Multi-Phase Flow Metering

On its way from nursing to mature technology

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Prepared for Hydrocarbon Production Accounting workshop
Moscow, 16-17 Dec 2008
1981–1986, Shell Research
- Production technologist/Investigation Leader
  Prod. Tech Research / Field trials / Audits / Reviews in various OU’s

1987–1991, NAM, Assen
- Sr. Fiscalisation Engineer
  Responsible for all aspects of production measurements, reconciliation, HC oil and gas accounting, contracts and sales allocation

1991 - now, Shell Research / SIEP / Shell GS
- Sr. Research Physicist/Sr. Production Measurement Consultant
- Shell’s Principal Technical Expert (PTE) on Metering and Allocation
  Production measurement research and developments, service and advice to Shell Operating Units, standardization activities, chairman ISO TC193
Objectives / Expectations and Presentation Rules

Objective / Expectations

Present an overview of the various MPFM’s currently in use

- Technology
- Applications
- Installation, operation and maintenance issues
- Uncertainty

Presentation Rules

- Workshop format rather than a presentation format
- Everybody to contribute rather than just a few
- There are no stupid questions, if unclear or vague, please ask
- If things can’t be solved or answered we will park them
1. Introduction
2. Stripping the Facilities
3. Multiphase Flow Metering
4. Performance Maps
5. MPM Technology
6. Conclusions
Introduction
- The product balance

PRODUCTION FACILITY
for each phase
$\Sigma_{in} = \Sigma_{out}$
Introduction
- Flowrate measurements (1)

Fiscal allocation
- Taxation / royalty / sales
- Production allocation to partners in joint pipelines
- Mutually agreed accuracy
- Control by contract and/or legislation

Reputation management
- Environmental measurement
- Forecasting

Well allocation
- Allocate bulk measurements to individual wells or reservoir

Some upstream metering might also be categorized as fiscal metering !!!
Introduction
- Flowrate measurements (2)

Reservoir management
• Maximise hydrocarbon recovery at prevailing economic and technical conditions, e.g.
  • Planning primary, secondary and tertiary development
  • Depletion policy
  • Injection/production balance
  • Production forecast
  • Future project ranking

Operational control
• Well surveillance
• Artificial lift optimisation
• Process and equipment performance
• Production targets and constraints
Data acquisition
- Accuracy vs. Costs (specification per project)

Cost Effectiveness of Measuring Equipment

![Graph]

- Losses and risks (wrong decisions) increase with increasing uncertainty
- Measurement costs decrease with increasing uncertainty
- Optimum cost per measurement
When reviewing measurement proposals for a “marginal field”, the DTI is fully prepared to relax measurement requirements in the interest of encouraging the development of remaining North Sea oil and gas potential.

Justification should include the following:
- Relevant field economics
- Measurement options considered
- Costs of various project options
What are Critical Measurements

For oil wells
1) Net oil flow rate
2) Gross liquid flow rate
3) Watercut
4) GOR - Gas/Oil Ratio
5) FGOR - Formation GOR

For gas wells
1) Gas flow rate
2) CGR - Condensate/Gas Ratio
3) WGR - Water/Gas Ratio
4) Water content

In contrast with the 1985 requirements, which presented the requirements in terms of oil, water and gas flow rates, it now becomes clear that often watercut and GOR are also prominent parameters.

Uncertainty vs Repeatability?
Production Measurement
- Who is involved

Operations
- Maintenance free
- Calibration free
- Moderate accuracy
- Trending

Petroleum and Reservoir Engineers
- Moderate accuracy
- Trending

Projects
- Options development
- Project execution

Contract and Finance
- Fiscal standards
- High accuracy
- Reliable

Third Parties
- Fiscal standards
- Accuracy negotiable

Instrument Engineers
- What the customer wants
- Standards, procedures, etc.

Government Bodies
- Fiscal standards
- High accuracy
- Reliable

Sales parties
- Fiscal standards
- High accuracy
- Reliable
- Traceable
- Contracts

Custodian?
Auditable?
1. Introduction
2. Stripping the Facilities
3. Multiphase Flow Metering
4. Performance Maps
5. MPM Technology
6. Conclusions
Production facility configuration
- Conventional facilities
Multi-Phase Flow Meters are around already for years ...........

