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Using the Equal Slope Method to Optimized Two Types of Artificial Lift in K Field Under Limited Conditions

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ABSTRACT

Equal slope method is the simplest method in gas lift allocation and includes a linear optimization method. Where this method looks for the same gradient or degree of slope in gas lift performance curve. Optimization in a field with more than one artificial lift method is usually done using computational methods, while simple optimization methods such as equal slope have so far been applied to the field with one artificial lift, in gas lift only. So far, the application of the equal slope method to artificial lift other than gas lift has not been applied. In this study, we propose the use of the equal slope method to optimize the field using artificial lift such as an electrical submersible pump (ESP) and a gas lift to be simultaneously. The results showed that the equal slope method can be used to optimize the field with two lifting methods simultaneously. Before being applied to optimize the gas lift and ESP simultaneously, the proposed equal slope method is first tested to optimize other artificial lift besides gas lift. Using equal slope to optimize the ESP pump in the K field I s quick and simple. The results of the optimization with the proposed method for the K field with processing capacity limits (the maximum liquid processing capacity limit is 70,000 bpd, the maximum oil processing limit is 34,500 bopd), the ESP pump selected for the KE-1 well is the HN13500 pump, for the 2nd well the J7000N pump and K-3 well pump HN13500, with a QLtotal of 38,861 bbl / d, QOtotal 7,763.29 bbl / d and QWtotal 31,097.71 bbl / d. The case of optimization of two artificial lift on the ESP pump and gas lift that needs to be considered is the performance curve graph before combining, the curve on the x-axis must be in a similar variable so that it can be added to the master slope. Optimization using the equal slope method in field conditions that have two artificial lifts, for ESP and gas lift, in limited gas conditions and there are limitations on surface facilities, the field production rate is 61,361 bbl / d with a well flow rate using a gas lift of 22,500 bbl / d and wells using ESP of 38,861 bbl / d. Whereas for unlimited gas, the field production rate was 65,271 bbl / d with a well flow rate using gas lift of 26,271 bbl / d.

Keywords: Equal slope, artificial lift, electrical submersible pump, gas lift.

1. Introduction

Selection of artificial lift method must considering to several aspects such as producing optimum fluid and profitability (Thanawit at al., 2019). Although it is appropriate to choose an artificial lift method, the production performance in a field will decrease over time, decrease in the production capacity of a well can be caused by the reservoir condition and the performance factor of the artificial lift installed in the well, it is necessary to do optimization (Freitas at al., 2019). Optimization is done by using several methods, either conventional methods or software assistance to find a solution for decline in production performance that occurs. According to Ranjan et al., 2015, in fields that have more than one artificial lift, computation (software) is the only method used for optimization, so far there has been no conventional and simple method as another alternative in production optimization. The equal slope method is known as a method that has long been applied in the field for optimization of gas lift allocation (Khabibullin at al., 2015). In addition, the use of the equal slope method as an optimization solution has so far been applied only to gas lifts (Kanu et al., 1981). Because the equal slope method has not been applied to other types of artificial lift and the combination of gas lift with other artificial lift. That’s way by this study the authors try to provide a simple proposed method for optimization activities in a production field that has two types of artificial lifting methods (electrical submersible pump and gas lift).

2. Literature Review

Initially, optimization in the oil and gas industry was carried out using linear programming. Linear programming is an optimization method that is carried out mathematically, using a method to find the optimal value of the function given by certain limitations. The goal is to find the maximum or minimum value given by a limit. Linear programming is also a method by optimizing the objective function and limits in the optimization model linearly. Attra, et al. (1961), conducted a study on large-scale oil fields using conventional linear program optimization methods, the results of this study showed that linear programs were very effective when applied to fields that experienced production problems and were able to detect certain conditions or parameters that could increase yields. Production, on the other hand, also has an effect on significantly improved parameters. Linear programming is also called a numerical procedure which is designed to investigate systematically on a problem so that it is possible to provide solutions to problems that have been identified, optimally and quickly. As it is well known that linear programming is a numerical optimization method, a number of variables in a field can be

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defined in a series of linear equations or inequalities that have dependence. The relationship of each variable can be solved simultaneously using the matrix solution as a form of determining the optimal values for each production variable so as to maximize the expected objective function. Equal Slope method is the first proposed method used as a method to optimize artificial lift. This method is the earliest and simplest method used in allocating gas lift. This method is an optimization method that is linear, the use of this method is based on profitability. The gas used in the injection as a reference to determining the total production rate. The process of gas injection into the well requires accuracy because the gas that is injected excessively can cause an imbalance between operating costs and revenue. High gas prices and inefficient gas allocation compression costs can reduce profits and conversely, limited gas availability also reduces profits because it cannot produce optimal production. The basis for using this method is to find a gradient that is the same or has the same degree of slope (equal) from the performance gas lift (GLPC) curve. The equal slope method was proposed by Kanu et al. (1981), this method can be applied to oil production fields using gas lifts, where field conditions can be adjusted according to the availability of gas, limited or unlimited. The implementation of the equal slope method is based on the concept of slope equality, which states that the solution for the optimal state is that the slope set on the gas lift performance curve is the same for all wells. This method is practical and efficient when applied to conditions where the amount of gas stock for injection in the field has limitations.

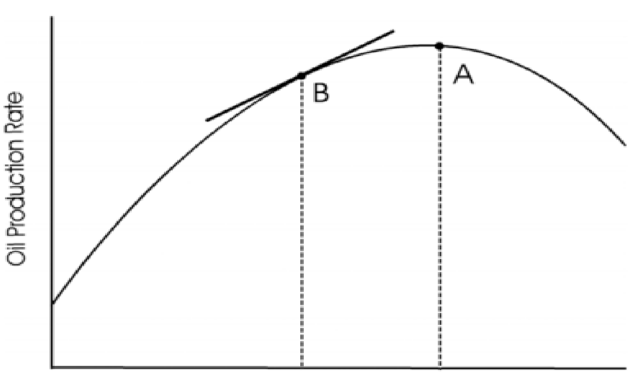

Fig II.1 Type of GLPC (Bezerra at al., 2019).

The gas lift performance curve depicting the injection rate against the production rate is shown in Figure II.2. Q is the gas injected against the slope, from this condition we can determine the slope for the field actually. If the field has an unlimited amount of gas (unlimited gas), then it can select a zero slope for the field with the cumulative amount of injection gas Q in accordance with what is in the curve of the Q plot of injection gas against the slope, where at the zero slope price The gas lift performance curve for each well will give the maximum production Q price for an optimum Q price of injection gas. Quasi-Newton is a non-linear method and a new method for optimally injecting gas into a gas lift well in a group of wells in a production field, with the aim of estimating the initial injection rate and being used in limited or unlimited gas conditions so that widely use more than equal slope method. This method uses non-linear optimization combined with the gradient projection method.

