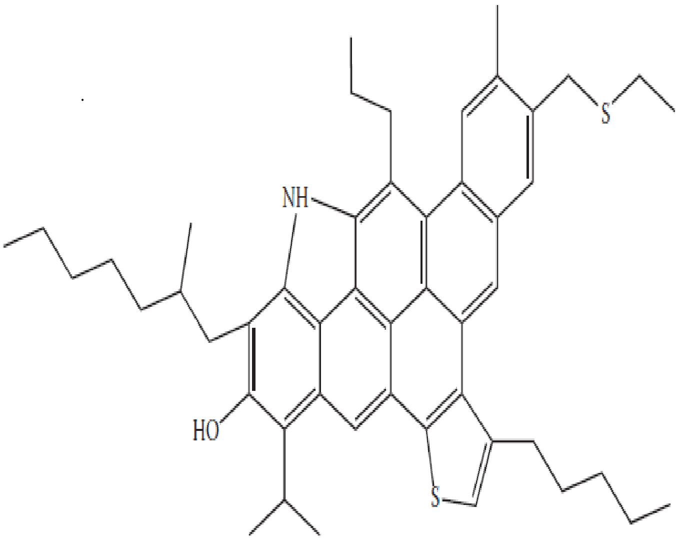
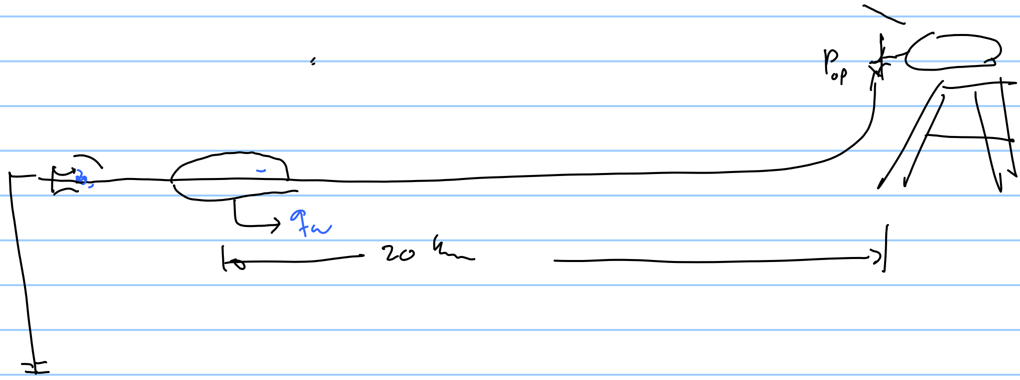
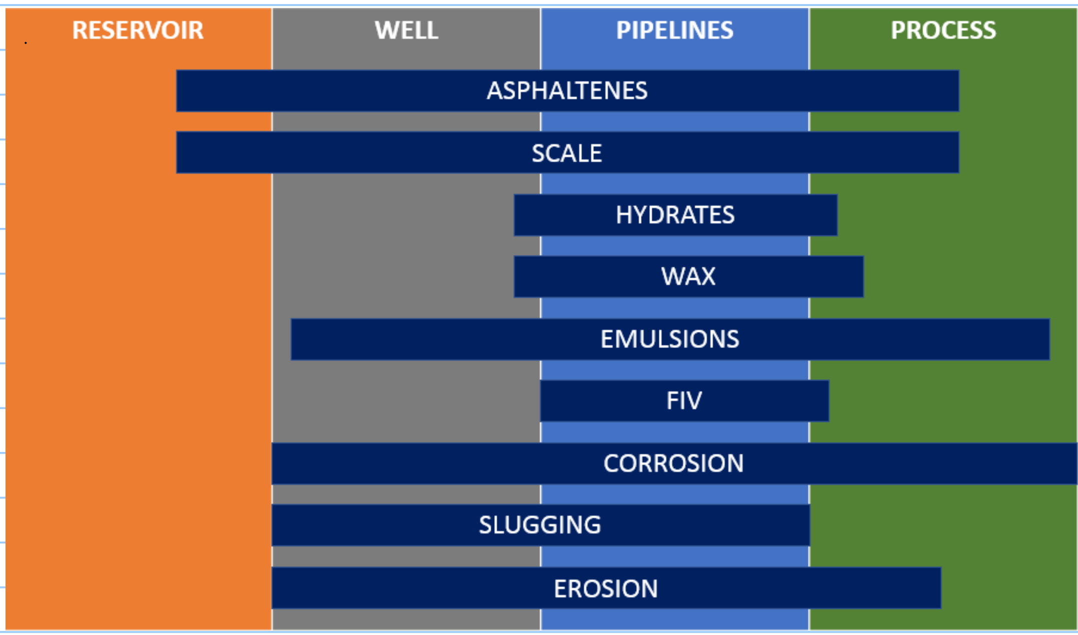
asphaltene molecule

