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DEPLETED GAS RESERVOIR MANAGEMENT IMPROVEMENT BY IMPLEMENTING SPECIALIZED MOBILE TEAMS

1. INTRODUCTION

Throughout the life cycle of a hydrocarbon reservoir, specific operations are carried out in accordance with the reservoir potential assessed at a given moment, as well as the medium and long term development field plan.

When the reservoir reached the maturity stage, production management teams focus their full efforts to reduce the production decline rate, to extend the production period time, respectively to postpone the abandonment time.

In this respect, the rehabilitation projects of brownfields have the role of capitalizing the effective potential of the reservoir in an efficient and rational manner over time in order to achieve attractive recovery factors.

An essential activity in terms of production and reservoir management is related to the maintenance operations which consists mainly in liquid unloading and flowback operations, monitoring dynamic production parameters, respectively ensuring integrity and leakage prevention within the production system.

A significant challenge in this context is represented by large exploitation perimeters as surfaces which requires special considerations due to the location of the wells and implicitly the execution of the maintenance program.

In order to mitigate the effects of the advanced state of depletion, a new approach to the execution of maintenance programs was considered by implementing the specialized mobile teams on extended exploitation perimeters as surfaces, this approach being under the scope of rehabilitation projects of depleted gas reservoirs.

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2. BACKGROUND OF THE IMPLEMENTATION CONCEPT OF SPECIALIZED MOBILE TEAMS TO IMPROVE THE RESERVOIR MANAGEMENT

It is unanimously recognized that the rehabilitation projects of depleted gas reservoirs, essentially, aim to increase the recovery factor and reduce the production decline profile, which ultimately add more value in late recovery stage of production (Fig. 1).

Both, the recovery factor and production decline are typical performance indicators, correlated with the drive mechanism, that finally highlight the efficiency of the reservoir management.

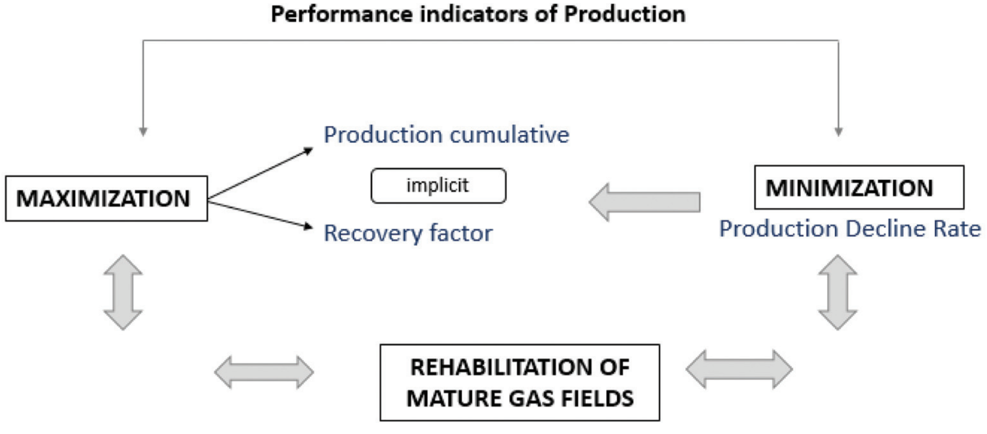


Fig. 1. Interdependency between Recovery Factor and Production Decline in Rehabilitation projects [3]

Mathematical expression for the recovery factor (f_r) and production decline (D_e) are as follow [4]:

$$f_r = \frac{\Delta G}{G_0} \tag{1}$$

where:

ΔG – cumulative production,

G_0 – initial gas resource in place (OGIP).

$$D_e = \frac{\Delta G_{n-1} - \Delta G_n}{\Delta G_{n-1}} \cdot 100 \tag{2}$$

where: ΔG_n and ΔG_{n-1} represents the cumulative gas production of the years $n-1$ and n.

Taking into account the dependence that exists between the production decline trends that relies on production history to extrapolate future production performance and the expected recovery factor, overall trends can be significantly affected by reservoir management improvement such us maintenance operations, workovers, stimulation and infill drillings.

From the analysis of qualitative graphical representation related in Figure 2 it can be noticed that significant values of the additional production are obtained in rehabilitation projects after performing a complex operations such wells reactivation, which are often based on application of new technology and equipment whose associated costs are significant (curve c). The other components of the extra gas production, namely the curves b and d are not to be neglected. If the rehabilitation model established and put it into practice gives expected results, respective, if the hydrodynamic conditions are met, the drilling of new wells (curve e) may add additional flow rates [1].

