Sudan University of Science and Technology

College of Petroleum Engineering and Technology

Department of Petroleum Enginerring

Project of:

Development of a computer Program to predict the Future Performance of Saturated Oil Reservoir

تصميم برنامج حاسوبي للتنبؤ بالأدائية المستقبلية لمكمن نفطي مشبع

Graduation project submitted to college of petroleum Engineering and Technology at Sudan University of Science and Technology
Partial fulfillment for one of requirements to take the degree of B.S.C in petroleum Engineering

Presented by:

1. **Ayman Abdulmutalib Ali Adam Ali**
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3. **Hamza Ahmed Mohamed Aldaw**
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Supervisor:

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This project is accepted by college petroleum Engineering and technology to department of petroleum Engineering.

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Date: / /2014

الإستهلال

قال تعالى :

بسم الله الرحمن الرحيم

﴿ كَمَا أَرْسَلْنَا فِيكُمْ رَسُولًا مِّنكُمْ يَتْلُوا عَلَيْكُمْ آيَاتِنَا وَيُزَكِّيكُمْ وَيُعَلِّمُكُمُ

﴾ الْكِتَابَ وَالْحِكْمَةَ وَيُعَلِّمُكُم مَّا لَمْ تَكُونُوا تَعْلَمُونَ

صدق الله العظيم

سورة البقرة الآية

﴿﴿151﴾﴾

Dedication

To:

Who taught us the meanings of life and values of generosity and faithfulness

Our mothers………….

Who suffered for making the best future to us and growing the flowers in our way,

Our fathers………….

Who supported and helped us,

Our brothers and sisters………….

Who made with us beautiful memories that will never die.

Our dear friends………….

Acknowledgement

We have exerted great efforts in this project, however; it would not been possible without the support and help of many individuals and organizations. We would like to extend our sincere thanks to all of them.

We would like to express our deepest thanks to **Dr. Tagwa A. Musa** for assistance, encouragement and guidance while we were doing our research.

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Our thanks and appreciations also comprise to our colleagues and college staffs those helped us to develop this project.

التجريد

تمَّ تصميم برنامج حاسوبي بلغةِ الماتلاب للتنبؤ بالآداء المستقبلي للمكمنِ المشبع إعتماداً على نظرية (Tracy) . ما يميزُ هذا البرنامجُ انه سهلٌ وسريعُ الآداءِ ودقيقٌ في النتائجِ بالإضافةِ إلى انه سهلُ الاستجابةِ للتغيراتِ في البياناتِ مثلُ النفاذيةِ النسبيةِ ومعاملاتُ التكوينِ الحجمي وذوبانيةُ الغازِ وخواصُ المكمنِ . أيضاً تمّتْ مقارنة نتائج هذا البرنامج مع النتائج التقليدية (manual) ونتائج (spreadsheet).

ABSTRACT

In this research a computer program has been designed to forecast the future performance of saturated oil reservoir with depletion drive by using MATLAB based on Tracy’s method. The program is easy to work, fast, accurate, and easy to respond to any changes in data such as the relative permeability data, formation volume factors for fluids, gas solubility and reservoir properties. In addition to the results of this program were compared with manual and spreadsheet results.

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Chapter 1

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Introduction

CHAPTER 1

Introduction

1.1. General Introduction:

Reservoir means the space of rock which contains oil under specific conditions. Oil reservoir classified based on its initial pressure to: Under-saturated oil reservoir where the initial reservoir pressure is greater than the bubble point pressure, Saturated oil reservoir where the initial reservoir pressure is equal to the bubble point pressure, and Gas cap reservoir, and if the initial reservoir pressure is below the bubble point pressure, the reservoir is termed as a gas cap oil reservoir.

For understanding reservoir behavior and predicting future performance, driving mechanisms that control the behavior of fluids within reservoirs should be known. The overall performance of oil reservoirs is determined based on the type of driving mechanism.

In general there are six types of driving mechanisms: Rock and liquid expansion, Gas cap, Water, Gravity drainage, Depletion (solution gas drive), and Combination drive. The differences between these types are shown in table (1.1).

This study is focusing on saturated oil reservoir where the drive mechanism is solution-gas-drive.

Table (1.1): Differences between Driving Mechanisms

Characteristics Drive Mechanism	Pressure	GOR	Water Production	Ultimate Oil Recovery
Rock and liquid	Decline rapidly	Constant	None	Weak

expansion				
Gas cap	Falls slowly and continuously	Rises continuously	Negligible	20% - 40%
Water	Remains high	Remains low	High and start early	35% - 75%
Gravity drainage	Decline rapidly	Low in structurally wells. Increase in structurally high wells.	Little or none	High
Combination	Decline rapidly	Increase if an expansion gas cap is present . Decrease in case of free gas production.	Small	Greater than depletion drive and less than water drive
Depletion	Decline rapidly and continuously	Rapidly increase	Little or none	5% - 30%

1.2. Introduction to Reservoir performance:

Reservoir performance studies related to forecasting future performance of the reservoir as a function of times or average reservoir pressure MBE simply provides performance as a function of the average reservoir pressure. Prediction of the reservoir future performance is ordinarily performed in two phases:

Phase one related to predict cumulative hydrocarbon production as a function of declining reservoir pressure. Without any consideration to Actual number of wells, Location of wells, Production rate of individual wells, and Time required depleting the reservoir.

Phase two is the time-production phase. In these calculations, the reservoir performance data, are calculated from phase one and after that correlated with time. It is necessary in this phase to account the number of wells and the productivity of each well.

All the methodologies that have been developed to predict the future reservoir performance are essentially based on employing and combining the MBE, saturation equations, instantaneous GOR, equation relating the cumulative gas-oil ratio to the instantaneous GOR.

The most methodologies that used in oil industry are Tracy's method, Muskat's method and Tarner's method.

These techniques are practically used to predict the primary recovery performance of a volumetric solution-gas-drive (depletion drive) reservoir**.**

1.3. Problem statement:

In oil industry there are many methods used to predict the future performance of saturated oil reservoir as a function of reservoir pressure declining; one of these methods is Tracy's method; this method is very difficult manually and take more time due to trial and error concept in each pressure step; at the same time this method is widely used; so this computer program is designed to make the calculations easy and fast.

1.4. Thesis Objective:

The main objective of this project is to design a computer program to predict the future performance of saturated oil reservoir by using Tracy's methods.

1.5. Methodology:

This program is designed by using MATLAB language (Graphical User Interface-GUI).

1.6. Thesis Outlines:

Chapter 2 of this thesis contains literature review, general prediction methods which containing MBE, DCA, reservoir simulation, classifications of reservoir simulators, and applications of reservoir simulation , Chapter 3 consists of introduction to prediction of future performance methods, Tracy assumptions, Tracy's method equation, Tracy's method steps, and introduction to MATLAB. Chapter 4 shows program designing steps, the case study, results and discussions, and comparison. Chapter 5 consist of conclusions and recommendations.

Chapter 2

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Literature Review and Theoretical Background

CHAPTER 2

Literature Review and Theoretical Background

2.1. Literature View:

There are many authors studied the reservoir performance and predicted its future performance using material balance equation and other methods. Some of them conducted a computer programs using several computer languages to get easy and fast results from the complicated methods and steps.

Kenneth W. *et al* described a computer model for forcasting production of oil and gas. It was developed and used to select the ratio of gas to oil produced by each gas-oil separator pressure (GOSP) in a series of oil fields in order to maximize/minimize either the gas or the oil production. The model is easy to construct and to adjust to change conditions, and the response is instantaneous.

Tarner (1944) suggested an iterative technique for predicting cumulative oil production Np and cumulative gas production Gp as a function of reservoir pressure. The method is based on solving the material-balance equation and the instantaneous gas-oil ratio equation simultaneously for a given reservoir pressure drop from p1 to p2. It is accordingly assumed that the cumulative oil and gas production has increased from Np1 andGp1 to Np2 and Gp2. To simplify the description of the proposed iterative procedure, the stepwise calculation is illustrated for a volumetric saturated-oil reservoir.

Muskat (1945) expressed the material balance equation for a depletion- drive reservoir in the differential form; Craft, Hawkins, and Terry (1991) suggested the calculations of differential form can be greatly facilitated by computing and preparing in advance in graphical form.

Tracy (1955) suggests that the general material balance equation can be rearranged and expressed in terms of three functions of PVT variables (discussed in chapter 3).

In 1978 Herman Dykstra3 studied and broadened the application of Cardwell and Person's method of predicting oil recovery under free-fall gravity drainage recovery, and he is expanded the account for residual oil saturation.

In 2003 Gawish developed a program for Forecasting the Future Production performance for depletion drive reservoirs using a new spreadsheet program and this program based on Tracy method. The output from this program includes charts and tables.

2.2. General Prediction Methods Background:

The following discussion shows methods that used to predict a reservoir performance, and these methods include:

2.2.1. Material Balance Equation (MBE):

The concept of the Material balance equation was presented by Schilthius in 1941. Material balance in another term means mass balance. It refers to a group of useful equations that are derived by recognizing the conservation of mass. these equations can be derived by equating masses of reservoir fluids that exist in and out of the reservoir at different times (lp.Dake,1998).

However, it is generally easier to derive the equations by equating volumes of reservoir fluids at different times.

The material balance equation is one of the basic tools in reservoir engineering. Practically all reservoir engineering techniques involve some applications of material balance. Although the principle of conservation of mass underlies the material balance equation, custom has established that the material balance be written on a volumetric basis, because oilfield measurements are volumetric and significant factors can only be expressed volumetrically.

The principle of conservation underpins the equation:

Mass of fluids originally in place = fluids produced + remaining reserves.

The material balance simply provides performance as a function of the average pressure in the reservoir. Thus, we may say that material balance provides us with a prediction of cumulative production versus average reservoir pressure for a reservoir.

The reservoir volume of original fluids in place = reservoir volume of fluids produced + volume of remaining reserves.

2.2.2 Decline Curves Analysis (DCA):

Decline curve analysis is a technique that can be applied to a single well, or an entire field .decline curves analysis routinely used by engineers to estimate initial hydrocarbon in place, hydrocarbon reserves at some abandonment conditions, and forecasting future production rate (Khulud, M., and et al.,2013). The remaining reserve depends on the production points that selected to represent the real well behavior, the way of dealing with the production data and the human errors that might happen during the life of the field. Decline curve analysis is the most currently method used for reserve estimation when historic production data are available and sufficient.

The decline curve most commonly used to represent or extrapolate the production data are members of a hyperbolic family, the method of extrapolating a "trend" for the purpose of estimating future performance must satisfy the conditions that the factors caused changes in past performance, for example, decline in the flow rate, will operate in the same way in the future (Ahmed, T, 2006). These decline curves are characterized by three factors:

i. Initial production rate, or the rate at some particular time.
ii. Curvature of the decline.
iii. Rate of decline.

Arps (1945) proposed that the "curvature" in the production-rate-versus-time curve can be expressed mathematically by a member of the hyperbolic family of equations. Arps recognized the following three types of rate-decline behavior:

i. Exponential decline.
ii. Harmonic decline.
iii. Hyperbolic decline.

Each type of decline curve has a different curvature, as shown in Fig. (2.1), this figure depicts the characteristic shape of each type of decline when the flow rate is plotted versus time or versus cumulative production on Cartesian, semi-log, and log-log scales. The main characteristics of these decline curves can be used to select the flow rate decline model that is appropriate for describing the rate–time relationship of the hydrocarbon system:

I. **Exponential decline**:

A straight-line relationship will result when the flow rate versus time is plotted on a semi-log scale and also when the flow rate versus cumulative production is plotted on a Cartesian scale.

II. **Harmonic decline**:

Rate versus cumulative production is a straight line on a semi-log scale; all other types of decline curves have some curvature. There are several shifting techniques that are designed to straighten out the curve which is result from plotting flow rate versus time on a log-log scale.

III. **Hyperbolic declin**e:

None of the above plotting scales, that is, Cartesian, semi-log, or log-log, will produce a straight-line relationship for a hyperbolic decline. However; if the flow rate is plotted versus time on log-log paper, the resulting curve can be straightened out with shifting techniques.

