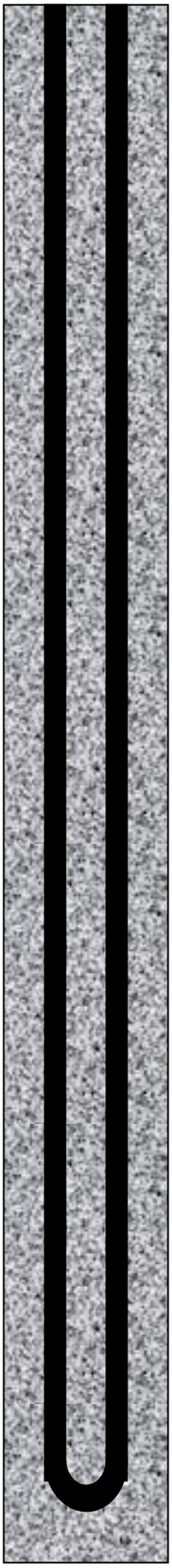
Best Practices for Geothermal Vertical Closed-Loop Installations



Michigan Department of Environmental Quality
Office of Drinking Water and Municipal Assistance
Noncommunity & Private Drinking Water Supplies Unit

April 2010

August 2015
Contact Information Updated

Michigan Department of Environmental Quality
Office of Drinking Water and Municipal Assistance

Best Practices for Geothermal Vertical Closed-Loop Installations

TABLE OF CONTENTS

Introduction

Geothermal heat pumps are being installed in increasing numbers due to their high energy efficiency and tax incentives. The United States (US) Department of Energy states that geothermal heat pumps have the lowest operating costs of all conventional heating/cooling technologies. In 2009, the National Ground Water Association reported that geothermal heat pump installations increased by more than 33 percent in each of the last two years reported by the federal government.

Vertical closed-loops (VCLs) are a type of heat exchanger used with many geothermal heat pump systems. They are often drilled to a depth of several hundred feet and penetrate drinking water aquifers. Large geothermal heat pump system projects for public buildings or commercial purposes use a series of dozens (or hundreds) of VCLs installed in a grid pattern. Each VCL consists of a borehole constructed with a conventional well drilling rig, into which a loop of flexible high-density polyethylene plastic pipe is inserted. The closed-loop piping contains a nontoxic or low toxicity heat transfer fluid that recirculates under pressure through the loop piping and heat pump. The fluid transfers heat from the earth to the heat pump and building interior during the heating season and moves heat into the earth from the building interior during the cooling season.

While conscientious, well trained professional installers construct VCLs in a safe manner, VCLs pose a threat to aquifers and nearby drinking water wells if improperly installed or abandoned. Among the public health and environmental concerns with VCL installations are:

- Improper grouting (sealing) or failure to grout the void space between VCL piping and the borehole can cause aquifer contamination, commingling of water from different aquifers, or loss of natural artesian pressure.

- Closed-loops taken out of service pose a threat unless the antifreeze heat transfer fluid is flushed out and the loops are properly plugged.

- Closed-loop installation sites need review beforehand to ensure that installations do not occur on sites of environmental contamination and that adequate setback from water wells, on-site wastewater systems, property boundaries, etc., is provided.

- A uniform statewide process is needed to record the location and construction details of VCLs. Knowing the location of VCLs before onsite excavation occurs will minimize damage of loops, thereby reducing the occurrence of heat transfer fluid releases, and assist with the placement of wastewater systems, water supply wells, building additions, and outbuildings.

Similar public health and environmental concerns are addressed in Michigan's longstanding regulations for water well construction. However, they are not currently addressed under Michigan's limited regulations pertaining to geothermal closed-loops. No state law or code addresses the need to grout the VCLs, how to seal them if they are no longer used, nor is there a requirement to record where or how they are being installed. State standards addressing the type of pipe used for VCLs, pipe joining methods, and pressure testing are contained within the Mechanical Code adopted under the Forbes Mechanical Contractors Act, 1984 PA 192, MCL 338.971, which is implemented by the Michigan Department of Licensing and Regulatory Affairs (MDLARA), Bureau of Construction Codes.

