MuFA – status

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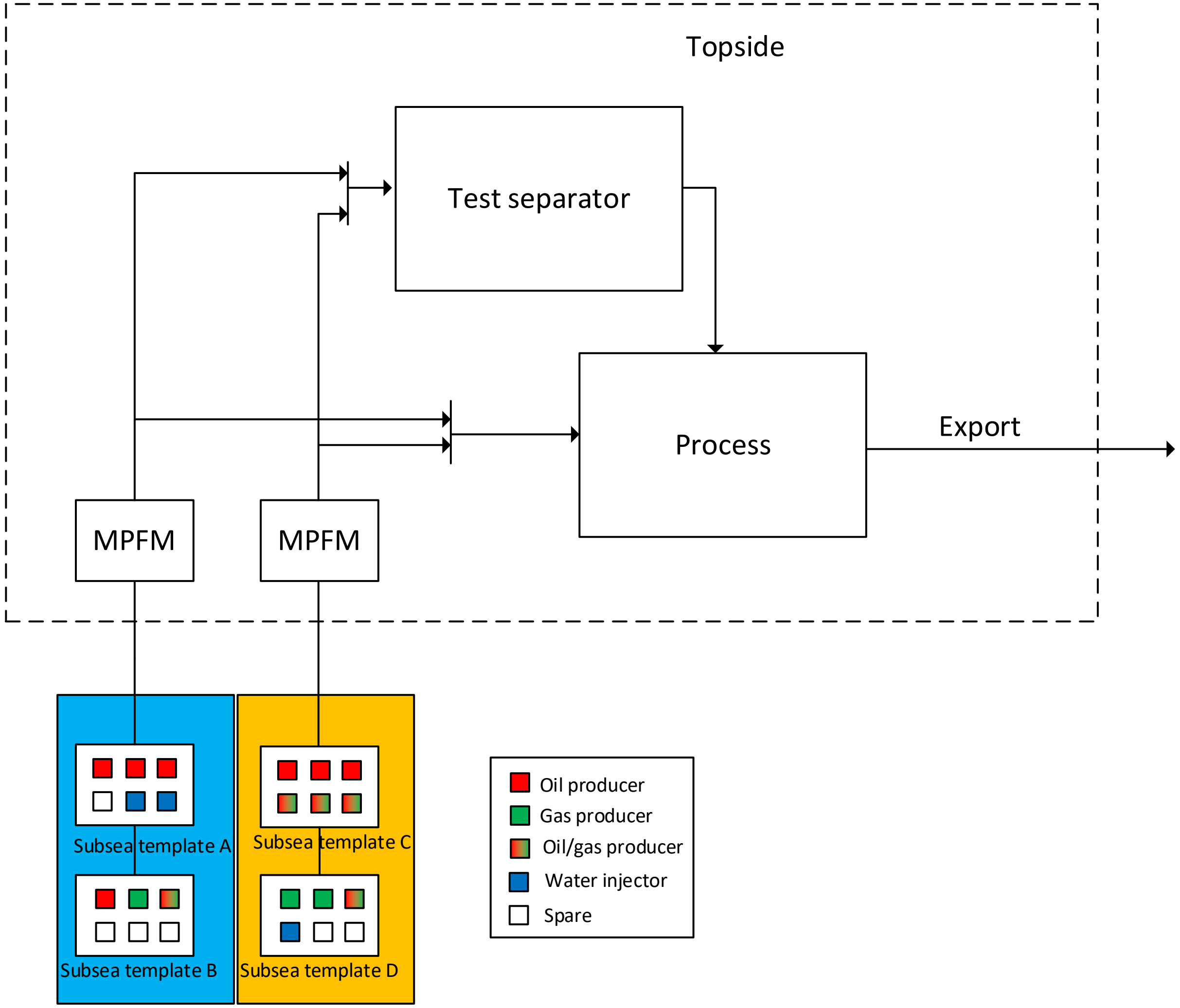
Outline

- Background – typical metering scope for subsea tie-ins
- Metering challenge and lack of updated input data
- Sampling and MuFA concept
- Some test results and summary

Typical metering scope for subsea tie-ins

- Subsea tie-ins with different ownership
  - Ownership allocation between subsea field and host
  - Ownership between subsea fields
  - Multiphase meters at inlet and possible to route to test separator for verification and sampling
- Measurement on each well for well allocation and allocation and production optimisation purposes
  - Multiphase meters on each well – verified against topside multiphase meter
  - Gas lift subsea single phase meters
  - Gas injectors subsea single phase meters
  - Water injector subsea single phase meters
- How can we ensure correct input data to the multiphase meters during changing conditions?

