Commissioning Report - Ground Heat Exchanger Testing and Observation

Minnesota Veterans Home – Bemidji, MN

October 3, 2023

Commissioning Report - Ground Heat Exchanger and Observations

Table of Contents

Appendix Items

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Initial contract date for commissioning services: May 6, 2022
Estimated completion date: February 2023

<u>Project Location:</u>

Minnesota Veteran's Home - Bemidji
920 Anne Street NW
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Report Affidavit

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

Jeff H. Walton
Thermal Dynamics Inc

October 3, 2023
Date

Initial Project Observations

This project is for the Minnesota Veterans Home in Bemidji, 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. Sandy soil conditions. Building project already underway at the time of commissioning for the Geothermal Loop Field installation.

The design consists of (48) horizontal heat exchangers which are situated in three layers that are ~ 15, 22.5 and 30 feet below the surface. Each layer consists of (16) loops of 500-foot finished length, spaced 8 feet apart. Each borehole is designed as a directionally drilled path with locating tracer wires that is grouted, using a tremie pipe, to assure expected thermal properties and to seal the borehole from cross connecting any existing water layers. The process will be observed, verified and photographed at increments during the construction process. Materials will be tested and verified as needed.

The installed loops are connected to six sets of supply/return lines using reducing headers and a set of similar 3" circuits in an eight-foot trench from the loopfield to the mechanical room of the building.

Once installed: the loops, reverse return connections; the run-ins to the utility room are pressure tested and filled with fluid prior to bedding of the trenches and loop tie-in areas. The system will be allowed to sit over the winter (per the contractor) and the final steps will be completed in the spring of 2023.

The system is then to be flushed with DI water, using a purge pump and filtration system to remove any air and debris and filled finally with a pre-mixed glycol solution. At completion, the fluid will be tested to assure proper protection from freezing during operation. The system is pressurized to 30 lbs. and valves are set to allow operation by the mechanical contractor responsible for the interior building systems.

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

The initial on-site observation was on May 13, 2022.

Initial Site Observations

May 13, 2022. No borings have been completed. The area for the loopfield is beneath a future driveway and parking lot. The staging of construction materials will interfere with boring and locating and will need to be relocated. There are fences on the E and S ends of the site. No driveways or parking areas in the vicinity of the loopfield work have been constructed at the time of the initial drilling. The area has been excavated and sandy soils are apparent. Access to the area is good.

Figure 1: Site facing - North to South for Loopfield Area

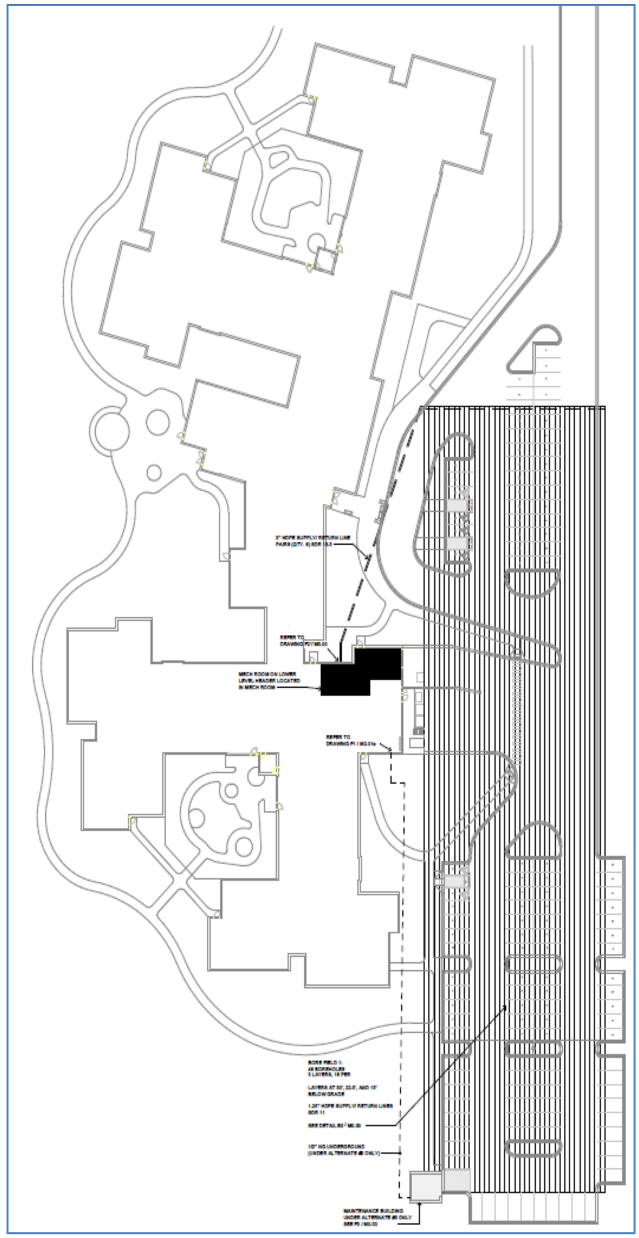

Figure 2: Geothermal Location on Site Plan

Materials, Equipment and Operator

Materials for the project were warehoused and some stored on the site. They were inspected and checked for compliance to the specifications:

