CHAPTER IV

RESULTS AND DISCUSSION

4.1 Field Measurements

Field measurements used in this study were obtained from Kamphaeng San Basin, Thailand by incorporating with Pan Orient (Siam) Company. This basin was located at the central plain of Thailand as shown in Figure 4.1. In this area, it was a part of Thailand Concession Block L53 which composed of area in Nakornpathom Province and a part of Kanchanaburi Province as shown in Figure 4.2. Four different onshore wells; A, B, C and D were directional drilling at target true vertical depth 935 m, 796 m, 1253 m, 1408 m respectively, and measured depth of 1660 m, 890 m, 1651 m, 1552 m, respectively. Wells were drilled in hole section of 26 inch, 17 ½ inch, 12 ¼ inch, 8 ½ inch and 6 $^{1}/_{8}$ inch with casing size 20 inch, 13 $^{3}/_{8}$ inch, 9 $^{5}/_{8}$ inch, 7 inch and 4 ½ inch respectively with drillpipe 5 inch following well program. Drilling fluid flow was approximately in range between 350- 750 gpm.

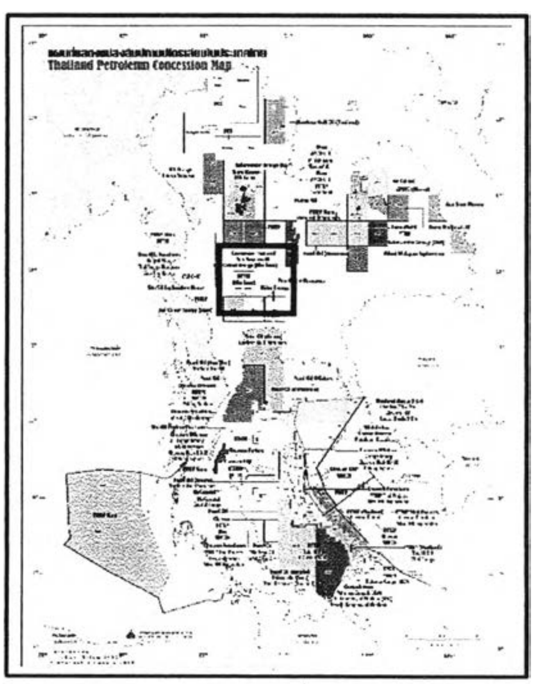

Figure 4.1 The location of Kampaeng San Basin in central plain of Thailand.

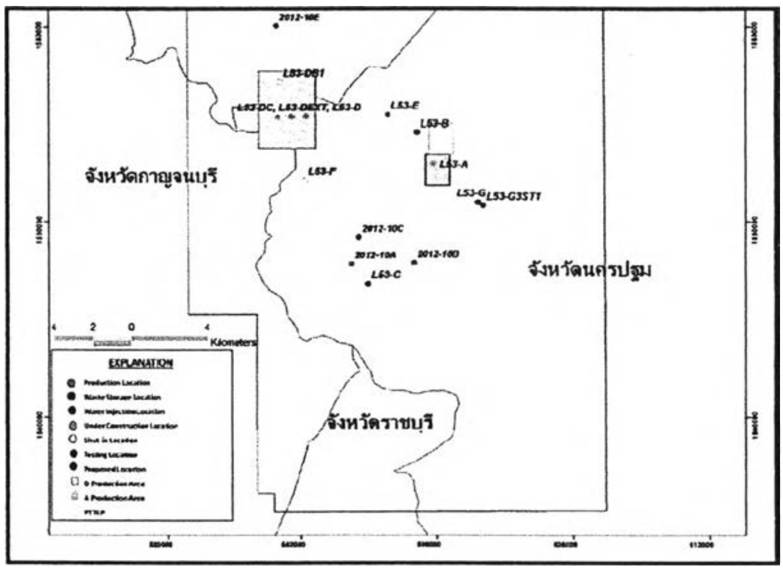

Figure 4.2 Surrounding area of Kampaengsan Basin.

4.2 Fluid Rheology Model

Drilling fluids rheology played an important role in calculating pressure loss and equivalent circulation density (ECD). They can be categorized by relationship between shear stress and shear rate which were identified by using Faan Viscometer (V-G meter) in field. The viscometer directly measured the dial reading at the given speed such as 6 rpm, 300 rpm and 600 rpm, and usually reported in term of plastic viscosity (PV, in units of cps) and yield point (YP, in units of lb/100 ft^2).

According to drilling fluids report from Pan Orient (Siam) Energy Co., Ltd, PV and YP of drilling mud in Well A, B, C and D were reported which calculated from dial reading at a given speed, practically 300 rpm and 600 rpm, following equations (4.1) and (4.2).

$$PV = \theta_{600} - \theta_{300} \tag{4.1}$$

$$YP = \theta_{300} - PV \tag{4.2}$$

The examples of PV, YP and dial reading of Well A, B, C, and D in hole section of 8.5 inch diameter are shown in Table 4.1. Typically, Non-Newtonian fluid was described as Bingham, power law and yield power law model depending on dial reading. To identify fluid rheology, dial reading from Faan Viscometer was importantly needed. The two dial reading values described Bingham fluid and power law fluid, while three dial reading values described only yield power law fluid. Thus, these two practical dial reading values were only fit with two rheological models, Bingham model and power law model. It cannot be described by the yield power law model because it required three practical dial reading values to identify initial yield stress. However, in oil industry, most of commercial drilling fluids were described using the power law model (INTEQ 1995, Lake 2006, Skalle 2013). Therefore the power law model was used in this research.

Table 4.1 Mud properties of Well A, B, C and D in hole section of 8.5 inch in diameter

Mud Properties	Unit	Well A	Well B	Well C	Well D
Plastic viscosity (PV)	cps	13	13.5	14.5	11
Yield Point (YP)	lb/100ft^2	17.5	17	16.5	18.5
Flow behavior index (n)	-	0.5122	0.5287	0.5536	0.4572
Consistency index (k)	eq.cp	638.32	575.96	501.22	869.91
Yield stress (τ_y)	lb/100ft^2	0	0	0	0

4.3 Annular Frictional Pressure Loss Calculation

4.3.1 Annular Frictional Pressure Loss with Casing Program

When the well was drilled in the first hole section without casing, for example start drilling in first section of 26 inch in diameter, pressure loss occurred only in the open hole section. Then, with casing 20 inch in diameter into the wellbore, the well was drilled in the next smaller section, 17 ½ inch in diameter, as shown in Figure 4.3. Hence, calculating pressure loss can be categorized into two parts. The first part was open hole section where fluid flow passing through annular space between the drillstring and the formation. The second part was casing section where fluid flows passing through annular space between the drillstring and the inner wall casing.

Therefore the proposed annular frictional pressure loss calculation combined with bit and casing program was expressed in equation (4.3).

$$\Delta P_{annular} = \Delta P_{annular,open\ hole} + \Delta P_{annular,casing} \tag{4.3}$$

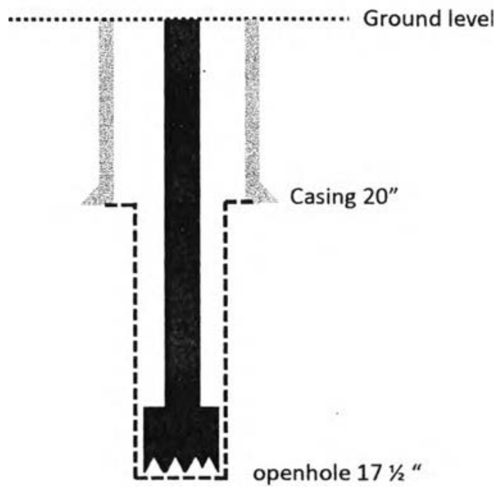

Figure 4.3 Drill bit with casing program in hole section 17 ½ inch in diameter.

4.3.2 Combination of Predictive Model of Annular Pressure Loss

Using the fluid parameters in Table 4.1 combined with bit and casing program from the actual well program, the annular frictional pressure loss models with and without pipe rotation were predicted and summarized in Table 4.2 in order to predict the downhole pressure. Consider predictive model without pipe rotation in Table 4.2, there were two model used in both laminar regime and turbulent regime. The first, Model A, was a common friction factor of fluid flowing in pipe, which was a useful fundamental in fluid mechanic. Typically, model was used in both Newtonian fluid and Non-Newtonian fluid. In case of laminar flow state, it was a simply equation while turbulent flow state required numerical method to determine solution. While another model, Blasius model, was a common friction factor only used for power law fluid.

