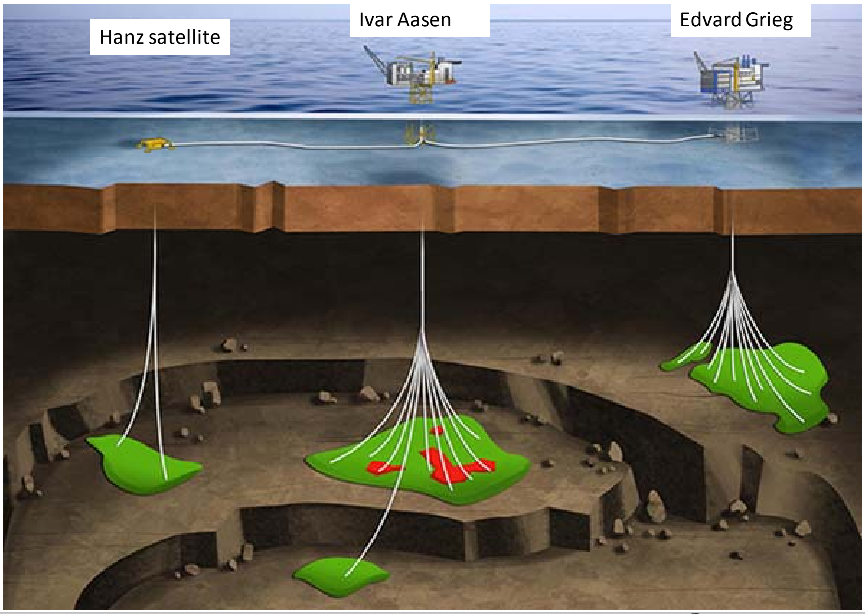
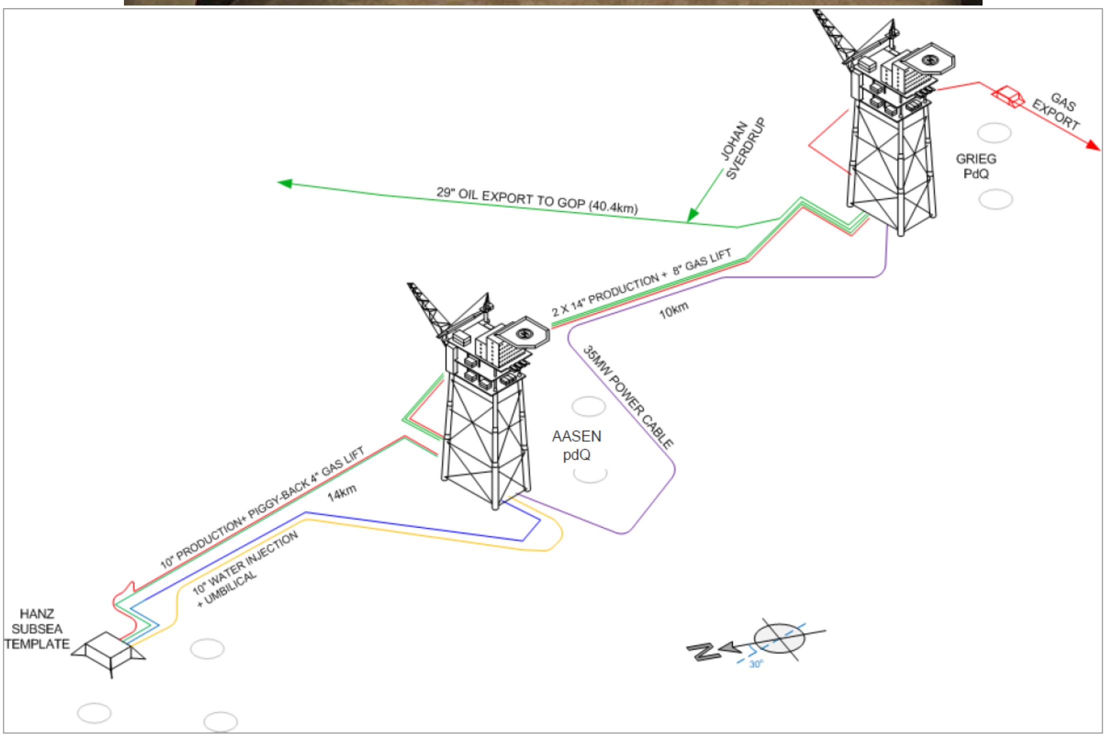
Exercise set 04

Problem 1: Early flow assurance studies for the satellite of Ivar Aasen.

