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Cite as: AIP Conference Proceedings **2363**, 020025 (2021); https://doi.org/10.1063/5.0061079
Published Online: 23 November 2021

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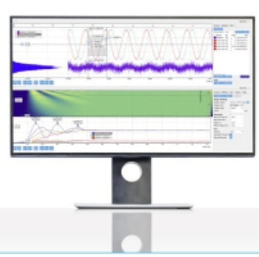

Re-Design of Electric Submersible Pump to Increase Production with Variable Stage and Frequency Sensitivity: Case Study Well "JTB-89"

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Abstract -- The JTB-89 well has been produced with an artificial lift method, which is the Electrical Submersible Pump, and type DN1100 / 47 Hz / 130 stages has been installed with fluid rate of 716 bfpd, oil production rate of 168 bopd, and 76% water cut with pump setting depth (PSD) of 4910.1 ft [8]. Based on Inflow Performance Relationship (IPR), this well needs to be optimized. If re-design is done, production capability can reach ± 70% of the maximum production rate. Therefore, it is necessary to increase production rates by evaluating pump setting depth (PSD), frequency, head/stages, and the number of stages on the installed ESP. After evaluating the installed pump, this well does not require to alter the pump type because of pump capacity is still in range. By changing the design of head/stages to 30 ft, increasing frequency to 65 Hz, an increasing number of stages to 160 stages, and increasing PSD to 6750 ft, this design can increase fluid rate production to 1006.85 bfpd

Keyword : Electric Submersible Pump (ESP), Pump Setting Depth (PSD), Stages, Frequency.

INTRODUCTION

The JTB-89 well has an Electric Submersible Pump (ESP) installed. The JTB-89 well produced with an ESP pump type DN1100/47 Hz/130 stages at PSD of 4910.16 ft with a production rate of 716 bfpd and volumetric efficiency of 71.2%. According to the Inflow Performance Relationship (IPR) curve, it can be seen that the optimum production flow rate is about 1006.85 bfpd while the existing fluid rate is 716 bfpd and can be concluded that "JTB-89" well has the potential to increase its production. For optimum result, it is necessary to evaluate and re-design the well with ESP installed so that optimum production rate can be achieved [1,2,7].

This design is assuming no pump type changing because of design rate is still in the range of pump capacity which is 600-1350 bfpd [6]. To optimize this well is by using several steps, the first is evaluating installed pump, re-design using rise up method with no pump type change assumption and do variable stage and frequency sensitivity [7]. The evaluation shows that problem is almost downthrust. Downthrust occurs in the pump stages when the impeller drifts the diffuser downwards because of low influx that enters the pump [1].

METHODOLOGY

Before evaluating the pump, we have to collect the input data. The data used in sizing an ESP must be accurate and reliable to ensure that the unit is properly matched to the well's inflow performance [3]. The data requirements for the selection of an ESP are categorized as mechanical data, production data, fluid data, and power supply [2]. Next is the data validation and construct an Inflow Performance Relationship (IPR) curve to determine the ability of producing well. IPR construction using Pudjo Sukarno Method with three phases fluid and high water cut assumption [4].

3rd International Conference on Earth Science, Mineral, and Energy
AIP Conf. Proc. 2363, 020025-1–020025-6; https://doi.org/10.1063/5.0061079
Published by AIP Publishing. 978-0-7354-4154-5/$30.00

The calculation is continued by evaluating the installed pump conditions on the actual flow rate and optimum flow rate. Pump conditions are determined by whether any problem occurs or not at each actual and optimum production flow rate. ESP re-design is done by calculating three steps, first is the sensitivity of pump setting depth, second is calculating a sensitivity of frequency, and determine the number of pump stages.

The final stage after re-design optimum pump is to determine ESP support equipment such as motors, cables, transformers, and switchboards so that they can support the ability and stability of the chosen ESP pump performance [8].