The quasi-newton method has the ability to accommodate the limited rate of gas injection in the well. The only requirement for fast convergence is that a precise estimate of the rate of gas injection to be injected into the well must be provided as a starting point for the optimization method. The unknown variables of this method function as constraints, such as the gas injection rate for each physical well. For example, gas injection should not be negative and the total injection rate must be ≤ 1 or equal to the total volume of gas available in the system. The quasi-newton non-linear optimization method is a method for expressing zero or local maximum and minimum function as alternatives in the newton method. This method was successfully tested by Nishikiori, et al. (1989), gave quite significant results, namely the estimated rate of gas injection was between ± 20% of the optimal value in a production field that had a limited or unlimited gas supply. This Ex-In Algorithm method can provide information about a nonlinear picture to determine the optimal distribution of the amount of gas injected into one well, without any limitations to the quantity of the well. Equal slope method and quasi-newton method cannot be implemented in wells if GLPC is not the main solution in gas injection.

The ex-in algorithm, is not sensitive to local deviations from the objective function, from that condition is a solution that can be used even when other algorithms fail due to deviations. This method is applied by Buitrago, et al. (1996), by conducting tests using computational assistance at a production field using gas lift and succeeded in reducing 14% of the total gas supply in 3 wells. Sequential Quadratic Programming (SQP) method is a method with certain properties of algorithms or computer programs to optimize nonlinear optimization. The SQP method is used in mathematical problems where the objective function and its limits are twice differentiated. SQP assumes the existence of the first and second derivatives continuously. The weakness of the SQP method is the existence of a second derivative which adds instability to the optimization problem solving.

The SQP method can be applied to provide solutions to fields experiencing production management problems. From the results of a study conducted by Kunal Dutta-Roy (1997), using the SQP method, in the analysis for field optimization case studies using artificial gas lifts and evaluating the effects of various gas price scenarios, it shows that the optimal compression strategy can change significantly. It is therefore important to re-evaluate future operating strategies each time on a contract system by producing significant

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variations from the estimated gas prices. The Sequential Linear Programming (SLP) method is a method of solving technically so that it can provide solutions to non-linear optimization problems and simulations on a large scale. The philosophy of this approach was first introduced by Griffith and Stewart by applying it to a field that was carrying out oil production activities. This method was successfully applied by Handly, (2000). In fields where the lifting method uses a gas lift, the results can increase oil recovery by 1% and reduce gas supply by 6% and reduce fuel in the compressor.

Programming using the Mixed Integer Nonlinear Programming (MINLP) method, the first thing to know is the limitation of the objective function. This method is applied by Sharma et. al (2014) to optimize ESP pumps which have problems in production, the problem faced in the field is the ESP performance which exceeds the pump speed limit, causing inefficient use of pumps and operating costs, all of the inefficiency problems are formulated into MINLP. The results of using this method can reduce the power load consumed by the pump which initially uses a frequency of 80 Hz to 45 Hz. In other studies, it is also said that the optimization method on the ESP can be done manually in the design system. According to Power (1988), the power required to install an ESP pump in a production well can generally be divided into three categories, namely; the power needed for the main job, the power absorbed as a result of tubing friction and the supply of electric current through the cable conductor.

The ESP pump itself needs to be optimized in order to increase oil production, the optimization activities are carried out based on the study of Bithin, et al. (1989), in a field with a low fluid viscosity or a water cut of more than 60%, this production increase was done by doubling the pump stages from the original design. the field. The Mixed Integer Linear Programming method is used to optimize artificial lift. This method was used by Stanco et al. (2015), to optimize a large-scale field and experience high water cut problems due to ineffective pump control. The application of this method is carried out by increasing the amount of production in the field through experiments increasing the variation of the pump frequency from the smallest to the highest. This study shows that increasing the pump frequency by 16% can increase oil production by 18.3% and reduce water production by 6.6%, especially in complex production network conditions.

3. Methodology

This research method is divided into 3 stages. The first is knowing the well production capability through the calculation of the inflow performance relationship (IPR), the second stage is identifying the well condition, the availability of pumps, production facilities and gas injection in the field. The third stage is performing optimization using the equal slope method for the artificial lift installed in K field either separately and together.

This optimization activity is only carried out on pumps that are installed by utilizing the availability of available pumps and injection gas according to the storage conditions on the surface. In K field it has a reservoir capacity for fluid of 70,000 bbl/d, oil of 34,500bbl/d and water of 31,500bbl/d. Gas lift and ESP pump. Propose optimization method (EQS) to optimize ESP and Gas in k field under limited conditions.

4. Result And Discussion

Optimization in oil field that has an artificial lift electric submersible pump (ESP) method and gas lift is usually done in a partial or per-device type optimization (Abhijee at al., 2019). If simultaneous optimization will be performed between the two appointment methods, it is usually assisted with commercial software. In this study the authors propose the equal slope method to optimize the use of production methods in the electrical submersible pump and gas lift separately or together.

K Field is the field that is the object of research, in this field using two artificial lift methods, namely the ESP pump and gas lift. The well with ESP pump is called KE well and KE well itself consists of 3 wells namely KE-1, KE-2 and KE-3 wells while for gas lift wells are called KG, and KG wells also consist of 3 wells namely KG-1 wells, KG-2 and KG-3 so that the total wells in K field are 6 wells.

4.1. Workflow Using the Equal Slope Method on a Gas Lift

The equal slope method is one of the optimization methods that is mathematical (kannu at al.,1981). The application of the equal slope method to gas lift includes several stages as shown in Figure IV.1. It can be seen in the first stage that the IPR curve is formed to determine the potential for deep wells to produce, the production rate is determined based on the amount of gas injected into the well. The second stage is to determine the amount of injection gas at the optimal flow rate based on the GLPC curve which is formed from the analysis of the relationship between the IPR curve and GLR. The third stage is to calculate the amount of slope in the well by comparing the injection rate to the production rate. The fourth stage is to combine the slope calculated wells and then add up the production rate and gas injection on the same slope to get the master slope. The fifth stage is to choose the slope according to field conditions, either the maximum or limited production rate, plotting can be done on the number of slopes against the injection rate or the number of slopes against the production rate.

