OAK RIDGE NATIONAL LABORATORY

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ORNL/TM-2011/65

Powertrain Component Inspection from Mid-Level Blends Vehicle Aging Study

November 2010

Prepared by

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Southwest Research Institute

UT-BATTELLE

ORNL-27 (4-00)

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POWERTRAIN COMPONENT INSPECTION FROM MID-LEVEL BLENDS VEHICLE AGING STUDY

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Date Published: November 2010

Prepared by
SOUTHWEST RESEARCH INSTITUTE
for
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831-6283
managed by
UT-BATTELLE, LLC
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-00OR2272

FOREWORD

The Energy Independence and Security Act of 2007 calls on the nation to significantly increase its use of renewable fuels to meet its transportation energy needs. The law expands the renewable fuel standard to require use of 36 billion gallons of renewable fuel by 2022. Given that ethanol is the most widely used renewable fuel in the U.S. market, ethanol will likely make up a significant portion of the 36-billion-gallon requirement.

The vast majority of ethanol used in the United States is blended with gasoline to create E10—gasoline with up to 10% ethanol. The remaining ethanol is sold in the form of E85—a gasoline blend with as much as 85% ethanol that can only be used in flexible-fuel vehicles (FFVs). Consumption of E85 is at present limited by both the size of the FFV fleet and the number of E85 fueling stations.

Gasoline consumption in the United States is currently about 140 billion gallons per year; thus the maximum use of ethanol as E10 is only about 14 billion gallons. While the U.S. Department of Energy (DOE) remains committed to expanding the E85 infrastructure, that market represented less than 1% of the ethanol consumed in 2010 and will not be able to absorb projected volumes of ethanol in the near term. Because of these factors, DOE and others have been assessing the viability of using mid-level ethanol blends (E15 or E20) as a way to accommodate growing volumes of ethanol. The DOE Mid-Level Ethanol Blends Test Program has been under way since 2007, supported jointly by the Office of the Biomass Program and the Vehicle Technologies Program. One of the larger projects, the Catalyst Durability Study, or Vehicle Aging Study, will be completed early in calendar year 2011. The following report describes a subproject of the Vehicle Aging Study in which powertrain components from 18 of the vehicles were examined at Southwest Research Institute under contract to Oak Ridge National Laboratory (ORNL). Any questions about the study can be addressed to the ORNL technical project manager, Brian West (westbh@ornl.gov).

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FUELS AND LUBRICANTS RESEARCH DIVISION
Fuels and Driveline Lubricants Research Department

Final Report

Powertrain Component Inspection from Mid-Level Blends Vehicle Aging Study

Conducted for

UT-Battelle, LLC
Oak Ridge, Tennessee

SwRI Project 08.15844
Proposal 08-58845

November 30, 2010

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I. INTRODUCTION

A. Background

The Oak Ridge National Laboratory (ORNL) project manager selected a subset of vehicles, aged in the DOE V4/CRC E-87-2 activity at Southwest Research Institute (SwRI), for powertrain component inspection. The full test-vehicle set in the program, which span a range of model years, were purchased in matched sets of three or four. Matched vehicles had the same EPA engine family, transmission, etc, and the odometer mileage range for a vehicle set was desired to be less than 10,000 miles. Actual odometers at the time of purchase for the vehicle groups involved in the inspection study are shown in Table 1. Vehicles were aged using the Standard Road Cycle (SRC) driving profile on mileage accumulation dynamometers (MADs) at SwRI. Mileage accumulation for each set was based on the highest mileage vehicle of a set, and all vehicles of a set were driven approximately the same distance, as shown in Table 1.

Each vehicle of a make/model/model year set was dedicated to a specific test fuel for aging. Aging fuels were retail top tier gasoline (RE0), and this RE0 gasoline was splash blended with ASTM D4806 ethanol to produce RE10, RE15, and RE20. Following completion of mileage accumulation and end of test (EOT) emissions tests, a subset of the vehicles entered the Powertrain Inspection Activity. The Oak Ridge contract for the E-87-2 program was modified on 6/28/2010 to include engine teardown and inspection of selected vehicles. The initial scope of work was limited to the RE0 and RE15 vehicles (listed below) of six make and model groups (total of 12 vehicles), which had recently completed mileage accumulation and emissions testing for the E-87-2 program.

1. Honda Accord ORHA0 and ORHA15
2. Chevrolet Silverado ORCS0 and ORCS15
3. Nissan Altima vehicles ORNA0 and ORNA15
4. Ford Taurus ORFT0 and ORFT15
5. Dodge Caravan ORDC0 and ORDC15
6. Chevrolet Cobalt ORCC0 and ORCC15

On 8/6/2010 the E20 vehicles from the six vehicle groups were also added to the scope of the inspection program with the direction to give the RE0 and RE15 vehicles the highest priority. This status report includes all of the results for the 18 vehicles.

Table 1. Odometer Mileage and Test Mileage

	Zero Odometer Miles	First Interval Test Miles	First Interval Odometer	Second Interval Test Miles	Test Miles	Final Odometer Miles
ORHAO	31,686	50,000	81,686	35,367	85,367	117,053
ORHA15	31,369	50,000	81,369	35,367	85,367	116,736
ORHA20	34,383	50,000	84,383	35,367	85,367	119,750
ORCS0	27,606	50,000	77,606	42,144	92,144	119,750
ORCS15	17,152	50,000	67,152	42,144	92,144	109,296
ORCS20	17,103	50,000	67,103	42,144	92,144	109,247
ORNA0	19,284	50,000	69,284	50,226	100,226	119,510
ORNA15	9,950	50,000	59,950	50,226	100,226	110,176
ORNA20	10,307	50,000	60,307	50,226	100,226	110,533
ORFT0	17,231	50,000	67,231	52,519	102,519	119,750
ORFT15	17,099	50,000	67,099	52,519	102,519	119,618
ORFT20	13,082	50,000	63,082	52,519	102,519	115,386
ORDC0	46,473	44,191	90,664	24,750	68,941	115,414
ORDC15	40,031	44,191	84,222	24,750	68,941	108,972
ORDC20B	50,809	44,191	95,000	24,750	68,941	119,750
ORCC0	38,894	47,282	86,176	24,750	72,032	110,926
ORCC15	47,718	47,282	95,000	24,750	72,032	119,750
ORCC20	38,499	47,282	85,781	24,750	72,032	110,531

B. **Inspection Summary**

A description of the measurements and checks which were conducted are given in the following sections.

1. **Evaporative Emissions System Integrity Check**

A Smoke Pro® Total-Tech™ device was used to check the integrity of the evaporative emissions systems of each of the original 12 vehicles and the six RE20 vehicles. The evaporative emissions systems were researched in the vehicles' service manuals and the SwRI technicians introduced smoke under low pressure from the vent valve to the fuel tank and also from the vent valve to the purge valve. In every case the systems held pressure and there was no visual evidence of smoke leaking from the system.

Because the vehicles in this program were driven on the MADs virtually around the clock, they spent very little time "soaking", which would have exercised the evaporative systems in a diurnal as they might experience in normal service. However, the evaporative systems were exercised at each refueling event due to the use of on-board refueling vapor recovery (ORVR). While mileage accumulation and fuel economy varies widely by vehicle set, a typical vehicle in this project would be refueled some 150-400 times during the mileage accumulation and emissions preps.

2. Cam Lobe Wear

The original plan was to measure cam lobe wear using a Precision Devices Micro/Analyzer-2000 (PDI machine). A surface trace was to be measured on the nose of each cam lobe and at a high wear area parallel to the centerline of the camshaft. The idea was to extend the trace from the front to the rear of the lobe to include the front and rear surfaces, which had not been worn. Thus the "lobe wear" would have been defined as the maximum distance from the worn surface to a straight line defined by the "unworn" edges.

However, the cam lobes of the engines either had wear at one of the edges or the lobes had a convex crown. After discussions with the ORNL Program manager, it was decided to take heel-to-toe measurements in the center of the wear area of each lobe with a calibrated micrometer. These measurements are complete for all 18 vehicles, and given in Appendix A. For vehicles whose service manual provides camshaft lobe lift specifications, base circle diameter measurements were performed to enable calculation of cam lift. Note that the Honda Accords are equipped with a primary and secondary intake camshaft lobe due to the VTEC feature of these engines.

Because the cams were not measured at the beginning of the program, and due to normal part-to-part variation, the measurements are potentially inconclusive with respect to any fuel-related differences in cam wear.

3. Valve Seat Width and Valve Surface Contour

The valves were measured in four radial traces at 90 degrees on the machined seating area. The width of the worn area is a measure of seating width. Refer to Appendix B for a photograph and schematic showing the measurement technique. Using a straight line datum between the un-worn areas at each end of the trace, the valve wear is computed. The measurements are complete and are given in Appendix B. No apparent trends based on differences in the aging fuel were observed.

4. Valve Stem Height

The valve stem height results for all 18 vehicles are included in Appendix C. The distance from the tip of the valve was measured back to the cylinder head surface for the valve spring. In cases where a washer is inserted in production between the cylinder head surface and the spring, the washer was removed for the measurement. The exception was the Dodge Caravan which was measured with the washer in place because the valve stem height was specified in the service manual with the washer installed. The valve stem height measurement can be an indicator of valve seat wear. Because valve stem heights at the beginning of the program are not known, and because of variations in actual cylinder head geometry and valve length, it is not possible to draw any conclusions about valve seat wear from these measurements.

5. Intake Valve Deposit

The intake valve deposit (IVD) of the valves was photographed. These photographs have been uploaded to a password protected ftp site, which will remain in operation at least until 12/31/2012. To access the site:

ftp://ftp.swri.edu
Open site in Windows Explorer
Click File, Login As
Username: OKRD
Password: KYR745it

Two group photographs of all the intake valves from an engine were taken. For both views the valves are lined up left to right from cylinder one (front, if two intake valves per cylinder) to the last cylinder (rear, if two intake valves per cylinder). In the first view the intake valves are rotated so that the side with the most visual deposit is facing the camera. For the second view the opposite side of each valve is facing the camera. A sample of group photographs of the intake valves from Honda Accord vehicles ORHA0 and ORHA15 are included in Appendix D.

The intake valve deposit weight of each valve was measured as follows. Intake valve deposit weights for all 18 vehicles are given in Appendix D.

a. Each valve is carefully removed from the cylinder head so that no IVD is scraped from the valve.
b. The valves are then placed in a desiccator until they are photographed or prepared for weighing.
c. Each valve face is buffed.
d. The valves are rinsed with hexane.
e. The valves are dried by heating to 200+/-5°F for 5 minutes.
f. The valves are then placed in a desiccator cabinet for a minimum of one hour.
g. Each valve is weighed on a calibrated scale.

h. After the photographs have been taken, the valves are cleaned of all deposits, prepared (b. through f.) and weighed again in the same manner.
i. The IVD weight is the difference between the dirty and clean valve weight.

In many cases, the IVD weight is considerably greater for the E15 engines when compared to the E0 (Top Tier fuel) counterpart. In most cases the E20 engine IVD weight is greater than the E15 engine IVD weight. While IVD levels at the beginning are not known, this increased IVD may be related to the dilution effect of ethanol on the fuel's detergent additive package. During this program, Top Tier E0 fuel was splash blended with ASTM D4806 denatured road-grade ethanol for RE10, RE15, and RE20. No attempt was made to determine the effectiveness of the detergent additive in the fuel after diluting it with ethanol.

For perspective, note that the specification limit for Top Tier gasoline with respect to the average IVD weight per valve in the ASTM D6201 2.3L IVD procedure is 50 mg maximum. Some intake valves did exceed 50 mg, but a D6201 test result of 50 mg does not necessarily guarantee a 50 mg result in another vehicle, which is being run in a different driving cycle for many more hours

6. ASTM D5185 Analyses of Engine Oil Drain Samples

Engine oil samples of the engine oil drains were taken at each oil change interval and stored. Three samples listed below from each of the 18 SwRI RE0, RE15, and RE20 vehicles and three samples from each of 12 new 2009 vehicles tested at the Transportation Research Center were analyzed.

1. The first sample was taken during the second oil change. The first oil change defined the start of test.
2. The second oil sample was taken from the drain oil of the oil change prior to the mid-mileage emissions interval.
3. The third oil sample was taken from the drain oil of the last oil change prior to end-of test emissions.

The results are given in the tables in Appendix E. There do not appear to be any unusually high wear metal levels in any of the engine oil drains.

7. Fuel Pump Performance Evaluation and Inspection

The fuel pump modules removed from each vehicle have been evaluated. The results are given in Appendix F. During the program the fuel feed nipple of the fuel pump module of Chevrolet Cobalt ORCC15 cracked. The fuel pump module was replaced. This incident has been reported in a previous ORNL E-87-2 monthly status report. This relatively new pump was evaluated along with the original pump.

The "dead-head" pressure of each module for all 18 vehicles was measured. Except for the Chevrolet Cobalt, which has an external pressure regulator, this measurement is a measure of the regulator pressure. The Chevrolet Cobalt fuel pump modules were measured with and without the external pressure regulator.

Fuel pump flow was measured at pressures above and below the mean expected pressure specified in the service manual of the vehicle. Those results for all 18 vehicles are also given in Appendix F.

The fuel pumps from the E0, E15, and E20 vehicles have been disassembled, inspected, and photographed with three exceptions. The photographs and inspection comments are also included in Appendix F. The Chevrolet Silverado truck fuel pumps from the E0 and E15 trucks as well as the Chevrolet Cobalt fuel pump with the broken connector (E15 pump) were inadvertently lost prior to disassembly/inspection.

While pump characteristics prior to the vehicle aging program are unknown, there do not appear to be any serious differences between the RE0, RE15 and RE20 fuel pumps.

8. Fuel Injector Flow Rates

The fuel injectors were removed from the 18 RE0, RE15, and RE20 vehicles and flow tested at three duty cycles, 25%, 35%, and 75% using iso-octane. The fuel pressure was maintained at the mean pressure specified in the service manual of each vehicle. Flow test results of the fuel injectors for all 18 vehicles are complete and are given in Appendix G. Typical part-to-part variability for the average of the three pulse widths in gasoline engines is in the mean +/- 3% range. All injectors from a given set of vehicles fall within this range.

9. Visual Inspection of Valve Seals

The intake valve seals from all 18 vehicles have been visually rated by a calibrated rater (based on previous Coordinating Research Council workshops) and the results are included in Appendix H. Sample photographs of seals from Honda Accords ORHA0 and ORHA15 are included in Appendix H. The photographs were taken using the following procedure based on the ratings:

1. Only one "typical" seal was photographed for each engine.
2. The photographed "typical" seal was the one closest to the front on the cylinder head or in the case of a "V" engine, the left cylinder head.
3. Two views of the "typical" seal "front angle" and "rear angle" were taken with adjusted lighting to get a view of a portion of the inside seal lip.
4. Seals that the rater identified as being "different" than "typical" were also photographed.

5. For each of these "different" seals the two angles, front and rear, were photographed. If those views did not pick up the "flaw" a third view was taken.
6. The size of each seal in the photographs was adjusted to be about the same for all photos (except the third view if it took a zoom in to see the "flaw")
7. Photographs for all 18 vehicles have been uploaded to the password-protected ftp site referenced above in section 5.

10. Evaporative Canister Working Capacity

Evaporative canisters from the six teardown vehicle sets were removed from the vehicles and tested for working capacity at two different laboratories. Multiple laboratories were selected in order to meet the requested time schedule.

Canisters from the E0, E15, and E20 fueled Nissan Altimas, Chevrolet Cobalts, Dodge Caravans, and Chevrolet Silverados (12 canisters) were tested at Detroit Testing Laboratory (DTL) for butane or gasoline working capacity. DTL dedicated two butane working capacity test stands for our canister testing. The canisters that required shorter run times were started first so that some data would be available earlier. The butane working capacity tests require approximately five to six days to complete a full test sequence of 15 cycles.

To accelerate the time to completion, the canisters from the Dodge Caravan and the Chevrolet Silverado vehicle sets were selected for testing on two gasoline working capacity (GWC) test stands. The GWC test can be performed in significantly less time because the test cycles are shorter and the number of required cycles for a complete test sequence is fewer (only ten cycles are required for a complete GWC test compared to the 15 cycles for the BWC test).

Evaporative canisters from the E0, E15, and E20 fueled Honda Accords and Ford Tauruses (6 canisters) were tested at Environmental Testing Corporation (ETC) for butane working capacity under contract with National Renewable Energy Laboratory (NREL). Results for the Accord and Taurus vehicle canister tests are reported here for convenience.

Evaporative canister working capacity data for the six selected teardown vehicles are summarized in Appendix I, Table I-1. Test results show a slightly decreasing canister working capacity with increasing fuel ethanol content on two of the six vehicle sets tested. The other four vehicle canister data sets show neutral or slightly increasing working capacity with increasing fuel ethanol content. No statistically significant difference in evaporative canister working capacity is suggested with this small data set. Evaporative canister working capacity test reports for individual canisters are provided in Appendix I.

11. Visual Inspections of Fuel Tanks, Fuel Lines, and Evaporative Emissions Lines

The fuel feed lines and hoses; and evaporative emissions lines and hoses were removed from the vehicles. The inside surfaces of each end of the lines and hoses (as far inside as possible) were inspected by a CRC calibrated rater. The fuel tanks were also removed and inspected.

The observations were recorded and are included in Appendix J. The following is a description of the observations:

a. Percent clean – No visual deposits and no distress
b. Percent white deposit – A white colored deposit is visually present on the given percent of the area. No attempt has been made to quantify the chemistry of the deposit.
c. All the o-rings appeared to be in good condition.
d. In some cases rust deposits were observed. These deposits could have formed during the life of the vehicle (either prior to acquisition for this program, or during the program), or in the time interval between part removal and rating.
e. Debris – Particles of foreign matter were observed. No attempt has been made to quantify the chemistry of the debris.

While fuel system component characteristics prior to the vehicle aging program are unknown, there do not appear to be any serious differences among the RE0, RE15 and RE20 fuel systems inspected.

Appendix A
Cam Lobe Wear

Oak Ridge National Laboratory
Proposal 08-58845 Powertrain Inspection
Camshaft Heel to Toe Measurement

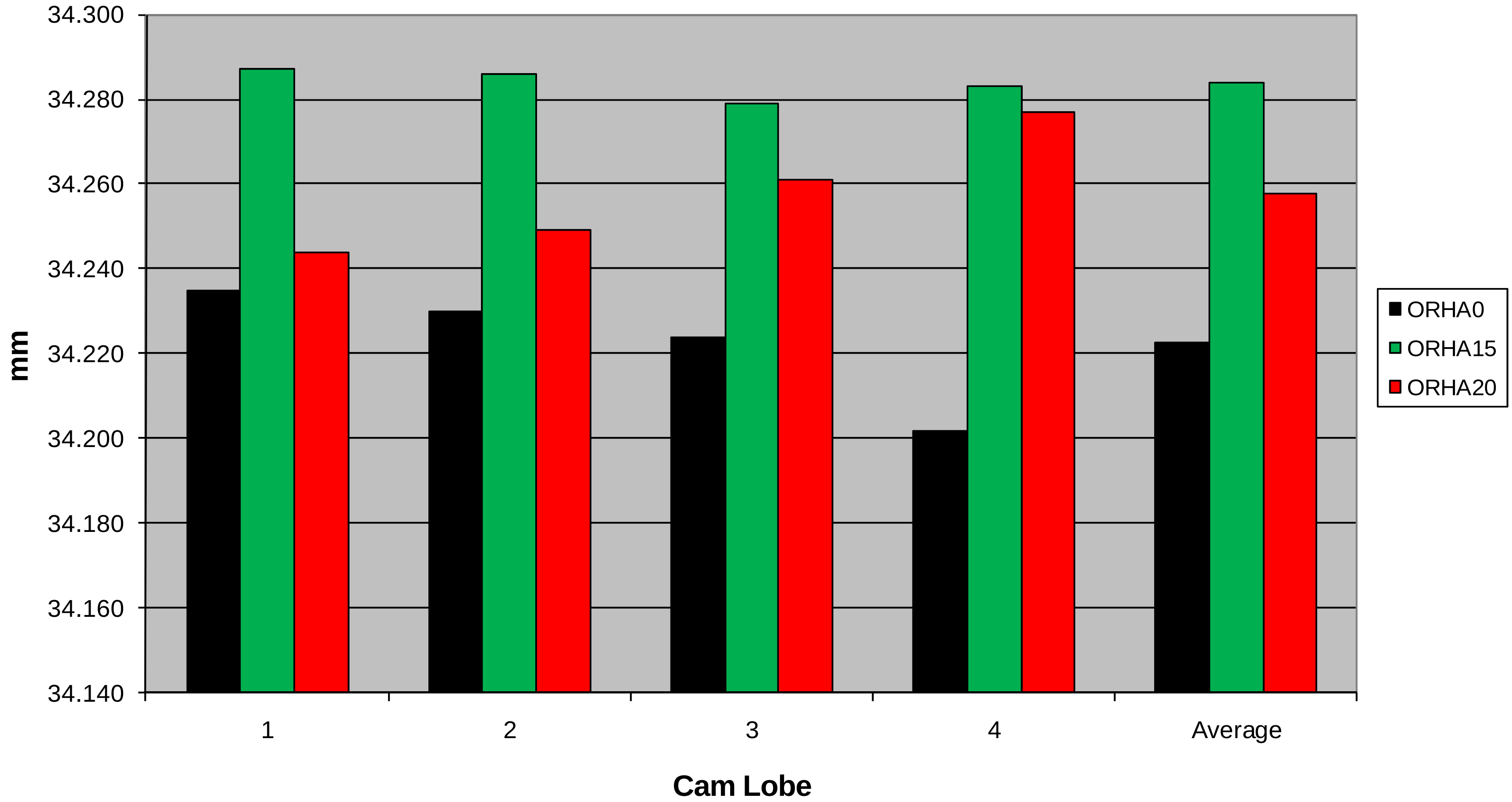
Date: 18-Aug-10 Technician: RT

ORHA0 Micrometer: AN 003857 ORHA15 /ORHA20 Micrometer: AN 005423
Standard: AN006504
Measurements in mm
Lobes are numbered from front to rear on cam

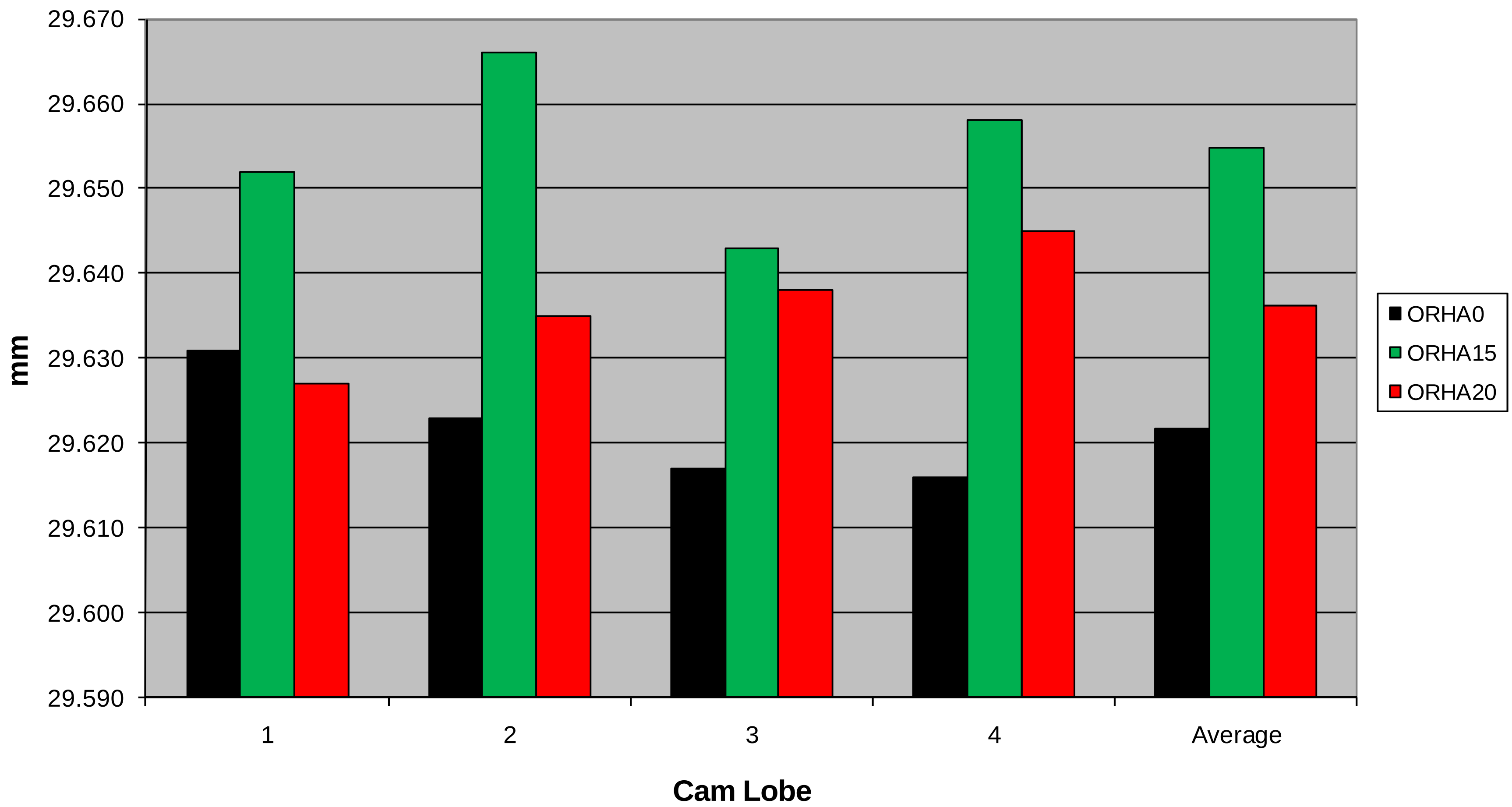
		Intake Cam			Exhaust Cam		
Cylinder	Lobe	ORHA0	ORHA15	ORHA20	ORHA0	ORHA15	ORHA20
1	1	34.235	34.287	34.244	34.096	34.114	34.121
2	2	34.230	34.286	34.249	34.096	34.089	34.110
3	3	34.224	34.279	34.261	34.079	34.103	34.110
4	4	34.202	34.283	34.277	34.085	34.103	34.109
	Average	34.223	34.284	34.258	34.089	34.102	34.113
	StDev	0.015	0.004	0.015	0.008	0.010	0.006
	Max	34.235	34.287	34.277	34.096	34.114	34.121
	Min	34.202	34.279	34.244	34.079	34.089	34.109

		Intake Cam - Secondary Lobe		
Cylinder	Lobe	ORHA0	ORHA15	ORHA20
1	1	29.631	29.652	29.627
2	2	29.623	29.666	29.635
3	3	29.617	29.643	29.638
4	4	29.616	29.658	29.645
	Average	29.622	29.655	29.636
	StDev	0.007	0.010	0.007
	Max	29.631	29.666	29.645
	Min	29.616	29.643	29.627

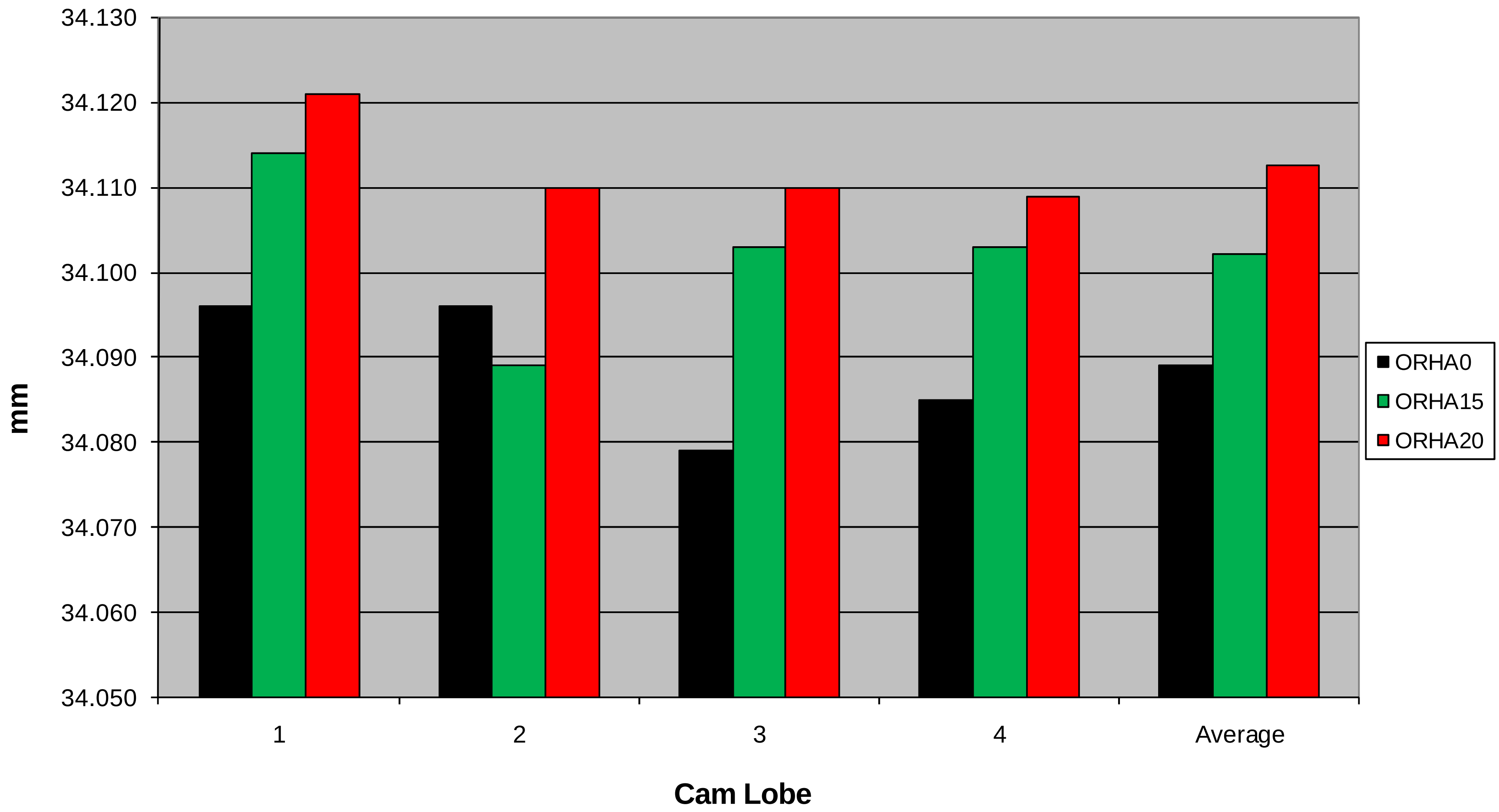
Oakridge National Laboratory
2007 Honda Accord
Intake Camshaft Lobe Heel to Toe Measurements at EOT



Oakridge National Laboratory
2007 Honda Accord
Intake Camshaft Secondary Lobe Heel to Toe Measurements at EOT



Oakridge National Laboratory
2007 Honda Accord
Exhaust Camshaft Lobe Heel to Toe Measurements at EOT



Oak Ridge National Laboratory
Proposal 08-58845 Powertrain Inspection
Camshaft Heel to Toe Measurement

