Simulating Well Performance and Optimizing production from an HPHT Gas Reservoir Using IPM Suite – A case study

ISSN (e) 2520-7393
ISSN (p) 2521-5027
Received on 26 Sept, 2018
Revised on 2, Oct, 2018
www.estirj.com

Yasir Ali Memon[1], Muzaffar Ali Mahar[2], Naveed Ahmed Ghirano[3], Abdul Basit Balouch[4]

[1, 3, 4] *Institute of Petroleum and Natural Gas Engineering, Mehran University of Engineering and Technology, Jamshoro*
[2] *Production Department, Pakistan Petroleum Limited.*

Abstract: Lack of integration between reservoir, well and surface network modeling results in reduced rates from oil and gas well. Production optimization techniques are the essential key to resolve this issue and optimize the well productivity during the entire life of the well. The objective of this study is to optimize the production of an X well in Pakistan using the Integrated Production Modeling (IPM) suite. In this study three worthwhile softwares (MBAL, PROSPER, GAP) are used. MBAL used to predict reserves up to 2031 which were found 64 BCF. Gas reserve based on volumetric estimate is 795.68 BCF. In January 2017, cumulative gas production G_p is 9.026 BCF. Using prosper, the measured gas rate is found almost similar to software calculated gas rate and result variation is less than 2%. Furthermore the impact of each parameter such as well stimulation, tubing size, water gas ratio, condensate gas ratio, well head pressure and average reservoir pressure are also observed to identify any bottleneck in the production system. GAP software analysis is also implemented to optimize the production of this X-well. Network Solver is run to investigate various types of separator pressure using different tubing diameters to analyze the impact gas rate and flow rate. In this case it is found when selected tubing diameter 3.5in and separator pressure is 500psi (pound per square foot), the flow rate of the well using GAP is 17.04 MMscf/day and observed zero flow rates on 2/9/2022. And when using tubing diameter 3.5in and separator pressure is 700psi (pound per square foot), the flow rate of the well is found 16.01 MMscf/day and observed zero flow rates on 8/1/2020.

Keywords: *Production Optimization; HPHT Reservoir; Gas condensate reservoir; Integration production modeling, sensitivity analysis*

1. Introduction

1.1 Background

This study is carried out on a well of a gas-condensate field located in Pakistan. The well was started to produce from December 2011. From start of the production till to the now, the well had sudden changes in its behavior. The goal of this study is to employ an efficient optimization method to optimize the production and analyzing the production system by simulation using the Integrated Production Modeling (IPM) suite's worthwhile softwares MBAL, PROSPER, GAP. Reservoir performance and reserve estimation by MBAL, Production scenario by PROSPER and the surface scenario by GAP Analysis. The reservoir characteristics like reservoir pressure, porosity, permeability, pay thickness, skin, wellbore storage, and further relevant information has been used to estimate the reserves and to optimize the production of the well.

1.2 Problem statement

Lack of integration between reservoir, well and surface network modeling results in reduced rates from oil and gas well which in term will need a unique optimization technique to recover the reservoir fluids commercially at optimum rates. Reduction in residual gas saturation and optimization of production can be achieved through proper management with sensitive use of production engineering, reservoir engineering and finest planning therefore production optimization plays a key role in optimizing production. Integration of items of surface network that will affect production can enhance production at optimum flow rates.

1.3 Well Performance

It is the monitoring solution that enables the users to proactively assess the production performance of the oil and gas wells. The measurement of production of well of oil and gas related to wells anticipated productive capacity, pressure drop, or flow rate. For oil well production performance is often estimated by productivity index [1]. MBAL software is used to analyze the reservoir behavior and modeling the reservoir. It helps to better describe drive mechanism and reserves prediction and also provide the extensive matching facilities.

1.4 *High Pressure High Temperature (HPHT)*

High pressure high temperature wells are normally defined as well has undisturbed pore pressure greater than 0.8psi/ft. and temperature greater than 300 ºF (149ºC) or requiring a blow out preventer with a rating excessive than 10000 psi. [2].

1.5 *Network Modeling*

Corresponding author Email address*: yasirmemon2772@gmail.com*

Network modeling system helps to identify any bottlenecks, allocate production and gain better control of operating data and optimizing solutions [4]. Building complex network models helps to provide accurate economic and engineering solutions. Network modeling using GAP Analysis was implemented to eliminate artificial boundary conditions in reservoir, well and surface network. GAP is also able to consider the multiphase network response of multiple wells producing into a common producing system. The objective of network modeling is to analyze the behavior of hydrocarbon field using physical description of items that could affect production rate. GAP analysis approach builds a model for surface network work system [6].

1.6 *Tubing performance relationship (TPR)*

TPR is defined as at fix wellhead pressure or bottom hole flowing pressure the resulting relationship between 'Q' and P_{wf} is TPR [4]. The tubing performance shows flow along the tubing from subsurface to surface and this affect by pressure gradient due to restriction in the well tubing through valves, connections, and chokes.

We either fix well head pressure or bottom hole pressure at given rates, then the resulting pressure loss among the tubings can be determined through correlations and then the pressure at the bottom of the tubing can be found. The resulting relationship (Pwf vs. Q) is effective only for particular wellhead pressure. [5].

There are two versions of the Tubing Performance Curve used in practice. The primary version defines the relationship between delta P and Q at the well head. The second one represents the relation between Pwf and top site flow rate Q. [6].

