



Reservoir Fluid Sampling for Flow Assurance Fluid Characterization

October 25, 2017
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Visuals include: Evaluate reservoir performance, Sample reservoir fluids, and Optimize reservoir production.

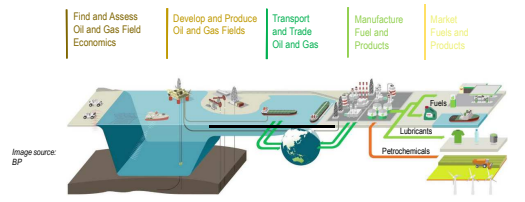
Presentation Outline

- Review the role of fluid behaviour in FDP and AO workflows/models
- Review fluid property measurement needs for typical workflows
- Discuss methods for obtaining samples for fluid characterization
- Discuss subsea sampling equipment requirements
- Present two examples of subsea sampling operations

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Oil and Gas Companies Find, Produce, and Sell Fluids



Find and Assess
Oil and Gas Field
Economics

Develop and Produce
Oil and Gas Fields

Transport and Trade
Oil and Gas

Manufacture
Fuel and
Products

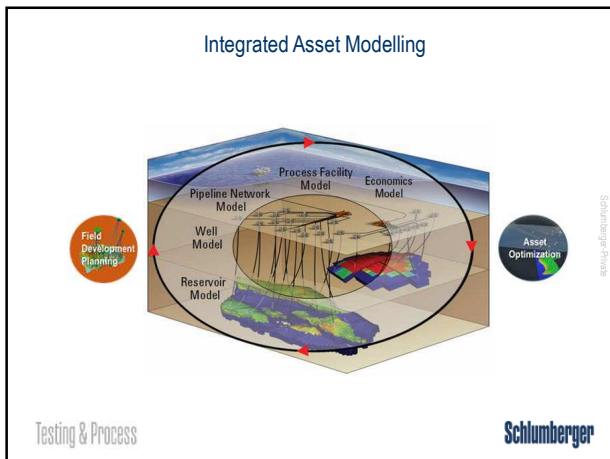
Market
Fuels and
Products

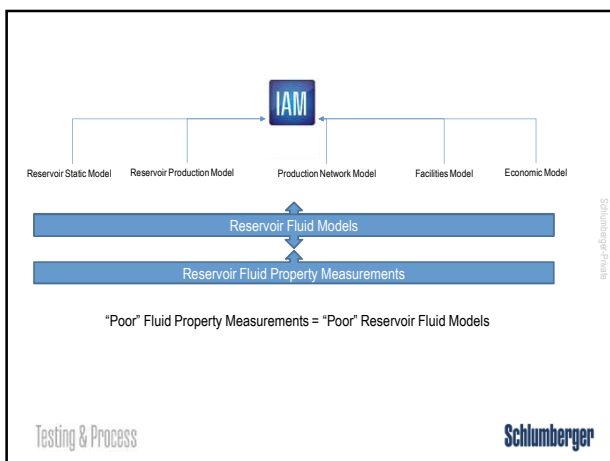
Image source: BP

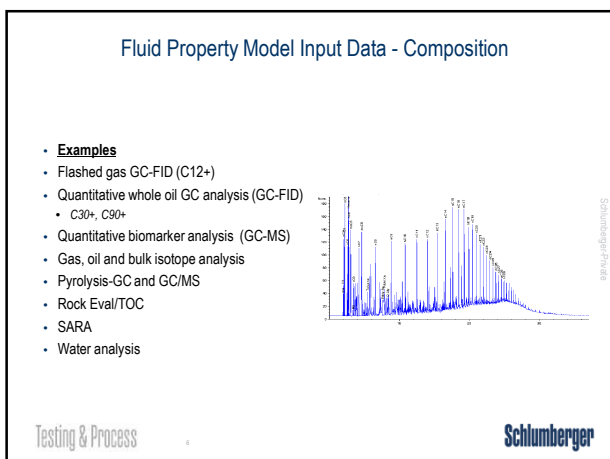
Assuring Flow is Integral to this Process

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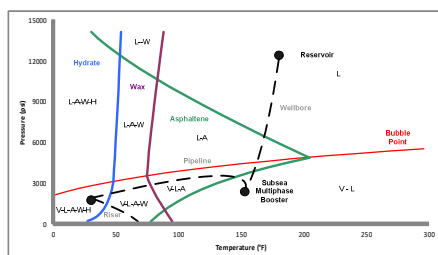
Range of Composition by Fluid Type

