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Gas Lift and Electric Submersible Pump Combination used to Activate a Dead Well

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Abstract

The well-called KD-2 (for confidential reasons) is not producing because the bottom hole pressure of the well is greater than the reservoir pressure. The purpose of this paper is to activate the well KD-2 by the gas lift and electric submersible pump (ESP) with a rotating gas separator combination in order to increase its production. The completion and the pressure, volume, and temperature (PVT) data are processed under Pipesim and by integrating a certain number of calculations by the nodal analysis and the decline curve methods. The results obtained show that well KD-2 activated by the gas lift provides a flow rate of 3038.019 STB/day. In order to increase the flow rate of well KD-2 activated by the gas lift, the ESP with rotating gas separator is added and the flow rate becomes 4845.325 STB/day which represents a gain of 59.48% in flow rate. In addition, the gas lift and ESP with rotating gas separator combination guarantees an eight-year operating period for a probability of $ 3,601,197 with a return on investment of 2 months. The gas lift and ESP with rotating gas separator gas combination can be used to optimize the production of low-flow wells in the same geographical areas and to consider the reactivation of dead wells.

Keywords: Dead well, gas lift, electric submersible pump, nodal analysis, optimization, return on investment.

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1- Introduction

Natural production from an oil reservoir depends on the pressure built up in the rock during its formation [1-3]. Over time, the pressure in the reservoir decreases due to increased pressure losses in the production column, and the reservoir may no longer be able to produce naturally [4-6]. As production increases, the field matures and reservoir pressure falls [7-10]. To overcome the problem of fluids not rising naturally to the surface, activation methods involve reducing the hydrostatic column in the well [11-13]. There are several activation methods: the progressive cavity pump, the sucker rod pump, the ESP, the diver lift, the hydraulic pump and the gas lift [14-16].

It has been shown that it is possible to combine two methods, such as gas lift activation, for a high production yield [17-20]. In the literature, there are some relevant studies involving gas lift and ESP combinations to enhance the productivity of oil well [21-24]. In the case of well KD-2, production, which was occurring naturally, has fallen considerably to the point where it is no longer possible to lift the fluid to the surface. Given the size of the reserves still in place, i.e. 13 million barrels of oil, it is important to combine two activation methods, gas lift and ESP, to guarantee a good production yield. The aim of this study is to propose a model of well KD-2 activated by the combination of gas lift and ESP and to evaluate the well's productivity. To accomplish this work, we will: Perform a nodal analysis to assess the production status of the well; implement the gas-lift to show its performance on well KD-2 in terms of production rate; design the ESP to determine some of its characteristics (such as the optimum depth, the number of stages and the operational flow rate) and draw up an economic balance sheet to justify the choice of method. To achieve these objectives, this study uses volumetric methods based on empirical formulae, and graphical methods based on the interpretation of abacuses applied to well completion and PVT data processed in Pipesim and Excel software. This paper is structured in three sections, the first of which presents the introduction. The second section presents the

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material, the methods used and the different results obtained. The third section presents the conclusion.

2- Data, Methods, and Results

The main data used in this paper are PVT and completion data. The PVT data are presented in Table 1. The completion data is presented in Table 2.

Table 1. PVT Data

Parameters	Values
GOR	237 SCF/STB
Bubble pressure	1881.696 Psia
Temperature	204 ^{0}F
Productivity index	5
API of the oil	27
Wellhead pressure	87.21 Psia
Reservoir pressure	3489 Psia
Duse	3 Inch
Reserve in place	13 million barrels of oil

From the data in Table 1 and Table 2, we note a fairly high deviation angle, a fairly low water production, and a low oil-to-gas ratio. Thus, it is ideal for the well to be activated by the combination of gas lift and ESP.

2.1. Methods

PVT and completion data analyzed in Pipesim and Excel using nodal analysis and decline curve methods are used to achieve the objectives of this paper.

2.1.1. Decline curve methods

The analytical method developed here is that of the Arps empirical model [25]. By varying the production rate as a function of time, Arps obtains the following generalized equation:

$$q_t = \frac{q_i}{(1+bD_i t)^{1/b}} \quad (1)$$

Where q_t is the production rate in a time t (barrels/day); q_i is the initial production rate (barrels/day); D_i is the nominal decline rate at $t = 0(day^{-1})$; t is time (day) and b is the decay exponent. Depending on the value of the decay exponent (b), Arps distinguished three scenarios: Exponential decline $(b = 0)$, harmonic decline $(b = 1)$, and hyperbolic decline $0 < b < 1$.

