KROHNE

achieve more

Multiphase flow measurements

based on

Magnetic Resonance Technology

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Flow & Analyse event 2015

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1. KROHNE
2. Multiphase flow in the oil industry
3. Magnetic Resonance
4. Flow measurements
5. Performance
6. Conclusions and Outlook

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Agenda

KROHNE:

- Supplier of innovative measurement solutions for the process industry
- Founded in 1921
- 100% family owned
- World wide presence (> 3000 employees)

- In Dordrecht (NL): R&D and production of flow meters (>400 employees)

KROHNE:
Product portfolio

Flow measurement


Level measurement


Pressure measurement


Temperature measurement

Analysis products


Communications


KROHNE Services


Systems for marine industry


Systems for oil and gas industry

KROHNE:

New development

Flow measurement

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- Multiphase flow measurement
- Oil and gas industry
- Magnetic Resonance

Collaboration between
SHELL and KROHNE

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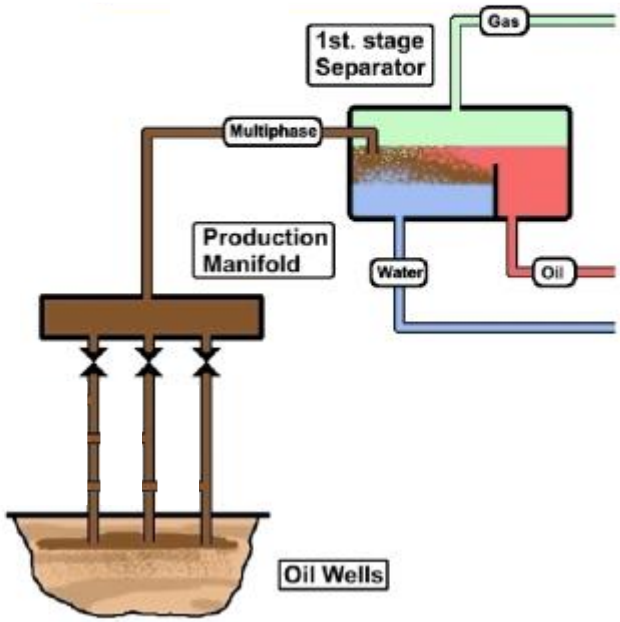
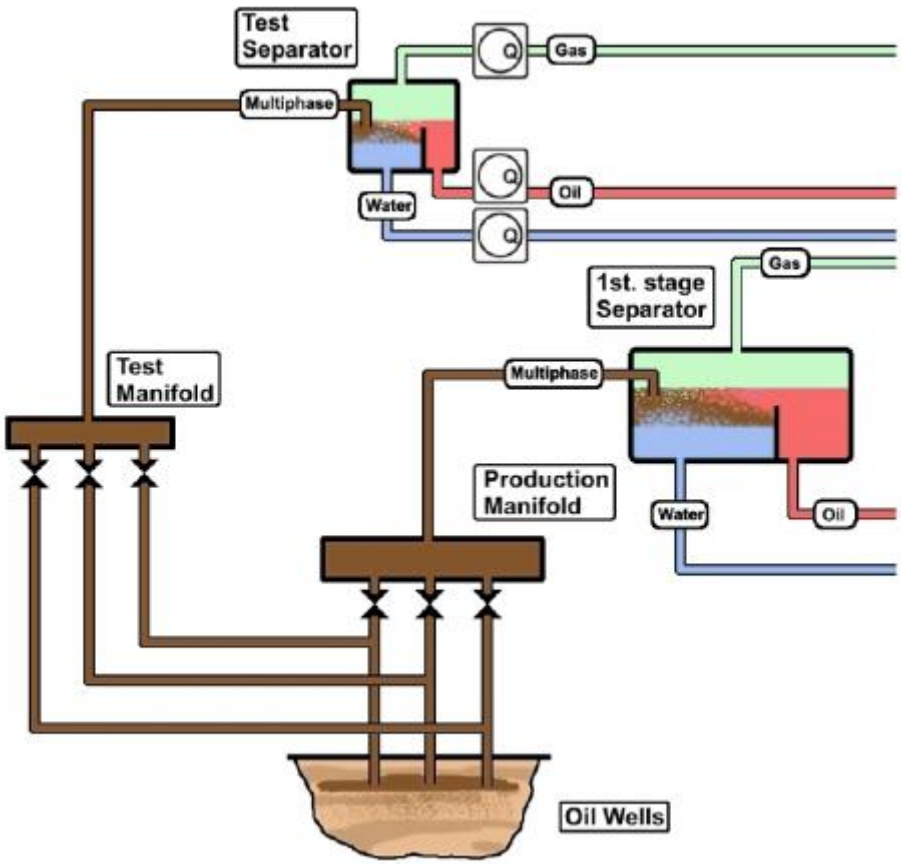
Multiphase Flow Measurement in Oil Production



NFOGM handbook of MPFM

- Over 800,000 oil wells world wide
- Oil wells produce a mixture of oil, water and gas.
- Multiple well producing to one main production line (sometimes up to 40!)
- Sometimes wells are owned by different companies
- Separation takes place on ***comingled*** flow
- Information is needed on flow performance of ***individual wells***:
  - *Production allocation*
  - *Production optimization*

Multiphase Flow Measurement in Oil Production



NFOGM handbook of MPFM

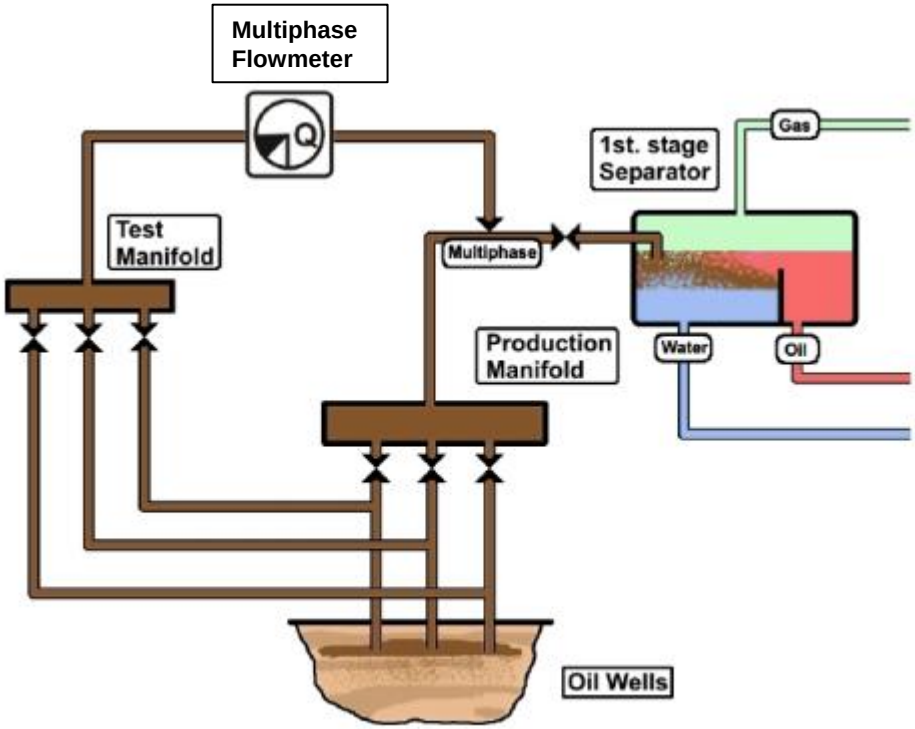
Test separator:

- Test manifold with bypass lines
- Individual well can be selected
- Single phase flowmeters to measure oil, water and gas

Note:

- Bulky configuration
  - Large space claim
  - Long stabilization time
- Regular maintenance needed
  - Valves
  - Calibration of flowmeters
- Limited rangeability regarding production rate:
  - Variations from well to well
  - Variations over lifetime

Multiphase Flow Measurement in Oil Production

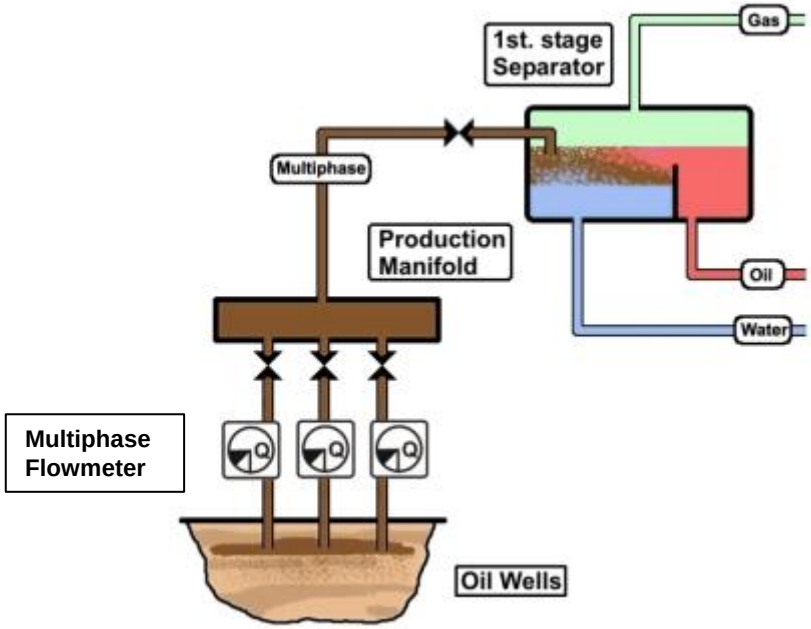


NFOGM handbook of MPFM

Multiphase flowmeter:

- One multiphase flowmeter
- Replaces test separator
- Test manifold and test line needed for well test purposes.
- Save on:
  - *Space*
  - *Weight*
  - *Cost*
  - *Test time*

Multiphase Flow Measurement in Oil Production



NFOGM handbook of MPFM

Multiple multiphase flowmeters:

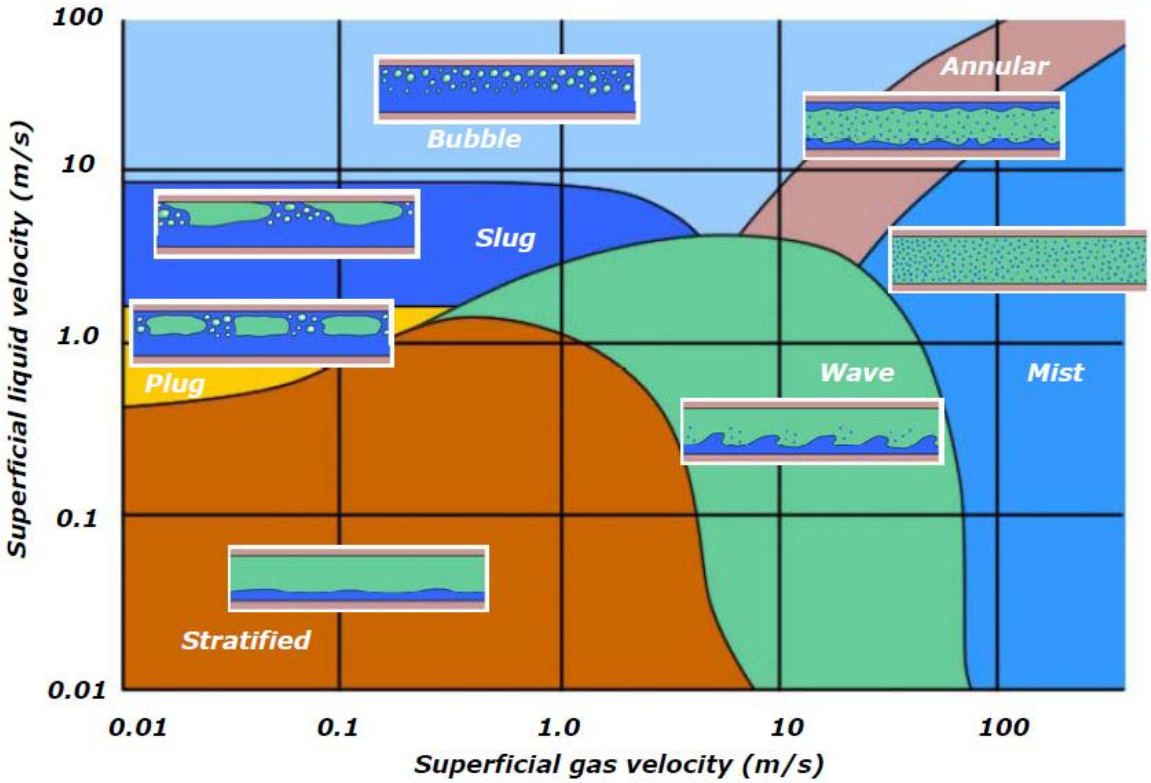
- One multiphase flowmeter per well
- Replaces test separator and test manifold
- Installation close to the well head possible
- Continuously monitoring of production rate:
  - Well testing
  - Flow assurance
  - Allocation

Multiphase flow:

- Complex flow, several different flow regimes
- Heavy unsteady flow conditions possible
- Oil / Water / Gas ratio can fluctuate

Challenge for flow measurement

→ magnetic resonance!



