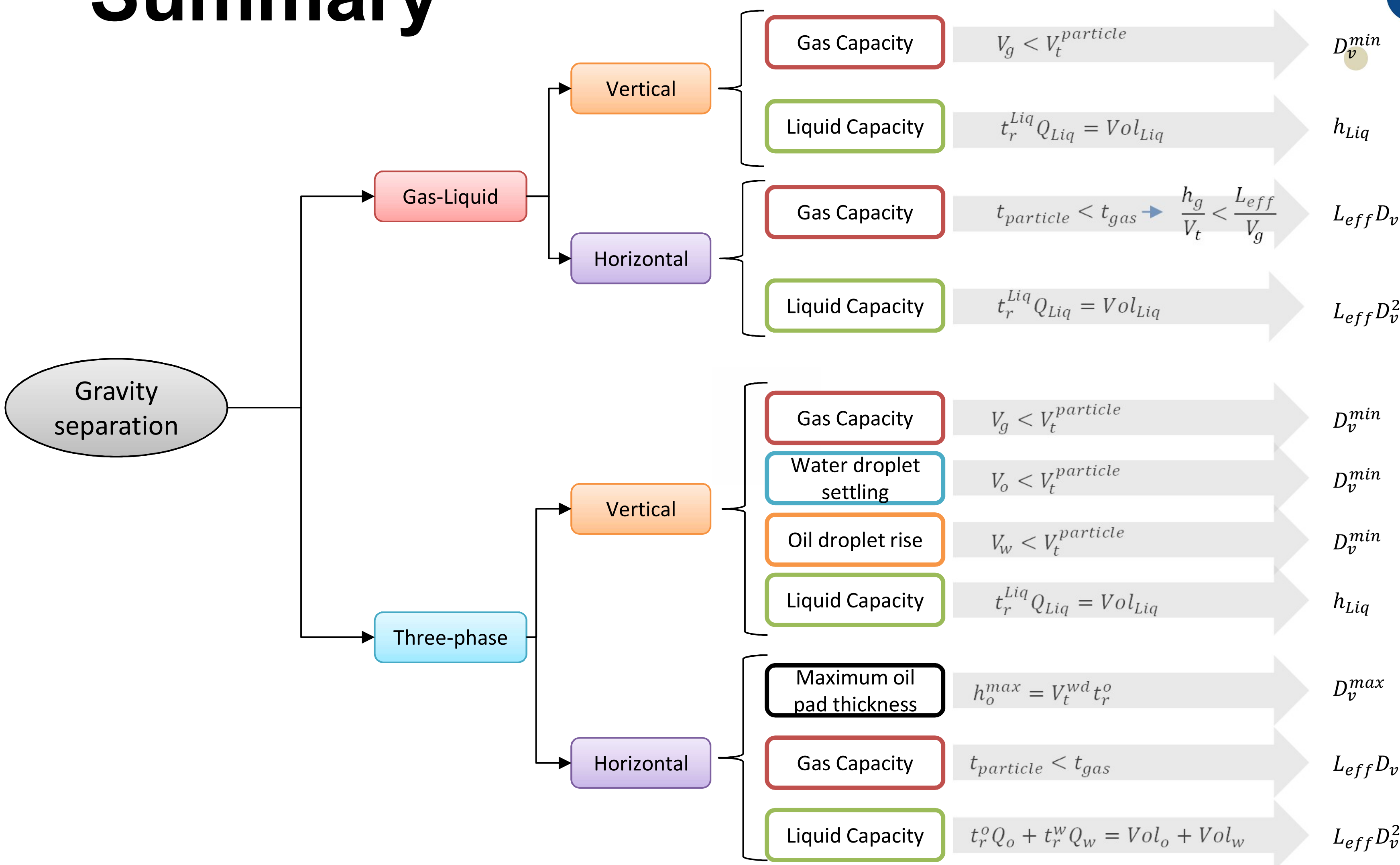
NTNU – Trondheim
Norwegian University of
Science and Technology

Production Technology

Field Processing and Systems

Postdoc Mariana Díaz
02 /05/2019

Summary



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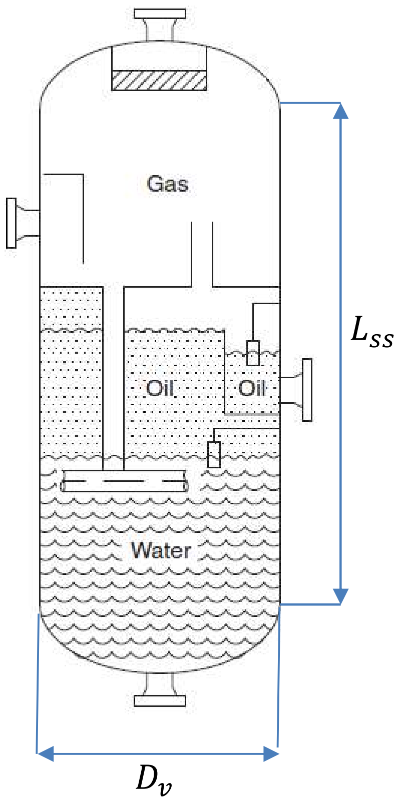
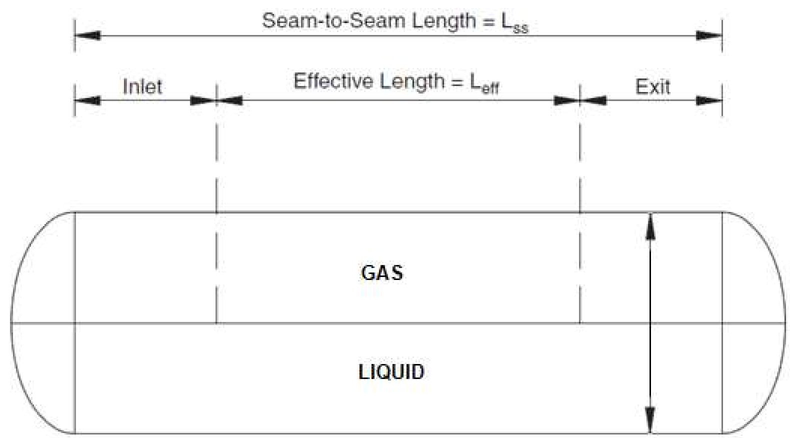
Design Theory-Horizontal Vessel





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MECHANICAL DESIGN OF PRESSURE VESSELS

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Mechanical Design of Pressure Vessels

- Selecting of design pressure rating
- Wall thickness
- Estimate vessel weight

- Most pressure vessels used in the oil and gas industry are designed according to the **American Society of Mechanical Engineers (ASME)**

- Design Methods: (ISO 16528-1:2007)
  - **Design by rule** (ASME Division 1) : normally used for low pressure vessels
  - **Design by analysis** (ASME Division 2): normally used for high pressure vessels
  - **Design by experiment or testing**

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Mechanical Design of Pressure Vessels

Design Considerations

- Maximum and minimum **design temperature** determine the **maximum allowable stress** value permitted for the **material**

  - **Tmax** >= Mean metal temperature expected
  - **Tmin** = lowest expected in service

- The maximum allowable stress values are given in the ASME code for many different materials

- **Design pressure** : “Maximum Allowable Working Pressure” (MAWP).

