Optimization of Oil Production by Gas Lift Macaroni in "X" Field

(Optimasi Produksi Minyak dengan Gas Lift Macaroni di Lapangan "X")

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Latar belakang penelitian ini adalah bahwa di X Field banyak sumur gas telah berhenti mengalir bertahun-tahun yang lalu dan produksi tidak ekonomis lagi. Oleh karena itu perusahaan telah memutuskan untuk menggunakan lift gas yang sesuai dengan karakteristik reservoir minyak berpasir. Tubing sumur tersebut tidak dilengkapi dengan mandrel gas lift karena sumur itu adalah produsen gas. Tujuan dari penelitian ini adalah untuk merancang gas lift makaroni (GLM) untuk mengoptimalkan tingkat produksi minyak. Perancangan penelitian ini adalah bahwa tabung ramping baru 1.315 inci, yang disebut tabung makaroni, dipasang di dalam tabung 3. 5 inci yang ada. Katup lift gas dipasang di dalam tabung makaroni. Pengumpulan data terdiri dari data reservoir, data permukaan, dan diagram sumur.

Hasil penelitian ini adalah bahwa instalasi makaroni gas lift dapat menghasilkan tingkat produksi minyak 425 STB / hari dari tiga sumur. Katup pengangkat gas sumur A, B, dan C berturut-turut adalah empat,lima, dan tiga katup.Selisih perhitungan piranti lunak dan manual untuk penentuan kedalaman katup kurang dari 1%. Penghematan biaya dengan memasang gas lift makaroni dibandingkan operasi workover untuk mengganti tubing yang ada dengan tabung baru yang dilengkapi dengan katup gas lift adalah USD 5.620.955 dari ketiga sumur.

Kata-kata kunci: sumur mati, gas lift macaroni, laju produksi minyak, gradien tekanan

Abstract

The background of this research was that in X Field many gas wells have stopped flowing years ago and not economical production anymore. Therefore the company has decided to use gas lift which is proper to the sandy oil reservoir characteristic. The tubing of the well has no gas lift mandrel completion as the well was a gas producer. The objectives of this research was that to design gas lift macaroni (GLM) to optimize oil production rate. The design of this research was that the new slim tubing 1.315 inch, called as macaroni tubing, was installed inside the existing 3. 5inch tubing. The gas lift valves are installed inside macaroni tubing. The data collection consists of reservoir data, surface data, and well diagram. The result of this research was that the gas lift macaroni installation can generate oil production rate of 425 STB/day of the three wells. Gas lift valves of well A is four valves, well B is five valves, and well C is three valves. The deviation of software and manual calculation of valves depth is less than 1%. The cost saving by installing gas lift macaroni instead of workover operation to change the existing tubing with new tubing equipped with gas lift valves is USD 5,620,955 of three wells.

Keywords: dead well, gas lift macaroni, oil production rate, pressure gradient

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I. INTRODUCTION

In X Field, most of the wells have multi zones/layers as gas well producers. Several gas wells have stopped flowing years ago due to not economical production anymore. According to the reservoir study, the oil reservoir has been found on the above zones of dead gas zones. However the oil cannot flow naturally to the surface, therefore the company has to use an artificial lift to activate the oil well.

The company found that the field has formation of unconsolidated sand which produces sandy oil. The company has to choose the proper artificial lift for sandy oil well. The pump is not proper because the impellers of the pump will easily be worn out by the sandy oil. The proper artificial lift for sandy oil well is a gas lift. The company also has much available gas well from the field.

Gas lift is a method of artificial lift that uses an external source of high-pressure gas for supplementing formation gas to lift the well fluids. The principle of gas lift is that gas injected into the tubing or casing at some predetermined depth to reduce the density of the fluids in the tubing or casing, so that it reduces the pressure opposite the producing formation.

The outside diameter (OD) of tubing is 3.5 inch. It is found that the tubing of the wells have no gas lift mandrel completion as the wells were gas producers. It will be high cost to change the tubing with the new tubing equipped with gas lift mandrel by workover operation. To reduce the cost, the company has decided to install the slim tubing OD 1.315 inch inside the tubing OD 3.5 inch. The slim tubing OD 1.315 inch is called as tubing macaroni[1].

