

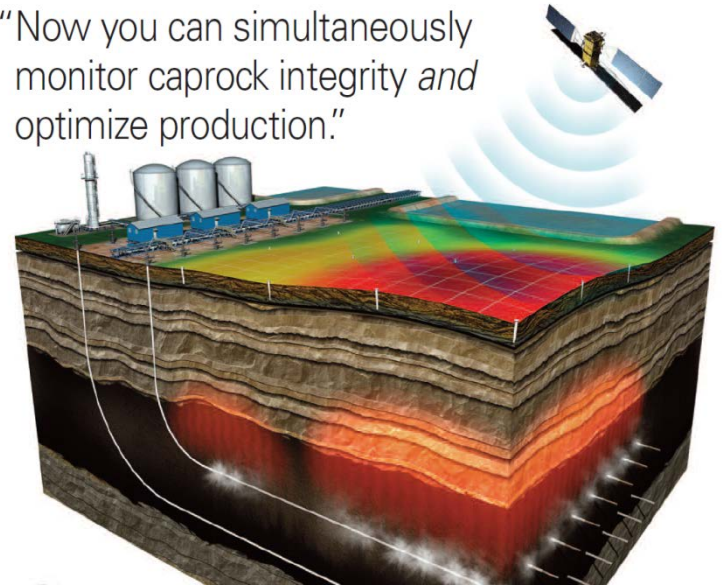
ICOTA Roundtable Retrievable Temperature Logging using DTS

October 20, 2011

Agenda

- Who is Pinnacle?
 - Why Fiber Optics?
 - Value of Distributed Temperature Sensing (DTS) Data
 - DTS Theory
 - Pinnacle Dual Laser DTS
 - Pinnacle MM fiber
 - Fiber Deployment Methods
 - Pinnacle Retrievable Coil Tubing Specs
 - Case Histories

"Now you can simultaneously monitor caprock integrity *and* optimize production."



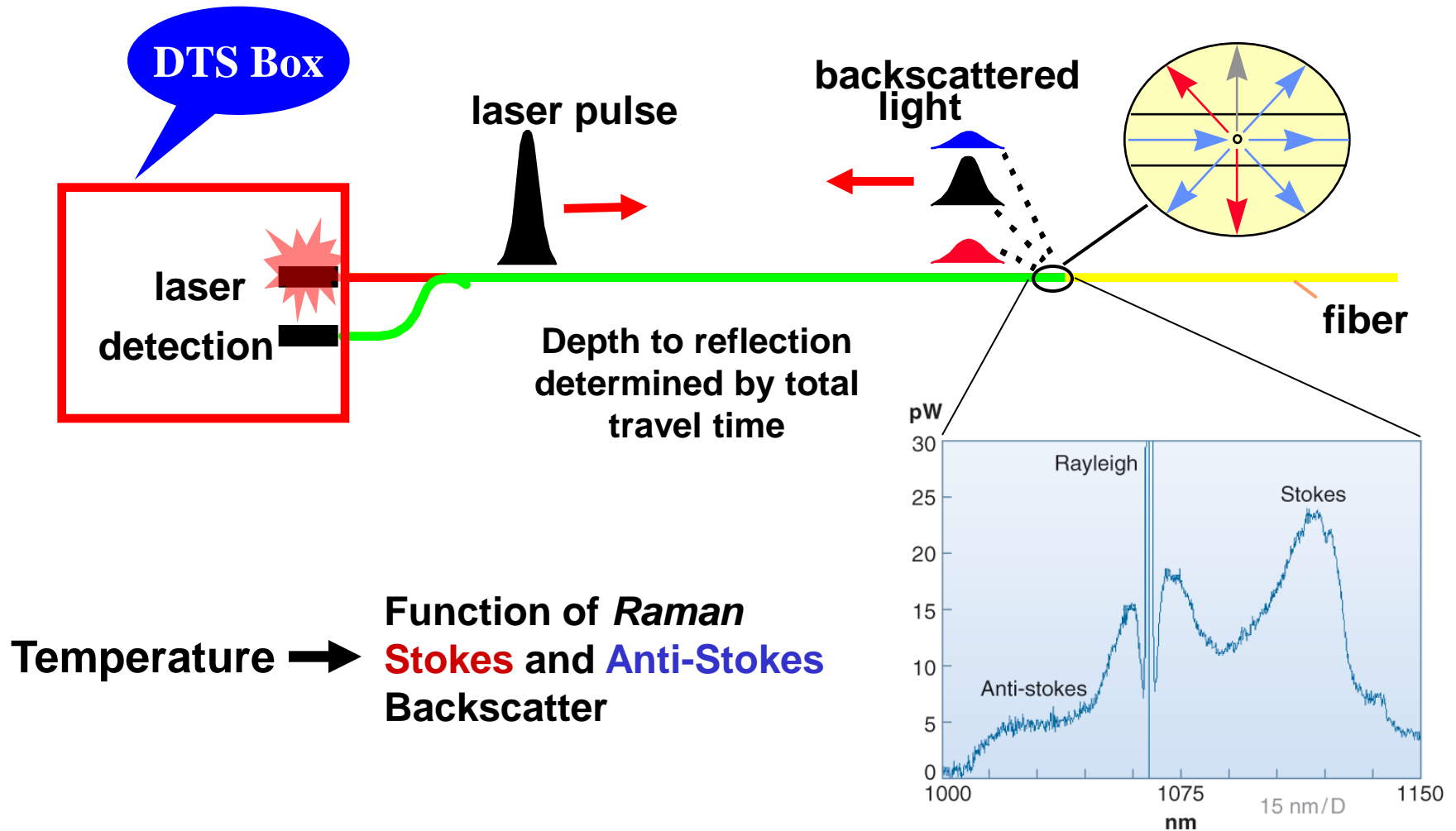
Who is Pinnacle?

