COMPUTER SOFTWARE DEVELOPMENT FOR OPTIMIZING ARTIFICIAL LIFT SYSTEM SELECTION FOR OIL FIELDS IN PHITSANULOK BASIN

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การพัฒนาโปรแกรมคอมพิวเตอร์เพื่อเลือกชนิดอุปกรณ์ช่วยผลิต ที่เหมาะสมสำหรับแหล่งน้ำมันในแอ่งพิษณุโลก

นายณสรกฤษช วัชระคุปต์

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิศวกรรมศาสตรมหาบัณฑิต

สาขาวิชาเทคโนโลยีธรณี

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COMPUTER SOFTWARE DEVELOPMENT FOR OPTIMIZING ARTIFICIAL LIFT SYSTEM SELECTION FOR OIL FIELDS IN PHITSANULOK BASIN

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

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ณสรกฤษช วัชระคุปต์ : การพัฒนาโปรแกรมคอมพิวเตอร์เพื่อเลือกชนิดอุปกรณ์ช่วยผลิตที่เหมาะสมสำหรับแหล่งน้ำมันในแอ่งพิษณุโลก (COMPUTER SOFTWARE DEVELOPMENT FOR OPTIMIZING ARTIFICIAL LIFT SYSTEM SELECTION FOR OIL FIELDS IN PHITSANULOK BASIN) อาจารย์ที่ปรึกษา : รศ. เกรียงไกร ไตรสาร, 186 หน้า.

โปรแกรมถูกพัฒนาสำหรับการเลือกระบบช่วยผลิตที่เหมาะสมสำหรับแหล่งน้ำมันในแอ่งพิษณุโลกและสนับสนุนการออกแบบระบบช่วยผลิตภายใต้เงื่อนไขทางด้านวิศวกรรมปิโตรเลียม ระบบช่วยผลิตที่ถูกเลือกในการศึกษาได้แก่ ปั๊มไฟฟ้ากึ่งจมกึ่งลอย การใช้ก๊าซยกเป็นช่วง ๆ และปั๊มม้าหัวโยก ในที่นี้จะเรียกชื่อโปรแกรมว่า ALOP (Artificial Lift Oil Fields in Phitsanulok basin) ระบบของโปรแกรม ALOP ตั้งอยู่บนพื้นฐานของความรู้ความเข้าใจสมการและทฤษฎีของระบบช่วยผลิตซึ่งไม่รวมถึงการนำเอาประสบการณ์ในการทำงานมาพิจารณาในการพัฒนาโปรแกรม โครงสร้างของโปรแกรม ALOP ถูกพัฒนาโดย Microsoft Visual Basic V.6 ซึ่งเป็นภาษาคอมพิวเตอร์ที่นิยมในปัจจุบัน เนื่องจากเป็นโปรแกรมที่ใช้งานง่ายและสะดวกต่อการพัฒนาแก้ไขและปรับปรุง ข้อมูลนำเข้าที่จะใช้ในการประมวลผลของโปรแกรม ALOP ถูกแบ่งออกเป็นหลายกลุ่ม ดังนี้ ข้อมูลที่เกี่ยวกับการผลิต แหล่งกักเก็บ หลุมเจาะ และอื่น ๆ ที่เกี่ยวข้องกับทางด้านวิศวกรรมปิโตรเลียม เป็นต้น การวิเคราะห์ข้อมูลนำเข้าที่จะใช้ในการประมวลผลของโปรแกรม ALOP เป็นขั้นตอนแรกของการประมวลผลเพื่อตรวจสอบฐานข้อมูลว่ารองรับข้อมูลนำเข้าที่จะใช้ในการประมวลผลของโปรแกรม ALOP หรือไม่ ข้อมูลนำเข้าเหล่านั้น ได้แก่ อัตราการผลิตความถ่วงจำเพาะ ความลึก ขนาดและชนิดของท่อผลิต และประสิทธิภาพของปั๊ม เป็นต้น ข้อมูลที่ใช้ในการประมวลผลของโปรแกรม ALOP นำมาจากหลุมผลิตจริงจากแหล่งน้ำมันลานกระบือ โดยในการวิเคราะห์ได้มีการแบ่งกรณีศึกษาออกเป็นกรณีต่าง ๆ ภายใต้การพิจารณาตัวแปรควบคุมดังต่อไปนี้ ความดันก้นหลุมและสัดส่วนก๊าซกับน้ำมัน ดัชนีชี้วัดการผลิต ขนาดของท่อผลิตและความหลากหลายในการผลิต ซึ่งตัวแปรควบคุมจะถูกแบ่งออกเป็น 2 กรณีศึกษา คือกรณีที่ตัวแปรควบคุมมีค่าต่ำและสูง โปรแกรม ALOP จะระบุรายละเอียด ขั้นตอนการออกแบบ เครื่องมืออุปกรณ์พื้นฐานและข้อมูลที่จำเป็น โดยโปรแกรม ALOP จะเลือกวิธีการออกแบบที่เหมาะสมและเป็นไปได้ที่สุดสำหรับระบบช่วยผลิตแต่ละชนิด ดังเช่น ข้อมูลของปั๊มหรือปริมาณก๊าซที่ใช้ในการยกเพื่อช่วยผลิต ในการพิจารณาทางด้านเทคนิคจะเป็นการพิจารณาวิธีช่วยผลิตที่เหมาะสมที่สุดในแหล่งน้ำมันลานกระบือ พบว่า วิธีช่วยผลิตที่เหมาะสมที่สุดในแหล่งน้ำมันลานกระบือ คือ การประยุกต์วิธีช่วยผลิตแบบการใช้ก๊าซยกเป็นช่วง ๆ รองลงมาคือปั๊มไฟฟ้ากึ่งจมกึ่งลอยและปั๊มม้าหัวโยกตามลำดับ การพิจารณาทางด้านเศรษฐศาสตร์จะเป็นการพิจารณาวิธีช่วยผลิตที่ให้ผลตอบแทนดีที่สุดในแหล่ง

น้ำมันลานกระบือ พบว่า วิธีช่วยผลิตที่ให้ผลตอบแทนดีที่สุดในแหล่งน้ำมันลานกระบือ คือ การประยุกต์วิธีช่วยผลิตแบบการใช้ก๊าซยกเป็นช่วง ๆ (อัตราการคืนทุน 22.52% และสัดส่วนกำไรต่อเงินลงทุน0.81) รองลงมาคือปั๊มไฟฟ้ากึ่งจมกึ่งลอย (อัตราการคืนทุน 21.60% และสัดส่วนกำไรต่อเงินลงทุน 0.74) และปั๊มม้าหัวโยก (อัตราการคืนทุน 21.29% และสัดส่วนกำไรต่อเงินลงทุน 0.66) ตามลำดับ

สาขาวิชาเทคโนโลยีธรณี	ลายมือชื่อนักศึกษา ______________________
ปีการศึกษา 2552	ลายมือชื่ออาจารย์ที่ปรึกษา________________
	ลายมือชื่ออาจารย์ที่ปรึกษาร่วม_____________

NASORNKRIT VATCHARAKUP : COMPUTER SOFTWARE DEVELOPMENT FOR OPTIMIZING ARTIFICIAL LIFT SYSTEM SELECTION FOR OIL FIELDS IN PHITSANULOK BASIN. THESIS ADVISOR : ASSOC. PROF. KRIANGKRI TRISARN, 186 PP.

SOFTWARE DEVELOPMENT/ARTIFICIAL LIFT/PHITSANULOK BASIN

The software has been developed for optimizing artificial lift system selection for oil fields in Phitsanulok basin and designing of artificial lift system under various petroleum engineering requirements, including electrical submersible pump, intermittent flow gas lift and sucker rod pump. The software hereafter is called ALOP (Artificial Lift for Oil Fields in Phitsanulok basin). The proposed system is based on the known analytical solutions and theories, but is not based on the heuristic knowledge, inference procedure and experience of artificial lift expert backed by the rationale and logic. The program structure is developed on Microsoft Visual Basic V 6 software, and hence makes it interactive, user-friendly and revisable. The input artificial lift parameters are hierarchically characterized into several groups using various criteria, e.g., production, reservoir and well conditions, petroleum engineering requirements, design constraints and project goals, etc. The input analysis is first performed to check probable process of data base, e.g., production rate, specific gravity, depth, tubing size and type and volumetric efficiency. The predictive capability of the proposed system has been verified by comparing with actual wells under Lankrabue oil fields. The bottom hole pressure and gas liquid ratios, productivity index, size of tubing and variable rates are the controlling factors in the selection of the method of lift, which are divided into 2 cases (low and high) for study and analysis result of ALOP. The results are satisfactory. For the designing, the system first identifies detail, step of design, basic facilities and necessary information. Based on production rates, the system selects the most suitable and available design solution for each artificial lift system. They comprise different combinations of the design components (e.g., pump data, minimum gas required, etc.). In term of technical consideration, the probable applications of artificial lift for Lankrabue oil fields are most suitable ranking for intermittent flow gas lift, electrical submersible pump and sucker rod pump respectively. In term of economic consideration, the best return on investment of artificial lift for Lankrabue oil fields intermittent flow gas lift (IRR 22.52% and PIR 0.81), electrical submersible pump (IRR 21.60% and PIR 0.74) and sucker rod pump (IRR 21.29% and PIR 0.66) respectively.

School of Geotechnology	Student Signature ____________________
Academic Year 2009	Advisor Signature ___________________
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The author would like to express appreciation to his thesis committee members, Dr. Chongpan Chonglakmani, Assoc. Prof. Kriangkrai Trisarn, Dr. Tawisak Silakul, Dr. Akkhapun Wannakomol, Dr. Prachya Tepnarong and Asst. Prof. Thara Lekuthai.

