

Research Article

# Oil Production Optimization with Gas Lift Method

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## Abstract

Hydrocarbon specially oil & gas are mostly used worldwide as an energy source, During the production life, reservoir pressure declines as in result oil production decreases and percentage of water cut increase. This scenario has inspired the researchers and professionals to explore new application for increasing oil production and to minimize water cut to make production economical. Well design, well performance prediction and well optimization programs for most of the well configurations are carried out by IPM Prosper. It aids to adjust the variables and investigate effects on the production. Impact of various gas injection rates and water cut on well performance has observed and investigated that it has great influence on oil production rates. This research study is focused on design of reliable well model, with the ability to cover each aspect of wellbore modeling, Fluid component such as fluid characterization, Vertical Lift performance correlation and reservoir inflow performance of producing well system are simulated. Further each component of the simulated system is compared by performance matching to field data. After that, combine results are generated by changing injection rates and water cut. The result showed that increase with oil production is only possible with minimum gas injection rates.

**Keywords:** Artificial lift, Gas injection rate sensitivity analysis, Gas lift, Production optimization, Water cut sensitivity analysis.

## 1. Introduction

During reservoir producing life, the pressure drops due to the oil production decline. Further, increase in water cut ratio may resulted shut-in production. This situation motivates to the oil industry professionals and researchers to work on the modern application for demolishing the problems to reservoir producing life. Artificial lift systems are designed to help natural drive reservoir to move formation fluids to the surface at desired rates (Flatern, 2015).

Major artificial lift methods used in oil the industry are Gas Lift (GL), Electrical Submersible Pump (ESP), Sucker Rod Pump (SRP), Hydraulic Pump (HP), Progressive Cavity Pump (PCP)(D.D. Smallwood, 1990). Gas lift system is a technique which is widely applied in the oil industry and fluids to move the fluid to flow towards surface by injecting compressed high-pressure gas in production string (tubing) through gas lift valve. which results lower in hydrostatic pressure in tubing and boost differential pressure between reservoir a fluid and wellbore ('Gas-Lift Equipment Catalog', 2014). In view of the water cut and production shut-in, well should put on artificial lift to energize fluid to move the surface. Gas Lift System is

one of the most efficient artificial lift methods employed worldwide. The purpose in such operations is to reduce the fluid density and the hydrostatic pressure loss in wellbore by compressing gas at the surface and injecting it into the well (Petroleum Experts, 2015). Gas lift is particularly applicable for lifting fluids and simulation study of gas lift may be done with the IPM Prosper application. IPM Prosper is the most common application used in the oil industry for production and system analysis. Reservoir and Production engineers also get help for reliable forecasting of production tubing hydraulics, Pipeline hydraulics and temperature for both naturally flowing and artificially lifted well (Miresmaeili *et al.*, 2018).

The scope of this research is to optimize the production life of the naturally flowing well with gas lift system. Therefore, this research study is consisting on developing a well model with reliable wellbore modeling, generating IPR curves, VLP plots, similarly build well model with application of gas lift system by simulating each component and generating IPR & VPR for gas lift system.

## 2. Literature Review

The technique of lifting liquids with the help of gas was introduced in the 18<sup>th</sup> century, Air was used to lift the water from the shaft of the flooded mine. In the year

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1865, gas lift was applied for oil lifting in Pennsylvania oil field. During the year 1900, gas lift become intensively applied in Texas-Louisiana Gulf oil fields. Around in the year of 1910, natural gas was utilized as alternative of air in the California USA. This advancement in gas lift technology proved more satisfactory, air has corrosive nature and it need to be compressed for maintaining the pressure (Kirkpatrick, 1959). Figure 1(A) shows the simple gas lift system. Injection of high pressure gas through the annulus by using gas lift valve increases oil production by using gas lift method. It expands liquid flow in two ways (Ibrahim, 2007).

