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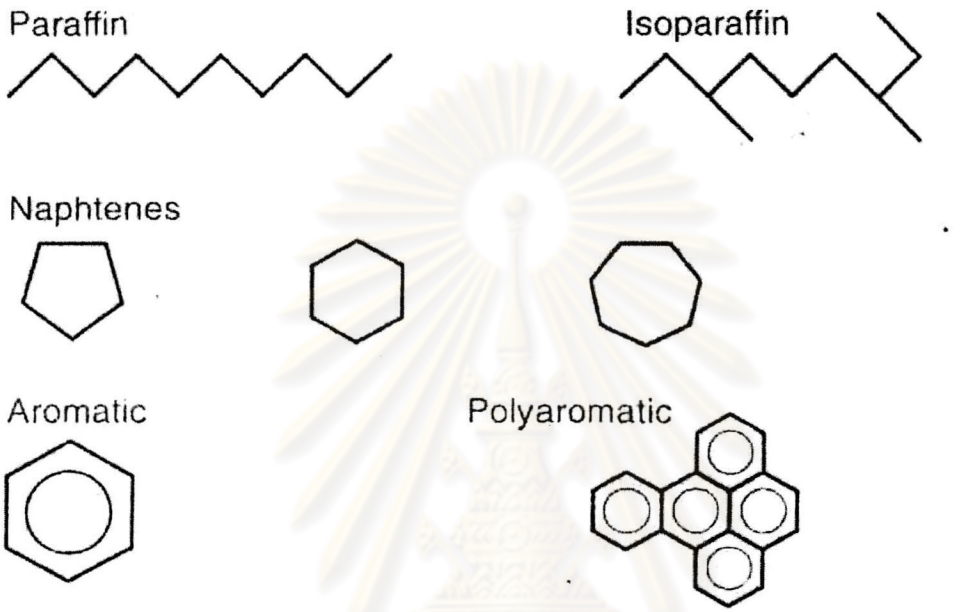
APPENDICES

APPENDIX 1 The basic structure of a mineral oil

The basic hydrocarbon structures in a mineral oil are paraffins, naphthenes, aromates and polyaromates.



Hydrocarbon structures in a mineral oil.

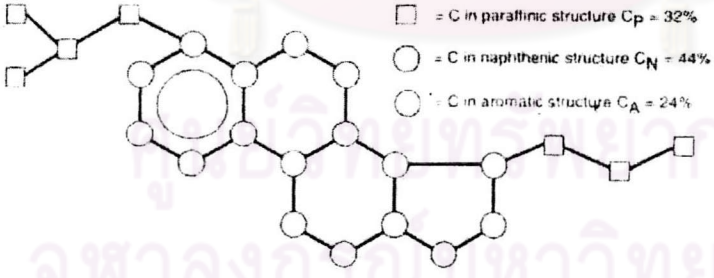
Paraffinic structures can either be straight or branched chains. Waxes are straight type N-alkanes. At cloud point, the waxes begin to crystallize, which leads to a two-phase system. Oils which are used in cold climates, must have the wax content reduced.

Paraffinic structures provide inferior solubility of water and oxidation products, which may lead to precipitated sludge in the oil system. The advantage with paraffinic oils however is their high viscosity index.

Naphthenic structures are also called cycloalkanes. They have excellent low temperature properties and better solubility than N-alkanes. The ring structure can have five, six or seven carbons-six being the predominant number.

Aromatic molecules are ring structures with alternating double bonds. They are totally different from paraffinic and naphthenic molecules, chemically and physically. Nearly all the sulphur and nitrogen in an oil are present in its aromatic structures. Aromates can be present both as monoaromates and polyaromates. Polyaromates have several aromatic rings directly adjacent to each other.

A typical "oil molecule" is illustrated in fig.2. One way of characterizing oils is by carbon-type analysis, of which there are several methods. One of these measures the amount of carbons bonded to aromatic or paraffinc structures by using an IR (infra-red) technique.



