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TECHNICAL AND ECONOMIC ANALYSIS OF THE IMPACT OF COMPRESSORS INSTALLED AT WELL CLUSTERS

1. INTRODUCTION

Concerns of gas production specialists for maintaining production at the highest level have gained a new dimension under the current economic and geo-political context.

For the gas offer to keep up with the market demand there are a few directions to follow: diversification and globalisation of gas markets, liquefied gas trading, gas production from unconventional fields. Another important trend relates to improving the production performance of mature fields under advanced stage of depletion. Therefore several technologies can be applied, one of them being the continuous reduction of counter pressure at the christmas tree by reconsidering the gas compression system.

2. THE INFLUENCE OF COMPRESSION ON GAS RESERVOIRS PRODUCTION

As is well known, the gas flow rate of a perfect hydrodynamic well, producing under linear filtration and stabilised regime, is given by the equation [1]:

$$Q_{st} = \frac{\pi k h T_{st}}{\overline{\mu_g} p_{st} \overline{Z} T_z \left(\ln \frac{0,472 r_{ct}}{r_s} \right)} \left(p_m^2 - p_{dp}^2 \right) \tag{1}$$

where:

- Q_{st} – gas flow rate under reference conditions,
- k – permeability of the layer,

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h – thickness of the producing layer,
μ_g – average gas viscosity,
Z – gas compressibility factor,
T_{st}, p_{st} – reference temperature and pressure,
T – reservoir temperature,
r_{ct} – inflow contour radius,
r_s – well radius,
p_m – average pressure in the well drainage area,
p_{dp} – dynamic pressure in well perforations.

Equation (1) can be written as:

$$p_m^2 - p_{dp}^2 = a_z Q_0 \tag{2}$$

where: a_z – flow resistance factor of productive layer expressed as:

$$a_z = \frac{\overline{\mu_g} p_{st} T_z \overline{Z}}{\pi k h T_{st}} \left(\ln \frac{0,472 r_{ct}}{r_s} \right) \tag{3}$$

Further to analysing equation (1) it may be observed that the flow rate can be maintained at a constant level, under a decreasing variation of pressure in time on the inflow contour (for reservoirs with impermeable boundaries), by reducing dynamic pressure of the well, which can be achieved by use of compressors.

The impact of compression on the gas recovery factor can be emphasized by applying the zero dimensional volumetric model to impermeable boundaries gas reservoirs which are specific to Transylvanian Basin.

Thus, by using this model we obtain the linear function of the *p/Z* ratio depending on the recovery factor, as follows:

$$\frac{p}{Z} = \frac{p_i}{Z_i}\left(1 - f_r\right) \tag{4}$$

where:

p, Z – are pressure and compressibility factor at a given moment in time
p_i, Z_i – are the initial pressure and compressibility factor values
f_r – recovery factor.

Representation of function (3) using real data provides various scenarios for gas reservoirs exploitation behaviour.

Figure 1 can establish the energy level of a gas reservoir that is going to be exploited by use of compression and how much can the recovery factor be increased when a compressor is installed close to the christmas tree of the well; from this energy level the reservoir exploitation can continue down to a minimum reservoir pressure.

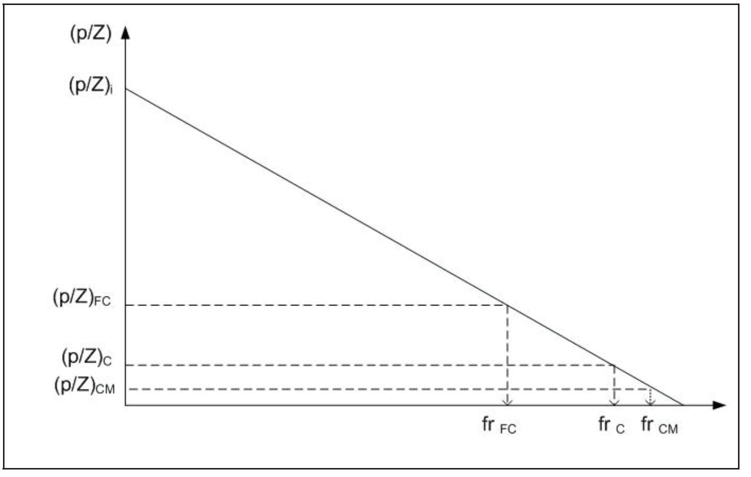

Fig. 1. Graph of function *p/Z = f (f$_r$)*
indices meaning: *i* –initial; *FC* – without compression;
C – using compression; *CM* – compression with mobile units

