MuFA – MultiFluid Analyser

NFOGM Fagdag 30. mars 2023

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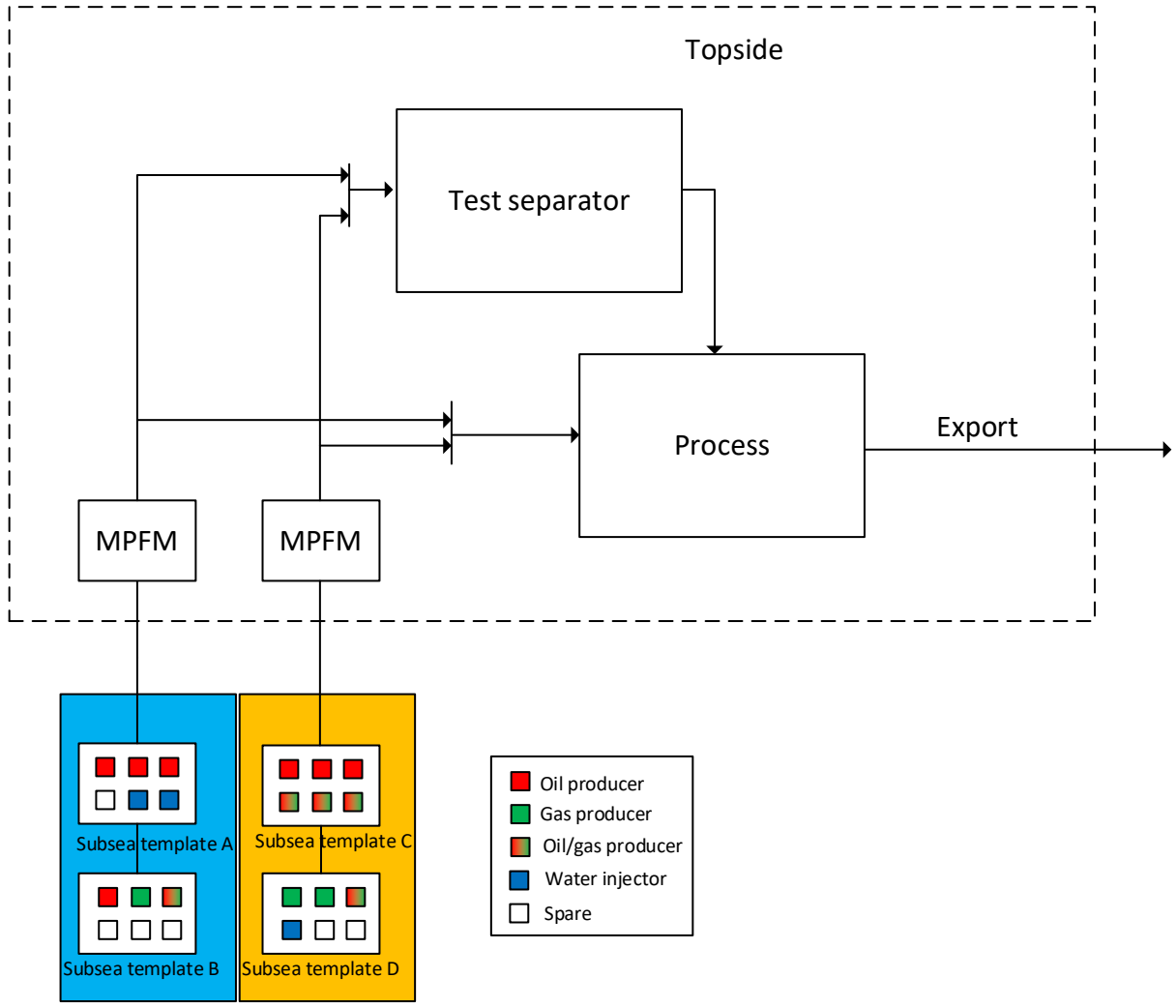
Topics

- Background
- Introduction to MuFA
- Test results from K-lab
- Residual risks
- Way forward
- TQP and Technology qualification report

Typical metering scope for subsea tie-ins

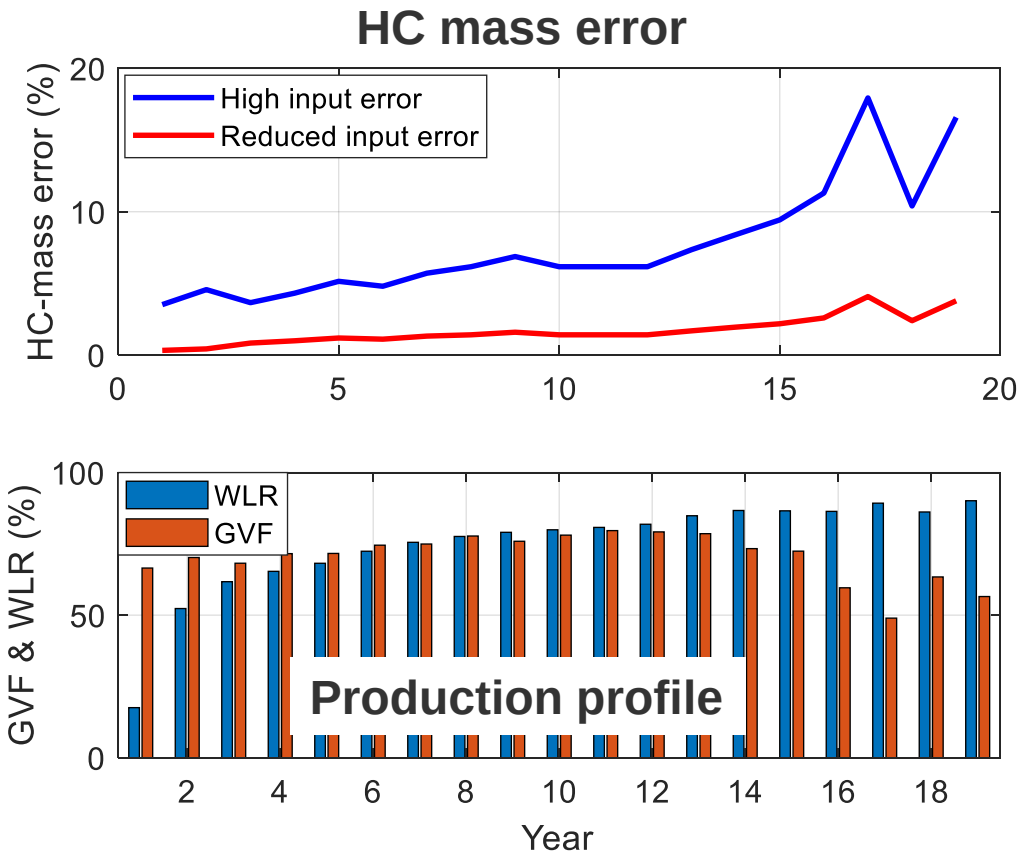
- Subsea tie-ins with different ownership
  - Ownership allocation between subsea field and host
  - Ownership between subsea fields
  - Multiphase meters at inlet and possible to route to test separator for verification and sampling
- Measurement on each well for well allocation and allocation and production 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

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

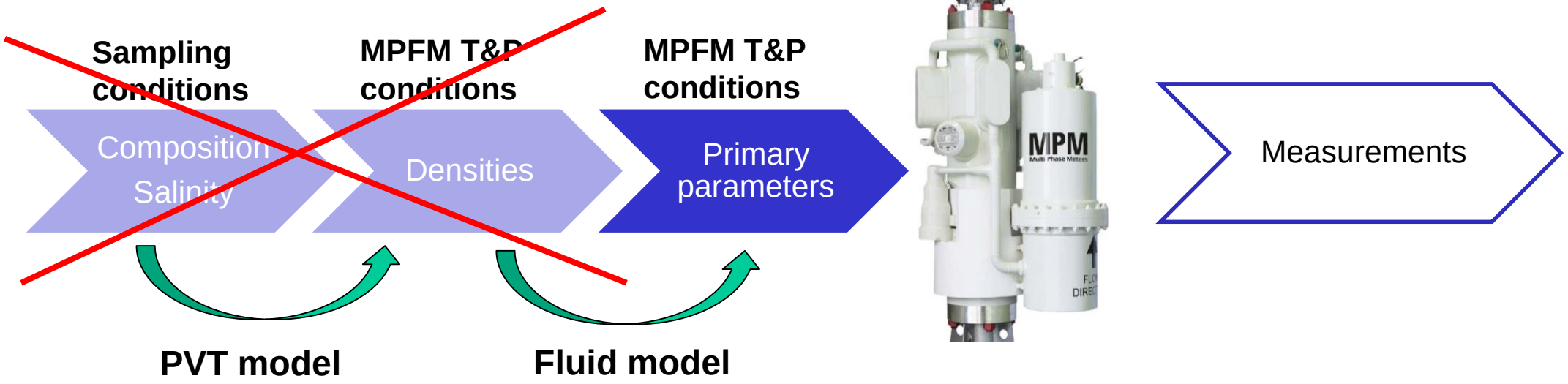
GVF: Gas Volume Fraction
WLR: Water Liquid Ratio

