REFERENCES

1. Mortier, R.M. and Orszulik, S.T. **Chemistry and Technology of Lubricants.** UK : Blackie Academic & Professional, Glasgow, (1993).
2. Wills, J.G. **Lubrication Fundamental.** New York : Marcel Dekka Inc., (1980).
3. Asseff, P.A. **Lubrication Theory and Practice.** Ohio : The Lubrizol Co.,Press, (1984).
4. Piggott, L.F. **Synthetic Lubricants.** Singapore : Technical Training, Castrol International Training.
5. Gunderson, R.C. and Hart, A.W. **Synthetic Lubricants.** London : Rienhold Publishing Corporation, (1962), p.93-101.
6. Bartz, W.J. "Comparison of Synthetic Fluids" **Lub. Eng.**, Vol. 48, (1992), p.765-774.
7. Mcketta, J.J. **Encyclopedia of Chemical Processing and Design.** Vol. 28, New York : Marcel Dekka Inc., (1988).
8. Hobson, G.D. **Modern Petroleum Technology.** 5th ed., London : John Wiley & Sons, part 1-2, (1984).
9. Lao, D.A., Lohuis, J.R., Breau, J.Y. and Harlow, A.J. " Development and Performance Advantages of Industrial, Automotive and Aviation Synthetic Lubricants" **J. Syn. Lub.**, Vol. 1, 1, (1984), p.6-32.
10. Williamson, E.I. "Commercial Developments in Synthetic Lubricants" **J. Syn. Lub.**, Vol. 2, 4, (1986), p.330-332.

11. Neadle, D.J. "Synthetic Lubricants for Turbocharged Passenger Cars" **J. Syn. Lub.**, Vol. 2, 4, (1986), p.311-327.

12. Southcombe, J.E. **Lubricating Oil Test and Their Significants.** 4th ed., London : Germ Lubricant Limited, (1935).

13. ASTM D 1500 "Standard Test Method for ASTM Color of Petroleum Products" **American Society for Testing & Material.** Vol. 05.01, (1999), p.526-530.

14. ASTM D 445 "Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids" **American Society for Testing & Material.** Vol. 05.01, (1999), p.169-176.

15. ASTM D 2270 "Standard Practice for Calculating Viscosity Index from Kinematic Viscosity at 40 and 100°C" **American Society for Testing & Material.** Vol. 05.01, (1999), p.745-750.

16. ASTM D 97 "Standard Test Method for Pour Point of Petroleum Products" **American Society for Testing & Material.** Vol. 05.01, (1999), p.73-80.

17. ASTM D 92 "Standard Test Method for Flash and Fire Points by Cleveland Open Cup" **American Society for Testing & Material.** Vol. 05.01, (1999), p.33-39.

18. Aboul, E.I., Naga, H.H. and Salem, A.E.M. "Base Oil Thermooxidation" **Lub. Eng.** Vol. 42, 4, (1986), p.210-217.

19. Swern, D. **Barley's Industrial Oil and Fat Products,** 4th ed., London : John Wiley & Sons, (1971).

20. Madhusudhana Rao, A., Srivastava, S.P. and Mehta, K.C. "Synthetic Lubricants in India" **J. Syn. Lub.**, Vol. 4, 2, (1987), p.137-145.

21. Phatanaphakdee, K. "Synthesis of Lubricating Base Oils from Palm Oil" **Master Thesis.** Multidisciplinary Program of Petrochemistry and Polymer Science, Chulalongkorn University, (1995).

22. Suwanprasert, T. "Synthesis Lubricant from Soybean Oil" **Master Thesis.** Multidisciplinary Program of Petrochemistry and Polymer Science, Chulalongkorn University, (1996).

23. Tungwongcharoen, S. "Synthesis of Lubricating Oil from Castor Oil" **Master Thesis.** Multidisciplinary Program of Petrochemistry and Polymer Science, Chulalongkorn University, (1994).

24. Wattanapute, N. "Synthesis of Lubricating Oil from Coconut Oil" **Master Thesis.** Multidisciplinary Program of Petrochemistry and Polymer Science, Chulalongkorn University, (1996).

25. Furniss, B.S., Hannaford, A.J., Rogers, V., Smith, P.W.G. and Tatchell, A.R. **Textbook of Practical Organic Chemistry.** 4th ed. English Language Book Society, (1993).

