Type Curve Analysis For An Oil Well Using PanSystem

by

Ahmad Firdaus bin Ahmad Zubir

13601

Dissertation submitted in partial fulfillment of

the requirements for the

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(Petroleum)

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the

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Approved by,

____

(Dr Muhannad Talib Shuker)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

May 2014

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.

AHMAD FIRDAUS BIN AHMAD ZUBIR

ABSTRACT

This study is about the type curve analysis, as part of the technique used in analyzing well test. It involves the usage of solutions of flow equations, and their parameters presented as dimensionless ones. Furthermore, it centers on the usage of software known as the PanSystem, which is developed by Weatherford. On the literature review section, explanation will be made upon the basic introductory of type curve, its analysis as well as application that has been studied on various papers. A set of data will be used for the study as well as analyzing the functions of the software itself. Several values will be computed and comparison will be made on different method of matching. Further recommendations will also be explained in the study in order to strengthen the foundation of learning of the type curve.

ACKNOWLEDGEMENT

The author would like to take the opportunity to express his deepest gratitude to the following people who provide him the possibility to complete this report:

The supervisor, Dr Muhannad Talib Shuker for providing guidance throughout the year so that the author will have a better understanding in the knowledge related to the study. His enthusiasm had inspired the author to strive harder in completing the study.

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CHAPTER 1

PROJECT BACKGROUND

1.1 Background Study

A well test analysis model can be defined as using either physical or mathematical ways to reproduce the oil or gas process in the actual reservoir. The physical reproduction of flow in oil and gas layers is the best to describe the concept of a physical well test model.

However, for well test model (mathematical), differential equations related to boundary and initial conditions of the well test are shown. Graphical forms are expressed as the variation of pressure with respect to time either on the Cartesian plot, semi log plot or log-log plot of pressure versus time (derivative of pressure versus time). In terms of interpretation wise, type curve is widely used for well test analysis as flow of the regime of the well is clearly shown graphically.

In well test, type curve offers a way for interpreting both pressure drawdown and buildup test in a graphical presentation. It is origin from analytical solution of the diffusivity equation of selected initial and boundary conditions. The solutions plotted in the type-Curve are presented in dimensionless variables. The plot of these solutions are shown in variables that are dimensionless.

For a vertical well of an infinite-acting homogeneous reservoir, there are several ways that can be used to interpret a test on it such as McKinley (1971) type curve, Earlougher and Kersch (1977) type curves and Gringarten type curves (Gringarten et al., 1979). In this paper, a software named PanSystem will be used to generate type curve on a reservoir model and matching of type curve will be explained more in Literature Review section.

1.2 Problem Statement

There are many ways and kinds of type curve can be obtained manually. All type curves basically are pre-plotted solutions of flow equations for selected reservoir types and selected initial and boundary conditions. The test data is prepared for analysis by tabulating pressure change versus time both for pressure buildup and pressure drawdown test. Derivative of pressure with respect to natural logarithm of time is calculated for derivative curve. After doing matching type-curve matching and select the pressure and time match points from the plot, permeability is then calculated as well as wellbore storage coefficient and skin factor. All these steps required are time consuming when are done manually and more preferable method is needed to ensure the smoothness of the analysis without error detection.

1.3 Objective

The objective of this study is to perform type curve analysis for an oil well by simulation. Simulation is done by using PanSystem software, which is developed by Weatherford. Analysis on the type curve includes several different parameters on reservoir condition. Comparison will be made on manual matching and 'auto match' analysis.

1.4 Scope of Study

As for the scope of study, the project is limited to only simulation studies. The subject of the project focuses on oil well with reserves. The usage of simulation is mainly on PanSystem, with the minimal use of Microsoft Excel and Notepad. For the initial study on the project, test data model will be used for analysis and further scope will be expanded to the study on actual well data with additional parameter added.

CHAPTER 2

LITERATURE REVIEW

In this section, explanation will be made on the concept of type curve, its analysis and application that has been written on various papers. A model of well test analysis simply means the use of physical or mathematical methods to reproduce the process flow of hydrocarbons in the real reservoir.

According to Gringarten (1987), theoretical reception during a test of any model interpretation which represents the tested well and reservoir in that generates graphical representation is best to describe definition of a type curve. Basically, type curves are derived from answers to the flow equations under specific conditions of the reservoir. The presentations of type curves are in the dimensionless variable, such as dimensionless pressure versus a dimensionless time.

Gringarten type curve is a commonly used type curve which has been widely practiced for a long time (Gringarten et al., 1979). The usage of the type curve follows several assumptions which are constant production rate of a vertical well; single phase with slightly compressible liquid flow as well as homogeneous reservoir with the characteristic of infinite-acting. Basically, the usage of Gringarten type curve are most useful for drawdown test in undersaturated oil reservoir. All variables used as basically dimensionless ones which are dimensionless pressure, dimensionless time, skin factor and also wellbore storage coefficient. Plotting the type curve is done on a log-log graph with dimensionless parameters of pressure versus time over wellbore storage coefficient

$$p_D = -\frac{1}{2} Ei\left(-\frac{r_D^2}{4t_D}\right).$$

$$p_D \equiv \frac{kh(p_i - p)}{141.2qB\mu}, \qquad t_D \equiv \frac{0.0002637kt}{\phi \mu c_t r_w^2}, \qquad r_D \equiv \frac{r}{r_w}.$$

FIGURE 1. Dimensionless Parameter of Pressure, Time, and Radius That are Taken Into Account for Type Curve Analysis

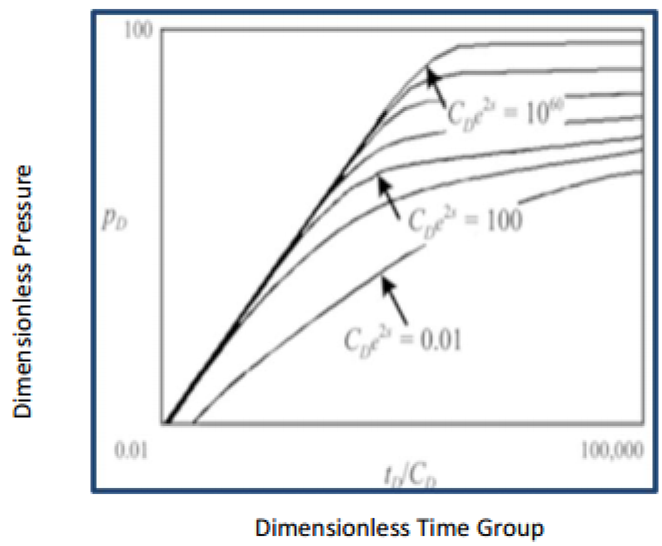


FIGURE 2. Gringarten Type-Curve

Derivative type-curve presents the graphical solution of diffusivity equation in terms of the pressure derivative was introduced by Bourdet et al. (1984). On the root to the diffusivity equation, its logarithm derivation is shown on the type curve. That explains the term ‘derivative’ on type curve. The derivative appears on a log-log graph as a straight line.