An "oil molecule"

APPENDIX 2

Greases, Characteristics, and Usage

Type	Characteristics/Strengths	Weaknesses	Usage
	Simple Soaps		
Aluminum	Smooth, gel-like appearance Good Water Resistance	Low Dropping point Poor low temp pump ability Poor shear stability Softening/hardening tendencies greatly dependent On shear rate	Lubricate low-speed bearings Wet applications Possible USDA H-1 products Usage decreasing
Barium	Good heat resistance Good water resistance Avg. shear stability Fibrous texture	Poor low temp pump ability	Usage decreasing Possible environmental concerns
Calcium-Anhydrous	Smooth, buttery appearance Excellent water resistance Good water resistance Good shear stability. Good low temperature properties Less energy is required for manufacturing. Can be used for USDA H-1, approved grease.	280°F to 310°F Dropping point Not appropriate for high temperature applications. Low Cost	Bearings in wet applications Railroad Rail lubricant
Calcium-Water-stabilized	Smooth, buttery appearance Moderate water resistance Good pump ability Low Cost	200°F Dropping Point Not for high temperature applications Poor storage stability Poor Oxidation Resistance	Bearings in wet applications Railroad Rail lubricant Launching Grease

Type	Characteristics/Strengths	Weaknesses	Usage
	Simple Soaps		
Lithium	Smooth, buttery to slightly stringy appearance Dropping Point 350°F to 400°F Good storage characteristics Good water resistance Good shear stability Low oil separation Good oxidation resistance Good flow properties at low temperature.	Very high temperature application limited Additives are needed if rust resistance is required Moderate cost Requires high temperature for saponification	Automotive chassis lubricant Automotive wheel bearings General industrial grease Thread lubricants for the oil drilling industry
Sodium	Rough, fibrous appearance Moderate dropping point 350°F to 370°F Natural Rust Protection Adequate Shear Stability Good adhesive (cohesive) properties Low Cost	Soluble in water Poor low temp pump ability Poor Oxidation Resistance	Older industrial equipment where relubrication is frequent Rolling contact bearings

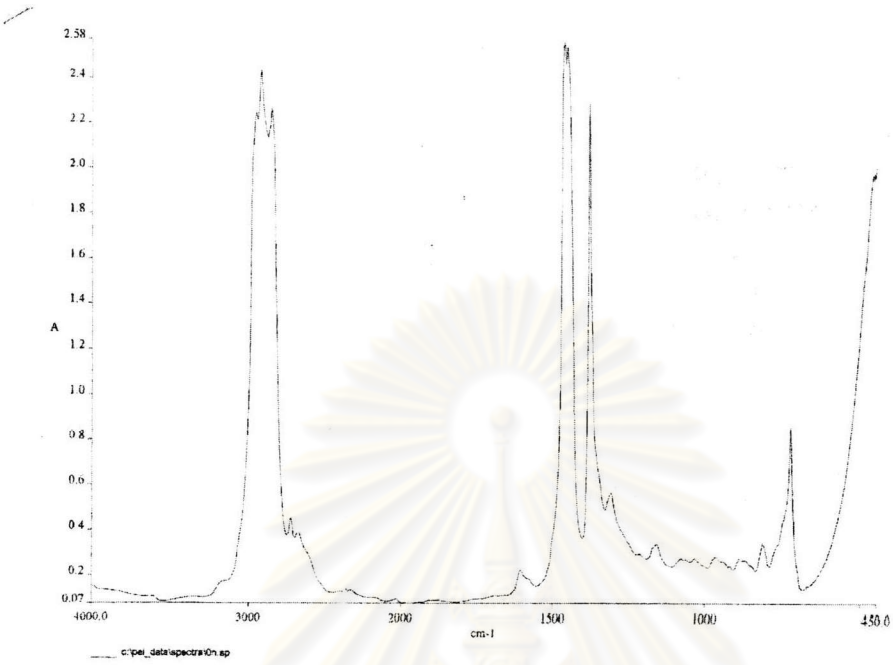
Type	Characteristics/Strengths	Weaknesses	Usage
	Complex Soaps		
Aluminum complex	Smooth, slight gel-like appearance Dropping points above 450°F, Good water resistance Resistant to softening Good to excellent shear stability Very good water resistance	Shorter life at high temperature Fair low temperature properties Fairly high cost	Steel mill roll neck, rolling, and plain bearings
Calcium complex	Smooth, buttery appearance Dropping points above 450°F Good water resistance Inherent EP or load-carrying capabilities	High thickener content/poor pump ability Storage hardening may occur Moderate Cost	High-temperature industrial and automotive bearing applications
Lithium complex	Dropping points above 450°F Resistant to softening and leakage Moderate water resistance	Moderate to fairly high cost	Automotive wheel bearings High-temperature industrial service including various roller element bearing applications