Formation Productivity

Formation productivity is the ability of the formation to flows reservoir fluids into wells that have certain conditions. Productivity index (PI) is an index used to express the ability of a well to produce fluids. According to the designing of a well, or to see the behavior of a well to produce, PI can be stated graphically. The methods of measuring productivity are many and varied, depending on the well condition. In this study, Pudjo Soekarno's method is used with the assumption well with high water cut [4].

Electrical Submersible Pump

The working principle of an electrical submersible pump is based on the working principle of a centrifugal pump. Centrifugal pump is a hydraulic motor by turning fluid through the impeller, liquid enters the impeller according to the pump shaft, collected in the pump housing or diffuser and then thrown out. By the mechanical power impeller, the motor is converted to hydraulic power. The impeller consists of two disks in which there are blades, when the impeller is rotated with an angular velocity W, the liquid in the impeller is thrown out with a certain potential and kinetic energy. The liquid accommodated in the pump housing is evaluated through an outlet (diffuser), wherein some of the kinetic energy is converted into potential energy in the form of pressure. Because the liquid is thrown out, the sucking process occurs [7].

The estimated pump setting depth is a general limitation for determining the location of pump depth in a well and the pump must be submerged in the well. Before calculating estimated PSD, need to determine the static fluid level (SFL) and working fluid level (WFL) from the sonolog job with the assumption the well does not use a packer at first. If the well used a packer, the determination of SFL and WFL is carried out with the approaching [5].

The minimum position in a short time will occur pump-off that caused by the height of the fluid level above the pump which is relatively very small or very short so the gas will be pumped. In this condition, Pump Intake Pressure (PIP) will be small. If PIP is below Pb would be lead into the decreasing of volumetric efficiency of the pump (due to the release of solution gas).

RESULTS AND DISCUSSION

From the IPR curve, this well is actually still capable for producing up to 70% of the AOFP which is about 1006.85 bfpd. Current production is still around 50% of AOFP. IPR plot results from JTB-89 well can be seen in the following **FIGURE 1**.

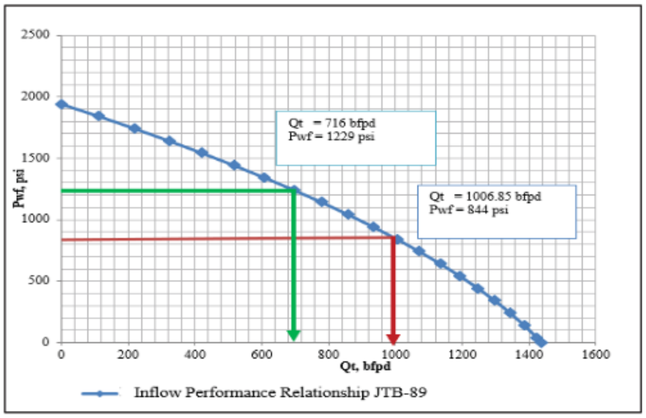

FIGURE 1. Inflow Performance Relationship JTB-89 Well

Therefore, ESP that has been installed is DN1100 type, with 130 stages, Pwf = 1229 psi, PIP = 106.5 psi, TDH = 5851.77 ft, Head / Stage = 45.01 ft/stage, fluid rate = 716 bfpd, Pump efficiency 51% and volumetric efficiency 71.1%. As evaluation result for this pump, it can be seen that actual production is within minimum pump operating range which is 600-1350 bfpd, and it can cause downthrust problem. Downthrust occurs in the pump stages when the impeller drifts the diffuser downwards. The pump performance curve is shown in **FIGURE 2** below.

