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GASLIFT OPTIMIZATION IN HIGHLY DEVIATED WELLS

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KeyWords
Gaslift, Optimization, Highly deviated, Wells.

ABSTRACT

Although gas lift technology has been applied to lift oil production in highly deviated wells increasingly, the differences between the gas lift design of deviated and vertical wells still exist. How these differences vary with the increase of the angle of inclination, which parameters are more sensitive to the design differences and how to choose the design parameters reasonably to optimize the gas lift design in the deviated wells are all always the difficulties for gas lift design reasonable in the deviated wells and few studies have been done in this field. In view of these problems, this work takes a deviated well of an oilfield as an example. According to the measured data, the optimum method for productivity prediction calculation is chosen for the design for gas lift in the deviated and vertical wells in the same conditions. By keeping other parameters constant and only changing the value of important parameter one by one, the changing regularity of gas injection depth and production with the change of inclination angles are analyzed, and the sensitivity parameters of gas lifting design for the deviated wells are then obtained, which can provide an important reference for the optimization and adjustment of gas lift design parameters in the deviated wells, and also provide a strong guarantee for high efficiency production. The percentage difference in oil rate between the deviated well and vertical well is 17.32%, which is on a high side. Also, the formation productivity index, PI has a percentage difference of 2.49 %, which is significant. The maximum production rate possible from a deviated well will be less than for a vertical well due to additional pressure loss at the same operating conditions. To obtain the same rate from a highly deviated well, increase either the volume of injected gas.

1 INTRODUCTION

Generally, in oil production, crude oil flows through well tubing naturally by primary oil recovery, which involves natural drive mechanisms that lift crude oil from the oil reservoir to the surface without any artificial method or aid. Nevertheless, in most cases, this primary oil recovery will not last for a long period and becomes inefficient production process. This is due to the reservoir pressure being depleted and lacking sufficient energy to lift the crude oil to the surface. Other artificial lift methods can also be used to lift crude oil to production facilities, such as electric submersible pumps (ESPs), sucker rod pumps, hydraulic pumps and gas lift methods (Schlumberger, 1999, Forero *et al.*,1993). The gas lift method is known as an effective artificial lift technique. When bottom-hole pressure decreases, this allows the production from the reservoir to increase (Guet, 2004). The optimization of the gas lift method mainly relies on a good understanding of the reduction effects that each

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parameter is capable of causing on the total oil production. These parameters include gas flow rate, gas injection pressure, port size, depth, gas lift valve spacing and the two-phase flow behaviors along production tubing which has a crucial phenomenon known as gas lift flow instability (Ebrahimi, 2010). Although the concept of drilling a deviated well was developed as early as 1891, with smalleycomphell patent on using a flexible shaft to rotate drill pipe, but the first recorded truly deviated horizontal well was not completed until 38 years later in Texas and the regular practice of drilling horizontal and directional wells was not achieved until early 1980s due to modern day technology. (Kaiser, J., 2007). More than half of the wells drilled in US are horizontal wells (Halliburton Completions Book, 2011). There is several artificial liftmethods used in the oil industry to maintain or supplement oil reservoir energy, such as thegas injection method, water injection method, electrical submersible pump (ESP), hydraulicpump and gas lift method. The design of any artificial lift method is largely dependent on theexisting reservoir driving mechanisms. The oil reservoir driving mechanism is the ability of the reservoir to deliver fluid to the surface naturally, including gas cap solution, water drive mechanism, dissolved gas drive and a combination of all of these. Secondly, well completion should be considered in the design for a single point lift and with all modes of operation in mind. Finally, detailed attention must be paid to the stability of the gas lift, which can be achieved by understanding the unloading process and multi-phase flow behaviors in the vertical production string (Forero *et al*., 1993). Gas lift is one of the most common artificial lift methods used in the oil production industry. The principle of gas lift is explained by the injection of external energy such as natural gas through a casing annulus down into the tubing through subsurface gas lift valves. . The surface equipment consist of a gas source which is separated from crude oil by production facilities (production separators), and then this gas is dehydrated by a special dehydration unit or filters and then compressed to a certain pressure depending on theinjection pressure of the oil reservoir in the compressor station (Schlumberger, 1999).The gas isinjected from the surface to the casing annulus down to the well and then it enters theproduction tubing through unloading valves to lift the long accumulated fluid column abovethese valves. This process is known as the kick operation. Clegg (1988) mentioned some economic factors such as: revenue, operational and investment costs as the basis for Artificial Lift selection. He believed that the selected Artificial Lift method could have the best production rate with the least value of operational costs. Ayatollahi et al., (2001) used PVT data combined with fluid and multiphase flow correlations to optimize the continuous gas lift process in Aghajari oil field. From actual pressure and temperature surveys and determining the point of injection, a gas lift performance curve was constructed. Heinze et al. (1995) used a decision tree to evaluate artificial lift selection based on a longtime economic analysis which considered primary investment, operational costs, and life time cost and energy efficiency. Moreover, continuous gas lift can also be applied to offshore fields, due to its influential water drive mechanism compared to other artificial lift methods; but this depends on the availability of gas in that particular field (Kaji et al., 2009).

2. MATERIALS AND METHODS

2.1 Materials

1. PROSPER Software
2. Production data

2.2 Design of gas lift installations

The following procedure is proposed for the design of a gas lift installation for a directional well:

l. Determine the vertical and measured tubing lengths along with the angle of deviation.

2. Calculate the pressure traverse in the directionally drilled well and transpose these pressure equivalent vertical depths.

3.Using the pressure traverses as calculated in Step 2 design the gas lift installation and illustrate the effect of deviation angle to possible flow rates and required injection gas volumes.

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2.3Building and Matching the Well Model in Prosper

Building the well model in Prosper consists of modeling the physical part, PVT matching and IPR/VLP quality check. PROSPER software is built to let the user design an artificial lift method for a well based on the entered data that the user will provide, normally the artificial lift design in PROSPER is achieved after designing and matching a naturally flow single well model. In case of naturally flow wells, where matching the well parameter in its natural flow condition is the corner stone to build an accurate artificial lift design by eliminating the uncertainty when a correct matching is achieved.

