Design and Optimization of Suitable Artificial Lift For High BHP Wells

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Abstract

Based on the available reservoir and production data of a given field, it was understood that few wells were unable to generate the hydrocarbons on account of certain fluid properties, wellbore depth and decline in reservoir pressure. The BHP of these wells and PI is found to be higher. But the wells were either not productive enough or were not able to deliver up to the mark on account of necessity of reservoir pressure. Here, the challenge was to overcome the hydrostatic column pressure. Since the IPR and TPC were not intersecting. Accordingly, study of IPR, TPC and VLT was completed. Available resources in the given oil-field were taken into consideration, selection criteria of artificial lifting were applied and initial scrutiny was conducted to decide an artificial lifting method. Finally, gas lifting technique was found to be more suitable. The wells are generating oil & gas for a number of years, but now the production rate is minimizing with the time. Based upon initial calculations, screening criteria, availability of excessive gas in the same field and the potential of data; Continuous gas lifting has been found to be more appropriate and the best option to increase Production rate. Accordingly, this research purpose is to study the whole mechanism of artificial GL optimization to maximize oil and gas generation for the wells under consideration. Design of a GL system suited to the proper well condition and ready to maximize the production of the well has been worked out in this project. It will help to maximize the generation by optimizing GLR, number of gas injection valves and their spacing along with daily gas injection pressure and volumetric gas injection rate. The total gas used for oil generation is restricted by daily obtainability restrictions and maximum injection volume into each well. The problem is to recognize the injection of the optimum amount of gas into each well to maximize the total amount of oil generation from the high BHP reservoir on a daily basis has been addressed. IPM Prosper and manual design engineering calculations have been used to come to a conclusion. It is desired that, this kind of approach will be helpful to all those oil wells to derive productive gain and faster large financial benefits for such wells.
OBJECTIVE: As the oil filed gets matured, the generation of the oil filed is minimizing over a number of years. This is occurring due to the truth that pressure inside the reservoir getting reduced as the oil & gas generated from the reservoir increasing, thus minimizing the flow of oil & gas from the reservoir. Design of a GL system convenient for the genuine well condition and able to maximize the oil and gas generation of the well. The purpose of this research is to study of GL system based on genuine data from an oil well and choose a system best convenient to maximize the generation of the oil field.

IndexTermsOptimization, Gas Lift, Artificial lift, High BHP well

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Introduction

When BHP will have reduced and well is not capable to produce fluid from a reservoir, the artificial lift installation will require to maintain BHP and pressure drawdown. 6 types of artificial lift are used in industries: Sucker rod pumping, Gas Lift, Electrical submersible pumping, Plunger lift, Progressing cavity pumping and Hydraulic pumping.

When some amount of gas left in reservoir and that well is not producing much fluid for this consideration GL is used. This technology maximizes oil generation rate by injecting a gas into the lower section of tubing through the casing-tubing annulus and an orifice installed in the tubing string. Upon entering the tubing, the compressed gas affects liquid flow in 2 ways:

- The energy of expansion pushes oil to the surface.
- The gas aerates the oil so that the effective density of the fluid is less so easier to get to the surface.

There are 4 categories of wells in which a GL van be considered:

- High PI, high BHP
- High PI, low BHP
- Low PI, high BHP
- Low PI, low BHP

Wells having PI of 0.5 or less are classified as lo PI wells and wells having a PI greater than 0.5 are classified as high PI wells. High BHP will support a fluid column is equal to 70% of well depth and low BHP will support a fluid column less than 40% of well depth. There are 2 basic type of Artificial GL use in the oil and gas industries. 1). Continuous GL and 2). Intermittent GL.

There are 2 common type of Artificial GL valve too. 1). Casing Operated and 2). Tubing Operated

Continuous GL	Intermittent GL
In this method, the gas is continuously injected from the operating valve and we get continuous generation of reservoir fluids. This GL is recommended for high BHP wells and high PI. The range of production rate is 100 to 75000 bbl/day. It has static BHP greater than 0.3 psi/ft., flowing BHP greater than 0.8 psi/ft. and injection pressure greater than 100 psi per 1000 ft. of lift. The range of injection gas is about 50 to 250 per 1000 ft. of lift. It is recommended for larger volume gas injection rate.	In this method, the gas is injected in time interval via operating valve. This GL is recommended for low BHP wells at low PI and low BHP wells at high PI. The range of production rate is up to 500 bbl/day. It has static BHP less than 0.3 psi/ft., flowing BHP equal to or greater than 150 psi, and injection pressure less than 100 psi per 1000 ft. of lift. The range of injection gas is about 250 to 500 per 1000 ft. of lift. It is recommended for smaller volume gas injection rate.

