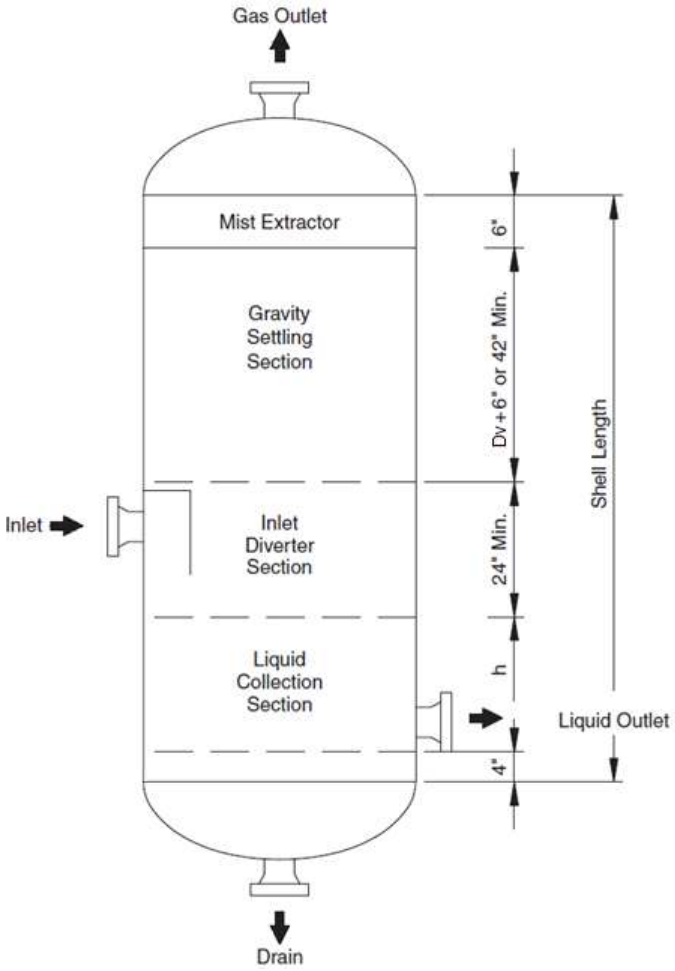
NTNU – Trondheim
Norwegian University of
Science and Technology

Production Technology

Field Processing and Systems

Postdoc Mariana Díaz
01 /29/2019

Vertical gas-liquid separator



Vapor Capacity

Calculate V_t

Calculate A_v

Calculate D_v

Operability Requirements

Adjust Lsem

Adjust Retention time

For a **t** and **Dv** calculate h

Liquid Capacity

Calculate L_{sem}

Calculate L_{sem}/D_v

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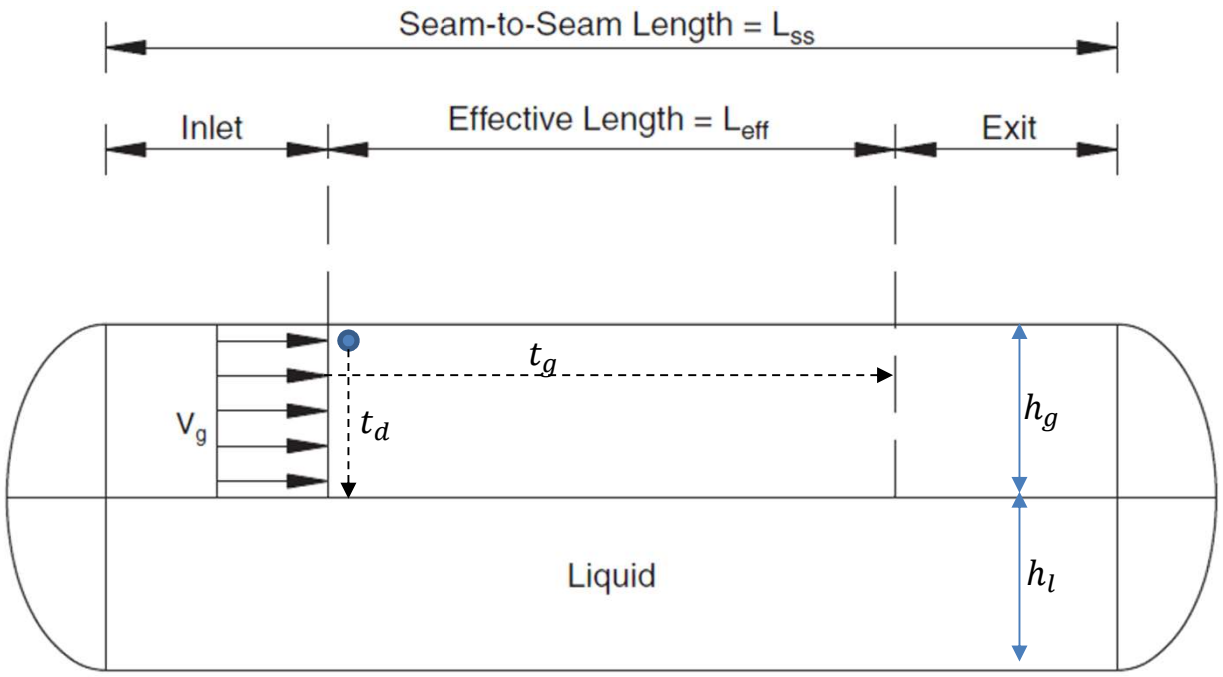
Horizontal separator sizing



$$t_d < t_g$$

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Horizontal separator sizing

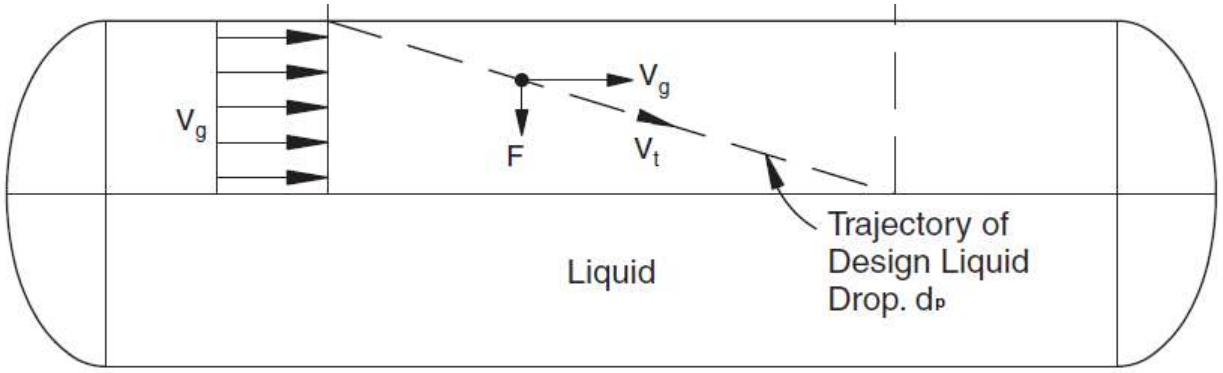
Gas Capacity → $\frac{L_{eff} A_g}{h_g} > \frac{Q_g}{V_t}$

Liquid Capacity → $t\, Q_l = L_{eff} A_l$

Half Full

$L_{eff} D_v > \frac{4}{\pi} \frac{Q_g}{V_t}$

$L_{eff} D_v^2 = \frac{t\, Q_l 8}{\pi}$



Max($L_{ss}^{Gas} = L_{eff} + d$; $L_{ss}^{Liq} = \frac{4}{3} L_{eff}$)

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THREE PHASE SEPARATION

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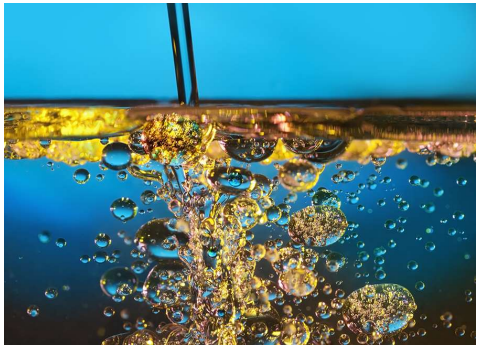
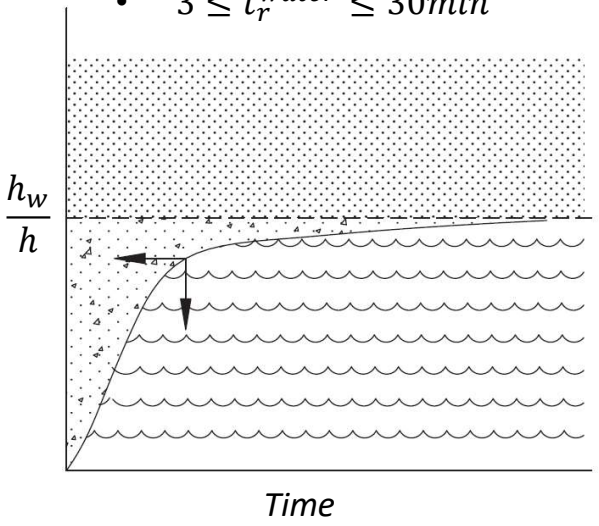
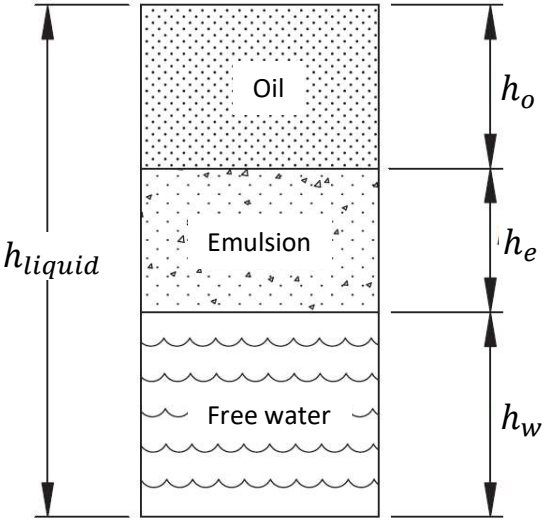
OIL-WATER SEPARATION

- Separation of two immiscible liquid phases



- Settling time
- $3 \leq t_r^{water} \leq 30min$





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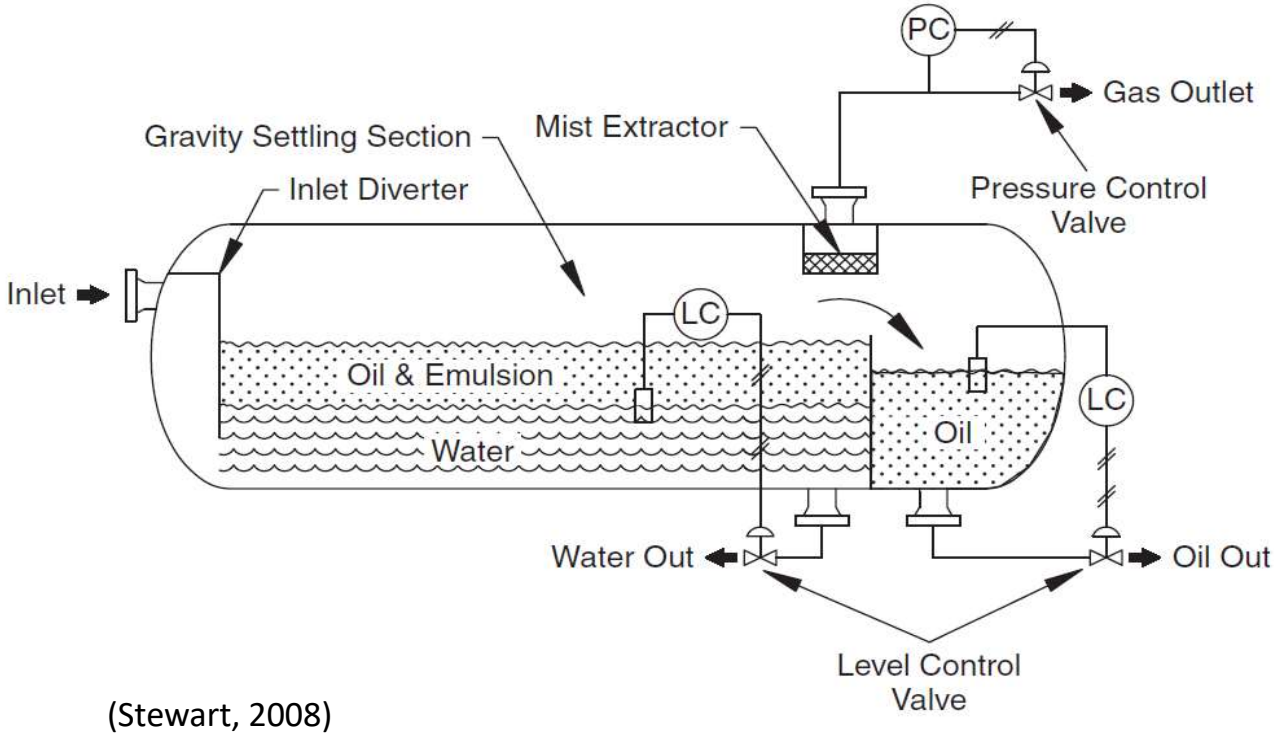
OIL-WATER SEPARATION