When pipe rotation effect was considered in downhole pressure prediction, several literatures proposed empirical correlation and mechanistic model developed from experiments or field measurements. The increase-pressure loss model, equation (2.15), and PRL ratio, equation (2.16) were combined with Model A and Blasius formula. In addition, the empirical correlations, Model C and D, were also used in annular frictional pressure loss calculation.

Table 4.2 Predictive models of annular pressure loss with and without drillpipe rotation

Model without pipe rotation	Model with pipe rotation
Equation (2.12), (2.13) (Model A)	Equation (2.12), (2.13), (2.15) ---> Model A1
	Equation (2.12), (2.13), (2.16) ---> Model A2
Equation (2.12), (2.13) (Blasius formula)	Equation (2.12), (2.14), (2.15) ---> Model B1
	Equation (2.12), (2.14), (2.16) ---> Model B2
	Equation (2.18) – (2.29) ---> Model C
	Equation (2.30) – (2.33) ---> Model D

4.3.3 Downhole Pressure or Equivalent Circulating Density (ECD) Calculation

Downhole pressure was the sum of hydrostatic pressure and annular frictional pressure loss as shown in equation (2.2). Thus after predicted annular pressure loss calculation was done, it was used in downhole pressure calculation. In oil and gas industry, downhole pressure also referred as equivalent circulating density (ECD) which was widely used in drilling operation. ECD was a common value to represent downhole pressure while circulating drilling mud in order to balance formation pressure. This ECD can be determined using equation (2.3). Hence this research was shown the calculated downhole pressure in term of ECD.

4.4 Predicted ECD Using Field Measurements

Field measurements used in this research composed of four different onshore directional wells: Well A, Well B, Well C and Well D which were in Kampaeng San

Basin in Thailand. Drilling fluid circulation was considered on the basis of that there was no fluid loss into formation. All fluids as liquid phase and cuttings as solid phase were homogeneous mixture, which drilling fluid density was density of mixture. Well was perfectly drilled which indicated that wellbore was cylindrical shape. Then, the calculation of fluid properties were conducted. Fluid behavior index (n) and consistency index (k) were determined using plastic viscosity (PV) and yield point (YP) from Table 4.1. Then effective viscosity of fluid was determined using fluid behavior index and consistency index. Drilling fluid flow state in annulus was determined by Reynold number whether it was in laminar, transition or turbulent regime. An annular frictional pressure loss calculation with and without pipe rotation effect was conducted using predictive model in Table 4.2 combining bit and casing program. Then annular pressure loss were added by hydrostatic pressure, and expressed calculated downhole pressure in term of ECD in pound per gallon (ppg).

4.4.1 Field Measurement: Well A

4.4.1.1 No Drillpipe Rotation Effect

Using calculation model ignoring pipe rotation effect, the comparison between calculated and measured ECD without pipe rotation effect based on field measurement of Well A was shown in Figure 4.4. It indicated that the Blasius model gave a good agreement with field measurements more than Model A because the Blasius formula was developed using only power law fluid information while model A was commonly used for both Newtonian fluid and Non-Newtonian fluid. However, error lines in Figure 4.4 were plot in range 5 % and 10%. It indicated that both models were under predicted for ECD or downhole pressure estimation, but most of the results from both models were fairly good agreement with error less than 5% even there were some values slightly not to give a good estimation. Additionally, usual measured ECD were in range 9-13 ppg, but there were some abnormal data in range 16-19 ppg, which was over the normal range because of oilfield data transformation.

Regarding to oilfield data record, all drilling information were recorded as time log including data not only in drilling activities but also others such as hole cleaning, back reaming operation, tripping in-out and pipe connection. Transforming time log to depth log, which was considered only in drilling activities, might not have an appropriate algorithm of transformation. Therefore, some drilling data based on depth log might not be related to drilling activity. This problem possibly caused of abnormal pressure in Figure 4.4. Considering data of Well A, measured ECD and pore pressure were plotted as pressure window based on depth log as shown in Figure 4.5. There were pressure peaks at measured depth 850 to 1000 m or true vertical depth at 550-600 m. These abnormal pressure peaks were compared with fluid flow rate as shown in Figure 4.6 and pipe rotating speed as shown in Figure 4.7. The operation was in normal drilling activity due to an existence of pipe rotating speed, but there were some peaks of flow rate higher than usual flow. The normal flow rate was approximately 600-700 gpm, while that abnormal peaks were more than 1000 gpm which might be flow rate used in hole cleaning. Hence these errors came from data transformation. Additionally, an unusual flow rate directly affected ECD. On the other hand, it indicated that flow rate was a major influence of estimating ECD and pressure loss. In addition, an error became more fluctuating at depth deeper than 780 m or ECD in range of 11-12 ppg since it changed the bit from 12 ¼ inch to 8 ½ inch bit diameter with 5 inch drillpipe diameter. An annular gap width became narrower, and also influenced pressure loss.

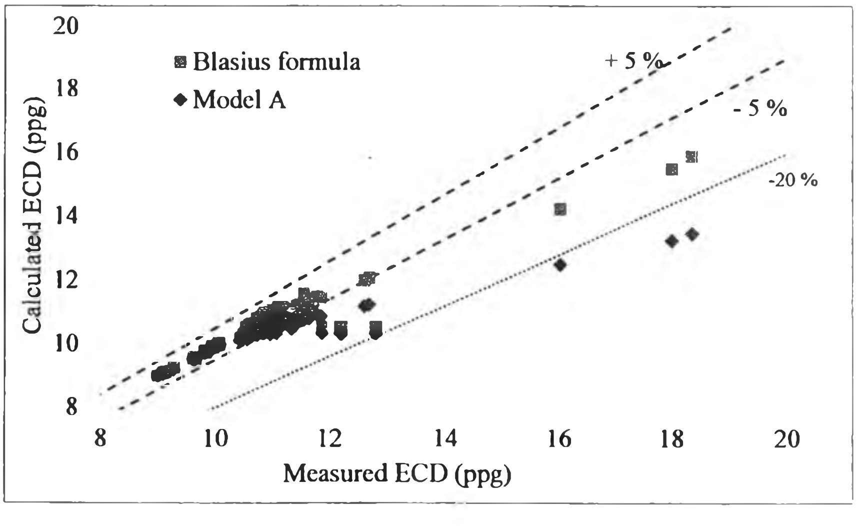

Figure 4.4 A comparison between calculated ECD and measured ECD from Blasius formula and Model A using Well A data.

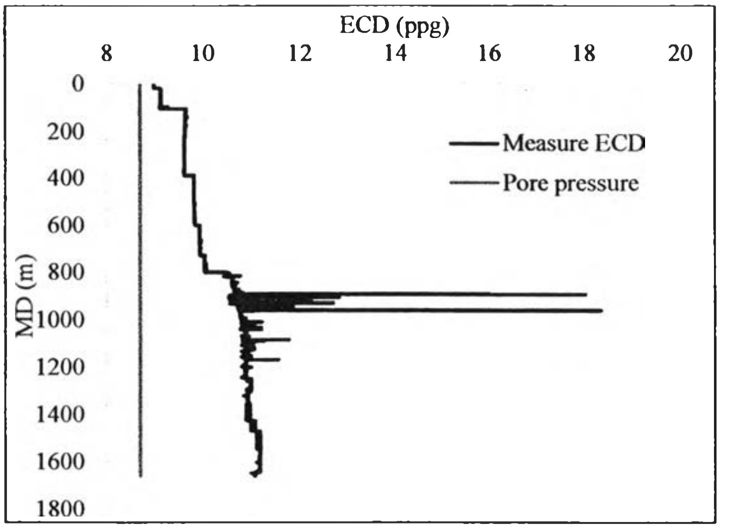

Figure 4.5 Measured ECD window base on depth log with pore pressure.

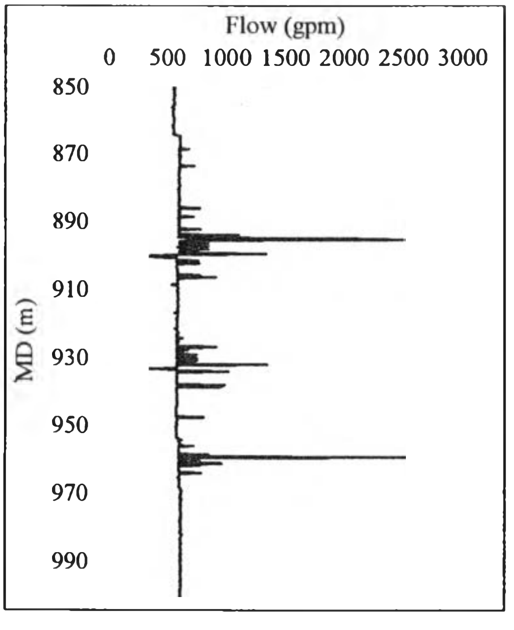

Figure 4.6 Fluid flow rate in wellbore.

