Assessment of measurement error due to phase contamination in turbine and Coriolis meters

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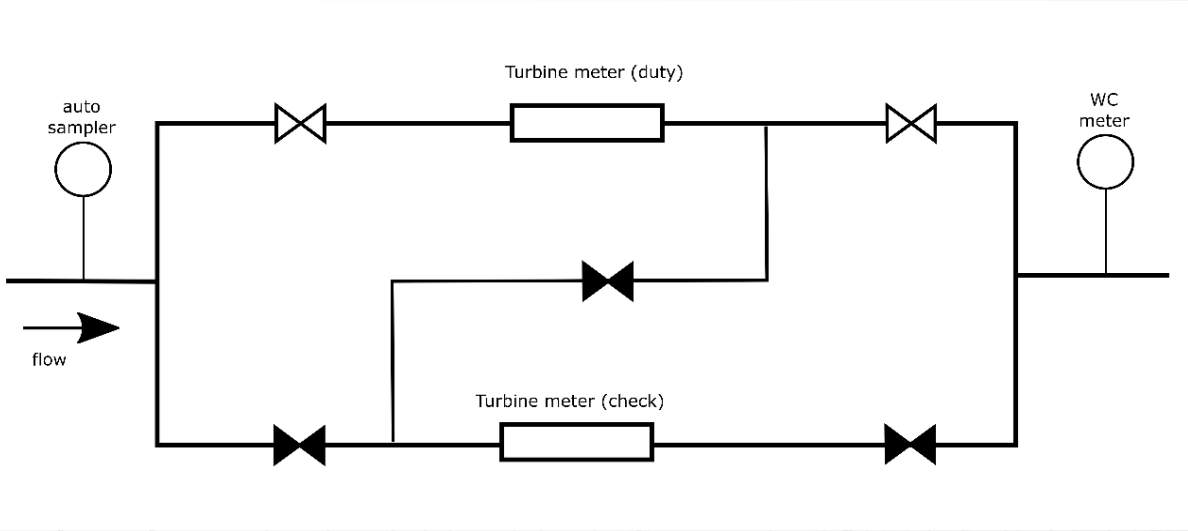
Introduction

- PTTEP field case:
  - PTTEP operates multiple brown fields in Malaysia
  - Crude oil production is of main interest
  - Recent years, production rate has decreased while WLR has increased and fluctuates
  - Custody transfer liquid metering system on these fields similar:
    - Downstream gas-liquid separator, typically 8-10”
    - Helical turbine meter for total liquid measurement
    - WLR from autosampler and WC meter
    - Typical conditions: WLR = 5-70%, Q_l < 250m^3/h



