Petroleum and Coal

Article **Open Access**

COMPARATIVE APPROACH TO OPTIMUM SELECTION OF ARTIFICIAL LIFT SYSTEM

Kevin Chinwuba Igwilo[1], Emeka Emmanuel Okoro[1] and Samuel Ubanatu[2]

[1] *Petroleum Engineering Department, Covenant University Ota, Nigeria*
[2] *Petroleum Engineering Department, Federal University of Technology Owerri, Nigeria*

Received December 11, 2017; Accepted March 19, 2018

Abstract

Artificial lifts are used around the world in approximately 85% of the wells and its overall efficiency cannot be overestimated. The specific lift method for a particular application is largely accomplished by production engineers; they apply both field / operational experience, and modern knowledge. This quality has been recognized as a defect in most engineering disciplines and have led to sub-optimal design in projects. Improper selection of artificial lifts can lead to a reduction in production and a significant increase in operating costs. Once a decision is made about the type of lift that will be installed in a well, whether or not this method is chosen optimally for the existing conditions of the well; very little can be done after installation. This paper analyzed the selection criteria for various artificial lift techniques and illustrate why the selection made is the most suitable technique to be applied in that particular well condition. For optimum decision making, the study considered the characteristics of the reservoir, their operational and design characteristics, the location of the facility and the artificial lift system economic. The economic evaluation of each case was carried out taking into account the capital and operating cost for each option.

Keywords: *Artificial Lift; Optimum Lift Selection; Decision Matrix.*

1. Introduction

The in-situ fluids naturally flow from the reservoir to the surface when the well is completed if the fluid/pore pressure is sufficient to lift the fluid from the matrix and transfer it to the well and lift it to the surface. During the production of the reservoir, the pressure will decrease and this will probably lead to an increase in water cut and a gas fraction decrease. This will prevent the in-situ fluids in the formation not to flow out easily into the well or even stop the flow of liquid. To prevent production decline, it is necessary to use some techniques. Thus, to raise the fluids to the surface, additional energy must be added and applying artificial lift technology will add energy to the fluid. An artificial lift is a method used to lower the pressure at the bottom hole of a well in order to maintain production from the reservoir and accelerate well production. It adds energy to the well fluid, which when it enters the available energy, which is naturally provided in the reservoir itself; flows well at a very economical performance. Nevertheless, the artificial lift system is extensive and diverse, and the key to selection does not necessarily depend on the simplest method; but on the most suitable method. A common method that is often used to select an artificial lift system are based on feedback or acquaintance, rather than a strategic optimization plan. An additional component for proper planning of optimum selection of the artificial lift method must be initiated during design, drilling and completion. There are a number of well parameters needed to select the best wellbore system. These include downhole pressure, the type of liquid to be discharged, the amount of fluid to be produced, the geometry of the well, the location well (offshore or land) and the total depth of the well. Not having this parameters/information can make the selection more difficult.

The choice of the right method of artificial lift is crucial for the long-term profitability of most oil and gas wells. Poor choice can reduce production and significantly increase operating costs [1]. In addition, a change in the type of lift already installed in a well will cost money and it implies that an incorrect system was chosen initially. Though, production engineers must constantly check the efficiency of the lift method to change operating parameters or even to assess how to change it; but it usually remains unchanged after selection. Clegg *et al.* [1] compared the main characteristics of the selection of the eight main artificial lift methods and gave practical guidance on the effectiveness and operational capabilities of methods based on proven real technologies.

The optimization of production and the savings in the costs of the artificial lift system are interdependent and can be achieved by properly planning a strategic project that takes into account the individual characteristics of the well and the actual operational capabilities of the lifting system.

It is important to choose the lift system that best suits the well from the widespread range of artificial lifts; taking into account the location, depth, expected yield, storage characteristics and other factors available. This study was developed from the five (5) P's for artificial lift systems developed by the service companies from their practical experience. These P's are represented in the slogan, "Proper Planning Prevents Poor Performance". This study ensures that the most appropriate artificial lift systems are selected based on the conditions and limitations in the well reservoir and the surface [1].