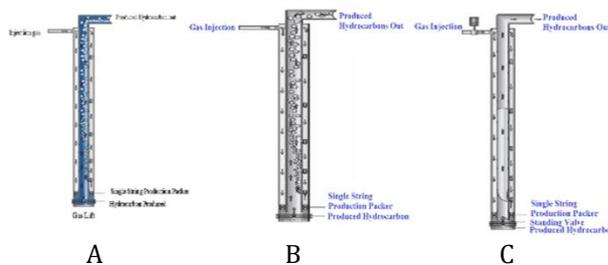
- Expansion of energy that pushes oil to the surface.
- Fluid density decreases when gas is agitated with oil. Desired flow rates are obtained when injected gas leads the differential pressure and decreases the Bottom hole flowing Pressure (BHP).

Large numbers of wells can be lifted at very low cost without any limitation of depth. It can also be applied to offshore operations. Gas lift technology is classified into two types (Coutinho *et al.*, 2017).

- A- Continuous Gas Lift
- B- Intermittent Gas Lift

**A- Continuous Gas Lift:** Gas Lift is one of the best system used as artificial lift system in the world because of low operating cost and easy availability of gas. Steady state fluid flow from wellbore to surface may result of continuous lift operation. Injection of high pressure gas in low pressure well result expansion of gas and reduction in gravity and density of fluid in the well column which boost the immobile well fluid to produce at efficient production rates (Tetoros, 2015). Figure 1(B) shows the continuous gas lift system, it comprises of surface and subsurface equipment. In surface equipment, a gas compressor used for obtaining desired injection rates. A manifold containing control valves, flow meter and distributing lines are used for connecting and controlling the flow of well. Subsurface equipment comprises of gas lift valve and Side Pocket Mandrel (SPM). SPM is used to permit gas lift valve to be installed or recover in live wells with the application of wireline job (*Api Gas Lift Manual*. 3rd edn, 2006).

**B- Intermittent Gas Lift:** Intermittent as reflect from name, it lifts fluid intermittently or irregularly for obtaining production at desired production rates. It is special form of gas lift in which high pressure gas is injected to well column cyclically which expands and energize the accumulated fluid in the tubing to move towards the surface in form of slugs ('Gas Lift Systems OPEX', 2014). Intermittent has successful production rate of more than 500bbl/day. Figure 1(C) shows the intermittent gas lift system. This system is more efficient in low productivity indices wells and low Bottom Hole Pressure (BHP) wells.



A - Simple Gas Lift System, B-Continuous Gas Lift, C- Intermittent Gas Lift

**Fig.1** Gas Lift Types (Ibrahim, 2007)(Salahshoor, Zakeri and Haghghat Sefat, 2013)

### 2.1 Advantages of Gas Lift

Gas Lift is most preferred due to following advantages ('Gas lift Continuous-flow gas lift Intermittent-flow gas lift', 2018).

- Maximum liquid production
- Flexible & wide range of lift depth
- Best for handling sand and solid material
- Can be applied on deviated well
- Occupy less space, more suitable for offshore due to space limitations
- Easy to implement, pulled, repair or replace
- Less maintenance cost
- Low operating cost
- Less data required to design gas lift system

### 2.2 IPM Prosper

IPM Prosper is an application widely used for designing, optimizing and performance modeling of well. It also aids engineers to forecast the performance of well. The sensitivity analysis feature of IPM Prosper allows to evaluate the effects of alterations made in any system parameter for optimization of existing well design (IPM Prosper Manual, 2010).

Reliable well model can also be constructed comprised of all fluid characterization, vertical lift and inflow performance. Detail study of flow at subsurface and surface level can be assure by matching the fluids, flow correlations and inflow performance with measured field data to create a reliable well model before applied to simulation (Onbergenov *et al.*, 2017).