3. SELECTION CRITERIA FOR RESERVOIRS WHERE CLUSTER COMPRESSORS ARE TO BE USED

If during the final phase of exploitation of a reservoir the pressure in the gathering system is not reduced, the christmas tree dynamic pressure will equal the gathering pressure, making reservoir exploitation impossible. Therefore, a viable solution in this case is to install low inlet pressure compressors on the inlet of well clusters manifold or even on the well flow pipelines, as close as possible to the christmas tree, in order to eliminate the inconvenient of additional pressure losses on the gathering system, upstream the compressor. The result in terms of flow rate increase following the reduction of gathering pressure, verified by an economic analysis, is a key factor in deciding if the investment effort is justified.

Following the experiments performed in some wells in the Transylvanian Basin related to the influence of gathering pressure reduction (down to a minimum of 0.5 bar) on gas well productivity, a number of selection criteria were set for candidate wells with local compression, namely:

- Depleted fields. The depleted gas layer/reservoir concept defined by an advanced stage of production and reduced pressure, implicitly (very much below original pressure), is more and more used by the specialized literature. Unfortunately, this type of reservoirs can be found in most gas production blocks of Romania and especially in the Transylvanian Basin, in all the three geological sequences of major interest, namely Sarmatian, Buglovian, and Badenian.
- The best candidates of all depleted fields are those with lowest flow resistance coefficient while flowing through the pay zone ($a_z < 100 \cdot 10^{-3}$ bar$^2 \cdot$day/ cm).

- Average and small size fields, with flow rates below 150 thousand Stcm/day.
- Reservoirs with actual gathering pressure between 6 and 12 bar, as required by the transmission system operating pressure where the reservoirs are connected or by the operating parameters of the compressor stations servicing such fields.
- Reservoirs accumulating bottom hole water where the gas critical flow rate required to carry over the liquid phase is not reached if the gas gathering pressure is not reduced.
- Reservoirs where there is no other alternative to reduce the gathering pressure, but to direct the gas towards a low pressure system or towards local consumers.

4. CASE STUDY THE IMPACT OF CLUSTER COMPRESSION ON THE PRODUCTION OF CHIRPĂR FIELD

4.1. Field Description

Chirpăr field belongs to the gas domes group located in the southern area of the Transylvanian Basin and was discovered by area and detailed seismic surveys performed in the years 1980s.

The first well was drilled on the structure in 1981 and crossed Sarmatian, Buglovian and Badenian age formations. Starting from 1984, 23 of the wells drilled on the field became production wells. Currently this field produces through 20 wells, at a flow rate between 1 and 7 thousand m^3/day.

The gas produced by the 20 wells is gathered in a cluster, transported in a gathering pipeline at an average pressure of 7 bar which fluctuates by the seasons, namely during the warm season the pressure is 9-10 bar. During this season well operation is difficult because the pressure at the christmas tree, namely the dynamic pressure in the tubing is between 7.5 and 14 bar.

4.2. Production Simulation

The above mentioned findings were the assumptions of the scenario for the next exploitation phase of Chirpăr field where the pressure was reduced by installing a compressor on the gathering system, at the cluster.

In the first phase nodal analysis was performed with PIPESIM software for each of the 20 wells, by simulating the gathering pressure decrease from the current average pressure of 7 bar down to a minimum of 1 bar.

The analysis performed on well 16 Chirpăr is shown as an example that is considered significant for the way the reservoir reacts to the decrease of gathering pressure. This well has a positive reaction to the decrease of gathering system pressure, according to the information provided by the performance curves represented in Figure 2. In this case the sensitivity analysis shows an increase of flow rate as the dynamic pressure in the tubing measured at the christmas tree decreases.

