INCREASING CRUDE OIL PRODUCTION BY INTERMIT OPERATION IN MAE SOON OIL FIELD, FANG BASIN

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A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Engineering in Geotechnology

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การเพิ่มปริมาณการผลิตน้ำมันดิบด้วยการปฏิบัติการเปิด-ปิดหลุมเป็นครั้งคราว ในแหล่งน้ำมันแม่สูน แอ่งฝาง

นางสาวเสาวลักษณ์ พิทักษ์วงศ์

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิศวกรรมศาสตรมหาบัณฑิต

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Suranaree University of Technology has approved this thesis submitted in partial fulfillment of the requirements for a Master’s Degree.

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อาจารย์ที่ปรึกษา : อาจารย์ ดร.อัฆพรรค์ วรรณโกมล, 122 หน้า.

การศึกษาครั้งนี้ได้ทำการทดลองเพิ่มปริมาณการผลิตน้ำมันดิบโดยการปฏิบัติการเปิด-ปิดหลุมเป็นครั้งคราวกับหลุม FA-MS-07-08 ซึ่งอยู่ในแหล่งน้ำมันแม่สูนซึ่งเป็นแหล่งน้ำมันที่มีความสำคัญมากที่สุดของแอ่งฝาง หลุมนี้มีอัตราการผลิตน้ำมันน้อยซึ่งส่วนมากจะผลิตได้น้ำและมีอัตราการผลิตน้ำมันลดลงในปัจจุบันเมื่อเทียบกับอัตราการผลิตน้ำมันในอดีต ในเมื่อไม่สามารถเพิ่มอัตราการผลิตน้ำมันได้ จึงมีความจำเป็นอย่างยิ่งที่จะต้องหาวิธีการลดค่าใช้จ่ายในส่วนต่าง ๆ เพื่อให้ยังคงได้กำไร วิธีการปฏิบัติการเปิด-ปิดเป็นครั้งคราว ถูกเลือกนำมาใช้ศึกษาในการวิจัยนี้เพื่อตอบสนองวัตถุประสงค์ดังกล่าว โดยที่หลักการ ของการปฏิบัติการเปิด-ปิดเป็นครั้งคราวคือลดชั่วโมงการทำงานของอุปกรณ์ช่วยผลิตแบบก้านชักจากเดิมทีทำการผลิตวันละ 24 ชั่วโมง มาเป็นการผลิตเพียงวันละ 12 ชั่วโมง วิธีการในการศึกษาประกอบไปด้วย (1) ทำการรวบรวมข้อมูลการผลิต ข้อมูลการเจาะและข้อมูลแหล่งกักเก็บของแหล่งน้ำมันแม่สูน (2) ทำการเก็บข้อมูลของหลุมเจาะเมื่อทำการเปิด และ ปิด อุปกรณ์ช่วยผลิตแบบก้านชัก (3) ทำการวิเคราะห์และทดสอบตัวอย่างน้ำมันที่เก็บมาจากหลุมทดสอบในห้องปฏิบัติการ (4) ทำการวิเคราะห์ทางเศรษฐศาสตร์จากการนำเอาวิธีการ การปฏิบัติการเปิด-ปิดเป็นครั้งคราวมาประยุกต์ใช้ในหลุมทดสอบ ซึ่งจากการศึกษาครั้งนี้สามารถสรุปได้ว่าสามารถลดค่าใช้จ่ายในส่วนของค่าไฟฟ้าในการปฏิบัติงานของอุปกรณ์ช่วยผลิตแบบก้านชักได้ประมาณ เดือนละ ประมาณ 5,680 บาท และวิธีการนี้สามารถเพิ่มอัตราการผลิตน้ำมันเพิ่มขึ้นมากกว่าเดิมประมาณ 64 เปอร์เซ็นต์ และยังสามารถเพิ่มรายรับจากการขายน้ำมันได้ ประมาณเดือนละ 552,320 บาทอีกด้วย ผลการศึกษาในครั้งนี้สามารถเป็นประโยชน์ในการวางแผนการผลิตน้ำมันดิบของแหล่งน้ำมันฝางของกรมการพลังงานทหารได้ต่อไปในอนาคต

สาขาวิชาเทคโนโลยีธรณี ลายมือชื่อนักศึกษา ____________
ปีการศึกษา 2554 ลายมือชื่ออาจารย์ที่ปรึกษา ____________

SAOWALUCK PITUKWONG : INCREASING CRUDE OIL PRODUCTION BY INTERMIT OPERATION IN MAE SOON OIL FIELD, FANG BASIN. THESIS ADVISOR : AKKHAPUN WANNAKOMOL, Ph.D., 122 PP.

INTERMIT OPERATION/CRUD OIL PRODUCTION/BS&W MEASUREMENT/ MAESOON OIL FIELD/FLUID LEVEL SURVEY

This study conducted an experiment to increase crude oil production by Intermit operation method in FA-MS-07-08 well, located in Mae soon oil field which is the most important oil field of Fang basin. This well has a few amount of oil production, the most products are water, and present day oil production rate is decreased compared to the rate of oil production in the past. When it is not able to increase oil product, therefore, it is necessary to find solutions to reduce the production cost to get profit. The Intermit operation was selected to study in this research to meet the mentioned objective. The principle of Intermit operation is to reduce the operating hours of the sucker rod pump from 24 hours per day to 12 hours per day. The methodology for this study were as follows: 1) collected the production history data, drilling data and reservoir data of Mae Soon oil field, 2) collected the well bore data when start and stop the Sucker rod pump, 3) analyzed and tested oil samples collected from tested well in laboratory, and 4) conducted economic analysis resulted from applying the Intermit operation method to the tested well. As a result from this study, it can be concluded that the Intermit operation method could be reduce the electricity power cost of sucker rod operation about 5,680 Baht per month. This method can increase oil production rate about 64 percent, and can also increase

income from selling crude oil about 552,320 Baht per month. The result of this study can be useful for crude oil production planning of Fang oil fields in the future.

School of Geotechnology Student's Signature ____________________

Academic Year 2011 Advisor's Signature ____________________

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Saowaluck Pitukwong

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SYMBOLS AND ABBREVIATIONS

A	=	Ampere
API	=	America petroleum Institute
bbl	=	barrel
BHP	=	Bottom hole pressure
b/d	=	barrel per day
b/d/well	=	barrel per day par well
BS&W	=	Basic sediment and water
CCOP	=	Coordinating Committee for Geoscience Programmes
D	=	depth
EOR	=	Enhance oil recovery
F/L	=	Fluid Level Depth
FOP	=	Fluid on Pump Depth
ft	=	feet
GOC	=	Gas oil contact
H	=	Holiday
in	=	Inch
Kb	=	Absolute permeability
KB	=	Kelly Bushing
km	=	Kilometer
KS	=	Kamphaeng Sean

SYMBOLS AND ABBREVIATIONS (Continued)

KW	=	Kilowatt
Kx	=	effective permeability
Ma	=	Million ages
MMbaht	=	Million baht
MMbbl	=	Million barrel
MS	=	Mae Soon oil field
NW	=	North-West
No.	=	number
OP	=	Off Peak
P	=	On Peak
PF	=	Power factor
Q	=	flow rate
Ro	=	vitrinite reflectance
S	=	Stroke
SCF/bbl	=	Standard cubic foot per Stock tank barrel
SE	=	South-East
SG	=	Specific gravity
SKJ	=	Sung Kajai
SRP	=	Sucker rod pump
SW	=	South-West
Sp	=	Plunger stroke length

SYMBOLS AND ABBREVIATIONS (Continued)

sq.in	=	Square inch
sq.km	=	Square kilometer
Tmax	=	Temperature Maximum
TWM	=	Total Well Management
TOC	=	Total Organic Carbon
TOU	=	Time of use
US$	=	Dollars
US$/bbl	=	Dollar per barrel
Vo	=	Volume of oil
Vsc	=	volume of sediment ate from centrifuge
Vw	=	Volume of water
Vwc	=	Volume of water from centrifuge
WOC	=	Water oil contact
η	=	coefficient of viscosity
	=	fluid viscosity, (cp)
		fluid density
τ	=	shear stress
$\partial u/\partial y$	=	proportional to the velocity gradient
Δp	=	pressure drop

CHAPTER 1

INTRODUCTION

1.1 Background and rationale

Fang basin is a northern basin of Thailand where the first drilling for oil and gas has been conducted since 1922 (a just about after the survey of American geologist Mr. Wallace Lee) by Italian driller. Oil has been produced, using primary and secondary methods, from sandstone of the Mae Sod Formation in the Mae Soon, San Sai, Nong Yao, Sam Jang and Ban Thi structures. Most oil fields in Fang basin were produced by natural flows which now are expelled by low differential pressures and finally caused the low production efficiency. Present day sucker rod pumping are used to improve oil recovery of these oil fields. These oil fields have a long history of operation and production in some tracts has decreased, with many wells currently exhibiting water cut increases. In order to reduce operating expenditures on electricity for sucker rod pumping unit, Intermit operation is selected to study in this research. The methods of Intermit operation is built up the pressure in hole by shut in well for 12 hrs and then open hole for normal flow for 12 hrs. As a result, the work hour of sucker rod pump is reduced. Moreover, the useful life of sucker rod pumping unit could also be extended and this can reduce its maintenance and spare parts costs.

1.2 Research objective

The objective of this study are to increasing oil production and reduce the expenses in electricity cost and extend the useful life of the sucker rod pump of Mae Soon oil field by using Intermit operation method.

1.3 Scope and limitations of the study

This study is focused on the Fang oil field, which located in the Northern part of Thailand. Selected well was from the Mae Soon Oil Field due to this field has been produced for a long production period. In addition, the selected well should has low oil production efficiency even it was installed a sucker rod pumping unit. Testing period was limited to only 8 days because this test must not disturb the production capacity of the study oil field.

1.4 Study area

1.4.1 Location and Accessibility

The study oil field is situated between latitude 19 43 north and 20 04 north and longitude 99 05 E and 99 30 E. The area can be reached by car from Chiang Mai via highway no.107, the distance being about 140 km. (Figure 1.1).

Fang basin is situated in the northern part of Thailand and occupies the area around Amphoe Fang, Mae Ai and Chaiprakarn, this being approximately 600 square kilometers (Figure 1.2). The study area lies within topographic map sheet NE 47-3, series 1501 S, edition 1, scale 1:250,000, of the Royal Thai Survey Department, Changwat Chiang Rai, Thailand, Laos, and the Union of Myan Mar.

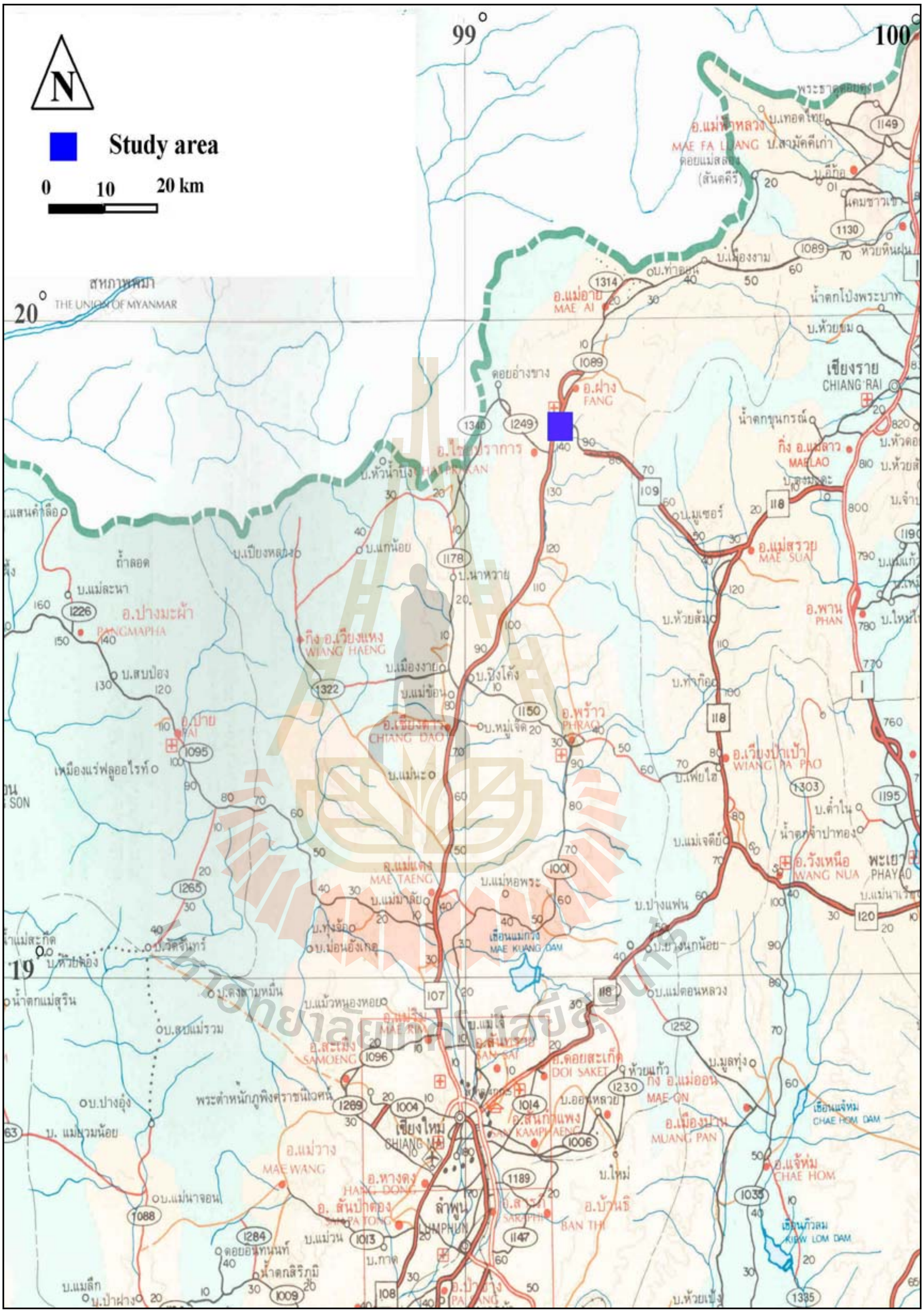


Figure 1.1 Map showing location of study area, national and provincial highways in northern Thailand (after Roads Association of Thailand, 2000).

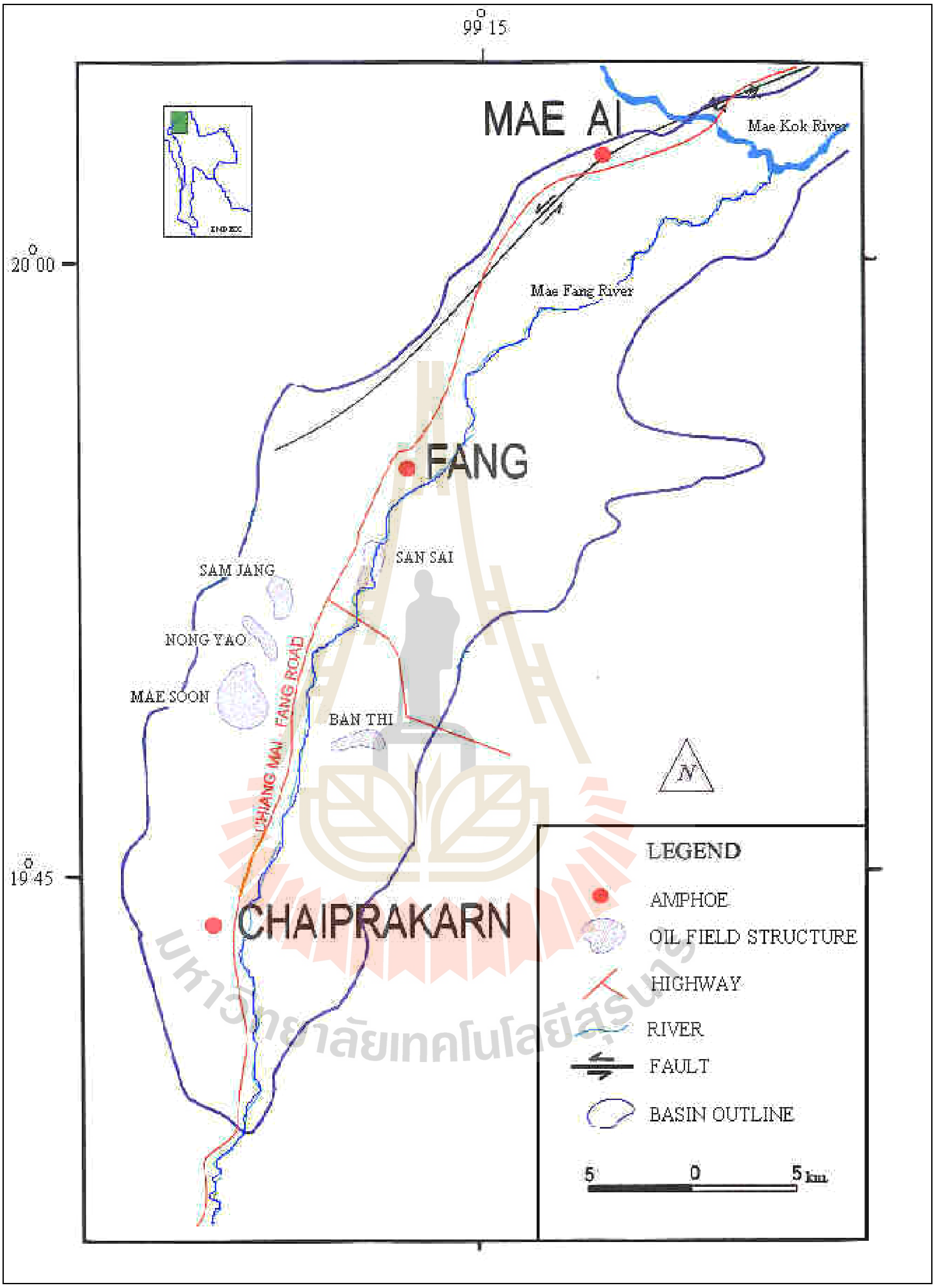


Figure 1.2 Fang basin out line and oil field structure (modified after Polachan and Sattayarak, 1989)

1.4.2 Physiography of the basin

The Fang basin is a present-day mixture of flat plain and small hills. It is surrounded by a high mountain range that is up to 1,400 meters above means sea level to the west and up to 500 to 550 meters to the east. The basin is elongate in shape. The axis of the basin trends north northeast-south southwest. The major river in the basin is the Mae Fang River. The Mae Soon, Nong Yao, and Sam Jang structures are situated in the western side of the basin, at an elevation of 460 to 480 meters. The San Sai and Ban Thi structures are in the center and east side of the basin, respectively, at elevations of approximately 460 to 480 meters.

1.5 Research methodology

1.5.1 Literature review

Relevant literatures were searched, reviewed, summarized and documented. Initially, all source of the data concerning with Fang basin were collected and examined. These data included geology of Fang basin, petroleum system, stratigraphy and structure of Mae Soon Oil Field. Production history data, porosity calculations of reservoir rocks, field works and the laboratory work then followed.

1.5.2 Crude oil sample collection and preparation

Crude oil samples were collected from FA-MS-07-08 located in Mae Soon oil field well during 13 to 19 September 2011. Crude oil samples were taken during sucker rod pump was operated. Samples were taken every 1 hour until up to 13 samples per day. Crude oil samples were kept in plastic bag. Sample preparation had been carried out to the laboratory at Defence Energy Department, Thailand.

1.5.3 Measurement in laboratory

In laboratory, Bottom Sediment & Water (BS&W) measurements of the 13 samples were usually done within 12 hours every day. This is because when removed from an oil reservoir, the crude oil were usually contained some amount of water and particulate matter from the reservoir formation.

1.5.4 Economic Analysis

In order to conduct economic analysis, crude oil production between normal production operation (24 hours operation) and Intermit production operation (12 hours operation) were compared, in addition with their electricity costs and possible income from both operations.

1.5.5 Thesis writing and presentation

All research activities, methods, and results were consequently documented and presented in the thesis. It included comprehensive methodology, results, discussions and conclusions of the study.

CHAPTER II

LITERATURE REVIEW

2.1 Geology of Fang basin

The base of sedimentary sequence in Fang basin is marked by unconformity as a result of a great period of erosion that preceded the sedimentation of Miocene-Pliocene deposits. At the end of Pliocene the series of deposits was followed by sedimentation in fluviatile and continental environment as a result of filling basin. The character of lacustrine deposit of Miocene-Pliocene is indicated by numerous coal seams and carbonaceous sediment. The dominant lithologic type in Miocene-Pliocene deposits is dark clays and sandy clays with lignite. Fang basin had a subsidence in the central part with about 3,000 m thick of sediment. The wedging out of the beds and the prograding sedimentation are characteristic of delta rivers zone (Dutescu et al., 1980).

The Fang basin is on the western margin of the Sukhothai fold belt, which comprises Paleozoic and Triassic strata and volcanic rocks that accumulated on the eastern margin of the Shan-Thai craton prior to the Indosinian orogeny. This fold belt is complex and trends north northeast-south southwest. These rocks were uplifted and deformed by granitic intrusions during the collision of the Indochina and Shan-Thai cratons (Bunopas and Vella, 1983).

The Fang basin was filled with rocks of Tertiary and Quaternary age. These Cenozoic rocks and sediments consist of shale, sandstone, conglomerate, sand, and gravel (Baum, Braun and Hahn, 1976).

Settakul (1985) classified sediments and rocks in the Fang basin into two units. These units are the Mae Fang Formation and the Mae Sod Formation. The depositional environment in the Tertiary time was fluvial-lacustrine and changed to fluvial and alluvial in Quaternary time. The tertiary rocks of the Fang basin are conglomerate, sandstone, claystone, and shale. The Quaternary deposits are silt, clay, sand, and gravel and occur as stream channels, terrace deposits, and alluvial fans. These sediments are covered by recent soil and lateritic sand. The Pre-Tertiary basement rocks consist of sedimentary, metamorphic, and igneous rocks. On the western side of the basin, the rocks are Cambrian-Permian age, and include Carboniferous granite. On the eastern side of the basin, the rocks are Silurian-Devonian and Jurassic, along with Triassic granite as showed in Figure 2.1.

2.2 Structural of Fang basin

2.2.1 Structural Settings

Zollner and Moller (1996) summarized structural setting of Fang basin as a series of intramontane basin generally trending NNE-SSW. These basins were formed in Early-Mid Tertiary times as pull-apart basins in a transtensional regime followed by Pliocene to Pleistocene compressional tectonics. Fang basin is subdivided into three sub basins separated by basement ridges. It composed of the Huai Pa Sang sub basin, the Huai Ngu sub basin and the Pa Ngew sub basin. The basin has an elongated. rhomboedric outer shape. The southern part is nearly trending N-S and the northern part the basin axis is changing to a NE-SW direction. The investigated 3D survey the Fang basin is bordered to the west by a steep dipping NNE-SSW trending basin margin fault. In the east basement outcrops at the surface.

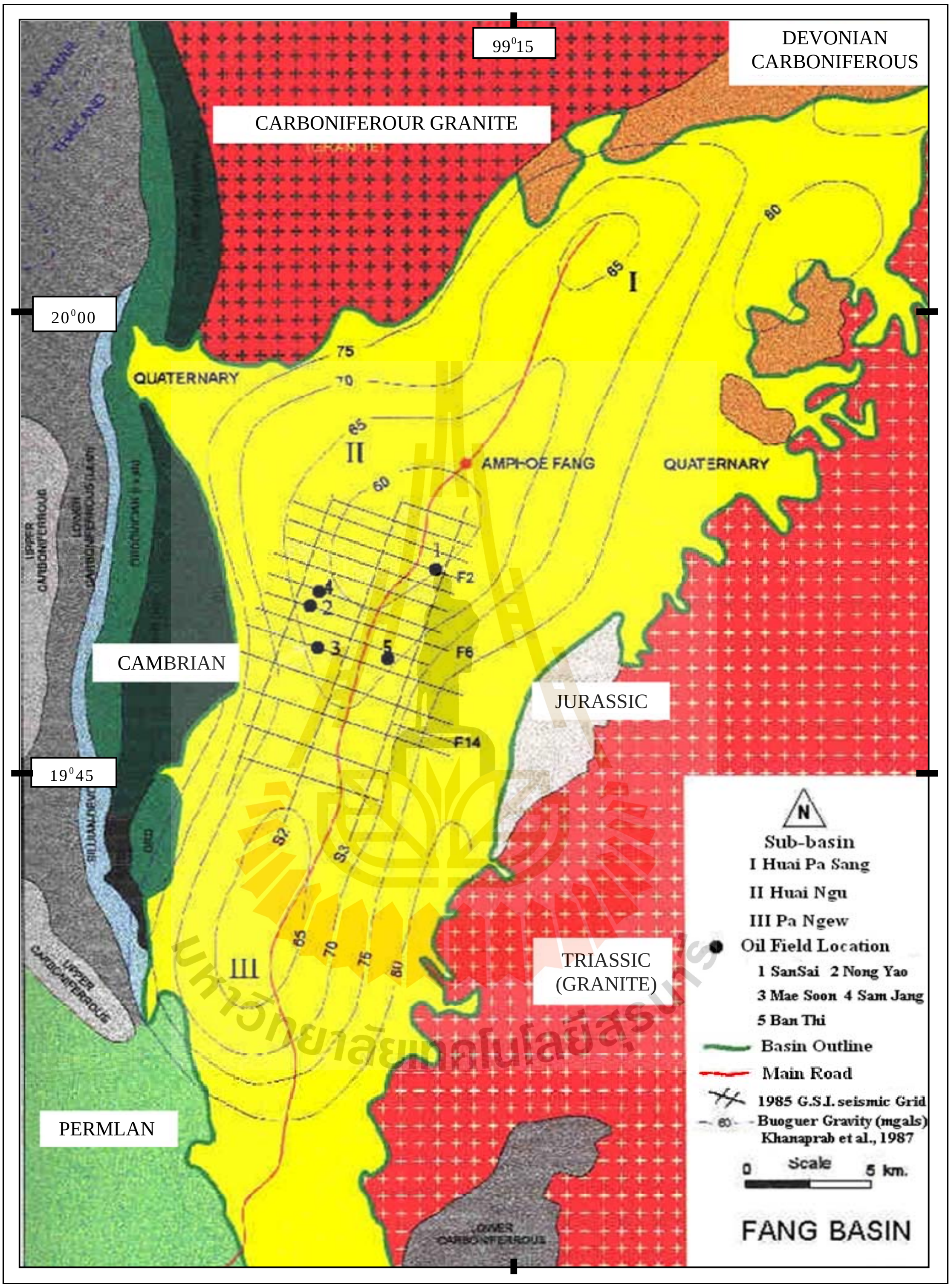


Figure 2.1 Fang basin geology and sub-basin division (modified from Petro-Canada Resources, 1988).

The basin margin fault has in the north a convex shape towards the south the shape changes from convex to concave and back to convex. In the Northwest a graben structure with normal faults is developed and SW is dipping major fault. The Southwest is represented by a faulted and anticline consist of Mae Soon oil field and Ban Nong Yao oil field. The east of the investigated area is dominated by west dipping, NNE-SSW trending faults. The structural nose of the San Sai oil field is related to one of these normal fault trends.

In 2002 Coordinating Committee for Geoscience Programmes in East and Southeast Asia (CCOP) also supported pull apart basin idea, which described The Fang basin formed as a series of pull apart basins of mainly north-south trending half grabens. The area is bounded to the south by the Uttaradit Fault Zone and its assumed south westward projection. Basins are generally narrow but deep and occasionally emit an abnormal high heat flow. Petroleum is produced from fluvio-lacustrine sandstones which are sealed and sourced by lacustrine shales of similar age. A variety of structural traps are present, such as antithetic and synthetic faults, rollover anticline and normal fault. Oil shows from well penetrating Triassic sandstone basement does not rule out the possibility of finding hydrocarbon in pre-Tertiary rocks in the area.

