

SHRP-A-645

**SHRP Materials Reference Library:
Asphalt Cements:
A Concise Data Compilation**

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Purpose

This report presents a concise compilation of the chemical and physical properties of the asphalt cements contained in the Strategic Highway Research Program's Materials Reference Library (MRL).

Introduction

Forty-eight (48) asphalts were collected into the MRL during the 5-year Strategic Highway Research Program (SHRP) to provide: 1) a common set of materials for use in all the SHRP research studies and 2) a long-term library of materials for use by future researchers to validate and expand upon the findings of the SHRP research.

During the research many data were generated. Selected data that were judged of immediate, continuing use to the SHRP researchers were put for ready reference into a computer-based spreadsheet. This was distributed periodically to SHRP contractors and other interested agencies. SHRP ended March 31, 1993, and with it the flow of new data. This report represents the final compilation of those data.

The Materials Reference Library

The MRL consists of samples of aggregates and asphalt cements that were collected and stored under carefully controlled conditions. The samples collected were large enough that substantial stocks of both aggregate and asphalt cements remained at the end of SHRP. This library of materials will be maintained for an indefinite period of time by the Federal Highway Administration. Researchers interested in procuring MRL materials should contact the Chief, Long-Term Pavement Performance Division, Federal Highway Administration, Washington DC 20590.

Caution

The reader should note that much more chemical and physical data were generated during SHRP than is presented here, and that this report does not include any of the extensive engineering property data that was also generated. A complete data compilation is contained in the computer-based SHRP Asphalt Database. For information on accessing or obtaining data from this database, the reader should contact the Transportation Research Board, Special Programs Division, Washington DC 20007.

Data Sources

Many research organizations contributed to the SHRP program, and these data are drawn from the quarterly and final reports of the various contracts. Where possible the spreadsheet attributes data to the organization that generated it. A listing of the major contributors includes:

The Asphalt Institute, Lexington, KY. - classical asphalt properties (penetration, viscosity).

Western Research Institute, Laramie, WY - chemical analysis of asphalts, chromatographic analysis, infra-red spectroscopic analysis.

Pennsylvania State University, State College, PA - rheological analysis of binders.

Montana State University, Bozeman, MT - Nuclear Magnetic Resonance (NMR) analysis.

INTEVEP, S.A., Caracas, Venezuela - Wax analysis.

The University of Texas at Austin, Austin, TX - rheological analysis of binders.

Readers with questions concerning the techniques used to generate the data should refer to the pertinent SHRP final reports, or contact the above organizations.

Other Relevant References

Materials Reference Library Asphalt Selection Process, SHRP Report SHRP-A-303.

The SHRP Materials Reference Library Aggregates: Chemical, Mineralogical, and Sorption Analyses, SHRP Report SHRP-A/UIR-91-509.

MRL ASPHALT PROPERTIES

MRL Code	AAA-1	AAA-2	AAB-1	AAB-2	AAC-1	AAC-2	AAD-1
Crude Oil Source	Lloydminster		WY Sour		Redwater		Ca Coast
Visc./Pen Grade	150/200	200/300	AC-10	AC-5	AC-8	AC-5	AR-4000
SHRP PG Grade	PG58-28	PG46-34	PG58-22	PG52-22	PG58-16	PG52-22	PG58-28
Original Asphalt							
Viscosity							
140°F, poise	864	363	1029	403	419	304	1055
275°F, cSt	283	189	289	193	179	143	309
Penetration, 0.1 mm							
(77°F, 100g, 5s)	160	291	98	166	133	200	135
(39.2°F, 100g, 5s)	15	27	6	13	7	9	9
Ductility, cm							
(39.2 °F, 1cm/min)	150+	150+	40.1	81	137	150+	150+
Softening Point (R&B), °F	112	102	118	115	109	107	118
Component Analysis, %							
Asphaltenes (n-heptane)	16.2	16.2	17.3	16.7	10.1	9.8	20.5
Asphaltenes (iso-Octane)	3.4		2.0		3.1	3.4	3.4
Polar Aromatics	37.3	36.0	38.3	35.7	37.4	35.4	41.3
Naphthene Aromatics	31.8	36.1	33.4	36.5	37.1	37.0	25.1
Saturates	10.6	11.4	8.6	10.8	12.9	16.6	8.6
Elemental Analysis							
C, %	83.9	84.12	82.3	85.7	86.5	86.6	81.6
H, %	10.0	10.59	10.6	10.59	11.3	10.6	10.8
O, %	0.6		0.8		0.9	1.0	0.9
Nitrogen, %	0.50	0.50	0.54	0.54	0.66	0.90	0.77
Sulfur, %	5.50	6.00	4.70	5.40	1.90	1.90	6.90
Vanadium, ppm	174	138	220	163	146	100	310
Nickel, ppm	86	77	56	36	63	55	145
Fe, ppm	<1		16			29	13
Aromatic C, %	28.1		31.9		24.7		23.7
Aromatic H, %	7.68		7.12		6.41		6.81
Molecular wt. (Toluene)	790		840		870	870	700
% WAX (INTEVEP)	1.62	1.56	3.85	5.05	5.06	4.56	1.94
WAX M. P. (deg. C)	35.8	38.6	62.1	64.3	65.7	66.9	50.6

WRI data in italics PSU data in Monaco UT data in bold
 TAI data in Helvetica MSU data in outline

MRL ASPHALT PROPERTIES

MRL Code	AAA-1	AAA-2	AAB-1	AAB-2	AAC-1	AAC-2	AAD-1
Crude Oil Source	Lloydminster		WY Sour		Redwater		Ca Coast
Visc./Pen Grade	150/200	200/300	AC-10	AC-5	AC-8	AC-5	AR-4000
SHRP PG Grade	PG58-28	PG46-34	PG58-22	PG52-22	PG58-16	PG52-22	PG58-28
Aged Asphalt							
(Thin Film Oven Test)							
Mass Change, %	-0.3115	-0.5370	-0.0362	-0.0149	-0.2590	-0.2780	-0.8102
Viscosity							
140°F, poise	1901	869	2380	1073	1014	648	3420
275°F, cSt	393	270	393	263	239	185	511
Viscosity Ratio (140°F)	2.20	2.39	2.31	2.66	2.42	2.13	3.24
IEC Separations (wt %)							
	AAA-1		AAB-1		AAC-1		AAD-1
Strong Acid*	6.4		15.0		7.5		11.0
SA Mol. Wt, VPO, Toluene	2790		2390				2500
Amphoterics*	11						15
Strong Base	6.4		9.2		7.4		7.8
Weak Acid	8.7		8.6		8.3		7.8
Weak Base	5.0		6.5		7.2		5.5
Neutral	59.6		56.9		68.2		51.7
Neutrals plus acids**							60.0
Amphoterics**							25.7
Bases**							9.3
Neutral Fraction							
Viscosity, poise, 77°F	355		1,553		3,100		197
*calculated **WRI Method							
SEC Fraction, MW							
VPO, Toluene							
I	11000		9200		7380		7000
SEC I, TFAAT Aged	11500		9800		8400		13900
II							
Fraction II - wt. %	78.2		78.3		85.8	87.8	76.6
Visc. with SEC fraction 1 removed (77°F, poise)	5064		13675		86020	53590	3366
Visc. of whole asphalt, 77°F, Poise x10E-3	275.4		1,125		945.4		405.7

