Separator measurement

Errors in level measurement and their solutions
Introduction

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23 year C&I, mainly O&G level
FS Eng (TÜV Rheinland)
Desired Outcome:
1. Gas with acceptable liquid content
2. Hydrocarbon liquid with acceptable water content
3. Water with acceptable hydrocarbon content
4. Safe
5. Maximise throughput

Control Parameters:
1. Pressure
2. Inlet flow rate
3. Bulk level (HC outlet)
4. Interface level (water outlet)
**Typical observations**

- Level and interface measurements 100mm or more error
- Slow response times
- No / incorrect measurement during startup
- Increased measurement error during upset conditions
- Bridles needing regular blowdowns
- Drift over time
- Errors due to density changes
- Errors caused by mounting
- Regular intrusive maintenance required

All of these problems have solutions
Typical 3 phase separator

What the data sheet said...

The reality can be more challenging!

- Emulsion
- Sand
- Foam
- Entrained gas
- Entrained liquids
- Changes to HC properties
- Etc…
Typical 3 phase separator

Requirements of level measurement

- Accurate measurement of levels
- No drift over time
- Low maintenance
- Ability to cope with upset conditions
- Ability to cope with changing operating parameters

The perfect separator

Is reliable level information enough?
Typical 3 phase separator

More information from your separator

- Sand level
- Presence of emulsion
- Density profile
- Foam measurement

The less than perfect separator

Knowing what is actually happening allows informed decisions about how to operate the separator.
Bridle mounted

Measurement in a bridle has advantages and disadvantages:

For:
- Easy calibration*
- Isolation for cleaning*
- Isolation for repair*
- Less emulsion in bridle

Against:
- Sand blocking lower tapping
- Waxing due to lower temperature
- Care required with tapping point heights
- Bridle balances hydrostatically with the vessel

* With modern capacitance or guided wave radar transmitters that have no moving or electronic parts in the process these factors become less important.
Potential Error

Vessel and bridle balance hydrostatically

306mm error in bridle measurement
Vessel mounted

Measurement directly in the vessel has advantages and disadvantages:

For:
- Direct measurement of actual vessel conditions.
- Problems with tapping points eliminated.
- Can measure the full vessel range, useful during startup or upset conditions.

Against:
- Isolation for removal or repair not possible without shutdown. *
- Large diameter stilling well needed if buildup possible.

* With modern capacitance or guided wave radar transmitters that have no moving or electronic parts in the process these factors become less important.
GWR build up

Why intermediate spacers are not desirable

The image is from a dehydrator where it was necessary to remove intermediate spacers due to them acting as sites for asphaltene formation as pictured.

Correctly a 100mm stilling well had been used as build up was a known issue.
Guided wave radar – The hype

The technology is not affected by media density, varying temperatures or pressures, and provides reliable, accurate measurements in demanding applications.

What are the advantages of guided wave radar?

Guided wave radar technology is ideal for a variety of applications because it is impervious to shifts in pressure, temperature, or product-specific gravity. Setup and volume measurement of liquids and solids. It is unaffected by changes in process conditions, high temperatures and pressures, and steam.

changes in density, dielectric or conductivity of the fluid. Further, he says changes in pressure, temperature and most vapor space conditions have no impact on measurement accuracy; GWR is unaffected by high turbulence or

Is this true?
For a constant pressure a fixed compensation could be applied.

If a constant correction is applied the error will be in the opposite direction when depressurised.

Is the error large enough to be of concern?
Polar Gases

**Polar media:**
One atom has a greater electro-negativity than the other \( \rightarrow \) constant dipole moment

\[
\varepsilon = 1 + \left( \frac{\rho}{\varepsilon_0 \cdot k \cdot T} \right) \left( \alpha + \frac{d^2}{3 \cdot k \cdot T} \right)
\]

- Molecules align with the electric field of the applied microwave pulse.
- This effects the wave propagation speed and hence the accuracy of the device.
- The presence of polar molecules in a gas has a great effect on the microwave propagation speed.
- Always taken into consideration with GWR on steam applications.
Non-polar gases

- Is there an effect with non-polar gas molecules?