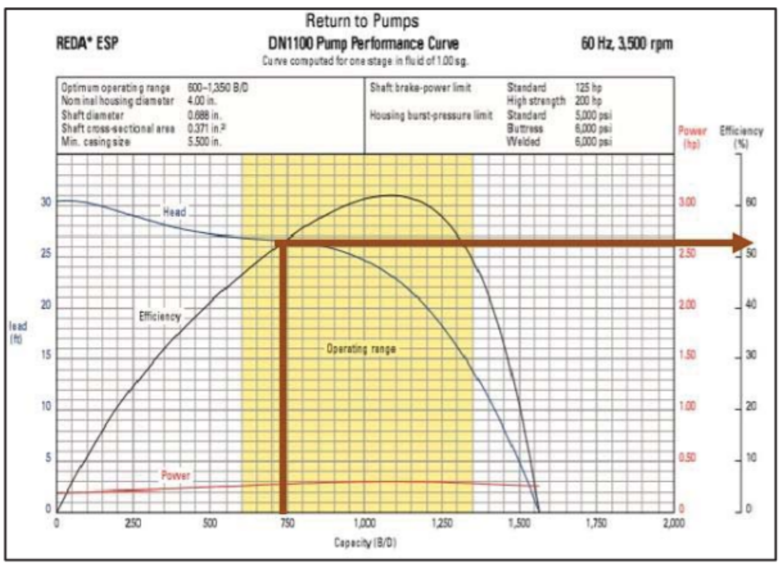

FIGURE 2. Pump Performance Curve of DN1100 Type

ESP optimization can be done by two methods, that is Rise Up and Size Up. The Rise Up method uses the same pump and a constant production rate, but the PSD, the number of pump stages, and the frequency are changed. The Size Up method is a method that uses the same pump type but the number of pump stages and the frequency are changed. The result of the optimization is shown in **TABLE 1.**

TABLE 1. Variable Pump Setting Depth Design

Pump Design	Pump Setting Depth				
	Min				Max
	6073	6250	6500	6750	6923
PIP, psi	235.6	313.4	423.3	533.2	609.2
Rs, scf/stb	10.5	14.7	21.1	27.7	32.4
Volumetric rate liquid (ql), bpd	1032.2	1032.9	1033.8	1034.8	1035.5
Volumetric rate gas (qg'), bpd	1962.5	1459.1	1063.3	830.7	718.9
% Free gas	65.5	58.6	50.7	44.5	41
Natural Gas separation					
Natural gas separation (ηn), %	0.757	0.757	0.756	0.756	0.8
Volumetric rate free gas in pump (q'ing), bpd	476.2	354.6	259	202.8	202.8
Turpin parameter (φ) < 1	1.3	0.7	0.4	0.2	0.2
Volumetric rate total, bpd	1508.4	1387.4	1292.8	1237.5	1237.5
% Gas bebas	31.6	25.6	20	16.4	16.3
Rotary Gas Separator					
Efficiency RGS, %	95	95	95	95	95
Volumetric rate free gas in pump (q'ing),bpd	23.8	17,7	12.9	10.1	8.8
Turpin parameter (φ) < 1	0.065	0,037	0.020	0.012	0.012
Volumetric rate total, bpd	1056	1050,6	1046.7	1044.9	1035.5
% Free gas	2.25	1,69	1.24	0.97	1

Based on **TABLE 1** above, shown a comparison of pump setting depth (PSD) at three kind of depths between the minimum and the maximum PSD. In ESP, the percentage of free gas must be highly considered because it will be affect to the effectiveness of the pump. By natural gas separation, the percentage of free gas is classified as large, so a rotary gas separator is needed to produce free gas <1%. It can be seen at 6750 ft had the lowest percentage of free gas compared to other pump setting depths, so that an optimum PSD of 6750 ft can be set to produce design rate.

Based on pump frequency sensitivity in **FIGURE 3** below, it is found that the best efficiency pump (BEP) curve that intersects Q vs head/stage curve at various pump frequencies, the most optimum for DN1100 pump is 65 Hz which produces a production rate of 1006.85 bfpd. It is considered as the most optimal because of the intersection is close to the best efficiency pump (BEP) line.