MRL ASPHALT PROPERTIES

MRL Code	AAA-1	AAA-2	AAB-1	AAB-2	AAC-1	AAC-2	AAD-1
Crude Oil Source	Lloydminster		WY Sour		Redwater		Ca Coast
Visc./Pen Grade	150/200	200/300	AC-10	AC-5	AC-8	AC-5	AR-4000
SHRP PG Grade	PG58-28	PG46-34	PG58-22	PG52-22	PG58-16	PG52-22	PG58-28
Viscoelastic Properties	DSR Rheometer, Bending Beam Rheometer, Direct Tension						
Tank Asphalt							
Td, Tank, °C	-19.3		-11.6		-5.5		-17.1
R, Tank	1.50		1.76		1.63		1.66
G*, Pa, 60°C, 10 rad/s	2860		2486		2152		3148
δ @ 60° (deg)	84.3		85.2		85.7		81.7
G*/sinδ, kPa, 52°C	2.48	46° 1.67		1.90	2.98	1.83	3.16
G*/sinδ, kPa, 58°C	0.96	52° .78	1.86	0.84	1.08	0.81	1.47
G*/sinδ, kPa, 64°C			0.83		0.51		0.69
G*/sinδ, kPa, 70°C							
TFOT Residue							
Td, TFOT, °C	-14.3		-5.3		-3.8		-13.3
R, TFOT	1.75		2.06		1.80		1.80
G*, Pa, 60°C, 10 rad/s	2723		3229		2664		3784
δ @ 60° (deg)	83.0		83.3		85.0		78.4
RTFOT Residue							
G*/sinδ, kPa, 52°C	4.92	46° 4.49		4.82	5.50	3.36	
G*/sinδ, kPa, 58°C	2.40	52° 2.01	3.34	1.89	2.34	1.49	4.29
G*/sinδ, kPa, 64°C			1.39				1.97
G*/sinδ, kPa, 70°C							
PAV Residue							
Td, PAV, °C	-14.5		-6.0		3.5		-8.7
R, PAV	1.90		2.13		2.10		2.07
G*, Pa, 60°C, 10 rad/s	5899		8888		7175		11319
δ @ 60° (deg)	79.2		79.0		82.3		72.6
G* sinδ, MPa @ 10° C		4.2					
G* sinδ, MPa @ 15° C		2.1					
G* sinδ, MPa @ 20° C	2.7	1.1	3.8	2.9	6.6	3.4	2.8
G* sinδ, MPa @ 25° C	1.3		2.4	1.6	2.9	1.8	1.7
G* sinδ, MPa @ 30° C							
S(t), MPa, @ 0°C					30		
S(t), MPa, @ -10°C	50		125	65	186	98	83
S(t), MPa, @ -20°C	246	92	471	237		370	346
S(t), MPa, @ -30°C		375					
m @ 0° C					0.40		
m @ -10° C	0.41		0.34	0.36	0.30	0.37	0.38
m @ -20° C	0.33	0.38	0.25	0.28		0.27	0.31
m @ -30° C		0.29					
Failure strain 0°C							
Failure strain -10°C	10.70	>12	7.23	7.63	4.07	4.12	10.51
Failure strain -20°C	0.38	0.47				0.83	

MRL ASPHALT PROPERTIES

MRL Code	AAA-1	AAA-2	AAB-1	AAB-2	AAC-1	AAC-2	AAD-1
Crude Oil Source	Lloydminster		WY Sour		Redwater		Ca Coast
Visc./Pen Grade	150/200	200/300	AC-10	AC-5	AC-8	AC-5	AR-4000
SHRP PG Grade	PG58-28	PG46-34	PG58-22	PG52-22	PG58-16	PG52-22	PG58-28

Functional Group Analysis

(By Infra-Red Analysis)

Carboxylic Acids							
(Tank)	0.015		<.005		0.010	<.005	0.015
Acid Salts							
(Tank)	<.005		<.005		<.005	<.005	<.005
Acid Anhydrides							
(Tank)	0.000		0.000		0.000		0.000
(POV (144 hr.))					0.012		
Quinolones							
(Tank)	0.011		0.012		0.011	0.010	0.027
Ketones							
(Tank)	<.005		<.005		<.005	<.005	<.005
(TFO)	0.020		0.000		0.020		0.040
(POV (144 hr.))	0.040		0.050		0.090	0.090	0.070
Phenols							
(Tank)	0.080		0.060		0.040	0.010	0.130
Sulfoxides							
(Tank)	0.037		0.064		0.029	0.144	0.036
(TFO)	Tr		0.080		Tr		Tr
(POV (144 hr.))	0.220		0.250		0.190	0.220	0.250
Pyrroles							
(Tank)	0.120		0.140		0.220	0.214	0.190

MRL ASPHALT PROPERTIES

MRL Code	AAD-2	AAE(blow)	AAF-1	AAF-2	AAG-1	AAG-2	AAH
Crude Oil Source	Ca Coast	Lloydminst	W Tx Sour		Ca Valley		Rangely
Visc./Pen Grade	AR-2000	60/70	AC-20	AC-10	AR-4000	AR-2000	AC-10
SHRP PG Grade	PG52-28	PG70-22	PG64-10	PG58-16	PG58-10	PG58-16	PG58-22
Original Asphalt							
Viscosity							
140°F, poise	600	3634	1872	867	1862	1056	1058
275°F, cSt	225	560	327	223	243	170	298
Penetration, 0.1 mm							
(77°F, 100g, 5s)	195	73	55	82	53	76	95
(39.2°F, 100g, 5s)	17	7	0	2	2		7
Ductility, cm							
(39.2 °F, 1cm/min)	150+	32.5	7.6	47.1	0.0	150+	18.8
Softening Point (R&B), °F	117	125	122	117	120	111	114
Component Analysis, %							
Asphaltenes (n-heptane)	21.3	22.9	13.3	13.0	5.0	5.0	15.9
Asphaltenes (iso-Octane)	3.1	1.9	3.1		3.3	2.8	3.8
Polar Aromatics	40.1	30.5	38.3	38.7	51.2	51.0	41.4
Napthene Aromatics	26.7	31.6	37.7	34.6	32.5	35.3	28.6
Saturates	10.0	12.7	9.6	11.9	8.5	6.6	13.5
Elemental Analysis							
C, %	81.9	83.8	84.5	84.8	85.6	87.0	86.3
H, %	10.3	10.1	10.4	10.2	10.5	10.5	10.1
O, %		1.0	1.1		1.1		1.0
Nitrogen, %	0.90	0.70	0.55	0.28	1.10	1.15	0.80
Sulfur, %	8.30	5.20	3.40	4.60	1.30	2.90	2.80
Vanadium, ppm	266	179	87	102	37	33	84
Nickel, ppm	135	91	35	22	95	11	43
Fe, ppm		6	100		48		105
Aromatic C, %			32.3		28.3		
Aromatic H, %			8.66		7.27		
Molecular wt. (Toluene)		820	840		710		840
% WAX (INTEVEP)	1.41	1.23	4.19	4.20	1.13	1.11	4.41
WAX M. P. (deg. C)	58.7	42.5	59.6	60.4	33.0	34.6	52.8

WRI data in italics PSU data in Monaco UT data in bold
 TAI data in Helvetica MSU data in outline

MRL ASPHALT PROPERTIES

MRL Code	AAD-2	AAE(blow)	AAF-1	AAF-2	AAG-1	AAG-2	AAH
Crude Oil Source	Ca Coast	Lloydminste	W Tx	Sour	Ca Valley		Rangely
Visc./Pen Grade	AR-2000	60/70	AC-20	AC-10	AR-4000	AR-2000	AC-10
SHRP PG Grade	PG52-28	PG70-22	PG64-10	PG58-16	PG58-10	PG58-16	PG58-22

**Aged Asphalt
(Thin Film Oven Test)**

Mass Change, %	-0.7085	-0.2888	-0.0921	-0.0685	-0.1799	-0.0190	-0.4524
Viscosity							
140°F, poise	1715	11589	4579	2011	3253	1781	2809
275°F, cSt	370	914	472	321	304	216	441
Viscosity Ratio (140°F)	2.86	3.19	2.45	2.32	1.75	1.69	2.66

IEC Separations (wt %)

