Compact Cyclone Multiphase Meter (CCM) Discussion of Metering Principle, Slug Handling Capacities and Flow Measurement Results

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Abstract

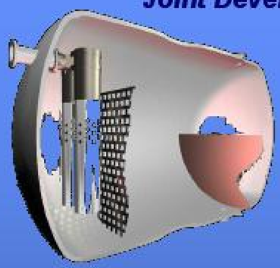
This paper presents the Compact Cyclone Multiphase (CCM) meter – the metering principle, slug handling capacities and flow measurement results. The CCM meter has previoiusly been presented in various papers /1/-/4/. It is a "separation type multiphase meter" utilising cyclonic separation technology for compact separation of gas and liquid. After the gas/liquid separation, gas and liquid is measured individually by conventional single phase instruments before the phases are re-mixed for further multiphase transport.

Background

Oil&Gas

KPS Gas/Liquid Cyclone Products

Joint Development with STATOIL

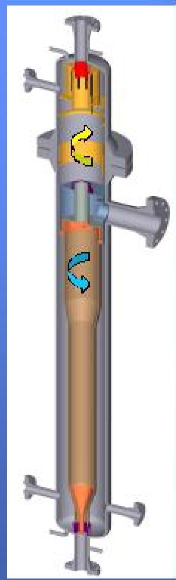


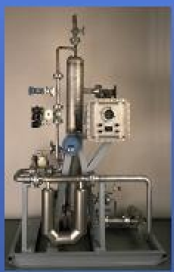
Cyclonic Inlet Device (G-Sep™ CCI)

- Debottlenecking device
- New separators can be smaller
- Reduced chemical consumption

Compact Cyclonic Degasser (G-Sep™ CCD)

- Replacement for 2 phase separators
- Integral scrubbing sections
- Component in CYSEP - Compact Separation Skid





Compact Cyclonic Multiphase Meter

- A spin-off product from the above separation equipment development

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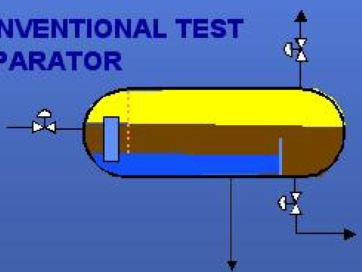
Background

Oil&Gas

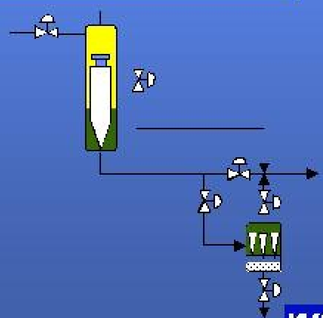
Multiphase Meter vs. Test Separator

Functions provided by the test separator	Can the same functions be provided by the CCM ?
•Well testing	•Yes
•Well clean-up	•No (Yes by integrating sand cyclones)
•Spare production capacity	•No
•Test bed for new chemicals	•No

CONVENTIONAL TEST SEPARATOR



CCM METER



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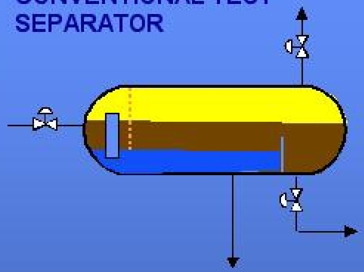
Weight comparison: Replacing a test separator with a CCM

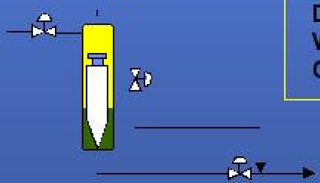
CONVENTIONAL TEST SEPARATOR



Design Capacity	100%	33% (1)
Liquid production rate [SM3/D]	10 000	3 300
Gas production rate [MSM3/D]	3.0	1.0
GOR [SM3/SM3]	300	300
Operating pressure [barg]	14	14
Temperature [ºC]	80	80

Note 1) 33% case designed for well testing, not spare production capacity.