2. Literature

Optimal decision-making is a constant problem in the technique for production. The dynamic nature of the wells, other formation conditions and the company's policy during the project can cause complications. Technological constraints, existing cost structures and reservoir characteristics affect the optimal production strategies. There are no single calculation or a simple solution to solving all production situations. Conversely, there are several strategies for artificial lift and possible combinations to achieve the desired results within acceptable limits. Sometimes technical envelopes and functions of the artificial lift system overlap. Depending on the situation, it is necessary to fill the lifting gap, but other scenarios depend on the most effective time to switch the artificial lift system. Combining systems and effectively switching the system in the production of the optimum amount of oil at a low cost per barrel is not an easy task for Production Engineer [2].

In 1994, more than 900,000 wells were discovered worldwide [2]. Only 7% of them proceeded naturally, and the remaining 93% required some form of artificial left. The average yield per well was less than 70bpd. An artificial left is a method of reducing bottom hole pressure of the formation so as to increase the rate of well production. When producing from the well, the potential energy is converted into kinetic energy associated with fluid motion. This disperses the potential energy of the reservoir, reducing the flow and eventually make the flow to cease. In production stage of a well, it may be economical to maintain or even increase production rates using artificial lift to compensate for the dissipation of reservoir energy.

2.1. Natural flow of a well

The natural flow occurs when the pressure in the reservoir exceeds the pressure loss through the producing well from the subsurface to the surface (Fig. 1). This occurs under two conditions:

1) Normal or over-pressured reservoir. In this case, the pore and the in-situ fluid pressure with respect to their depth exerts a pressure below the reservoir pressure. Many unconventional deposits are over-pressured, so this usually leads to a natural flow for a short period of time in most cases.
2) The velocity of the fluid in the well gives sufficient gas production to carry the liquid obtained to the surface. It is usually called the "critical rate" for the liquid lifting.

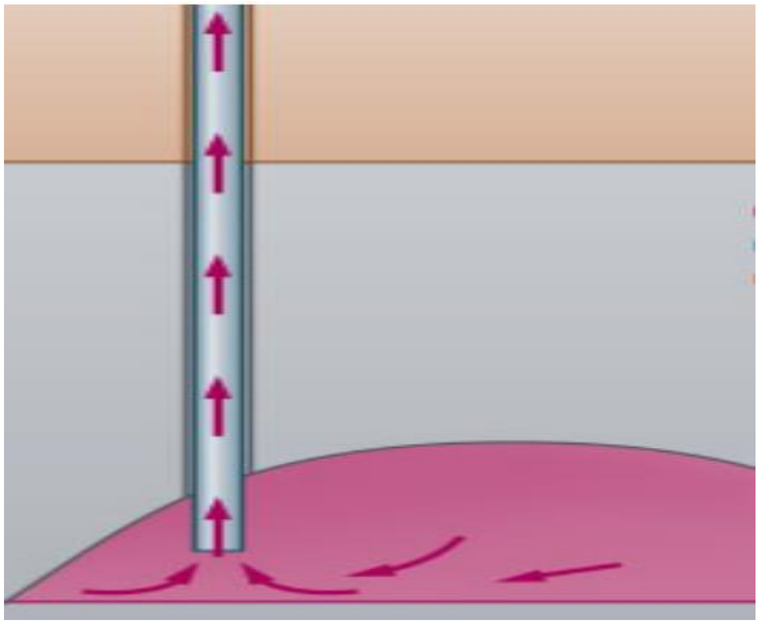


Figure 1. Primary production in a reservoir

The simplified technique to calculate where this condition exists is found in Turner *et al.* [3]. The correlation of Turner can correlate the critical velocity with the properties of the reservoir fluid, the surface pressure and the cross-sectional area of the fluid flow.