Past attempts to regulate geothermal closed-loops in Michigan have been unsuccessful. House Bill (HB) 4093 in the 1999-2000 legislative session, HB 4117 in the 2001-02 session, and HB 4295 in the 2003-04 session included geothermal closed-loops along with the various "geotechnical wells" to be covered by the proposed legislation. In the absence of a state regulation, about 30 counties amended their water well permitting programs to enable them to oversee VCL installations.

Best Practices Development Process

The practices recommended in this document are the result of the involvement and dedication of dozens of individuals from industry organizations and state and local public health agencies. In early 2009, the Michigan Department of Environmental Quality (MDEQ), (formerly the Michigan Department of Natural Resources and Environmental), began a stakeholder process to explore industry practices, discuss public health and environmental concerns, and formulate a regulatory plan of response.

The **Geothermal Heat Pump Stakeholder Forum** met five times over a nine-month period in 2009. The following organizations and agencies participated in the open, consensus-building stakeholder process:

1. Michigan Geothermal Energy Association
2. Michigan Ground Water Association
3. Michigan Association of Local Environmental Health Administrators
4. Michigan Plumbing and Mechanical Contractors Association
5. Michigan Environmental Health Association
6. MDLARA, Michigan Agency for Energy
7. MDLARA, Bureau of Construction Codes, Mechanical Division
8. MDEQ

Among the numerous topics discussed during the stakeholder meetings were (1) minimum qualifications of VCL installers, (2) training opportunities for installer accreditation, (3) minimum separation distances from contamination sources; buildings, property lines, etc., (4) installation of direct-exchange system, (5) heat transfer fluids, (6) methods for accurately recording the locations and construction details of VCL installations, (7) grouting field practices, (8) grout limitations and advantages under different geological settings, (9) grout thermal conductivities and hydraulic conductivities, (10) interactions between piping and grout due to thermal cycling, (11) borehole completion methods, and (12) closed-loop decommissioning techniques.

Participants were urged to submit position papers, suggestions outlining a regulatory plan, and to comment on various drafts prepared by MDEQ staff. Throughout the project written comments submitted to the MDEQ were shared with stakeholders for their review and input. This open approach enabled those who participated in the meetings to review comments from those who only communicated directly with MDEQ staff outside of the committee setting.

The industry practices recommended in this document are aimed at addressing public health and environmental concerns. A goal is to provide statewide uniformity on an interim basis until legislation can be enacted that incorporates these practices into law.

Note: These recommendations focus on protecting groundwater and drinking water supplies and do not include all design aspects necessary for optimal operation of a geothermal heat pump system.

Definitions

Bentonite grout - means a slurry consisting of sodium montmorillonite bentonite and water with a solids concentration of not less than 20 percent. A slurry of drilling fluid bentonite and water or drilled cuttings, either singularly or in combination, is not bentonite grout.

Cementitious grout - means a mixture of the following components, or other cement-based admixtures designed for geothermal applications as recommended by the department prior to use:

1. Six and two-tenths (6.2) gallons of fresh water.

2. Two hundred (200) pounds of silica sand with not less than 80 percent of the sand having a diameter smaller than 0.0117 inches and passing through a US Sieve #50.

3. One (1) pound of 200-mesh sodium montmorillonite bentonite.

4. Ninety-four (94) pounds of Type I Portland cement conforming to ASTM International Standard C150 – 07, Standard Specification for Portland Cement.

5. A Type F water reducing admixture or plasticizer conforming to ASTM International Standard C494/C494M – 08a, Standard Specification for Chemical Admixtures for Concrete. Refer to the NSF/ANSI Standard 60 – 2005 - Drinking Water Treatment Chemicals - Health Effects product listing for recommended maximum use levels.

Concrete grout - means a mixture of cement, sand, and water in the proportion of one (1) bag of cement (94 pounds), an equal volume of one (1) cubic foot of dry sand or gravel aggregate, and not more than six (6) gallons of fresh water.

Department – means the Michigan Department of Environmental Quality.

Geothermal heat pump system - means a mechanical system for space heating or cooling that relies on the transfer of thermal energy between the earth and a heat transfer fluid and consists of a heat pump, a heat exchange well, and a heat distribution network.

