Planning Design of Artificial Lift Hydraulic Jet Pump at Suspend Well in PT Pertamina EP Field

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ABSTRACT

Artificial lift aims to assist to lift fluid from the bottom of the well (reservoir) to the surface. Well-X is a suspend well planned to be reactivated using artificial lift suitable for further production operations. The Water Injection Plant's availability as a power fluid supply makes the Hydraulic Jet Pump an efficient artificial lift to be operated on wells in this field. Hydraulic Jet Pump design planning requires well data, reservoir data, production data, fluid characteristic data and Pressure, Volume, Temperature for calculations with quantitative methods. The surface injection pressure parameter is subjected to sensitivity analysis to obtain the production rate that can be optimally produced in accordance with the Inflow Performance Relationship. The results of the analysis show that the surface injection pressure in the range of 500-800 psi does not intersect with the Inflow Performance Relationship Figure and is recommended not to exceed 2000 psi with the limitation of cavitation value and Maximum Allowable Working Pressure according to existing data in the field.

Keywords: Suspend, Reactivation, Hydraulic Jet Pump

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1. Introduction

The current demand for oil and gas in Indonesia is not proportional to the production. According to Arifin Tasrif, Minister of Energy and Mineral Resources (ESDM) who revealed that reserves in Indonesia are estimated to last only 9 to 10 years if there is no discovery of new oil and gas reserves in reservoirs in Indonesia's oil and gas fields. There are several strategies prepared to increase oil and gas production to achieve the production target of 1 million barrels per day (bpd) by 2030. The planned strategy is to increase well exploration, optimize wells, and reactivate Iddle (suspended) Wells that are considered to still have the potential to store oil and gas reserves.

Field facts in this well research, it is known that the water content began to dominate, so the well was deactivated (suspended well) because the well was considered no longer economical.[1] In addition, the use of artificial lift methods with the Electrical Submersible Pump (ESP) type is no longer economically valuable in this well with slowly decreasing production.[2] However, it is possible to reactivate suspend wells with all the considerations available as optimization to increase production by re-opening old wells that are expected to produce the targeted or expected production. If the well has been reactivated, another type of artificial lift method will be used, one of which is the Hydraulic Jet Pump with consideration of the availability of existing facilities in the field such as the Water Injection Plant (WIP) as a supply of power fluid).

The working principle of this Hydraulic Jet Pump, pressurized fluid coming out of the nozzle will pass through the narrowing (venturi effect). This is an interpretation of the Bernoulli principle law which states that in a fluid flow, the fluid velocity will increase which can cause a decrease in pressure in the flow. Then the power fluid will decrease in pressure which can allow the production fluid from the reservoir to flow from high to low pressure.[3] In addition, the high temperature of the power fluid causes the viscosity to decrease so that the fluid can be lifted to flow up to the surface to be produced. The production fluid will flow at low pressure and mix with the injected pressurized fluid. Then both pressurized fluid and production fluid will be simultaneously produced to the surface. This type of artificial lift has not previously been installed in this field. [4]Consideration of the selection of artificial lift methods in accordance with the conditions in the field is needed so that the Hydraulic Jet Pump design planning can be analyzed based on available data to produce appropriate calculations. Jet Pump have advantages such as produce high fluid[5] volume, no moving part , and easily retrieved and replace.[6] Another advantages is tolerance to gas.[7] Furthermore, an evaluation will be carried out on the artificial lift against changes in production rates if a Hydraulic Jet Pump installation is carried out in the research field where there is a suspend well to find out how far the performance is owned to achieve the optimal production rate. [8]

2. Methods

This research will discuss how to calculate the design before the Hydraulic Jet Pump will be installed using the quantitative calculation method so that the performa analysis of the artificial lift type can be carried out as in the research flow diagram in Figure 1.

