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Success Story of Sucker Rod Pump and Wellhead Compressor Implementation to Handle Liquid Loading Problem in Gas Well, Kampar Block, Indonesia

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Abstract.
An accurate and easy-to-use method is highly desirable. This paper fills that gap. Starting from *Turner et al* (1969), *Coleman et al* (1991) equations for determining the critical rate as the main cause of liquid loading problem. Gas critical velocity is the minimum parameter that is required to lift liquid droplets to surface. This paper will use unusual method to carry out fluid in the wellbore using a sucker rod pump and wellhead compressor to help stabilize gas rate after the liquid loading problem solved. The author made a breakthrough using a sucker rod pump that is uncommon used in gas well to lift formation fluid from tubing pump that causes liquid loading and also increase gas velocity. When the gas velocity is increasing, the gas rate will also increase, so the gas will flow / produce through the annulus.
The key success affecting this method, is how to design the appropriate tubing pump size according to liquid level and type of Sucker Rod Pump needed. In determining the design for SRP, the first thing that needs to be done is to calculate the weight of the polish rod string from the surface to the desired Pump Setting Depth. Next, we need to calculate the minimum and maximum tensile stress of the string. After that, we performed calculate the value of counterbalance from the SRP and then calculate the peak torque required. The final step is to calculate the horsepower of the electric motor needed to move the SRP, along with the right stroke per minute (SPM) and the stroke length (SL).
The uncommon method that have been carried out in the gas wells of the Kampar block, are proven to be successful to handle the problem of liquid loading in gas wells with the proper pump size and sucker rod pump design. The use of SRP is also proven to be an effective method to lift produced water from wellbore. Produced water flows to surface through the tubing pump and gas flows through annulus. Wellhead compressor is also proven to be an effective way in maintaining gas rate in Gas Well to optimize its production so that the produced gas could be used as a gas feed for gas engine generator and gas fuelled heater to reduce operational cost in diesel fuel for power generation.
Keyword(s): Liquid Loading; Sucker Rod Pump; Gas Rate; Pump Design; Wellhead Compressor

Introduction

The Kampar PSC Block is located in the Middle Sumatera Basin Riau, Indonesia. On January 1st, 2016, PT PHE Kampar officially operates the Kampar Block covering an area of 469 km^2 for 20 years contract period with current production ±900 BOPD with 102 oil producing wells and 2 gas producing wells with current production ±0.15 MMSCFD.
Source of gas in PT PHE Kampar come from well Merbau-1 and Panduk-2, with Merbau-1 contributed as a dominant gas producer in PT PHE Kampar. Merbau-1 produced from Binio Sand Layer since 1987. Gas from the wells is used to fired up gas engine generator to generate electricity, and indirect heater as a first stage of crude oil separation process.

Over certain period of time, wells encountered a depletion phase, which reduce the total amount of both oil and gas produced daily. Along with the depletion itself, comes another challenges that need to be handled, one of which is the increasing operational cost respectively caused by the increase of diesel fuel as a substitute of gas to generate electricity. Gas well usually produce natural gas, carrying liquid, water and/or condensate in the form of mist. As the reservoir pressure gradually depleted, carrying capacity from the gas is decreased. As the velocity of the gas in the production conduit drops within time, the velocity of the liquid carried by the gas decreases even faster. As a result, liquids begin to collect on the walls of the conduit, liquid slugs begin to form, and eventually liquids accumulate in the bottom well. This phenomenon is called Liquid Loading.
Several methods are taken into consideration to solve Liquid Loading problem. The use of conventional method, such as soap stick to create a foam within the wellbore to reduce water density, in order to let the gas flow to surface. Any other option taken into consideration is the utilization of smaller tubing size to reduce drawdown pressure and gas critical rate within tubing. Conventional method explained above, apparently didn't give significant effect in Merbau-1 Gas Well. So, what should we do to cope with the Liquid Loading problems in the gas well?

Data and Method
In this analysis we will used a method start from collecting data from the daily production rate, pressure, temperature, and tubing size for determining the critical rate and occurrence of liquid loading in well MB-01. The collected data combined with swab test result, are used to design SRP specification to unload the liquid in the wellbore.