	AAF-1	AAG-1
Strong Acid*	15.4	18.1
SA Mol. Wt, VPO, Toluene	1170	1080
Amphoterics*		
Strong Base	6.1	12.0
Weak Acid	9.8	11.4
Weak Base	8.5	9.1
Neutral	56.7	50.4
Neutrals plus acids**		67.6
Amphoterics**		18.5
Bases**		12.0
Neutral Fraction		
Viscosity, poise, 77°F	4,795	2,605
*calculated **WRI Method		

SEC Fraction, MW

VPO, Toluene						
I			8690		7900	
SEC I, TFAAT Aged			10100		7800	
II						
Fraction II - wt. %	76.8	73.6	85.6		87.1	89.2
Visc. with SEC fraction 1 removed (77°F, poise)		3144	533500		623800	36540
Visc. of whole asphalt, 77°F, Poise x10E-3			3,078		3,540	

MRL ASPHALT PROPERTIES

MRL Code	AAAD-2	AAE(blow)	AAF-1	AAF-2	AAG-1	AAG-2	AAH
Crude Oil Source	Ca Coast	Lloydminste	W Tx	Sour	Ca Valley		Rangely
Visc./Pen Grade	AR-2000	60/70	AC-20	AC-10	AR-4000	AR-2000	AC-10
SHRP PG Grade	PG52-28	PG70-22	PG64-10	PG58-16	PG58-10	PG58-16	PG58-22
Viscoelastic Properties							
Tank Asphalt							
Td, Tank, °C			-7.0		-3.9		
R, Tank			1.60		1.24		
G*, Pa, 60°C, 10 rad/s			3547		8171		
δ @ 60° (deg)			87.5		88.2		
G*/sinδ, kPa, 52°C	1.41			3.25		4.61	3.80
G*/sinδ, kPa, 58°C	0.67	4.52	2.60	1.39	3.02	1.88	1.66
G*/sinδ, kPa, 64°C		2.15	1.13		1.24	0.77	0.79
G*/sinδ, kPa, 70°C		1.06	0.53		0.57		
TFOT Residue							
Td, TFOT, °C		-18.9	-1.4		0.8		-1.5
R, TFOT		2.05	1.77		1.35		2.08
G*, Pa, 60°C, 10 rad/s		9656	5457		4310		4363
δ @ 60° (deg)		73.3	86.2		88.8		83.3
RTFOT Residue							
G*/sinδ, kPa, 52°C	4.43			7.95		6.48	
G*/sinδ, kPa, 58°C	2.08		5.83	3.27	4.58	2.38	4.75
G*/sinδ, kPa, 64°C		5.87	2.51	1.46	1.77	0.98	2.14
G*/sinδ, kPa, 70°C		2.82					
PAV Residue							
Td, PAV, °C			5.2		2.7		
R, PAV			2.02		1.44		
G*, Pa, 60°C, 10 rad/s			18845		9581		
δ @ 60° (deg)			81.5		87.5		
G* sinδ, MPa @ 10° C							
G* sinδ, MPa @ 15° C							
G* sinδ, MPa @ 20° C	2.2						
G* sinδ, MPa @ 25° C	1.0	2.3		4.6		4.8	2.5
G* sinδ, MPa @ 30° C		1.4	3.8	2.2	3.4	1.7	
S(t), MPa, @ 0°C			90		99	50	
S(t), MPa, @ -10°C		100	333	149		417	132
S(t), MPa, @ -20°C	162	334		448		1219	
S(t), MPa, @ -30°C	562						
m @ 0° C			0.30		0.49	0.46	
m @ -10° C		0.31	0.27	0.32		0.34	0.31
m @ -20° C	0.34	0.29		0.23		0.14	
m @ -30° C	0.25						
Failure strain 0°C		13.21	10.04		5.23	>1.0	
Failure strain -10°C	7.33			0.92			0.33
Failure strain -20°C	0.23						

MRL ASPHALT PROPERTIES

MRL Code	AAD-2	AAE(blown	AAF-1	AAF-2	AAG-1	AAG-2	AAH
Crude Oil Source	Ca Coast	Lloydminste	W Tx Sour		Ca Valley		Rangely
Visc./Pen Grade	AR-2000	60/70	AC-20	AC-10	AR-4000	AR-2000	AC-10
SHRP PG Grade	PG52-28	PG70-22	PG64-10	PG58-16	PG58-10	PG58-16	PG58-22

Functional Group Analysis

Carboxylic Acids							
(Tank)	<i>0.020</i>	<i>0.015</i>	<i><.005</i>		<i><.005</i>		<i><.005</i>
Acid Salts							
(Tank)	<i><.005</i>	<i><.005</i>	<i><.005</i>		<i>0.055</i>		<i><.005</i>
Acid Anhydrides							
(Tank)		<i>0.000</i>	<i>0.000</i>		<i>0.000</i>		
(POV (144 hr.))							
Quinolones							
(Tank)	<i>0.018</i>	<i>0.008</i>	<i>0.007</i>		<i>0.010</i>		<i>0.008</i>
Ketones							
(Tank)	<i><.005</i>	<i><.005</i>	<i><.005</i>		<i><.005</i>		<i><.005</i>
(TFO)		<i>0.035</i>	<i>0.000</i>		<i>0.030</i>		<i>0.005</i>
(POV (144 hr.))	<i>0.070</i>	<i>0.090</i>	<i>0.070</i>		<i>0.120</i>	<i>0.140</i>	<i>0.130</i>
Phenols							
(Tank)	<i>0.032</i>	<i>0.029</i>	<i>0.010</i>		<i>0.140</i>		<i>0.017</i>
Sulfoxides							
(Tank)	<i>0.016</i>	<i>0.028</i>	<i>0.050</i>		<i>0.046</i>		<i>0.073</i>
(TFO)		<i>tr</i>	<i>0.060</i>		<i>Tr</i>		<i>0.067</i>
(POV (144 hr.))	<i>0.280</i>	<i>0.340</i>	<i>0.250</i>		<i>0.180</i>	<i>0.240</i>	<i>0.280</i>
Pyrroles							
(Tank)	<i>0.213</i>	<i>0.132</i>	<i>0.140</i>		<i>0.380</i>		<i>0.180</i>

MRL ASPHALT PROPERTIES

MRL Code	AAJ	AAK-1	AAK-2	AAL	AAM-1	AAM-2	AAN
Crude Oil Source	OK Mix	Boscan	Boscan	Cold Lake	W Tx Inter		Bow Riv
Visc./Pen Grade	AC-20	AC-30	AC-10	150/200	AC-20	AC-10	85/100
SHRP PG Grade	PG64-22	PG64-22	PG58-28	PG58-28	PG64-16	PG58-22	PG58-16
Original Asphalt							
Viscosity							
140°F, poise	1765	3256	996	800	1992	924	1429
275°F, cSt	415	562	320	259	569	407	328
Penetration, 0.1 mm							
(77°F, 100g, 5s)	67	70	154	156	64	102	90
(39.2°F, 100g, 5s)	0	2	12	16	4	3	2
Ductility, cm							
(39.2 °F, 1cm/min)	14.7	27.8	150+	150+	4.6	8.4	51.8
Softening Point (R&B), °F	118	121	108	107	125	116	110
Component Analysis, %							
Asphaltenes (n-heptane)	<i>10.6</i>	<i>20.1</i>	<i>19.2</i>	18.9	<i>4.0</i>	<i>4.8</i>	<i>15.7</i>
Asphaltenes (iso-Octane)	<i>3.9</i>	<i>2.8</i>	<i>2.5</i>		<i>5.4</i>	<i>4.5</i>	<i>2.8</i>
Polar Aromatics	41.5	41.8	39.4	37.3	50.3	50.0	33.9
Naphthene Aromatics	35.9	30.0	30.6	30.3	41.9	41.3	40.1
Saturates	10.9	5.1	7.5	12.1	1.9	3.0	10.3
Elemental Analysis							
C, %	<i>86.5</i>	<i>83.7</i>	83.2	<i>83.4</i>	<i>86.8</i>	87.3	<i>84.5</i>
H, %	<i>10.7</i>	<i>10.2</i>	10.3	<i>10.1</i>	<i>11.2</i>	11.0	<i>10.2</i>
O, %	<i>0.7</i>	<i>0.8</i>		<i>1.0</i>	<i>0.5</i>		<i>0.8</i>
Nitrogen, %	<i>0.60</i>	<i>0.70</i>	0.70	<i>0.60</i>	<i>0.55</i>	0.55	<i>0.70</i>
Sulfur, %	<i>1.90</i>	<i>6.40</i>	6.90	<i>5.50</i>	<i>1.20</i>	1.90	<i>4.30</i>
Vanadium, ppm	<i>148</i>	<i>1480</i>	1165	<i>244</i>	<i>58</i>	54	<i>157</i>
Nickel, ppm	<i>74</i>	<i>142</i>	117	<i>98</i>	<i>36</i>	32	<i>65</i>
Fe, ppm	<i>63</i>	24		<i>8</i>	255		<i>21</i>
Aromatic C, %		31.9			24.7		
Aromatic H, %		6.83			6.51		
Molecular wt. (Toluene)	<i>1030</i>	<i>860</i>		<i>760</i>	<i>1300</i>		<i>890</i>
% WAX (INTEVEP)	4.91	1.17	1.14	1.23	4.21	6.41	2.74
WAX M. P. (deg. C)	43.2	56.1	54.1	43.9	32.9	32.5	55.3

