1- **Introduction:**

Throughout the exploitation of a gas field, actions are taken to ensure the best recovery of liquid and gaseous products. In this paper we will discuss the problems associated with the pressure drop in the reservoir and the consequences on the recovery of liquids for wet gases and condensates.
The question is how to adapt the Process of the plant during the decline of the natural energy of the reservoir, for a better recovery of liquids. In addition, we will try to demonstrate whether this recovery of liquids, especially of LPG, is justified by additional investments at the beginning of the decline in reservoir production.
To develop this topic, we need to know the mechanisms that govern the production of natural gas as well as the characteristics and specificities of each type of gas.

2**- Types of gas fields**:

The gases contained in gas reservoir are divided into 3 types:
- Dry gas
- Wet gas
- Condensate gas

2-1- Properties of these gases:

a- Dry gas: this gas contains no liquids or very few quantities. The flow from the reservoir to the surface is single-phase and the composition of this type of gas does not change over time.
b- Wet gas: this gas contains liquids but their deposits are only come under surface conditions. The flow at surface conditions can be two-phase under certain temperature and pressure conditions. The composition of this gas varies little over time.
c- Condensate gas: this gas is characterized by liquid deposits in the reservoir under the decline in pressure at constant temperature (retrograde condensation) and in surface conditions.

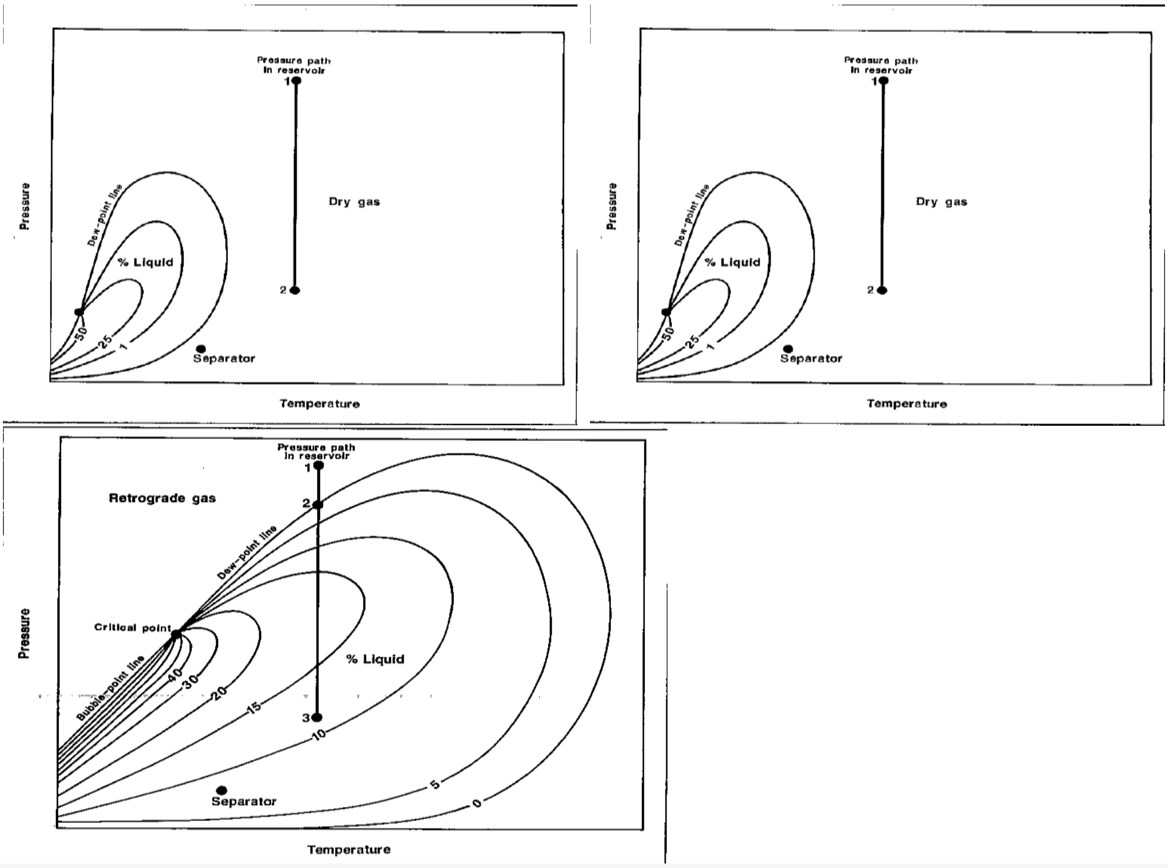


Diagramme de phases:[1]**(Source: *The Properties of Petroleum Fluids*,** 2ed**, by William D. McCain Jr. Copyright Pennwell Books, 1990.)**

