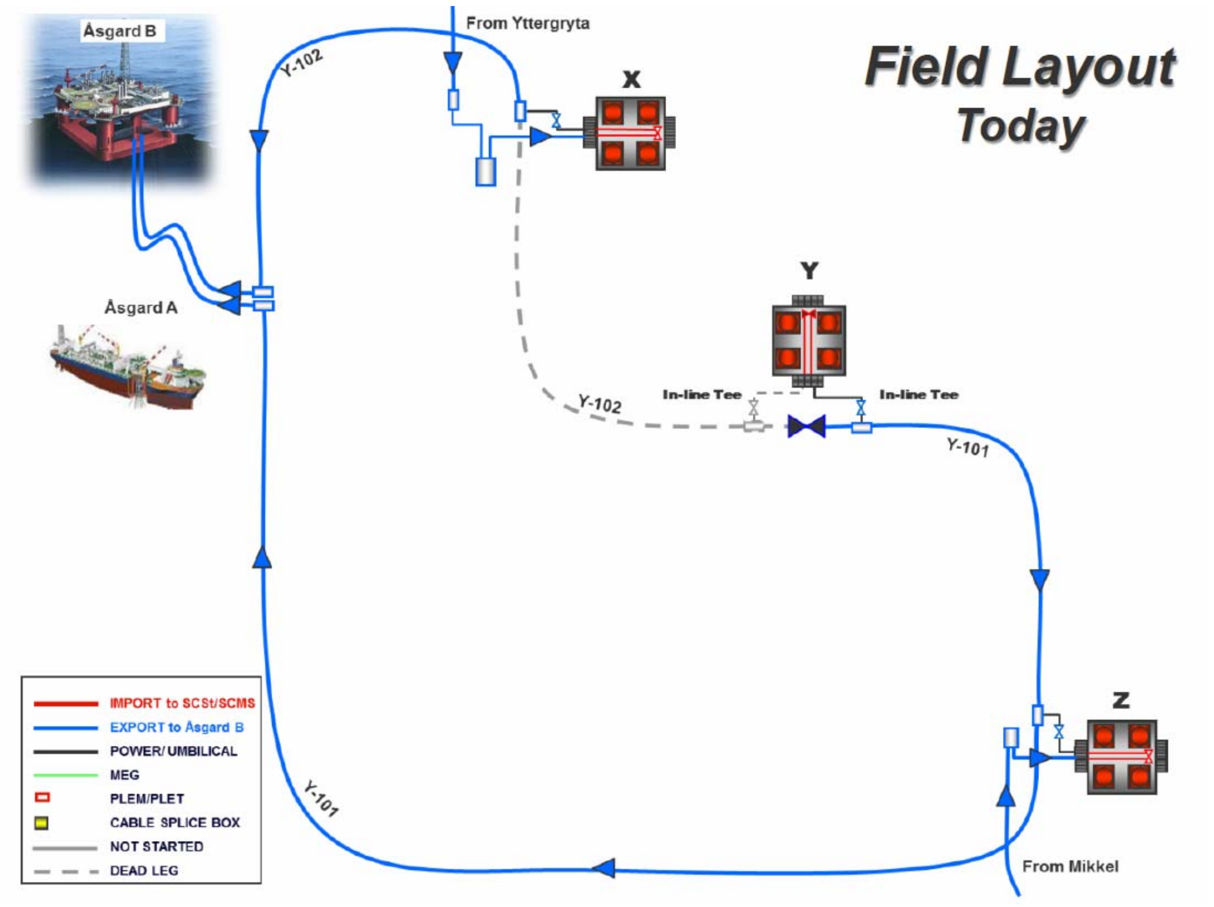
Exercise set 02

Problem 1: **Production system layout of a part of the Asgard subsea field;**

Field Description

Asgard is a subsea field producing oil, gas and condensate, at a water depth between (240-300) m, located about 50 kilometers south of the Heidrun field on the Halten bank in the Norwegian Sea. The field has been developed with subsea template wells tied-back to Åsgard A (FPSO) and B (semi-submersible). The sandstone reservoirs are located at a depth of approx. 4850 m.

In this task you will focus on the production system that produces from the Midgard reservoir and where the production from Mikkel and Yttergryta is tied-in. A sketch of the system is shown below.



