smart fibres™

Pioneering Optical Fibre Sensing

Distributed Pressure Sensing Case Study

December 2016

Project Objective:

- To develop and deploy a low-cost distributed pressure and temperature measurement system as a novel new technology to manage fractured carbonate oil rim reservoirs
- To replace the conventional method of reservoir management via repeated, periodic gradio surveys

- Project Sponsors:
  Shell, NL
  PDO, Oman

The Challenge: Fractured Carbonate Reservoirs

Typical Situation Faced by Operators

- Very large reservoirs, multiple wells
- Thin oil rim with gas cap above and aquifer below
- Oil rim must align with the perforations in producing wells

But

- Oil is very mobile in carbonates – fractured / high permeability
- Leads to a dynamic oil rim

The Solution: production optimization

- Track the oil rim position across the reservoir ← How?
- Select which wells to produce and when
- Inject water or gas to control the oil rim position

Production Optimization: Current Methodology

Measure fluid levels in well bores

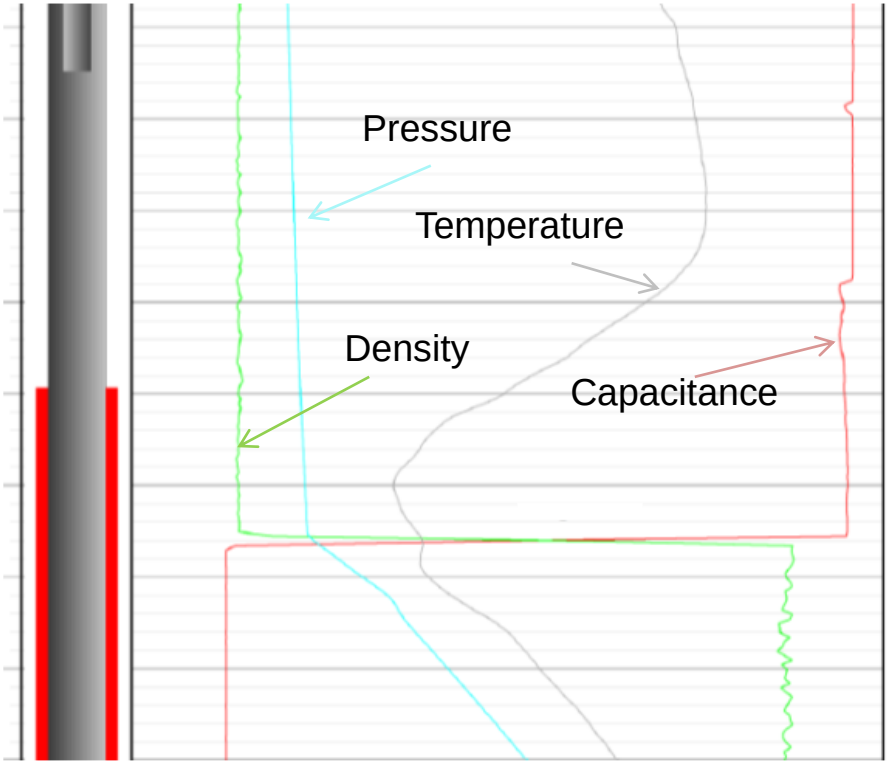
- Indicative of levels in the reservoir if perforated well casing and fractured, permeable formation

Use a Wireline Gradio Survey

- Multiple measurand (P, T, *C*, ρ) tool lowered into well

Sounds good – is it Effective ?