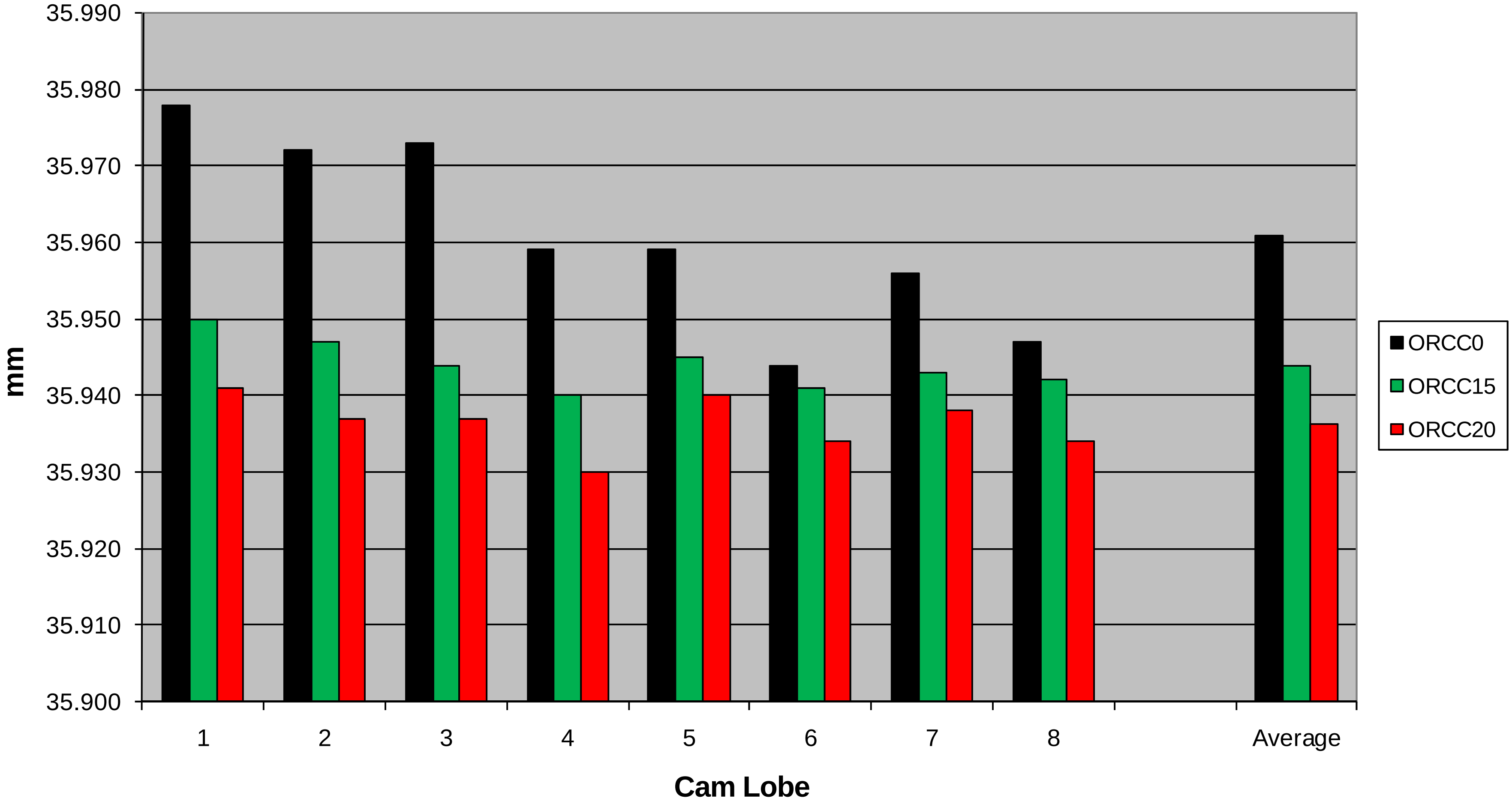
Date: 18-Aug-10 Technician: TP

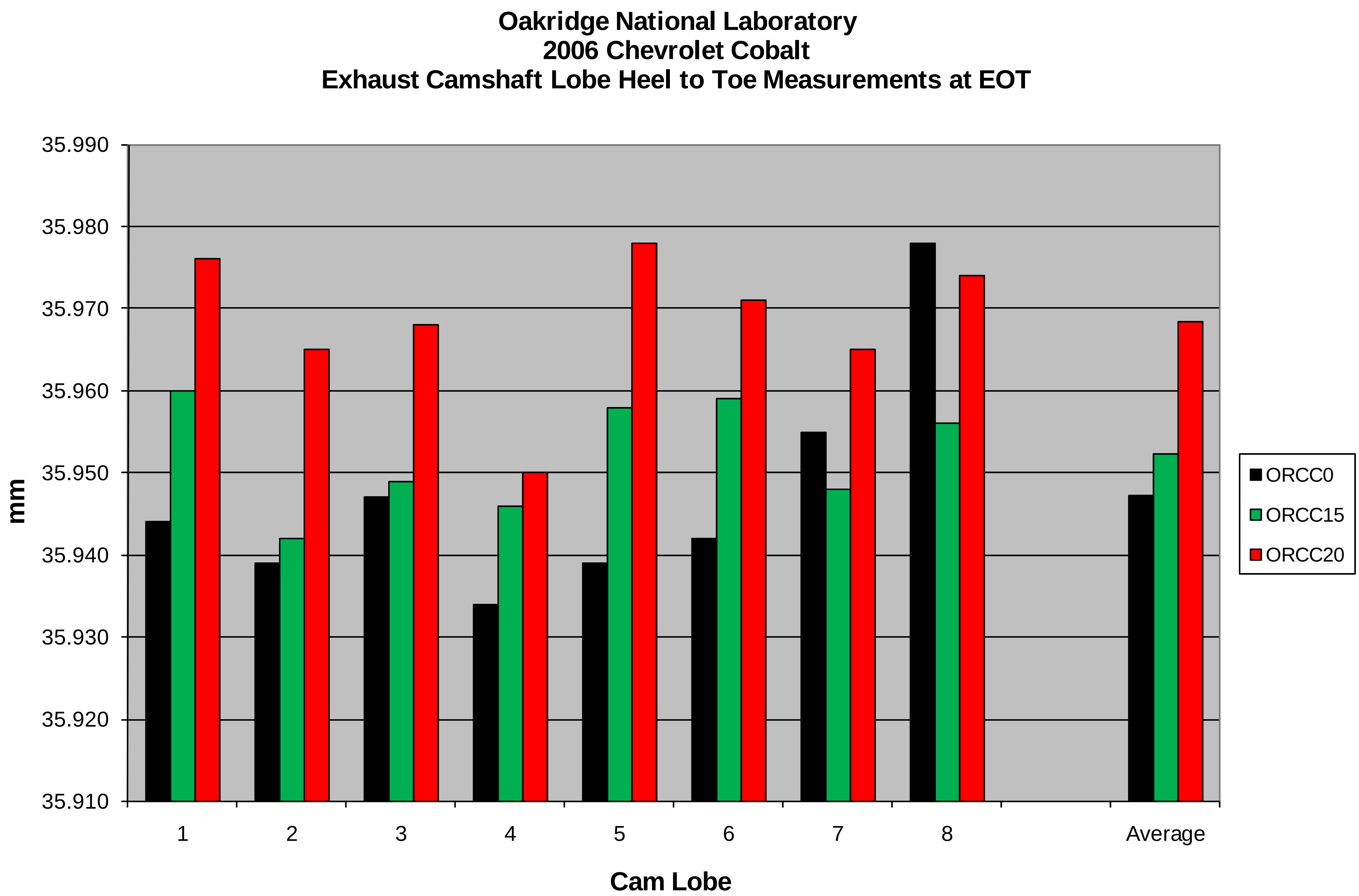
Micrometer: AN 003857 and AN 005423
Standard: AN006504
Measurements in mm
Lobes are numbered from front to rear on cam

		Intake Cam			Exhaust Cam		
Cylinder	**Lobe**	**ORCC0**	**ORCC15**	**ORCC20**	**ORCC0**	**ORCC15**	**ORCC20**
1	1	35.978	35.950	35.941	35.944	35.960	35.976
	2	35.972	35.947	35.937	35.939	35.942	35.965
2	3	35.973	35.944	35.937	35.947	35.949	35.968
	4	35.959	35.940	35.930	35.934	35.946	35.950
3	5	35.959	35.945	35.940	35.939	35.958	35.978
	6	35.944	35.941	35.934	35.942	35.959	35.971
4	7	35.956	35.943	35.938	35.955	35.948	35.965
	8	35.947	35.942	35.934	35.978	35.956	35.974

Average	35.961	35.944	35.936	35.947	35.952	35.968
StDev	0.012	0.003	0.004	0.014	0.007	0.009
Max	35.978	35.950	35.941	35.978	35.960	35.978
Min	35.944	35.940	35.930	35.934	35.942	35.950

Oakridge National Laboratory
2006 Chevrolet Cobalt
Intake Camshaft Lobe Heel to Toe Measurements at EOT





Oakridge National Laboratory
2006 Chevrolet Cobalt
Exhaust Camshaft Lobe Heel to Toe Measurements at EOT
mm
35.990
35.980
35.970
35.960
35.950
35.940
35.930
35.920
35.910
1
2
3
4
5
6
7
8
Average
Cam Lobe
ORCC0
ORCC15
ORCC20

Oak Ridge National Laboratory
Proposal 08-58845 Powertrain Inspection
Camshaft Heel to Toe Measurement

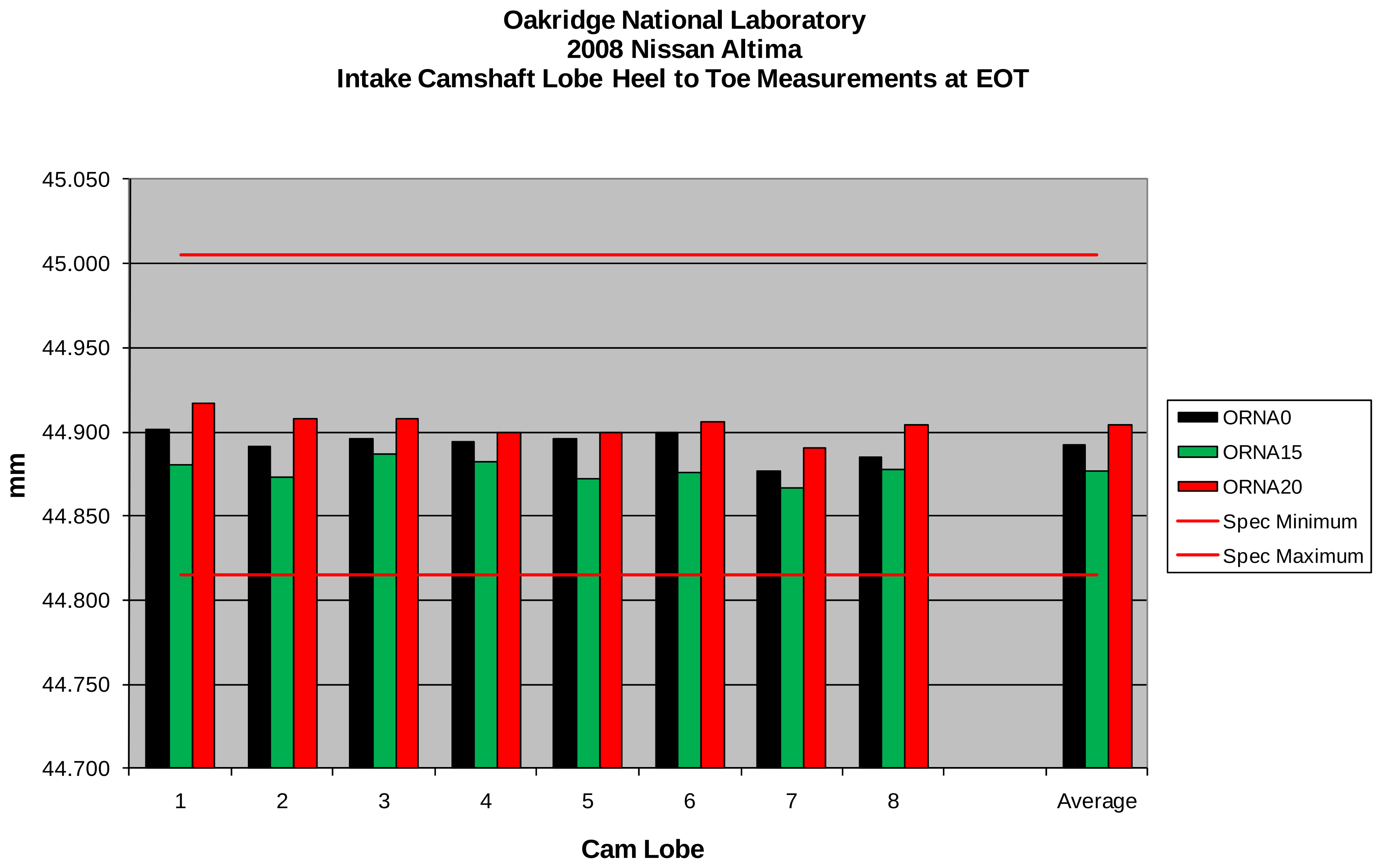
Date: 28-Jul-10 Technician: RT

Micrometer: AN 005423
Standard: AN006504
Measurements in mm
Lobes are numbered from front to rear on cam

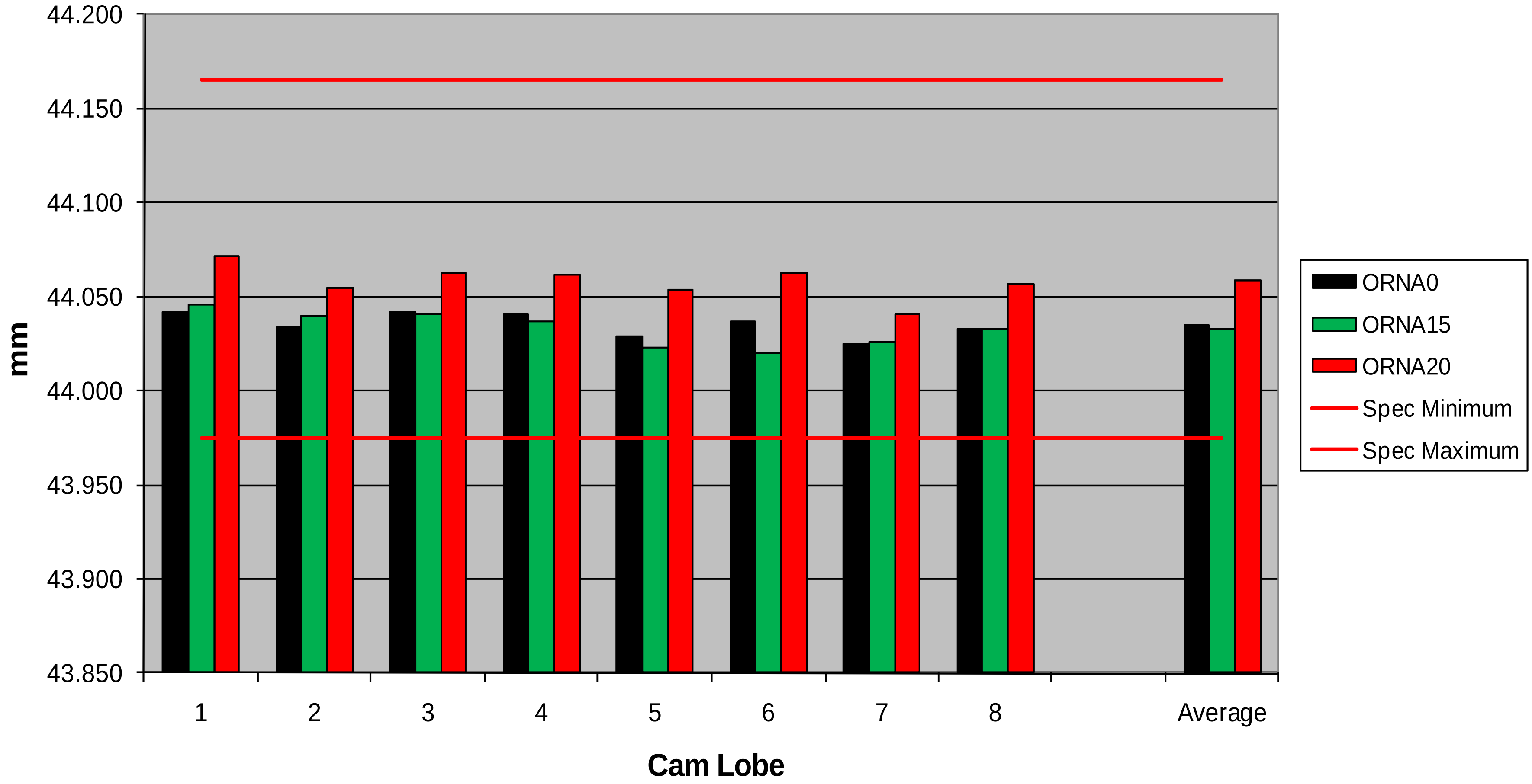
		Intake Cam			Exhaust Cam		
Cylinder	**Lobe**	**ORNA0**	**ORNA15**	**ORNA20**	**ORNA0**	**ORNA15**	**ORNA20**
1	1	44.901	44.880	44.917	44.042	44.046	44.072
	2	44.891	44.873	44.908	44.034	44.040	44.055
2	3	44.896	44.887	44.908	44.042	44.041	44.063
	4	44.894	44.882	44.900	44.041	44.037	44.062
3	5	44.896	44.872	44.900	44.029	44.023	44.054
	6	44.900	44.876	44.906	44.037	44.020	44.063
4	7	44.877	44.867	44.890	44.025	44.026	44.041
	8	44.885	44.878	44.904	44.033	44.033	44.057

Average	44.893	44.877	44.904	44.035	44.033	44.058
StDev	0.008	0.006	0.008	0.006	0.009	0.009
Max	44.901	44.887	44.917	44.042	44.046	44.072
Min	44.877	44.867	44.890	44.025	44.020	44.041

		Intake Cam	Exhaust Cam
Spec	Max	45.005	44.165
	Min	44.815	43.975


Oakridge National Laboratory
2008 Nissan Altima
Intake Camshaft Lobe Heel to Toe Measurements at EOT
45.050
45.000
44.950
44.900
44.850
44.800
44.750
44.700
mm
1
2
3
4
5
6
7
8
Average
Cam Lobe
ORNA0
ORNA15
ORNA20
Spec Minimum
Spec Maximum

Oakridge National Laboratory
2008 Nissan Altima
Exhaust Camshaft Lobe Heel to Toe Measurements at EOT



Oak Ridge National Laboratory
Proposal 08-58845 Powertrain Inspection
Camshaft Heel to Toe Measurement

Date: 18-Aug-10 Technician: RT

Micrometer: AN 005423
Standard: AN006504
Measurements in mm
Lobes are numbered from front to rear on cam
Service Manual indicates lobe lift = 9.6798 mm, max lobe lift loss = 0.062 mm
Lobe lift loss = 9.6798 - (Heel to Toe - Base Circle)

		ORFT0					
		Intake			Exhaust		
Cylinder	Bank-Lobe #	Heel-Toe	Base Circle	Lobe Lift Loss	Heel-Toe	Base Circle	Lobe Lift Loss
1	Right-1	45.651	35.982	0.011	45.670	36.010	0.020
	Right-2	45.679	36.006	0.007	45.671	35.994	0.003
2	Right-3	45.656	35.982	0.006	45.688	36.020	0.012
	Right-4	45.676	36.002	0.006	45.686	36.024	0.018
3	Right-5	45.649	35.985	0.016	45.696	36.090	0.074
	Right-6	45.644	35.979	0.015	45.689	36.056	0.047
4	Left-1	45.637	35.972	0.015	45.712	36.038	0.006
	Left-2	45.647	35.978	0.011	45.710	36.036	0.006
5	Left-3	45.640	35.973	0.013	45.703	36.028	0.005
	Left-4	45.660	35.986	0.006	45.702	36.025	0.003
6	Left-5	45.651	35.983	0.012	45.710	36.033	0.003
	Left-6	45.647	35.980	0.013	45.717	36.039	0.002
Average		45.653	35.984	0.011	45.696	36.033	0.016
StDev		0.013	0.010	0.004	0.016	0.024	0.022
Max		45.679	36.006	0.016	45.717	36.090	0.074
Min		45.637	35.972	0.006	45.670	35.994	0.002

Oak Ridge National Laboratory
Proposal 08-58845 Powertrain Inspection
Camshaft Heel to Toe Measurement

Date: 18-Aug-10 Technician: RT

Micrometer: AN 005423
Standard: AN006504
Measurements in mm
Lobes are numbered from front to rear on cam
Service Manual indicates lobe lift = 9.6798 mm, max lobe lift loss = 0.062 mm
Lobe lift loss = 9.6798 - (Heel to Toe - Base Circle)

		ORFT15					
		Intake			Exhaust		
Cylinder	**Bank-Lobe #**	**Heel-Toe**	**Base Circle**	**Lobe Lift Loss**	**Heel-Toe**	**Base Circle**	**Lobe Lift Loss**
1	Right-1	45.649	36.013	0.044	45.651	36.010	0.039
	Right-2	45.683	36.006	0.003	45.647	35.991	0.024
2	Right-3	45.660	35.994	0.014	45.673	36.002	0.009
	Right-4	45.682	36.007	0.005	45.672	36.000	0.008
3	Right-5	45.658	35.991	0.013	45.687	36.018	0.011
	Right-6	45.653	35.988	0.015	45.682	36.014	0.012
4	Left-1	45.689	36.026	0.017	45.694	36.022	0.008
	Left-2	45.672	36.006	0.014	45.703	36.028	0.005
5	Left-3	45.672	36.001	0.009	45.697	36.023	0.006
	Left-4	45.694	36.023	0.009	45.699	36.025	0.006
6	Left-5	45.670	36.025	0.035	45.688	36.018	0.010
	Left-6	45.693	36.041	0.028	45.690	36.018	0.008
Average		45.673	36.010	0.017	45.682	36.014	0.012
StDev		0.016	0.016	0.012	0.018	0.011	0.010
Max		45.694	36.041	0.044	45.703	36.028	0.039
Min		45.649	35.988	0.003	45.647	35.991	0.005

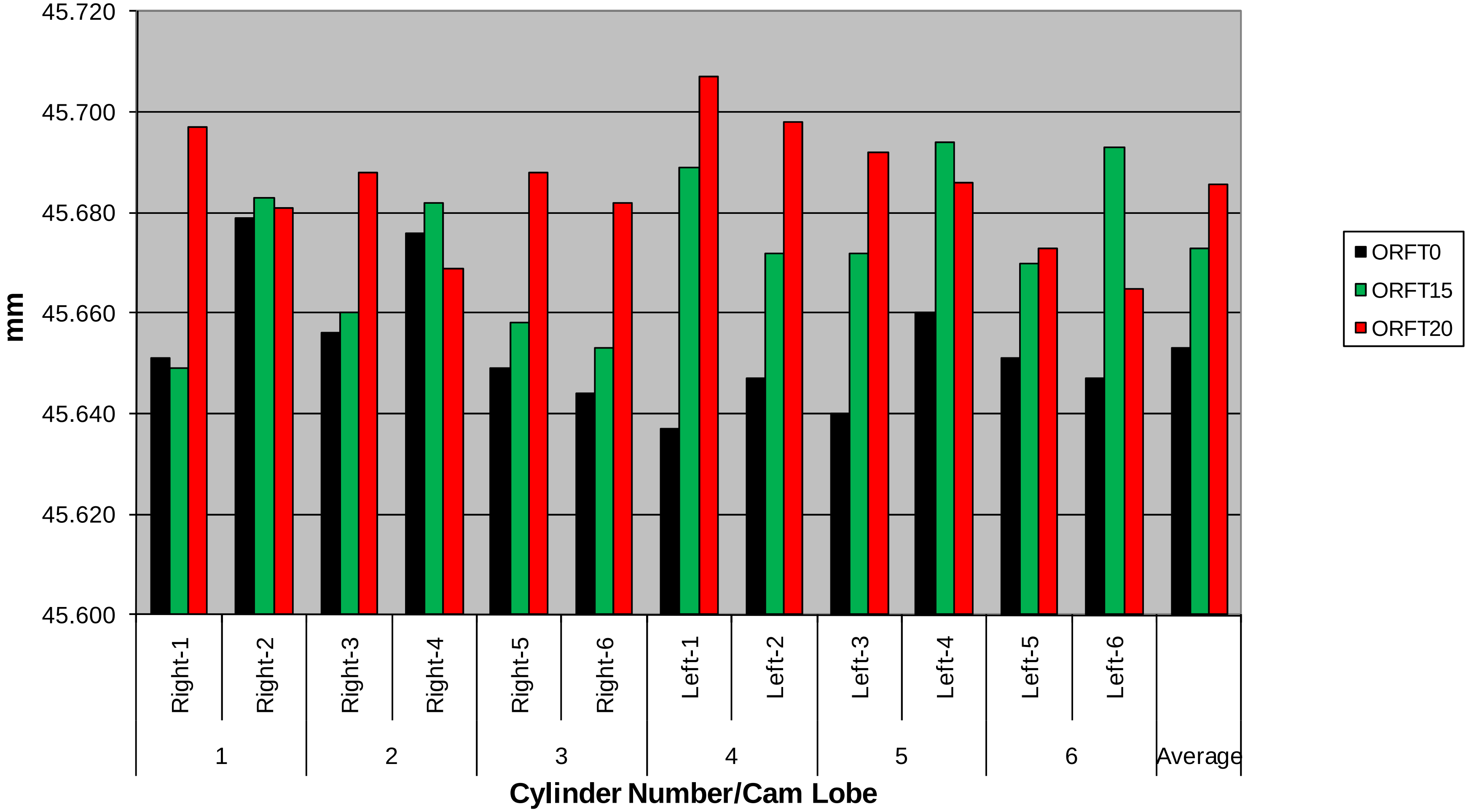
Oak Ridge National Laboratory
Proposal 08-58845 Powertrain Inspection
Camshaft Heel to Toe Measurement

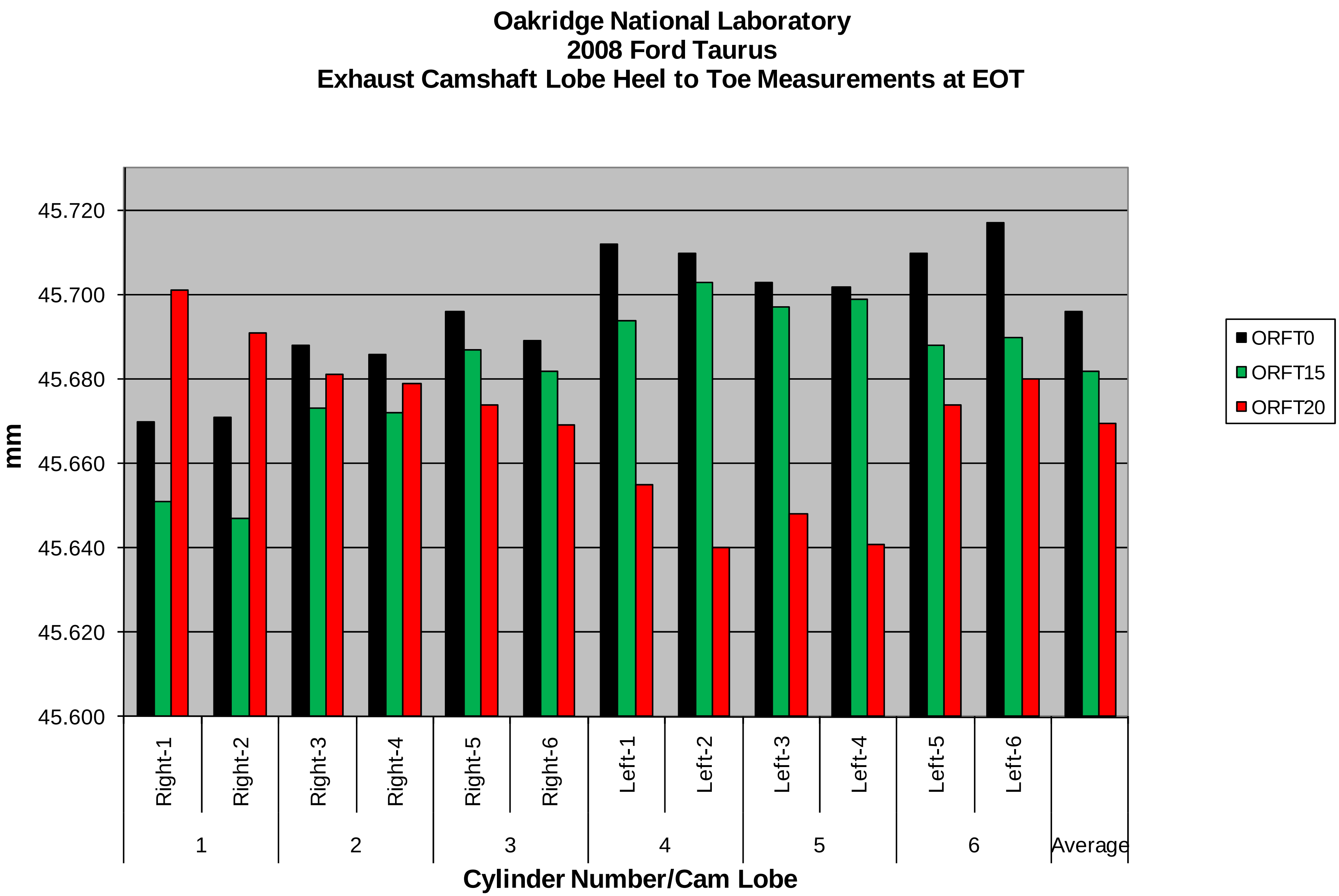
Date: 21-Sep-10 Technician: RT

Micrometer: AN 005423
Standard: AN006504
Measurements in mm
Lobes are numbered from front to rear on cam
Service Manual indicates lobe lift = 9.6798 mm, max lobe lift loss = 0.062 mm
Lobe lift loss = 9.6798 - (Heel to Toe - Base Circle)

		ORFT20					
		Intake			Exhaust		
Cylinder	Bank-Lobe #	Heel-Toe	Base Circle	Lobe Lift Loss	Heel-Toe	Base Circle	Lobe Lift Loss
1	Right-1	45.697	36.039	0.022	45.701	36.036	0.015
	Right-2	45.681	36.019	0.018	45.691	36.028	0.017
2	Right-3	45.688	36.026	0.018	45.681	36.020	0.019
	Right-4	45.669	36.011	0.022	45.679	36.013	0.014
3	Right-5	45.688	36.026	0.018	45.674	36.009	0.015
	Right-6	45.682	36.021	0.019	45.669	36.006	0.017
4	Left-1	45.707	36.037	0.010	45.655	35.994	0.019
	Left-2	45.698	36.033	0.015	45.640	35.979	0.019
5	Left-3	45.692	36.026	0.014	45.648	35.986	0.018
	Left-4	45.686	36.019	0.013	45.641	35.980	0.019
6	Left-5	45.673	36.002	0.009	45.674	36.005	0.011
	Left-6	45.665	35.997	0.012	45.680	36.017	0.017
Average		45.686	36.021	0.016	45.669	36.006	0.016
StDev		0.012	0.013	0.004	0.020	0.018	0.002
Max		45.707	36.039	0.022	45.701	36.036	0.019
Min		45.665	35.997	0.009	45.640	35.979	0.011