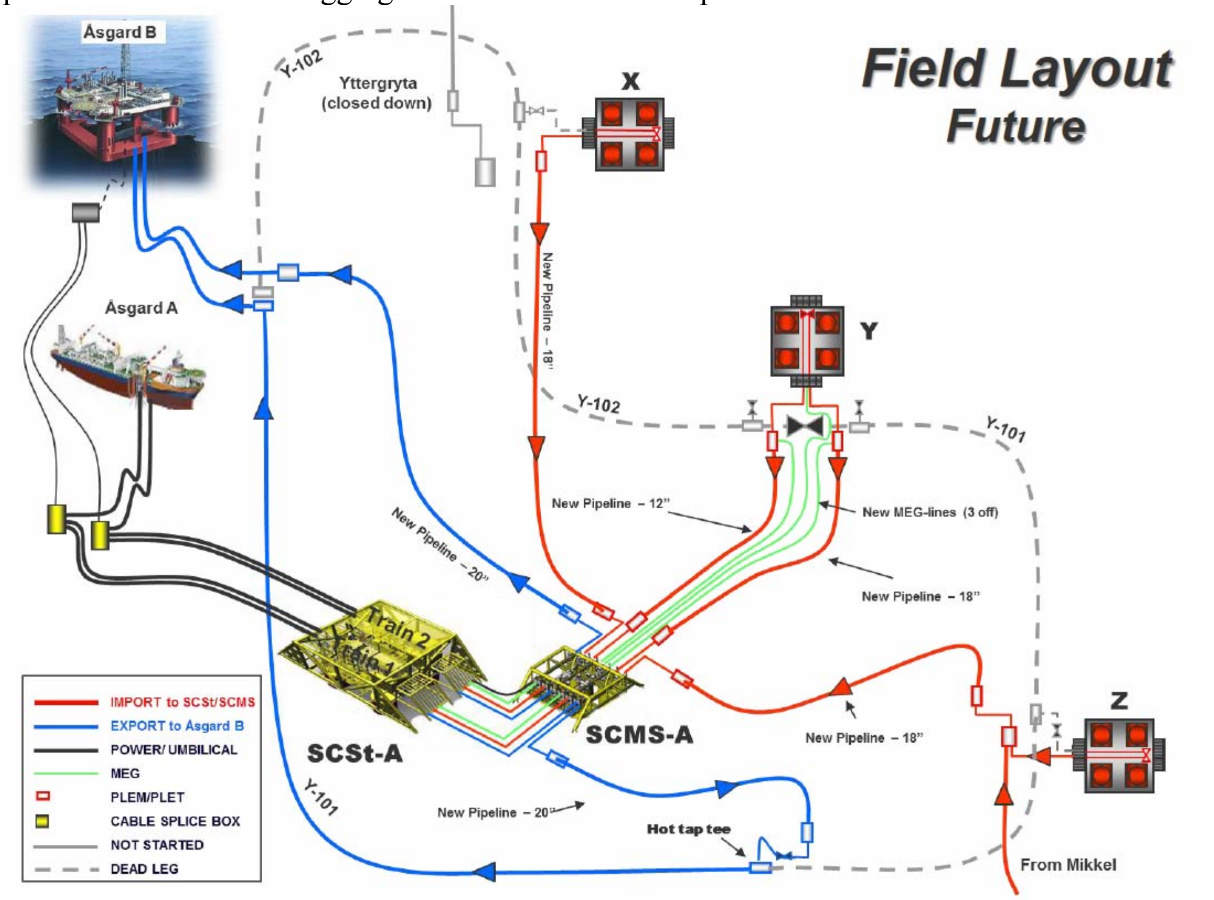
The subsea well templates are typical 4-well slot templates with the manifold module located in the center of the template. There is one well producing in template Z, 4 wells in template Y and 4 in template X. Your tasks are as follow:

1. Propose a simplified P&I diagram of the subsea system (please refer to page 105 in the compendium for a quick orientation about engineering diagrams). Show in your sketch the entire system from the wellhead to the (single) separator on the Semi-sub. Your diagram should show the main valves on the wells X-mas tree, the routing valves on

the manifold and the arrangement of valves. Define clearly what is on the subsea template, what is on the seabed and what is topside.

