Integrating & Operating A New Salinity Measurement System As Part of A Wet Gas Meter

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Product Manager, Emerson

Subsea Flow Metering

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Outline

- Operator Challenges - Flow Assurance and Integrity Strategies
- Roxar Subsea Wetgas Meter
  - Experience
  - System overview
- Salinity System
  - Salinity detection
  - Salinity probe
- Test Results
- Summary

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Changing Operating Conditions Influence Flow Assurance and Integrity Strategies

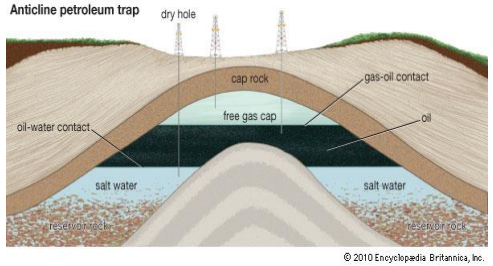
Immediate risk

- **Formation water breakthrough:**
  - Increases risk of hydrate formation and therefore the need for increased MEG injection
  - Jeopardizes hydrocarbon production due to water coning in the reservoir
  - Increased water flow and injected chemicals in lieu of hydrocarbon production

Long term risk

- **Formation water production threatens pipeline integrity:**
  - Pipeline scaling
  - Pipeline corrosion & erosion

FORMATION WATER BREAKTHROUGH



HYDRATES

SCALE AND EROSION

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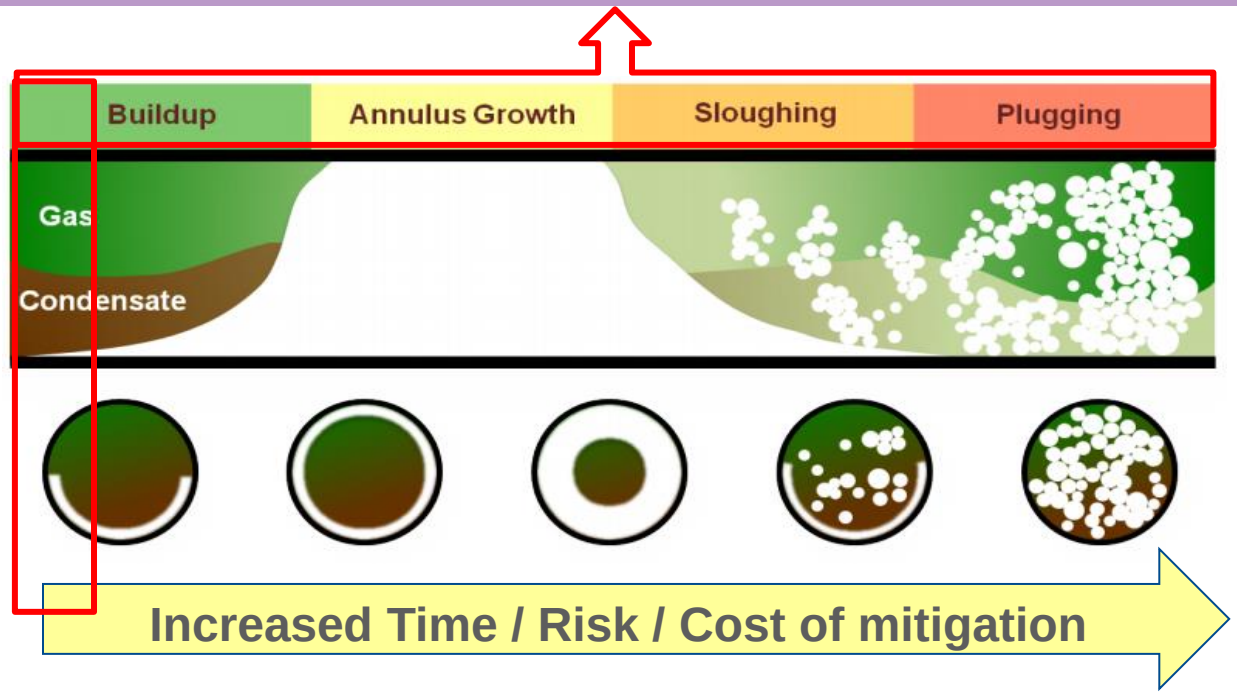
Hydrate Formation – Critical Time Window of a Plug Forming

1. Formation water breakthrough - water droplets emerge
2. Hydrate nucleation, growth at the water-hydrocarbon interface
3. Hydrate particles form large aggregates
4. Jamming of large aggregates to suspend flow