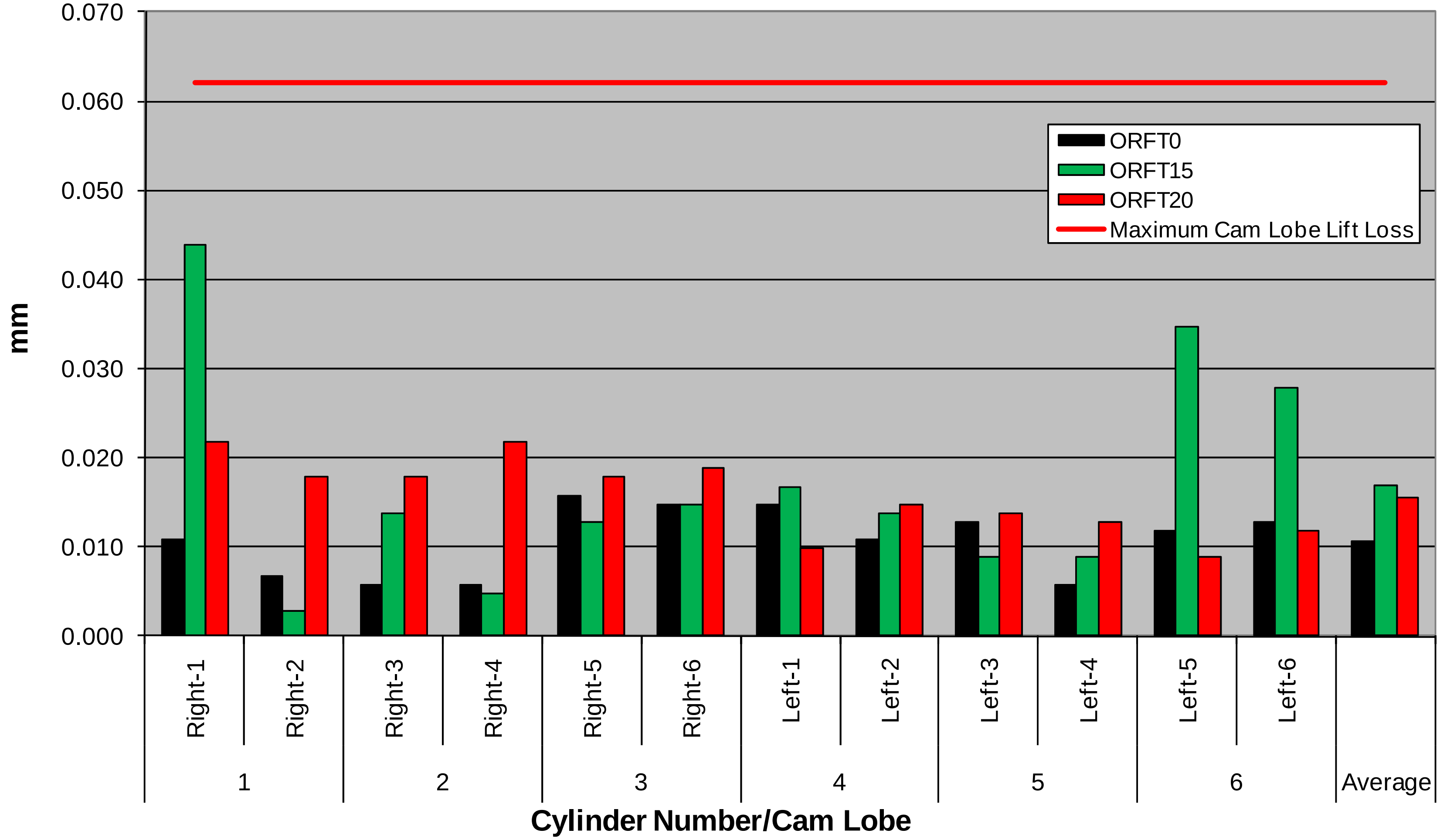
Oakridge National Laboratory
2008 Ford Taurus
Intake Camshaft Lobe Heel to Toe Measurements at EOT



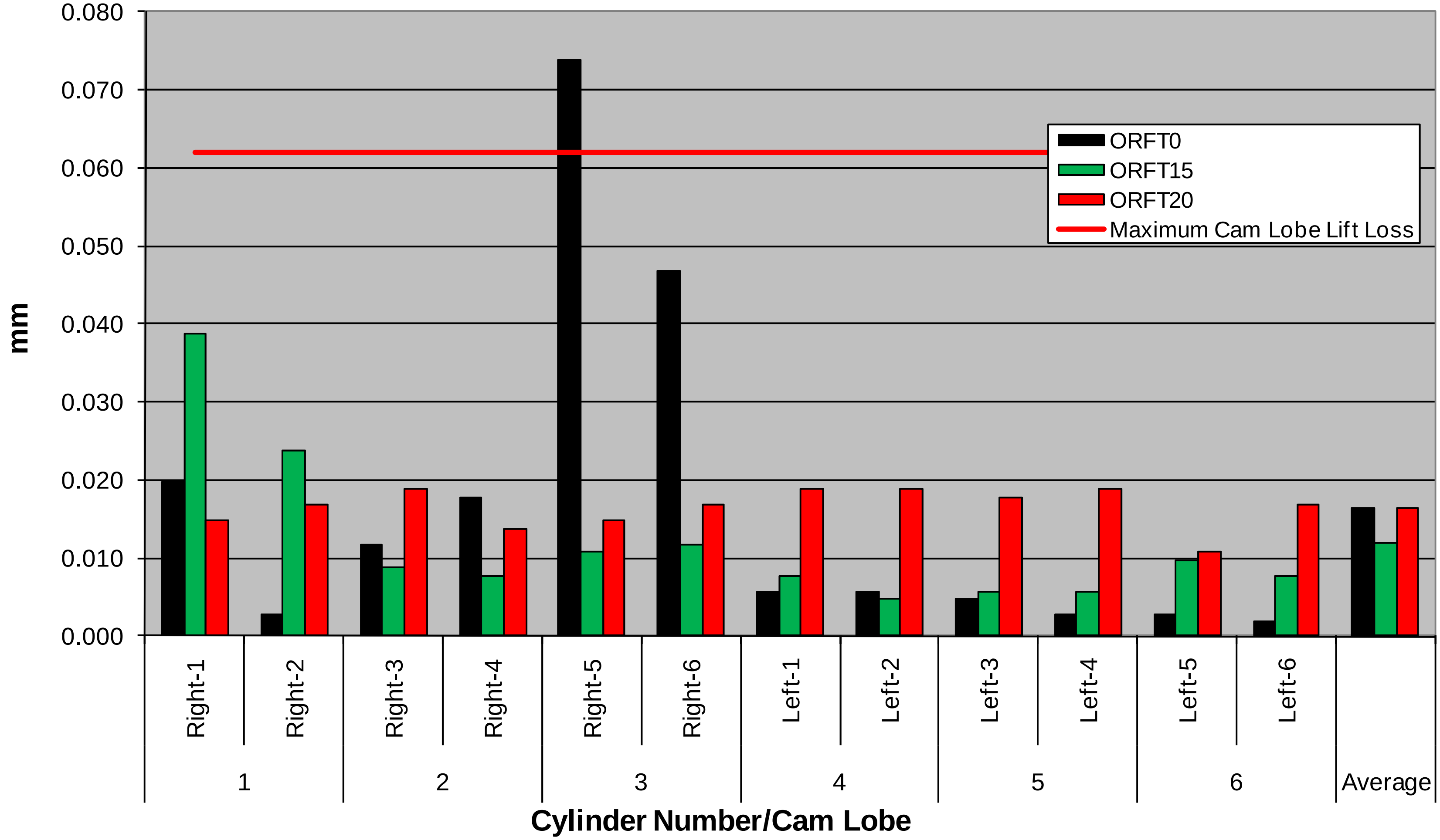


Oakridge National Laboratory
2008 Ford Taurus
Exhaust Camshaft Lobe Heel to Toe Measurements at EOT
mm
45.720
45.700
45.680
45.660
45.640
45.620
45.600
Right-1
Right-2
Right-3
Right-4
Right-5
Right-6
Left-1
Left-2
Left-3
Left-4
Left-5
Left-6
1
2
3
4
5
6
Average
Cylinder Number/Cam Lobe
ORFT0
ORFT15
ORFT20

Oakridge National Laboratory
2008 Ford Taurus
Intake Camshaft Lobe Lift Loss Measurements at EOT



Oakridge National Laboratory
2008 Ford Taurus
Exhaust Camshaft Lobe Lift Loss Measurements at EOT



Oak Ridge National Laboratory
Proposal 08-58845 Powertrain Inspection
Camshaft Heel to Toe Measurement

Date: 18-Aug-10 Technician: RT

Micrometer: AN 005423
Standard: AN006504
Measurements in mm
Lobes are numbered from front to rear on cam

ORDC0

Intake				
Cylinder	**Lobe #**	**Heel-Toe**	**Base Circle**	**Lift**
1	3	40.261	33.926	6.335
2	2	40.264	33.929	6.335
3	7	40.255	33.918	6.337
4	6	40.248	33.918	6.330
5	11	40.252	33.914	6.338
6	10	40.250	33.915	6.335
Average		40.255	33.920	6.335
StDev		0.006	0.006	0.003
Max		40.264	33.929	6.338
Min		40.248	33.914	6.330

Exhaust				
Cylinder	**Lobe #**	**Heel-Toe**	**Base Circle**	**Lift**
1	1	40.267	33.916	6.351
2	4	40.260	33.911	6.349
3	5	40.256	33.910	6.346
4	8	40.248	33.899	6.349
5	9	40.256	33.908	6.348
6	12	40.248	33.906	6.342
Average		40.256	33.908	6.348
StDev		0.007	0.006	0.003
Max		40.267	33.916	6.351
Min		40.248	33.899	6.342

Oak Ridge National Laboratory
Proposal 08-58845 Powertrain Inspection
Camshaft Heel to Toe Measurement

Date: 18-Aug-10 Technician: RT

Micrometer: AN 005423
Standard: AN006504
Measurements in mm
Lobes are numbered from front to rear on cam

ORDC15

Intake				
Cylinder	**Lobe #**	**Heel-Toe**	**Base Circle**	**Lift**
1	3	40.318	33.986	6.332
2	2	40.316	33.981	6.335
3	7	40.330	33.994	6.336
4	6	40.324	33.987	6.337
5	11	40.332	33.992	6.340
6	10	40.324	33.991	6.333
Average		40.324	33.989	6.336
StDev		0.006	0.005	0.003
Max		40.332	33.994	6.340
Min		40.316	33.981	6.332

Exhaust				
Cylinder	**Lobe #**	**Heel-Toe**	**Base Circle**	**Lift**
1	1	40.314	33.961	6.353
2	4	40.328	33.978	6.350
3	5	40.323	33.983	6.340
4	8	40.334	33.984	6.350
5	9	40.329	33.980	6.349
6	12	40.335	33.984	6.351
Average		40.327	33.978	6.349
StDev		0.008	0.009	0.005
Max		40.335	33.984	6.353
Min		40.314	33.961	6.340

Oak Ridge National Laboratory
Proposal 08-58845 Powertrain Inspection
Camshaft Heel to Toe Measurement

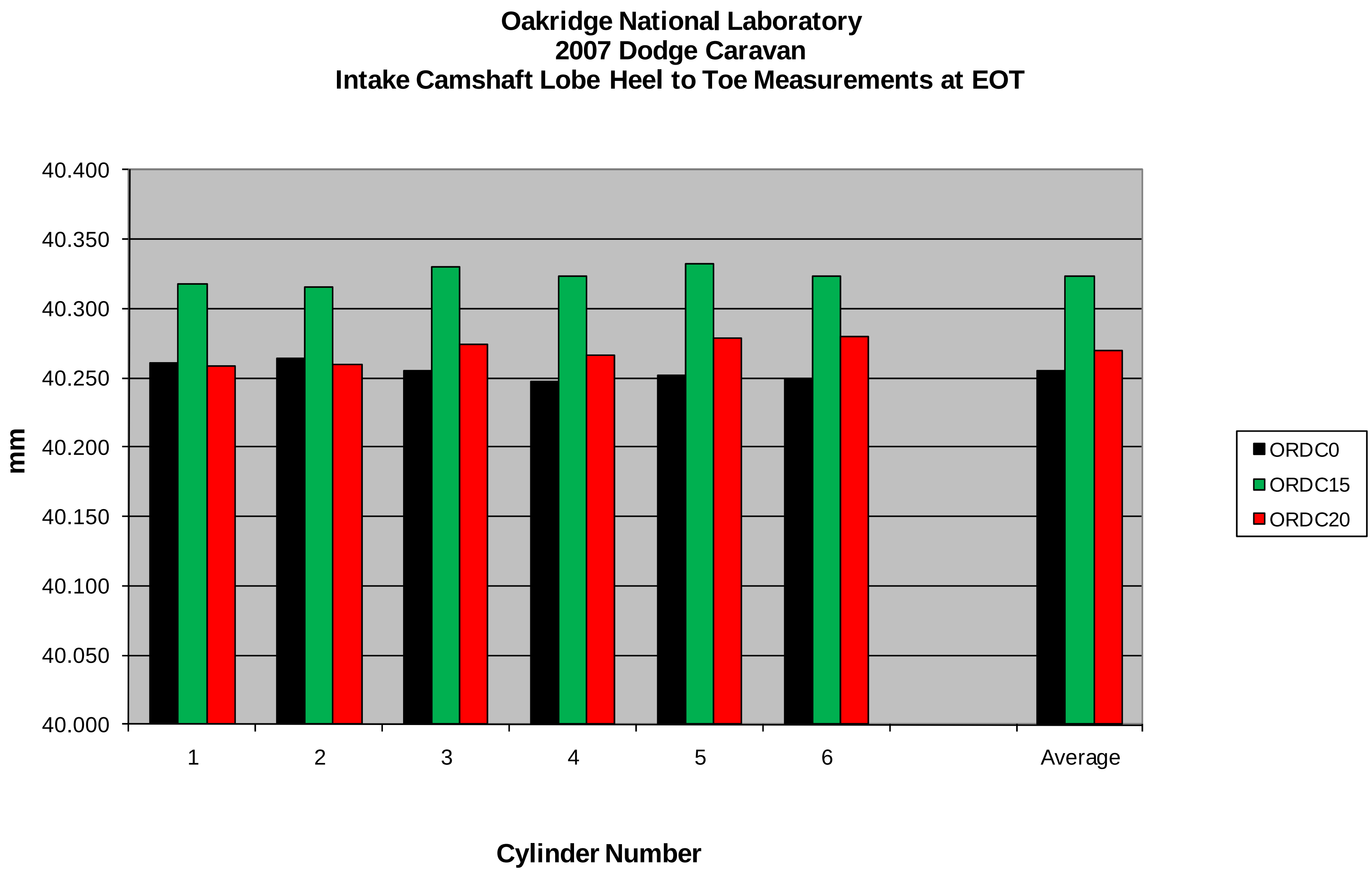
Date: 17-Sep-10 Technician: RT

Micrometer: AN 005423
Standard: AN006504
Measurements in mm
Lobes are numbered from front to rear on cam

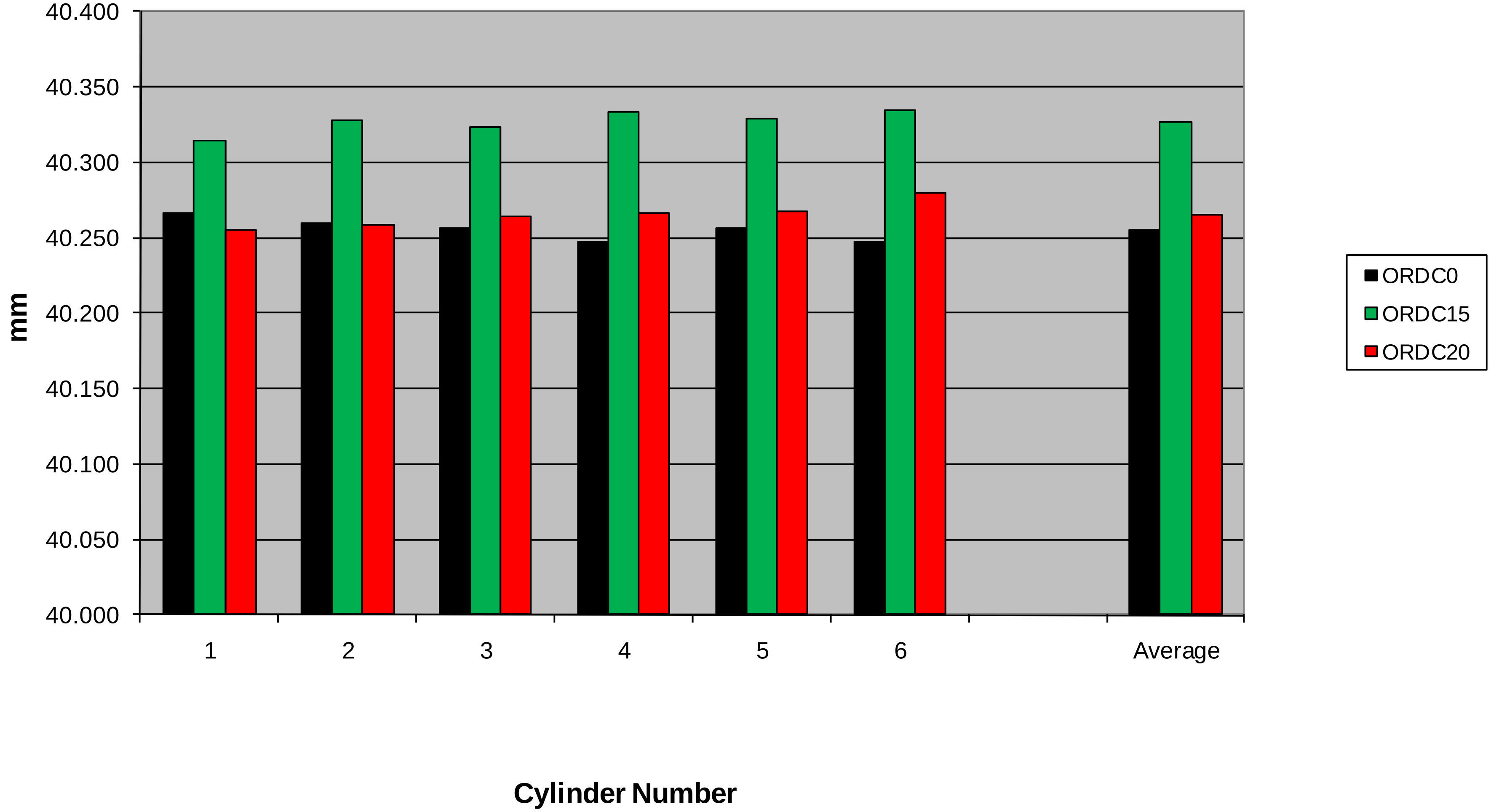
ORDC20

Intake				
Cylinder	**Lobe #**	**Heel-Toe**	**Base Circle**	**Lift**
1	3	40.259	33.924	6.335
2	2	40.260	33.925	6.335
3	7	40.274	33.932	6.342
4	6	40.267	33.928	6.339
5	11	40.279	33.939	6.340
6	10	40.280	33.937	6.343
Average		40.270	33.931	6.339
StDev		0.009	0.006	0.003
Max		40.280	33.939	6.343
Min		40.259	33.924	6.335

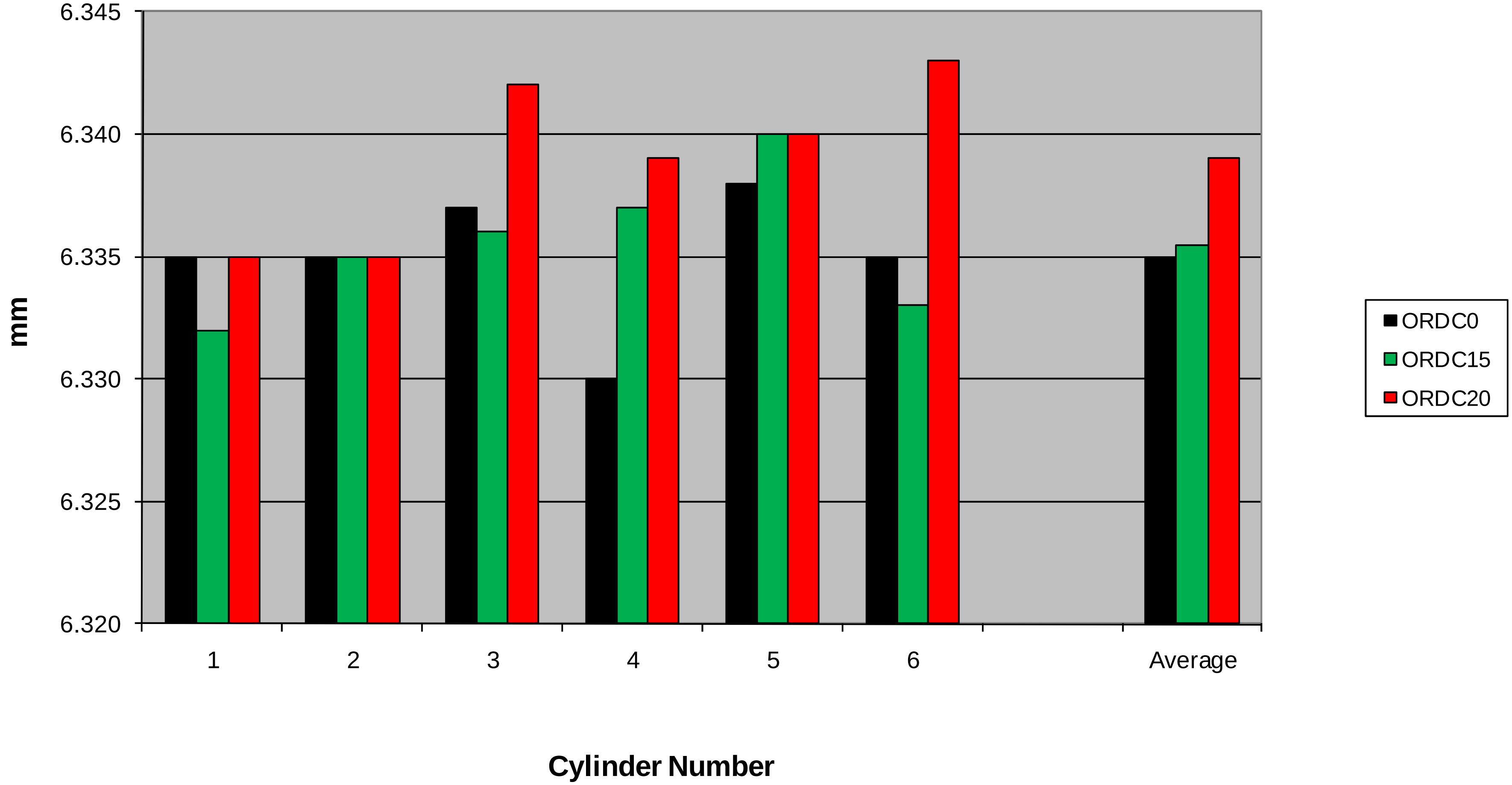
Exhaust				
Cylinder	**Lobe #**	**Heel-Toe**	**Base Circle**	**Lift**
1	1	40.255	33.907	6.348
2	4	40.259	33.912	6.347
3	5	40.264	33.914	6.350
4	8	40.267	33.918	6.349
5	9	40.268	33.922	6.346
6	12	40.280	33.933	6.347
Average		40.266	33.918	6.348
StDev		0.009	0.009	0.001
Max		40.280	33.933	6.350
Min		40.255	33.907	6.346


Oakridge National Laboratory
2007 Dodge Caravan
Intake Camshaft Lobe Heel to Toe Measurements at EOT
40.400
40.350
40.300
40.250
40.200
40.150
40.100
40.050
40.000
mm
1
2
3
4
5
6
Average
Cylinder Number
ORDC0
ORDC15
ORDC20

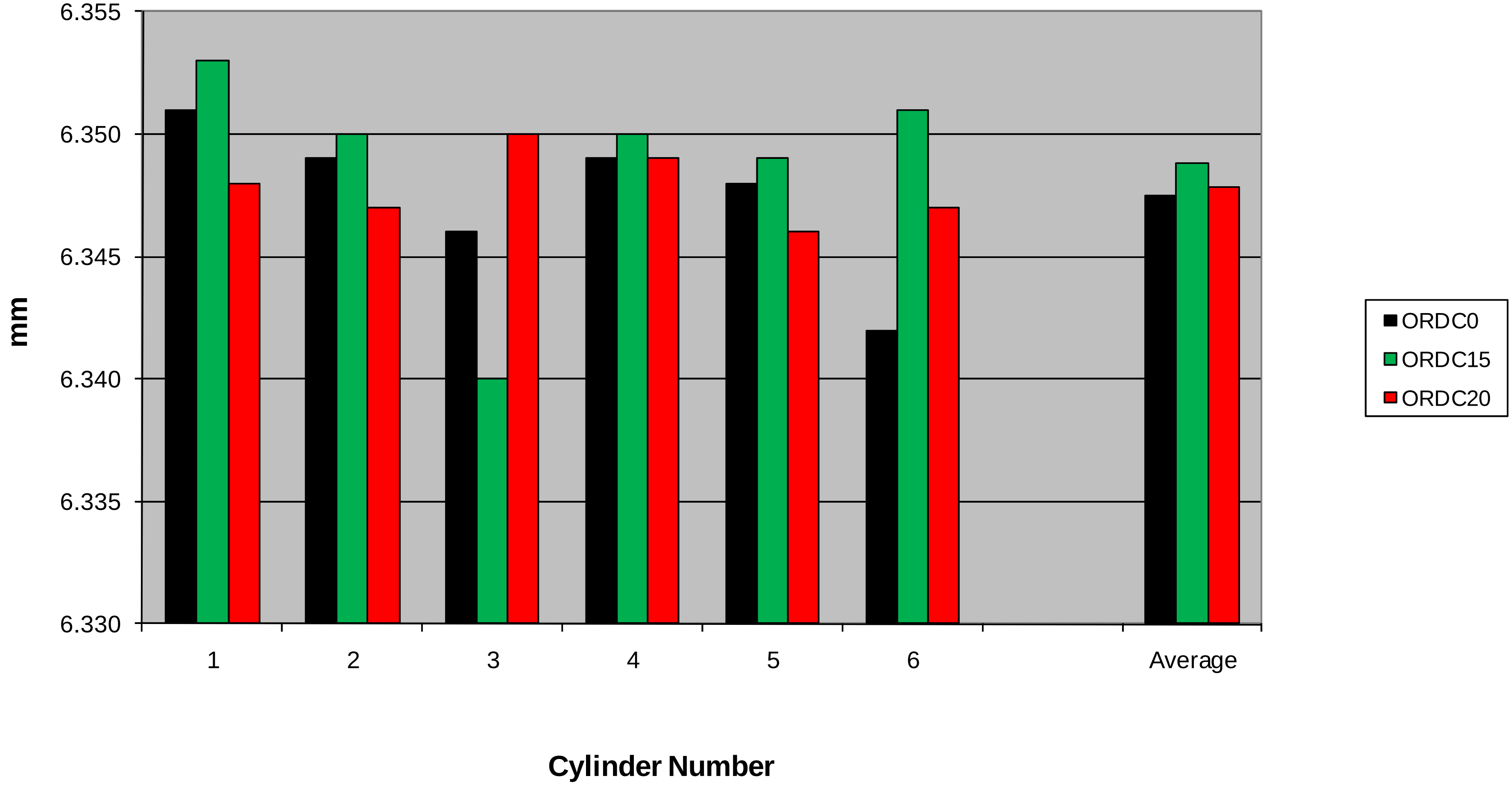
Oakridge National Laboratory
2007 Dodge Caravan
Exhaust Camshaft Lobe Heel to Toe Measurements at EOT



Oakridge National Laboratory
2007 Dodge Caravan
Intake Camshaft Lobe Lift Measurements at EOT



Oakridge National Laboratory
2007 Dodge Caravan
Exhaust Camshaft Lobe Lift Measurements at EOT



Oak Ridge National Laboratory
Proposal 08-58845 Powertrain Inspection
Camshaft Heel to Toe Measurement

Date: 18-Aug-10 Technician: RT

Micrometer: AN 005423
Standard: AN006504
Measurements in mm
Lobes are numbered from front to rear on cam
Service manual specification for cam lobe lift - Intake - 6.82 mm
Service manual specification for cam lobe lift - Exhaust - 6.96 mm

ORCS0

Intake				
Cylinder	**Lobe #**	**Heel-Toe**	**Base Circle**	**Lift**
1	1	46.562	39.378	7.184
2	4	46.547	39.394	7.153
3	5	46.573	39.397	7.176
4	8	46.549	39.374	7.175
5	9	46.556	39.396	7.160
6	12	46.568	39.398	7.170
7	13	46.584	39.394	7.190
8	16	46.566	39.384	7.182
Average		46.563	39.389	7.174
StDev		0.012	0.009	0.012
Max		46.584	39.398	7.190
Min		46.547	39.374	7.153

Exhaust				
Cylinder	**Lobe #**	**Heel-Toe**	**Base Circle**	**Lift**
1	3	46.540	39.391	7.149
2	2	46.562	39.385	7.177
3	7	46.540	39.370	7.170
4	6	46.568	39.388	7.180
5	11	46.563	39.392	7.171
6	10	46.560	39.396	7.164
7	15	46.562	39.388	7.174
8	14	46.576	39.390	7.186
Average		46.559	39.388	7.171
StDev		0.013	0.008	0.011
Max		46.576	39.396	7.186
Min		46.540	39.370	7.149

Oak Ridge National Laboratory
Proposal 08-58845 Powertrain Inspection
Camshaft Heel to Toe Measurement

Date: 18-Aug-10 Technician: RT

Micrometer: AN 005423
Standard: AN006504
Measurements in mm
Lobes are numbered from front to rear on cam
Service manual specification for cam lobe lift - Intake - 6.82 mm
Service manual specification for cam lobe lift - Exhaust - 6.96 mm

ORCS15

Intake				
Cylinder	**Lobe #**	**Heel-Toe**	**Base Circle**	**Lift**
1	1	46.561	39.373	7.188
2	4	46.580	39.396	7.184
3	5	46.577	39.393	7.184
4	8	46.577	39.384	7.193
5	9	46.565	39.390	7.175
6	12	46.582	39.402	7.180
7	13	46.580	39.396	7.184
8	16	46.561	39.391	7.170
Average		46.573	39.391	7.182
StDev		0.009	0.009	0.007
Max		46.582	39.402	7.193
Min		46.561	39.373	7.170

Exhaust				
Cylinder	**Lobe #**	**Heel-Toe**	**Base Circle**	**Lift**
1	3	46.574	39.389	7.185
2	2	46.564	39.382	7.182
3	7	46.579	39.388	7.191
4	6	46.571	39.390	7.181
5	11	46.567	39.385	7.182
6	10	46.570	39.398	7.172
7	15	46.564	39.385	7.179
8	14	46.573	39.388	7.185
Average		46.570	39.388	7.182
StDev		0.005	0.005	0.005
Max		46.579	39.398	7.191
Min		46.564	39.382	7.172

Oak Ridge National Laboratory
Proposal 08-58845 Powertrain Inspection
Camshaft Heel to Toe Measurement