- Founded in 1992, acquired by Halliburton in October 2008
- Leader in and pioneered:
 - Tilt monitoring (deformation)
 - Microseismic for frac stimulations
 - Stimulation monitoring and production analysis
 - Temperature monitoring for SAGD and Cyclical Steam Oil applications
 - Center of Excellence created in 2011, R&D budget of \$ 70 million over next 3 Years
- Completed in excess of 300 pumped permanent and retrievable fiber installs in Canada, 30 in Q2 in 2011
- Completed in excess of 600 permanent fiber optic installs of which over 100 were installed in heavy oil applications.
- Pinnacle is scheduled to perform 30 additional permanent installs in Q4 2011 in heavy oil.

Why Fiber Optics ?

- Can provide data in real time
- Can be deployed easily in both Vertical and Horizontal wells
- Easily converted from retrievable to permanent deployment
- Operable in high temperature environments > 300C
- High Temperature resolution (.5 meter sampling)
- Eliminates need for logging tools
- Can determine precisely where your steam is going?

The Theory of DTS



Distributed Temperature Sensing

DTS provides:

- Real time temperature data (typically 2-3 min intervals)
- Wellbore profiling (0.5 meter resolution)
- Data resolution and frequency can be adjusted to account for time and changing reservoir conditions
- HT DTS Performance:
 - 1m spatial resolution
 - 0.5m sampling resolution
 - 0.1C temp resolution
 - Measurement range of 5km

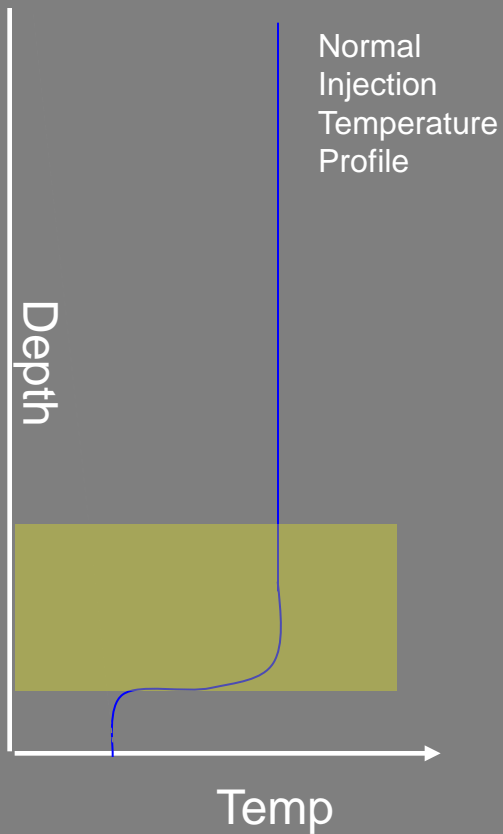
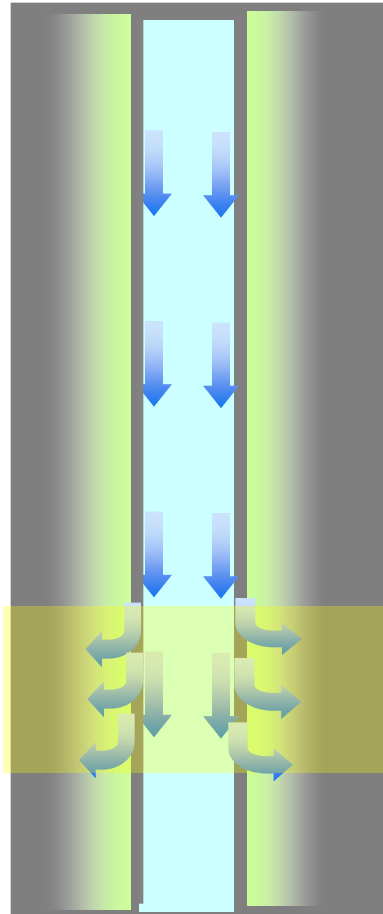
Value of DTS

Determines:

- Location of steam chamber (maximize steam placement during pre-heat)
- Monitor steam trap/sub-cool
- Monitor Artificial Lift Systems
- Monitor thief zones
- Monitor inflow conformance (liner inflow)
- Identify fluid entry points in low pressure wells requiring pressure maintenance
- Assist with flow assurance – monitor uniform temp fronts on injectors as well as hydrocarbon sweep from injectors to producers
- Rapidly identify problems such as steam breakthrough, cooling or deterioration of steam front efficiency at specific intervals
- Casing/Packer failure

