EMRP
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VSL
Dutch Metrology Institute

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OneSubsea
A Schlumberger Company

Results from an intercomparison between multiphase flow test facilities

EMRP ENG58 – MultiFlowMet-I

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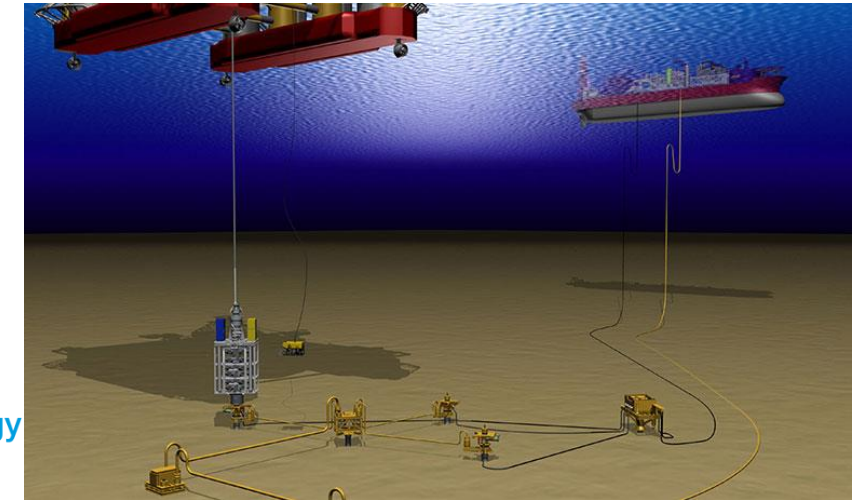
Background

- Multiphase flow meters measure simultaneously the flow rates of oil, water and gas flowing through a pipe line
- Important meters for oil and gas industry, especially for subsea fields
- Traceability, calibration and testing of single phase flow meters is well established, but this is not the case for multiphase flow meters
- In EMRP project ENG58: *Multiphase flow metrology in oil and gas production*, 2014 – 2017 (MultiFlowMet) an intercomparison was organised
- NEL, DNV GL and OneSubsea, a Schlumberger Company (OSS) took part
- VSL acted as independent witness, audited the uncertainty budges and analysed the data
- Intensive discussions between the partners and with Euramet on the outcomes of the intercomparison



Images courtesy of OSS

Test protocol

- MUT: Schlumberger PhaseTester Vx52 (D = 4 inch) with Venturi tube (β = 0.5). P, T, dP, γ-ray measurement.
- Specified inlet section: 100D straight pipe + viewing section + 90 degree bend
- 3 facilities took part, with repeated measurements at NEL
- Averaging times per test point between 10 and 30 minutes

Test round	Test period
NEL Round 1	27 July 2015 – 7 Aug 2015
DNV GL	13 July 2016 – 19 July 2016
NEL Round 2	29 Aug 2016 – 12 Sept 2016
OneSubsea	22 Nov 2016 – 12 Dec 2016

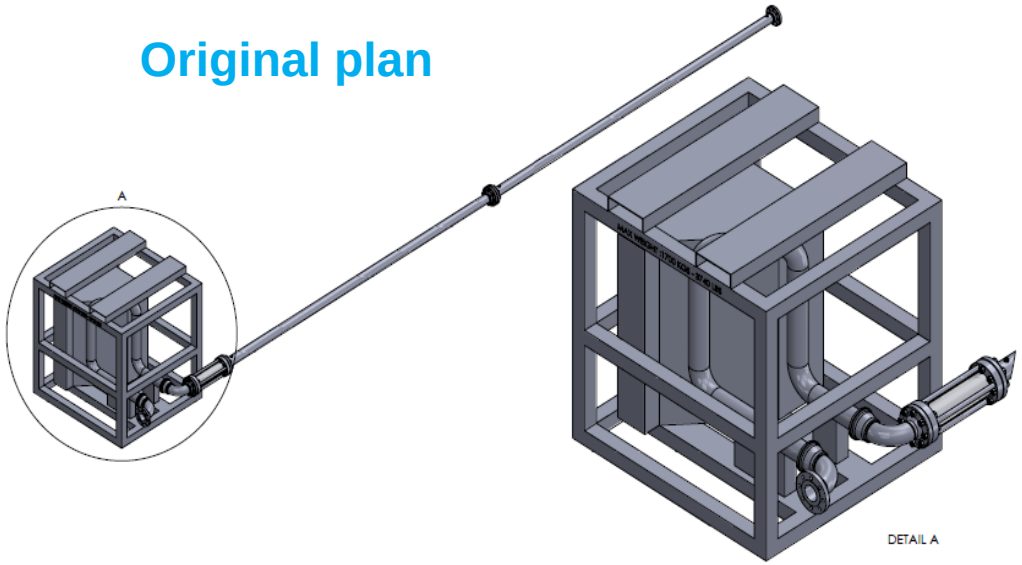
Liquid Flow	Gas Volume Fraction / %					
m^3/h	25	55	70	84	92	96
9					X	O
18				X	O	X
35		O	X	O	X	
50	O	X	O	X		
70	X	O	X			
90	O					

