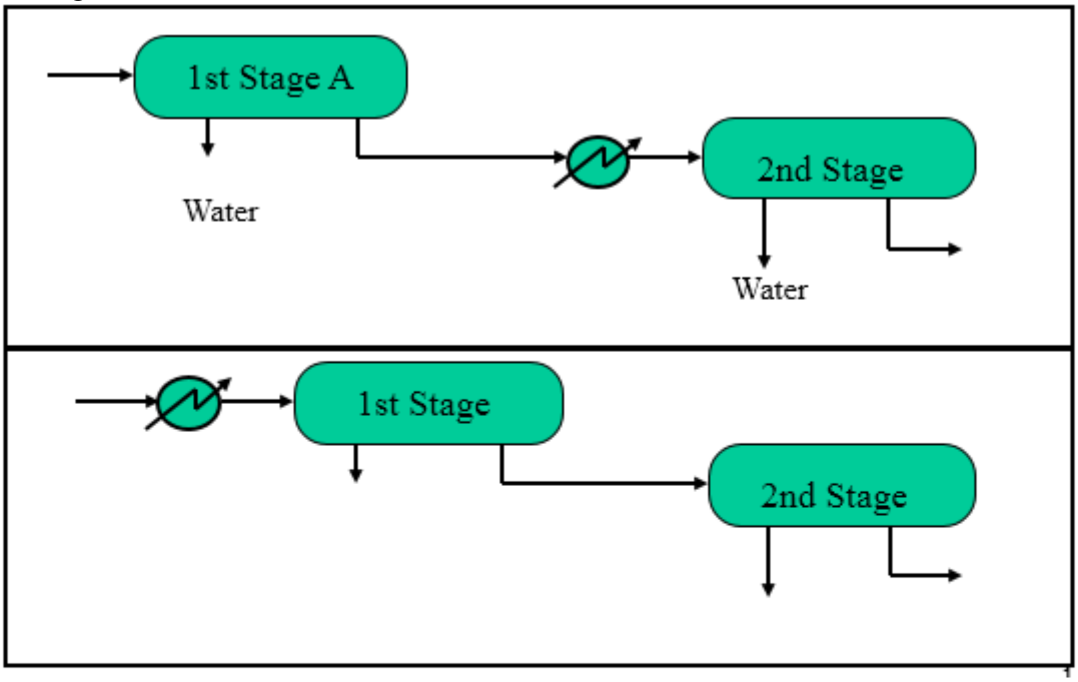
SOLUTION SEPARATION SYSTEMS ASSESSMENT

Configuration Selection



First arrangement: lower heat requirements more stable, single phase flow

Production Data

Oil production	: 89,000 bpd = 590 m3/hr
Water production	: 60,000 bpd = 397m3/hr
Watercut	: 397/(590+397) = 0.4 = 40%
Feed temperature	: 50 °C

