Software Development for Calculations of Voidage Replacement Ratio (VRR)

by

Nazrulhisham bin Osman

Dissertation submitted in partial fulfilment of
the requirements for the
Bachelor of Engineering (Hons)
(Mechanical Engineering)

JANUARY 2003

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CERTIFICATION OF APPROVAL

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Approved by,

(Pn Norrulhuda Haji Mohd Taib)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

January 2003

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

NAZRULHISHAM BIN OSMAN

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ABSTRACT

The objective of this project is to develop a software for the calculations of Voidage Replacement Ratio (VRR). VRR is an indicator of the performance of the water injection process. Water injection is used to control and maintain the reservoir pressure. In doing the calculations, there is a need for all these data required for the calculation to be managed and used as input for the VRR calculations. Such data are the well test data and data from daily activity report of the offshore operations.

Currently, all the data management and calculations are performed using Microsoft Excel Spreadsheet. This method lacks security integrity and is vulnerable to the data. Therefore, appropriate software must be developed in order to manage the data and calculations properly and also to provide a secure database system.

To understand the calculation procedures and the relevance of various input data, research was performed on reservoir pressure maintenance concepts, in general and the water injection process, in particular.

Research was done on the basic reservoir engineering principles in reservoir behavior such as fluids properties and PVT diagram and enhanced oil recovery by waterflooding. In developing the software or system, which can perform the calculations of VRR, four software were utilized. The software was Dreamweaver, which was used to create the interfaces. Internet Information Services (IIS) software was used to make the computer act as a server. Active Server Pages (ASP), which is in the form of source code, was used to responds to the users' request and finally Microsoft Access was used to develop the database for the software.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Crude oil in the reservoir flow to the surface because the pressure in the reservoir is higher than the surface pressure. Through time, as the oil is produced, the reservoir pressure depletes until it cannot push the oil to the surface. To optimize the oil production from the reservoir, the reservoir pressure needs to be monitored and controlled so as to ensure pressure does not deplete but maintained at desired level. One of the methods of maintaining the reservoir pressure is by using waterflooding. The concept of waterflooding involves injecting water into the reservoir to replace the void spaces created as a result of oil production. Concept of material balance is employed to maintain the volume of the reservoir and at the same time maintain the reservoir pressure.

This is where the Voidage Replacement Ratio (VRR) takes place. It indicates the performance of waterflooding in maintaining the reservoir pressure. In determining the value of VRR, various data needs to be entered daily into the calculations. To understand the calculations and appreciate the value of these data, detailed understanding of overall pressure maintenance scheme using the waterflooding process is required.

1.2 Problem Statement

Voidage Replacement Ratio (VRR) is one of the key performance indicators for the efficiency of waterflooding system that is used for the reservoir pressure maintenance purpose. Various data are involved in calculation procedures such as data obtained from the well test and data obtained from the from daily activity report. Currently, all the data management and calculations were done using the spreadsheet. Since the spreadsheet is not really secured, proper software, which can store the data safely and performs the VRR calculations, must be developed.

1.3 Objectives and Scope of Study

The objective of this project is to conduct research about overall pressure maintenance scheme using the waterflooding process and to develop proper software that can be used to manage the data into a secure database system and perform the calculations of Voidage Replacement Ratio (VRR).

In completing the project, research about the reservoir pressure maintenance scheme using the waterflooding process must be done so that the calculations process can be understood. Relevant topics that have to be studied by the author are the formation volume factor of oil and gas, general behavior of the fluids and PVT diagram, primary recovery of the oil, central and peripheral flooding, sweep efficiency for the pattern floods, effect of free gas production at reservoir pressure and waterflooding process in oil recovery method.

Studies also need to be done on the availability of some software in the market, which capable of developing the software for the VRR calculations purposes. At initial stage, the proposed software is the Microsoft Visual Basics Software and studies have to be done on its criteria and constraints in developing the software needed for the calculations of VRR. After a few testing, a lot of limitations of this software were found, such as that any new database that are going to be entered in the future must be specified at the software development stage and the page cannot easily be scrolled up and down. Therefore, a study to find a proper software was continued and as a result, the software are Dreamweaver, Microsoft Internet Information Services (IIS), Active Server Pages (ASP) and Microsoft Access, which will be discussed in detail in Chapter 4. Author also need to determine how the data must be managed in order to make the database system secured, simple and convenient to retrieve.

This project was completed in 2 semesters. All the research related to this project, interfaces development for the software and the calculations steps were developed in the first semester. The database system development was developed during the second semester (Please refer the Gantt chart in Appendix 1).

CHAPTER 2

LITERATURE REVIEW AND THEORY

2.1 Concept of Waterflooding in Maintaining Reservoir Pressure

The concept of waterflooding is to replace the oil produced from the reservoir in order to maintain the reservoir volume and at the same time maintaining the reservoir pressure. In implementing the waterflooding process, water is injected into the reservoir and its volume must be equal to the reservoir withdrawal volume. It is important to know that when the oil is produced, it is also producing the gas and water at the same time. Therefore, the reservoir withdrawal volume is the withdrawal of the oil, gas and water.

One of the key performance indicators of the efficiency of waterflooding is by calculating Voidage Replacement Ratio (VRR) or the injection ratio. It indicates the ratio of injection volume over the reservoir withdrawal volume.

$$\text{VRR} = \frac{\text{Injection Volume}}{\text{Reservoir Withdrawal Volume}}$$

Using water injection, the VRR must be equal to 1 since it indicates that the balance between water injection and off take rate is achieved. There are several technical calculations that have to be performed daily in order to obtain the VRR of the reservoir.

2.2 Fluids and PVT Diagram

In understanding reservoir behavior, one must understand the fluids properties and (Pressure, Volume and Temperature) PVT diagram. The basic PVT diagram is for the pure substances fluids, which consist of identical molecules. The pressure/specific volume diagram, also known as Clapeyron diagram, is shown as in Figure 2.1 below.

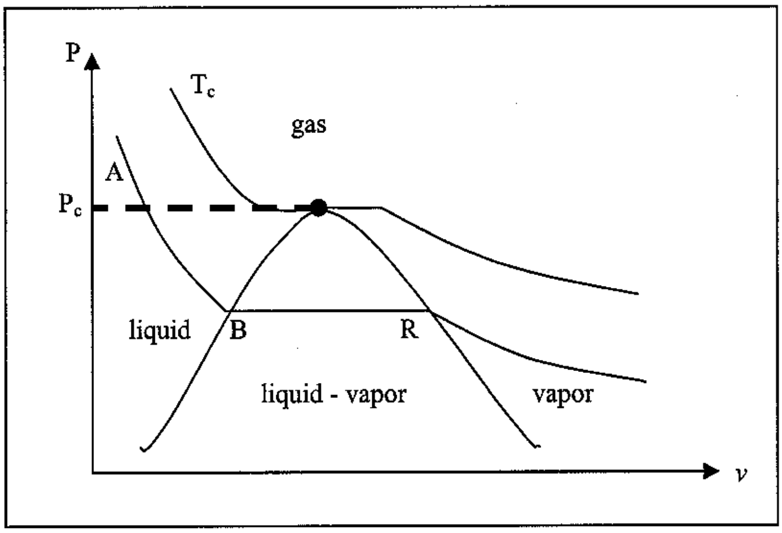


Figure 2.1: Pressure/Specific Volume Diagram (Clapeyron Diagram)

In explaining the above diagram, it is assumed that the volume of fluids available in the substance increased very slowly at constant temperature. The explanations are:

a) Point A is the pure substance in liquid state.
b) At point B, vapor state appears. This point also known as bubble point pressure.
c) From point B to point R, the pressure is remains constant but the vapor phase tends to increase and the liquid phase tends to decrease.
d) Point R is known as dew point pressure, where the disappearance of the last drop of liquid happened.

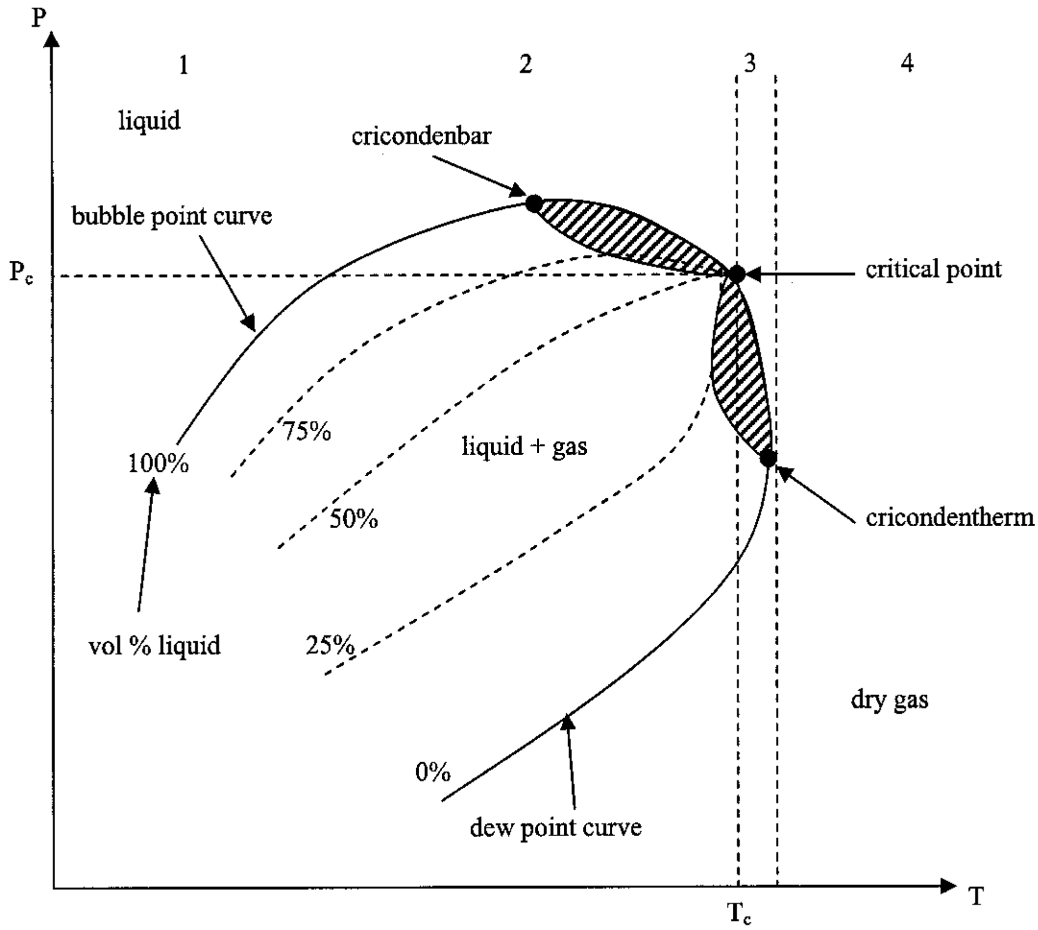
e) After point R, only vapor phase exist, which are compressible and the pressure decreases slowly.
f) T_c and P_c is the critical temperature and critical pressure respectively. Above the T_c, the pure substance is always one-phase irrespective of the pressure and it is known as supercritical state (gas).

