Thermal Dynamics, Inc.
Maple Plain, MN 55359

Commissioning Report - Ground Heat Exchanger Testing and Observation

Minnesota Veterans Home – Montevideo, MN

June 28, 2023

Commissioning Report - Ground Heat Exchanger and Observations

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Initial contract date for commissioning services: June 15, 2022

Project Location:

Minnesota Veteran's Home - Montevideo
2190 William Avenue
Montevideo, Minnesota 56265

Commissioning Client and Geothermal Contractor:

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Project Manager:
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Site Supervisor:
Matt Schwartz - 612-250-5632 - IGHSHPA Installer # 2756582, valid until 06/30/2025

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Report Affidavit

This report was prepared by Jeff Walton of Thermal Dynamics Inc. from direct observation, reports and communications with the involved parties that performed the work and designs.

________________________	________________________
Jeff H. Walton	**Date**
Thermal Dynamics Inc	

Initial Project Observations

This project is for the Minnesota Veterans Home in Montevideo, MN and the multi-use care and housing facility will utilize a geothermal heat exchanger for heating and cooling systems. The site was a previously undeveloped parcel.

The design consists of (54) horizontal heat exchangers which are situated in three layers that are ~ 16, 24 and 36 feet below the surface. Each layer consists of (18) loops of 500-foot finished length, spaced 8 feet apart. Each borehole is designed as a directionally drilled path that is grouted to assure expected thermal properties and to seal the borehole from cross connecting any existing water layers.

The installed loops are connected to a geothermal vault, located in the vicinity of the loops using reverse return connections to 3" circuit pipes which are routed to the vault with each circuit connected to (6) supply and return loops. The geothermal vault is connected to the building utility room by a set of valved 8" lines. All (6) supply and (6) return circuits are connected and valved within the geothermal vault.

Once installed: the loops, reverse return connections; the run-ins to the utility room are pressure tested and filled with fluid pending final flushing and installation of proper antifreeze solution.

The system is then flushed to remove any air and debris and filled with a premixed glycol solution. Valves are set to allow operation by the mechanical contractor responsible for the interior building operation.

Observations, samples and photos to be taken in coordination with the work performed by the contractors.

Initial Site Observations

The initial site observation was on June 21, 2022. Bergerson Caswell performed the Horizontal Loop Installations. Noted that the borings were being installed in an open area on the East side of the site which is bordered by a city street on the N; a County Road on the E and a corn field on the S. There are fences on the N and S ends of the site. A holding pond has been excavated directly above the area intended for the loopfield. No driveways or parking areas in the vicinity of the loopfield work have been constructed at the time of the initial drilling.

Figure 1: East Side - Facing N to S

Figure 2: East Site Fence - Facing N to S

Figure 3: Site facing W. Holding Pond in foreground

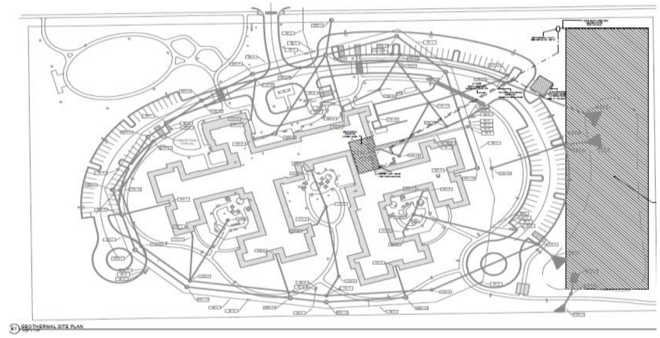


Figure 4:Geothermal Site Plan

Materials, Equipment and Operator

Materials for the project were present on the site and inspected for compliance to the specifications:

- Directional boring machine: Vermeer D24x40. Placarded with 2022 MDH license.
- Operator Matt Schwartz, Bergerson-Caswell. IGHSHPA Installer # 2756582, valid 06/30/2025.
- MDH Permit VL5280 for Bergerson-Caswell to construct BGHE at site issued 1/14/2022.
- Loops: Centennial Plastics – CenFuse HDPE 4710 Earth Loops, 1.25" – 520 foot reels
  Note: reverse rolled with U-Bend to the exterior.
- Piping: Centennial Plastics – CenFuse HDPE 4710 2", 3" pipe
- Fittings: Georg Fischer Central Plastics PE Fusion Fittings - various molded fittings
- Building connections: WL Plastics PE4710 pipe – 8" (already installed) Jan 2022?
- Pro-Line Safety Products – 2" safety marking tape – Caution Buried Geothermal Line Below
- Pro-Line Safety Products – Solid CU HDPE 45 Mil Tracer Wire
- Geothermal Grout: Haliburton Barotherm Gold - Two Part Bentonite Grout
- Grout Enhancer: GeoPro PowerTEC Graphite Grout Enhancer
- Drilling Fluid: Halliburton Baroid – Quik-Bore HDD Drilling Fluid

