

CRC Project No. CM-136-09-1B

Engine Durability Study of Mid-Level Ethanol Blends

Status Meeting – June 2011

June 13th, 2011

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Background

- ❑ There is interest in expanding the amount of ethanol that can be used in conventional vehicles beyond the current 10% limit. This is due to:
 - ❑ Rising ethanol production from the Energy Independence and Security Act, passed in December 2007. This mandates 36 billion ethanol equivalent gallons of bio-fuel be used by 2022

- ❑ Higher ethanol content could have an impact on these main areas of the engine and emissions performance:
 - ❑ Valve & valve seat wear and bore wear
 - ❑ Abrasive and adhesive wear and corrosion
 - ❑ Can lead to compression loss, misfire, and catalyst damage
 - ❑ Catalyst durability issues from ethanol effects on calibration



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Study Objective

This study will investigate the effects of mid-level ethanol blends, starting with E20, on the current on-road, non-flex fuel vehicle population. The effects of the fuel on engine durability will be studied in detail.

- Engines failing on E20 will be retested on E15 and then, if they do not pass, tested on E0



Pass/Fail Criteria

Description	Requirement for pass/fail
Emissions	The given vehicle must pass the FTP75 emissions standards given by EPA for the mileage of the vehicle.*
DTC (Diagnostic Trouble Code)	No powertrain or emissions related DTCs during testing.
Valve Clearance	The values must be within the specifications provided in the OEM's service manual.
Cylinder Leakdown	The values must be at 10% leakage or less.
Cylinder Compression	The values must be within the specifications provided in the OEM's service manual.

*The vehicle also was evaluated on the USO6 test, but the USO6 test was not used as a pass/fail criterion.

The engine / vehicle and all data is provided to each OEM representative. The final determination of pass / fail is made by OEM / Committee after examination of this information.



Vehicle Selection - E20

Eight pairs of specific vehicle model years and models were selected. The pairs of vehicles sampled are as follows:

Round 1 & 2 (E20 Testing)

- | | |
|--------------------------------|---------------------------------------|
| ❑ 2007 Ford Edge, 3.5L V6 | Tier 2-Bin 5; (17,906 & 14,450 Miles) |
| ❑ 2009 Dodge Caliber, 2.4L I4 | Tier 2 Bin4; (11,941 & 12,494 Miles) |
| ❑ 2004 Scion xA, 1.5L I4 | Tier 2 Bin9; (61,351 & 56,671 Miles) |
| ❑ 2005 Chevy Colorado, 3.5L I5 | Tier 2 Bin 9; (48,109 & 33,972 Miles) |

Round 3 & 4 (E20 Testing)

- | | |
|----------------------------|--|
| ❑ 2009 Chevy Aveo, 1.6L I4 | Tier 2 Bin 5 & Tier 2 Bin 4; (8,327 & 3,758 Miles) |
| ❑ 2007 Dodge Ram, 5.7L V8 | Tier 2 Bin 5; (28,597 & 26,078 Miles) |
| ❑ 2002 VW Jetta, 2.0L I4 | Tier 1 NLEV; (77,891 & 106,761 Miles) |
| ❑ 2001 Honda CR-V, 2.0L I4 | Tier 1 NLEV; (71,412 & 110,681 Miles) |



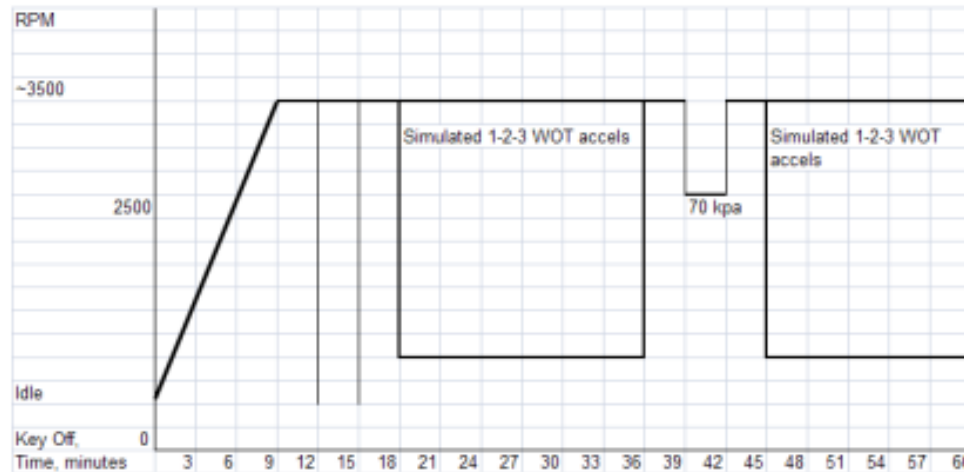
Engine Test Lifecycle

1. Pre-test vehicle to ensure the vehicle meets specifications and document condition
2. Run aging cycle
3. Post-test vehicle testing to determine if there are any changes