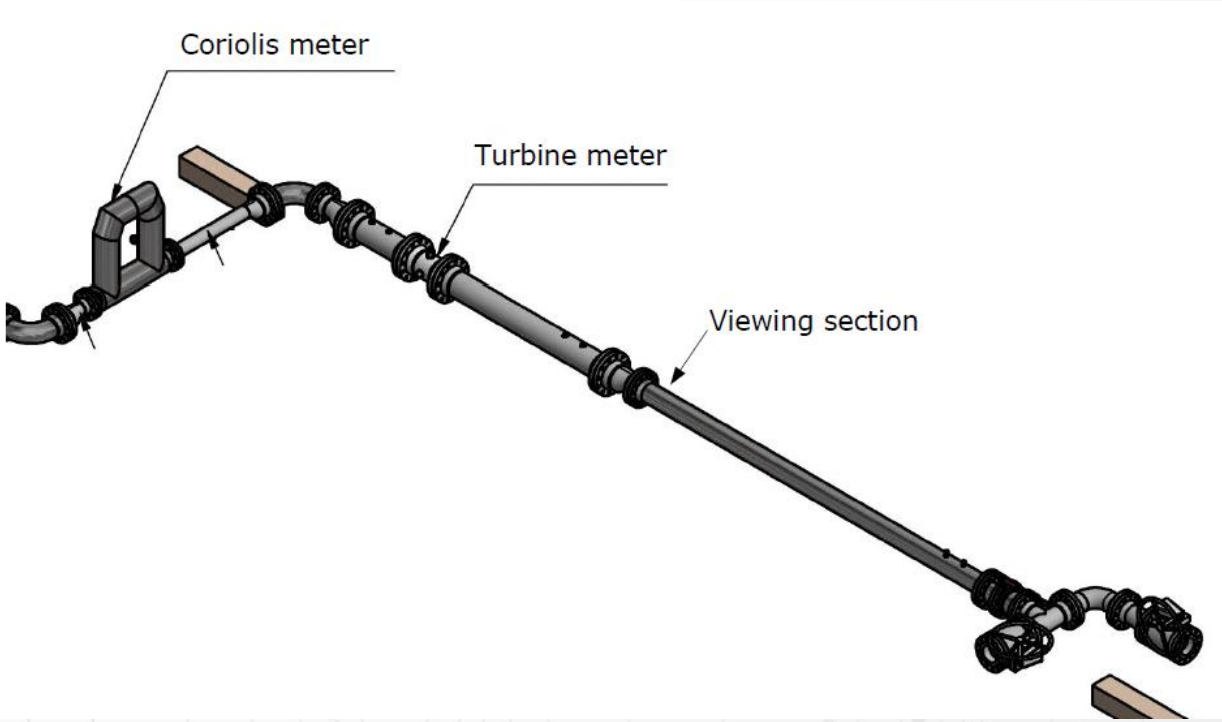
Introduction cont'd

- Aim of the study:
  - Assess the performance of the turbine meter under two-phase conditions
  - Assess the potential impact of oil degassing or gas carry-under
  - Provide correction for potential systematic biases on liquid flow
  - Assess a potential alternative metering system

- Approach:
  - Test of an 8" helical turbine meter (Faure Herman TZN200) at DNV GL multiphase test facility under two-phase and mild multi-phase conditions (GVF<12%)
  - Selected a 4" Coriolis meter as an alternative flow metering technology

Test setup and matrix

- Test setup and matrix focused on reproducing the in-field flow regimes:
  - Matching flow rate and WLR and pipe layout of the field (many mixing elements)
  - Matching oil properties (Exxsol D120)
    - Oil viscosity and density close to field values
    - Oil-water surface tension expected lower in the field
    - Upstream geometry to promote mixing of oil and water phases
  - Gas introduction by means of degassing the Exxsol D120 oil
    - Results in small bubbles mimicking degassing or gas carry-under



Test results: oil-water flows

- Two-phase flow regimes dictated by liquid Froude number:

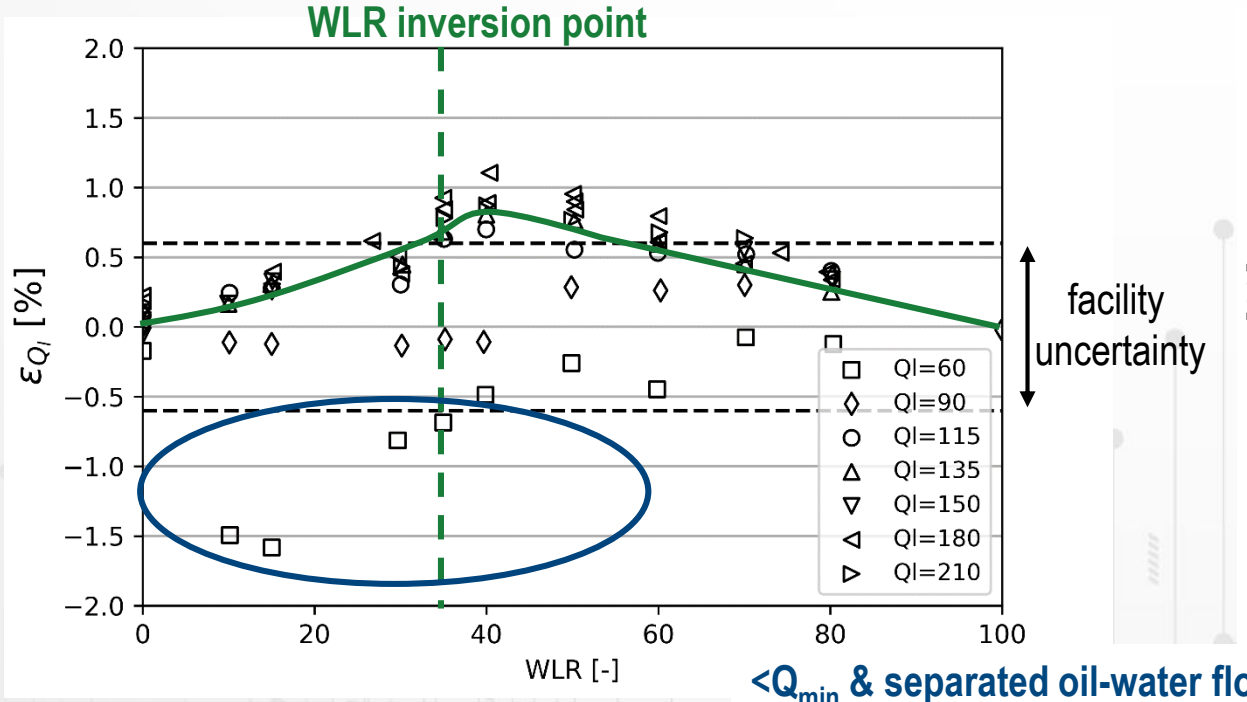
$$\mathrm{Fr}_l = \frac{u_{sl}}{\sqrt{gD}}$$