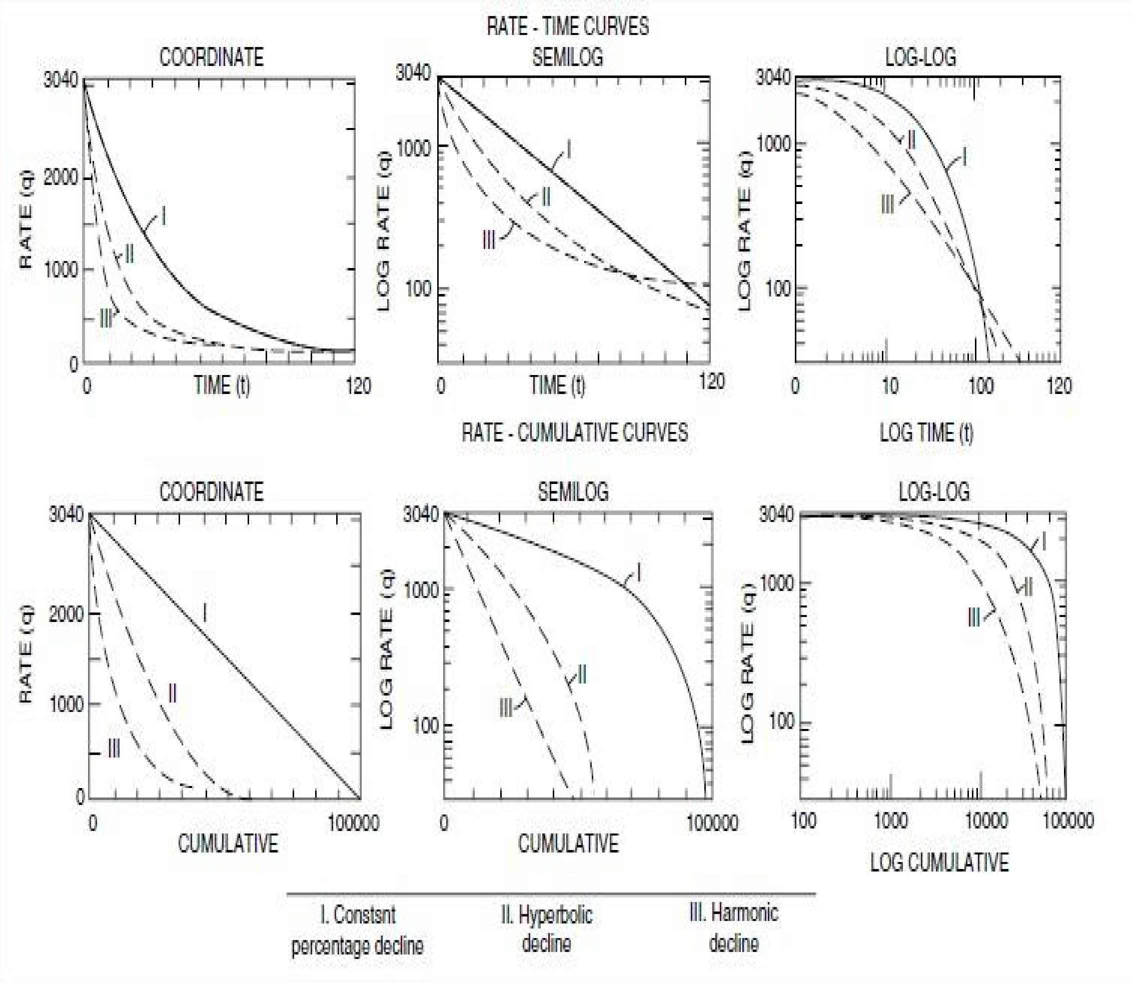

Fig.(2.1): Classification of Production Decline Curves (Ahmed, T.2006).

2.2.3. Reservoir Simulation:

Reservoir simulation is the art of combining physics, mathematics, reservoir engineering and computer programming to develop a tool for predicting hydrocarbon reservoir performance under various operating strategies.

Over recent years, as increasingly powerful computers have enabled the application of large numerical reservoir simulators, some have looked down on the simple material balance equation and the tank model of the reservoir which it represents.

Reservoir simulators however apply the material balance approach within each of their multi-dimensional cells.

The need of reservoir simulation stems from the requirement for petroleum engineers to obtain accurate performance prediction for hydrocarbon reservoir under different operating condition.

Reservoir simulation by computers allows a more detailed study of the reservoir by dividing the reservoir into a number of blocks (sometimes several thousands) an applying fundamental equation for flow in porous media to each block. Digital computer programs that perform the necessary calculations to do such model studies are called computer models.

Because of the advances made since the early 1950s in computer hardware and software technology is now possible to write rather sophisticated models to simulate some of the very complex processes that take place in reservoirs during the implementation of recovery schemes. Reservoir simulation technology is being constantly improved and enhanced (Khalid, A. 1983).

New models to simulate more and more complex recovery schemes are being proposed all the time.

Computer models can be valuable tools for the petroleum engineer attempting to answer questions (Khalid, A. 1983) of the following type:

i. How should a field be developed and produced in order to maximize the economic recovery of hydrocarbons?
ii. What is the best enhanced recovery scheme for the reservoir? How and when should it be implemented?
iii. Why is the reservoir not behaving according to predictions made by previous reservoir engineering or simulation studies?
iv. What is the ultimate economic recovery for the field?
v. What type of laboratory data is required?
vi. What is the sensitivity of model predictions to various data?
vii. Is it necessary to do physical model studies of the reservoir? How can the results be scaled up for field applications?

viii. What are the critical parameters that should be measured in the field application of a recovery scheme?

ix. What is the best completion scheme for wells in a reservoir?

x. From what portion of the reservoir is the production coming?

These are some general questions; many more specific questions may be asked when one is considering a particular simulation study.

Reservoir simulators based on reservoir and fluid descriptions fall into two categories:

i. Black-oil simulators are used in situations where recovery processes are insensitive to compositional changes in the reservoir fluids. In black-oil simulators, mass transfer is assumed to be strictly pressure dependent. In these simulators, the fluid properties R_s, B_o and B_g govern PVT behavior.

ii. Compositional simulators are used when recovery processes are sensitive to compositional changes. These situations include primary depletion of volatile-oil and gas-condensate reservoirs, as well as pressure-maintenance operations in these reservoirs.

Reservoir simulation is generally performed in several steps these steps are shown below:

i. Set the study objectives. The first step of any successful simulation study is to set clear, achievable objectives. These objectives must be compatible with available data and production history. Objectives are used to set goals, define basic strategy, identify available resources, and determine what is to be learned from the study.

ii. Acquire and validate all reservoir data. Once the study objectives have been defined, reservoir and production data are gathered.

iii. Construct the reservoir model. After the data have been gathered and validated, the simulation model is built. In this step the reservoir is divided into grid blocks different grid cells can have different reservoir properties; however, reservoir properties are assumed to be homogeneous within a grid cell. Because different cells can have different properties, areal and vertical trends in data can be incorporated into the model. At this stage of the study, all data must be properly scaled for the simulation grid.

iv. History matching of the reservoir model. Once the simulation model has been built it must be tuned, or history matched, with available production data because much of the data in a typical simulation model is not known for certain but is the result of engineers' and geologists' interpretations. Although these interpretations are generally the best representation of available data, they are still subjective and may require modifications.

v. Run prediction cases.

The main objective of any simulation study is to gain knowledge of the subject reservoir. In most simulation studies, most of the knowledge is gained during the data-gathering, history-matching, and prediction phases. During the data-gathering and history-matching phases, all relevant reservoir data are collected, validated, and synthesized into a coherent field model. This process will inevitably yield information about the reservoir that was unknown before the study. During the prediction phase, questions concerning the subject reservoir can be addressed and most of the study objectives are met.

Chapter 3

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Prediction of Future Performance Methods and MATLAB Software

CHAPTER 3

Prediction of Future Performance Methods (Saturated Oil Reservoir) and MATLAB Software

3.1. Introduction:

This chapter contains the equation that tracy's method based on, assumptions, explaining of tracy's method steps, brief background of MATLAB and flow chart which was used to design this program.

3.2. Equations that Tracy's method based on:

All techniques that are used to predict the future performance of a reservoir are based on combining the appropriate MBE with the instantaneous GOR using the proper saturation equation. The calculations are repeated at a series of assumed reservoir pressure drops.

Then find that Tracy method based on:

3.2.1. MBE:

In general MBE can be written as follows:

$$A+B=C+D+E+F+G+H+I \ldots \qquad .\ (3\text{-}1)$$

Where:

A= Pore volume occupied by the oil in place at pi

$$A= NB_{oi} \ \ldots \qquad .\ (3\text{-}2)$$

B= Pore volume occupied by the gas in the gas cap at pi

$$B=(N-N_P)B_{oi} \ldots \qquad .\ (3\text{-}3)$$

C= Pore volume occupied by the remaining oil at p

$$C=(N-N_P)B_{oi} \ \ldots \qquad .\ (3\text{-}4)$$

D= Pore volume occupied by the gas in the gas cap at p

$$D=\frac{mNB_{oi}}{B_{gi}}B_g \ \ldots \qquad .\ (3\text{-}5)$$

E= Pore volume occupied by the evolved solution gas at p

$$E=\left[NR_{si}-NpR_S-\left(N-N_p\right)R_s\right]B_g \ \ldots \qquad .\ (3\text{-}6)$$

F= Pore volume occupied by the net water influx at p

$$\mathbf{F=W_e - W_bB_w} \quad \ldots \qquad \mathbf{.\ (3\text{-}7)}$$

G= Change in pore volume due to connate water expansion and pore volume reduction due to rock expansion.

$$\mathbf{C=\frac{NB_{oi}(1+m)}{1-S_{wi}}c_f\Delta p} \quad \ldots \qquad \mathbf{.\ (3\text{-}8)}$$

H= Pore volume occupied by the injected gas at p

I= Pore volume occupied by the injected water at p

$$\mathbf{H+I=totalvolume = GinjBinj + WinjBw} \qquad \mathbf{.\ (3\text{-}9)}$$

Then after substitute above term in (3-1) and rearrange gives:

$$\mathbf{N = \frac{N_pB_O+(G_p-N_pR_s)B_g-(W_e-W_pB_w)-G_{inj}B_{inj}-W_{inj}B_{ginj}}{(B_O-B_{Oi})+(R_{si}-R_s)B_g+mB_{oi}\left[\frac{B_g}{B_{gi}}-1\right]+B_{oi}(1+m)\left[\frac{S_{wi}c_w+c_f}{1-S_{wi}}\right]\Delta p}} \quad \ldots \qquad \mathbf{(3\text{-}10)}$$

Where:

N =oil initially in place, STB

$\boldsymbol{B_{oi}}$ =oil formation volume factor at initial reservoir pressure pi,bbl/STB

$\boldsymbol{N_p}$ =cumulative oil production, STB

$\boldsymbol{B_o}$ =oil formation volume factor at reservoir pressure p, bbl/STB

$\boldsymbol{B_{gi}}$ =gas formation volume factor at initial reservoir pressure, bbl/scf

$\boldsymbol{B_g}$ =current gas formation volume factor, bbl/scf

$\boldsymbol{R_{si}}$ =net cumulative produced gas-oil ratio, scf/STB

$\boldsymbol{R_s}$ =current gas solubility factor, scf/STB

$\boldsymbol{W_e}$ =cumulative water influx, bbl

$\boldsymbol{W_p}$ =cumulative water produced, STB

$\boldsymbol{B_w}$ =water formation volume factor, bbl/STB

Δp =change in reservoir pressure, (pi -p), psi

$\boldsymbol{c_w}$ =water compressibility coefficient, psi^{-1}

m =ratio of the volume of the gas-cap gas to the reservoir oil volume, bbl/bbl

$\boldsymbol{G_{inj}}$ =cumulative gas injected, scf

$\boldsymbol{B_{ginj}}$ =injected gas formation volume factor, bbl/scf

$\boldsymbol{W_{inj}}$ =cumulative water injected, STB

The above material balance equation contains two unknowns, which are:

- Cumulative oil production $\mathbf{N_p}$
- Cumulative gas production $\mathbf{G_p}$

The following reservoir and PVT data must be available in order to predict the primary recovery performance of a depletion-drive reservoir in terms of $N_p$andG_p:

1) Initial oil-in-place N:

Generally the volumetric estimation of oil in-place is used in calculating the performance. Where there is sufficient solution-gas-drive history, however, this estimate may be checked by calculating a material-balance estimation.

2) Hydrocarbon PVT data:

Since differential gas liberation is assumed to best represent the conditions in the reservoir, differential laboratory PVT data should be used in reservoir material balance. The flash PVT data are then used to convert from reservoir conditions to stock-tank conditions. If laboratory data are not available, reasonable estimates may sometimes be obtained from published correlations. If differential data are not available, the flash data may be used instead; however, this may result in large errors for high-solubility crude oils.

3) Initial fluid saturations:

Initial fluid saturations obtained from a laboratory analysis of core data are preferred; however, if these are not available, estimates in some cases may be obtained from a well-log analysis or may be obtained from other reservoirs in the same or similar formations.

4) Relative permeability data:

Generally, laboratory determination of $\frac{K_g}{K_o}$ and K_{ro} data are averaged to obtain a single representative set for the reservoir. If laboratory data are not available, estimates in some cases may be obtained from other reservoirs in the same or similar formations.

