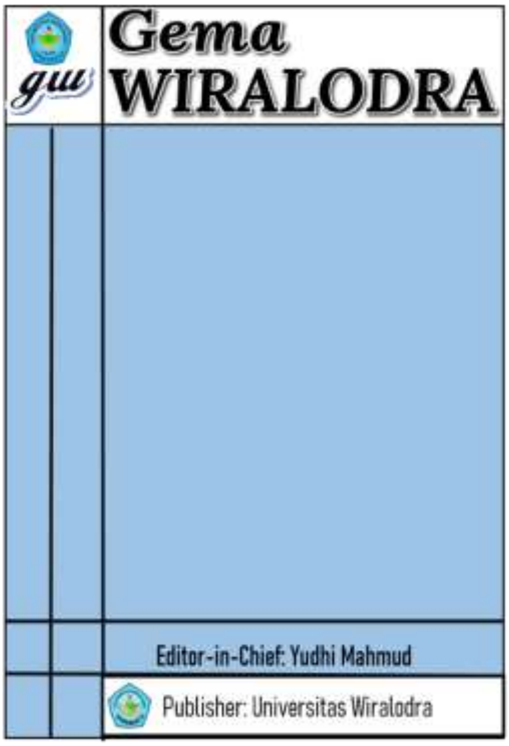
Gema Wiralodra

Publication details, including instructions for authors and subscription information:
https://gemawiralodra.unwir.ac.id



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Adrian Indarti[a*], Alfisyahri Nasution[b]
[a*]Institut Teknologi Petroleum Balongan, Indonesia, adrianindarti88@gmail.com
[b,]Institut Teknologi Petroleum Balongan, Indonesia, alfisyahrinasution@gmail.com

To cite this article:
Indarti, A., Nasution, A. (2024). Design Evaluation Of Hydraulic Pumping Unit At Well Alf-04 Kawengan Field. *Gema Wiralodra*, 15(2), 682 - 692
To link to this article:
https://gemawiralodra.unwir.ac.id/index.php/gemawiralodra/issue/view/25
Published by:
Universitas Wiralodra
Jln. Ir. H. Juanda Km 3 Indramayu, West Java, Indonesia

p-ISSN: **1693-7945**
e –ISSN: **2622 - 1969**

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Design Evaluation Of Hydraulic Pumping Unit At Well Alf-04 Kawengan Field

Adrian Indarti[a*], Alfisyahri Nasution[b]
[a*]Institut Teknologi Petroleum Balongan, Indramayu, Indonesia, adrianindarti88@gmail.com
[b] Institut Teknologi Petroleum Balongan, Indramayu, Indonesia, alfisyahrinasution @gmail.com

***Correspondence: adrianindarti88@gmail.com**

Abstract
The methods of lifting fluid from the well to the surface consists of natural wells method and artificial lift method. One type of artificial lifting is Hydraulic Pumping Unit (HPU) method. In this case, well ALF-04 as the HPU well in Kawengan field which faces lower actual production compare to its theoritic production calculation then decided need to be redesigned. The objectives of redesigned is to reach optimum flow rate of the well. Recently actual flow rate of this well is 309.2 bfpd, and then the result of IPR calculation by Vogel shows the Q max is 957.25 bfpd, it means this well production is still feasible to be optimized till approximately 765.8 bfpd. After redesign calculation , obtained pump setting depth 755 m, plunger size of 2.5 ", 120" stroke length, and speed of 6 spm, pump displacement 568.425 bpd. For the rod diameter was changing from 0.75 inch to 0.875 inch with total length 2395m , it greatly affects the maximum stress value of 22,774.03 psi, and also has an influence to the increasing of PPRL value of 8243.26 lb, and the MPRL value of 3000 lb.
Keywords: Hydraulic Pump, Stroke Per Minute, Peak Polished Rod Load, Pump Displacement