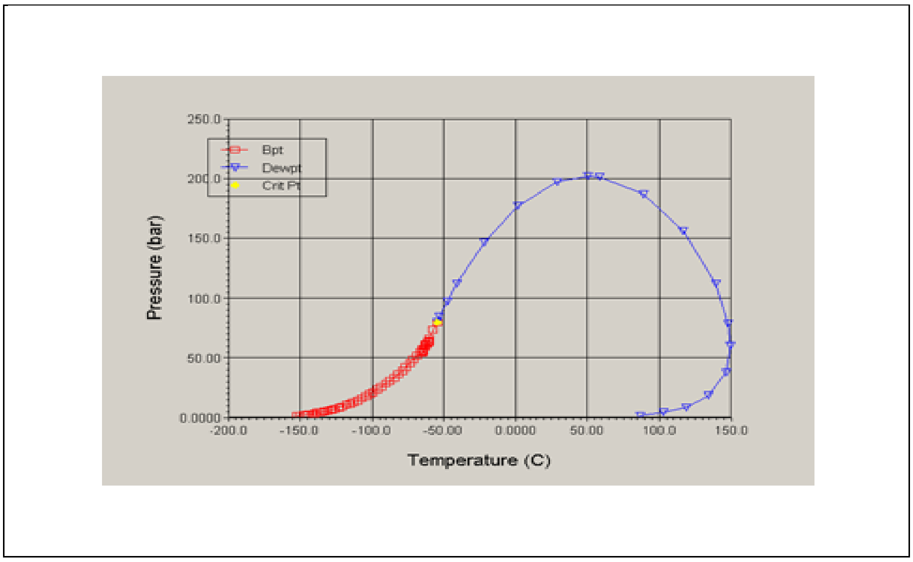


Diagramme de phases d'un gaz à condensat d'un gisement Algérien

3- **Natural and assisted recovery of natural gas**:

For dry gases and wet gases, when the M.E.R is well studied, the production plateau can be maintained long enough with the natural recovery.
For condensate gas, it is necessary to "recycle" dry gas in the reservoir, from the start of production, to avoid a fast drop in pressure which would lead to a significant deposit of

condensate in the reservoir, due to the retrograde condensation. It should be noted that the condensate which is deposited in the reservoir will only be partially recovered or not at all. While the condensate deposition phenomenon only affects the area around producing wells at the beginning, it will extend far into the reservoir as the pressure drops.
This is an important element to consider in the exploitation of this type of reservoir.

