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GAS-LIFT WELLS OPTIMIZATION AT THE OIL FIELD "K"

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Abstract: Optimization the operating parameters of a group of gas-lift wells in an oil field is a complex procedure. It is important to match parameters such as gas compression pressure, gas injection pressure, separation pressure at the gathering station, diameters of distribution pipelines, injection gas quantities as well as all individual operating parameters of the gas-lift wells.

In this paper, a model for determining the optimum gas injection rate was created. Also, it is described the procedure for gas-lift well optimization at the oil filed "K" and its results. For all five wells, the optimum amount of injected gas and required number of gas-lift valves were determined.

Keywords: Oil well, Gas distribution, Gas-lift, Optimization

1 INTRODUCTION

In the past period, the prices of natural gas and energy were significantly lower than today. For this reason, it was not so important how much of injected gas was used in order to maximize the oil production rate. Optimization of gas-lift conditions is achieving the maximum possible oil production rate, regardless of the injected gas volume (Brown, 1980). The significant increases in energy demand and natural gas prices have completely changed this situation, so now the optimum conditions for gas injection are based on the economic parameters. (Takacs, 2005).

The main objective of the oil production process is to obtain the optimum oil production while operating costs are minimized (Danilović et al., 2016a; Danilović et al., 2016b). During oil production by gas-lift wells, the gas processing and gas compression represent a significant cost. In order to reduce costs and enable the maximum oil production rate, it is crucial that the compression pressure and the quantity of injected gas be minimized. Defining the optimum parameters of the gas-lift wells, it can be determined the adequate volume of gas injection (Danilović et al., 2016b).

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The proper distribution of the amount of gas injection for two or more gas-lift wells within one gathering station is important part in production optimizing process since the production of each well depends on the injection gas rate.

Based on published model for the distribution of gas for several wells (Danilović et al., 2014), gas-lift curve, gradient curves and cumulative curve will be calculated in this paper, in order to determine the optimum operating parameters of the gas lift wells.

2 DETERMINING THE OPTIMUM AMOUNG OF GAS INJECTION

The gas-lift curve represents the relationship between quantity of gas injection and oil production rate (Figure 1). Gas-lift curve is determined based on the inflow performance relationship (IPR) curve and the vertical lift performance (VLP) curves (Shedid and Yakoot, 2016). Vogel's method is used to calculate the IPR curve, since a single pressure and production measurement was available. Each intersection points of IPR and VLP represents one point of the gas-lift curve. At the beginning, the gas injection rate directly affects on increasing the amount of oil produced (Figure 1 – curve A). Further increase of gas injection rate caused a slight upward trend of oil production rate (Figure 1 – curve B). Since the diameter of the tubing is limited, further increase of injected gas begins to negatively affect the oil flow, primarily due to significantly worse rheological characteristics, i.e., oil density and viscosity. Additional buildup of injection rate result in extremely small increase (Figure 1 - curve C) or a reduction of oil production (Figure 1 - curve D). The optimum amount of gas injection is represented by curve B (Soleša, 2003).

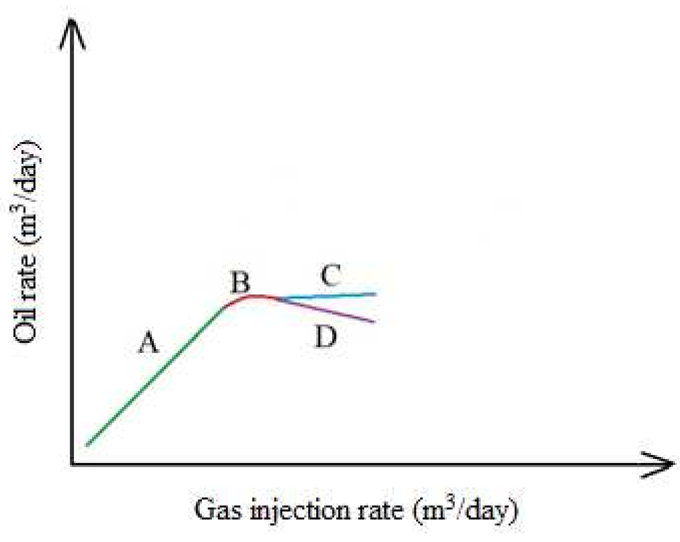

Figure 1 The gas-lift curve

The gas-lift curve is fundamental to design the optimum amount of gas injection. Mathematically analyzing, the maximum value of the function can be determined based on the first derivative of the function. By applying the previous step, the gas-lift curve can be approximated by the appropriate function that represents the quantity of gas injection, then find its first derivative and determine the maximum value that will represent the optimum amount of gas injection. The amount of injecting gas can be approximated by various functions such as polynomial, logarithmic, exponential, and linear function, with a polynomial function being the most adequate (Saepudin et al., 2007).