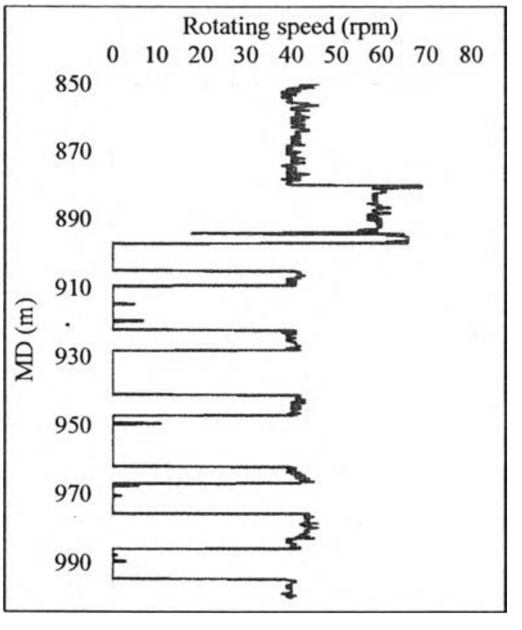

Figure 4.7 Pipe rotating speed.

4.4.1.2 With Drillpipe Rotation Effect

The gap width between drillpipe and wellbore or inner casing can cause pipe rotation effect becoming more dominant especially in hole section of 8 ½ inch diameter or narrower annular gap. Since an inner pipe rotational speed at the pipe wall affected axial velocity and it impacted overall shear rate that controls pressure loss, the effect of drillpipe rotation on pressure loss was considered to evaluate ECD or downhole pressure using models in Table 4.2. Predictive models of annular frictional pressure loss with pipe rotation were conducted to calculate ECD or downhole pressure based on Well A while circulating power law fluid in hole section of 8 ½ inch diameter. The comparison between calculated ECD and measured ECD from Model A1 and A2, Model B1 and B2, and Model C and D are shown in Figure 4.8, 4.9, and 4.10 respectively. The error lines of 5% and 20% were plot with the results which positive error meant over prediction while negative error meant under prediction.

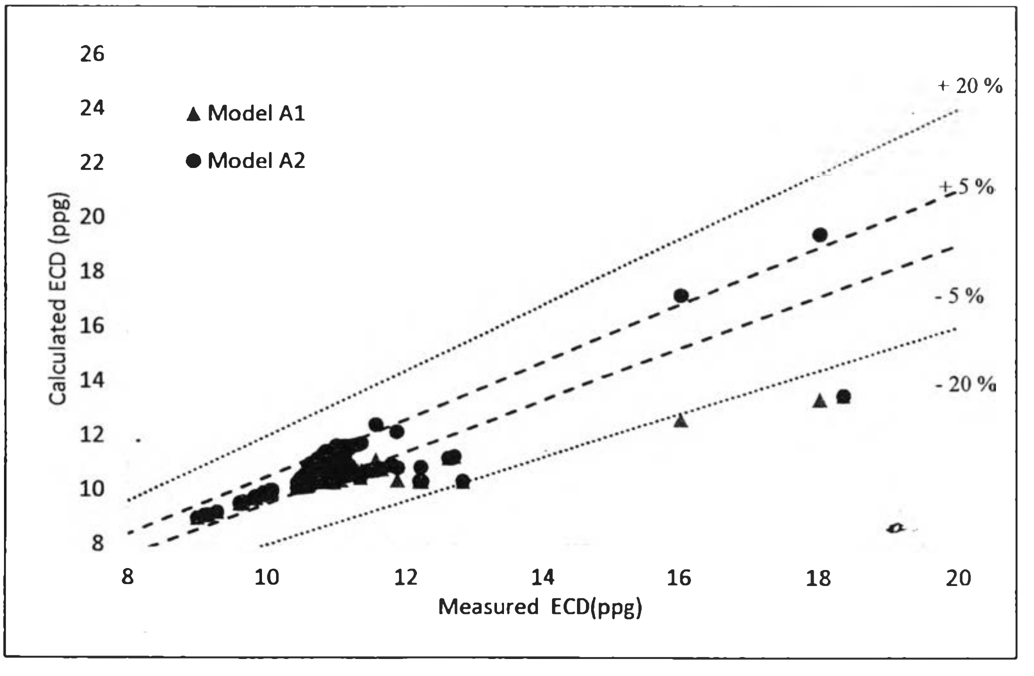

Figure 4.8 A comparison between calculated ECD and measured ECD from Model A1 and Model A2 using Well A data.

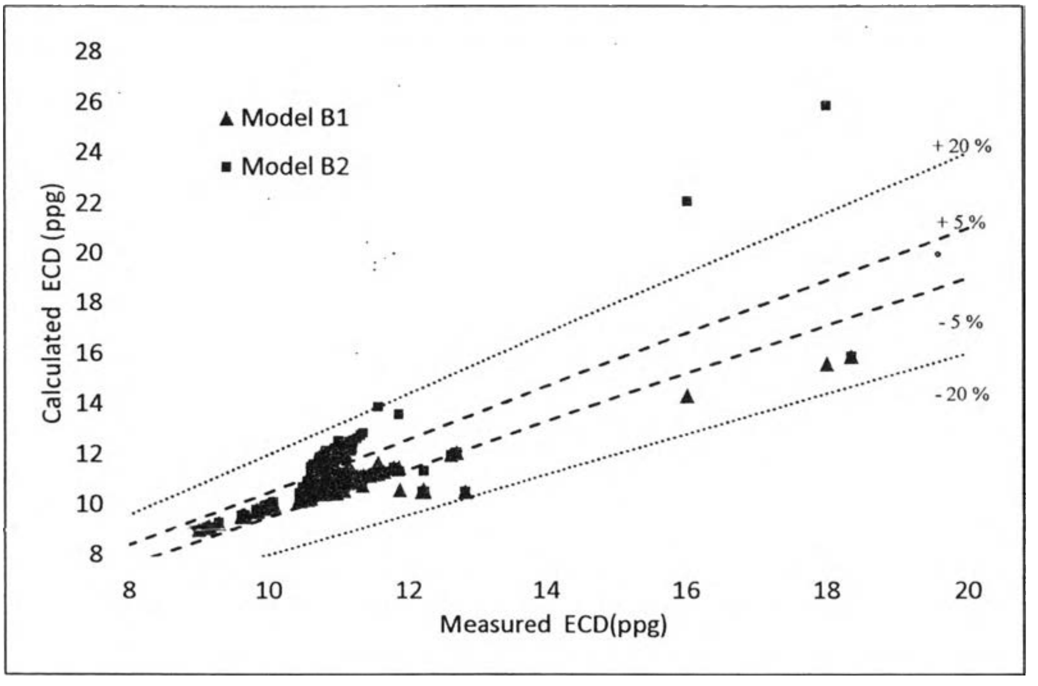

Figure 4.9 A comparison between calculated ECD and measured ECD from Model B1 and Model B2 using Well A data.

Figure 4.8 and Figure 4.9 indicated that Model A1 and B1 using increase-pressure-loss model gave a good agreement with with field measurement with slightly under prediction. While Model A2 and B2 using pressure loss ratio (PLR) gave slightly over prediction. An increase-pressure-loss model was more accurate than pressure loss ratio model because an increase-pressure-loss model was developed from several field measurement based on different well geometry or diameter ratio between drillpipe and wellbore diameter. While PLR was developed from field measurement based on drilling fluid properties which PLR can be used either in power law fluid or yield power law fluid. On the other hand, due to Model A1 and B1, annular gap width or diameter ratio between drillpipe and wellbore significantly impact on ECD or downhole pressure while drillipipe is rotating.