Various types of method have been introduced to determine Pwf of gas wells as the pressure gauges installed at the bottom of the well cannot detect the pressure. A combination of outflow and inflow curves generally defines the Q the flow rate and Pwf wellbore bore flowing pressure at specified pressures and tubing parameters such as sizes of tubing and wellhead pressures, this can now be said as deliverability or instantaneous flow by the combination of outflow and inflow curves. The point of intersection inflow performance and tubing performance curve defines the performance of tubing and called as natural point. [7].

1.7 Phase Behavior

The reservoir fluid is/are categorized basically into three kind of phase single phase, two phases, or a combination of both so this type of information is used to determine the type of IPR equation to use . Reservoir temperature, T_R, greater than critical temperature of the hydrocarbons is called as gas reservoir[8]. Phase diagram for a gas reservoir is given in Figure-1.

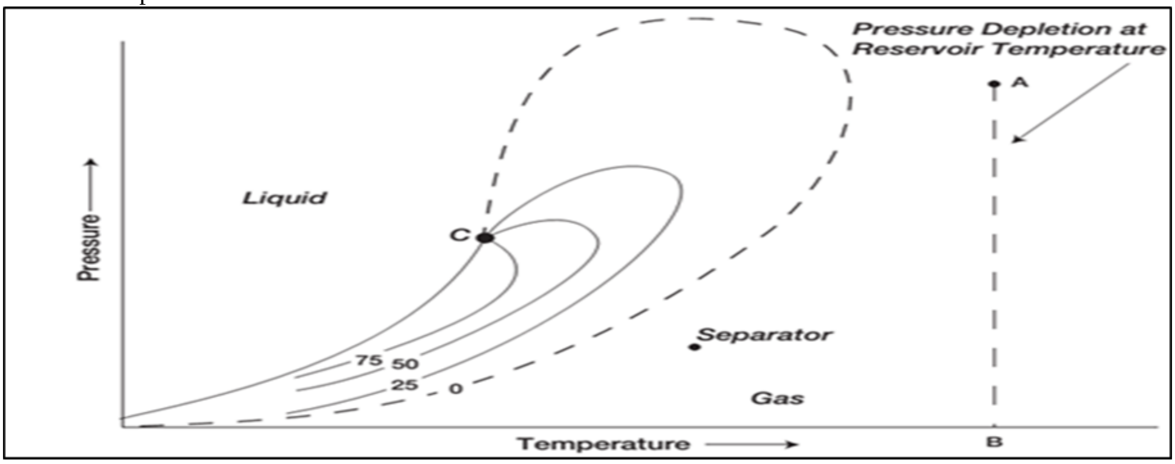

Figure 1: Phase behavior of a gas reservoir

2.Objectives and Motivation

The role of production optimization is the key consideration for the production engineer after the well has been drilled till to the well life expiry hence cannot be neglected. Production optimization is one of the techniques that are applied on each of the well. It is the essential key to optimize the well productivity during the entire life of the well. The present research work will analyze the well by predicting the reserves using MBAL, evaluating well performance by analyzing sensitivity of parameters using PROSPER and optimization of surface network system by analyzing separator pressure versus well life expiry using GAP analysis software.

The aims and objective of this study are

- To predict reserves up to 15 years using MBAL software
- To establish well models to analyze parameter sensitivity using Prosper
- To build comprehensive well model to analyze separator pressure versus time using GAP ANALYSIS.

The tubing size plays significant role in producing fluid with optimum rates. If increasing the diameter, it increases the rate of natural flow. Smaller tubing sizes have highier frictional losses and tend to have highier gas velocities which can deliver better transport for produceding fluid. Excessive tubing sizes have the lower frictional losses, pressure drops because of the minimum gas velocities and the lesser capacity for liquid carrying.

3. Methods and Material

From the beginning of model till to the results the research aim and objectives listed above was succeeded through various stages, techniques and methods using the integrated production modeling softwares (MBAL, PROSPER, GAP).

3.1 *MBAL*

MBAL Software is a reservoir analysis tool that uses production history of a reservoir and PVT fluid characterization to achieve mass balance calculations and to determine stock tank original oil in place. Also identify the mechanism of driving fluid to surface with in the reservoir, MBAL need an accurate fluid characterization and reservoir history for calculations. Material balance equation is based on principal of conservation of mass.

Material balance is zero dimensional, based on tank model and doesn't bring shape of reservoir etc. into account. MBAL is the software that consist various tools to help a user to better explain reservoir behavior and carry prediction run tool 1) Material balance 2) Allocation of reservoir 3) Monte Carlo volumetric 4) Decline curve analysis 5) 1D model 6) Multi-layer.

3.2 PROSPER

Prosper is an optimization tool, design and model the well for optimization of production and is the section of Integrated production modeling (IPM). PROSPER allows an engineer to build the reliable models with the ability to take each expect of wellbore modeling. PROSPER provides applications which could alter or adjust various type of fluid data, multi-phase correlations and inflow performance relationship to correlate the measured field data and build a model to use in prediction, it also enables surface pipeline performance, pipeline stability and design, stability, slug and frequency [9].

3.2.1 Inflow performance relationship (IPR)

Inflow performance curve is the correlation of 'Q' flow rate and Pwf wellbore flowing pressure of a well. The tool used in field production system to analyze wellbore performance by building a relation between flow rate and flowing bottom hole pressure [10].