However Woganan et al., (2001) described structure setting of Fang basin as a rift basin about 18 km wide and 40 km long and produces a modest amount of hydrocarbons. Three main depocentres are present. The basin is bounded by a N–S-trending, east-dipping boundary fault, which turns into the ENE–WSW-trending Mae Chan fault at the northern margin of the basin. The Mae Chan fault is one of the enigmatic strike-slip faults of Thailand, and has been regarded as one of the dominant set of strike-slip faults developed during escape tectonics. Instead the Mae Chan fault must turn into the east-dipping boundary fault of the Fang basin, and does not extend westwards into basement rocks. Hence the Mae Chan fault appears to be kinematically linked with basin bounding extensional faults, and probably represents an oblique slip transfer fault. The fault zone occupies a valley and its linear trace is very apparent on satellite images. The geomorphology of the hills flanking the fault zone shows no evidence for recent fault activity. The results contrast with two ages for granites on the southeastern flank of the Fang basin that show onset of cooling during the Late Cretaceous–Early Tertiary and slow uplift during the Tertiary.

The Department of Mineral Resources (1998) encourages of rift basins idea, which Fang basin occurred as intermontane and rift basins. The long axis of the basins normally oriented in N-S direction that were related to the collision of India with Asia. It has a half-graben geometry the east dipping boundary fault, and in the north by ENE-WSW trending Mae Chan fault, thickening westward with a maximum total thickness of about 2800-3000 m. Based on bouguer gravity contour map (Petro-Canada Resources, 1988), the Fang Basin consists of 3 extensional sub-basins i.e. Huai Pa Sang, Huai Ngu and Pa Ngew. Six structural oil fields were recognized, namely Chai Phra Karn, Mae Soon, Pong Nok, Huay Born, Pha Dang, and Pha Ngew,

Petersen (2007) described that the Fang basin is Cenozoic rift-basins onshore Thailand are 2-4 km deep. Approximately 800 bbl/day of crude oil is produced from the Fang field (Fang Basin), which in reality consists of a number of minor structures including Ban Thi, Pong Nok, San Sai, Nong Yao and Mae Soon.

Dutescu et al., (1980) supported intracratonic basin idea that the Tertiary Fang basin was formed during intramiocene orogeny as a result of epirogenitic movement that conducted to the forming a graben type structure on the central zone of Shan-Thai Craton. The basement of this basin is rather complex. On the tentative structural map the Fang basin appears asymmetric basin. The eastern flank dipping gentle while the western one is more steep an faulted by the Mae Soon fault. From south to north the basin is divided in three small basin separated by the saddles. The three basins are most important as hydrocarbon generating possibility seems to be the central part of Fang basin.

2.2.2 Structural style

The structural style of Fang basin can be explained by transtensional and transpresstional left-lateral tectonic system. Zollner and Moller (1996) summarized a tectonic development with an initial transtensional tectonic phase with left-lateral movements is interpreted to be responsible for the rhomboedric. Outline of the Fang Basin with +/- N-S trending basin margins in the west and east and +/- NE-SW trending basinmargins in the north and south. A conjugated system of NW-SE trending faults is interpreted to be responsible for this displacement. This conjugated fault system is represented within the 3D-survey by the major NW-SE trending normal fault. During this transtensional phase as well trending normal faults are generated. Compressional tectonic phase generated of both structural high trends (Mae Soon/Ban Nong Yao and San Sai) has to be related to the Pliocene/Pleistocene. During this compressional phase the old extensional faults were reactivated as reverse faults. The San Sai structure could be formed only by compression from the west whereas the Ban Nong Yao / Mae Soon structure required compression from the east to be developed. Similar tectonic features as they are represented by the Ban Nong Yao / Mae Soon structure are described by SHAW et al., (1994). These forms of anticlines are related to the change of dip of the underlying thrust fault (basin margin fault) resulting in an anticline in the area where the thrust fault changes its character from convex to concave and back to convex. The resulting extension at the top of the structure is in the Fang basin compensated by crestal collapse graben structures.

However Woganan et al., (2001) described structure style of Fang Basin to show such rift basin cycles. The early stage is a period of relatively slow subsidence that may be due to slow strain rates or to the characteristics of early fault linkage geometries. Later as boundary faults become well established, subsidence becomes greater. Given the right climate and sediment supply conditions, more permanent and commonly deep water lacustrine environments become established. In the relatively small rift basins of northern Thailand long-lived deep water lacustrine conditions were difficult to maintain. Instead in the deeper parts of the basins, adjacent to boundary faults, rift sediments cycled through deeper to shallow water lacustrine environments where organic rich were deposited in deeper lacustrine. Passing towards the flexural margins or horst blocks, lacustrine deposits between the split coal seams pinch out, and the coal becomes concentrated into one or a few thicker seams, commonly cut by fluvial sandstones and gravels. As subsidence rates decrease during the final stages of rifting, sediment supply begins to exceed the subsidence rate and lacustrine conditions give way to final rift infilling of fluvio-deltaic sediments. If inversion occurs at the end of rifting it will not only halt subsidence, but promote uplift and increase sediment supply. Hence, inversion is likely to enhance the development of late fluvio-deltaic conditions in rifts. As the lakes became in filled, larger fluvial systems developed that could traverse multiple rift basins.

2.3 Stratigraphy

According to works of Settakul (1985) the stratigraphy of the Mae Soon structure is typical of the Fang basin. Based on seismic data, drill cuttings, and well logs, the stratigraphy of Mae Soon structure was separated into two formations. These formations are the Mae Fang Formation, above, and the Mae Sod Formation, below which are illustrated in Figure 2.2.

2.3.1 Mae Fang Formation

The Mae Fang Formation is composed of Quaternary sediments. It varies in thickness from 330 meters on the crest of the Mae Soon structure and to 540 meters on the flank of the structure. Six meters of lateritic sand and soil occur at the top of the formation. Below this, the formation is composed of loose sand that contains pebbles and cobbles. This sand alternates with blue, and grey clay. The sand is 94 percent quartz and 5 percent feldspar. It also has some carbonized wood fragments. The quartz grains are coarse to very coarse, angular to sub-angular, poorly to moderately sorted. The upper part of formation is interpreted as an energetic alluvial and fluvial facies while the lower part is regraded as a fluvial-lacustrine sequence that is characteristic of a tropical and an oxidizing facies. The formations was presumed to have been deposited in Pleistocene to Recent time.

2.3.2 Mae Sod Formation

The Mae Sod Formation is Tertiary in age. It is an altering sequence of shale, claystone, and fine-grained sandstone. The sandstone occurs as interbeds 0.3 to 9 meters thick. There is a high frequency of interbedded sandstone in the upper part of formation, down to a depth of about 750 meters. The lower part of the Mae Sod formation is composed mainly of shale. The lower part of the formation was deposited in an oxidizing and reducing environment. The sandstone interbeds in the upper part of the formation can be divided into groups on the basis of well logging data. Each of these groups consists of three to five of sandstone beds. The sandstone is compacted, fine- to coarse-grained, and brown to grey. Each sandstone group is interbedded with 30 to 60 meters of shale. The maximum thickness of Mae Sod Formation in the Mae Soon structure is 1,985 meters. The sandstone reservoirs of the Fang basin oil fields are divided into five units on the basis of logging data from well FA-MS-26-39 of the Mae Soon structure. Details of these five units can be summarized as follows (Figure 2.2):

1. Song Khwae Sand (D-Sand unit) : Four beds, 3 to 4.5 meters thick and at depths of 484 to 514 meters.

2. Nong Yao Sand (E-Sand unit) : Two beds, 3 to 4.5 meters thick and at depths of 540 to 570 meters.

3. Ban Yang Sand (F-Sand unit) : Three beds, oil bearing, 3 to 4.5 meters thick and at depths of 598 to 619 meters.

4. Pang Sak Sand (G-Sand unit) : Five beds, oil bearing, 1.5 to 4.5 meters thick and at depths of 648 to 677 meters.

5. Ang Khang Sand (H-Sand unit) : Four beds, oil bearing, 1.5 to 13.5 meters thick and at depths of 716 to 746 meters.

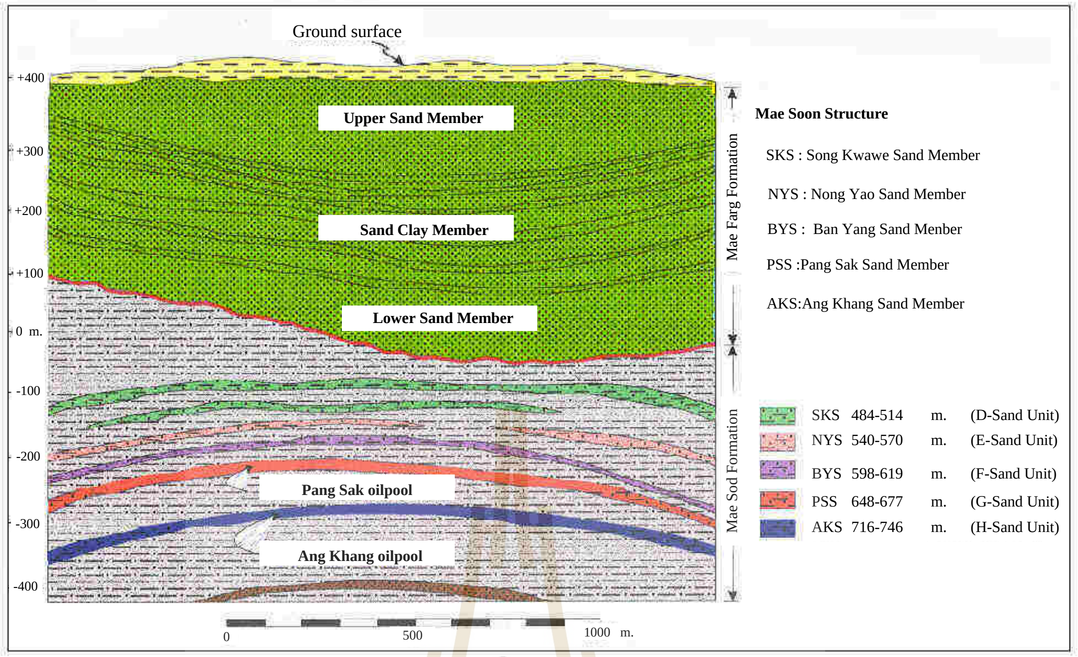


Figure 2.2 Geological cross section showing five sandstone units of the Mae Soon structure (modified from Settakul, 1985).

The San Sai structure contains both the Mae Fang and Mae Sod formations. The Mae Fang is composed of coarse to very coarse sand interbedded with grey, blue, and brown clay. The sequence was deposited in a fluvial environment and occurs down to a depth of 774 meters. The Mae Sod Formation of the San Sai structure was separated into three zones, upper, middle, and lower Mae Sod. Oil productive sandstone occurs in two zones, one at about 1,115 meters depth and one at 1,300 meters depth. The Nong Yao structure is the same as the Mae Soon structure. The upper part of the Mae Sod Formation is divided into five units, D, E, F, G, and H. The oil productive zones are units G and H, at about 774 meters depth and 805 meters respectively. In the Ban Thi structure, the Mae Fang Formation is occurs down to a depth of 242 meters. It is composed of sand and gravelly sand and is interbedded with grey, brown, and black clay. The Mae Sod Formation is composed of brown and grey shale and grey claystone and has interbeds of fine- to very coarse-grained sandstone. A coal bed occurs at the depth 1,115 to 1,146 meters. The structure has two oil productive zones, one at 341 meters and one between 1,174 and 1,240 meters. In the Sam Jang structure, the Mae Fang Formation occurs down to a depth of 585 meters. It is composed of gravelly sand and coarse- to very coarse-grained sand interbedded with yellowish brown clay. The Mae Sod Formation is composed of conglomerate and fine- to very coarse-grained sandstone interbedded with shale. Oil productive zones are occurs at depth of 1,146 meters and 1,207 meters.

2.4 Source Rock

2.4.1 Depositional System

Source rock data in Fang Basin have been analyzed by Core Laboratories Malaysia SDN BHL (Peter, 1992). In general the complete sequence of rock is deposited in a continental environment, covering purely continental to lacustrine depositional environments. The ages and character of each of the main depositional sequences present in the Fang basin are summarized in Figure 2.3. Five major sequence packages are identified.

The evolution of the depositional environments active in the Fang basin during Tertiary time began with localized Undifferentiated continental (marginal lacustrine) in the late Eocene (Sequence 1). Overlain are these rock by layers of reddish brown shales and sands. The sand are describe as poorly sorted, angular and rock fragment rich. They are interpreted as the initial conyinental basin fill deposited during the opening of the basin from both basinmargins. At the top of sequence 1 have bituminous shales and lignite occur, interpreted to represent good source rock.

Increasing tectonic activity then result in the development of halfgraben basin is represented in the Oligocene (Sequence 2). In the lower most of this sequence can be describe as a from east to west prograding sequence with infill the developing half graben basin. It is represent by a series of sub angular to subrounded, moderately to well sorted grayish sandstones interbedded with shales. The lake deposits are represented in this sequence which consists of predominantly shales and coals. The coals are interpreted to be developed along the margin of the lake in a possible swampy environment that relative to low energy depositional environment. This halfgraben-type of lake deposits is know to have good source rock potential in several basins around the world. The upper of this sequence have ceasing tectonic activity then the basin is filled up with prograding sediment which consists of sub angular to subrounded, moderate sorted sands interbedded with shales. At the top of sequence 2 mark the end of the extensional tectonic phase.

Sequence 3 and Sequence 4 represent a tectonic quiet phase during which the complete basin subsides of sequence 3 that have sand interbedded with shales were deposited. Sequence 4 is represent by shaly interval with minor sands. The top of sequence 4 represents an unconformity marking the beginning of the compressional tectonic phase.

Sequence 5 is overlain by thick sand prone sediment.

The main hydrocarbon bearing reservoir in the Fang basin are Fluvial and Fluvio-Lacustrine in sandstone with in sequence 3 and sequence 4 and the prograding sand of sequence 2. The potential source rock will be describe above the bituminous shales and lignite of sequence 1 as well as the coal in sequence 2. Mostly intra formational shale layers are interpreted is a seal. The generation of structures is related to the compresstional tectonic phase at Pliocene/Pleistocene times. Migeation pathways are interpreted updip and along fault.

2.4.2 Source rock geochemistry

Source rock richness, as measured by percentage of total organic carbon, varies both laterally and vertically across the Fang Basin. Wells drilled in the region show pronounced TOC variances with depth that are facies controlled. Coal beds typically measure over 50% total organic carbon and coaly shales routinely contain 10%-50% TOC, but non-coaly shales have less than 5% TOC. Coal beds are discontinuous, relatively thin, and make up a small percentage of the total section within the basin.

2.4.3 Oil-prone source rocks

In the upper portion of the well at a depth of sequence 4 approximately 4,300 ft to 4,800 ft revealed the presence of much good quality, oil prone, type I kerogen. This good quality kerogen is predominantly algal derived and is considered to have been deposited in a lacustrine setting with some fluvial. These oils consistently yield low pristine/phytane ratio indicative of low oxygen condition typical of lake environments.

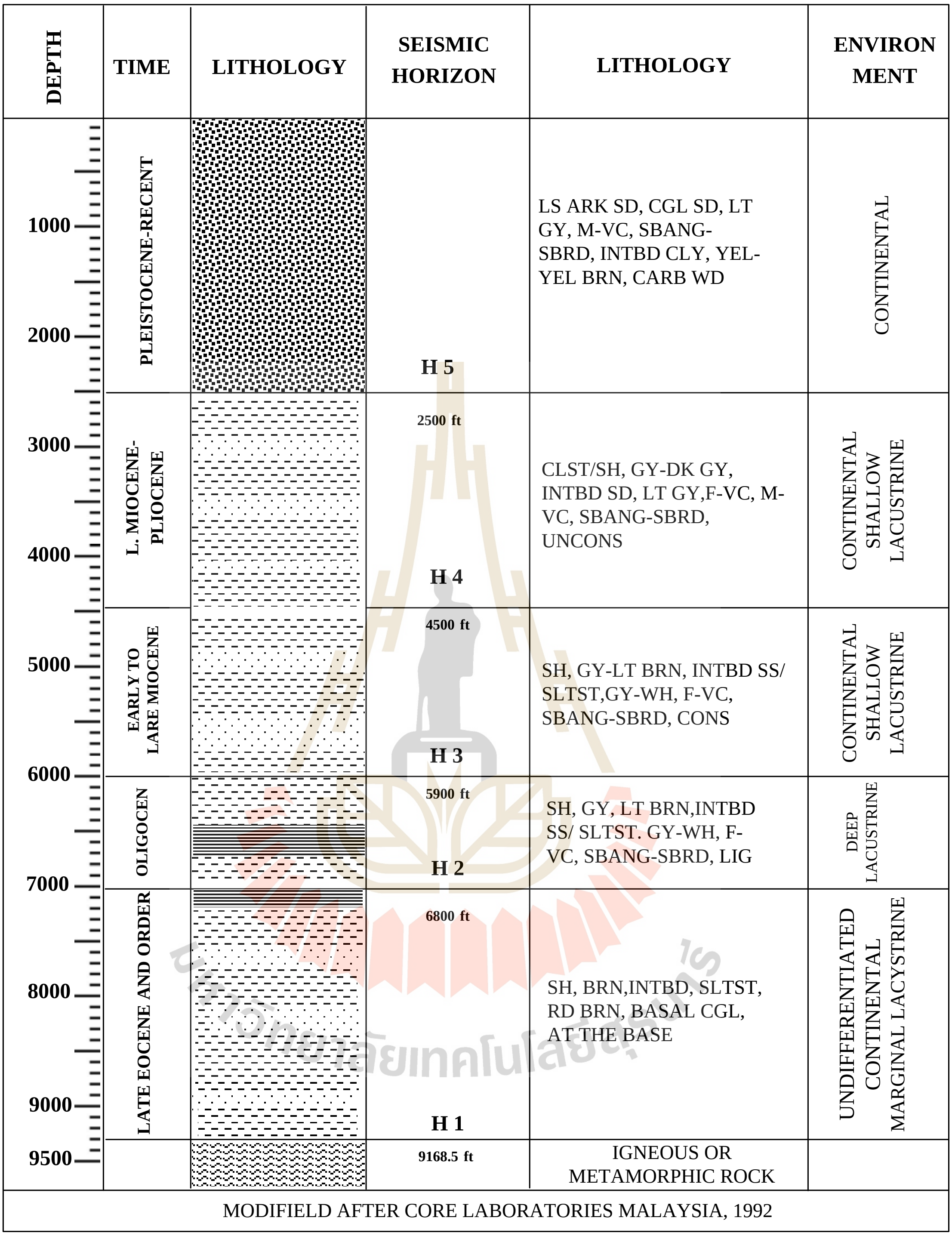


Figure 2.3 Stratigraphic summaries of the 5 major depositional sequences

2.4.4 Gas-prone source rocks

The sequence 1 and sequence 2 is predominantly gas prone and may have begun to generate hydrocarbon gas. The sequence 3 represent a transistion sequence in the well between oil-prone above and gas-prone below. This section is early mature and so slight oil and gas generation may have begun. The visual kerogen typing analysis of sequence 5 has revealed a predominance of Type III and Type IV kerogen suggesting only gas-generating ability. The kerogen assemblage dominate by land-derived material such as sporinite and resinite suggests a predominant a Fluvial depositional environment is a possibility. Geochemical analysis of gas condensate yields relatively high pristine/phytane ratio indicative of oxic source condition typical of terrestrial (fluvial-coal swamp) depositional environment.

2.4.5 Thermal maturity

The thermal stages of hydrocarbon generation used for interpretation of the petroleum systems active in the Fang basin are based on maturity measurements of sample. The hydrocarbon maturities are established using measured biomarker ratio and the Radke (1988) calibration to vitrinite reflectance (Ro), TAI, Tmax.

At optimum thermal maturiry of sequence 4, the section of the well down to 5400 ft (predominantly Early-Late Miocene) is considerate to be thermally immature for significant hydrocarbon generation to have occurred. At greater depth the same organic facies persists significant oil generation could be expected. Sequence 3 is early mature and so slight oil and gas generation may have begun. In sequence 1 and sequence 2, although optimally mature for hydrocarbon generation is predominantly gas prone and may have bugun to generate hydrocarbon gas.

2.5 Trap of Fang basin

Settakul (1985) Classified trap of Fang basin as stratigraphic trap and structural trap. Fang basin now produces oil from five structures, all of which are in the Huai Ngu sub-basin. These are the Mae Soon, Nong Yao, Sam Jang, San Sai, and Ban Thi structures.

Ban Thi structure is a structural trap compose of monocline and fault trap. Monocline dips northwest about 10º to 20 and west-dipping normal faults in the eastern part of area.

Traps in the Nong Yao structure are both structural and stratigraphic trap. Structure is an asymmetrical anticline fold, its axis is east-west. Many major and minor normal faults occur in the area and faults trend north-south.

The Mae Soon structure is a combination of structural and stratigraphic traps. The structural trap is anticlinal. Lateral lithofacies changes and pinchouts to impermeable rocks form the stratigraphic traps. Three fault zones occur in the Mae Soon area. These are a combination of thrust faults with a strike slip fault oriented northeast-southwest and dipping 85 to the northwest.

The San Sai structure is a monocline that dips about 10º to 20 to the central part of basin. There are two major faults in eastern part of the structure that trap oil. Oil is also trapped stratigraphically in this structure.

Traps of Sam Jang structure are both structural and stratigraphic. The structure is an anticline fold.

2.6 Case Study of Intermit test in Development Plans

In Thailand, Intermit operation was applied at UT1-7/D5 and UT1-7/D8 wells located in U-Thong oil field of PTTEP in Central plain Thailand. The trial of intermit operation provided major benefits to reduce the cost of electricity and could also increase oil recovery factor.

As a result, production data, production rate and summary of electricity bill of both well during applied Intermit operation period are summarized and illustrated in Table 2.2 – Table 2.3 and Figure 2.18-Figure 2.19 respectively.

Well UT1-7/D8 started applying Intermit operation method in April 2010 and could reduce the electricity bill as showed in Table 2.4. Intermit test method to produce the same amount the volume of production or decreased only slightly when compared with online sucker rod pump 24 hrs. The BS&W of this well resulted from Intermit operation was decreased with an average of 81.66% whilst the oil production rate was increased with an average of 7.045 BBL. In the present UT1-7/D8 well has production in the range 08:00-18.00.

Table 2.1 Summary of the production data results of intermit test UT1-7/D5 well

Date	Total (bbl)	Crude (bbl)	Water (bbl)	F/L (start)	FOP (start)	F/L (stop)	FOP (stop)	BS&W (%)	Time
28/06/10	-	-	-	-	-	992	21	29	14:00-08:00
29/06/10	100.74	71.522	29.213	847	166	986	27	29	14:00-08:00
30/06/10	97.72	69.380	28.338	833	180	978	35	29	14:00-08:00
01/07/10	105.92	75.303	30.717	837	176	-	-	29	14:00-08:00
02/07/10	105.56	74.948	30.612	800	213	985	28	29	14:00-08:00
03/07/10	113.57	80.635	32.935	800	213	-	-	29	14:00-08:00
04/07/10	158.16	112.294	45.866	-	-	-	-	29	14:00-08:00
05/07/10	114.79	81.501	33.289	-	-	-	-	29	14:00-08:00
06/07/10	116.41	82.651	33.759	-	-	989	24	29	14:00-08:00
07/07/10	111.90	79.449	32.451	816	197	995	18	29	14:00-08:00
08/07/10	113.10	80.301	32.799	844	169	984	29	29	14:00-08:00
09/07/10	107.37	76.233	31.137	833	180	1004	9	29	13:00-08:00
10/07/10	115.21	81.799	33.411	840	173	1000	13	29	13:00-08:00
11/07/10	117.20	83.212	33.988	-	-	-	-	29	13:00-08:00
12/07/10	110.82	78.682	32.138	850	163	953	60	29	12:00-08:00
13/07/10	102.48	72.761	29.719	-	-	950	63	29	12:00-08:00
14/07/10	94.28	66.939	27.341			841	172	29	12:00-08:00
15/07/10	136.52	96.929	39.591	977	36	760	253	29	12:00-08:00
16/07/10	136.64	97.014	39.626	990	23	990	23	29	15:00-08:00
17/07/10	127.88	90.799	37.085	-	-	-	-	29	08:00-08:00
AVG	112.73	80.78	32.99	-	-	-	-	29	-

Table 2.2 Summary of the production data results of intermit test UT1-7/D8 well

Date	Total (bbl)	Crude (bbl)	Water (bbl)	F/L (start)	FOP (start)	F/L (stop)	FOP (stop)	BS&W (%)	Time
27/04/10	69.48	8.338	61.142	1002	161	1171	-8	88	08:00-20:00
28/04/10	57.67	6.920	50.750	1086	77	-	-	88	08:00-20:00
29/04/10	25.94	5.188	20.752	-	-	-	-	80	08:00-20:00
30/04/10	26.24	5.248	20.992	1019	144	1167	-4	80	08:00-20:00
01/05/10	44.32	8.864	35.456	-	-	-	-	80	08:00-20:00
02/05/10	28.35	4.253	24.089	-	-	-	-	85	08:00-20:00
03/05/10	34.02	6.804	27.216	-	-	-	-	80	08:00-20:00
04/05/10	35.12	7.024	28.096	-	-	1144	19	80	08:00-20:00
05/05/10	39.20	7.056	32.144	963	200	1144	19	82	08:00-20:00
06/05/10	38.19	6.874	31.316	990	173	1157	6	82	08:00-20:00
07/05/10	38.48	7.696	30.784	968	195	-	-	80	08:00-20:00
08/05/10	35.14	7.028	28.112	974	189	1147	16	80	08:00-20:00
09/05/10	47.50	9.500	38.000	989	174	1161	2	80	08:00-20:00
10/05/10	39.21	7.842	31.368	951	212	1152	11	80	08:00-20:00
11/05/10	37.94	7.588	30.352	953	210	-	-	80	08:00-20:00
12/05/10	36.43	7.286	28.144	970	193	1116	47	80	08:00-20:00
13/05/10	41.98	8.396	33.584	953	210	1141	22	80	08:00-20:00
14/05/10	33.65	5.048	28.603	974	189	1150	13	85	08:00-20:00
AVG	39.92	7.045	32.873	-	-	-	-	81.66	-

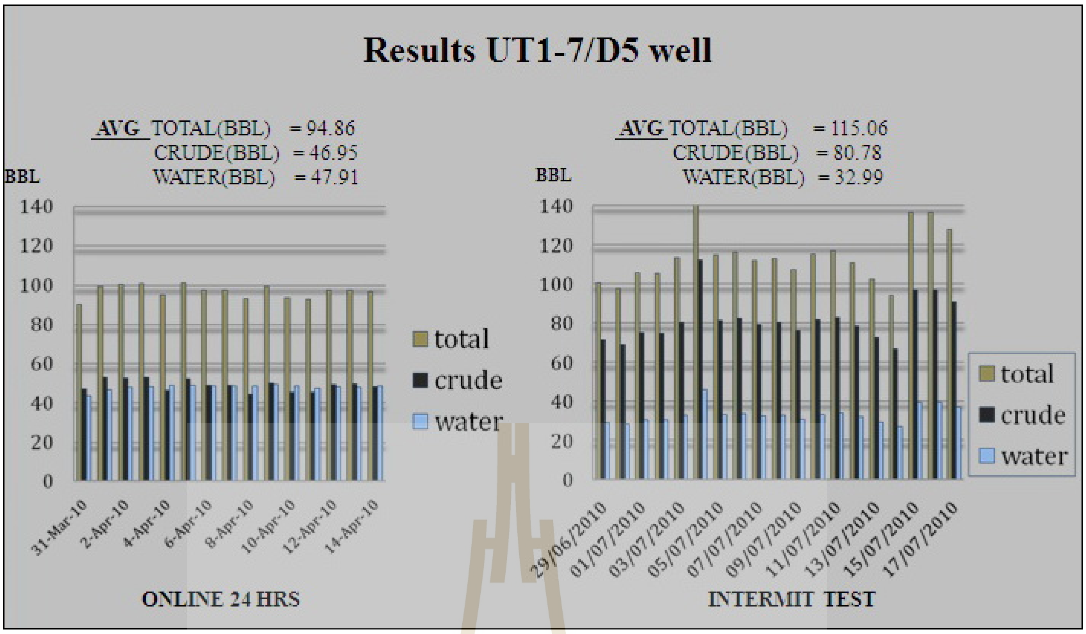


Figure 2.4 The results of the production rate between online 24 hrs of Intermit operation of UT1-7/D5 well.