Input: MultiPhase Flow
Output: Oil, Water and Gas Production Figures

MPFM mainstream development started around 1990
Laboratory trials 1991 - 1995
Field trials 1993 - 1996
Commercially available from 1996
Production facility configuration
- Manifolded Multiphase Flowmeter

Wells

Wells Test header

Bulk header

Upto 20 km

Multiphase Flow Meter

MPFM

To Bulk separator
Production facility configuration
- Manifolded Multiphase Flowmeter
Production facility configuration
- MSV and Multiphase Flowmeter

Wells
Multi-Selector Valve (MSV)
Multiphase Flow Meter
Test line
Bulk line
To Bulk separator
upto 20 km
Well test skid with MSV and Coriolis meter
Production facility configuration
- Wellhead multiphase flow meters

The ultimate aim !!!! surface MPFM or sub-surface MPFM per individual well
Production facility configuration
- Increased well test frequency

Brown field development

Wells

Test header

Multiphase Flow Meter

To Bulk separator
Production facility configuration
- Increased production capacity

Brown field development
Generic Two-Phase Flow Map
Concepts and definitions
Multi-phase flow regimes

1. Multi-phase
   \((\text{GVF} < 80 - 85\%)\)

2. High-GVF multi-phase
   \((80 - 85\% < \text{GVF} < 90 - 95\%)\)

3. Wet-gas
   \((\text{GVF} > 90\%)\)
Video on SIEP's Multiphase Flowloop "The DONAU"
1. Introduction
2. Stripping the Facilities
3. Multiphase Flow Metering
4. Performance Maps
5. MPM Technology
6. Conclusions
Multiphase and Wet gas Flowmeter
- Issues

Price
- 50k to 400k US$, different performance specifications

Limitations
- In-line MPFM's
  - > deteriorated performance at hi-GVF and hi-watercut
- Partial separation MPFM's
  - > space and weight
- Wet Gas meters
  - > calibration issues

HSE&S
- Radioactive sources (licensees, dedicated staff, barriers, etc)

Lack of confidence (create awareness)
- Performance testing/ Calibration / FATs
- Flow models often manufacturers IP (no clarity)
- Complicated equipment and not yet “fit and forget” technology
- Field verification tools/processes
- Standardisation, best practise guidelines
- Training

High intervention
- Nursing technology rather than mature technology
Multiphase Flow Metering - Building Blocks

1. Conditioning
   - Separation
   - Mixer
   - No conditioning (in-line, models)

2. Flowrate/Velocity
   - Positive displacement meter
   - Venturi/Orifice measurement
   - Cross correlation

3. Composition
   \[ \alpha_{\text{Water}} + \alpha_{\text{Oil}} + \alpha_{\text{Gas}} = 1 \]
   - Capacitance
   - Microwave
   - Conductive / Inductance
   - Dual venturi
   - Gamma or x-ray absorption

4. Algorithms
   - MPF Models
   \[ \sqrt{\alpha \sum \beta} \]
Schlumberger MultiPhase Flow Meter

Building Blocks

\[ \sqrt{\alpha \sum \beta} \]
Agar MultiPhase Flow Meter

Building Blocks

THE AGAR MPFM 400 SERIES

FLUIDIC DIVERSION LOOP

DATA ANALYSIS SYSTEM

DEDICATED COMPUTER
HAND HELD TERMINAL
MODBUS PROTOCOL
OPTIONS:
OPTIONAL I/O PORTS
COMMUNICATION AND
OUTPUT DEVICES

OIL

GAS

WATER

FFD™

MPFM 200

MPFM 300

MPFM 400

EXCLUSION VALVE

MONITOR

LAPTOP

AGAR CORPORATION

LS, Nov 2008
Building Blocks

\[ \alpha \sum_{\beta} \]

Haimo MultiPhase Flow Meter
PietroFiorentini (ex-FlowSys) MultiPhase Flow Meter
- IP now sits with Shell

Building Blocks

Flow Models

Fraction Models

Capacitance and Conductance

Venturi (dp)

Capacitance and Conductance electrodes

Venturi (diff. pressure)

X-correlation (Velocity)

Flow direction

WC

GVF

Oil

Water

Gas
AccuFlow MultiPhase Flow Meter

Building Blocks

Single Phase Liquid

Single Phase Gas

Accuflow™ Multiphase Metering System
MPM MultiPhase Flow Meter

Building Blocks

Compact design
Simple field configuration
Redundancy

WetGas / MultiPhase Mode
Water salinity measurement

Design press. up to 15,000 psi
Design temp up to 250 degC

Topside (and SubSea)