O : WLR = 0, 25, 45, 70, 90 and 100 %
X : WLR = 25, 45, 70 and 90 %

Inlet flow topology

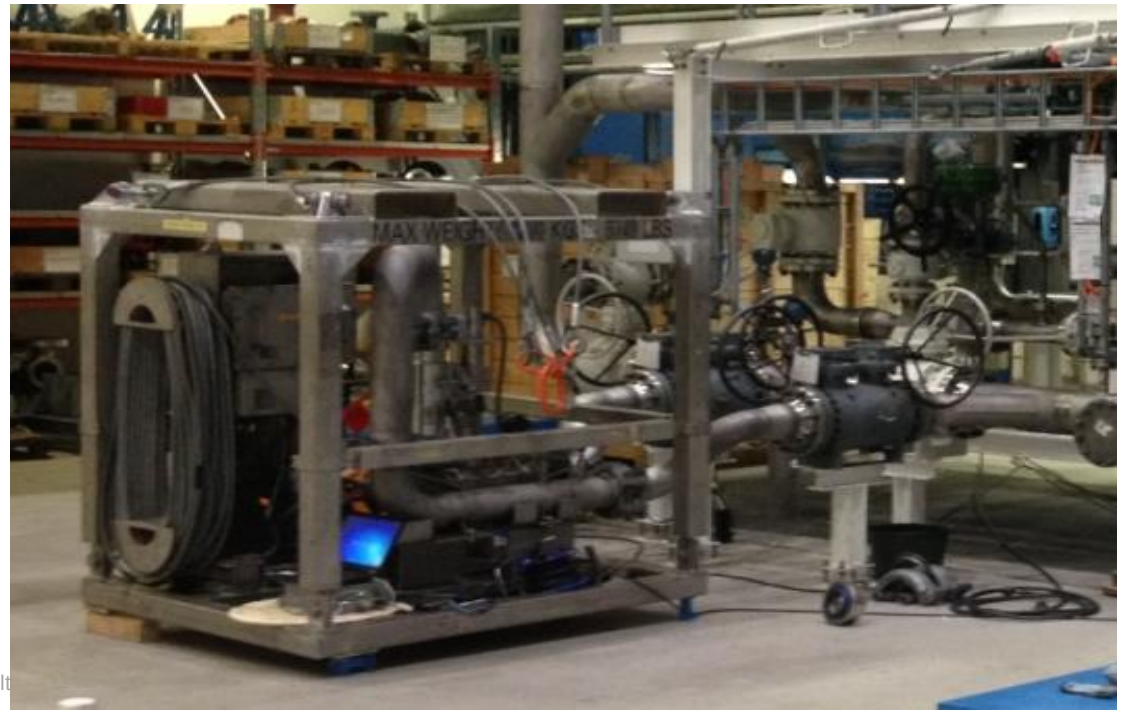
- 100D straight pipe + viewing section + 90 degree bend
- Installed at NEL and DNV GL
- Turned out not to be possible at OneSubsea

Original plan



DNV GL

OneSubsea



Characteristics and differences between the various facilities

Characteristic	NEL	DNV GL	OneSubsea
Pressure at MUT / barg	2.1 to 9.5	7.3 to 8.3	15.9 to 17.1
Temperature at MUT / °C	38 to 45	19 to 21	11 to 17
Oil viscosity / cP	7.5 to 9.1	4.6 to 5.0	1.7 to 1.9
Water density / kg/m^3	1015 to 1029	1029 to 1030	999 to 1000
Flow loop design	Open loop	Closed loop	Closed loop
Distance of mixing point / m	11	20	3
U(*q*-single-phase)	< 0.9 %	< 1.0 %	Oil & Water: 1.5 % Gas: 5 %
U(WLR)	< 0.23 %	< 0.17 %	< 0.6 %
U(GVF)	< 0.14 %	< 0.24 %	< 1.3 %

Data evaluation procedure

- Measurand for a test facility (*A, B*): MUT deviation for a quantity j (e.g. gas flow rate) at flow conditions i (mainly specified by q_{liquid}, GVF and WLR, or by the individual phase flow rates)
- The facility provides the deviation d_{ij}^{A} and the uncertainty $u(d_{ij}^{A})$ (derived from the uncertainty of the reference flow rates)
- The MUT has a reproducibility uncertainty $u(r_j^{\mathrm{MUT}})$ assumed independent of flow conditions, and present at each facility
- The results of the facilities *A* and *B* for quantity *j* at flow point *i* are judged consistent if

$$|d_{ij}^{A} - d_{ij}^{B}| \leq 2\sqrt{u^2(d_{ij}^{A}) + u^2(d_{ij}^{B}) + 2\,u^2(r_j^{\mathrm{MUT}})}$$