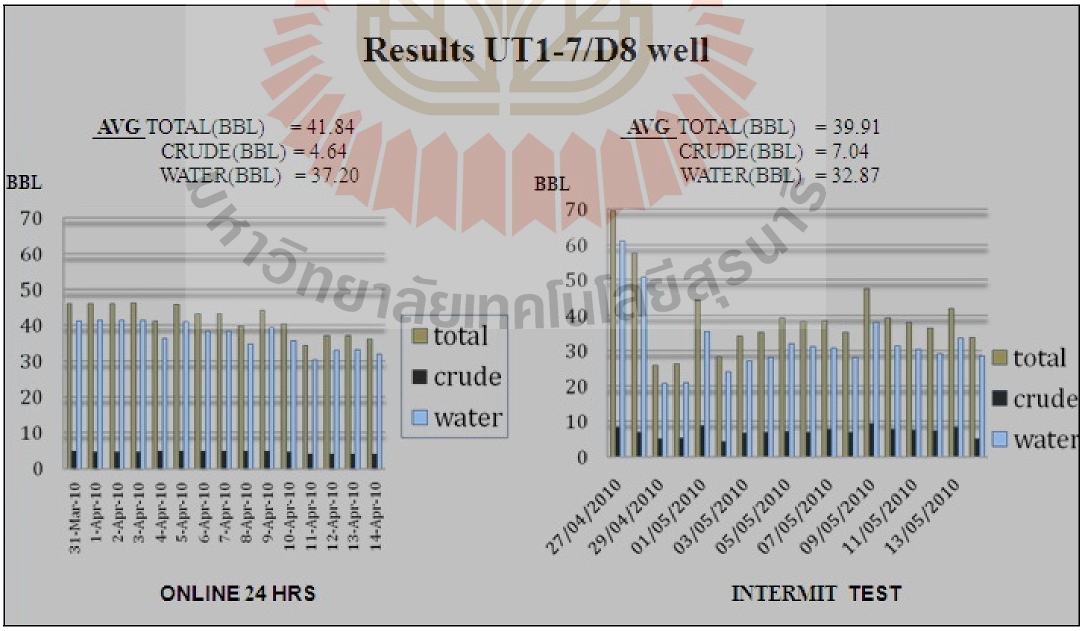


Figure 2.5 The results of the production rate between online 24 hrs of Intermit test method of UT1-7/D8 well.

Table 2.3 Summary of the electricity bill from March to June 2010 of UT1-7/D8 well from (Time of Use Tariff : TOU Tariff)

Mount	**Maximum of Electric Power (KW)**			**electricity bill (Baht)**
	P	**OP**	**H**	
March	242.4	189.6	188.4	383357.31
April	186.0	181.2	183.6	359361.58
May	180.0	174.0	172.8	359958.11
June	182.4	168.0	175.2	318595.55

Remark : P = On Peak
OP = Off Peak
H = Holiday

Therefore, as Fang basin is an onshore and having the same conditions in production operation as in U-Thong oil field, it is reasonable that Intermit operation could be applied to and may give positive results as in U-Thong oil field.

CHAPTER III

METHODOLOGY

3.1 Theory

Some theory backgrounds involved in study are given as in the following sections.

3.1.1 Water coning

Coning is a term used to describe the mechanism underlying the upward movement of water and/or the downward movement of gas into the perforations of a producing well. Petroleum reservoirs often have a gas cap an aquifer.

In these situations they are subjected to rapid gas or water movement towards the well as a result of a sharp pressure drop in the direction of the well. Prior to production, these reservoirs have defined fluid contacts: Water-Oil Contacts (WOC) and Gas-Oil Contacts (GOC). Once production commences, the previously defined contacts (WOC or GOC) now become deformed from its plane shape to form a cone or a crest. If a field is developed by vertical wells, the deformation is referred to as a cone. For horizontal wells, it is known as a crest. For the purpose of quantitative discussion, either the term "cresting" or "coning" may be used. Even in horizontal well cases, most engineers adapt the term "coning" to describe the simultaneous production of gas/water (Figure 3.1).

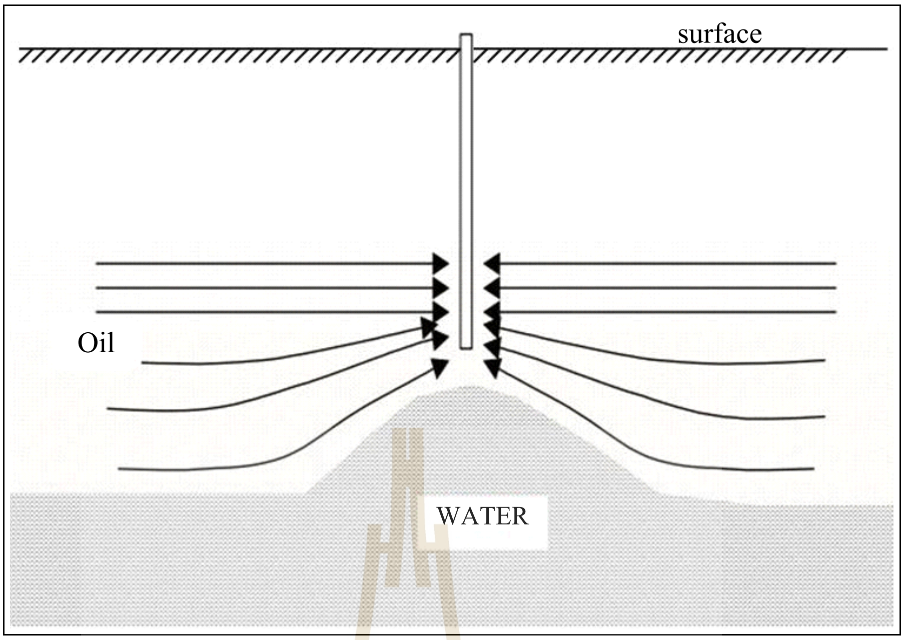


Figure 3.1 Schematic representation water coning in vertical wells.

The occurrence of water coning has been known for at least 60 years. In thin oil or gas pay sections, the presence of an oil-water or gas-water contact. Even when relatively thick pay sections are found, the encroachment of water when a water drive is present will eventually pose serious water coning problems. Briefly, water coning to the producing interval in a well is due to pressure gradients resulting from the production of fluid from the reservoir. These pressure gradients will cause a water cone to rise toward the bottom of the producing interval if a water-oil or water-gas contact exists.

In general, if water coning is occurred around producing interval or at well, it well obstruct oil flow into the well and cause lower oil production rate. For water flow to take in the reservoir, 3 factors must be present.

Source of water

The sources of produced water in clued formation water, aquifer, and inject water. The formation water can be originated from a water saturated zone whining the reservoir or zone above or below the pay zone.

Pressure gradient

Production of oil and gas from reservoir can only be achieved by applying a pressure draw-down at a well bore which create a pressure gradient within the formation.

Favorable relative permeability to water

For water to flow though a zone, the water saturation in that zone must exceed irreducible water saturation. As water saturation increase beyond the irreducible saturation, the relative permeability to water increase and relative permeability to hydrocarbon decrease. Oil, gas and water flow mainly along the path of least resistance, which are usually the higher permeability parts to the reservoir.

3.1.2 Flow in porous media

This section gives some useful about parameters that play an important role in flow in porous media including mobility ratio, relative permeability and viscosity.

Mobility ratio, M

The National Petroleum Council (NPC) defines Enhanced Oil Recovery (EOR) as "Incremental oil that can be economically produced over that which can be economically recoverable by conventional primary and secondary methods". The main goals of any EOR method are increasing the capillary number and providing 'favorable' mobility ratios.

The mobility ratio, M, is defined as the ratio of mobility of the displacing fluid to that of the displaced fluid.

$$M = \frac{(k/\ \ )_{displacing}}{(k/\ \ )_{displaced}} \tag{3.1}$$

$$M = \frac{(k_{rw}/\ \ _{w})}{(k_{ro}/\ \ _{o})} \tag{3.2}$$

Where k_{rw} = relative permeability of water

k_{ro} = relative permeability of oil

= viscosity

Relationships amongst mobility ratio, displacement efficiency and recovery efficiency, are demonstrated in Figure 3.2

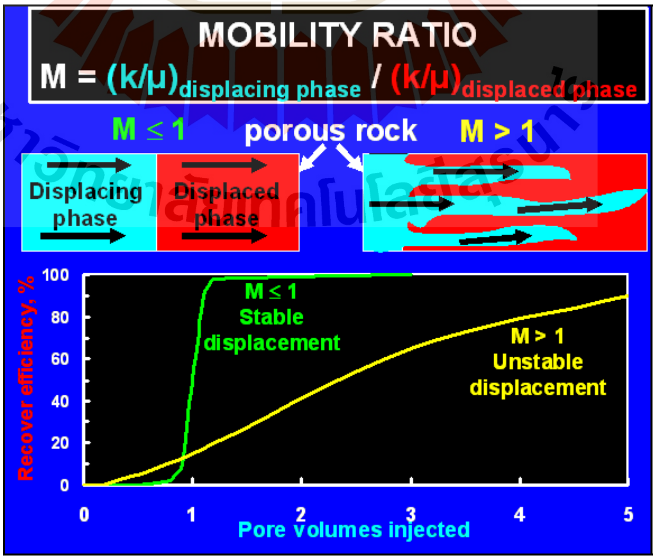


Figure 3.2 Relationships amongst mobility ratio, displacement efficiency and recovery efficiency (after Peter, 1964)

From Figure 3.2, it can be noted that. when Mobility ratios <1 is favorable mobility ratio, oil (displaced phase) flow > water (displacing phase) flow, and when Mobility ratios >1 is unfavorable mobility ratio, oil (displaced phase) flow < water (displacing phase) flow

Relative Permeability, k_{rx}

In case of two or more fluids flowing simultaneously through a porous medium, a relative permeability for each of the fluids can be defined. It describes the extent to which one fluid is hindered by the other. The relative permeability is defined by setting-up the Darcy equation individually for each phase i that flows in the pore space:

$$Qi \quad \frac{(K k_{ri})}{(\mu_i)} A \frac{(\Delta P_i)}{(\Delta x)} \qquad (3.3)$$

Where Q_i = flow rate of phase i

k_{ri} = relative permeability of phase i

μ_i = viscosity of phase i

Δp_i = the pressure drop within phase i.

Relative permeability is the ratio of effective permeability of a particular fluid at a particular saturation to absolute permeability of that fluid at total saturation. If a single fluid is present in a rock, its relative permeability is 1.0.

Calculation of relative permeability allows comparison of the different abilities of fluids to flow in the presence of each other, since the presence of more than one fluid generally inhibits flow.

$$k_{rx} \quad \frac{(k_x)}{(k_b)} \tag{3.4}$$

Where Kb = absolute permeability

Kx = effective permeability

Viscosity, μ

Viscosity is a measure of the resistance of a fluid which is being deformed by either shear or tensile stress. In everyday terms (and for fluids only), viscosity is thickness or internal friction. Thus, water is thin there having a lower viscosity, while oil is thick is having a higher viscosity. Put simply, the less viscous the fluid is, the greater its ease of movement. Viscosity describes a fluid's internal resistance to flow and may be thought of as a measure of fluid friction. In any flow, layers move at different velocities and the fluid's viscosity arises from the shear stress between the layers that ultimately oppose any applied force in Figure 3.3.

$$T = \eta \frac{(\ u)}{(\ y)} \tag{3.5}$$

Where η = coefficient of viscosity

τ = shear stress

∂u/∂y = proportional to the velocity gradient

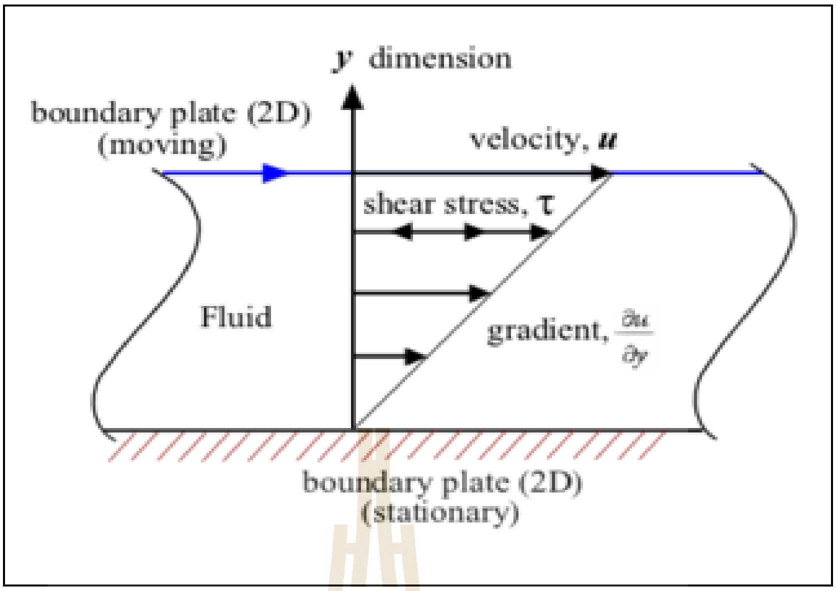


Figure 3.3 Laminar shear of fluid between two plates. Friction between the fluid and the moving boundaries causes the fluid to shear.

3.1.3 Sucker rod pumping system

The most common type of artificial lift pump system applied is beam pumping (Figure 3.4), which engages equipment on and below the surface to increase pressure and push oil to the surface. Consisting of a sucker rod string and a sucker rod pump, beam pumps are the familiar jack pumps seen on onshore oil wells. Above the surface, the beam pumping system rocks back and forth. This is connected to a string of rods called the sucker rods, which plunge down into the wellbore. The sucker rods are connected to the sucker rod pump, which is installed as a part of the tubing string near the bottom of the well. As the beam pumping system rocks back and forth, this operates the rod string, sucker rod and sucker rod pump, which works similarly to pistons inside a cylinder. The sucker rod pump lifts the oil from the reservoir through the well to the surface.

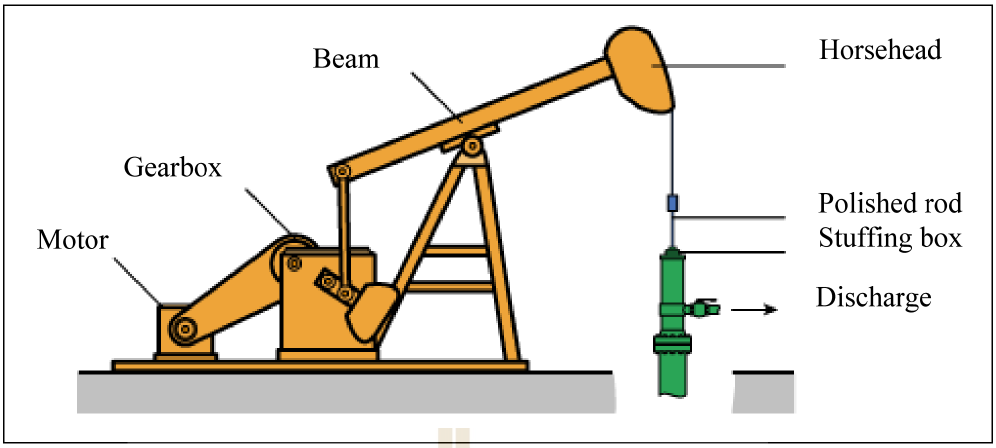


Figure 3.4 Equipments and compositions of sucker rod pump system (after Zaba, 1943).

A motor and gearbox supply power to turn the power shaft. There is a counterweight at the end of the crank. A pitman arm is attached to the crank and it moves upward when the crank moves counterclockwise. The Samson arms support the walking beam. The walking beam pivots and lowers or raises the plunger. The rod attaches the plunger to the horsehead. The horsehead (not rigidly attached) allows the joint (where rod is attached) to move in a vertical path instead of following an arc. Every time the plunger rises, oil is pumped out through a spout. The pump consist of a four bar linkage is comprised of the crank, the pitman arm, the walking beam, and the ground.

3.1.4 Electricity power cost calculation

Fang oil fields used sucker rod pumps for producing oil. The electricity power consumption (in Kilowatt) of Fang oil fields can be calculated by;

$$KW = \frac{1.73 * A * V * PF}{1000} \tag{3.6}$$

Where KW = Kilowatt

A = Ampere

V = Volt

PF = Power factor

3.2 Tested well background

Some information on tested well can be summarized as follows;

Well Name : FA-MS-07-08

Coordinate Easting 516410 Northing 2193580

Elevation Ground Level 505.06 m. 1656.59 ft.

Kelly Bushing 508.33 m. 1667.32 ft.

Target Depth 2569 ft.

Spudded Date 13 February. 1964

Completion Date 18 March.1964

Production Date 18 March.1964

3.2.1 Geology of tested well

The FA-MS-07-08 is located S 46 W from well FA-MS-07-07 at a distance of 330 m. FA-MS-07-08 (Figure 3.5) is near shot point no.242 line E seismic which shows a still dipping slope on the Mae Soon dermal structure although it is on gently dipping slope of same. It was therefore expected that oil be struck at the appropriate depth as FA-MS-07-08 is net far distant from FA-MS-07-07.

The upper Pleistocene at this bore hole was pierced through at 110ft. Depth past boulder bed of Korat sandstone, arkosic sand and basal plastic clay as usual. Next come the Mae Fang sand & arkosic sand with carbonized wood down to

123ft. beyond this the carbonized wood seems to be missing altogether. The brown & blue clays of Mae Fang age with thin porous sand beds were drilled past as usual as far as 993ft. The depth from 993-1,019 ft. occur porous sand with a base of interbedded dark sandy clay & clay. This is equivalent to the sand bed with Chai Prakarn oil of FA-MS-07-07 from 991-1,006 ft. but here there was an only trace of oil. The transitional zone to Mae Sod clay starts from 1,062-1,342 ft. consisting of sapropelic sands & sandy clays of grey to dark colour with very little lignlite debris as usual.

Top of Mae sod clay begins at 1,342 ft. with dark clay & sandy clays with a few thinner quartz sand. Beyond 1,480 ft., siltstone seems to form part of the dark sandy cloy, thereafter to be followed by thin & few pebbly horizons in clay shale. Quartz sands encountered are few and too thin to warrant any attention. Then occur compact clay shale from 1,789 ft. downwards. Core No. I from 2,109-2,110 ft. show compact pebbly shale with no oil sign of dip. Oil show was strong between 2,245-2,256 ft. but the usual porous sand break was missing due perhaps to the existence of compact sandstone instead of loose sand. Similar horizon was passed through between 2,373-2,413 ft. and perhaps down to 2,500 ft. but the oil show is less. The strata passed through seemed to be an alternation of hard clay shale, siltstone and sandstone characteristic of Chai Prakarn sands. After 2,500 ft. Core No 2 from 2,500-2,505 ft. disclosed 4 ft. of recovered core with an alternation of dense clay shale, thin oil impregnated siltstone and much sandy clay & 6 inches of oil impregnated fine sandstone.

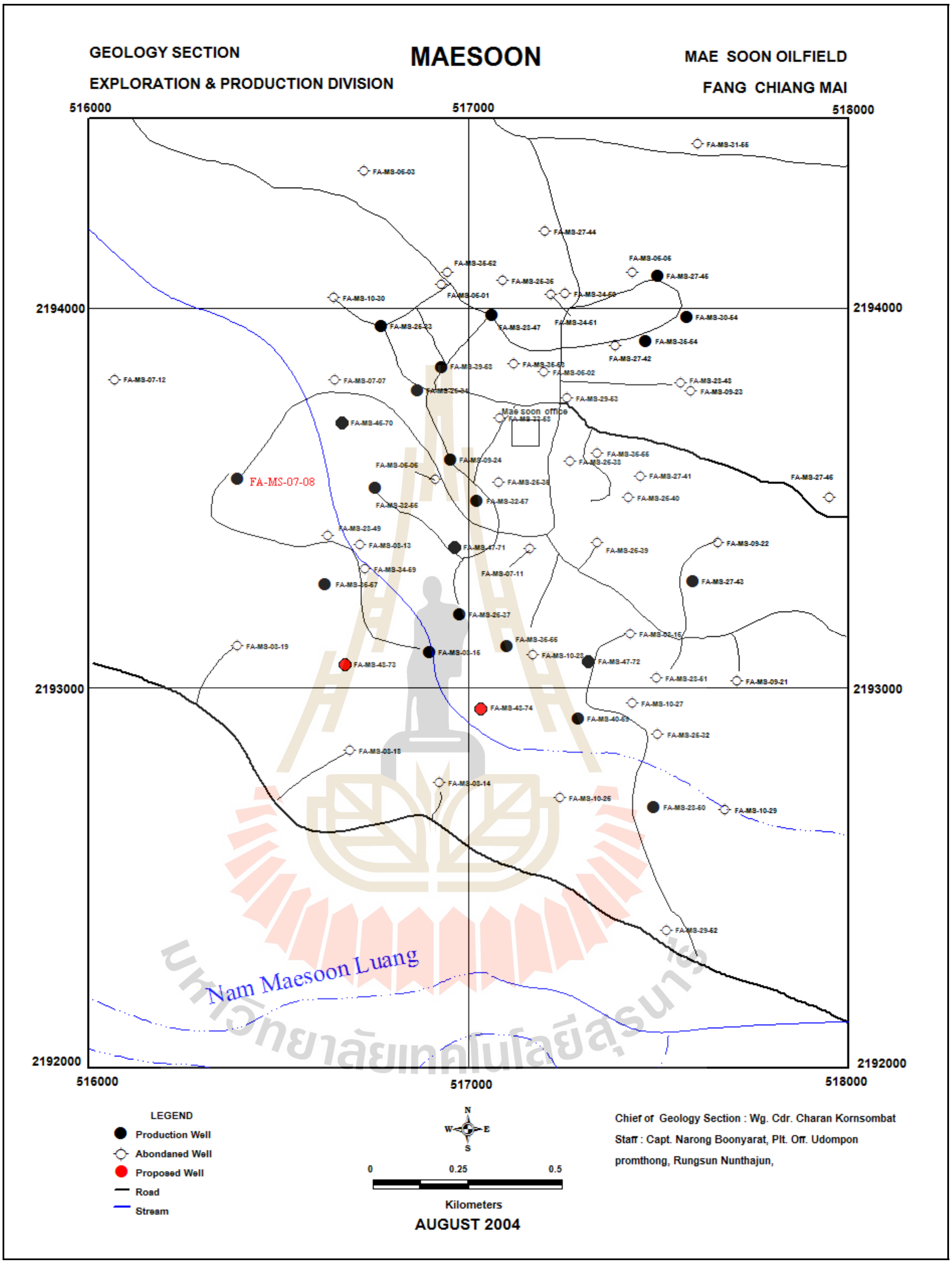


Figure 3.5 The location Map of production oil well of Mae Soon oil field (after DED, 2002)

The flat dip from 5-10 indicated a high position in the Mae soon dome just as expected. Drilling was resumed down to 2,269 ft. where again much oil on the screen was observed. Testing from 2,469-2,569 ft. revealed 1,200 ft. of oil without any water. Therefore, it became necessary to test various sections to find out the water sands within this new oil zone. The results are enumerated below.

2,552 – 2,569 ft. test yielded 460 ft. oil column without water

2,556 – 2,569 ft. test yielded 434 ft. oil with 2.8% water. It was therefore accepted as a production well.

Probable Reservoir No 1 "C" sand from 2,246 – 2,256 ft.

Quartz sand interbedded with oil siltstone, a little organic clay shale and a little dark and whitish sandstone.

Probable Reservoir No2 "D" sand from 2,373 – 2,404 ft.

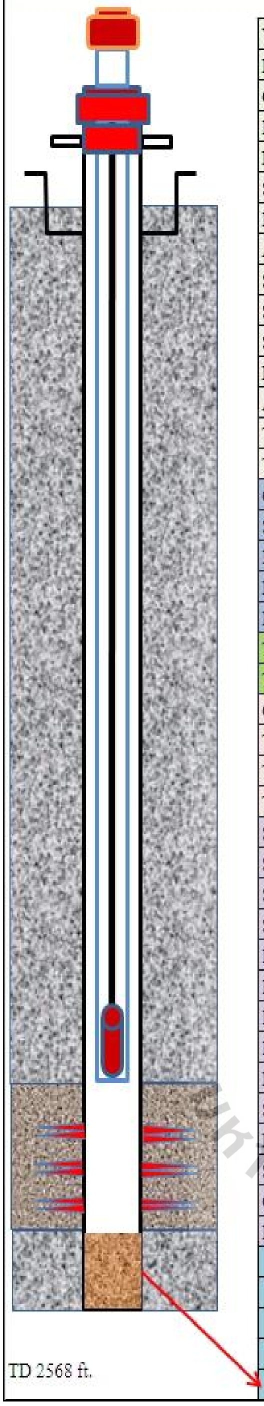
Much dark and whitish sand whitish sandstone of probable korat origin, oil siltstone & same schist with a little quartz, probably forming a pebbly to sand bed. Actual Reservoir No 3 "E" sand from 2,500 – 2,551 ft.

Sand of quartz and korat sandstones with some organic clay shale & pieces of sandy clay, thin oil sands &thin oil siltstone. Silicified bluish compact sandstone found in the 2,500-2,565 section but may be stray boulders. (See examination of rock section) from 2,551 – 2,569 ft.

Places of Korat dark grey sandstone with some quartz sand & organic clay shale. Otherwise the real nature of this rock section will be open to our decision.

3.2.2 Well completion data

The FA-MS-07-08 was begun to completion well on 18 March.1964 in the production zone the completion well data is illustrated in figure 3.6



Well Name	BS-68-11						
Location	Fang						
Counrty	Chiang Mai						
Field	Maesoon						
Drilling Rig	IDECO						
Surface Equipments							
Pumping Unit	Chur Chill						
API	C57-109-48						
Serial No.	C5706445						
Stroke Length	48	inc.	48,36,25				
Stroke Per Minute	10	Spm.					
Master Wright	2000	lbs.					
AUX Wright		lbs.					
Total Wright	2000	lbs.					
Tank Size	200	BBL.			1 Set		
Casing Data	Size		Wt. (lbs.)	Grade	Total Joints	Depth(ft.)	
Surface Casing	10-3/4"		32.75 lbs./ft.	J-55		129	
Intermediates							
Production Casing	7"		23 lbs./ft.	J-55		1841.2	
Production Casing	6 5/8"		20 lbs./ft	J-55		658.8	
Tubulars	ID.	OD.	Wt. (lbs.)	Grade	Total Joints	Depth (ft.)	
Tubing	2.441	2.875	6.5 lbs./ft.	J-55	50	1585	
Completion Equipments	ID.	OD.	Grade	Joints.	lbs./ft.	Wright (lbs.)	Depth (ft.)
Tubing 2.875 EUE							
Tubing 2.875 NonUpset	2.441	2.875	J-55	50	6.4	10080	1585
Total				50			1585
Sucker Rod Number 66							
Sucker Rod 7/8"x25'		0.875	C	1	2.21	55.25	25
Sucker Rod 3/4"x25'		0.75	C	61	1.63	2485.75	1525
Sucker Rod 5/8"x25'		0.62	C		1.12		
Pony Rod 3/4"x2'							
Pony Rod 3/4"x4'				1			4
Pony Rod 3/4"x6'				1			6
Pony Rod 3/4"x8'							
Polished Rod				1			14
Subsurface Pump				1			12
Blank							
Screen							
Gas Anchor							
PumpDepth							1586

Perforation	Top	Bottom	Net Pay(ft.)	Shot Density	Formation	Date	Remarks
1	2334	2350					
2	2359	2367					
3	2410	2430					
4	2499	2568				13-Mar-07	Screen

Figure 3.6 The well completion data of FA-MS-07-08

3.2.3 Production data

Fang oil fields have produced oil from the Mae Sod Formation since 1959. There are 246 wells had been drilled in the basin. The 40 percent of these wells have produced oil, though the producing life of individual wells has varied considerably. The Fang basin now has only 33 producing wells. There are 21 wells are in the Mae Soon structure, 6 wells in the San Sai structure, 4 wells in the Nong Yao structure, 1 well in the Ban Thi structure, and 1 well in the Sam Jang structure.

The production zone of FA-MS-07-08 well is at 2,333.89-2,568.01 ft. below and the measured depth of this well is 2,569 ft. below KB. Total oil reserve of Mae soon oil field is 2,969.04 M bbl and whilst the well MS-07-08 has a reserve of 4.04508 M bbl Figure 3.7 and Figure 3.8.