(Stewart, 2008)

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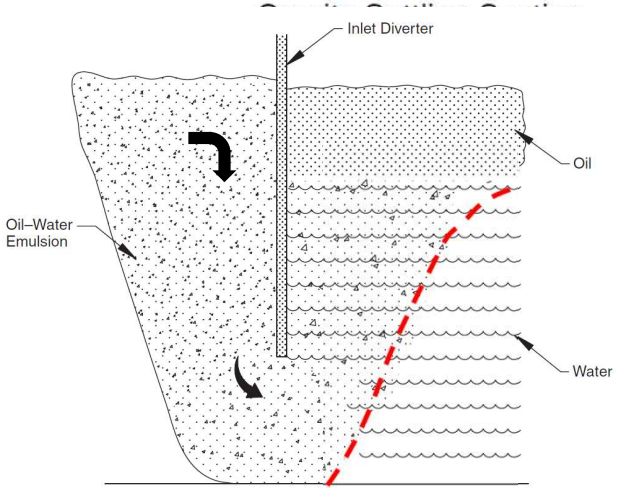
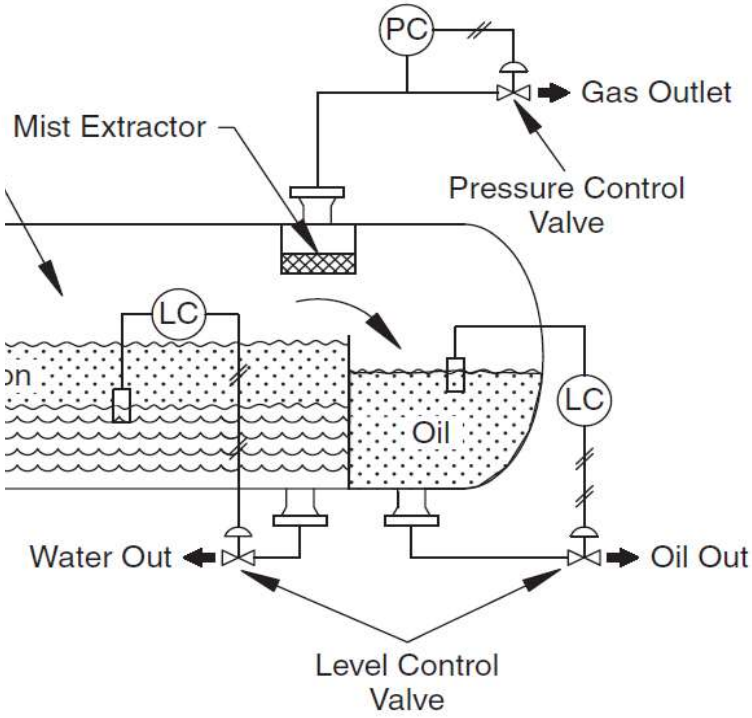
Water Washing



(Stewart, 2008)



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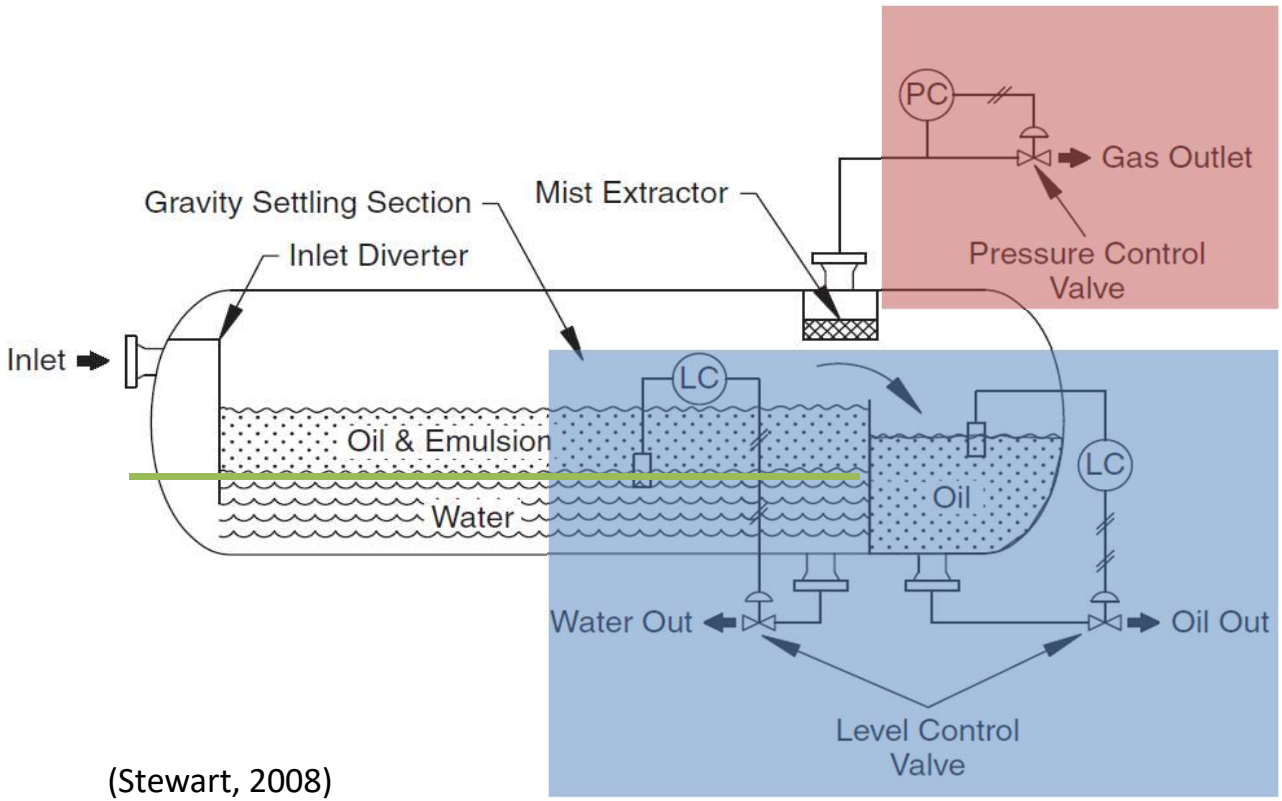
Control system



(Stewart, 2008)

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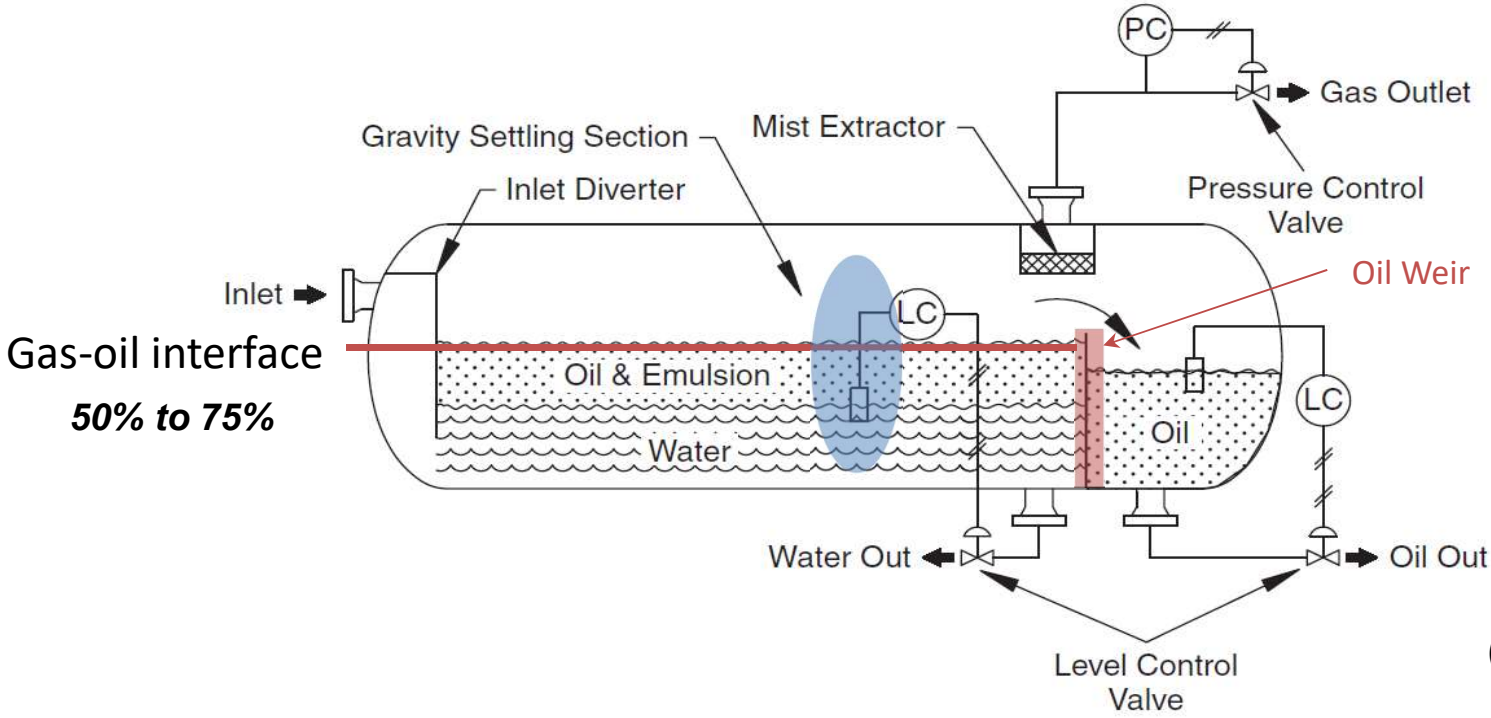
Control system

Interface control design



(Stewart, 2008)

- Most effective with **high oil flow** rates and/or **large density differences**.

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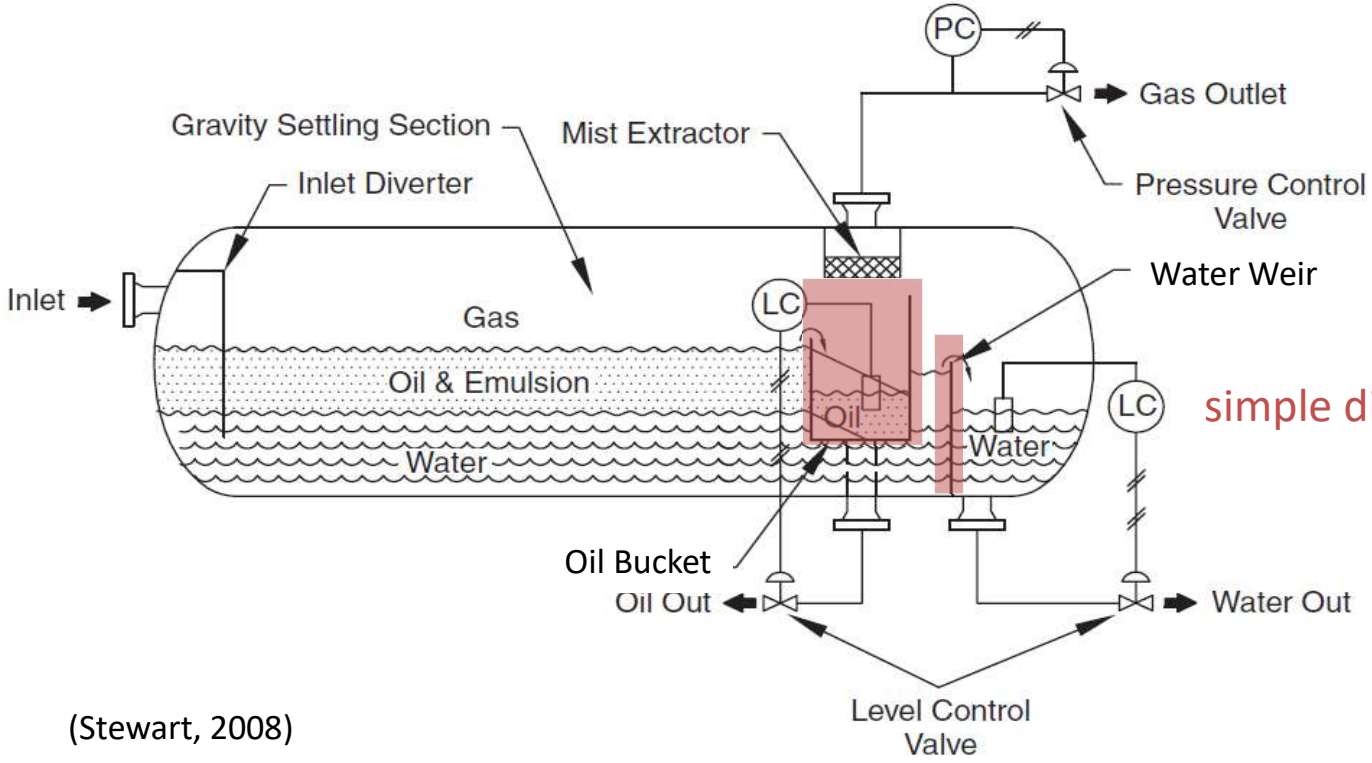
Horizontal configurations

bucket and weir configuration



simple displacer float

(Stewart, 2008)

