

ASTM D2 Meeting - San Diego, CA
June 19, 2001

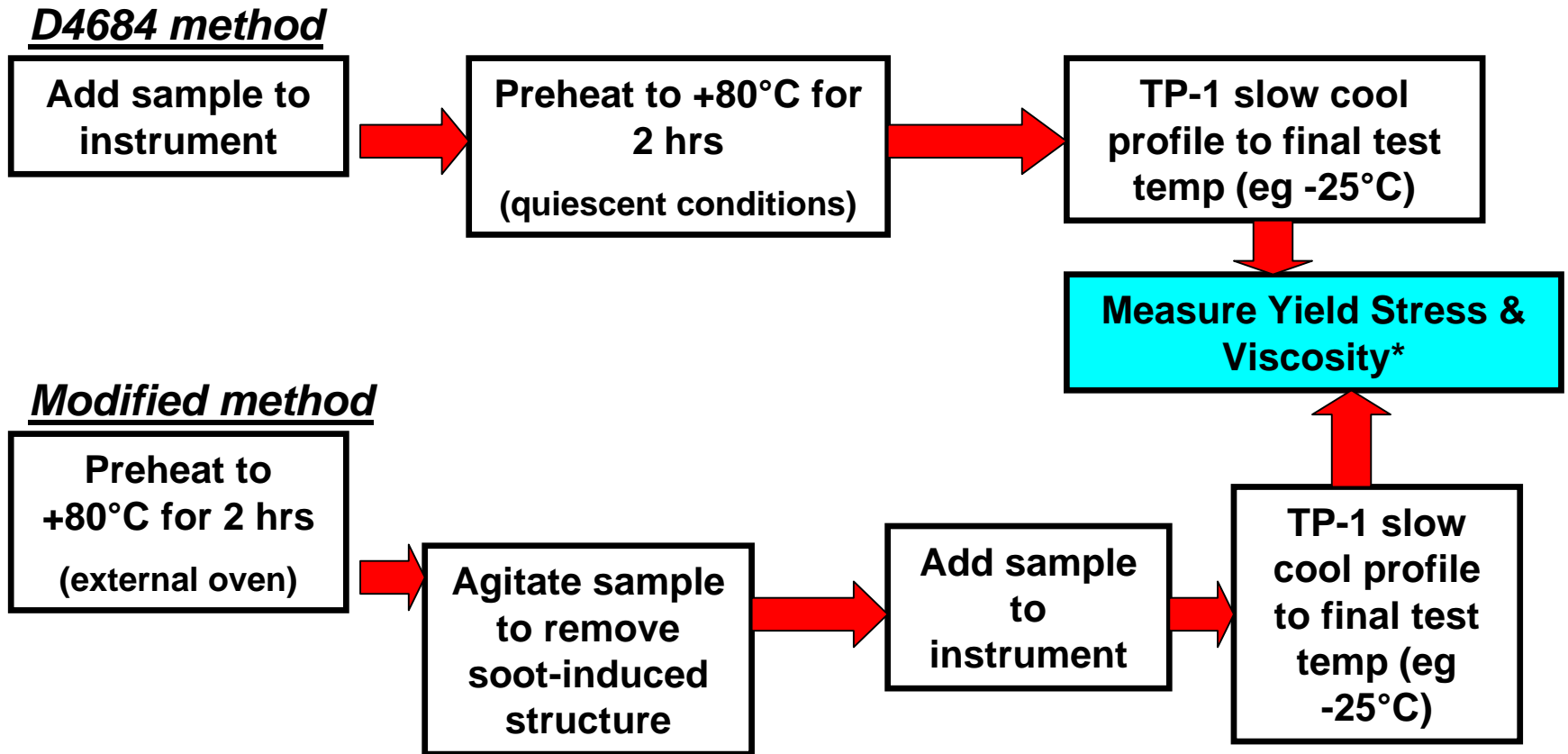
**UPDATE ON ASTM LOTRUO
ACTIVITIES AND LOW TEMPERATURE
PROPERTIES OF PC-9 MATRIX OILS**

