Multiple Zone Stimulation of EGS Wells – Key to Reservoir Optimization

Geothermal Energy Utilization Associated with Oil and Gas Development

SMU
June 13-15, 2011

Susan Petty, Daniel Bour, Yini Nordin, Laura Nofziger – AltaRock Energy Inc.

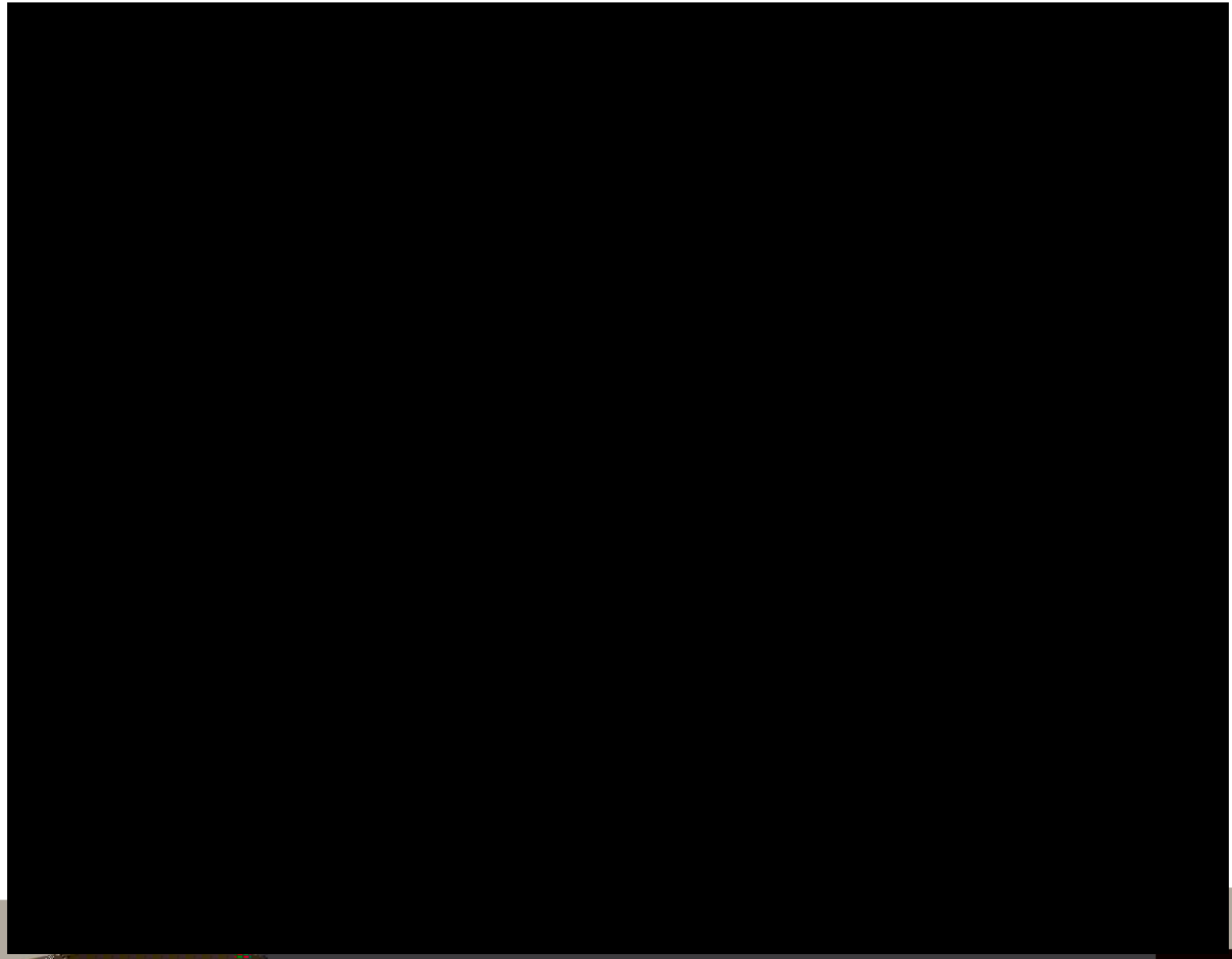
Outline

- Introduction ð Geothermal & EGS Power
- EGS Lessons Learned
- Current Stimulation Technology
- Reservoir Optimization
- Temporary Diverters
  - Benefits
  - Design
  - Application
- GETEM Modeling Results
- Description of Operations
- Outcome & Conclusions