MPFM input parameters

- 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

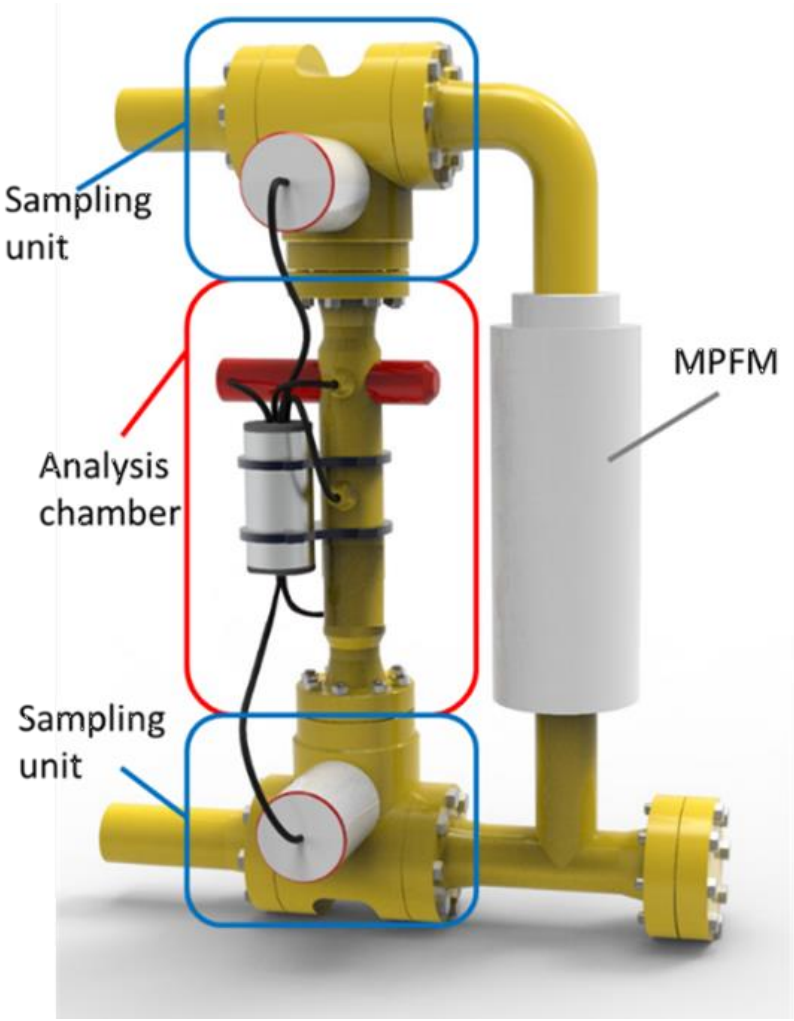
Measured directly with MuFA



MPFM relies on accurate fluid information

MuFA concept

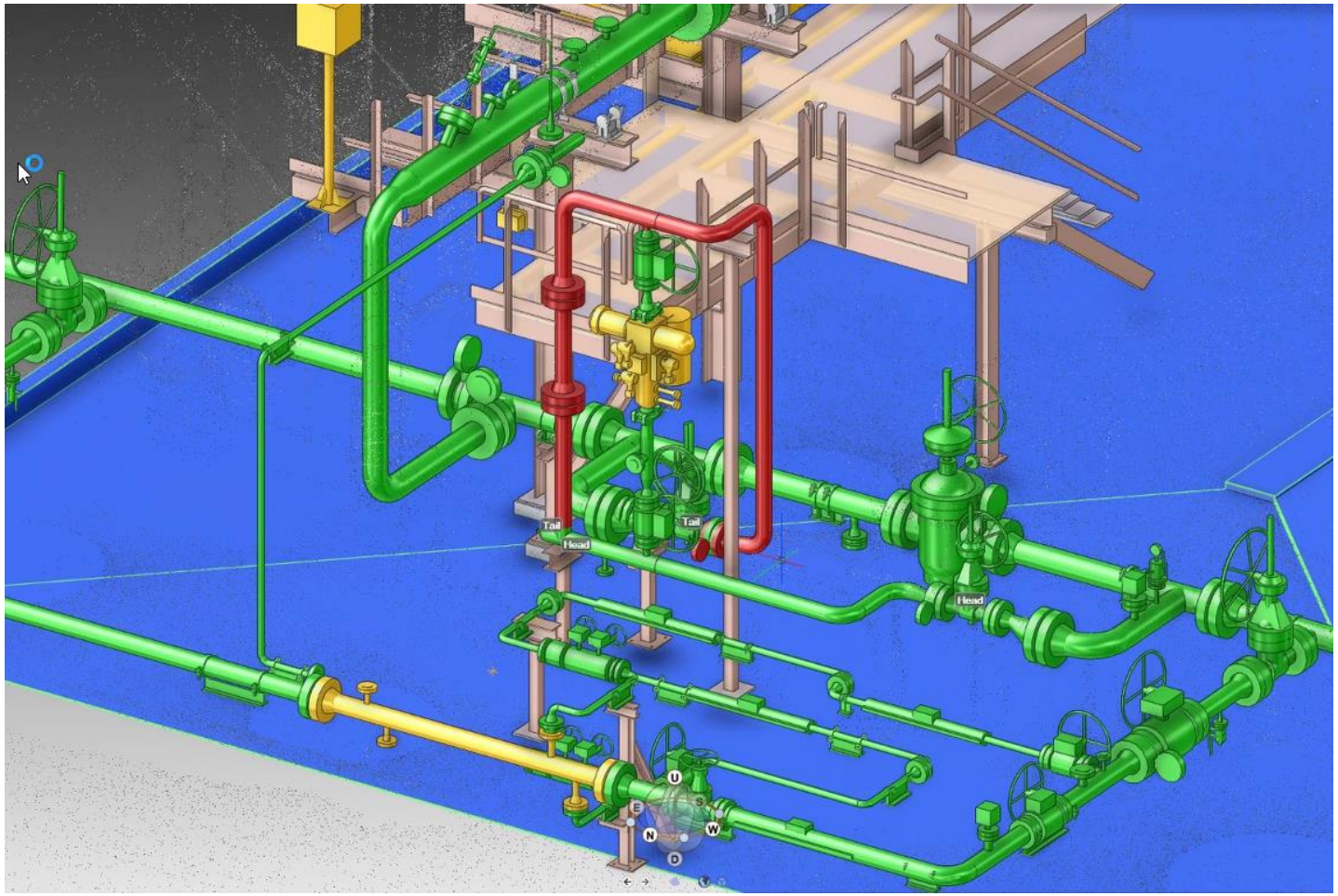
- Sample the multiphase flow in a by-pass pipe
- Measure primary input parameters directly at operating conditions
- Activated based on need or expected change of fluid properties – for instance starting production from a new well or from a new zone
- Fluids sampled and analysed one-by-one (sequentially) 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



K-lab test Nov - Dec 2022

- Use electric actuated gate valves – Valland–Rotok
  - Equal percentage valve characteristic
  - 18s opening time
- Implementation of control algorithms in the control system (ABB) at K-lab
- A dP venturi (5'' and beta 0,7) to replicate the actual line pressure upstream and downstream the MuFA/MPM
- K-lab is 3 phase closed flow loop - gas from Kårstø processing plant
- Crude oil – Troll Blend

Conditions	
Pressure	80-90 barg – set point (90 barg)
Temperature	~ 60 °C
GVF	40% – 70%
WLR	30-70%



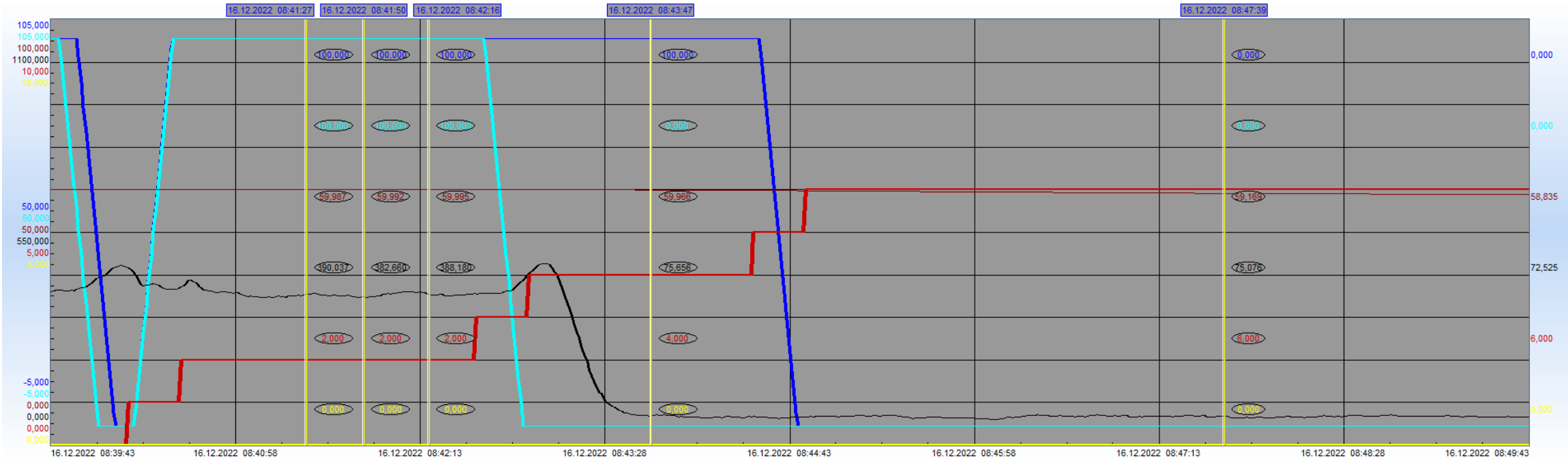
Test scope

	Number of test points	Range WLR [%]	Range GVF [%]	Total rate [m3/h]
Gas analysis	47	0 - 100	40 - 100	80 - 780
Oil analysis	43	0 - 70	40 - 80	120 - 780
Water analysis	35	20 - 100	40 - 80	250 - 900

Sample	Temperature [°C]	Pressure [Barg]	Salinity [%weight]	Conductivity @ 25°C [mS/cm]	Density [kg/m3]
#1	25	0	2.84	45.3	1017.3
#2	25	0	5.15	74.9	1034.1

