

# สารหล่อลื่นพื้นฐานสังเคราะห์ประเภทไดเอสเทอร์จากน้ำมันปาล์ม

นางสาวดรุณี ทับทิม



วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต

สหสาขาวิชาปิโตรเคมี-โพลีเมอร์

บัณฑิตวิทยาลัย จุฬาลงกรณ์มหาวิทยาลัย

ปีการศึกษา 2539

ISBN 974-636-167-8

ลิขสิทธิ์ของบัณฑิตวิทยาลัย จุฬาลงกรณ์มหาวิทยาลัย

**SYNTHETIC DIESTER LUBRICATING BASE OILS  
FROM PALM OIL**



**Miss Darunee Tubthim**

ศูนย์วิทยทรัพยากร

**A Thesis Submitted in Partial Fulfilment of the Requirments  
for the Degree of Master of Science**

**Multidisciplinary of Petrochemistry and Polymer**

**Graduate School**

**Chulalongkorn University**

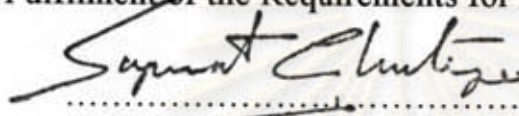
**Academic Year 1996**

**ISBN 974-636-167-8**


Thesis Title            Synthetic Diester Lubricating Base Oils from Palm Oil  
By                         Miss Darunee Tubthim  
Department            Petrochemistry  
Thesis Advisor        Associate Professor Sophon Roengsumran, Ph.D.  
Thesis Co-advisor    Mrs. Ratanavalee In-ochanon


---

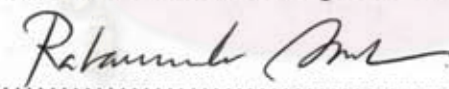
Accepted by the Graduate School, Chulalongkorn University in  
Partial Fulfilment of the Requirements for the Master's Degree.

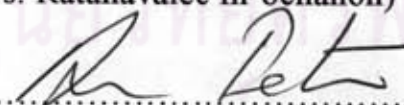
.....Dean of Graduate School  
(Professor Supawat Chutivongse, M.D.)

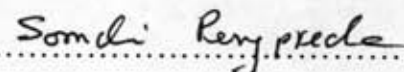
Thesis Committee


.....Chairman  
(Associate Professor Supawan Tantayanon, Ph.D.)

.....Thesis Advisor  
(Associate Professor Sophon Roengsumran, Ph.D.)

.....Thesis Co-advisor  
(Mrs. Ratanavalee In-ochanon)

.....Member  
(Assistant Professor Amorn Petsom, Ph.D.)

..... Member  
(Assistant Professor Somchai Pengprecha, Ph.D.)

.....Member  
(Assistant Professor Wimonrat Trakarnpruk, Ph.D.)

พิมพ์ต้นฉบับบทคัดย่อวิทยานิพนธ์ภายในกรอบสี่เหลี่ยมนี้เพียงแผ่นเดียว

ดร.ตรี ทับทิม : สารหล่อลื่นพื้นฐานสังเคราะห์ประเภทไดเอสเทอร์จากน้ำมันปาล์ม  
(SYNTHETIC DIESTER LUBRICATING BASE OILS FROM PALM OIL)  
อ.ที่ปรึกษา : รศ.ดร. โสภณ เรืองสำราญ อ.ที่ปรึกษาร่วม : คุณรัตนาวดี อินโชนานนท์,  
168 หน้า. ISBN 974-636-167-8