- Sometimes not…



Example Oil - Water Interface

Wireline Gradio Survey: Drawbacks

Data not real time

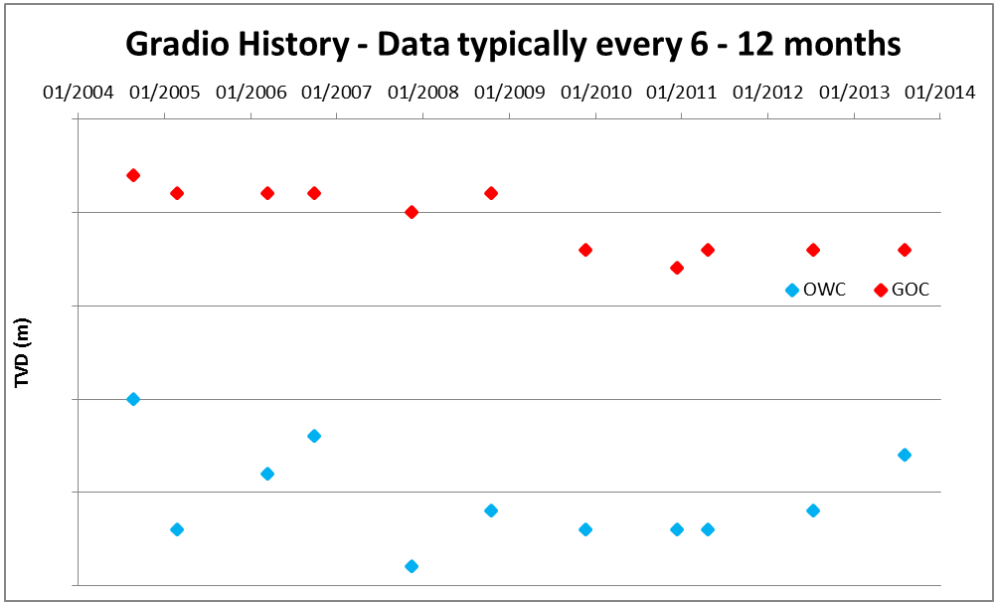
- True dynamic information missed…

Data accuracy questionable

- Differences between repeated gradio runs "orders of magnitude greater than the interpretation required" [1]

HSE Risks Involved

- Each survey requires a manned well intervention



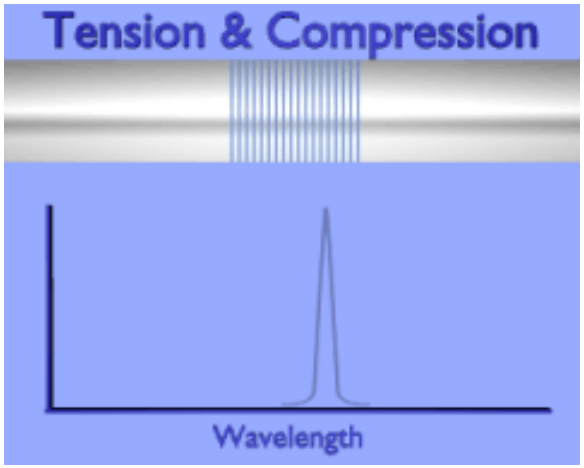
[1] Shanks, David. April 2016. Digital Oilfield Monitoring Artificial Lift. SPE Webinar.

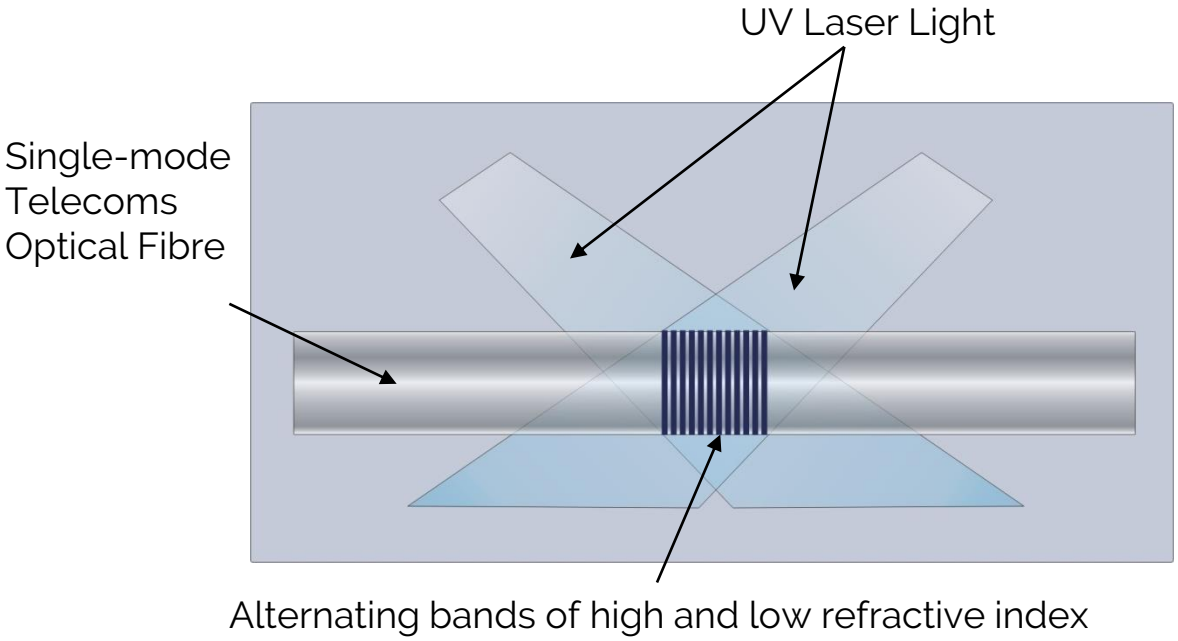
New Methodology: Distributed Pressure Sensing With Fiber Bragg Gratings

