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Production optimization in Well A and Well B using electric submersible pump (ESP)

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Abstract

This research discusses the optimization of production carried out in Well A and Well B. The two Wells are production Well with three production layers (multilayer) that have different characteristics for each layer. Based on the performance evaluation of the production Wells, it's known that Well A and Well B are no longer able to produce naturally (natural flow). Therefore, it's necessary to have an artificial lift in order to be able to produce. The artificial lift method used for Well A and Well B is to install an electric submersible pump (ESP), because based on the screening criteria of artificial lift, both Wells can use an electric submersible pump. It's known that Well A has an absolute open flow (AOF) value of 5840 stb/d and Well B of 3874 stb/d. The production optimization carried out has a production target of 70% of the absolute open flow value. Therefore, the selection of the electric submersible pump for each Well must have an operating flowrate that is in accordance with the production target of the two Wells and must perform a sensitivity test on the selected electric submersible pump to obtain the optimal scenario. So that, the electric submersible pump design for Well A is REDA D4300N with operating frequency of 60 hz and 156 stages, while for Well B is REDA DN3100 with operating frequency of 70 hz and 188 stages.

INTRODUCTION

Initially, hydrocarbons from the reservoir can flow towards the surface naturally *(natural flow),* but in reality, this condition cannot occur continuously. Over time, there will come a time when the reservoir pressure decreases which can cause the Well to stop production. It is necessary to know the performance of production Wells to show Well productivity. Well productivity is an ability to produce fluid from the productive layer or reservoir under certain conditions. Parameters that can express the productivity of a production Well are productivity index, reservoir deliverability, and Well deliverability. Reservoir deliverability is usually illustrated by an inflow performance relationship (IPR), whereas Well deliverability is illustrated by a nodal analysis. From the inflow performance relationship curve, you will be able to determine the AOF value of the production Well. Then to find out whether a Well can produce or not can be seen from the results of nodal analysis. After the performance of production Wells is known, Well development can be carried out, If the production Wells are no longer able to produce naturally, then one of the efforts that can be made is to instal artificial lifts (Abdelhady et al., 2020; Brown, 1984; Mohammed et al., 2019).

Artificial lift is one of the artificial methods used to optimize production. This method is used to increase reservoir pressure and lift oil to the surface which is used when the natural driving energy of the reservoir is not strong enough to produce oil to the surface. This method is used to overcome bottom-hole pressure

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so that the oil Well can produce at the desired rate, either by injection of gas to reduce hydrostatic pressure or using a pump to increase lift pressure. In selecting the right type of artificial lift method, it is very important for the profitability of the production Wells, because an inappropriate choice will lead to low production and high operating costs. There are two main categories of artificial lift methods, namely gas lift and pump lift (Abdelhady et al., 2020; Brown, 1984; Mohammed et al., 2019).

Electric submersible pump (ESP) is one of artificial lift method that uses a type of centrifugal pump with several arrangements satges inside it. Operation ESP is by passing the electric current from the transformer that is on the surface through electric cables to electric motor that installed in subsurface. The electric motor will convert electrical energy into magnetic and the rotor will move based on the change in the magnetic. After that, the movement of the rotor will rotate impeller inside the pump where kinetic energy is converted to potential energy. The process will occur repeatedly until the last stage, so that the fluid can be produced towards the surface through the production tubing (Bellarby, 2009; Guo et al., 2007; Stel et al., 2015)

Electric submersible pumps have surface and subsurface equipments. Surface equipment consists of Wellhead, transformer, switchboard, junction box, and variable speed drive (VSD). While subsurface equipment includes pressure sensing instrument (PSI) unit, electric motor, electric cable, protector, intake, and pump unit (Amao, 2014; Kerunwa et al., 2022; Olivia et al., 2017). The adventages of electric submersible pump is efficient, can operate at high speed, capable to pump out large volumes of fluid, can separate gases using gas separator, suitable for installation in inclined Well, can solve the problem of paraffin and high viscosity fluids at low temperatures, and operation costs are relatively small when compared to the production rate obtained. Then, the disadventages of electric submersible pump is the first cost of installing is relative expensive than another artificial lift system, not good for Wells that have sand problem, and generates an emulsion from high rotation of the pump impeller. In a Well that is a saturated reservoir with a layer pressure below the saturation pressure, the gas in the pumped liquid can reduce the pump efficiency and gas locking can occur (Cortes et al., 2019; Mahgoub et al., 2005; Sucipto et al., 2018; Takacs, 2009).