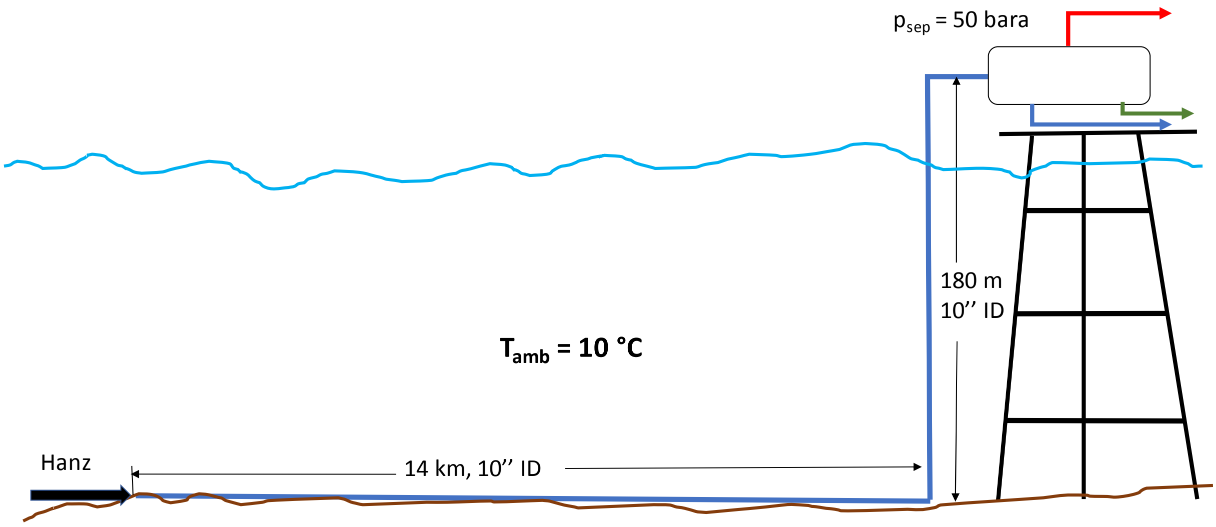
It is currently year 2010 and Det Norske (aka Aker BP) is performing field development studies for the Ivar Aasen field. The field will produce three reservoirs: Ivar Aasen, Hanz and West Cable. Ivar Aasen and West Cable will be produced with wells drilled from a fixed steel jacket. Hanz is located about 14 km from the platform, thus it will be produced using 1 subsea well in a template and tied-back to the platform. The production well will be gas lifted. There will be also a water injector on the template for pressure support.

The platform will have only one stage separator of oil, gas and water. The production will be transported further to the platform of Lundin, Edvard Grieg.





You are in the flow assurance team of Det Norske. Your first task is to compute the pressure and temperature profiles in the main transportation pipe. The pipeline profile is presented below.



The composition of the fluid at production startup is presented below.

Component	Mole Fraction
Nitrogen	0.0013
CO2	0.0003
Methane	0.8551
Ethane	0.0149
Propane	0.0095
i-butane	0.0047
n-butane	0.0028
i-pentane	0.0025
n-pentane	0.0016
Hexanes	0.0057
Heptanes	0.0130
Octanes	0.0158
Nonanes	0.0120
Decanes	0.0607

Your tasks are:

Compute the temperature drop from the wellhead to the separator (co-current). Assume that the wellhead temperature is 85 C.

Compute the pressure drop counter current starting from the separator. Use two segments in the vertical section (each of 90 m) and 14 segments of 1km length in the horizontal section.

The total mass flow of hydrocarbons is 27000 kg/h. Assume that, at production startup, no water is being produced.

