

## High Temperature 300°C Directional Drilling System

Project Officer: Bill Vandermeer

Total Project Funding: \$ 5 M

May 11, 2015

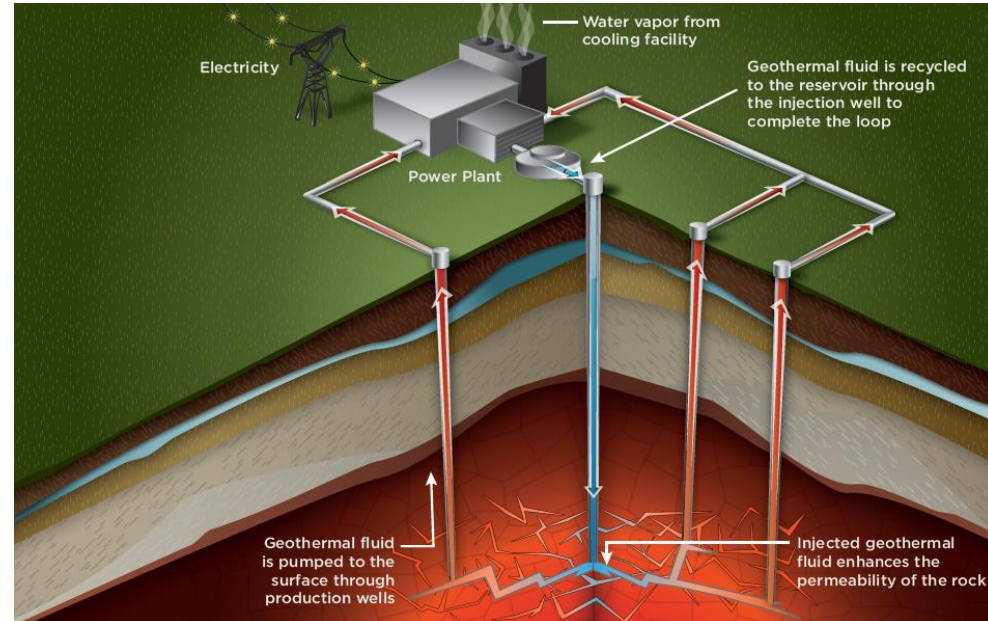
Kamalesh Chatterjee

**EE0002782**

**Baker Hughes**

Track 3 EGS1 - High Temp Tools, Drilling Systems

A Directional Drilling System (DDS, EE0002782) and directional Measurement-While-Drilling system (MWD, EE0005505) for geothermal applications will operate in hard rock at depths as great as 10,000 meters and temperatures as high as 300°C.



- Commercial DDS tools are functional up to 175°C/200°C
- Aligned with GTO R & D goals
  - Directional Drilling of EGS wells at high temperature.
  - Drilling cost a significant part of total budget in geothermal wells.
  - Conventional rotary drilling not practical for directional wells.

