Separator measurement

Errors in level measurement and their solutions

Introduction

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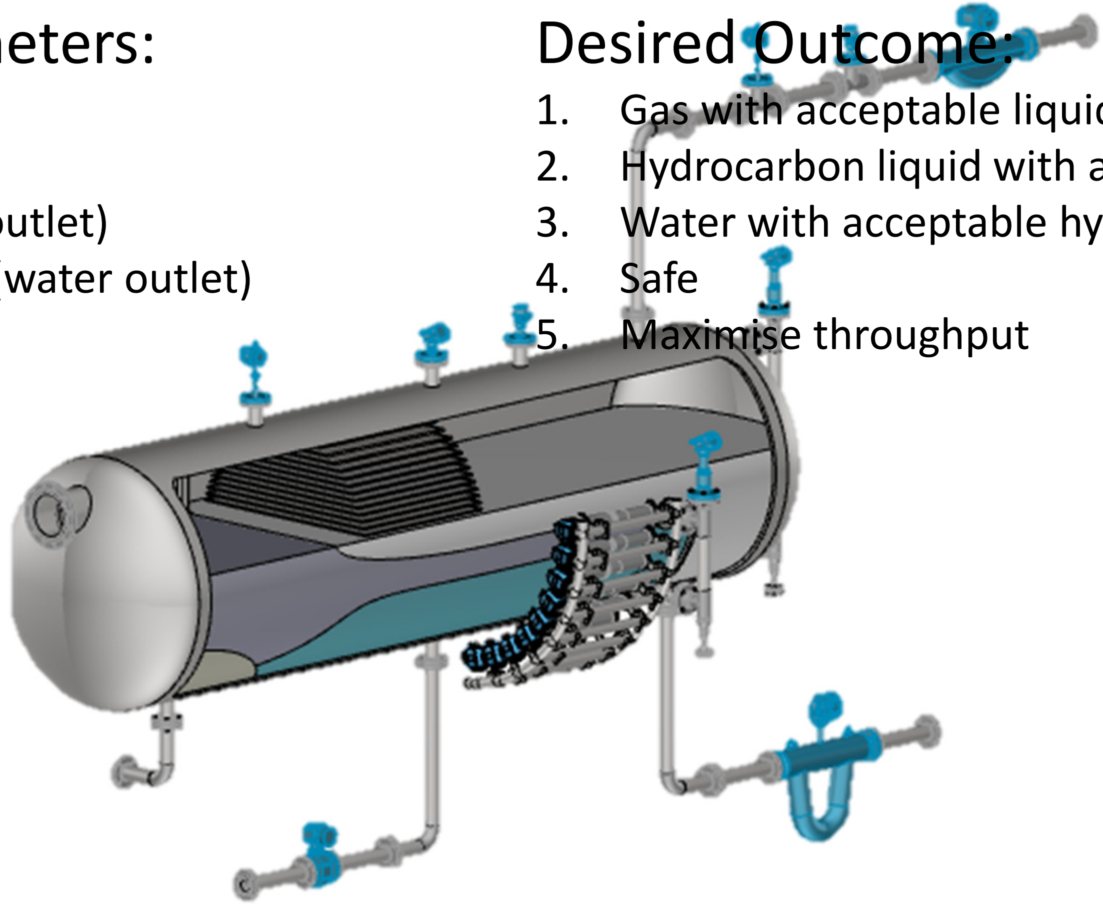
Separation

Control Parameters:

1. Pressure
2. Inlet flow rate
3. Bulk level (HC outlet)
4. Interface level (water outlet)

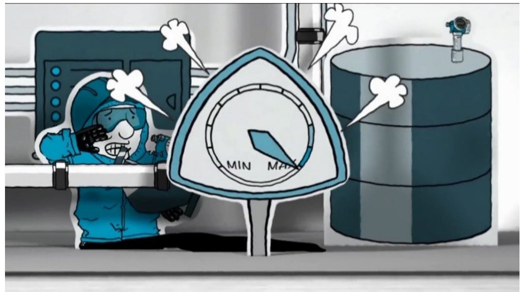
Desired Outcome:

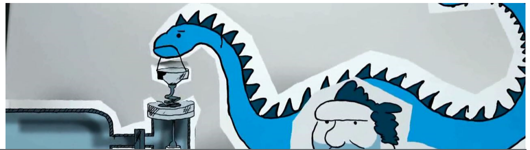
1. Gas with acceptable liquid content
2. Hydrocarbon liquid with acceptable water content
3. Water with acceptable hydrocarbon content
4. Safe
5. Maximise throughput



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



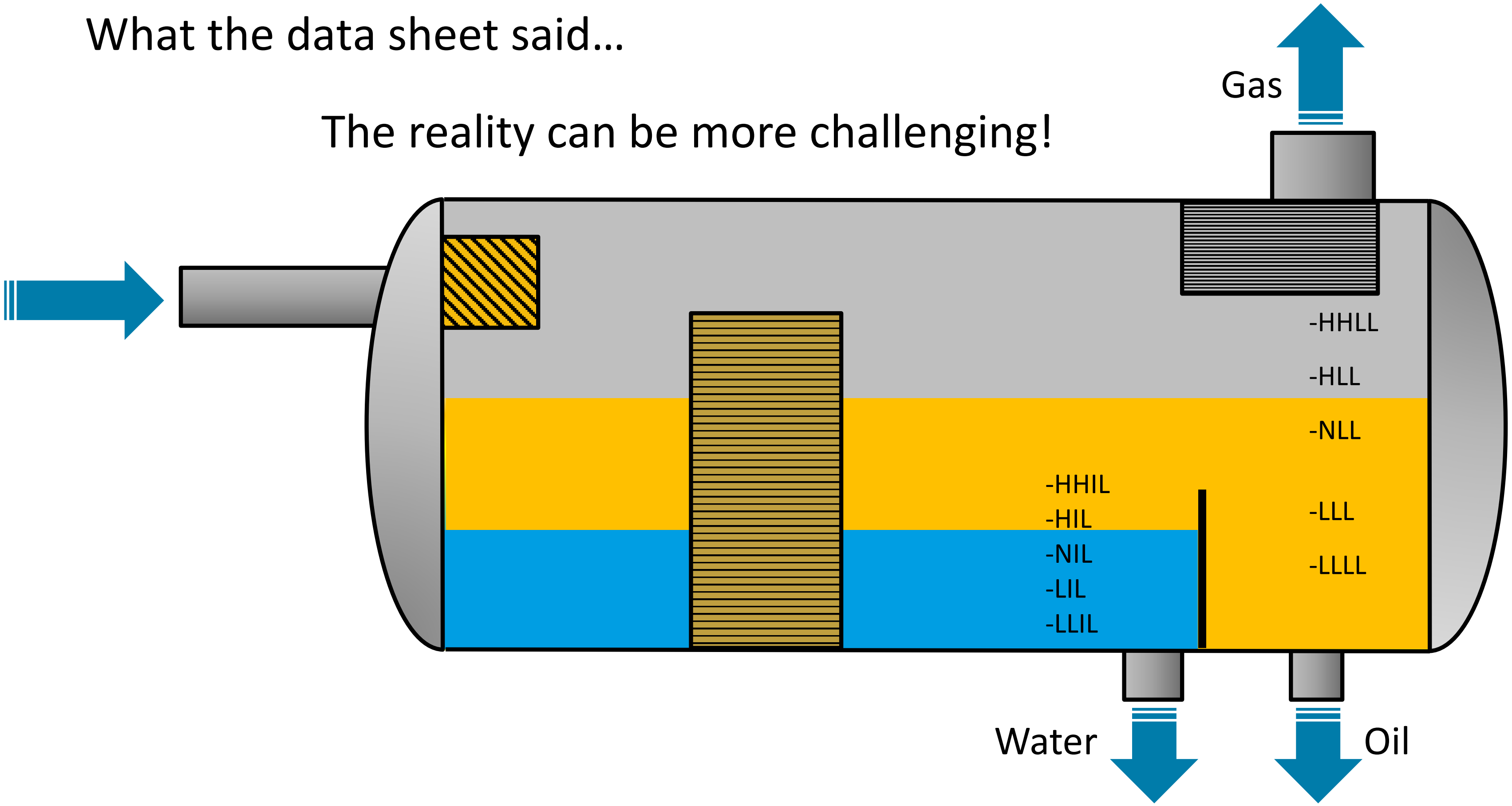


All of these problems have solutions

Typical 3 phase separator

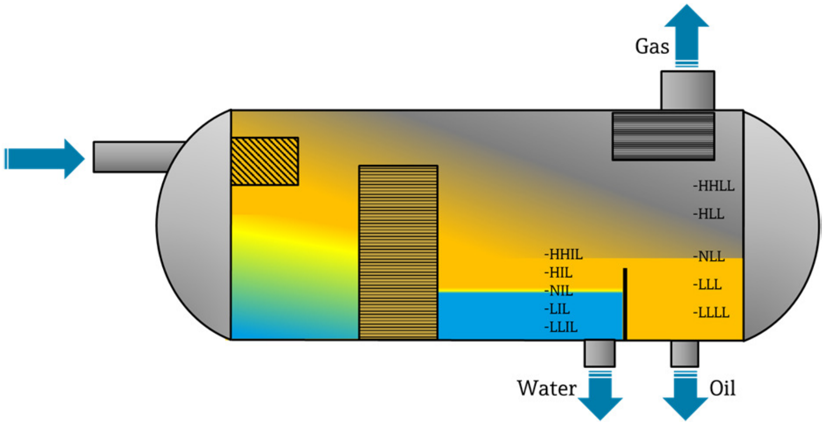
What the data sheet said…

The reality can be more challenging!



- Emulsion
- Sand
- Foam
- Entrained gas
- Entrained liquids
- Changes to HC properties
- Etc…

Typical 3 phase separator



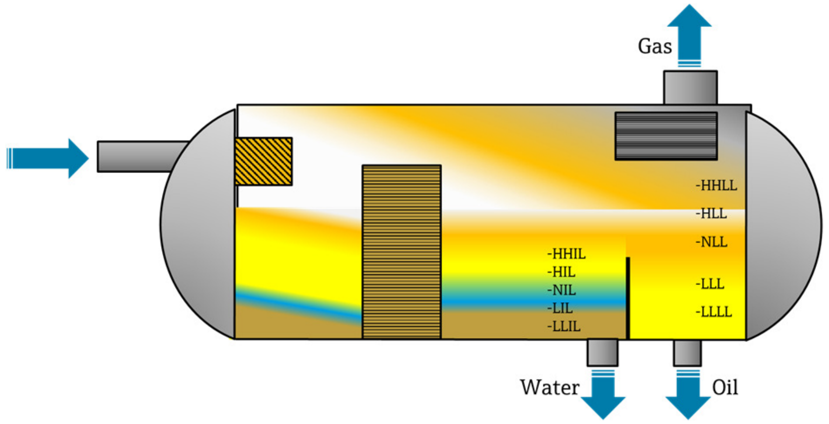
The perfect separator

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

Is reliable level information enough?

Typical 3 phase separator



The less than perfect separator

More information from your separator

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

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

Bridle mounted

Measurement in a bridle has advantages and disadvantages:

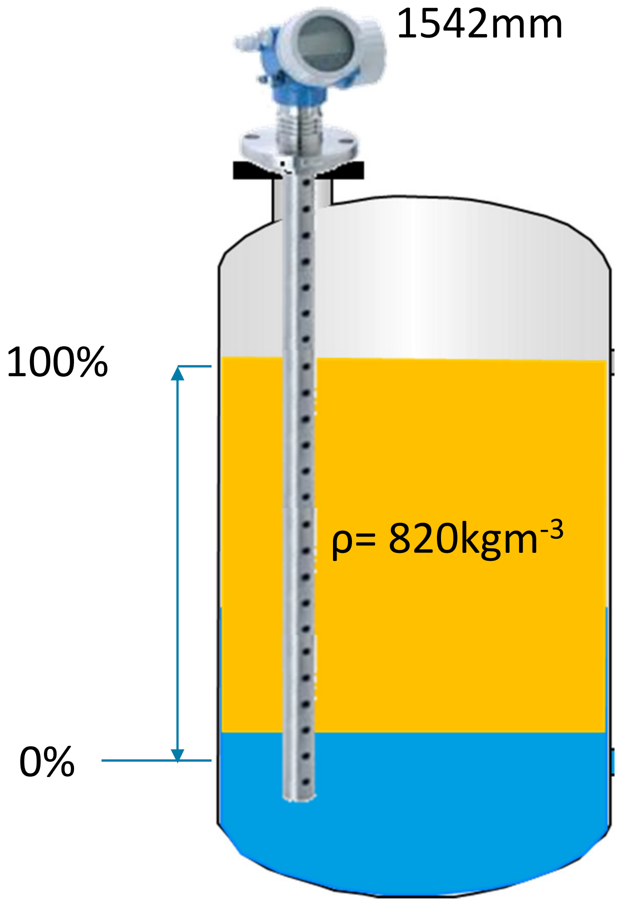
For:
- Easy calibration*
- Isolation for cleaning*
- Isolation for repair*
- Less emulsion in bridle

Against:
- Sand blocking lower tapping
- Waxing due to lower temperature
- Care required with tapping point heights
- Bridle balances hydrostically 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.

