

OGE-OSU GEOTHERMAL HEAT LOOP RESEARCH PROJECT

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Field Notes

Introduction

Beginning in April, 2011, Oklahoma Gas and Electric Company in conjunction with Oklahoma State University began a geothermal heat loop research study at Hope Crossing, Habitat for Humanity in Oklahoma City, Oklahoma. The information in this paper describes drilling equipment, borehole configurations and thermally enhanced bentonite based grouts. Information was gathered on eleven of the thirteen bore holes drilled.

Caliper, gamma, spontaneous potential, 16 inch normal resistivity, 64 inch normal resistivity and point resistivity logs were run on some of the boreholes. The formations encountered were of sandstone and shale. The resistivity logs were to determine an estimation of penetration of drilling fluids into the formations.

Grout samples were collected from the blending tanks of the grouters prior to pumping into the borehole. These samples were sent to a lab and measured for thermal conductivity using the ASTM D 5334 Standard Test Method for Determination of Thermal Conductivity of Soil and Soft Rock by Thermal Needle Probe.

Address: 928 83rd Street (DaqUnit07)

Date: April 20, 2012

The drilling rig utilizes the sonic process of drilling, with 2-7/8 inch horizontal directional drill pipe in 10 foot lengths. The drill bit size was 4.75 inches. Air was used as the medium to remove cuttings from the bore hole. The rate of penetration was five feet per minute in a sandstone formation. At eighty feet of depth the hole began making water and at 270 feet the amount of water was approximately 50 gallons per minute. The total depth was 320 feet.

The loop installed in the borehole is a 1 inch single loop.

The grout chosen for this bore hole was Baroid IDP Barotherm Gold 1.0 which is a blend of sodium bentonite and high quality silica sand and has a thermal conductivity of 1.0 BTU/hr·ft·°F (1.73 watts/m·°C) when 4 50 pound bags are mixed with 12.3 gallons of water. The expected density would be 14.0 pounds per gallon with 66.0% solids. The grouter used was a Geo Loop 50-500. The tremie line is 1.25 inches in diameter made of HDPE. The make-up water for the mix is pretreated with soda ash to remove calcium and increase the pH to 9.5. Single batches of 6 sacks of grout to 18.5 gallons of water are mixed. The tremie line is run to bottom of the bore hole and the grout is pumped with the tremie line submerged in the grout as it is being retrieved to surface.

Address: 813 83rd Street (DaqUnit05)

Date: April 22, 2012

The drilling rig utilizes the sonic process of drilling, with 2-7/8 inch horizontal directional drill pipe in 10 foot lengths. The drill bit size was 5.5 inches and total depth was 260 feet. There were no reported hole problems.

The loop is 1 inch double u tube. The grouter is a Geo Loop 50-500. The thermally enhanced grout was Baroid IDP Barotherm Gold 1.0 which is a blend of sodium bentonite and silica sand and has a thermal conductivity of 1.0 BTU/hr·ft·°F(1.73 watts/m·°C) when 6- 50 pound bags are mixed with 18.5 gallons of water. The resulting slurry would have an expected density of 14.0 pounds per gallon with 66.0% solids.

Address: 833 83rd Street (DaqUnit03) west bore hole

Date: May 3, 2011

The drilling equipment is a direct rotary with an onboard 300 CFM compressor. The drill rod is horizontal directional drilling type, 2 inches in diameter in ten foot lengths with a 4 inch diameter hammer. The rig used air as the medium to excavate drill cuttings from the bore hole. Ground water was encountered at 70 feet. Total depth of the bore hole was 130 feet. There were no borehole problems while drilling.

The grouter is manufactured by Dyno Drill. It has a blending tank with a capacity of 53 gallons and a one ribbon paddle at the bottom of the tank. There is a hose reel with 300 hundred feet of $\frac{3}{4}$ inch tremie line on the reel.

The geothermal heat loop is coaxial manufactured by Amasond. The outer sleeve is ribbed and has a diameter of 2.5 inches. The loop was weighted to help facilitate installation into the bore hole. A $\frac{3}{4}$ inch tremie line for the grout was taped to the bottom of the loop.

Baroid IDP Barotherm Max was the thermal enhanced grout used for this bore hole. Barotherm Max is a mix of bentonite and graphite with an expected thermal conductivity of 1.6 Btu/hr·ft·°F and a density of 11.6 pounds per gallon with a solids content of 45.0% when 7 gallons of water is mixed with each bag.