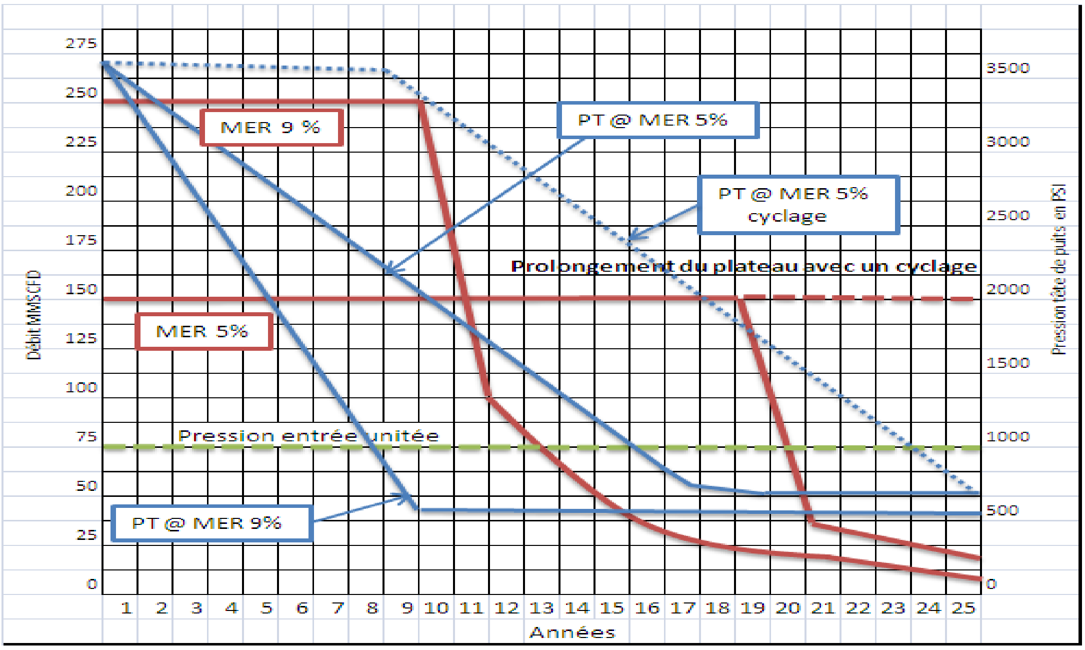


Fig.1- behaviour of gas reservoir for different MER

Source: Sonatrach for a gas field in Algeria

Figure 1 above shows the look of the shape in the pressure drop at the producing wells head according to the different M.E.R. In the case of cycling the production plateau is maintained for a longer time and the pressure decrease slowly in the reservoir. This scenario guarantees optimal recovery of liquids.

4- Processing sections:

In the treatment units, the gas passes through several sections:
-The separation
-The dehydration
- Refrigeration
- Rectification
- The export of products (dry gas, condensates and LPG)
- Re-injection of gas into the reservoir to maintain pressure
Sometimes it's necessary to add decarbonation and desulfurization when the gas contains a high percentage of CO_2 and H_2S (CO_2> 2% mole, H_2S> 1 ÷ 4 ppm).

4.1- Separation:

To make better use of natural energy, the pressure of the first separation stage is quite high and is sometimes around 100 bars. This pressure is necessary for the process (expansion valves, turbo-expander).
The configuration of the separation depends on the type of gas. The liquids contained in gases and which can be separated at ambient temperatures are water and condensate. The water is removed through molecular sieve dryers or the glycol process.

4.2- Dehydration:

There are two main commonly used dehydration methods:
- Absorption: this process uses tri-ethylene glycol (T.E.G)
- Molecular sieves: the gas charged with water passes through a molecular sieve which retains all the water and gives a very high drying purity (around 1 ppm). This system is used in the LPG extraction process.

4.3- Refrigeration:

Refrigeration is the most important section of the gas treatment process when it is necessary to recover LPG. Depending on the desired percentage of liquid there are several methods:
- Joule Thomson effect (J.T valve)
- Refrigerated propane loop (-20 ° c)
- Turbo-expander (-30 ° c)
- Association of two or three types (>-60 ° c)

4.4-rectification:

For the final separation of liquids, two columns are used:

- The de-ethanizer: remove of methane and ethane from C3 +
- The Debutaniser: separation of the LPG from the Condensate

