THE INFLUENCE OF TECHNOLOGICAL PROBLEMS OF THE WELLS ON THE ENERGY POTENTIAL OF THE NATURAL GAS FIELDS

INFLUENȚA DIFICULTĂȚILOR TEHNOLOGICE ALE SONDELOR ASUPRA POTENȚIALULUI ENERGETIC AL ZĂCĂMINTELOR DE GAZE NATURALE

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Abstract: *The energy potential of a commercial natural gas field is estimated from the complex stage of the exploration works, which include, among others, geochemical analyzes, 2D and 3D seismic investigations, exploration drilling etc. The favorable results obtained from this stage open the way to the next stage, namely that of achieving the optimum number of the exploitation wells. This is the stage after which the dimension of the energy potential is well outlined and a series of technical-economic forecasts can be made regarding the performance in the exploitation of the reservoir. The behavior in time of the respective commercial field is largely conditioned by the reservoir characteristics as well as the state of the productive infrastructure, which is comprises the wells, the surface facilities, the drying and gas compression stations, environmental protection installations etc.This article will present a series of difficulties of the wells frequently encountered in the activity of the exploitation of the natural gas fields, the impact of the malfunctions on the performance of the reservoir and some approaches to overcome them.*

Keywords*:* gas wells, technological problems, energy potential

Rezumat: *Potențialul energetic al unui zăcământ comercial de gaze naturale se conturează încă din etapa complexă a lucrărilor de explorare, care cuprind, în principiu, printre altele, analize geochimice, investigații seismice 2D şi 3D, foraje de explorare etc. Rezultatele favorabile obținute în urma acestor foraje deschid calea spre următoarea etapă şi anume aceea a realizării gabaritului optim al sondelor de exploatare. Aceasta este etapa în urma căreia dimensiunea potențialului energetic este bine conturată şi se pot face o serie de prevederi în termeni tehnico-economici privind performanța în exploatare a zăcământului. Comportarea în timp a respectivului zăcământ comercial este condiționată în mare măsură de caracteristicile zăcământului*

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precum şi de starea infrastructurii productive care se compune atât din fondul de sonde cât şi de întregul ansamblu de instalaţii tehnologice de suprafaţă ale sondelor, staţii de uscare şi comprimare a gazelor precum şi instalaţii protecţiei mediului.În acest articol se vor prezenta o serie de dificultăţi ale sondelor frecvent întâlnite în activitatea exploatării zăcămintelor de gaze naturale, impactul disfuncţionalităţilor asupra performanţei zăcământului şi modalităţi de remediere a lor.

Cuvinte cheie: sonde de gaze naturale, dificultăţi tehnologice, potenţial energetic

1. Introduction

The exploitation of mature natural gas fields has been and will be an increasingly topic that will attract the attention of the production companies, given that most of the production, about 60-70%, comes from these reservoirs.

Mature fields or brownfields are those hydrocarbon reservoirs characterized by an advanced stage of reservoir pressure depletion, have difficulties and various operational challenges such as blockages of the productive layers, liquid loading, sand production, high water rates etc. Also, mature fields, after decades of exploitation, are characterized by difficulties and / or challenges related to the exploitation of surface facilities in the sense that the equipment can have a high degree of wear which can generate a lower operating safety level.

Analyzing the qualitative graph of productive life cycle of a gas reservoir (Figure 1), it can be seen that mature fields no longer fall in the areas II and III (known in the literature as "peak production" or "plateau production" - productive period of reservoir that highlight the increasing trend and production stability), but fit into the area where declining production trend is beginning to register (zones IV, V and VI).

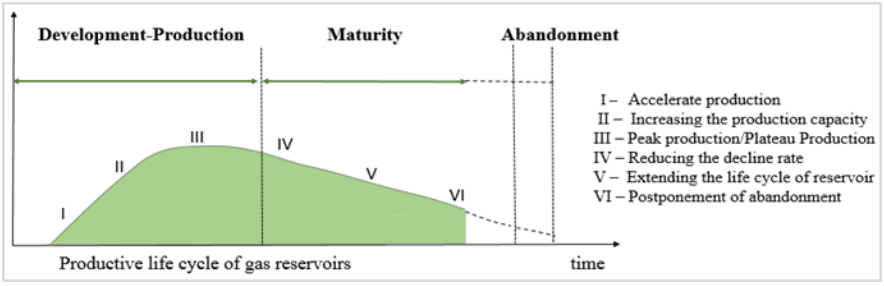

Figure 1 - Graphical representation of productive lifecycle of a gas reservoir [3]

The "maturity" stage of natural gas reservoirs has a particular correspondent in the exploitation activity, as the productive potential of these reservoirs can be still tempting in terms of the economic benefits.