Sponsors
Venturi-Tracer Wet Gas Meter

Tracer mass balance:

\[ \text{Liquid flow rate} = \frac{C_o}{C_s} \times \text{Injection flow rate} \]

Building Blocks

- Tracer supply bottle
- Metering pump
- Wet gas flow
- Mixing distance
- Liquid sample

Tracers

\[ \sqrt{\alpha \sum \beta} \]

Venturi over-reading

Lockhart-Martinelli parameter

Graph showing lockhart-martinelli parameter vs. venturi over-reading.
Building Blocks

- \( \mu \)
- \( \sqrt{\alpha \sum \beta} \)
- \( pVT \)
Solartron ISA Wet Gas Meter

Building Blocks

- Loss
- Wedge

\[ \sqrt{\alpha \sum \beta} \]

Gas/Liquid calibration
Mera well test unit

Building Blocks

Single Phase Liquid

Single Phase Gas

MPF in

GAS

LIQUID

SEPARATING VESSEL

METERING VESSEL

MPF in

MPF in

MPF in

MPF out
Mera well test unit
**Mode of operation:**
- Big separator vessel >> Gas/Liquid separation
- Subsequently measures Gas, Liquid, Gas, Liquid, ..........
- Gas flowrate with gas meter
- Liquid flowrate with $\Delta T_{\text{filling}}$
- Watercut from $\Delta p$ and $\rho_{\text{oil}}$ and $\rho_{\text{water}}$

**Issues:**
- Low GVF >> low driving force for liquid
- Leaking valves
- Base density ($\rho_{\text{oil}}$ and $\rho_{\text{water}}$) variations
- Foaming
- High failure rate, control and mechanical problems
- Dead volumes
Mode of operation:

- Bubbles below a critical size are entrained in the liquid, will give the liquid velocity
- Average velocity of all bubbles, will give the gas velocity
- Phase fractions either with single or dual energy gamma ray absorption.
- Fast signal processing

Suitable for:

- Lower GVF's
- Viscous/Heavy oil
Manufacturers
- Based on sales

Front Runners
- Roxar (Fluenta)
- Schlumberger/Framo
- Haimo
- MPM
  - Agar
  - AccuFlow

Others
- Kvaerner DUET
- Jiskoot MixMeter
  - WellComp
  - Kvaerner CCM
- ISA
  - ESMER
- Daniel
  - Pietro Fiorentini
  - Abbon
  - epSolutions
  - Neftemer
  - Mera

Apply radioactive sources
Possible issues with MPFM's

<table>
<thead>
<tr>
<th>Issues can be:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• In-line calibration / verification</td>
</tr>
<tr>
<td>• Sensitivity for physical parameters</td>
</tr>
<tr>
<td>• Operational envelope</td>
</tr>
<tr>
<td>• Water flow rate measurement (WGM)</td>
</tr>
<tr>
<td>• Water-cut in high WC oil wells</td>
</tr>
<tr>
<td>• Reliability</td>
</tr>
<tr>
<td>• Erosion/Corrosion</td>
</tr>
<tr>
<td>• Wax deposition</td>
</tr>
<tr>
<td>• Scale deposition</td>
</tr>
<tr>
<td>• Sand tolerance</td>
</tr>
<tr>
<td>• Sensors in contact with well fluids</td>
</tr>
</tbody>
</table>
MPFM Diversity

Large diversity in available technology which results in a large diversity in:
- Uncertainty specification
- Performance specifications
- Influence of fluid parameters
- Operating Envelopes
- Presentation of test results

hence need for:
- Guidance on which technology should be used
- How to determine operating envelopes
- How to test meters What is accuracy
- Limitations

It is too early for standards on the technology itself but it is possible to produce guidelines and/or standards on how to test, implement and use the technology
1. Introduction
2. Stripping the Facilities
3. Multiphase Flow Metering
4. Performance Maps
5. MPM Technology
6. Conclusions
Current activities regarding best practices and/or guidelines for the design and operation of MultiPhase Flow Meters

- **DTI (UK)**
  - Guidance notes for Petroleum Measurement, 
    *Module 7 (Dec 2003)*

- **API**
  - Multiphase Flow - White paper
  - *RP86*, Well rate determination

- **NFOGM**
  - Handbook for Multiphase Flow Measurement
    1st version issued 1995
    2nd version issued 2005