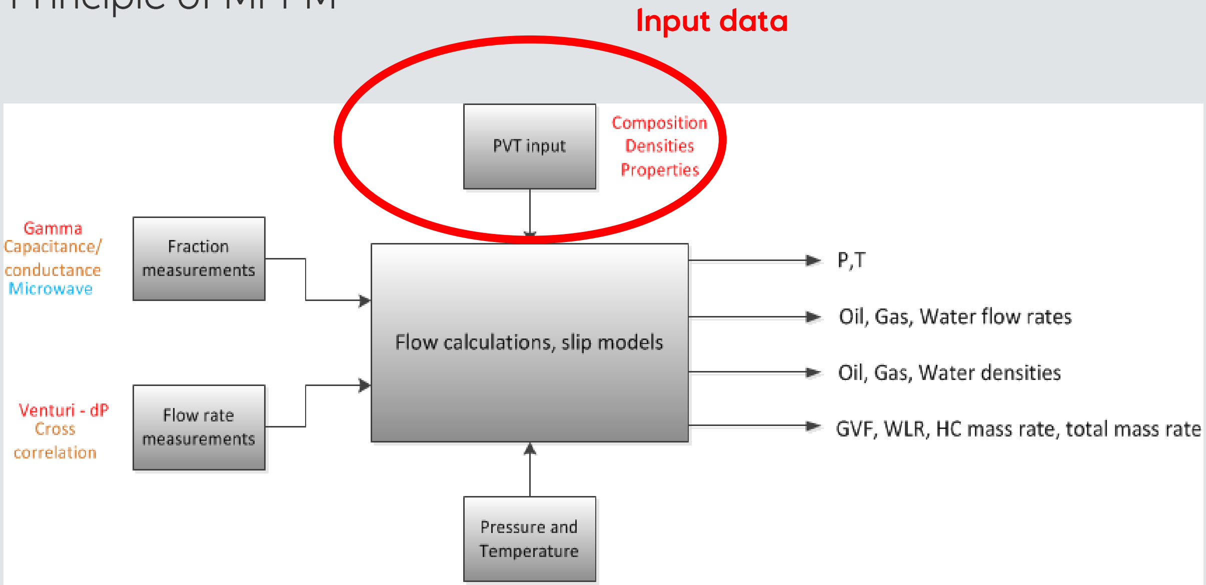


Subsea MPFM on each producer
Subsea SPFM on each injector

Metering challenges

- Production from several segments with multiple reservoir zones – ranging from oil producers to gas/condensate producers
- Fluid properties and compositions change with
    - Commingled production
    - Production from different zones
    - Gas injection
    - Gas lift
    - Water injection
- Multiphase meters require correct input data (fluid properties) to meet the performance
    - If not - meter will drift off and will result in measurement errors
- Significant production loss if samples are required from single producers due to shut-in of the other producers
- Test separator may not be available everywhere

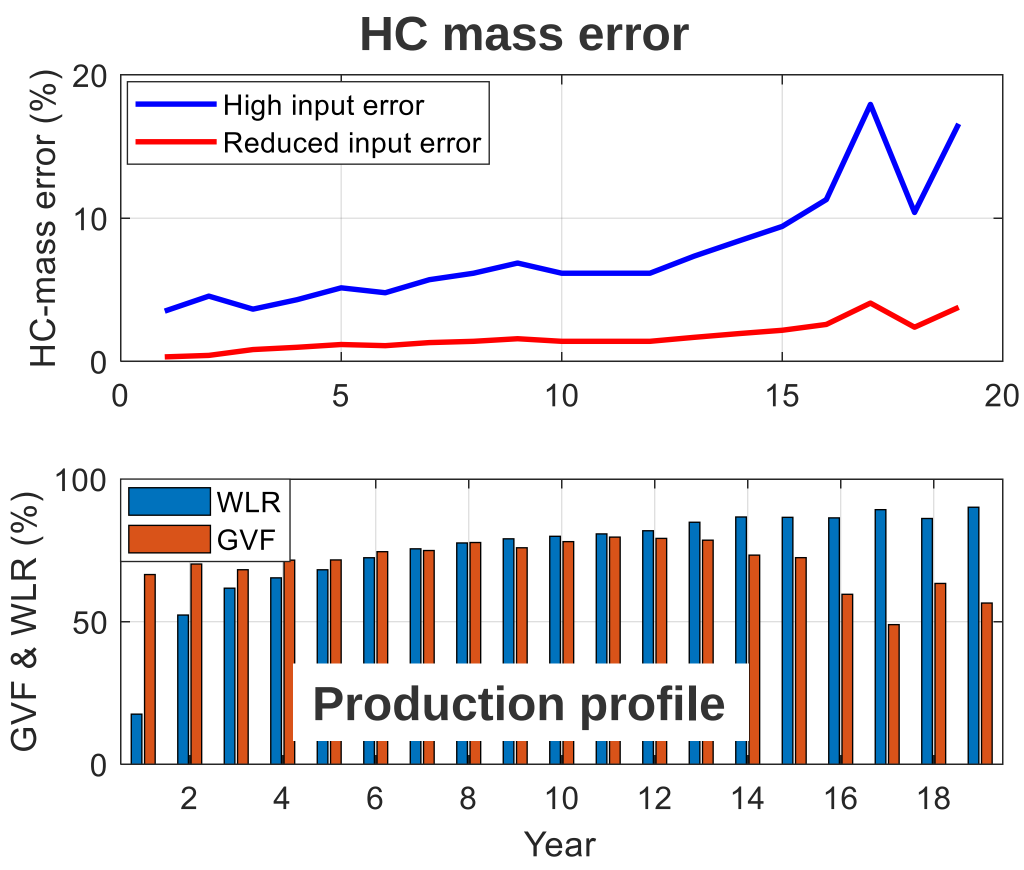
Principle of MPFM



Deviations in input data result in errors in fraction measurements (GVF,WLR) and in the split between phases

Uncertainty propagation

- Example: Estimated error in HC-mass



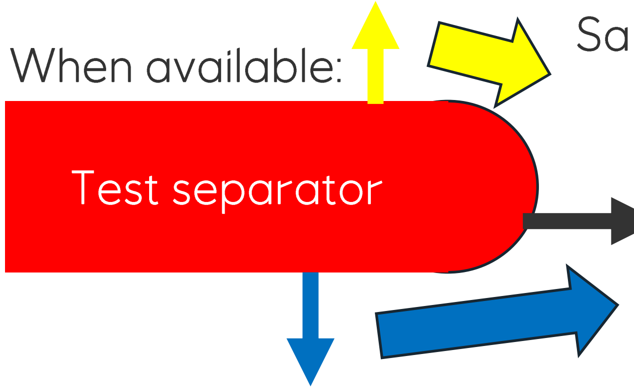
Case: High input error
10% density errors
5% salinity error

Case: Reduced input error
1% density errors
1% salinity error

GVF: Gas Volume Fraction
WLR: Water Liquid Ratio

Traditional method to capture fluid data vs MuFA

When available:



Sample

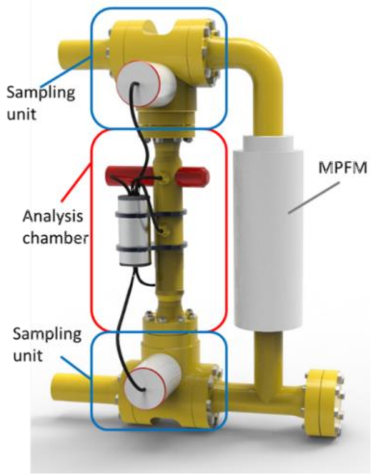
Lab analyses

Thermodynamic models

Quantity	General Equation	Isobaric $\Delta p = 0$	Isochoric $\Delta V = 0$	Isothermal $\Delta T = 0$	Adiabatic $Q = 0$
Work W	$\delta W = p dV$	$p\Delta V$	0	$nRT \ln \frac{V_2}{V_1}$	$C_V (T_1 - T_2)$
Heat Capacity C	(as for real gas)	$C_p = \frac{5}{2} nR$	$C_V = \frac{3}{2} nR$		
Internal Energy ΔU	$\Delta U = \frac{3}{2} nR\Delta T$	$Q - W$ $Q_p - p\Delta V$	Q $C_V (T_2 - T_1)$	0 $Q = W$	$-W$ $C_V (T_2 - T_1)$
Enthalpy ΔH	$H = U + pV$	$C_p (T_2 - T_1)$	$Q_V + V\Delta p$	0	$C_p (T_2 - T_1)$
Entropy ΔS	$ds = c_p \frac{dT}{T} - R \frac{dp}{p}$	$C_p \ln \frac{T_2}{T_1}$	$C_V \ln \frac{T_2}{T_1}$	$nR \ln \frac{V_2}{V_1}$ $\frac{Q}{T}$	$C_p \ln \frac{V_2}{V_1} + C_V \ln \frac{p_2}{p_1} = 0$

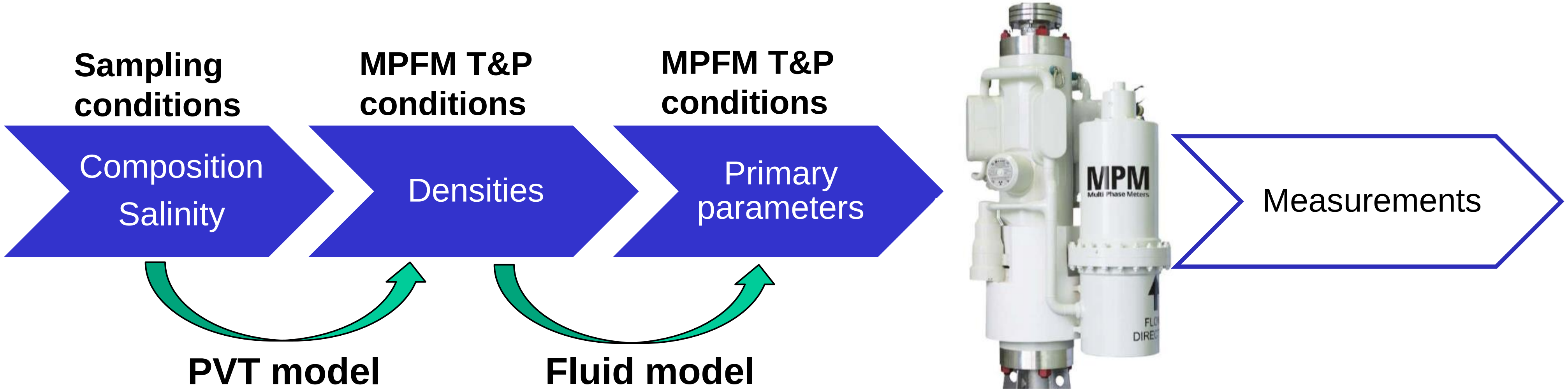
Improvement:

Multiphase flow analyser, MUFA



MPFM input parameters

- Fluid parameters typically estimated from HC composition
  - Additional uncertainty due to flashing/PVT calculations and fluid models



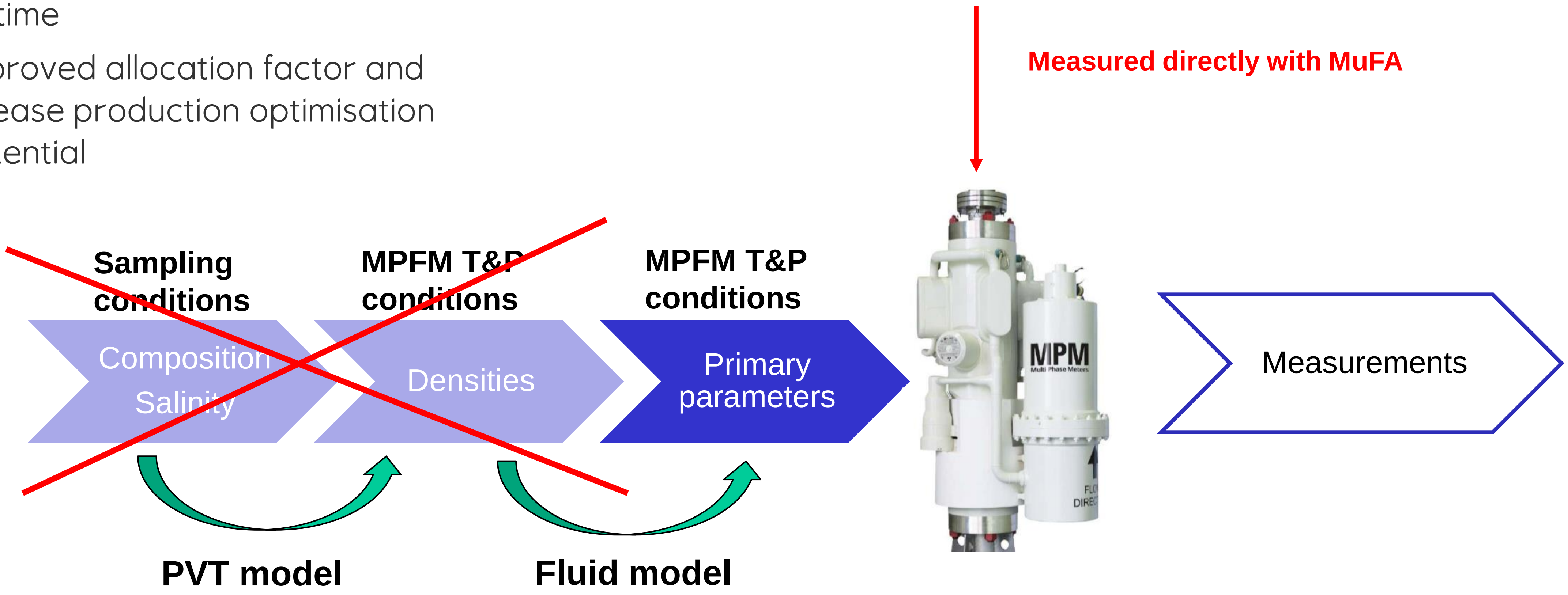
Primary input parameters
Oil: permittivity and attenuation constants
Gas: permittivity and attenuation constants
Water: conductivity and attenuation constants