Inside the tubing macaroni is installed gas lift valves. The design of the gas lift macaroni will be studied further for three wells to obtain the optimum oil production rate with economical operation cost. Prosper software is utilized to obtain optimum result of oil production rate. Manual calculation of pressure gradient and manual graph plotting is performed to compare with Prosper calculation of valves depth.

The slim tubing OD 1.315 inch called tubing macaroni [1] will be installed inside the existing tubing OD 3.5 inch. Gas lift valves will be installed inside the tubing macaroni. It will be called as gas lift macaroni. Prosper software will be used to design the gas lift macaroni to solve the problem to activate oil production with economical operation cost. The company has a plan to install tubing macaroni OD 1.315 inch equipped with gas lift valves for three wells to generate oil production.

The objectives of this study are to design gas lift macaroni to optimize production rate and to calculate the cost saving and payout time to use gas lift macaroni instead of workover operation to change the existing tubing.

II. METHOD

The data collection is performed firstly by surveying the well platform in delta area to understand the method of installation of gas lift valves macaroni. The data of three wells is collected from the company. The data consists of reservoir data, surface data, and well diagram.

The data will be analyzed by two methods which are calculation by Prosper and by manual graph plotting. Prosper is utilized to perform IPR and VLP graph drawing and analysis. Then, gas lift valves depth is calculated by Prosper and manual calculation by graph plotting. The deviation of the calculation result is considered to the accuracy of Prosper.

Prosper is utilized to design gas lift valves by iteration calculation to find optimum oil production rate, gas injection rate, gas injection pressure, and valves depth. The result of calculation also includes opening and closing valves pressure, dome pressure, and test rack opening pressure. Prosper calculation is performed by entering the data on the system, and manual calculation is performed by determining static BHP gradient, flowing BHT gradient, casing gradient, tubing gradient, and plotting graph of valves depth. Prosper will perform to calculate oil production rate and gas injection rate. Cost saving evaluation is performed by comparing between installation cost of new gas lift macaroni and changing the tubing with new one equipped with gas lift valves. Prosper is performed calculation by iteration process to obtain the optimum valves depth, opening and closing pressure, dome pressure, test rack opening pressure, oil production rate, gas injection rate, and gas injection pressure.

Cost benefit analysis is performed by comparing cost data of workover operation and installing gas lift valves macaroni. The cost items are:

1. Cost of workover operation consists of rental swamp rig, price of new tubing 3.5 inch, required tubing length.
2. Cost of gas lift valves macaroni installation consists of rental swamp barge for slickline and snubbing unit, new tubing 1.315 inch, required tubing length.

The difference of both cost results will be the saving cost for three wells. The method of cost calculation is by investigating the price of rental swamp rig, rental swamp barge services, and tubing price as of January 2017. The length of tubing is based on Prosper calculation.

Payout time or payback period calculation is useful to determine how long it will take a project tobe profitable. Payback period is calculated by dividing the cost of the project by annual or monthly cash inflows to find number of years or months to become profitable. The company will get more benefit with shorter payback period.

III. DATA ANALYSIS

Data analysis is performed by reviewing IPR and VLP graph intersection. If the graphs do not intersect to each other it means the dead well. After simulation of gas lift installation, the graph of IPR and VLP will be reviewed again for the intersection. If there is intersection meaning the well is able to flow. Estimated gas injection rate and oil production can be reviewed from Gas Lift Performance Curve (GLPC).

After gas lift simulation, Prosper is inputted by additional required data to design gas lift valves. Prosper will calculate with iteration process to obtain optimum gas lift design. The depth of gas lift valves is obtained and it needs to compare with manual graph plotting.

Manual calculation of static BHP gradient, flowing BHP gradient, casing gradient, tubing gradient, and kill fluid gradient are necessary before plotting on the coordinate graph. The manual graph will generate each valves depth. The valves depth will be compared between Prosper calculation and manual graph plotting.

