



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

**Study of the Effects of Intermediate Ethanol-Blended
Gasoline Fuels (E20, E15) on Engine Durability**

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Introduction

- ❑ Project started in fall 2009
- ❑ Testing concluded in December 2011
- ❑ A project status update presentation was given at the 2011 CRC Real World Emissions Workshop (RWEW)
- ❑ Please refer to presentation material from 2011 CRC RWEW for additional information about the overall program objectives and details about the testing process
- ❑ A final report for CRC project CM-136-09-1B will soon be published and will be available on the CRC website at <http://www.crcao.org>

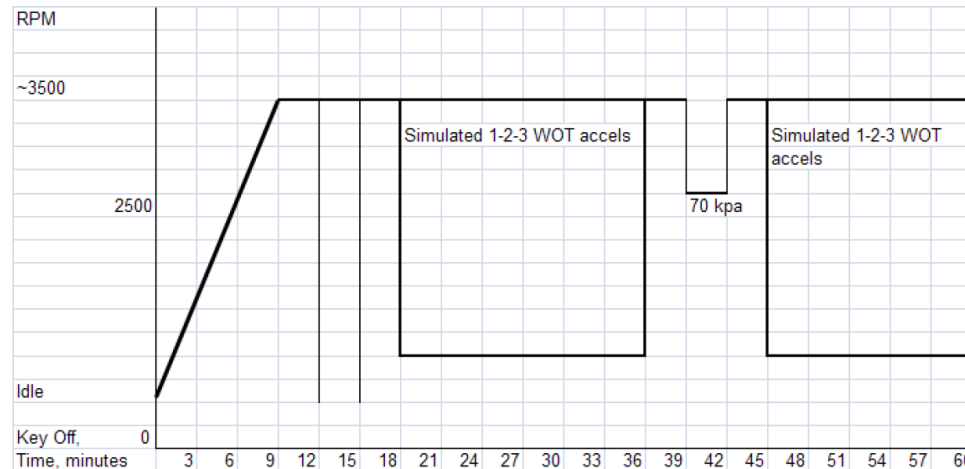


Project Objective

- ❑ 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.
- ❑ This engine durability study has investigated the effects of intermediate ethanol blends, E20 and E15, on the current on-road, non-flex fuel vehicle population.
- ❑ This study is part of a broader ongoing effort sponsored by the oil and auto industries through CRC to better understand the emissions, air quality and performance impacts of intermediate-level ethanol blends for consumers.

Aging Cycle

The following aging cycle is used to test the engine durability using intermediate-level ethanol blend fuels:



The test lasts for 500 total cycles and each cycle is 60 minutes in duration.
The maximum speed for any engine is 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.

Engine Testing Sequence

- ❑ Engines were always tested in duplicates
- ❑ Engines which passed testing on E20 are assumed to pass also on E15 → No further testing was conducted
- ❑ Engines which failed on E20 were retested on E15:
 - ❑ Pass on E15 → No further testing conducted
 - ❑ Fail on E15 → Reference testing on E0
- ❑ Reference testing on E0 was necessary for failed E15 tests in order to rule out engine specific durability issues for the chosen 500 hour low speed durability test cycle

Vehicle Selection

Eight pairs of specific vehicle model years and models were selected.

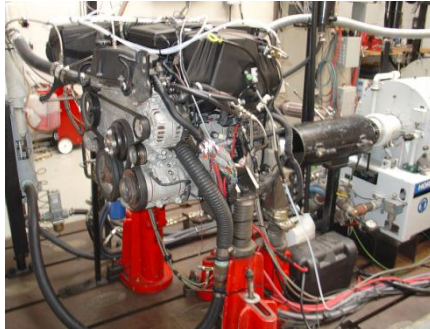
The pairs of vehicles sampled are as follows (mileage in brackets are shown for initial engine duplicates of vehicles which were tested on E20):