The natural decrease in accumulated reservoir pressure affects the flow of oil, gas or water, which causes instability and reduces production. The pressure and heat of the reservoir allows dissolved natural gas to always be present in the oil. When the oil is produced from the reservoir through the well, the pressure drops. At this stage, the gas will be out of the oil thereby expanding in volume. Expanding gas in the gas cap also helps maintain the pressure in the oil column high enough to allow oil to flow to the surface without artificial lift. The water of the aquifer can also maintain pressure in the oil column. This is called a natural flow, because the oil flowed to the surface without artificial help. The natural flow can be maintained by ensuring artificially high reservoir pressures (example, by pumping water or gas into non-production wells in the same field). Natural flow is the cheapest way of production; thus, we make every effort to keep it as long as possible.

2.2. Artificial lift

Neely *et al.* [4] defined some methods of artificial lift and studied the method of application, disadvantages, advantages and limitations of each method. Geographical and environmental conditions were considered as one of the main factors in the choice of selecting artificial lift and other sub-factors such as; reservoir fluid characteristics and pressure, the productivity index and inflow performance. Hwang and Yoon [5] used the concept of order of preference, based on a similarity to the ideal solution model (TOPSIS). The main idea of this program is that the most suitable method is the shortest distance from the ideal solution, and the worst method is the furthest from the ideal solution. Thus, the artificial lift methods should be evaluated in the range from 0 to 10.

According to the Schlumberger report, the value of 1 is evaluated perfectly, the 10-point conversion scale is 7. The value of 2 is considered fair, the 10-point scale is 7; and the value of 3 is considered unsatisfactory. Because the value is 3 on a 10-point scale. Each method of artificial lift has operational limitations.

Valentine *et al.* [6] used the "Optimal Pumping Unit Search" (OPUS) to select an artificial lift. OPUS was an intelligent integrated system with artificial lift method characteristics. It had the ability to monitor the technical and financial aspects of the artificial lift method. The technical and financial evaluation of this procedure was carried out using specific computer algorithms. The final results of OPUS were obtained in three stages:

1) Introduction of well data into the program
2) Data analysis
3) Recommendations of experts with technical and economic considerations

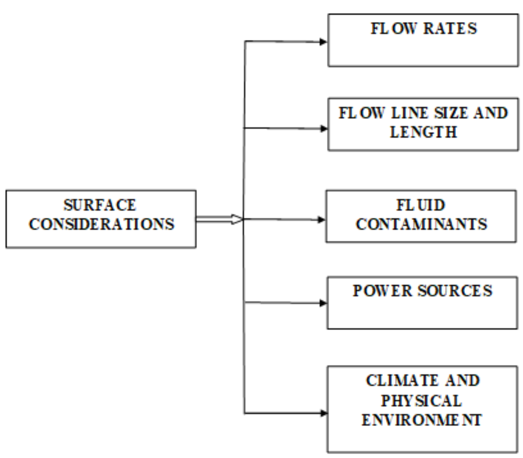
Clegg [7] cited economic factors such as income, maintenance costs and investment as the basis for choosing artificial lift. He believed that the chosen method of artificial lifting could provide the maximum production rate with minimum operating costs. Clegg *et al.* [1] studied the operational and structural characteristic of artificial lift method and classified them into three types based on comparison and development of global capability of artificial lift method.

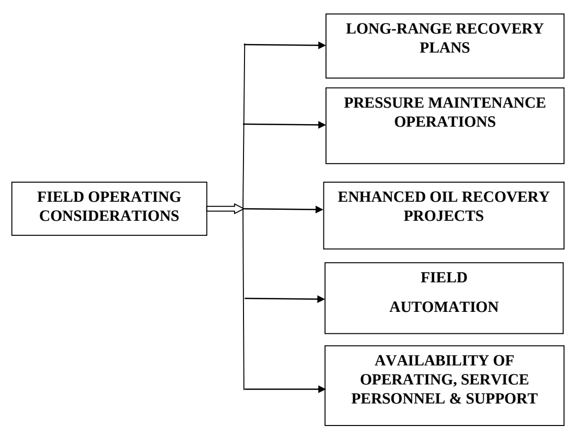
Espin *et al.* [8] used SEDLA to select artificial lifts. SEDLA was a computer program with the characteristics of an artificial method of investigation. This program includes: Expert modules, design modules and economic modules. Module 1 is a specialized module that includes a knowledge base consisting of human knowledge, accessible theoretical knowledge and calculations of the "general rule" type. Module 2 includes a simulation program and component specifications for all the lifting methods considered. Module 3 is an economic evaluation module that includes a cost database and a cost analysis program that calculates the profitability of the lift.