WRI data in italics PSU data in Monaco UT data in bold
 TAI data in Helvetica MSU data in outline

MRL ASPHALT PROPERTIES

MRL Code	AAJ	AAK-1	AAK-2	AAL	AAM-1	AAM-2	AAN
Crude Oil Source	OK Mix	Boscan	Boscan	Cold Lake	W Tx Inter		Bow Riv
Visc./Pen Grade	AC-20	AC-30	AC-10	150/200	AC-20	AC-10	85/100
SHRP PG Grade	PG64-22	PG64-22	PG58-28	PG58-28	PG64-16	PG58-22	PG58-16

**Aged Asphalt
(Thin Film Oven Test)**

Mass Change, %	0.0260	-0.5483	-1.2305	-0.4151	+0.0516	+0.0671	-0.0502
Viscosity							
140°F, poise	4021	9708	3098	2180	3947	1816	3027
275°F, cSt	550	930	533	403	744	526	460
Viscosity Ratio (140°F)	2.28	2.98	3.11	2.73	1.98	1.96	2.12

IEC Separations (wt %)

	AAK-1	AAM-1
Strong Acid*	3.7	4.7
SA Mol. Wt, VPO, Toluene	2780	3040
Amphoterics*	15	9
Strong Base	8.0	10.4
Weak Acid	8.6	10.0
Weak Base	7.5	9.1
Neutral	52.5	53.4
Neutrals plus acids**	61.6	65.0
Amphoterics**	24.3	18.5
Bases**	9.9	14.3
Neutral Fraction		
Viscosity, poise, 77°F	463	11,910
*calculated **WRI Method		

SEC Fraction, MW

VPO, Toluene							
I		10000			4600		
SEC I, TFAAT Aged		13000			5700		
II							
Fraction II - wt. %	78.9	74.1	76.5	77.3	69.5	72.5	79.2
Visc. with SEC fraction 1 removed (77°F, poise)	47220	11240			263500		23710
Visc. of whole asphalt, 77°F, Poise x10E-3		1,077			1123		

MRL ASPHALT PROPERTIES

MRL Code	AAJ	AAK-1	AAK-2	AAL	AAM-1	AAM-2	AAN
Crude Oil Source	OK Mix	Boscan	Boscan	Cold Lake	W Tx Inter		Bow Riv
Visc./Pen Grade	AC-20	AC-30	AC-10	150/200	AC-20	AC-10	85/100
SHRP PG Grade	PG64-22	PG64-22	PG58-28	PG58-28	PG64-16	PG58-22	PG58-16
Viscoelastic Properties							
Tank Asphalt							
Td, Tank, °C		-14.7			1.0		
R, Tank		1.60			1.93		
G*, Pa, 60°C, 10 rad/s		5445			3784		
δ @ 60° (deg)		80.0			84.0		
G*/sinδ, kPa, 52°C			2.76	2.44			
G*/sinδ, kPa, 58°C	2.62	3.79	1.32	1.13	2.43	1.72	1.86
G*/sinδ, kPa, 64°C	1.19	1.78			1.15	0.84	0.84
G*/sinδ, kPa, 70°C		0.86			0.57		
TFOT Residue							
Td, TFOT, °C	-4.3	-9.3		-18.0	4.8		-1.0
R, TFOT	1.92	1.80		1.67	2.21		2.02
G*, Pa, 60°C, 10 rad/s	5570	8442		2664	4857		3742
δ @ 60° (deg)	83.4	76.2		83.0	82.0		84.6
RTFOT Residue							
G*/sinδ, kPa, 52°C			8.05	5.71		7.76	
G*/sinδ, kPa, 58°C	6.78	9.55	3.69	2.54	5.51	3.31	3.34
G*/sinδ, kPa, 64°C	2.96	4.50	1.77		2.46	1.37	1.50
G*/sinδ, kPa, 70°C		2.21			1.17		
PAV Residue							
Td, PAV, °C		-9.2			6.0		
R, PAV		1.94			2.61		
G*, Pa, 60°C, 10 rad/s		20221			14458		
δ @ 60° (deg)		71.5			74.2		
G* <i>sinδ</i> , MPa @ 10° C							
G* <i>sinδ</i> , MPa @ 15° C							
G* <i>sinδ</i> , MPa @ 20° C			2.7	2.6	3.2	2.7	
G* <i>sinδ</i> , MPa @ 25° C	3.0	3.1	1.2	1.3	1.9	1.5	2.6
G* <i>sinδ</i> , MPa @ 30° C		1.5					
S(t), MPa, @ 0°C							
S(t), MPa, @ -10°C	135	150	46	64	146	95	145
S(t), MPa, @ -20°C			235	276		313	
S(t), MPa, @ -30°C							
m @ 0° C							
m @ -10° C	0.32	0.35	0.42	0.41	0.29	0.33	0.30
m @ -20° C			0.33	0.31		0.26	
m @ -30° C							
Failure strain 0°C		>3.48	>10.6			>5.91	
Failure strain -10°C	4.33	3.48	0.46	3.74	5.23	5.91	1.09
Failure strain -20°C							

MRL ASPHALT PROPERTIES

MRL Code	AAJ	AAK-1	AAK-2	AAL	AAM-1	AAM-2	AAN
Crude Oil Source	OK Mix	Boscan	Boscan	Cold Lake	W Tx Inter		Bow Riv
Visc./Pen Grade	AC-20	AC-30	AC-10	150/200	AC-20	AC-10	85/100
SHRP PG Grade	PG64-22	PG64-22	PG58-28	PG58-28	PG64-16	PG58-22	PG58-16