Field examples exist where this period is < 20 minutes

CRITICAL TIME WINDOW



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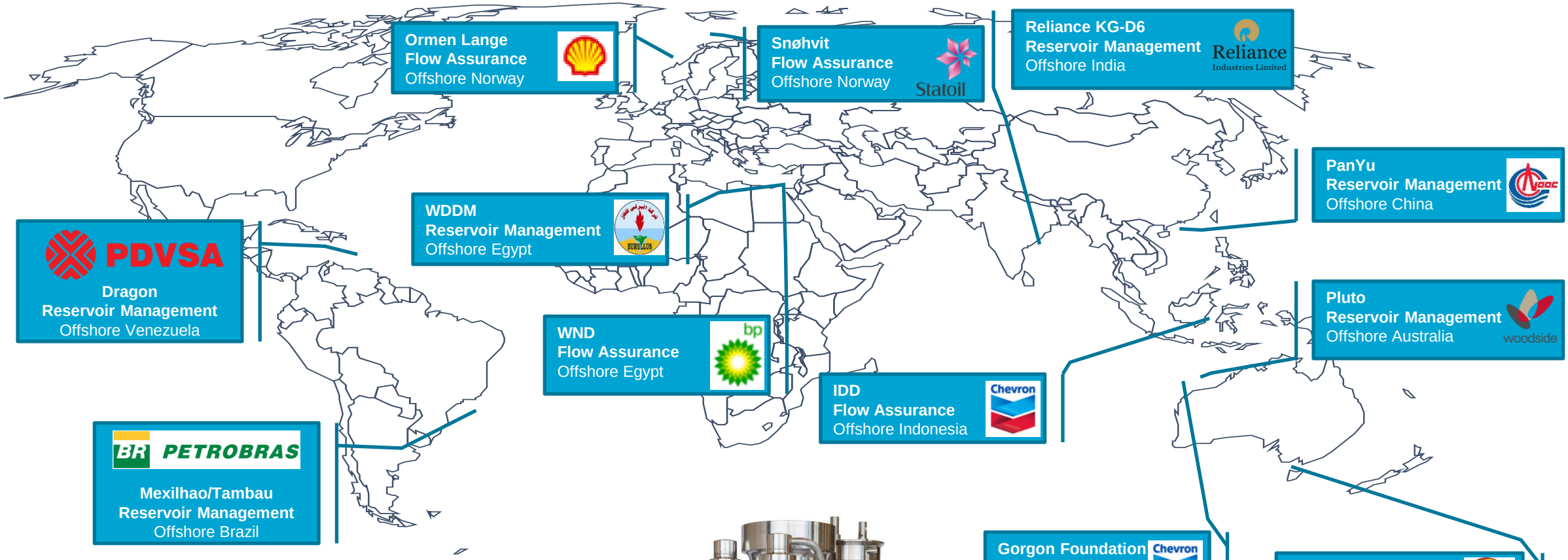
Source: Luis E. Zerpa A PRACTICAL MODEL TO PREDICT GAS HYDRATE FORMATION, DISSOCIATION AND TRANSPORTABILITY IN OIL AND GAS FLOWLINES 2013

A Specialised Wetgas Meter for Gas and Gas Condensate Fields



Ormen Lange
Flow Assurance
Offshore Norway

Snøhvit
Flow Assurance
Offshore Norway
Statoil

Reliance KG-D6
Reservoir Management
Offshore India
Reliance Industries Limited

PanYu
Reservoir Management
Offshore China

WDDM
Reservoir Management
Offshore Egypt

PDVSA
Dragon
Reservoir Management
Offshore Venezuela

WND
Flow Assurance
Offshore Egypt
bp

Pluto
Reservoir Management
Offshore Australia
woodside

IDD
Flow Assurance
Offshore Indonesia
Chevron

PETROBRAS
Mexilhao/Tambau
Reservoir Management
Offshore Brazil

Gorgon Foundation
Flow Assurance
Offshore Australia
Chevron

Otway
Reservoir Managment
Offshore Australia
origin energy

- Worldwide installed base:
  - ~ 250 x Subsea WGM
  - ~ 100 x Topside WGM
- First installed subsea 2004

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Roxar Subsea WetGas Meter – All in One Compact Solution