2. Is it possible to test the production of an individual well in this system without significantly disrupting/stopping production? Please explain.
3. Is it possible to perform pigging in this system?. If yes, please explain what valves should be open, what valves should be closed during pigging operations and make a sketch about how will the pigging facilities will look like on the platform.
4. For template Y, make suggestions (using a simplified P&I diagram) for an arrangement where the testing of individual wells is done by a single multiphase meter (MFM) located on the manifold module.

In 2015, the subsea layout was modified significantly to install two subsea compressors (depicted with the names “Train 2” and “Train 1” on the module SCSt-A), to increase production and avoid slugging issues in the main transportation lines.



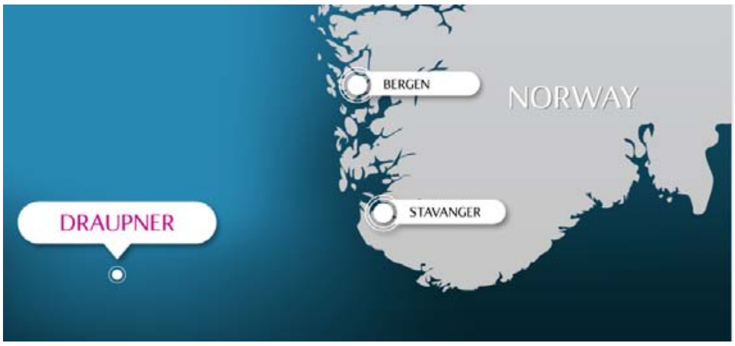
The following additional tasks are given:

1. Is it necessary to modify the subsea well templates to make this modification?. Explain your answer.
2. Make a simplified P&I diagram of the subsea compressor manifold station (SCMS) considering it has the following functionality:
   - There are 6 pipelines connected to the SCMS. 4 of them bring production from templates Z,Y,X and Mikkel and 2 send production to Asgard B.
   - The SCMS has two suction headers (I and II). The production from each of the pipelines entering the SCMS can be routed at will either to header I or II.
   - There is a flowline that goes from each suction header (separately) to each compressor.

- There are two flowlines coming from the discharge of each compressor (separately) to the discharge headers at the SCMS.
- There are two discharge headers (III and IV) on the SCMS. The headers can be connected to either pipeline Y-101 or "New Pipeline – 20".

<u>Problem 2:</u> Wave statistics on wave elevation data from the Draupner platform.

Draupner is a complex consisting of two jacket-type platforms (Draupner S and E) in the Norwegian part of the North Sea, in a water depth of 70 m. The platforms are not used for hydrocarbon production but for monitoring pressure, rates and quality of the gas leaving Norway to the European and UK markets through the gas pipelines.



Wave elevation data has been recorded with a sampling frequency of 2 Hz using a downward pointing laser attached to one of the legs of Draupner S. The data is provided in the excel file attached Problem_2.xls.

PART 1.

You have been asked to analyze the measured data and find: The peak period T_p, the dominant wave amplitude ζ_p, the significant wave height (H_s) and to verify if it is possible to represent the spectral energy of the wave signal using the empirical JONSWAP equation.

Suggestions for solving the exercise:

- Perform an Discrete Fourier Transform (DFT) of the data provided. Do this in excel and follow the instructions in the attached document "Frequency Domain Using Excel" written by Larry Klingenberg, from San Francisco State University. Please note that the procedure provided by Prof. Klingenberg already calculates the wave amplitude (in m), **NOT** the wave energy.
  Plot the wave amplitude spectrum (amplitude in m vs frequency) and report the peak spectral period (the period with the highest amplitude) and its dominant amplitude. Remember that the period is the inverse of the frequency.

  Calculate the wave energy S [m^2 s] using the expression $S_i = \dfrac{\zeta_i^2}{4 \cdot \pi \cdot \Delta f}$ for each amplitude value calculated with the DFT. Plot the wave energy spectrum (wave energy S versus frequency).