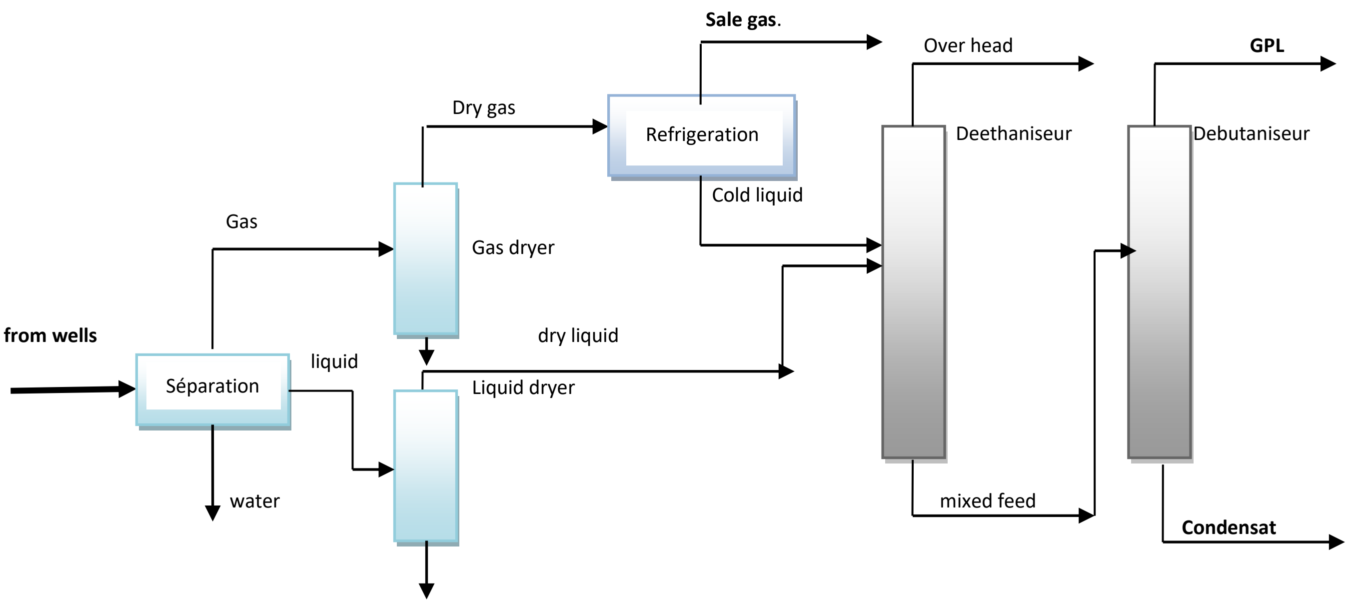


fig.2- Simplified gas treatment unit

5- **Upgrade of processing units**:

Depending on the M.E.R used, the lifecycle of gas fields is variable but rather long over time, depending of course on the mode of production. Taking into account the decline in reservoir pressure, along the time, the CPF treatment pressures can be readjusted accordingly. The most common technique is the installation of compressors at the inlet of the CPF (boosting) to maintain the pressure at its initial design value. The goal is to keep the same operating parameters and especially those related to the turbo-expander and the expansion valves, to ensure the recovery of liquids.

6- **Solutions to the problem of pressure decline**:

Faced with the increasing systematic use of boosting, it is necessary to study other mining methods, which could be less expensive, while considering the particularities of each reservoir and each process.
For this study, we consider an existing gas condensate treatment unit, where the Initial design conditions are as follows:
- Pressure and temperature at the inlet of the CPF: 70 barg and 100 ° C
- Gas flow rate (standard conditions): 6.2 million m3 / d
The treatment is made according to the process diagram (fig. 2) above.

6-1 the facts of the problem:

We will compare the treatment results of each section of the process chain using different pressures (60 and 43 bar) at the inlet of the CPF while keeping the same flow rate, the same temperature and the same gas composition. We consider a natural depletion of the reservoir without the introduction of boosting at the inlet of the CPF. If we refer to the diagram in Figure 1, we see that the pressure drop, below the CPF inlet pressure, occurs towards the end of the production plateau. With cycling, for an operating life of 25 years, the effect of head pressure is negligible. Is it necessary, in this case, to intervene to maintain the pressure at its design value? This is what we will try to develop further.
Cycling has been stopped in the considering reservoir a few years ago. We must consider hypotheses into these conditions.
Assumptions considered:
1- No change to the specifications of existing equipment – Definition of the limits of use.
2- Proposed changes necessary on certain equipment to respect the new conditions of service.

6-2 Comparison parameters under the different level of pressures:

- Fluid volume inlet expander at PT
- Inlet and outlet temperatures expander
- Inlet and outlet pressures expander
- Cold liquid temperature entering deethanizer and volume
- Process compressor inlet and outlet pressure (compressor / turbo-expander)
- Process compressor input and output volume at PT
- Sales gas compressor inlet pressure and volume
- Liquid recovery from Debutaniser (LPG / C5 +)
- HHV of sales gas

Remark: The existing CPF process, taken as an example in this study, was re-simulated under initial conditions.