1. Introduction

Selection of the right artificial lift method is necessary to obtain optimum oil production. One of the artificial lift methods that can be chosen is the Hydraulic Pump Unit method. In the operation of HPU in oil fields, there is oftena mismatch problem between the desired production rate (theoretically) and the actual production rate (low pump volumetric efficiency), so an evaluation of the performanceof the HPU is needed to obtain optimum pump performance and production result. For that purpose, then it is necessary to pay attention the condition of the well, Hydraulic Pumping Unit is very suitable for wells that are <1000 m, it is also necessary be more concern to the flow rate of the well production, the bottom pressure of the well, and the character of the well fluid, so that the HPU method can operate as expected.

After calculating the IPR using Vogel method forundersaturated oil reservoir, it shows that the production of the ALF-04 well can still be optimized beyond the current actual production, by redesigning the HPU. In theory, the redesign of the HPU aims to increase production or optimize it by re determine the rod size, SL, SPM, pump setting depth, plunger diameter and total stress. The "ALF-04" well has an actual production of 309.2 bfpd and the IPR calculation shows that the well's optimum flow rate is 749.86 bfpd, so it still has the potential for being optimized.Those are the background of this study . Then, the objectives of this redesaigned are to reach optimum flow rate of the well.

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2. Method

2.1 Basic theory

HPU is one type of pumping unit. Pumping units are usedas an alternative method of artificial lift. The use of a HPU is carried out because there is not enough gas available in the field, so the gas lift system cannot be implemented.

By selecting the method using the HPU, need attention to what well conditions are in the use of this method. The HPU is suitable for well conditions with a depth of <1000 m, it is also necessary to attention to the known flow rate of the well so that the method can be ensured lifting the production fluid.

2.2 HPU (Hydraulic Pumping Unit)

HPU or hydraulic piston pump, its systems can lift large volumes of liquid from great depths by pumpingwells down to fairly low pressures. Crooked holes present minimal problems. Both natural gas and electricity can be used as a power source. They are also applicable to multiple completions and offshore operations. Their major drawbacks include power oil systems being fire hazards and costly, power water treatment problems, and high solids production beingtroublesome (Guo : 2006).

2.3 HPU Working Principle

The working principle of the HPU installation are :

1. *Hydraulic fluid* high pressure from the power pack is pumped to the hydraulic jack to transmit the pressure from the hydraulic fluid into an up and down motion on the hydraulic jack.
2. From the hydraulic movement earlier, it is then forwarded by the polished rod, then the sucker rod and to the plunger, so that the plunger moves up and down, which isa circular motion step of the pump.
3. If the plunger moves up (up-stroke), then under the plunger there will be a pressure drop, so that the bottompressure of the well is greater than the pressure in the pump, this condition causes the standing valve to openand fluid enters the pump.

   At the end of the up stroke the volume below theplunger is completely filled with liquid and when the plunger moves down (down-stroke), the standing valvewill close because the plunger presses on the fluid, at the same time the fluid will press down on the traveling valve, so that the fluid comes out of the plunger and enters the tubing
4. This process takes place repeatedly, so that the fluid inthe tubing will move up to the surface and flow towardsthe separator through the flow line.

2.4 Advantages of HPU

1. It does not require a foundation so it is easy to move from well to another and is simple in technical adjustment.

   Determination of SPM and stroke length is easier, because it does not require replacement of the pulleyand does not require heavy equipment to shift the crank pin in

p-ISSN: **1693-7945**
e –ISSN: **2622 - 1969**

determining the stroke length as in a bouncy pump.
2. Optimizing wells with HPU can be done easily and precisely because the parameters of pump speed andsteps can be done at any time with a shorter time, sothat production losses can be minimized.
3. Setting HPU steps is easier because all you have to do is change the Hydraulic settings.

2.5 Disadvantages of HPU
1. Not suitable for large production (Q HPU bpd).
2. Limited well depth (pump depth<1000m).
3. Not suitable for inclined wells.