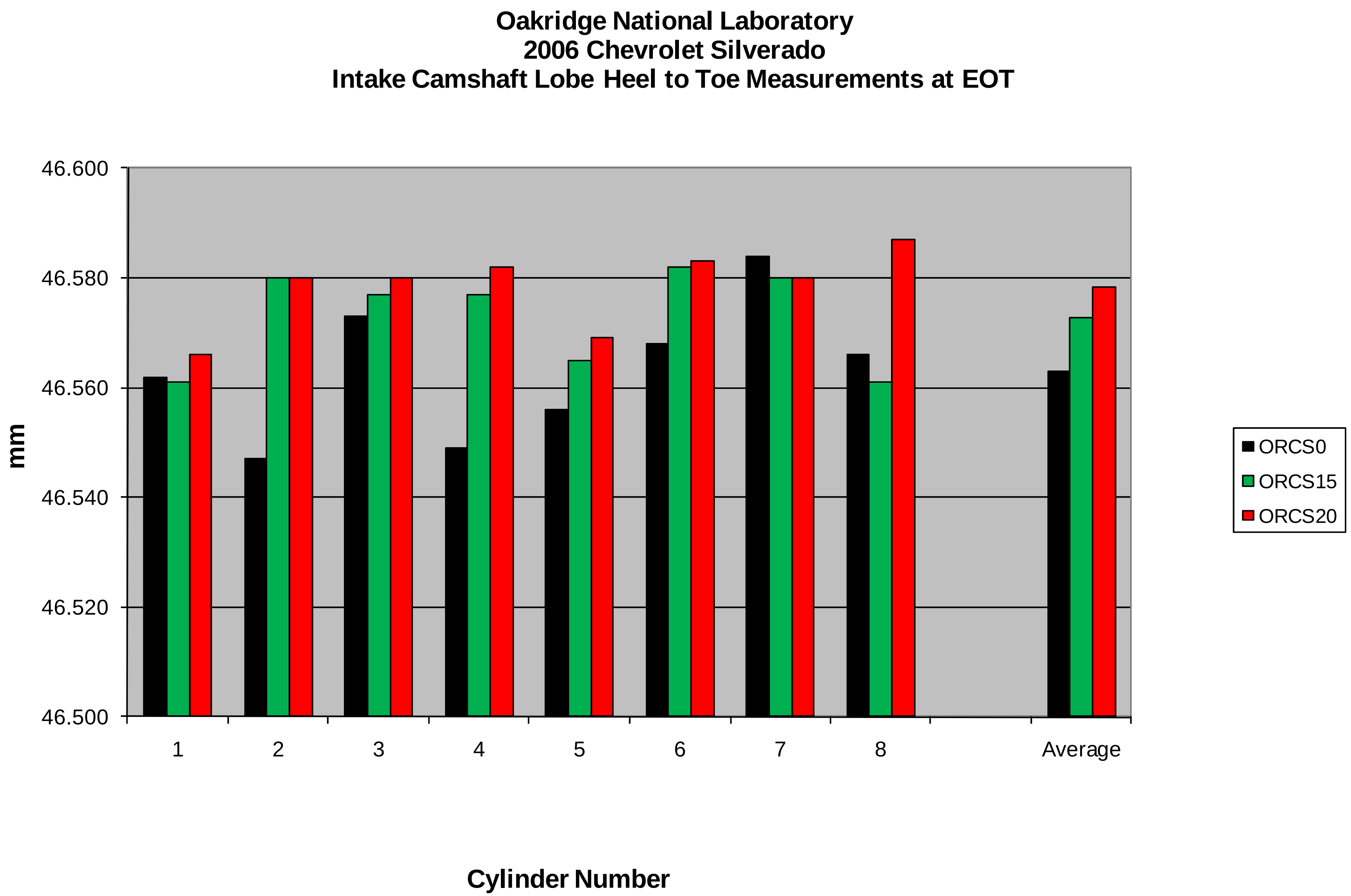
Date: 17-Sep-10 Technician: RT

Micrometer: AN 005423
Standard: AN006504
Measurements in mm
Lobes are numbered from front to rear on cam
Service manual specification for cam lobe lift - Intake - 6.82 mm
Service manual specification for cam lobe lift - Exhaust - 6.96 mm

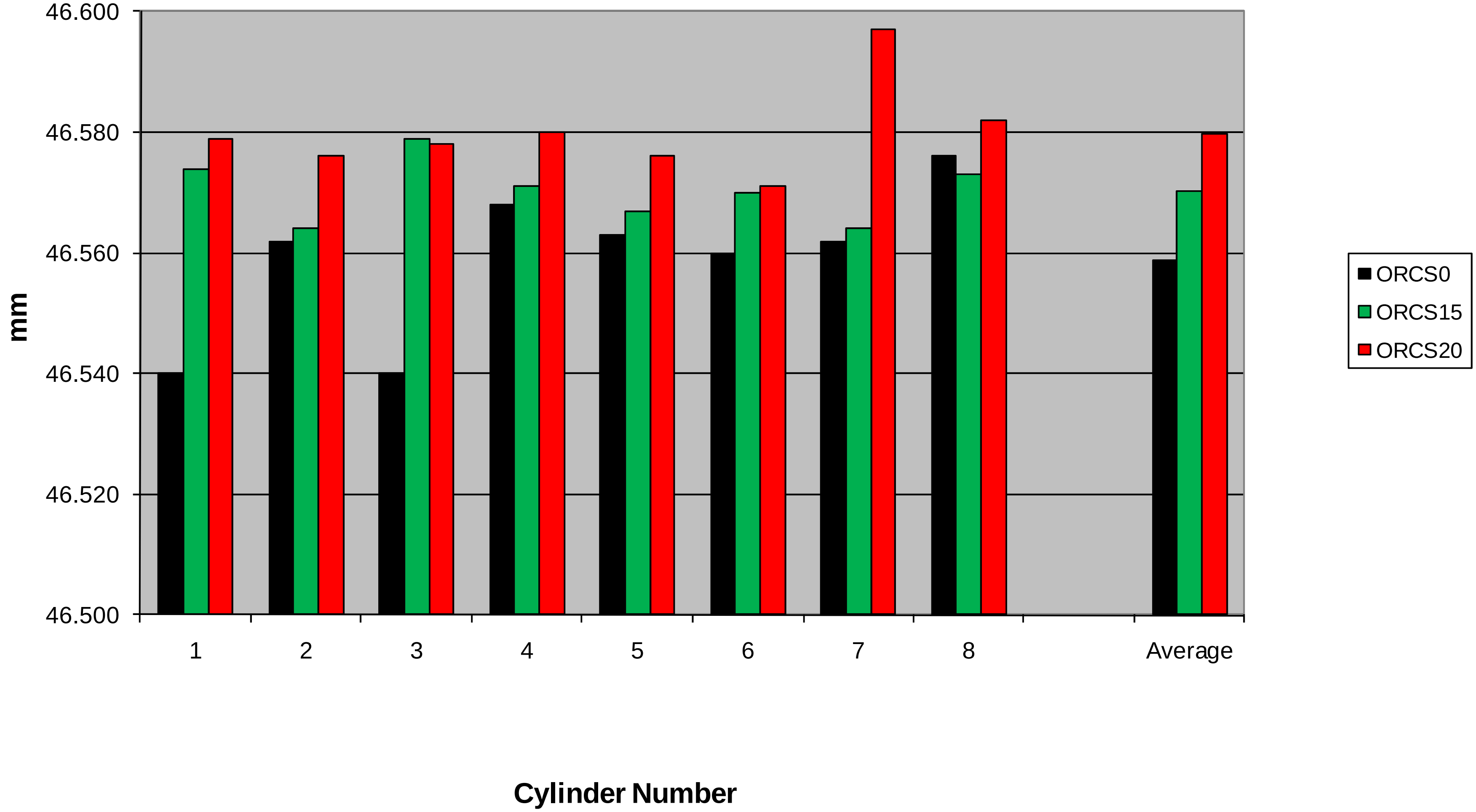
ORCS20

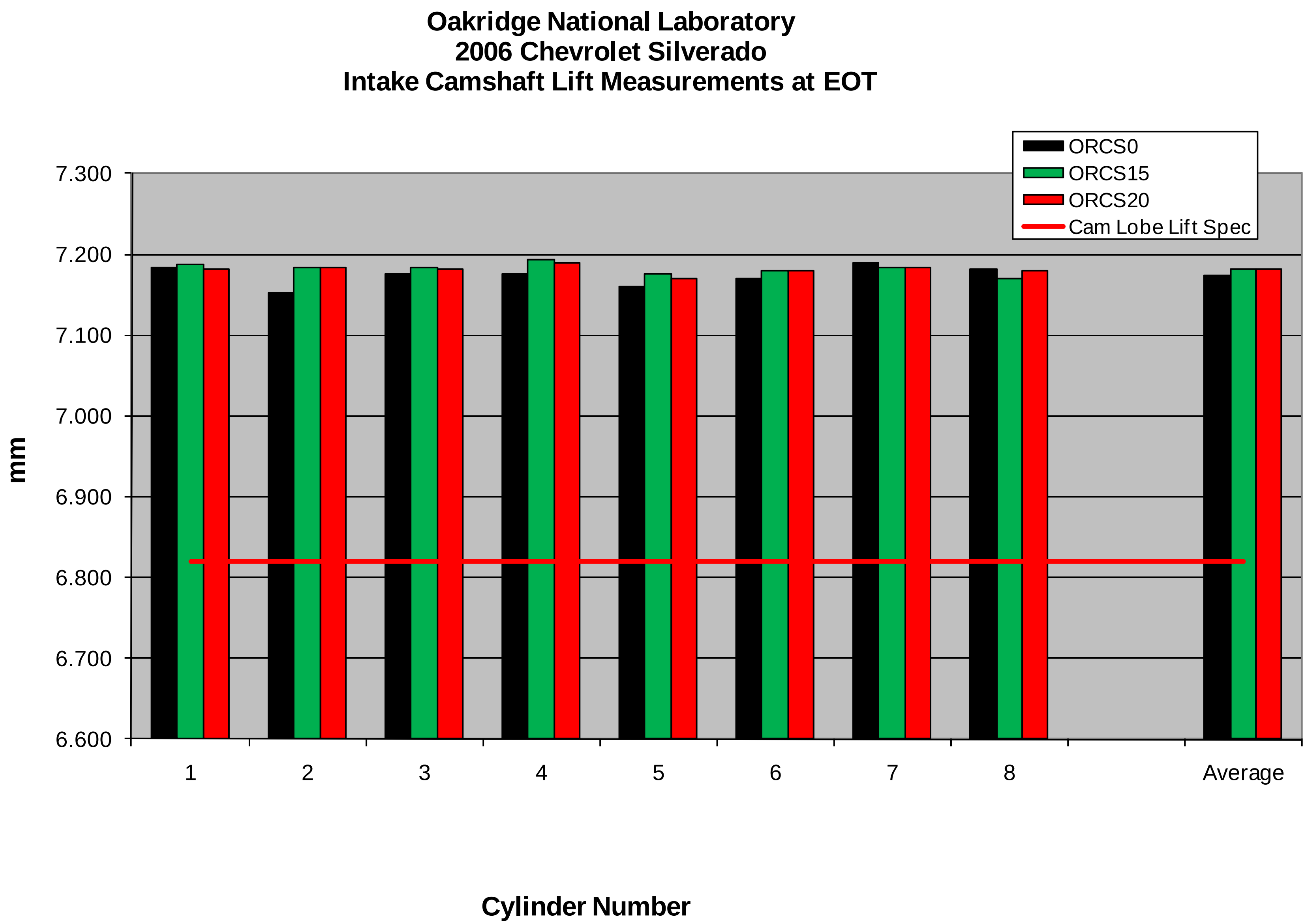
Intake				
Cylinder	**Lobe #**	**Heel-Toe**	**Base Circle**	**Lift**
1	1	46.566	39.385	7.181
2	4	46.580	39.397	7.183
3	5	46.580	39.399	7.181
4	8	46.582	39.392	7.190
5	9	46.569	39.400	7.169
6	12	46.583	39.403	7.180
7	13	46.580	39.396	7.184
8	16	46.587	39.407	7.180
Average		46.578	39.397	7.181
StDev		0.007	0.007	0.006
Max		46.587	39.407	7.190
Min		46.566	39.385	7.169

Exhaust				
Cylinder	**Lobe #**	**Heel-Toe**	**Base Circle**	**Lift**
1	3	46.579	39.396	7.183
2	2	46.576	39.396	7.180
3	7	46.578	39.392	7.186
4	6	46.580	39.396	7.184
5	11	46.576	39.398	7.178
6	10	46.571	39.397	7.174
7	15	46.597	39.410	7.187
8	14	46.582	39.399	7.183
Average		46.580	39.398	7.182
StDev		0.008	0.005	0.004
Max		46.597	39.410	7.187
Min		46.571	39.392	7.174

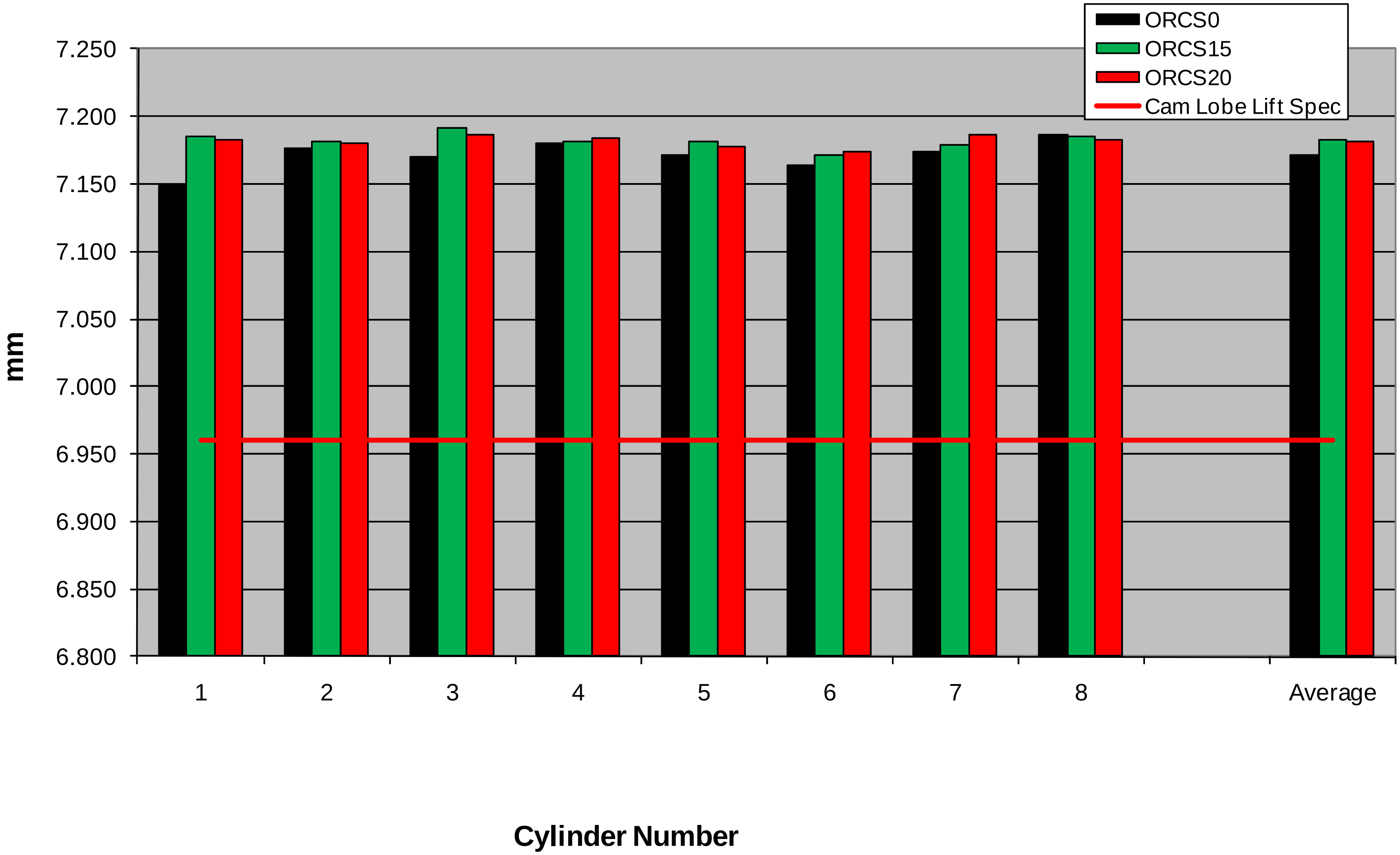

Oakridge National Laboratory
2006 Chevrolet Silverado
Intake Camshaft Lobe Heel to Toe Measurements at EOT
46.600
46.580
46.560
46.540
46.520
46.500
mm
1
2
3
4
5
6
7
8
Average
Cylinder Number
ORCS0
ORCS15
ORCS20

Oakridge National Laboratory
2006 Chevrolet Silverado
Exhaust Camshaft Lobe Heel to Toe Measurements at EOT



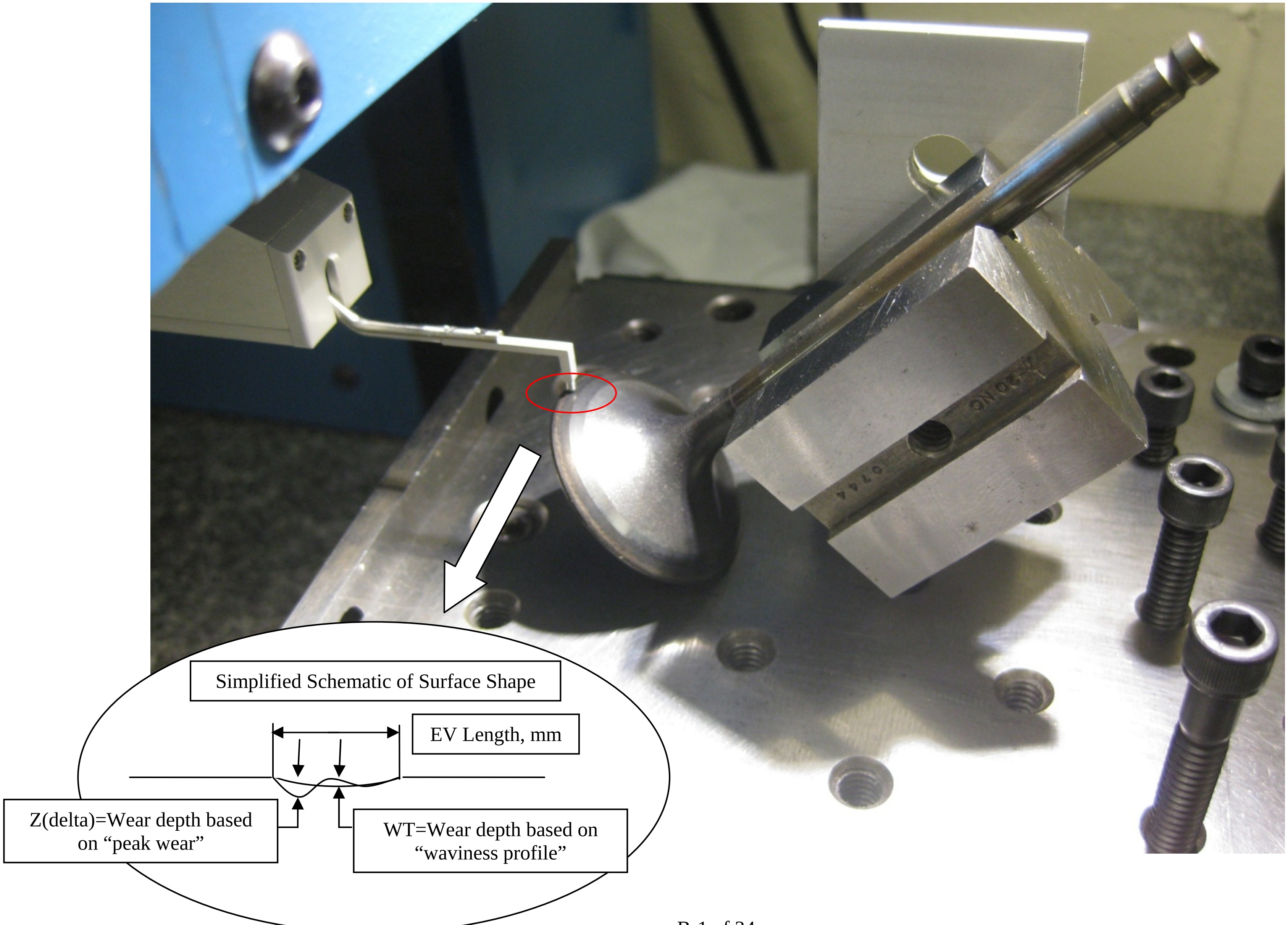

Oakridge National Laboratory
2006 Chevrolet Silverado
Intake Camshaft Lift Measurements at EOT
ORCS0
ORCS15
ORCS20
Cam Lobe Lift Spec
7.300
7.200
7.100
7.000
6.900
6.800
6.700
6.600
mm
1
2
3
4
5
6
7
8
Average
Cylinder Number

Oakridge National Laboratory
2006 Chevrolet Silverado
Exhaust Camshaft Lift Measurements at EOT



Appendix B
Valve Seat Width and Valve Surface Contour

Intake Valve Measured in the Precision Surface Measurement Machine



Oak Ridge National Laboratory
Proposal 08-58845 Powertrain Inspection
Valve Contour Measurements
ORHA0

Measured Data				
Intake Valve #	Position	z(delta), µm	Ev. Length, mm	Wt, µm
1	1	-1.398	1.07	0.72
	2	-1.558	0.97	0.93
	3	-1.266	0.98	0.76
	4	-1.727	0.97	1.26
2	1	-1.648	1.14	0.99
	2	-1.566	1.16	1.00
	3	-1.908	1.13	1.43
	4	-1.107	1.01	0.76
3	1	-2.177	0.97	1.81
	2	-2.137	0.98	1.68
	3	-2.331	0.98	1.87
	4	-1.791	0.99	1.37
4	1	-1.485	0.73	0.83
	2	-1.590	0.85	1.22
	3	-2.029	1.08	1.40
	4	-2.292	1.10	1.73
5	1	-2.141	1.07	1.38
	2	-2.085	0.98	1.04
	3	-1.594	1.13	0.94
	4	-1.047	0.99	0.73
6	1	-1.789	0.99	1.52
	2	-2.223	1.03	1.31
	3	-1.412	0.87	1.17
	4	-2.960	0.97	2.29
7	1	-2.321	1.01	0.40
	2	-1.921	1.13	1.47
	3	-2.717	1.14	1.81
	4	-1.848	1.10	1.36
8	1	-3.123	1.24	2.25
	2	-2.994	1.00	2.05
	3	-2.223	1.29	1.62
	4	-2.449	1.43	1.65

Averages by Valve			
Intake Valve #	ORHA0 z(delta), µm	ORHA0 Ev. Length, mm	ORHA0 Wt, µm
1	-1.487	0.998	0.918
2	-1.557	1.110	1.045
3	-2.109	0.980	1.683
4	-1.849	0.940	1.295
5	-1.717	1.043	1.023
6	-2.096	0.965	1.573
7	-2.202	1.095	1.260
8	-2.697	1.240	1.893
Overall Avg.	-1.964	1.046	1.336
Overall StDev	0.526	0.131	0.466
Overall Max	-1.047	1.430	2.290
Overall Min	-3.123	0.730	0.400

Oak Ridge National Laboratory
Proposal 08-58845 Powertrain Inspection
Valve Contour Measurements
ORHA0

Measured Data				
Exhuast Valve #	Position	z(delta), µm	Ev. Length, mm	Wt, µm
1	1	-20.852	1.52	20.16
	2	-9.930	1.55	9.57
	3	-6.215	1.43	5.97
	4	-11.875	1.35	11.38
2	1	-7.420	1.36	6.47
	2	-8.095	1.43	7.65
	3	-9.901	1.28	8.33
	4	-22.050	1.57	20.13
3	1	-17.324	1.23	16.80
	2	-10.292	1.55	9.43
	3	-13.401	1.58	12.91
	4	-8.651	1.59	7.70
4	1	-8.201	1.62	6.97
	2	-10.773	1.64	9.59
	3	-7.370	1.48	6.66
	4	-10.042	1.53	9.45
5	1	-10.306	1.68	9.92
	2	-10.353	1.60	9.75
	3	-6.717	1.61	6.05
	4	-7.660	1.69	6.72
6	1	-7.126	1.46	6.61
	2	-6.441	1.45	5.67
	3	-9.106	1.54	8.09
	4	-4.961	1.52	4.29
7	1	-9.944	1.55	9.32
	2	-7.731	1.52	7.34
	3	-11.075	1.73	10.38
	4	-11.401	1.68	10.75
8	1	-8.439	1.61	7.78
	2	-8.647	1.59	8.29
	3	-7.663	1.53	7.19
	4	-8.222	1.56	7.73

Averages by Valve			
Exhaust Valve #	ORHA0 z(delta), µm	ORHA0 Ev. Length, mm	ORHA0 Wt, µm
1	-12.218	1.463	11.770
2	-11.867	1.410	10.645
3	-12.417	1.488	11.710
4	-9.097	1.568	8.168
5	-8.759	1.645	8.110
6	-6.909	1.493	6.165
7	-10.038	1.620	9.448
8	-8.243	1.573	7.748
Overall Avg.	-9.943	1.532	9.220
Overall StDev	3.825	0.115	3.719
Overall Max	-4.961	1.730	20.160
Overall Min	-22.050	1.230	4.290

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ORHA15

Measured Data				
Intake Valve #	Position	z(delta), µm	Ev. Length, mm	Wt, µm
1	1	-1.129	1.57	0.79
	2	-1.041	1.36	0.94
	3	-1.272	1.59	1.28
	4	-1.247	1.61	1.32
2	1	-1.270	0.86	0.87
	2	-1.823	1.06	1.44
	3	-1.123	1.12	1.12
	4	-1.274	0.86	1.38
3	1	-2.212	1.19	1.76
	2	-1.562	1.08	1.27
	3	-2.707	1.23	1.29
	4	-1.032	1.20	0.73
4	1	-1.846	1.05	1.23
	2	-2.446	1.03	1.74
	3	-0.749	0.83	1.20
	4	-1.682	0.99	1.39
5	1	-2.535	1.70	2.24
	2	-2.869	1.64	2.50
	3	-2.722	1.49	2.45
	4	-3.394	1.68	3.02
6	1	-3.415	1.66	2.86
	2	-3.382	1.58	3.66
	3	-3.212	1.70	2.82
	4	-3.767	1.69	3.29
7	1	-2.821	1.70	2.35
	2	-2.451	1.69	2.19
	3	-1.669	1.54	2.14
	4	-2.105	1.54	1.97
8	1	-2.752	1.69	2.55
	2	-2.935	1.68	2.87
	3	-2.921	1.71	2.95
	4	-3.146	1.69	2.84

Averages by Valve			
Intake Valve #	ORHA15 z(delta), µm	ORHA15 Ev. Length, mm	ORHA15 Wt, µm
1	-1.172	1.533	1.083
2	-1.373	0.975	1.203
3	-1.878	1.175	1.263
4	-1.681	0.975	1.390
5	-2.880	1.628	2.553
6	-3.444	1.658	3.158
7	-2.262	1.618	2.163
8	-2.939	1.693	2.803
Overall Avg.	-2.203	1.407	1.952
Overall StDev	0.870	0.307	0.820
Overall Max	-0.749	1.710	3.660
Overall Min	-3.767	0.830	0.730

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ORHA15

Measured Data				
Exhuast Valve #	Position	z(delta), µm	Ev. Length, mm	Wt, µm
1	1	-9.906	1.55	9.02
	2	-10.619	1.49	10.23
	3	-8.937	1.49	7.04
	4	-8.162	1.48	7.40
2	1	-3.326	1.32	2.98
	2	-9.819	1.34	8.93
	3	-8.059	1.42	7.34
	4	-4.193	1.48	3.68
3	1	-11.855	1.34	11.04
	2	-4.315	1.45	3.65
	3	-9.438	1.44	8.80
	4	-5.471	1.50	4.61
4	1	-5.337	1.31	4.89
	2	-9.715	1.26	8.99
	3	-4.707	1.26	4.16
	4	-3.028	1.19	2.59
5	1	-7.123	1.50	5.91
	2	-8.530	1.31	7.58
	3	-5.725	1.25	5.01
	4	-3.023	1.20	3.23
6	1	-6.749	1.48	7.20
	2	-3.823	1.48	2.76
	3	-5.724	1.23	5.06
	4	-9.258	1.52	8.49
7	1	-2.837	1.57	9.97
	2	-12.444	1.30	11.75
	3	-4.098	1.33	3.86
	4	-14.283	1.46	12.84
8	1	-8.990	1.55	8.44
	2	-15.397	1.52	14.44
	3	-2.992	1.35	4.15
	4	-8.686	1.29	7.79

Averages by Valve			
Exhaust Valve #	ORHA15 z(delta), µm	ORHA15 Ev. Length, mm	ORHA15 Wt, µm
1	-9.406	1.503	8.423
2	-6.349	1.390	5.733
3	-7.770	1.433	7.025
4	-5.697	1.255	5.158
5	-6.100	1.315	5.433
6	-6.389	1.428	5.878
7	-8.416	1.415	9.605
8	-9.016	1.428	8.705
Overall Avg.	-7.393	1.396	6.995
Overall StDev	3.412	0.114	3.128
Overall Max	-2.837	1.570	14.440
Overall Min	-15.397	1.190	2.590

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ORHA20

Measured Data				
Intake Valve #	Position	z(delta), µm	Ev. Length, mm	Wt, µm
1	1	-1.443	0.85	1.17
	2	-1.407	0.77	1.28
	3	-1.406	0.76	1.18
	4	-0.839	0.68	0.70
2	1	-1.117	0.66	0.95
	2	-1.004	0.71	0.77
	3	-1.200	0.95	1.06
	4	-1.225	0.70	0.91
3	1	-1.145	0.74	0.89
	2	-0.897	0.66	0.71
	3	-2.557	0.76	1.93
	4	-1.157	0.67	0.84
4	1	-1.389	0.84	1.15
	2	-1.267	0.80	1.08
	3	-1.407	0.79	1.08
	4	-1.208	0.76	1.14
5	1	-1.511	1.13	1.29
	2	-2.098	1.15	1.73
	3	-1.588	1.16	1.39
	4	-1.631	1.13	1.40
6	1	-1.068	0.80	0.82
	2	-0.720	0.81	0.61
	3	-1.143	0.87	0.71
	4	-1.012	0.78	0.65
7	1	-1.883	1.10	1.69
	2	-1.646	0.77	1.46
	3	-2.133	1.11	1.88
	4	-1.867	1.11	1.55
8	1	-1.167	0.84	0.62
	2	-1.319	0.76	0.94
	3	-1.321	0.85	0.99
	4	-1.016	0.76	0.62

Averages by Valve			
Intake Valve #	ORHA20 z(delta), µm	ORHA20 Ev. Length, mm	ORHA20 Wt, µm
1	-1.274	0.765	1.083
2	-1.137	0.755	0.923
3	-1.439	0.708	1.093
4	-1.318	0.798	1.113
5	-1.707	1.143	1.453
6	-0.986	0.815	0.698
7	-1.882	1.023	1.645
8	-1.206	0.803	0.793
Overall Avg.	-1.368	0.851	1.100
Overall StDev	0.402	0.161	0.377
Overall Max	-0.720	1.160	1.930
Overall Min	-2.557	0.660	0.610