Within the subject of current paper, the efforts are focused on the curve b, namely to add production from well optimization and maintenance operation.

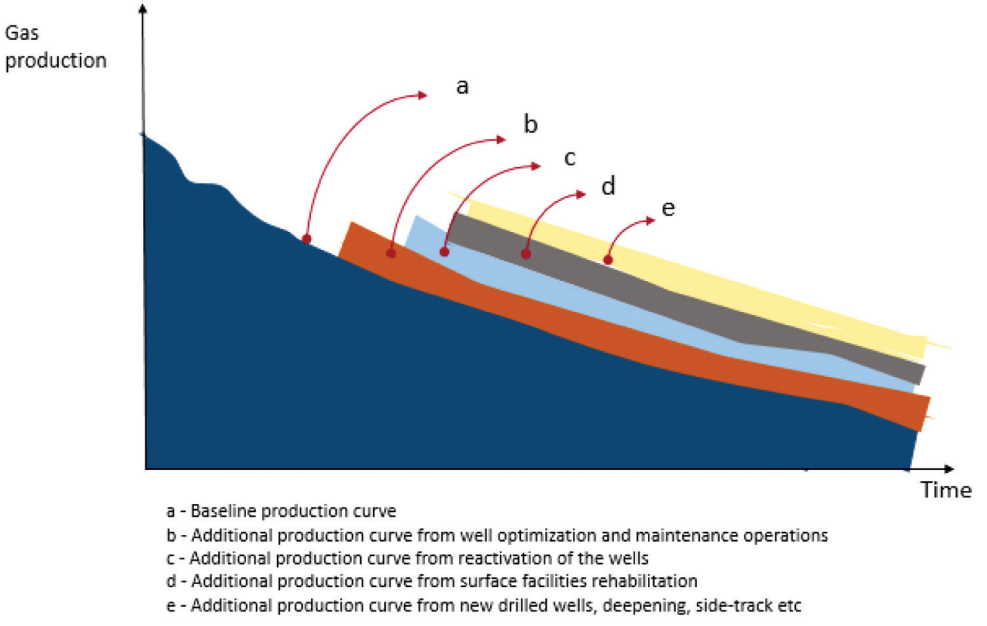


Fig. 2. Additional gas production by time (qualitative graphical representation) [1]

At the maturity stage of the production of the gas reservoirs, with its depletion there are more challenges to maintaining the wells on production at optimal operating parameters.

An important and necessary aspect of maintaining the wells on production, respectively improving the productive performance, is the maintenance activity on daily basis which means liquid unloading using artificial lifts methods, monitoring the production parameters and intervene in the right time to prevent the gas flow rate drop, ensuring integrity and preventing possible pressure leaks that may be caused by the long-term exploitation of the facilities constituting the surface production system.

The maintenance activity is usually performed with specialized personnel assigned to the technological groups where a limited number of gas wells are connected for separation-measurements processes and eventually, local field compression.

It has been noticed throughout the production history that the wells located on extended exploitation perimeters as surfaces, some of them being placed in isolated areas, have low productivity and do not produce at their potential. The location of the wells on large surface exploitation perimeters definitely affects the execution of daily maintenance programs due to the relatively difficult access or distance from the technological group to the wells.

Also, the identified causes of what has been mentioned previously related to the low productivity of the wells are as follows:

1. The wells are liquid flooded or loaded and are not able to unload using their own energy being in an advanced stage of depletion.

This statement is supported by the results obtained after interpreting the data acquired through wellbore gradients surveys performed in flowing and static conditions. Wellbore data or information obtained through pressure gradients surveys such us bottomhole flowing pressure (p_{wf}), bottomhole liquid level, bottomhole mechanical conditions through drifting can lead to the identification of quick real-time solutions to optimize the gas flow from reservoir. Correlating this information with the well construction and with theoretical aspects developed for critical well flow rate for liquid unloading, give us a more realistic idea about how we should proceed to optimize the productive performance of the well. System nodal analysis tools have been used to analyze the effects of liquid loading on the gas wells because it uses the flow correlations for vertical two-phase and we are able to predict the variation of pressure with elevation along the length of the flow string, respectively the flow regimes.