2.4. Data for Vertical/DeviatedFlowing Well

Table 2.1: Fluid, Well and Reservoir Parameters

Fluid	Oil & Water
PVT method	Black Oil
Separator	Single-Stage Separator
Flow Type	Tubing Flow
Emulsions	No
Well type	Producer
Lift method	None
Predicting	Pressure & Temperature (Offshore)
Completion	Cased hole
Gravel Pack	No

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Table 2.2: PVT Input Data

Solution GOR	700 scf/stb
Oil Gravity	30 API
Gas Gravity	0.75 (Air =1)
Water Salinity	80000 ppm
CO_2	0
H_2S	0
N_2	0
Bubble Point Pressure	3906psig @ 260 degF

Table 2.3: Further PVT data @ 260 degF

Pressure in psig	Gas Oil Ratio	Oil FVF	Oil Viscosity
2000	317.548	1.26821	0.46018
2500	413.133	1.31	0.41103
3000	512.36	1.36	0.36816
3500	614.727	1.41	0.3314
4000	700	1.45	0.30786
4500	700	1.44	0.31945

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Table 2.4: Deviation Survey Data for Deviated Well

Measured Depth in ft	True Vertical depth in ft
0	0
7500	7000
9500	8000

Table 2.5: Deviation Survey Data for Vertical Well (Assumed)

Measured Depth in ft	True Vertical depth in ft
0	0
7500	7500
9500	9500

Table 2.6: Down-hole Equipment Data

Equipment type	Measured depth in ft	Internal diameter in inches	Roughness	Rate multiplier
Tubing	7500	3.068	0.0018	1
Casing	9500	6.4	0.0018	1

Table 2.7: Fluid Temperature Survey

Measured Depth in ft	Static Temperature in degF
0	50
9500	260

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Overall Heat Transfer Coefficient = 8 BTU/h/ft

Table 2.8: IPR Model Selection

IPR Model	Darcy/Enter skin by hand
Static reservoir pressure	3242.8 psig
Reservoir temperature	260 degF
Water cut	25 %
Total GOR	700 scf/stb

Table 2.9: IPR Data Entry

Permeability	90 mD
Reservoir Thickness	110 ft
Drainage Area	350 Acres
Dietz Shape Factor	31.6
Wellbore Radius	0.354 ft
Skin	4
Formation Vertical Formation Anisotropy	0.1 (Fraction)
Local Vertical anisotropy	0.1 (Fraction)
Horizontal Length to Reservoir Edge	2150 ft
Vertical Depth To Top Of Reservoir (starting from origin of deviation survey)	8000 ft
Perforation Interval in Measured Depth	9500ft– 9800ft
Perforation Depth in True Vertical Depth	8000ft – 8100ft

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Table 2.10: Well Production Data

Oil Production rate, (STB/d)	5100
Water Cut, (%)	25
WH Flowing Temperature, (°F)	50
Pressure at Christmas tree, (psia)	300
Skin (Well Test)	4
PI or J (Well Test), (STB/d/psi)	19

Table 2.11: Gas-Lift Design Parameters

Maximum gas available	10MMscf/d
Maximum gas available during unloading	10MMscf/d
Flowing top node pressure	500psig
Unload top node pressure	500psig
Operating injection pressure	2000psig
Kick-off injection pressure	2000psig
Desired dp across valve	50psig
Maximum depth of gas-lift injection	7500ft
Design water cut	50%
Static gradient of kill fluid	0.45 psi/ft
Total GOR	700 scf/stb
Design rate method	Calculated from max. Production

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Maximum liquid rate	30000stb/d
Check rate conformance with IPR	Yes
Use IPR for unloading	Yes
Orifice sizing on	Calculated dp@orifice
Vertical lift correlation	Petroleum Experts 2
Surface pipe correlation	Beggs and Brill