Figure 5 - Drilling Fluid

Figure 6 – Geothermal Grout

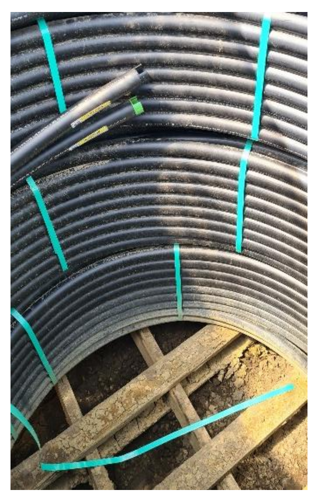


Figure 7- Factory U-Bend Loops - 520'

Figure 8 - Graphite Grout Enhancer

Figure 9 - Factory Loop Markings

Figure 10 - Vermeer D24x40 Horizontal Boring Machine. Licensed for 2022.

Horizontal Loop Drilling and Installation

Site visits for boring, installation of loops and associated observations were made on:

- June 21, 2022
- July 12, 2022
- August 10, 2022

Summary Observation: Directional boring was done from North to South in groups of three. The top borehole at 16-feet depth was drilled first, followed by the 24-foot bore and finally, the 32-foot bore. The next set were marked 8-feet to the west and the process was repeated. The boring was completed with a 5.5” bit and the return pull used an 8” back ream with 5.5” puller. Each bore took 3-3.5 hours to drill and roughly 1 hour to grout. The factory loop U-bend pipes were completely unwound from the reel and stretched out so that the sealed ends could be pulled in first. The reels were reverse wound, which required the loops to unwound so that the U-bend entered the borehole last. The initial location of the first row of boreholes were marked with a stake by the site manager. Subsequent markings were performed by the drilling contractor at 8-foot spacing, moving East to West. Spacings were confirmed by measurement. Subsequent spacings were confirmed by direct measurements on each visit.

Drilling logistics were tricky due to a couple limiting site factors. The available N-S space was restricted by fences on each end. The amount of room available to setup and work was limited by the required finished length of the loop and the drilling angles necessary. To achieve a 500-foot length at the correct depth, both the drilling rig and the grouting machine were up against the fences on each end, which made the job more difficult. Confinement of the drilling mud with limited space meant that the drill was forced to work in the tailings that came to the surface during the pulling of the loop into the borehole. Each depth of boreholes started just a few feet apart at the surface due to the lack of space. The angle of the drilling also made the extraction of the tremie pipe during grouting difficult. A couple early holes were abandoned during the course of the project when the tremie pipe could not be extracted due to the sharp angles. Replacement holes were drilled and offset by a couple feet and amounts of drilling fluid were adjusted. All completed loops checked for length using factory markings.

Figure 11 - Locating. Typical Procedure

Figure 12 - Locating

Figure 13 - Locating w/ DigiTrak F5+

Locating did not encounter any issues with other utilities in the area. A drilling log was retrieved which shows the depths and locations of each borehole. The pond presented difficulties due to deep mud and the need to travel through areas of standing water. A pump was needed to drain water that accumulated. Better planning might have timed the excavation after the loops were installed.

Figure 14 - Locating Challenges with Pond

Figure 15 - A Row of Loops Under Pressure Test for 24 Hrs after Grouting

Figure 16 - Loops Pressure Tested to 80PSI

On completion of each borehole, the loop was pulled back through the borehole along with a third "tremie" pipe which was used for grouting. The pipes were factory capped and pressurized for the insertion process. After the drilling was completed each day, the loops were filled with water and fittings were applied to allow the pipes to be pressurized for a minimum of 24 hours at 80PSI per the specification. In the photos above, this group of three loops are all filled and pressurized.