CCM METER



Weight comparison	TEST SEP.	CCM METER	% REDUCTION
Dry weight vessel [Tons]	26	4.4 (0.7)	83 (97)
Wet test weight vessel [Tons]	96	18 (2.1)	81 (98)
Operating weight vessel [Tons]	68	10 (1.3)	85 (98)

( ) - 33% of design capacity

/4/

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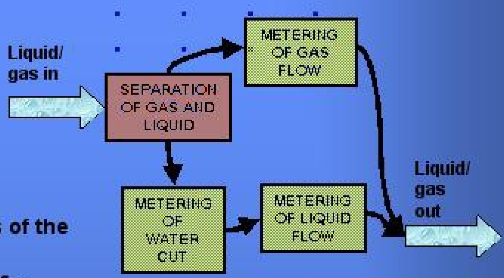
Features & Benefits

Oil&Gas

Separation - measuring - recombining

- High accuracy. Individual gas/liquid single phase meters are much more accurate than meters measuring both phases together
- Can meter single phase as well as multiphase:
  - Will measure either one of the phases regardless of the actual flow of the other phase
- Possibility for sampling of liquid and gas phase for analysis



Off the shelf meters

- Calibration done at factory or in laboratory - no need for time consuming and inaccurate “field calibrations”
- Proven technology - high accuracy, tracability, repeatability and serviceability
- Proven, high and known durability of each individual meter

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Features & Benefits

Oil&Gas

State of the art in compact separation

- Cyclone principle for small footprint and minimum weight
- 2 stages of cyclone separation yields high separation efficiency
  - Clean liquid phase [0 - 10 vol% of gas in the liquid ok for the CCM]
  - Clean gas phase [0 - 0,01 vol% of liquid in the gas ok for the CCM]
- Unique combination of hydraulic design and control system makes it possible to achieve high separation performance even at severe slugging conditions.
- Turndown of 100% with respect to separation (Gas Void Fraction can range from 0% to 100%).

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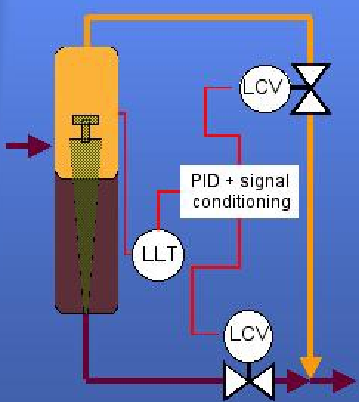
Features & Benefits

Oil&Gas

Control system and flow computer in one unit

- Simple operation: Start, stop and reading of results.
- EX rated for stand-alone installations in hazardous areas.
- Graphical interface for reading of flow values and trends.
- Connection to SCADA system through digital lines for accurate and reliable readings.



Control system

- One liquid level PID controller controls both valves for optimum turn-down (0-100% GVF) and minimal pressure loss. The signal is split using a very simple algorithm.

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Features & Benefits

Oil&Gas

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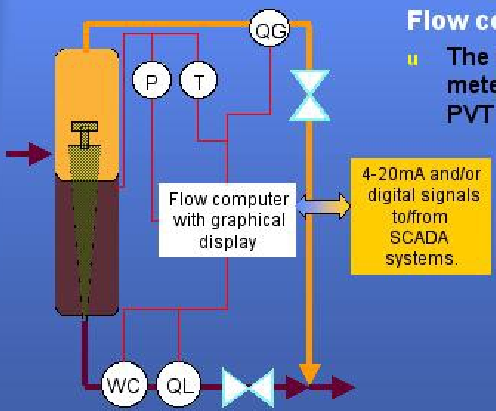

Flow computer

- The flow computer collects inputs from the meters and calculate oil, water and gas rates. PVT data can be used for high accuracy.