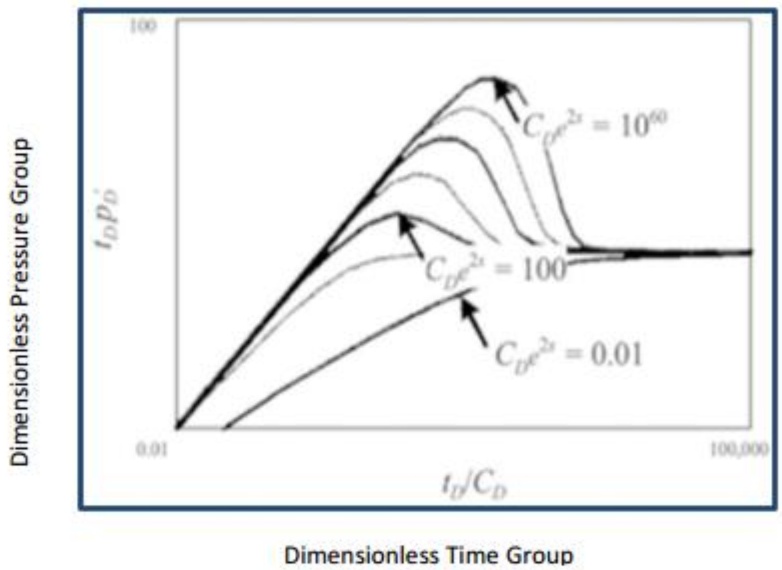


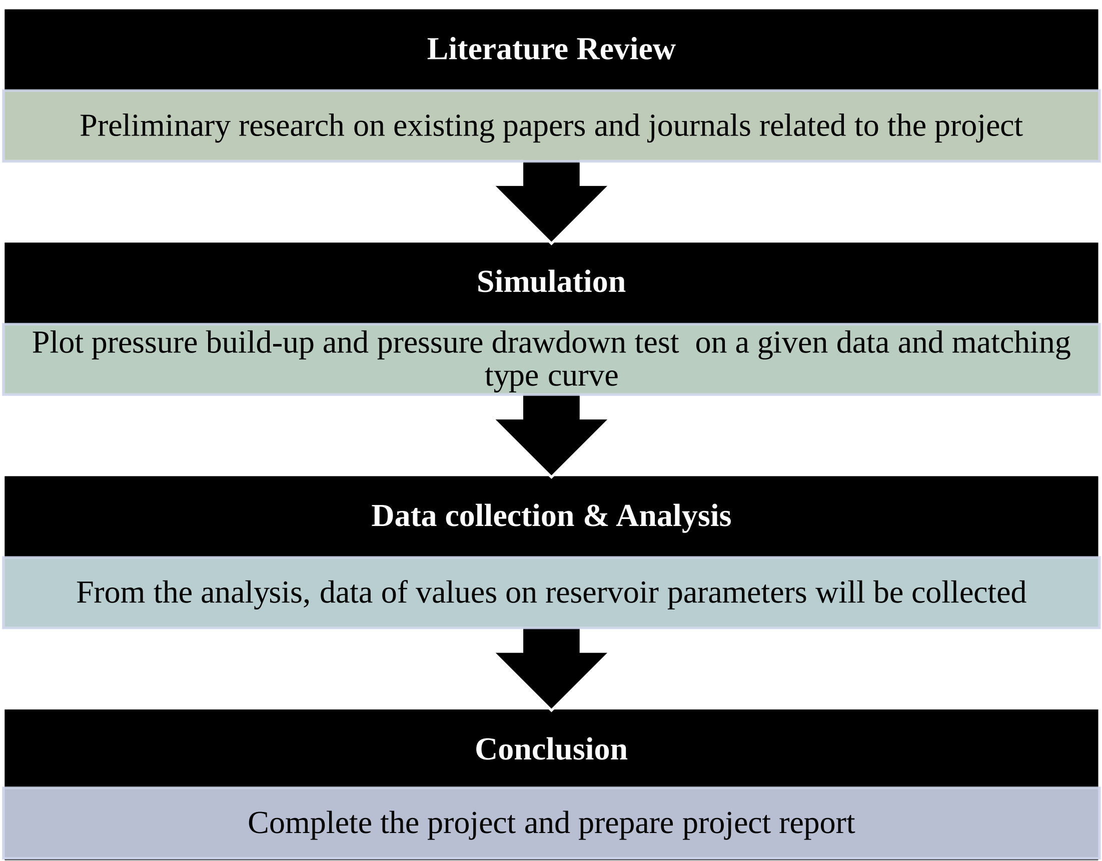
FIGURE 3. Derivative Type-Curve for Infinite Acting Reservoir

Analyzing type curve can be defined as finding and matching the real response of the well and reservoir on its specific type curve. The graph of actual test data will be superimposed together with type curve and best fit is searched based on type curve used, as a mean of graphically method. As a result, reservoir and well parameters such as permeability and skin can be calculated based on the dimensionless parameters that define the particular type curve. The usage of type curve analysis has been widely used in studies. Cox et al. (1996) applied the usage of the type curve analysis for hydraulically fractured wells with linear flow. The case studies cover on the Piceance Basin and Green Basin in such a way to demonstrate how skin effect has a critical effect on early performance on tight gas wells. For Soliman et al. (1984) , the usage of type curves involve for well having fracture and produce under constant flowing pressure. Further results from the analysis include the design for fracturing treatment by changing fracture length as well as its conductivity. Later on, history match technique is done as the final evaluation on the study. Duong and Foster (1989) develop a new type curve by combining dimensionless parameter from the basic type curves so that matching with the test data do not require any movement vertically and horizontally. On top of that, the wellbore constant, C_D can be read directly on the scale from field data plot. From the study, we can say that it is a way of producing an automatic matching type curve.