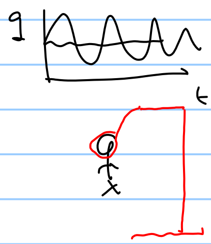


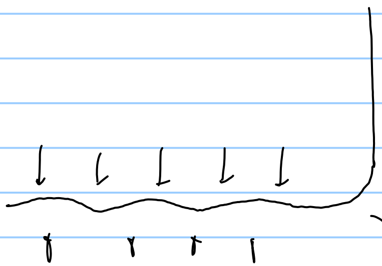
emulsion

$$\rho_{mix} = \rho_w \alpha_w + (1-\alpha_w)\rho_o$$









slugging in wells

- Others issues to consider are :
  - bacteria (biocide)
  - against O_2, H_2S (scavengers for O_2 H_2S sequestration) corrosion
  - anti foamers liquid + gas
  - DRA ~ Drag reducing agent ~ reduce Δp in pipe

Production chemicals
- → cost
- → compatibility
- → environmental impact

EOR processes ~ polymers
→ nanoparticles

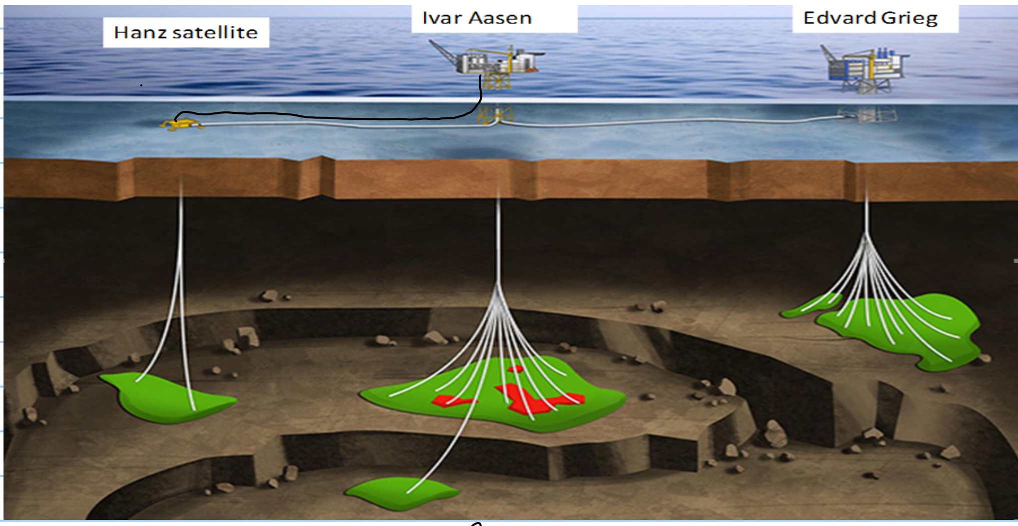
→ many of production chemicals will end up in liquid phase ~ oil
→ water

better for environ
bad for refinery

injection

disposal to sea

under allowable concentration



Ivar Aasen Consequence study

Tabell 5-2. Foreløpig oversikt over kjemikalietyper

Type kjemikalie	Konsentrasjon (ppm vol.)	Tilsettes i	Frekvens
Avleiringshemmer A	50	Produsert vann	Kontinuerlig
Avleiringshemmer B	20-50	Sjøvann	Kontinuerlig
Korrosjonshemmer	50	Produsert vann	Kontinuerlig
Emulsjonsbryter	50	Total væske 1)	Kontinuerlig ved behov
Skumdemper	5	Total væske	Periodisk
Flokkulant	10	Produsert vann	Kontinuerlig
Vokshemmer	150	Total væske 1)	Periodisk
Biocid	80	Total væske 1)	Kontinuerlig
Oksygenfjerner	5	Sjøvann	Kontinuerlig
H2S fjerner	150	Produsert vann	Kontinuerlig ved behov
MEG	Batch	Brønnstrøm	Ved behov

1) Olje og produsert vann.

scale

defoamer

flocculat

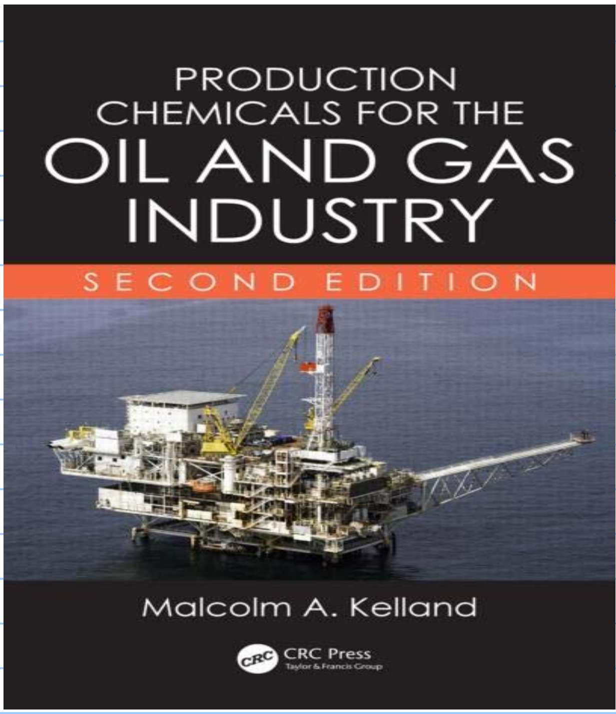
wax

hemmer : inhibitor

- continuous
- periodic
- as required. ← to remove scale deposits
  → during shutdown period
  - hydrate
  - wax

most of these chemicals are not recovered, reclaimed

except
MEG
MeOH
TEG



1. increased Δp, flow restriction, blockage
2. integrity problems
3. Loss in functionality of components