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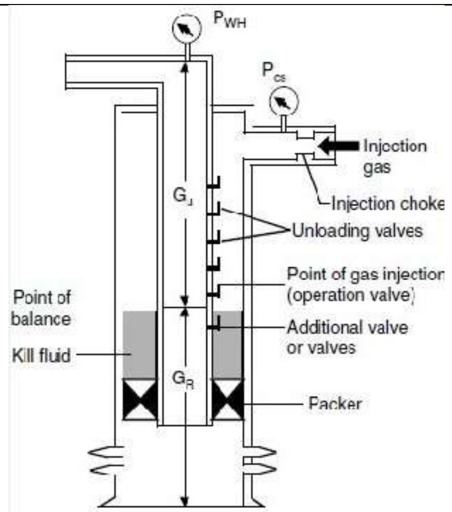

Figure 1.1: Continuous GL,
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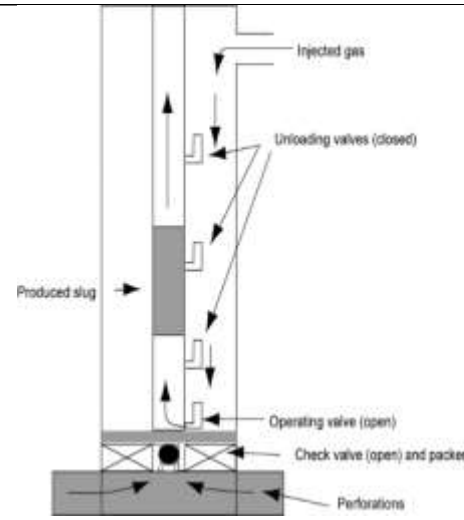

Figure 1.2:Intermittent GL,
Joe Dunn Clegg, (2006).
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<tr><td colspan="2">Advantages</td></tr>
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<td>
• This takes full advantage of gas energy is ready to use in the reservoir.
• This is a high volumetric method.
• Equipment can be under one roof.
• This system can handle sand best.
• In this system, valves may be wireline or tubing rectify.
</td>
<td>
• This system can acquire lower manufacturing pressure than continuous GL acquires and at low rates.
• Equipment can be under one roof.
• In this system, valves may be wireline or tubing rectify.
</td>
</tr>
<tr><td colspan="2">Disadvantages</td></tr>
<tr>
<td>
• Minimum bottom hole generating pressure maximizes both with depth and volume.
• In this system, it is mandatory to have a source of gas.
</td>
<td>
• This system has a limit in greatest volume.
• This system causes surges on surface equipment.
• This system is in need of more attention than continuous flow.
• In this GL, cyclic lift causes struggle with gas measurement and gas supply.
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<tr><td>Casing Operated GL Valve</td><td>Tubing Operated GL Valve</td></tr>
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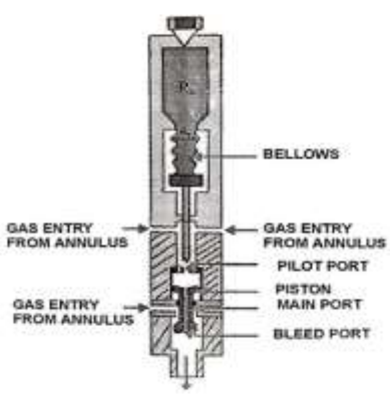

Figure 1.3: Casing Operated GL Valve
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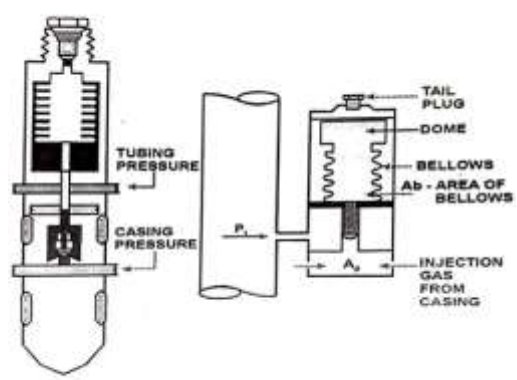