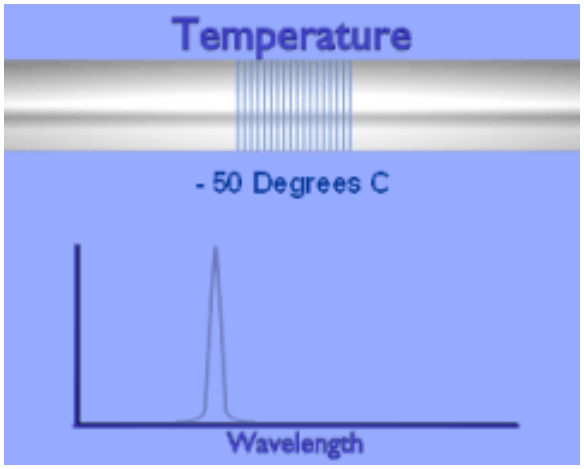
- A collaborative development project:
  - Shell Global Solutions – Project Initiators and Sponsor
  - Smart Fibres – Solution Developers
  - Petroleum Development Oman – Field trial hosts and first end user
- Project Timeline:
  - Initial engagement: 2003
  - Solution development: 2003-2010
  - Trial deployments and solution optimisation: 2010-2015
  - Commercialisation: 2016

Technology Background
The Fibre Bragg Grating (FBG)

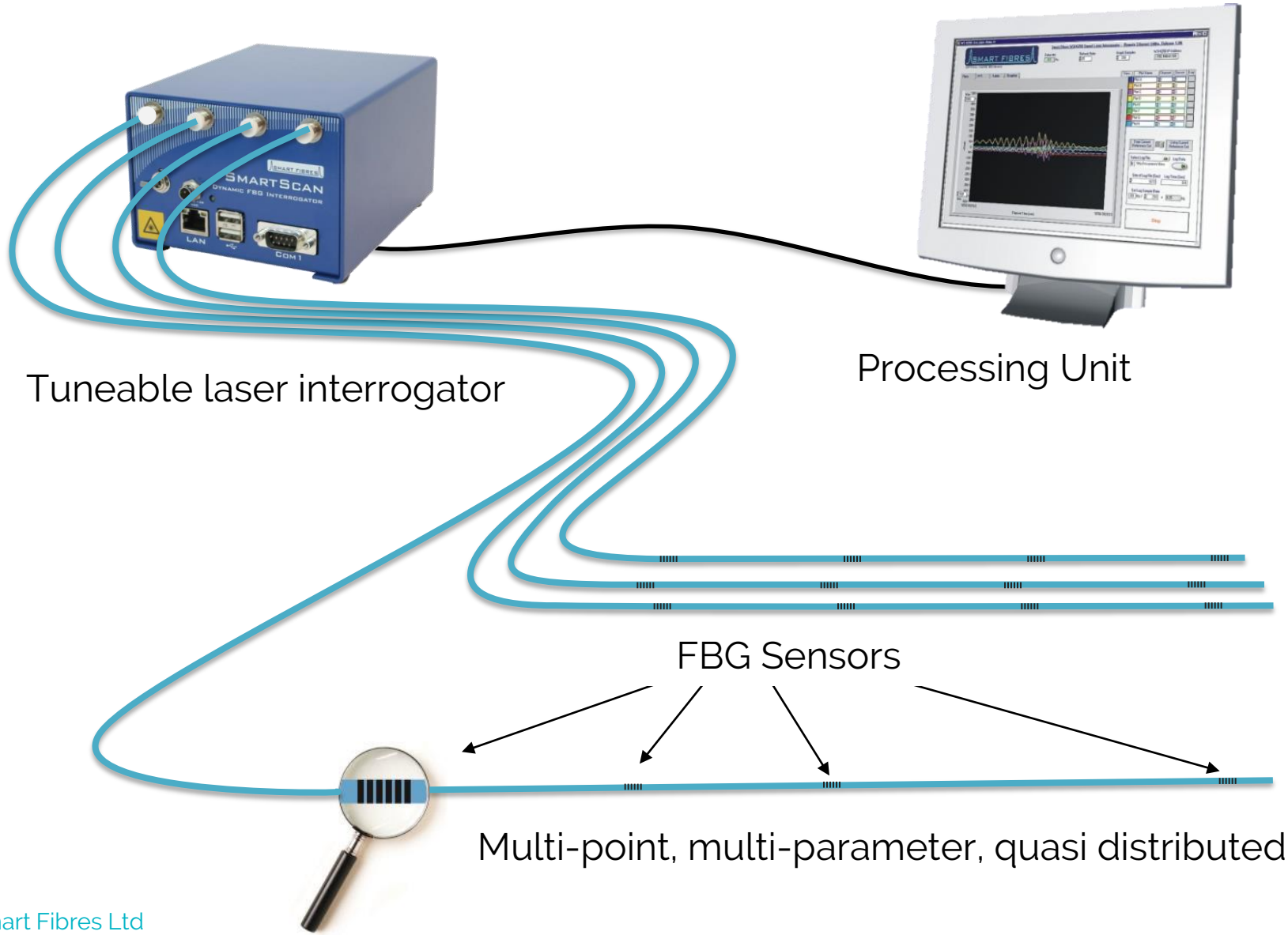
- A Fibreoptic Sensor
- Recorded with UV laser light
- Reflected wavelength varies with strain and Temperature