Type	Characteristics/Strengths	Weaknesses	Usage
	Nonsoap Thickeners		
Polyurea	Smooth, slightly opaque appearance Dropping points above 450°F Good water resistance Oxidation resistant	Less resistant to softening and leakage	Industrial roller-element bearings Automotive constant-velocity joints
Organo-clay	Smooth and buttery appearance Dropping points above 500°F Resistance to Leakage Good Water Resistance	Additive sensitive Moderate to fairly high cost	High temperature bearings with frequent relubrication Steel mill roll neck bearings

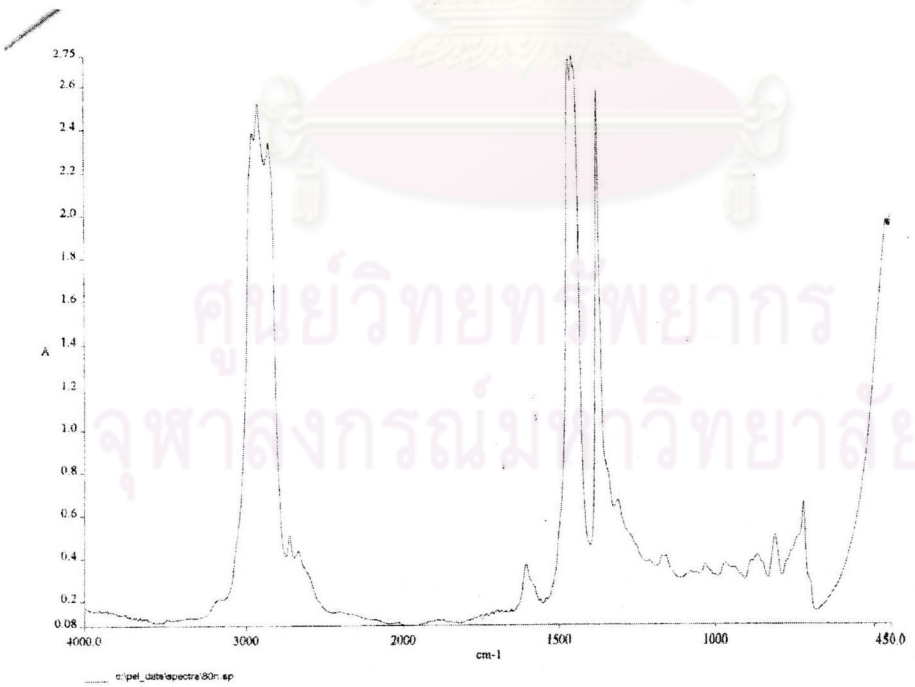
APPENDIX 3 Specification of grade 1 calcium grease for general purpose

Item	Test method	No. of cone penetration			
		No. 1	No. 2	No. 3	No. 4
Worked penetration	JIS K2220 (5.3)	310 to 340	265 to 295	220 to 250	175 to 205
Dropping point °C	JIS K2220 (5.4)	80 min.	85 min.	85 min.	90 min.
Copper corrosion (room temp, 24h)	JIS K2220 (5.5 method A)	No change to green or black colour on copper plate.			
Ash content, mass %	JIS K2220 (5.10)	3.0 max.	3.5 max.	4.0 max.	4.5 max.
Water washout resistance (38°C, I h), mass%	JIS K2220 (5.12)	20 max.	20 max.	20 max.	20 max.
Water content, mass %	JIS K2220 (5.18)	2.0 max.	2.5 max.	2.5 max.	3.0 max.

