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# 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.

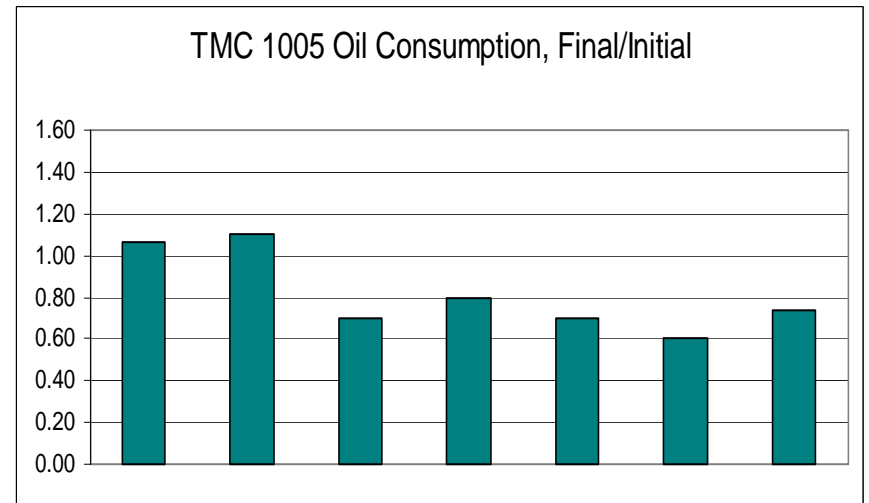
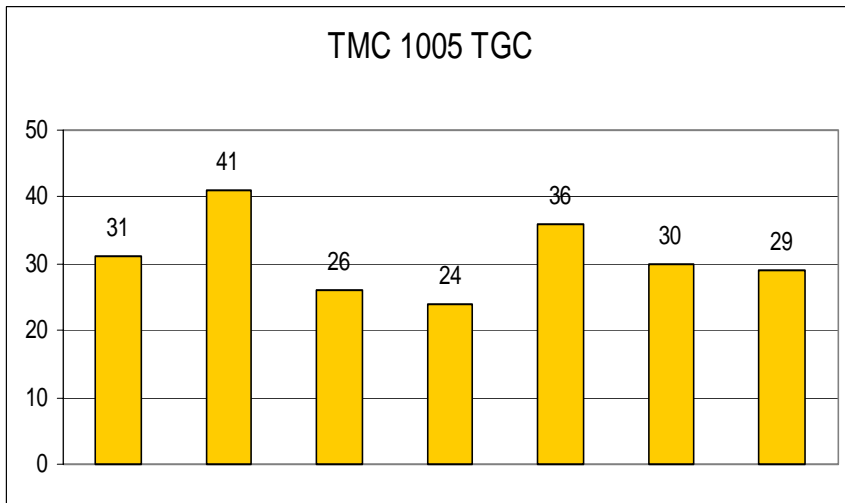
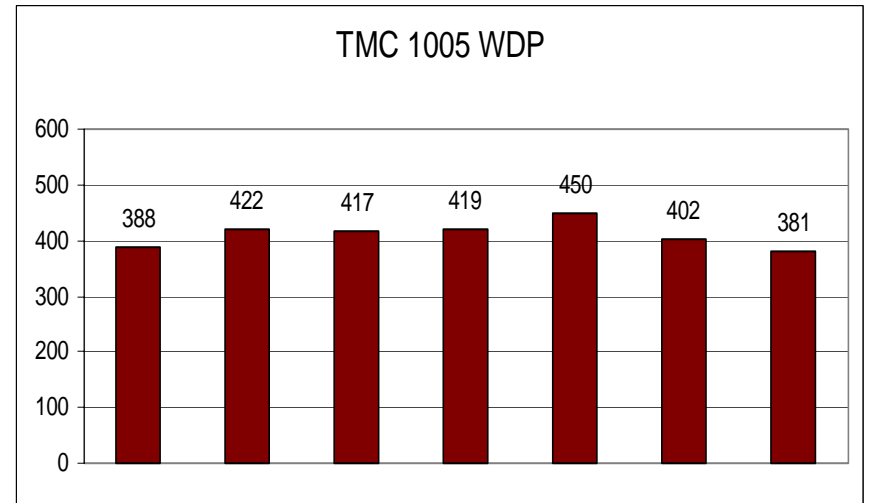
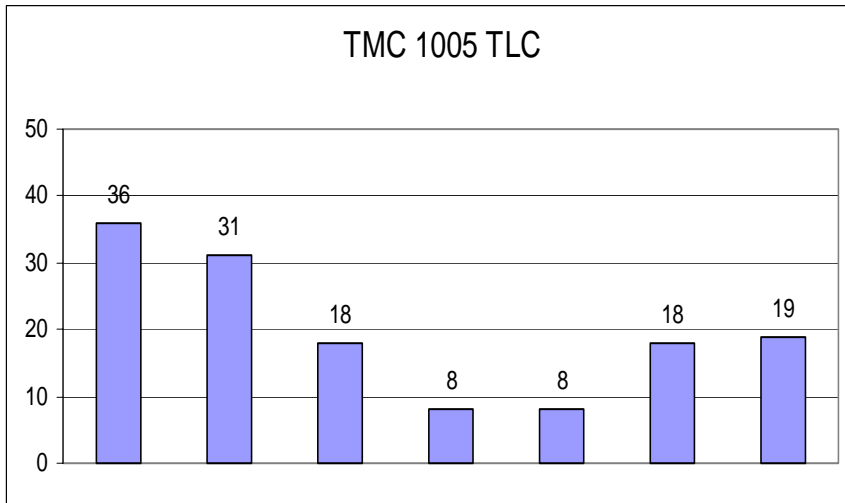
# 1Q Test Report for PC-9 Precision