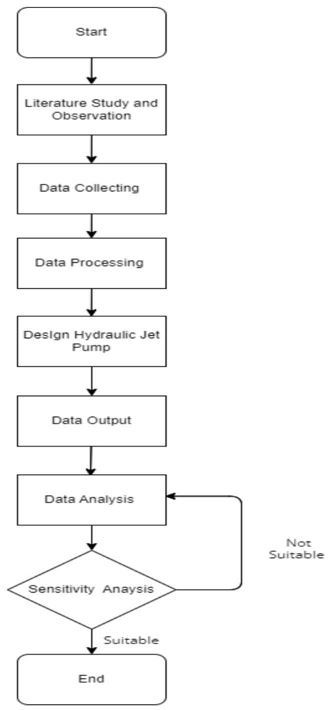

Figure 1 Research Flow Chart

Based on the field data obtained, data processing is carried out with the calculation stages of the artificial lift Hydraulic Jet Pump design as follows:

1. Determine the gradient value of suctioned production fluid (G_s)

$$G_s = G_o\ (1-f_w) + G_w\ f_w \qquad (1)$$

where,

$$G_x = 0.433 \text{ x } SG_x \qquad (2)$$

2. Determine the gradient value of power fluid (G_n)

$$G_n = 0.433 \text{ x } SG_{powerfluid} \qquad (3)$$

3. Determine the minimum value of the suction area (A_{min})

$$A_{min} = q_s \left[\frac{1}{691}\sqrt{\frac{G_s}{P_s}} + \frac{(1-f_w)GOR}{24650\ P_s}\right] \qquad (4)$$

Where,

$$p_s = Pwf \text{ x } \Delta p \qquad (5)$$

= Pwf x (Depth bottom perforation – Pump Depth)

4. Annular area selection

In selecting the annular area, the selected value must be greater than the minimum section area area (A_{min}) that has been calculated in Equation (4) to avoid cavitation.

5. Selection of injection pressure value on the surface (P_{inj})

This surface injection pressure value is based on the Kobe Inc. specification in Table 1, which is in the range of values between 500 and 2500 psi. This selection is based on consideration of other parameters that can affect cavitation.

Table 1 Nozzle - Throat Size Spesification

Manufacturer A				Manufacturer B				Manufacturer C			
Nozzle		Throat		Nozzle		Throat		Nozzle		Throat	
Number	Area	Number	Area	Number	Area	Number	Area	Number	Area	Number	Area
1	0.0024	1	0.0064	1	0.0024	1	0.0060	DD	0.0016	000	0.0044
2	0.0031	2	0.0081	2	0.0031	2	0.0077	CC	0.0028	00	0.0071
3	0.0039	3	0.0104	3	0.0040	3	0.0100	BB	0.0038	0	0.0104
4	0.0050	4	0.0131	4	0.0052	4	0.0129	A	0.0055	1	0.0143
5	0.0064	5	0.0167	5	0.0067	5	0.0167	B	0.0095	2	0.0189
6	0.0081	6	0.0212	6	0.0086	6	0.0215	C	0.0123	3	0.0241
7	0.0103	7	0.0271	7	0.0111	7	0.0278	D	0.0177	4	0.0314
8	0.0131	8	0.0346	8	0.0144	8	0.0359	E	0.0241	5	0.0380
9	0.0167	9	0.0441	9	0.0186	9	0.0464	F	0.0314	6	0.0452
10	0.0212	10	0.0562	10	0.0240	10	0.0599	G	0.0452	7	0.0531
11	0.0271	11	0.0715	11	0.0310	11	0.0774	H	0.0661	8	0.0661
12	0.0346	12	0.0910	12	0.0400	12	0.1000	I	0.0855	9	0.0804
13	0.0441	13	0.1159	13	0.0517	13	0.1292	J	0.1257	10	0.0962
14	0.0562	14	0.1476	14	0.0668	14	0.1668	K	0.1590	11	0.1195
15	0.0715	15	0.1879	15	0.0863	15	0.2154	L	0.1963	12	0.1452
16	0.0910	16	0.2392	16	0.1114	16	0.2783	M	0.2463	13	0.1772
17	0.1159	17	0.3046	17	0.1439	17	0.3594	N	0.3117	14	0.2165
18	0.1476	18	0.3878	18	0.1858	18	0.4642	P	0.3848	15	0.2606
19	0.1879	19	0.4938	19	0.2400	19	0.5995			16	0.3127
20	0.2392	20	0.6287	20	0.3100	20	0.7743			17	0.3750
						21	1.0000			18	0.4513
						22	1.2916			19	0.5424
						23	1.6681			20	0.6518
						24	2.1544				