C.J. May

Used HD Engine Oil MRV Round Robin

- **Round robin and analysis successfully completed in 1Q2001**
 - **9 samples at two temperatures (-20/-25°C) using two methods (D4684 or modified preheat); results distributed to working group members and reviewed with HDEOCP in mid-May**
- **D4684 MRV viscosity at -20°C has poorer precision than stated for fresh oils, but at -25°C, appears to be close to that stated for D4684**
 - **poorer precision of used oils displaying structure (yield stress) consistent with early D4684 MRV round robin on similar fresh oils**
- **Modified D4684 viscosity measurements at -20/-25°C (separate external preheat/agitation) have better repeatability but about the same reproducibility**
 - **the two methods give similar mean viscosities but significantly higher percentage of oils show yield stress with the standard D4684 procedure ⇒ evidence of soot agglomeration during sample preheat**

2 DIFFERENT METHODS COMPARED IN LOTRUO ROUND ROBIN



* Note that MRV test evaluates both yield stress and viscosity; for >35 Pa yield stress (failing), viscosity not normally measured, but for round robin, labs asked to report both

Next Steps

- **Complete statistical analysis of yield stress**
- **Generate research report on used oil MRV R/R**
- **Incorporate results into D4684 (likely as annexes to the method) along with guidelines for handling of used oils**
 - **obvious need for precautions associated with hazardous material**
 - **have noted in MRV clean-up that more flushing necessary**
- **Also looking at other methods of relevance (e.g. extended range SBR)**

- **To date, Imperial Oil has received 32 E-O-T drain samples from the PC-9 precision matrix including 16 M11-EGR, 15 Mack T-10 and 1 Cat 1Q sample (volumes range from 4-6 L) >> an excellent range of samples for future potential use by the task force**
 - **IOL has conducted CCS, MRV and modified MRV testing on a number of these oils**

LOW TEMP DATA ON T10 MATRIX OILS

SRC Data, Updated: June 14, 2001

SRC Code	CMIR Code	Matrix Code	Lab Code	Lab	Test	Qty	%	TGA		-20°C D4684		-25°C D4684		-20°C Mod. MRV		-25°C Mod. MRV	
								Soot	D5293	-15C, MRV	-20C, MRV	-25C MRV	-25C MRV	-20C MRV	-25C MRV	-25C MRV	-25C MRV
								cP	cP	Vis., cP	Y. Str., Pa	Vis., cP	Y. Str., Pa	Vis., cP	Y. Str., Pa	Vis., cP	Y. Str., Pa
S201-077	38810	PC-9A	A	SWRI	T-10	4L	6.0	7,030		24,500	0<Y<=35	53,100	0<Y<=35			54,200	0<Y<=35
S201-044	38811	PC-9A	D	Ethyl	T-10	4L	5.5	5,900	11,910	19,900	0<Y<=35	43,900	0<Y<=35			43,100	0<Y<=35
S201-048	38814	PC-9A	F	EMRE	T-10	4L	5.7	7,990		26,400	0<Y<=35	59,300	0<Y<=35			59,400	0<Y<=35
S201-122	38942	PC-9A	A	SWRI	T-10	4L	4.8	5,900		19,100	0<Y<=35	42,100	0<Y<=35			41,800	0<Y<=35
S201-117	38951	PC-9A	G	PEAR	T-10	4L	5.9	7,090		22,800	0<Y<=35	51,000	0<Y<=35			51,500	0<Y<=35
S201-079	38939	PC-9C	A	SWRI	T-10	4L	5.4	7,650		23,200	0<Y<=35	61,300	0<Y<=35			58,700	0<Y<=35
S201-137	38949	PC-9C	G	PEAR	T-10	4L	7.6	12,350		37,300	0<Y<=35					96,200	0<Y<=35
S201-118	38937	PC-9E	A	SWRI	T-10	4L	4.8	5,190		19,500	0<Y<=35	102,400	140<Y<=175			203,500	175<Y<=210
S201-055	38945	PC-9F	D	Ethyl	T-10	4L	5.3	6,020		17,300	0<Y<=35	76,100	35<Y<=70			69,100	0<Y<=35
S201-076	38947	PC-9H	G	PEAR	T-10	4L	7.1	7,270		19,900	0<Y<=35	57,100	0<Y<=35			58,100	0<Y<=35
S201-051	38953	PC-9H	F	EMRE	T-10	4L	5.2	5,630		14,600	0<Y<=35	45,300	0<Y<=35			44,900	0<Y<=35
S201-183	38941	PC-9G	A	SWRI	T-10	4L	5.5									46,900	0<Y<=35
S201-176	38938	PC-9J	A	SWRI	T-10	4L	6.2			17,100	0<Y<=35					44,000	0<Y<=35
S201-136	38948	PC-9J	G	PEAR	T-10	4L	5.7			17,600	0<Y<=35						
S201-054	38813			PEAR	T-10	4L		8,290		25,900	0<Y<=35	60,200	0<Y<=35			59,900	0<Y<=35
S201-184	38940	PC-9E	A	SWRI	T-10	4L	5.9										