Borehole Grouting and Sealing

After each loop and tremie pipe was pulled back through the borehole, the borehole was "grouted" to provide good thermal contact with the surrounding soils and to seal the borehole path to prevent any water layers from cross connecting along the path from the surface or any point below the surface. The grout consisted of a mixture of bentonite and graphite mixed with water to a slurry that was pumped into the borehole as the tremie pile was pulled. The contractor used a hydraulic pump and reel system to pull the tremie pipe back through the borehole while pumping the grout. The tremie pipe was pulled some distance back into the borehole before starting the grout pump. When the grout appeared at the surface

Figure 17 - Preparing to Pull the Loop and Tremie Pipe back into the Borehole

Figure 18 - The Tremie Line and Loop Ready to Pull Back Into Borehole

of the open borehole, the tremie pipe was pulled at a steady pace while pumping to provide uniform filling of the borehole and loopfield pipes. The grouting process took roughly one hour per borehole.

Grout was mixed by means of a tank on the grout machine filled with ~45 gallons of water per batch. Each borehole took roughly 5 bags of PowerTec Enhanced Graphite and 15 bags Barotherm Gold grout. The graphite in the grout mix provided a contrast to the drilling fluid and tailings due to the dark mud appearance with the graphite providing a nearly black, shiny appearance to the mud. During the course of the grouting, samples of the grout mix were taken from an outlet on the grouting machine immediately at the beginning of the tremie line. Samples were taken on several visits and were taken at the beginning, middle and end of the mixing to assure uniform mixing was occurring during the grouting process. Samples were analyzed at the end of each visit and also shipped to Halliburton for independent test confirmation.

There were a couple instances in the grouting process where the tremie line could not be successfully pulled back from the borehole due to the sharp angle of drilling which was required due to inadequate space on the jobsite for such long bores. In a couple instances, the Engineer made the decision to require the boreholes to be redrilled and grouted in a new location just above the abandoned boreholes where the pipes were cut off and abandoned.

Figure 19 - Grouting Machine and Operator Extracting Tremie Pipe Using a Hydraulic Reel. Note Proximity to Fence.

Figure 20 - Tremie Pipe Separation. Borehole Angle and Resistance Prevent Successful Grouting of Early Borehole

Figure 21 - A Row of Loops After Grouting

Figure 22 - Loop and Tremie Being Pulled Back Through Borehole

Figure 23 - Evidence of Graphite as Grout is Pumped Into Borehole from Tremie Pipe

There were some issues with the grouting process due to the pond being excavated prior to the loopfield being installed. In addition to the locating job being made difficult, the bottom of the pond was very close to the upper layer of loops at ~16 ft below grade. When boring and grouting is being done, there are tremendous hydraulic pressures from the drilling fluid and from the grout pump and fluids will find the path of least resistance. On multiple occasions, the fluids broke through the bottom of the pond and made grouting coverage of the borehole difficult. There were multiple "break-throughs" of the fluid which caused wasted grout. Grout samples were taken on three different days and tested to assure TC.

Figure 24 - Hydraulic Pressure Breakthrough on Pond Bottom. Note Evidence of Graphite in Grout.

Figure 25 - Hydraulic Pressure Breakthrough on Pond Bottom. Note Evidence of Graphite in Grout.

Geothermal Vault, Building Supply/Return Connection

The Geothermal Vault installation and circuit tie-ins from the loopfield to the vault were done by Bruns Headering. The vault is located directly west of the area where the loops were terminated by the drilling contractor. The vault is installed such that the access cover for maintenance is located at finished grade surface level. The base of the vault was secured by 4-5 yards of concrete for anchoring after the proper elevations were established.

- ISCO Circuit Maker Vault® with metal valves, 8" MAINs, w/(8) 3" CIRCUITS
- Piping: Centennial Plastics – CenFuse HDPE 4710 2", 3" pipe
- Fittings: Georg Fischer Central Plastics PE Fusion Fittings - various molded fittings