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ORHA20

Measured Data				
Exhuast Valve #	Position	z(delta), µm	Ev. Length, mm	Wt, µm
1	1	-7.544	1.61	6.74
	2	-14.879	1.64	13.65
	3	-11.177	1.63	10.48
	4	-8.226	1.68	6.86
2	1	-8.910	1.59	8.09
	2	-5.983	1.49	5.85
	3	-5.829	1.62	4.63
	4	-10.544	1.63	8.84
3	1	-14.191	1.68	13.55
	2	-11.424	1.66	11.05
	3	-8.672	1.67	8.16
	4	-8.465	1.71	7.86
4	1	-11.533	1.63	10.58
	2	-8.638	1.69	7.82
	3	-11.821	1.72	10.82
	4	-10.658	1.67	10.19
5	1	-16.121	1.92	15.15
	2	-15.420	1.87	14.55
	3	-12.300	1.86	11.69
	4	-13.125	1.90	12.00
6	1	-17.155	1.81	16.33
	2	-18.205	1.73	17.35
	3	-14.757	1.74	14.28
	4	-15.079	1.74	13.91
7	1	-18.805	2.00	17.98
	2	-16.680	1.82	15.72
	3	-9.851	1.66	9.03
	4	-12.752	1.80	12.02
8	1	-8.907	1.79	8.56
	2	-14.977	1.81	14.09
	3	-15.031	1.76	14.23
	4	-10.652	1.82	9.89

Averages by Valve			
Exhaust Valve #	ORHA20 z(delta), µm	ORHA20 Ev. Length, mm	ORHA20 Wt, µm
1	-10.457	1.640	9.433
2	-7.817	1.583	6.853
3	-10.688	1.680	10.155
4	-10.663	1.678	9.853
5	-14.242	1.888	13.348
6	-16.299	1.755	15.468
7	-14.522	1.820	13.688
8	-12.392	1.795	11.693
Overall Avg.	-12.135	1.730	11.311
Overall StDev	3.526	0.111	3.489
Overall Max	-5.829	2.000	17.980
Overall Min	-18.805	1.490	4.630

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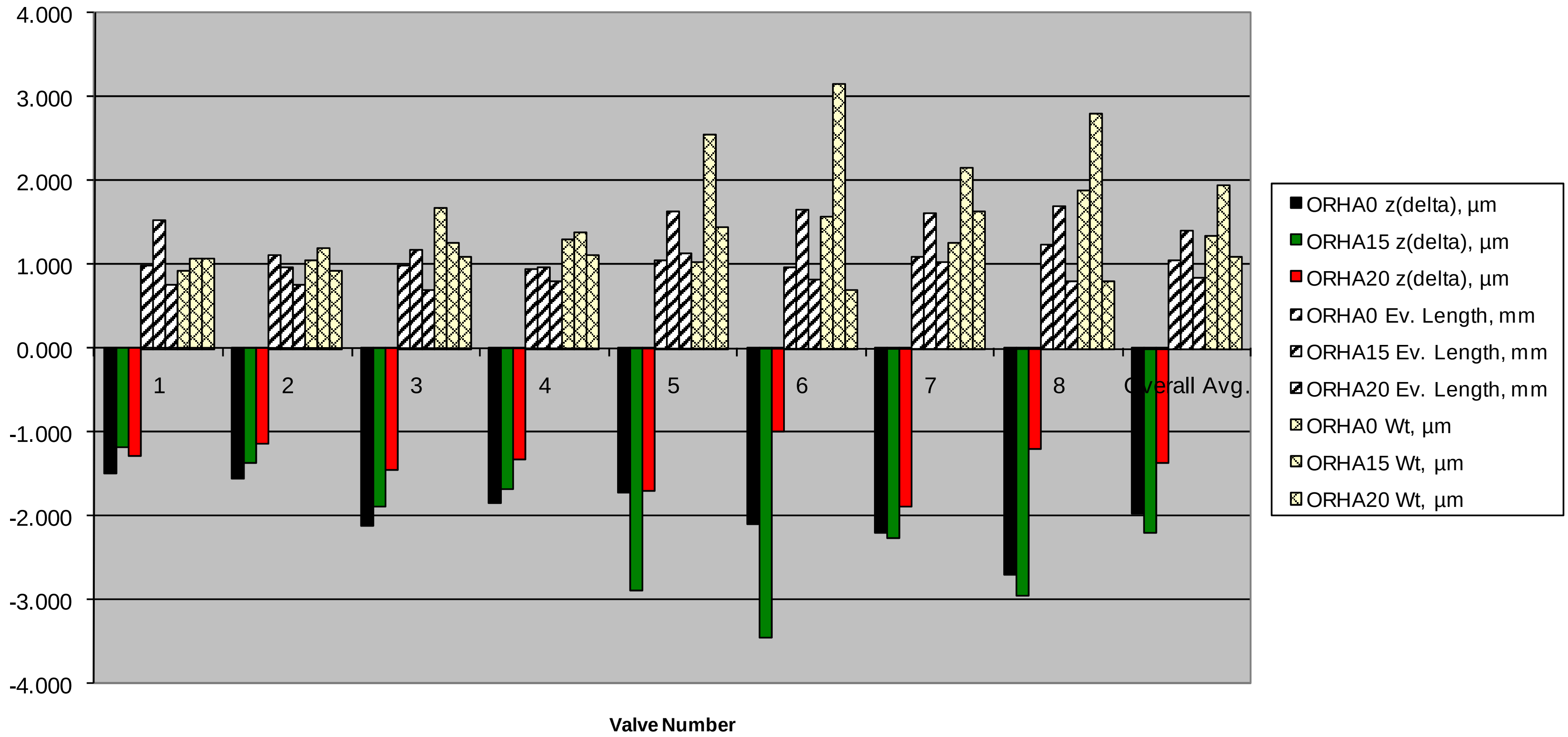
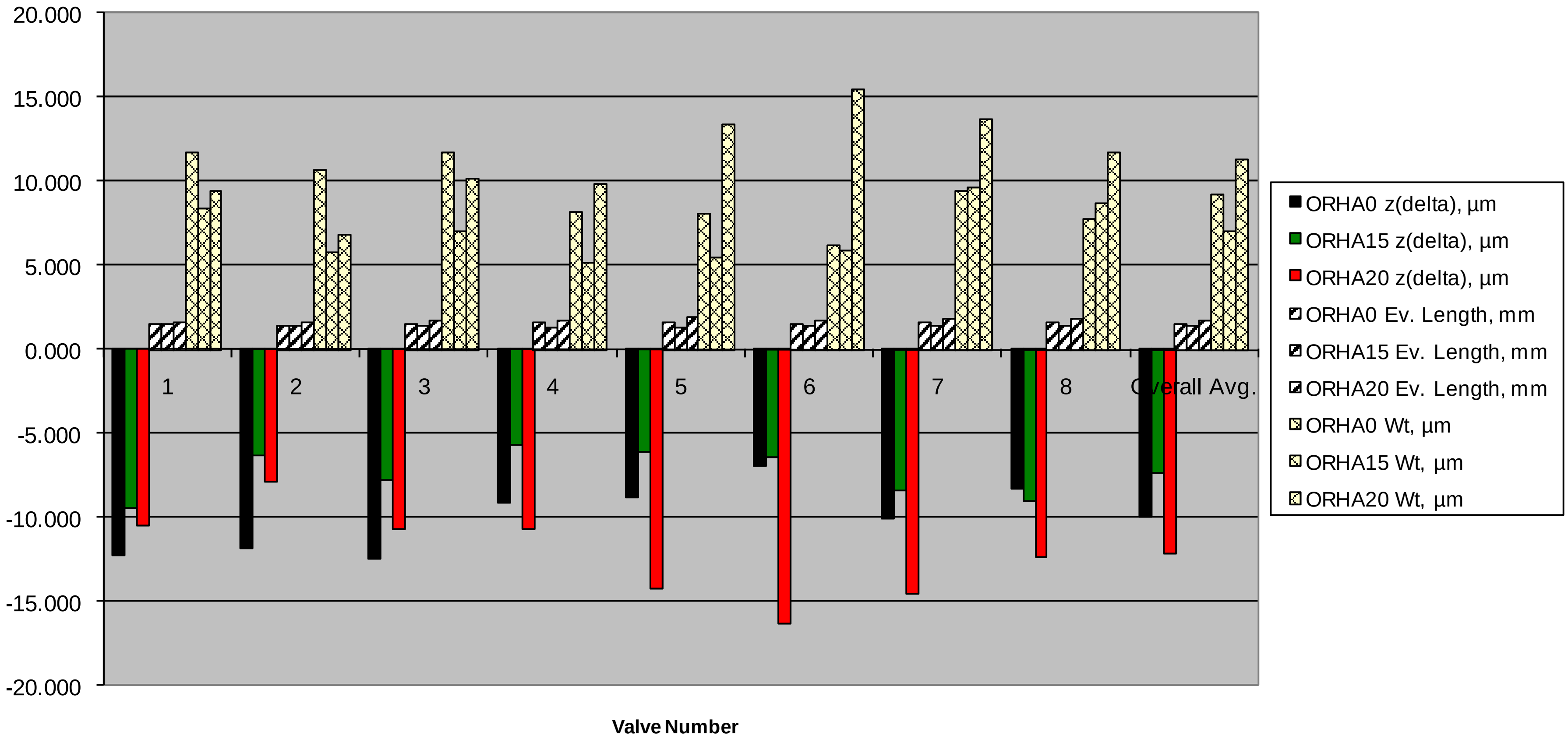
2007 Honda Accord
Intake Valve Contour Measurements at EOT



Oakridge National Laboratory
2007 Honda Accord
Exhaust Valve Contour Measurements at EOT



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Valve Contour Measurements

ORDC0					ORDC15				
Intake Valve #	Position	z(delta), µm	Ev. Length, mm	Wt, µm	Intake Valve #	Position	z(delta), µm	Ev. Length, mm	Wt, µm
1	1	-3.485	1.27	1.73	1	1	-3.401	1.96	2.43
	2	-3.727	1.22	2.15		2	-2.485	2.14	1.64
	3	-3.507	1.28	2.33		3	-2.429	2.01	1.49
	4	-3.157	1.44	2.36		4	-2.924	2.06	2.25
2	1	-3.497	1.42	2.54	2	1	-5.197	2.20	3.43
	2	-11.840	1.34	9.84		2	-5.731	2.31	5.05
	3	-6.574	1.44	5.24		3	-5.339	1.63	4.34
	4	-4.129	1.44	3.48		4	-5.127	1.87	4.68
3	1	-2.974	1.95	2.27	3	1	-5.549	2.06	4.49
	2	-2.719	1.94	2.19		2	-3.940	1.98	3.44
	3	-4.126	1.92	2.58		3	-4.040	2.51	3.53
	4	-2.530	2.00	1.89		4	-5.491	2.24	4.78
4	1	-2.319	1.10	1.20	4	1	-3.301	2.39	2.52
	2	-1.469	0.97	1.14		2	-3.024	2.39	2.04
	3	-2.013	1.13	1.43		3	-2.630	2.46	2.13
	4	-3.606	1.17	1.56		4	-3.568	2.30	2.69
5	1	-3.012	0.91	2.38	5	1	-2.990	2.09	2.28
	2	-2.328	0.75	1.63		2	-2.444	2.03	1.76
	3	-3.212	1.38	2.70		3	-2.730	2.00	3.46
	4	-3.349	1.20	2.32		4	-3.550	1.87	2.50
6	1	-3.604	1.44	2.12	6	1	-3.146	1.42	2.41
	2	-3.491	1.38	1.84		2	-2.177	1.41	1.38
	3	-4.366	1.38	2.75		3	-2.049	1.31	1.45
	4	-2.635	1.35	2.04		4	-2.991	1.33	1.84

Averages by Valve				Averages by Valve			
Intake Valve #	ORDC0 z(delta), µm	ORDC0 Ev. Length, mm	ORDC0 Wt, µm	Intake Valve #	ORDC15 z(delta), µm	ORDC15 Ev. Length, mm	ORDC15 Wt, µm
1	-3.469	1.303	2.143	1	-2.810	2.043	1.953
2	-6.510	1.410	5.275	2	-5.349	2.003	4.375
3	-3.087	1.953	2.233	3	-4.755	2.198	4.060
4	-2.352	1.093	1.333	4	-3.131	2.385	2.345
5	-2.975	1.060	2.258	5	-2.929	1.998	2.500
6	-3.524	1.388	2.188	6	-2.591	1.368	1.770
Average	-3.653	1.368	2.571	Average	-3.594	1.999	2.834
StDev	2.002	0.322	1.754	StDev	1.181	0.354	1.151
Max	-1.469	2.000	9.840	Max	-2.049	2.510	5.050
Min	-11.840	0.750	1.140	Min	-5.731	1.310	1.380

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ORDC0

Exhaust Valve #	Position	z(delta), µm	Ev. Length, mm	Wt, µm
1	1	-26.525	1.84	26.90
	2	-22.266	1.96	21.39
	3	-32.723	2.02	31.58
	4	-31.927	2.06	30.99
2	1	-15.561	2.11	17.16
	2	-5.598	2.22	12.86
	3	-19.420	2.15	18.01
	4	-14.352	2.17	13.17
3	1	-9.563	1.95	12.59
	2	-8.267	1.95	15.76
	3	-9.070	1.67	8.95
	4	-18.693	1.78	17.68
4	1	-14.822	2.02	13.45
	2	-25.436	2.06	22.83
	3	-21.528	2.16	20.52
	4	-11.848	2.16	12.97
5	1	-18.130	2.02	20.97
	2	-34.011	1.56	32.67
	3	-13.396	2.05	14.52
	4	-17.132	2.10	15.91
6	1	-20.460	2.10	19.22
	2	-41.688	2.03	40.61
	3	-9.324	1.79	10.33
	4	-21.709	2.11	20.54

ORDC15

Exhaust Valve #	Position	z(delta), µm	Ev. Length, mm	Wt, µm
1	1	-7.861	2.17	6.00
	2	-14.234	2.17	13.04
	3	-7.819	2.17	6.82
	4	-13.977	2.13	13.65
2	1	-12.893	1.97	15.40
	2	-20.452	2.15	19.35
	3	-9.203	1.93	8.33
	4	-13.683	2.11	11.86
3	1	-20.185	2.05	22.68
	2	-15.918	2.13	15.69
	3	-15.687	2.01	14.97
	4	-14.804	2.17	13.79
4	1	-12.829	2.07	13.34
	2	-10.545	2.13	11.19
	3	-10.341	2.03	11.43
	4	-6.212	1.76	7.01
5	1	-19.312	2.06	17.95
	2	-9.403	2.05	7.64
	3	-9.120	1.90	8.09
	4	-8.127	1.80	7.43
6	1	-20.106	2.15	18.88
	2	-24.426	1.59	23.35
	3	-16.544	1.70	19.45
	4	-14.040	1.63	13.31

Averages by Valve

Exhaust Valve #	ORDC0 z(delta), µm	ORDC0 Ev. Length, mm	ORDC0 Wt, µm
1	-28.360	1.970	27.715
2	-13.733	2.163	15.300
3	-11.398	1.838	13.745
4	-18.409	2.100	17.443
5	-20.667	1.933	21.018
6	-23.295	2.008	22.675
Average	-19.310	2.002	19.649
StDev	9.165	0.166	7.911
Max	-5.598	2.220	40.610
Min	-41.688	1.560	8.950

Averages by Valve

Exhaust Valve #	ORDC15 z(delta), µm	ORDC15 Ev. Length, mm	ORDC15 Wt, µm
1	-10.973	2.160	9.878
2	-14.058	2.040	13.735
3	-16.649	2.090	16.783
4	-9.982	1.998	10.743
5	-11.491	1.953	10.278
6	-18.779	1.768	18.748
Average	-13.655	2.001	13.360
StDev	4.809	0.180	5.076
Max	-6.212	2.170	23.350
Min	-24.426	1.590	6.000

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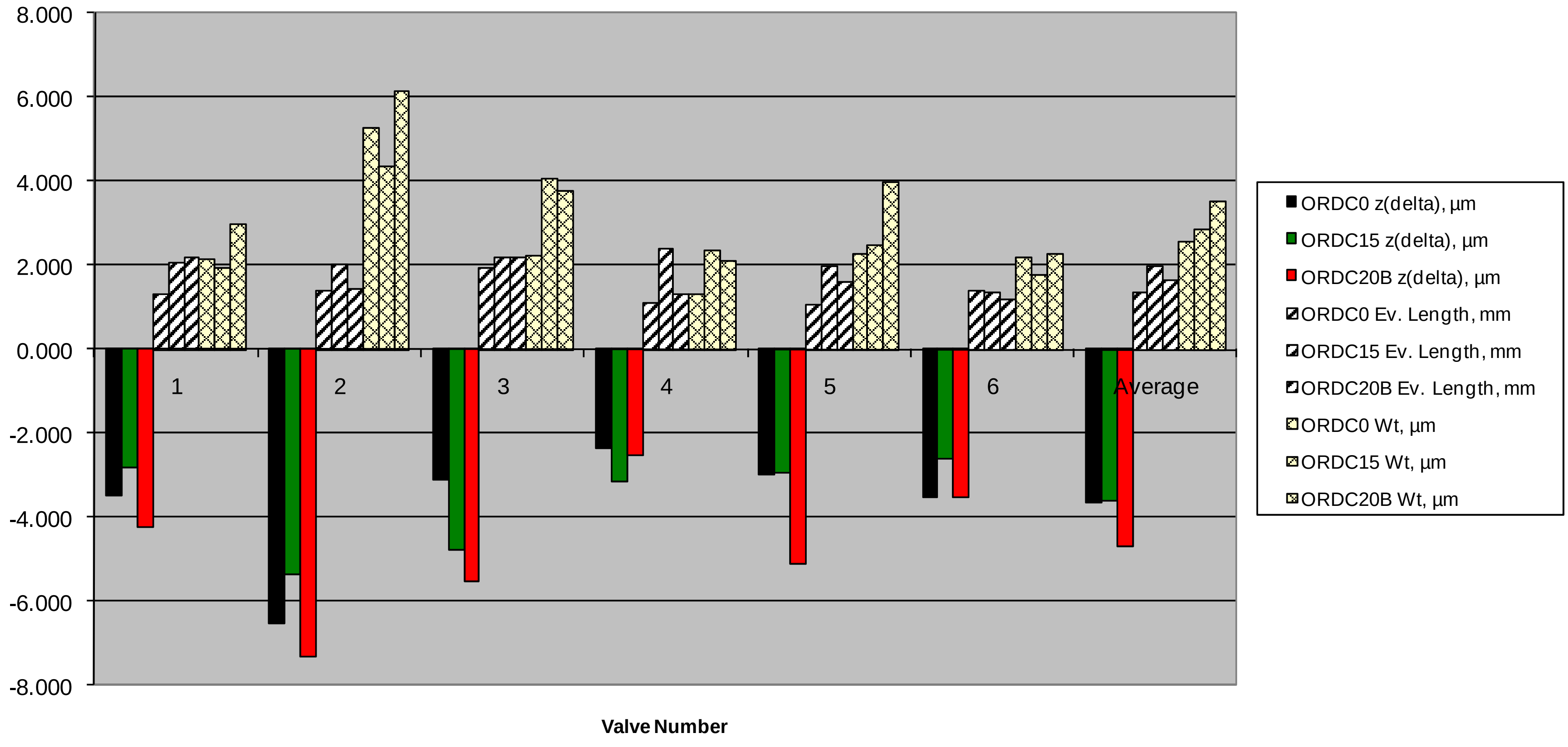
ORDC20B				
Intake Valve #	Position	z(delta), µm	Ev. Length, mm	Wt, µm
1	1	-5.163	2.25	3.84
	2	-3.807	2.22	2.49
	3	-4.253	2.16	2.88
	4	-3.637	2.10	2.69
2	1	-7.067	1.44	6.20
	2	-6.161	1.38	5.15
	3	-8.106	1.46	7.19
	4	-7.953	1.53	5.97
3	1	-6.708	2.35	4.83
	2	-5.074	2.29	3.44
	3	-5.578	2.20	3.67
	4	-4.781	1.97	3.19
4	1	-2.515	1.44	2.81
	2	-1.826	1.19	1.71
	3	-2.410	1.30	1.67
	4	-3.402	1.29	2.15
5	1	-4.514	1.79	3.98
	2	-4.575	1.79	3.32
	3	-4.131	1.51	3.19
	4	-7.221	1.37	5.47
6	1	-2.968	1.21	2.00
	2	-3.762	1.11	2.25
	3	-4.192	1.13	2.44
	4	-3.183	1.24	2.45

ORDC20B				
Exhaust Valve #	Position	z(delta), µm	Ev. Length, mm	Wt, µm
1	1	-17.187	2.09	15.83
	2	-17.645	1.84	17.01
	3	-11.615	1.94	10.34
	4	-14.395	1.59	12.27
2	1	-23.509	2.13	23.07
	2	-27.055	2.26	25.52
	3	-17.626	2.19	16.85
	4	-29.492	1.96	27.85
3	1	-17.716	2.01	16.31
	2	-17.576	1.92	16.53
	3	-31.377	2.06	30.52
	4	-15.049	2.00	16.78
4	1	-14.180	1.83	13.49
	2	-12.732	1.94	15.10
	3	-19.513	2.07	23.59
	4	-16.881	1.93	15.93
5	1	-13.022	2.03	16.39
	2	-15.027	2.03	18.39
	3	-20.056	2.07	21.22
	4	-20.366	1.99	19.53
6	1	-13.572	1.81	12.62
	2	-31.321	2.19	28.90
	3	-20.677	2.11	25.81
	4	-27.028	2.06	26.58

Averages by Valve			
Intake Valve #	ORDC20B z(delta), µm	ORDC20B Ev. Length, mm	ORDC20B Wt, µm
1	-4.215	2.183	2.975
2	-7.322	1.453	6.128
3	-5.535	2.203	3.783
4	-2.538	1.305	2.085
5	-5.110	1.615	3.990
6	-3.526	1.173	2.285
Average	-4.708	1.655	3.541
StDev	1.749	0.427	1.516
Max	-1.826	2.350	7.190
Min	-8.106	1.110	1.670

Averages by Valve			
Exhaust Valve #	ORDC20B z(delta), µm	ORDC20B Ev. Length, mm	ORDC20B Wt, µm
1	-15.211	1.865	13.863
2	-24.421	2.135	23.323
3	-20.430	1.998	20.035
4	-15.827	1.943	17.028
5	-17.118	2.030	18.883
6	-23.150	2.043	23.478
Average	-19.359	2.002	19.435
StDev	5.963	0.144	5.725
Max	-11.615	2.260	30.520
Min	-31.377	1.590	10.340

Oakridge National Laboratory
2007 Dodge Caravan
Intake Valve Contour Measurements at EOT



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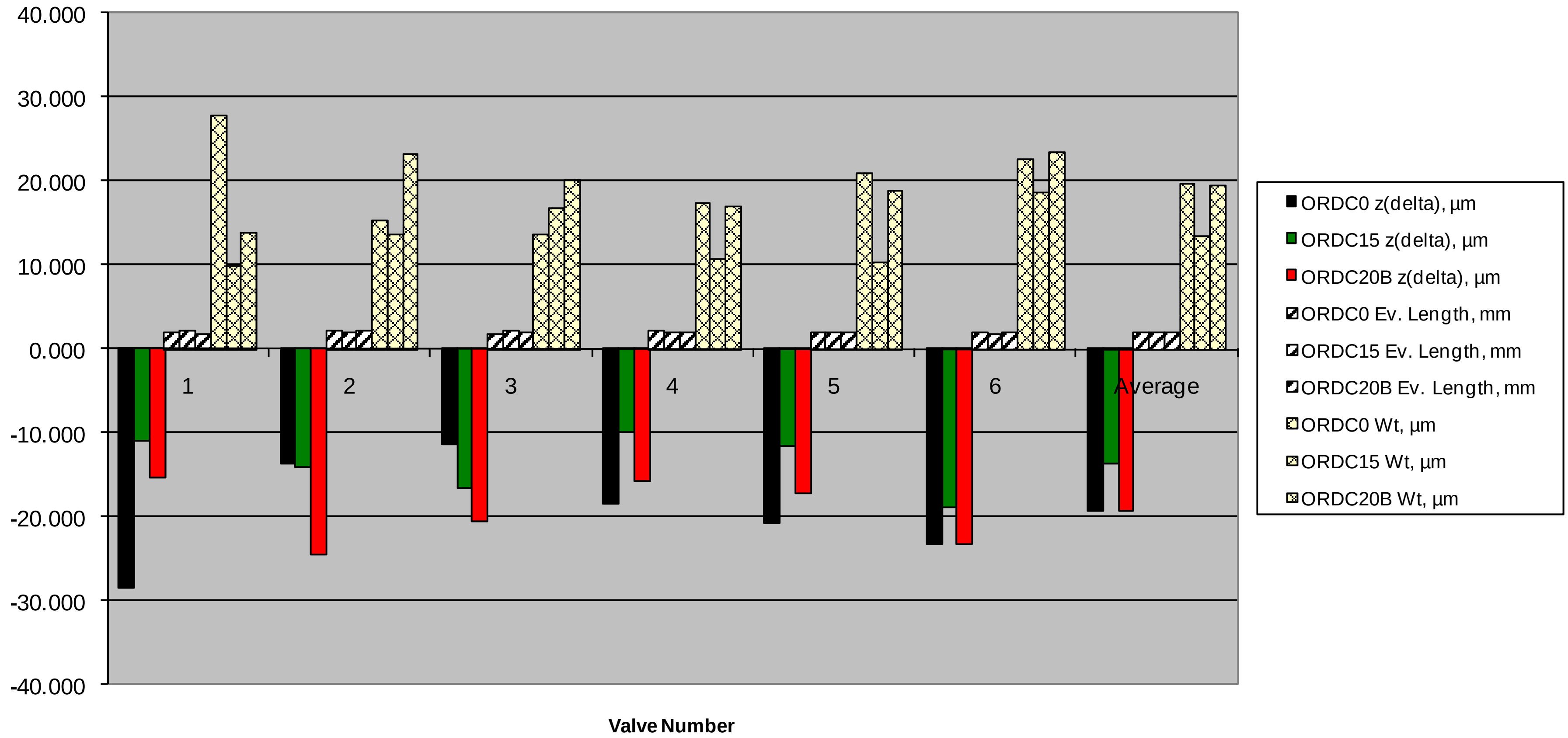
2007 Dodge Caravan
Exhaust Valve Contour Measurements at EOT



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Valve Contour Measurements

ORCS0					ORCS15				
Intake Valve #	Position	z(delta), µm	Ev. Length, mm	Wt, µm	Intake Valve #	Position	z(delta), µm	Ev. Length, mm	Wt, µm
1	1	-3.451	1.09	2.83	1	1	-6.371	1.22	6.04
	2	-3.228	0.96	2.18		2	-6.200	1.18	5.55
	3	-3.340	1.07	3.10		3	-5.468	1.12	4.93
	4	-2.869	0.95	1.51		4	-6.319	1.15	5.24
2	1	-3.668	1.41	2.73	2	1	-9.580	1.20	7.85
	2	-3.529	1.46	2.58		2	-7.093	1.04	6.92
	3	-3.738	1.41	2.65		3	-7.793	1.00	7.50
	4	-4.508	1.46	3.95		4	-7.158	1.08	6.78
3	1	-11.142	1.49	10.99	3	1	-4.867	1.22	4.50
	2	-8.352	1.42	7.88		2	-5.433	1.24	4.76
	3	-6.953	1.44	6.61		3	-6.378	1.24	5.61
	4	-7.133	1.42	6.85		4	-7.018	1.24	5.48
4	1	-5.077	1.39	4.66	4	1	-7.154	1.28	6.66
	2	-6.890	1.40	6.24		2	-6.676	1.20	6.09
	3	-6.405	1.42	5.85		3	-7.873	1.22	6.98
	4	-5.029	1.38	4.77		4	-7.763	1.25	7.10
5	1	-5.957	1.42	5.40	5	1	-4.199	1.28	3.85
	2	-4.941	1.25	4.85		2	-3.622	1.16	3.17
	3	-6.050	1.40	5.48		3	-2.879	1.08	2.82
	4	-6.661	1.46	6.00		4	-4.516	1.04	3.66
6	1	-3.871	0.77	3.44	6	1	-4.206	1.30	3.42
	2	-3.059	0.76	2.90		2	-2.129	1.13	2.26
	3	-3.633	0.72	3.44		3	-4.148	1.24	3.92
	4	-3.097	0.72	2.99		4	-3.501	1.21	2.88
7	1	-3.662	1.51	2.92	7	1	-8.288	1.20	7.91
	2	-4.333	1.60	4.00		2	-7.324	1.16	6.68
	3	-3.886	1.51	3.23		3	-6.808	1.15	6.44
	4	-4.946	1.51	4.03		4	-7.042	1.08	6.77
8	1	-3.140	0.98	2.89	8	1	-4.001	1.01	3.74
	2	-3.368	0.99	3.16		2	-3.627	0.99	3.41
	3	-3.363	0.83	3.09		3	-5.140	1.22	5.03
	4	-3.484	1.02	2.95		4	-4.453	0.87	3.62

Averages by Valve				Averages by Valve			
Intake Valve #	ORCS0 z(delta), µm	ORCS0 Ev. Length, mm	ORCS0 Wt, µm	Intake Valve #	ORCS15 z(delta), µm	ORCS15 Ev. Length, mm	ORCS15 Wt, µm
1	-3.222	1.018	2.405	1	-6.090	1.168	5.440
2	-3.861	1.435	2.978	2	-7.906	1.080	7.263
3	-8.395	1.443	8.083	3	-5.924	1.235	5.088
4	-5.850	1.398	5.380	4	-7.367	1.238	6.708
5	-5.902	1.383	5.433	5	-3.804	1.140	3.375
6	-3.415	0.743	3.193	6	-3.496	1.220	3.120
7	-4.207	1.533	3.545	7	-7.366	1.148	6.950
8	-3.339	0.955	3.023	8	-4.305	1.023	3.950
Average	-4.774	1.238	4.255	Average	-5.782	1.156	5.237
StDev	1.882	0.280	1.974	StDev	1.787	0.101	1.641
Max	-2.869	1.600	10.990	Max	-2.129	1.300	7.910
Min	-11.142	0.720	1.510	Min	-9.580	0.870	2.260

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ORCS0

Exhaust Valve #	Position	z(delta), µm	Ev. Length, mm	Wt, µm
1	1	-16.330	1.80	15.26
	2	-16.626	1.68	14.83
	3	-21.172	1.82	20.61
	4	-14.499	1.82	12.89
2	1	-21.144	1.90	19.69
	2	-28.255	1.83	26.48
	3	-23.895	1.74	23.15
	4	-21.677	1.55	20.06
3	1	-21.100	1.66	20.57
	2	-32.367	2.19	31.89
	3	-10.650	1.39	9.18
	4	-14.832	1.38	13.89
4	1	-25.062	1.84	24.21
	2	-11.630	1.59	9.75
	3	-20.025	1.75	18.64
	4	-18.593	1.62	17.92
5	1	-7.855	1.85	7.17
	2	-15.268	1.82	14.74
	3	-12.618	1.76	11.43
	4	-27.399	1.98	26.76
6	1	-22.268	1.77	20.83
	2	-25.892	1.81	25.06
	3	-24.874	1.95	24.78
	4	-21.773	1.86	20.71
7	1	-11.782	2.01	10.41
	2	-27.189	2.06	26.34
	3	-17.471	1.67	16.34
	4	-21.954	1.76	20.39
8	1	-16.574	1.94	15.33
	2	-11.279	1.36	10.61
	3	-18.911	1.43	17.71
	4	-23.563	2.03	23.20