## Drill Bit

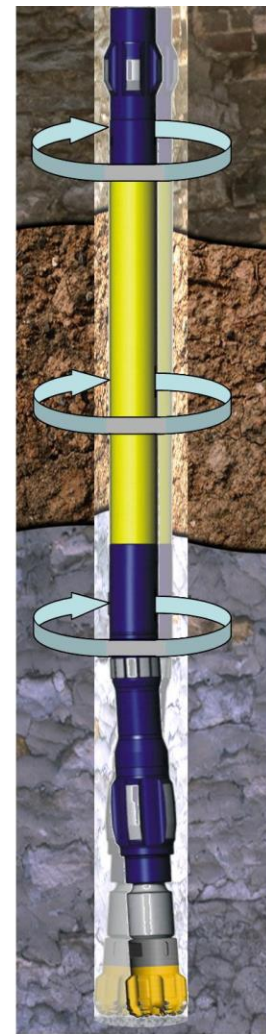
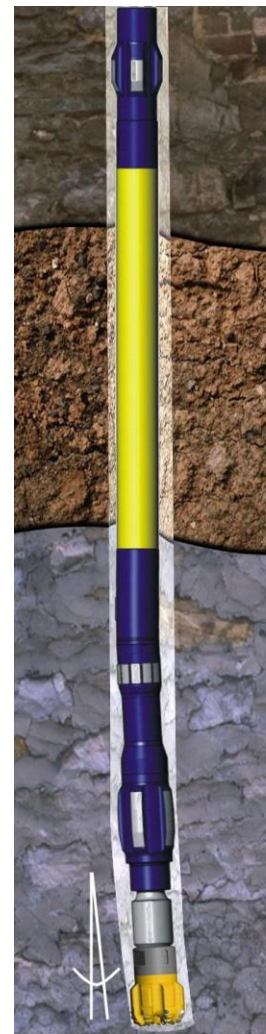
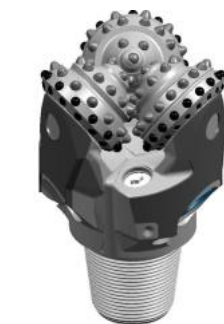
Tricone (hard) and Kymera hybrid (interbedded) matched to motor and fluid requirements