2.1.2. Economic analysis method

An economic model is built to help evaluate the NPV of the well KD-2. The mathematical Eqs. 2 to 7 are formulated to encompass all the parameters used for the economic analysis.

$$NCF = (N_p \; x \; O_{price}) - \begin{pmatrix} CAPEX + OPEX + W_p x W_{cost} + ROYALTY + TAX + \\ LABOR + OTHER\ EXPENSES \end{pmatrix} \quad (2)$$

$$\text{IMPOSED TAX}=(N_p \text{ x } O_{price}) - (\text{OPEX+ROYALTIES}) \quad (3)$$

$$\text{TAXES=TAX RATE x IMPOSED TAX} \quad (4)$$

$$\text{VA (annual)} = \frac{NCF}{(1+i)^n} \quad (5)$$

$$NPV=\sum_{n=0}^{9} \frac{NCF}{(1+i)^n} \quad (6)$$

$$RI=\frac{\text{Total expenses}}{\text{Oil revenues}} \quad (7)$$

Where *NCF* is Net Cash Flow in dollars ($),$N_p$ is the annual cumulative oil production (stb), O_{price} is the average price of oil over the year ($/stb), *CAPEX* is capital expenditures for drilling and completion of the Wells ($), *OPEX* is field operating expenses ($),$W_p$ is the annual cumulative water production (bbls), W_{cost} is the average cost of water treatment, *VA* is the current value ($), i is the (effective) discount rate (%),n is the number of interest compounding periods, *NPV* is the net present value ($) and *RI* is the return on investment.

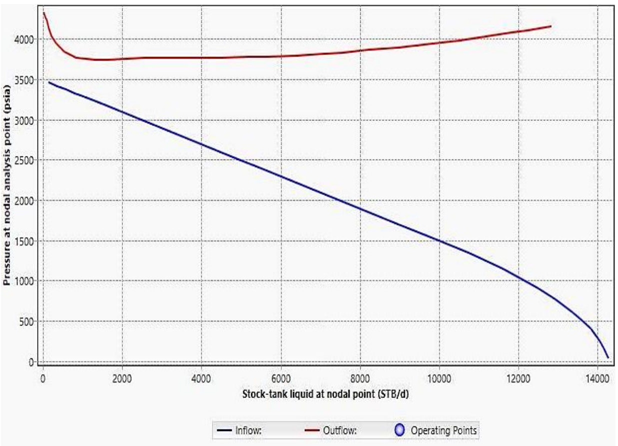
2.2. Results of combined gas lift and ESP activation with rotating gas separator in well KD-2

The nodal analysis carried out in well KD-2 and its profile in the initial state are shown in Fig. 1.

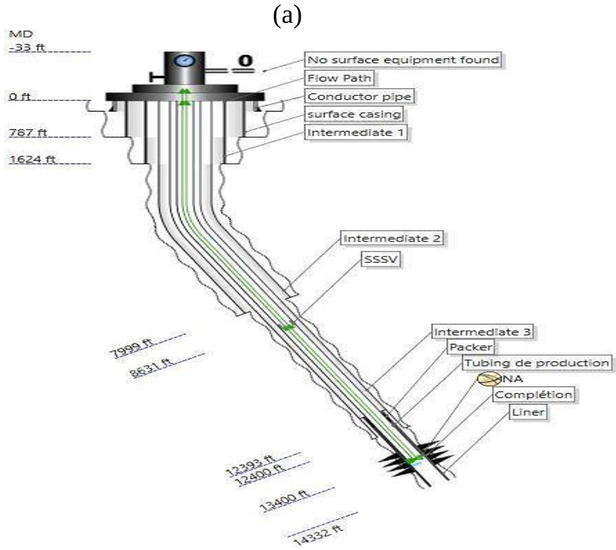
Well KD-2 does not flow any fluids at the surface because the blue IPR (Inflow performance relation) curve and the red VFP (Vertical flow performance) curve do not cross, as shown in Fig. 1 a. Gas lift activation is first used to bring well KD-2 on stream. Fig. 2 shows a constant gas injection pressure CHP = 884.922 Psia, a maximum depth of 6078.717 ft, and an oil flow rate of 3290 STB/day with a variation in the gas injection flow rate.