From a practical point of view, a polynomial of the third degree is satisfactory and the easiest to solve (Vieira, 2015), since after derivation, a polynomial of the second degree (a quadratic equation) is obtained, which can be quickly and easily solved.

In this paper, a model for determining the optimum gas injection rate was created. During the first phase, the gas-lift curve is determined. In the next step, the gas-lift curve is approximated with different polynomial functions. Based on the functions thus determined, the one that best approximates the amount of gas injection is chosen.

For the selected function, the first derivative of the function and its maximum value, which represents the optimum value, are required. Figure 2 shows a simplified algorithm of the developed model for determining the optimum quantity of gas injection.

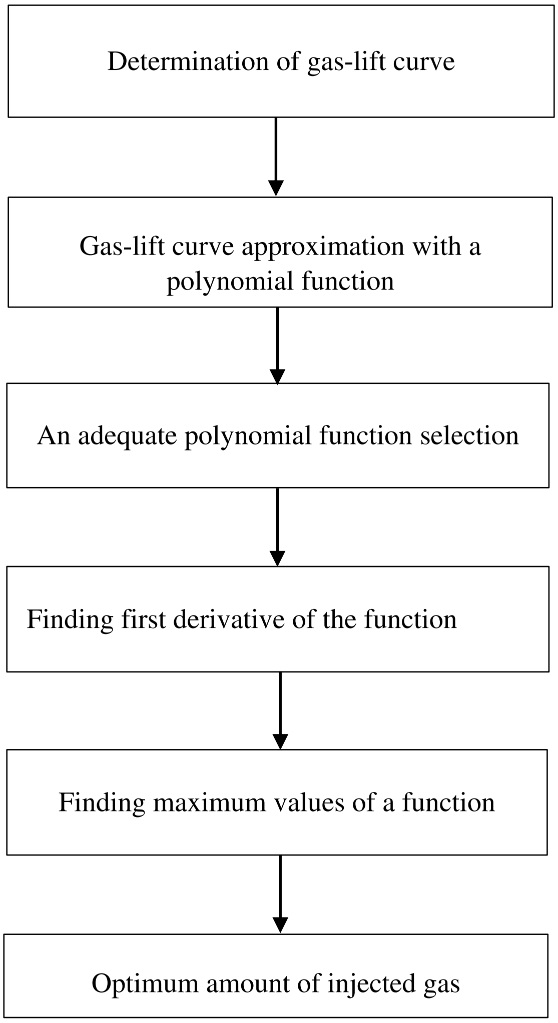

Figure 2 Model for determining the optimum amount of gas injection

3 GAS-LIFT WELLS′ OPTIMIZATION – CASE STUDY

In this field, oil production through four collecting stations KI, CPF (Central processing facility), KW and KS (Figure 3) is carried out. In addition to the oil production, the final preparation of the fluid and gas compression at the gathering station CPF is performed.

Determining the optimum amount of gas injection will be shown in the example of the gathering station KI, which has five gas-lift wells in operation.

For the purpose of making the production process more efficient, the operation of the gas-lift system was optimized.