This research was conducted on Well A and Well B which have three production layers with different conditions (multilayer). With all three layers, Well A and Well B cannot produce naturally, therefore an artificial lift is required to optimize the two production Wells. In this case, electric submersible pumps are used to optimize production in Well A and Well B.

MATERIALS AND METHODS

Simulation study

To conduct production optimization studies in Well A and Well B, the PIPESIM software is used. With the software, it's possible to determine the optimal scenario in the development of production Wells using electric submersible pump. Some of the required data such as completion data, PVT data, Well pressure and temperature data, and production rate data are used as input data.

The methodelogy used to study optimization of oil and gas Well production is by screening Well criteria for the use of electric submersible pump (Figure 1). This is done to determine whether the characteristics of the Well are suitable when ESP is installed. Then, input Well data into the software to evaluate Well performance and create development scenarios using ESP. By evaluating the nodal analysis, it can be seen whether the production Wells have production rates according to the target or if they cannot produce naturally. If it's known that a Well is no longer able to produce naturally or has a production rate less than the target, it's necessary to optimize production by installing an ESP in the Well. The selection of the type of ESP pump for a Well is based on the most optimal pump efficiency and the value of the production rate that can be generated from using the pump. Therefore, it's necessary to test the sensitivity of the pump operating frequency to find out the optimal scenario in the study of optimization of oil and gas Well production using ESP. The operating frequency values for the pump sensitivity test are 40 hz, 50 hz, 60 hz, and 70 hz.

