# Radiometric Measurement

Italy Section

## Using nucleonic technologies for extreme applications with high benefit of reliability and efficiency in O&G and Petrochemical Plants

**Ralf Matthaes**
Head of Department
Business Development /
Gamma Project Team



Endress+Hauser
People for Process Automation

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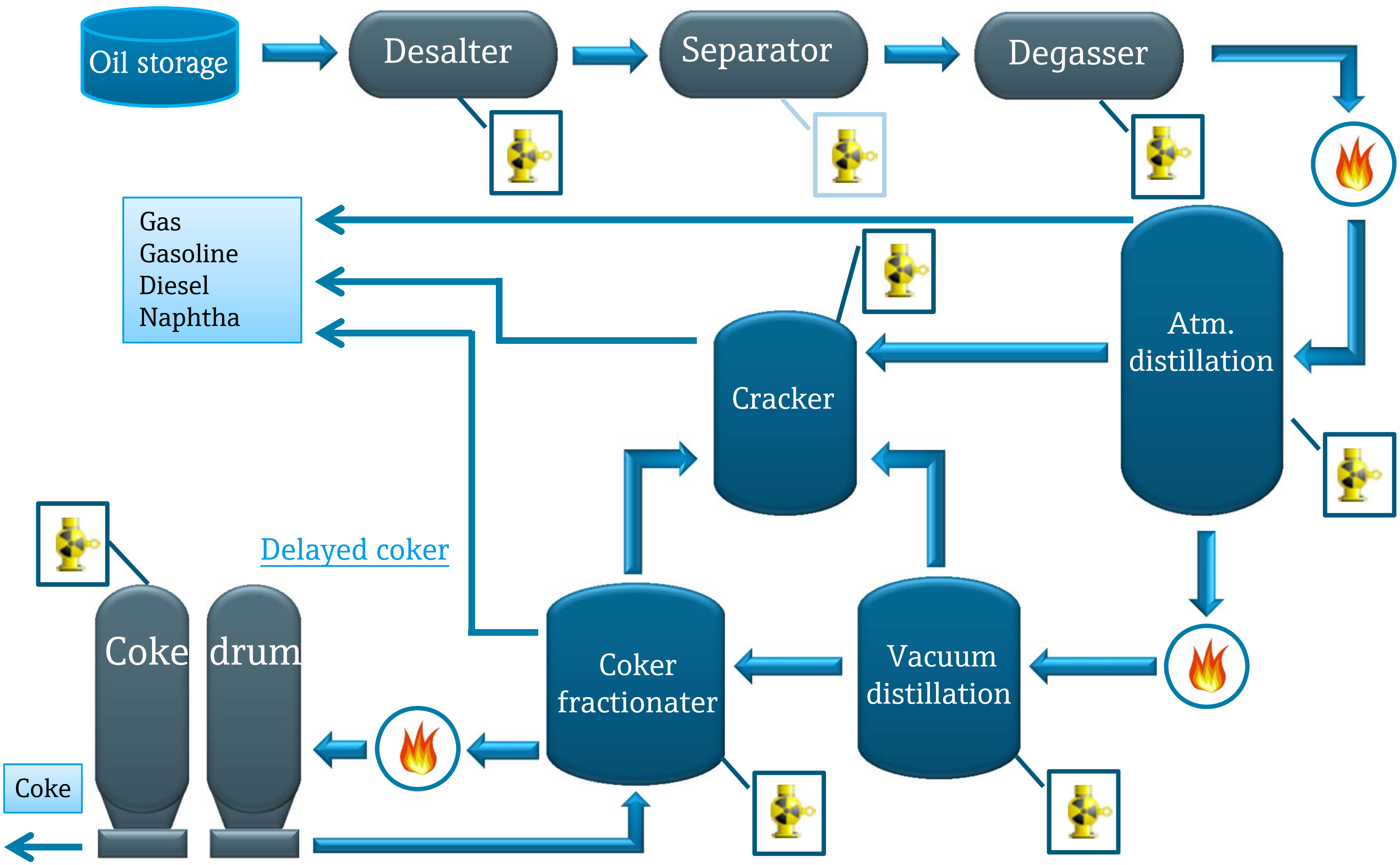
# Overview – Applications

## Applications

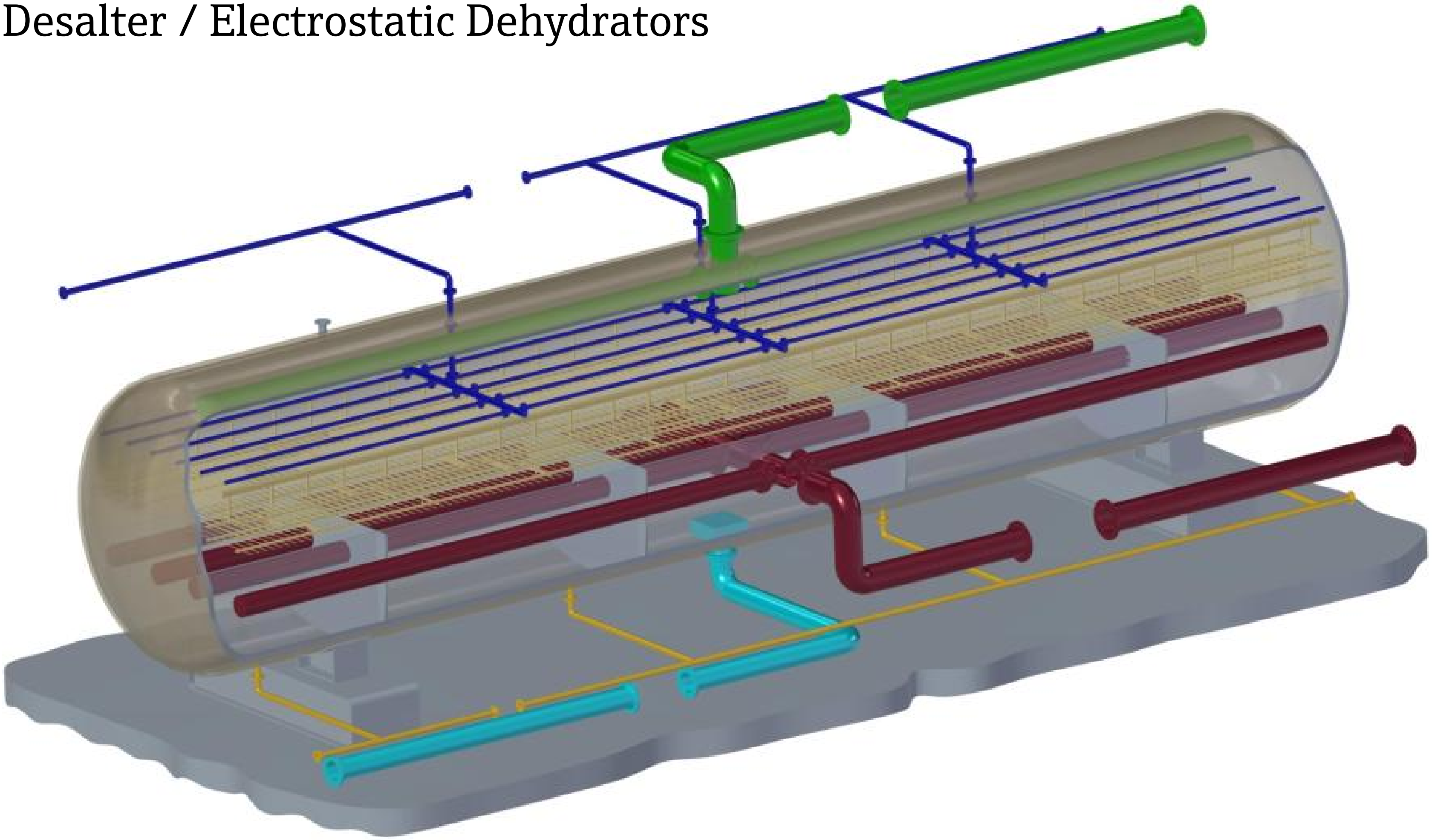
- Oil & Gas – **General** / Offshore / Oil sands / Gas / Fracking / Refinery
- Petrochemical / Chemical – **General** /
  Borstar (PP/PE) / PP Novolen / PP Chisso / Unipol (PP/PE/…)
  PE Hostalen* / PE Lupotech / PE Spherilene* / LDPE / LLDPE /
  PTA / PET / PS / PVC / PUR_MDI_TDI / Ammonia / Urea / $TiO_2$*
- Primaries – **Mining General** / Metals: Ni/Cu/Au / Aluminum / Steel
  Minerals: Uranium / Coal
  Precious stones: Diamond
  Cement / Sand & Gravels, Suction dredger / Molten glass
- Pulp&Paper
- Power – Integrated Gasification IGCC / Coal / Biomass / Incineration
- Others

# Oil & Gas – Refinery (Downstream)



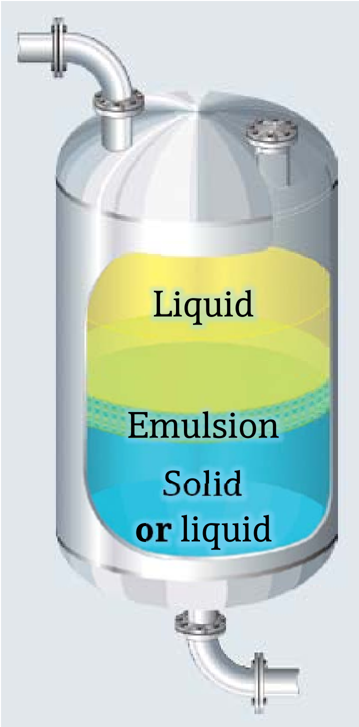
# Density Profiling System (DPS) in Desalter

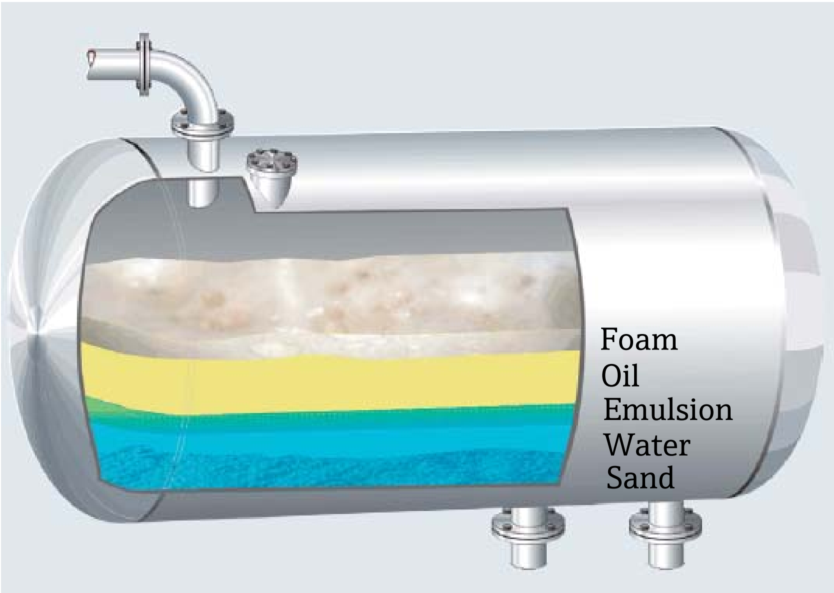
## Desalter / Electrostatic Dehydrators



# Interface – Interface Layers

| **Clear interface** in steady processes | Interface **with emulsion layer** in dynamic processes | **"Multilayer"** – Complex interfaces for example in the crude oil extraction process |
|---|---|---|

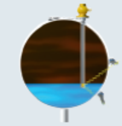
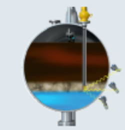




We offer you transparency in relation to possibilities, physical limitations and commissioning of the individual measuring principles.

**Guided radar, Multi-parameter, capacitance instrumentation or radiometry**

# Interface – Comparison of measuring principles

| | Guided radar Levelflex FMP51/52/54 | Multiparameter Levelflex FMP55 | Capacitance Liquicap FMI51/52 | Radiometry Gammapilot FMG60 |
|---|---|---|---|---|
| |  |  |  |  |
| Clear interface liquid / liquid  | **Total level + interface layer** | Total level + interface layer | Interface layer | Interface layer (Total level with separate measurement)  |
| Interface with emulsion layer liquid / liquid  | Not possible | **Total level + interface layer** | Interface layer | Interface layer + emulsion thickness (Total level with separate measurement)  |
| ▪ Interface with emulsion layer liquid / liquid<br>▪ Interface liquid / solid<br>▪ Multiple layer interfaceliquid / solid  | Not possible | Not possible | Not possible | **Interface-density-profile** (Total level with separate measurement)  |

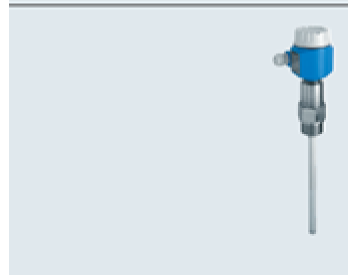
# Interface – Which instrument for which API Grade

## Internal Definition

Multiparameter
Levelflex FMP55

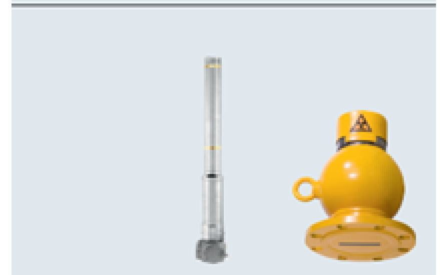
API 25… 70
(grey zone: 15… 25)

Capacitance
Liquicap FMI51/52



API 20… 70

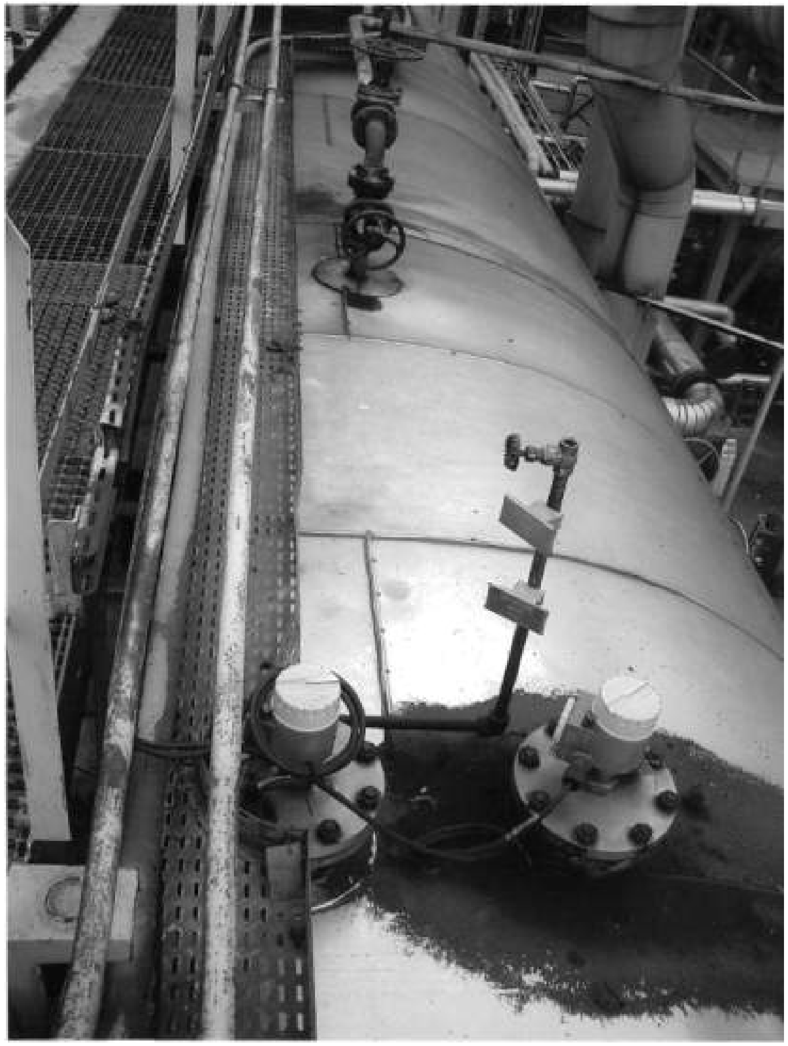
Radiometry
Gammapilot FMG60



API 0… 70

| Generic Oil Name | API Grade | Density at 15,6 °C | Interface Coaxial | Interface Stillingwell | Interface Grid | Density Profiling |
|---|---|---|---|---|---|---|
| Light | 45 - 31.1 | < 870 kg/m³ | Yes | Yes | Yes | Yes |
| Medium | 31,1 - 22,3 | 870 - 920 kg/m³ | Yes / No | Yes | Yes | Yes |
| Heavy | 22,3 - 10,0 | 920 - 1000 kg/m³ | No | Yes / No | Yes | Yes |
| Extra Heavy | <10 | > 1000 gk/m³ | No | No | Yes | Yes |

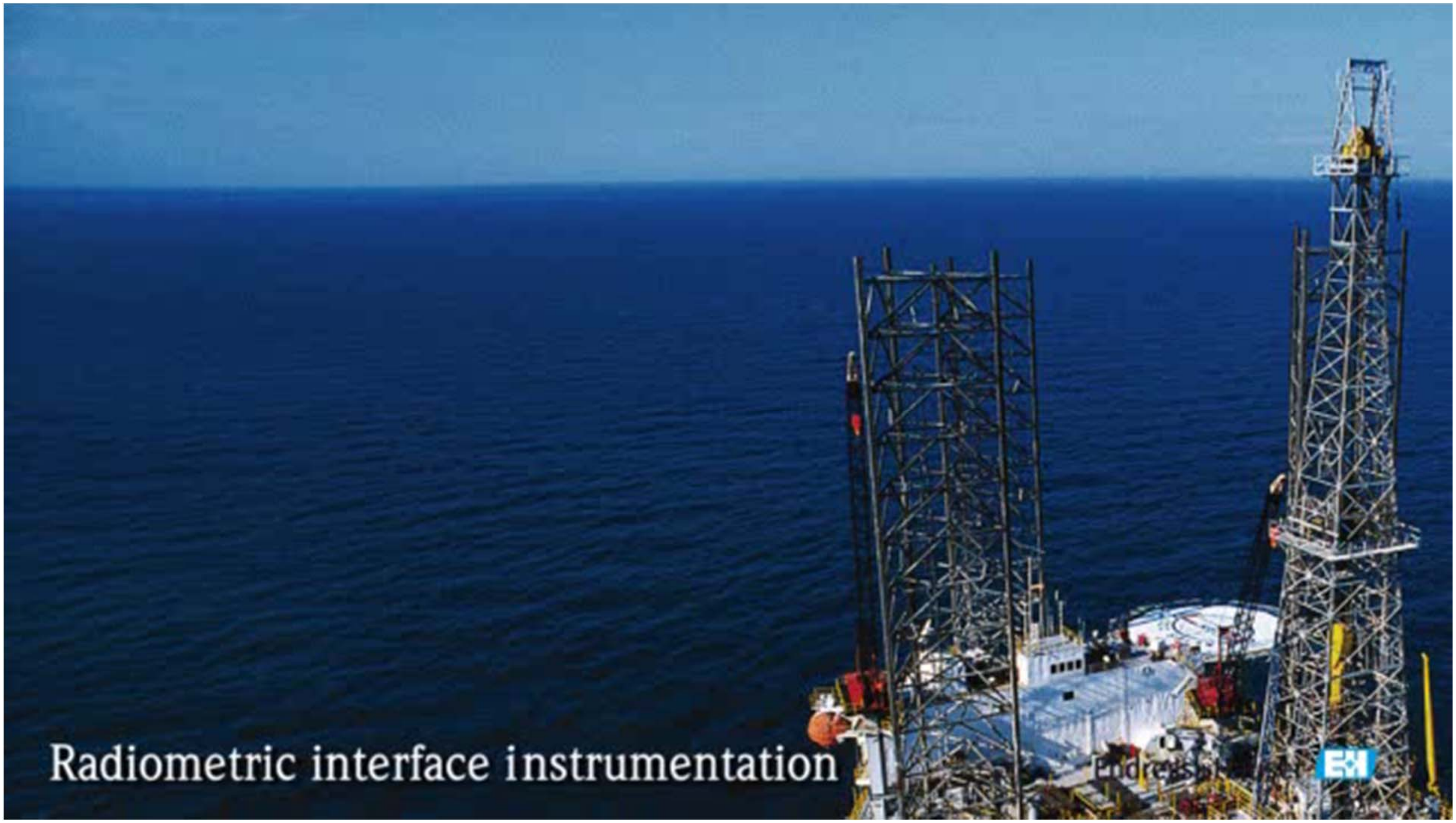
# Interface application from an European refinery



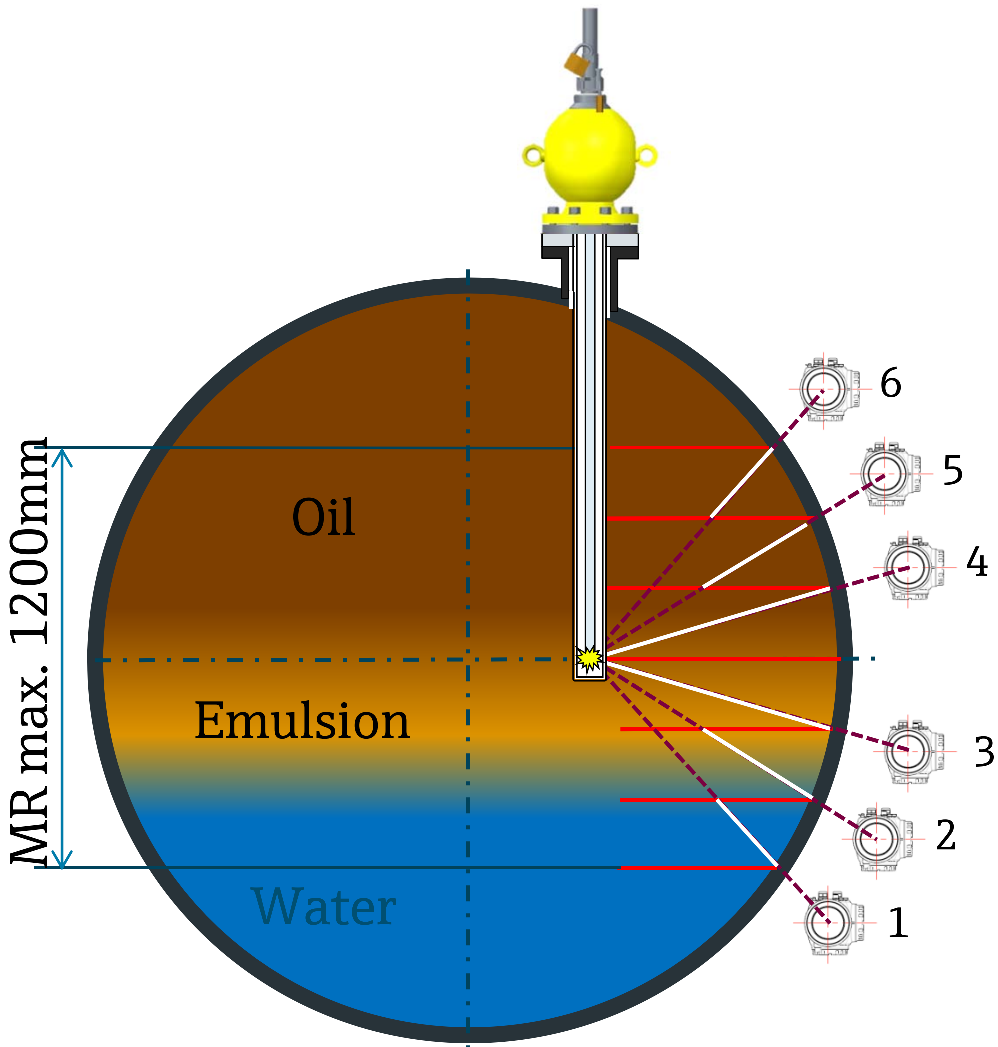
... after a while, that's the risk

Capacitance probe
with special grounding rods
for sticky applications – strong build up limits the application.
Cleaning required.