Heat exchange well - means a well or excavation for the purpose of utilizing the geothermal properties of subterranean geologic materials for heating or cooling with a geothermal heat pump system.

Horizontal closed-loop - means a heat exchange well consisting of a loop of sealed piping installed horizontally at a depth of less than 15 feet below the ground surface.

Neat cement grout - means a mixture of one (1) bag of Portland cement (94 pounds) and not more than six (6) gallons of fresh water. Drilling fluid bentonite that is not more than five (5) percent by weight of cement and additional water that is not more than 0.6 gallons for each one (1) percent of bentonite may be added to neat cement grout.

Thermally-conductive bentonite grout - means a bentonite grout, into which silica sand or other materials approved by the department have been added to improve the thermal characteristics for geothermal applications, with a minimum solids content of 60 percent.

Vertical closed-loop - means a heat exchange well consisting of a loop of sealed piping installed either singularly, or in a series or parallel pattern, or other devices installed in the earth in boreholes in a vertical, angled, or diagonal configuration, extending 15 feet or more below the ground surface, for the purpose of transferring heat between a building space and the earth in a geothermal heat pump system.

Vertical closed-loop contractor - means a person qualified to engage in the business of constructing, installing, repairing, or decommissioning VCLs or other heat exchange wells. "Vertical closed-loop contractor" does not include an employee of a vertical closed-loop contractor or a contractor who installs horizontal closed-loops.

Qualifications of Installers

Before engaging in the business of constructing VCLs, an installer should possess both of the following:

1 A Certificate of Registration as a Water Well Drilling Contractor in accordance with the procedures in Part 127, Water Supply and Sewer Systems, of the Public Health Code, 1978 PA 368, MCL 333.12701 to 333.12771.

2. Accreditation as a geothermal installer or VCL driller by the International Ground Source Heat Pump Association (IGSHPA) , 374 Cordell South, Oklahoma State University, Stillwater Oklahoma, 74078-8018, or an equivalent accreditation or certification from a nationally-recognized organization, as determined by the department.

A person who meet meets the preceding qualifications may install VCL piping but is not authorized to install horizontal header or manifold piping unless that person also possesses a valid license under the Forbes Mechanical Contractors Act, 1984 PA 192, MCL 338.971. The Forbes Mechanical Contractors Act is implemented by the Michigan Department of Licensing and Regulatory Affairs, Bureau of Construction Codes (See References).

The installation of a VCL system should be supervised by a person who is IGSHPA accredited as a geothermal installer or VCL driller, who is contracted by a licensed mechanical contractor. The supervisor should assure compliance with the practices described herein.

Notification Before Installation

Mechanical contractors and VCL installers should notify their local health department (county or district health department) before installing a geothermal heat pump system. Some local health departments adopted ordinances requiring that a construction permit be obtained before installing a geothermal VCL or an open-loop system. These permits are separate from the mechanical permits required statewide for the installation of the geothermal heat pump. Installers must comply with local ordinances and may be subject to civil penalties or other local enforcement actions if they fail to do so. It may be necessary to vary VCL construction, notification or reporting practices from those described in this document, in order to comply with local codes.

Not less than seven (7) business days before starting to install a vertical closed-loop, the property owner or his or her authorized representative (installer) should furnish the local health department with detailed plans of the proposed VCL installation using the **Geothermal Closed-Loop Construction Notice** form in the Appendix.

Evaluation of the proposed VCL installation site before beginning construction should include a thorough search to locate known contamination sites and assure that setback distances are met. VCL installation may not be appropriate in cases where a contaminant plume will be penetrated or a contamination remediation project is in progress. The Environmental Mapper website at http://www.mcgi.state.mi.us/environmentalmapper/ is recommended for determining if contamination sites are in the vicinity of the proposed VCL installation. Mapping out the location of on-site features such as permanent structures, water wells, on-site wastewater disposal systems, underground pipes, and utilities (buried and overhead) will help assure that damage and disruption of services does not occur during the installation.

If the submitted information shows that the installation is contrary to these best practices or may influence the movement or occurrence of groundwater contamination, the property owner should be promptly notified in writing. Discussion should take place among the parties (owner, installer, and regulatory agency) to resolve any issues of concern before the installation begins.