2.6 Damage to the HPU
Damage to the HPU well is caused by sand, rust, andgas problems.
The parts that were damaged include:
1. Plunger, the presence of sand or scale on the plunger, resulting in stuck with the working barrel.
2. The ball is oval in shape (not round) because of sand,scale and the impact between the ball and the cage wall.
3. Working barrel becomes concave/flat.
4. The stuffing box leaked when setting the HPU.
5. The rod broke because of the corrosive fluid.

2.7 Calculation of Well Productivity ALF-04
2.7.1 Productivity Index (PI)
Productivity Index is an index used to express the ability ofa well to produce under certain conditions, or expressed asa comparison between the rate of production of a well at a certain price of well bottom flow pressure (pwf) and the difference in well bottom pressure in static conditions (Ps)and bottom pressure well at the time of flow (pwf), expressed in stock tank barrels per day.
The easiest approach to describe the capability of production wells is to use the concept of PI which has beendeveloped with the following assumptions:
a. Steady flow (steady state) and the viscosity of theflowing fluid remains constant.
b. The stream flowing in a radial well.
c. The flow consists of a single-phase incompressible fluid.
d. The permeability around the wellbore is homogeneous.
e. The formation is completely saturated with flowing fluid

2.7.2 Inflow Performance Relationship (IPR)
The IPR curve is a curve that describes the ability of a wellto produce, which is expressed in the form of a relationshipbetween production rate (q) and bottom well pressure(Pwf).
In preparing for the IPR curve, it is necessary to know the PIof the well, which is a qualitative description of the ability ofa well to produce.
1. Single Phase IPR Curve

The IPR curve for one phase will form a linear line with a constant PI value for each pwf

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price. This happens when thereservoir pressure (Pr) is greater than the oil bubble pressure (Pb). Fluid flow at reservoir pressure is greater than bubble pressure or constant PI and Ps is also constant, so the variables are q and pwf. Pwf and production rate have a linear relationship, called the Inflow Performance Relationship, which describes thereactions of the reservoir when there is a pressure difference in it.

2. Two Phase IPR Curve

Because there is a change in pressure at the bottom of thewell, when the pressure at the bottom of the well is belowthe bubble point pressure (Pb) of oil, the gas that was originally dissolved will be released and turn the fluid into two phases which will form the curved IPR curve.

This shows that the PI will decrease as the production rateincreases. This two-phase IPR equation has been developed by Vogel. The Vogel method can be used for pressure conditions above and below the bubble point pressure. The IPR curve above the bubble point pressure will be in the form of a straight line, while for below the bubble point pressure the IPR curve will be in the form ofa curved line. In this study, the IPR method was used by *Vogel for undersaturated reservoir*.Vogel developed equation use assumptions that :

a. Reservoir pressure below bubble point pressure.
b. The skin factor is zero.

3. Three Phase IPR Curve

For three-phase IPR, the Wiggins method can be used, for the Wiggins method it is a development of the Vogelmethod which takes into account the rate of oil and waterproduction.

3. Results and Discussion

3.1 Well and Production Data

Table 1

Well Data

Pump Type	TH 2,75" HPU 120"
Casing Diameter	5"
Tubing Diameter	2 7/8"
Plunger Diameter	2,5"
Length of Barrel	3 ft
Rod Diameter	3/4", 7/8"
Rod 3/4 length	1178 m
Rod 7/8 length	1217 m
Rod 3/4 weight (in air)	1,634 lb/ft
Rod 7/8 weight (in air)	2,367 lb/ft
Rod Number	API 76
Stroke length (S)	130 inch
Pump Speed (N)	5 SPM

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Total Depth	2659,1 ft (810 m)
Pump Setting Depth (PSD)	2477 ft (755 m)
Top Perforation	644 m
Mid Perforation	647,8 m
Bottom Perforation	650 m

Well data (Table 1) is the data that presents depth, completion , and equipments string of the well. Those datas are needed for design calculation of the well such to determine PPRL (peak polished rod load), MPRL (minimum polished rod load), weight of fluid, weight of tubing, and pump displacement.