3. Methodology

This paper adopts the study of some criteria presented in the form of input parameters in accessing and comparing the various types of artificial lift systems mentioned. These selection criteria are classified as follows:

1. Surface conditions
2. Field operating conditions
3. Reservoir Characteristics
4. Well considerations
5. Field location
6. Economics

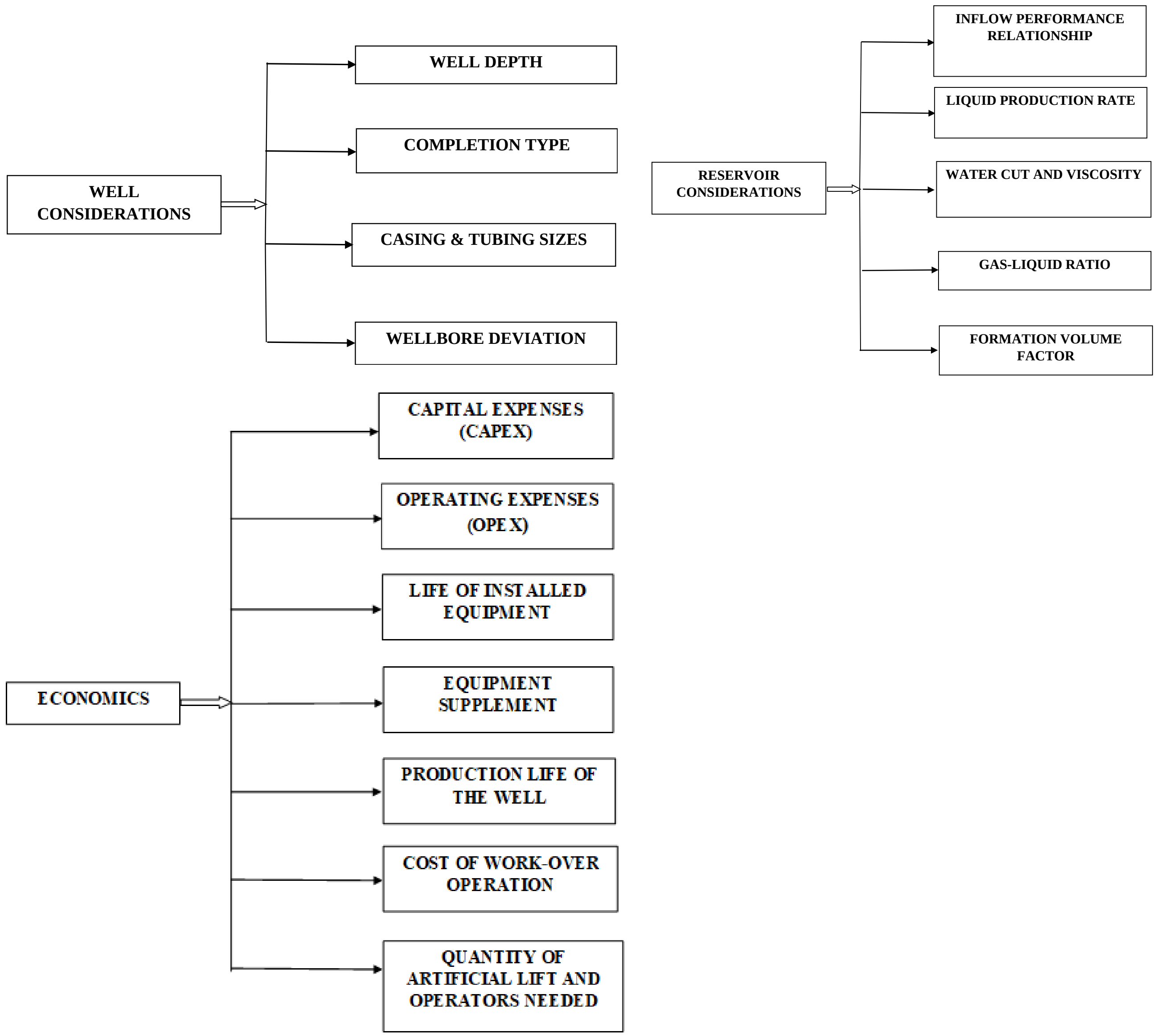




According to Clegg *et al.* [1], the initial capital costs play an important role in establishing the required artificial lift. However, operating costs are more important than the initial capital costs throughout the entire life cycle of the well. It is important to ensure the installation of reliable equipment, which will lead to a reduction in operating costs and a reduction in production costs. The key issues affecting operating costs are energy efficiency and reliability. Workover cost depends on the location of the operating area, as well as on the terms of the contract service (which requires high costs for remote areas).

Another important factor affecting operating costs is the number of wells that require the installation of an artificial lift. The number of employers who will need to install and monitor equipment will affect operating costs.

For the purpose of this study, the data were mainly obtained from a review of related literature, all of which were published and unpublished and includes conference paper, journals, seminars and textbooks.



3.1. Method of selection

The study covers the well and reservoir formation characteristics, operating conditions of the well, the location of the deposit and small economic analysis; in achieving the research objective, the range of values was formed in accordance with each parameter to access the artificial lift system excluding the economic analysis.