Duplex
Super Duplex
Inconel

900 mm
~850 kg

Low power consumption
26W

Optional
Gamma system
Salinity system

10k PSI
150 C

Modbus RTU,
SIIS Level 2, SIIS Level 3
IWIS

Redundant
Flow computer
& electronics

Redundant dP, P and T

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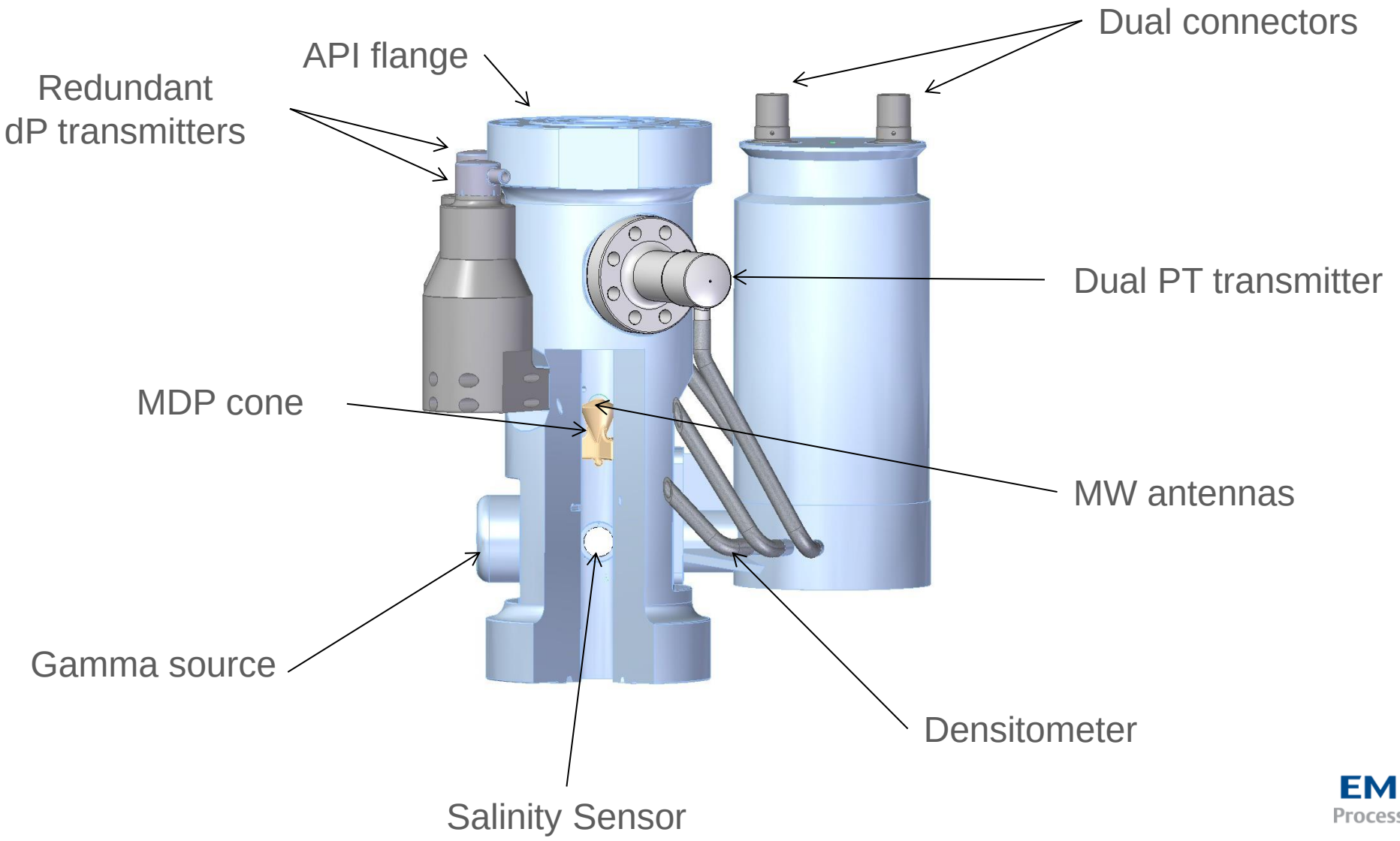
Compact & Flexible Design – Fully Integrated Solution