ORCS15

Exhaust Valve #	Position	z(delta), µm	Ev. Length, mm	Wt, µm
1	1	-22.636	1.80	21.29
	2	-28.347	1.79	27.29
	3	-43.478	1.73	41.76
	4	-27.519	1.41	26.48
2	1	-58.818	1.80	57.63
	2	-22.309	1.96	20.86
	3	-26.097	1.98	25.44
	4	-21.148	1.76	20.47
3	1	-24.515	1.49	23.15
	2	-24.166	1.41	23.04
	3	-16.096	1.07	14.29
	4	-16.493	1.00	15.22
4	1	-25.910	1.63	24.86
	2	-29.314	1.52	28.39
	3	-21.953	1.48	20.23
	4	-16.838	1.56	15.90
5	1	-20.700	1.53	18.61
	2	-25.348	1.64	24.10
	3	-29.293	1.98	27.62
	4	-24.043	1.95	23.22
6	1	-20.946	1.76	19.82
	2	-26.362	1.87	25.52
	3	-12.792	1.78	11.81
	4	-27.597	1.95	25.89
7	5	-23.327	1.91	23.16
	6	-23.091	1.84	20.81
	7	-24.037	1.77	22.66
	8	-34.526	1.66	33.74
8	9	-21.970	1.77	19.58
	10	-8.770	1.37	7.98
	11	-5.981	1.60	5.62
	12	-11.251	1.81	11.71

Averages by Valve

Exhaust Valve #	ORCS0 z(delta), µm	ORCS0 Ev. Length, mm	ORCS0 Wt, µm
1	-17.157	1.780	15.898
2	-23.743	1.755	22.345
3	-19.737	1.655	18.883
4	-18.828	1.700	17.630
5	-15.785	1.853	15.025
6	-23.702	1.848	22.845
7	-19.599	1.875	18.370
8	-17.582	1.690	16.713
Average	-19.516	1.769	18.463
StDev	5.901	0.201	6.048
Max	-7.855	2.190	31.890
Min	-32.367	1.360	7.170

Averages by Valve

Exhaust Valve #	ORCS15 z(delta), µm	ORCS15 Ev. Length, mm	ORCS15 Wt, µm
1	-30.495	1.683	29.205
2	-32.093	1.875	31.100
3	-20.318	1.243	18.925
4	-23.504	1.548	22.345
5	-24.846	1.775	23.388
6	-21.924	1.840	20.760
7	-26.245	1.795	25.093
8	-11.993	1.638	11.223
Average	-23.927	1.674	22.755
StDev	9.632	0.244	9.513
Max	-5.981	1.980	57.630
Min	-58.818	1.000	5.620

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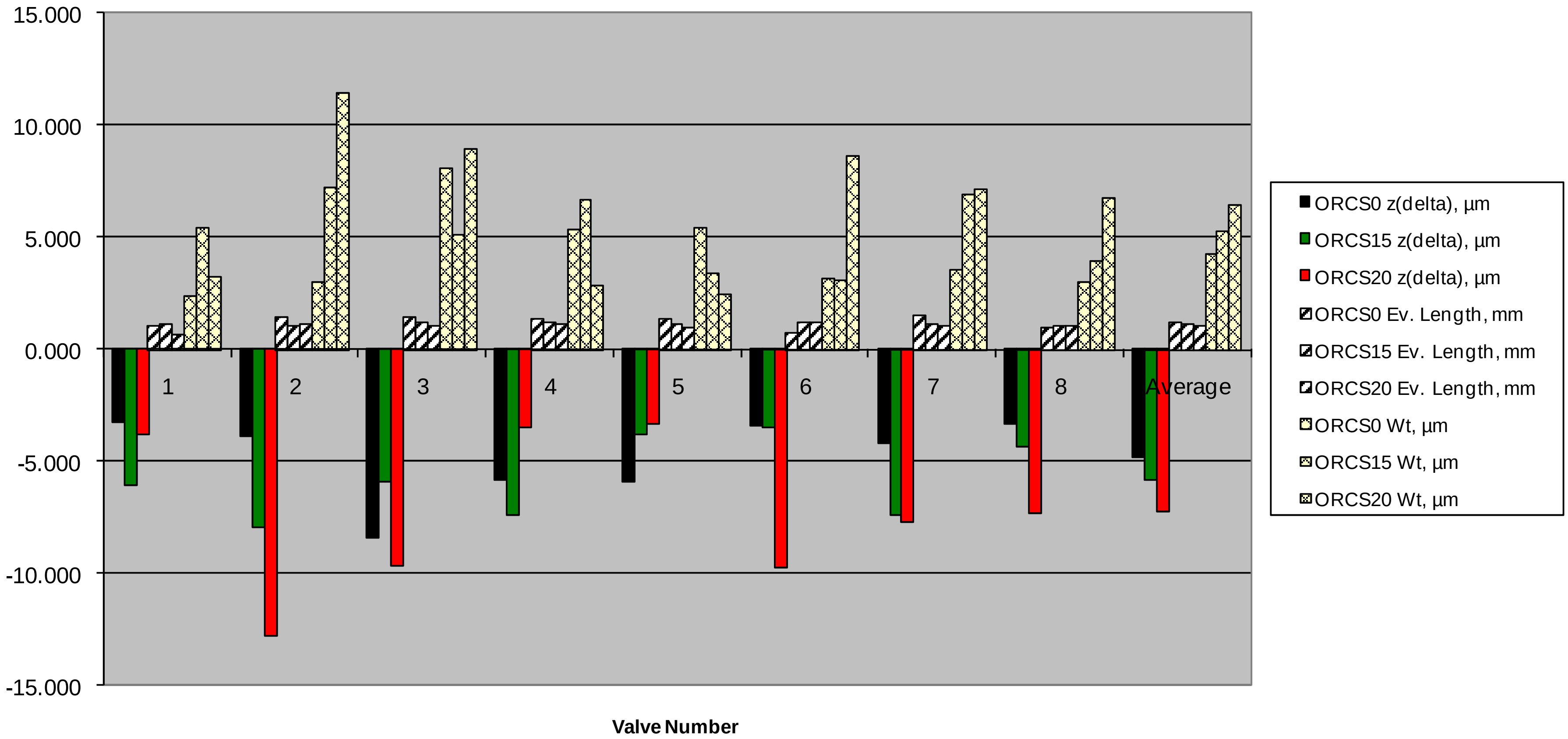
ORCS20						ORCS20				
Intake Valve #	Position	z(delta), µm	Ev. Length, mm	Wt, µm		Exhaust Valve #	Position	z(delta), µm	Ev. Length, mm	Wt, µm
1	1	-3.860	0.70	3.27		1	1	-14.988	1.51	13.10
	2	-3.617	0.58	3.40			2	-6.880	1.61	6.68
	3	-4.742	0.78	3.94			3	-9.563	1.59	8.59
	4	-2.899	0.51	2.42			4	-20.964	1.78	21.57
2	1	-13.962	1.15	11.96		2	1	-20.750	1.89	20.13
	2	-11.332	1.26	10.53			2	-11.808	1.94	11.68
	3	-10.119	1.08	9.87			3	-18.332	1.98	17.26
	4	-15.798	1.07	13.43			4	-22.527	1.97	22.24
3	1	-11.124	1.12	9.86		3	1	-24.090	2.21	22.29
	2	-9.956	1.02	9.31			2	-13.739	2.09	12.62
	3	-9.342	1.08	8.74			3	-15.820	1.77	15.39
	4	-8.068	1.06	7.75			4	-21.821	1.94	20.70
4	1	-3.631	1.23	3.16		4	1	-19.223	1.60	19.24
	2	-2.959	1.09	2.73			2	-26.374	1.67	25.86
	3	-3.999	1.00	2.71			3	-15.056	1.94	14.61
	4	-3.182	1.13	2.81			4	-17.430	1.85	15.82
5	1	-2.314	1.03	2.10		5	1	-18.974	1.83	18.90
	2	-3.397	0.91	2.10			2	-11.186	1.79	9.67
	3	-3.930	0.97	3.09			3	-7.913	1.61	8.19
	4	-3.594	1.08	2.69			4	-29.496	2.09	28.46
6	1	-6.303	1.14	5.81		6	1	-15.110	2.03	15.73
	2	-14.539	1.39	12.73			2	-15.224	2.60	14.39
	3	-12.735	1.12	11.28			3	-17.807	1.48	17.37
	4	-5.440	1.11	4.85			4	-17.030	1.89	18.66
7	1	-7.598	1.03	6.81		7	1	-29.749	1.57	29.27
	2	-6.793	1.22	6.19			2	-40.270	2.10	39.79
	3	-7.490	1.05	7.08			3	-16.526	1.45	15.77
	4	-8.767	1.05	8.36			4	-22.256	1.34	21.17
8	1	-8.091	1.23	7.63		8	1	-27.011	1.47	25.44
	2	-7.376	1.04	6.62			2	-15.249	1.80	14.35
	3	-6.369	1.04	5.94			3	-8.970	1.71	8.61
	4	-7.308	1.00	6.77			4	-15.321	1.71	16.07

Averages by Valve					Averages by Valve			
Intake Valve #	ORCS20 z(delta), µm	ORCS20 Ev. Length, mm	ORCS20 Wt, µm		Exhaust Valve #	ORCS20 z(delta), µm	ORCS20 Ev. Length, mm	ORCS20 Wt, µm
1	-3.780	0.643	3.258		1	-13.099	1.623	12.485
2	-12.803	1.140	11.448		2	-18.354	1.945	17.828
3	-9.623	1.070	8.915		3	-18.868	2.003	17.750
4	-3.443	1.113	2.853		4	-19.521	1.765	18.883
5	-3.309	0.998	2.495		5	-16.892	1.830	16.305
6	-9.754	1.190	8.668		6	-16.293	2.000	16.538
7	-7.662	1.088	7.110		7	-27.200	1.615	26.500
8	-7.286	1.078	6.740		8	-16.638	1.673	16.118
Average	-7.207	1.040	6.436		Average	-18.358	1.807	17.801
StDev	3.742	0.183	3.422		StDev	7.095	0.262	7.022
Max	-2.314	1.390	13.430		Max	-6.880	2.600	39.790
Min	-15.798	0.510	2.100		Min	-40.270	1.340	6.680

Oakridge National Laboratory
2006 Chevrolet Silverado
Intake Valve Contour Measurements at EOT



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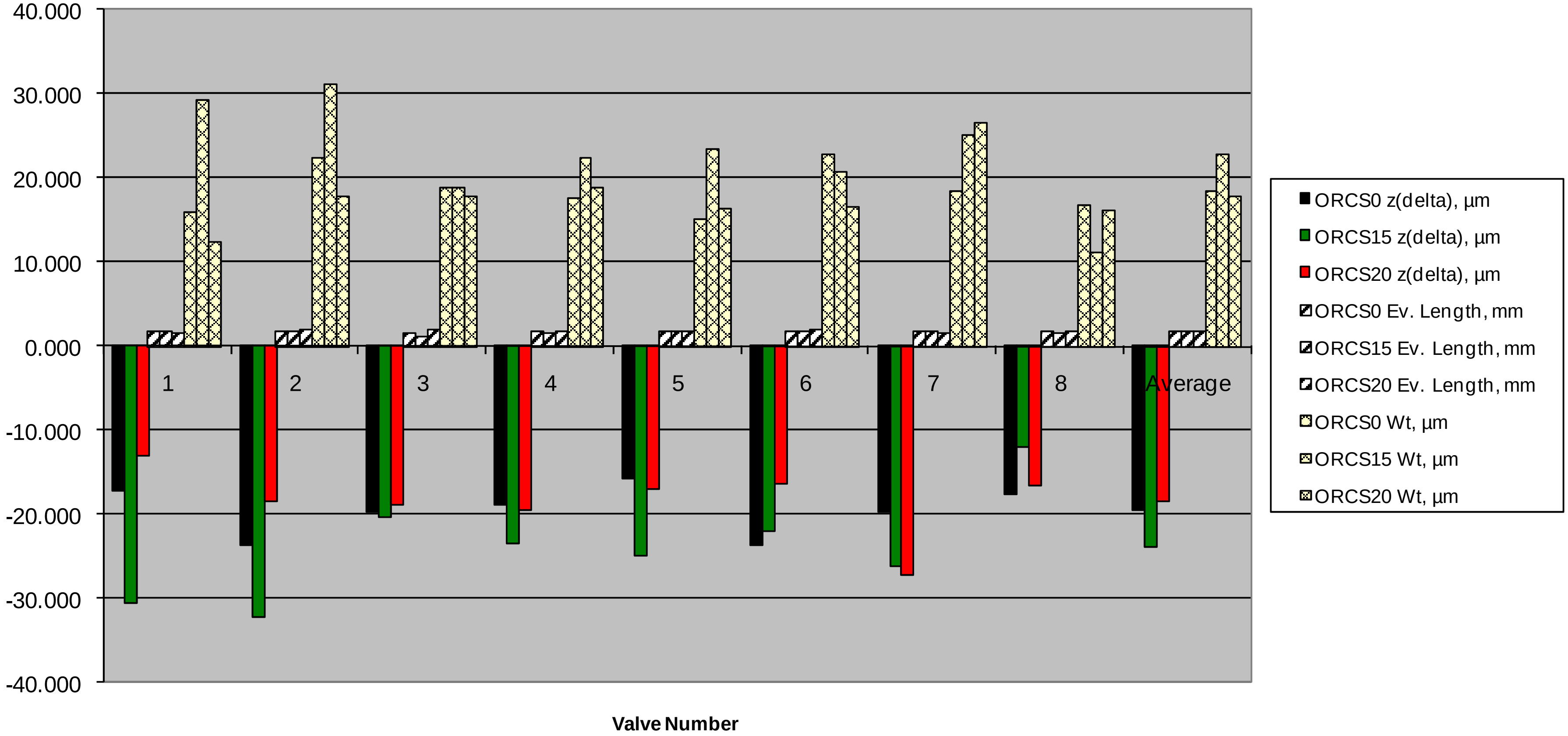
Exhaust Valve Contour Measurements at EOT



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Valve Contour Measurements

ORCC0

Intake Valve #	Position	z(delta), µm	Ev. Length, mm	Wt, µm
1	1	-3.445	1.29	3.25
	2	-4.164	1.23	3.94
	3	-3.554	1.30	3.02
	4	-3.338	1.29	2.73
2	1	-2.047	1.04	3.02
	2	-4.833	1.08	5.89
	3	-3.135	1.02	2.59
	4	-3.344	1.06	2.93
3	1	-2.662	0.93	2.43
	2	-4.338	1.01	5.39
	3	-5.611	1.05	5.12
	4	-6.099	0.97	4.80
4	1	-5.946	1.32	7.05
	2	-4.656	1.30	3.78
	3	-5.425	1.30	6.17
	4	-4.806	1.35	4.06
5	1	-3.195	1.16	2.69
	2	-4.538	1.30	4.13
	3	-5.635	1.41	5.10
	4	-4.258	1.17	3.33
6	1	-1.147	0.91	0.96
	2	-1.066	0.91	0.99
	3	-1.914	1.20	1.81
	4	-2.114	1.20	1.95
7	1	-5.005	1.39	4.54
	2	-3.399	1.28	3.23
	3	-3.901	1.37	4.60
	4	-4.922	1.35	4.18
8	1	-4.396	1.36	3.41
	2	-1.421	1.38	4.53
	3	-4.062	1.31	4.40
	4	-2.452	1.25	4.17

ORCC15

Intake Valve #	Position	z(delta), µm	Ev. Length, mm	Wt, µm
1	1	-1.576	1.12	1.17
	2	-2.626	0.94	2.39
	3	-3.156	1.48	2.93
	4	-3.569	1.79	3.02
2	1	3.046	1.18	3.02
	2	2.273	1.12	2.24
	3	3.375	1.28	3.99
	4	2.713	1.27	4.19
3	1	2.662	0.93	3.95
	2	2.524	0.97	3.96
	3	2.718	0.97	4.20
	4	1.271	0.97	3.72
4	1	-1.810	0.92	1.17
	2	-2.345	1.33	2.04
	3	-1.134	1.16	0.90
	4	-1.270	1.20	0.87
5	1	4.650	1.20	4.44
	2	5.440	1.22	5.10
	3	6.155	1.29	5.10
	4	4.785	1.21	4.45
6	1	-1.661	1.17	1.59
	2	2.481	1.10	2.59
	3	2.745	1.18	2.89
	4	1.608	0.78	1.44
7	1	2.258	1.29	1.86
	2	3.182	1.30	2.81
	3	-2.739	1.41	2.37
	4	-3.097	1.36	2.76
8	1	-2.167	1.17	1.43
	2	-3.259	1.24	2.79
	3	-1.715	0.97	1.33
	4	-1.197	1.06	0.94

Averages by Valve

Intake Valve #	ORCC0 z(delta), µm	ORCC0 Ev. Length, mm	ORCC0 Wt, µm
1	-3.625	1.278	3.235
2	-3.340	1.050	3.608
3	-4.678	0.990	4.435
4	-5.208	1.318	5.265
5	-4.407	1.260	3.813
6	-1.560	1.055	1.428
7	-4.307	1.348	4.138
8	-3.083	1.325	4.128
Average	-3.776	1.203	3.756
StDev	1.398	0.156	1.415
Max	-1.066	1.410	7.050
Min	-6.099	0.910	0.960

Averages by Valve

Intake Valve #	ORCC15 z(delta), µm	ORCC15 Ev. Length, mm	ORCC15 Wt, µm
1	-2.732	1.333	2.378
2	2.852	1.213	3.360
3	2.294	0.960	3.958
4	-1.640	1.153	1.245
5	5.258	1.230	4.773
6	1.293	1.058	2.128
7	-0.099	1.340	2.450
8	-2.085	1.110	1.623
Average	0.643	1.174	2.739
StDev	2.947	0.196	1.276
Max	6.155	1.790	5.100
Min	-3.569	0.780	0.870

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ORCC0					ORCC15				
Exhaust Valve #	Position	z(delta), µm	Ev. Length, mm	Wt, µm	Exhaust Valve #	Position	z(delta), µm	Ev. Length, mm	Wt, µm
1	1	-7.924	1.58	8.26	1	1	-7.656	1.57	6.47
	2	-4.627	1.55	4.91		2	-0.719	1.72	5.91
	3	-2.289	1.57	2.62		3	-15.562	1.86	15.20
	4	-2.491	1.61	3.04		4	-6.167	1.76	6.30
2	1	-7.135	1.60	7.32	2	1	-4.431	1.57	4.39
	2	-11.942	1.54	12.09		2	-2.278	1.85	4.01
	3	-6.414	1.34	6.77		3	-3.606	1.39	3.10
	4	-6.848	1.30	7.17		4	-8.248	1.49	8.14
3	1	-8.209	1.74	7.54	3	1	-4.779	1.66	4.46
	2	-6.707	1.79	7.90		2	-5.011	1.72	4.76
	3	-8.308	1.64	9.09		3	-12.213	1.08	11.78
	4	-9.698	1.82	9.35		4	-5.397	1.74	5.04
4	1	-5.227	1.42	5.55	4	1	-10.636	1.99	9.64
	2	-5.798	1.51	7.31		2	-4.487	1.83	3.90
	3	-7.288	1.46	6.72		3	-7.505	1.23	7.19
	4	-3.408	1.55	4.18		4	-7.081	2.00	6.79
5	1	-3.887	1.52	4.41	5	1	-2.587	1.65	1.92
	2	-2.423	1.49	5.04		2	-6.035	1.65	5.57
	3	-4.013	1.53	7.60		3	-6.567	1.54	5.93
	4	-3.154	1.40	5.20		4	-4.932	1.77	4.61
6	1	-2.715	1.65	4.03	6	1	-3.557	1.73	6.23
	2	-5.698	1.83	5.33		2	-3.951	1.58	4.67
	3	-3.095	1.60	2.88		3	-3.180	1.79	5.14
	4	-3.450	1.39	4.66		4	-2.069	1.83	2.63
7	1	-13.041	1.82	14.05	7	1	-3.031	1.59	3.70
	2	-2.776	1.48	2.78		2	-5.222	1.56	5.79
	3	-6.773	1.52	6.53		3	-5.867	1.69	6.86
	4	-7.144	1.55	6.91		4	-8.538	1.79	9.44
8	1	-1.471	1.48	3.19	8	1	-2.857	1.07	2.37
	2	-10.943	1.85	11.69		2	-4.627	1.61	4.23
	3	-5.005	1.53	5.29		3	-4.654	1.60	4.30
	4	-4.877	1.36	5.27		4	-4.765	1.50	4.14

Averages by Valve				Averages by Valve			
Exhaust Valve #	ORCC0 z(delta), µm	ORCC0 Ev. Length, mm	ORCC0 Wt, µm	Exhaust Valve #	ORCC15 z(delta), µm	ORCC15 Ev. Length, mm	ORCC15 Wt, µm
1	-4.333	1.578	4.708	1	-7.526	1.728	8.470
2	-8.085	1.445	8.338	2	-4.641	1.575	4.910
3	-8.231	1.748	8.470	3	-6.850	1.550	6.510
4	-5.430	1.485	5.940	4	-7.427	1.763	6.880
5	-3.369	1.485	5.563	5	-5.030	1.653	4.508
6	-3.740	1.618	4.225	6	-3.189	1.733	4.668
7	-7.434	1.593	7.568	7	-5.665	1.658	6.448
8	-5.574	1.555	6.360	8	-4.226	1.445	3.760
Average	-5.774	1.563	6.396	Average	-5.569	1.638	5.769
StDev	2.924	0.146	2.752	StDev	3.056	0.218	2.747
Max	-1.471	1.850	14.050	Max	-0.719	2.000	15.200
Min	-13.041	1.300	2.620	Min	-15.562	1.070	1.920

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ORCC20				
Intake Valve #	Position	z(delta), µm	Ev. Length, mm	Wt, µm
1	1	-3.273	1.39	2.41
	2	-4.040	1.45	3.20
	3	-3.835	1.53	3.26
	4	-5.948	1.45	5.13
2	1	-4.783	1.19	4.26
	2	-3.596	1.21	2.90
	3	-3.880	1.13	3.41
	4	-3.657	1.06	3.36
3	1	-2.495	0.51	1.62
	2	4.177	0.98	2.99
	3	4.287	0.94	3.23
	4	1.908	0.64	1.39
4	1	-2.767	1.11	2.17
	2	-1.883	1.06	1.33
	3	-3.379	1.09	2.52
	4	-2.457	1.19	2.07
5	1	-3.125	1.04	2.82
	2	-3.935	1.41	3.56
	3	-4.840	1.38	4.17
	4	-3.824	1.33	3.17
6	1	-8.064	1.51	7.10
	2	-7.310	1.37	6.12
	3	-6.192	1.31	5.34
	4	-5.858	1.12	5.28
7	1	2.482	0.92	1.84
	2	2.994	0.98	2.20
	3	2.802	0.84	1.66
	4	1.769	0.82	1.87
8	1	3.156	1.21	2.46
	2	2.643	1.06	2.01
	3	3.505	1.32	2.73
	4	2.857	1.31	2.06

ORCC20				
Exhaust Valve #	Position	z(delta), µm	Ev. Length, mm	Wt, µm
1	1	-4.477	1.72	4.06
	2	-4.214	1.81	3.58
	3	-4.609	1.91	4.01
	4	-5.814	1.83	5.15
2	1	8.012	1.52	7.21
	2	7.592	1.63	6.96
	3	-8.704	0.77	8.63
	4	5.704	1.19	5.87
3	1	8.582	1.95	7.71
	2	4.351	1.97	4.22
	3	7.914	2.03	6.62
	4	12.804	1.99	12.03
4	1	4.652	1.91	4.46
	2	3.772	1.72	3.79
	3	12.755	1.89	12.32
	4	9.335	1.92	8.16
5	1	-3.732	1.24	3.12
	2	-6.533	1.20	6.23
	3	-3.222	1.17	2.90
	4	-4.070	1.42	3.00
6	1	5.086	1.44	4.00
	2	4.152	1.41	3.79
	3	7.886	1.92	7.32
	4	6.892	1.85	6.34
7	1	-5.893	1.30	5.86
	2	-6.028	1.73	5.18
	3	-3.022	1.80	2.25
	4	-5.128	1.45	4.22
8	1	4.821	1.68	4.56
	2	7.341	1.67	6.67
	3	5.331	0.99	5.10
	4	2.365	0.85	2.13

Averages by Valve			
Intake Valve #	ORCC20 z(delta), µm	ORCC20 Ev. Length, mm	ORCC20 Wt, µm
1	-4.274	1.455	3.500
2	-3.979	1.148	3.483
3	1.969	0.768	2.308
4	-2.622	1.113	2.023
5	-3.931	1.290	3.430
6	-6.856	1.328	5.960
7	2.512	0.890	1.893
8	3.040	1.225	2.315
Average	-1.768	1.152	3.114
StDev	3.740	0.246	1.412
Max	4.287	1.530	7.100
Min	-8.064	0.510	1.330

Averages by Valve			
Exhaust Valve #	ORCC20 z(delta), µm	ORCC20 Ev. Length, mm	ORCC20 Wt, µm
1	-4.779	1.818	4.200
2	3.151	1.278	7.168
3	8.413	1.985	7.645
4	7.629	1.860	7.183
5	-4.389	1.258	3.813
6	6.004	1.655	5.363
7	-5.018	1.570	4.378
8	4.965	1.298	4.615
Average	1.997	1.590	5.545
StDev	6.361	0.351	2.447
Max	12.804	2.030	12.320
Min	-8.704	0.770	2.130

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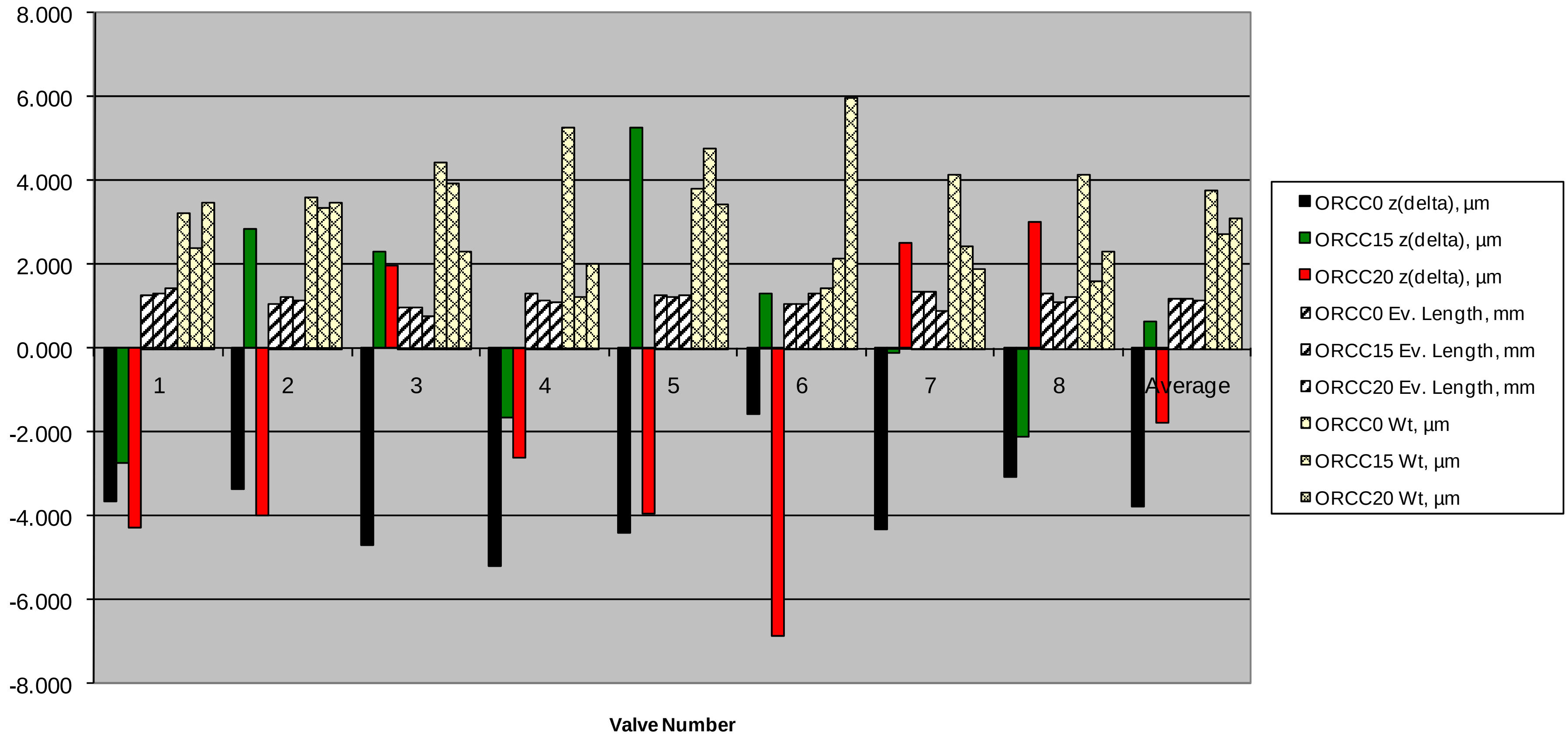
2006 Chevrolet Cobalt
Intake Valve Contour Measurements at EOT



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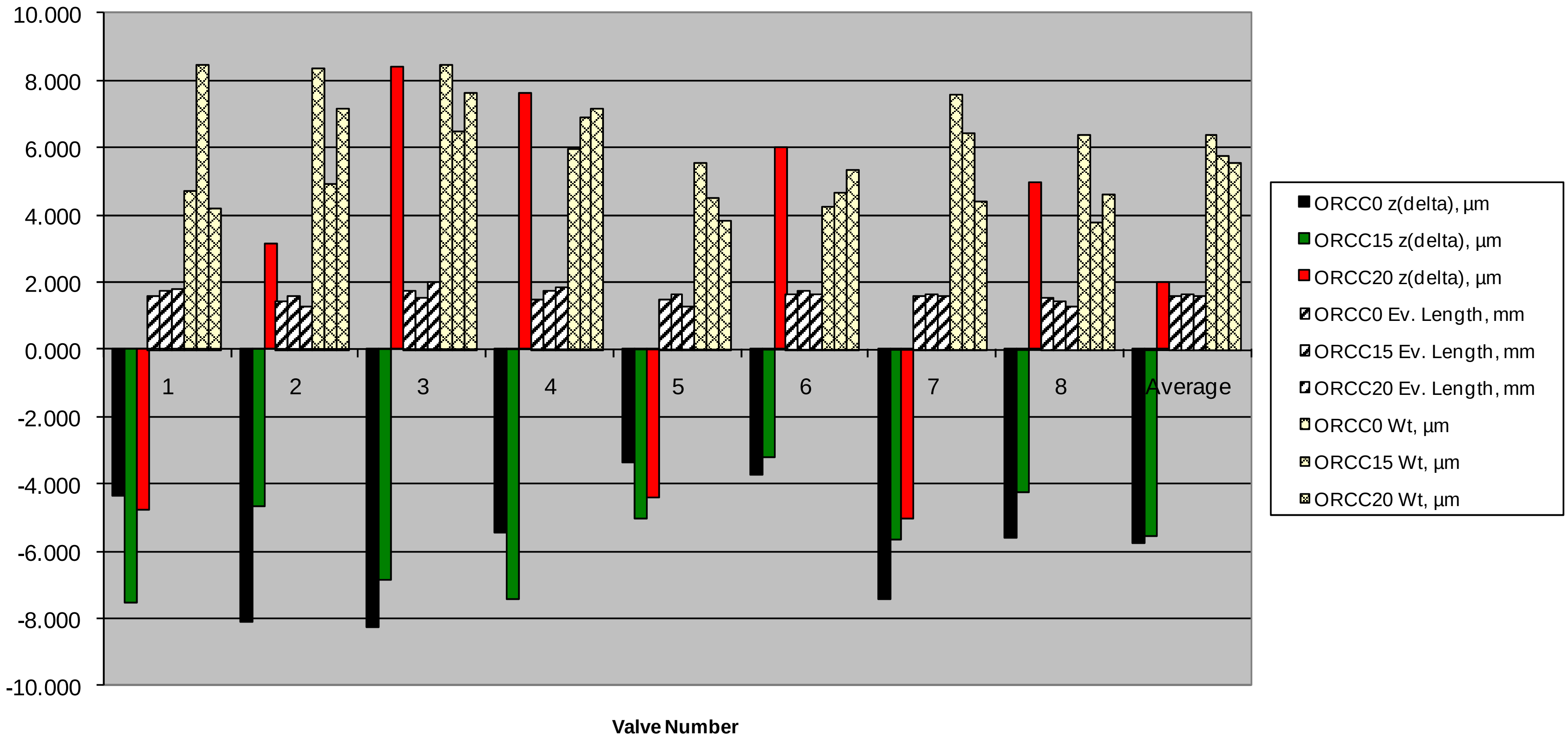
2006 Chevrolet Cobalt
Exhaust Valve Contour Measurements at EOT