Endress+Hauser

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?

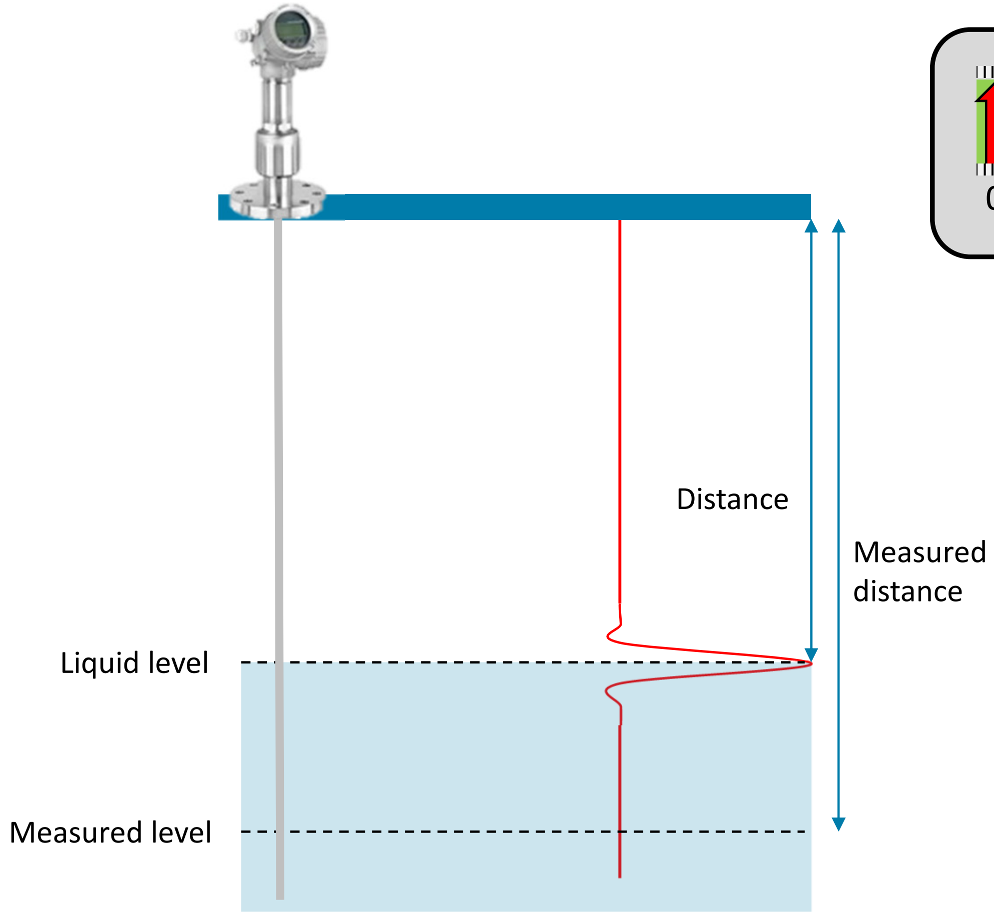
Guided wave radar technology is ideal for a variety of applications because it is impervious to shifts in pressure, temperature, or product-specific gravity. Setup

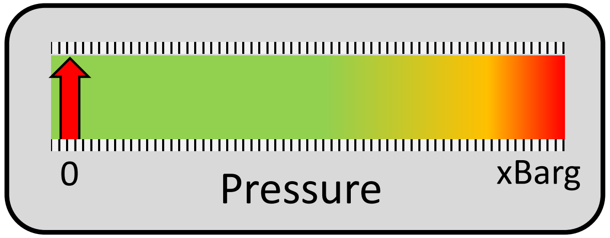
and volume measurement of liquids and solids. It is unaffected by changes in process conditions, high temperatures and pressures, and steam.

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?

The truth - Gas phase effects





- 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.

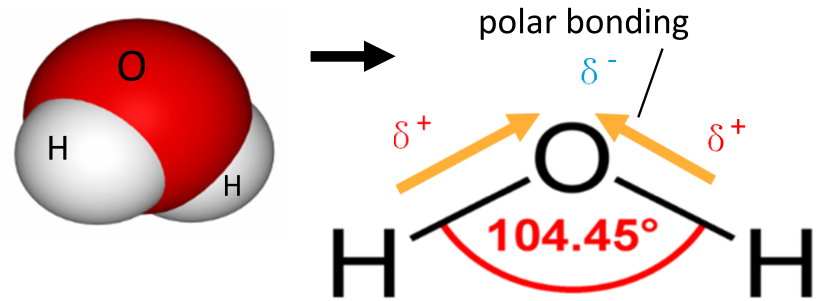
Is the error large enough to be of concern?

Polar Gases

Polar media:

One atom has a greater electro-negativity than the other → constant dipole moment

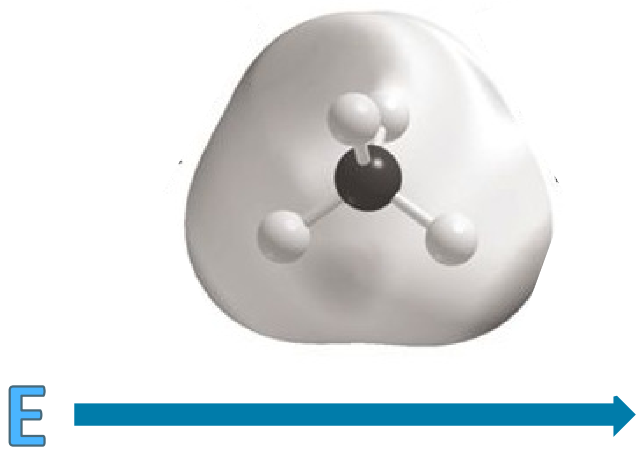
$$\varepsilon = 1 + \frac{p}{\varepsilon_0 \cdot k \cdot T} \cdot \left(\alpha + \frac{d^2}{3 \cdot k \cdot T} \right)$$



- 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.

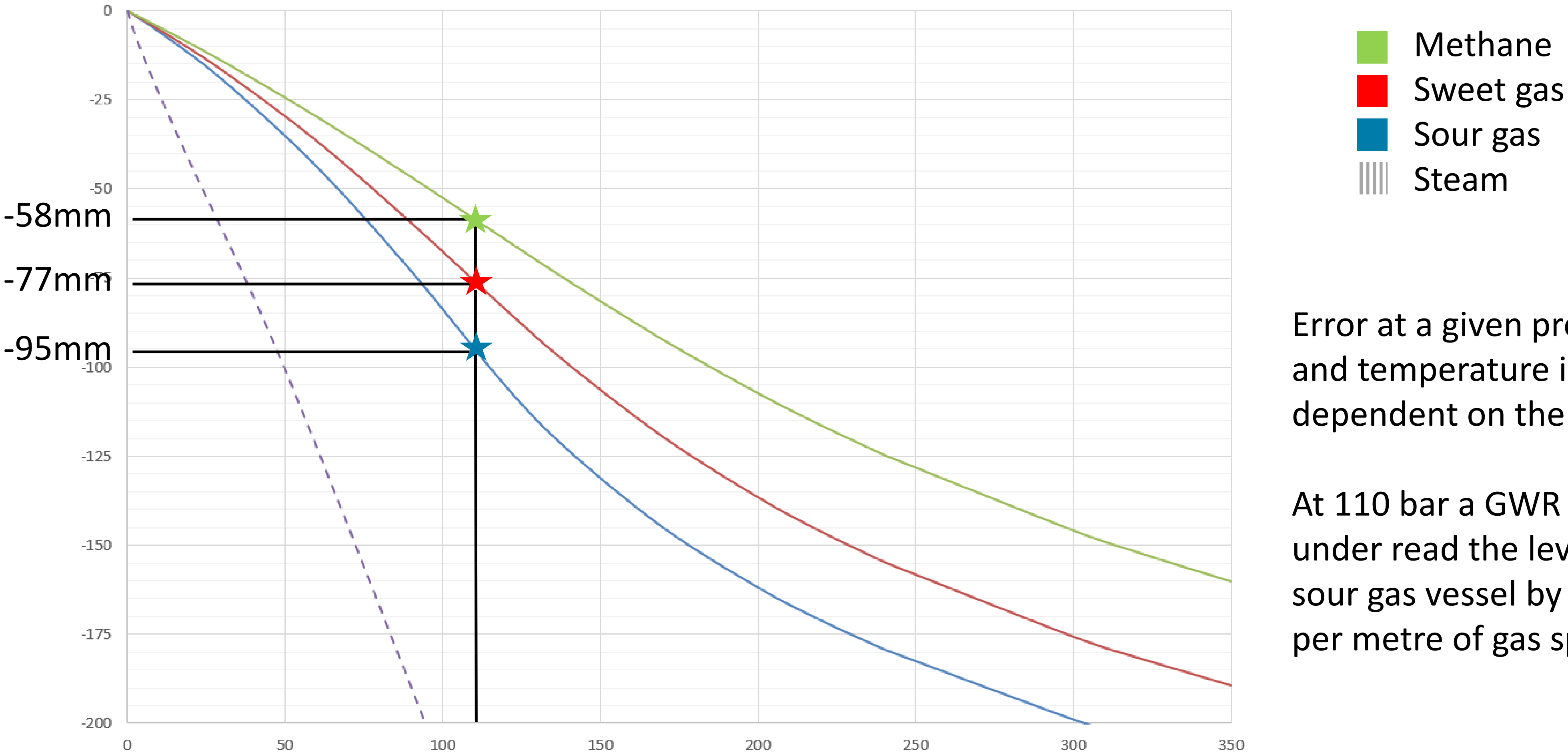
Non-polar gases

- 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.

