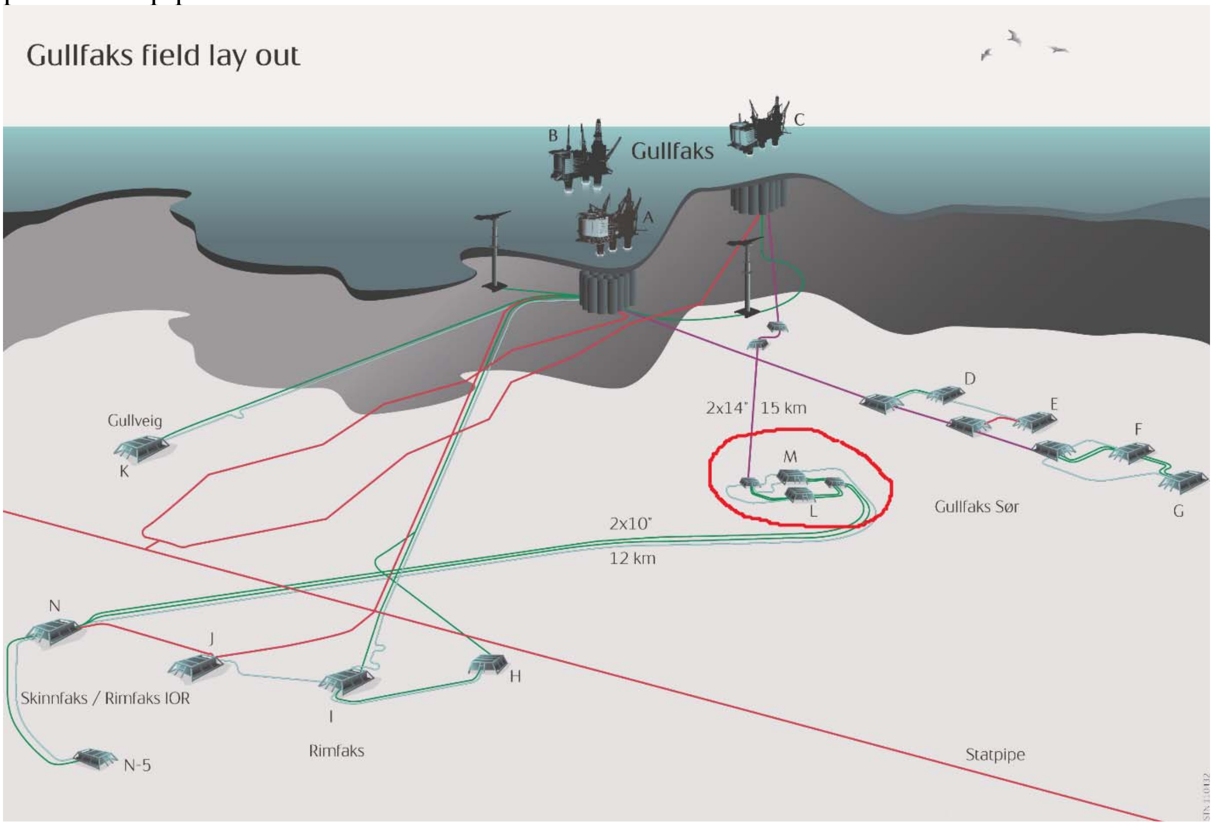
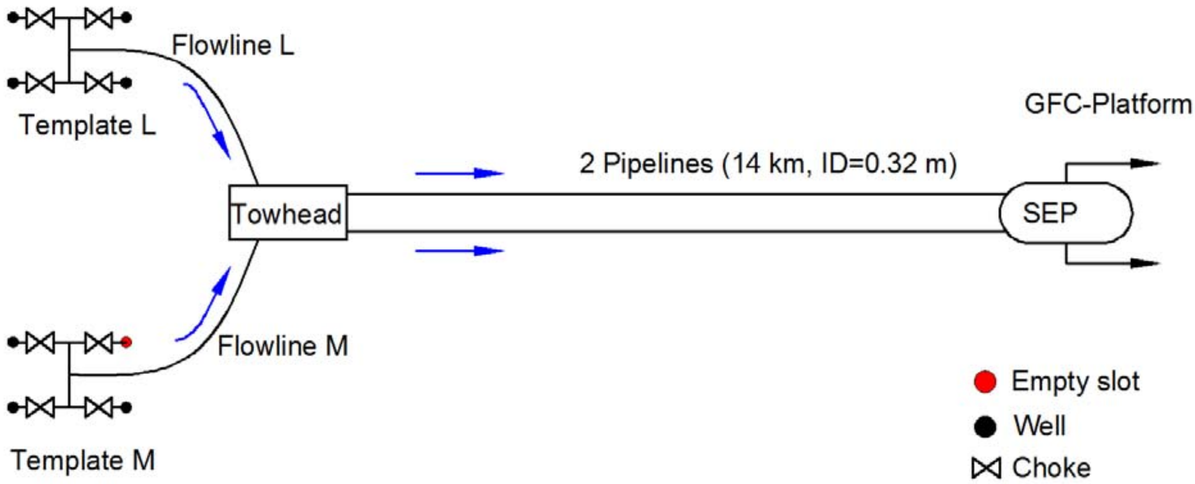
Exercise set 03

