Weatherford®

OmniWell™ Production & Reservoir Monitoring

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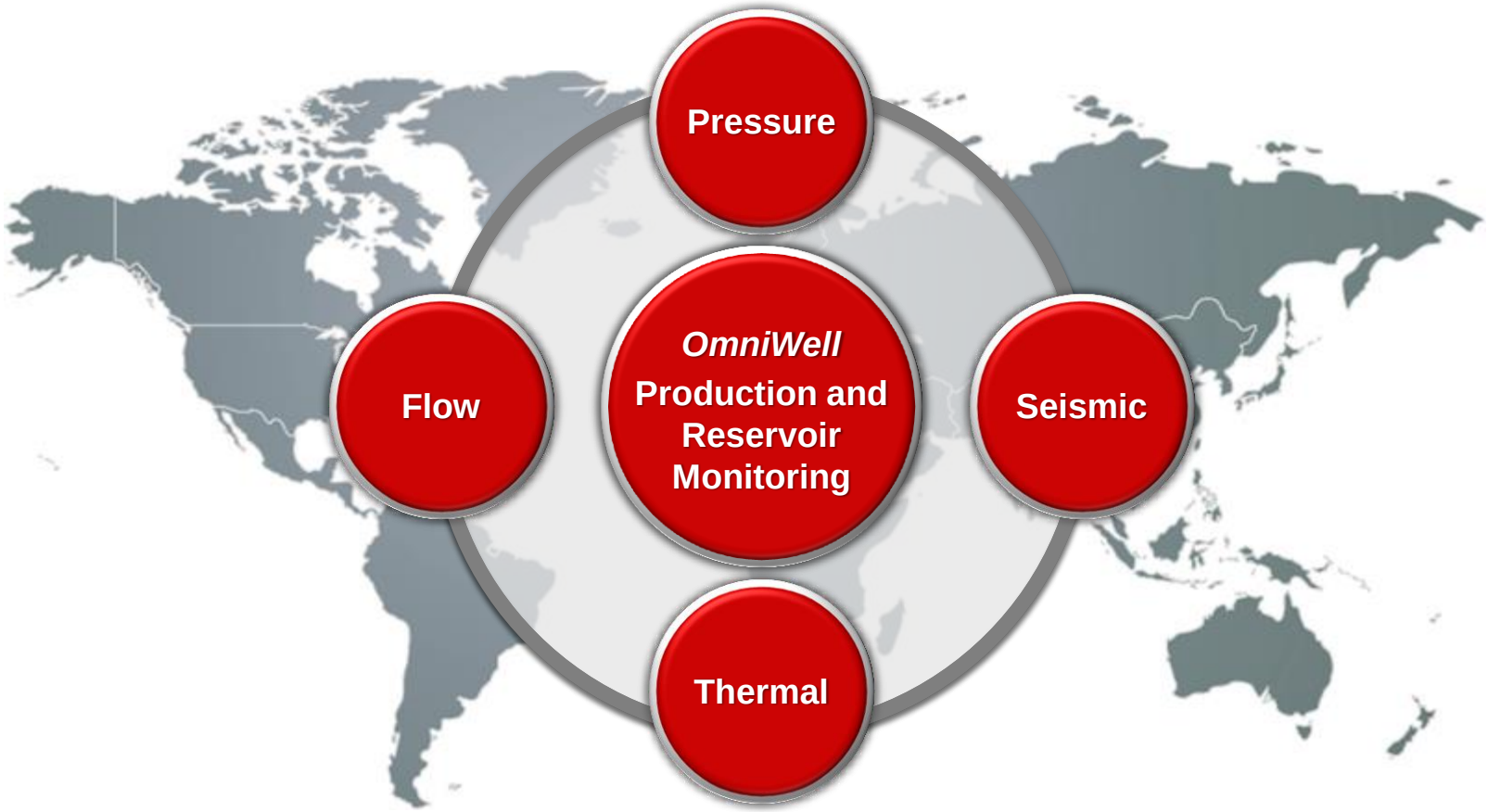
Agenda

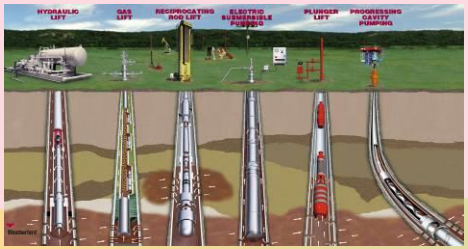
- Real time reservoir monitoring.
- OmniWell ™ System - LxATS subsurface monitoring
  - LxATS slimline instrumentation capillary with Fiber Bragg grating (FBG) / ATS temperature and pressure real-time monitoring
  - RMS Surface data acquisition system
  - Reliability / Hydrogen darkening
  - LxATS installation methods
- Field data of real-time monitoring of SAGD in circulation & SAGD production mode
  - Efficiency metrics SOR / cSOR , local Subcool & steam chamber growth
  - Real-time, accurate and trustworthy thermal profiles
  - Manage stimulation processes in production mode
  - Lower Operational Cost and increase Production Rate
- Questions

OmniWell™ Family



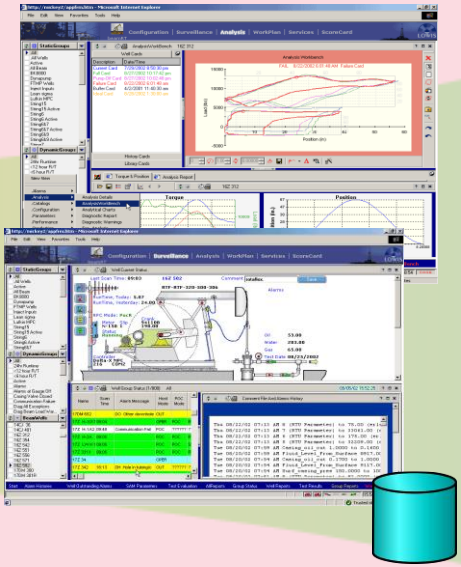
OmniWell™ Production Optimization Solution

Field Systems



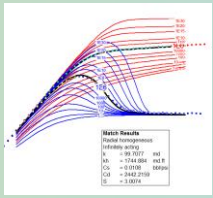
- Multiphase Flow Meters
- Monitor Water Cut
- Downhole Sensors
- Controllers
- Artificial Lift Systems