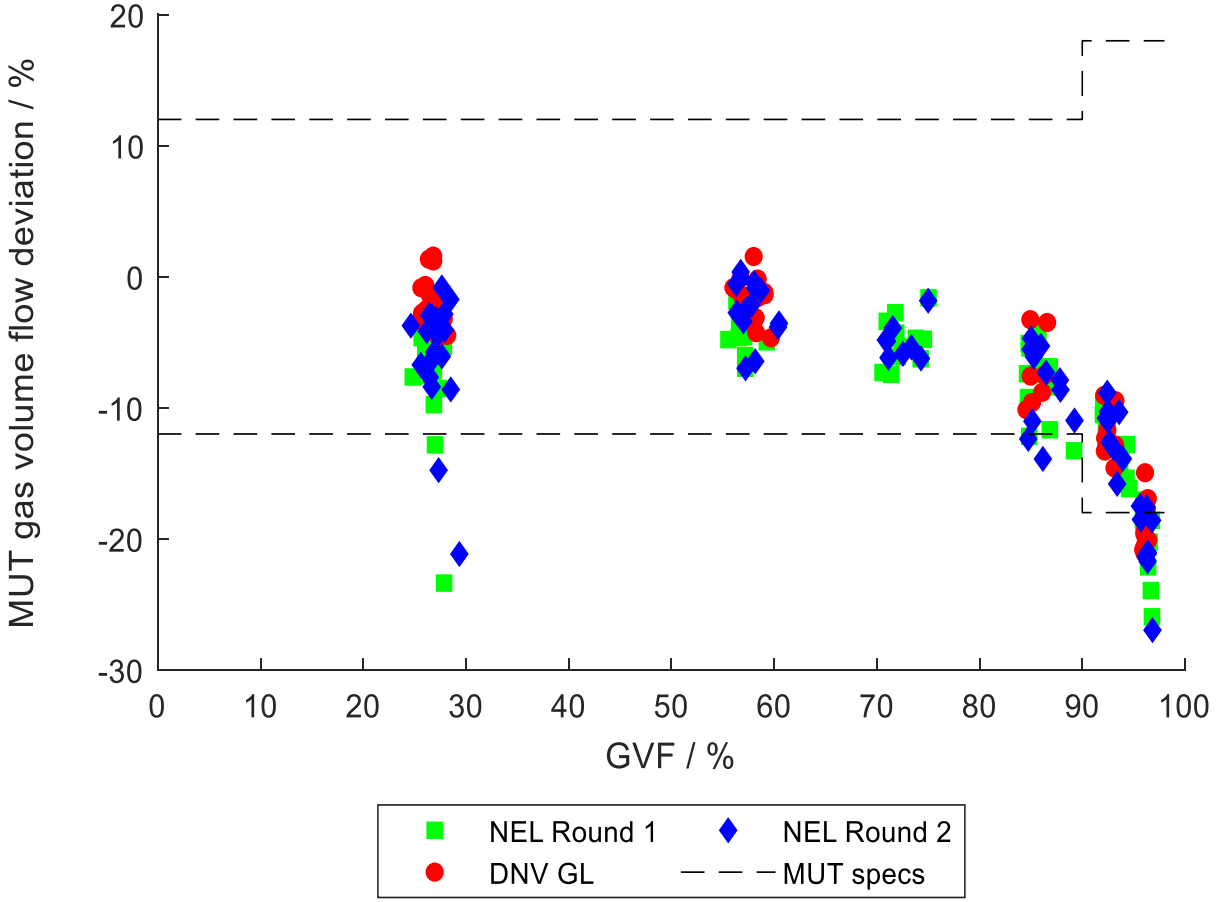
- Note that the standard deviations of the phase flow rates are seen as irrelevant. Testing times should be long enough to average them out (or the test facilities should incorporate their effect in their uncertainty statements).