ALTA
ENERGY INC

Heat Stored in Rock

AltaRock Confidential



Worldwide EGS Lessons Learned

Project	Timeline	Deformation Mode on Fractures	Thermal Output (MWe equiv)	Problems encountered
Fenton Hill				

Worldwide EGS Lessons Learned

- First well needs to be drilled and stimulated in order to design the entire system
- Stimulation is through shearing of pre-existing fractures instead of creating new tensile fractures
- High flow rates with long path length are needed
- Need technology for multiple zone stimulation
  - We currently do not have reliable open-hole packer for zonal isolation

Current Stimulation Technology

- Inject fluid from the surface
- Most permeable zone in well takes fluid and is stimulated
- Remaining zones only take limited amounts of fluid.
- Increasing flow by increasing injection pressure risks induced seismicity

Reservoir Optimization

Single Fracture Network

Limitations of Single Fracture

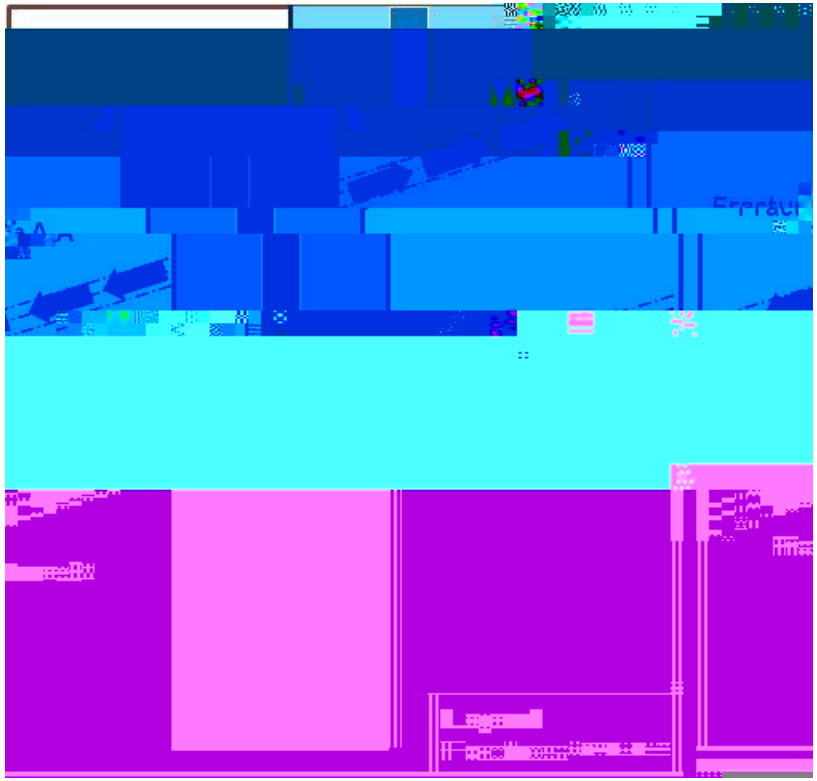
- Flow through a single stimulated fracture network provides minimial heat exchange area
- Flow rates are then limited by the maximum injection pressure which will extend fractures
  - Increase the rate of cooling at the production well
-

Reservoir Optimization

Benefits of Multiple Fractures

- Multiple fractures allow for flow through two or more fracture networks
- More rock heat exchange area is contacted
- Pressure drop through system is reduced allowing higher flow rates
- Additional flow will allow for greater production on a per well basis

