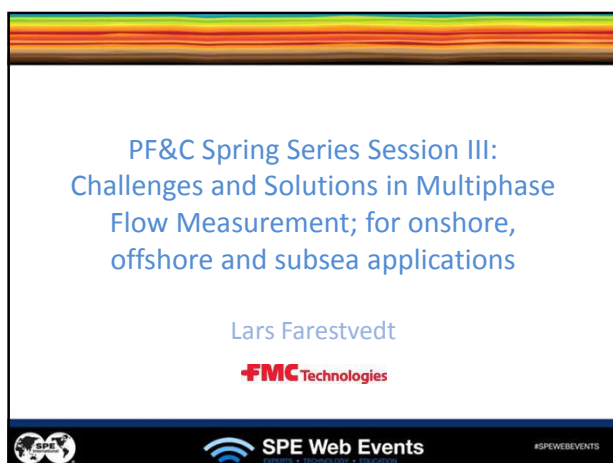








Presentation Overview

- Brief History of Multiphase Flow Meters
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SPE Web Events

#SPEWEBEVENTS

Multiphase Flow Meter System



SPE Web Events

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Research / Development (early 90's)

- Oil Co's saw the need for MPFM/WGFM
- Various R&D JIP's (Manufacturers and Oil Co's)
- Oil Co own R&D projects

Initial testing / field installations (mid 90's)

- First prototypes in the field but still **nursing technology**
- Poor experience, lack of confidence, testing
- JIP's focused on operational aspects rather than R&D

Current status

- MPFM/WGFM have developed to **mature technology**
- Extensive testing has been executed
- User confidence has grown (e.g. sales allocation)

What is next

- Downhole MPFM's



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Operational Control

- Well surveillance
- Artificial lift optimization
- Process and equipment performance
- Production targets and constraints
- Allocation individual wells or reservoir

Reservoir Management

- Planning primary, secondary and tertiary development
- Depletion policy, Injection/production balance
- Production forecast and future project ranking

Fiscal/Sales Allocation

- Taxation / Royalty / Sales
- Production/Sales allocation to partners in joint Ventures

mid 90's

mid 00's

MRFM/GFM INVOLVEMENT OVER TIME



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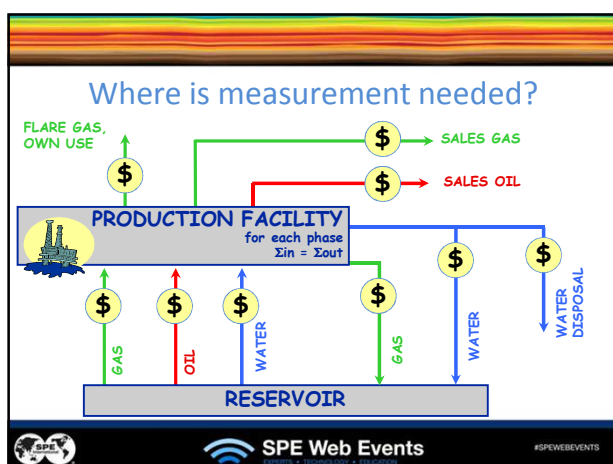
Presentation Overview

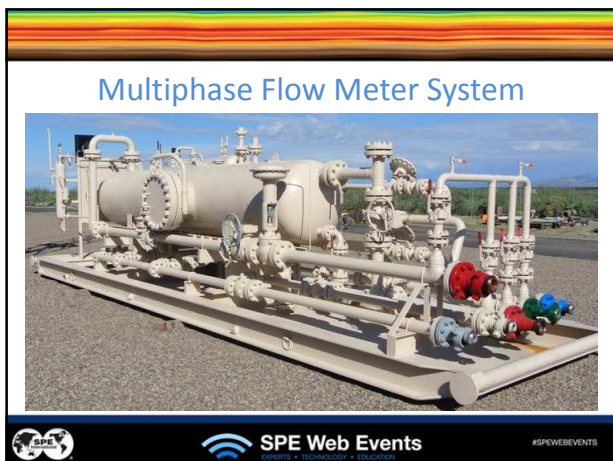
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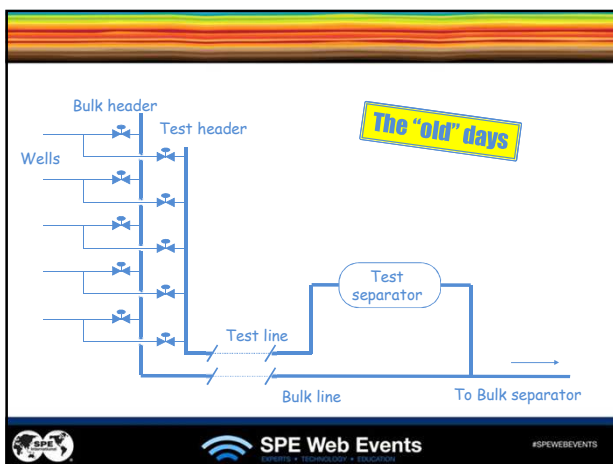