Figure 26 - Geothermal Vault after Placement

Figure 27 - Geothermal Vault After Cement Base Applied

Figure 28 – The First 8" Supply/Return Line is Fused to the Vault

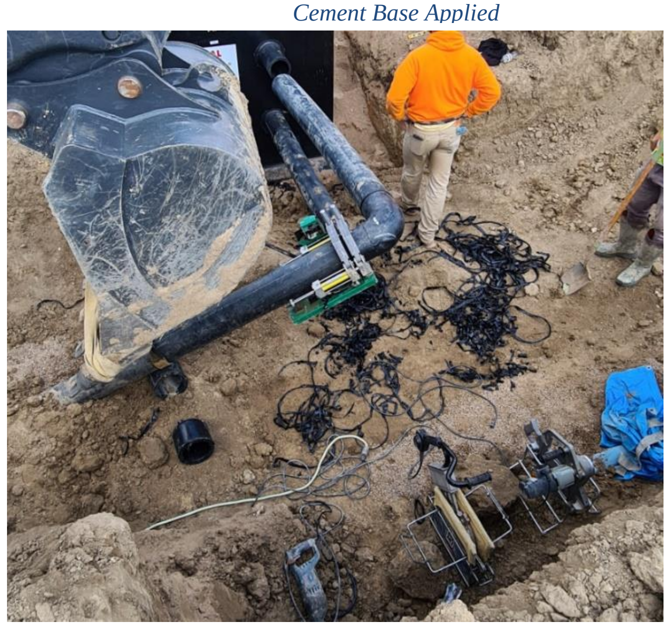


Figure 29 - Geothermal Vault - Preparation to Fuse 8" Supply/Return Lines

Building Supply Return Lines

The 8” Supply/Return lines were the first pipes to be attached to the geothermal vault and the process was observed for preparation, pressure, temperature and cleanliness of the pipe and surfaces.

Figure 30 - Fusion Preparation for the 8" Return Line to the Geothermal Vault

Figure 31 – Checking the Fusion Pressure

The 8” Supply/Return fusions were observed and inspected for the roll and uniformity.

Figure 32 – Supply/Return Fusion of 8" HDPE Pipe

Figure 33 – Supply/Return Fusion of 8" HDPE Pipe

The installation of the 8” Supply/Return Lines was actually completed in January of 2022, prior to the contracting for the Commissioning process. The geothermal contractor, Bergerson Caswell provided photos of the installation and pipe fusion work. The trenching work was completed and the pipes were fused and laid in the trenches from the vault location to the entry where the future mechanical room would be in the building.

Figure 34 – Trench Excavation for 8” Supply/Return Lines (1/18/2022)

Figure 35 – 8” Pipe Prepared for Fusion

Figure 36 – Fusion Process for 8” Line

Figure 37 – Completed 8” Fusion Joint

The correct lengths and angles were fabricated so that the bulk of the pipe could be fused at the surface and lowered into the trench as a finished unit.

Figure 38 – Pre-fused 8" Lines Ready to be Placed in Trench Between Building and Vault

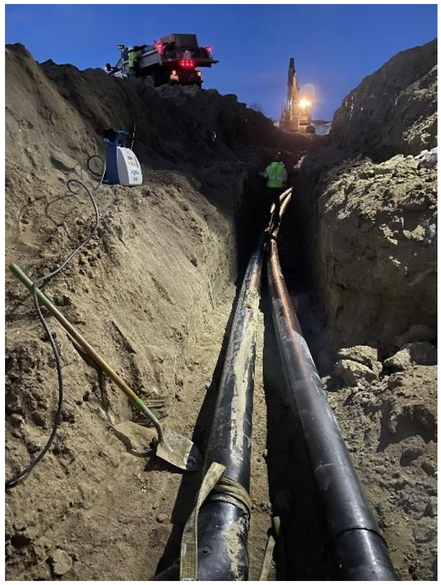


Figure 39 – Lines Lowered and Placed into Trench

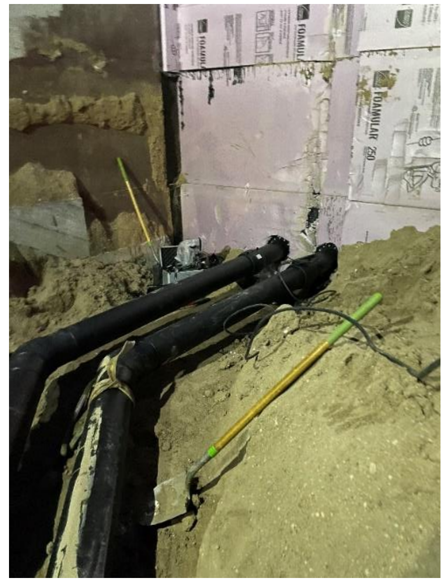


Figure 40 – Lines Entering Foundation to Mechanical Room and Bedded into Trench

Loopfield Circuit – Tie-Ins

The 54 loops are connected to the Geothermal Vault in six sets of reverse supply/return circuits that enter the vault in 3" HDPE pipes. The factory loops are excavated to the ~ 12-foot deep level to expose the layers of pipes for connection to the circuits. The HDPE circuit pipes consist of a series of 3" pipes that are stepped down to the 1.25" loop size through a series of reducing tees that are fused together to create a circuit that balances the flow through the loops on each end of the circuit.