Engine Durability Cycle

□ The following durability cycle is used to test the engine durability using a mid-level ethanol blend fuel:



□ The test lasts for 500 total cycles and each cycle is 60 minutes in duration.

□ The maximum speed for any engine was 3500 RPM.

- This was chosen because high speed testing can conceal wear issues by increasing oil pullover through PCV and lubricating valve seats.
- This test cycle is substantially less severe than a standard high RPM durability cycle and should ensure that the engine will complete the test.

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Engine Data Measurements

Measurement	Description	Measurement Frequency		
		SOT	Every 50 hrs	EOT
Vehicle FTP 75	A baseline emissions test is completed on the vehicle to determine that it meets the required specifications for emissions levels	X		X**
Valve Measurements	Valve clearance measurements are conducted per the service manual unless otherwise instructed by the OEM.	X		X
Engine Dynamometer FTP	The same schedule that was completed on the vehicle level was replicated at the engine/dyno level to correlate the results from the vehicle to the engine dyno.	X*		X*
Engine 7 Steady State Point FTP correlation	It calculates the areas of concentrated operation points and reduces the second by second data (speed and load) from the FTP75 cycle into 7 representative points. These 7 speed & load points are run every 50 hours.	X	X	X
Cylinder Compression	If any value is below service manual limits, then the technical contact is notified immediately	X	X	X
Leakage	If any of the values is above the 10% threshold, the technical contact is notified immediately	X	X	X



*Round 3 & 4 engines will be re-installed into the vehicle at end of test for emissions testing. No Engine Dynamometer FTP will be completed.

** Vehicle FTP 75 at end of test is only completed on Round 3 and later.



Engine Service Intervals

□ The figure below illustrates the service intervals for all engines:

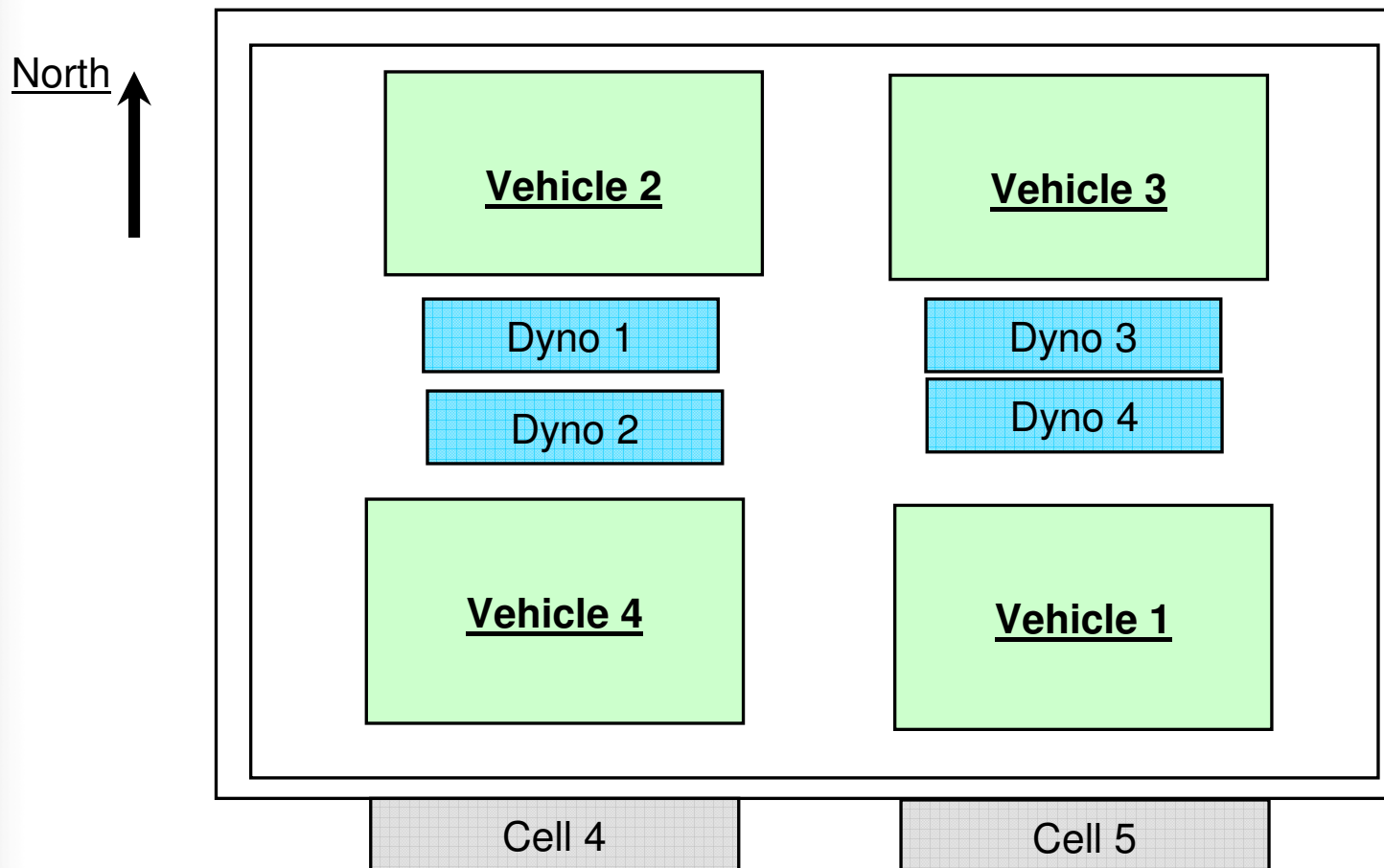
Engine Checks every 50 hours											
	0	50	100	150	200	250	300	350	400	450	500
Engine Fluid Levels	X	X	X	X	X	X	X	X	X	X	X
Oil & Filter Change	X	X	X	X	X	X	X	X	X	X	X
Oil Sample & Keep Oil Filter	X	X	X	X	X	X	X	X	X	X	X
Cylinder Compression	X	X	X	X	X	X	X	X	X	X	X
Cylinder Leak-Down	X	X	X	X	X	X	X	X	X	X	X
Spark Plug Inspection		X		X		X		X		X	
Spark Plug Change	X		X		X		X		X		X
Air Filter Replacement	X		X		X		X		X		X
Valve Clearance Measurement	X										X

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Set-up of Engines in Test Cells

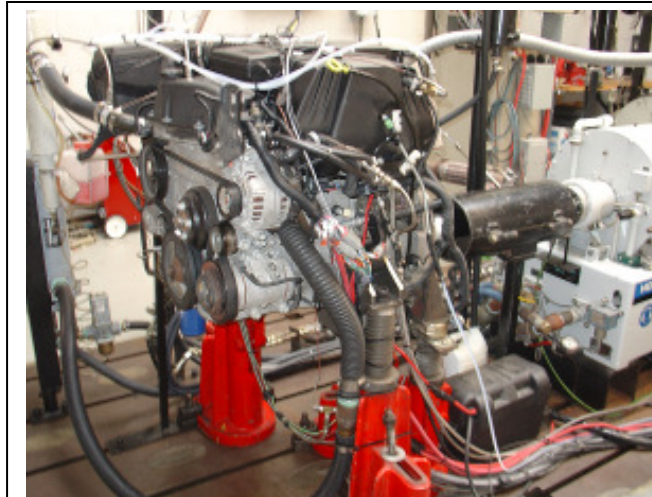
□ The figure below shows an example of the engine combinations in each of the test cells for Rounds 1 & 2. Similar setups are used for all testing.



Set-up of Engines in Test Cells

- Test Cell 4
 - Example Engine Setup: Round 1 & 2

North
↑



Vehicle 2

Dyno

Dyno

Vehicle 4



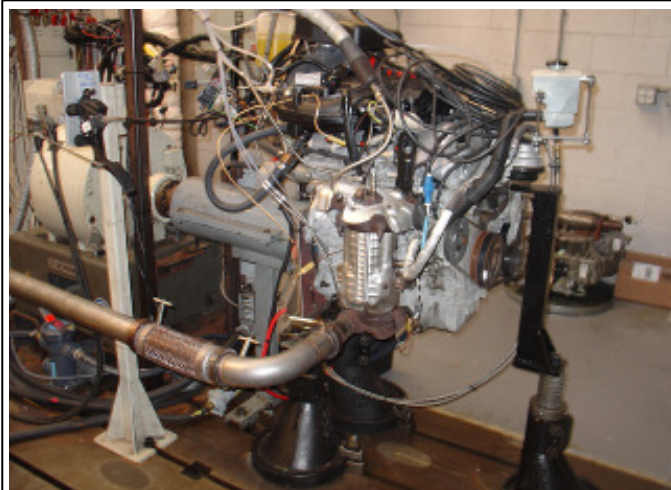
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Set-up of Engines in Test Cells