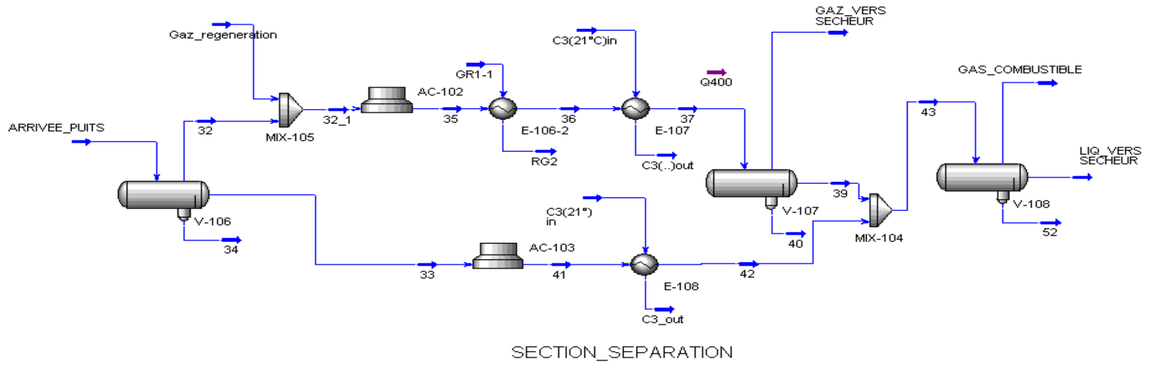


Fig.3 - separation

a- Séparation

Conditions Entrée CPF	Cas initial 70 B/100°C	Cas 1 60B/100°C	Cas 2 40B/100°C
Liq. out separation(kmole/h)	677	632	548
MW-g/mole (Gaz vers sécheur)	21.05	21.10	21.20
Volume gaz entrée CPF (10^6 Sm3 /jour	6.2	6.2	6.2

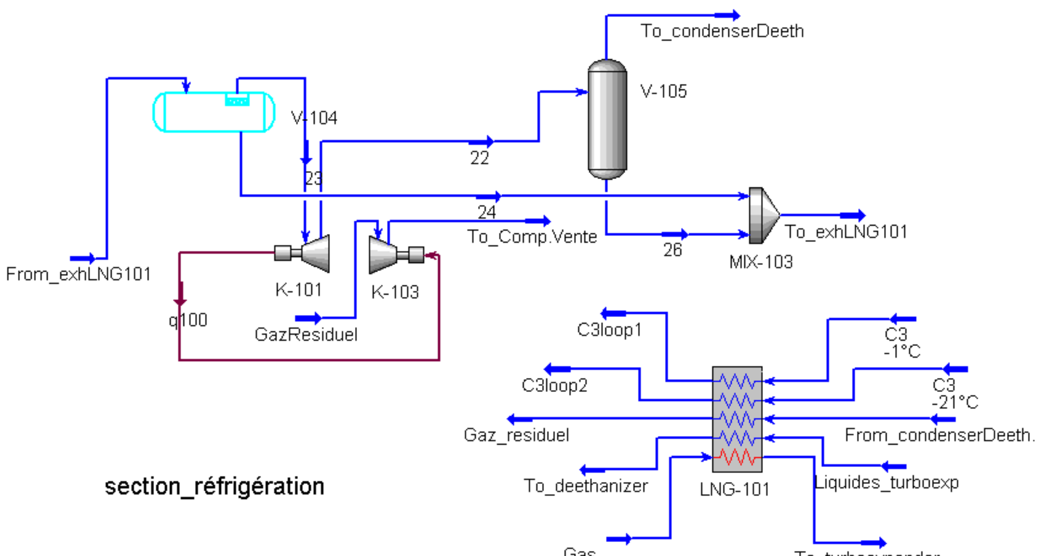


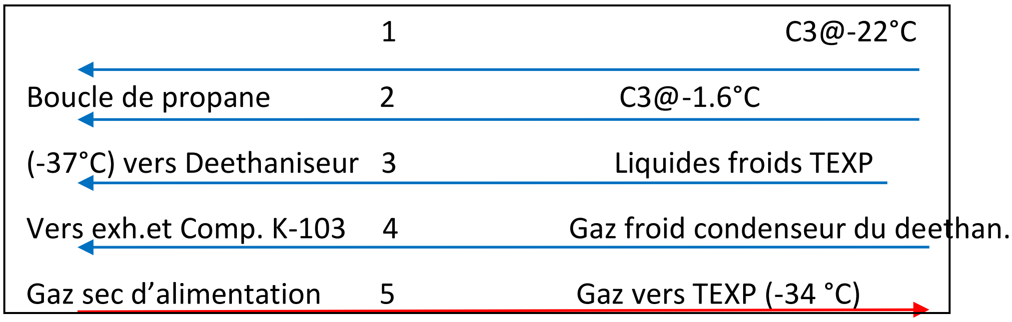
Fig.4 - refrigeration

b- Réfrigération

Conditions Entrée CPF	Cas initial 70B/100°C	Cas 1 60B/100°C	Cas 2 40B/100°C
Actuel volume (**in**)expander (m3/h) [1]	1629	1977	4800
Températures (**in & out**) expander (T°C)	-34/-65	-34/-62	-34/-63
Pressions (**in & out**) expander (bar)	63.5/30	56/29	35/16.4