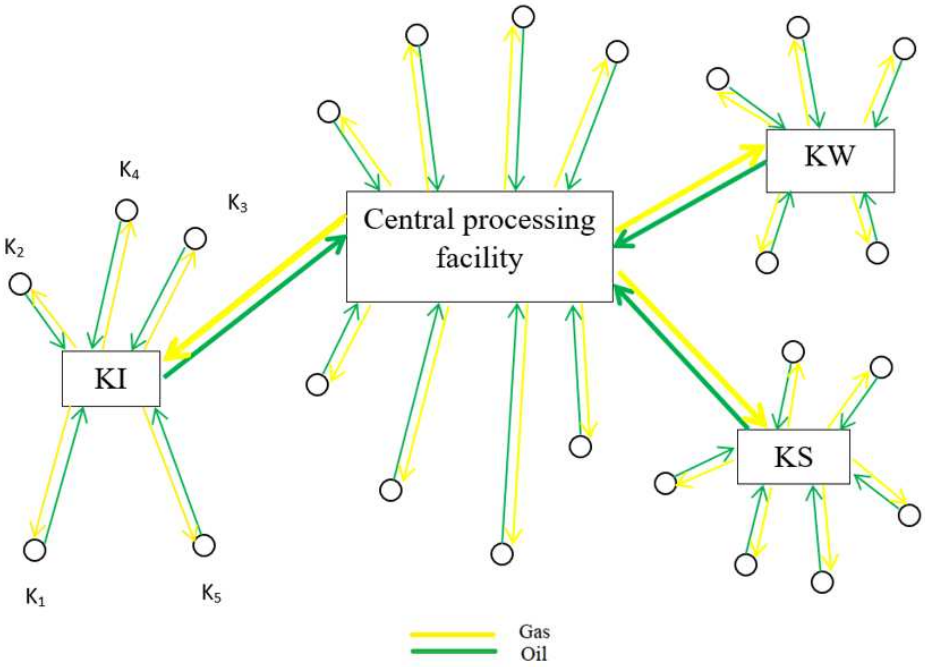

Figure 3 Schematic of gathering stations

The wells′ data are given in Table 1.

Table 1 Wells′ data

	Wells				
	K1	**K2**	**K3**	**K4**	**K5**
Well depth (m)	1540	1560	1620	1580	1650
Reservoir pressure (bar)			110,4		
Flowing pressure (bar)	85	91	89	90	95
Oil production (m^3/day)	5,2	8,3	6,5	7,8	9,2
Injection pressure (bar)			29		
Wellhead pressure (bar)			5		

During the first step, the gas-lift curve for wells K_1, K_2, K_3, K_4 and K_5 is calculated (Figures 4, 5, 6, 7 and 8). For gas-lift curve determination it is required to calculate the inflow performance relationship curve (IPR) and vertical lift performance curves (VLP) for various values of the gas oil ratio (GOR).