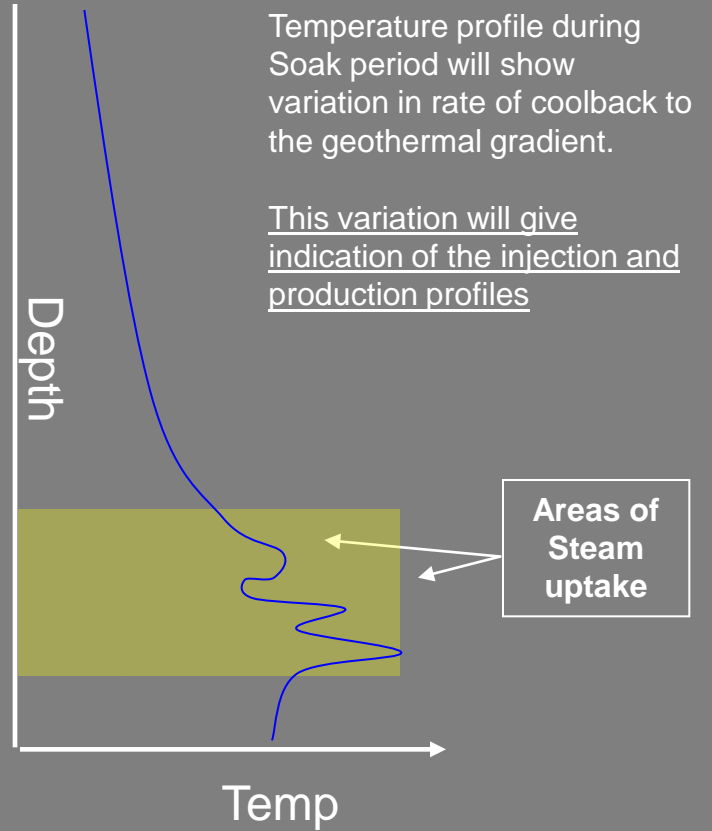
Injection Profiling in CSS Wells

T1 – Injection Phase



Normal
Injection
Temperature
Profile

T2 –Soak Phase

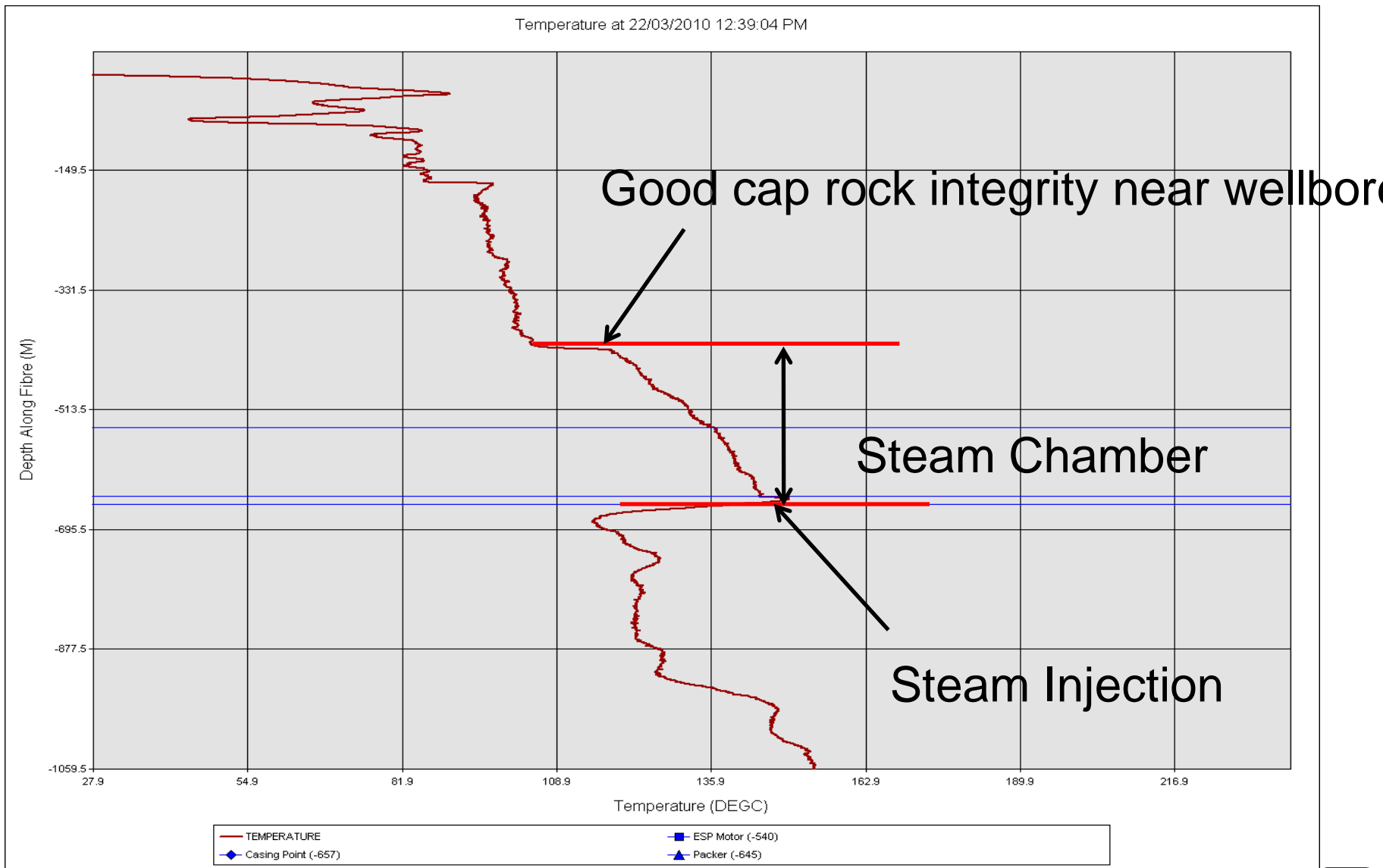


Temperature profile during
Soak period will show
variation in rate of coolback to
the geothermal gradient.