# Interface and DPS – Movie



# Density Profiling – Working principle




- Source container with rod extension for source to be installed in a dip pipe
- 6-10 detectors are mounted on the tank wall
- The measuring range is subdivided into zones
- Density value **is calculated** for each zone



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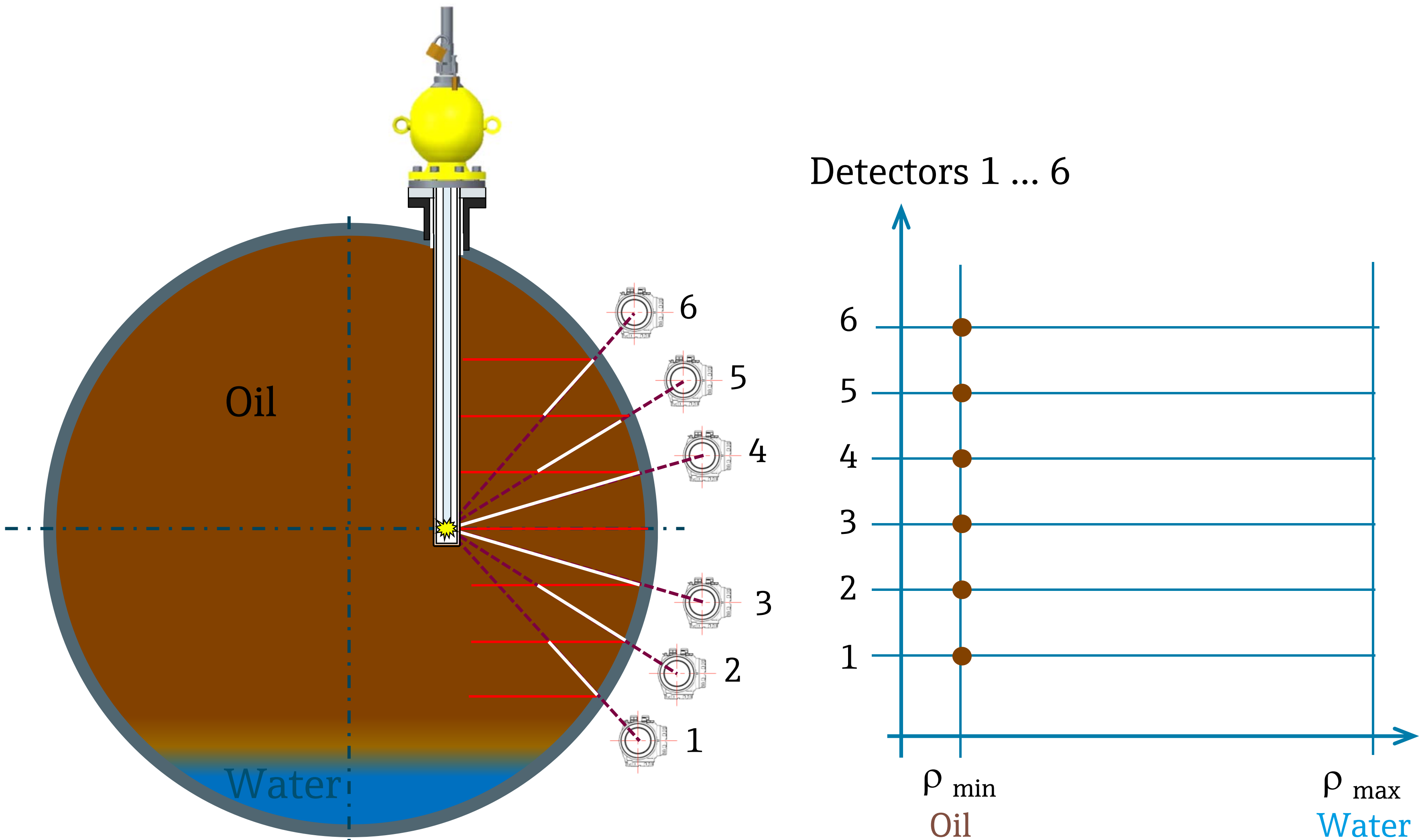
# Density Profiling – Working principle



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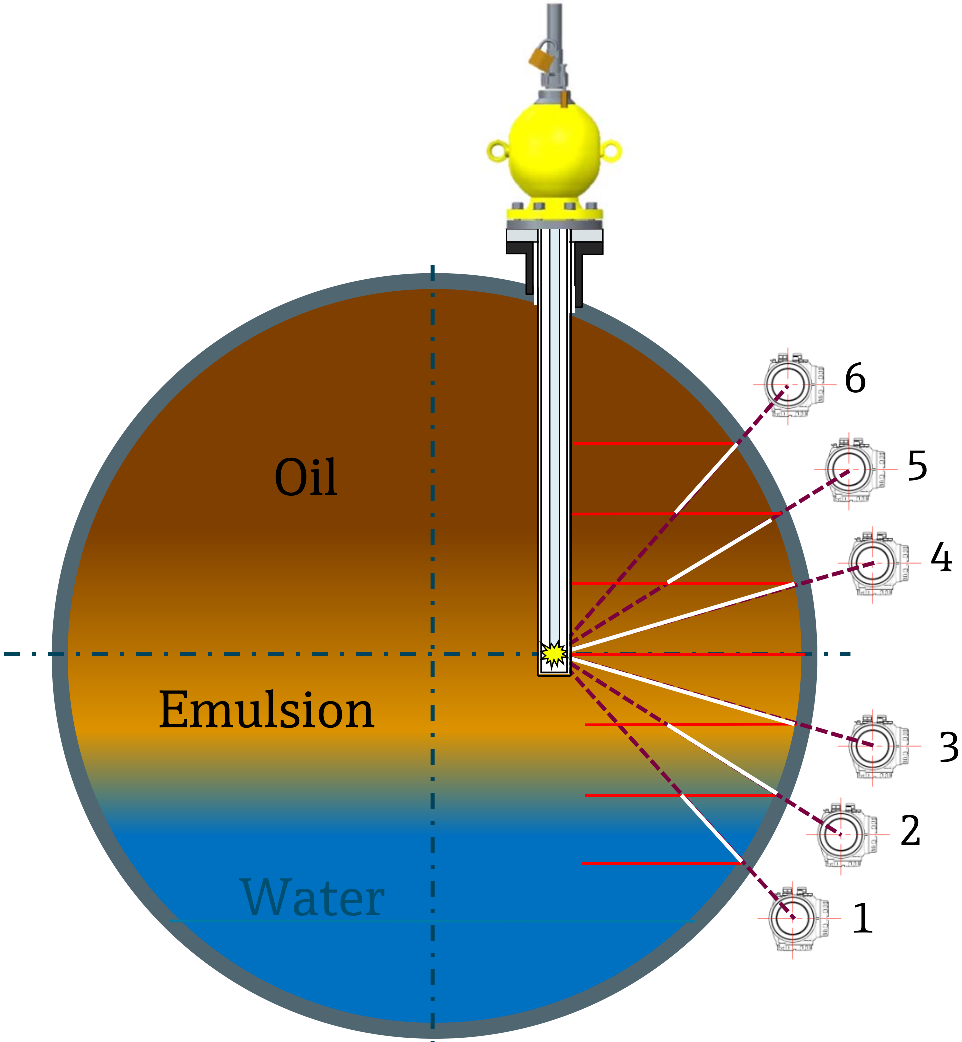


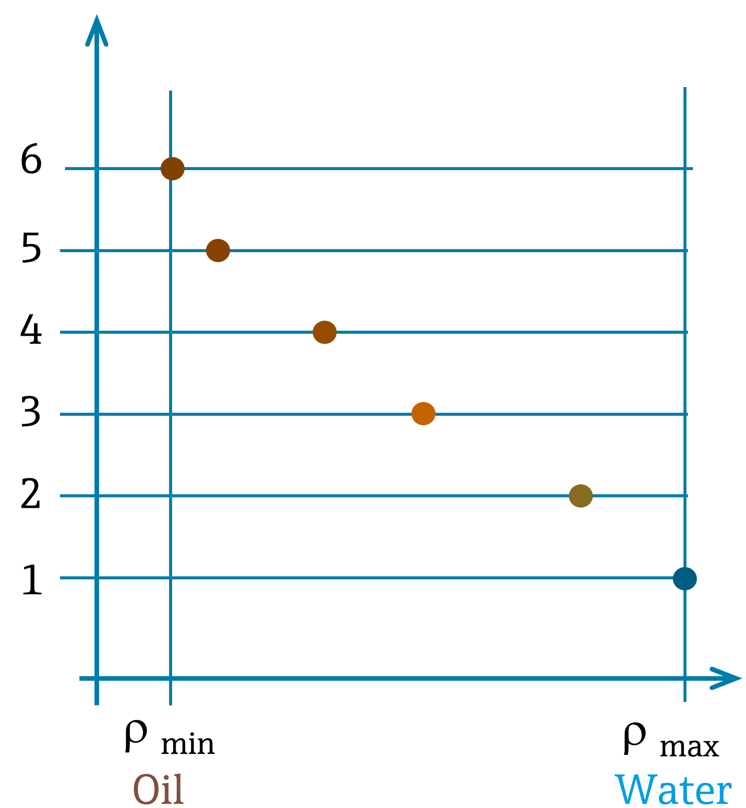

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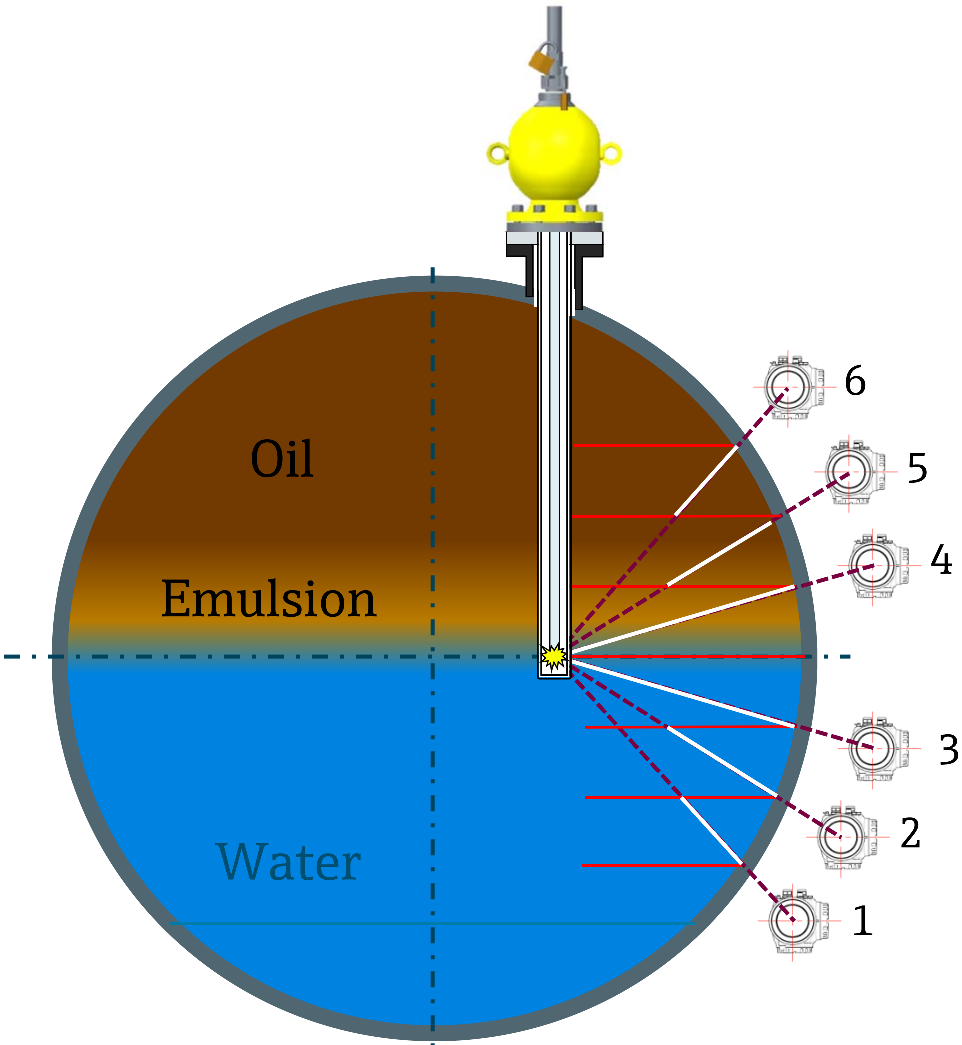