### 2.3 Well Performance

#### 2.3.1 Inflow Performance Relationship (IPR)

The term inflow performance is defined as capacity of well to deliver fluid, indicates its performance. Well flowing with pressure above bubble point at steady state condition can expressed by Darcy equation for single and center located drainage area (Beggs, 1991).

$$q = \frac{2\pi kh}{\mu B} \frac{P_e - P_{wf}}{\ln(r_e/r_w) + S} \tag{1}$$

Where,

- q= Flowrate, STB/Day
- k= Permeability, md
- h= Thickness, ft
- μ= Viscosity, cp
- β= Formation volume factor, RB/STB
- P<sub>e</sub> = External boundary radius pressure, psi
- P<sub>wf</sub>=Bottom hole flowing pressure, psi
- r<sub>e</sub> = External boundary radius, ft
- r<sub>w</sub> = Wellbore radius, ft
- S= Skin factor

2.3.2 Productivity Index (PI)

It is mathematical expression for exhibiting well deliverability. Productivity Index is dependent on fluid and reservoir properties. Inspection of reservoir has an ability to produce oil to wellbore can be performed by measuring the ability of well to deliver the fluids. It is mainly calculated during the well testing (Journal and Harcourt, 2015).

$$J = \frac{q}{(p_e - p_{wf})} = \frac{2\pi kh}{\mu B} \frac{1}{\ln(r_e/r_w)} + S \tag{2}$$

If data of productivity index is available, flowrates under bottom hole flowing pressure (P<sub>wf</sub>) is straight forward. And can be calculated as,

$$Q = J(p_e - p_{wf}) \tag{3}$$

Where,

- J = Productivity index, STB/day/psi
- Q = Flowrate, STB/Day
- P<sub>e</sub> = External boundary radius pressure, psi
- P<sub>wf</sub>= Bottom hole flowing pressure, psi

An integrated optimization procedure was developed for well performance optimization for gas lift operation in a heterogeneous reservoir. The optimized value showed that 7% change in productivity index (PI) value that will result in 4% change in optimal gas flow rate (M. Soleimani 2017).

2.3.3 Inflow Performance Relationship Curve (IPR Curve)

Ability of reservoir/well to deliver fluid can be expressed by plotting the production rates and bottom hole flowing pressure. Construction of IPR curves required various production rates and drawdown pressure (Ahmed, 2001).

2.3.4 Vertical Lift Performance (VLP)

VLP/tubing performance is an important factor for designing a well. Production performance can be affected by tubing pressure losses. Major pressure losses occur in well bore to surface movement of fluids,

only 20% of losses happened in reservoir (‘Wellbore flow performance Pressure loss through the wellbore Single - phase liquid flow Single - phase vapor flow Multiphase flow Nomenclature’, 2018). VLP can be accesses by plotting surface Production rates by drawdown pressure. It reflects the performance of completion string i.e. tubing and completion components (‘tubing performance curve ( TPC )’, 2018).

3. Methodology

IPM Prosper is an application, where the calculations for study of production system and improve the recovery of oil for natural drive and artificial lift application can be done. Gas lift techniques are used to provide additional potential to increase the production rates by decreasing bottom hole pressure for providing high drawdown pressure. Gas lift along with IPM Prosper are widely used for Well model, designs and well performance program. Figure 2 shows the flow chart for detailed Methodology.

The field data for the well A1 is analyzed. PVT data, IPR data, deviation survey & equipment data are use based on Simulation input requirement. Table 1 shows the input data used in the simulation.