Reservoir data and surface data of well A, B, and C are processed and calculated by Prosper software. The valves depth calculation is determined by Prosper and manual graph plotting to ensure the accuracy of Prosper calculation. The deviation between two methods of valves depth calculation is as the accuracy reference.

Prosper will provide the result of optimization by the data of oil production rate, gas injection rate, gas injection pressure, opening and closing pressure, dome pressure, and test rack opening pressure.

Well A

At initial condition, the well A was a dead well which can be seen from the graph of IPR (Inflow Performance Relationship) and VLP (Vertical Lifting Performance). The graph of IPR and VLP is not intersected which means well A is a dead well and the oil cannot flow naturally. It shows in Figure 1.

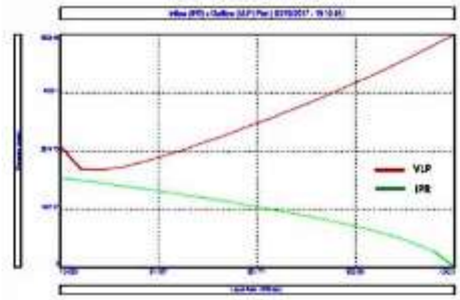

Fig.1 IPR and VLP show a dead well

IPR graph shows that AOF (Absolute Open Flow) is 1243 STB/day. Tubing dimension is OD 3.5 inch and ID 3.068 inch, and depth is 7584 ft. While Casing dimension is OD 7 inch and ID 6.366 inch, and depth is 8000 ft.

The oil cannot flow naturally to surface because the reservoir pressure is low and the tubing is still full of kill fluid up to surface level. From the above condition, the gas lift system is designed to reactivate the well to produce the oil.

Simulation of Gas Lift Design of Well A

Gas lift design is simulated by entering the data into Prosper which are reservoir data, PVT data, productivity index. The additional data of gas lift for simulation are:

1. Gas Gravity of Gas Lift = 0.8062
2. H_2S = 0 %
3. CO_2 = 10.46 %
4. N_2 = 0.21 %
5. GLR Injected = 915 SCF/STB
6. Injected Gas Rate = 1 MMscf/day
7. Fixed depth of gas injection = 7584 ft

The macaroni tubing OD 1.315 in., ID 1.049 in. is inserted into tubing OD 3.5 in., ID 3.068 in.

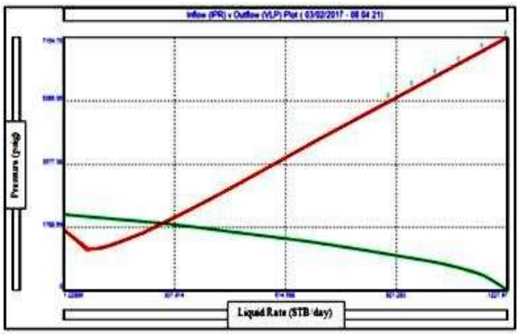

Fig.2 After GLM Installation

The simulation result of installation of tubing macaroni 1.315 in. inside tubing 3.5 in and gas lift injected 1 MMscf/day can be seen on Figure 2. It shows that IPR graph intersects VLP graph on a certain point of pressure and liquid rate. It means the oil flowing to surface after installation of gas lift valves macaroni. After processing the data, Prosper can show the gas lift performance curve as Figure 3.

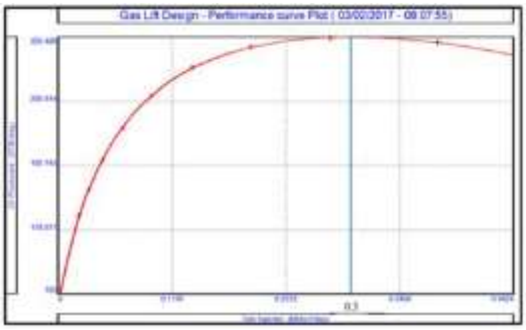

Fig.3 Gas Lift Performance Curve of Well A

Sensitivity Analysis of Well A

Sensitivity analysis is performed by utilizing data of gas lift performance curve.

