

SPEE Denver Chapter July 16, 2025 Luncheon Meeting. Speaker: Mr. Patrick Mays, GTO Technologies, Co-Founder and COO will be speaking on: A Roadmap to Enhanced Geothermal Systems Economic Viability



Definition: Enhanced Geothermal Systems (EGS) adapt oil and gas technologies, particularly hydraulic fracturing, to access geothermal energy from hot, but less permeable, underground rock. EGS creates artificial reservoirs by fracturing the rock and circulating water to extract heat, potentially providing a significant source of renewable energy.

Abstract: In this presentation we examine the fundamental well design concepts for **Enhanced Geothermal Systems** (EGS). Beyond the fundamentals of well design, we will also examine the critical aspects of well design that impact economics. These topics include the impact of parasitic losses on electrical generation, specifically, rate vs. wellbore geometry and this relation in doublet vs. triplet well systems. Additionally, we will evaluate the impact of conformance control on the life and economics of EGS including the critical design considerations and how traditional measures used in oilfield waterfloods impact the economics of EGS.

Speaker Bio: **Mr. Patrick Mays** is a seasoned professional with extensive expertise in operations excellence, drilling, and completions engineering. With a career spanning three decades, he has consistently delivered innovative solutions to improve safety, cost efficiency, and performance in the energy sector.

Currently serving as Co-Founder and COO of GTO Technologies, Patrick is dedicated to advancing carbon-free electricity through Enhanced Geothermal Systems. He collaborates with staff at the Colorado School of Mines to address technological gaps in geothermal energy development, focusing on drilling and completion phases.

Previously, Patrick held leadership roles at Chevron, where he managed complex international projects across Angola, China, Venezuela, Thailand, and the U.S. His achievements include optimizing well designs, reducing drilling and completion times, and implementing cutting-edge technologies such as remote directional drilling and monobore well designs.

Patrick holds a BS in Petroleum Engineering from the Colorado School of Mines and an MBA from UCLA's Anderson School of Business. He is a licensed Professional Engineer in Petroleum Engineering (California) and holds an IADC Well Control Certification.

With expertise in risk management, performance benchmarking, and advanced project modeling, Patrick is committed to driving innovation and operational excellence in the energy industry. www.GTO-EGS.com

SPEE Presentation

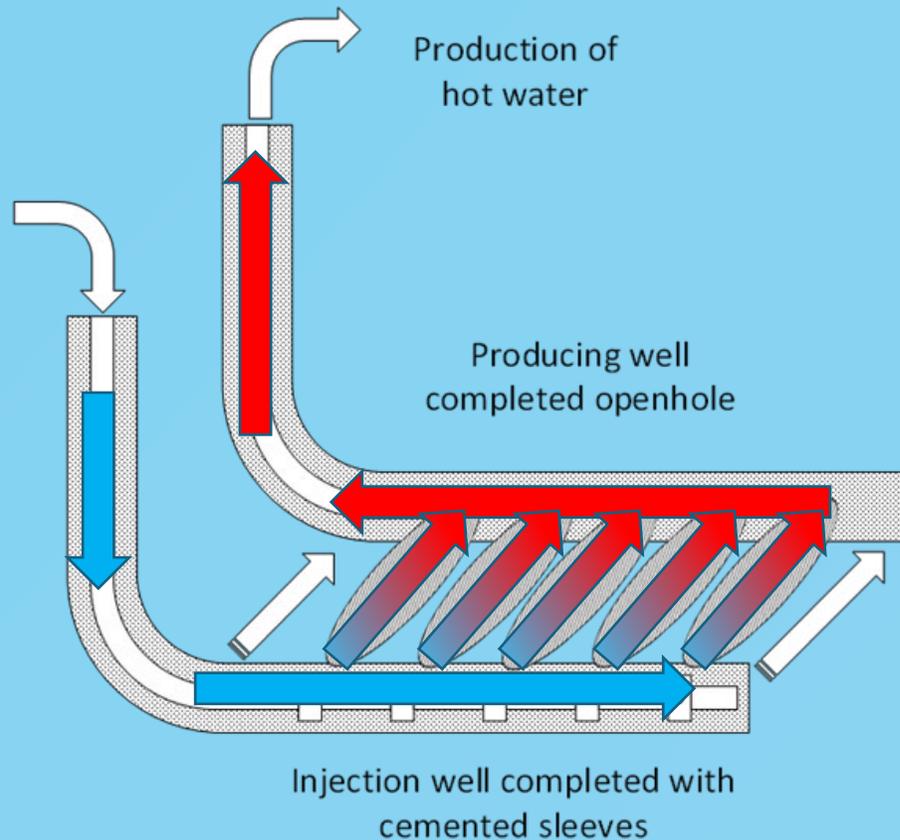
A Roadmap to EGS Economic Viability

Patrick Mays & William Fleckenstein

www.gto-egs.com

July 2025

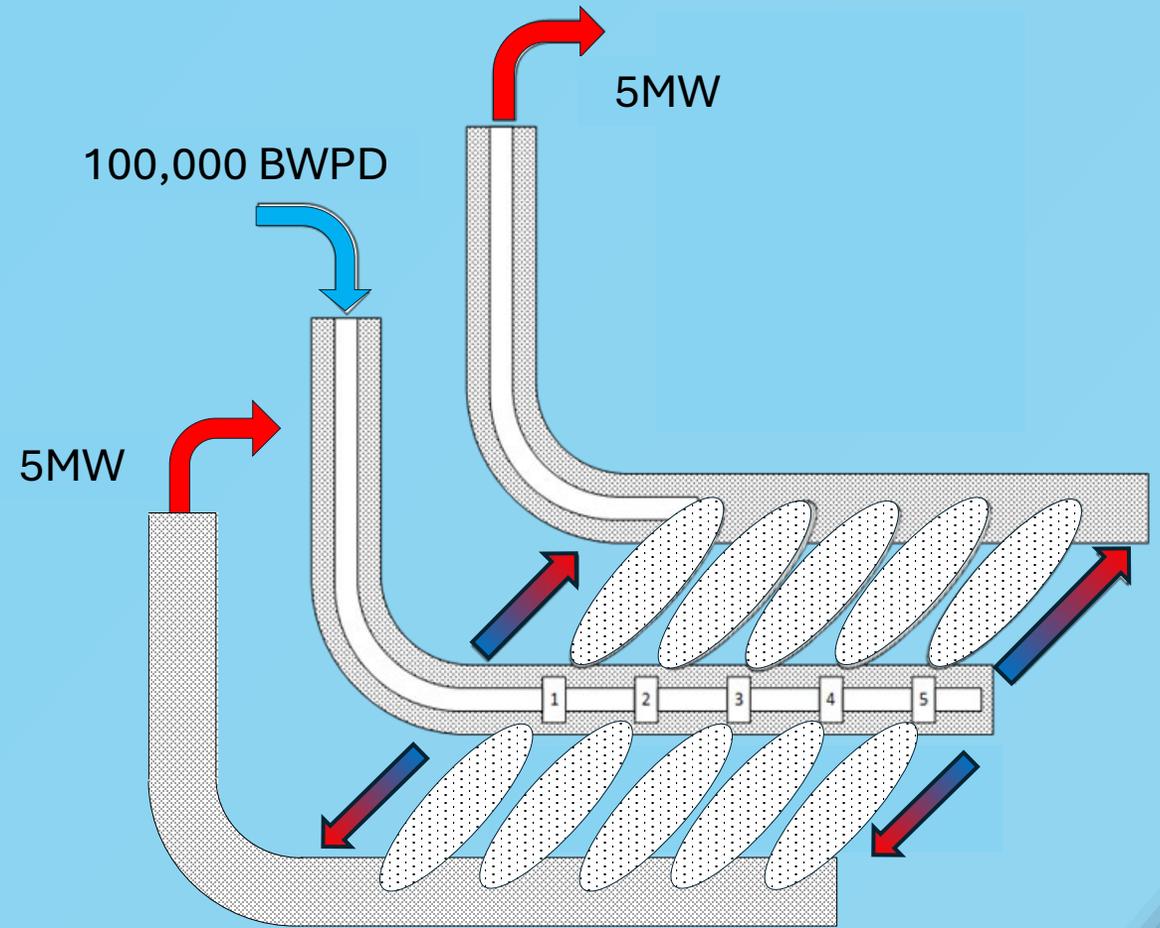
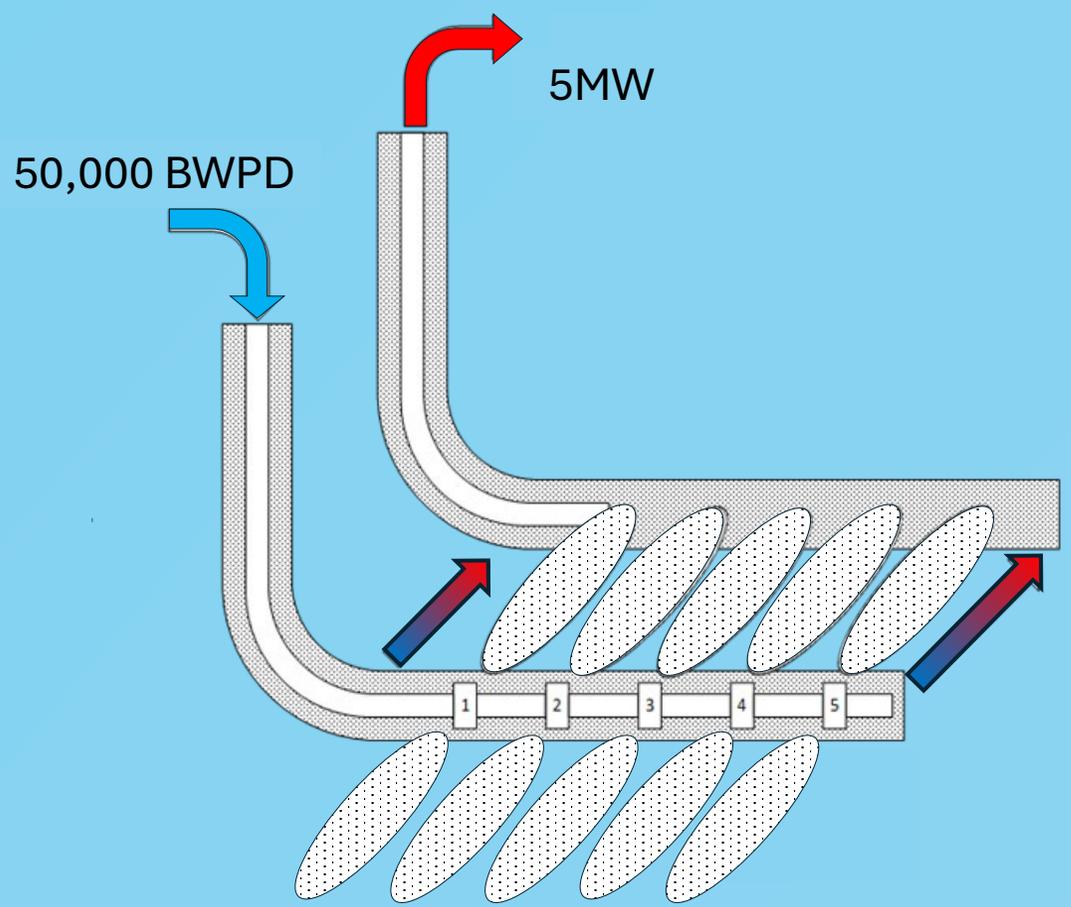
What are Enhanced Geothermal Systems (EGS)?



