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# **SUBSEA MULTIPHASE FLOW METER**

## **OPTICAL INWELL FLOWMETER & WATER CUT**

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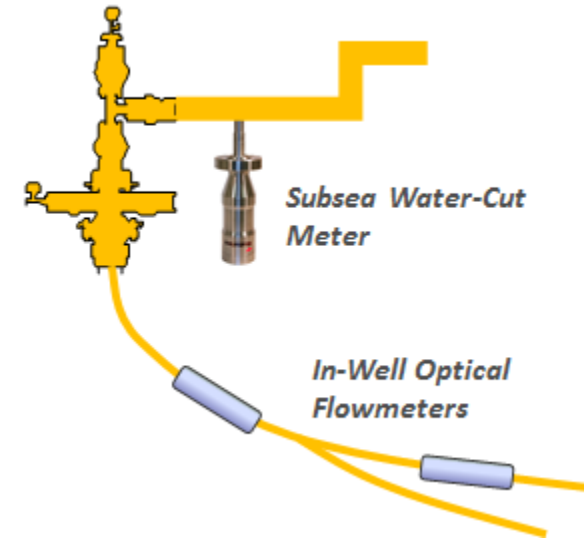
3rd October 2017

# OUTLINE

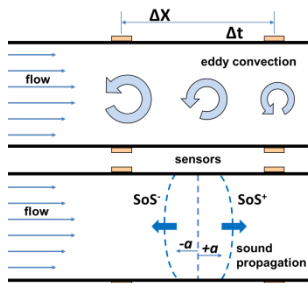
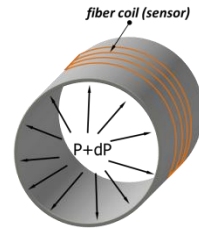
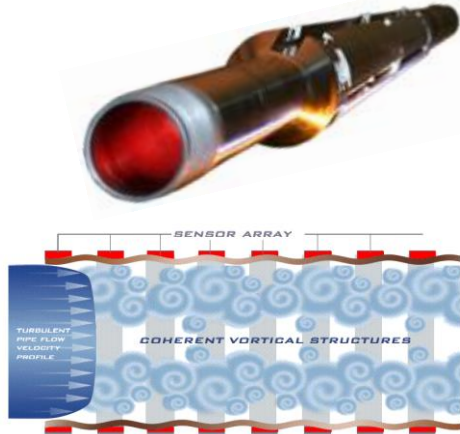
- Historical Background / Motivation
- Measurement Principles
- Flow Loop Tests
- Summary of Results
- Conclusions and Benefits

# Historical Background / Motivation

- 1998 – First NIR water-cut meter introduced
- 2000 – First optical flowmeter (OFM) in deep-water, GoM
- 2000-2016 – World-wide installations of OFMs and water-cut meters
- 2010 – Subsea water-cut meter development started
- 2012 – Upon success of OFM and WC meter, hybrid approach introduced
- 2014 – Hybrid system was tested in multiphase loop
- 2015 – Analysis completed, performance verified

