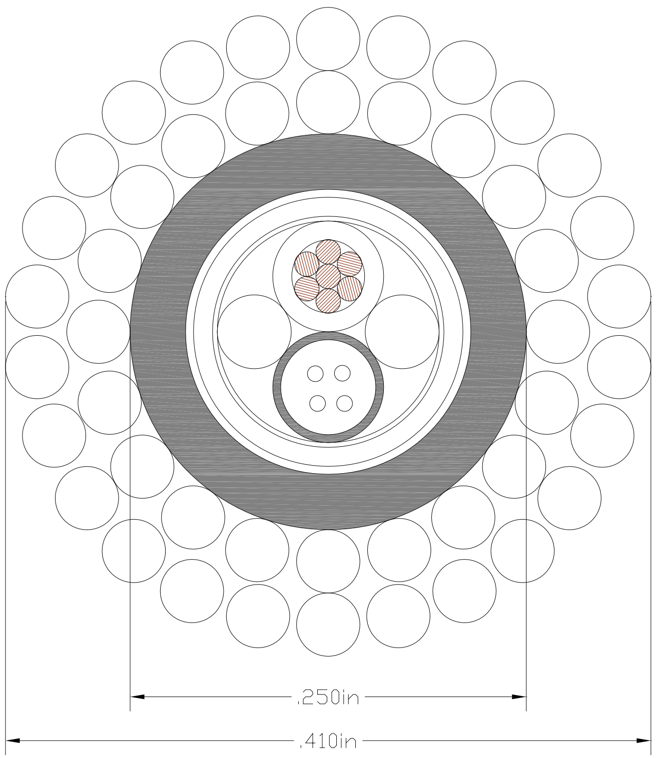
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy



Complete Fiber/Copper Cable Solution for Long-Term Temperature and Pressure Measurement in Supercritical Reservoirs and EGS Wells

Project Officer: William Vandermeer

Total Project Funding: $3,222,398

April 23, 2013

Kendall Waterman

Draka Cableteq USA. Prysmian Group

Track 2

Relevance/Impact of Research

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Geothermal energy production can be greatly aided by tools which give the operator the data they need to optimize the performance of the well, particularly the temperature over the length of the well and the pressure in the well.

This project supports an overall EGS R&D objective for Downhole Tools for depths of 10,000 meters and 300°C.

The cable development provide a distributed fiber optic temperature sensor as well as a power/communication link to a downhole discrete P/T tool.

EGS Challenges for Cable Performance:

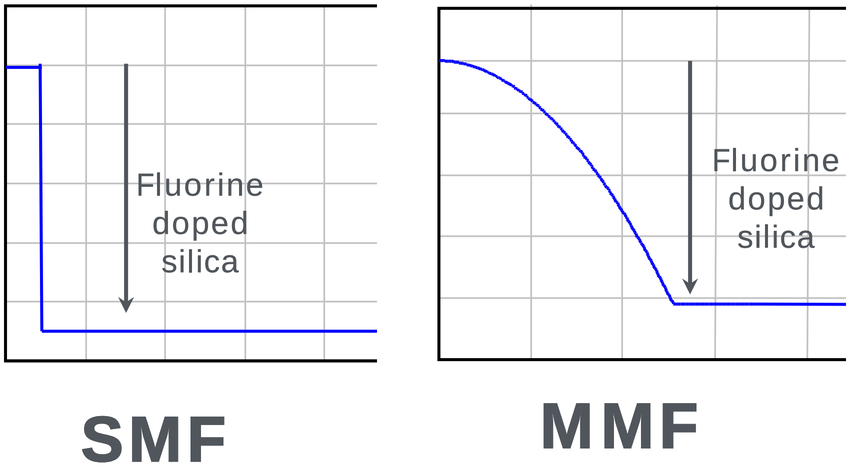
- Very high temperatures
- Highly corrosive environment
- High pressure
- Self supporting deployment

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Innovative Aspect: Unique Glass Chemistry Process