Functional Group Analysis

Carboxylic Acids (Tank)	<i><.005</i>	<i>0.012</i>	<i>0.023</i>	<i>0.013</i>	<i><.005</i>	<i>0.008</i>	<i><.005</i>
Acid Salts (Tank)	<i><.005</i>	<i><.005</i>	<i><.005</i>	<i><.005</i>	<i><.005</i>	<i><.005</i>	<i><.005</i>
Acid Anhydrides (Tank)		<i>0.000</i>			<i>0.000</i>		<i>0.000</i>
(POV (144 hr.))							
Quinolones (Tank)	<i>0.008</i>	<i>0.014</i>	<i>0.010</i>	<i>0.011</i>	<i>0.013</i>	<i>0.006</i>	<i>0.014</i>
Ketones (Tank)	<i><.005</i>	<i><.005</i>	<i><.005</i>	<i><.005</i>	<i><.005</i>	<i><.005</i>	<i><.005</i>
(TFO)	<i>0.020</i>	<i>0.030</i>			<i>0.020</i>		<i>0.010</i>
(POV (144 hr.))	<i>0.130</i>	<i>0.050</i>	<i>0.060</i>		<i>0.110</i>	<i>0.110</i>	<i>0.070</i>
Phenols (Tank)	<i>0.036</i>	<i>0.030</i>	<i>0.006</i>	<i>0.045</i>	<i>0.070</i>	<i>0.034</i>	<i>0.030</i>
Sulfoxides (Tank)	<i>0.036</i>	<i>0.022</i>	<i>0.107</i>	<i>0.031</i>	<i>0.023</i>	<i>0.016</i>	<i>0.033</i>
(TFO)	<i>tr</i>	<i>Tr</i>			<i>Tr</i>		<i>tr</i>
(POV (144 hr.))	<i>0.190</i>	<i>0.210</i>	<i>0.230</i>		<i>0.100</i>	<i>0.100</i>	<i>0.330</i>
Pyrroles (Tank)	<i>0.218</i>	<i>0.120</i>	<i>0.182</i>	<i>0.166</i>	<i>0.170</i>	<i>0.187</i>	<i>0.168</i>

MRL ASPHALT PROPERTIES

MRL Code	AAO	AAP	AAQ	AAR	AAS-1	AAS-2	AAS-3
Crude Oil Source	Arab Hvy	OK Mix	WY/Can	Maya/Wy		Arab Hvy	
Visc./Pen Grade	AC-10	AC-20	AC-10	AC-20	AC-20	AC-10	AC-30
SHRP PG Grade	PG58-22	PG64-22	PG58-22	PG64-22	PG64-22	PG58-28	PG64-22
Original Asphalt							
Viscosity							
140°F, poise	1151	2300	994	1896	2187	1220	3129
275°F, cSt	335	505	239	390	472	358	557
Penetration, 0.1 mm							
(77°F, 100g, 5s)	106	71	92	76	64	96	52
(39.2°F, 100g, 5s)	8	1	4	6	8	10	5
Ductility, cm							
(39.2 °F, 1cm/min)	55.3	11.2	25.3	17.3	13.7	66.1	7.7
Softening Point (R&B), °F	115	120	108	120	121	112	124
Component Analysis, %							
Asphaltenes (n-heptane)	16.4	12.6	16.2	18.4	18.4	17.1	17.3
Asphaltenes (iso-Octane)					2.9		
Polar Aromatics	32.9	36.9	25.9	30.5	34.1	30.0	37.7
Napthene Aromatics	41.8	36.4	44.8	41.1	39.7	46.4	39.9
Saturates	8.6	13.2	12.5	10.0	5.9	6.4	3.8
Elemental Analysis							
C, %	83.8	85.9	85.5	84.1	84.0	83.1	81.7
H, %	10.1	10.9	10.1	10.1	10.0	9.8	10.1
O, %	0.5	0.8	0.5	0.6	0.8		
Nitrogen, %	0.40	0.60	0.60	0.69	0.60	0.44	0.48
Sulfur, %	5.00	1.70	3.60	4.60	5.40	6.76	6.21
Vanadium, ppm	163	128	126	334	159	133	137
Nickel, ppm	46	68	51	79	52	37	40
Fe, ppm	18	48	80	13	51		
Aromatic C _r , %							
Aromatic H _r , %							
Molecular wt. (Toluene)	930	1090	810	880	960		
% WAX (INTEVEP)	2.56	4.77	3.55	2.76	2.89	2.85	3.53
WAX M. P. (deg. C)	59.8	51.3	61.6	57.3	55.8	58.9	66.0

WRI data in italics PSU data in Monaco UT data in bold
 TAI data in Helvetica MSU data in outline

MRL ASPHALT PROPERTIES

MRL Code	AAO	AAP	AAQ	AAR	AAS-1	AAS-2	AAS-3
Crude Oil Source	Arab Hvy	OK Mix	WY/Can	Maya/Wy		Arab Hvy	
Visc./Pen Grade	AC-10	AC-20	AC-10	AC-20	AC-20	AC-10	AC-30
SHRP PG Grade	PG58-22	PG64-22	PG58-22	PG64-22	PG64-22	PG58-28	PG64-22

**Aged Asphalt
(Thin Film Oven Test)**

Mass Change, %	-0.0071	-0.0527	-0.0864	-0.0972	--0.0394	--0.0160	--0.0550
Viscosity							
140°F, poise	2332	5854	1872	4224	4827	2739	7547
275°F, cSt	442	712	299	518	659	495	789
Viscosity Ratio (140°F)	2.03	2.55	1.88	2.23	2.21	3.25	2.41

IEC Separations (wt %)

Strong Acid*
 SA Mol. Wt,VPO, Toluene
 Amphoterics*
 Strong Base
 Weak Acid
 Weak Base
 Neutral
 Neutrals plus acids**
 Amphoterics**
 Bases**
 Neutral Fraction
 Viscosity, poise, 77°F
 *calculated **WRI Method

SEC Fraction, MW

VPO, Toluene

I
 SEC I, TFAAT Aged
 II

Fraction II - wt. %	77.0	75.6	81.4	76.4	76.5
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Visc. with SEC fraction 1
 removed (77°F, poise)
 Visc. of whole asphalt,
 77°F, Poise x10E-3

13130

MRL ASPHALT PROPERTIES

MRL Code	AAO	AAP	AAQ	AAR	AAS-1	AAS-2	AAS-3
Crude Oil Source	Arab Hvy	OK Mix	WY/Can	Maya/Wy		Arab Hvy	
Visc./Pen Grade	AC-10	AC-20	AC-10	AC-20	AC-20	AC-10	AC-30
SHRP PG Grade	PG58-22	PG64-22	PG58-22	PG64-22	PG64-22	PG58-28	PG64-22
Viscoelastic Properties							
Tank Asphalt							
Td, Tank, °C							
R, Tank							
G*, Pa, 60°C, 10 rad/s							
δ @ 60° (deg)							
G*/sinδ, kPa, 52°C			3.12				
G*/sinδ, kPa, 58°C	1.93	3.47	1.40	2.27	2.24	2.07	4.31
G*/sinδ, kPa, 64°C	0.92	1.60	0.63	1.06	1.11	0.99	1.94
G*/sinδ, kPa, 70°C							0.94
TFOT Residue							
Td, TFOT, °C	-7.8	-7.8	-3.0	-7.4	-8.0		
R, TFOT	1.78	2.08	1.78	1.82	1.84		
G*, Pa, 60°C, 10 rad/s	3323	6621	2675	4722	5751		
δ @ 60° (deg)	83.6	82.9	85.9	81.7	81.0		
RTFOT Residue							
G*/sinδ, kPa, 52°C			6.25				
G*/sinδ, kPa, 58°C	3.05	6.22	2.69	5.04	6.02	3.16	8.52
G*/sinδ, kPa, 64°C	1.45	2.87	1.19	2.38	2.67	1.51	3.86
G*/sinδ, kPa, 70°C							
PAV Residue							
Td, PAV, °C							
R, PAV							
G*, Pa, 60°C, 10 rad/s							
δ @ 60° (deg)							
G*sinδ, MPa @ 10° C							
G*sinδ, MPa @ 15° C							
G*sinδ, MPa @ 20° C	3.2	3.3		4.6		2.5	
G*sinδ, MPa @ 25° C	1.6	2.0	2.9	2.5	2.2	1.5	3.2
G*sinδ, MPa @ 30° C							1.8
S(t), MPa, @ 0°C							
S(t), MPa, @ -10°C	107	93	157	132	109	58	121
S(t), MPa, @ -20°C						243	
S(t), MPa, @ -30°C							
m @ 0° C							
m @ -10° C	0.35	0.32	0.34	0.35	0.35	0.38	0.35
m @ -20° C						0.30	
m @ -30° C							
Failure strain 0°C							>2.55
Failure strain -10°C	4.14	5.32	0.88	2.13	3.24	6.37	2.55
Failure strain -20°C							