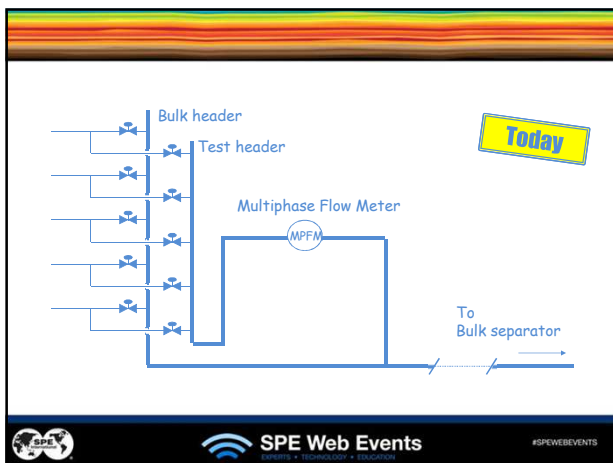
SPE Web Events

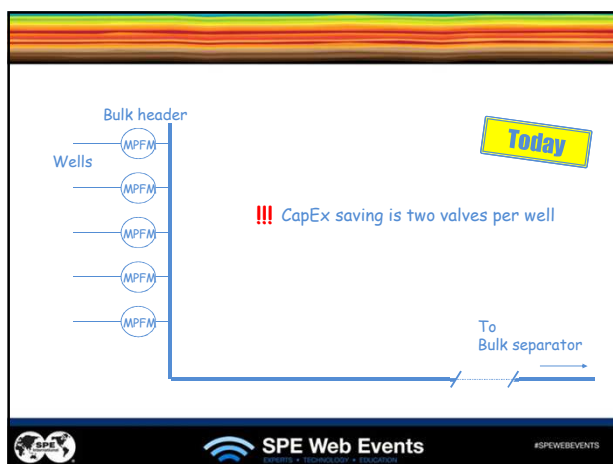
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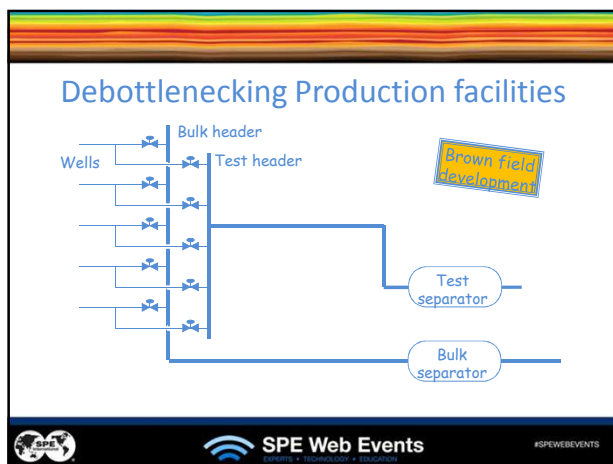


