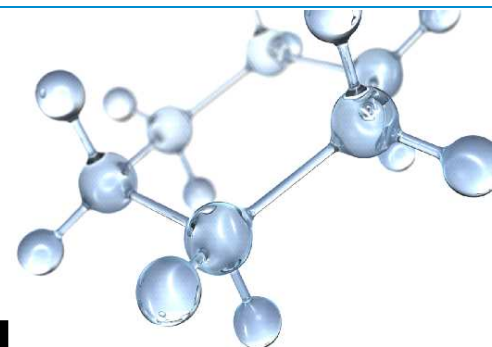


ExxonMobil

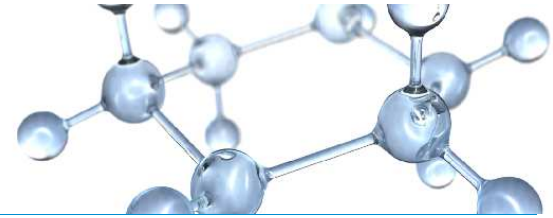
Research and Engineering






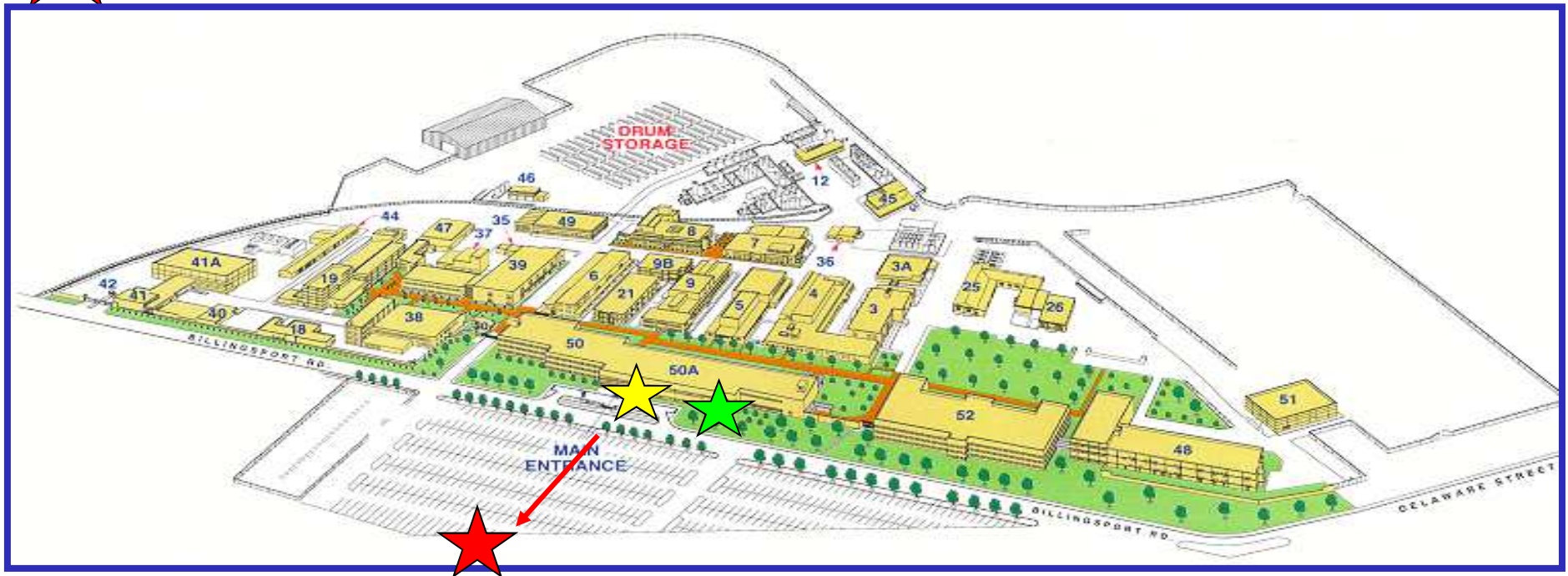
Mack T-13 Task Force Meeting

Paulsboro Technical Center, NJ
July 18, 2012

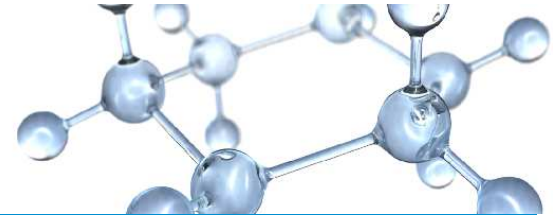
PTC Safety Information



-  **Current Location (50A Building)**
-  **Safe Haven (50A Building, First Floor, Main Lobby)**
-  **Exit Path (50A Main Lobby Exit to Parking Lot)**

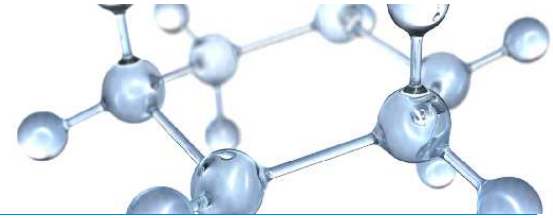


Agenda

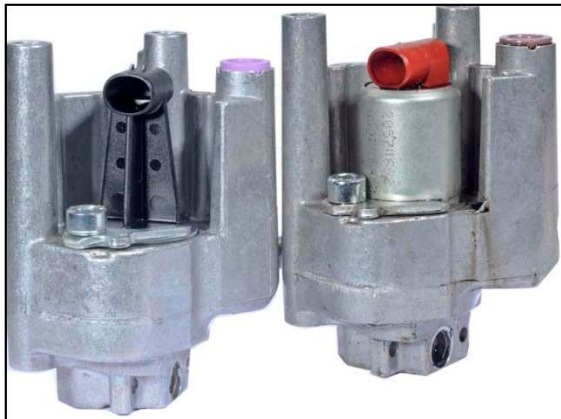


- Safety Briefing
- **Tour**
- Taskforce Membership
- Test Scope and Objectives
- Timeline
- Engine Stand Setup
- Initial Cycle and Results
- Proposed Cycle
- Oil Analysis Scheme
- Wear Measurement Methods
- Critical Hardware (initial)
- Hardware Procurement
- Reference Oils
- Topics for Next Meeting
- Schedule for Next Meeting
- **Tour**