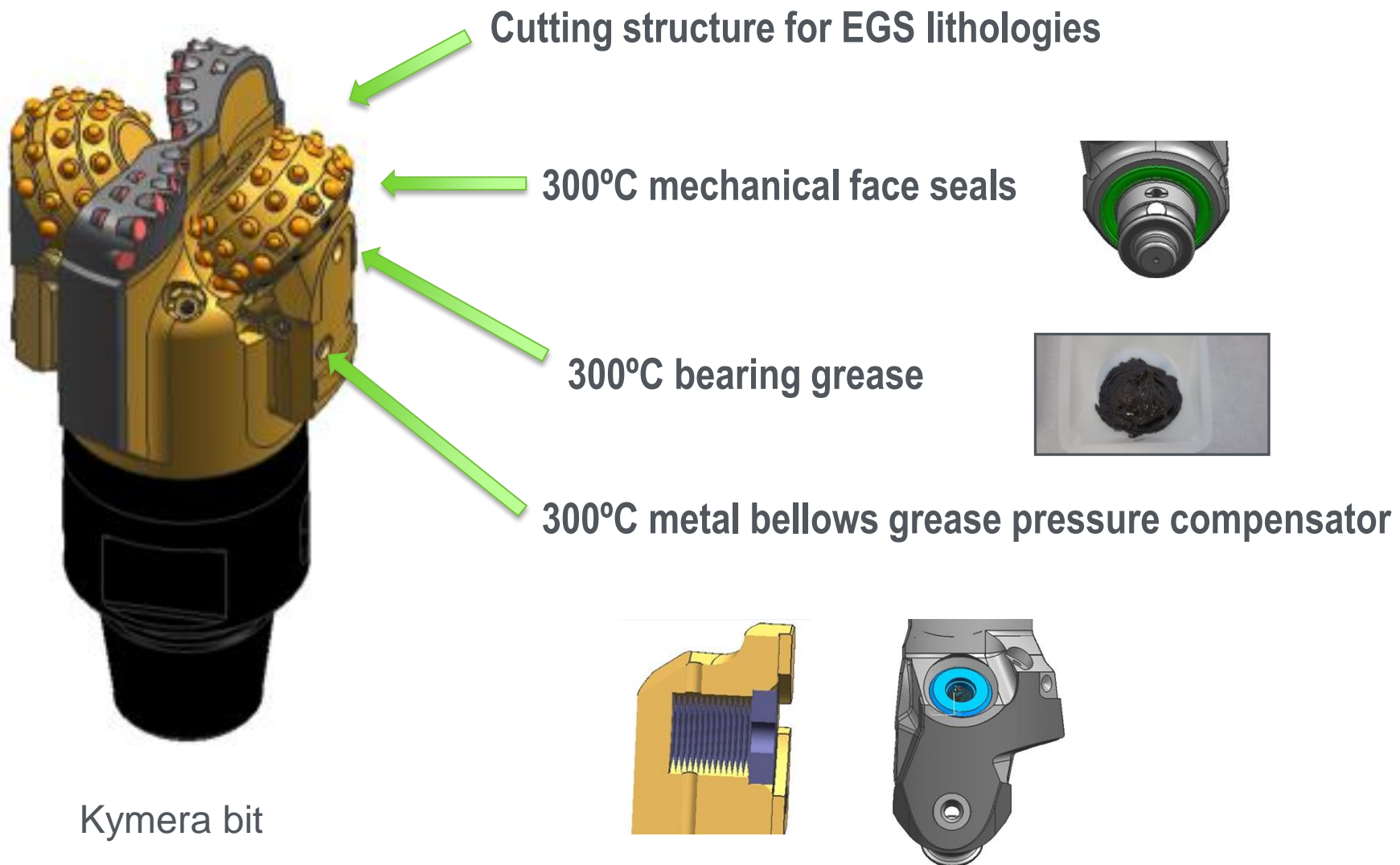
## Directional Motor

Metal to metal Positive Displacement Motor (PDM), 5/6 lobe 150 rpm, 4000 ft lb torque

## Drilling Fluid / Equipment

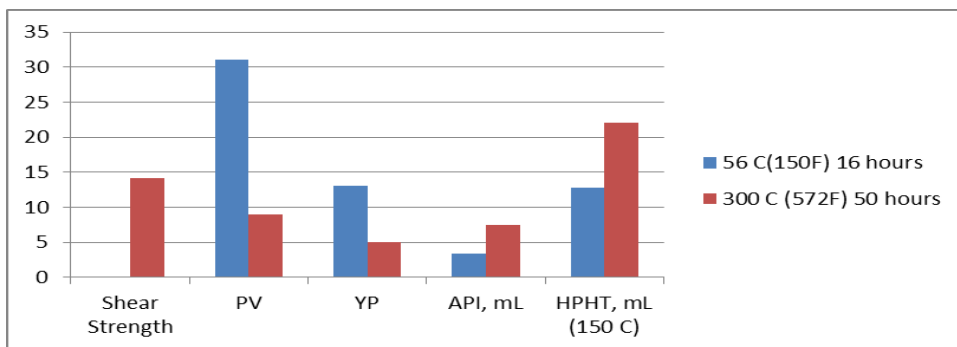
300°C stable, lubricant for metal to metal motor operation



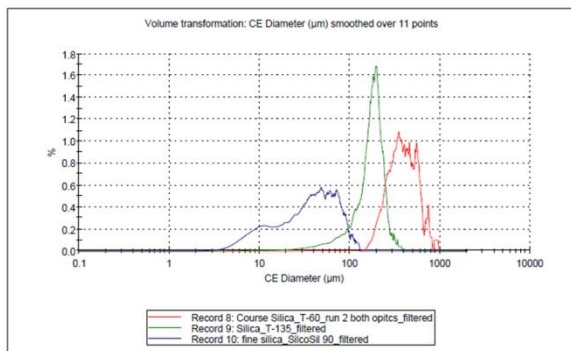


## 300°C Drilling Fluid

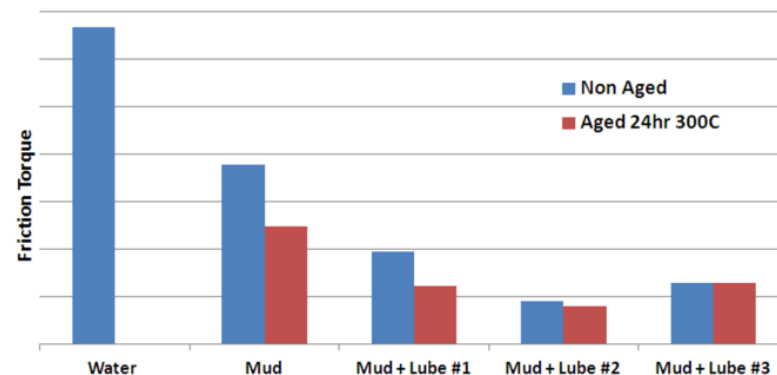
- Thermally stable drilling fluid aging @ 300°C