Figure 1.4: Tubing Operated GL Valve
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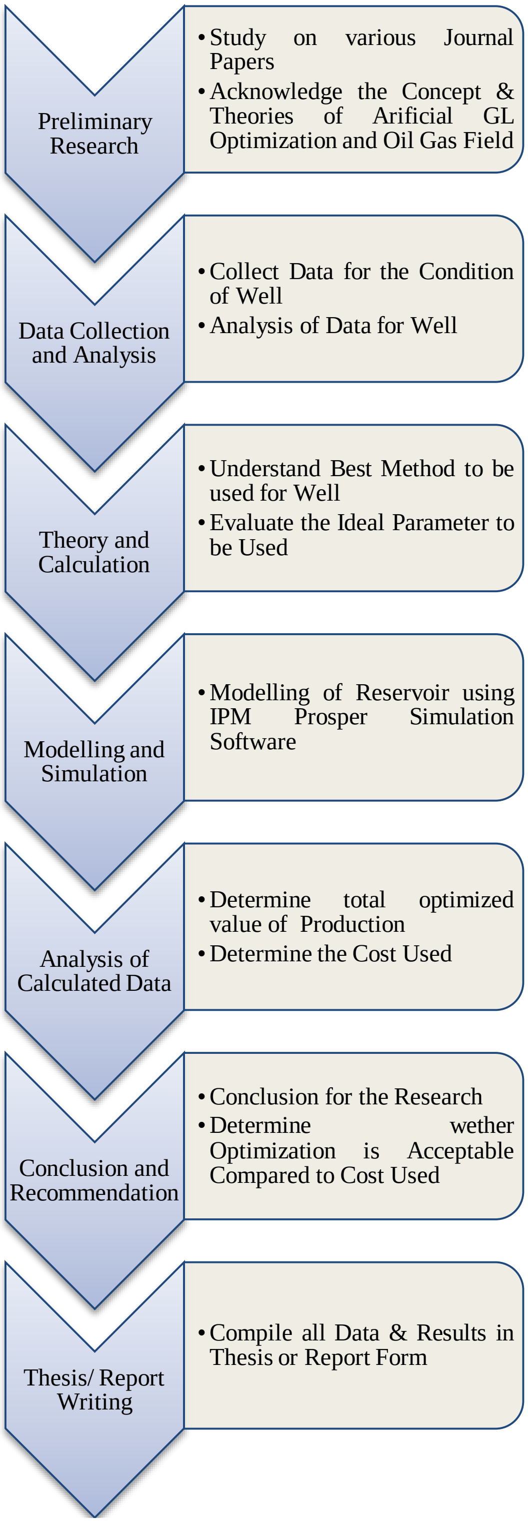


Figure 3: Methodology

Methodology:

2.1 Design of Continuous GL:

To design a continuous GL, the following data is required. They are:

- Tubing size
- Casing size
- Depth to the center of the perforated interval
- API gravity of oil
- Formation gas-oil ratio
- SG of the injection gas
- SG of the formation gas
- Liquid producing rate
- SG of the water
- Flowing WH tubing pressure
- Injection gas pressure available at reservoir
- Volume of injection gas available
- Static BHP
- Flowing BHP
- PI or IPR
- BH temperature
- Flowing WH temperature
- Type of reservoir with expected depletion performance

The following procedure for design of continuous flow GL is…

- Calculate BH temperature with the help of Geothermal gradient.
- Injection pressure will be calculated via temperature average and Z average. Z average value is assumed and it will be 0.84.
- Hagedorn and Brown curve will select for production rate. From this curve, we get measured BHP.
- Joined THP and BHP with depth of well, we got the minimum gradient line.
- Zero GLR line is drawn and on the vertical gradient curve we get depth with the help of located THP.
- Pressure is marked at the depth and get calculated GLR.
- After that calculate GL valve depth and draw this valve on graph. From that we

get temperature of valve from the gradient temp. line.

- Calculate flow rate and corrected Q via getting data of GLR, pressure and injection pressure from graph.
- All valve calculated via above method, after that calculate the additional tubing effect and all valve design those are used for production of a well.
- Draw IPR curve and VLP curve with the help of given data and calculated data of GL.
- Then, do IPR and VLP matching from Gilbert's curve. From that we get reservoir pressure and flow rate.
- Draw a curve of Q vs Pwf, we get FBHP and liquid production rate.