Table 2

Production Data

Static Fluid Level (SFL)	275,82 m
Dynamic Fluid Level (DFL)	364,78 m
Oil Specific Gravity (SGo)	0,828
Water specific gravity (SGw)	1
Liquid specific gravity (SGl)	0,882
Qo	309,2 bopd
Water Cut (WC)	95,1%
Pwf	1622 psi
Ps	2200 psi
Pb	1817 psi
Flow Efficiency (FE)	1

Production data (Table 2) that shows above will be used to calculate the value of PI (Productivity Index) and create IPR curve (Inflow performance Relationship). Production data is so important, from this data, to see how much production rate and the condition of bottom hole pressure in the production zone.

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3.2 Well Profile

Figure 1

Well Profile of ALF-04

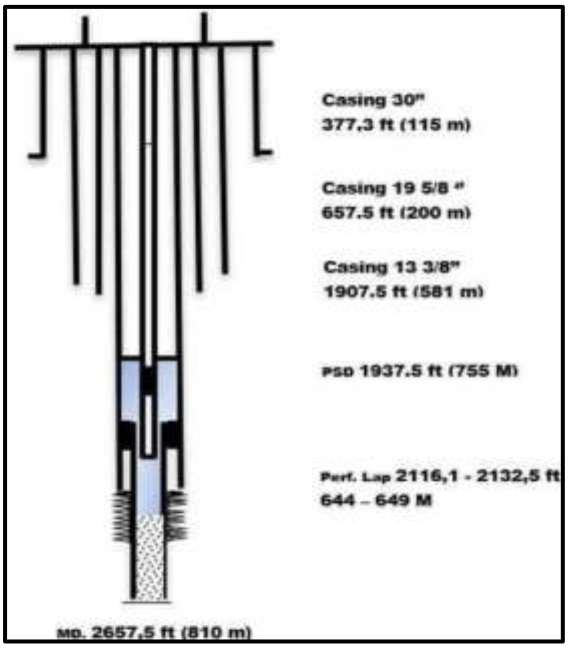

Figure 1 shows the sketch of the well, the data of well total depth in 2657,5 ft (810 m). perforation interval 2116,1 ft-2132,5 ft (644 m – 649 m), and existing pump setting depth in 1937,5 ft (581m).Then the casing data, there are four types of casing installed in this well, first 30 inch conductor casing installed till 377,3 ft (115 m), second 19 5/8 inch surface casing installed till 657,5 ft (200 m), third 13 3/8 inch intermediate casing installed till 1907 ft (581 m).

3.3 Data Processing

All data collected will be used to calculate IPR, PPRL, MPRL, rod acceleration, and pump displacement.

IPR calcultion start from determine value of PI (Productivity Index) by following formula :

$$\boldsymbol{PI} = \frac{q}{(\mathrm{Pr} - Pwf)} \quad (1)$$

Vogel Formula :

$$\frac{Qo}{Qmax} = 1 - 0,2\left(\frac{Pwf}{Pr}\right) - 0,8\left(\frac{Pwf}{Pr}\right)^2 \quad (2)$$

For undersaturated reservoir condition, which Pr > Pb, Pwf test < Pb, follow below formula:

$$q_{ob} = q_o - \left\{\frac{q_o . P_b}{1.8\left(\overline{P_R} - P_{wf}\right)}\right\}\left\{1 - 0.2\frac{P_{wf}}{P_b} - 0.8\left(\frac{P_{wf}}{P_b}\right)^2\right\} \quad (3)$$

$$q_{o\ \max} = \frac{q_o P_b}{1.8\left(\overline{P_R} - P_{wf}\right)} + q_{ob} \quad (4)$$

$$\frac{q_o - q_{ob}}{q_o \max - q_{ob}} = 1 - 0.2\frac{P_{wf}}{P_b} - 0.8\left(\frac{P_{wf}}{P_b}\right)^2 \quad (5)$$