In this study, the production history data was considered only from January 2008 – 19 September 2011. Trend of the decreasing of oil and increasing of water of the current productive can be observed in Table 3.1.

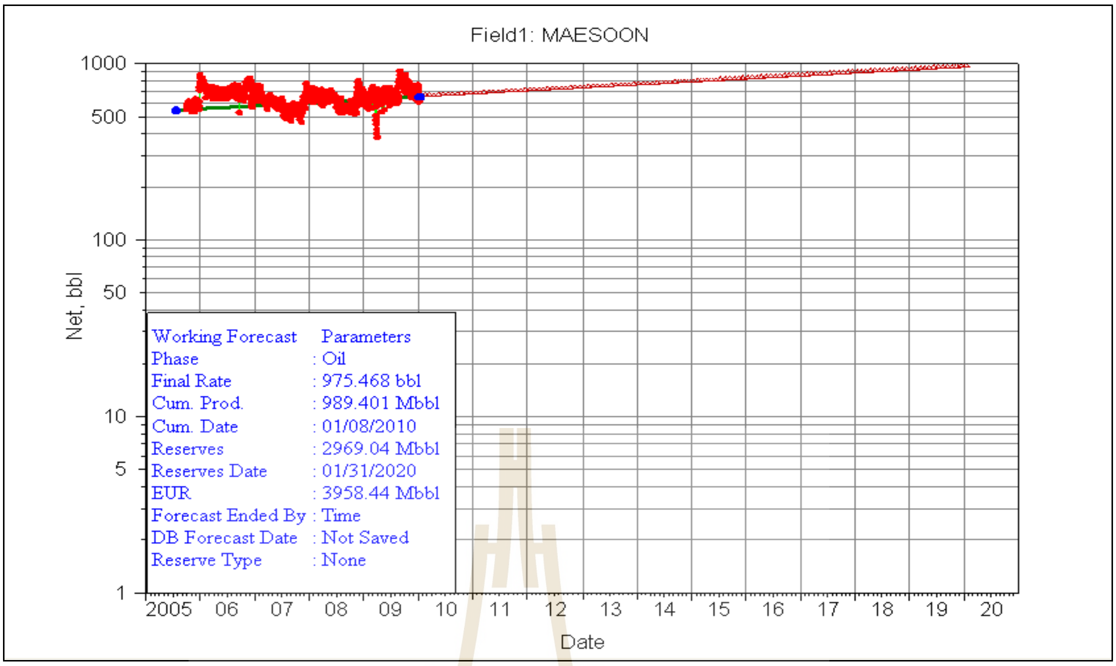


Figure 3.7 Production forecast of Mae Soon oil field

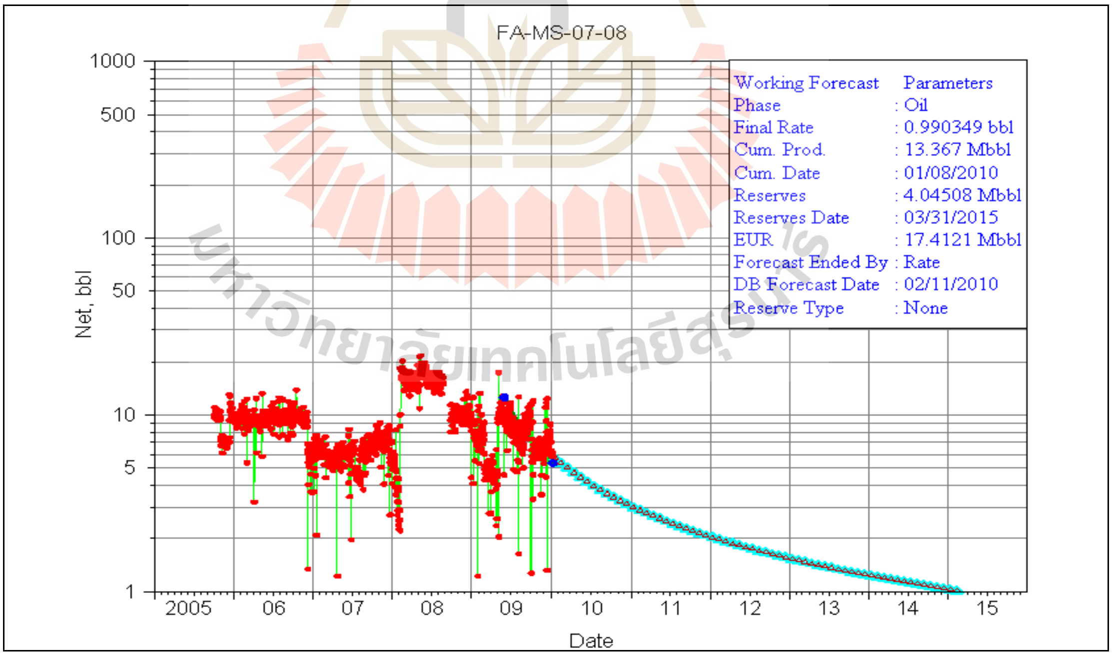


Figure 3.8 Working Forecast of the well FA –MS-07-08

Table 3.1 Production history data from 2008-2011 of well FA-MS-07-08

Year	Mount	Gross avg. (BBL)	Net avg. (BBL)	% Water Cut (avg.)
2011	January	122.45	6.26	94.89
	February	118.48	8.38	92.93
	March	122.00	9.85	91.93
	April	112.76	7.23	93.59
	May	111.30	9.81	91.19
	June	123.86	9.74	92.14
	July	117.71	9.77	91.46
	August	122.89	10.22	91.68
	19-Sep	101.28	7.80	92.30
2010	January	83.93	6.03	92.82
	February	76.68	5.48	92.85
	March	48.21	5.02	89.59
	April	43.88	3.88	91.16
	May	127.32	11.28	89.92
	June	148.92	10.48	92.96
	July	137.50	8.98	93.47
	August	129.53	7.73	94.03
	September	130.13	8.99	93.09
	October	134.11	8.24	93.86
	November	125.77	8.14	93.53
	December	132.45	10.74	91.89
2009	January	92.92	7.14	92.31
	February	103.60	7.66	92.61
	March	68.65	3.45	94.98
	April	90.41	4.54	94.98
	May	88.91	9.64	89.14
	June	88.21	9.76	88.94
	July	86.24	7.70	91.07
	August	84.17	7.46	91.14
	September	85.70	9.35	89.09
	October	91.72	6.36	93.07
	November	87.05	6.03	93.07
	December	87.72	6.81	92.25
2008	January	74.01	4.56	93.84
	February	100.02	9.18	91.78
	March	131.56	15.38	88.31
	April	129.12	15.09	88.31
	May	127.62	17.50	86.29
	June	128.53	16.21	87.38
	July	124.36	15.45	87.58
	August	124.72	15.49	87.58
	September	111.99	10.29	90.84
	October	108.59	9.83	90.95
	November	124.14	14.49	88.41
	December	111.61	9.99	91.05

Table 3.2 Production history data average in 2008-2011 of well FA-MS-07-08

Year	Gross avg. (BBL)	Net avg. (BBL)	% Water Cut (avg.)
2011	116.97	8.78	92.47
2010	109.86	7.89	92.43
2009	87.94	7.16	91.88
2008	116.35	12.79	89.36

The values from Table 3.1 were collect and plotted the relationship between Gross Average, Net Average and % Water Cut Average and Production time from January 2008 - September 2011and illustrated Figure 3.9, Figure 3.10 and Figure 3.11.

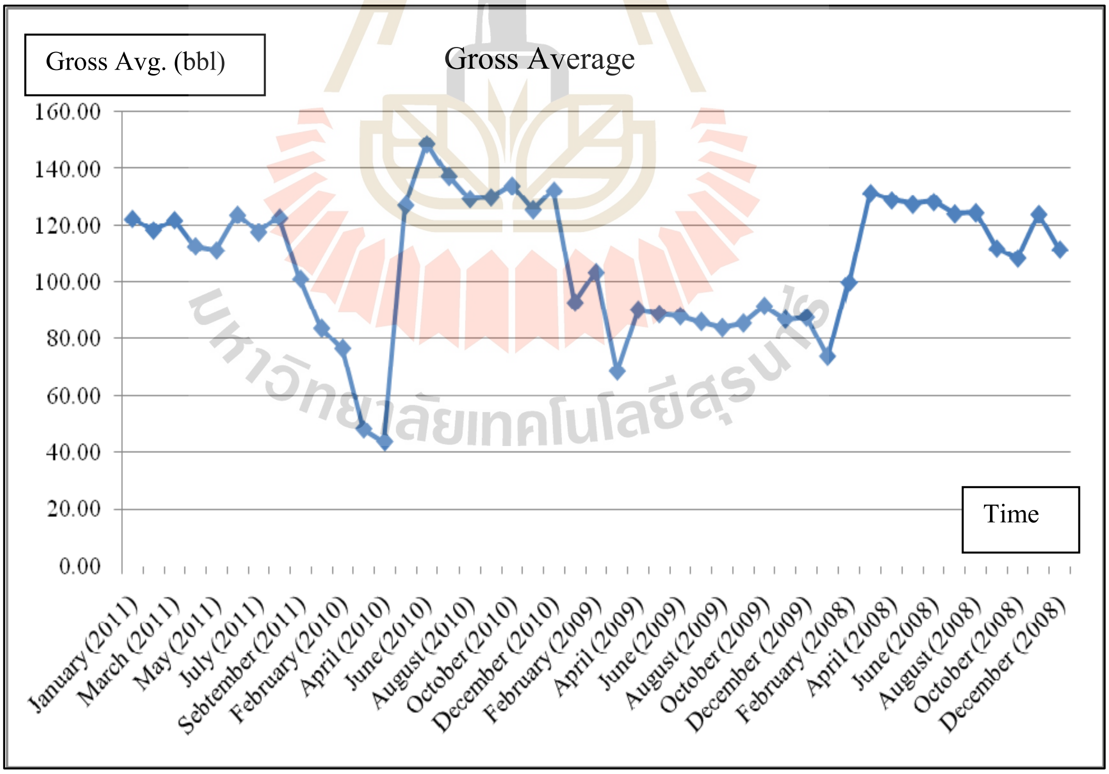


Figure 3.9 Graph showing average gross production (bbl) and production time from January 2008 – September 2011

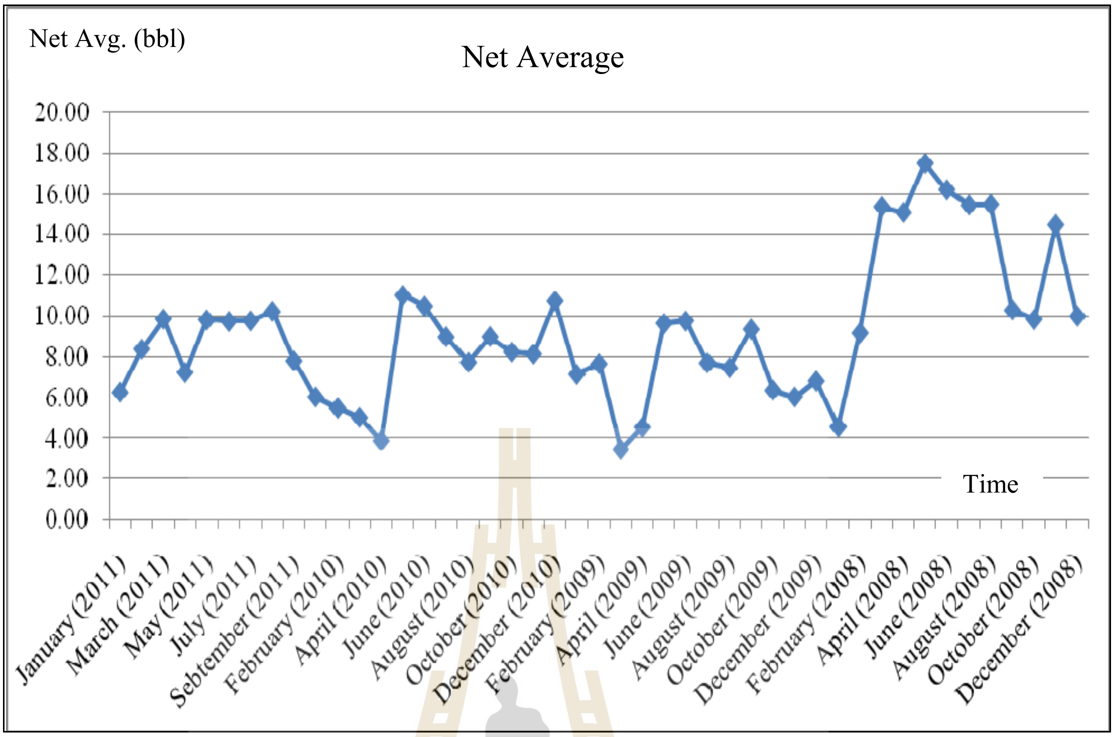


Figure 3.10 Graph showing average net oil production (bbl) and production time from January 2008 – September 2011

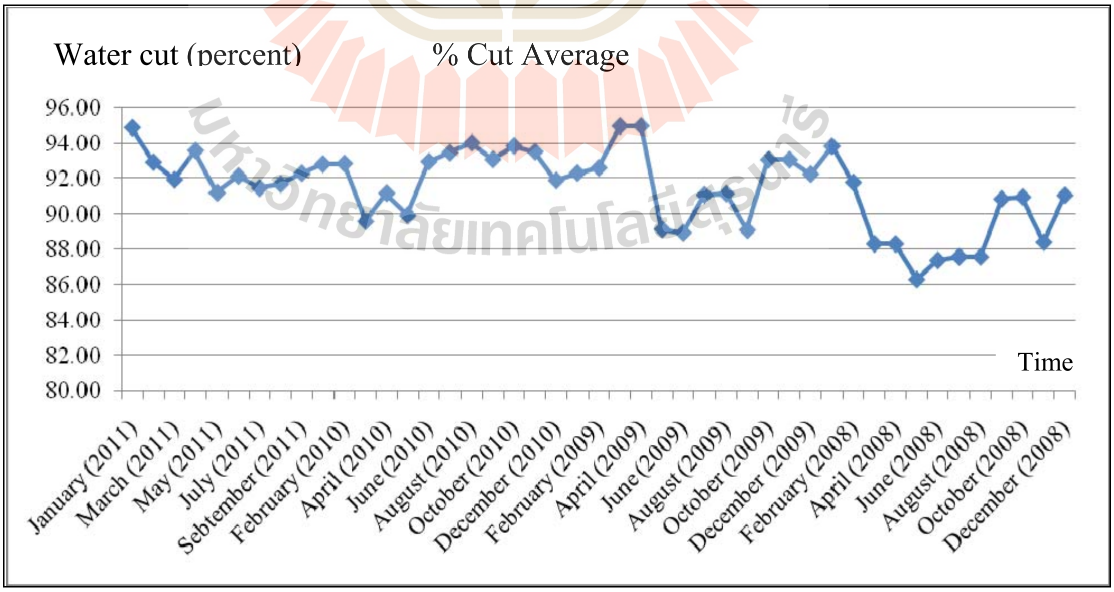


Figure 3.11 Graph showing water cut (percent) and production time from January 2008 – September 2011

3.3 Intermit operation

As previous mentioned the main objective of this study is to reduce the production cost and improve oil recovery by applying Intermit operation to FA-MA-07-08 well of Mae Soon oil field. The principle is to reduce operation hours of the Sucker rod pumping while as the obtained oil production should be the same as without applying Intermit operation. Usually sucker rod pump is run 24 hours the Intermit operation is applied, the machine works only 12 hours per day. In this study the sucker rod pump was turned on at 8.00-20.00 and after that it was turned off since 20.00-08.00 each day. The net oil and net water were performed by BS&W measurement in laboratory each day. Intermit operation procedures are listed as follows;

Stop the sucker rod pump at 20:00 for a period of 12 hours.

When close to 12 hours measure the oil level in oil tank calculates day rate production.

Measure fluid level survey in the tested well

Start sucker rod pump for 12 hours from 8:00 – 20:00, and collect oil samples every 1 hour while sucker rod pump is running.

Measure BS&W of oil samples in laboratory.

Stop sucker rod pump at 20:00 again and record oil level in oil tank.

Calculate net oil (bbl), net water (bbl) and water cut (percent) from day rate production and BS&W measurement.

3.4 In field measurement

In order to measure crude oil and water production, some in field measurements including day rate production and fluid level survey in well had been conducted in this study. Methods and equipments used in previous mentioned measurements can be summarized as in the following sections.

3.4.1 Day rate production measurement

The objective of this measurement is identified and record depth of empty tank, using sounding tape. Sounding tape (Figure 3.12) used to determine the level of tank liquid from the bottom of the tank to the liquid surface. Slack tape measure oil dipping into the storage tank oil and then read the values to calculate the oil volume in tank that convert to standard chart in Appendix B (Table tank calibration)

Figure 3.12 Sounding tape

3.4.2 Fluid level survey

Fluid level surveys have been accepted as the primary diagnostic tool for down hole monitoring and problem confirmation. The level of fluid in a well is the first thing that the operator checks if production drops. In stripper wells and rod pumps that pound fluid, fluid levels are run at some time in the well life to determine if the well is really pumped off, or if gas interference in the pump is a problem. Occasional fluid levels are taken to identify pump problems as they develop, and/or to monitor bottom hole pressure and fluid entry variations such as in water floods, water drive reservoirs, and most other secondary or tertiary recovery operations. Fluid level surveys determination by acoustic wave survey is a part of Well Analyzer System, a commercial computer software with applicable in multi-measurement, including acoustic well survey, dynamometer survey, beam pump balancing and torque analysis, pressure transient testing and liquid level survey.

The principal objectives for making acoustic well surveys are: determining the presence of liquid in the annulus above the pump, measurement of the depth to the liquid level, determination of bottom hole pressure, annular pressure distribution and estimation of the inflow performance of the well. If liquid was found over the pump then the operator knew that additional production was available if a larger pump was installed if the pump was not operating properly, that the pump should be pulled and repaired.

The position of the liquid level in the annulus is an important indicator of the well's pressure balance condition. This is especially important during work over operations when the Christmas tree is not in place and during well killing procedures when the well pressure status must be inferred.

The summary to use for acoustic well surveys are

1. Attach the echometer gas gun (Nitrogen gas) to the well (Figure 3.13 and Figure 3.14). Check the threads on the wellhead valve for corrosion when attaching the echometer gun. Leave the valve to the wellhead closed.

Figure 3.13 echometer gas gun

Figure 3.14 Attach the echometer gas gun to the well

2. Connect the pressure transducer, if present, to the gas gun.

3. Connect the cables to the gas gun and to the well analyzer as shown below.

4. Turn on well Analyzer and wait for GREEN LED. Turn on the computer and start the TWM program.

4.1 Start TWM. Select acquire mode (Figure 3.15).

4.2 Select the serial number of the pressure transducer. Use creates new if your serial number is not found in the list (Figure 3.15). Make sure all coefficients are enter

4.3 Start process of zeroing transducer by selecting Obtain zero offset buttons (Alt-3). Once the reading displayed in present zero offset has stabilized press update zero offset with present reading button to record this valued as typed on transducer label (Figure 3.15). Also enter gun parameters at bottom.

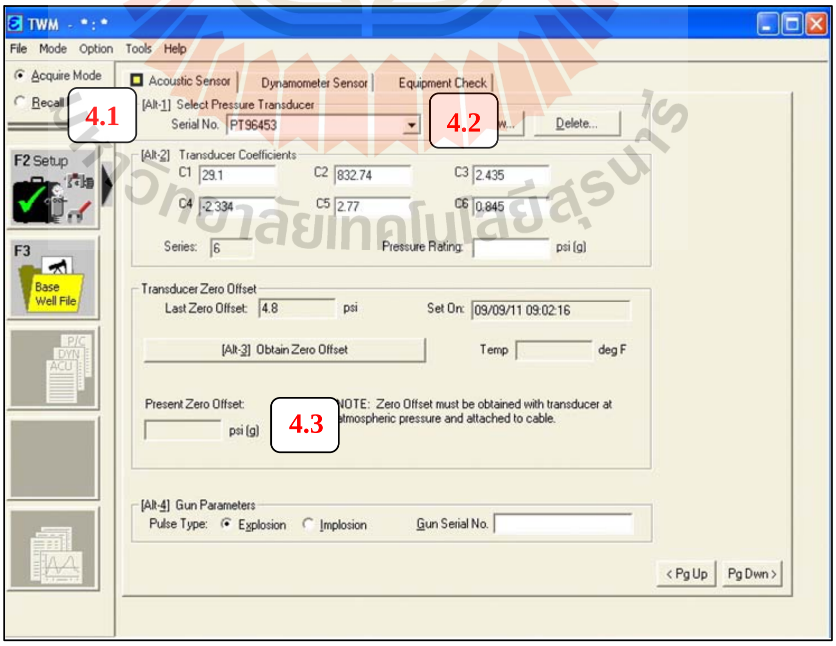


Figure 3.15 Total well management program (TWM)

4.4 Open base well file for the well where data is to be acquired (Figure 3.16). Use new to create a base well file if one does not exist. Be sure to enter at least pump and formation depths.

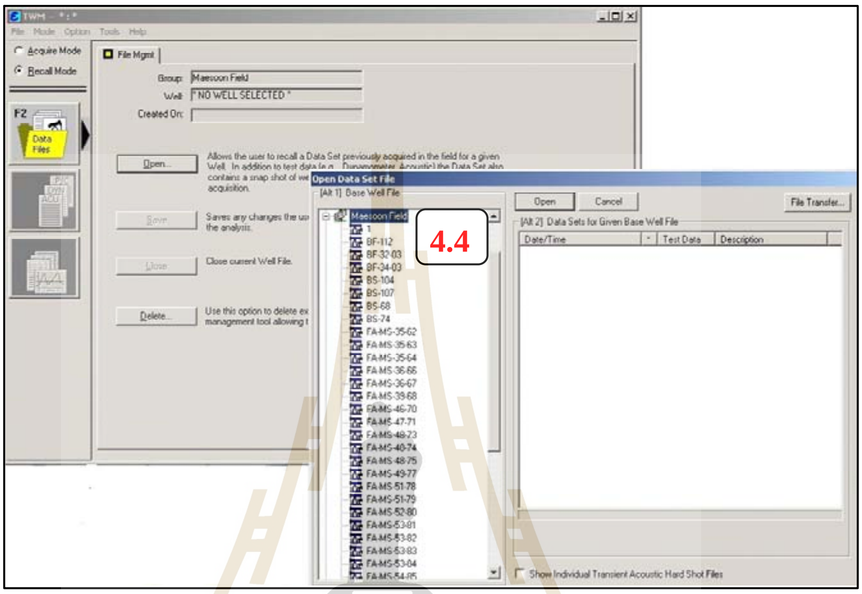


Figure 3.16 Total well management program (TWM)

4.5. From the “F4” select test screen pick the acoustic tab to indicate that acoustic test data is to be acquired (Figure 3.17).

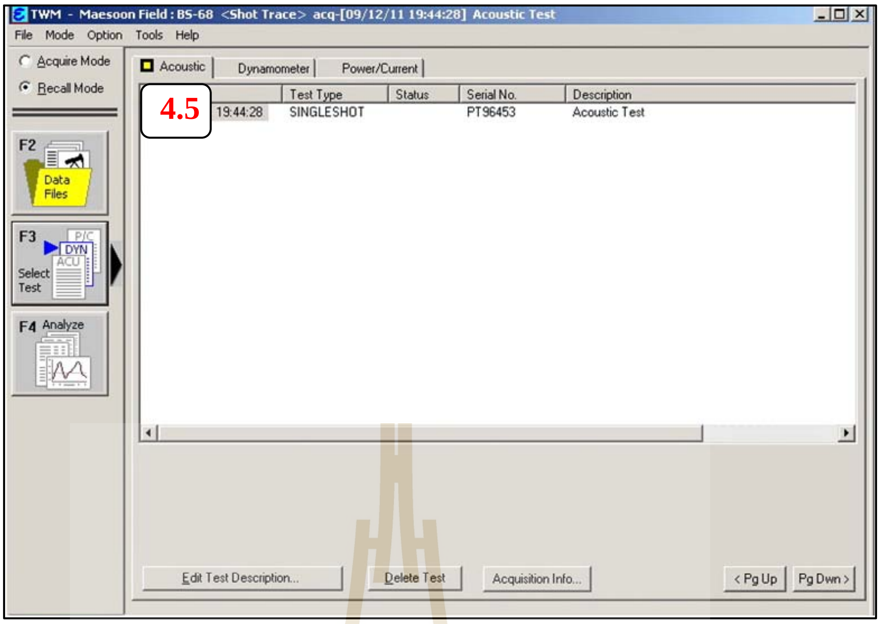


Figure 3.17 Total well management program (TWM)

4.6 Prepare to acquire shot "F5" by following steps detailed on instructions panel.

4.7 The message "Shot PULSE was detected from gun is displayed once the gun is fired. Then shot data is acquired for a predetermined numbers of seconds based on the given formation depth.

4.8 Once the shot has been acquired a dialog appears. At this point the data can be saved or discarded so another shot can be taken. A brief comment can be entered into the description field. Otherwise, just enter (press OK) to save the data set.

4.9 When the data is saved TWM automatically goes to the select liquid level tab in the analyze section (Figure 3.18). Note, TWM has calculated and selected a candidate for the best kick. Use the ← Left and Right → buttons to fine tune the selected kick. The graph in the lower right shows a close-up of the kick

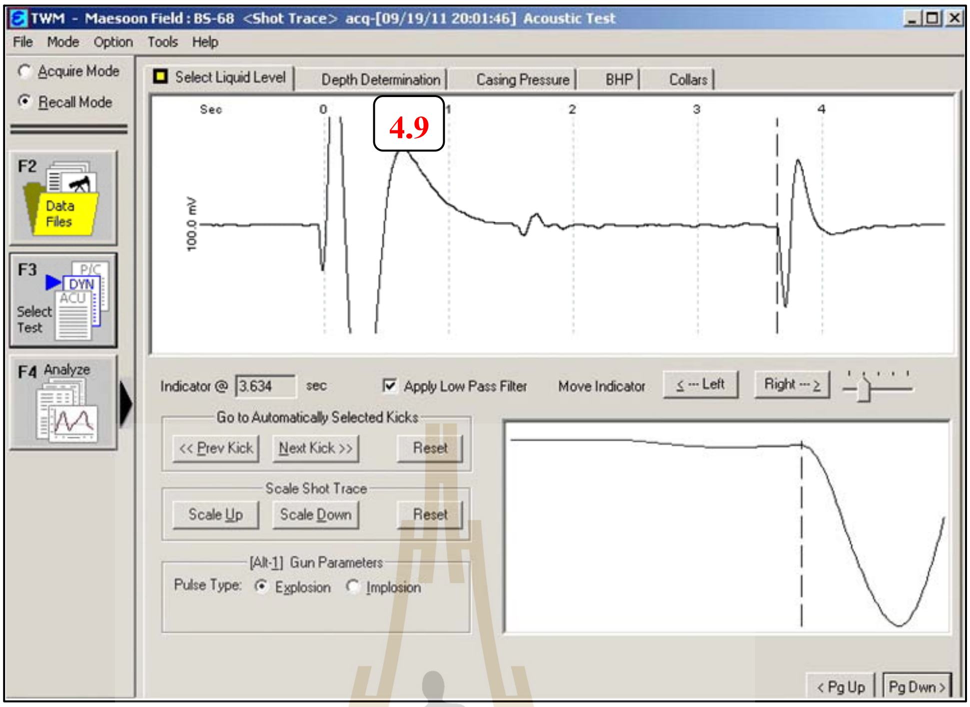


Figure 3.18 Total well management program (TWM)

4.10 Now go to the depth determination Tab. Here TWM displays the calculated depth to the previously selected kick. The depth is calculated using an acoustic velocity determined by the automatic spreader analysis, shown in the graph on lower left (Figure 3.19).