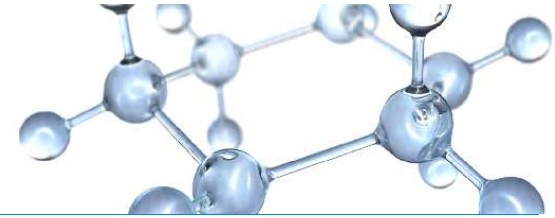
Engine/Stand Set-Up



- Mack MP8 505M US10 with following parts:
 - No-Brake Camshaft P/N 21219818 with “Dummy” Control Solenoid Valve P/N 21105100
 - Front Bowl Steel Oil Pan P/N 21144321
 - US07 Oil Filter Housing P/N 21183257
- Engine Diagnostic and Control
 - Control Box provided by Volvo
 - Volvo VCADS Premium Tech Tool Version 2.39.43



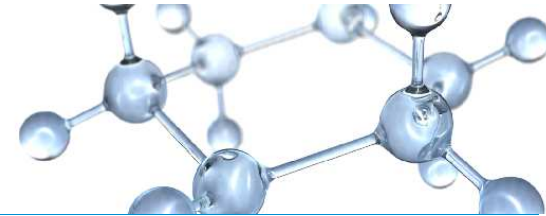
Initial Test Cycle



- 400-h High-Torque Single Phase with:
 - 3500 PSIG Peak Cylinder Pressure
 - ~9% Overfueling
 - EGR fraction controlled by ECU
 - Forced Oil Additions every 50-h
 - 22.8 kg (~28 qts) Oil Charge

Main Test	
Speed, rpm	1200
Torque, Nm	2615
Fuel Flow, kg/h (nominal)	(64.6)
Coolant Out Temp, °C	110
Fuel In Temp, °C	35
Inlet Air Temp, °C	30
Intercooler Out Temp, °C	43
Oil Gallery Temperature, °C	125
EGR Out Temperature, °C	NA
Intake Air Press, kPaG	-2.0
Exhaust BackPress, kPaG	15.0
Front Cooling Fan	On