Address: 833 83rd Street (DaqUnit03) west bore hole - CONTINUED

A progressive cavity pump was used to pump the grout. During pumping of the grout, the ¾ inch tremie line ruptured and was discarded. A one inch tremie line was installed but also ruptured and grout was pumped into the bore hole from the surface.

Address: 833 83rd Street (DaqUnit03) east bore hole

Date: May 5, 2011

This bore hole was also drilled by a Dyno Drill model CD 300 with an onboard 350 cfm compressor. The drill rod is horizontal direction drilling type, two inch outside diameter in ten foot lengths. The drill bit is 5.25 in diameter attached to a ten foot auger.

This bore hole was also drilled with air as the medium to remove the drill cuttings. There were no additives used with the air. Ground water was encountered at a depth of 100 feet. The total depth of the bore hole was 135 feet.

The geothermal heat loop is coaxial manufactured by Amasond. The outer sleeve is ribbed and has a diameter of 2.5 inches. A weight was attached to the outer sleeve near the bottom. The 1.25 inch diameter tremie line was also taped near the bottom of the sleeve.

Baroid IDP Barotherm Max was the thermally enhanced grout chosen for the bore hole. Barotherm Max is a mix of bentonite and graphite with an expected thermal conductivity of 1.6 Btu/hr·ft·°F and a density of 11.6 pounds per gallon with a solids content of 45.0% when 7 gallons of water is mixed with each bag.

The grouter used was manufactured by Dyno Drill which has a 53 gallon blending tank and a one ribbon paddle at the bottom the tank. A progressive cavity pump was used to pump the grout.

Address: 833 83rd Street (DaqUnit03) center bore hole

Date: May 6, 2011

This hole was drilled with a direct mud rotary rig. The drill bit was a 4.5 inch diameter drag bit with 2.75 inch drill pipe. The drilling fluid was water only with no additives. The rig utilized a duplex mud pump to pump the drilling fluid and a drill through pit for the mud pit. The rig equipment did not include solids control equipment. The formation types are shale and sandstone with some clay. Formation water was encountered at approximately 80 feet. The bore hole was drilled to a total depth of 135 feet without any drilling problems.

The geothermal heat loop chosen for the bore hole was an Amasond coaxial with a 2.5 inch diameter. A weight was taped to the bottom of the loop along with a 1.25 inch diameter tremie line. Water was added to the heat loop to overcome the buoyancy of the formation water in the bore hole.

Baroid IDP Barotherm Max was chosen as the thermally enhanced grout for the bore hole. Barotherm Max is a blend of bentonite and graphite with an expected thermal conductivity of 1.6 Btu/hr·ft·°F and a density of 11.6 pounds per gallon with a solids content of 45.0% when 7 gallons of water is mixed with each bag.

The grouter used was shop made with a 200 gallon horizontal blending tank. Blending vanes are mounted on a horizontal shaft mounted along the center of the tank. The grout pump was a 7 inch diameter single action pump. The tremie line was removed from the bore hole as the grout was being pumped to the surface.

Address: 925 83rd Street (DaqUnit01) west bore hole

Date: May 5, 2011

This bore hole was drilled with a direct rotary mud rig. The mud pump is a duplex rig mount type. The mud pit is a drill through type, 300 gallon capacity without baffles. The rig equipment did include solids control equipment. The bit used was a drag bit style, 4.5 inch diameter with 2.75 inch drill pipe.

The drilling fluid was water without any additives. The formations were shale and sandstone with some clay. The depth drilled was 160 feet at the end of the day.

Date: May 6, 2011

The hole was entered to make a clean out run for any possible sloughing. The bit used was a 4.5 inch drag bit with 2.75 inch drill pipe.

To facilitate hole cleaning, 50 pounds of Quik-Gel high yield bentonite was mixed into 200 gallons of water treated with 2 pounds of soda ash. The soda ash reduced the water hardness from 250 ppm to 50 ppm and increased the pH from 6.5 to 9.0.

The depth of the bore hole was increased to 173 feet. The drilling fluid was then circulated for 10 minutes to remove any cuttings and or any formation solids. The drilling fluid had the following properties:

Address: 925 83rd Street (DaqUnit01) west bore hole - CONTINUED

Viscosity – 32 seconds per quart measured with a Marsh funnel

Density- 9.1 pounds per gallon

Sand content-4.5% by volume

Filtrate-52cc by 30 minute filter press test

The geothermal heat loop is coaxial type with a 2.5 inch outside diameter and manufactured by Amasond. A weight was attached to the bottom of the loop along with a 1.25 inch diameter tremie line. The loop was filled with water to overcome the buoyancy factor from the formation water. Water was pumped into the tremie ahead of the grout.