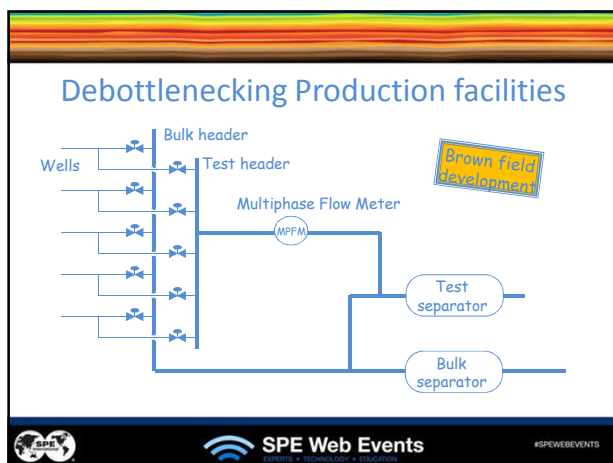


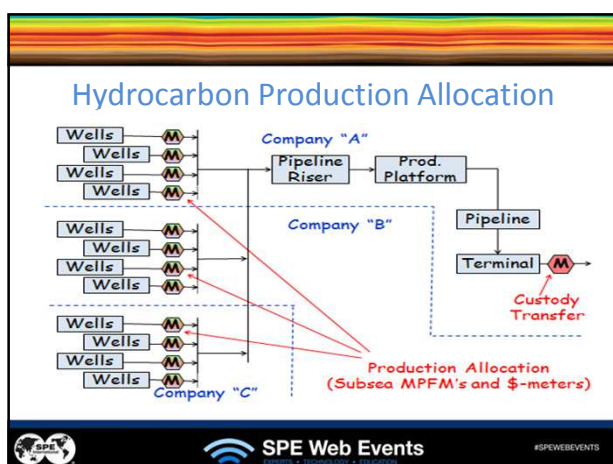


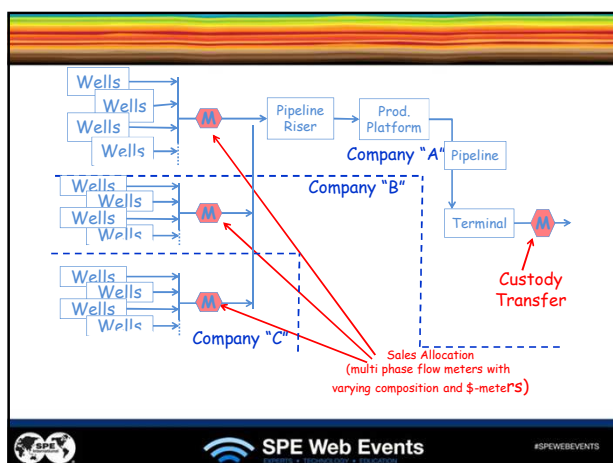


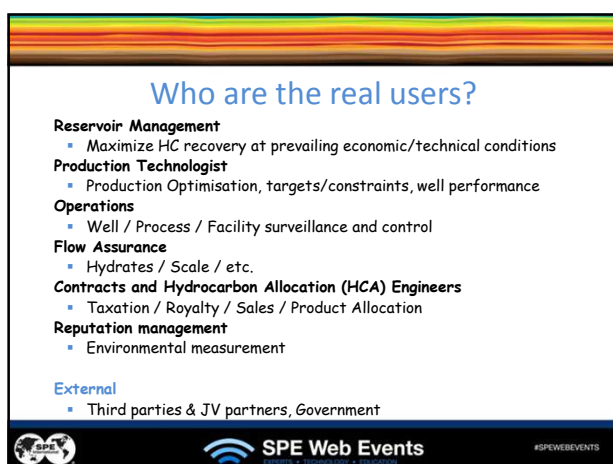






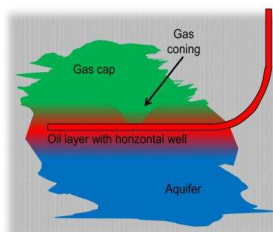






Producing Under GOR control

- Critical to avoid production from gas cap
- Maintaining gas pressure in the reservoir
- Close monitoring of GOR

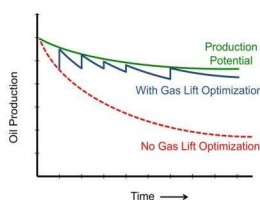


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Gas Lift Optimization

- Optimize gas lift flow rate
- Minimizing gas injection
- Fast meter response needed
- Meter can give good data in 1 hour (separator may need 12 hours)



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#SPEWEBEVENTS

Hydrate Control/Management in Gas Developments

- Free water as condensed or formation can cause hydrates
- Critical at high pressure and low temperature
- Costs of removing hydrates plugs can be astronomical (subsea)
- Adequate quantities of hydrate inhibitors (MEG) are required
- High accuracy of water flow rates are needed
- Challenge at high GVF



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Wax and Scale Detection

- Low temperatures at sea bed depth can cause wax deposit on pipe wall
- Significant reduction in pipe section or even blockage
- Monitoring wax deposits or scale formation is very important
- Inhibitor injection, pigging operation frequency, etc