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LIST OF ABBREVIATIONS

Al	=	Aluminium
A_p	=	Plunger area
ARPOF	=	Artificial lift system at Phitsanulok oil fields
A_t	=	Tubing area
bbl	=	barrel
BHP	=	Botton hole pressure
bbl/cycle	=	barrel per cycle
bbl/ft	=	barrel per feet
bbl/year	=	barrel per year
b/d	=	barrel per day
b/d/in/spm	=	barrel per day per inch per stroke per minute
b/d/psi	=	barrel per day per psi
b/d/well	=	barrel per day par well
cm	=	Centimeter
C_i	=	Ideal counter balance
Cu	=	Copper
D	=	depth
D_s	=	Static fluid level
D_w	=	working fluid level
E	=	Endurance limit of sucker rods

LIST OF ABBREVIATIONS (Continued)

ESP	=	Electrical submersible pump
E_v	=	Volumetric efficiency
FH	=	Friction head
ft	=	feet
ff/1,000 ft	=	feet per 1,000 feet
GOR	=	Gas oil ratio
GLR	=	Gas liquid ratio
GUI	=	Graphical user interface
G_s	=	Static gradient
H	=	head
H_b	=	Brake horsepower
H_f	=	Friction horsepower
H_h	=	Hydraulic horsepower
Hp	=	Horsepower
IFGL	=	Intermittent flow gas lift
in	=	Inch
Intang	=	intangible
in-lb	=	inch-pound
IRR	=	Internal rate of return
IRR_{avg}	=	Average of internal rate of return
J	=	Productivity index
km	=	Kilometer

LIST OF ABBREVIATIONS (Continued)

KS = Kamphaeng Saen

L = depth to operating sucker rod pump

LKB = Lan Krabur

LPG = Liquefied petroleum gas

lb/ft = pound per foot

M = Tubing weight

Ma = Million ages

max = Maximum

min = Minute

MMbaht = Million baht

MMbbl = Million barrel

MMSCF/d = Million standard cubic foot per day

N = pumping speed

NE = North-East

NW = North-West

No. = number

NPV_{avg} @ 10% = Average of Net present value at 10%

O.D. = Outside diameter

PIR = Profit to investment ratio

PIR_{avg} = Average of profit to investment ratio

P_{avg} = Average pressure

P_{bh} = bottom hole pressure

LIST OF ABBREVIATIONS (Continued)

P_{so}	=	Surface operating pressure
P_t	=	Tubing pressure
P_{wf}	=	Well flow pressure
$P_{v,min}$	=	Minimum valve opening pressure
$q_{o,avg}$	=	Average of oil rate
R	=	Tapered sucker rod string
RF_{avg}	=	Average of recovery factor
S	=	Stroke
SE	=	South-East
SG	=	Specific gravity
SH	=	Head due to system backpressure
SKJ	=	Sung Kajai
SRP	=	Sucker rod pump
SW	=	South-West
S_p	=	Plunger stroke length
SCF/bbl	=	Standard cubic foot per barrel
sq.in	=	Square inch
sq.km	=	Square kilometer
SCF/stb	=	Standard cubic foot per standard stock tank barrel
SCF/cycle	=	Standard cubic foot per cycle
Tang	=	tangible
TDH	=	total dyramil head

LIST OF ABBREVIATIONS (Continued)

V_{sc}	=	Minimum gas required
T_P	=	Peak torque
UT	=	U-tong
US$	=	Dollars
US$/bbl	=	Dollar per barrel
v/1,000 ft	=	volt per 1,000 feet
V.6	=	Version 6
WB	=	Wichian Buri
W_f	=	Fluid load
W_{max}	=	Maximum bream load
W_r	=	Weight of rod string

CHAPTER I

INTRODUCTION

1.1 Problem and rationale

Petroleum is the most important energy sources for social and economic development in Thailand. At the present, the petroleum demand is increasing due to the Thai’s economic expanding both industry and agriculture. However, oil prices are increased while discoveries of new oil fields are not sufficient in Thailand. In addition, petroleum exploration and development in Thailand are only moderately successful, that is not enough for present consumption. The indigenous petroleum production is accounted about 25 percent of petroleum consumption in Thailand and the left has to be imported. The reserves of hydrocarbon in Thailand are limited. The conservation of this hydrocarbon is important. This can be achieved either by finding new oil fields or increasing the recovery from the existing ones. Furthermore, large quantities of residual oil have remained in oil reservoirs, the oil production will be about 10-30 percent of oil in place. Thus, it is important to look for the additional recovery from the existing oil fields.

Almost oil fields in Thailand are produced by natural flows which now are expelled by decreasing pressures and finally caused the low production efficiency. To improve this oil recovery in most oil fields in Thailand, the artificial lift system must be installed. Such as, the Sirikit oil field, Wichienburi oil field and U Thong oil field are using pump and gas lift as the artificial lift. However, the previous study, analysis and collection of optimizing artificial lift in Thailand onshore oil fields are not distinct and clearly explained. Therefore, the objectives of this research are to (1) develop software using Microsoft visual basic version 6.0 that is enterprise edition with source code and utilities (service pack 5) for optimizing artificial lift system selection for oil field in Phitsanulok basin and designing of artificial lift system under various petroleum engineering requirements, hereafter is called ALOP (Artificial Lift for Oil field in Phitsanulok basin) (2) compare various artificial lift methods, including electrical submersible pump, intermittent flow gas lift and sucker rod pump both in terms of technical and economical considerations. In term of technical considerations, the minimum requirement information such as the production, reservoir and well conditions will be collected and analyzed from Sirikit oil field and input to the ALOP for determination the most suitable artificial lift method which can improve oil recovery for oil field in Phitsanulok basin. In term of economical considerations, cost of each artificial lift method will be compiled and analyzed to determine the best Internal Rate of Return (IRR) and Profit to Investment Ratio (PIR) for oil field in Phitsanulok basin.

1.2 Literature review

The previous study and collection of optimizing artificial lift in Thailand onshore oil fields are not distinct and clearly explained while this activity in abroad is well performed. In addition, the applications of artificial lift in each oil field is the secret of each oil companies and so cause the each oil fields are installed by the artificial lift differently. Example, the Sirikit oil field was installed by the gas lift system at the first time because the reservoir fills high gas oil ratio. Due to not efficient gas lift condition in some wells and the remote oil wells which have no gas supply cause geologist and petroleum engineering determined to use electrical submersible pump and sucker rod pump. The economic consideration is a factor for determination the artificial lift. Next example, the Wichienburi oil field was installed by the sucker rod pump and the jet pump at the first time and after that the field change method to lift with all sucker rod pump system due to sand problem. The quantity of gas cap, reservoir pressure, oil in place, production rate, production total and etc., these factors are studied and analyzed for determination the artificial lift in terms of technical considerations. The installation cost, maintenance cost, operation cost, oil lifting cost, oil price and etc are studied and analyzed for optimizing artificial lift system selection in term of economical considerations. Finally, the U Thong oil field was installed with sucker rod pump system only. For the design, the artificial lift software is continually developed which helps and supports design for the artificial lift optimization with well, reservoir, and production conditions. The csSubs Suite, WinGlu, and QRod are the commercial software for electrical submersible pump, gas lift and sucker rod pump analysis and design respectively. The commercial software has high efficiency and accurate but they must be bought costly with copyright, register, annual contact and etc.

1.3 Research objectives

The objectives of this research are (1) to develop software using Microsoft visual basic version 6.0 that is enterprise edition with source code and utilities (service pack 5) for optimizing artificial lift system selection for oil field in Phitsanulok basin and artificial lift system design support under various petroleum engineering requirements, hereafter is called ALOP (Artificial Lift for Oil field in Phitsanulok basin) (2) to compare various artificial lift methods, including electrical submersible pump, intermittent flow gas lift and sucker rod pump both in terms of technical and economical considerations. In term of technical considerations, the minimum requirement information of production, reservoir and well conditions will be collected and analyzed from Sirikit oil field and input to the ALOP for determination the most suitable artificial lift method which can improve oil recovery for oil field in Phitsanulok basin. In term of economical considerations, cost of each artificial lift method will be collected and analyzed to determine the best Internal Rate of Return (IRR) and Profit to Investment Ratio (PIR) at Phitsanulok oil field. Finally, the results of this research will be used as the fundamental data to improve oil recovery and as data base for anyone who interests to study and research the artificial lift method to improve oil recovery.

1.4 Scope and limitations of the study

The ALOP has been developed for optimizing artificial lift selection for oil field in Phitsanulok and design support under petroleum engineering requirements, including electrical submersible pump, intermittent flow gas lift and sucker rod pump. The proposed system is based on the known analytical solutions and theories, but is not based on the heuristic knowledge and experience of artificial lift expert backed by the rationale and logic. The program structure is developed on Microsoft visual basic 6.0 that is enterprise edition with source code and utilities, service pack 5. The input analysis is first performed to check probable process of data base, e.g., fluid specific gravity, depth, tubing size, tubing type and volumetric efficiency. The predictive capability of the proposed system has been verified by comparing with 7 actual wells in Lankrabue oil field. The bottom hole pressure and gas liquid ratios, productivity index, size of tubing and variable rates are the controlling factors in the selection of the method of lift, which are divided into 2 cases (low and high) for study and analysis result of ALOP. For the support design, the system first identifies detail, step of design, basic facilities and necessary information. Based on production rates, the system selects the most suitable and available design solution for each artificial lift system. In term of technical consideration, this study determines the most suitable artificial lift method which can improve oil recovery. In term of economic consideration, cost of each artificial lift system will be studied and analyzed to determine the best Internal Rate of Return (IRR) and Profit to Investment Ratio (PIR).

1.5 Research methodology

1.5.1 Reviewing history of artificial lift selection at Phitsanulok oil field and studying development of artificial lift software

Literature review will be carried out to study the artificial lift system for Thailand onshore oil fields are the Sirikit oil field, the U Thong oil field, the Wichienburi oil field and etc. The artificial lift methods used in this study are electrical submersible pump, intermittent flow gas lift, and sucker rod pump. In addition, the commercial software of the artificial lift will be studied and analyzed about properties, process, code and etc. The sources of information are from journals, technical reports, conference papers, internet and oil field. A summary of the literature review will be given in the thesis.