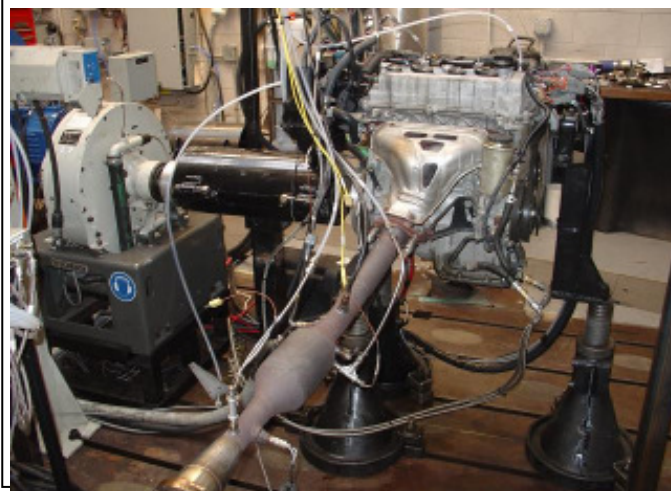
- Test Cell 5
 - Example Engine Setup: Round 1 & 2

North
↑



Vehicle 3

Dyno



Dyno

Vehicle 1

Set-up of Engines in Test Cells

□ The test vehicles require an “umbilical cord setup” for this testing. The vehicle shells are located outside the test cell and wire extensions are made to connect the engine harness inside the test cell to the vehicle harness outside the test cell.



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Round 1 & 2 Summary

Round 1 & 2 have been completed.

Pass/Fail Result Summary

Round	Description	Emissions	DTC	Valve Clearance	Compression	Leakage
1	Vehicle 1 – E20	N/A	Pass	Pass	Pass	Pass
1	Vehicle 2 – E20	Pass	Pass	Pass	Pass	Fail
1	Vehicle 3 – E20	Pass	Pass	Pass	Pass	Pass
1	Vehicle 4 – E20	Pass	Pass	Pass	Pass	Fail
2	Vehicle 1 – E20	Pass	Pass	Pass	Pass	Pass
2	Vehicle 2 – E20	Pass	Pass	Pass	Pass	Fail
2	Vehicle 3 – E20	Pass	Pass	Fail	Pass	Fail
2	Vehicle 4 – E20	Pass	Pass	Pass	Pass	Pass

E15 Re-Test Vehicles:

Note: Leakage on vehicle 4 was on one cylinder with 11% at EOT only marginal above threshold, therefore it was decided not to retest vehicle 4 on E15.

Description	Re-Test?
Vehicle 1	No
Vehicle 2	Yes
Vehicle 3	Yes
Vehicle 4	No (see note)

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Round 3 & 4 Summary

Pass/Fail Result Summary

Round	Description	Emissions	DTC	Valve Clearance	Compression	Leakage
3	Vehicle 5 – E20	Fail	Fail	Pass	Pass	Pass
3	Vehicle 6 – E20	Pass	Pass	Pass	Pass	Fail
3	Vehicle 7 – E20	Pass	Pass	Pass	Pass	Pass
3	Vehicle 8 – E20	Fail	Pass	Pass	Fail	Fail
4	Vehicle 5 – E20	Pass	Pass	Pass	Pass	Pass
4	Vehicle 6 – E20	Pass	Pass	Pass	Pass	Fail
4	Vehicle 7 – E20	Pass	Pass	Pass	Pass	Pass
4	Vehicle 8 – E20	N/A	TBD	TBD	TBD	Fail

E15 Re-Test Vehicles:

Note: Vehicle 5 has known issues with catalysts and the respective OEM is therefore offering extended warranty for catalyst replacement. Due to this and the fact that vehicle 5 engines passed all other criteria the overall result for vehicle 5 was deemed to be passed and therefore no re-testing on E15 is necessary.