CHAPTER 3

METHODOLOGY

3.1 Project Flow Chart



3.2 Project Gantt Chart

TABLE 1. Gantt Chart for FYP1

Detail/Week	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Selection of Project Topic														
Preliminary Research Work														
Submission of Extended Proposal														
Proposal Defence														
Continuation of Project Work														
Submission of Interim Draft Report														
Submission of Interim Report														

TABLE 2. Gantt Chart for FYP2

Detail/Week	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**
Continuation of Project Work														
Submission of Progress Report														
Continuation of Project Work														
Pre SEDEX														
Submission of Draft Final Report														
Submission Dissertation (soft bound)														
Submission of Technical Paper														
Viva														
Submission of Project Dissertation														

	Process
	Key Milestone

3.3 Key Milestones

TABLE 3. Key Milestones for the Final Year Project (2 Semesters)

No	Item	Week
1	Submission of Extended Proposal	6
2	Proposal Defence	8
3	Submission of Interim Draft Report	13
4	Submission of Interim Report	14
5	Submission of Progress Report	21
6	Pre SEDEX	24
7	Submission of Draft Final Report	25
8	Submission of Technical Paper	26
9	Viva	27
10	Submission of Project Dissertation	28

3.4 Project Methodology

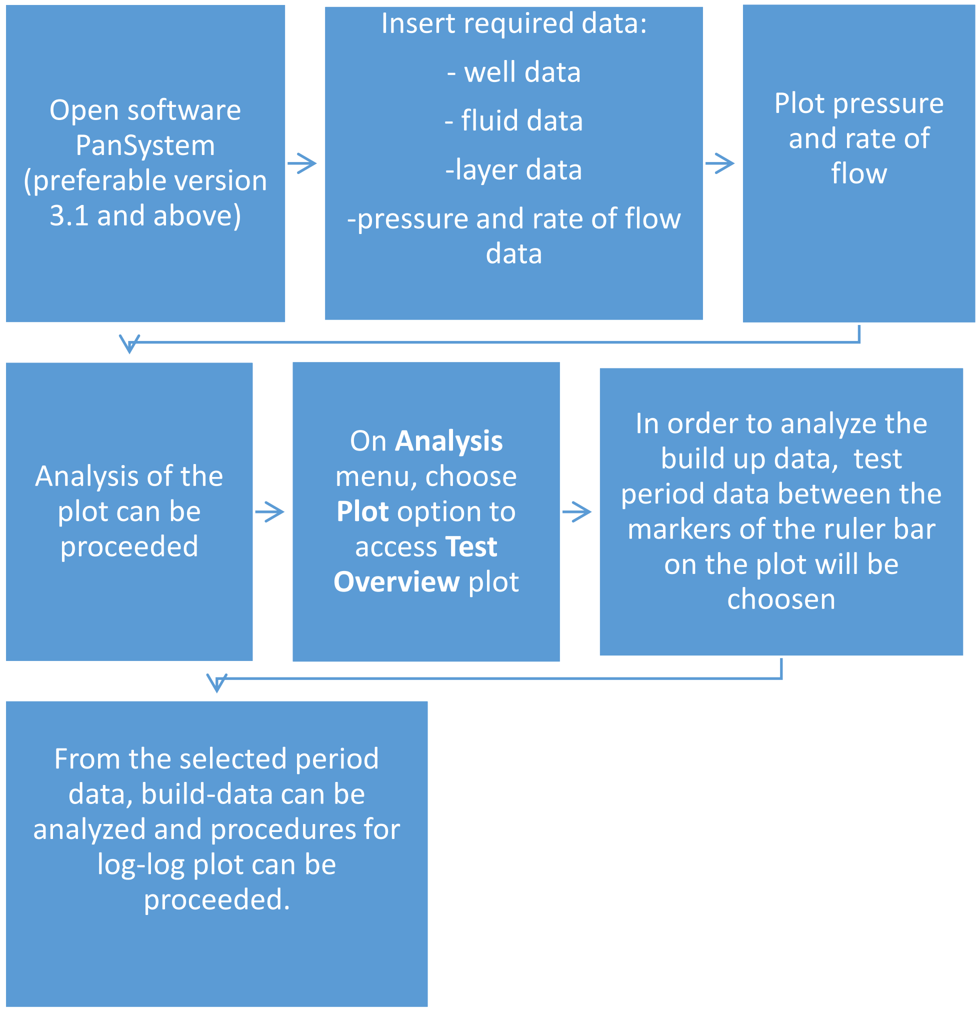


FIGURE 4: Project Methodology Flow Part 1

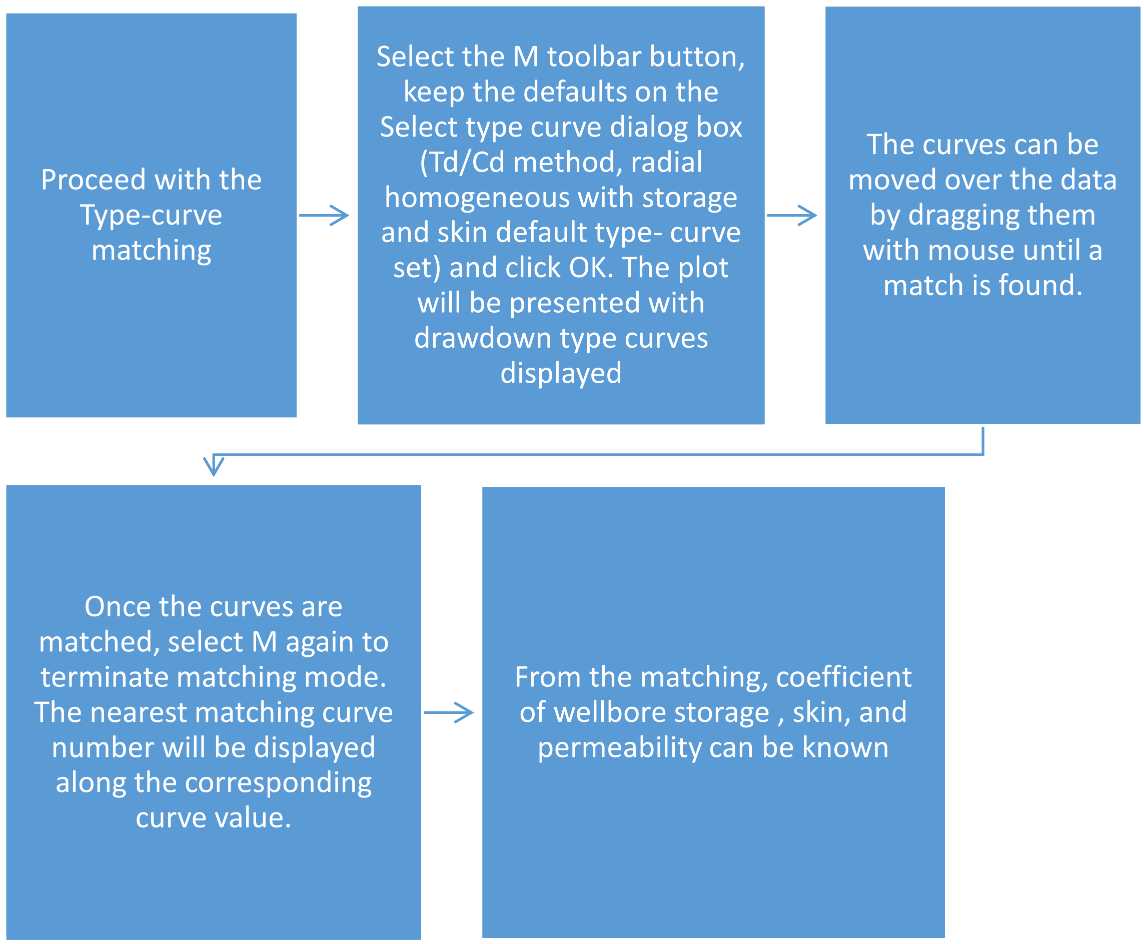


FIGURE 5. Project Methodology Flow Part 2

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Analysis on Test Data

In this section, a sample set of test data will be entered in the software. Using parameter of radial homogeneous reservoir, vertical oil well, a presentation of graphical solution will be shown in determining the values of reservoir permeability, skin factor and wellbore storage coefficient. A set of sample test data consisting of thirty six point data with time and pressure provided by the software is tabulated before plotting is made for analysis.

TABLE 4. Sample test of time and pressure data entry tabulated as display provided by the software itself

Time (hour)	Pressure (psia)	Time (hour)	Pressure (psia)
0.0125	3096.55	2.5	3763.43
0.025	3106.77	3.25	3794.06
0.0375	3116.48	4	3815.96
0.0583	3128.95	4.75	3823.69
0.0833	3147.63	5.5	3832.63
0.1208	3178.38	6.25	3838.93
0.1625	3205.95	7.75	3843.01
0.2125	3238.37	9.25	3847.51
0.2917	3287.2	10.75	3850.75
0.4167	3356.27	12.25	3853.51
0.5417	3413.89	13.75	3855.5
0.667	3466.26	16	3857.98
0.8127	3518.62	18.25	3859.98
1	3571.75	20.25	3861.48
1.1875	3617.4	23.25	3863.21
1.375	3652.85	26.25	3864.48
1.625	3692.27	30	3865.73