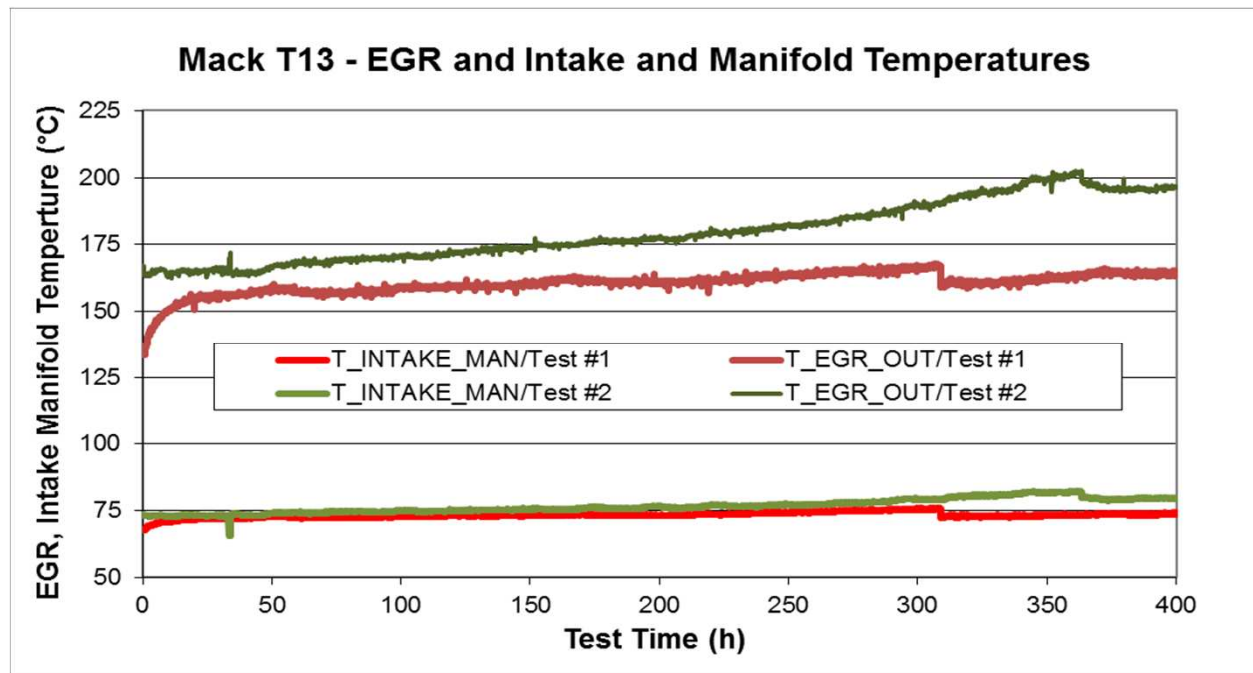
Test Operation



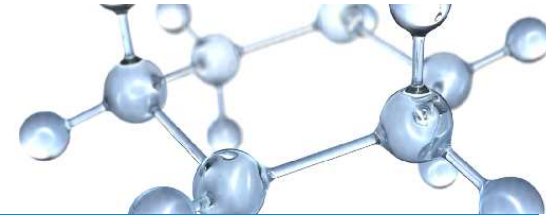
- Consistent EGR control between tests

	Test #1	Test #2
EGR Fraction	22.9	22.9
SD	0.53	0.43

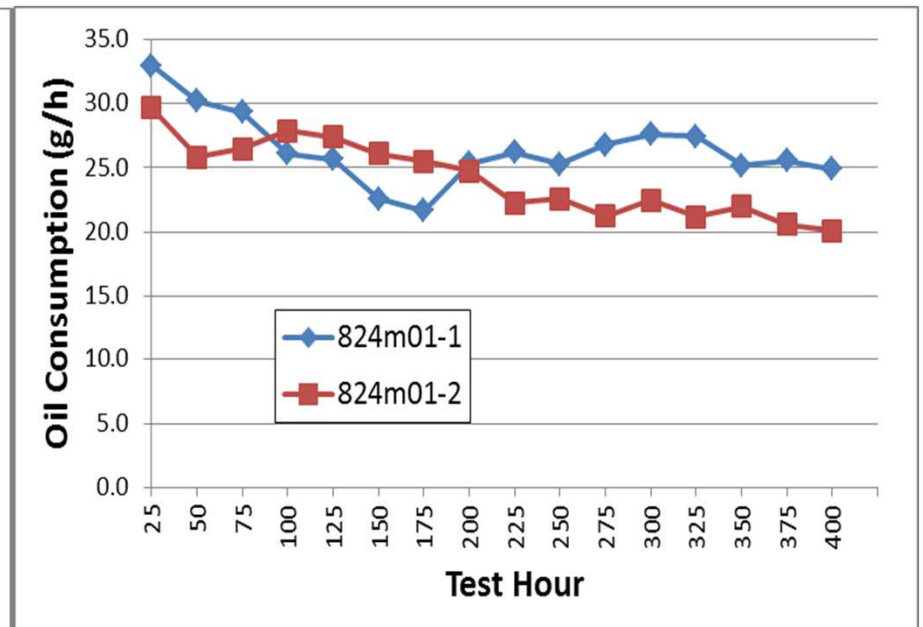
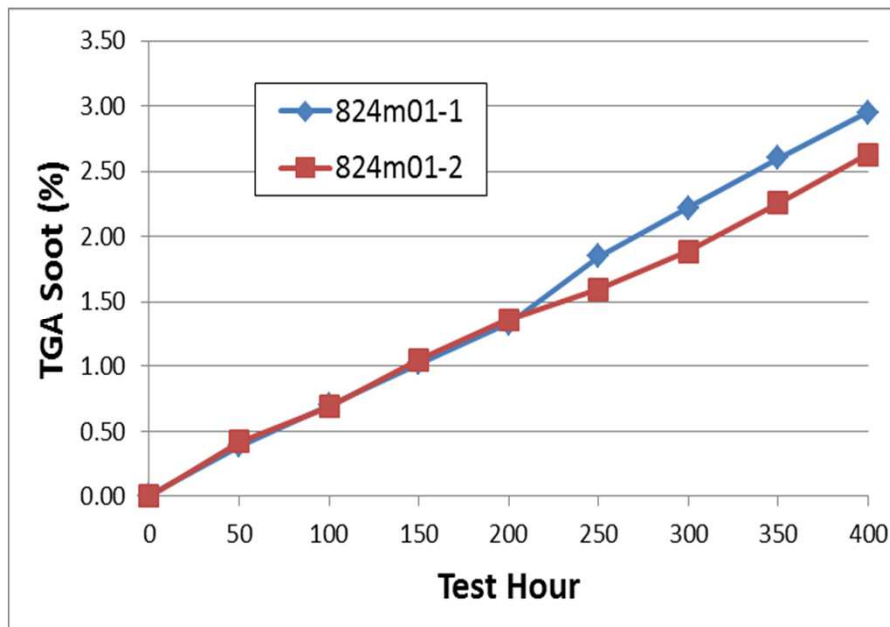
- but variability of EGR gas out temperature



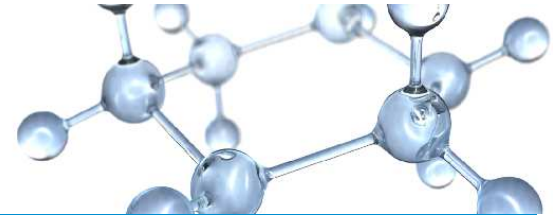
Test Operation (cont'd)



- Linear soot profile most likely affected by oil consumption difference between tests



Initial Results



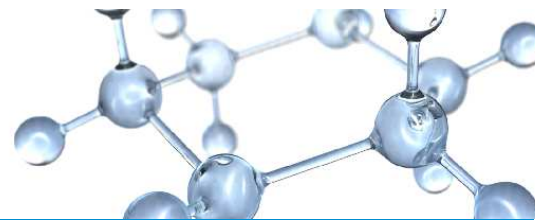
- Initial cycle used for 2 tests
 - Commercial CJ-4 10W-30
 - TMC 821 (15W-40)
- Oils showed signs of oxidation/nitration but minimal liner wear
- Some differences in UOA values between SwRI and PTC measurements
 - Soot
 - TBN/TAN
 - IR (due to method difference)