A comparison between calculated ECD and measured ECD from Model C and D are shown in Figure 4.10. It was obviously that Model C slightly over predicted ECD while Model D was more acceptable. Both empirical correlation of Model C and D were developed using experimental data in different technique. A friction factor in Model C was in range of total Reynold number which expressed in term of axial and rotational Reynold number. A coefficient of both axial and rotational Reynold were developed using experimental data considered pipe rotation. An experiment used rotation speed in range 0-120 rpm and flow capacity of 250 gpm. However, rotation speed was in range of field data while flow capacity was much less than field data. Hence these coefficients might not be appropriate to use in downhole pressure calculation. Considering Model D, empirical correlation of drillpipe rotation effect was developed using experimental data with dimentionless technique. This experiment used rotation speed in range of 0-120 rpm and flow capacity of 120 gpm. Even the experimental condition didn't close to field condition, the coefficient of rotation effect using dimensionless technique gave a good practice in pressure loss calculation. In addition, abnormal ECD data in Figure 4.10 were occured by an error of oilfield data transformation which was mentioned in section 4.4.1.1.

To identify good practice model, the statistical analysis was conducted using two methods; mean absolute relative deviation (MARD) and root mean square error (RMSE). The detail are shown in section 4.4.5.

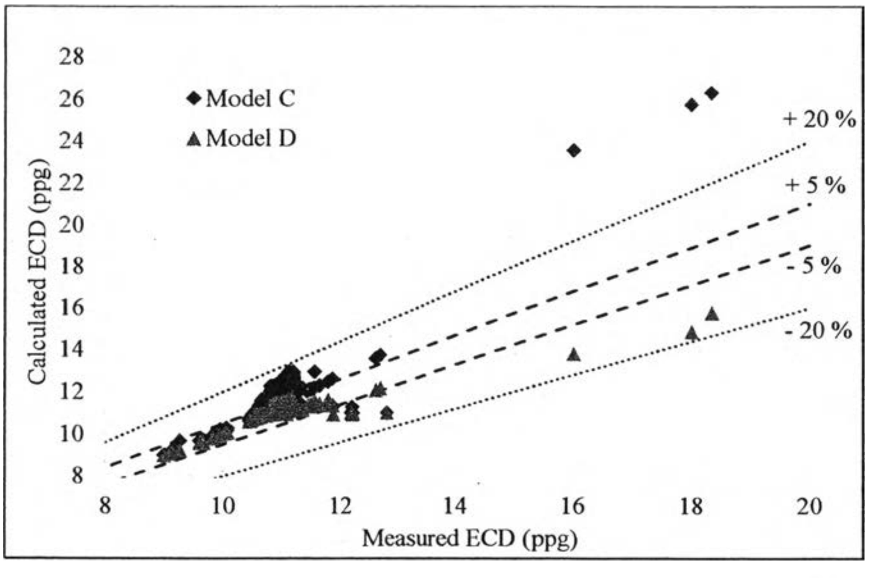

Figure 4.10 A comparison between calculated ECD and measured ECD from Model C and Model D using Well A data.

4.4.2 Field Measurement: Well B

4.4.2.1 No Drillpipe Rotation Effect

Ignoring pipe rotation, downhole pressure or ECD prediction using several predictive models was done using field measurement Well B. The comparison between measured ECD and calculated ECD is shown in Figure 4.11. It indicated that calculated ECD from both Blasius model and Model A gave good agreement with an error less than 5%. However it seemed that Blasius formula gave more accurate results especially ECD value in range 10-10.5 ppg because these ECD values were measured in hole section of 8½ inch in diameter, which was a narrow annular gap. Hence annular gap width significantly affect annular pressure loss calculation.

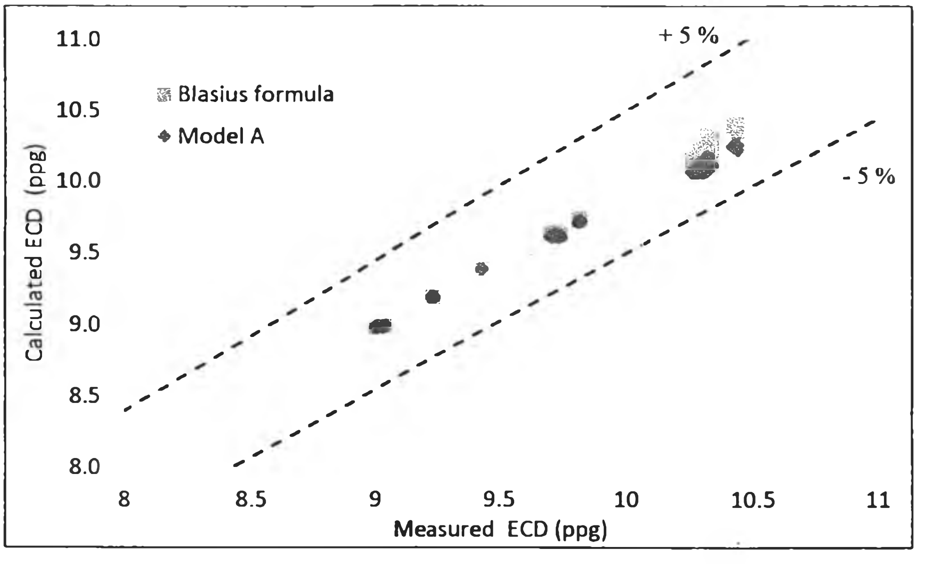

Figure 4.11 A comparison between calculated ECD and measured ECD from Blasius formula and Model A using Well B data.

4.4.2.2 With Drillpipe Rotation Effect

When pipe rotation was considered in pressure loss estimation to be more realistic, selected models with pipe rotation effect in Table 4.2 were used in downhole pressure calculation. The comparisons between measured ECD and calculated ECD are shown in Figure 4.12, Figure 4.13 and Figure 4.14.

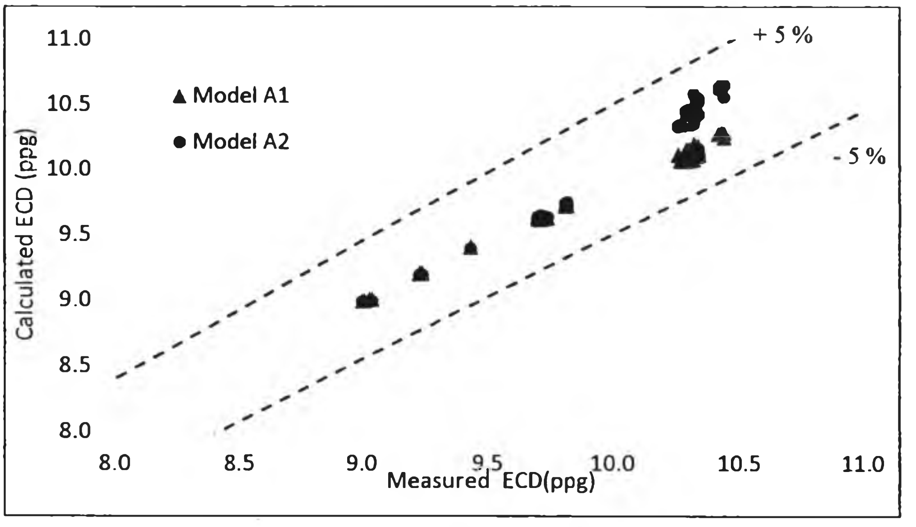

Figure 4.12 A comparison between calculated ECD and measured ECD from Model A1 and Model A2 using Well B data.

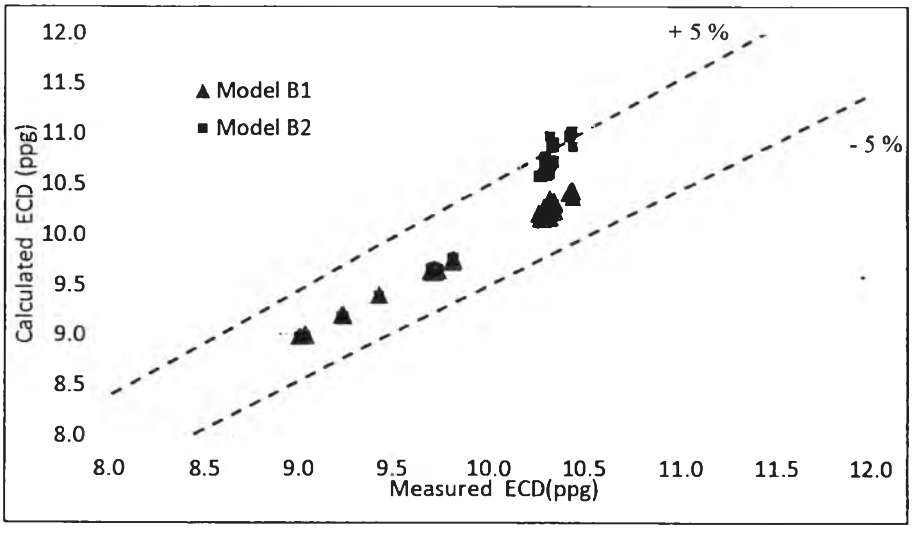

Figure 4.13 A comparison between calculated ECD and measured ECD from Model B1 and Model B2 using Well B data.