3.2.2 Vogel Method

In1968 Vogel method proposed an equation shaping of inflow curve. An empirical solution for IPR in modeling solution gas drive based on computer model results and fluid properties is shown below.

$$\frac{q}{q'} = 1 - .2\left(\frac{p_{wf}}{\bar{p}}\right) - .8\left(\frac{p_{wf}}{\bar{p}}\right)^2$$

3.2.3 Factor affecting inflow performance relationship

Inflow performance flow relationship can also be characterized by constant J (productivity index). It can be graphically represented by linear with a slope (-1/J) of line and intercepts will be $P_{wf} = P_R$ and Q= $Q_{max.}$ At values of Q=0 and P_{wi}=0 respectively. If the j changes with time, the IPR plot will be changed and a combination of Pwf and Q will be no longer. The principle factors affecting IPR are [11]:

1) An increase in gas saturation and decrease in relative oil permeability
2) An decrease in pressure due to increase in oil viscosity.
3) Oil shrinkage and gas evolution due to decrease in oil pressure.
4) Skin factor (S=0) around the wellbore
5) An increase in turbulence term D_q as q_o increases.

3.2.4 PVT Data Matching

It is necessary to predict the fluid properties for calculation of temperature and pressure changes, Where both basic fluid data and some PVT laboratory measurements are available, the program can modify the black oil correlations to best-fit the measured data using a non-linear regression technique.

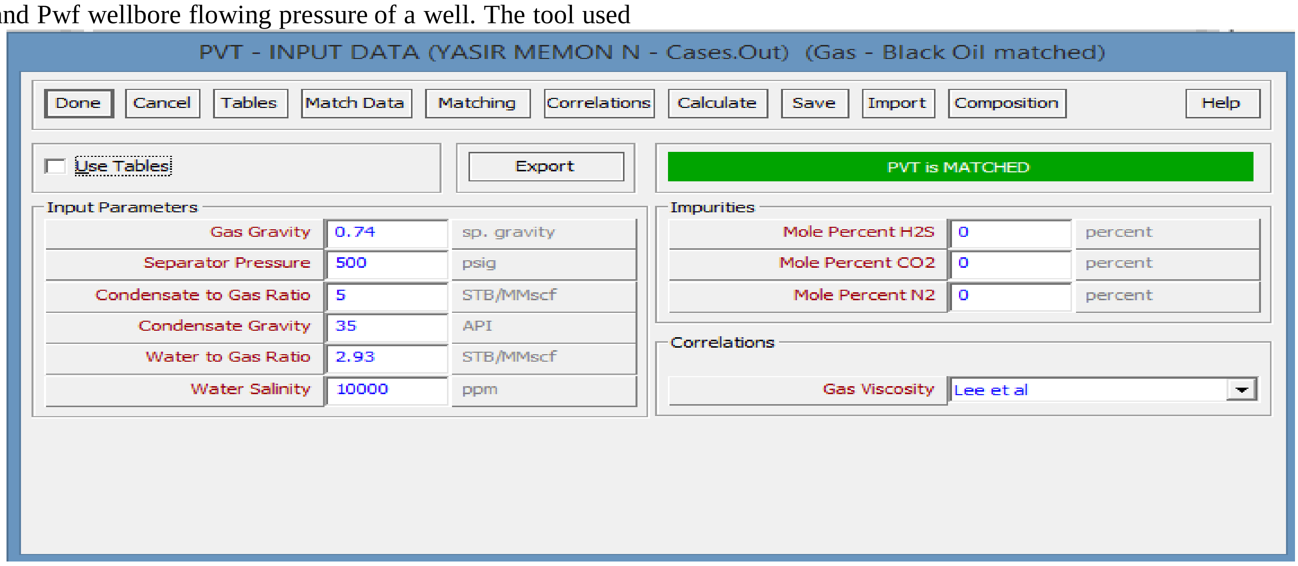

Figure 2: PVT Data matching using prosper

3.2.5 Matching of VLP curve

The defining phase for choosing well bore multiphase correlations to best fit with measured downhole pressures and rates, when the rough approximation method is used this model allows U value to be estimated. Once the Vertical Lift Performance curve is matched, the inflow performance curve can be adjusted to match observed rates and flow rates.

3.2.6 Linking MBAL and Prosper into GAP

GAP was linked with MBAL and PROSPERS software to update data with in Gap. Reservoir performance is achieved by importing MBAL, production and injection models can be run with GAP by calculation of injection pressures and optimization of production at every step. Production forecasting was achieved by importing prosper into GAP.

3.2.7 Gas well performance

Gas estimation in recent years was analyzed as opening flow into atmosphere in order to measure the flow rate but this was appeared as wastage of the flow of gas and may also cause hazardous to environment/surrounding. AOF (Absolute Open flow) is the representative of well productivity and states to maximum well flow against back pressure.

