ELECTRICAL SUBMERSIBLE PUMPS (ESP) DESGIN OF WELLS (FD32) (FB18) NC-174, ALFEEL FIELD IN MORZUQ BASINE

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Abstract

The main objective of this study is to identify and select an electric submersible pump to produce high flow rates of oil. The electric submersible pump was chosen because it provides good flow rates in a given range. This electric submersible pump was used to raise production rates.

The study was conducted on two wells from Mellitah Oil Company in El Feel field and the results were as follows. Well (FD32) results were the required rate of 3283STB/d can be obtained using only 166 stages, while Well (FB18) results were 6180STB/d and 204 stages, and this required 2300V.

Keywords: Electrical Submersible Pump (ESP); Pump; Well head; Alfeel Field; Morzuq Basine.

Introduction

Electrical Submersible Pump (ESP) System Previous Studies

An Electrical Submersible Pump is usually composed of a motor, a seal (protector), a gas separator, a multistage centrifugal pump, an electric cable, a switchboard and a transformer Figure (1), shows a typical complete system of ESP. (Beggs, H.D., OGCI Publications, 1991).

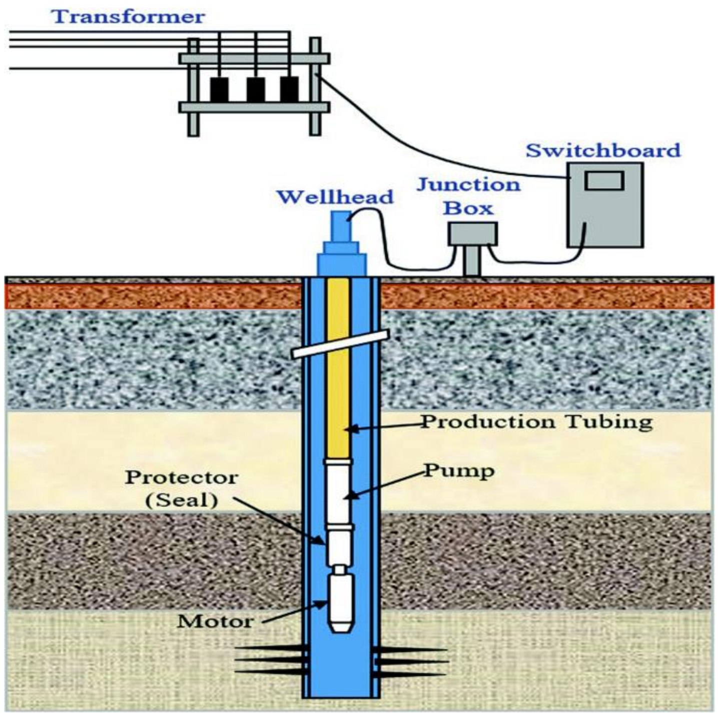

Figure (1): Standard ESP Complete Setup (John Bearden, August 2007).

Submersible Pump

Pumps used in ESPs are usually multi staged and centrifugal ones. Every stage includes an impeller and a stationary diffuser. The type of the stage determines the produced fluid, while the number of stages define the generated total head and the required horse power. Pumps are manufactured with different capacities and types to accommodate different well conditions.

The change in the pressure energy is obtained by the pumped liquid as it surrounds the impellers. The pumped fluid is affected by two factors: tangential and radial forces. As the impeller rotates, it imposes a rotating motion to the pumped liquid. It also imposes a motion that is tangential to the impeller's outer diameter.

The result of this motion is a centrifugal force that forces the liquid to flow in a radial direction. The second part of the pump stage is the diffuser. The purpose of the diffuser is to reduce high velocity energy to low velocity. Also, it helps in directing the pumped fluid into the next impeller (Brown, K.E., 1980).

When designing for an ESP installation, choosing the right submersible pump is critical since each pump has its own limitations and works for certain applications. Usually, the normal length of a single pump is about 20 – 25 ft., which is to accommodate handling and assembling pumps. Depending on the required head to produce the fluid, pumps can be joined together to create the required head (John Bearden, August 2007).

Location of Study Area

It is located in the Murzuq basin in south-western Libya in the western part of concession NC174 and has been discovered in October 1997.

The case study is on wells (FD32) & (FB18) Figure (2). (http://www.Mellitah Oil & Gas Company).