Multiple Fracture Network



GETEM Modeling Results

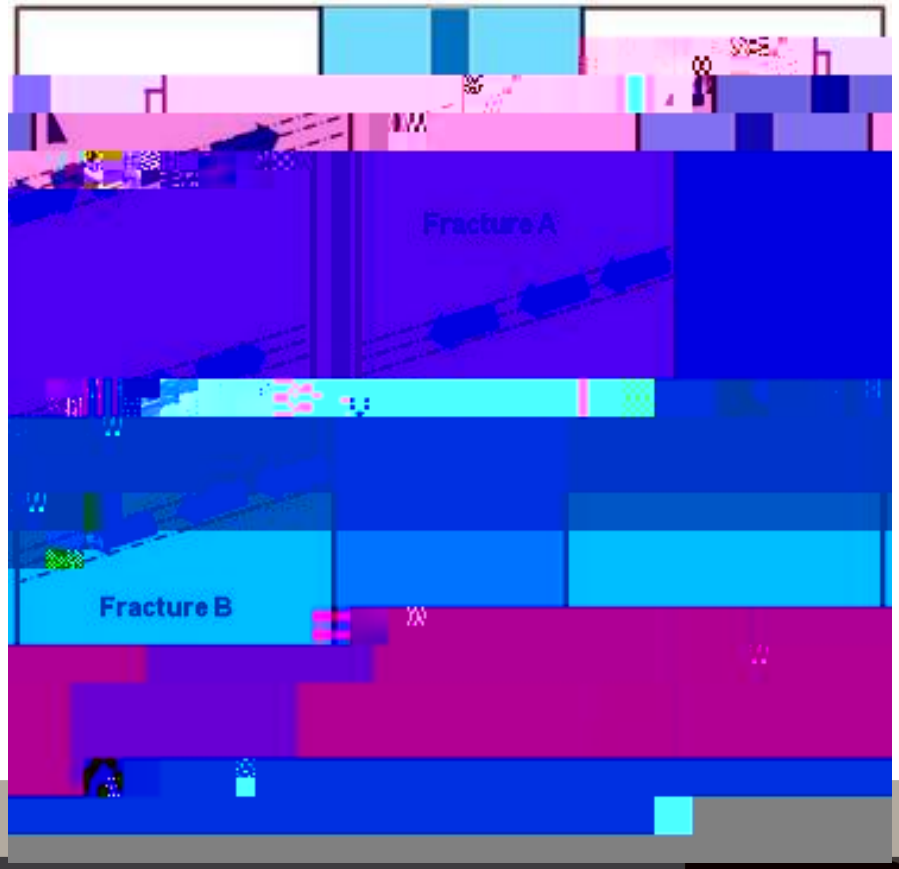
- Inputs
  - 30 kg/sec base flow
  - 4 km depth well
- Results
  - Flash system had 40% reduction in power cost
  - Binary system had 50% reduction in power cost

Flash/Binary	Temperature (° C)	Improvement	Cost of Power 2010 (cent/kw)

