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Kuwait Oil Company
Kuwait 4th Flow Measurement Technology Conference

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Hilton Kuwait Resort
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Operations Team Lead – Flow Measurement

Weatherford
Field Testing an Accurate, Non-nuclear, Inline Wet Gas Multiphase Meter
DID YOU KNOW?

- FORESITE FLOW
- NON-NUCLEAR
- FULL RANGE 0-100% GVF
- Same Technology, Same Hardware
CONTENTS

• Introduction
• VSR Technology
• Field Testing
• Results
• Conclusions
INTRODUCTION

• What is wet gas?
  • GVF > 90%
  • $X_{LM} \leq 0.3$

• Applications:
  • Well Testing
  • Production Optimization
  • Allocation Metering
  • Process Metering

• Challenges in wet gas measurement.
Key Features

- Compact
- Non-nuclear
- Minimal calibration requirements
- Low power consumption
- Broad ambient-temperature ratings
- Easy maintenance
Ideal DP element
- Low pressure loss
- Natural mixing
- Very robust
- Handle low flows

Measurement of flow momentum

Mixture density and gas volume fraction (GVF)
VSR TECHNOLOGY

- Piezoceramic sensors
- Phased array processing algorithm
- Convective flow velocity and Volumetric flow rate
- Non-intrusive.
VSR TECHNOLOGY

- NIR Absorption
- 0-100% WC
- Upto 99.9% GVF
- Emulsion and Sand effect
- Water-salinity effect
- H2S and CO2 effect
- All crude oil types
VSR TECHNOLOGY

- **Venturi (V)**
  - Well documented performance
  - Sensitive to liquid content

- **Sonar (S)**
  - Based on downhole fiber optic multiphase flowmeter technology
  - Relatively insensitive to liquid content
  - Large turndown ratio

- **RedEye (R)**
  - Based on Near-Infrared Technology
  - 0-100% Water Cut (WC).
VSR TECHNOLOGY

- Over-reading
- Primarily dependent on liquid loading
- ORV and ORS
- Better contrast than alternative technology.
$1.5M SAVED
Reduced OPEX costs for an offshore Alaska well

$7.5M SAVED ANNUALLY
Delivered ongoing OPEX reductions for 50+ Middle East Wells

$10M SAVED
Reduced CAPEX costs for 10 wells in the South Pacific
FIELD TESTING

- Objective & Need
- 2-inch ANSI 600# VS, RE MP Meter
- Process flow conditions:

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>RANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure</td>
<td>80 - 90 bara</td>
</tr>
<tr>
<td>Temperature</td>
<td>47 – 52 °C</td>
</tr>
<tr>
<td>Water Cut</td>
<td>2 – 10 %</td>
</tr>
<tr>
<td>Liquid Flowrate (at std conditions)</td>
<td>80-95 m³/day</td>
</tr>
<tr>
<td>GVF</td>
<td>95 – 98 %</td>
</tr>
<tr>
<td>Oil Density</td>
<td>67 °API</td>
</tr>
<tr>
<td>Gas Specific Gravity</td>
<td>0.72</td>
</tr>
</tbody>
</table>
FIELD TESTING
RESULTS

GAS FLOW RATE COMPARISON

OIL FLOW RATE COMPARISON

WWW.KUWAIT-MEASUREMENT.COM
# Results

## Water Flow Rate Comparison

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Gas Flowrate</th>
<th>Oil Flowrate</th>
<th>Water Flowrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Deviation</td>
<td>-4%</td>
<td>+2%</td>
<td>-6%</td>
</tr>
</tbody>
</table>
CONCLUSIONS

• Good agreement between separator and VSR meter.

• VSR meter provided steadier water flowrate measurement.

• For light oil applications, two-stage separators versus ‘single’ VSR meter.
CONCLUSIONS

• No operational problems were observed.

• Replace test separator
  – accurate measurement
  – continuous monitoring
  – significantly reduces CAPEX and OPEX
  – increased operational reliability.
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References


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\[ \dot{m}_{\text{total}} = C_m \times C_d \times E \times \varepsilon \times A_{\text{throat}} \times \sqrt{2 \times \rho \times \Delta P} \]

\( \Delta P \): Inlet to throat pressure difference
\( \rho \): gas density
\( \varepsilon \): compressibility effects
\( E, A_{\text{throat}} \): Geometry
\( C_d \): Viscous Losses

\( C_m \): Wet Gas Losses (DP over – read model)
\[ \dot{m}_{total} = Q_g \cdot \rho_g + Q_l \cdot \rho_l \]
\[ Q_{total} = Q_g + Q_l \]
\[ Q_g = V_g \cdot A_g \]
\[ Q_l = V_l \cdot A_l \]

\[ \text{Slip} = \frac{V_g}{V_l} \quad \text{(wet gas slip model)} \]
\[ V_g = V_{sonar} \quad \text{(wet gas velocity model)} \]
WET GAS MODEL IMPROVEMENT

Then

- Published DP and slip models
  - e.g. de Leeuw
- Size and pressure specific DP models
- Non-convergence for near dry gas conditions
  - Elevated liquid loading uncertainty above 98% GVF

Now

- Custom DP and slip models
  - Developed from larger database of flow loop testing
  - Optimized for VS spool geometry and orientation
  - Generalized across nominal sizes and operating pressures
- Enhanced iteration method
  - Faster and more robust convergence.
- Reduced liquid rate uncertainty
THANK YOU