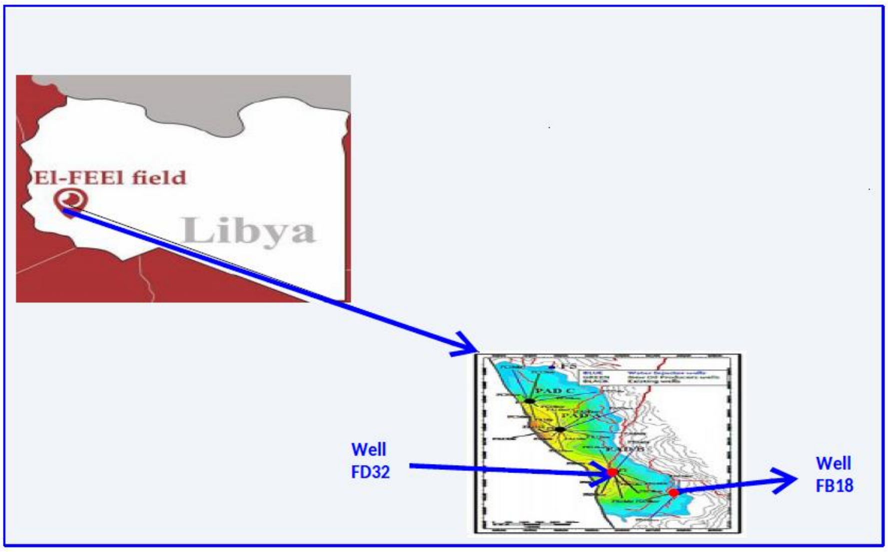

Figure (2): Location of Study Area (Http://Www.Mellitah Oil & Gas Company).

Methodology

The study followed the following procedure.

1- data collection

2- Calculating oil specific gravities (γ_o) oil $\text{Sp.gr} = \dfrac{1415}{131.5 + API}$

3- $Average\ Sp.Gr(\ \gamma_{\text{ave}}\ ) = (\gamma_o * O_c) + (\gamma_w * W_C)$

4- average liquid gradient $L.G = \ \gamma_{\text{ave}} * 0.433$

5- Calculate Flowing bottom hole pressure (Pwf) = Pws – (Q/PI)

6- Total Dynamic Head calculation TDH = Hd + Pd + Ft

7- Dynamic fluid level (Hd)= Datum – (Pwf / ALG)

8- Well head (Pd) = (Pwh / ALG)

9-10- Calculating voltage drop $VD = \frac{total - depth * correction\ factor * voltage\ dropper . 1000\ ft}{1000}$

11- Calculating the required surface voltage (Vs) = Voltage Drop + Motor Voltage

12- Calculating the size of transformer $KVA = \frac{1.732 * Vs * Amp}{1000}$

13- Calculating the fluid velocity beside the motor $Vf = 1.19 \times 10^{-2} \frac{Q}{ID_c^{\ 2} - 0D_m^{\ 2}}$

14- End design

Data Collection of Well (FD32 - NC174).

Table (1): Reservoir Parameters (Http://Www.Mellitah Oil & Gas Company).

Reservoir Parameters / Production Data	
Tubing size	3 ½″
Casing size	7
PI	8.5
Reservoir Pressure psia (Static BHP)	950
Temperature at reservoir F	175
Stock tank oil gravity, API	38.5
Bubble point pressure Pb, psia	130
Well head pressure, psi	150
Desired Production Rate, bbl/day	3283
Water specific gravity	1.04
Wc	61
GOR	18

Data Collection of Well (FB18 -NC174)

Table (2): Reservoir Parameters. (http://www.Mellitah Oil & Gas Company).

Reservoir Parameters / Production data	
Tubing size	4 ½″
Casing size	8 ½″
PI	8.5
Reservoir Pressure psia (Static BHP)	950
Temperature at reservoir F	180
Stock tank oil gravity, API	38
Bubble point pressure Pb, psia	142
Well head pressure, psi	115
Desired Production Rate, bbl/day	6180
Water specific gravity	1.04
Wc	35
GOR	17