6. Calculating the pressure on nozzle (P_n)

$$P_n = P_{inj} + G_n\ D - \Delta P_f \qquad (6)$$

7. Calculating the flow rate of nozzle (q_n)

$$q_n = 832\ A_n \sqrt{\frac{P_n - P_s}{G_n}} \qquad (7)$$

8. Determine the value of the mixed fluid property (power fluid and production fluid)

- Flow rate discharge (q_d)

$$q_d = q_n + q_s \qquad (8)$$

- Discharge water cut (f_{wd})

$f_{wd} = \frac{q_n + f_w\, q_s}{q_d}$ (9)

- Discharge Gas Oil Ratio (GOR_d)

$GOR_d = \frac{q_s + (1 - f_w)\, GOR}{q_d\, (1 - f_{wd})}$ (10)

- Discharge viscosity

$\mu_s = \mu_o\, (1 - f_w) + \mu_w\, f_{wd}$ (11)

9. Calculate the discharge pressure value with Hagedorn and Browm Correlation.

10. Calculating the value dimensionless pressure ratio (F_{pD})

$F_{pD} = \frac{P_d + P_s}{P_n - P_d}$ (12)

11. Calculating the value dimensionless mass flow ratio (F_{mfD})

$F_{mfD} = \frac{q_s[(1 + 2.8(\frac{GOR}{P_s})^{1.2})\, (1 - f_w) + f_w]\, G_s}{q_n\, G_n}$ (13)

12. Check the value of the dimensionless mass ratio between the calculation in Equation (13) Jet Pump Dimensionless Performance Curve

$\mathbf{q_s^{new} = q_s^{old}\, \frac{F_{mfD}^{read}}{F_{mfD}^{calculated}}}$ (14)

13. Calculate area throat

$A_t = \frac{A_n}{F_{aD}}$ (15)

14. Calculate the limit of the cavitation rate (q_{sc})

$q_{sc} = q_{si}\, \frac{(A_t - A_n)}{A_{cm}}$ (16)

15. Calculate the pump power

$HP_{triplex} = 1.89 \times 10^{-5}\, q_n\, P_{inj}$ (17)

16. Repeat the above steps with different surface injection pressure values.

17. Create a sensitivity analysis drawing to compare the performance of the plan artificial lift Hydraulic Jet Pump.[9]

3. Results

Suspend well NVR-057 in PT Pertamina Hulu Indonesia Regional 3 Zone 9 Sangatta Field, East Kalimantan is planned for reactivation to increase the existing production rate in the field. [10]After this well is successfully reactivated, it is necessary to plan an artificial lift method that is in accordance with field conditions with the availability of supporting facilities in the field. With the supporting data from the well, the installation will be planned using the artificial lift method with the Hydraulic Jet Pump type. Reservoir data, production data, fluid characteristics data and PVT (Pressure, Volume, Temperature) [11] as in Table 1 and active well data before the well became a suspend well in Table 2 are used to produce design specifications that are in accordance with field conditions with the calculation stages from Equation (1) until (17)

Table 2 Hydraulic Jet Pump Design

Data	Nilai	Satuan
Well & Reservoir Data		
ID Tubing	2.441	inch
Depth	4167	ft
Setting depth	2952	ft
Preservoir	1182	psi

Bottomhole Temperature	158	Farenheit
Surface Temperature	85	Farenheit
Production Data		
Production rate/Intake flow rate	220	bbl/d
Fluid Characteristics & PVT		
Oil Spesific Gravity	0.86	
Water Spesific Gravity	1.01	
Gas Spesific Gravity	0.8	
Water Cut	98	%
Oil Viscosity	0.62	cSt
Water Viscosity	0.6	cSt
Gas Oil Ratio	405	scf/bbl
Pump Intake Pressure	1011	psi
Ploss	0	psi
Diameter pipe	2.875	inch

Table 3 Well Data in 2020

Well Data 2020		
Static level	53	meter
Flowing level	208	meter
Pump depth	900	meter
Bottom Perfo	982	meter
Production rate	227	bbl/day
Preservoir/SBHP	1182	psi
Pwf	1033	psi
Qmax	1060	bbl/day

From the last active well data in Table 3, the Pump Intake Pressure value based on the targeted production rate can be determined according to the maximum production rate (q_{max}) value depicted by the Inflow Performance Relationship in Figure 2.[12]