10W-30 Used Oil Analysis



Viscometrics		<u>New Oil</u>	<u>50-h</u>	<u>100-h</u>	<u>150-h</u>	<u>200-h</u>	<u>250-h</u>	<u>300-h</u>	<u>350-h</u>	<u>400-h</u>
	KV100	11.84	11.81	12.3	12.25	11.87	12.4	13.34	14.5	15.72
	KV40	76.83	77.63	83.02	83.52	82.49	90.59	100.7	112.9	127.1
	TGA Soot	0.01	0.39	0.7	1.02	1.33	1.85	2.22	2.6	2.95
Wear Metals										
	Iron	0.83	9	17	22	29	39	48	57	65
	Lead	<2	4.7	6.7	9.3	17	34	55	77	98
	Copper	<0.5	4.9	8.5	8.8	9.4	10	11	14	19
	Calcium	1380	1430	1480	1500	1540	1580	1610	1650	1690
	Magnesium	821	835	862	881	901	921	942	959	979
Oxidation										
	PDSC	127.03	39.99	32.01	<10	<10	<10	<10	<10	<10
	FTIR-Oxidation	0.12	8.09	15.27	22.46	40.13	63.45	75.69	8.35	84.11
	FTIR-Nitration	0.07	0.2	0.31	1.87	7.35	6.42	7.11	6.69	6.46
	TAN (D664)	2.8	3.15	3.94	4.56	7.79	9.26	11	10.74	16.42
	TBN (D4739)	9	7.8	5.8	5	3.2	1.7	<0.5	5	4.2

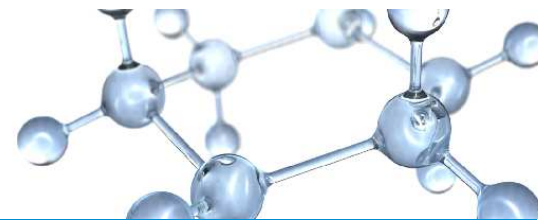
10W-30 Liner Wear



Position	Cylinder Number						
	1	2	3	4	5	6	
1:00	2.9	1.3	1.7	1.3	2.4	3.1	
2:00	1.5	2.4	1.4	1.3	2.7	2.8	
3:00 (Thrust)	2.9	2.2	2.0	1.6	2.0	2.8	
4:00	1.4	1.3	1.4	1.9	1.9	2.9	
5:00	1.8	1.7	1.2	2.0	1.3	2.2	
6:00 (Rear)	2.5	1.1	1.8	2.7	2.3	2.6	
7:00	1.5	1.6	1.7	2.1	1.6	1.7	
8:00	2.0	2.9	2.0	1.6	1.9	1.9	
9:00 (A/T)	1.4	2.3	1.2	2.0	2.2	3.4	
10:00	2.5	3.5	2.5	1.6	1.5	1.7	
11:00	2.4	1.9	2.3	1.7	2.6	NA	
12:00	2.0	2.1	1.7	1.2	2.7	2.9	
<i>Avg as measured</i>	2.1	2.0	1.7	1.8	2.1	2.6	2.0
<i>Stdev as measured</i>	0.6	0.7	0.4	0.4	0.5	0.6	0.3
<i>Min as measured</i>	1.4	1.1	1.2	1.2	1.3	1.7	1.1
<i>Max as measured</i>	2.9	3.5	2.5	2.7	2.7	3.4	3.5

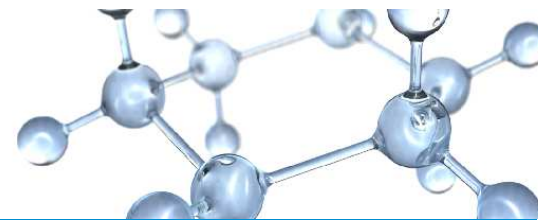
	Avg	SD	Min	Max
Front (11, 12, 1)	2.1	0.6088	1.2	3.1
Thrust (2,3,4)	2.0	0.6058	1.3	2.9
Rear (5,6,7)	1.8	0.4752	1.1	2.7
Antithrust (8,9,10)	2.1	0.6387	1.2	3.5

10W-30 Main Bearing Wear



Position	Location	SOT Wt.,g	EOT Wt.,g	Wt. Change, mg
1	UPPER	116.1565	116.1419	14.6
2	UPPER	116.6885	116.6833	5.2
3	UPPER	117.2225	117.2154	7.1
4	UPPER	117.1505	117.1421	8.4
5	UPPER	115.8804	115.8728	7.6
6	UPPER	117.8052	117.8014	3.8
7	UPPER	116.8266	116.8215	5.1
<i>Upper Bearing Average Weight Loss, mg</i>				7.4
<i>Upper Bearing Average Weight Loss, Std. Dev., mg</i>				3.6
<i>Upper Bearing Minimum Weight Loss, mg</i>				3.8
<i>Upper Bearing Maximum Weight Loss, mg</i>				14.6
Position	Location	SOT Wt.,g	EOT Wt.,g	Wt. Change, mg
1	LOWER	129.2639	129.2513	12.6
2	LOWER	128.9992	128.9830	16.2
3	LOWER	129.4760	129.4586	17.4
4	LOWER	129.1277	129.1136	14.1
5	LOWER	129.6521	129.6362	15.9
6	LOWER	129.3437	129.3303	13.4
7	LOWER	129.5865	129.5753	11.2
<i>Lower Bearing Average Weight Loss, mg</i>				14.4
<i>Lower Bearing Average Weight Loss, Std. Dev., mg</i>				2.2
<i>Lower Bearing Minimum Weight Loss, mg</i>				11.2
<i>Lower Bearing Maximum Weight Loss, mg</i>				17.4
<i>Total Average Main Bearing Wt. Loss (mg)</i>		21.8		

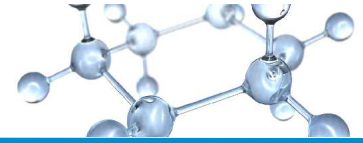
10W-30 Rod Bearing Wear



Position	Location	SOT Wt.,g	EOT Wt.,g	Wt. Change, mg
1	UPPER	147.2871	146.9180	369.1
2	UPPER	147.5831	147.2404	342.7
3	UPPER	146.9757	146.6276	348.1
4	UPPER	147.3948	147.2547	140.1
5	UPPER	147.0817	146.9842	97.5
6	UPPER	147.9485	147.7696	178.9
<i>Upper Bearing Average Weight Loss, mg</i>				246.1
<i>Upper Bearing Average Weight Loss, Std. Dev., mg</i>				120.6
<i>Upper Bearing Minimum Weight Loss, mg</i>				97.5
<i>Upper Bearing Maximum Weight Loss, mg</i>				369.1