Results and Discussion

1. Calculations of Well (FD32)

Calculating the oil specific gravities, average liquid gradient, and average fluid specific gravities

$$(\gamma_o)\ \text{oil Sp.gr} = \frac{1415}{131.5 + API}$$

$$(\gamma_o)\ \text{oil Sp.gr} = \frac{1415}{131.5 + 38.5} = 0.730$$

$$Average\ Sp.Gr(\ \gamma_{\text{ave}}\ ) = (\gamma_o * O_c) + (\gamma_w * W_C)$$

$$Average\ Sp.Gr(\ \gamma_{\text{ave}}\ ) = (0.730 * 0.39) + (1.04 * 0.61) = 0.919$$

$$L.G = \gamma_{\text{ave}} * 0.433$$

$$L.G = 0.919 * 0.433 = 0.397\ psi\ /\ ft$$

2. Calculating Flowing Bottom Hole Pressure (Pwf).

$$Pwf = Pws – (Q/PI)$$

$$= 950-(3283/8.5) = 563.7 \text{ Psi}$$

3. Total Dynamic Head Calculation

$$TDH = Hd + Pd + Ft$$

3.1 Dynamic Fluid Level (Hd)

$$Hd= Datum – (Pwf / ALG)$$

$$= 6980 – (563.7 /0.397) = 5560 \text{ ft}$$

3.2 Well Head (Pd)

$$Pd = (Pwh / ALG)$$

$$= 150/0.397 = 377 \text{ ft}$$

3.3 Frictional Head Loss In 4.5" Tubing @ 3283 B/D

By using frictional head chart

$$\text{Friction loss (ft)} = (30/1000 \text{ ft}) * \text{Pump set depth}$$

$$= 0.030 * 6150 = 184 \text{ ft}$$

$$TDH = 5560 + 377 + 184 = 6121 \text{ ft}$$

4. Pump Selection

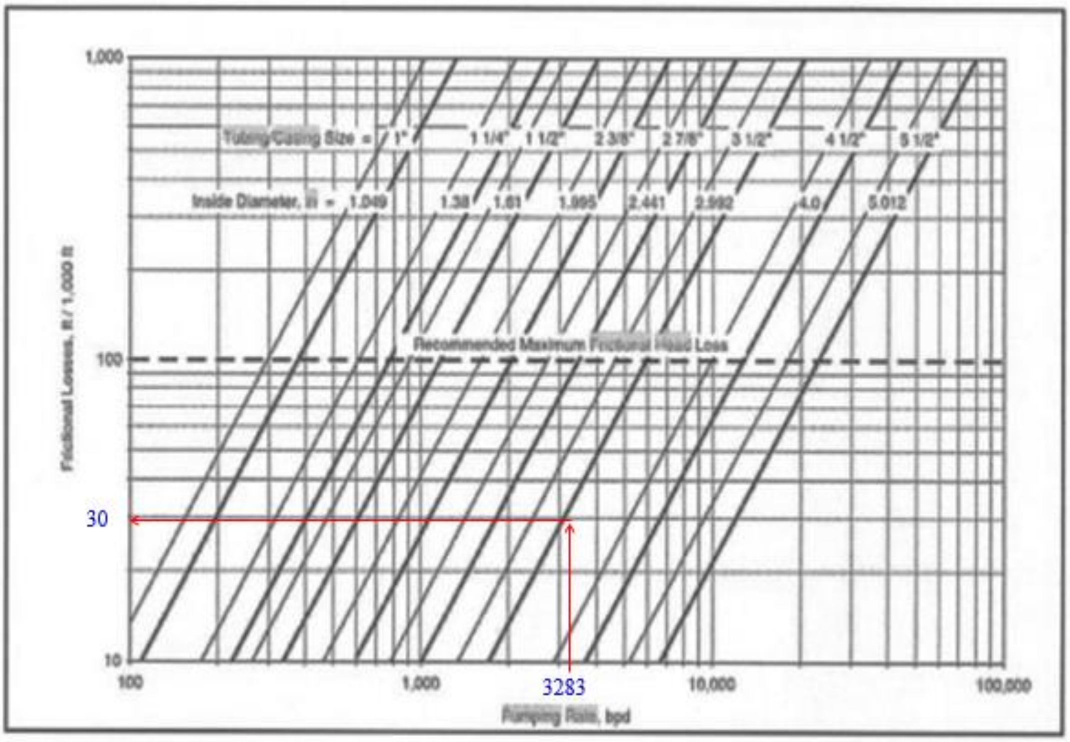

Figure (4): Friction Loss (Ft) of FD32. (Sevin, B., November 12 – 14, 1991).