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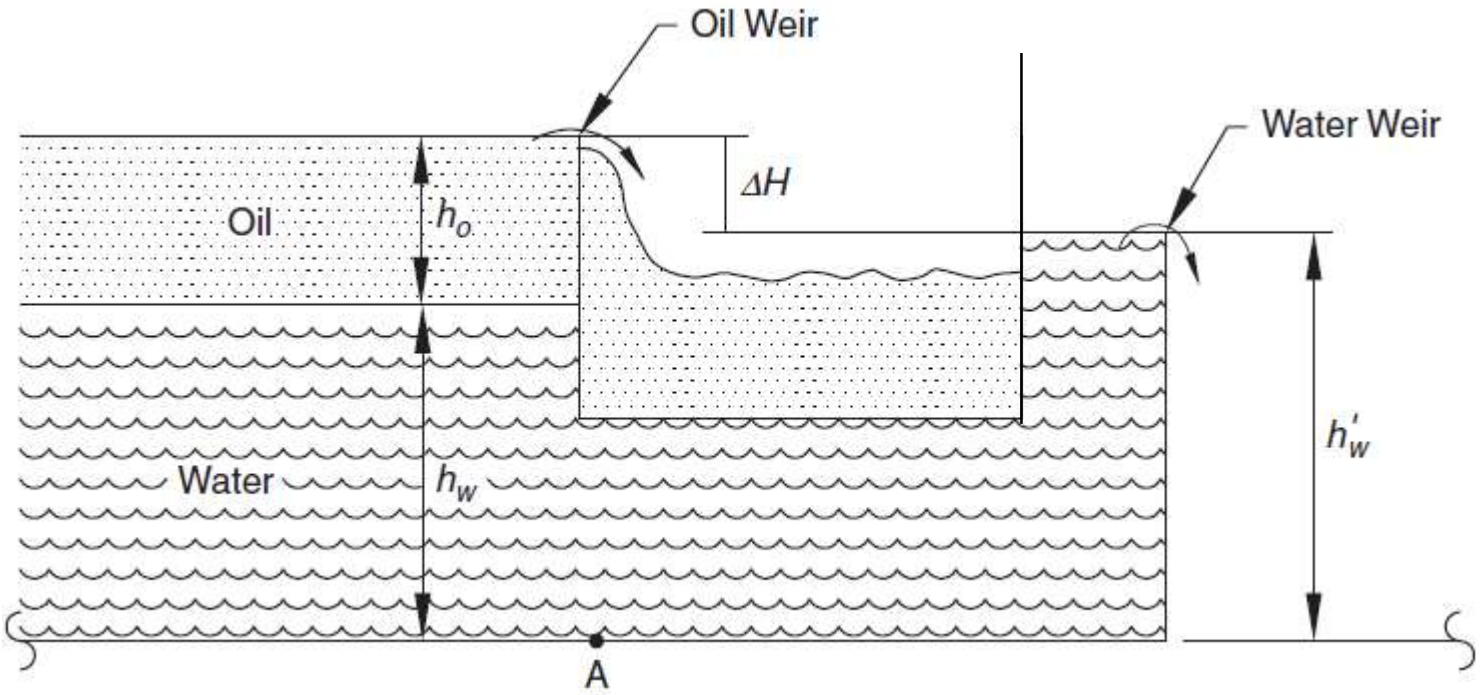
Horizontal configurations

bucket and weir configuration



(Stewart, 2008)

$$\Delta H = h_O \left[1 - \left(\frac{\rho_o}{\rho_w}\right)\right]$$

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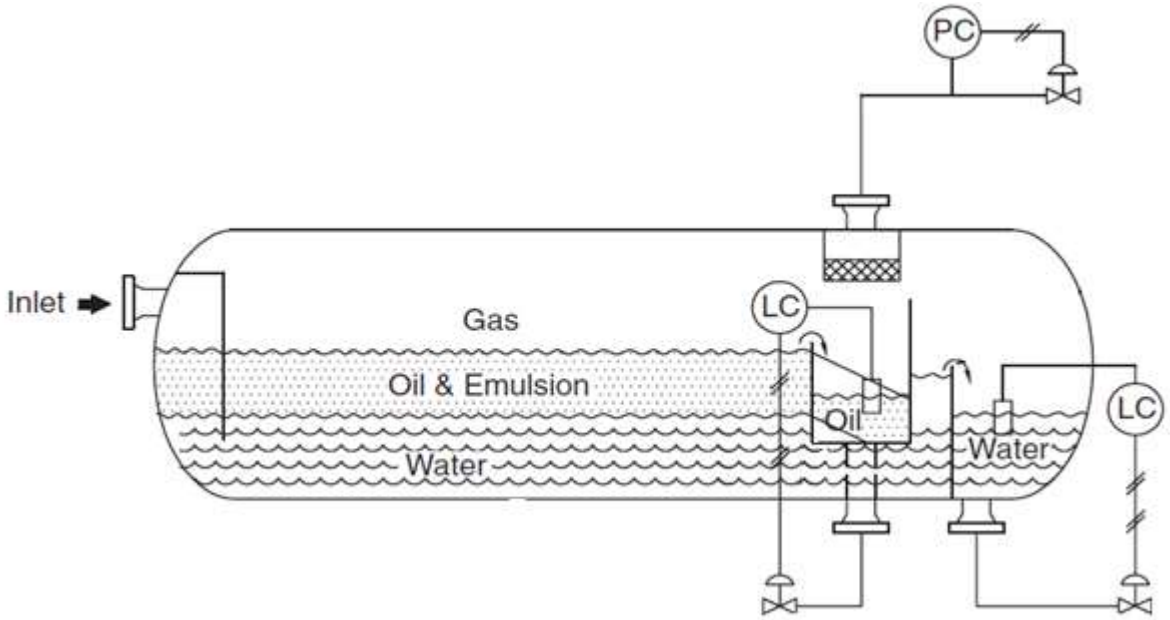
Horizontal configurations

bucket and weir configuration



- Most effective with **high water-to-oil flow** rates and/or **small density differences**.
- **Heavy oil** applications
- Large amounts of **emulsion or paraffin**

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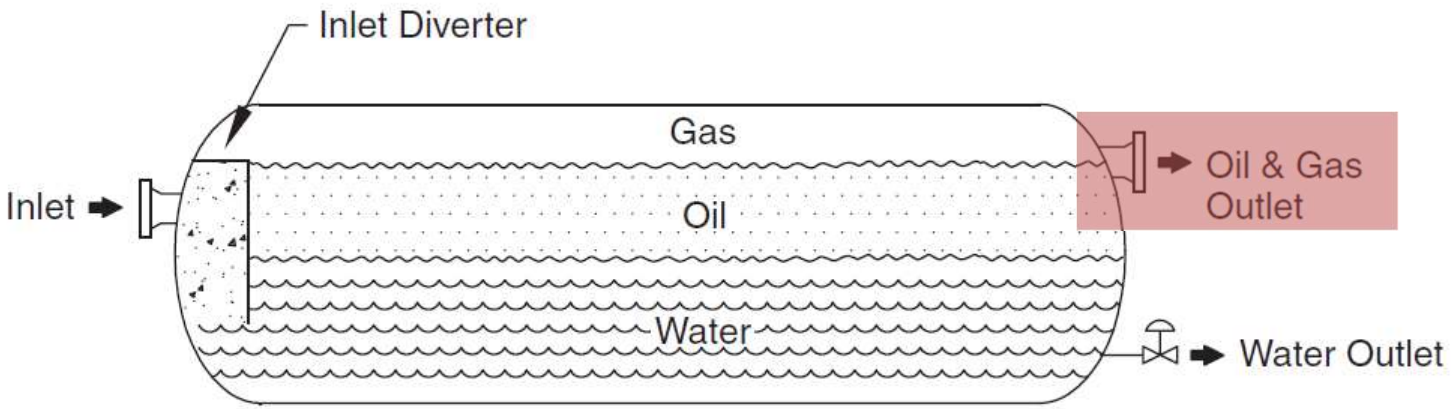
Horizontal configurations

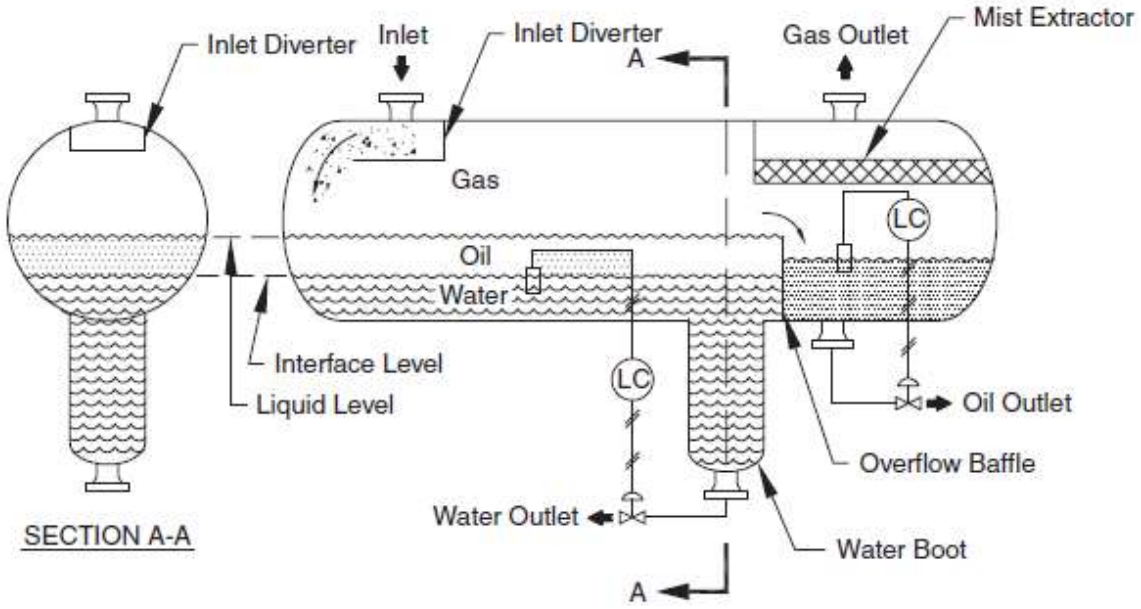
Free-Water Knockout (FWKO)



- Fluid stream with **little gas ratio**

Horizontal configurations

Liquid "Boot"



(Stewart, 2008)

- Water flow rate is very low relative to the oi flow rate

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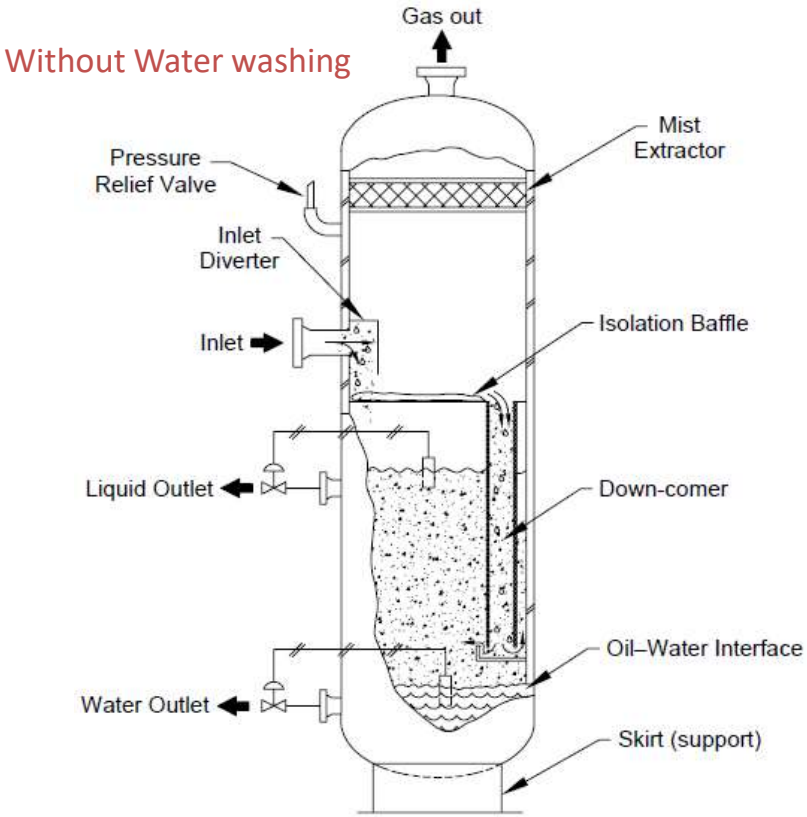
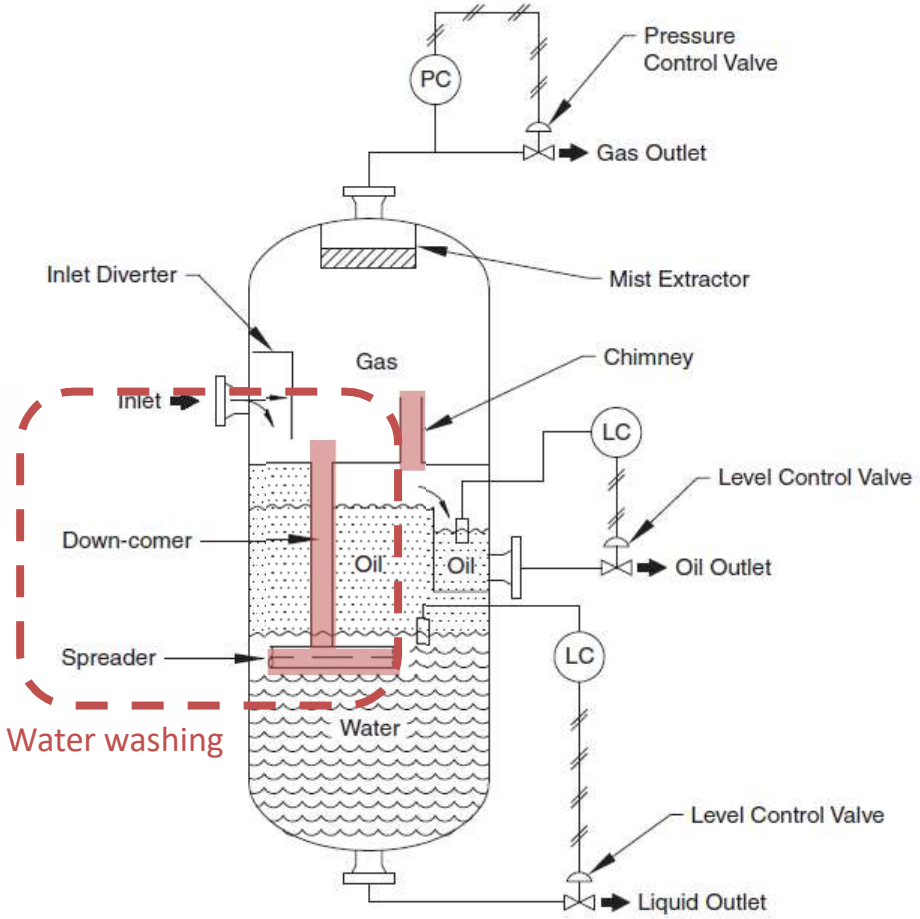
Vertical configurations