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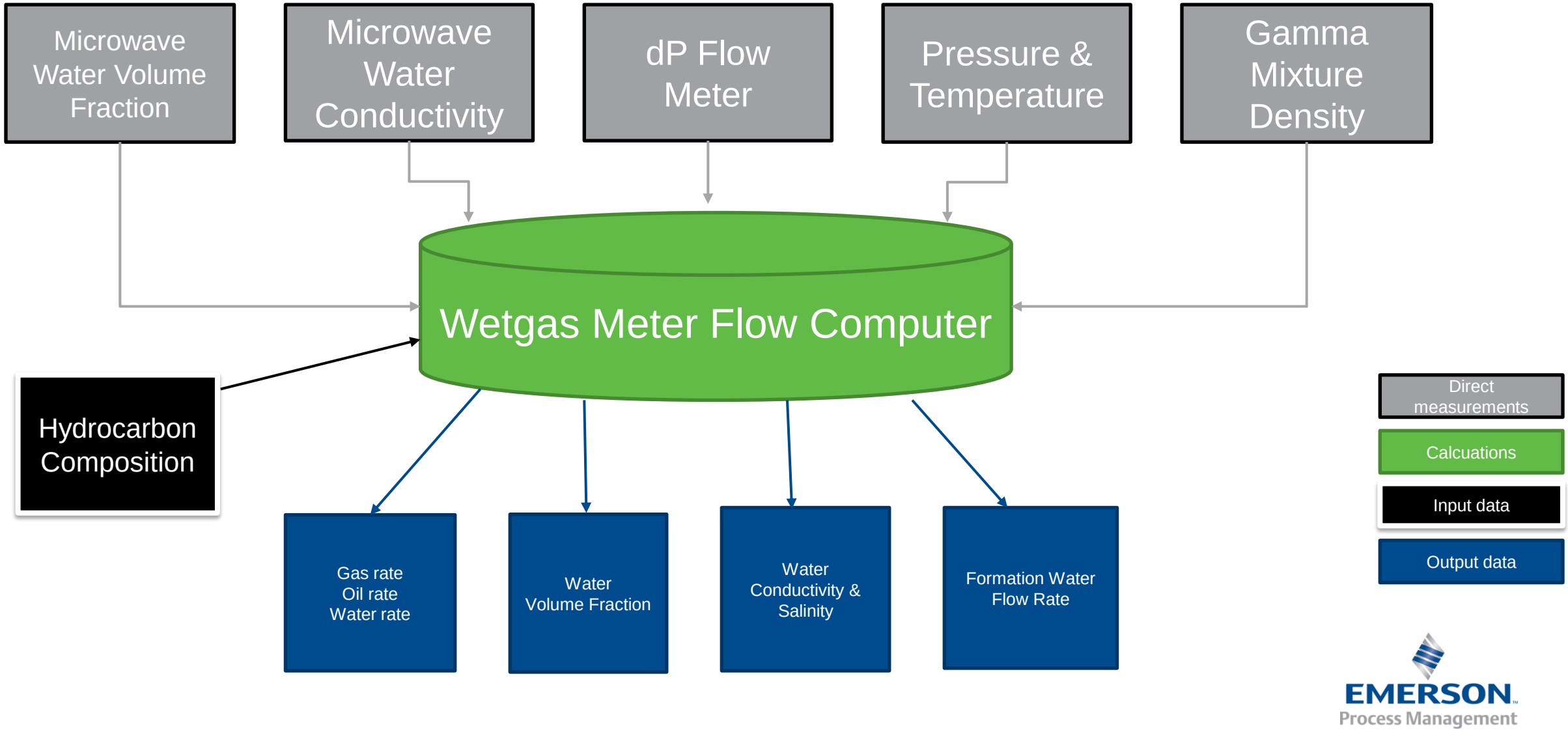
Roxar Subsea Wetgas Meter Measurement Principle