2.2 Optimization of GL:

GL optimization is a continuous procedure for maximizing the production, reduction in injection gas quantities and reducing cost. Well performance is constantly monitored for identification of under-performing. The information gathered from the monitoring tools is analyzed by accurately modeling the wells. Based on the data and model results, suitable corrective measures are taken to optimize the wells and continuously maintain the system efficiency such as enhanced production, effective utilization of resources like injection gas etc., more stable well and system operation, base for performing wider optimization strategies. The parameters for optimization are:

- Gas Injection Pressure
- Injection gas Rate
- Total Gas Rate
- Well Head Pressure
- Operating Valve Depth
- Tubing Fluid Gradient

2.3 IPM Prosper:

PROSPER is a modelling and optimization software made by the company named Petroleum Experts Limited. It can help to predict tubing, pipeline hydraulics and temp. for assist production and reservoir engineers with high accuracy and speed. It has some features like powerful and sensitive calculation, plotting the graph and future changes parameters are used to assessed optimization of the existing design. This software is for single well performance and optimization of the artificial lift design with consideration of industry standards. Mostly all types of well completions are also designed by the help of PROSPER. Variables like well configuration, PVT, multiphase VLP correlations and various IPR models have ability to build a well models. Matching the data is the main ability to designed a model in different scenarios with maximum accuracy.

The major application of this software is to calculate VLP using multiphase flow correlations with the help of VLP variables. Artificial lift can also be designed by using this software. A full range of well type can be modeled is PROSPER including gas, oil, water, condensate and steam. Different configuration such as angled, multi-layer and multi-laterals can also be modeled. A full range of IPR models can also be used in this software. The first screen that displayed after starting the PROSPER is divided in to 6 parts contains:

Section 1: Option Summary

The menu is used to input the characteristics of the well like the type of well, fluid description, if any artificial lift system is used or not, type of well completion.

Section 2: PVT Data

This menu is used to input the fluid properties to estimate or predict the pressure and temperature changes from the reservoir.

Section 3: IPR Data

Here, different reservoir models are used to generate the IPR corresponding to well data such as Pr, Tr, water cut, GOR, PI etc. So, as to estimate the AOF.

Section 4: Continuous GL Data

Section 5: Equipment Data

This menu is used to define the deviation in the well, surface equipment and downhole equipment used, geothermal gradient and average heat capacities.

Section 6: Analysis Summary

Figure 2.3: IPM Prosper Main Window

Technical Solution:

Data:

Production Rate	: 1500 BPD
Depth	: 6000 ft.
Tubing	: 2 7/8" Casing
GL valve	: J-40
GL mandrel	: 2 7/8"
Gas injection pressure	: 1100 psi
Separator pressure	: 120 psi
Flowing THP	: 160 psi
Load fluid (or kill fluid) gradient	: 0.45 psi/ft.
Static WH temperature	: 74° F
Geothermal gradient	: 0.0190 F/ft.
GOR	: 300 SCF/bbl
Oil gravity	: 350 API
Water cut	: 50 %
GLR	: 150 SCF/bbl
Static BHP	: 2020 psi at 6000 ft.
Flowing BHP	: 1780 psi at 6000 ft.
PI	: 4.6 b/d/psi

Solution: Analytical and graphical procedures of GL well design

Step 1: Calculate Bottom Hole Temperature

- $Geothermalgradient = \frac{1.90° \, F}{100 \, ft.} = 0.019° \, F$
- $Bottomholetemperatureat \; 6000 \; ft. = 74° \, F + (0.019 \; \times 6000)° \, F = 188° \, F$

Temperature 74° F at surface and Temperature 180° F at depth 6000 ft. are joined to get temperature gradient line on the graph sheet.

Step 2: Injection pressure at 6000 ft.

- $T_{avg} = (74° \, F + 188° \, F) \times 1/2 = 131° \, F = (131 + 460)° \, R = 591° \, R$
- $Z_{avg} = 0.84 \; (Assumed)$
- $Injection pressure at depth, P_d = 1100 \times e^{[\, 0.65 \times 6000/(53.3 \times 591 \times 0.84)]} = 1100 \times 1.158$

$= 1274 \; psi at \; 6000 \; ft.$

Pressure 1100 psi at the surface and Pressure 1274 psi at 6000 ft. are joined to get injection pressure gradient line 1, on the graph sheet.

Step 3:

- Hagedorn and Brown curve is selected for 1500 b/d producing rate through 2 7/8" tubing with producing fluid all water at average flowing temp. 131°F.
- With the help of above vertical gradient curve, the minimum gradient line on the graph sheet is drawn with THP = 160 psi.
- 160 psi is located at 950 ft. on the vertical gradient curve and therefore at 6000 ft. + 950 ft. = 6950 ft., the pressure = 1355 psi is noted.
- This pressure is marked on the graph paper at 6000 ft.

By joining THP and pressure 1355 psi point at depth 6000 ft., the minimum gradient line is got on the graph sheet.

Step 4:

- The zero GLR line is drawn on the graph sheet in the similar way.
- On the vertical gradient curve, 160 psi THP is located at 325 ft.
- At 5325 ft., the pressure is read as 2520 psi.
- Therefore, pressure 2520 psi is marked at depth 5000 ft. on the graph sheet and 280 GLR line is drawn.