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Applications

Oil&Gas

- **Used as an ordinary multiphase meter the CCM can be installed at any location topside/land based and measure the flow.**
  - Any flow regime
  - Single phase as well as multiphase flow
  - Well testing/reservoir management
- **It can be used for fast well testing on land or topside. Typically 4 hours per well (land based).**
- **It can be used as a mobile test facility mounted on a truck.**

Applications where the CCM has special advantages:

- **High GVF applications** ⇒ *The small liquid fraction is measured separately*
- **Low Oil fraction applications**
- **In areas where on-site "field calibration facilities" are not available**
  - Use a CCM for "flow calibration" of in-line multiphase meters?
- **Where multiphase separation & metering in combination is required**

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CCM Metering Principle

Oil&Gas

Instrumentation

- **Gas flow meter**
  - V-Cone, Annubar, Venturi or Orifice plate ... are options
- **Microwave Full Range Water Cut Analyzer**
  Supplier: *Phase Dynamics Inc.*
  - Housing the CCM control system and overall flow computer
  - Kværner owns rights to sell PDI Water Cut Analyzers world wide outside the Americas
- **Coriolis Liquid flow meter**
  - Turbine, Venturi or PD ... are options
- **Pressure: Absolute and differential**

➡ **Factory/laboratory calibration of each individual instrument according to national standards, i.e. tracability.**

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CCM Metering Principle

Oil&Gas

Flow calculations, basics

- $Q_{gas} = Q_{gas,gas\ line} + Q_{gas,\ liq\ line}$
- $Q_{liq} = Q_{liq,liq\ line} + \cancel{Q_{gas\ line}}$
- $Q_{wtr} = Q_{wtr,liq\ line} + \cancel{Q_{r,\ gas\ line}}$
- $Q_{oil} = Q_{oil,liq\ line} + \cancel{Q_{,\ gas\ line}}$

Flow calcs. are performed
with PVT corrections

Main flow calculations, from measurements

- **Seen by the watercut meter:**

$$WC_T = \frac{Q_W}{Q_W + Q_O + Q_G} \quad \left(WC = \frac{Q_W}{Q_W + Q_O} \right)$$

- **Seen by the Coriolis meter**

$$Q_{TV} = \frac{\dot{m}_T}{\rho_T}$$

$$\boxed{\begin{aligned} Q_W &= WC_T \cdot Q_{TV} \\ Q_O &= (1 - WC_T - GVF_U) \cdot Q_{TV} \\ Q_{GU} &= GVF_U \cdot Q_{TV} \end{aligned}}$$

$$GVF_U = \frac{\rho_T - WC_T \cdot \rho_W - (1 - WC_T)\rho_O}{\rho_G - \rho_O}$$

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CCM Metering Principle

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Utility System

- **Control valves require:**
  - Pneumatic, Electrical or Hydraulic operation
- **Power Supply required:**
  - 120 VAC, 230 VAC 50/60 Hz, or
  - 24 VDC
- **Power consumption:**
  - Typically 100 Watts (higher if electrical control valves are used)

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CCM Performance

Oil&Gas

Reference fluids

Crude/ Company ref.	Oil density [API]	Pressure [barg]	Temperature [°C]	Gas Void Fraction [%]
Oseberg Norsk Hydro	36	30-90	60-90	40-98
Troll Oil Norsk Hydro	25	23-35	60	30-98
Grane Norsk Hydro	19	10-20	60	40-97
Ladybug Texaco	32	15	40	40 -99
Vic Bilh Elf	23	15	60	< 80

- Norsk Hydro : High Pressure Test Rig in Porsgrunn, Norway
- Texaco : Humble Test Facility, Houston, US
- Elf : Pou, France

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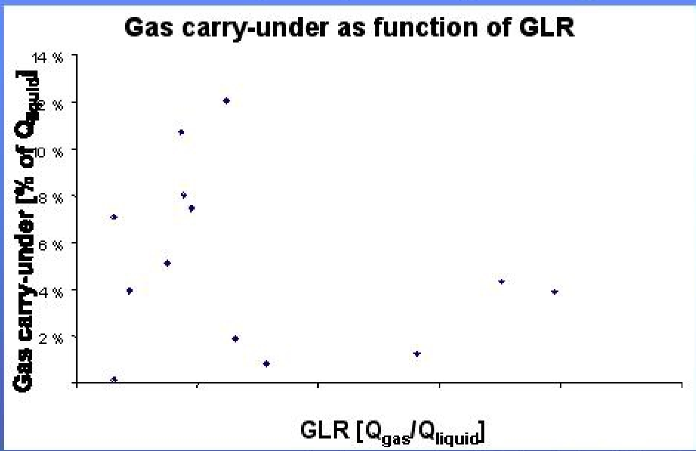
Separation efficiency