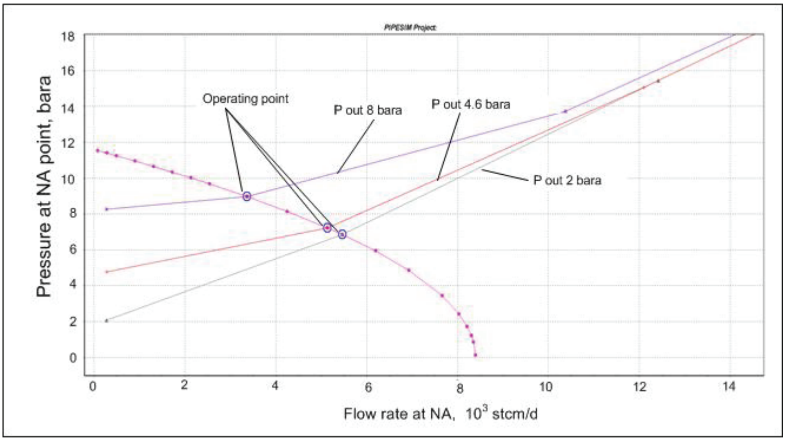

Fig. 2. Sensitivity analysis for well 16 Chirpăr

According to the sensitivity analysis the following pressure-flow rate pairs are obtained:

- 8 bara – 3.3 thousand m^3/day;
- 4.6 bara – 5. thousand m^3/day;
- 2 bara – 5.5 thousand m^3/day.

The flow rates obtained from sensitivity analysis have been used as initial moment in elaborating reserve estimation for each of the 20 wells and for the entire field, on the basis of average production well. Simulation of behaviour during exploitation was made with Oil Field Manager using two scenarios: with and without local compression. The scenario of pressure decrease using local compression indicates the extension of the field life and implicitly the increase of reserve.

Figure 3 shows the simulation results for well 16 and figure 4 shows the simulation results for the entire Chirpăr field, which approximately overlaps with the summation of the results from individual simulation of each well.

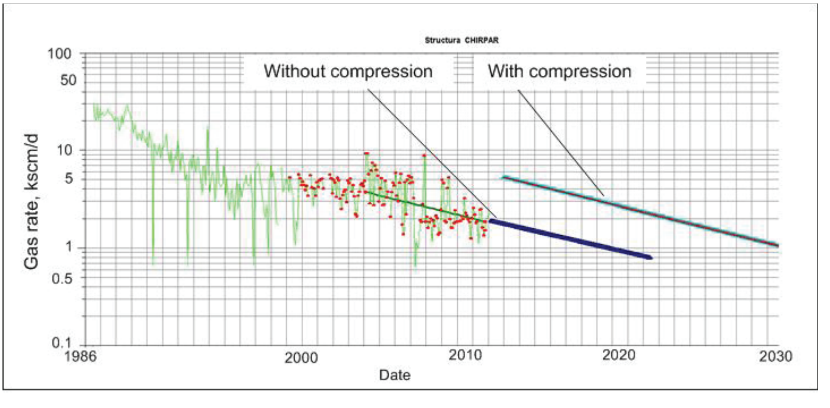

Fig. 3. Reserve estimation for well 16 using both scenarios

The analysis of reservoir behaviour for the two scenarios shows an extension of the field life, respectively the increase of recovery factor for the scenario with compressor installation.

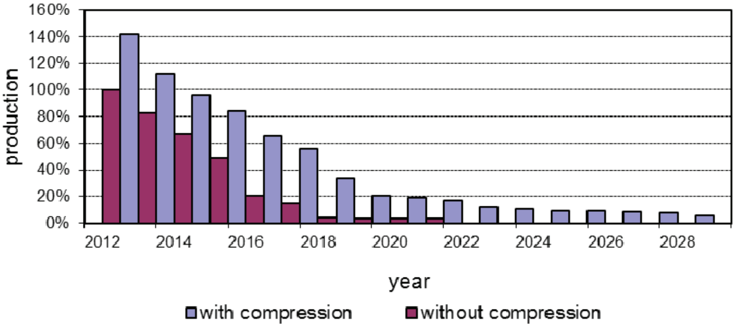

Fig. 4. Reserve estimation for Chirpăr field using both scenarios

4.3. Economic analysis

In order to appraise the efficiency of continuing the production from Chirpăr field with compression, a technical-economic analysis has been performed, namely the "Discounted Cash-Flow" method, considering a discounted rate for determining the NPV of 10% and working with constant currencies.