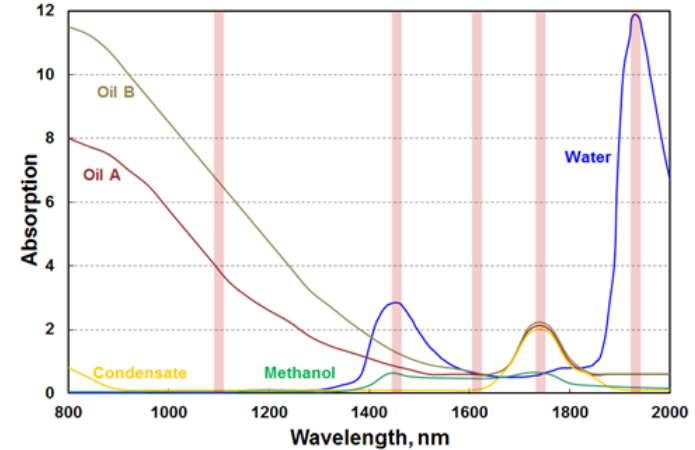


# Subsea MPFM – Operating Principles (Component Level)



## Optical FM

- Velocity
- Sound Speed

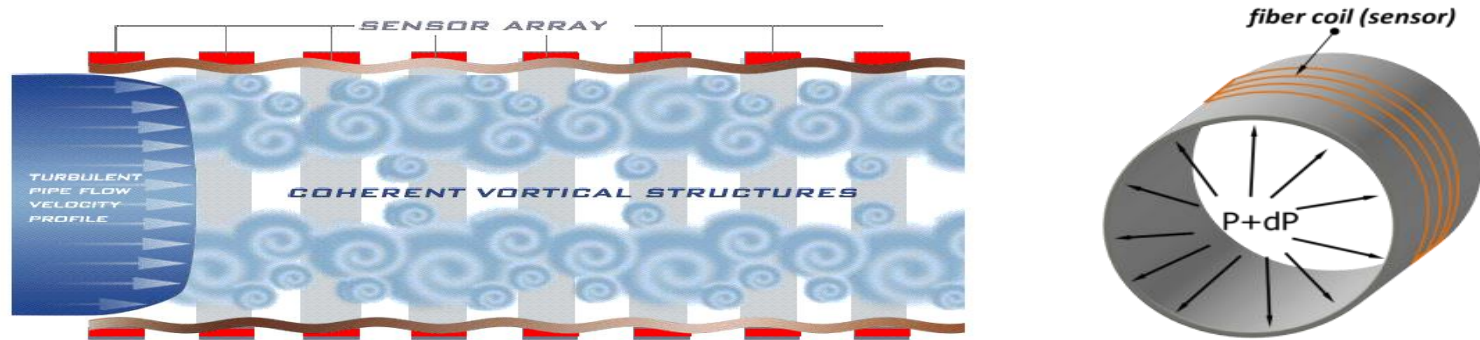


## NIR Water-Cut meter

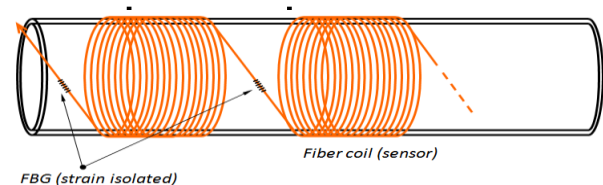
- WLR



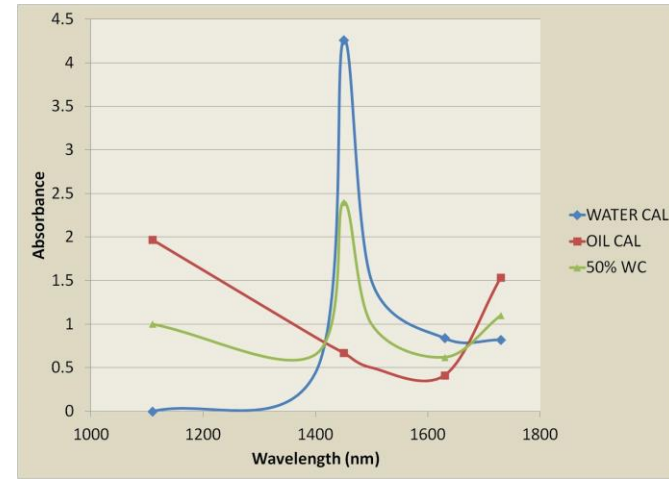