Technology Background - A FBG Sensing System

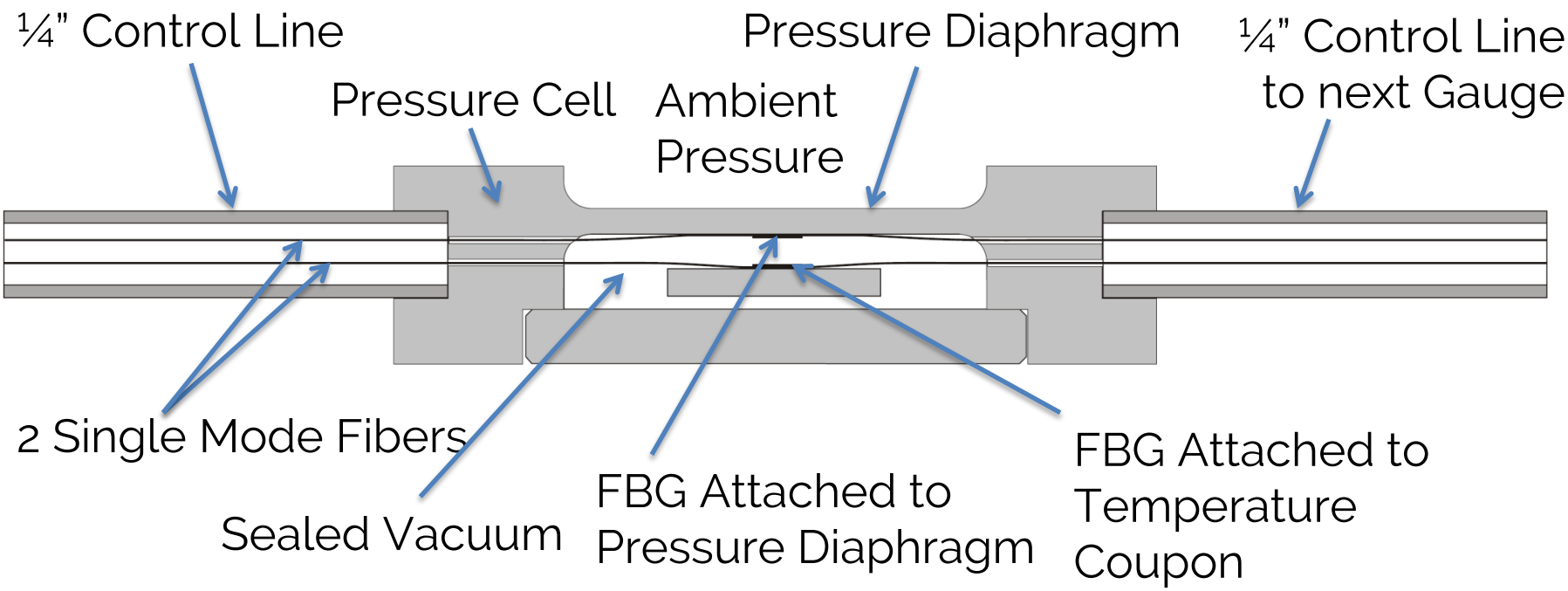


Key Technology Benefits

No electronics at point of measurement	Long service in ultra harsh environments (temperature, vibration, EM, HV, radiation) Reduced system complexity and parts count
Multiplexing capability	Multi-parameter measurements on one conductor, fewer connections/penetrations
Remote Monitoring	Instrument in ‘safe’ area, tens of Km from sensors