(Stewart, 2008)

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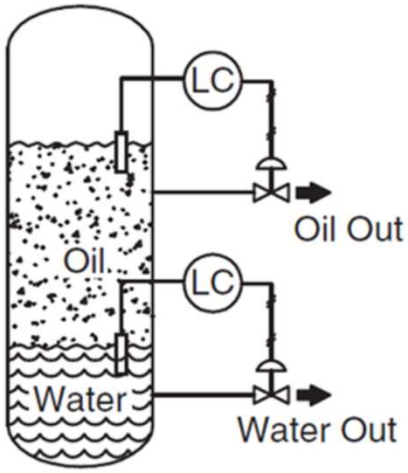
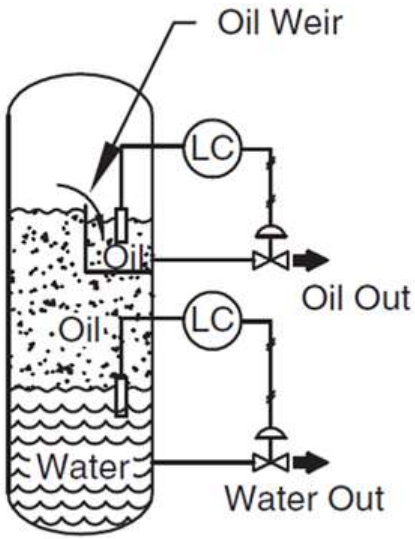
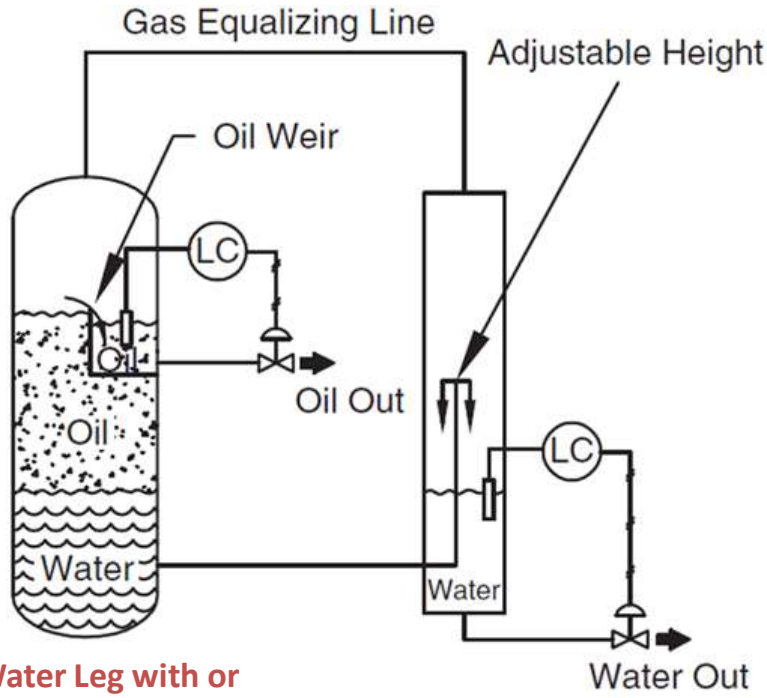
Vertical Liquid Control Strategies



Interface Level Control



Interface Level Control with oil chamber



Water Leg with or without Oil Chamber

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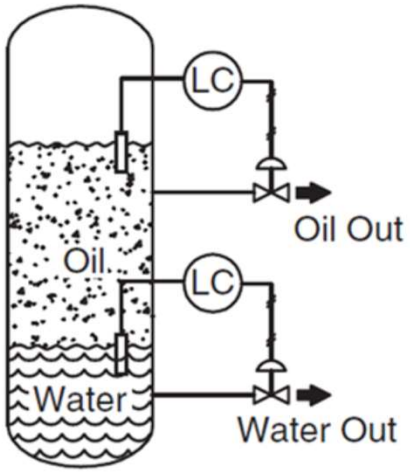
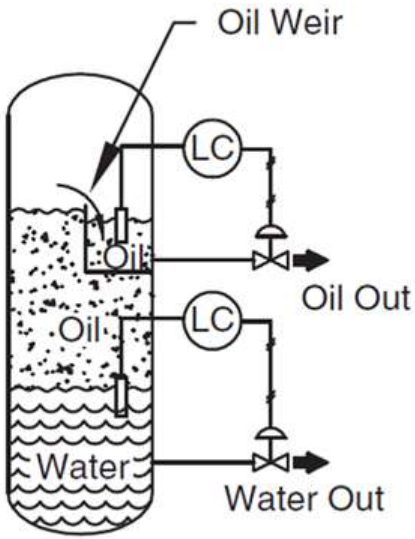
Vertical Liquid Control Strategies



Interface Level Control

- This type of systems is the **easiest to fabricate** because it does not include internal baffling or weirs.
- It is also **easier to handle sand** and solids production

Vertical Liquid Control Strategies



Interface Level Control with oil chamber

- Better water separation

But,

- The oil box takes up some vessel volume
- Fabrication should be customized
- Some solids could accumulate in the oil box
- It might be necessary a separate low-level shut down to prevent any fail on the oil-control-valve

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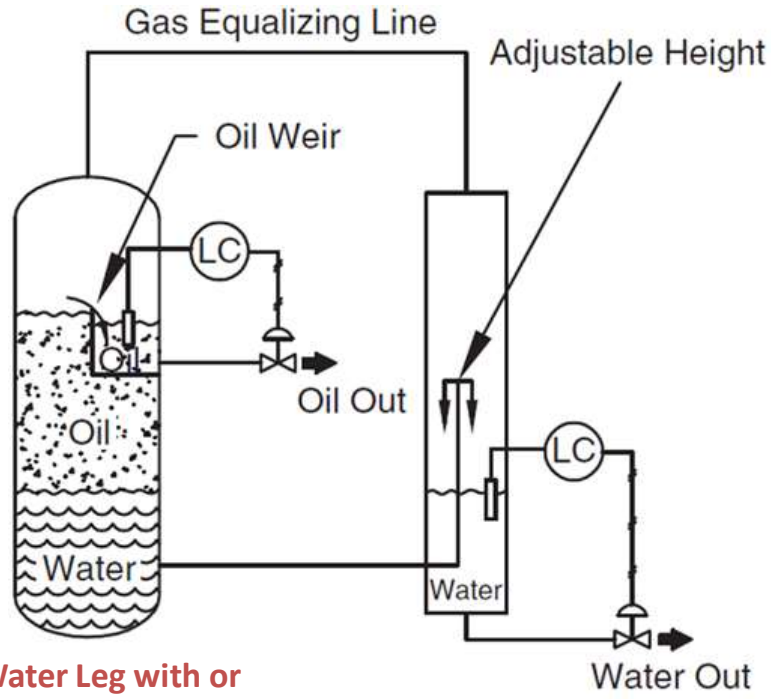
Vertical Liquid Control Strategies

Eliminates the need for the **interface float since**

But,

Required additional external piping and space



Water Leg with or without Oil Chamber

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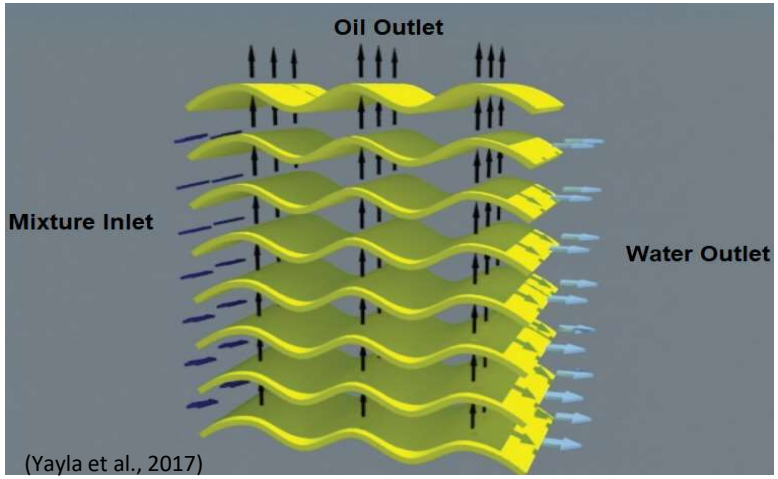
Internals

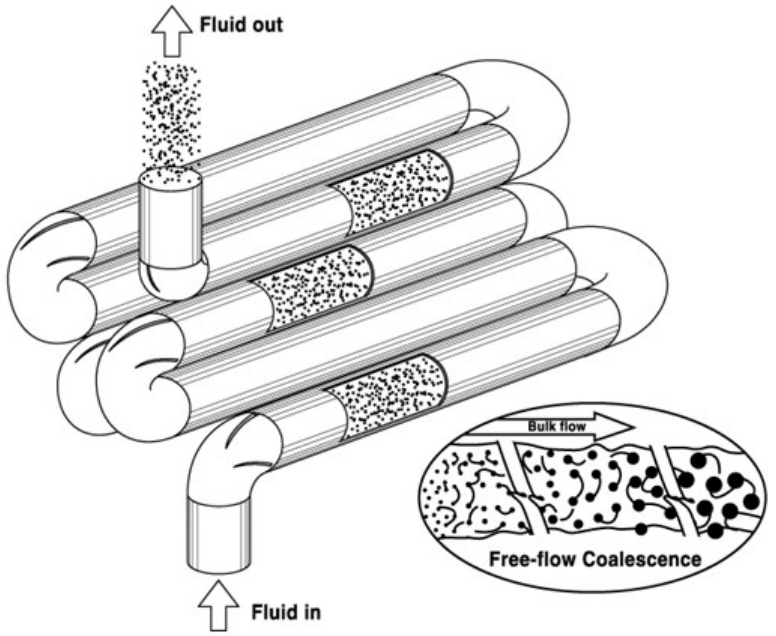
Coalescing Plates

(www.oreco.com)



(Yayla et al., 2017)

Turbulent Flow Coalescers



(Arnold, 1998)

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Horizontal vs Vertical

Horizontal

+

- Smaller than vertical tanks for a given gas-liquid flow rate
- Commonly used for high gas-liquid ratios and foaming crude
- The interface are is large in horizontal than verticals so it is easier for the gas com out of the liquid and reach the vapor space
- **Horizontal have greater interface areas, which improve phase equilibrium**
- **More economical for normal oil-water separation, specially when problems with emulsions and foam**

−

- They are not so good as vertical for solid handling
- Can have less liquid surge than vertical vessels
- surges in horizontal vessels could create internal waves, which could activate the high-level sensor prematurely
- Harder to clean

Vertical

+

- Commonly used for low to intermediate gas-liquid ratio.
- Suited for production containing solids and sediments
- Save space

−

- Less tendency for re-evaporation of liquid into the gas
- Wall might need to thicker due to the distribution of supports
- Some relief valves and controls systems may be difficult to service without special ladders and platforms

*High gas-liquid ration, a vertical separator is a scrubber

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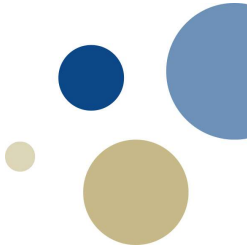