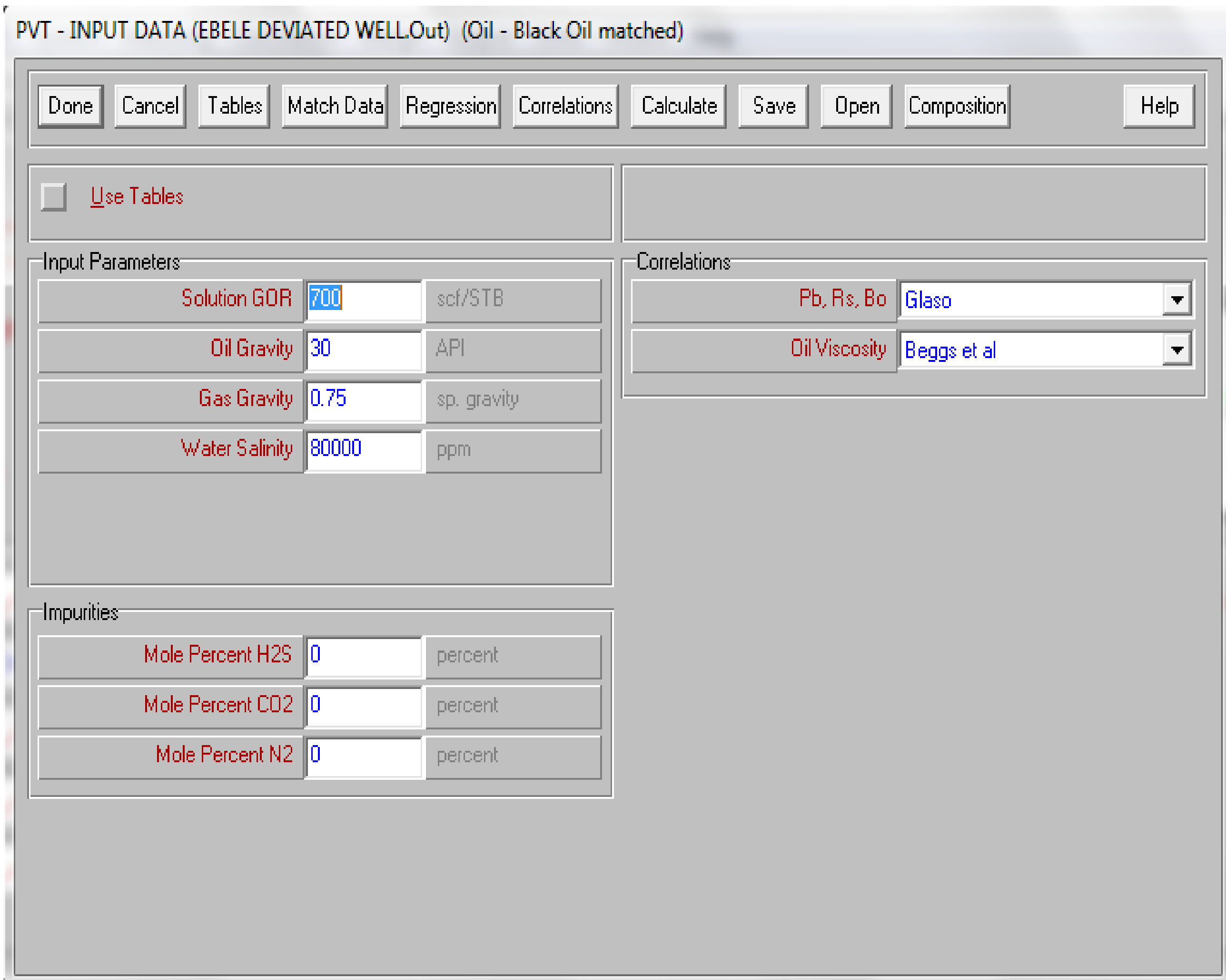

Figure 2.1: PVT Input Data

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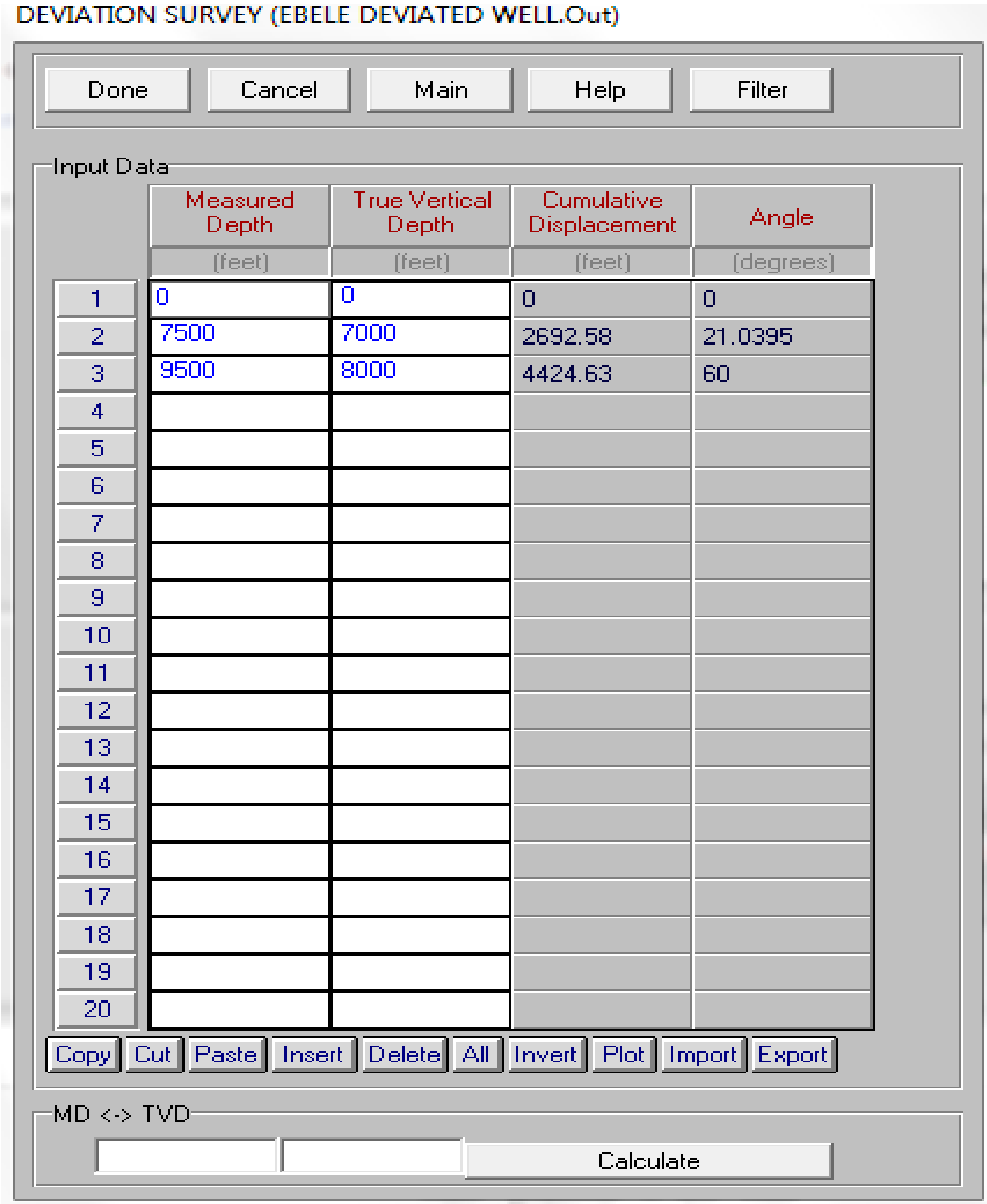

Figure 2.2 Deviation Survey for Deviated Well

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3. RESULTS AND DISCUSSION

3.1 Model for Deviated Well

Well deliverability is determined by a well's inflow performance. The Inflow Performance Relationship (IPR) is defined as the functional relationship between the production rate and the bottom hole flowing pressure. Productivity Index (PI or J) expresses the ability of a reservoir to deliver fluids to the wellbore.

Table 3.1 Matching the Model for Well

Oil Rate (STB/D)		
Measured	Calculated	% Difference
5100	5083.1	0.3
Formation PI (STB/D/Psi)		
Measured	Calculated	%
19	18.8	1.05

Check Table 3.10 for measured Oil Rate, Formation Productivity Index, PI and Figure 3.1 and Figure 3.2 for IPR Plot and (VLP-IPR Match) for PI and Calculated Oil Rate respectively.

