Geothermal Research at Sandia National Laboratories

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Sandia’s Focus
Drilling, Monitoring, and Analysis

- Geothermal well construction
  - “Most” difficult on a per-foot basis
  - Broad technology areas
    - High-temperature electronics
    - Diagnostics
    - Rock reduction technologies
    - Wellbore integrity and lost circulation
    - Drilling dynamics mod/sim
    - Vibration mitigation
    - Downhole telemetry
  - Key to future EGS

- Applying capability and technology to other industries and agencies
  - Frontier O&G, unconventionals, environmental, NIOSH, others
Significant Geothermal Accomplishments – Technology and Products to Industry

- Polycrystalline diamond compact (PDC) bits
- High-temperature electronics
- Diagnostics-while-drilling
- LEAMS
- Active vibration control
- Slimhole drilling
- Acoustic telemetry
- Rolling float meters
- Insulated drill pipe
- Cavitating mud jets
- Drilling dynamics simulator
- Well cost models
- …
Polycrystalline Diamond Compact (PDC) Bits

- Fundamental work
  - FEM analyses
  - Bonding
  - Cutter tests
  - Bit design / analysis
  - Lab / field testing
  - CRADAs
- Catalyzed a major industry
- PDC bits now a ~ $1.5 billion industry
- PDC bits save industry $ billions annually
- Over 60% of world footage today

DOE Energy 100 Award for Synthetic Diamond Drill Bits
Acoustic Telemetry

- Communication between the bit and the surface via pressure waves in the drill pipe
  - Downhole telemetry a big need with today’s tools
  - Mud pulse the standard (2 – 5 bits/sec)
  - Acoustic telemetry ~ 10x mud pulse

- Enabled by Sandia’s theoretical, manufacturing and testing capabilities
  - Physics issues – propagating waves through drill pipe
  - Engineering and Applications Codes
  - Design and manufacturing of prototypes
  - Field testing

- Product licensed to several entities
  - Commercially available through Xact (STV and Extreme Eng JV)

R&D 100 Award for Acoustic Telemetry
Field Trials of Drilling Systems

- Apply mature/proven rock penetration systems used in Oil & Gas/Mining industry to improve geothermal drilling technology

- Partner with
  - Navy Geothermal Program
  - Barber Drilling
  - National Oilwell Varco Reed Hycalog
  - Atlas Copco
DTTH Research

- Hammers are a very efficient method to drill hard rock
- Current limitations in HT Environment
- Working with DOE and Industrial partners in HT hammers and down-hole motors
Environmentally Friendly High-Rate Well Stimulation Methods

- Develop new high energy stimulation techniques to enhance EGS permeability through dynamic loading of the formation
  - Enable near wellbore fracturing along with shear destabilization in the far field
  - Novel reactive gas generating materials and injection methods to fracture the formation are being developed suitable for use at EGS well temperatures
High-Temperature Electronics

- Includes components, tools, seals, batteries, fiber, ...
- The enabling technology
  - High Temperature = High Reliability
- De facto “UL Labs” for high-temperature components
  - Work with almost all manufacturers
- Analyze failure and provide solutions
  - Exploit capabilities from weapons programs
- Develop tools and fabrication methods
  - Prototypes supplied to industry
- Broad application
  - Geothermal, aerospace, auto, O&G, PV, ...
- Long-term testing
- Extensive interactions w/ industry motivate work activities

Crystalline Bronze

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High Temperature Seismic Tool

- **Capabilities**
  - Operation up to 210°C
    - SOI electronics except FPGA and Primary ADC
    - 24-bit ADC
  - Three-axis accelerometer measurements
    - 30 Hz – 1000 Hz bandwidth
    - 20 V/g sensitivity
    - 295 μg – 165 mg measurement range
High Temperature Fiber Optic Data Transmission

- The goal of this project is to develop a high temperature (>250°C) high speed (>1 Mbit/s) fiber optic data link.

- High speed downhole data links are required for imaging tools and multi-level seismic tools.
  - High temperature wireline is generally limited to 200 kbps or less depending on cable length and characteristics.

- A high temperature data link coupled with high temperature sensor electronics can allow real-time tools to stay in the well for longer periods of time.
**Drilling Dynamics Increase Drilling Costs**

- **Drilling dynamic dysfunctions** are one of the leading causes of Non-Productive Time.

- The bit, BHA / drillstring and formation interact in a complex way resulting in a variety of vibration related problems:
  - Low Rate of Penetration -- Inefficient Drilling
  - Bit & Tool Failure -- Excessive Tripping

- **Vibrations cause significant economic losses**
  - For example: Tripping the drillstring to replace the bit on an off-shore rig can exceed 1 million dollars.
Simulation of Drilling Dynamics

- **Existing drilling research laboratories**
  - Unrealistically rigid drill stems
  - Effective for evaluation of cutting structures, hydraulics, etc.
  - Don’t address vibration

- **Sandia is pursuing an innovative capability**
  - Laboratory simulation of field conditions
  - Will improve bit and tool performance before committing to expensive field drilling

- **Benefits**
  - Improved capability for predicting bit vibration
  - Identify deficiencies in drill bit material properties and designs
  - Validate development of hardware and software for downhole tools that reduce vibration
  - Develop *Best Practices* for handling vibration
Active Vibration Control

- Drill bits are susceptible to failure under shock & vibration
  - Dampers installed in down-hole tools can help
  - Optimal damper for each drilling condition

- Active vibration control tool developed using controllable fluids
  - Based on Magneto-Rheological (MR) Fluids
    - Carrier fluid with iron particle suspensions
    - Controllable damping force
    - Fast response (~ milliseconds) and low power (~ Watts)
    - Remotely powered and controlled
  - Controllability ensures applicability to broad range of drilling conditions
    - Drillstring changes with depth
    - Variable rock lithologies
    - Sidewall friction, etc.

- Intellectual property licensed to industry
Diagnostics-While Drilling (DWD)

**Measurement sub** – acquires, conditions, and transmits downhole sensor data

**Data Link** - carries information and control signals between surface and downhole

**Instrumented Drill Rig** – provides for display and archive of surface drilling data

**Driller’s Display** - displays selected set of real-time, high-resolution data from both downhole and surface. Display can be either raw or processed (FFTs, etc.) data.

**Driller** – experienced and willing driller can use more sophisticated display than traditional console.
DWD Systems Can Help the Driller
Drillers Can Use DWD

Driller identified “stick-slip” with RPM going to zero