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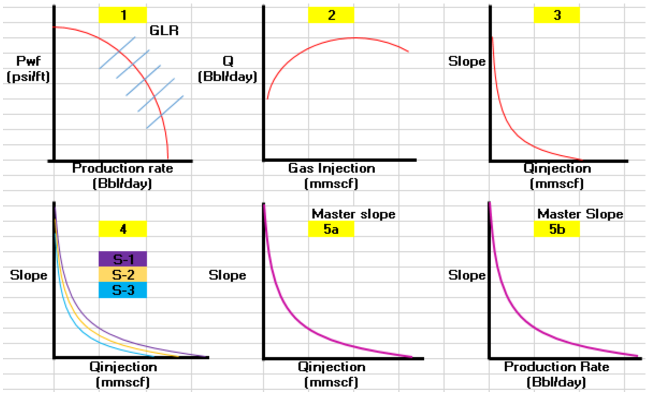

Fig IV.1 Gas Lift Equal Slope Method Step.

4.2. Workflow Using the Equal Slope Method in ESP

As previously discussed, the equal slope method in the field is only applied to artificial lifting methods that use gas lift, because the equal slope method is a mathematical method that can be determined based on the affecting variables, this method can also be applied to other artificial lifting methods, in this research is ESP. Can be seen in Figure IV.2. The application of the equal slope method to the ESP pump includes several criteria and steps that we need to know first. In determining ESP optimization using the equal slope, the criterion that affects is the type of pump, where the available pump must be compatible with all existing wells in the same well completion conditions. The choice of pump type is also influenced by whether there are production limitations in the field. The following are the stages of using the equal slope method on an ESP pump:

a) The graph in Figure IV.2 no 1 shows the price of the production rate for each type of pump obtained by calculating nodal analysis according to well conditions. In the nodal evaluation, each pump is calculated at the same number of stages and the same frequency, to simplify the calculation of the initial stages it is determined to be 100 stages and the frequency of 80 Hz is the largest frequency of the optimized pump.
b) In the graph shown in Figure IV.2 no 2, it shows each type of pump which is quantified and sorted from the pump that has the lowest production rate to the highest then plotted into a pump curve type.
c) In the graph contained in Figure IV.2 No.3, shows Calculating the slope on the ESP pump through the polynomial quadratic equation, to get a mathematical equation to calculate the slope at the production rate of each ESP pump, to get an accurate mathematical equation in calculating the slope, then the slots on the y and x axes are reduced to a 1: 1 scale.
d) The graph in Figure IV.2 no 4 shows the results of calculations using the equal slope method in wells from various types of pumps by producing liquid under certain conditions.
e) The graph shown in Figure IV.2 No. 5 shows the combination of wells that have been calculated slope, if there are more than one wells in a field. The purpose of the amalgamation is to find the same slope and then add the production rate to get the master slope in the field.
f) On the graph shown in Figure IV.2 no 6, it shows the master slope of a field. After getting the master slope, choose one of the slopes with the optimum production rate, then evaluate the position of the optimum point in the curve. When the optimum point lies in the two types of pumps evaluated. Choose a pump with a larger capacity between the two pumps. In order to adjust the flow rate to suit the curve, adjustments of stages and frequencies can be made.
g) If a field has more than one different artificial lifting method, then when combining the slope calculation results for each well as in Figure IV.2 no 5, the curve variables on the x-axis and the y-axis must be plotted the same so that the variables can be added.

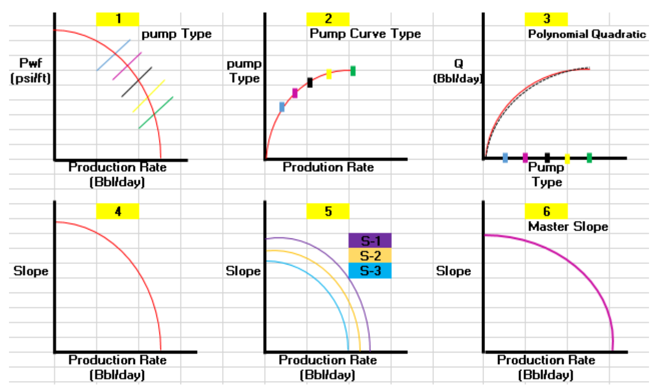

Fig IV.2 ESP Equal Slope Method Step.

4.3. ESP Pump Optimization Using the Equal Slope Method

The goal of optimizing assets in the field is a management target that needs to be achieved with optimal results (Wang at al., 2004). The work carried out in the K field study is to increase production results and field performance through optimization of artificial lifts, especially ESP pumps and gas lifts installed in wells in K field. Optimization activities are carried out using the Equal Slope optimization method by utilizing input data such as The number of stages, pump frequency and injection gas are the optimization variables that affect the flow rate (QO, QW

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and QL), in this case the artificial lift and surface facility limits, as the analysis parameters. The equal slope optimization method is very commonly used to perform optimization in fields where gas lift wells are installed. This method is used because of its simplicity and effectiveness when applied. The same thing was expressed by Kanu, et al. (1981), which states that the equal slope method is the simplest gas lift allocation method and includes a linear optimization method, where this method looks for the same slopes or has the same degree of slope (equal) from the gas lift performance curve. Electrical submersible pump (ESP) which is also called an immersion pump with its working mechanism dipping the pump into the well then circulating the available electric power above the surface through the cable and into the main pump so that it converts electrical energy into motion energy (impeller) to lift the fluid up to the surface (Sunder at al., 2020). The production process using ESP often experiences problems, especially mechanical problems, namely a decrease in pump performance caused by the pump's not optimal lifting fluid.
Use of the equal slope method in the K field case, can help provide a fast and efficient solution in optimizing and selecting the right type of pump for the needs of the field when management conditions in the field have difficulty finding or selecting the type of pump that is in accordance with field conditions in using pumps long period of time. Availability of ESP pumps in K field are: Reda (GN10000, SN8500, J7000N, HN13500, HN13000).

4.4. Nodal Analysis Calculations

Optimizing with the equal slope method, what must be considered is that each pump is conditioned at the same maximum frequency and number of stages, so that the adjustment and selection of the pump type is easier to do, if you have got the pump type on the same slope, the pump is included in it. This rate or slope will be set according to the limits and simultaneously change the pump parameters that were initially set to the maximum that can be lowered. The initial pump set is not performed at minimum conditions because it will be more difficult to reach the optimum point at the selected pump.