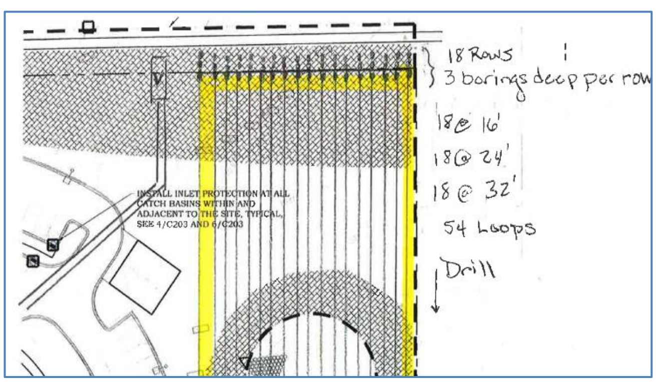


Figure 41 – Overview of Loopfield – 54 Loops at (3) Levels

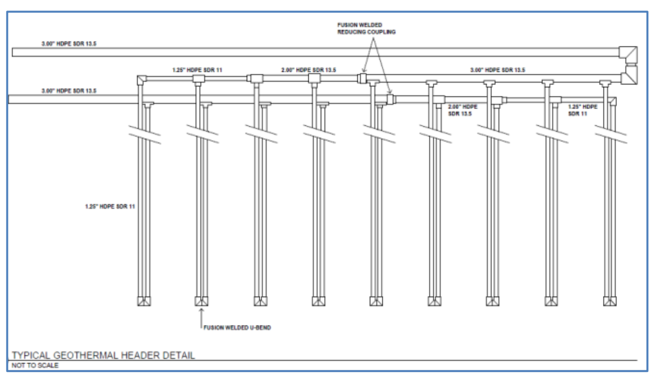


Figure 42 – Typical Circuit Configuration – 9 Loops / Circuit

Bruns Headering performed all of the work to create the circuit tie-ins to the geothermal vault. Much of the preliminary fabrication of the HDPE pipes to connect to the loops was performed on the surface prior to excavation of the tie-in trench. The partially fabricated connections were then lowered into the trench for connection to the loops.

Figure 43 – Loop Ends and Staked Area for Excavation of Trench for Circuit Tie-Ins

Figure 44 – Field Fabricated Circuit Tie-In Pipes

Figure 45 – Factory Tees and Pipe Fusions for Tie-Ins

Figure 46 – Trench with Circuit Tie-Ins connected to Loops in 12-ft Deep Excavated Trench. The Trench Measures Roughly 90 ft x30 ft x 12 ft

Figure 47 – Pressurized Circuit Under 24 Hour Test and Isolated in the Geothermal Vault.

Each loop is fused to the supply/return circuits that connect to the Geothermal Vault. Each circuit with the previously pressure-tested loops is individually pressurized and tested for 24 hours. The pipes in the trench are all bedded by hand and separated at crossings to provide a stable foundation prior to any backfilling of the trench to assure a leak-free system. Each connection was visually inspected and photos were taken of each group of loops. There were also a couple abandoned loops and tremie pipes that were cut off and spray painted to prevent accidentally connecting those loops. The abandoned pipes were sealed to prevent any ground water flow. Tracer wires are connected to each circuit pair for future location purposes.

Figure 48 – #12 GA Direct Contact Tracer Wire

Figure 49 – Tracer Wire on Each Circuit

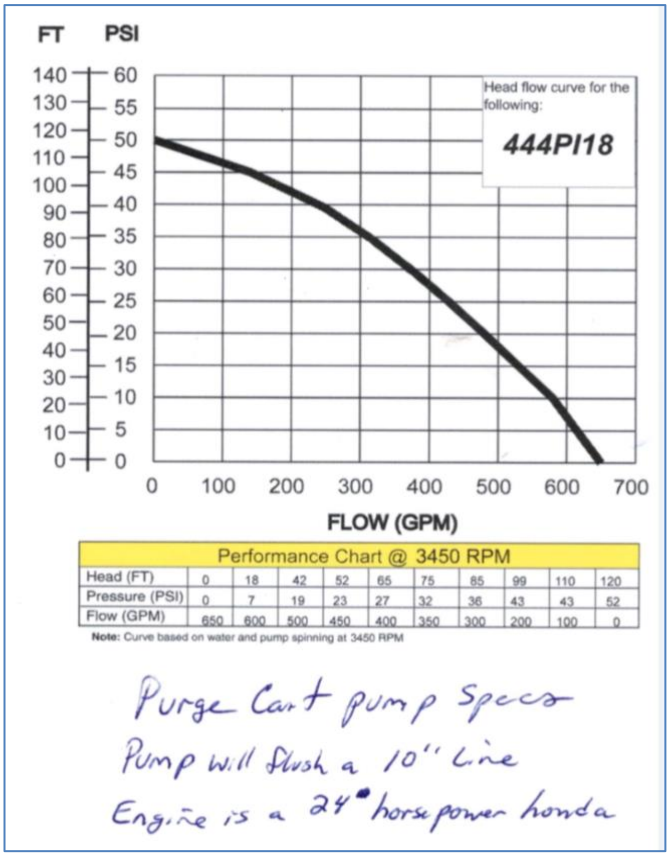
Figure 50 – Circuit Connections from Trench to Vault