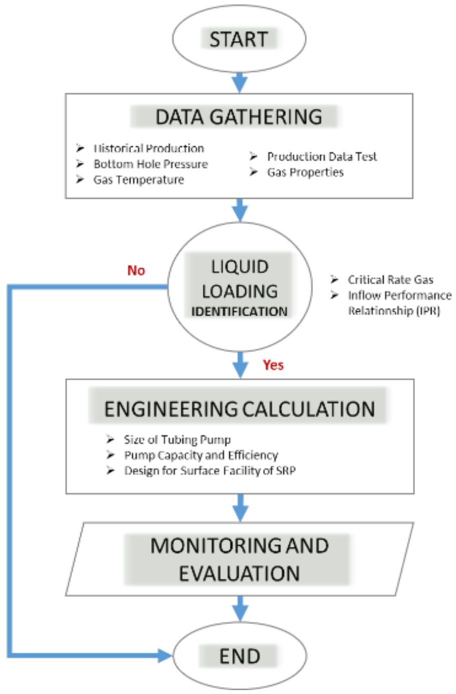

Figure 1. Diagram Workflow

This paper presents the strategy of liquid loading handling in Kampar Field. Most of the gas production in the study area comes from biogenic gas, which does not contain CO_2 and H_2S. Several considerations to be chosen for consideration, namely from the total fluid in the well. The study begins with an analysis of the bottom hole pressure with the SBHP test and determines the value of the Inflow Performance Relationship. Determination of the fluid flow rate in the well by doing a swab job using a rig for designing the optimal sucker rod pump specifications, pump design and then determining the right pumping unit size. as a form of de-watering mechanism in the wellbore

Result and Discussion

1. Determining Critical Gas Rate Liquid Loading

In determining the Critical rate, three methods are used, Turner's Equation, Coleman's Equation, and Li's Equation. Parameter data show in below to the result from the calculation.

Table 1. Well Parameter Data MB-01

Well Name	MB-01	Unit	Remarks
Input Data:			
Pressure Wellbore Flowing, Pw	307	psia	Actual Data
Temperature	100	F	Actual Data
Gas Gravity	0,6264		Actual Data
Z Factor	0,9976		Actual Data
Liquid Density	62,4	lb/ft3	Asume
Surface Tension	60	dyne/cm	Asume
Casing ID	4,95	in	Actual Data
Area of tube	0,13357	ft2	Calculated
Density Gas	0,92907022	lbm/ft3	Actual Data

From the data table 1 then calculate the critical rate for Well MB-01 using three methods : Turner, Coleman, and Li:

Turner Equation :

$$U=1{,}92\,\frac{\sigma^{1/4}(\rho_L-\rho_g)^{1/4}}{\rho_g^{1/2}} \quad \text{………………(e.q 1.1)}$$

Li's Equation :

$$U=0.73\,\frac{\sigma^{1/4}(\rho_L-\rho_g)^{1/4}}{\rho_g^{1/2}} \quad \text{……………..(e.q 1.3)}$$

Coleman Equation :

$$U=1{,}59\,\frac{\sigma^{1/4}(\rho_L-\rho_g)^{1/4}}{\rho_g^{1/2}} \quad \text{…………..(e.q 1.2)}$$

Calculating Critical Gas Rate :

$$q_g=\frac{3{,}067PV_gA}{(T+460)Z}\ MMscf/D \quad \text{…………(e.q 1.4)}$$

So the result is shown by table 2 and figure 2 that MB-01 at bottom hole pressure 307 psi have Critical rate 3,48 MMSCFD for Tuner's Equation, 2,89 MMSCFD for Coleman's Equation, and 1.32 MMSCFD for Li's Equation.

Table 2. Critical Velocity & Gas Critical Rate Well MB#01

Pwf (psi)	Tuner Model	Coleman's Model	Li,s Model
	Qo (MMSCFD)	Qo (MMSCFD)	Qo (MMSCFD)
350	3,72	3,08	1,414
307	3,48	2,89	1,32
300	3,44	2,85	1,310
250	3,15	2,61	1,196
200	2,82	2,33	1,071
150	2,44	2,02	0,928
100	1,99	1,65	0,758
75	1,73	1,43	0,657
50	1,41	1,17	0,536
25	1,00	0,83	0,379
10	0,63	0,52	0,240

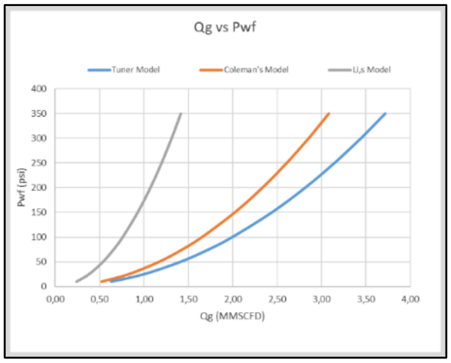

Figure 2. Graphic Critical Rate Vs Pwf

From Table 2 and Figure 2 shows that well MB#01 has critical rate with the variant of *Pwf*, so when gas production is below the critical rate, the liquid loading problem occurred.