- JONSWAP[1] is an empirical relationship that is typically used to describe the distribution of spectral wave energy with frequency when no wave measurements are available. The equation is the following:

$$S(\omega) = \bar{\alpha} g^2 \omega^{-5} \exp(-1.25[\omega/\omega_p]^{-4}) \times \gamma^{[\exp\{-(\omega-\omega_p)^2/(2\sigma^2\omega_p^2)\}]}$$

With:

$$\gamma = 5 \quad \text{for } Tp/\sqrt{H_s} \leq 3.6; \quad \text{and}$$

$$\gamma = \exp\left(5.75 - 1.15\frac{T_p}{\sqrt{H_s}}\right) \quad \text{for } T_p/\sqrt{H_s} > 3.6 \qquad (3.22)$$

The value of $\vec{\alpha}$ for the North Sea application is commonly computed from

$$\vec{\alpha} = 5.058\left[\frac{H_s}{(T_p)^2}\right]^2 (1 - 0.287 \ln \gamma) \qquad (3.23)$$

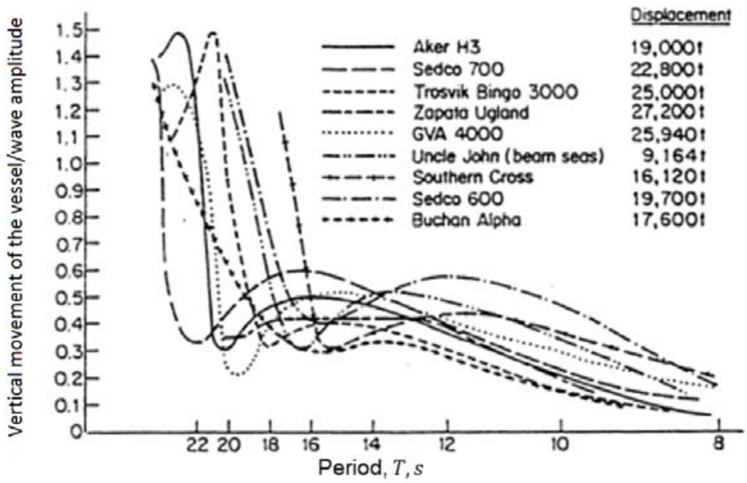
NOTE: these equations have already been programed for you in Excel VBA. They are grouped under the User defined function called: "JONSWAP_S".

- If one assumes the wave elevation displays a normal distribution and the wave height (distance between consecutive crest and valley) displays a Raleigh distribution, the significant wave height H_s can be expressed as $H_s = 4 \cdot \sigma_\zeta$, where σ_ζ is the standard deviation of the wave elevation data. Using this assumption, **you don't have to compute the wave height and wave height distribution to calculate H_s, calculate it based on the standard deviation of the wave elevation data.**

PART 2.

When an offshore structure is impacted by a wave with certain dominant amplitude and frequency, it will exhibit a displacement and movement that depends on the characteristics of the structure (support mechanism, weight, flexibility, damping, etc.).
In the lab tests or in real life, keeping the wave frequency fix, the displacement of the structure and its corresponding wave amplitude are measured and the ratio computed. The procedure is repeated for multiple wave frequencies. A graph can then be made that shows the ratio between structure displacement and wave amplitude for different wave frequencies. Such a plot is shown below for a variety of semisubmersibles with different weights.

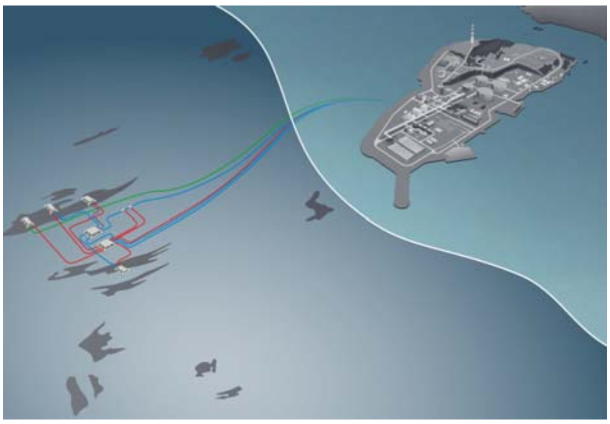
[1] Joint North Sea Wave Project



Your task is: if a wave with the peak period and the dominant wave amplitude found in part 1 impacts the semisub Sedco 600, what would be the expected vertical movement (heave) of the vessel?