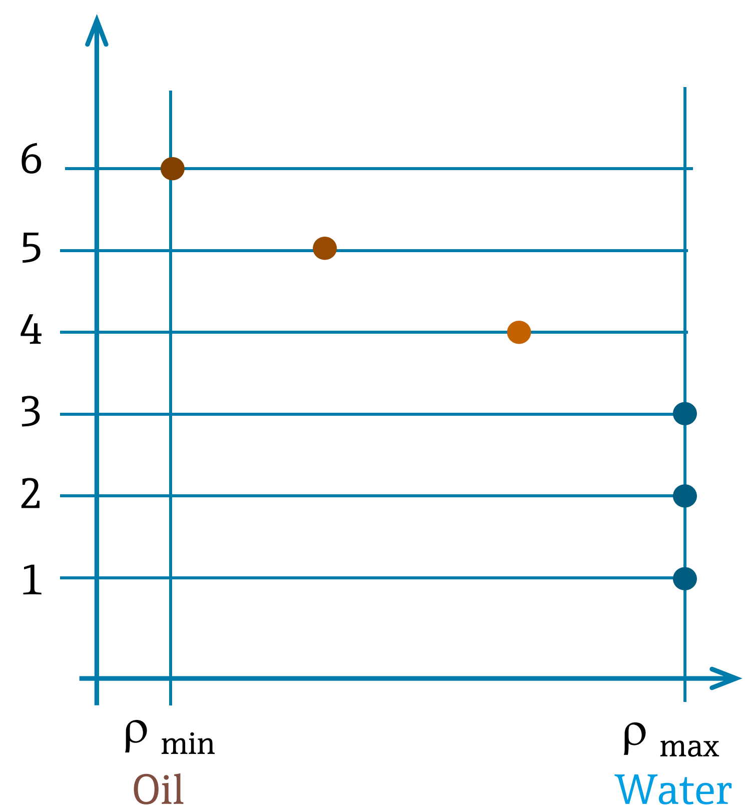




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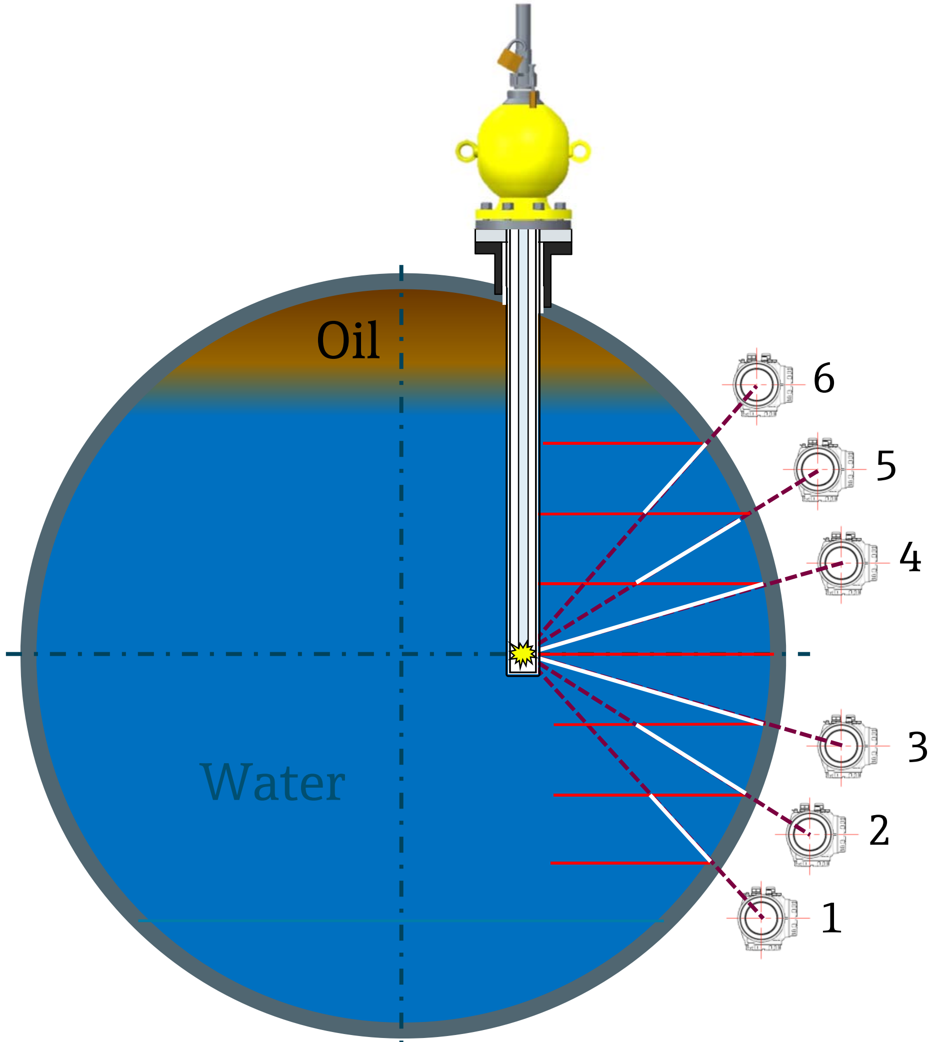
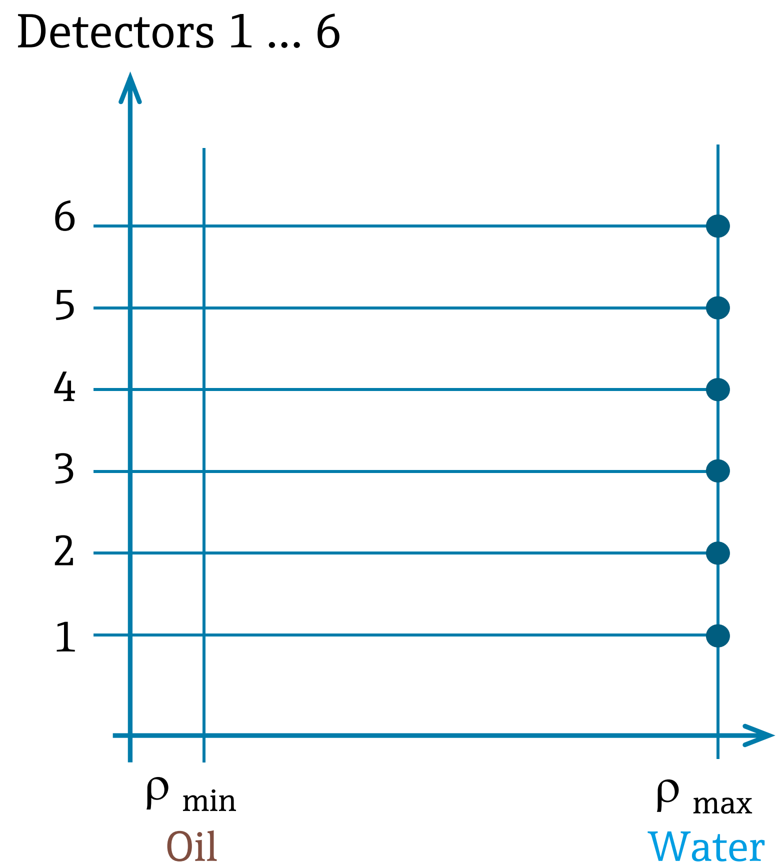
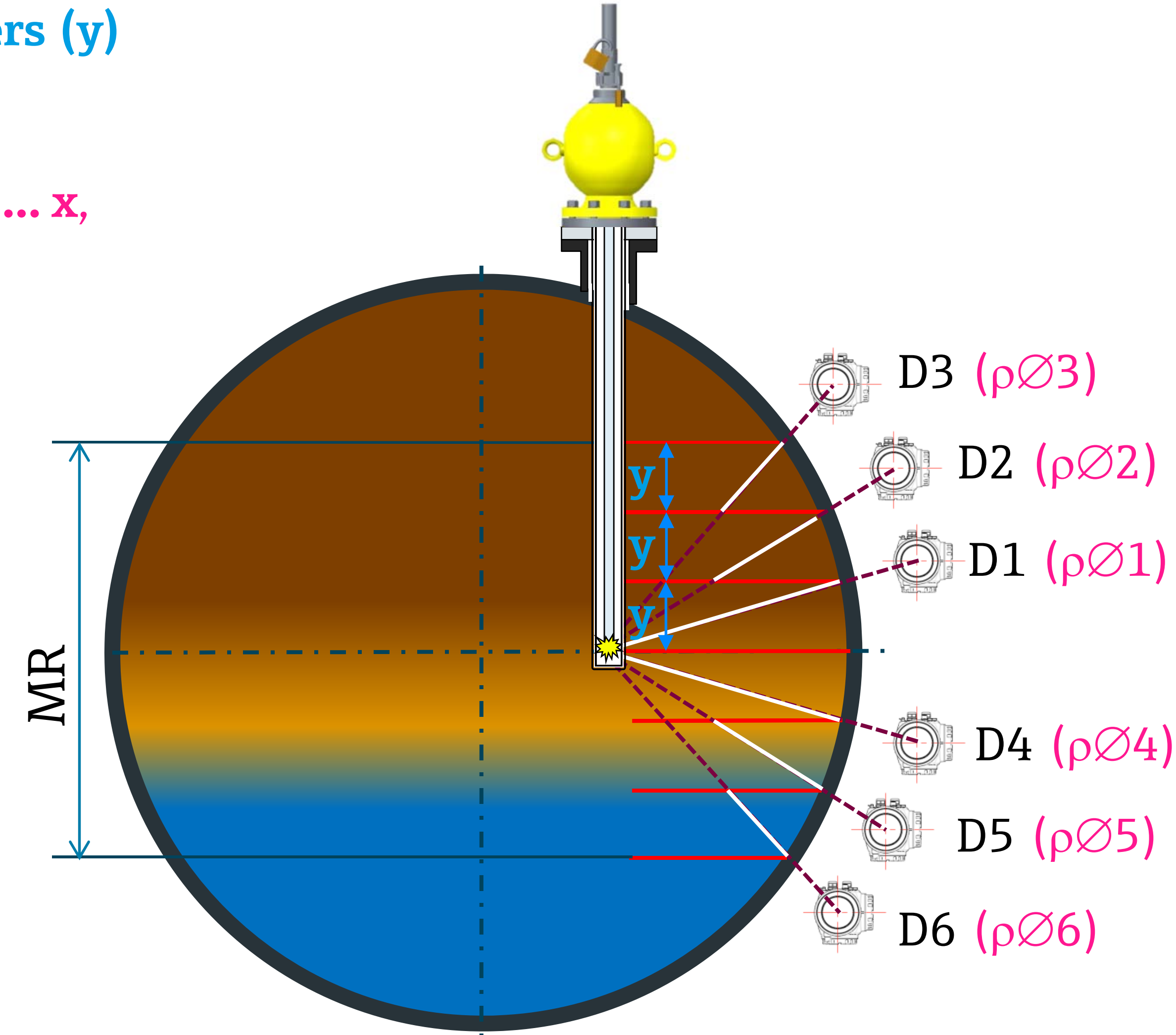
# Density Profiling – Working principle



# Density Profiling – Calculation of density

The density of the **layers (y)** is calculated from the measured **average densities ρ∅1 ... x,** evaluated by the detectors D1 ... Dx.

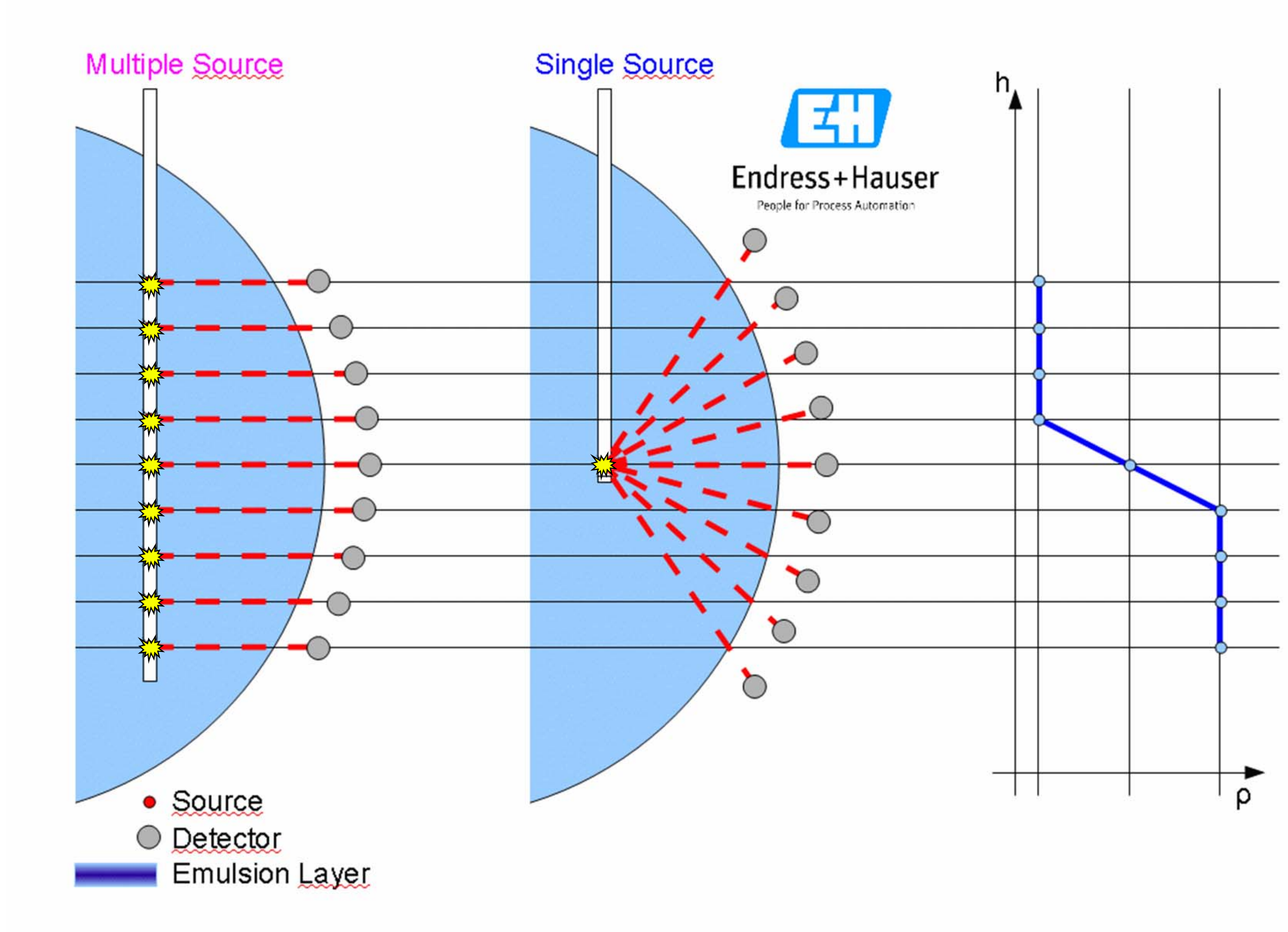


# Density Profiling – Calculation of density

| Data Report | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Detector No. | Distance (source to ...) | | Dose Rate (µSv/h) | | Puls Rate (cps) | | | Detector Length | Accuracy | | Location |
| | Inn. Wall | Detector | Max. | Min. | Max. | Min. | Delta | | kg/m³ | % | |
| 1 | 890,2 | 1173,8 | 3,07 | 1,03 | 6143 | 2070 | 4074 | 200 | 8,7 | 4,3% | ↑ |
| 2 | 858,5 | 1137,3 | 4,00 | 1,40 | 8009 | 2804 | 5205 | 200 | 6,5 | 3,3% | ↑ |
| 3 | 833,3 | 1108,0 | 4,97 | 1,79 | 9932 | 3586 | 6346 | 200 | 4,7 | 2,4% | ↑ |
| 4 | 814,9 | 1086,5 | 5,82 | 2,15 | 11644 | 4300 | 7344 | 200 | 3,2 | 1,6% | ↑ |
| 5 | 803,7 | 1073,4 | 6,42 | 2,40 | 12839 | 4806 | 8033 | 200 | 1,7 | 0,9% | ↑ |
| 6 | 803,7 | 1073,4 | 6,42 | 2,40 | 12839 | 4806 | 8033 | 200 | 1,7 | 0,9% | ↓ |
| 7 | 814,9 | 1086,5 | 5,82 | 2,15 | 11644 | 4300 | 7344 | 200 | 3,2 | 1,6% | ↓ |
| 8 | 833,3 | 1108,0 | 4,97 | 1,79 | 9932 | 3586 | 6346 | 200 | 4,7 | 2,4% | ↓ |
| 9 | 858,5 | 1137,3 | 4,00 | 1,40 | 8009 | 2804 | 5205 | 200 | 6,5 | 3,3% | ↓ |
| 10 | 890,2 | 1173,8 | 3,07 | 1,03 | 6143 | 2070 | 4074 | 200 | 8,7 | 4,3% | ↓ |

- Average density calculation for all layers
- Continuous interface measurement between all layers
- Continuous reading of the emulsion layer thickness.

# Comparison – Solution single /multiple source



# Density Profiling System (DPS) in Desalter

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# Density Profiling System (DPS) in Desalter

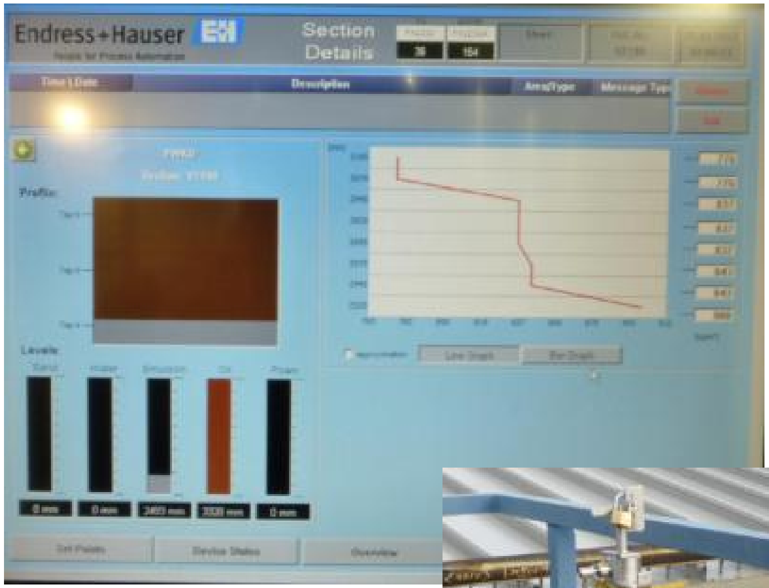
# Desalter – Gaps of improvement / optimization

- Heat exchanger → energy effiency
- Demulsifier injection → reduction of high costs of demulsifier
- Oil quality → less downstream corrosion
- Water quality →easier treatment
- Water control → separation efficiency

# Desalter – Optimization of Demulsifier chemicals

- Demulsifier = Emulsion breaker / neutralize the emulsifier agent
- A demulsifier is implemented **to optimize the process**. It effects the water-oil interface
- It is common that a demulsifier chemical is also added, usually 0.005 to 0.01 lb/barrel (= 1.4 ml/100 l to 2.85 ml/100 l).
- Note: 2ml/100l = 2226 l / 70,000 bpd => approx. 22,000 USD / day spending → **possible saving: 1000 USD / day**

# Desalter – DPS visualization for optimization



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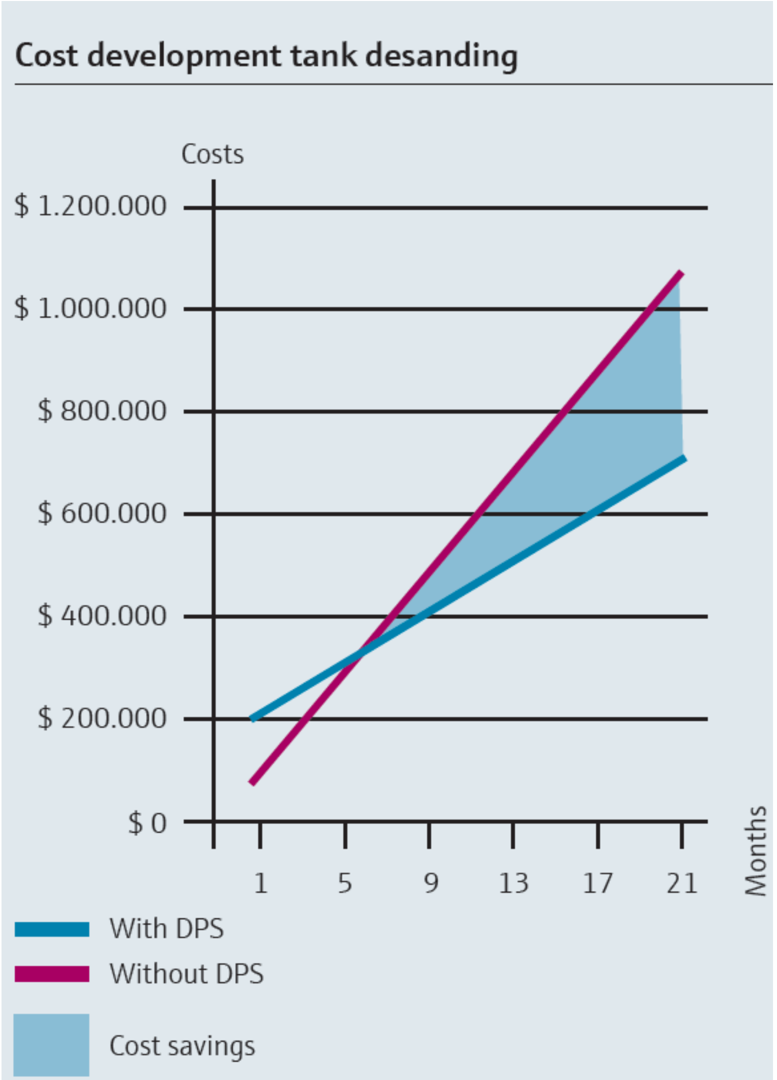
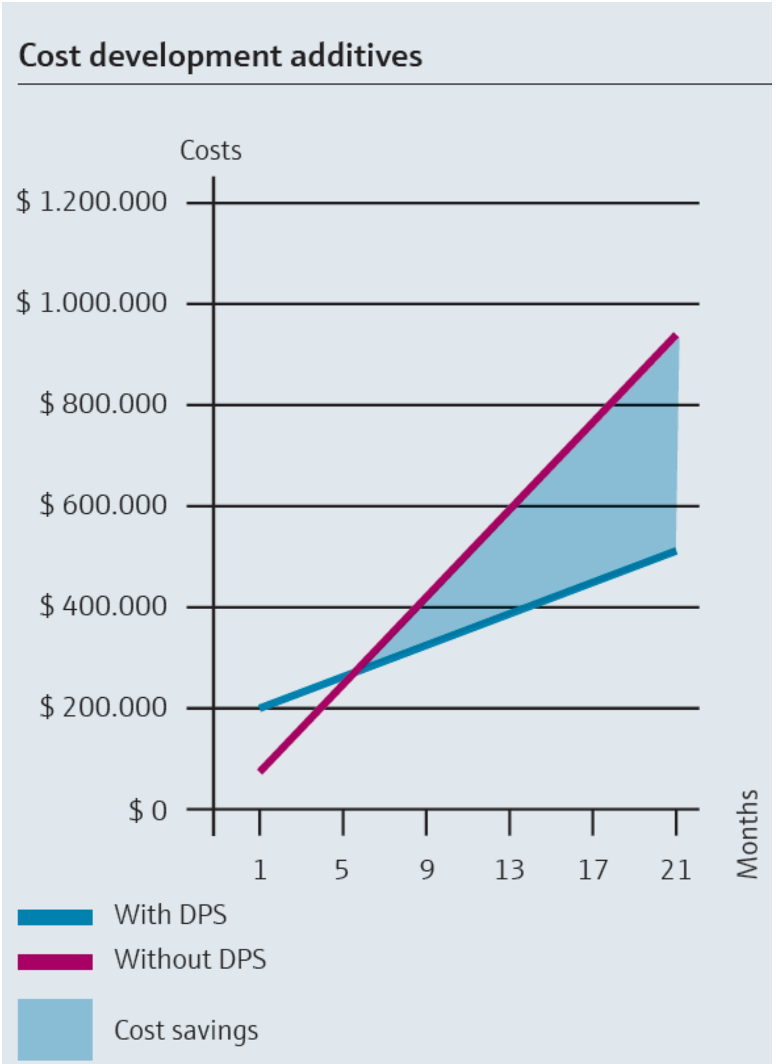
# Desalter – Tank Desanding




- Desanding twice a month in average
- Average costs of US$ 24,000 / each
- More than US$ 1 million during 24 month

- **With DPS a saving of 400k USD is possible**

# Desalter – Demulsifier / Additives




- Additives attain a faster separation of water and oil.
- Savings of additives in the desalting process of US$ 1000 per day on average.
- The investment in one Profile Vision unit is thus already amortized after approx. 6-12 months.

# Desalter – Refineries with potential for DPS

- Low API grade oil (<25)
- Old desalter vessels with low efficiency
- Changing crude with different API grades
- Any issue with build-up / coating with other measuring technologies
- Any issues with higher sulfur content
- Whenever emulsion > 100mm is present or is being created

# Desalter – Conclusion

## Advantages – Density profile measurement in desalting processes

- Reliable reduction of salt in the process
- Reduction of plant downtimes and maintenance costs due to improved capacity utilization
- Salt build-up can be prevented in good time by exact measurements and process control
- Optimized use of chemicals due to an efficient desalting process
- Return of Invest typically 6-12 month

# What about in Petrochemical plants?

Is the return of
invest measurable?