Description	Re-Test?
Vehicle 5	No <small>(see note)</small>
Vehicle 6	Undecided
Vehicle 7	No
Vehicle 8	Yes



Round 5 & 6 Summary

□ Round 5 & 6

□ Pass/Fail Result Summary

Round	Description	Emissions	DTC	Valve Clearance	Compression	Leakage
5	Vehicle 2 – E15	Fail	Pass	Pass	Pass	Pass
5	Vehicle 3 – E15	Pass	Pass	Pass	Pass	Fail
6	Vehicle 2 – E15	Pass	Pass	Pass	Pass	Fail
6	Vehicle 3 – E15	Pass	Pass	Pass	Pass	Pass

□ E0 Re-Test Vehicles:

Description	Re-Test?
Vehicle 2	Yes
Vehicle 3	Yes



Round 7 & 8 Summary

Round 7 & 8

Pass/Fail Result Summary

Round	Description	Emissions	DTC	Valve Clearance	Compression	Leakage
7	Vehicle 8 – E15	TBD	TBD	Pass	Pass	Fail
7	Vehicle 3 – E0	Pass	Pass	Pass	Pass	Pass
8	Vehicle 8 – E15	TBD	TBD	TBD	TBD	TBD
8	Vehicle 3 – E0	TBD	TBD	TBD	TBD	TBD

E0 Re-Test Vehicles

Description	Re-Test?
Vehicle 8	Yes



Next Steps

❑ FEV will continue with execution of the program as follows:

- ❑ Complete durability testing on Round 7 & 8 engines (E15 & E0)
 - ❑ 500 hour durability schedule with standardized maintenance
 - ❑ Conduct EOT engine measurements for valve wear
 - ❑ EOT Vehicle FTP Testing
- ❑ Conduct durability testing on Round 9 & 10 engines (E0)
 - ❑ SOT Vehicle FTP Testing
 - ❑ Periodic engine measurements at FTP correlation points
 - ❑ 500 hour durability schedule with standardized maintenance
 - ❑ Conduct EOT engine measurements for valve wear
 - ❑ EOT Vehicle FTP Testing

- ❑ Decide on further testing with E0 and E15.

- ❑ Complete Final Report for delivery to CRC

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General Test Summary

- Some select test results are found on the following pages.

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Round 1 Testing Summary

Vehicle 1		E20
Cycles Completed	500	
Compression & Leakdown	Data shows less than 10% leakage & a less than 10% degradation in compression.	
Valve Measurements	No degradation of the clearance over the durability testing. All values were within the required OEM specification.	
Engine FTP Test	<u>Emissions Test Method:</u> FEV Engine Dyno Method for predicted vehicle emissions. The FTP simulation data was unrepeatable.	
Engine Teardown	Not necessary	





Round 1 Testing Summary

Vehicle 2		E20
Cycles Completed	550	
Compression & Leakdown	The leakdown measurements all remained below 10% until 450 hrs. At 500 hrs, the leakdown measurements on 2 cylinders increased to 22% and 18%, respectively. The leakage numbers decreased in the 50 additional hours on 2 cylinders to 15% and 9%, respectively. All other cylinders were OK.	
Valve Measurements	There was no degradation of the clearance over the durability testing.	
Engine FTP Test	<u>Emissions Test Method:</u> FEV Engine Dyno Method for predicted vehicle emissions. At the end of test, using the FEV predicted emissions method, the emissions passed the required standard.	
Engine Teardown	Valve seats showed unusual pitting and wear.	



Round 1 Testing Summary

Vehicle 3		E20
Cycles Completed	500	
Compression & Leakdown	Data shows less than 10% leakage & compression was within an acceptable range.	
Valve Measurements	The valve clearance measurements revealed that there was no degradation of the clearance over the durability testing. All values were within the required OEM specification.	
Engine FTP Test	<u>Emissions Test Method:</u> FEV Engine Dyno Method for predicted vehicle emissions. The emissions results degraded over the test for HC and CO values. However, using the FEV predicted emissions method, the emissions passed the required standard.	
Engine Teardown	OEM has received the engine and catalyst for inspection.	