Step 5: Depth of top valve

- $The depth of the top valve, L_1 = (P_{so} \; - \; P_{wh})/Kill fluid gradient = (1100 - 160)/0.45 \frac{psi}{ft.} = 2088 \; ft.$

L1 is marked on the graph sheet, T1 = 114° F, as obtained from temperature gradient line.

Step 6:

From L1 depth line, a second injection pressure gradient line (line 2), which is less by 50 psi than injection line 1, is drawn parallel to injection line 1.

Step 7: Calculate gas through put, Q

From flowing gradient chart,

- $GLR at L_1 = 500 \; scf/bbl$
- $P_{min} at L_1 = 560 \, psi$
- $P_{inj} at L_1 = 1160 \; psi$
- $Gas throughput (Q) \; = (1500 \; b/d \; \times 500 \; scf/b)/1000 = 750 \; MCFD$
- $Qcorrected = Q_{cal}/0.0544 \sqrt{[S.G. \; \times (T + 460)]} = 750/1.05 = 714 \; MCFD$

Use thorn hill and carver chart to determine the port size for passing 714 MSCFD of gas for the above injection and tubing pressure which comes at 11/64 = 3/16 inch.

Step 8: Calculate second valve

- Locating 2nd valve, draw a line from balance point to intersect minimum grad line take minimized injection pressure by 50 psi and draw a parallel Line to injection line.
- Above this point the tubing would get aerated while the tubing below is full with kill fluid.

- Draw a Kill fluid grad from the intersection on minimum grad line to intersect the available injection pressure line.
- The intersection point gives the position of the second valve 3345 ft. Drop horizontal line from L0 to get temperature and the point on the min grad line.

Step 9: Calculating additional tubing effect / Safe pressure

- Join THP point and L2 point on the injection lite and note the pressure Pmax = 790 psi at the intersection on the L1 depth line.
- $Additional tubing effect = (P_{max} at L_1 - P_{min} at L_1) T.E.F. = (790 - 560) \times 0.104\ (for\ 3/16\ in valve) = 24\ psi$

Valve No.	Depth (ft.)	Port Size (in)	Valve Type	Temp (° F)	Max. Pressure (psi)	Min. Pressure (psi)
1	2088	3/16	J-40	114	790	560
2	3345	1/4	J-40	137	970	820
3	4300	5/16	J-40	152	1050	1040
4	4760	5/16	J-40	161	1070	1060

Table 3.1.1: GL Valve Design of Well

IPR

J = 4.6 b/d/psi
Pr = 2020 psi
Pb = 1500 psi
Pwf = 1780 psi
Q = J (Pr – Pb) = 4.6 (2020-1500) = 2392 STB/day
AOF = J × Pb = 4.6 × 1500 = 6900 STB/day

VLP/IPR Matching

- The matching of IPR with VLP is obtained from Gilbert's curve.
- Draw the IPR for the well using the PI of 4.6 b/d/psi and the static pressure Pr of 2020 psi.
-

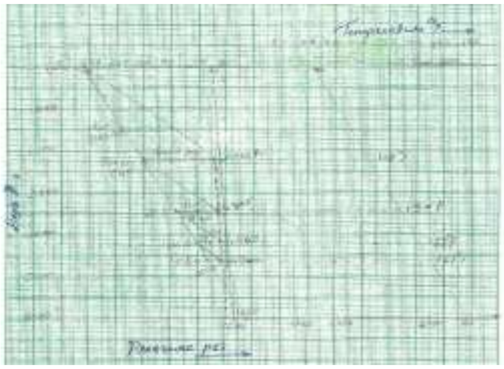
When Q = 0
Pr = 2020 psi
J = 4.6 b/d/psi
Pwf = 0
Calculated Flow Rate, Q = 2020 × 4.6 = 9292 bbl/d

- The flowing well performance relationship must now be developed by calculating Pwf for various assumed flow rates using the THP of 160 psi.