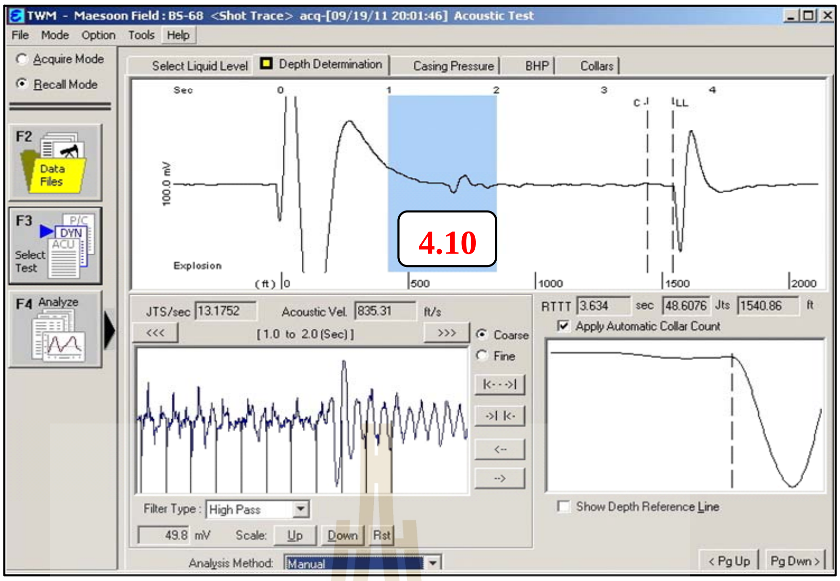


Figure 3.19 Total well management program (TWM)

4.11 The casing pressure Tab displays pressure data TWM has been acquiring every 15 seconds and press end (Figure 3.20).

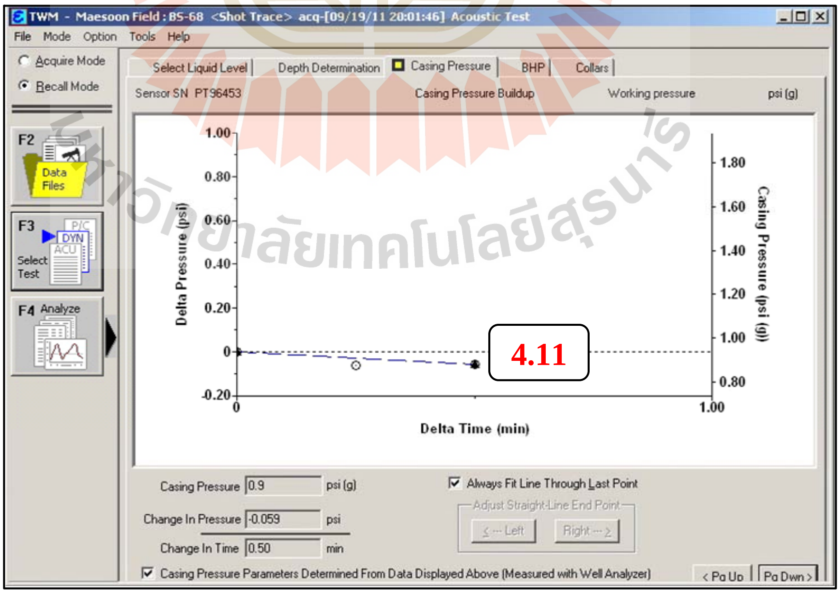


Figure 3.20 Total well management program (TWM)

4.12 Finally, go to the BHP tab (Figure 3.21). Here TWM displays results based on the determined liquid level, acquired casing pressure, and well file data. Please, refer to the TWM Manual for a more detailed discussion of the analysis and calculated results.

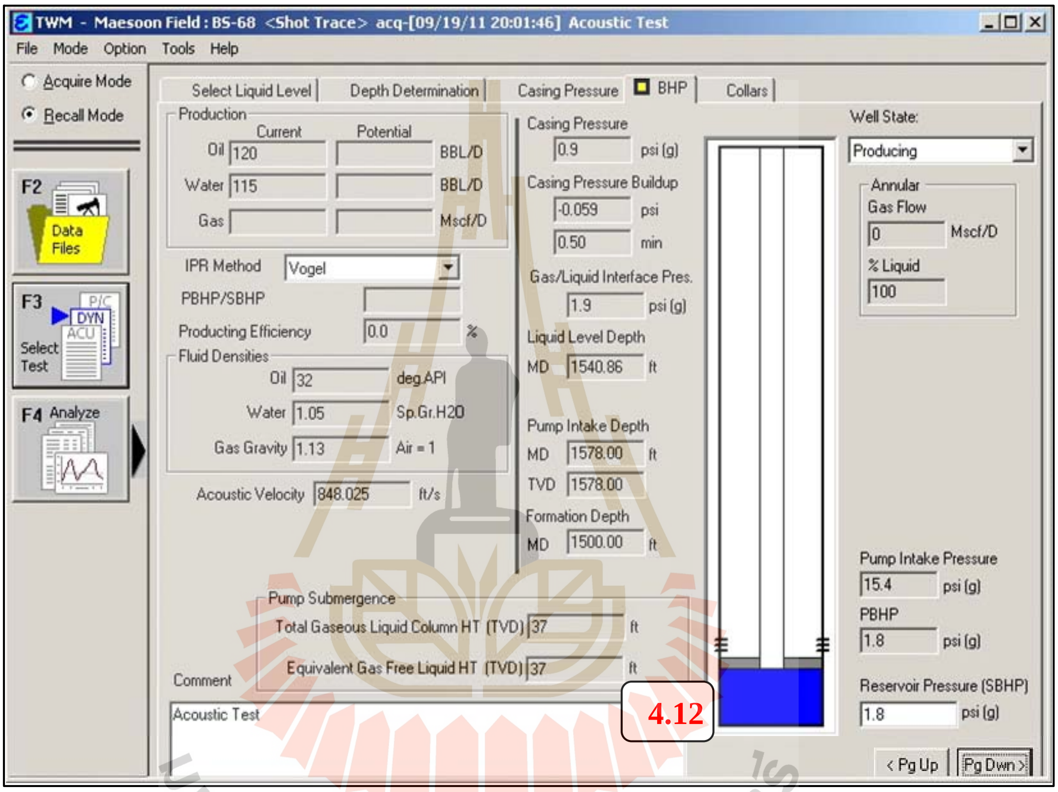


Figure 3.21 Total well management program (TWM)

3.5 Laboratory experiments

Laboratory experiments had been performed to determine net oil (bbl), net water (bbl), and BS&W content produced in an operation and entrained material within the oil bulk, including solid particles and dispersed water. The sample preparation, test methods, results and discussion of experiment work are described in the following sections.

3.5.1 Sample collection and preparation

Oil samples were collected from well FA-MS-07-08 of Mae Soon oil field. Oil sample was kept in a plastic bag (Figure 3.22) every hour and there were 13 samples a day.

Figure 3.22 Crude oil samples collection with a plastic bag

Figure 3.23 Crude oil samples in plastic bag

3.5.2 BS&W Measurement

When extracted from an oil reservoir, crude oil contain some amount of saltwater and particulate matter from the reservoir formation. The particulate matter is also known as sediment or mud. The water content can vary greatly from field to field, and may be present in large quantities if oil extraction is enhanced using water injection technology. The bulk of the water and sediment is usually separated at the field to minimize the quantity that needs to be transported further. The residual content of these unwanted impurities is measured as BS&W.

Crude oil is seldom produced alone because it generally is commingled with water. The water creates several problems and usually increases the unit cost of oil production. The produced water must be separated from the oil, treated, and disposed of properly. All these steps increase costs. Furthermore, sellable crude oil must comply with certain product specifications, including the amount of bottom sediment and water (BS&W) and salt, which means that the produced water must be separated from the oil to meet crude specifications.

BS&W measurement is used to determine net oil, net water, and a water cut. Water cut meter measures the water content (cut or percentage) of a specific product as it flow through a sucker rod. The analyzer measures the differential flow characteristics of water and other components of the liquid to determine the percentage of water.

Sampling is a vital part of the test procedure. If the tested oil sample is not representative of the whole batch to be treated, the conclusions drawn during the test procedure may be invalid. Samples should be taken from the top, middle, and bottom then mixed thoroughly. Ideally, a sample should be taken after mixing the entire contents of the storage tank. Separate samples should be taken at regular intervals from the pipeline during transfer of the oil.

Materials for BS&W Measurement

- Well fluid sample
- 1-2 doz. beaker
- Water Bath
- Demulsifier (Figure 3.24)
- Centrifuge clinical (Figure 3.25)
- Glass rod
- Toluene chemical

Figure 3.24 Demulsifier

Figure 3.25 Centrifuge (clinical)

Laboratory procedures

- Put oil sample to beaker.

- Drop demulsifier into oil sample in beaker about 2-3 drops, and mix them together. Demulsification is the process that breaking of a crude oil emulsion into oil and water phases.

- Boil emulsion at a hot plate for approximately 10-15 minutes.

- Stir sample with a glass rod.

- When oil and water begin separation. Fill sample 100 ml into 2 centrifuge cylinders and add toluene chemical to the oil sample.

- Place the tubes on opposite sides of the centrifuge to balance the load, close the lid and centrifuge for a minimum of 5 min.

- Read and record the combined sediment and water content at the bottom of each tube.

- Determine the BS&W by the centrifuge method.

BS&W calculation

- Percent of water and oil in boiled sample calculation

When boiled sample was clearly seen oil and water separately, oil volume (Vo) and water volume (Vw) were read record in milliliter. Then following equations were used to calculate percent of oil and water volume of the boiled sample.

$$\% \text{ Volume of water} = \frac{Vw*100}{Vw \quad Vo} \tag{3.7}$$

$$\% \text{ Volume of oil} = \frac{Vo*100}{Vw \quad Vo} \tag{3.8}$$

Where Vo = Volume of Oil from boiler (ml)

Vw = volume of Water from boiler (ml)

- Percent of water and sediment in centrifuge tube calculation

After boiled sample had been centrifuged already, water volume in centrifuge tube (Vwc) and sediments volume in centrifuge tube (Vsc) were read and recoded. Then following equations were used to calculate percent of water and sediments in centrifuge sample.

$$\text{Water in oil} = \frac{Vo * Vwc}{100} \tag{3.9}$$

$$\text{And} \quad \% \text{ Water in oil} = \frac{\text{water in oil} * 100}{Vo \quad Vw} \tag{3.10}$$

$$\text{Sediment in oil} = \frac{Vo * Vsc}{100} \tag{3.11}$$

$$\text{And} \quad \% \text{ Sediment in oil} = \frac{\text{sediment in oil} * 100}{Vo \quad Vw} \tag{3.12}$$

Where Vwc = volume of water from centrifuge

Vsc = volume of sediment ate from centrifuge

Vo = Volume of Oil from boiler

Vw = volume of Water from boiler

- Percent of total water volume in oil (water cut percent) calculation

In order to calculate percent of total water cut, following equations were used.

$$\% \text{ Water cut} = \% \text{ Volume of water} + \% \text{ Water in oil} + \% \text{ Sediment in oil} \tag{3.13}$$

$$\text{So,} \quad \% (\text{Oil})_{all} = 100 - (\% \text{ water cut}) \tag{3.14}$$

- Net oil and net water calculation

Consequently, net oil production (barrel per day) and net water production (barrel per day) could be calculated by using following equations.

$$\text{Net water} = \frac{\%\,\text{water cut} * \text{Total production (bbl/d)}}{100} \tag{3.15}$$

$$\text{And Net oil} = \text{Total production (bbl/d)} - \text{Net water} \tag{3.16}$$

3.6 Economic evaluation

Well FA-MS-07-08 has started its oil production since 18 March 1964. Now the oil production has decreased and currently exhibiting water cut increases. Economic evaluation on Intermit operation was divided into 2 parts as electricity power cost and income from an incremental crude oil analysis.

3.6.1 Electricity power cost analysis

Mainly due to its long history, sucker-rod pumping is a very popular means of artificial lift all over the world; roughly two-thirds of the producing oil wells are on this type of lift. Fang oil field used a sucker rod pump for producing oil for a long time as well. In the study, it is believed that intermit operation can reduce production costs as this operation was performed on a sucker rod pump running only 12 hours a day and turn off 12 hours.

Therefore, equation 3.6 had been used to calculate the electricity power cost comparison between before and after Intermit operation method was applied to the sucker rod pumping unit.

3.6.2 Income from an incremental crude oil

Incomes from crude oil selling before and after the Intermit operation was applied were compared to each other in order to evaluate an incremental benefit from Intermit operation applying.

CHAPTER IV

RESULT & DISCUSSION

4.1 Results

Results from this study including day rate production measurement, fluid level survey in well, BS&W measurement and economic evaluation were addressed as in following sections.

4.1.1 Day rate production measurement

Result from tank oil level survey which were numbers and height volume then they were converted to be day rate production (bbl/day) by using the Tank Calibration Table of Fang oil field (see Appendix B). The day rate production during applying Intermit operation are summarized in Table 4.1.

Table 4.1 Summary of the Day rate production (total production)

Date	Height Volume from tank oil level survey	Day rate production (BBL/D)
13/10/2011	2’- 3.5”	76.97
14/10/2011	2’- 2.8”	74.30
15/10/2011	2’- 4”	77.28
16/10/2011	2’- 7.6”	87.66
17/10/2011	2’- 4”	77.28
18/10/2011	2’- 6”	82.56
19/10/2011	2’- 4”	77.28

4.1.2 Fluid level survey

The Fluid Level Survey had been conducted in this study in order to determine the fluid depth of the wells by the Nitrogen gas gun as described in previous chapter. As a result, fluid level survey within tested well FA-MS-07-08 which had been recorded during applying Intermit operation are presented in Table 4.2.

Table 4.2 Summary of the fluid level survey in FA-MS-07-08

Date	Time	Start Pump		Stop Pump	
		F/L (ft)	FOP (ft)	F/L (ft)	FOP (ft)
12/10/2554	08.00-20.00	-	-	1538.33	40
13/10/2554	08.00-20.00	1330.00	248	1524.85	53
14/10/2554	08.00-20.00	1325.73	252	1556.49	22
15/10/2554	08.00-20.00	1325.08	253	1526.50	51
16/10/2554	08.00-20.00	1308.61	269	1529.56	48
17/10/2554	08.00-20.00	1310.11	268	1531.79	46
18/10/2555	08.00-20.01	1322.11	256	1545.24	33
19/10/2556	08.00-20.02	1304.10	274	1540.86	37

Remark : F/L = Fluid Level Depth

FOP = Fluid on Pump Depth

4.1.3 BS&W calculations

Results of BS&W content measurement from previous mentioned equations (3.7-3.16) during applying Intermit operation period are summarized in Table 4.3

Table 4.3 Summary of BS&W measurement of tested well FA-MS-07-08

Date	Time	Total (bbl/d)	Crude (bbl/d)	Water (bbl/d)	Water cut (%)
12/10/2554	08.00-20.00	-	-	-	-
13/10/2554	08.00-20.00	76.97	11.06	65.91	85.63
14/10/2554	08.00-20.00	74.30	14.84	59.45	80.02
15/10/2554	08.00-20.00	77.28	11.38	65.90	85.27
16/10/2554	08.00-20.00	87.66	18.88	68.78	78.46
17/10/2554	08.00-20.00	77.28	15.28	62.00	80.23
18/10/2555	08.00-20.01	82.56	17.11	65.45	79.28
19/10/2556	08.00-20.02	77.28	17.72	59.56	77.07

The value of % water cut showed in the table 4.3 is an average value. Details of BS&W measurement and calculation are presented in Appendix C.

4.1.4 Economic evaluation

In order to evaluate economic return of using Intermit operation, some calculations on electricity power cost and incomes from selling oil had been conducted. Results of these calculations are presented in the following sections.

4.1.4.1 Electricity power cost calculation

In this study, Intermit operation was performed on the sucker rod pumping unit of the tested well as turning on the pumping unit 12 hours and turning off the pumping unit 12 hours each day alternately. Therefore, electricity power cost can be calculated from the following equation.

$$KW = \frac{1.73 * A * V * PF}{1000} \quad (4.1)$$

Where KW = Kilowatt

A = Ampere

V = Volt

PF = Power factor

In well FA-MS-07-08 it was observed that with in1 hour operation the pumping unit consumed electricity of 10Amp, 380 V and then the power factor is 0.8., Therefore,

$$KW = \frac{1.73*10*380*0.8}{1000} = 5.258 \text{ kw/ hour}$$

Then for 1 day operation in pumping unit consumes electricity power equal to KW = 5.258 * 24= 126.22 kw /Day, Next, assume that the electricity power cost 3 Baht per 1KW, then 1 day of pumping unit costs = 126.22 (kw) * 3(Baht/kw) = 378.648 Baht/Day

In this study Intermit operation had been conduced 8 days (12-19 October, 2011). Then the electricity power cost during this operation was equal to; Electricity power cost during applying Intermit operation at tested well is Electricity power cost = 378.648 (Baht/Day) * (8*(1/2))(Day) = 1,514.59 Baht

Then the electricity power cost comparing between normal operation (24 hours operation) and Intermit operation (12 hours operation) can be further predicted as showed in Table 4.4.

Table 4.4 Predicted electricity power cost on 24 hours operation and Intermit operation.

Time	Electricity power cost on 24 hours operation (Baht)	Electricity power cost by Intermit operation on12 hours operation (Baht)
1 day	378.65	189.32
8 day	3029.20	1,514.56
1 month	11,359.50	5,679.60
1 year	138,207.00	69,101.80
5 year	691,036.00	345,509.00

4.4.1.2 Incomes from crude oil selling

As noticeable from previous sections, Intermit operation can increase crude oil production rate in total. Details of each day production during applying Intermit operation are depicted in Table 4.5.

Table 4.5 Summary of the BS&W measurement including net oil, net percent of water cut during applying Intermit operation period.

Date	Time	Start Pump	Stop Pump	Total (bbl/d)	Crude (bbl/d)	Water (bbl/d)	Water cut (%)
		F/L (ft)	FOP (ft)	F/L (ft)	FOP (ft)		
12/10/54	8.00-20.00	-	-	1538.3	40	-	-
13/10/54	8.00-20.00	1330.0	248	1524.9	53	76.97	11.06
14/10/54	8.00-20.00	1325.7	252	1556.5	22	74.30	14.84
15/10/54	8.00-20.00	1325.1	253	1526.5	51	77.28	11.38
16/10/54	8.00-20.00	1308.6	269	1529.6	48	87.66	18.88
17/10/54	8.00-20.00	1310.1	268	1531.8	46	77.28	15.28
18/10/55	8.00-20.00	1322.1	256	1545.2	33	82.56	17.11
19/10/56	8.00-20.00	1304.1	274	1540.9	37	77.28	17.72
AVG.						77.12	14.39

Remark : F/L = Fluid Level Depth

FOP = Fluid on Pump Depth

As seen in section 3.2, the production history of this tested well has an average net oil production 8.78 bbl/day whilst after applying Intermit operation, an average net oil production of this tested well has been increased up to 14.39 bbl/day or increasing about 64 percent. In term of incomes, present day crude oil prices of Defence Energy Department, Thailand is 3,281.76 Baht per Barrel (include VAT 7%), then predicted incomes from crude oil selling of this tested well both in 24 hours operation and Intermit operation can be calculated and compared as showed in Table 4.6.

Table 4.6 Summary incomes on 24 hours operation and Intermit operation (12 hours operation).

Time	Predicted income on 24 hours operation (Baht)	Predicted income by Intermit operation income on 12 hours operation (Baht)
1 day	28,813.9	47,224.53
8 day	230,511	377,796.24
1 month	864,416	1,416,735.9
1 year	10,517,073	17,236,953.5
5 year	52,585,367	86,184,767.3

4.2 Discussion oil recovery process

When fluid are producing from drilled well, there are some parameters and conditions that control flow behavior of produced fluid e.g. mobility ratio, gas-oil ratio, differential pressure between bottom hole and well head, water coning, etc. This section discusses only on water coning and mobility ratio because they are believed to be the main parameter that concerning to oil and water flow correlation during the Intermit operation is applying.

4.2.1 Water coning

In this study water coning was considered both in dynamic (fluid flow) condition and in static (fluid does not flow but segregate) condition.

Dynamic condition

Dynamic condition in this study means situation that well fluids are producing during sucker rod pump is turned on. In general water can flow more easier than oil, therefore in dynamic condition water coning tend to occur (Figure 4.1).

From equation (3.2), In dynamic condition the perforated interval, even near by formation, is saturated with mostly water and then causing $k_{rw} > k_{ro}$. If assume μ_o equal μ_w and they are constant from above equation, the mobility ratio is greater than 1, and it will be unfavorable mobility ratio (water flow easier than oil flow). Then production well will produce water more than oil.

Static Condition

Static condition in this study means the situation that occurred when the sucker rod pump is turned off and there is no fluid flow in well. In this condition fluid both in well and in surrounding formation does not flow but segregates instead. During this period water and oil are segregates from each other. As a result, oil saturation around perforated interval tends to increase and resulting in increasing in k_{ro}. Therefore, when the sucker rod pump is turned on again, oil will flow more than water in this interval, and resulting in having high oil production rate again (Figure 4.2).

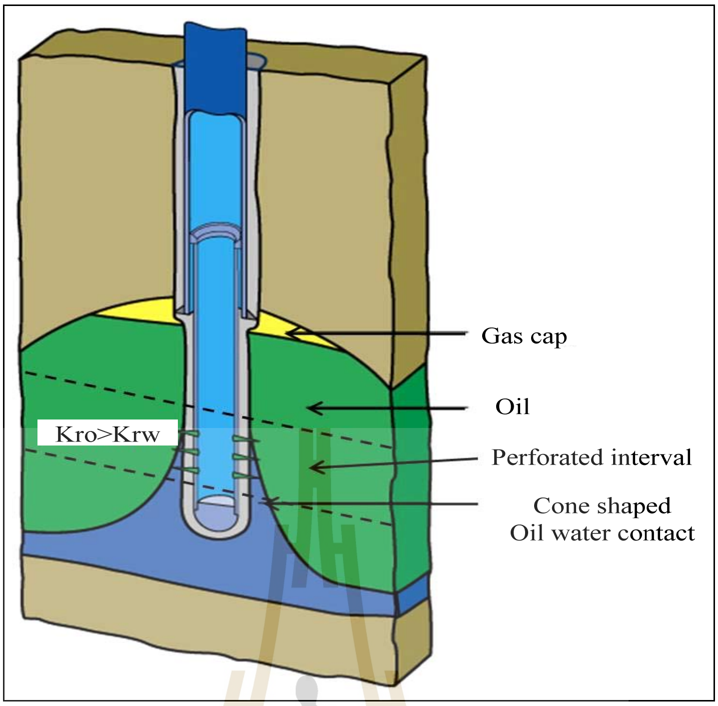


Figure 4.1 water coning in “Dynamic Condition”

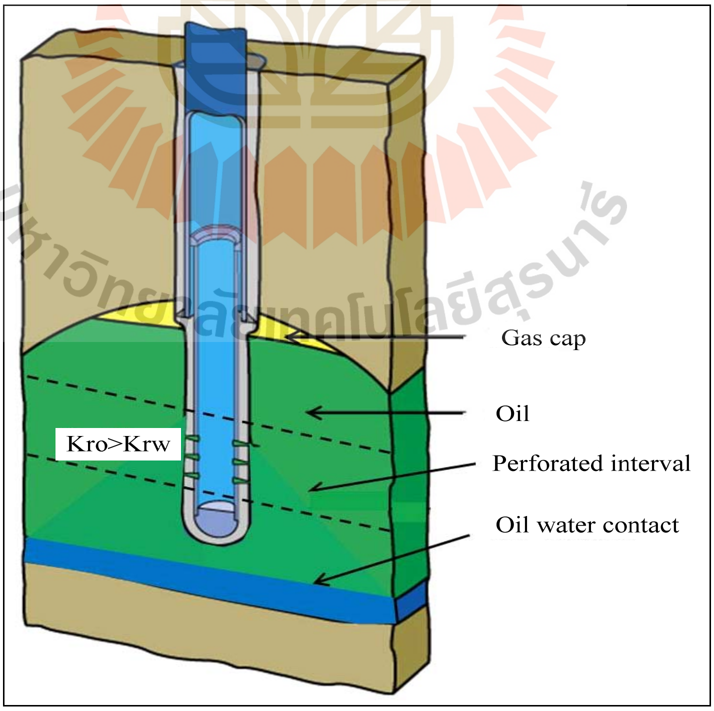


Figure 4.2 Oil and water segregation in “Static Condition”

4.2.2 Mobility ratio, M

From equation (3.1), Where k and μ are the relative or effective permeability and viscosity, respectively.If Mobility ratios <1 is favorable mobility ratio (oil flow > water flow) and if Mobility ratios >1 is unfavorable mobility ratio (oil flow < water flow)

In Intermit operation, when the sucker rod pump is turn off, oil and water both in well and in reservoir will be segregated from each other by its different in density. In general, production well is usually perforated in oil-bearing formation, therefore, when sucker rod pump is stop, oil should be accumulated at this perforated interval and resulting in increasing k_{ro}.Therefore, from below relation;

$$M = \frac{(k_{rw}/\quad_{w})}{(k_{ro}/\quad_{o})} \tag{4.2}$$

When Mae Soon oil field have $\mu_o = 0.0136$ cp and $\mu_w = 1$ are to

$$M = \frac{(k_{rw}/1)}{(k_{ro}/0.0136)} \tag{4.3}$$

Considering in the perforated interval, $k_{ro} > k_{rw}$, and $\mu_w > \mu_o$ then resulting in $M < 1$. Consequently, when the sucker rod pump is turned on again, oil flow more easier than water within the perforated interval around the well, and causing an increasing in oil production rate as a result.

CHAPTER V

CONCLUSTION & RECOMMEDATIONS

5.1 Conclusion

In term of technical consideration, the Intermit operation that allow turning off the sucker rod pump for 12 hours will cause the segregation of oil and water and lowering down water coning within the surrounding formations. These two situations give a good condition to oil flow, especially in the perforated interval, and result in having move oil production when the sucker rod pump is turned on again.

After the study had been accomplished, some advantages of using Intermit operation on the tested well FA-MS-07-08 can be summarized as follows;

During the Intermit operation had been applied, the electricity power cost for the sucker rod pumping unit of the tested well had been reduced up to 50 percent.

There was an incremental oil production about 64 percent during the Intermit operation had been used comparing to the normal (24 hours) operation

In term of incomes from selling crude oil, it can be seen that predicted incomes on selling crude oil produced by Intermit operation is about twice time to those of normal (24 hours) operation.

Table 5.1 summaries the forecast profit of the tested well FA-MS-07-08 when applying the Intermit operation through the period of times.

Table 5.1 Summary of the forecast profit from Intermit operation method

Time	Profit from electricity power cost reducing (Baht)	Profit from crude oil selling (Baht)	The total Profit (Baht)
1 day	189.33	18,410.68	18,600.01
8 day	1,514.64	147,285.44	148,800.1
1 month	5,679.90	552,320.4	558,000.3
1 year	69,105.45	6,719,880.5	6,788,986
5 years	345,527.00	33,599,400	33,944,927

5.2 Recommendations for Future Research Study

This Intermit operation had been conducted in a short time period (only 8 days). Therefore, this gave a few production data and might give some errors in calculations and interpretations. The future study should conduct this kind of operation in longer period of time, e.g. weeks or months, for getting more production data.

Further study should try to change duration of turning on and turning off the sucker rod pumping time to test the relationship between oil/water flow behavior and pump shut-down time. Then, the optimized turning off and turning on period of time that gives the optimized production rate might be reached.