Guest lecture and lab visit

Håvard Slettahjell Skjefstad

NTNU
Norwegian University of Science and Technology

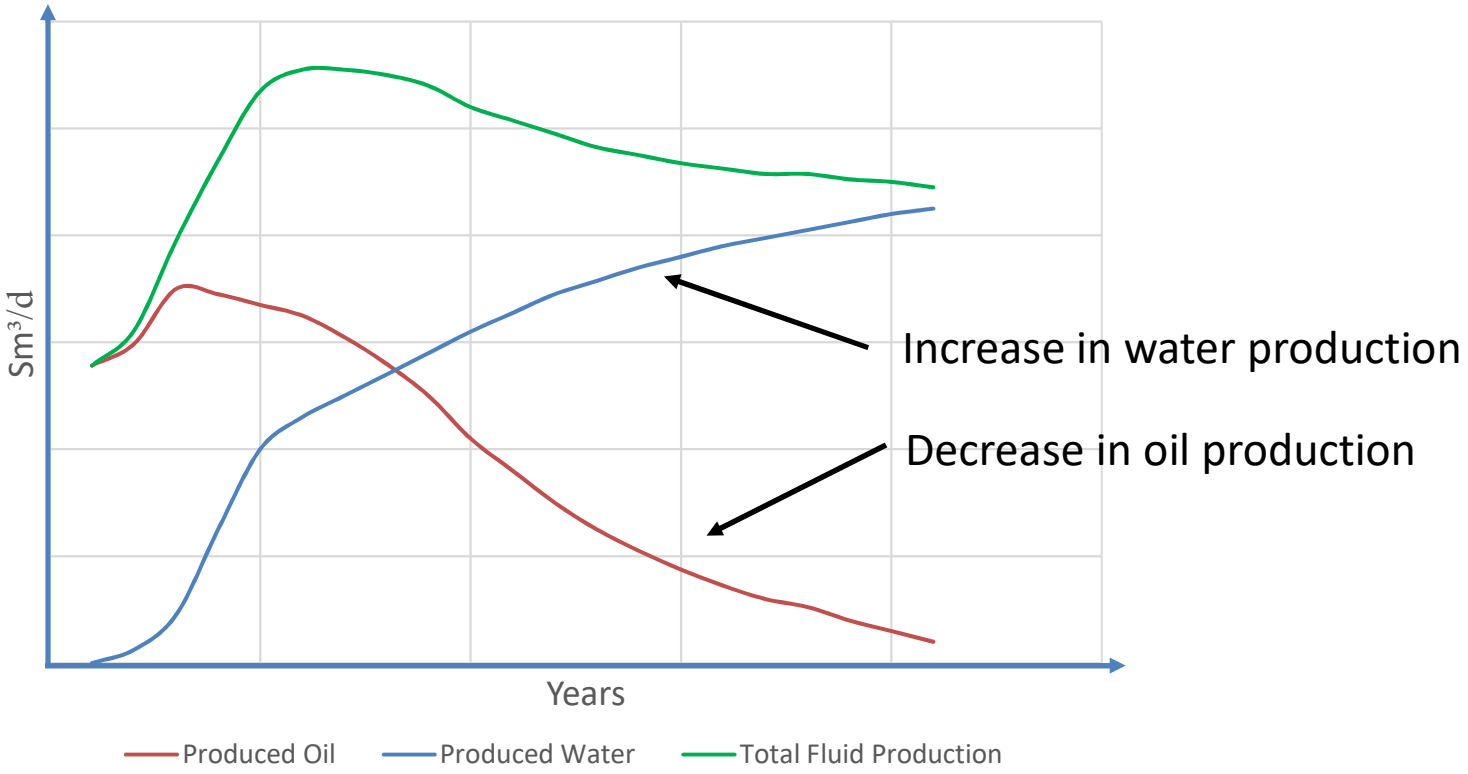
SUBPRO
SUBSEA PRODUCTION AND PROCESSING

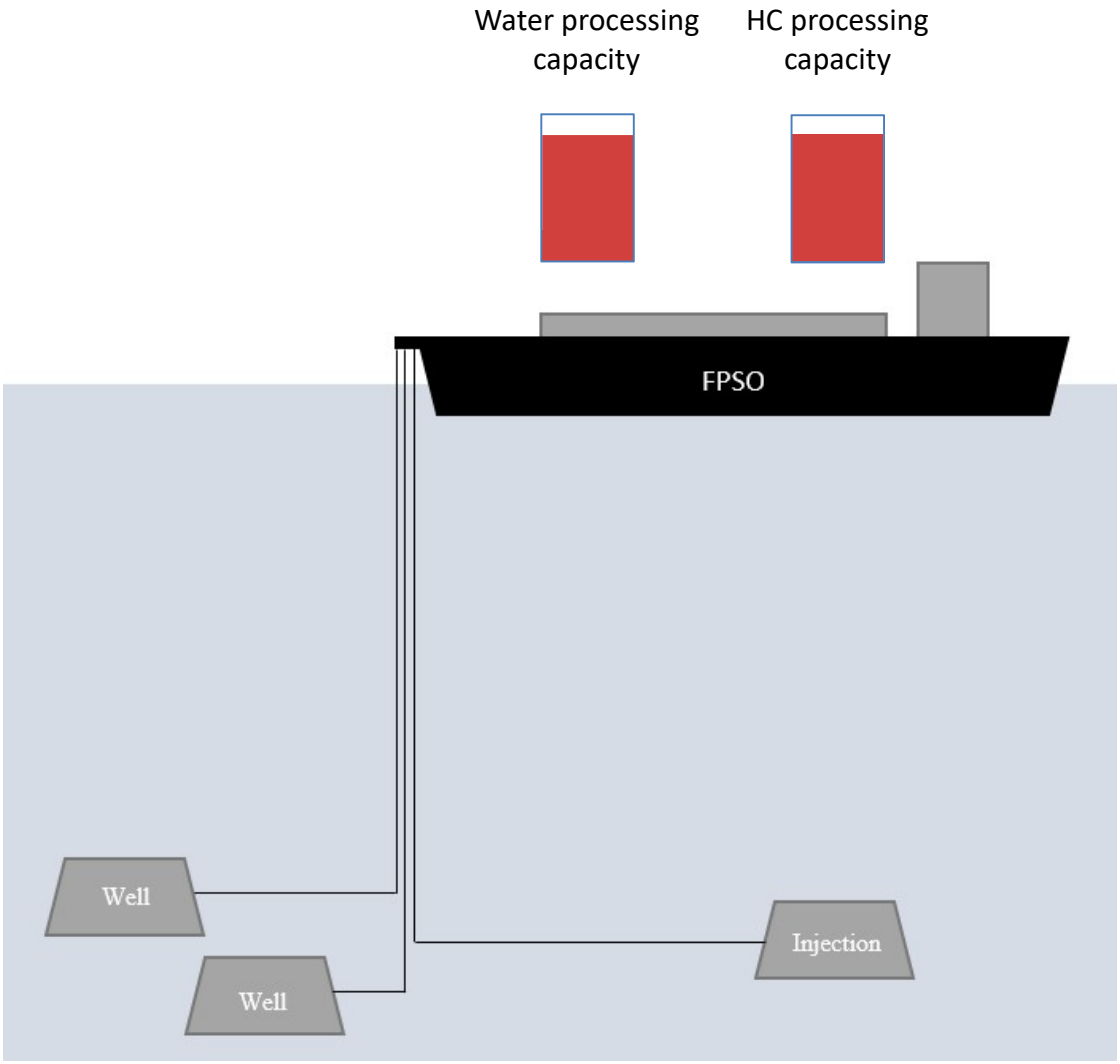
Subsea separation of produced water

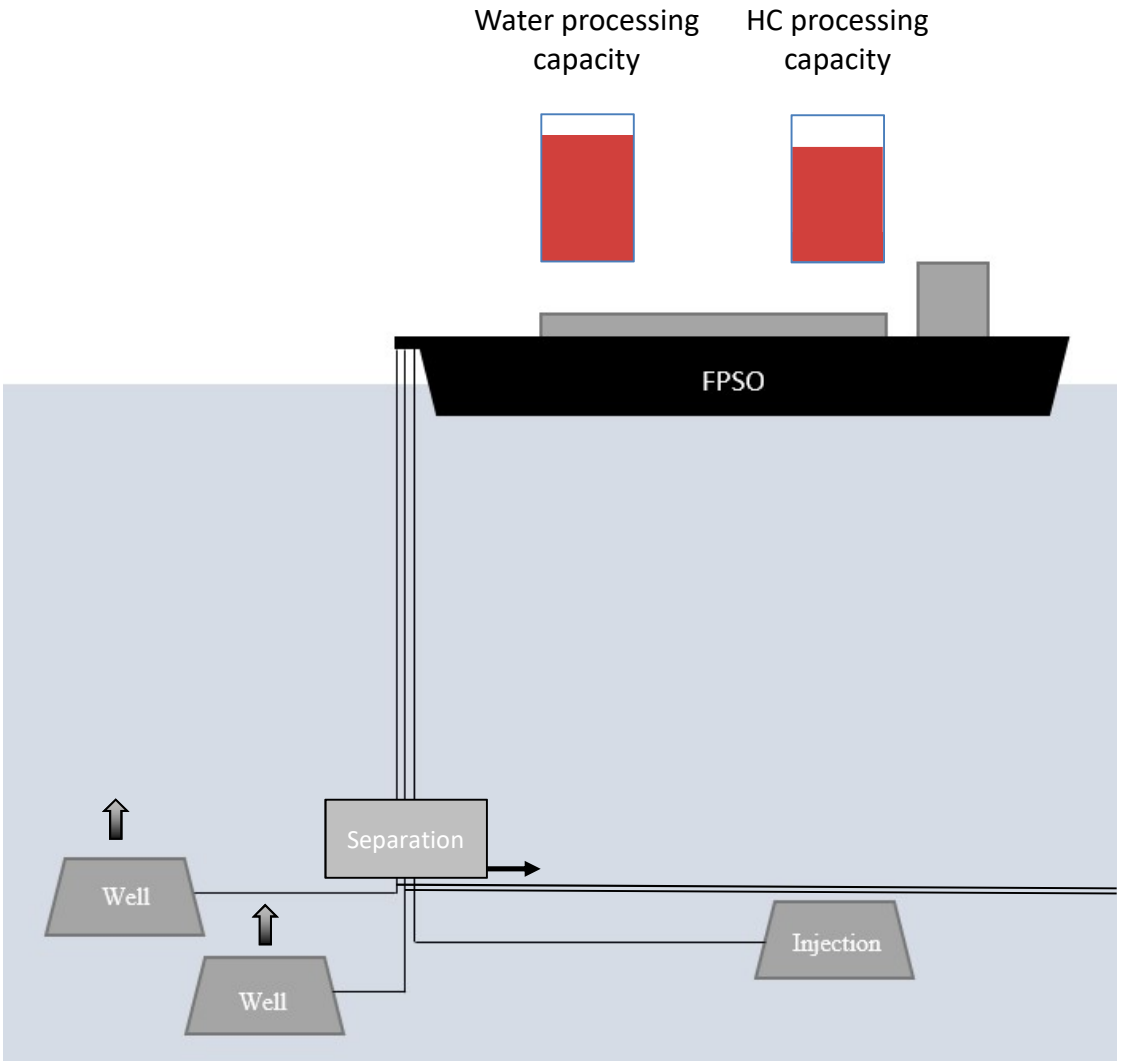
PhD candidate: Håvard S. Skjefstad

Date: 29.01.2019

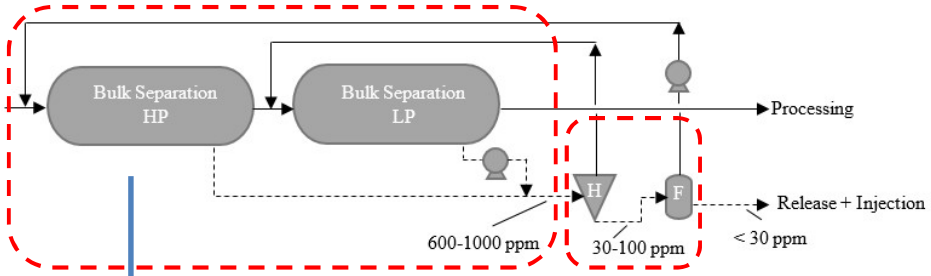
Example of a production profile

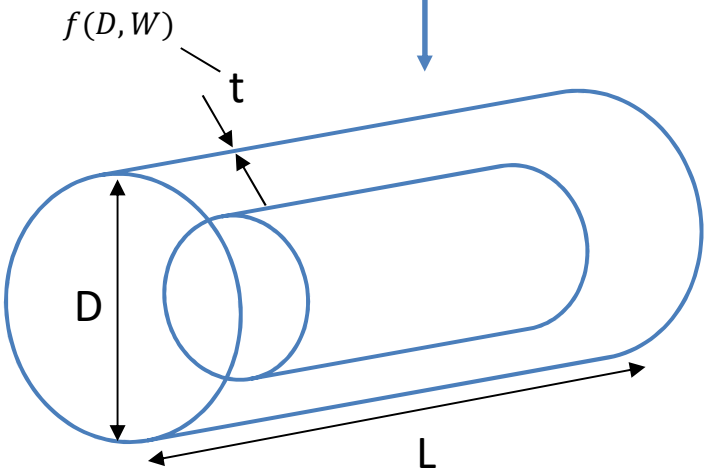



Water processing capacity
HC processing capacity
FPSO
Well
Well
Injection


Water processing capacity
HC processing capacity
FPSO
Separation
Well
Well
Injection