- **Example 1: GRANE crude (API 19):** Norsk Hydro Porsgrunn Test Facility



- Note : There are some more gas carry-under than expected, this is due to (i) the viscous oil (ii) "early version separator internals" and (iii) the fact that the CCM meter are configured for higher flow. An increase in GLR gives better separation due to higher centrifugal forces. /1/

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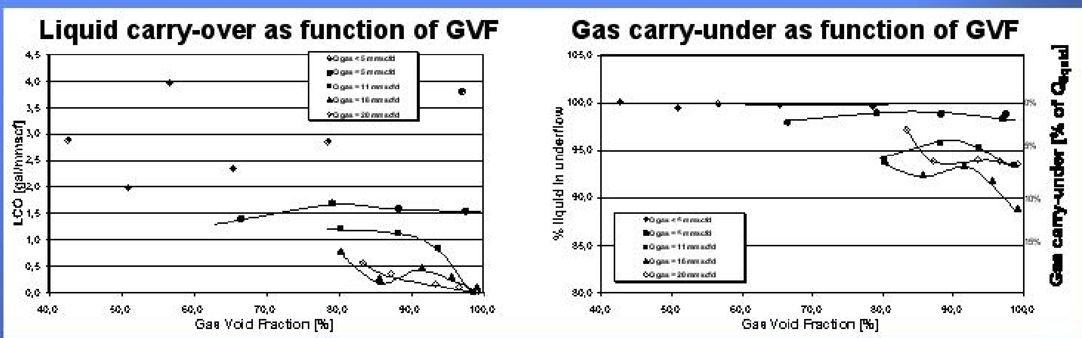
Separation efficiency

- **Example 2: LADYBUG crude (API 32):** Texaco Humble Test Facility



- Note : Liquid carry-over measured from a reference gas scrubber downstream the gas outlet. Gas carry-under measured by a gamme denistometer on the liquid leg

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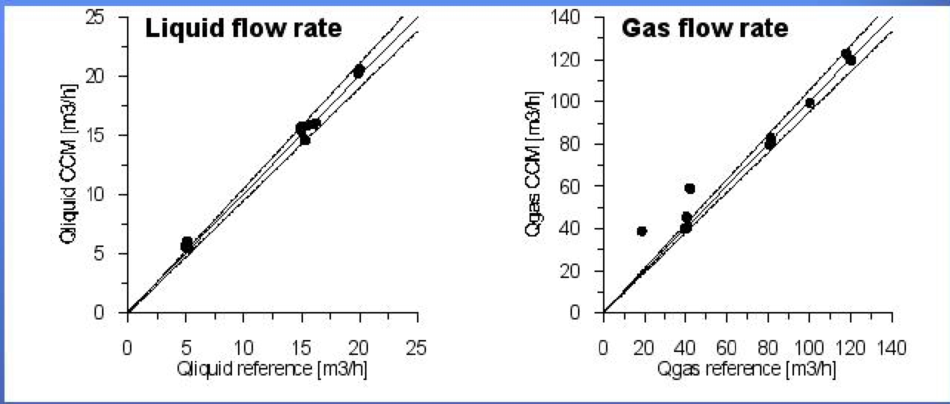
Flow measurement results:

- **Example 1: GRANE crude (API 19):** Norsk Hydro Porsgrunn Test Facility



- Note : Liquid and gas flow as measured by the CCM meter and compared to the reference. The stapled lines are ±5 % lines. /1/