สารหล่อลื่นพื้นฐานสังเคราะห์ประเภทไดเอสเทอร์ เตรียมโดยปฏิกิริยาทรานเอสเทอร์น้ำมันปาล์ม และปฏิกิริยาเอสเทอร์กรดน้ำมันปาล์ม ได้แก่ กรดโอเลอิก, กรดสเตียริก และ กรดปาล์มมิติก กับ 1,3-โพรเพนไดออล, 1,4-บิวเทนไดออล, 1,5-เพนเทนไดออล, 2,2-ไดเมทิล-1,3-โพรเพนไดออล โดยใช้กรดซัลฟูริกเป็นตัวเร่งปฏิกิริยา ผลิตภัณฑ์ที่ได้จากปฏิกิริยาดังกล่าวมี 2 สถานะ คือ ของแข็ง และของเหลว เนื่องจากของแข็งไม่สามารถวัดสมบัติทางกายภาพ เช่น ความหนืด และจุดไหลเท ของสารสังเคราะห์ได้ ทำให้สารสังเคราะห์ที่เป็นของแข็งไม่เหมาะที่จะใช้เป็นสารหล่อลื่นในเครื่องยนต์ แต่ผลิตภัณฑ์แต่ละตัวที่ได้จากปฏิกิริยาทรานเอสเทอร์ และปฏิกิริยาเอสเทอร์กับ 2-เอทิล-1,3-เฮกเซนไดออล เป็นของเหลว และมีสมบัติทางกายภาพและทางเคมีที่ดี เช่น ผลิตภัณฑ์ 2-เอทิล-1,3-เฮกเซนไดเอสเทอร์ จากน้ำมันปาล์ม มีสมบัติทางกายภาพและทางเคมีคือ ค่าดัชนีความหนืด 170.83 จุดไหลเท  $-9^{\circ}\text{C}$  จุดวาบไฟ  $208^{\circ}\text{C}$  และมีความเสถียรต่อความร้อนและการถูกออกซิไดซ์ได้ดี ผลที่ได้แสดงให้เห็นว่าไดเอสเทอร์สังเคราะห์ที่ได้จากปฏิกิริยาทรานเอสเทอร์น้ำมันปาล์ม และปฏิกิริยาเอสเทอร์กรดน้ำมันปาล์มกับ 2-เอทิล-1,3-เฮกเซนไดออล เหมาะสมในการนำไปใช้เป็นสารหล่อลื่นในเครื่องยนต์

ศูนย์วิทยทรัพยากร  
จุฬาลงกรณ์มหาวิทยาลัย

ภาควิชา..... สาขาวิชา.....  
ปีการศึกษา.....  
.....

ลายมือชื่อนิติ.....  
ลายมือชื่ออาจารย์ที่ปรึกษา.....  
ลายมือชื่ออาจารย์ที่ปรึกษาร่วม.....





## ACKNOWLEDGEMENTS

The author would like to express her sincere thanks to her advisor, Associate Professor Dr. Sophon Roengsumran for his encouraging guidance, supervision and helpful suggestions throughout this research. She is grateful to Mrs. Ratanavalee In-ochanon, her co-advisor, and Assistant Professor Dr. Amorn Petsom for their valuable criticism and helpfulness. In addition, she is also grateful to Associate Professor Dr. Supawan Tantayanon, Assistant Professor Dr. Somchai Pengpreecha and Assistant Professor Dr. Wimonrat Trakarnpruk, serving as chairman and members of her thesis committee, respectively, for their valuable comments.

The special thanks are due to the Petroleum Authority of Thailand and the Chemistry Department, Chulalongkorn University for their help in permitting use of some equipment and their support during this research.

Finally, the author would like to express her gratitude to her family for their support throughout her entire education.