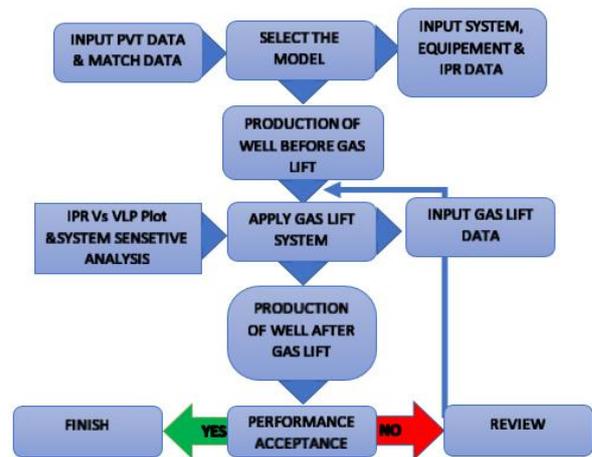


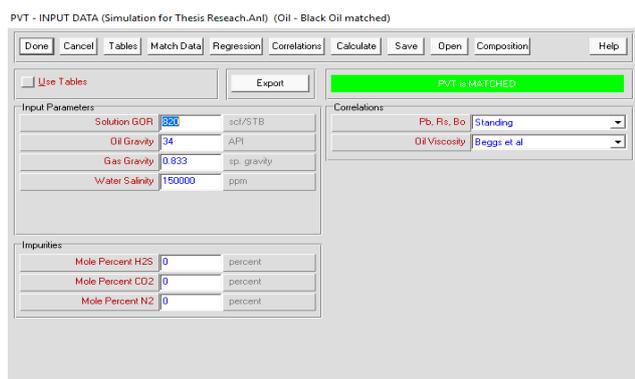
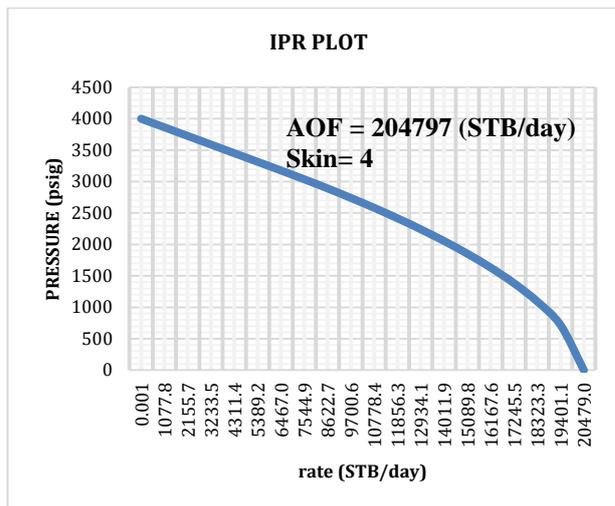
Fig.2 Flow chart for research study

Parameter	Value
Solution GOR (SCF/STB)	820
Oil gravity (°API)	34
Gas gravity	0.833
Water salinity (ppm)	150000
Mole % H <sub>2</sub> S (%)	0
Mole % Co <sub>2</sub> (%)	0
Mole % N <sub>2</sub> (%)	0
Bubble point pressure (psig)	3256
Temperature (°F)	210
Oil FVF (bbl/STB)	1.491
Oil viscosity (cp)	0.435

After selecting the best fit correlations, input data is matched with simulated data as shown in the Figure 2 PVT IS MATCHED. Table 2 show the input data for generating IPR Curve and the input data for gas lift section is shown in Table 3.

**Table 2:** IPR Data (IPM User Manual, 2010)

Parameters	Value
Reservoir Pressure (psig)	4000
Reservoir temperature (°F)	210
Water cut (%)	15
Total GOR (Scf/STB)	820



**Fig 3** IPM Prosper input data screen

**Table 3** Gas Lift Data (IPM User Manual, 2010)

Parameter	Input
Gas Lift Method	No Friction loss in annulus
Gas Lift Type	Fixed Depth of Injection
Gas Lift Gravity	0.8
Mole % of H <sub>2</sub> S (%)	0
Mole % of Co <sub>2</sub> (%)	0
GLR Injected (scf/STB)	0
Gas lift valve Depth Measured (ft)	6480.0