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Measurement principle: Magnetic Resonance

www.nobelprize.org

- Various Nobel prizes have been awarded related to magnetic resonance:
  - 1943, O. Stern: magnetic moment of a proton
  - 1944, I. Rabi: magnetic resonance (MR) of a proton
  - 1952, F. Bloch, E. Purcell: MR in liquids and solids
  - 1991, R. Ernst: MR spectroscopy (chemistry)
  - 2002, K. Wüthrich, Fenn, Tanaka: MR spectroscopy for resolving 3D structures
  - 2003, P. Lauterbur, P. Mansfield: Magnetic Resonance Imaging (Medical)

- Various instruments have been based on magnetic resonance, e.g.:

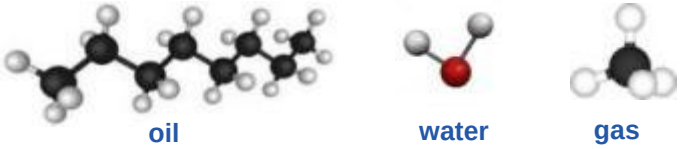
MRI medical scanner
www.philips.com

Table top MR analyzer
www.oxford-instruments.com

Measurement principle: Magnetic Resonance

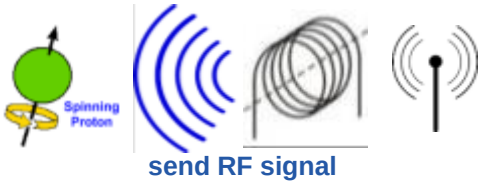
- Makes use of very fundamental physical property of atoms, and allows you to ‘count’ hydrogen atoms

- The principle:
  - Oil, water and gas contain hydrogen atoms



  - In a magnetic field the nucleus of the hydrogen atom (proton):
    - **aligns** with the applied magnetic field
    - **precesses** around magnetic field lines (frequency proportional to magnetic field strength).

  - When irradiated with radio waves of the same frequency, the protons resonate (react to the RF signal)



  - The protons absorb and re-emit the radio energy of the same frequency. The emitted signal (echo) is proportional to the number of protons

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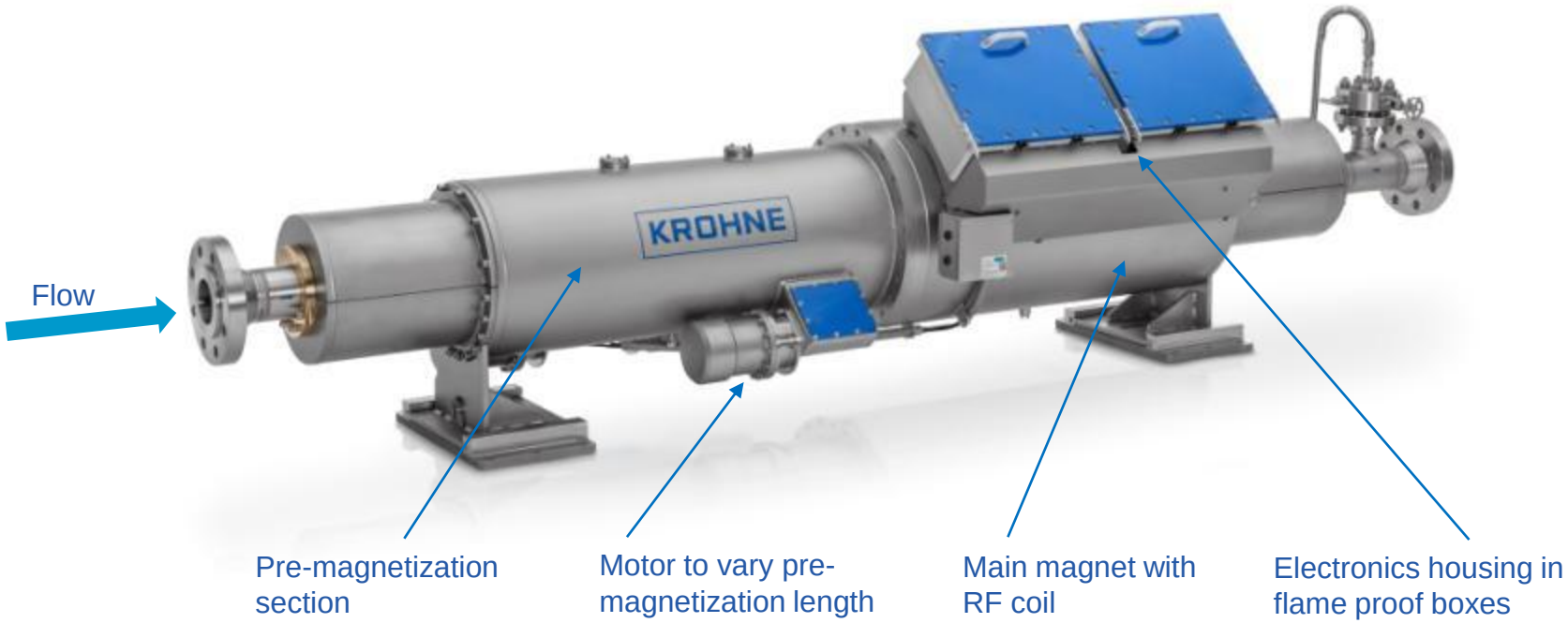
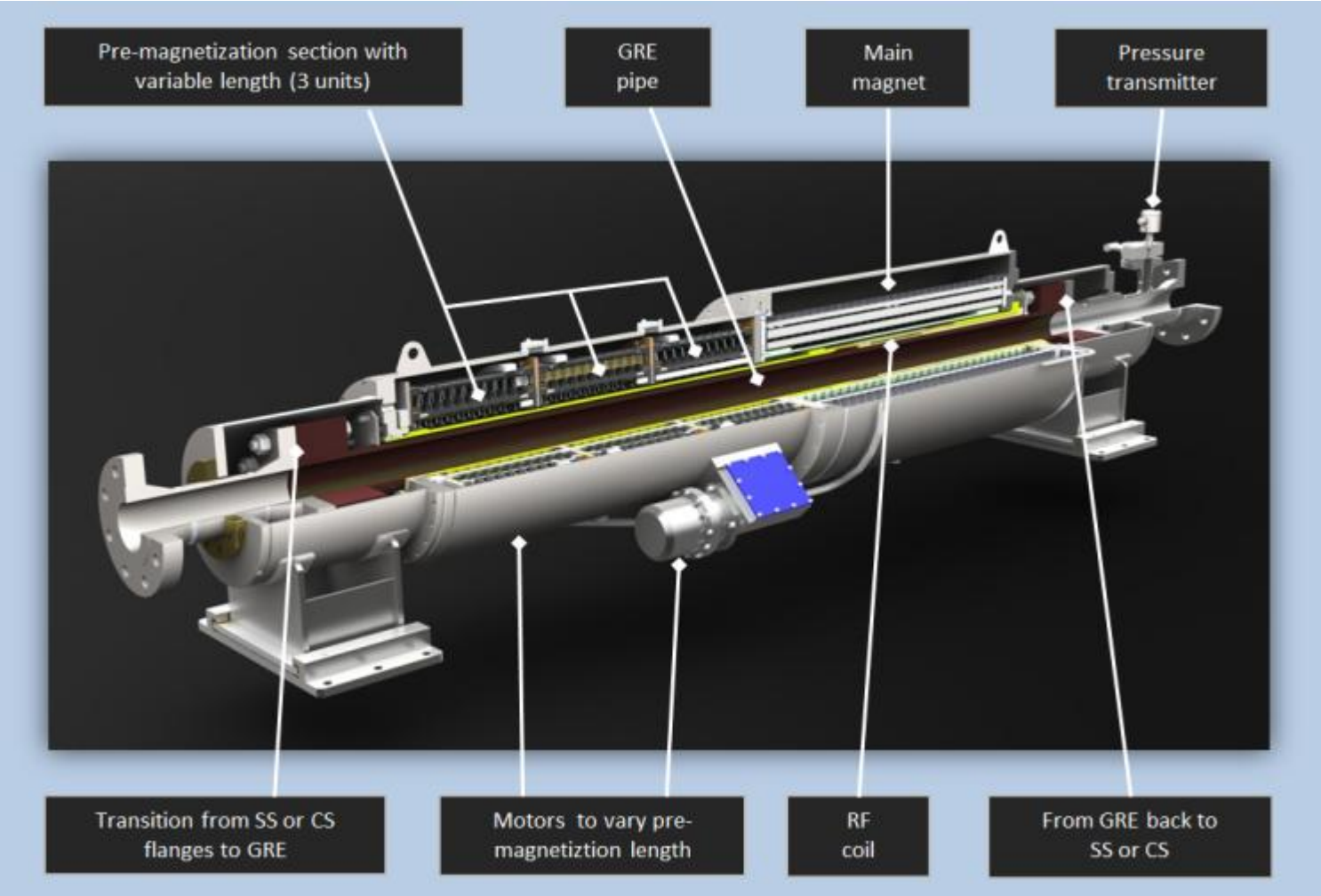
Mechanical Design:

- 100mm (4inch), full bore pipe, horizontal configuration, length approx. 3.5m.
- Ambient operating temperature: -40°C to + 65°C, process temperature: 93 °C
- Process pressure: 100 bar
- All electronics mounted directly on the flowmeter in two flame-proof boxes



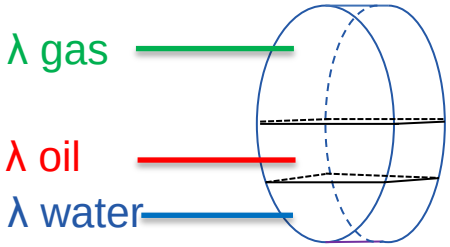
Mechanical design (interior)



MR measurement principle for flow measurements

- In the flow meter, we are mainly measuring 2 properties:

1. The fraction (λ) of oil, water and gas is in the measurement section

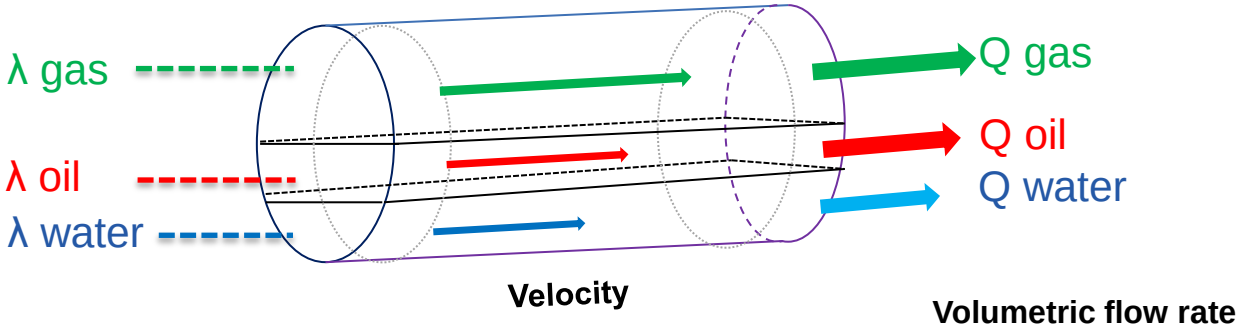


MR measurement principle for flow measurements

- In the flow meter, we are mainly measuring 2 properties:

1. The fraction (λ) of oil, water and gas is in the measurement section
2. What is the velocity (v) at which it travels

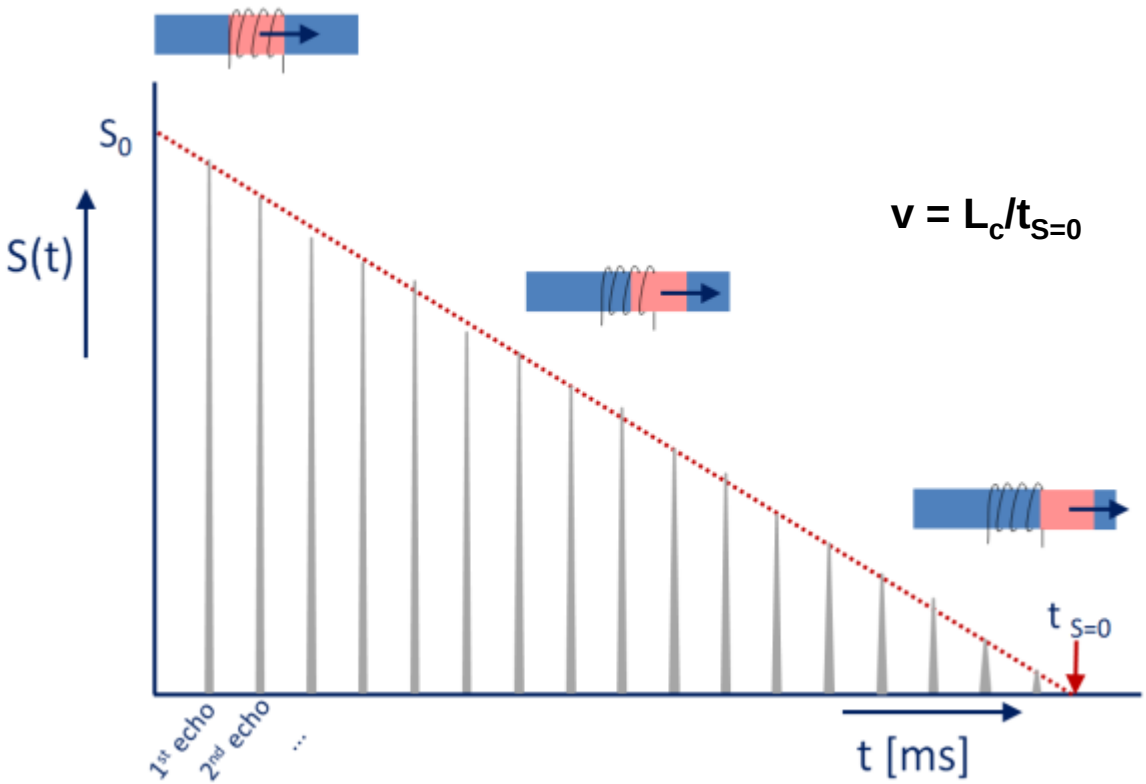
- From this data the volumetric flow rates (Q) can be calculated