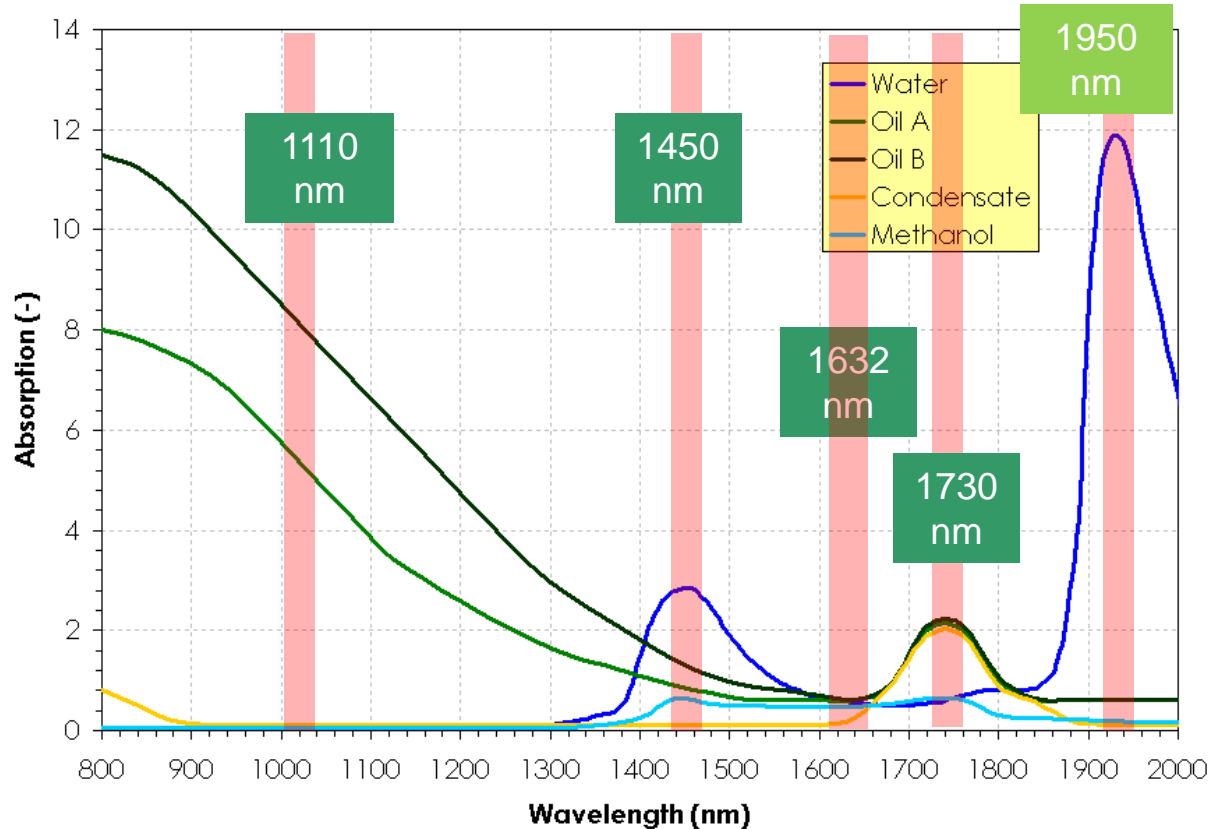
# Downhole Optical Flowmeter – Technology



- Turbulent pipe flow contains eddies (vortical structures)
- Eddies exert dynamic pressure onto pipe causing strain
- Sensors outside the pipe track eddie



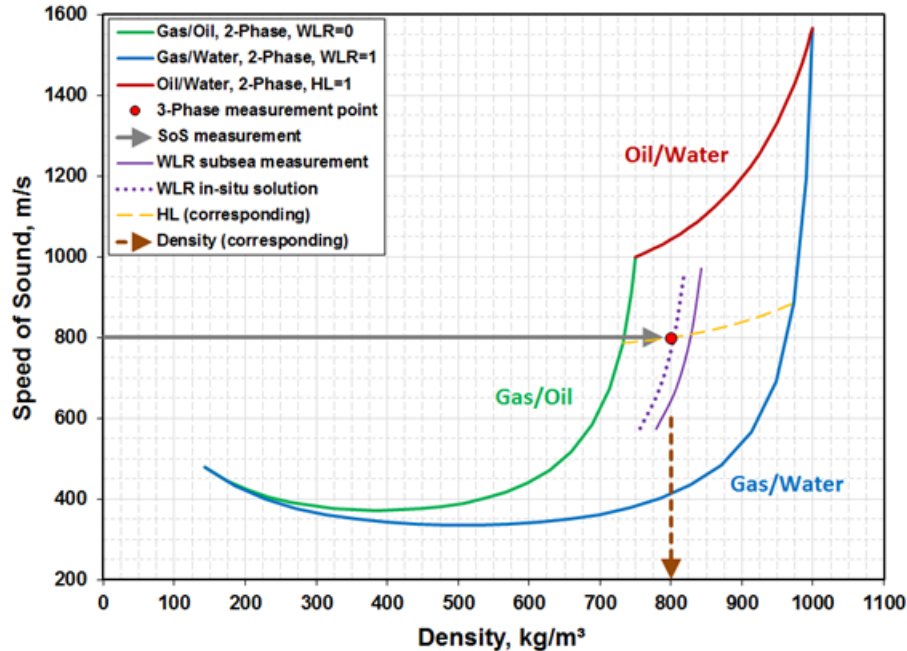
# NIR Water-Cut How Does it Work?