Then,

$$Q\ optimum = 80\%\ x\ Qo\ max \quad (6)$$

PPRL

$$PPRL = \mathrm{Wf} + (\mathrm{Wr\ x\ Impluse\ Faktor}) \quad (7)$$

$$Wf = 0,433\ x\ Gx\ D\ x\ Ap \quad (8)$$

$$Wr = (M\ x\ L)0,875 \quad (9)$$

MPRL

$$MPRL = \mathrm{Wr\ x}\ (1 - \alpha - 0,127\mathrm{G}) \quad (10)$$

Rod Acceleration

$$a = \frac{S\ N^2}{70500} \quad (11)$$

Pump Displacement

$$PD = 0,0166\ x\ Ap\ x\ Sp\ x\ N \quad (12)$$

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3.4 IPR Curve Analysis Use Vogel Method

To analyze the IPR curve, it is carried out through the stages when the condition is Pr > Pb and Pwf < Pb. Using the Vogel (Undersaturated oil Reservoir) method and calculating the optimum production rate of the well. Furthermore, the rate of oil production (q) can be determined for various variations in Pwf prices.

Calculations that need to be done for undersaturated reservoir include PI, determining the value of Qob, determining the value of Qo max, determining the value of q at various pwf value when Pwf > Pb, using the value of q at various Pwf value when Pwf<Pb and the last stage, value plots q vs Pwf.

Table 3

Pwf Value Variation For Crook Curve

Pwf ass < Pb	Pwf ass/Pb	(Qo-Qob)/(Qo max- Qob)	Qo
0	0	1	749,86
300	0,16510732	0,945170194	720,25
600	0,33021464	0,846723706	667,09
1817	1	0	209,86

Table 3 shows the calculation result of Qo (oil flow rate) for each Pwf assumption value (Pwf < Pb). This value of Qo and Pwf will be plotted in the IPR chart to create the crook curve of the IPR.

Table 4

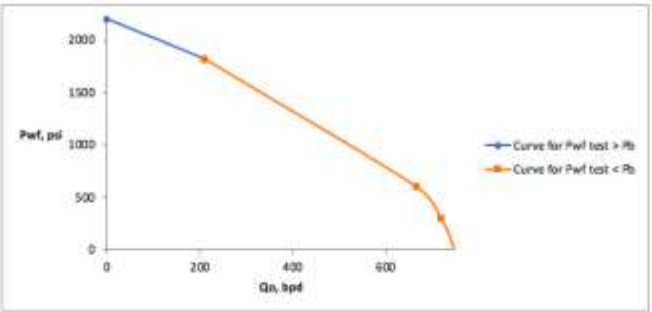
Pwf Value Variation For Straight Curve

Pwf ass	Qo
2200	0
1817	209,86
0	

Table 4 shows the calculation result of Qo (oil flow rate) for each Pwf assumption value (Pwf ≥ Pb). This value of Qo and Pwf will be plotted in the IPR chart to create the straight curve of the IPR, and the IPR curve shows below :

Figure 2

IPR Curve



So, from Figure 2, above results calculation of Pr > Pb, Pwf test < Pb shows Qob 209.86 bpd and Qo max has a result of 749.86 bopd

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3.5 Calculation of Parameters Design

Table 5

Result of Calculation Design

PARAMETERS	RESULT
Plunger area	3.97 $inch^2$
Top Rod area	0.601 $inch^2$
Acceleration (a)	0.06 ft/s
Rod String Weight	4024.79 lb
Fluid Weight	3759.32 lb
Imfulse Factor	1.06 ft/s
Peak Polished Rod Load	8243.26 lb
Minimum Polished Rod Load	3000 lb
Maximum Stress	22,774.03 lb/in^2
Minimum Stress	4985.75 lb/in^2
Plunger Overtravel	0.63 inch
Pump DisplaceTment	568.425 Bpd

Table 4 shows the result of design parameters calculation for HPU well. There 12 parameters calculated (plunger area, top rod area, acceleration, rod string weight, fluid weight, impulse factor, peak polished rod load, minimum polished rod load, maximum stress, minimum stress, plunger overtravel, and pump displacement).