As this project deals mainly with the concept of pressure maintenance of the oil reservoirs, the behavior of the oil reservoirs under various thermodynamic conditions need to be fully analyzed. In oil reservoirs, the temperature is lower than the critical temperature of the mixture contained therein. In under-saturated reservoir, which are initially one-phase and the same mixture exists throughout the reservoir, the important point is the one at which a gas phase appears. As explain in the Clapeyron diagram above, this point is known as bubble point pressure or saturation pressure. When the reservoir pressure drop and reach this point on, the passage availability to the oil decrease and its viscosity also increases hence decreasing the productivity of the wells. Moreover, the gas which was initially trapped then begins to flow increasingly faster. The production of a unit volume of oil tends to decrease the pressure and at the same time produce more and more in gas. This phenomenon is leading to low recovery of the reservoir.

In the oil reservoir with the gas cap, assuming the hydrocarbon liquid phase and vapor phase are initially in equilibrium, part of the gas released by production can be added to the gas cap. If the gas cap is not produced, it tends to create a 'piston' effect that maintain the pressure and help to improve the recovery. In this situation, the initial bubble-point pressure of the hydrocarbon liquid phase is the pressure of the gas cap and the oil is said to be saturated.

No matter the oil is initially one phase or not, the bubble point pressure of the oil generally decreases with increasing depth for a given reservoir. This means that the composition of the oil varies vertically with the oil at the top zone is slightly lighter than the lower zone. In some cases, the bubble point also varies laterally in the reservoir.

Other types of reservoirs based on thermodynamic criteria are the retrograde condensate gas reservoirs and gas reservoirs without retrograde condensation. The classification of hydrocarbon reservoirs based on thermodynamic criteria is shown in Figure 2.2.



Zone 1: Little or no influence of dissolve gas
Zone 2: Significant influence of dissolve gas (volatile oil)
Zone 3: Retrograde with condensation of liquid in the reservoir
Zone 4: Dry or wet gas

Figure 2.2: Classification of Hydrocarbon Reservoirs Based on Thermodynamic Criteria: P/T Diagram

2.3 Volume Factor of Gas, B_g

The quantities of gas in place, reserves, flow rates and cumulative production are expressed as standard volumes, corresponding to given pressures and temperatures. The most commonly used are:

$P_{std} = 76$ cmHg, $T_{sd} = 0°C$ (standard conditions)

$P_{std} = 75$ cmHg, $T_{sd} = 15°C$ (SNEA (P))

$P_{std} = 76$ cmHg, $T_{sd} = 15°C$ (US standard)

For above conditions, the compressibility factor is assumed as 1, $Z_{std} = 1$
The volume factor of a gas, B_g (gas bulk volume) is determined based on the formula below:

$$B_g = \frac{\text{Volume occupied at P and T by a mass of gas m}}{\text{Standard volume of the mass m}}$$

$$B_g = \frac{P_{std}}{P} . Z . \frac{T}{T_{std}}$$

* Standard volume of mass m = volume that mass m would occupy at P_{std} and T_{std} if it was in the vapor state in these conditions.

2.4 Volume Factor of Oil, B_o

When the oil is produced and flowed to the surface, a number of phenomena occurred, which is the drop in temperature and pressure. These phenomena tend to make initially-dissolved gas evolved from the solution. In explaining these phenomena, the following terms are employed:

a) Formation Volume Factor (FVF) B_o (oil bulk volume): the volume of reservoir liquid phase that has yielded a unit volume of oil in stock tank conditions.
b) Solution Gas Oil Ratio (GOR) R_s (solution ratio): the standard volume of gas recovered with a unit volume of stock tank oil.

Above phenomenon can be explained using Figure 2.3 below:

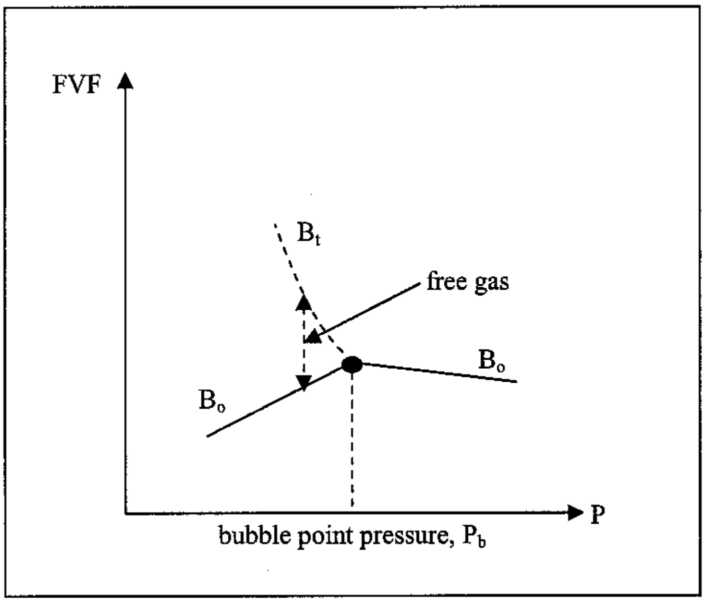


Figure 2.3: Formation Volume Factor (FVF) vs Pressure (P)

In Figure 2.3, the important parameter is the bubble point pressure, which represents the pressure at which the gas is released from the solution. The FVF of the oil B_o decreases as the pressure falls for $P < P_b$ because of the decrease in volume due to the gas coming out of the solution. Total volume, B_t occupied for $P < P_b$ when the pressure decreases is also shown in the figure. B_t is actually equal to the volume of oil and dissolved gas. Take note that the $P < P_b$ and in this case the volume of the dissolve gas is the volume of gas released from the solution. It is shown in the following equation:

$$B_t = B_o + (R_{si} - R_s)B_g$$

where R_{si} is the initial solution GOR at $P = P_i$

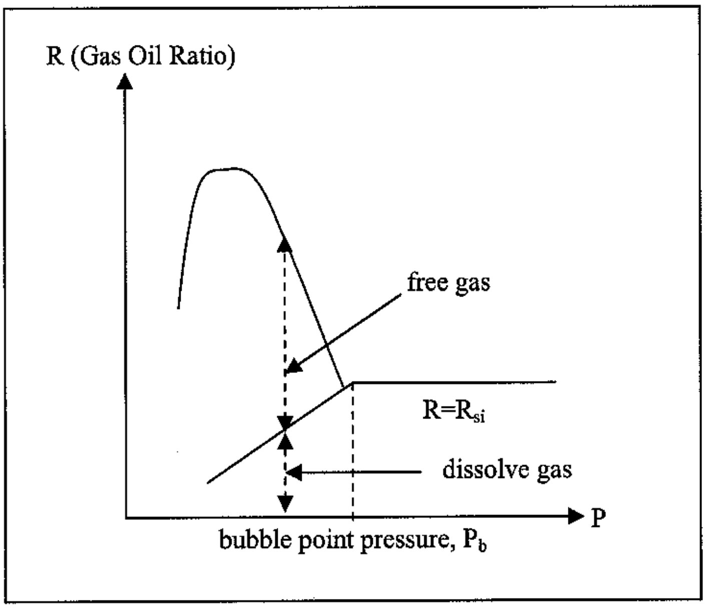


Figure 2.4: Production GOR (R) vs Pressure (P)

In Figure 2.4, for $P > P_b$, the gas produced originates only from the dissolved gas. The production GOR is constant and equal to the initial solubility R_{si}. For $P < P_b$, only part of the gas produced originates in dissolved gas. This part decreases with the pressure. The rest derives from free gas. When a sufficient saturation (critical gas saturation, S_{gc}) is reached, this gas begins to flow.

The gas flow rate, Q in reservoir conditions increases with saturation, hence with decreasing pressure. GOR corresponds to the gas measured in standard conditions. Due to this fact, the gas flow rate can be equated in the equation below:

$$\frac{Q.P}{Z.T} = \frac{Q_{std}.P_{std}}{1.T_{std}}$$

(P, Q, T, Z are in reservoir conditions reproduced by the laboratory measurement cell and subscript std = standard)

Q_{std} depends on Q, which is increases as Pressure, P decreases. Therefore, it explains that R reaches a peak when the pressure keeps decreasing. This means that if nothing is done to prevent pressure from falling below the bubble point, each cubic meter of oil volume produced tends to produced more gas and decrease the energy of the reservoir. It is because gas is the highest energy component in the reservoir. These phenomena can leads to low recovery of the reservoir.

2.5 Factors Influencing Oil Recovery

In secondary oil recovery, it involves sweeping the reservoir between injection wells and production wells. Some of the factors that influencing the recovery are the fluid flow, reservoir rock characteristics, types of fluids in place and injected fluids.

2.5.1 Reservoir geology

Impermeable barriers in the reservoir could lower down the sweep efficiency effect of the fluids. A small fault also can prevent any sweep in specific zone. This barriers and faults sometimes are difficult to identify. Therefore detailed analysis of cores and logs should be done to understand the communications between injector and producer wells.

2.5.2 Permeability

Good permeability is favorable for the secondary oil recovery because it indicates the existence of large diameter of pores. This can provides high flow rate for the fluids, thus increasing the well spacing. At the same time, it also reduces the flooding pressure required.

