

1Q Test Report for PC-9

1. Precision Results
2. Effects of EGR on Deposits
3. Discrimination & Oil Performance
4. EGR cooler modifications

1Q Test Report for PC-9 Precision

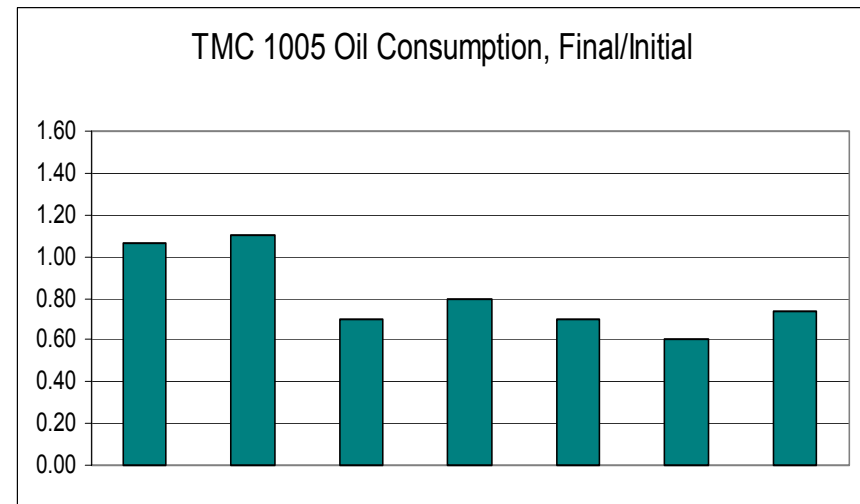
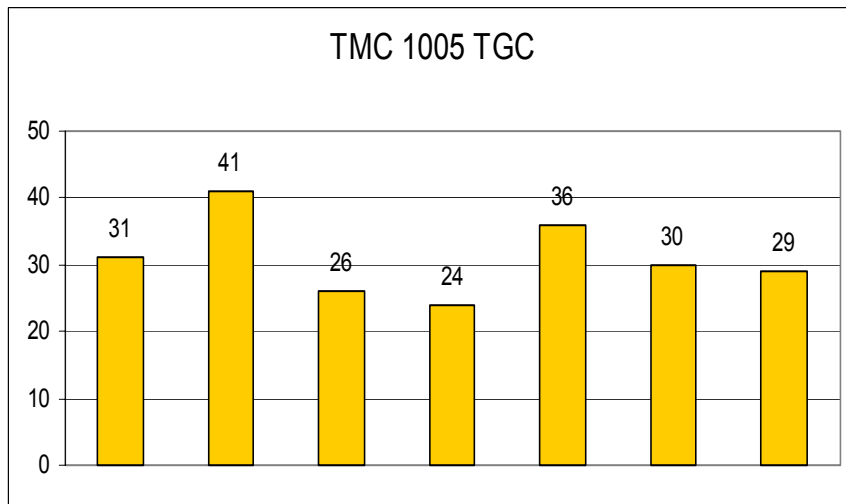
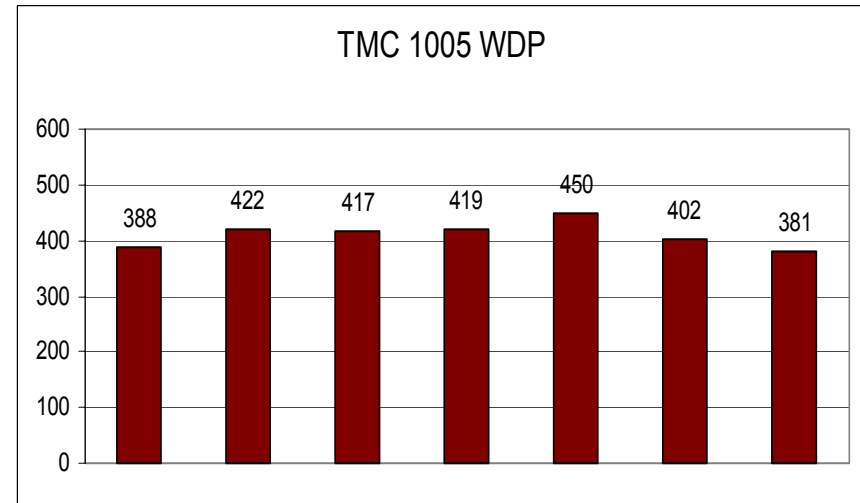
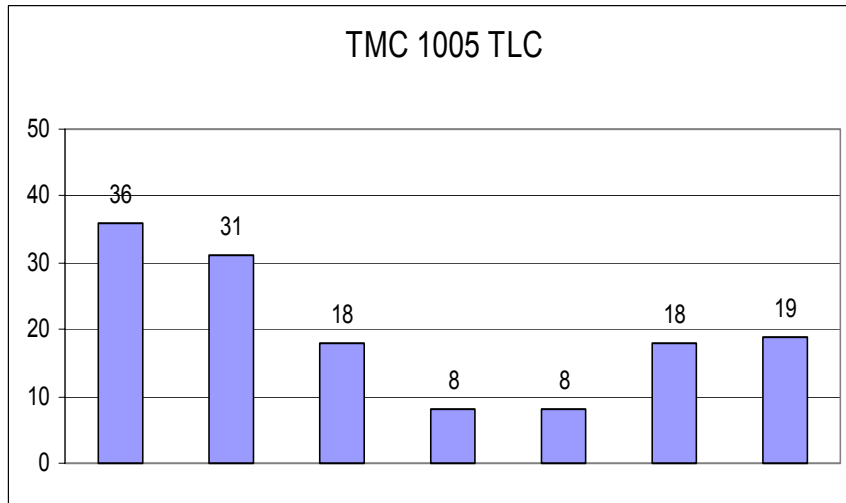
- 1Q Precision with TMC 1005
 - Seven 1Q tests have been completed in six labs.
 - ✧ Five of these labs will participate in the matrix.
 - All seven runs completed the 504 hour test with stable oil consumption.
 - Piston deposit levels were very consistent between runs.