Oil specification

TVP = 0.82 bar at 37.8 °C
BS&W = 0.5% v/v

Use the following guidelines and information:-

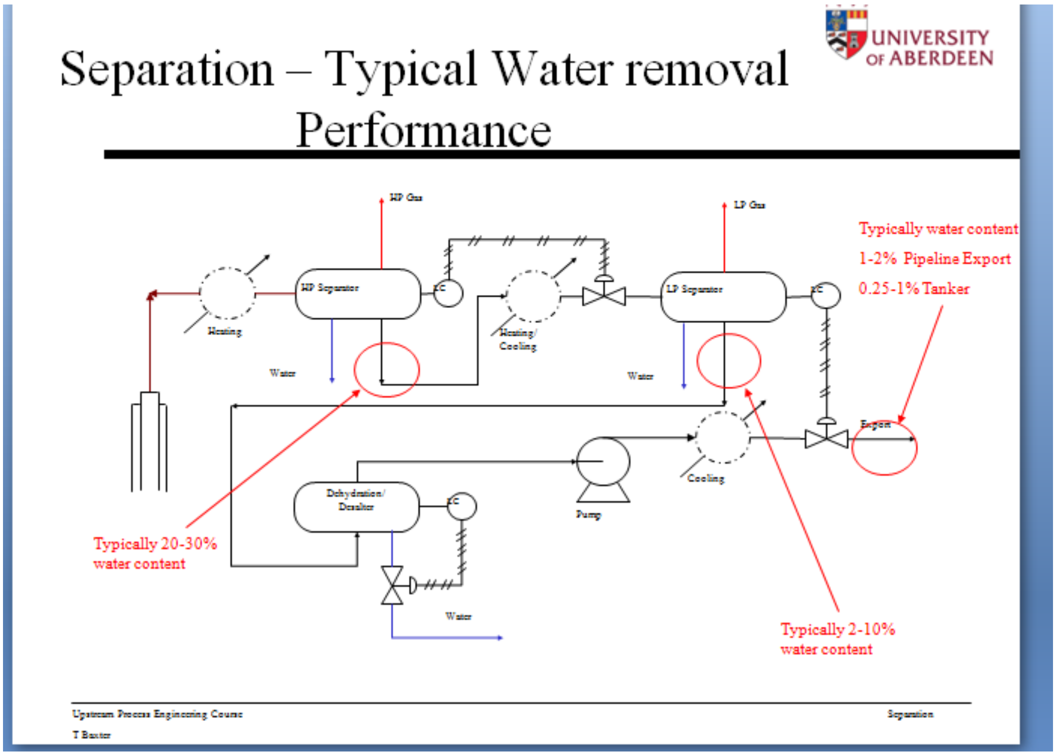
- Typical L/D ratios for oil water separator is approx. 3
- Normal liquid level in separators is 50%
- Arrival temperature of fluids is 50°C
- Arrival pressure is 10 bara
- Gas oil ratio in first stage is 60 sm^3/m^3 of oil and gas mol wt is 20
- Gas oil ratio in second stage is 10 sm^3/m^3 of oil and gas mol wt is 35
- 2nd stage separator operating pressure is to be determined to produce required oil TVP.

1^{st} stage (HP) separator

The aim of the first HP separation is to reduce the watercut to approximately 20%, which is a typical number for real systems.
Note 4.6m diameter is largest for UK road transport.

L/D	: 3
Design pressure HP separator	:11 bara (operating + 10%)
Allowable stress (S)	: 155 N/mm^2
Joint efficiency (E)	: 1

Normal Liquid Level (NLL) : 50%
The residence time for the oil is determined from the bottle tests.

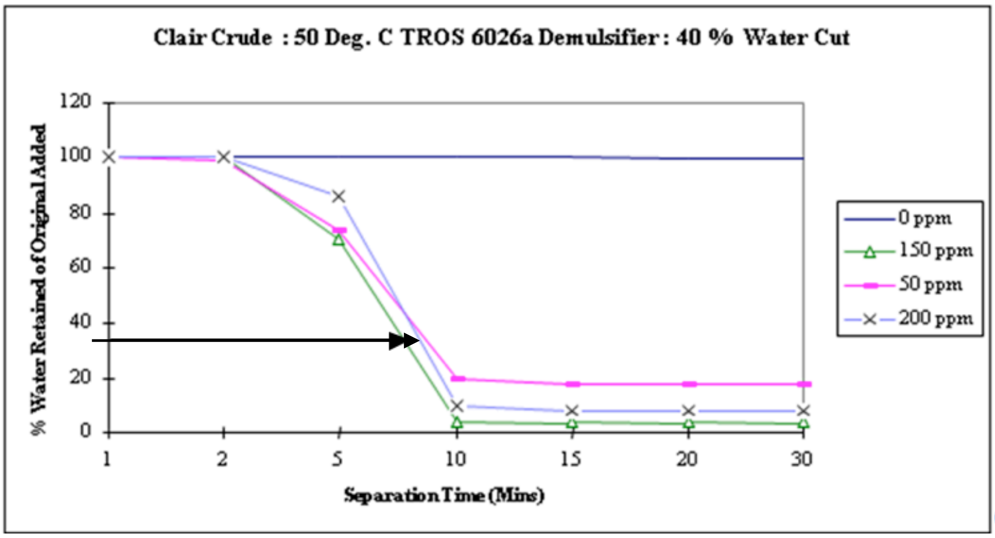


$$Watercut = \frac{100 * .\phi_{v,water}}{\left(\phi_{v,oil} + \phi_{v,water}\right)}$$