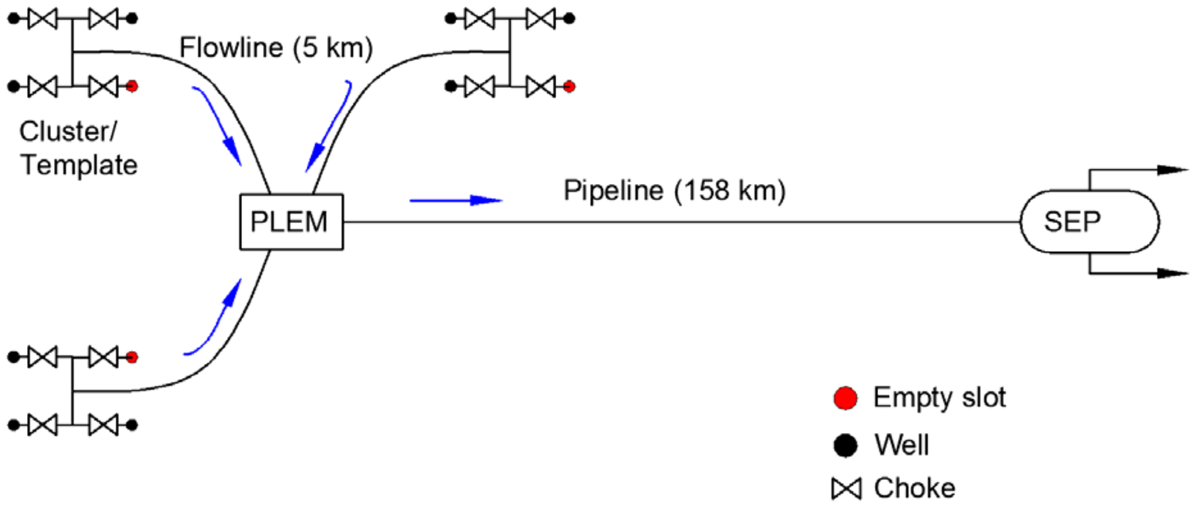
<u>Problem 3:</u> Production scheduling calculations for the Snøhvit field

Snøhvit is an offshore gas field located in the Barents Sea 158 km from Hammerfest currently in operation. The field was developed with the "subsea to beach" concept. The gas production is 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.



According to the base case Scenario (BCS) selected for the study, the field is completed subsea with three subsea templates, each with 4-slots. Only three wells are completed in each template. The templates are symmetrically positioned at 5 km away from the subsea Pipeline Entry Module (PLEM). Each template is connected by flow line to the PLEM where the production streams of all the templates are commingled (combined and mixed). The PLEM is on the seabed approximately 158 km from shore and is connected by the main field export pipeline to the slug catcher (separator) on shore.

All the wells are identical (in structure and productivity and all other design and operation parameters) and produce from the same reservoir (tank model). Due to the fact that all wells are identical and symmetrical, it is possible to perform flow equilibrium calculations considering only the flowpath: wellbore-tubing, flowline from template to PLET and pipeline. However, remember to use the appropriate rate in each pipe segment.



TASK 1. For initial reservoir pressure, compute the available pressure curve at the wellhead as a function of single well rate and the required pressure curve at the template as a function of single well rate. Plot the two curves and calculate the intersection point. What does this rate represent?