Table 2. Completion Data

Type of casing	Depth (ft)	Internal diameter (Inch)	External diameter (Inch)
Conductor pipe	10	35	37
Surface casing	787	30	30.722
Intermediate 1	1624	20	20.59669
Intermediate 2	7999	13.375	13.82331
Production casing	12400	7,625	7.931198
Production tubing	13400	4.2	4,5
Liner	12350	5	6
Safety Valve	8631		
Packer	12393		



(a)



(b)

Fig. 1. (a) Nodal Analysis and (b) Profile of Well KD-2 in its Initial State

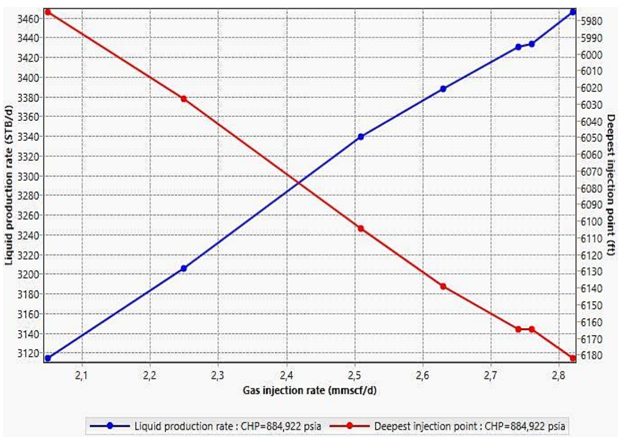


Fig. 2. Performance Curve for the Gas Lift-Activated Well KD-2

Fig. 2 shows the intersection of the blue curve and the red curve, which characterizes the gas injection pressure. On the x-axis is the optimum gas injection flow rate of 2.41 MSC/day, on the y-axis is the oil production flow rate, and on the right is the maximum injection depth of 6078.717 ft. The optimum point for gas injection into well KD-2 is calculated as a function of wellbore height, wellbore pressure, wellbore temperature, and absolute wellbore open flow rate at the time when the wellbore pressure is greater than the reservoir pressure, as shown in Fig. 3.

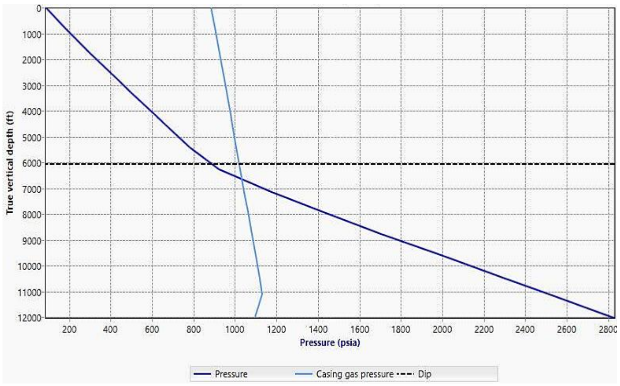
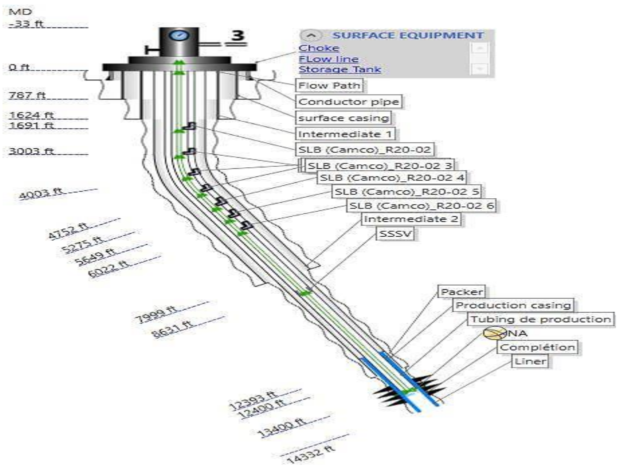


Fig. 3. Deepest Injection Point of Well KD-2

The intersection of the pressure curve, casing gas pressure curve, and depth curve gives the maximum height at 6078.717 ft and at this depth, the first valve is installed as shown in Fig. 3. The profile and operating point of the gas lift activated well KD-2 is shown in Fig. 4.