3.6 Discussion

Based on the results of the redesign Hydraulic Pumping Unit at ALF-04 Well, the actual production of the well is 309.2 bpd and after calculations are obtained, the Qmax result is 749.86 bpd. It means the production of the well can still be optimized by conducting a proper design of hydraulic pumping unit pump. The size of the rod used is 7/8" and 3/4" in diameter, the selection of this rod affects the stress rod value of 22,774 psi, Stroke Length of 120" and the number of spm is 6 steps using plunger 2 ½ inch and pump setting depth in 755 m .Then, the pump displacement results are 568.42 bpd, the maximum weight received by the Hydraulic Pumping Unit is 8670.86 lbs. If we correlate the HPU design of ALF-04 well with the Screening Criteriaof Artificial Lift (Table 5) , this well is suitable and the Hydraulic Pumping Unit still can be used on the ALF-04 well because this well has total depth of 2659.1ft (below the maximum depth of 17.000ft), and also this well produces 568.42 bfpd(below Maximum Operation Volume 8000 bfpd).

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e –ISSN: **2622 - 1969**

Table 6

Screening Criteria of Artificial Lift Selection

ALS Application Screening Criteria

Form of lift	Rod Lift	PCP	Gas Lift	Plunger Lift	Hydraulic Lift	Hydraulic Jet	ESP	Capillary Technologies
Maximum operating depth, TVD (ft/m)	16,000 4,878	12,000 3,658	18,000 4,572	19,000 5,791	17,000 5,182	15,000 4,572	15,000 4,572	22,000 6,705
Maximum operating volume (BFPD)	6,000	4,500	50,000	200	8,000	20,000	60,000	500
Maximum operating temperature (°F/°C)	550° 288°	250° 121°	450° 232°	550° 288°	550° 288°	550° 288°	400° 204°	400° 204°
Corrosion handling	Good to excellent	Fair	Good to excellent	Excellent	Good	Excellent	Good	Excellent
Gas handling	Fair to good	Good	Excellent	Excellent	Fair	Good	Fair	Excellent
Solids handling	Fair to good	Excellent	Good	Fair	Fair	Good	Fair	Good
Fluid gravity (°API)	>8°	<40°	>15°	>15°	>8°	>8°	>10°	>8°
Servicing	Workover or pulling rig		Wireline or workover rig	Wellhead catcher or wireline	Hydraulic or wireline		Workover or pulling rig	Capillary unit
Prime mover	Gas or electric	Gas or electric	Compressor	Well's natural energy	Multicylinder or electric	Multicylinder or electric	Electric motor	Well's natural energy
Offshore application	Limited	Limited	Excellent	N/A	Good	Excellent	Excellent	Good
System efficiency	45% to 60%	50% to 75%	10% to 30%	N/A	45% to 55%	10% to 30%	35% to 60%	N/A

Values represent typical characteristics and ranges for each form of artificial lift. Parameters will vary according to well situations and requirements and must be evaluated on a well-by-well basis.

(Source: *Weatherford catalog)*

Table 5 explains the screening data for artificial lift selection that published by Weatherford. There are 11 criterias or parameters that need to be considered to be matched to which the proper type of artificial lift can be selected as the lifting method of a production well.