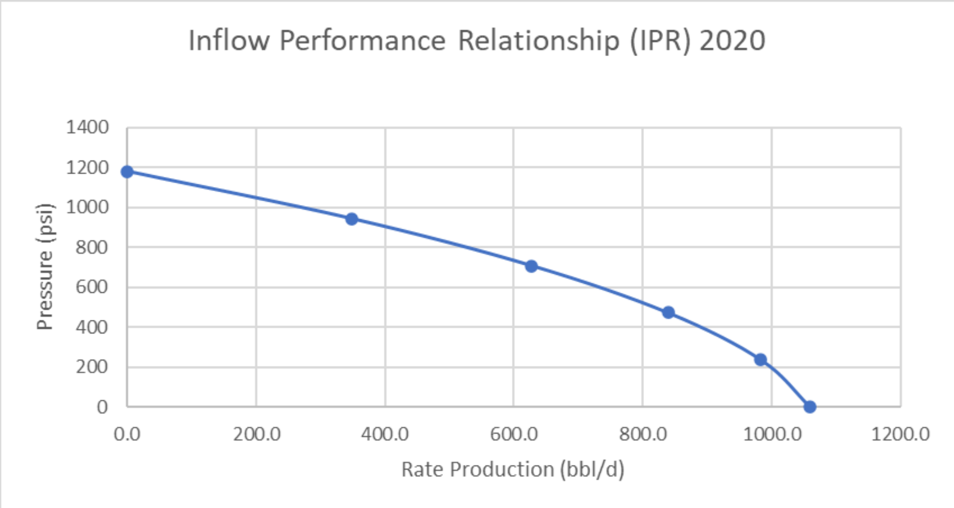

Figure 2 Inflow Performance Relationship 2020

Based on Figure 2, the intake pump pressure value can be known as the discharge pressure as in Table 4, and the discharge pressure value with the Hagedorn and Brown correlation as in the 9th stage. The data parameters in Table 4 are used to determine other parameters until the value of the production rate that may be produced is known as in Table 5 and Table 6.

Table 4 Pump Intake Pressure and Discharge Pressure Data at a Specific Rate

Liquid Rate (bbl/d)	Pump Intake Pressure (psi)	Pdischarge (psi)
100	1082	1417
100	1082	1417
200	1011	1375
300	966	1341
400	886	1312
500	786	1286
600	746	1265
700	626	1243
800	526	1226
900	386	1209
1000	186	1194

Table 5 Data on Pump Intake Pressure 1011 psi

Pump Intake Pressure (psi)	Surface Injection Pressure (psi)	Dimensionless Pratio	Dimensionless mass flow ratio	Read	Liquid Rate New (bbl/d)
1082 psi	500	0.9	0.6	0.12	19
	600	0.7	0.57	0.13	23
	700	0.58	0.53	0.25	46
	800	0.49	0.51	0.48	94
	900	0.43	0.48	0.74	152
	1000	0.38	0.46	0.82	176

Pump In-take Pressure (psi)	Surface Injection Pressure (psi)	Dimensionless Pratio	Dimensionless mass flow ratio	Read	Liquid Rate New (bbl/d)
	1100	0.34	0.44	1	223
	1200	0.31	0.43	1.1	255
	1300	0.28	0.41	1.18	283
	1400	0.26	0.4	1.22	302
	1500	0.24	0.39	1.26	321
	1600	0.22	0.38	1.38	362
	1700	0.21	0.37	1.4	377
	1800	0.2	0.36	1.44	396
	1900	0.18	0.35	1.5	425
	2000	0.178	0.34	1.51	436
	2100	0.169	0.336	1.56	463
	2200	0.161	0.329	1.58	479
	2300	0.15	0.32	1.6	495
	2400	0.147	0.316	1.64	517
	2500	0.141	0.31	1.7	546

Table 6 Data on Pump Intake Pressure 186 psi

Pump In-take Pressure (psi)	Surface Injection Pressure	Dimensionless Pratio	Dimensionless mass flow ratio	Read	Liquid Rate New (bbl/d)
186 psi	500	1.68	4.64	0.1	21
	600	1.4	4.51	0.18	39
	700	1.26	4.38	0.2	45
	800	1.12	4.26	0.22	51
	900	1	4.16	0.25	60
	1000	0.9	4	0.3	73
	1100	0.84	3.96	0.35	85
	1200	0.77	3.87	0.38	98
	1300	0.72	3.79	0.4	105
	1400	0.67	3.72	0.41	110
	1500	0.63	3.64	0.415	113
	1600	0.59	3.58	0.43	120
	1700	0.56	3.51	0.45	128
	1800	0.53	3.45	0.46	133
	1900	0.5	3.39	0.48	141
	2000	0.48	3.34	0.5	149
	2100	0.45	3.29	0.52	158
	2200	0.43	3.24	0.54	166
	2300	0.42	3.19	0.55	172
	2400	0.4	3.14	0.56	178