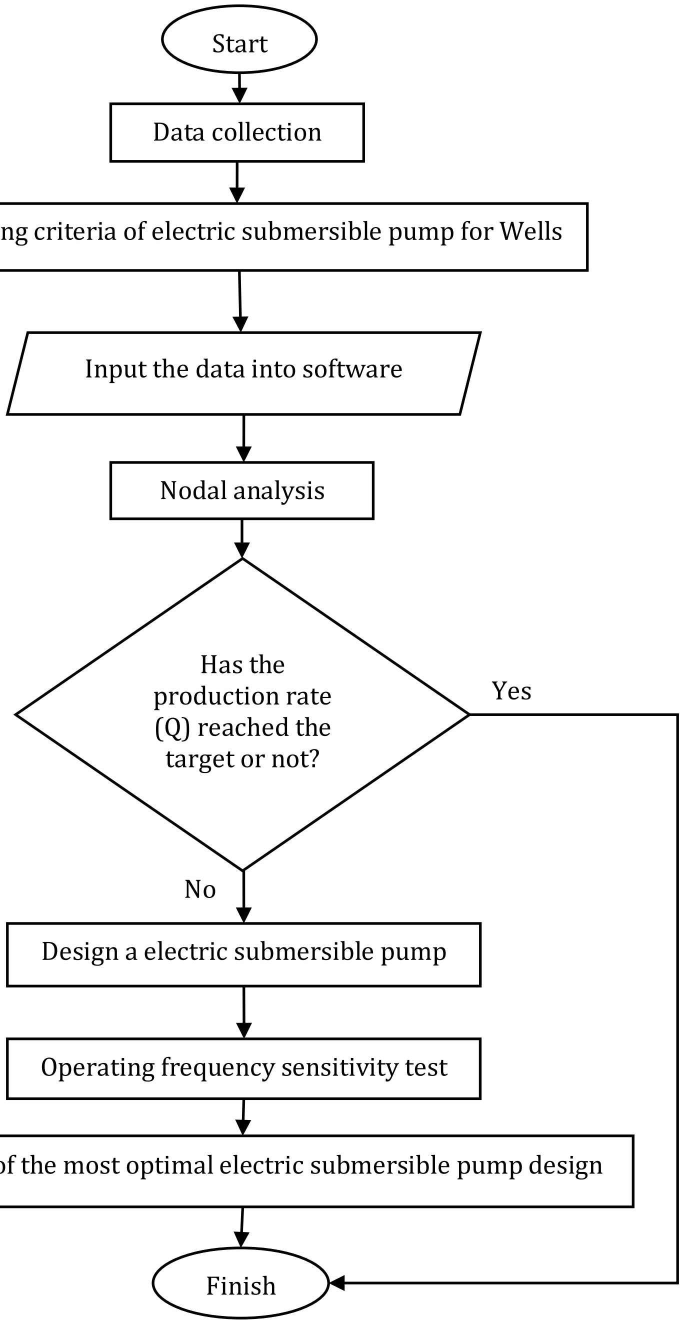

Figure 1. Flowchart of simulation design.

Characteristic data of Well A and Well B

In this case to obtain the necessary data then done by reading references from paper, journals, or from another research. The data obtained below is secondary data (Table 1-5).

Table 1. Well completion data.

Parameter		Well A	Well B	Unit
Casing diameter	OD	7	7	inch
	ID	6.366	6.366	inch
Tubing diameter	OD	3.5	3.5	inch
	ID	2.992	2.992	inch
Mid. Perforation	layer 1	2800	3025	ft
	layer 2	2890	3163	ft

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	layer 3	3331	3214	ft

Table 2. PVT data.

Parameter		Well A	Well B	Unit
Gas oil ratio	GOR	1071	969	scf/stb
Oil gravity	γo	36.5	36	°API
Gas gravity	γg	0.65	0.65	-
Water gravity	γw	1	1	-
Water salinity	-	17000	17000	ppm
Oil viscosity	μo	1.2	1.2	cP
FVF oil	Bo	3.3	3.3	bbl/stb
Mol H2S	-	0	0	%
Mol CO2	-	3	3	%
Mol N2	-	0	3	%
Water cut	WC	81	91	%

Table 3. Permeability and thickness of layer.

Parameter		Well A	Well B	Unit
	layer 1	500	350	
Permeability (k)	layer 2	2.7	30	mD
	layer 3	300	270	
	layer 1	67	130	
Thickness (h)	layer 2	45	29	ft
	layer 3	116	34	

Table 4. Pressure and temperature data.

Parameter		Well A	Well B	Unit
	layer 1	642	612	
Reservoir pressure (Pr)	layer 2	690	670	psi
	layer 3	784	823	
	layer 1	502	520	
Bottom hole pressure (Pwf)	layer 2	525	550	psi
	layer 3	586	613	
	layer 1	186	195	
Reservoir temperature (Tr)	layer 2	190	202	°F
	layer 3	210	205	
Wellhead pressure (Pwh)		200	200	psi
Bubble point pressure (Pb)		4430.10	4248.08	psi

Table 5. Maximum rate data.

Parameter		Well A	Well B	Unit
Maximum rate (Q max)	layer 1	2516	2892	BFPD
	layer 2	10	64	
	layer 3	3343	929	

RESULTS AND DISCUSSION

Electric submersible pump (ESP) screening criteria for Well A and Well B

To determine the suitability of production Well in using an ESP, it must do screening criteria on the characteristics of the production Well. Screening criteria for Well A and Well B referring to Appendix 1, the following are the results (Table 6).

Table 6. Result of ESP screening criteria for Well A and Well B.