Summary table

flow assurance issue	consequence	corrective measures
Slugging	1, 2, 3	selection of ϕ, trajectory of pipeline, filling or digging the seabed, control scheme. slug catcher ~ 1st stage separator
wax	1	insulation design, heat tracing requirement of pigging loop chemical inhibitor ~ amounts to inject → distribution system
hydrate	1, 3	insulation design, heat tracing, chemical inhibitor ~ amounts → distribution system
scale	1, 3	chemical inhibitor ~ amounts → distribution system ← in well injection

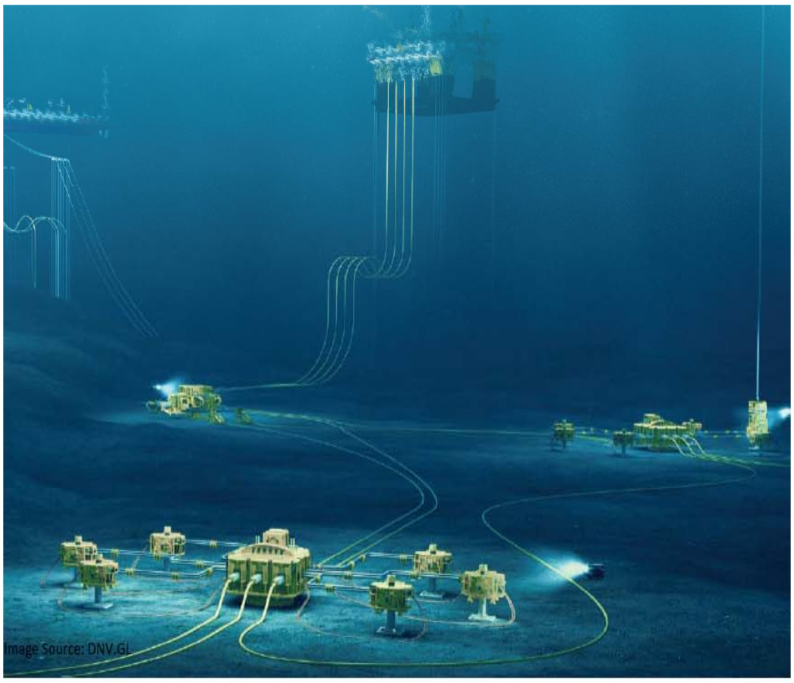
Erosion	2, 3	• pipe size and diameter • flowline dimensioning • component dimensioning
Corrosion	2	chemical inhibitor → amounts → distribution system ← in well injection
Emulsion	1	chemical inhibitor → amounts → distribution system ← in well injection

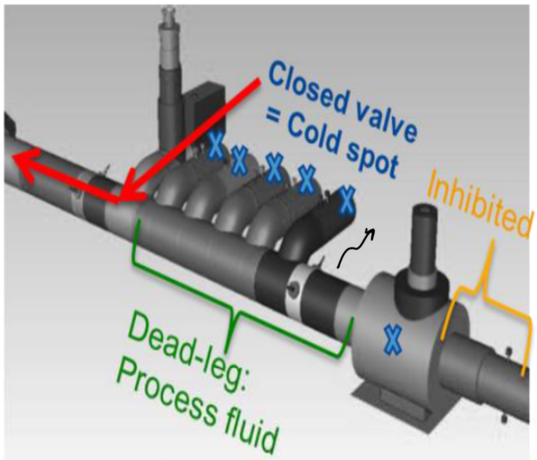
design and study of flow assurance problems in dead legs is also importants

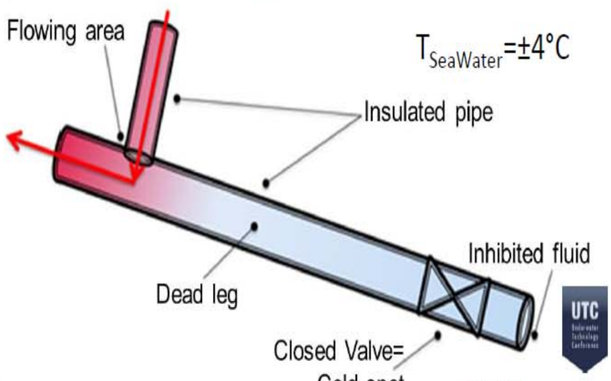
places where there is no flow during normal operations

Subsea manifold and dead-leg geometry

• Dead-legs are inherently present







Considerations during field development:

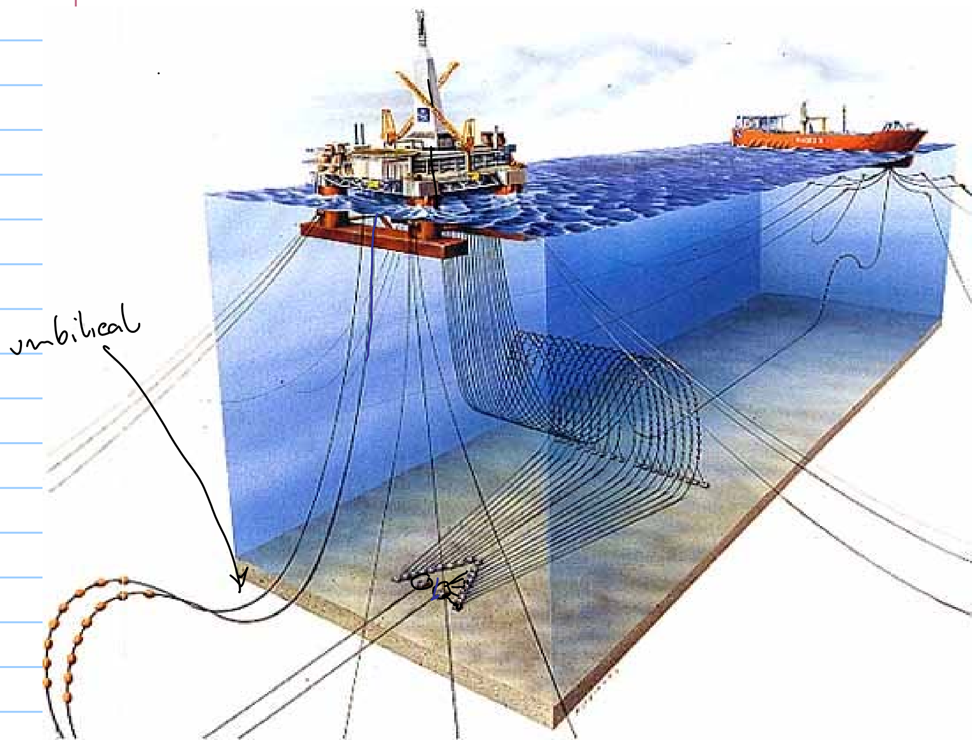
Early studies → many development options
↳ detect potential showstoppers
- ↳ slugging
- ↳ wax
- ↳ hydrate

↳ FEED → (Front End Engineering design)
a specific alternative selected
↳ in detail study →
- hydrate management plan
- ↳ wax management plan
- ↳ detailed pipeline design
- ↳ prediction of temperature, velocities, pressures in components: dead legs, erosion, cold spots
- FIV

↳ EPC Engineering Procurement Construction

- Tools used for analysis
  - multiphase flow simulator {hysys, gap, pipesim}
  - transient flow simulators {olga, Leda, Flow manager}
    ↳ predict {P, T, α_o, α_g, α_w} along the pipe for different times.
  - PVT analysis
    - Lab test
    - develop a EOS that represents with an acceptable accuracy my fluid
    - Wax (WAT), hydrate, scale, emulsion
  - Lab test → predict erosion rates
  - CFD computational fluid dynamics {V_x, V_y, V_z, P, T in a 3D domain}
  - FEA Finite element analysis {displacement, stresses in a 3D geometry}
  - Standards ~ cookbook, Recommended practice.

delivery system for production chemicals:



Njord

CDU
control distribution unit
SDU
subsea distribution unit

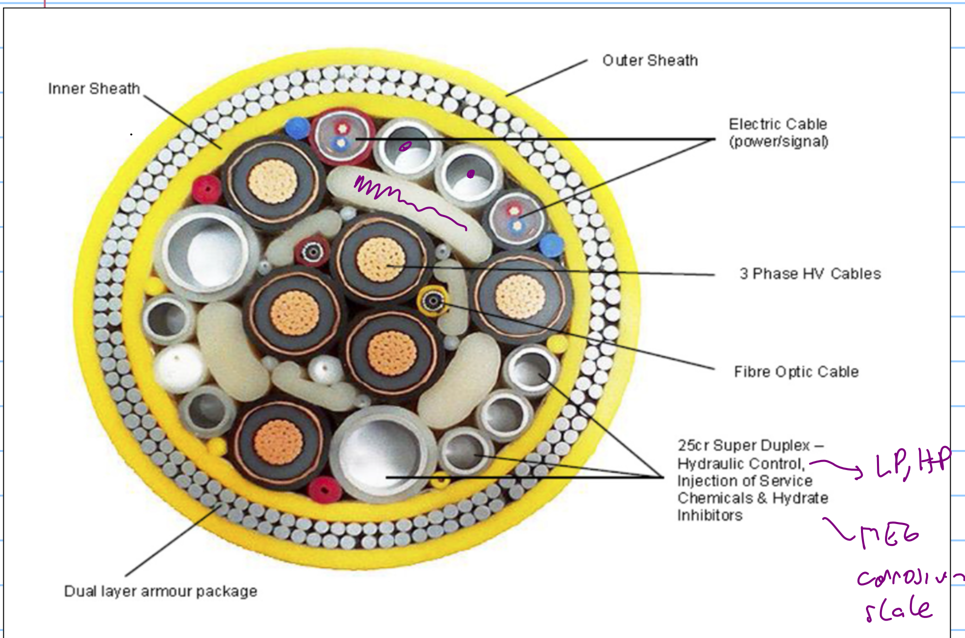
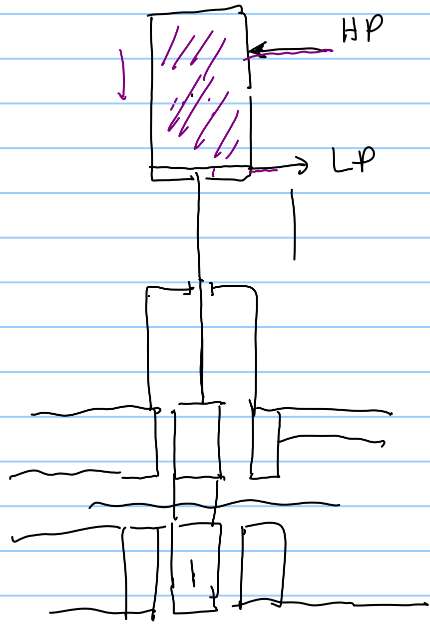
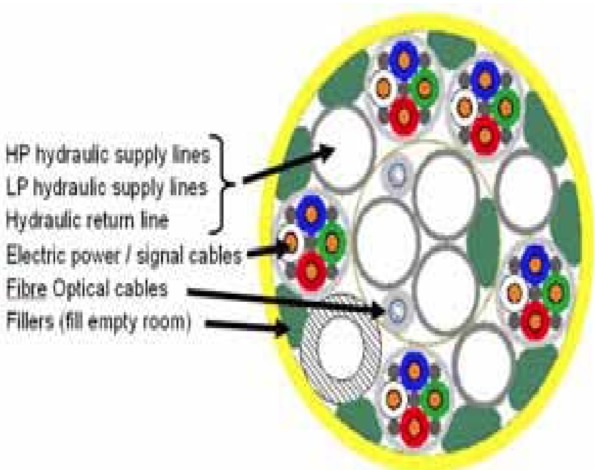
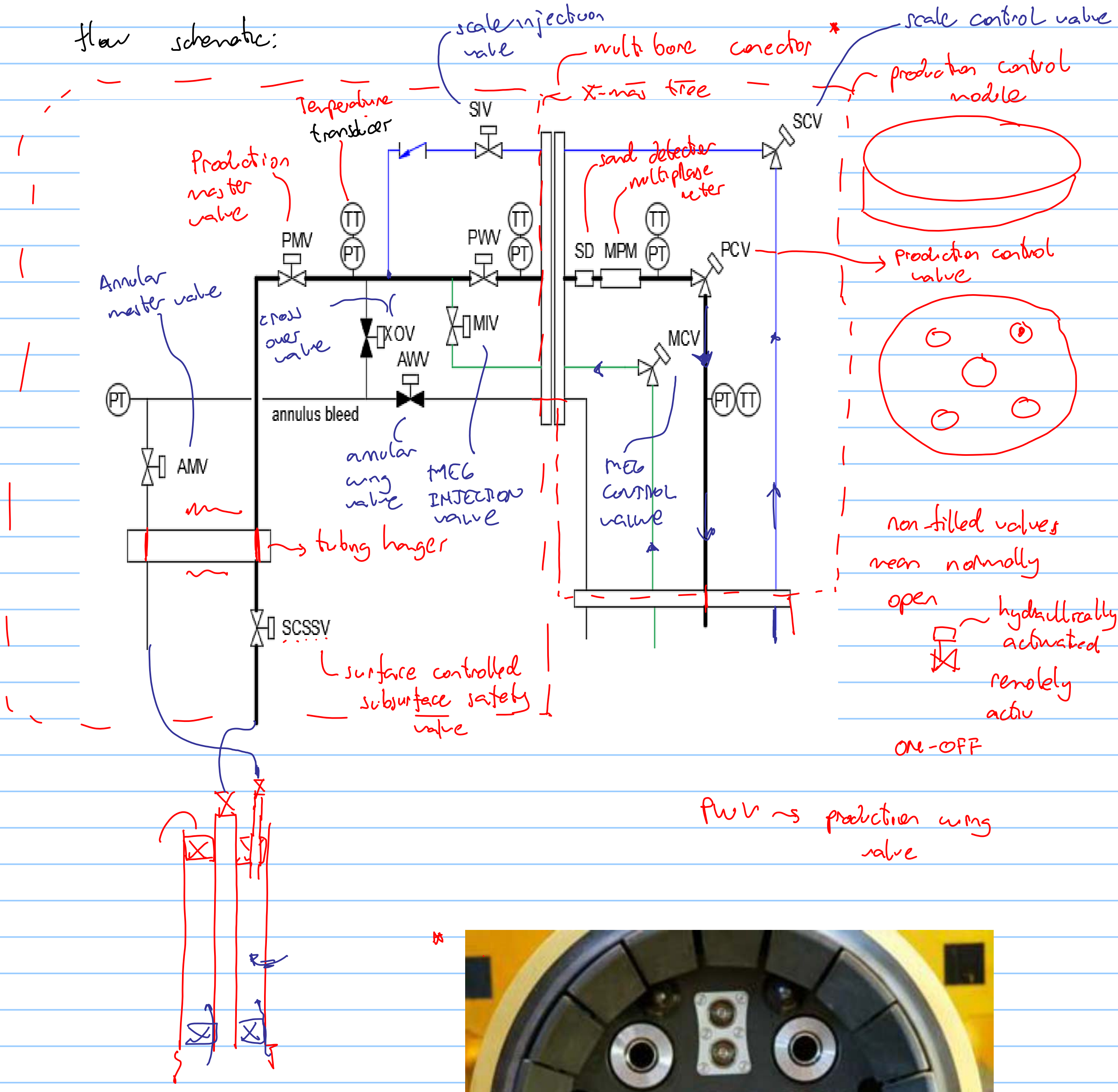