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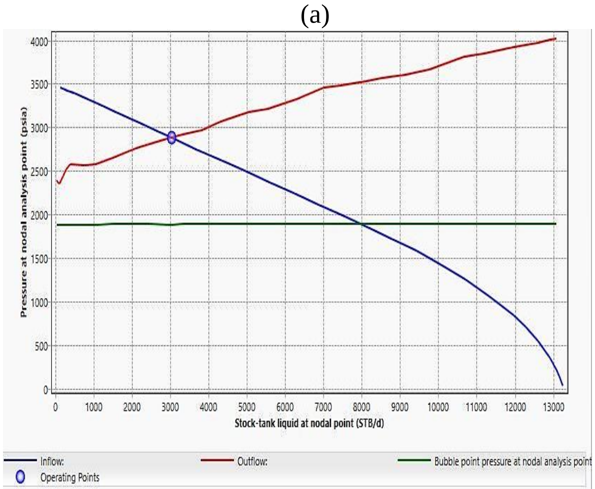


(b)

Fig. 4. (a) Profile and (b) Operating Point of the Gas Lift Activated Well KD-2

The gas lift activated well KD-2 has seven valves in which the first valve is at 1690.513 ft, the second is at 3002.543 ft, the third is at 4003.2 ft and the fourth is at 4751.601 ft, the fifth is at 5275.14 ft, the sixth is at 5648.521 ft and the seventh is at 6021.902 ft as shown in Fig. 4 a. This is a deviated well that is essentially made up of the production tubing, the conductor pipe, the surface casing, two intermediate casings, the production casing, the production packer, a safety valve, a liner, and their various heights. Fig. 4 b shows the intersection of the IPR curve in blue and the VFP curve in red, giving the flow rate produced by the gas lift-activated well KD-2, which is 3038.019 STB/d with a bottomhole pressure of 2881.396 Psia. This means that the gas lift has been well installed, as the pressure at the bottom of the well has fallen from 4500 Psia to 2881.396 Psia. To increase the production rate, the ESP with a rotating gas separator is added to the gas lift-activated well KD-2. The ESP with a rotating gas separator was chosen to achieve a flow rate of 4,500 STB/day. It must be able to remain at the bottom of the well while having a diameter that can be integrated into the production tubing, which has an internal diameter of 4.2", given that the ESP with rotating gas separator must have a diameter smaller than the diameter of the production tubing. The design of the ESP with a rotating gas separator after stimulations gives the characteristics shown in Table 3.

Table 3. Characteristics of the ESP with Rotating Gas Separator

Parameters	Values
Pump model	**Centrilift P60**
Pump power	**127.5 Hp**
Pump frequency	**60 Hz**
Pump depth	**13400 ft**
Number of stages	**326**
Activation mode	**Rotating separator**

Fig. 5 shows the various parameters that will help to optimize the ESP with a rotating gas separator.