- Highly tuned and controlled, optimized glass chemistry using "down doped fluorine" profiles,
- Industrial manufacturing thanks to Proprietary PVCD process

→Enhanced tolerance to hydrogen darkening for both SMF and MMF

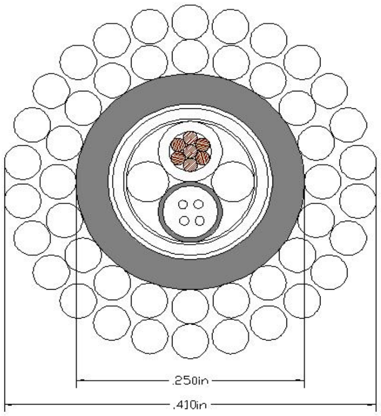


U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Innovative Aspect: Unique Cable Design Elements

- Non-conventional gel for fiber support
  - Unsuccessful in finding traditional gel for 300°C
  - Developed non-conventional solution
  - Non-Provisional patent filed in Feb. 2013
- 300°C insulation
  - Unique material developed by DuPont
- Long length reinforced
  - Armor needed for long self supporting lengths (> 10,000 ft.)

Cable Design



Current cable design per TA – 121511

- Uses 1 conductor with the tube/armor as the return
- All polymeric material is DuPont Ecctreme polymer
- Metal tube wall thickness is currently 0.035", this could be reduced to 0.028 if larger conductor is needed.

Phase 1 – Optical Fiber Development

- Task 1: Fiber Development
  - Made numerous (> 20) preforms with varied chemistries
  - Developed model for hydrogen test results
- Task 2: Coatings Development
  - Numerous fiber draw trials with several unique coating chemistries from Tetramer Technologies and compared to commercially available high temperature coatings
- Task 3: Fiber Testing and Validation
  - Tested for heat aging with TGA techniques
  - Examined effects of optical fiber strength with H_2O exposure
  - Examined performance with and without carbon coating

Phase 2 – Cable Development

- Task 1: High Temperature Fiber in Metal Tube (FIMT)
  - Explored options for high temperature gel
- Task 2: High Temperature Cable Development
  - Tested heat aging of 300°C insulation
- Task 3: Tube Encapsulated Cable (TEC) Development
  - Modeled maximum self supporting length.

Phase 3 – Cable Testing and Validation

- Task 1: Short-term Downhole Test (14 days)
  - Work with installation specialist to plan well-site equipment

- Task 2: Medium-term Downhole Test (1 month)
  - Begin DTS and pressure monitoring and work out data collection methods.
  - Evaluate performance of fiber

- Task 3: Long-term Downhole test (3 months)
  - Evaluate DTS and pressure performance over longer period

Phase 1 – Optical Fiber Development (Since May 2011)

- Developed model for hydrogen test results
- Selected best 300°C rated coating.
- Demonstrated carbon coating not necessary at 300°C
- Completed 4 rounds of H2 testing at Sandia Labs

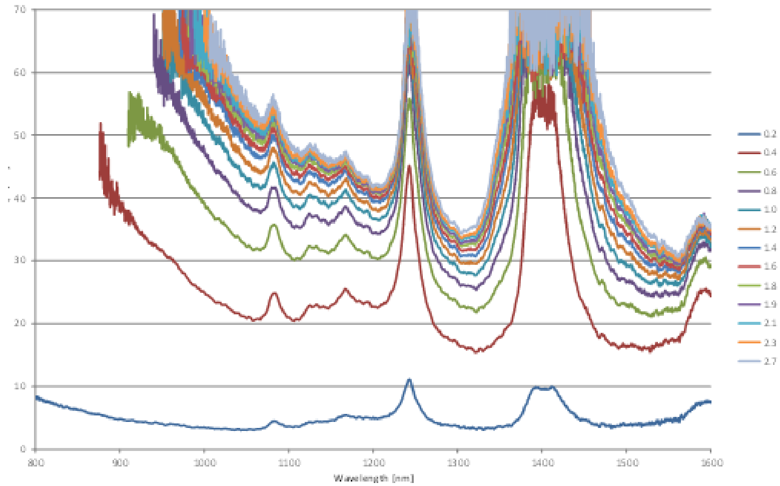
Phase 2 – Cable Development (Since May 2011)