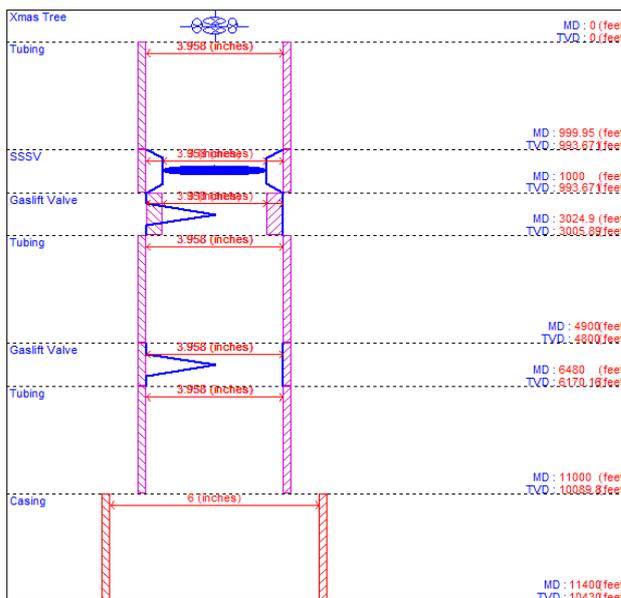
**4. Result & Discussion**

**4.1 IPR Curves**

It is found from result that GOR is approximately the same for both PVT and IPR curve, so the same value of GOR was used for gas lift system. Figure 4 shows the IPR Curve generated in the software, the IPR curve had been generated after putting the all values in IPR section. In this Figure 4, IPR defined the Absolute Open Flow (AOF) at zero drawdown pressure and positive skin.

**Fig 4** Generated IPR-Curve

Deviation and downhole completion data are shown in Figure 5 well completion diagram, Downhole equipment installed are casing, tubing, SSSV and gas lift valves. Two gas lift valves are installed at the depth 3024.9 ft. and 6480 ft. Simulation study is carried out on Gas lift valve which is installed at the depth of 6480 ft.



**Fig 5** Well completion diagram

**4.2 IPR & VLP Curves**

Inflow & outflow performance of well A-1 are simulated before the gas injection. In which Well A-1 has over all liquid production of 9765.5 STB/day, oil production of 8293 STB/day at solution node pressure of 2738.30 psig, 15 % water cut and 820 SCF/STB as shown in the figure 6.

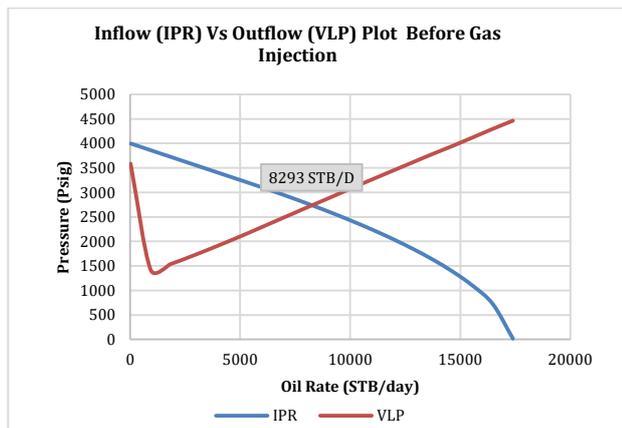


Fig 6 IPR Vs VLP curve prior to gas injection

4.3 Optimization by using gas lift

it is observed that injection of gas is independent of the GOR, hence the IPR & VLP is potted after application of gas lift method & It is also observed that at injection rate of 1 MMSCF/D causes increase in oil production 3400 /day at 15 % water cut and GOR 820 SCF/ STB as shown in Figure 7.

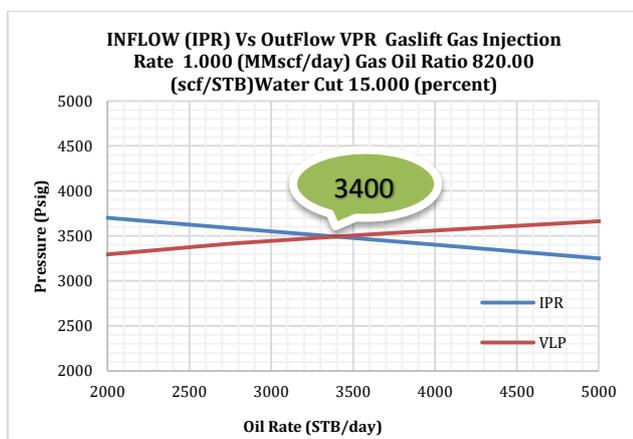


Fig 7 IPR & VLP After gas Injection

For optimization, different injection rates are simulated by using IPM Prosper as shown in figure 8. Injection of gas increase the production of oil sensitivity analysis is done for interpretation of different injection rates. Figure 9 exhibits the sensitivity graph and sensitivity analysis of production rate after injection is summarized in table 4.