For most gas structures, most of the times, the gas rates were imposed for reasons of progress and industrial development. This fact seen through the life cycle of a natural gas field has generated major investments in the development-production phase, respectively in the constant level of production, but correlated, over time, with certain dysfunctions between the productive possibilities of the fields and the demand for gas. The dysfunctions that appear in the complex process of gas extraction are reflected by a series of inconsistencies between the production provisions, based on the production history and the cumulative gases extracted. These discrepancies may belong to fields in which we have a special interest, and the value of current recovery factors are not at the expected level [4].

2. The main difficulties encountered in the exploitation of natural gas fields

The problems encountered in the exploitation of gas fields can be divided into three major categories:

- Difficulties related to the exploitation of the reservoir,
- Difficulties in operating wells,
- Difficulties related to the operation of the facilities or production infrastructure.

Figure 2 shows a diagram with the technological problems related to the three categories mentioned above, but also solutions to remedy them, solutions that can be partial or total.

The technological problems associated with the exploitation of the gas field presented in fig.2 are coexistent and lead to the decrease of productivity, thus influencing the production decline and the final gas recovery factor.

The decline in production and the gas recovery factor are two key indicators for assessing the operating performance of wells and reservoirs, so that by applying techniques and solutions to technological problems seeks to reduce the rate of decline and maximize the recovery factor.

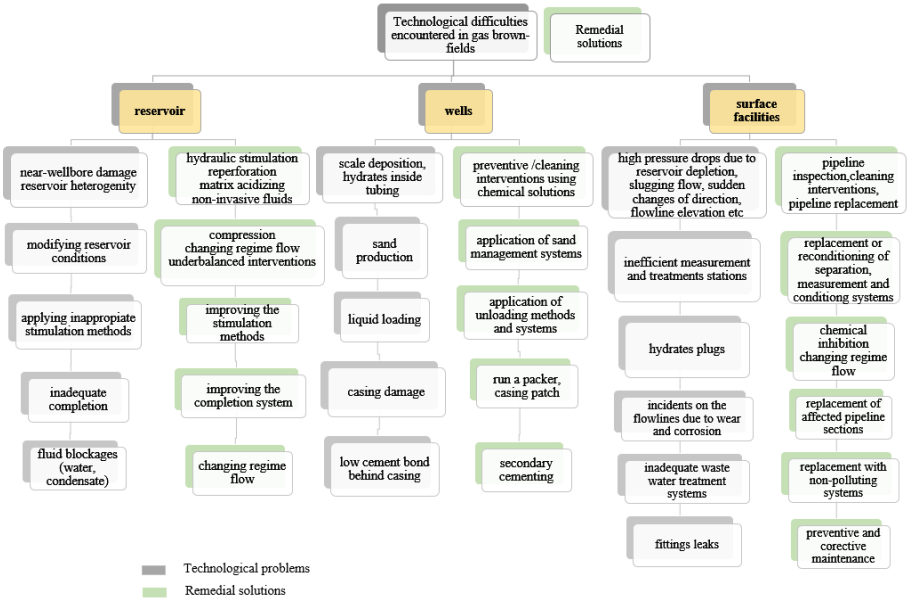

Figure 2 - Technological issues of a gas field vs. possible mitigations solutions

3. Remedying the technological problems of natural gas wells through the concept of rehabilitation - a current approach in order to capitalize the energy potential of mature fields

Continuing to exploit mature natural gas fields is a complex challenge, but there are still several viable options that can be considered and successfully applied to reduce the rate of decline and extend the life cycle of the mature fields that will eventually lead to obtain higher recovery factors.

One of the ultimate options for maximizing the recovery factor is the so-called rehabilitation concept.

Rehabilitation operations apply to mature gas fields, which, although having a significant production history, still have an energy capacity that could be exploited in economic conditions. Conceptually, the rehabilitation of a mature natural gas field can be divided into three sequences: field, wells, surface facilities. Intervention in one sequence or another, or concomitant intervention in the three sequences is dictated by a reason based on the technical-economic tandem [6].

In other words, the rehabilitation of mature hydrocarbon fields, in particular natural gas, is the stage after which the structure considered as a

field and productive infrastructure will have to produce, over time, a larger volume of fluids than those related to natural decline.