Example – gas sequence

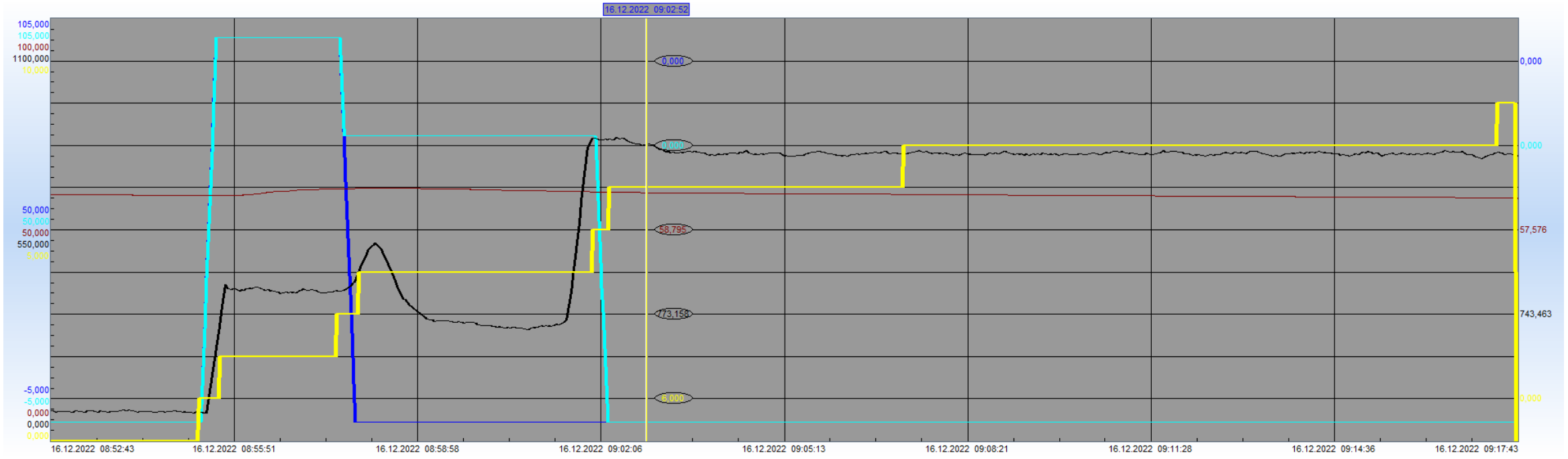
Flushing **Sampling** ← **Analysing** →



Name	Data Source	Map	Description	Value	Level	Status	Aut	Plot Min	Plot Max	Units	Shift	TZ	Type	Period	Method	Ste	Ext
399-ZT-3003	KA-IP21	IP_ANALOG	Posisjon MuFa-ventil 399-LV-3003	0,000	Good	Good	☐	-5,000	105,000	%	0	0:00:0		Best Fit	1 Hour	☐	☐
331_MPM-1037	KA-IP21	IP_ANALOG	GammaCounts1Inst	***			☑	14000,0(	34000,0(	timer	0	0:00:0		Best Fit	1 Hour	☐	☐
399-ZT-3004	KA-IP21	IP_ANALOG	Posisjon MuFa-ventil 399-LV-3004	0,000	Good	Good	☐	-5,000	105,000	%	0	0:00:0		Best Fit	1 Hour	☐	☐
331-TT-3002	KA-IP21	IP_ANALOG	Temp msler 2, testseksjon.	58,835	Good	Good	☐	0,000	100,000	°C	0	0:00:0		Best Fit	1 Hour	☐	☐
331_MPM-4165	KA-IP21	IP_AnalogMa	Density gamma	72,525	Good	Good	☐	0,000	1100,00(	Kg/m3	0	0:00:0		Best Fit	1 Hour	☐	☐
=MovingAverage({331_MPM-4165},0.0005)	KA-IP21	Fixed	Ad hoc calculation	***			☐	0	1050		0	0:00:0		Best Fit	1 Hour	☐	☐
331_MPM-4169	KA-IP21	IP_ANALOG	PermittivityD9	1,849	Good	Good	☐	0,000	5,000	-	0	0:00:0		Best Fit	1 Hour	☐	☐
331_MPM-4167	KA-IP21	IP_ANALOG	PermittivityD7	1,753	Good	Good	☐	0,000	5,000	-	0	0:00:0		Best Fit	1 Hour	☐	☐
331_MPM-4089	KA-IP21	IP_ANALOG	Inlet dP (used)	191,065	Good	Good	☐	0,000	300,000	mbarg	0	0:00:0		Best Fit	1 Hour	☐	☐
399-MuFa-GasSeq	KA-IP21	IP_ANALOG	Mufa Gassekvens step-nr	6,000	Good	Good	☐	0,000	10,000		0	0:00:0		Best Fit	1 Hour	☐	☐
399-MuFa-OilSeq	KA-IP21	IP_ANALOG	MuFa oljesekvens step-nr	0,000	Good	Good	☐	0,000	10,000		0	0:00:0		Best Fit	1 Hour	☐	☐
399-MuFa-WtrSeq	KA-IP21	IP_ANALOG	MuFa vannsekvens step-nr	***			☐	0,000	10,000		0	0:00:0		Best Fit	1 Hour	☐	☐

Example – oil sequence WLR 50%

Flushing Sampling Analysing



Name	Data Source	Map	Description	Value	Level	Status	Aut	Plot Min	Plot Max	Units	Shift	TZ	Type	Period	Method	Ste	Ext
399-ZT-3003	KA-IP21	IP_ANALOG	Posisjon MuFa-ventil 399-LV-3003	0,000	Good	Good	☐	-5,000	105,000	%	0 0:00:0		Best Fit	1 Hour		☐	☐
331_MPM-1037	KA-IP21	IP_ANALOG	GammaCounts1Inst	***			☑	14000,0	34000,0	timer	0 0:00:0		Best Fit	1 Hour		☐	☐
399-ZT-3004	KA-IP21	IP_ANALOG	Posisjon MuFa-ventil 399-LV-3004	0,000	Good	Good	☐	-5,000	105,000	%	0 0:00:0		Best Fit	1 Hour		☐	☐
331-TT-3002	KA-IP21	IP_ANALOG	Temp msler 2, testseksjon.	57,576	Good	Good	☐	0,000	100,000	°C	0 0:00:0		Best Fit	1 Hour		☐	☐
331_MPM-4165	KA-IP21	IP_AnalogMa	Density gamma	743,463	Good	Good	☐	0,000	1100,00	Kg/m3	0 0:00:0		Best Fit	1 Hour		☐	☐
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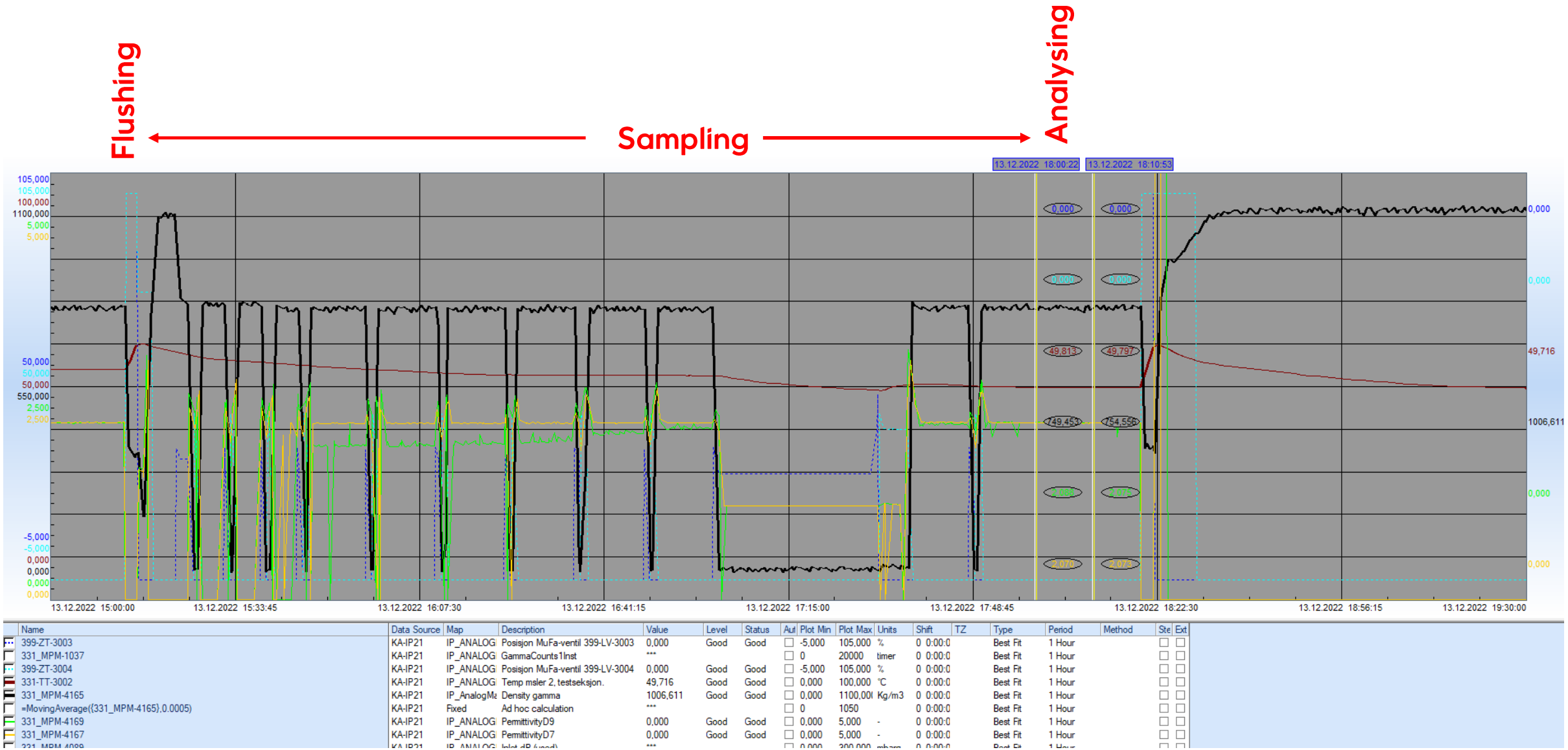
331_MPM-4169	KA-IP21	IP_ANALOG	PermittivityD9	1,849	Good	Good	☐	0,000	5,000	-	0 0:00:0		Best Fit	1 Hour		☐	☐
331_MPM-4167	KA-IP21	IP_ANALOG	PermittivityD7	1,753	Good	Good	☐	0,000	5,000	-	0 0:00:0		Best Fit	1 Hour		☐	☐
331_MPM-4089	KA-IP21	IP_ANALOG	Inlet dP (used)	191,065	Good	Good	☐	0,000	300,000	mbarg	0 0:00:0		Best Fit	1 Hour		☐	☐
399-MuFa-GasSeq	KA-IP21	IP_ANALOG	Mufa Gassekvens step-nr	6,000	Good	Good	☐	0,000	10,000		0 0:00:0		Best Fit	1 Hour		☐	☐
399-MuFa-OilSeq	KA-IP21	IP_ANALOG	MuFa oljesekvens step-nr	0,000	Good	Good	☐	0,000	10,000		0 0:00:0		Best Fit	1 Hour		☐	☐
399-MuFa-WtrSeq	KA-IP21	IP_ANALOG	MuFa vannsekvens step-nr	***			☐	0,000	10,000		0 0:00:0		Best Fit	1 Hour		☐	☐