LOW TEMP DATA - M11 EGR & 1Q MATRIX

OILS

SRC Data, Updated: June 14, 2001

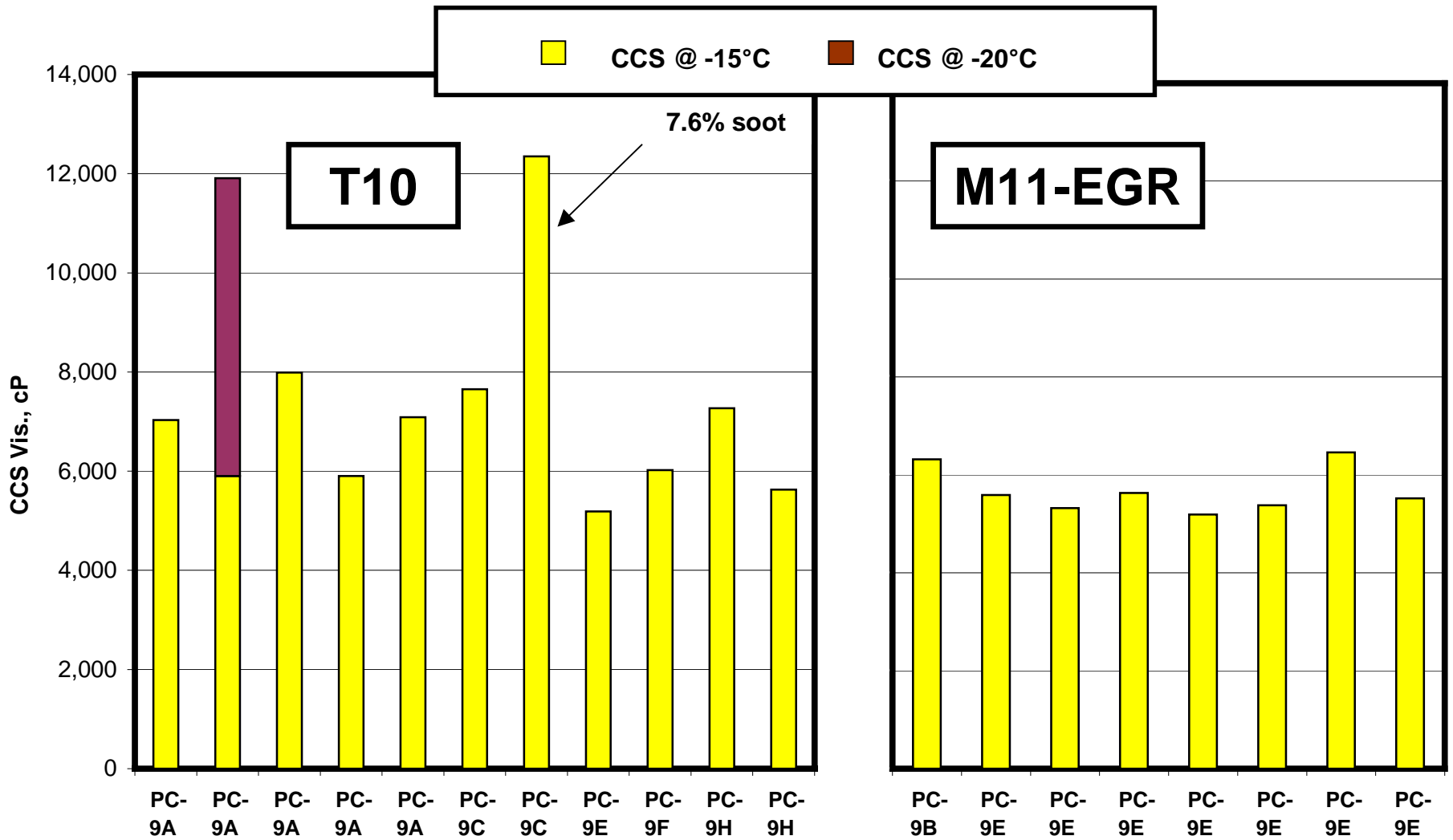
SRC Code	CMIR Code	Matrix Code	Lab Code	Lab	Test	Qty	%	TGA									
								Soot	D5293		-20°C D4684		-25°C D4684		-20°C Mod. MRV		-25°C Mod. MRV
								-15C, cP	-20C, cP	MRV Vis., cP	Y. Str., Pa	MRV Vis., cP	Y. Str., Pa	-20C MRV Vis., cP	Y. Str., Pa	-25C MRV Vis., cP	Y. Str., Pa
S201-081	38967	PC-9B	A	SWRI	M11 EGR	8L	8.0	6,320		22,600	0<Y<=35	70,400	0<Y<=35			70,700	0<Y<=35
S201-125	38927	PC-9E	G	PEAR	M11 EGR	4L	9.1	5,590		26,300	0<Y<=35						
S201-124	38928	PC-9E	G	PEAR	M11 EGR	4L	7.8			22,300	0<Y<=35						
S201-078	38929	PC-9E	G	PEAR	M11 EGR	4L	8.8			29,400	0<Y<=35	208,500	140<Y<=175				
S201-121	38930	PC-9E	G	PEAR	M11 EGR	4L	8.6			32,900	0<Y<=35	343,100	140<Y<=175				
S201-045	38931	PC-9E	D	Ethyl	M11 EGR	4L	8.1	5,320		28,200	0<Y<=35	214,100	105<Y<=140				
S201-046	38932	PC-9E	A	SWRI	M11 EGR	4L	8.7	5,630		38,900	0<Y<=35	305,400	175<Y<=210				