- **MAWP** determines the settling of the **relief valve** and must be higher than the operating pressure

- The MAWP of the vessel cannot exceed the MAWP of the nozzles, valves and pipes connected to the vessel

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Mechanical Design of Pressure Vessels

Design Considerations

Settling Maximum Allowable Working Pressure

Operating Pressure	Minimum Differential Between Operating Pressure and MAWP
Less than 50 psig	10 psi
51–250 psig	25 psi
251–500 psig	10% of maximum operating pressure
501–1000 psig	50 psi
1001 psig and higher	5% of maximum operating pressure

Vessels with high-pressure safety sensors have an additional 5% or 5 psi, whichever is greater to the minimum differential.

(Arnold and Stewart, 2008)

Mechanical Design of Pressure Vessels

Design Considerations

Maximum Allowable Stress Value for Common Steels

			ASME Section VIII 2007 Edition	
			Div. 1	Div. 2
Metal		**Not Lower Than**	**–20°F**	**–20°F**
Temperature		**Not Exceeding**	**650°F**	**100°F**
Carbon steel plates and sheets	SA-516	Grade 55	15,700	18,300
		Grade 60	17,100	20,000
		Grade 65	18,600	21,700
		Grade 70	20,000	23,300
	SA-285	Grade A	12,900	15,000
		Grade B	14,300	16,700
		Grade C	15,700	18,300
	SA-36		16,600	16,900

(Arnold and Stewart, 2008)

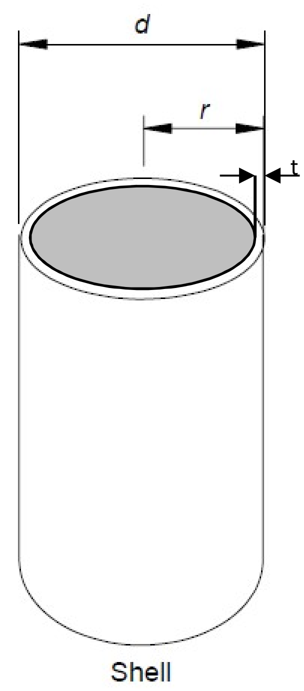
Mechanical Design of Pressure Vessels

Determining wall thickness

- **Design by rule (VESSELS UNDER INTERNAL PRESSURE)**

Cylindrical Shells:

$$t = \frac{P\,r}{SE - 0.6P}$$



S: maximum allowable stress value (psi)
t: thickness (in)
P: MAWP (psig)
r: inside radius (in)
d: inside diameter (in)
E: efficiency of welded joints
α: half the angle of the apex of the cone

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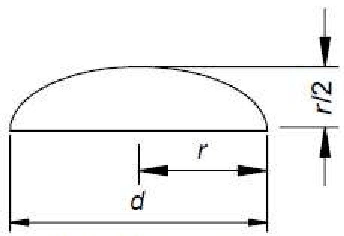
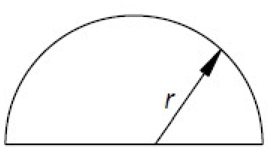
Mechanical Design of Pressure Vessels

Determining wall thickness



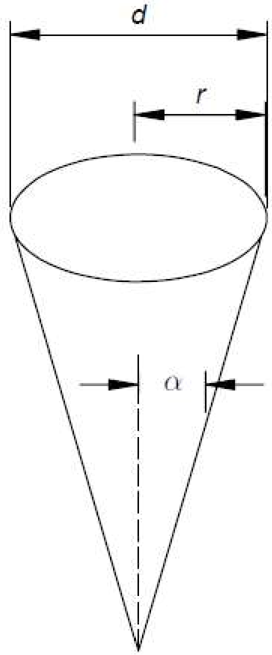
Ellipsoidal head

$$t = \frac{P\,d}{2\,S\,E - 0.2\,P}$$



Hemispherical head

$$t = \frac{P\,r}{2\,S\,E - 0.2\,P}$$



Conical section

$$t = \frac{P\,d}{2\cos\alpha\,(S\,E - 0.6\,P)}$$

$\alpha \rightarrow 30° \; to \; 45°$

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Mechanical Design of Pressure Vessels

Determining wall thickness

$$t = \frac{P\,r}{SE - 0.6P}$$

Efficiency of Welded Joints (E)

Type of Joint	(a) Fully Radiographed	(b) Spot Examined	(c) Not Spot Examined
Double welded bolt joint or single welded bolt joint with backing strip with does not remain in place	1	0.85	0.70
Single-welded bolt joint with backing strip which remains in place	0.90	0.80	0.65
Single-welded bolt joint without use of backing strip	-	-	0.6

(ARNOLD, K. & STEWART, M. 2008)

Mechanical Design of Pressure Vessels

Corrosion Allowance

Required thickness = $t = \frac{P\,r}{SE - 0.6P}$ + corrosion allowance

Typical corrosion allowance

- For non- corrosive service: 0.125 in
- For corrosive service: 0.250 in

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Mechanical Design of Pressure Vessels

Vessel Weights

FIELD UNITS

Vessel Weight *= Shell + Heads + (Internals + Nozzles) + Vessel Support*

$$W_v = W_s + W_H + W_I + W_B$$

Weight of the Shell

$$W_s = 11\ d\ t\ L$$

Weight of the head

Ellipsoidal head 2:1

$$W_H \approx 0.34\ t\ d^2 + 1.9\ t\ d$$

Conical head

$$W_H \approx 0.23 \frac{td^2}{\sin\alpha}$$

Weight of nozzles and internals

$$W_I = (W_s + W_H) * f$$

f →5% to 10%

Weight of vessel support

Vertical vessel support $W_B = 11\ d\ t^*\ L_s$

Ellipsoidal head → $L_s = \dfrac{0.25d}{12} + 2$

Conical head → $L_s = \dfrac{0.5d}{12\tan\alpha} + 2$

Horizontal vessel support $W_B = 10\%\ W_v$

W: weight (lb)
d : internal diameter (in)
t : wall thickness (in)

t* : wall thickness neglecting corrosion (in)
L : shell length (ft)
Ls: skirt length (ft)

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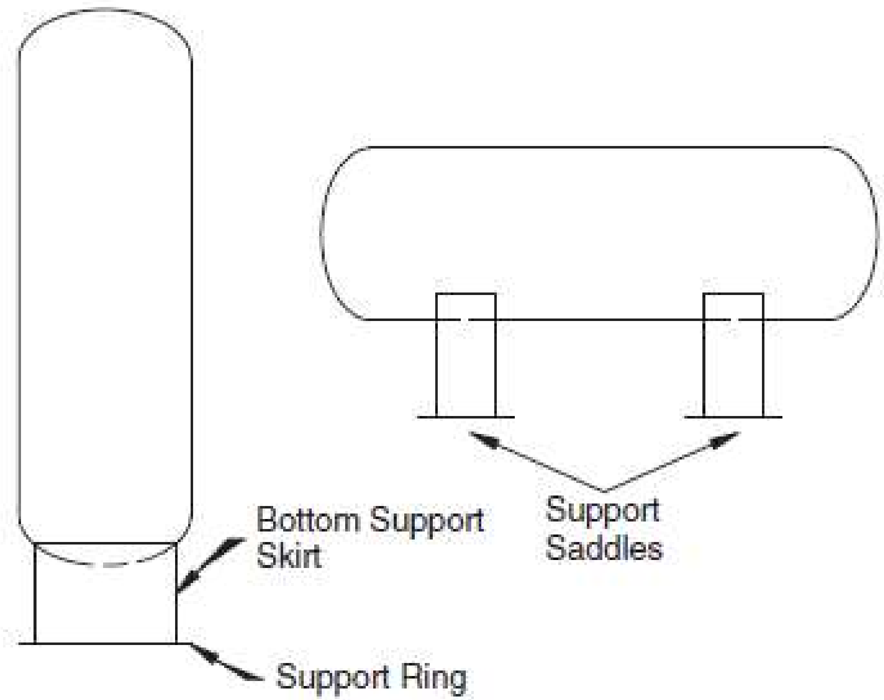