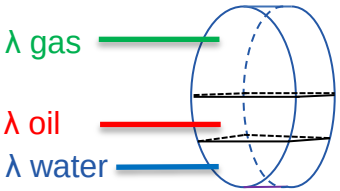
1) Measurement of liquid and gas velocity

Fluid Velocity determination:

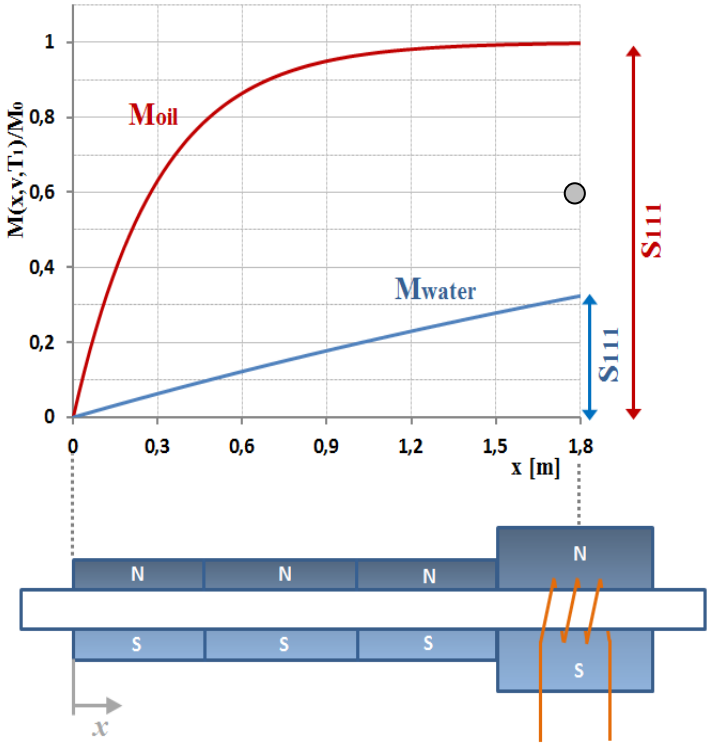
- ‘Convective decay’ method
- Excited protons are leaving the coil due to flow
- Measure the decrease in amplitude of the echoes



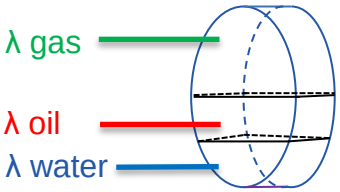
2) Measurement of oil and water fraction



- We make use of the fact that oil and water magnetize at a different rate (time constant)
- This difference creates a contrast between the oil and the water



2) Measurement of oil and water fraction



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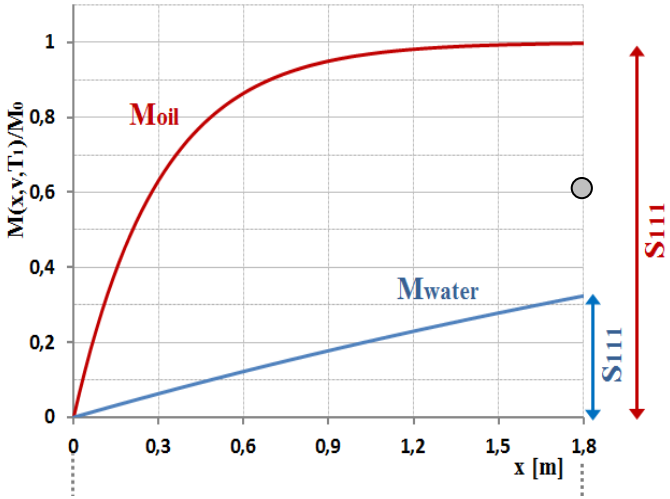

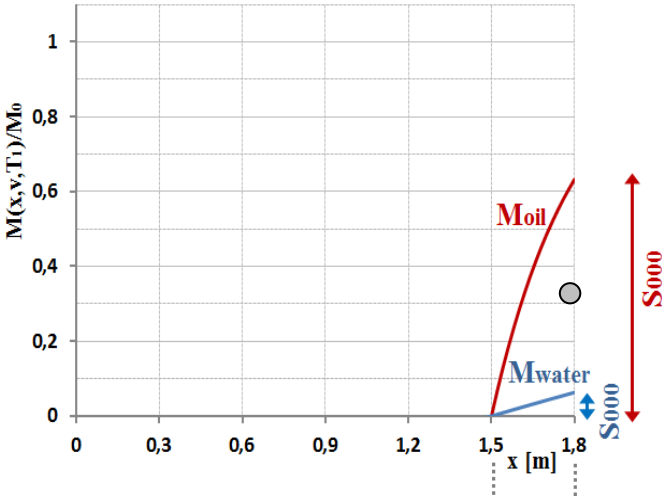

By measuring the signal for two different magnetization lengths, and calculating the ratio, the fraction of oil and water can be derived

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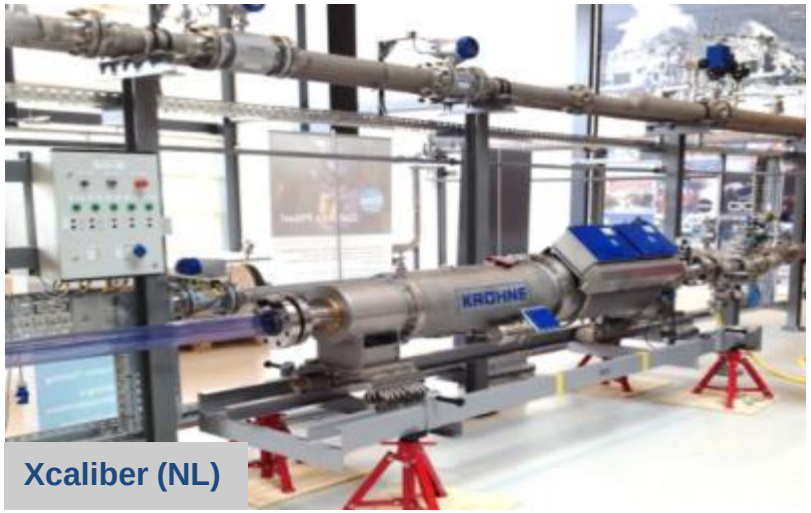
Overview (multiphase) flow test locations

SwRI (TX, USA)

Donau Shell (NL)