$$\phi_{v,water} = \frac{Watercut \cdot \phi_{v,oil}}{\left(100 - Watercut\right)} = \frac{20 * 590}{\left(100 - 20\right)} = 148\ m^3 / hr$$

The inlet water rate is 397 m^3/hr, therefore the amount of water retained in the outgoing oil is 100 * 148/397 = 37%.

Consider the bottle test graph for 50°C and 40% watercut. In order to retain 37% of the water in the outlet oil the separation time, i.e. oil residence time ($t_{res,oil}$), should be in the region of 7.5 minutes.



$V_{oil} = \varphi_{v,oil} * t_{res,oil} = 590/60*7.5 = 73.8\ m^3$

$V_{water} = \varphi_{v,water} * t_{res,water} = 397/60*7.5 = 46.4\ m^3$

The total liquid volume in the separator is $V_{oil} + V_{water} = 120.2\ m^3$

The normal liquid level (NLL) in the separator is 50%. Therefore the separator volume will be 120.2 /0.5 = 240.4 m^3.

The volume of a vessel with 2:1 ellipsoidal dished ends is given by:

$$V = \frac{1}{12}\cdot\pi\cdot D^3 + \frac{1}{4}\cdot\pi\cdot D^2\cdot L = \frac{1}{12}\cdot\pi\cdot D^3 + \frac{1}{4}\cdot\pi\cdot D^3\cdot\left(\frac{L}{D}\right)$$

Rewriting equation yields:

$$D = \sqrt[3]{\frac{V}{\frac{1}{12}\cdot\pi + \frac{1}{4}\cdot\pi\cdot\left(\frac{L}{D}\right)}} = \sqrt[3]{\frac{240.4}{\frac{1}{12}\cdot\pi + \frac{1}{4}\cdot\pi\cdot(3)}} = 4.5\ m$$

L = 3* D = 3 x 4.5 = 13.5 m

The wall thickness (Wt) of the vessel is calculated with:

$$Wt = \frac{P_{design}\cdot D}{\left(20\cdot\left(S\cdot E - 0.06\cdot P_{design}\right)\right)}$$

$$Wt = \frac{11 * 4.5}{\left(20 * \left(155\cdot 1 - 0.06 * 11\right)\right)} = 0.016\ m = 16\ mm$$

Add corrosion allowance of 3mm

Wt = 19mm

The surface area of the vessel is calculated with:

$$A = \pi \cdot D \cdot L + 0.8 \cdot \pi \cdot D^2$$

$$A = \pi * 4.5 * 13.5 + 0.8 * \pi * 4.5^2 = 222.5 m^2$$

The weight of the vessel is calculated with:

$$W = 8000 * A * Wt$$

$$W = 8000 * 222.5 * 0.019 = 33820\ kg$$

Add 20% for internals, nozzles, saddles;

$$W = 40600\ kg$$

Operating weight = 40600 + 120.2 x 1000 = 160800 kg

<u>Entrainment check</u>

Gas rate = 590 x 60/3600 = 9.83 sm^3/s

Actual gas rate = 9.83 *1/11 * (273+50)/(273+15) = 0.86m^3/s

Gas CSA = 3.14 * $4.5^2/8$ = 7.95m^2

Gas velocity = 0.86/7.95 = 0.108 m/s

Limiting gas velocity

$$v_s = k \cdot \left(\frac{\rho_l - \rho_g}{\rho_g} \right)^{0.5} \times \left(\frac{L}{6} \right)^{0.58}$$

v_s	= superficial gas velocity (m/s)
k	= constant typically 0.133
L	= separator length (t/t) (m)
ρ_l	= liquid density (kg/m^3)
ρ_g	= gas density (kg/m^3)