1.5.2 Data collection and analysis

The data and information of geological conditions and petroleum engineering requirement will be collected and analyzed from Sirikit oil field. The input artificial lift parameters are hierarchically characterized into several groups using various criteria, e.g., production, reservoir and well conditions, petroleum engineering requirements, design constraints and project goals, etc.

1.5.3 Software development

The artificial lift software is developed using Microsoft visual basic version 6 that is enterprise edition with source code and utilities, service pack 5 for optimizing artificial lift system selection for oil field in Phitsanulok basin, including electrical submersible pump, intermittent flow gas lift and sucker rod pump. The artificial lift software includes necessary command button as same as commercial software, such as “check input”, “design”, “save&print” (translate data file to be text, Microsoft word or documents), “clear screen” and “back” (to main page). The artificial lift software includes a main page and 3 modules. The hot keys are developed for quick and comfortable usage. The artificial lift software is developed by using orange, green, gray and pink color is agent of input, output, command button and help respectively.

1.5.4 Software (ALOP) testing

The minimum requirement information will be collect and analyze from oil field in Phitsanulok basin and so input to the artificial lift software for study, analysis and design the artificial lift system, including electrical submersible pump, intermittent flow gas lift and sucker rod pump. After that, the research will be studied and analyzed optimizing artificial lift system selection for oil field in Phitsanulok basin both in terms of technical and economical considerations.

1.5.5 Petroleum technical and economic considerations

In term of technical considerations, production, reservoir and well condition will be collected, analyzed and input to the artificial lift computer software for determination the most suitable artificial lift method which can improve oil recovery. In term of economical considerations, cost of each artificial lift method will be studied and analyzed to determine the best Internal Rate of Return (IRR) and Profit to Investment Ratio (PIR).

1.5.6 Thesis writing and presentation

All research activities, methods, and results to improve oil recovery in term of technical and economic considerations will be fully documented, complied, concluded and discussed in the thesis. Finally, the thesis will be submitted at the end of the research.

1.6 Expected results

The researcher develops freeware for optimizing artificial lift system for oil field in Phitsanulok basin. The research involves in the improvement and increment of the oil recovery and is minimized oil left in reservoir with the optimizing method by artificial lift system. Experimental results are useful in planning to provide energy sources for Thailand industrial and economic development. The research could be database to study improved oil recovery. Finally, researcher earned the experience in term of developing artificial lift software and programming application. Specially, the result of the research will be informatively support and persuade the international oil companies to invest in Thailand in the future.

1.7 Thesis contents

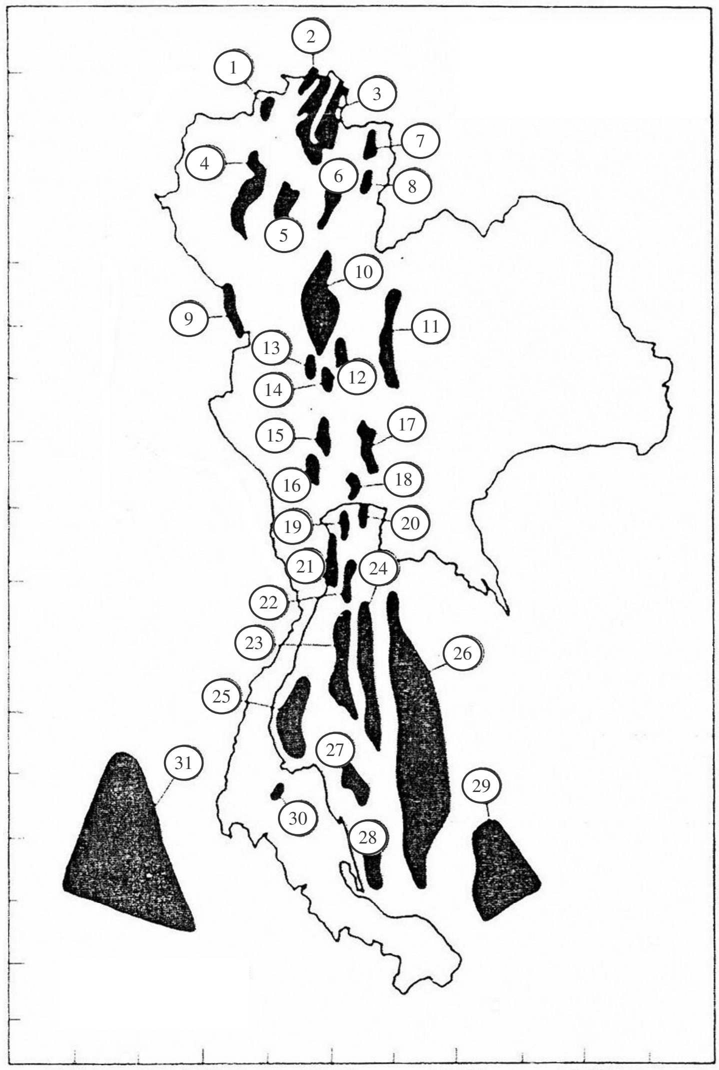
Chapter 1 states the problem and rationale, literature review, research objectives, scope and limitations of the study, research methodology and expected result. **Chapter 2** summarizes results of the literature review of artificial lifts which are applied to oil field in Phitsanulok basin. **Chapter 3** describes software development. **Chapter 4** analyzes result of ALOP both in terms of technical and economic considerations. Conclusion and discussion for future research needs are given in **Chapter 5**. **Appendix A** collects artificial lift system for thesis study. **Appendix B** explains variable decralation, flow chart and programming. Publication is shown in **Appendix C.**

CHAPTER II

LITERATURE REVIEW

2.1 Cenozoic basins in Thailand

There are over 60 Cenozoic basins distributed in various parts of Thailand, both onshore and offshore. These basins are mainly N-S trending half grabens and most were initiated in the Late Oligocene. The structural framework of the basins is generally governed by N-S trending extensional faults which are spatially related to the movement of the NW-SE and NE-SW trending strike-slip faults that have been active since the Oligocene. The NW-SE faults are the principal dextral strike-slip faults whereas the NE-SW faults are the conjugate sinistral strike-slip faults. The collision of the India Craton with Southern Asia since 40-50 Ma caused clockwise rotation of Southeast Asia and movement of the strike-slip faults with the associated development of Cenozoic basins in this region. Four major Cenozoic basins, Mergui, Pattani, Malay and Phitsanulok, contain up to 8,000 m of sediments. Generally, the Cenozoic fills are continental sediments, except in the Mergui basin in the Andaman Sea where the sedimentary fill is mainly marine sediments. Fluviatile with occasional lacustrine deposits were prominent in the gulf of Thailand and onshore basins during the Oligocene to early Miocene. From early to Middle Miocene, widespread perennial lake conditions were well development in the onshore basins and in the Western Graben area of the gulf of Thailand. A change in tectonic and/or climatic conditions took place in the Middle to Late Miocene times resulting in the cessation of perennial lake conditions and development of a regional unconformity.



1. Fang
2. Mae Sai
3. Chiang Rai-Payao
4. Chiang-Mai
5. Lampang
6. Phrae
7. Pua
8. Nan
9. Mae Sod
10. Phitsanulok
11. Phetchabun
12. Nong Bua
13. Lad Yao
14. Nakhon Sawan
15. Supanburi
16. Kampaengsan
17. Ayutthaya
18. Thon Buri
19. Sakhon
20. Paknom
21. Hua Hin
22. N. Western
23. Western
24. Kra
25. Chumphon
26. Pattani
27. Nakhon
28. Songkhla
29. Malay
30. Khiensa
31. Mergui

Figure 2.1 Significant cenozoic basins in Thailand (Knox and Wakefield, 1983).

2.2 Stratigraphy of Cenozoic basins in central Thailand

There are seven major Cenozoic basins in central Thailand; Phitsanulok, Phetchaboon, Nong Bua, Supanburi, Kampaengsan, Ayutthaya and Thon buri. These basins are formed as N-S trending, elongated half grabens (Figure 2.3). The Phitsanulok basin is the largest and deepest basin in this area. It contains up to 8,000 m of sedimentary fill (Knox and Wakefield, 1983). Sedimeantary deposited in other basins in the area range in thickness from 2,000–4,000 m. The pre-tertiary basement underlying these sediments comprises; Mesozoic-Palaeozoic sedimentary, volcaniclastic, metamorphic and igneous rocks.

Knox and Wakefield (1983) described the geology of the Phitsanulok basin and divided the Tertiary sediments into five formations, namely, the Nong Bua, Lankrabue, Pratu Tao, Yom and Ping. Studies of seismic data and drilling results suggest a similar stratigraphic succession in other basins of this area. The generalized stratigraphy of the basins in central Thailand, complied after Knox and Wakefield (1983), consisting of four stratigraphic units (Figure 2.2-2.3).

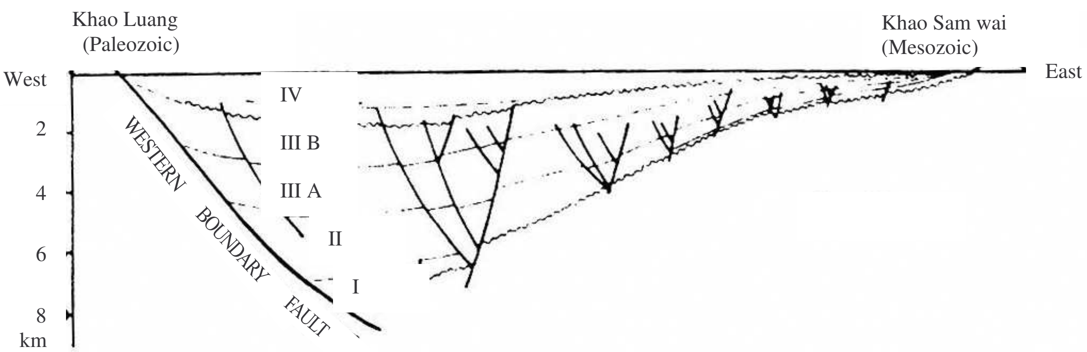


Figure 2.2 Schematic cross section of the Phitsanulok basin (Knox and Wakefield, 1983).