Position	Location	SOT Wt.,g	EOT Wt.,g	Wt. Change, mg
1	LOWER	132.5099	132.5025	7.4
2	LOWER	132.5285	132.5200	8.5
3	LOWER	132.6935	132.6845	9.0
4	LOWER	132.6377	132.6325	5.2
5	LOWER	133.0386	133.0311	7.5
6	LOWER	132.9977	132.9964	1.3
<i>Lower Bearing Average Weight Loss, mg</i>				6.5
<i>Lower Bearing Average Weight Loss, Std. Dev., mg</i>				2.9
<i>Lower Bearing Minimum Weight Loss, mg</i>				1.3
<i>Lower Bearing Maximum Weight Loss, mg</i>				9.0

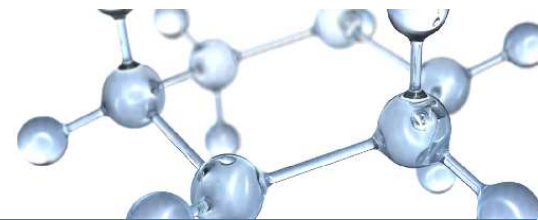
Total Average Rod Bearing Wt. Loss (mg)	252.5
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10W-30 Ring Weight Loss

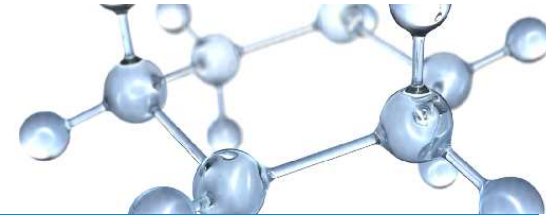
Cylinder	TOP SOT Wt.,g	TOP EOT Wt.,g	TOP Wt. Change, mg
1	38.8935	38.7651	128.4
2	38.8611	38.7760	85.1
3	38.8233	38.7310	92.3
4	38.7153	38.6975	17.8
5	38.7022	38.6760	26.2
6	38.7187	38.6500	68.7
<i>Top Ring Average Weight Loss, mg</i>			69.8
<i>Top Ring Average Weight Loss, Std. Dev., mg</i>			41.9
<i>Top Ring Minimum Weight Loss, mg</i>			17.8
<i>Top Ring Maximum Weight Loss, mg</i>			128.4
Cylinder	2'nd SOT Wt.,g	2'nd EOT Wt.,g	2'nd Wt. Change, mg
1	33.2648	33.2640	0.8
2	33.2906	33.2904	0.2
3	33.3988	33.3984	0.4
4	33.3015	33.3009	0.6
5	33.0941	33.0940	0.1
6	33.3401	33.3390	1.1
<i>2'nd Ring Average Weight Loss, mg</i>			0.5
<i>2'nd Ring Average Weight Loss, Std. Dev., mg</i>			0.4
<i>2'nd Ring Minimum Weight Loss, mg</i>			0.1
<i>2'nd Ring Maximum Weight Loss, mg</i>			1.1
Cylinder	Oil Ring SOT Wt.,g	Oil Ring EOT Wt.,g	Oil Ring Wt. Change, mg
1	15.0239	15.0119	12.0
2	15.0609	15.0483	12.6
3	15.0429	15.0308	12.1
4	15.0103	14.9984	11.9
5	15.0174	15.0051	12.3
6	15.0245	15.0119	12.6
<i>Oil Ring Average Weight Loss, mg</i>			12.2
<i>Oil Ring Average Weight Loss, Std. Dev., mg</i>			0.3
<i>Oil Ring Minimum Weight Loss, mg</i>			11.9
<i>Oil Ring Maximum Weight Loss, mg</i>			12.6
<i>Total Average Top Ring Wt. Loss (mg)</i>		69.8	

TMC 821 Used Oil Analysis



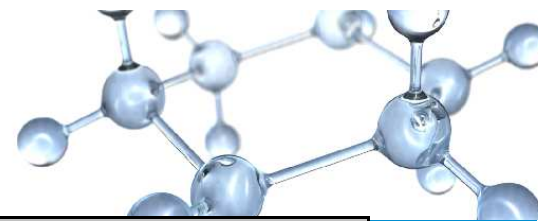
Viscometrics		<u>New Oil</u>	<u>50-h</u>	<u>100-h</u>	<u>150-h</u>	<u>200-h</u>	<u>250-h</u>	<u>300-h</u>	<u>350-h</u>	<u>400-h</u>
	KV100	15.55	15.04	15.13	15.8	16.34	16.35	15.98	16.44	17.32
	KV40	117.2	114.2	117.2	124	131.4	131.6	131.1	137.5	147.3
	TGA Soot	0	0.42	0.69	1.05	1.36	1.6	1.89	2.26	2.63
Wear Metals										
	Iron	0.86	9.3	15	19	26	32	40	47	61
	Lead	<2	5.2	7.9	8.9	12	18	32	48	75
	Copper	<0.5	3	4.5	6.3	7.9	9	11	12	17
Oxidation										
	PDSC	48.4	20.05	12.35	<10	<10	<10	<10	<10	<10
	FTIR-Oxidation	0.08	6.44	12.89	18.43	21.85	27.27	37.73	47.76	52.93
	FTIR- Nitration	0.09	0.44	0.83	0.66	0.16	1.05	4.3	6.21	6.2
	TAN (D664)	2.69	2.99	2.74	3.97	4.34	4.58	6.54	6.84	8.62
	TBN (D4739)	8.7	6.8	6	5.1	6.7	6.4	6	6.3	2.5