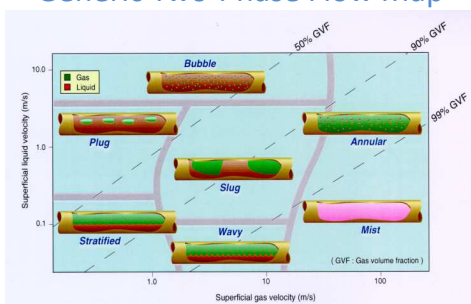
<http://www.worldoil.com/April-2006-France-Germany-Monitoring-field-pipewall-deposition-with-a-new-non-intrusive-device.html>



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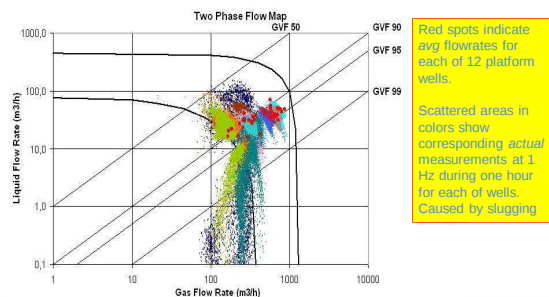
Generic Two-Phase Flow Map



SPE Web Events

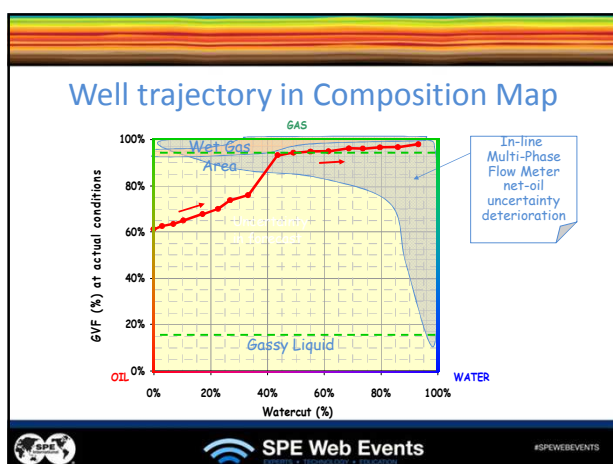
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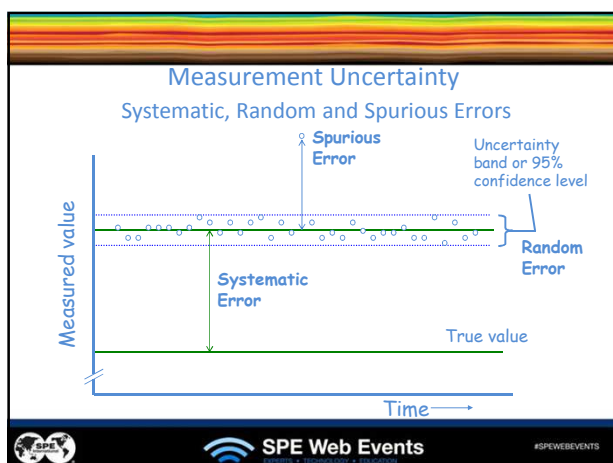
Slug Flow ?

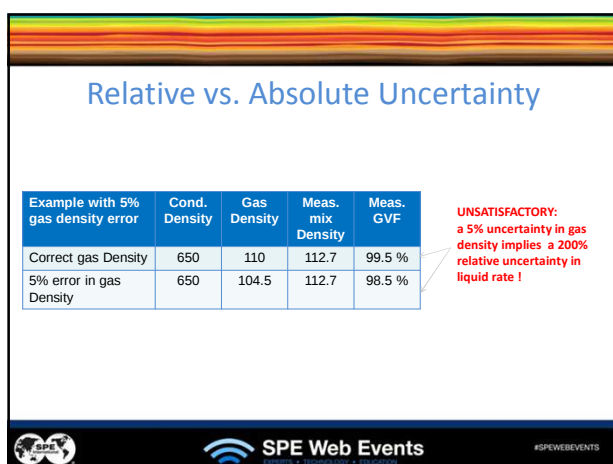


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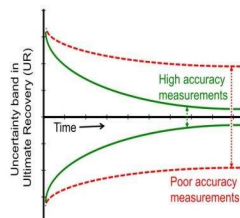






Lower uncertainty for Ultimate Recovery (UR)