- A minimum of 2 'horizontal' wells
- Interconnected with fractures
- Inject water down one well
- Water is heated across the fractures
- Hot water is produced and converted to electricity



Doublet vs. Triplet Design





Comparison to Unconventional Wells

- Similarities
 - Predominantly horizontal wells with fracture stimulations
 - Approximately 1-mile laterals as a starting point
 - Single pad for multiple wells
 - Allows for zipper fracs
 - Reduces footprint and pad costs



Comparison to Unconventional Wells

- Differences

- **VOLUME!** Doublets ~50,000 BPD, Triplets ~100,000 BPD
- Large bore: minimum 7” casing in laterals
- Temperature >400F: extreme conditions for electronics packages, etc.
- Depth: 12,000’ -20,000’ TVD to reach desired temp
- Rock: Usually drilling in basement (granitoid)
- Mud program: Very simplistic (water + FR)
- Cement: Special requirements for strength at temp, avoid flash set
- Thermal Expansion: wellheads, trees, etc.



The Four C's of EGS

- Celsius
 - Temperature is critical; minimum economic temperature of 200C
- Connection
 - The wells must be interconnected with natural or engineered fractures
- Conductivity
 - The fractures must be able to transmit large volumes of fluid (50,000 – 100,000 BBL per day per 2-3 well system)
- Conformance
 - The working fluid (water) must flow down each fracture relatively evenly

Without the four C's, EGS are doomed to economic failure



Connection

- **Project Red (Fervo) and Forge Data Access (DOE)**
- **Both Project Red and Forge proved successful connection**
 - Forge: ~14,400 BPD rate @ ~3,000 psi
 - 10 stages Injector; 4 stages + 1 perf only Producer
 - 90% circulation efficiency (water produced / water injected)
 - 380F produced water
 - Project Red: ~22,300 BPD rate @ ~2,000 psi
 - 16 stages Injector, ~16 stages Producer
 - ~92% circulation efficiency (water produced / water injected)
 - 336F produced water
 - 2.0-2.5 MW avg. electricity production

*Based on current public data (FORGE / Project Red)



Conductivity

- Project Red Conductivity Calculations

- Calculated individual fracture conductivity of 300 md · ft to 400 md · ft
- Based on circulating pressures for the system (project red)
- Expected pressure drop across reservoir: about 300 to 450 psi

- *Based on “Commercial-Scale Demonstration of a First-of-a-Kind Enhanced Geothermal System” Jack H. Norbeck and Timothy M. Latimer

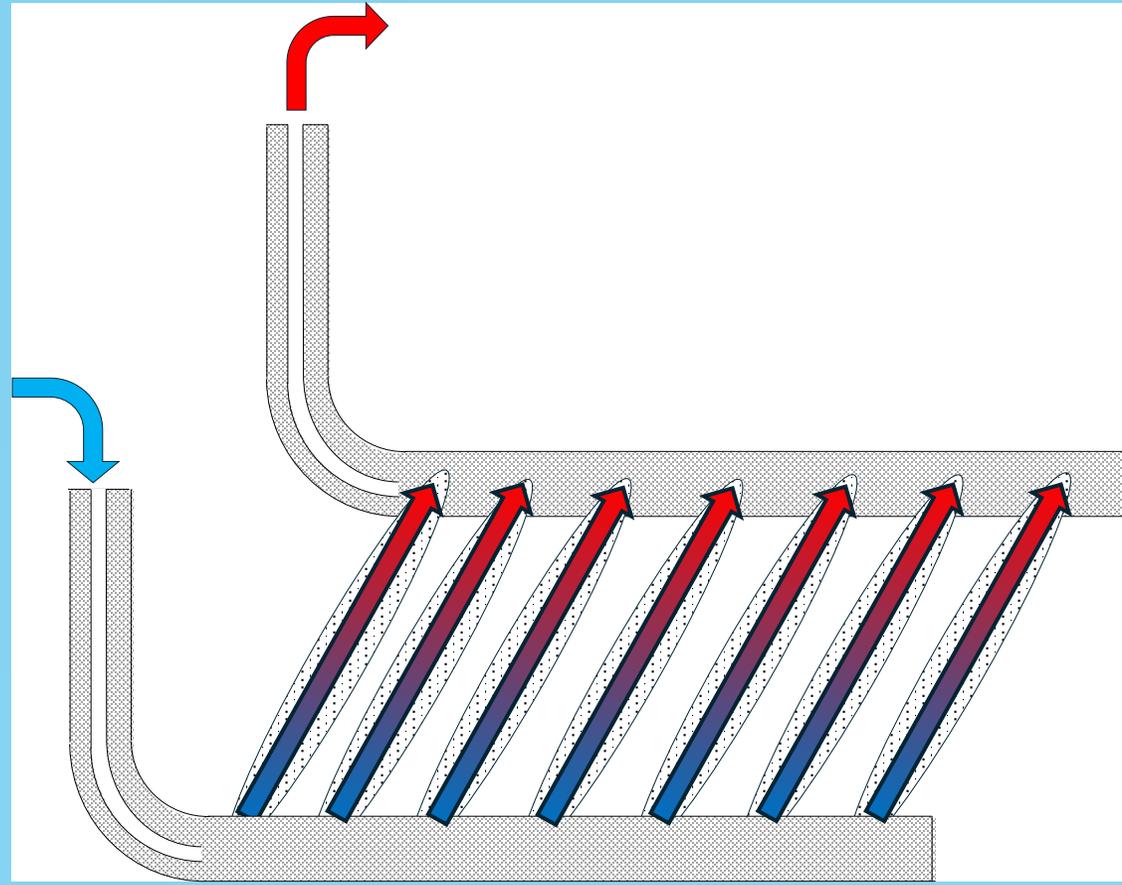
- HHP Requirement

- Based on circulating 13 bpm to 18 bpm through the system (Project Red)
- Expected pressure drop across reservoir: about 300 to 450 psi