- Produced first trial lengths with armor
- Completed all electric 400°C cable
- Did not find a conventional gel for the fiber in metal tube (FIMT)
- Developed non-conventional gel solution (patent filed)
- Determined need for additional reinforcement and found solution

Accomplishments, Results and Progress

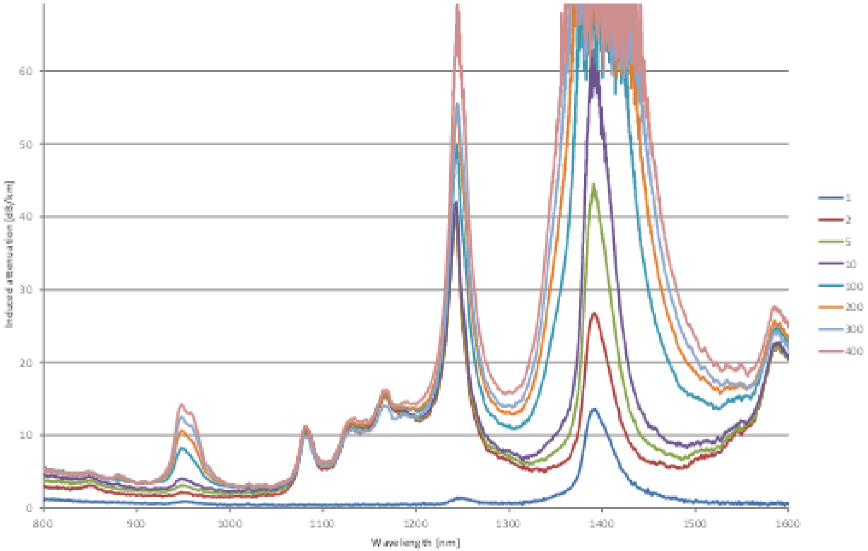
Germanium doped MMF – Attenuation vs. Wavelength by Time

- Laboratory: Sandia Laboratories
- Exposure conditions: 300°C, 4400 psi 5% H_2 in Air, 220 psi H_2 (= 15 bar H_2)
- **Result: high H_2 Induced Losses across entire spectrum in very short time, only 2.7 hours**



Fluorine doped MMF – Attenuation vs. Wavelength by Time

- Laboratory: Sandia Laboratories
- Exposure conditions: 300°C, 4400 psi 5% H_2 in Air, 220 psi H_2 (= 15 bar H_2)
- **Much lower effect, especially below 1200 nm, even at extended time period, 400 hours**



Future Directions

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Milestone or Go/No-Go	Status & Expected Completion Date
Complete two long cables (primary and backup)	April 2013
Install cable in well and start monitoring	May 2013
Complete three month well monitoring	September 2013
Complete Final Report	December 2013
Begin Cable Commercialization	End 2013

Summary

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

- Fiber development and new products being commercialized
- Cable manufacture has been a challenge.
- Cable development is nearly complete.
- Prototype for down-hole trials nearly complete.
- Final arrangements for down-hole trial need to be completed very soon
- Well monitoring to be completed by September

Project Management

Timeline:

Planned Start Date	Planned End Date	Actual Start Date	Current End Date
1/29/2010	3/31/2013	1/29/2010	9/30/2013

Budget:

Federal Share	Cost Share	Planned Expenses to Date	Actual Expenses to Date	Value of Work Completed to Date	Funding needed to Complete Work
3,222,398	1,001,993	4,224,391	3,040,824	3,040,824	800,279

- A special report was submitted notifying DOE about project delays due to cable production problems.
- DOE extended the project completion date from March 31, 2013 to September, 2013.