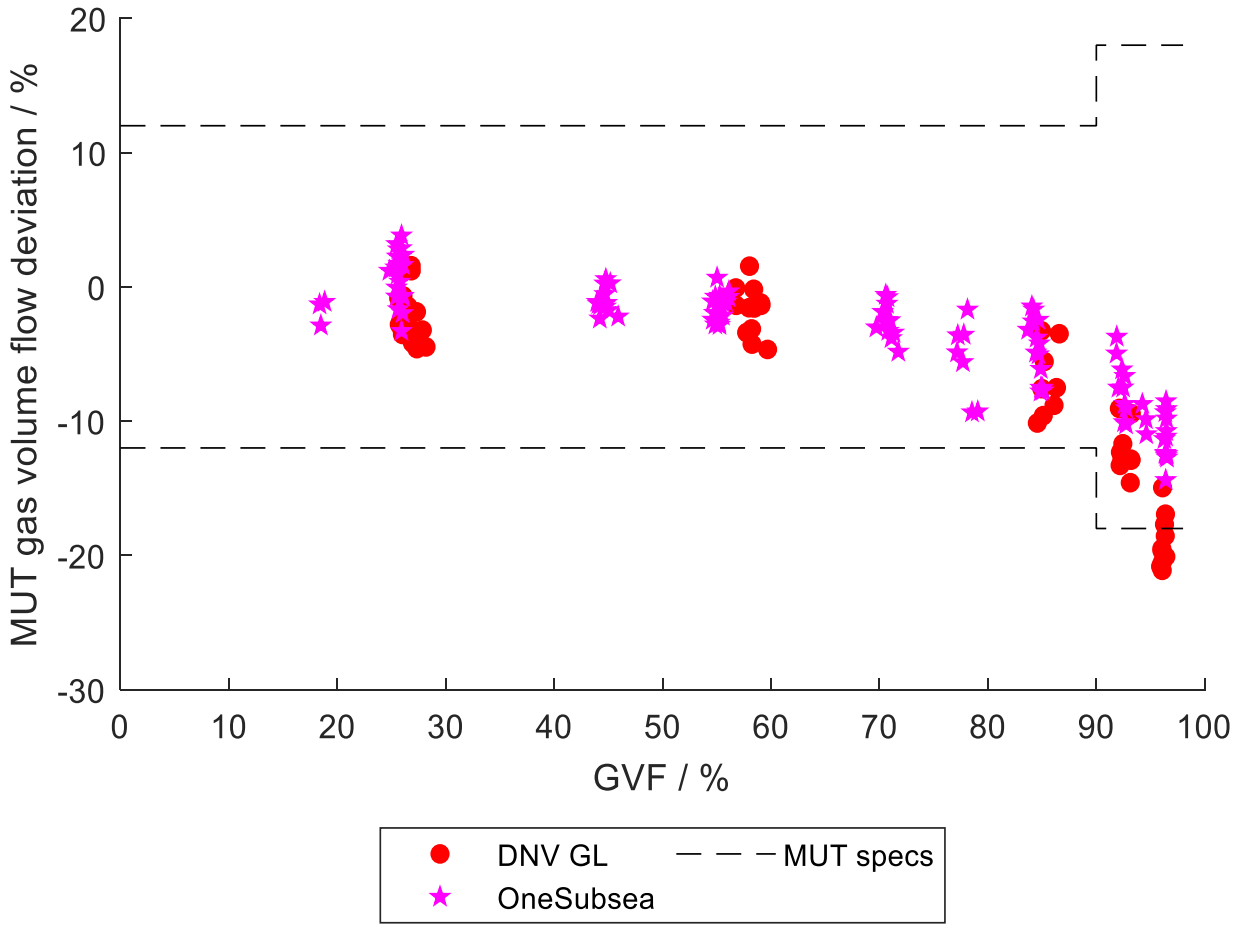
Reproducibility

- Determined by comparing the results of 56 test points measured at NEL in August 2015 and September 2016
- RMS value of differences has been calculated, table shows $U_{\mathrm{repro}} = 2\sqrt{2}u\left(r_j^{MUT}\right)$ per quantity j
- Value includes reproducibility of both MUT and NEL test facility
- Value does NOT include reproducibility of the MUT at different facilities
- This value has been assumed representative for the reproducibility of the MUT at any facility for the sake of the intercomparison. (It makes no sense to blame the MUT for every observed difference between the test facilities.)

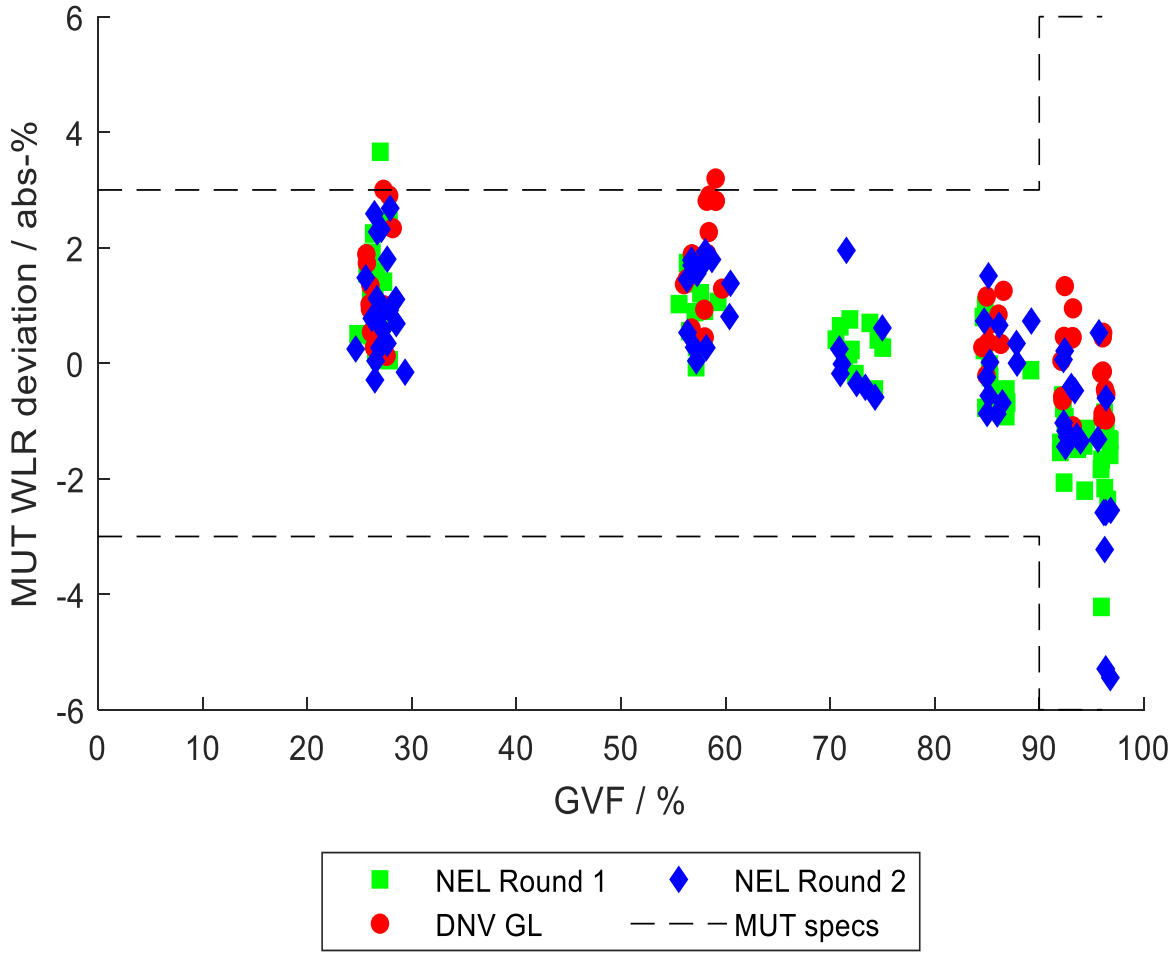
Quantity	U_{repro} (all GVFs)	U_{repro} (GVF ≤ 90 %)	U_{repro} (GVF = 92 %)	U_{repro} (GVF = 96 %)
Total mass flow rate, $q_{\mathrm{m,\,total}}$	2.2 %	2.0 %	2.3 %	3.5 %
Total volume flow rate, q_{total}	2.2 %	2.1 %	2.1 %	3.0 %
Gas volume flow rate, q_{gas}	3.2 %	3.3 %	2.1 %	2.9 %
Liquid volume flow rate, q_{liquid}	2.4 %	2.0 %	2.4 %	4.2 %
Water liquid ratio, WLR	1.9 %-abs	1.2 %-abs	1.6 %-abs	4.4 %-abs
Gas volume fraction, GVF	0.7 %-abs	0.8 %-abs	0.2 %-abs	0.2 %-abs
Oil volume flow rate, q_{oil}	5.6 %	4.3 %	8.7 %	8.5 %
Water volume flow rate, q_{water}	3.4 %	3.0 %	3.0 %	5.7 %