APPENDICES

APPENDIX I

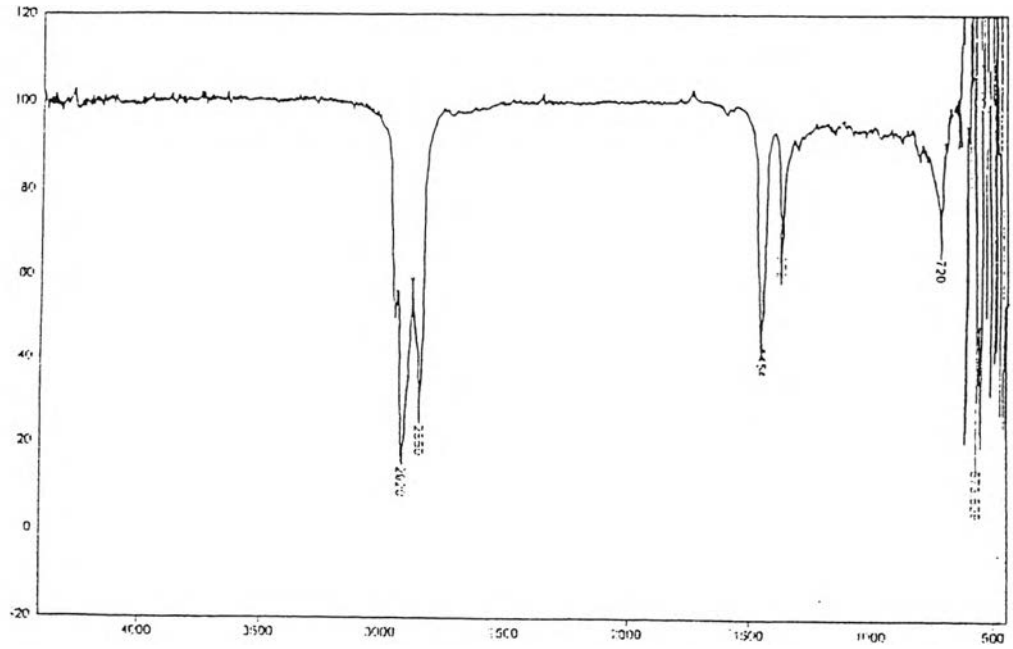

Fig. A-1 FTIR Spectrum of 60 SN

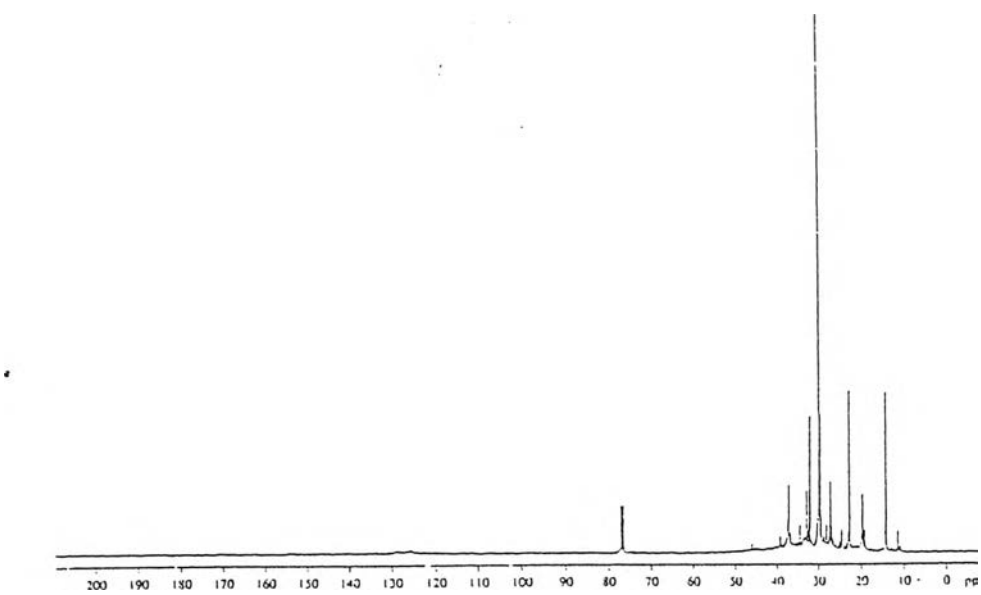

Fig. A-2 C^{13} NMR Spectrum of 60 SN

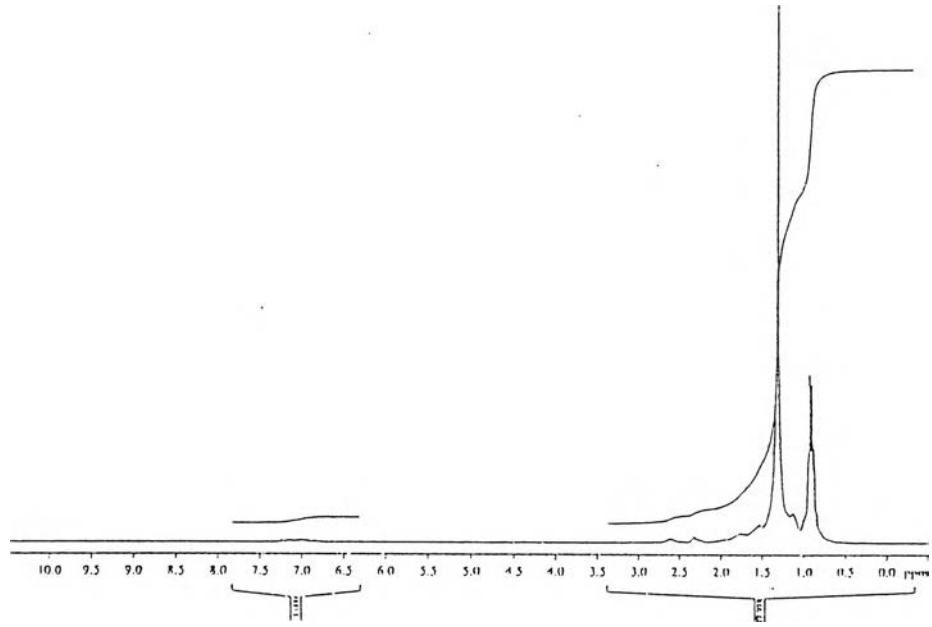

Fig. A-3 H^1 NMR Spectrum of 60 SN

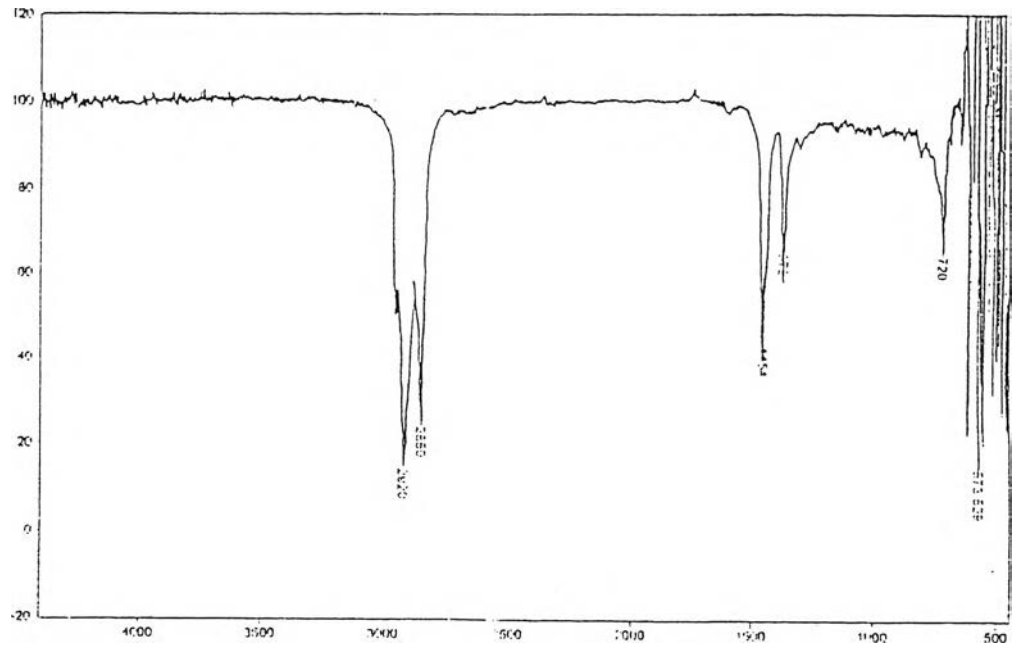

Fig. A-4 FTIR Spectrum of 150 SN

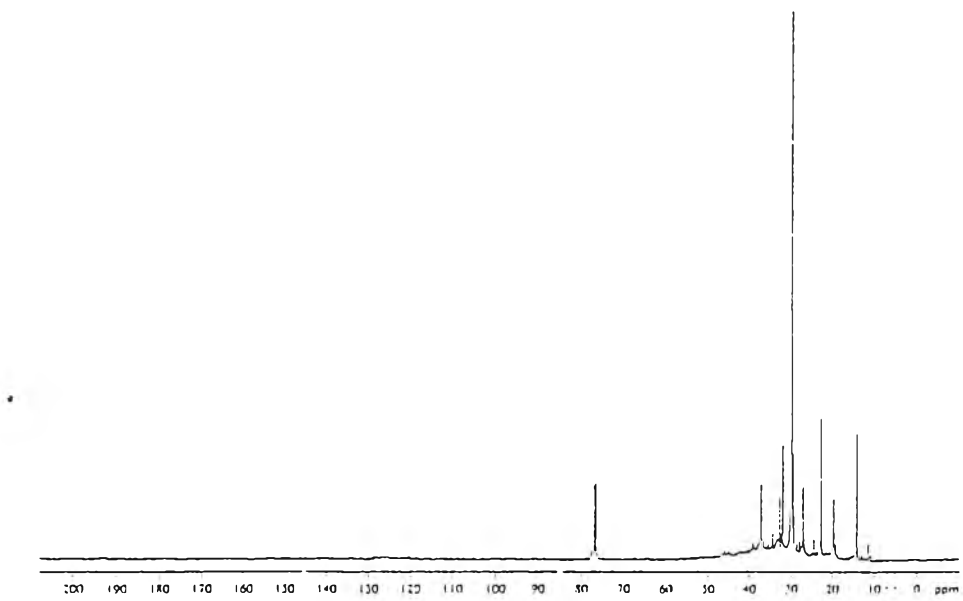

Fig. A-5 C^{13} NMR Spectrum of 150 SN

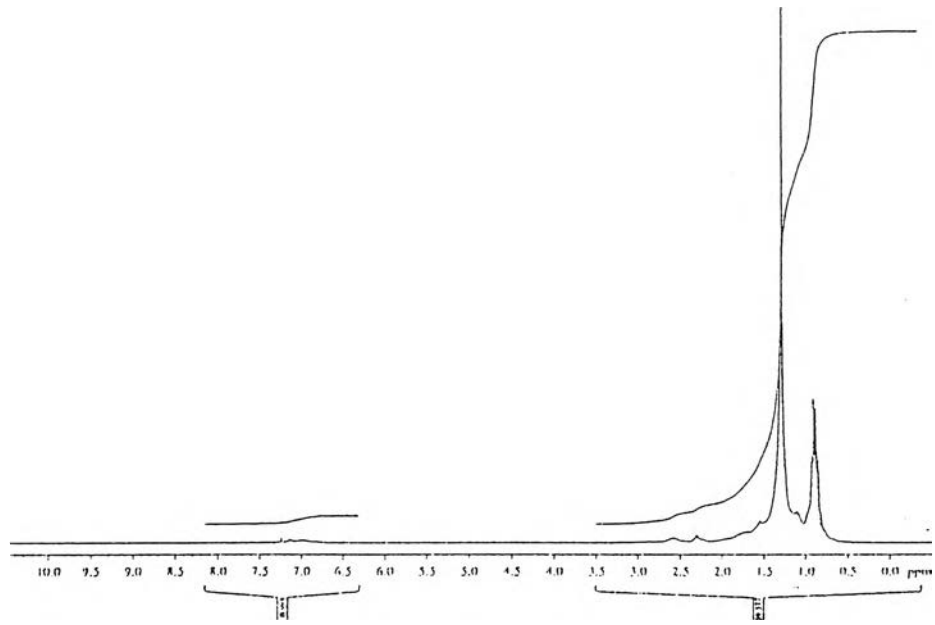