Temporary Diverters

Diverter Sealing Zone

Degraded Diverter



AltaRock Proprietary Temporary Diverters

Design

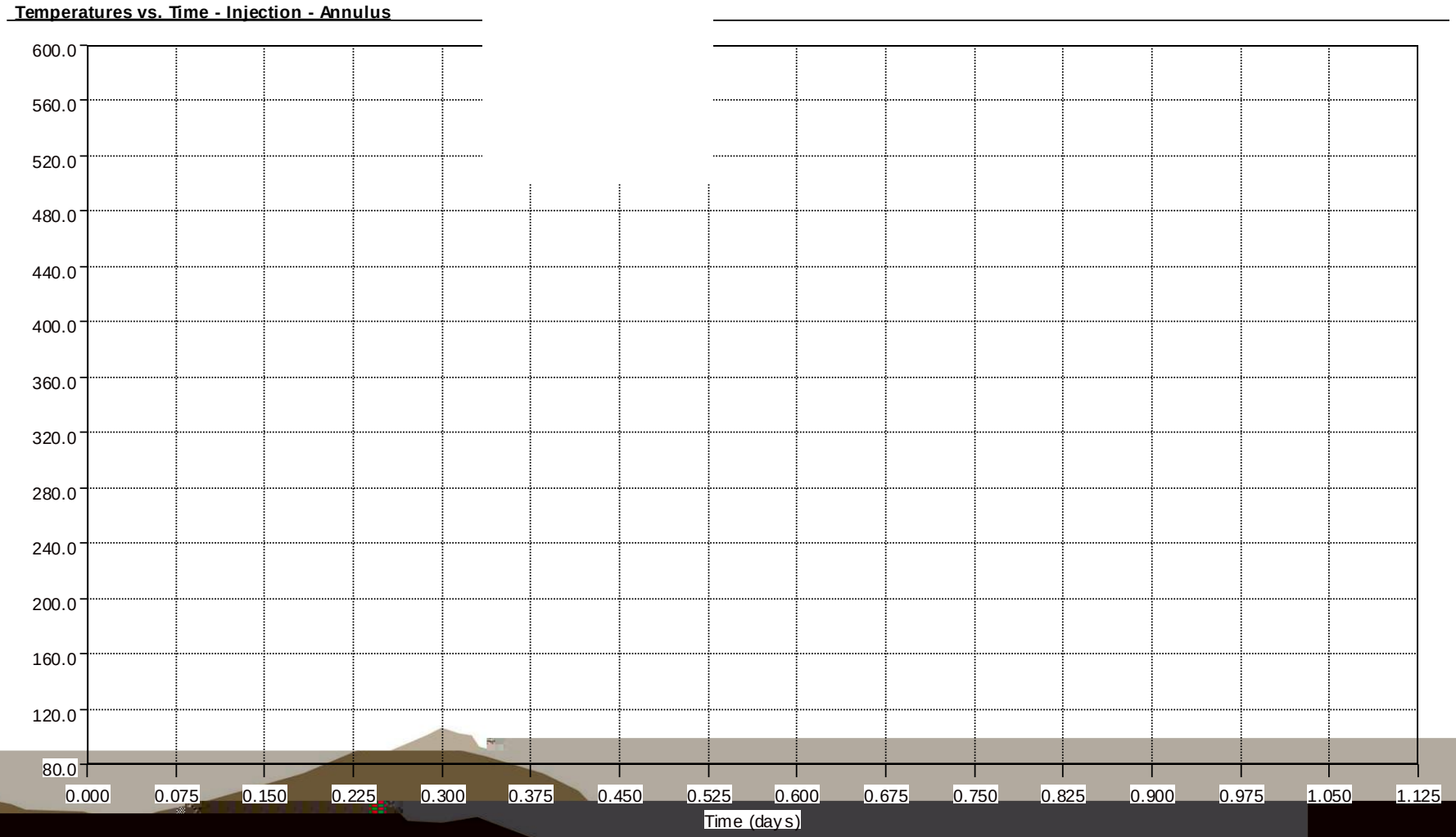
- Particle size distribution of material that will allow for packing and sealing of fracture
- Remain in place and withstand differential pressure during 2nd stimulation
- Degrade to non-damaging products after stimulation as well heats back up
- Require instruments in hole during treatment to monitor and verify that diversion has occurred

Benefits

- Increased production reduces cost of power production
- No Rig required during treatment
  - Major cost Savings
  - Reduce Operational risk
  - Create fractures in succession without moving packer and waiting on rig
- Can be used even when slotted liner is in place
  - Cannot use mechanical isolation like packers in well with slotted liner