Table 1 Sensitivity Data of Well A

Gas Injected (MMscfd)	Oil Produced (STB/day)
0.002	165.3
0.021	182.3
0.031	187.7
0.045	193.9
0.065	201.1
0.095	207.7
0.136	213.8
0.195	218.3
0.276	220.4
0.383	219.4
0.462	216.5

Data of gas injected and oil produced are approached by polynomial regression line to find the correlation.

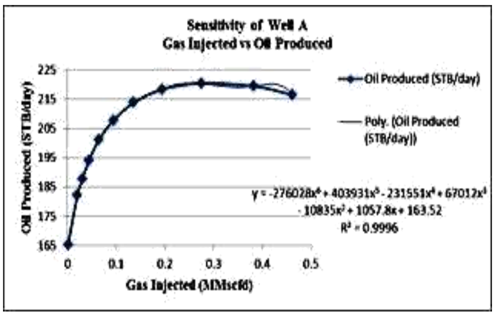

Fig. 4 Sensitivity graph of well A

The correlation of gas injected and oil produced is:

y = -276028x6 + 403931x5 - 231551x4 + 67012x3 - 10835x2 + 1057.8x +163.52

where: x: Gas Injected (MMscfd)
y: Oil Produced (STB/day)

Table 2 Optimum gas injected of well A

Gas Injected (MMscfd)	Oil Produced (STB/day)
0.195	218.59
0.205	219.16
0.215	219.63
0.225	219.99
0.235	220.24
0.245	220.39
0.255	220.44
0.265	220.40
0.275	220.29
0.285	220.12
0.295	219.91
0.305	219.68

According to the correlation, the optimum gas lift injection rate is 0.255 MMscfd to produce oil rate 220.44 STB/day.

Optimization of Gas Lift Design of Well A

Prosper will calculate the optimum design of gas lift and determine the depth of valves. The additional data are entered to Prosper as shown below:

1. Max. Gas injection available = 1 MMscfd
2. Gas injection pressure = 1000 psig
3. Drop pressure across valve = 100 psi
4. Static gradient of load fluid = 0.437 psi/ft
5. Vertical lift correlation = Dun and Ros Original
6. Injection point = orifice
7. Gas lift valve = Camco, type BK
8. Maximum port size of valve = 20 / 64 inch

As shown in Fig.6, the optimum design of gas lift is by 3 unloading valves at depth of 1962 ft, 3134 ft, and 3764 ft. The operating valve is at 4029 ft.

Fig. 5 Optimum Gas Lift Design

Prosper will calculate by iteration process to obtain the optimum design of gas lift, and the result is shown in Fig.5 inside the red box.

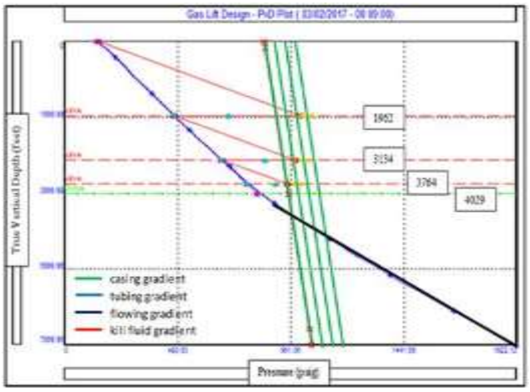

Fig.6 Optimum Design Graph

Prior to installation, each unloading valves are set in the workshop according to the data of Test Rack Opening Pressure which is the bellow pressure corrected to standard condition with tubing pressure set at 0 psi. The optimum design of gas lift at well A is shown in Figure 7 for each valve.