- Directional boring machine: Ditch Witch JT-28. Placarded with 2022 MDH license.
- Operator Willie Borstad, Borstad Drilling. IGHSHPA Installer # 144740, valid 06/30/2025. Others from North Central Services under supervision of Willie Borstad.
- MDH Permit VL554 issued to Borstad Drilling to construct BGHE at site issued 4/27/2022.
- Loops: Centennial Plastics – CenFuse HDPE SDR-11, 1.25" – 500-foot reels with field fused U-Bends Centennial CenFuse SDR-11, 1.25" Geothermal Coupling Fusion
- Other Piping: Centennial Plastics – CenFuse HDPE 4710 2", 3" pipe, Fusion Fittings - various molded fittings
- Building connections: Performance Pipe - Driscoplex 1000 HDPE PE4710 pipe – 3"
- Marking Tape – 3" safety marking tape – Kraus/Anderson Caution Safety Yellow
- KrisTech – Solid 12AWG Steel Clad CU HMWPE 45 Mil Tracer Wire - Blue
- Geothermal Grout: GeoPro TG Lite - bentonite-based thermal grout
- Grout Enhancer: GeoPro PowerTEC Graphite Grout Enhancer
- Drilling Fluid: Wyo-Ben TruBore and DRILPLEX HDD drilling fluid viscosifier

Figure 3 - Drilling Fluid

Figure 4 – Geothermal Grout

Figure 5- 500' HDPE Reels

Figure 6: Graphite Grout Enhancer

Figure 7: Field Fuseable U-Bends

Figure 8 – Tracer Wire

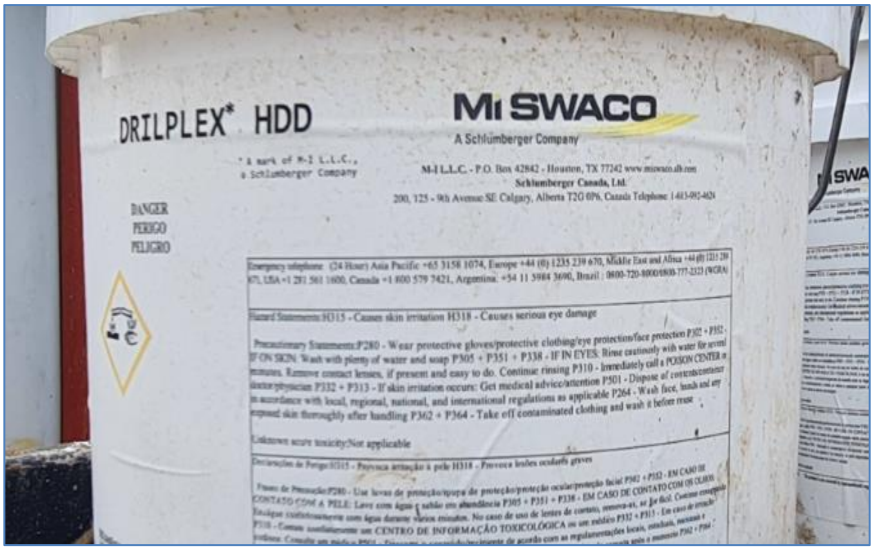

Figure 9 – Drilling Fluid Viscosifier

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:

- Initial site visit: May 13, 2022
- Drilling and Grouting Observation: May 31, 2022; June 14, 2022; July 7, 2022; August 3, 2022
- Circuit and Building Tie-In Observation: August 25, 2022; September 6, 2022
- Collection of Loopfield Fluid Samples: August 31, 2023

Photos were taken of the different parts of each process on each visit.

Summary Observations: Directional boring was intended to be done from North to South in groups of three. The top borehole at 15-feet depth was drilled first, followed by the 22.5-foot bore and finally, the 30-foot bore. The order of drilling of the initial holes was not fully followed due to an issue with utilities in the path and an issue with the locators being able to work around some large steel culverts that interfered with the communication between the locator and the drill head. Four different locators were used before settling on a Digitrak F5+. The rows were well marked and labeled to establish an 8-foot spacing between the sets. The general contractor provided the stakes and marking and the markers were replaced whenever traffic or other activities interfered. Spacings were confirmed by measurement on each visit. It was noted that the project site manager needed to arrange to move materials, trailers and vehicles in order to allow the locator to properly mark and locate the drilling in process. The accommodations were made and visible after the first visit and request.

The borings were completed with a 5.5" bit and the return pull used an 8" back ream with 5.5" puller. The initial bores took 4-5 hours to drill and roughly 1 hour to grout. The grouting process was interesting in that there was no hydraulic reel available to pull the tremie lines and it required a crew of 6-8 workers to pull the tremie line while injecting grout from the grout pump.

The soil conditions were primarily sandy with some bluish clay encountered in the deepest boreholes. Adjustments were made to use more drilling fluid for the deeper boreholes due to high drilling resistance through some of the areas with the thickest clay. Initial deep boreholes were slow and multiple pull-backs were required until adjustments were made to use more drilling fluid. There was initially no water available on site and water was trucked in for mixing the drilling fluid and grout. Later in the project, an operational hydrant in the vicinity of the loopfield was installed and turned on, which expedited the process.