3.2.2. Saturation equations:

$$\mathbf{S_o} = \frac{\textbf{\textit{Remaining oil volume}}}{\textbf{\textit{pore volume}}} \quad \dots \qquad .\ \mathbf{(3\text{-}11)}$$

$$\textbf{\textit{Remaining oil volume}} = (\mathbf{N} - \mathbf{N_p})\mathbf{B_o}\,) \dots \qquad .\ \mathbf{(3\text{-}12)}$$

$$pore\ volume = \frac{NB_{oi}}{(1-S_{wi})} \quad \dots \qquad .(3-13)$$

By substitute (3-12) and (3-13) in (3-11) and rearrange gives:

$$S_o = (1 - S_{wi})\left(1 - \frac{N_p}{N}\right)\left(\frac{B_o}{B_{oi}}\right) \dots \qquad .(3-14)$$

3.2.3. Instantaneous GOR:

$$GOR=\frac{Q_o R_s + Q_g}{Q_o} \quad \dots \qquad .(3-15)$$

$$Q_o = \frac{K_{ro} Kh}{\mu_o B_o}\frac{dp}{dr} \dots \qquad .(3-16)$$

$$Q_g = \frac{K_{rg} Kh}{\mu_g B_g}\frac{dp}{dr} \dots \qquad .(3-17)$$

By substitute (3-16) and (3-17) in (3-15) and rearrange gives:

$$GOR = R_s + \left(\frac{K_{rg}}{K_{ro}}\frac{\mu_o B_o}{\mu_g B_g}\right) \dots \qquad .(3-18)$$

3.2.4. Cumulative Gas Production and Instantaneous GOR relationship:

From figure (3-1) we find that:

$$\Delta G_p = \int_{N_{p2}}^{N_{p1}} GOR\, dN_p \dots \qquad .(3-19)$$

$$\Delta G_p = \frac{GOR_1 + GOR_2}{2}(N_{p2} - N_{p1}) \dots \qquad .(3-20)$$

$$\Delta G_p = GORavg \Delta N_p \dots \qquad .(3-21)$$

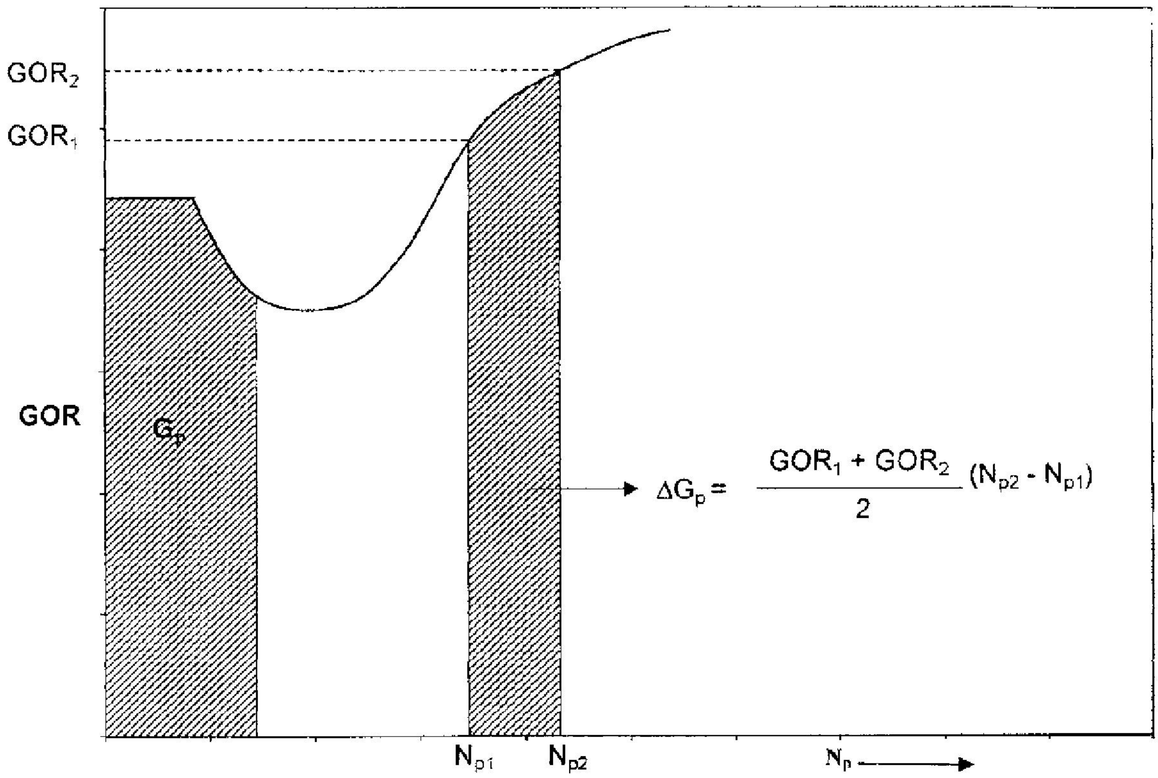


Fig (3.1) : Relationship between GOR and G_p(Ahmed, T. 2006).

3.3. Tracy's Method:

Tracy (1955) suggested that the general material balance equation (3-10) can be rearranged and expressed in terms of three functions of PVT variables:

$$N = N_P\varphi_o + G_p\varphi_g + (W_pB_w - W_e)\varphi_w \quad \ldots \quad .(3\text{-}22)$$

Where:

$$\varphi_o = \frac{B_o - R_sB_g}{Den} \quad \ldots \quad .(3\text{-}23)$$

$$\boldsymbol{\varphi_g = \frac{B_g}{Den}} \quad \ldots \qquad .(3\text{-}24)$$

$$\boldsymbol{\varphi_w = \frac{1}{Den}} \quad \ldots \qquad .(3\text{-}25)$$

$$\mathbf{Den = (B_o - B_{oi}) + (R_s - R_{si})B_g + mB_{oi}\left(\frac{B_g}{B_{gi}} - 1\right)} \quad \ldots \qquad .(3\text{-}26)$$

For a solution-gas-drive reservoir; Equations (3-22) and (3-26) are reduced to the following expressions, respectively:

$$\boldsymbol{N = N_P\varphi_o + G_p\varphi_g} \quad \ldots \qquad .(3\text{-}27)$$

$$\mathbf{Den = (B_o - B_{oi}) + (R_s - R_{si})B_g} \quad \ldots \qquad .(3\text{-}28)$$

Phi factors can be calculated at all desired pressures using data from a reservoir fluid analysis. Then a table or plot of these factors can be used to calculate oil in place or predict future performance. Phi factors are infinite at the bubble point and decline rapidly as pressure declines below the bubble point.

Tracy's calculations are performed in series of pressure drops that proceed from known reservoir conditions at the previous reservoir pressure p* to the new assumed lower pressure p. The calculated results at the new reservoir pressure become "known" at the next assumed lower pressure.

In progressing from the conditions at any pressure p* to the lower reservoir pressure p, consider that the incremental oil and gas production are ΔN_pandΔG_p or:

$$\mathbf{N_p = N_p^{*} + \Delta N_p} \ldots \qquad .(3\text{-}29)$$

$$\mathbf{G_p = G_p^{*} + \Delta G_p} \ldots \qquad .(3\text{-}30)$$

Where:

N_p^*, G_p^* ="known" cumulative oil and gas production at previous pressure level p*

N_p, G_p ="unknown" cumulative oil and gas at new pressure level p

By substitute (3-29) and (3-30) in (3-27) find that:

$$\mathbf{N=(N_p^*+\Delta N_p)\varphi_o + (G_p^* + \Delta G_p)\varphi_g} \quad \dots \qquad \mathbf{.(3\text{-}31)}$$

By substitute (3-21) in (3-31) and rearrange for N=1find that:

$$\mathbf{\Delta N_p = \frac{1-(N_p^*\varphi_o+G_p^*\varphi_g)}{\varphi_o+GORavg\varphi_g}} \quad \dots \qquad \mathbf{.(3\text{-}32)}$$

$$\mathbf{GORavg = \frac{GOR^*+GOR}{2}} \quad \dots \qquad \mathbf{.(3\text{-}33)}$$

Tracy suggested the following alternative technique for solving Equation (3-32):

Step 1: .Set pressure step p.

Step 2: Calculate the values of PVT functions $\varphi_o$and φ_g from equ. $(3-23)$and $(3-24)$ respectively after calculating Den from equ. $(3-26)$.

Step 3: Assume GOR at p.

Step 4: Calculate the average instantaneous GOR from equ. $(3-33)$.

Step 5: Calculate the incremental cumulative oil production from equ. $(3-32)$.

Step 6: Calculate cumulative oil production from equ. $(3-29)$.

Step 7:.Calculate the oil and gas saturations at selected average reservoir pressure from equ. $(3-14)$ and S_g from:

$$\mathbf{S_g = 1 - S_o - S_{wi}} \quad \dots. \qquad \mathbf{.(3\text{-}34)}$$

Step 8: from relative permeability curve determine $\mathbf{\frac{K_{rg}}{K_{ro}}}$ **at $\mathbf{S_g}$.**

Step 9: Calculate the instantaneous GOR from equ. $(3-18)$.

Step 10:.Compare the estimated GOR in Step 3 with the calculated GOR in Step 9; if the values are within acceptable tolerance, proceed to next step; if not within the tolerance then set the estimated GOR equal to the calculated GOR and repeat the calculations from step 3.

Step 11: Calculate the cumulative gas production from:

$$\mathbf{G_p = G_p^* + GORavg\Delta N_p} \quad \ldots \qquad \mathbf{.(3\text{-}35)}$$

Step 12:.Since results of the calculations are based on 1 STB of oil initially in place, a final check on the accuracy of the prediction should be made on the MBE, or:

$$\mathbf{N_P\varphi_o + G_p\varphi_g = 1 \pm tolerance} \quad \ldots \qquad \mathbf{.(3\text{-}36)}$$

Step 13: Repeat calculation from Step 1.

3.4. Tracy Assumptions:

a. Uniformity of the reservoir at all times regarding porosity, fluid saturations and relative permeability.
b. Uniform pressure throughout the reservoir in both the gas and oil zones. This means the gas and oil volume factors, the gas and oil viscosities, and the solution gas will be the same throughout the reservoir.
c. Negligible gravity segregation forces.
d. Equilibrium at all times between the gas and the oil phases.
e. A gas liberation mechanism which is the same as that used to determine the fluid properties.
f. No water encroachment and negligible water production.

3.5. MATLAB Introduction:

The name of MATLAB stands for **MAT**rix-**LAB**oratory. MATLAB was written originally to provide easy access to matrix software developed by the LINPACK (linear system package) and EISPACK (Eigen system package) projects (Houcque, D., 2005).

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming environment. Furthermore, MATLAB is a modern programming language environment: it has sophisticated data structures, contains built-in editing and debugging tools, and supports object-oriented programming. These factors make MATLAB an excellent tool for teaching and research (Houcque, D., 2005).

MATLAB has many advantages compared to conventional computer languages (e.g., C, FORTRAN) for solving technical problems. MATLAB is an interactive system which

basic data element is an array that does not require dimensioning. The software package has been commercially available since 1984 and is now considered as a standard tool at most universities and industries worldwide.

3.5.1. MATLAB Advantages:

- MATLAB may behave as a calculator or as a programming language.
- Combine nicely calculation and graphic plotting.
- Is relatively easy to learn.
- Is interpreted (not compiled), errors are easy to fix.
- Is optimized to be relatively fast when performing matrix operations.
- Does have some object-oriented elements.

3.5.2. Introduction to Graphical User Interface (GUI):

The MATLAB® Graphical User Interface development environment, provides a set of tools for creating graphical user interfaces (GUIs) (Houcque, D., 2005). These tools greatly simplify the process of designing and building GUIs. You can use the GUIDE tools to

Lay out the GUI:

Using the GUIDE Layout Editor, you can lay out a GUI easily by clicking and dragging GUI components such as panels, buttons, text fields, sliders, menus, and so on — into the layout area.

Program the GUI:

GUIDE automatically generates an M-file that controls how the GUI operates. The M-file initializes the GUI and contains a framework for all the GUI callbacks are the commands that are executed when the user clicks a GUI component using the M-file editor. You can add code to the callbacks to perform the functions that you want.