MRL ASPHALT PROPERTIES

MRL Code	AAO	AAP	AAQ	AAR	AAS-1	AAS-2	AAS-3
Crude Oil Source	Arab Hvy	OK Mix	WY/Can	Maya/Wy		Arab Hvy	
Visc./Pen Grade	AC-10	AC-20	AC-10	AC-20	AC-20	AC-10	AC-30
SHRP PG Grade	PG58-22	PG64-22	PG58-22	PG64-22	PG64-22	PG58-28	PG64-22

Functional Group Analysis

Carboxylic Acids (Tank)	<i>0.008</i>	<i><.005</i>	<i><.005</i>	<i>0.009</i>	<i><.005</i>		
Acid Salts (Tank)	<i><.005</i>	<i><.005</i>	<i><.005</i>	<i><.005</i>	<i><.005</i>		
Acid Anhydrides (Tank) (POV (144 hr.))					<i>0.000</i>		
Quinolones (Tank)	<i>0.008</i>	<i>0.010</i>	<i>0.011</i>	<i>0.018</i>	<i>0.009</i>		
Ketones (Tank) (TFO) (POV (144 hr.))	<i><.005</i>	<i>0.022</i>	<i><.005</i>	<i><.005</i>	<i><.005</i>	<i>0.000</i>	<i>0.070</i>
Phenols (Tank)	<i>0.003</i>	<i>0.047</i>	<i>0.015</i>	<i>0.013</i>	<i>0.013</i>		
Sulfoxides (Tank) (TFO) (POV (144 hr.))	<i>0.052</i>	<i>0.041</i>	<i>0.073</i>	<i>0.040</i>	<i>0.022</i>	<i>tr</i>	<i>0.290</i>
Pyrroles (Tank)	<i>0.171</i>	<i>0.183</i>	<i>0.173</i>	<i>0.190</i>	<i>0.118</i>		

MRL ASPHALT PROPERTIES

MRL Code	AAT	AAU	AAV	AAW	AAX	AAZ	AAZ
Crude Oil Source	MayaBlend	ANS/Ca	ANS	W TX/Maya	Potaku/La	Maya/Arab	WTx/Cost
Visc./Pen Grade	AC-20	AC-20	AC-5	AC-20	AC-20	AC-20	AC-20
SHRP PG Grade	PG64-16	PG64-16	PG52-22	PG64-16	PG64-16	PG64-22	PG58-16
Original Asphalt							
Viscosity							
140°F, poise	2092	2073	561	1971	1908	2155	1952
275°F, cSt	395	381	240	384	380	425	359
Penetration, 0.1 mm							
(77°F, 100g, 5s)	63	68	121	64	51	82	58
(39.2°F, 100g, 5s)	5	2	8	1	4	5	3
Ductility, cm							
(39.2 °F, 1cm/min)	9.9	11.1	150+	8.3	7.3	13.9	13.9
Softening Point (R&B), °F	120	121	110	120	121	119	117
Component Analysis, %							
Asphaltenes (n-heptane)	17.3	17.7	9.7	17.9	12.0	22.4	9.2
Asphaltenes (iso-Octane)			3.3	2.9	3.1		4.0
Polar Aromatics	42.5	40.5	39.5	35.7	41.3	31.4	42.0
Napthene Aromatics	32.3	33.6	38.9	37.1	39.6	35.4	43.1
Saturates	7.7	7.9	10.9	9.3	7.9	9.4	6.8
Elemental Analysis							
C, %	83.9	84.4	86.4	84.5	86.6	83.7	85.0
H, %	10.1	10.2	10.5	10.1	10.4	10.1	10.0
O, %	0.7	0.7	1.1	0.9	1.1	0.5	0.9
Nitrogen, %	0.60	0.80	0.80	0.70	0.80	0.60	0.60
Sulfur, %	5.10	4.00	2.40	4.50	2.40	5.40	4.40
Vanadium, ppm	201	197	92	334	116	439	102
Nickel, ppm	80	98	41	80	56	88	35
Fe, ppm	54	22	6	33	94	16	40
Aromatic C, %							
Aromatic E, %							
Molecular wt. (Toluene)	880	880	890	890	970	860	970
% WAX (INTEVEP)	2.55	2.35	3.13	4.20	3.51	2.60	2.54
WAX M. P. (deg. C)	63.1	58.6	61.3	62.6	55.1	62.3	43.8

WRI data in italics PSU data in Monaco UT data in bold
 TAI data in Helvetica MSU data in outline

MRL ASPHALT PROPERTIES

MRL Code	AAT	AAU	AAV	AAW	AAX	AAZ	AAZ
Crude Oil Source	MayaBlend	ANS/Ca	ANS	W TX/Maya	Potaku/La	Maya/Arab	WTx/Cost
Visc./Pen Grade	AC-20	AC-20	AC-5	AC-20	AC-20	AC-20	AC-20
SHRP PG Grade	PG64-16	PG64-16	PG52-22	PG64-16	PG64-16	PG64-22	PG58-16

**Aged Asphalt
(Thin Film Oven Test)**

Mass Change, %	-0.1559	-0.6364	-0.1338	-0.0819	-0.0576	-0.1877	0.0716
Viscosity							
140°F, poise	5297	5526	1037	4868	4048	6356	3214
275°F, cSt	562	566	293	526	503	664	446
Viscosity Ratio (140°F)	2.53	2.67	1.85	2.47	2.12	2.95	1.65

IEC Separations (wt %)

Strong Acid*
 SA Mol. Wt, VPO, Toluene
 Amphoterics*
 Strong Base
 Weak Acid
 Weak Base
 Neutral
 Neutrals plus acids**
 Amphoterics**
 Bases**
 Neutral Fraction
 Viscosity, poise, 77°F
 *calculated **WRI Method

SEC Fraction, MW

VPO, Toluene

I
 SEC I, TFAAT Aged
 II
 Fraction II - wt. %

76.0	78.9	84.3	80.1	81.8	74.0	84.6
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Visc. with SEC fraction 1 removed (77°F, poise)	36930	42770	137700	228300
Visc. of whole asphalt, 77°F, Poise x10E-3				

MRL ASPHALT PROPERTIES

MRL Code	AAT	AAU	AAV	AAW	AAX	AAZ	AAZ
Crude Oil Source	MayaBlend	ANS/Ca	ANS	W TX/Maya	Potaku/La	Maya/Arab	WTx/Cost
Visc./Pen Grade	AC-20	AC-20	AC-5	AC-20	AC-20	AC-20	AC-20
SHRP PG Grade	PG64-16	PG64-16	PG52-22	PG64-16	PG64-16	PG64-22	PG58-16
Viscoelastic Properties							
Tank Asphalt							
Td, Tank, °C							
R, Tank							
G*, Pa, 60°C, 10 rad/s							
δ @ 60° (deg)							
G*/sinδ, kPa, 52°C			1.70				
G*/sinδ, kPa, 58°C	3.68	2.67	0.77	3.12	2.19	2.97	2.43
G*/sinδ, kPa, 64°C	1.60	1.21		1.41	1.04	1.36	1.09
G*/sinδ, kPa, 70°C							
TFOT Residue							
Td, TFOT, °C	-4.3	-4.1	-5.5	-1.4		-9.2	
R, TFOT	1.69	1.64	1.50	1.80		2.12	
G*, Pa, 60°C, 10 rad/s	6741	7374	1332	4978	6003	6221	4290
δ @ 60° (deg)	82.3	82.0	87.9	81.2	85.1	75.1	87.8
RTFOT Residue							
G*/sinδ, kPa, 52°C			3.38				
G*/sinδ, kPa, 58°C	6.22	7.74	1.46	7.60	5.21	10.42	4.58
G*/sinδ, kPa, 64°C	2.75	3.30		3.31	2.26	4.82	1.96
G*/sinδ, kPa, 70°C		1.49				2.32	
PAV Residue							
Td, PAV, °C							
R, PAV							
G*, Pa, 60°C, 10 rad/s							
δ @ 60° (deg)							
G*sinδ, MPa @ 10° C							
G*sinδ, MPa @ 15° C							
G*sinδ, MPa @ 20° C			3.8				
G*sinδ, MPa @ 25° C	6.0		1.8	3.7	4.6	2.1	4.2
G*sinδ, MPa @ 30° C	3.2	2.6		2.0	2.3	1.0	1.8
S(t), MPa, @ 0°C	64	69		54			
S(t), MPa, @ -10°C	217	242	124	200	209	104	235
S(t), MPa, @ -20°C						316	
S(t), MPa, @ -30°C							
m @ 0° C	0.40	0.41		0.40			
m @ -10° C	0.29	0.30	0.39	0.30	0.30	0.33	0.34
m @ -20° C						0.27	
m @ -30° C							
Failure strain 0°C	7.17	6.16		7.30	6.58	11.41	8.47
Failure strain -10°C			2.14		0.92		
Failure strain -20°C							