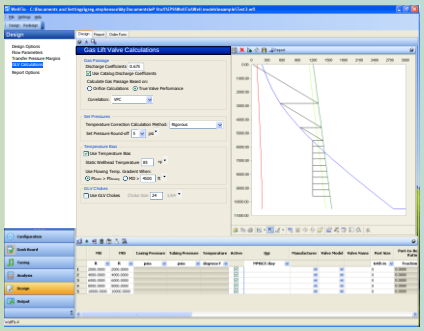
Real-Time Data Collection



- Automation & Control
- R-T Data Store
- Scorecard
- Decision Support

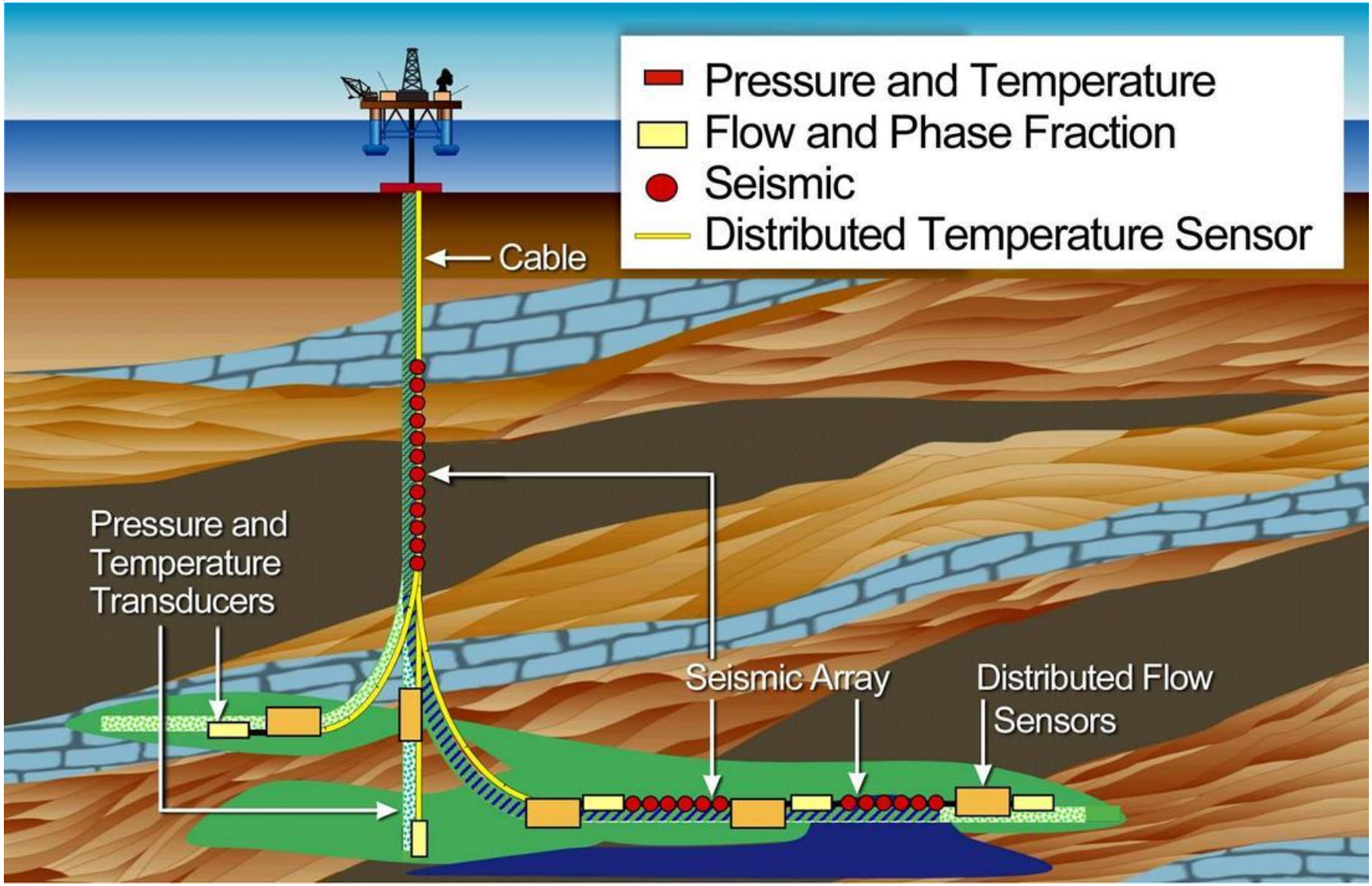
Engineering Analysis





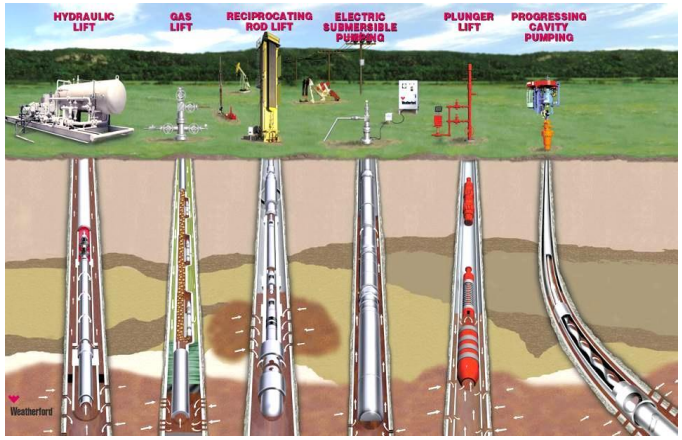
- WellFlo
- PanSystem
- ReO
- ReOForecast
- PLATO

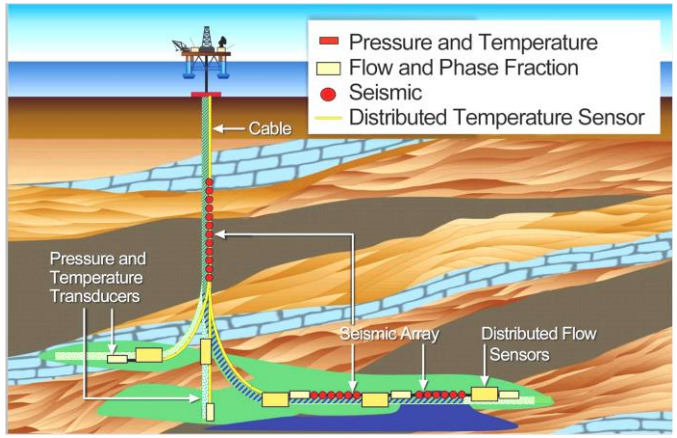
OmniWell Integrated Optical Sensing System



Applications Experience

- Complete production and reservoir permanent monitoring solutions
  - Artificial lift.
  - Coal bed methane / coal seam gas.
  - Gas storage.
  - High temperature and pressure.
  - Heavy oil / thermal recovery.
  - Intelligent wells.
  - Sand face monitoring.
  - **Shale / multi-stage fracturing.**
  - Subsea.



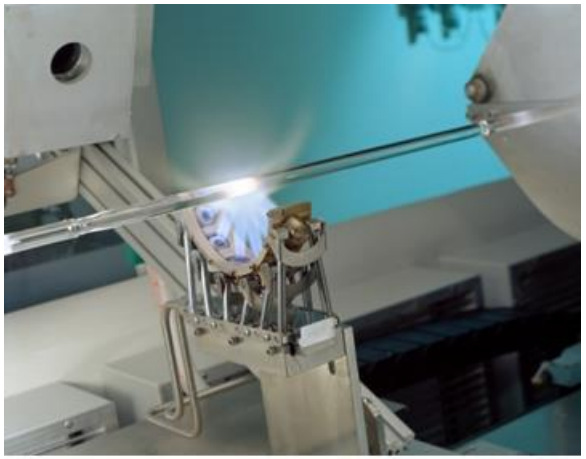


OmniWell™ Technology

- **Electronic sensing systems**
  - Pressure, temperature and vibration sensing.
  - Up to 392° F (200° C) and 25,000 psi (1,724 bar).
  - Over 5500 gauges installed worldwide.
- **Optical sensing**
  - Pressure/temperature gauges – Cane & LxPT.
  - Distributed temperature & Multi-point temperature arrays – DTS, DTS+, ATS * LxATS.
  - The pressure & temperature sensors operating environments include 572° F (300° C) and 30,000 (2,068 bar).
  - Full bore downhole multiphase flowmeter.
  - Multi-component in-well seismic.