Method for analyzing the gas well based on lots of tests is proposed by Rawlins and Schellhardt. They obtained a straight line when plotted square of Pwf and average reservoir pressure while following corresponding flow rate. [12] It was proposed as in equation form:

$$\boxed{q_g = C\left(\bar{p}_R^2 - p_{wf}^2\right)^n}$$

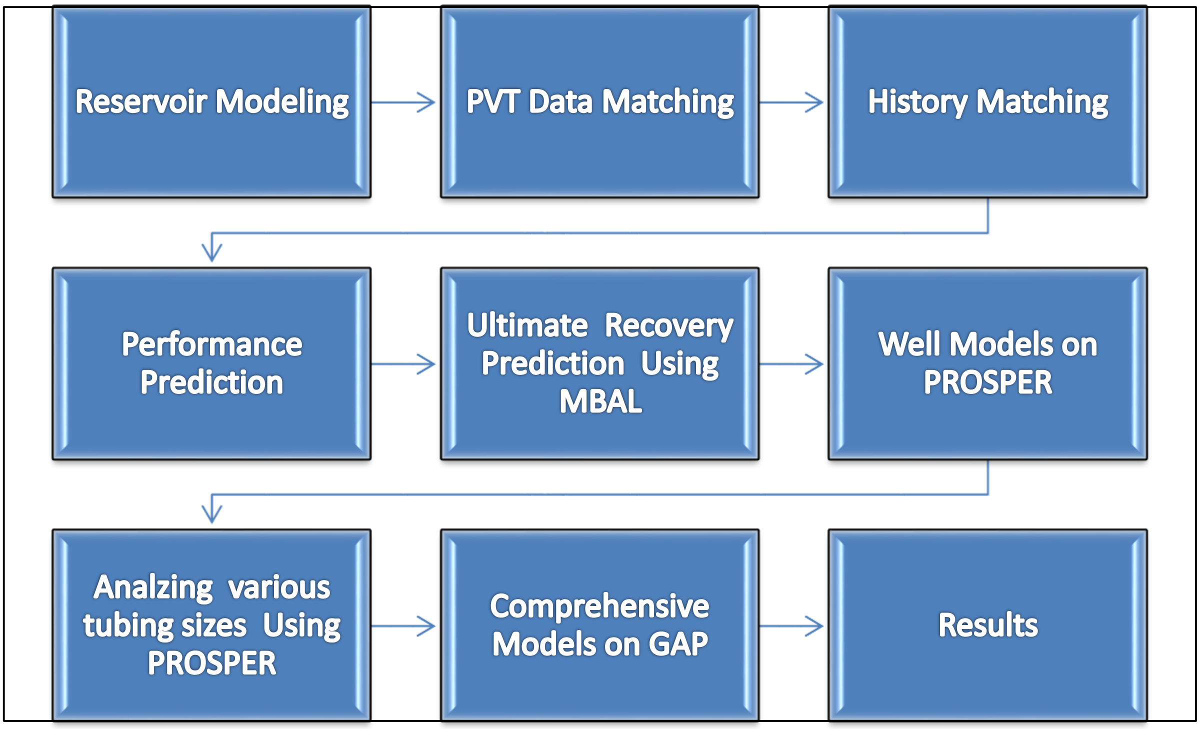

Figure 3: workflow diagram of models

4. Result and Discussion

4.1 Prediction of production using MBAL

The material balance method is the tool for determining reserves quantity. Material balance also models the linear/radial/bottom drive reservoir and the aquifers. It includes the typical use calculation measured in this method for history matching the graphical approach like Hevlena-Odeh. PVT models can be built for the condensate reservoir, gas reservoir or oil reservoir. Furthermore prediction of the reserves can be made using relative permeabilities.

The prediction step is followed to predict reservoir behavior, and at a date choose by engineer the program can switch from history simulation to prediction session. In this paper, reservoir production is predicted up to 15 years using MBAL software which is determined gas production as 64 BCF and reservoir pressure as 4210 psi. Gas production and pressure versus time up to 15 years was predicted to analyze the performance of the reservoir, shown in figure-3 and figure-4.