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Round 1 Testing Summary

Vehicle 4		E20
Cycles Completed	500	
Compression & Leakdown	Data shows less than 10% leakage & less than 10% degradation in compression for all cylinders except 1 cylinder had 11% leakage at EOT, compression was within specification.	
Valve Measurements	No degradation of the clearance over the durability testing. All values were within the required OEM specification.	
Engine FTP Test	<p><u>Emissions Test Method:</u> FEV Engine Dyno Method for predicted vehicle emissions.</p> <p>At the end of test, the emissions did not pass the required standard. However, a test of the actual catalyst by the OEM indicated that it was still performing within specification at the end of the durability test.</p>	
Engine Teardown	No unusual wear noted on valve or valve seats. Valve lash within tolerance.	



Round 2 Testing Summary

Vehicle 1		E20
Cycles Completed	500	
Compression & Leakdown	Data shows less than 10% leakage & compression was within an acceptable range.	
Valve Measurements	There was no degradation of the clearance over the durability testing. All measurements were within specification at end of test.	
Engine FTP Test	<p><u>Emissions Test Method:</u> FEV Engine Dyno Method for predicted vehicle emissions.</p> <p>EOT emissions values were elevated past the acceptable standard level for CO, but were OK for NOx. However, the OEM reviewed the data and it was found to be OK. Therefore, the FTP test was determined to be a “pass” by the technical specialists.</p>	
Teardown	Not necessary	



Round 2 Testing Summary

Vehicle 2		E20
Cycles Completed	500	
Compression & Leakdown	The leakdown measurements all remained below 10% until 450 hrs. At 500 hrs, the leakdown measurements on 2 cylinders increased to 16% and 17%, respectively. All other cylinder were OK. The compression on all cylinder was OK throughout the test.	
Valve Measurements	There was no degradation of the clearance over the durability testing.	
Engine FTP Test	<u>Emissions Test Method:</u> FEV Engine Dyno Method for predicted vehicle emissions. At the end of test, the emissions passed the required standard.	
Engine Teardown	Engine and catalysts were delivered to OEM for inspection.	

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Round 2 Testing Summary

Vehicle 3		E20
Cycles Completed	500	
Compression & Leakdown	Leakdown on 1 cylinder increased beyond 10% at 100 cycles and remained high throughout testing. Other cylinders remained below 10% leakage until 325 cycles, when 1 cylinder increased to 12% while another cylinder measured a high of 60%. These 2 cylinders remained high for the rest of the testing. Compression in 1 cylinder was low at 100 cycles and by the end of test was low in 2 cylinders, however it was still within the 25% range of maximum compression. Engine power & torque was down 7-9%.	
Valve Measurements	Degradation of the clearance measured over the durability testing for one of the intake valves on cylinder 5 was 0.0005" lower than specification by end of test.	
Engine FTP Test	<u>Emissions Test Method:</u> FEV Engine Dyno Method for predicted vehicle emissions. Emissions passed the required standard at end of test.	
Engine Teardown	OEM has received the engine and catalyst for inspection.	



Round 2 Testing Summary

Vehicle 4		E20
Cycles Completed	500	
Compression & Leakdown	The leakdown measurements all remained below 10% at EOT. The 150 hour checks showed, high leakage, but all other checks showed less than 10% leakage. Compression was good throughout testing.	
Valve Measurements	No degradation of the clearance over the durability testing. All values were within the required OEM specification.	
Engine FTP Test	<p><u>Emissions Test Method:</u> FEV Engine Dyno Method for predicted vehicle emissions.</p> <p>The emissions results degraded over time. Using the FEV predicted emissions method, the emissions did not pass the required standard. However, the engine was reinstalled in a production vehicle and it successfully passed the chassis rolls emissions test.</p>	
Engine Teardown	Vehicle, engine, transmission and catalysts were delivered to OEM for inspection.	



Round 3 Testing Summary

Vehicle 5		E20
Cycles Completed	500	
Compression & Leakdown	The leakdown measurements all remained below 10%. The compression on all cylinders was at an acceptable level.	
Valve Measurements	Valve measurements were completed and found to be acceptable by the OEM technical contact.	
Vehicle FTP Test	<p><u>Emissions Test Method:</u> Complete vehicle, Chassis Dynamometer.</p> <p>Note: A DTC of P0420 was set when the engine was re-installed in the vehicle. It was not seen during dyno testing. P0420 is a code for a catalyst efficiency low and the service manual instructs the repair facility to replace the catalyst. The vehicle was run with this code active for the end of test emissions testing. The catalyst was not replaced.</p> <p>The vehicle failed emission for NOx and CO at the 100k standard.</p>	
Engine Teardown	TBD	