Gas Density = 20/22.4 * 11/1 * 273/323 = 8.3 kg/m^3
Oil density, 22 API , sg = 141.5/(API + 131.5) = 0.92

Vs = 2.23 m/s

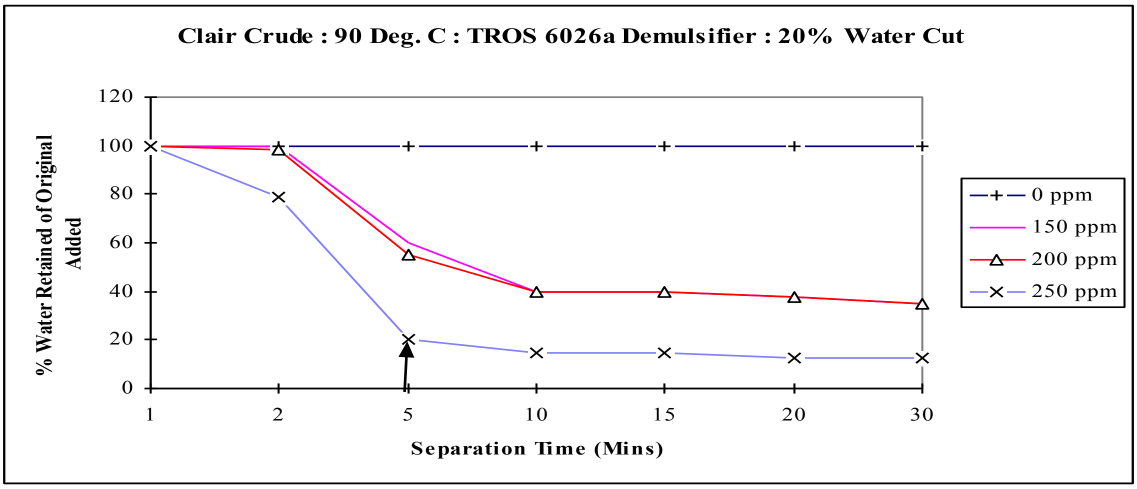
No entrainment potential

<u>2nd stage separator</u>

The calculation of weight and footprint of the 2^{nd} stage separator is analogous to the 1^{st} stage separator.

The bottle test graphs show that the best separation is achieved at high temperatures (90 degC).

Look at the bottle test graph for 20% watercut and 90°C. It appears that after 5 minutes the amount of water retained is 20%. The separation does not significantly improve after 5 minutes.



