speed pump controller is relatively high in frequency. Based on sound emissions alone, this controller would not be appropriate to locate within an occupied room, as these sounds, even at their relatively low sound level, would be rather bothersome due to their prevalence of high frequency sounds. Fortunately, these sounds are well attenuated by the architectural demising constructions that are typically used in residences and should not introduce acoustical impacts to adjacent occupied spaces.

4.2 Zone Control Valves

The selection of the type of zone control valve plays an important factor in the potential sound impacts of the ground water systems. These are discussed below.

4.2.1 Globe Valve

Subjectively, the globe valve generated sound levels that were audible, but did not have significant variation over the course of the valve operation. The valve produces somewhat more noise when it is fully open and allowing the water flow to occur. The globe valve has less substantial noise when the valve is opened and closed. Airborne noise mitigation of this valve may be possible using typical residential demising constructions. Mitigation of the structureborne noise and vibration should be handled with resilient plumbing clamps for supporting the associated piping in which the valve is installed.

4.2.2 Ball Valve

The ball valve generates significant noise for the 1-2 seconds while the ball opens and closes. After the valve is opened, the water flow noise through the valve is minimal. Where possible, the location of valve should be selected to avoid placing the valves near noise sensitive spaces within residences. Airborne noise mitigation of the valve noise may be possible with typical residential demising constructions. The mitigation of the structureborne noise and vibration should be handled by using resilient plumbing clamps once a less intrusive valve location has been determined.

5. CONCLUSIONS

The modifications to the ground water system serving the geothermal heat pumps has resulted in both somewhat lower and somewhat higher sound levels from the system under different operating conditions. The substitution of the pressure switch with the pressure sensor removed the impulsive noise generated by the electric relay as the switch engages or disengages the well pump controller. The new variable speed drive reduced the noise of the well pump, by operating the well pump at a lower capacity, but introduced new high frequency noises associated with the controller's electronics, which modulate the pump capacity. The substitution of the original globe valve with the new ball valve reduced the sound levels when the valve is open and water is flowing, but significantly increased the sound when the ball valve opens and closes. In many situations, these changes many have little to no impact for residences, particularly where living spaces are distant from where the equipment is located in the residence, typical residential demising constructions are used and the piping is resiliently supported from the building structure.

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