Fig.7 Optimum valves design

1. Valve opening pressure is the pressure for opening the valve at valve depth
2. Valve closing pressure is the pressure for closing the valve at valve depth.
3. Dome pressure is the bellow pressure at 60^0F.
4. Test rack opening pressure is the bellow pressure corrected to standard condition with tubing pressure set at 0 psi.
5. Opening CHP is the casing pressure at surface to open the valve.
6. Closing CHP is the casing pressure at surface to close the valve

The calculation result of the gas lift macaroni design at Well A is as follows:

1. Liquid rate = 242 STB/day
2. Oil rate = 203 STB/day
3. Injected gas rate = 0.12 MMscfd
4. Injection pressure = 850 psig

Depth Comparison with Manual Calculation

Manual calculation is performed by plotting the graph on the coordinate paper according to static BHP gradient, flowing BHP gradient, casing gradient, tubing gradient, wellhead pressure, and kill fluid gradient.

A. Determine Static BHP Gradient

1. Water cut = 16%
2. SG oil, γ_o = 0.871
3. SG salt water, γ_{sw} = 1.07
4. Water gradient, G_w = 0. 433 psi/ft
5. Static BHP, p_s = 2176 psi

Oil gradient, $G_o = \gamma_o \times G_w$
G_o = 0.871 x 0.433 = 0.377 psi/ft
Salt water gradient, $G_{sw} = \gamma_{sw} \times G_w$
G_{sw} = 1.07 x 0.433 = 0.463 psi/ft.
Composite static gradient below point of injection,
$G_s = (G_o \times f_o) + (G_{sw} \times f_{sw})$
G_s = ((0.377 x 84%) + (0.463 x 16%)) = 0.391 psi/ft
Well depth at 0 psi, $D_0 = D_d - ps/Gs$
D0 = 7584 – (0.3912176) = 2020 ft
Draw line from static BHP to well depth at 0 psi with static gradient.

B. Determine Flowing BHP Gradient

1. Desired fluid production, q = 250 STB/day
2. Productivity Index, J = 1

Drawdown, Δp = qJ
Δp = 2501 = 250 psi
Flowing BHP, $p_{wf} = p_s - \Delta p$
p_{wf} = 2176 – 250 = 1926 psi
Draw line upward from flowing BHP at depth parallel with static gradient line.

C. Determine Casing Gradient

1. Surface casing pressure, p_c = 1000 psi
2. Well depth, D_d = 7584 ft

Half depth, $D_m = D_{2d}$ = 75842 = 3792 ft
3. Find pressure of half depth by graph on Figure 8 =1090 psi
Casing gradient, $G_c = (p_m - p_c)/D_m$
G_c = (1090−1000)/3792 = 0.024 psi/ft
Draw line from surface casing pressure to downward until intersecting with flowing gradient line. The intersection is the point of pressure in tubing is equal to pressure in casing.

D. Determine Depth of Operating Gas Lift Valve

Approximate a coordinate depth of operating gas lift valve by assuming a differential of 100 psi across the valves. The depth at which there is a 100 psi differential across the valve between tubing and casing is approximately depth 5100 ft and pressure 960 psi according to the manual graph.

E. Determine Tubing Gradient

The flowing gradient above the point of injection is the tubing gradient line. Draw the tubing gradient line by connecting the point of gas injection with wellhead pressure 142 psi.
Tubing gradient, $G_t = (p_{inj} - p_{wh})/D_{inj}$
G_t = (960−142)/5100 = 0.16 psi/ft