Figure 51 – 3" HDPE Circuits from Trench to Vault Level

Flushing and Purging of the GHX System

The Geothermal Heat Exchanger System was allowed to sit over the winter and was flushed in May of 2023. Each circuit was flushed individually in both directions at 100 GPM. The water for flushing was taken directly from a potable hydrant on site. There were no issues with achieving the necessary flow rates in the loop circuits.

The 8" HDPE lines from the Geothermal Vault to the mechanical room were flushed separately. There was an issue with the plumbing in the mechanical room as only a 3" crossover was provided between the 8" lines. The engineer requested that the 3" pipes be replaced by 6" but the work was not completed, so it was necessary to flush the 8" lines with a 3" restriction. All of the work was done from the Geothermal Vault as there were no purge connections available inside the mechanical room. The 8" lines were purged for one hour and a flow of 250 GPM was achieved. After completion of the flushing. The water in the 8" pipes was filtered through 5-micron filtration bags for 30 minutes each direction. The additional restriction of the filter limited the flow to ~205 GPM. On completion, the valves to the building and all circuits were opened and the system was pressurized to 100 PSI and allowed to stand for 24 hours. The system held full pressure for the 24-hour period.



Performance Chart @ 3450 RPM										
Head (FT)	0	18	42	52	65	75	85	99	110	120
Pressure (PSI)	0	7	19	23	27	32	36	43	43	52
Flow (GPM)	650	600	500	450	400	350	300	200	100	0