TMC 821 Liner Wear



Position	Cylinder Number						
	1	2	3	4	5	6	
1:00	2.0	3.2	5.4	2.2	3.2	2.3	
2:00	1.9	2.6	2.1	2.1	2.8	1.9	
3:00 (Thrust)	3.3	2.3	1.9	4.2	2.8	3.4	
4:00	1.6	1.8	1.4	3.5	2.0	1.2	
5:00	2.5	1.9	2.2	1.0	2.2	2.1	
6:00 (Rear)	2.6	5.3	1.2	2.5	2.1	1.7	
7:00	3.0	2.3	1.3	2.1	2.3	2.4	
8:00	2.4	1.6	1.6	1.8	2.2	1.4	
9:00 (A/T)	3.5	1.8	3.4	2.1	2.6	2.6	
10:00	2.6	2.0	2.4	2.1	2.9	2.7	
11:00	1.5	2.8	3.7	2.4	2.5	1.7	
12:00	1.9	1.4	4.9	2.8	3.0	2.0	
<i>Avg as measured</i>	2.4	2.4	2.6	2.4	2.5	2.1	2.4
<i>Stdev as measured</i>	0.7	1.0	1.4	0.8	0.4	0.6	0.9
<i>Min as measured</i>	1.5	1.4	1.2	1.0	2.0	1.2	1.0
<i>Max as measured</i>	3.5	5.3	5.4	4.2	3.2	3.4	5.4
	Avg	SD	Min	Max			
Front (11, 12, 1)	2.7	1.0862	1.4	5.4			
Thrust (2,3,4)	2.4	0.7998	1.2	4.2			
Rear (5,6,7)	2.3	0.9153	1.0	5.3			
Antithrust (8,9,10)	2.3	0.5851	1.4	3.5			

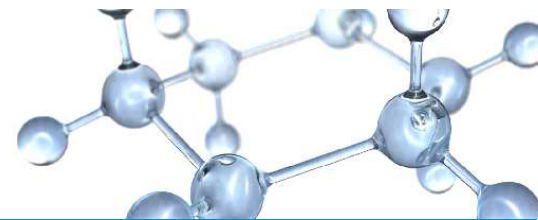
TMC 821 Main Bearing Wear



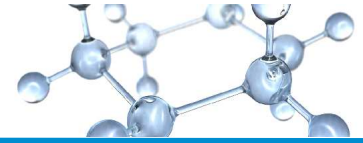
Position	Location	SOT Wt.,g	EOT Wt.,g	Wt. Change, mg
1	UPPER	116.5132	116.4983	14.9
2	UPPER	116.3963	116.3828	13.5
3	UPPER	116.6467	116.6352	11.5
4	UPPER	115.987	115.9747	12.3
5	UPPER	117.3765	117.365	11.5
6	UPPER	116.4643	116.4507	13.6
7	UPPER	116.4998	116.4824	17.4
<i>Upper Bearing Average Weight Loss, mg</i>				13.5
<i>Upper Bearing Average Weight Loss, Std. Dev., mg</i>				2.1
<i>Upper Bearing Minimum Weight Loss, mg</i>				11.5
<i>Upper Bearing Maximum Weight Loss, mg</i>				17.4
Position	Location	SOT Wt.,g	EOT Wt.,g	Wt. Change, mg
1	LOWER	129.3340	129.3197	14.3
2	LOWER	129.4207	129.4024	18.3
3	LOWER	129.2271	129.2047	22.4
4	LOWER	129.4283	129.4143	14.0
5	LOWER	129.3047	129.2874	17.3
6	LOWER	129.0354	129.0132	22.2
7	LOWER	129.0866	129.0694	17.2
<i>Lower Bearing Average Weight Loss, mg</i>				18.0
<i>Lower Bearing Average Weight Loss, Std. Dev., mg</i>				3.4
<i>Lower Bearing Minimum Weight Loss, mg</i>				14.0
<i>Lower Bearing Maximum Weight Loss, mg</i>				22.4

Total Average Main Bearing Wt. Loss (mg)	31.5
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TMC 821 Rod Bearing Wear