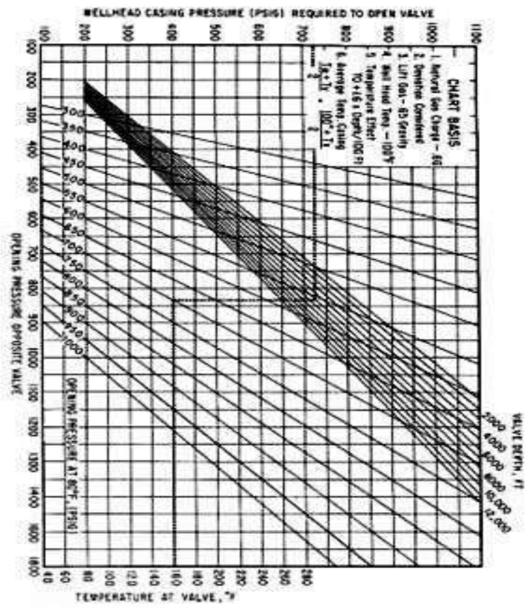

Fig. 8 Chart of Pressure at surface and at valves depth

F. Valve Locating

By drawing in the kill fluid gradient line 0.437 psi/ft until intersecting the 950 psi kickoff pressure line at 1950 ft. Extend a line horizontally to the left from the depth of Valve #1 at 1950 ft until intersecting the tubing gradient line. From this point draw a line parallel to the previously-drawn kill fluid gradient line of 0.437 psi/ft until intersecting the 900 psi gas line. This locates Valve #2 at 3150 ft.

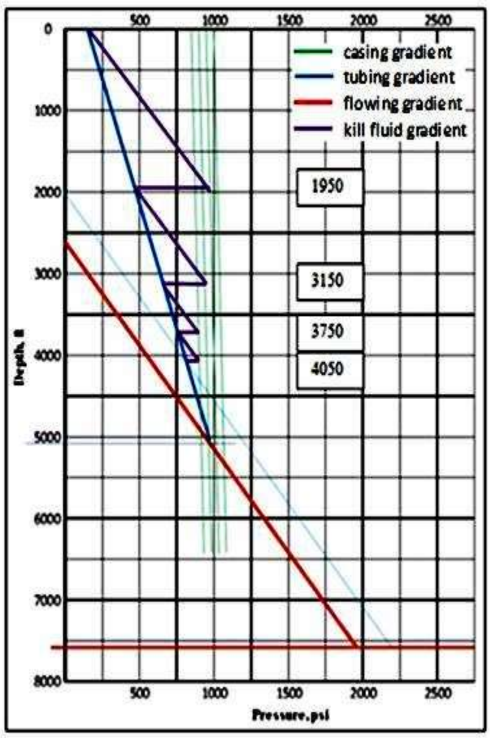

Fig.9 Manual Graph of Valves Depth

Repeat this procedure until reaching the point of gas injection by continuing to take the 50 psi drop between valves. This locates Valves #3 at 3750 ft and Valves #4 at 4050 ft.

According to the design result, Figure 10 shows the comparison of valve depth between Prosper and Manual Calculation. The deviation between Prosper and Manual Calculation is -0.5% ~ 0.6%. The deviation is still acceptable as it is less than 5% deviation.

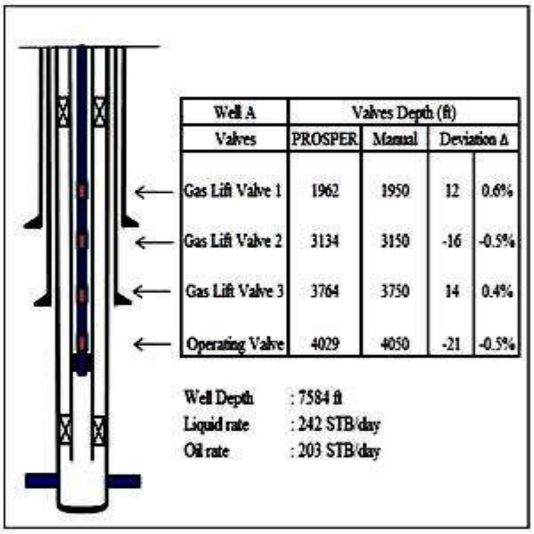

Fig.10 Spacing of unloading valves and operating valve

This procedure is repeated for well B and well C.

Oil Production After Gas Lift Macaroni Installation

After gas lift valves macaroni installation, three wells is able to produce the oil with total production rate is 425 STB/day as shown in Table 3.

According to the simulation data of well A with injection rate 1MMscfd and fixed depth valve at 7584 ft, the GLPC shows maximum oil rate is 220 STB/day and optimum gas injection rate is 0.3 MMscfd. After designing the gas lift with 4 valves, the data shows that oil rate is 203 STB/day and gas injection rate is 0.12 MMscfd.

The difference occurred because of there is loss due to gravitation force and friction loss between oil and tubing wall throughout the tubing during vertical flowing. Such kind of friction loss is also occurred at well B and well C.