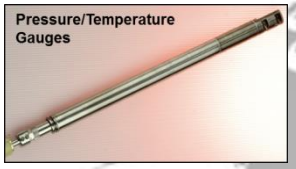
OmniWell The Case for Fiber Optic Sensors

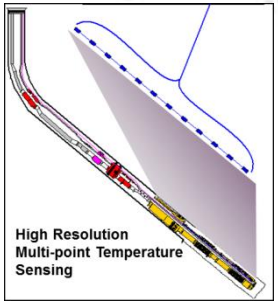
- High Reliability
  - No Downhole Electronics
  - No Moving Parts
  - Minimal Part Count
- Ideally Suited For Harsh Environments
  - High Temperature Capability
  - Vibration and Shock Tolerant
- High Data Transmission Capability
  - Multiple Sensors on Common Fiber Infrastructure
  - Technological Advances Driven by Telecom
- Distributed Sensing
  - Sensing Over the Entire Length of the Fiber

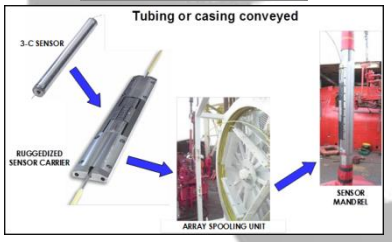


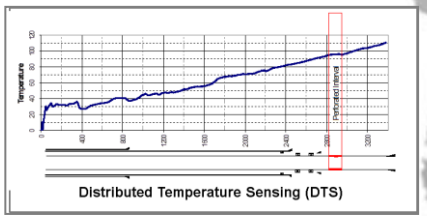
OminWell Integrated Monitoring Approach

Unified Monitoring Solutions



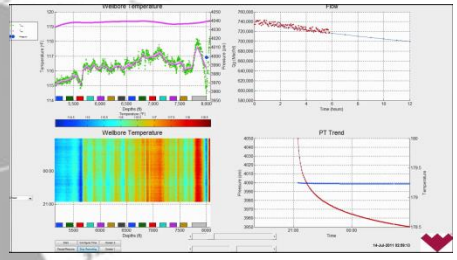


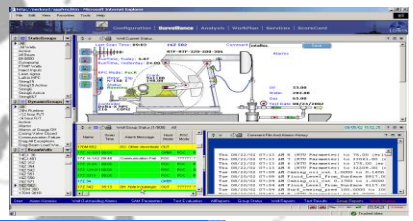


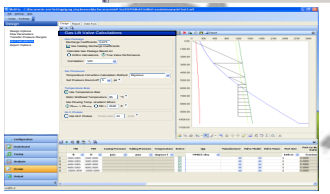


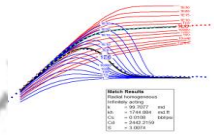
All Wells

Actionable Real-time Data





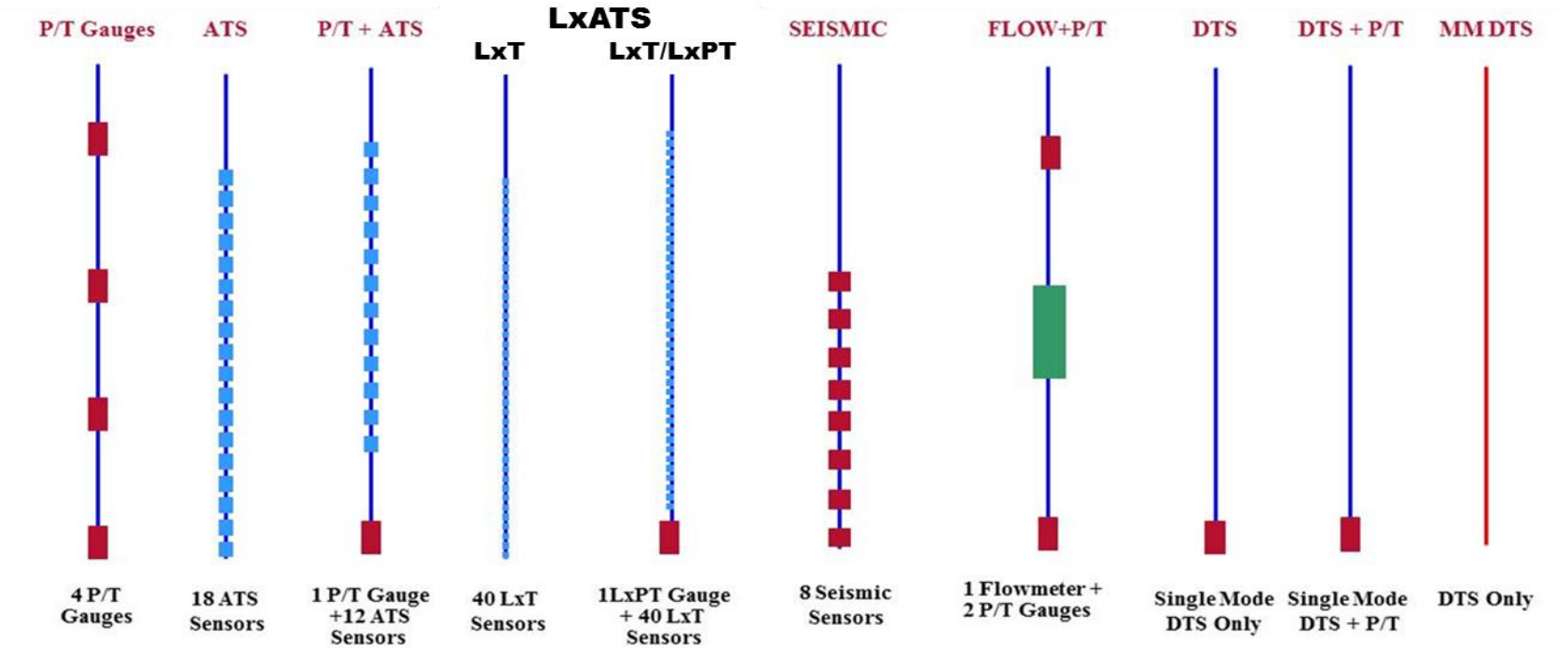




OmniWell™ Production & Reservoir Technology

Optical Sensing Technology Configurations

Each optical fiber can support a variety of monitoring combinations to meet application requirements



P/T = Pressure/Temperature; ATS = Array Temperature Sensor, LxPT/ LxT = FBG; DTS = Distributed Temperature Sensor

Optical Sensing Evolution - Weatherford

WORLD-FIRST DOWNHOLE FIBER OPTIC INSTALLATIONS:

1993 First In-well Optical **P/T Gauge**

1996 First Subsea Optical **P/T Gauge**

1999 First In-well Bragg Grating **P/T Gauge**

1999 First In-well Fiber Optic **Seismic** Accelerometer

2000 First Non-intrusive In-well Fiber Optic **Flowmeter**

2001 Optical **P/T Gauge** and **DTS** in Single Completion

2002 Multiple Optical **P/T Gauges** in Single Completion

2003 Full 3-phase Fiber Optic **Flowmeter** with **P/T Gauges**

2003 Multi-zone Optical **P/T Gauges** and **Remote Flow Control**

2004 Multi-zone Optical **P/T Gauges** and **Flowmeters** with **Remote Flow Control**

2004 Casing-conveyed, Multi-station, **Seismic** with **P/T Gauge**

2005 Multiple Optical **P/T Gauges** and **DTS** Integrated with **Sand Control**

2006 First **Offshore Permanent Seismic Arrays** interfaced to OBS Systems

2007 First SAGD LxATS Injector / Producer slimline CT deployed

2008 First Subsea Optical system for **Array Temperature Sensing**

2009 First LxPT installed intake pressure ESP SAGD & at Toe

2010 First combined **ATS + DTS** system for **Sandface Monitoring**

2011 First combined offshore flowmeters, P/T and Distributed Acoustic Sensing (DAS – 3rd party) monitoring.

2012 First offshore DAS (3rd party) concurrent multi-well seismic survey (Weatherford cable)

2013 First DTS, LxATS, CanePT, PDAS Thermal well s

Offshore Optical P/T

Client	BP
Location	Pampano, GoM
When	2000 onward
Environment	Platform Gas condensate TMD > 15,000 ft (4,572 m) BHP ~ 3,500 PSI (24.13 mPa) BHT ~ 150°F (65.5°C) 77° deviation

Highlights

- Four optical PT gauges and DTS installed
- First offshore P/T installation
- Zero NPT on first installation
- Proving installation for deepwater GoM application

Optical Flowmeter

Client	Shell
Location	Mars, GoM
When	2000
Environment	2,945 ft (897.6 m) water depth TMD > 22,000 ft (6,705.6 m) BHP ~ 8,000 to 9,000 PSI (55.15 to 62.05 mPa) BHT ~ 160°F (71°C) Platform 5,000 BOPD

Highlights

- World's first optical flowmeter
- Pressure, temperature and volumetric flow rate data.
- Confirmed ± 5% resolution of flow rate and phase fraction
- Two- phase oil + water

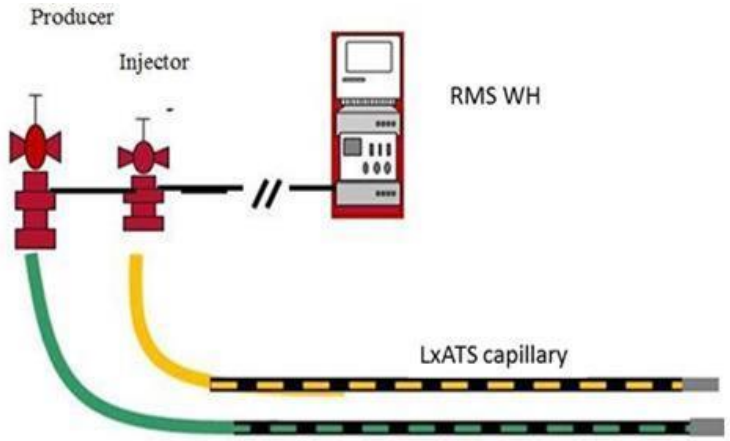
LxATS – High Density Array Temperature Sensing

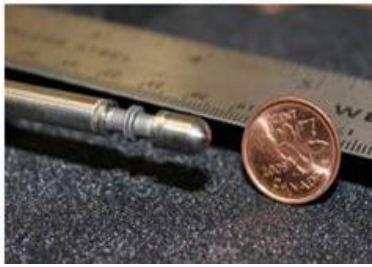
Experiences monitoring in thermal Oil fields

LxATS Ultra High temp P/T sensing

LxATS & LxPT

- FBG Sensors at 300^0 C & 1,200 psi (8,500 kPa)
- Accurate sensing suitable for extreme High Temp
- No calibration fiber from Hydrogen
- Reliable & permanent string, > 10 years lifetime
- Multi-functional P,T in real time
- Varied monitoring spatial resolution along well
- Survives shut-ins / Thermal expansion
- Production Automation
- Detailed thermal analysis studies





Mechanical Properties Gauge		
Gauge Outside Diameter (in/mm)	0.25 (6.35)	
Gauge Length (in/mm)	3.875 (98.4)	
Mechanical Properties Cable	**1/4-in Cable (Inc 825)**	
	0.028-in wall	**0.035-in wall**
Weight in air (lb/ft)	0.1	0.11
Collapse pressure (psi/bar)	>30,000 (*2,068*)	>35,000 (*2,413*)
Burst pressure (psi/bar)	20,000 (*1,379*)	25,000 (*1,724*)
Maximum tensile load (lb/kg)	1,500 (*680*)	2,000 (*907*)

LxATS Ultra High Temperature Monitoring

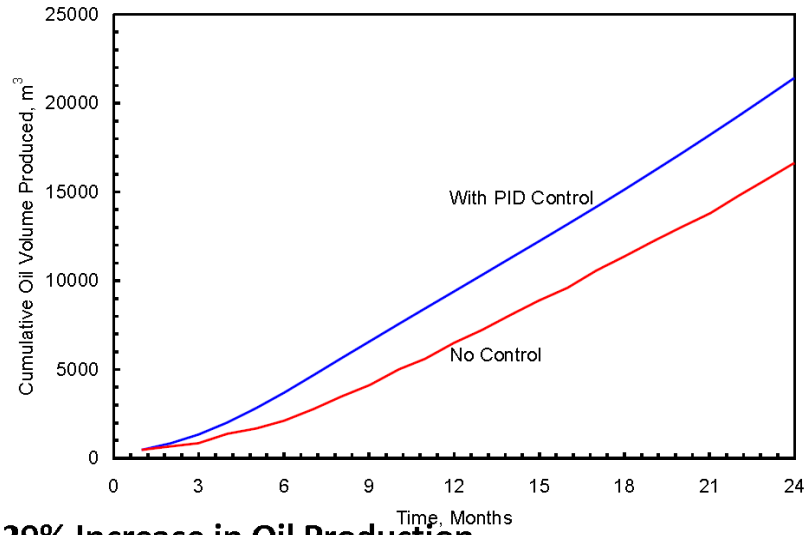
- Highest reliability and accuracy with real time sub-surface monitoring
  - First system installed Nov 2007 continuous operation in Injector
- Distributed multi-point Temperature and Pressure optical sensors
- Field proven optimization of SAGD and Steam flood recovery, reducing the operational costs & environmental footprint.
  - PID Control increases production rate by 29% lowers steam cost by 20%.