The following sections provide an overview of creating GUIs with GUIDE:

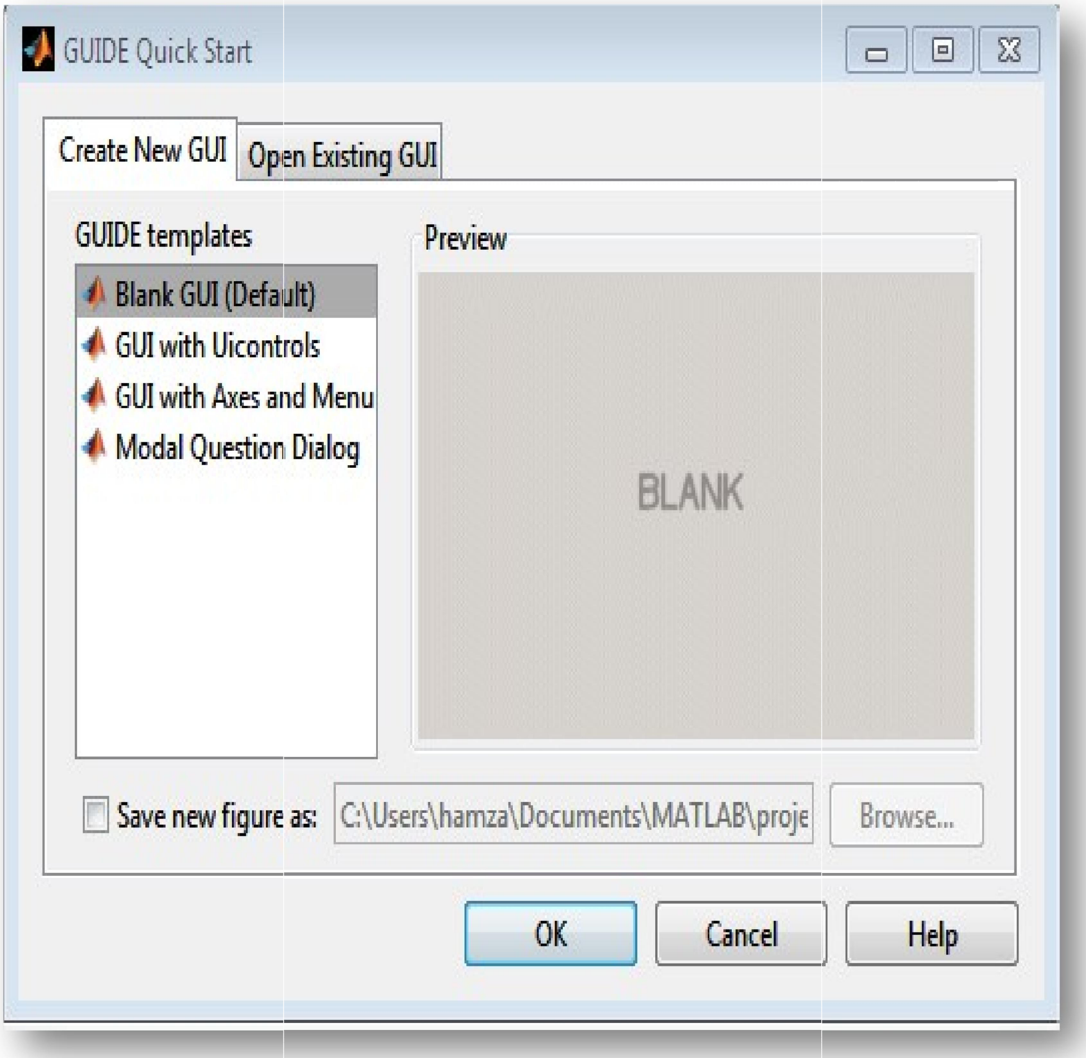
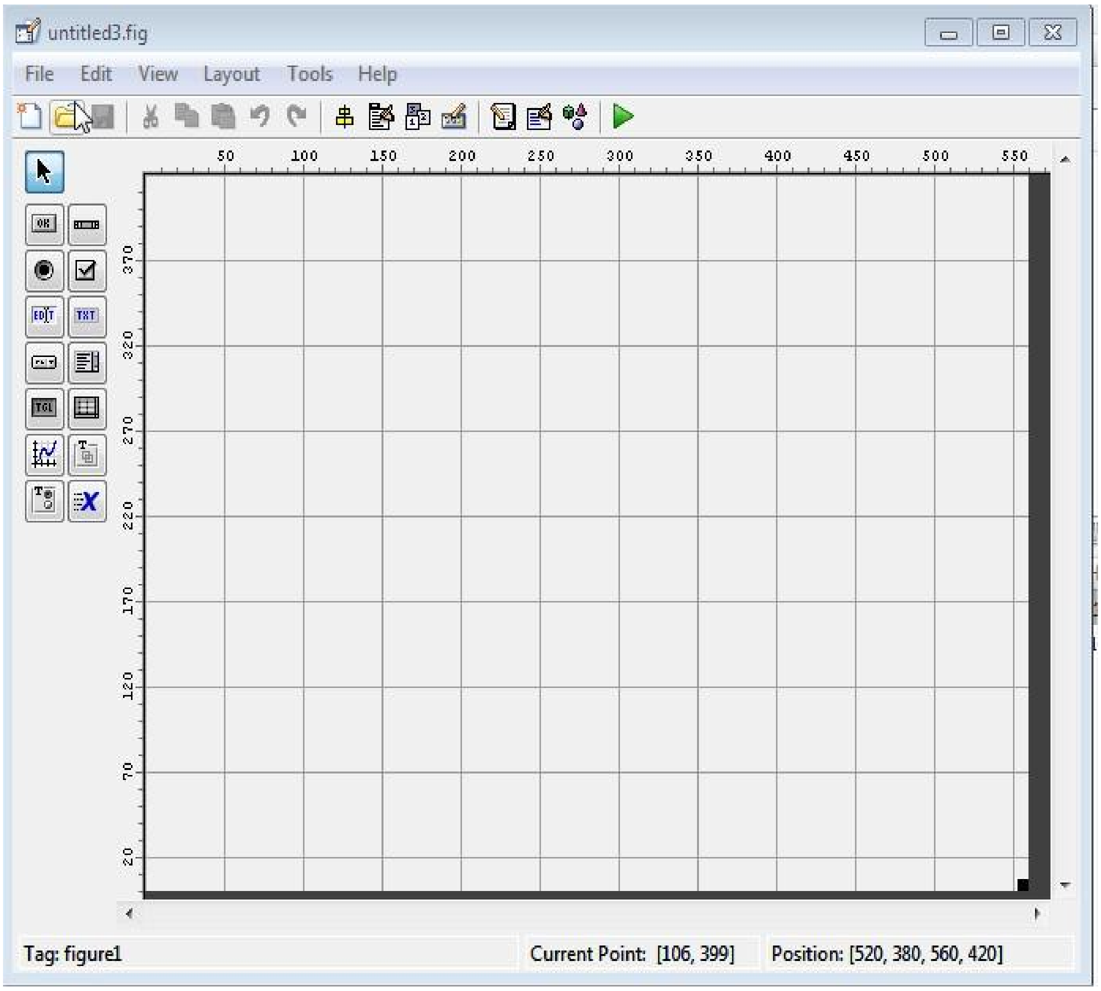


Fig. (3.2) Guide Quick Start(Published with MATLAB® 7.10)



Tag: figure1

Current Point: [106, 399]

Position: [520, 380, 560, 420]

Fig. (3.3): The Layout Editor (Published with MATLAB® 7.10)

Chapter 4

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Results and Discussions

CHAPTER 4

Results and Discussions

4.1. Introduction:

Tracy's method for prediction of future reservoir performance is programmed in a software using MATLAB.

In this part the steps of building TPP(standing from Tracy's Prediction Program), procedures and program details will be discussed in this chapter; in addition to comparison of the program results with results from manual calculations and results from A. Gawishy, (2003) excel sheet program using data from case study.

4.2. Program Designing Steps:

4.2.1. TPP program is designed by the following steps:

1) Creating program flow chart:

The flow chart shown in fig.(4.1) summarized Tracy's method steps, input data and general output; also TPP program is designed based on this flow chart.

2) Writing M-files:

The M-file is a conversion of flow chart into a MATLAB code by using special command in MATLAB language. In this program there are 9 M-files of TPP consist of 2357 programming lines.

3) Creating TPP Graphical User Interface:

This can be achieved by using the layout editor as shown in fig.(3.2) and this program consists of 9 GUI.

4) Testing (Validity Check) of TPP program by comparing its results with another programs results, here we will compare TPP results with manual and spread sheet result.

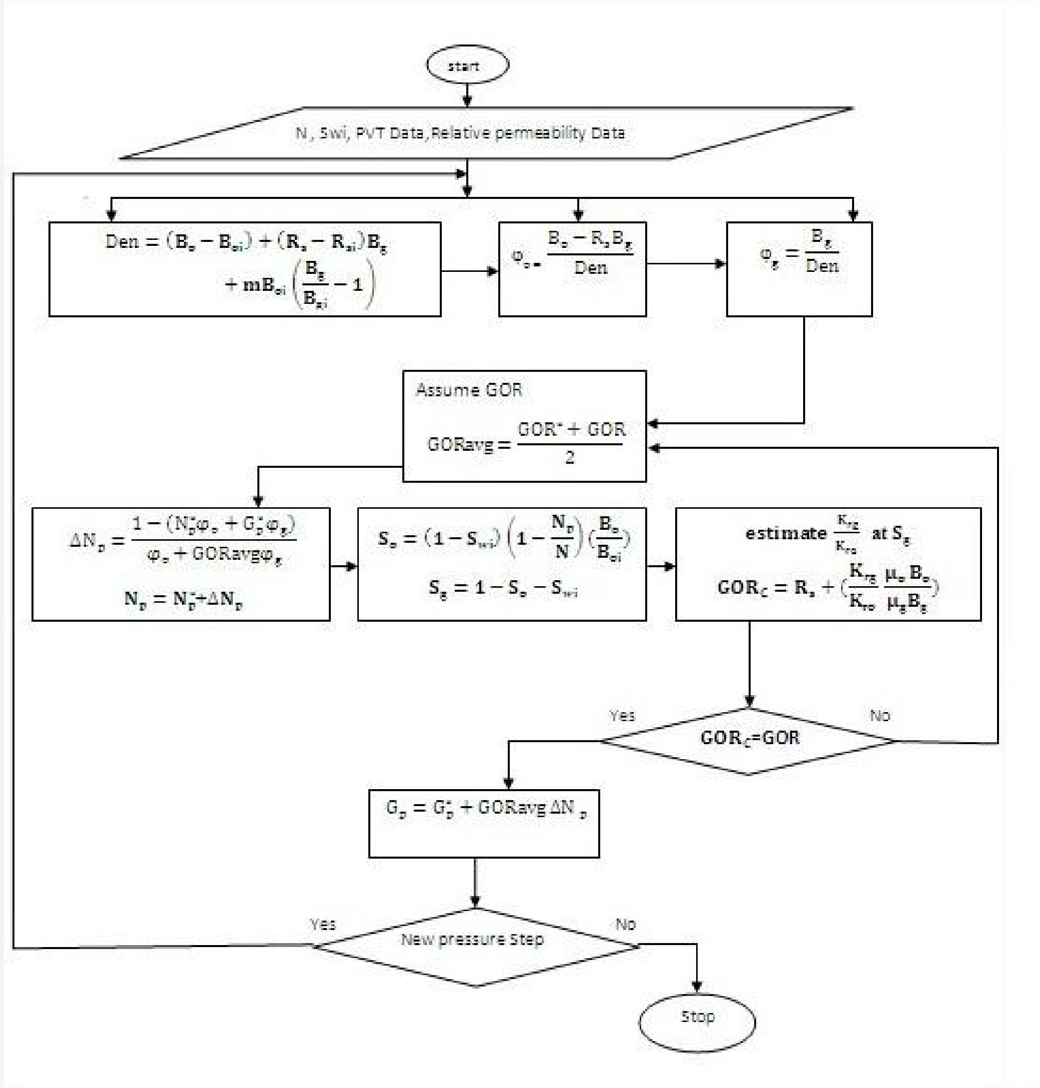


Fig. (4.1): Program Flow Chart

4.2.2 Assumptions of Designing TPP:

i. Constant step of gas saturation in which relative permeability data was determined.

ii. Instead of calculating relative permeability data from curves; it will be calculated based on input data by using special function in MATLAB called (INTERP1) to interpolate the relative permeability value at specific gas saturation when assumption in (i) realized.

4.3. The Case Study:

4.3.1. PVT Data:

The following PVT Data characterize a solution-gas-drive reservoir for X field:

Table (4.1): PVT Data for X Field (Ahmed .T, 2006)

P (psi)	B_o (bbl/SB)	B_g (bbl/scf)	R_s (bbl/scf)	μ_o (cp)	μ_g (cp)
4350	**1.430**	**0.00069**	**840**	**1.7**	**0.023**
4150	**1.420**	**0.00071**	**820**	**1.7**	**0.023**
3950	**1.395**	**0.00074**	**770**	**1.7**	**0.023**
3750	**1.380**	**0.00078**	**730**	**1.7**	**0.023**
3550	**1.360**	**0.00081**	**680**	**1.7**	**0.023**
3350	**1.345**	**0.00085**	**640**	**1.7**	**0.023**

4.3.2. Reservoir data:

The following additional data are available for X field:

- p_i=p_b = 4350 psi
- s_{wi}= 30 %
- N = 15 MMSTB

4.3.3. The Relative Permeability Data:

The relative permeability data of X field shown in fig.(4.2).

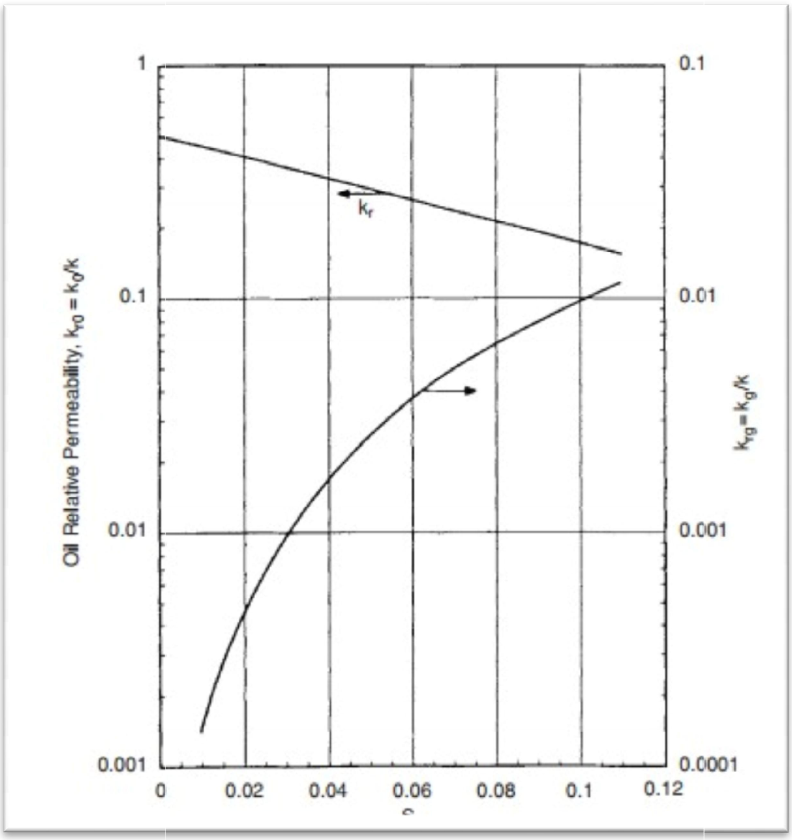


Fig. (4.2): Relative Permeability Data For X Field (Ahmed,T.2006)

Predict the cumulative oil and gas production to 3350 psi.