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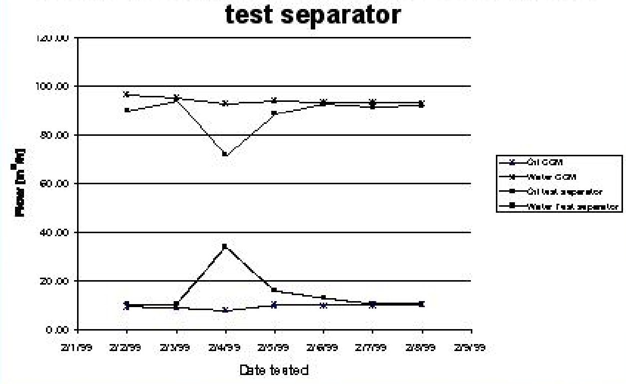
Flow measurement results:

- **Example 2: Everglades (API 15):** Renaissance Energy, Canada

Test flow as measured with the CCM and the test separator



- Note :
  Tests run for 24 hour compared to the results from the test separator. At 2/4/99 additional gas form the fuel gas system was added. It is assumed that the increased gas flow damaged separation in the test separator, giving a high water carry-over into the oil outlet (i.e. increased oil flow and reduced water flow).

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Repeatability on a flowing well

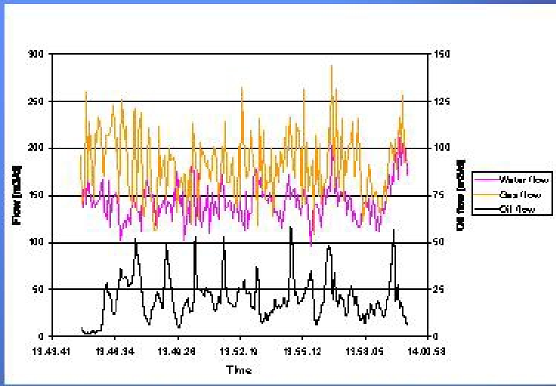
- **What repeatability is achievable?**
- **Conditions typical for land based wells with heavy oil shown in the graph**
- **If the curve is fitted to a Normal distribution we find that for a 24 hour test the repeatability of the flow is:**

$$Q_{oil} = 20.55\,m^3/d \pm 19.2\% \quad (\pm 3\sigma)$$

$$Q_{water} = 143.6\,m^3/d \pm 4.4\% \quad (\pm 3\sigma)$$

$$Q_{gas} = 182.2\,m^3/d \pm 6.0\% \quad (\pm 3\sigma)$$

- **Regardless of instrument this is the the flow of the well in a 24 hour period**



Gas and liquid flow variations measured at the tests at Everglades

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Oil&Gas

Slug handling capacities

Experience from the field

- **No separation problems experienced**

Experience from test facilities like Norsk Hydro Porsgrunn and Texaco Humble

- **Slugging flow experienced especially on high watercut flow rates.**
  - No separation problems experienced

Experience from KPS in-house laboratory, Trondheim, Norway

- **Slug test of a 12" unit Degasser** (Compact Gas/Liquid Cyclone Separator)
- **Pupose:**
  - Test the Degasser's ability to handle slugs using normal control routines.
  - The slugs are artificially made using valves.

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Slug Test on 12” unit

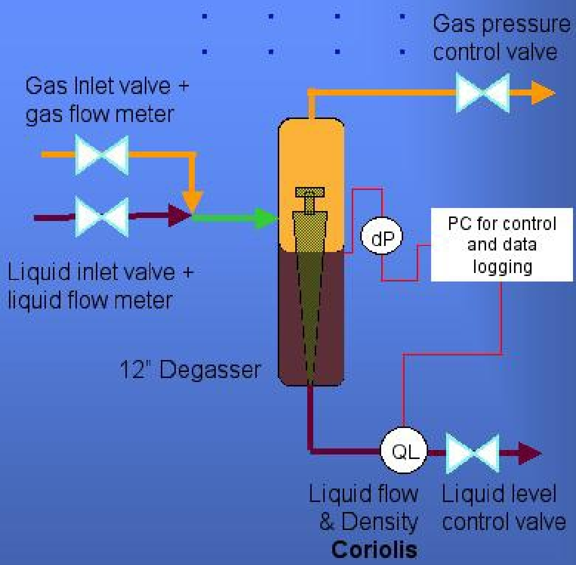
Oil&Gas

Control

- **Level and gas pressure control of the Degasser.**
- **Inlet valves control inlet flow, slug frequency and amplitude.**