Oil rate of well A is the highest because the reservoir pressure is high 2175 psi, the water cut is low 16%, and the porosity is quite high 23%. Wellhead pressure of well A is small, so that the oil is more easily to flow to the surface because low back pressure from the wellhead.

While oil rate of well C is the lowest because the reservoir pressure is low 1866 psi, the water cut is very high 65%. Although well C has highest permeability of 373 mD, but due to high water cut, the production mostly 65% is water and oil only 35%. Wellhead pressure of well C is very high at 329 psi and it causes very high back pressure so that the oil also quite difficult to flow to surface.

Table 3 Summary of Gas Lift Valves Macaroni Installation

		Prosper Calculation	Manual Calculation	Deviation of Prosper vs Manual	Prosper Calculation			
		Valves Depth (ft)	Valves Depth (ft)		Gas Injection Rate (MMscfd)	Gas Injection Pressure (psi)	Liquid Rate (STB/day)	Oil Rate (STB/day)
Well A	Valve 1	1962	1950	0.6%	0.12	850	242	203
	Valve 2	3134	3150	-0.5%				
	Valve 3	3764	3750	0.4%				
	Valve 4	4029	4050	-0.5%				
Well B	Valve 1	1933	1950	-0.9%	0.27	800	133	133
	Valve 2	3396	3400	-0.1%				
	Valve 3	4478	4450	0.6%				
	Valve 4	5239	5200	0.7%				
	Valve 5	5723	5700	0.4%				
Well C	Valve 1	1513	1500	0.9%	0.12	900	256	89
	Valve 2	2384	2400	-0.7%				
	Valve 3	2818	2800	0.6%				

The trend of oil production in other wells is 5% declining per month, the estimated trend of oil production in the three wells are shown in Figure 11. The economic limit of oil production is 15STB/day.

Cost Benefit Analysis

The oil cannot flow naturally to the surface and the well completion has no gas lift mandrel installation due to previously the well was a gas well. There are two options to install gas lift valves to the well which has no gas lift mandrel completion, which are by changing the existing tubing 3.5 inch and installation of gas lift mandrel by workover operation or installation of gas lift macaroni 1.315 inch equipped with gas lift valves inside existing tubing 3.5 inch. The cost of both options are:

a. The cost to change tubing 3.5 inch with new tubing mandrel 3.5 inch equipped with gas lift valves by workover operation for all three wells as Table 4.

b. The cost to install gas lift macaroni 1.315 inch equipped with gas lift valves inserted into existing tubing 3.5 inch is shown in Table 5.

From the calculation above, the cost saving is USD 6,352,140 – USD 731,185 = USD 5,620,955. for three wells by installing gas lift macaroni 1.315 inch instead of changing out tubing 3.5 inch with mandrel completion by workover job. The most saving cost is from rental a Swamp Barge Services (Slickline and Snubbing Barge), instead of rental a Swamp Rig.

The payout time or payback period is calculated for each well comparing the cash flow between both options. Oil price assumption is USD 50 per barrel.

The payout time and cash flow analysis is calculated without considering production sharing contract calculation. It is shown that by changing the existing tubing with new tubing mandrel the payout time is 9 ~ 21 months, while by installing the gas lift macaroni inside the existing tubing the payout time is 1 ~ 2 months.