Topside processing:





Challenges

- Heavy constructions
- Expensive to install
- Difficult to retrieve/replace
- Expensive to manufacture

Required residence time

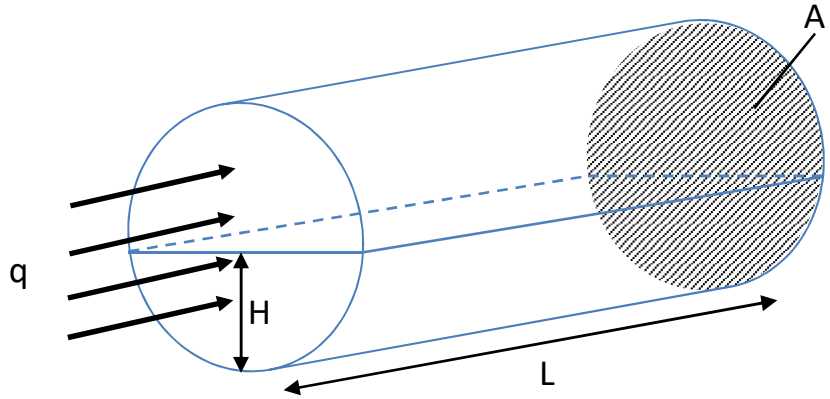
Stoke's law:

$$u = \frac{2(\rho_s - \rho_f) g r_s^2}{9\mu_f}$$

$$t_{res} = \frac{\mathrm{H}}{\mathrm{u}}$$

$$t_{res} = \frac{L}{U_m} = \frac{LA}{q} = \frac{V}{q}$$

$$V = \frac{Hq}{u} = \frac{9Hq\mu_f}{2(\rho_s - \rho_f) g r_s^2}$$



Decrease H:
Reduce vessel diameter

Decrease q:
Reduce total throughput (upstream removal of gas)

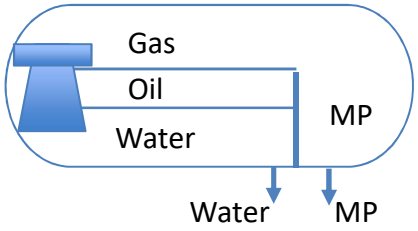
Increase g:
Introduce centrifugal acceleration

Increase r_s:
Include coalescence enhancing technologies

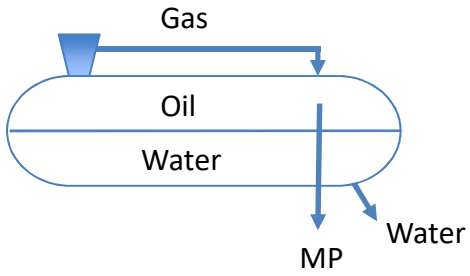
[1]

[2]

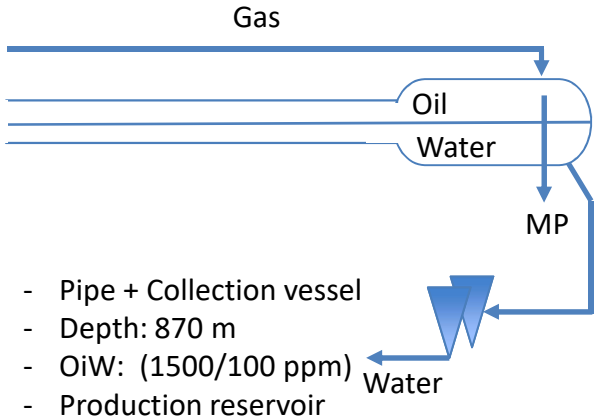
[3]



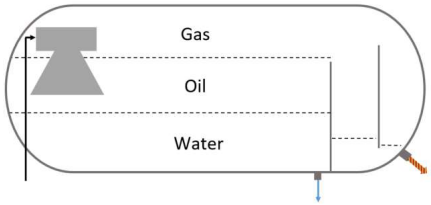
- "Traditional separation"
- Depth: 340 m
- OiW: < 1000 ppm
- Disposal reservoir

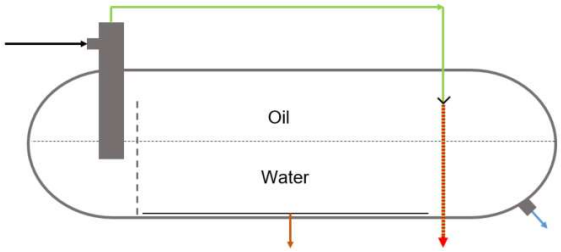


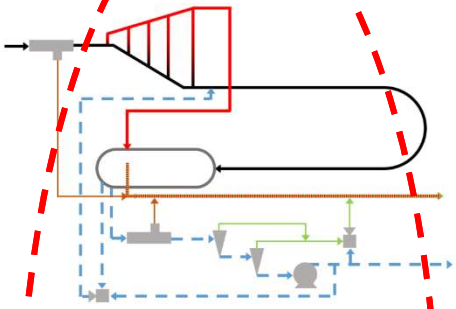
- Semi-compact
- Depth: 210 m
- OiW: < 1000 ppm
- Disposal reservoir/Topside



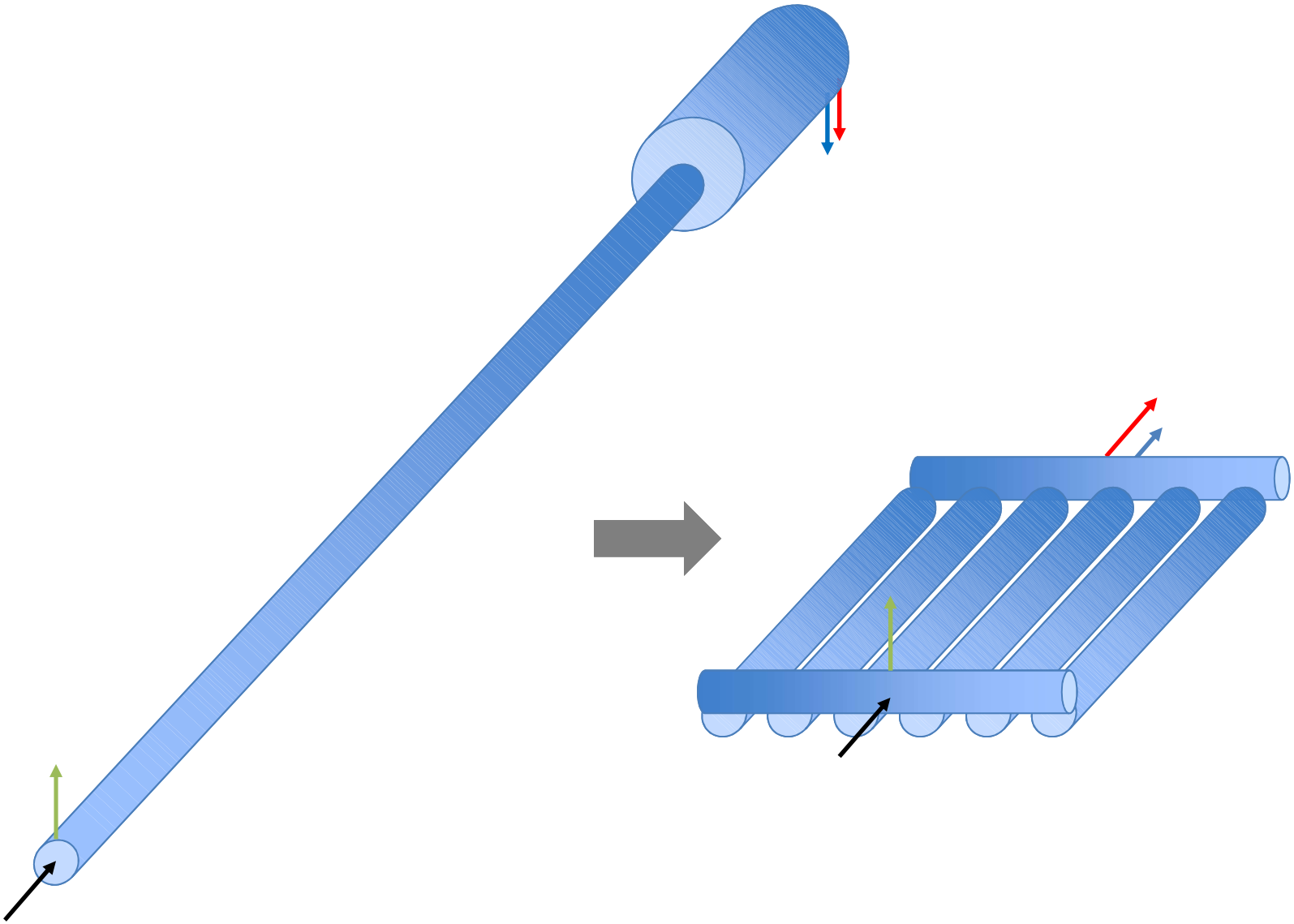
- Pipe + Collection vessel
- Depth: 870 m
- OiW: (1500/100 ppm)
- Production reservoir