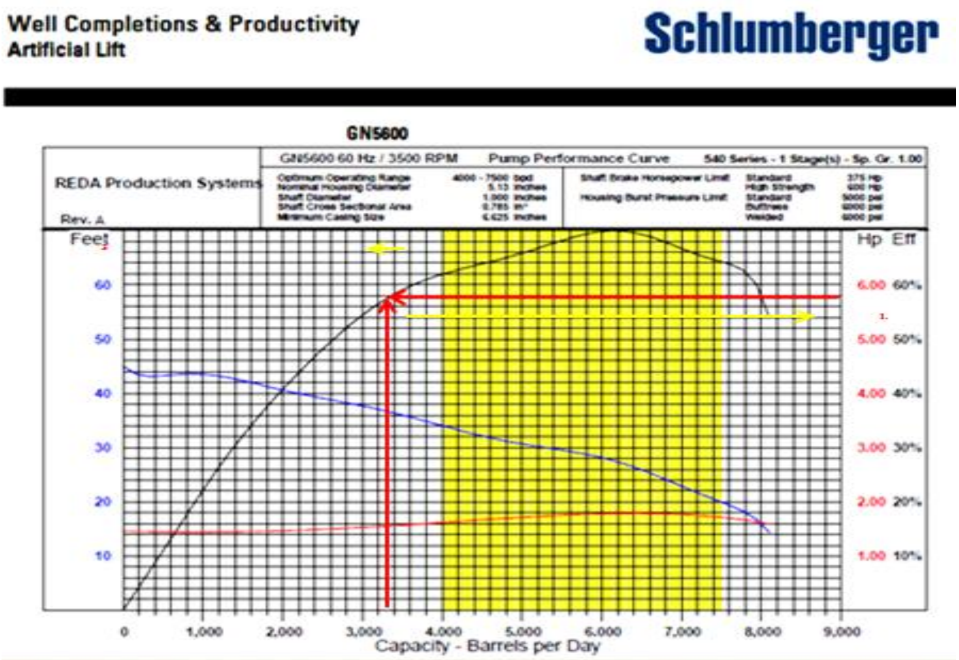

Figure (5): Flow Efficiency of FD32 (Gabor Takacs, May 2009).

Table (3): Pump Selection.

EFFICIENCY (%)	HEAD (ft /stage)	HP per stage (ft/stage)	NO. SERIES	TYPE
58	37	1.6	540	SN-3600 60 HZ

5 Calculating the Required Number of Stage

NO. Of stages required = TDH / Head per stage.

$$\textbf{NO. Of stages required} = \frac{6121}{37} = 165 \ \ Stages$$

Motor Selection

HP required = HP per stage × NO. Of stages × S.G + 5

= 1.6*165*0.919+5 = 247 HP

6. Determining the motor voltage and motor amperes

Table (4): Determine the Motor Voltage and Motor Amperes. (Sevin, B., November 12 – 14, 1991).

Well Completions & Productivity
Artificial Lift

Schlumberger

540 Series Motors - SK Type

HP 60 HZ	HP 50 HZ	Volts 60 HZ	Volts 50 HZ	Amps	Type	L (Ft)	Wt (Lbs)	SK Carbon Steel Part Number	SK Redalloy Part Number
125	104	1315	1096	60	S	15.7	1007	1049246	1049469
					UT	15.8		1049311	1049535
		2425	2021	32	S	15.7	1007	1049238	1049451
					UT	15.8		1049303	1049527
150	125	1170	975	78	S	19.4	1194	1059864	1060318
					UT	18.5		1060011	1060466
					CT	18.8		1066570	1066646
		2380	1983	38	S	19.4	1194	1059955	1060409
					UT	18.5		1060102	1060557
175	146	1070	892	99.5	S	22.2	1380	1066829	1066968
					UT	21.2		1066430	1066992
					CT	21.5		1066589	1066653
		1350	1125	78.5	S	22.2	1380	1066836	1066976
					UT	21.2		1066448	1067008
					CT	21.5		1066596	1066661
		2200	1833	48	S	22.2	1380	1059872	1060326
					UT	21.2		1060029	1060474
200	167	1220	1017	99	S	24.1	1580	1059880	1060334
					UT	24.0		1060037	1060482
					CT	24.3		1066604	1066679
		2175	1813	56	S	24.1	1580	1059898	1060342
					UT	24.0		1060045	1060490
		4140	3450	29	S	24.1	1580	1108786	TBA
225	188	1000	833	133	S	27.6	1793	1059906	1060359
					UT	26.7		1060052	1060508
					CT	27.0		1066612	1066687
		1365	1138	100	S	27.6	1793	1066844	1066984
					UT	26.7		1066455	1067016
					CT	27.0		1066620	1066695
		2075	1729	64	S	27.6	1793	1059914	1060367
					UT	26.7		1060060	1060516
		2425	2021	56	S	27.6	1793	1059922	1060375
					UT	26.7		1060078	1060524
250	208	1100	833	135.5	S	30.4	1978	1059930	1060383
					UT	29.5		1060086	1060532
					CT	29.7		1066638	1066703
		1375	1146	110	UT	29.5	1978	1105873	TBA
					CT	29.7		1105881	TBA
		2300	1917	65	S	30.4	1978	1059949	1060391
					UT	29.5		1060094	1060540