Table IV.2 shows the types of pumps available in K field; REDA GN10000, REDA SN8500, REDA J7000N, REDA HN13500, REDA HN13000. The use of the equal slope method at an early stage that needs to be done is to calculate the production rate at each well, using nodal analysis. The calculation results for the KE-1 well have a Qmax of 53,826 Stb / d with an ESP pump type GN10000 resulting in a liquid rate of 10,364.2 bbl/d, type SN8500 11,149.3 bbl/d, type J7000N 12,905.7 bbl/d, type HN13500 16,283.8 bbl/d, type HN13000 16,930.5 bbl/d, for the 2nd well which has a Qmax 1,5845 Stb/d. The results of the analysis of the nodal point for the GN10000 pump type produce a liquid rate of 6,607.18 bbl/d, type SN8500 7,585.03 bbl/d, type J7000N 9,692.88 bbl/d, type HN13500 9,706.47, type HN13000 10,738.6 bbl/d. Whereas for the 3rd well whose Qmax is greater than the two in the K field, amounting to 56,530 stb/d, from the results of the nodal analysis in this well the pump type GN10000 9,863.54 bbl/d, type SN8500 11,125.2 bbl/d, type J7000N 12,969.7 bbl/d, type HN13500 16,371.3 bbl/d and HN13000 bbl/d. For more details, see table IV.2.

Table IV.2 ESP Pump Availability and Production Rate in Field.

Well			KE-1	KE-2	KE-3
Pump Type	Frq hz	Stg	Q_{Liquid} (bbl/d)	Q_{Liquid} (bbl/d)	Q_{Liquid} (bbl/d)
REDA (GN10000)	80	100	10364.1	6607.18	9863.58
REDA (SN8500)	80	100	11149.3	7585.03	11125.2
REDA (J7000N)	80	100	12905.6	9692.88	12969.6
REDA (HN13500)	80	100	16283.8	9706.47	16371.3
REDA (HN13000)	80	100	16930.5	10738.6	17002

4.5. Pump Curve Type

Pump curve type is the relationship between pump parameters and pump efficiency at a certain production rate (. Figure IV.3 shows the pump curve type for the 3rd well which states the relationship between pump types at the same conditions, namely the number of 100 stages and a frequency of 80 Hz. From the results of the analysis of the nodal point of each pump, the production rate varies, from the smallest to the highest production rate. For the number zero (0) is a condition in which no pump is installed in the well so that the production rate is 0, while for numbers one (1) to 5 it is the quantified pump type.

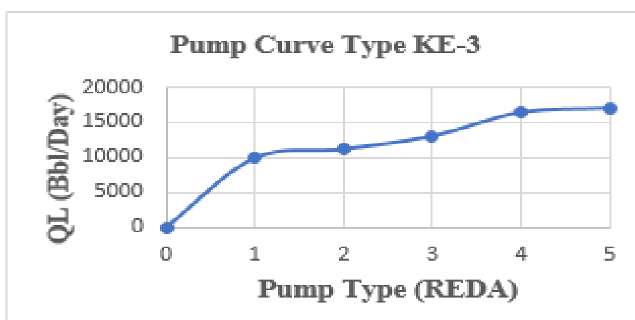

Fig IV.3 Pump Curve Type Well KE-3.

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The five types of pumps installed, the nodal analysis gives a difference in the results of the production rate. As shown in Figure IV.3, the highest QL in the HN13000 pump type is 17002 bbl / d, for the HN13500 pump type produces QL 16371.3 bbl / d, the J7000N pump type produces QL 12969.7 bbl / d, the SN8500 pump type produces a liquid rate of 11125.2 while the smallest rate of the four other pump types is the GN10000 pump type producing QL 9863.5 bbl / d. For wells KE-1 and KE-2 can be seen in table IV.3.

Table IV.3 Results of Nodal Analysis for ESP Installed

Well			KE-1	KE-2	KE-3
Pump Type	**Frq hz**	**Stg**	**Q_{Liquid} (bbl/d)**	**Q_{Liquid} (bbl/d)**	**Q_{Liquid} (bbl/d)**
0	0	0	0	0	0
REDA (GN10000)	80	100	10364.1	6607.18	9863.58
REDA (SN8500)	80	100	11149.3	7585.03	11125.2
REDA (J7000N)	80	100	12905.6	9692.88	12969.6
REDA (HN13500)	80	100	16283.8	9706.47	16371.3
REDA (HN13000)	80	100	16930.5	10738.6	17002

4.6. Linearization Polynomial Quadratic Equation.

To find the slope of each pump in the well in K field requires an equation. In this case the quadratic polynomial equation is a solution in finding the slope to optimize the pump. Figure IV.4 shows an equation with R2 of 0.935. From the resulting equation then calculates the slope by displaying the production rate for each type of pump. The results of the equation with the actual conditions have an insignificant difference, from 0.4% to 1.4%, it can be said that this equation is suitable to be used as a reference in calculating the slope of each well.

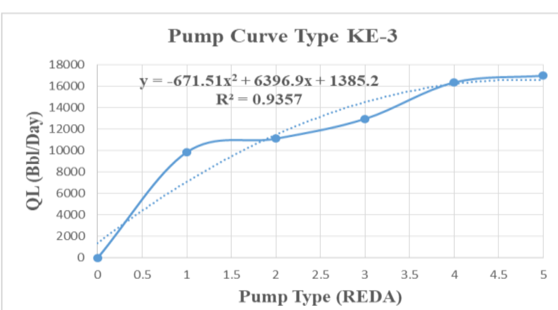

Fig IV.4 Pump Curve Type with Polynomial Equations in the KE-3 well.

4.7. Equal Slope in ESP

Equal slope method is commonly used to calculate gas allocation in fields where the availability of gas supply for injection has limited or unlimited, the use of this method aims to find the equality of slope in each well. The same thing was also expressed by Kanu et al. (1981) which states that the equal slope method is the earliest and simplest gas lift allocation method and includes a linear optimization method, where this method looks for the same slopes or has the same degree of slope (equal) from the gas lift performance curve. In this case, using the equal slope method to optimize the availability of ESP pumps in field K and to determine the type of ESP pump that will be used in each well in K field as shown in Figure IV.5 on slope 0 is the type of pump HN13000 which has a QL. amounting to 16,582 bbl/d, this slope is the slope with the highest liquid production of the other slopes, for the slope 1,024.82 is the Pump type HN13500 with QL 16,228.6 bbl/d, slope 2,367.84 is the pump type J7000N with QL 14,532.3 bbl/d, slope 3,710.86 is a type of pump SN8500 with a liquid production rate of 11493 bbl / d and slope 5,053.88 is a type of pump GN10000 with QL 7,110.59 bbl/d, for wells KE-1 and KE-2 can be set in table IV.4.