- **Large number of publications**
NFOGM
Multiphase Flow Metering Handbook

Produced for:
The Norwegian Society for Oil and Gas Measurement and
The Norwegian Society of Chartered Technical and Scientific Professionals

by
• Shell
• BP
• Total
• ConocoPhillips
• Norsk Hydro
• CMR
• Roxar
• Framo/Schlumberger

http://www.nfogm.no/
Presentation of performance [3] - Liquid Flowrate and Watercut as function of GVF

- Deviation in Liquid Flow Rate (%)
  - Water continuous
  - Oil-continuous

- Deviation in Gas Flow Rate (%)
  - Water continuous
  - Oil-continuous

- Deviation in Watercut (%)
  - Water continuous
  - Oil-continuous
Presentation of performance [4]  
- Based on Generic Two-Phase Flow Map
Presentation of performance [4]
- Based on Two-Phase Flow Map and a Diameter
Well Trajectory in Two-Phase Flow Map

In-line Multi-Phase Flow Meter problem area

Typical position of boundary between slug and mist flow

Uncertainty in prediction

GVF=99.0%

GVF=99.9%

GVF=90.9%

GVF=50%

GVF=9.1%

Liquid Flowrate (m$^3$/d)

Gas Flowrate (m$^3$/d) at actual conditions
Well trajectory in Composition Map

In-line Multi-Phase Flow Meter net-oil uncertainty deterioration

GAS

Wet Gas Area

Uncertainty in prediction

Gassy Liquid

OIL

WATER

Watercut (%)

GVF (%) at actual conditions

LS, Nov 2008
MultiPhase Flow Meter test results in 2-phase flowmap

- Gas Flowrate (m³/d) at actual conditions
- Liquid Flowrate (m³/d)
- GVF=9.1%
- GVF=50%
- GVF=90.9%
- GVF=99.0%
- GVF=99.9%
- Uncertainty
  - ±5% Liquid
  - ±5% Gas
  - ±10% Liquid
  - ±10% Gas

- Reference
- MPFM

Reference MPFM
MultiPhase Flow Meter test results in composition map

- Watercut (%)
- GVF (%) at actual conditions

- Wet Gas Area
- Gassy Liquid
- Reference
- MPFM

Uncertainty:
- ±7.5% watercut
- ±5.0% watercut
- ±2.5% watercut

Uncertainty >10% watercut

GAS

Reference
MPFM
Liquid, Gas and Water Cumulative Deviation Plots
Meter E

Liquid, Gas and Watercut Cumulative Deviation Plots

Meter E

Cumulative
(% of test points)

Deviation (%)

- Liquid
- Gas
- Watercut
1. Introduction
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6. Conclusions
- Eliminating measurement errors due to annular gas concentration (in vertical flow)
- Provide fast measurements to capture correctly the fast fluctuations in the flow (slugs, etc)
- Ensure more accurate watercut measurements at high watercuts and at high GVF’s to measure flow rates of oil more precisely
- Combine Multi-phase and Wet Gas Flow Measurement in one single meter.
- Measure water conductivity, rather than require input from user; simplify field configuration and reduce errors
Based on new patented technology, and resulting from 3½ years comprehensive development program

- 5 Patents

**Topside** (available Dec 2006)

- 1 Meter delivered,
- 5 Meters sold

**SubSea Meter available summer 2007**

- Full qualification as per ISO standards and DNV RP203.
MPM High Performance Meter

Measurements

3D BroadBand
- Measurement of dielectric constant in 3D
- Measurement of annular gas concentration
- Measurement of water conductivity, salinity and density

Venturi
- Flow rate measurement
- Flow conditioning

Gamma Ray Absorption
- Composition

Temperature and Pressure

RUN VIDEO
Integrated Configuration
- Combined MultiPhase or Wet Gas Flowmeter

High performance in both modes

**WetGas Mode**
- Stable flow conditions
- Small liquid fractions
- Software configured for maximum measurement resolution & sensitivity

**MultiPhase Mode**
- Large and fast flow variations
- Software configured for maximum measurement speed
Field Qualification Program
- Timing

All tests performed using the same unit
- 3” MPM Meter
- Made as per Gullfaks Specifications

Field test program conducted by Statoil
Field Qualification Program
- Test conditions, Sep 2006 - Jan 2007