MPFM input parameters

equinor

- Provide accurate fluid information for oil, gas and water over field lifetime
- Improved MPFM accuracy over field lifetime
- Improved allocation factor and release production optimisation potential

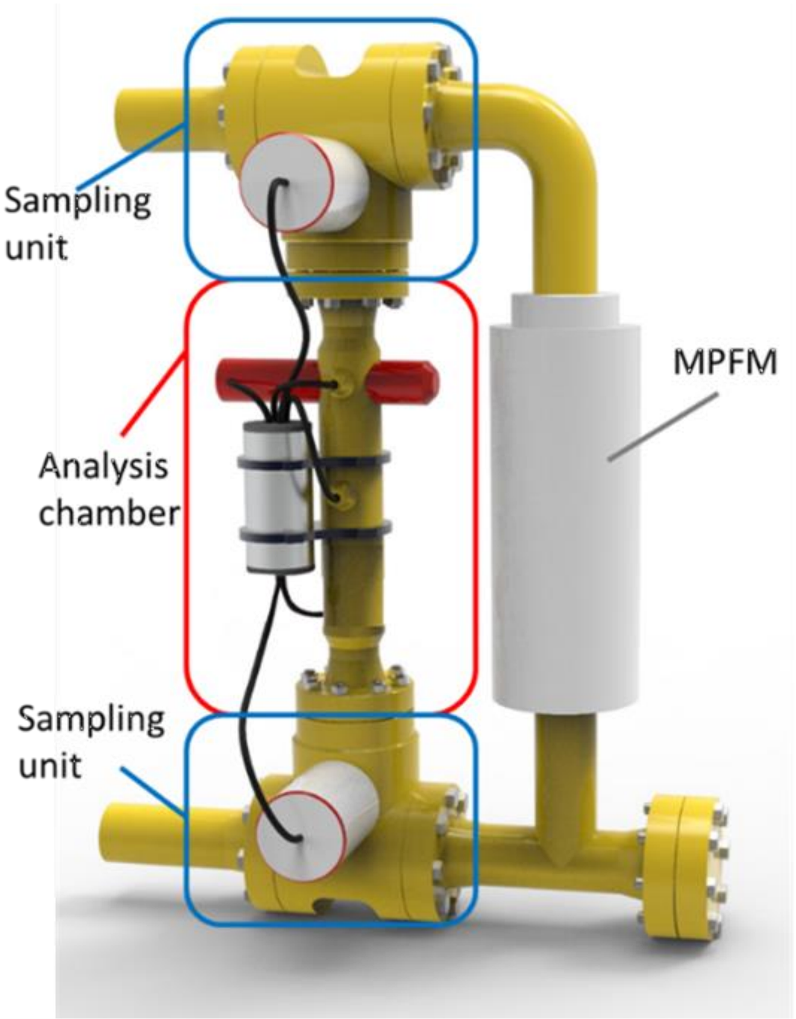
Primary input parameters
Oil: permittivity and attenuation coefficients
Gas: permittivity and attenuation coefficients
Water: conductivity and attenuation coefficients