Figure 4.12 and Figure 4.13 indicated that calculated ECD from both Model A2 and B2 slightly over predicted at high pressure because these two models used pressure loss ratio (PLR). While Model A1 and B1 slightly under predicted because these two models used increase-pressure loss equation. Moreover two models gave more accurate prediction. By the way, the deviation of ECD data in range of 10-10.5 ppg was occurred because this section was 8½ inch openhole diameter and 5 inch drillpipe, which the annular gap width was smaller than other sections. A small annular gap width influenced on frictional pressure loss when pipe rotation existed.

Figure 4.14 indicated that Model C gave slightly over prediction, and some calculated data were more than 5%, while Model D gave an error less than 5%. In addition, results showed that most error were in ECD rage of 10-10.5 ppg which was in hole section of 8½ inch in diameter. On the other hand, it indicated that annular gap width played an important role in frictional annular pressure loss. Pipe rotation also affected an increase in annular pressure loss when annular gap width was narrower. According to Figure 4.12, Figure 4.13 and Figure 4.14, Model A1, B1 and D accurately predicted ECD, but an appropriate model was not specified. To identify good practical predictive model, the statistical analysis was conducted using two method; mean absolute relative deviation (MARD) and root mean square error (RMSE). The detail is shown in section 4.4.5.

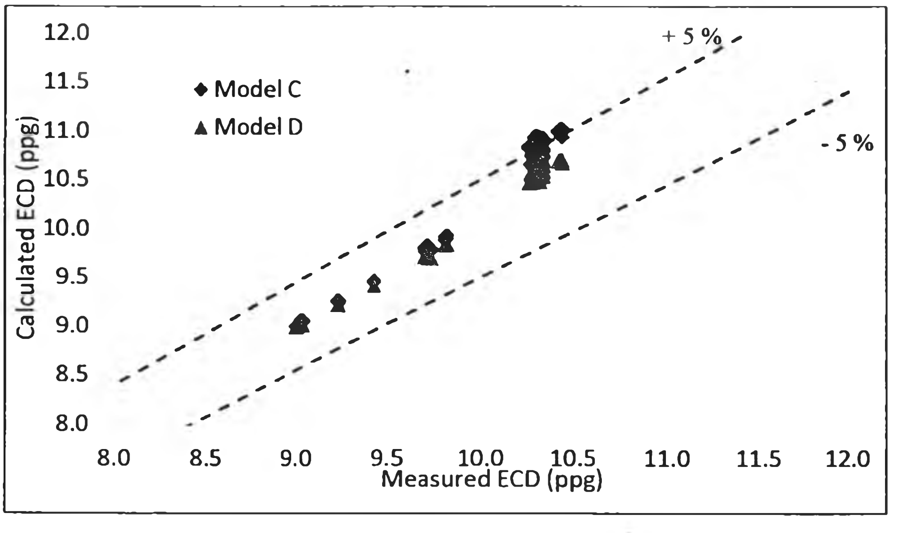

Figure 4.14 A comparison between calculated ECD and measured ECD from Model C and Model D using Well B data.

4.4.3 Field Measurement: Well C

4.4.3.1 No Drillpipe Rotation Effect

Ignoring pipe rotation, downhole pressure or ECD prediction using several predictive models was done using field measurement Well C. The comparison between measured ECD and calculated ECD is shown in Figure 4.15. It indicated that calculated ECD from both Blasius model and Model A gave good agreement with an error less than 5%. However it seemed that Blasius formula gave more accurate results except ECD value in range 10-11 ppg because these ECD values were measured in hole section of 8½ inch in diameter, which was a narrow annular gap. Hence annular gap width significantly affect annular pressure loss calculation.

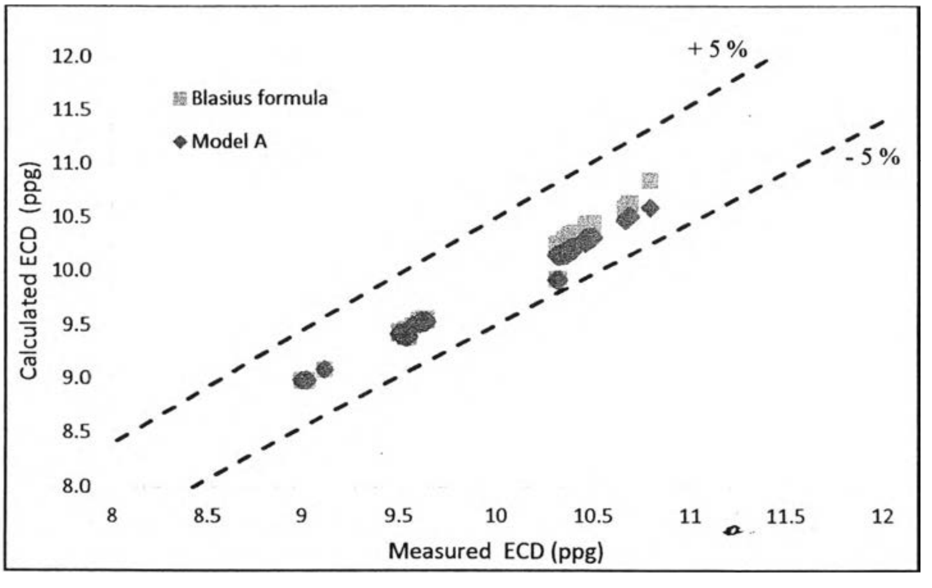

Figure 4.15 A comparison between calculated ECD and measured ECD from Blasius formula and Model A using Well C data.

4.4.3.2 With Drillpipe Rotation Effect

When pipe rotation was considered in pressure loss estimation to be more realistic, selected models with pipe rotation effect in Table 4.2 were used in downhole pressure calculation. The comparisons between measured ECD and calculated ECD are shown in Figure 4.16, Figure 4.17 and Figure 4.18.

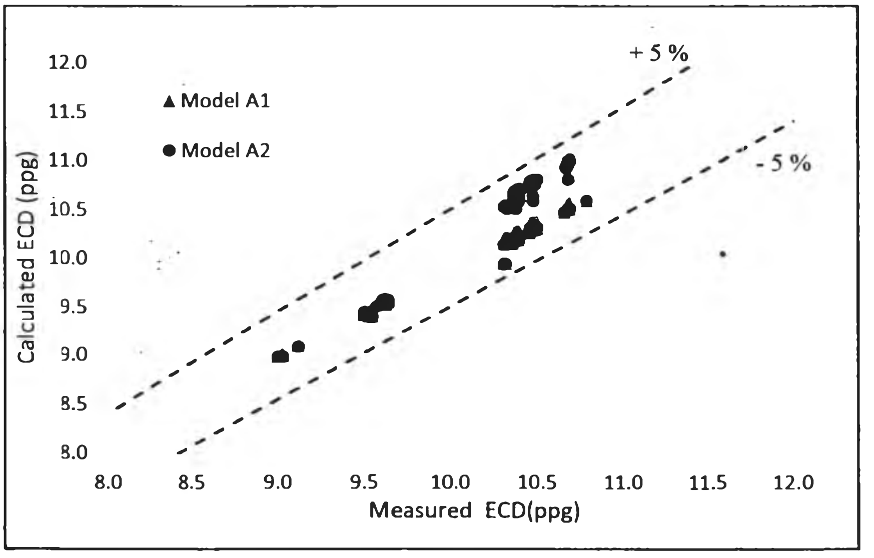

Figure 4.16 A comparison between calculated ECD and measured ECD from Model A1 and Model A2 using Well C data.