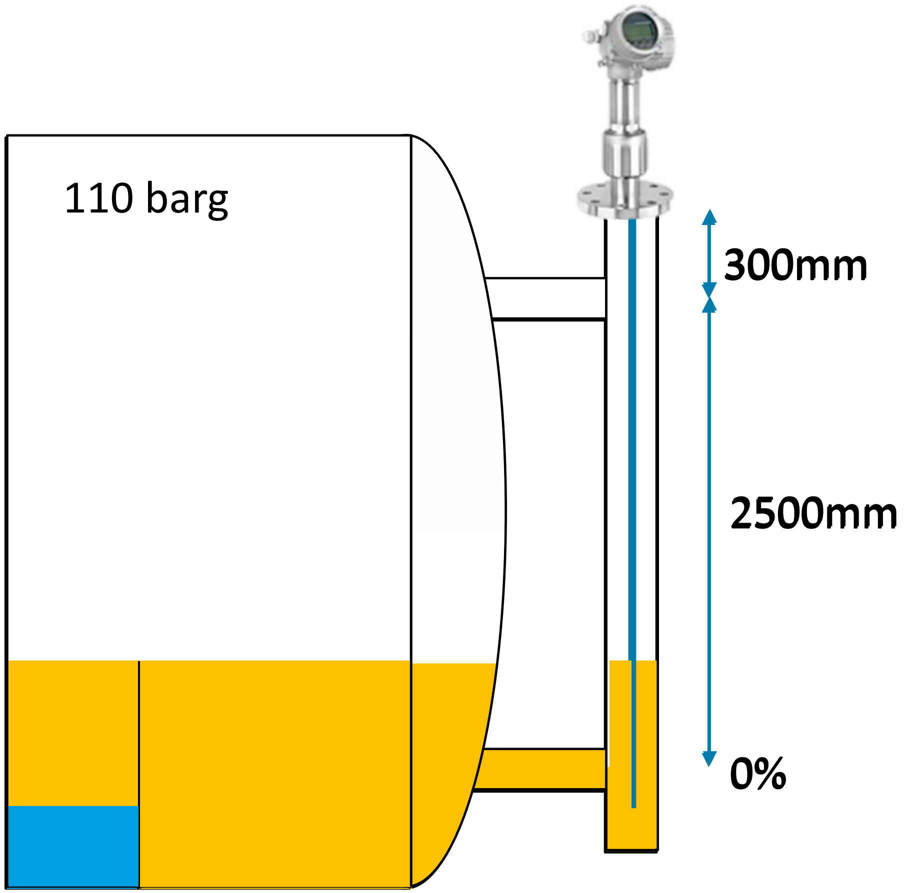
GWR error per metre of gas



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



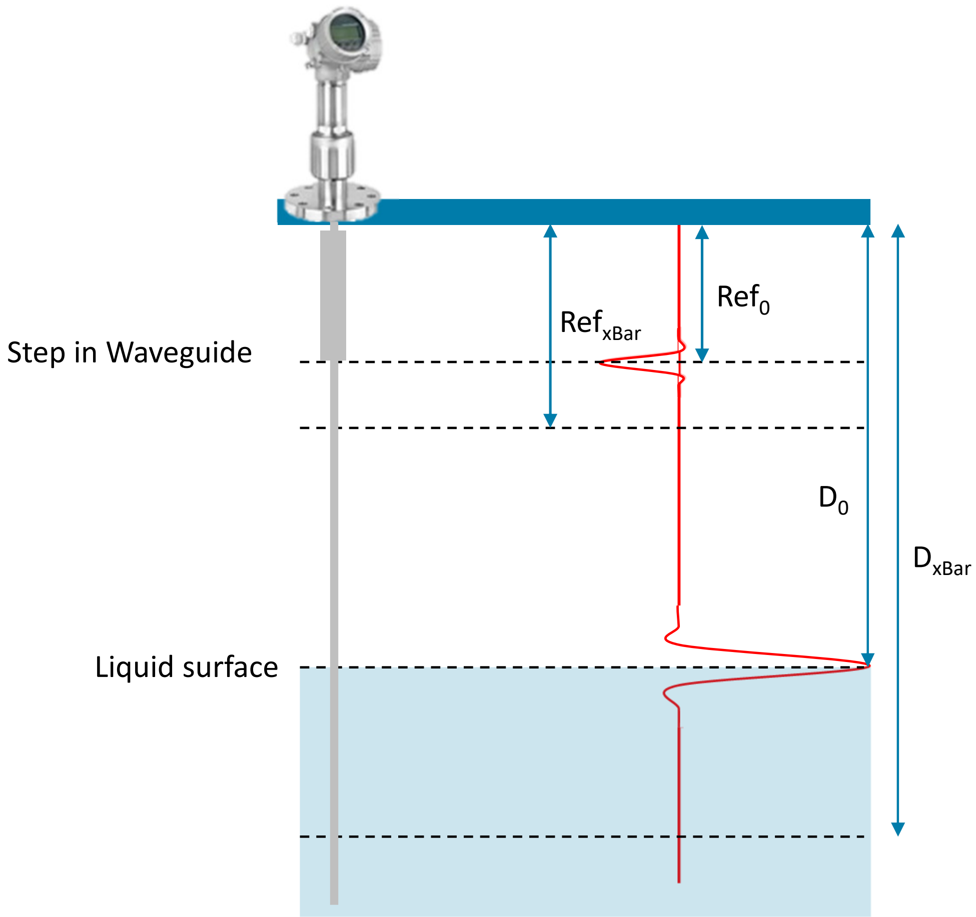
Indicated Level 0%... But is this correct?

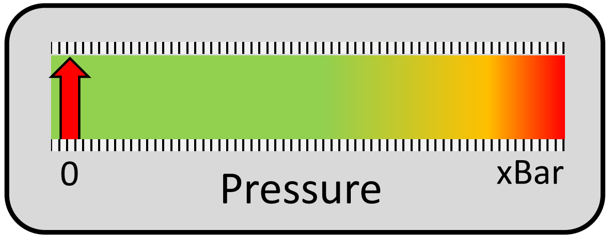
Actual level 9.2%

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

Would this be considered acceptable?

Gas phase compensation





$$\frac{D_0}{D_{xBar}} = \frac{Ref_0}{Ref_{xBar}} \quad x$$

- The reference distance is a constant physical distance.
- D_{xBar} and are Ref_{xBar} measured.
- Therefore D_0 is calculated directly.

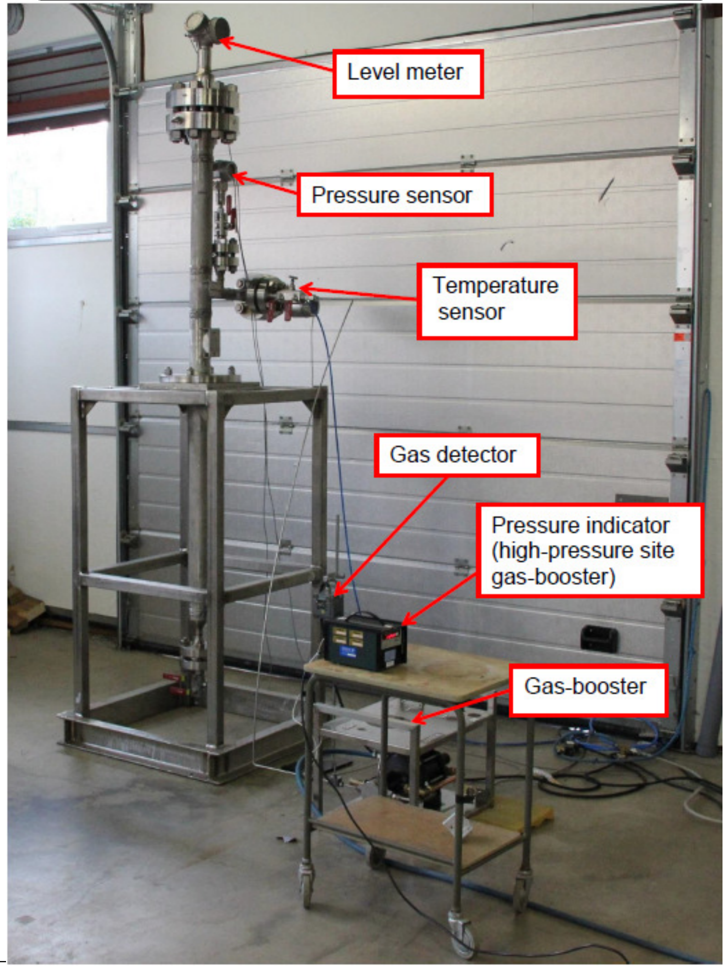
Gas phase compensation

- 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



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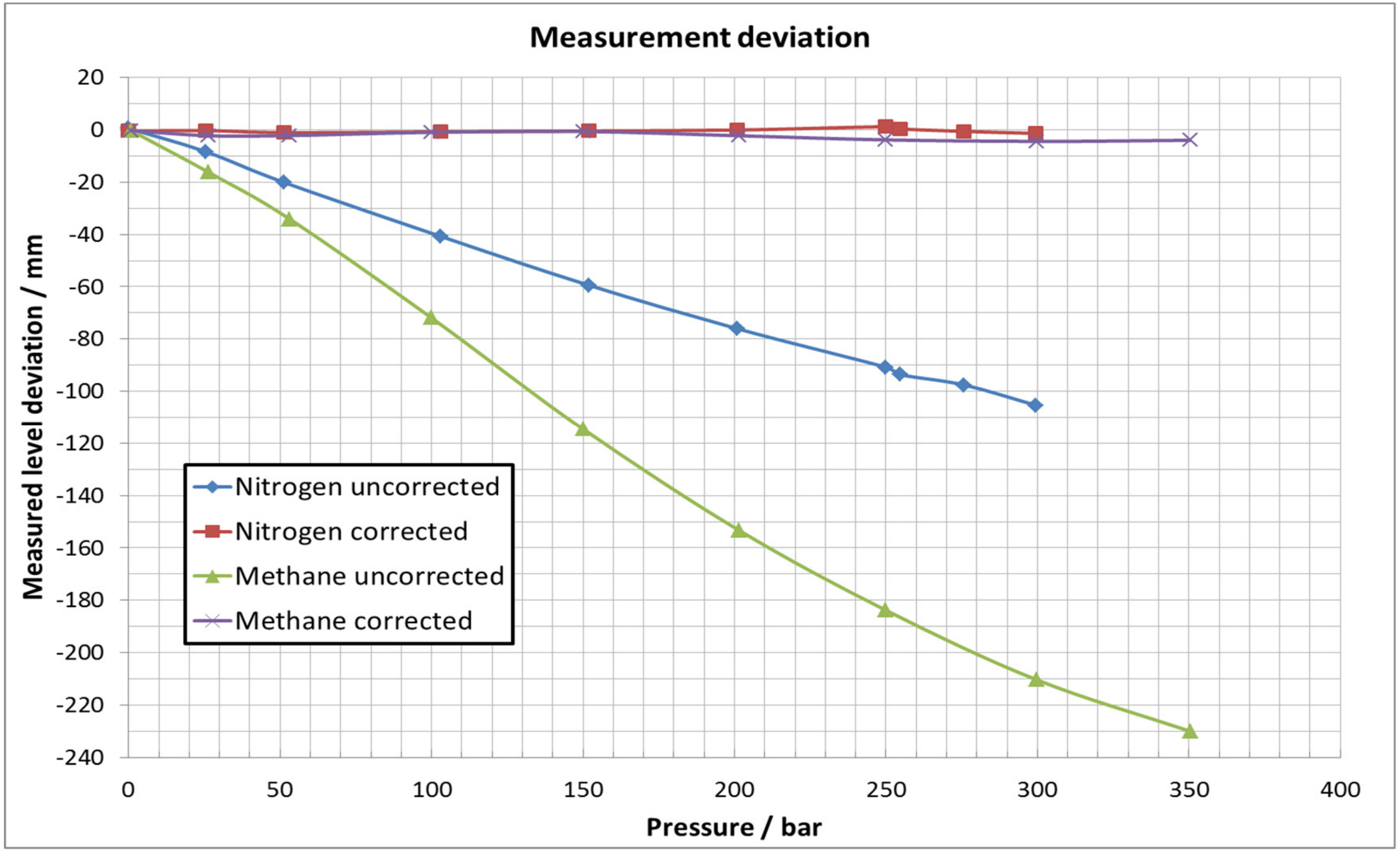
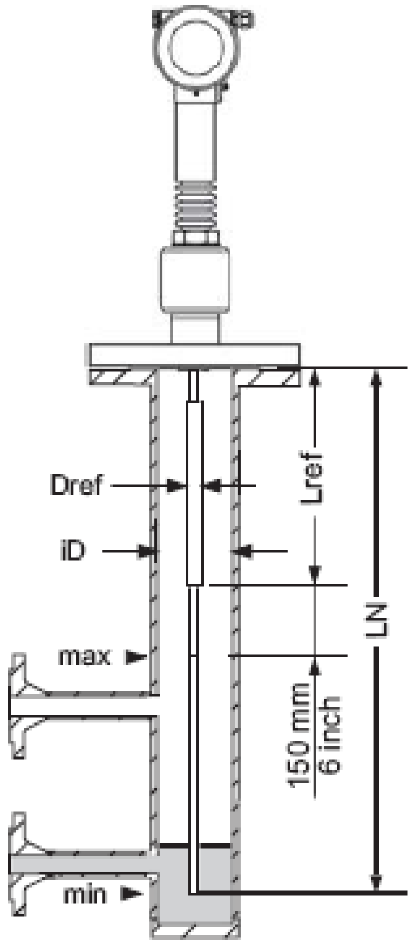
Methane and nitrogen