Reporting of Installation Details

After completing the installation of a VCL, the contractor should provide the property owner, local health department, and the department with a record of the installation that includes at least the following information:

1. A dimensioned site layout showing the distances between buried VCL piping and permanent structures, water wells, on-site wastewater systems, utility lines, roadways, and property lines.

2. The depth and diameter of VCL piping.

3. Latitude and longitude coordinates of all VCLs using a global positioning system. The coordinates should be reported in decimal degrees with accuracy to five (5) decimal places.

4. The volume, concentration, and chemical type of heat transfer fluid in the VCLs.

It is recommended that the construction report (use the **Geothermal Closed-Loop Construction Notice** form in the Appendix) be submitted by the mechanical contractor or VCL installer within 60 days following completion of the installation.

Location of Vertical Closed-Loops

The following minimum horizontal separation distances should be maintained when installing a vertical (or horizontal) closed-loop:

- 50 feet from a household drinking water well.
- 75 feet from a Type IIb or Type III public water supply well, as defined in R 325.10502 of the Michigan Administrative Code (MAC).
- 200 feet from a Type I or Type IIa public water supply well, as defined in R 325.10502 of the MAC.
- 25 feet from an on-site wastewater system serving a single-family dwelling.
- 10 feet from a buried water service line or sewer line.
- 10 feet from a property boundary.

Water lines and sewer lines that are crossed by VCL piping or header piping should be protected by insulation and not less than 3 feet of separation.

Local health department permitting ordinances may require different minimum horizontal separation distances.

Vertical Closed-Loop Piping

The Standard Dimension Ratio and working pressure rating of VCL piping should be sufficient to accommodate system prepressurization and the total dynamic head. The total system pressure should remain below the working pressure of the pipe.

VCL piping materials, joining methods, and pressure testing before backfilling or grouting shall adhere to the following provisions of the Michigan Residential Code (MRC), R 408.30401 of the MAC:

> ***M2104.2.1 Polyethylene plastic pipe and tubing for ground source heat pump loop systems.*** *Joints between polyethylene plastic pipe and tubing or fittings for ground source heat pump systems shall be heat fusion joints conforming to Section M2104.2.1.1, electrofusion joints conforming to M2104.2.1.2, or stab-type insertion joints conforming to M2104.2.1.3.*
>
> > ***M2014.2.1.1. Heat-fusion joints.*** *Joints shall be of the socket-fusion, saddle fusion or butt fusion type, fabricated in accordance with the piping manufacturer's instructions. Joint surfaces shall be clean and free of moisture. Joint surfaces shall be heated to melt temperatures and joined. The joint shall be undisturbed until cool. Fittings shall be manufactured in accordance with ASTM D 2683.*

M2104.2.1.2. Electrofusion joints. *Joint surfaces shall be clean and free of moisture, and scoured to expose virgin resin. Joint surfaces shall be heated to melt temperatures for the period of time specified by the manufacturer. The joint shall be undisturbed until cool. Fittings shall be manufactured in accordance with ASTM F 1055.*

M2104.2.1.3. Stab-type insert fittings. *Joint surfaces shall be clean and free of moisture. Pipe ends shall be chamfered and inserted into the fitting to full depth. Fittings shall be manufactured in accordance with ASTM D 2513.*

M2105.1. *The assembled loop system shall be pressure tested with water at 100 psi (690 kPa) for 30 minutes with no leaks observed before connection (header) trenches are backfilled. Flow rates and pressure drops shall be compared to calculated values. If actual flow rate or pressure drop figures differ from calculated values by more than 10 percent, the problem shall be identified and corrected.*

Polyethylene piping and tubing used in a vertical closed-loop borehole should be factory assembled and pretested prior to insertion into the borehole. Spacing devices intended to place VCL piping in direct contact with the borehole wall should not be used.

Copper piping for direct exchange geothermal VCLs should not be used unless the grout/piping combination has been shown by a third party testing laboratory to not result in pipe corrosion and testing reports have been submitted to the department.