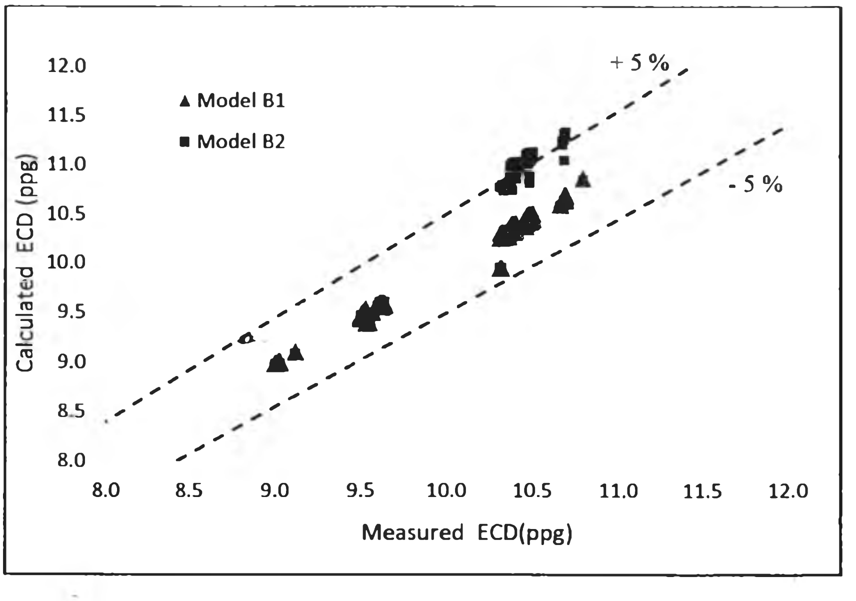

Figure 4.17 A comparison between calculated ECD and measured ECD from Model B1 and Model B2 using Well C data.

Figure 4.16 and Figure 4.17 indicated that calculated ECD from both Model A2 and B2 slightly over predicted at high ECD because these two models used pressure loss ratio (PLR). While Model A1 and B1 slightly under predicted because these two models used increase-pressure loss equation. Moreover two models gave more accurate prediction. A deviation of ECD in range of 10-11 ppg was occurred in hole section of 8½ inch, which annular gap width was small. When rotation existed, it became more influence on frictional pressure loss.

Figure 4.18 indicated that Model C gave slightly over prediction, and some calculated data were more than 5%, while Model D gave an error less than 5%. In addition, results showed that most error were in ECD rage of 10-11 ppg which was in hole section of 8½ inch in diameter. On the other hand, it indicated that annular gap width played an important role in frictional annular pressure loss. Pipe rotation also affected an increase in annular pressure loss when annular gap width was narrower. According to Figure 4.16 and Figure 4.17, both Model A1 and B1 accurately predicted ECD. However it cannot specified which model was an appropriate model. To identify good practice model, the statistical analysis was conducted using two method; mean absolute relative deviation (MARD) and root mean square error (RMSE). The detail was shown in section 4.4.5.

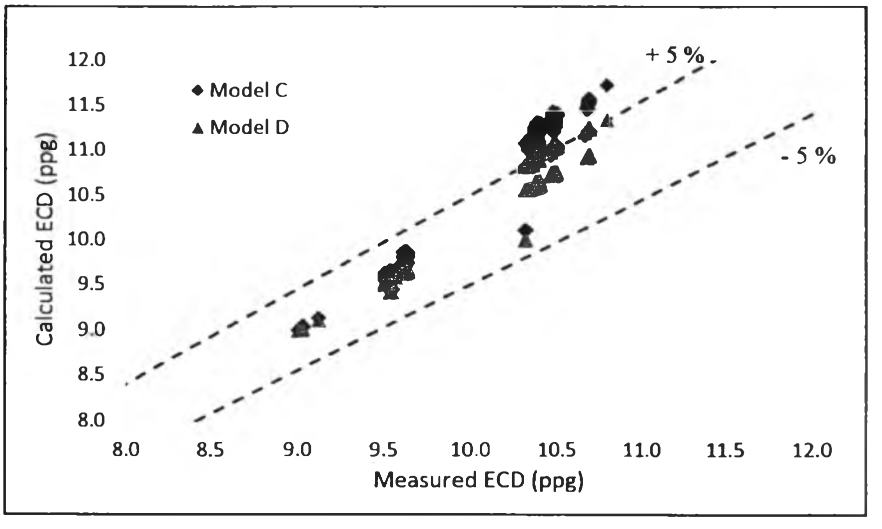

Figure 4.18 A comparison between calculated ECD and measured ECD from Model C and Model D using Well C data.

4.4.4 Field Measurement: Well D

4.4.4.1 No Drillpipe Rotation Effect

Ignoring pipe rotation, downhole pressure or ECD prediction using several predictive models was done using field measurement Well D. The comparison between measured ECD and calculated ECD was shown in Figure 4.19. It indicated calculated ECD from both Blasius model and Model A gave good agreement with an error less than 5%. However it seemed that Blasius formula gave more accurate results especially ECD value in range 10-11 ppg because these ECD values were measured in hole section of 8½ inch in diameter, which was a narrow annular gap. Hence annular gap width significantly affect annular pressure loss calculation.

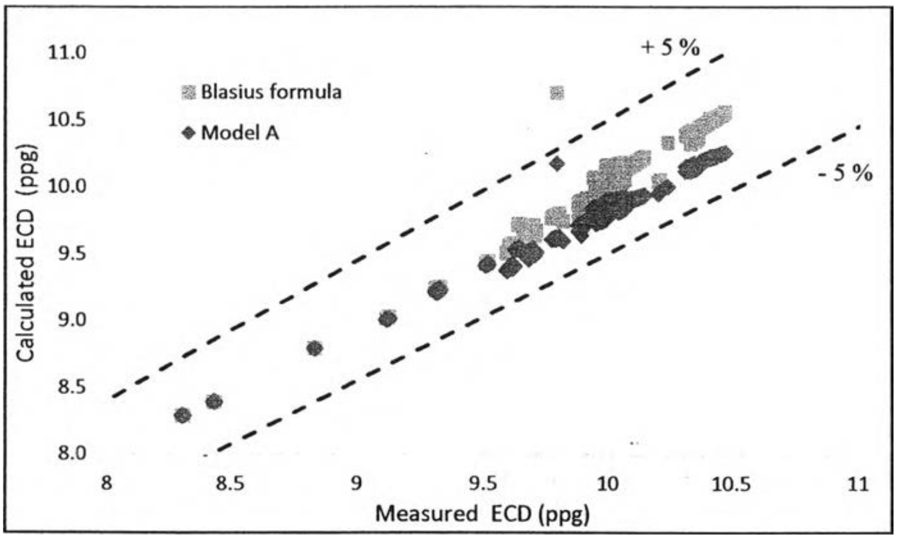

Figure 4.19 A comparison between calculated ECD and measured ECD from Blasius formula and Model A using Well D data.

4.4.4.2 With Drillpipe Rotation Effect

When pipe rotation was considered in pressure loss estimation to be more realistic, selected models with pipe rotation effect in Table 4.2 were used in downhole pressure calculation. The comparisons between measured ECD and calculated ECD were shown in Figure 4.20, Figure 4.21 and Figure 4.22.

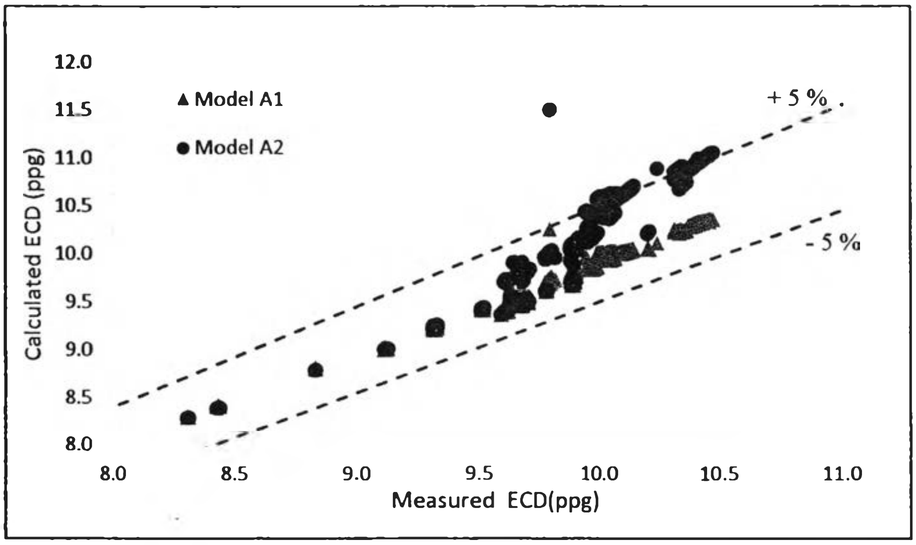

Figure 4.20 A comparison between calculated ECD and measured ECD from Model A1 and Model A2 using Well D data.