4.4. Results and Discussions:

The data from the case study was used to predict the cumulative oil and gas production to 3350 psi using the manual steps method, A. Gawishy Spreadsheet method, and the program developed in this study. The results from the three methods are described below:

4.4.1. Results from Manual calculations:

Sample of the Tracy's calculation procedures are performed at 4150 psi

Step 1: Calculate Tracy's PVT functions at 4150

- Calculate the term Den from equ. $(3-26)$:

$Den = (1.42 - 1.43) + (840 - 820)(7.1 * 10^{-4})$=0.0042

- Calculate $\emptyset_o$ and $\emptyset_g$by using equ. $(3-23)$and $(3-24)$ respectively:

$$\emptyset_o = \frac{[1.42-(820)(7.1*10^{-4})]}{0.0042} = 199$$

$$\emptyset_g = 7.1*10^{-4}/0.0042=0.17$$

- Similarly these PVT variables are calculated for all other pressures to give:

Table (4.2): Tracy's PVT Function (Ahmed, T.2006)

P	$\emptyset_o$	$\emptyset_g$
4350	—	—
4150	**199**	**0.17**
3950	**49**	**0.044**
3750	**22.6**	**0.022**
3550	**13.6**	**0.014**
3350	**9.42**	**0.010**

Step 2: Assume a value of GOR at 4150 psi; as an example 850 SCF/STB

Step 3: Calculate the average GOR from equ. $(3-33)$:

$(\boldsymbol{GOR})_{avg}$**= (840+850)/2 =845 SCF/STB**

Step 4: Calculate the incremental cumulative oil production ΔN_p from equ. $(3-32)$

$$\mathbf{N_p = 0 + 0.00292 = 0.00292}$$

Step 5: calculate cumulative oil production from equ. $(3-29)$:

Step 6: Calculate oil and gas saturations from equ. $(3-14)$ *and* $(3-34)$ respectively:

$$\mathbf{s_o = (1 - 0.00292)\left(\frac{1.42}{1.43}\right)(1 - 0.3) = 0.693}$$

$$\mathbf{s_g = 1 - 0.3 - 0.639 = 0.007}$$

Step 7: Determine the relative permeability ratio k_{rg}/k_{ro} from fig. (4.1) to give:

$$\mathbf{\frac{k_{rg}}{k_{ro}} = 8 * 10^{-5}}$$

Step 8: By using $\mu_o = 1.7\ cp\ and\ \mu_g = 0.023\ cp$, calculate the instantaneous GOR from equ. $(3 - 18)$.

GOR=820 + (1.7*10^{-4}) (1.7)(1.42)/(0.023)(7.1*10^{-4}) =845scf/STB

That agreed with the assumed one.

Step 9: Calculate cumulative gas production by using equ. $(3 - 35)$.

$\boldsymbol{G_p = 0 + (0.00292)(8\ 50)}$**=2.48 SCF**

By the same way refine the steps for each pressure until reach 3350 psi, these calculations shown in table (4.3) below.

Table (4.3): Manual Calculation Continue (Ahmed, T. 2006)

P	ΔN_p	N_p	$(GOR)_{av}$	ΔG_p	G_p (scf/STB)	$N_P =$ $15 * 10^6$N STB	$G_P =$ $15 * 10^6$N scf
4350	—	—	—	—	—	—	—
4150	**0.00292**	**0.00292**	**845**	**2.48**	**2.48**	**0.0438*10^6**	**37.2*10^6**
3950	**0.00841**	**0.0110**	**880**	**7.23**	**9.71**	**0.165∗ 10^6**	**145.65*10^6**
3750	**0.0120**	**0.0230**	**1000**	**12**	**21.71**	**0.180*10^6**	**325.65*10^6**
3550	**0.0126**	**0.0356**	**1280**	**16.1**	**37.81**	**0.534*10^6**	**567.15*10^6**
3350	**0.0110**	**0.0460**	**1650**	**18.2**	**56.01**	**0.699*10^6**	**840*10^6**

4.4.2. Results from A. Gawishy Spreadsheet Program:

This spreadsheet was designed in 2003 using excel-sheet program by Ahmed-Gawishy and the out-put of this program including tables only; the tolerance of it within allowable tolerance range.

The same data from the case study; was inserted in Gawishy spread sheet. The results of spreadsheet program as shown in table (4-4).

Table (4.4): Spreadsheet Predicting Table (Gawishy, A.2003)

P	ΔN_p	N_p	ΔG_p	G_p (scf/STB)	$(GOR)_a$	s_o	Tolerance
4350	—	—	—	—	—	—	—
4150	**0.002943031**	**0.002943**	**2.42716**	**2.42716**	**840**	**0.6930592**	**1**
3950	**0.009006309**	**0.0119493**	**6.9348577**	**9.3775737**	**830**	**0.67477073**	**1**
3750	**0.006924333**	**0.0188737**	**16.904912**	**26.282485**	**770**	**0.6627748**	**0.999981516**
3550	**0.007070887**	**0.0259446**	**21.377732**	**47.660217**	**2441.5**	**0.6484621**	**0.999851129**
3350	**0.0060654**	**0.03201**	**22.17807009**	**60.83828604**	**3023.5**	**0.637316519**	**1.00002067**

4.4.3. Results from TPP (the Current Developed Program):

4.4.3.1. Program Starting Window:

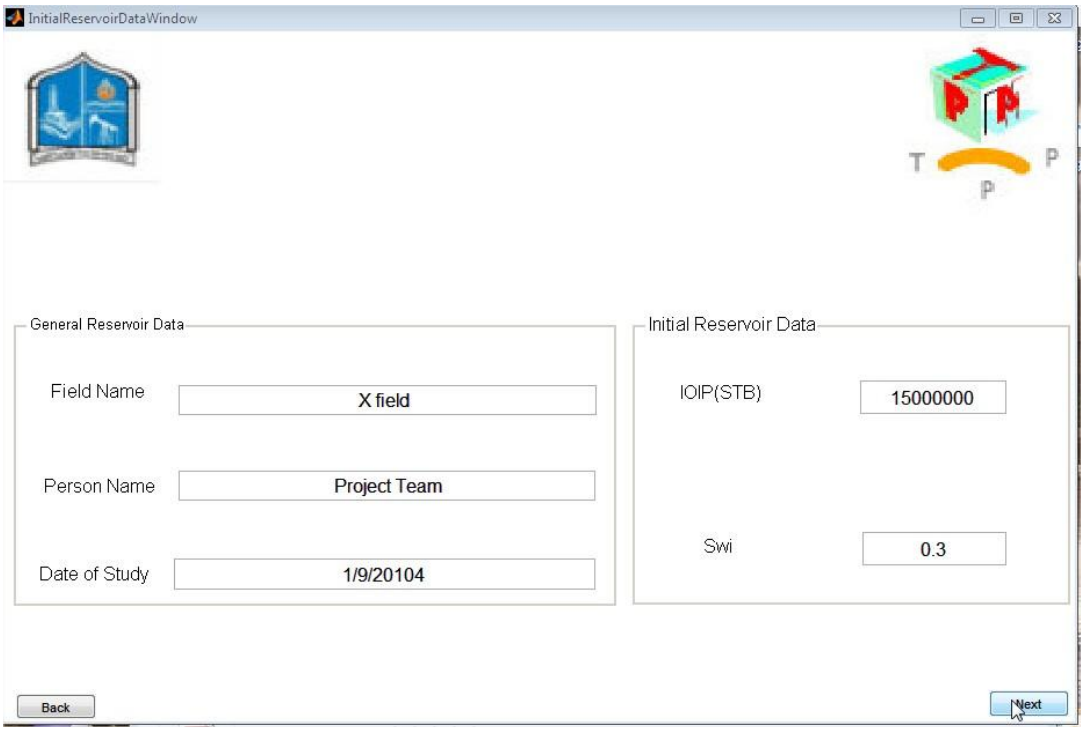
The program has (.exe) format, after opening the program the first window that will appear is program starting window as shown in fig. (4.2).

4.4.3.2 Input Data Windows:

The first input data window is initial reservoir data window as shown in fig. (4.3) which appears after pressing the start bottom in program starting window, this window consists of two parts: first part for general reservoir data and the other part for entering initial oil in place and initial water saturation.

When clicking the next bottom as shown in fig. (4.3) the PVT data and relative permeability data windows will appear as shown in fig. (4.4) and (4.5) respectively.

Fig. (4.3): Program Starting Window



General Reservoir Data

Field Name: X field

Person Name: Project Team

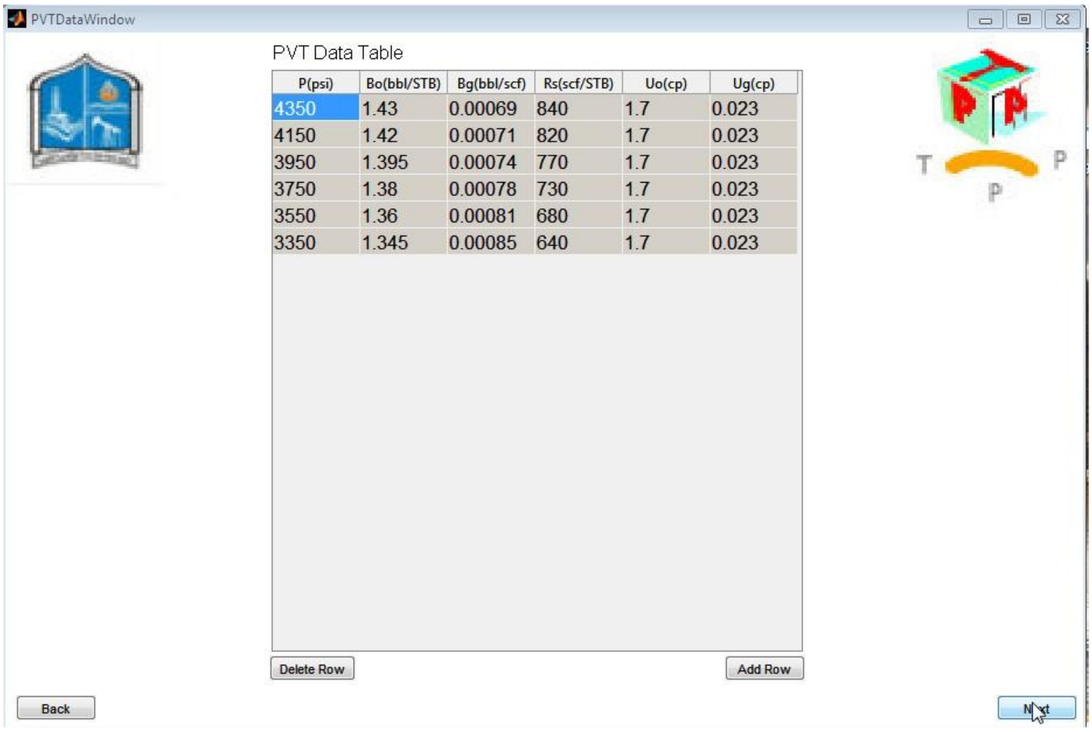
Date of Study: 1/9/20104

Initial Reservoir Data

IOIP(STB): 15000000

Swi: 0.3

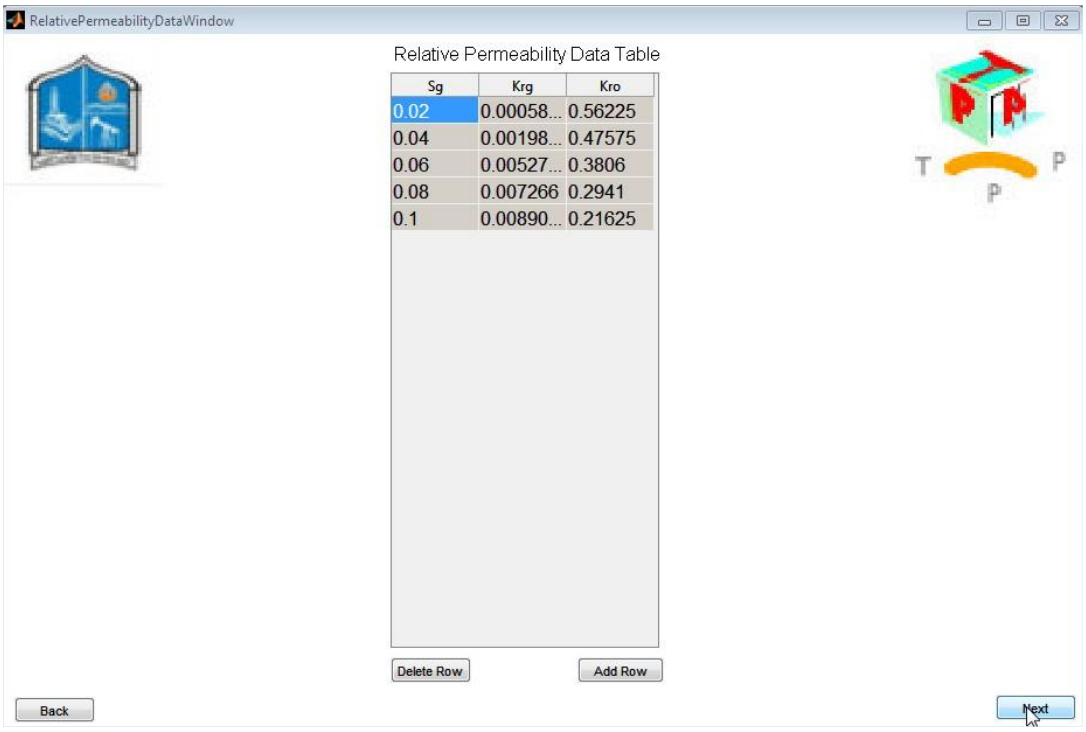
Fig. (4.4): Initial Reservoir Data Window



