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## **APPENDIX**

**Table A1 Results of single Viscosity Index Improver blended with base oil**

VI improver		Base oil			Base oil containing VI improvers					
Type	Concentration (%)	KV@40°C*, (cSt.)	KV@100°C*, (cSt.)	VI	KV@40°C**, (cSt.)	KV@100°C**, (cSt.)	VI	VI improved (%)	Thickening effect (%)	Viscosity@-15°C (cP.)
OCP	2	76.72	9.42	99	86.09	10.61	107	8	13	5539
OCP	5	76.72	9.42	99	103.04	12.77	119	20	36	5673
OCP	9	76.72	9.42	99	130.21	16.10	133	34	71	5724
SIP	2	78.13	9.36	96	80.22	9.85	102	10	5	5424
SIP	5	78.13	9.36	96	86.59	10.76	109	11	15	5164
SIP	9	78.13	9.36	96	97.47	12.15	117	12	30	4784
PMA	2	77.07	9.53	100	103.20	12.48	114	13	31	6515
PMA	5	77.07	9.53	100	157.44	18.58	133	19	95	7159
PMA	9	77.07	9.53	100	260.18	29.36	150	29	208	8447
PIB	2	77.32	9.52	100	83.16	9.52	90	-10	0	6881
PIB	5	77.32	9.52	100	92.87	10.67	98	-2	12	8104
PIB	9	77.32	9.52	100	107.35	11.83	99	-1	24	10157

**Table A2 Results of 2 Type of Viscosity Index Improver blended with base oil**

VI improver			Base oil			Base oil containing VI improvers						
Type	Ratio	Concentration (%)	KV@40°C*, (cSt.)	KV@100°C*, (cSt.)	VI	KV@40°C**, (cSt.)	KV@100°C**, (cSt.)	VI	VI improved (%)	Thickening effect (%)	Viscosity@-15°C (cP.)	
OCP	SIP	1:2	2	76.72	9.42	99	82.21	10.18	105	6	8	5198
			5	76.72	9.42	99	92.21	11.44	112	13	21	5060
			9	76.72	9.42	99	107.49	13.35	122	23	42	4894
OCP	SIP	1:1	2	76.72	9.42	99	83.02	10.27	105	6	9	5215
			5	76.72	9.42	99	94.33	11.74	114	15	25	5144
			9	76.72	9.42	99	112.21	14.03	125	26	49	4987
OCP	SIP	2:1	2	72.25	9.15	101	79.71	10.09	107	6	10	5356
			5	72.25	9.15	101	92.51	11.63	115	14	27	5249
			9	72.25	9.15	101	113.40	14.08	125	24	54	5128
OCP	PMA	1:2	2	74.62	9.26	99	98.75	11.67	111	12	26	6274
			5	74.62	9.26	99	135.1	16.08	126	27	74	6767
			9	74.62	9.26	99	206.1	23.86	144	46	158	7705

**Table A2 (continued.)**

VI improver			Base oil				Base oil containing VI improvers					
Type	Ratio	Concentration (%)	KV@40°C*, (cSt.)	KV@100°C*, (cSt.)	VI	KV@40°C**, (cSt.)	KV@100°C**, (cSt.)	VI	VI improved (%)	Thickening effect (%)	Viscosity@-15°C (cP.)	
OCP	PMA	1:1	2	74.62	9.26	99	93.18	11.42	110	11	23	6182
			5	74.62	9.26	99	126.70	15.20	124	25	64	6642
			9	74.62	9.26	99	186.00	31.76	140	41	243	7296
OCP	PMA	2:1	2	74.62	9.26	99	89.27	10.96	108	9	18	6093
			5	74.62	9.26	99	115.10	13.95	121	22	51	6321
			9	74.62	9.26	99	164.5	19.65	138	39	112	6969
OCP	PIB	1:2	2	72.25	9.15	101	78.94	9.88	104	3	8	5684
			5	72.25	9.15	101	90.09	11.01	108	7	20	6446
			9	72.25	9.15	101	107.30	12.69	112	11	39	7540
OCP	PIB	1:1	2	74.62	9.26	99	81.59	10.03	103	4	8	6001
			5	74.62	9.26	99	94.1	11.42	108	9	23	6525
			9	74.62	9.26	99	115.20	13.50	114	15	46	7401