Round 3 Testing Summary

Vehicle 6		E20
Cycles Completed	500	
Compression & Leakdown	The leakdown measurements all remained below 10% for 400 cycles. At 450 cycles, the leakage increased above the threshold on 1 cylinder. At the 500 cycle checks, the cylinder was below 10% again. The compression on all cylinders was OK throughout the testing.	
Valve Measurements	Valve measurements were completed and found to be within specification.	
Vehicle FTP Test	<p><u>Emissions Test Method:</u> Complete vehicle, Chassis Dynamometer.</p> <p>The vehicle passed FTP75 emissions test, but emissions were 15x higher for the US06 test at EOT. The US06 test has not been used in the past to indicate pass/fail for the program. However, the 15x increase in CO emissions is a concern. This has not been seen on other engines. (Note: The dyno coefficients had to be derived since the testing is run in a different way from when the Vehicle was originally certified because the certification labs can't run the old version of the emissions test.)</p>	
Engine Teardown	Vehicle to be returned to OEM for further investigation.	



Round 3 Testing Summary

Vehicle 7		E20
Cycles Completed	500	
Compression & Leakdown	The leakdown measurements all remained below 10% for all 500 cycles. The compression on all cylinders was OK throughout the test.	
Valve Measurements	Valve measurements were completed and found to be within specification.	
Engine FTP Test	<u>Emissions Test Method:</u> FEV Engine Dyno Method for predicted vehicle emissions. At the end of test, using the FEV predicted emissions method, the emissions passed the required standard.	
Engine Teardown	Not Necessary	



Round 3 Testing Summary

Vehicle 8		E20
Cycles Completed	500	
Compression & Leakdown	<p>The leakdown measurements all remained below 10% until the engine reached 300 cycles. At that time, 1 cylinder increased beyond the 10% threshold and increased throughout the remainder of the testing. The engine was then monitored every 25 cycles. Another Cylinder increased beyond 10% leakage at 375 cycles and continued to increase for the rest of testing. All other cylinders remained below the 10% specification.</p> <p>The compression on 1 cylinder was low as well. It failed the compression spec at 450 and 500 cycles. (Spec = lowest compression cylinder is within 25% of highest). The rest of the cylinders had good leakage and compression for the duration of the 500 cycles.</p>	
Valve Measurements	Valve measurements completed and sent to OEM for review.	
Vehicle FTP Test	<p><u>Emissions Test Method</u>: Complete vehicle, Chassis Dynamometer.</p> <p>Vehicle failed emissions testing for NOx at the 50k emissions standard</p>	
Engine Teardown	Engine to be evaluated once it is returned to OEM.	



Round 4 Testing Summary

Vehicle 5		E20
Cycles Completed	500	
Compression & Leakdown	The leakdown measurements all remained below 10%. The compression on all cylinders was at an acceptable level.	
Valve Measurements	Valve measurements were completed and found to be within a reasonable range.	
Vehicle FTP Test	<u>Emissions Test Method:</u> Complete vehicle, Chassis Dynamometer. The vehicle passed the FTP75 emissions standard and had no issues with the US06 emissions test.	
Engine Teardown	Not Necessary	



Round 4 Testing Summary

Vehicle 6		E20
Cycles Completed	500	
Compression & Leakdown	The leakdown measurements all remained below 10% for 50 cycles. At 50 cycles, the leakage increased above the threshold to 11% on 1 cylinder. The same cylinder has had a leakage between 11% - 15% throughout the 500 cycles. The leakage on another cylinder reached 11% at 150 and 400 cycles. The compression is good on all cylinders for all 500 cycles of testing.	
Valve Measurements	Valve measurements were completed and found to be within specification.	
Vehicle FTP Test	<u>Emissions Test Method:</u> Complete vehicle, Chassis Dynamometer. The end of test emissions evaluations were completed in vehicle. It passed FTP75 emissions test, but emissions were slightly elevated for the US06 test at EOT. The data was sent to the OEM for review.	
Engine Teardown	TBD	



Round 4 Testing Summary

Vehicle 7		E20
Cycles Completed	500	
Compression & Leakdown	The leakdown measurements all remained below 10% for all 500 cycles. The compression on all cylinder was OK throughout the test.	
Valve Measurements	Valve measurements were completed and found to be within specification.	
Vehicle FTP Test	<u>Emissions Test Method:</u> Complete vehicle, Chassis Dynamometer. The vehicle passed FTP75 emissions test, but emissions were slightly elevated for the US06 test at EOT. The test was deemed a “pass” by the OEM.	
Engine Teardown	Not Necessary	