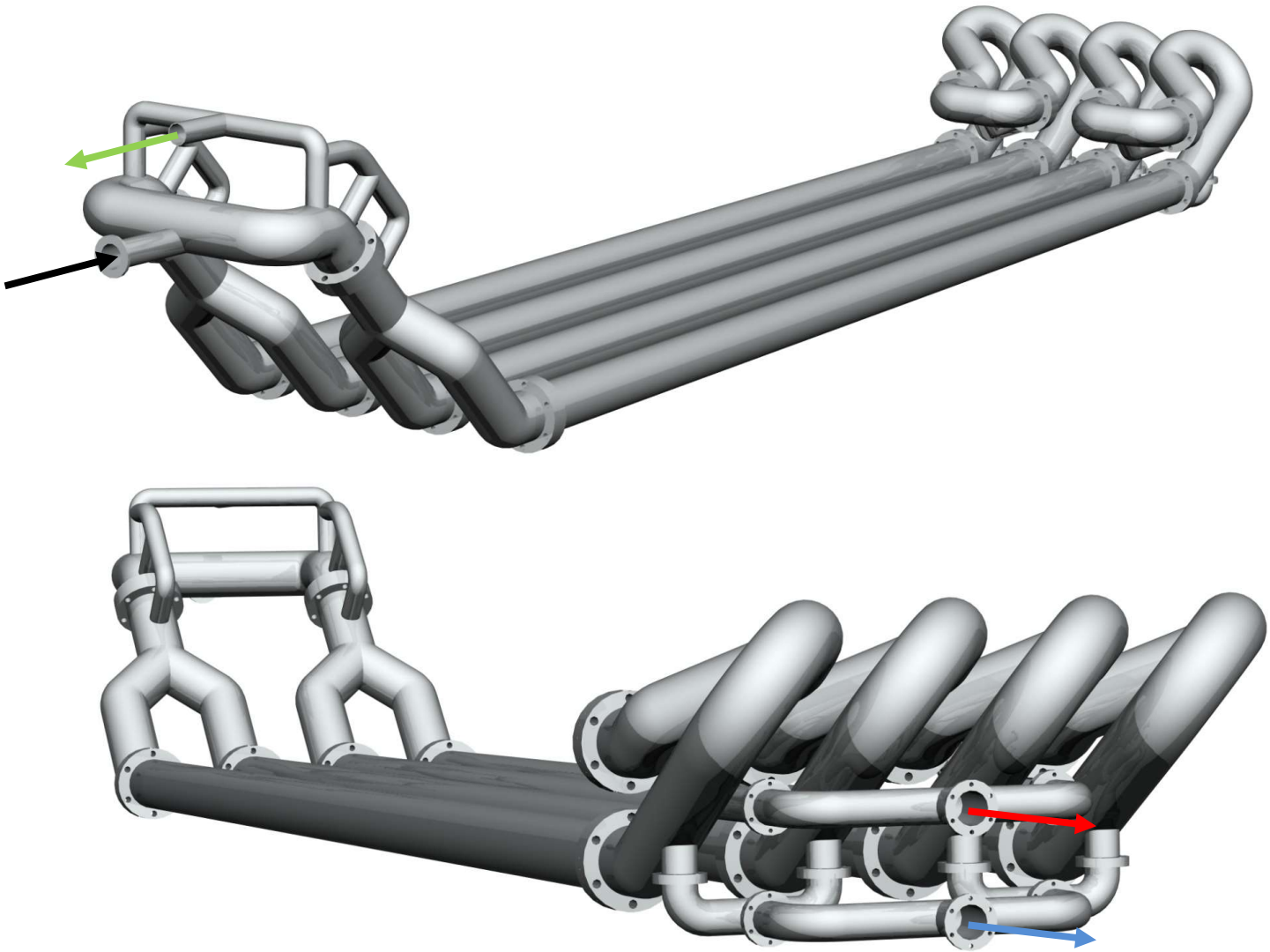


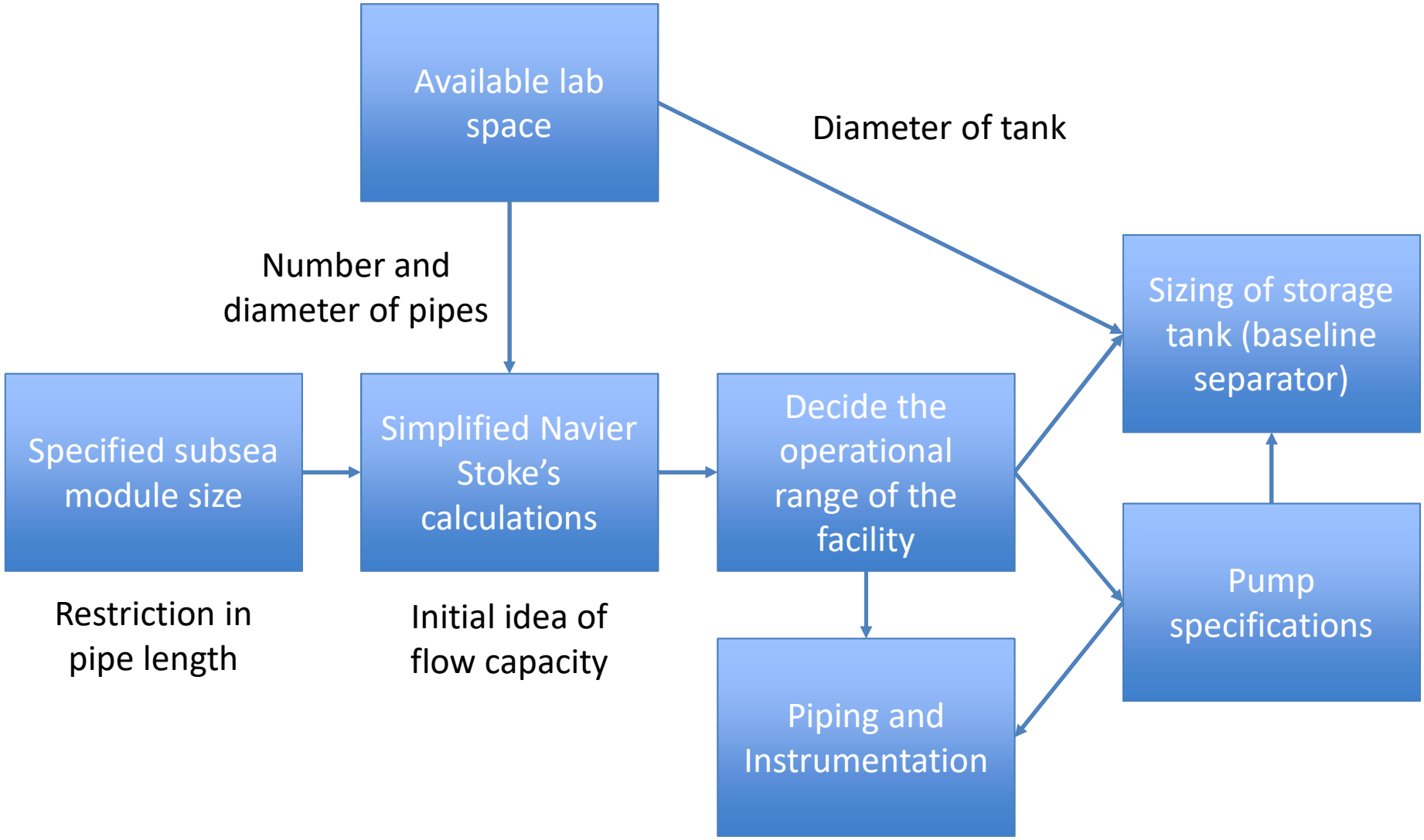




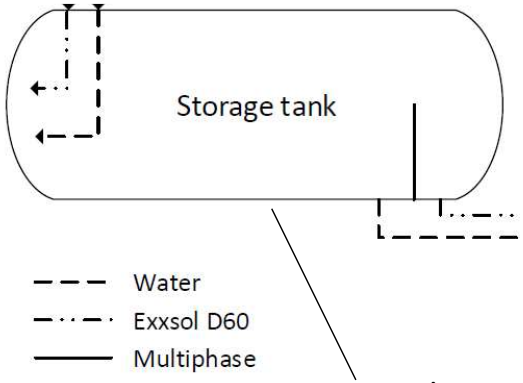
- Robust - Qualified	- Robust - Qualified - Gas-bypass	- Qualified - Gas-bypass - Eligible for deep waters - Pipe code manufacturing
- Large separator modules - Expensive for large water depths	- Large separator modules - Expensive for large water depths	- Large separator modules - Limited flow capacity - Separate extraction vessel



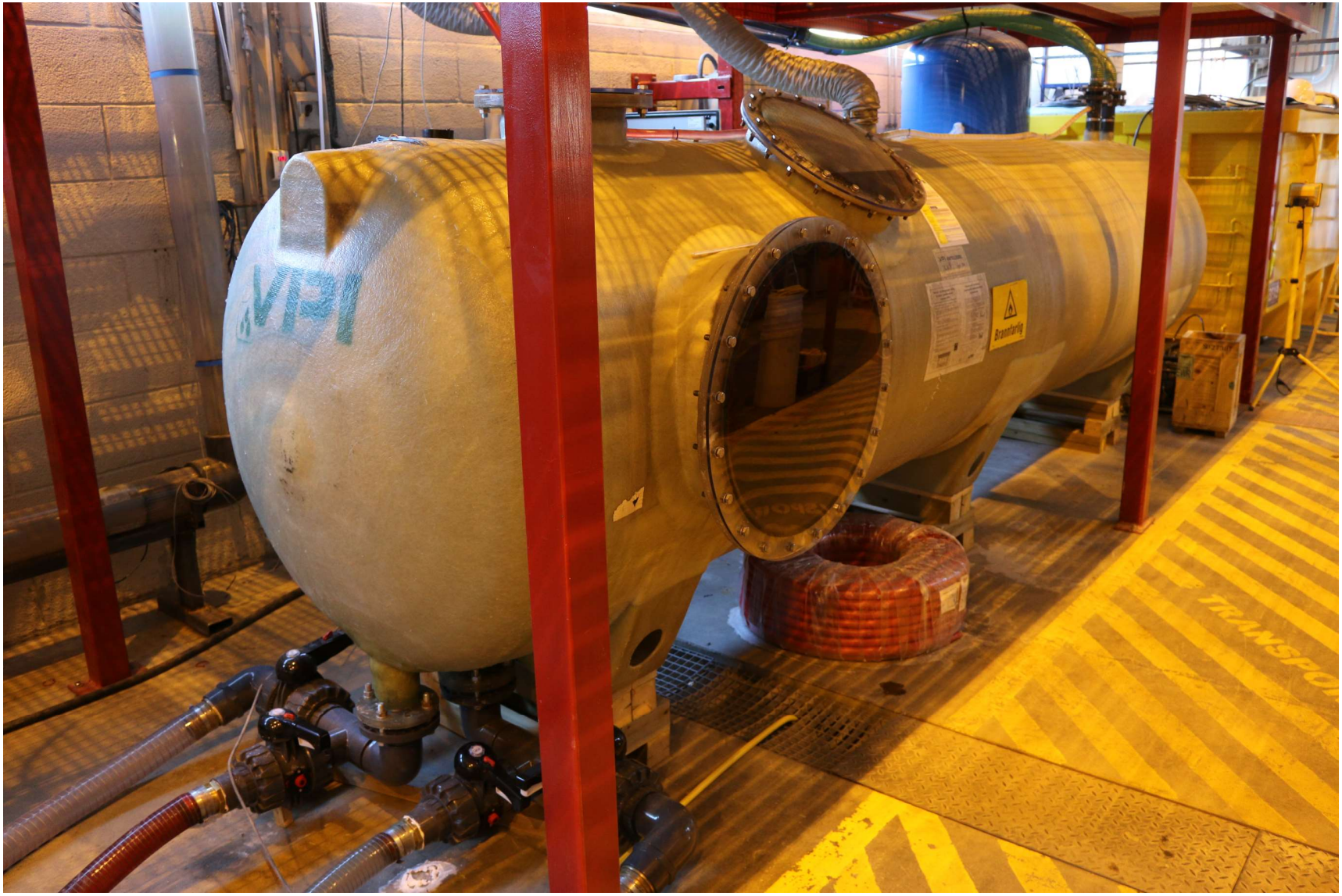


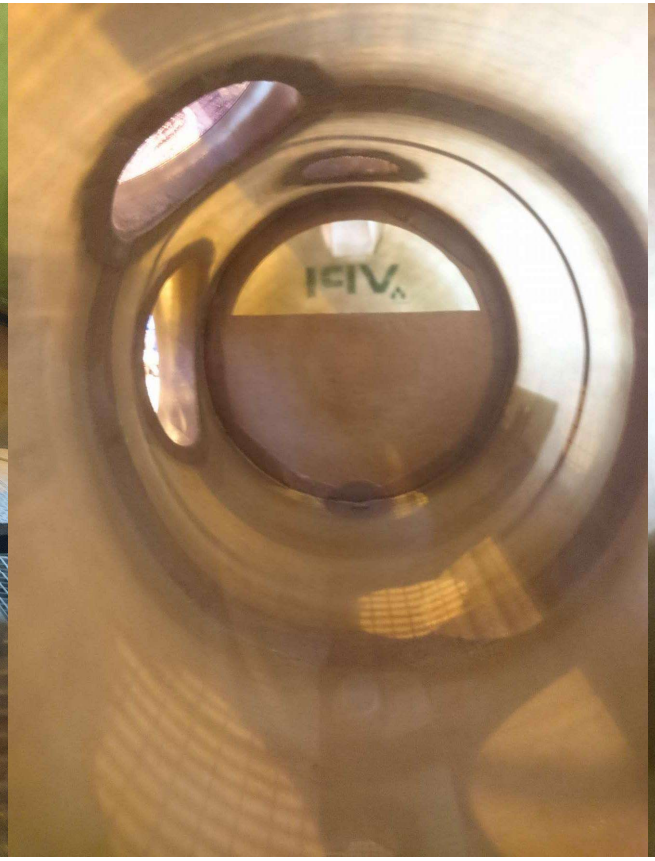

Available lab space
Diameter of tank
Number and diameter of pipes
Sizing of storage tank (baseline separator)
Specified subsea module size
Simplified Navier Stoke's calculations
Decide the operational range of the facility
Pump specifications
Restriction in pipe length
Initial idea of flow capacity
Piping and Instrumentation