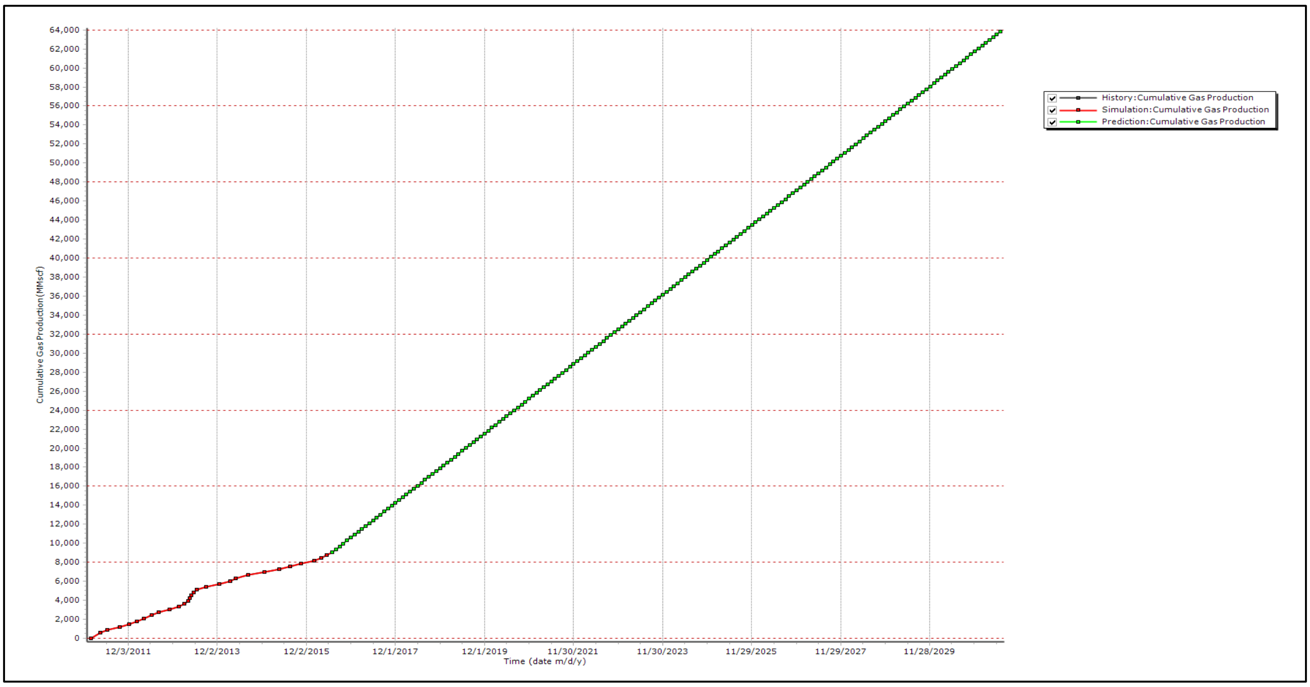

Figure 4: Gas production versus time

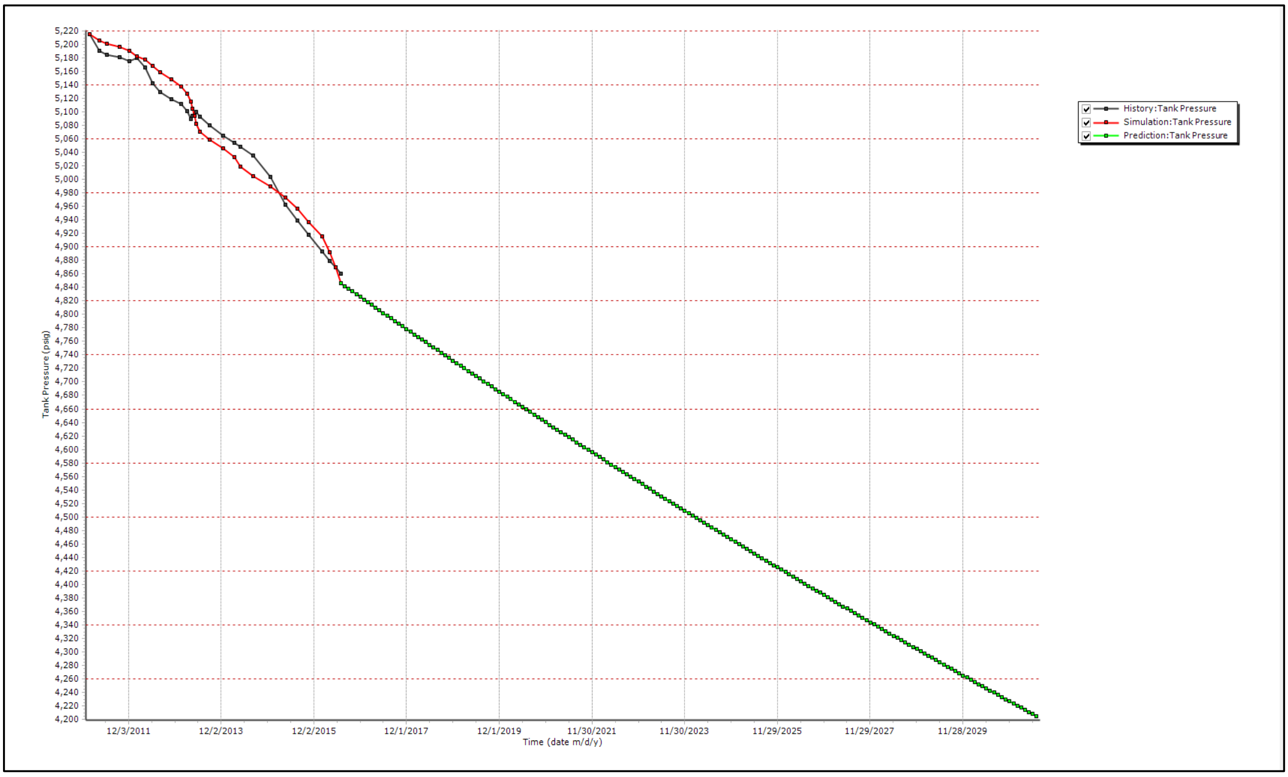

Figure 5: pressure versus time

4.2 Prosper

4.2.1 VLP/IPR Matching

The defining phase for choosing well bore multiphase correlations to best fit with measured downhole pressures and rates, when the rough approximation method is used this model allows U value to be estimated. Once the Vertical Lift Performance curve is matched, the inflow performance curve can be adjusted to match observed rates and flow rates. Using prosper, analyzed individually impact of various reservoir parameters on flow rate and similarly calculated the effect of combined various reservoir parameters on flow rate. The tubing performance relationship versus inflow performance relationship found by Prosper, in which the matching point found as 16.79 MMscf/day is shown in figure-5.