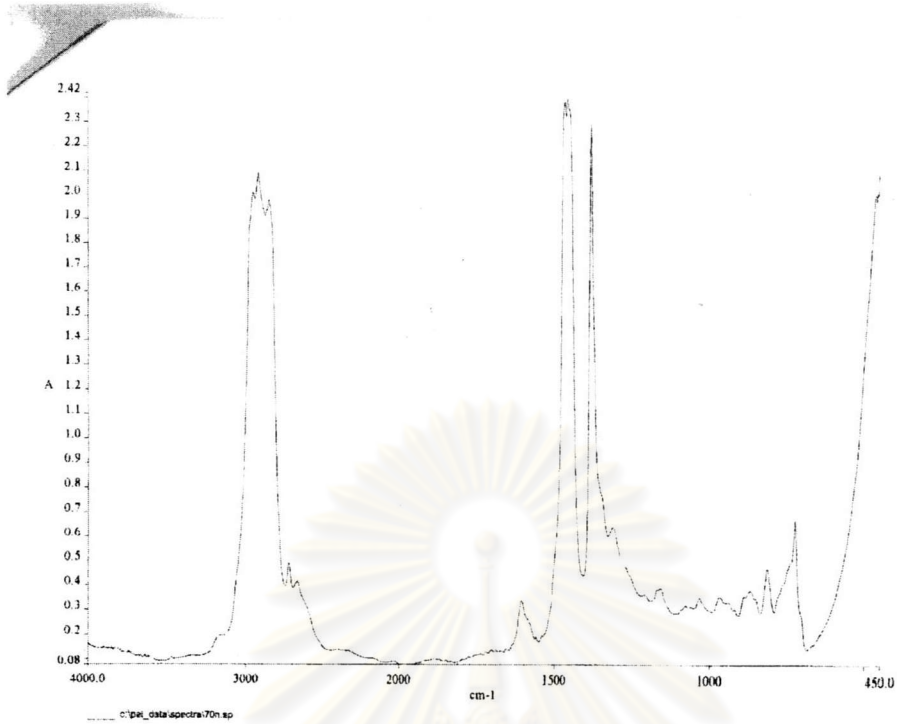
APPENDIX 4 FTIR Spectrums of base oil type for analysis hydrocarbon type