The piping used for each loop involved field construction of the loop using the 4710 HDPE and fusion joined U-Bends. Apparently, there was a sourcing issue with the factory-made loops so the contractor bought 500-foot reels of pipe to join with prefabricated U-Bends. The specifications for the project allows for field fabrication with approved U-Bends. Since each finished loop needed to be 500' in length, it was necessary to add extra tail pieces to each loop to allow for the finished loops to be the correct length when tied into the circuit. The shallow loops used 25-foot tails and the deeper loops used 50-75 foot tails. The starting drilling points for the different depths were spaced 10-20 feet apart and plenty of length was left above the surface. The space was available to be generous with the length of the tail-pieces and these extra spliced tail pieces were removed later when the circuits were tied into the building. Completed loops were sampled for length using a 600' fiberglass tape, as the pipe markings were not reliable for length verification due to field fabrication of the U-Bends and tail pieces.

Each loop was fabricated with a U-Bend at the time of pulling the pipes and tremie into the completed borehole. Observations and photos were taken of the 15-20 minute fusion process, which was done by a worker with the correct fusion certifications. Temperatures were checked and each joint was properly timed. Samples of coupling fusions were taken and destructively checked for uniformity and completeness of the fusion. The observed process was done with properly cleaned pipe ends and equipment in good order.

Figure 11 – Preparing back-reamer for pulling the loop into the borehole

Figure 12 – Preparing the pipes to add the U-Bend to be pulled into the borehole

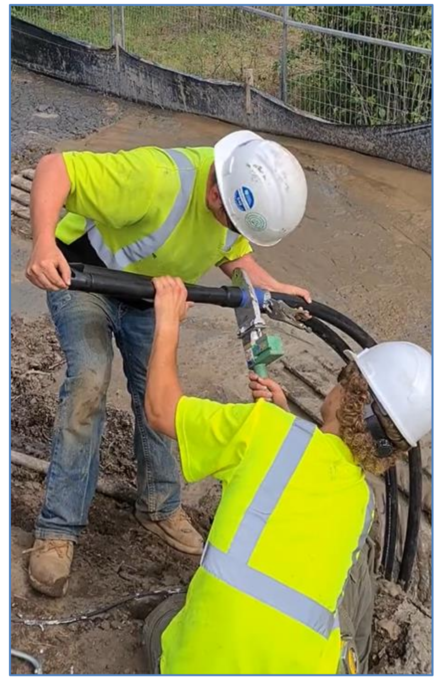

Figure 13 – Fusing the U-Bend to the loop pipes before pulling into the borehole

On completion of each borehole, the loop was pulled back through the borehole along with a tracer wire and third "tremie" pipe which was used for grouting. Each loop was pressurized to 100 PSI for 24 hours to test the integrity of the loop after being pulled into the 500-feet of borehole. In this installation, the testing assures that the tailpieces and U-Bend fusions were satisfactory, as well as whether the loop suffered any damage from rocks or other debris that may have been encountered in the pulling process. The pipes were joined in sets of multiple loops with a temporary "manifold" to allow one gauge to be used for pressure testing of more than one loop as each loop was completed. The loops were immediately capped and fittings were applied to protect the pipes from debris. The pipes were pressurized for a minimum of 24 hours at 100 PSI.

The contractor chose to use air to pressurize the loops, which is not the best or safest way to do the testing and it required a lot of air compressor time to apply enough pressure. They did not have sufficient numbers of pressure gauges available to put separate gauges on each loop, so they were permitted to check multiple loops at a time. At the end of the 24 hours, the pressure observed for detection of any leaks and the air was released. The temporary manifolds were removed and the loops were individually capped. A better method would have been to fill the pipes with water and use the compressor to pressurize only a small amount of air in each pipe.

Figure 14 – Pressurizing a completed loop

Figure 15 – Temporary manifold to pressure test more than one loop at a time.

Figure 16 – 100PSI for 24 hours

Locating was mostly uneventful and paint markings were used along the entire length of each loop path. A drilling log was retrieved which shows most of the depths of each borehole. We did not receive all of the drilling logs due to the issues with using four different locators until one was found to navigate around the steel culverts. Also, the logs did not include the GPS locations, only the depth of each loop. Some of the boreholes in the vicinity of the building were drilled deeper than the spec to avoid the transformer pad and associated wiring that were located roughly 12-13 feet below the surface. The driller opted to provide extra clearance around the electrical utilities and to maintain separation between the layers of boreholes and the loops.

Figure 17 - Locating. Working around some of the materials being used on-site

Figure 18 - Locating w/ DigiTrak F5+

Figure 19 – Loop tails from installed loop in borehole

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 through the tremie pipe as it was pulled. The contractor used a Rose-Wall 11600 grout pump with a 1.25 high-pressure tremie line to inject grout into the hole as the tremie pipe was slowly removed from the borehole. It was necessary to enlist a crew of workers to pull the tremie line or a small Bobcat tractor when the pulling was too difficult to get the pipe started. Grouting was started immediately after pulling the loop into the borehole to take advantage of the viscosity of the grout before the grout could start to setup in the borehole.