Note 1: For case 60B, the over design of the expander covers the excess power.
For case 40B, the temperature conditions for the given volume will be reached only if the **the expander power increases to 2633 KW**.
The power of the existing expander is 1796 KW.
For the existing case, the conditions for the plate heat exchanger (LNG-101) were set to maintain constant temperatures for the following flows:
- Cold liquids to the deethanizer (to_deethanizer): - 37 ° C
- Feed gas to turbo-expander (to_turboexpander): -34 ° C

Note2: the calculation of the plate heat exchanger could be revised to ensure these conditions, or maintained as it is if the temperature of -37 ° C of the flow feeding the deethanizer is not a constraint.
Compared to the initial design data, the Duties of the different flows in the exchanger will be:



Duty en 10^6 Kcal/h:

Flux	Duty cas initial	Duty cas 1	Duty cas 2
1	2.029	1.712	1.797
2	2.190	2.373	1.678
3	1.898	1.243	1.133
4	5.188	5.5O4	7.550
5	-11.305	-10.834	-10.380

c- **Debutanizer liquid recovery**

Table C

Parameters	Condensat			LPG		
	Initial	**Cas 60 b**	**Cas 40 b**	**Initial**	**Cas 60 b**	**Cas 40 b**
MW-g /mole	107	107	107	49.5	49.5	49.7
Rate – Kg/h	48252	47940	48070	31370	31170	32930
C5+ TVR0.4 & 37.8 °c	0.4	0.4	0.4	-	-	
C2- % mole	< 3	< 3	< 3			
C5+% mole	< 0.4	< 0.4	< 0.4			

PCS gas Kcal/m3	9300	9300	9700
Dry gas Sm3/day	5 174 400	5 227 000	5 580 000

d- **Compression** – Turbo-expander

Table D

	Data Performances					
Equipement	**Expander**			**Compressor**		
Conditions	Initial	Cas1 (60B)	Cas2 (40B)	Initial	Cas1 (60B)	Cas2 (40B)
Inlet flow rate Kmole/h	8158	8494	10860	7267	7531	10100
Weight flow rate Kg/h	155677	162300	177500	131574	138100	191600
Inlet volume m3/h	1635	1977	4800	7177	7581	15320
Molecular weight	19.08	19.10	19.30	18.11	18.34	18.97
Suction pressure Bar abs Temp °C	63.51 -34	56 -34	36 -34	26.40 26	25 26	16 26
Discharge pressure Bar abs Temp °C	29.94 -65	28.63 -62	16.40 -63	32.96 74	30.57 75	21 51

7- Results Analysis:

We remind that this study was carried out in order to compare the recoveries of liquids (condensate and LPG) under different operating conditions of the treatment unit.
We note that the recovery of liquids (table-C) is practically identical for the 3 cases, and this is due to the change of the existing Turbo-expander by a new one, slightly more powerful by 30%.
To meet export requirements, it is necessary to review and readjust the compression section to the new operating conditions.

8-Plant upgrade:

In the case of 40 bars, there is an insufficient delivery pressure for the compressor /expander. The supply of gas compressors can therefore no longer be assured.
A modification of the compression section is necessary to ensure the delivery conditions, keeping the same sales gas compressors.
This modification consists of changing the turbo-expander, as described above (In b-refrigeration) and add a motor-compressor (K-102-Booster) DOWNSTREAM of the expander compressor as shown in the scheme below:

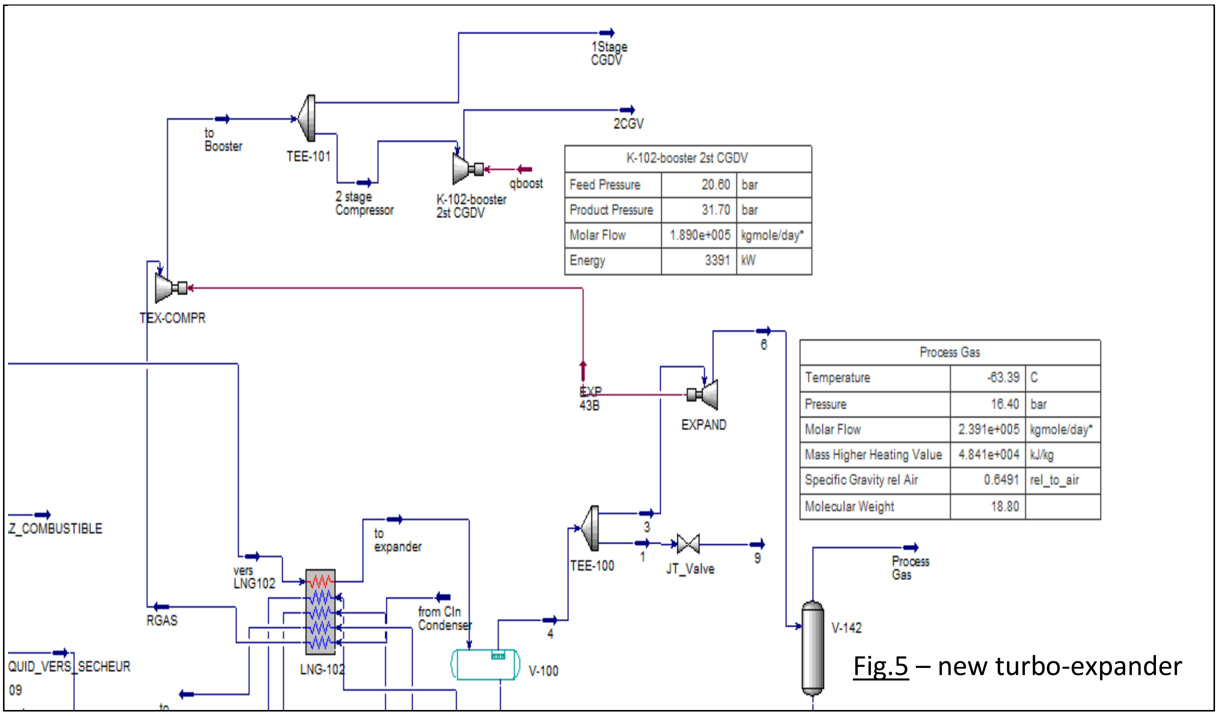


Fig.5 – new turbo-expander

8.1-Description of the new pre-compression:

The residual gas arrives at the suction of the compressor of the expander (TEX-COMPR) at a pressure of 16 bars and a temperature of 26 ° C. A centrifugal compressor, driven by an electric motor, with a power of 3391 kW is necessary to ensure a pressure of 32 bars at the suction of the 2nd stage of the sales gas compressor. Supplying the 2nd stage of the sales gas compressor at the required pressure will ensure the 84 bars necessary for gas export.

In order to adjust the flow rate at the suction of the first stage of the sales gas compressor, and to fill the gas deficit leaving the deethanizer, a defined quantity of gas output TEX-COMPR is directed to the 1st compression stage. With this scheme, the sales gas compressor is put into the design conditions in terms of pressure.

9- Conclusion:

Boosting at the inlet of gas treatment units may be necessary if the process is essentially based on the generation of cold by expansion (JT valve and turbo-expander). The pressure in this case is the main element of the process compared to the use of a propane loop which is only partially dependent on this parameter.

The simulations carried out for the different cases of operating pressures of the CPF show the limits of the turbo-expander + propane loop refrigeration process in the case of a drop in pressure at the inlet of the CPF.

We find that as long as it is possible to ensure an appreciable ΔP in the expander, with a limit of its output pressure, we remain on the correct rates and specifications of products.

We can therefore conclude that it is possible to operate correctly the facility at eligible low pressures, without using the booster at the input, by acting only on the expander. The addition of a booster in the compression chain (fig.5), in our case, is not linked to the recovery of liquids, but to the need to ensure sufficient pressure at the suction of the sales gas compressor.

Questions can be asked about the processing capacity of the CPF inlet separator under the conditions of different pressures with constant flowrate. Calculations carried out at constant flow and constant temperature is made in terms of comparison. In reality, neither the flow rates nor the temperature remain constant with a natural depletion. The production plateau, after its forecast period, can only be maintained if the withdrawal is increased by the full open of the wells or the commissioning of new wells and this is not without consequences for the reservoir.

We considered in our calculation hypothesis, only the important equipments. In order to optimize the operation of the CPF, it would be necessary to adapt the process parameters to the actual conditions of flowrates and temperatures at the inlet of the CPF. Intervention on other equipment, such as heat exchangers may be necessary.