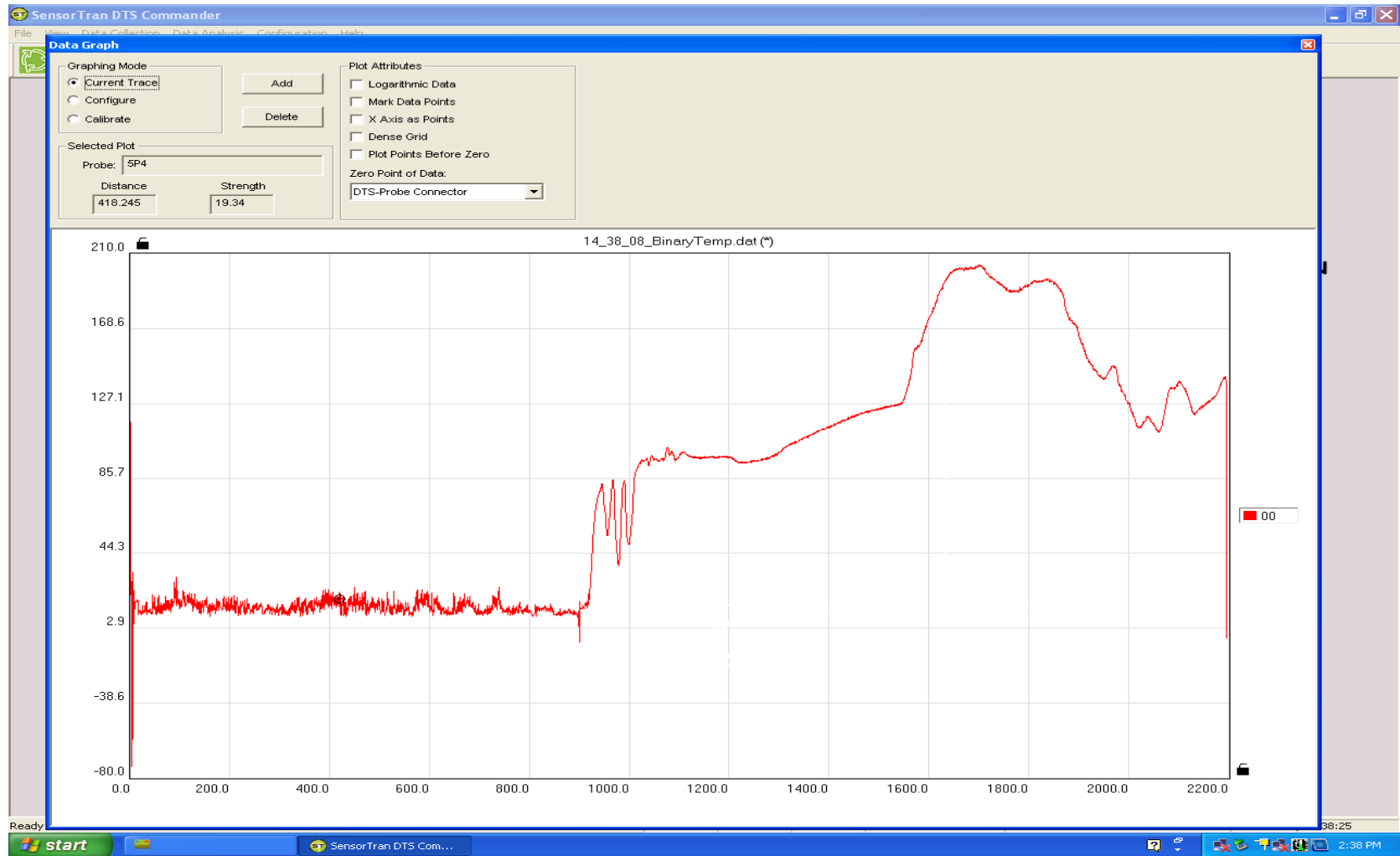
This variation will give
indication of the injection and
production profiles