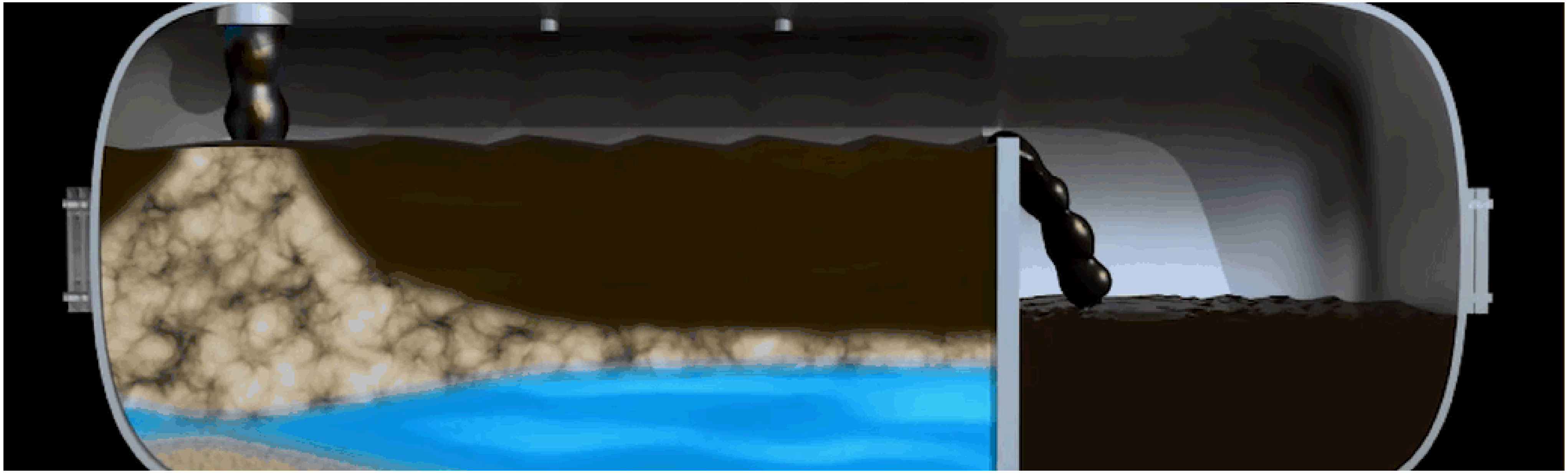
Gas phase implications

- 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

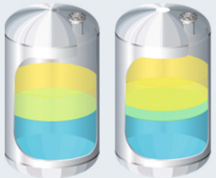
Performance / Reliability

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

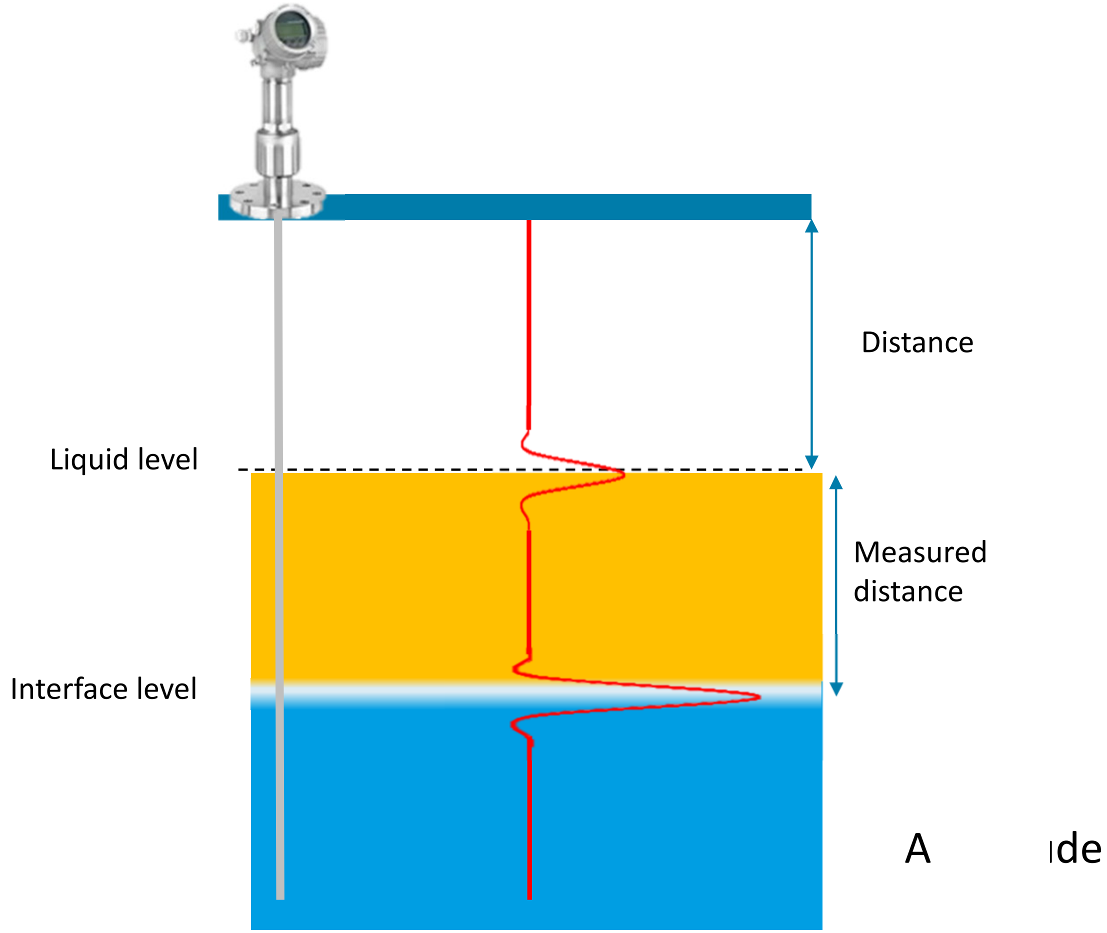
Liquicap FMI51/52

Multiparameter

- Overall level
- Clear interface liquid / liquid
- Interface with emulsion layer liquid / liquid

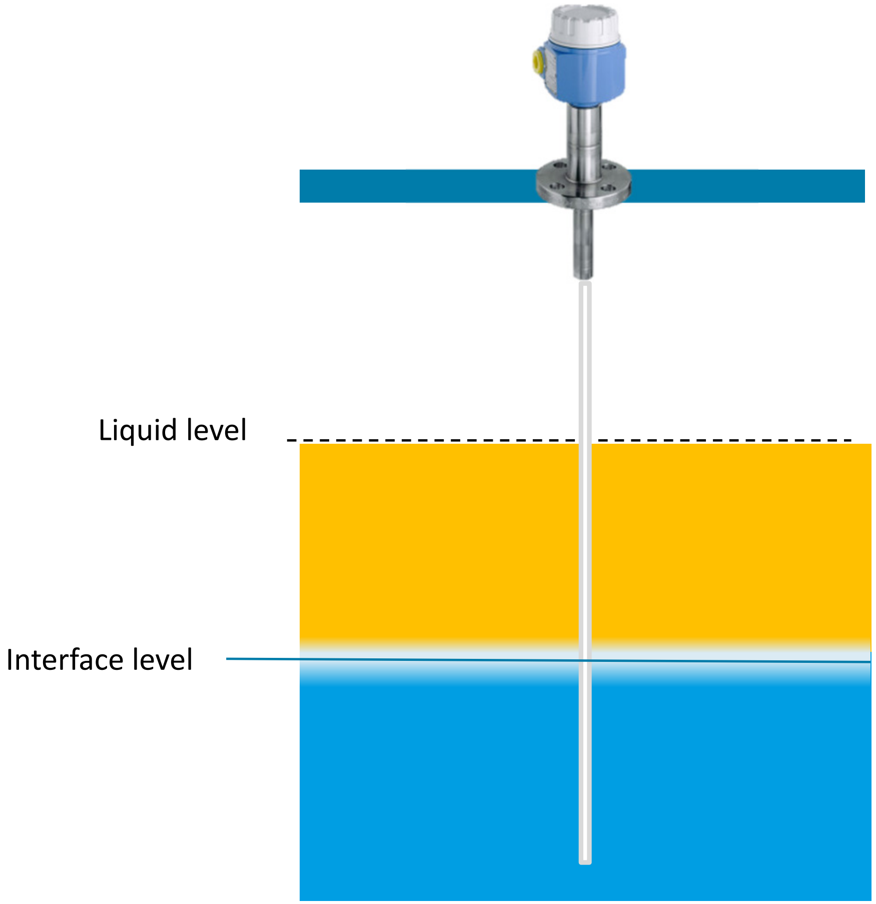
Levelflex FMP55

Guided wave radar interface



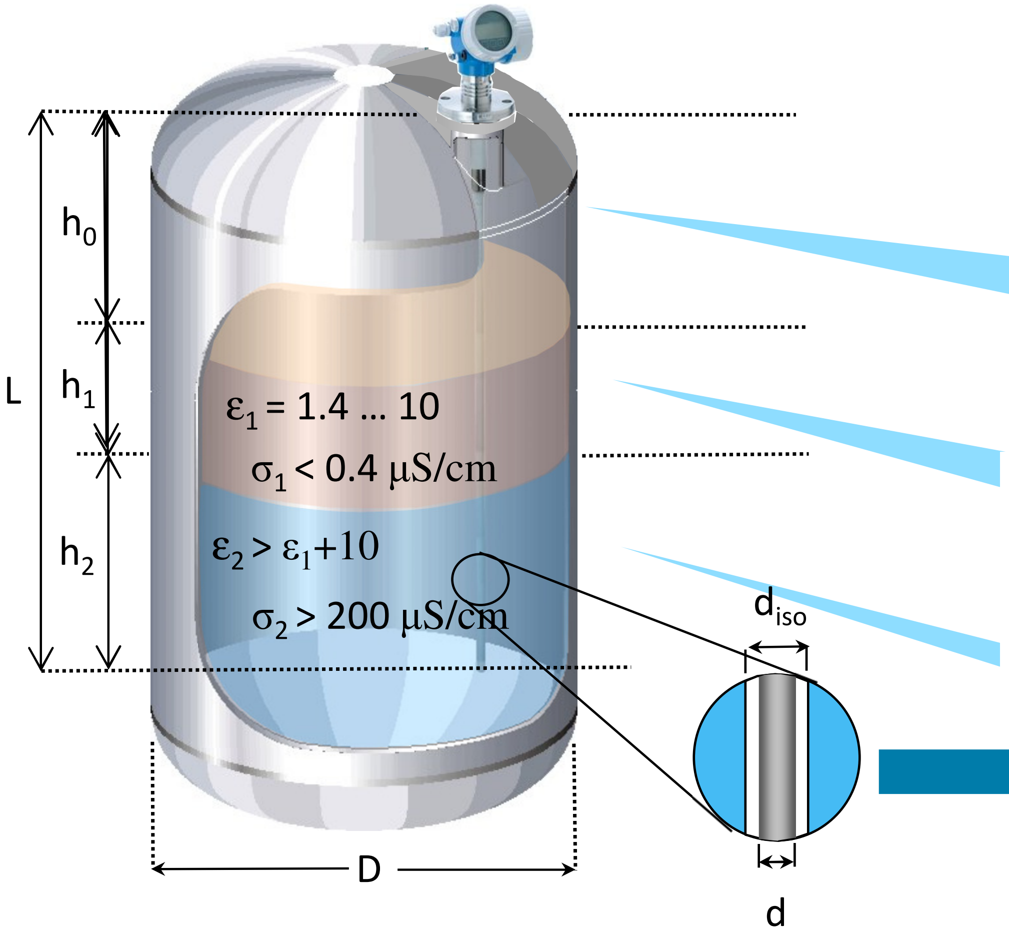
- In an emulsion there is little or no step change in dielectric.
- This can mean that no interface echo is present.
- Alternatively an echo may be received from the top of the emulsion
- The amplitude may be used to indicate the thickness of the emulsion…

Capacitance interface



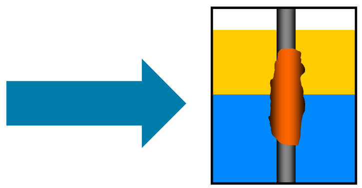
- Measured capacitance increases with an increasing water level.
- Not effected by the presence of emulsion – measured interface somewhere in emulsion
- Effected by build-up. Non-conductive wax build up will cause an under-reading of the interface level