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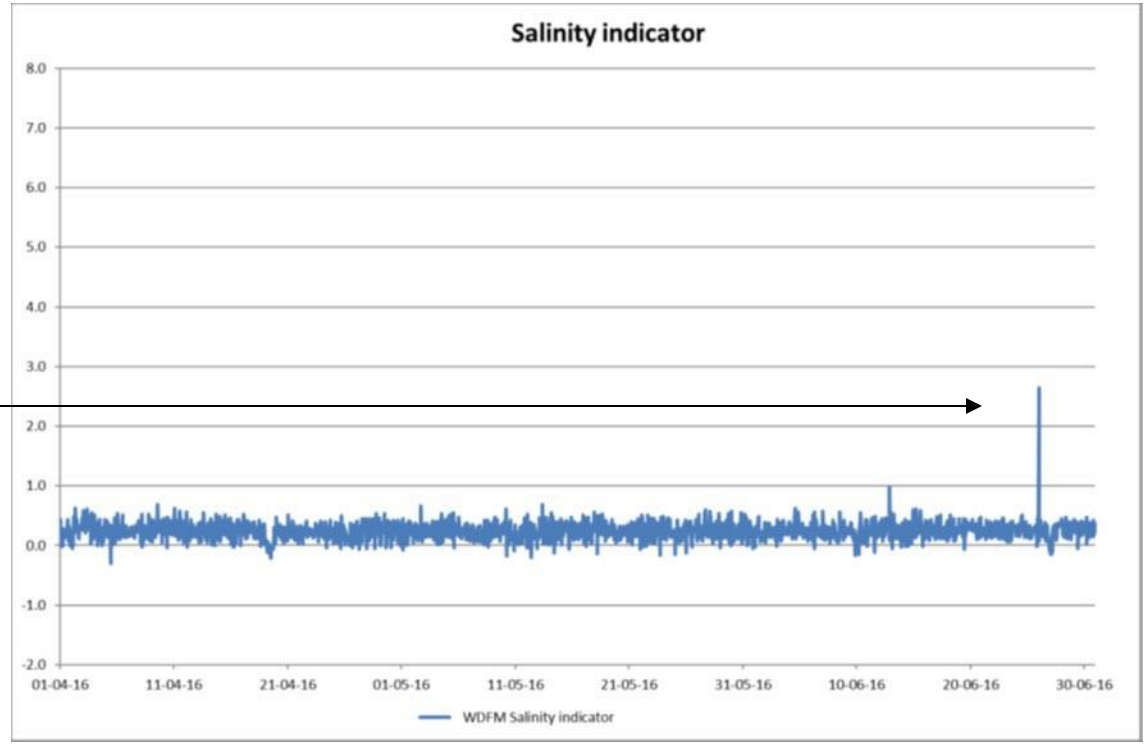
Formation Water Detection - Salinity Detection Since 2004

- SI – Salinity indicator
- In use on >50% of installed base
- Trending horizontal, indicating no change to salinity
- Signal spike indicating change in conductivity
- Gradual increase in trend would indicate a more saline water



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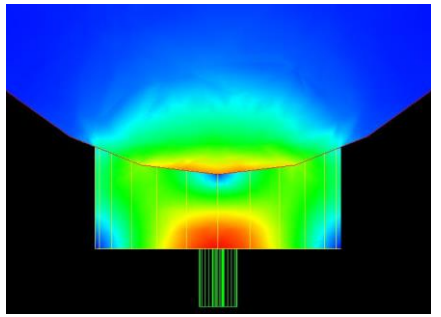
Accurate Water Salinity Measurement – Less Than One Droplet of Water is Detectable

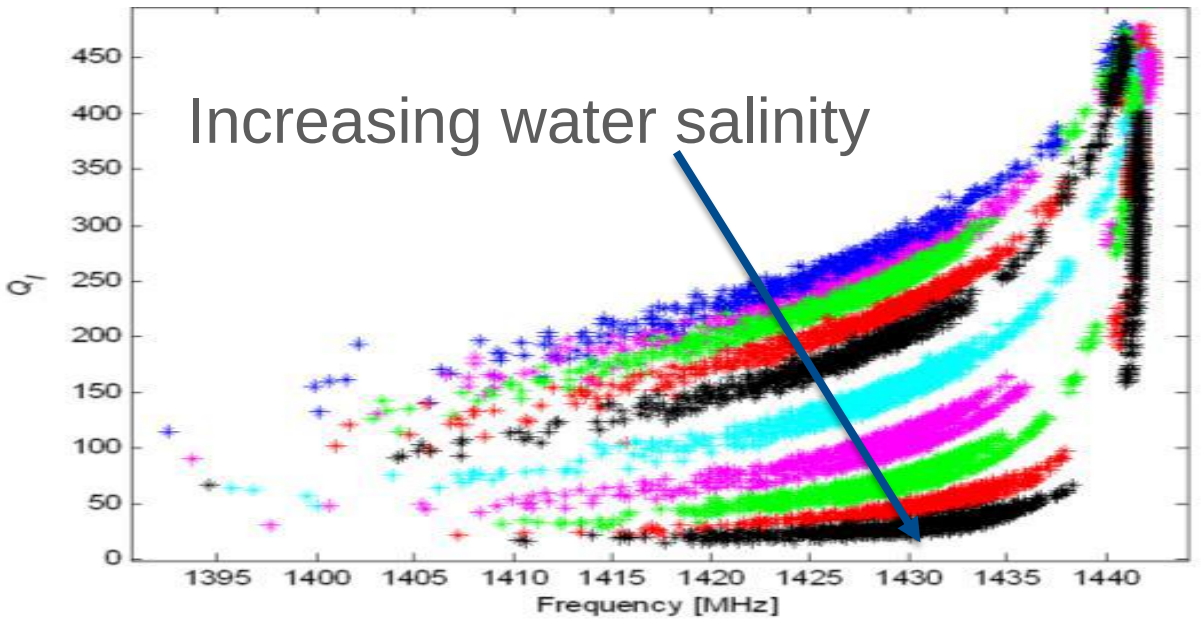
- Dedicated salinity probe for gas applications
- Fully integrated into the meter
- Optimised for high GVF / Wetgas flow