Areas of
Steam
uptake

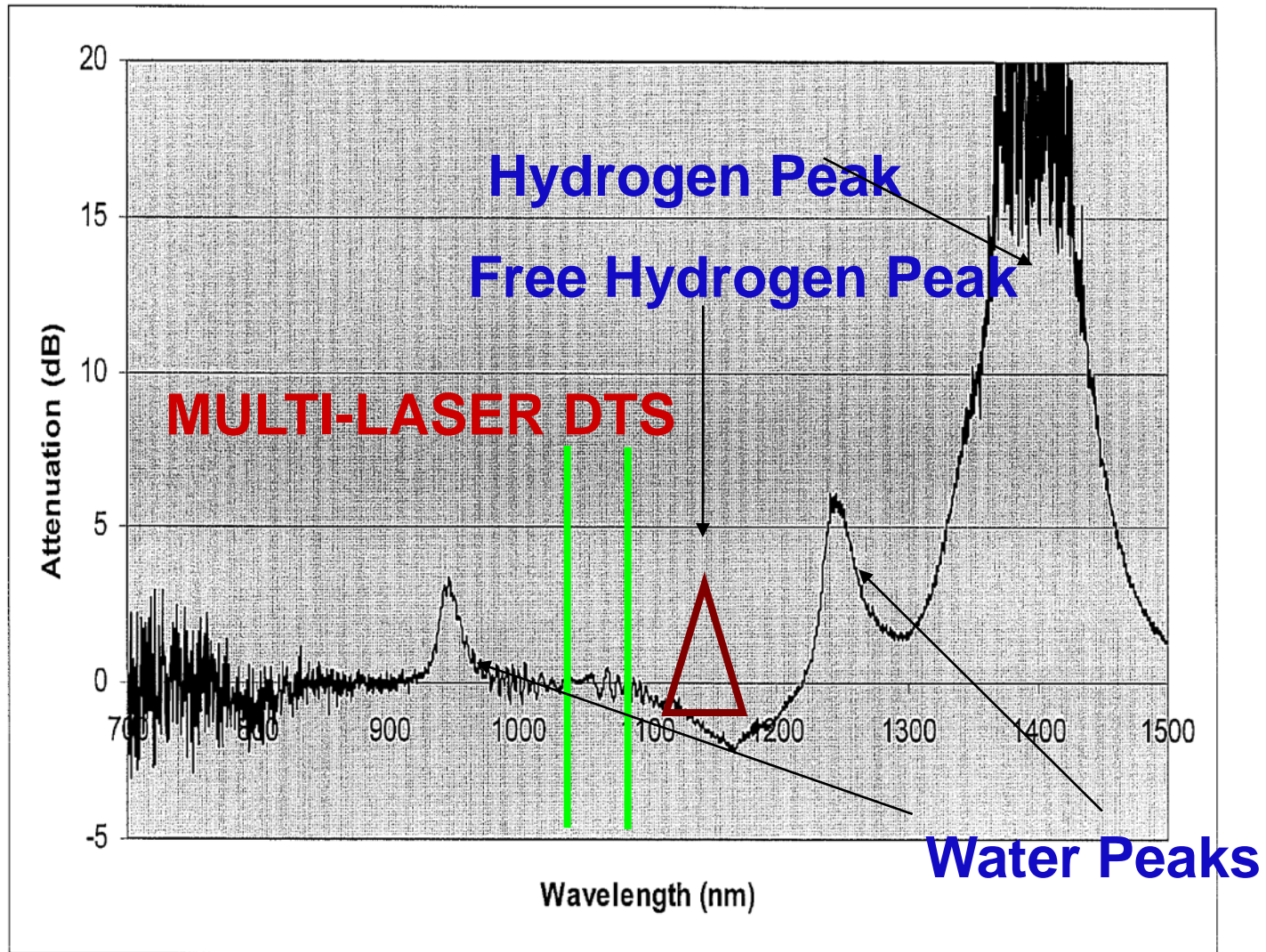
Identify Steam breakthrough location



Illustrate Well Inflow and SAGD Chamber Growth



DTS Dual Laser

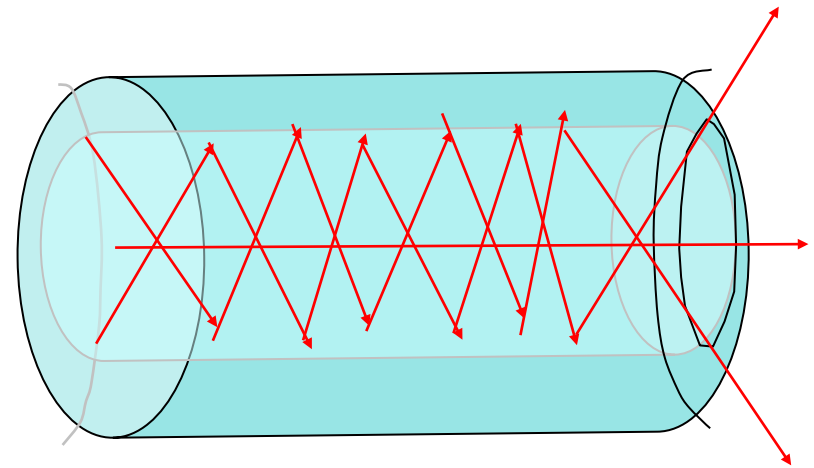


Dual Laser and Multi Mode Fiber Package

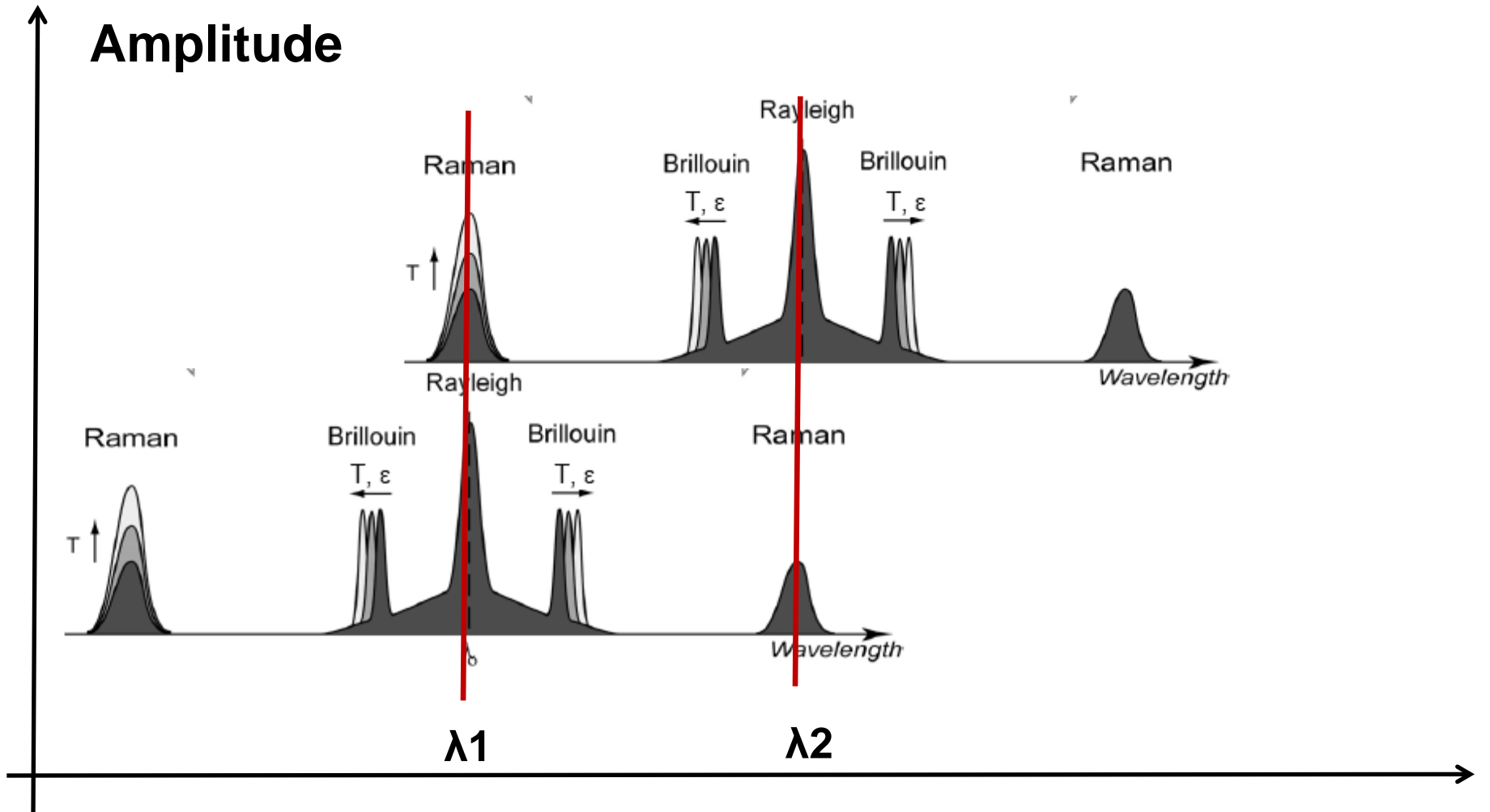
Dual Laser DTS and Pinnacle fiber:

- Multi Mode fiber customized to operate with the Dual Laser DTS
- operates in bands of low attenuation peaks
 - (Rayleigh wavelength 1 at 1015 nm overlaps the anti-stokes from wavelength 2 at 1015 nm) per meter
 - **Wavelength intervals are patented and exclusive to Pinnacle**
 - **Longest experience utilizing the Dual Laser HT DTS in Heavy Oil (5 years)**
- self calibrates and adjusts for hydrogen and water attenuation
- Multi Mode Fiber:
 - Able to tolerate large light loss, best for pumping and less sensitive to splice loss
 - Shows loss at specific wavelengths.
 - Carbon coated
 - less sensitive to micro-bends

Multi - Mode



Dual laser DTS



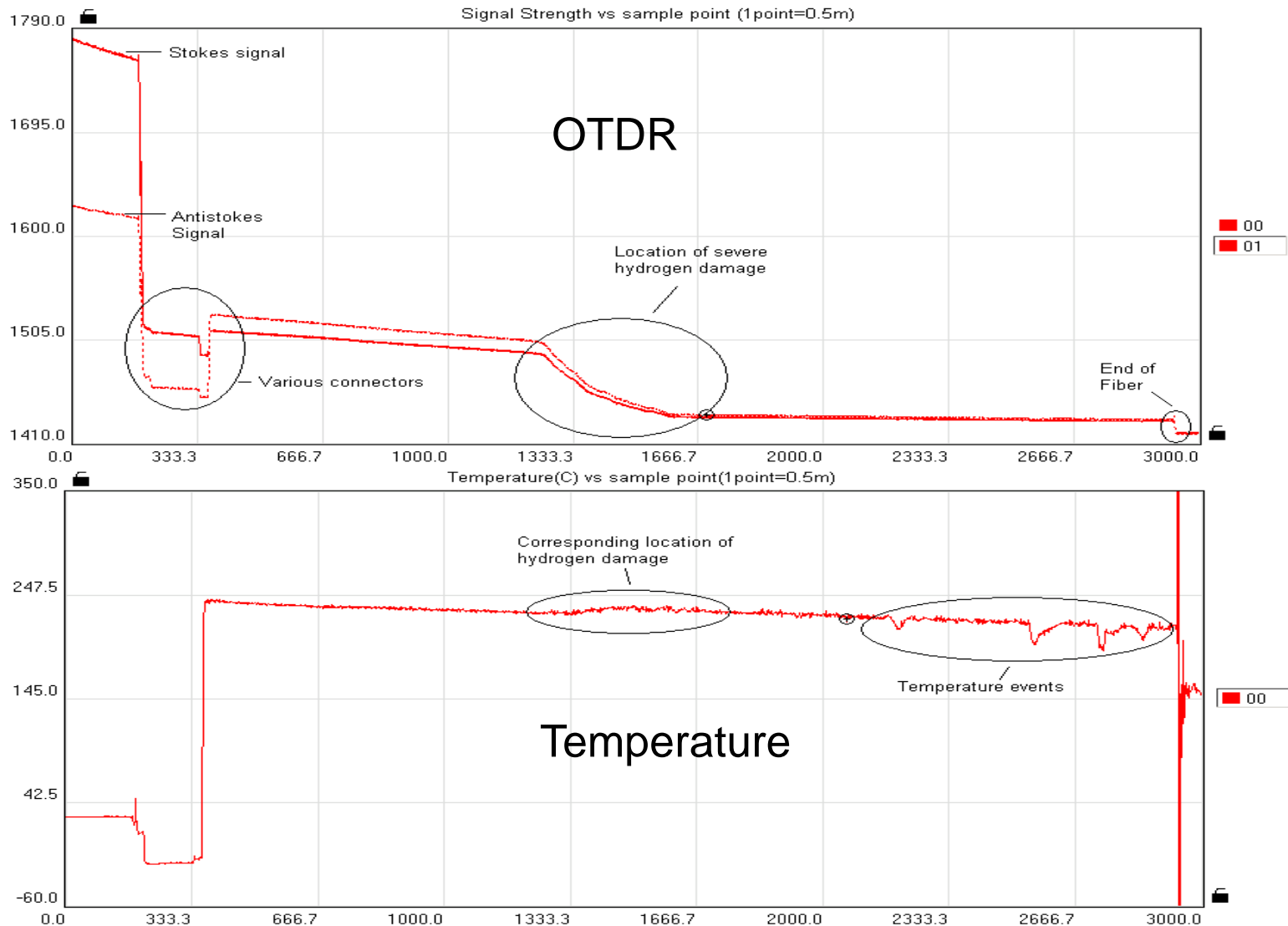
Assumption: Loss λ_1 = Loss λ_2 Anti-Stokes, Loss λ_2 = Loss λ_1 Stokes,