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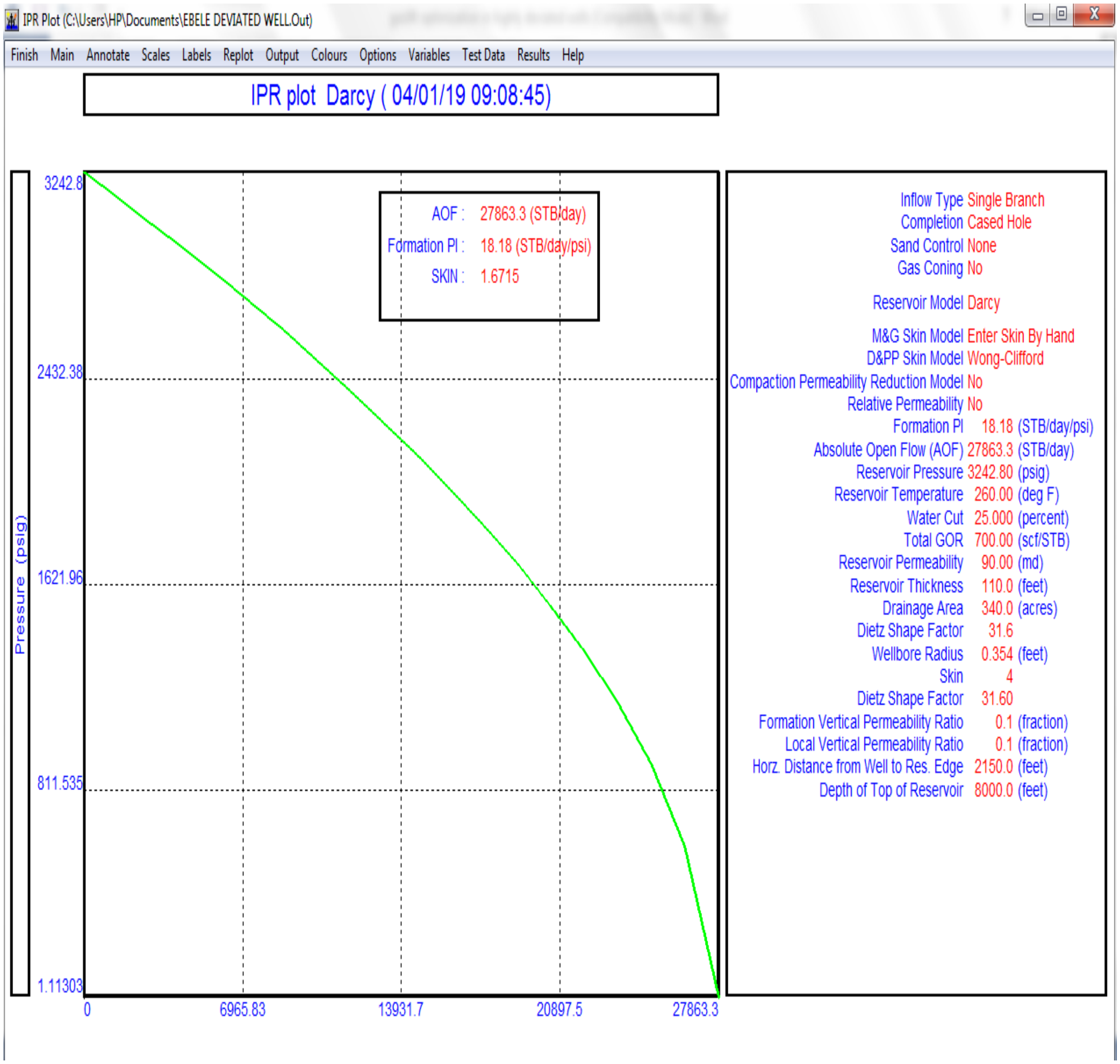

Figure 3.1: IPR Plot for Deviated Well

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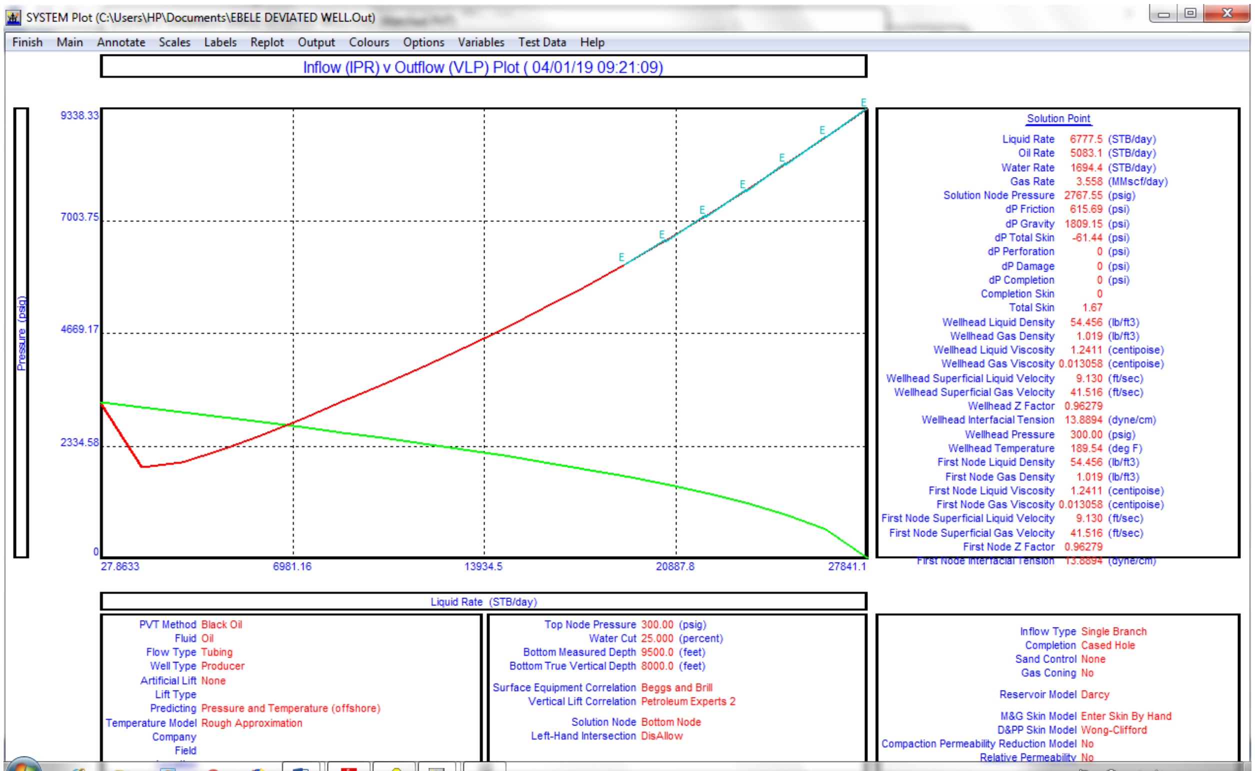