7. Determining Voltage Drop in the Cable & Correction Factor

Voltage drop in the cable = 23

Correction factor = 1.21

Table (5): Motor Selection.

Motor Amperes	Motor Voltage	Motor Hp	Motor Series
65	2300	249	540, 60 HZ

8. Calculate Voltage Drop (VD)

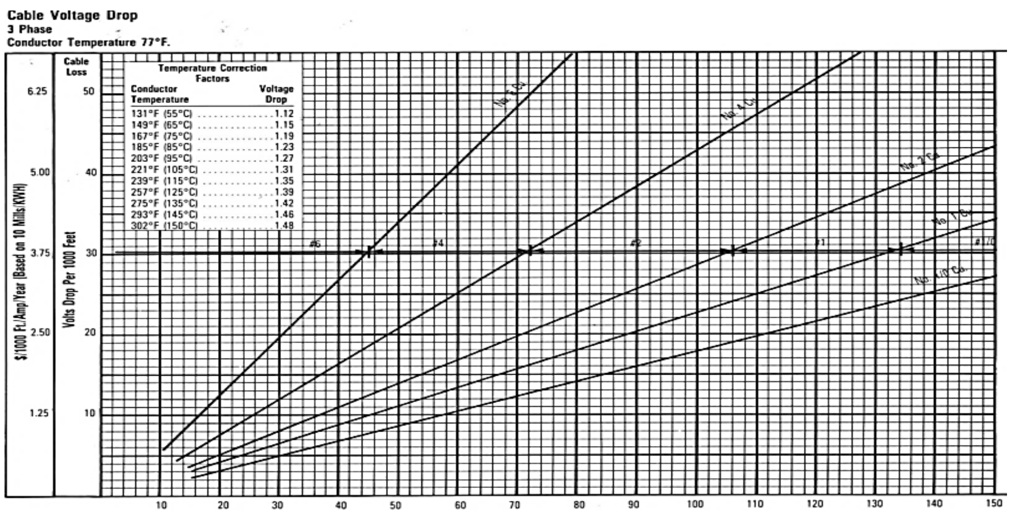

Figure (6): Voltage Drop (VD) Well of FD32 (Gilbert, W.E., 126 – 57, 1954).

$$VD = \frac{total - depth * correction factor * voltage drop per.1000\,ft}{1000}$$

$$VD = \frac{6980 * 1.21 * 25}{1000} = 211.14 Volt$$

9. Calculating the Required Surface Voltage (Vs)

Vs = Voltage Drop + Motor Voltage

=211.14+2300=2511.14

10. Calculating the Size of Transformer (KVA)

$$KVA = \frac{1.732 * Vs * Amp}{1000}$$

$$KVA = \frac{1.732 * 2511.14 * 65}{1000} = 282.7$$

11. Calculating the Fluid Velocity Beside the Motor (Vf)

$$Vf = 1.19 \times 10^{-2} \frac{Q}{ID_C^{\ 2} - 0D_m^{\ 2}}$$

$$Vf = 1.19 \times 10^{-2} \frac{3283}{6.23 - 5.4}$$

Table (6): Select of Motor.

Cooling efficiency	VF	KVA	VS	VD	HP	TYPE
GOOD	19Ft/sec	282.7	2511.14volt	211.14 volt	249 hp	540,60 HZ

Weight (Ibm)	Length(ft)	Actual No. Of Stages	Series	Pump Type
1978	30	166	540	SN-3600,60Hz

Calculations of Well (FB18)

1. Calculating the Oil Specific Gravities, Average Liquid Gradient, and Average Fluid Specific Gravities

$$(\gamma_o) \text{ oil Sp.gr} = \frac{1415}{131.5 + API}$$

$$(\gamma_o) \text{ oil Sp.gr} = \frac{1415}{131.5 + 38} = 0.732$$

$$Average\ \ Sp.Gr(\ \gamma_{ave}\ ) = (\gamma_o * O_c) + (\gamma_w * W_C)$$

$$Average\ \ Sp.Gr(\ \gamma_{ave}\ ) = (0.732 * 0.65) + (1.04 * 0.35) = 0.839$$

$$L.G = \gamma_{ave} * 0.433$$

$$L.G = 0.839 * 0.433 = 0.363 psi / ft$$

2. Calculating Flowing Bottom Hole Pressure (Pwf).

Pwf = Pws – (Q/PI)