Borehole Construction

During construction of a borehole for a VCL installation, drilling fluid consisting of a bentonite clay viscosifier and water mixture should be circulated to form a filter cake on the borehole wall to minimize borehole collapse. The borehole should be kept full of bentonite drilling fluid until the loop piping is installed. Before grouting, the drilling fluid in the borehole should be thinned until the drilling fluid density is lower than the grout density.

Surface water should not be used as a source of water during the drilling of a VCL borehole unless it is obtained from a municipal water supply system. Water that is used for drilling purposes should be potable water that contains a free chlorine residual of not less than 10 milligrams per liter. Chlorine test strips are a quick and convenient way to check chlorine residual levels.

Grouting of Vertical Closed-Loops

The following provisions are recommended for grouting (sealing) of the void space between the piping and borehole of a VCL:

1. Grouting is to be completed in a manner that prevents the introduction of surface or near surface contaminants into an aquifer, the interchange of water from different aquifers, or the loss of natural artesian pressure from an aquifer.

2. The void space between the VCL piping and the borehole should be grouted in a continuous operation from bottom to top using grout placement procedures set forth in the Groundwater Quality Control Rules, R 325.1601 of the MAC or the IGSHPA Grouting for Vertical Heat Pump Systems, Engineering Design and Field Manual, 2000.

3. A tremie pipe (grout pipe) not less than 1.25 inches nominal diameter should be placed to the bottom of the borehole before grouting. The tremie pipe may be used to push the closed-loop piping into the borehole and should be retracted as grouting proceeds. The tremie pipe should be removed from the borehole upon completion of grouting.

4. Grout should be pumped through the tremie pipe until the density of the grout flowing from the borehole at the ground surface equals the density of the grout being pumped in.

5. Each VCL borehole should be grouted upon completion. The contractor should monitor each borehole for settling for a period of not less than 12 hours. Additional grout should be added and the monitoring period shall be extended until the settling of grout stops.

6. A VCL borehole drilled using horizontal directional drilling techniques should be grouted by pumping grout as the tremie pipe is retracted through the borehole.

7. Grout manufacturers' product specifications should be followed when mixing and pumping grout.

Grout Selection

The following table should be used to select an appropriate grouting material, based on the geological conditions expected to be encountered during the VCL installation.

Geological Conditions	Recommended Grouts
Saturated unconsolidated sand, gravel, clay, or a combination thereof	Neat cement grout Cementitious grout Concrete grout Bentonite grout Thermally-conductive bentonite grout
Unsaturated, unconsolidated sand, gravel, clay, or a combination thereof	Neat cement grout Concrete grout Cementitious grout Thermally-conductive bentonite grout
Consolidated geologic formations, such as sandstone, shale, limestone, dolomite, granite, schist, or conglomerates	Neat cement grout Cementitious grout Concrete grout.

Geological Conditions continued	Recommended Grouts continued
Fractured, crevised, jointed, or cavernous limestone	Neat cement grout Cementitious grout Concrete grout If lost circulation zones are encountered, grouting in the bedrock lost circulation zones may be conducted using a mixture of cementitious grout and clean peastone aggregate, or layered with a combination of either cementitious grout or neat cement grout and short intervals of bentonite chips or clean peastone aggregate
Flowing artesian groundwater, methane or other subterranean gas, or groundwater with total hardness over 500 milligrams per liter (mg.l) or chloride over 1,500 mg/l	Neat cement grout Cementitious grout Concrete grout

To minimize potential leaching of chemical constituents into an aquifer, grouts, drilling fluids, and additives to grouts and drilling fluids, including sand added to grout as a thermal-enhancer for VCL applications, should meet NSF/ANSI Standard 60 – 2005, Drinking Water Treatment Chemicals – Health Effects.

The maximum allowable permeability value of the set grout should be 1×10^{-7} centimeters per second, as determined in accordance with ASTM D5084-03, Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter.

The Appendix contains a listing of geothermal grouts that shows thermal conductivity figures and other characteristics as determined by the manufacturer..

Heat Transfer Fluids

Heat transfer fluids used in a VCL should be one of the following:

1. Food-grade propylene glycol-water solution at a concentration specified by the product manufacturer.

2. Methanol-water solution up to 20 percent methanol by volume.

3. Ethanol-water solution up to 20 percent ethanol by volume.

4. Nontoxic compounds meeting IGSHPA Closed-Loop/Geothermal Heat Pump Systems, Design, and Installation Standards, 2009 Edition, Section 3B and 3C, and which are compatible with heat pump manufacturers' specifications.