Fig. A-6 H^1 NMR Spectrum of 150 SN

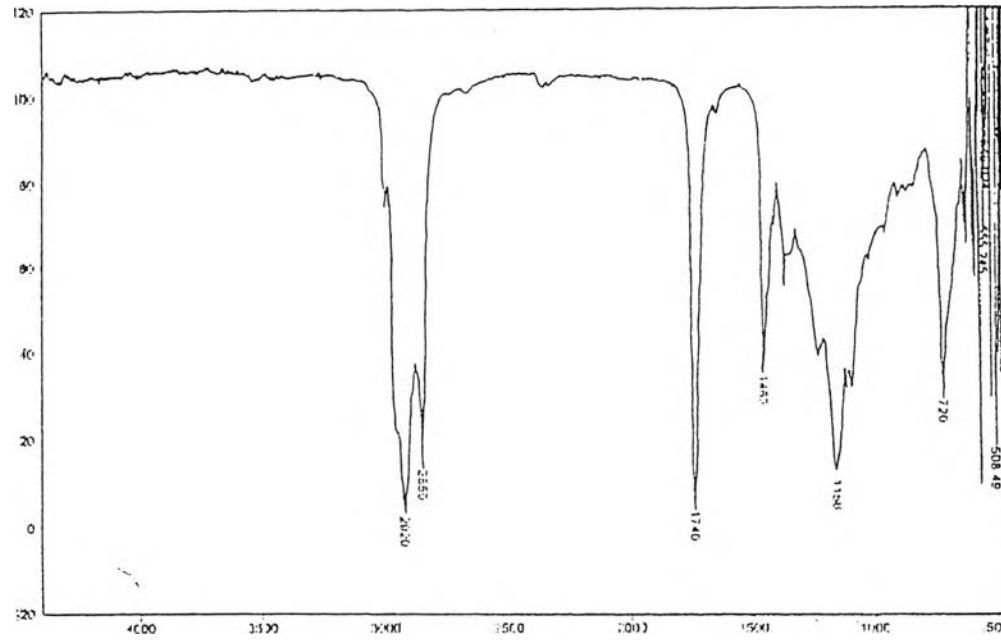

Fig. A-7 FTIR Spectrum of rice bran oil

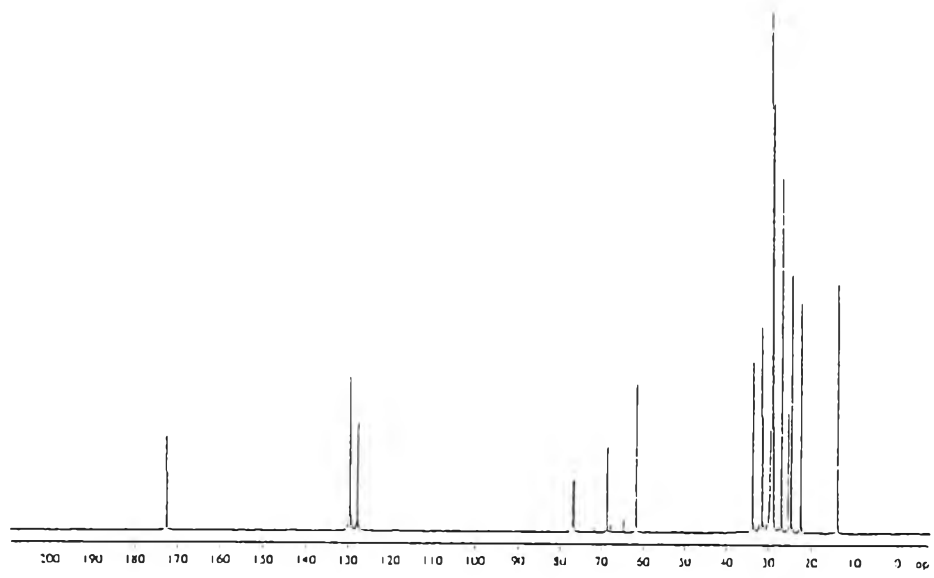

Fig. A-8 C^{13} NMR Spectrum of rice bran oil

Fig. A-9 H^1 NMR Spectrum of rice bran oil

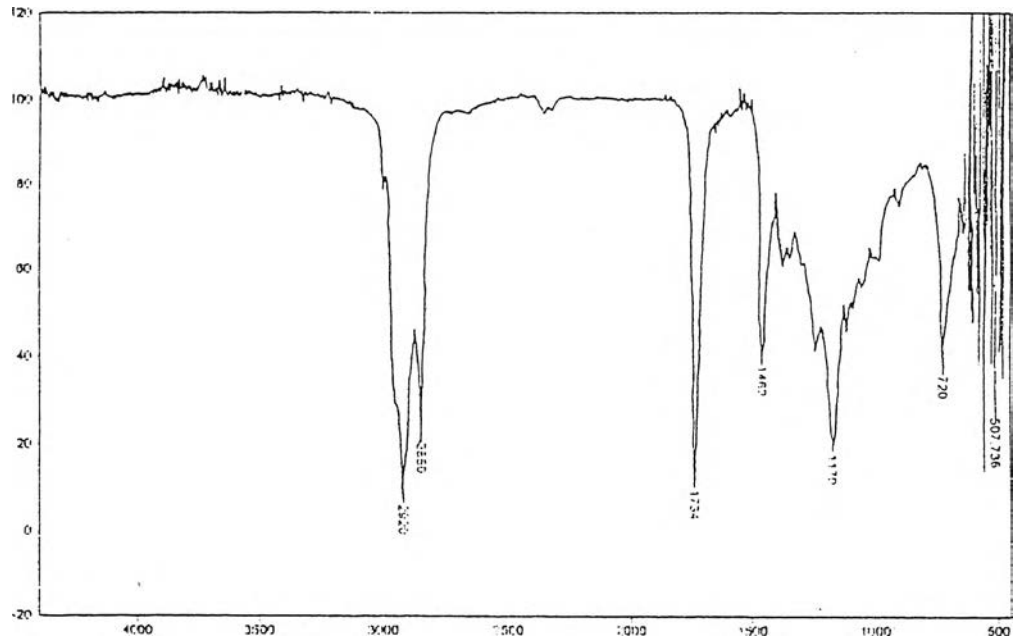

Fig. A-10 FTIR Spectrum of butyl ester

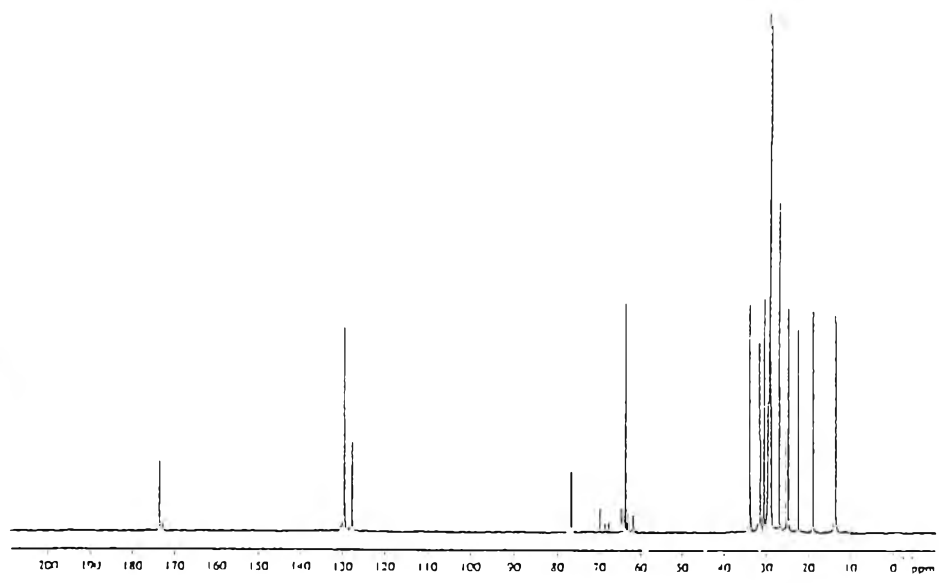

Fig. A-11 C^{13} NMR Spectrum of butyl ester