The "Discounted Cash-Flow" substantiates a system of indicators that characterize the production process of a hydrocarbon reservoir as an economic activity able to generate profit. Therefore the economic limit of producing from a hydrocarbon reservoir determines the time until production is profitable, namely the time until profit per production unit is equal to zero. According to the "Discounted Cash-Flow" method, the economic limit of production is reached when the cumulative net present value (NPVC) equals zero, or less.

Figure 5 shows the results of the cash-flow analysis for the two scenarios related to continuing production from Chirpăr filed. As shown in the graphic, in case of production without compression the economic time limit is year 2018 and in case of production with compression - year 2024. The difference between the two scenarios means for the scenario with compression, from an economic point of view - an increase of the cumulative net present value of 72%, and from a technical point of view – an increase of the recovery factor with 3%.

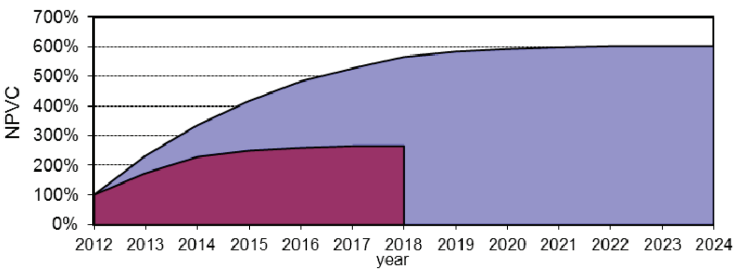

Fig. 5. Cash flow analysis

4.4. From theory to practice: project implementation

As mentioned before, Chirpăr is a depleted field that has been producing for 30 years with problems related to maintaining wells in production at potential capacity because of the dynamic pressure drop to values close to the gathering pressure value.

Based on the technical-economic analysis it was decided to procure and install two compressor units at the cluster where gas is gathered from all 20 producing wells.

These compressors were commissioned at the end of May 2013, and the impact on the total reservoir flow rate is shown in figure 6. The production behaviour, at least in the first 8 months further to installing the compressors, confirms the results of the simulation tests, being slightly better [2].

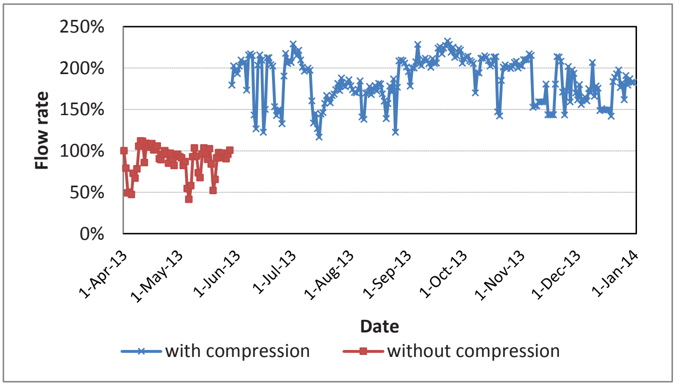

Fig. 6. Dynamics of the daily flow rate on Chirpăr field

5. CONCLUSIONS

- A viable solution for increasing the gas recovery factor is installing low inlet pressure compressors as close as possible to the christmas tree.
- Depleted fields with lowest flow resistance coefficient are best candidates for production with local compression, as well as reservoirs accumulating bottom hole water where the gas critical flow rate required to carry over the liquid phase is not reached if the gas gathering pressure is not reduced.
- Chirpăr is a depleted reservoir, with dynamic pressures and reduced production flow rates where production without compression is difficult.
- Simulating production with local compression at the cluster on Chirpar field and the economic analysis indicated an additional production (increase of the recovery factor by 3%) and highlighted a strong positive cash flow.
- The reservoir behaviour further to commissioning the compressors confirmed the simulation results, future perspectives of consolidating the production and increasing income are certain.

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