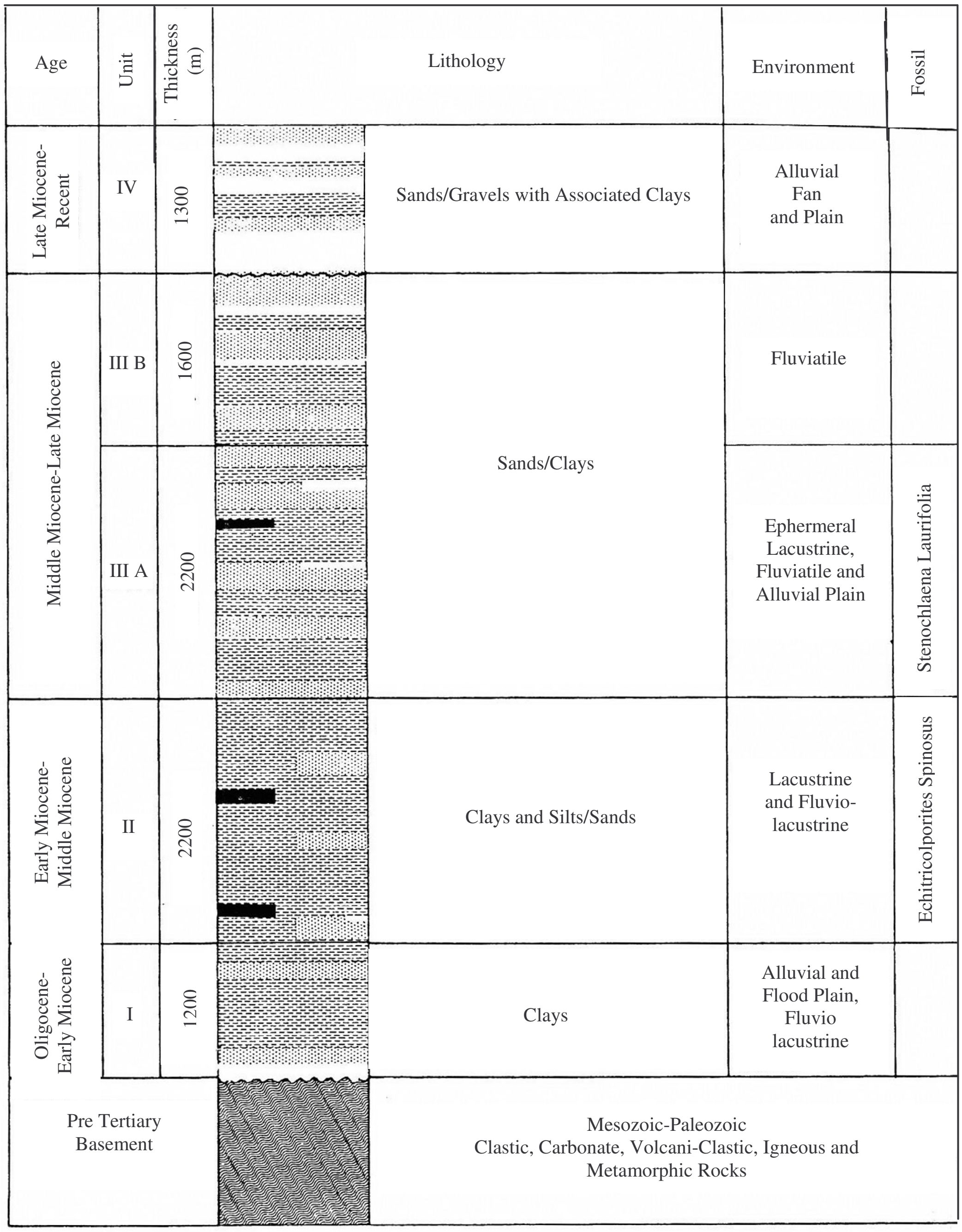


Figure 2.3 Generalized stratigraphy of Cenozoic basins in central Thailand (Knox and Wakefield, 1983).

2.3 Petroleum resources and potential in Phitsanulok basin

2.3.1 Basin type

The Phitsanulok basin is common throughout SE Asia and reveals striking geological similarities. The Phitsanulok basin originated during the early Tertiary as a result of extension rifting related to the collision of India with Asia. The Phitsanulok basin has half graben geometry and show elevated heat flows, typical of lift basins. Strike slip movements are common and lead in combination with extensional faulting to very complex, densely faulted basin margins. The Phitsanulok basin was starting characteristically as narrow, rapidly subsiding rift grabens with fault controlled lacustrine sedimentation. The rifts are then aborted and flexural movements of the cooling phase create larger depressions with mainly alluvial deposits. The Phitsanulok basin was initiated during Paleocene time on an eroded Paleozoic to Mesozoic surface. In Oligocene or early Miocene time a widespread paleo lake Phitsanulok developed for the first time. Fluviolacustrine sands pushed out into the lake particularly from west and north and local source centers in the east (Lankrabue formation). During middle Miocene times, channel sands associated with distal alluvial/fluvial plain and ephemeral lacustrine sediments appeared over much of the basin, marking the disappearance of the extensive and permanent lake (Pratu Tao formation).

2.3.2 Source rock

The sedimentary fill of the Phitsanulok and the other central plain basins consists of a continental series of alluvial plain, fluvial and lacustrine clastic sediments deposited during early to mid Miocene. The major source rocks are the clays of the Chum Saeng formation, which are widespread throughout the basin. Net thickness exceeding 100 m has been encounted adjacent to the Sukhothai depression.

2.3.3 Reservoir

The Lankrabue fluvio lacustrine sandstones constitute one of the reservoir targets of the basin. They form the main reservoir targets of the basin. They form the main reservoirs in the Sirikit field where porosities range form 20-30%. Reservoir continuity has proven to be variable. At any particular depth a wide range of porosities are observed. The maximum depth for 12% porosity cut off is 3,900 m. Good lateral continuity exists in distributary channel or composite sand unit whereas mount bar and delta front sands are limited in extent. The sands of the Prato Tao formation are prime reservoir targets in the basin. They are composite, meter beded, sorted, fine to coarse with massive clay interbeds. Porosities can be variable from 12-30%.

2.3.4 Trap and seal

Clay smear controlled fault seals, the main trapping mechanism in marine deltas, are less well developed in the continental setting of Thailand's intra montane basins (mainly due to different properties of alluvial clays) and across fault leakage is the rule. These factors result in a low retention potential of the basins, with repeated redistribution of hydrocarbon accumulations and the inherent migration loss of a very large part of the generated hydrocarbons.

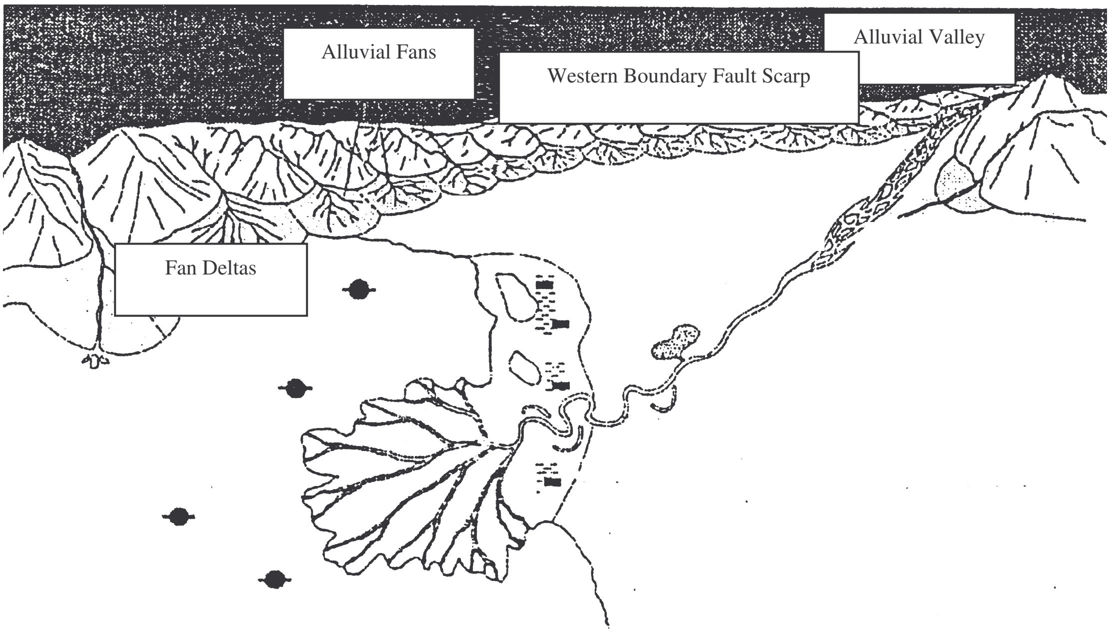


Figure 2.6 Depositional model for Miocene basin fills in Phitsanulok Blasin (Knox and Wakefield, 1983).

2.4 Artificial lift system

Artificial lift is any system that adds energy to the fluid column in a wellbore with the objective of initiating and improving production from the well. Planning for artificial lift is important, design considerations must begin before a well or group of wells are drilled. To provide optimum production rates by artificial lift methods at some future date, sufficient tubular clearances should be provided for. Analysis of specific installation type should begin while the wells are still flowing. Application of a certain lift method depends upon whether a group, lease, or field will be lifted or if only an isolated well require artificial lift. This leads to the basic methods of artificial lift in service. Based on world wide installations the relative standing of lift methods is as follows:

a. Sucker rod or beam pumping

b. Gas lift

c. Hydraulic pumping

d. Electric submersible pumping

e. Jet pumping

f. Plunger or free piston lift

g. Other methods

This may differ from field to field, state to state, and country to country. However, this research studies and analyzes electrical submersible pump, gas lift and, sucker rod pump only (The analytical solutions and theories of these artificial lift are shown in appendix B), because the application and utilization of these artificial lift systems have been continued and increased in Thailand onshore oil fields.