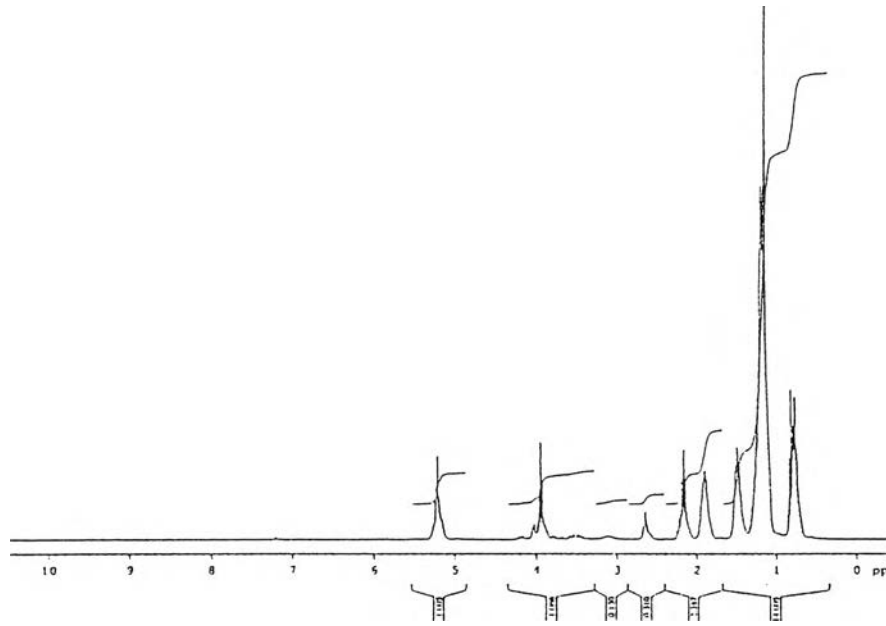

Fig. A-12 H^1 NMR Spectrum of butyl ester

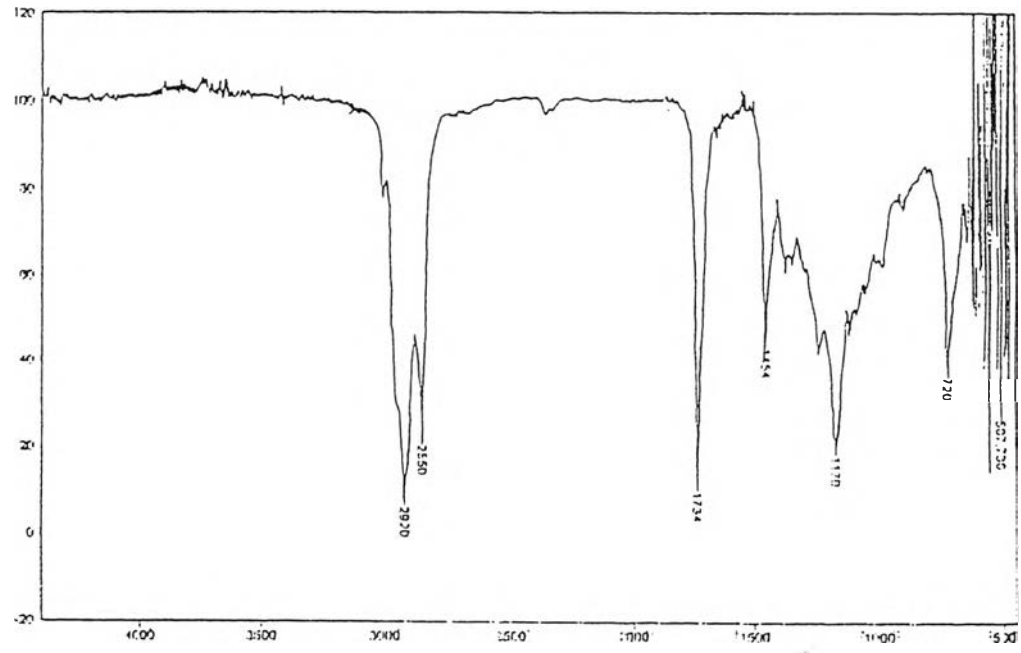

Fig. A-13 FTIR Spectrum of hexyl ester

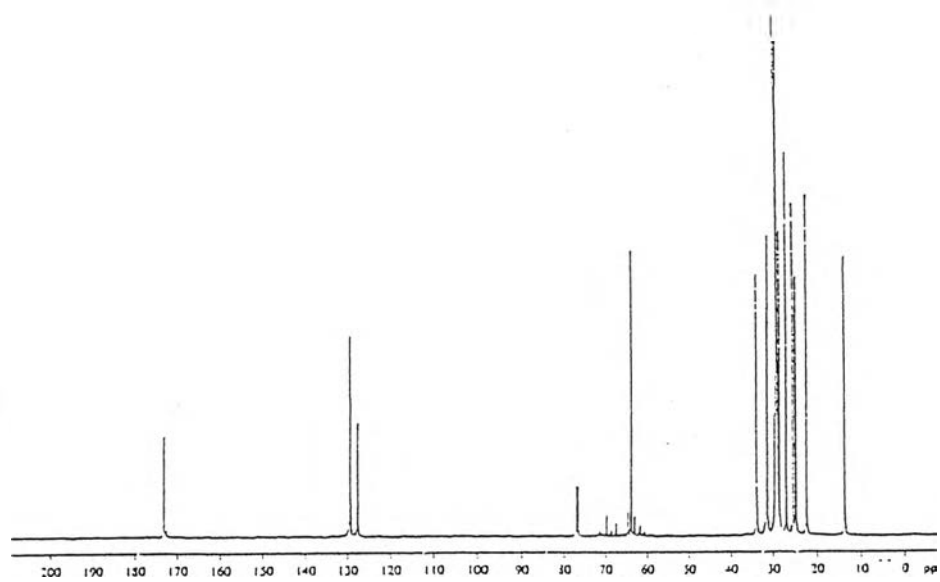

Fig. A-14 C^{13} NMR Spectrum of hexyl ester

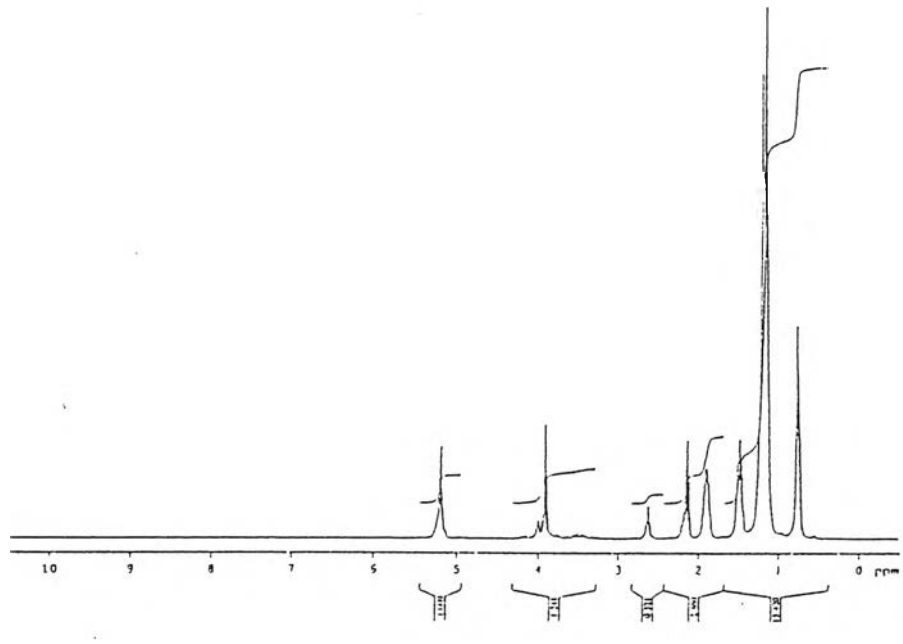

Fig. A-15 H^1 NMR Spectrum of hexyl ester

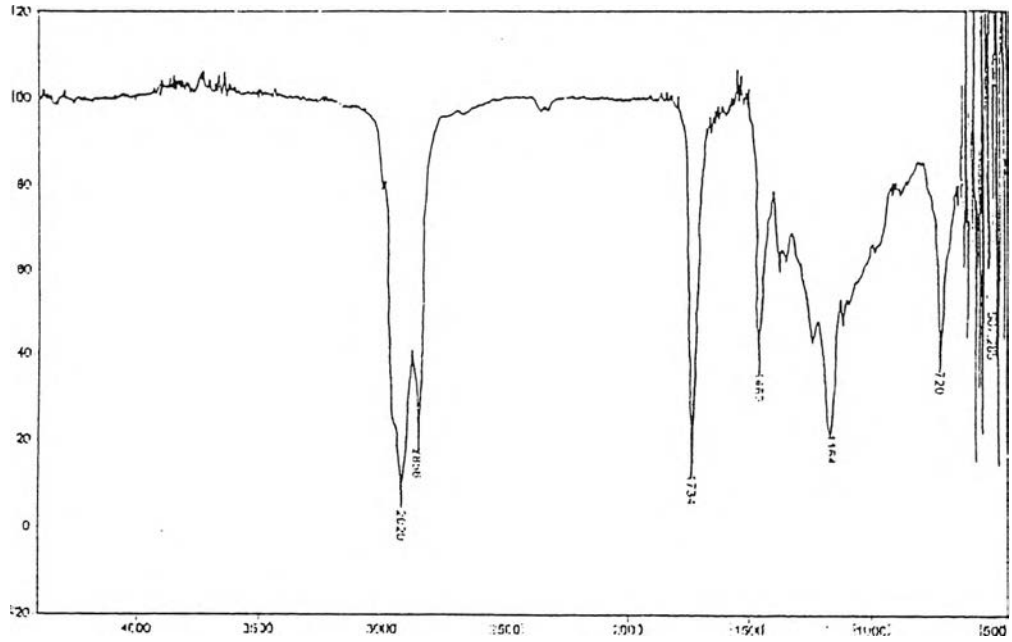

Fig. A-16 FTIR Spectrum of octyl ester

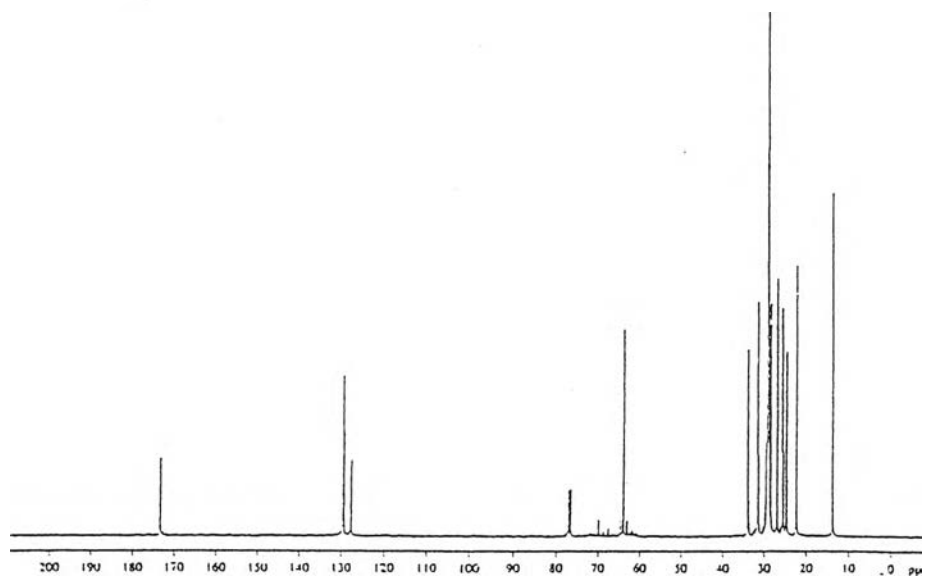