Pump Intake Pressure (psi)	Surface Injection Pressure	Dimensionless Pratio	Dimensionless mass flow ratio	Read	Liquid Rate New (bbl/d)
	2500	0.38	3.1	0.57	182

Table 7 Cavitation Data

Liquid Rate	Fad	An (in)	At (in)	Cavitation (bbl/d)
220 bbl/d	0.3	0.005	0.0167	384
	0.5	0.005	0.01	149

4. Discussion

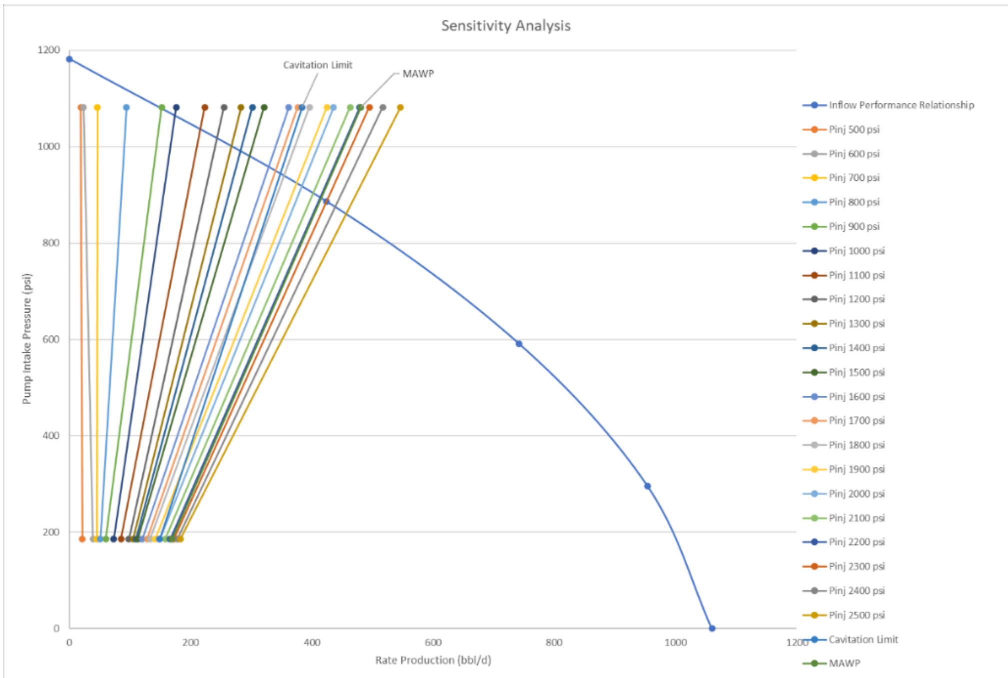

Figure 3 Sensitivity Analysis: MAWP and Cavitation Limit

This sensitivity analysis uses the parameters of the estimated production rate that can be produced with the surface injection pressure value. The sensitivity analysis was performed on a range of pump intake pressure values from 1011 psi to 186 psi as shown in Table 4. This value is based on the target production rate estimated based on previous production data, namely with a well capable of producing approximately 200 bbl/d. In this sensitivity analysis, injection pressures of 500 psi to 800 psi do not intersect with the Inflow Performance Relationship graph. Figure 3 also shows that surface injection pressures of more than 2000 psi are not recommended for use in nozzle and throat areas that have been designed with several requirements and considerations. Pressures above 2000 psi exceed the limits of cavitation as shown in Table 7 or the formation of gas in the flow which is something that is avoided as well as the limitation of the Maximum Allowable Working Pressure (MAWP) value of 2250 psi according to the availability and conditions in the field.