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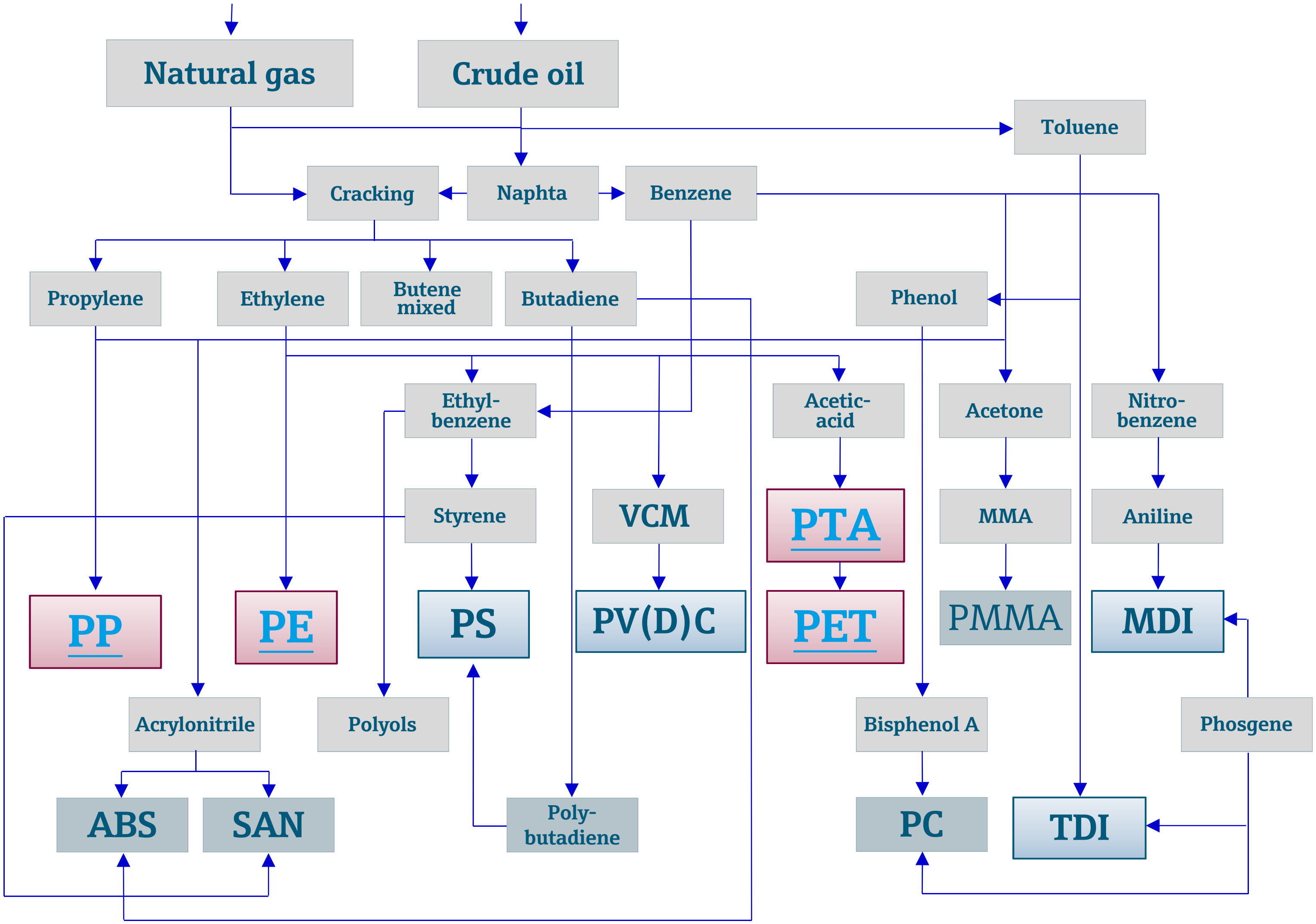
# Petrochemical Industry – Overview



# Radiometric Measurement

Unipol – PP / PE / HDPE / LLDPE

# Unipol Process Overview

Production process of linear low-density polyethylene (LLDPE/HDPE)

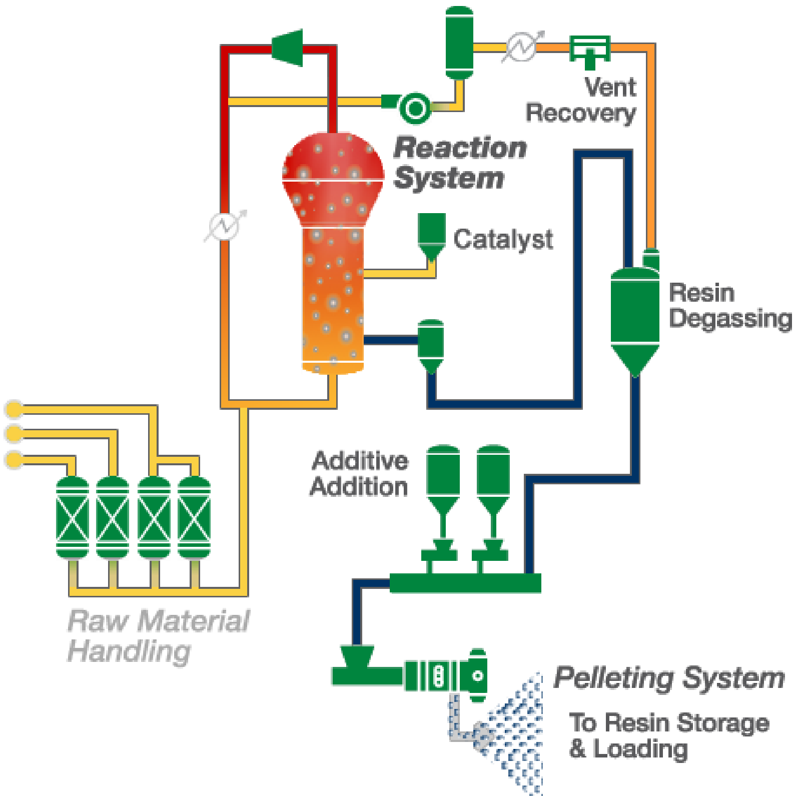



**Fig. 1:** UNIPOL™ LLDPE/HDPE process using an fluidized bed reactor

Polymerization is possible in
- Solution phase
- gas phase reactors (common industrial solution).



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# Fluidized bed Reactor

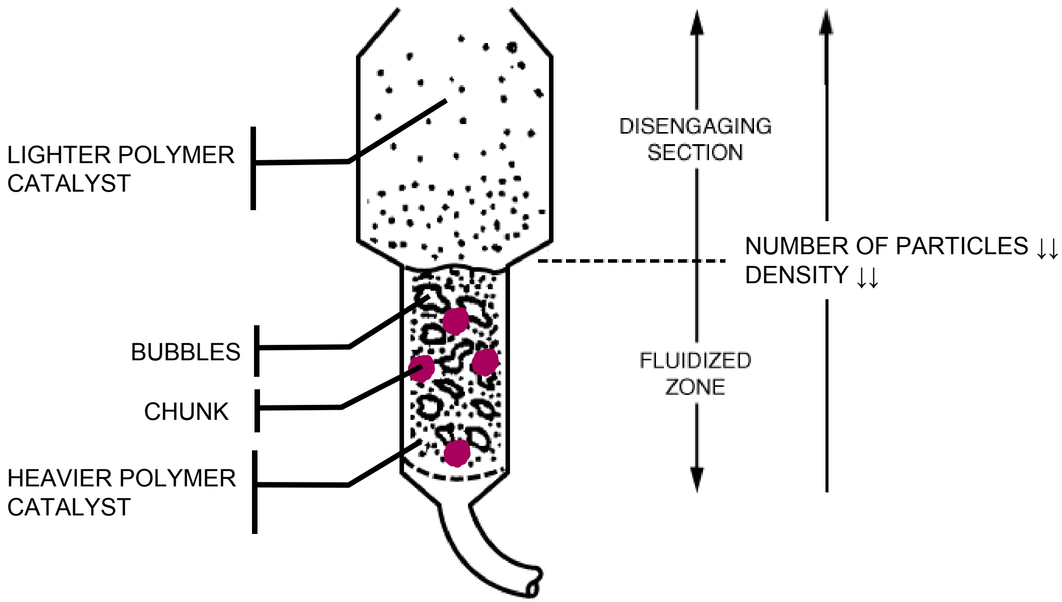



**Fig.:** Fluidized bed reactor

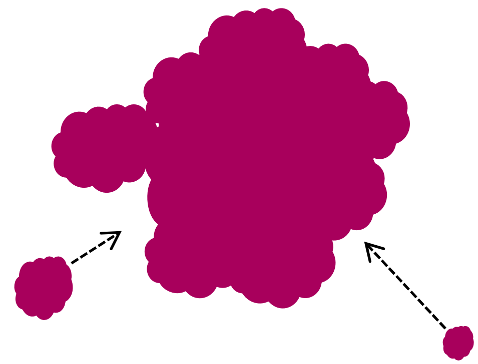


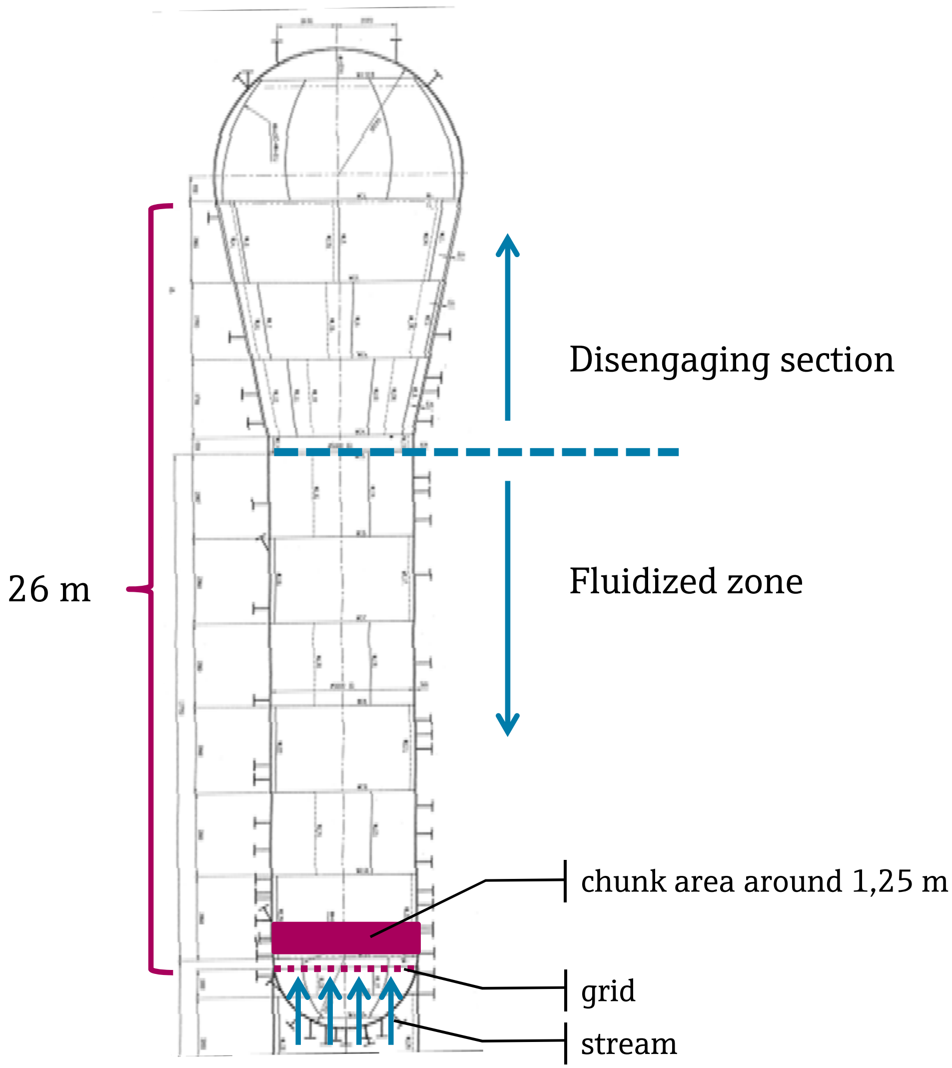
**Fig.:** Agglomerates of heavier polymer catalyst (chunk) with a size of around 150mm

Reaction process depends on the process conditions

- temperature [t]
- pressure [p]
- particle velocity [v]

Sometimes, the reactor produces oversized **chunks (agglomerates) of polyethylene** which contains fluidized polyethylene powder and hydrocarbons.

# Fluidized bed reactor




It is highly desirable that these chunks be **detected and removed before they become too large and disturb the process.** These chunks are of a higher density than the fluidized bed and settle in the bottom of the reactor. There, they may be detected by the chunk detector.

# LLDPE or PE-LLD

- Process based on Ziegler-Natta-Catalyst/Method
- Process conditions
  - 1-50 bar
  - 20 – 150 °C
- LLDPE
  - has a defined by a density range of 0.87–0.94 g/cm$^3$
  - is produced as an granulate

# Chunk detection

Chunk has a higher density and is moving around in the vessel.
The target is to detect the chunk with the highest and fastest possibility

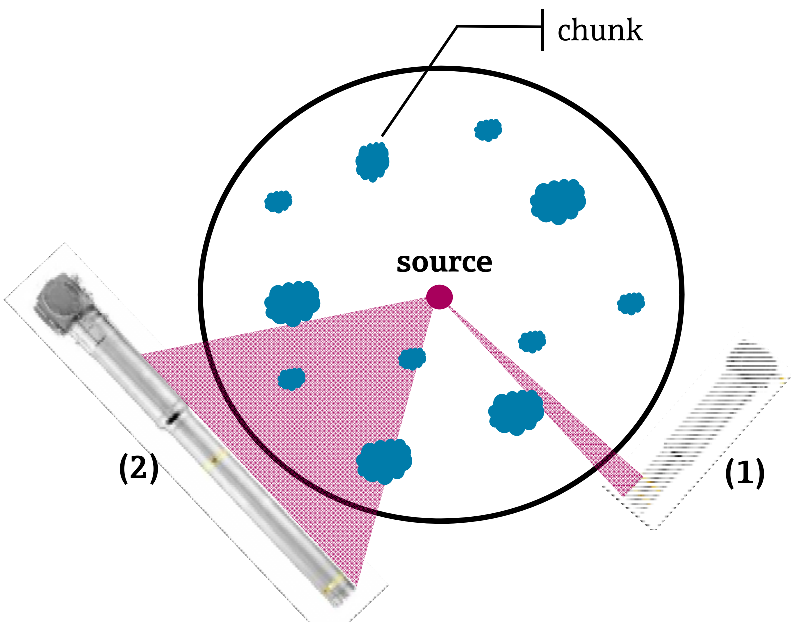
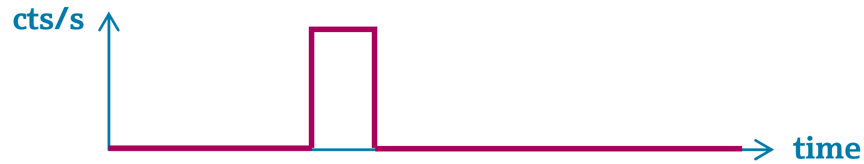



**Fig. :** Fluidized bed reactor top view with an NaJ and an scintillator detector

**(1)** NaJ detector (sensing range: 50x50 mm)
- the possibility to hit chunk ↓
- high signal change Δcps




**(2)** PVT detector (sensing rang: 40x400 mm)
- the possibility to hit chunk ↗
- lower signal change Δcps↘
- sensing range can´t be enlarged too much
- otherwise signal change decrease hardly Δcps↓↓



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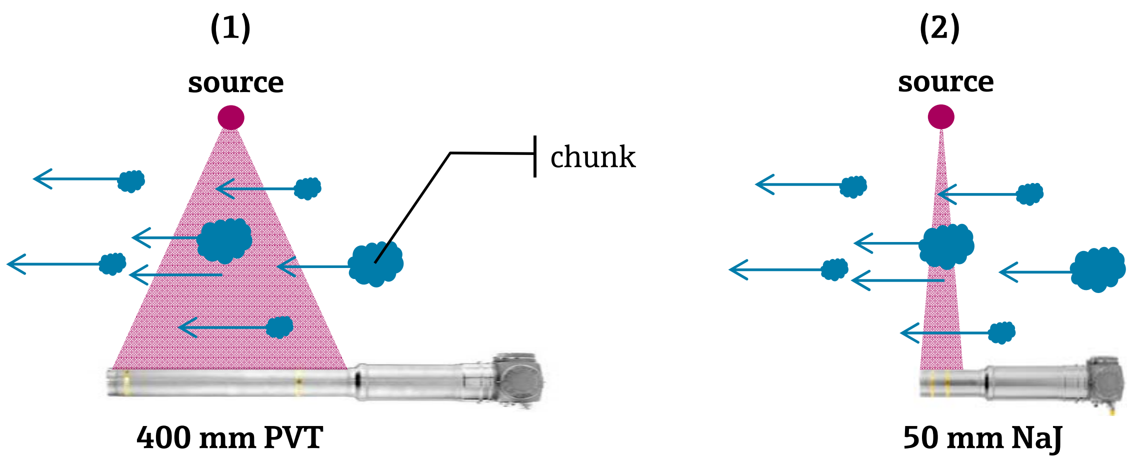
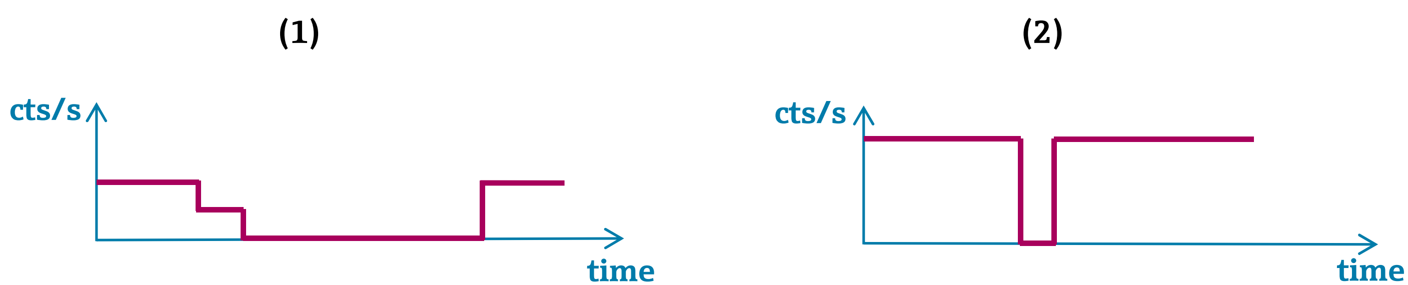
# Chunk detection

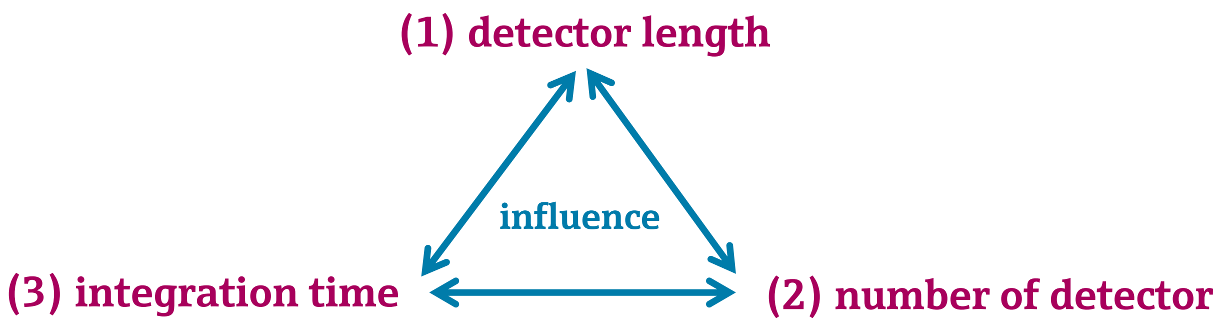



At the same detector integration time of the cases (1) and (2) the polymer particles which move around with same velocity create a different pulse rate [cts].
(1) will detect more chunk and create at least in sum the higher pulse rate.