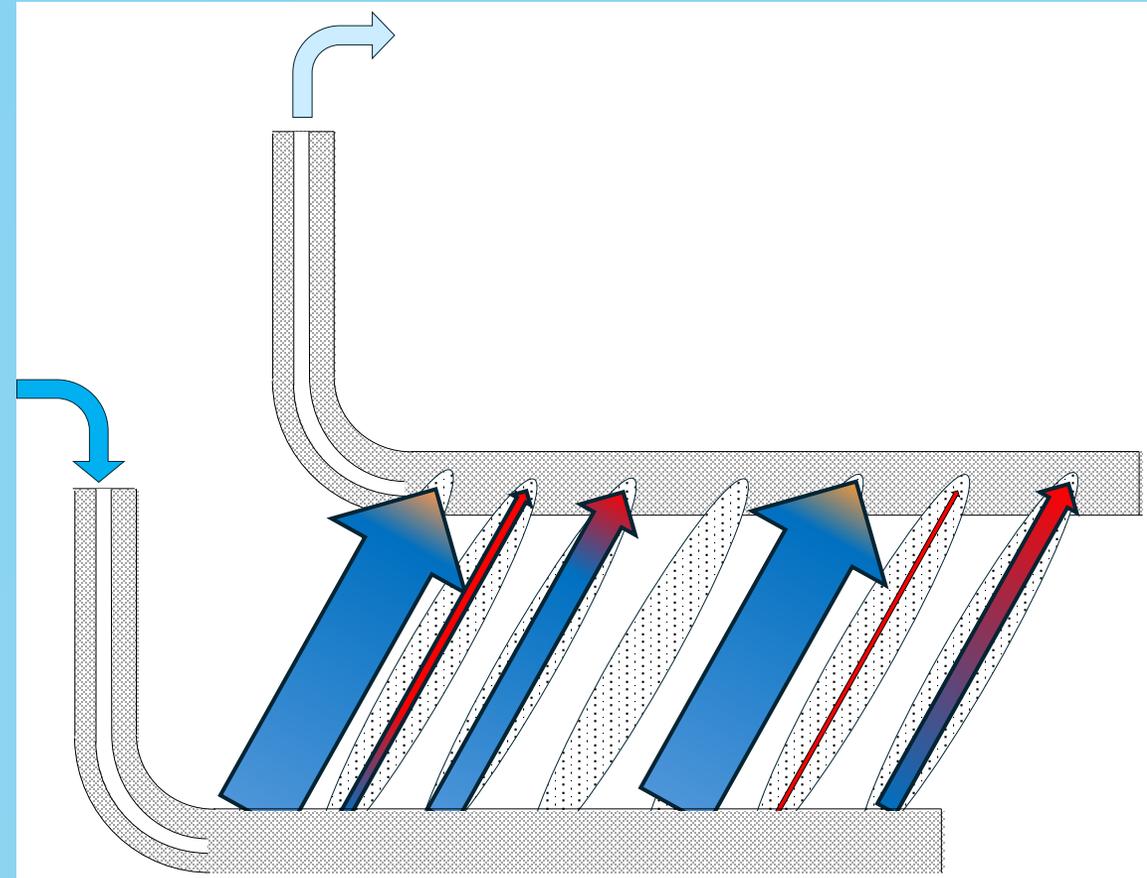
- $$\frac{13\text{BPM} \cdot 42 \frac{\text{gal}}{\text{bbl}} \cdot 300\text{psi}}{1714} = \mathbf{95 \text{ HHP}}$$
 to
$$\frac{18\text{BPM} \cdot 42 \frac{\text{gal}}{\text{bbl}} \cdot 450\text{psi}}{1714} = \mathbf{200 \text{ HHP}}$$

- 95 HHP = 0.07 MW
- 200 HHP = 0.15 MW
- ~3% - 7% Electrical generation lost across reservoir

Conformance Control



Ideal Scenario

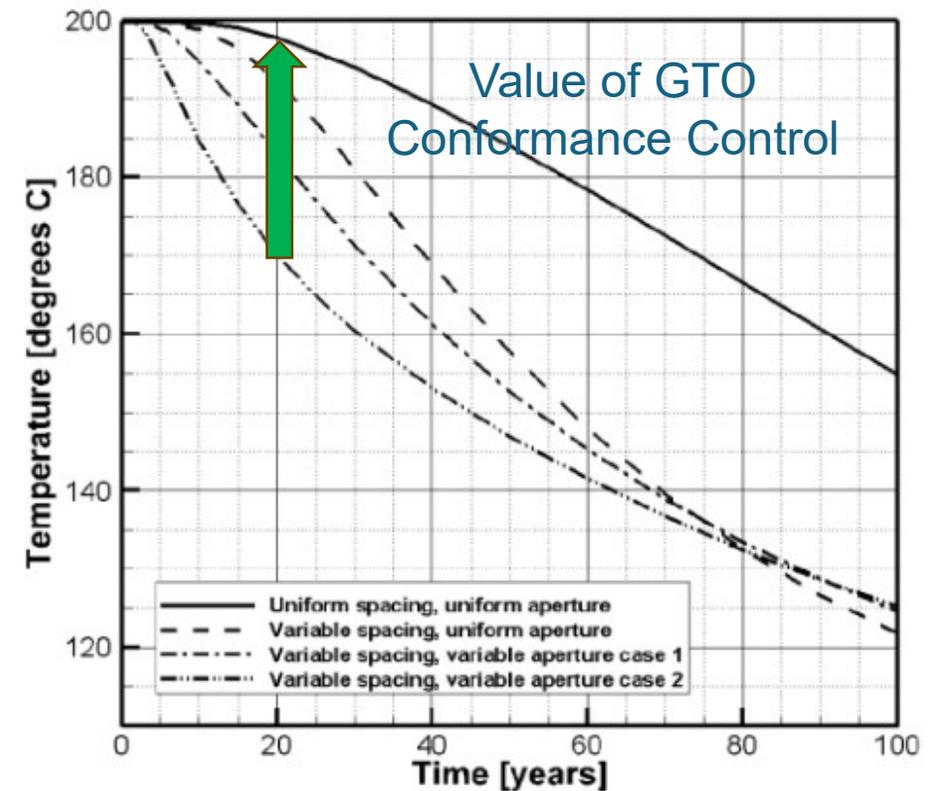


Reality

Conformance Control is the Key to EGS Economic Viability

- Conformance control
 - Control injection evenly into each fracture
- Failure of conformance control:
 - Faster thermal decline
 - Reduced plant efficiencies
 - Reduced electric generation
 - Poor project economics

EGS Thermal Decline Curves



Golder Associates: Thomas Doe



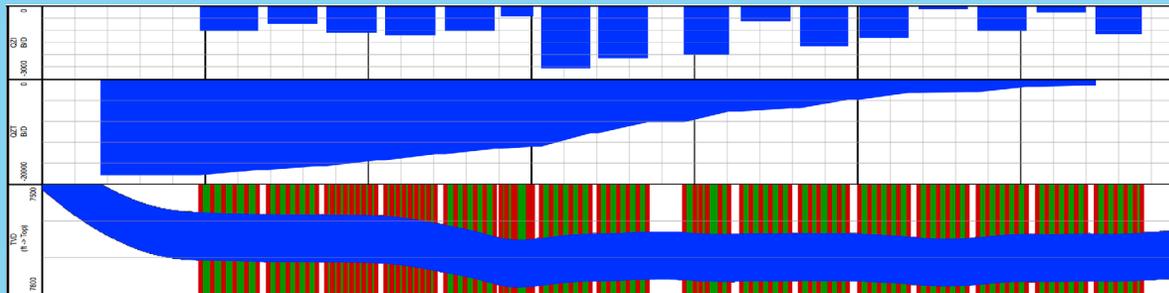
Recent EGS Development – Project Red

Project Red EGS Injection Log

Injection Rate per Zone

Cumulative Injection

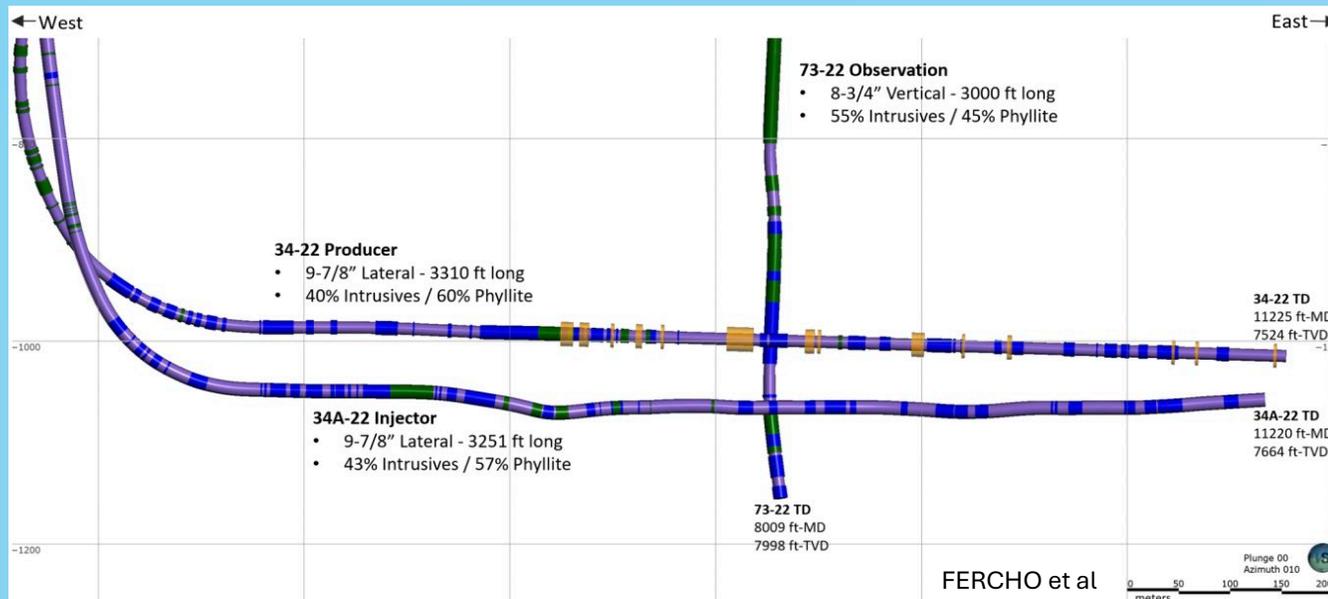
Horizontal Profile vs Stages and Clusters



Project Red is a 2 wells EGS

Blue bars (Top Row) show the ILT injection distribution

The inconsistent size of the blue bars show the variable injection into each zone (0 – 2600 BPD per zone)