2. De-watering Wellbore with Tubing Pump Design

To be able to handle the liquid from the wellbore, based on static bottom hole pressure (SBHP) performed on well Merbau-01, the level of liquid filled in wellbore at 581 ft, and the pressure is 307 psi, measured in the depth of 1209 ft.

WELL DATA		REPORT	
Field	: Kampar	Ps @ Meas.	: 307 psi
Well	: MB-01	Ps @ Perfo.	: 307 psi
Depth	: 2570 ft	Pwf @ Meas.	: N/A psi
KB (Kelly Bushing)	: 114 ft	Pwf @ Perfo.	: N/A psi
BH (Braden Head)	: 97 ft	Depth Meas.	: 1209 ft
Lifting	: N/A	Temp. Meas.	: 140 °F
Status	: Produksi	Static Fluid Level	: 581 ft
Tubing	: -	Water-Oil Contact	: - ft
Packer	: -		
Perforation	: Binio Sand (1205 - 1213 ft)	Daily Production	
		Oil	: 0 bbl/d
		Water	: N/A bbl/d
		Gas	: N/A mscf/d
		Water Cut	: 100 %

Table 3. SBHP data input & report

PI = 3.288 bpd/psi

Pwf (psig)	Q (bfpd)
307.00	0
234.00	240
0.00	908

Table 4. Production Data Test

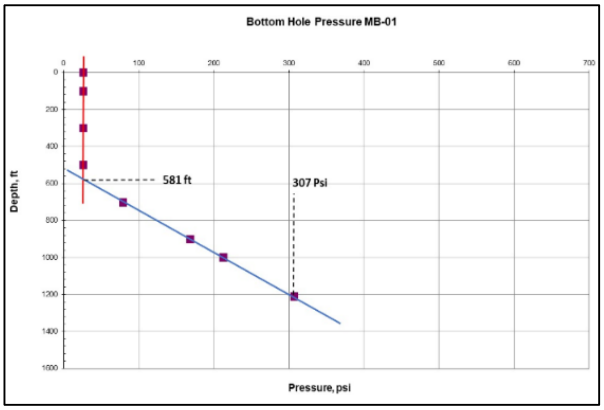

Figure 3. SBHP MB-01 Result

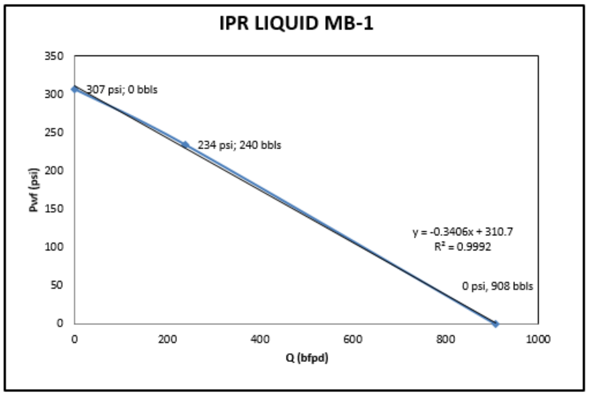

Figure 4. IPR Liquid MB-01

Based on the measurement at Fig. 3 and Fig. 4, taken on well Merbau-01, shows us that the gas is no longer able to flow to the surface caused by rising liquid, at level 628 ft.

The swab test done on well Merbau-01 showed that it need approximately 480 BFPD to indicate the first kick on the gas well. Thus, this data is used to design the optimum tubing pump size. Based on the calculation on Table 3, the optimum tubing size is 3 Inch with the estimated efficiency 80%. Based on the calculation, tubing pump could unload the liquid with estimate number in 541,6 BFPD.