DTS Hardware

- DTS Surface Acquisition System
 - Scalable system
 - Longest track record in heavy oil (5 years)
 - Located inside spooling truck for retrievable surveys
 - Pad configuration only requires one DTS
- Permanent Systems
 - Solar Panel
 - MCC (AC Power/Ethernet)

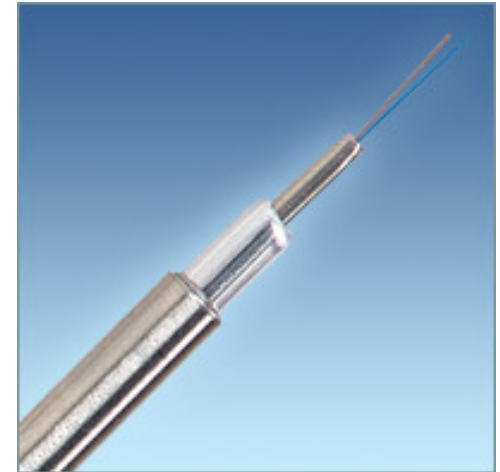


High Temperature Fiber Performance on Hydrogen Attenuated Fiber



DTS Permanent Installations for SAGD

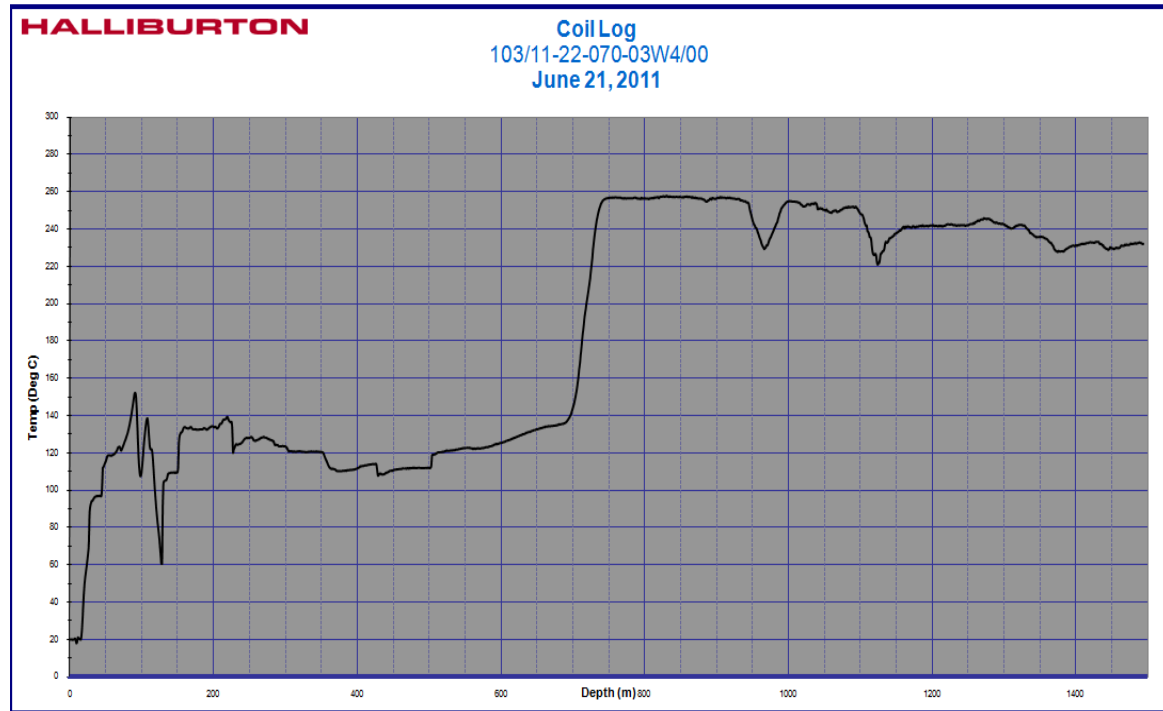
- Pumped DTS System
 - Two ¼" capillary lines installed in a loop configuration (Producer/Injector)
 - Single ¼" capillary line suspended (Observation)
 - Best suited by SAGD and Cyclical Steam
 - Guide strings
 - Coil tubing
 - Tubing conveyed
 - Casing conveyed
- optical fiber is deployed into a standard hydraulic control line while in-situ.
- technique allows for future replacement of the fiber **without intervention, lost production/injection or the need for service or coil rigs.**
- Able to pump fiber in cold or heated wells