Characteristic	ESP	Well data		Screening
		Well A	Well B	
Maximum operating depth (ft)	15000	3600	3350	✓
Maximum operating temperature (°F)	400	186	195	✓
Fluid gravity (°API)	>10	36	36	✓
Offshore application	Excellent	offshore	offshore	✓
Gas handling	Fair	GOR = 1071 scf/stb	GOR = 969 scf/stb	✓
Servicing	Workover, pulling rig	OK	OK	✓
Prime mover	Electric motor	OK	OK	✓

From Table 6 above, it can be seen that based on the known characteristics for Well A and Well B, the production optimization of the two Wells can use electric submersible pump.

Well completion

The Well A and Well B completion are using a single string type, the casing used has an inner diameter of 6.366 inch and an outer diameter of 7 inch. While the production tubing used has an inner diameter of 2.992 inch and an outer diameter of 3.5 inch. Illustration of Well completion for Well A and Well B can be seen in Figure 2.

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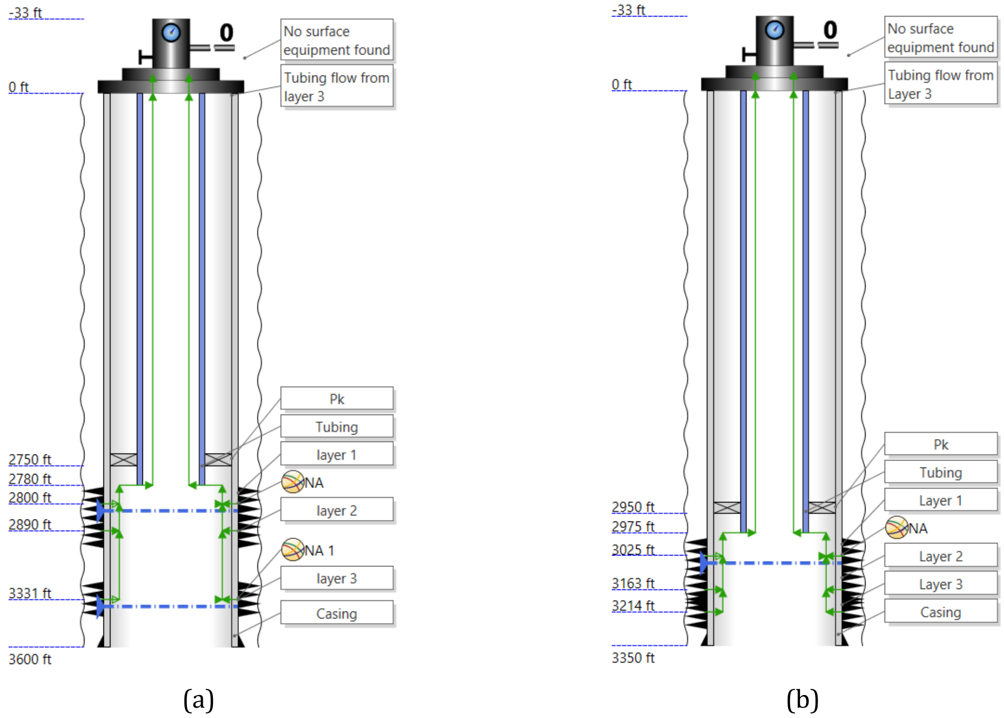

Figure 2. a) Complation of Well A, b) Completion of Well B.

Figure 2 shows an illustration of Well completion from Well A and Well B. It can be seen from the figure that both have different depth and perforation zones.

Reservoir deliverability

Inflow performance relationship (IPR)

Inflow performance curve (IPR) is a curve that shows the ability of the Well to produce which is illustrated by the relationship between production rate and Well bottom pressure (Gunawan, 2021). Well A and Well B IPR curves can be seen in Figure 3 and Figure 4.