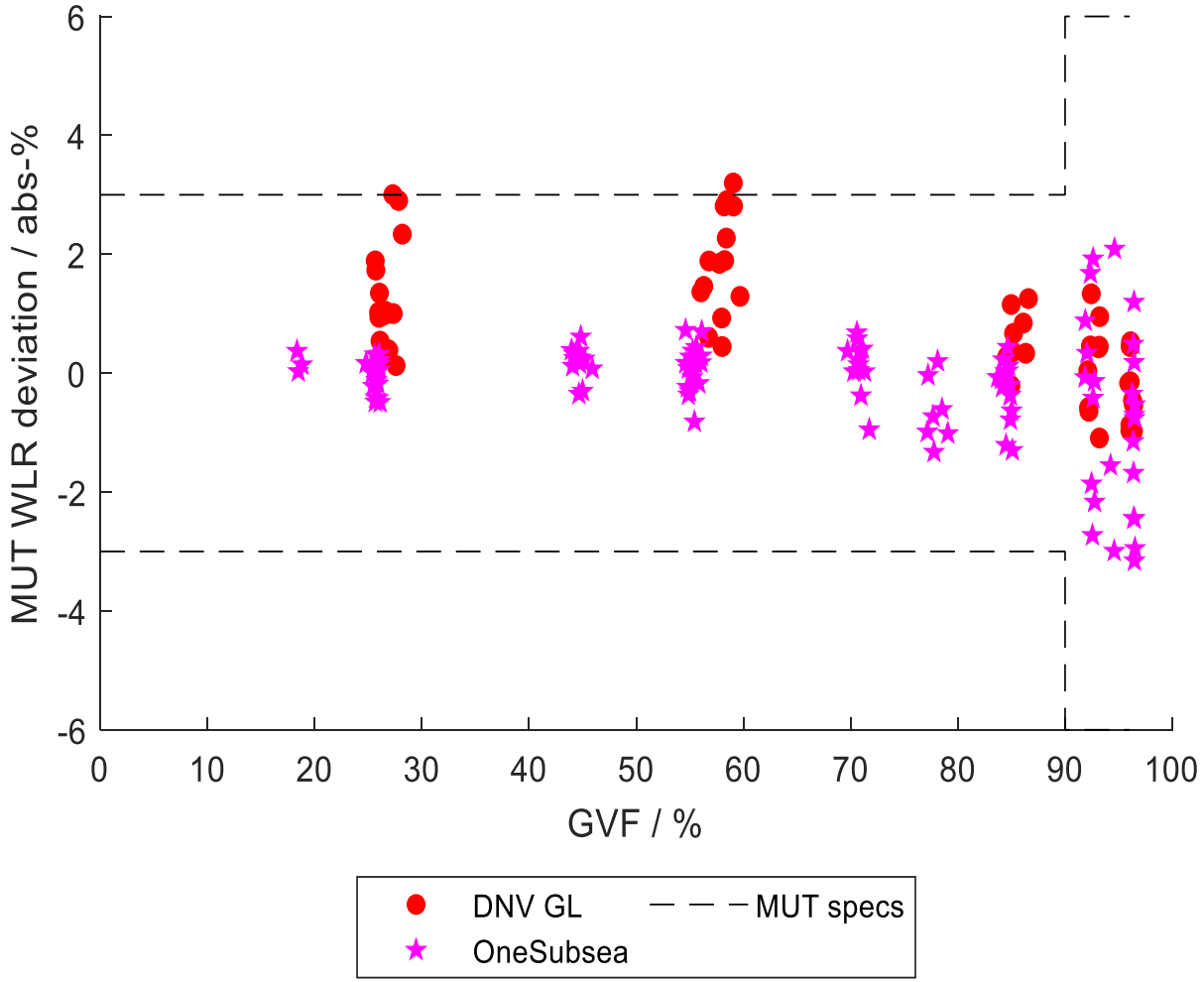
MUT gas volume flow deviation as function of GVF