- Molecules are polarized by and align with the electric field of the applied microwave pulse.

- A smaller effect than for molecules with a permanent dipole.

- Not always considered when applying GWR.
GWR error per metre of gas

Error at a given pressure and temperature is dependent on the gas.

At 110 bar a GWR will under read the level in a sour gas vessel by 95mm per metre of gas space.
Typical example

Indicated Level 0%... But is this correct?

Actual level 9.2%

The actual vessel level is 230mm higher than the measured level!

Would this be considered acceptable?
Gas phase compensation

- The reference distance is a constant physical distance.
- $D_{\text{ref}}$ and are $Ref_{\text{ref}}$ measured.
- Therefore $D_0$ is calculated directly.
Gas phase compensation

- Despite gas phase compensation being in regular use on steam boiler applications for many years no tests had been carried out on hydrocarbon gases.

- Tests carried out in collaboration with a major global oil company in 2015

- Independent test found error reduced from 230mm with methane to ~4mm

- Full report available
Methane and nitrogen

![Graph showing measurement deviation for nitrogen and methane](image)

- **Nitrogen uncorrected**
- **Nitrogen corrected**
- **Methane uncorrected**
- **Methane corrected**

**Measurement deviation**

**Pressure / bar**

**Measured level deviation / mm**
Gas phase implications

- The error caused by the gas phase will cause the transmitter to under read the level if not corrected.

- In a normal downward looking level measurement the error is greatest at 0%.

- The error increases the further the measured liquid is from the transmitter.

- Safety implications particularly for high level trip points low down in a vessel.
Interface measurement

- Capacitance
- Guided wave radar
- Capacitance and GWR combined
- Nucleonics
**Interface measurement**

**Performance / Reliability**

- **Guided radar**
  - Overall level
  - Clear interface liquid / liquid
  - Levelflex FMP51/52/54

- **DP**
  - Clear interface
  - Interface with emulsion layer liquid / liquid
  - Deltabar FMD7x

- **Capacitance**
  - Clear interface
  - Interface with emulsion layer liquid / liquid
  - Liquicap FMI51/52

- **Multiparameter**
  - Overall level
  - Clear interface liquid / liquid
  - Interface with emulsion layer liquid / liquid
  - Levelflex FMP55
Guided wave radar interface

- In an emulsion there is little or no step change in dielectric.
- This can mean that no interface echo is present.
- Alternatively an echo may be received from the top of the emulsion
- The amplitude may be used to indicate the thickness of the emulsion...
• Measured capacitance increases with an increasing water level.

• Not effected by the presence of emulsion – measured interface somewhere in emulsion

• Effected by build-up. Non-conductive wax build up will cause an under-reading of the interface level
Capacitance measurement

Capacitance:
\[ C = \frac{\varepsilon_1}{\ln(d_{iso}/d)} + \frac{\varepsilon_2}{\ln(D/d_{iso})} \]

The result of non-conductive build-up is an under-reading of the interface measurement.

\( \varepsilon_1 = 1.4 \ldots 10 \)
\( \sigma_1 < 0.4 \, \mu \text{S/cm} \)
\( \varepsilon_2 > \varepsilon_1 + 10 \)
\( \sigma_2 > 200 \, \mu \text{S/cm} \)
FMP55 – operation

Automatically recalibrates the capacitance to match the GWR – Compensates for build-up

If the GWR signal is lost due to emulsion - interface level from the capacitance value

Interface echo loss

<table>
<thead>
<tr>
<th>TDR</th>
<th>Overall Level</th>
<th>Interface</th>
<th>Capacitance</th>
<th>Capacitive value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
<td>✗</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

DC 1 = const.