Long-term Stability	No inherent measurement drift No need for periodic recalibration
Zero Power	EMI immune, intrinsically safe System ATEX certified for Zone 0 operation
Fatigue Durability	Sensors proven for millions of high strain cycles
Sensor Size	Miniature sensors can go almost anywhere

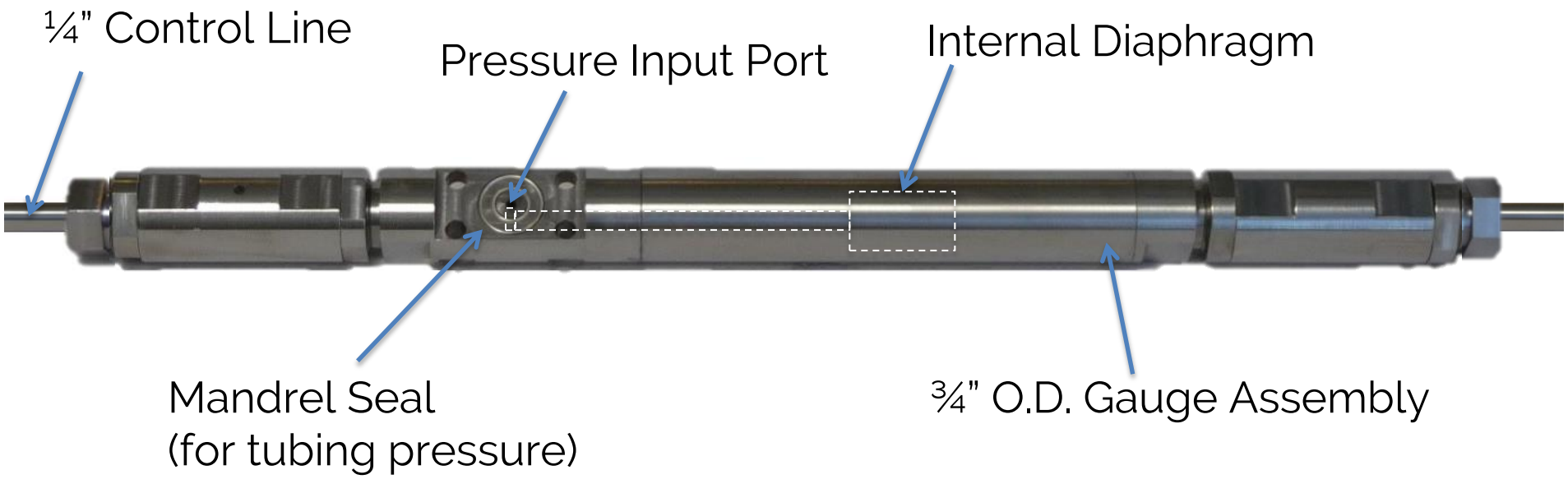
New Methodology: Pressure / Temperature Sensing With FBGS

