Importance of Grouting in Geothermal Systems
OVERVIEW

- Define and compare grouting vs backfilling
- Define what is grout and its importance
- Define the reasons for grouting
- Determine the minimum requirements for an acceptable grouting material
- What types of grouting materials are available
- Grout Industry History
GROUTING VS. BACKFILLING

• Grouting- Placement of low permeability material into annular space between the borehole wall and the pipes suspended in the borehole
  — Conscious effort made to form a hydraulic seal
    • Controlled process with goal to form hydraulic seal through all critical sections of the borehole

• Backfilling- The practice of placing drill cuttings or other material into borehole
  — Primary focus is filling the borehole volume
    • No specific effort directed toward creating a hydraulic barrier
WHAT IS GROUT?

GROUT:
Sealing material placed in the annular space between the u-bend assembly and the bore hole wall.

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WHAT IS GROUT?

GROUT: Placed the entire bore length
5.8.3.1.2

Unless otherwise approved by an engineer or geologist, grouting procedures shall be carried out as follows:

(a) grout shall be placed in the borehole by pressure pumping through a tremie pipe after enough water or other drilling fluid has been circulated in the annular space to clear obstructions;

(b) tremie grouting of the entire vertical borehole using the grout material specified in Clause 5.8.3.1.3 shall be done immediately following drilling and heat exchanger installation;

(c) once started, the grouting procedure of a borehole shall not be interrupted until completed;

(d) the borehole shall be grouted from the end to the starting point;

(e) the tremie pipe shall be lowered to the bottom of the borehole and raised slowly as the grout is introduced;
(3) Grouting for Closed Loop Geothermal Boreholes

(a) The entire borehole surrounding the closed loop shall be filled with a grout material approved by the Department. A cover from land surface to five (5) feet below land surface comprised of native soil material may be used in closed loop geothermal boreholes.

(c) All grouting shall be accomplished using forced injection to emplace the grout. When emplacing the grouting material, the tremie pipe shall be lowered to the bottom of the zone to be grouted. The tremie pipe shall be kept full continuously from start to finish of the grouting procedure, with the discharge end of the tremie pipe being continuously submerged in the grout until the zone to be grouted is completely filled.

(d) The driller shall take all steps necessary to maintain safety around the borehole until the closed loop is installed and grouted in the borehole. Each ungrouted borehole or loop shall have a protective cover, or sand bag placed over the open borehole. The closed loop u-bend or dropline pipe shall be placed into the borehole to its proper depth and grouted in place within five (5) days of drilling each borehole unless the u-bend dropline pipe has been installed to its maximum depth with a dedicated tremie pipeline.
REASONS FOR GROUTING

REGULATORY:

• To prevent *surface water* contamination.
• To prevent *inter-aquifer* communication.
• To comply with local regulation and/or industry standards.
REASONS FOR GROUTING

THERMODYNAMIC:

- To promote heat transfer between the fluid in the pipe and the geological formation.
5.8.3 Grouting

5.8.3.1 General

5.8.3.1.1
Unless otherwise approved by an engineer or a geologist, boreholes shall be grouted to
(a) ensure continuous contact between the ground heat exchanger and the borehole annulus for
   efficient heat transfer;
(b) prevent potential migration of surface water into confined aquifers pierced by the borehole;
(c) prevent potential cross-contamination path between one confined aquifer to another confined
   aquifer; and
(d) surround the outside of the pipe, thereby balancing the hydrostatic pressure of the fluid inside the
   pipe.
CRITERIA FOR OBTAINING A PROPER SEAL

• Low Permeability (< 1x10^-7 cm/s)
• Reasonably High Thermal Conductivity
• No Contaminants
• Chemically and Physically Inert
  • Native host soil/rock and piping material
• Short Hydration Time, Permanence, and Flexibility
  • Settling in Borehole
  • Changes with expansion/contraction of pipe
• Long-Lasting
  • Hydraulic barrier over the intended life of the GHEX
5.8.3.1.3

5.8.3.1.3.1
Once settled, all grouting mixtures being used shall
(a) have a minimum grout thermal conductivity of 0.71 W/(m\(^{\circ}\)K) (0.41/btu/hr-ft\(^{\circ}\)F);
(b) have a hydraulic conductivity not greater than \(1 \times 10^{-7}\) cm/sec (\(3.94 \times 10^{-8}\) in/sec);
(c) remain “malleable” or flexible through the life span of the project;
(d) be inert and non toxic; and
(e) not be biodegradable.

5.8.3.1.3.2
Grout mixture should keep its thermal, hydrological and mechanical properties over time with less than
10% degradation over a 100 year time frame.
INDEPENDENT VERIFICATION

Target = 1.20 Btu/hr ft °F

1.294 (2.239) per D-5334

3.69 x 10⁻⁸ per D-5084

Target = <6.9 x 10⁻⁸ cm/sec
NSF PRODUCT & SERVICE LISTING

Typical NSF Listing as printed from the Internet

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SAMPLE TC TESTING

• Performed according to industry standards
  – ASTM D-5334 “Line Source Method”

• Free service (certain manufacturers)
  – Blind testing to guarantee accuracy
  – Recommend corrective action when necessary
  – Turnaround 3-5 days after receiving samples

• Contact your manufacturer to request forms & containers
SAMPLING ISSUES

• **Sampling error**
  – Most common reason for missing TC target

• **Proper sampling is critical**
  – Mixing tank: take from center
    • Don’t skim off top
  – Tremie line: take at middle-end of pumping a batch
    • Usually have leftover material in tank when a bore is full
GROUT TYPES

• Material types:
  • Bentonite-based (sodium bentonite)
    – Conventional Bentonite Grout (20% - 30% Solids)
    – Thermally-Enhanced Bentonite Grout (30% to 80% Solids)
  • Cement-based
    – Neat Cement: *Portland Cement & 6 gal (22.7 L) of Water*
    – Sand / Cement: >2:1 ratio by weight & 6 gal (22.7 L) of Water
    – Grout 111: *Thermally-Enhanced Cement Grout*
  • Hybrid Products
    – Cement/Bentonite: Combination that provides benefits of both (25% to 33% Solids)
(b) Grout in closed loop geothermal boreholes is to be composed of cement, a bentonite cement mixture, high solids sodium bentonite or other grout material approved by the Department. Thermal grout, Thermal Grout Lite and Mix 111 Grout are three specific type grouts approved by the board for the grouting and closure of closed loop geothermal boreholes.