Starting from this premise, there is the problem of establishing the optimal period for starting the rehabilitation process of a deposit, respectively establishing the criteria for which a deposit can be considered rehabilitative.

Determining the period for which the implementation of the rehabilitation concept or the project management concept on a field is optimal is based on future intentions related to that productive structure.

The implementation of project management in the oil and gas industry appeared as a result of the fact that within the execution of operational programs a project management was systematically developed with the aim of improving the decision-making process and the general execution of the operation, where usually they went through five stages: evaluation, planning, execution and control [7].

The sequences or phases of a rehabilitation project are those of the classical / traditional approach (related to any type of project). Taking into account the activities specific to the exploitation of hydrocarbon fields, a scenario in which the phases of project management are foreseen from the perspective of rehabilitation of mature natural gas fields (Figure 3).

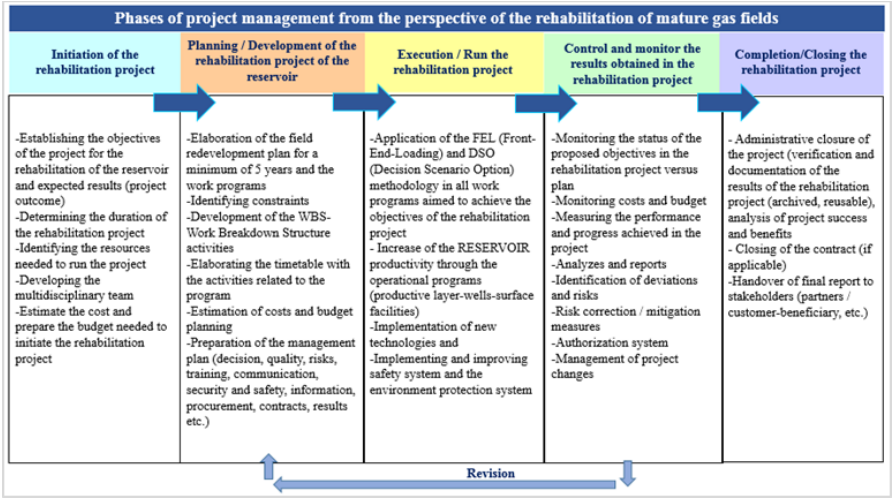

Figura 3 - Phases of project management from the perspective of rehabilitation of mature gas field [3]

In order to implement the concept of rehabilitation in the gas areas, technical-economic documentation must be prepared to justify the proposed works to increase productivity. These documents are:

- The development plan of the field is the reference documentation based on which the petroleum operations are carried out on the exploitation-production perimeters taken in concession and is a control tool regarding the exploitation of the fields. The development plan is essentially the document that substantiates the quantity and quality of geological resources and reserves, this being confirmed / approved by the competent authority.
- The annual work program is a technical-economic document in which is presented the program of operations to be executed in the following year and the necessary budget. Compared to the development plan, the work program has a much more detailed structure and is an internal document of the rehabilitation project, approved by the executive magement, but it must include the works provided in the development plan which are obligations, but also other additional works aimed to recover the reserves and increasing the recovery factor.

The work programs should generally include the following:

- Remedial programs for the difficulties of exploiting the reservoir for the immediate period in which concrete actions are taken to reduce the rate of decline and to improve the productivity of the wells in order to achieve the objectives of the rehabilitation project (workovers, well completion, production stimulation-acidizing, re-perforation underbalance, fracturing, modernization of surface facilities, installing compression etc.)
- Program for assessing the potential of the reservoir for both productive and by-passed or even undiscovered layers. This program may include seismic data acquisition, geophysical investigations, geological studies and detailed field engineering, field research, laboratory research and experiments etc. In practice, the additional evaluation program aims to acquire new data leading to new work programs to be carried out within the rehabilitation project.
- The budget required to carry out all the works to increase the productivity and the reservoir evaluation program, is broken down into operating expenses and capital expenditure (OPEX and CAPEX).

Within the field rehabilitation project, the constraints or restrictions that may condition or limit the development plan and work programs must be identified. Constraints are in principle related to resources and time, but once they are identified, a contingency plan is created to avoid unforeseen situations and to effectively manage risks (risk management plan).

The additional production resulting from petroleum operations may come from operations / interventions as follows: well maintenance optimization, well re-activation, well equipment or re-equipment, well deepening, well side-tracks, new well drilling, operations to stimulate the productivity of wells, rehabilitation of surface infrastructure by minimizing pressure drops in the production system, etc.