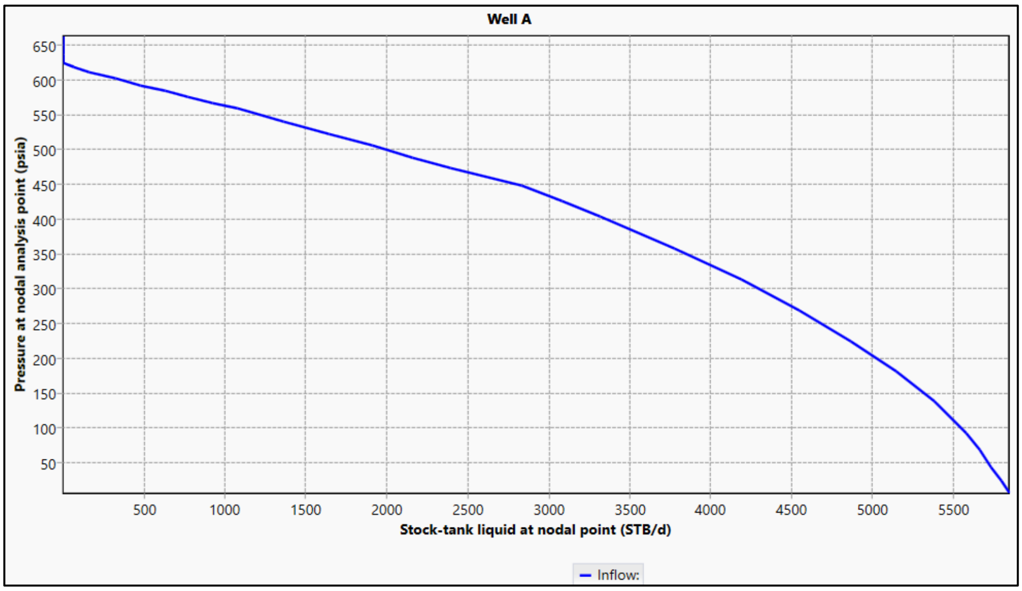

Figure 3. IPR curve of the Well A.

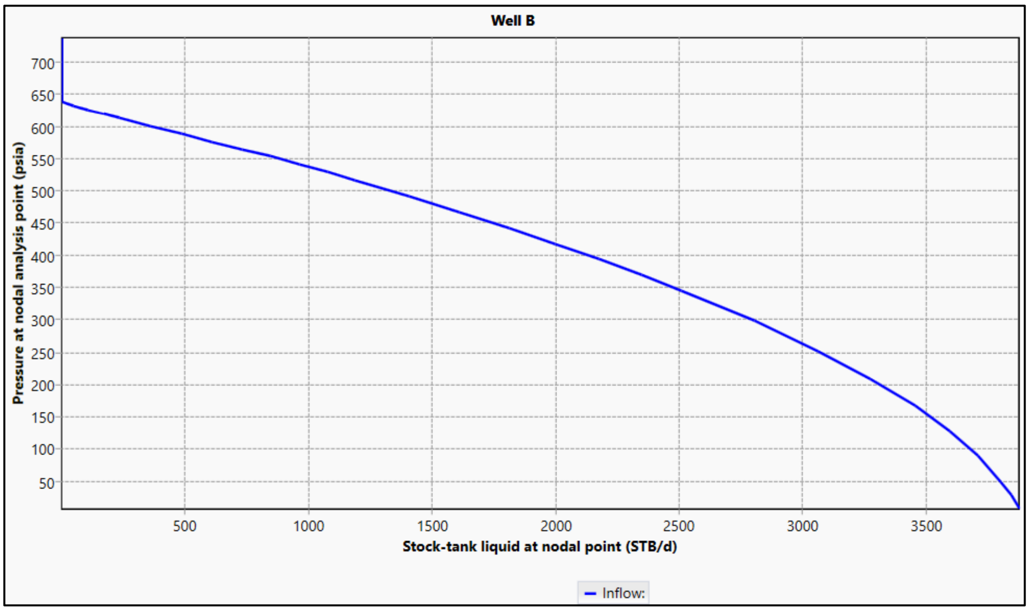

Figure 4. IPR curve of the Well B.