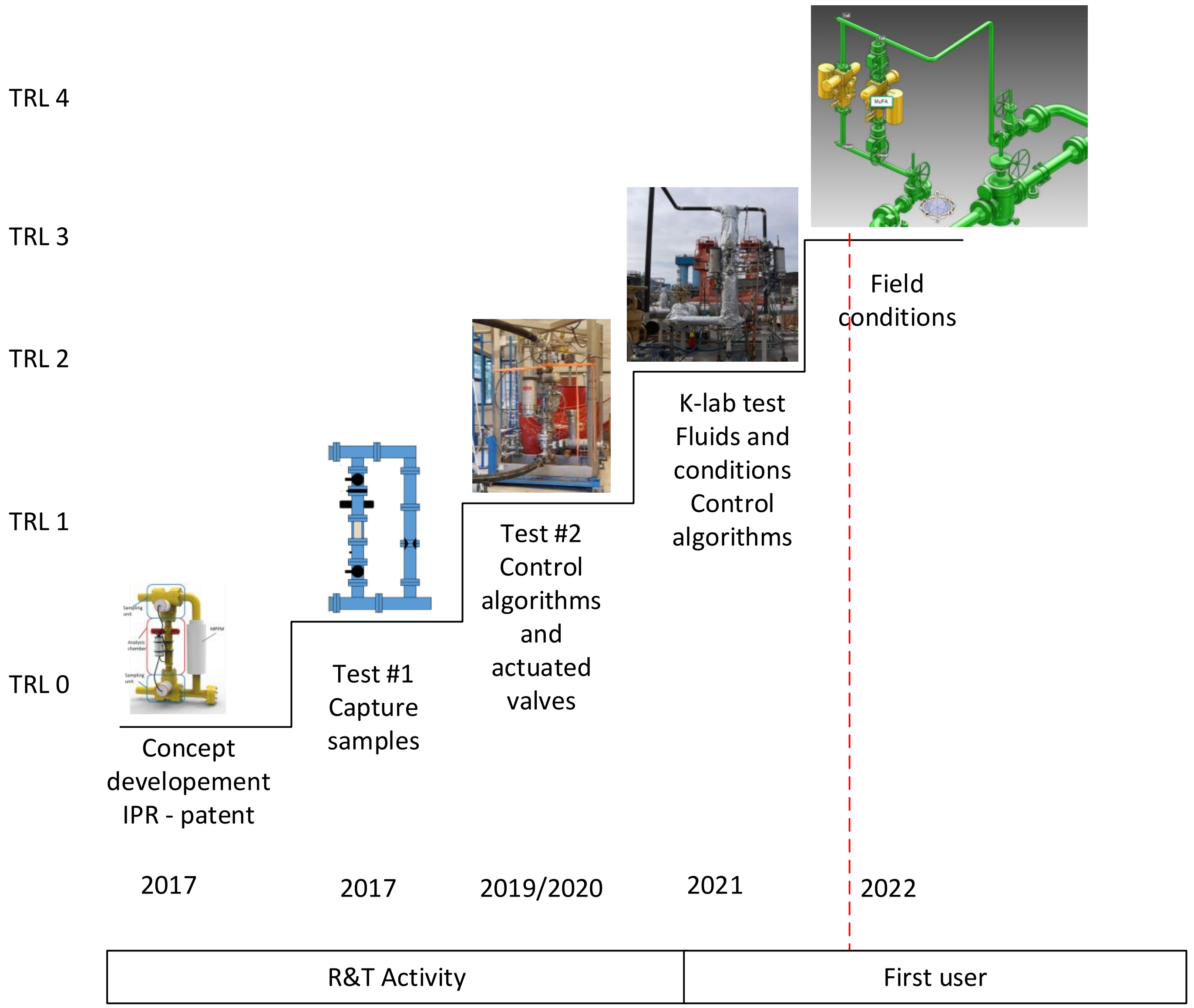
MPFM relies on accurate fluid information

MuFA concept

- MuFA – Multiphase Fluid Analyser
- Concept developed in cooperation between Norce and Equinor
- Available MPM meters have been used for testing at Norce and K-lab
- Sample the multiphase flow in a by-pass pipe
- Let fluids separate
- Measure primary input parameters directly at operating conditions
- Activated based on need or expected change of fluid properties – for instance starting production from a new well or from a new zone
- Fluids sampled and analysed one-by-one (sequentially) using one sensor set
- Fluid analysis without shut-in of production
- Consists of one simplified 3" meter, two (2") valves and control system
- Controlled with automatic sequences



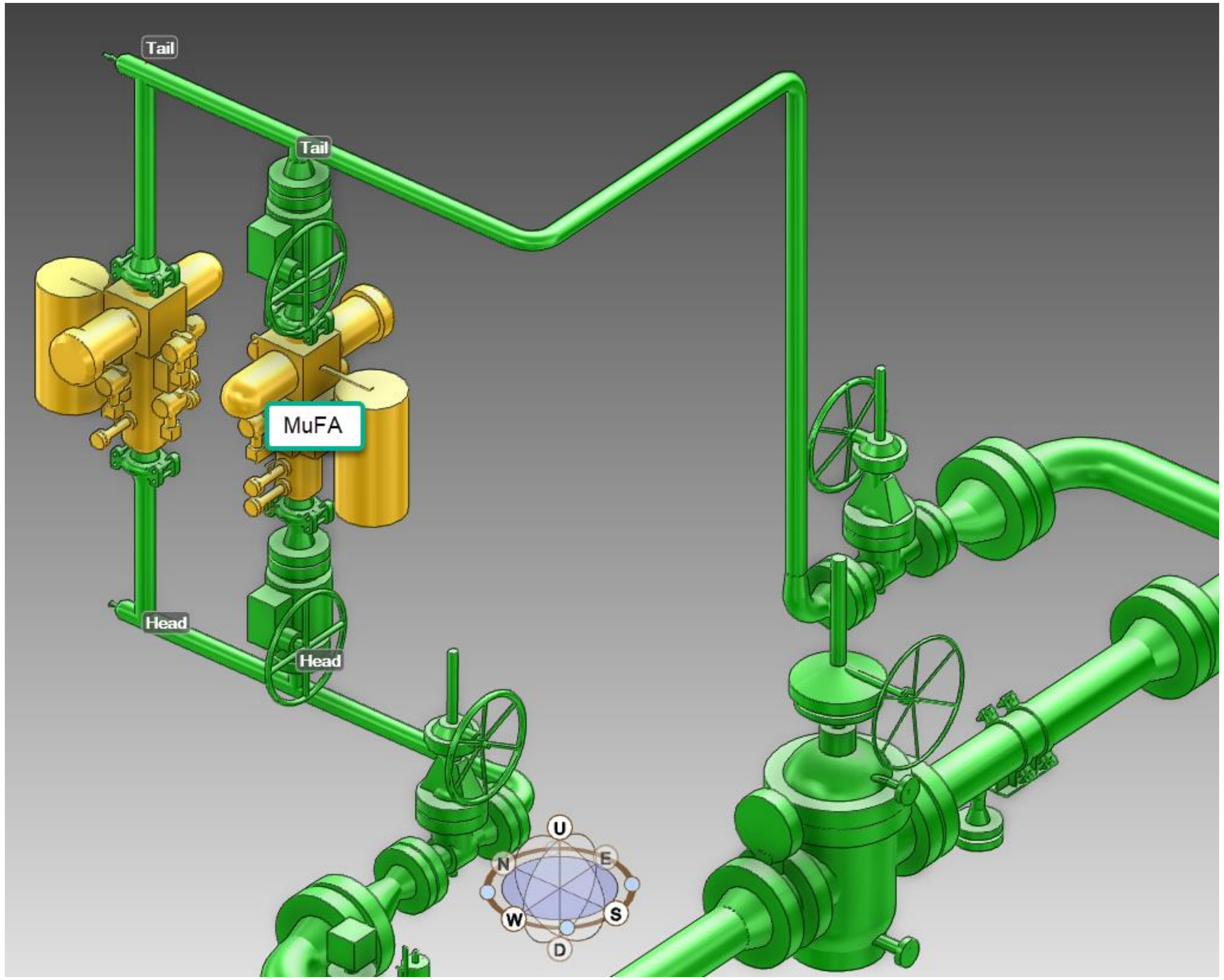
Road map


TRL 4
TRL 3
TRL 2
TRL 1
TRL 0
Concept developement IPR - patent
Test #1 Capture samples
Test #2 Control algorithms and actuated valves
K-lab test Fluids and conditions Control algorithms
Field conditions
2017
2017
2019/2020
2021
2022
R&T Activity
First user

