How to Select Materials

GHP Piping Systems

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In an effort to reduce energy consumption on a larger scale, engineers have started applying the geothermal heat pump (GHP) technology to buildings with larger connected loads in a central plant configuration. It is not uncommon in a central plant system that the aboveground piping selections include steel, iron, copper and PVC. Obviously, the material selections are driven by cost.

Below ground, the material selections are not debatable. Above ground, there are more options. When engineers introduce dissimilar metals into closed-loop hydronic piping systems, improperly address water treatment requirements for their designs, and are not properly informed of the local ground water regulations, water quality problems are created for ground loop systems.

The effect of poor water quality contributes to a decline in mechanical system performance, the creation of maintenance headaches for facilities and maintenance staff and may reduce the useful lifetime of GHP system components. The purpose of this article is to provide the practicing engineer with guidance in the design of the hydronic piping system with a focus on maintaining hydronic system water quality.

Background

Historically, GHP systems were limited mostly to residential applications. Schools were the next segment of the market to adopt the technology with their simple distributed designs to condition classrooms with residential size heat pumps. Potable water or an antifreeze solution, depending upon geographical location, is circulated between the ground loop and the heat pumps in the school.

As application of GHP technology continues to grow so does the need to educate the engineers who design and specify these systems. While there is some guidance in the *ASHRAE Handbook* chapters on geothermal energy and water treatment,[1] there is little detailed information to assist the engineer with the proper selection of aboveground piping system materials and the circulating heat transfer fluids. In some cases, this can be attributed to the varying standards governing local, state and federal GHP installations. It may also be the result of engineers' lack of experience in considering issues encountered outside the building perimeter.

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For more than 20 years, the standard for the ground loop pipe has been high density polyethylene. Since the pipe is in the ground and warranted for up to 50 years, it is required that the piping materials only be fusion welded. For this reason, the current International Ground Source Heat Pump Association[2] Design and Installation Standards lists only high density polyethylene (HDPE) or cross-linked polyethylene (PEX-a) for buried pipe.[2] In most cases, this pipe is buried without insulation. Once this pipe is terminated above ground into the mechanical room for connection to a building system, the challenge begins.

It is the responsibility of the design engineer to select the proper piping materials for each application and to select only those materials allowed by code.[3] Design engineers must also be well-versed in the pros and cons of each type of piping material or piping system selected. As noted previously, it is common in large building systems that the aboveground piping specifications will include steel, iron, copper and PVC. Where the hydronic mains are 4 in. (102 mm) or larger, it is often more cost-effective to specify steel pipe. Specifying steel pipe may require some type of water treatment to inhibit general corrosion and dielectric isolation when connected to geothermal heat pumps.

Another scenario where dissimilar piping materials may be encountered is a retrofit project. Often, engineers are working with a client to integrate all, or part, of an existing building system with a ground loop. If the existing system components are steel, it is likely that the system is already provided with a chemical treatment regimen, and this will require the treated water to be circulated through the ground loop. So why is any of this a problem?

Water Treatment Systems

The standard working fluid in small residential closed-loop piping systems is either potable water or an antifreeze solution to protect the system in colder regions from freezing. Where required, the antifreeze solution is introduced after the ground loop is properly pressure-tested, flushed and purged of debris and air. There has been little problem with, or concern about, water quality in these

GHP systems, since the piping materials have historically been HDPE, copper and stainless-steel hose kits for final connection at the heat pumps.

In the larger building systems, this issue of managing piping systems of different materials hasn't been a big concern. Many options exist for managing the water treatment of the working fluids in these systems. The type of chemicals used for water treatment in closed loop systems is based on several criteria including, the materials being protected, the quality of the water in the piping system, local regulations, and cost. These systems are typically specified to include a rigorous process for cleaning the distribution piping, flushing the piping systems of air and debris and then adjusting the water quality of the final "local" water to meet the long-term performance requirements of the building systems. The chemicals used to adjust water quality for these larger systems are often not acceptable for use when the circulating fluid is also connected to a ground loop. While this is not a problem unless there is a pipe failure or problem with the ground loop, a *potential* leak is starting to concern some of the folks tasked with protecting our groundwater resources.

Photo 1: Ground loop and building systems must be properly flushed and purged of debris. Debris clogs system equipment and biological material contributes to a drop in water pH as it decays.

Heat Transfer Fluids

The regulatory authority appointed to protect groundwater resources varies from state to state. In California, the State Water Resources Board and Counties have the authority to define and enforce regulations regarding the well (ground-loop) construction. The State Department of Health Services or local authority is given the responsibility for maintaining the highest quality of water (i.e., through water providers or districts) for the communities they serve. California's Draft Ground Heat Exchanger Well Standard currently allows for potable water or antifreeze solutions that comply with IGSHPA.[2] Some of the more stringent guidelines in California allow only potable water to be circulated through closed loop pipe due to the planned proximity to shallow drinking water aquifers.

The problem with potable water is that it has varying levels of quality, depending upon the resource. Because of this, the EPA has established drinking water standards.[4] In many states, such as California, more stringent regulations are in place. In any case, potability does not imply acceptability for use in a mechanical system. Water chemistry is one contributor to corrosion and water quality problems in closed-loop piping systems.[5] This means that the engineer needs to be more precise when creating hydronic piping system specifications. "Fill with potable water" is no longer sufficient.