Figure 20 – The dual tank grout pump with materials staged for mixing

Figure 21 – Grouting mud being mixed and discharged into the pump chamber.

Figure 22 – When manpower was not enough to remove the tremie pipe

Figure 23 – Manpower was used to extract the tremie pope as grout was pumped into the borehole

The tremie pipe was charged with grout and when the grout appeared at the surface of the open borehole at the far end, 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. A hydraulic reel for the tremie pipe would have been an easier and more uniform pulling process.

Grout was mixed by means of two separate mixing tanks on the grout machine. The total amount of grout used per borehole was roughly 8 bags of PowerTec Enhanced Graphite and 24 bags of PowerTech TG Lite bentonite grout. The graphite in the grout mix provided a visual 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 three visits and were taken at the beginning, middle and end of the mixing process to assure uniform mixing was occurring during the grouting process. Samples were analyzed at the end of each visit and also shipped to GeoPro for independent test confirmation.

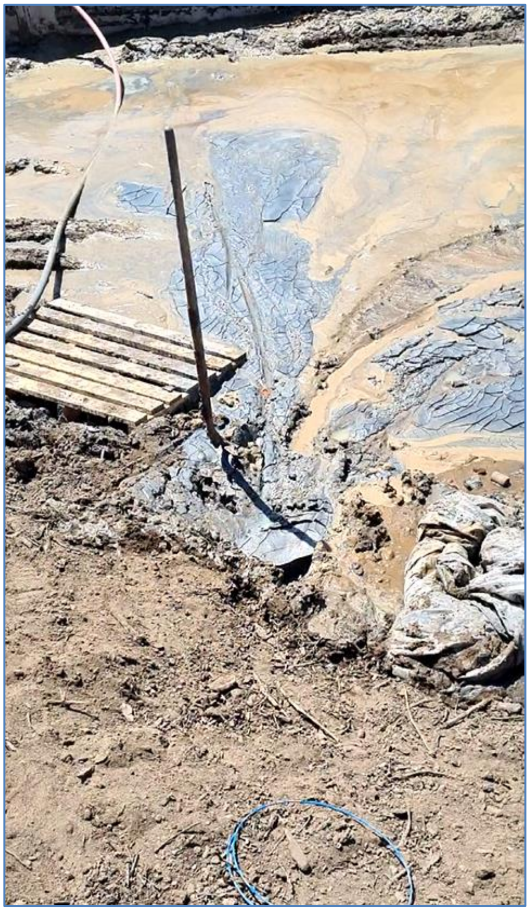

Figure 24 - Evidence of Graphite in Grout

Figure 25 - Evidence of Graphite in Grout.

Figure 26 – The tailpieces of numerous installed loops

Figure 27 - Mud pumps used to manage grout and mud

Figure 28 – Mud pumps used to manage grout and mud

Figure 29 – Checking locations of loops that run beneath the electrical service hookups

Circuit Tie-Ins; Building Supply/Return Connection
Site visits for boring, installation of loops and associated observations were made on:

- August 25, 2022 – Excavation and Supply/Return circuits
- September 6, 2022 – Circuit Tie-Ins; Testing and Bedding of Piping

The Geothermal circuit tie-ins from the loopfield to the vault were done in early to mid-September by Borstad Drilling after all of the loops had been installed, grouted and tested.

Building Supply Return Lines

The 3" Supply/Return lines were trenched from the tie-in area to the building mechanical room. There are six sets of supply and return lines, for a total of twelve pipes that enter the building. Circuits all marked and identified by letter on each pipe in the trench and in the Mechanical room.

Figure 30 – HDPE supply/return lines from the loopfield to the Building Mechanical Room

Figure 31 – Supply/Return run-outs from the Mechanical Room to the loopfield Tie-Ins

Figure 32 – Supply/Return trench and circuits across the front of the building

Figure 33 – Supply/Return Lines showing butt fusions

Figure 34 – Close-up of butt fusion of the 3" supply line

The pipe fusions of all of the connections between the loopfield and the building were made on-site with approved 4710 HDPE pipe and a Widos-Polypress 4600 fusion machine. Butt fusions, saddle fusions and coupling fusions were observed and several destructive tests were made. Fusions were timed and temperature monitored per guidelines for Centennial plastics and also compared to the ISCO handbook for fusions. Both workers had valid and current fusion certifications for this work.

Figure 35 – Widos-Polypress 4600 Fusion Machine

Figure 36 – Destructive Sample

Figure 37 – Controls for fusion machine

Figure 38 – 3" Butt fusion in process

Figure 39 – Area excavated for circuit tie-ins to loopfield and working area for preparation of 3" circuit supply/return lines.