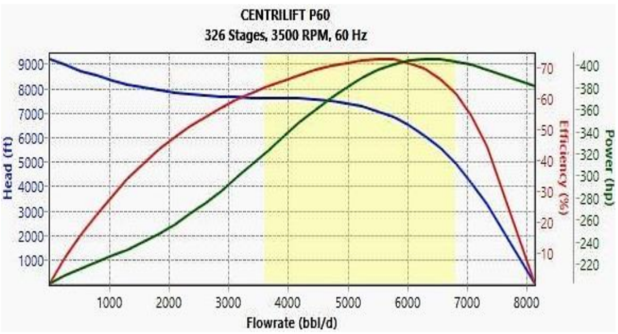
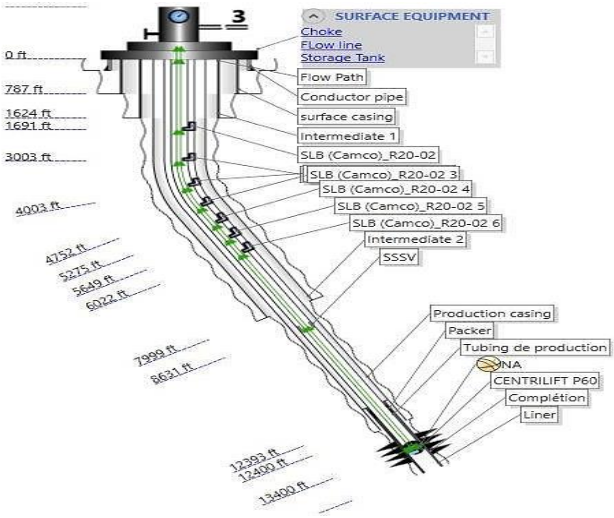
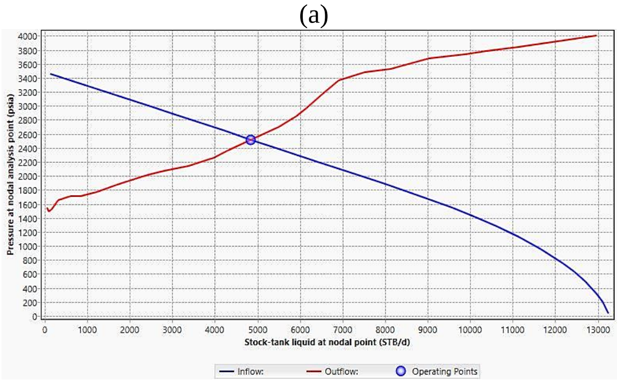


Fig. 5. Performance Curve of the ESP Pump with Rotating Gas Separator

Fig. 6 shows the profile and operating point of well KD-2 activated by the gas lift and ESP combination with a rotating gas separator.



(a)



(b)

Fig. 6. (a) Profile and (b) Operating Point of Well KD-2 Activated by the Combined Gas Lift and ESP with Rotating Gas Separator

After installing the gas lift equipment and the ESP with a rotating gas separator in well KD-2 as shown in Fig. 6 a. The intersection of the IPR and VFP curves gives the well flow rate for the combination of gas lift and ESP with rotating gas separator as 4845.325 STB/day and the well bottom pressure as 2570 Psia as shown in Fig. 6 b.

2.3. Economic evaluation

The expenses include the Capex and the Opex to implement the project as shown in Table 4.

From Table 4, it is found that annual production revenue is $21,829,063; annual taxation is $18,336,413; annual energy cost is $720; total annual expenditure is $18,893,133 and annual cash flow is $2,935,930. The lifespan of well KD-2 activated by the combined gas lift and ESP with the rotating gas separator is determined using the exponential decline model given in Fig. 7.

Fig. 7 shows that well KD-2 activated by the combined gas lift and ESP with rotating gas separator has a production lifespan of eight years since the flow rate at year eight is 3247.918477 STB/d higher than the gas lift flow rate (see Table 5).

Table 4. Summary Table of Production Costs for Well KD-2 Activated by the Combined Gas Lift and ESP with Rotating Gas Separator

	Gas lift	ESP	
CAPEX	**Cost**	**Cost**	**Total**
Equipment	220000 $	240000 $	460000 $
Monthly tax	7%	7%	7%
OPEX	**Cost**	**Cost**	**Total**
Maintenance	45000 $	51000 $	96000 $
Price per barrel of oil	93 $	93 $	93 $
Energy cost per barrel of oil	30 $	30 $	

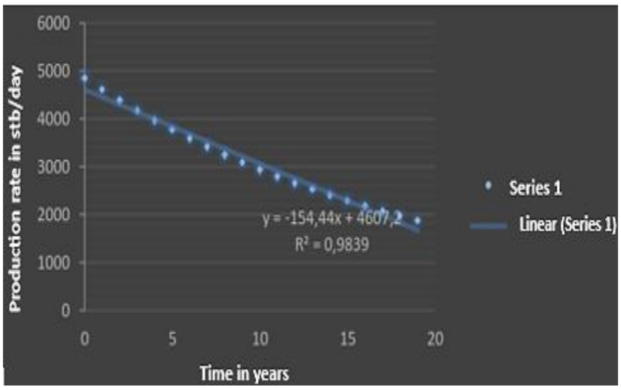


Fig. 7. Production Decline Analysis Curve for Well KD-2 Activated by the Combined Gas Lift and ESP with Rotating Gas Separator

The initial reserve quantity in place is 13 million barrels of oil. The well KD-2 activated by the combined gas lift and ESP with rotating gas separator will be operated over eight years. The annual profitability of well KD-2 activated by the combined gas lift and ESP with rotating gas separator is $3,601,197, and the payback period for the investment in bringing back well KD-2 activated by the combined gas lift and ESP with rotating gas separator on stream is 2 months.