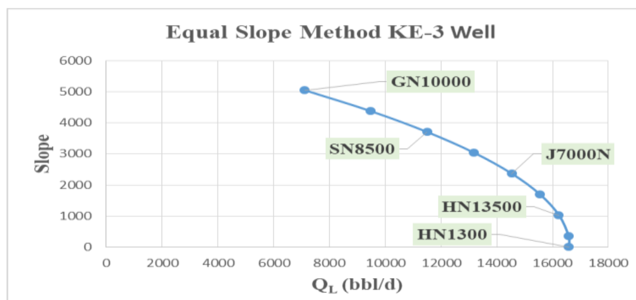

Fig IV.5 Equal Slope Method in ESP-installed KE-3 well and

4.8. Selection of the Same Slope at the ESP Pump in the K Field

Each well in field K whose slopes have been calculated are combined then add up the production rate of QL / Qo on the same slope according to the equal slope method, which is based on the concept of slope equality, which states that the solution is optimal. This concept is the reference for use in the artificial lifting of the electrical submersible pump, by selecting the type of pump on the same slope through the sum of the production rates of each well. As previously discussed, the ESP pump available in K field has 5 types with a number of stages of 100 and a pump frequency of 80 Hz to produce

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a liquid that varies from the smallest production rate to the highest production rate. To get the optimal production rate and determine the pump type, it is necessary to optimize and choose the type of pump with the optimal production rate, so that it can be used in K field. As shown in curve IV.6, each well that has calculated slope is combined, then add up the production rates over the same slope to find the master slope.

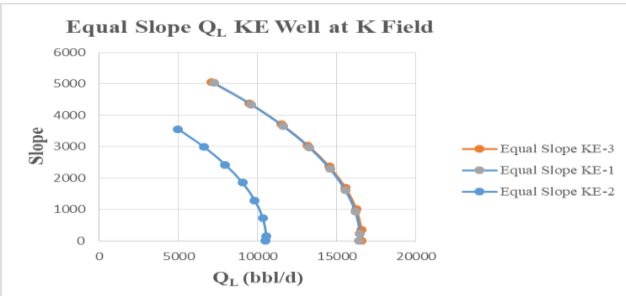

Fig IV.6 Determining the Amount of Slope in ESP Well

4.9. Available Production Facilities

Limitations in a field are the obstacles and challenges faced by engineers in making decisions to design artificial lifts or perform field optimization (Lichi 2019). On the basis of demands for field development or optimization of assets in a field, if the reservoir conditions are still productive, it is necessary to carry out optimization activities using several alternatives or methods to increase production. In this K field, there are several limitations, both the availability of ESP Pumps, surface facilities (storage) and injection gas in limited and unrestricted conditions.

Limitations for surface facilities, especially the storage of fluid from the production results, are one of the criteria or limitations that need to be considered for the production process or setting the production rate and optimization activities in a field.

4.10. Master Slope of ESP Pump under Limited Conditions

The choice of slope and pump type in this case is based on the availability of above-surface storage facilities. As discussed previously, the limits on the surface of the amount of QL are 70,000 bbl / d, QO 34,500 bbl / d and QW 31,500 bbl / d. So at this stage it is necessary to select the right slope to determine the amount of production rate in accordance with the existing limitations. As shown in Figure IV.7, the 2,000 slope has a QLtotal of 38,861 bbl / d, a QOtotal of 7,763.29 bbl / d and a QWtotal of 31,097.7 bbl / d for three wells in field K that have ESP installed. Slope 1,500 has a total QLtotal of 40,000 bbl / d, QOtotal 8,187.77 and QWtotal 31,812.2 bbl / d while for slope 0 it has a QLtotal of 43,514.7 bbl / d, QOtotal 8,996.36 bbl / d and QWtotal 34,518.4 bbl / d. Of the three slopes, one has to choose the most optimum slope according to the existing limitations, then the 2,000 slope is chosen because it has a total production rate of both liquid, oil and water, which is still below or nearing the predetermined limits according to the storage conditions above the surface. On this slope 2,000, for wells KE-1 and KE-3 there is a pump type HN13500, while for wells KE-2 there is a pump type J7000N. Well KE-1 on slope 2000 has a QL of 15,030 bbl / d, QO 1,503 bbl / d and QW 13,527 bbl / d, for wells 2 on slope 2,000 has QL 8,831 bbl / d, QO 5,210.29 bbl / d and QW 3,620.71 bbl / d while the 3rd well on slope 2,000 has a QL of 15,000 bbl / d, QO 1,050 bbl / d and a QW of 13,950 bbl / d. For more details, see table IV.6.

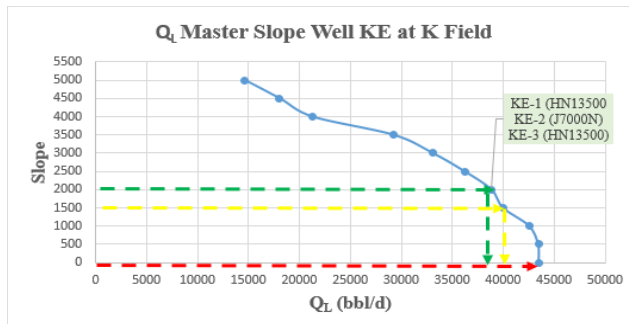

Fig IV.7 Master Slope in ESP Installed Wells. And

4.11. Optimization of ESP Pumps in Limited Conditions

Optimizing the ESP pump in this case, there are a number of things that need to be considered, such as the expected fluid production rate according to the storage limit above the surface. With these considerations, it can be determined the number of stages, frequency and pump type according to the number of slopes at the production rate in the field required to produce a production rate within the limits. The determination of the number of stages and the frequency of the pump is carried out by calculating nodal analysis involving the IPR curve.

Production Constrain at **surface**		
Fluid Max	70,000	Bpd
Oil Max	34,500	Bpd
Water Max	31,500	Bpd

Table IV.6 Each ESP Installed Well in Production.

Increasing or optimizing pump efficiency can be done by increasing or adjusting the production rate by changing pump parameters, especially pump frequency and stages. This is also confirmed by Bithin, et al. (1989), in his study in one field with low fluid viscosity or a weter cut of more than 60%. The process of increasing this production is done by

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doubling the pump stages from the original design, the results of this implementation are then applied and get a 40% increase in oil production in the field.

In this case, because the field conditions have limited pumps and surface facilities, it is necessary to optimize using the equal slope to get the slopes according to the limitations in the field. As previously explained, the selected slope in the K field is the 2000 slope.In the 2000 slope in well KE-1 there is an HN13500 pump which has a 100 stage number and a frequency of 80 Hz with an initial production rate or the pump has not been set to produce a flow rate according to conditions. field.