Under the circumstances mentioned above, the reservoir pressure depletion is another factor which has an adverse impact on liquid unloading. At this stage of exploitation, the reservoir pressure has obviously low values, considering that the reservoir is producing through gas expansion drive mechanism. Under permanent pressure drawdown conditions correlated with the final recovery factor estimated in the rehabilitation process, an additional effort through field compression has been made in the field. The effect of compression has a positive influence on production, and to be specific in the case of a field that will be taken later as an example, additional gas production obtained from compression represents approximately 30% of the total daily production, which is not negligible.

2. There are not enough representative production data recorded to monitor the real performance and intervene in the right time, in order to improve the well productivity.

This affirmation is based on the fact that although a real time monitoring system is currently implemented in the field for gas rate and field pressure, these are not enough in order to intervene in the proper time to maintain the well at optimum flowing parameters. This means that the data recorded through monitoring system must be checked and confirmed by production teams to make more accurate production forecasts, respectively to create work programs that achieves the set out objectives.

Integrating all aspects mentioned above, namely the relatively large distances between the wells and the technological groups inside of large exploitation perimeters as surfaces and the identified causes for low productivity, in the rehabilitation project it was considered appropriate to look for a new approach to execute the maintenance program.

It is worth to mention that the maintenance program was in place and executed by specialized personnel assigned to technological group but, operationally speaking, due to difficult access to well location, especially in isolated area, when the weather conditions are unfavorable, sometimes the monitoring process and execution of daily programs is difficult to be done.

In this context, it was considered necessary to conduct a pilot test for the implementation of mobile teams consisting of existing specialist personnel in the field. If until now it was assigned to a technological group and worked in shifts as per working rules in force, this new approach comes with team work concept, definitely respecting the existing working rules. In fact, is a new approach of field management to execute daily maintenance program.

To exemplify this new approach of field management with implementation of specialized mobile teams on delimited zones, in the next chapter will be taken a large exploitation perimeter as a case study.

3. CASE STUDY – IMPLEMENTATION OF SPECIALIZED MOBILE TEAMS TO IMPROVE THE FIELD MANAGEMENT

The new approach of reservoir management for maintenance program execution by implementing specialized mobile teams is a particular application for a Romanian gas field whose exploitation perimeter is located on large surface, more than 5,000 km^2.

The main considerations behind the implementation of this approach are the following:

- Large distances between the wells and the technological groups.
- Difficult access to the well location, especially during winter season.
- To ensure a safe exploitation process of the productive infrastructure.
- To improve the field management activity.
- To increase the wells productivity.

Starting from these aspects have been created workflow scenarios taking into account the following criteria:

- Delimiting work areas/zones to cover the entire productive area of the field.
- Balanced distribution in terms of the distance of each specialized mobile team.
- Execution of the maintenance program and other specific activities related to the production process at all active wells.
- Teams of specialists will be made up of 3–4 specialized people depending on the specificity of each area.

Integrating the aforementioned aspects led to the organization of the extraction process on the gas field "X", taken as a case study, which will be carried out according to the delimitation plan from Figure 3, where 5 work areas are illustrated. It is obvious that the productive zone it can be delimited according to the conditions imposed in each project without affecting the existing resources. Figure 3 is only a representation map of the exploitation perimeter for gas field "X" on which were mapped the zone limits, where each team will be responsible for the execution of the work program [1].