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ORNA0						ORNA15				
Intake Valve #	Position	z(delta), µm	Ev. Length, mm	Wt, µm		Intake Valve #	Position	z(delta), µm	Ev. Length, mm	Wt, µm
1	1	-1.051	0.42	0.79		1	1	-2.663	1.04	1.46
	2	-2.744	0.66	2.26			2	-3.835	1.06	2.76
	3	-3.262	0.55	2.43			3	-2.213	0.95	1.60
	4	-2.059	0.67	1.47			4	-2.190	0.94	1.78
2	1	-1.593	0.68	1.37		2	1	-1.363	0.72	1.24
	2	-1.628	0.49	1.38			2	-1.689	0.40	0.88
	3	-1.456	0.46	0.79			3	-2.029	0.47	1.16
	4	-1.943	0.49	1.40			4	-2.448	0.53	1.71
3	1	-3.180	0.73	2.92		3	1	-1.554	0.40	1.08
	2	-1.834	0.69	1.30			2	-1.531	0.47	0.86
	3	-3.180	0.63	2.31			3	-0.841	0.53	0.44
	4	-1.888	0.55	1.49			4	-1.782	0.51	1.12
4	1	-1.635	0.49	1.10		4	1	-2.301	0.65	1.32
	2	-3.491	0.66	2.88			2	-1.509	0.57	0.99
	3	-2.228	0.69	2.48			3	-3.513	0.79	3.11
	4	-3.100	0.51	2.37			4	-1.376	0.51	0.99
5	1	-2.663	0.67	2.13		5	1	-1.800	0.42	1.60
	2	-2.303	0.59	1.79			2	-4.045	0.69	3.58
	3	-2.013	0.61	1.78			3	-1.431	0.35	0.71
	4	-3.993	0.72	3.10			4	-1.120	0.35	0.40
6	1	-4.504	0.84	3.44		6	1	-1.441	0.48	0.81
	2	-3.371	0.76	2.62			2	-1.479	0.41	1.38
	3	-2.442	0.74	2.17			3	-2.359	0.48	1.88
	4	-3.498	0.71	2.56			4	-1.313	0.44	0.94
7	1	-2.432	0.75	1.61		7	1	-1.713	0.53	1.24
	2	-2.310	0.82	2.11			2	-2.157	0.46	1.62
	3	-4.199	0.73	3.18			3	-1.163	0.55	1.31
	4	-2.385	0.68	1.72			4	-1.307	0.41	0.93
8	1	-2.288	0.76	1.94		8	1	-3.548	0.72	2.49
	2	-3.124	0.96	2.97			2	-1.254	0.65	0.77
	3	-1.596	0.58	1.36			3	-2.441	0.66	1.60
	4	-1.543	0.75	1.84			4	-1.250	0.58	1.04

Averages by Valve					Averages by Valve			
Intake Valve #	ORNA0 z(delta), µm	ORNA0 Ev. Length, mm	ORNA0 Wt, µm		Intake Valve #	ORNA15 z(delta), µm	ORNA15 Ev. Length, mm	ORNA15 Wt, µm
1	-2.279	0.575	1.738		1	-2.725	0.998	1.900
2	-1.655	0.530	1.235		2	-1.882	0.530	1.248
3	-2.521	0.650	2.005		3	-1.427	0.478	0.875
4	-2.614	0.588	2.208		4	-2.175	0.630	1.603
5	-2.743	0.648	2.200		5	-2.099	0.453	1.573
6	-3.454	0.763	2.698		6	-1.648	0.453	1.253
7	-2.832	0.745	2.155		7	-1.585	0.488	1.275
8	-2.138	0.763	2.028		8	-2.123	0.653	1.475
Average	-2.529	0.658	2.033		Average	-1.958	0.585	1.400
StDev	0.865	0.121	0.704		StDev	0.820	0.194	0.724
Max	-1.051	0.960	3.440		Max	-0.841	1.060	3.580
Min	-4.504	0.420	0.790		Min	-4.045	0.350	0.400

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ORNA0

Exhaust Valve #	Position	z(delta), µm	Ev. Length, mm	Wt, µm
1	1	-4.582	1.38	4.06
	2	-9.665	1.45	9.46
	3	-12.477	1.49	18.62
	4	-15.625	1.40	15.00
2	1	-15.327	1.79	17.11
	2	-9.870	1.66	9.40
	3	-17.179	1.44	21.90
	4	-30.462	1.76	29.72
3	1	-17.691	1.21	15.68
	2	-16.194	1.57	17.46
	3	-15.443	1.64	16.46
	4	-9.187	1.59	10.01
4	1	-15.601	1.46	15.18
	2	-16.764	1.75	16.60
	3	-9.465	1.63	11.84
	4	-10.515	1.69	11.58
5	1	-6.958	1.26	6.42
	2	-16.216	1.61	16.36
	3	-13.695	1.65	16.33
	4	-11.639	1.05	11.49
6	1	-6.352	1.15	6.27
	2	-5.842	1.41	7.46
	3	-5.523	1.08	5.26
	4	-4.659	1.62	4.75
7	1	-7.892	1.46	7.68
	2	-7.252	1.39	6.40
	3	-6.129	1.48	5.85
	4	-16.531	1.10	16.14
8	1	-22.623	1.64	22.38
	2	-19.952	1.70	19.57
	3	-24.253	1.13	23.74
	4	-19.589	1.85	18.67

ORNA15

Exhaust Valve #	Position	z(delta), µm	Ev. Length, mm	Wt, µm
1	1	-12.968	1.57	12.03
	2	-18.614	1.58	17.91
	3	-25.610	1.73	27.53
	4	-12.959	1.53	12.18
2	1	-16.505	1.57	15.83
	2	-18.029	1.23	19.03
	3	-15.298	0.86	15.22
	4	-24.416	1.75	23.00
3	1	-4.075	1.29	4.00
	2	-3.251	1.13	3.44
	3	-5.793	1.29	5.79
	4	-5.605	1.37	5.27
4	1	-7.847	1.29	7.27
	2	-3.582	1.22	3.10
	3	-2.340	1.15	2.04
	4	-3.413	1.31	2.83
5	1	-12.169	1.06	11.79
	2	-2.332	1.10	2.47
	3	-4.994	1.62	4.86
	4	-5.162	1.46	6.10
6	1	-4.936	1.01	4.75
	2	-8.765	1.41	8.07
	3	-5.363	1.29	4.47
	4	-7.137	1.20	6.99
7	1	-9.135	1.23	8.48
	2	-5.116	1.01	5.46
	3	-9.279	1.32	9.69
	4	-6.682	1.60	8.02
8	1	-12.443	1.52	13.53
	2	-4.124	1.09	3.48
	3	-8.404	1.45	8.89
	4	-10.178	1.63	9.84

Averages by Valve

Exhaust Valve #	ORNA0 z(delta), µm	ORNA0 Ev. Length, mm	ORNA0 Wt, µm
1	-10.587	1.430	11.785
2	-18.210	1.663	19.533
3	-14.629	1.503	14.903
4	-13.086	1.633	13.800
5	-12.127	1.393	12.650
6	-5.594	1.315	5.935
7	-9.451	1.358	9.018
8	-21.604	1.580	21.090
Average	-13.161	1.484	13.589
StDev	6.269	0.223	6.370
Max	-4.582	1.850	29.720
Min	-30.462	1.050	4.060

Averages by Valve

Exhaust Valve #	ORNA15 z(delta), µm	ORNA15 Ev. Length, mm	ORNA15 Wt, µm
1	-17.538	1.603	17.413
2	-18.562	1.353	18.270
3	-4.681	1.270	4.625
4	-4.296	1.243	3.810
5	-6.164	1.310	6.305
6	-6.550	1.228	6.070
7	-7.553	1.290	7.913
8	-8.787	1.423	8.935
Average	-9.266	1.340	9.168
StDev	6.155	0.228	6.255
Max	-2.332	1.750	27.530
Min	-25.610	0.860	2.040

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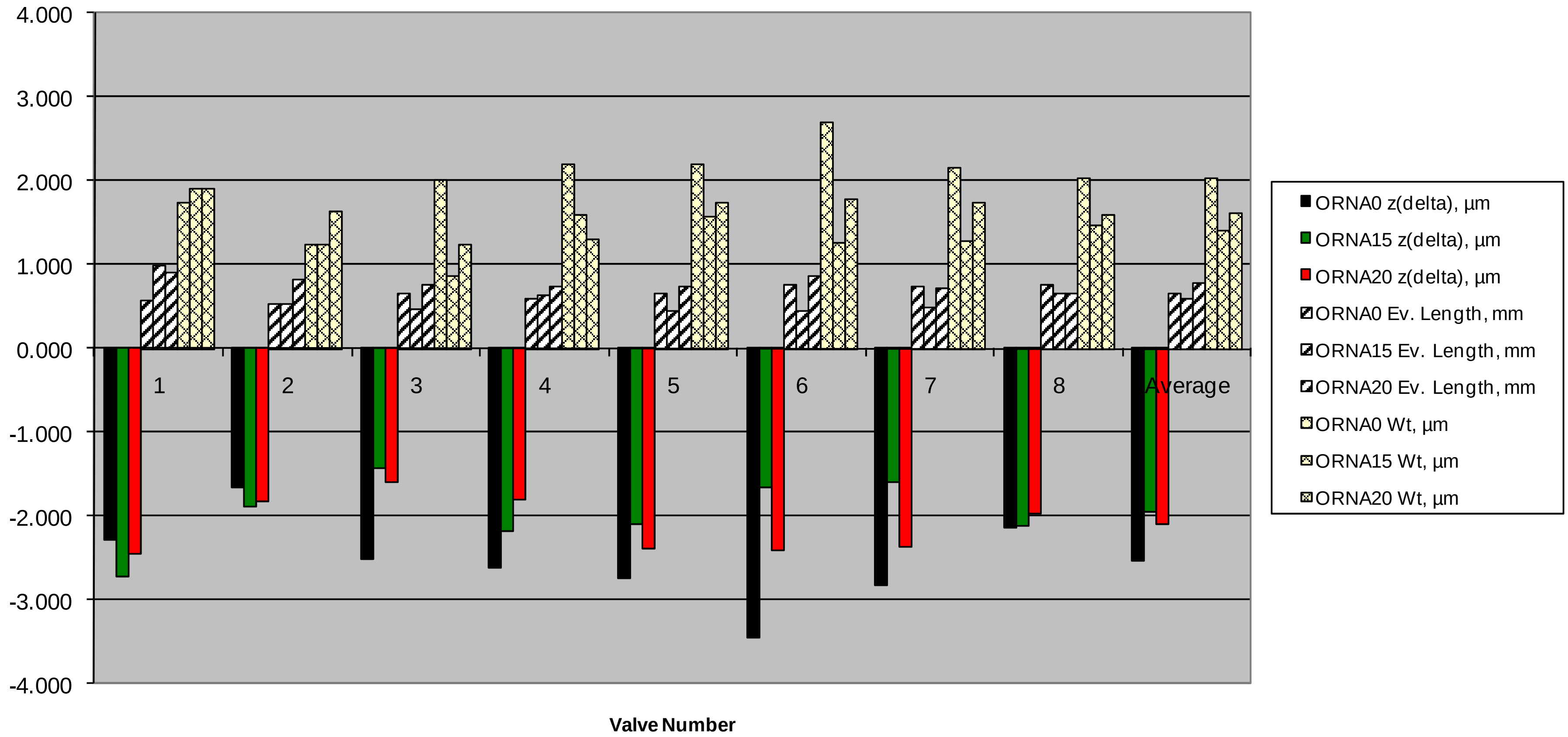
ORNA20				
Intake Valve #	Position	z(delta), µm	Ev. Length, mm	Wt, µm
1	1	-2.369	0.87	2.14
	2	-2.758	0.91	2.17
	3	-2.446	0.91	1.89
	4	-2.260	0.90	1.43
2	1	-2.614	1.00	2.17
	2	-2.802	0.88	2.26
	3	-0.491	0.79	0.91
	4	-1.357	0.59	1.20
3	1	-1.809	0.92	1.55
	2	-1.508	0.64	1.16
	3	-1.388	0.68	0.96
	4	-1.695	0.84	1.32
4	1	-3.131	0.69	2.58
	2	-0.728	0.67	0.39
	3	-1.831	0.95	1.26
	4	-1.535	0.63	0.96
5	1	-2.204	0.80	1.51
	2	-1.401	0.62	1.00
	3	-2.331	0.66	1.68
	4	-3.565	0.85	2.74
6	1	-3.196	0.90	2.55
	2	-1.797	0.94	1.44
	3	-2.249	0.82	1.60
	4	-2.366	0.84	1.55
7	1	-3.041	0.72	2.25
	2	-2.404	0.74	1.58
	3	-2.184	0.74	1.80
	4	-1.870	0.66	1.33
8	1	-3.229	0.70	2.71
	2	-0.780	0.51	0.55
	3	-1.667	0.51	1.16
	4	-2.221	0.88	1.96

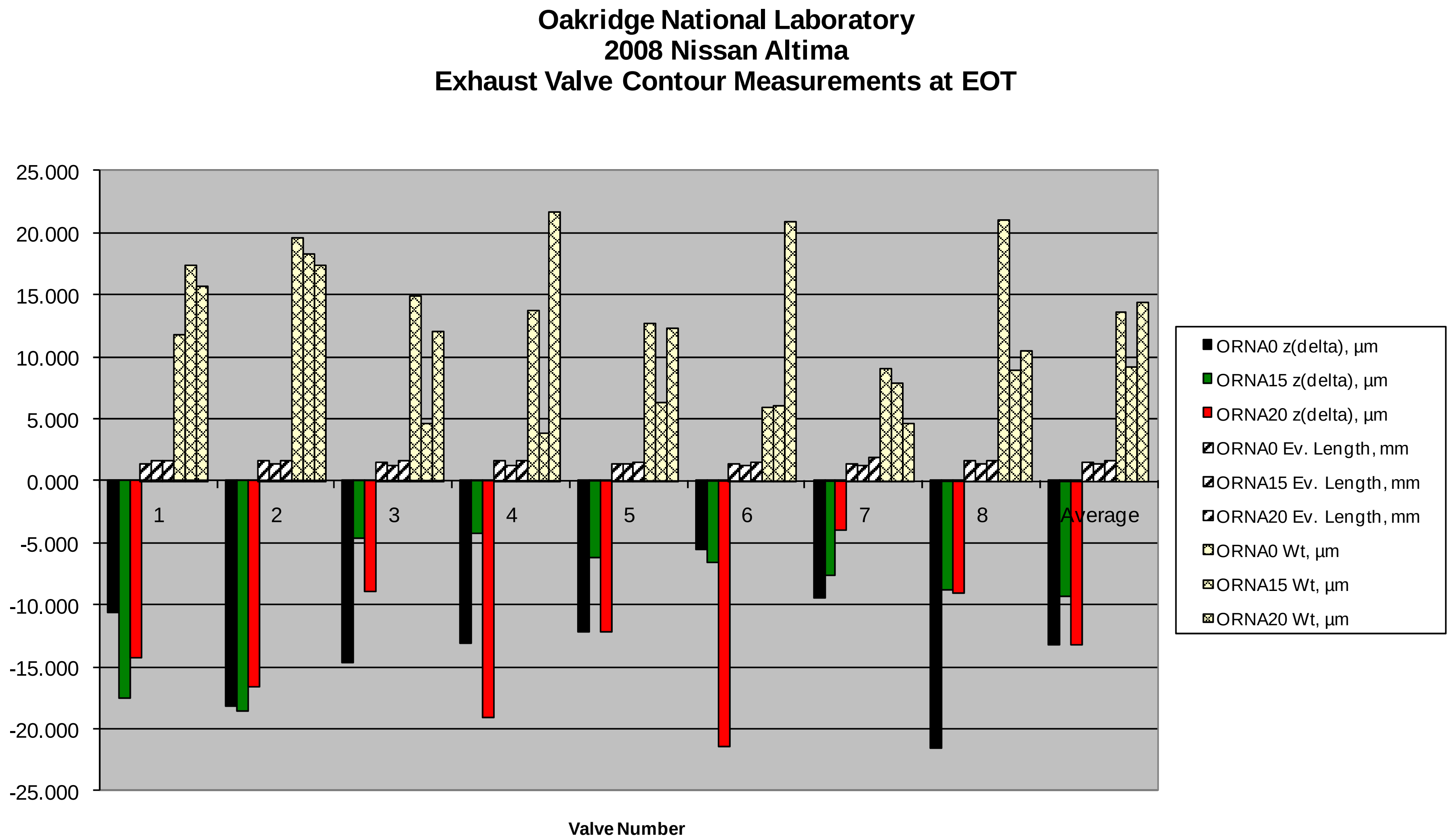
ORNA20				
Exhaust Valve #	Position	z(delta), µm	Ev. Length, mm	Wt, µm
1	1	-4.554	1.70	4.22
	2	-25.494	1.79	28.33
	3	-8.465	1.46	9.27
	4	-18.606	1.51	21.04
2	1	-14.848	1.51	16.35
	2	-15.794	1.71	16.44
	3	-23.593	1.67	22.76
	4	-12.086	1.73	13.90
3	1	-9.013	1.63	12.25
	2	-7.173	1.71	11.23
	3	-6.468	1.31	7.98
	4	-12.880	1.78	16.74
4	1	-28.396	1.62	32.90
	2	-11.171	1.37	13.52
	3	-21.730	1.88	24.43
	4	-15.081	1.76	15.98
5	1	-19.357	1.23	18.85
	2	-5.631	1.57	5.89
	3	-7.295	1.43	7.27
	4	-16.249	1.71	17.21
6	1	-24.117	1.48	22.71
	2	-28.639	1.57	28.96
	3	-16.797	1.24	15.71
	4	-16.141	1.50	16.40
7	1	-3.078	1.87	2.72
	2	-3.266	1.82	3.98
	3	-6.081	1.84	8.80
	4	-3.440	2.04	2.88
8	1	-8.870	1.72	8.40
	2	-4.576	1.28	6.23
	3	-12.222	1.86	13.33
	4	-10.333	1.77	13.86

Averages by Valve			
Intake Valve #	ORNA20 z(delta), µm	ORNA20 Ev. Length, mm	ORNA20 Wt, µm
1	-2.458	0.898	1.908
2	-1.816	0.815	1.635
3	-1.600	0.770	1.248
4	-1.806	0.735	1.298
5	-2.375	0.733	1.733
6	-2.402	0.875	1.785
7	-2.375	0.715	1.740
8	-1.974	0.650	1.595
Average	-2.101	0.774	1.618
StDev	0.748	0.133	0.610
Max	-0.491	1.000	2.740
Min	-3.565	0.510	0.390

Averages by Valve			
Exhaust Valve #	ORNA20 z(delta), µm	ORNA20 Ev. Length, mm	ORNA20 Wt, µm
1	-14.280	1.615	15.715
2	-16.580	1.655	17.363
3	-8.884	1.608	12.050
4	-19.095	1.658	21.708
5	-12.133	1.485	12.305
6	-21.424	1.448	20.945
7	-3.966	1.893	4.595
8	-9.000	1.658	10.455
Average	-13.170	1.627	14.392
StDev	7.566	0.205	7.838
Max	-3.078	2.040	32.900
Min	-28.639	1.230	2.720

Oakridge National Laboratory
2008 Nissan Altima
Intake Valve Contour Measurements at EOT

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Exhaust Valve Contour Measurements at EOT
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10.000
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0.000
-5.000
-10.000
-15.000
-20.000
-25.000
1
2
3
4
5
6
7
8
Average
Valve Number
ORNA0 z(delta), µm
ORNA15 z(delta), µm
ORNA20 z(delta), µm
ORNA0 Ev. Length, mm
ORNA15 Ev. Length, mm
ORNA20 Ev. Length, mm
ORNA0 Wt, µm
ORNA15 Wt, µm
ORNA20 Wt, µm

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ORFT0					ORFT15				
Intake Valve #	Position	z(delta), µm	Ev. Length, mm	Wt, µm	Intake Valve #	Position	z(delta), µm	Ev. Length, mm	Wt, µm
1	1	-3.211	1.43	2.32	1	1	-3.141	0.75	2.44
	2	-2.387	1.20	1.72		2	-2.278	1.62	1.60
	3	-2.702	1.23	2.20		3	-2.848	1.41	2.31
	4	-2.863	1.29	2.46		4	-3.466	1.36	2.84
2	1	-3.075	0.95	2.79	2	1	-2.559	1.53	2.05
	2	-2.969	0.66	1.77		2	-4.439	1.17	3.51
	3	-3.158	0.66	2.16		3	-3.398	0.68	2.49
	4	-3.722	0.65	2.19		4	-3.149	0.96	3.11
3	1	-4.066	0.50	3.55	3	1	-2.894	0.75	2.73
	2	-4.898	0.73	4.07		2	-2.383	0.79	2.05
	3	-2.724	0.70	1.84		3	-3.275	1.29	2.53
	4	-2.491	0.77	1.77		4	-3.938	1.06	3.34
4	1	-3.147	0.71	2.48	4	1	-3.321	1.48	3.14
	2	-3.290	0.65	2.46		2	-4.082	0.97	3.59
	3	-2.506	0.64	1.83		3	-4.298	1.03	3.35
	4	-2.209	0.73	1.87		4	-3.598	1.01	2.59
5	1	-3.284	0.95	2.16	5	1	-2.030	1.18	1.48
	2	-3.183	0.66	2.39		2	-1.380	0.61	1.61
	3	-3.220	0.87	2.55		3	-2.469	0.89	1.62
	4	-2.403	0.89	2.13		4	-2.257	1.01	1.86
6	1	-3.349	0.75	2.31	6	1	-3.276	1.27	2.27
	2	-4.264	0.72	3.20		2	-3.859	1.20	2.87
	3	-3.597	1.05	2.86		3	-2.398	0.84	1.61
	4	-3.619	1.12	2.54		4	-2.171	1.03	1.56
7	1	-2.890	0.50	2.19	7	1	-2.467	0.97	2.03
	2	-2.357	0.93	1.43		2	-2.506	1.58	2.14
	3	-2.341	0.98	1.69		3	-3.319	1.40	1.84
	4	-3.869	1.60	2.69		4	-3.128	1.58	2.20
8	1	-2.789	1.57	2.28	8	1	-2.776	1.12	2.52
	2	-2.343	1.56	1.87		2	-3.091	1.02	2.38
	3	-2.246	0.82	1.46		3	-3.043	0.74	2.32
	4	-2.102	1.37	1.59		4	-2.167	0.92	1.65
9	1	-3.043	1.50	2.30	9	1	-3.518	0.82	2.71
	2	-2.513	1.23	2.16		2	-6.120	1.46	5.53
	3	-4.432	1.58	3.84		3	-3.409	1.41	2.63
	4	-2.436	0.78	2.40		4	-3.741	1.04	2.98
10	1	-2.839	1.05	2.30	10	1	-4.196	2.08	3.69
	2	-3.447	1.48	2.40		2	-4.332	1.94	3.64
	3	-2.972	1.05	2.07		3	-3.158	1.35	2.37
	4	-4.357	1.96	3.12		4	-3.907	1.08	2.96
11	1	-4.623	1.32	3.89	11	1	-2.451	0.71	1.95
	2	-2.189	0.72	1.70		2	-2.600	1.13	1.83
	3	-4.685	1.34	3.95		3	-2.747	1.37	3.39
	4	-2.954	0.74	2.59		4	-2.448	1.11	1.82
12	1	-3.374	1.08	2.50	12	1	-3.786	1.31	2.58
	2	-2.676	0.98	1.76		2	-2.627	0.94	1.97
	3	-2.443	0.76	1.65		3	-4.595	1.09	3.06
	4	-3.022	1.39	2.34		4	-3.029	1.21	2.47

Averages by Valve				Averages by Valve			
Intake Valve #	ORFT0 z(delta), µm	ORFT0 Ev. Length, mm	ORFT0 Wt, µm	Intake Valve #	ORFT15 z(delta), µm	ORFT15 Ev. Length, mm	ORFT15 Wt, µm
1	-2.791	1.288	2.175	1	-2.933	1.285	2.298
2	-3.231	0.730	2.228	2	-3.386	1.085	2.790
3	-3.545	0.675	2.808	3	-3.123	0.973	2.663
4	-2.788	0.683	2.160	4	-3.825	1.123	3.168
5	-3.023	0.843	2.308	5	-2.034	0.923	1.643
6	-3.707	0.910	2.728	6	-2.926	1.085	2.078
7	-2.864	1.003	2.000	7	-2.855	1.383	2.053
8	-2.370	1.330	1.800	8	-2.769	0.950	2.218
9	-3.106	1.273	2.675	9	-4.197	1.183	3.463
10	-3.404	1.385	2.473	10	-3.898	1.613	3.165
11	-3.613	1.030	3.033	11	-2.562	1.080	2.248
12	-2.879	1.053	2.063	12	-3.509	1.138	2.520
Average	-3.110	1.017	2.371	Average	-3.168	1.151	2.525
StDev	0.720	0.349	0.651	StDev	0.839	0.317	0.763
Max	-2.102	1.960	4.070	Max	-1.380	2.080	5.530
Min	-4.898	0.500	1.430	Min	-6.120	0.610	1.480

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ORFT0

Exhaust Valve #	Position	z(delta), µm	Ev. Length, mm	Wt, µm
1	1	-4.883	2.02	4.40
	2	-2.966	2.17	3.19
	3	-4.119	2.22	3.59
	4	-4.428	1.96	3.88
2	1	-12.791	1.89	12.19
	2	-5.794	1.94	4.82
	3	-16.221	2.05	15.86
	4	-13.069	2.02	12.38
3	1	-11.412	1.95	11.28
	2	-6.616	1.74	4.22
	3	-12.227	1.81	11.82
	4	-6.448	2.00	6.28
4	1	-16.381	2.16	16.09
	2	-11.577	1.92	11.02
	3	-6.929	1.93	6.43
	4	-10.968	1.84	10.81
5	1	-19.103	1.72	18.48
	2	-11.220	1.91	10.47
	3	-7.683	1.74	6.87
	4	-12.722	1.82	11.78
6	1	-14.001	1.87	14.26
	2	-12.593	1.80	12.57
	3	-5.338	1.99	4.69
	4	-9.235	1.78	8.36
7	1	-8.661	1.70	8.93
	2	-20.228	1.74	19.65
	3	-20.746	1.93	20.94
	4	-24.783	1.70	23.81
8	1	-21.697	1.61	21.32
	2	-11.065	1.98	10.55
	3	-15.471	1.92	16.94
	4	-14.366	1.90	16.69
9	1	-16.957	1.27	16.17
	2	-18.092	1.18	17.95
	3	-6.773	1.91	8.21
	4	-18.569	1.50	17.96
10	1	-6.557	1.63	7.24
	2	-6.241	1.83	5.52
	3	-12.112	1.59	10.82
	4	-6.381	1.41	6.10
11	1	-4.508	1.82	4.02
	2	-23.711	1.85	23.15
	3	-7.512	1.87	7.55
	4	-17.606	1.74	17.27
12	1	-9.213	1.87	8.48
	2	-8.106	1.93	7.09
	3	-11.069	1.75	10.82
	4	-7.772	2.18	8.68

ORFT15

Exhaust Valve #	Position	z(delta), µm	Ev. Length, mm	Wt, µm
1	1	-11.421	1.50	11.62
	2	-23.019	1.65	22.10
	3	-11.562	1.61	13.21
	4	-3.502	1.79	3.92
2	1	-11.294	1.89	13.35
	2	-10.566	1.37	11.62
	3	-5.784	1.74	7.52
	4	-9.489	1.65	9.29
3	1	-6.289	1.74	7.39
	2	-4.772	1.83	7.51
	3	-7.026	1.20	6.45
	4	-7.777	1.84	8.24
4	1	-5.484	1.60	5.25
	2	-3.248	1.67	6.22
	3	-5.773	1.93	6.25
	4	16.678	2.05	16.34
5	1	-10.278	1.58	9.22
	2	4.724	1.62	5.89
	3	-5.981	1.69	5.23
	4	-9.051	1.72	8.90
6	1	-3.876	1.59	2.98
	2	-4.022	1.71	3.56
	3	-5.627	1.73	5.87
	4	-3.542	1.81	2.95
7	1	-4.129	1.39	3.03
	2	-6.856	1.96	6.15
	3	-6.367	1.96	5.39
	4	-6.048	1.76	5.61
8	1	-14.962	1.88	14.22
	2	-7.965	2.07	7.52
	3	-10.580	1.95	10.02
	4	-4.603	1.93	4.53
9	1	-9.188	1.66	9.84
	2	-9.954	1.80	9.27
	3	-10.781	1.90	9.76
	4	-11.020	1.95	10.65
10	1	-3.074	1.95	2.64
	2	-12.099	1.82	12.81
	3	-5.152	1.76	4.66
	4	-10.359	1.87	12.23
11	1	-17.835	1.75	17.05
	2	-10.722	1.57	11.90
	3	-12.497	1.74	10.95
	4	-6.687	1.31	5.94
12	1	-15.467	1.50	14.92
	2	-12.157	1.62	11.56
	3	-3.064	1.57	2.48
	4	-4.114	1.44	4.18

Averages by Valve

Exhaust Valve #	ORFT0 z(delta), µm	ORFT0 Ev. Length, mm	ORFT0 Wt, µm
1	-4.099	2.093	3.765
2	-11.969	1.975	11.313
3	-9.176	1.875	8.400
4	-11.464	1.963	11.088
5	-12.682	1.798	11.900
6	-10.292	1.860	9.970
7	-18.605	1.768	18.333
8	-15.650	1.853	16.375
9	-15.098	1.465	15.073
10	-7.823	1.615	7.420
11	-13.334	1.820	12.998
12	-9.040	1.933	8.768
Average	-11.603	1.835	11.283
StDev	5.611	0.210	5.671
Max	-2.966	2.220	23.810
Min	-24.783	1.180	3.190

Averages by Valve

Exhaust Valve #	ORFT15 z(delta), µm	ORFT15 Ev. Length, mm	ORFT15 Wt, µm
1	-12.376	1.638	12.713
2	-9.283	1.663	10.445
3	-6.466	1.653	7.398
4	0.543	1.813	8.515
5	-5.147	1.653	7.310
6	-4.267	1.710	3.840
7	-5.850	1.768	5.045
8	-9.528	1.958	9.073
9	-10.236	1.828	9.880
10	-7.671	1.850	8.085
11	-11.935	1.593	11.460
12	-8.701	1.533	8.285
Average	-7.576	1.721	8.504
StDev	5.796	0.193	4.303
Max	16.678	2.070	22.100
Min	-23.019	1.200	2.480