K-lab Test setup MuFA (Multiphase Flow Analyser)

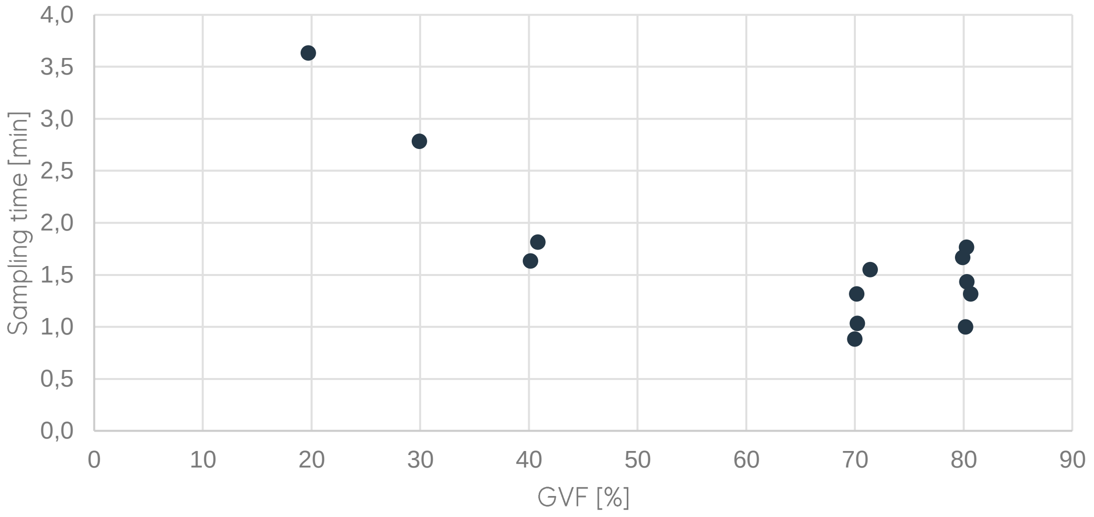
- Test performed at K-lab in the time period 18th to 26th of March 2021
- Total of 52 testruns
- Control algorithm for the valves developed by Norce and implemented at K-lab for the test, but manual valves
- Planned test at K-lab using actuated valves and heavier crude

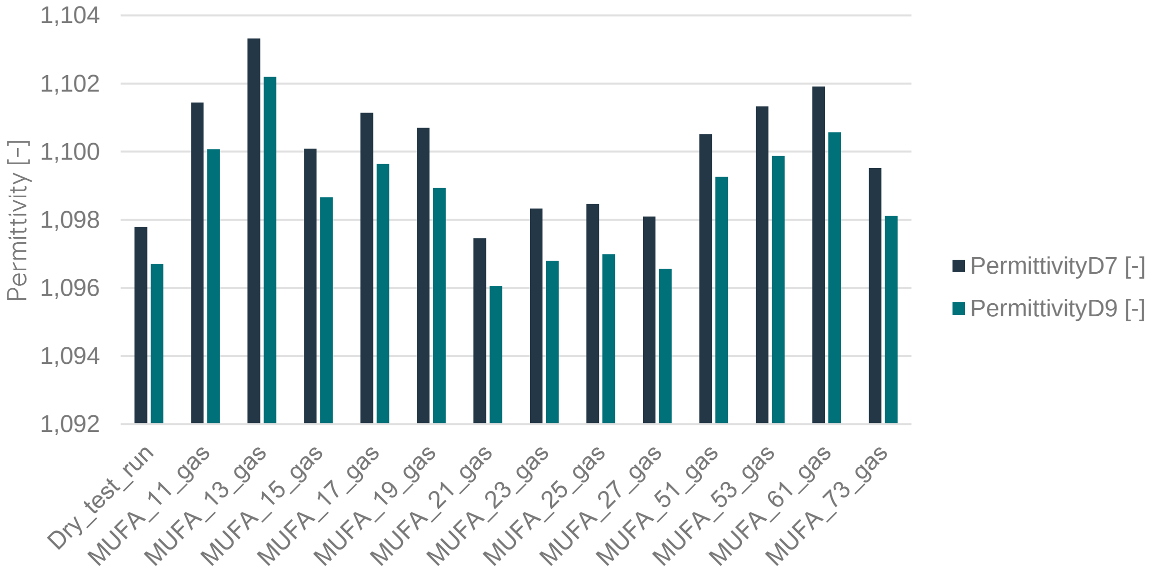
Conditions	
Pressure	~ 90 barg
Temperature	~ 60 °C
GVF	20, 30, 40, 50, 70, 80, 90 %
WLR	0, 20, 40, 60, 80, 100 %