The temperature drop along a pipe segment can be estimated using the expression below:

$$T(x) = T_{amb} + \left[T(x=0) - T_{amb}\right] \cdot e^{-x/A} + \frac{1}{C_p} \cdot g \cdot \sin(\theta) \cdot A \cdot \left(1 - e^{-x/A}\right)$$

Where

$$A = \frac{\dot{m} \cdot c_p}{2 \cdot \pi \cdot r_a \cdot U}$$

Nomenclature for temperature calculations:

$T(x)$ = Temperature of flowing fluid at given position “x” [°C]

$T(x=0)$ = Fluid temperature at inlet of the section [°C]

T_{amb} = ambient temperature (ocean) [°C]

x = distance along the pipe [m]

$\dot{m}$ = mass flow rate, [kg/s]

r_a =External radius of the conduit (with insulation) [m], 12”

c_p = heat capacity of flowing fluid, [2.45 kJ/kg °C]

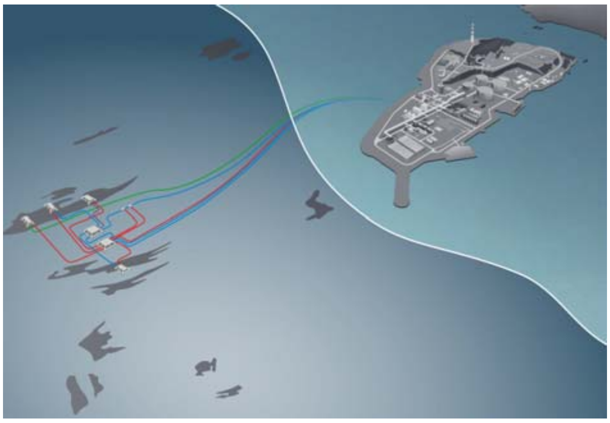
U = Overall heat transfer coefficient [2.5 W / m^2 °C]

θ = pipe angle (in radians) from the horizontal

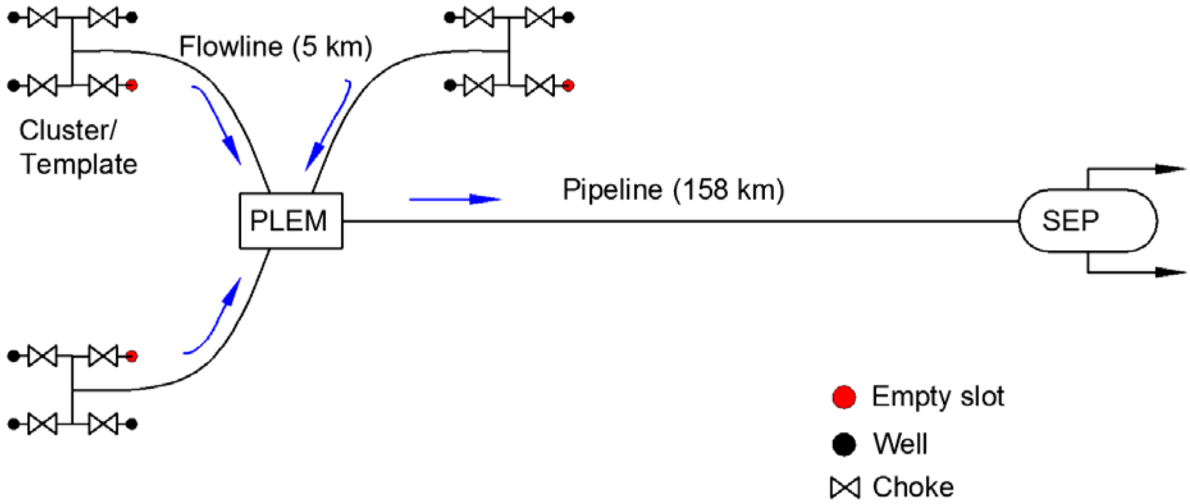
If the WAT is 32.5 °C. Is there any risk of wax formation in the pipeline?

PROBLEM 2: Flow assurance analysis of the Snøhvit pipeline using Hysys

It is year 1999. Snøhvit is an offshore gas field located in the Barents Sea 158 km from Hammerfest currently under development. The field will be developed with the “subsea to beach” concept. The gas production will be taken by a LNG plant and transported further in LNG carrier to customers in US and Spain. The plateau rate of the field has been set to 20E6 Sm^3/d and Statoil plans to maintain it until year 2032.