Table 4. Tubing Pump Design Parameter

	Purpose	Unit
Well Name	MB-01	-
Test, based on Swab Test	480	bbls
Purpose Pump size (inch)	2.75 THM (BN)	inch
SL (inch)	64 /max	inch
Stroke / Minute	12	Spm
Pump Cap (Bfpd)	677	bfpd
Pump Cap 80 % Eff(Bfpd)	541,6	bfpd
Q Max	908	bfpd
Perf. Interval	1205-1213 ft	ft

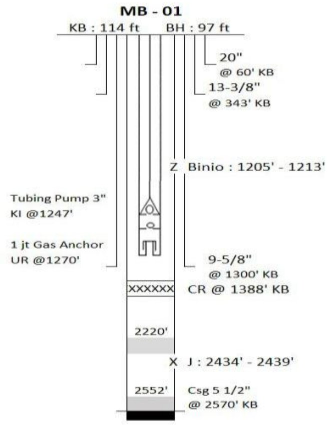

Figure 5. Proposed Well Diagram Program De-watering MB-01

On Fig. 5 above, showed a well diagram which the Pump Setting Depth is designed below perforation zone, with the purpose to de-water the liquid continously with optimum result. Due to the risk of gas lock which could interfere with pump performance, we used gas anchor approximately 1 joint beneath the tubing pump.

3. Sucker Rod Pump Surface Design

Based on the design parameter on Table 3, we need to estimate the appropriate Sucker Rod Pump surface design to be able to perform de-watering process in Well MB#01, De-watering process, used SRP & tubing as a media for liquid to flow, thus the gas could flow through the annulus and the liquid flow within the tubing. The data and calculation needed to estimate the optimum surface unit of sucker rod pump are described below :

Table 5. Parameter Pump Selection

Input Data		
Description	Amount	UOM
Fluid Level, H	581	Ft
Pump depth, L	1219	Ft
Pumping speed, N	13	SPM
Length of Stroke, S	64	in
Plunger Diameter, D	2.75	in
Spec. Gravity of Fluid, G	1.015	
Sucker Rods	66	
Calculation Data		
Peak Polished Rod Load	10882.104	lbs
Peak Torque	38053.582	lb in
Pumping Unit Selection	C-114D-143-64	

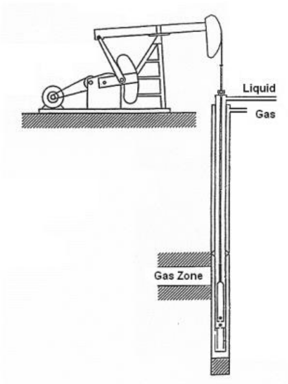

Figure 6. A Typical Pumping Gas Well

Considering the installation SRP in liquid loading, Fig. 6 above illustrates a pumping system that is usually used to pump liquids for oil wells but in this case, we use for gas wells which require special consideration in determining PSD which is installed below the perforation zone to maximize de-watering wellbore.

4. Wellhead Compressor Implementation

Wellhead compressor is used to maintain the wellhead pressure when the gas well is already flow to the surface. The use of wellhead compressor help the optimization process could be done continously for the use of internal necessity. Wellhead compressor specification is described below:

Engine/Compressor Type	V-8 design, 460 C.I.D. gray iron casting, patented compressor head.	
Maximum Rated Speed (rpm)	2200	Maximum
Recommended Operating Speed (rpm)	1400 - 2100	
Minimum Operating Speed (rpm)	1100	Minimum
Jacket Water Temp	190	degrees F.
Ignition System	Electronic	Altronic CD 200
Fuel Type	NAT GAS	
Engine Rating		
Engine Power	46	hp
Engine Specifications		
Bore	4,36	in.
Stroke	3,85	in.
Ignition Timing	38	degrees before top dead center
Powerside Displacement	230	cu. in.
Fuel Comsumption	6 - 9	mscf
Number of Power Cylinders	4	
Compressor Data		**Compressor Type:** Integrated Reciprocating
MP Compressor Model (Medium Pressure)		
Bore	3,75	in.
Stroke	3,85	in.
Displacement	170	cu. in.
Number of Compressor Cylinders	4	
Compression Ratio	Wide range ratio	
Suction Pressure	-18" Hg - 60 psig	
Discharge Pressure	50 - 400 psig	
Vessel Certificate	ASME & U Stamp	
Design class	Class I Division 2	
Blow case cap	50 bbl/day	
Foot print (Noise) Level	<85 dBa	

Type	Reciprocating, Integrated, Single stage
Package model	Portable
Power Draw	46 HP
Speed	1,100 – 2,200 RPM
Noise Level	< 85 dBa
Compression Ratio	Wide range ratio, up to 1 : 18
Suction Pressure	minus 18" Hg till 60 psig
Discharge Pressure	Up to 400 psig
Discharge Temperature	Up to 350 deg F
Flow Rate	Up to 750 MSCFD Depends of gas characteristic, suction & discharge pressure
Blowcase Capacity	50 bbl/day
Dimension and Weight	L x W x H (cm) : 375 x 198 x 250 Weight gross : 7000 Lbs
Fuel Consumption	6 - 12 MSCFD
Fuel Specs	> 800 - 1300 BTU, CO_2 < 15%, H_2S < 50 ppm