Note: Curve based on water and pump spinning at 3450 RPM

Purge Cart pump Specs
Pump will flush a 10" Line
Engine is a 24 horsepower honda

Figure 52 – Pump Performance Curve

Figure 53- Purging Pump

Figure 54 – Flow During 8" Purge Operation

Figure 55 – Purging Pressure Through 8" Lines to Mechanical Room

Figure 56 – Filtration Bags

Figure 57 – Pump Connections into Geothermal Vault

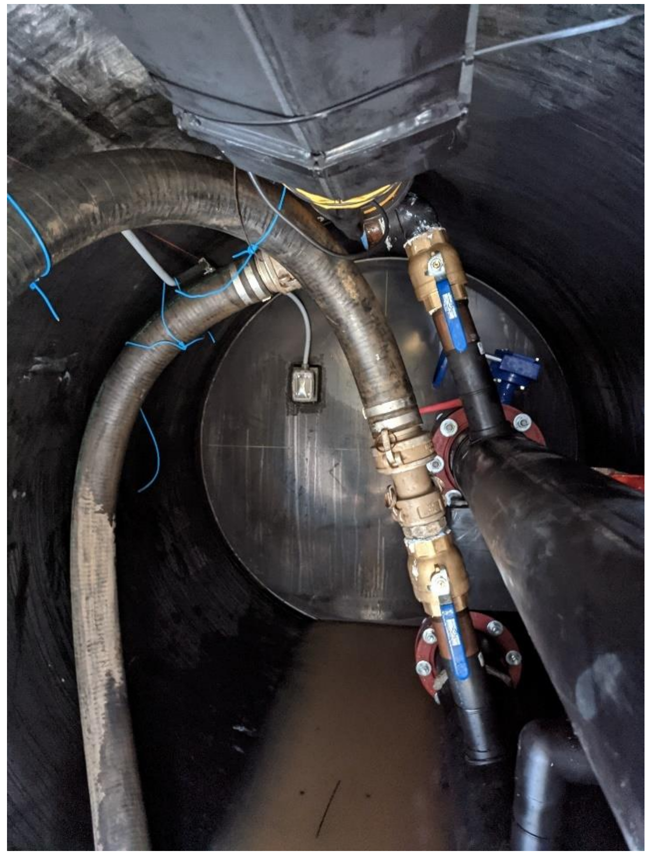


Figure 58 – Interior Geothermal Purging and Filling Connections

Installation of the Glycol Solution

The Glycol Solution was installed on June 1-2, 2023 and was a 25% pre-mix to meet 23-21-13 requirements. It was delivered by tanker truck from the supplier factory to the site in two batches of ~4,000-gallons. Prior to the introduction of the Glycol, the system was found to be holding at 100 PSI as it was left on 5/9/23. The solution was delivered into the Geothermal Vault through 2 ½" supply lines which were checked for clean connections prior to delivery. The 8" supply/return lines to the mechanical room were filled first and separately from the circuit lines to the loops. Inside the mechanical room, the 3" bypass was closed and the filters before the interior pumps were opened and cleaned by the mechanical contractor. The valves were opened to allow circulation through the pumps and interior 8" piping. Once the pumping was started from the tanker, the tanker was checked by weight and it was found to be a little less than half full by weight when evidence of glycol was seen at the discharge. The 8" lines to the mechanical room were shut off and switched over to the first loopfield circuit. Roughly 2 ½ circuits were completed before the tanker was emptied. The process was continued on June 2 when the second tanker arrived on site from the factory. On completion, the system was pressurized to ~30 PSI. A sample of the fluid was drawn from a valve in the mechanical room at the lowest point by the pump. The line was discharged for ~15 seconds to assure a fresh sample. Later testing with a glycol refractometer showed that the solution was good to ~12 degrees F. Based on a small amount of sediment in the sample, it was recommended to circulate the solution through fresh filters before operating the system.

Figure 59 – Glycol Delivery to Site

Figure 60 – Preparing the System to Receive Glycol

Figure 61 – Flushing the Delivery Line

Figure 62 – Filling the System

Figure 63 – Evidence of Glycol in System

Figure 64 – Glycol Sample Point

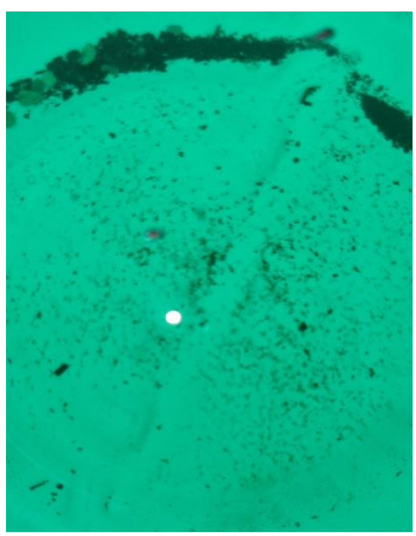


Figure 65 – Glycol in Sample Container Noted Sediment

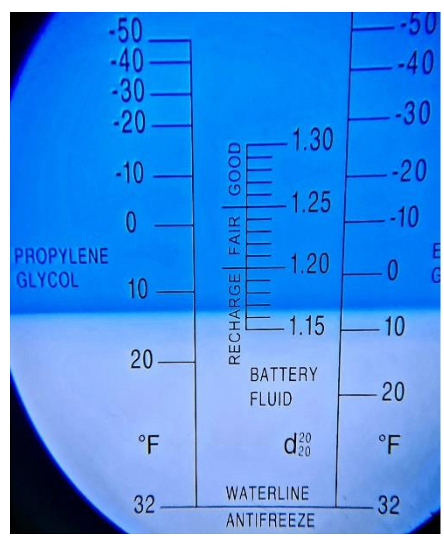


Figure 66 – Glycol Refractometer Results

Report Summary

The project was completed to meet the design intent of the specification. Observations and testing of materials confirm that the work was done in a manner that is consistent with good construction practices using materials and techniques that meet the intent of the specification. The workers had the proper observed certifications for the work which was being performed.