5<sup>th</sup> optical filter (channel) allows:

- ✓ 3 phase (>20% GVF), or,
- ✓ very low water content application

# Subsea MPFM – Operating Principles (System Level)



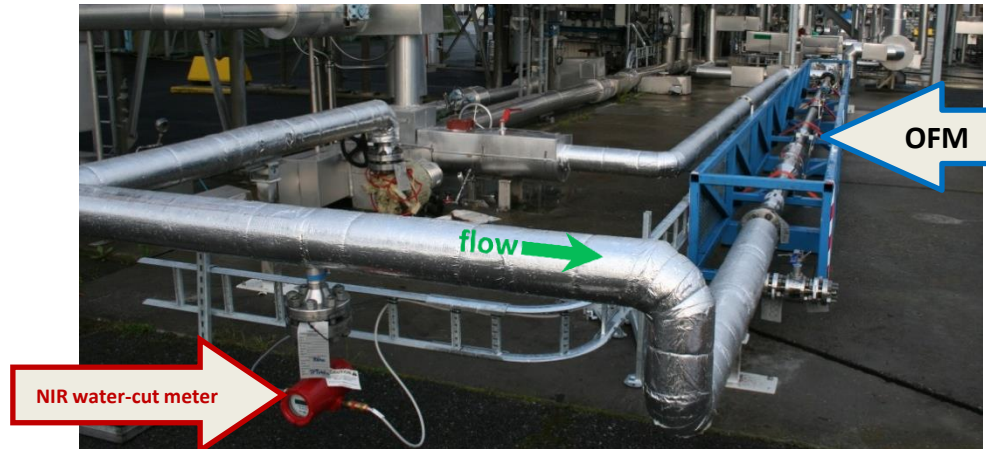
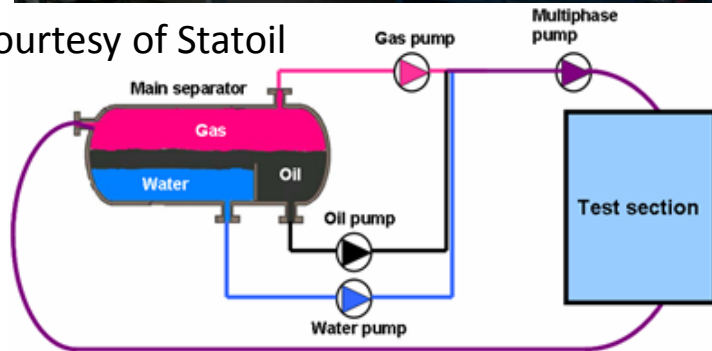
- Optical flowmeter
  - Velocity
  - Speed of Sound (SoS)
- NIR water-cut meter
  - Water cut (WLR)
- SoS/WLR → Holdup (HL)
  - WLR, HL → phase fractions
- Velocity → total flow rate,  $Q$
- Phase flow rates →  $Q_o, Q_g, Q_w$

# Flow Loop Tests – Facility

Porsgrunn multiphase flow loop  
(September 8 – 18, 2014)