Screen dump – oil sequence – WLR 70%



Name	Data Source	Map	Description	Value	Level	Status	Aut	Plot Min	Plot Max	Units	Shift	TZ	Type	Period	Method	Ste	Ext
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331_MPM-1037	KA-IP21	IP_ANALOG	GammaCounts1Inst	***				0	20000	timer	0 0:00:0		Best Fit	1 Hour			
399-ZT-3004	KA-IP21	IP_ANALOG	Posisjon MuFa-ventil 399-LV-3004	0,000	Good	Good		-5,000	105,000	%	0 0:00:0		Best Fit	1 Hour			
331-TT-3002	KA-IP21	IP_ANALOG	Temp msler 2, testseksjon.	49,716	Good	Good		0,000	100,000	°C	0 0:00:0		Best Fit	1 Hour			
331_MPM-4165	KA-IP21	IP_AnalogMa	Density gamma	1006,611	Good	Good		0,000	1100,00	Kg/m3	0 0:00:0		Best Fit	1 Hour			
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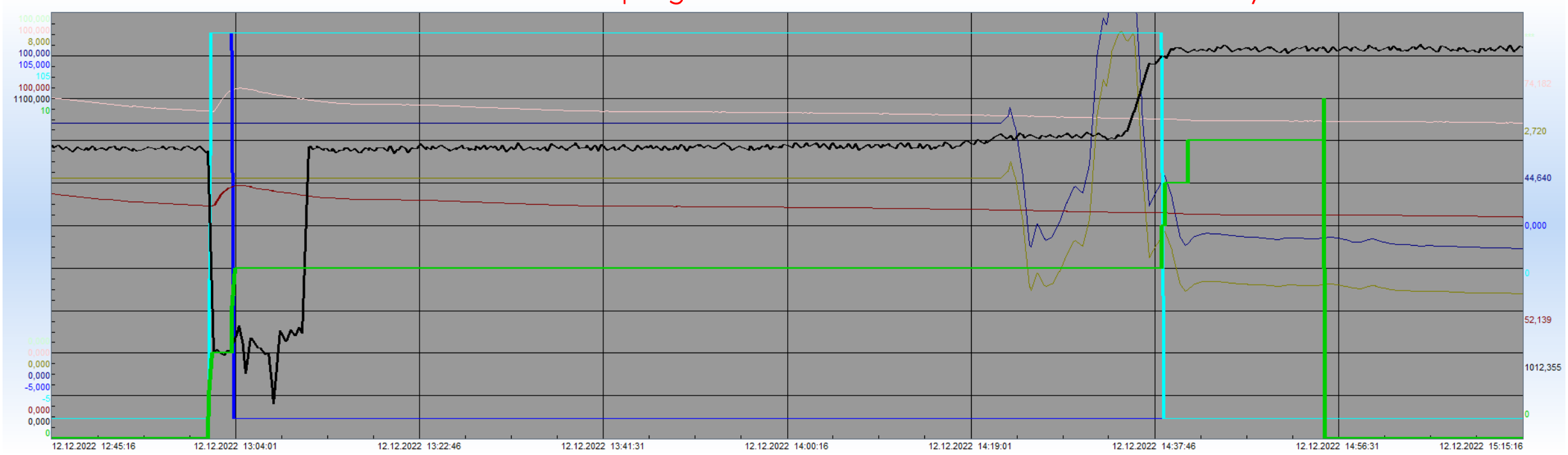
331_MPM-4169	KA-IP21	IP_ANALOG	PermittivityD9	0,000	Good	Good		0,000	5,000	-	0 0:00:0		Best Fit	1 Hour			
331_MPM-4167	KA-IP21	IP_ANALOG	PermittivityD7	0,000	Good	Good		0,000	5,000	-	0 0:00:0		Best Fit	1 Hour			

Example - Water sampling WLR 20%

Sampling → Analysis



Name	Data Source	Map	Description	Value	Level	Status	Aut	Plot Min	Plot Max	Units	Shift	TZ	Type	Period	Method	Ste	Ext
331_MPM_2-4805	KA-IP21	IP_AnalogMa	salinity index	***				0,000	100,000	kg/t	0	0:00:0	Best Fit	1 Hour			
331_MPM-4109	KA-IP21	IP_AnalogMa	Conductivity of water at TP used	74,182	Good	Good		0,000	100,000	1/s	0	0:00:0	Best Fit	1 Hour			
331_MPM-4103B	KA-IP21	IP_AnalogMa	Measured water salinity	2,720	Good	Good		0,000	8,000	%	0	0:00:0	Best Fit	1 Hour			
331_MPM-4101B	KA-IP21	IP_AnalogMa	Measured water conductivity conv	44,640	Good	Good		0,000	100,000	1/s	0	0:00:0	Best Fit	1 Hour			
399-ZT-3003	KA-IP21	IP_ANALOG	Posisjon MuFa-ventil 399-LV-3003	0,000	Good	Good		-5,000	105,000	%	0	0:00:0	Best Fit	1 Hour			
331_MPM-1037	KA-IP21	IP_ANALOG	GammaCounts1Inst	***				0	20000	timer	0	0:00:0	Best Fit	1 Hour			
399-ZT-3004	KA-IP21	IP_ANALOG	Posisjon MuFa-ventil 399-LV-3004	0	Good	Good		-5	105	%	0	0:00:0	Best Fit	1 Hour			
331-TT-3002	KA-IP21	IP_ANALOG	Temp msler 2, testseksjon.	52,139	Good	Good		0,000	100,000	°C	0	0:00:0	Best Fit	1 Hour			
331_MPM-4165	KA-IP21	IP_AnalogMa	Density gamma	1012,355	Good	Good		0,000	1100,000	Kg/m3	0	0:00:0	Best Fit	1 Hour			
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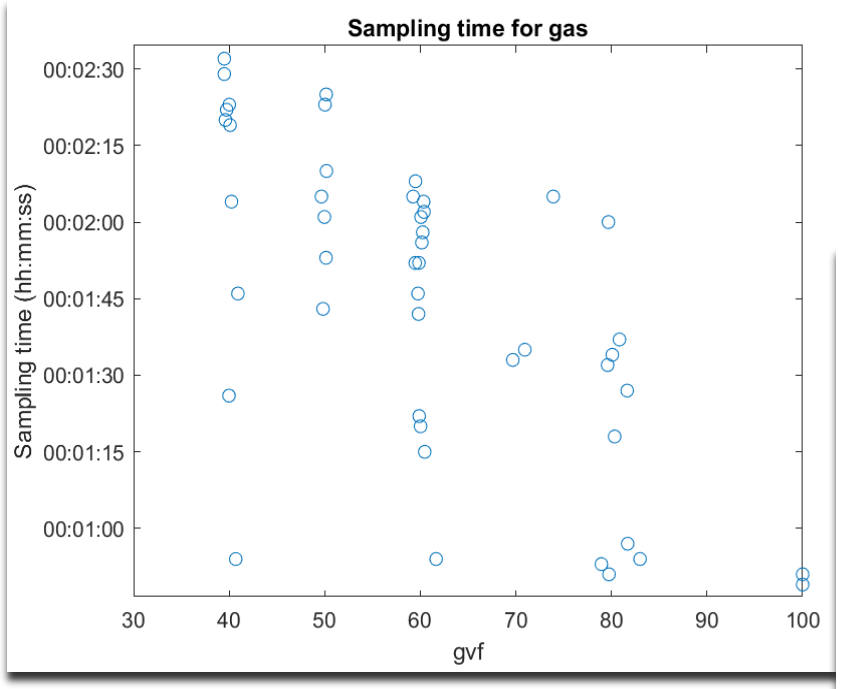
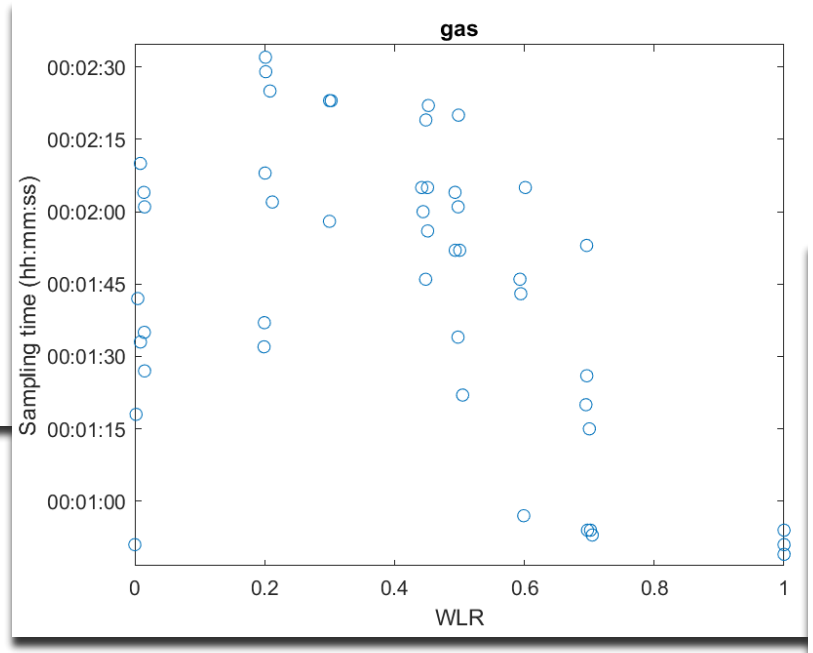
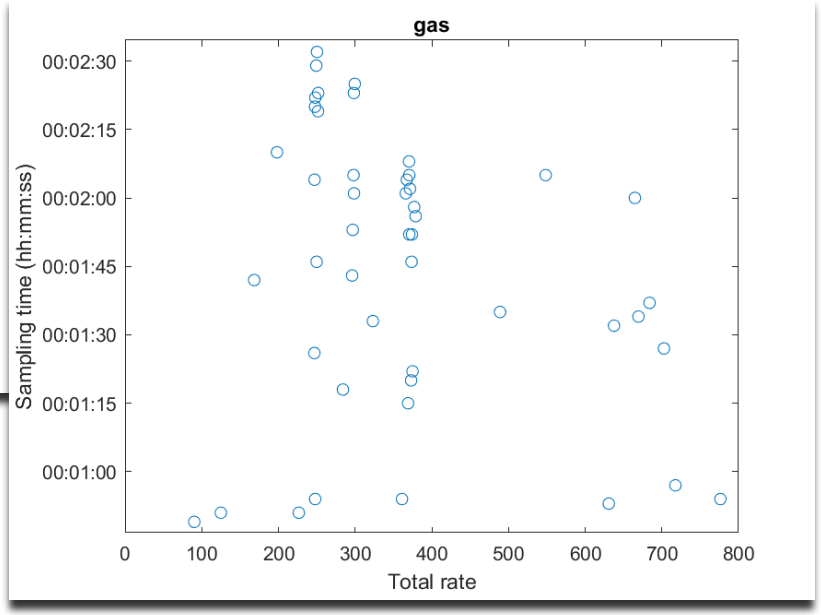
331_MPM-4169	KA-IP21	IP_ANALOG	PermittivityD9	0,000	Good	Good		0,000	5,000	-	0	0:00:0	Best Fit	1 Hour			
331_MPM-4167	KA-IP21	IP_ANALOG	PermittivityD7	0,000	Good	Good		0,000	5,000	-	0	0:00:0	Best Fit	1 Hour			
331_MPM-4089	KA-IP21	IP_ANALOG	Inlet dP (used)	234,278	Good	Good		0,000	300,000	mbarg	0	0:00:0	Best Fit	1 Hour			