Fig. A-17 C^{13} NMR Spectrum of octyl ester

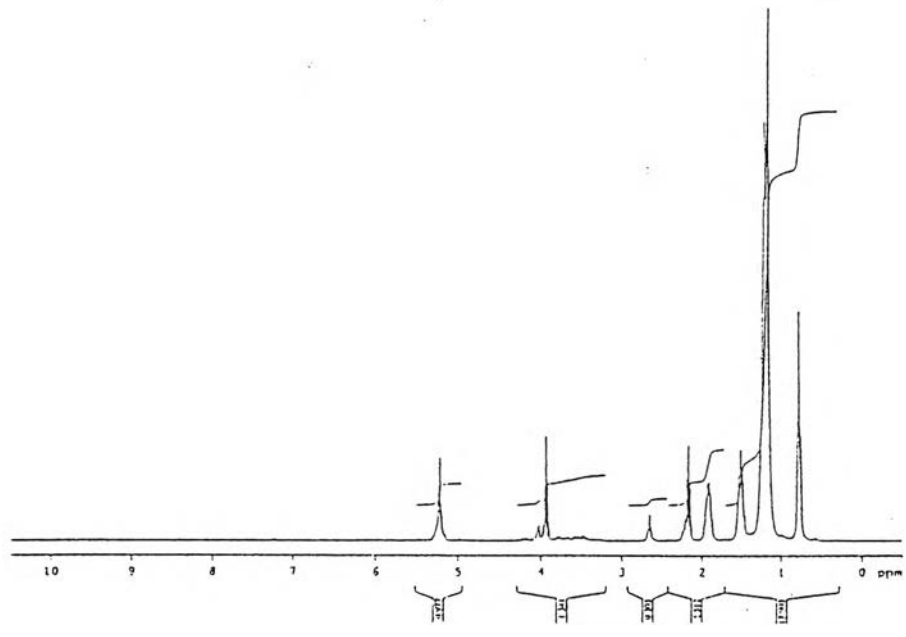

Fig. A-18 H^1 NMR Spectrum of octyl ester

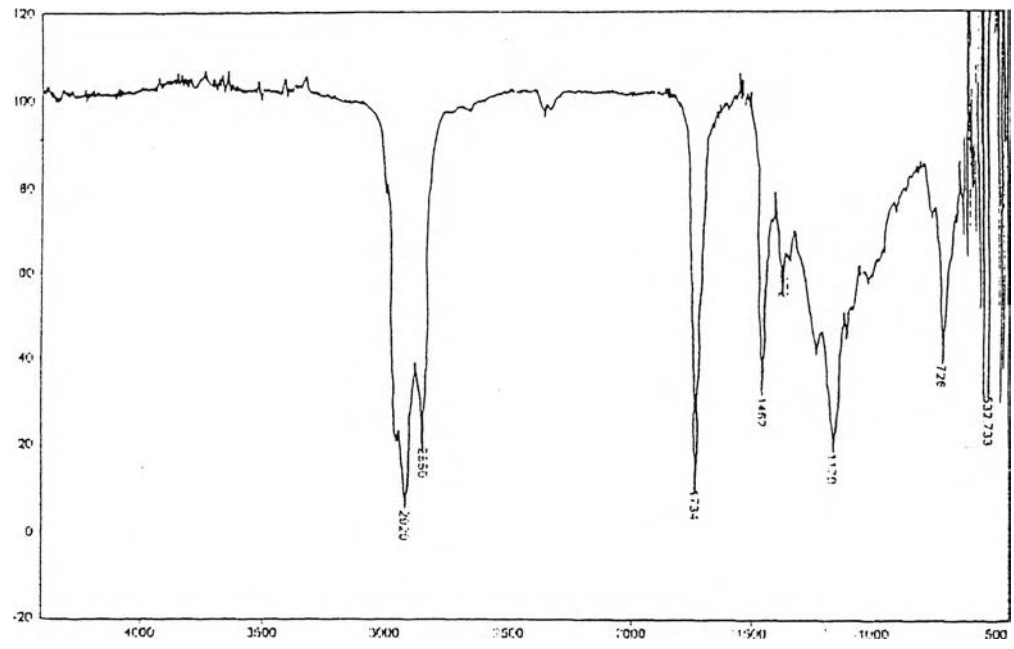

Fig. A-19 FTIR Spectrum of 2-ethyl-1-hexyl ester

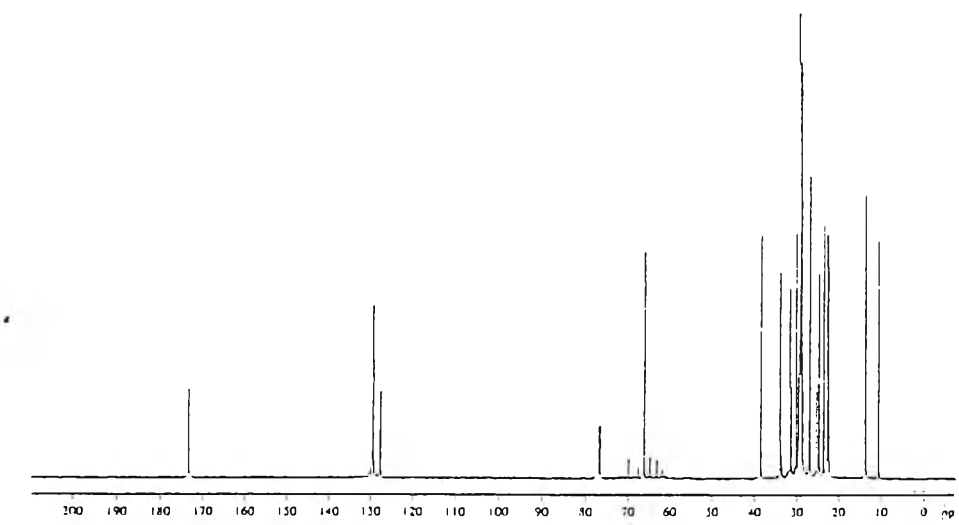

Fig. A-20 C^{13} NMR Spectrum of 2-ethyl-1-hexyl ester

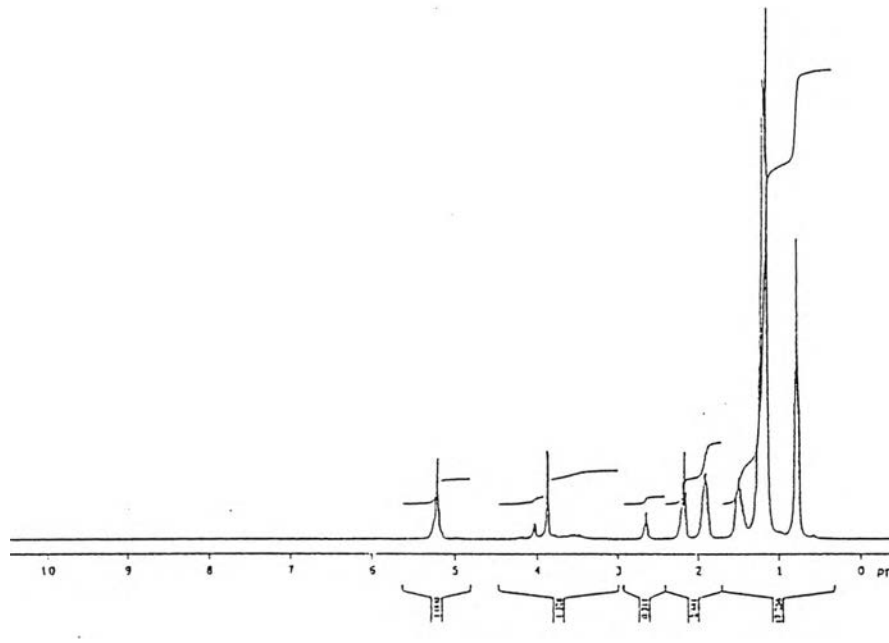

Fig. A-21 H^1 NMR Spectrum of 2-ethyl-1-hexyl ester

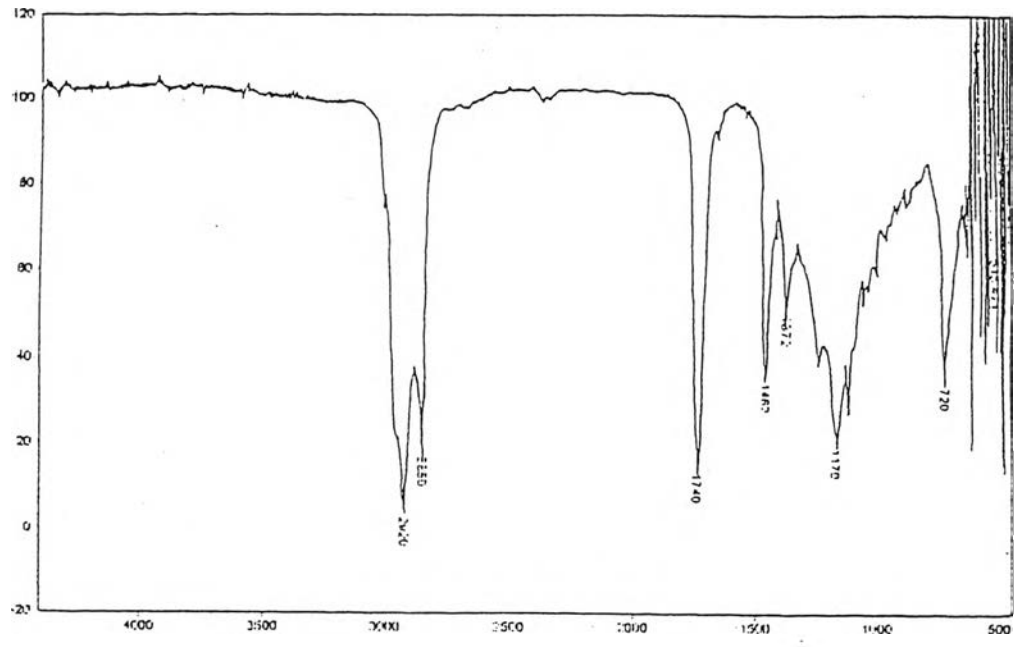