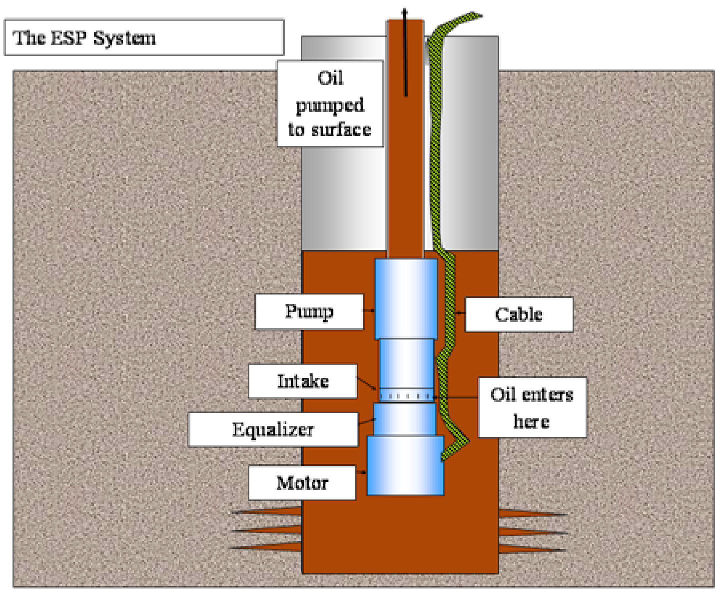


Figure 2.5 Equipments and compostions of electrical submersible pumps system (Zaba, 1943).

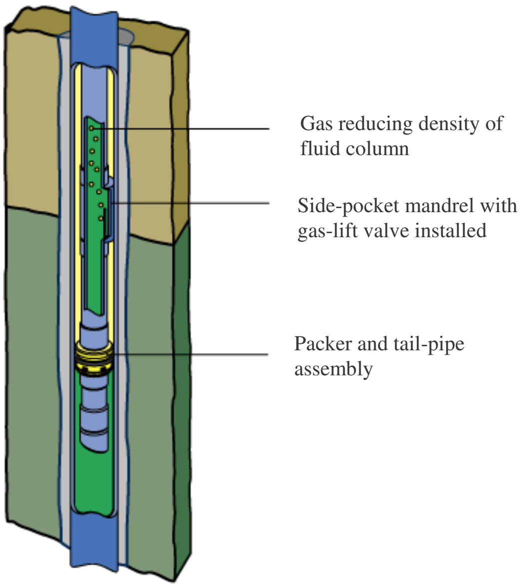


Figure 2.6 Equipments and compostions of gas lift system (Zaba, 1943).

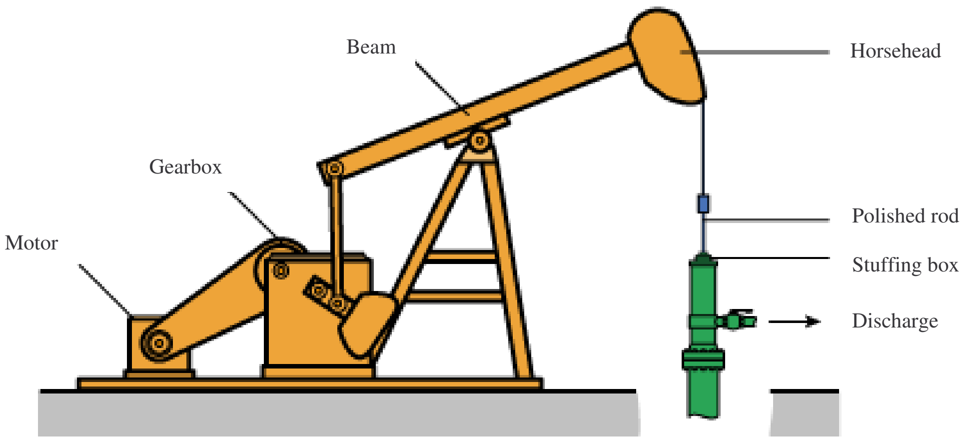


Figure 2.7 Equipments and compositions of sucker rod pump system (Zaba, 1943).

2.5 Application of the artificial lift system in Thailand onshore oil fields

2.5.1 Sirikit oil field in Phitsanulok basin

The Sirikit oil field locates at Lankrabue Aumpher, Kampaengphet province. The field has been explored and developed by Thai Shell and PTTEP since 1981. The oil property of Sirikit field is 40° API with 0.05% of sulfur. The Sirikit oil field produces oil, LPG and gas with the rate of 20,900 bbl/day, 251 Tonnes/day and 26 MMSCF/day respectively. The Sirikit oil field is a big field in Thailand onshore oil fields. The oil and gas reserve of Sirikit oil field is proved about 150 MMbbl and 245 MMSCF respectively. In addition, the oil is transported by trains from the Sirikit oil fields to refineries at Chon Buri and Bangkok and the gas is transported to EGAT for power generation. Moreover, the Sirikit oil fields produce oil, LPG and gas by natural flow and artificial lift about 16% and 84 % respectively. The application of artificial lift in Sirikit oil fields are gas lift and pump about 75% and 9 % respectively. The gas lifts system in Sirikit oil field consist of 3 methods that are continuous, intermittent and modified chamber gas lift. In addition, the pump system in Sirikit oil field are progressive cavity, electrical submersible and sucker rod pumps, these pumps were first introduced in 1998, 2001 and 2007 respectively.

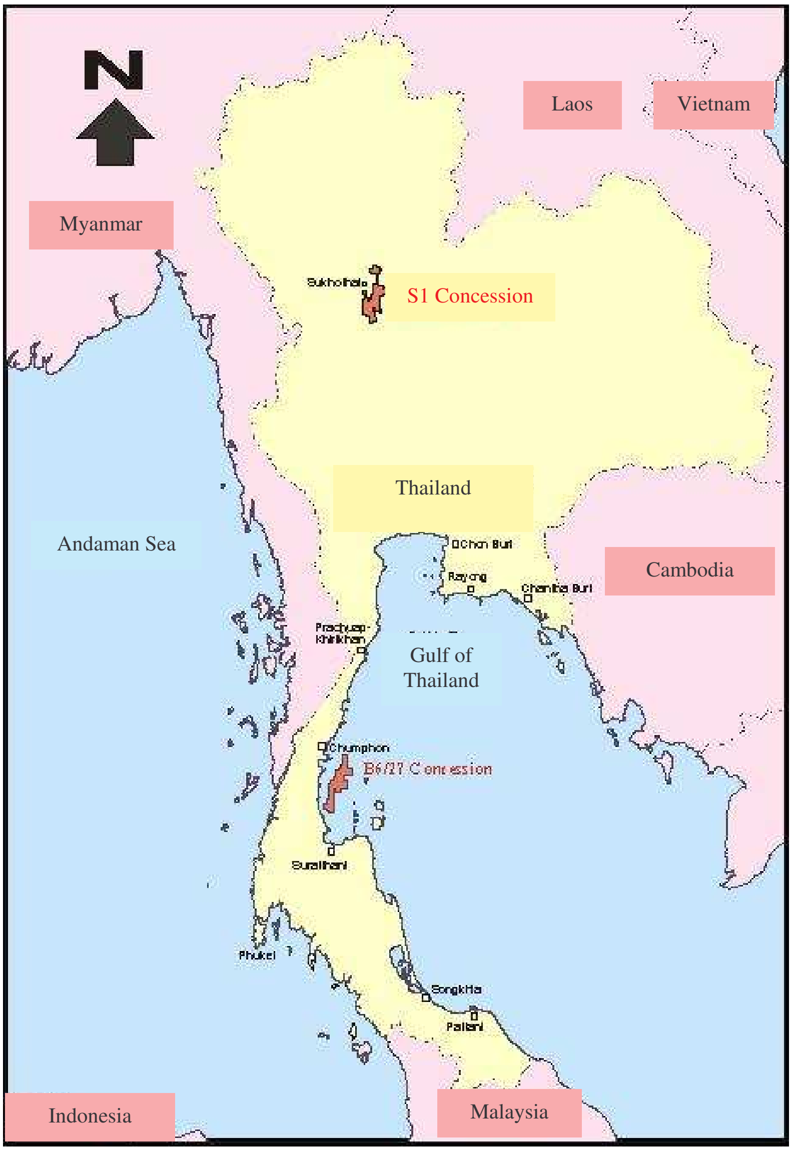


Figure 2.8 The concession of Sirikit oil field (PTT Exploration and Production Public Company Limited, 2007).

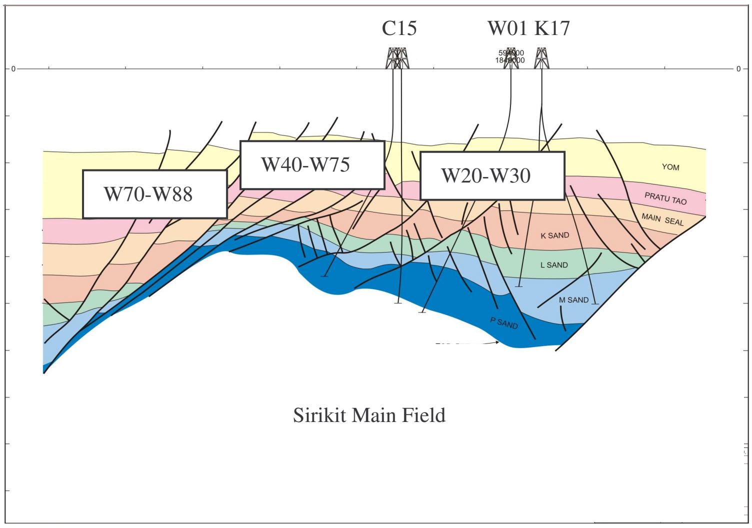


Figure 2.9 The Structure geology of Sirikit oil field (PTT Exploration and Production Public Company Limited, 2007).