<table>
<thead>
<tr>
<th></th>
<th>MPM Flow Lab</th>
<th>K-Lab Test</th>
<th>(1) Gullfaks A</th>
<th>(1) Gullfaks A</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FAT Sept '06</td>
<td>Oct '06</td>
<td>Dec '06</td>
<td>Jan '07</td>
</tr>
<tr>
<td>No of test points</td>
<td>220</td>
<td>46</td>
<td>13</td>
<td>10</td>
</tr>
<tr>
<td>GVF</td>
<td>0 - 92 %</td>
<td>25 - 99,9 %</td>
<td>40 - 96 %</td>
<td>20 - 95 %</td>
</tr>
<tr>
<td>WLR</td>
<td>0 - 95 %</td>
<td>0 - 70 %</td>
<td>2 - 78 %</td>
<td>2 - 85 %</td>
</tr>
<tr>
<td>Pressure</td>
<td>&lt; 10 bar</td>
<td>120 bar</td>
<td>60 bar</td>
<td>60 bar</td>
</tr>
<tr>
<td>Oil</td>
<td>Exxol D 140</td>
<td>Condensate</td>
<td>Crude</td>
<td>Crude</td>
</tr>
<tr>
<td></td>
<td>830 kg/m3</td>
<td>620 kg/m3</td>
<td>780 - 840 kg/m3</td>
<td>780 - 840 kg/m3</td>
</tr>
</tbody>
</table>

Note: (1) Reference system improvements from Dec '06 to Jan '07
Meter taken into permanent use in Feb '07 - for well testing
Field Qualification Program, MPM flowloop
- Overview

- The MPM Laboratory is made to enable developing and testing of Flow meters at Field alike conditions.

- It offers a large variety in flow rates and flow regimes, and has highly accurate reference instrumentation.
Field Qualification Program, MPM flowloop
- Testing of 15 “Gullfaks wells” in 2 hours

Test of Gullfaks A Wells (MPM Flow Laboratory)
Field Qualification Program, MPM flowloop
- Two Phase Flow Map (zoomed)

Two-Phase Flowmap

Gas Flowrate (m³/h) at actual conditions

GVF=50.0%

Liquid Flowrate (m³/h)

Reference measurement
MPFM measurement

Sep 2006
Field Qualification Program, MPM flowloop
- Two Phase Composition Map
Field Qualification Program, MPM flowloop
- Cumulative Deviation Plot

MPM Multiphase Flowmeter

Cumulative (% of test points)

0% 2% 4% 6% 8% 10% 12% 14% 16% 18% 20%

Deviation (%)

- Liquid
- Gas
- Watercut

Average = 0.60 %  StDev = 1.87 %
Used liquid testpoints = 97
Average = 1.02 %  StDev = 3.65
Used gas testpoints = 75
Average = -0.24 abs%  StDev = 1.27 abs%
Used watercut testpoints = 97

Sep 2006
Sensitivity to oil and gas density changes

MPM Flow Laboratory, March 27th 2007
Test of sensitivity to Oil and Gas Density Changes

- **Oil Density:**
  - Base: 838
  - 828
  - 813
  - 788
  - 738
  - 838
  - 838
  - 838

- **Gas Density:**
  - Base: 10
  - 10
  - 10
  - 10
  - 10
  - 10
  - 5
  - 20

**GVF:** 84%
**WLR:** 10%
**Oil Density:** 838 kg/m³
**Gas Density:** 10 kg/m³
Field Qualification Program, K-Lab
- Installation and Commissioning
Field Qualification Program, K-Lab
- Cumulative Deviation Plot

MPM Multiphase Flowmeter

- Liquid testpoints = 39
  Average = -0.43 %
  StDev = 4.96 %

- Gas testpoints = 46
  Average = 1.24 %
  StDev = 1.94 %

- Watercut testpoints = 39
  Average = -0.52 abs %
  StDev = 2.20 abs %
A constant gas flow rate of 300 m³/h was used, with water injections of

<table>
<thead>
<tr>
<th>m³/h</th>
<th>water%</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.008</td>
<td>0.0026%</td>
</tr>
<tr>
<td>0.043</td>
<td>0.0143%</td>
</tr>
<tr>
<td>0.086</td>
<td>0.0287%</td>
</tr>
</tbody>
</table>

MPM meters can detect water fraction changes less than 0.0025%
Field Qualification Program, Gullfaks A, Statoil
- Cumulative Deviation Plot