S201-049	38933	PC-9E	A	SWRI	M11 EGR	6L	7.7	5,190		24,000	0<Y<=35	135,000	140<Y<=175				
S201-120	38934	PC-9E	A	SWRI	M11 EGR	6L	7.8	5,380		31,300	0<Y<=35	262,300	140<Y<=175			311,200	140<Y<=175
S201-075	38962	PC-9F	G	PEAR	M11 EGR	4L	8.7	6,460		28,900	35<Y<=70	133,600	70<Y<=105			106,800	35<Y<=70
S201-174	38968	PC-9A	A	SWRI	M11 EGR	4L	7.9			23,000	0<Y<=35						
S201-126	38935	PC-9E	A	SWRI	M11 EGR	4L	8.0			23,800	0<Y<=35						
S201-119	38969	PC-9G	A	SWRI	M11 EGR	8L	7.8	5,520		64,800	210<Y<=245	683,700	315<Y<=350			529,700	210<Y<=245
S201-080	38966	PC-9J	A	SWRI	M11 EGR	4L	8.0			31,800	105<Y<=140	77,900	140<Y<=175				
S201-123	38958			PEAR	M11 EGR	4L				20,800	0<Y<=35	55,100	0<Y<=35				
S201-175	38970	PC-9F	A	SWRI	M11 EGR	4L	7.9			24,600	0<Y<=35						
S201-047	38821			SWRI	1Q	4L				20,800	0<Y<=35	50,600	0<Y<=35				
					M11 EGR		16										
					T-10		15										
					1Q		1										