# Chunk detection

**Summery:** Impact of integration time, number and length of detectors

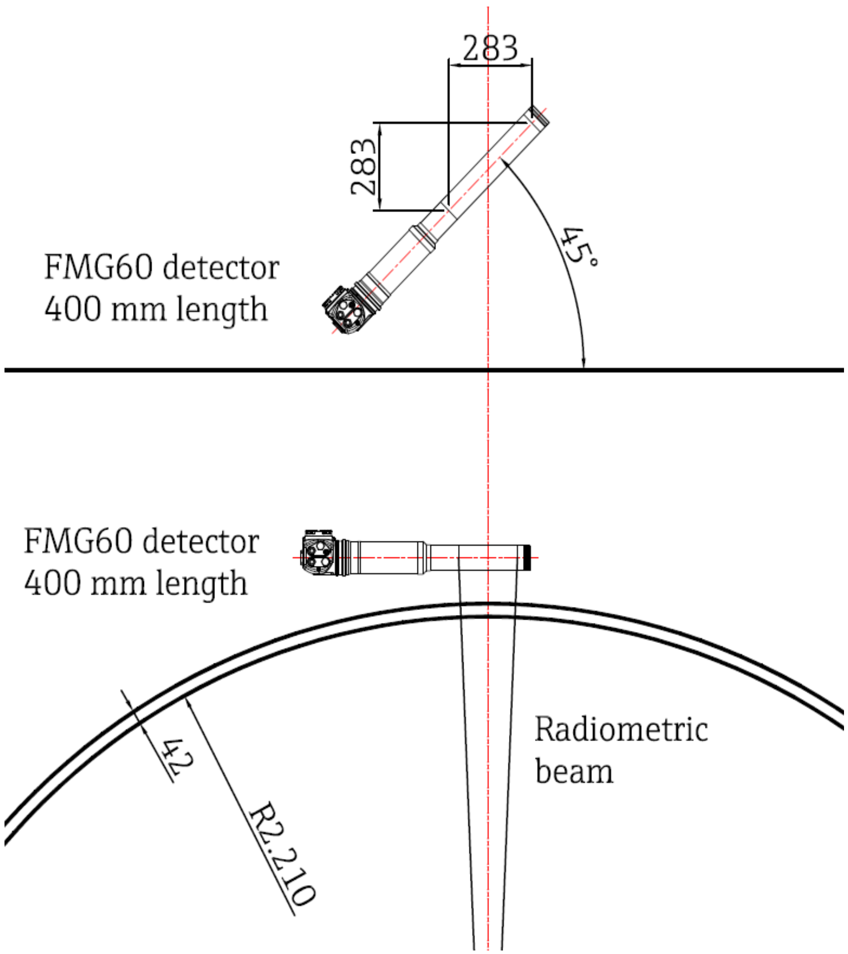



**(1)** As longer as the detector length is as more chunk will be detected but as weaker the signal is. We recommend a detector length of 400 mm

**(2)** As more detectors you mount around round the vessel as more chunk will be detected but as higher are the costs. We recommend 8 to 12 detectors

**(3)** As higher the integration time is as higher is the possibility to detect chunk but as weaker the signal is.

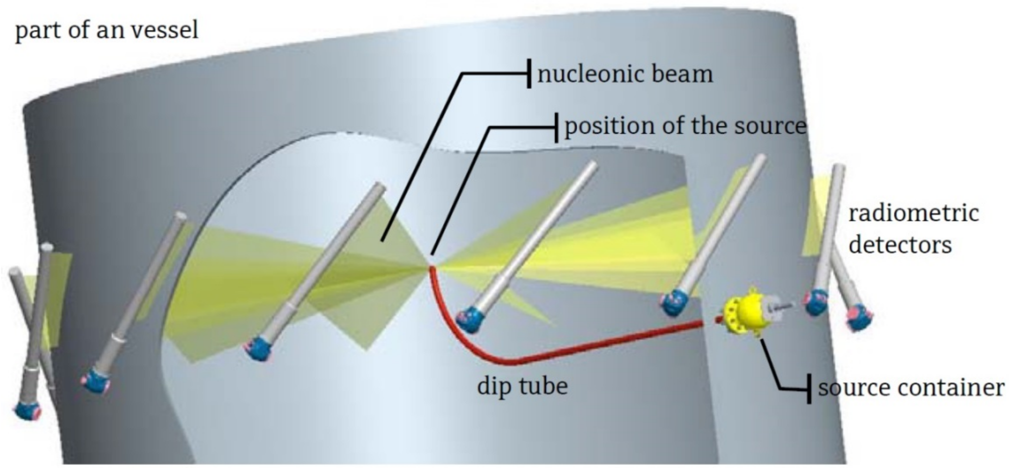
# Chunk detection




- The detector orientation enlarges additionally the probability to detect chunks
- The highest probability is here given with an mounting angle of 45°
- The best count rate [cts/s] is given with an FMG60 with a length of400 mm

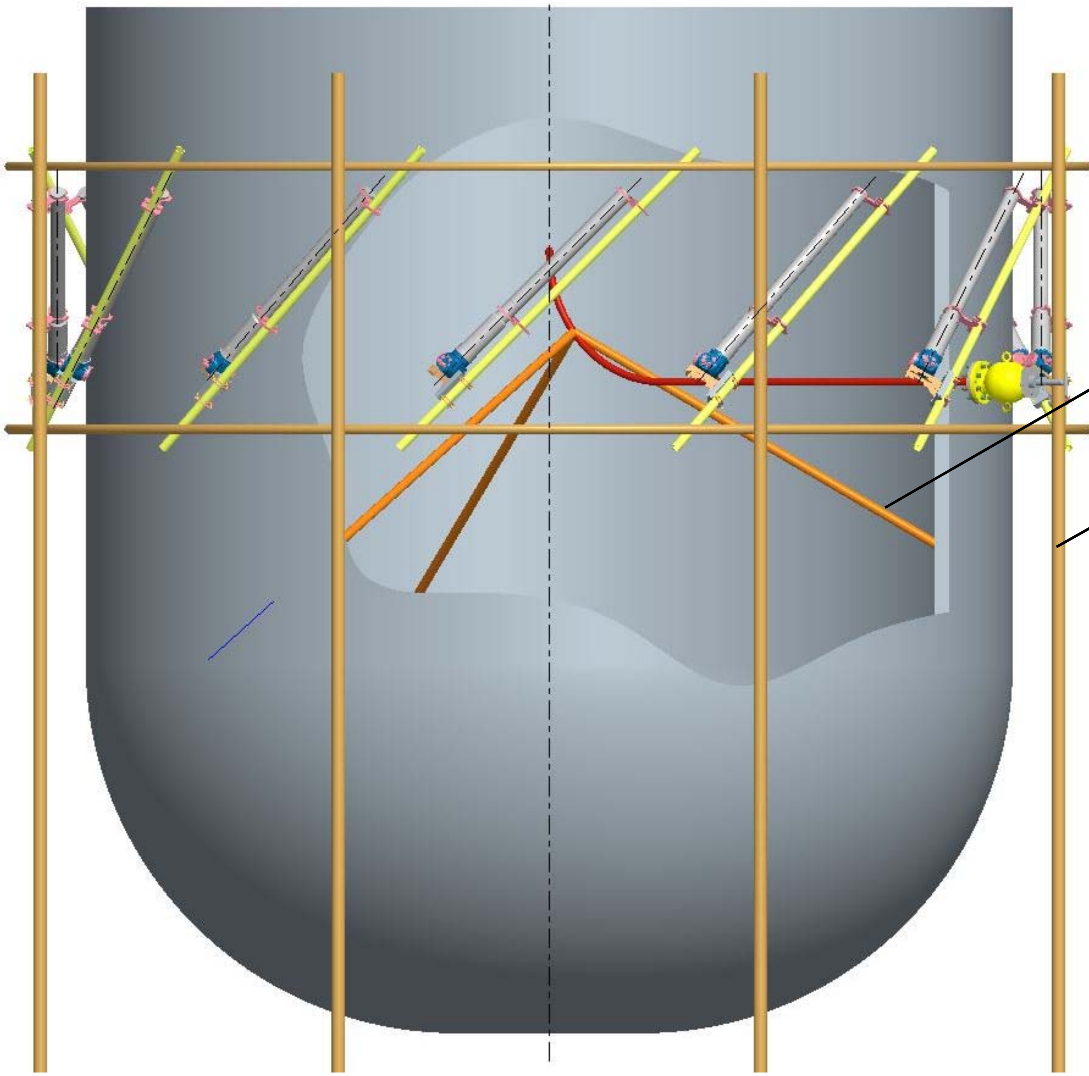
# Chunk detection setup

With the number of detectors the probability to detect chunk will also increase.

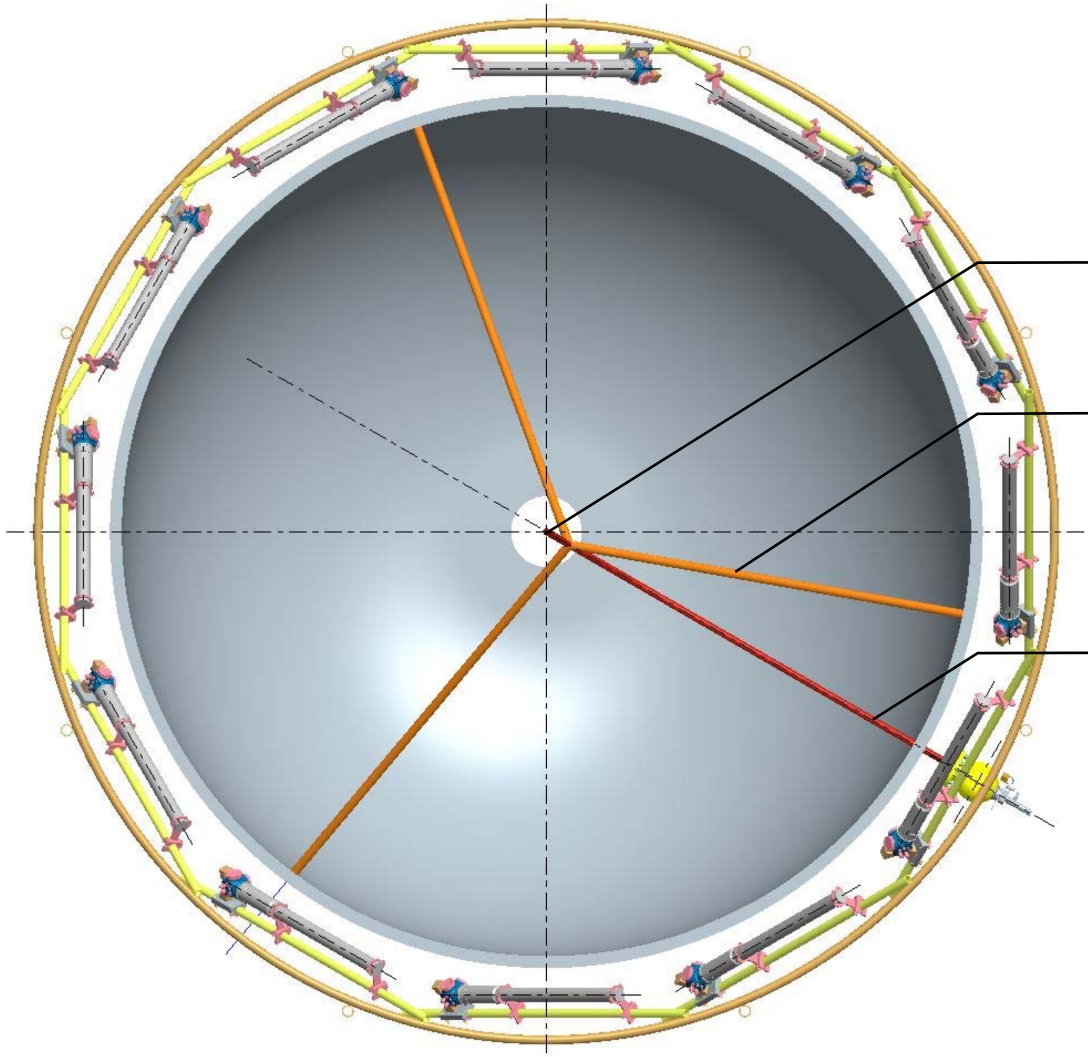



- source of nuclear radiation located in the center of the reactor
- array of radiation detectors spaced around the perimeter of the outside of the reactor
- radiation is absorbed by the chunk and the change in the radiation field strength is sensed at the detector

# Side view with support brackets



# Top view with support brackets



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# Application for small vessel IDs

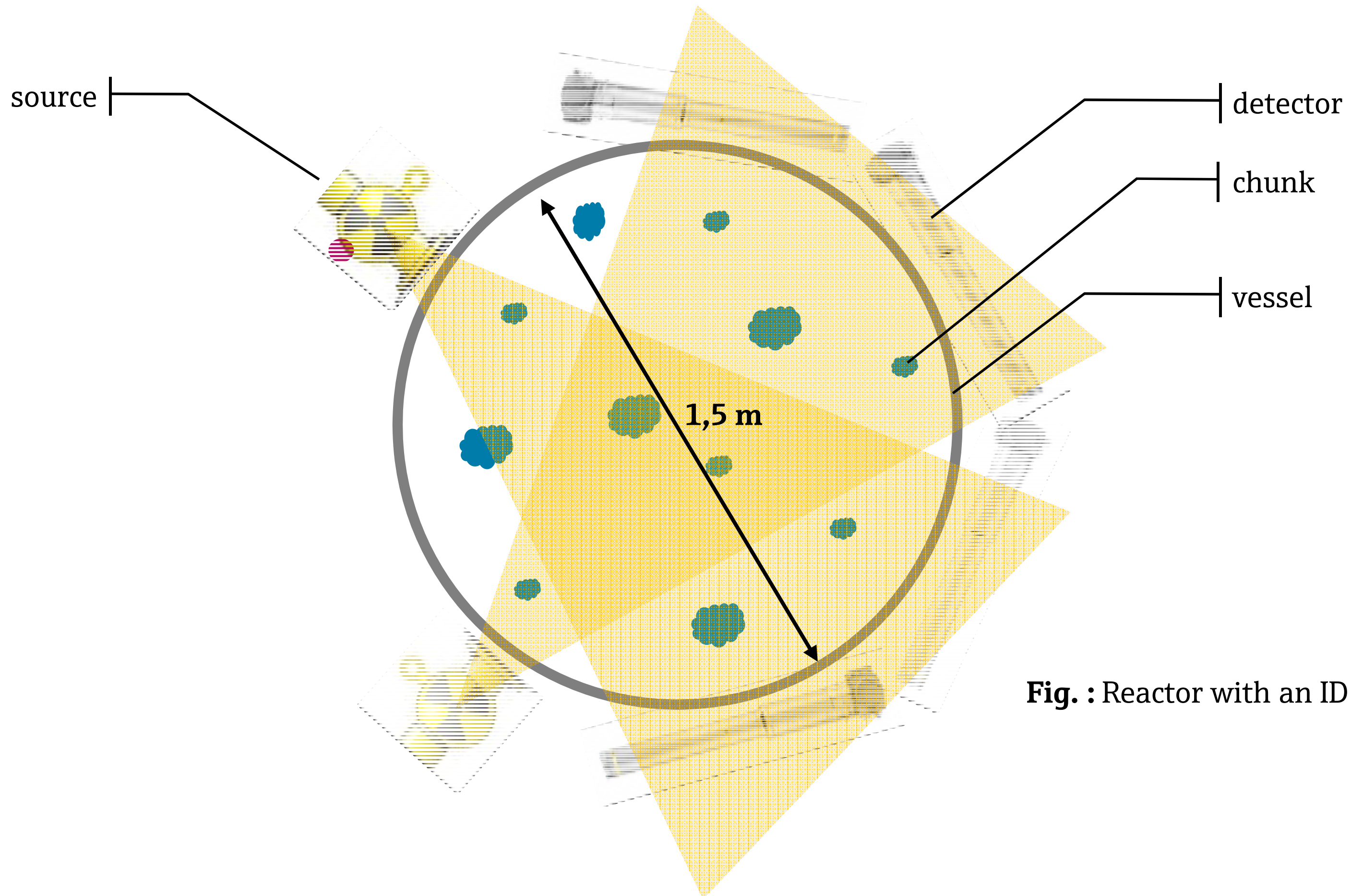



**Fig. :** Reactor with an ID of 1,5 m.

# Chunk size

**Nomenclature:**

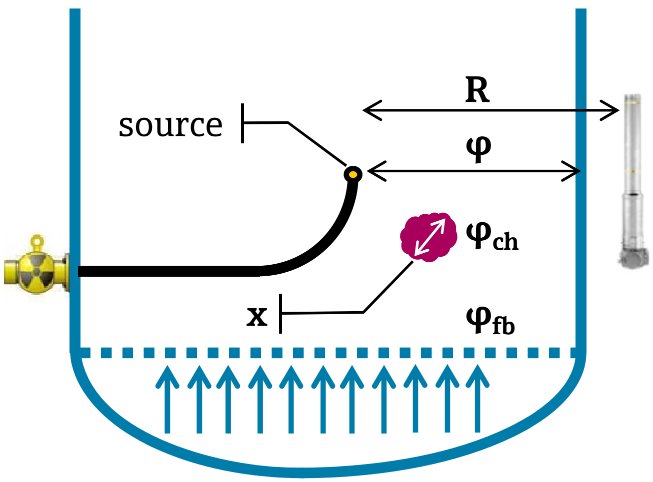
density chunk [$\varphi_{ch}$]

density fluidized bed [$\varphi_{fb}$]

average density beam path [$\varphi$]

distance source detector [R]

size chunk [x]




$$R \cdot \varphi = x \cdot \varphi_{ch} + (R - x) \cdot \varphi_{fb} \qquad (1)$$

$$x = \frac{R \cdot (\varphi - \varphi_{fb})}{\varphi_{ch} - \varphi_{fb}} \qquad (2)$$

The fluctuation of the bed density is written as

$$\varphi_{fb} = \varphi_{fb\,min} \cdots \varphi_{fb\,max} \qquad (3)$$

It´s considered that chunk can be reliably detected if the measured average density is at least 20 % higher (that means in equation (4) times 1,2) than the highest bed density at the lowest bed density characterized by

$$\varphi \geq 1{,}2 \cdot \varphi_{fb\,max} \quad \text{at} \qquad (4)$$

$$\varphi_{fb} = \varphi_{fb\,min}$$

# Calculation example

**Example: calculation of the chunk size**

The calculation of the chunk dimension depends on different process conditions ([p], [v], [t], …). The following examples give a small overview to the influence given as ± 10%.

$$\varphi_{fb} = 128\ \frac{kg}{m^3} \pm 10\ \%$$

$$\varphi_{ch} = 900\ \frac{kg}{m^3}$$

$$\mathrm{R} = 2210\ mm$$

$$\varphi_{fb\ min} = 0{,}9 \cdot 128 \approx 115\ \frac{kg}{m^3}$$

$$\varphi_{fb\ max} = 1.1 \cdot 128 \approx 141\ \frac{kg}{m^3}$$

$$x = \frac{\mathrm{R}\ (1{,}2 \cdot \varphi_{\mathrm{fb\ max}} - \varphi_{\mathrm{fb\ min}})}{\varphi_{\mathrm{ch}} - \varphi_{\mathrm{fb\ min}}}$$

$$x = \frac{2210 \cdot (1{,}2 \cdot 141 - 115)}{900 - 115}$$

$$x = 152\ mm$$



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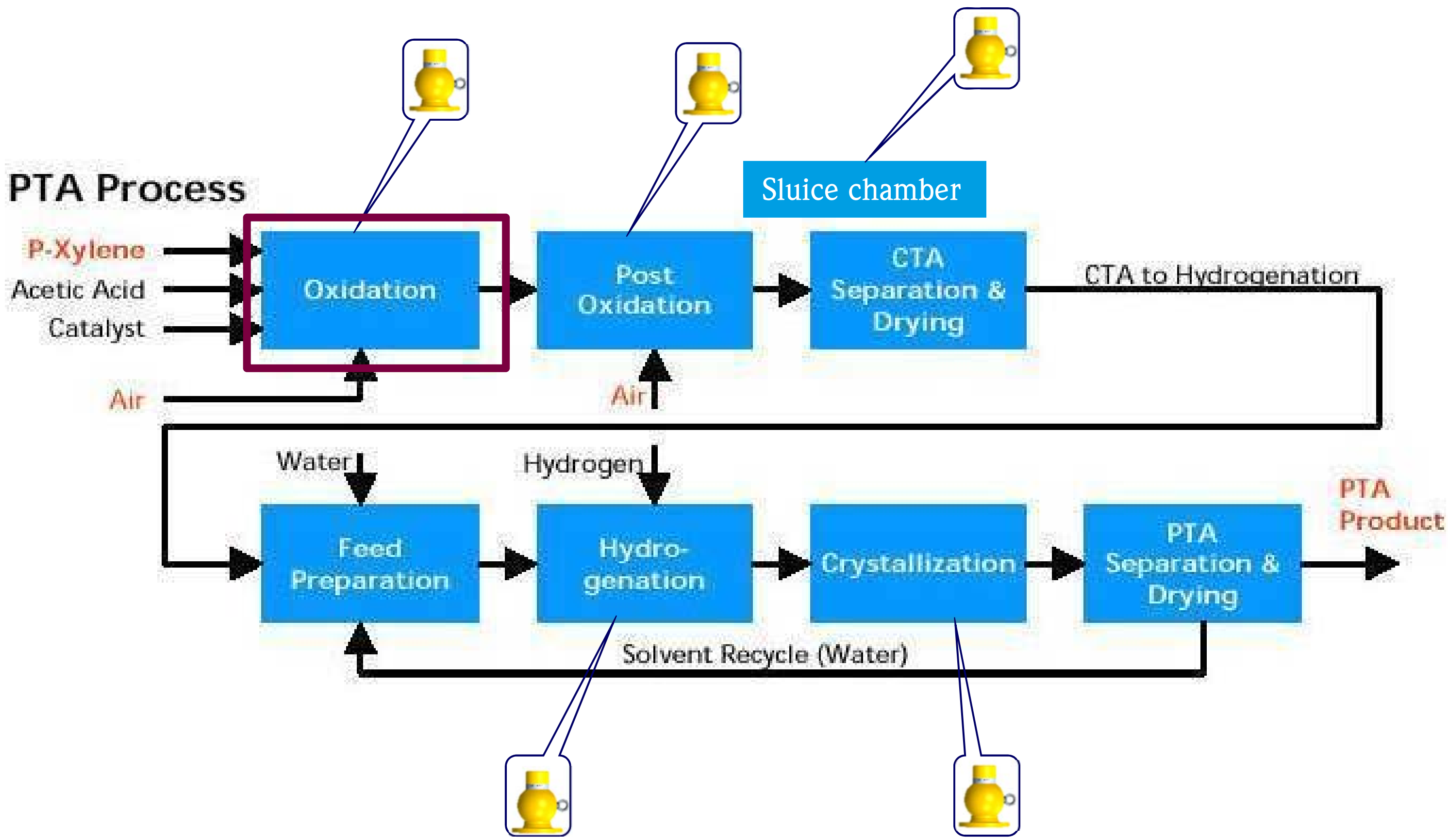
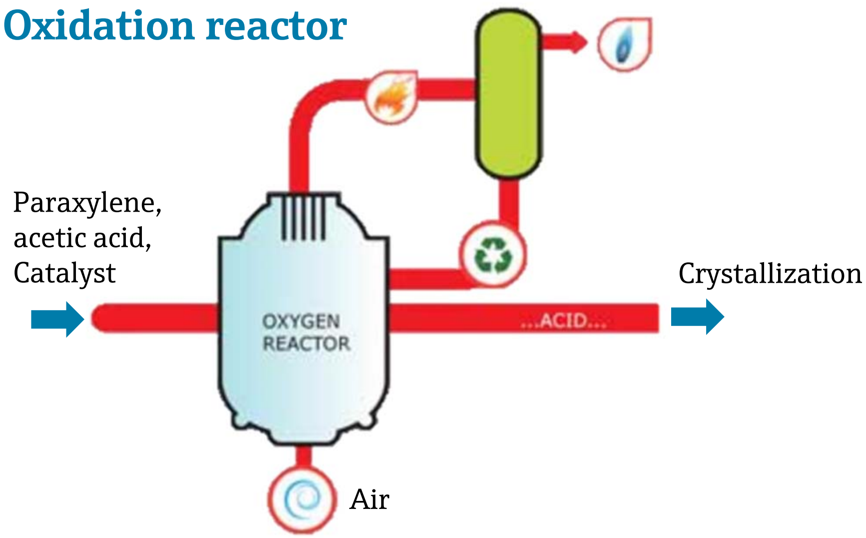
# PTA – Process