**Table A2 (continued.)**

VI improver			Base oil			Base oil containing VI improvers						
Type	Ratio	Concentration (%)	KV@40°C*, (cSt.)	KV@100°C*, (cSt.)	VI	KV@40°C**, (cSt.)	KV@100°C**, (cSt.)	VI	VI improved (%)	Thickening effect (%)	Viscosity@-15°C (cP.)	
OCP	PIB	2:1	2	74.62	9.26	99	82.54	10.24	105	6	11	6088
			5	74.62	9.26	99	96.59	11.8	112	13	27	6466
			9	74.62	9.26	99	118.30	14.21	120	21	54	6986
SIP	PMA	1:2	2	74.62	9.26	99	92.69	11.35	110	11	23	5992
			5	74.62	9.26	99	123.20	14.86	123	24	61	6251
			9	74.62	9.26	99	161.10	19.21	136	37	108	6388
SIP	PMA	1:1	2	74.62	9.26	99	88.49	10.90	108	9	18	5895
			5	74.62	9.26	99	120.93	10.94	114	15	18	6001
			9	74.62	9.26	99	161.10	19.21	136	37	108	6388
SIP	PMA	2:1	2	72.25	9.15	101	87.49	10.84	109	8	19	5821
			5	72.25	9.15	101	113.90	13.67	118	17	49	6662
			9	72.25	9.15	101	161.00	18.44	128	27	102	7967

**Table A2 (continued.)**

VI improver			Base oil				Base oil containing VI improvers					
Type		Ratio	Concentration (%)	KV@40°C*, (cSt.)	KV@100°C*, (cSt.)	VI	KV@40°C**, (cSt.)	KV@100°C**, (cSt.)	VI	VI improved (%)	Thickening effect (%)	Viscosity@-15°C (cP.)
SIP	PIB	1:2	2	74.62	9.26	99	79.33	9.73	101	2	5	6326
			5	74.62	9.26	99	86.64	10.41	102	3	12	6821
			9	74.62	9.26	99	98.87	11.50	104	5	24	7658
SIP	PIB	1:1	2	78.31	9.39	96	79.33	9.73	101	2	5	6326
			5	78.31	9.39	96	86.64	10.41	102	3	12	6821
			9	78.31	9.39	96	98.87	11.50	104	5	24	7658
SIP	PIB	2:1	2	72.25	9.15	101	78.82	9.76	102	1	7	6075
			5	72.25	9.15	101	83.20	10.40	108	7	14	5611
			9	72.25	9.15	101	93.35	11.57	113	12	27	5142
PMA	PIB	1:2	2	74.62	9.26	99	86.69	10.53	104	5	14	6331
			5	74.62	9.26	99	107.50	12.60	110	11	36	7420
			9	74.62	9.26	99	142.20	16.03	118	19	73	8999



**Table A2 (continued.)**

VI improver			Base oil			Base oil containing VI improvers						
Type		Ratio	Concentration (%)	KV@40°C*, (cSt.)	KV@100°C*, (cSt.)	VI	KV@40°C**, (cSt.)	KV@100°C**, (cSt.)	VI	VI improved (%)	Thickening effect (%)	Viscosity@-15°C (cP.)
PMA	PIB	1:1	2	74.48	9.34	101	91.45	11.10	107	6	19	6005
			5	74.48	9.34	101	118.72	13.93	116	15	49	6897
			9	74.48	9.34	101	168.63	18.92	127	26	103	8268
PMA	PIB	2:1	2	74.48	9.34	101	93.92	11.42	109	8	22	6008
			5	74.48	9.34	101	131.15	15.40	122	21	65	7031
			9	74.48	9.34	101	194.43	21.90	136	35	135	8134