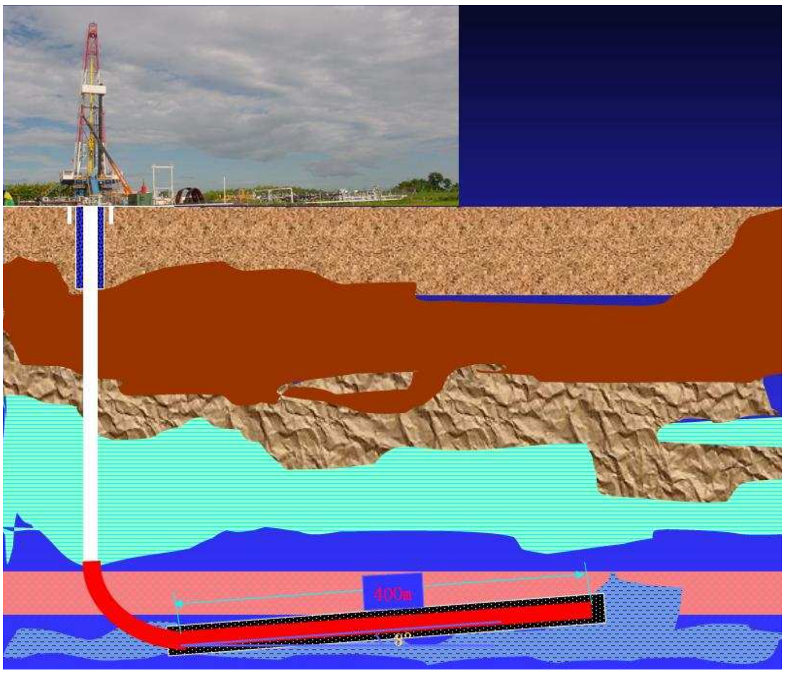


Figure 2.10 The drilling and completion well of Sirikit oil field (PTT Exploration and Production Public Company Limited, 2007).

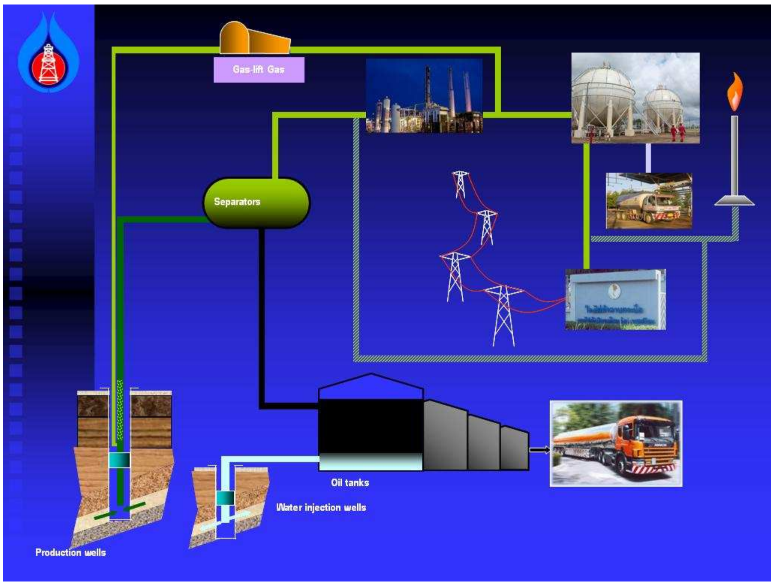


Figure 2.11 The petroleum production process of Sirikit oil field ((PTT Exploration and Production Public Company Limited 2007).

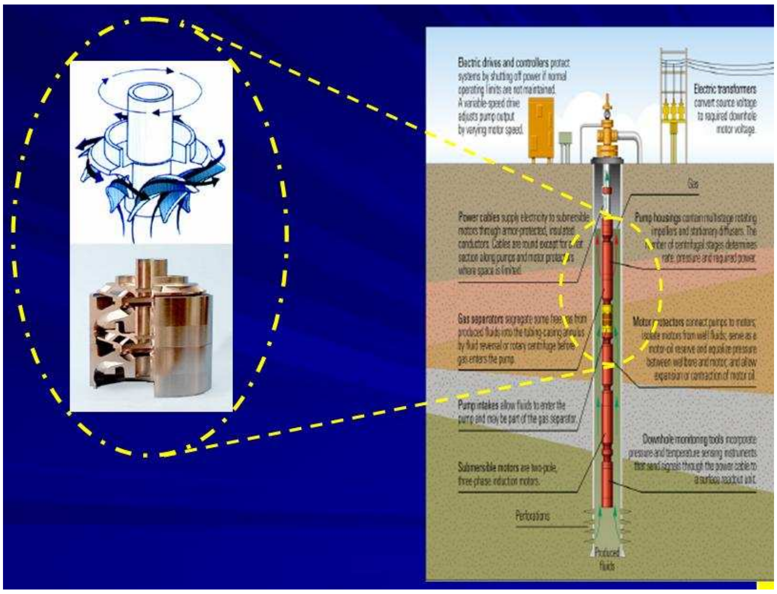


Figure 2.12 The process of electrical submersible pump in Sirikit oil fields (PTT Exploration and Production Public Company Limited, 2007).

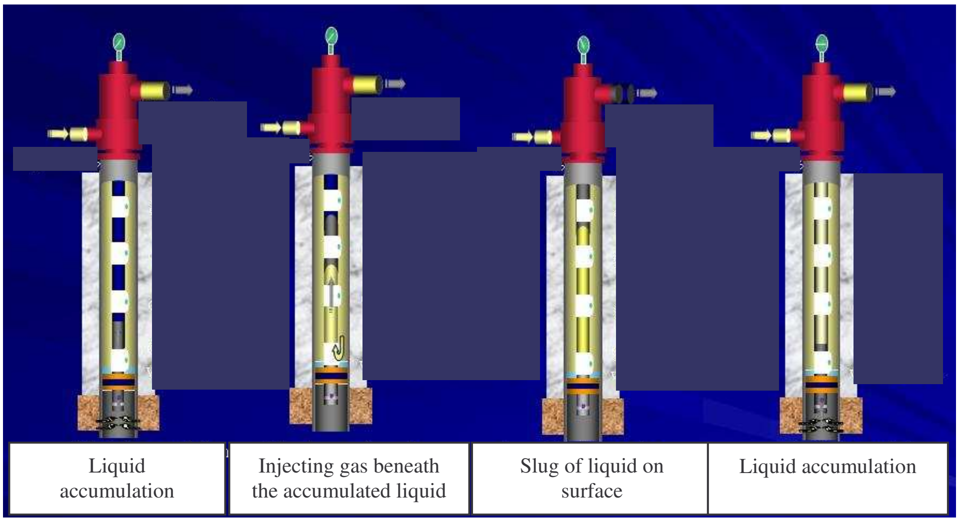


Figure 2.13 The process of gas lift in Sirikit oil fields (PTT Exploration and Production Public Company Limited, 2007).

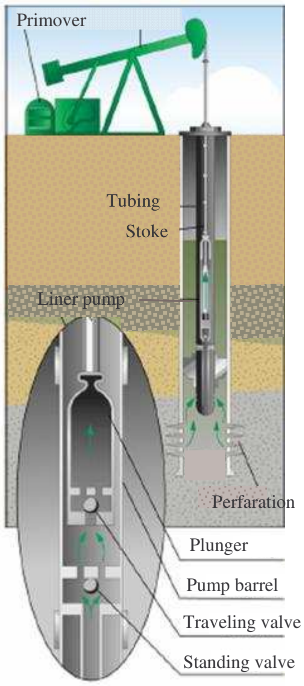


Figure 2.14 The process of sucker rod pump of Sirikit oil fields (PTT Exploration and Production Public Company Limited, 2007).

Figure 2.15 Characteristic of oil in Sirikit oil fields.

Figure 2.16 Whetherford's controller of electrical submersible pump in Sirikit oil fields.

Figure 2.17 The application of electrical submersible pump in Sirikit oil fields.

Figure 2.18 The application of gas lift in Sirikit oil fields.

Figure 2.19 The application of Lufkin's sucker rod pump in Sirikit oil field.

2.5.2 Wichienburi oil field in Wichienburi basin

The Wichienburi oil field locates in Wichienburi aumpher, Phetchaboon province. The field has been explored and developed by Pacific Tiger since 1988. The wild cat was Wichienburi1 (WB-1) which produced oil about 32 bbl/day. At the present, the Wichienburi oil field consist of 8 wells, namely, WB-1, WB-A1, WBN-01, WBN-02, WBN-03, WBN-04, WBN-06 and WBN-8. The oil production of all wells is 139 bbl/day. In addition, the oil property of Wichienburi fields is 29-30° API. The Wichienburi oil field is a small field in Thailand onshore oil fields. The oil reserve of Wichienburi oil field is proved about 955,875 bbl.