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APPENDIX A

LABORATORY EXPERIMENT DATA WELL

FA-MS-07-08, MAE SOON OIL FIELD

Table A.1 Lab experiment history of BS&W measurement on September and August 2011

Date	Gross (avg.)	Net (avg.)	% Cut (avg.)	Date	Gross (avg.)	Net (avg.)	% Cut (avg.)
19-Sep-11	82.56	6.36	92.30	31-Aug-11	126.73	10.54	91.68
18-Sep-11	77.28	5.95	92.30	30-Aug-11	118.49	9.86	91.68
17-Sep-11	87.66	6.75	92.30	29-Aug-11	126.59	10.53	91.68
16-Sep-11	77.28	5.95	92.30	28-Aug-11	124.03	10.32	91.68
15-Sep-11	74.30	5.72	92.30	27-Aug-11	131.99	10.98	91.68
14-Sep-11	76.97	5.93	92.30	26-Aug-11	113.16	9.41	91.68
13-Sep-11	79.65	6.13	92.30	25-Aug-11	137.07	11.40	91.68
12-Sep-11	121.31	9.34	92.30	24-Aug-11	113.16	9.41	91.68
11-Sep-11	123.89	9.54	92.30	23-Aug-11	123.92	10.31	91.68
10-Sep-11	102.08	7.86	92.30	22-Aug-11	126.55	10.53	91.68
09-Sep-11	115.92	8.93	92.30	21-Aug-11	138.60	11.53	91.68
08-Sep-11	71.76	5.53	92.30	20-Aug-11	118.60	9.87	91.68
07-Sep-11	99.01	7.62	92.30	19-Aug-11	150.58	12.53	91.68
06-Sep-11	118.41	9.12	92.30	18-Aug-11	126.83	10.55	91.68
05-Sep-11	129.30	9.96	92.30	17-Aug-11	118.60	9.87	91.68
04-Sep-11	123.65	9.52	92.30	16-Aug-11	135.04	11.24	91.68
03-Sep-11	123.65	9.52	92.30	15-Aug-11	121.17	10.08	91.68
02-Sep-11	121.34	9.34	92.30	14-Aug-11	123.88	10.31	91.68
01-Sep-11	118.26	9.11	92.30	13-Aug-11	126.71	10.54	91.68
Average	101.28	7.80	92.30	12-Aug-11	114.00	9.48	91.68
				11-Aug-11	102.32	8.51	91.68
				10-Aug-11	90.19	7.50	91.68
				09-Aug-11	145.74	12.13	91.68
				08-Aug-11	104.83	8.72	91.68
				07-Aug-11	134.86	11.22	91.68
				06-Aug-11	104.70	8.71	91.68
				05-Aug-11	129.55	10.78	91.68
				04-Aug-11	123.76	10.30	91.68
				03-Aug-11	115.85	9.64	91.68
				02-Aug-11	121.40	10.10	91.68
				01-Aug-11	120.82	10.05	91.68
				Average	122.89	10.22	91.68

Table A.2 Lab experiment history of BS&W measurement July and June 2011

Date	Gross (avg.)	Net (avg.)	% Cut (avg.)	Date	Gross (avg.)	Net (avg.)	% Cut (avg.)
31-Jul-11	118.65	9.61	91.90	30-Jun-11	121.05	9.51	92.14
30-Jul-11	115.80	9.38	91.90	29-Jun-11	115.76	9.10	92.14
29-Jul-11	126.68	10.26	91.90	28-Jun-11	124.12	9.76	92.14
28-Jul-11	118.59	9.61	91.90	27-Jun-11	134.76	10.59	92.14
27-Jul-11	107.49	8.71	91.90	26-Jun-11	113.16	8.89	92.14
26-Jul-11	126.55	10.25	91.90	25-Jun-11	126.41	9.94	92.14
25-Jul-11	113.16	9.17	91.90	24-Jun-11	126.65	9.95	92.14
24-Jul-11	118.51	9.60	91.90	23-Jun-11	129.42	10.17	92.14
23-Jul-11	148.67	12.04	91.90	22-Jun-11	116.99	9.20	92.14
22-Jul-11	124.05	10.05	91.90	21-Jun-11	118.44	9.31	92.14
21-Jul-11	118.49	9.60	91.90	20-Jun-11	137.78	10.83	92.14
20-Jul-11	137.64	11.15	91.90	19-Jun-11	126.90	9.97	92.14
19-Jul-11	118.45	9.59	91.90	18-Jun-11	129.60	10.19	92.14
18-Jul-11	55.06	11.92	78.36	17-Jun-11	118.42	9.31	92.14
17-Jul-11	112.88	9.14	91.90	16-Jun-11	129.60	10.19	92.14
16-Jul-11	126.42	10.24	91.90	15-Jun-11	118.62	9.32	92.14
15-Jul-11	118.45	9.59	91.90	14-Jun-11	126.84	9.97	92.14
14-Jul-11	129.43	10.48	91.90	13-Jun-11	131.93	10.37	92.14
13-Jul-11	123.96	10.04	91.90	12-Jun-11	98.67	7.76	92.14
12-Jul-11	126.59	10.25	91.90	11-Jun-11	121.15	9.52	92.14
11-Jul-11	118.56	9.60	91.90	10-Jun-11	123.61	9.72	92.14
10-Jul-11	120.61	9.77	91.90	09-Jun-11	126.79	9.97	92.14
09-Jul-11	121.07	9.81	91.90	08-Jun-11	121.27	9.53	92.14
08-Jul-11	107.89	8.74	91.90	07-Jun-11	132.02	10.38	92.14
07-Jul-11	100.28	8.12	91.90	06-Jun-11	129.45	10.17	92.14
06-Jul-11	113.16	9.17	91.90	05-Jun-11	129.28	10.16	92.14
05-Jul-11	110.82	8.98	91.90	04-Jun-11	123.92	9.74	92.14
04-Jul-11	115.92	9.39	91.90	03-Jun-11	118.49	9.31	92.14
03-Jul-11	110.93	8.99	91.90	02-Jun-11	120.68	9.49	92.14
02-Jul-11	114.78	9.30	91.90	01-Jun-11	123.92	9.74	92.14
01-Jul-11	129.46	10.49	91.90	Average	123.86	9.74	92.14
Average	117.71	9.77	91.46				

Table A.3 Lab experiment history of BS&W measurement on May and April 2011

Date	Gross (avg.)	Net (avg.)	% Cut (avg.)	Date	Gross (avg.)	Net (avg.)	% Cut (avg.)
31-May-11	126.56	11.15	91.19	30-Apr-11	111.59	7.15	93.59
30-May-11	121.05	10.66	91.19	29-Apr-11	104.24	6.68	93.59
29-May-11	121.18	10.68	91.19	28-Apr-11	103.55	6.64	93.59
28-May-11	121.32	10.69	91.19	27-Apr-11	108.82	6.98	93.59
27-May-11	118.46	10.44	91.19	26-Apr-11	101.47	6.50	93.59
26-May-11	109.25	9.63	91.19	25-Apr-11	114.48	7.34	93.59
25-May-11	99.63	8.78	91.19	24-Apr-11	114.73	7.35	93.59
24-May-11	106.41	9.38	91.19	23-Apr-11	101.47	6.50	93.59
23-May-11	103.78	9.14	91.19	22-Apr-11	114.57	7.34	93.59
22-May-11	103.65	9.13	91.19	21-Apr-11	97.98	6.28	93.59
21-May-11	102.51	9.03	91.19	20-Apr-11	111.64	7.16	93.59
20-May-11	103.43	9.11	91.19	19-Apr-11	112.76	7.23	93.59
19-May-11	114.80	10.11	91.19	18-Apr-11	106.49	6.83	93.59
18-May-11	108.85	9.59	91.19	17-Apr-11	98.08	6.29	93.59
17-May-11	111.12	9.79	91.19	16-Apr-11	117.43	7.53	93.59
16-May-11	108.95	9.60	91.19	15-Apr-11	109.05	6.99	93.59
15-May-11	106.37	9.37	91.19	14-Apr-11	107.03	6.86	93.59
14-May-11	111.33	9.81	91.19	13-Apr-11	112.43	7.21	93.59
13-May-11	153.12	13.49	91.19	12-Apr-11	103.57	6.64	93.59
12-May-11	109.03	9.61	91.19	11-Apr-11	115.24	7.39	93.59
11-May-11	106.49	9.38	91.19	10-Apr-11	125.30	8.03	93.59
10-May-11	106.31	9.37	91.19	09-Apr-11	101.80	6.53	93.59
09-May-11	100.84	8.88	91.19	08-Apr-11	119.68	7.67	93.59
08-May-11	109.18	9.62	91.19	07-Apr-11	115.92	7.43	93.59
07-May-11	106.26	9.36	91.19	06-Apr-11	114.13	7.32	93.59
06-May-11	108.84	9.59	91.19	05-Apr-11	118.85	7.62	93.59
05-May-11	106.25	9.36	91.19	04-Apr-11	170.84	10.95	93.59
04-May-11	114.49	10.09	91.19	03-Apr-11	112.91	7.24	93.59
03-May-11	107.15	9.44	91.19	02-Apr-11	121.21	7.77	93.59
02-May-11	117.32	10.34	91.19	01-Apr-11	115.40	7.40	93.59
01-May-11	106.24	9.36	91.19	Average	112.76	7.23	93.59
Average	111.30	9.81	91.19				

Table A.4 Lab experiment history of BS&W measurement on March and February 2011

Date	Gross (avg.)	Net (avg.)	% Cut (avg.)	Date	Gross (avg.)	Net (avg.)	% Cut (avg.)
31-Mar-11	126.72	10.23	91.93	28-Feb-11	118.65	8.39	92.93
30-Mar-11	115.10	9.29	91.93	27-Feb-11	121.26	8.57	92.93
29-Mar-11	129.42	10.44	91.93	26-Feb-11	121.35	8.58	92.93
28-Mar-11	104.88	8.46	91.93	25-Feb-11	124.13	8.78	92.93
27-Mar-11	123.78	9.99	91.93	24-Feb-11	118.43	8.37	92.93
26-Mar-11	123.73	9.99	91.93	23-Feb-11	126.80	8.96	92.93
25-Mar-11	115.28	9.30	91.93	22-Feb-11	121.03	8.56	92.93
24-Mar-11	124.08	10.01	91.93	21-Feb-11	121.21	8.57	92.93
23-Mar-11	126.31	10.19	91.93	20-Feb-11	118.53	8.38	92.93
22-Mar-11	120.63	9.73	91.93	19-Feb-11	123.85	8.76	92.93
21-Mar-11	123.45	9.96	91.93	18-Feb-11	126.51	8.94	92.93
20-Mar-11	128.61	10.38	91.93	17-Feb-11	115.72	8.18	92.93
19-Mar-11	126.22	10.19	91.93	16-Feb-11	129.35	9.14	92.93
18-Mar-11	125.88	10.16	91.93	15-Feb-11	118.59	8.38	92.93
17-Mar-11	131.65	10.62	91.93	14-Feb-11	126.80	8.96	92.93
16-Mar-11	128.64	10.38	91.93	13-Feb-11	121.10	8.56	92.93
15-Mar-11	126.57	10.21	91.93	12-Feb-11	121.36	8.58	92.93
14-Mar-11	140.61	11.35	91.93	11-Feb-11	123.94	8.76	92.93
13-Mar-11	123.32	9.95	91.93	10-Feb-11	121.38	8.58	92.93
12-Mar-11	121.35	9.79	91.93	09-Feb-11	126.85	8.97	92.93
11-Mar-11	126.68	10.22	91.93	08-Feb-11	126.87	8.97	92.93
10-Mar-11	113.12	9.13	91.93	07-Feb-11	110.23	7.79	92.93
09-Mar-11	121.16	9.78	91.93	06-Feb-11	21.78	1.54	92.93
08-Mar-11	115.86	9.35	91.93	05-Feb-11	118.41	8.37	92.93
07-Mar-11	110.31	8.90	91.93	04-Feb-11	124.09	8.77	92.93
06-Mar-11	113.52	9.16	91.93	03-Feb-11	122.66	8.67	92.93
05-Mar-11	118.68	9.58	91.93	02-Feb-11	123.38	8.72	92.93
04-Mar-11	131.91	10.65	91.93	01-Feb-11	123.20	8.71	92.93
03-Mar-11	112.82	9.10	91.93	Average	118.48	8.38	92.93
02-Mar-11	113.92	9.19	91.93				
01-Mar-11	117.93	9.52	91.93				
Average	122.00	9.85	91.93				

Table A.5 Lab experiment history of BS&W measurement on January 2011

Date	Gross (avg.)	Net (avg.)	% Cut (avg.)
31-Jan-11	123.36	6.30	94.89
30-Jan-11	127.73	6.53	94.89
29-Jan-11	114.60	5.86	94.89
28-Jan-11	134.09	6.85	94.89
27-Jan-11	125.39	6.41	94.89
26-Jan-11	122.61	6.27	94.89
25-Jan-11	117.78	6.02	94.89
24-Jan-11	117.69	6.01	94.89
23-Jan-11	126.34	6.46	94.89
22-Jan-11	126.27	6.45	94.89
21-Jan-11	136.17	6.96	94.89
20-Jan-11	117.68	6.01	94.89
19-Jan-11	123.16	6.29	94.89
18-Jan-11	119.88	6.13	94.89
17-Jan-11	118.21	6.04	94.89
16-Jan-11	78.45	4.01	94.89
15-Jan-11	189.55	9.69	94.89
14-Jan-11	117.78	6.02	94.89
13-Jan-11	106.48	5.44	94.89
12-Jan-11	114.76	5.86	94.89
11-Jan-11	125.41	6.41	94.89
10-Jan-11	125.93	6.44	94.89
09-Jan-11	123.24	6.30	94.89
08-Jan-11	114.71	5.86	94.89
07-Jan-11	123.39	6.31	94.89
06-Jan-11	125.24	6.40	94.89
05-Jan-11	116.69	5.96	94.89
04-Jan-11	120.53	6.16	94.89
03-Jan-11	161.60	8.26	94.89
02-Jan-11	76.40	3.90	94.89
01-Jan-11	124.83	6.38	94.89
Average	122.45	6.26	94.89

Table A.6 Lab experiment history of BS&W measurement on December and November 2010

Date	Gross (avg.)	Net (avg.)	% Cut (avg.)	Date	Gross (avg.)	Net (avg.)	% Cut (avg.)
01-Dec-10	122.75	10.02	91.84	01-Nov-10	132.96	8.62	93.52
02-Dec-10	106.83	8.72	91.84	02-Nov-10	141.36	9.16	93.52
03-Dec-10	117.49	9.59	91.84	03-Nov-10	130.22	8.44	93.52
04-Dec-10	137.88	11.25	91.84	04-Nov-10	144.10	9.34	93.52
05-Dec-10	124.08	10.13	91.84	05-Nov-10	138.68	8.99	93.52
06-Dec-10	138.48	11.30	91.84	06-Nov-10	143.86	9.32	93.52
07-Dec-10	135.67	11.07	91.84	07-Nov-10	138.32	8.96	93.52
08-Dec-10	141.20	11.52	91.84	08-Nov-10	139.17	9.02	93.52
09-Dec-10	132.83	10.84	91.84	09-Nov-10	132.87	8.61	93.52
10-Dec-10	144.00	11.75	91.84	10-Nov-10	138.73	8.99	93.52
11-Dec-10	105.40	8.60	91.84	11-Nov-10	128.58	8.33	93.52
12-Dec-10	117.56	9.59	91.84	12-Nov-10	123.26	7.99	93.52
13-Dec-10	193.90	15.82	91.84	13-Nov-10	123.20	7.98	93.52
14-Dec-10	77.65	6.34	91.84	14-Nov-10	121.44	7.87	93.52
15-Dec-10	135.59	11.06	91.84	15-Nov-10	115.92	7.51	93.52
16-Dec-10	138.19	11.28	91.84	16-Nov-10	122.32	7.93	93.52
17-Dec-10	141.50	11.55	91.84	17-Nov-10	119.92	7.77	93.52
18-Dec-10	138.29	11.28	91.84	18-Nov-10	119.69	7.76	93.52
19-Dec-10	140.97	11.50	91.84	19-Nov-10	123.35	7.99	93.52
20-Dec-10	135.68	11.07	91.84	20-Nov-10	128.63	8.33	93.52
21-Dec-10	138.60	11.31	91.84	21-Nov-10	114.02	7.39	93.52
22-Dec-10	133.17	10.87	91.84	22-Nov-10	116.26	7.53	93.52
23-Dec-10	135.57	11.06	91.84	23-Nov-10	114.46	7.42	93.52
24-Dec-10	138.56	11.31	91.84	24-Nov-10	120.62	7.82	93.52
25-Dec-10	144.19	11.77	91.84	25-Nov-10	119.52	7.74	93.52
26-Dec-10	135.41	11.05	91.84	26-Nov-10	108.32	7.02	93.52
27-Dec-10	143.98	11.75	91.84	27-Nov-10	118.27	7.66	93.52
28-Dec-10	149.37	12.19	91.84	28-Nov-10	115.14	7.46	93.52
29-Dec-10	126.89	10.35	91.84	29-Nov-10	114.19	7.40	93.52
30-Dec-10	136.91	11.17	91.84	30-Nov-10	117.27	7.60	93.52
31-Dec-10	104.08	8.49	91.84	Average	125.77	8.14	93.53
Average	132.45	10.74	91.89				

Table A.7 Lab experiment history of BS&W measurement on October and September 2010

Date	Gross (avg.)	Net (avg.)	% Cut (avg.)	Date	Gross (avg.)	Net (avg.)	% Cut (avg.)
01-Oct-10	130.54	8.20	93.72	01-Sep-10	126.56	7.56	94.03
02-Oct-10	123.11	7.73	93.72	02-Sep-10	128.98	7.70	94.03
03-Oct-10	131.73	8.27	93.72	03-Sep-10	127.86	7.63	94.03
04-Oct-10	141.52	8.89	93.72	04-Sep-10	128.72	7.68	94.03
05-Oct-10	136.63	8.58	93.72	05-Sep-10	113.79	6.79	94.03
06-Oct-10	144.11	9.05	93.72	06-Sep-10	119.40	7.13	94.03
07-Oct-10	163.68	10.28	93.72	07-Sep-10	150.91	9.01	94.03
08-Oct-10	138.90	8.72	93.72	08-Sep-10	114.94	6.86	94.03
09-Oct-10	139.15	8.74	93.72	09-Sep-10	116.15	6.93	94.03
10-Oct-10	145.62	9.14	93.72	10-Sep-10	127.99	7.64	94.03
11-Oct-10	126.38	7.94	93.72	11-Sep-10	103.52	6.18	94.03
12-Oct-10	130.37	8.19	93.72	12-Sep-10	135.56	8.09	94.03
13-Oct-10	143.78	9.03	93.72	13-Sep-10	172.61	10.30	94.03
14-Oct-10	141.05	8.86	93.72	14-Sep-10	149.78	8.94	94.03
15-Oct-10	142.01	8.92	93.72	15-Sep-10	126.16	7.53	94.03
16-Oct-10	133.00	8.35	93.72	16-Sep-10	150.17	8.96	94.03
17-Oct-10	147.12	9.24	93.72	17-Sep-10	117.74	7.03	94.03
18-Oct-10	130.67	8.21	93.72	18-Sep-10	126.93	7.58	94.03
19-Oct-10	141.28	8.87	93.72	19-Sep-10	128.78	7.69	94.03
20-Oct-10	138.29	8.68	93.72	20-Sep-10	123.15	7.35	94.03
21-Oct-10	138.70	8.71	93.72	21-Sep-10	120.51	7.19	94.03
22-Oct-10	141.01	8.86	93.72	22-Sep-10	136.14	8.13	94.03
23-Oct-10	138.46	8.70	93.72	23-Sep-10	124.09	7.41	94.03
24-Oct-10	138.30	8.69	93.72	24-Sep-10	125.18	7.47	94.03
25-Oct-10	141.13	8.86	93.72	25-Sep-10	172.15	10.28	94.03
26-Oct-10	135.70	8.52	93.72	26-Sep-10	128.92	7.70	94.03
27-Oct-10	136.29	8.56	93.72	27-Sep-10	104.67	6.25	94.03
28-Oct-10	138.43	8.69	93.72	28-Sep-10	105.06	6.27	94.03
29-Oct-10	138.63	8.71	93.72	29-Sep-10	142.39	8.50	94.03
30-Oct-10	138.67	8.71	93.72	30-Sep-10	137.12	8.19	94.03
31-Oct-10	144.41	9.07	93.72	Average	130.13	8.99	93.09
Average	134.11	8.24	93.86				

Table A.8 Lab experiment history of BS&W measurement on August and July 2010

Date	Gross (avg.)	Net (avg.)	% Cut (avg.)	Date	Gross (avg.)	Net (avg.)	% Cut (avg.)
01-Aug-10	133.15	9.20	93.09	01-Jul-10	131.69	8.59	93.48
02-Aug-10	103.80	7.17	93.09	02-Jul-10	150.01	9.78	93.48
03-Aug-10	136.21	9.41	93.09	03-Jul-10	136.41	8.89	93.48
04-Aug-10	138.93	9.60	93.09	04-Jul-10	140.42	9.16	93.48
05-Aug-10	134.30	9.28	93.09	05-Jul-10	133.40	8.70	93.48
06-Aug-10	128.07	8.85	93.09	06-Jul-10	112.32	7.32	93.48
07-Aug-10	144.46	9.98	93.09	07-Jul-10	210.94	13.75	93.48
08-Aug-10	141.97	9.81	93.09	08-Jul-10	166.83	10.88	93.48
09-Aug-10	109.83	7.59	93.09	09-Jul-10	142.05	9.26	93.48
10-Aug-10	139.00	9.61	93.09	10-Jul-10	147.46	9.61	93.48
11-Aug-10	123.32	8.52	93.09	11-Jul-10	135.97	8.87	93.48
12-Aug-10	133.24	9.21	93.09	12-Jul-10	86.38	5.63	93.48
13-Aug-10	132.16	9.13	93.09	13-Jul-10	138.52	9.03	93.48
14-Aug-10	127.22	8.79	93.09	14-Jul-10	123.19	8.03	93.48
15-Aug-10	128.86	8.90	93.09	15-Jul-10	150.24	9.80	93.48
16-Aug-10	145.28	10.04	93.09	16-Jul-10	128.82	8.40	93.48
17-Aug-10	133.19	9.20	93.09	17-Jul-10	136.16	8.88	93.48
18-Aug-10	133.13	9.20	93.09	18-Jul-10	141.94	9.25	93.48
19-Aug-10	150.51	10.40	93.09	19-Jul-10	128.96	8.41	93.48
20-Aug-10	98.48	6.81	93.09	20-Jul-10	130.90	8.53	93.48
21-Aug-10	141.48	9.78	93.09	21-Jul-10	140.07	9.13	93.48
22-Aug-10	87.36	6.04	93.09	22-Jul-10	133.44	8.70	93.48
23-Aug-10	145.54	10.06	93.09	23-Jul-10	126.06	8.22	93.48
24-Aug-10	124.86	8.63	93.09	24-Jul-10	136.24	8.88	93.48
25-Aug-10	128.99	8.91	93.09	25-Jul-10	128.07	8.35	93.48
26-Aug-10	126.21	8.72	93.09	26-Jul-10	150.11	9.79	93.48
27-Aug-10	119.58	8.26	93.09	27-Jul-10	117.87	7.69	93.48
28-Aug-10	157.81	10.90	93.09	28-Jul-10	130.62	8.52	93.48
29-Aug-10	136.02	9.40	93.09	29-Jul-10	147.53	9.62	93.48
30-Aug-10	130.37	9.01	93.09	30-Jul-10	125.89	8.21	93.48
31-Aug-10	120.64	8.34	93.09	Average	137.50	8.98	93.47
Average	129.53	7.73	94.03				

Table A.9 Lab experiment history of BS&W measurement on June and May 2010

Date	Gross (avg.)	Net (avg.)	% Cut (avg.)	Date	Gross (avg.)	Net (avg.)	% Cut (avg.)
01-Jun-10	163.74	11.53	92.96	01-May-10	50.04	9.05	81.92
02-Jun-10	144.77	10.19	92.96	02-May-10	44.55	8.05	81.92
03-Jun-10	166.40	11.71	92.96	03-May-10	38.93	7.04	81.92
04-Jun-10	135.95	9.57	92.96	04-May-10	55.46	10.03	81.92
05-Jun-10	155.26	10.93	92.96	05-May-10	50.12	9.06	81.92
06-Jun-10	147.22	10.36	92.96	06-May-10	30.83	5.57	81.92
07-Jun-10	166.22	11.70	92.96	07-May-10	36.18	6.54	81.92
08-Jun-10	163.62	11.52	92.96	08-May-10	55.48	10.03	81.92
09-Jun-10	158.43	11.15	92.96	09-May-10	50.02	9.04	81.92
10-Jun-10	152.88	10.76	92.96	10-May-10	28.01	5.06	81.92
11-Jun-10	158.40	11.15	92.96	11-May-10	99.69	18.02	81.92
12-Jun-10	130.54	9.19	92.96	12-May-10	184.02	33.27	81.92
13-Jun-10	87.36	6.15	92.96	13-May-10	202.48	36.61	81.92
14-Jun-10	186.10	13.10	92.96	14-May-10	193.88	35.05	81.92
15-Jun-10	158.07	11.13	92.96	15-May-10	180.53	32.64	81.92
16-Jun-10	153.75	10.82	92.96	16-May-10	180.14	32.57	81.92
17-Jun-10	114.16	8.04	92.96	17-May-10	186.18	33.66	81.92
18-Jun-10	119.88	8.44	92.96	18-May-10	179.64	32.48	81.92
19-Jun-10	125.04	8.80	92.96	19-May-10	188.72	34.12	81.92
20-Jun-10	110.75	7.80	92.96	20-May-10	166.22	30.05	81.92
21-Jun-10	270.96	19.08	92.96	21-May-10	179.85	32.52	81.92
22-Jun-10	144.45	10.17	92.96	22-May-10	163.68	29.59	81.92
23-Jun-10	138.62	9.76	92.96	23-May-10	163.87	29.63	81.92
24-Jun-10	139.03	9.79	92.96	24-May-10	160.79	29.07	81.92
25-Jun-10	144.70	10.19	92.96	25-May-10	160.92	29.09	81.92
26-Jun-10	144.70	10.19	92.96	26-May-10	174.62	31.57	81.92
27-Jun-10	144.56	10.18	92.96	27-May-10	147.42	26.65	81.92
28-Jun-10	139.11	9.79	92.96	28-May-10	166.57	30.12	81.92
29-Jun-10	155.69	10.96	92.96	29-May-10	144.68	26.16	81.92
30-Jun-10	147.24	10.37	92.96	30-May-10	150.29	27.17	81.92
Average	148.92	10.48	92.96	31-May-10	133.23	24.09	81.92
				Average	127.32	11.02	89.92

Table A.10 Lab experiment history of BS&W measurement on April and March 2010

Date	Gross (avg.)	Net (avg.)	% Cut (avg.)	Date	Gross (avg.)	Net (avg.)	% Cut (avg.)
01-Apr-10	35.88	3.17	91.16	01-Mar-10	54.31	5.65	89.59
02-Apr-10	45.96	4.06	91.16	02-Mar-10	87.47	9.11	89.59
03-Apr-10	38.64	3.42	91.16	03-Mar-10	84.66	8.81	89.59
04-Apr-10	51.52	4.55	91.16	04-Mar-10	29.47	3.07	89.59
05-Apr-10	38.64	3.42	91.16	05-Mar-10	46.06	4.80	89.59
06-Apr-10	41.40	3.66	91.16	06-Mar-10	87.57	9.12	89.59
07-Apr-10	46.07	4.07	91.16	07-Mar-10	37.85	3.94	89.59
08-Apr-10	34.94	3.09	91.16	08-Mar-10	13.07	1.36	89.59
09-Apr-10	41.40	3.66	91.16	09-Mar-10	46.64	4.86	89.59
10-Apr-10	35.88	3.17	91.16	10-Mar-10	50.01	5.21	89.59
11-Apr-10	48.90	4.32	91.16	11-Mar-10	65.45	6.81	89.59
12-Apr-10	54.31	4.80	91.16	12-Mar-10	36.26	3.78	89.59
13-Apr-10	59.78	5.28	91.16	13-Mar-10	49.49	5.15	89.59
14-Apr-10	34.94	3.09	91.16	14-Mar-10	49.46	5.15	89.59
15-Apr-10	106.73	9.44	91.16	15-Mar-10	35.53	3.70	89.59
16-Apr-10	49.47	4.37	91.16	16-Mar-10	53.14	5.53	89.59
17-Apr-10	16.41	1.45	91.16	17-Mar-10	47.29	4.92	89.59
18-Apr-10	27.96	2.47	91.16	18-Mar-10	43.77	4.56	89.59
19-Apr-10	30.76	2.72	91.16	19-Mar-10	49.46	5.15	89.59
20-Apr-10	35.88	3.17	91.16	20-Mar-10	52.13	5.43	89.59
21-Apr-10	84.70	7.49	91.16	21-Mar-10	44.43	4.63	89.59
22-Apr-10	0.42	0.04	91.16	22-Mar-10	69.30	7.21	89.59
23-Apr-10	41.75	3.69	91.16	23-Mar-10	27.92	2.91	89.59
24-Apr-10	41.75	3.69	91.16	24-Mar-10	41.11	4.28	89.59
25-Apr-10	44.44	3.93	91.16	25-Mar-10	52.44	5.46	89.59
26-Apr-10	41.63	3.68	91.16	26-Mar-10	35.88	3.74	89.59
27-Apr-10	58.25	5.15	91.16	27-Mar-10	45.87	4.78	89.59
28-Apr-10	33.45	2.96	91.16	28-Mar-10	38.64	4.02	89.59
29-Apr-10	47.27	4.18	91.16	29-Mar-10	35.07	3.65	89.59
30-Apr-10	47.16	4.17	91.16	30-Mar-10	38.64	4.02	89.59
Average	43.88	3.88	91.16	31-Mar-10	45.95	4.78	89.59
				Average	48.21	5.02	89.59