Figure 4 shows a qualitative graphical representation of the way in which the efficiency of rehabilitation projects is evaluated in terms of the field productivity.

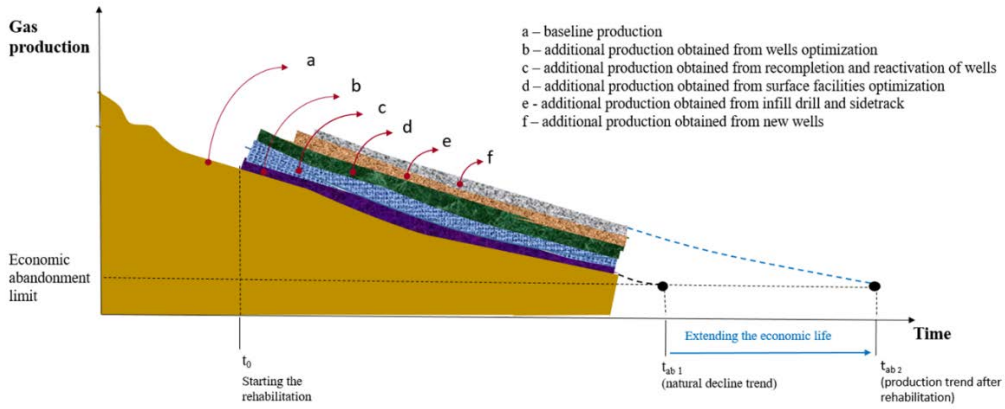

Figure 4 - Qualitative graphic representation of additional productions obtained through various petroleum operations [4]

Referring to the graph in fig. 4., if in the basic scenario, the economic limit of abandonment of the field shall occur on at time ”tab_1”, it can be seen that the increase in production brought through reabilitaion works, the economic viability of the field to the time extende until time ”tab_2”, which means that a higher volume of reserves has been recovered from reservoir.

4. Case studies. Perspectives to continue the exploitation of mature gas fields

To support the theoretical aspects presented previously, the following two case studies will exemplify approaches of the remediation of technological problems associated with mature fields through the view of the concept of rehabilitation.

Case study no.1. *Remedying technological problems in gas wells by removal of carbonate scale from perforation zone*.

Scales are minerals that have precipitated due to changing physico-chemical conditions during the exploitation of the productive layer. The physico-chemical conditions changed either naturally due to the depletion of the reservoir or during the operations performed in the wells, during which fluids with a different chemical composition were used compared to the composition of the fluids from reservoir and which reacted with the rock minerals. Thus, by scale formation on the walls of the tubing, in the flow of gas pattern to the surface appear some additional resistances that oppose the free movement of natural gas, and the effects are much more pronounced in the case of depleted reservoirs.

The most encountered type of scales in Transylvanian basin are halit scales and carbonate scales.

Figure 5 - Carbonate scale inside tubing (*foto left side*) and halit scale *(foto right side)*

In the Transylvanian basin, a common practice of removing scales deposits is acid wash, which is performed in the perforation zone and tubing inside. The operation is executed with the coiled tubing equipment and a depth device called a wash-nozzle.

Fig. 6 shows the gas production profile of well A after a wash acid intervention was performed, the solution prepared contained 16% formic acid (HCOOH). The injection rate of acid was solution was 140 liters/minute near by production zone and the injection time was approximatevely 5 minute/station. As it can be observed in fig. 6, the production of the well increasead from 6 to 18 kscm/d, therefore an additional gas production of 12 kscm/d was gained.

The productivity index of this well was doubled, the bottomhole flowing pressure increased from 13 bar to 29 bar, which assume that the blockage caused by carbonate scale was removed.

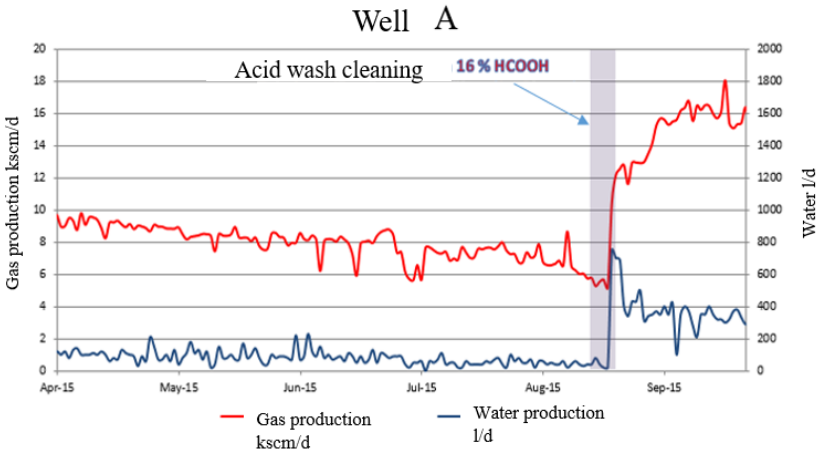

Figure 6 - Gas production profile of well A after acid wash was performed to remove the carbonate scale