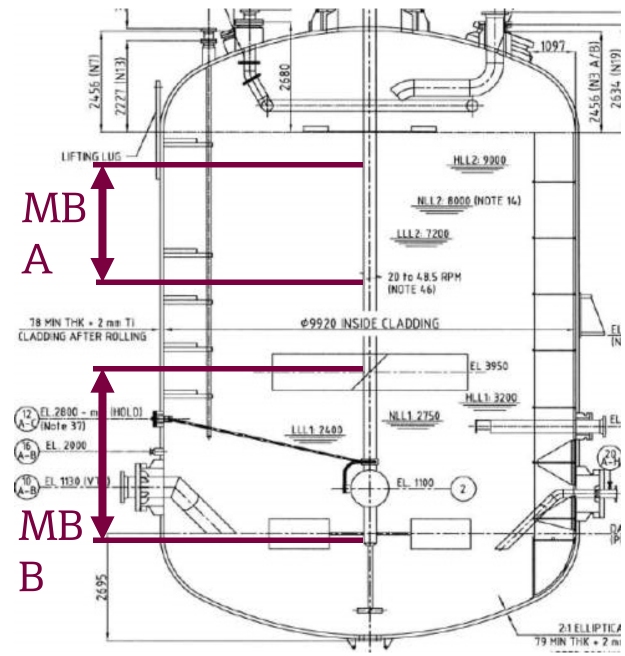


PTA Process
P-Xylene
Acetic Acid
Catalyst
Air
Oxidation
Post Oxidation
Air
Sluice chamber
CTA Separation & Drying
CTA to Hydrogenation
Water
Hydrogen
Feed Preparation
Hydro-genation
Crystallization
PTA Separation & Drying
PTA Product
Solvent Recycle (Water)

# PTA – Oxidation Reactor

## Oxidation reactor




| | |
|---|---|
| Vessel data | Height: 10m<br>Ø 9,9m<br>Vessel wall:<br>78 mm steel<br>MR: ~6m<br>Agitator |
| Temperature<br>Pressure | 200°C<br>14.3 bar |

### Measuring tasks / Challenge:

- Level measurement in two areas, between 0 - 4m and 7- 9,3m
- Pressure change
- Strong build up at the vessel wall



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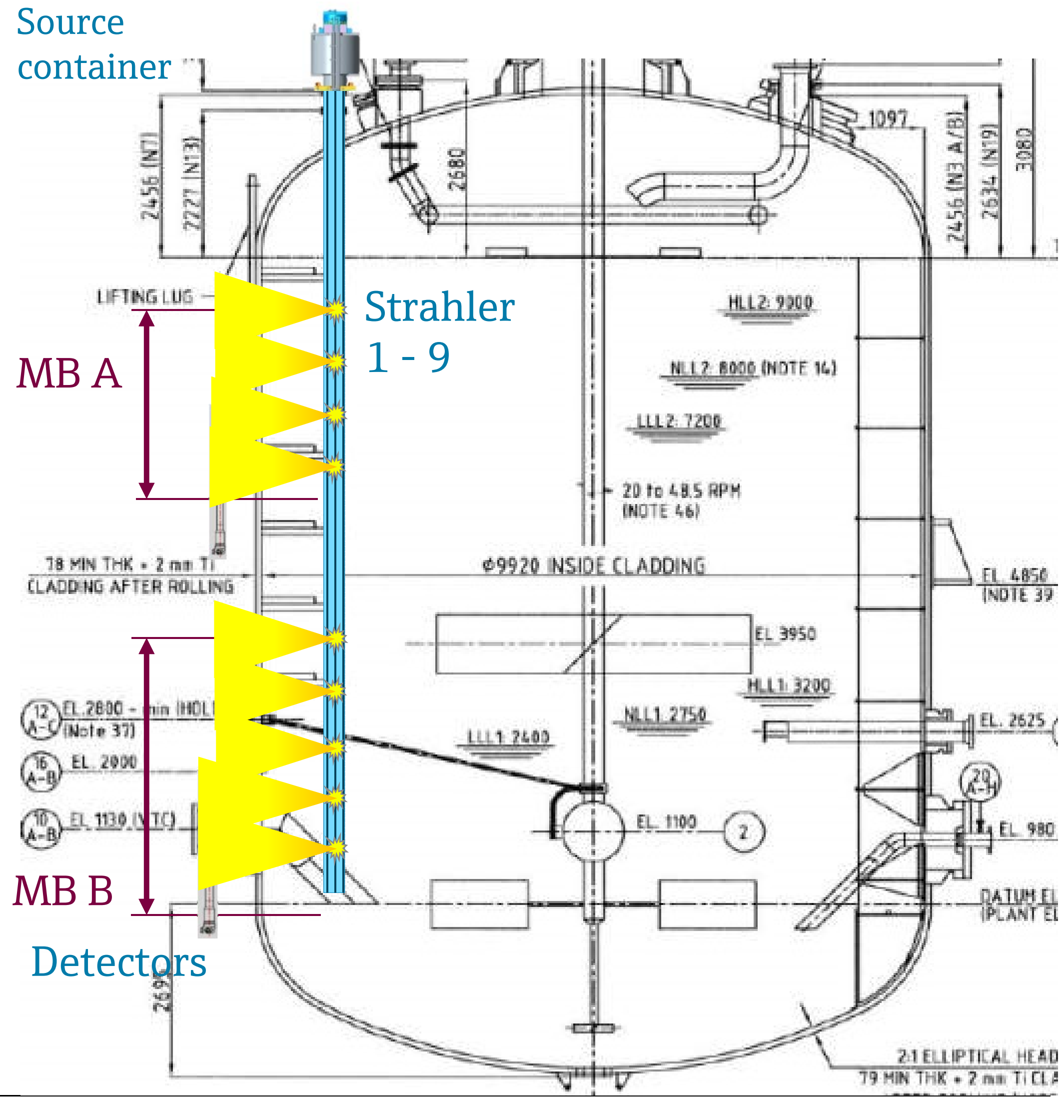
# PTA – Oxidation Reactor / Devices + Solution

## Devices and solution:

- Reducing influence of build up and pressure change with internal source
- 9 sources inside dip pipe 9x 20mCi Cs137
- Source container, Multiplex 9S, for installation of up to 9 sources with guiding pipes for the rope extensions of the sources
- 4 Detectors: MR A: 2x FMG60-1200 MR B: 2x FMG60-2000



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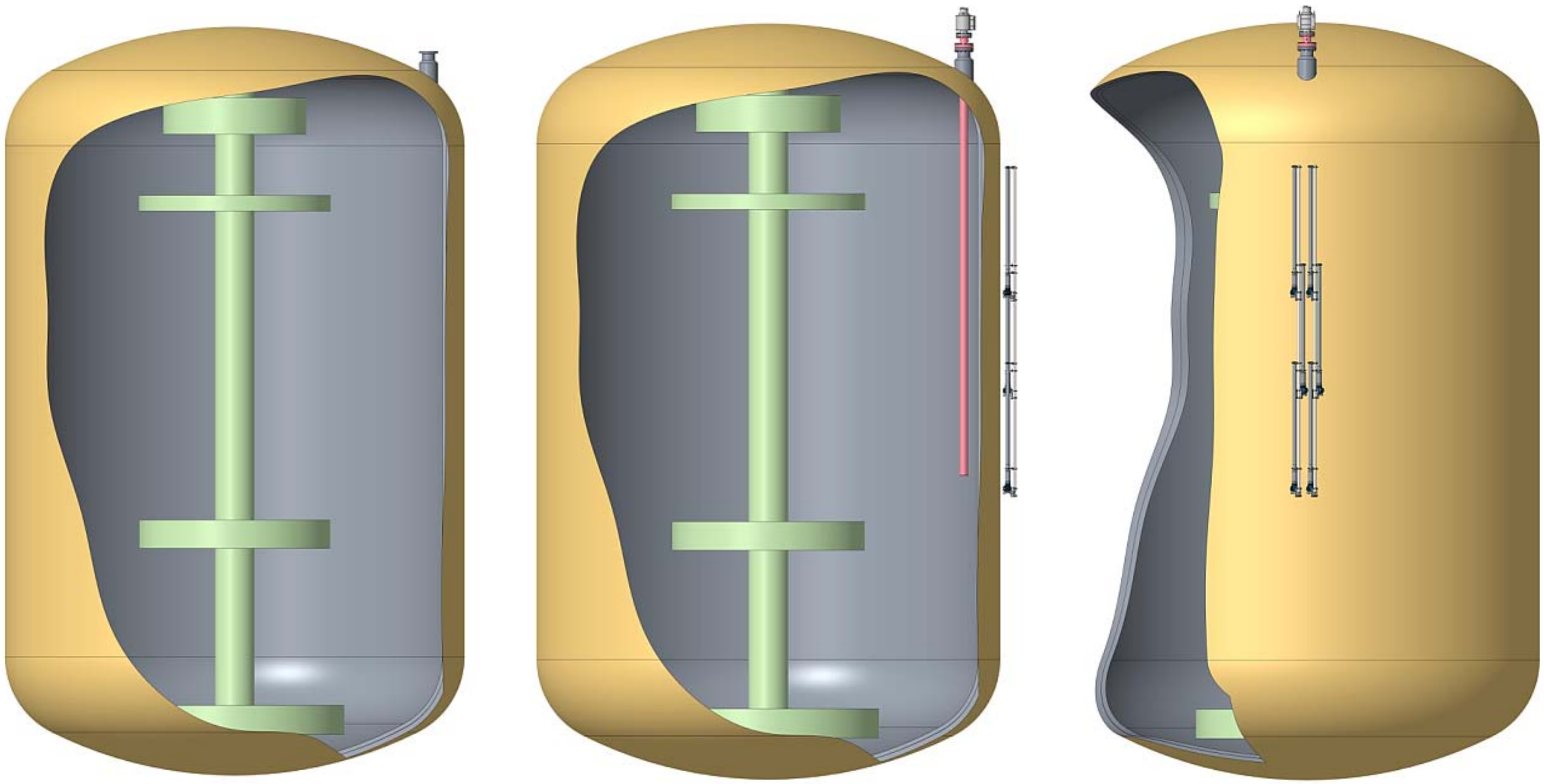
# PTA – Oxidation Reactor / Devices + Solution





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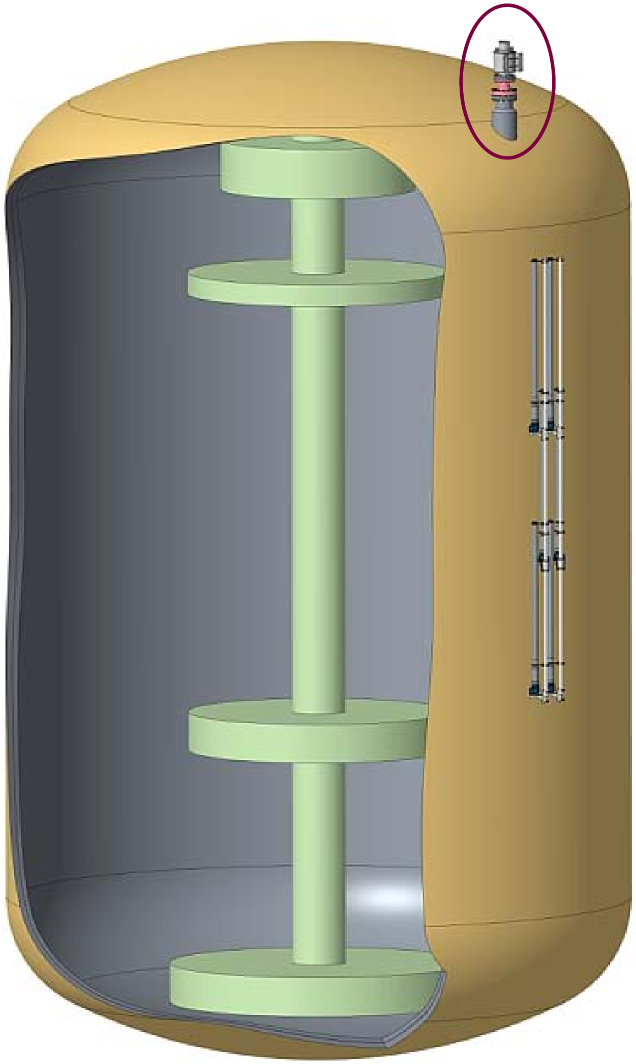
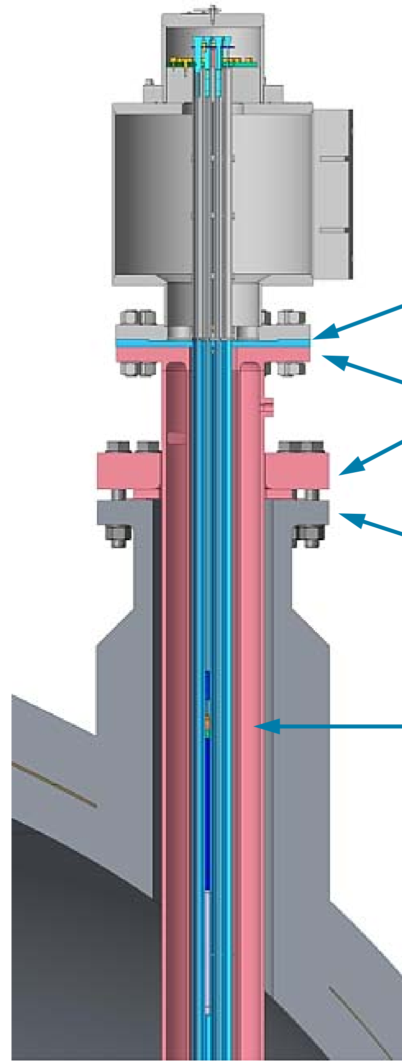
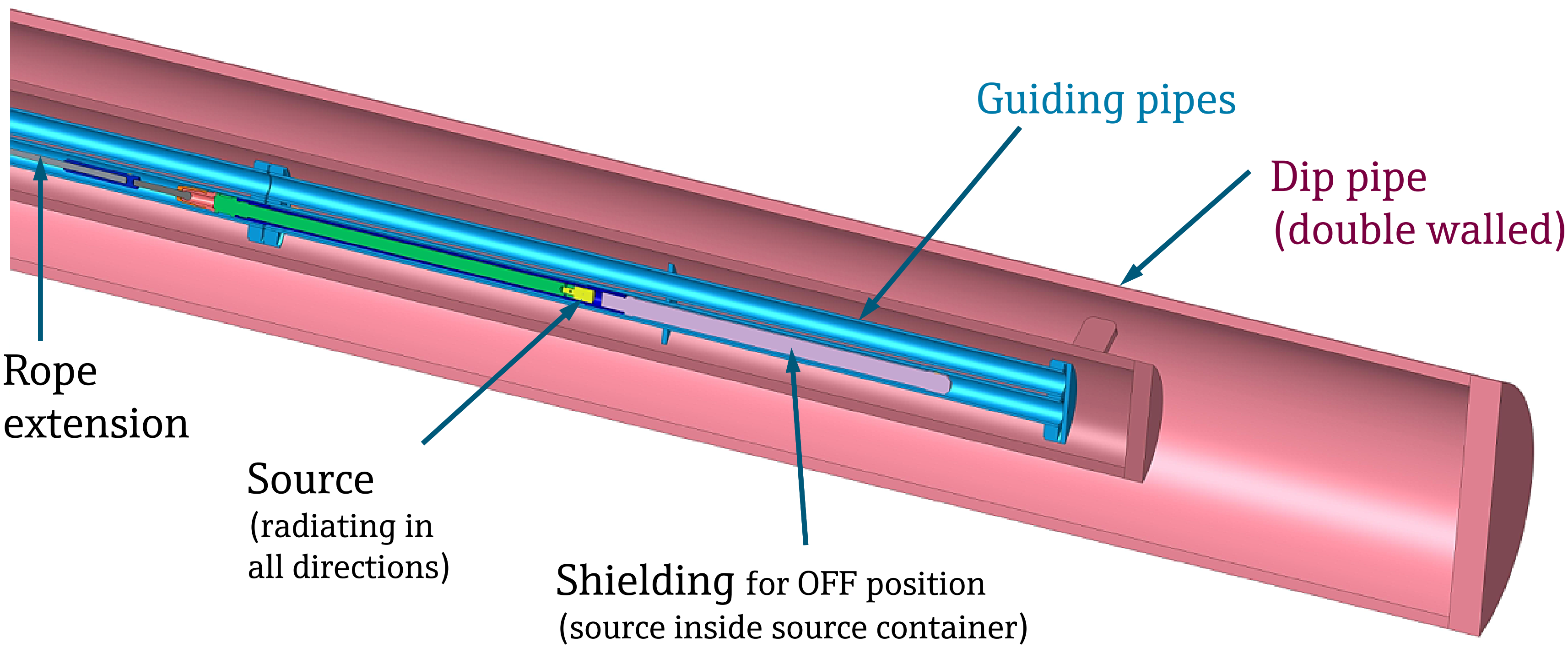
# PTA – Oxidation Reactor / Installation source container



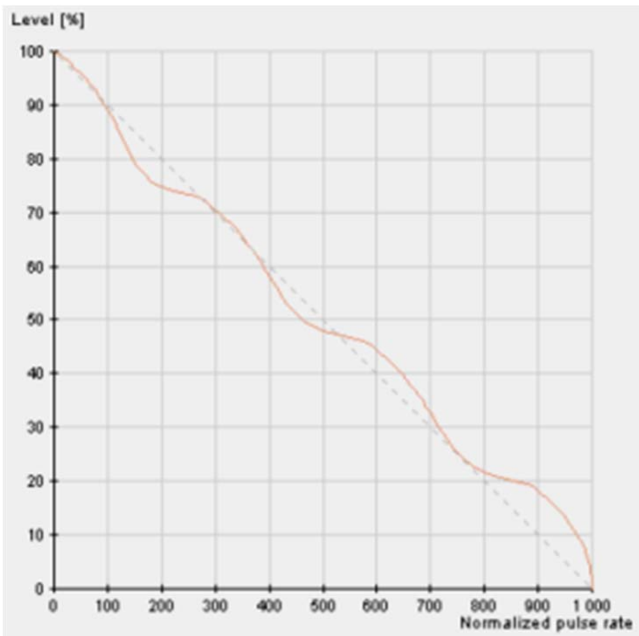


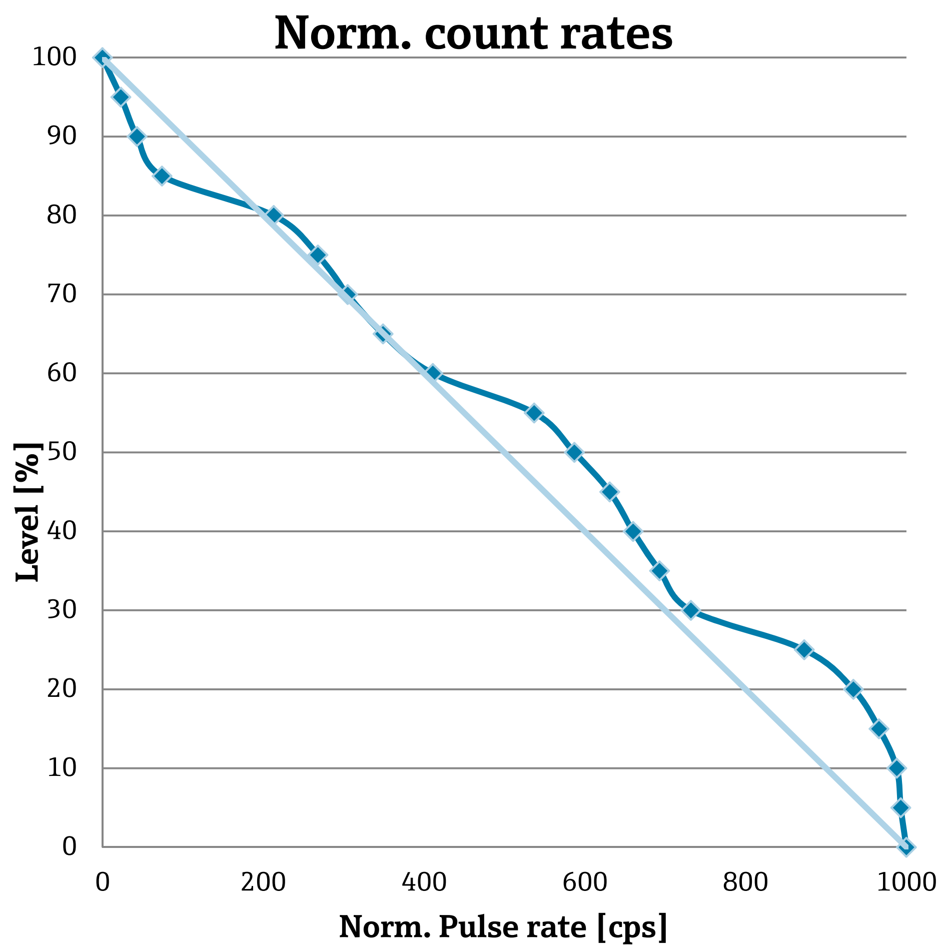
# PTA – Oxidation Reactor / Position of source