= 950-(6180/23) = 681 Psi

3. Total Dynamic Head Calculation

TDH = Hd + Pd + Ft

3.1 Dynamic Fluid Level (Hd)

Hd= Datum – (Pwf / ALG)

= 8588 – (681 /0.363) = 5200 ft

3.2 Well Head (Pd)

Pd = (Pwh / ALG)

= 115/0.363 = 316.8 ft

3.3 Frictional Head Loss in 3.5” Tubing @ 6180 B/D

By using frictional head chart

Friction loss (ft) = (28/1000 ft) * Pump set depth

= 0.030 * 6200 = 186 ft

TDH = 5200 + 316.8 + 186 = 5700 ft

Figure (7): Friction Loss (Ft) of FB18 (Sevin, B., November 12 – 14, 1991).

4. Pump Selection

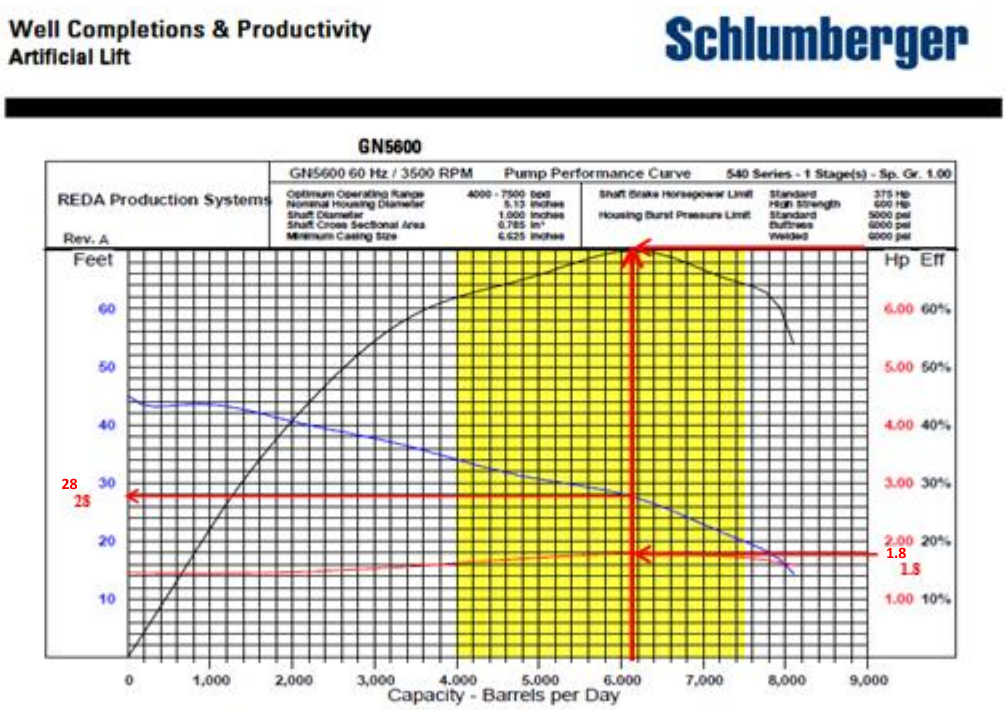

Figure (8): Flow Efficiency of FB18 (Gabor Takacs, May 2009).

Table (7): Pump Selection.

EFFICIENCY (%)	HEAD (ft /stage)	HP per stage(ft/stage)	NO. SERIES	TYPE
58	28	1.8	540	HN-3600,60 HZ

5. Calculating the Required Number of Stage

NO. Of stages required = TDH / Head per stage.

$$\textbf{NO. Of stages required} = \frac{5700}{28} = 204 \ \ Stages$$

6. Motor Selection

HP required = HP per stage × NO. Of stages × S.G + 5

= 1.8*204*0.839+5 = 313 HP

7. Determining the Motor Voltage and Motor Amperes

Table (8): Determine the Motor Voltage and Motor Amperes. (Sevin, B., November 12 – 14, 1991).