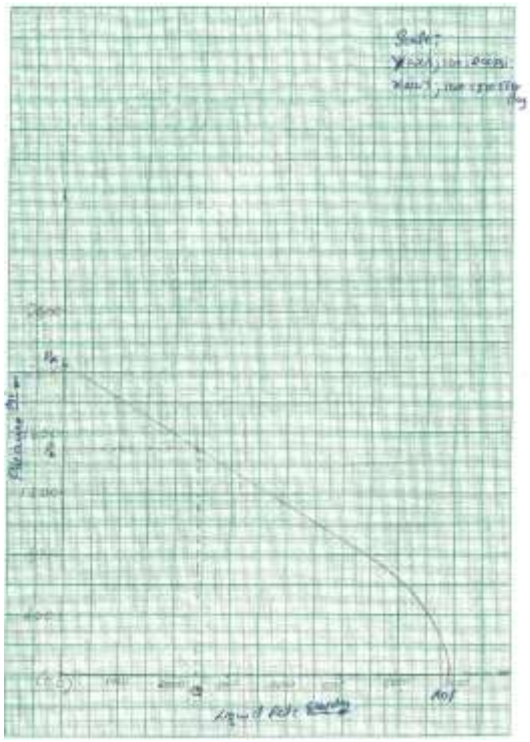
Assumed Flow rate in bbl/day	Equiv. Depth of a THP of 160 psi at assumed flow rate in ft.	Equiv. Depth of a well ft.	Flowing BHP in psi
1000	1900	7900	1250
2000	1500	7500	1400
3000	1200	7200	1570

Table 3.1.2: VLP/IPR matching of well

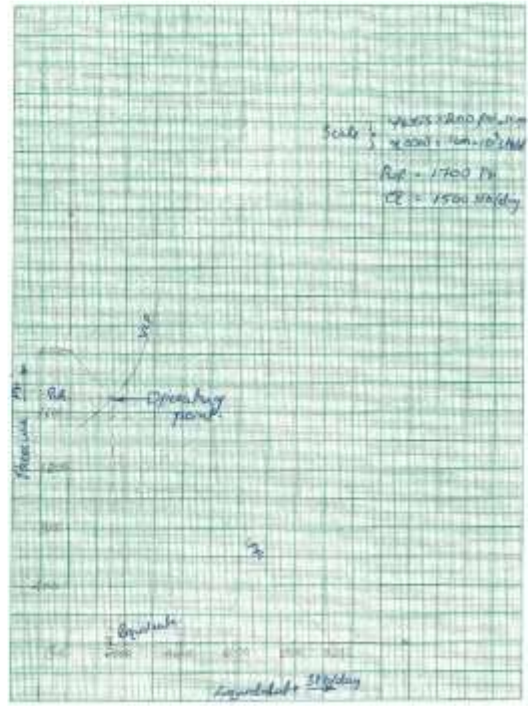
From the above table, plot Q versus Pwf and the intersection of the curves yields a flow rate of 1500 bbl/day and pressure 1355 psi FBHP, which satisfies both IPR and the flowing tubing pressure drop relationship.



Graph 1: GL Valve Design Plot Manually



Graph 2: IPR Curve



Graph 3: VLP Curve

9245

2.4 IPM PROSPER SOLUTION:

Reservoir Model	PI Entry	
Relative Permeability	No	
Absolute Open Flow (AOF)	[illegible]	(STB/day)
Reservoir Pressure	[illegible]	(psig)
Reservoir Temperature	[illegible]	(deg F)
Water Cut	[illegible]	(percent)
Productivity Index	[illegible]	(STB/day/psi)