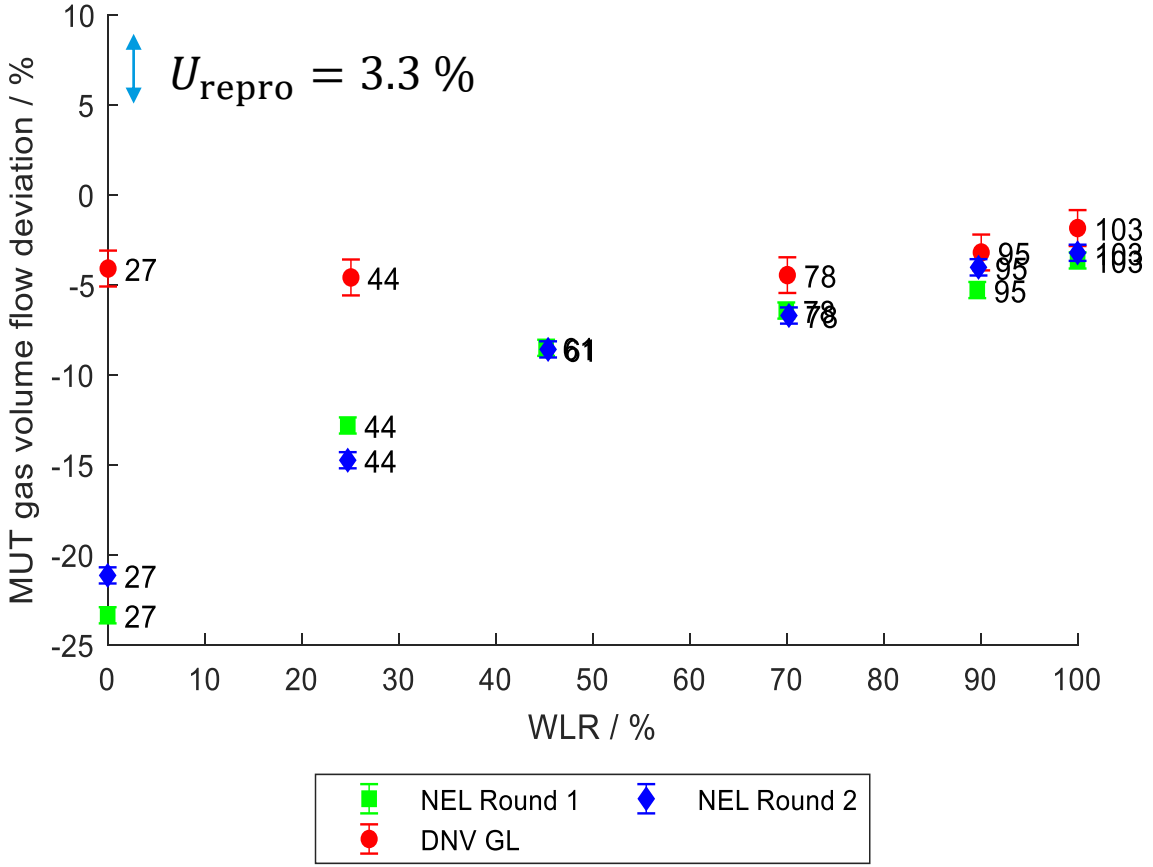


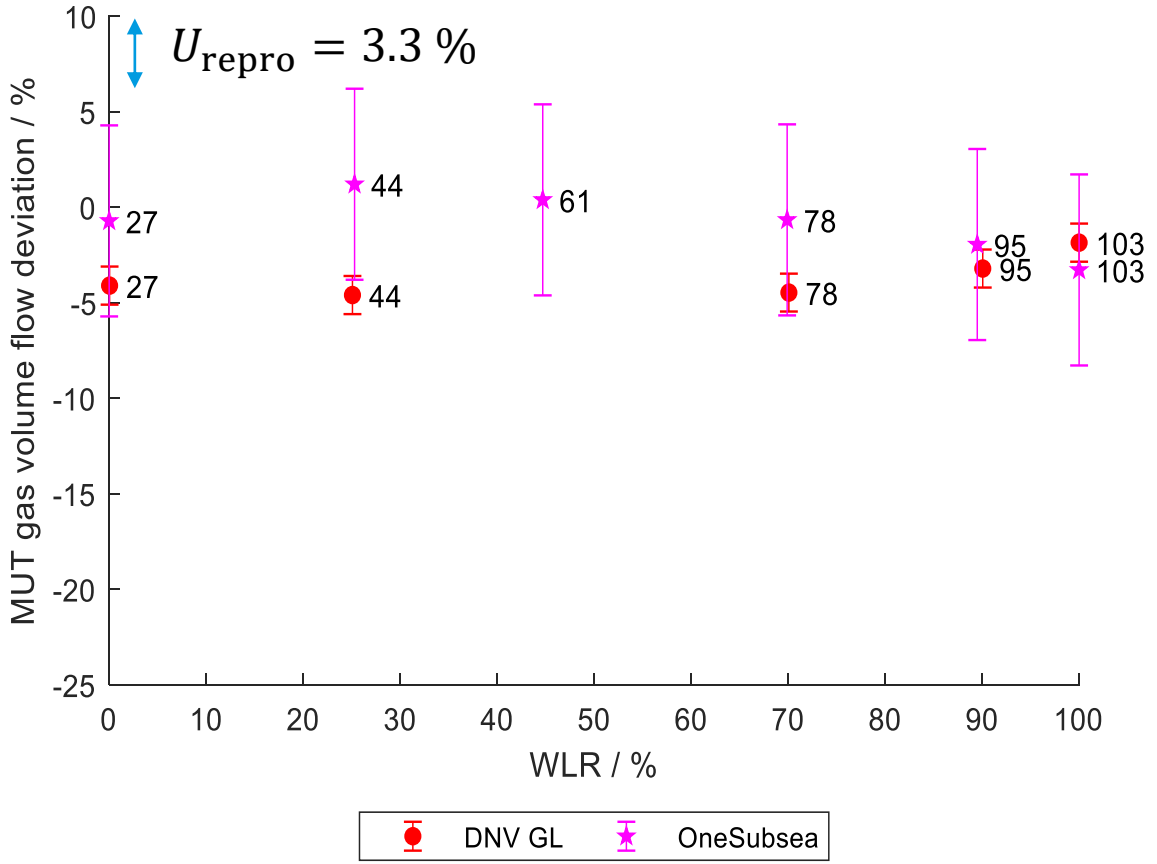
MUT WLR deviation as function of GVF



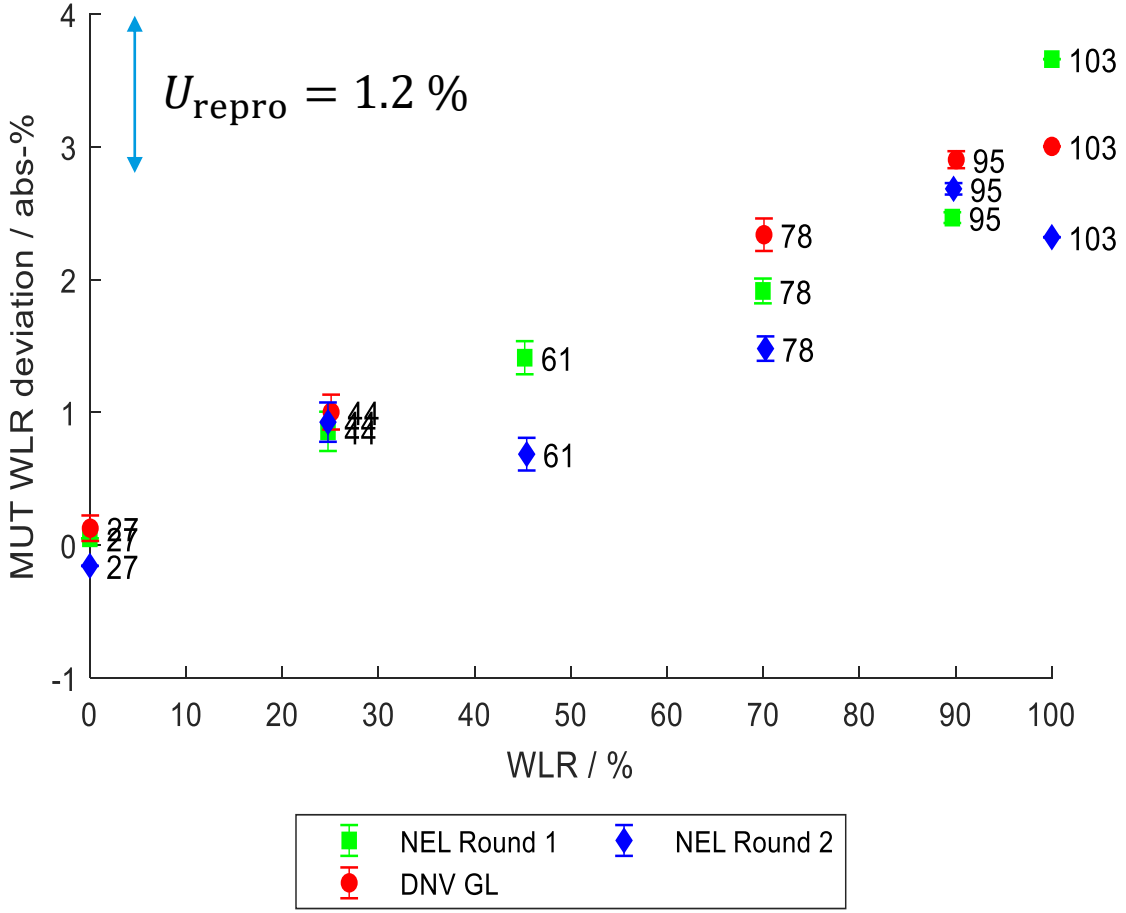


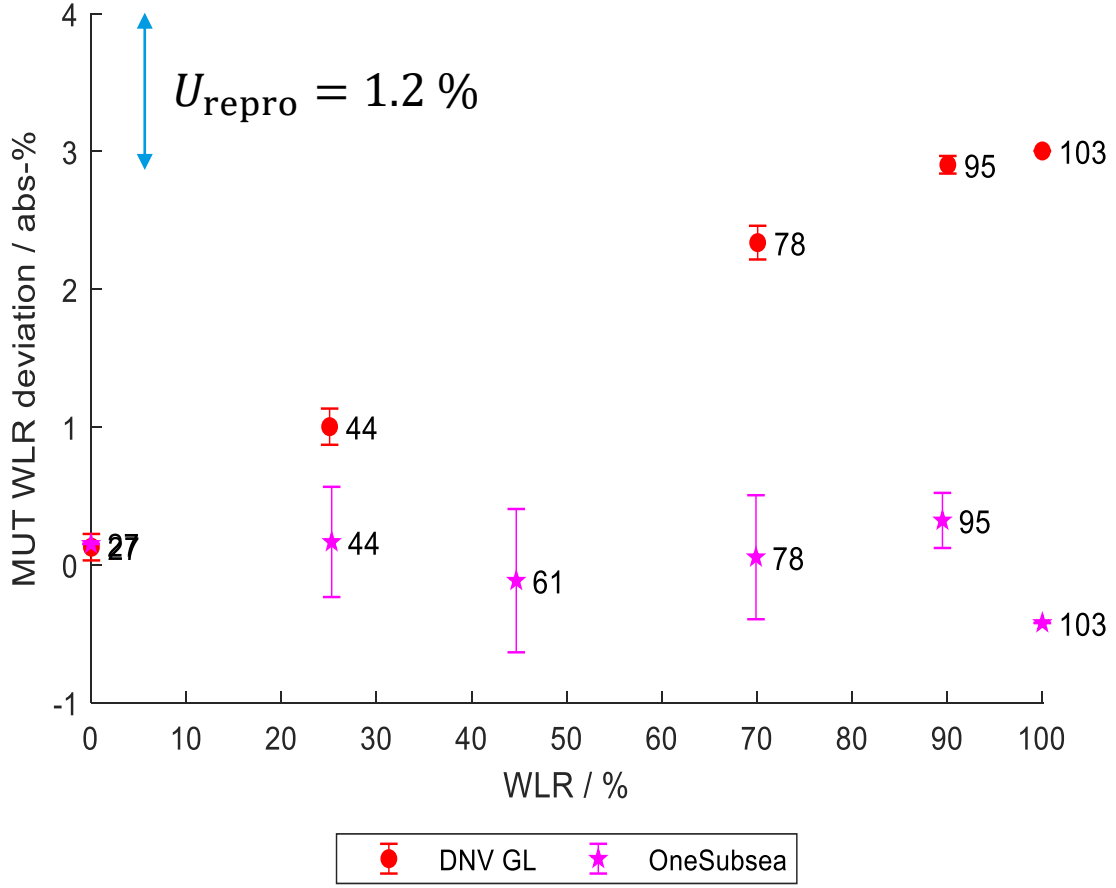
Point wise comparison of measured MUT q_{gas} deviation @ q_{liquid} = 90 m³/h and GVF = 25 % as function of WLR





Point wise comparison of measured MUT WLR deviation @ q_{liquid} = 90 m³/h and GVF = 25 % as function of WLR





Summary of pair-wise consistency results

Tests	$q_{m,\,total}$	q_{total}	q_{gas}	q_{liquid}	WLR	GVF	q_{oil}	q_{water}	Mean
NEL-R1 – NEL-R2	91%	95%	98%	93%	96%	96%	92%	96%	**95%**
NEL-R1 –DNV GL	89%	78%	69%	87%	95%	71%	88%	90%	**83%**
NEL-R2 –DNV GL	85%	75%	75%	90%	93%	79%	84%	86%	**78%**
DNV GL – OSS	82%	74%	78%	74%	80%	100%	58%	80%	**78%**

For more information on the MultiFlowMet-I project, see:

- EMRP ENG58 MultiFlowMet, *Multiphase flow metrology in oil and gas production*, 2014 – 2017.
- "ENG 58 Final Publishable JRP Report and Associated Annex A", Euramet, 2018.
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