1Q Test Report for PC-9 Precision

- 1Q results with TMC 1005

Test Type	1Q Oil Type	Piston Deposits			Oil Consumption			Soot and Wear Metals				
		TLC	TGC	WDP	Initial g/hr	Final g/hr	Ratio F/I	TGA - %	Fe	Cr	Cu	Pb
1Q (EGR)	TMC 1005	36	31	388	11.2	11.9	1.1	1.6	74	7	21	9
	TMC 1005	31	41	422	12.8	14.0	1.1	3.6	201	23	7	7
	TMC 1005	18	26	417	9.6	6.9	0.7	2.8	172	12	6	6
	TMC 1005	8	24	419	12.2	9.2	0.8	2.8	220	11	32	9
	TMC 1005	8	36	450	10.6	7.5	0.7					
	TMC 1005	18	30	402	11.2	6.9	0.6		113	12	44	3
	TMC 1005	19	29	381	10.4	7.5	0.7					
	mean	20	31	411	11.1	9.1	0.8	2.7	156	13	22	7
	1 sigma	11	6	23	1	3						

1Q Test Report for PC-9 Precision



1Q Test Report for PC-9 Precision

Test Type	Oil Type	Piston Deposits			Oil Consumption			Tests
		TLC	TGC	WDP	Initial g/hr	Final g/hr	Ratio F/I	
1Q Mean	TMC 1005	20	31	411	11.1	9.1	0.8	7
1Q Sigma		11	6	23	1	3		
1P Mean	TMC 1005	31	30	308	6.2	4.3		6
1P Sigma		9	8	44	3.5	2.3		

- ▶ The 1Q test has demonstrated improved precision in the areas of oil consumption and WDP, compared to the 1P test.
- ▶ The 1Q test has similar precision to the 1P in the Top Groove Carbon measurement.
- ▶ The 1Q precision on Top Land Carbon is worse than the 1P.