Figure 3 – Umbilical Cross Section Example





Flow schematic:



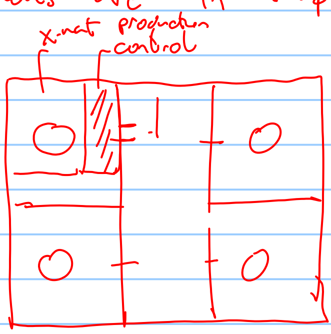
non-filled valves mean normally open

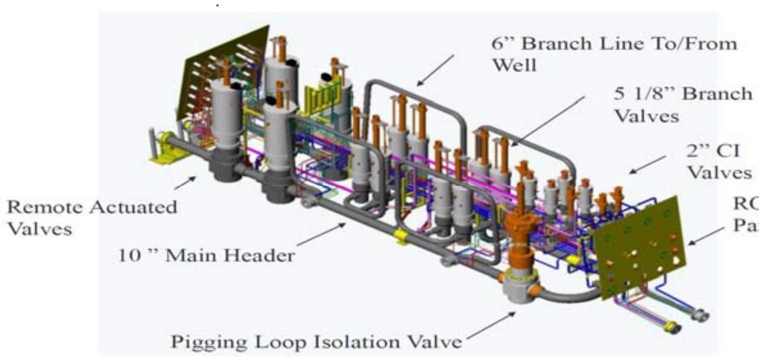
hydraulically activated remotely activ

ON-OFF

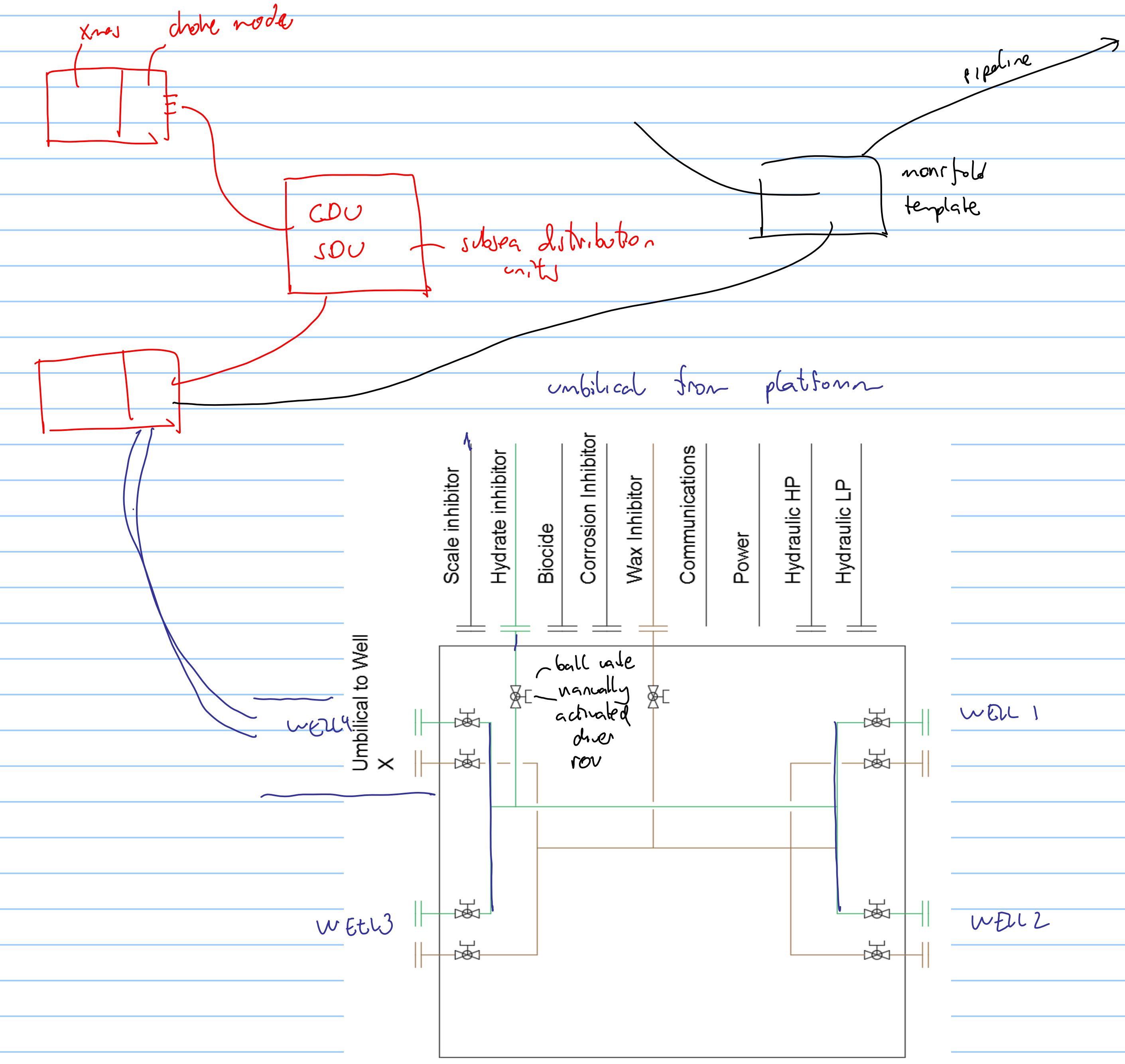
PWV → production wing valve

if the wells are in templates

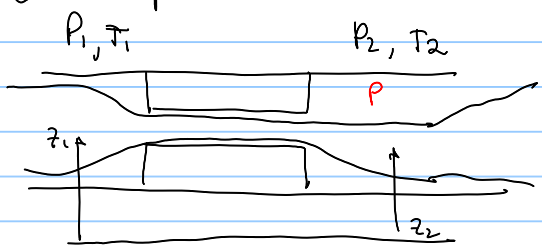




sf well are satellite



fluid Cooling due to expansion in chokes

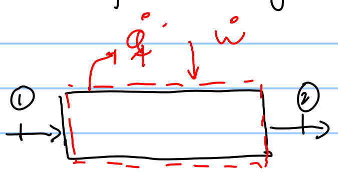


$\Delta p = P_1 - p_2$

$T_1 \approx T_R$

T_2 might be very different from T_1, specially if mainly gas

1rst law of thermodynamics for open systems



$$\dot{q} - \dot{w} = \dot{m}\left(u_2 + \frac{P_2}{\rho_2} + \cancel{z_2 g} + \cancel{\frac{v_2^2}{2}} - u_1 + \frac{P_1}{\rho_2} + \cancel{z_1 g} - \cancel{\frac{v_1^2}{2}}\right)$$