MRL ASPHALT PROPERTIES

MRL Code	AAT	AAU	AAV	AAW	AAX	AAZ	AAZ
Crude Oil Source	MayaBlend	ANS/Ca	ANS	W TX/Maya	Potaku/La	Maya/Arab	WTx/Cost
Visc./Pen Grade	AC-20	AC-20	AC-5	AC-20	AC-20	AC-20	AC-20
SHRP PG Grade	PG64-16	PG64-16	PG52-22	PG64-16	PG64-16	PG64-22	PG58-16

Functional Group Analysis

Carboxylic Acids (Tank)	0.006	0.007	<.005	<.005	0.009	<.005	0.008
Acid Salts (Tank)	<.005	<.005	<.005	<.005	<.005	<.005	<.005
Acid Anhydrides (Tank) (POV (144 hr.))				0.000			
Quinolones (Tank)	0.012	0.019	0.007	0.017	0.011	0.012	0.008
Ketones (Tank) (TFO) (POV (144 hr.))	<.005	<.005	<.005 0.005 0.100	<.005 0.000 0.070	<.005 0.005 0.120	<.005	<.005
Phenols (Tank)	0.017	0.043	0.036	0.052	0.048	0.027	0.022
Sulfoxides (Tank) (TFO) (POV (144 hr.))	0.057	0.039	0.033 tr 0.270	0.030 tr 0.340	0.075 0.080 0.240	0.048	0.045
Pyrroles (Tank)	0.214	0.239	0.196	0.155	0.196	0.204	0.166

MRL ASPHALT PROPERTIES

MRL Code	ABA(blown	ABC	ABD	ABF	ABG	ABH	ABK
Crude Oil Source	WTxI/S	Ms Valley	Ca Valley	TiaJuana(H)	Laguna	Russian	CaWilm
Visc./Pen Grade	AC-20	AC-20	AR-4000	AC-20	B-85	AC-20	AR-4000
SHRP PG Grade	PG64-16	PG64-28	PG58-10	PG64-28	PG64-28	PG58-22	PG64-16
Original Asphalt							
Viscosity							
140°F, poise	1822	2091	2112	2527	2226	782	2148
275°F, cSt	356	474	241	416	392	212	275
Penetration, 0.1 mm							
(77°F, 100g, 5s)	70	76	47	66	89	98	56
(39.2°F, 100g, 5s)	8	10	1	5	7	5	3
Ductility, cm							
(39.2 °F, 1cm/min)	5.5	31.4	0	103.5	112.4	69.6	0
Softening Point (R&B), °F	120	117	120	119	118	114	119
Component Analysis, %							
Asphaltenes (n-heptane)	15.7	25.6	7.0	15.4	15.7	19.5	9.3
Asphaltenes (iso-Octane)			3.2				
Polar Aromatics	34.1	23.2	52.7	32.0	18.7	26.4	46.3
Napthene Aromatics	37.5	44.0	28.4	40.0	46.6	44.3	33.1
Saturates	11.2	7.1	10.4	11.2	19.1	9.7	10.4
Elemental Analysis							
C, %	86.4	83.2	86.8	85.5	83.7	89.8(?)	85
H, %	10.8	9.9	10.7	10.28	11.2	11.0	10.7
O, %	1.5	0.4	1.2				
Nitrogen, %	0.42	0.30	1.20	0.85	0.38	0.72	1.03
Sulfur, %	2.30	6.40	1.60	3.50	4.05	2.69	2.79
Vanadium, ppm	28	37	62	612	494	141	64
Nickel, ppm	14	25	123	82	82	40	113
Fe, ppm	61	12	54				
Aromatic C, %							
Aromatic H, %							
Molecular wt. (Toluene)		870	728				
% WAX (INTEVEP)	4.85	2.90	0.81	0.78	0.91	3.52	1.03
WAX M. P. (deg. C)	66.2	56.6	38.2	24.5	24.3	64.3	56.5

WRI data in italics PSU data in Monaco UT data in bold
 TAI data in Helvetica MSU data in outline

MRL ASPHALT PROPERTIES

MRL Code	ABA(blown	ABC	ABD	ABF	ABG	ABH	ABK
Crude Oil Source	WTxI/S	Ms Valley	Ca Valley	TiaJuana(H)	Laguna	Russian	CaWilm
Visc./Pen Grade	AC-20	AC-20	AR-4000	AC-20	B-85	AC-20	AR-4000
SHRP PG Grade	PG64-16	PG64-28	PG58-10	PG64-28	PG64-28	PG58-22	PG64-16

**Aged Asphalt
(Thin Film Oven Test)**

Mass Change, %	-0.0205	-0.219	-0.1208	-0.1445	-0.288	0.0303	-0.1521
Viscosity							
140°F, poise	4024	5009	3800	5231	5415	1967	4212
275°F, cSt	456	668	321	581	577	317	378
Viscosity Ratio (140°F)	2.21	2.4	1.79	2.07	2.43	2.51	1.96

IEC Separations (wt %)

Strong Acid*
 SA Mol. Wt, VPO, Toluene
 Amphoterics*
 Strong Base
 Weak Acid
 Weak Base
 Neutral
 Neutrals plus acids**
 Amphoterics**
 Bases**
 Neutral Fraction
 Viscosity, poise, 77°F
 *calculated **WRI Method

SEC Fraction, MW

VPO, Toluene

I
 SEC I, TFAAT Aged
 II

Fraction II - wt. %	78.3	71.5	88.7	79.4	86.6
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Visc. with SEC fraction 1 removed (77°F, poise)	686800
Visc. of whole asphalt, 77°F, Poise x10E-3	

MRL ASPHALT PROPERTIES

MRL Code	ABA(blown	ABC	ABD	ABF	ABG	ABH	ABK
Crude Oil Source	WTxl/S	Ms Valley	Ca Valley	TiaJuana(H)	Laguna	Russian	CaWilm
Visc./Pen Grade	AC-20	AC-20	AR-4000	AC-20	B-85	AC-20	AR-4000
SHRP PG Grade	PG64-16	PG64-28	PG58-10	PG64-28	PG64-28	PG58-22	PG64-16
Viscoelastic Properties							
Tank Asphalt							
Td, Tank, °C							
R, Tank							
G*, Pa, 60°C, 10 rad/s							
δ @ 60° (deg)							
G*/sinδ, kPa, 52°C							
G*/sinδ, kPa, 58°C							
G*/sinδ, kPa, 64°C							
G*/sinδ, kPa, 70°C							
TFOT Residue							
Td, TFOT, °C							
R, TFOT							
G*, Pa, 60°C, 10 rad/s							
δ @ 60° (deg)							
RTFOT Residue							
G*/sinδ, kPa, 52°C							
G*/sinδ, kPa, 58°C							
G*/sinδ, kPa, 64°C							
G*/sinδ, kPa, 70°C							
PAV Residue							
Td, PAV, °C							
R, PAV							
G*, Pa, 60°C, 10 rad/s							
δ @ 60° (deg)							
G*sinδ, MPa @ 10° C							
G*sinδ, MPa @ 15° C							
G*sinδ, MPa @ 20° C							
G*sinδ, MPa @ 25° C							
G*sinδ, MPa @ 30° C							
S(t), MPa, @ 0°C							
S(t), MPa, @ -10°C							
S(t), MPa, @ -20°C							
S(t), MPa, @ -30°C							
m @ 0° C							
m @ -10° C							
m @ -20° C							
m @ -30° C							
Failure strain 0°C							
Failure strain -10°C							
Failure strain -20°C							