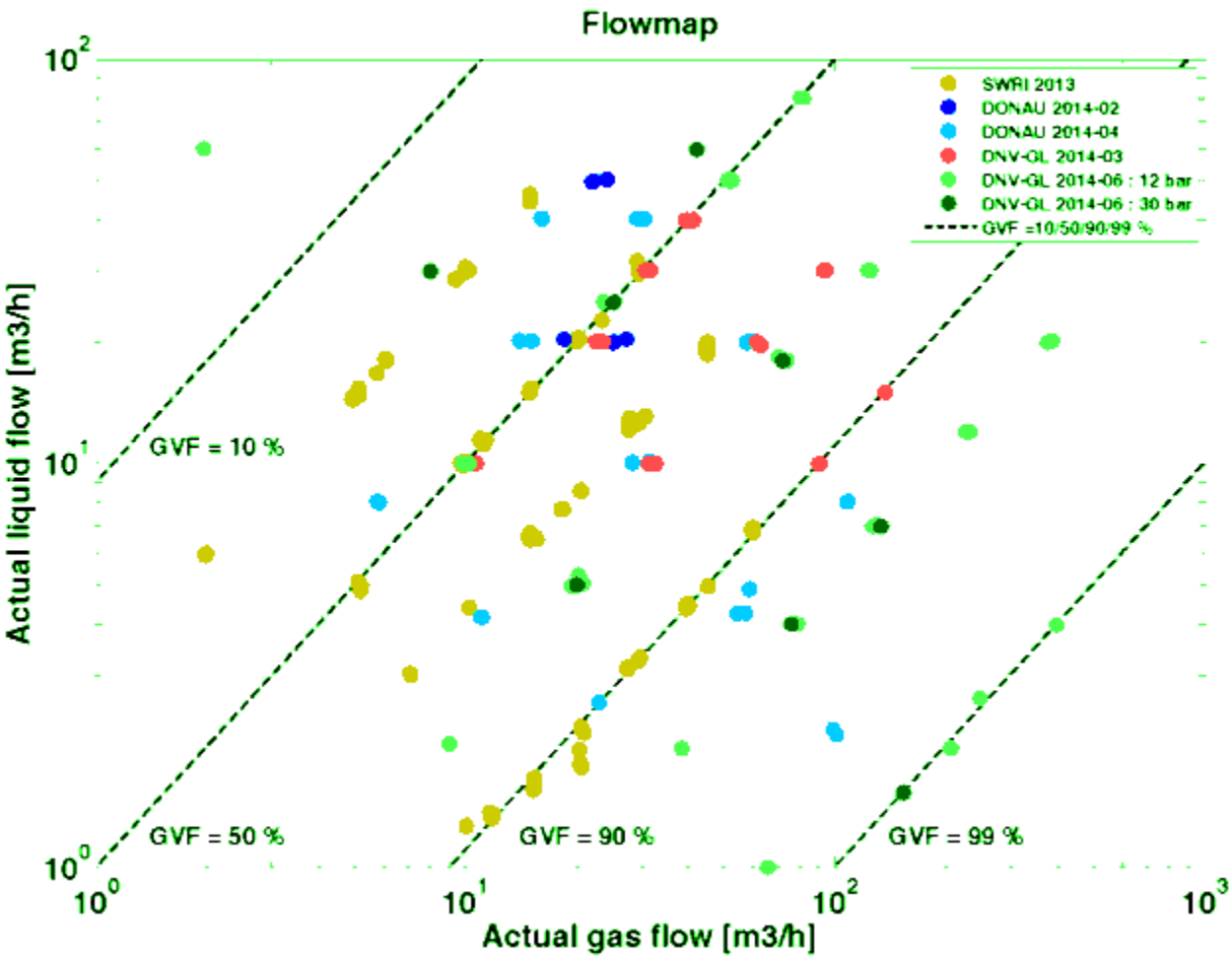


Xcaliber (NL)

DNV – GL (NL)

Performed tests

Overview test points



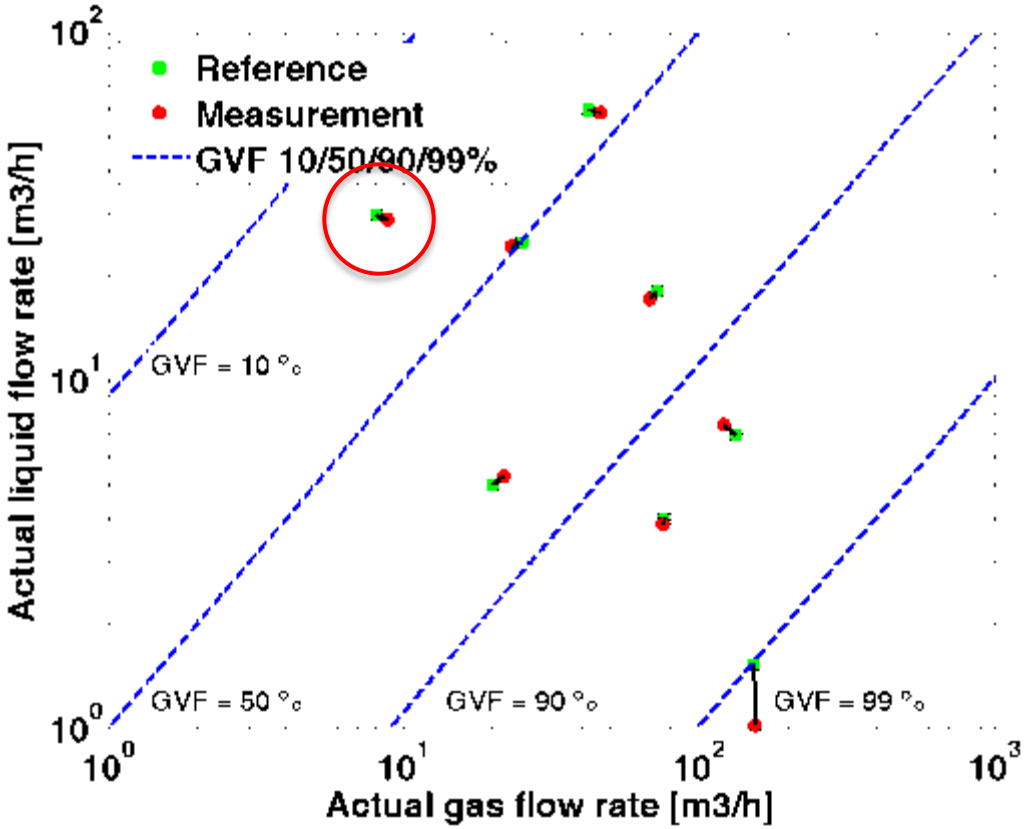
Parameter range:

Pressure:	3-90 barg
Temperature:	25-40 °C
Salinity:	0-250 g/l
Viscosity:	1-45 cSt

Performed tests; DNV-GL o/w/g

Good accuracy both in liquid and gas flow rate:

- No systematic error
- Good accuracy for both liquid and gas flow rates
- Accuracy achieved over large dynamic range