Outputs:

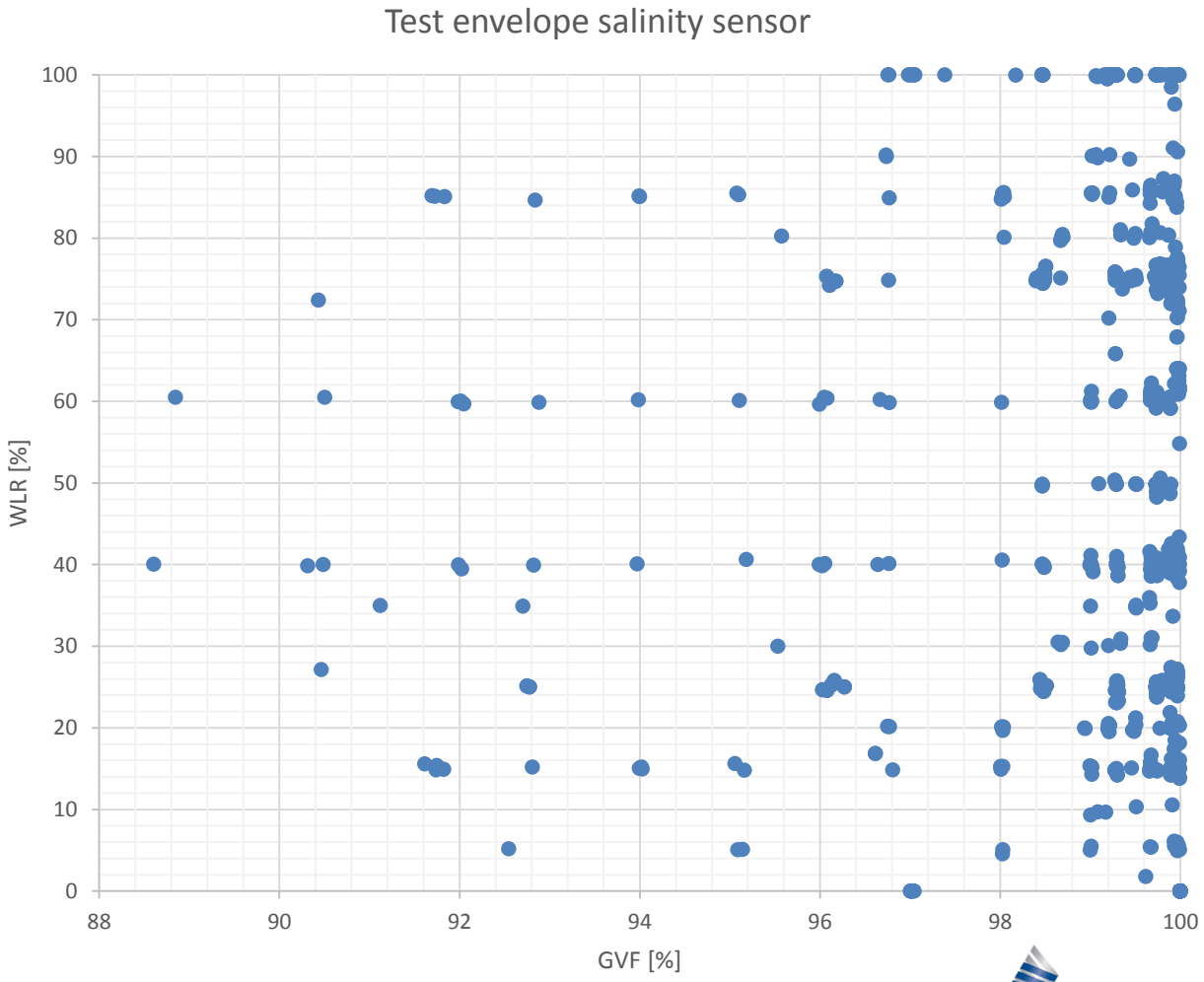
- Salinity
- Conductivity
- Formation Water Indicator
- Formation Water Flow Rate
- Condensed Water Flow Rate

Increasing amount of water



Performance Testing Of Salinity Probe

- Test conducted in full range of SWGM
  - 88% to 100% GVF
  - 0-100% WLR
  - Velocities from 3 to 40 m/s
  - 3 separate flow tests 2014-2016
  - Close to 700 test points at CEESI
  - Wide Range of conductivities