Main measurements

- **Coriolis meter in liquid outlet for separated liquid density and flow.**
- **Liquid carry-over by visual inspection**
- **Flow (slugs) into the Degasser.**



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Slug Test on 12” unit

Oil&Gas

Summary of results

- **At low frequency the slugs are so long that the gas/liquid valves will go to fully closed positions and remain there for a while. This causes several things to happen:**
  - Oil and water are separated in the annulus. The liquid density curves drops from 950 to 830 kg/m^3 because liquid goes from almost clean water to almost clean oil when level varies. No gas carry under is detected (visual inspection through transparent tubing) and no liquid carry over is detected.
  - Liquid flow coming out of the separator have twice the magnitude (peaks). This is because of the pressure caused by the gas slug entering the separator when the liquid valve is almost fully open and the gas valve is closed. The instantaneous excess gas will push the level down faster than the liquid valve initially can respond.
- **At higher frequencies the slugs are just “absorbed” by the Degasser. At lower frequencies the behavior will be like the 0.01 Hz or better. A continuos frequency of 0.01 Hz is the worst scenario for this separator, and not likely to occur in real installations).**

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Slug Test on 12” unit

Oil&Gas

Conclusions from the tests

- The Degasser can handle slugs without effecting performance in any detectable degree, at least not in the laboratory
- Faster reacting valves will reduce the largest total level variation and pressure variation.
- Ordinary control valves were used in the experiments. The valve closure speed should be about the same or faster than the time it takes to empty the liquid in the vessel at fully open liquid valve.
- If severe slugging is not anticipated, the speed of the valves are not important.

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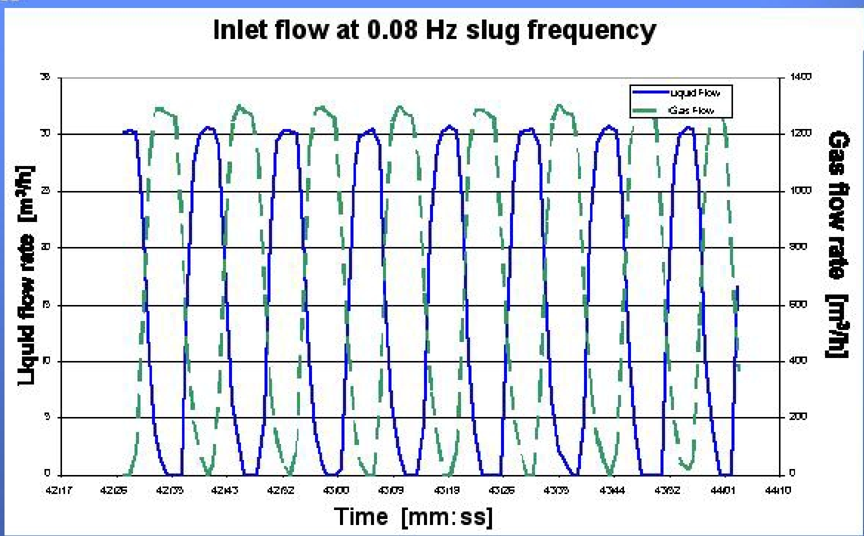
Slug Test on 12” unit