The ESP pump type HN13500 produces a QL of 16283.81 bbl / d, a QO of 1628.38 bbl / d and a QW of 14655.43 bbl / d, the 2nd well on the 2000 slope has a pump with the J7000N type which produces QL before optimization of 9692.88 bbl / d, QO 5718.79 bbl / d and QW 3974.08 bbl / d and the last well KE-3 on the 2000 slope there is a pump type HN13500 with a QL rate before the pump is optimized of 16371.31 bbl / d, QO 1145.99 bbl / d and QW of 15225.32 bbl / d, for more can clearly be seen in table IV.2. Because the pump has not been optimized and set according to the limitations of surface facilities (shelter), it is necessary to optimize it to obtain an efficient pump condition, so that the pump needs to be set for each well. So in the KE-1 well type HN13500 pump initially has a stage number of 100 and a frequency of 80 Hz, producing liquid based on a nodal point of 16283.81 when it is set according to field conditions, the HN13500 pump has a number of stages 177 and a frequency of 65 Hz with QL 15030 bbl / d, QO 1503 and QW 13527 bbl / d.

For the 2nd well with the J7000N pump type initially having a stage number of 100 and a frequency of 80 Hz producing a QL of 9692.88 bbl / d when it is set according to the limits and getting the optimum pump efficiency, the J7000N pump in this KE-2 well has 129 stages and pump frequency 65 Hz while for the 3rd well with the pump type HN13500 it has the same number of stages and frequency as the previous two pumps, which produces QL before it is set at 16371.31 bbl / d and after it is set this HN13500 pump has a number of stages of 176 and a pump frequency of 65 Hz, for more clearly can be seen in the table IV.7.

4.12. Gas Lift Optimization Using the Equal Slope Method

Optimization methods base on Computer is applied simultaneously in field conditions of more than two artificial ones that we have often encountered in previous studies, however, the conventional equal slope optimization method has been applied to two artificial lifts such as ESP and gas lift so far it has not been found. Research in the application of this method is carried out on the basis of solving problems in a production field using the equal slope method. This method itself is mathematical, simple and can be applied to field conditions that experience constraints on production management or other constraints, namely limited facilities.

4.13. Gas Lift

The artificial lift method using gas lift is one of the methods often used by oil and gas companies in production, by utilizing gas around the well in a field and then injecting it into the well either periodically or continuously with the aim that the gas entering the well can change The physical properties of the fluid in the reservoir become lighter and rise to the surface, this injection process is carried out with the hope of minimizing the pressure on the compressor but producing an optimal production rate, the same thing was expressed by Clegg (1988), the injection gas pressure needs to be determined so that it can be produces the lowest pressure at the compressor in producing fluid when the injection is close to the optimal gas volume value, this condition indicates that the injection gas pressure must be high enough to be able to lift the fluid up to the surface. The process of injecting gas to produce fluid in the reservoir at the wells in the field does not all run smoothly, because the availability of gas above the surface has a limitation, so that it can have an impact on the well to produce. To get a balance in production in productive wells, it is necessary to optimize the gas allocation. One of the optimization methods used is the equal slope method. In this study, researchers used the equal slope method as an optimization method in the K field.

4.14. Gas Lift Performance Curve (GLPC)

Gas lift performance curve (GLPC) is the relationship between the rate of the injected gas to the fluid production rate. The injection process can be carried out from above the surface continuously and also gradually, both are applied depending on the situation in the field and well conditions.

In K field has a gas lift well (KG) consisting of KG-1, KG-2 and KG-3, each well has a production rate and the amount of gas injection that varies according to the nodal analysis on the GLPC curve, which shows that along with the volume of gas injected into the well the production rate has increased but at a certain volume injection rate the production rate will not increase significantly but will flatten out and decrease this is due to the gas which initially acts as a pressurized gas which will become a barrier or change the form of the gas to liquid so that pressing the fluid cannot be lifted up to the surface. Alhaneti (1993) states that the injection and control of the valve above the surface is very influential with the production conditions, so the subsurface pressure must be estimated accurately so that the gas pressure generated from above the surface can lift the fluid instead of inhibiting the fluid to be produced.

In the case of the K field, it can be seen in curve IV.8 which shows the condition of 0 mmscf injection gas producing QL 3,430 bbl / d, 0.5 mmscf injection gas

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producing QL 4,794 bbl / d, 1.2 mmscf injection gas producing QL 5,958 bbl / d, injection gas 1.8 produces QL 6,592 bbl / d, injection gas 2.9 mmscf produces QL 7,319 bbl / d, injection gas 5.3 produces QL 8,140 bbl / d, injection gas 7.7 produces QL 8,531 bbl / d and injection gas 8.1 mmscf produces QL 8,583 bbl / d. For wells KG-1 and KG-3 can be seen in IV.8.

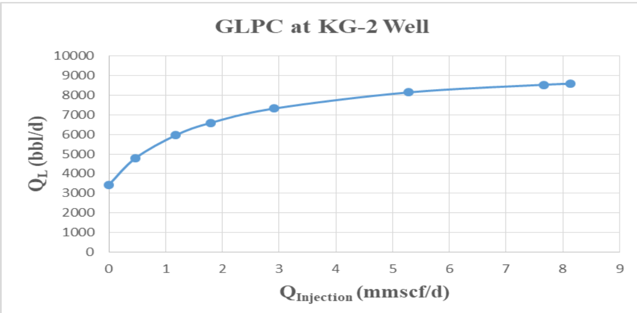

Fig IV.8 GLPC Curves in KG-2 Wells.

Table IV.8 Each Well Installed Gas Lift in Production

KG-1 Well		KG-2 Well		KG-3 Well	
Q_{Liquid}	$Q_{injeksi}$	Q_{Liquid}	$Q_{injeksi}$	Q_{Liquid}	$Q_{injeksi}$
bbl/d	**mmscf/d**	**bbl/d**	**mmscf/d**	**bbl/d**	**mmscf/d**
8358	0.0	3430	0	9565	0.0
10321	0.5	4794	0.5	11682	0.6
12081	1.1	5958	1.2	12439	1.0
12746	1.5	6592	1.8	13178	1.4
13976	2.4	7319	2.9	13810	1.8
14485	2.8	8140	5.3	14373	2.2
14941	3.3	8531	7.7	14882	2.6
15362	3.8	8583	8.1	15343	3.1
15742	4.3			15762	3.6
16394	5.2			16149	4.1
16972	6.3			16810	5.1
17855	8.4			17403	6.1

4.15. Equal Slope in Gas Lift

Equal slope method, as previously explained, is the optimization method by adding the gas injection rate or liquid rate on the same slope to get the optimum production rate on the master slope. Curve IV.9 shows the KG-2 well when calculating using the equal slope method, namely the slope of the amount of gas injection, when the slope is 0, the maximum gas injection amount with an injection price of 8.1 mmscf produces a QL of 8583 bbl / d, a slope of 155 Injection of 7.7 mmscf QL 8531, slope 255 Q injection 5.3 yields QL 8140 bbl / d, slope 445 Q injection 2.9 produces QL 7319 bbl / d, slope 785 Q injection 1.8 mmscf yields QL 6592 bbl / d, slope 1352 Q injection 1.2 mmscf yields QL 5958 and the last slope 2143 Qinjection 0.5 yields QL 4794 bbl / d. For KG-1 and KG-3 wells can be seen in table IV.9.