Figure 3.1: IPR Input Data

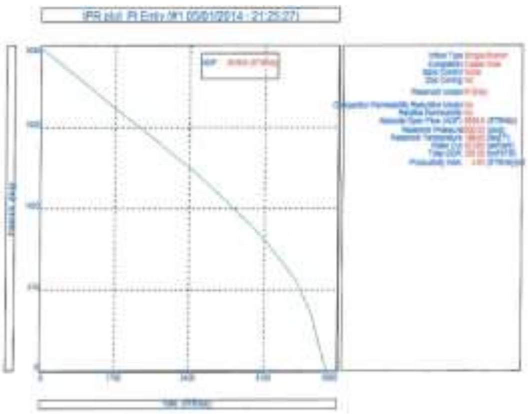


Figure 3.2: IPR Curve

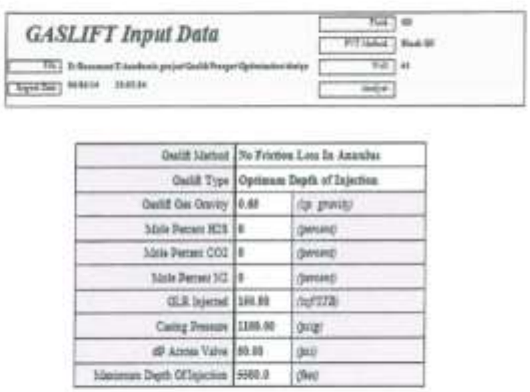


Figure 3.3: GL Input Data

Figure 3.4: GL Design Data

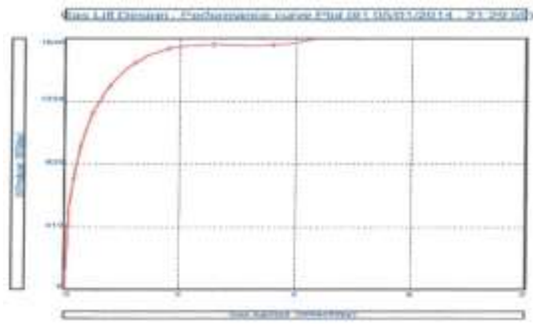


Figure 3.5: GL Performance Curve

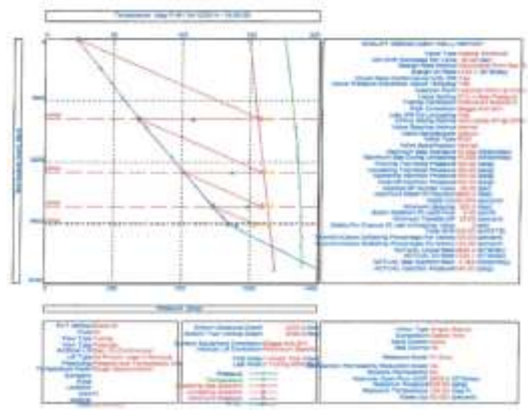


Figure 3.6: GL Valve Design Plot

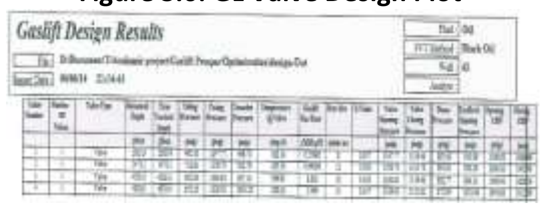


Figure 3.7: GL Valve Design Results

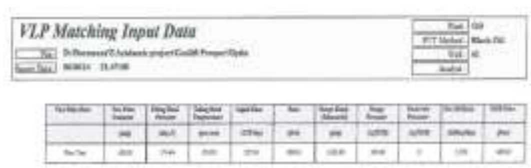


Figure 3.8: VLP Matching Input Data

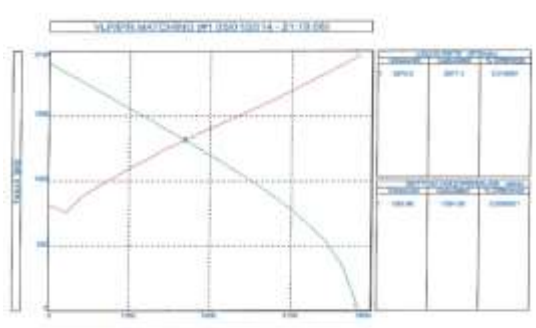


Figure 3.9: VLP/IPR Matching Plot

Figure 3.10: Quick Look Input Data

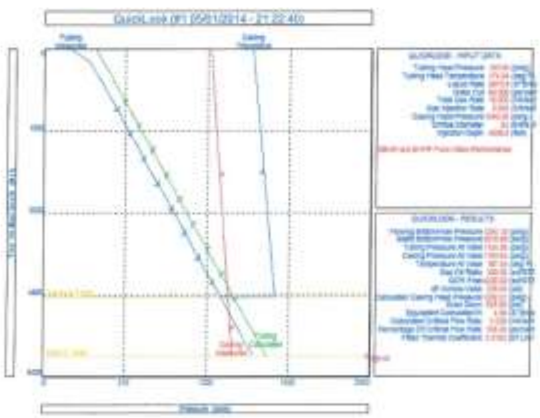


Figure 3.11: Quick Look Plot

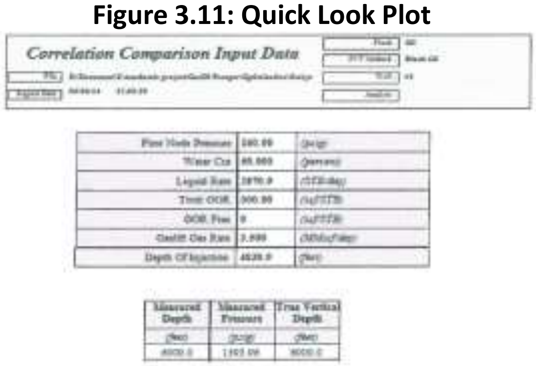


Figure 3.12: Tubing Correlation Data

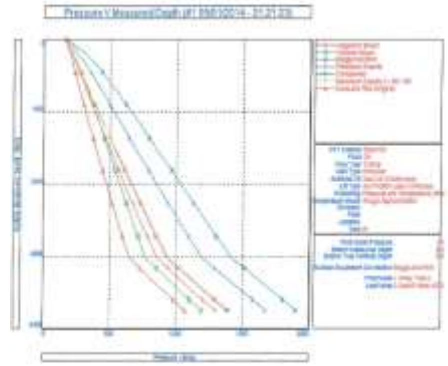


Figure 3.13: Tubing Correlation Plot

Figure 3.14: System Input Data

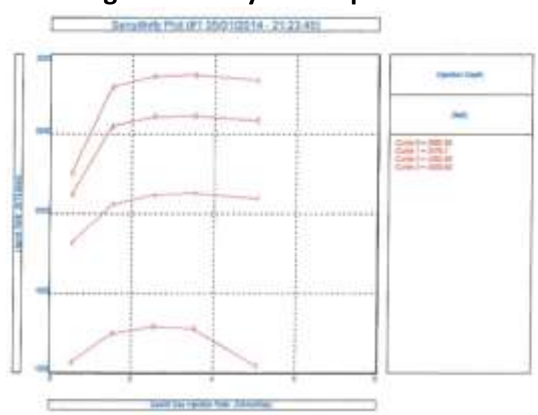


Figure 3.15: Sensitivity Plot

RESULTS:

Manual Calculation Results			IPM Prosper Results	
AOF (STB/day)	6900		AOF (STB/day)	6539.6
Calculated Gas Injected Pressure (psi)	1274		GL Injection Rate (MMscf/day)	3.5
Calculated GLR (SCF/bbl)	500		Matching for viscosity	standing and beggs et al
Calculated BHP (psig)	1355		Measured BHP (psig)	1393.96
Measured Liquid Production Rate (STB/day)	1500		Heat Transfer Co-efficient (BTU/h/ft²/F)	2
Curve Used	Hagedorn and Brown		Maximum Liquid Production Rate (STB/day)	2870.9
Depth of Valve 1 (ft.)	2088		Depth of Valve 1 (ft.)	2083.9
Depth of Valve 2 (ft.)	3345		Depth of Valve 2 (ft.)	3478.1
Depth of Valve 3 (ft.)	4300		Depth of Valve 3 (ft.)	4363
Depth of Valve 4(ft.)	4760		Depth of Valve 4 (ft.)	4838.9

Table 5: Comparative Results

Conclusion:

- If wells are self-flowing, it is recommended to go for artificial gas lifting in view of the more returns on the investment.
- In view of the availability of excess gas in same field than Artificial gas lifting is recommended.