2.5.3 Heterogeneities

There are many layers or beds in the reservoir and each bed may have different permeability. In this case, the movement of displacement fluids is faster in the more permeable beds than in other beds. Through time, the imbalance of displacement fluids between the beds will increase. If the differences in the permeability are wide, the displacement fluids tend to break trough into the production well via preferential paths. Fracture may occur between the paths of the injection and production wells and create direct communication between the wells. Since the displacement fluids are less viscous and move faster than the oil, it will be produced from the production wells and all the oil would remain trapped. Therefore, great heterogeneity in permeability is not favorable for the injection.

Others factors that influence the oil recovery are viscosity of the oil, capillary pressures, the dip of the beds and the depth of the reservoir.

2.6 Injection Efficiency and Type of Sweep

The total efficiency is the recovery factor (for the zone subjected to flooding) in reservoir conditions can be determined by the formula below:

$$E = E_A . E_v . E_D$$

where,

E = total efficiency

E_A = areal sweep efficiency

E_v = vertical or invasion efficiency

E_D = displacement efficiency, at the scale of pores.

The example of how the areal sweep reacts can be shown in the five-spot pattern in Figure 2.5 below:

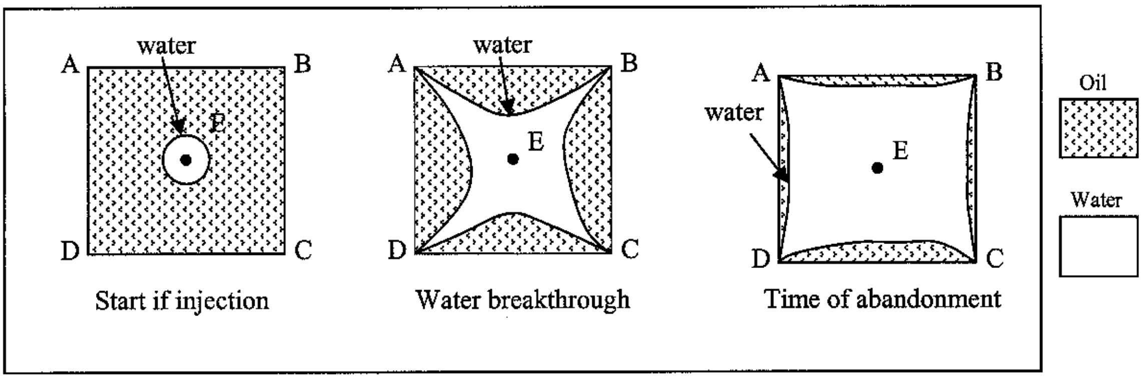


Figure 2.5: Example of Areal Sweep

In Figure 2.5, A, B, C and D are the injector wells while E is the producer well. Several periods after the injection started, water tends to breakthrough to the producer well, E. Areal sweep occurred in the same phase as the layer or bed. At time of abandonment, it can be seen that the waterflooding has covered almost all the area.

In vertical efficiency, the swept effect reacts in the vertical direction. Since there are some cases, which the beds may have different permeability, strata or fracture, fingering effect could occur in the vertical sweep as shown in Figure 2.6 below. In the figure, water that migrate through layers or beds that have lower permeability is slower that water that pass through layers, which have higher permeability.

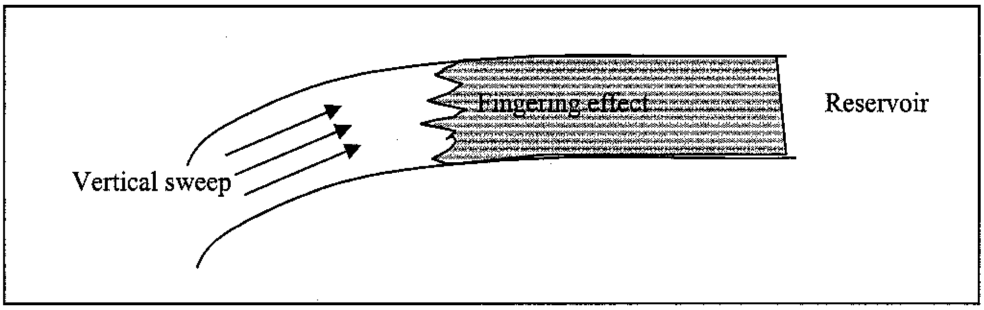


Figure 2.6: Example of Vertical Sweep

Displacement efficiency occurred at scale of pores and it also known as microscopic efficiency. In this case, some volume of oil are displaced trough the pores of the reservoir. These three efficiencies increase as a function of time. That means the injected volume of fluid increase with time in the specified area of flooding.

2.7 Implementations of Waterflooding

Waterflooding goals are to increase recovery and also to accelerate production. In other words, it is used to slow down the production decline. As discussed before, undersaturated reservoir is where the crude oil contains less than it is required to saturate the oil at the pressure and temperature of the reservoir. When the oil is highly undersaturated, much of the reservoir energy is stored in the form of liquid and rock compressibility. Pressure declines rapidly as fluids are withdrawn from the undersaturated reservoir until the bubble point pressure, P_b is reached. Then the solution gas drive becomes the source of energy for the fluid displacement. These types of reservoirs are good candidates for water injection to maintain a high reservoir pressure and to increase oil recovery.

In general, waterflooding are the favorable for light oil (low-viscosity oil) reservoir because its mobility ratio is higher than the heavy oil. The reservoirs also should have sufficient permeability and compatible for the waterflooding process so that the water can be injected sufficiently.

The time to start waterflooding also an important factor in determining its efficiency. It is not advisable to start the waterflooding too early because the production data at this early stage can be used to identify any natural drive mechanisms and activity of aquifer in the reservoir. There are many assumptions in predicting the right time to implement the waterflooding process. Detailed studies about the reservoir have to be done to determine the perfect timing.

Waterflooding process requires additional facilities on the production infrastructure, such as:

a) Sufficient and continuous water supply in terms of quantity, quality and regularity.
b) Water treatment installation at the surface (prevention of incompatibility with formation water and with the rock, filtration and elimination of the bacteria).
c) Suitable completion of the injection wells and sometimes it is necessary to close the more permeable zones to prevent water breakthrough at the production wells.
d) Pumping installations (if necessary).
e) System to monitor the flooding and sweeping such as using radioactive tracers.

CHAPTER 3

METHODOLOGY/PROJECT WORK

3.1 Procedure Identification

The procedures of the project are divided into 3 major phases, which will be implemented during the allocated 2 semesters. Phase 1 will be implemented during the first semester while phase 2 and phase 3 will be implemented during the second semester. All the tasks for each phase are outlined as in the following:

3.1.1 Phase 1

- Perform research on overall pressure maintenance scheme using the water flooding process.
- Perform research on the availability and suitability of the Microsoft Visual Basics Software and other software in developing the software for the calculations of VRR.
- Determine measures on how data need to be managed such that it is secure and easy to retrieve.
- Identify the process flow chart of the software development and database management system.
- Develop the interface (software) using the most suitable software for data entry and calculations purposes.
- Preparation for progress report 1 and oral presentation.

3.1.2 Phase 2

- Develop a database management system.

3.1.3 Phase 3

- Ensure all the developed software and database management system run as per plan.
- Poster preparation.
- Preparing technical report and dissertation.
- Preparing for oral presentation.

3.2 Tools/equipment Required

The tools and equipments that are required in this project are as below:

- Microsoft Visual Basics (VB) Software.
- Microsoft Access Software.
- Dreamweaver Software.
- Microsoft Internet Information Services (IIS) Software.
- Active Server Pages (ASP) Software.
- Reservoir Engineering and Reservoir Pressure Maintenance Books.
- Personal Computers.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Suitable Software Used to Develop Software for VRR Calculations

At initial stage, Visual Basics (VB) software was chosen to develop the software for Voidage Replacement Ratio (VRR) calculations. After some research and testing of the VB software, the author has encountered some problems that the software cannot solve due to the software's limitations. After some discussions with IT experts, author has found new software applications that can overcome the problem that VB software cannot solve. The problems that were encountered with the VB software were:

a) The VRR calculation requires that lots of data need to be input in daily. As example if the page's size exceeds the size of the screen of monitor, user has to scroll it down to view the whole page. The main problem with VB is the interfaces are difficult to develop a 'scroll function'. This means that the interface cannot easily being scroll up and down.

b) In VRR calculations, there are many occasions where new data needs to be entered whenever required. It means that, the user should have the flexibility to add new entry automatically into the database system through the user interface itself, not through the coding system of the software. VB software can perform this type of function but the software developer has to predetermine specifically during software development stage the amount of data that needs to be entered in the future. This method is inappropriate as the developer has no means of estimating the future data entry requirements.

Due to these limitations as stated above, the author decided to use alternative software applications that do not present such predicaments. The alternatives software identified were:

4.1.1 Dreamweaver

Dreamweaver will be utilized to create interface for the client level. Users will input and view retrieved information from database system through this interface. The interface will only be functional for display. The other considered tool for client level was Microsoft Visual Basic but Dreamweaver was preferred as its application is drag and drop basis and requires minimal scripting compared to Microsoft Visual Basic. Furthermore, Dreamweaver produces more interesting and refreshing interface compared to Microsoft Visual Basic. Using Dreamweaver, the page can easily be scrolled up and down just like surfing through internet. All the interfaces that were created using this software has to located in one folder so that users can access it from the server.

4.1.2 Microsoft Internet Information Services (IIS)

IIS is an enterprise-level web server that is included with Microsoft 2000. IIS is applicable for both (Local Area Network) LAN and (Wide Area Network) WAN usage. It allows computers to serve documents. IIS will allow computer to act as host or server to connect client level and information level. IIS will be the front end of the middle level. IIS will control data traffic between client level and database system. IIS was chosen on the basis that the identified facility uses Microsoft 2000 as its operating system.

Microsoft Internet Information Services is used to make the interfaces able to be accessed through network. For the purpose of this project, the interfaces are only applicable to be access through Local Area Network (LAN). To access it, user has to type http:// in front of the address of the interfaces.

IIS is an add-on component of Windows 2000 and Windows XP operating system. In order to setup a computer as a server, the following steps have to be implemented (the steps below are developed for the Windows 2000 operating system):

a. Install IIS in the above operating system.
b. Click **Start** > **Settings** > **Control Panel** and double click on **Administrative Tools**.
c. Double click on the **Internet Services Manager**.
d. Click on the **computer's name** (e.g. voidage).
e. Right click on the Default Web Site and select New > Virtual Directory.
f. A **New Virtual Directory Creation Wizard** will come out and click **Next** to continue.
g. Type any name in the form below the **Alias** (e.g. fyp) and click **Next.**
h. Select the directory where the interfaces are located (e.g. E:\My Documents\FYP\dreamweaver) and click **Next** until the wizard is complete.
i. The interfaces can now be run using the browser.