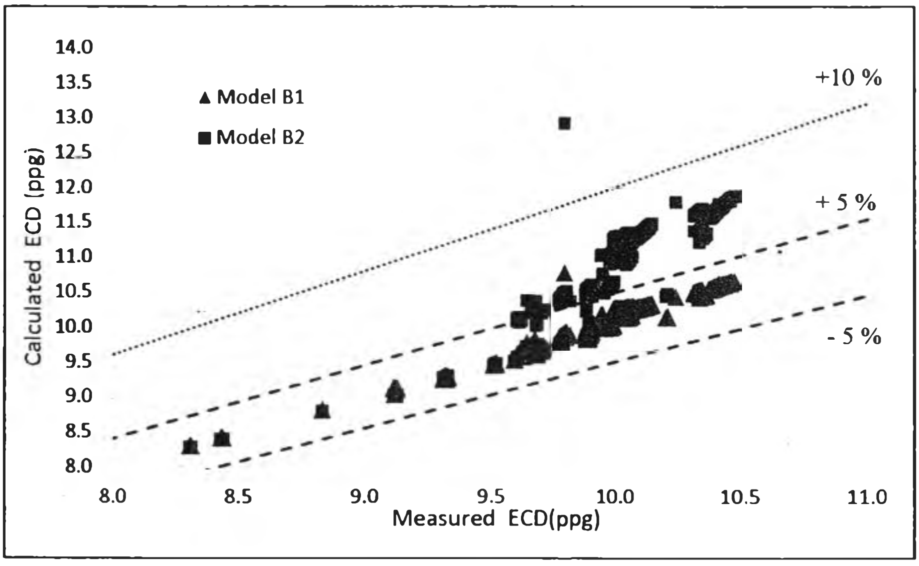

Figure 4.21 A comparison between calculated ECD and measured ECD from Model B1 and Model B2 using Well D data.

Figure 4.20 and Figure 4.21 indicated that calculated ECD Model A2 slightly over predicted while Model B2 much over predicted because these two models used pressure loss ratio (PLR). Model A1 slightly under predicted but Model B1 slightly over predicted because these two models used increase-pressure loss equation. Moreover they gave more accurate prediction. A deviation in ECD range of 9.5-10.5 was occurred in hole section of 8½ inch, which was small annular gap width. Thus, rotation became more influence in annular pressure loss.

Figure 4.22 indicated that Model C gave much over prediction with an error more than 5%, while Model D gave an error less than 5%. In addition, results showed that most error were in ECD rage of 9.5-10.5 ppg which was in hole section of 8½ inch in diameter. On the other hand, it indicated that annular gap width played an important role in frictional annular pressure loss. Pipe rotation also affected an increase in annular pressure loss when annular gap width was narrower.

According to Figure 4.20, Figure 4.21 and Figure 4.22, both Model A1 and B1 accurately predicted ECD. However it cannot specified which model was an appropriate model. To identify good practice model, the statistical analysis was conducted using two method; mean absolute relative deviation (MARD) and root mean square error (RMSE). The detail were shown in section 4.4.5.

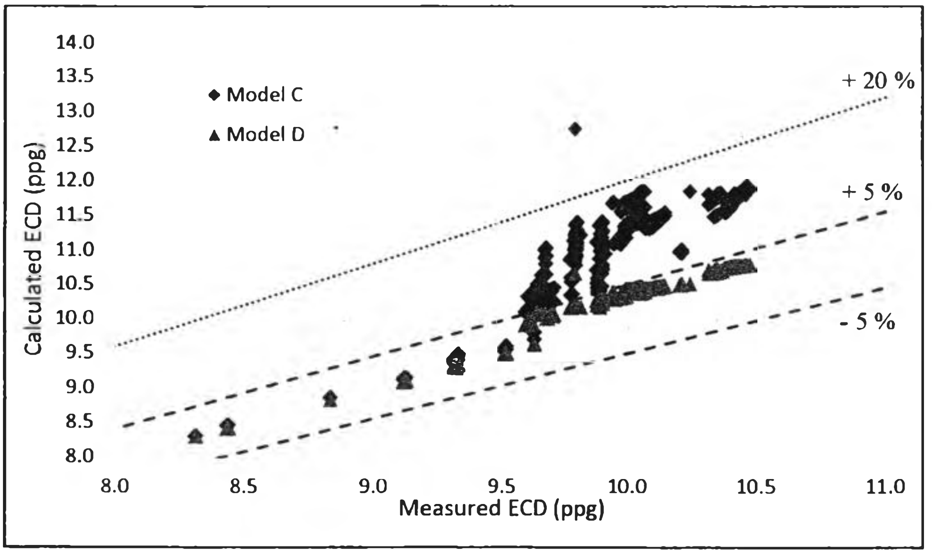

Figure 4.22 A comparison between calculated ECD and measured ECD from Model C and Model D using Well D data.

4.4.5 Practical Predictive Models Identification

To identify an appropriate model used in developed user-friendly software, the results from four different wells were analyzed by two statistical methods; mean absolute relative deviation (MARD) and root mean square error (RMSE) as shown in Table 4.3. A deviation of predicted data were compared with measured data in every recorded depth. The less statistical value of deviation gave more accurate result, so it was obvious that the combination of Blasius formula and increased-pressure-loss equation proposed by Hemphill et al. (2008) (Model B1) accurately estimated downhole pressure in practical field in both stationary situation and rotating drillpipe. On the other hand, decreasing annular gap width will increase pressure loss. Even though downhole pressure with the pipe rotation was presented, but if rotation effect was neglected, it causes frictional pressure loss under predicted.

Table 4.3 Statistical results of four different wells with different predictive models

		Well A		Well B		Well C		Well D	
		MARD	RMSE	MARD	RMSE	MARD	RMSE	MARD	RMSE
No rotation	Model A	0.0203	0.0730	0.0143	0.0253	0.0128	0.0191	0.0150	0.0240
	Blasius formula	0.0085	0.0151	0.0080	0.0074	0.0067	0.0049	0.0057	0.0043
Rotation	Model A1	0.0158	0.0512	0.0132	0.0220	0.0113	0.0156	0.0195	0.0127
	Model A2	0.0212	0.0817	0.0123	0.0198	0.0133	0.0240	0.0203	0.0639
	Model B1	0.0079	0.0137	0.0050	0.0035	0.0039	0.0021	0.0070	0.0087
	Model B2	0.0422	0.4297	0.0157	0.0518	0.0119	0.0456	0.0410	0.3599
	Model C	0.0664	1.0839	0.0242	0.1067	0.0325	0.1891	0.0631	0.7010
	Model D	0.0206	0.0979	0.0128	0.0341	0.0113	0.0258	0.0228	0.0825

4.5 A User-friendly Software Development

A user-friendly software was developed using graphic user interface (GUI) in MATLAB platform to estimate real-time ECD only in drilling activity. Typically, oilfield data was recorded in Logging ASCII Standard (LAS) file, and needed file transformation and data arrangement to be used in pressure calculation and also displayed in GUI. A flowchart of user-friendly software was shown in Figure 4.23. An interface software is shown in Figure 4.24. There were three processes in this software. First was input file section. Second was calculation section, and last section was display section.

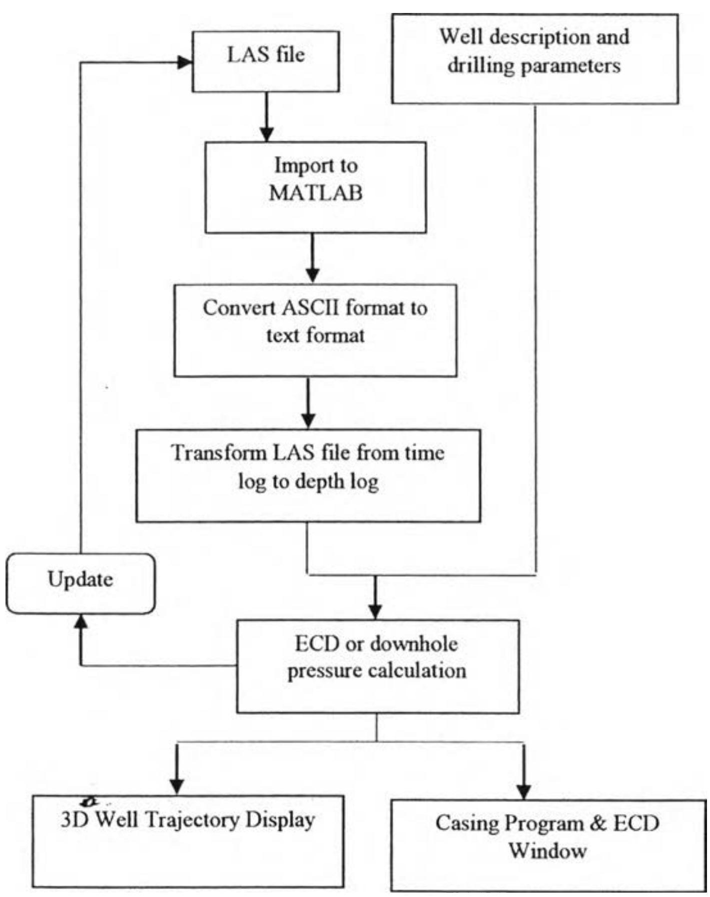

Figure 4.23 A flowchart of user-friendly software.