Circuit Tie-Ins to Loopfield Borehole Pipes

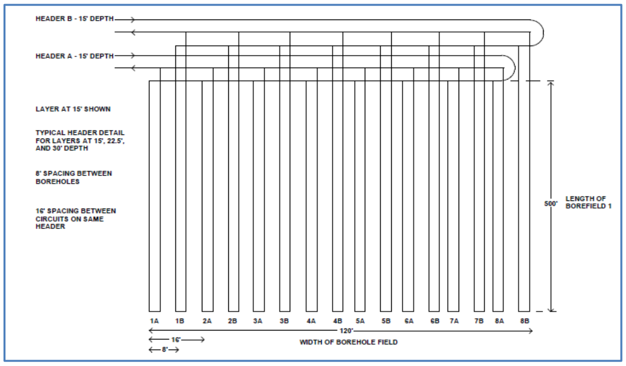

Figure 40 – Overview of Loopfield – 48 Loops at (3) Levels

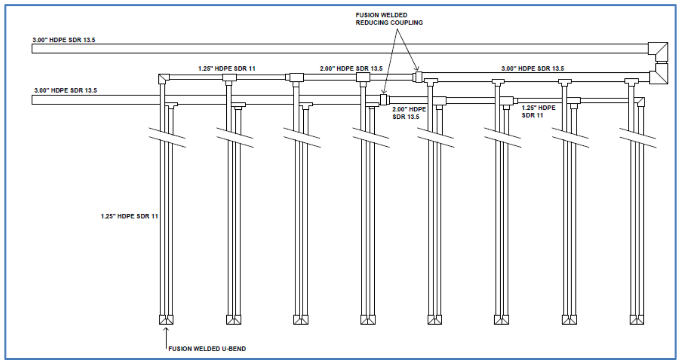

Figure 41 – Typical Circuit Configuration – 8 Loops / Circuit

The tie-ins to the loopfield were done 8-9 feet below grade in an area that was fully excavated to allow equipment to drive and compact soils at the end of the process. Noted that there is a hydrant line that runs roughly two feet below where all of the tie-is are made. Caution will be needed if any hydrant or water main work needs to be done in this area. Yellow caution tape is placed about 4-5 feet below the surface and directly above each running supply/return pipe that extends to connect the GHX loops. All tracer wires tied to their related circuits. The loopfield tie-ins and reducing headers which connect to the 3" circuit pipes were all inspected for proper fusions all crossings of pipe were hand bedded to reduce any stress on the pipes. The material excavated consists primarily of sandy soils with very few small rocks. Crews walked the area and removed any stones larger than a couple inches across. The walls were not very stable as sand did collapse from the sides during the time that the pit was open. Ladders were utilized to climb in and out of the pit. Loopfield pipes exited the bottom of the south wall and came up from the floor of the area excavated. There was good evidence of grout wherever the loops entered the floor or the bottom of the sidewall, which indicates that the boreholes grouting was effective. Supply and return lines connect to the 3" circuits through a series of reducing headers that are configured in reverse-return configuration from 1.25" pipe through 2" and 3" connections. Noted on the East area of

Figure 42 – Concrete culvert temporarily removed during the excavation of the tie-in area for the GHX.

the trench, there is a 16" concrete culvert running N-S which was temporarily removed as it ran above the area where the tie-ins were connected. I did not observe the replacement prior to leaving the site. The piping and connections and tracer wires are all very neatly configured and prepared.

Figure 43 – Loop Tie-ins and reducing headers connected to the circuit piping.
Pipes were hand bedded for separation prior the system being covered.
Tracer wires showing and connected back to each circuit pipe into the mechanical room.

Figure 44 – Typical Saddle Fusion and Circuit Markings

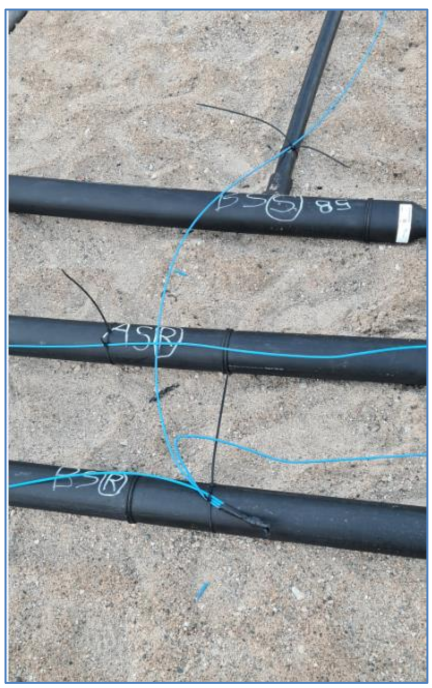

Figure 45 – Supply/Return Circuit Markings and Tracer Wires

Figure 46 – Circuits at E Wall of Trench where the Connections Reverse

Figure 47 – Circuits and Tie-Ins ready for Pressure Testing

After all connections were completed, each fusion was visually inspected prior to pressurizing the system. Each circuit (x6) and connected loops (x8 loops/circuit) were filled with mains water from the Mechanical room and pressurized to 100PSI for 24 hours prior to backfilling. Temporary plumbing was affixed to each of the supply/return pipes to allow for filling and pressurization.