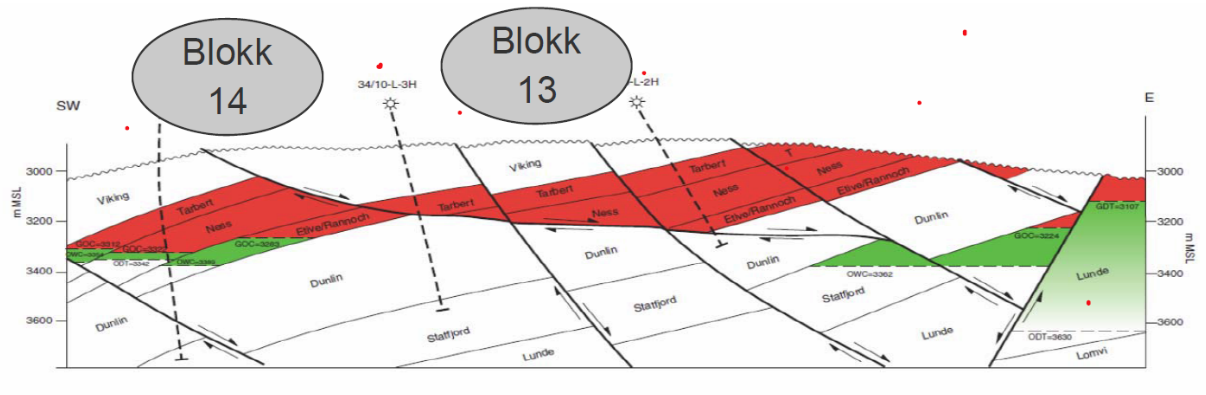
PROBLEM 1:

Two reservoir units in Gullfaks South field (Block 13 and Block 14) have been producing oil and gas since 1999 by two subsea templates (Template L and M). The production is commingled in a manifold (called "Towhead") and is transported further using two identical production pipelines to the Gullfaks C GBS.





Due to the depletion of the oil layer in the formations, the wells from templates M and L have been recompleted in 2009 to produce liquid rich gas. The liquid comes from gas condensate in one formation and from mobile liquid oil in the bottom of the reservoir of the other formation. From 2009, the field is produced in plateau mode with a total rate of 10 E6 Sm^3/d.



Your main task is to develop an excel sheet to calculate the length of the production plateau and compute post plateau production profile.

Being a preliminary study, considerable simplification assumptions will be used:

- The gas is dry, its depletion and recovery characteristics can be modeled by reservoir tank model
- The flow in the wells and the pipeline can be represented by isothermal flow equations.
- Consider that all wells in each template are identical (i.e. produce the same, so it is necessary to model only one well).
- Wells are equipped with wellhead chokes to adjust the rate when required.

The table below (given in the the attached excel sheet) contain all the data necessary to run your calculations.