- The topmost valve must be installed as up as possible to unload the well efficiently.
- Considering the high BHP, high PI well conditions continuous gas lifting is recommended.
- 4 GL valves are recommended with the deepest one at a depth of a well.
- Tubing pressure operated GL valve is recommended.
- It is recommended to conduct the cost benefit analysis for well to decide the investment strategy.

Do's:

- GL wells should be operated with minimum backpressure. It is preferred that wells have independent flow lines till GGS. Avoid interconnection.
- If interconnection is unavoidable every well should have NRV at the upstream of interconnection point. This is very critical for the intermittent lift wells because during the tubing ideal phase of the intermittent lift, well fluid from other well can enter in to its tubing.
- After gas injection line repair, the line should be flushed with water and then purged with air keeping FCVS and DMVs in full open condition to remove the debris.
- Drain the liquid regularly from the filter to avoid chocking of regulator.

Do not's:

- Do not circulate liquid through GLVs. Hot oil circulation or water circulation through GLV can damage its seat. Circulation should be carried out as a last resort to rectify the GLV malfunctioning.
- Do not disturb the setting of FCV for during scrapping operation. Use annulus valve or bypass valve.
- Do not wind the clock of the timer without loosening timer wheel. This

damages the clock. Loosen the timer wheel and do winding.

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NOMENCLATURE:

GL:	Gas Lift
BHP:	Bottom Hole Pressure
PI:	Productivity Index
THP:	Tubing Head Pressure
GLR:	Gas Liquid Ratio
GOR:	Gas Oil Ratio
IPR:	Inflow Performance Relationship
PVT:	Pressure Volume Temperature
VLP:	Vertical Lift Performance Relationship
WH:	Well Head
SG:	Specific Gravity
Pr:	Reservoir Pressure
Tr:	Reservoir Temp.

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