Water used to dilute the antifreeze heat transfer fluids should be of potable quality. Final heat transfer fluid solutions should not be flammable.

A VCL for a direct exchange geothermal system should use only a nonozone depleting refrigerant such as R-410A, R-407C, R-22, or an equally safe refrigerant as specified by the heat pump manufacturer, as a heat transfer fluid.

A geothermal heat pump system using a VCL should have a permanent label at the loop charging valve identifying the antifreeze type and concentration, service date, and the name and phone number of the service company.

Backflow Prevention

A temporary water line connected to a flush and fill port of a closed-loop must be protected with a backflow prevention device as specified in Section P2902 of the Michigan Residential Code, R 408.30401 of the MAC or Section 608.1 of the Michigan Plumbing Code, R 408.30701 of the Michigan Administrative Code.

Decommissioning of Vertical Closed Loops

A VCL that is leaking or is no longer used should be decommissioned by flushing the heat exchange fluid with air and completely filling the loop or loop field and header piping with grout. Proper disposal of the heat exchange fluid in accordance with applicable state waste disposal regulations is expected. Decommissioning of the closed-loop piping should be completed by a Michigan Registered Water Well Drilling Contractor or an IGSHPA accredited geothermal installer or vertical loop installer.

The contractor who decommissioned the loop should furnish the property owner, the local health department, and the department with a record of the decommissioning procedure within 30 days after the decommissioning is completed.

Permit Requirements

A permit pursuant to the Natural Resources and Environmental Protection Act, 1994 PA 451, is required to be obtained from the MDEQ if the VCL or header piping connected to a VCL is to be installed at or near the land/water interface. Specifically, a permit is needed if the VCL is proposed to be installed in a wetland, or within a 100-year floodplain, critical dune area, or high-risk erosion area. A permit application (Form EQP 2731) is available from the MDEQ website. If a VCL installation will disturb over one (1) acre of land or is within 500 feet of a water body (lake, river, stream), a soil erosion and sedimentation permit must be obtained from the county soil erosion agency (typically within the building department or drain commissioner's office) or from the local health department.

Contact Information

If you have questions, please contact:
Michigan Department of Environmental Quality
Office of Drinking Water and Municipal Assistance
Environmental Health Section
Noncommunity and Private Drinking Water Supplies Unit
Well Construction Program
P.O. Box 30241
Lansing, MI 48909-7741
(517) 284-6542
(517) 241-1328 FAX
http://www.michigan.gov/waterwellconstruction

References

1. International Ground Source Heat Pump Association, Closed-Loop/Geothermal Heat Pump Systems: Design and Installation Standards, 2009 Edition, International Ground Source Heat Pump Association (IGSHPA), 374 Cordell South, Oklahoma State University, Stillwater, OK 74078-8018, website: http://www.igshpa.okstate.edu.

2. Grouting for Vertical Geothermal Heat Pump Systems, Engineering Design and Field Manual, 2000, IGSHPA.

3. Ground Source Heat Pump Residential and Light Commercial Design and Installation Guide, 2009, IGSHPA.

4. Guidelines for the Construction of Vertical Boreholes for Closed-Loops Heat Pump Systems, Second Edition, 2009, National Ground Water Association Press, 601 Dempsey Road, Westerville, OH 43081-8978, website: http://www.ngwa.org.

5. Michigan Water Well Construction and Pump Installation Code, Groundwater Quality Control Rules, R 325.1601 *et seq.,* adopted under authority of Part 127, Water Supply and Sewer Systems, of the Public Health Code, 1978 PA 368, as amended, MCL 333.12701 *et seq*. These regulations are available online at http://www.michigan.gov/deqwaterwellconstruction.

6. NSF/ANSI Standard 60 - 2005 – Drinking Water Treatment Chemicals – Health Effects, NSF International, World Headquarters, 789 North Dixboro Road, Ann Arbor, MI 48105, website: http://www.nsf.org.