for chokes $\dot{q} = 0$ $\quad z_1 \approx z_2 \quad v_1 \approx v_2$

$\dot{w} = 0$

h enthalpy   for values $h_1 = h_2$ isenthalpic

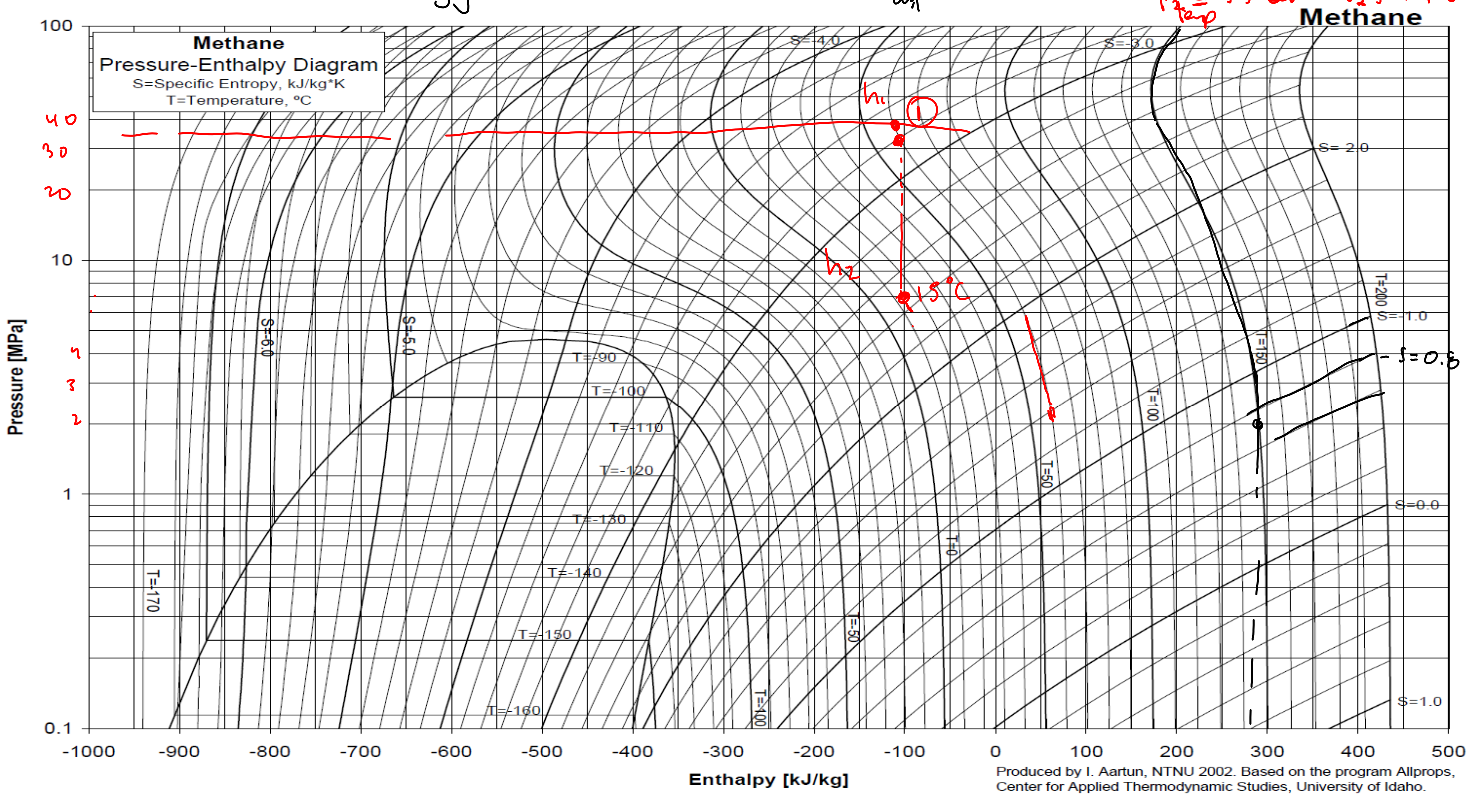
$h = u + pv$ $v = \frac{1}{\rho}$

↳ internal energy

$T_1 = 70°C$ $\Delta P_{choke} = 267$ bara

$P_{wh} = 343$ bara

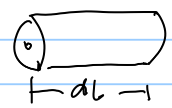
$P_2 = 77$ bar   7.7 MPa



Temperature drop in pipe ~ conduits

$$\dot q - \cancel{\dot w} = \dot m \left(u_2 + \frac{P_2}{\rho_2} + \cancel{z_2 g} + \cancel{\frac{v_2^2}{2}} - u_1 + \frac{P_1}{\rho_2} + \cancel{z_1 g} - \cancel{\frac{v_1^2}{2}}\right)$$

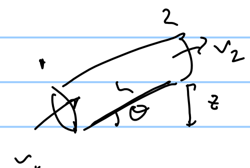
$$d\dot q = \dot m \left(dh + dz\, g + v\, dv\right)$$ divide by dL



$$\frac{d\dot q}{dL} = \dot m \left(\frac{dh}{dL} + \frac{dz}{dL} g + v\frac{dv}{dL}\right)$$

$$\frac{dz}{dL} = \sin(\theta)$$

pipe inclination



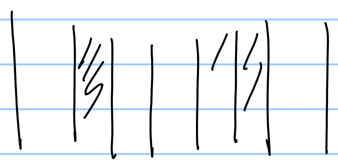