Figure 3.2: System Plot of a Deviated (IPR+VLP) Well.

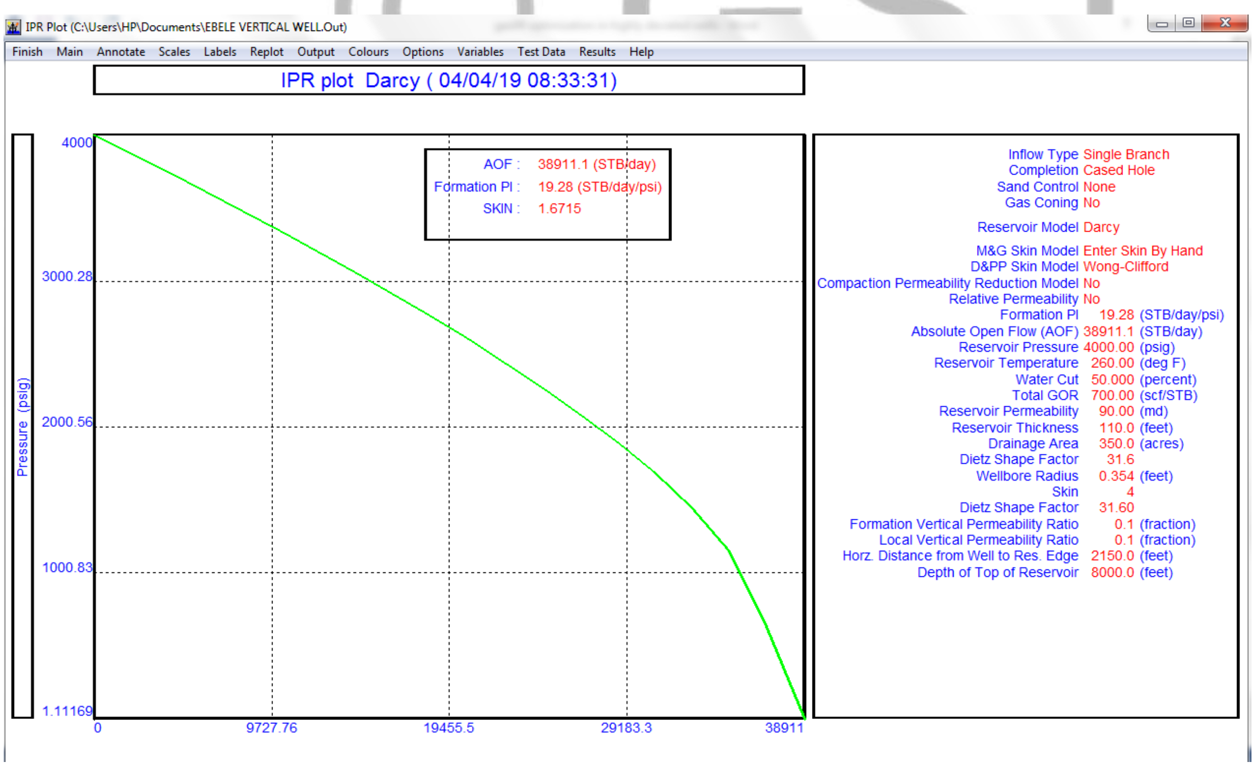

Figure 3.3: IPR Plot for Vertical Well

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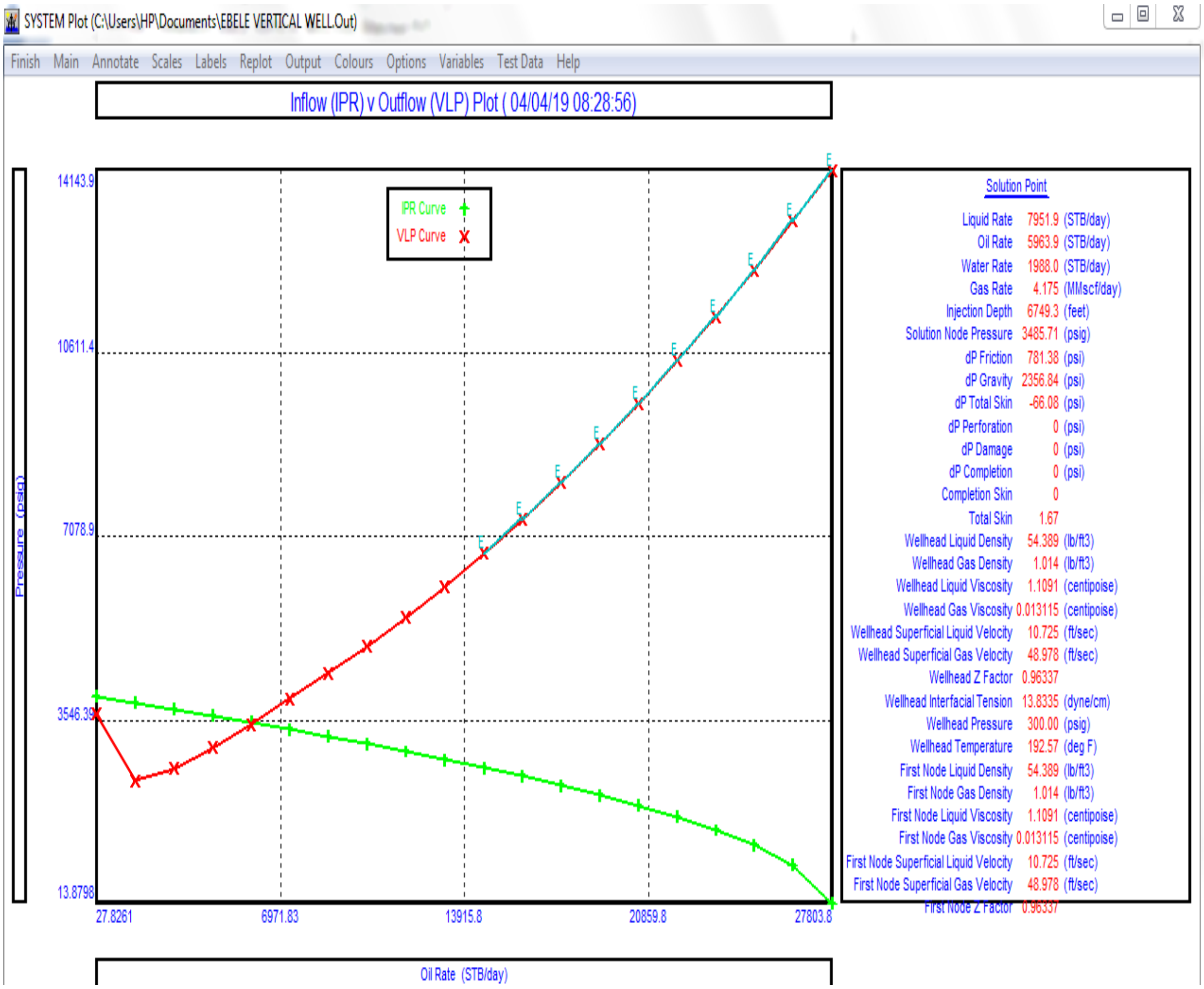