7. Forbes Mechanical Contractors Act, Michigan Mechanical Code, and Michigan Residential Code, available from the Michigan Department of Energy, Labor and Economic Growth, Bureau of Construction Codes, Mechanical Division, website: http://michigan.gov/lara/0,4601,7-154-10575_17394_17566---,00.html.

8. ASTM C150 – 07, Standard Specification for Portland Cement, ASTM International, which is available for purchase from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959,
website: http://www.astm.org.

9. ASTM C494/C494M – 08a, Standard Specification for Chemical Admixtures for Concrete, ASTM International.

10. ASTM D 2513, Standard Specification for Thermoplastic Gas Pressure Pipe, Tubing, and Fittings, ASTM International.

11. ASTM D 2683, Standard Specification for Socket –Type Polyethylene Fittings for Outside Diameter-Controlled Polyethylene Pipe and Tubing, ASTM International.

12. ASTM D5084-03, Standard Test Methods for Measurement of Hydraulic Conductivity of Saturate Porous Materials Using a Flexible Wall Permeameter.

13. ASTM F 1055, Standard Specification for Electrofusion Type Polyethylene Fittings for Outside Diameter Controlled Polyethylene Pipe and Tubing, ASTM International.

MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY
OFFICE OF DRINKING WATER AND MUNICIPAL ASSISTANCE

Geothermal Vertical Closed-Loop/Water Well Grout Properties

This listing summarizes product characteristics as reported by grout manufacturers. The MDEQ does not endorse specific products and this listing is not an assurance of product performance.

Product	Mfg.	Permeability	Thermal Conductivity *	NSF-60	Grout Weight	Solids %
Aqua-Grout Benseal	Baroid IDP	1.5×10^{-8} cm/sec	0.39	Yes	9.6	23
Barotherm Gold	Baroid IDP	$<1 \times 10^{-7}$ cm/sec	0.4 to 1.2	Yes	10.1 to 15 lbs/gal	28.1 to 72
Benseal/EZ Mud Slurry	Baroid IDP	1.2×10^{-8} cm/sec	0.43	Yes	9.5 lbs/gal	20
EZ-Seal	Baroid IDP	1×10^{-9} cm/sec	0.41	Yes		15 to 23
Geothermal Grout	CETCO	$<5.2 \times 10^{-9}$ cm/sec	0.4 to 1.40	Yes	10.2 to 14.6 lbs/gal	30.0 to 71.0
High TC Geothermal Grout	CETCO	3.25×10^{-8} to 8.38×10^{-8} cm/sec	0.4 to 1.21	Yes	10.2 to 15.1 lbs/gal	30.0 to 72.0
PureGold Grout	CETCO	1×10^{-7} to 1×10^{-9} cm/sec	0.43	Yes		30
Volclay Granular Grout	CETCO	$<1\text{-}5.2 \times 10^{-8}$ cm/sec	0.43 to 0.90	Yes	11.3 lbs/gal	20 to 40
BH 20 Grout	GeoPro, Inc.	$<1 \times 10^{-7}$ cm/sec	0.42 to 0.45	Yes	9.4 lbs/gal	20.0 to 25.0
Thermal Grout Lite	GeoPro, Inc.	$<6.9 \times 10^{-8}$ cm/sec	0.45 to 1.00	Yes	9.8 to 13.9 lbs/gal	30.0 to 66.0
Thermal Grout Select	GeoPro, Inc.	$<6.9 \times 10^{-8}$ cm/sec	1.00 to 1.20	Yes	14.1 to 14.9 lbs/gal	66.6 to 71.4
Geo Supergrout	SuperGrout Products, LLC	2×10^{-6} to 5×10^{-11} cm/sec	1.0 to 1.1	Yes	15.8 lbs/gal	62.7
Grout-Well	Wyo-Ben	1×10^{-8} cm/sec	0.42	Yes	9.4 to 9.5 lbs/gal	17.7 to 20.0
Therm-Ex Grout	Wyo-Ben	2×10^{-8} to 6×10^{-8} cm/sec	0.93 to 1.05	Yes	13.6 to 14.4 lbs/gal	64.0 to 67.0

* Thermal conductivity rating in Btu/hr ft ^{o}F

Updated 9/2010