Table A.11 Lab experiment history of BS&W measurement on February and January 2010

Date	Gross (avg.)	Net (avg.)	% Cut (avg.)	Date	Gross (avg.)	Net (avg.)	% Cut (avg.)
01-Feb-10	76.19	5.47	92.82	01-Jan-10	82.15	5.90	92.82
02-Feb-10	81.87	5.88	92.82	02-Jan-10	84.85	6.09	92.82
03-Feb-10	84.68	6.08	92.82	03-Jan-10	86.89	6.24	92.82
04-Feb-10	79.26	5.69	92.82	04-Jan-10	81.80	5.87	92.82
05-Feb-10	73.47	5.28	92.82	05-Jan-10	84.67	6.08	92.82
06-Feb-10	82.80	5.95	92.82	06-Jan-10	81.73	5.87	92.82
07-Feb-10	84.05	6.04	92.82	07-Jan-10	84.70	6.08	92.82
08-Feb-10	78.99	5.67	92.82	08-Jan-10	81.82	5.87	92.82
09-Feb-10	84.65	6.08	92.82	09-Jan-10	90.11	6.47	92.82
10-Feb-10	96.23	6.91	92.82	10-Jan-10	87.43	6.28	92.82
11-Feb-10	60.96	4.38	92.82	11-Jan-10	76.38	5.48	92.82
12-Feb-10	71.76	5.15	92.82	12-Jan-10	87.41	6.28	92.82
13-Feb-10	84.74	6.08	92.82	13-Jan-10	82.26	5.91	92.82
14-Feb-10	73.83	5.30	92.82	14-Jan-10	89.96	6.46	92.82
15-Feb-10	73.61	5.29	92.82	15-Jan-10	81.56	5.86	92.82
16-Feb-10	69.67	5.00	92.82	16-Jan-10	94.78	6.81	92.82
17-Feb-10	82.97	5.96	92.82	17-Jan-10	94.26	6.77	92.82
18-Feb-10	79.17	5.68	92.82	18-Jan-10	89.99	6.46	92.82
19-Feb-10	82.65	5.93	92.82	19-Jan-10	73.98	5.31	92.82
20-Feb-10	95.69	6.87	92.82	20-Jan-10	81.92	5.88	92.82
21-Feb-10	54.24	3.89	92.82	21-Jan-10	88.32	6.34	92.82
22-Feb-10	73.22	5.26	92.82	22-Jan-10	37.66	2.70	92.82
23-Feb-10	76.31	5.48	92.82	23-Jan-10	92.84	6.67	92.82
24-Feb-10	45.80	3.21	93.00	24-Jan-10	114.86	8.25	92.82
25-Feb-10	109.47	7.66	93.00	25-Jan-10	83.77	6.01	92.82
26-Feb-10	76.47	5.35	93.00	26-Jan-10	80.04	5.75	92.82
27-Feb-10	59.88	4.19	93.00	27-Jan-10	81.88	5.88	92.82
28-Feb-10	54.38	3.81	93.00	28-Jan-10	79.13	5.68	92.82
Average	76.68	5.48	92.85	29-Jan-10	83.72	6.01	92.82
				30-Jan-10	76.47	5.49	92.82
				31-Jan-10	84.60	6.07	92.82
				Average	83.93	6.03	92.82

Table A.12 Lab experiment history of BS&W measurement on December and November 2009

Date	Gross (avg.)	Net (avg.)	% Cut (avg.)	Date	Gross (avg.)	Net (avg.)	% Cut (avg.)
01-Dec-09	81.66	6.98	91.45	01-Nov-09	89.97	6.23	93.07
02-Dec-09	84.44	7.22	91.45	02-Nov-09	81.80	5.67	93.07
03-Dec-09	84.62	7.24	91.45	03-Nov-09	84.47	5.85	93.07
04-Dec-09	81.74	6.99	91.45	04-Nov-09	84.43	5.85	93.07
05-Dec-09	87.17	7.45	91.45	05-Nov-09	106.39	7.37	93.07
06-Dec-09	78.73	6.73	91.45	06-Nov-09	87.25	6.05	93.07
07-Dec-09	129.50	11.07	91.45	07-Nov-09	87.35	6.05	93.07
08-Dec-09	52.03	4.45	91.45	08-Nov-09	90.15	6.25	93.07
09-Dec-09	87.25	7.46	91.45	09-Nov-09	103.89	7.20	93.07
10-Dec-09	94.23	8.06	91.45	10-Nov-09	84.71	5.87	93.07
11-Dec-09	108.49	9.28	91.45	11-Nov-09	97.44	6.75	93.07
12-Dec-09	138.50	11.84	91.45	12-Nov-09	84.73	5.87	93.07
13-Dec-09	145.06	12.40	91.45	13-Nov-09	82.80	5.74	93.07
14-Dec-09	15.42	1.32	91.45	14-Nov-09	92.53	6.41	93.07
15-Dec-09	87.46	7.48	91.45	15-Nov-09	89.99	6.24	93.07
16-Dec-09	84.63	7.24	91.45	16-Nov-09	90.04	6.24	93.07
17-Dec-09	78.78	6.74	91.45	17-Nov-09	89.92	6.23	93.07
18-Dec-09	90.05	7.70	91.45	18-Nov-09	51.15	3.54	93.07
19-Dec-09	77.67	6.64	91.45	19-Nov-09	99.35	6.88	93.07
20-Dec-09	90.14	7.71	91.45	20-Nov-09	65.80	4.56	93.07
21-Dec-09	90.15	7.71	91.45	21-Nov-09	84.59	5.86	93.07
22-Dec-09	87.37	7.47	91.45	22-Nov-09	90.14	6.25	93.07
23-Dec-09	84.72	7.24	91.45	23-Nov-09	98.02	6.79	93.07
24-Dec-09	74.52	6.37	91.45	24-Nov-09	81.66	5.66	93.07
25-Dec-09	92.32	7.89	91.45	25-Nov-09	93.40	6.47	93.07
26-Dec-09	87.39	7.47	91.45	26-Nov-09	82.28	5.70	93.07
27-Dec-09	81.79	6.99	91.45	27-Nov-09	82.01	5.68	93.07
28-Dec-09	103.85	8.88	91.45	28-Nov-09	82.80	5.74	93.07
29-Dec-09	95.84	8.19	91.45	29-Nov-09	76.93	5.33	93.07
30-Dec-09	90.11	7.70	91.45	30-Nov-09	87.05	6.03	93.07
31-Dec-09	82.24	7.03	91.45	Average	87.05	6.03	93.07
Average	87.72	6.81	92.25				

Table A.13 Lab experiment history of BS&W measurement on October and September 2009

Date	Gross (avg.)	Net (avg.)	% Cut (avg.)	Date	Gross (avg.)	Net (avg.)	% Cut (avg.)
01-Oct-09	18.29	1.27	93.07	01-Sep-09	85.56	9.33	89.09
02-Oct-09	167.04	11.58	93.07	02-Sep-09	92.98	10.14	89.09
03-Oct-09	92.06	6.38	93.07	03-Sep-09	83.09	9.07	89.09
04-Oct-09	105.84	7.34	93.07	04-Sep-09	89.18	9.73	89.09
05-Oct-09	79.18	5.49	93.07	05-Sep-09	84.63	9.23	89.09
06-Oct-09	84.49	5.86	93.07	06-Sep-09	90.07	9.83	89.09
06-Oct-09	84.49	5.86	93.07	07-Sep-09	84.59	9.23	89.09
07-Oct-09	131.61	9.12	93.07	08-Sep-09	84.45	9.21	89.09
08-Oct-09	78.00	5.41	93.07	09-Sep-09	83.12	9.07	89.09
09-Oct-09	83.25	5.77	93.07	10-Sep-09	67.19	7.33	89.09
10-Oct-09	48.15	3.34	93.07	11-Sep-09	83.28	9.09	89.09
11-Oct-09	66.24	4.59	93.07	12-Sep-09	74.77	8.16	89.09
12-Oct-09	173.88	12.05	93.07	13-Sep-09	88.83	9.69	89.09
13-Oct-09	98.29	6.81	93.07	14-Sep-09	79.99	8.73	89.09
14-Oct-09	92.77	6.43	93.07	15-Sep-09	80.15	8.74	89.09
15-Oct-09	84.41	5.85	93.07	16-Sep-09	74.40	8.12	89.09
16-Oct-09	92.01	6.38	93.07	17-Sep-09	77.53	8.46	89.09
17-Oct-09	84.62	5.86	93.07	18-Sep-09	73.37	8.00	89.09
18-Oct-09	87.45	6.06	93.07	19-Sep-09	101.31	11.05	89.09
19-Oct-09	92.68	6.42	93.07	20-Sep-09	95.32	10.40	89.09
20-Oct-09	89.88	6.23	93.07	21-Sep-09	89.80	9.80	89.09
21-Oct-09	82.05	5.69	93.07	22-Sep-09	89.81	9.80	89.09
22-Oct-09	95.65	6.63	93.07	23-Sep-09	84.52	9.22	89.09
23-Oct-09	91.36	6.33	93.07	24-Sep-09	87.24	9.52	89.09
24-Oct-09	103.85	7.20	93.07	25-Sep-09	94.63	10.32	89.09
25-Oct-09	84.59	5.86	93.07	26-Sep-09	95.48	10.42	89.09
26-Oct-09	92.79	6.43	93.07	27-Sep-09	90.83	9.91	89.09
27-Oct-09	103.77	7.19	93.07	28-Sep-09	82.80	9.03	89.09
28-Oct-09	84.51	5.86	93.07	29-Sep-09	104.71	11.42	89.09
29-Oct-09	84.44	5.85	93.07	30-Sep-09	77.28	8.43	89.09
30-Oct-09	90.05	6.24	93.07	Average	85.70	9.35	89.09
Average	91.72	6.36	93.07				

Table A.14 Lab experiment history of BS&W measurement on August and July 2009

Date	Gross (avg.)	Net (avg.)	% Cut (avg.)	Date	Gross (avg.)	Net (avg.)	% Cut (avg.)
01-Aug-09	62.46	5.53	91.14	01-Jul-09	88.01	9.73	88.94
02-Aug-09	87.23	7.73	91.14	02-Jul-09	87.04	7.71	91.14
03-Aug-09	79.09	7.01	91.14	03-Jul-09	91.76	8.13	91.14
04-Aug-09	60.72	5.38	91.14	04-Jul-09	91.08	8.07	91.14
05-Aug-09	18.41	1.63	91.14	05-Jul-09	90.38	8.01	91.14
06-Aug-09	143.52	12.72	91.14	06-Jul-09	92.52	8.20	91.14
07-Aug-09	80.42	7.13	91.14	07-Jul-09	85.56	7.58	91.14
08-Aug-09	103.18	9.14	91.14	08-Jul-09	92.48	8.19	91.14
09-Aug-09	85.56	7.58	91.14	09-Jul-09	89.75	7.95	91.14
10-Aug-09	87.23	7.73	91.14	10-Jul-09	109.14	9.67	91.14
11-Aug-09	71.76	6.36	91.14	11-Jul-09	87.33	7.74	91.14
12-Aug-09	97.44	8.63	91.14	12-Jul-09	102.91	9.12	91.14
13-Aug-09	99.24	8.79	91.14	13-Jul-09	55.20	4.89	91.14
14-Aug-09	87.20	7.73	91.14	14-Jul-09	79.09	7.01	91.14
15-Aug-09	86.46	7.66	91.14	15-Jul-09	87.39	7.74	91.14
16-Aug-09	92.78	8.22	91.14	16-Jul-09	88.32	7.83	91.14
17-Aug-09	95.63	8.47	91.14	17-Jul-09	97.13	8.61	91.14
18-Aug-09	79.39	7.03	91.14	18-Jul-09	92.81	8.22	91.14
19-Aug-09	87.24	7.73	91.14	19-Jul-09	84.48	7.49	91.14
20-Aug-09	81.80	7.25	91.14	20-Jul-09	83.66	7.41	91.14
21-Aug-09	90.07	7.98	91.14	21-Jul-09	84.56	7.49	91.14
22-Aug-09	85.56	7.58	91.14	22-Jul-09	88.32	7.83	91.14
23-Aug-09	98.45	8.72	91.14	23-Jul-09	84.51	7.49	91.14
24-Aug-09	68.13	6.04	91.14	24-Jul-09	87.33	7.74	91.14
25-Aug-09	56.78	5.03	91.14	25-Jul-09	87.06	7.71	91.14
26-Aug-09	76.42	6.77	91.14	26-Jul-09	84.42	7.48	91.14
27-Aug-09	73.50	6.51	91.14	27-Jul-09	54.02	4.79	91.14
28-Aug-09	100.26	8.88	91.14	28-Jul-09	81.66	7.24	91.14
29-Aug-09	98.50	8.73	91.14	29-Jul-09	81.80	7.25	91.14
30-Aug-09	90.28	8.00	91.14	30-Jul-09	87.39	7.74	91.14
31-Aug-09	84.65	7.50	91.14	31-Jul-09	76.35	6.76	91.14
Average	84.17	7.46	91.14	Average	86.24	7.70	91.07

Table A.15 Lab experiment history of BS&W measurement on June and May 2009

Date	Gross (avg.)	Net (avg.)	% Cut (avg.)	Date	Gross (avg.)	Net (avg.)	% Cut (avg.)
01-Jun-09	90.04	9.96	88.94	01-May-09	95.56	4.80	94.98
02-Jun-09	89.97	9.95	88.94	02-May-09	81.81	9.05	88.94
03-Jun-09	98.57	10.90	88.94	03-May-09	87.51	9.68	88.94
04-Jun-09	79.12	8.75	88.94	04-May-09	85.56	9.46	88.94
05-Jun-09	84.52	9.35	88.94	05-May-09	18.48	2.04	88.94
06-Jun-09	92.72	10.25	88.94	06-May-09	156.99	17.36	88.94
07-Jun-09	87.23	9.65	88.94	07-May-09	93.53	10.34	88.94
08-Jun-09	84.41	9.34	88.94	08-May-09	89.91	9.94	88.94
09-Jun-09	95.84	10.60	88.94	09-May-09	99.49	11.00	88.94
10-Jun-09	73.42	8.12	88.94	10-May-09	88.32	9.77	88.94
11-Jun-09	76.14	8.42	88.94	11-May-09	106.86	11.82	88.94
12-Jun-09	84.48	9.34	88.94	12-May-09	92.99	10.29	88.94
13-Jun-09	56.91	6.29	88.94	13-May-09	93.09	10.30	88.94
14-Jun-09	98.42	10.89	88.94	14-May-09	92.91	10.28	88.94
15-Jun-09	87.28	9.65	88.94	15-May-09	90.11	9.97	88.94
16-Jun-09	76.20	8.43	88.94	16-May-09	101.16	11.19	88.94
17-Jun-09	86.08	9.52	88.94	17-May-09	95.69	10.58	88.94
18-Jun-09	92.57	10.24	88.94	18-May-09	84.48	9.34	88.94
19-Jun-09	105.01	11.61	88.94	19-May-09	100.85	11.15	88.94
20-Jun-09	90.09	9.96	88.94	20-May-09	89.87	9.94	88.94
21-Jun-09	92.95	10.28	88.94	21-May-09	98.34	10.88	88.94
22-Jun-09	95.14	10.52	88.94	22-May-09	86.64	9.58	88.94
23-Jun-09	81.34	9.00	88.94	23-May-09	92.79	10.26	88.94
24-Jun-09	84.71	9.37	88.94	24-May-09	115.62	12.79	88.94
25-Jun-09	88.32	9.77	88.94	25-May-09	87.08	9.63	88.94
26-Jun-09	87.50	9.68	88.94	26-May-09	108.61	12.01	88.94
27-Jun-09	97.95	10.83	88.94	27-May-09	98.38	10.88	88.94
28-Jun-09	105.63	11.68	88.94	28-May-09	93.13	10.30	88.94
29-Jun-09	85.56	9.46	88.94	29-May-09	41.40	4.58	88.94
30-Jun-09	98.28	10.87	88.94	30-May-09	0.00	0.00	88.94
Average	88.21	9.76	88.94	31-May-09	82.80	9.16	88.94
				Average	88.91	9.64	89.14

Table A.16 Lab experiment history of BS&W measurement on April and March 2009

Date	Gross (avg.)	Net (avg.)	% Cut (avg.)	Date	Gross (avg.)	Net (avg.)	% Cut (avg.)
01-Apr-09	73.30	3.68	94.98	01-Mar-09	98.13	4.93	94.98
02-Apr-09	95.66	4.80	94.98	02-Mar-09	102.63	5.15	94.98
03-Apr-09	109.88	5.52	94.98	03-Mar-09	101.98	5.12	94.98
04-Apr-09	95.64	4.80	94.98	04-Mar-09	92.64	4.65	94.98
05-Apr-09	117.63	5.90	94.98	05-Mar-09	99.11	4.98	94.98
06-Apr-09	98.32	4.94	94.98	06-Mar-09	92.88	4.66	94.98
07-Apr-09	97.36	4.89	94.98	07-Mar-09	104.24	5.23	94.98
08-Apr-09	95.46	4.79	94.98	08-Mar-09	88.32	4.43	94.98
09-Apr-09	87.33	4.38	94.98	09-Mar-09	102.72	5.16	94.98
10-Apr-09	106.75	5.36	94.98	10-Mar-09	88.32	4.43	94.98
11-Apr-09	95.09	4.77	94.98	11-Mar-09	85.47	4.29	94.98
12-Apr-09	95.52	4.79	94.98	12-Mar-09	107.06	5.37	94.98
13-Apr-09	82.19	4.13	94.98	13-Mar-09	107.47	5.40	94.98
14-Apr-09	84.58	4.25	94.98	14-Mar-09	105.39	5.29	94.98
15-Apr-09	88.32	4.43	94.98	15-Mar-09	109.61	5.50	94.98
16-Apr-09	85.56	4.30	94.98	16-Mar-09	106.65	5.35	94.98
17-Apr-09	92.66	4.65	94.98	17-Mar-09	110.03	5.52	94.98
18-Apr-09	83.70	4.20	94.98	18-Mar-09	90.24	4.53	94.98
19-Apr-09	91.08	4.57	94.98	19-Mar-09	99.07	4.97	94.98
20-Apr-09	89.55	4.50	94.98	20-Mar-09	98.48	4.94	94.98
21-Apr-09	92.76	4.66	94.98	21-Mar-09	55.20	2.77	94.98
22-Apr-09	93.36	4.69	94.98	22-Mar-09	13.80	0.69	94.98
23-Apr-09	126.96	6.37	94.98	23-Mar-09	0.00	0.00	94.98
24-Apr-09	46.92	2.36	94.98	24-Mar-09	0.00	0.00	94.98
25-Apr-09	76.52	3.84	94.98	25-Mar-09	0.00	0.00	94.98
26-Apr-09	51.30	2.58	94.98	26-Mar-09	0.00	0.00	94.98
27-Apr-09	95.84	4.81	94.98	27-Mar-09	0.00	0.00	94.98
28-Apr-09	80.04	4.02	94.98	28-Mar-09	0.00	0.00	94.98
29-Apr-09	92.93	4.66	94.98	29-Mar-09	0.00	0.00	94.98
30-Apr-09	90.20	4.53	94.98	30-Mar-09	0.00	0.00	94.98
Average	90.41	4.54	94.98	31-Mar-09	55.20	2.77	94.98
				Average	68.65	3.45	94.98

Table A.17 Lab experiment history of BS&W measurement on February and January 2009

Date	Gross (avg.)	Net (avg.)	% Cut (avg.)	Date	Gross (avg.)	Net (avg.)	% Cut (avg.)
01-Feb-09	85.22	6.30	92.61	01-Jan-09	0.00	0.00	91.05
02-Feb-09	152.47	11.27	92.61	02-Jan-09	91.08	8.15	91.05
03-Feb-09	71.69	5.30	92.61	03-Jan-09	103.89	9.30	91.05
04-Feb-09	93.84	6.93	92.61	04-Jan-09	104.05	9.31	91.05
05-Feb-09	97.27	7.19	92.61	05-Jan-09	99.27	8.88	91.05
06-Feb-09	180.48	13.34	92.61	06-Jan-09	140.76	12.60	91.05
07-Feb-09	111.33	8.23	92.61	07-Jan-09	0.00	0.00	92.61
08-Feb-09	93.67	6.92	92.61	08-Jan-09	55.51	4.10	92.61
09-Feb-09	101.91	7.53	92.61	09-Jan-09	100.34	7.42	92.61
10-Feb-09	93.77	6.93	92.61	10-Jan-09	101.02	7.47	92.61
11-Feb-09	106.61	7.88	92.61	11-Jan-09	106.65	7.88	92.61
12-Feb-09	87.41	6.46	92.61	12-Jan-09	109.90	8.12	92.61
13-Feb-09	92.76	6.85	92.61	13-Jan-09	105.30	7.78	92.61
14-Feb-09	136.15	10.06	92.61	14-Jan-09	120.47	8.90	92.61
15-Feb-09	101.08	7.47	92.61	15-Jan-09	74.52	5.51	92.61
16-Feb-09	107.18	7.92	92.61	16-Jan-09	107.97	7.98	92.61
17-Feb-09	104.65	7.73	92.61	17-Jan-09	98.82	7.30	92.61
18-Feb-09	117.72	8.70	92.61	18-Jan-09	107.32	7.93	92.61
19-Feb-09	103.87	7.68	92.61	19-Jan-09	98.26	7.26	92.61
20-Feb-09	97.50	7.21	92.61	20-Jan-09	98.90	7.31	92.61
21-Feb-09	110.11	8.14	92.61	21-Jan-09	93.84	6.93	92.61
22-Feb-09	93.84	6.93	92.61	22-Jan-09	90.85	6.71	92.61
23-Feb-09	93.69	6.92	92.61	23-Jan-09	109.93	8.12	92.61
24-Feb-09	98.43	7.27	92.61	24-Jan-09	96.60	7.14	92.61
25-Feb-09	104.88	7.75	92.61	25-Jan-09	92.67	6.85	92.61
26-Feb-09	81.81	6.05	92.61	26-Jan-09	96.60	7.14	92.61
27-Feb-09	123.39	9.12	92.61	27-Jan-09	96.60	7.14	92.61
28-Feb-09	57.96	4.28	92.61	28-Jan-09	142.89	10.56	92.61
Average	103.60	7.66	92.61	29-Jan-09	16.56	1.22	92.61
				30-Jan-09	93.84	6.93	92.61
				31-Jan-09	126.05	9.32	92.61
				Average	92.92	7.14	92.31

Table A.18 Lab experiment history of BS&W measurement on December and November 2008

Date	Gross (avg.)	Net (avg.)	% Cut (avg.)	Date	Gross (avg.)	Net (avg.)	% Cut (avg.)
01-Dec-08	102.21	9.15	91.05	01-Nov-08	104.88	9.39	91.05
02-Dec-08	102.12	9.14	91.05	02-Nov-08	116.67	10.44	91.05
03-Dec-08	99.36	8.89	91.05	03-Nov-08	124.04	11.10	91.05
04-Dec-08	103.41	9.26	91.05	04-Nov-08	112.38	10.06	91.05
05-Dec-08	117.92	10.55	91.05	05-Nov-08	109.29	9.78	91.05
06-Dec-08	151.63	13.57	91.05	06-Nov-08	109.25	9.78	91.05
07-Dec-08	108.88	9.75	91.05	07-Nov-08	108.18	9.68	91.05
08-Dec-08	116.63	10.44	91.05	08-Nov-08	120.67	10.80	91.05
09-Dec-08	117.56	10.52	91.05	09-Nov-08	118.68	10.62	91.05
10-Dec-08	144.09	12.90	91.05	10-Nov-08	108.95	9.75	91.05
11-Dec-08	120.47	10.78	91.05	11-Nov-08	120.54	10.79	91.05
12-Dec-08	140.19	12.55	91.05	12-Nov-08	102.21	9.15	91.05
13-Dec-08	101.19	9.06	91.05	13-Nov-08	101.34	9.07	91.05
14-Dec-08	124.53	11.15	91.05	14-Nov-08	102.12	9.14	91.05
15-Dec-08	106.44	9.53	91.05	15-Nov-08	102.12	9.14	91.05
16-Dec-08	126.59	11.33	91.05	16-Nov-08	123.49	11.05	91.05
17-Dec-08	121.19	10.85	91.05	17-Nov-08	111.92	10.02	91.05
18-Dec-08	99.36	8.89	91.05	18-Nov-08	103.87	9.30	91.05
19-Dec-08	125.84	11.26	91.05	19-Nov-08	103.74	9.28	91.05
20-Dec-08	103.88	9.30	91.05	20-Nov-08	109.49	9.80	91.05
21-Dec-08	104.02	9.31	91.05	21-Nov-08	98.11	8.78	91.05
22-Dec-08	112.83	10.10	91.05	22-Nov-08	102.12	9.14	91.05
23-Dec-08	96.60	8.65	91.05	23-Nov-08	99.36	8.89	91.05
24-Dec-08	108.02	9.67	91.05	24-Nov-08	98.25	8.79	91.05
25-Dec-08	103.85	9.30	91.05	25-Nov-08	112.29	10.05	91.05
26-Dec-08	114.92	10.29	91.05	26-Nov-08	137.60	12.31	91.05
27-Dec-08	106.47	9.53	91.05	27-Nov-08	107.45	9.62	91.05
28-Dec-08	113.00	10.11	91.05	28-Nov-08	106.62	9.54	91.05
29-Dec-08	105.51	9.44	91.05	29-Nov-08	101.01	9.04	91.05
30-Dec-08	49.58	4.44	91.05	30-Nov-08	101.48	9.08	91.05
31-Dec-08	0.00	0.00	91.05	Average	124.14	14.49	88.41
Average	111.61	9.99	91.05				

Table A.19 Lab experiment history of BS&W measurement on October and September 2008

Date	Gross (avg.)	Net (avg.)	% Cut (avg.)	Date	Gross (avg.)	Net (avg.)	% Cut (avg.)
01-Oct-08	110.99	10.04	90.95	01-Sep-08	141.41	17.56	87.58
02-Oct-08	96.60	8.74	90.95	02-Sep-08	128.56	11.64	90.95
03-Oct-08	107.55	9.73	90.95	03-Sep-08	118.68	10.74	90.95
04-Oct-08	109.21	9.88	90.95	04-Sep-08	121.65	11.01	90.95
05-Oct-08	104.88	9.49	90.95	05-Sep-08	124.84	11.30	90.95
06-Oct-08	101.46	9.18	90.95	06-Sep-08	137.26	12.42	90.95
07-Oct-08	104.88	9.49	90.95	07-Sep-08	119.98	10.86	90.95
08-Oct-08	119.59	10.82	90.95	08-Sep-08	131.29	11.88	90.95
09-Oct-08	102.12	9.24	90.95	09-Sep-08	124.53	11.27	90.95
10-Oct-08	117.48	10.63	90.95	10-Sep-08	72.60	6.57	90.95
11-Oct-08	104.88	9.49	90.95	11-Sep-08	88.73	8.03	90.95
12-Oct-08	111.80	10.12	90.95	12-Sep-08	119.77	10.84	90.95
13-Oct-08	106.52	9.64	90.95	13-Sep-08	106.44	9.63	90.95
14-Oct-08	112.08	10.14	90.95	14-Sep-08	103.47	9.36	90.95
15-Oct-08	106.40	9.63	90.95	15-Sep-08	102.12	9.24	90.95
16-Oct-08	88.58	8.02	90.95	16-Sep-08	131.72	11.92	90.95
17-Oct-08	91.72	8.30	90.95	17-Sep-08	102.94	9.32	90.95
18-Oct-08	118.38	10.71	90.95	18-Sep-08	109.59	9.92	90.95
19-Oct-08	108.59	9.83	90.95	19-Sep-08	107.56	9.73	90.95
20-Oct-08	125.03	11.32	90.95	20-Sep-08	106.06	9.60	90.95
21-Oct-08	109.35	9.90	90.95	21-Sep-08	109.17	9.88	90.95
22-Oct-08	122.28	11.07	90.95	22-Sep-08	106.28	9.62	90.95
23-Oct-08	103.94	9.41	90.95	23-Sep-08	102.12	9.24	90.95
24-Oct-08	103.65	9.38	90.95	24-Sep-08	102.04	9.23	90.95
25-Oct-08	109.42	9.90	90.95	25-Sep-08	89.00	8.05	90.95
26-Oct-08	102.12	9.24	90.95	26-Sep-08	126.90	11.48	90.95
27-Oct-08	111.05	10.05	90.95	27-Sep-08	103.46	9.36	90.95
28-Oct-08	115.17	10.42	90.95	28-Sep-08	112.76	10.20	90.95
29-Oct-08	111.26	10.07	90.95	29-Sep-08	104.88	9.49	90.95
30-Oct-08	118.52	10.73	90.95	30-Sep-08	103.91	9.40	90.95
31-Oct-08	110.71	10.02	90.95	Average	111.99	10.29	90.84
Average	108.59	9.83	90.95				