Figure 3.4: System Plot of a Vertical (IPR+VLP) Well

From Table 4.2, the percentage difference in oil rate between the deviated well and vertical well is 17.32%, which is on a high side. Also, the formation productivity index, PI has a percentage difference of 2.49 %, which is significant.

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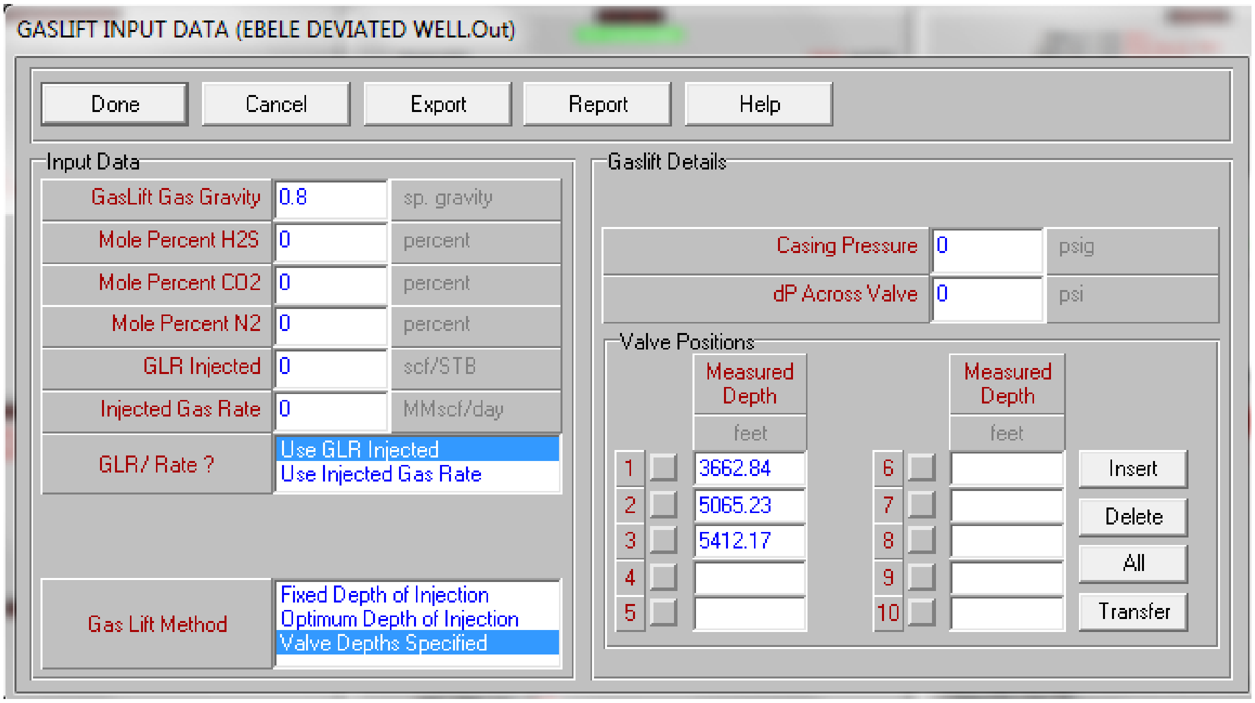