Capacitance measurement



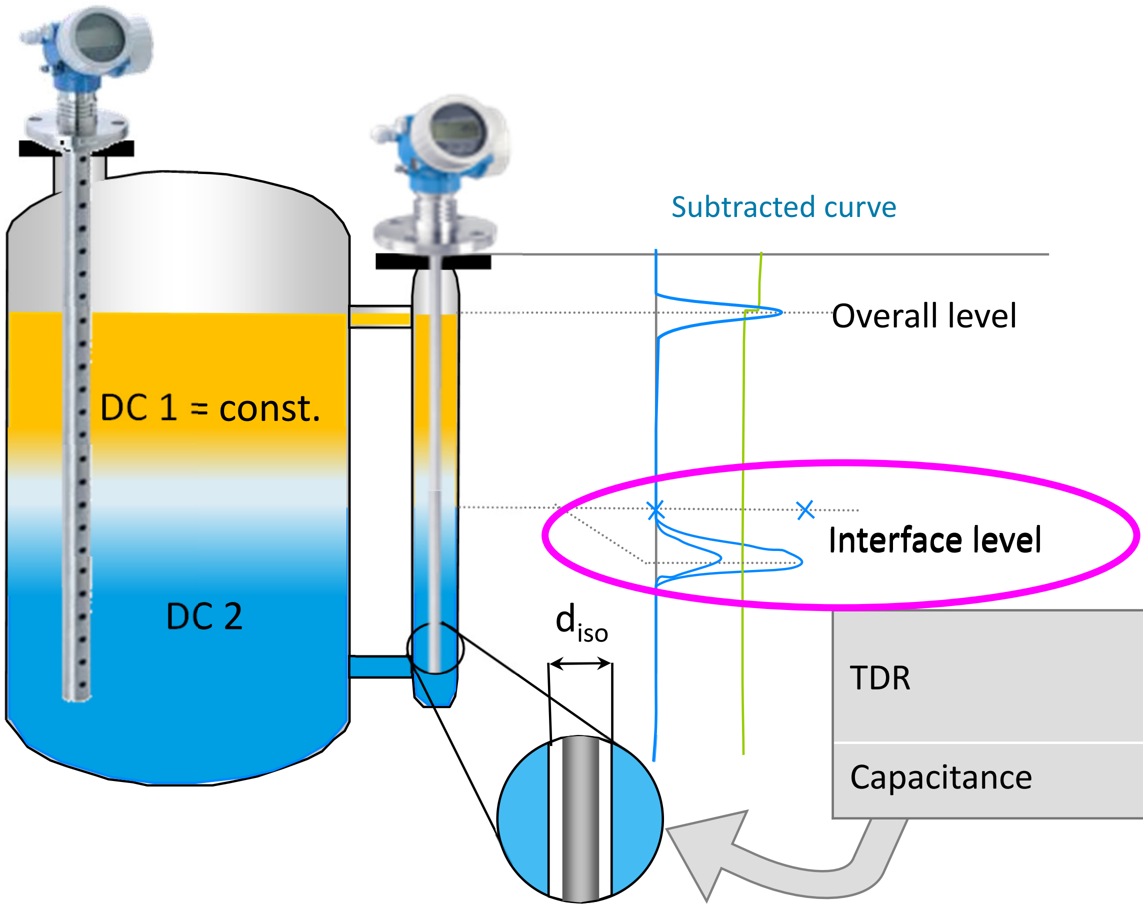
Capacitance:

$$C = 55{,}6\,pF/m \cdot \left(\frac{h_0}{\frac{\ln(d_{iso}/d)}{\varepsilon_{iso}} + \ln(D/d_{iso})} + \frac{h_2 \cdot \varepsilon_{iso}}{\ln(d_{iso}/d)} \right)$$



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

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

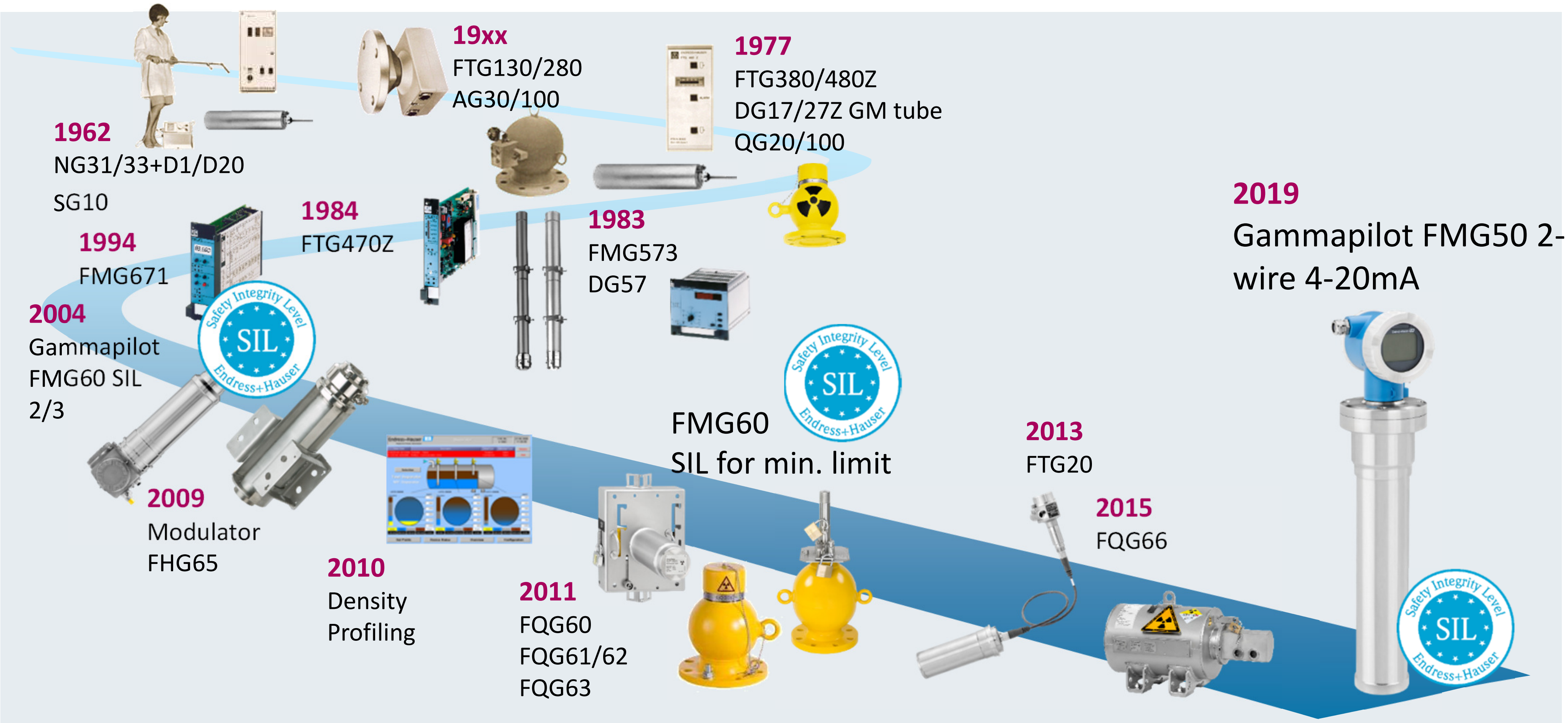
TDR	Overall Level	✓
	Interface	✗
Capacitance	Capacitive value	✓

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



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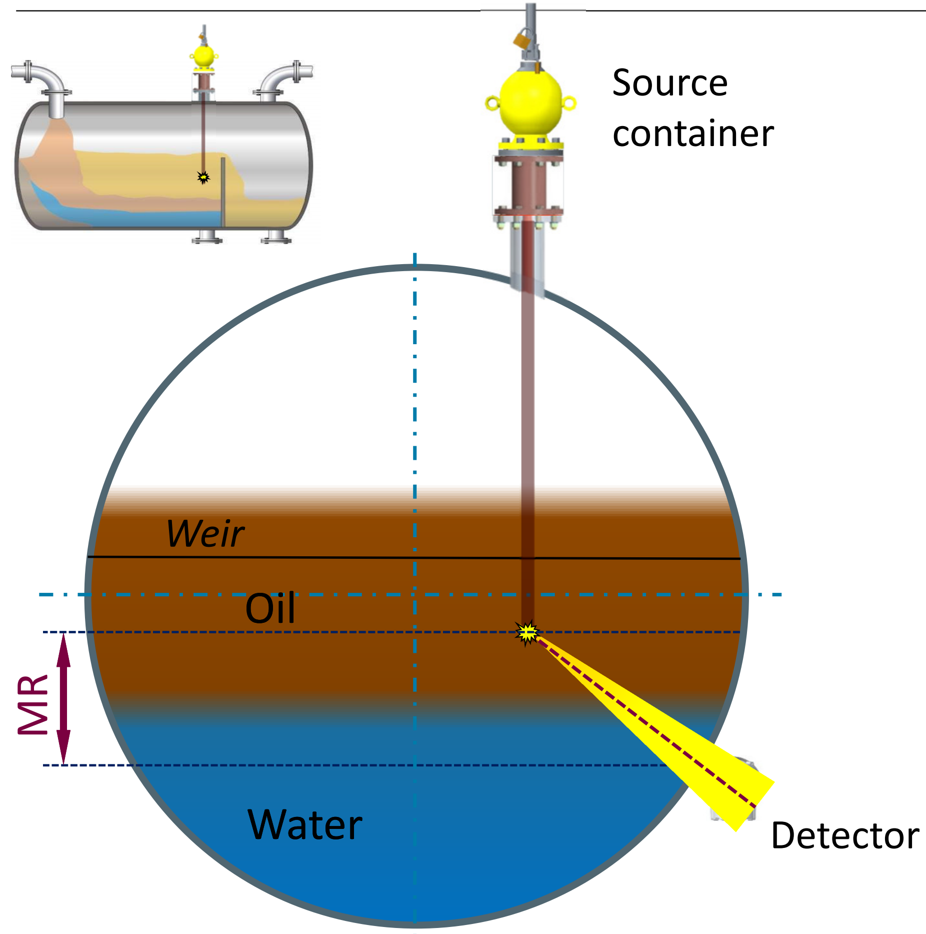
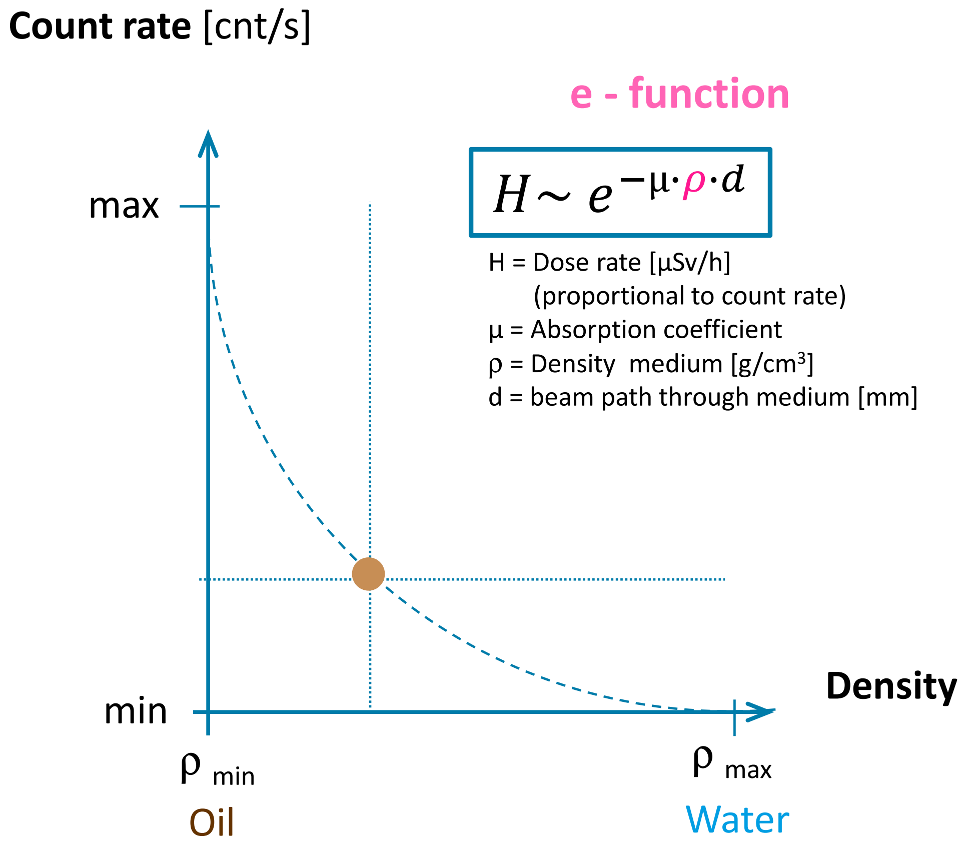
Interface – Working principle