In this study, about 100 variants of all input parameters for the artificial lift system were used, and it was found that the ratio of the simple probability matrix presented in the table 1 is the optimal artificial lift system.

Table 1. Decision Matrix for ArtLOp

Parameters	Artificial Lift Systems						
	Gas Lift	ESP	SRP	PCP	HP	Total	Probability
Production Rate							
0-1,000	•	•	•	•	•	5	100.00%
1,001-2,000	•	•	•	•	•	5	100.00%
2,001-3,000	•	•	•	•	•	5	100.00%
3,001-4,000	•	•	•	•	•	5	100.00%
4,001-5,000	•	•	•	•		4	80.00%
5,001-10,000	•	•	•			3	60.00%
10,001-15,000	•	•				2	40.00%
15,001-30,000	•	•				2	40.00%
30,001-45,000	•	•				2	40.00%
Above 45,000		•				1	20.00%
Well Depth							
0-2,500	•		•	•	•	4	80.00%
2,501-5,000	•		•	•	•	4	80.00%
5,001-7,500	•		•	•	•	4	80.00%
7,501-10,000	•	•	•		•	4	80.00%
10,001-12,500	•	•	•		•	4	80.00%
12,501-15,000	•	•	•		•	4	80.00%
15,001-17,500		•			•	2	40.00%
17,501-20,000		•				1	20.00%
Above 20,000		•				1	20.00%
Casing Size							
4.500		•			•	2	40.00%
5.000		•			•	2	40.00%
5.500	•	•	•	•	•	5	100.00%
6.625	•	•	•	•	•	5	100.00%
7.000	•	•	•	•	•	5	100.00%
7.625	•	•	•	•	•	5	100.00%
8.625	•	•	•	•	•	5	100.00%
9.625	•	•	•	•	•	5	100.00%
10.625	•	•	•	•	•	5	100.00%
Above 10.625	•	•	•	•	•	5	100.00%
Wellbore Deviation							
0-10	•	•	•	•	•	5	100.00%
11-20	•	•	•	•	•	5	100.00%
21-30	•	•	•	•	•	5	100.00%
31-40	•	•	•	•	•	5	100.00%
41-50	•	•	•	•	•	5	100.00%
51-60	•	•	•	•	•	5	100.00%
61-70	•	•	•	•	•	5	100.00%
71-80		•	•	•	•	4	80.00%
81-90		7.	•	•	•	3	60.00%
Temperature							
0-50		•	•	•	•	4	80.00%
51-100		•	•	•	•	4	80.00%
101-150	•	•	•	•	•	5	100.00%
151-200	•	•	•	•	•	5	100.00%
201-250	•		•	•	•	4	80.00%