ศูนย์วิทยทรัพยากร  
จุฬาลงกรณ์มหาวิทยาลัย

## CONTENTS

	Page
ABSTRACT IN THAI .....	iv
ABSTRACT IN ENGLISH .....	v
ACKNOWLEDGEMENTS .....	vi
CONTENTS.....	vii
LIST OF TABLES .....	ix
LIST OF FIGURES .....	xi
ABBREVIATIONS .....	xx
CHAPTER I : INTRODUCTION.....	1
1.1 General.....	1
1.2 Objectives.....	2
1.3 The Scope of the Investigation.....	2
CHAPTER II : THEORETICAL CONSIDERATION.....	4
2.1 Fat and Fatty Oils.....	4
2.1.1 Composition and Properties .....	4
2.1.2 Extraction and Refining.....	7
2.2 Palm Oil.....	8
2.2.1 Origin and Systematic.....	10
2.2.2 Composition and Properties.....	10
2.2.3 Industrial Applications.....	12
2.3 Lubricating Base Oils.....	14
2.3.1 Sources.....	14
2.3.2 The Basic Functions of Lubricants.....	14
2.3.3 The Principle Properties and Tests.....	16
2.4 Synthetic Lubricants.....	20
2.5 Synthetic Ester Lubricants.....	24

	Page
2.5.1 Physicochemical Properties of Ester Lubricants.....	24
2.5.2 Application Areas.....	32
2.5.3 Future Trends.....	35
2.6 Transesterification.....	35
2.7 Esterification .....	37
2.8 Literature Review.....	38
CHAPTER III: EXPERIMENTAL.....	40
3.1 Chemicals .....	40
3.2 Apparatus and Instruments.....	41
3.3 Experimental Procedures.....	41
3.3.1 Transesterification of Palm Oil with Methanol.....	41
3.3.2 Re-transesterification of Methyl Ester with Diols.....	43
3.3.3 Esterification of Fatty Acids with Diols.....	45
CHAPTER IV: RESULTS AND DISCUSSION .....	48
CHAPTER V : CONCLUSION.....	92
REFERENCES.....	95
APPENDIX.....	97
VITA.....	168

ศูนย์วิทยทรัพยากร  
จุฬาลงกรณ์มหาวิทยาลัย



## LIST OF TABLES

Table	Page
2.1 The properties of common fats and oils.....	6
2.2 The properties of pure fatty acids.....	7
2.3 Nomenclature and formulae of common fatty acids found in palm oil.....	11
2.4 Properties of palm oil.....	12
2.5 Primary applications for synthetic lubricants.....	21
2.6 Comparison of some important properties of major synthetic lubricants .....	23
2.7 The major types of ester.....	25
2.8 Summary of ester properties .....	26
4.9 The physical and chemical properties of palm oil and methyl ester of palm oil.....	51
4.2 The physical and chemical properties of palm oil and 2,2-dimethyl-1,3-propanediester product of palm oil.....	61
4.3 The physical and chemical properties of palm oil and 2-ethyl-1,3-hexanediester product of palm oil.....	64
4.4 The physical and chemical properties of 1,3-propanediolate.....	66
4.5 The physical and chemical properties of 1,4-butanediolate.....	68
4.6 The physical and chemical properties of 1,5-pentanedioleate.....	71
4.7 The physical and chemical properties of 2,2-dimethyl-1,3- propanediolate.....	72
4.8 The physical and chemical properties of 2-ethyl-1,3-hexane- dioleate.....	74

Table	Page
4.9 The physical and chemical properties of 2-ethyl-1,3-hexane-distearat.....	82
4.10 The physical and chemical properties of 2-ethyl-1,3-hexane-dipalmitate.....	91
5.1 The optimum conditions for synthesis of 2-ethyl-1,3-hexane-diester products.....	93
5.2 Comparison of the physical and chemical properties of lubricating base oil (150SN) and 2-ethyl-1,3-hexanediester product from palm oil and its fatty acid.....	93