Table 4: Increase in Production rate after different gas injection rate

GOR, (scf/STB)	820	Increase in Q <sub>o</sub> , (STB/Day)
Water Cut, (%)	15	
Q <sub>g</sub> (MMscf/Day)	Q <sub>o</sub> , (STB/day)	
1	3400	0
2	4035	635
3	4381	346
4	4592	211
5	4731	139
6	4814	83

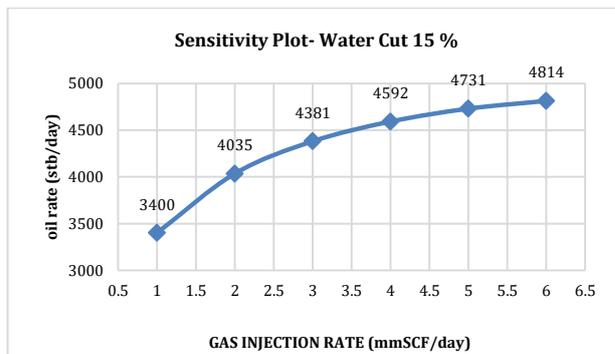


Fig 8 IPR vs VLP after Gas injection at different rates

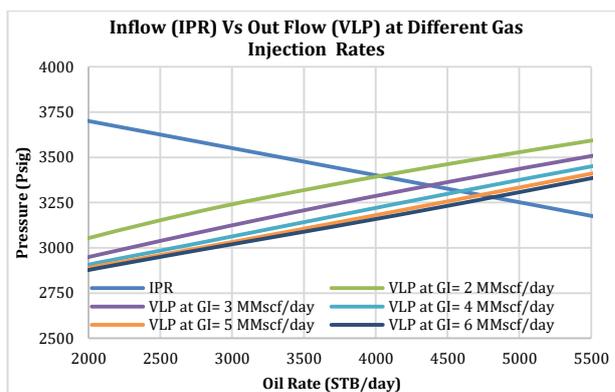


Fig 9 Sensitivity graph

From our findings, it has been interpreted that gas injection at constant rate increase the rate of oil production. By increasing the rate of injection increase in production is less than the previous i.e. Injection from 1 to 2 MMSCF has less increase in production rate than the 2 to 3 as shown in Table 4. Higher injection rates may not be economical dependent on the economic characteristics.

Water cut at different injection are also evaluated and compression of all oil rates with gas injection rate. Figure 10 shows the IPR Vs VLP after gas injection at different gas injection rates at 30 % Water cut.

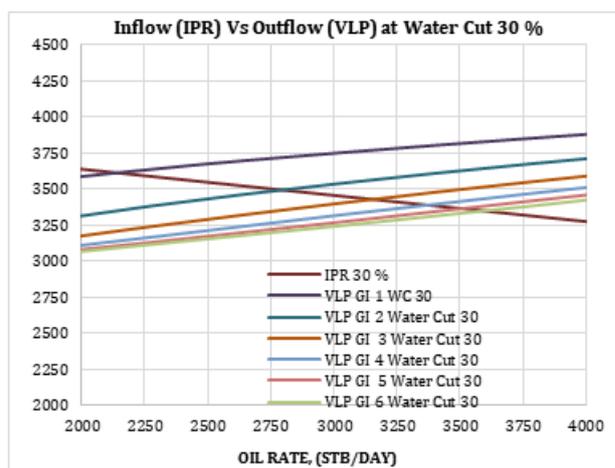


Fig 10 IPR Vs VLP at different gas injection rates and 30 % water cut

Figure 11 shows the IPR Vs VLP after gas injection at different gas injection rates and at 45 % Water cut. Furthermore, Sensitivity analysis of oil production at different injection rates and different water cuts is also carried out as shown in figure 12. All the results are summarized in table 5. it shows oil production at different injection rates of 1, 2, 3, 4, 5 and 6 MMSCF and oil production at different water cuts 15, 30 and 45 %.