- More than 300 High Temperature/Pressure operating in Injector, Producer, infill and Observation wells (Q1 2015 – temperature range 220 – 300 C)

LxATS Systems with PID Control

Results: Cumulative Oil Production

- ✓ **Production Increase 29%**
- **Local Sub-cool measurements**
- **Steam Breakthrough**
- **Flow obstruction and thief zones**
- **Measure and improve conformance**
- **Performance of gas lift valve & ESP**
- **Validate reservoir models & lifetime**
- **Injection & production rates, pressures**

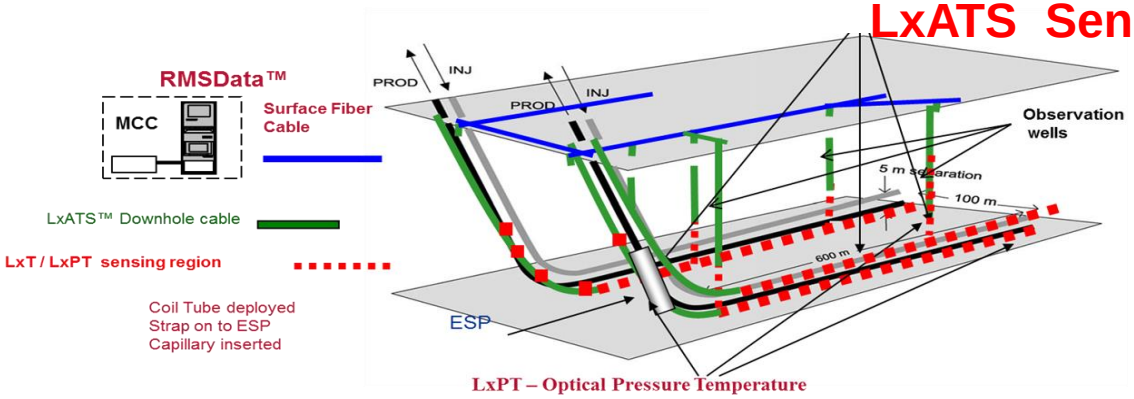


29% Increase in Oil Production

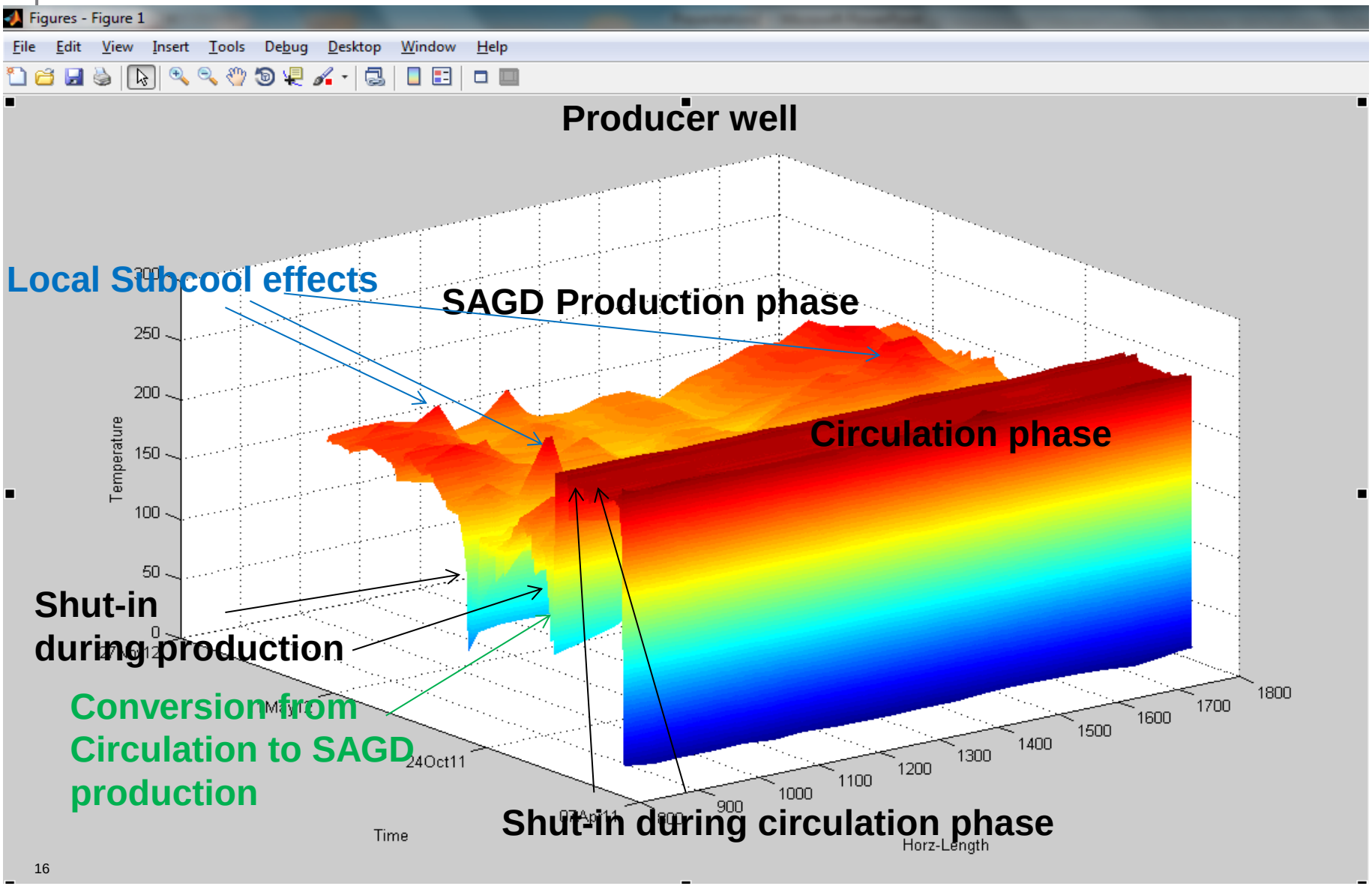
Improved Control of Steam = More Mobilized Oil