ศูนย์วิทยทรัพยากร  
จุฬาลงกรณ์มหาวิทยาลัย

## LIST OF FIGURES

Figure	Page
2.1a A plantation oil palm tree.....	9
2.1b Palm fruit and palm kernel.....	9
2.2 Concept of dynamic viscosity.....	15
2.3 Comparison between typical model curves for both TG thermal and thermooxidation stabilities.....	19
2.4 Biodegradability of lubricants as measured by the DEL-33-T-82 Test.....	32
A1 $^{13}\text{C}$ NMR ( $\text{CDCl}_3$ ) spectrum of palm oil.....	98
B1 IR spectrum of palm oil.....	98
A2 $^{13}\text{C}$ NMR ( $\text{CDCl}_3$ ) spectrum of oleic acid.....	99
B2 IR spectrum of oleic acid.....	99
A3 $^{13}\text{C}$ NMR ( $\text{CDCl}_3$ ) spectrum of stearic acid.....	100
B3 IR spectrum of stearic acid.....	100
A4 $^{13}\text{C}$ NMR ( $\text{CDCl}_3$ ) spectrum of palmitic acid.....	101
B4 IR spectrum of palmitic acid.....	101
A5 $^{13}\text{C}$ NMR ( $\text{CDCl}_3$ ) spectrum of methanol.....	102
B5 IR spectrum of methanol.....	102
A6 $^{13}\text{C}$ NMR ( $\text{CDCl}_3$ ) spectrum of 1,3-propanediol.....	103
B6 IR spectrum of 1,3-propanediol.....	103
A7 $^{13}\text{C}$ NMR ( $\text{CDCl}_3$ ) spectrum of 1,4-butanediol.....	104
B7 IR spectrum of 1,4-butanediol.....	104
A8 $^{13}\text{C}$ NMR ( $\text{CDCl}_3$ ) spectrum of 1,5-pentanediol.....	105
B8 IR spectrum of 1,5-pentanediol.....	105
A9 $^{13}\text{C}$ NMR ( $\text{CDCl}_3$ ) spectrum of 2,2-dimethyl-1,3-propanediol.....	106

Figure	Page
B9 IR spectrum of 2,2-dimethyl-1,3-propanediol.....	106
A10 $^{13}\text{C}$ NMR ( $\text{CDCl}_3$ ) spectrum of 2-ethyl-1,3-hexanediol.....	107
B10 IR spectrum of 2-ethyl-1,3-hexanediol.....	107
A11 $^{13}\text{C}$ NMR ( $\text{CDCl}_3$ ) spectrum of methyl ester of palm oil.....	108
B11 IR spectrum of methyl ester of palm oil.....	108
A12 $^{13}\text{C}$ NMR ( $\text{CDCl}_3$ ) spectrum of diester obtained from methyl ester of palm oil and 1,3-propanediol.....	109
B12 IR spectrum of diester obtained from methyl ester of palm oil and 1,3-propanediol.....	109
A13 $^{13}\text{C}$ NMR ( $\text{CDCl}_3$ ) spectrum of diester obtained from methyl ester of palm oil and 1,4-butanediol.....	110
B13 IR spectrum of diester obtained from methyl ester of palm oil and 1,4-butanediol.....	110
A14 $^{13}\text{C}$ NMR ( $\text{CDCl}_3$ ) spectrum of diester obtained from methyl ester of palm oil and 1,5-pentanediol.....	111
B14 IR spectrum of diester obtained from methyl ester of palm oil and 1,5-pentanediol.....	111
A15 $^{13}\text{C}$ NMR ( $\text{CDCl}_3$ ) spectrum of diester obtained from methyl ester of palm oil and 2,2-dimethyl-1,3-propanediol.....	112
B15 IR spectrum of diester obtained from methyl ester of palm oil and 2,2-dimethyl-1,3-propanediol.....	112
A16 $^{13}\text{C}$ NMR ( $\text{CDCl}_3$ ) spectrum of diester obtained from methyl ester of palm oil and 2-ethyl-1,3-hexanediol.....	113
B16 IR spectrum of diester obtained from methyl ester of palm oil and 2-ethyl-1,3-hexanediol.....	113
A17 $^{13}\text{C}$ NMR ( $\text{CDCl}_3$ ) spectrum of diester obtained from oleic acid and 1,3-propanediol.....	114