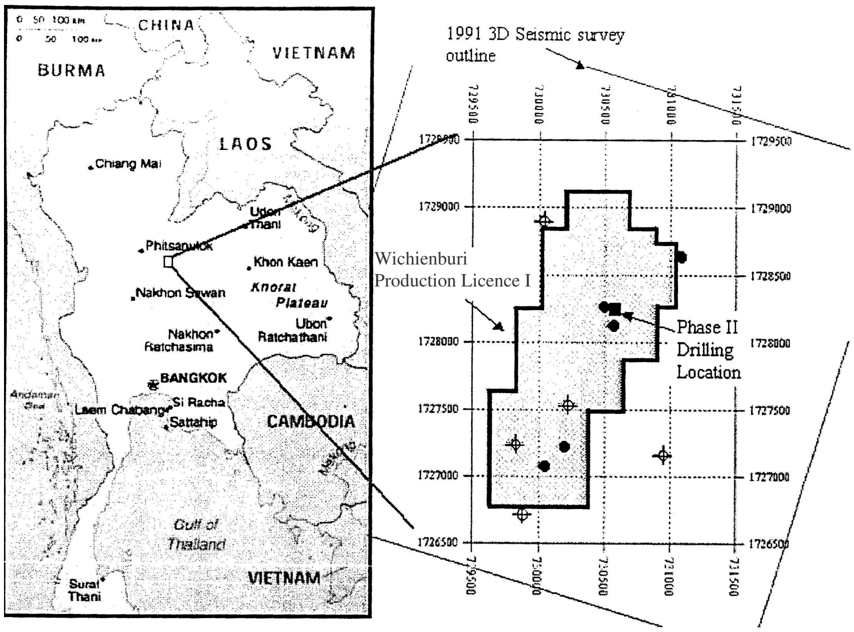


Figure 2.20 The map of Wichienburi oil fields (Hawkes, et al, 2002).

Figure 2.21 The Sentry International's sucker rod pump in Wichienburi oil fields.

2.5.3 Kampaengsan, Sangkrajai and U Thong oil fields in Supanburi basin

The field had explored and developed by B.P. Petroleum Development Ltd. since 1985. However, B.P. Petroleum Development was conceded by PTTEP in 1993 (Triamwichanon, 1999). The production area of these fields is 9.04 sq.km., including Kampaengsan oil field is 2.00 sq.km., Sangkrajai is 1.98 sq.km., and U Thong oil field is 5.06 sq.km. The production site of Kampaengsan oil field is KS1-1 that has 1 production well and 1 disposal well. The production site of Sangkrajai oil field is SKJ that has 2 production wells. There are 2 production sites in U Thong oil field, which are UT1-3 has 1 production well and 1 injection well and UT1-7 has 8 production wells and 1 injection well. The oil property of these fields is 25-34° API with 5 SCF/STB of gas oil ratio and 0.14% of sulphur. The fields produce oil about 550 bbl/day. The oil reserve of these fields is proved about 4.782 MMbbl and the ulimate reserve identified, cumulative production and remaining reserve of each oil field are shown in Table 2.1. The oil is sold to PTT and transported to Bangchak refinery.

Table 2.1 Reserves as of 31 Aug 06.

Oil fields	Ulimate reserve identified (MMbbl)	Cumulative production (MMbbl)	Remaining Reserves (MMbbl)
KS	0.363	0.329	0.034
U-Thong	3.979	3.735	0.244
SKJ	0.440	0.329	0.111
Total	4.782	4.393	0.389

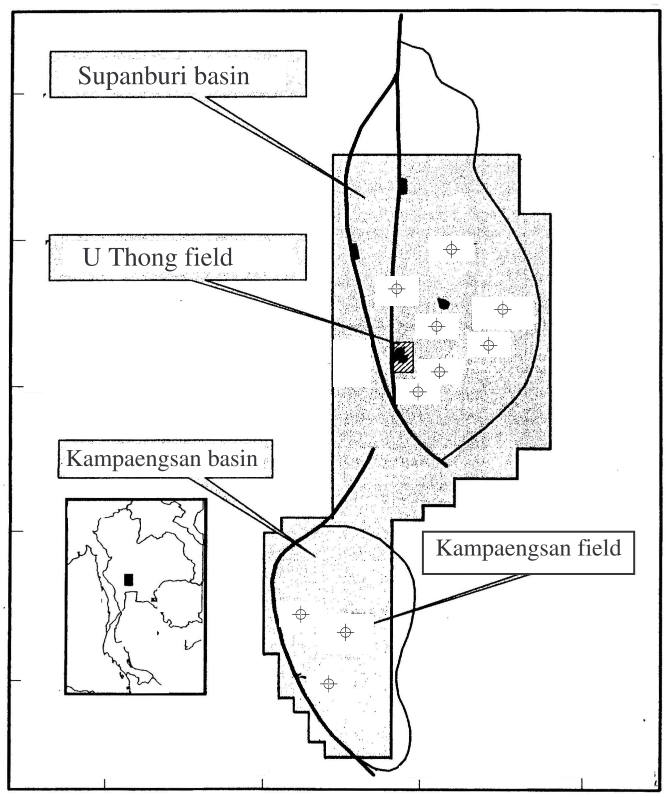


Figure 2.24 The map of Supanburi basin (Hatairat Triamwichanon, 1999).

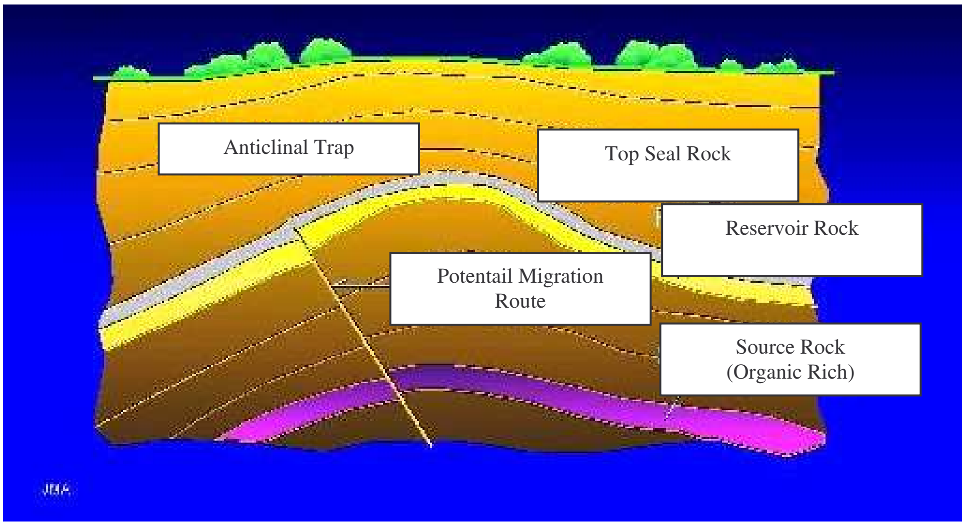


Figure 2.23 Petroleum system of Supanburi basin (Triamwichanon, H. 1999).

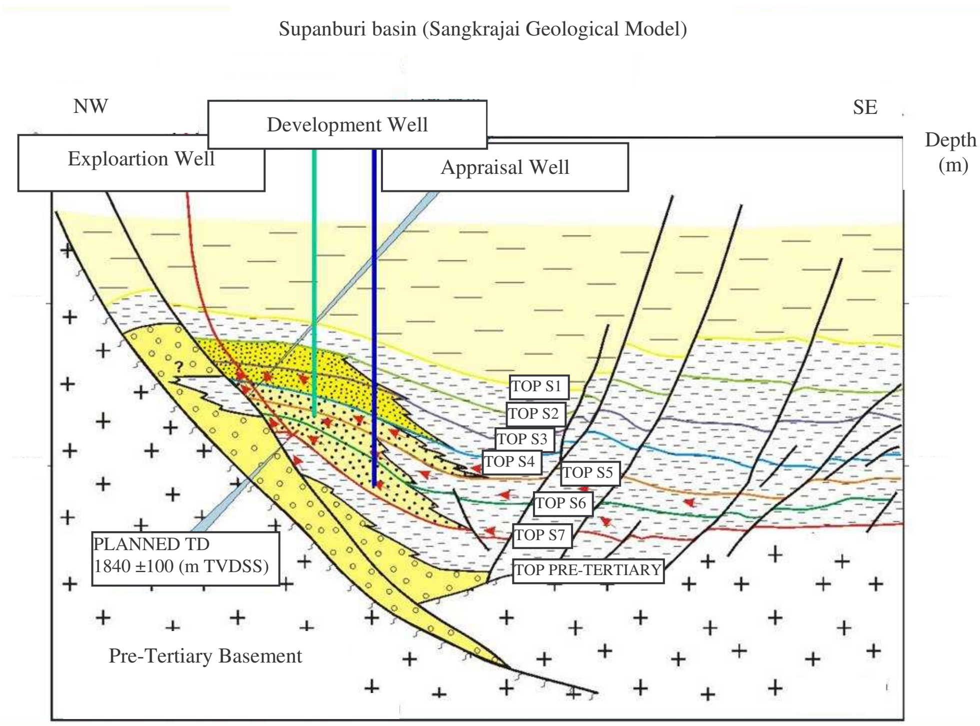


Figure 2.24 Geological model of Sangkrajai oil fiels (Triamwichanon, H. 1999).

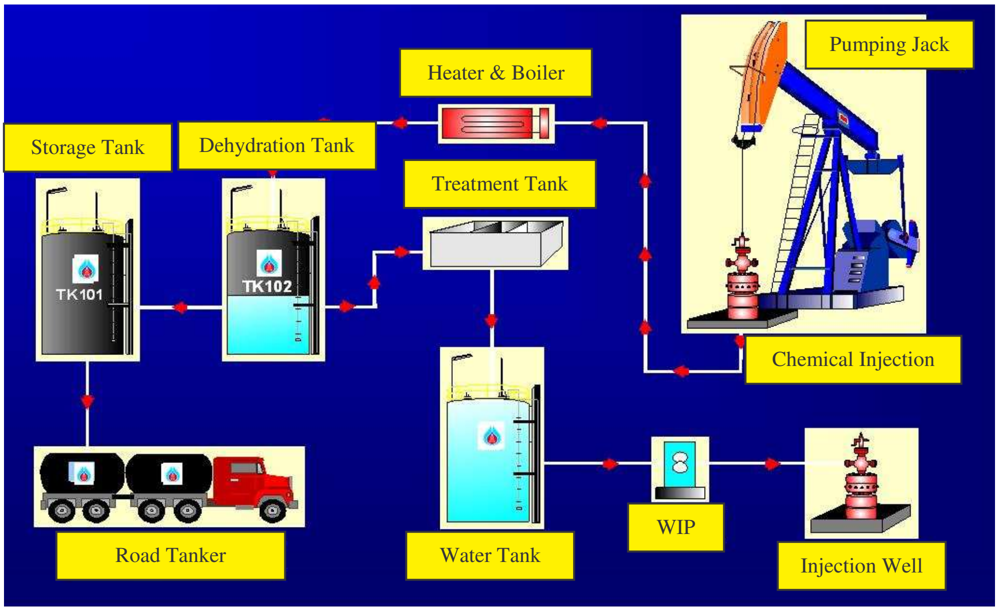


Figure 2.25 The process of Kampaengsan, Sangkrajai and U Thong oil fields in Supanburi basin (PTT Exploration and Production Public Company Limited, 2007).