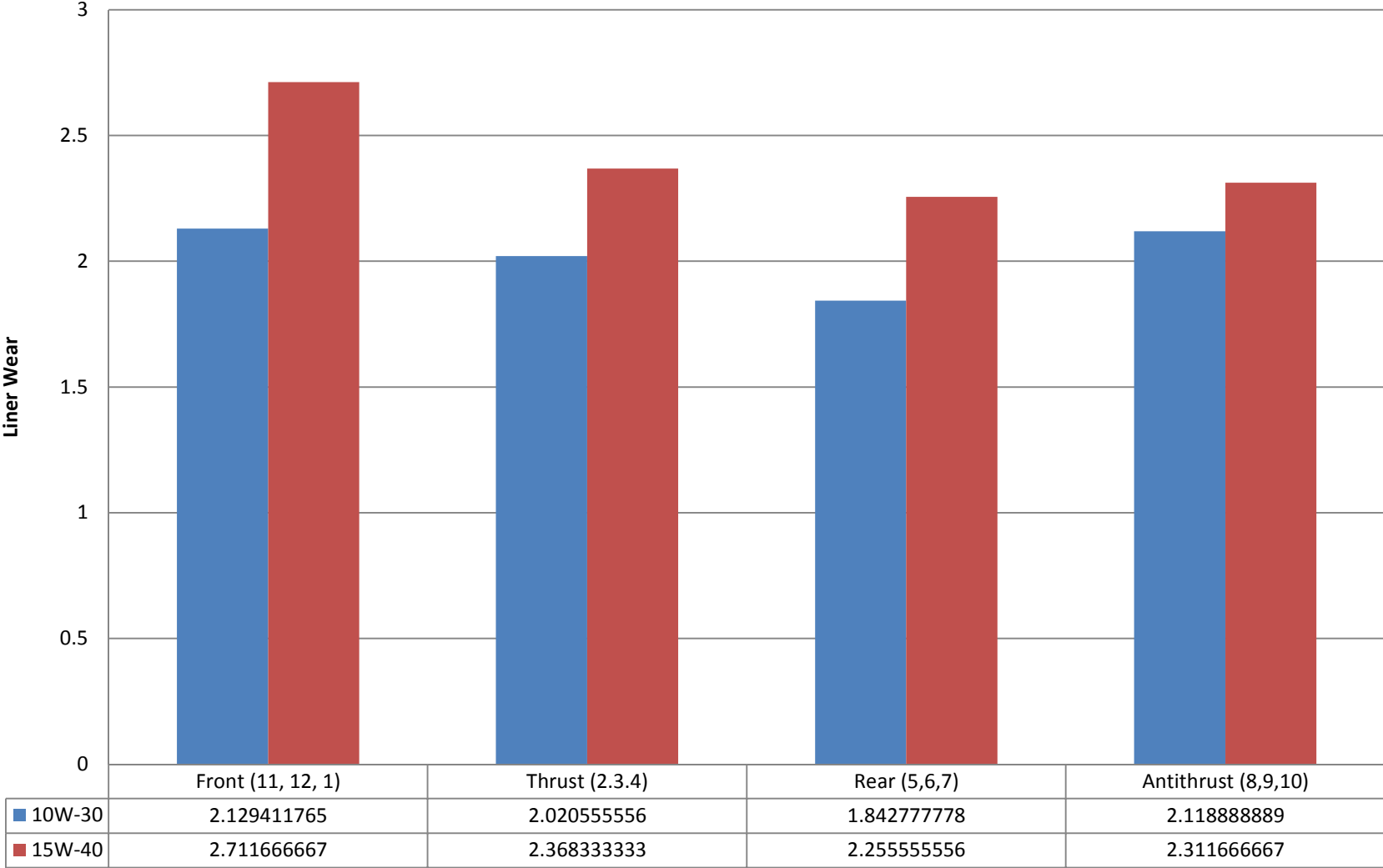
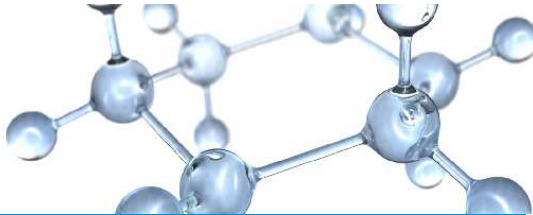
Position	Location	SOT Wt.,g	EOT Wt.,g	Wt. Change, mg
1	UPPER	146.9642	146.6256	338.6
2	UPPER	148.0748	147.7747	300.1
3	UPPER	147.0672	146.7181	349.1
4	UPPER	147.9561	147.7650	191.1
5	UPPER	147.3228	147.1674	155.4
6	UPPER	147.2273	146.3831	844.2
<i>Upper Bearing Average Weight Loss, mg</i>				363.1
<i>Upper Bearing Average Weight Loss, Std. Dev., mg</i>				248.6
<i>Upper Bearing Minimum Weight Loss, mg</i>				155.4
<i>Upper Bearing Maximum Weight Loss, mg</i>				844.2
Position	Location	SOT Wt.,g	EOT Wt.,g	Wt. Change, mg
1	LOWER	133.1785	133.1782	0.3
2	LOWER	132.9876	132.9861	1.5
3	LOWER	132.9410	132.9376	3.4
4	LOWER	133.0492	133.0483	0.9
5	LOWER	133.0956	133.0945	1.1
6	LOWER	132.9626	132.8913	71.3
<i>Lower Bearing Average Weight Loss, mg</i>				13.1
<i>Lower Bearing Average Weight Loss, Std. Dev., mg</i>				28.5
<i>Lower Bearing Minimum Weight Loss, mg</i>				0.3
<i>Lower Bearing Maximum Weight Loss, mg</i>				71.3
<i>Total Average Rod Bearing Wt. Loss (mg)</i>		376.2		
<i>Outlier Screened Avg Wear</i>		268.3		