1Q Test Report for PC-9 Deposits

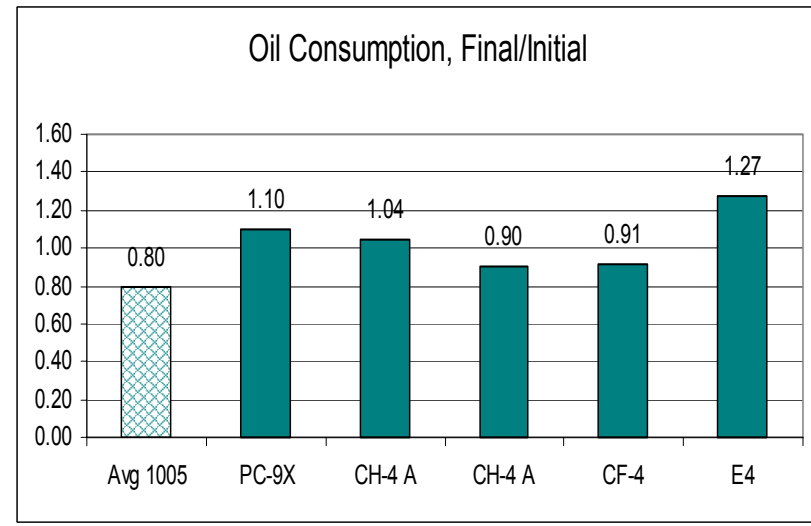
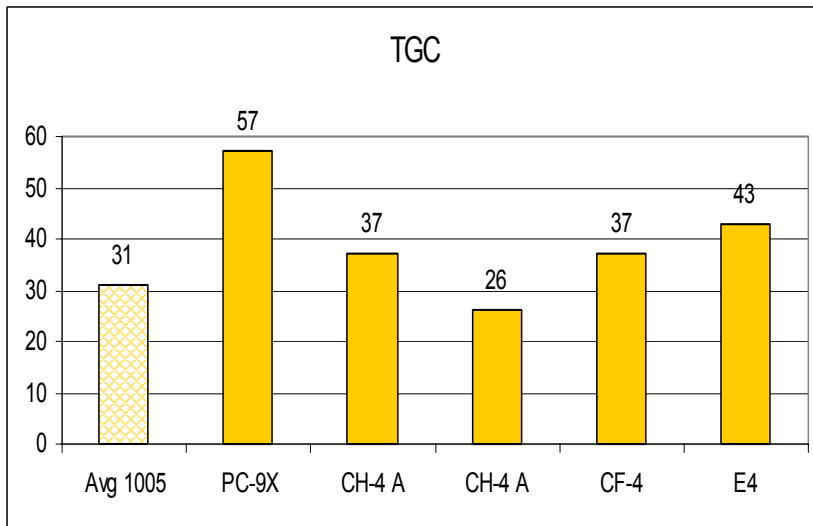
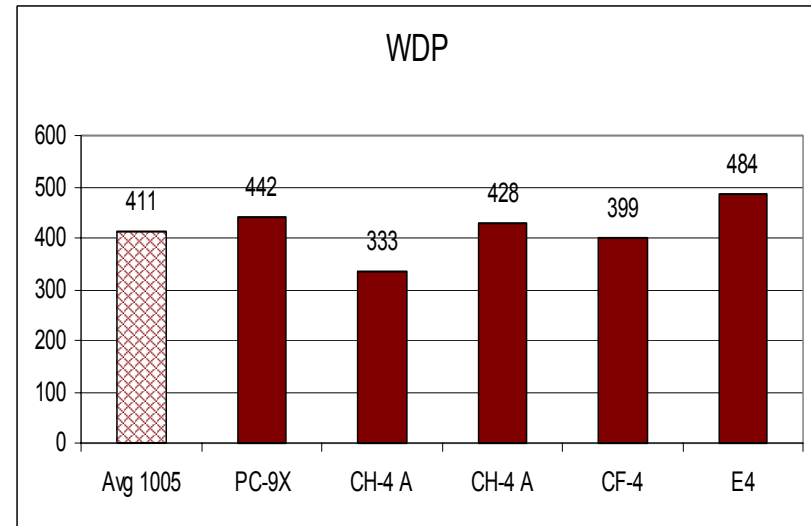
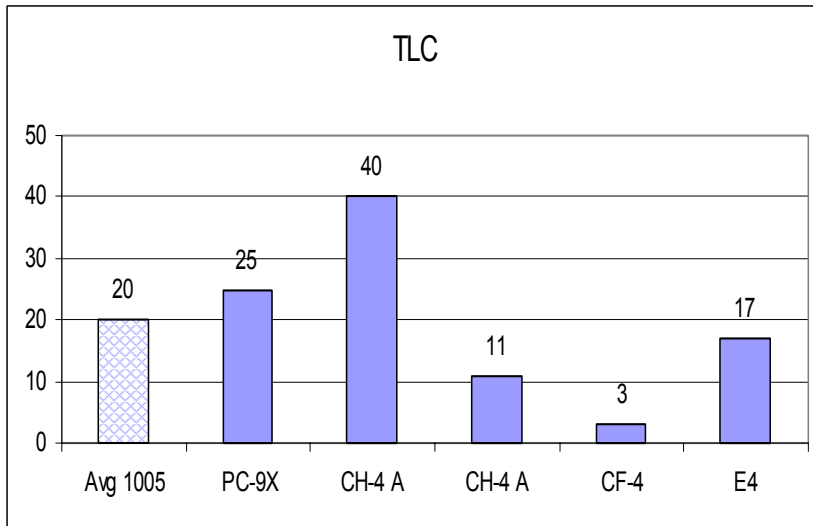
Test Type	Oil Type	Piston Deposits			Oil Consumption			Soot	Comments
		TLC	TGC	WDP	Initial g/hr	Final g/hr	Ratio F/I	%TGA	
1R Mean	TMC 1005	18	30	298	9.1	8.4	0.9	0.6	5 tests, No EGR
1Q Mean	TMC 1005	20	31	411	11.1	9.1	0.8	2.7	7 tests with EGR
3406E	PC-9X	36	47	200			1.2	0.7	550 HP for 500 Hrs
3406E EGR	PC-9X	35	42	252			?	0.9	475 HP 16% EGR for 500 Hrs
1Q	PC-9X	25	57	442	8.9	10.0	1.1	1.5	1 test with EGR