In Washington state, currently no regulation specifies what fluid can be used in a closed loop system.[6] When the system is permitted, the local, state or federal agencies can specify the fluid as a permit condition. Each permit application is reviewed on a case-by-case basis.

In Missouri, the regulation of the heat transfer fluid is very specific and aligns closely with what is published by Heinonen and Tapscot[7] (an ASHRAE-sponsored research project completed in 1996). Their research looked in detail at the impacts of different antifreeze solutions from the energy, environmental and safety perspectives. This information has also been incorporated into the IGSHPA Standards[2] and the National Ground Water Association (NGWA) Guidelines.[8] Instead of being specific about the type of working fluids permitted, the properties of the fluid are listed for compliance. The section of interest follows.[9]

"*(B) The fluid as it is used in a diluted state in the closed-loop must have the following properties:*

1. Be 90% biodegradable;

2. Demonstrate low corrosion to all materials common to ground source heat pump systems;

3. Be homogeneous, uniform in color, free from lumps, skins and foreign material that would be detrimental to fluid usage;

4. Not have a flash point lower than 194°F (90°C);

5. Not have a five-day biological oxygen demand (BOD) at 50°F (10°C) that exceeds two-tenths gram oxygen per gram nor be less than one-tenth gram oxygen per gram;

6. Not have a toxicity that is less than lethal dose (LD) 50 oral-rats of five grams per kilogram;

7. Show neither separation from exposure to heat or cold, nor show an increase in turbidity; and

(C) While this rule attempts to define antifreeze fluids that will protect the environment, it is the responsibility of the permittee to become familiar with safe and proper use of these fluids and to take necessary precautions to ensure groundwater protection."

In the "Live Free or Die" state of New Hampshire, the Department of Environmental Services was recently given statutory authority to regulate the type of fluids used in geothermal heat pump systems. The drafted rules are out for public comment.

Equally important to understanding the building codes is a comprehensive knowledge of the local regulations governing the protection of groundwater when designing GHP systems.

Recommendations

To assist those who may be designing GHP systems and to ensure the continued success of the technology, the following guidance is provided.

1. Before the design of a GHP system begins, consult the local regulatory agency for guidance on requirements related to the ground loop portion. In many locations, this may be the Departments of Health or Environmental Services. Drilling for a vertical closed loop system may not be allowed. Local groundwater conditions may limit the use of certain working fluids due to the sensitive nature of the resource and the concern for contamination.

2. Conform to applicable codes for addition of non-potable chemicals to building mechanical piping systems and for any discharge to public sewage systems.

3. Note that corrosion occurs at some level in all hydronic systems. The best GHP distribution system is one which includes only HDPE. While this is not always practical, it is the one material that contributes least to system corrosion due to piping materials. Breaking the piping the system down into subcentral or individual loops may accommodate the use of all polyethylene in large buildings.

4. Fittings, valves, specialties and pumps perform best when their main components that come in contact with the water are stainless steel or bronze.

5. Even though the piping system is designed to be closed loop, it is possible for air to be introduced due to the expansion and contraction of the pipe and the occasional addition of makeup water. For suspended gasses in fluid, it is recommended that some type of deaeration is provided to reduce the potential for corrosion. Typically, this is done through air separators being installed prior to the pumps with an expansion tank. For dissolved gasses, particularly oxygen, the problem can only be addressed with chemical treatment.

6. It is *very* important that all ground loop and building systems are properly flushed and purged of debris. Not only will debris clog system equipment (*Photo 1*), but biological material contributes to a drop in water pH as it decays. The relationship between biological material and pH is that in areas of accumulated biological material, an anaerobic zone can be created between the foreign material and the pipe wall and an extremely low pH can develop.

7. Take a water sample of the local potable water supply if it is planned to be used as a basis of the working fluid for the hydronic system. If dissimilar metals are used and/or the local water quality is poor, solicit the assistance of a water-treatment specialist to assist in the selection of a water treatment regimen for the system.

8. If a chemical pot feeder is added into the system as a place to introduce the chemicals for the hydronic system, include an integral filter. The filter will help to maintain water quality and removes residual debris, which may break loose after the system has been properly flushed and purged.

9. If propylene glycol is to be used as an antifreeze, note that propylene glycol at less than 20% may promote bacterial growth. Check this percentage with the supplier.[8]

References

1. ASHRAE. 2011. *ASHRAE Handbook—HVAC Applications*, Chapters 34 and 49.

2. IGSHPA. 2011. International Ground Source Heat Pump Association, *Closed Loop/Geothermal Heat Pump Systems—Design and Installation Standards*.

3. IMC. 2009. International Mechanical Code, Chapter 12 – Hydronic Piping.

4. EPA. 2012. http://water.epa.gov/lawsregs/rulesregs/sdwa/currentregulations.

5. Rafferty, K. 2012. Telephone interview, November 14.

6. Governor's Office of Regulatory Assistance, November 8, 2012, Department of Ecology NWRO, Bellevue, Wash.

7. Heinonen, E.W., R.E. Tapscott. 1996. *Assessment of Anti-Freeze Solutions for Ground-Source Heat Pump Systems*, ASHRAE RP-908.

8. National Ground Water Association. 2010. *Guidelines for the Construction of Loop Wells for Vertical Closed Loop Ground Source Heat Pump Systems*, Appendix A.

9. Missouri Department of Natural Resources. 2009. *Missouri Well Construction Rules*, "Heat Transfer Fluid," Chapter 5-4.

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