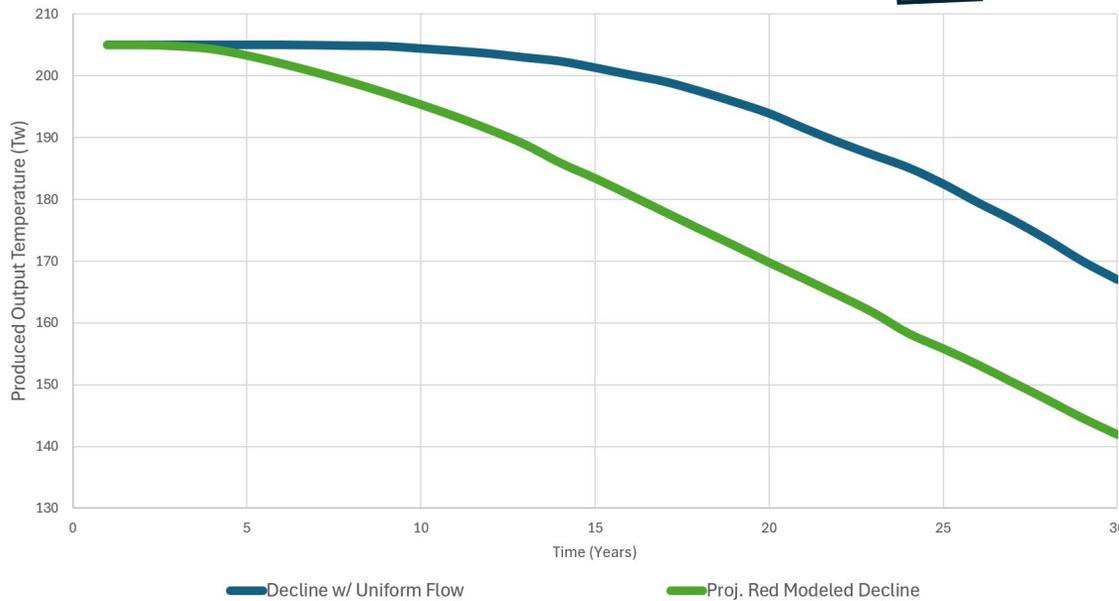
Recent EGS Development – Project Red

Project Red EGS scaled to 205C and 50,000BWPD

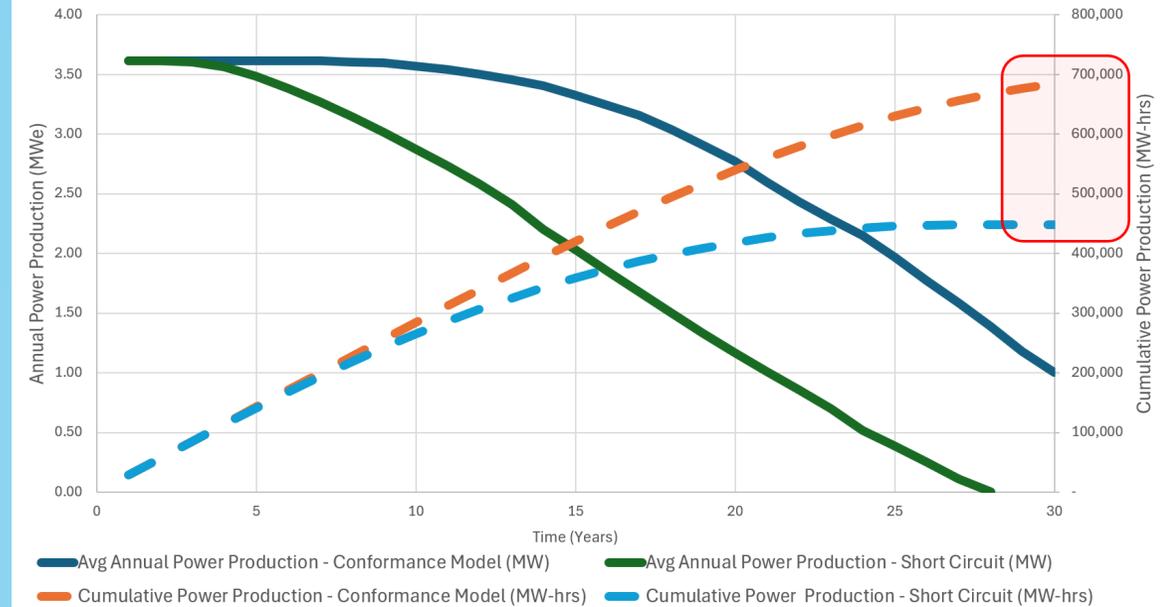


35% Less Power Production!!

Modeled Thermal Decline Due to Short Circling

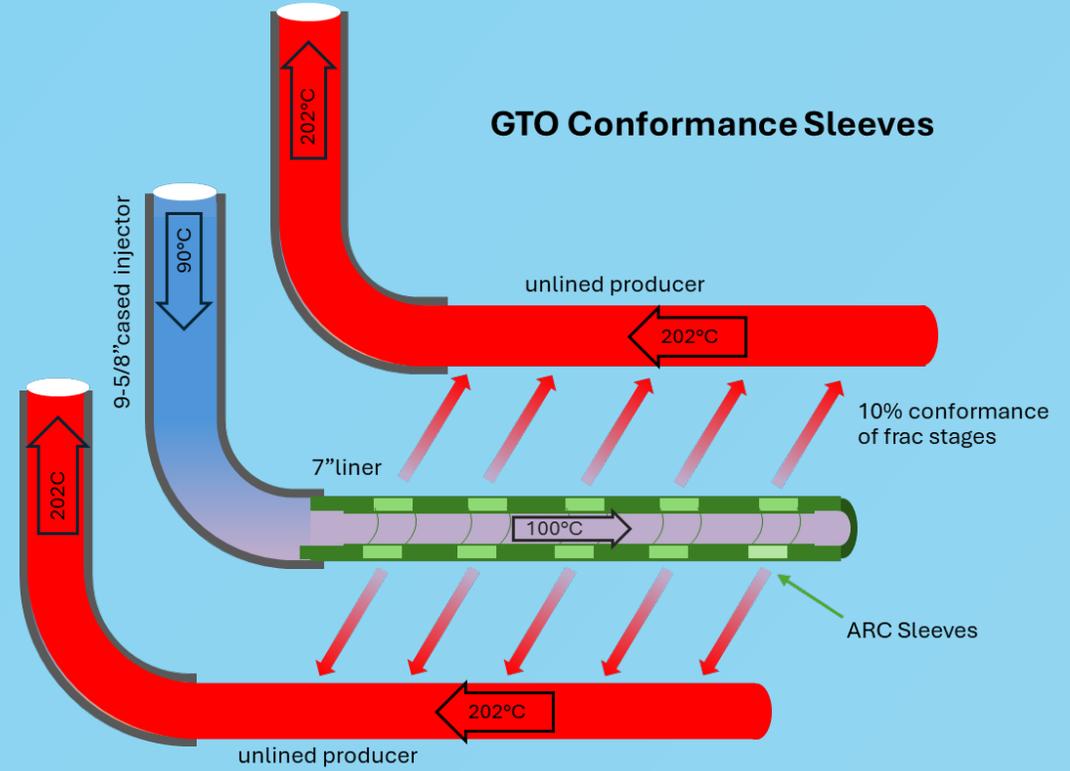
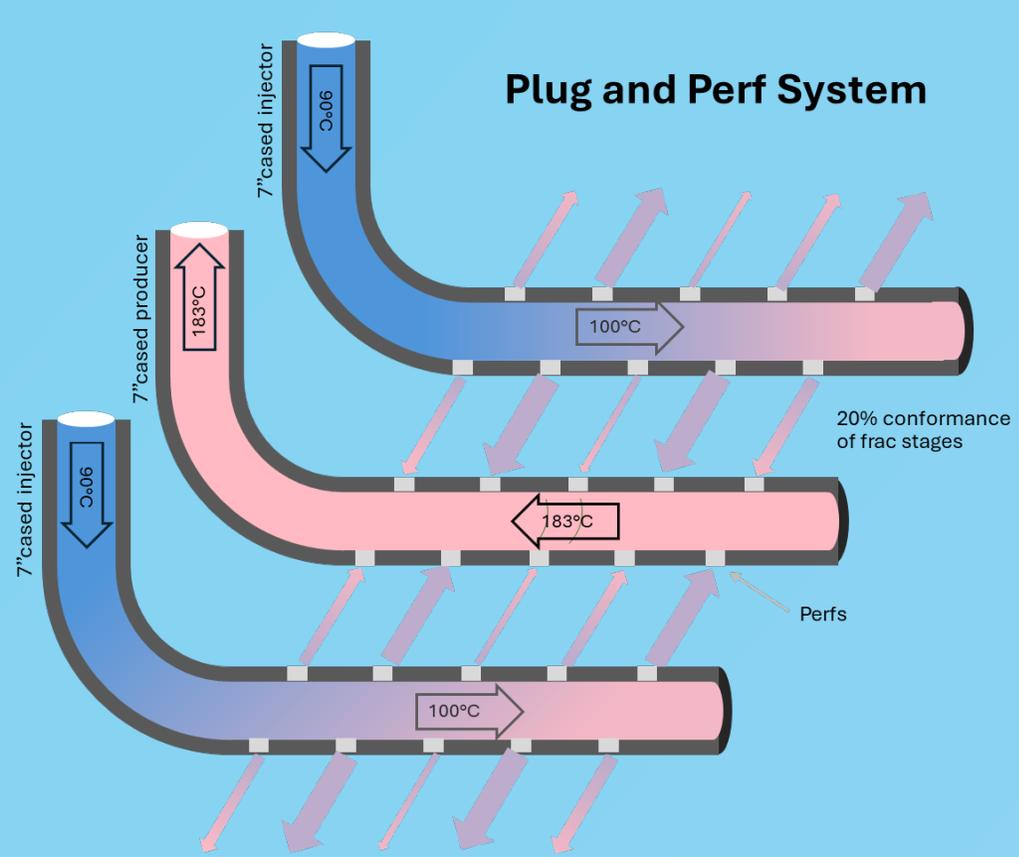