# PTA – Oxidation Reactor / Linearization

Sized linearization:




Commissioning values:

Full cal. 1000 c/s

Empty cal. 37,950 c/s

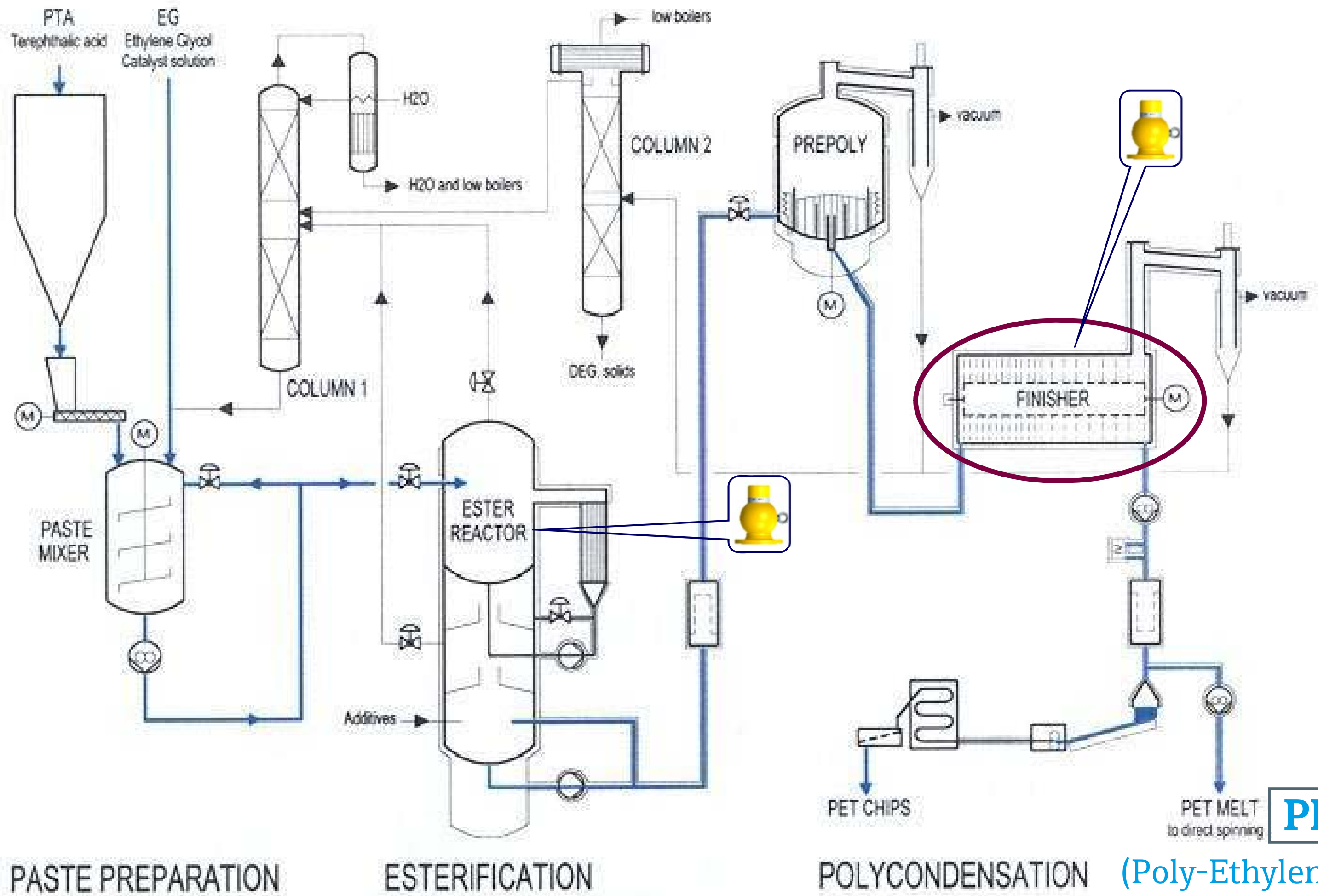
# PTA – Oxidation Reactor / Pictures


- Easy start-up
- High reliability
- All wetted parts made from SS316L
- Perfect engineering support


Both detectors
with water cooling jacket

# PET Polyethylene Terephthalate – Process

PTA (M)EG PTA (Purified Terephthalic Acid) MEG (Mono Ethylene Glycol)




PET (Poly-Ethylene Terephthalate)

# PET – Finisher

## Challenges:

Level measurement in the finisher at the inlet and outlet.

Level at the inlet and outlet are related to the viscosity of the product.

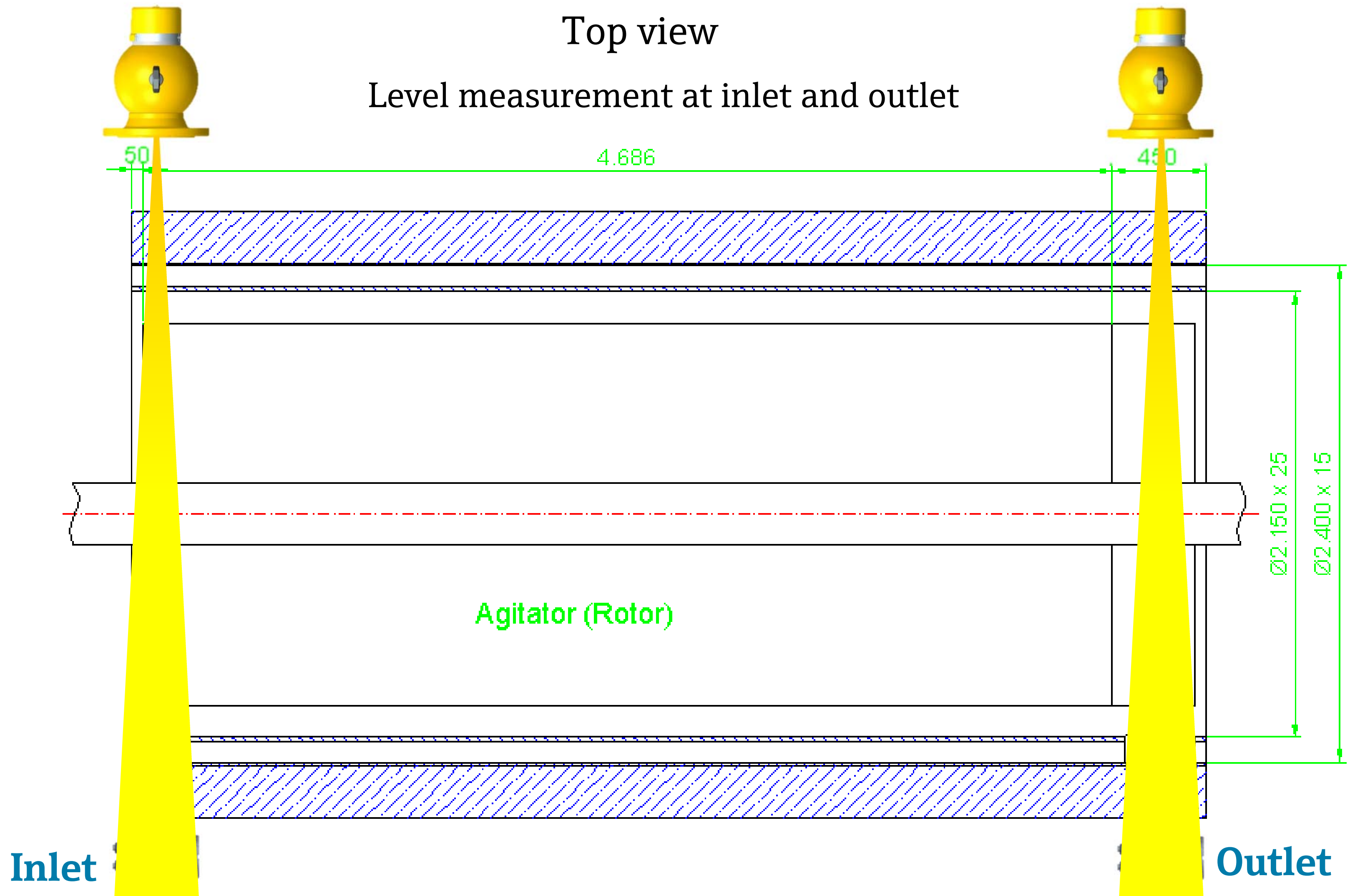
- Rotating installation inside
- No flat surface due to the high viscosity of the medium.



# PET – Finisher

Top view

Level measurement at inlet and outlet

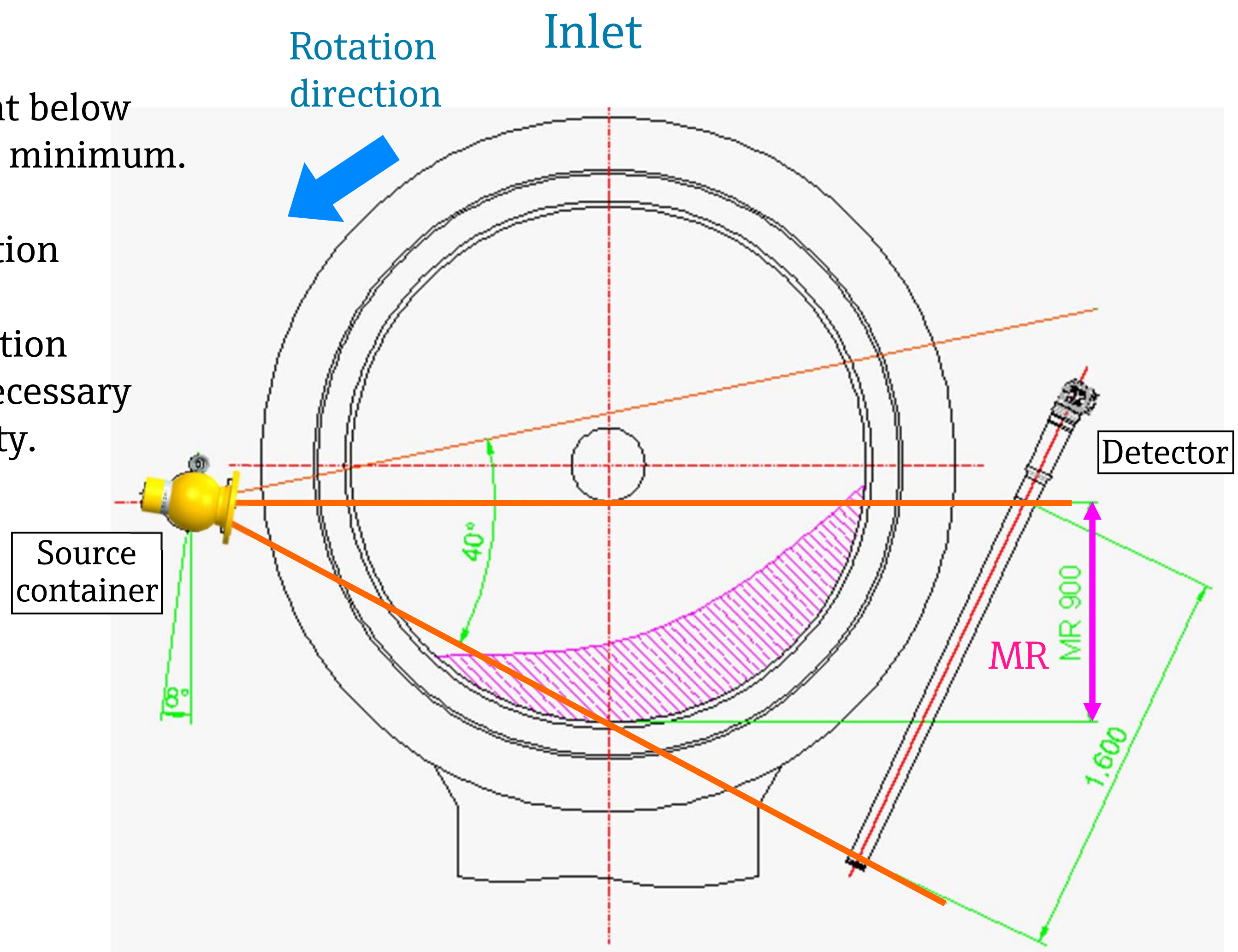


# PET – Finisher / Solution with rotation direction

**Solution:**

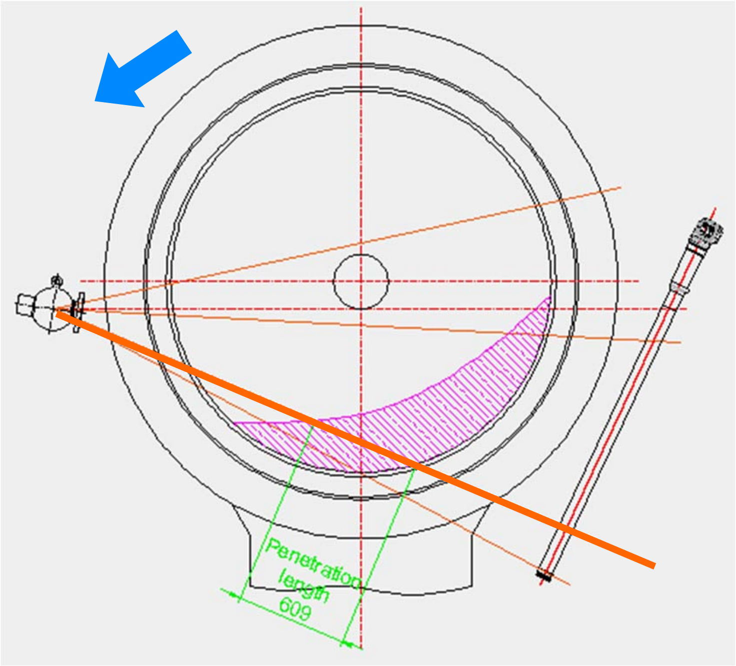
Level measurement below the shaft up to the minimum.

The rotation direction in combination with the configuration of the devices is necessary for the functionality.



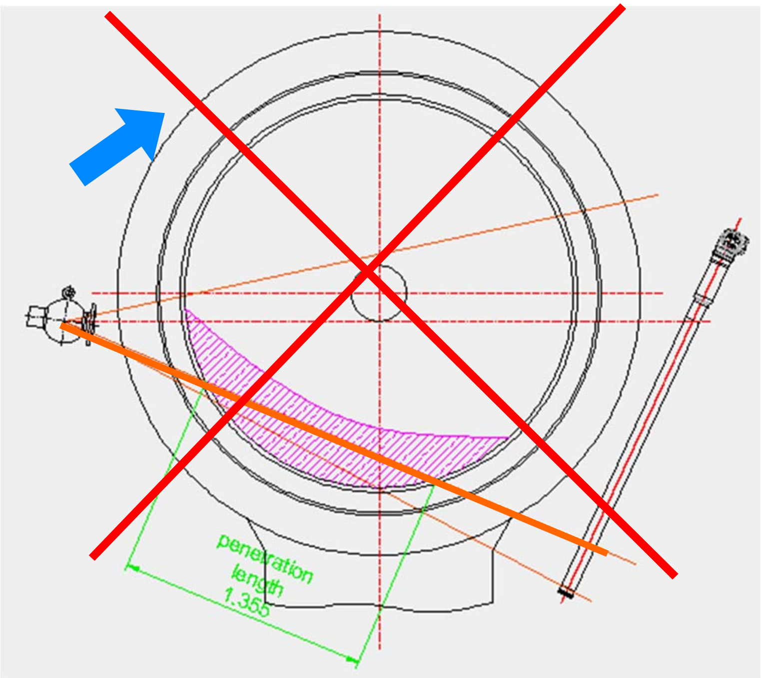
# PET – Finisher

Correct configuration




For the functionality
the correct rotation direction
in combination with the
configuration of the devices
is absolutely necessary

Wrong configuration




Complete absorption
with already 50% level.

# Summary



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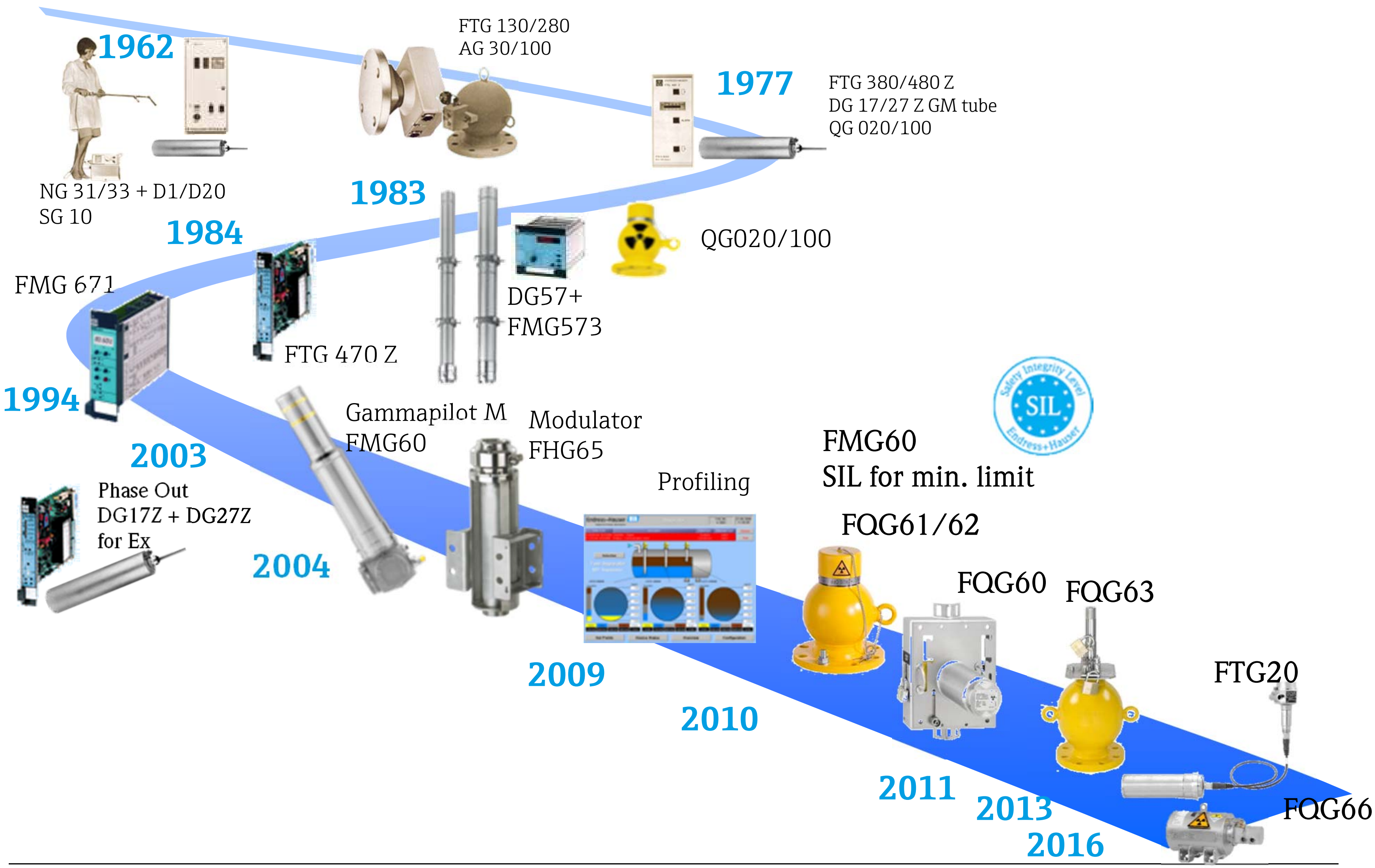
# Over 50 years of experience!



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# Products which fit your needs!