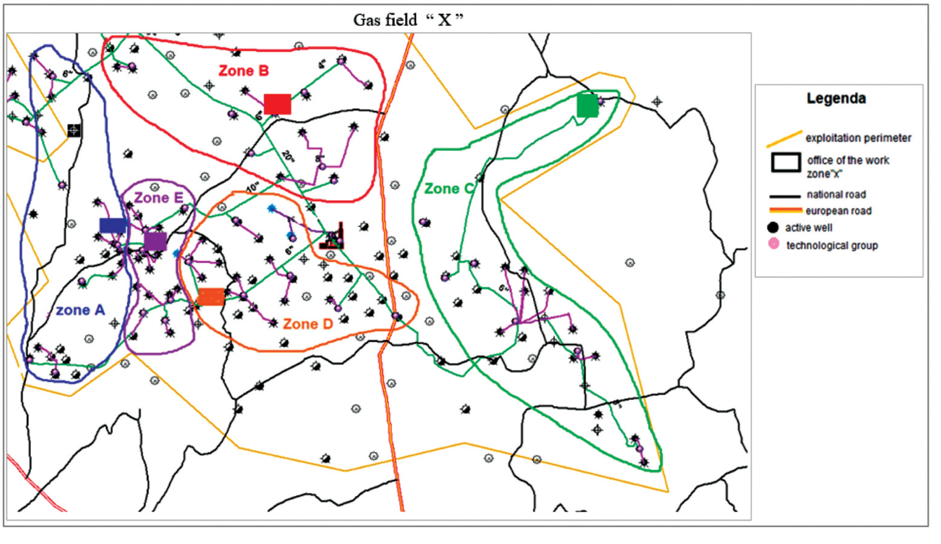


Fig. 3. Delimitation plan of the working areas on the gas field "X" for specialized mobile teams [2]

As can be noticed in Figure 3, inside of each delimited working area are allocated a number of wells and technological groups, and an office where the specialized mobile teams prepare the necessary materials for the daily maintenance programs, prepare the well reports in daily basis, and the shift reports.

For each well, an individual maintenance program was performed according to a number of factors:

- The productive potential resulted from nodal analysis in which the key input elements were represented by bottomhole flowing pressure, reservoir pressure and surface restrictions.
- Well construction (net pay zone /perforations, tubing, packer, existing debris or even junk tools in the wellbore).
- Liquid-gas ratio.

Based on individual maintenance program per well, a series of activities to be performed in the field have been generated, whether they are daily, periodical or exceptional. These activities are presented in Figure 4 in a brief form.

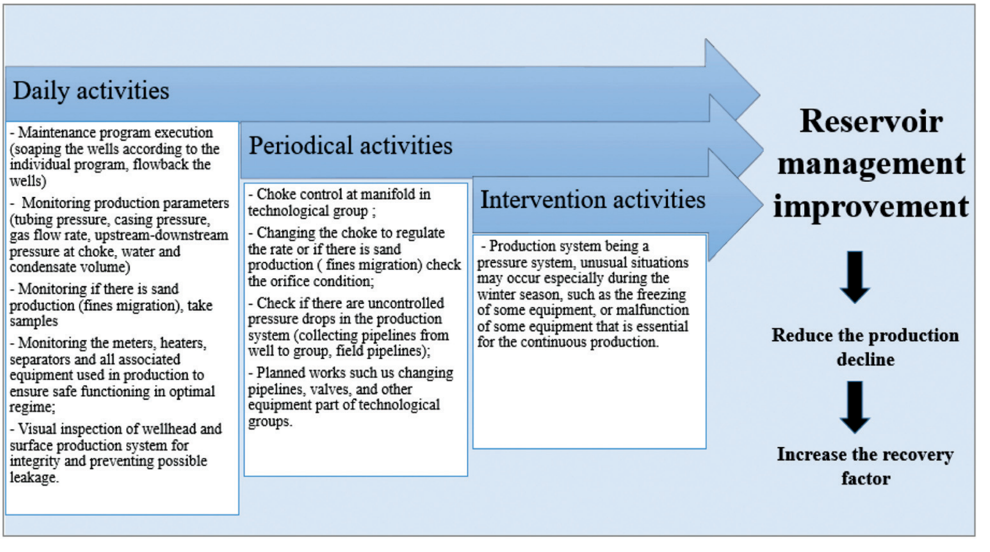


Fig. 4. Summary of the activities to be performed by specialized mobile team in each delimited working zone [2]

As can be seen in Figure 4 these activities have a significant role in field management, which ultimately contributes to production decline rate reduction and increasing the recovery factor by ensuring a continuous production process, respectively prevents premature flooding of the well.

From the 5 delimited working areas was chosen as an example (zone B) to illustrate in a flow process the activities to be executed in daily basis within 24 hours (see Fig. 5).

The flow process has been created for each zone in order to structure the complex activities which must be carried out by specialized mobile teams. It can be noticed the fact that the implementation of mobile teams in the field means practically a continue process of monitoring the wells performance and a safe exploitation of the productive infrastructure.