MATRIX TESTS POSTED BY TMC, BUT NO USED OIL SAMPLES RECEIVED

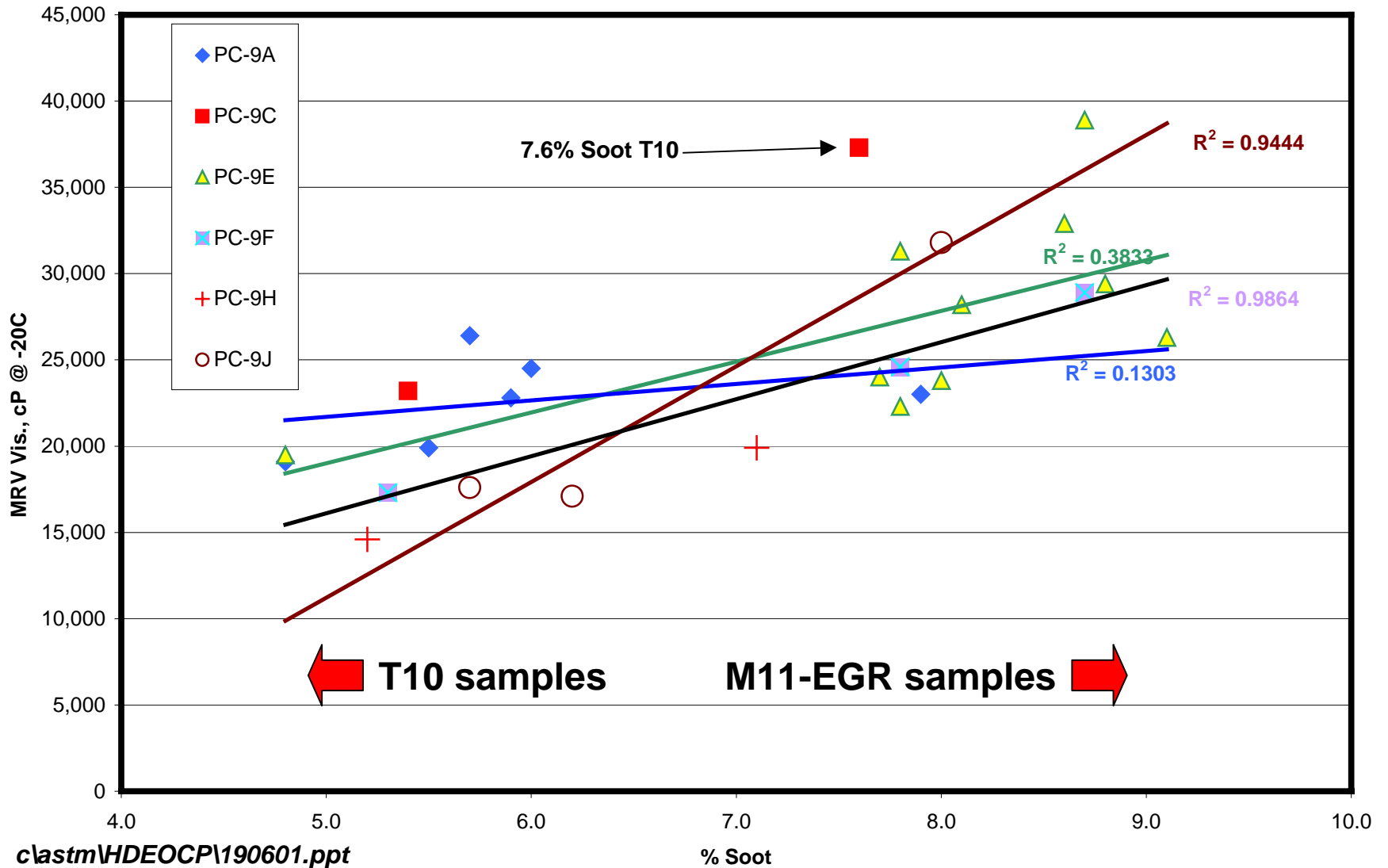
SRC Data, Updated: June 14, 2001

SRC Code	CMIR Code	Matrix Code	Lab Code	Lab	Test	Qty
	38809	PC-9A	A	SWRI	T-10	
	38815	PC-9A	B		T-10	
	38954	PC-9A	F	EMRE	T-10	
	38943	PC-9B	D	Ethyl	T-10	
	38957	PC-9D	B		T-10	
	38952	PC-9F	F	EMRE	T-10	
	40919	PC-9B	B		T-10	
	38946	PC-9D	G	PEAR	T-10	