MPM Multiphase Flowmeter

- **Liquid**
  - Used 10 liquid test points
  - Average = 2.74 %
  - StDev = 3.40 %

- **Gas**
  - Used 10 gas test points
  - Average = -0.33
  - StDev = 3.12 %

- **Watercut**
  - Used 10 watercut test points
  - Average = 1.12 abs %
  - StDev = 2.07 abs %
Assuming MPM Meter is used for well testing - reservoir management

- Measurement uncertainty on each well / test point is of interest
- Table below shows difference between MPM Meter and Reference system

<table>
<thead>
<tr>
<th>Individual wells / test points</th>
<th>MPM Lab</th>
<th>K-Lab</th>
<th>Gullfaks Dec</th>
<th>Gullfaks Jan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil Flow rate</td>
<td>± 5 to 10 %</td>
<td>± 4 to 10 %</td>
<td>± 8 %</td>
<td>± 6 %</td>
</tr>
<tr>
<td>Gas Flow rate</td>
<td>± 6 %</td>
<td>± 5 %</td>
<td>± 8 %</td>
<td>± 3 %</td>
</tr>
</tbody>
</table>

Notes:
- Across full range of GVF and WLR
- Difference includes measurement uncertainty of reference and MPM meter, as well as other potential errors
- 90 % confidence level
MPM Multiphase Flowmeter Test
- SouthWest Research, San Antonio
MPM Multiphase Flowmeter Test
- SouthWest Research, San Antonio

Cumulative
(% of test points)

MPM Multiphase Flowmeter

Deviation (%)

Liquid test points = 50
Average = -0.01 %
StDev = 3.92 %

Gas test points = 52
Average = 1.75 %
StDev = 1.06 %

WLR test points = 50
Average = -0.004 abs %
StDev = 1.84 abs %

WVF test points = 50
Average = -0.004 abs %
StDev = 0.027 abs %

Liquid
Gas
WLR
WVF

LS, Nov 2007
LS, Nov 2008
MPM Multiphase Flowmeter Test
- SouthWest Research, San Antonio

Cumulative
(% of testpoints)

MPM Multiphase Flowmeter

Liquid test points = 50
Average = -0.01 %
StDev = 3.92 %

Gas test points = 52
Average = 1.75 %
StDev = 1.06 %

WVF test points = 50
Average = -0.03 %
StDev = 1.84 abs %

WLR test points = 50
Average = -0.004 %
StDev = 0.027 abs %
Field Qualification
Verification of major user benefits

MPM meter bridges the gap between wetgas and multiphase flow conditions
- Dual mode functionality verified
- Unique results obtained for both modes; repeatability, sensitivity and accuracy.

Oil flow rates can be measured precisely (within ± 8%)
- Over full range of GVF’s
- Over full range of WLR’s - both oil and water continuous emulsions
- Automatic detection of water salinity - (self calibration modus)

Simple field configuration
- Water density and water conductivity measured by MPM Meter
- Densities of oil and gas entered by the user (not sensitive)

The self diagnostics functionality was demonstrated and proved its capabilities and advantages for the user.
Field Qualification

Very good operational experiences

Installation and Commissioning done in few hours

Meter start-up and signal interfacing quickly in place

Superb Operational Stability
  - 100 % uptime since commissioning

Meter performance within specifications
  - The repeatability of the MPM Meter was demonstrated to be extremely good, by testing the same wells at several times.

The self calibration modus is imperative at high WLR's and changing water properties

Flexibility demonstrated
  - Can go directly from MPM lab to field whilst maintaining performance
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**Conclusions**

- **MultiPhase and Wet Gas Flow Metering**

- Multiphase Flow Metering (MPFM) is on its way from nursing to mature technology, however proper attention is required in the implementation and operational phases.

- Wet Gas Flow Metering (WGFM) capabilities in MPFM are improved (ref MPM and Schlumberger)

- MPFM and WGM issues that require further attention
  - Limited number of manufacturers
  - Use of radioactive sources
  - High GVF and high watercut performance
  - Pricing (accuracy vs CAPEX/OPEX)
  - Specification and performance formats
  - Standardisation / Guidelines
  - Improved accuracy (for fiscal/allocation service)
    - Achievable today; Liquid 5%, Gas 5%, WLR 2% (ok for WRM)
    - Need for Fiscal/Sales allocation; Oil 2%, Gas 2%
  - Testloop and Field verification procedures