Lab facilities

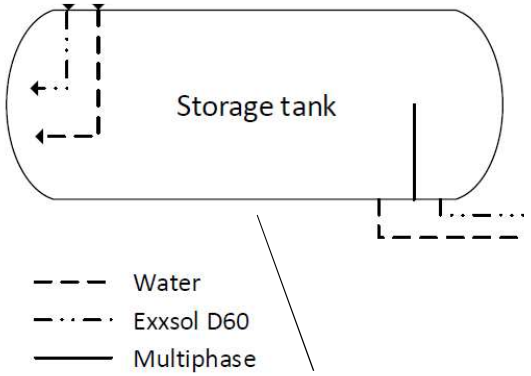


Storage tank
- ø1200 x L 5500
- 6.2 m^3


VPI
Brannfarlig

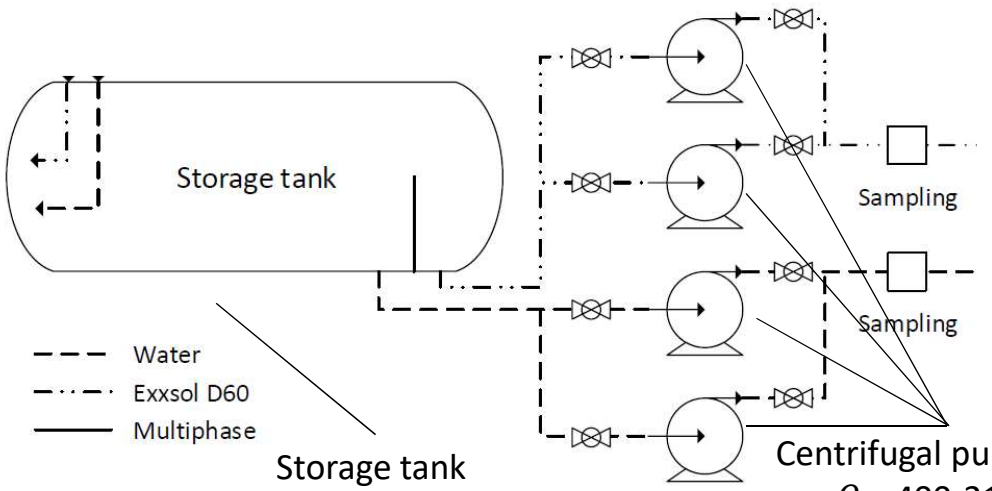

Lab facilities



Storage tank

- ø1200 x L 5500
- 6.2 m^3

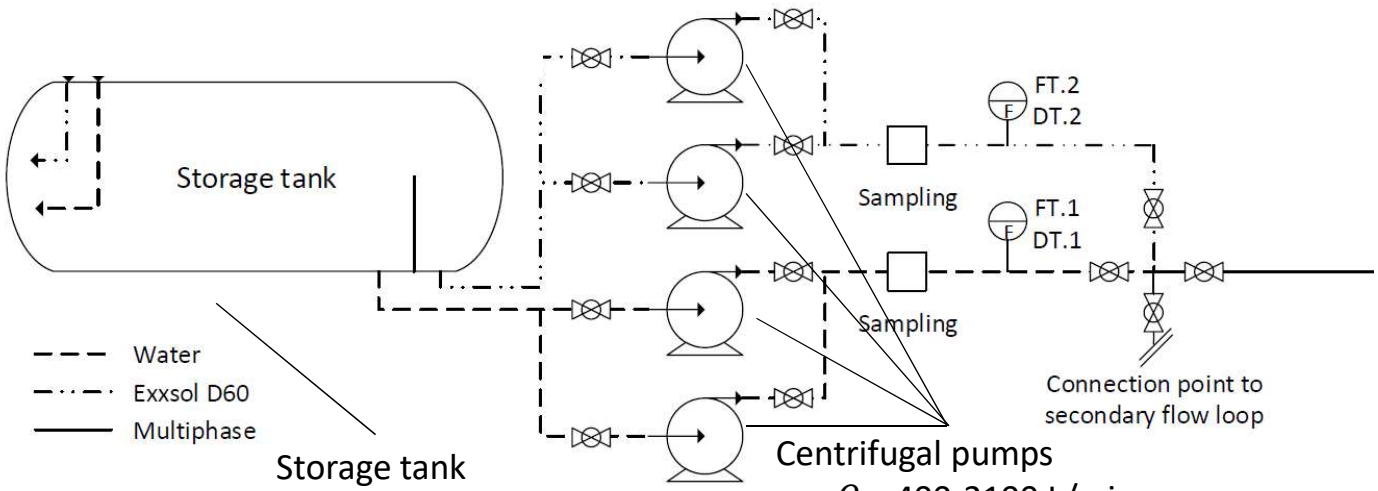
Lab facilities



Storage tank
- ø1200 x L 5500
- 6.2 m^3

Centrifugal pumps
- Q_1=400-2100 L/min
- Q_2=400-1700 L/min
- Q_3/Q_4=100-700 L/min

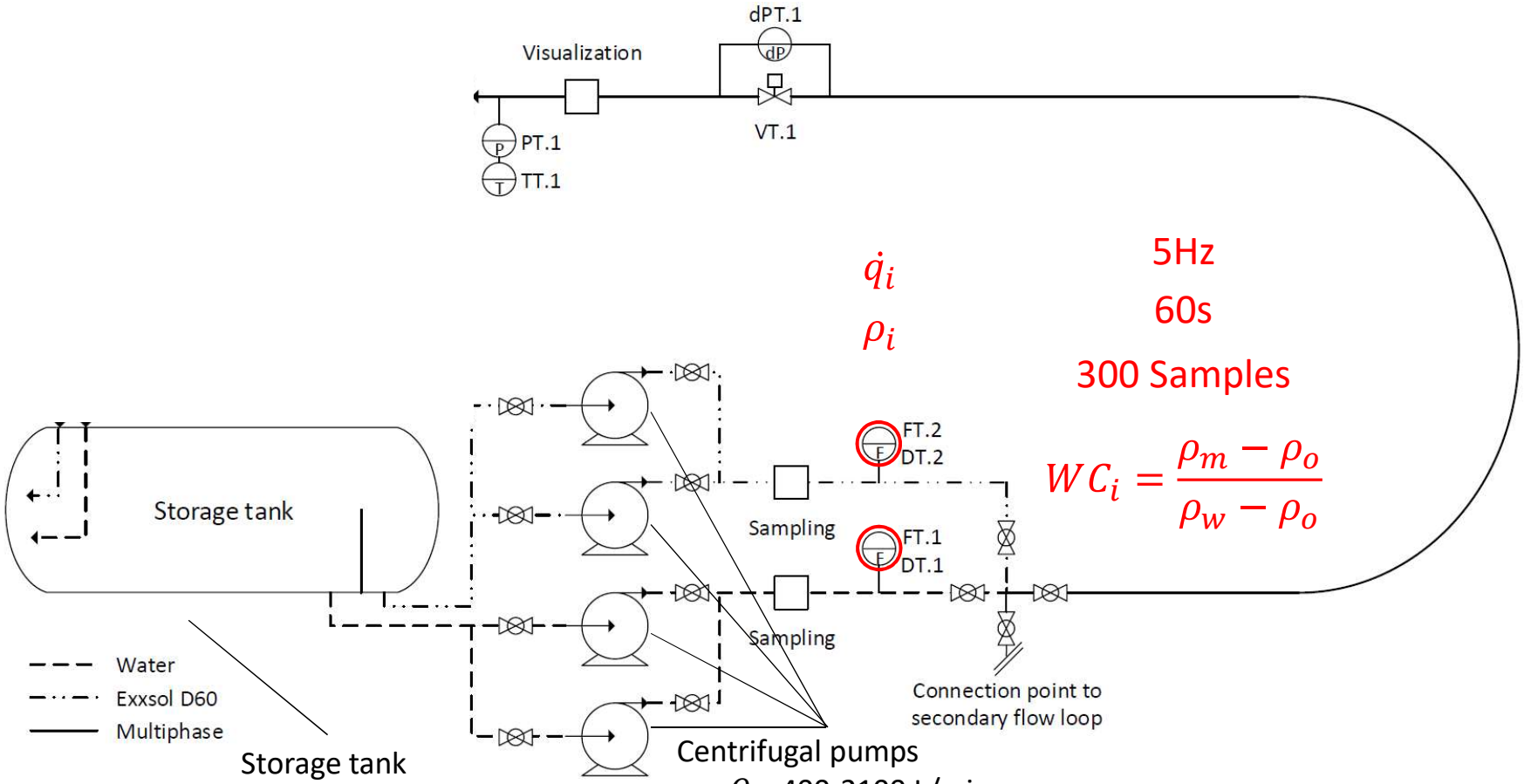
Lab facilities



Storage tank
- ø1200 x L 5500
- 6.2 m^3

Centrifugal pumps
- Q_1=400-2100 L/min
- Q_2=400-1700 L/min
- Q_3/Q_4=100-700 L/min

Lab facilities



Storage tank
- ø1200 x L 5500
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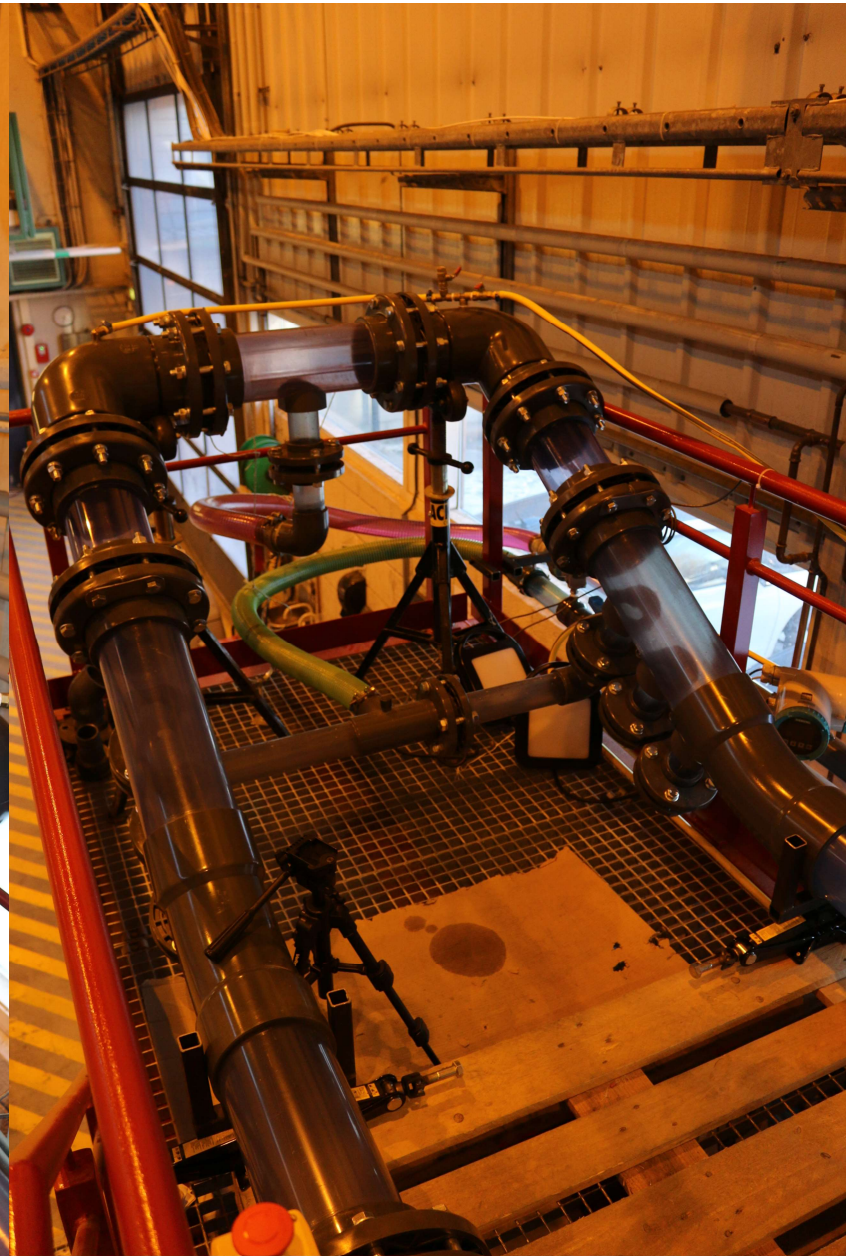
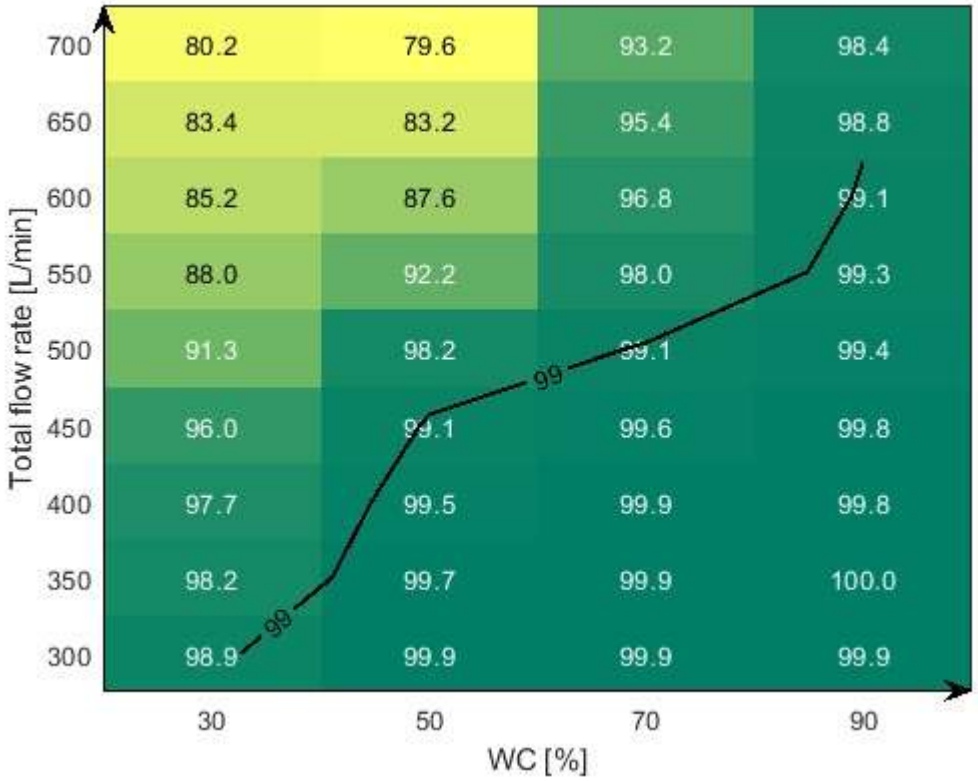


Simplified Navier stoke's estimates

Internal pipe diameter [mm]	Cut off diameter [μm]	Total liquid flow capacity [l/min] (bbl/day)			
		WC 30%	WC 50%	WC 70%	WC 90%
150	150	281(2542)	370(3353)	393(3558)	307(2783)
	175	382(3459)	504(4563)	535(4843)	418(3788)
	200	499(4518)	658(5960)	698(6326)	546(4948)

Actual performance data, WC ratio [%] (WC3/WC1)



Source location for pictures

[1]: http://www.npd.no/publikasjoner/rapporter/miljoteknologi/4-produksjon
[2]: http://www.drillingcontractor.org/subsea-automation-on-path-for-closed-loop-controls-intelligence-20389
[3]: http://www.offshore-mag.com/articles/2012/04/otc-2012--petrobras--fmc-subsea-separation-system.html