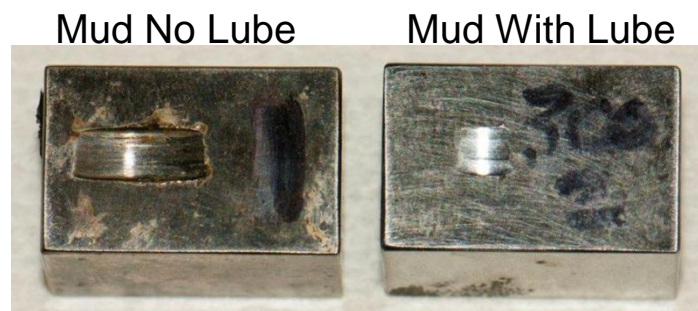
- Test fluids with abrasive particles for metal-metal motor coating tests

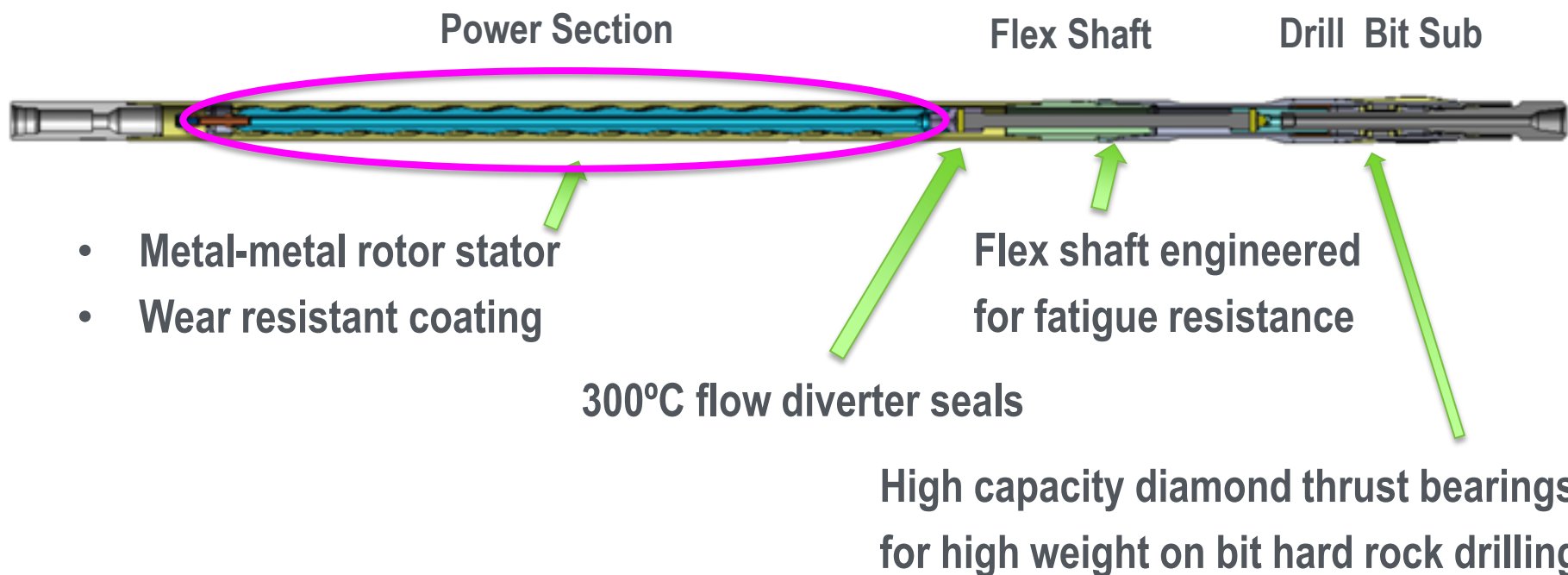


- Lubricant / Wear reduction – Increase motor run time

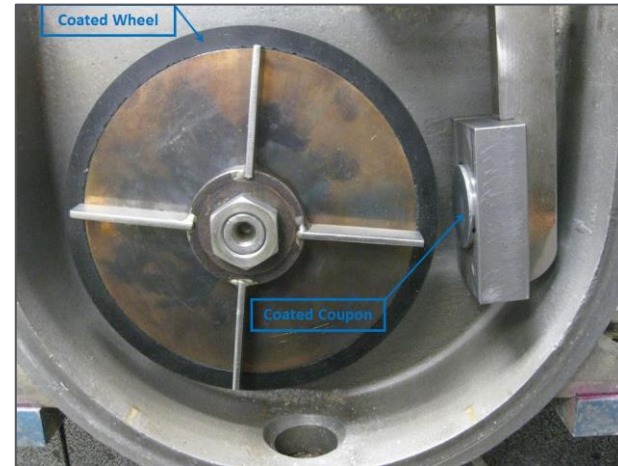


- Block on ring wear test





**Challenges -** Manufacturing  
Coating  