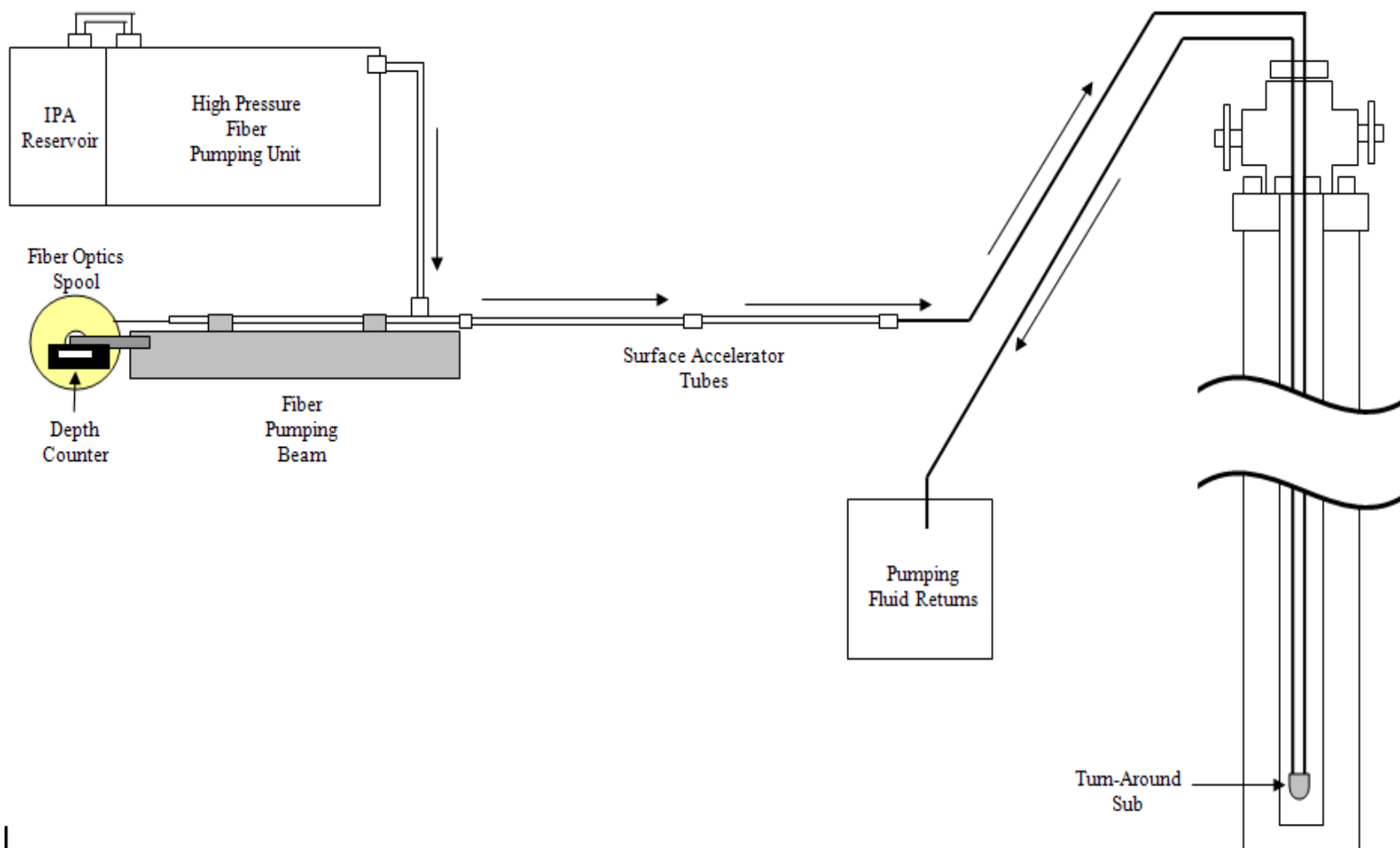
Retrievable DTS Surveys

Retrievable DTS Coil Surveys

- 2000m 1.25" coil tubing string designed for retrievable surveys
- 600m – 1000m ¼" capillary line, fiber pumped in at surface for vertical wells
- Coil string or capillary line is unspooled into producer or injector well
- Surface Dual Laser HT DTS located in truck
- Designed to operate in high temperature environments (300C)
- Surveys 12-24 hours
- Services provide high resolution data (1 meter)
- Data is provided in automated CSV. Format
- Service performed in Canada for the past 5 years



Typical Fiber Optic Pumping Diagram



DTS Projects in Canada

Permanent Install Projects:

- Conventional/Unconventional Gas (StimWatch):
 - Shell Groundbirch
 - Shell Deep Basin
 - Conoco Phillips Jupiter
- Thermal Recovery (FiberWatch):
 - Suncor Firebag
 - JACOS Hangingstone
 - Statoil Leismer
 - CNRL Wolf Lake
 - Penn West Seal
 - Sunshine Oil Sands Harper
 - Cenovus Christina Lake
 - Husky Tucker Lake
 - Husky Sunrise
 - Cenovus Foster Creek
- Retrievable Coil Logging using DTS:
 - Suncor MacKay River
 - Shell Peace River
 - Suncor Firebag
 - CNRL Wolf Lake
 - Cenovus Christina Lake
 - Cenovus Foster Creek
 - Husky Tucker Lake
 - Husky Celtic
 - Conoco Surmont
 - Laricina Saleski

Summary

- Retrievable DTS Temperature Surveys:
 - Provides quick snapshots of reservoir dynamics
 - Cost effective DTS monitoring
 - Requires no capex
 - Pinnacle Dual Laser HT DTS corrects and calibrates for attenuation of the fiber due to hydrogen and water
 - Effective deployment
 - Proven value in monitoring caprock, maximizing production and minimizing SOR's
 - Growing client list in Canada and International
 - Large R&D budget, future development of fiber optic technology
 - Center of Excellence
 - Seasoned and experienced team

Thank You

- Questions?