- | | |
|---|--|
| <input type="checkbox"/> 2001 Honda CR-V, 2.0L I4 | Tier 1 NLEV; (71,412 & 110,681 Miles) |
| <input type="checkbox"/> 2002 VW Jetta, 2.0L I4 | Tier 1 NLEV; (77,891 & 106,761 Miles) |
| <input type="checkbox"/> 2004 Scion xA, 1.5L I4 | Tier 2 Bin 9; (61,351 & 56,671 Miles) |
| <input type="checkbox"/> 2005 Chevy Colorado, 3.5L I5 | Tier 2 Bin 9; (48,109 & 33,972 Miles) |
| <input type="checkbox"/> 2007 Dodge Ram, 5.7L V8 | Tier 2 Bin 5; (28,597 & 26,078 Miles) |
| <input type="checkbox"/> 2007 Ford Edge, 3.5L V6 | Tier 2-Bin 5; (17,906 & 14,450 Miles) |
| <input type="checkbox"/> 2009 Dodge Caliber, 2.4L I4 | Tier 2 Bin 4; (11,941 & 12,494 Miles) |
| <input type="checkbox"/> 2009 Chevy Aveo, 1.6L I4 | Tier 2 Bin 5 & Tier 2 Bin 4; (8,327 & 3,758 Miles) |

Setup of Engines in Test Cells

2005 Chevy Colorado

164 kW @ 5600
305 Nm @ 2800



2009 Dodge Caliber

128 kW @ 6000
224 Nm @ 4400

2007 Ford Edge

198 kW @ 6250 339
Nm @ 4500



2004 Scion xA

81 kW @ 6000
142 Nm @ 4200

Setup of Engines in Test Cells

All engines were setup together with vehicles in test cell hallway using FEV's "umbilical cord" method.

The vehicle shells are located outside the test cell and wire extensions are made to connect the engine harness to the vehicle harness.





Overall Testing Summary

Sample ----- Vehicle	E20		E15		E0	
	Sample A	Sample B	Sample C	Sample D	Sample E	Sample F
Vehicle 1	Pass	Pass				
Vehicle 2	Fail (L)	Fail (L)	Fail (E)	Fail (L)	Pass	Pass
Vehicle 3	Pass	Fail (V,L)	Fail (L)	Pass	Pass	Pass
Vehicle 4	Waived (L)	Pass				
Vehicle 5	Waived (E,D)	Pass				
Vehicle 6	Waived (L)	Waived (L)				
Vehicle 7	Pass	Pass				
Vehicle 8	Fail (E,C,L)	Fail (C,L)	Fail (E,L)	Fail (C,L)	Fail (E,C,L)	Fail (E,L)

Waived = Vehicle did not pass all specified criteria after the 500 hour durability test, but was not retested on E15 or E0 after a detailed review of the data with the respective OEM contact and agreement with CRC group

Letters in brackets indicate cause of failure:

E = Emissions, D = Diagnostic Trouble Code (DTC), V = Valve Clearance, C = Compression, L = Leakage

Conclusions

- ❑ Out of eight different tested engine types, one had a design that was inappropriate for the test cycle, two failed on E20 and E15, and five passed on E20 and by assumption E15 and E0.
- ❑ Out of the two failed tested engine types, both successfully completed the reference testing on E0.
- ❑ For the failed engines which successfully completed the E0 reference fuel tests, the ethanol content can be inferred with 89% confidence as an influential factor for the engine failures.
- ❑ For the failed engine which also failed on E0 reference fuel, the failures can not be directly linked to the ethanol content. The design of the engine interacting with the test cycle is the reason cited by the OEM maker to be the responsible cause for the occurred failures.
- ❑ The occurred failures don't show that specific valvetrain types are more or less sensitive to ethanol content.
- ❑ The majority of the failures can be linked to issues with valve seats, either related to material or wear/deformation.

The study has shown that two popular gasoline engines used in light-duty automotive applications of vehicles from model years 2001 through 2009 failed with mechanical damage when operated on intermediate-level ethanol blends (E15 and E20)



Thank you for your attention!

Questions?

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