Table A.20 Lab experiment history of BS&W measurement on August and July 2008

Date	Gross (avg.)	Net (avg.)	% Cut (avg.)	Date	Gross (avg.)	Net (avg.)	% Cut (avg.)
01-Aug-08	121.36	15.07	87.58	01-Jul-08	125.86	15.63	87.58
02-Aug-08	115.92	14.40	87.58	02-Jul-08	134.08	16.65	87.58
03-Aug-08	141.11	17.53	87.58	03-Jul-08	128.33	15.94	87.58
04-Aug-08	124.20	15.43	87.58	04-Jul-08	130.83	16.25	87.58
05-Aug-08	132.17	16.41	87.58	05-Jul-08	136.58	16.96	87.58
06-Aug-08	124.34	15.44	87.58	06-Jul-08	120.36	14.95	87.58
07-Aug-08	126.03	15.65	87.58	07-Jul-08	128.72	15.99	87.58
08-Aug-08	118.68	14.74	87.58	08-Jul-08	129.66	16.10	87.58
09-Aug-08	117.06	14.54	87.58	09-Jul-08	123.68	15.36	87.58
10-Aug-08	125.29	15.56	87.58	10-Jul-08	140.95	17.51	87.58
11-Aug-08	121.24	15.06	87.58	11-Jul-08	135.04	16.77	87.58
12-Aug-08	113.66	14.12	87.58	12-Jul-08	128.42	15.95	87.58
13-Aug-08	106.04	13.17	87.58	13-Jul-08	107.20	13.31	87.58
14-Aug-08	131.50	16.33	87.58	14-Jul-08	134.28	16.68	87.58
15-Aug-08	130.19	16.17	87.58	15-Jul-08	117.13	14.55	87.58
16-Aug-08	134.23	16.67	87.58	16-Jul-08	111.37	13.83	87.58
17-Aug-08	126.10	15.66	87.58	17-Jul-08	114.68	14.24	87.58
18-Aug-08	134.33	16.68	87.58	18-Jul-08	114.50	14.22	87.58
19-Aug-08	124.53	15.47	87.58	19-Jul-08	125.71	15.61	87.58
20-Aug-08	123.43	15.33	87.58	20-Jul-08	118.31	14.69	87.58
21-Aug-08	122.51	15.22	87.58	21-Jul-08	120.65	14.99	87.58
22-Aug-08	130.40	16.20	87.58	22-Jul-08	117.62	14.61	87.58
23-Aug-08	121.44	15.08	87.58	23-Jul-08	125.08	15.54	87.58
24-Aug-08	122.27	15.19	87.58	24-Jul-08	125.57	15.60	87.58
25-Aug-08	130.55	16.21	87.58	25-Jul-08	119.87	14.89	87.58
26-Aug-08	114.91	14.27	87.58	26-Jul-08	120.81	15.00	87.58
27-Aug-08	124.20	15.43	87.58	27-Jul-08	121.12	15.04	87.58
28-Aug-08	122.53	15.22	87.58	28-Jul-08	130.96	16.27	87.58
29-Aug-08	125.20	15.55	87.58	29-Jul-08	123.12	15.29	87.58
30-Aug-08	135.37	16.81	87.58	30-Jul-08	124.20	15.43	87.58
31-Aug-08	125.55	15.59	87.58	31-Jul-08	120.59	14.98	87.58
Average	124.72	15.49	87.58	Average	124.36	15.45	87.58

Table A.21 Lab experiment history of BS&W measurement on June and May 2008

Date	Gross (avg.)	Net (avg.)	% Cut (avg.)	Date	Gross (avg.)	Net (avg.)	% Cut (avg.)
01-Jun-08	123.26	17.49	85.81	01-May-08	124.20	14.52	88.31
02-Jun-08	133.16	18.90	85.81	02-May-08	139.46	16.30	88.31
03-Jun-08	124.11	17.61	85.81	03-May-08	139.06	16.26	88.31
04-Jun-08	129.01	18.31	85.81	04-May-08	138.34	16.17	88.31
05-Jun-08	126.02	15.65	87.58	05-May-08	125.80	14.71	88.31
06-Jun-08	126.82	15.75	87.58	06-May-08	92.97	10.87	88.31
07-Jun-08	118.72	14.75	87.58	07-May-08	151.80	21.54	85.81
08-Jun-08	128.05	15.90	87.58	08-May-08	124.00	17.60	85.81
09-Jun-08	127.80	15.87	87.58	09-May-08	124.22	17.63	85.81
10-Jun-08	129.72	16.11	87.58	10-May-08	127.22	18.05	85.81
11-Jun-08	127.21	15.80	87.58	11-May-08	153.55	21.79	85.81
12-Jun-08	115.92	14.40	87.58	12-May-08	123.15	17.47	85.81
13-Jun-08	118.62	14.73	87.58	13-May-08	138.86	19.70	85.81
14-Jun-08	126.96	15.77	87.58	14-May-08	127.65	18.11	85.81
15-Jun-08	115.43	14.34	87.58	15-May-08	130.64	18.54	85.81
16-Jun-08	123.10	15.29	87.58	16-May-08	128.00	18.16	85.81
17-Jun-08	124.98	15.52	87.58	17-May-08	123.86	17.58	85.81
18-Jun-08	129.93	16.14	87.58	18-May-08	130.90	18.57	85.81
19-Jun-08	117.11	14.55	87.58	19-May-08	132.36	18.78	85.81
20-Jun-08	119.49	14.84	87.58	20-May-08	129.89	18.43	85.81
21-Jun-08	119.70	14.87	87.58	21-May-08	118.68	16.84	85.81
22-Jun-08	125.20	15.55	87.58	22-May-08	137.21	19.47	85.81
23-Jun-08	138.54	17.21	87.58	23-May-08	120.87	17.15	85.81
24-Jun-08	125.33	15.57	87.58	24-May-08	117.58	16.68	85.81
25-Jun-08	125.02	15.53	87.58	25-May-08	118.68	16.84	85.81
26-Jun-08	117.85	14.64	87.58	26-May-08	122.22	17.34	85.81
27-Jun-08	125.84	15.63	87.58	27-May-08	126.05	17.89	85.81
28-Jun-08	124.92	15.52	87.58	28-May-08	114.10	16.19	85.81
29-Jun-08	125.38	15.57	87.58	29-May-08	116.77	16.57	85.81
30-Jun-08	132.11	16.41	87.58	30-May-08	139.41	19.78	85.81
Average	128.53	16.21	87.38	31-May-08	118.68	16.84	85.81
				Average	127.62	17.50	86.29

Table A.22 Lab experiment history of BS&W measurement on April and March 2008

Date	Gross (avg.)	Net (avg.)	% Cut (avg.)	Date	Gross (avg.)	Net (avg.)	% Cut (avg.)
01-Apr-08	127.51	14.91	88.31	01-Mar-08	142.35	16.64	88.31
02-Apr-08	121.03	14.15	88.31	02-Mar-08	129.04	15.08	88.31
03-Apr-08	128.58	15.03	88.31	03-Mar-08	126.55	14.79	88.31
04-Apr-08	129.25	15.11	88.31	04-Mar-08	128.50	15.02	88.31
05-Apr-08	134.49	15.72	88.31	05-Mar-08	144.43	16.88	88.31
06-Apr-08	134.07	15.67	88.31	06-Mar-08	132.48	15.49	88.31
07-Apr-08	126.66	14.81	88.31	07-Mar-08	123.65	14.46	88.31
08-Apr-08	126.54	14.79	88.31	08-Mar-08	140.09	16.38	88.31
09-Apr-08	121.44	14.20	88.31	09-Mar-08	126.37	14.77	88.31
10-Apr-08	120.65	14.10	88.31	10-Mar-08	134.95	15.78	88.31
11-Apr-08	133.02	15.55	88.31	11-Mar-08	134.72	15.75	88.31
12-Apr-08	121.42	14.19	88.31	12-Mar-08	129.30	15.12	88.31
13-Apr-08	120.72	14.11	88.31	13-Mar-08	134.46	15.72	88.31
14-Apr-08	131.14	15.33	88.31	14-Mar-08	131.99	15.43	88.31
15-Apr-08	149.36	17.46	88.31	15-Mar-08	134.34	15.70	88.31
16-Apr-08	125.76	14.70	88.31	16-Mar-08	126.96	14.84	88.31
17-Apr-08	121.44	14.20	88.31	17-Mar-08	137.27	16.05	88.31
18-Apr-08	124.20	14.52	88.31	18-Mar-08	152.70	17.85	88.31
19-Apr-08	123.96	14.49	88.31	19-Mar-08	131.84	15.41	88.31
20-Apr-08	123.81	14.47	88.31	20-Mar-08	109.77	12.83	88.31
21-Apr-08	126.32	14.77	88.31	21-Mar-08	144.82	16.93	88.31
22-Apr-08	134.51	15.72	88.31	22-Mar-08	118.86	13.89	88.31
23-Apr-08	123.76	14.47	88.31	23-Mar-08	123.21	14.40	88.31
24-Apr-08	140.12	16.38	88.31	24-Mar-08	126.37	14.77	88.31
25-Apr-08	146.89	17.17	88.31	25-Mar-08	129.33	15.12	88.31
26-Apr-08	128.48	15.02	88.31	26-Mar-08	139.50	16.31	88.31
27-Apr-08	128.78	15.05	88.31	27-Mar-08	126.63	14.80	88.31
28-Apr-08	163.81	19.15	88.31	28-Mar-08	136.38	15.94	88.31
29-Apr-08	115.81	13.54	88.31	29-Mar-08	127.79	14.94	88.31
30-Apr-08	119.96	14.02	88.31	30-Mar-08	121.44	14.20	88.31
Average	129.12	15.09	88.31	31-Mar-08	132.14	15.45	88.31
				Average	131.56	15.38	88.31

Table A.23 Lab experimet history of BS&W measurement on February and January 2008

Date	Gross (avg.)	Net (avg.)	% Cut (avg.)	Date	Gross (avg.)	Net (avg.)	% Cut (avg.)
01-Feb-08	36.39	2.24	93.84	01-Jan-08	80.04	4.93	93.84
02-Feb-08	41.40	2.55	93.84	02-Jan-08	85.56	5.27	93.84
03-Feb-08	16.05	0.99	93.84	03-Jan-08	90.11	5.55	93.84
04-Feb-08	46.92	2.89	93.84	04-Jan-08	84.78	5.22	93.84
05-Feb-08	35.88	2.21	93.84	05-Jan-08	82.44	5.08	93.84
06-Feb-08	140.43	8.65	93.84	06-Jan-08	88.19	5.43	93.84
07-Feb-08	162.42	10.01	93.84	07-Jan-08	100.28	6.18	93.84
08-Feb-08	157.00	18.35	88.31	08-Jan-08	90.65	5.58	93.84
09-Feb-08	156.06	18.24	88.31	09-Jan-08	87.86	5.41	93.84
10-Feb-08	140.76	16.45	88.31	10-Jan-08	87.86	5.41	93.84
11-Feb-08	136.69	15.98	88.31	11-Jan-08	95.93	5.91	93.84
12-Feb-08	153.88	17.99	88.31	12-Jan-08	90.47	5.57	93.84
13-Feb-08	156.22	18.26	88.31	13-Jan-08	85.08	5.24	93.84
14-Feb-08	150.97	17.65	88.31	14-Jan-08	79.42	4.89	93.84
15-Feb-08	158.90	18.57	88.31	15-Jan-08	63.48	3.91	93.84
16-Feb-08	147.82	17.28	88.31	16-Jan-08	134.27	8.27	93.84
17-Feb-08	150.68	17.61	88.31	17-Jan-08	57.27	3.53	93.84
18-Feb-08	172.78	20.20	88.31	18-Jan-08	77.45	4.77	93.84
19-Feb-08	150.69	17.62	88.31	19-Jan-08	57.96	3.57	93.84
20-Feb-08	150.83	17.63	88.31	20-Jan-08	71.13	4.38	93.84
21-Feb-08	153.80	17.98	88.31	21-Jan-08	71.38	4.40	93.84
22-Feb-08	147.94	17.29	88.31	22-Jan-08	63.11	3.89	93.84
23-Feb-08	137.64	16.09	88.31	23-Jan-08	46.92	2.89	93.84
24-Feb-08	131.57	15.38	88.31	24-Jan-08	52.44	3.23	93.84
25-Feb-08	132.13	15.45	88.31	25-Jan-08	44.16	2.72	93.84
26-Feb-08	117.91	13.78	88.31	26-Jan-08	63.48	3.91	93.84
27-Feb-08	143.06	16.72	88.31	27-Jan-08	60.51	3.73	93.84
28-Feb-08	137.40	16.06	88.31	28-Jan-08	51.96	3.20	93.84
29-Feb-08	134.39	15.71	88.31	29-Jan-08	71.07	4.38	93.84
Average	100.02	9.18	91.78	30-Jan-08	40.54	2.50	93.84
				31-Jan-08	38.64	2.38	93.84
				Average	74.01	4.56	93.84

APPENDIX B

TANK CALIBRATION TABLE OF

FANG BASIN, THAILAND

.

Table B.1 TABLE TANK CALIBRATION OF 500 BBL.

(HV = HEIGHT VOLUME)

Barrel	HV in.	HV in.	Barrel	Barrel	HV in.	HV in.	Barrel
-	0-0	16-1	532.68	60.72	1-10	14-3	471.96
2.76	0-1	16-0	529.92	63.48	1-11	14-2	469.20
5.52	0-2	15-11	527.16	66.24	2-0	14-1	466.44
8.28	0-3	15-10	524.40	69.00	2-1	14-0	463.68
11.04	0-4	15-9	521.64	71.76	2-2	13-11	460.92
13.80	0-5	15-8	518.88	74.52	2-3	13-10	458.16
16.56	0-6	15-7	516.12	77.28	2-4	13-9	455.40
19.32	0-7	15-6	513.36	80.04	2-5	13-8	452.64
22.08	0-8	15-5	510.60	82.80	2-6	13-7	449.88
24.84	0-9	15-4	507.84	85.56	2-7	13-6	447.12
27.60	0-10	15-3	505.08	88.32	2-8	13-5	444.36
30.36	0-11	15-2	502.32	91.08	2-9	13-4	441.60
33.12	1-0	15-1	499.56	93.84	2-10	13-3	438.84
35.88	1-1	15-0	496.56	96.60	2-11	13-2	436.08
38.64	1-2	14-11	494.04	99.36	3-0	13-1	433.32
41.40	1-3	14-10	491.28	102.12	3-1	13-0	430.56
44.16	1-4	14-9	488.52	104.88	3-2	12-11	427.80
46.92	1-5	14-8	485.76	107.64	3-3	12-10	425.04
49.68	1-6	14-7	483.00	110.40	3-4	12-9	422.28
52.44	1-7	14-6	480.24	113.16	3-5	12-8	419.52
55.20	1-8	14-5	477.48	115.92	3-6	12-7	416.76
57.96	1-9	14-4	474.72	118.68	3-7	12-6	414.00

Table B.1 TABLE TANK CALIBRATION OF 500 BBL. (Continued).

Barrel	**HV in.**	**HV in.**	**Barrel**	**Barrel**	**HV in.**	**HV in.**	**Barrel**
121.44	3-8	12-5	411.24	182.16	5-6	10-7	350.52
124.2	3-9	12-4	408.48	184.92	5-7	10-6	347.76
126.96	3-10	12-3	405.72	187.68	5-8	10-5	345.00
129.72	3-11	12-2	402.96	190.44	5-9	10-4	342.24
132.48	4-0	12-1	400.20	193.20	5-10	10-3	339.48
135.24	4-1	12-0	397.44	195.96	5-11	10-2	336.72
138.00	4-2	11-11	394.68	198.72	6-0	10-1	333.96
140.76	4-3	11-10	391.92	201.48	6-1	10-0	331.20
143.52	4-4	11-9	389.16	204.24	6-2	9-11	328.44
146.28	4-5	11-8	386.40	207.00	6-3	9-10	325.68
149.04	4-7	11-7	383.64	209.76	6-4	9-9	322.92
151.80	4-7	11-6	380.88	212.52	6-5	9-8	320.16
154.56	4-8	11-5	378.12	215.28	6-6	9-7	317.40
157.32	4-9	11-4	375.36	218.04	6-7	9-6	314.64
160.08	4-10	11-3	372.60	220.80	6-8	9-5	311.88
162.84	4-11	11-2	369.84	223.56	6-9	9-4	309.12
165.60	5-0	11-1	367.08	226.32	6-10	9-3	306.36
168.36	5-1	11-0	364.32	229.08	6-11	9-2	303.60
171.12	5-2	10-11	361.56	231.84	7-0	9-1	300.84
173.88	5-3	10-10	358.80	234.60	7-1	9-0	298.08
176.64	5-4	10-9	356.04	237.36	7-2	8-11	295.32
179.40	5-5	10-8	353.28	240.12	7-3	8-10	292.56

Table B.1 TABLE TANK CALIBRATION OF 500 BBL. (Continued).

HV in.	Barrel	HV in.	Barrel
242.88	7-4	8-9	289.80
245.64	7-5	8-8	287.04
248.40	7-6	8-7	284.28
251.16	7-7	8-6	281.52
253.92	7-8	8-5	278.76
256.68	7-9	8-4	276.00
259.44	7-10	8-3	273.24
262.20	7-11	8-2	270.48
264.96	8-0	8-1	267.72

Table B.2 TABLE TANK CALIBRATION OF 200 BBL

(HV = HEIGHT VOLUME)

HV in.	Barrel	HV in.	Barrel	HV in.	Barrel	HV in.	Barrel
0	0.000	21	20.916	43	42.828	65	64.74
1	0.996	22	21.912	44	43.824	66	65.73
2	1.992	23	22.908	45	44.820	67	66.73
3	2.988	24	23.904	46	45.816	68	67.72
4	3.984	25	24.900	47	46.812	69	68.72
5	4.980	26	25.896	48	47.808	70	69.72
6	5.976	27	26.892	49	48.804	71	70.71
7	6.972	28	27.888	50	49.800	72	71.71
8	7.968	29	28.884	51	50.796	73	72.70
9	8.964	30	29.880	52	51.792	74	73.70
10	9.960	31	30.876	53	52.788	75	74.70
11	10.956	32	31.872	54	53.784	76	75.69
12	11.952	33	32.868	55	54.780	77	76.69
13	12.948	34	33.864	56	55.776	78	77.68
14	13.944	35	34.860	57	56.772	79	78.68
15	14.940	36	35.856	58	57.768	63	62.74
16	15.936	37	36.852	59	58.764	64	63.74
17	16.932	38	37.848	60	59.760	65	64.74
18	17.928	39	38.844	61	60.756	66	65.73
19	18.924	40	39.840	62	61.752	67	66.72
20	19.920	41	40.836	63	62.748	68	67.728
21	20.916	42	41.832	64	63.744	69	68.724

Table B.2 TABLE TANK CALIBRATION OF 200 BBL (Continued).

HV in.	Barrel	HV in.	Barrel	HV in.	Barrel	HV in.	Barrel
70	69.720	92	91.632	114	113.544	136	135.456
71	70.716	93	92.628	115	114.540	137	136.452
72	71.712	94	93.624	116	115.536	138	137.448
73	72.708	95	94.620	117	116.532	139	138.444
74	73.704	96	95.616	118	117.528	140	139.440
75	74.700	97	96.612	119	118.524	141	140.436
76	75.696	98	97.608	120	119.520	142	141.432
77	76.692	99	98.604	121	120.516	143	142.428
78	77.688	100	99.600	122	121.512	144	143.424
79	78.684	101	100.596	123	122.508	145	144.420
80	79.680	102	101.592	124	123.504	146	145.416
81	80.676	103	102.588	125	124.500	147	146.412
82	81.672	104	103.584	126	125.496	148	147.408
83	82.668	105	104.580	127	126.492	149	148.404
84	83.664	106	105.576	128	127.488	150	149.400
85	84.660	107	106.572	129	128.484	151	150.396
86	85.656	108	107.568	130	129.480	152	151.392
87	86.652	109	108.564	131	130.476	153	152.388
88	87.648	110	109.560	132	131.472	154	153.384
89	88.644	111	110.556	133	132.468	155	154.380
90	89.640	112	111.552	134	133.464	156	155.376
91	90.636	113	112.548	135	134.460	157	156.372

Table B.2 TABLE TANK CALIBRATION OF 200 BBL (Continued).

HV in.	Barrel	HV in.	Barrel
158	157.368	176	175.296
159	158.364	177	176.292
160	159.360	178	177.288
161	160.356	179	178.284
162	161.352	180	179.280
163	162.348	181	180.276
164	163.344	182	181.272
165	164.340	183	182.268
166	165.336	184	183.264
167	166.332	185	184.260
168	167.328	186	185.256
169	168.324	187	186.252
170	169.320	188	187.248
171	170.316	189	188.244
172	171.312	190	189.240
173	172.308	191	190.236
174	173.304	192	191.232
175	174.300	193	192.228

APPENDIX C

BS&W MEASURMENT LABORATORY

OF INTERMIT OPERATION

.

Table C.1 The value of BS&W Laboratory measurement on 13 September 2011

Time	Volume of all sample (ml)	Volume of water (ml.)	volume of oil (ml.)	% water cut	% volume of oil
8.00	650	250	400	38.46	61.54
9.00	670	610	60	91.04	8.96
10.00	600	470	130	78.33	21.67
11.00	700	600	100	85.71	14.29
12.00	650	580	70	89.23	10.77
13.00	600	550	50	91.67	8.33
14.00	710	640	70	90.14	9.86
15.00	810	730	80	90.12	9.88
16.00	600	550	50	91.67	8.33
17.00	670	620	50	92.54	7.46
18.00	600	550	50	91.67	8.33
19.00	620	560	60	90.32	9.68
20.00	900	830	70	92.22	7.78
Average				85.63	14.37

Table C.2 The value of BS&W Laboratory measurement on 14 September 2011

Time	Volume of all sample (ml)	Volume of water (ml.)	volume of oil (ml.)	% water cut	% volume of oil
8.00	620	350	270	56.45	56.45
9.00	630	580	50	92.06	92.06
10.00	790	650	140	82.28	82.28
11.00	710	340	370	47.89	47.89
12.00	820	450	370	54.88	54.88
13.00	650	550	100	84.62	84.62
14.00	560	490	70	87.50	87.50
15.00	600	500	100	83.33	83.33
16.00	610	540	70	88.52	88.52
17.00	620	550	70	88.71	88.71
18.00	640	580	60	90.63	90.63
19.00	550	500	50	90.91	90.91
20.00	530	490	40	92.45	92.45
Average				80.02	19.98

Table C.3 The value of BS&W Laboratory measurement on 15 September 2011

Time	**Volume of all sample (ml)**	**Volume of water (ml.)**	**volume of oil (ml.)**	**% water cut**	**% volume of oil**
8.00	610	390	610	63.93	63.93
9.00	580	540	40	93.10	93.10
10.00	570	400	170	70.18	70.18
11.00	640	510	130	79.69	79.69
12.00	820	700	120	85.37	85.37
13.00	650	580	70	89.23	89.23
14.00	570	500	70	87.72	87.72
15.00	630	550	80	87.30	87.30
16.00	460	410	50	89.13	89.13
17.00	650	590	60	90.77	90.77
18.00	670	610	60	91.04	91.04
19.00	550	500	50	90.91	90.91
20.00	510	460	50	90.20	90.20
Average				85.27	14.73

Table C.4 The value of BS&W Laboratory measurement on 16 September 2011

Time	Volume of all sample (ml)	Volume of water (ml.)	volume of oil (ml.)	% water cut	% volume of oil
8.00	580	300	280	51.72	51.72
9.00	510	470	40	92.16	92.16
10.00	500	280	220	56.00	56.00
11.00	610	360	250	59.02	59.02
12.00	550	450	100	81.82	81.82
13.00	690	520	170	75.36	75.36
14.00	590	490	100	83.05	83.05
15.00	470	410	60	87.23	87.23
16.00	650	560	90	86.15	86.15
17.00	550	480	70	87.27	87.27
18.00	550	470	80	85.45	85.45
19.00	520	450	70	86.54	86.54
20.00	590	520	70	88.14	88.14
Average				78.46	21.54

Table C.5 The value of BS&W Laboratory measurement on 17 September 2011

Time	**Volume of all sample (ml)**	**Volume of water (ml.)**	**volume of oil (ml.)**	**% water cut**	**% volume of oil**
8.00	540	250	290	46.30	46.30
9.00	520	470	50	90.38	90.38
10.00	610	360	250	59.02	59.02
11.00	630	390	240	61.90	61.90
12.00	550	450	100	81.82	81.82
13.00	640	530	110	82.81	82.81
14.00	470	400	70	85.11	85.11
15.00	520	450	70	86.54	86.54
16.00	520	460	60	88.46	88.46
17.00	500	440	60	88.00	88.00
18.00	490	440	50	89.80	89.80
19.00	610	560	50	91.80	91.80
20.00	560	510	50	91.07	91.07
Average				80.23	19.77

Table C.6 The value of BS&W Laboratory measurement on 18 September 2011

Time	Volume of all sample (ml)	Volume of water (ml.)	volume of oil (ml.)	% water cut	% volume of oil
8.00	650	280	370	43.08	43.08
9.00	590	520	70	88.14	88.14
10.00	560	330	230	58.93	58.93
11.00	610	440	170	72.13	72.13
12.00	600	500	100	83.33	83.33
13.00	580	490	90	84.48	84.48
14.00	540	440	100	81.48	81.48
15.00	600	510	90	85.00	85.00
16.00	550	460	90	83.64	83.64
17.00	600	510	90	85.00	85.00
18.00	580	510	70	87.93	87.93
19.00	560	500	60	89.29	89.29
20.00	510	450	60	88.24	88.24
Average				79.28	20.72

Table C.7 The value of BS&W Laboratory measurement on 19 September 2011

Time	Volume of all sample (ml)	Volume of water (ml.)	volume of oil (ml.)	% water cut	% volume of oil
8.00	610	100	510	16.39	16.39
9.00	540	490	50	90.74	90.74
10.00	640	340	300	53.13	53.13
11.00	610	420	190	68.85	68.85
12.00	580	440	140	75.86	75.86
13.00	620	500	120	80.65	80.65
14.00	690	570	120	82.61	82.61
15.00	650	570	80	87.69	87.69
16.00	650	560	90	86.15	86.15
17.00	600	530	70	88.33	88.33
18.00	720	650	70	90.28	90.28
19.00	610	550	60	90.16	90.16
20.00	560	510	50	91.07	91.07
Average				77.07	22.93

BIOGRAPHY

Miss. Saowaluck Pitukwong was born on the 20th of April 1985 in Chiang Mai province. She earned her Bachelor's Degree in Petroleum Engineering from Suranaree University of Technology (SUT) in 2006. After graduation, she continued her master's degree in the School of Geotechnology, Institute of Engineering at SUT with the major in Petroleum Engineering. During 2007-2011, she was a part time worker in positions of teaching assistant and research assistant at SUT. Her strong background is in the areas of production management.