Oil&Gas

Results



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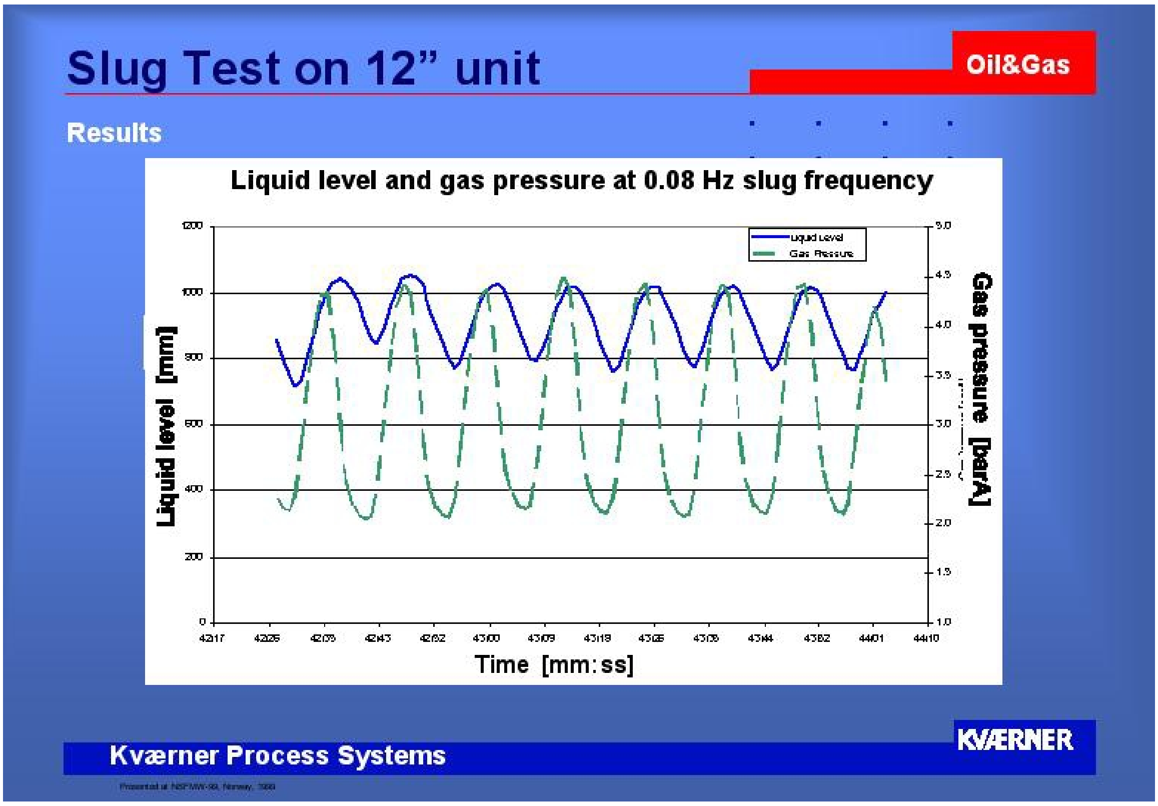
Slug Test on 12" unit
Oil&Gas
Results
Liquid level and gas pressure at 0.08 Hz slug frequency
Liquid level [mm]
Gas pressure [barA]
Liquid Level
Gas Pressure
Time [mm:ss]
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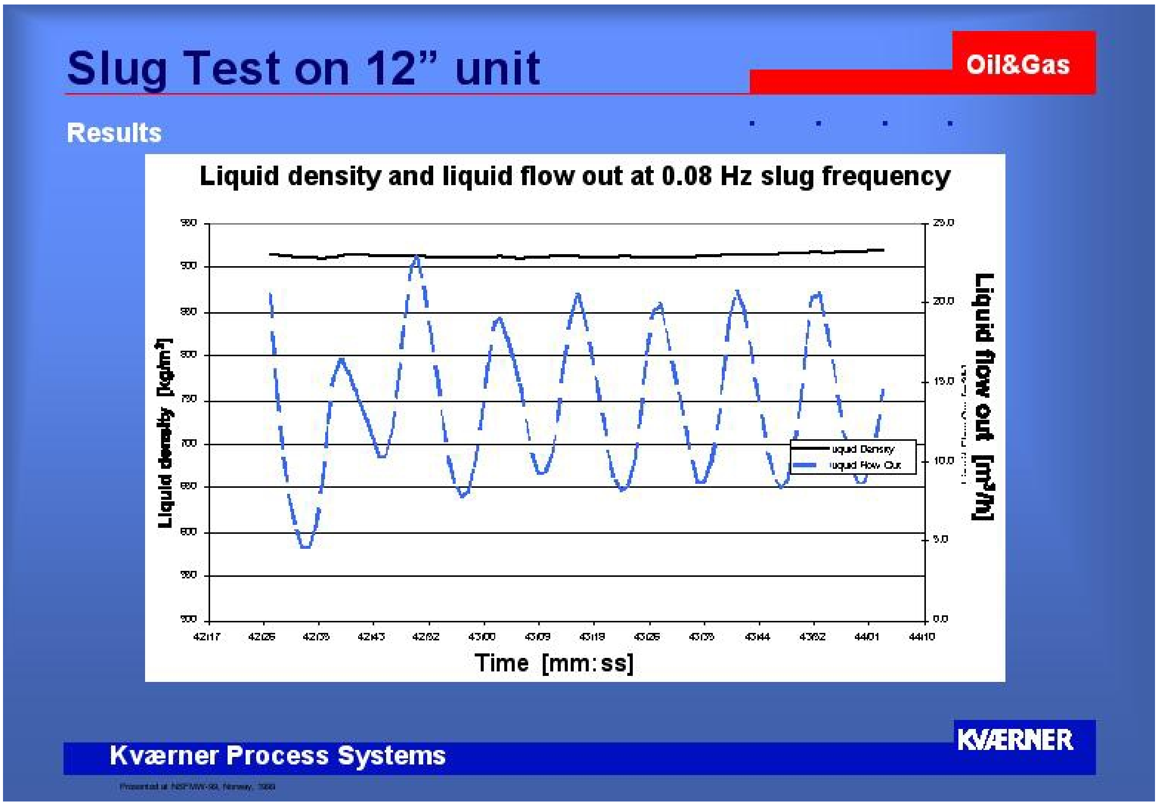
Slug Test on 12" unit
Oil&Gas
Results
Liquid density and liquid flow out at 0.08 Hz slug frequency
Liquid density [kg/m³]
Liquid flow out [m³/h]
Liquid Density
Liquid Flow Out
Time [mm:ss]
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CCM Performance