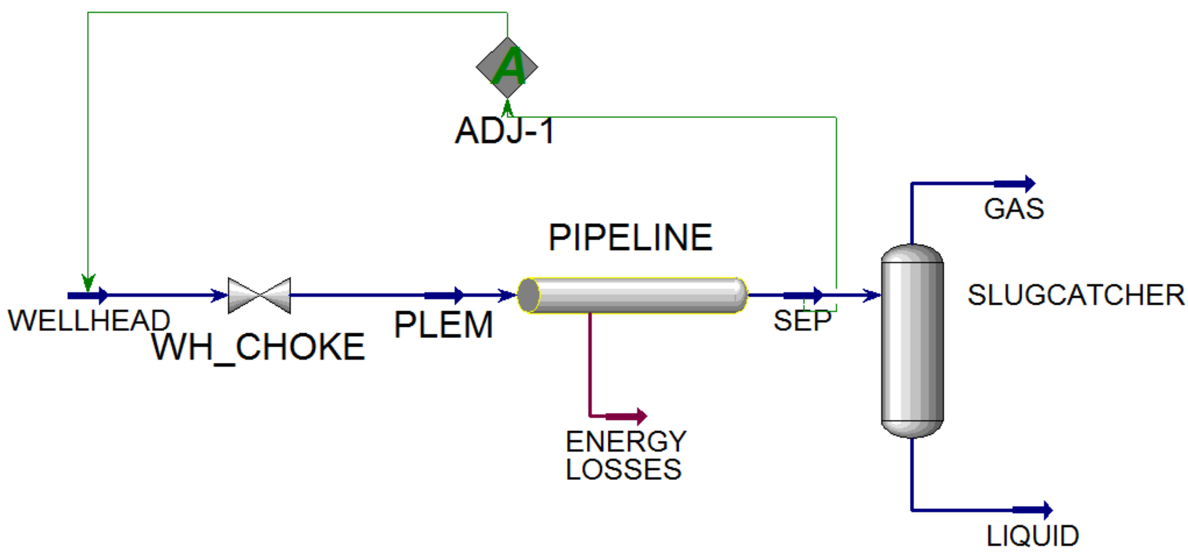
According to the base case Scenario (BCS) selected for the study, the field is completed subsea with three subsea templates, each with 4-slots.



You are asked to perform a simulation to compute pressure and temperature drop along the main transportation line of (approx. 158 km) from the PLEM (pipeline entry module) to the slug catcher. Most of the relevant information required is given at the end of the exercise.

The inlet temperature to the pipeline is the biggest unknown. Experts have estimated that the temperature at the wellhead (upstream the choke) will be very similar to reservoir temperature (90 °C). However, they have also indicated that, to keep plateau production, the choke will generate a significant pressure drop (starting from 162 bara the first day of production). The expansion in the choke will create a cooling effect reducing dramatically the temperature of the fluid.

In your studies, assume that the wellhead temperature is 90 °C. Perform an isenthalpic expansion and then use that temperature as the temperature at the inlet of the pipeline (neglect the temperature drop along the flowline between the template and the PLEM. Your Hysys layout should look something like the picture below:



Tasks:

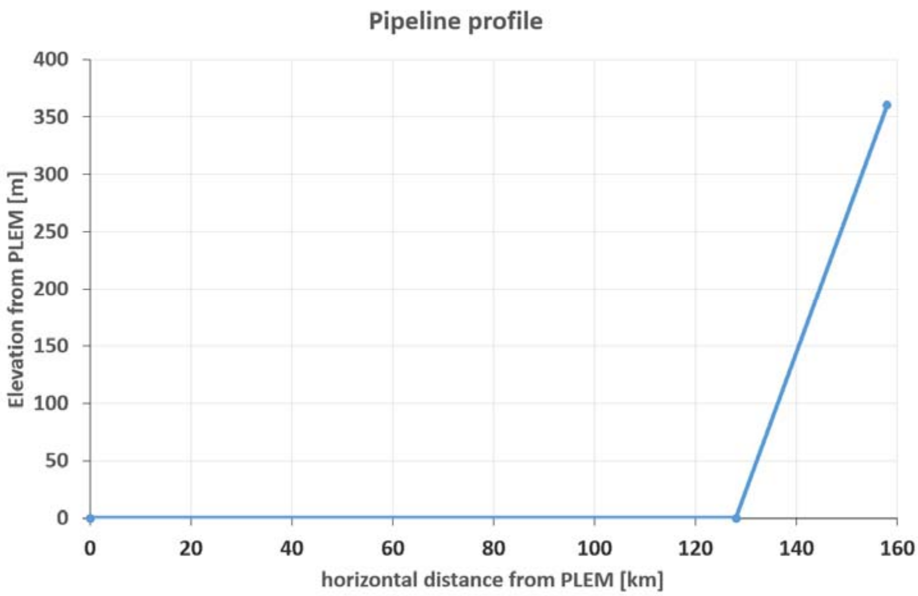
- Tabulate and plot pressure, temperature and liquid holdup along the pipeline.
- Plot the phase envelope (P-T diagram) of the gas mixture illustrating the saturation lines (bubble and dew point lines) and the quality lines inside the two-phase region