Power Generation Loss Due to Short Circling





Impact of Conformance by Year 15





Keys to Conformance

- Cement Isolation
 - Zonal Isolation Does Not Exist with Flow Behind Pipe
- Manage Parasitic Losses
 - Minimize Wellbore Friction While Controlling the Fluid
- Control Conformance Mechanically at Injector
 - Maintain Flow Per Fracture at $\pm 10\%$



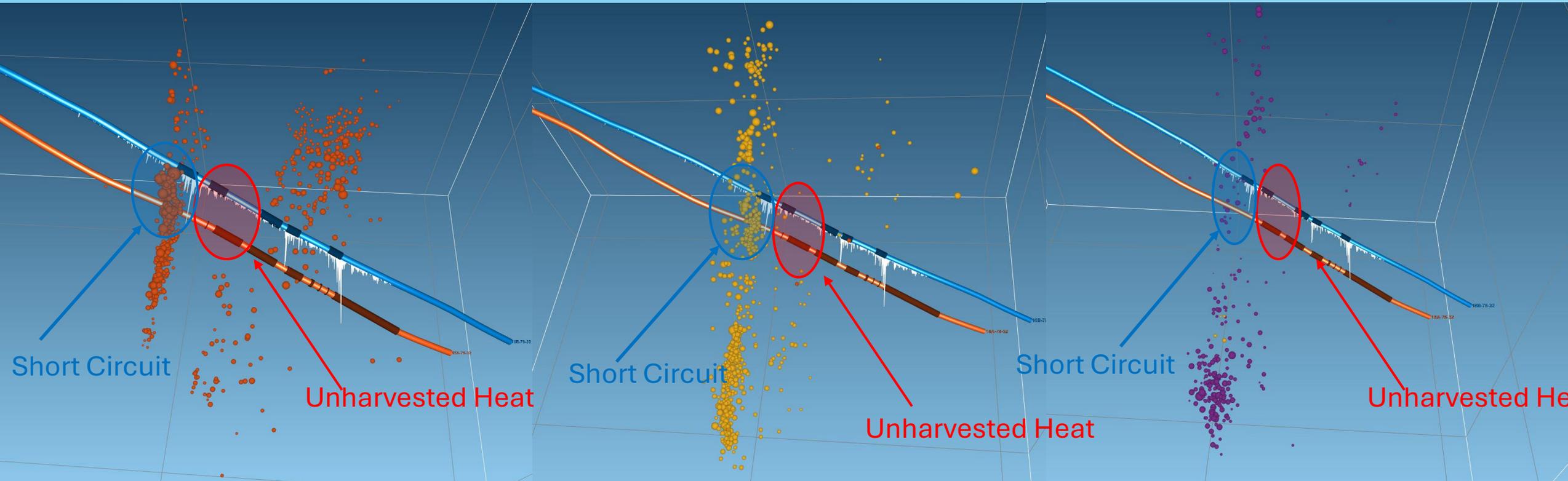
Annular Isolation is Critical to Conformance

Micro Seismic of Stages 8, 9 & 10 (Forge 16A)

16A, Stage 8

16A, Stage 9

16A, Stage 10





Keys to Cementing

- Rotation and Reciprocation are Critical
 - Impact of long string vs liner
 - Impact of Fiber Optics on pipe movement
- Centralization
 - Casing must have standoff from bottom of hole to prevent channeling
- Slurry Stability
 - Model slurry due to rapid Temperature swings
 - Understand impact from long duration silo storage
 - FORGE 16B Poor cement execution

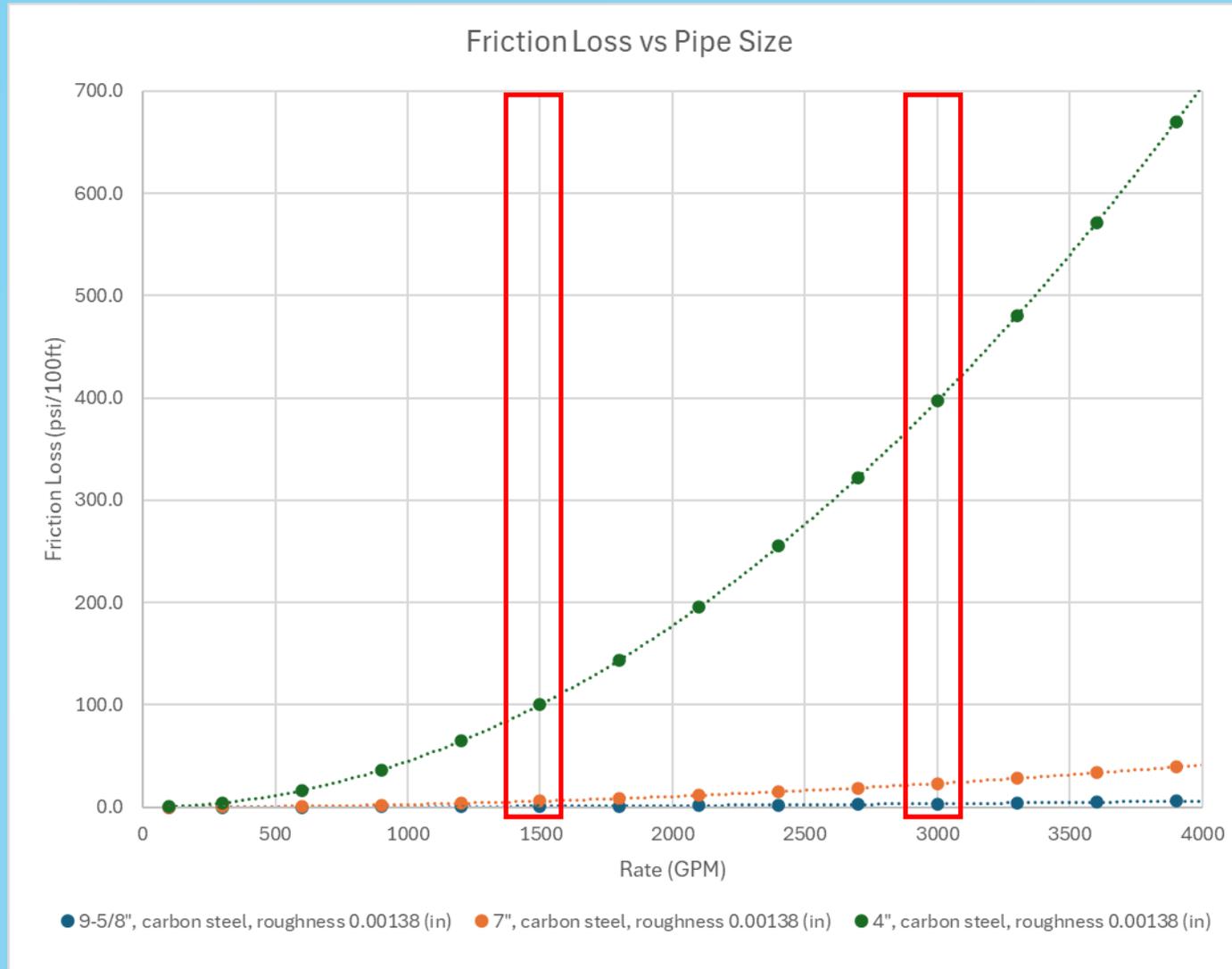


Parasitic Losses

- Traditionally in Geothermal Parasitic Losses include
 - Run the binary pumps
 - Cooling tower fans
 - Lighting
 - Control room
 - Typically, ~8%
- EGS Parasitic Losses also include
 - **HHP to run circulation pumps**