Gullfaks South L-M satellite system Ignoring liquid production (Start Jan 2009)	**East Tank L-Template Fault Block 13 Brent Formation**	**West Tank M-Template Fault Block 14 Brent Formation**		
G=GIIP-Gas cap (31 December 2008)	54.2E+9	17.5E+9	Sm3	
Daily Plateau production rate (per template)-Precompression mode			Sm3/d	
Wells per template (Pre compression)	4	3		
Production days per year	328	330	day	
T_R	128	112	°C	
Pi, initial Res pressure (01 Jan 2009)	240	210	bara	
C, inflow Back pressure coefficient	1000	700	Sm3/bar^2n	
n, backpressure, exponent	0.8	0.8		
Tubing MD	3515	2800		
Tubing TVD	3100	2500		
Ct, Tubing coefficient 7" (ID=6.094")	38152	41163	Sm3/bar	
Elevation coeff Tubing, S	0.43	0.34		
C_{FL} .Template-to-Towhead (ID= 12") Spool	1403054	1397663	Sm3/bar	
$C_{PL\ Pipeline}$ 14" Towhead-to-GFC 14000m (ID=0.32m)	148220	148220	Sm3/bar	
Separator pressure GFC (Inlet Sep)			60	bara
Gas molecular weight (Methane)	19	19	kg/kmole	
Gas specific gravity	0.66	0.66	Gas specific gravity	
Total plateau rate			1.00E+07	Sm3/d

Task 1. Conduct a plateau length analysis and determine the production profile until a minimum economical rate of 2 E6 Sm^3/d. The plateau production of each template is calculated at the end of year 2008 by running an open choke network simulation. Then, a split factor is calculated for each template as q_temp_L/q_field and q_temp_M/q_field. Use the split factors to determine how much each template will produce of the desired plateau rate.

The plateau rate of each template remains constant while deltap choke > 0. Once deltap choke becomes < 0 for one of the templates, the field production will decline. The new rate has to be calculated using flow equilibrium.

Plot the results of your calculations and the change of pressure in the important nodes of the system versus time. Indicate on the plot the end of the plateau. (Important pressure nodes are reservoirs, bottom-holes, wellheads, pressure drop across the choke, template pressure, at the towhead and separator).

Plot the field gas production profile and the template gas production profile for the complete life of the asset.

Task 1.a Propose another template rate splitting for the plateau period to prolong plateau duration. Compute the new production profile and the new plateau duration.

Task 2. The company is evaluating using a subsea compressor at the towhead to prolong plateau. Estimate (and plot) the production profile, the pressure boost required by the compressor with time, the pressure ratio and the local rate at the inlet of the compressor. Consider that the compressor requires a minimum pressure of 5 bar at the inlet to operate and the pressure boost cannot exceed 50 bar. If you reach these limits, you have to reduce the field rate. The temperature at the suction of the compressor is 70 C.

Task 3. The German company MAN has proposed a specific compresor model to use in the system. The compressor map, measured for test conditions are provided in the excel sheet.

The compression station has a choke valve at the inlet, an inlet cooler and an outlet cooler. In normal operating conditions, the choke is fully open. Some operational constraints are the following:

- The discharge temperature of the compressor has to be below 120 C to avoid problems in the seals of the compressor, avoid structural integrity issues in the discharge pipelines and avoid vaporization of the hydrate inhibitor.
- The motor of the compressor has a maximum capacity of 12 MW.
- The minimum temperature possible to achieve after the inlet cooler is 20 C.
- Assume that the compressor operates with a polytropic efficiency of 70%.
- The outlet cooler can provide a temperature drop of 20 C.

If during your analysis the operating point falls outside the operational map of the compressor or doesn't fulfill the operational constraints, consider the following options:

- Use the valve at the inlet of the compressor station as a choke valve to drop the inlet pressure and increase the compression ratio
- Use the coolers
- Reduce field rate.