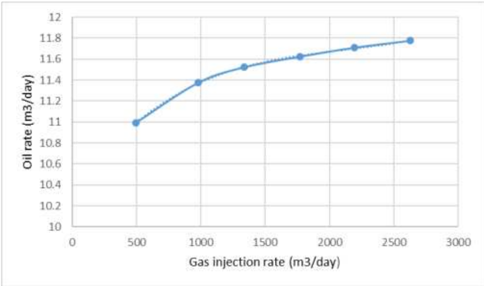

Figure 4 The gas-lift curve for well K_1

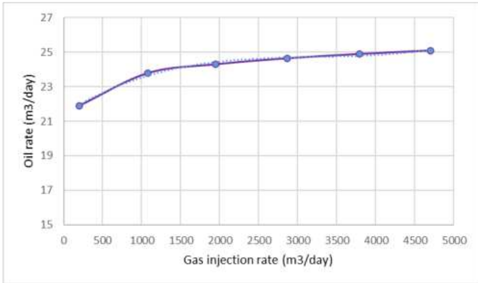

Figure 5 The gas-lift curve for well K_2

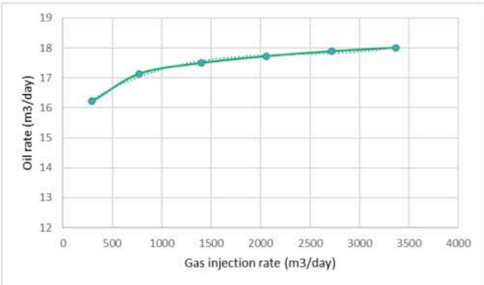

Figure 6 The gas-lift curve for well K_3

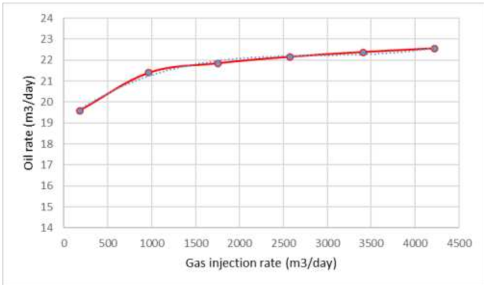

Figure 7 The gas-lift curve for well K_4

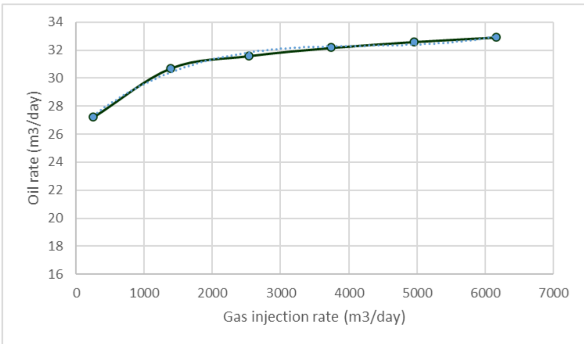

Figure 8 The gas-lift curve for well K_5

In the next step, the limited quantity of gas is distributed to five wells. Based on mathematical model (Danilović et al., 2014; Elhaddad, 2015), the gradient curves for wells K_1, K_2, K_3, K_4 and K_5 were calculated and shown in Figure 9. The cumulative curve (Figure 9) based on which gas can be distributed to individual wells, is obtained by adding the gradient of the curves.

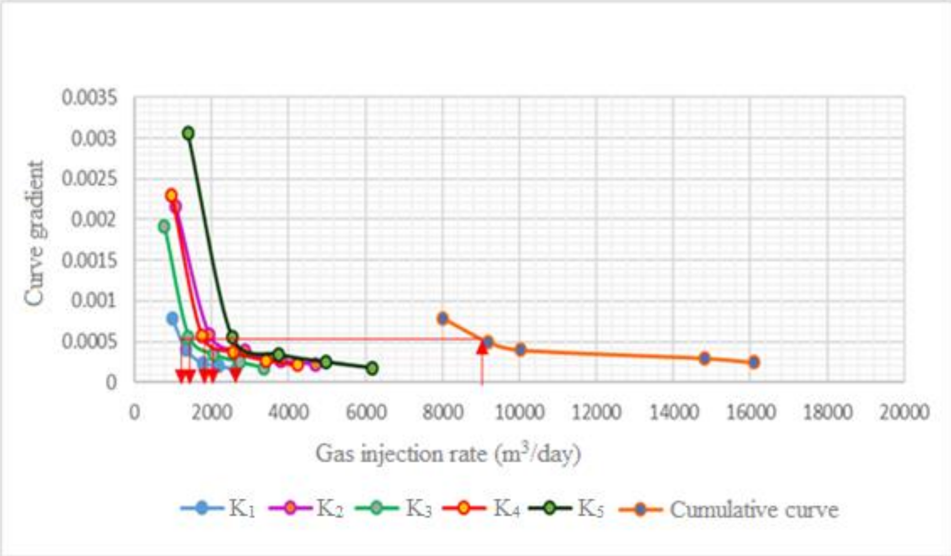

Figure 9 Gradient curves for wells K_1, K_2, K_3, K_4 and K_5 and cumulative curve

Gas distribution to wells K_1, K_2, K_3, K_4 and K_5 is carried out according to the inflow performance relationship curve using cumulative curves. At the gathering station KI, 9000 m^3/day of gas was distributed to five wells. Based on the gradient curve and the cumulative curve (Figure 9), the gas injection rate per well is determined: 1200 m^3/day (K_1), 2000 m^3/day (K_2), 1450 m^3/day (K_3), 1850 m^3/day (K_4) and 2500 m^3/day (K_5).

By approximating the gas-lift curve (Figures 4, 5, 6, 7 and 8) with a polynomial function of the third degree, and finding the first derivative of the function, the optimal production for each well was determined (Table 2).