Based on Figure 4, the relationship between surface injection pressure and pump power is comparable. The greater the surface injection pressure value, the greater the pump power. The calculation of the required power value is influenced by several parameters, namely surface injection pressure, pressure at the nozzle, pump intake pressure, and flowrate at the nozzle.

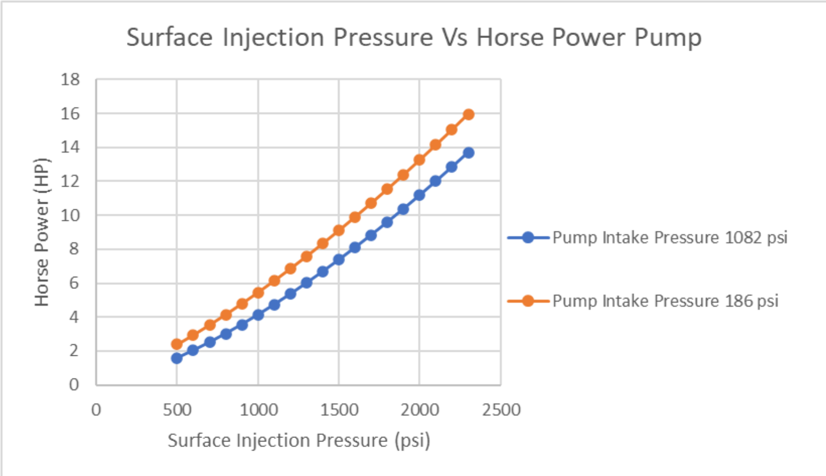

Figure 4 Surface Injection Pressure vs. horse Power

5. Conclusion

Based on the Hydraulic Jet Pump design calculation research, several things can be concluded, namely as follows:

1. The installation of Artificial Lift Hydraulic Jet Pump in the reactivation of well NVR-057 can be an option with consideration of sufficient performance, production rate, relatively low cost, temperature and other parameters such as the availability of Water Injection Plant (WIP) in the field as a pressurized fluid supply.
2. Hydraulic Jet Pump design is obtained from the calculation of well and reservoir data, production data, PVT data, and fluid properties that can produce output values of nozzle area, throat area, surface injection pressure, production rate, and pump power.
3. Hydraulic Jet Pump design calculations result in a recommended size of 4 manufacturer A nozzle and 5 manufacturer A throat by specifications. The maximum pump power required is 13 HP.
4. Factors affecting changes in production rates are the limitation of surface injection pressure values, cavitation, and Maximum Allowable Working Pressure (MAWP).
5. The sensitivity analysis figure shows the effect of surface injection pressure that can produce the optimal production rate where the values of 500 psi to 800 psi do not intersect. Then the magnitude of the value can not achieve the production rate under the conditions of the well. If the value is greater than 2000 psi, cavitation or gas formation in the flow may occur. The maximum value is based on the limitation of the Maximum Allowable Working Pressure (MAWP) value of 2250 psi according to existing data in the field.

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List of Symbols

A_{min} : *Minimum section area*, sq. in
A_n : *Nozzle area*, sq.in
A_t : *Area throat,* sq.in
D : *Pump depth*, ft
f_w : *Water cut*, %
f_{wd} : *Discharge water cut*, %
F_{ad} : $\frac{Area\ Nozzle}{Area\ Thorat}$
G_n : *Power fluid gradient (nozzle)*, psi/ft
G_s : *Pump intake gradient*, psi/ft
G_o : *Oil gradient*, psi/ft
GOR : *Gas-Oil Ratio*, SCF/bbl
SG : *Spesific Gravity*
P_d : *Discharge pressure*, psi
q_s^{new} : *Intake flow rate new*, bbl/d
P_{inj} : *Surface injection pressure*, psi
P_n : *Pressure at nozzle*, psi
p_s : *Pump intake pressure*, psi
q_d : *Discharge flow rate*, bbl/d
q_n : *Flowrate of nozzle*, bbl/d
q_s : *Pump intake flowrate*, bbl/d
q_{sc} : *Flow rate before cavitation*, bbl/d
q_{si} : *Initial assumed value of* qs (prod), bbl/d
ΔP_f : *Friction losses*, psi
μ_s : *Discharge viscosity*, cSt
μ_o : *Oil viscosity*, cSt
μ_w : *Water viscosity*, cSt
F_{mfD} : *Dimensionless mass flow ratio*