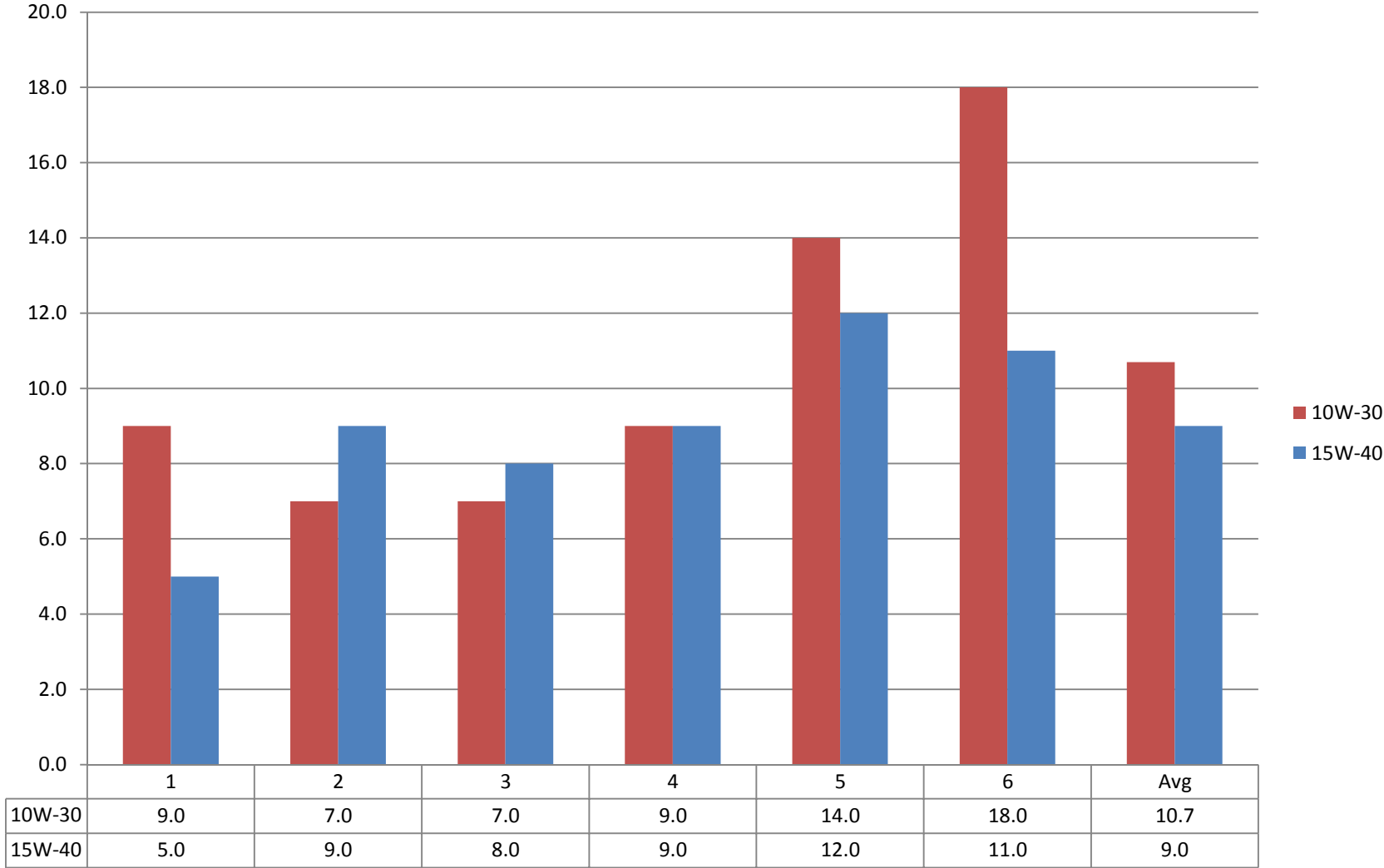
TMC 821 Ring Weight Loss

Cylinder	TOP SOT Wt.,g	TOP EOT Wt.,g	TOP Wt. Change, mg
1	38.8828	38.8518	31.0
2	38.8827	38.8449	37.8
3	38.9090	38.8249	84.1
4	38.9361	38.8555	80.6
5	38.8813	38.7605	120.8
6	38.8843	38.8605	23.8
<i>Top Ring Average Weight Loss, mg</i>			63.0
<i>Top Ring Average Weight Loss, Std. Dev., mg</i>			38.2
<i>Top Ring Minimum Weight Loss, mg</i>			23.8
<i>Top Ring Maximum Weight Loss, mg</i>			120.8
Cylinder	2 nd SOT Wt.,g	2 nd EOT Wt.,g	2 nd Wt. Change, mg
1	33.4139	33.4125	1.4
2	33.4271	33.4264	0.7
3	33.3219	33.3206	1.3
4	33.3116	33.3110	0.6
5	33.3540	33.3533	0.7
6	33.2729	33.2712	1.7
<i>2nd Ring Average Weight Loss, mg</i>			1.1
<i>2nd Ring Average Weight Loss, Std. Dev., mg</i>			0.5
<i>2nd Ring Minimum Weight Loss, mg</i>			0.6
<i>2nd Ring Maximum Weight Loss, mg</i>			1.7
Cylinder	Oil Ring SOT Wt.,g	Oil Ring EOT Wt.,g	Oil Ring Wt. Change, mg
1	15.0262	15.0125	13.7
2	15.0676	15.0578	9.8
3	15.0614	15.0518	9.6
4	14.9774	14.9681	9.3
5	15.0547	15.0444	10.3
6	15.0348	15.0256	9.2
<i>Oil Ring Average Weight Loss, mg</i>			10.3
<i>Oil Ring Average Weight Loss, Std. Dev., mg</i>			1.7
<i>Oil Ring Minimum Weight Loss, mg</i>			9.2
<i>Oil Ring Maximum Weight Loss, mg</i>			13.7
<i>Total Average Top Ring Wt. Loss (mg)</i>		63.0	

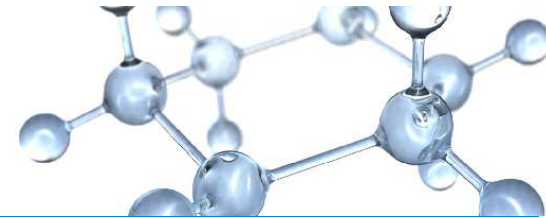
Liner Wear Comparison



Bore Polish Comparison



Proposed New Test Cycle



- 400-h Two Phases with:
 - Phase I with Retarded Injection Timing targeting 3.5-4.0% soot in 96-h
 - Phase II with 3700 PSIG Peak Cylinder Pressure
 - Forced Oil Addition every 48/50-h in Phase II only
 - EGR Gas Temperature controlled by Test Cell

Main Test		
	Ph.I	Ph. II
Length, hours	96	TBD
Speed, rpm	1650	1200
Torque, Nm (nominal)	()	2615
Throttle Position, % (nominal)	100	(75.0)
Fuel Flow, kg/h (nominal)	()	(64.6)
<hr/>		
Coolant Out Temp, °C	110	110
Fuel In Temp, °C	35	35
Inlet Air Temp, °C	30	30
Intake Manifold Temp, °C	78	78
Oil Gallery Temperature, °C	125	125
EGR Out Temperature, °C	TBD	TBD
Intake Air Press, kPaA	97.8	99.3
Exhaust BackPress, kPaA	125.3	116.3
Front Cooling Fan	On	On