Based on the IPR curve, it can be seen that the absolute open flow value of Well A is 5840 stb/d and Well B is 3874 stb/d. By knowing the absolute open flow value, it can determine the production target for each Well.

Nodal analysis

Nodal analysis is a curve that shows the relationship between the inflow curve and the outflow curve (). Nodal analysis for Well A and Well B is carried out by selecting the bottom hole as the nodal point, so the curve depicted is the relationship between the inflow performance relationship (IPR) curve and vertical lift performance (VLP) curve. The results of the nodal analysis of Well A and Well B can be seen in Figure 5 and Figure 6.

Figure 5. Nodal analysis of Well A.

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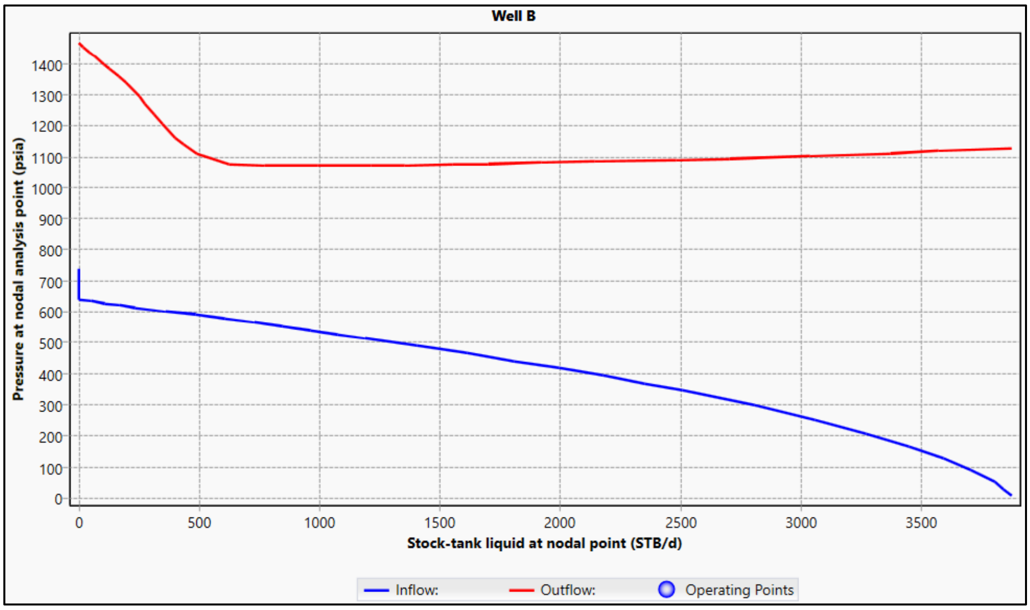

Figure 6. Nodal analysis of Well B.

Based on the results of the nodal analysis of the Wells, it's known that there is no intersection between the IPR curve and VLP curve, so it can be concluded that Well A and Well B are no longer able to produce naturally. Therefore, an artificial lift using electric submersible pump (ESP) is needed to optimize production in Well A and Well B.

Production optimization

Production optimization carried out in Well A and Well B is by using electric submersible pump. The production target is 70% of the absolute open flow of each Well. From the known absolute open flow value, it's found that the production target for Well A is 4088 stb/d and Well B is 2712 stb/d.

The development scenario for Well A uses three pump types, there are REDA D4300N, Alkhorayev WG-4000, and XPC G4500EZ. Then, for the Well B scenario, three different pump types are also used, there are REDA DN3100, Borets B400-2400, and XPC D3100EZ. The use of this pump type is based on the available catalog and the range of operating flowrate it has. For Well A the ESP pump was installed at a depth of 2730 ft, while for Well B it was installed at a depth of 2930 ft.

Table 7. Electric submersible pump design for Well A and Well B.