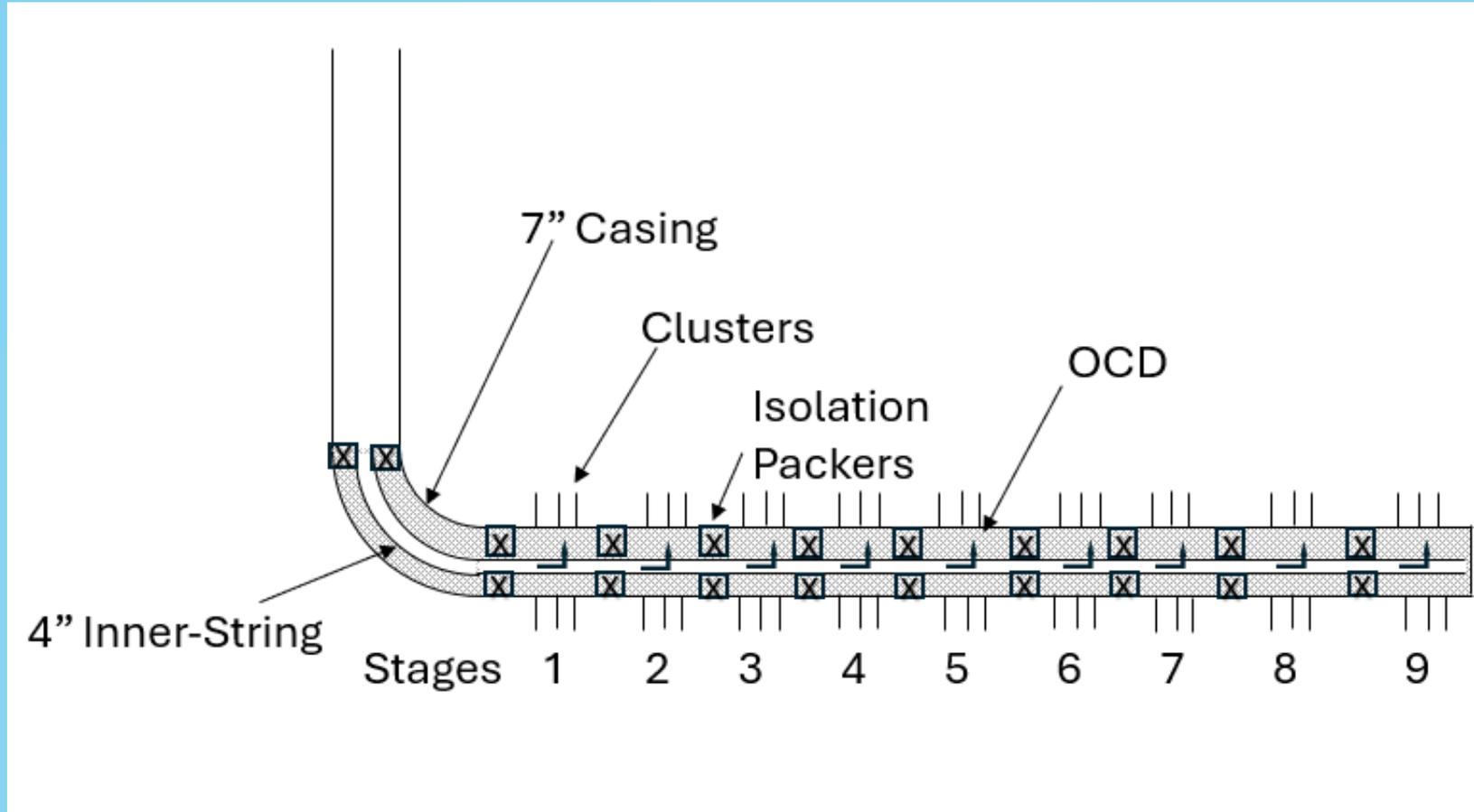


Well Design Impact on Friction



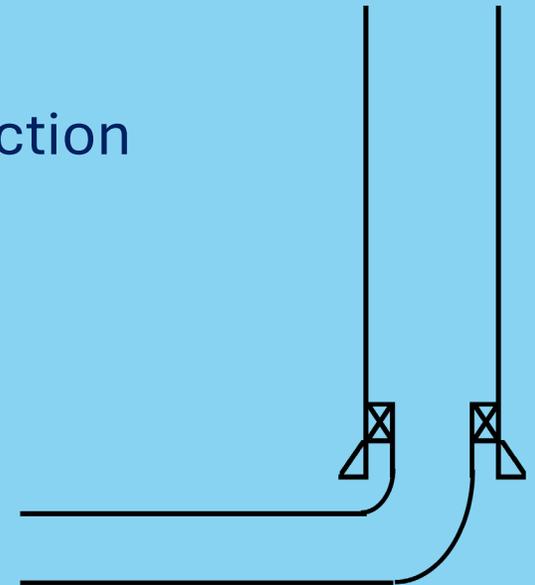
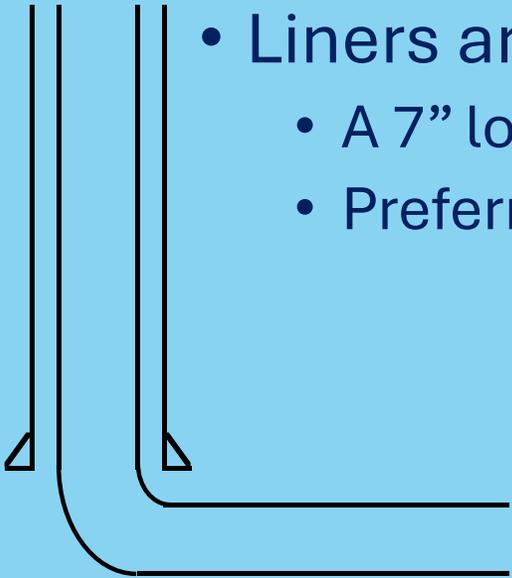


Mechanical Conformance Control in Traditional Waterfloods



Key to Managing Parasitic Losses

- Conformance Method Must be Full Bore
 - Inner-string friction is critically high
 - Inner-strings require packers (\$\$)
- High Fracture Conductivity
 - \uparrow frac conductivity = \downarrow parasitic losses & \downarrow operating costs
 - Without mechanical conformance, \uparrow frac conductivity = short circuits
- Liners are critical if using 7" casing
 - A 7" long string of casing to surface generates too much friction
 - Preferred casing design is intermediate string and liner





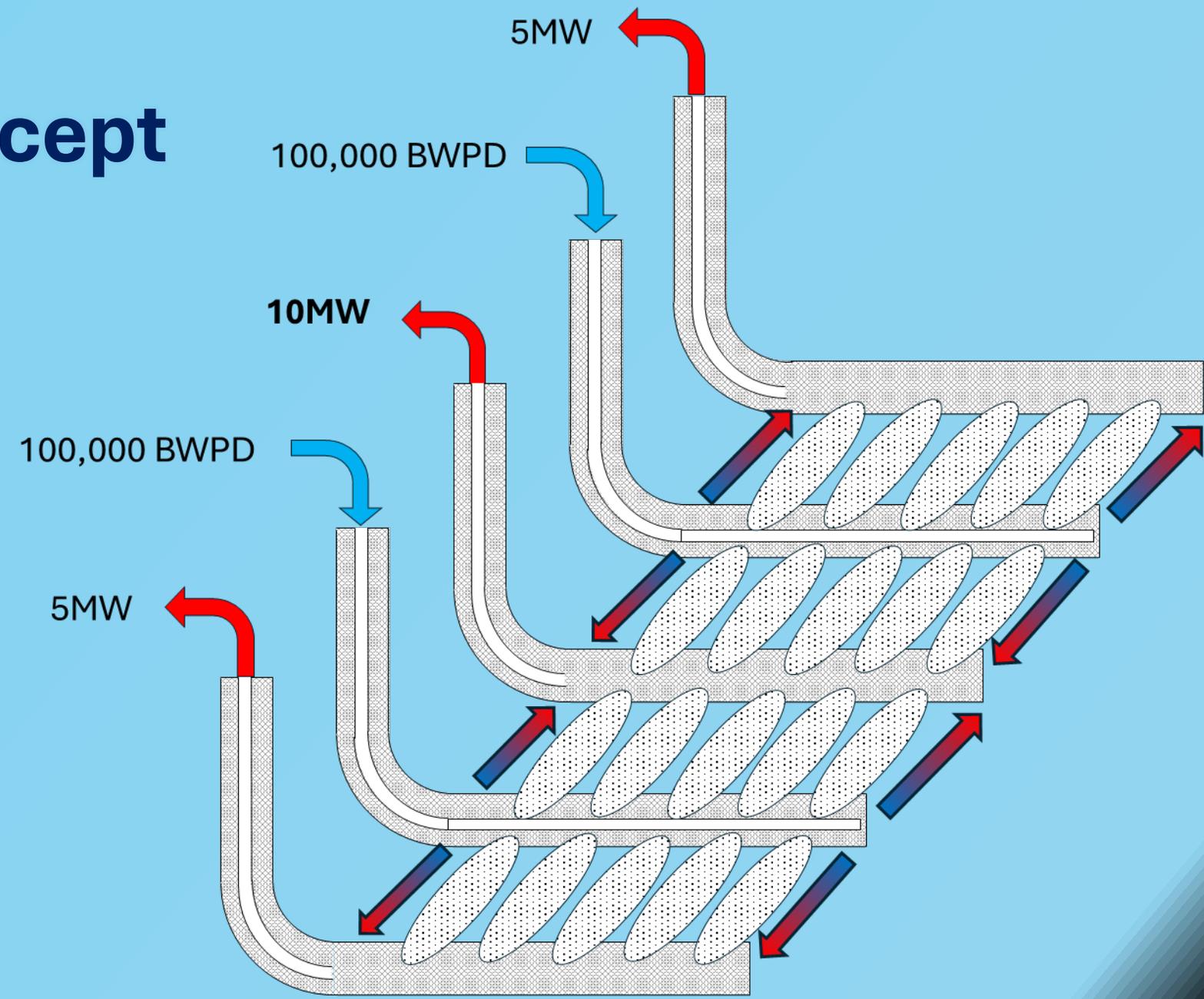
Well Architecture & Net Power

Injector Architecture	Producer Architecture	Doublet / Triplet	Injection Rate	Friction Loss	Net Power (Gross – Parasitic)
7" Long String	7" Long String	Doublet	50,000 BWPD	2,380 psi	5.0 – 1.9 = 3.1MW
7" Long String + 4" Inner-string	7" Long String	Doublet	50,000 BWPD	3,780 psi	5.0 – 3.0 = 2.0MW
9-5/8" Int. & 7" Liner	9-5/8" Int. & 7" Liner	Doublet	50,000 BWPD	1,000 psi	5.0 – 0.8 = 4.2MW
9-5/8" Int. & 7" Liner +4" Inner-string	9-5/8" Int. & 7" Liner	Doublet	50,000 BWPD	2,400 psi	5.0 – 1.9 = 3.1MW
7" Long String	7" Long String	Triplet	100,000 BWPD	5,300 psi	10.0 – 8.4 = 1.6MW
9-5/8" Int. & 7" Liner	9-5/8" Int. & 7" Liner	Triplet	100,000 BWPD	1,740 psi	10.0 – 2.7 = 7.3MW