PVT Data Table

P(psi)	Bo(bbl/STB)	Bg(bbl/scf)	Rs(scf/STB)	Uo(cp)	Ug(cp)
4350	1.43	0.00069	840	1.7	0.023
4150	1.42	0.00071	820	1.7	0.023
3950	1.395	0.00074	770	1.7	0.023
3750	1.38	0.00078	730	1.7	0.023
3550	1.36	0.00081	680	1.7	0.023
3350	1.345	0.00085	640	1.7	0.023

Fig. (4.5): PVT Data Window



Relative Permeability Data Table

Sg	Krg	Kro
0.02	0.00058...	0.56225
0.04	0.00198...	0.47575
0.06	0.00527...	0.3806
0.08	0.007266	0.2941
0.1	0.00890...	0.21625

Fig. (4.6): Relative Permeability Data Window

4.4.3.3 Results of TPP (The Current Developed Program):

The output of this program takes many forms including tables, graphs, and single pressure step predicting (quick prediction window).

After entering all input data the next window which will appear related to output form selection as shown in fig. (4.6), this window allows to user to choose the output form; the next window based on user selection. These results are discussed as follow:

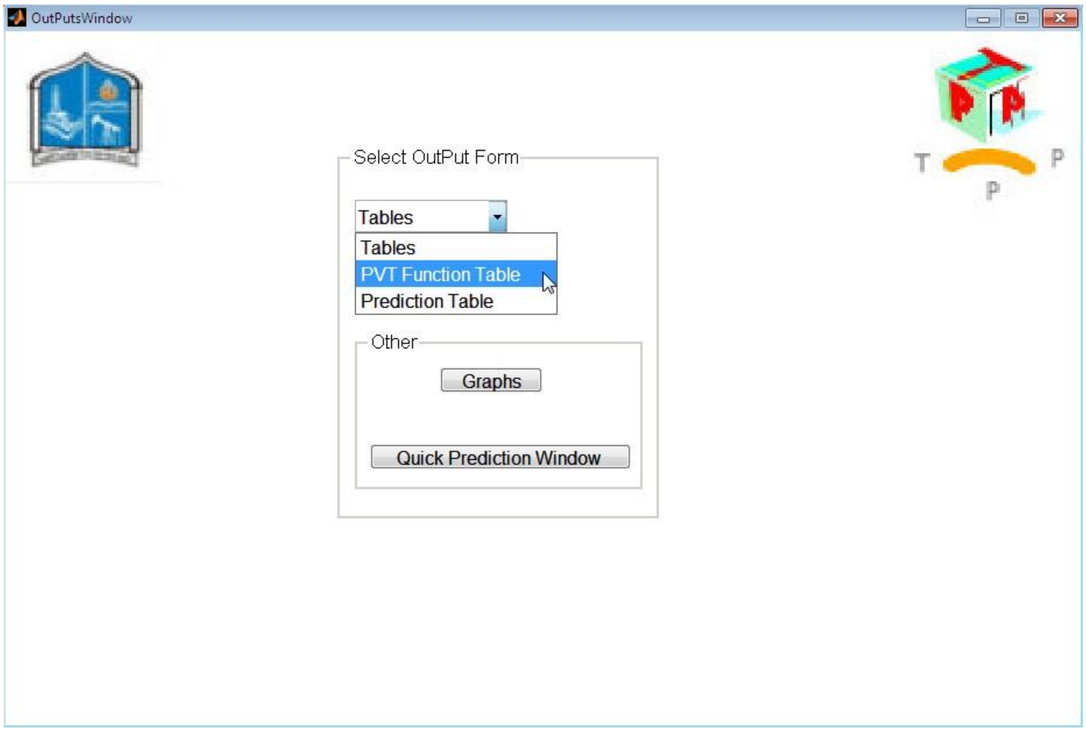
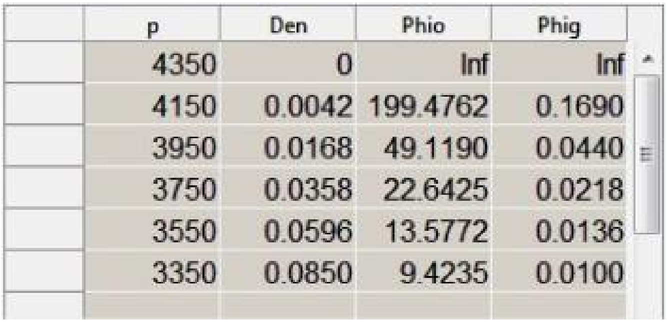


Fig. (4.7): Output Selection Window

Firstly: Results in tables form:

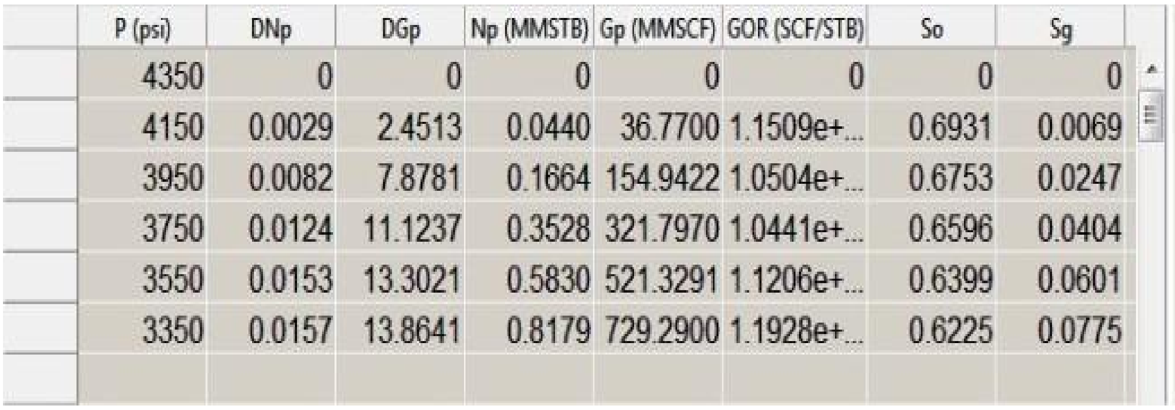
If user selects tables form then there are two choices; the first choice is a table that shows PVT function with the pressure (table 4.5) and the second choice is a table that shows a predicting variables versus pressure (table 4.6). It is clear that there are no differences between the results from this program and from the manual calculations and A. Gawishy results.

Table (4.5): program Calculation- PVT Function



p	Den	Phio	Phig
4350	0	Inf	Inf
4150	0.0042	199.4762	0.1690
3950	0.0168	49.1190	0.0440
3750	0.0358	22.6425	0.0218
3550	0.0596	13.5772	0.0136
3350	0.0850	9.4235	0.0100

Table (4.6): program Predicting parameters versus Pressure



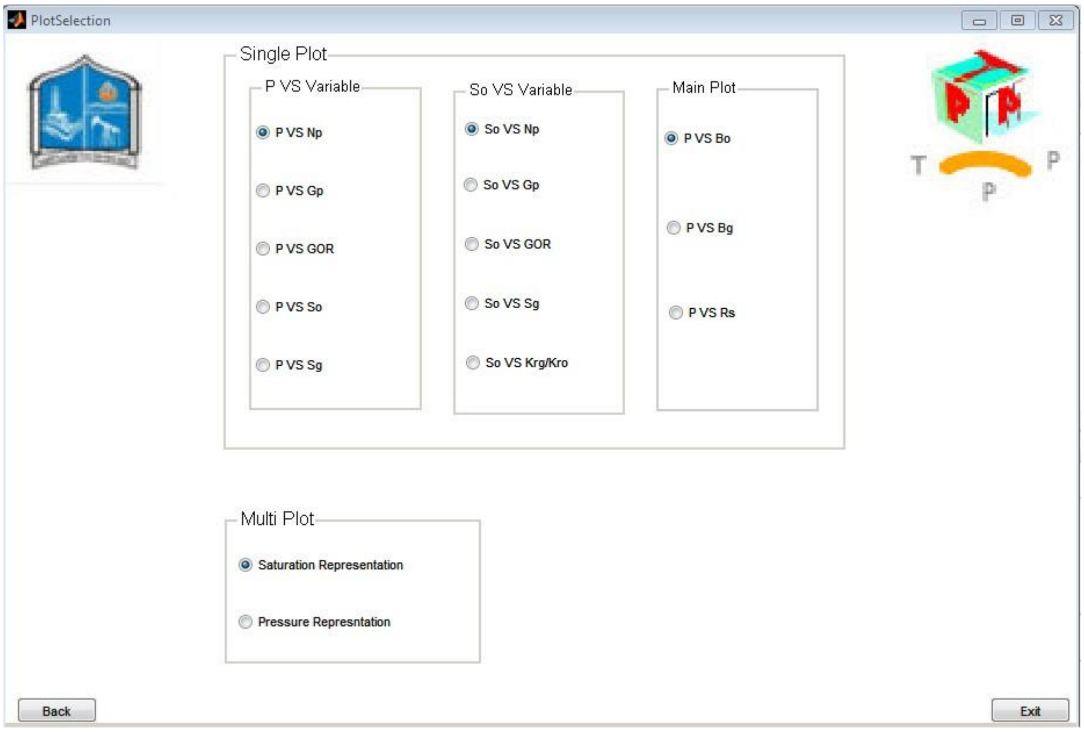
P (psi)	DNp	DGp	Np (MMSTB)	Gp (MMSCF)	GOR (SCF/STB)	So	Sg
4350	0	0	0	0	0	0	0
4150	0.0029	2.4513	0.0440	36.7700	1.1509e+...	0.6931	0.0069
3950	0.0082	7.8781	0.1664	154.9422	1.0504e+...	0.6753	0.0247
3750	0.0124	11.1237	0.3528	321.7970	1.0441e+...	0.6596	0.0404
3550	0.0153	13.3021	0.5830	521.3291	1.1206e+...	0.6399	0.0601
3350	0.0157	13.8641	0.8179	729.2900	1.1928e+...	0.6225	0.0775

Secondly: Results in Graphs Form:

If user selects a graphs form as shown in fig. (4.7) then there are many graphs that can be generated by using this program; in general they divided into two groups:

1) **Single Plot Group:**

Single plot group also divided into three categories including pressure dependent plots (pressure versus variables), saturation dependent plots (S_o versus variables) and main plots (pressure versus PVT data) an example of these plots shown in fig. (4.9), (4.10) and (4.11).