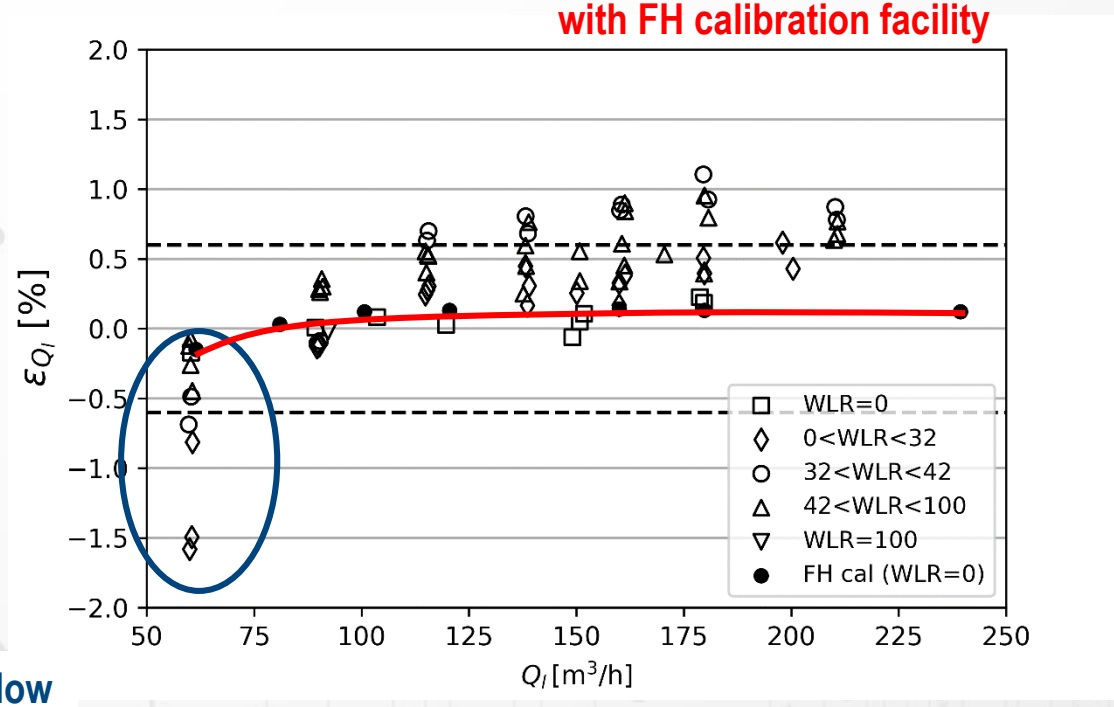
  - For Exxsol D120 fluid properties:
    - Dispersed for **$\mathrm{Fr}_l \geq 2.5$**, and partially segregated for **$\mathrm{Fr}_l < 2.5$**