Carbon Management Canada

LxATS Sensors

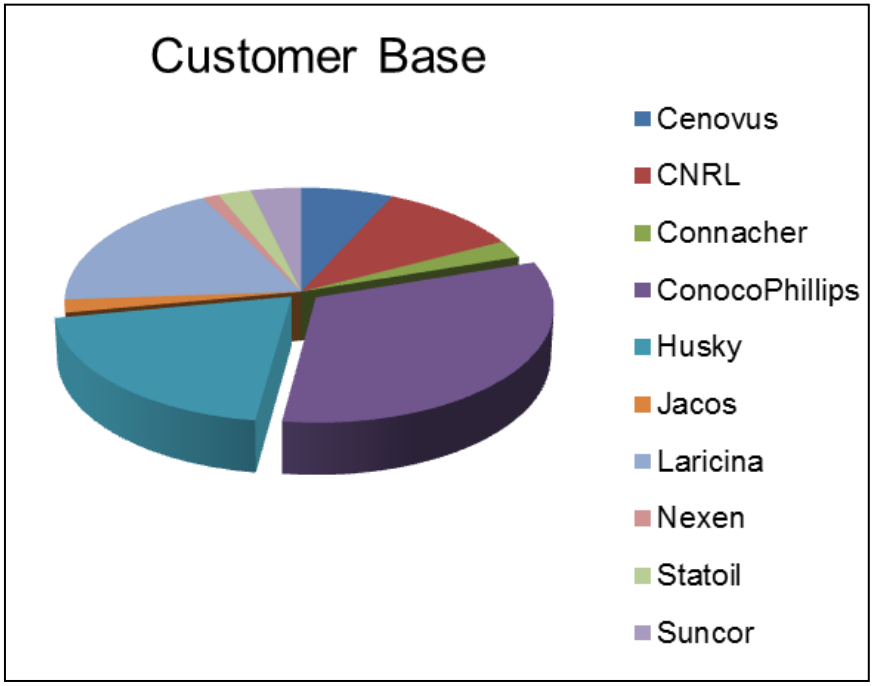


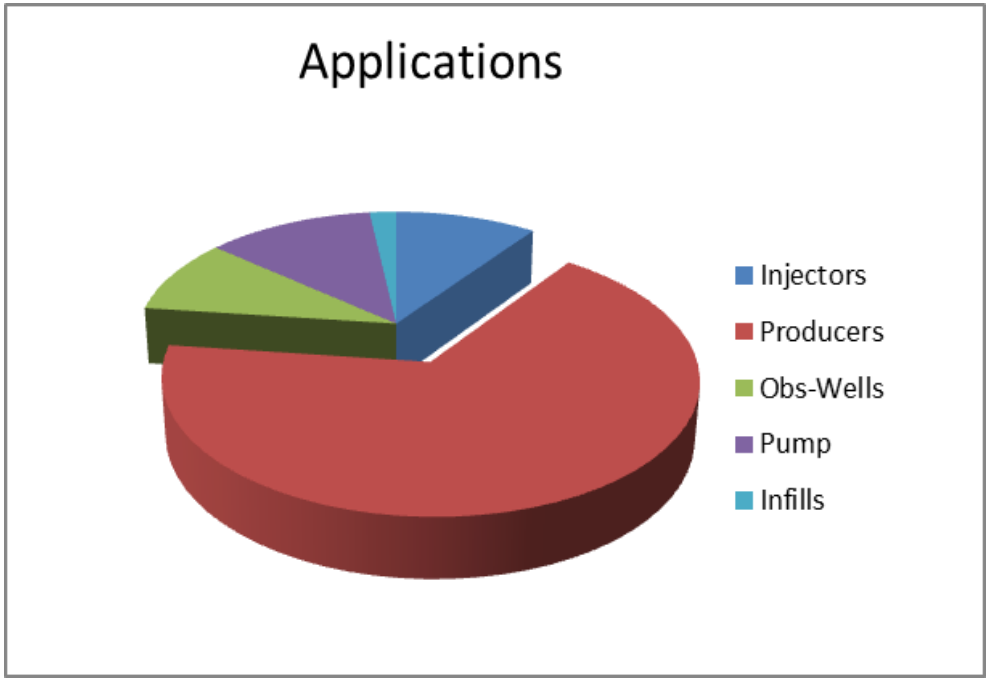
OmniWell™ Production & Reservoir Monitoring



Monitoring Experiences with thermal HO fields in Canada

- Nexen Pilot – LxATS installed Injector well November 2007
- Alberta Oilsands Monitoring Experiences
- LXPT optical pressure temperature gauge installed in 2009
- LxPT monitor intake pressure at ESP

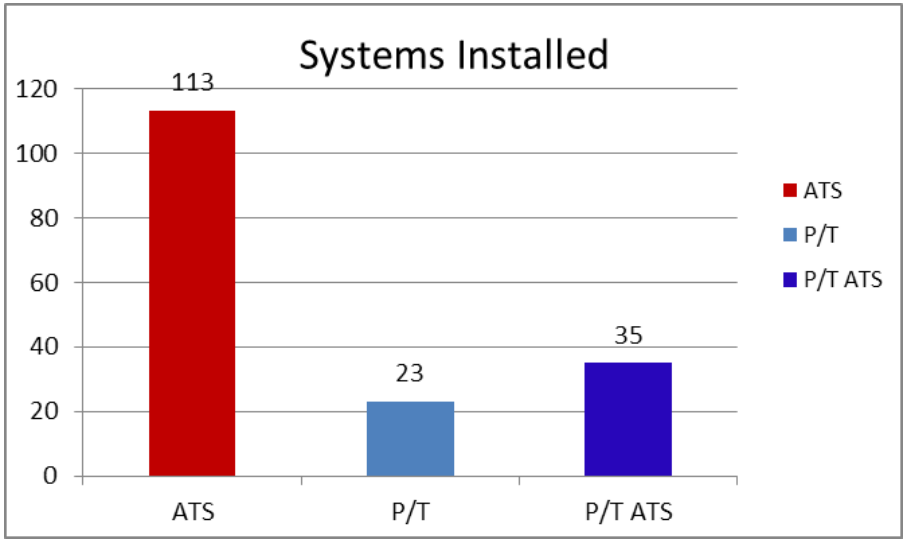


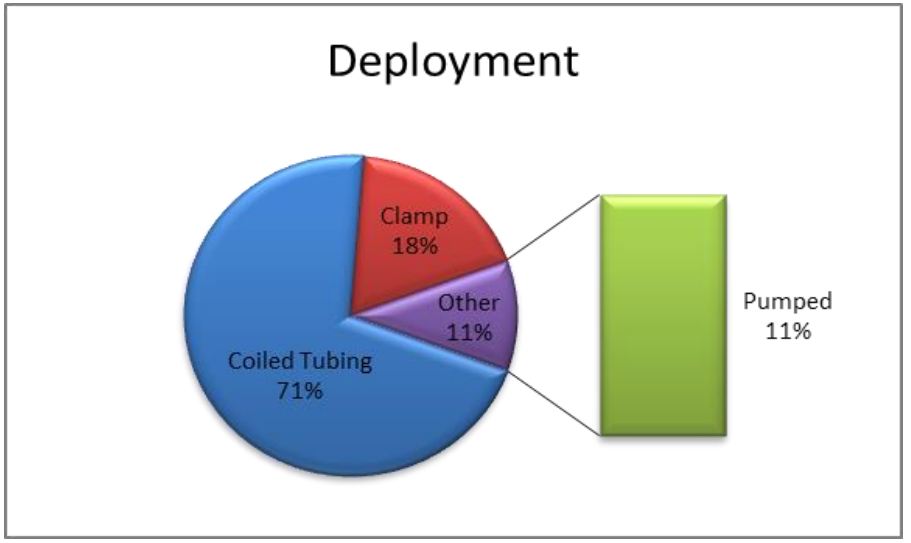


Permanent Monitoring of High Viscosity SAGD Wells in Alberta Canada

- Experiences in monitoring high-viscosity oil fields Canada
- Nexen Pilot installed Injector well November 2007
- Optimize the Circulation Phase of SAGD Wells in Canada
- Optimize Production Phase of SAGD Wells in Canada