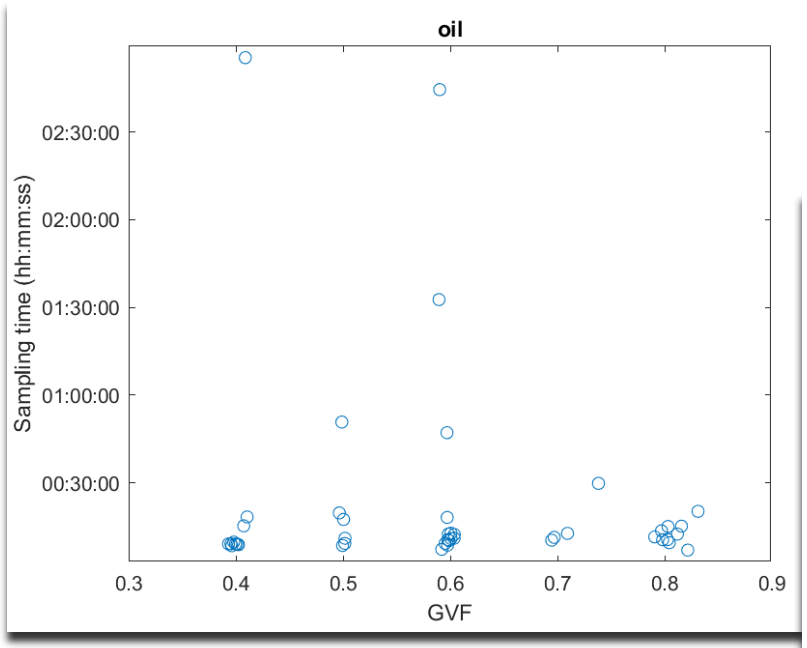
Sampling time for gas

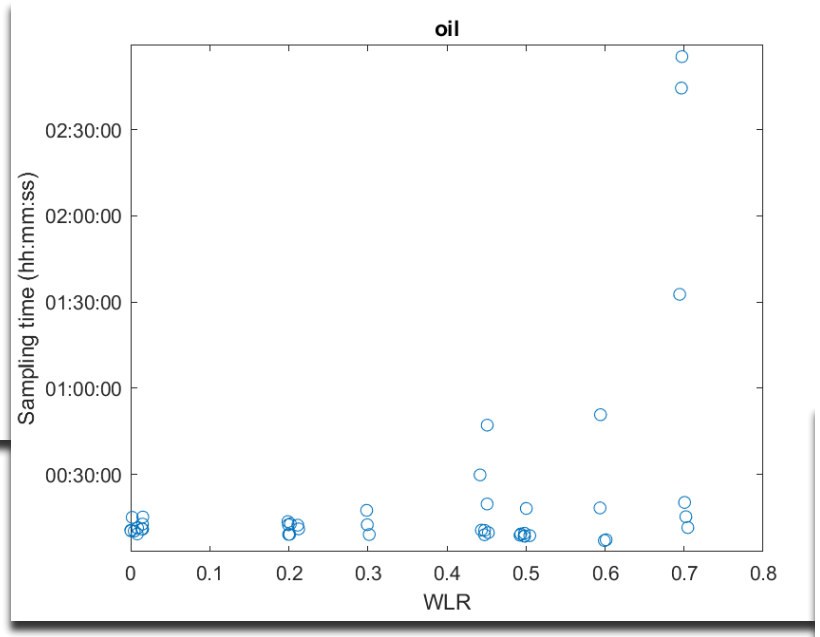


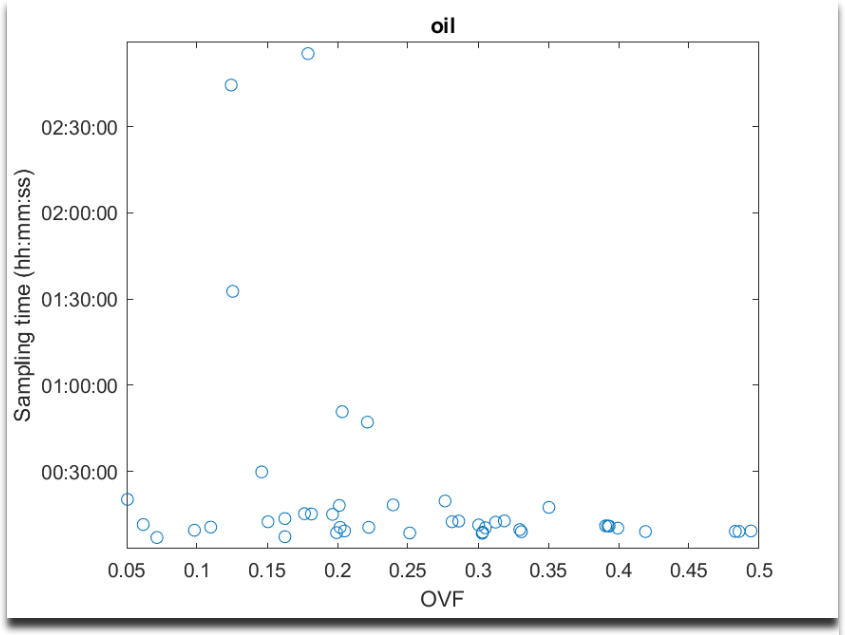


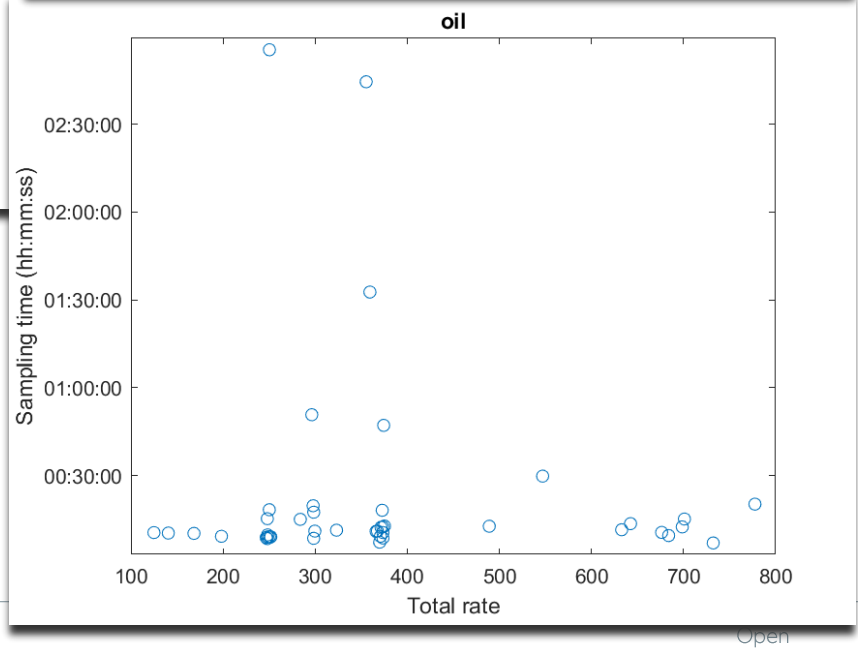


Sampling time for oil

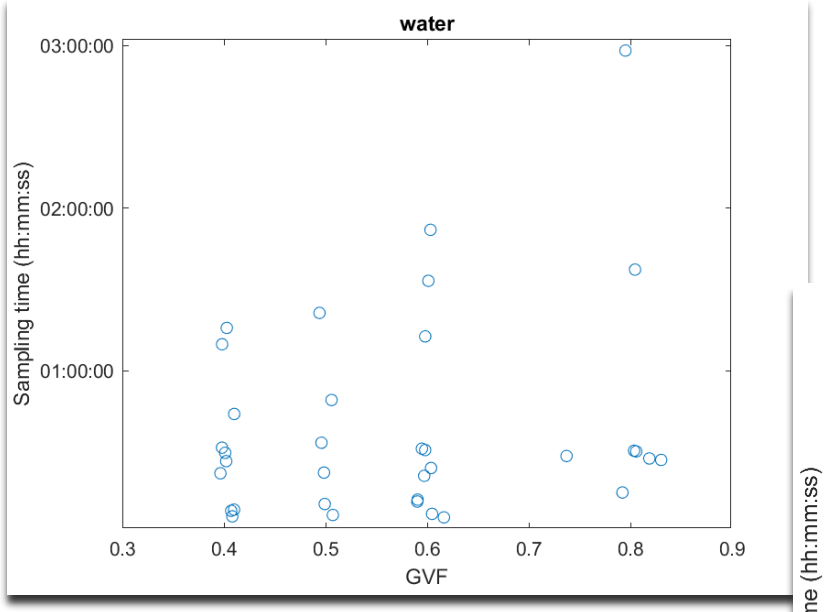


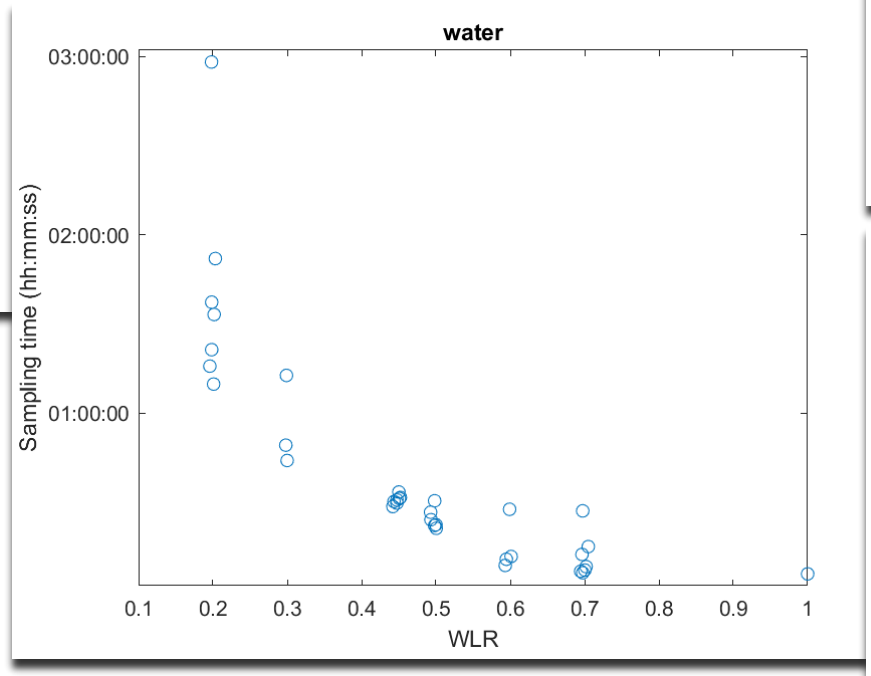


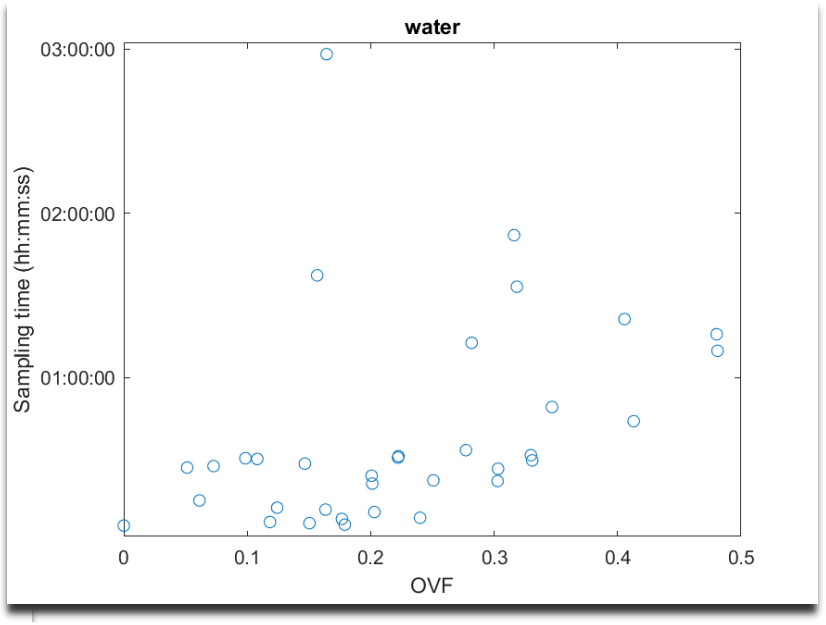


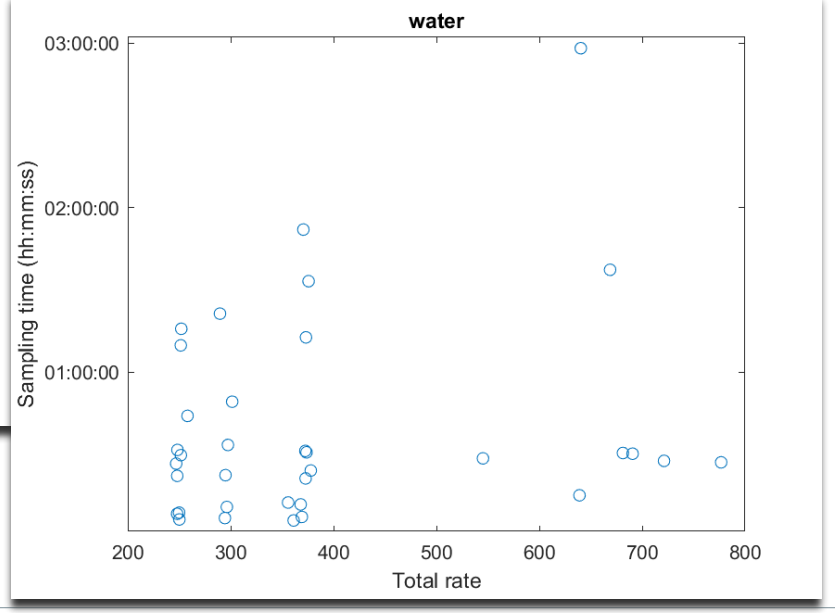


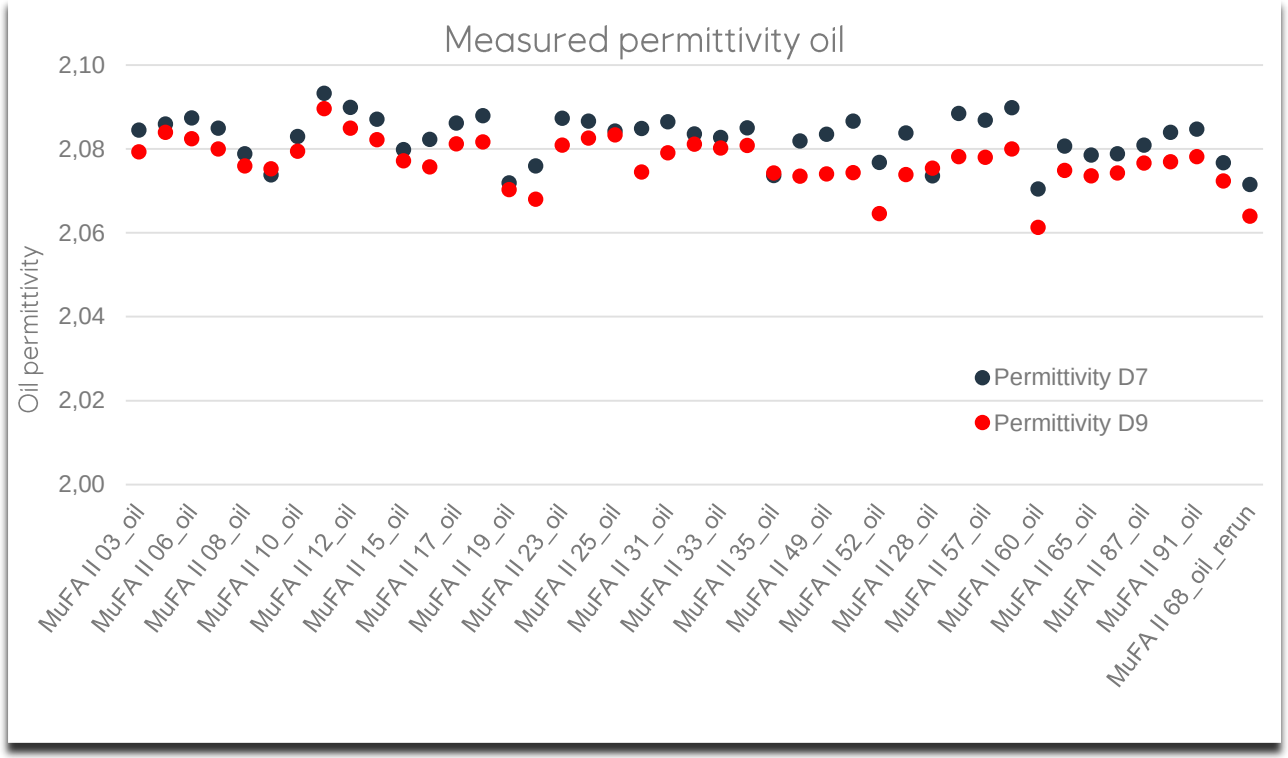
Sampling time for water



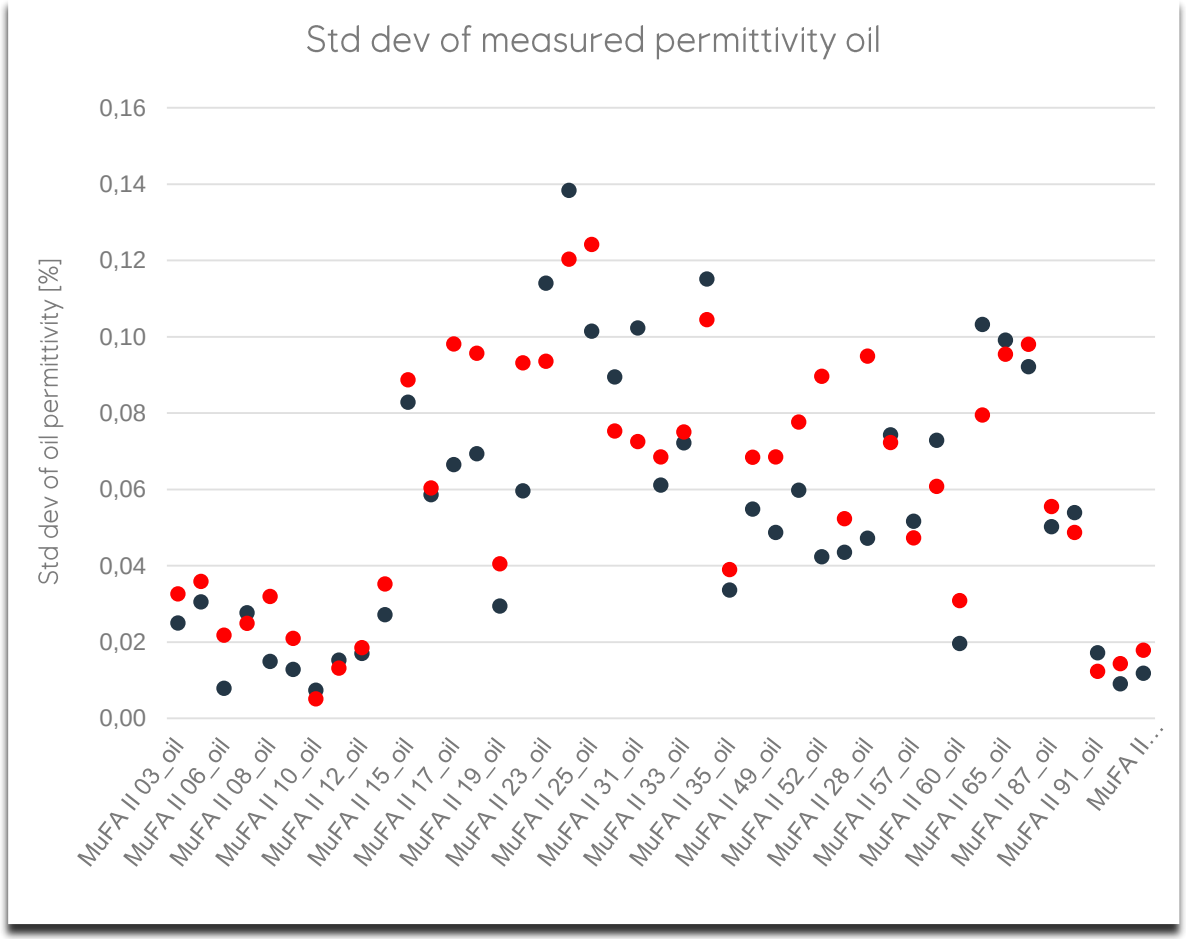




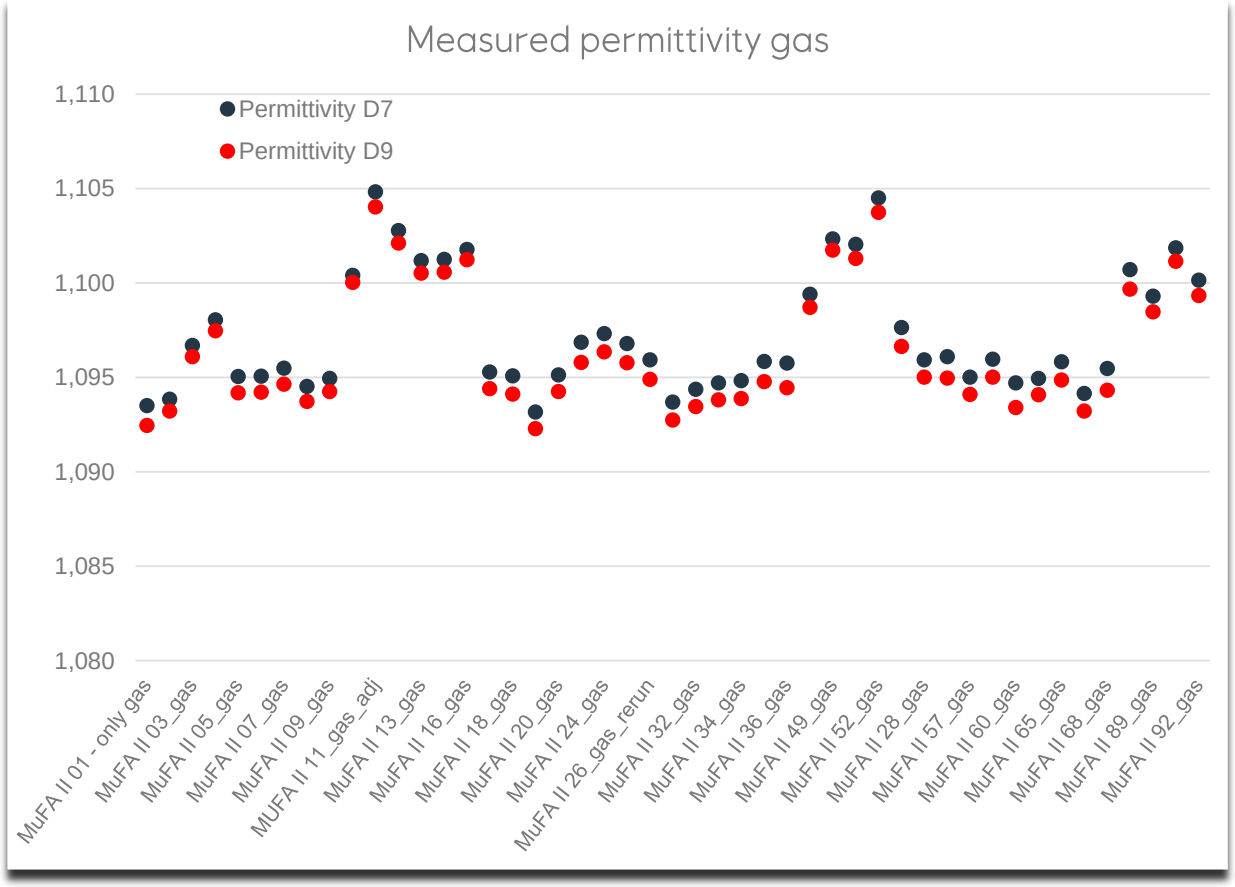




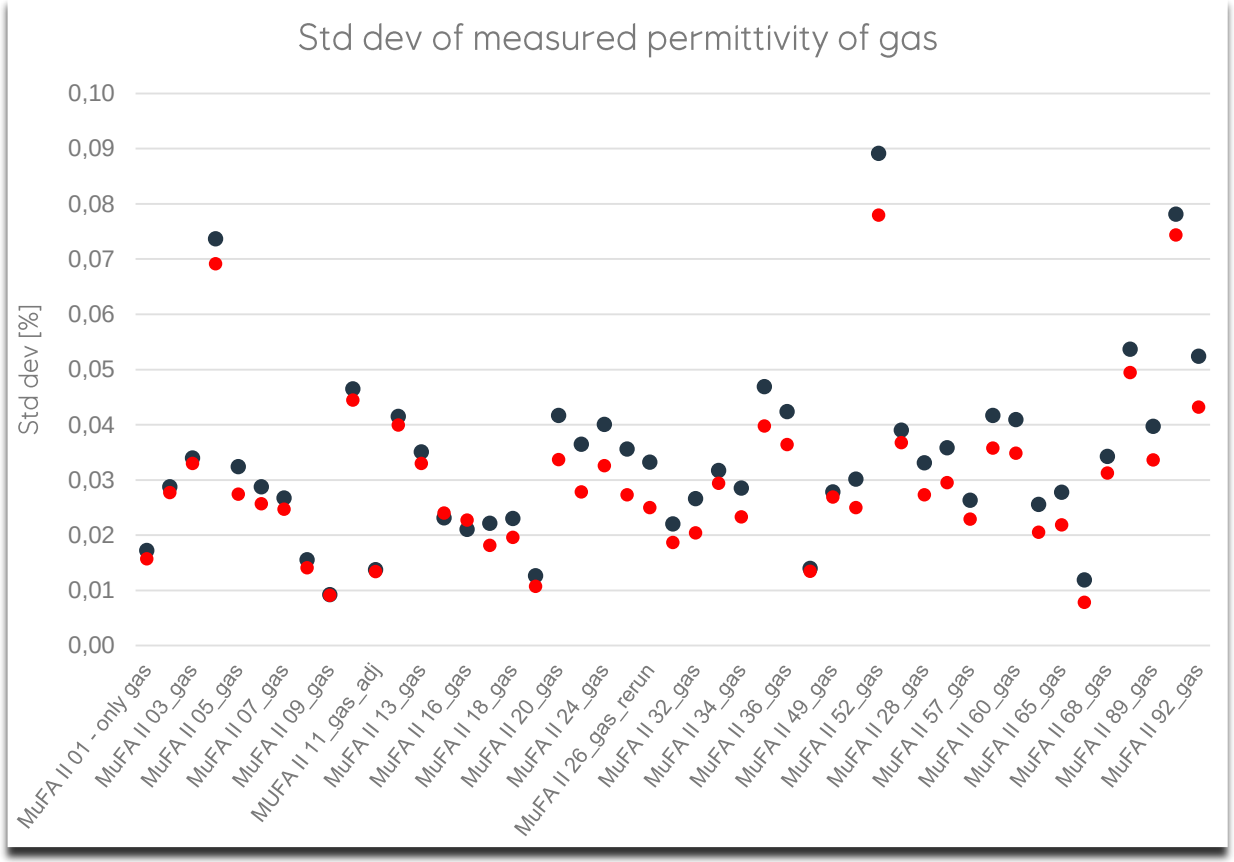
- All oil test points presented – logged for 10 minutes
- Each test points - average value of 600 measurement readings
- Low spread for all data points (2*stdev, k=2)