	Dry Gas	Wet Gas	Gas Condensate	Volatile Oil	Black Oil
N ₂	0.3	0.2	3.68	1.21	0.36
CO ₂	1.1	2.1	1.28	2.10	0.29
C ₁	90.0	85.0	85.2	60.50	23.97
C ₂	4.9	4.7	5.36	7.75	6.42
C ₃	1.7	3.2	1.75	4.75	7.64
i-C ₄	0.6	1.2	0.36	2.27	1.79
n-C ₄	0.5	1.0	0.46	2.01	5.29
i-C ₅	0.3	0.9	0.19	1.96	2.98
n-C ₅	0.2	0.8	0.16	0.88	3.27
C ₆	0.2	0.3	0.22	1.90	4.85
C ₇	+0.2	+0.6	0.39	2.51	7.09
C ₈			0.44	2.45	7.67
C ₉			0.20	1.68	5.19
C ₁₀			0.12	1.45	4.47
C ₁₁			0.06	1.05	2.96
C ₁₂			0.15	5.53	15.76
+					

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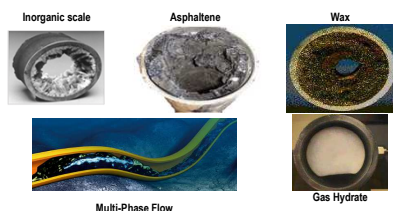
Fluid Property Model Tuning and Validation – Phase Behavior



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Fluid Property Model Tuning and Validation – Deposition Tendency



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Factors Influences Fluid Property Data

- Sampling
- Competency of engineers
- On-site transfer
- On-site measurements/methods
- Laboratory practices
- Calibration of instruments
- Quality of analytical equipment

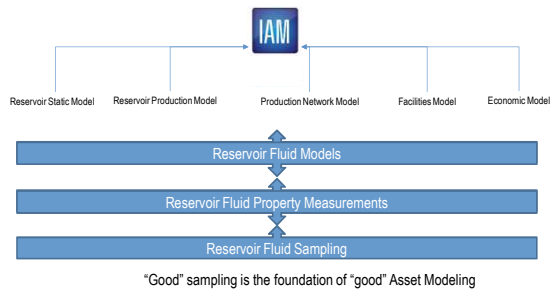
SEVERITY



'Bad' sample = 'bad' results (irrespective of lab quality, people)

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Sampling Reservoir Fluids for Field Development Planning

Exploration/Appraisal/Development Wells

- Bottom Hole Sampling
 - Open Hole - While Drilling and/or during Formation Testing
 - Cased Hole - Well Testing
- Surface Sampling
 - Test Separator

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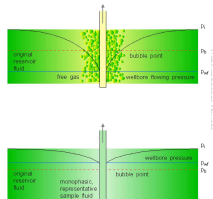
What type of samples do we need?

Reservoir sample that is representative of the zone of interest

- Oil reservoir samples w/ all the light ends in solution
- Gas reservoir samples w/ heavy ends in solution
- Formation water samples w/ gases/salts in solution

Samples are:

- Single Phase (preferably kept $> p_i$ to the laboratory)
- Organic & inorganic solids should also remain in solution



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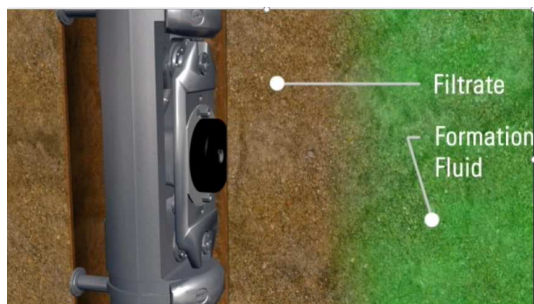
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Open Hole Formation Testing Sampling

Video

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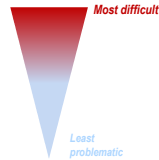


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Open Hole Sampling Challenge — Fluid Sample Contamination by Drilling Fluids

- **Reservoir fluids** – oil, condensate, gas, water
- **Contaminants** – water-base (WBM), oil-base (OBM), and synthetic-base (SBM)
- **Possible scenarios**
 - Condensate and OBM/SBM
 - Water and WBM
 - Oil and OBM/SBM
 - Gas and OBM/SBM
 - Heavy oil and unconsolidated formations
 - Hydrocarbon and WBM, or water and OBM/SBM

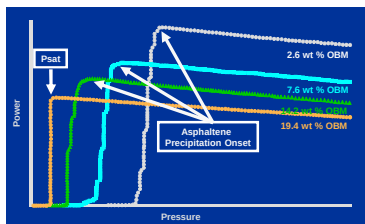


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Effect of OBM Contamination @ Tres with Syn-Tec