Well Completions & Productivity
Artificial Lift

Schlumberger

540 Series Motors - SK Type

HP (60 HZ)	HP (50 HZ)	Volts (60 HZ)	Volts (50 HZ)	Amps	Type	L (Ft)	Wt (Lbs)	SK Carbon Steel Part Number	SK Redalloy Part Number
125	104	1315	1096	60	S	15.7	1007	1049246	1049469
					UT	15.8		1049311	1049535
		2425	2021	32	S	15.7	1007	1049238	1049451
					UT	15.8		1049303	1049527
150	125	1170	975	78	S	19.4	1194	1059864	1060318
					UT	18.5		1060011	1060466
					CT	18.8		1066570	1066646
		2380	1983	38	S	19.4	1194	1059955	1060409
					UT	18.5		1060102	1060557
175	146	1070	892	99.5	S	22.2	1380	1066828	1066968
					UT	21.2		1066430	1066992
					CT	21.5		1066588	1066653
		1350	1125	78.5	S	22.2	1380	1066836	1066976
					UT	21.2		1066448	1067008
					CT	21.5		1066596	1066661
		2200	1833	48	S	22.2	1380	1059872	1060326
					UT	21.2		1060029	1060474
200	167	1220	1017	99	S	24.1	1580	1059880	1060334
					UT	24.0		1060037	1060482
					CT	24.3		1066604	1066679
		2175	1813	56	S	24.1	1580	1059898	1060342
					UT	24.0		1060045	1060490
		4140	3450	29	S	24.1	1580	1108786	TBA
225	188	1000	833	133	S	27.6	1793	1059906	1060359
					UT	26.7		1060052	1060508
					CT	27.0		1066612	1066687
		1365	1138	100	S	27.6	1793	1066844	1066984
					UT	26.7		1066455	1067016
					CT	27.0		1066620	1066695
		2075	1729	64	S	27.6	1793	1059914	1060367
					UT	26.7		1060060	1060516
		2425	2021	56	S	27.6	1793	1059922	1060375
					UT	26.7		1060078	1060524
250	208	1120	933	135.5	S	30.4	1978	1059930	1060383
					UT	29.5		1060086	1060532
					CT	29.7		1066638	1066703
		1375	1146	110	UT	29.5	1978	1105873	TBA
					CT	29.7		1105881	TBA
		2300	1917	65	S	30.4	1978	1059948	1060391
					UT	29.5		1060094	1060540