The grouter is shop made with a blending tank capacity of 200 gallons. Blending vanes are mounted to a horizontal shaft that is placed through the center of the tank. The grout pump is a single action with a 7 inch diameter cylinder.

The grout chosen for this bore hole was Baroid IDP Barotherm Gold 1.0, a blend of bentonite and high quality silica sand. The expected thermal conductivity is to be 1.0 Btu/·ft·°F when 4 bags are mixed with 12.3 gallons of water and have a density of 14.0 pounds per gallon and total solids of 66.0%. Pumping of the grout ceased when the grout that reached the surface had the same appearance as that was mixed.

Address: 925 83rd Street (DaqUnit01) east bore hole

Date: May 5, 2011

This bore hole was drilled with a direct rotary drilling rig. The mud pump is a duplex rig mounted type. The mud pit is a drill through pan with a capacity of 300 gallons. The rig equipment did not include solids control equipment. The drill bit is 4.5 inch drag bit with 2.75 diameter drill pipe.

The drilling fluid was water without any additives. The formations encountered were shale and sandstone with some clay. Total depth of the bore hole was 177 feet. There were no bore hole problems encountered while drilling.

The geothermal heat loop was coaxial type with a 2.5 inch outside diameter and manufactured by Amasond. A metal weight was attached to the bottom of the loop to help overcome the buoyance factor from formation water in the bore hole.

The grouter is shop made with a blending tank capacity of 200 gallons. Blending vanes are mounted to a horizontal shaft that is placed through the center of the tank. The grout pump is a single action with a 7 inch diameter cylinder.

Address: 925 83rd Street (DaqUnit01) east bore hole - CONTINUED

The grout chosen for this bore hole was Baroid IDP Barotherm Gold 1.0, a blend of bentonite and high quality silica sand. The expected thermal conductivity is to be 1.0 Btu/·ft·°F when 4 bags are mixed with 12.3 gallons of water and have a density of 14.0 pounds per gallon and total solids of 66.0%. Pumping of the grout ceased when the grout that reached the surface had the same appearance as that when mixed.

Address: 944 83rd Street (DaqUnit09) east bore hole

Date: May 9, 2011

This bore hole was drilled by a horizontal directional drilling rig, modified to drill vertically. The drill bit was a single cone type with auger teeth attached. The drill pipe was HDD with an outside diameter of 2.75 inches at the shoulder of the joint. Solids control equipment was a screen inside a tank to catch the drill solids.

The drilling fluid make up water was treated with soda ash to reduce the hardness level to 50 ppm and to raise the pH to 9.5. Ten ounces of Baroid IDP Poly-Bore, a partially hydrolyzed polyacrylamide polymer, was mixed into 300 gallons of the treated make up water. Poly-Bore polymer was chosen to reduce the amount of stickiness of the native clay formation to the bit and tooling surface.

The bore hole was drilled to a total depth of 160 feet and no drilling problems were encountered.

The grouter, manufactured by The Charles Machine Company, has a 50 gallon blending tank with two paddle arms. The grout pump is a progressive cavity type.

Address: 944 83rd Street (DaqUnit09) east bore hole - CONTINUED

The geothermal heat loop was coaxial, 2.5 inches outside diameter, and manufactured by Geothex. A weight was attached to the bottom of the loop and 1.25 inch tremie line. Due to a significant amount of resistance to installing the loop to the bore hole, the rigid tremie line was replaced with a soft sided tremie line.

The grout chosen for this bore hole was Baroid IDP Barotherm Gold 1.0, a blend of bentonite and high quality silica sand. The expected thermal conductivity is to be 1.0 Btu/·ft·°F when 4 bags are mixed with 12.3 gallons of water treated with soda ash. The resulting density would be 14.0 pounds per gallon and total solids of 66.0%. Pumping of the grout ceased when the grout that reached the surface had the same appearance as that was mixed.

Address: 944 83rd Street (DaqUnit09) west bore hole

Date: May 9, 2011

This bore hole was drilled by a horizontal directional drilling rig, modified to drill vertically. The drill bit was a single cone type with auger teeth attached. The drill pipe was HDD with an outside diameter of 2.75 inches at the shoulder of the joint. Solids control equipment was a screen inside a tank to catch the drill solids.