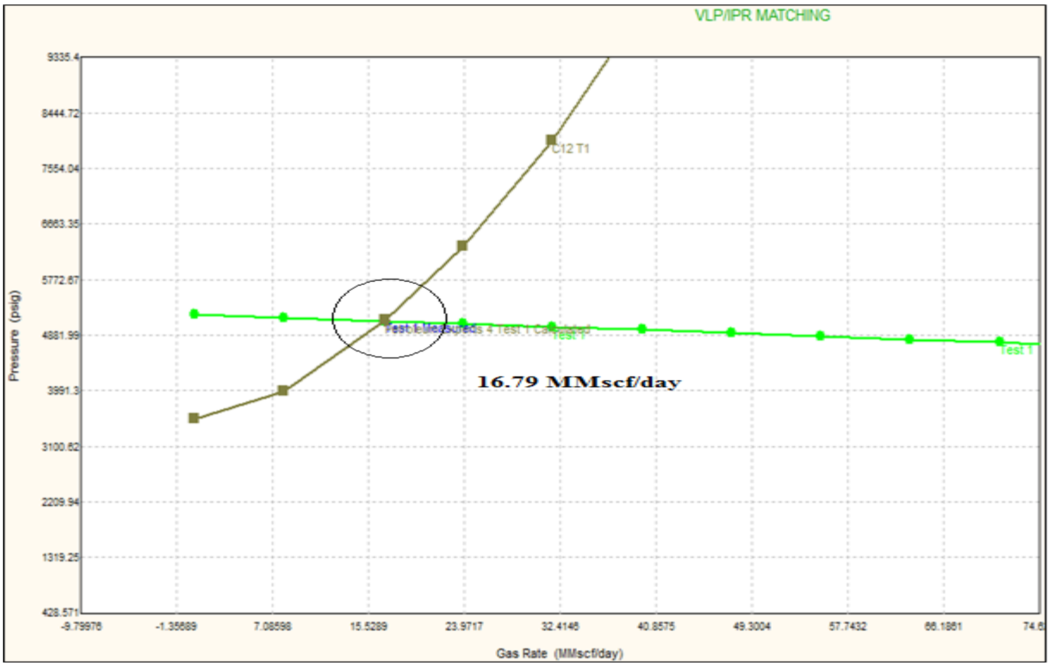

Figure 6: shows TPR/IPR plot

4.2.2 Effect of tubing size on flow rate

It is observed that flow rate is decreasing due to decrease in tubing diameter. The pressure drop varies with flow rate in any component, thus a plot of node pressure versus flow rate will constructed, the intersection of which will give the conditions of satisfactory. At a pressure below bubble point when the gas is moving within reservoir, this gives a straight line in single phase flow thus it is not a linear relationship. Pressure drop and relative permeability are the factors that influence the shape of inflow curves across the reservoir. Increasing diameter increases rate of natural flow until the critical diameter is reached. Table-1: show tubing size effect on flow rate

Table 1: shows the flow rate effect due to changes of tubing diameters.

Tubing Size ID (in)	Gas Rate (MMscf/d)
2.091	8.240
2.75	16.921
3.75	36.491

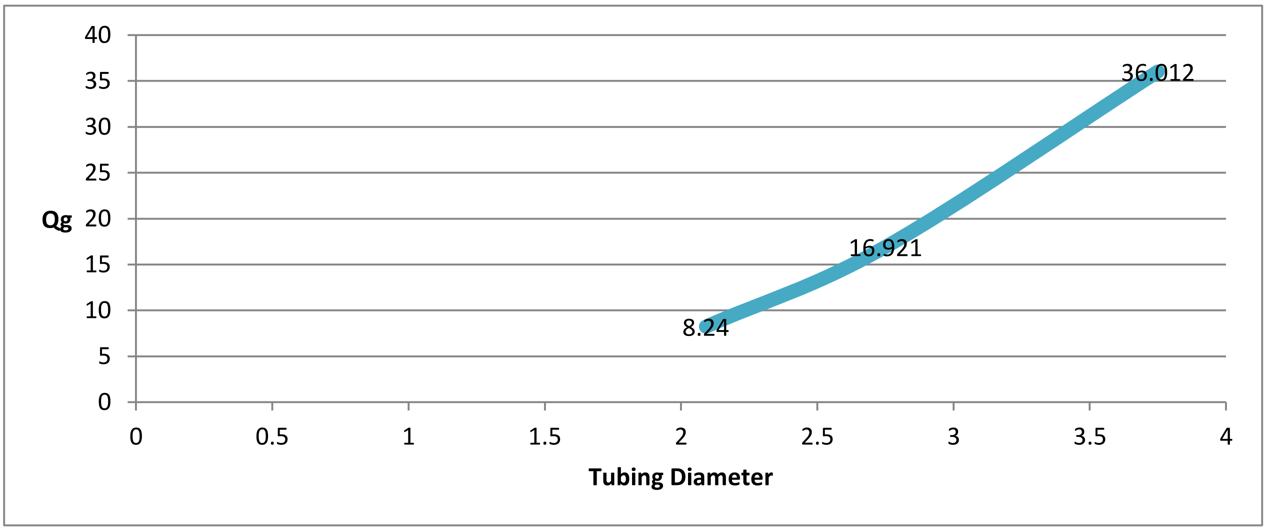

Figure 7: shows graphically effect of flow rate due to change of tubing

4.2.3Effect of parameters

Prosper has also the capability to run sensitivity analysis of the reservoir parameters, using the sensitivity technique, analyzed the integrated various reservoir items to determine the bottleneck in reservoir production. As the condition of the reservoir changes, the impact on flow rate appears. Many of the ideal conditions was carried out to observe the reservoir scenario or the reservoir reaction against flow rate to optimize the production Shown in Table-2