(Stewart and Arnold, 2008)

Vertical separator Mechanical Design

Exercise

$Q_g = 11803\ scm/hr$

$Q_o = 13.25\ m^3/hr$

$\rho_g = 59.6\ kg/m^3$

$\rho_o = 825\ kg/m^3$

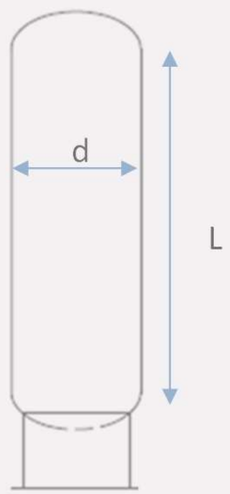
$\mu_g = 0.013\ cp$

$d_m = 140\mu m$

$z = 0.84$

$P = 6900\ kPa$ *=1000 psi*

$T = 15.6\ C$ *=60 F*



L=2.4m = 9.65 ft.

d=36 in

Corrosive service

Material SA 516 GRADE 70

Efficiency of the weld= 0.85

Ellipsoidal head

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Vertical separator Mechanical Design

Exercise

$Q_g = 11803\ scm/hr$

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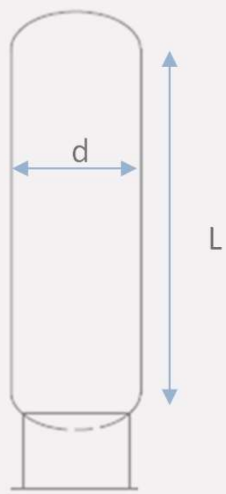

L=2.4m = 9.65 ft.

d=36 in

Corrosive service

Material SA 516 GRADE 70

Efficiency of the well = 0.85

Design Pressure = ? ⟹ $50 psi + P = 1050\ psi$

Stress Value = ? ⟹ *S= 23 300 psi*

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Vertical separator Mechanical Design

Exercise

Cylindrical Shells <u>Thickness</u>:

$$t = \frac{P\,r}{SE - 0.6P} = \frac{1050 * 18}{23\,300 * 0{,}85 - 0.6 * 1050} = 0.986\ in$$

Required thickness → $t_r = t + corrosion\ allowanse = 1.236\ in$

Cylindrical Shells <u>*Weight*</u>:

$$W_s = 11\ dt_rL = 11 *\ 36 * 1.236 * 9.65 = 4722\ lb$$

Ellipsoidal Head <u>Thickness</u>:

$$t = \frac{P\ d}{2\ S\ E - 0.2\ P} = 0.959\ in$$

$$t_r = t + corrosion\ allowanse = 1.209\ in$$

Ellipsoidal Head <u>*Weight*</u>:

$$W_H \approx 0.34\ t\ d^2 + 1.9\ t\ d = 615.6\ lb$$

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Vertical separator Mechanical Design

Exercise

Skirt *Weight* :

$$W_B = 11\ d\ t^*\ L_s$$

$$L_s = \frac{0.25d}{12} + 2 = 2.75\ ft$$

$$W_B = 11\ 36\ * 0.986\ * 2.75 = 1074\ lb$$

Weight of nozzles and internals:

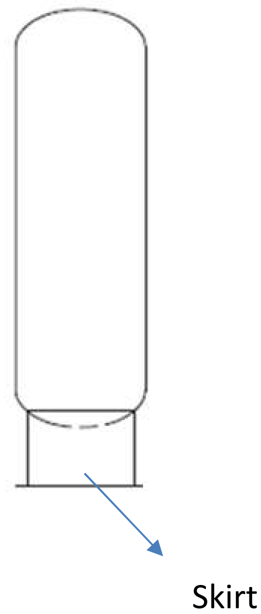
$$W_I = (W_s + W_H) * 10\% = 595\ lb$$

Total *Weight* :

$$W_v = W_s + W_H + W_I + W_B$$

$$W_v = 4722\ + 2 * 615.6 + 595 + 1074$$

$$W_v = 7622\ lb = 3457\ kg$$



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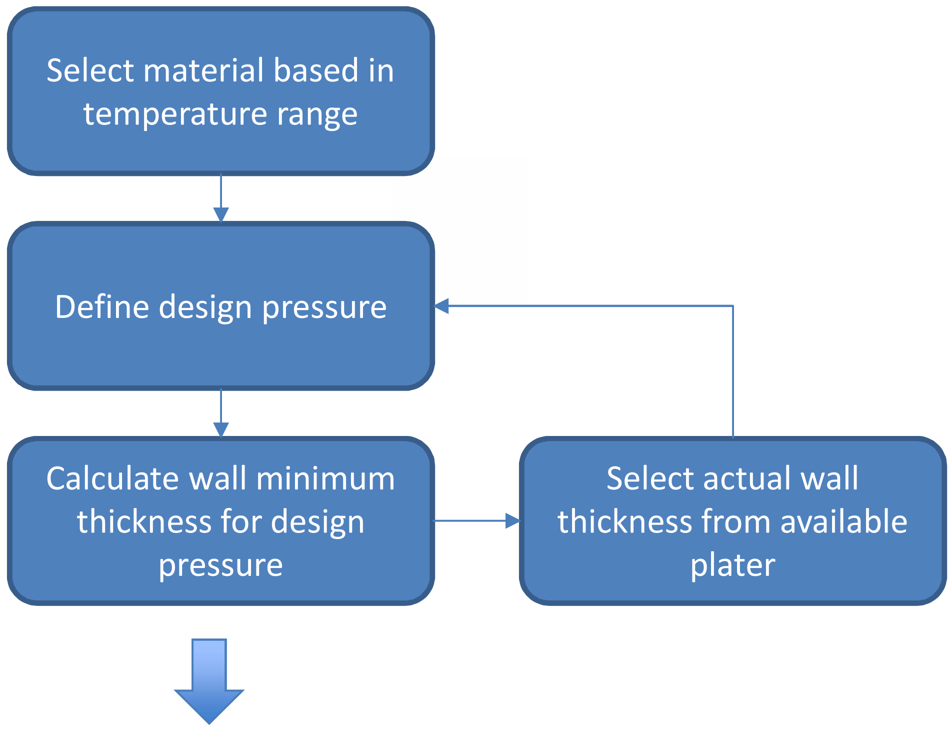
Mechanical Design of Pressure Vessels



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CYCLONIC

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https://www.youtube.com/watch?v=QfTZUMq-LGI