Measured permittivity of gas

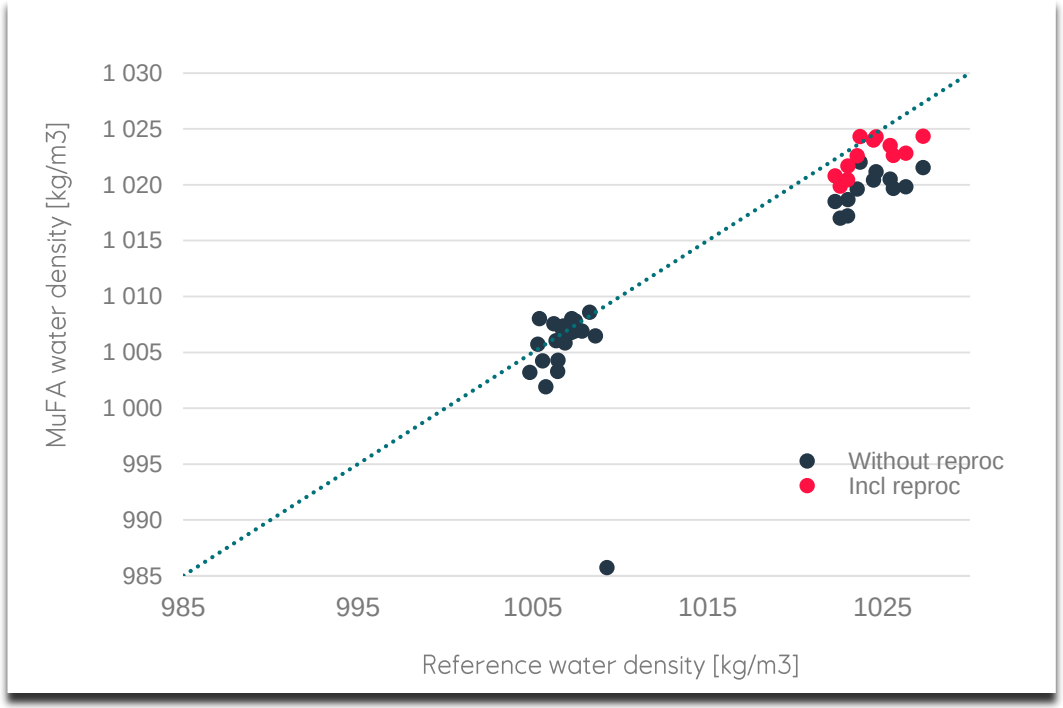


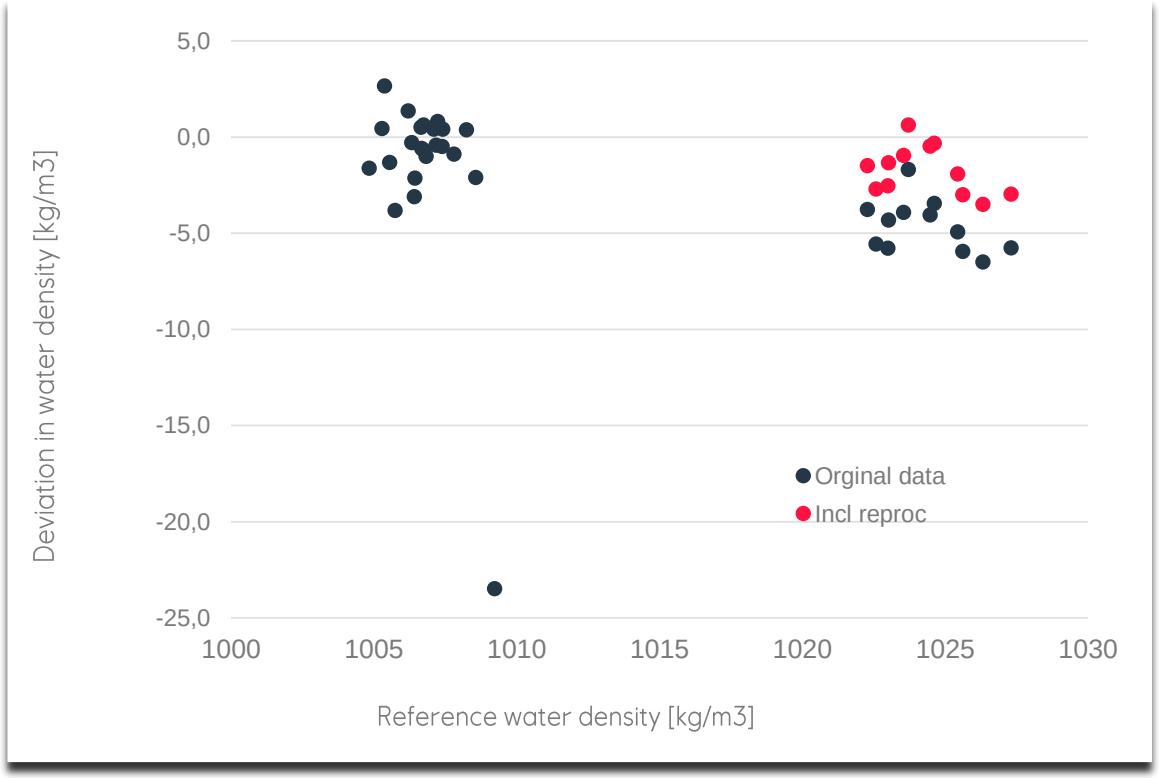
- All test points presented – logged for 10 minutes
- Each test points - average value of 600 measurement readings



- Similar results and spread D7 and D9 internal measurement directions
- Variations in measured permittivities follow changes in gas densities (pressure)

Water properties – all test points





- Water density within 0.48% (2*std dev) to the reference density

Summary of test results

Parameter/fluid property	Test results	Comment
Oil permittivity	0.52% (2*stddev)	Based on standard deviation of measured permittivity for all oil test points – calculation based on 1 test point