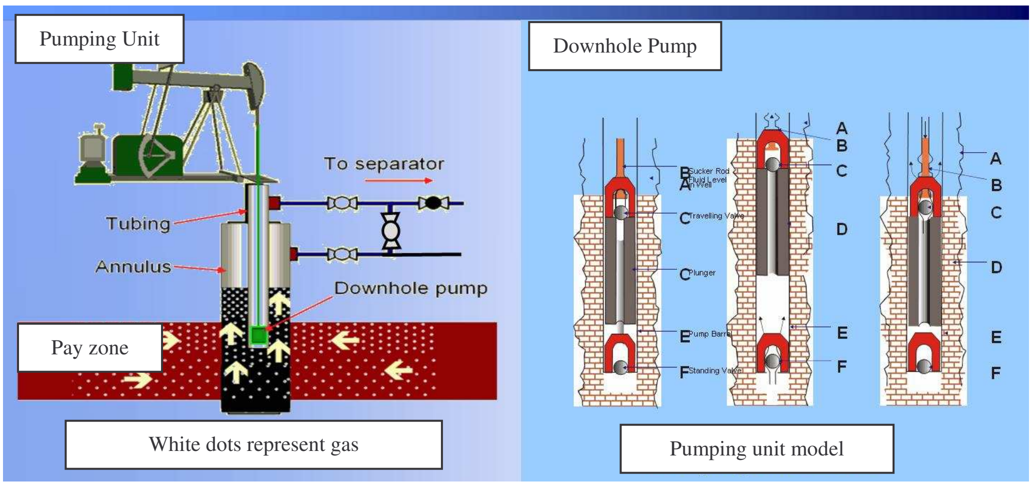


Figure 2.26 The process of sucker rod pump in Kampaengsan, Sangkrajai and U Thong oil fields (PTT Exploration and Production Public Company Limited, 2007).

Figure 2.27 Lufkin’s sucker rod pump in Kampaengsan oil fields.

Figure 2.28 Sentry International’s sucker rod pump in Sangkrajai oil fields.

Figure 2.29 Lufkin's sucker rod pump in U Thong oil fields.

Figure 2.30 Lufkin's ball valves of sucker rod pump in U Thong oil fields.

2.6 The application of commercial software for artificial lift system

2.6.1 Submersible ESP software

The csSubmersible provides a user with the ability to control, monitor, track trends, and report on their ESP wells. This means that in just minutes upon arriving at work, the operator can see which wells need immediate action. Time is spent solving problems rather than searching for them. The csSubmersible can be integrated with other modules of the csLIFT family to create a complete system for operating an entire oil field. The csSubmersible collects and analyzes information needed to discover inappropriate operation of ESP wells. Watching the trends of information such as amperage (current) usage can indicate potential problems that are occurring at the pump level. For instance, corrective action for paraffin buildup and sanding can be taken before the pump fails.

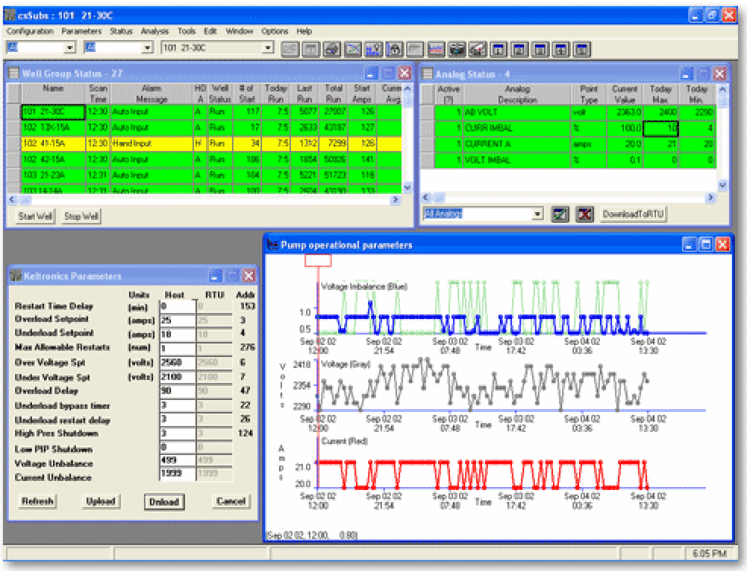


Figure 2.31 csSubmersible ESP software overview (Zaba, 1943).

2.6.2 PIPESIM Gas Lift optimization software

The PIPESIM optimization simulator provides fieldwide solutions using an algorithm to identify the best distribution of gas lift injection gas throughout production system. Complex constraints such as water and gas handling capacity can be included in the model at any point. The optimization solver is designed to be used in daily operations and can be allocated artificial lift within large fields in just a few seconds. The system model can be integrated with production databases and SCADA systems for real-time production optimization using the latest data delivered through ProdManreal-time well and facilies diagnostic system. Beneficial using of PIPESIM Gas Lift Optimization Software

a. Maximize production from limited available lift gas

b. Increase gas sales by identifying system gas lift needs

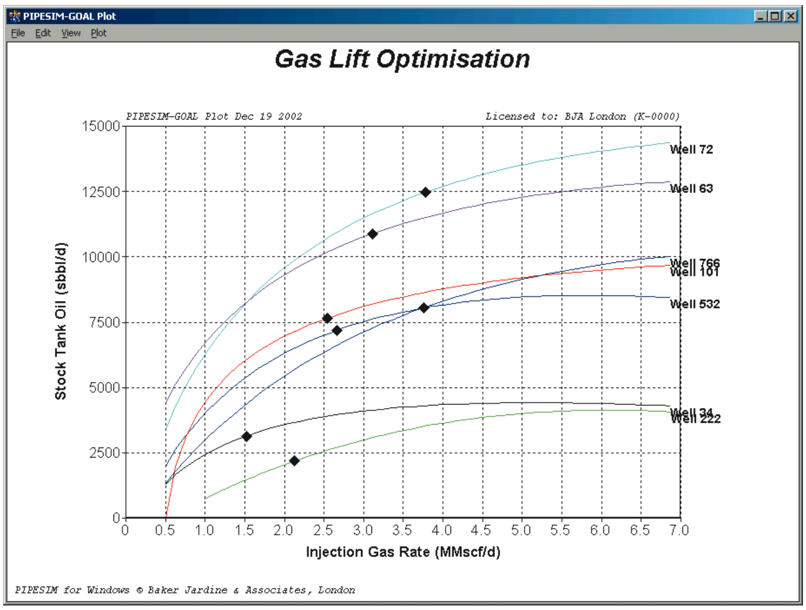


Figure 2.32 PIPESIM gas lift optimization module (Zaba, 1943).

2.6.3 Echometer QRod software

The Echometer QRod software is the most widely used for the design and prediction of the performance of sucker rod pump installations. QRod's objective is to help the sucker rod pump system designer implement state of the art design technology without getting buried with details. The program uses a wave equation solution to accurately predict the surface dynamometer loads, gearbox torque and pump capacity, with a minimum amount of input. The effect of changing a parameter such as tubing anchor, stroke length, stroke rate, and pump diameter can be immediately seen in the dynamically updated plots. Available as a software option in QRod for the PC, the user can select the output and display language. The output of the QRod program includes pump displacement, rod string loading, surface unit and motor size requirements for any input depth and design production rate.

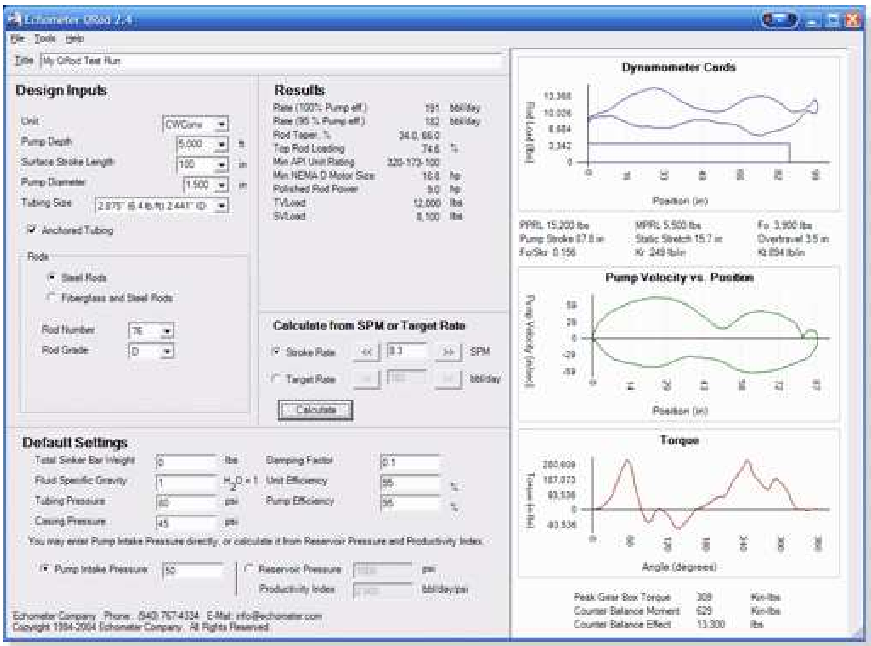


Figure 2.33 The Echometer QRod software (Zaba, 1943)**.**