In the table below are presented the parameters takend into account for productivity idex calculation of well A.

Table 1 – *Productivity index calculation-parameters for well A*

	Before acid wash	***After acid wash***
Gas production (kscm/day)	9	16
Average reservoir pressure (bar)	65	65
Aaverage bottomhole flowing pressure (bar)	12.5	29.3
Productivity index (kscm/day/bar^2)	2.21	4.75

Within an annual program in which 10 such operations were performed on a gas field, an additional natural gas flow of approx. 60 kscm/d and an NPV (Net Present Value) of approximately $ 500,000 were obtained (Figure 7)

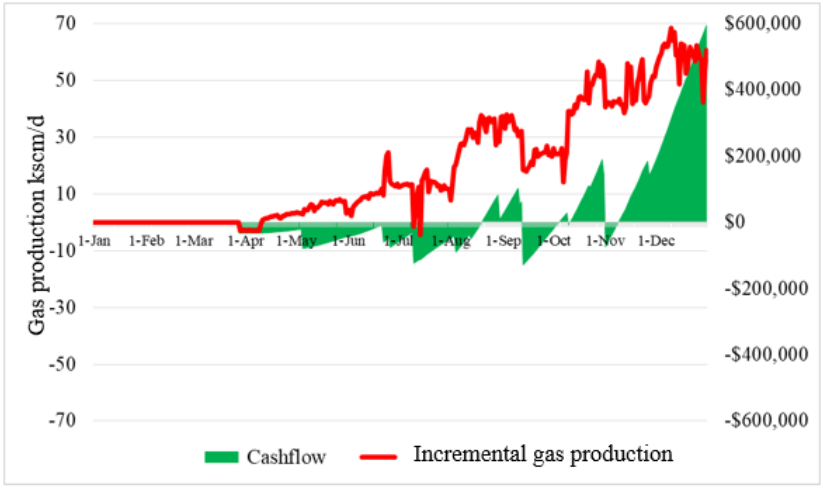

Figure 7 - The economic results obtained after remedial interventions were executed in 10 gas wells (removal of carbonate scale)

Case study no.2. *Remedying technological problems in tight gas reservoir through underbalanced perforation.*

The gas reservoirs located in the Transylvanian basin, especially those located in Badenian geological unit, are tight reservoirs, these are highly compacted with interbedded sandstones in shale matrix, the permeability is between 0.1-2 mD. The challenge related to the exploitation of these reservoirs is that the wells are producing at very low flow rate and the current recovery factors are between 30-60% [2].

In order to stimulate the productivity of these kind of unconventional reservoirs, in general, the techniques consist in hydraulic stimulation, perforations with deep penetration technologies and drilling high deviated well trajectories. A current trend to stimulate the productivity of wells that open “tight” gas formations is to combine the advantages of the deviated wells with the advantages of hydraulic stimulation or deep penetration perforation [1].

A current approach in the case of stimulating tight reservoirs from Transylvanian basin is underbalance perforation or reperforation. The perforation systems suitable for tight gas formations are those that use the deep penetration technique, where the communication channel made between the well and the layer is made on long perforation length. A particularity of mature reservoirs is that the reservoir have low pressures, and to obtain maximum productivity of the well, the perforation operation

must be performed underbalance, which means that the hydrostatic pressure of the fluid in the well must be less than the gas pressure in the rock. The purpose of this underbalance is to prevent the invasion of the fluid in the near-wellbore area and to increase the gas inflow into the well.

Figure 8 shows an example with the production profile of well B, located on a field in the center of the Transylvanian basin, following the stimulation by re-perforation of the productive layer. During the stimulation operation, the advantages of the deep penetration technique were combined with the underbalanced conditions. To perform the operation, the Snubbing installation was used (working under pressure installation) so that it was no longer necessary to kill the well. The perforating system was chosen based on the results obtained in a specialized program of perforation analysis which took into account the physical properties of the rock and the well completion, so that the perforation system applied was 3 3/8" High Shot Density, Power Jet Omega 3506, HMX, 60 degree, penetration depth 13,69 inch (348 mm), AOF- Absolut Open Flow 20.35 cm^2/m.