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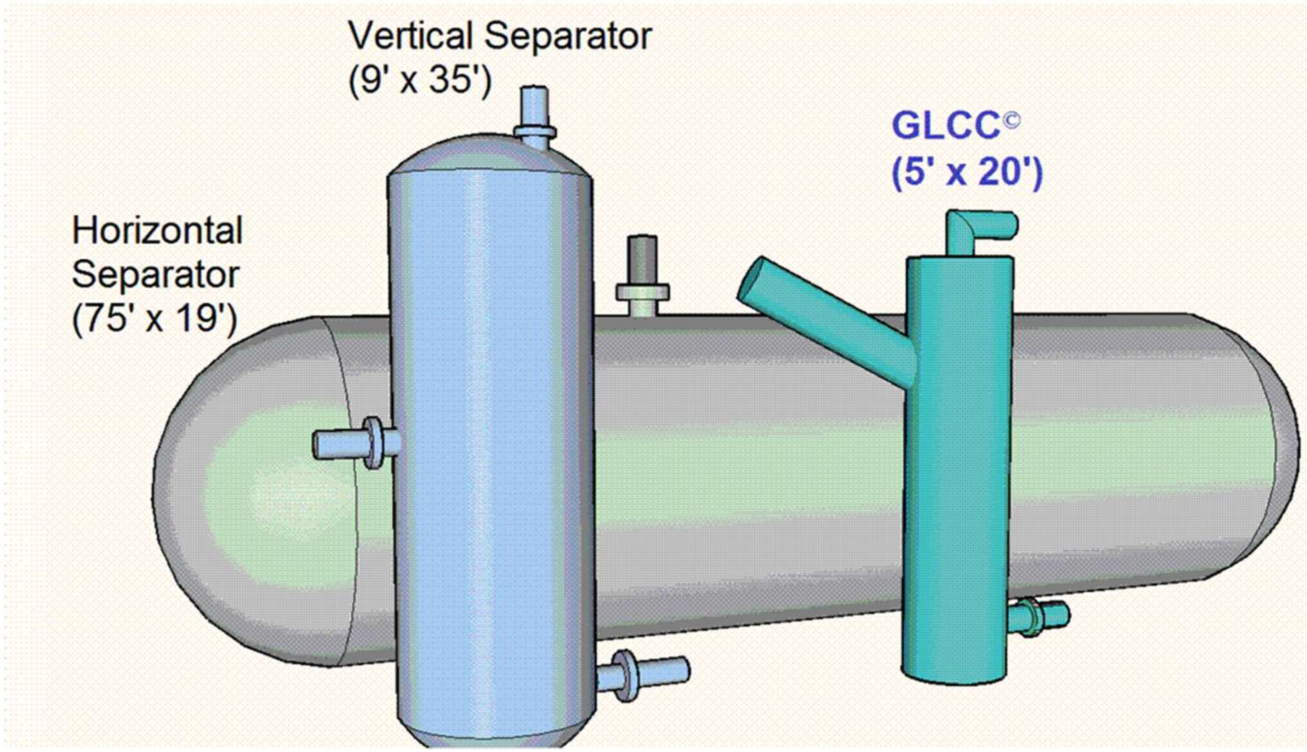

http://www.msieng-int.com/page.aspx?pageid=19

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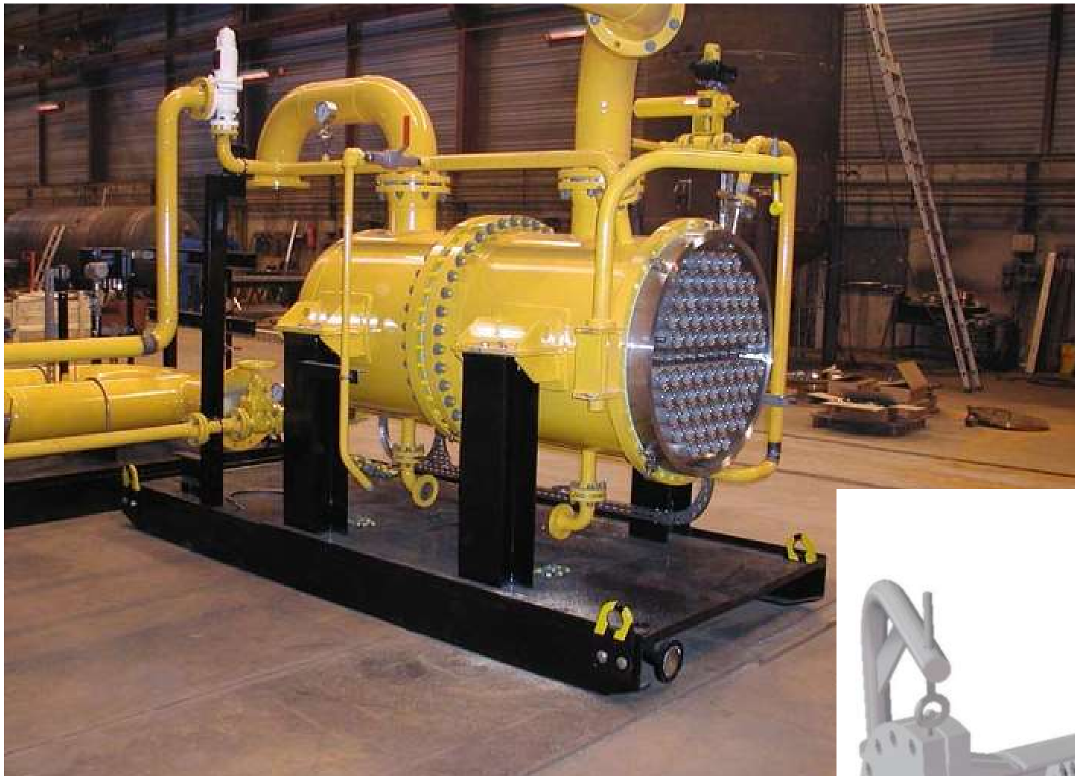
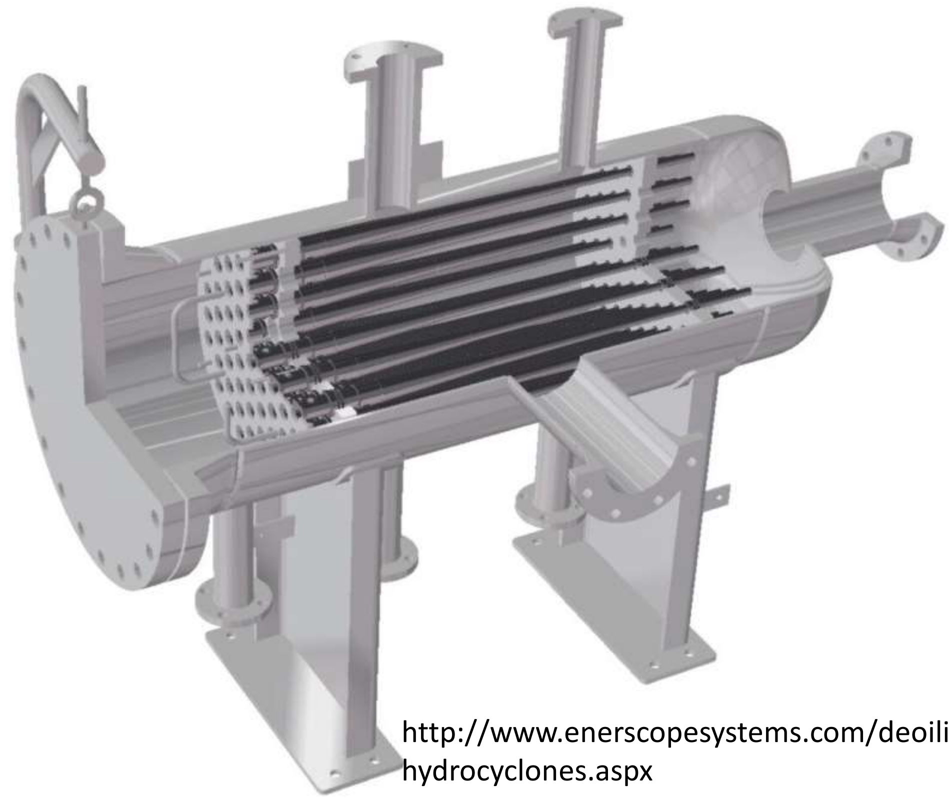
Hydrocyclone