Temperature Modeling

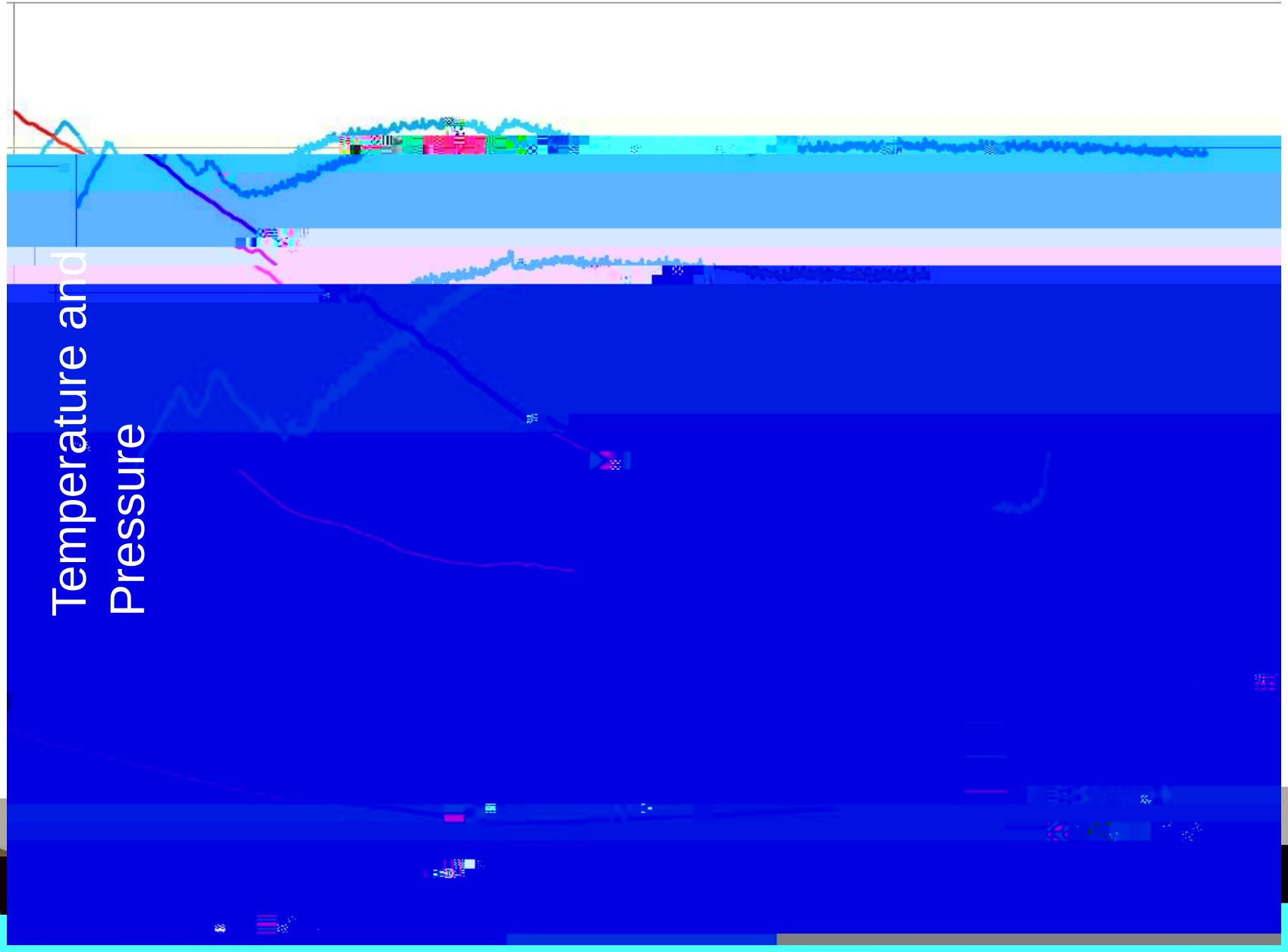
Thermal Cooling from Injection ð 10 bpm



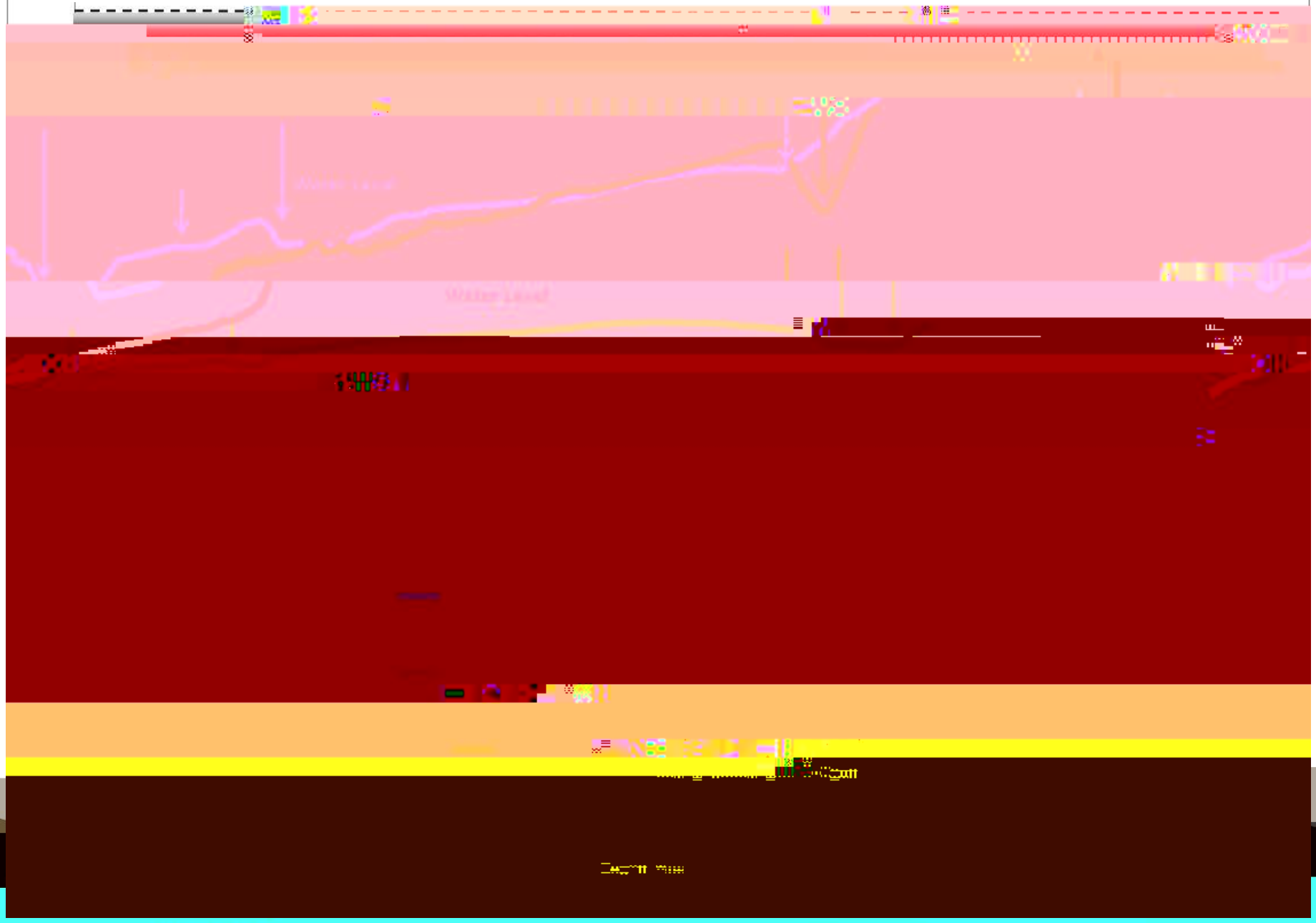
Diverter Test No.1

- Injected water into well prior to the diverter test
- Multiple rates of 150, 300, and 500 gpm
- Measured temperature at bottom of hole