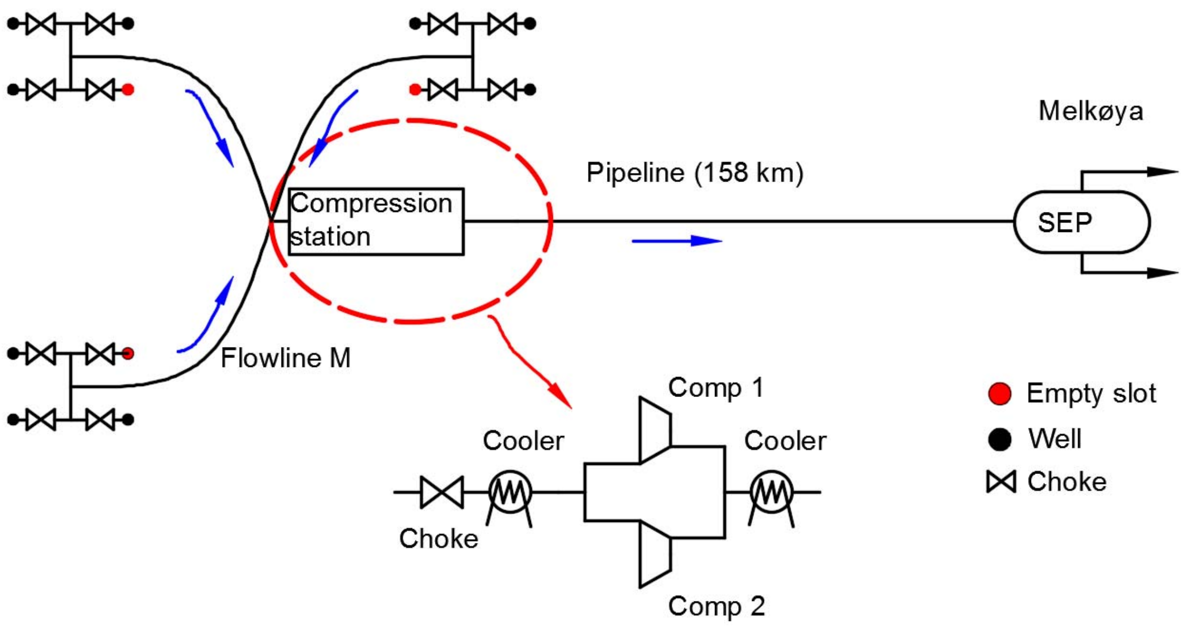
TASK 2. Calculate the plateau length of the field and production profile (until the field gas rate reaches a minimum economical rate of 5 E06 Sm^3/d). Perform this calculation on a year basis. Plot the evolution of all relevant pressures in the system (p_R, p_{wf}, p_{wh}, p_{temp}, p_{PLET} and p_{sep}) versus time. Plot the production profile versus time.

TASK 3. The multiphase/flow assurance expert working on this project has said that the prediction of the pressure drop in the main transportation pipeline using commercial tools (e.g. Olga®) could be extremely unreliable. This is because of the hilly profile of the pipeline and the presence of some liquid flowing together with the gas. He says that the error associated with the pressure drop estimation might be of ±50%. He therefore suggested to perform an experimental campaign in the large scale multiphase loop of SINTEF (http://sintefloops.com/?page_id=962) in Trondheim to verify and reduce the inaccuracy of the pressure drop models. The experimental campaign costs 5 E06 USD.

Before taking the decision, your manager has asked you to determine what would be the influence of an inaccuracy of 50% in the prediction of the pressure drop in the production profile of the Block 2 field. Specifically on the duration of the plateau. **Your task is then to add 50% to the original pressure drop in the pipeline and calculate the production profile again. Discuss your results.**

TASK 4. Conduct an analysis to evaluate the impact of using subsea compression to maintain plateau production after the natural plateau end is reached. Expand the excel sheet provided to calculate the length of the production plateau in the compression period and compute post plateau production profile (when operationally, due to compressor constraints, it is not possible to maintain plateau production any longer). **Perform your calculations on a yearly basis until the end of year 28.**

The proposed layout for the installation of the compressor (suggested by Aker solutions) is shown in the figure below:



The compression station has a choke valve, a cooler and two identical compressors in parallel. 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 140 C to avoid problems in the seals of the compressor, avoid structural integrity issues in the pipeline and avoid vaporization of the hydrate inhibitor.
- The maximum power per compressor is 11 MW.
- The minimum temperature possible to achieve in the inlet cooler is 20 C.
- The minimum suction pressure to the compressor is 15 bara.
- Assume that the compressors operate with a polytropic efficiency of 70%.
- The gas temperature at the inlet of the compressor station is 67 C.

The German company MAN has already proposed a specific compresor model to use in the system. The compressor map, measured for test conditions is also included in the excel sheet.

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.
- Wells are operating with fully open choke during the compression period.
- All wells, templates, and infield flow lines are symmetric in configuration and capacity.

If, during your analysis, the operating point falls outside the operational map of the compressor, 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
- Use single compressor, two compressor in parallel or two compressors in series.
- 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 cooler is 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.