Test results TM: oil-water flows

- Turbine meter (TM) response on liquid flow: WLR and $Q_l(Fr_l)$

$$\varepsilon_{Q_l} = \frac{Q_l^{MUT} - Q_l^{ref}}{Q_l^{ref}}$$





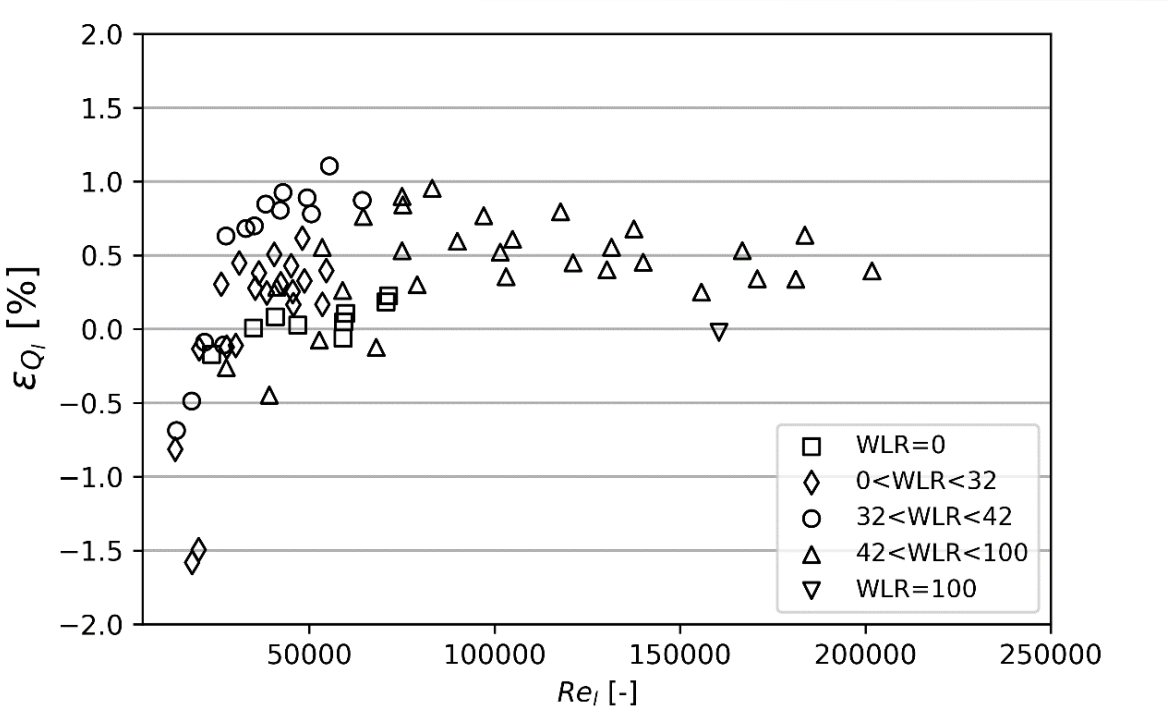
<Q_{min} & separated oil-water flow

Test results TM: oil-water flows cont'd

- Explanation of the results:
  - Reynold number effect

$$Re_l = \frac{\rho_l u_{sl} D}{\mu_l(WLR, r_d)}$$

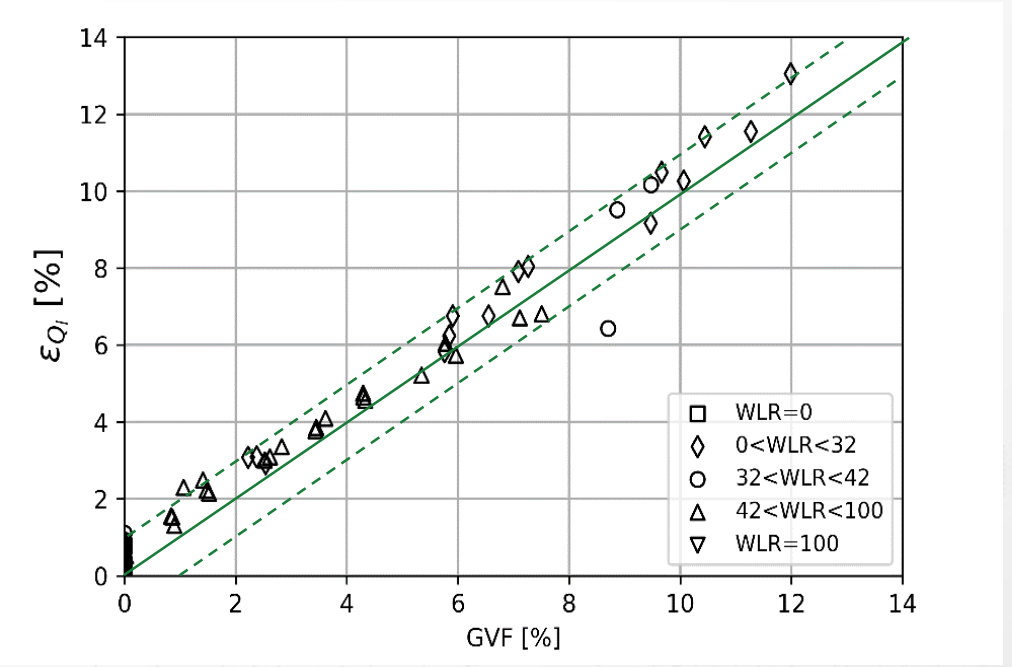
  - Effective viscosity of oil-water mixture is higher than oil viscosity and a function of droplet size
  - Applying Brinkman effective viscosity model does not lead to consistent trend in Re-number
  - Comprehensive TM model (e.g. Lee model) may be required (bearing friction, Reynolds number)



Test results TM: gas-oil-water flows

- Gas bubbles introduced by degassing the oil stream:
  - Relative high facility uncertainty (+/-1% GVF)
  - Very linear trend with GVF (small bubbles, near zero slip, homogeneous flow)
  - Results include WLR variations (no compensation applied yet)

- Same analysis performed for the Coriolis meter, for results see the paper



Conclusion

- Good match between FH calibration facility and DNV GL facility on pure phases
- For sufficient high flow rates: systematic over-reading of the TM as function of WLR
- The behavior cannot be explained in terms of Reynold by standard effective viscosity models, more research needed (TM model and mixture viscosity)
- Non-linear behavior requires a continuous WLR input for correction model in the field

- Gas response is very predictable (linear in GVF) due to small bubbles/homogeneous flow

Thank you!

NORTH SEA FLOW MEASUREMENT WORKSHOP

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