Assembly



Rotor coating - Tungsten Carbide

Stator coating – diffusion process  
Gas Nitriding + K12 seal

Tested coatings with coupons

4  $\frac{3}{4}$  motors for performance testing

6  $\frac{3}{4}$  motors are DOE deliverables

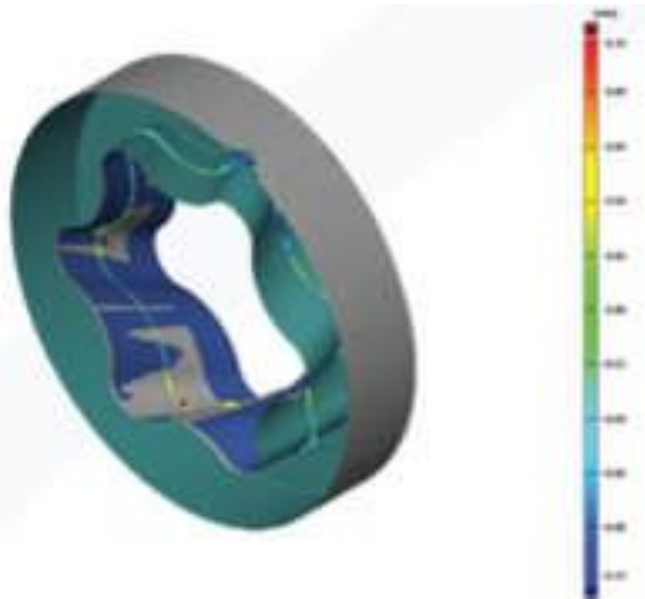
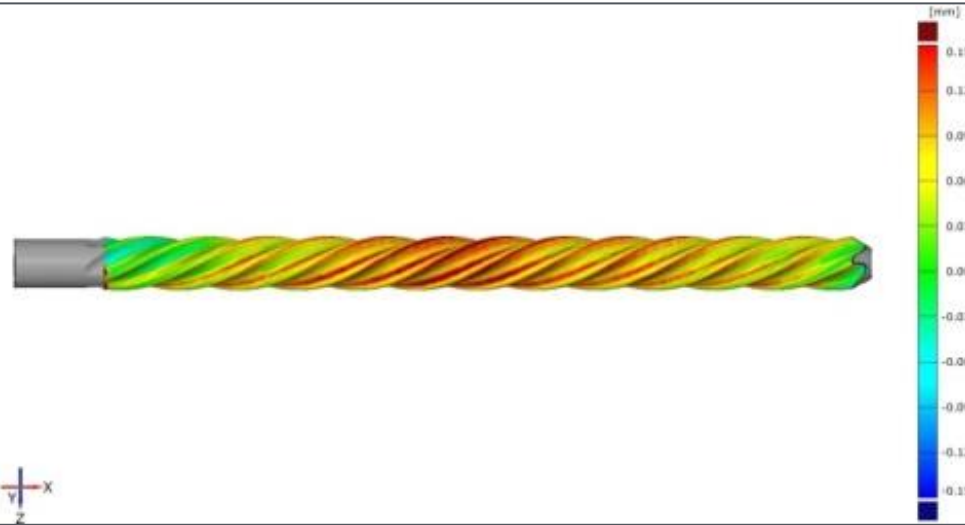
Testing:

- Hardness testing
- Slurry abrasion testing
- Measure wear through surface profilometry
- Aging
- Pitting corrosion potential
- Fluid erosion test

Stator and rotor design and machining at Celle, Germany

# Challenges: machining and assembly

Tolerance = 0.5 mm





# High temperature test stand

**Main Frame**

**Pressurization  
System**

**Test Vessel with  
Motor Inside**

**Cooling  
Unit**

**Mechanical  
Seal**

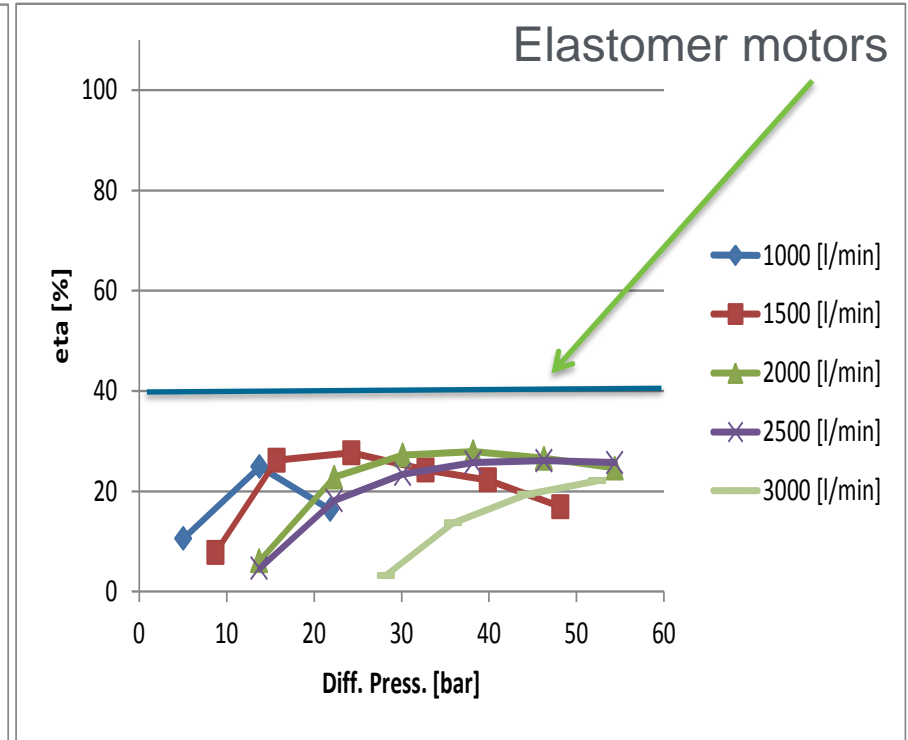
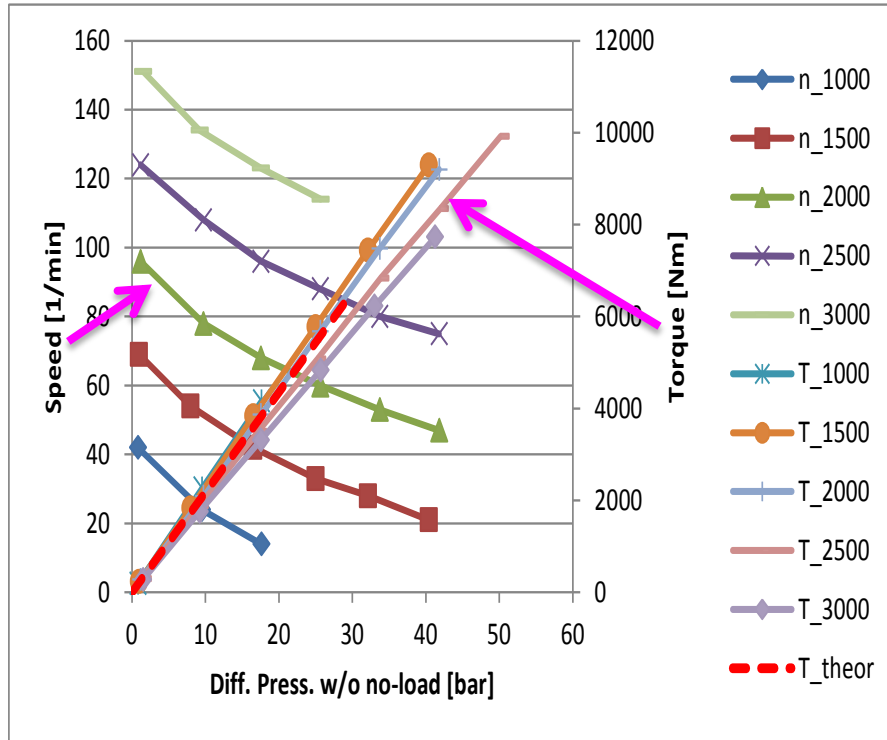
**Mechanical  
Seal Support  
System**