DBR/Chevron/BHP - IBC Aberdeen - Oct. '99

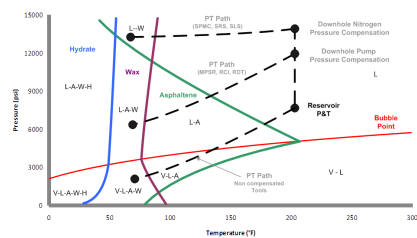


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Sample Recovery Pressure

– Pressure Compensation vs. Conventional Bottomhole Sampling



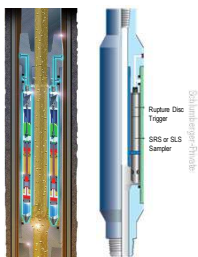
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Cased Hole Sampling During Well Testing Operations



- Run as part of DST toolstring
- Typically fired by applying annulus pressure (New Muzic Trigger)
- 2.25 inch full bore
- 5 to 7.75 inch OD
- 6 SRS (3.6 L) or 8-10 SLS (2.4-3.0 L) chambers in a carrier
- Little to no oil based mud contamination



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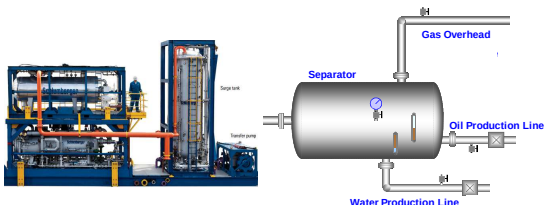
Sample Carrier (SCAR-A) Assembly



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Test Separator Sampling



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Sampling Reservoir Fluids for Asset Optimization

Production Well Sampling

- Bottom Hole
- Wellhead
- Surface Separator or MPFM
- Subsea

- Typically fluids below Psat – Multiphase (gas, oil, water)

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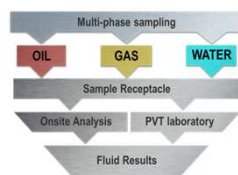
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Multi-Phase Representative Sampling

- Cannot directly sample correct volumetric proportions
- Must sample each phase individually
 - Strategically chosen, phase-rich sampling points
 - Isothermal and isobaric required in many cases
 - Ex. separator calibration
- Need an independent measurement of phase fractions
 - If reservoir fluid re-creation is required
 - Not always necessary



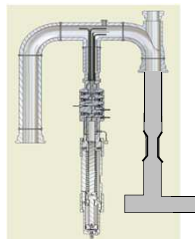
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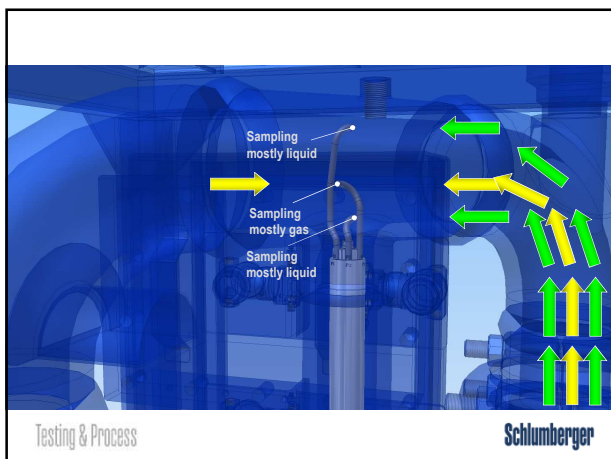
Sampling at Line Conditions