FBG Pressure Temperature Transducer Schematic

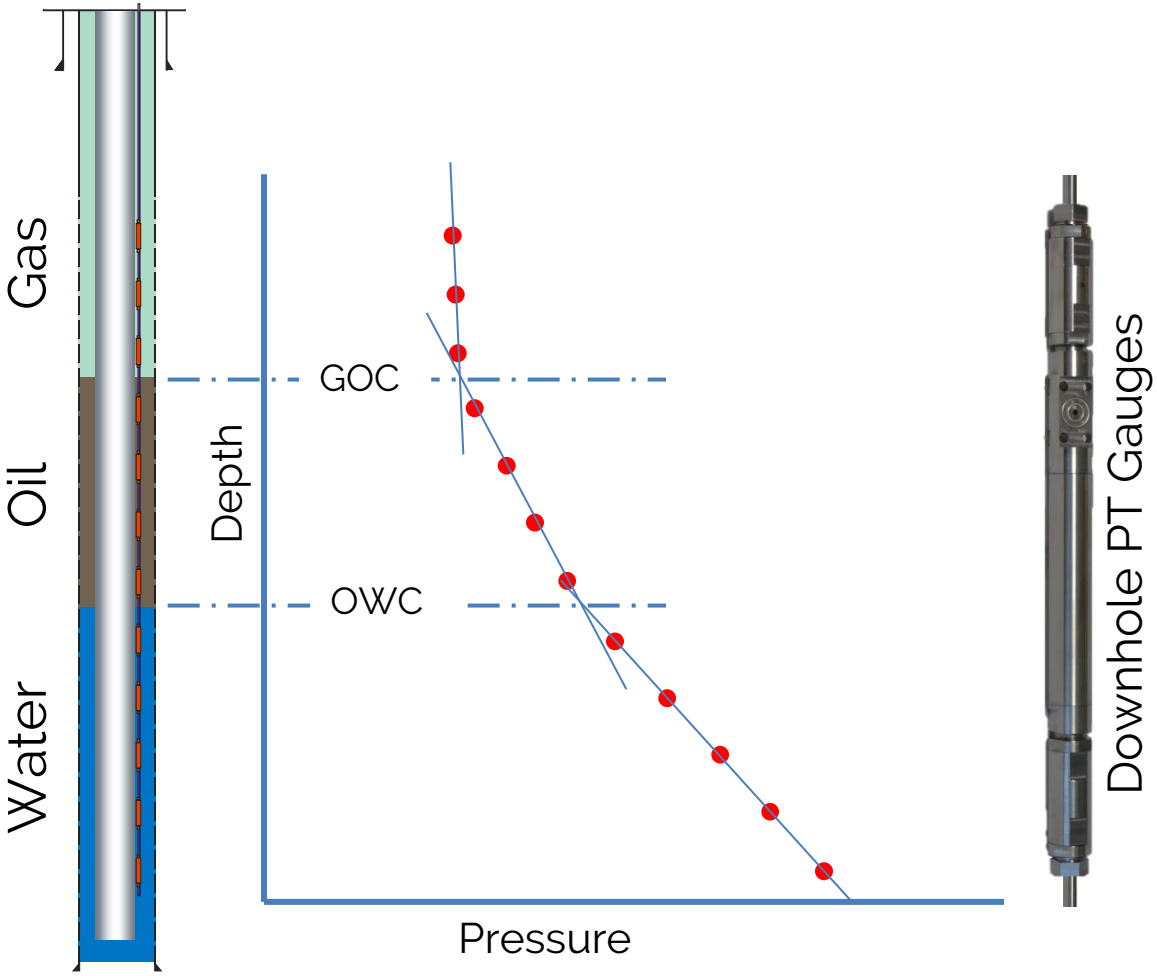


New Methodology: Pressure / Temperature Sensing With FBGS

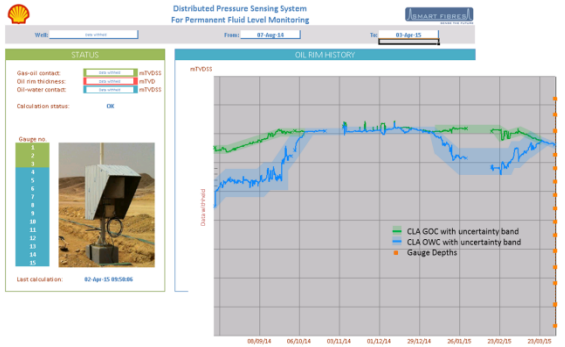
FBG Pressure Temperature Transducer Product: SmartPort