Figure 48 – All Circuit Pipes in Mechanical Room Temporarily Plumbed for Testing

Figure 49 – Each Circuit (x6) Filled with Mains Water and Pressurized to 100PSI

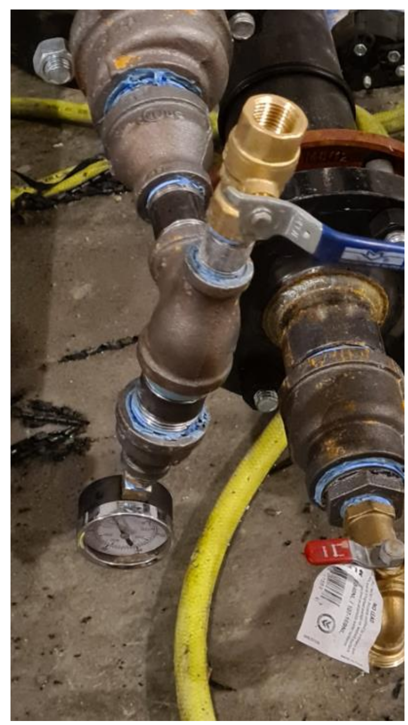

Figure 50 - Each Circuit (x6) Filled with Mains Water and Pressurized to 100PSI

Flushing and Purging of the GHX System

The flushing/purging and filling operations were performed when the Commissioning Agents were unavailable to be on site due to advance scheduling issues. Reporting and photos were provided by PSM and Mineral Services Plus, the purging subcontractor.

The Geothermal Heat Exchanger System was allowed to sit over the winter and was flushed/purged in August of 2023 by Mineral Services Plus (Danny Knubbe IGSHPA #20041-0509. Each of the (6) circuits were flushed individually for 45 minutes in both directions at ~104 GPM and ~48 PSI supply pressure per photo and video. The initial water for system was taken directly from a potable source on site in September of 2022 for pressure testing the GHX piping prior to backfill of the trenches. A portable purge pump, Goulds Water Technology 50SPM20F, was used for the flush/purge operation. The setup included a 5-micron filter bag assembly and an air separation tank. Connections were made through a reversing valve manifold assembly using 3" hose connections.

Figure 51 – Geo System Mechanical Room

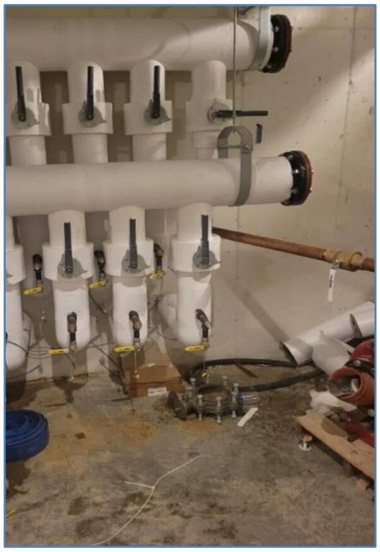

Figure 52 – Geo System Mechanical Room

Figure 53 – Geo System Building Pumps

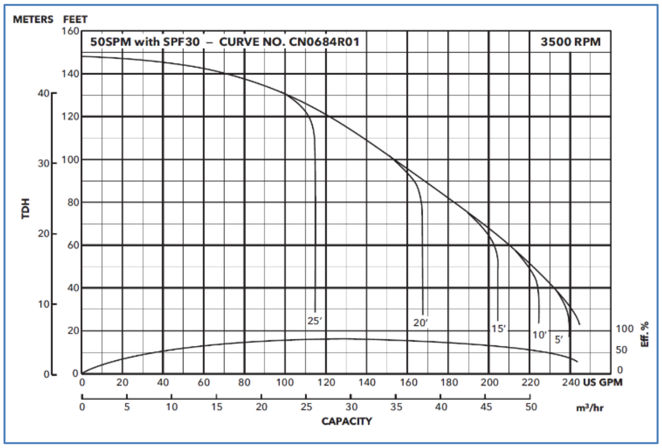

Figure 54 – Pump Performance Curve - 50SPM20F

Figure 55 - Goulds Water Technology 50SPM20F Purge Pump w/pressure and flow meters.

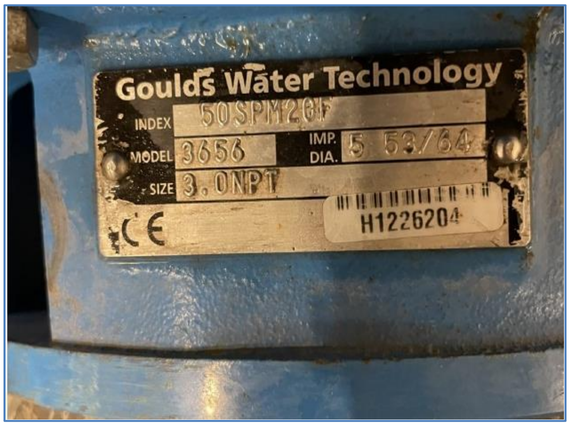

Figure 56 -Purge Pump Nameplate

Figure 57 – Purging Pressure from Pump. No documentation provided for GPM, although a meter is present in Photos

Figure 58 – Air Separation Tank for Purging

Figure 59 – Portable filtration unit

Figure 60 – Polypropylene Felt Bag Filter w/ Carbon Steel Ring – 5 Micron

The flushing/purging took a full work day to complete based on the required time to flush/purge each circuit in both directions for 45 minutes each. The valving setup on the purge pump provided minimal setup time as the directions were changed and the circuits were individually processed. PSM reports that Mineral Services completed the operation between 9:00AM and 6:15PM on August 1, 2023. There were no reported issues with any of the circuits and all were reported to have flowed properly with no evidence of blockage. It is not known what system pressure was applied at the conclusion of the flushing/purging operation.