2	3732.22		

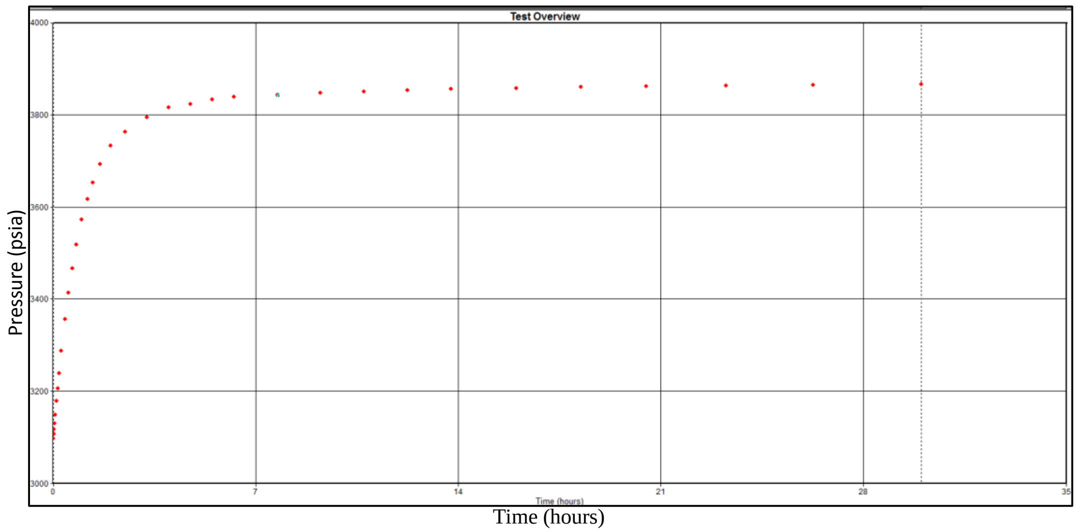


FIGURE 6. Plotting raw Data

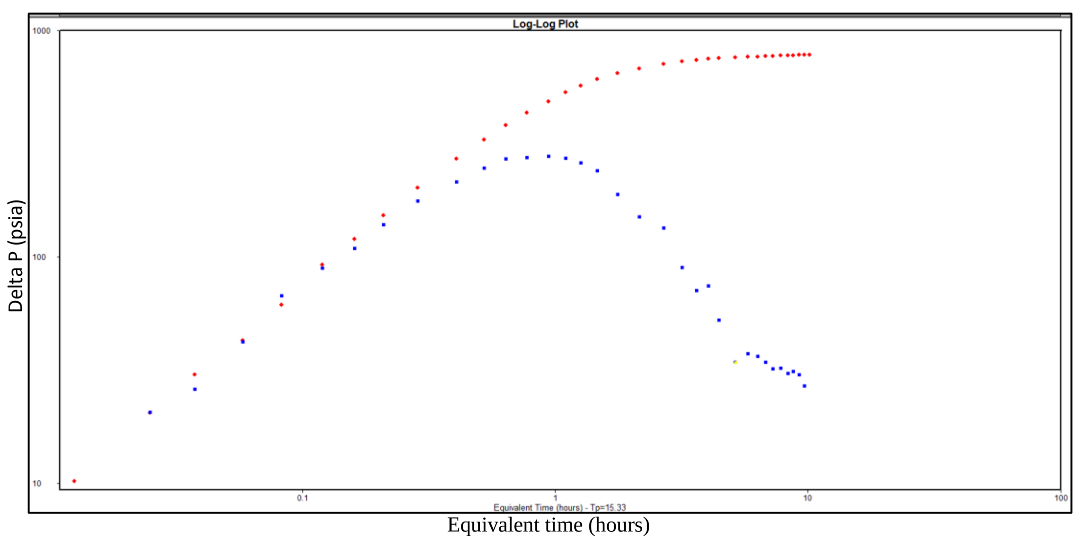


FIGURE 7: Log-log Plot

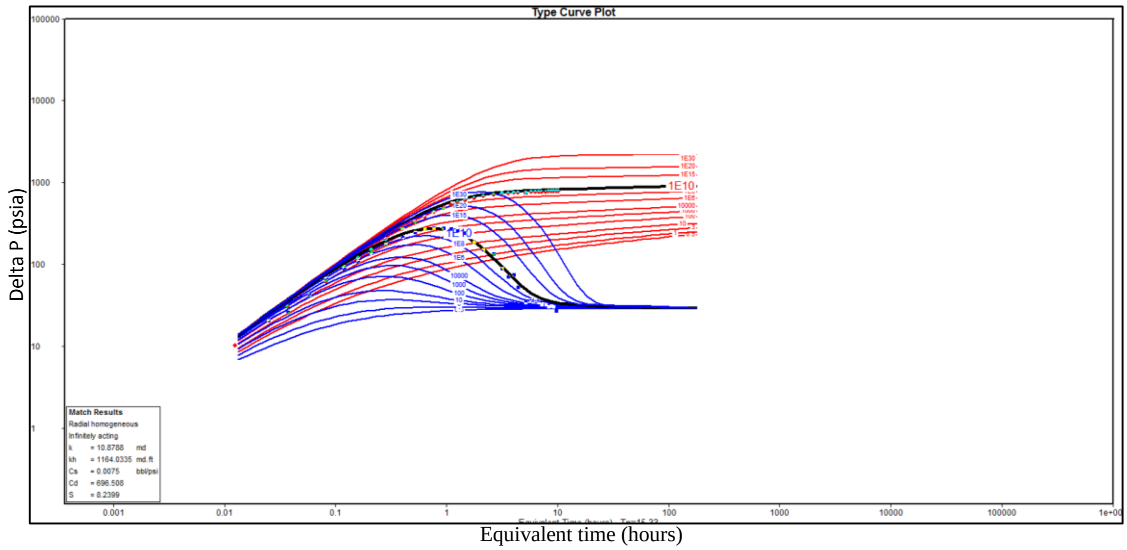


FIGURE 8. Type Curve Matching

TABLE 5. Values of Permeability, Wellbore Storage Coefficient and Skin Factor After Type Curve Matching

Solutions computed	Manual Matching	Automatic Matching
Permeability, k (md)	11.3249	11.3123
Wellbore storage coefficient, C_s (bbl/psi)	0.00822399	0.00738578
Skin factor, S	8.23035	8.24555

For the simulation work to be done in proper manner, several steps and data are required to be fulfilled. Based on the methodology on the simulation, it is required to enter data of well, layer, fluid and pressure gauge and rate data. For well data, essential items that are needed to be initialized are the well radius and wellbore storage model. Based on the scope of the study, selection for fluid type will be on oil (single-phase). For early scope for Final Year Project 1 (FYP1), the principal well orientation should be set to vertical. Formation thickness and porosity are needed to be known as parts of the layer parameters. All these data are known as the non-time-based data. An example of thirty six point's data consisting of time and pressure are allocated as a mean of either drawdown or buildup data for the test. In order to complete the data entry, history of the flowrate must also be entered.

Analysis is made after plotting is completed. Choosing one of the test periods is necessary in order to analyze the build-up data. From there, log-log plot can be established. One of the notable functions of the PanSystem is the usage of type curve matching in analysis of well testing. Following the reservoir parameter preferable to the reservoir condition, the type curve can be moved over the data with mouse dragging until a good match is detected. Upon confirming the location of the both graphs that are superimposed to each other, the software will do the calculation based on the model parameters. The behavior of moving the type curve to a suitable matching is still consider as manual matching though. PanSystem has an automatic matching method as an alternative for the manual matching. From the log-log plot of the test data, it will directly compute the parameters needed from the curve without any to hovering method mentioned earlier. As a result, it produces more accurate answer.

4.2 Analysis on Previous Studies and Comparison

A set of test data is taken from a research paper in order to validate the usage of PanSystem for type curve analysis from Gringarten et al (1979) in their study on comparing the relationship between skin and wellbore storage type-curves for early transient analysis. A set of both drawdown and build-up pressure and time data with parameters of vertical well with constant production rate, infinite acting reservoir, homogeneous reservoir, single-phase fluid and constant wellbore storage coefficient are taken into plot.

TABLE 6: Data for Sample Test (Gringarten et al, 1972)

Δt (min)	Pws (psi)	Δt (min)	Pws (psi)
3	3105	334	3203
5	3108	423	3208
9	3115	574	3216
16	3125	779	3222
30	3139	1092	3228
40	3146	1674	3234
66	3159	2186	3238
100	3171	2683	3242
138	3180	3615	3246
252	3195	4281	3246

