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

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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
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
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

Increased Time / Risk / Cost of mitigation

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

- Worldwide installed base:
  - ~ 250 x Subsea WGM
  - ~ 100 x Topside WGM
- First installed subsea 2004
Roxar Subsea WetGas Meter – All in One Compact Solution

- Duplex
  - Super Duplex
  - Inconel
- 10k PSI
- 150 °C
- Low power consumption
  - 26W
- Optional
  - Gamma system
  - Salinity system
- Modbus RTU,
  - SIIS Level 2, SIIS Level 3
  - IWIS
- Redundant Flow computer
  & electronics
- Redundant dP, P and T
- 900 mm
- ~850 kg
Compact & Flexible Design – Fully Integrated Solution

- Redundant dP transmitters
- API flange
- MDP cone
- Gamma source
- Densitometer
- Dual PT transmitter
- MW antennas
- Dual connectors

Salinity Sensor
Roxar Subsea Wetgas Meter Measurement Principle

- Microwave Water Volume Fraction
- Microwave Water Conductivity
- dP Flow Meter
- Pressure & Temperature
- Gamma Mixture Density

Wetgas Meter Flow Computer

- Gas rate
  - Oil rate
  - Water rate
- Water Volume Fraction
- Water Conductivity & Salinity
- Formation Water Flow Rate

Hydrocarbon Composition

Direct measurements
Calculations
Input data
Output data
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
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 water salinity

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
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

<table>
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<th>GVF</th>
<th>WLR</th>
<th>Conductivity [S/m]</th>
<th>Abs Uncertainty [S/m]</th>
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<td>85% -100%</td>
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<td>&lt;2</td>
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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% GVFR
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