**Table A3 Results of finish lubricating oil using dual of viscosity index improver**

VI improver type		Ratio	KV@40°C	KV@100°C (before shearing)	VI	KV@100°C (after shearing)	CCS@-15°C	PVL	SSI	HTHS	Thickening effect
Unit			cSt.	cSt.		cSt.	cP.	%			%
Specification*				16.3-21.9*			Max 9500*			Min 3.7*	
OCP	SIP	1:1	136.60	16.16	125	15.17	6720	6.1	0.15	4.33	61.26
OCP	PMA	2:1	191.44	22.13	139	18.73	8193	15.4	0.27	5.37	115.05
OCP	PIB	2:1	142.30	16.23	121	15.17	8253	6.5	0.15	4.48	61.89
SIP	PMA	1:2	217.47	24.78	143	20.27	8384	18.2	0.29	5.63	138.92
SIP	PIB	1:1	122.10	13.88	112	13.66	8599	1.6	0.05	3.98	40.72
PMA	PIB	1:2	174.8	18.76	121	16.62	11249	11.4	0.23	4.86	84.68

\*Source: Society of Automotive Engineers (SAE), December 1999

**Table A4 Results of finish lubricating oil using single viscosity index improver**

<b>VII type</b>	<b>Treat rate,</b>	<b>KV@40°C,</b>	<b>KV@100°C</b>	<b>VI</b>	<b>CCS@-15°C</b>
<b>Unit</b>	%wt.	cSt.	cSt.	-	cP.
<b>Specification*</b>			<b>16.3-21.9*</b>	<b>Min 120</b>	<b>Max 9500*</b>
OCP	8.8	153.0	17.80	129	6119
SIP	15.0	145.86	17.60	133	6243
PMA	4.0	144.5	17.35	131	7113
PIB	20	219.9	19.39	100	27097

\* Source: Society of Automotive Engineers (SAE), December 1999

**Table A5 Formulations and results of finish lubricating oil using dual viscosity index improvers**

	Formulation, %wt.											
VII Type	OCP:SIP		OCP:PMA		OCP:PIB		SIP:PMA		SIP:PIB		PMA:PIB	
Ratio	1:1		2:1		2:1		1:2		1:1		1:2	
	Initial	Adjusted	Initial	Adjusted	Initial	Adjusted	Initial	Adjusted	Initial	Adjusted	Initial	Adjusted
<b>Components</b>												
150 SN	16.6	13.0	16.6	25.0	16.6	11.6	16.6	19.0	16.6	5.4	16.6	20.4
500 SN	65.0	68.6	65.0	56.6	65.0	70.0	65.0	65.4	65.0	70.0	65.0	58.0
PPD	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
VI Improver	8.8	8.8	8.8	8.8	8.8	8.8	8.8	6.0	8.8	15.0	8.8	12.0
Package additive	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
<b>Properties</b>												
Kinematic Viscosity @ 40°C	136.6	139.51	191.44	174.89	142.3	151.69	217.47	164.48	122.1	166.3	174.80	205.75
Kinematic Viscosity @ 100°C	16.16	16.30	22.13	20.68	16.23	16.94	24.78	19.19	13.88	17.46	18.76	21.61
Viscosity Index	125	124	139	139	121	120	143	133	112	114	121	126
CCS @ -15°C	6720	6590	8193	6288	8253	8471	8567	7783	8599	12084	11249	10569
HTHS	4.33	-	5.37	-	4.48	-	5.63	-	3.98	-	4.86	-
PVL	6.1	-	15.4	-	6.5	-	18.2	-	1.6	-	11.4	-
SSI	0.15	-	0.27	-	0.15	-	0.29	-	0.05	-	0.23	-
Cost of production, \$/Ton	-	416	-	403	-	376	-	394	-	443	-	396

## CURRICULUM VITAE

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