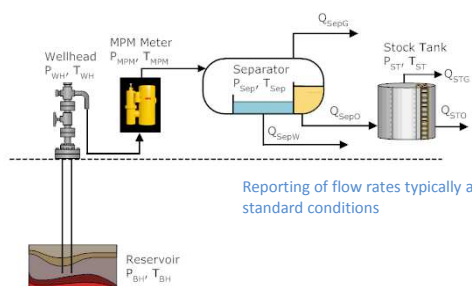
- Data from production measurements in one of the inputs of reservoir modeling
- Better data leads to better models
- Poor data or low frequency of data causes uncertainty of UR be large
- Continuous data acquisition and better quality of data reduces significantly the UR uncertainty
- Reducing financial risks, improving recovery



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Standard Conditions



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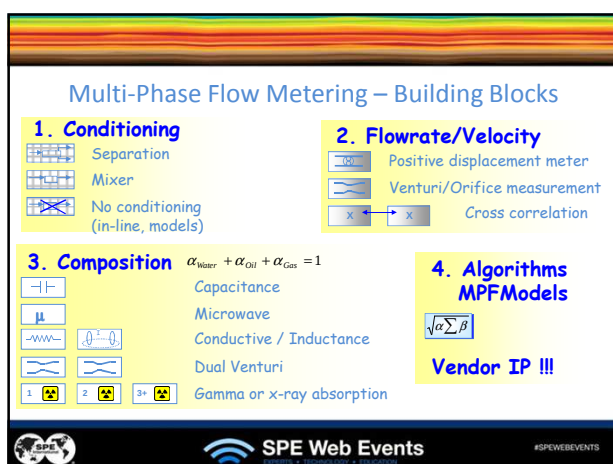


SPE Web Events

#SPEWEBEVENTS







Schlumberger Multi-Phase Flow Meter

Building Blocks



MAX WEIGHT - 1500KG

Schlumberger

OneSubsea
A Cameron & Schlumberger Company

SPE Web Events

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[illegible]

MPM Multi-Phase and Wet Gas Flow Meter

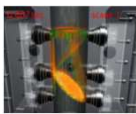
Building Blocks




3D Broadband tomography
(multidimensional and multi frequency)





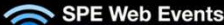






FMC Technologies





#SPEWEBEVENTS

Agar Multi-Phase Flow Meter

Building Blocks

THE AGAR MPFM 400 SERIES

FLUIDIC DIVERSION LOOP

FFD™

MPFM 300

MPFM 400

DATA ANALYSIS SYSTEM

- DEDICATED COMPUTER
- HAND HELD TERMINAL
- MODBUS PROTOCOL

OPTIONS:

- OPTIONAL I/O PORTS
- COMMUNICATION AND OUTPUT DEVICES

AGAR CORPORATION

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Haimo Multi-Phase Flow Meter

Building Blocks

1

2

$\sqrt{\alpha \sum \beta}$

HAIMO

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Pietro Fiorentini Multi-Phase Flow Meter

Building Blocks

FlowSys

Pietro Fiorentini

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AccuFlow Multi-Phase Flow Meter

Building Blocks

- Single Phase Liquid
- Single Phase Gas



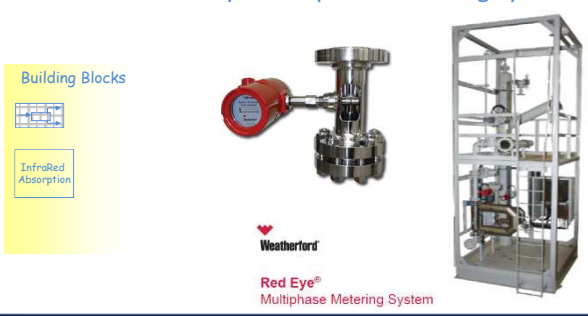
The image shows the AccuFlow Multi-Phase Flow Meter system, which includes a large horizontal pipe with a red band, a vertical pipe, and a control unit. The system is labeled "Accuflow™ Multiphase Metering System".

SPE Web Events
#SPEWEBEVENTS

Weatherford Red Eye Multiphase Metering System

Building Blocks

- InfraRed Absorption



The image shows the Weatherford Red Eye Multiphase Metering System, which includes a red eye-shaped sensor and a large metal frame. The system is labeled "Weatherford Red Eye® Multiphase Metering System".