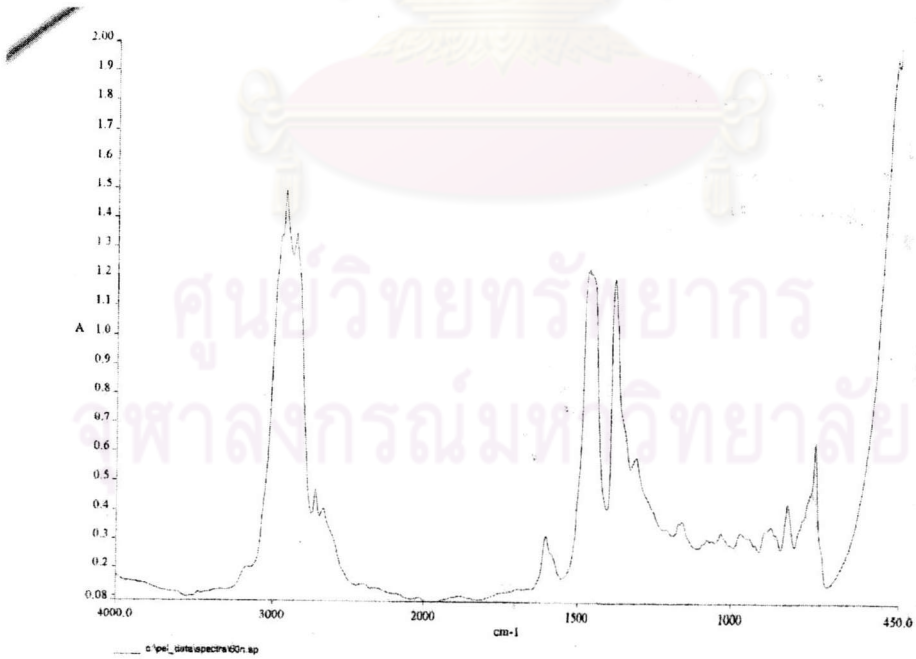
FTIR Spectrum of 100% naphthenic oil



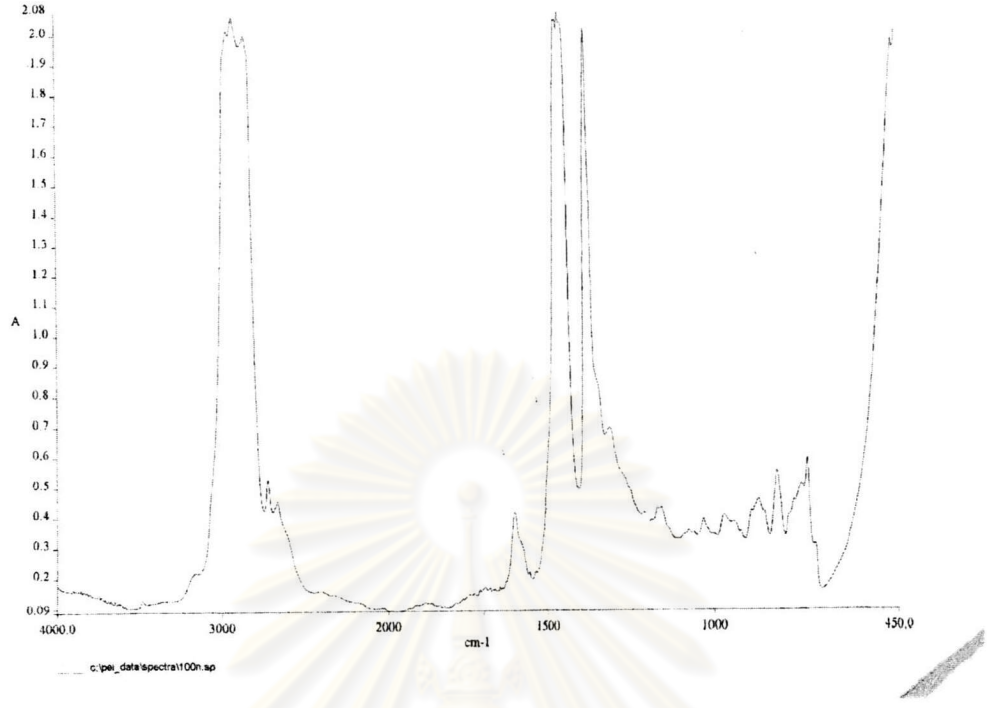
FTIR Spectrum of N:P ratio; 80:20



FTIR Spectrum of N:P ratio; 70:30



FTIR Spectrum of N:P ratio; 60:40



FTIR Spectrum of 100% paraffinic oil

APPENDIX 5 Properties of calcium grease in varying base oil type

ITEM	TEST NO.	BASE OIL TYPE				
		100 % N	N:P 80:20	N:P 70:30	N:P 60:40	100 % P
Penetration; Unworked	I	225	218	222	224	286
	II	225	216	220	222	294
	III	230	221	221	218	292
	Average	**227**	**218**	**221**	**221**	**291**
Penetration; Worked	I	245	240	233	229	240
	II	241	235	235	226	242
	III	242	234	234	225	246
	Average	**243**	**236**	**235**	**227**	**243**
Dropping Point; ^{o}C	I	110	110	111	110	109
	II	110	111	111	109	110
	III	110	110	110	110	109
	Average	**110**	**110**	**111**	**110**	**109**
Water Washout	I	2.33	0.95	0.82	0.94	3.48
(38 ^{o}C/1 h), mass %	II	2.05	0.77	0.70	1.08	3.66
	Average	**2.19**	**0.86**	**0.76**	**1.01**	**3.57**
Water Content, mass	I	0.65	0.66	0.63	0.67	0.63
%	II	0.67	0.67	0.65	0.64	0.70
	III	0.71	0.63	0.64	0.64	0.64
	Average	**0.68**	**0.65**	**0.64**	**0.65**	**0.66**