4.1.3 Active Server Pages (ASP)

ASP will be utilized as back-end of the middle level. ASP is a server technology that dynamically builds documents in response to client requests. ASP will be in the form of source code or scripting. ASP is processed by an ActiveX component called a scripting engine. An ASP file has the file extension .asp and the common languages like JavaScript and VBScript are used as for ASP scripting. ASP was chosen because it is the back-end and scripting program for IIS.

In this project, both language, JavaScript and (Visual Basic) VBScript are used together for ASP scripting to respond to the client or user request. For this software, user has to insert the data in the form that was developed on the interface. After that, once the user click the submit button, these data will be stored in the database. This data insertion job is done daily. Therefore it is really important for the user to ensure the date that was selected is right before submitting the data to the database system. The reason for doing this is to make sure that the right date is selected for the right data and when user want to retrieve back the data, they have to enter the date they want. If they do not select the right date when submitting these data to the database, they might found problems in retrieving the data.

To ensure the above tasks can be performed, the processes of developing the ASP script are outline as following:

a) Create a link that can connect the interfaces and the database together.
b) Declare all the variables that are going to be used. These variables determine the locations of the data that will be stored in the database system.
c) Develop the ASP script to store the data to the database system once the user click the submit button.

d) Develop the ASP script for retrieval of the data from the database system. User has to select the data they want to recall the data.

The ASP script for the production data interface was successfully developed. User can insert the data through the interface and then can retrieve back the data by selecting the desired date. The sample of the ASP script for production data interface is attached as Appendix 2.

4.1.4 Microsoft Access

Microsoft Access is utilized as a database for the input daily data. Microsoft Access is the information level. The database will store all input data and also stored data for the retrieval by user. Microsoft Access was preferred because it is not complex and user friendly compared to Oracle and Visual Basic. Microsoft Access provides an interface for user to build database but Oracle requires user to do scripting. Microsoft Access is the obvious alternative as time is constraint in completing this study and learning scripting requires considerable time resource. The database is developed by using table format. Since there are lots of data need to be input and stored, each interface of the software will have their own table. This is to simplify the data management and to link these data with the interfaces.

This database system file has to be located in the same folder of the interfaces created using the Dreamweaver software. To communicate the database system with the interfaces, a link has to be created using ASP script. This ASP script is shown as Appendix 3 and the steps to develop the link between the interfaces and the database system are outline as below:

a. Create an ASP script for the link and save it into the same folder of the interfaces and database system. As an example, let say the name for the link file is inc.asp.

b. In the link file above, state the directory of the database system (e.g. E:\My Documents\FYP\dreamweaver\database\db1.mdb)

c. Include the inc.asp file in each interface that was created using the Dreamweaver software.

d. The link between the interfaces and the database system has been developed.

The integration of the software development is shown in Figure 4.1 below:

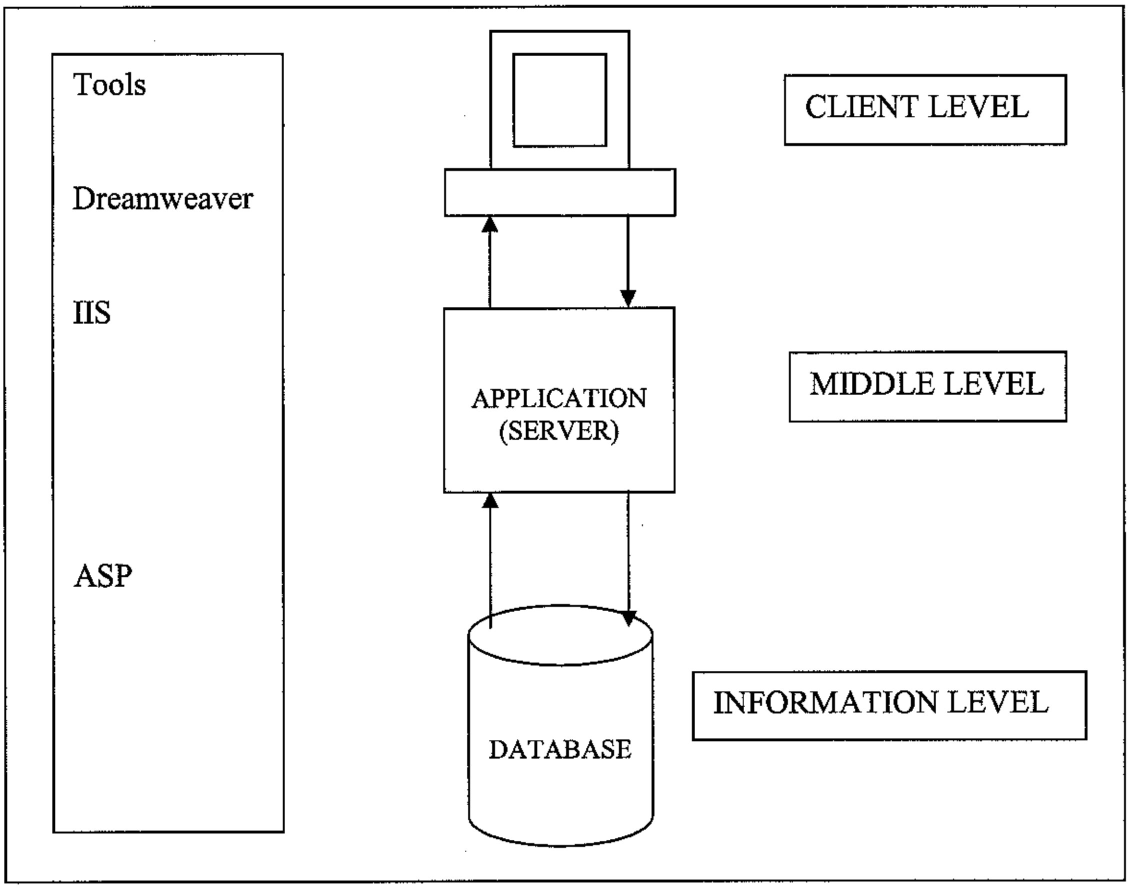


Figure 4.1: Process Flow Chart for the Software Development

4.2 Case Study and Sample of Calculations

For this project, Angsi Field, which is located at Terengganu offshore, was chosen as case study. It was chosen because it is using waterflooding process as the method to maintain the pressure of oil reservoir. For purpose of this project, there are some modifications made to the software so that it is applicable to be used to other field, which using waterflooding process as their reservoir pressure maintenance method. It means that the concepts of the calculations were made based on the Angsi Field data. The interfaces that were developed were based on the following criterion:

- There are 1 well head area at the field, which is Platform A and all the hydrocarbon production from the field are from this well head area.
- There are 3 oil reservoirs in the field (Reservoir 1, 2, and 3).
- Each reservoir has different number of oil producer wells and water injector wells.
- The VRR of every reservoir is calculated separately.

In this project, the calculations of VRR in the software were made based on actual data. Sample of VRR calculations is attached as Appendix 4. Actual data is not used in the sample calculations. It just shows the concept of VRR calculations, which are:

$$VRR = \frac{\text{Injection Volume}}{\text{Reservoir Withdrawal Volume}}$$

The calculations attached are to find the VRR for Reservoir 1. Then, to find VRR for other reservoirs, the same concept can be used.

4.3 Interfaces Development for the VRR Calculations Software

There were 14 interfaces that have been developed for the software development using Dreamweaver software. The interfaces are:

4.3.1 Login Interface

This is the first interface that the users will go through. User has to enter their username and password to login to the daily data input. It is to make sure that only the authorized person can access the software. The figure of the interface is attached as Appendix 5.

4.3.2 Production Data Interface

General daily data were input to the database through this interface (Appendix 6). Such data are the total crude oil production, total gas production, total sales gas and etc. These data were measured using meter and it is used to calculate the profactor using the equation below:

$$\text{Profactor} = \frac{\text{Measured data}}{\text{Estimated data from well test}}$$

4.3.3 Oil Test Interface

At this interfaces, the estimated value of production of oil for every well, which was get from the well test was input to get the downtime corrected data. These data then were multiplied by the profactor of oil to get the profactor corrected data. There were 3 Oil Test Interfaces, which represent 3 reservoirs in the field. The figure of the interface is attached as Appendix 7.

4.3.4 Gas Test Interface

The function of this interface is same as the Oil Test Interface but instead of estimated value of oil production, estimated value of gas production from every well was input here. These data then were multiplied by profactor of gas to get profactor corrected data. This interface also represents 3 reservoirs. The figure of the interface is attached as Appendix 8.

4.3.5 Produced Water Interface

The function of this interface is same as the Oil Test and Gas Test Interface but instead of estimated value of oil and gas production, estimated value of water production from every well was input here. These data then were multiplied by profactor of water to get profactor corrected data. This interface also represents 3 reservoirs. The figure of the interface is attached as Appendix 9.

4.3.6 Profactor Interface

The value of profactor of oil, water and gas are shown at this interface. Profactor is defined as actual data over estimated data from well test. From the daily production data, only total oil production and total gas production that was measured. To calculate Voidage Replacement Ratio, the production of oil, gas and water from each single well must be known. To know this, well test is conducted but it only gives estimated values of production. Therefore, profactor of oil and gas were introduced to get the corrected value of the estimated data. The equation used to calculate the profactor was shown in section 4.3.2. The figure of the interface is attached as Appendix 10.

4.3.7 Water Injection Interface

Since Voidage Replacement Ratio is calculating the ratio of water injection volume to reservoir withdrawal volume, the daily water volume that was injected into the reservoir has to be recorded. The water injection data is entered to the database through this interface. The figure of the interface is attached as Appendix 11.

4.3.8 Total Voidage Interface

Here, only the value of reservoir pressure has to be entered into the database system. This value is really important since it is used to determine the value of formation volume factor of oil, water and gas since these three values depend on the reservoir pressure. The Voidage Replacement Ratio (VRR) for that particular date is calculated at this interface. The data that were input through previous interfaces are used to calculate the VRR. The figure of the interface is attached as Appendix 12.