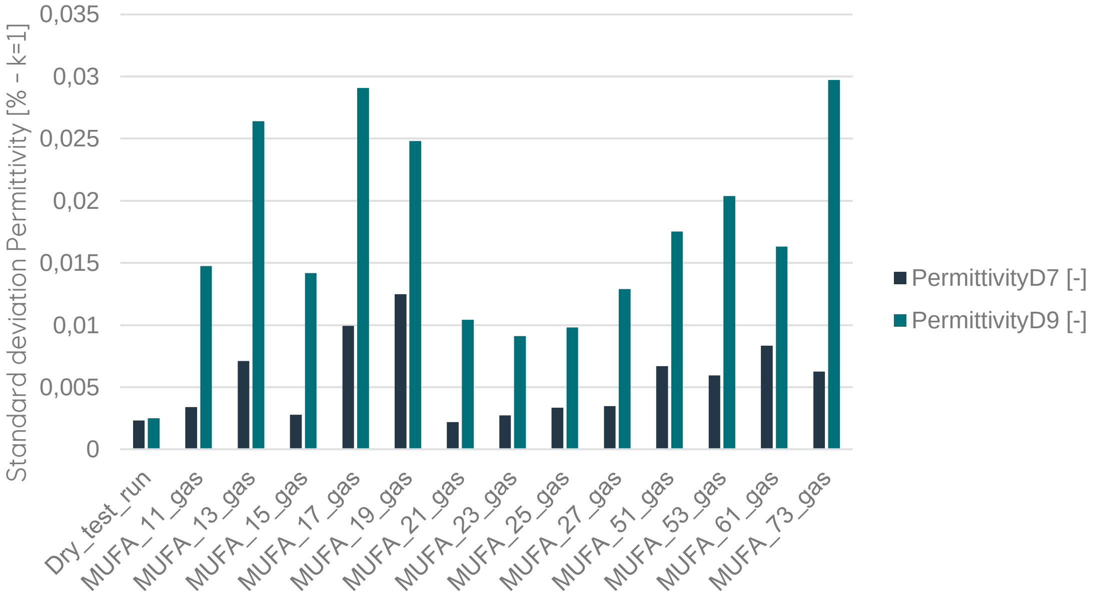


Gas sampling and analysis

- Quick sampling at all test points. Slightly higher sampling time at low GVF
- Stable permittivity readings