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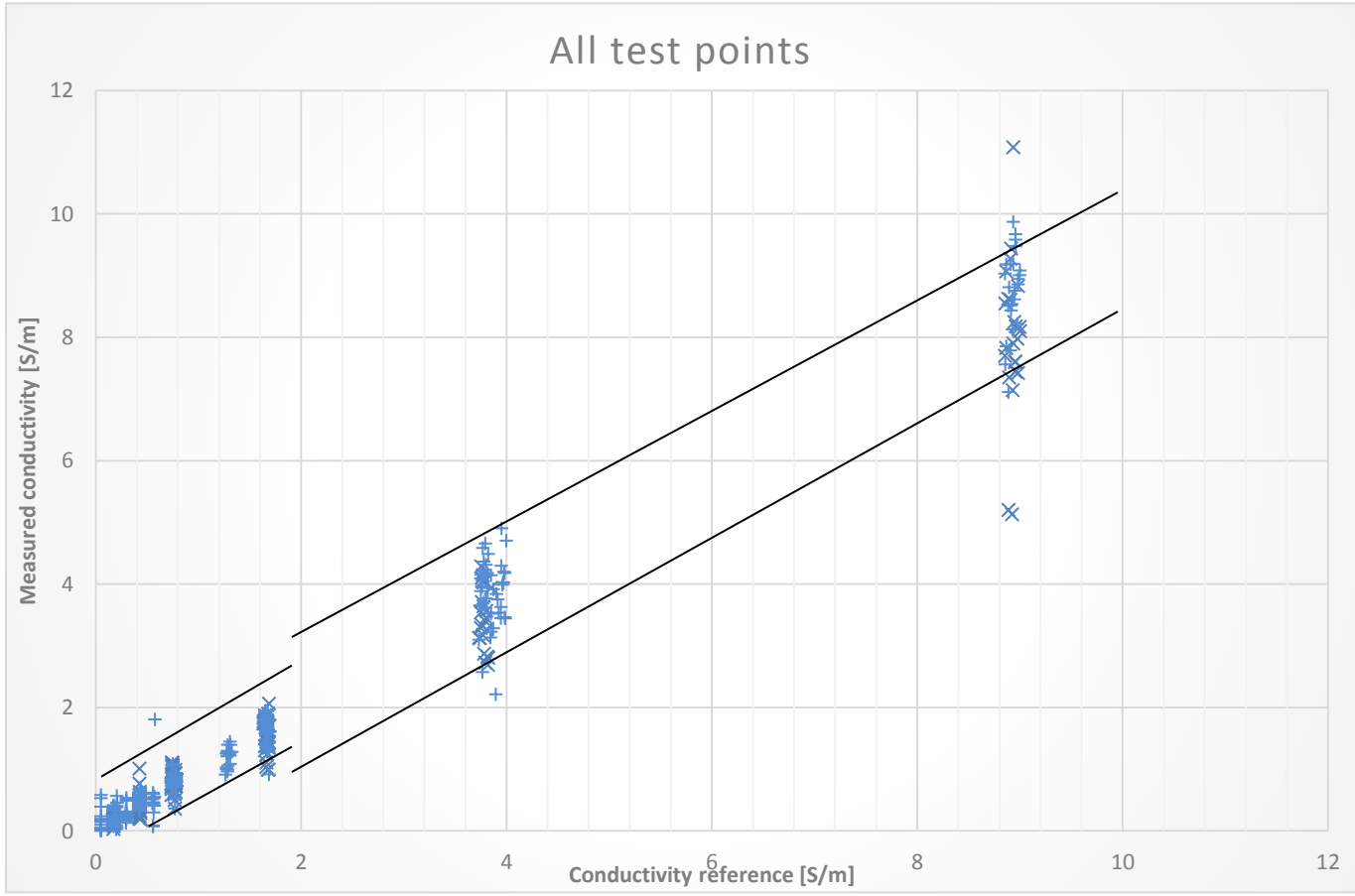
Summary of Salinity Testing

- Conductivities:
  - 0.05 S/m --> CEESI's fresh water
  - 0.17 S/m
  - 0.2 S/m
  - 0.3 S/m
  - 0.42 S/m
  - 0.55 S/m
  - 0.75 S/m
  - 1.3 S/m
  - 1.65 S/m
  - 3.75 S/m
  - 3.95 S/m
  - 8.9 S/m



GVF	WLR	Conductivity [S/m]	Abs Uncertainty [S/m]
85% -100%	0-100%	<2	± 0.5
		<11	± 0.8