Fig. A-22 FTIR Spectrum of 4-methyl-2-pentyl ester

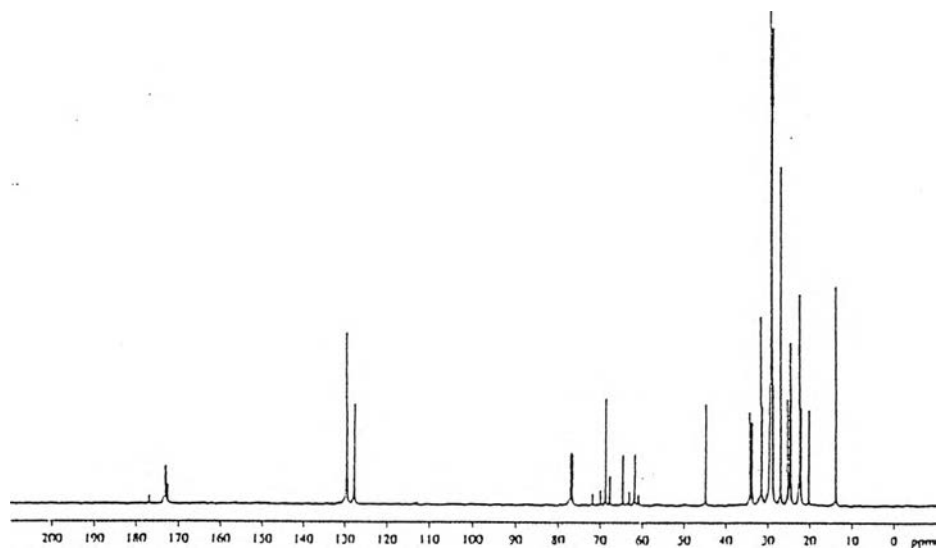

Fig. A-23 C^{13} NMR Spectrum of 4-methyl-2-pentyl ester

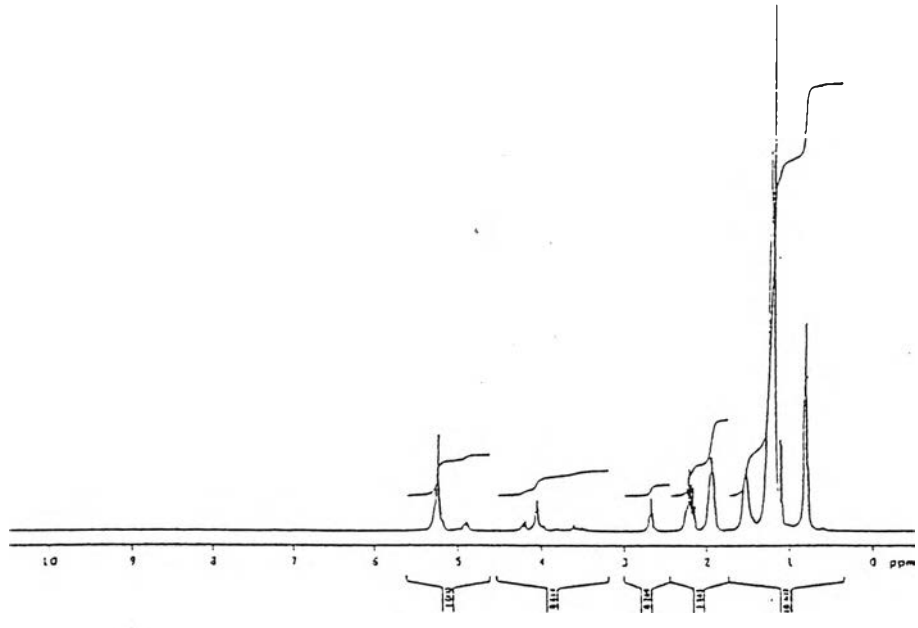

Fig. A-24 H^1 NMR Spectrum of 4-methyl-2-pentyl ester

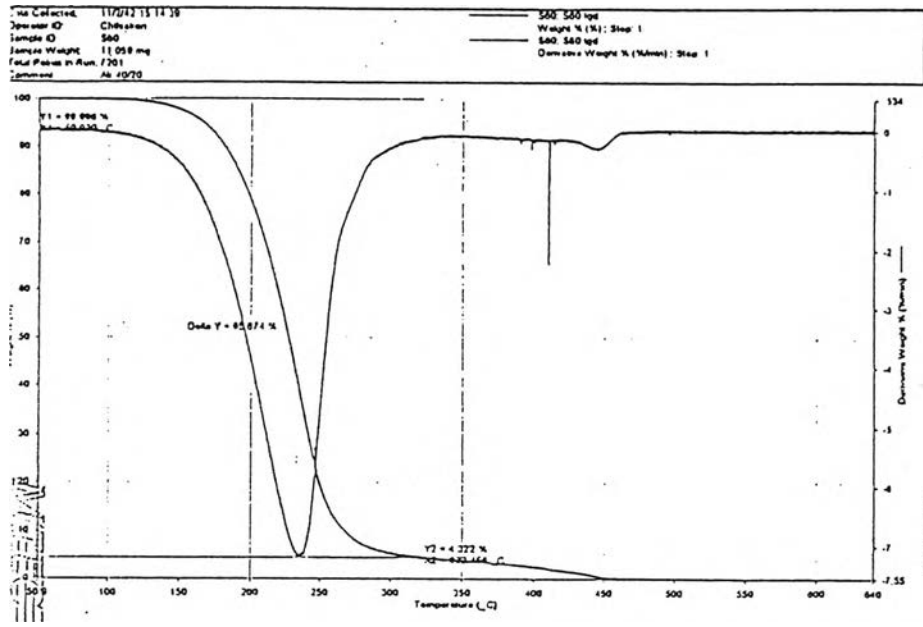

Fig. A-25 TGA Thermogram of Base oil (60 SN)

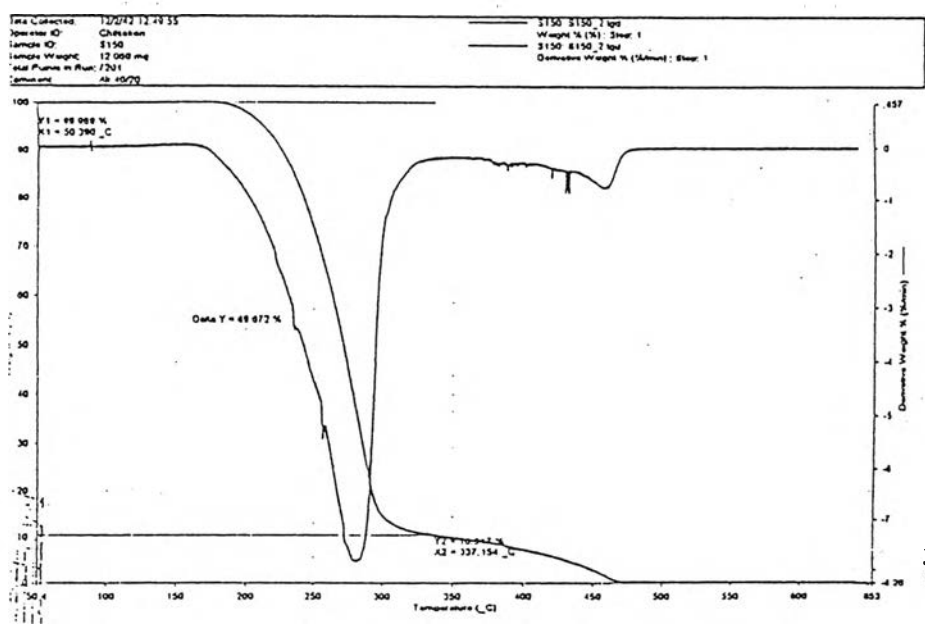

Fig. A-26 TGA Thermogram of Base oil (150 SN)