Diverter Test No.1 T & P vs. Time Monitomtted@504



Diverter Test Temperature vs. Depth Monitoring



Injection Pressure Comparison

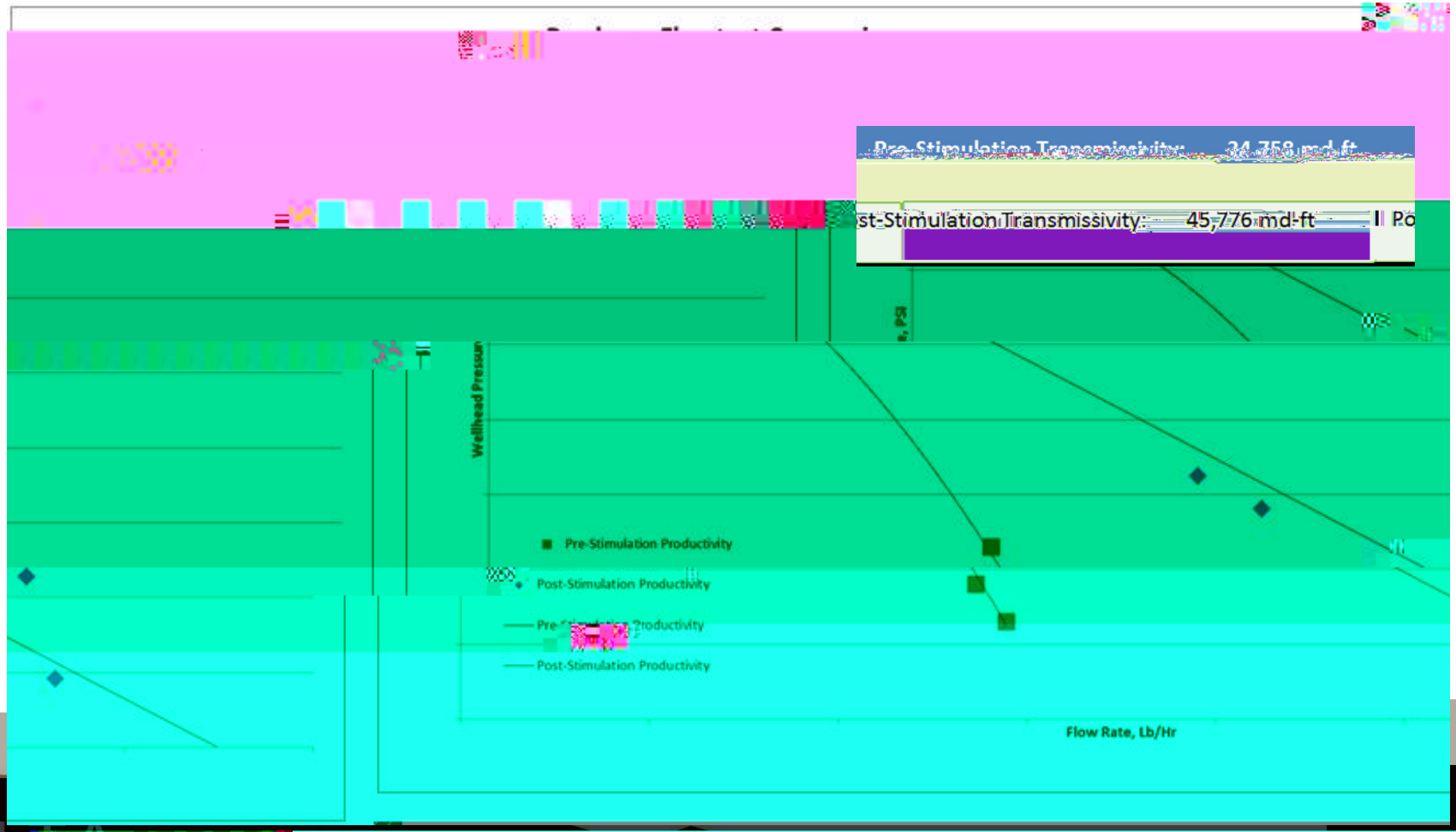
Outcomes & Conclusions ð Test No.1

- The first field trial of AltaRock Proprietary Diverter successful
- Highly permeable fractures temporarily sealed
- The presence of a slotted liner with ı ó slots did not pose a problem
- Injection profile in well could be modified temporarily
- Fluid could be pushed deeper into the wellbore
- Finally, transmissivity calculations (kh) before and after the test imply full degradation of the diverter material ð value held steady at 55,000 md-ft.

Tracer Test Results ð Test No.2

Å

Flow Test Results - Test No.2



Outcomes & Conclusions ð Test No.2

- Successful diversion and stimulation (tracer tests)
- Improved long term production
- Improved permeability due to stimulation (Transmissivity)
- Enhanced production from deeper interval

Conclusions

- AltaRock Proprietary Chemical Diverters have potential to greatly reduce the cost of EGS power and to enhance production of hydrothermal production wells
  - Increase power production on a per well basis
  - GETEM modeling indicates up to 50% or more reduction in power costs
- Field tests provide support of concept of using chemical diverters to temporarily divert flow in actual wells
  - Even with slotted liners already in place

Questions?