	38950	PC-9E	G	PEAR	T-10	
	38944	PC-9G	D	Ethyl	T-10	
	38956	PC-9J	B		T-10	
	38936	PC-9E	B		M11-EGR	
	38963	PC-9D	D	Ethyl	M11-EGR	
	38968	PC-9A	A	SWRI	M11-EGR	
	38935	PC-9E	A	SWRI	M11-EGR	
	38959	PC-9A	G	PEAR	M11-EGR	
	38971	PC-9D	B		M11-EGR	
	38961	PC-9G	G	PEAR	M11-EGR	

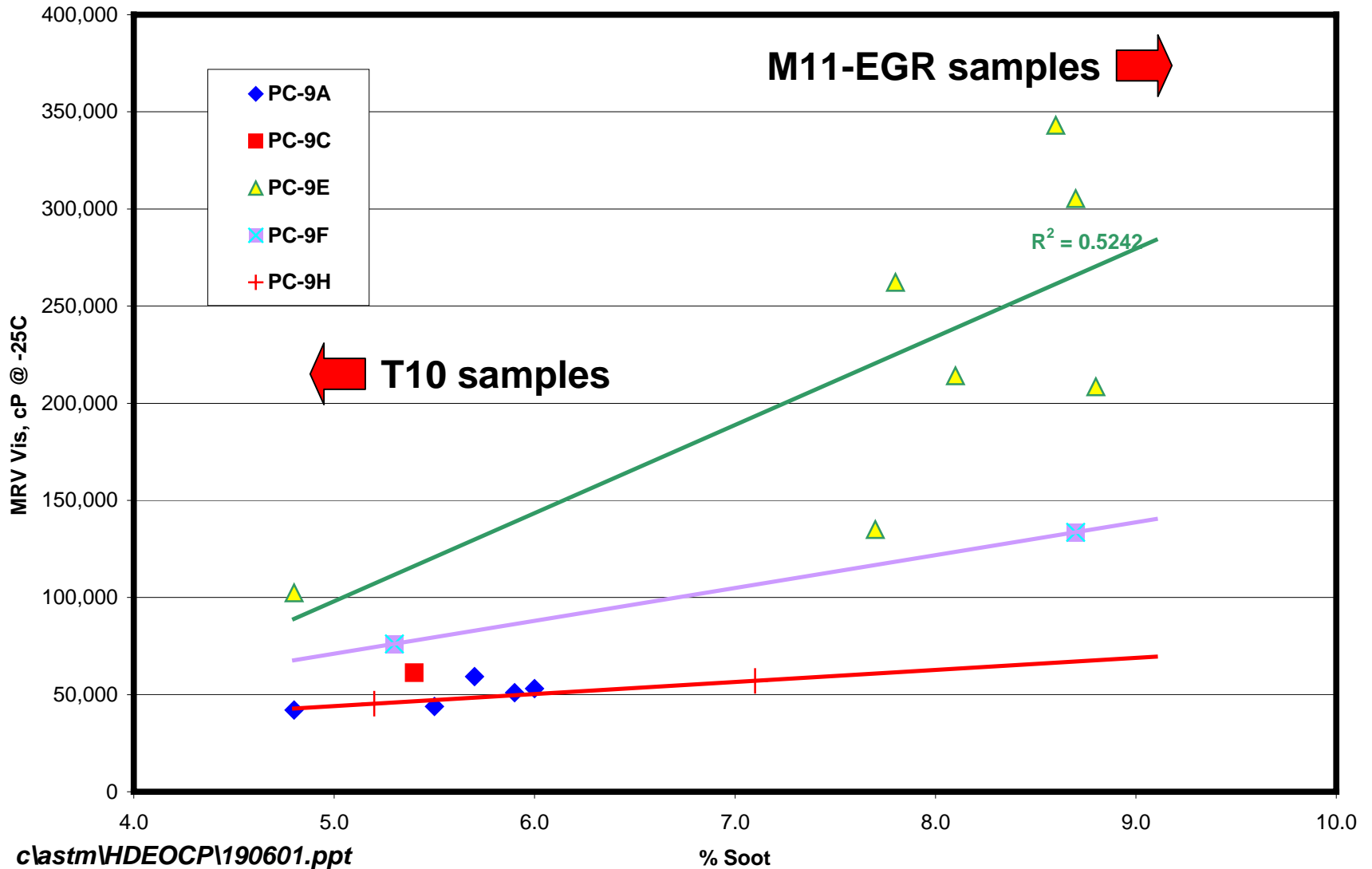
CCS ANALYSIS: MOST USED OILS IN THE 5-8,000 cP RANGE AT -15°C (~10-16,000 cP @ -20°C)