Q= 800 STB/D

μ= 1.0 cp

r_w= 0.3 ft

β= 1.25 RB/STB

h= 30 ft

ø= 0.15

C_t= 10 x 10^{-6} psi^{-1}

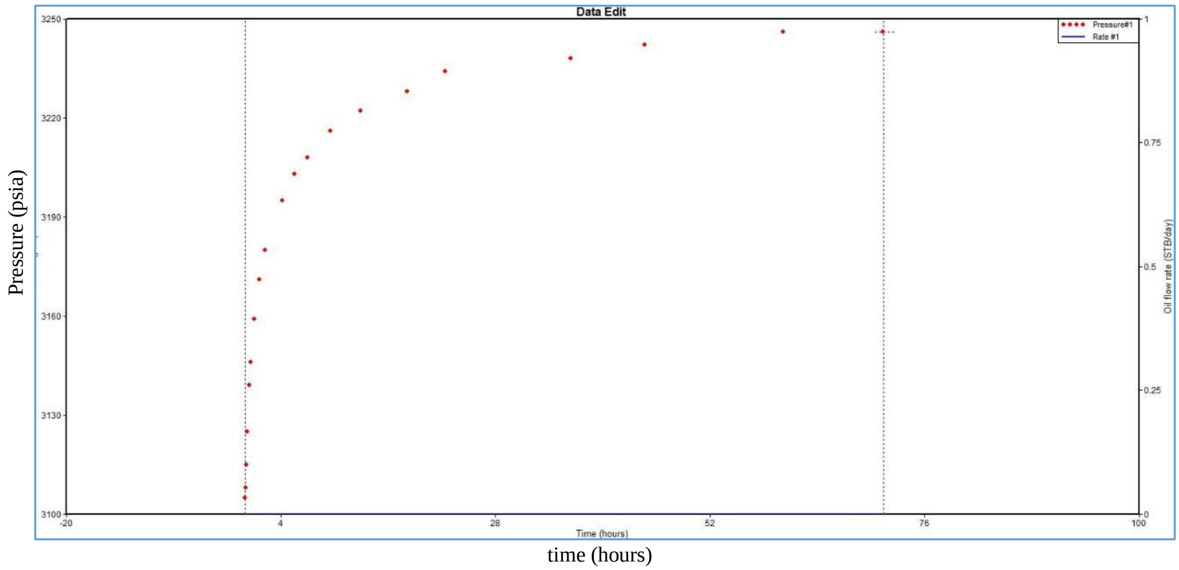


FIGURE 9. Plotting Pressure Versus Time in Linear Graph

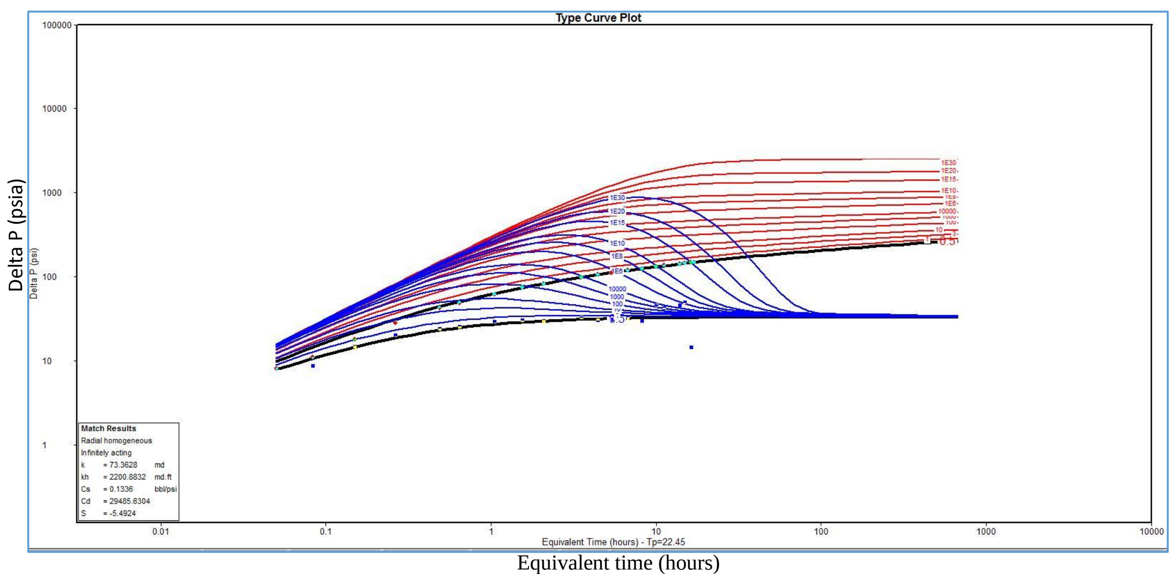


FIGURE 10. Type Curve Matching

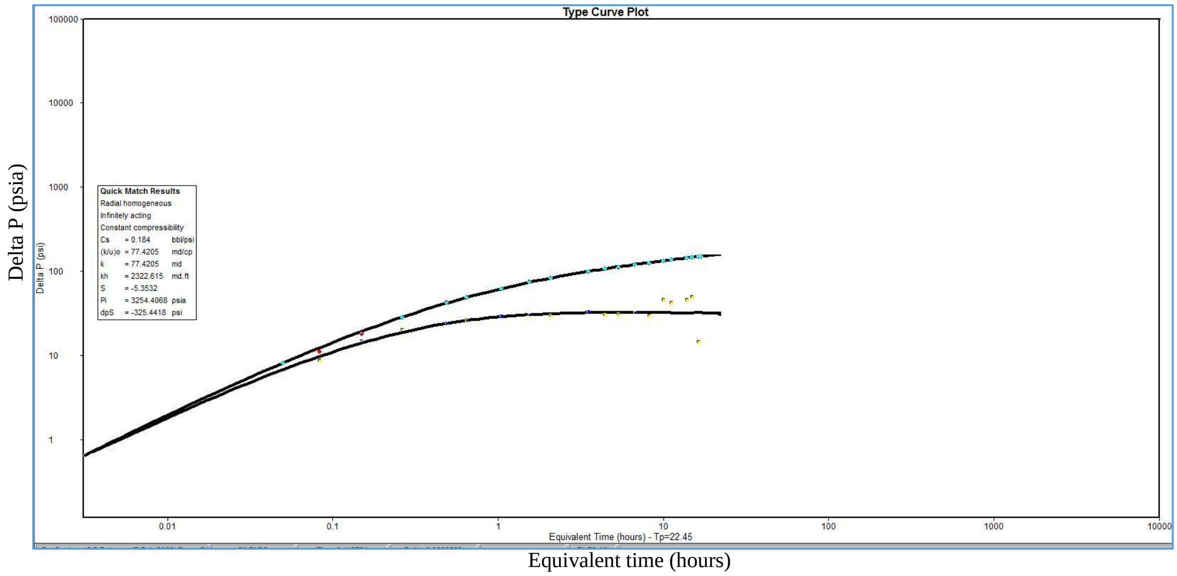


FIGURE 11. Auto-Matching From Type Curve Analysis

The results of permeability, wellbore storage coefficient and skin factor are tabulated as follow:

TABLE 7. Tabulation of Values Obtained From Both PanSystem and the Previous Study

Solutions computed	**Manually Done**	**Type-Curve Matching (PanSystem)**	**Automatic Matching (PanSystem)**
Permeability, k (md)	75.3000	73.3628	77.4205
Wellbore storage coefficient, C_s (bbl/psi)	0.19000	0.1336	0.184
Skin factor, S	-5.1000	-5.4924	-5.3532

In Table 7, it can be seen that the values obtained show slight differences among each other. Considering the values from automatic matching to be baseline in the result, it can be observed the values from the manually calculated deviates around 2.74% percent in terms of permeability, 3.26% in terms of wellbore storage coefficient as well as the skin factor (4.73%). This can be known that there was human error during type-curve matching that was done manually. Thus, resulting in different value computed. This is the representation on how PanSystem works in well testing (type-curve analysis in this case) with reservoirs of infinite acting, homogeneous and vertical.

4.3 Further use of PanSystem for Type-Curve Analysis Using Different Assumptions of Well and Reservoir Parameters

Further application of the software is done for hydraulically factured wells. It involves the usage of type curves for the well that has vertical fractures. Additional assumptions for the study of type curve conclude two equal length wings, fracture that has uniform flux, finite reservoir that has uniform initial pressure, and has constant rate of drawdown test. Values from sample test are input as well as the flow rate, viscosity, formation volume factor, porosity, formation thickness and total compressibility (refer to Table 9)

For the type curve matching, the estimation of values that will be obtained from analysis are the formation permeability and fracture length. The comparison of results are tabulated in Table 8. It can be seen that percentage of error calculated (consider values from automatic matching as the baseline) occurred due to human error probably during matching the type curve with the test data.

TABLE 8. Tabulation of Values in Comparison for Permeability and Fracture Length

Solutions computed	**Manually Done**	**Type-Curve Matching (PanSystem)**	**Automatic Matching (PanSystem)**	**Percentage of error (%)**
Permeability, k (md)	4.50	4.54	4.54	0.88
Fracture length, L_f (ft)	59.7	54.1	54.1	10.35

TABLE 9. Buildup Test Data for Fractured Well (Gringarten et al., 1972)

Δt (hours)	$P_{ws-}\ P_{wf}$ (psi)	Δt (hours)	$P_{ws-}\ P_{wf}$ (psi)
0	0	0.833	100
0.0833	31	0.917	100
0.167	43	1.00	100
0.250	54	1.25	114
0.330	66	2.00	136
0.417	66	2.50	159
0.500	72	4.00	181
0.583	78	4.75	206
0.667	83	6.00	218

0.75	89		

Q= 2750 STB/D　　μ= 0.25　　r_w= 0.3 ft

β= 1.76 RB/STB　　h= 230 ft

ø= 0.3　　C_t= 30 x 10^{-6} psi^{-1}

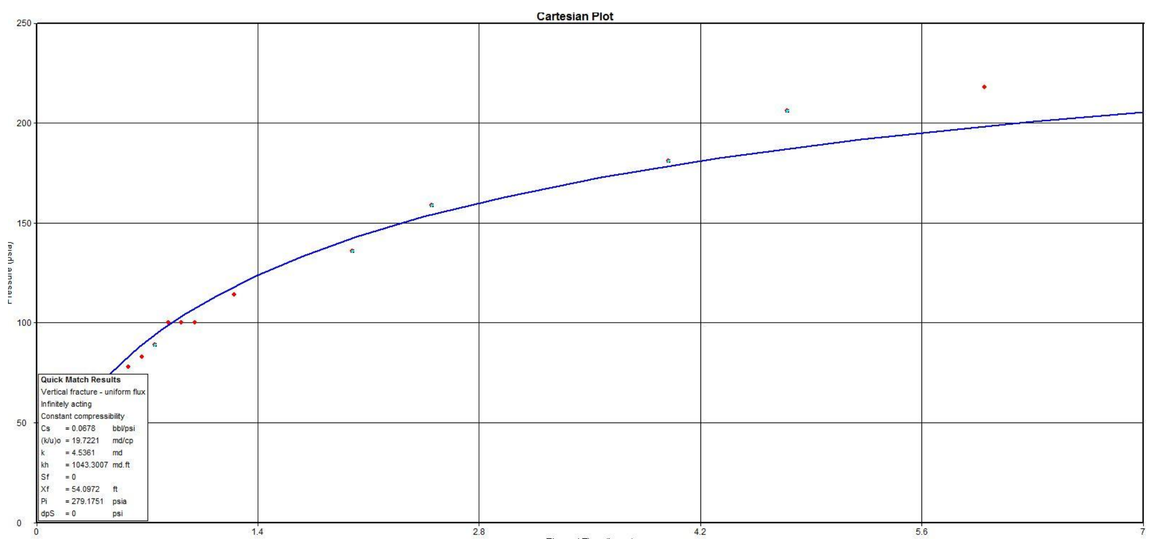


FIGURE 12. Linear Plot of Pressure Versus Time (Hydraulically Fractured Well)