Figure	Page
B17 IR spectrum of diester obtained from oleic acid and 1,3-propanediol.....	114
A18 $^{13}\text{C}$ NMR ( $\text{CDCl}_3$ ) spectrum of diester obtained from oleic acid and 1,4-butanediol.....	115
B18 IR spectrum of diester obtained from oleic acid and 1,4-butanediol.....	115
A19 $^{13}\text{C}$ NMR ( $\text{CDCl}_3$ ) spectrum of diester obtained from oleic acid and 1,5-pentanediol.....	116
B19 IR spectrum of diester obtained from oleic acid and 1,5-pentanediol.....	116
A20 $^{13}\text{C}$ NMR ( $\text{CDCl}_3$ ) spectrum of diester obtained from oleic acid and 2,2-dimethyl-1,3-propanediol.....	117
B20 IR spectrum of diester obtained from oleic acid and 2,2-dimethyl-1,3-propanediol.....	117
A21 $^{13}\text{C}$ NMR ( $\text{CDCl}_3$ ) spectrum of diester obtained from oleic acid and 2-ethyl-1,3-hexanediol.....	118
B21 IR spectrum of diester obtained from oleic acid and 2-ethyl-1,3-hexanediol.....	118
A22 $^{13}\text{C}$ NMR ( $\text{CDCl}_3$ ) spectrum of diester obtained from stearic acid and 1,3-propanediol.....	119
B22 IR spectrum of diester obtained from stearic acid and 1,3-propanediol.....	119
A23 $^{13}\text{C}$ NMR ( $\text{CDCl}_3$ ) spectrum of diester obtained from stearic acid and 1,4-butanediol.....	120
B23 IR spectrum of diester obtained from stearic acid and 1,4-butanediol.....	120

Figure	Page
A24 $^{13}\text{C}$ NMR ( $\text{CDCl}_3$ ) spectrum of diester obtained from stearic acid and 1,5-pentanediol.....	121
B24 IR spectrum of diester obtained from stearic acid and 1,5-pentanediol.....	121
A25 $^{13}\text{C}$ NMR ( $\text{CDCl}_3$ ) spectrum of diester obtained from stearic acid and 2,2-dimethyl-1,3-propanediol.....	122
B25 IR spectrum of diester obtained from stearic acid and 2,2-dimethyl-1,3-propanediol.....	122
A26 $^{13}\text{C}$ NMR ( $\text{CDCl}_3$ ) spectrum of diester obtained from stearic acid and 2-ethyl-1,3-hexanediol.....	123
B26 IR spectrum of diester obtained from stearic acid and 2-ethyl-1,3-hexanediol.....	123
A27 $^{13}\text{C}$ NMR ( $\text{CDCl}_3$ ) spectrum of diester obtained from palmitic acid and 1,3-propanediol .....	124
B27 IR spectrum of diester obtained from palmitic acid and 1,3-propanediol .....	124
A28 $^{13}\text{C}$ NMR ( $\text{CDCl}_3$ ) spectrum of diester obtained from palmitic acid and 1,4-butanediol.....	125
B28 IR spectrum of diester obtained from palmitic acid and 1,4-butanediol.....	125
A29 $^{13}\text{C}$ NMR ( $\text{CDCl}_3$ ) spectrum of diester obtained from palmitic acid and 1,5-pentanediol.....	126
B29 IR spectrum of diester obtained from palmitic acid and 1,5-pentanediol.....	126
A30 $^{13}\text{C}$ NMR ( $\text{CDCl}_3$ ) spectrum of diester obtained from palmitic acid and 2,2-dimethyl-1,3-propanediol.....	127