Parameter	Well A			Well B			Unit
	REDA D4300N	Alkhorayev WG-4000	XPC G4500EZ	REDA DN3100	Borets B400-2400	XPC D3100EZ	
Design Flowrate	4080	4080	4080	2712	2712	2712	stb/d
Design frequency	60	60	60	60	60	60	hz
Operating flowrate	4087.83	4085.57	4093.35	2709.81	2711.78	2712.70	stb/d
Outlet pressure	200	200	200	200	200	200	psia
Total dynamic head (TDH)	2228.94	2229.34	2235.08	3109.19	3107.21	3108.3	ft
Intake pressure (PIP)	312.01	312.26	311.38	292.56	292.25	292.10	psia
Intake liquid rate	4256.26	4253.92	4261.98	2815.40	2817.44	2818.40	bbl/d
Intake gas rate	0.01128	0.011261	0.0113	0.0035	0.0035	0.0035	mmcf/s
Intake gas volume fraction	0.32061	0.320413	0.3211	0.1811	0.18126	0.1813	fraction

Stages	156	88	81	188	218	180	stages
Speed	3499.99	3499.992	3500	3500	3499.99	3500	rpm
Efficiency	59.75	64.61	65.43	66.55	55.72	65.15	%
Power	110	101.70	100.86	92.38	110.33	94.43	hp
Head	2228.94	2229.34	2235.08	3109.19	3107.21	3108.31	ft
Differential pressure	764.99	764.80	766.64	1051.41	1050.52	1050.79	psi
Discharge pressure	1077.00	1077.06	1078.02	1343.98	1342.77	1342.89	psia
Fluid temperature rise	2.12893	1.731736	1.6744	2.0999	3.31712	2.2341	°F

Table 8. Well production and pump performance of ESP design in Well A and Well B.

Parameter	Well A			Well B			Unit
	REDA D4300N	Alkhorayev WG-4000	XPC G4500EZ	REDA DN3100	Borets B400-2400	XPC D3100EZ	
Liquid rate	4153.82	4203.29	4244.37	2709.81	2711.78	2712.70	stb/d
Oil rate	789.23	798.62	806.43	243.88	244.06	244.14	stb/d
Head capacity	3383.19	3032.49	2908.32	3933.25	4814.23	3549.52	ft
Pump efficiency	70.17	69.55	68.90	67.03	65.76	65.98	%
Power	147.42	134.81	130.60	117.03	145.00	114.74	hp

Table 7 shows the results of the electric submersible pump simulation design for Well A and Well B with a design frequency of 60 hz and an outlet pressure of 200 psia. Then Table 8 is the result of nodal analysis after electric submersible installation and pump performance in both Wells. However, henceforth a sensitivity test of the operating frequency is carried out for each of these pumps. Operating frequency sensitivity test is performed to determine the most optimal scenario. The operating frequency used for the sensitivity test are 40 Hz. 50 Hz. 60 Hz. and 70 Hz.

Table 9. Optimum scenario of pump design for Well A and Well B.

Scenario			Pump Performance			
			Q. Liquid	P @NA	Q. Oil	Efficiency
			(stb/d)	(psia)	(stb/d)	(%)
Well A	REDA D4300N	(60 hz. 156 stages)	4087.42	323.72	776.61	70.04
	Alkhorayev WG-4000	(60 hz. 88 stages)	4085.33	323.96	776.21	69.24
	XPC G4500EZ	(60 hz. 81 stages)	4093.95	322.99	777.85	68.62
Well B	REDA DN3100	(70 hz. 188 stages)	3163.57	231.27	284.72	67.04
	Borets B400-2400	(70 hz. 218 stages)	3122.97	239.51	281.07	65.80
	XPC D3100EZ	(70 hz. 180 stages)	3214.25	220.72	289.28	65.34

After the operating frequency sensitivity test was carried out, the optimum conditions for each pump were obtained as shown in Table 9. Based on the results of the sensitivity test, the most efficient type of pump can be determined from the pump efficiency value obtained. So, with pump efficiency and production targets obtained, the best scenario for optimizing production in Well A is the REDA D4300N pump which is operated at a frequency of 60 hz and 156 stages, the pump performance curve can be seen in Figure 8. While

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the best scenario for optimizing production in Well B is using a REDA DN3100 pump which is operated at a frequency of 70 hz and 188 stages that the pump performance curve can be seen in Figure 9.