Daily activities flow for zone "B"		Time (hour)												
Activity code	**Activity description**	6	7	8	9	10	11	12	13	14	15	16	17	18-05
A1	Shift report													
	Prepare the materials, tools for daily program execution													
A2	well#1 – daily activities execution according to well program													
A3	well#2 – daily activities execution according to well program													
A4	well#3 – daily activities execution according to well program													
A5	well#4 – daily activities execution according to well program													
A6	well#5 – daily activities execution according to well program													
A7	Meal break													
A7	well#5 – daily activities execution according to well program													
A8	well#7 – daily activities execution according to well program													
A9	well#8 – daily activities execution according to well program													
A10	well#9 – daily activities execution according to well program													
A11	Reporting the production parameters and events to production center of the company/production department/subsidiary													
A12	Creating the daily report Shift report													
A13	Monitoring production parameters													
	Monitoring production equipment to ensure safe process													
	Intervene and Report if there are malfunctions in the system													

Fig. 5. Daily activities-flow process corresponding to zone "B" [2]

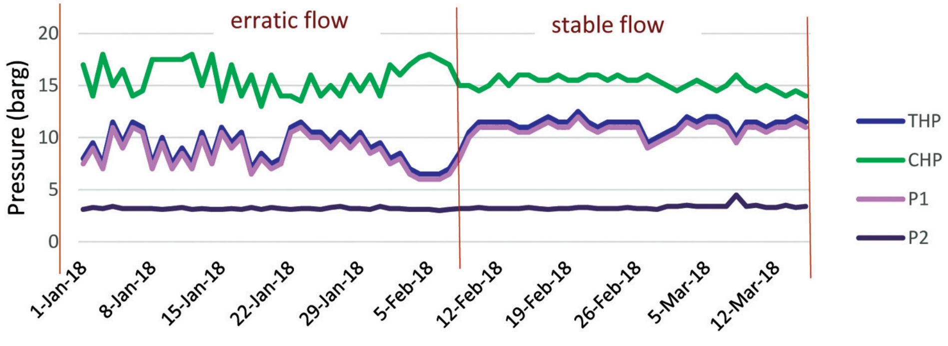
This application is really necessary in the conditions in which the gas reservoir is at an advanced stage of depletion and the related facilities have been exploited for a long period.

4. EXPERIMENTAL RESULTS OBTAINED FROM A PILOT TEST RUN IN THE GAS FIELD "X"

As already it has been mentioned the considerations which underlying the implementation concept of specialized mobile teams in gas field "X", the authors of this paper consider that is necessary to show some results after a pilot test was run in the field on zone "B".

For example, in the case of well#1 (Fig. 6) it can be noticed that before implementing the specialized mobile teams, the well was produced under erratic conditions and slugging flow, even if the maintenance program was executed, but being at high distance from technological group, the access and possibilities to soap and flowback the wells, was more difficult during winter season. Also the well was produced at lower rate than predicted by the reservoir inflow performance relationship.

a)



b)

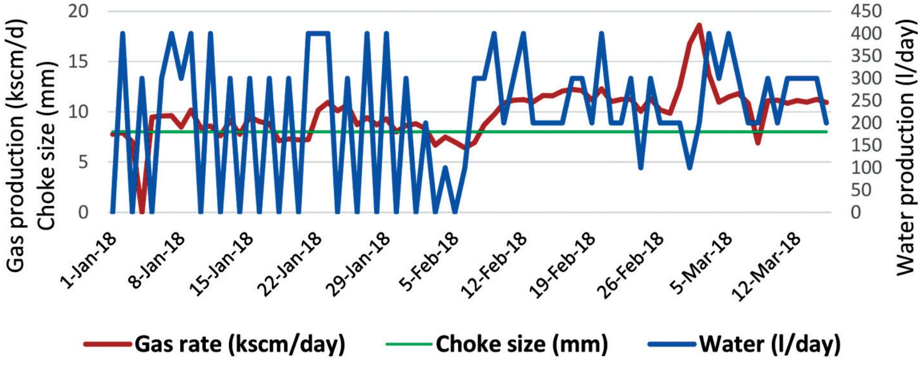
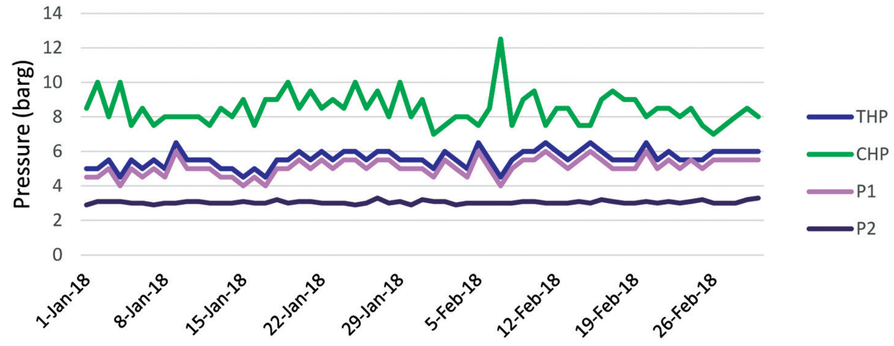