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#SPEWEBEVENTS

New developments

GE sensing

- Multiple Sensors :
 - Impedance
 - Capacitance
 - Dual Venturi and various DP sensors
 - GE designed microwave sensors
 - Ultrasound Doppler
- Algorithms/Modelling



Krohne

- R&D collaboration Shell and Spinlock
- KROHNE : manufacturing, marketing and sales
- Concept based on :
 - Magnetic Resonance principle
 - Alignment of nuclear spins in a magnetic field,
 - Followed by perturbing this alignment with a radio frequencies

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Flow loop testing of MPFM's

Key word here is "Blind Test"

- Good preparation essential, compile and agree test program. Use different fluid or run sensitivity analyses.
- Allow vendors do the basic set-up (no test runs !!) and subsequently chase them off the flow loop premises
- Run the test as if it was a "subsea installation", no tuning after set-up, unless it is part of the meter functionality
- Oil company (or their representative) should coordinate and steer test program and collect/report data
- Vendor should not have any further access to the meter



Schlumberger San Antonio, Texas



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K-Lab Multiphase Flowloop

Operational parameters

independent closed loop which gives control of compositions, test conditions and stable flow regimes
 liquid injection points immediately upstream each test object
 adjustable temperature range from 20°C to 60°C (68-140 F)
 pressure range from 20 barg to 138 barg (290-2000 psi)
 adjustable flow rates for test fluids:
 HC Gas 6000 Am³/h
 HC liquid / water 150 Am³/h
 VLR range of 0-100%
 GVR range of 30-100%

"There is no other alternative test facility to K-Lab with this combination of dimensions, flowrates, pressure, and real fluids to cover 50+ years worth of years to come."

For 50+ years, Schlumberger has been the world leader in flow loop testing.



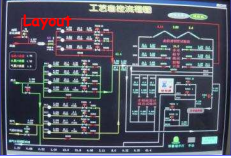
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#SPEWEBEVENTS

Multiphase Flowloop, Daqing China







Reference measurement

Control room

Flowloop

多相流量计标定室

Layout

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ProlabNL




High pressure compact separation system at ProlabNL

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MPFM and WGFM Diversity

How to see the forest for the trees

Large diversity in available technology which results in a large diversity in:

- Uncertainty specification
- Performance specifications
- Influence (sensitivity) of fluid parameters
- Operating Envelopes
- Presentation of test results

And some guidance is required to guarantee uniform approach regarding specifications, testing, etc.

!!! It is too early for standards on the technology itself but it is possible to produce guidelines and/or standards on how to specify, test, implement and use the technology



#SPEWEBEVENTS



Current activities regarding best practices and/or guidelines for the design and operation of Multi-Phase Flow Meters

- API
 - ~~Multiphase Flow White paper~~
 - ~~RP86, Well rate determination~~
 - API MPMS Measurement of Multiphase Flow, Chapter 20.3 (Jan 2013)
 - API 175 RP (soon to be released)
- UK Regulator (DECC)
 - Guidance notes for Petroleum Measurement, Issue 8 (July 2012)
- NFOGM
 - Handbook for Multiphase Flow Measurement
 - 1st version issued 1995
 - 2nd version issued 2005



#SPEWEBEVENTS



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Summary and Conclusions

- Multiphase Flow Metering (MPFM) and Wet Gas Flow Metering (WGFM) is considered mature technology today, however proper attention is required in the implementation and operational phases, it is not yet "plug and play"
- MPFM and WGM issues that require further attention
 - Limited number of manufacturers
 - Use of radioactive sources
 - High GVF and high watercut performance
 - Dissemination of knowledge (data users/providers)
 - Pricing (uncertainty vs. CAPEX/OPEX)
 - Sensitivity to fluid properties
 - Standardisation / Guidelines
 - Improved accuracy (for fiscal service)
 - Test loop (blind testing) and Field verification procedures
 - Redundancy (backup) should be an integral part of the meter design
 - An MPFM verification campaign should be part of the operation phase



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Can we calibrate a MPFM ?

Example orifice plate

- Calibrate individual components
- ISO standard
- Combination OK
- No testloop required

Example turbine meter, PD meter, Coriolis meter, US flowmeter

- Meter prover or Testloop required

What about MPFM's or WGFM's ?

- Large diversity in technology
- Complicated individual components
- Protected Intellectual Property (Black Box)
- Need a system calibration
- Testloop required

What we do in practice is
more a verification of
individual components



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