Remark: *N = Naphthenic Oil ; P = Paraffinic Oil*

APPENDIX 6 Penetration number at 1, 7 and 30 days in varying base oil type

BASE OIL TYPE	TEST NO.	PENETRATION (UNWORKED/WORKED)					
		1 Day		7 Days		30 Days	
		Unworked	Worked	Unworked	Worked	Unworked	Worked
100 % N	I	225	245	230	244	221	237
	II	225	241	232	245	220	238
	III	230	242	236	248	224	235
	Average	**227**	**243**	**233**	**246**	**222**	**237**
N:P = 80:20	I	218	240	220	228	219	228
	II	216	235	217	227	216	225
	III	221	234	216	227	215	229
	Average	**218**	**236**	**218**	**227**	**217**	**227**
N:P = 70:30	I	222	233	210	224	224	224
	II	220	235	215	223	219	227
	III	221	234	213	227	222	223
	Average	**221**	**235**	**212**	**225**	**221**	**225**
N:P = 60:40	I	224	229	224	231	215	225
	II	222	226	228	228	214	223
	III	218	225	225	232	216	222
	Average	**221**	**227**	**226**	**230**	**216**	**223**

Remark: N = Naphthenic Oil ; P = Paraffinic Oil

APPENDIX 7 Properties of calcium grease in varying water content

ITEM	TEST NO.	WATER CONTENT (%)				
		6%	8%	10%	12%	14%
Penetration; Unworked	I	268	230	224	231	225
	II	266	233	223	230	223
	III	262	228	220	237	222
	Average	**265**	**230**	**222**	**233**	**223**
Penetration; Worked	I	271	233	237	239	235
	II	273	235	235	238	234
	III	269	234	237	242	236
	Average	**270**	**233**	**236**	**240**	**235**
Dropping Point; ^{o}C	I	110	112	111	111	111
	II	110	111	111	111	110
	III	110	112	110	110	111
	Average	**110**	**112**	**111**	**111**	**111**
Water Washout	I	0.73	0.68	0.79	1.19	1.43
(38 ^{o}C/1 h), mass %	II	0.74	0.70	0.74	1.24	1.48
	Average	**0.73**	**0.69**	**0.76**	**1.21**	**1.46**
Water Content, mass	I	0.30	0.56	0.66	0.90	1.15
%	II	0.32	0.55	0.65	0.85	1.12
	III	0.29	0.54	0.64	0.86	1.10
	Average	**0.30**	**0.54**	**0.65**	**0.87**	**1.12**

APPENDIX 8 Penetration number at 1, 7 and 30 days in varying water content

WATER CONTENT	TEST NO.	PENETRATION (UNWORKED/WORKED)					
		1 Day		7 Days		30 Days	
		Unworked	Worked	Unworked	Worked	Unworked	Worked
6%	I	268	271	253	253	257	252
	II	266	273	250	256	260	249
	III	262	269	250	252	262	252
	Average	**265**	**270**	**251**	**254**	**259**	**251**
8%	I	230	233	241	242	244	238
	II	233	235	240	243	245	237
	III	228	234	244	241	241	240
	Average	**230**	**233**	**242**	**242**	**243**	**238**
10%	I	224	237	227	243	229	268
	II	223	235	226	244	230	266
	III	220	237	229	242	226	262
	Average	**222**	**236**	**227**	**243**	**228**	**239**
12%	I	231	239	248	247	241	238
	II	230	238	247	248	240	242
	III	237	242	250	249	243	241
	Average	**233**	**240**	**247**	**247**	**242**	**240**
14%	I	225	235	230	230	226	235
	II	223	234	224	231	224	235
	III	222	236	226	232	226	237
	Average	**223**	**235**	**227**	**231**	**225**	**236**