Round 4 Testing Summary

Vehicle 8		E20
Cycles Completed	500	
Compression & Leakdown	<p>The leakdown measurements all remained below 10% until the engine reached 250 cycles. At that time, 1 cylinder increased beyond the 10% threshold and increased throughout the remainder of the testing.</p> <p>The compression on same 1 cylinder was low as well, but still within specification. (Spec = lowest compression cylinder is within 25% of highest).</p> <p>The rest of the cylinders had good leakage and compression for the duration of the 500 cycles.</p> <p>At the EOT WOT check, the engine showed a drop in power. The leakage in 1 cylinder was 100% and compression was 0. The root cause is being investigated.</p>	
Valve Measurements	Valve measurements will be completed by OEM.	
Vehicle FTP Test	Will not be completed due to 0 compression in 1 cylinder.	
Engine Teardown	Engine sent to OEM for evaluation & inspection.	



Round 5 Testing Summary

Vehicle 2		E15
Cycles Completed	500	
Compression & Leakdown	The leakdown measurements have remained below 10% for 500 cycles and compression was also within specification.	
Valve Measurements	Valve measurements were completed and found to be within specification.	
Vehicle FTP Test	<u>Emissions Test Method:</u> Complete vehicle, Chassis Dynamometer. The end of test emissions evaluations were completed in vehicle. It failed FTP75 and had elevated emissions during US06 emission tests at EOT. The data was sent to the OEM for review.	
Engine Teardown	Cylinder head sent to OEM for analysis	



Round 5 Testing Summary

Vehicle 3		E15
Cycles Completed	500	
Compression & Leakdown	The leakdown measurements were below 10% for 300 cycles. At 300 cycles the leakage on 2 cylinders increased to 16% on both. (As a side note, the E20 Vehicle 3 that had issues started to show high leakage at 100 cycles). The leakage on 3 cylinders were above the 10% threshold at the end of testing (15, 18 and 14%, respectively). The cylinder compression was within specification.	
Valve Measurements	Valve measurements were completed and found to be within specification.	
Vehicle FTP Test	<u>Emissions Test Method:</u> Complete vehicle, Chassis Dynamometer. The end of test emissions evaluations were completed in vehicle. It passed FTP75 and US06 emissions at EOT. The data was sent to the OEM for review.	
Engine Teardown	Engine sent to OEM for analysis.	



Round 6 Testing Summary

Vehicle 2		E15
Cycles Completed	500	
Compression & Leakdown	The leakdown measurements for three cylinders were above 10% after 500 cycles and compression was within specification.	
Valve Measurements	Valve measurements were completed and found to be within specification.	
Vehicle FTP Test	<u>Emissions Test Method:</u> Complete vehicle, Chassis Dynamometer. To be completed	
Engine Teardown	Cylinder head sent to OEM for analysis	



Round 6 Testing Summary

Vehicle 3		E15
Cycles Completed	500	
Compression & Leakdown	The leakdown measurements have remained below 10% for 500 cycles and compression was also within specification.	
Valve Measurements	Valve measurements were completed and found to be within specification.	
Vehicle FTP Test	<u>Emissions Test Method:</u> Complete vehicle, Chassis Dynamometer. To be completed	
Engine Teardown	Not necessary	



Round 7 Testing Summary

Vehicle 3		E0
Cycles Completed	500	
Compression & Leakdown	The leakdown measurements have remained below 10% for 500 cycles and compression was also within specification except at 450 hours inspection, 1 cylinder had 11% leakdown.	
Valve Measurements	Valve measurements were completed and found to be within specifications	
Vehicle FTP Test	Vehicle passed End of test emissions tests including FTP75 and US06.	
Engine Teardown	Not necessary	



Round 7 Testing Summary

Vehicle 8 *		E15
Cycles Completed	350	
Compression & Leakdown	The leakdown measurements have exceeded 10% in multiple cylinders at 350 hours inspection. 1 Cylinder had leakage above 10% at 100 & 150 Hours More than 3 cylinders had leakage above 10% at 200 hour, 250 hour and 300 hour inspections	
Valve Measurements	Valve measurements completed at end of test and found to be within OEM specifications.	
Vehicle FTP Test	The end of test emissions evaluations needs to be completed (In Progress)	
Engine Teardown	TBD	

* Engine was decided to be removed from test cell with consent from OEM. Engine assembled in vehicle for EOT emissions