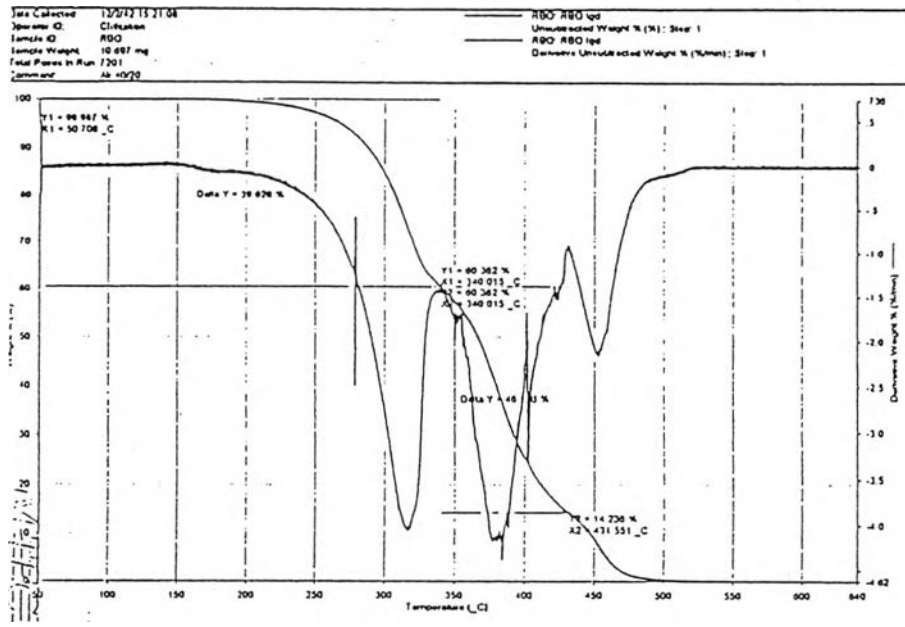

Fig. A-27 TGA Thermogram of Rice Bran oil

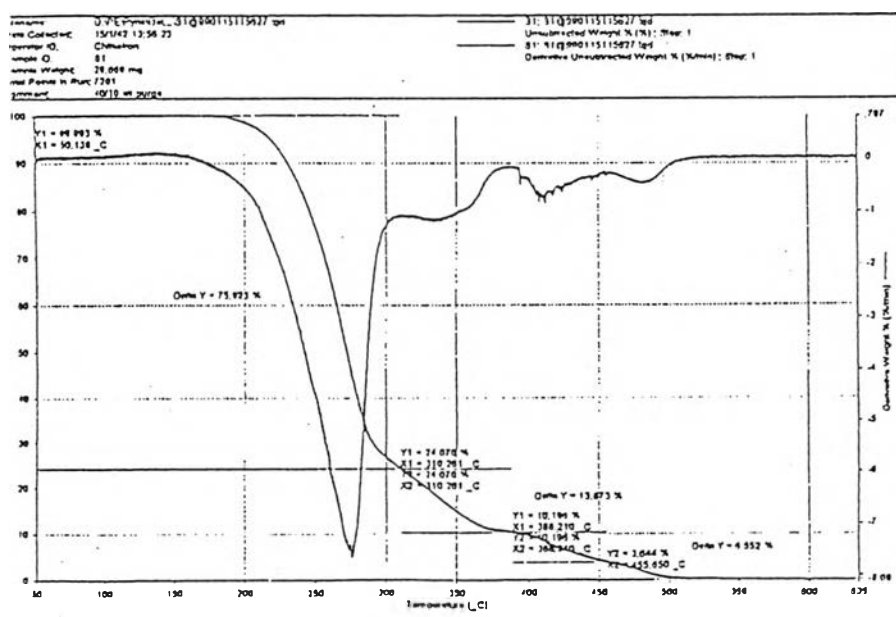

Fig. A-28 TGA Thermogram of Butyl ester

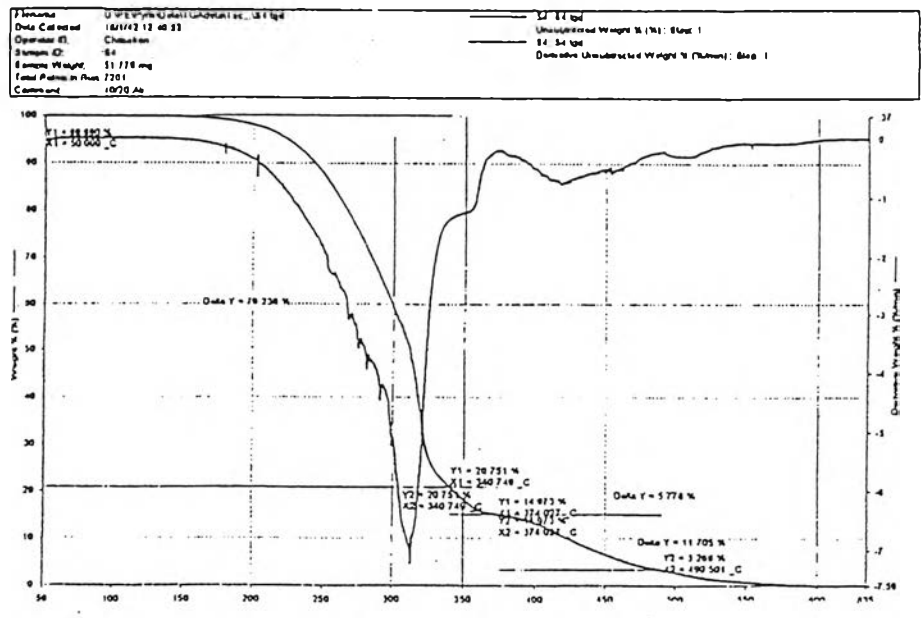

Fig. A-29 TGA Thermogram of Hexyl ester

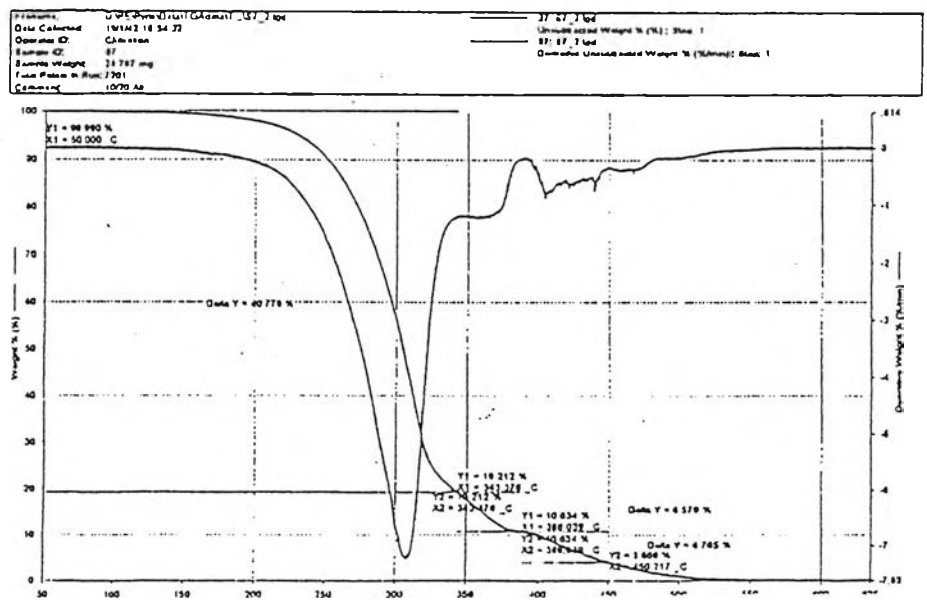

Fig. A-30 TGA Thermogram of Octyl ester

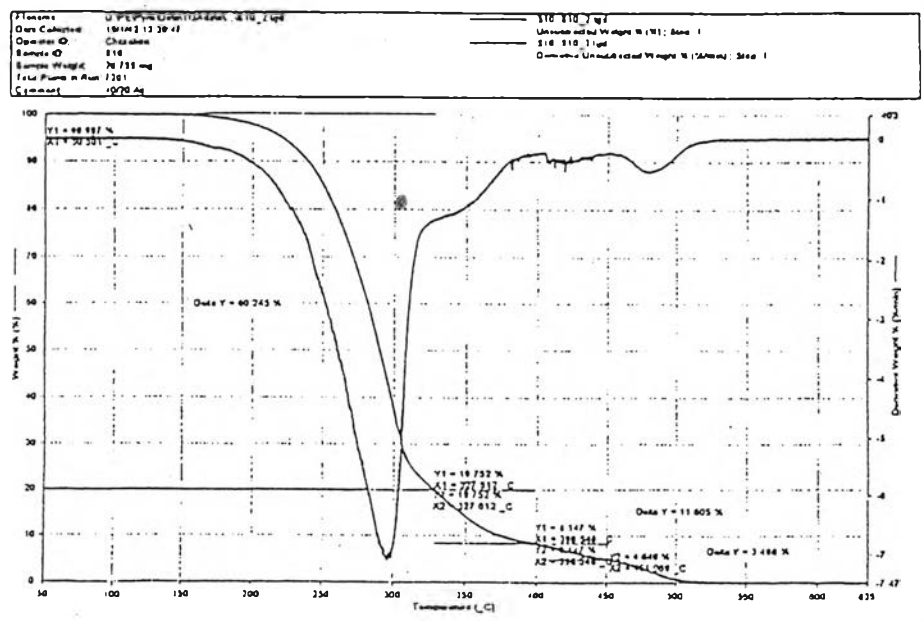

Fig. A-31 TGA Thermogram of 2-Ethyl-1-hexyl ester

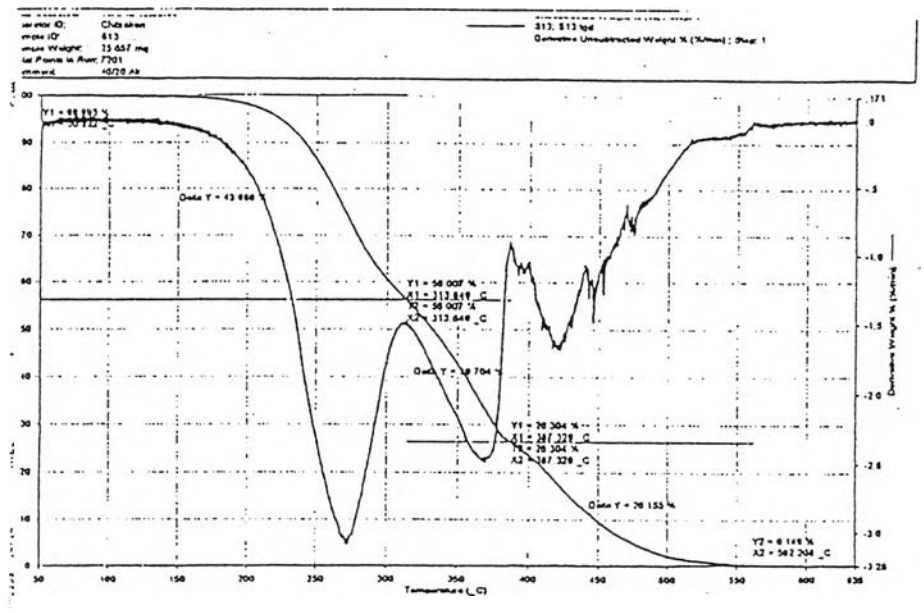

Fig. A-32 TGA Thermogram of 4-Methyl-2-pentyl ester

APPENDIX II

% Fatty acid composition of vegetable oils

Type of Fatty acid	*Sunflower oil*	*Castor oil*	*Coconut oil*	*Palm oil*	*Rice bran oil*	*Soybean oil*
Palmitic	3-6	2	8-11	32-45	12-18	7-11
Stearic	1-3	1	1-3	2-7	1-3	2-6
Myristic	-	-	13-19	0.5-6	0.4-1	trace-0.5
Oleic	14-43	trace-7	5-8	38-52	40-50	15-33
Linoleic	44-75	3-5	trace-2.5	5-11	29-42	43-56
Ricinoleic	-	85-95	-	-	-	-
Hexadecanoic	-	-	-	0.8-1.8	-	-
Linolenic	-	-	-	-	trace-1	5-11
Palmitoleic	-	-	0-1	-	0.2-0.4	-
C_{20}-C_{22} saturated	-	-	-	-	1	-
Lauric	-	-	44-52	-	-	-
Capric	-	-	6-10	-	-	-
Caprylic	-	-	5-9	-	-	-