e - function

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

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

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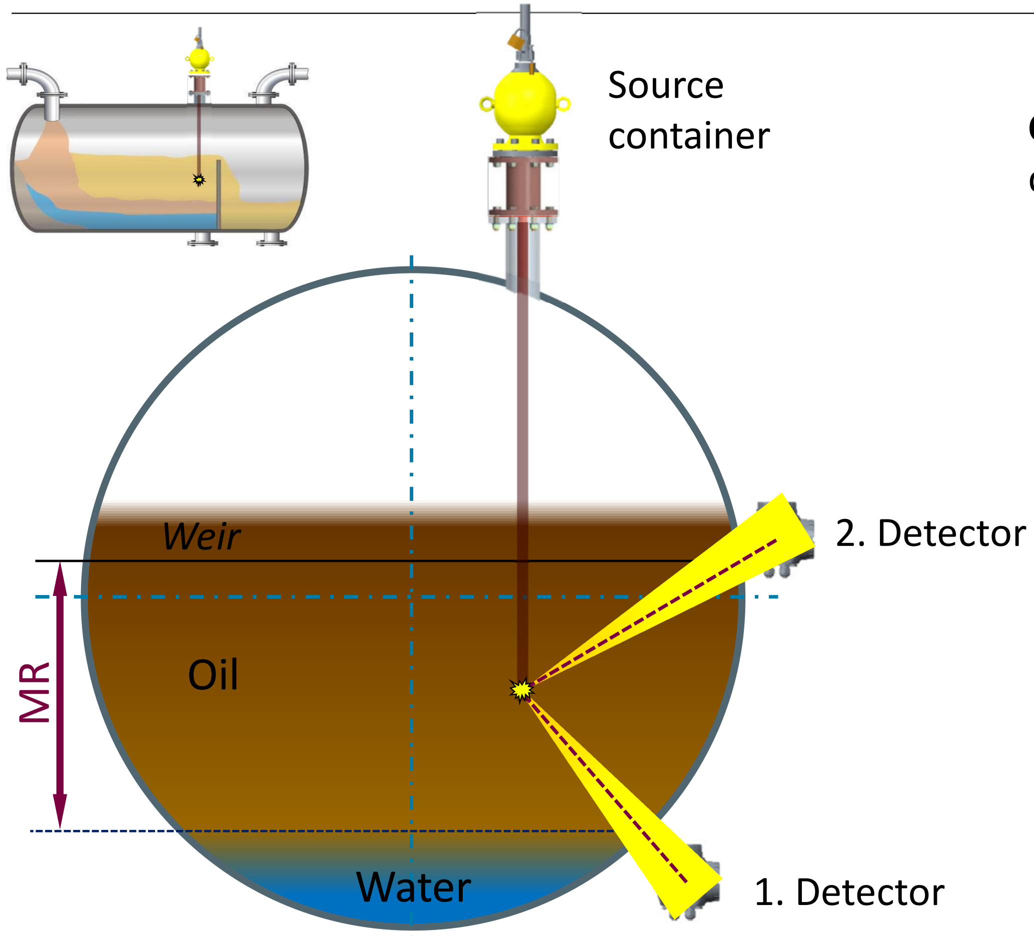
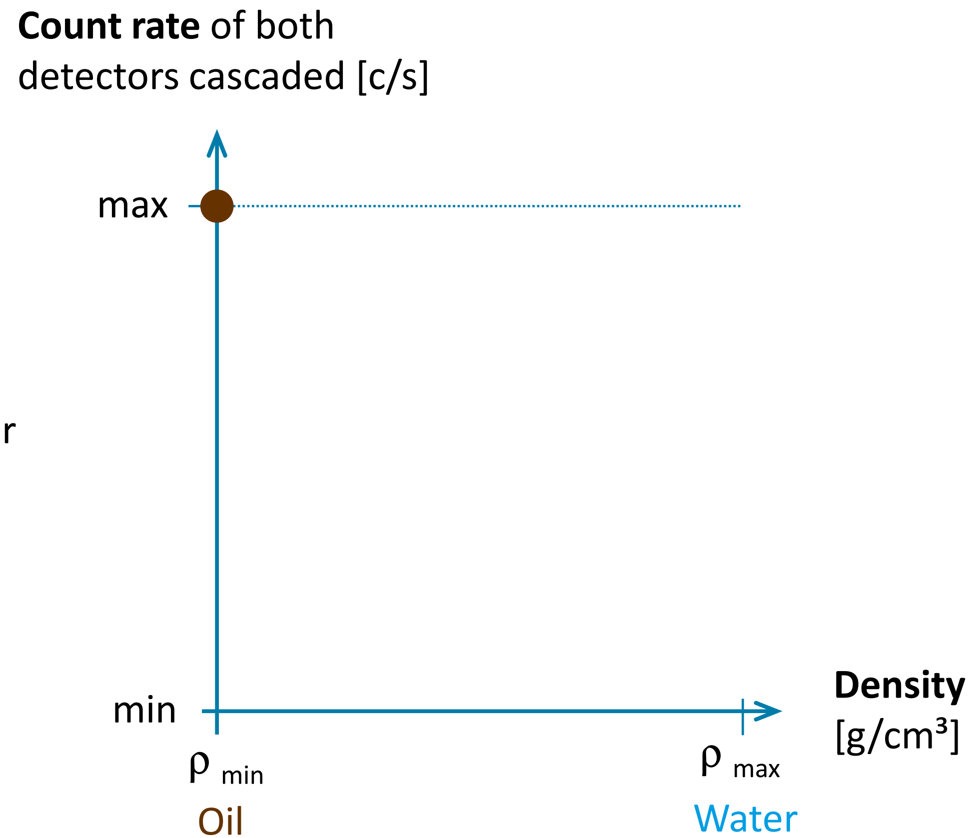
Interface – Working principle with 2 detectors





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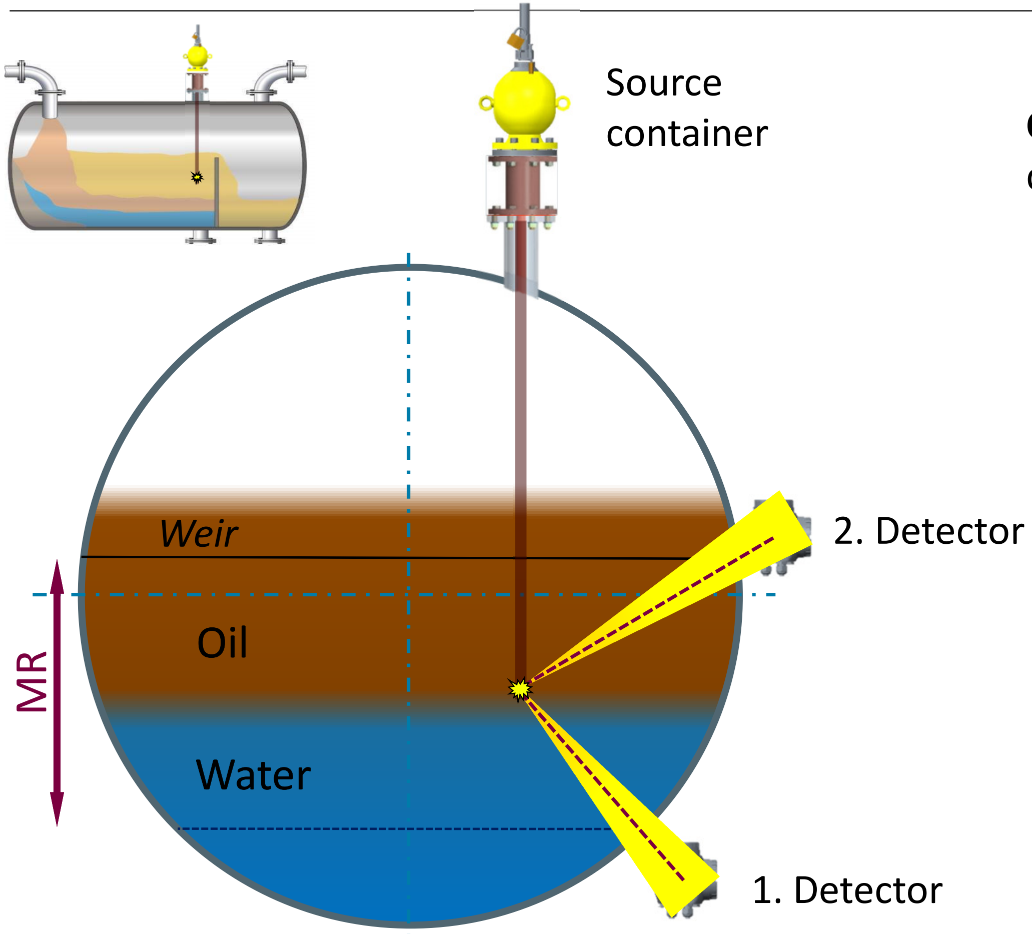
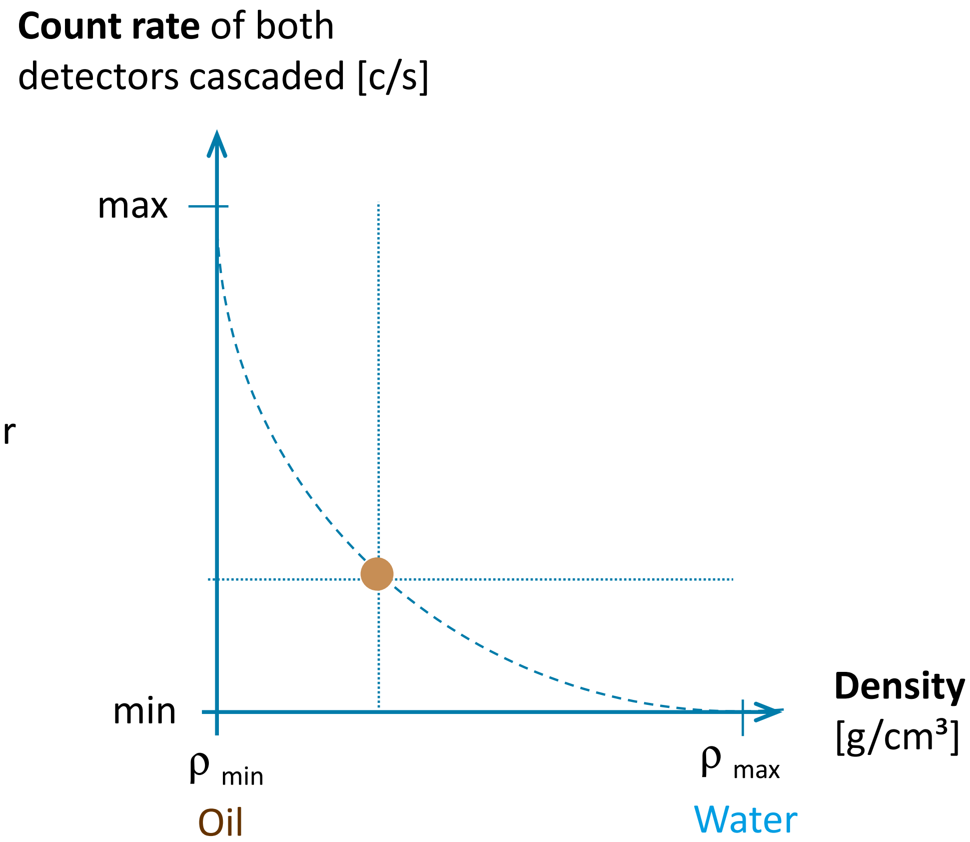
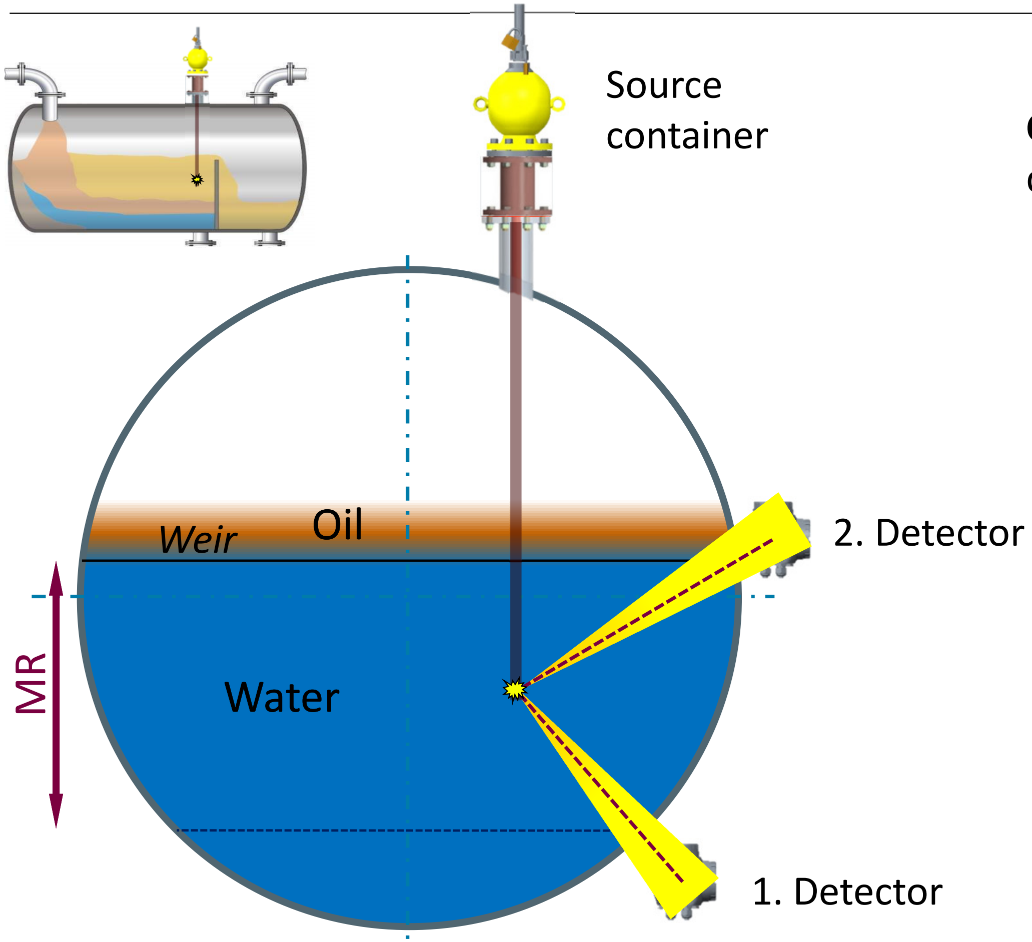
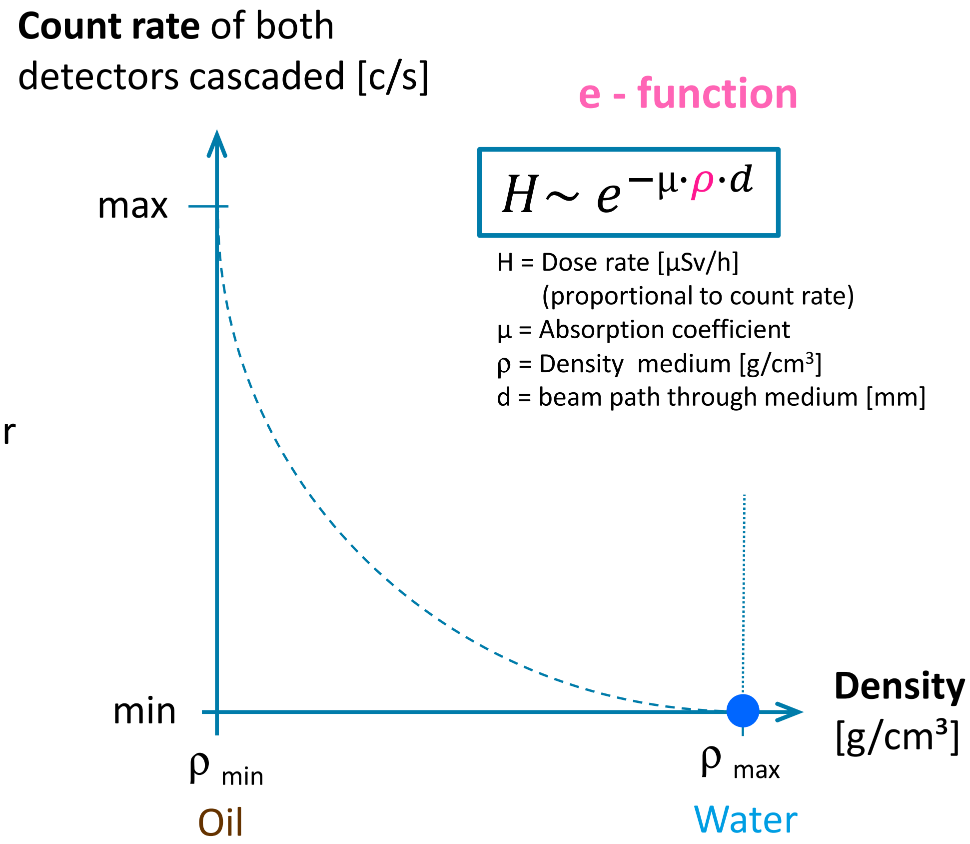
Interface – Working principle with 2 detectors, water level low