Wine Rack Concept

Wine Racks allow for a more efficient version of the triplet





The Solution to Conformance

- Selective Frac Sleeves with Conformance Control
- Provide Full Bore Conformance
- Allow Rotation and Reciprocation During Cementing

Only patents for EGS conformance control

U.S. Patent Apr. 16, 2024 Sheet 3 of 20 US 11,959,666 B2

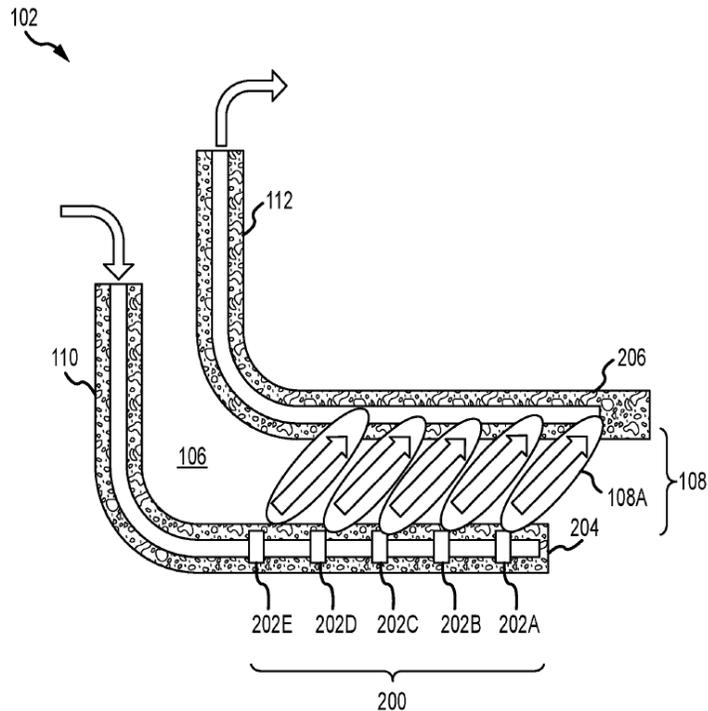


FIG. 2

What is claimed is:

1. A method of harvesting geothermal energy in a subterranean formation, comprising:
 - providing an injection wellbore that extends into the subterranean formation;
 - positioning a plurality of selectively opening sleeves in the injection wellbore spaced apart within the subterranean formation, each of said plurality of selectively opening sleeves being actuatable between an open position and a closed position, wherein said plurality of selectively opening sleeves are threadably connected to a casing string, and wherein at least some of said plurality of selectively opening sleeves are encased in cement;

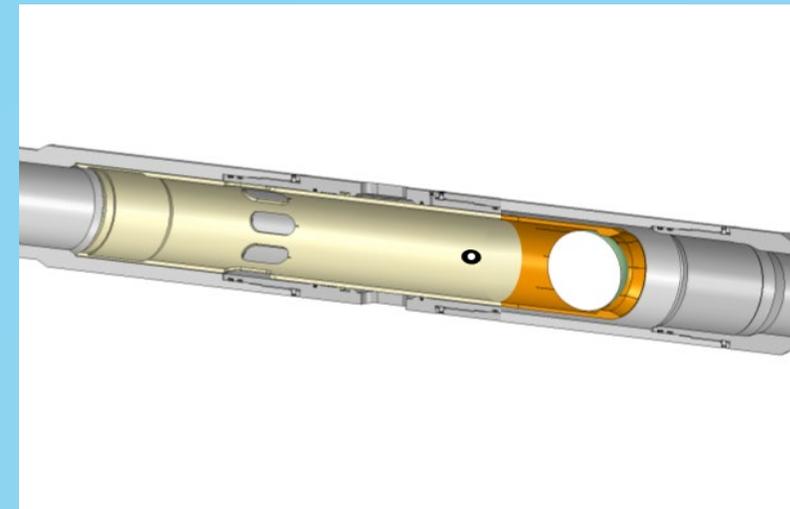
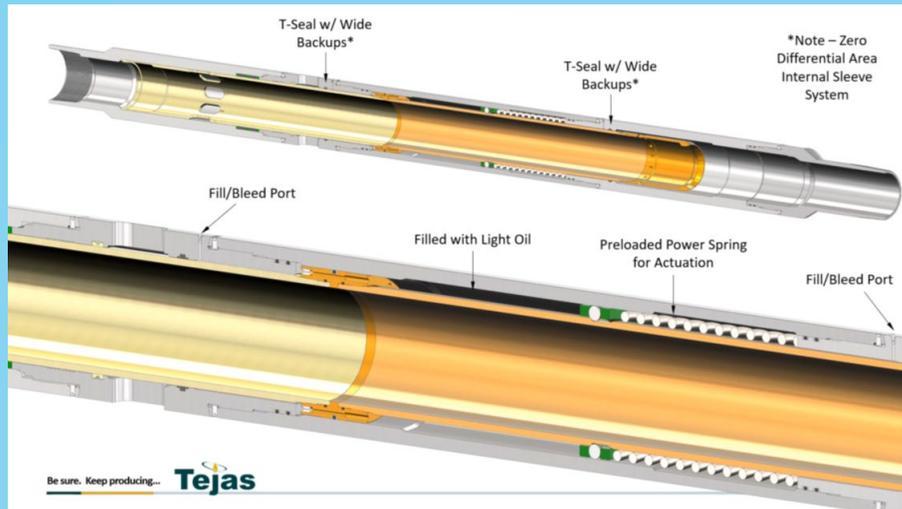
Sleeve Evolution

Generation 1 (FORGE)

- Proof of concept on collets
- Complex actuation system
- Difficult seal requirements
- Large & expensive
- 2 Position sleeve

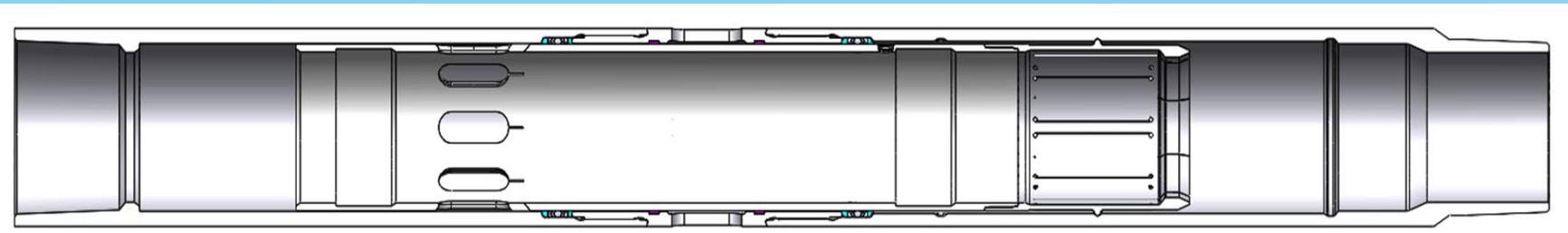
Generation 2

- Utilize proven collet system
- Simplified actuation system
- Simplified seal requirements
- Small, cost effective
- 3 Position conformance control

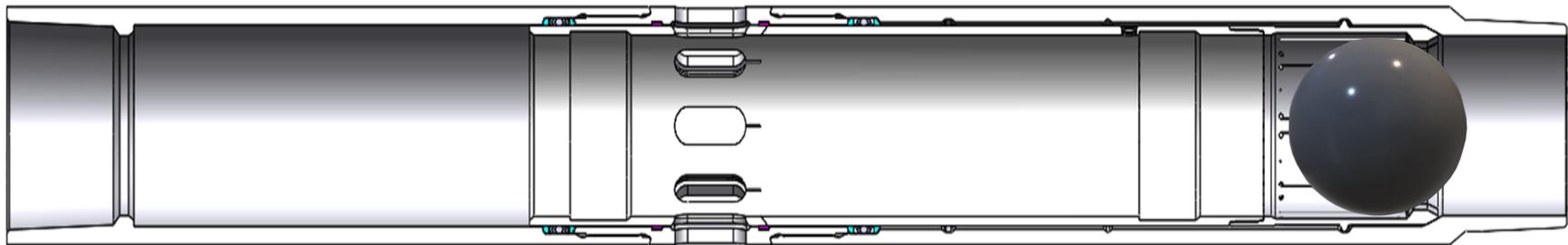




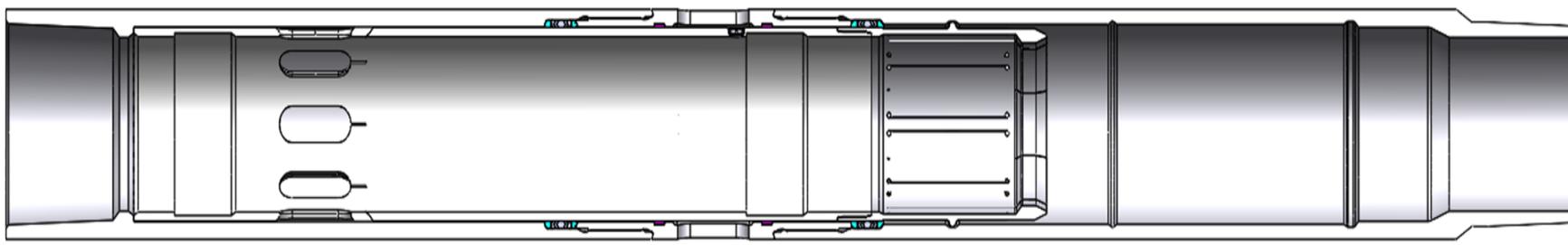
Generation 2 Sleeve and Actuation Tool



Closed (Run-in Position)