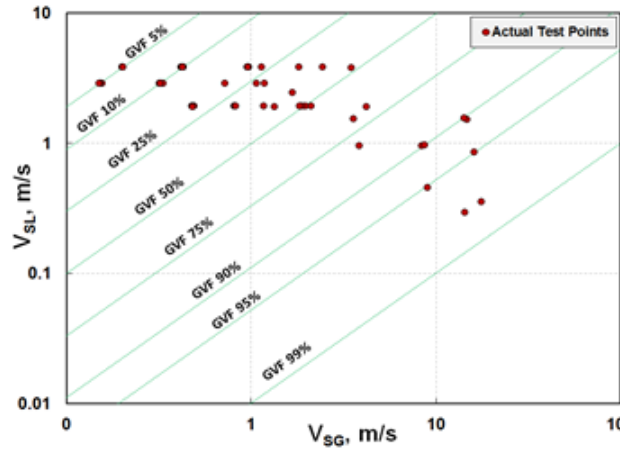
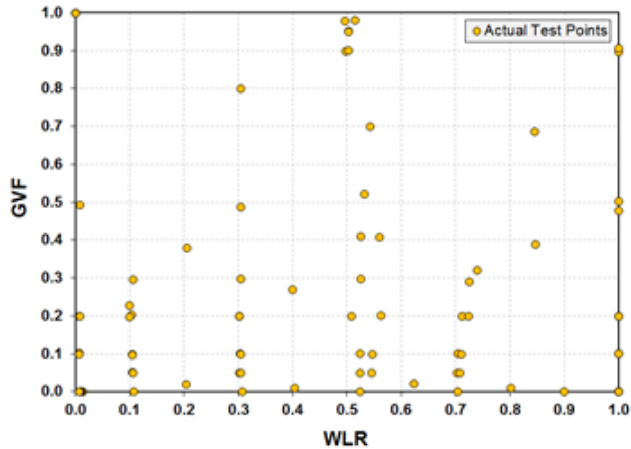