APPENDIX 9 Properties of calcium grease in varying saponification rate

ITEM	TEST NO.	SAPONIFICATION RATE (°C/MIN)		
		2.0	2.5	3.0
Penetration; Unworked	I	268	230	224
	II	266	233	223
	III	262	228	220
	Average	**237**	**223**	**237**
Penetration; Worked	I	231	227	234
	II	234	226	235
	III	235	228	234
	Average	**234**	**227**	**234**
Dropping Point; °C	I	110	111	111
	II	111	111	111
	III	111	111	110
	Average	**111**	**111**	**111**
Water Washout (38 °C/1 h), mass %	I	0.86	0.75	0.95
	II	0.80	0.82	0.88
	Average	**0.85**	**0.78**	**0.91**
Water Content, mass %	I	0.60	0.58	0.59
	II	0.61	0.60	0.52
	III	0.60	0.57	0.54
	Average	**0.60**	**0.58**	**0.55**

APPENDIX 10 Penetration number at 1, 7 and 30 days in varying saponification rate

SAPON. RATE	TEST NO.	PENETRATION (UNWORKED/WORKED)					
		1 Day		7 Days		30 Days	
		Unworked	Worked	Unworked	Worked	Unworked	Worked
2.0	I	268	231	243	240	247	244
	II	266	234	240	245	248	243
	III	262	235	242	244	246	246
	Average	**237**	**234**	**242**	**243**	**247**	**244**
2.5	I	230	227	233	235	225	226
	II	233	226	232	233	224	225
	III	228	228	233	233	225	224
	Average	**223**	**227**	**233**	**234**	**225**	**226**
3.0	I	224	234	244	243	246	240
	II	223	235	247	243	245	244
	III	220	234	246	242	247	241
	Average	**237**	**234**	**246**	**243**	**246**	**242**

APPENDIX 11 Properties of calcium grease in varying surfactant content in 100%P

ITEM	TEST NO.	SURFACTANT CONTENT (%)			
		0%	1%	2%	3%
Penetration; Unworked	I	286	305	290	275
	II	294	300	286	274
	III	292	304	287	273
	Average	**291**	**303**	**288**	**274**
Penetration; Worked	I	240	285	271	268
	II	242	285	275	269
	III	246	284	272	269
	Average	**243**	**285**	**273**	**269**
Dropping Point; ^{o}C	I	109	108	108	108
	II	109	109	108	108
	III	109	108	108	108
	Average	**109**	**108**	**108**	**108**
Water Washout (38 ^{o}C/1 h), mass %	I	3.48	3.52	3.57	3.53
	II	3.65	3.45	3.49	3.46
	Average	**3.57**	**3.48**	**3.53**	**3.50**
Water Content, mass %	I	0.63	0.60	0.69	0.72
	II	0.70	0.61	0.60	0.70
	III	0.64	0.61	0.66	0.73
	Average	**0.66**	**0.61**	**0.65**	**0.72**

APPENDIX 12 Properties of calcium grease in varying surfactant content in N:P ratio; 60:40

ITEM	TEST NO.	SURFACTANT CONTENT (%)			
		0%	1%	2%	3%
Penetration; Unworked	I	224	203	252	261
	II	222	206	250	259
	III	218	205	249	260
	Average	**221**	**205**	**250**	**260**
Penetration; Worked	I	229	252	276	295
	II	226	248	277	300
	III	225	250	280	297
	Average	**227**	**250**	**278**	**297**
Dropping Point; ^{o}C	I	110	108	108	106
	II	109	109	108	107
	III	110	108	108	106
	Average	**110**	**108**	**108**	**106**
Water Washout (38 ^{o}C/1 h), mass %	I	0.94	1.93	2.29	2.45
	II	1.08	2.12	2.18	2.35
	Average	**1.01**	**2.02**	**2.23**	**2.40**
Water Content, mass %	I	0.67	0.88	0.90	0.75
	II	0.64	0.86	0.81	0.83
	III	0.64	0.87	0.84	0.80
	Average	**0.65**	**0.87**	**0.85**	**0.79**

VITA

Miss Sumalee Roopkom was born on January 5, 1974 in Nakhonsrithammarach, Thailand. She received a Bachelor's Degree of Science in Chemistry at Prince of Songkha University in 1996. Since 2000, She has been a graduate student in the Program of Petrochemistry and Polymer Science, Faculty of Science, Chulalongkorn University and completed her M.Sc.degree in 2003. She has worked as a QA SUPERVISOR in the Quality Assurance Section, P.S.P. Specialties Co., Ltd.