MRL ASPHALT PROPERTIES

MRL Code	ABA(blow	ABC	ABD	ABF	ABG	ABH	ABK
Crude Oil Source	WTxl/S	Ms Valley	Ca Valley	TiaJuana(H)	Laguna	Russian	CaWilm
Visc./Pen Grade	AC-20	AC-20	AR-4000	AC-20	B-85	AC-20	AR-4000
SHRP PG Grade	PG64-16	PG64-28	PG58-10	PG64-28	PG64-28	PG58-22	PG64-16

Functional Group Analysis

Carboxylic Acids (Tank)	0.025
Acid Salts (Tank)	<.005
Acid Anhydrides (Tank) (POV (144 hr.))	
Quinolones (Tank)	0.015
Ketones (Tank)	<.005
(TFO)	0.030
(POV (144 hr.))	0.150
Phenols (Tank)	0.077
Sulfoxides (Tank)	0.024
(TFO)	tr
(POV (144 hr.))	0.300
Pyrroles (Tank)	0.376

MRL ASPHALT PROPERTIES

MRL Code	ABL-1	ABL-2	ABL-3	ABM-1	ABM-2
Crude Oil Source		Boscan		Ca Valley	
Visc./Pen Grade	AC-20	EB-10	AC-10	AR-4000	AR-2000
SHRP PG Grade	PG64-	PG58-	PG58-	PG58-	PG58-
Original Asphalt					
Viscosity					
140°F, poise	2201	1097	1051	2230	1388
275°F, cSt	441	338	321	243	189
Penetration, 0.1 mm					
(77°F, 100g, 5s)	87	169	137	48	64
(39.2°F, 100g, 5s)	9	12	12	0	1
Ductility, cm					
(39.2 °F, 1cm/min)	54	150	150	0	0
Softening Point (R&B), °F	117	106	111	120	116
Component Analysis, %					
Asphaltenes (n-heptane)	22.3	17.0	20.8	7.1	6.4
Asphaltenes (iso-Octane)					
Polar Aromatics	46.1	47.6	39.1	52.4	50.0
Naphthene Aromatics	22.4	24.9	28.6	29.6	33.1
Saturates	7.3	8.6	9.5	9.0	9.1
Elemental Analysis					
C, %	83	82.3	82.8	86.3	86.6
H, %	9.72	10.14	10.33	10.3	10.2
O, %					
Nitrogen, %	0.59	0.50	1.48	1.09	1.00
Sulfur, %	5.82	6.28	5.86	1.28	1.28
Vanadium, ppm	1469	1484	1309	63	55
Nickel, ppm	129	134	118	111	98
Fe, ppm					
Aromatic C _r , %					
Aromatic H _r , %					
Molecular wt. (Toluene)					
% WAX (INTEVEP)	2.58	2.11	2.42	1.10	0.97
WAX M. P. (deg. C)	52.2	45.6	41.1	36.8	36.2

WRI data in italics PSU data in Monaco UT data in bold
 TAI data in Helvetica MSU data in outline

MRL ASPHALT PROPERTIES

MRL Code	ABL-1	ABL-2	ABL-3	ABM-1	ABM-2
Crude Oil Source		Boscan		Ca Valley	
Visc./Pen Grade	AC-20	EB-10	AC-10	AR-4000	AR-2000
SHRP PG Grade	PG64-	PG58-	PG58-	PG58-	PG58-

**Aged Asphalt
(Thin Film Oven Test)**

Mass Change, %	-0.566	-1.335	-0.399	-0.248	-0.248
Viscosity					
140°F, poise	5788	3700	2604	3603	2223
275°F, cSt	716	596	484	301	232
Viscosity Ratio (140°F)	2.63	3.37	2.48	1.62	1.6

IEC Separations (wt %)

Strong Acid*
 SA Mol. Wt,VPO, Toluene
 Amphoterics*
 Strong Base
 Weak Acid
 Weak Base
 Neutral
 Neutrals plus acids**
 Amphoterics**
 Bases**
 Neutral Fraction
 Viscosity, poise, 77°F
 *calculated **WRI Method

SEC Fraction, MW

VPO, Toluene
 I
 SEC I, TFAAT Aged
 II
 Fraction II - wt. %

Visc. with SEC fraction 1
 removed (77°F, poise)
 Visc. of whole asphalt,
 77°F, Poise x10E-3

MRL ASPHALT PROPERTIES

MRL Code	ABL-1	ABL-2	ABL-3	ABM-1	ABM-2
Crude Oil Source		Boscan		Ca Valley	
Visc./Pen Grade	AC-20	EB-10	AC-10	AR-4000	AR-2000
SHRP PG Grade	PG64-	PG58-	PG58-	PG58-	PG58-
Viscoelastic Properties					
Tank Asphalt					
Td, Tank, °C					
R, Tank					
G*, Pa, 60°C, 10 rad/s					
δ @ 60° (deg)					
G*/sin δ , kPa, 52°C	5.46	2.57			
G*/sin δ , kPa, 58°C	2.52	1.21	1.20	2.79	2.31
G*/sin δ , kPa, 64°C	1.21		0.62	1.19	0.97
G*/sin δ , kPa, 70°C					
TFOT Residue					
Td, TFOT, °C					
R, TFOT					
G*, Pa, 60°C, 10 rad/s					
δ @ 60° (deg)					
RTFOT Residue					
G*/sin δ , kPa, 52°C			6.58		7.82
G*/sin δ , kPa, 58°C	6.27	4.21	3.05	4.74	2.89
G*/sin δ , kPa, 64°C	3.00	2.01	1.52	1.88	1.24
G*/sin δ , kPa, 70°C					
PAV Residue					
Td, PAV, °C					
R, PAV					
G*, Pa, 60°C, 10 rad/s					
δ @ 60° (deg)					
G*sin δ , MPa @ 10° C					
G*sin δ , MPa @ 15° C					
G*sin δ , MPa @ 20° C					
G*sin δ , MPa @ 25° C					
G*sin δ , MPa @ 30° C					
S(t), MPa, @ 0°C					
S(t), MPa, @ -10°C					
S(t), MPa, @ -20°C					
S(t), MPa, @ -30°C					
m @ 0° C					
m @ -10° C					
m @ -20° C					
m @ -30° C					
Failure strain 0°C					
Failure strain -10°C					
Failure strain -20°C					

MRL ASPHALT PROPERTIES

MRL Code	ABL-1	ABL-2	ABL-3	ABM-1	ABM-2
Crude Oil Source		Boscan		Ca Valley	
Visc./Pen Grade	AC-20	EB-10	AC-10	AR-4000	AR-2000
SHRP PG Grade	PG64-	PG58-	PG58-	PG58-	PG58-

Functional Group Analysis

Carboxylic Acids

(Tank)

Acid Salts

(Tank)

Acid Anhydrides

(Tank)

(POV (144 hr.))

Quinolones

(Tank)

Ketones

(Tank)

(TFO)

(POV (144 hr.))

Phenols

(Tank)

Sulfoxides

(Tank)

(TFO)

(POV (144 hr.))

Pyrroles

(Tank)

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