$V_{oil} = = \varphi_{v,oil} * t_{res,oil} = 590/60*5 = 49.1\ m^3$

$V_{water} = \varphi_{v,water} * t_{res,water} = 148/60*5 = 12.3\ m^3$

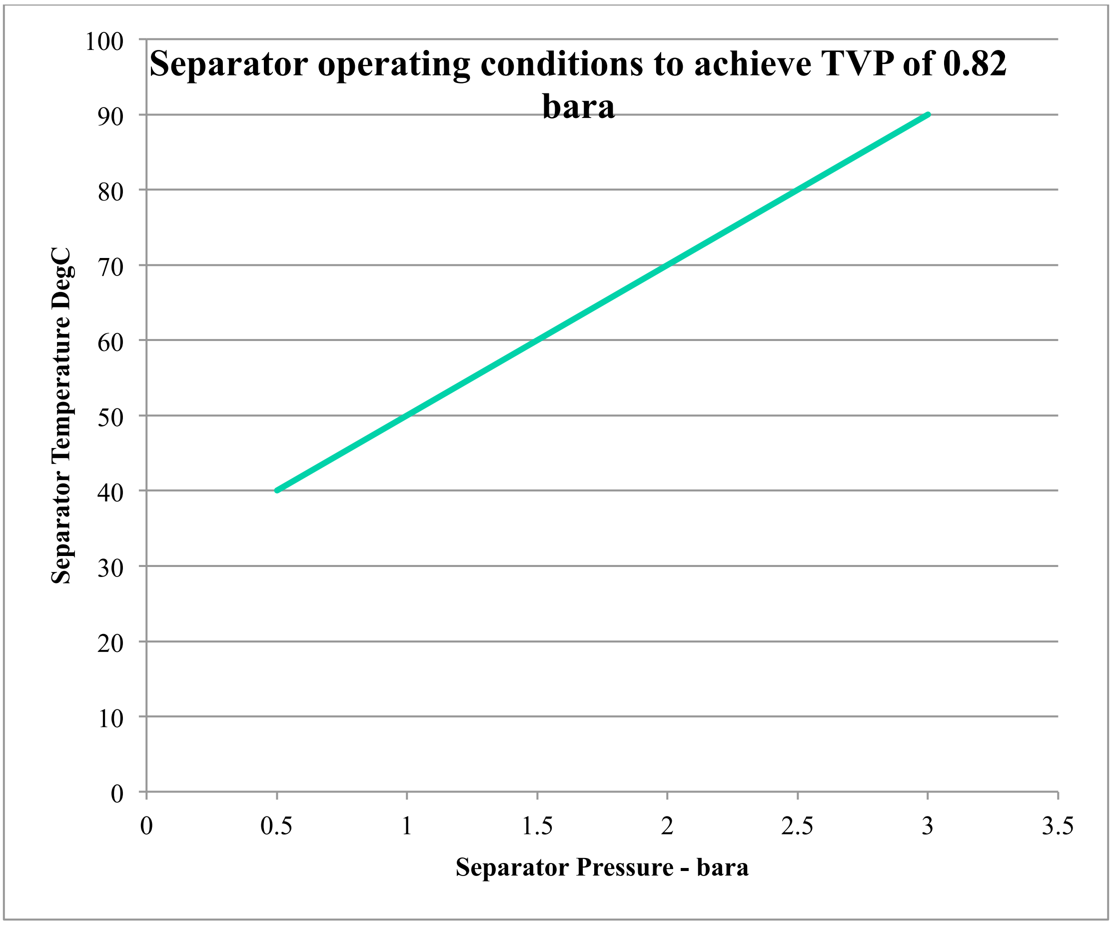
The total liquid volume in the separator is $V_{oil} + V_{water} = 61.4\ m^3$

The normal liquid level (NLL) in the separator is assumed to be 50%. Therefore the separator volume will be $61.4/0.5 = 122.8\ m^3$.

$$D = \sqrt[3]{\frac{V}{\frac{1}{12}\cdot\pi + \frac{1}{4}\cdot\pi\cdot\left(\frac{L}{D}\right)}} = \sqrt[3]{\frac{122..8}{\frac{1}{12}\cdot\pi + \frac{1}{4}\cdot\pi\cdot(3)}} = 3.6\ m$$

L = 3D = 10.8 m

Operating pressure has to meet TVP



Operating pressure = 3 bara
Design pressure = 3 bar +1 = 4 bara

The wall thickness (Wt)

$$Wt = \frac{P_{design} \cdot D}{\left(20 \cdot \left(S \cdot E - 0.06 \cdot P_{design}\right)\right)}$$

$$Wt = \frac{4 * 3.6}{\left(20 * \left(155 \cdot 1 - 0.06 * 4\right)\right)} = 0.0046\ m = 4.6\ mm$$

Wt = 4.6 mm which is smaller than minimum recommended which is 12 mm

(Coulson and Richardson, Vol6, 13.4.8 – Minimum Practical Wall Thickness)

Wt = 12 = 3 = 15mm

The surface area (A)

$$A = \pi * 3.6 * 10.8 + 0.8 * \pi * 3.6^2 = 154.6 m^2$$

The vessel weight (W)

$W = 8000 * 154.6 * 0.015 = 18600\ kg$

Add 20% for internals, nozzles, saddles;

$W = 22300\ kg$

Operating weight = 22300+ 122.8 x 1000 = 125100 kg

Gas velocity check – no entrainment isues.