SOOT:MRV-20 RELATIONSHIP, T10 & M11EGR DRAINS



SOOT:MRV-25 RELATIONSHIP, T10 & M11EGR DRAINS



REPEAT T10 TESTS, MRV USED/FRESH

CMIR Code	38811	38814	38810	38951	38942	
Ind. Oil Code	PC-9A	PC-9A	PC-9A	PC-9A	PC-9A	PC-9A
Lab Code	D	F	A	G	A	
Engine Source	T-10	T-10	T-10	T-10	T-10	(Fresh)
% Soot Reported	5.5	5.7	6.0	5.9	4.8	

@ -20°C

MRV Vis., cP	19,900	26,400	24,500	23,400	19,100	
MRV Y. Str., Pa	0<Y<=35	0<Y<=35	0<Y<=35	0<Y<=35	0<Y<=35	

@ -25°C

MRV Vis., cP	43,900	59,300	53,100	51,000	42,100	23,900
MRV Y. Str., Pa	0<Y<=35	0<Y<=35	0<Y<=35	0<Y<=35	0<Y<=35	0<Y<=35

@ -25°C

Mod. MRV Vis., cP	43,100	59,400	54,200	51,500	41,800	
Mod. MRV Y. Str., Pa	0<Y<=35	0<Y<=35	0<Y<=35	0<Y<=35	0<Y<=35	

REPEAT T10 TESTS, MRV USED/FRESH (Cont'd)

CMIR Code	38931	38932	38933	38929	38930	38927	38928	38934	
Ind. Oil Code	PC-9E	PC-9E	PC-9E	PC-9E	PC-9E	PC-9E	PC-9E	PC-9E	PC-9E
Lab Code	D	A	A	G	G	G	G	A	
Engine Source	M11 EGR	M11 EGR	M11 EGR	M11 EGR	M11 EGR	M11 EGR	M11 EGR	M11 EGR	(fresh)
% Soot Reported	8.1	8.7	7.7	8.8	8.6	9.1	7.8	7.8	
<u>@ -20°C</u>									
MRV Vis., cP	28,200	38,900	24,000	29,400	31,200	26,300	22,300	31,300	
MRV Y. Str., Pa	0<Y<=35	0<Y<=35	0<Y<=35	0<Y<=35	0<Y<=35	0<Y<=35	0<Y<=35	0<Y<=35	
<u>@ -25°C</u>									
MRV Vis., cP	214,100	305,400	135,000	208,500	343,100			262,300	59,300
MRV Y. Str., Pa	105<Y<=140	175<Y<=210	140<Y<=175	140<Y<=175	140<Y<=175			140<Y<=175	105<Y<=140
<u>@ -25°C</u>									
Mod. MRV Vis., cP								311,200	
Mod. MRV Y. Str., Pa								140<Y<=175	