Gas permittivity	0.57% (2*stddev)	Based on standard deviation of measured permittivity for all gas test points – calculation based on 1 test point
Water conductivity	4.76% rel (2*stddev) 4.14% rel (2*stddev)	Based on measured density For water salinity 2.84wt% NaCl – calculation based on 8 test points For water salinity 5.15wt% NaCl – calculation based on 2 test points
Oil linear attenuation coefficient **Oil density**	0.47% (2*stddev)	Based on standard deviation of measured density for all oil test points
Gas linear attenuation coefficient **Gas density**	3.86% (2*stddev)	Based on standard deviation of measured density for all gas test points
Water linear attenuation coefficient **Water density**	0.48% (2*stddev)	Based on standard deviation of measured density for all water test points. One outlier has been removed from calculation

Summary from the test

- Samples have been captured correct for all test points, wide range of GVF, WLR at realistic conditions and type of crude, means
  - No failures in valve operations during the test
  - Selected electric actuators and gate valves (equal percentage with opening time of 18s) worked
  - Only one point is off (water) wrong readout of density
- Control algorithms worked for all test points – valves opened in correct sequences to separate single phase samples
  - Following analysis performed sucessfully:
    - Gas - 47 test points
    - Oil - 43 test poins
    - Water - 35 test point – two different salinities 2.84wt% NaCl and 5.15wt% NaCl