In-Situ Thermal Response Tests on Various Borehole Configurations

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Participant in the
OG&E Ground Source Heat Exchanger Study
OG&E Ground Heat Exchanger Study

• Hope Crossing (Habitat for Humanity), Oklahoma City, OK
• Ten installations/homes
• In-situ thermal response tests
• One-year performance data
Acknowledgments

- OG&E coordinated study
- Homeowners
- Many collaborators in the study
- Garen Ewbank
  Ewbank Geo Testing, L.L.C. performed in-situ thermal response tests
In-Situ Thermal Response Test

- U-tube boreholes – 2
- Double U-tube boreholes - 1
- Coaxial boreholes - 3
In-Situ Thermal Response Test

Heater

Pump

$T_{inlet}$

$T_{out}$

Borehole heat exchanger
Mean Temperature Approximation

Temperature °C

Time (hr)

- **Inlet**
- **Outlet**
- **Mean**
In-Situ Thermal Response Test

- Estimate soil thermal conductivity
- Estimate of borehole resistance

Soil Thermal Conductivity $\sim \frac{1}{\text{Slope}}$
Soil Thermal Conductivity

Soil Thermal Conductivity (Btu/(hr-ft-F)) vs. Active Depth (ft)

- Thermal Conductivity values range from 1.5 to 2.5 Btu/(hr-ft-F).
- Active depth values range from 100 ft to 400 ft.

The graph shows a trend where soil thermal conductivity increases as the active depth increases.
Borehole Thermal Resistance, $R_b$

$R_b = \frac{T_f - T_b}{q/L}$

$R_s = \frac{T_b - T_s}{q/L}$
Borehole Resistance ~ Intercept
Two Boreholes

![Graph showing Dimensionless Temperature Rise, $T_D$, against ln(Time(hr)) with and without spacers. The graph compares the temperature rise with spacers at 10 ft apart.]
Boreholes With U-tubes

Single U-tube
• Slim hole (2-3/4” diameter)
• Gravel pack below 70 ft
• Bentonite grout above 70 ft

Single U-tube
• Enhanced grout (kg = 0.8 Btu/(hr-ft-F))

Double U-tube
• Enhanced grout (kg = 0.8 Btu/(hr-ft-F))
Single U-tube in Slim Hole

![Graph showing temperature vs. ln(time)](image)

- **Temperature (°F)**
- **ln(Time (hr))**
- **Mean Temp.**
- **Fit Line**
Borehole Resistance

Borehole Resistance (Btu/(hr-ft-F))

- Reference Borehole
- Single U-Tube Slim Hole
- Single U-tube Enhanced Grout
- Double U-tube Enhanced Grout
Coaxial Heat Exchanger

- Central Pipe
- External Pipe
- Borehole Wall
- Soil or Rock
- Grout
Model and Measured Temperatures
Geothex® Coaxial Heat Exchanger
Model and Measured Temperatures
Geothex® Coaxial Heat Exchanger

![Graph showing model and measured temperatures over time. The x-axis represents time in hours (0.01 to 100), and the y-axis represents temperature in °F (60 to 100). The graph compares measured temperatures (circles) with the vertical profile model (red line).]
Vertical Temperature Profiles

U-tube

Coaxial

Mean temp. approx.
Shunt-circuit effects

More accurate temp. profile

Shunt-circuit effects
Borehole Resistance, $R_b$, in Coaxial Heat Exchanger

Fluid enters the central pipe
Borehole Resistance

<table>
<thead>
<tr>
<th></th>
<th>Borehole Resistance (Btu/(hr-ft-F))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference Borehole</td>
<td>0.3</td>
</tr>
<tr>
<td>Single U-Tube Slim Hole</td>
<td>0.2</td>
</tr>
<tr>
<td>Single U-tube Enhanced Grout</td>
<td>0.2</td>
</tr>
<tr>
<td>Double U-tube Enhanced Grout</td>
<td>0.1</td>
</tr>
<tr>
<td>Geothex® Max k Grout</td>
<td>0.2</td>
</tr>
<tr>
<td>Geothex® Enhanced Grout</td>
<td>0.3</td>
</tr>
<tr>
<td>Amasond® Enhanced Grout</td>
<td>0.3</td>
</tr>
</tbody>
</table>
Borehole Resistance
With Enhanced Grout

Borehole Resistance
(Btu/(hr-ft-F))

Reference Borehole
Single U-tube
Double U-tube
Geothex®
Potential Percent Length Reduction With Enhanced Grout

![Bar graph showing potential percent length reduction with enhanced grout. The x-axis represents soil thermal conductivity (Btu/(hr*ft*F)), with values 0.6, 1.6, and 2.2. The y-axis represents percent reduction. The graph compares single U-tube and double U-tube systems.]
Conclusions

- In-situ thermal response test
- Ranking based on thermal resistance
  - Double U-tube with enhanced grout
  - Single U-tube/Coaxial with enhanced grout
  - Baseline single U-tube with std. grout
Conclusions

• In-situ thermal response test
• Percent reduction in borehole length
  – Double U-tube: 20% to 40%
  – Single U-tube/enhanced grout: 12% to 24%
  – Coaxial/enhanced grout: 10% to 20%