- 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							

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# 1Q Test Report for PC-9 Precision



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# 1Q Test Report for PC-9 Precision

		Piston Deposits			Oil Consumption			Tests
		TLC	TGC	WDP	Initial g/hr	Final g/hr	Ratio F/I	
1Q Mean	TMC 1005	<b>20</b>	<b>31</b>	<b>411</b>	11.1	9.1	0.8	7
1Q Sigma		11	6	23	1	3		
1P Mean	TMC 1005	<b>31</b>	<b>30</b>	<b>308</b>	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.

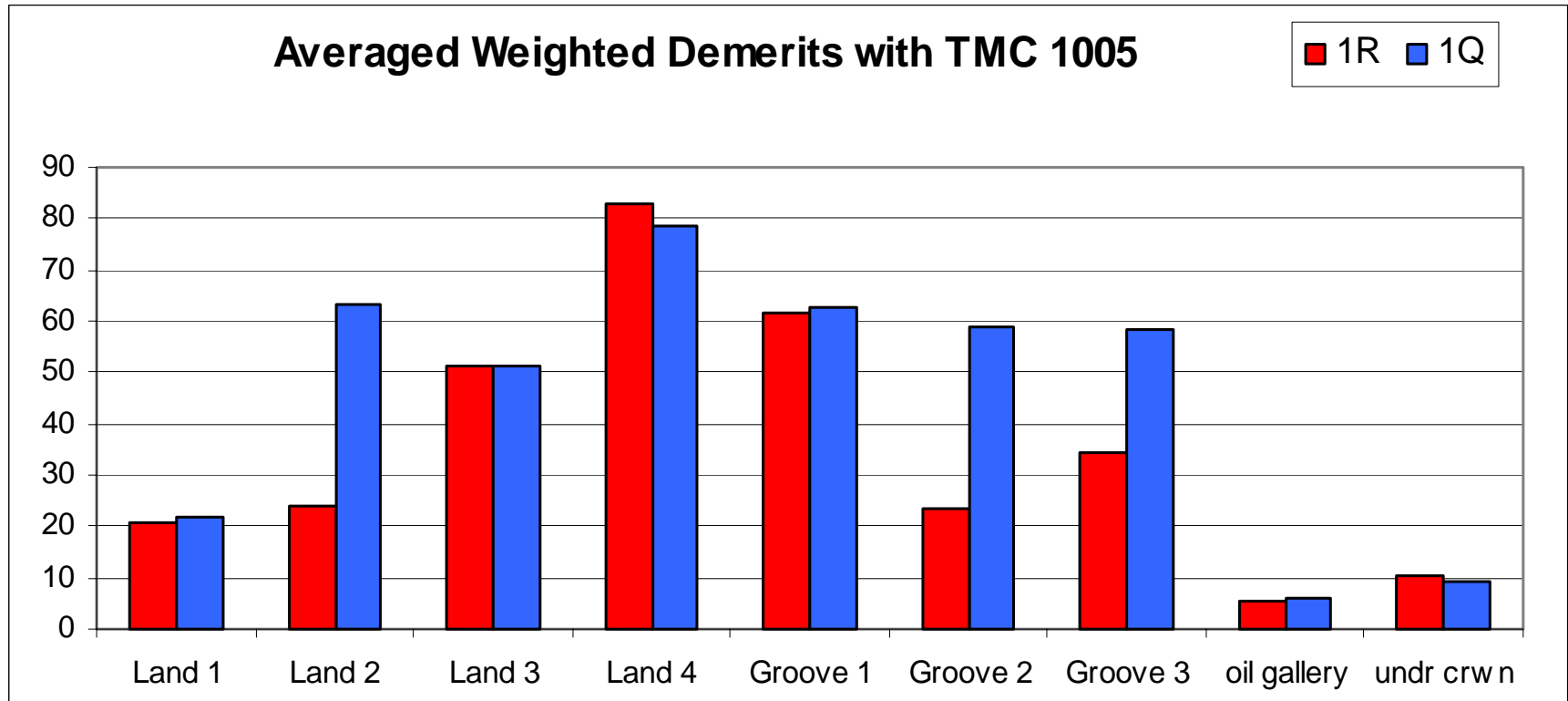
# 1Q Test Report for PC-9 Deposits

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	<b>315</b>	9.1	8.4	0.9	0.6	5 tests, No EGR
1R Sigma		<b>11</b>	<b>5</b>	<b>35</b>					
1R	E4	<b>54</b>	<b>46</b>	<b>374</b>	<b>10.1</b>	<b>13.6</b>	<b>1.3</b>		single run
1Q Mean	TMC 1005	20	31	411	11.1	9.1	0.8	2.7	7 tests with EGR
1Q Sigma		<b>11</b>	<b>6</b>	<b>23</b>					
1Q Mean	E4	<b>35</b>	<b>57</b>	<b>582</b>	<b>7.5</b>	<b>22.4</b>	<b>2.8</b>		average of 2 tests
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 on the 2nd land.
- ▶ Deposits in these areas can result in ring sticking and loss of oil control.