Installation of the Glycol Solution

Information on the installation of the glycol solution is based on photos and information obtained from PSM. The Commissioning Agents were unavailable to be on site due to advance scheduling issues.

The Glycol Solution was installed beginning August 2, 2023 from glycol concentrate that was "field Mixed" from 250-gallon totes of concentrate, as shown in photos. A small electric transfer pump and 1" hose line were used to introduce the field mixed glycol into a port in the mechanical room per photos.

PSM estimates that 1,750 total gallons of concentrate were used and that included an additional 250 gallons of concentrate installed at a later date as the initial needed quantity on-site was short by one tote.

Figure 61 – PSM Photo of Glycol Totes

Figure 62 – PSM Photo – Small Electric Pump Extracting Concentrate from Tote

Figure 63 – PSM Photo of "Glycol Displacing Water"

Figure 64 – PSM Photo of Tote Label

Figure 65 – PSM Photo. From Glycol pump?

The Glycol Solution which was installed was "Field-Mixed" as opposed to the expected factory 25% premix solution. The field mix was created by means of manually mixing the clear concentrate and local water which was run through a set of filter tanks. The "field mix" was reported to be a ~30% solution by volume and there is no information regarding the mixing process (mechanical paddle mix or simple introduction of glycol to water using the small electric transfer pump). After the field mixed solution was created, the 250-gallon tote was pumped into the system using the small electric transfer pump.

Figure 66 – Filtration Tanks Used to Treat Municipal Water

Figure 67 – Filter Information

Figure 68 – Mechanical area with GHX Circuits and Final Valve Positions. The Tote to the right is for the 55-gallon supply of Glycol Solution to be left for future use as needed. It is the 30% field mix that is used in the GHX.

There were (3) samples taken on 8/31/23 from the taps on the supply and return lines to test the concentration of the fluid. Note that the system was active and pumps were running during the time that the fluid was extracted. Samples were taken about 5 minutes apart. All of the samples were evaluated with a glycol refractometer on return to the office and found to be ~30% concentration.

A small sample was separated to submit for chemical testing of the solution.

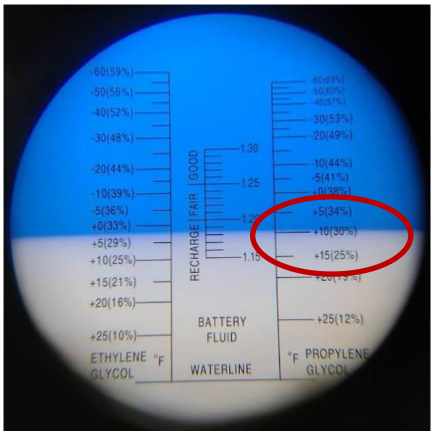

Figure 69 – Glycol concentration Sample 1

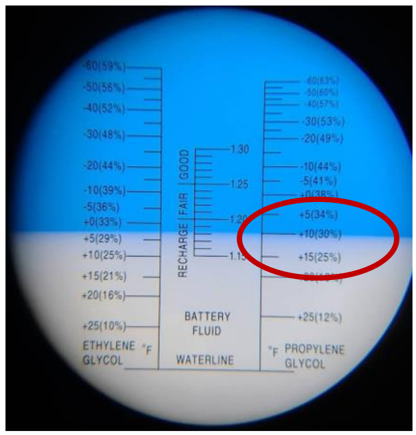

Figure 70 - Glycol concentration Sample 2

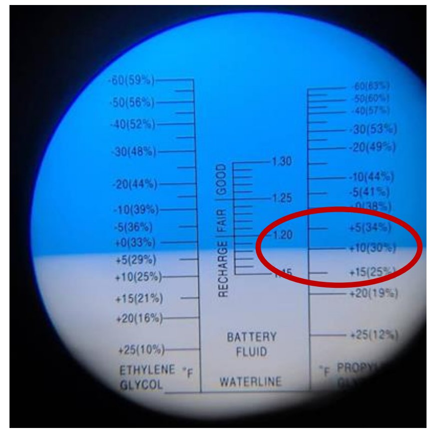

Figure 71 - Glycol concentration Sample 3

Analysis of the solution by Kurita America confirmed the solution percentage to be ~27% glycol and the additional chemical analysis of the solution and make-up water is provided in the report appendix. A comparative report for a factory grade premix solution was not available.

Report Summary

The underground GHX portion of the project was satisfactorily completed to meet the design intent of the specifications. 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 fully meet the intent of the specification. The on-site workers had the proper observed certifications for the work which was being performed and the construction proceeded smoothly. The underground work and results were very good.

Based on the photos and notes received from PSM, the installation of the glycol into the system does not meet the glycol premix specification requirements.