Table-2: Impact of parameters

S. no.	Reservoir pressure	Top node pressure	Water gas ratio	Condensate gas ratio	Gas flow rate MMscf/day
01	5000	3000	15	20	**16.34**
02	5000	3000	05	15	**16.57**
03	5000	3000	10	20	**16.42**
04	4750	3000	15	20	**15.06**
05	4750	3000	10	15	**15.38**
06	4750	3000	5	10	**15.72**
07	4500	3000	5	10	**14.06**
08	4500	3000	10	15	**13.77**
09	4500	2700	15	20	**15.23**
10	4500	2700	05	10	**15.89**

4.3 Prediction of production using GAP

GAP optimizes the production of well using prediction of production of surface network using various separator pressures or chokes sizes. Reservoir pressures are achieved from simulation models and material balance or decline curve analysis techniques. GAP Analysis software is used to predict the effect of various separator pressures versus reservoir life, shown in figure-6. Analyzed the Average gas rate (MMscf/day) versus time at separator pressure of 500psi which was found as 17.04 MMscf/day and found zero flow rates on 2/9/2022 simultaneously analyzed the average gas rate (MMscf/day) versus time at separator pressure of 700psi which was found as 16.01 MMscf/day and found zero flow rates on 8/1/2020 shown in figure 6 and figure 7.

GAP was linked with MBAL and PROSPERS software to update data with in Gap. Reservoir performance is achieved by importing MBAL, production and injection models can be run with GAP by calculation of injection pressures and optimization of production at every step. Production forecasting was achieved by importing prosper into GAP.