CONCLUSION

Based on the research and data processing that has been done, it is known that Well A and Well B are no longer able to produce naturally. Therefore, electric submersible pump is used for the two wells in order to achieve the production target of 4088 stb/d for Well A and 2712 stb/d for Well B. The best scenario for Well A is to use REDA D4300 pump which is operated at a frequency of 60 hz and 156 stages, while for Well B using the REDA DN3100 pump which is operated at a frequency of 70 hz and 188 stages. With the pump used, Well A can produce liquid of 4087.42 stb/d with a pump efficiency value of 70.04%. Then, Well B can produce liquid of 3163.37 stb/d with a pump efficiency value of 67.04%.

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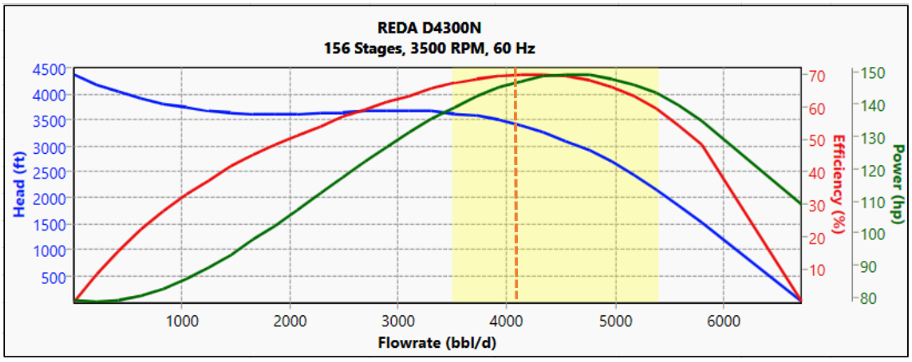
APPENDIX

ALS Application Screening Criteria

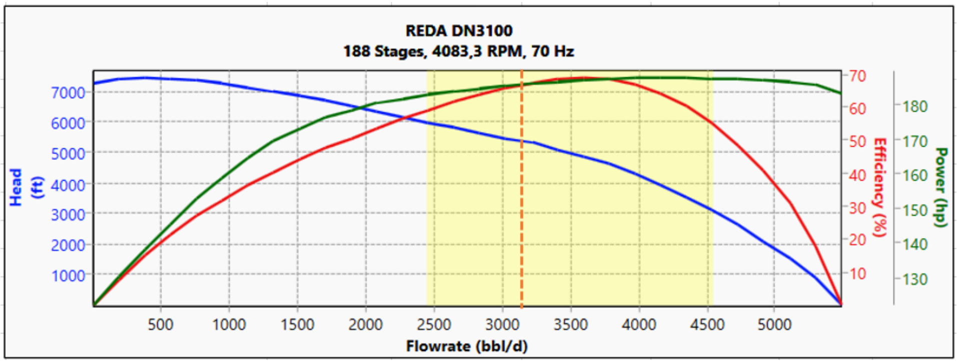
Form of lift	Rod Lift	PCP	Gas Lift	Plunger Lift	Hydraulic Lift	Hydraulic Jet	ESP	Capillary Technologies
Maximum operating depth, TVD (ft/*m*)	16,000 *4,878*	12,000 *3,658*	18,000 *4,572*	19,000 *5,791*	17,000 *5,182*	15,000 *4,572*	15,000 *4,572*	22,000 *6,705*
Maximum operating volume (BFPD)	6,000	4,500	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.

Appendix 1. Artificial lift screening criteria (Source: Weatherford).



Appendix 2. Pump performance curve of REDA D4300N (60 Hz, 156 stages).



Appendix 3. Pump performance curve of REDA DN3100 (70 Hz, 188 stages).