Figure 3.5: Gas-lift Input data for Deviated Well

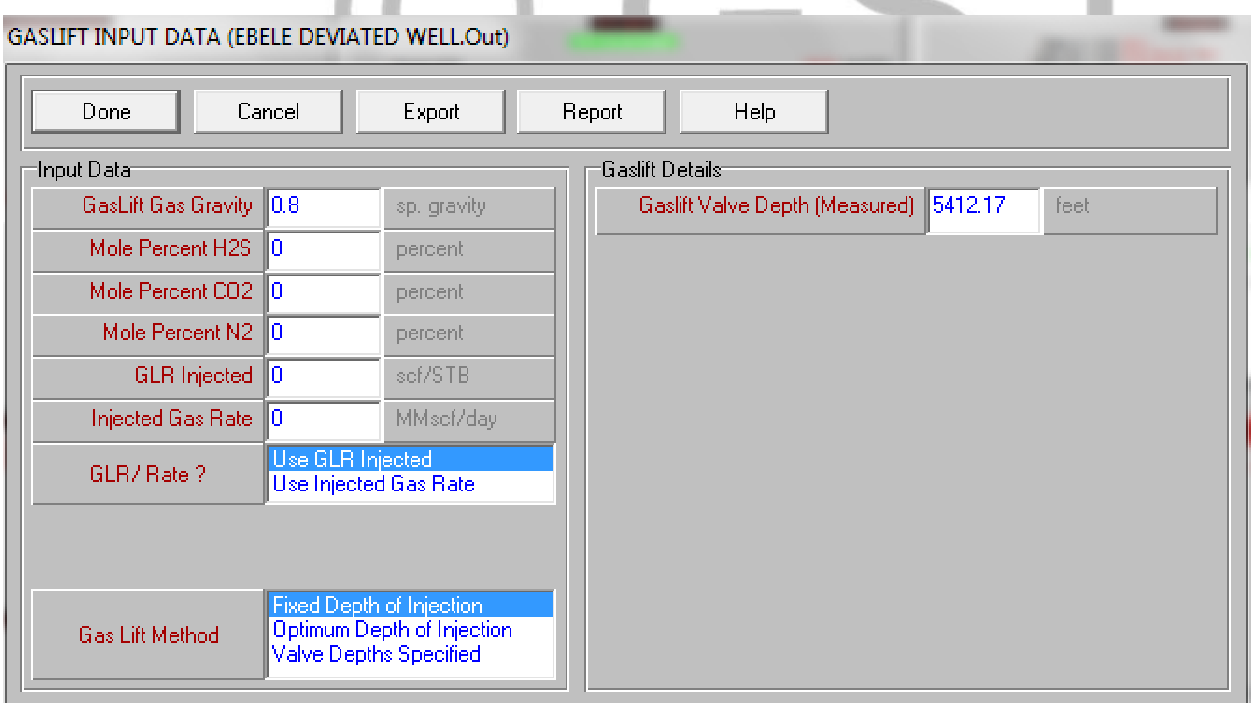

Figure 3.6: Gas-lift Input data for Deviated Well

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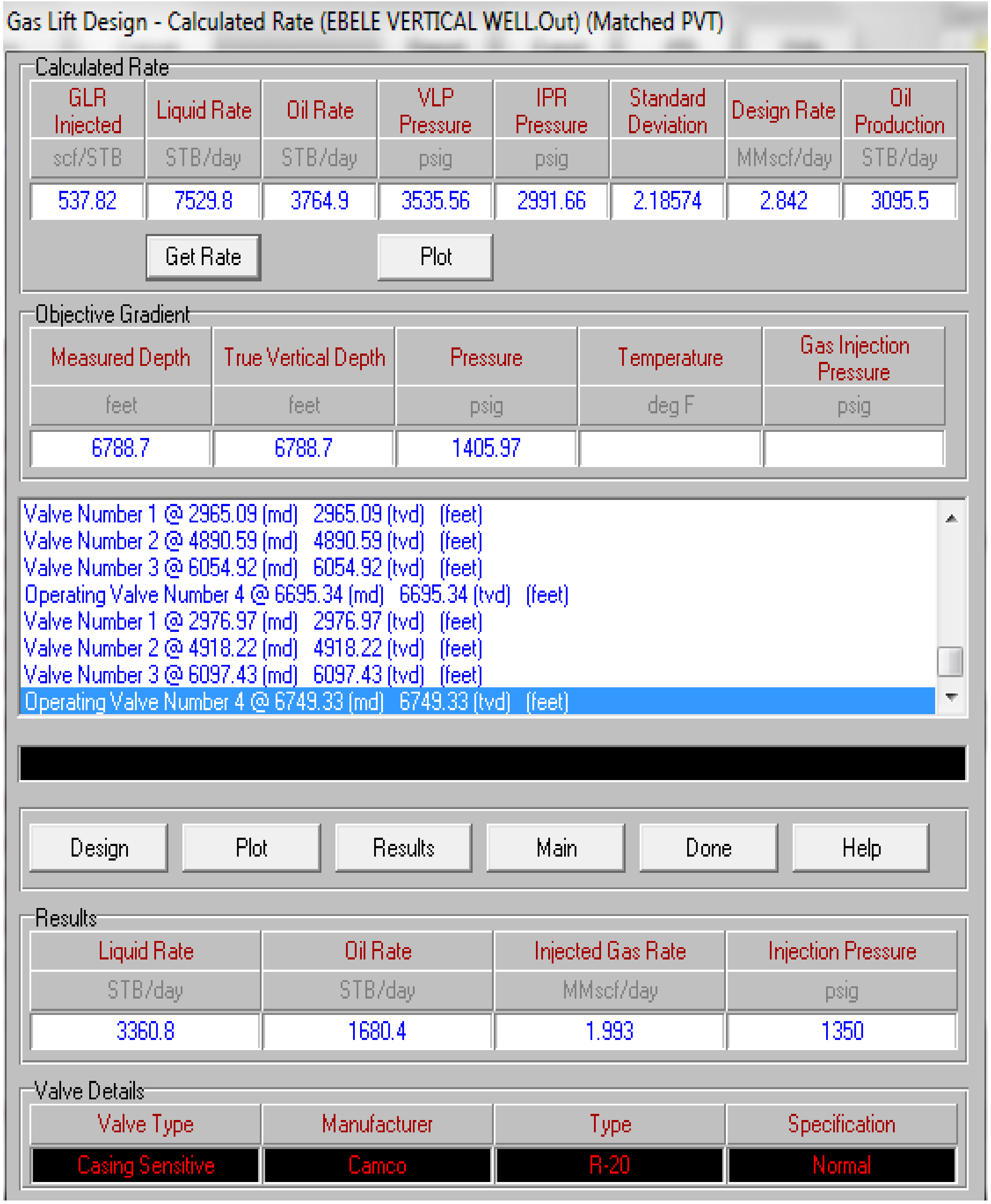