**Rotation  
Module**

**Control  
Room**

**Heating  
Unit**





Torque : 4000 ft lb = 5423 N m was achieved at approx. 30 bar = 435 psi

Scope for efficiency improvement: Tighter tolerance, increased pressure

# BETA test - drilling in experimental well



System drilled 180 ft in  
hard granite 15-25  
ft/hour

Build-up-rate  
6°/100ft

Dog-leg-severity  
7.2°/100ft

Metal to metal motor is  
used to drill a  
directional well in  
granite – first in  
industry

# Wear of rotor after drilling test



**Special screens are necessary at the surface**

- All project tasks close to completion except the field trial. Tools are ready for field trial scheduled for July.
- The directional drilling system (metal to metal motor) has been used to drill a directional well in granite – first in industry.
- System drilled 180 ft in hard granite 15-25 ft/hour
- Build-up-rate 6°/100ft, dog-leg-severity 7.2°/100ft
- Flow loop test of motor completed, efficiencies compared, drill bit simulator test completed
- High temperature test stand to compare motor parameters is operational. Tests have been conducted and results being analyzed.

# Accomplishments - II

Original Planned Milestone/ Technical Accomplishment	Actual Milestone/Technical Accomplishment	Date Completed
Phase 1 <b>Concept</b>	System concepts created	Q2 2011
Phase 2 <b>Design</b>	Designs created for Tricone and Kymera hybrid bits, metal-metal motor, drilling fluid with lubricant additive	Q3 2013
Phase 3 <b>Manufacture</b>	2 tools ready for field trial, 3 <sup>rd</sup> in assembly	Q4 2014
Phase 4 <b>Testing</b>	Flow loop test of motor	April 2014
	Simulator test of drill bit	Q2 2014
	BETA test	April 2014
	Motor test stand	Q2 2015
	Field test	Q3 2015

2014 Geothermal Energy Association (GEA) Honors award for Technological Achievement (August 5, 2014)

- Complete assembly of the 3<sup>rd</sup> tool (two are complete)
- Conduct the field test at as high a temp as possible
- Follow up on the patent/invention disclosures and publications
- Complete the final project report

Milestone or Go/No-Go	Status & Expected Completion Date
Field test	7/31/2015
Project end	Sept 2015



- Successful completion of a High Temperature 300°C Directional Drilling System.
- 300°C drill bits without elastomers tested in BETA
- Metal to metal motor (without elastomers) is used to drill a directional well in granite – first in industry
- 300°C fluid with lubricant ready for field test.
- Flow loop test demonstrated efficiency ~30%
- High temperature test stand complete, ready to compare metal to metal motors with conventional ones
- 2 tools ready for field trial, expected in Q3 2015