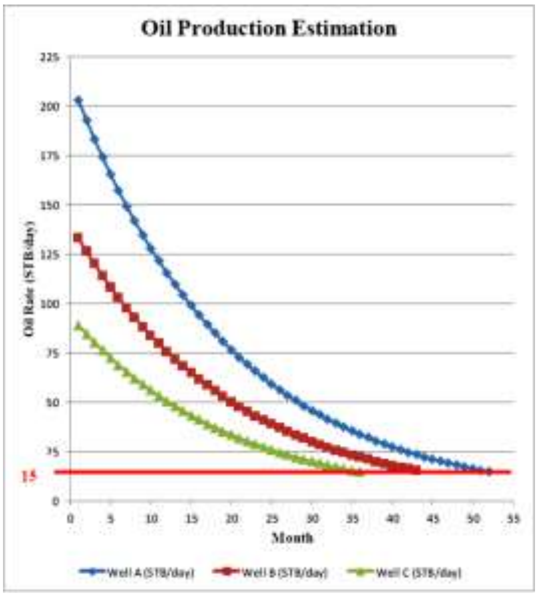

Fig.11 Oil Production Estimation

Table 4 Cost to change tubing 3.5 in. with new tubing mandrel

	unit	Well			Total
		A	B	C	
Rental swamp rig	USD/day	150,000	150,000	150,000	
Duration of workover	day	14	17	11	
Cost of rental swamp rig	USD	2,100,000	2,550,000	1,650,000	6,300,000
Length of new tubing 3.5 in.	ft	7,584	9,145	5,704	
Price of new tubing 3.5 in.	USD/lb	0.227	0.227	0.227	
Weight of new tubing 3.5 in.	lb/ft	10.25	10.25	10.25	
Cost of new tubing 3.5 in.	USD	17,627	21,255	13,258	52,140
Total installation cost of new tubing 3.5 in.	USD	2,117,627	2,571,255	1,663,258	6,352,140

Table 5 Cost to install macaroni 1.315 in. inserted into existing tubing

	unit	Well			Total
		A	B	C	
Rental swamp barge services	USD/day	25,000	25,000	25,000	
Duration of GL Macaroni installation	day	10	12	7	
Cost of rental swamp rig	USD	250,000	300,000	175,000	725,000
Length of new tubing 1.315 in.	ft	4,029	5,723	2,818	
Price of new tubing 1.315 in.	USD/lb	0.227	0.227	0.227	
Weight of new tubing 1.315 in.	lb/ft	2.17	2.17	2.17	
Cost of new tubing 1.315 in.	USD	1,983	2,816	1,387	6,185
Total installation cost of GL Macaroni 1.315 in.	USD	251,983	302,816	176,387	731,185

According to cost benefit analysis and payout time, it is clear that the installation of gas lift macaroni inside the existing tubing is much more low cost operation and profitable compared with changing

IV. CONCLUSIONS

The conclusions of this research are:

1. The result of valves depth calculation by Prosper are :
   a. Well A: 4 valves at depth of 1962 ft, 3134 ft, 3764 ft, 4029 ft
   b. Well B: 5 valves at depth of 1933 ft, 3396 ft, 4478 ft, 5239 ft, 5723 ft
   c. Well C: 3 valves at depth of 1513 ft, 2384 ft, 2818 ft
2. The calculation of gas lift design of three wells has been performed by Prosper and manual graph plotting. The result of design comparison between Prosper and manual graph plotting has acceptable deviation which is less than 1% deviation of the valves depth. It means Prosper has acceptable accuracy.
3. The design of gas lift macaroni 1.315 inch equipped with gas lift valves to be installed inside existing tubing OD 3.5 inch will support oil flowing to surface. The company can obtain oil rate 425 STB/day for three wells after installation of tubing macaroni equipped with gas lift valves.
4. Company can obtain cost benefit by installing gas lift macaroni compared with workover operation to change the existing tubing with new tubing mandrel equipped with gas lift valves. The cost comparison shows that the company can save cost USD 5,620,955 for three wells. The most saving cost is that the rental of Swamp Barge is much more economical than Swamp Rig. The payout time of changing the existing tubing to new tubing mandrel is 9~21 months, while the payout time of installation of gas lift macaroni is 1~2 months.

The recommendations of this research are:

1. According to the study that the deviation of valves depth calculation between Prosper and manual is less than 1%, therefore it is recommended that Prosper can be utilized to perform the design of gas lift.
2. Installation of gas lift valves with tubing macaroni 1.315 inch is the economical solution to reactivate the oil well which is unable to flow naturally. Installation of gas lift macaroni only need swamp barge, slickline and snubbing unit. The payout time of installing gas lift macaroni is much shorter compared with changing the existing tubing with new tubing mandrel .

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