http://www.enerscopesystems.com/deoiling-hydrocyclones.aspx

SUBSEA AND NO STANDARD SEPARATORS

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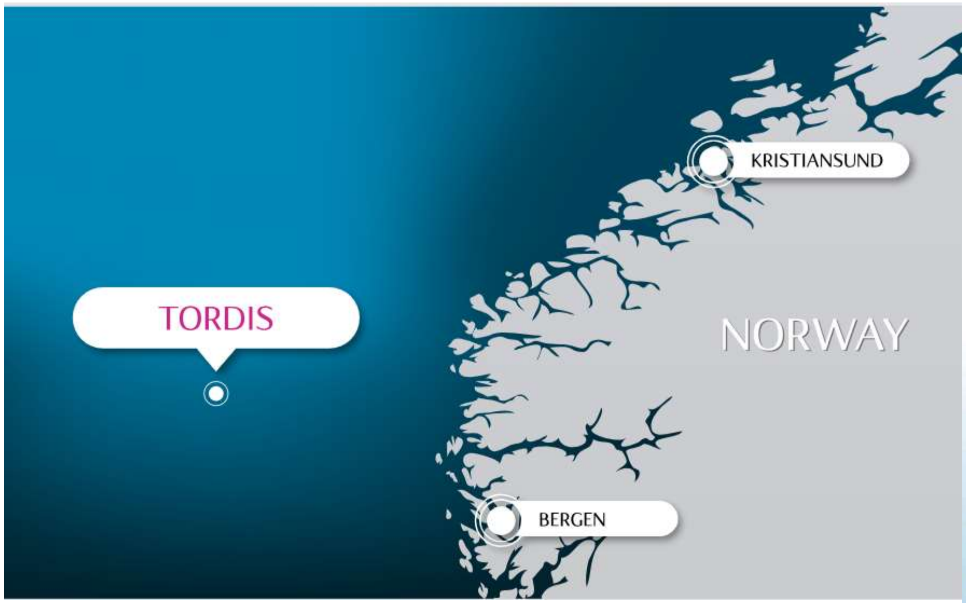
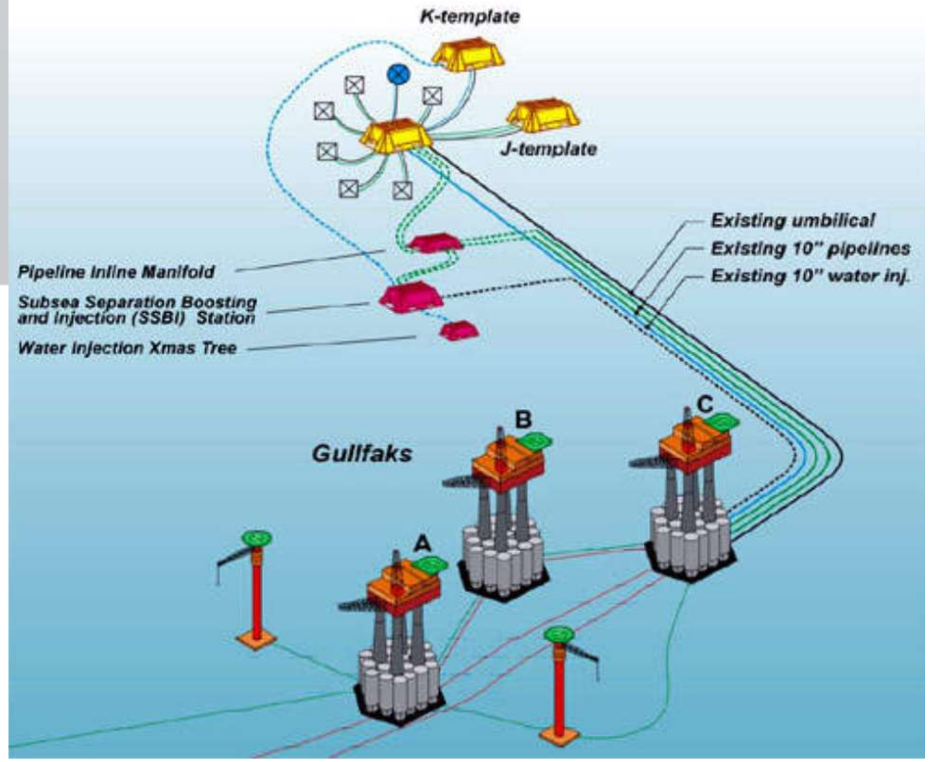
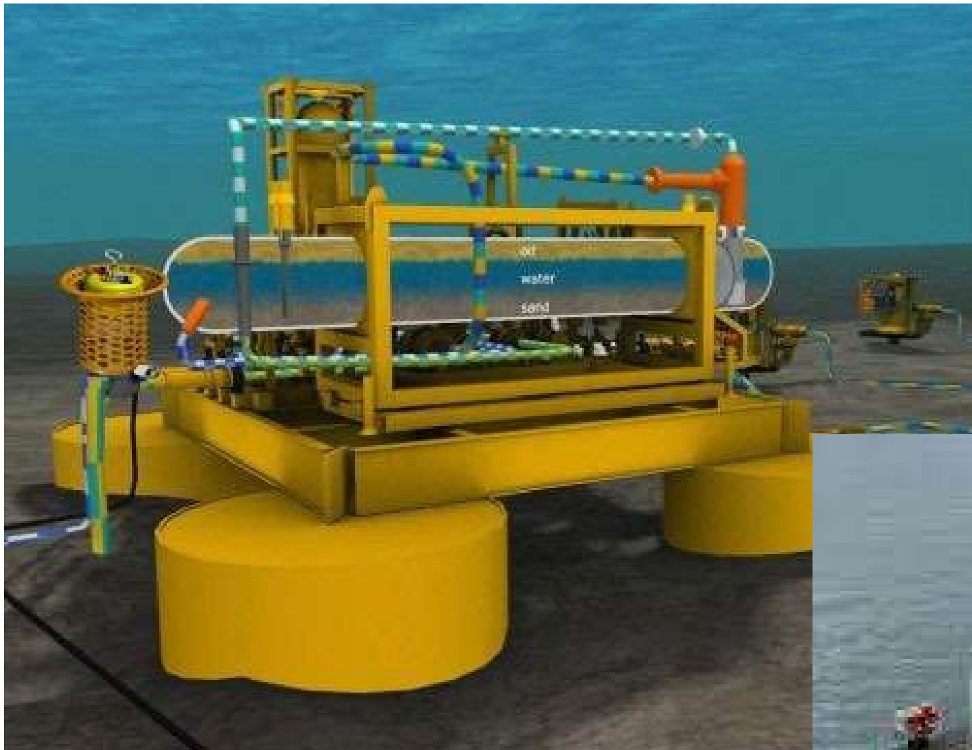
Tordis