4. Conclusion

Based on the results of the discussion that has been carried out, several conclusions can be drawn as follows :

1. At ALF-04 Well, this well has an actual flow rate of 309.2 BFPD. Production potential calculations are carried out through Vogel IPR under conditions Pr > Pb, Pwf Test < Pb , obtained that Qo max is 749.86 bopd, it was quite feasible to optimize the well ALF-04 production rate.
2. After redesign, determined the new value of plunger size of 2.5 ", pump setting depth 755 m , 120" stroke length, pump speed of 6 spm, and pump displacement 568.425 bpd.
3. Known that the parameters which affect the amount of fluid can be lifted are the stroke length (SL) and the pumping speed (N). After changing the rod diameter from 0.75 inch to 0.875 inch, it greatly affects the maximum stress value of 22,774.03 psi, and also has an influence on the PPRL value of 8243.26 lb, and the MPRL of 3000 lb.
4. Compare to other research studies (Reno Pratiwi, 2022) that optimize the HPU design based on the calculation of the existing volumetric efficiency value, if the volumetric efficiency is below 50% , the pump will be redesigned, while in this paper, the productivity of the well or production potential as the based to redesign the well.

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GLOSSARY OF TERMS

Symbol	Definition	Unit
Ap	Area of Plunger	inch²
Ar	Area of Rod	inch²
At	Area of Tubing	inch²
DFL	Dynamic Fluid Level	ft
Er	Elastic rod	inch
Et	Elastic tubing	inch
HP	Horse Power	HP
MPRL	Minimum Polished Road Load	lb
SL	Stroke Length	inch
SPM	Stroke Per Minute	
PD	Pump Displacement	bpd
PI	Productivity Index	bpd/psi
Pr	Reservoir Pressure	psi
Ps	Static Pressure	psi
PSD	Pump Setting Depth	ft
Pwf	Flowing Well Pressure	psi
SFL	Static Fluid Level	ft
SGo	Specific Gravity of Oil	-
SGw	Specific Gravity of Water	-
SGf	Specific Garvity of fluid	-
Wr	Weight of rod	lb
Wf	Weight of fluid	lb

5. References

Brown. K. E, 1980, "The Technology of Artificial Lift Methods Volume 2a dan 2b",PennWell Publishing Company , Tulsa, Oklahoma.

Brown. K. E,1984, "The Technology of Artificial Lift Methods Volume 4",PennWell Publishing Company ,Tulsa, Oklahoma.

Errata,1988,"American Petroleum Institute Recommended Practice 11 L For Design Calculation", Dallas : API.

Expertest. 2001https://www.expertest.id/index.html

H.Dale Beggs, 2002, "Production Optimization Using Nodal Analysis", Houston,

Noor,Lazuardy A.B., Aditsania A., Gunawan P.H, 2019, 'Rayleigh Ritz Cubic Spline Method for Displacement Simulation Sucker Rod', Indo Journal of Computing, Vol 4, issue 3, pp 15-22.

Pertamina.2021. "Production History Sumur.

Subianto Ahmad, Ginting Mulia, Pratiwi Reno; EVALUASI OPTIMASI HYDRAULIC PUMPING UNIT PADA SUMUR AN-01 DI LAPANGAN X. (2022). *PETRO: Jurnal Ilmiah Teknik Perminyakan*, *11*(2), 130-141. https://doi.org/10.25105/petro.v11i2.14369

Takacs,Gabor.2015."Sucker Rod Pumping Handbook, Production Engineering Fundamental and Long Stroke Rod".University of Miskolc: Hungary.

Tobing,Edward.2007.Analisis Produktivitas Sumur Diperforasi Menggunakan Persamaan Kurva IPR Aliran Dua Fase.Lembaran Publikasi Minyak dan Gas Bumi. Vol 41 No 2.

Tobing.Edward.2013. Influence of Flow Rate and Time on Skin Factor in Solution Gas Drive Oil Reservoir. Lembaran Publikasi Minyak dan Gas Bumi.Vol 47 No 3.

Tutta. 2013."Hydraulic Pumping Unit Operational Manual"