Parameters	Artificial Lift Systems						
	Gas Lift	ESP	SRP	PCP	HP	Total	Probability
251-300	•		•		•	3	60.00%
301-350	•		•		•	3	60.00%
351-400	•		•		•	3	60.00%
401-450	•		•		•	3	60.00%
451-500	•		•		•	3	60.00%
Above 500	•		•			2	40.00%
Flowing Pressure							
Less than 1,000	•	•	•	•	•	5	100.00%
Greater than 1,000	•	•	•	•	•	5	100.00%
Water Cut							
0-10	•	•	•	•	•	5	100.00%
11-20	•	•	•	•	•	5	100.00%
21-30	•	•	•	•	•	5	100.00%
31-40	•	•	•	•	•	5	100.00%
41-50	•	•	•	•	•	5	100.00%
51-60		•	•	•	•	4	80.00%
61-70		•	•	•	•	4	80.00%
71-80		•	•	•	•	4	80.00%
81-90		•	•		•	3	60.00%
91-100		•	•		•	3	60.00%
Fluid Viscosity							
0-20	•	•	•	•	•	5	100.00%
21-40	•		•	•	•	4	80.00%
41-60	•		•	•	•	4	80.00%
61-80	•		•	•	•	4	80.00%
81-100	•		•	•	•	4	80.00%
Above 100	•		•	•		3	60.00%
Fluid Gravity							
0-10				•		1	20.00%
11-20	•		•	•	•	3	80.00%
21-30	•	•	•	•	•	5	100.00%
31-40	•	•	•	•	•	5	100.00%
41-50	•	•	•	•	•	5	100.00%
Above 50	•	•	•	•	•	5	100.00%
GOR							
0-100	•	•	•	•	•	5	100.00%
101-200	•	•	•	•	•	5	100.00%
201-300	•	•	•	•	•	5	100.00%
301-400	•		•	•		3	60.00%
401-500	•					1	20.00%
501-600	•					1	20.00%
Above 600	•					1	20.00%
Sands and Abrasives							
0-10	•	•	•	•	•	5	100.00%
11-20	•			•	•	3	60.00%
21-30	•			•		2	40.00%
31-40	•			•		2	40.00%
41-50	•			•		2	40.00%
Above 50	•					1	20.00%

Parameters	Artificial Lift Systems						
	Gas Lift	ESP	SRP	PCP	HP	Total	Probability
Corrosion Fluid Type							
Carbon dioxide	•				•	2	40.00%
Hydrogen Sulphide	•				•	2	40.00%
None	•	•	•	•	•	5	100.00%
Field Location							
Onshore	•	•	•	•	•	5	100.00%
Offshore	•	•		•	•	4	80.00%
Power Source							
Electricity	•	•		•	•	4	80.00%
Natural Gas	•				•	2	40.00%
Others			•		•	2	40.00%
Fluid Contaminants							
Scales		•				1	20.00%
Paraffin		•				1	20.00%
Salt		•				1	20.00%
None	•	•	•	•	•	5	100.00%
Pressure Maintenance Operations							
Gas Injection	•					1	20.00%
Water Injection	•	•	•	•	•	5	100.00%
Total	80	68	73	67	77		
Probability	80%	68%	73%	67%	77%		

4. Results and discussion

After a careful study of the selection criteria as shown in the table above, a decision matrix was designed as shown in table 1.

4.1. Description of decision matrix

The decision matrix is designed using Microsoft Excel 2007. Each option under each input parameter is represented on the matrix as it is programmed on the software. The bullets in each option for each input parameter signify that the option satisfies the criteria for the corresponding artificial lift system. For instance; the options under the input parameter "Production Rate". Looking at the bullets under the column for gas lift, it fills the options in the column from 30,001 - 45,000 to 0 - 10,000. This means that gas lift as an artificial lift system can only lift fluid volumes not greater that 45,000 bfpd. This same principle applies for the rest of the input parameters and their options.