Table 2 Polynomial function of the third degree

Well	Equation	Optimum production (m^3/day)
K_1	$y = 10^{-10} \cdot x^3 - 7 \cdot 10^{-7} \cdot x^2 + 0{,}0016 \cdot x + 10{,}354$	11,4
K_2	$y = 9 \cdot 10^{-11} \cdot x^3 - 9 \cdot 10^{-7} \cdot x^2 + 0{,}0029 \cdot x + 21{,}407$	24,0
K_3	$y = 2 \cdot 10^{-10} \cdot x^3 - 10^{-6} \cdot x^2 + 0{,}0026 \cdot x + 15{,}583$	17,2
K_4	$y = 10^{-10} \cdot x^3 - 10^{-6} \cdot x^2 + 0{,}0031 \cdot x + 19{,}111$	21,5
K_5	$y = 8 \cdot 10^{-11} \cdot x^3 - 10^{-6} \cdot x^2 + 0{,}0041 \cdot x + 26{,}364$	30,8

The calculated optimum operating parameters of the gas-lift system for wells are shown in Figures 10, 11, 12, 13 and 14 such as valve opening and closing pressure, injection pressure, set pressure, valve depth, liquid level line and gradient line. The gas lift is designed using the injection pressure reduction method.

The number of gas-lift valves is determined so the well unloading process takes place smoothly and that the operating gas-lift valve in the well is at least 150 m below the dynamic fluid level.