# 1Q Test Report for PC-9 Deposits



## ► Effects of EGR on Deposits

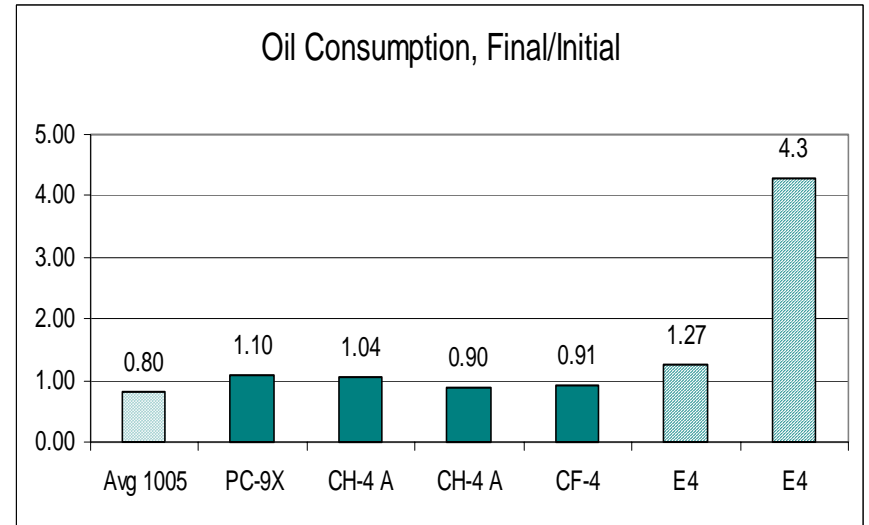
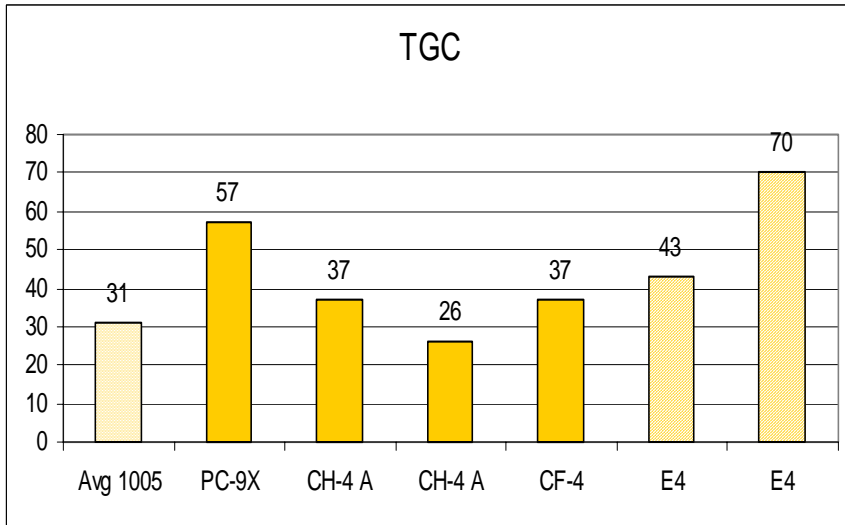