Fig. 6. Well#1 production performance before and after implementation of specialized mobile teams in the field: a) pressure evolution; b) gas and water production

Also, it can be observed in Figure 6 that the gas rate increased from an average gas production of 8.4 kscm/d to 11.3 kscm/d, respectively the water volume produced has begun to have relatively constant values. By maintaining the well in stable flowing conditions which means eliminating pressure fluctuations and a constant deliquification program, more accurate production forecasts can be made, and implicitly the production decline can be reduced. Definitely, this application is a complementary action in reservoir management considering the positive effects of compression.

In terms of well#2, it can be observed in Figure 7 that the gas flow rate increased with 50% after the specialized mobile team was implemented on zone "B", without changing the operating conditions in the field.

a)



b)

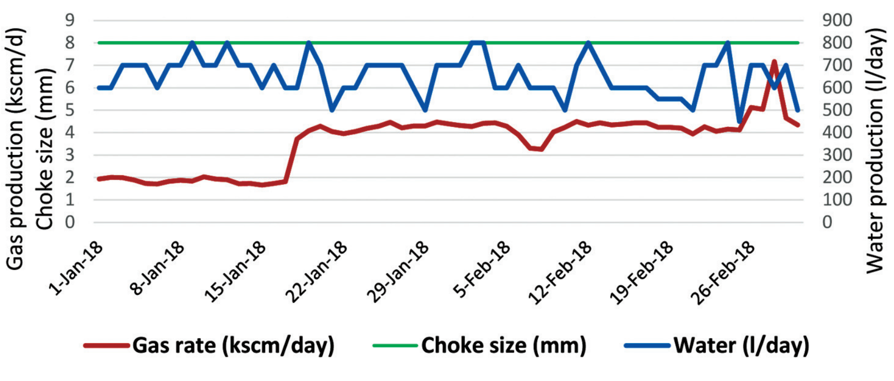


Fig. 7. Well#2 production performance before and after implementation of specialized mobile teams in the field: a) pressure evolution; b) gas and water production

If we are looking to the casing pressure and tubing pressure, we can observe some symptoms of liquid loading in the well. The tubing pressure decreased while the casing pressure started to increased. The values are sensitive, but after the maintenance program has been implemented with specialized mobile teams, the liquid hold-up was decreased, thereby the gradient in the tubing was reduced as well as the backpressure on formation.

These two examples of the paper have been presented to illustrate some of the results obtained in the rehabilitation project of gas field “X” whose exploitation perimeter is a very large area, where the concept of carrying out the maintenance program with specialized mobile teams has been implemented under the form of a pilot test on zone “B”.

Of course this approach of reservoir management is in incipient phase, it is still under testing and after a period that will be considered sufficient and conclusive the future actions will be outlined.

5. CONCLUSIONS

The new approach of implementing the specialized mobile teams to execute the maintenance program on large exploitation perimeters as surfaces, is a preventing action to extend the life cycle of the well, respectively to postpone the abandonment of the well. These actions, certainly contributes to the increase of the recovery factor and to the reduction of the production decline rate, concomitant with other methods and technologies applied in the maturity stage of gas reservoirs.

As the approach for carrying out maintenance programs with specialized mobile teams is in the testing phase can be drawn the following conclusions:

1. The large exploitation perimeters as surfaces experiencing typical challenges due to the relatively high distances between the well and technological groups, especially when the weather conditions are not favorable, thereby it requires more special attention from production teams.
2. Production management teams must follow the behavior of the wells and find the optimum solution to maintain the well on production by preventing the liquid loading problems.
3. The reservoir management improvement aims to reduce the decline rate and maximize the recovery factor order to add more value to the reservoir at maturity stage, and definitely as has been illustrated in Figure 2 to contribute on curve b.
4. Economic analysis and production results are decisive in this respect, namely the extension of the implementation of this new concept on the large perimeter gas fields.

Acknowledgement: SNGN Romgaz SA.

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