4.5.1 <u>File and Information Input Section</u>

Most of all oilfield data were recorded in LAS file as in time log or depth log depending on rig company. When raw LAS file was in depth log, it was comfortable for software to process data and sent to calculation section. On the contrary, raw LAS file recorded in time log needed some data transformation from time log to depth log. This software was provided an algorithm of data transformation based on drilling parameters such as bit depth, hole depth, fluid flow rate, surface weight on bit (SWOB) and drillpipe velocity to ensure that the output of depth log was considered only in drilling activity excluding hole cleaning, pipe tripping in-out and others.

In addition, software required well description, bit and casing program, drilling fluid properties and formation pressure were also required to manually input in software interface. Well description part was about reference depth of well which consisted of ground level, rotary kelly bushing level (RKB level) and water depth in case of offshore operation. Ground level was the level of that well above sea level. Rotary kelly bushing level (RKB level) was the level of the drill floor on the rig that is used to drill the well. Normally measured depth was commonly referenced to the RKB level. Water depth was used in offshore operation to specified average height of sea level above sea floor. In case of offshore operation, there were frictional pressure loss and hydrostatic pressure in liner, which was a pipe of drilling fluid flowing from drilling platform to sea floor. Bit and casing program section described size of openhole and casing following well program. Drilling fluid property section described fluid properties: mud weight, plastic viscosity and yield point. The last section, formation pressure, described two terms of pressure based on depth: pore pressure and fracture gradient, which can be plot as pressure window. All of these sections were importantly required to be filled before calculation was conducted.

4.5.2 Calculation Section

After LAS file was input into software, drilling parameters in LAS file whether in depth log or time log were accessed by MATLAB algorithm in order to rearrange necessary data into depth log. If LAS file was based on time log, it firstly required data transformation to record in depth log. The initial stage of transformation was to consider only bit depth and hole depth. Whenever bit depth and hole depth was the same, it meant that the operation was in drilling activity. In some case, bit depth and hole depth was not provided or not available. There were other drilling parameters such as SWOB, ROP and drillpipe velocity to indicate what kind of operation had been done. After all well information had been arranged, the pressure loss calculation was done using appropriate predictive model. An appropriate model of calculating pressure loss analyzed by statistical method was integrated with well descriptions and drilling parameters. Due to the technical limitation of accessing LAS file from service company, this research cannot update the predicted result in every single seconds as real time concept. The software updated the data manually only when the user received LAS file from service company which was likely semi-realtime software.

4.5.3 Display Section

A user-friendly program can display well trajectory where the position of well has been drilled, casing program with measured depth, also pressure window between ECD in unit of pound per gallon and measured depth in unit of meter. This displayed ECD window, widely used in oil and gas industry, was plotted comparing with pore pressure and fracture gradient. Pore pressure, which was determined from repeat formation tester (RFT), was the pressure contains fluid inside pore volume of formation. Hence, estimated real-time ECD should be kept above pore pressure. Unfortunately, the interface in Figure 4.24 displayed pressure window consisting only pore pressure and ECD. There was a lack of fracture gradient because operating company did not have fracture gradient. This problem usually occurred when the well was drilled in the same concession as previous well, where formation was well-known and the difference between pore pressure and fracture gradient was very large. Hence operating company can neglect this fracture gradient. By the way for safety issue the pressure window should maintain both pore pressure and fracture gradient. In drilling operation, whenever ECD or downhole pressure was out of range from this window, for example below pore pressure, user or driller will be warned that drilling condition is harmful, and possibly lost well control.

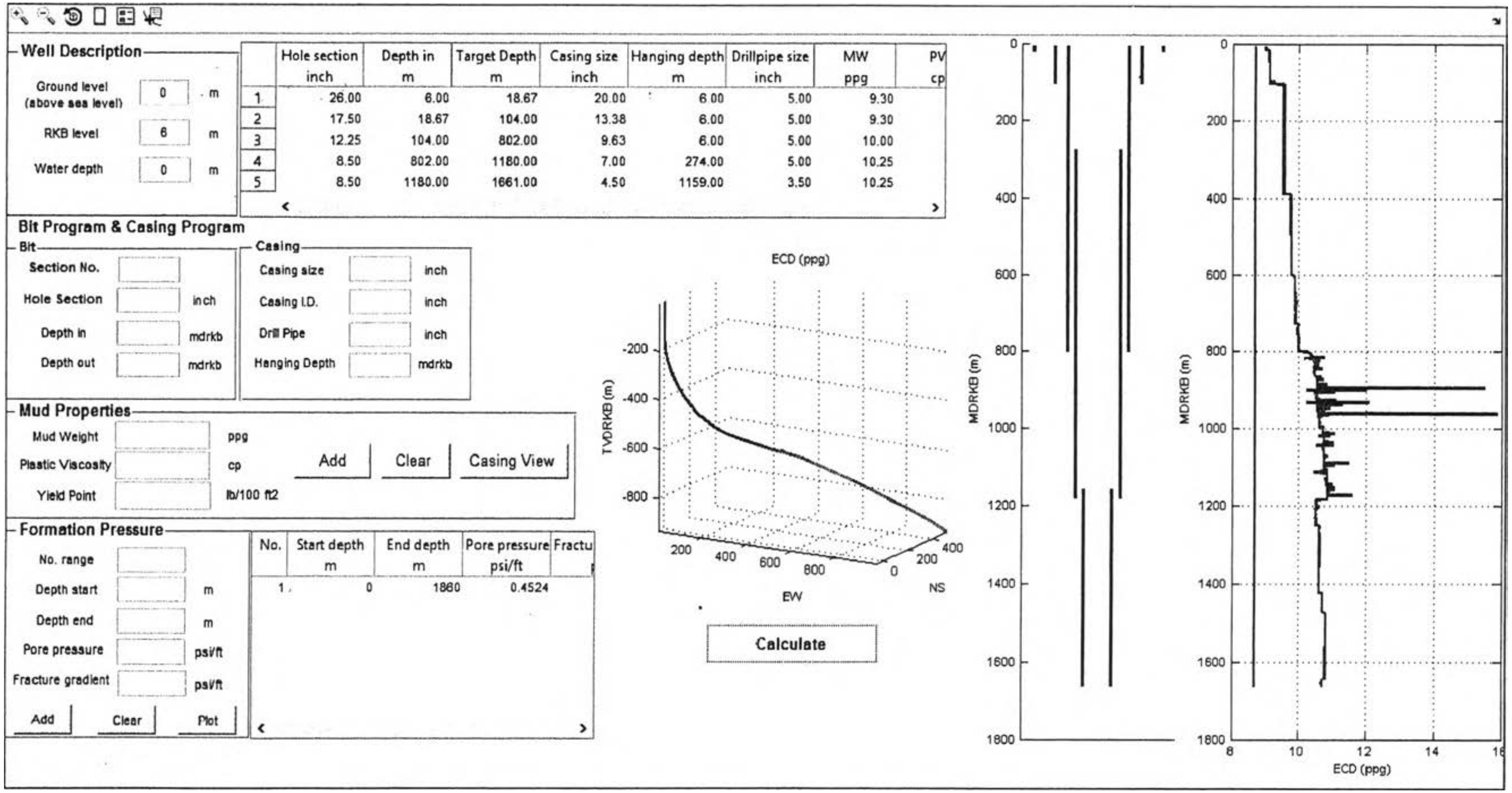

Figure 4.24 A user-friendly software interface