Figure	Page
B30 IR spectrum of diester obtained from palmitic acid and 2,2-dimethyl-1,3-propanediol.....	127
A31 <sup>13</sup> C NMR (CDCl <sub>3</sub> ) spectrum of diester obtained from palmitic acid and 2-ethyl-1,3-hexanediol.....	128
B31 IR spectrum of diester obtained from palmitic acid and 2-ethyl-1,3-hexanediol.....	128
C1 GC-chromatogram of methyl ester of palm oil.....	129
D1 Mass spectrum of ethyl palmitate at retention time 9.085 min.....	129
D2 Mass spectrum of ethyl oleate at retention time 10.396 min.....	130
C2 GC-chromatogram of diester obtained from methyl ester of palm oil and 1,3-propanediol.....	131
D3 Mass spectrum of 1,3-propanedipalmitate at retention time 10.594 min.....	131
D4 Mass spectrum of 1,3-propanepalmitate-oleate at retention time 12.392 min.....	132
C3 GC-chromatogram of diester obtained from methyl ester of palm oil and 1,4-butanediol.....	133
D5 Mass spectrum of 1,4-butanepalmitate at retention time 11.016 min.....	133
D6 Mass spectrum of 1,4-butanepalmitate-oleate at retention time 12.547 min.....	134
C4 GC-chromatogram of diester obtained from methyl ester of palm oil and 1,5-pentanediol.....	135
D7 Mass spectrum of 1,5-pentanepalmitate at retention time 11.412 min.....	135
D8 Mass spectrum of 1,5-pentanepalmitate-oleate at retention time 13.049 min.....	136

Figure	Page
C5 GC-chromatogram of diester obtained from methyl ester of palm oil and 2,2-dimethyl-1,3-propanediol.....	137
D9 Mass spectrum of 2,2-dimethyl-1,3-propanedipalmitate at retention time 12.342 min.....	137
D10 Mass spectrum of 2,2-dimethyl-1,3-propanepalmitate-oleate at retention time 14.244 min.....	138
C6 GC-chromatogram of diester obtained from methyl ester of palm oil and 2-ethyl-1,3-hexandiol.....	139
D11 Mass spectrum of 2-ethyl-1,3-hexanedipalmitate at retention time 10.724 min.....	139
D12 Mass spectrum of 2-ethyl-1,3-hexanepalmitate oleate at retention time 12.125 min.....	140
C7 GC-chromatogram of diester obtained from oleic acid and 1,3-propanediol.....	141
D13 Mass spectrum of 1,3-propanedioleate at retention time 13.354 min.....	141
D8 GC-chromatogram of diester obtained from oleic acid and 1,4-butanediol.....	142
D14 Mass spectrum of 1,4-butanedioleate at retention time 15.382 min.....	142
C9 GC-chromatogram of diester obtained from oleic acid and 1,5-pentandiol.....	143
D15 Mass spectrum of 1,5-pentanedioleate at retention time 16.898 min.....	143
C10 GC-chromatogram of diester obtained from oleic acid and 2,2-dimethyl-1,3-propanediol.....	144



Figure	Page
D16 Mass spectrum of 2,2-dimethyl-1,3-propanedioleate at retention time 14.427 min.....	144
C11 GC-chromatogram of diester obtained form oleic acid and 2-ethyl-1,3-hexanediol.....	145
D17 Mass spectrum of 2-ethyl-1,3-hexanedioleate at retention time 16.731 min.....	145
C12 GC-chromatogram of diester obtained from stearic acid and 1,3-propanediol.....	146
D18 Mass spectrum of 1,3-propanedistearate at retention time 10.724 min.....	146
C13 GC-chromatogram of diester obtained from stearic acid and 1,4-butanediol.....	147
D19 Mass spectrum of 1,4-butanedistearate at retention time 11.467 min.....	147
C14 GC-chromatogram of diester obtained from stearic acid and 1,5-pentanediol.....	148
D20 Mass spectrum of 1,5-pentanedistearate at retention time 11.367 min.....	148
C15 GC-chromatogram of diester obtained from stearic acid and 2,2-dimethyl-1,3-propanediol.....	149
D21 Mass spectrum of 2,2-dimethyl-1,3-propanedistearate at retention time 11.116 min.....	149
C16 GC-chromatogram of diester obtained from stearic acid and 2-ethyl-1,3-hexanediol.....	150
D22 Mass spectrum of 2-ethyl-1,3-hexanedistearate at retention time 12.355 min.....	150