4.3.9 Load Interface

This interface will pop up when the Load button is clicked. The function of this interface is to load or retrieve the previous data that was input into the database. The figure of the interface is attached as Appendix 13.

4.3.10 Add Well Interface

This interface will pop up when Add Well button is clicked. The function of this button is to add any new well that was drilled into the database system. This function was not successfully developed since the author has found problems in finding the ASP script to develop it. The figure of the interface is attached as Appendix 14.

4.3.11 Add Group Interface

This interface will pop up when the Add Group button is clicked. Its function is to add any new group of reservoir into the database system. Since the concept of this interface is quite similar with the Add Well Interface functions, the ASP script for this interface also failed to be developed. The figure of the interface is attached as Appendix 15.

4.3.12 Total Oil Interface

This interface will pop up when the Total Oil button is clicked. Its function is to show the results of the calculation from the data that were input through the Oil Test interface. The figure of the interface is attached as Appendix 16.

4.3.13 Total Gas Interface

This interface will pop up when the Total Gas button is clicked. Its function is to show the results of the calculation from the data that were input through the Gas Test interface. The figure of the interface is attached as Appendix 17.

4.3.14 Total Water Interface

This interface will pop up when the Total Water button is clicked. Its function is to show the results of the calculation from the data that were input through the Produced Water interface. The figure of the interface is attached as Appendix 18.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

As a conclusion, reservoir pressure maintenance process is suitable to be implemented for undersaturated reservoir so that the recovery can be increased, production accelerated production decline slowed down. Reservoirs, which already has its own sources of water is then flooded by water. This process helps to maintain the reservoir pressure above the bubble point pressure, P_b. This water injection process should be monitored daily so that it can maximize the recovery of the reservoirs. The performance of water injection process is assessed by calculating the Voidage Replacement Ratio (VRR) of the reservoirs.

The software that were selected for developing the software for VRR calculations are really user-friendly and easy to use, such as the Dreamwaver software, which use drag and drop concept. The interfaces were developed in such a way that the user can easily entered data into the database system.

The software was developed based on actual data, which was taken from daily data of Angsi field. Some modifications were made so that this software can also be used to calculate VRR of other field, which is using waterflooding process as their reservoir pressure maintenance methods. In real cases, there were possibilities that not all the water injected go into the dedicated reservoir. The water injected may be migrating out of the reservoir. The VRR calculations are just an indicator that show whether the volume of water injected is sufficient enough to cover the volume of hydrocarbon produced. It cannot tell what was happening in the subsurface but one can predict the problem by looking at the trend of the VRR calculations result. Therefore, it is really important to the oil company to do the pressure survey from time to time to monitor the reservoir pressure whether it is align with the VRR results.

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APPENDICES

Gantt chart for the First Semester of Final Year Project (Software Development for Calculation of Voidage Replacement Ratio)

No	Detail/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	SW	EW
1	Selection of Project Topic																
	- Propose Topic																
	- Topic assigned to student																
2	Preliminary Research Work																
	- Introduction																
	- Objective																
	- List of reference/literature																
	- Project Planning																
3	Submission of Preliminary Report				15/8												
4	Project Work																
	- Research on basic of reservoir engineering and pressure maintenance scheme using water injection																
	- Travel to Head Quarters Library, KLCC						29/8										
5	Submission of Progress Report									22/9							
6	Project Work Continue																
	- Identify tools and flow chart to develop the software and data management system. Develop the interfaces																
	- Travel to Head Quarters Library, KLCC											3/10					
7	Submission of Interim Report Final Draft													20/10			
8	Oral Presentation																
9	Submission of Interim Report																21/11

Gantt chart for the Second Semester of Final Year Project (Software Development for Calculation of Voidage Replacement Ratio)

No	Detail/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	SW	EW
1	Project Work Continue - Develop database management system		■	■	■												
2	Submission of Progress Report 1				●												
3	Project Work Continue - Develop software for the calculations					■	■	■	■								
4	Submission of Progress Report 2									●							
5	Project Work Continue - Final stage of development of the software and the database management system									■	■	■	■				
6	Submission of Dissertation Final Draft													●			
7	Oral Presentation															●	
8	Submission of Project Dissertation																●