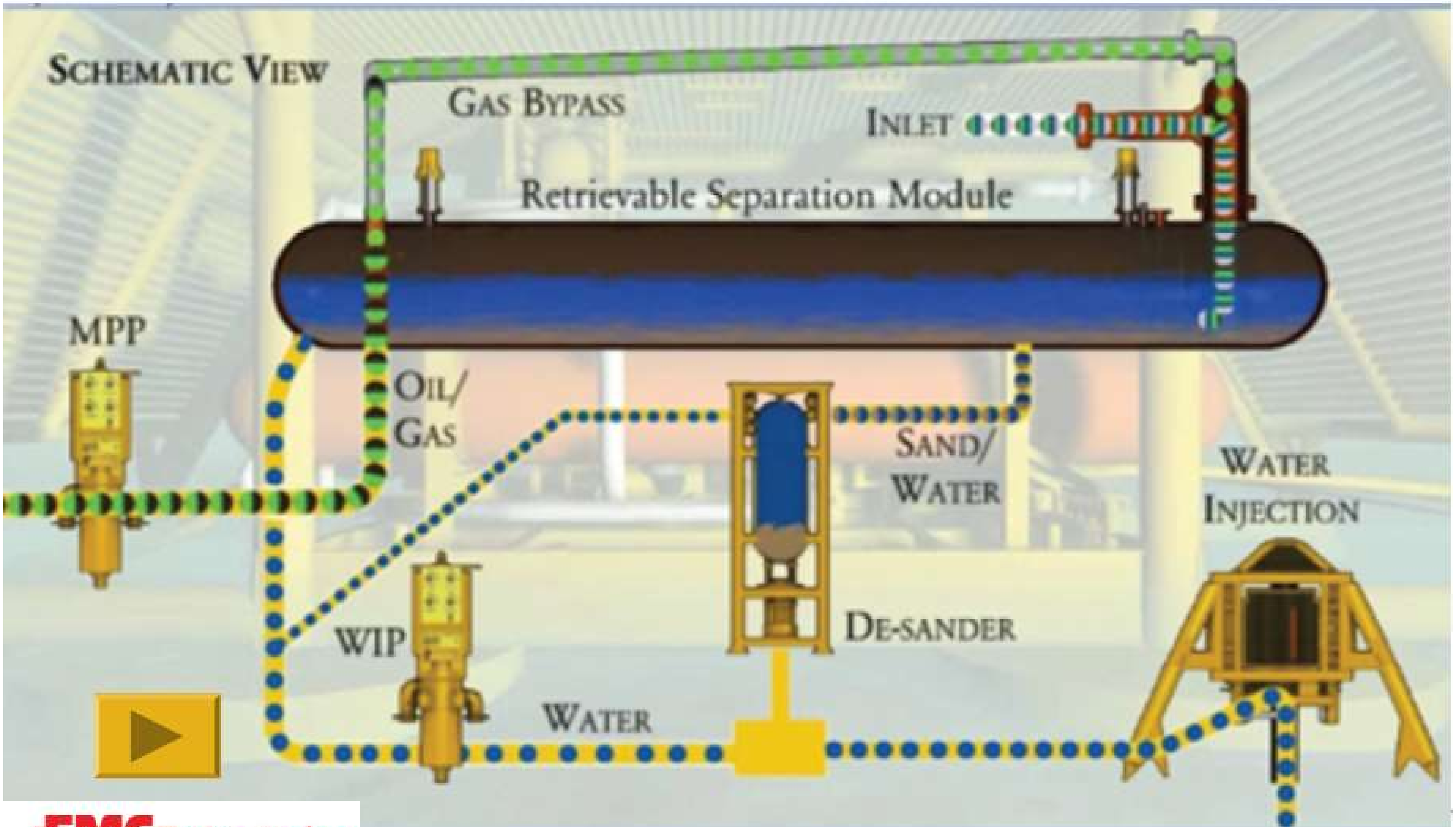


https://www.offshore-technology.com/projects/tordis/attachment/tordis1/

Tordis

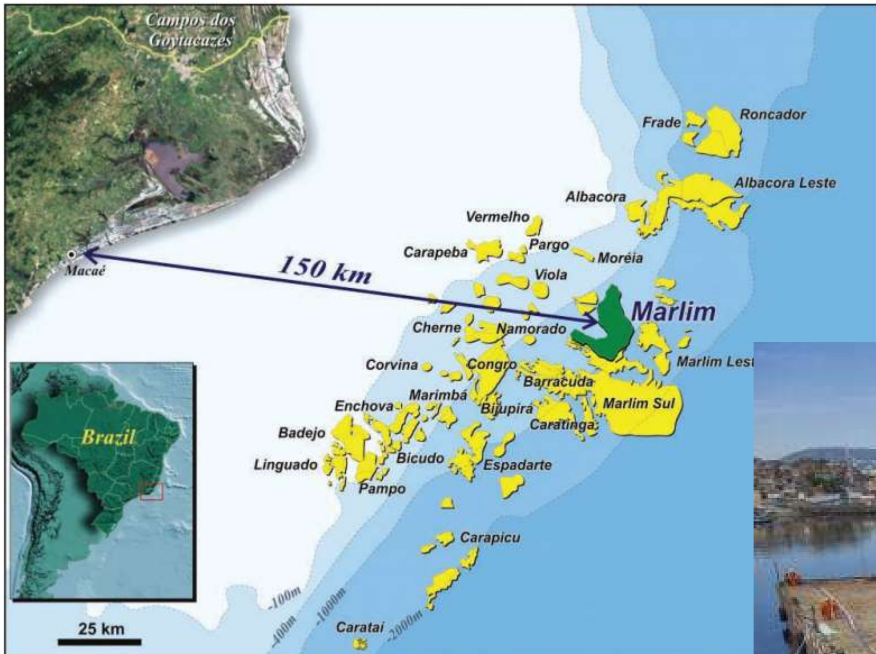


Tordis IOR SSBI
the worlds first full field subsea separation