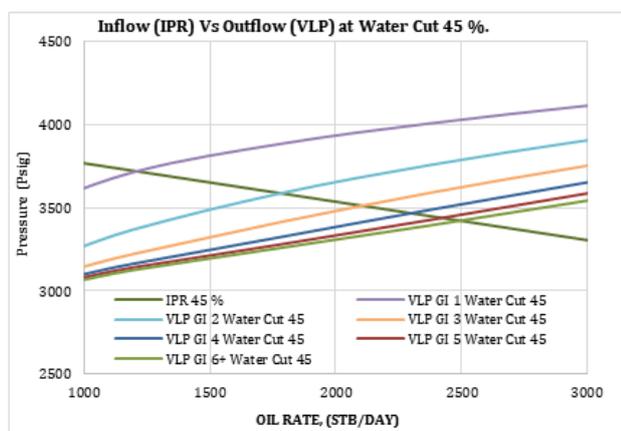


Fig 11 IPR Vs VLP at different gas injection rates and 45 % water cut

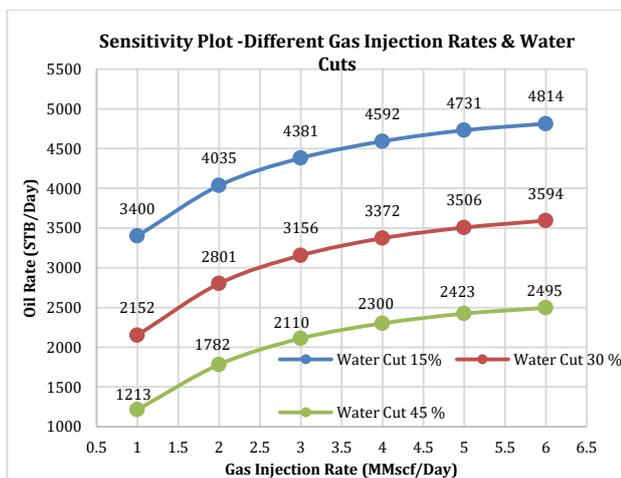


Fig 12 Sensitivity plot, showing oil rates at different injection rate & Water cut %.

Table 5: Oil rates at different injection rate & water cut %

GOR, (scf/STB)	820	Increase in Q <sub>o</sub> , (STB/Day)
Water Cut, (%)	15	
Q <sub>g</sub> (MMscf/Day)	Q <sub>o</sub> , (STB/day)	
1	3400	0
2	4035	635
3	4381	346
4	4592	211
5	4731	139
6	4814	83
Water Cut 30 %		
1	2152	0
2	2801	649

3	3156	355
4	3372	216
5	3506	134
6	3594	88
Water Cut 45%		
1	1213	0
2	1782	569
3	2110	328
4	2300	190
5	2423	123
6	2495	72

### Conclusions

- 1) Reservoir & production modelling technique are best for initial reservoir management preparation and plan development, field development, history matching, EOR project designing and other future planning for boosting hydrocarbon recovery.
- 2) Well design, well performance prediction and well optimization programs for most of the well configurations are carried out by IPM Prosper. It aids to adjust the variables and investigate effects on the production. Impact of various gas injection rates and water cut on well performance has observed and investigated that it has great influence on oil production rates.
- 3) Well A-1 is producing with GOR ratio of 820 SCF/STB, which is best match GOR.
- 4) Sensitivity analysis at 15 % water cut and the injection rate of 1, 2, 3, 4, 5 and 6 MMSCF/Day, Oil rate was observed to be 3400, 4035, 4381, 4592, 4731 and 4814 STB/day respectively. Sensitivity analysis at 30 % water cut and the injection rate of 1, 2, 3, 4, 5 and 6 MMSCF/Day, Oil rate was observed to be 2152, 2801, 3156, 3372, 3506 and 3594 STB/day respectively. Sensitivity analysis at 45 % water cut and the injection rate of 1, 2, 3, 4, 5 & 6 MMSCF/Day, Oil rate was observed to be 1213, 1782, 2110, 2300, 2423 & 2495 STB/day respectively. Constant increase in gas injection rate, increase in oil rate is not constant, obtain oil rate is less than the previous oil production by previous injection rate. Higher injection rates are not recommended for well A-1 and minimum gas injection rate will be suitable for application of gas lift and getting optimized production.

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