SW Study Week

EW Exam Week

APPENDIX 2

SAMPLE OF ASP SCRIPT FOR PRODUCTION DATA INTERFACE

```
<%@ Language=VBScript %>
<%
 Option Explicit
 'Buffer the response, so Response.Expires can be used
 Response.Buffer = TRUE
%>
<?xml version="1.0"?>
<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Transitional//EN" "http://www.w3.org/TR/xhtml1/DTD/xhtml1-
transitional.dtd">
<html xmlns="http://www.w3.org/1999/xhtml">
<!-- #include file="inc.asp" --><%'insert function to all pages%>
<head>
<%
'declare variable..
Dim Date_, TotalOil, TotalGas, SalesGas, ProducedWater, GasLift, Flaring, Fuel, WaterInjection
Dim HPComDischarge, Pipeline1P, Pipeline2P, WFOil, WFGas, WFWI, SDPlatform_A, SDPlatform_B, SDGasWells
Dim SDWIWells, Remarks
'standard---------------------------------------------
Dim cnnDB, rsInsert 'rsInsert is recordset
Set cnnDB = CreateCon 'set cnnDB as database connection
'-----------------------------------------------------
If Request.Form("formtype") = "insert" Then' to check if form insert submitted
		'if yes, insert to database
		'populate data to variables when form submitted
		'If Len(Request.Form("ID"))= 0 Then ID = " " Else ID = Replace(Request.Form("ID"), "'", "''")
		If Len(Request.Form("dd")) = 0 Or Len(Request.Form("mm")) = 0 OR Len(Request.Form("yy")) = 0 Then
			Date_ = Now()
		Else
			Date_ = Request.Form("dd") & "/" & Request.Form("mm") & "/" & Request.Form("yy")
		End If	'if not specified then default is today
		If Len(Request.Form("TotalOil"))= 0 Then TotalOil = "0" Else TotalOil = Replace(Request.Form("TotalOil"), "'", "''")
		If Len(Request.Form("TotalGas"))= 0 Then TotalGas = "0" Else TotalGas = Replace(Request.Form("TotalGas"), "'", "''")
		If Len(Request.Form("SalesGas"))= 0 Then SalesGas = "0" Else SalesGas = Replace(Request.Form("SalesGas"), "'", "''")
		If Len(Request.Form("ProducedWater"))= 0 Then ProducedWater = "0" Else ProducedWater =
Replace(Request.Form("ProducedWater"), "'", "''")
		If Len(Request.Form("GasLift"))= 0 Then GasLift = "0" Else GasLift = Replace(Request.Form("GasLift"), "'", "''")
		If Len(Request.Form("Flaring"))= 0 Then Flaring = "0" Else Flaring = Replace(Request.Form("Flaring"), "'", "''")
		If Len(Request.Form("Fuel"))= 0 Then Fuel = "0" Else Fuel = Replace(Request.Form("Fuel"), "'", "''")
		If Len(Request.Form("WaterInjection"))= 0 Then WaterInjection = "0" Else WaterInjection =
Replace(Request.Form("WaterInjection"), "'", "''")
		If Len(Request.Form("HPComDischarge"))= 0 Then HPComDischarge = "0" Else HPComDischarge =
Replace(Request.Form("HPComDischarge"), "'", "''")
		If Len(Request.Form("Pipeline1P"))= 0 Then Pipeline1P = "0" Else Pipeline1P = Replace(Request.Form("Pipeline1P"),
"'", "''")
		If Len(Request.Form("Pipeline2P"))= 0 Then Pipeline2P = "0" Else Pipeline2P = Replace(Request.Form("Pipeline2P"),
"'", "''")
		If Len(Request.Form("WFOil"))= 0 Then WFOil = "0" Else WFOil = Replace(Request.Form("WFOil"), "'", "''")
		If Len(Request.Form("WFGas"))= 0 Then WFGas = "0" Else WFGas = Replace(Request.Form("WFGas"), "'", "''")
		If Len(Request.Form("WFWI"))= 0 Then WFWI = "0" Else WFWI = Replace(Request.Form("WFWI"), "'", "''")
		If Len(Request.Form("SDPlatform_A"))= 0 Then SDPlatform_A = "0" Else SDPlatform_A =
Replace(Request.Form("SDPlatform_A"), "'", "''")
		If Len(Request.Form("SDPlatform_B"))= 0 Then SDPlatform_B = "0" Else SDPlatform_B =
Replace(Request.Form("SDPlatform_B"), "'", "''")
		If Len(Request.Form("SDGasWells"))= 0 Then SDGasWells = "0" Else SDGasWells =
Replace(Request.Form("SDGasWells"), "'", "''")
		If Len(Request.Form("SDWIWells"))= 0 Then SDWIWells = "0" Else SDWIWells =
Replace(Request.Form("SDWIWells"), "'", "''")
		If Len(Request.Form("Remarks"))= 0 Then Remarks = " " Else Remarks = Replace(Request.Form("Remarks"), "'", "''")
		'insert to database
		'getSQL(connection, SQL query string)
		Set rsInsert = getSQL(cnnDB, "INSERT INTO [Table1-Production_Data] ([Date], TotalOil, TotalGas, " & _
```

```
"SalesGas, ProducedWater, GasLift, Flaring, Fuel, WaterInjection, " & _
"HPComDischarge, Pipeline1P, Pipeline2P, WFOil, WFGas, WFWI, " & _
"[SDPlatform A], [SDPlatform B], SDGasWells, SDWIWells, Remarks) " & _
"VALUES ('" & Date_ & "', " & TotalOil & ", " & TotalGas & ", " & _
SalesGas & ", " & ProducedWater & ", " & GasLift & ", " & Flaring & _
", " & Fuel & ", " & WaterInjection & ", " & HPComDischarge & ", " & _
Pipeline1P & ", " & Pipeline2P & ", " & WFOil & ", " & WFGas & ", " & _
WFWI & ", " & SDPlatform_A & ", " & SDPlatform_B & ", " & SDGasWells & _
", " & SDWIWells & ", '" & Remarks & "')")
        'close
        Set cnnDB = Nothing
        Set rsInsert = Nothing
        'redirect
ElseIf Request.Querystring("formtype") = "load" Then 'if load
        date_ = request.QueryString("date")
        'get from dbase
        Dim rs
        Set rs = getSQL(cnnDB, "SELECT * FROM [Table1-Production_Data] WHERE [Date] LIKE '" & date_ & "'")
        If not rs.EOF Then
                Date_ = rs("Date")
                TotalOil = rs("TotalOil")
                TotalGas = rs("TotalGas")
                SalesGas = rs("SalesGas")
                ProducedWater = rs("ProducedWater")
                GasLift = rs("GasLift")
                Flaring = rs("Flaring")
                Fuel = rs("Fuel")
                WaterInjection = rs("WaterInjection")
                HPComDischarge = rs("HPComDischarge")
                Pipeline1P = rs("Pipeline1P")
                Pipeline2P = rs("Pipeline2P")
                WFOil = rs("WFOil")
                WFGas = rs("WFGas")
                WFWI = rs("WFWI")
                SDPlatform_A = rs("SDPlatform A")
                SDPlatform_B = rs("SDPlatform B")
                SDGasWells = rs("SDGasWells")
                SDWIWells = rs("SDWIWells")
                Remarks = rs("Remarks")
        End If
End If
%>
<title>Daily Production Data - Production Data</title>
<meta http-equiv="Content-Type" content="text/html; charset=iso-8859-1">
<script language="JavaScript1.2" src=myDate.js></script> <!--1st //-->
<script language="JavaScript1.2">
        <!--
                function loadPage()
                        {
                        window.open("load.asp?page=productiondata.asp", "newwindow","WIDTH=320,HEIGHT=155")
                        }
        //-->
</script>
<style type="text/css">
<!--
.style1 {
        font-family: Verdana, Arial, Helvetica, sans-serif;
        font-size: x-large;
        font-weight: bold;
        color: #FF0000;
}
.style2 {
        font-family: Verdana, Arial, Helvetica, sans-serif;
        font-weight: bold;
}
.style5 {
        font-size: medium;
        font-family: Verdana, Arial, Helvetica, sans-serif;
        color: #FF0000;
        font-weight: bold;
```

```
}
.style6 {
            color: #993333;
            font-size: large;
}
.data {font-family: Verdana, Arial, Helvetica, sans-serif; font-weight: bold; font-size: small; }
.style12 {font-family: Verdana, Arial, Helvetica, sans-serif; font-size: large; color: #993300; }
.style13 {font-size: x-small}
.style14 {font-family: Verdana, Arial, Helvetica, sans-serif; font-weight: bold; font-size: x-small; }
.style16 {font-family: Verdana, Arial, Helvetica, sans-serif; font-size: medium; color: #993300; }
-->
</style></head>
<body>

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 <input type="hidden" name="formtype" value="insert">

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             <td width="27"></td>
            </tr>
            <tr>
             <td></td>
             <td height="32" valign="top"><div align="center"><span class="style1">MENU</span></div></td>
             <td></td>
            </tr>
            <tr>
             <td></td>
             <td height="17"></td>
             <td></td>
            </tr>
            <tr>
             <td></td>
             <td height="20" valign="top"><div align="center" class="style2"><a href="productiondata.asp">Production Data</a>
</div></td>
             <td></td>
            </tr>
            <tr>
             <td></td>
             <td height="16"></td>
             <td></td>
            </tr>
            <tr>
             <td></td>
             <td height="19" valign="top"><div align="center"><span class="style2"><a href="oiltest.asp">Oil Test
</a></span></div></td>
             <td></td>
            </tr>
            <tr>
             <td></td>
             <td height="15"></td>
             <td></td>
            </tr>
            <tr>
             <td></td>
```

```
          <td height="18" valign="top"><div align="center"><span class="style2"><a href="gastest.asp">Gas Test</a>
</span></div></td>
          <td></td>
        </tr>
        <tr>
          <td></td>
          <td height="13"></td>
          <td></td>
        </tr>
        <tr>
          <td></td>
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</a></span></div></td>
          <td></td>
        </tr>
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          <td></td>
        </tr>
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          <td></td>
          <td height="18" valign="top"><div align="center"><span class="style2"><a href="profactor.asp">Profactor</a>
</span></div></td>
          <td></td>
        </tr>
        <tr>
          <td></td>
          <td height="14"></td>
          <td></td>
        </tr>
        <tr>
          <td></td>
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</a> </span></div></td>
          <td></td>
        </tr>
        <tr>
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          <td height="15"></td>
          <td></td>
        </tr>
        <tr>
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</a></span></div></td>
          <td></td>
        </tr>
        <tr>
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          <td></td>
        </tr>
        <tr>
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          <td height="19" valign="top"><div align="center" class="style5"><a href="default.asp">Logout</a></div></td>
          <td></td>
        </tr>
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          <td></td>
        </tr>
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      <tr>
```

```
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  <td width="22"></td>
  <td width="56"></td>
  <td width="16"></td>
  <td width="19"></td>
  <td width="68"></td>
  <td width="321"> </td>
  <td width="11"></td>
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                                                          var pday = new listday()
                                                </script>
        </select> <select name="mm" id="mm">
          <script language="JavaScript">
                                                          var pmnth = new listmnth()
                                                </script>
        </select>
       <select name="yy" id="yy">
        <script language="JavaScript">
                                                          var pyear = new listyear()
                                                </script>
       </select> </td>
    <td width="340"> </td>
      </tr>
      <tr>
       <td height="18"></td>
       <td></td>
       <td></td>
       <td></td>
      </tr>
     </table></td>
 <td></td>
</tr>
<tr>
 <td height="33"> </td>
 <td> </td>
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</tr>
<tr>
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     <td width="30" height="22" valign="top"><table width="100%" border="0" cellpadding="0" cellspacing="0">
      <!--DWLayoutTable-->
      <tr>
       <td width="33" height="17"> </td>
      </tr>
     </table></td>
     <td width="194" valign="top" class="style14">Total Oil </td>
```

```
      <td width="140" valign="top"><input type="text" name="TotalOil" value="<%=TotalOil%>"/></td>
      <td width="13" valign="top"><table width="100%" border="0" cellpadding="0" cellspacing="0">
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        <tr>
          <td width="13" height="22"> </td>
        </tr>
      </table></td>
      <td width="41" valign="top" class="style14">kl/d</td>
      <td width="178"> </td>
    </tr>
    <tr>
      <td height="5"></td>
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  <td></td>
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            <tr>
              <td width="30" height="19"> </td>
            </tr>
          </table></td>
          <td width="152" rowspan="2" valign="top" class="style14">Total Gas Production </td>
          <td width="41" height="19" valign="top"><table width="100%" border="0" cellpadding="0" cellspacing="0">
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              <td width="41" height="19"> </td>
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          <td width="144" rowspan="2" valign="top"><input type="text" name="TotalGas" value="<%=TotalGas%>"/></td>
          <td width="11" rowspan="2" valign="top"><table width="100%" border="0" cellpadding="0" cellspacing="0">
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              <td width="11" height="22"> </td>
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          <td width="3"> </td>
          <td width="51" rowspan="2" valign="top" class="style14">kl/d</td>
          <td width="166"></td>
        </tr>
        <tr>
          <td height="3"></td>
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        <td width="57" valign="top" class="style14">km3/d</td>
        <td width="163"> </td>
      </tr>
    </table></td>
    <td></td>
  </tr>
  <tr>
    <td height="19"> </td>
    <td> </td>
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        <td width="50" valign="top" class="style14">kl/d</td>
        <td width="167"> </td>
      </tr>
    </table></td>
```

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</tr>
<tr>
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      </table></td>
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      <td width="164"> </td>
    </tr>
  </table></td>
  <td></td>
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      </table></td>
      <td width="55" valign="top" class="style14">km3/d</td>
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</tr>
```

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    </table></td>
    <td width="53" valign="top" class="style14">km3/d</td>
    <td width="167"> </td>
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     </tr>
   </table></td>
   <td width="52" valign="top" class="style14">kl/d</td>
   <td width="168"> </td>
  </tr>
 </table></td>
 <td></td>
</tr>
<tr>
 <td height="18"></td>
```

```
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        </table></td>
        <td width="55" valign="top" class="style14">kPa</td>
        <td width="165"> </td>
      </tr>
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        </tr>
      </table></td>
      <td width="52" valign="top" class="style14">kPa</td>
      <td width="168"> </td>
    </tr>
  </table></td>
  <td></td>
</tr>
<tr>
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  <td></td>
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</tr>
<tr>
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```

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</tr>
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        <td width="144" valign="top"><input type="text" name="WFWI" value="<%=WFWI%>"/></td>
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      </tr>
  </table></td>
```

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<tr>
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       </table></td>
       <td width="149" valign="top"><input type="text" name="SDPlatform_A" value="<%=SDPlatform_A%>"/></td>
       <td width="223"> </td>
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  </table></td>
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</tr>
<tr>
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```

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      <td width="223"> </td>
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</tr>
<tr>
 <td height="30" colspan="6" valign="top" class="style16">Remarks</td>
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          <td width="56" valign="top"><input type="submit" name="Submit" value="Submit"></td>
          <td width="39"> </td>
        </tr>
        <tr>
          <td height="19"> </td>
          <td> </td>
          <td> </td>
          <td> </td>
          <td> </td>
        </tr>
    </table></td>
  </tr>
</table>

</div>
 </form>
</body>

</html>
```

APPENDIX 3

SAMPLE OF ASP SCRIPT TO LINK THE INTERFACES WITH THE DATABASE SYSTEM

```
<SCRIPT LANGUAGE="VBScript" RUNAT="Server">
        ' CreateCon:
        ' Returns a ADO Connection object
        Function CreateCon
                Dim strConn, cnnDB, strPath
                'Connection String
                'insert dtabase here
                strPath = "E:\My Documents\FYP\dreamweaver\database\db1.mdb"
                strConn = "Provider=Microsoft.Jet.OLEDB.4.0;Data Source=" & strPath & ";Persist Security Info=False"
                'On Error Resume Next
                ' Create and open the database connection and save it as a
                ' session variable
                Set cnnDB = Server.CreateObject("ADODB.Connection")
'               cnnDB.Mode = 3      '3 = adModeReadWrite
                cnnDB.Open(strConn)
                Set CreateCon = cnnDB
                'If Err.number<>0 then
                '       getErr()
                'End If
        End Function
        'getSQL
        ' Takes an input string which is the SQL query statement and
        ' returns the results of the query as a recordset if any
        ' results are returned.
        Function getSQL(cnnDB, queryStr)
                On Error Resume Next
                Dim adoRec
                Set adoRec = Server.CreateObject("ADODB.Recordset")
                adoRec.ActiveConnection = cnnDB
                adoRec.CursorLocation = 3       'adUseClient
                adoRec.CursorType = 3
                adoRec.Open(queryStr)
                Set getSQL = adoRec
                If Err.number<>0 then
                response.Write(querySTR)
                response.End()
'                       getErr()
                End If
        End Function
```