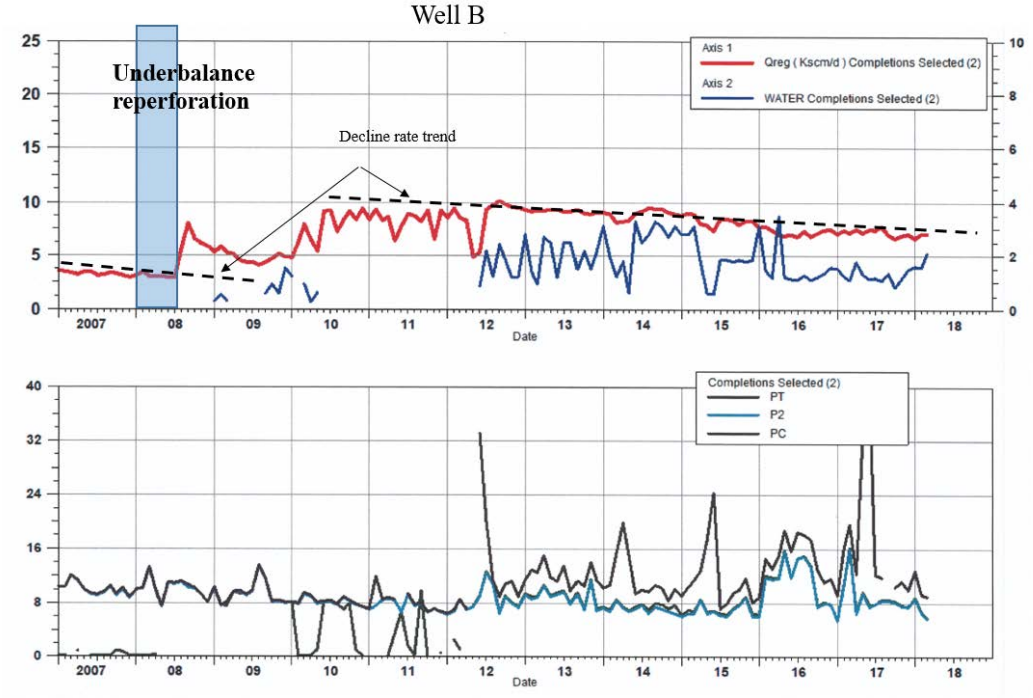

Figure 8 - Gas production profile of well B after underbalanced reperforation

As shown in Figure 8, the gas flow of well B increased by 50% (from 4.5 kscm /day to 10 kscm/day, the initial production decline rate trend was modified and the life of the well was extended.

The process of stimulation by re-perforation at underbalance conditions proved to be a very efficient in the gas field under reasearch.

The production of the wells in the Transylvanian basin, where this type of stimulation was performed, increased by approximately 60%[5].

6. Conclusions

1. The major challenge encountered in the exploitation of mature natural gas fields is the reduction of the natural decline of production and the extension of the exploitation duration in order to obtain attractive final recovery factors.

2. The technological problems associated with the exploitation of mature fields can be classified into three categories, namely: reservoir, wells and surface infrastructure. Their coexistence significantly influences the productivity of the fields, therefore, today is required a different approach than the ones applied so far.

3. The implementation of the rehabilitation concept has brought and brings remarkable results in the case of major gas fields in the Transylvania basin, where the annual gas production increased in the period 2016-2018 by approximately 11% (compared with natural decline).

4. After the implementation of techniques to remedy technological problems, the natural decline in production was canceled. Current techniques which are applied in the gas well in Transylvanian, with the scope of improving the production performance are the ones presented in case studies in this paper but also other applications (e.g. compression at wellhead, well completion techniques, removal of water from wells).

5. Underbalance perforation in depleted reservoirs which are facing carbonate or halit scale nearby perforated zone has proved to be a very efficient technique, especially in tight gas formations. The cumulative production in the wells where the underbalance perforation was applied increased by 60%.

6. The dynamism of gas demand is an external factor that directly influences the operating model of the field, so having an integrated, efficient and sustainable field management system will mitigate the adverse effects that may occur and also be able to meet the challenges from the energy market.

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