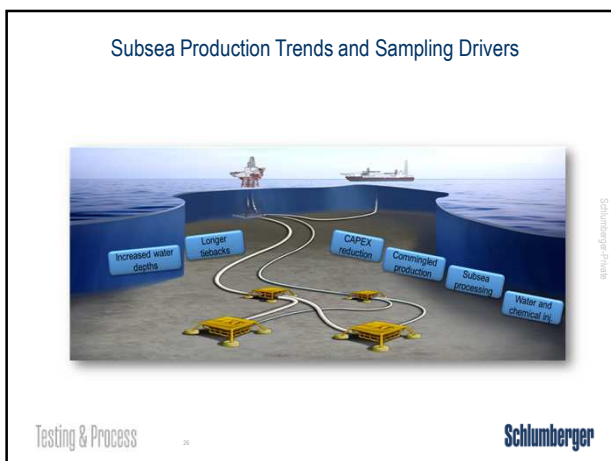


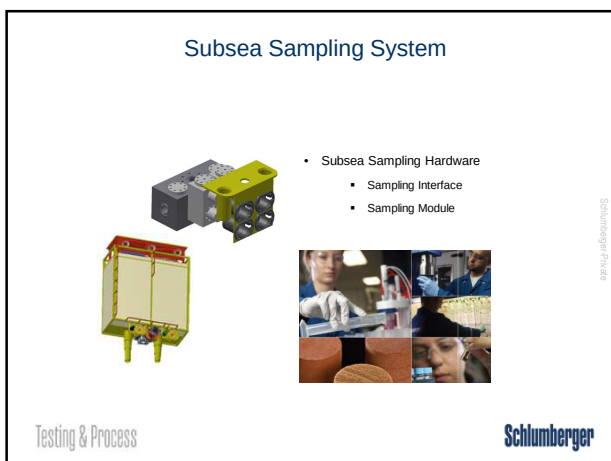
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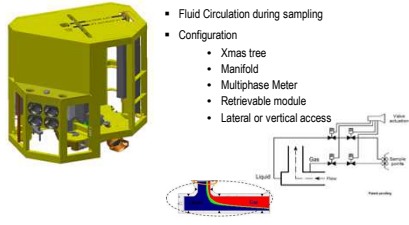
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Subsea Sampling Interface

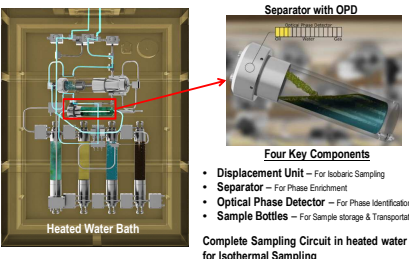


- Based on Blind T
- Two Sampling line for phase rich sample
- Fluid Circulation during sampling
- Configuration
 - Xmas tree
 - Manifold
 - Multiphase Meter
 - Retrievable module
 - Lateral or vertical access

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Subsea Sampling Module



Separator with OPD

Four Key Components

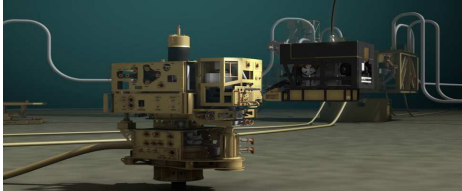
- Displacement Unit – For Isobaric Sampling
- Separator – For Phase Enrichment
- Optical Phase Detector – For Phase Identification
- Sample Bottles – For Sample storage & Transportation

Complete Sampling Circuit in heated water bath for Isothermal Sampling

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Subsea Sampling Concept



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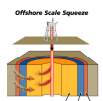
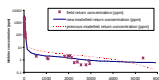
Project A – Subsea Sampling for Scale Squeeze Optimization

Offshore Scale Squeeze

- **Procedure**
 - Injection of inhibitors and retention
 - Inhibitor flowback for protection
- **Sampling and Analysis**
 - Inhibitor residual -> Re-squeeze when < MIC

Design Requirement

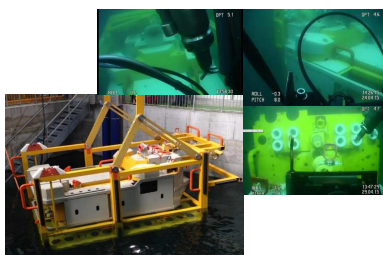
- Water Depth: 1100 m
- P/T: 10,000 psi and 121 degC
- Access: horizontal
- Samples: 4 x 600 cc



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System Testing



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Subsea Operation



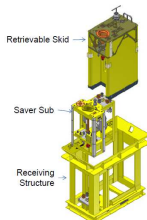
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Project B

– Subsea Sampling for Multi-zone Production Allocation Based on In-flow Tracers

Design Pressure – 15,000 psi
of Samples – 4
Volume/Sample – 900 cc
Design Water Depth – 3000 meters



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System Testing

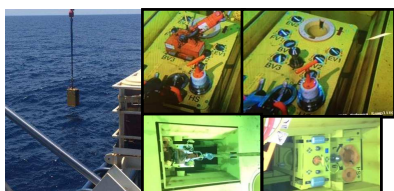


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Subsea Operations



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Conclusions

- Rigorous fluid characterization is necessary to insure robust Integrated Asset Modelling for FDP and AO
- In most cases fluid sampling is required to complete fluid characterization
 - Representative samples are essential for good fluid property characterization
 - Many methods for sample collection at various points in the life of well/field
- Increased subsea infrastructure complexity necessitates sampling closer to individual well source for subsea produced fluid characterization
 - Require pre-installed sampling interfaces for greenfield applications
 - Retro-fit options for some brownfield applications
- Successful subsea sampling operations completed in two example cases

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