```
            FUnction debug(strDis)
            Response.Write("-->" & strDis & "<--")
            response.End()
        End Function
</script>
```

APPENDIX 4

SAMPLE OF CALCULATIONS AND RESULT CALCULATED USING THE SOFTWARE

Assume that production of oil, gas and water that was metered is as below:

Oil	= 10000 kl/d
Gas (AG)	= 500 km^3/d
Water	= 150 kl/d
Water Injection rate	= 3000 kl/d

*Above data are entered at Production Data Interface.

Taking Reservoir 1 (R1) as example to calculate its VRR:

For oil,

- Let say total oil production of R1 based on well test data (downtime corrected) = 2000 kl/d (Oil Test Interface)
- Total oil production of all reservoirs (1, 2, & 3) based on well test data (downtime corrected) = 9000 kl/d (Total Oil Interface)

$$\text{Profactor} = \frac{\text{Metered Data}}{\text{Well Test Data (Downtime Corrected)}}$$

Therefore,

$$\text{Profactor of oil} = \frac{10000}{9000} = 1.11 \quad \text{(Profactor Interface)}$$

Then,

Profactor Corrected Data = 2000 x 1.11 = 2222.22 kl/d (Oil Test Interface)

Then,

Oil rate = Profactor Corrected Data x B_o

B_o = Formation Volume Factor of Oil = 1.4 rb/bbl (depends on reservoir pressure)

Therefore,

Oil rate = 2222.22 kl x 6.2898 bbl/kl x 1.4 rb/bbl = 19568.26 rb (Total Voidage Interface)

* 1 kl = 6.2898 bbl

* rb = reservoir barrel (volume of oil in the reservoir)

For Gas,

- Let say total gas production of R1 based on well test data (downtime corrected) = 300 km^3/d (Gas Test Interface)
- Total associated gas production of all reservoirs (1, 2,& 3) based on well test data (downtime corrected) = 450 km3/d (Total Gas Interface)

Therefore,

$$\text{Profactor of gas} = \frac{500}{450} = 1.111 \quad \text{(Profactor Interface)}$$

Then,

Profactor Corrected Data = 300 x 1.111 = 333.33 km^3/d (Gas Test Interface)

Then,

Gas rate = Profactor Corrected Data x B_g

B_g = Formation Volume Factor of Gas = 1.36 rb/MMscf (depends on reservoir pressure)

Therefore,

Gas rate = 333.33 km^3 x 0.0353147 MMscf/km^3 x 1.36 rb/MMscf = 16.01 rb (Total Voidage Interface)

* 1 km^3 = 0.0353147 MMscf

* rb = reservoir barrel (volume of gas in the reservoir)

For water,

- Let say total produced water of R1 based on well test data (downtime corrected) = 20 kl/d (Produced Water Interface)