Single Plot

P VS Variable
- ● P VS Np
- ○ P VS Gp
- ○ P VS GOR
- ○ P VS So
- ○ P VS Sg

So VS Variable
- ● So VS Np
- ○ So VS Gp
- ○ So VS GOR
- ○ So VS Sg
- ○ So VS Krg/Kro

Main Plot
- ● P VS Bo
- ○ P VS Bg
- ○ P VS Rs

Multi Plot
- ● Saturation Representation
- ○ Pressure Represntation

Fig. (4.8): Plot Selection Window

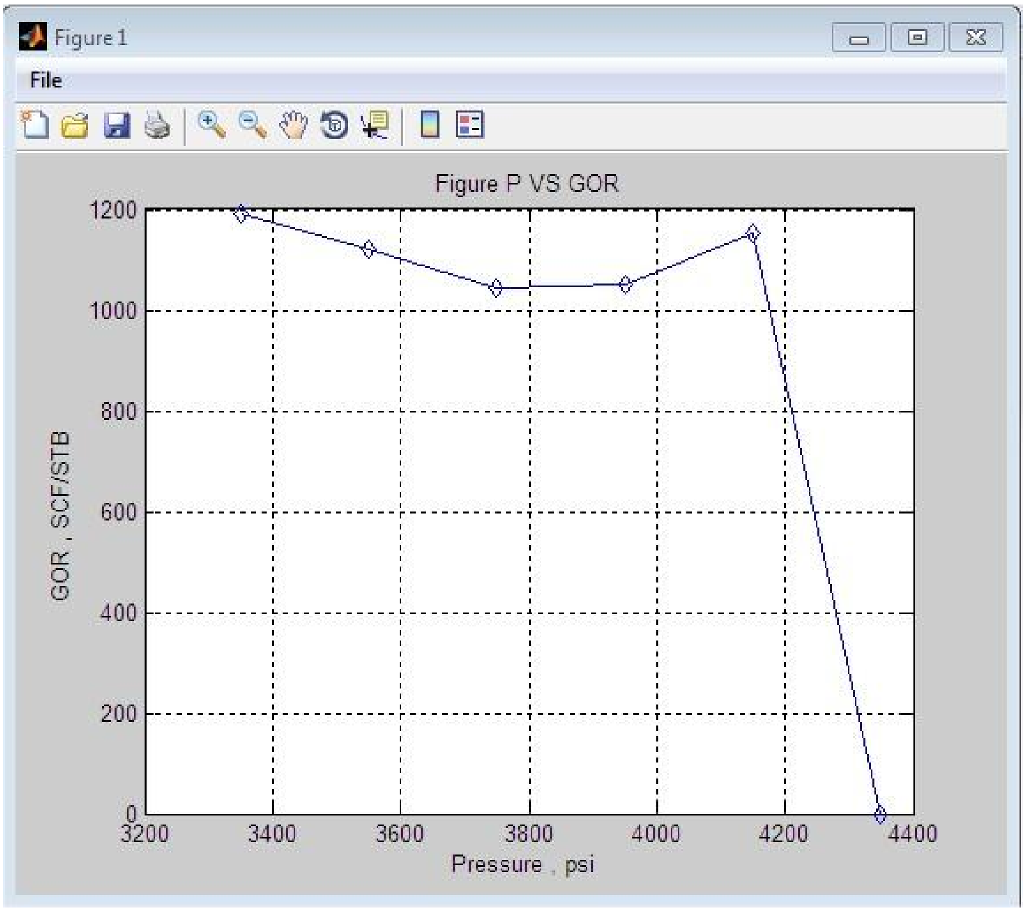


Fig. (4.9): Pressure versus GOR

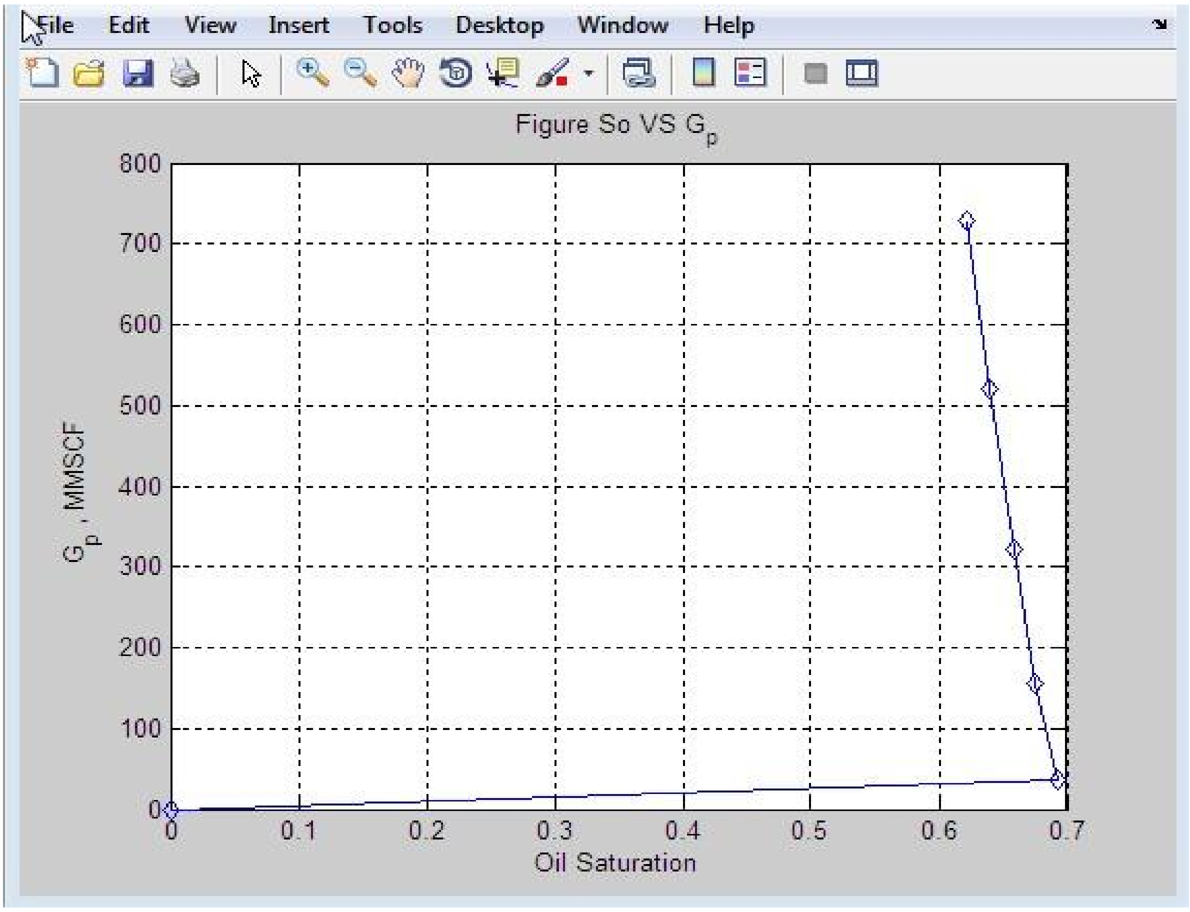


Fig. (4.10): Saturation versus Cumulative Gas Production

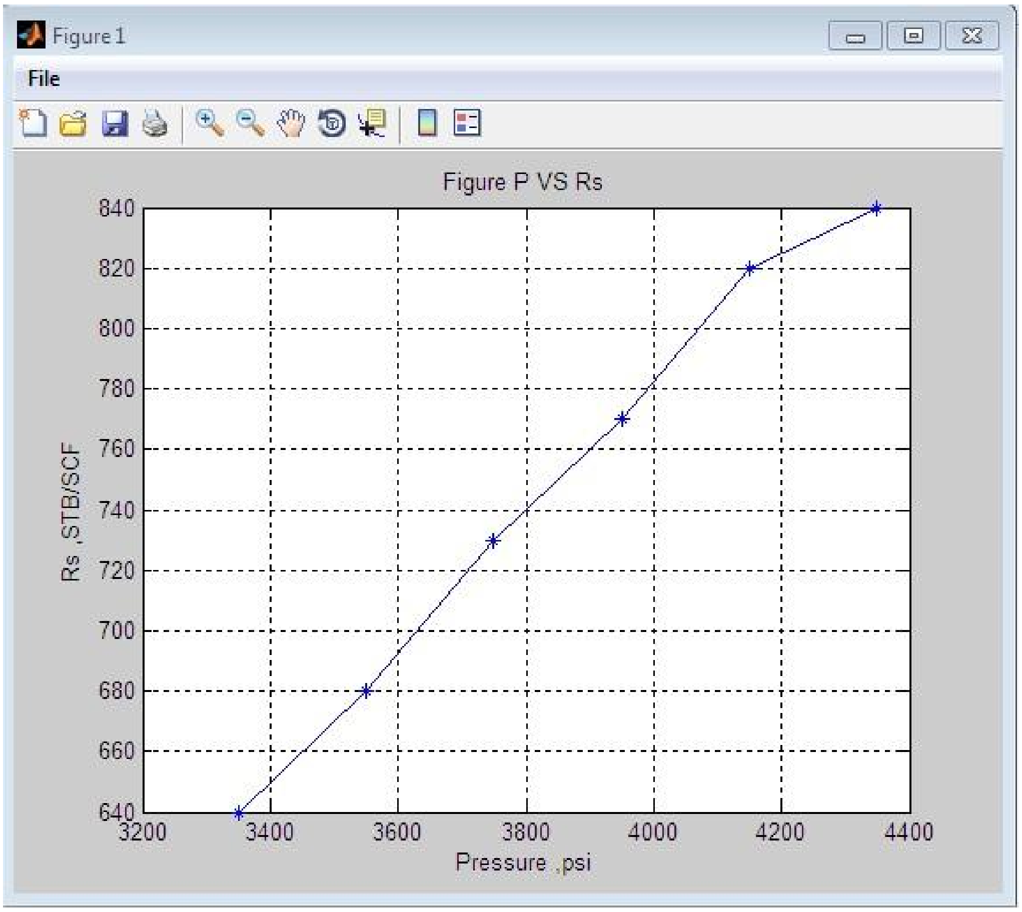


Fig. (4-11): Pressure Versus Gas Solubility

2) Multi Plot Group:

Multi plot group categorized into two graphical representations: including pressure graphical representation and saturation graphical representation. Fig.(4.12) shows an example of multi plot of pressure versus cumulative Oil Production, Cumulative Gas Production, Gas Oil Ratio and Relative Permeability Ratio.

From the above graphs it is clear that the graphs window makes a prediction more easy; for example if we want to predict the future performance at specific pressure, just go to the graph and read the variables which correspond to this pressure and in the same way for saturation.