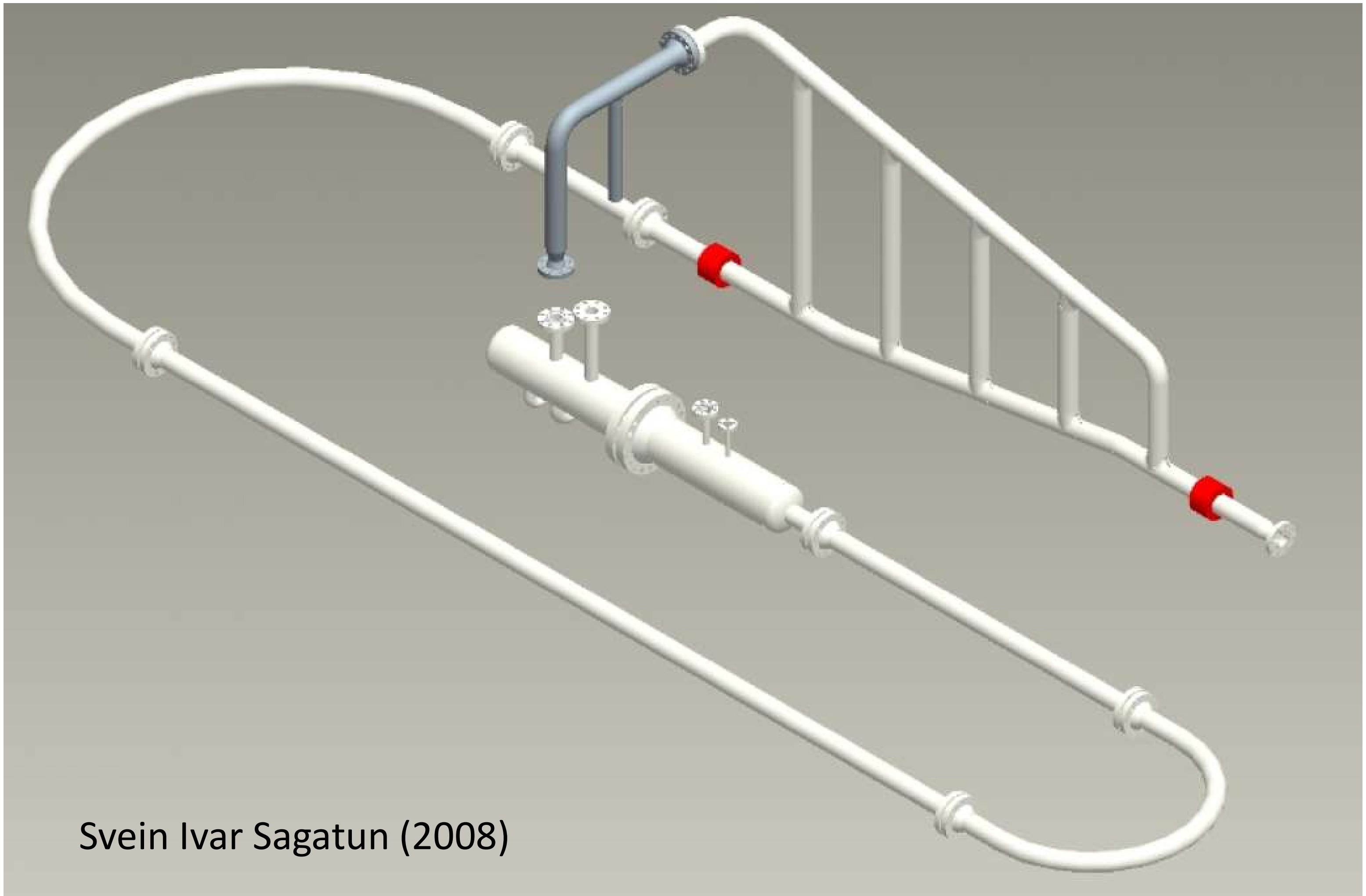
FMC Technologies

Marlim Field

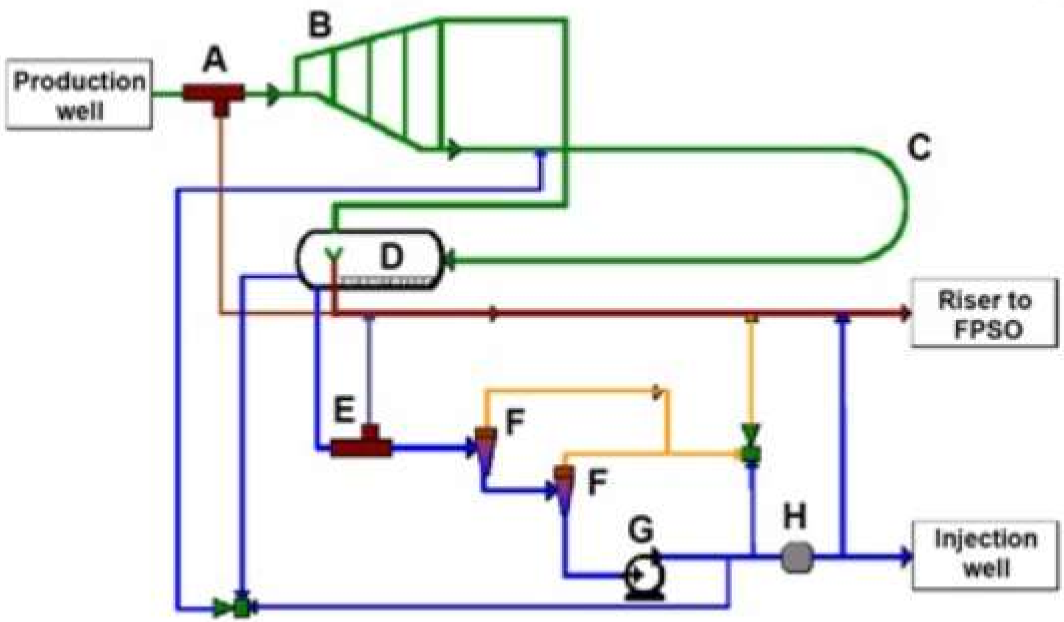


https://fuelfix.com/blog/2012/04/29/separation-system-removes-unwanted-water-at-seabed/