- Total produced water from all reservoirs (1, 2 & 3) based on well test data (downtime corrected) =120 kl/d

Therefore,

$$\text{Profactor of water} = \frac{150}{120} = 1.25 \quad \text{(Profactor Interface)}$$

Then,

Profactor Corrected Data = 20 x 1.25 = 25 kl/d (Produced Water Interface)

Then,

Water rate = Profactor Corrected Data x B_w

B_w = Formation Volume Factor of Water = 1.04 rb/bbl; (depends on reservoir pressure)

Therefore,

Water rate = 25 kl x 6.2898 bbl/kl x 1.04 rb/bbl = 163.53 rb (Total Voidage Interface)

* 1 kl = 6.2898 bbl

* rb = reservoir barrel (volume of water in the reservoir)

Voidage = Oil Rate + Gas Rate + Water Rate

= 19568.26 rb + 16.01 rb + 163.53 rb = 19747.80 rb (Total Voidage Interface)

Voidage Replacement = Water Injection Rate x B_w (Total Voidage Interface)

= 3000 kl x 6.2898 bbl/kl x 1.04 = 19624.18 rb

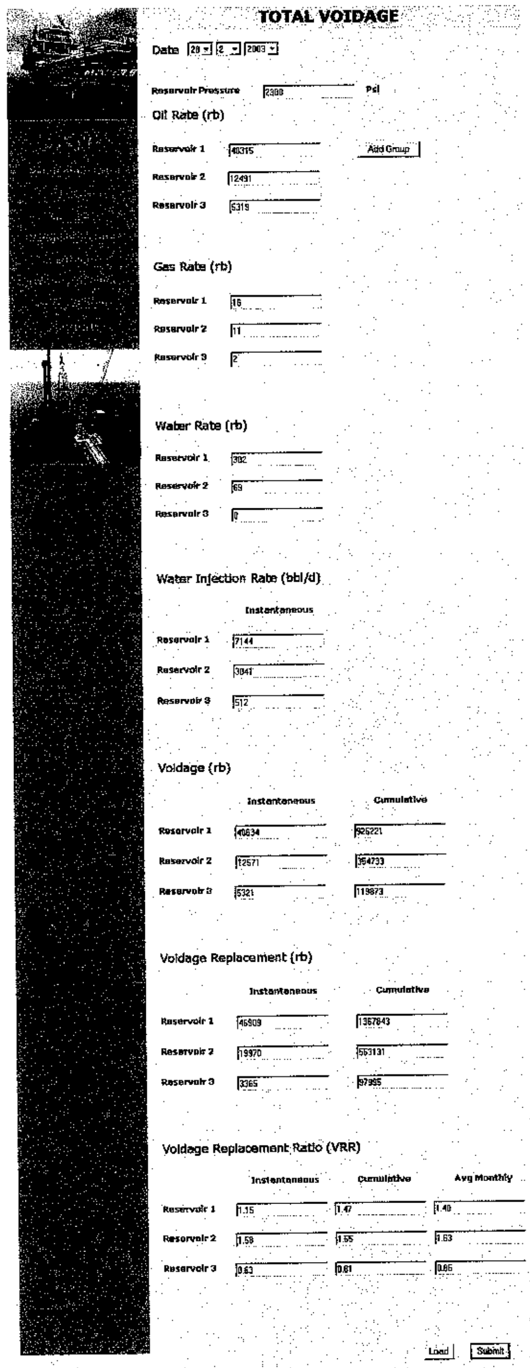
Thus,

$$VRR = \frac{\text{Voidage Replacement}}{\text{Voidage}}$$

Therefore,

$$VRR = \frac{19624.18}{19747.23} = 0.99$$

* The same concept applies for VRR calculations of other reservoirs and sample of the result calculated using the software is shown as below:



Sample of the Result of VRR Calculations Using the Software

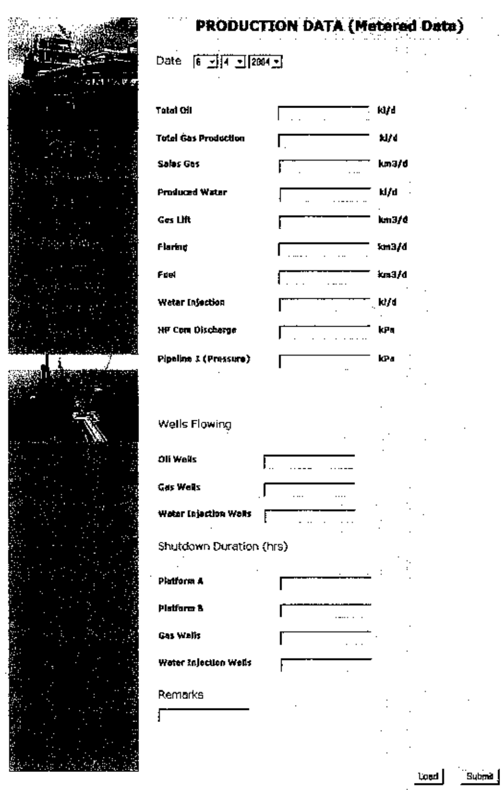
(Date: 28th February 2003)

APPENDIX 5

LOGIN INTERFACE

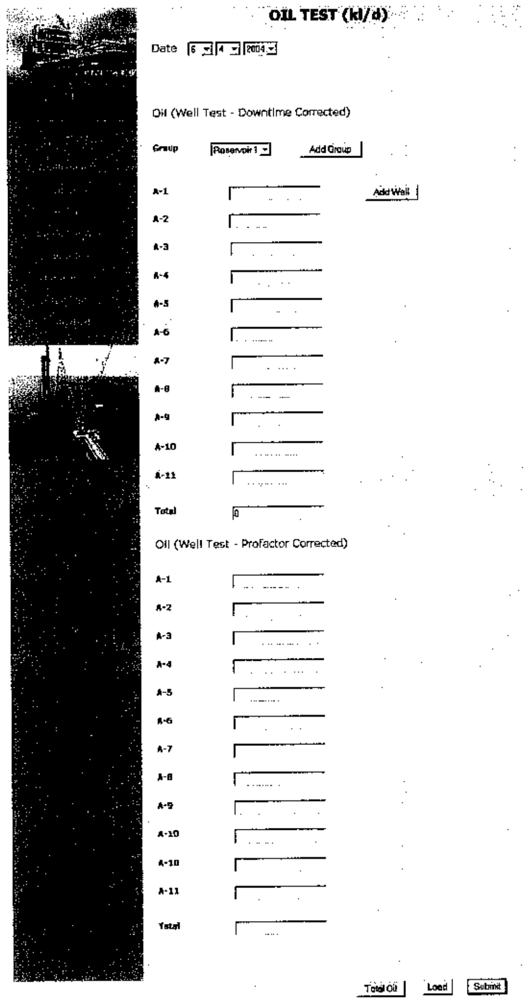
APPENDIX 6

PRODUCTION DATA INTERFACE



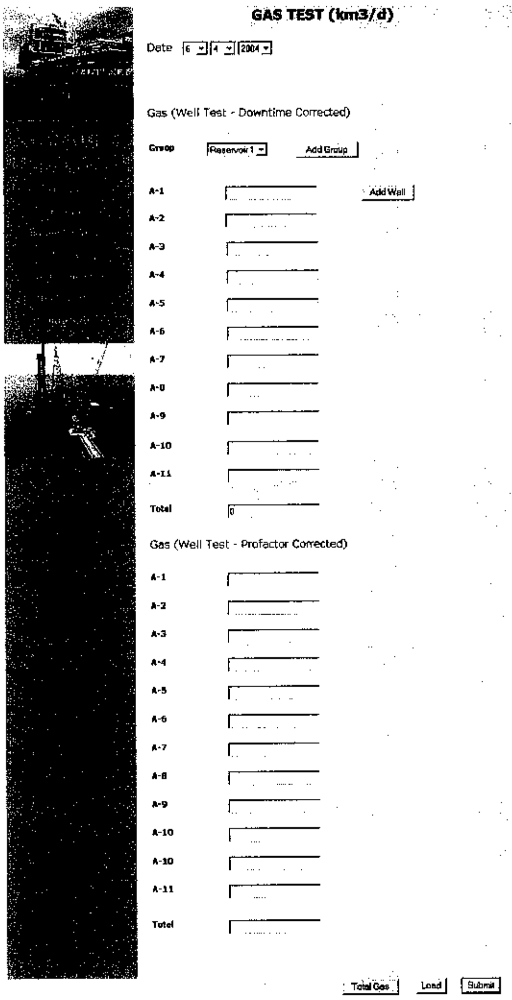
APPENDIX 7

OIL TEST INTERFACE



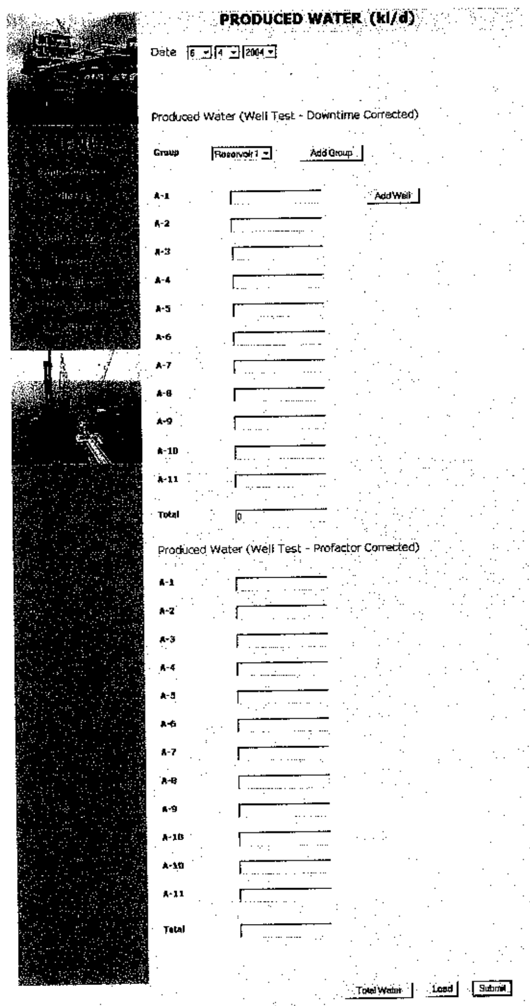
APPENDIX 8

GAS TEST INTERFACE



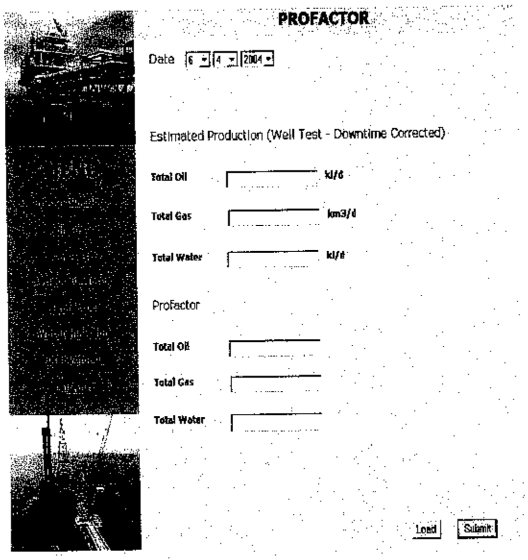
APPENDIX 9

PRODUCED WATER INTERFACE



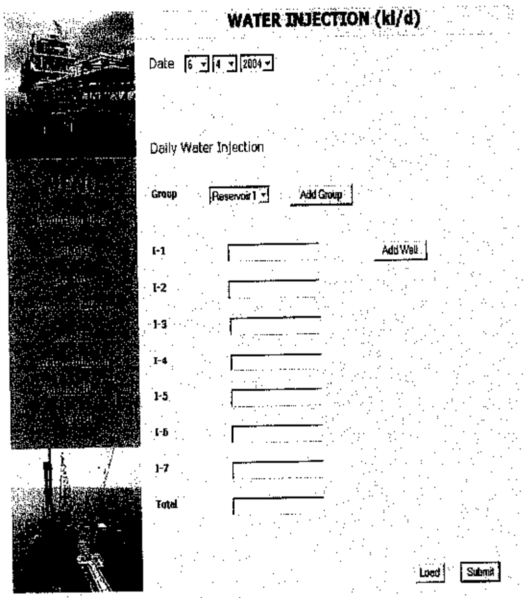
APPENDIX 10

PROFACTOR INTERFACE



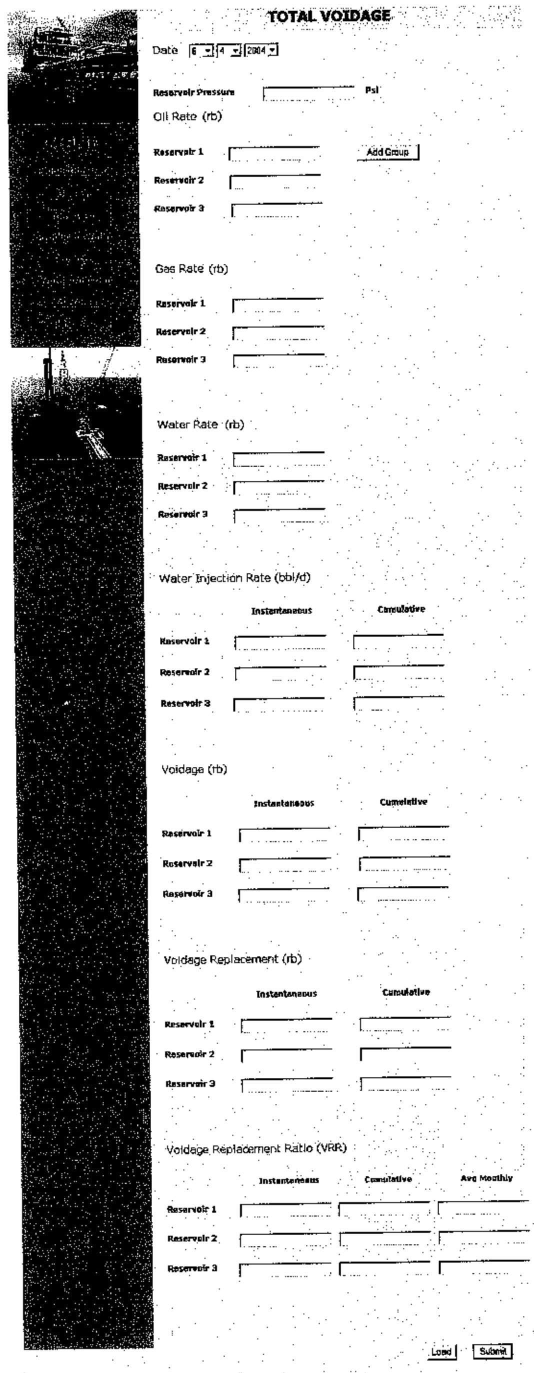
APPENDIX 11

WATER INJECTION INTERFACE



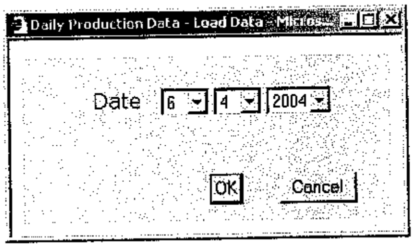
APPENDIX 12

TOTAL VOIDAGE INTERFACE



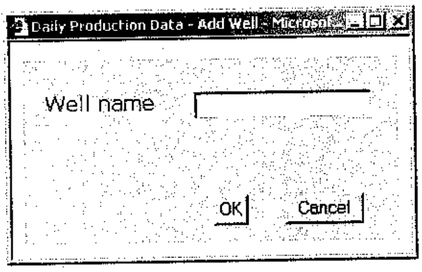
APPENDIX 13

LOAD INTERFACE



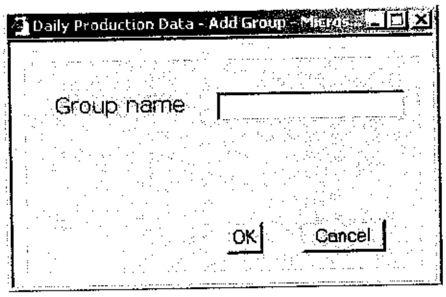
APPENDIX 14

ADD WELL INTERFACE



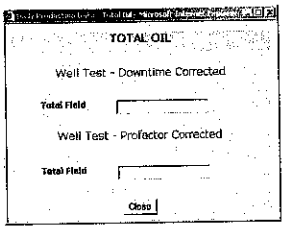
APPENDIX 15

ADD GROUP INTERFACE



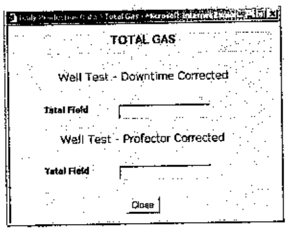
APPENDIX 16

TOTAL OIL INTERFACE



APPENDIX 17

TOTAL GAS INTERFACE



APPENDIX 18

TOTAL WATER INTERFACE