$$\underbrace{\frac{d\dot q}{dL}} = \dot m \left(\underbrace{\frac{dh}{dL}}_{EOS} + \sin\theta\, g + \underbrace{v\frac{dv}{dL}}\right) \frac{dp}{dL}$$

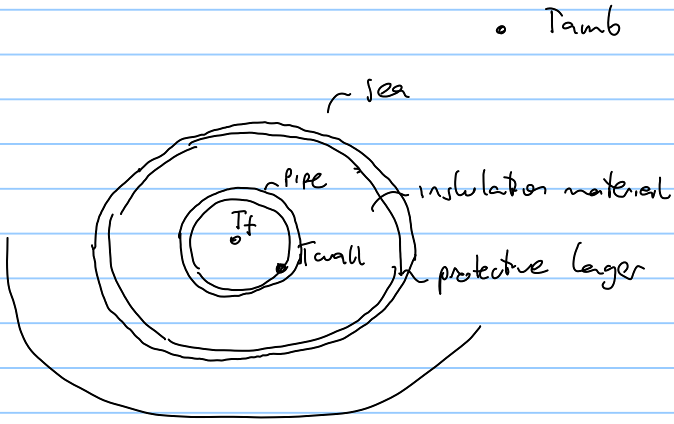
EOS

fluid model

$h = f(P, T)$

the cross section of a pipe segment

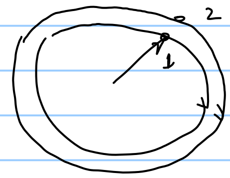




heat transfer

in solids conduction

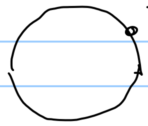
$$\dot{q} = 2\pi L \cdot \underbrace{k}_{\text{conductivity of material}} \left(\frac{T_1 - T_2}{\ln\left(\frac{r_2}{r_1}\right)} \right)$$



- pipe wall
- insulation material
- soil.

in liquid convection → free / → forced convection

$$\dot{q} = 2\pi r L h (T_1 - T_2)$$



$$(T_f - \cancel{T_{wall}}) = \frac{\dot{q}}{2\pi r L h_{int}}$$

$$(\cancel{T_{wall in}} - T_{wall out}) = \frac{q}{2\pi r L k} \ln\left(\frac{r_2}{r_1}\right)$$

$$(T_f - T_{amb}) = \dot{q} \left(\overset{con}{} + \overset{cond1}{} \quad \overset{cond2}{} \quad \overset{con3}{} \quad \overset{conv}{} \right)$$