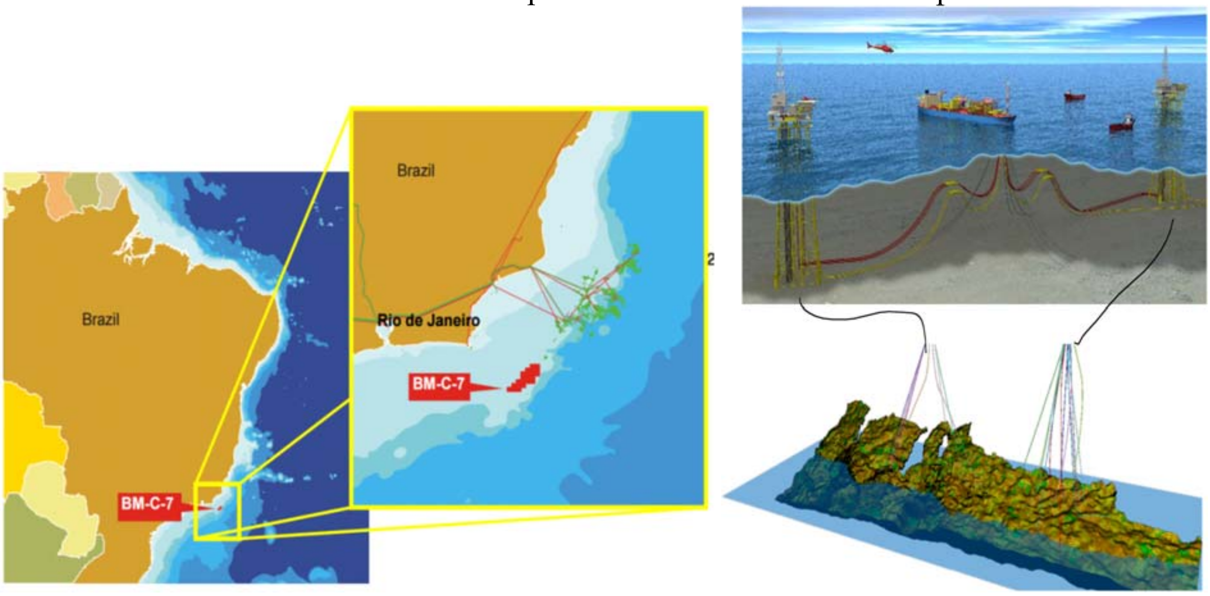
Some specific tasks are:

- Compute and plot the field gas production profile, deltaP compressor, compression ratio, suction pressure for the complete life of the asset.
- Determine when the coolers are required.
- Estimate the rotational speed of the compressor and the required compressor power for each compressor year.
- Plot the operational points on top of the compressor map (for test conditions).

- Your company is evaluating eliminating the suction and discharge coolers to reduce costs. Compute the production profile considering that there is no cooler and issue a recommendation on the matter.

PROBLEM 2: ESP design and verification with output from reservoir simulator for the Peregrino field

Peregrino is the largest oil field operated by Equinor outside of Norway. The field is located 85 km offshore Brazil in the Campos Basin at about 100 water depth.



The field is developed with two fixed platforms from which wells are drilled and completed. There are 40 producing wells in total. The production is taken to an FPSO where the processing takes place. The separated water is transported back to the platforms and injected in the lower part of the formation.

Wells are deviated with ESPs installed in them. The wells are classified in low, medium and high producers.

A particular ESP model has already been suggested by a manufacturer (Baker Hughes) based on the well layout and production rates desired.

On the 8th of February, 2019 your company (Equinor, the field operator) sent you to NTNU to attend a training session about ESP design analysis and verification session using Excel.

TASK 1

Back in the company, your task is to verify if the ESP proposed by the manufacturer will be able to produce the rate predicted by the reservoir simulator for four times provided in the excel sheet (In sheet "Data", dates 1.7, 7.5, 14.1 and 25 years). If it is not possible to deliver the rate, try to reduce or increase the rate so it will fall inside the operational envelope of the pump. Identify limiting factors. If you are using the excel solver to adjust automatically the rate, please specify clearly the objective, constraints and variables.

Determine ESP operational frequency, suction pressure, required power and emulsion viscosity for each year listed above.

If you are given budget to change something in the well, is there something in particular that you will prioritize to meet the reservoir production goals?.

Plot the operational points (both original rates from the reservoir simulator and corrected rates) overlapped in the ESP operational map for each year. (remember the pump map will be different for each year)

Provide your final recommendations if the ESP is adequate to deliver the desired rate or not.

Assumptions:

- Use the excel sheet provided.
- Assume maximum pump power = 950 Hp
- Assume that the total liquid productivity index (J) of the formation remains constant with time.