## Source

With nipple or thread

FSG 60 (Cs137)

FSG 61 (Co60)

Different activities

## Source container

Higher shielding capability

FQG 60

FQG 61

FQG 62 FQG 63

FQG 66

Multiplex - Source containers with extension(s) for source

## Detector / Transmitter

Gammapilot FTG 20

for point level

Separate transmitter

Gammapilot M FMG 60

Multifunctional Compact Transmitter


## Accessories

Field housing FHX40

with display VU331

FieldCare

Operating tool

(FDT / DTM)

Mounting accessories:

FHG 60

For level / limit / interface

FHG 61/62

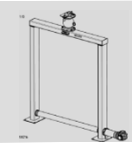
For density

Modulator

FHG 65

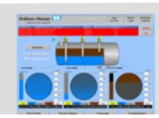
Frame

for bulk flow



Profile vision

for density profile measurement



Warning sign

916497-

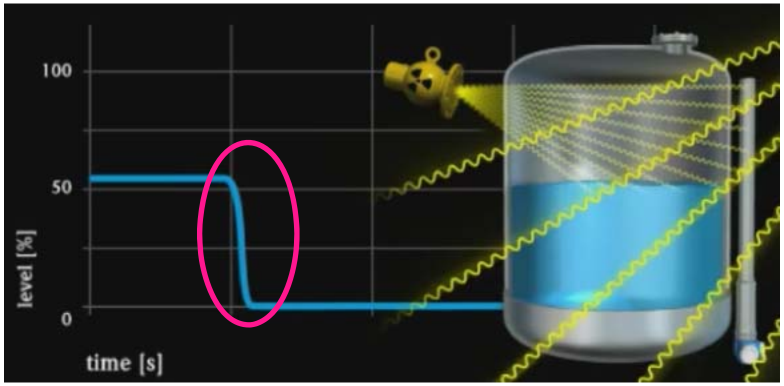
# Modulator – Suppression of external radiation

- First effective solution for suppression of external radiation from None Destructive Testing (NDT) or self radiation media
- **Modulator** is a turning absorber, producing a modulated signal. Detector separates the useful modulated signal from interference radiation

## Modulator

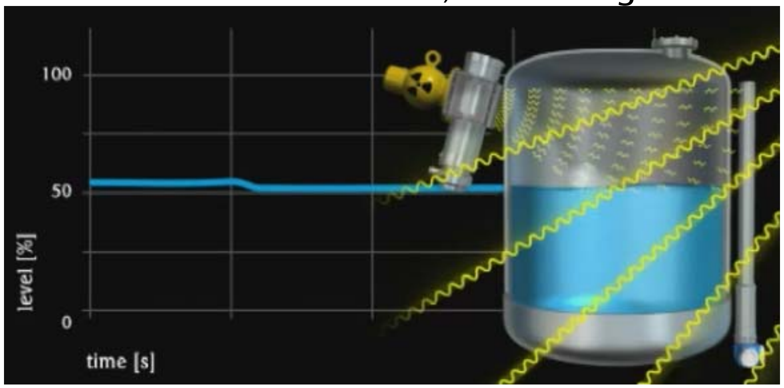

**Without Modulator**

Strong influence from  external radiation



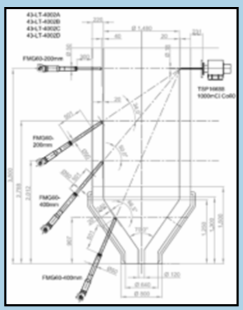

**With Modulator**

Reliable measurement, stable signal



# Strong support worldwide required!

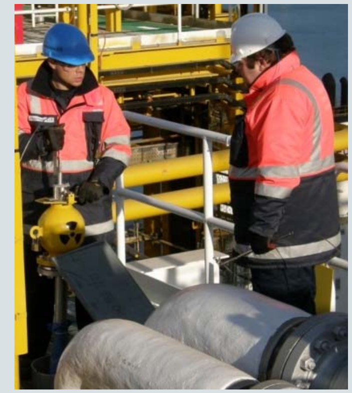
## Engineering



## Marketing

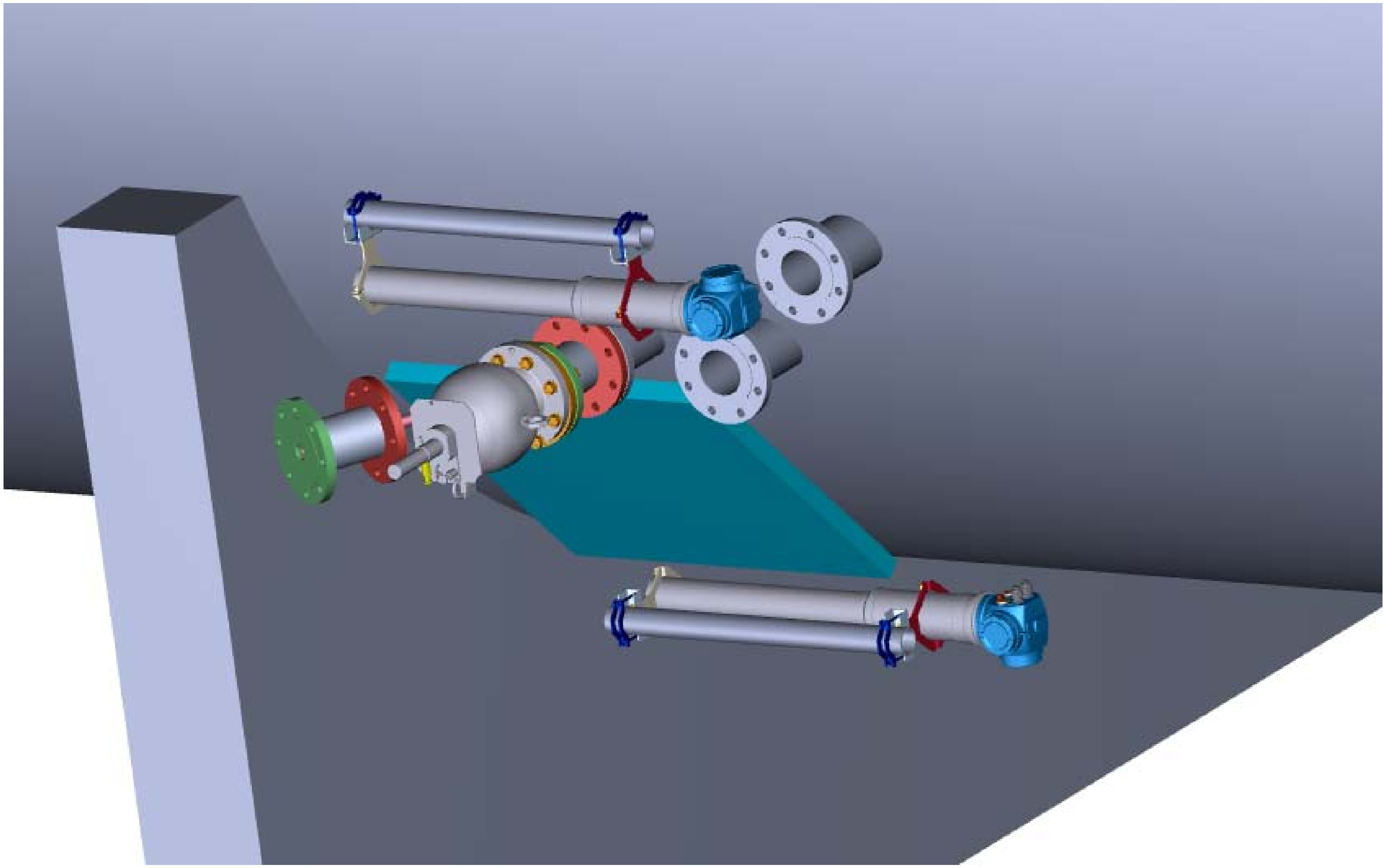

## Training Seminars


## On site advice

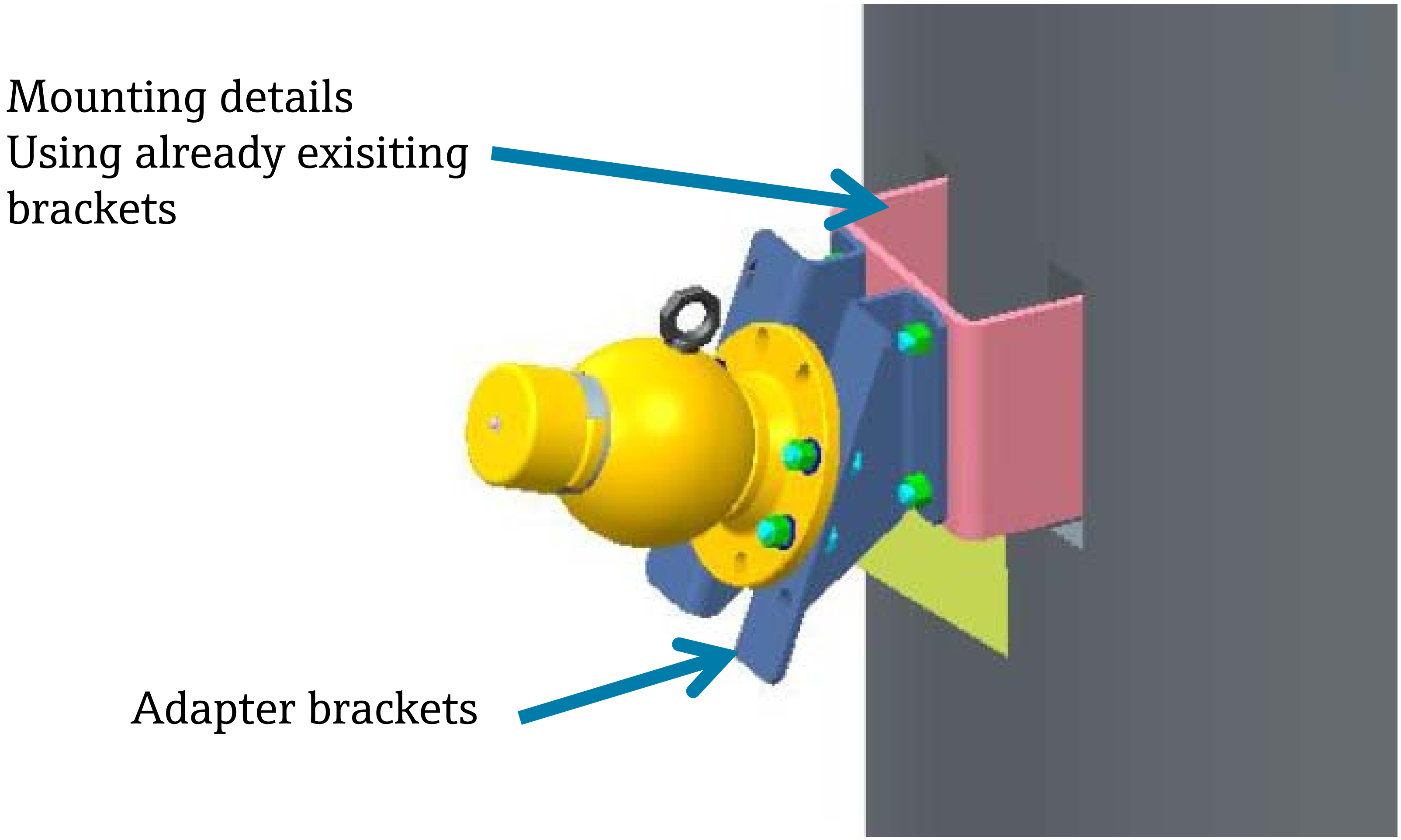


## Commissioning

# 3D engineering to realize mounting limits

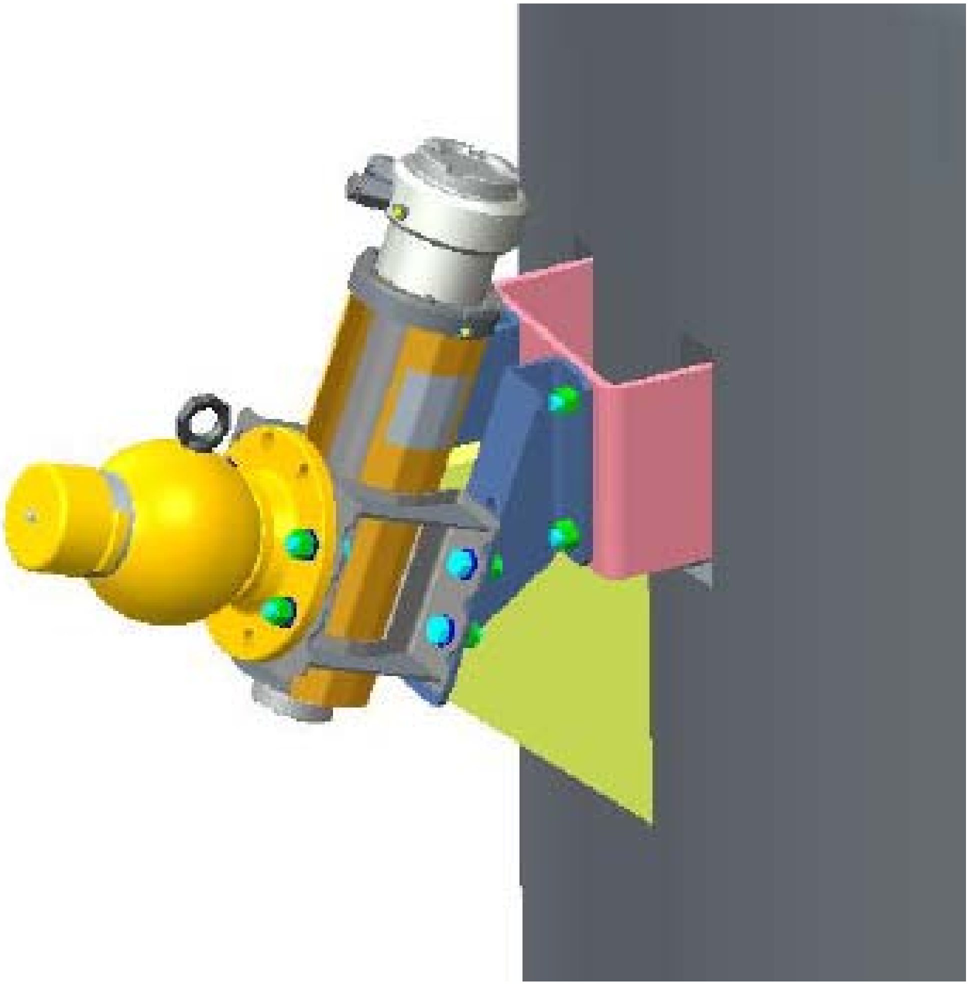


# 3D engineering to realize mounting limits



# 3D engineering to realize mounting limits

Flexible adapter bracket
To retrofit Modulator



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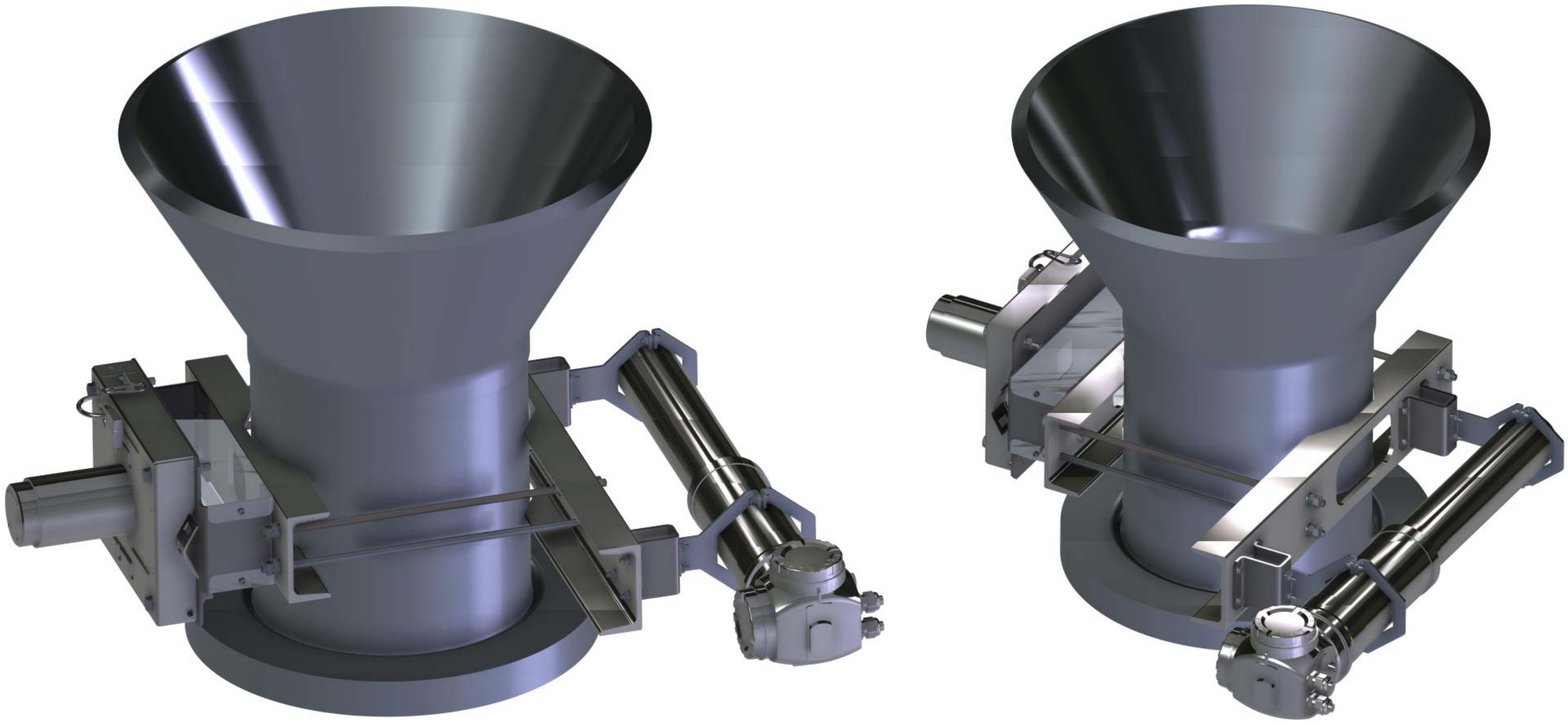
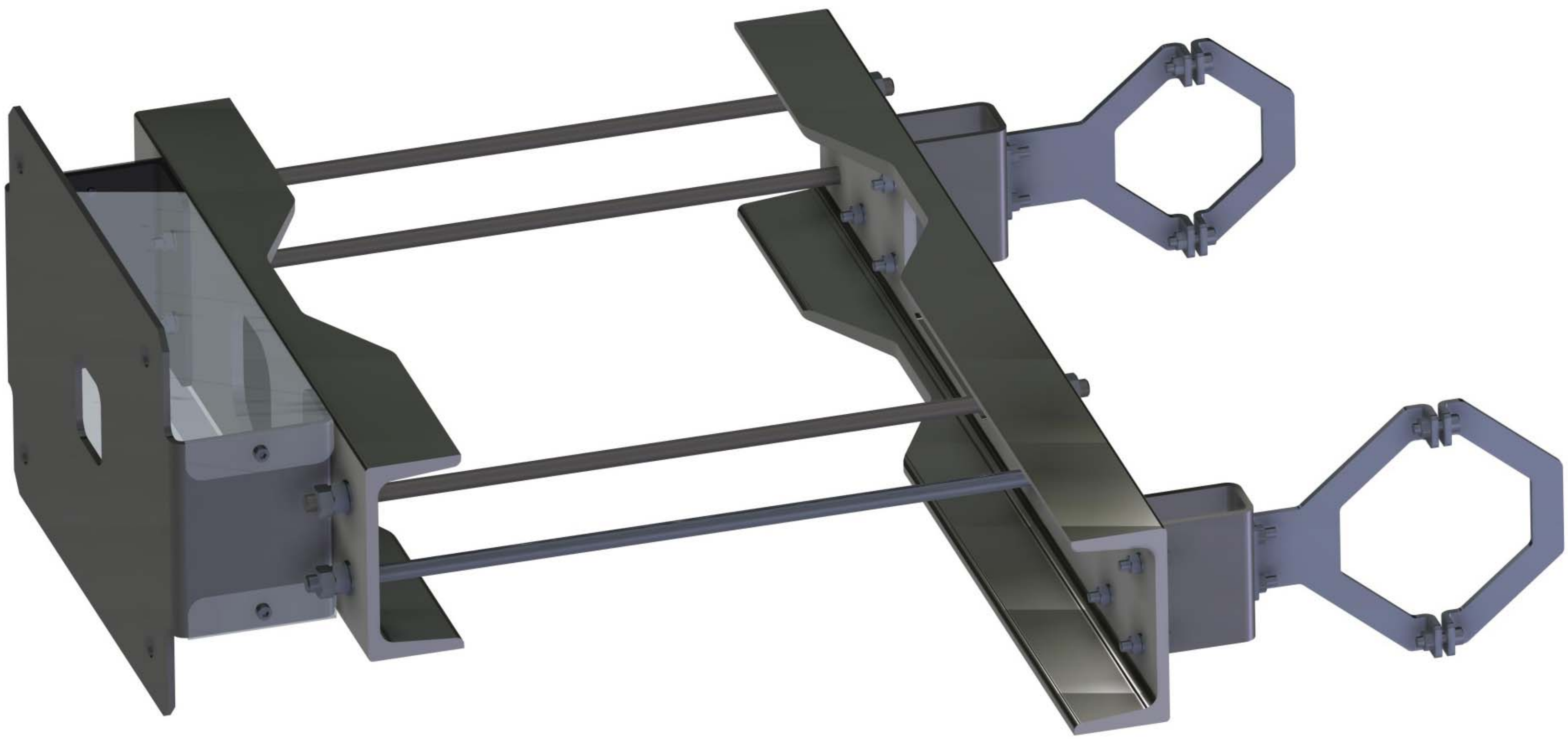


# 3D engineering to realize mounting limits



# Conclusion

- Gamma, if other physical principle fail
- Low radiation due to high sensitive detectors
- Reliable measurement for extreme applications
- Process Know How required
- 3D engineering to avoid surprises

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# Thank you very much for your attention