Interface – Working principle with 2 detectors, water level high





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H = Dose rate [µSv/h]
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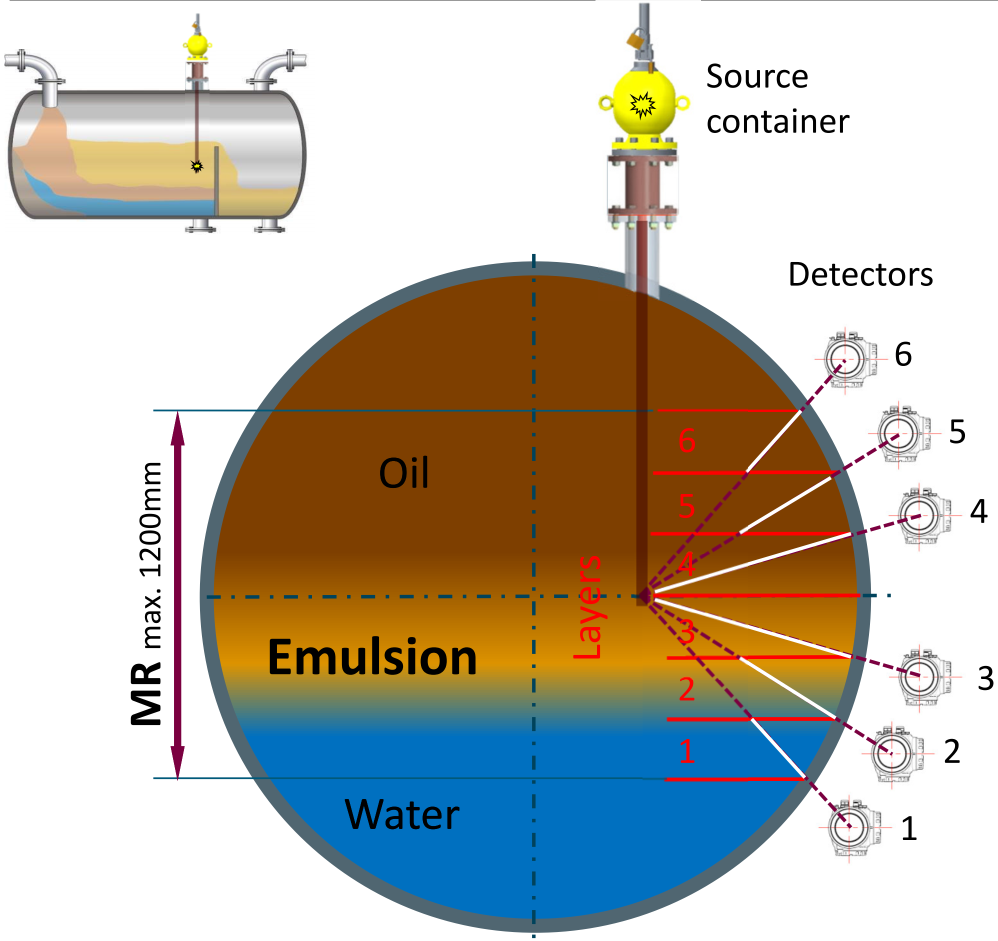
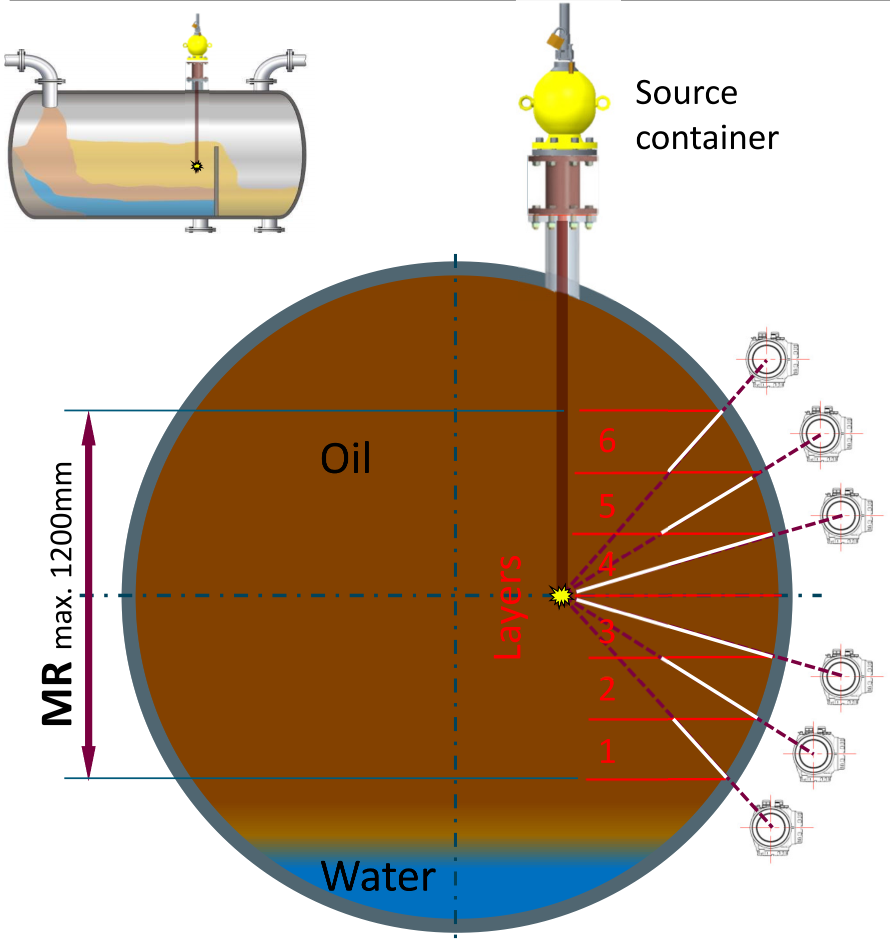
Density Profiling – Working principle

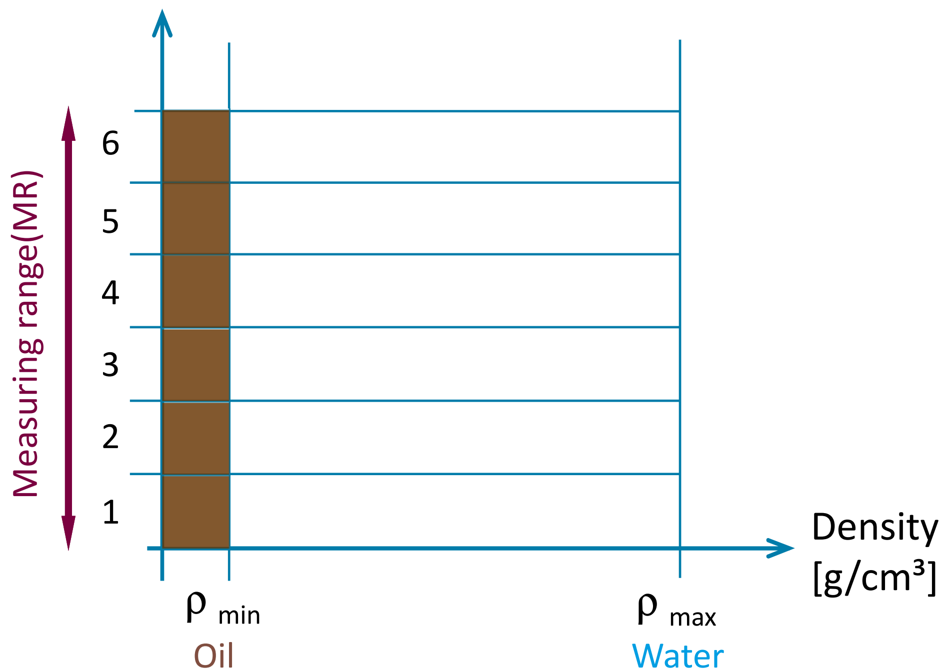


- Source container with extension for source is installed on flange connection with dip pipe
- Several detectors are mounted outside on the tank wall
- The measuring range **MR** is subdivided into **layers**
- Density value **is calculated** for **each layer**
- Analogue tracking of layer boundaries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