# Sensors	7200
# of Cables	171
Longest/mths	80
String Yrs	375.7
Max Depth	1960 meters
Max Temp	282° C





Monitoring Experiences with thermal HO fields in MENA

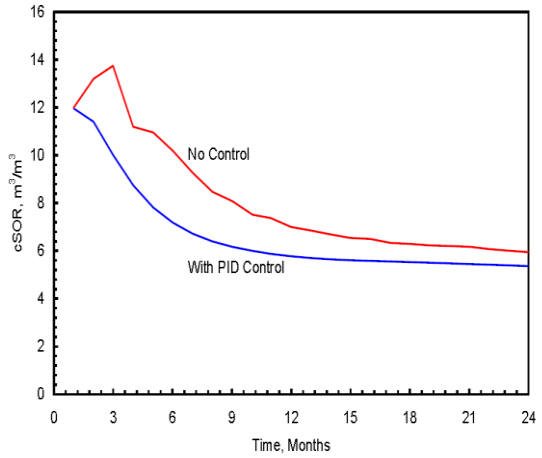
Oman:

- Qarn Alam – WFT UHT PT gauges installed (June 2012) Well under steam and Tmax = 230C
- Qarn Alam – WFT UHT PT gauges installed in (November 2013)
- Amal west – WFT UHT-DTS and LxATS installed in 7 wells (2014)
- Amal west – WFT UHT-DTS and LxATS to be installed in another 8 wells in 2015

Real Time Reservoir Monitoring Thermal wells

- **Towards "Best Practices"**
  - Subcool measurements
  - Steam Breakthrough & improve safety
  - Flow obstruction and thief zones
  - Tubing or casing leaks
  - Reduce probability of sand production
  - Reduce severity or impact of problem wells
  - Completion effectiveness
  - Measure and improve conformance
  - Optimize surface operations duration and costs
  - Optimize production & injection rates
  - Performance of gas lift valve
  - Validate reservoir models & reserve lifetime
  - Highest and most economical recovery
  - Injection & production profiles, rates, pressure

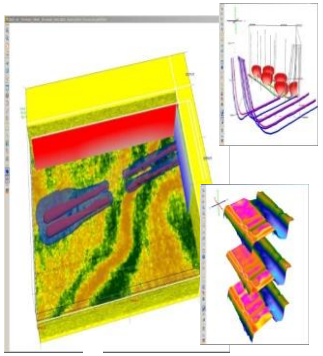
Results: Cumulative Steam-to-Oil Ratio



20% Reduction in cSOR

Means 20% reduction in GHG Emissions

Carbon Management Canada



Feedback & Control

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Data Interpretation

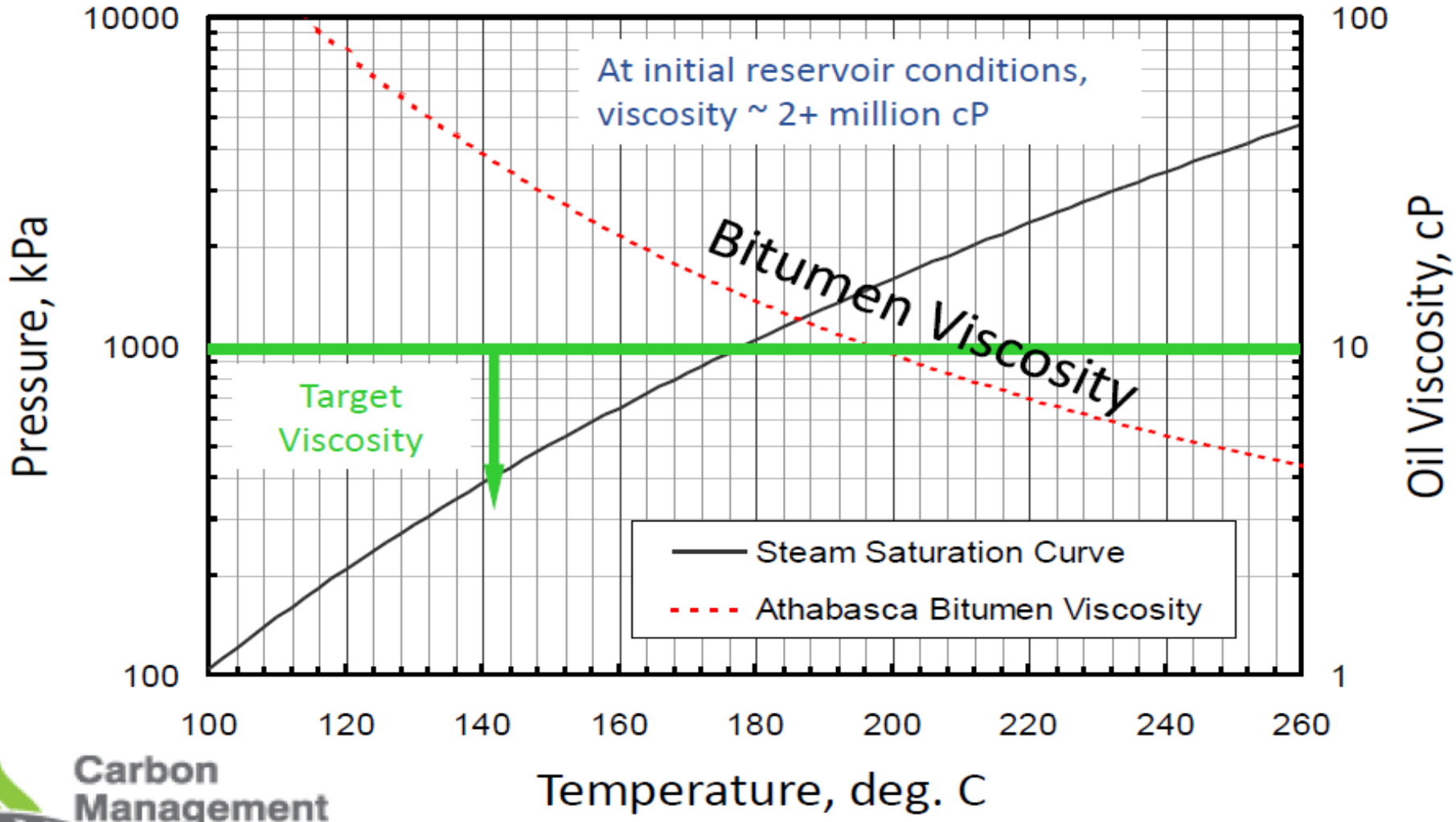
▲

Surface/Process Data

▲

Data Acquisition

Main knob (Viscosity vs. Temperature)