Courtesy of Statoil

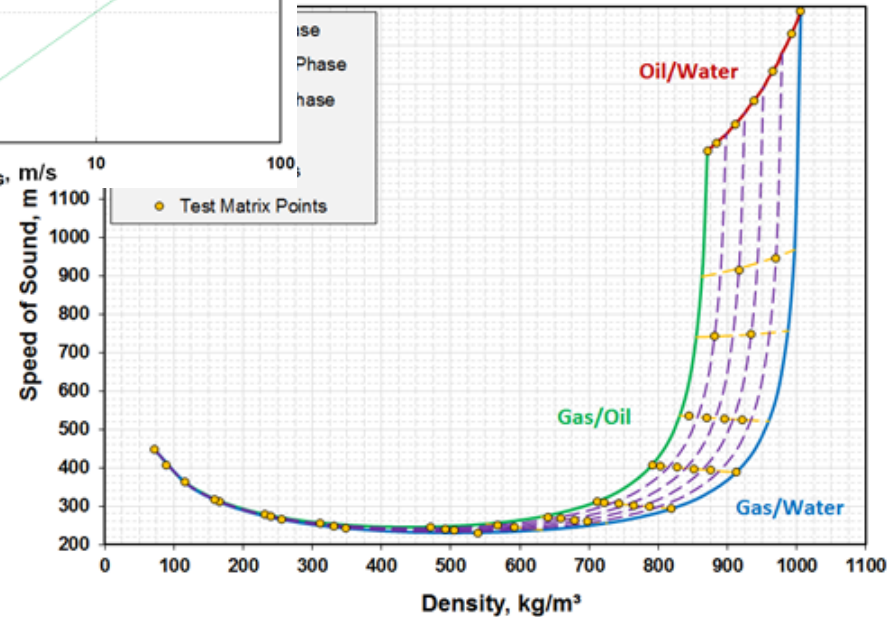




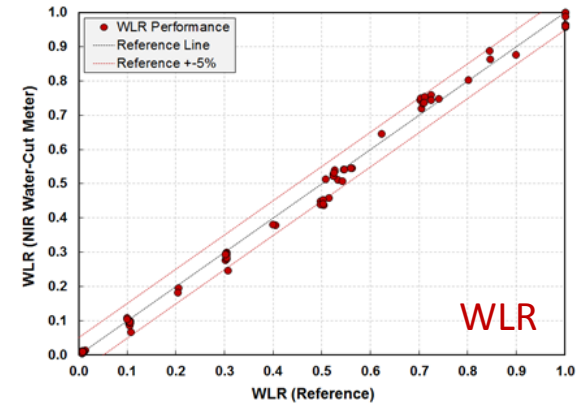
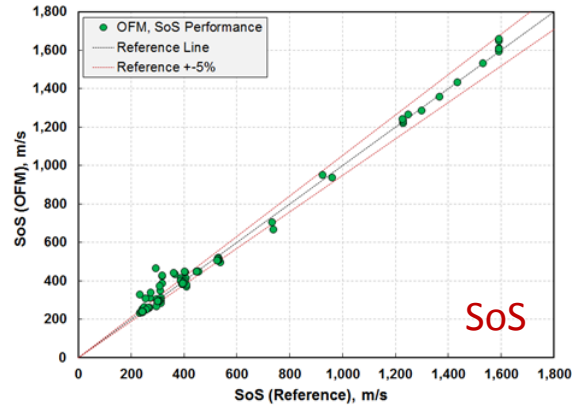
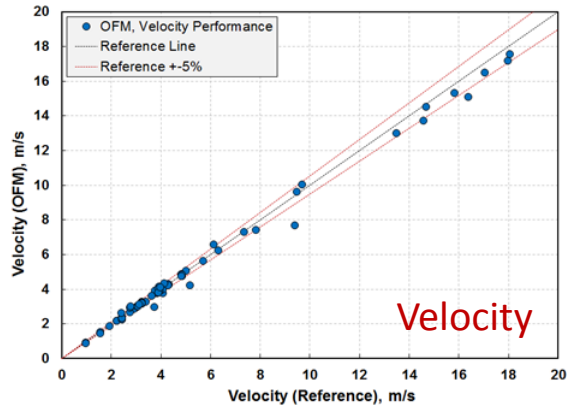
# Flow Loop Tests – Test Matrix



- Test duration: 10 days, 84 test points
- Test conditions:  $P=100$  bar,  $T=55$  °C
- Oil phase: 61% heavy oil + 39% diesel
- Average acquisition time: 12 minutes
- 1-P (single-phase), 2-P, and 3-P (multiphase)



# Summary of Results – Component Level



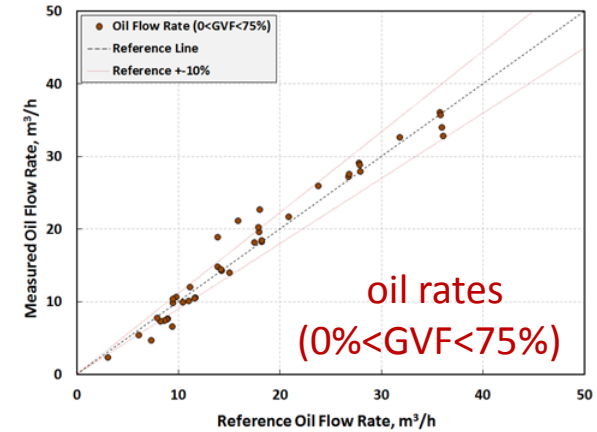
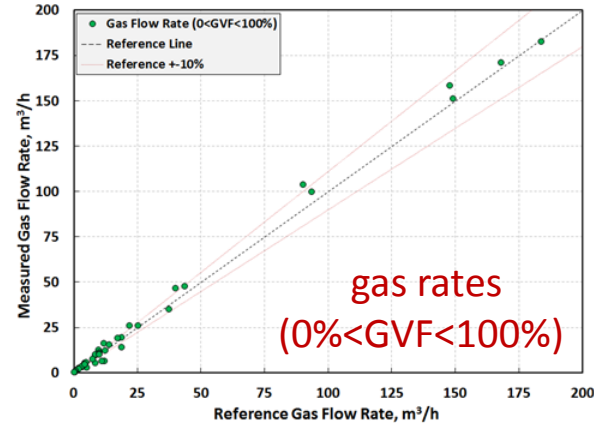
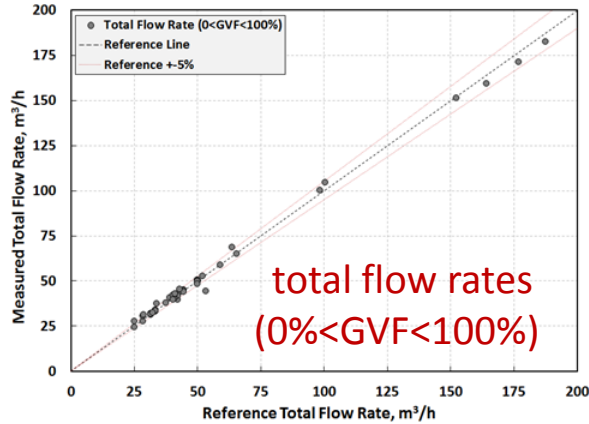
Optical Flowmeter (downhole)