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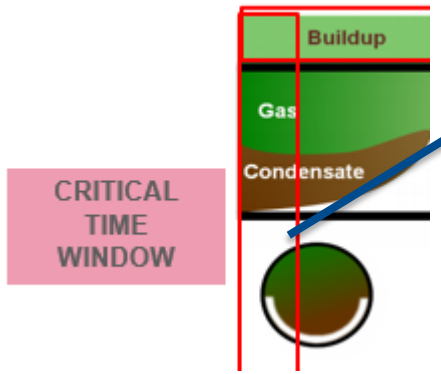
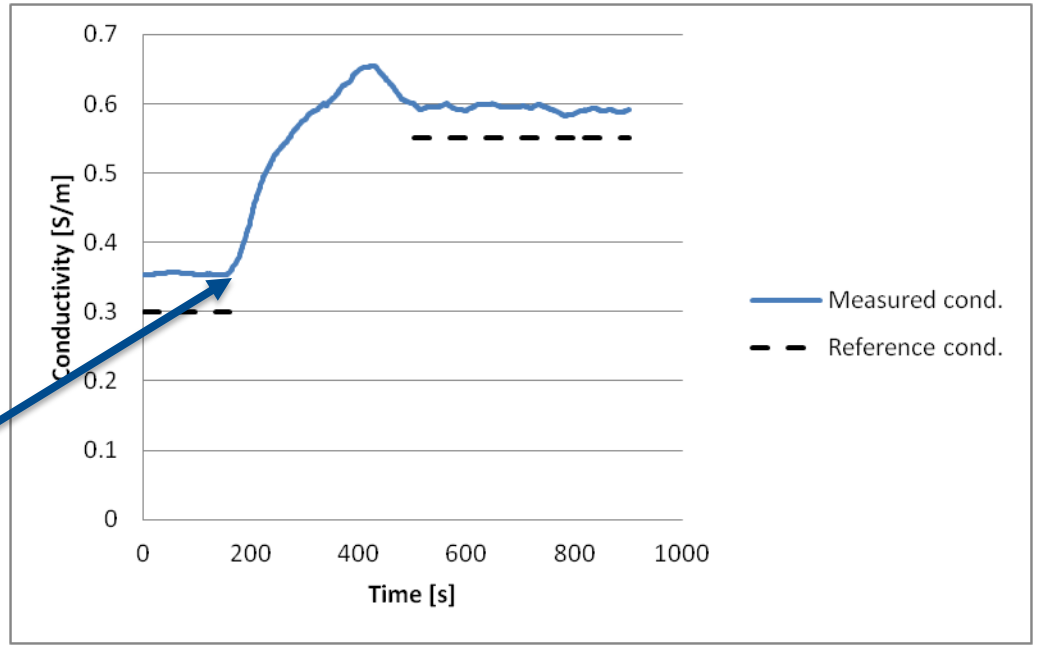
MW Resonance Sensitivity– Need For Speed!

- Ability to detect and measure extreme small changes of amount of water and conductivity instantaneously
  - ± 0.004 S/m
  - ± 0.00002% WVF





From 0.3 S/m to 0.55 S/m 98%GVF

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A Wet Gas Meter Solution for Wet Gas Challenges - summary

- Growth In Subsea Gas Field Developments Drives **Advanced Technology Solutions And Need For Metering**
- Subsea Wetgas Field Developments Are Prone To **Formation Water Breakthrough, Hydrate Formation And Pipeline Scaling And Corrosion**
- **Rapid, Highly Sensitive Measurements Are Needed** To Capture The Critical Time Window Of A Hydrate Plug Forming
- Roxar Offers A **Specialized Wetgas Meter** For Gas And Gas Condensate Fields, With More Than 250 Subsea Meters Installed
- Recent Improvements To The Subsea Wetgas Meter Includes A **Dedicated Salinity Probe** For Measuring Water Conductivity, Salinity And Formation Water Rate In **High GVF Applications** From 85-100% GVF, 0-100% WLR
- **Comprehensive Testing And Verification** Together With A Major Operator At CEESI Has Shown Performance Of:
  - As Low As **±0,15 S/m** Uncertainty For Water Conductivity
  - **± 0,004 S/m** Sensitivity To Changes In Water Conductivity
  - **± 0,00002 %** (0,2 ppm) Sensitivity To Changes In Water Volume Faction (WVF)

- The Roxar Wetgas Salinity Probe Is Able To **Detect Immediate Changes** To Formation Water Breakthrough And Water Salinity Changes, **Vital For Subsea Wetgas Field Developments**

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