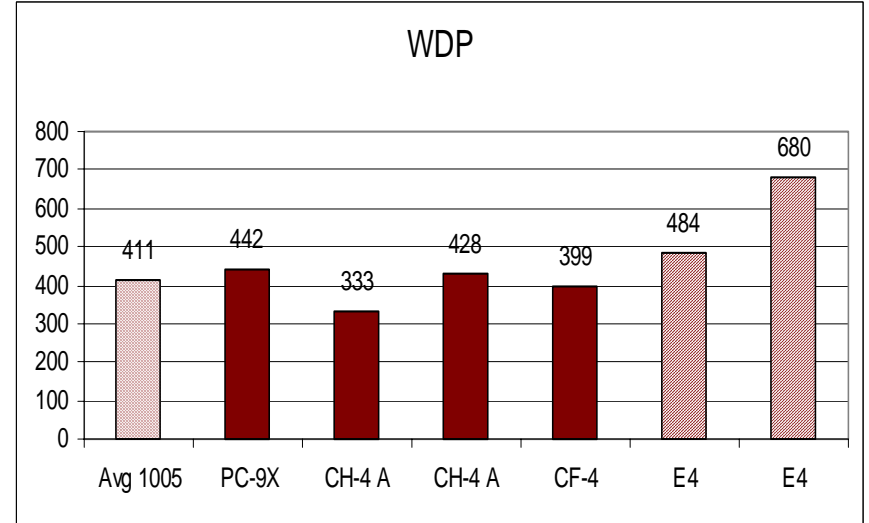
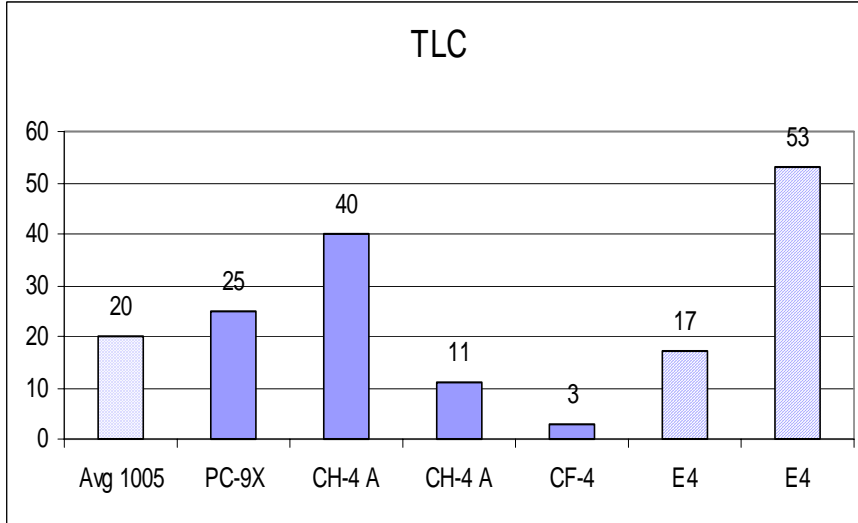
- ✧ Increased deposit levels are present in the 2nd and 3rd ring grooves and on the 2nd land.