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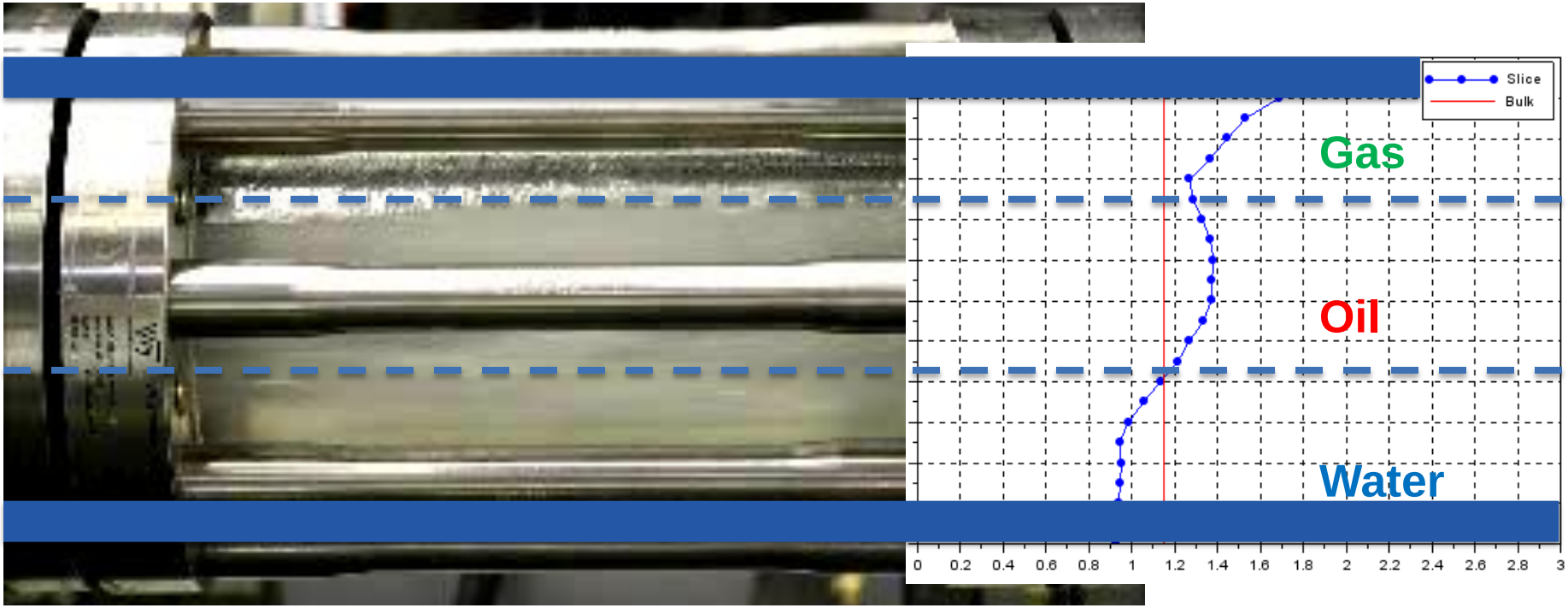


Velocity [m/s]

24 m³/h Oil, 6 m³/h Water, 8 Am³/h Gas, 4”pipe, P = 30 bar, T = 25 °C

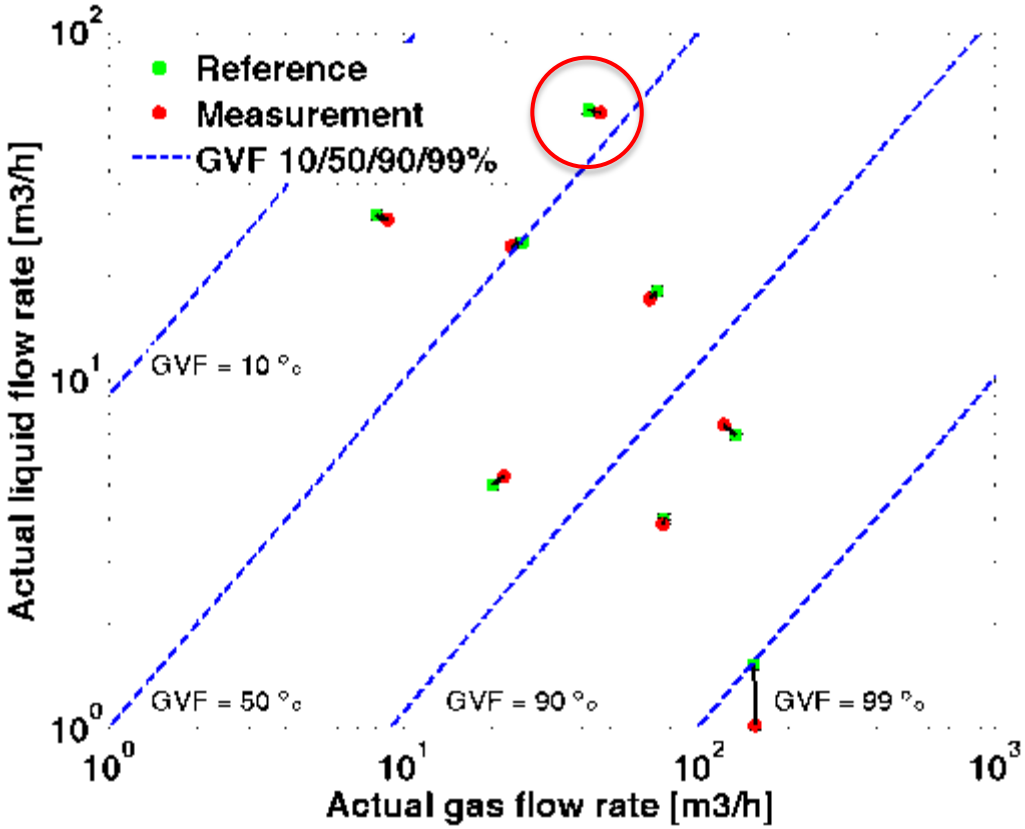
Performed tests; DNV-GL o/w/g

Gas results:

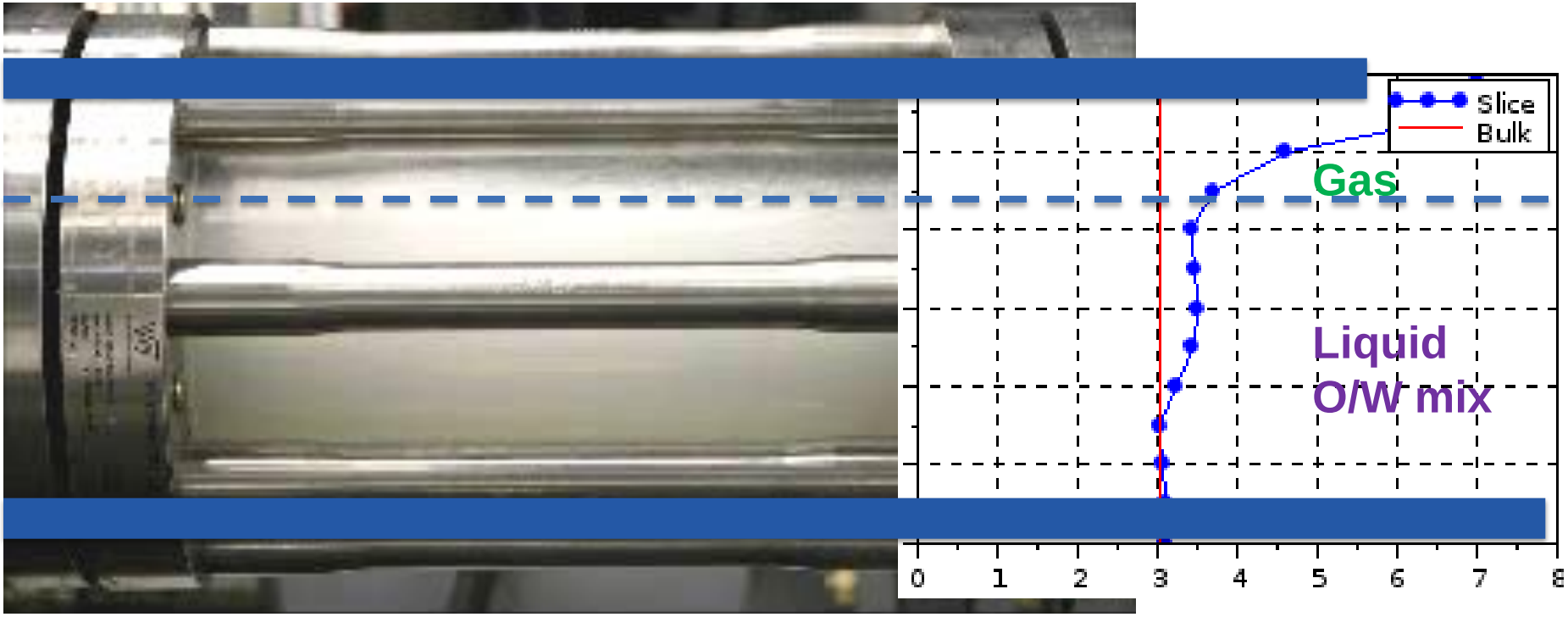
- Good performance
- No regime dependency

Liquid results:

- Good performance
- Increasing error GVF = 0.99



Performed tests; DNV-GL o/w/g

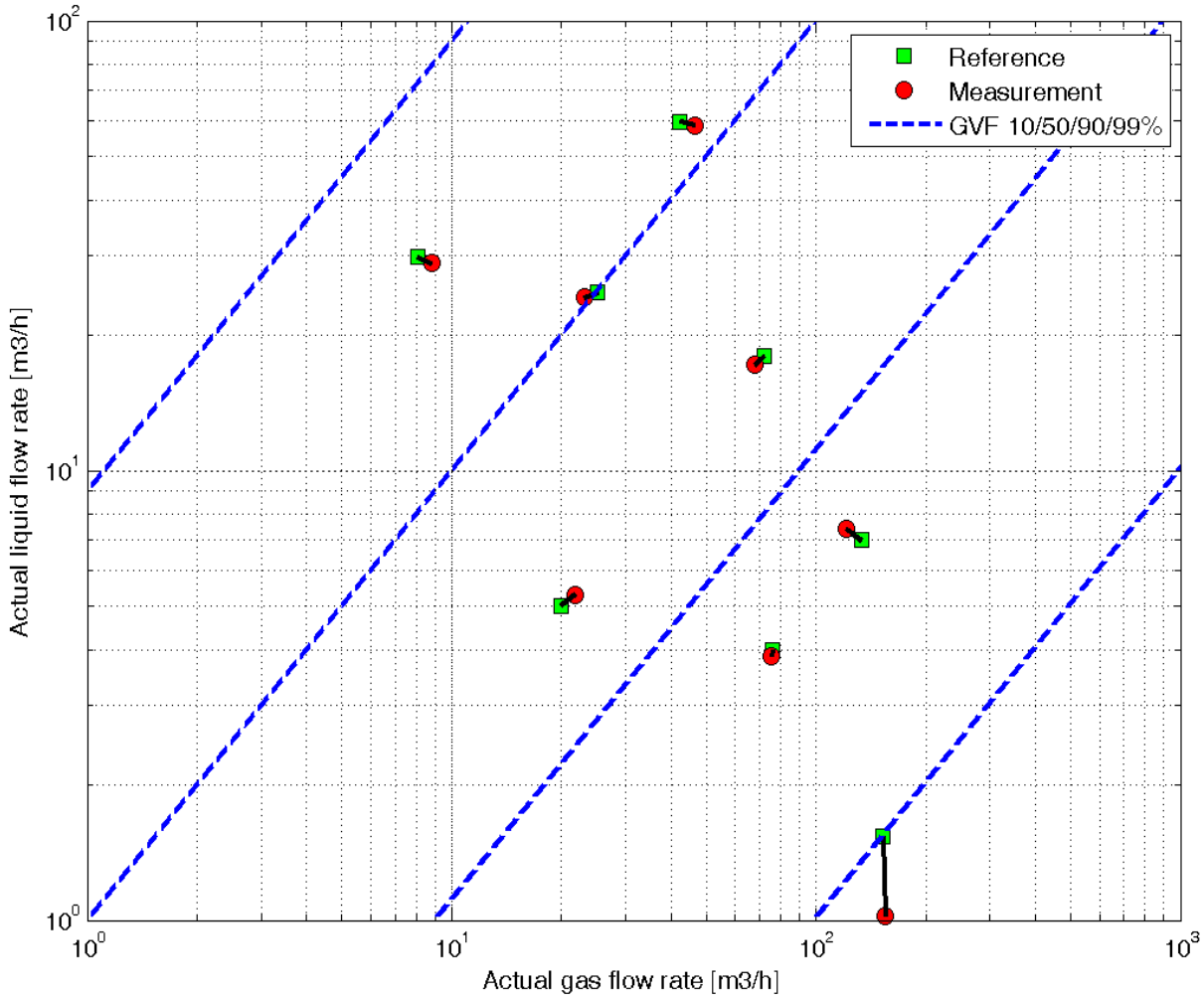


Velocity [m/s]

54 m³/h Oil, 6 m³/h Water, 60 Am³/h Gas, 4”pipe, P = 30 bar, T = 25 °C

Performed tests

Results plotted in flowmap *(for DNV-GL loop at 31 bar):*



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Field Test:

- NAM Rotterdam

The multiphase flow meter co-developed by Krohne and Shell and deployed at NAM Rotterdam

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Conclusions:

- M-PHASE 5000 is a multiphase flow meter for the oil and gas industry
- Measurement principle: Magnetic Resonance
- One single measurement principle for oil, water and gas flowrates
- Full bore design, no sensors inside pipe
- No radioactive sources
- Suited for a large range of flow conditions
- Easy to install

Outlook:

- Additional MR functionality, for example:
  - (spectral) analysis
  - imaging

KROHNE

achieve more

QUESTIONS?

Thank you for your attention!