New Methodology: Production Optimization Using DPS



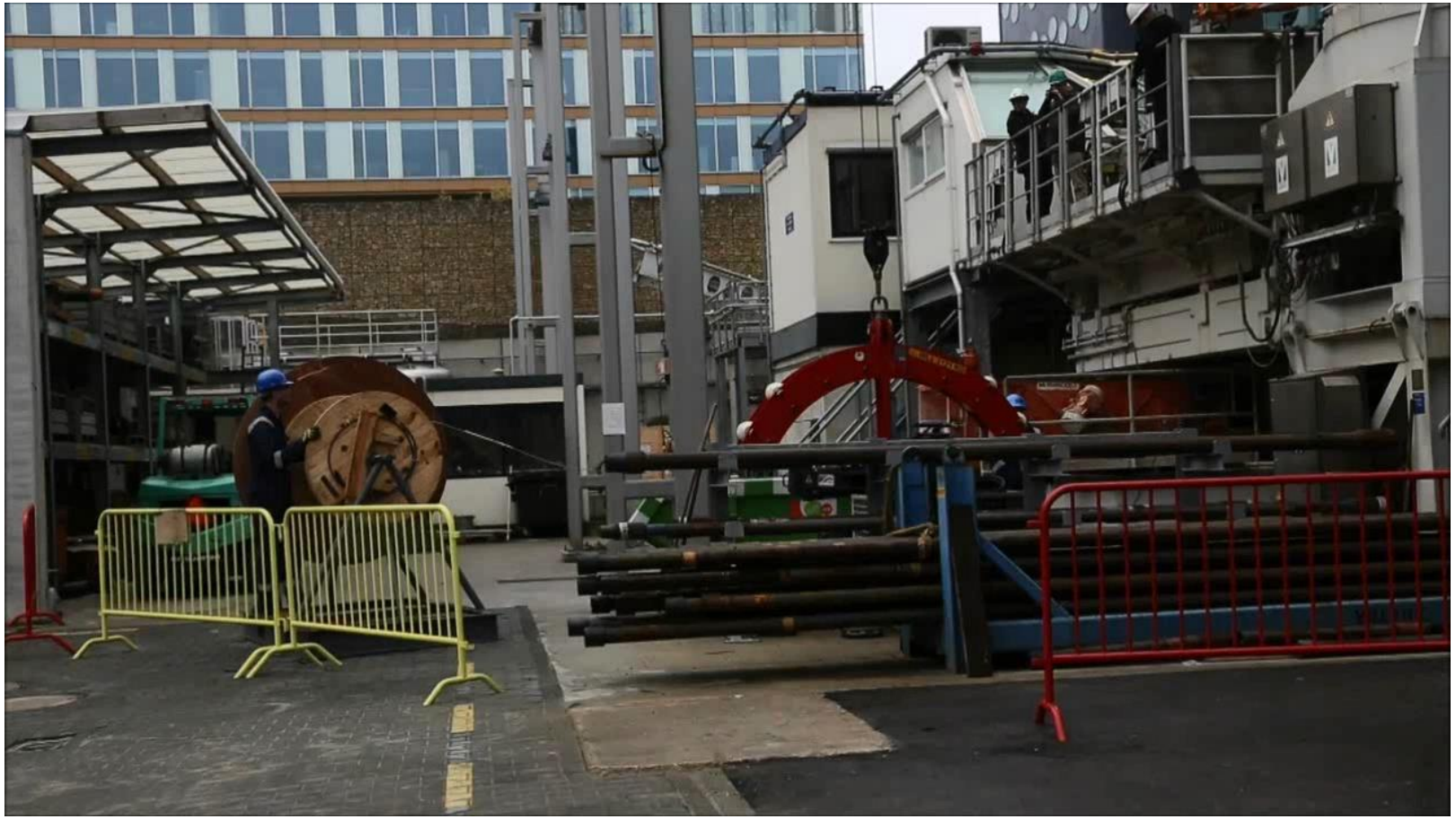
Pole Mounted Surface Instrument



Custom Software

Production Optimization Using DPS: Deployment Method

- Lifting the Custom Sheave



Production Optimization Using DPS: Deployment Method

- Lifting the Custom Sheave

Production Optimization Using DPS: Deployment Method

- Clamping Gauge to Tubing

Production Optimization Using DPS: Deployment Method

- Lowering the Gauge String

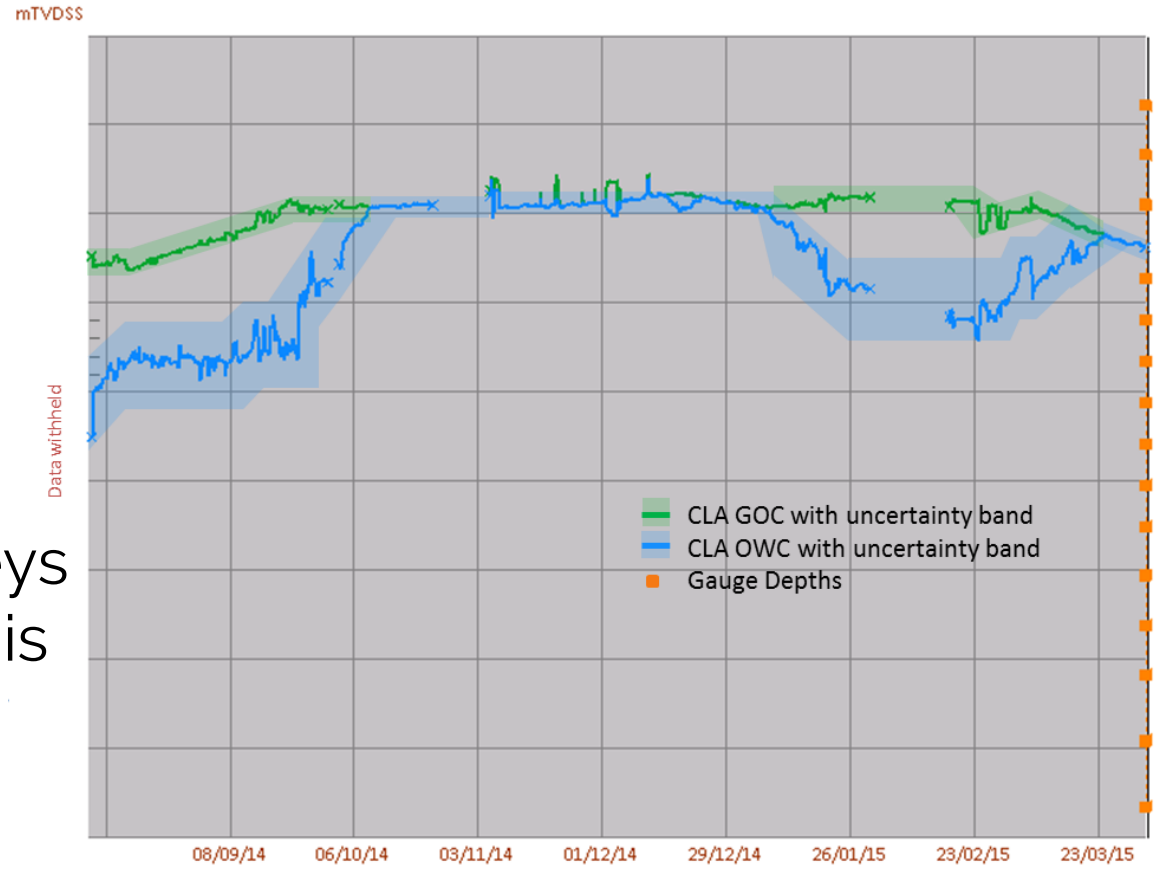
Production Optimization Using DPS: Deployment Method

- Adding Tubing Section

Production Optimization Using DPS: Field Data

Field Data, 2014/15

- Carbonate Reservoir
- 15 Gauges deployed
- 6 months of data shown
- Oil rim disappears twice
- Periodic gradio surveys give 1 data point in this time window
- i.e. completely miss this behaviour



Production Optimization Using DPS: Derived Value

- **Improved Reservoir Understanding**
  Gradio survey policy inconclusive. Real-time monitoring required
- **Production Improvement**
  More than X m^3/d production increase estimated (value withheld)
- **Avoid Production Deferment**
  e.g. prior loss of oil rim caused a production decrease of ~X m^3/d for Y months (values withheld)
- **OpEx Reduction**
  One time cost of permanent DPS system vs. repeated gradio survey costs
- **HSE Risk Reduction**
  1 well intervention for DPS vs. repeated gradio survey interventions
- **System Expansion Capability**
  DPS fibre could also be used for DAS, VSP or DTS

Production Optimization Using DPS: Future Developments

- **Increased Gauge Operating Temperature**
  Increase from 200°C to 280°C service (for thermal recovery wells)
- **Increased Surface Instrument Operating Temperature**
  Increase from 65°C to 70°C service (for desert use)
- **Reduced Gauge Diameter**
  Reduce from ¾" to ¼" for space critical applications
- **Integration of Quasi-Distributed Acoustic Sensing Between Gauges**
  Very high sensitivity, multi-point acoustic sensing
  Measurement between FBGs, selectable at surface by wavelength
  Can be used for *e.g.* gas lift valve of inflow control valve monitoring

Thank You
for your interest

For more information, please CONTACT US

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