- Effects of EGR on Deposits
 - EGR increases weighted demerits.
 - Increased deposit levels are present in the 2nd and 3rd ring grooves and lands.
 - Deposits in these areas can result in ring sticking and loss of oil control.

1Q Test Report for PC-9 Discrimination

- Several oils were tested to identify performance differences.
- None of these oils provided adequate deposit control for the lower part of the piston.
 - Oils Tested
 - ✧ PC-9X
 - ✧ CH-4 15W-40
 - ✧ CF-4 15W-40
 - ✧ ACEA E4 10W-40

1Q Test Report for PC-9 Discrimination



1Q Test Report for PC-9 Discrimination

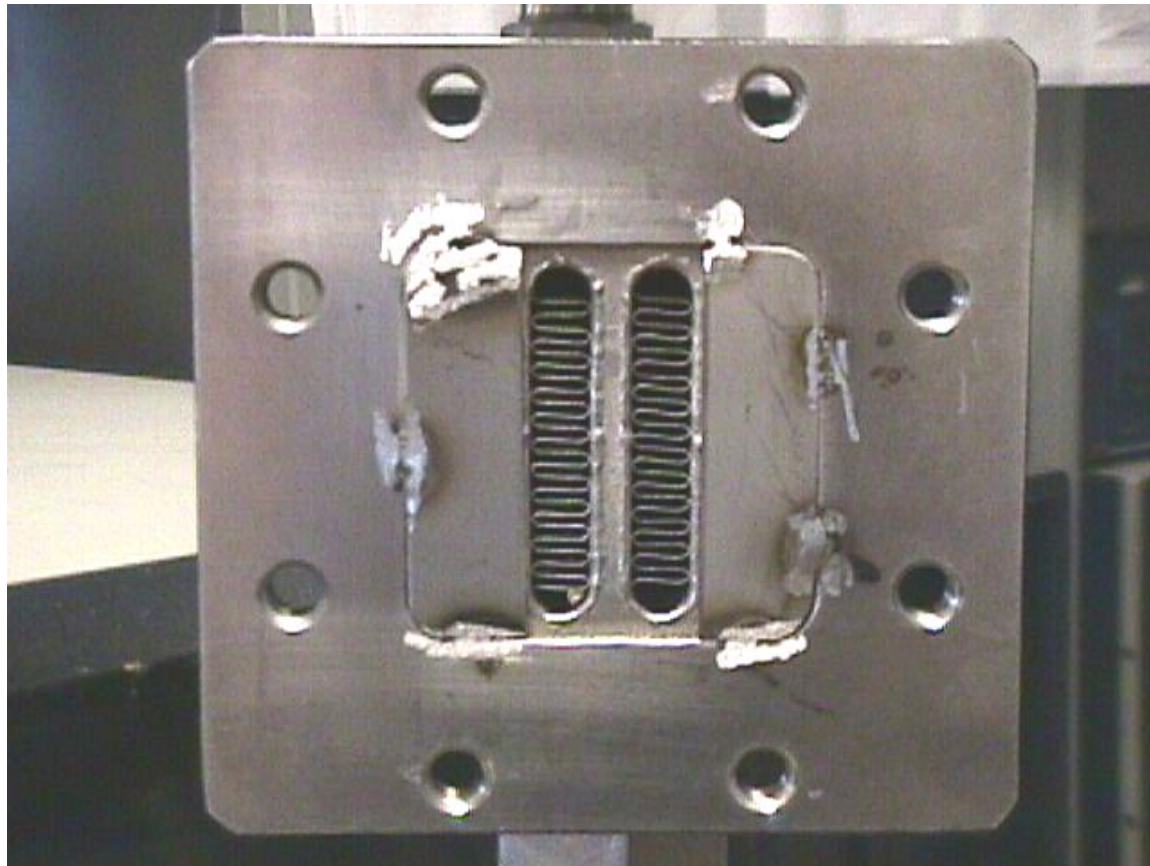
- Additional development must be done to provide a discrimination oil.
 - Reduced deposits in the 2nd and 3rd ring grooves.
 - No loss of deposit control on the upper portion of the piston.
 - Desired average performance (not limits)
 - ✧ 300 WDP
 - ✧ 30 % TGC
 - ✧ 25 % TLC

1Q Test Report for PC-9 EGR Cooler

- ▶ Based on model calculations from the EGR cooler supplier, a significant reduction in cooler fouling can be obtained by increasing the velocity and raising the outlet temperature.
 - ✧ Increased velocity and higher temperatures can be obtained by blocking two of the four cooler tubes.
 - ✧ Initial EGR cooler outlet temperatures will be higher.
 - ✧ Stabilized EGR outlet temperature should be lower.
 - ✧ Operating conditions will not change.
- ▶ Two labs are currently testing this concept

1Q Test Report for PC-9 EGR Cooler

- ▶ Modified 1Q EGR Cooler



1Q Test Report for PC-9 **Summary**

- ▶ The 1Q test has demonstrated precision with reference oil TMC 1005.
- ▶ The 1Q test discriminates differences in piston deposits when EGR is applied to a heavy duty diesel engine.
- ▶ The modified EGR cooler will make the test operationally ready.
- Based on the above statements, *Proof of Concept* has been demonstrated for the 1Q test in PC-9.

1Q Task Force Report for PC-9

- ▶ Lab visits are completed and the the labs are ready.
- ▶ A draft of the test procedure is complete.
- ▶ There is reasonable precision on all parameters except under-crown, based on TMC 1005 oil.
- ▶ Results on oil E4 indicate Discrimination on weighted demerits
 - ✧ An additional run on the E4 oil is desired (a volunteer sponsor is needed for this run)
- ▶ One more lab must run 1005 to demonstrate readiness.