Figure 7. Well Head Compressor Specification

From Fig. 7 above, wellhead compressor benefit us in a way that the equipment could perform with a wide range variety of suction and discharge pressure. Up to minus 60 psig in suction section, and 400 psig in discharge section. The implementation of wellhead compressor helped well Merbau-01 to produce gas in a lower bottom hole pressure consequently increasing gas rate. Produced gas flew to scrubber within the wellhead compressor package to remove any remaining moisture before compressed to the gathering station. Remaining moisture then collected in the form produced liquid then will flow using a flowline to gathering station

5. Monitoring Problem Analysis

It is proven that well Merbau-01 today, having a current gas rate below its critical gas velocity, proven by three available calculation method known, such as Turner, Coleman and Li. The use of SRP to produce liquid from the wellbore is proven to be an effective method to handle liquid loading in well Merbau-01. Other than that, the use of wellhead compressor have been successful in maintaining gas deliverability to the gathering station and utilize it better.

Conclusions :

A. The well Merbau-01 undergo liquid loading problem, proven by the data collected based on its pressure, fluid level and static bottom hole pressure. Furthermore, engineering calculation performed using Turner, Coleman and Li also backed up this hypothesis.

B. The use of tubing pump & sucker rod pump is proven to be an effective method to overcome the liquid loading problem in well Merbau-01. The liquid needed to be unload based on swab test data is approximately 480 BFPD. Tubing pump used in Merbau-01 having a size of 3 inch which could unload liquid within range of 450 – 550 BFPD, and sucker rod pump used in well Merbau-01 is Lufkin Type C-114D-143-64. Before implementing tubing pump in well Merbau-01, wellhead pressure was 0 Psi, and after implementing the program, the wellhead pressure increase to 30 Psi.

C. To stabilize the gas rate supply to Merbau Station, wellhead compressor considered to be an effective method, since the wellhead compressor could perform at negative pressure with relatively easy to be operate and maintain.

Appendices

Well Name: MB#01
Perfo Depth: 1205-1213 ft

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SWABING DATA SHEET

Time	Swab No	Swab Depth (m)	Fluid Level (m)	Fluid Swab (bbls)	Cum Fluid Swab (bbls)	Water %	Oil %	Mud %	Remarks
10.00	1	480	-	Dry					
10.06	2	900	814	0,5	0,5	100%	0%	0%	
10.12	3	1050	706	2	2,5	100%	0%	0%	
10.18	4	1050	706	2	4,5	100%	0%	0%	
					4,5				
10.28	5	1050	706	2	6,5	100%	0%	0%	
10.34	6	1050	706	2	8,5	100%	0%	0%	
10.40	7	1050	706	2	10,5	100%	0%	0%	
10.46	8	1050	706	2	12,5	100%	0%	0%	
10.52	9	1050	706	2	14,5	100%	0%	0%	
10.58	10	1050	706	2	16,5	100%	0%	0%	
11.04	11	1050	706		16,5				Intermitent Flowing (Gas + Water)
			706		16,5	100%	0%	0%	
11.14	12	1050	706	2	18,5	100%	0%	0%	
11.20	13	1050	706	2	20,5	100%	0%	0%	
11.26	14	1050	706		20,5				Well Flowing (Gas + Water) Stop Swab Job

Figure A1. Swab Test Result

References

[1] American Petroleum Institute Production Department. 1988. Recommended Practice for Design Calculations for Sucker Rod Pumping Systems (Conventional Unit). United State of America.

[2] Bolujo E.O et al. 2017. New Model for Predicting Liquid Loading in Multiphase Gas Well, International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12. Nigeria: Convenant University

[3] Guo, Boyun et al. 2007. Petroleum Production Engineering. A Computer-Assisted Approach. Elsevier Science & Technology Books.

[4] Peter O. Oyewole, SPE, BP, and James F. Lea, SPE, PL Tech LLC 2008. Artificial Lift Selection Strategy for the Life of a Gas Well with some Liquid Production

[5] R. G. Turner. 1969. Analysis and Prediction of Minimum Flow Rate for the Continuous Removal of Liquid from Gas Wells

[6] Yashaswini D. Nallaparaju 2012. Prediction of Liquid Loading in Gas Wells, SPE 155356, India: Pandit Deendayal Petroleum University.

Acknowledgments

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