Calculations

To determine the probability that a particular option will be selected for each artificial lift system: by dividing the total number of artificial lift system that satisfies that criteria to the total number of artificial lift system. Mathematically;

$P_{os} = \frac{Number\ of\ Artificial\ Lift\ Sytem\ that\ Satisfies\ the\ Option}{Number\ of\ Artificial\ Lift\ System} = \frac{P_{AO}}{N_A}$, where;

$P_{OS} = Probability\ that\ an\ Option\ will\ be\ Selected.$

For example, the probability that the option a fluid viscosity of 61-80cp is chosen;

$$P_{os} = \frac{P_{AO}}{N_A} = \frac{3}{5} = 60\%$$

This calculation is repeated for all the options and the result is shown in the last column of the decision matrix.

Next step is to estimate the probability that a particular artificial lift system is selected amongst other artificial lift system. The calculation is done by dividing the total number of options that a particular artificial lift system satisfies by the total number of options. Mathematically;

$$P_{AS} = \frac{Total\ Number\ of\ Options\ Satisfied}{Total\ Number\ of\ Options} = \frac{N_{OS}}{N_O}$$

Let's take for instance, the probability that gas lift as an artificial lift system is selected amongst other artificial lift system.

$$P_{AS} = \frac{N_{OS}}{N_O} = \frac{80}{100} = 80\%$$

This calculation is repeated for all the artificial lift systems and the results are shown in the last row of the decision matrix.

5. Conclusion

Selection of artificial lift system which gives optimum production and economic benefit had been a great challenge in the petroleum industry. This is why an optimum and more suitable technology known as the Gas Lift has been discovered and established which has given rise to better oil recovery results in production over time. Historically, electric submersible pumps (ESP) have been associated with the production of large volumes of liquid; but electric pumps require too many steps for gas treatment and it often loses efficiency.

For gas lifts, the recovery ratio was higher than the recovery rate of the ESP. so an economic assessment was made that the capital cost for ESP was higher than that of gas lift systems. The operating costs of the ESP exceed the operating costs of the gas lift system.

Gas Lift has edge over other artificial lift because it is safer, flexible and reliable. It is 80% effective and efficient to give optimum production. It is highly recommended that Gas Lift should be used in the petroleum industry especially here in Nigeria to improve the production of crude oil to meet the demands of the consumers. On the other hand, it will boost the nation's economy.

Acknowledgement

The authors express their profound and sincere gratitude to Department of Petroleum Engineering, Covenant University, and the entire Management of Covenant University Canaan Land Nigeria; for their support and enabling environment to embark on this study.

References

[1] Clegg JD, Bucaram SM, Heln J. Recommendations and comparisons for selection of Artificial Lift methods. J. Petroleum Technol., 1993; 45(12): 1128 -1167.
[2] Schlumberger (1999). Gas lift design and technology. Retrieved from http://igs.nigc.ir/STANDS/BOOK/Gas-LiftTechnology.pdf (accessed 9 March 2016).
[3] Turner RG, Hubbard MG, and Dukler AE. Analysis and prediction of minimum low rate for the continuous removal of liquids from gas wells. Journal of Petroleum Technology, 1969: 1475–1482.
[4] Neely B, Gipson F, Capps B, Clegg J, Wilson P. Selection of Artificial Lift method. Dallas, Texas, SPE#10337, 1981.
[5] Hwang CL, Yoon K. Multiple Attribute Decision Making: a state of the art survey. Springer-Verlog 1981.
[6] Valentine EP, Hoffman FC. OPUS: An expert adviser for Artificial Lift, IFP (1988) SPE#18184.
[7] Clegg JD. High-rate Artificial Lift. J. Petroleum Technol. SPE#17638 1988.
[8] Espin DA, Gasbarri S, Chacin JE, Intevep SA. Expert system for selection of optimum Artificial Lift method. Argentina, SPE#26967 1994.

To whom correspondence should be addressed: Dr. Emeka Emmanuel Okoro, Petroleum Engineering Department, Covenant University Ota, Nigeria, emeka.okoro@covenantuniversity.edu.ng