Table 5. Evolution of the Flow Rate of Well KD-2 Activated by the Combined Gas Lift and ESP with Rotating Gas Separator as a Function of Years

Lifespan	Daily flowrate (STB/day)	Annual flowrate (STB/day)
0	4845.325	
1	4609.015711	1682290.735
2	4384.231363	1600244.447
3	4170.409876	1522199.605
4	3967.016586	1447961.054
5	3773.542904	1377343.16
6	3589.505045	1310169.341
7	3414.442818	1246271.629
8	3247.918477	1185490.244

3- Conclusion

This paper focused on bringing the dead well KD-2 into production by the combined activation of a gas lift and a submersible electric pump with a rotating gas separator. Initially, well KD-2 was not producing due to the fact that the pressure at the bottom of well KD-2 was higher than the reservoir pressure. The aim was to increase production by integrating a gas lift activation system and a submersible electric pump with a rotating gas separator into well KD-2. Nodal analysis showed that the gas lift-activated well KD-2 has a flow rate of 3038.019 STB/day with a bottom hole pressure of 2881.396 Psia. To increase the production rate, a submersible electric pump with a rotating gas separator was added to the gas lift-activated well KD-2 and the flow rate obtained was 4835.325 STB/day. The profitability in one year of production of well KD-2 activated by the combination of the gas lift and a submersible electric pump with a rotating gas separator is $3,601,197, which is considerable for a return on investment after 2 months for eight years of production. For better optimization of production from the KD-2 well, it will be interesting to alternate activation by gaslift and activation by a submersible electric pump in order to reduce maintenance costs and increase the lifespan of the pump.

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استخدام مجموعة الرفع بالغاز و المضخات الكهربائية الغاطسة لتنشيط البئر الميت

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6 الكلية العليا لتدريب المعلمين الفنيين دوالا، جامعة دوالا، دوالا، الكاميرون

الخلاصة

البئر المسمى KD-2 (لايمكن البوح بها) لاينتج لان ضغط البئر السفلي اكبر من ضغط المكمن. ان الغرض من هذا البحث هو تفعيل البئر KD-2 بواسطة المضخة الغاطسة الغازية والكهربائية (ESP) مع فاصل الغاز الدوار من اجل زيادة انتاج البئر. تتم معالجة بيانات الاكمال والضغط والحجم ودرجة الحرارة (PVT) من خلال دمج عدد معين من الحسابات عن طريق التحليل العقدي وطريقة منحني الانخفاض. اظهرت النتائج التي تم الحصول عليها ان البئر KD-2 الذي تم تفعيله بواسطة الرفع الغازي يوفر معدل تدفق قدره ٣٠٣٨,٠١٩ برميل قياسي/ يوم. من اجل زيادة معدل التدفق للبئر KD-2 المنشط بواسطة الرفع الغازي، يتم اضافة ESP مع فاصل الغاز الدوار ويصبح معدل التدفق ٤٨٤٥,٣٢٥ بئر قياسي/ يوم وهو مايمثل زيادة بنسبة ٥٩,٤٨ % من معدل التدفق. بالاضافة الى ذلك، يضمن رفع الغاز والمرسب الكهروستاتيكي مع مجموعة فاصل الغاز الدوارة فترة تشغيل مدتها ثماني سنوات باحتمالية تبلغ ٣٦٠١١٩٧ دولارا امريكيا مع عائد على الاستثمار لمدة شهرين. يمكن استخدام نظام رفع الغاز والمرسب الكهروستاتيكي مع الغاز الناتج من مجموعة فاصل الغاز الدوارة لتحسين انتاج الابار المنخفضة التدفق في نفس المناطق الجغرافية والنظر في اعادة تنشيط الابار الميتة.

الكلمات الدالة: البئر الميت، الرفع الغازي، المضخة الغاطسة الكهربائية، التحليل العقدي، التحسين، العائد على الاستثمار.