<u>Interstage Heater</u>

In order to improve the oil/water separation, the oil from the 1st stage separator is heated to 90°C.

The heating duty follows from the following basic heat balance:

$$Q_{heater} = \left(\phi_{v,oil} \cdot \rho_{oil} \cdot Cp_{oil} + \phi_{v,water} \cdot \rho_{water} \cdot Cp_{water}\right) \cdot \Delta T$$

Filling in equation 7 yields:

Q_{heater} = (590/3600*922*2.1 + 148/3600*1030*4.2)*(90-50) = 19.8 MW

Heating medium inlet temperature 150°C, outlet temp 100°C

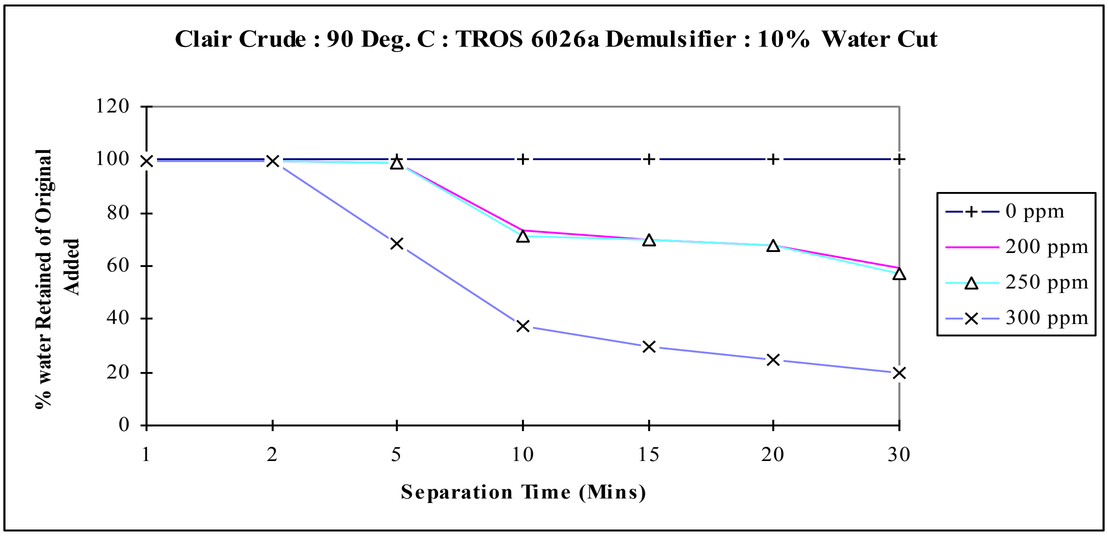
ΔT_{LM} =((150 – 90) – (100-50))/Ln(60/50) = 55°C

Typical OHTC, U = 400 W/m^{2o}C (C&R)

Hence exchanger area = 19.8 x 10^6 /(400 x 55) = 900 m^2

<u>Electrostatic Coalescer</u>

The 90 DegC bottle test is levelling off at 20% water retained. At 20% water cut this represents a product oil of 0.2 x 0.2 X 100% = 4%. Above export specification of 0.5%, hence Electrostatic Coalescer required.



Typical residence time 20 minutes based upon oil rate.

EC operates liquid full, hence volume of vessel = 590 x 20/60 = 196 m^3

As before for L:D = 3, then D = 4.2m, L = 12.6 m

Use same design pressure as LP separator

Wt will be too small so use min plus 3mm corrosion allowance 15mm

Vessel area

$$A = \pi \cdot D \cdot L + 0.8 \cdot \pi \cdot D^2$$

$$A = 210\ m^2$$

EC weight, 25200kg

20% for internals etc – 30240kg

Operating weight = 226240 kg

Control System