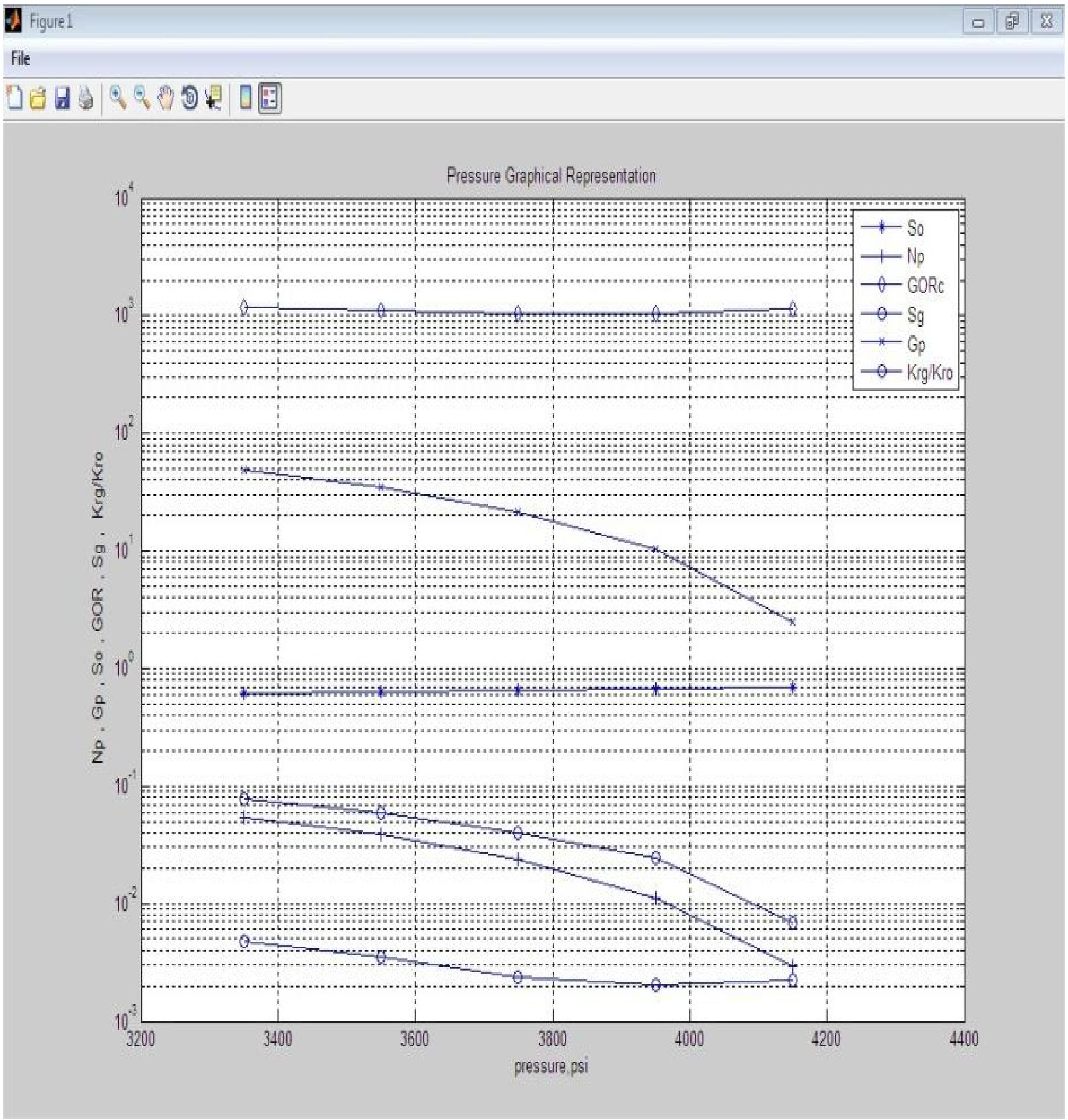
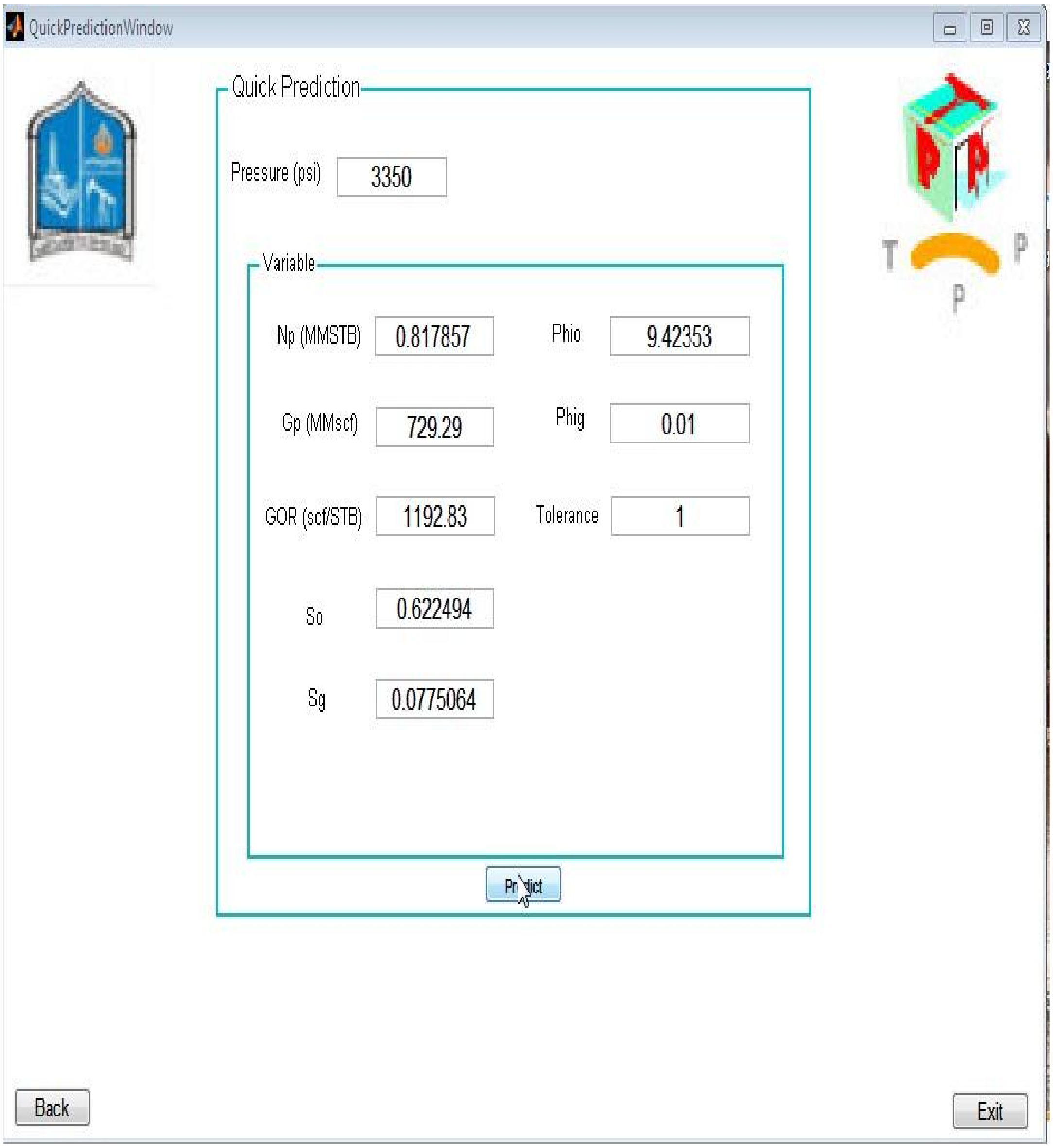


Fig. (4.12): Pressure Graphical Representation

Lastly: Quick Prediction Window:

It is a window for single pressure step prediction, if the user click on quick prediction window as shown in fig.(4.13) the window which will appear allows to user to predict the future performance of selected pressure .The tolerance of this window approximately equals to the allowable tolerance (allowable tolerance =0).

For example if the user selects the value which he wants it to calculate the cumulative hydrocarbon (3350 psi) then the result of running this window shown in fig.(4.13)



Quick Prediction

Pressure (psi) 3350

Variable

Np (MMSTB) 0.817857
Phio 9.42353
Gp (MMscf) 729.29
Phig 0.01
GOR (scf/STB) 1192.83
Tolerance 1
So 0.622494
Sg 0.0775064

. **Fig. (4.13): Quick Prediction Window for 3350 psi**

4.5. Comparison:

The comparison between these three methods at 3350 psi will be done by calculating the tolerance of each method by calculating the error with reference to the manual calculations:

$$\boldsymbol{Error} = \frac{\textbf{calculated with the program – manual calculation}}{\textbf{manual calculation}} \quad .... \quad \textbf{.(4-1)}$$

The comparison results between these three methods are shown in table (4.7) bellow.

It should be pointed that the difference between these methods as a result of assuming the value of GOR which affects in tolerance; so we can use $equ.(3-36)$ to calculate the tolerance of each method as shown in table (4.8) for 3350 psi.

Table (4.7): Error Based On Manual Calculation

NP (MMSTB)

Pressure	**Manual**	**Gawishy**	**TPP**	**Gawishy Error (%)**	**TPP Error (%)**
4150	$\mathbf{0.0438*10^6}$	$\mathbf{0.044145*10^6}$	$\mathbf{0.044*10^6}$	**0.7877**	**0.4566**
3950	$\mathbf{0.165*10^6}$	$\mathbf{0.1792395*10^6}$	$\mathbf{0.1664*10^6}$	**8.63**	**0.8485**
3750	$\mathbf{0.180*10^6}$	$\mathbf{0.28\ 31055*10^6}$	$\mathbf{0.3528*10^6}$	**57.2808**	**96**
3550	$\mathbf{0.534*10^6}$	$\mathbf{0.38\ 9169*10^6}$	$\mathbf{0.58\ 30*10^6}$	**-27.1291**	**9.1760**
3350	$\mathbf{0.699*10^6}$	$\mathbf{0.48\ 015*10^6}$	$\mathbf{0.8\ 179*10^6}$	**-31.3090**	**17.0100**

Table (4.8): Tolerance for Each Method

Variable	Manual	Spreadsheet	TPP Program
N_p	**0.046**	**0.03201**	**0.0545238**
G_p	**56.01**	**60.83828604**	**48.61933333**
φ_o	**9.42**	**9.4235294**	**9.42353**
φ_g	**0.01**	**0.01**	**0.01**
tolerance	**0.0066**	**0.00002971**	**0.000000001686**

Tables (4.7) and (4.8) above show that the results of TPP are more accurate than manual and spreadsheet program results.

Chapter 5

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Conclusions and Recommendations

CHAPTER 5

Conclusions and Recommendations

5.1. Conclusions:

Tracy method is programmed by using the MATLAB and used to predict future performance of X field at 3350 psi. The results were compared with manual calculation and Gawishy spreadsheet. The results from these three methods are summarized as follow:

- Manual calculation results found that the cumulative oil and gas production at 3350 psi are0.046 MMSTB and 56.01 MMscf respectively with tolerance equal to 0.00658.
- Spreadsheet results showed that that the cumulative oil and gas production at 3350 psi are0.03201 MMSTB and 60.83828604 MMscf respectively with tolerance equal to 0.00002971.
- The results from the current developed program (TPP) showed that the cumulative oil and gas production at 3350 psi are 0.0545238 MMSTB and 48.61933333 MMscf respectively with tolerance equal to 0.00000000168

5.2. Recommendations:

1) Tracy's method can be used with IPR curves to get more accurate results because it is combining the time and pressure as a function, this process considers production from each well and number of wells into account.

2) It is not recommended to use Tracy's method to predict the future performance at bubble point pressure.

3) The program can be developed to calculate relative permeability data by using correlations or exponential method at a given gas saturation instead of using relative permeability charts.

4) The program can be used with any other screening program to choose optimum EOR method for a given reservoir properties.

Appendix

Program Code

TPP CODE

The main code of this program (the m.file made up by MATLAB R2010a) and it is shown below:

```
GORavg(1,i)=(GOR(1,i-1)+GORa(1,i))/2;
DNp(1,i)=(1-(Np(1,i-1)*Oo(1,i)+Gp(1,i-
1).*Og(1,i)))/(Oo(1,i)+(GORavg(1,i).*Og(1,i)));
        Np(1,i)=DNp(1,i)+Np(1,i-1);
        So(1,i)=((1-Swi)*(1-Np(1,i))*(Bo(1,i)/Bo(1,1)));
        Sg(1,i)=1-So(1,i)-Swi;
        Krgo(1,i)=
interp1(Sgog,Kg,Sg,'cubic')/interp1(Sgog,Ko,Sg,'cubic');
         GORc(1,i)=Rs(1,i)+((Krgo(1,i)*Bo(1,i)*Uo)/(Bg(1,i)*Ug));
         if GORc(1,i)==GORa(1,i)
             GOR(1,i)=GORc(1,i);
         else
             GORa(1,i)=GORc(1,i);
             GOR(1,i)=GORc(1,i);
ha1=guidata(InitialReservoirDataWindow);
        ha2=guidata(PVTDataWindow);
        ha3=guidata(RelativePermeabilityDataWindow);
        ha4=guidata(PVTFunctionTable);
g=str2double(get(ha2.pvt,'data'));
g1=str2double(get(ha3.sk,'data'));
N=str2double(get(ha1.n,'String'));
Swi=str2double(get(ha1.swi,'String'));
p1=g(:,1);
Bo1=g(:,2);
Bg1=g(:,3);
Rs1=g(:,4);
Uo1=g(:,5);
Ug1=g(:,6);
Sgog1=g1(:,1);
Ko1=g1(:,3);
```

```
Kg1=g1(:,2);
Sgog=Sgog1';
Ko=Ko1';
Kg=Kg1';
p=p1';
Bo=Bo1';
Bg=Bg1';
Rs=Rs1';
Uo=Uo1';
Ug=Ug1';
Gp(1,1)=0;
Np(1,1)=0;
GOR(1,1)=Rs(1,1);
DNp(1,1)=0;
back = axes('unit', 'normalized', 'position', [0 0 1 1]);
bg = imread('back.jpg'); imagesc(bg);
set(back,'handlevisibility','off','visible','off')
uistack(back, 'bottom')
% Choose default command line output for ProgramStartingWindow
handles.output = hObject;
% Choose default command line output for InitialReservoirDataWindow
handles.output = hObject;
Np1=(N/1000000).*Np;
Gp1=(N/1000000).*Gp;
a1=str2double(get(handles.press,'string'));
f1a=interp1(p,Np,a1, 'cubic');
f2a=interp1(p,Gp,a1, 'cubic');
f1=interp1(p,Np1,a1, 'cubic');
f2=interp1(p,Gp1,a1, 'cubic');
f3=interp1(p,GORc,a1, 'cubic');
f4=interp1(p,So,a1, 'cubic');
f5=interp1(p,Sg,a1, 'cubic');
Oo1=Oo(2:length(p));
```

```
Og1=Og(2:length(p));
p1=p(2:length(p));
f6=interp1(p1,Oo1,a1, 'cubic');
f7=interp1(p1,Og1,a1, 'cubic');
f8=(f7*f2a)+(f6*f1a);
set(handles.np1,'string',f1);
set(handles.gp1,'string',f2);
d=get(handles.sk,'data');
v=str2double(d);
d=isnan(v);
z=isempty(find(d(d==1), 1));
if z==1
OutPutsWindow;
else
   warndlg('You must fill the cells of relative permeability data table
','Wait to input','Warning');
end
 ha=get(handles.sk, 'data');
ha1=ha (size(ha,1),:) ;                    %last line
ha2=cat(1,ha,ha1);
set(handles.sk,'data', ha2);
function back2_Callback(hObject, eventdata, handles)
% hObject    handle to back2 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
close;
PVTDataWindow;
% --- Executes on button press in pushbutton4.
function pushbutton4_Callback(hObject, eventdata, handles)
% hObject    handle to pushbutton4 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
ha=get(handles.sk, 'data');
ha(size(ha,1)-1,:)=[];
```

```
set(handles.sk, 'data',ha);
function rep_Callback(hObject, eventdata, handles)
% hObject    handle to rep (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
QuickPredictionWindow;
% --- Executes on button press in pushbutton3.
function pushbutton3_Callback(hObject, eventdata, handles)
% hObject    handle to pushbutton3 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
close;
% --- Executes on button press in pushbutton4.
function pushbutton4_Callback(hObject, eventdata, handles)
% hObject    handle to pushbutton4 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
close;
RelativePermeabilityDataWindow;
```

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