Oil&Gas

Other characteristics

- **Pressure drop:**
  - Typically 1 bar (14,5 psi)
- **Salinity dependencies:**
  - The PDI Water Cut meter will be affected through the calibration value for 100% water. The calibration data need to be adjusted accordingly.
    - Currently the adjustment is manual
    - The sensitivity is largest at small salt concentrations
  - The Coriolis meter will be affected through the density calibration value for 100%water
- **Viscosity dependencies:**
  - Moderate relationship between liquid viscosity and gas carry-under.
- **Effects of transient flow on the individual flow measurements:**
  - Effects has not been separately identified, but not seen as critical since all flow meters use a very short time window to calculate the instant flow rates.

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CCM Meter - Highlights

Oil&Gas

CCM - Compact Cyclone Multiphase meter
"Separation type" multiphase meter

- **The CCM meter is used to measure the flow rate of oil, water and gas**
  - Works on pure oil, pure water, pure gas and on any mixture of the phases.
- **Compact skid includes:**
  - Compact Gas/Liquid separator
  - Liquid/gas flow & WC measurements
  - Re-mixing of the phases at skid outlet
- **"Off the shelf" instruments are used**
- **Accurate flow measurements (i.e. single phase, gas and liquid)**
- **No need for on-site calibrations (i.e. factory calibration only)**
- **Easy maintenance (i.e. local)**
- **Regional fabrication by Kværner**

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References

/1/ D Kvamsdal, B Christiansen, I Hjelkrem,»Operational experiences with a gas liquid cyclone», BHR, Multiphase technology, pp 101-117, Bannf, Canada, 1998

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