1. Cement grout shall be composed of Class A, Type I Portland Cement mixed with not more than six (6) gallons of clean water per bag (one cubic foot or 94 pounds) of cement with a density of 15 to 16 pounds per gallon, or to manufacturer’s specifications.

2. Bentonite-cement grout shall be composed of powdered bentonite (less than 5% by weight) mixed at not more that 8 gallons of water to the bag, with a density of 14 to 15 pounds per gallon, or to manufacturer’s specifications.

3. High solids sodium bentonite grout shall have minimum of 20% solids and be mixed per manufacturer’s specifications with water and/or other required additives.
### 1.20 Recipe Comparison

<table>
<thead>
<tr>
<th>Silica Sand “Mix Batch”</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TG Select (lbs)</strong></td>
<td><strong>PowerTEC (lbs)</strong></td>
<td><strong>Silica Sand (lbs)</strong></td>
<td><strong>Water (gal)</strong></td>
<td><strong>Yield (gal)</strong></td>
<td><strong>Density (lbs/gal)</strong></td>
<td><strong>TS/AS (%)</strong></td>
</tr>
<tr>
<td>50 (1)</td>
<td>0</td>
<td>400 (8)</td>
<td>21.6</td>
<td>42.2</td>
<td>14.93</td>
<td>71.4/21.7</td>
</tr>
</tbody>
</table>

*PowerTEC “Mix Batch” (no sand)*

<table>
<thead>
<tr>
<th><strong>TG Lite (lbs)</strong></th>
<th><strong>PowerTEC (lbs)</strong></th>
<th><strong>Silica Sand (lbs)</strong></th>
<th><strong>Water (gal)</strong></th>
<th><strong>Yield (gal)</strong></th>
<th><strong>Density (lbs/gal)</strong></th>
<th><strong>TS/AS (%)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>100 (2)</td>
<td>32 (1)</td>
<td>0</td>
<td>30.0</td>
<td>36.4</td>
<td>10.5</td>
<td>34.5/28.6</td>
</tr>
</tbody>
</table>

*PowerTEC “Mix Batch” (CG PLUS)*

<table>
<thead>
<tr>
<th><strong>TG Lite (lbs)</strong></th>
<th><strong>PowerTEC (lbs)</strong></th>
<th><strong>TYPE II (lbs)</strong></th>
<th><strong>Water (gal)</strong></th>
<th><strong>Yield (gal)</strong></th>
<th><strong>Density (lbs/gal)</strong></th>
<th><strong>TS/AS (%)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>100 (2)</td>
<td>64 (2)</td>
<td>47 (2)</td>
<td>52.0</td>
<td>65.8</td>
<td>9.8</td>
<td>32.7/25.2</td>
</tr>
</tbody>
</table>
## Typical Thermal Conductivities

<table>
<thead>
<tr>
<th>Material</th>
<th>Thermal Conductivity (Btu/hr-ft-°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional Bentonite Grout</td>
<td>0.38 – 0.45</td>
</tr>
<tr>
<td>Neat Cement</td>
<td>0.55</td>
</tr>
<tr>
<td>Dry Bentonite Chips</td>
<td>0.20</td>
</tr>
<tr>
<td>Saturated Bentonite Chips</td>
<td>0.50</td>
</tr>
<tr>
<td>Thermally Enhanced Grout</td>
<td>0.57 – 1.60</td>
</tr>
<tr>
<td>Dry Sand</td>
<td>0.20</td>
</tr>
<tr>
<td>Saturated Sand</td>
<td>1.40</td>
</tr>
<tr>
<td>Heavy, Dry Soil</td>
<td>0.50</td>
</tr>
<tr>
<td>Heavy, Damp Soil</td>
<td>0.75</td>
</tr>
<tr>
<td>Heavy, Saturated Soil</td>
<td>1.40</td>
</tr>
<tr>
<td>Average Rock</td>
<td>1.40</td>
</tr>
<tr>
<td>Dense Rock</td>
<td>2.00+</td>
</tr>
</tbody>
</table>
INDUSTRY HISTORY

• 1990:
  o Charles Remund, Ph.D., started research on grouting materials used in geothermal heat pump applications.
  o Discovered conventional grout was a good insulator.

• 1993:
  o Remund published University research showing how thermal grout positively impacted the initial cost of installations.

• 1996:
  o Silica sand sources are identified nationwide.
    • A thermal grout product obtains first NSF/ANSI Standard 60 certification and listing.
INDUSTRY HISTORY

• 2001:
  o IGSHPAs “Grouting for Vertical GHP Systems” is published which addresses the importance of thermal grout TC value to system performance and installed cost.

• 2007:
  o Thermal enhancement with graphite-based additive is introduced to the market

• 2012:
  o Ball State University completely eliminates use of silica sand, making it the first large scale project to adopt graphite-based additive as the preferred thermal enhancement product

• 2016:
  o Graphite-based additives begin to replace silica sand as the preferred thermal enhancement compound
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