The drilling fluid make up water was treated with soda ash to reduce the hardness level to 50 ppm and to raise the pH to 9.5. Ten ounces of Baroid IDP Poly-Bore, a partially hydrolyzed polyacrylamide polymer, was mixed into 300 gallons of the treated make up water. Poly-Bore polymer was chosen to reduce the amount of stickiness of the native clay formation to the bit and tooling surface.

The bore hole was drilled to a total depth of 160 feet and no drilling problems were encountered.

The grouter, manufactured by The Charles Machine Company, has a 50-gallon blending tank with two paddle arms. The grout pump is a progressive cavity type.

The geothermal heat loop was coaxial, 2.5 inches outside diameter, and manufactured by Geothex. A weight was attached to the bottom of the loop and 1.25 inch tremie line.

Address: 944 83rd Street (DaqUnit09) west bore hole - CONTINUED

The grout chosen for this bore hole was Baroid IDP Barotherm Gold 1.0, a blend of bentonite and high quality silica sand. The expected thermal conductivity is to be 1.0 Btu/·ft·°F when 4 bags are mixed with 12.3 gallons of water treated with soda ash. The resulting density would be 14.0 pounds per gallon and total solids of 66.0%. Pumping of the grout ceased when the grout that reached the surface had the same appearance of as that was mixed.

Address: 8528 Durland Way (DaqUnit1) east bore hole

Date: May 17, 2011

This bore hole was drilled by the direct rotary method. The drill bit is 2.75 inch drag bit. The drill pipe, shop made, has a diameter of 1.25 inches. The mud pit is a drill through pan style with 300 gallon capacity. The mud pump is a duplex rig mounted type. The drilling equipment does not include solids control equipment or a mud mixing hopper.

The drilling fluid make up water was pretreated with soda ash to reduce the water hardness to 50 ppm and to raise the pH to 9.0 to increase the yield of bentonites and additives. Baroid IDP Quik-Gel bentonite was added to the water to insure hole stability, remove the drill cuttings to the surface and to build a high quality filter cake across the face of the bore hole annulus. The bentonite was mixed using the circulation method. The viscosity of the drilling fluid was 40 seconds per quart by Marsh funnel method.

After a few feet of drilling, all returns of the drilling fluid to the surface stopped. A type of fracture was suspected as the cause of the loss of circulation and a three inch diameter by three foot PVC pipe was placed in the bore hole as a collar. A second 200 gallon volume of drilling fluid was mixed containing soda ash to soften the hard water, Quik-Gel bentonite to stabilize the bore hole and Baroid IDP Quik-Trol Gold to strengthen the filter cake. Quik-Trol Gold, a cellulosic polymer, also reduces filtration loss.

Address: 8528 Durland Way (DaqUnit1) east bore hole - CONTINUED

The total depth of the bore hole was 180 feet. A sample of the drilling fluid was collected and tested with the following properties;

Viscosity- 40 seconds per quart

Density – 9.8 pounds per gallon

pH - 9.0

Hardness – 50 ppm

Sand content – 5.5% by volume

Filtration rate 17.6cc by filter press

Plastic viscosity – 13

Yield Point – 20

Gel strengths – ten second 23, ten minute 35

Water was pumped through a tremie line placed on the bottom of the bore hole to flush out any cuttings and or pieces of formation. A .75 inch single geothermal heat loop was placed into the bore hole and sand was placed from the depth of 180 feet to 70 feet which was the static level of the formation water. Bentonite 3/8 inch chips was then poured from the sack from the 70 foot level to surface.

Address: 8528 Durland Way (DaqUnit10) west bore hole

Date: May 17, 2011

This bore hole was drilled using a direct rotary drilling rig. The drill bit is a 2.75 inch drag bit. The drill pipe, shop made, has a diameter of 1.25 inches. The mud pit is a drill through pan style with 300 gallon capacity. The mud pump is a duplex rig mounted. The drilling equipment does not include solids control equipment or a mud mixing hopper.

The drilling fluid was water without additives.

At 25 feet, a sample of drill cuttings was collected and identified as mostly shale. At 65 feet a second sample was collected that was mostly sandstone. The total depth of the bore hole was 180 feet.

A .75 inch diameter single geothermal heat loop was placed into the bore hole. Silica sand was poured from surface and placed from 180 feet to 70 feet of depth. At 70 feet is the static level of the formation water. Bentonite chips was gravity placed from 70 feet to surface.