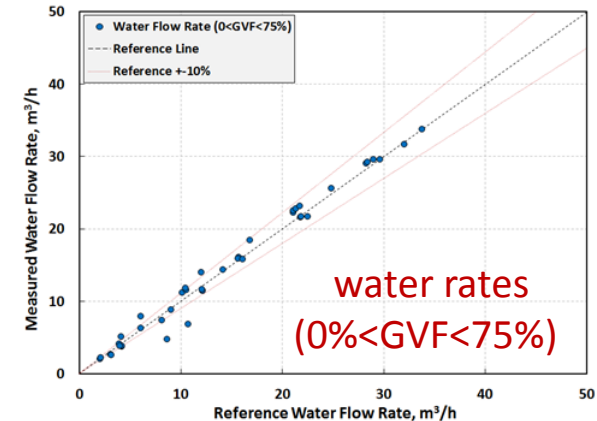
NIR Water-Cut Meter (subsea)



# Summary of Results – System Level



- Total flow rates are within  $\pm 5\%$  (0<GVF<100%)
- Gas flow rates are within  $\pm 10\%$  (0<GVF<100%)
- Oil and water flow rates are within  $\pm 10\%$  (0<GVF<75%)
- Test conditions can be improved
  - Oil phase issues (2-phase, density variation due to foaming)
  - More acquisition time between extreme points (human err)



# Optical FM Performance & Capabilities

	Optical FM Performance		Optical FM Options
Accuracy	Single phase liquid: +/- 1% Single phase gas: +/- 1% Multiphase: +/- 5%	Single-Phase	Zonal Isolation in water, gas, or WAG injectors. An integrated P/T gauge is recommended but not compulsory. P/T gauge is compulsory for gas injectors.
Repeatability	Low Standard Deviation Excellent	Two-Phase	L/L or G/L with integrated optical P/T gauge
Turndown ratio	Approximately 30:1	Three-Phase	G/L/L; Two Phase flowmeter with a secondary P/T gauge above the flowmeter to resolve the three phases measurements

**Optical FM Track Record :**  
**Platform & Subsea Wells = 100**

# Water Cut Meter Performance & Capabilities

GVF Level	Water-Cut Range and Accuracy	Additional Measurements
GVF < 20 % ( Liquid / Liquid Service)	0 – 100 % ±1 % <sup>a</sup>	<ul style="list-style-type: none"> <li>• Water Detection</li> </ul>
20 % < GVF < 98 % (Multiphase Flow Service)	0 – 100 % ±2 % <sup>a</sup>	<ul style="list-style-type: none"> <li>• Hydrate Inhibitor – Water-Oil Concentration<sup>b</sup></li> <li>• Slug Detection</li> <li>• Water Detection</li> </ul>
GVF > 98 % (Wet Gas Service)	0 – 100 % ±10 % <sup>a</sup>	<ul style="list-style-type: none"> <li>• MEG– Water-Oil Concentration<sup>bc</sup></li> <li>• Slug Detection</li> <li>• Water Fraction Tracking</li> <li>• Water Detection<sup>d</sup></li> </ul>

## NIR-Water Cut Track Record :

**Subsea** = 20 + 10 on Order  
**Topside/Land** = +3,000

<sup>a</sup> Error given in absolute terms

<sup>b</sup> Methanol or any common hydrate inhibitor

<sup>c</sup> Methanol-water concentration measurement uncertainty ±10%

<sup>d</sup> Water detection limit is 0.25 bbl/MMscfd.

# Subsea Multiphase Flowmeter – Benefits



- Wide range of applications (subsea, onshore, offshore)
- Nonnuclear, optical solution
- Zonal allocation in multizone wells
- High turndown ratio
- Bidirectional measurement
- Orientation free (any installation angle in the well)
- Better mixing of phases for robust flow measurement
- Less intrusive and solid-tolerant measurement
- Modularity
- Form factor and weight
- Production optimization
- Economics



Aberdeen Section

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# Thank You / Questions

## **SPE-182378-MS Subsea Multiphase Flowmeter: Performance Tests in Multiphase Flow Loop**

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### Acknowledgments

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