REPEAT M11-EGR TESTS, MRV USED/FRESH

CMIR Code	38931	38932	38933	38929	38930	38927	38928	38934	PC-9E
Ind. Oil Code	PC-9E	PC-9E	PC-9E	PC-9E	PC-9E	PC-9E	PC-9E	PC-9E	PC-9E
Lab Code	D	A	A	G	G	G	G	A	
Engine Source	M11 EGR	M11 EGR	M11 EGR	M11 EGR	M11 EGR	M11 EGR	M11 EGR	M11 EGR	(fresh)
% Soot Reported	8.1	8.7	7.7	8.8	8.6	9.1	7.8	7.8	
<u>@ -20°C</u>									
MRV Vis., cP	28,200	38,900	24,000	29,400	31,200	26,300	22,300	31,300	
MRV Y. Str., Pa	0<Y<=35	0<Y<=35	0<Y<=35	0<Y<=35	0<Y<=35	0<Y<=35	0<Y<=35	0<Y<=35	
<u>@ -25°C</u>									
MRV Vis., cP	214,100	305,400	135,000	208,500	343,100			262,300	59,300
MRV Y. Str., Pa	105<Y<=140	175<Y<=210	140<Y<=175	140<Y<=175	140<Y<=175			140<Y<=175	105<Y<=140
<u>@ -25°C</u>									
Mod. MRV Vis., cP								311,200	
Mod. MRV Y. Str., Pa								140<Y<=175	

TMC POSTED PROPERTIES OF PC-9 MATRIX OILS

Oil	Base Oil	Technology	SAE Vis	KV@100C	CCS@-15C	HTHS D4683	MRV @-25C
PC-9A	1	X	15W-40	15.20	3304	4.22	23,900/NYS
PC-9B	2	X	15W-40	15.18	3466	4.27	27,950/NYS
PC-9C	3	X	15W-40	15.14	3500	4.26	25,168/NYS
PC-9N	4	X	15W-40	---	---	---	---
PC-9D	1	Y	15W-40	15.76	3128	4.17	51,600/30g
PC-9E	2	Y	15W-40	15.47	3249	4.29	59,300/40g
PC-9F	3	Y	15W-40	16.03	3430	4.32	51,100/NYS
PC-9P	4	Y	15W-40	15.61	3201	4.28	26,000/NYS
PC-9G	1	Z	15W-40	15.13	3450	4.07	29,500/NYS
PC-9H	2	Z	15W-40	15.13	3350	4.14	19,100/NYS
PC-9J	3	Z	15W-40	15.07	3155	4.16	17,300/NYS
PC-9K	1	W	15W-40	15.49	3212	4.32	---
PC-9L	2	W	15W-40	15.51	3093	4.32	18,700/NYS
PC-9M	4	W	15W-40	15.88	3120	4.31	---

» ***Should verify whether PC-9D,9E,9F MRV properties are as poor as reported; would have relevance to used oil properties***

USED PC-9 MATRIX OIL ANALYSES: CONCLUSIONS **TO DATE**

- **E-O-T CCS VISCOSITIES @ -15°C IN THE 5-8,000 cP RANGE IN MOST CASES (Est. 10-16,000 cP @ -20°C)**
 - 1992 published cold-starting studies* on HD engines under idealized conditions indicated maximum CCS starting viscosities of ~7,000 cP for 2 engine types, ~14,000 cP for a 3rd engine type
- **T-10 E-O-T MRV VISCOSITIES GENERALLY IN THE 19,000-26,000 cP RANGE AT -20°C (ex. one 7.6% soot oil)**
 - 3-5x higher viscosities at -25°C
 - -25°C comparisons indicate modified MRV method gives comparable viscosities, generally same or lower yield stress than D4684 at this temperature
- **M11 EGR E-O-T MRV's ~22-65,000 cP @ -20°C**
 - consistent with general trend to higher MRV with more soot