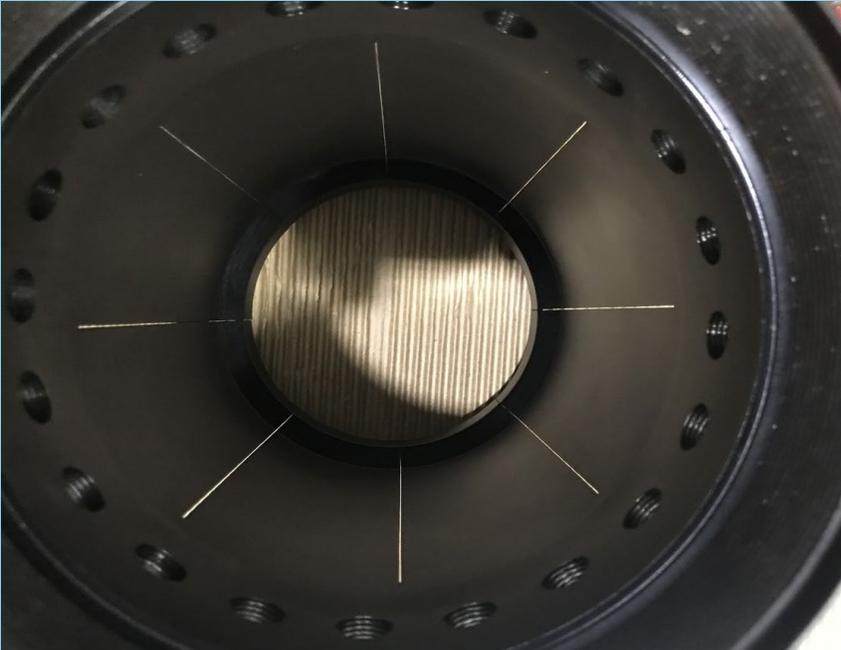
Fully Open (Stimulation Position; Frac Ball in Place)



Regulate (Production Position)

* Patent Pending

Developed Hardware





Conclusions

- The 4 C's are critical to economic viability
- Thermal Decline is key to long term electrical production
 - Conformance control cannot come at the cost of ↑ parasitic losses
 - Cement considerations are part of conformance control
- Parasitic losses
 - Salable electricity drives economics NOT produced electricity
 - Understand VOI tradeoffs (i.e. Fiber Optics vs Inner-string Friction)
- Understand well layout & spacing in your economic models
 - Doublet, triplet, or wine rack
- Full bore sleeves with regulation are the best alternative to provide long term economic viability



A Team with Extensive Experience



Dr. Will Fleckenstein
Co-Founder, CEO
Colorado School of Mines
FORGE Project PI.
Former CSM Petroleum
Department head



Patrick Mays
Co-Founder, COO
29 years operations
management,
CSM Engineering &
Anderson MBA (UCLA)

**Fractional
CFO**

Currently under hiring process

Garrett Casassa*
Senior Engineer
19 years engineering
design experience
Project Manager for
Generation 2 Sleeves

Ben Alexander*
Senior Engineer
11 years engineering
design experience
Design Engineer for
Generation 2 Sleeves

Jeff Rogers*
Senior Engineer
36 years engineering
design experience
Design Engineer for
Generation 2 Sleeves

* Czero Employee
** KSWC Employee
*** DHI Employee

George King**
KSWC Owner
41 years wireline
engineering design
experience
Generation 2 Actuators

Santos Ortiz**
Engineering Mgr
11 years wireline
engineering design
experience
Project Manager for
Generation 2 Actuators

Mariel Cantu**
Sr. Engineer
Engineering for
Generation 2 Actuators

Kris Wilden**
Sr. Technologist
Electronics for
Generation 2 Actuators

Joe Jordan***
DHI CEO
43 oilfield tool design
experience
Consultant for
Generation 2 Sleeves &
Actuators

Advisors

Terrance Leis
Finance Advisor
37 years executive
management experience
Former Credit Union of
Colorado CEO, CPA

Jens Zimmermann
Finance advisor
Infrastructure and Climate
Change Super-trends at
Credit Suisse.

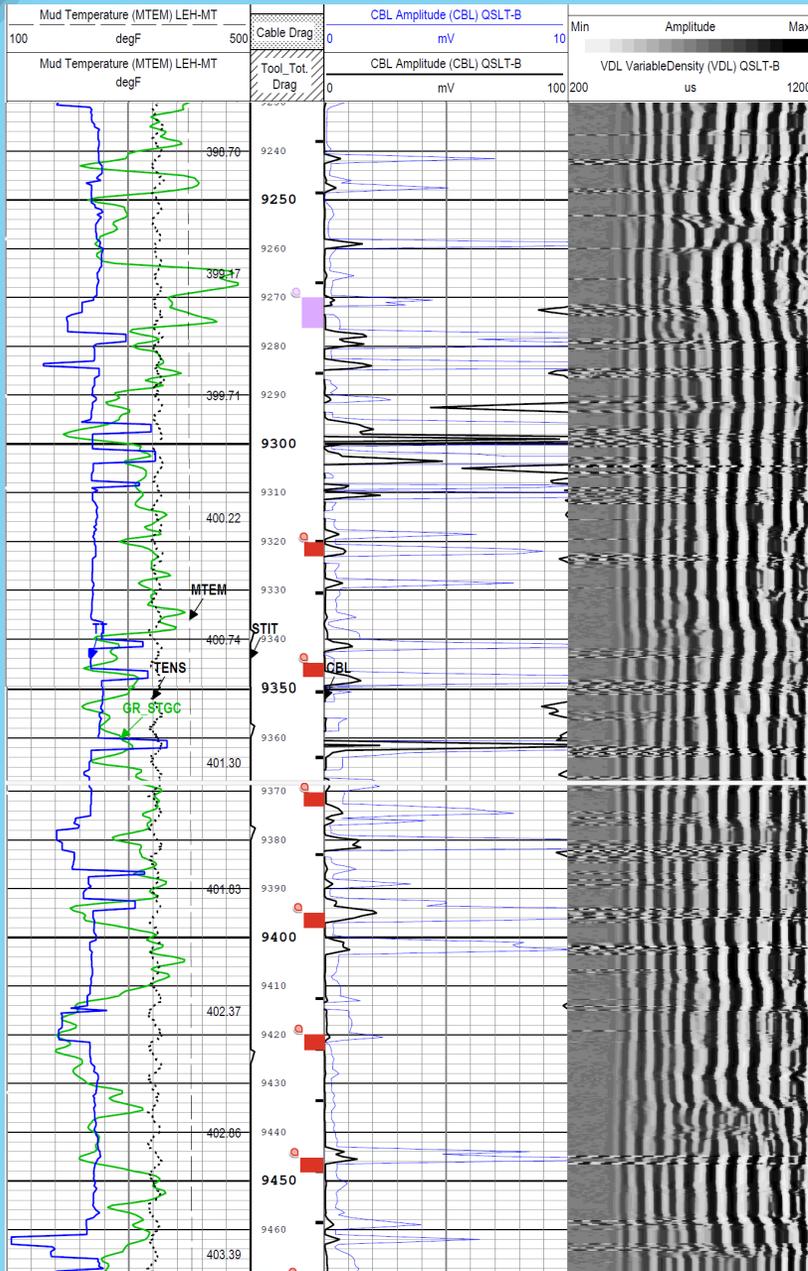


THANK YOU!

Questions & Answers



Back up slides



FORGE Cement Analysis (16A Injector)

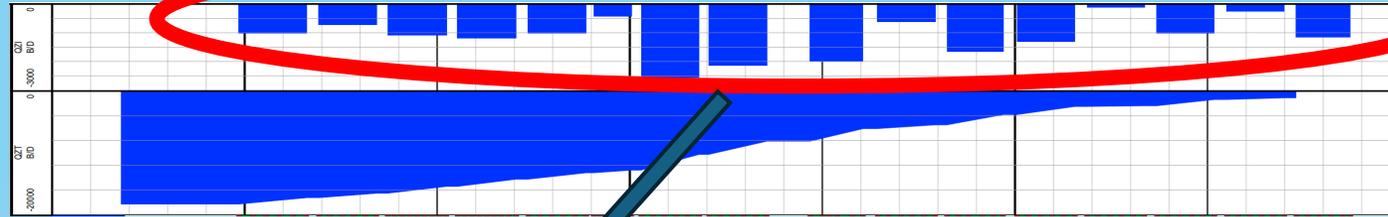
Snapshot of Stage 9 (red) and Stage 10 (purple)

CBL is suspect. Multiple Amplitudes > 10 mV and matching Chevrons in the VDL.



Conformance Impact on Super Hot EGS

Geophires: Triplet, 110,000 BWPD



20% Less Power Production!!