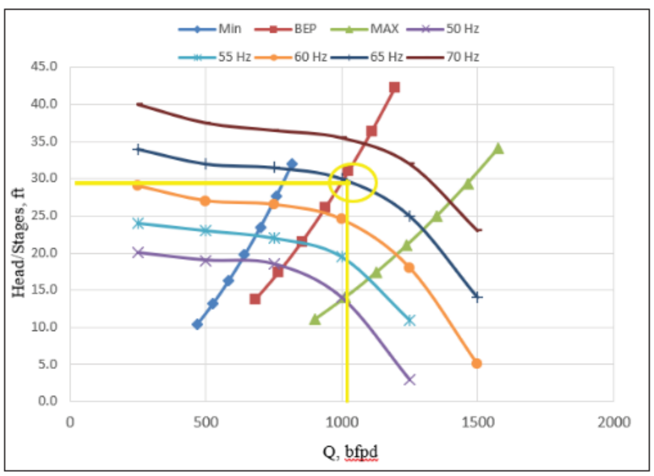

FIGURE 3. Sensitivity of Pump Frequency

Based on **FIGURE 4**, assuming frequency from 55 Hz-70 Hz. It can be seen that the frequency closest to the BEP to produce a production rate of 1006.85 bfpd is 65 Hz with a number of stages 160 stages.

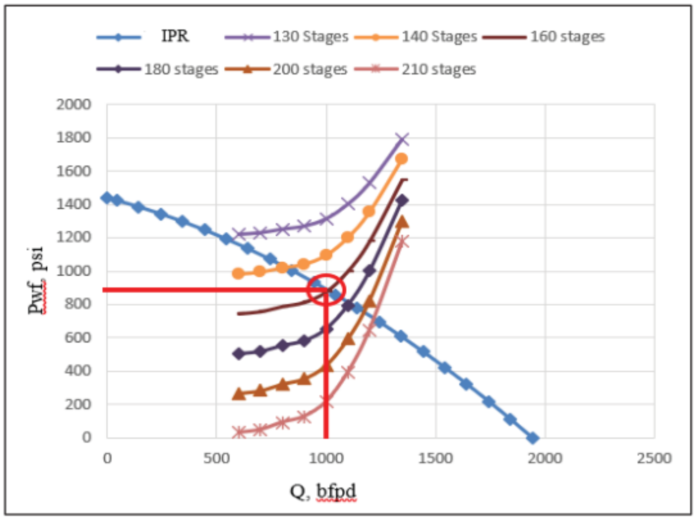

FIGURE 4. Sensitivity of Pump Variable Stages

Therefore, the motor used is 456 series with a 60 HP motor system using 439 Volts -35.0 Amperes. The selected cable AWG # 2 CU type Redhot Cable with a type (ESO) G5R AWG # 2 / solid is 6850 ft long, with a transformer of 10.08 kVA selected speed Star MVD NEMA-1, 447 kVA.

CONCLUSION

1. From the potential test of JTB-89 well using Pudjo Sukarno method, this well can increase the production rate up to 70% AOFP with a fluid rate of 1006.85 bfpd.
2. From a mid-perforation depth of 7457.1 ft and Pwf design 844 psi we got a WFL of 5538.92 ft. Optimum PSD is at 6750 ft which results in (Φ) of 0.97 (<1) indicating that the pump is operating stable and the gas separator used is working well.
3. Based on the results of pump frequency sensitivity obtained 65 Hz with head/stages of 30 ft to increase the rate of production to 1006.85 bfpd with 160 stages required.
4. In the motor selection, the motor used is 456 series with a 60 HP motor system using 439 Volts -35.0 Amperes. The selected cable AWG # 2 CU type Redahot Cable with a type (ESO) G5R AWG # 2 / solid is 6850 ft long, with a transformer of 10.08 kVA selected speedStar MVD NEMA-1, 447 kVA.

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