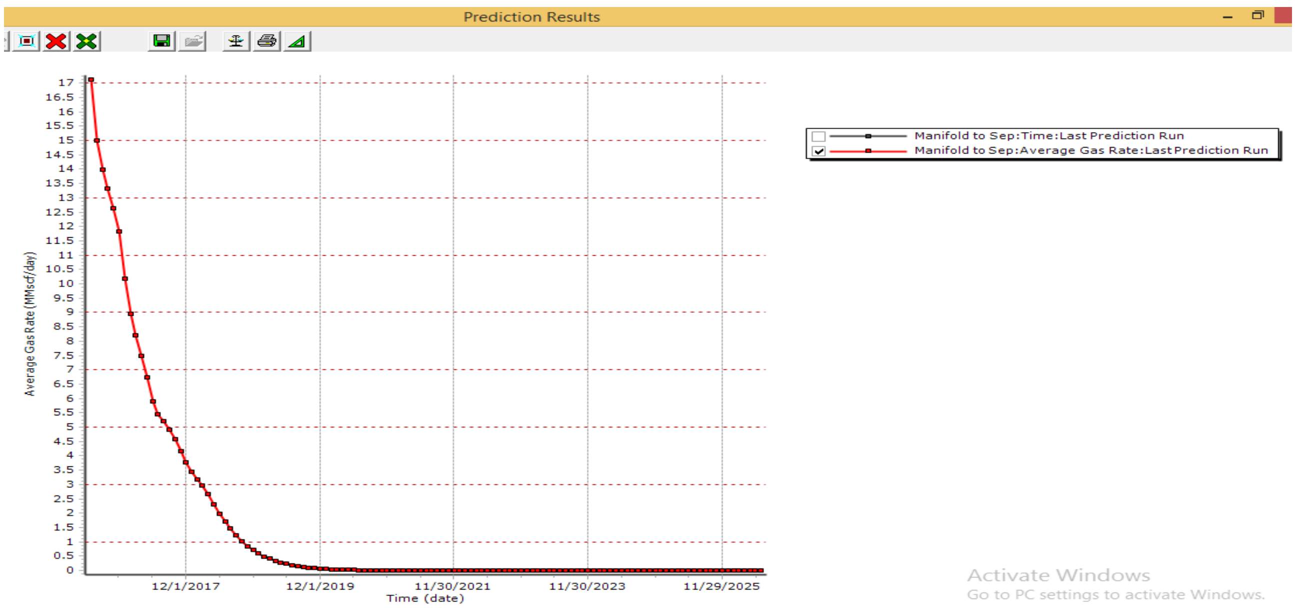

Figure 8: average gas rate versus time @ 500psi

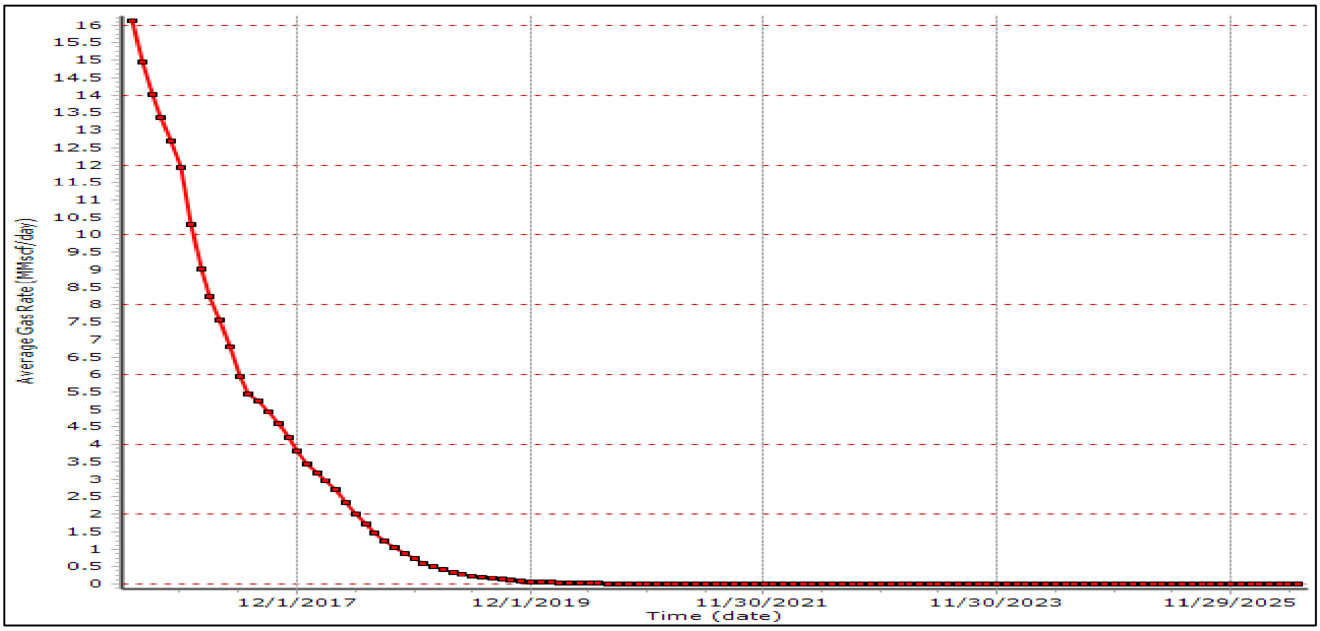

Figure 9: Gp versus Time @ 700psi

5. Conclusion

The simulation results allowed us to analyzed reservoir performance using MBAL, Prosper was also followed to optimize the production by analyzing the impact of flow rates, reservoir pressure, wellhead pressure etc. and finally GAP analysis approach allowed us to determine average gas production versus time. The total gas in place was estimated about 1795.68 BCF, and 9.026 BCF has been produced till now. By using MBAL we predicted reserves 64BCF with best development strategies for the next 15 years. Well performance model is analyzed using DST test results, which was matched with reference to these DST results for validation of the model. From the figure 19, intersection between IPR and VLP shows the measured gas rate is 17 (MMscf/day) whereas the calculated gas rate found using prosper is 16.79(MMscf/day) hence the difference of the measured gas rate and calculated gas rate found -1.22 %. The change in flow rate with respect to separator pressure with a tubing diameter 3.5 inch is investigated because it is influencing on two major parameters flow period and flow rate. In this case, as the separator pressure increases the flow rate is decreasing and hence flow period. Lowering the separator pressure will increase the flow rate thus may influence the well life.

6. Recommendations

1. The well is needed to be carrying out pressure survey test to find out current values of reservoir parameters.
2. The well condition should be monitor thus the well test must be performed regularly which will help prolong existence of production and production volumes in advance.
3. In this case, as the separator pressure increases the flow rate is decreasing and hence flow period. Lowering the separator pressure will increase the flow rate thus may influence the well life.

References

[1] Schlumberger: “Well Performance Manual.”

[2] Mir, A. (2011), Technology Business, “A study of production optimization of an oil well”

[3] High pressure high temperature reservoir manual https://www.glossary.oilfield.slb.com/Terms/h/hpht.aspx, retrieved on 8/2/2018

[4] Ahmed,Tariq 2010. Reservoir Engineering Handbook. Fourth Edition

[5] Tubing Performance Relationship, https://www.slideshare.net/akincraig/tubing-performance-relation-tpr, retrieved on 7/4/2017. .

[6] Z.J.G. Gromotka “The Stability region of the tubing performance relation curve, Delft University of technology, September 14, 2015

[7] Owusu. P.A (et. al), 2013, prognosticating the Production Performance of Saturated Gas Drive Reservoir: A Theoretical Perspective”

[8] Economides Micheal J.(edited by)(1993)Petroleum production system, christine ehlig- economides.

[9] Petroleum expert, IPM tutorial January 2010.

[10] Beggs, D. (2003) Production Optimization Using Nodal Analysis, Second Edition, OGCI and Petro skills Publications, Tulsa, Oklahoma.

[11] Inflow performance relationship https://infohost.nmt.edu/~petro/faculty/Kelly/IPR.pdf Retrieved on 5/3/2017.

[12] Rawlins E.L. and Schellhardt, M.A 1985. Back pressure data on natural gas wells and their application to production practices, Vol 7. Baltimore, Marland: Monograph series, US bureau of mines.

[13]

About Authors

Yasir Ali Memon has done Bachelor of Engineering (B.E) from Dawood University, Karachi and has done Master of Engineering (M.E) from Mehran University of Engineering and Technology, Jamshoro. yasirmemon2772@gmail.com

Muzaffar Ali Mahar has done B.E in Petroleum engineering from Ned University and M.E from University of Calgary, Canada and now working as a Senior Production Engineer in Pakistan Petroleum Limited. m_muzaffar@ppl.com.pk

Naveed Ahmed Ghirano has done B.E in Petroleum and Gas Engineering from Mehran University and M.E in Petroleum Engineering from Mehran University and now as Assistant Professor in Petroleum department in MUET. naveed.ghirano@faculty.muet.edu.pk

Abdul Basit Balouch has done B.E in P & G from MUET and has done M.E from Mehran University, Jamshoro. abdulbasit.muet@hotmail.com