Measurement challenges in realization of subsea factories

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Introduction
Industry focus

Further technology development is being pursued along the following four lines:

• compact and environment-friendly solutions
• solutions which improve recovery from the reservoirs
• technology which permits long tie-backs to land
• equipment for ultradeep water.

(…taken from Statoil’s web-pages)
Subsea processing is making its way up the technology curve, but still several challenges ahead

Press release, May 5, 2015
Rystad Energy

Mainly four technologies implemented by industry so far:

- Subsea boosting
- Subsea separation
- Subsea water injection
- Subsea compression
Obstacles to overcome:
• Power distribution
• Control system
• Oil storage
• Monitoring
• Subsea well intervention and maintenance
• Integration, reliability and cost
Subsea sales and allocation metering
Why do tie-in fields cause measurement challenges?

Owner group A

Mother field production → Processing unit → Sales measurement → Single phase oil and gas

Satellite field production → Multiphase oil, gas and water

Allocation measurement

Owner group B

Fiscal measurements

Courtesy: Christian Michelsen Research AS (www.cmr.no)
Offshore flow metering - simplified example

Platform

Subsea satellite

Subsea installation 1

Subsea installation 2

Emissions (fuel and flare)

Oil

Gas

Multi-phase

Courtesy: Christian Michelsen Research AS (www.cmr.no)
Subsea factory sales and allocation metering - simplified example
Subsea multiphase metering for allocation
# Multiphase flow meter principle

<table>
<thead>
<tr>
<th>PVT data (sampling)</th>
<th>Verification/calibration by test separator</th>
<th>No updated PVT data</th>
<th>No test separator</th>
</tr>
</thead>
<tbody>
<tr>
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</table>

## Topside Multiphase Flow Meter

**Output:**
- Flow rate of gas
- Flow rate of oil
- Flow rate of water

**Topside uncertainty:**
- 5 % or more

## Subsea Multiphase Flow Meter

**Output:**
- Flow rate of gas
- Flow rate of oil
- Flow rate of water

**Subsea uncertainty:**
- 10 – 15 % or more
Statoil:

• Improve measurement uncertainty, reliability and robustness of subsea multiphase flow meters
Subsea multiphase flow metering

The dependency of PVT data **MUST** be reduced!

- **Approach 1:** New technology combinations that are less dependent of the PVT data

- **Approach 2:** In-line measurement of PVT-data in the pipe

- **Approach 3:** Subsea sampling and analysis
Subsea single phase sales metering
Sales measurement of gas (simplified)

Equipment:
- Flow meters
- Pressure metering device
- Temperature metering device
- Online gas chromatograph

Actions:
- Calibration
- Verification
- Maintenance
- Re-calibration

Uncertainty requirements (Norway):
- 1.0 % of mass (95 % confidence level)
Subsea sales measurement of gas (simplified)

Equipment:
• Flow meters - doable
• Pressure metering device - exists
• Temperature metering device - exists
• Online gas chromatograph - no

Actions:
• Calibration - yes
• Verification - ???
• Maintenance - ???
• Re-calibration - ???

Uncertainty requirements (Norway):
• 1.0 % of mass (95 % confidence level) – not now
Sales measurement of oil (simplified)

Equipment:
- Flow meters
- Proving device
- Pressure metering device
- Temperature metering device
- Densitometer
- Sampling for water content and density

Actions:
- Calibration
- Proving
- Verification
- Maintenance
- Re-calibration

Uncertainty requirements (Norway):
- 0.30 % of standard volume (95 % confidence level)
Subsea sales measurement of oil (simplified)

Equipment:
- Flow meters - doable
- Proving device – depends…
- Pressure metering device - exists
- Temperature metering device - exists
- Densitometer – doable
- Sampling for water content and density - ???

Actions:
- Calibration - yes
- Proving - possible
- Verification - ???
- Maintenance - ???
- Re-calibration - ???

Uncertainty requirements (Norway):
- 0.30 % of standard volume (95 % confidence level) – not now
Sales measurements

• It is all about trust and confidence!
Flowmeter for single phase liquid and gas

• Ultrasonic flow meter widely used

Acoustic transit times
Up- and downstream

... gives flow velocity and velocity of sound
Subsea single phase measurement challenges

• Improved description of flow dynamics upstream and through flow meter
• Improved understanding of interactions between acoustics and flow
• More extensive use of relationships between measured velocity of sound and density.
• Build in as much redundancy as practically possible
Conclusions

• Several measurement challenges must be solved before allocation and sales measurements can be carried out subsea with the same confidence and traceability as top-side

• Important due to share of income

• A matter of trust