Subtracted curve

Overall level

DC 2

$d_{iso}$

Interface level
FMP55 – benefits

The multi-parameter device for interface measurement

- Up to 3 measurements (overall level, interface, upper phase thickness) with one device
- Determination of interface and/or level if one echo is lost (e.g. due to emulsion, damping, bypass fully flooded)
- Continuous plausibility check of TDR echoes
- Automatic recalibration of the capacitance measurement
Endress+Hauser Radiometrics

1962
NG31/33+D1/D20
SG10

1977
FTG380/480Z
DG17/27Z GM tube
QG20/100

1983
FMG573
DG57

1984
FTG470Z

1994
FMG671

2004
Gammapilot
FMG60 SIL 2/3

2009
Modulator
FHG65

2010
Density Profiling

2011
FQG60
FQG61/62
FQG63

2013
FTG20

2015
FQG66

2019
Gammapilot FMG50 2-wire 4-20mA
Interface – Working principle

Radiometric measurement - Principle Interface / Profile

**Source container**

**Count rate [cnt/s]**

\[ H \sim e^{-\mu \cdot \rho \cdot d} \]

- **H** = Dose rate [µSv/h] (proportional to count rate)
- **µ** = Absorption coefficient
- **ρ** = Density medium [g/cm³]
- **d** = beam path through medium [mm]

**Slide 30**
Interface – Working principle with 2 detectors

1. Detector

- Oil
- Water

<table>
<thead>
<tr>
<th>Count rate of both detectors cascaded [c/s]</th>
</tr>
</thead>
<tbody>
<tr>
<td>min</td>
</tr>
</tbody>
</table>

2. Detector

- Weir

<table>
<thead>
<tr>
<th>Density [g/cm³]</th>
</tr>
</thead>
<tbody>
<tr>
<td>ρ_{min} Oil</td>
</tr>
<tr>
<td>ρ_{max} Water</td>
</tr>
</tbody>
</table>

Source container

MR
Radiometric measurement - Principle Interface / Profile

**Interface – Working principle with 2 detectors, water level low**

- **Source container**
- **Weir**
- **1. Detector**
- **2. Detector**

**Count rate of both detectors cascaded [c/s]**

- **Oil**
- **Water**

<table>
<thead>
<tr>
<th>Density [g/cm³]</th>
<th>Count rate max</th>
<th>Count rate min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oil</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**MR**

- **Density [g/cm³]**
- **ρ_{max}**
- **ρ_{min}**

Endress+Hauser
Interface – Working principle with 2 detectors, water level high

Count rate of both detectors cascaded [c/s]

\[ H \sim e^{-\mu \cdot \rho \cdot d} \]

- \( H \) = Dose rate [\( \mu \text{Sv/h} \)]
- \( \mu \) = Absorption coefficient
- \( \rho \) = Density medium [\( \text{g/cm}^3 \)]
- \( d \) = Beam path through medium [\( \text{mm} \)]

Water

Oil

Weir

Source container

1. Detector

2. Detector

MR

\( \rho_{\text{min}} \)

\( \rho_{\text{max}} \)

Density [\( \text{g/cm}^3 \)]
Density Profiling – Working principle

- Several detectors are mounted outside on the tank wall.
- The measuring range MR is subdivided into layers.
- Density value is calculated for each layer.
- Analogue tracking of layer boundaries due to diagonal paths.

- Source container with extension for source is installed on flange connection with dip pipe.
- Several detectors are mounted outside on the tank wall.
- The measuring range MR is subdivided into layers.
- Density value is calculated for each layer.
- Analogue tracking of layer boundaries due to diagonal paths.
Density Profiling – Working principle

Layer (1 ... 6)

- \( \rho_{\text{min}} \) Oil
- \( \rho_{\text{max}} \) Water

Measuring range (MR)

Source container

MR max. 1200mm

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Density Profiling – Working principle

Layer (1 ... 6)

Measuring range (MR)

Density [g/cm³]

ρ_{min} Oil

ρ_{max} Water

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Profile Vision Compact

Example retrofit design

Source insertion drywell manufactured with adaptor flange to suit existing flange or stilling well

A variety of mounting methods for retrofit are available
Profile Measurement – Density profiling / 3D Density profiling

Density Profiling

3D-Density Profiling

To see the separation effect as a continues process
The bottom line

The benefits of getting it right

- Reduce trips
- Reduce maintenance
- Reduce chemical usage
- Increase safety
- Increase separation efficiency
- Increase long term flexibility

= Reduced Costs
Increased Operational Efficiency
Increased Safety
Any questions?