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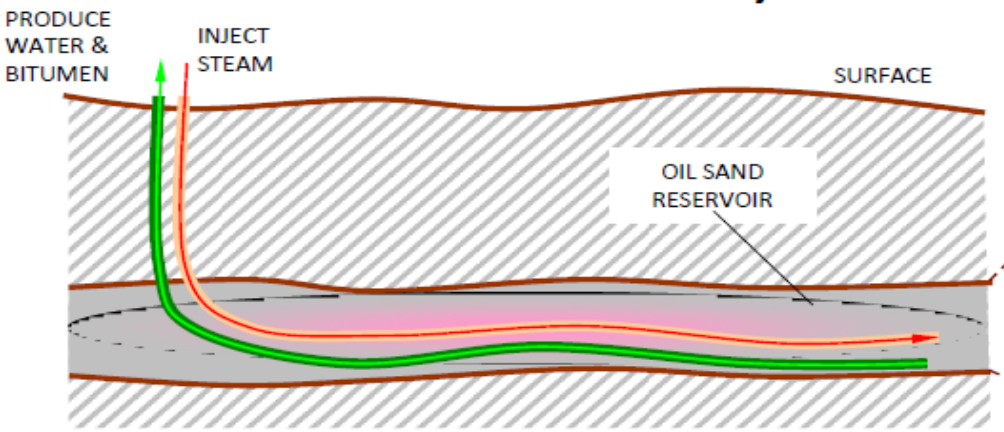
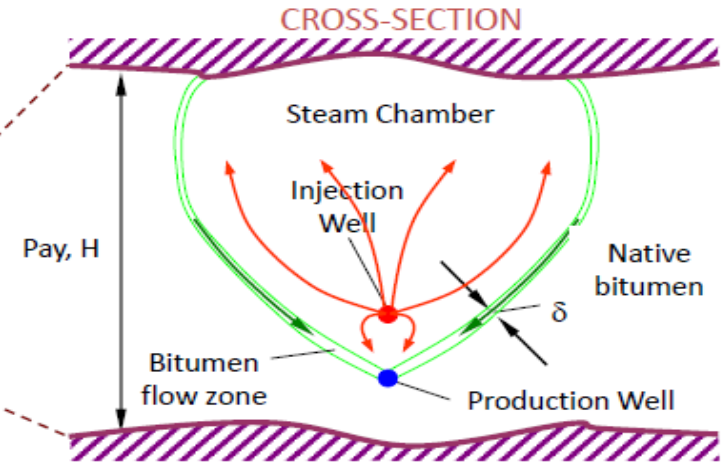
CMC-NCE

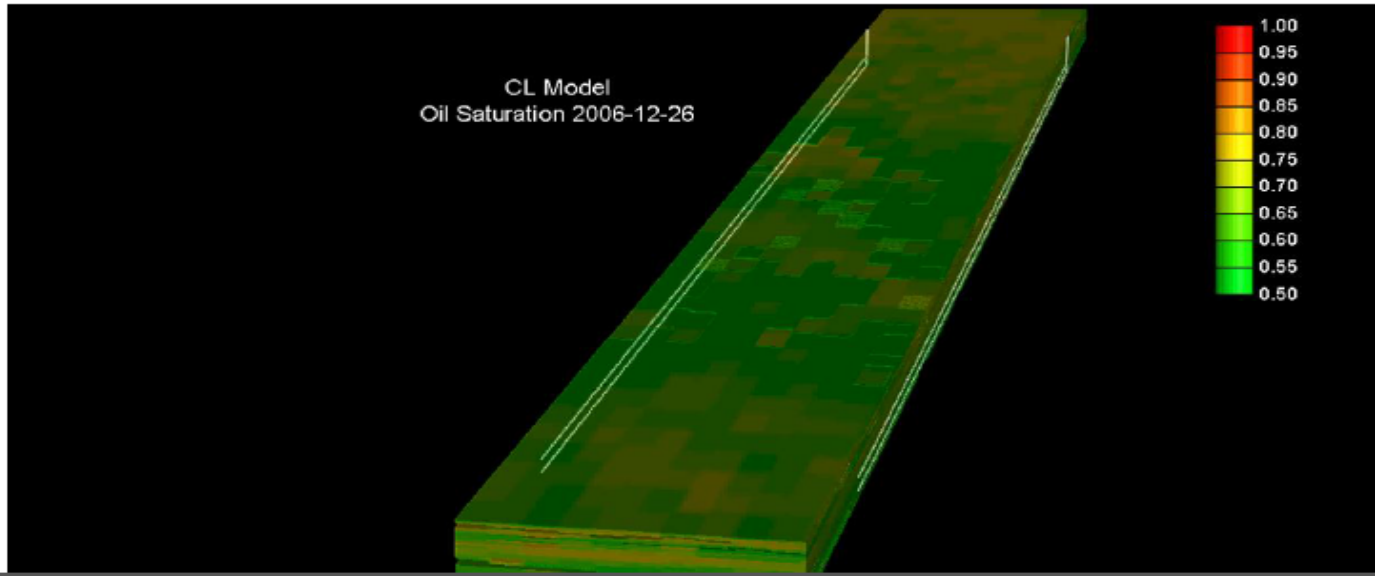
Commercial In-Situ Recovery Process

Steam-Assisted Gravity Drainage





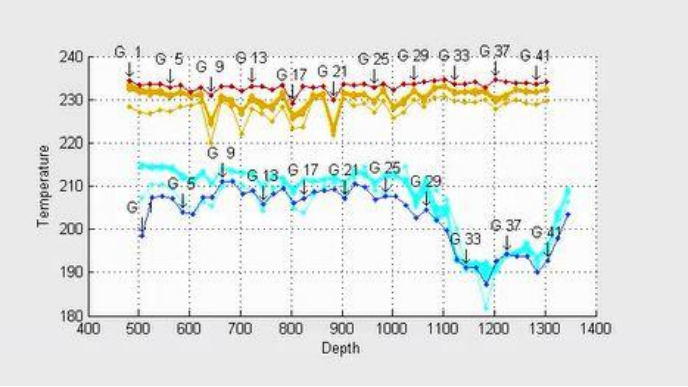
Chambers are Heterogeneous



Carbon Management Canada
CMC-NCE

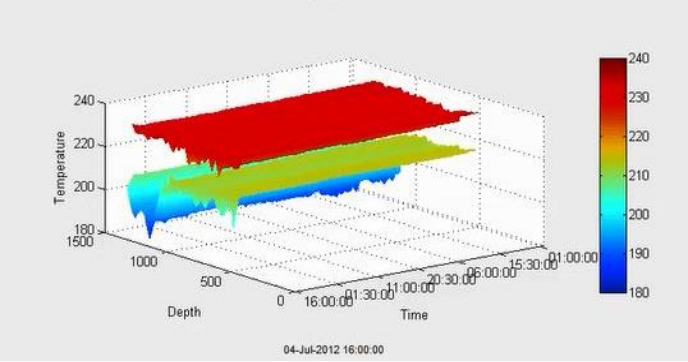
Monitored Data & Results

July 2012 using the WellVista™ real time software



- WellVista™ software enables processing of operational steam injection rates, surface pressures, pump variables and controls & subsurface pressures and temperature profiles

- Data from July 2012 shows local subcool at the 650 meter section as low as 15^{0}C and Instances when it drops to 10 ^{0}C



- Adjustments in temperature, pressure and rate of injected steam will have a delayed impact on the production rate due to the pre existing steam chamber

- Lifting rate has a more direct impact on the Δ T's along the horizontal

Video of WellVista™ real-time visualization July 2012

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Thank you & Questions