Horizontal Heat Exchangers

- All loops were found to be of proper length based on observation of the materials and the factory length markings. Note that the available space for installation of full-sized loops was inadequate due to physical obstructions at the site boundaries and required a sharper drilling angle and a great deal of extra effort to accomplish the task. This could have been addressed prior to the start of construction. The limited space caused the abandonment and redrilling of two loops due to failure to extract the tremie pipe.
- Available drilling logs show correct depths based on the design intent. There were issues with the construction of a holding pond directly above the loopfield area. The pond should have waited until after the installation of the loops. Hydraulic breakthroughs of drilling fluid, grout at the pond bottom would have been avoided and locating measurements of loop locations would have been more practical.
- Grouting of the holes was correct based on observed practices and the amount of the grouting material which was used for each borehole. The grouting was observed on three separate days and samples were taken and analyzed for correct mixture and results. Results were confirmed by first hand testing and independent testing at a lab. Evidence of graphite/grout was seen at each borehole completed.
- All loops were pressure tested for 24 hours at 80-100 PSI

Lateral Piping

- The lateral piping was prepared using factory connections which met the required specifications. The fusions of all types were performed by certified workers and fusion temperatures were maintained within the spec for the project and by the piping manufacturer. The layout was neat and orderly.
- Fusions were observed for all types of couplings; butt connections. Saddle connections were factory made. Destructive samples were taken of butt connections on couplings for 1.25” connections and for 3” butt connections. The samples showed excellent coverage. No samples were taken of 8” connections but the process was observed and photographed. The fusion rolls were textbook quality.
- I would estimate that I observed ~5 to 10% of the fusions made on multiple days. Visual examinations were made and photos were taken of all of the circuit pipes in the trench. Pre-fabricated circuits were observed prior to installation into the trench.
- Pipe bedding was observed and manual separation and bedding were done prior to any backfill work. Practices observed for the bedding and connections of the pipes were neat and orderly. There were only a couple observed connections that needed extra pipe length on loops and where there was any extra pipe, it was gently looped to provide connections with minimal stress. All of the reducing circuits were pre-measured and fabricated prior to loop fusions to the circuit. This allowed the time in the trench to be minimized. The bedding conditions were mostly good with a small amount of ice in the bottom of the trench on one morning. By later in the day, the conditions were just wet.

There was some evidence of wall movement within the trench but there was adequate excavation for safe work within the interior of the trench.

- Each loop was filled with water and pressure tested upon installation. The 12 circuit pipes to the vault were individually tested after connection, which tested both the loop and the lateral piping. There were no leaks observed or reported after 24 hours. Circuits and associated vault connections were tested to 100 PSI.
- All of the HDPE pipe were as specified in the material submittals to meet the standards as required by the provisions of the project specifications.
- Pipes and connections were safely stored and protected prior to installation to prevent any accidental damage by other equipment or conditions.
- Photo documentation was made of all loop sets and circuit piping.

Preparation for Service

- The system was fully and completely purged over a three-day period.
- Loops and circuits did not encounter any purging/flushing issues. There were no unexpected problems with pressure or flow. Pressures and flows were per spec.
- The Geothermal Vault had a valve failure where a pressure plug released in the 8” pipe inside the vault. It needed to be factory repaired prior to final service. The repairs were completed prior to filling the system.
- The 8” lines to the mechanical room from the area of the vault were installed prior to the commissioning contract being signed. Photos were obtained of the installation process were obtained and used for this report. The photos showed good installation practices and proper marking before backfilling. The pipe entrance to the mechanical room appeared correct in the photos and was observed to be correct during the system filling operation.
- Purging and flushing of the 8” lines to the mechanical room was not optimal. The cross connection provided was not adequate to meet the requirements needed for velocity in an 8” line. A 3” cross connection is not sufficient. The engineer ordered a correction in the mechanical room to supply a minimum 6” cross connection but the work was not done. The engineer approved using the best effort with the limitation of the 3” line. While 250GPM was achieved, the lateral flow rate was not sufficient for an 8” line. The commissioning visit report was shared and recommended additional filtering efforts prior to full operation with the pumps.
- The filling of the system with glycol was orderly and there were no unexpected issues except that the second taker truck was delayed by a day. The amount of glycol was as expected and testing of the solution revealed performance of 12 degrees F.
- Valves in the vault were opened to the loop circuits and to the mechanical room upon completion of the filling of the system with Glycol. The pressure was left at ~30 PSI as measured in the vault.

Appendix

Materials Submittals

- HDPE Pipe – 1.25” to 3”
- HDPE Pipe – 8”
- Central Plastics HDPE Fittings
- Circuit Maker Geothermal Vault
- Tracer Wire
- Locate Tape
- Bentonite Geothermal Grout – Barotherm Gold
- PowerTec – Geothermal Graphite Enhancement
- Quik Bore Drilling Fluid
- Glycol Premix

Certifications

- Driller IGSHPA Certification
- Pipe Fusion Certifications

Permits

Drilling Logs

Grout Testing Results

Communications Log for Vet Home - Montevideo