APPENDIX III

Structure and Molecular weight of Fatty acid

	Structure	MW.
Palmitic acid	$C_{16}H_{32}O_2$	256
Stearic acid	$C_{18}H_{36}O_2$	284
Myristic acid	$C_{14}H_{28}O_2$	228
Oleic acid	$C_{18}H_{34}O_2$	282
Linoleic acid	$C_{18}H_{32}O_2$	280
Ricinoleic acid	$C_{14}H_{26}O_3$	242
Linolenic acid	$C_{18}H_{30}O_2$	278
Palmitoleic acid	$C_{16}H_{30}O_2$	254
Lauric acid	$C_{12}H_{24}O_2$	200
Capric acid	$C_{10}H_{20}O_2$	172
C_{20}-C_{22} Saturated		

APPENDIX IV

Synthetic Base Fluid Specification

CASTROL INTERNATIONAL RAW MATERIALS SPECIFICATION (CIRMS)

BRAND	SUPPLIER	APPROVED
Emkarate 1090	ICI (CHEMICALS & POLYMERS)	
Emkarate 1090X	ICI (CHEMICALS & POLYMERS)	

AMENDMENT No: 5	DATE: 07/09/94	AUTHORISED: Charles Devroey. Technical Support (Europe). Automotive.

FUNCTION :	Base fluid - synthetic ester. Prime use in automotive gear oils.
CHEMISTRY :	Common: Di-isodecyl adipate. Per CAS: Hexanedioic acid, diisodecyl ester. Formula: C26 H50 O4.
C.A.S. NO(s)/ INVENTORY :	For "1090" only: TSCA EINECS AICS (Australia) CEPA (Canada) MITI (Japan)
CHEMSTOCK :	March 1989 (by Automotive). Superseded by amendment 004.
DESCRIPTION :	

TESTS AND INFORMATION:

DESCRIPTION	METHODS	MINIMUM	MAXIMUM	TYPICAL	UNITS	FREQUENCY/USE
The levels below (excepting Noack and Hydroxyl) are as per an ICI Selling Spec of 16-Aug-93 for the "1090X" version:						
Appearance	BAM 300	Clear liquid, substantially free from suspended matter.		-	-	Each Deliver
Density at 20°C	IP 160 / ASTM D 1298	0.915	0.925	-	g/ml	Each Deliver
Viscosity at 100°C	IP 71 / ASTM D 445	3.5	3.8	-	cSt	Each Deliver
Viscosity at 40°C	IP 71 / ASTM D 445	13.5	15.0	-	cSt	Each Deliver
Viscosity Index	IP 226 / ASTM D 2270	-	-	145	-	Each Deliver
Flash Point - COC	IP 34 / ASTM D 93	210	-	-	°C	Each Deliver
Pour Point	IP 15 / ASTM D 97	-	minus 60	-	°C	Each Deliver
Acid Value	IP 139 / ASTM D 974 : IP 1-A	-	0.10	-	mgKOH/g	Each Deliver
Noack Volatility	DIN 51581 / CEC L-40-T-87	-	-	18	% wt loss	Type Approve
Water content	(K.F) ASTM D 1744	-	0.10	-	% wt	Type Approve
IR trace	- labs equipped to run this test may wish to take a Master trace from a delivery which has given satisfactory products, and use this Master to check future deliveries.					
Colour - Hazen	ISO 2211	-	30	-	-	Information
Free Alcohol	C&P/AC/11/4 (per supplier)	-	0.10	-	% wt	Information
Hydroxyl Groups	ASTM E 326	-	1.0	-	mgKOH/g	Information

CASTROL INTERNATIONAL RAW MATERIALS SPECIFICATION (CIRMS)

BRAND	SUPPLIER	APPROVED
Emery 2934	HENKEL (EMERY DIVISION)	

AMENDMENT No: 3	DATE: 31/03/93	AUTHORISED: Jan Trocki. Technical Support. Automotive. Pangbourne.

FUNCTION :	Base fluid, synthetic ester type.
CHEMISTRY :	Common "TMP - C9" or trimethylolpropane tripelargonate. Per CAS. Nonanoic acid, 2-ethyl-2-{[(1-oxononyl)oxy]methyl}-1,3-propanediyl ester. Formula: C33 H62 O6
C.A.S. NO(s)/ INVENTORY :	126 - 57 - 8
CHEMSTOCK :	Approved: Oct-90 (by Auto). SUPERSEDED BY THIS AMEND.
DESCRIPTION :	

TESTS AND INFORMATION DESCRIPTION	METHODS	MINIMUM	MAXIMUM	TYPICAL	UNITS	FREQUENCY/USE
Appearance	BAM 300 (visual)	Clear, water-white liquid.			-	Each Deliver
Colour - ASTM	IP 196 / ASTM D 1500	-	0.5	-	-	-
Viscosity at 100°C	IP 71 / ASTM D 445	4.4	4.7	-	cSt	-
Viscosity Index	IP 226 / ASTM D 2270	135	-	-	-	-
Flash Point - COC	IP 36 / ASTM D 92	248	-	255	°C	-
TAN (Total Acid Number)	IP 1-A : ASTM D 974	-	0.05	-	mgKOH/g	-
Water content	(K.F) ASTM D 1744	-	500l	-	mg/kg	-
IR trace	Compare to standard	Reasonable agreement			-	-
Density at 20°C	IP 160 / ASTM D 1298	-	-	0.945	g/ml	Information
Viscosity at 40°C	IP 71 / ASTM D 445	20.0	-	-	cSt	-
Noack Volatility	DIN 51581 / CEC L-40-T-87		3.0	-	% wt loss	-

CASTROL INTERNATIONAL RAW MATERIALS SPECIFICATION (CIRMS)

BRAND	SUPPLIER	APPROVED
Hatcol 2910	HATCO CORP.	23/04/91

AMENDMENT No: 0	DATE: 25/06/91	AUTHORISED: Dave Wellum. Aviation. Industrial. Pangbourne.

FUNCTION :	Diester base stock for industrial gas turbine lubricant (Castrol 3000).
CHEMISTRY :	Diiso dioctyl adipate / diiso decyl adipate.
C.A.S. NO(s)/ INVENTORY :	
CHEMSTOCK :	Pending.
DESCRIPTION :	

TESTS AND INFORMATION:

DESCRIPTION	METHODS	MINIMUM	MAXIMUM	TYPICAL	UNITS	FREQUENCY/USE
Appearance	BAM 300	Colourless, mobile liquid. To be clear, bright and sediment free.				Each delivery
Viscosity at 100°C	IP 71 / ASTM D 445	3.5 and within 3% of Hatco result. *	3.7	-	cSt	"
Water content	(K.F.) ASTM D 1744	- and within 10% of Hatco result *	0.050	-	% wt	"
GLC trace	GLC (to be agreed with Hatco)	Similar to standard		-		"

* A copy of the Certificate of Analysis to be sent by Hatco with each delivery, and on request to Pangbourne.

In addition to the above checks, Castrol labs should make occasional random checks on the purchase specification below:

Density at 15°C	IP 160 / ASTM D 1298	0.917	0.925	-	g/ml	See above
Viscosity at 40°C	IP 71 / ASTM D 445	13	15	-	cSt	"
Flash Point - COC	IP 36 / ASTM D 92	216	-	-	°C	"
Pour Point	IP 15 / ASTM D 97	-	minus 57	-	°C	"
Total Acid Number	IP 177 / ASTM D 664	-	0.05	-	mgKOH/g	"

APPENDIX V

ABBREVIATIONS

K.V.	=	Kinematic Viscosity
KVI	=	Kinematic Viscosity Index
°C	=	Degree celcius
cSt.	=	Centistokes
COC	=	Cleveland Open Cup
ASTM	=	American Society for Testing & Material
ppm.	=	parts per million
Hrs.	=	Hours
PMCC	=	Pensky-Marten Close Cup
NMR	=	Nuclear Magnetic Resonance
Temp.	=	Temperature
TGA	=	Thermogravimetric Analyzer

VITA

Mr. KACHANE EIAMSUPASAWAT was born on April 7, 1970 in Bangkok. He received his Bachelor's degree of science in Chemistry from Faculty of Science, Kasetsart University in 1993. He is working in Quality Control Department, Castrol (Thailand) Limited.

He is pursuing a Master's Degree in Petrochemistry and Polymer Science, Graduate School, Chulalongkorn University in 1997 and completes the programme in 1999.