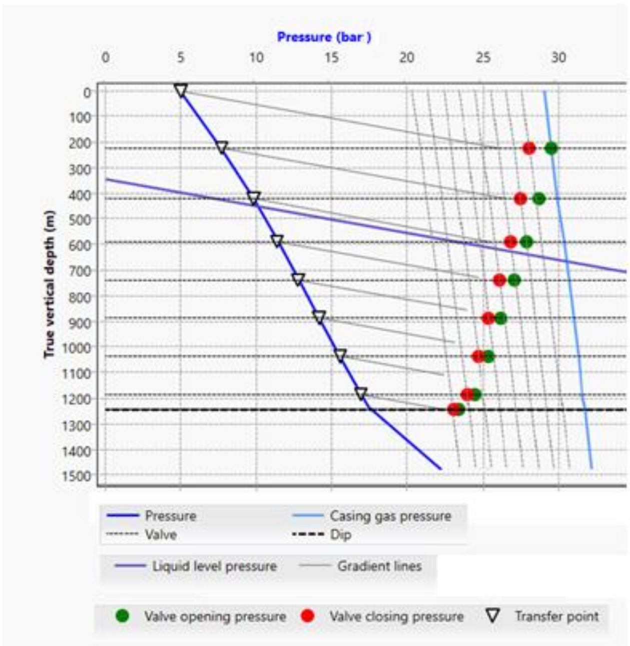

Figure 10 The gas-lift design for well K_1

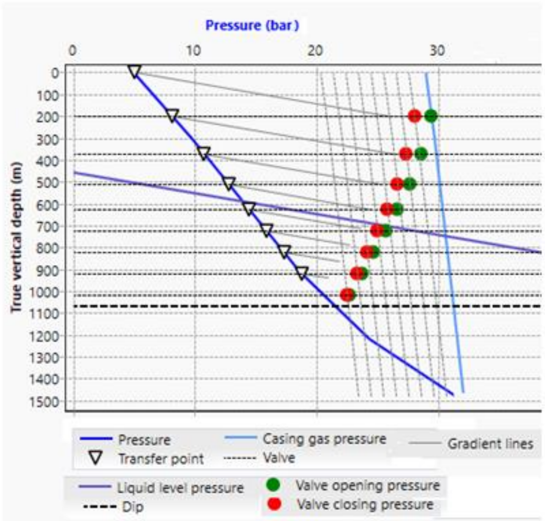

Figure 11 The gas-lift design for well K_2

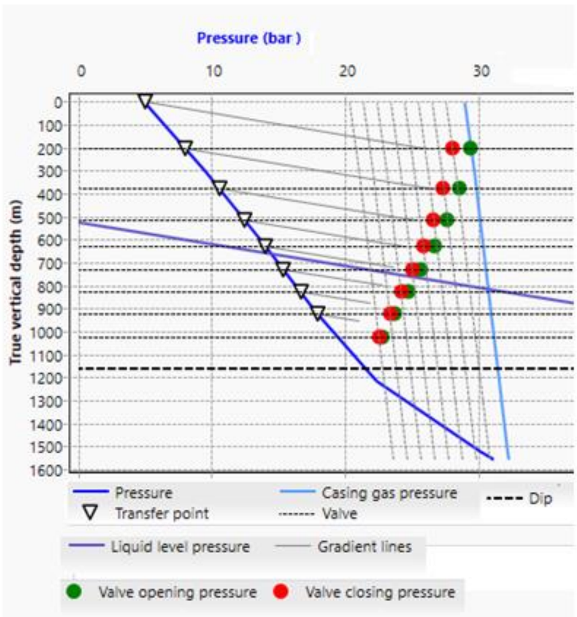

Figure 12 The gas-lift design for well K_3

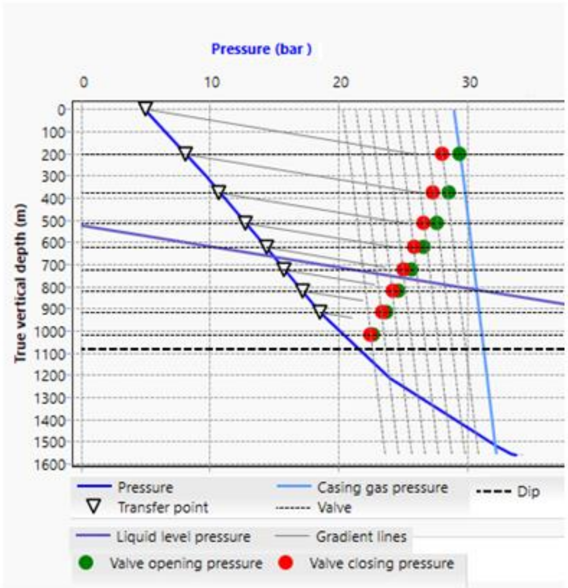

Figure 13 The gas-lift design for well K_4

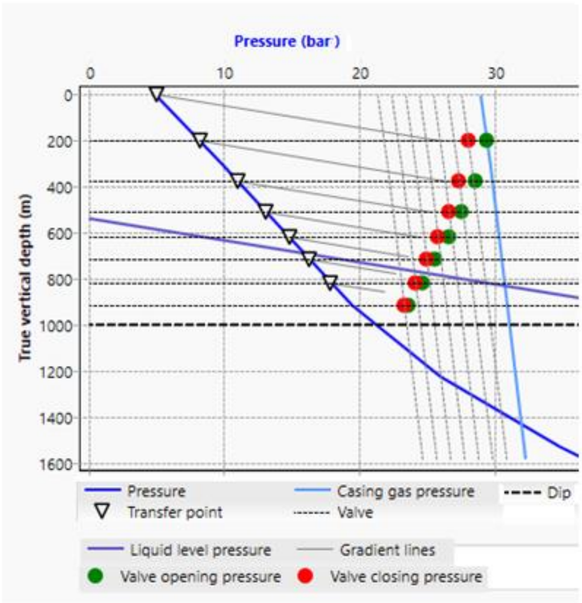

Figure 14 The gas-lift design for well K_5

Numbers and depth of gas-lift valves for each well are shown in Table 3. Wells K_1 to K_4 have eight gas-lift valves each while well K_5 has seven gas-lift valves.

Table 3 Numbers and depth of gas-lift valves

		Wells				
		K_1	**K_2**	**K_3**	**K_4**	**K_5**
Number of valves		**8**	**8**	**8**	**8**	**7**
Depth of gas-lift valve	L_1 (m)	220	200	199	202	200
	L_2 (m)	425	370	385	377	372
	L_3 (m)	590	510	505	508	508
	L_4 (m)	730	614	616	620	616
	L_5 (m)	880	715	720	721	714
	L_6 (m)	1035	820	815	812	812
	L_7 (m)	1190	910	917	916	911
	L_8 (m)	1245	1020	1018	1014	

4 CONCLUSION

The distribution of the gas quantity in several wells is very important in order to achieve optimum production of wells and the operation of the gas-lift system. This is especially important if there is a limited quantity of gas that is injected into the wells.

In this paper, a model for determining the optimum gas injection rate based on the first derivative of the gas-lift curve function was created.

The practical application of the model is shown in the example of the oil field K. Within one gathering station KI on oil field K, where there are five exploitation gas lift wells, the amount of gas injection into each well was calculated (1200 m^3/day (K_1), 2000 m^3/day (K_2), 1450 m^3/day (K_3), 1850 m^3/day (K_4) and 2500 m^3/day (K_5)). The optimum number of valves for each well was determined, as well as the installation depth.

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