(0.01, 0.02, 0.03, 0.04, 0.05, 0.1, 0.2). Plot also the hydrate line provided. Indicate in your plot the following:
- Cricondenbar and Cricondentherm points
- The region with retrograde condensate behavior (if any)
- Plot the p-T along the pipeline on top of the P-T diagram. Detect if there is any condensate retrograde behavior.
- Will hydrates form in the pipeline?

Solving suggestions

- Remember that Hysys performs its calculations co-current. This means that you provide a pwh pressure, Twh temperature, and a molar rate at the inlet of the pipe, and Hysys calculates the gas flow rates at the exit of the separator and the separator pressure. However, we now that separator pressure has to be 30 bara. In order to force Hysys to reach this value, it is necessary to use an ADJUST.
- Use increments of 1Km for your calculations.

Available information



Molar flow	**[kgmol/h]**	36829.34
Pout (Slug catcher pressure)	**[bara]**	30
Tsea	**[C]**	6
Pipe ID	**[in]**	26.7
Pipe OD (Including insulation)	**[in]**	30.6

Component	Mole %
Nitrogen	2.525
Carbondioxide	5.262
Methane	81.006
Ethane	5.027
Propane	2.534
i-Butane	0.4
n-Butane	0.83

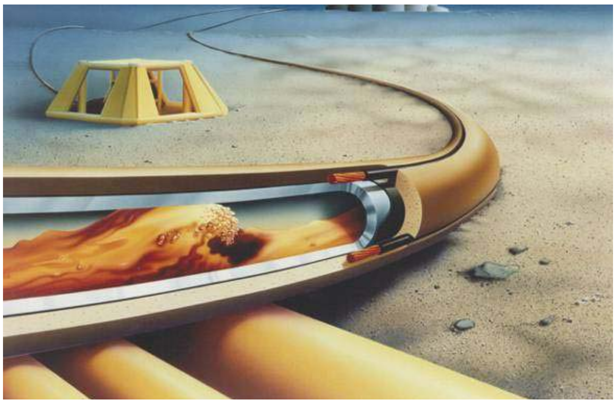
i-Pentane	0.281
n-Pentane	0.308
Hexanes	0.352
Heptanes	0.469
Octanes	0.407
Nonanes	0.203
Decanes	0.397

Real pipeline elevation profile (referenced relative to PLEM position)

X	Y	
[km]	[m]	
0	0	PLEM
128	0	
158	360	SEP

Estimate the overall heat transfer coefficient of the pipeline assuming that there is:

- Forced convection from the fluid to the pipe wall
- Conduction in the pipe wall
- Conduction in the insulation
- Free convection with the surrounding seabed.



Use the following information:

Inner diameter of the steel pipe ID, [mm]	**678.2**
Outer diameter of the steel pipe OD [mm]	**711.2**
Steel conductivity [W/m K]	**43**
Outer diameter of the Insulation layer OD* [mm]	**777.2**
Insulating material conductivity [W/m K]	**0.22**
Outer free convection coefficient (sea) [W/m^2 K]	**200**
Inner convection coefficient** (Gas cond) [W/m^2 K]	**11**

Hydrate line

T [C]	p[bara]
-20	3.7
-18	4.0
-16	4.4
-14	4.8
-12	5.2
-10	5.6
-8	6.1
-6	6.6
-4	7.2
-2	7.7
0	8.3
2	10.8
4	13.8
6	17.5
8	22.4
10	28.7
12	37.0
14	48.4
16	64.6
20	131.2
25	318.7

Some help with Hysys:

You can run Hysys remotely from your computer using
https://farm.ntnu.no
Alternatively, Hysys is installed in some computers in the computer lab on the 3rd floor.
If you need some help getting started with Hysys, watch the introductory video:
https://www.youtube.com/watch?v=3h6i_K_3yq0
A similar version of the exercise was partially solved in class in 2016:
From 1:07:43 https://www.youtube.com/watch?v=j5xA9DAd47k
From the beginning: https://www.youtube.com/watch?v=Jq5HcLIXI30