8. Determining Voltage Drop in Cable & Correction Factor

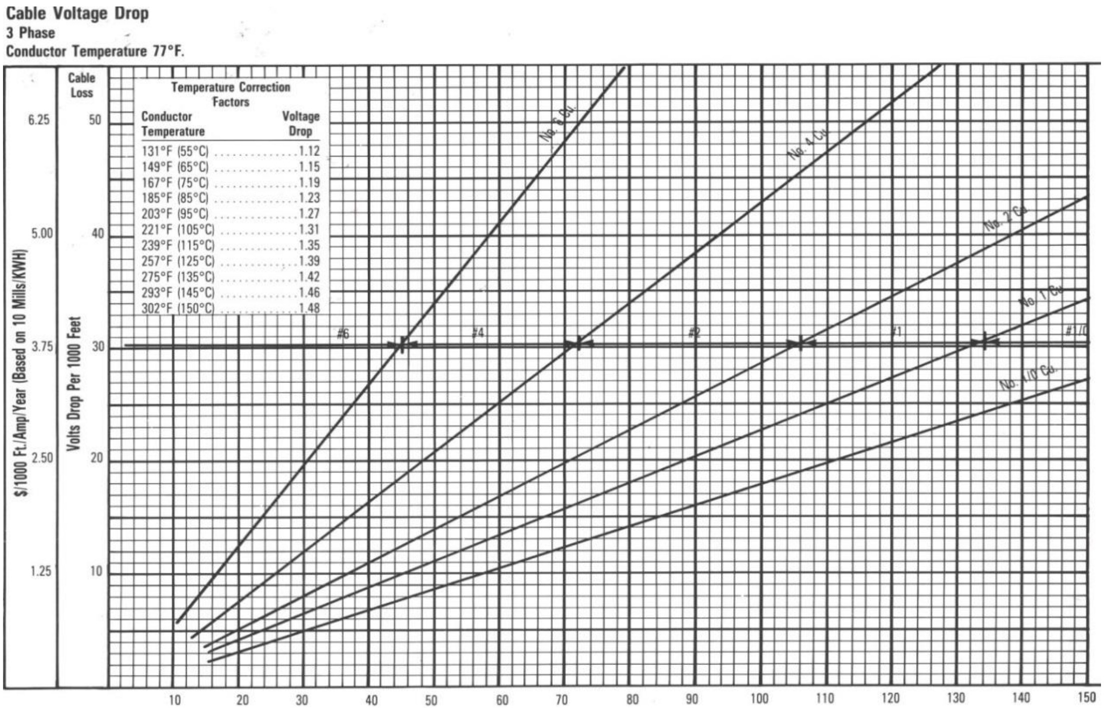

Figure (9): Voltage Drop (VD) Well of FB18. (Gilbert, W.E., 126 – 57, 1954).

Voltage drop in the cable = 25

Correction factor = 1.23

9. Calculate Voltage Drop (VD)

Table (9): Determine the Motor Voltage and Motor Amperes.

Motor Amperes	Motor Voltage	Motor Hp	Motor Series
65	2300	249	540,60 HZ

10. Calculating Voltage Drop

$$VD = \frac{total - depth * correction \ \ factor * voltage \ dropper.1000\, ft}{1000}$$

$$VD = \frac{8588 * 1.23 * 25}{1000} = 264 \ Volt$$

11. Calculating the Required Surface Voltage (Vs)

Vs = Voltage Drop + Motor Voltage

=264+2300=2564

12. Calculating the Size of Transformer (Kva)

$$KVA = \frac{1.732 * Vs * Amp}{1000}$$

$$KVA = \frac{1.732 * 2564 * 65}{1000} = 288$$

13. Calculating the Fluid Velocity Beside the Motor (Vf)

$$Vf = 1.19 \times 10^{-2} \frac{Q}{ID_C{}^2 - 0D_m{}^2}$$

$$Vf = 1.19 \times 10^{-2} \frac{6180}{6.23 - 5.4}$$

Table (10): Select Motor.

Cooling efficiency	VF	KVA	VS	VD	HP	TYPE
GOOD	19.2Ft/sec	288	2564 volt	264 volt	249 hp	540,60 HZ

Table (11): Calculations of Well (FB-18).

EFFICIENCY (%)	HEAD (ft /stage)	HP per stage (ft/stage)	NO. SERIES	TYPE
70	**28**	**1.8**	**540**	HN-3600,60 HZ

Weight (Ibm)	Length (ft)	Actual No. of Stages	Series	Pump Type
1978	30	204	540	HN-3600,60Hz

Results of ESP Design

Through the calculations for the design of the electric submersible pump for the two wells, the following information must be taken into account:

Table (12): Results of ESP Design.

Motor data						Pump selection				Well Number
hp	**volts**	**Amp**	**Vf (Ft/sec)**	**KVA**	**Motor type**	**TDH (Ft)**	**Pump type**	**Stages**	**Pump Depth (Ft)**	
247	2300	65	19Ft/sec	282.7	562	6107	SN-3600	166	5665	FD32
313	2300	65	9.2Ft/sec	288	562	6646	HN-3600 540	204	5653	FB18

Conclusion

Through the calculations for the design of the electric submersible pump for the two wells, the following points must be taken into account:

1- For FD32 well, to produce the required rate of 283STB/d, SN-3600 must be used and this requires 166 phases, 2300 volts, 65 amps, and 282.7 KVA.

2- For FB18 well, to produce the required rate of 6180STB/d, HN-3600 pump must be used, and this requires 204 phases, 2300 volts, 65 amps, and 288 KVA.

References

- Beggs, H.D., OGCI Publications, 1991. “Production Optimization Using Nodal Analysis”.
- Brown, K.E.,1980, “The Technology of Artificial Lift Methods”, Vol.2bPennWell Books, Tulsa, Oklahoma.
- Gabor Takacs, May 2009, “Electrical submersible pump manual: design, operations, and maintenance”.
- Gilbert, W.E.,126 – 57, 1954. “Flowing and Gas-Lift Well Performance”, API Drilling and Production Practice, 126 – 57, 1954.
- http://www.Mellitah Oil & Gas Company.
- John Bearden, August 2007, “Electrical Submersible Pumps”, Petroleum Engineering Handbook published by SPE, Volume IV.
- Sevin, B., November 12 – 14, 1991, “Design and Application of Submersible Pumps in Horizontal Wells in South Texas”, Paper presented at the 3rd International Conference on Horizontal Well Technology in Houston, Texas.