Marlim Field



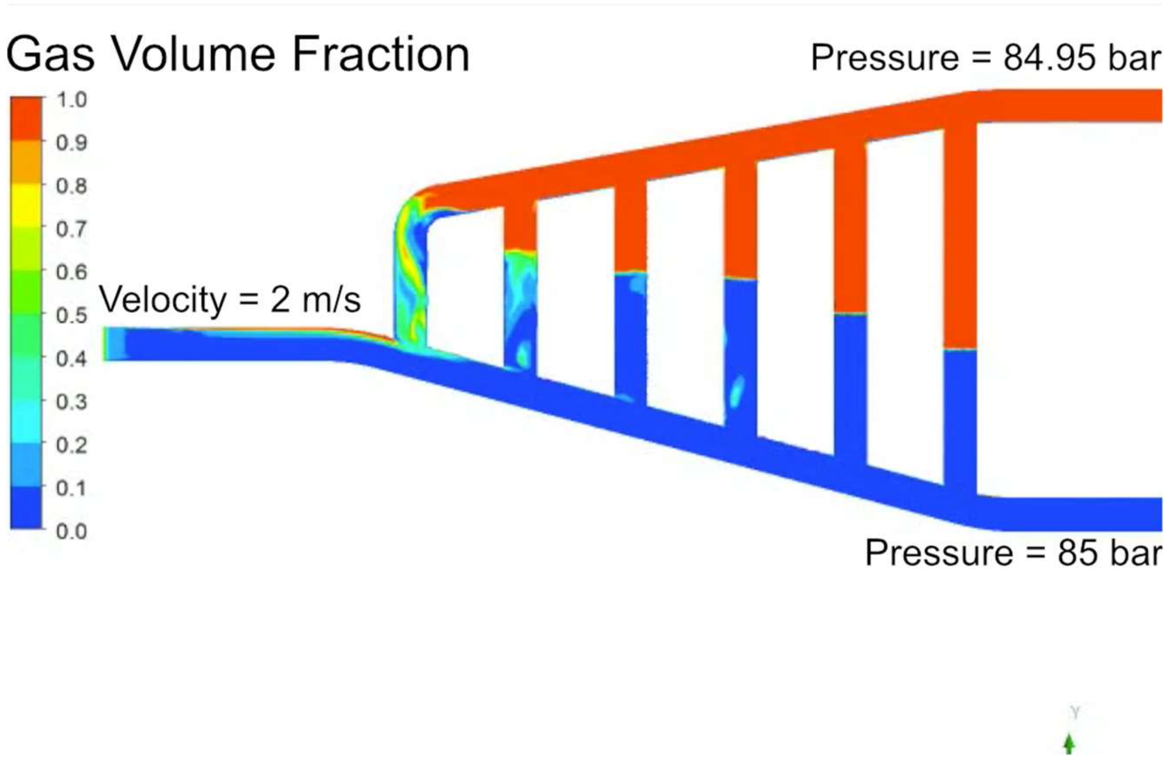
Marlim Field



A. Multiphase desander
B. Harp
C. Tubular separator
D. Outlet vessel
E. Water desander
F. Hydrocyclone
G. Pump
H. OIW monitor
I. Ejector

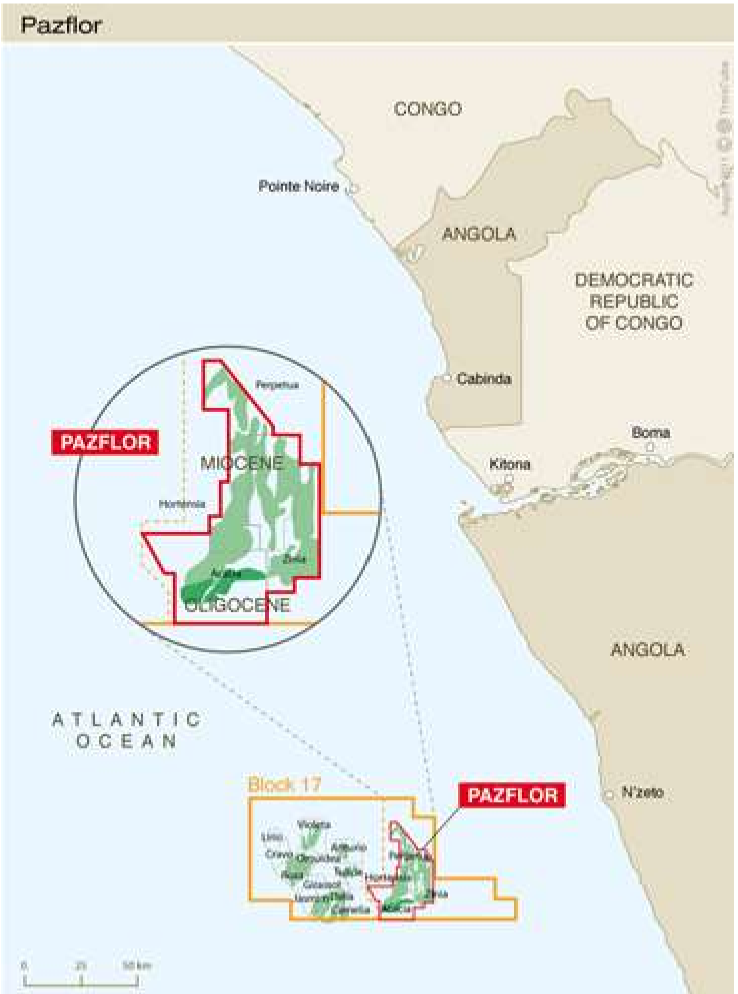
Carlos Capela Morales (2012)

Harp



REFSNES, H. S. (2018).

Pazflor


Pazflor
CONGO
Pointe Noire
ANGOLA
DEMOCRATIC
REPUBLIC
OF CONGO
Cabinda
Boma
Kitona
PAZFLOR
MIOCENE
OLIGOCENE
ANGOLA
ATLANTIC
OCEAN
Block 17
PAZFLOR
N'zeto

Plan

Week Nr.	Week starts	Topic	Lecturer
2	07.jan.19	Course introduction. Overview of field processing. Product specs.	MS
3	14.jan.19	Oil-Gas sep (VLE), Rachford Rice, EOS calculations.	MS
4	21.jan.19	Oil-Gas Separation . Introduction to process simulation (Hysys). Oil-Gas Separation. Bubble and droplet dynamics.	MD
5	28.jan.19	Separation capacity. Oil-water separation	MD
6	04.feb.19	Mechanical Design . Subsea and no standard separators	MD
7	11.feb.19	Water content in Natural gas. Gas dehydration (TEG)	MS
8	18.feb.19	Gas dehydration (TEG)	MS
9	25.feb.19	Pressure calculations in pipe (single and two-phase)	HA
10	04.mar.19	Pressure calculations in pipe (single and two-phase)	HA
11	11.mar.19	Heat transfer, pipe calculations, heat exchangers	HA
12	18.mar.19	Heat transfer, pipe calculations, heat exchangers	HA
13	25.mar.19	Pumping	MD
14	01.apr.19	Compression	HA
15	08.apr.19	Compression	HA
16	15.apr.19	Påskeferie	-
17	22.apr.19	Compression (probably one lecture only)	HA
18	29.apr.19	Spørretime	All

Monday: 12:15-14:00 (P12 PTS)
Tuesday: 14:15-16:00 (VG13 NHL)
Exercise: 16:15-18:00

Exam: 29.05, 15:00-19:00

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- YAYLA, S., IBRAHIM, S. S. & OLCAY, A. B. 2017. Numerical investigation of coalescing plate system to understand the separation of water and oil in water treatment plant of petroleum industry. Engineering Applications of Computational Fluid Mechanics, 11, 184-192.

Source location for pictures

- http://www.oilngasprocess.com/oil-handling-surfacefacilities/two-phase-oil-and-gas-separation/two-phase-separator-equipment/mist-extractor.html
- https://www.indiamart.com/mistermeshwireproducts/mist-eliminator.html
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- https://www.sulzer.com/en/shared/products/2017/03/28/13/41/knitmesh-wire-mesh-mist-eliminators
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- https://www.youtube.com/watch?v=QfTZUMq-LGI
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- http://www.enerscopesystems.com/deoiling-hydrocyclones.aspx
- https://www.forskningsradet.no/servlet/Satellite?blobcol=urldata&blobheader=application%2Fpdf&blobheadername1=Content-Disposition%3A&blobheadervalue1=+attachment%3B+filename%3DAnnChristinGjerdseth.pdf&blobkey=id&blobtable=MungoBlobs&blobwhere=1274467401857&ssbinary=true
- https://www.offshore-mag.com/articles/print/volume-68/issue-5/field-development/total-turns-to-subsea-separation-for-problematic-pazflor-crude.html
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