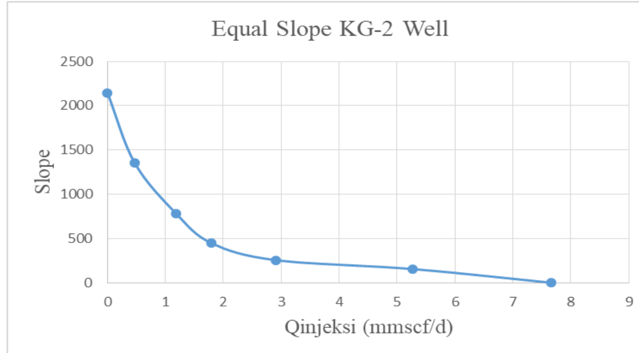

Fig IV.9 Equal Slope in KG-2 Well. And

IV.4.1.3 Condition of Injection Gas Availability in the K Field.

Field that has limitations is a challenge in doing optimization but it is not an obstacle that must be avoided or abandoned, the optimization method must have a purpose function to be achieved, both in maximizing the rate of liquid production by suppressing the rate of water production and so on. Limitations on K field include surface facilities (reservoirs), pump availability and for injection gas, it is assumed that there are two conditions namely limited injection gas.

4.16. Assumptions of Limited Gas in the K Field.

The optimization assumption uses the equal slope method in conditions of gas limitations in the K field.If optimization is carried out using the equal slope method in a field with limited gas injection conditions, the first thing to know is how much gas is available on the surface, as a reference for optimization. in that field, to get the gas allocation price for each well reaches an optimal condition so that the production process is as expected. (Kanu, et al., 1981) also revealed that if the field is experiencing limited gas injection, the thing that needs to be considered is that the gas allocation in each well must be optimal so that it reaches the expected production target.

For the case of K field with limited gas assumptions, it can be seen in Figure IV.13 that the gas lift wells in the K field have 3 production wells, namely KG-1, KG-2 and KG-3 wells, of these three wells rely on gas as an artificial method. elevator. Because the gas availability above the surface is 1.3 mmscf / d, it is necessary to optimize the gas allocation in the three wells to achieve optimal conditions. So for KG-1 wells at maximum conditions or slope 0 has a Qinjeksi of 0.6 mmscf / d, KG-2 well has a Qinjeksi of 0.1 mmscf / d while for KG-3 wells Qinjeksi is the same as the

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injection rate in KG-1 well which is 0.6 mmscf / d. From the three wells, the same slope was selected to add the injection rate, so the total injection rate was the same as the gas availability above the surface, namely 1.3 mmscf / d and the QLtotal in the limited conditions in this K field was 26410 bbl / d. Can be seen in the curve figure IV.14, IV.15 and IV.16.

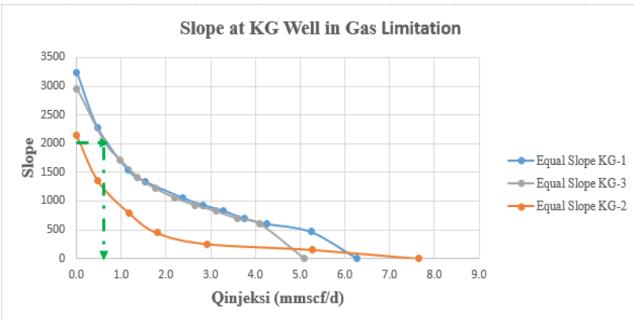


Fig IV.13 Equal slope in KG Well at Limited Gas.

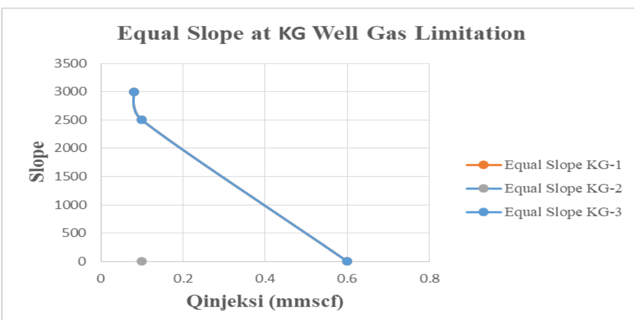
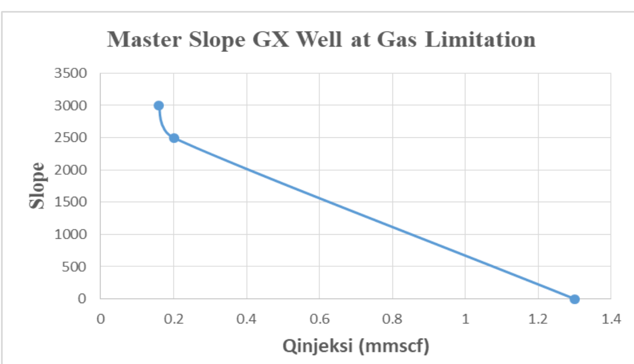
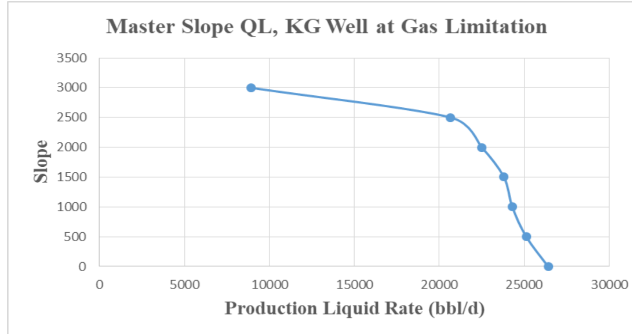


Fig IV.14 Combined Equal Slope of KG Well at Limited Gas.



FigIV.15 Master Slope on KG Well Limited Gas, Injection Rate.



FigIV.16 Master Slope on KG Well Injection Limited Gas, Liquid Rate.

4.17. Limited Injection Gas

Optimization of the ESP pump and gas lift simultaneously in fields that have limitations above the surface facility (shelter), the availability of pumps and limited injection gas, is an effort that needs to be achieved in obtaining an effective solution in optimization. The optimization method that will be applied in this condition is the equal slope method because the equal slope method is mathematical, simple and fast to provide a solution through an equation that produces slopes and then selects the same slopes in the well, both gas lift wells and ESP wells in field.