Figure	Page
C17 GC-chromatogram of diester obtained from palmitic acid and 1,3-propanediol.....	151
D23 Mass spectrum of 1,3-propanedipalmitate at retention 10.825 min.....	151
C18 GC-chromatogram of diester obtained from palmitic acid and 1,4-butanediol.....	152
D24 Mass spectrum of 1,4-butanedipalmitate at retention time 11.611 min.....	152
C19 GC-chromatogram of diester obtained from palmitic acid and 1,5-pentanediol.....	153
D25 Mass spectrum of 1,5-pentate dipalmitate at retention time 12.639 min .....	153
C20 GC-chromatogram of diester obtained from palmitic acid and 2,2-dimethyl-1,3-propanediol.....	154
D26 Mass spectrum of 2,2-dimethyl-1,3-propanedipalmitate at retention time 11.089 min .....	154
C21 GC-chromatogram of diester obtained from palmitic acid and 2-ethyl-1,3-hexanediol.....	155
D27 Mass spectrum of 2-ethyl-1,3-propanedipalmitate at retention time 12.597 min .....	155
E1 Thermogram of palm oil.....	156
E2 Thermogram of methyl ester of palm oil.....	156
E3 Thermogram of 1,3-propanediester of palm oil.....	157
E4 Thermogram of 1,4-butanediester of palm oil.....	157
E5 Thermogram of 1,5-pentanediester of palm oil.....	158
E6 Thermogram of 2,2-dimethyl-1,3-propanediester of palm oil.....	158
E7 Thermogram of 2-ethyl-1,3-hexanediester of palm oil.....	159

Figure	Page
E8 Thermogram of 1,3-propanediolate.....	159
E9 Thermogram of 1,4-butanediolate.....	160
E10 Thermogram of 1,5-pentandiolate.....	160
E11 Thermogram of 2,2-dimethyl-1,3-propanediolate.....	161
E12 Thermogram of 2-ethyl-1,3-hexandiolate.....	161
E13 Thermogram of 1,3-propanedistearate.....	162
E14 Thermogram of 1,4-butanadistearate.....	162
E15 Thermogram of 1,5-pentanedistearate.....	163
E16 Thermogram of 2,2-dimethyl-1,3-propanedistearate.....	163
E17 Thermogram of 2-ethyl-1,3-hexanedistearate.....	164
E18 Thermogram of 1,3-propanedipalmitate.....	164
E19 Thermogram of 1,4-butanadipalmitate.....	165
E20 Thermogram of 1,5-pentanedipalmitate.....	165
E21 Thermogram of 2,2-dimethyl-1,3-propanedipalmitate.....	166
E22 Thermogram of 2-ethyl-1,3-hexanedipalmitate.....	166
E23 Thermogram of lubricating base oil (150SN).....	167

ศูนย์วิทยทรัพยากร  
จุฬาลงกรณ์มหาวิทยาลัย

## ABBREVIATIONS

°C	=	degree Celsius
°F	=	degree Fahrenheit
VI	=	viscosity index
cSt	=	Centistoke unit
%wt	=	percent by weight
ml	=	millilitre
g	=	gram
sp.gr.	=	specific gravity
TGA	=	Thermogravimetry analyzer
ppm	=	part per million
cm <sup>-1</sup>	=	Wavenumber
SHF	=	synthesized hydrocarbon fluids
PAHs	=	polyaromatic hydrocarbons
PAOs	=	polyalphaolefins

ศูนย์วิทยทรัพยากร  
จุฬาลงกรณ์มหาวิทยาลัย