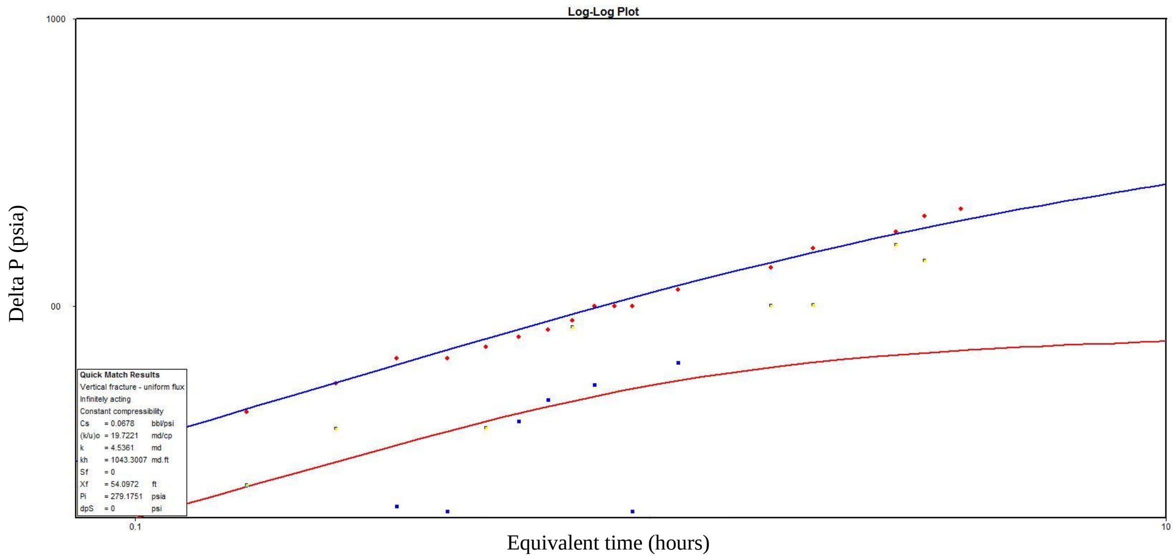


FIGURE 13. Log-log Plot of Delta Pressure Versus Equivalent Time (Hydraulically Fractured Well)

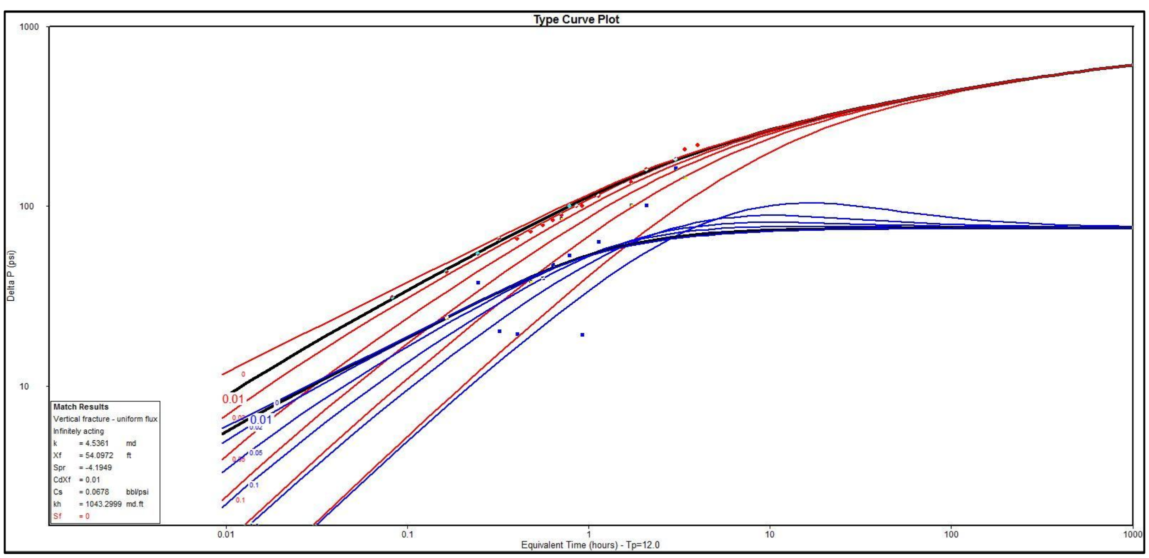


FIGURE 14. Type Curve Matching (Hydraulically Fractured Well)

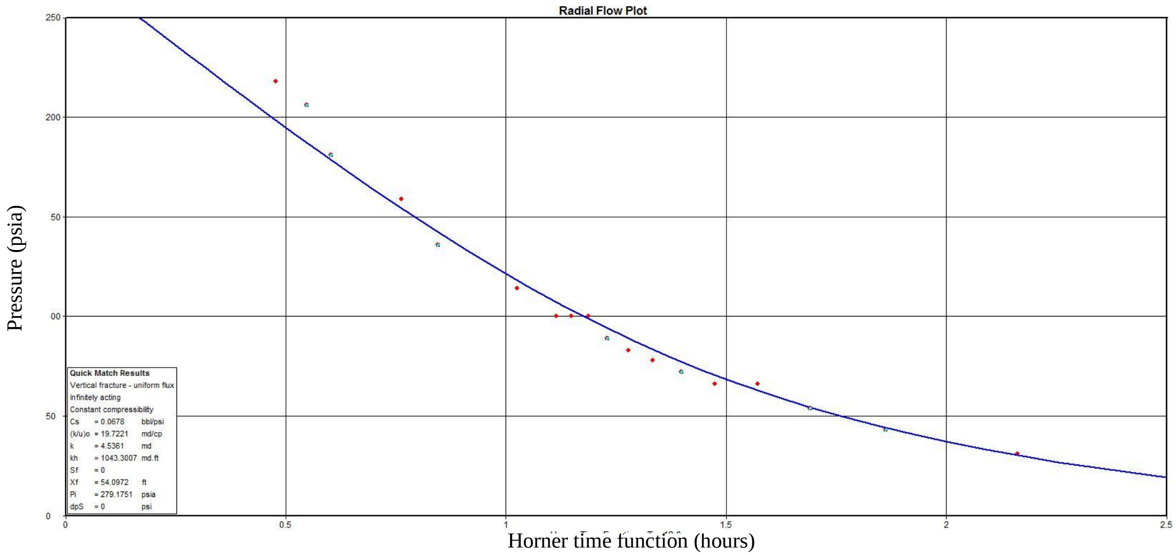


FIGURE 15. Auto Match on Radial Flow Rate Plot (Hydraulically Fractured Well)

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

Type curve is a tool in analyzing pressure drawdown and buildup test. The usage of PanSystem makes analysis of type curve easier with less error encounter. 'Auto Match' in PanSystem can be done accurately for performing the analysis and also acts a tool for checking any deviated error from the manual matching either in the software itself or by hand written. For this project, the project has relevancy to the background of study. Problem statement which has been stated is applicable and has impact on the society. Furthermore, objectives mentioned are achievable to the project within the time interval. The variety of literature review, project milestone and methodology stated shows the project plans are feasible.

As recommendation, the author would like to expand the study to the analysis on the actual well data of different reservoir characteristic that shall be used to analyze the different behavior or pattern of the type curve itself and logical explanation can be made based on the observation. Derivation of flow equation from type curve will be taken consideration as part of the explaining the pattern of the type curve.

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