Horizontal Heat Exchangers

- All loops were found to be of proper length based on observation of the materials and the length verification by fiberglass rod on each visit. Materials markings were not used to confirm length due to field fabrication of the U-Bends for each borehole. Tail pieces were added to assure sufficient finished length and the extra material was removed when the circuit tie-ins were made. The work was neat with good markings and site control.

- Available drilling logs show correct depths based on the design intent. The logs were incomplete due to switching the locator equipment due to issues with steel culverts and the inability to recover data from equipment that was exchanged. Noted that the logs did not contain the GPS coordinate, which would have been useful at a later date and the project template could have been more completely populated. For the purpose of depth and length verifications, the received logs are sufficient.

- Grouting of the holes was correct based on observed practices and the expected 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 and visible during the excavation of the circuit tie-ins.

- All loops were pressure tested for 24 hours at 100 PSI on initial borehole installation and again at the time of the total system check before backfilling the trench for the tie-ins. All connections held 100 PSI for 24 hours, without loss, and were inspected prior to approval to back-fill.

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 and the excavation allowed for extra care for pipe placement.

- Fusions were observed for all types of couplings; saddle and butt connections. Destructive samples were taken of butt connections on couplings for 1.25" connections and for 3" butt connections. The samples showed excellent coverage. The fusion rolls were textbook quality.

- I would estimate that I observed ~5 to 10% of the fusions made on multiple visits. Visual examinations were made and photos were taken of the circuit pipes in the trench. The circuit pipes were neatly spaced, properly identified and done in an orderly manner.

- Pipe bedding was observed and manual separation and bedding were done by hand prior to any backfill work. Practices observed for the bedding and connections of the pipes were neat and orderly. The bedding conditions were good with excellent and dry working conditions. There was a concrete culvert that was obstructing and removed during the tie-in process. There was some evidence of movement in the sandy walls within the trench but there was adequate excavation for safe work by persons and equipment within the interior of the trench. Ladders were placed where needed.

- Each loop was filled with water and pressure tested upon installation. The 12 circuit pipes to the building mechanical room were individually tested along with the connections to the loops. There were no leaks observed or reported after 24 hours. Circuits and associated connections were tested to 100 PSI. All of the HDPE pipe materials were as specified in the material submittals to meet the standards as required by the provisions of the project specifications. While the original submittal was for factory U-Bend loops, the materials and U-Bends that were fabricated on-site did match the expected pipe and U-Bends that would have been present in factory loops.

- 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 flushed/purged over a one-day period by Mineral Services Plus. The photo evidence and time are consistent with the expected procedures. The information on flow rate was via a flow meter present on the purge pump and a one-minute video of the gallonage counter dial. A 48PSI supply pressure and a purging/flushing is flow rate of ~104 GPM was used to assure sufficient fluid velocity to extract debris.

- Loops and circuits did not encounter any purging/flushing issues. There were no unexpected problems with flow or blockages.

- The filling of the system with glycol was done by means of injecting a glycol concentrate field-mix into the fluid present in the system using a small electric transfer pump. Refractometer tests show that the concentration is ~29-30% against a requirement of 25% min. The specifications in 3.07 call for a glycol pre-mix and it was expected that 100% of the previous fluid in the system would be fully displaced with an approved glycol/DI pre-mix solution provided by a supplier certified to deliver such a pre-mix solution. There was no make-up water analysis performed. A typical displacement of

GHX system fluid with pre-mix delivered by a large tanker truck(s) and positive displacement pump is a usual method for large systems. Based on the photos and information provided, the preparation for service did not use a required pre-mix and is not compliant with the specification expectations.

- A fluid sample was submitted to Kurita for a full chemical analysis and it is up to the project engineer to draw conclusions on the field mixing of the glycol and preparation for service.

- The analysis of the fluid by Kurita America confirms the concentration at 27.1%; a freeze point of 12-degrees; and pH balance of 8.84. These values are within the project specification required.

  The sample temperature was not reported in the analysis and values like conductivity are subjective without a temperature reference. The fluid makeup may require additional inhibitors and stabilizers and are beyond the scope of this evaluation. See Analysis report from Kurita America Labs.

- Valves in the manifold were opened to the loop circuits in the mechanical room upon completion of the filling of the system with Glycol. The pressure was observed at ~38 PSI supply and ~34 PSI return as measured on the supply and return manifolds with system pumps operating.

- A tote containing the required spare fluid mixture of >55 gallons of glycol solution was present in the mechanical room.

Appendix

Materials Submittals

- HDPE Pipe – 1.25" to 3"
- HDPE Loops -
- Central Plastics CenFuse HDPE Fittings
- Tracer Wire - KrisTech
- Bentonite Geothermal Grout – GeoPro TG Lite
- PowerTec – Geothermal Graphite Enhancement
- Wyo-Ben TruBore and DRILPLEX HDD drilling fluid viscosifier
- Glycol – Kurita 9134FG Concentrate

Certifications

- Driller IGSHPA Certification
- Pipe Fusion Certifications

Permits – State of MN

Drilling Logs

Grout Testing Results – GeoPro Inc.

Glycol Analysis Report – Kurita America

Communications Log for Vet Home - Bemidji