Endress+Hauser

Density Profiling – Working principle





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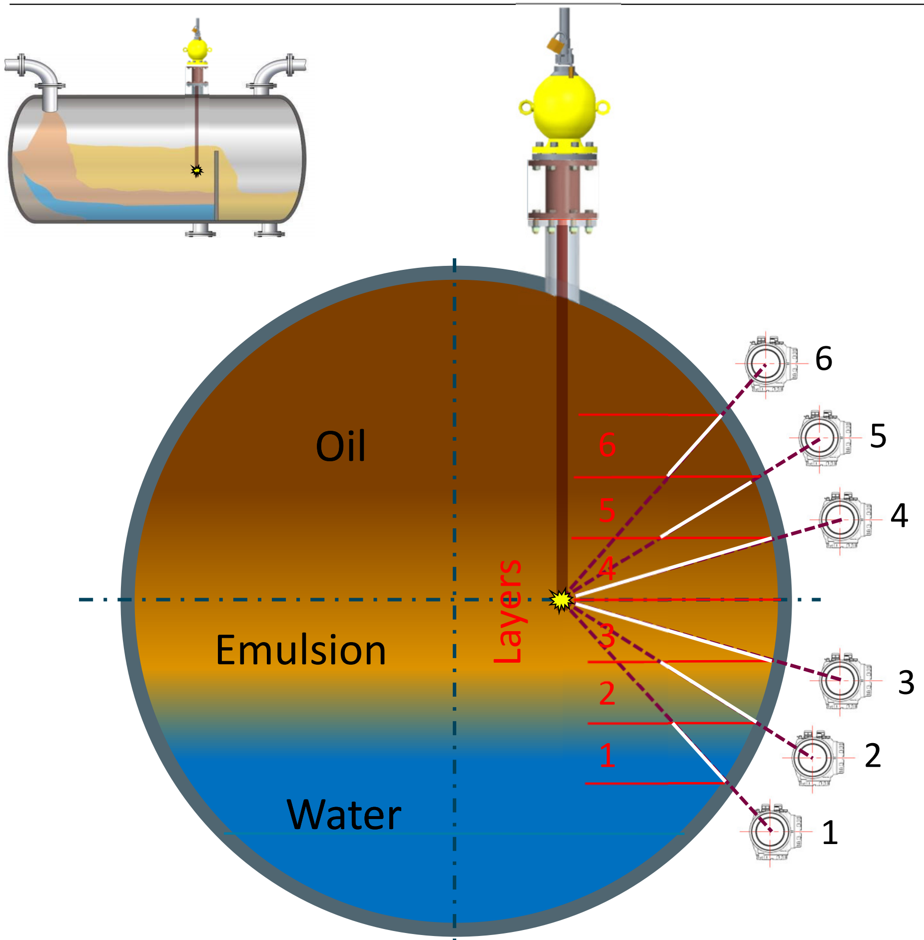
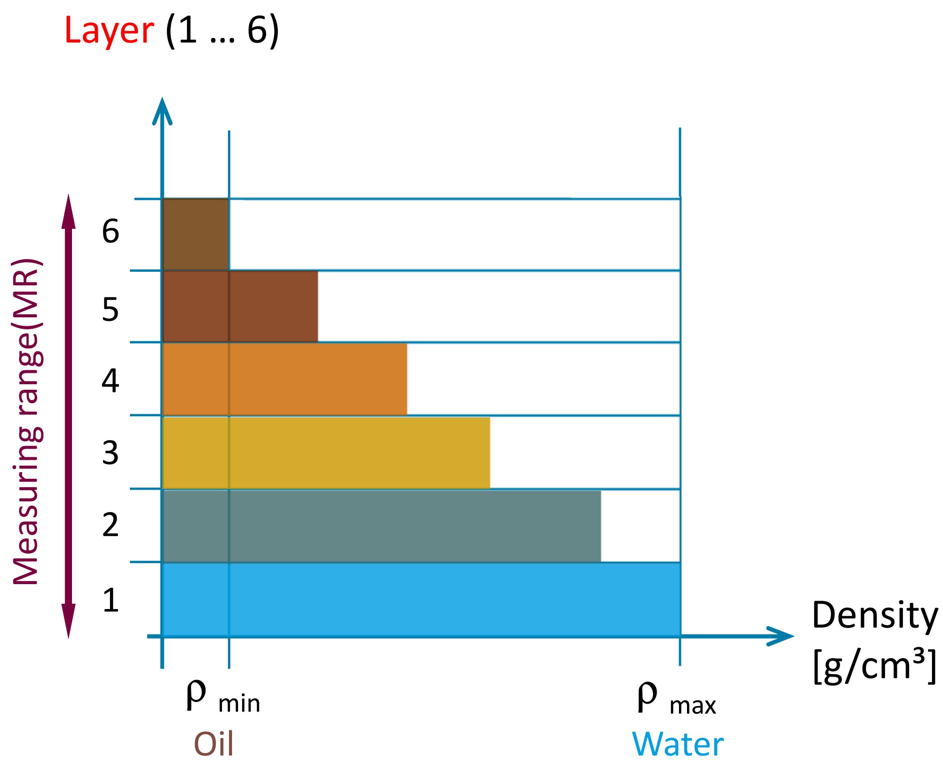
Density Profiling – Working principle





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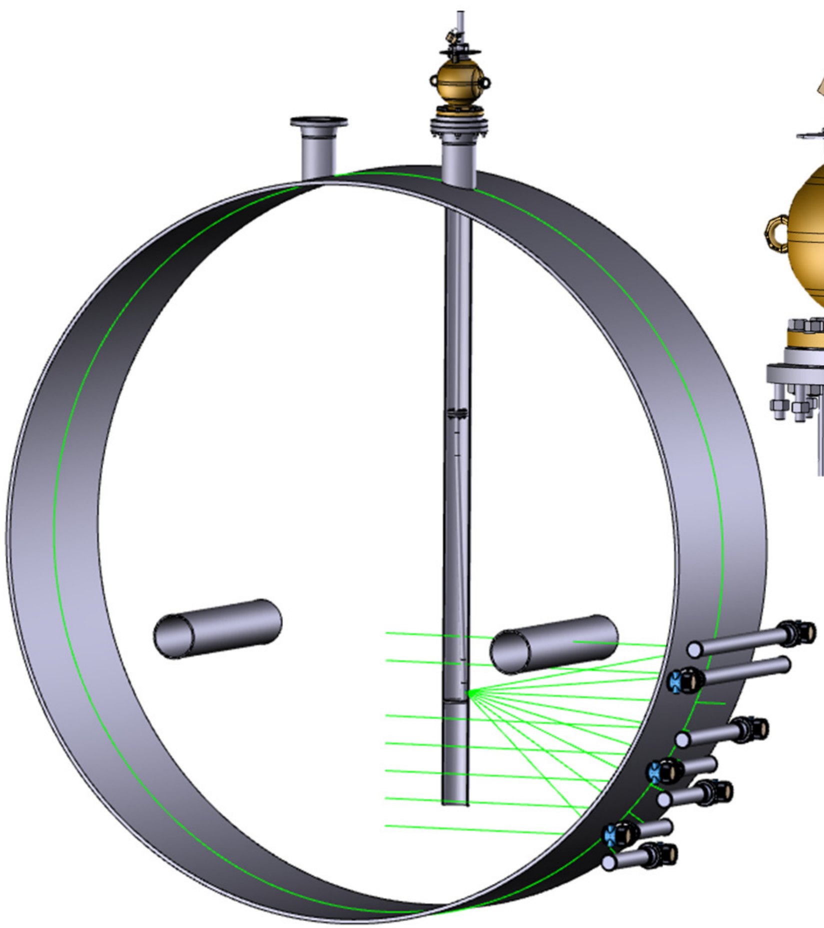
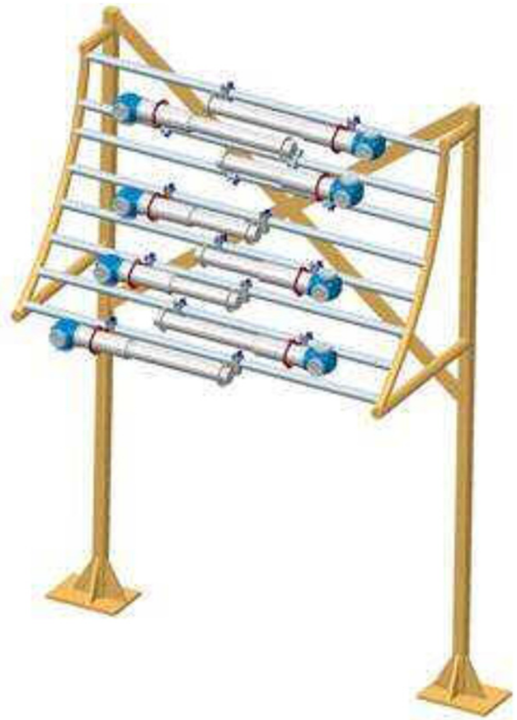
Example retrofit design



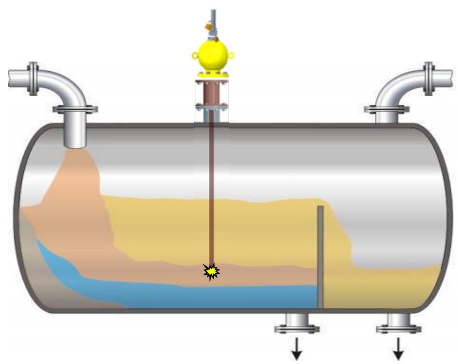
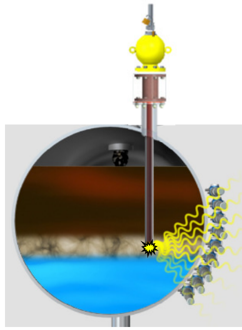
Source insertion drywell manufactured with adaptor flange to suit existing flange or stilling well



A variety of mounting methods for retrofit are available

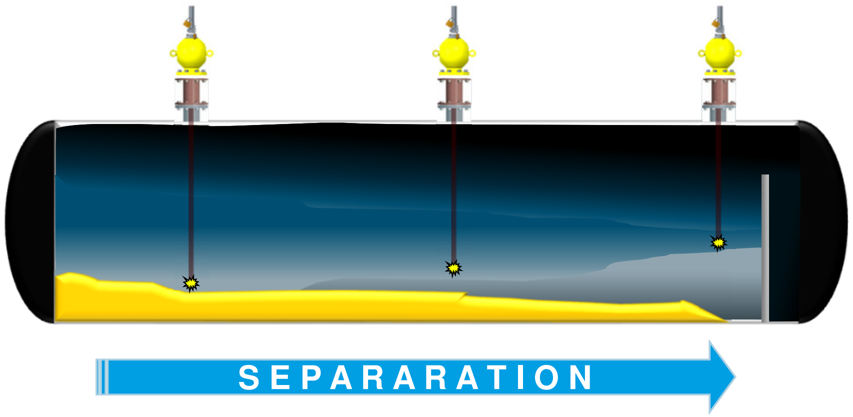
Profile Measurement – Density profiling / 3D Density profiling

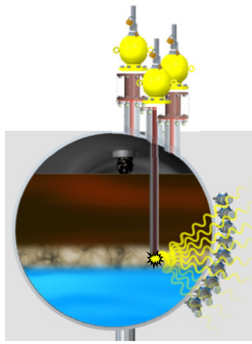
Density Profiling

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

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Reduced Costs
Increased Operational Efficiency
Increased Safety

Any questions?

Endress+Hauser