Figure 3.7: Gas-lift Input data for Vertical Well

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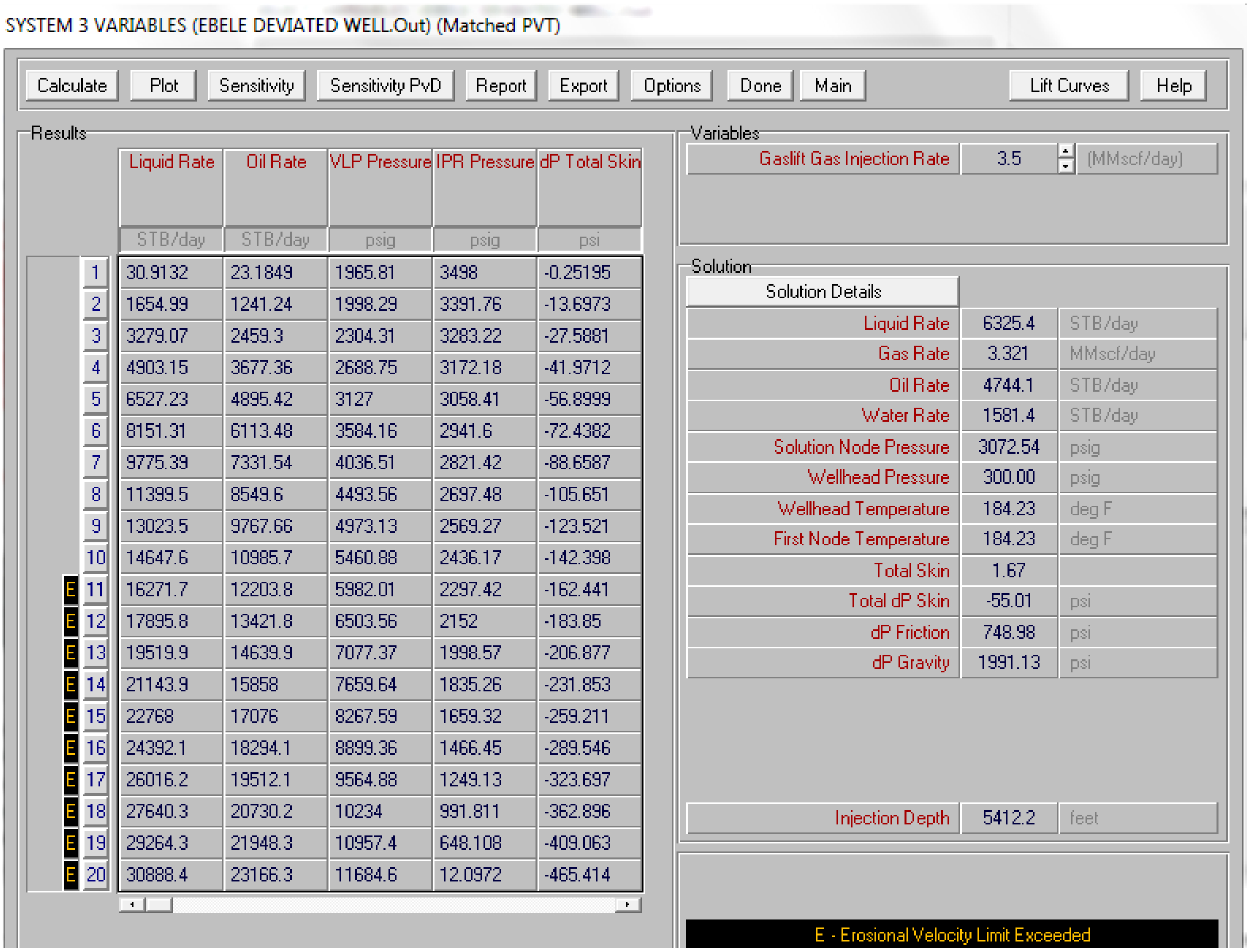

	Liquid Rate (STB/day)	Oil Rate (STB/day)	VLP Pressure (psig)	IPR Pressure (psig)	dP Total Skin (psi)
1	30.9132	23.1849	1965.81	3498	-0.25195
2	1654.99	1241.24	1998.29	3391.76	-13.6973
3	3279.07	2459.3	2304.31	3283.22	-27.5881
4	4903.15	3677.36	2688.75	3172.18	-41.9712
5	6527.23	4895.42	3127	3058.41	-56.8999
6	8151.31	6113.48	3584.16	2941.6	-72.4382
7	9775.39	7331.54	4036.51	2821.42	-88.6587
8	11399.5	8549.6	4493.56	2697.48	-105.651
9	13023.5	9767.66	4973.13	2569.27	-123.521
10	14647.6	10985.7	5460.88	2436.17	-142.398
E 11	16271.7	12203.8	5982.01	2297.42	-162.441
E 12	17895.8	13421.8	6503.56	2152	-183.85
E 13	19519.9	14639.9	7077.37	1998.57	-206.877
E 14	21143.9	15858	7659.64	1835.26	-231.853
E 15	22768	17076	8267.59	1659.32	-259.211
E 16	24392.1	18294.1	8899.36	1466.45	-289.546
E 17	26016.2	19512.1	9564.88	1249.13	-323.697
E 18	27640.3	20730.2	10234	991.811	-362.896
E 19	29264.3	21948.3	10957.4	648.108	-409.063
E 20	30888.4	23166.3	11684.6	12.0972	-465.414

Figure 3.8: Solution Details for increased Gas-lift Injection rate for Deviated Well

4. Conclusion

The maximum production rate possible from a deviated well will be less than for a vertical well due to additional pressure loss at the same operating conditions.

To obtain the same rate from a highly deviated well, increase either the volume of injected gas or operating gas pressure, or both. Where possible, use tubing flow because of the inherent additional instabilities encountered in annular flow for directional wells.

The percentage difference in oil rate between the deviated well and vertical well is 17.32%, which is on a high side. Also, the formation productivity index, PI has a percentage difference of 2.49 %, which is significant.

The design of gas lift installations in highly deviated wells can be accomplished by projecting the pressure traverses of the deviated well to equivalent vertical depths. Once this has been done, the design proceeds in the normal manner as for a vertical well. Once the projected equivalent vertical pressures are determined, the spacing of the valves can proceed in a normal manner and the proper valve can be selected. The only differences in valve design will be in port size selection, due to larger gas volume requirements of the directional wells for the same flow rate.

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