# 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

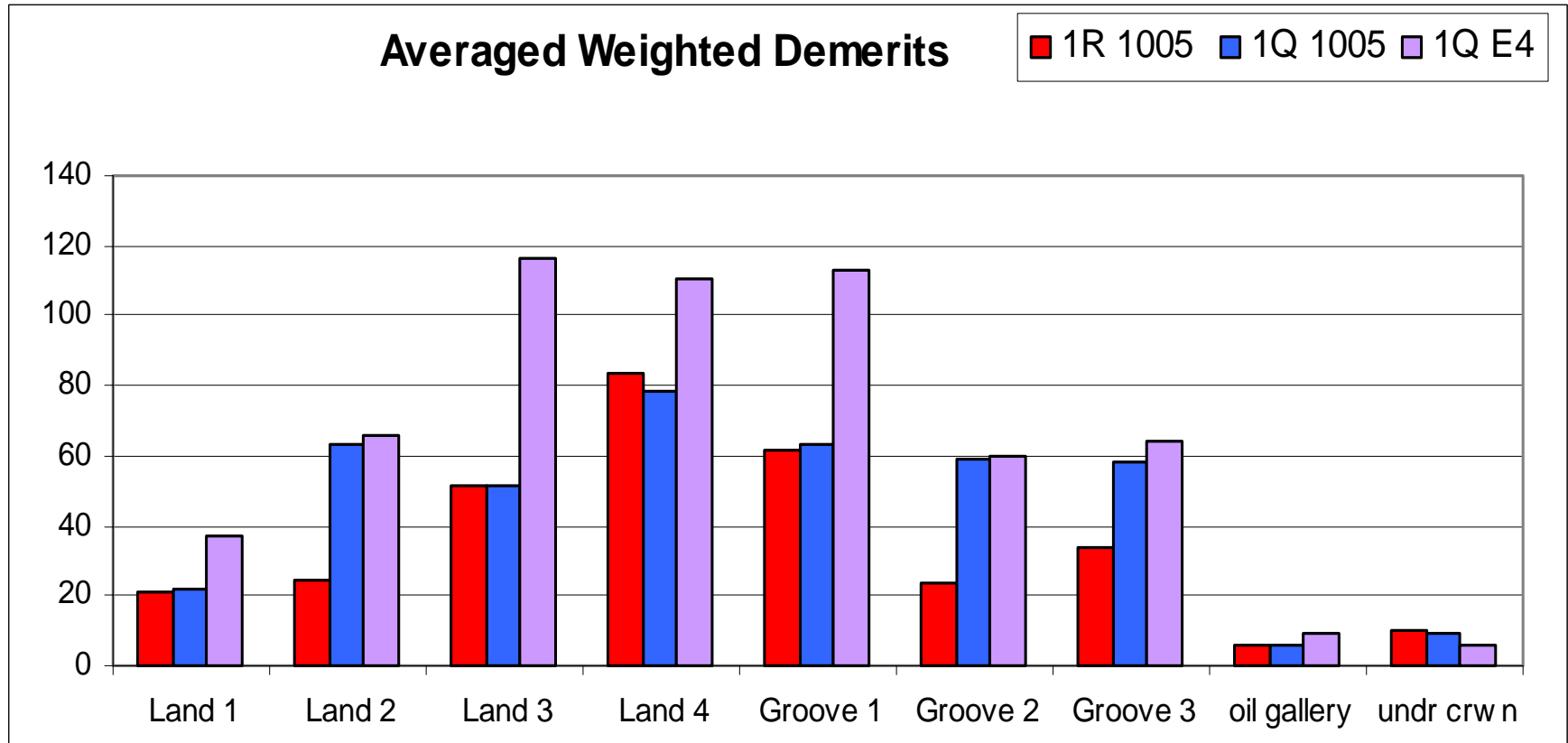


# 1Q Test Report for PC-9 Discrimination



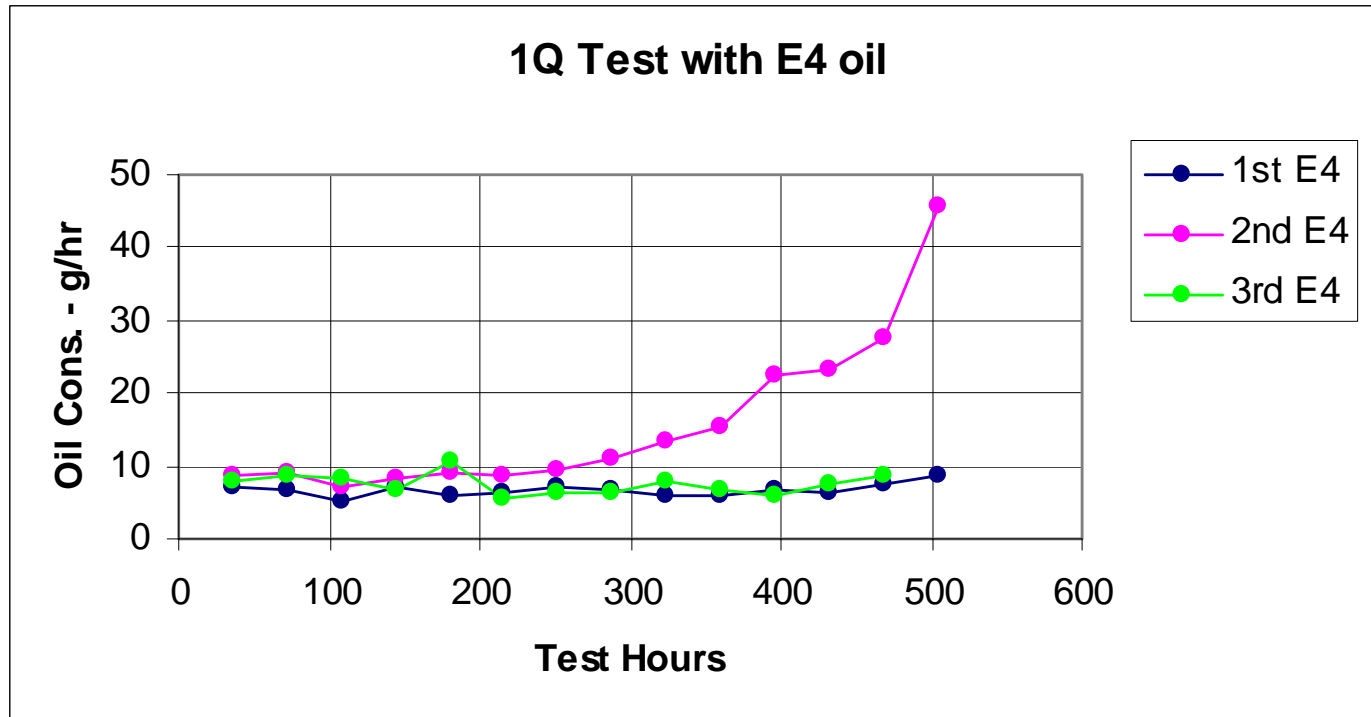
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# 1Q Test Report for PC-9 Discrimination



- ▶ The E4 oil increased deposits on the 3rd and 4th land, and in the 1st groove

# 1Q Test Report for PC-9 Discrimination



- ▶ A third run with the E4 oil is almost completed.
- ▶ Oil consumption is very similar to the first run.

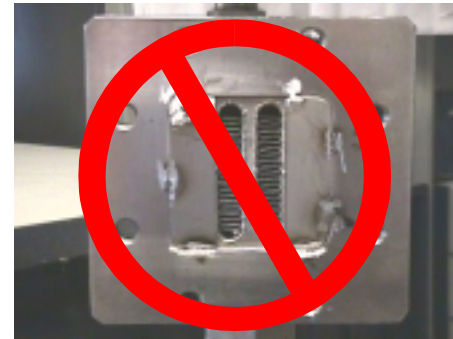
# 1Q Test Report for PC-9 Discrimination

- 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

## ▸ Modified 1Q EGR Cooler

- ✧ The modified EGR cooler, with two tubes, did not adequately reduce fouling.
- ✧ This modification will not be used for the matrix tests. All EGR coolers will maintain their current four tube configuration.
- ✧ The heat exchanger will be cleaned as needed during a 1Q run. This procedure has been in place throughout the development of the test.



# 1Q Test Report for PC-9 EGR Cooler

- ▶ Modified 1Q EGR Cooler
  - ✧ Caterpillar is pursuing alternate EGR cooler designs for the 1Q test.
  - ✧ If one these designs proves acceptable, it would be incorporated in the 1Q test after completion of the matrix.

# 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 HD diesel engine.
  - ✧ The 1Q test demonstrates discrimination between CH-4 type oils and a high ash E4 type oil.
  - ✧ The 1Q task force has approved the 1Q test procedure and hardware configuration.
- ▶ Based on the above statements, 1Q test is ready for matrix testing in PC-9.