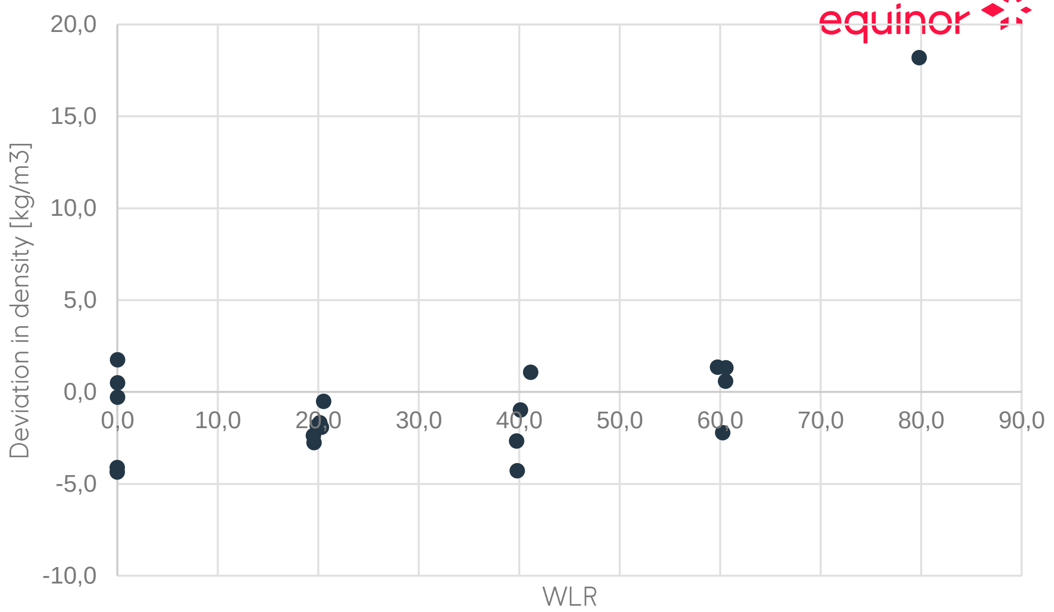


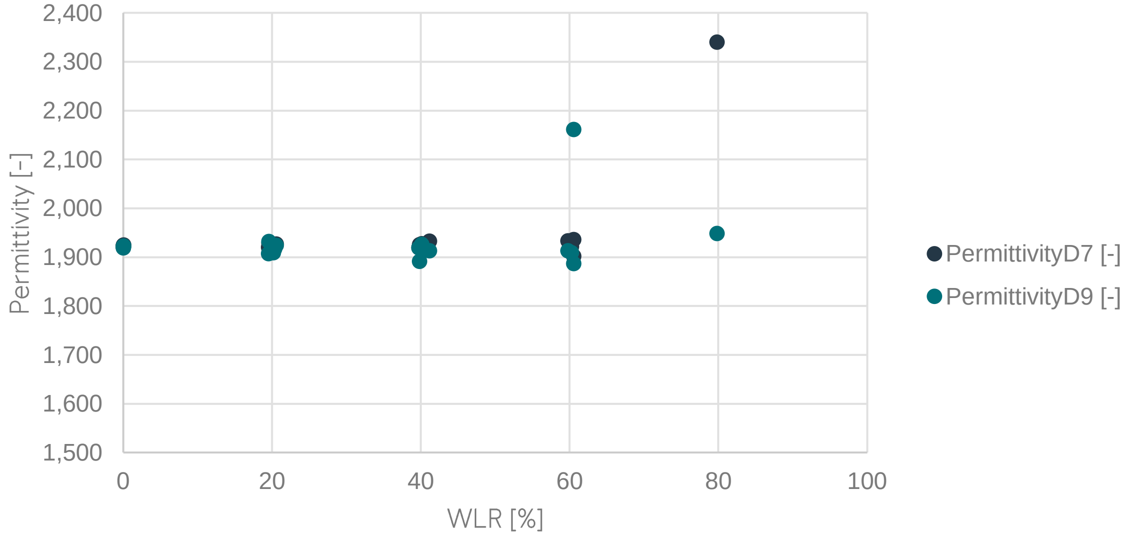


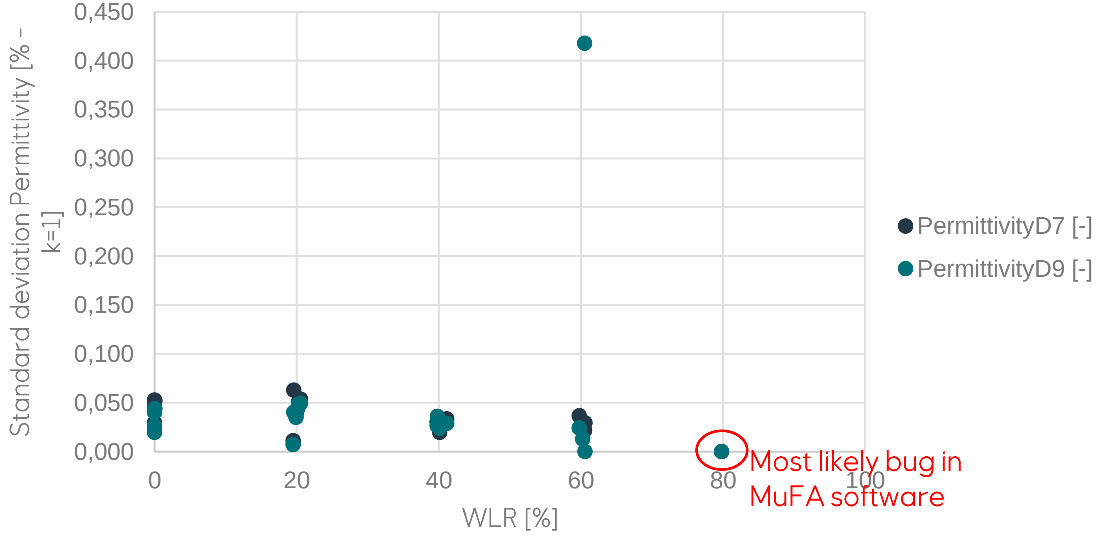


Condensate sampling and analysis

- Density deviation between MuFA gamma density and reference condensate density about ± 3 kg/m3 (+/- 0.5 %)
- Time to separate and stablise condensate from water – less than 45 minutes
- Expected to be longer with heavier crude – ongoing

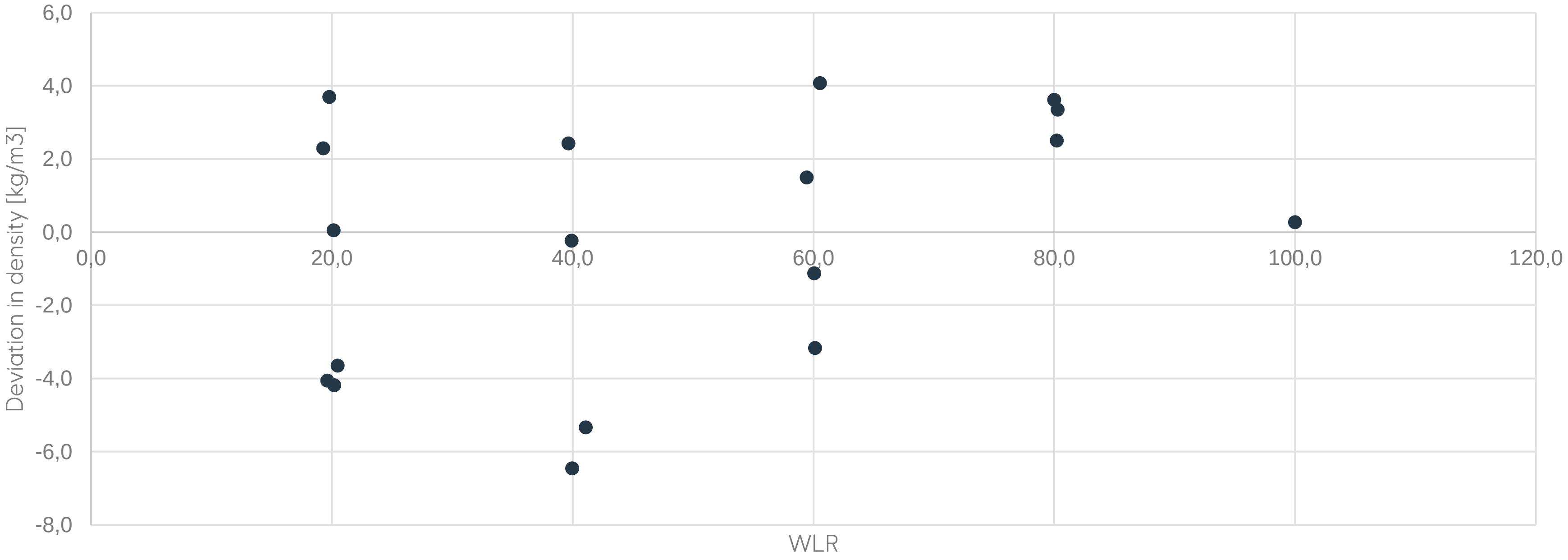






Water sampling and analysis

- Deviation between MuFA gamma density and reference water density was within ±6,5 kg/m3 (0,65 %) for all test points
- The density deviation may appear to be larger at lower WLR, can be due to reference density at these points, due to the use of a smaller coriolis meter at these points (pressure effect on coriolis meters)



Summary

- Main need is for subsea tie-in and for subsea MPFM, but can also be implemented for topside MPFM
- Simple concept – software and assembly of components using exsiting technologies
- Capturing fluid properties without any production loss
- Update input data in MPFM instantly without weeks for lab analysing and reporting
- Test results show sucessfully captures of all phases in a range of GVF and WLR at 90bar/60C (K-lab test) and accurate readings of fluid properties
- Due to pratical and economical reasons - no other alternatives exists
    - Minimize measurement errors in MPFM due to challenging production scenarios and complex field lay outs

Thank you!
Questions?