After selecting the same slope, the next step is to add the production rate (QL / QO) of each well to obtain the total flow rate according to the principle of the equal slope method. For the optimization case in the dual artificial lift conditions on the ESP pump and gas lift what needs to be considered is the plotting of the performance curve before combining it, the x-axis curve must be in the same variable so that it can be added to the master slope. As shown in curve figure IV.17, K field has two types of wells with different production methods, KG wells are wells with a gas lift which are divided into 3 wells namely KG-1, KG-2 and KG-3 wells, wells. -this well separately in calculating the slope has been discussed in the previous sub-chapter and for discussion in this section it discusses the master slope, the same thing as the KE well which is an ESP well which is divided into 3 wells such as KE-1, KE-2 and 3rd, the same thing as in KG wells, This section does not recalculate to select the slope for each well because the previous sub-chapters have been discussed in detail. So in the discussion of this sub-chapter combines the slope in the two artificial lifts, namely the KE (ESP) well and the KG (gas lift) well in the K field. In Figure IV.17 below shows the conditions of the K field with limited gas and a combination of the slopes of the two artificial lifts different. Slope 0 for KG wells has a QL of 26,410 bbl / d and for wells KE on slope 0 QL is 43,514.77 bbl / d. From the two well slopes with different artificial lift methods are used as the master slope, then add up the production rate on

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the same slope to get the optimal production rate according to the limits that will be determined on the surface.

As in curve IV.18, it shows that slope 0 on the master slope in field K has a QLtotal of 70,000 bbl / d, slope 1,000 has a total production rate of 66,873 bbl / d, and slope 2,000 has a QLtotal of 61,361 bbl / d. If optimization is carried out or adjusted to the limit on the amount of production in the K field, the slope target that is included in the category is the slope of 2,000, namely with the total liquid production rate from KE wells of 38,861 bbl / d and KG wells, the liquid production rate is 22,500 bbl /d If the total liquid production rate is 61361 bbl / d, the total oil production rate is 30,263 bbl / d and for the total water production rate is 31,097.7 bbl / d. The choice of slope 2000 is due to the production rate of total liquid, oil and water under the storage limit of 70,000 bpd, 34,500 bpd of oil and 31,500 bpd for water.

The selected slope is in accordance with the limitations, the next step is to select the type of pump, especially for wells whose production uses ESP which is included in the slope range of 2,000, and performs optimization or sets of pumps, according to existing production limits. He did a reset on the pump because from the beginning of the calculation using the equal slope optimization method, all pump frequencies were set to the maximum condition, namely 80 Hz, can be seen in table IV.1. The condition of the pump is set to get optimal results can be seen in table IV.11, while for wells that are installed with gas lift on slope 2.000, it has an injection of 0.4 mmscf / d, it can be seen in curve figure IV.18.

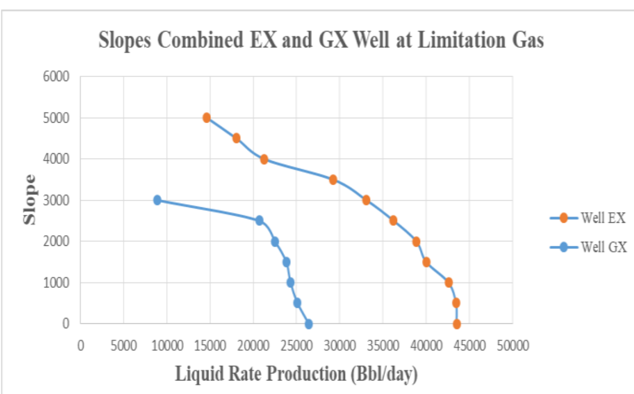

Figure IV.17 Combined Slope in KE and KG Gas for Limited Injection Gas.

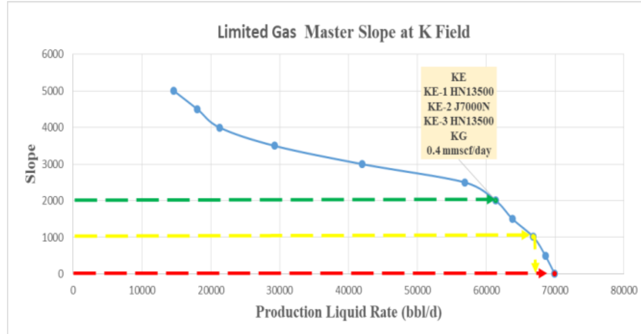

Figure IV.18 Master Slope on K Field into Limited Gas Injection. And Table IV.11 Sat Artificial Lifts According to Shelter Capacity, Limited Gas.

5. Conclusion and Recommendation

5.1. Conclusion

Based on the results of the study using the equal slope method on two artificial lifts (electrical submersible pump (ESP) pumps and gas lifts), in the K field with limited conditions such as surface facilities, pump availability, limited or unlimited injection gas, several conclusions can be drawn regarding the research in including:

a) Equal slope method is a method that is usually used in the optimization of the injection rate or allocating injection gas. In this study, it was found that the equal slope method can also be used as a method to optimize the ESP pump. In the case of the K field, the optimum conditions in the field were obtained at a slope of 2,000, with the optimum total liquid flow rate at the pump of 38,861 bbl / d, oil flow rate of 7,763.29 bbl / d and water flow rate of 31,097.71 bbl / d . From the optimization results, the KE-1 well uses the HN13500 pump, the 2nd well of the J7000N pump and the 3rd well of the HN13500 pump.

b) Optimization for different artificial lift is usually carried out separately. In this study, the equal slope method can be used to optimize the two artificial lift simultaneously. From the K field case with the limiting conditions of surface facilities, it is found that the optimum conditions are at 2,000 bbl / d slope, with field production rates for ESP 38,861 bbl / d and for gas lift 26,410 bbl / d.

c) The results of optimization of artificial lift simultaneously with the limiting conditions of surface facilities and the availability of injection gas in the K field, that the optimum conditions are in the 2,000 slope, with the field fluid production rate for ESP 38,861 bbl / d and for gas lift 22,500 bbl / d.

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5.2. Recommendation

a) Optimization of calculations using the equal slope method in this study is still very limited to ESP pumps and gas lifts, so it can be tried by other researchers for other artificial lift conditions, because the nature of this method is done mathematically and does not require many limitations and data input and derivative.
b) Use of this method can be done, to evaluate certain field conditions that have limited operating costs, and optimization can be done in seeing other parameters that directly play a role in the pump, one of which is the distribution of electrical energy.
c) Use of this method can be done, to evaluate certain field conditions that have limited operating costs, and can be optimized in seeing other parameters that directly contribute to the pump, one of which is the distribution of electrical energy.

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