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Intake Valve #	Position	ORFT20 z(delta), µm	ORFT20 Ev. Length, mm	ORFT20 Wt, µm
1	1	2.508	0.38	1.79
	2	4.512	0.52	4.61
	3	3.027	1.54	2.37
	4	3.911	0.75	3.07
2	1	2.347	0.66	1.79
	2	2.619	0.25	2.03
	3	2.963	0.79	2.33
	4	2.808	0.45	1.93
3	1	2.997	0.32	2.06
	2	1.989	0.37	1.57
	3	1.602	0.52	1.20
	4	0.865	0.37	1.24
4	1	0.934	0.34	1.12
	2	2.691	0.65	2.56
	3	1.728	0.40	1.50
	4	1.722	0.43	1.30
5	1	2.653	0.65	2.04
	2	2.159	0.60	1.78
	3	2.166	0.59	1.82
	4	1.943	0.39	1.58
6	1	1.588	0.55	1.46
	2	2.753	0.61	2.76
	3	-1.566	0.52	1.90
	4	4.537	0.68	3.73
7	1	1.460	0.38	1.23
	2	-2.370	0.43	2.27
	3	1.537	0.28	1.44
	4	-1.896	0.80	1.88
8	1	2.629	0.64	2.41
	2	2.163	0.45	1.92
	3	1.526	0.38	1.38
	4	-2.775	0.71	2.68
9	1	-2.504	0.48	2.19
	2	2.212	0.45	2.00
	3	-1.787	0.25	1.48
	4	-2.935	0.25	2.14
10	1	-1.111	0.28	0.82
	2	-2.225	0.53	1.99
	3	3.596	0.75	3.22
	4	2.076	0.37	1.89
11	1	1.759	0.45	1.47
	2	2.276	0.51	1.88
	3	3.343	0.58	3.14
	4	1.135	0.35	0.90
12	1	1.936	0.51	1.71
	2	2.476	0.76	2.37
	3	2.823	0.68	2.43
	4	2.943	0.63	2.32

Exhaust Valve #	Position	ORFT20 z(delta), µm	ORFT20 Ev. Length, mm	ORFT20 Wt, µm
1	1	-9.363	1.61	9.35
	2	-16.665	1.90	17.16
	3	-9.278	1.46	9.51
	4	-9.255	1.92	9.83
2	1	-12.672	1.73	12.63
	2	-11.424	2.05	12.78
	3	-8.554	1.87	6.09
	4	-16.057	1.83	14.95
3	1	-2.840	1.99	3.09
	2	-3.006	1.80	2.55
	3	-3.024	1.60	2.23
	4	-8.453	1.50	7.79
4	1	-8.120	1.11	7.11
	2	-7.278	1.78	6.94
	3	-6.011	1.74	5.42
	4	-6.341	1.82	5.59
5	1	-11.504	1.76	11.07
	2	-8.032	1.79	8.31
	3	-10.789	1.77	9.98
	4	-3.892	1.85	3.04
6	1	-12.411	1.65	13.48
	2	-6.453	1.87	5.68
	3	-7.913	1.40	7.12
	4	-3.658	1.74	3.77
7	1	-6.665	1.37	5.60
	2	-6.769	1.62	8.63
	3	-8.118	1.67	10.13
	4	-3.660	1.92	3.59
8	1	-12.501	1.77	11.49
	2	-17.090	1.62	16.65
	3	-7.098	1.53	6.47
	4	-17.457	1.87	17.12
9	1	-3.606	1.97	2.25
	2	-3.773	1.45	2.97
	3	-5.331	1.60	4.78
	4	-4.372	1.96	4.15
10	1	-3.091	1.44	2.64
	2	-3.231	1.43	2.80
	3	-5.874	1.84	4.35
	4	-4.229	1.82	5.56
11	1	-6.942	1.43	5.75
	2	-12.309	1.68	12.02
	3	-5.037	1.63	4.23
	4	-7.426	1.52	8.06
12	1	-7.294	1.81	6.42
	2	-12.790	1.58	11.72
	3	-10.043	1.82	9.97
	4	-10.499	1.94	10.46

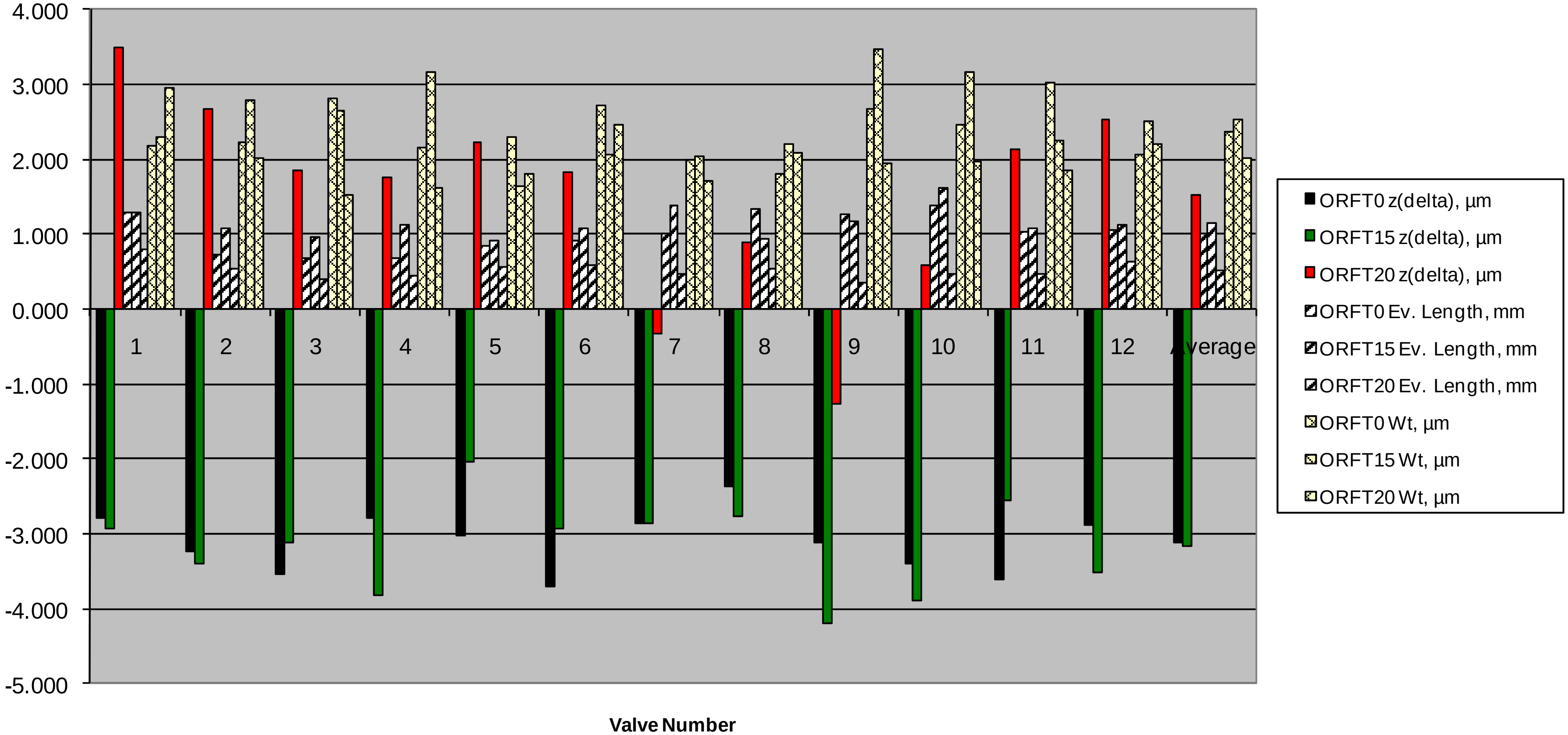
Averages by Valve

Intake Valve #	ORFT20 z(delta), µm	ORFT20 Ev. Length, mm	ORFT20 Wt, µm
1	3.490	0.798	2.960
2	2.684	0.538	2.020
3	1.863	0.395	1.518
4	1.769	0.455	1.620
5	2.230	0.558	1.805
6	1.828	0.590	2.463
7	-0.317	0.473	1.705
8	0.886	0.545	2.098
9	-1.254	0.358	1.953
10	0.584	0.483	1.980
11	2.128	0.473	1.848
12	2.545	0.645	2.208
Average	1.536	0.526	2.015
StDev	1.954	0.215	0.718
Max	4.537	1.540	4.610
Min	-2.935	0.250	0.820

Averages by Valve

Exhaust Valve #	ORFT20 z(delta), µm	ORFT20 Ev. Length, mm	ORFT20 Wt, µm
1	-11.140	1.723	11.463
2	-12.177	1.870	11.613
3	-4.331	1.723	3.915
4	-6.938	1.613	6.265
5	-8.554	1.793	8.100
6	-7.609	1.665	7.513
7	-6.303	1.645	6.988
8	-13.537	1.698	12.933
9	-4.271	1.745	3.538
10	-4.106	1.633	3.838
11	-7.929	1.565	7.515
12	-10.157	1.788	9.643
Average	-8.087	1.705	7.777
StDev	3.971	0.197	4.130
Max	-2.840	2.050	17.160
Min	-17.457	1.110	2.230

Oakridge National Laboratory
2008 Ford Taurus
Intake Valve Contour Measurements at EOT



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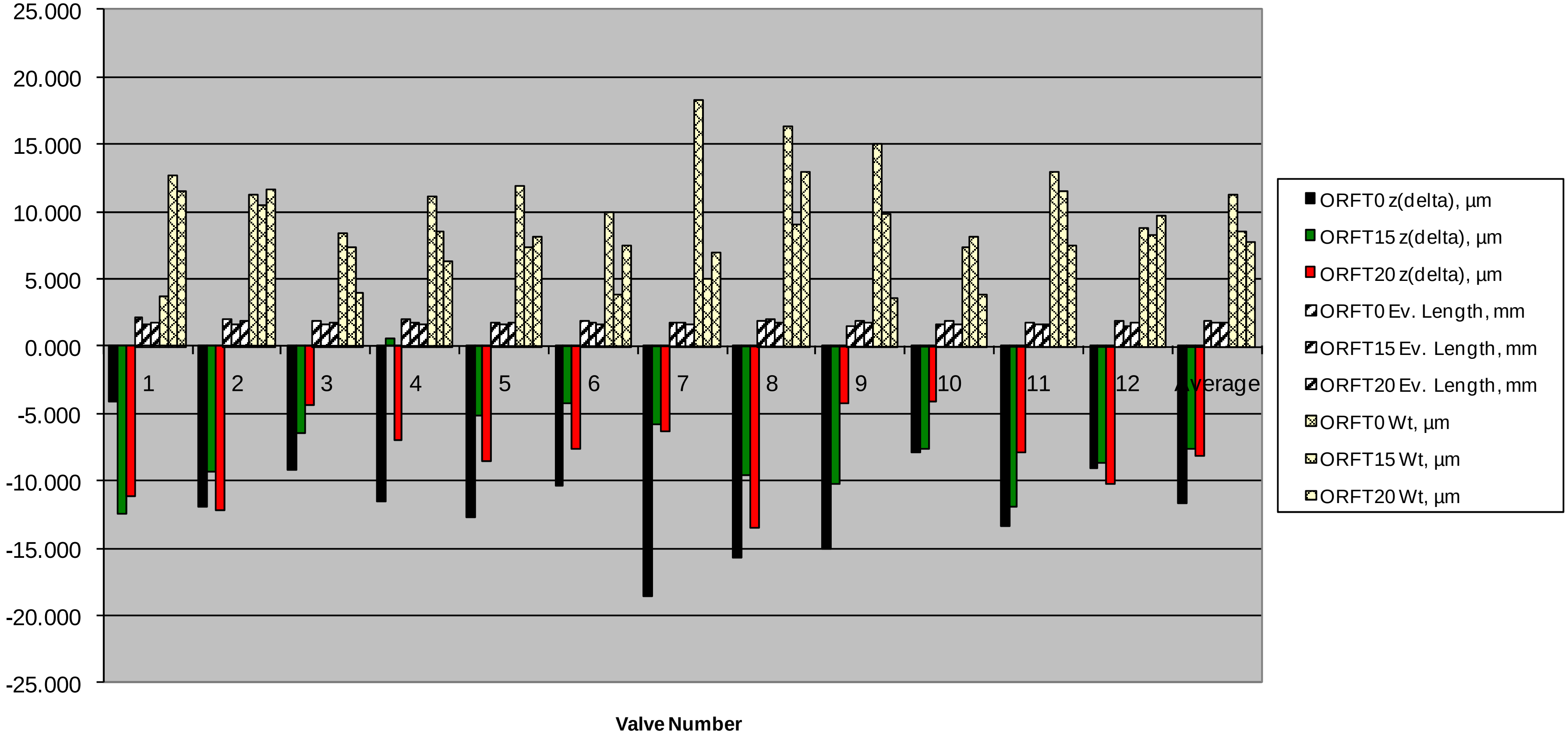
2008 Ford Taurus
Exhaust Valve Contour Measurements at EOT



Appendix C
Valve Stem Height

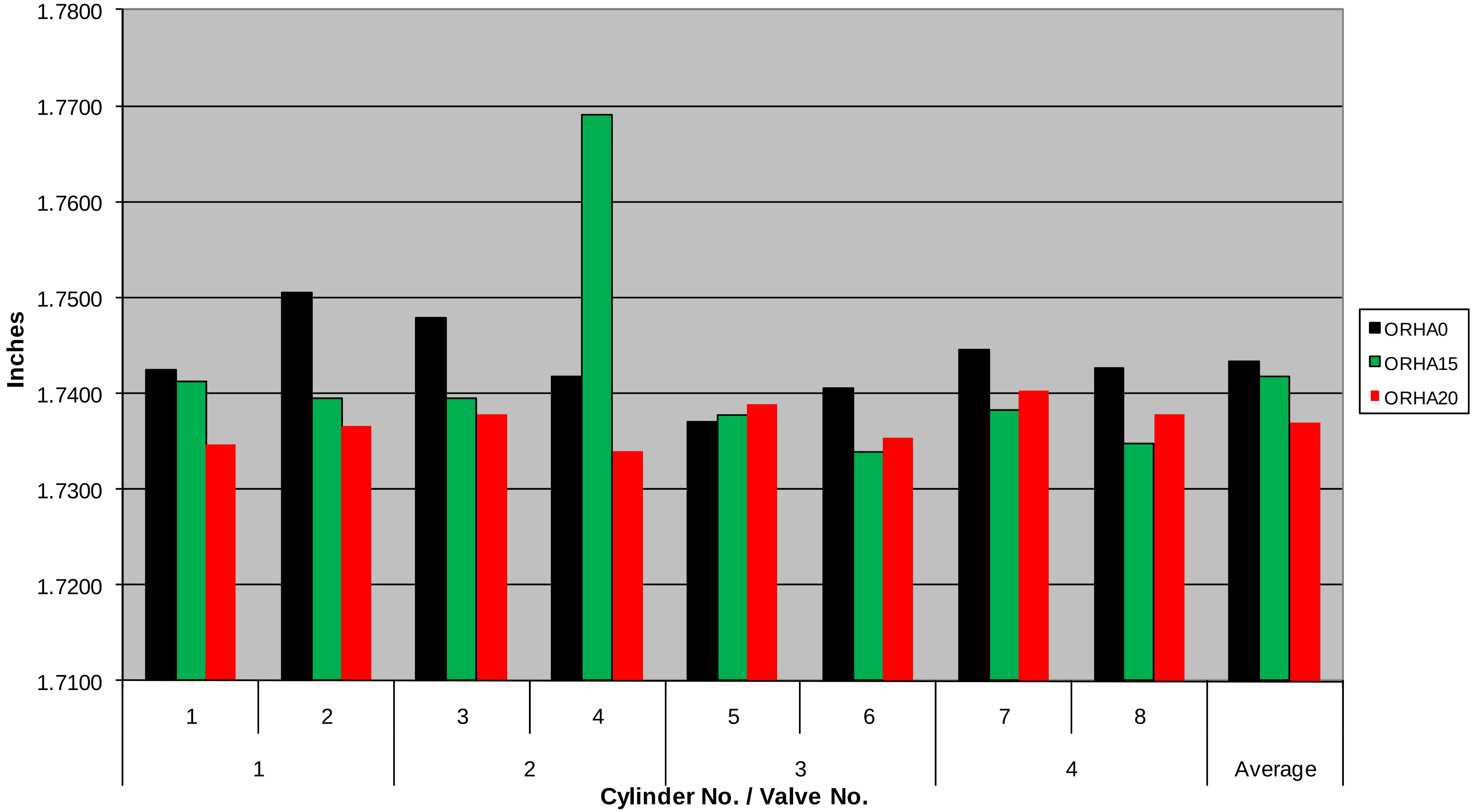
Oak Ridge National Laboratory
Proposal 08-58845 Powertrain Inspection
Valve Stem Height

Date: 31-Aug-10 Technician: LJ

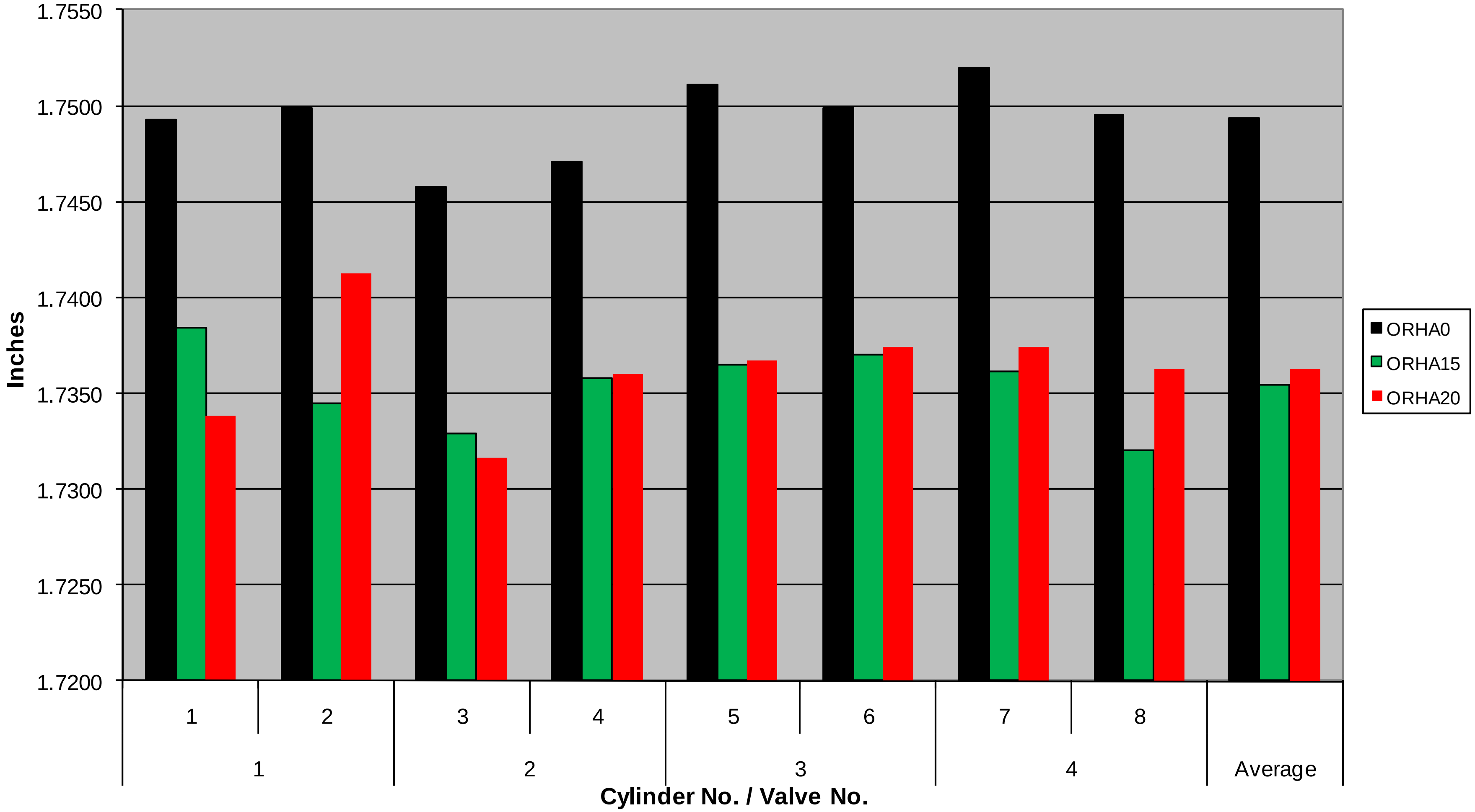
Measured from tip of valve stem to cylinder head
Measurements in inches
No specified service limit

		Intake			Exhaust		
Cylinder #	**Valve #**	**ORHA0**	**ORHA15**	**ORHA20**	**ORHA0**	**ORHA15**	**ORHA20**
1	1	1.7424	1.7413	1.7347	1.7493	1.7384	1.7338
	2	1.7505	1.7394	1.7366	1.7499	1.7345	1.7413
2	3	1.7478	1.7394	1.7378	1.7458	1.7329	1.7316
	4	1.7417	1.7690	1.7340	1.7471	1.7358	1.7360
3	5	1.7370	1.7378	1.7389	1.7511	1.7365	1.7367
	6	1.7405	1.7338	1.7354	1.7499	1.7370	1.7374
4	7	1.7445	1.7383	1.7402	1.7520	1.7361	1.7374
	8	1.7427	1.7348	1.7379	1.7495	1.7320	1.7363
Average		1.7434	1.7417	1.7369	1.7493	1.7354	1.7363
Stdev		0.0042	0.0113	0.0021	0.0020	0.0021	0.0028
Max		1.7505	1.7690	1.7402	1.7520	1.7384	1.7413
Min		1.7370	1.7338	1.7340	1.7458	1.7320	1.7316

Oakridge National Laboratory
2007 Hond Accord
Intake Valve Stem Height Measurements at EOT



Oakridge National Laboratory
2007 Hond Accord
Exhaust Valve Stem Height Measurements at EOT



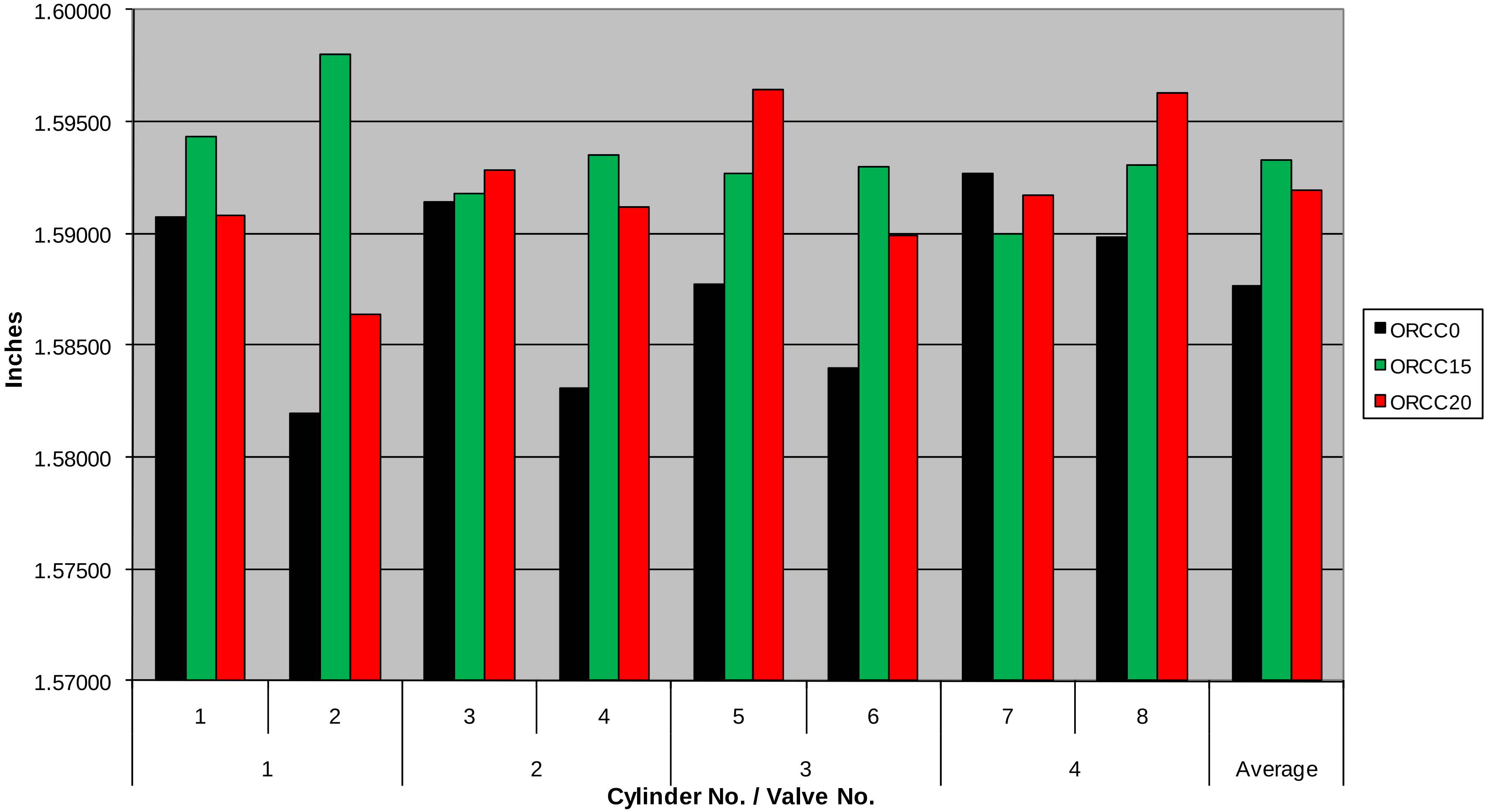
Oak Ridge National Laboratory
Proposal 08-58845 Powertrain Inspection
Valve Stem Height

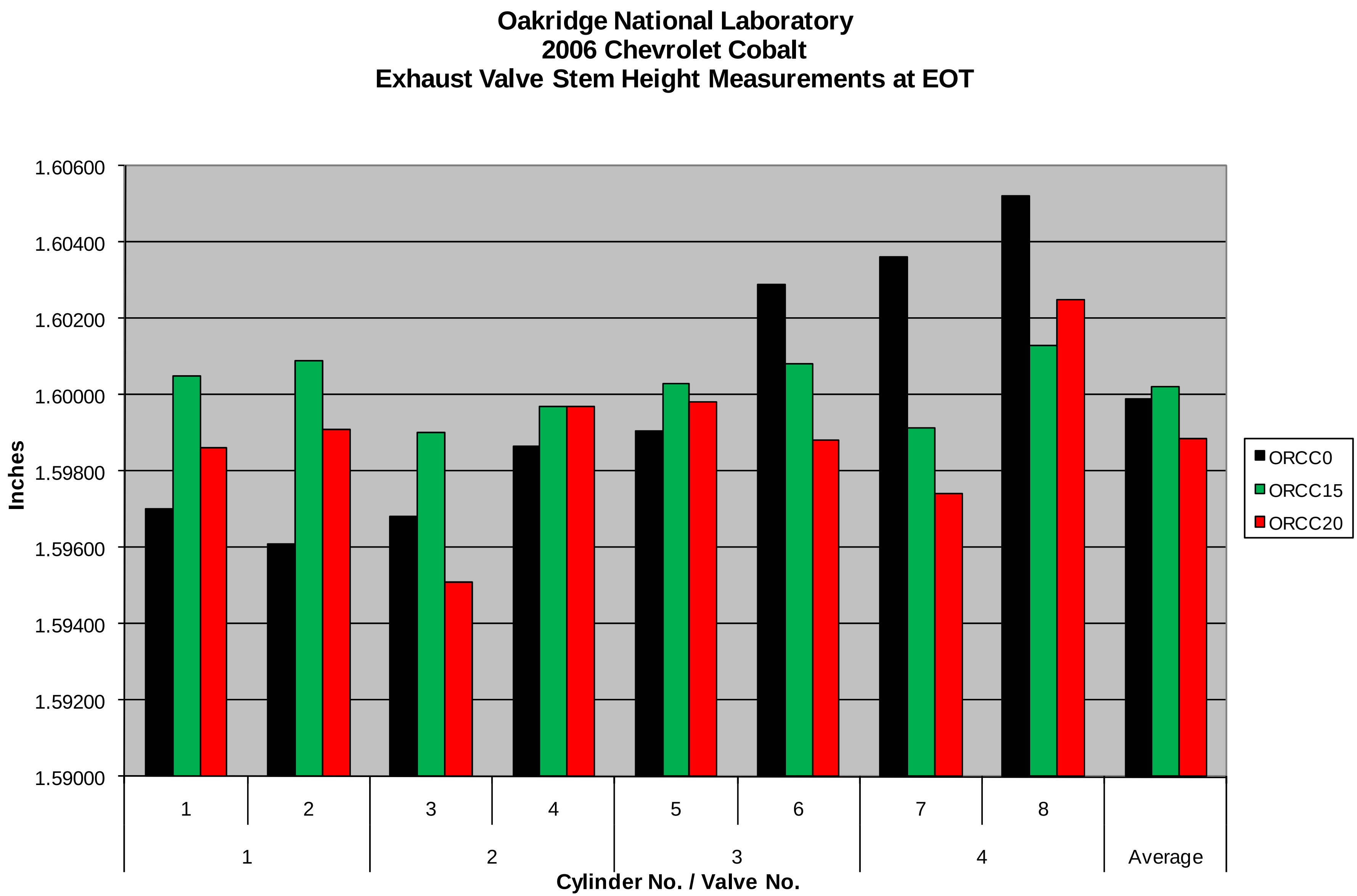
Date: 28-Aug-10 Technician: JM

Measured from tip of valve stem to cylinder head
Measurements in inches
No specified service limit

		Intake			Exhaust		
Cylinder #	**Valve #**	**ORCC0**	**ORCC15**	**ORCC20**	**ORCC0**	**ORCC15**	**ORCC20**
1	1	1.59070	1.59435	1.59080	1.59700	1.60050	1.59860
	2	1.58195	1.59800	1.58640	1.59610	1.60090	1.59910
2	3	1.59140	1.59175	1.59280	1.59680	1.59900	1.59510
	4	1.58305	1.59350	1.59120	1.59865	1.59970	1.59970
3	5	1.58775	1.59270	1.59640	1.59905	1.60030	1.59980
	6	1.58400	1.59300	1.58990	1.60290	1.60080	1.59880
4	7	1.59270	1.59000	1.59170	1.60360	1.59915	1.59740
	8	1.58985	1.59305	1.59630	1.60520	1.60130	1.60250
Average		1.58768	1.59329	1.59194	1.59991	1.60021	1.59888
Stdev		0.00415	0.00230	0.00330	0.00350	0.00084	0.00211
Max		1.59270	1.59800	1.59640	1.60520	1.60130	1.60250
Min		1.58195	1.59000	1.58640	1.59610	1.59900	1.59510

Oakridge National Laboratory
2006 Chevrolet Cobalt
Intake Valve Stem Height Measurements at EOT





Oakridge National Laboratory
2006 Chevrolet Cobalt
Exhaust Valve Stem Height Measurements at EOT
1.60600
1.60400
1.60200
1.60000
1.59800
1.59600
1.59400
1.59200
1.59000
Inches
ORCC0
ORCC15
ORCC20
1
2
3
4
5
6
7
8
1
2
3
4
Average
Cylinder No. / Valve No.

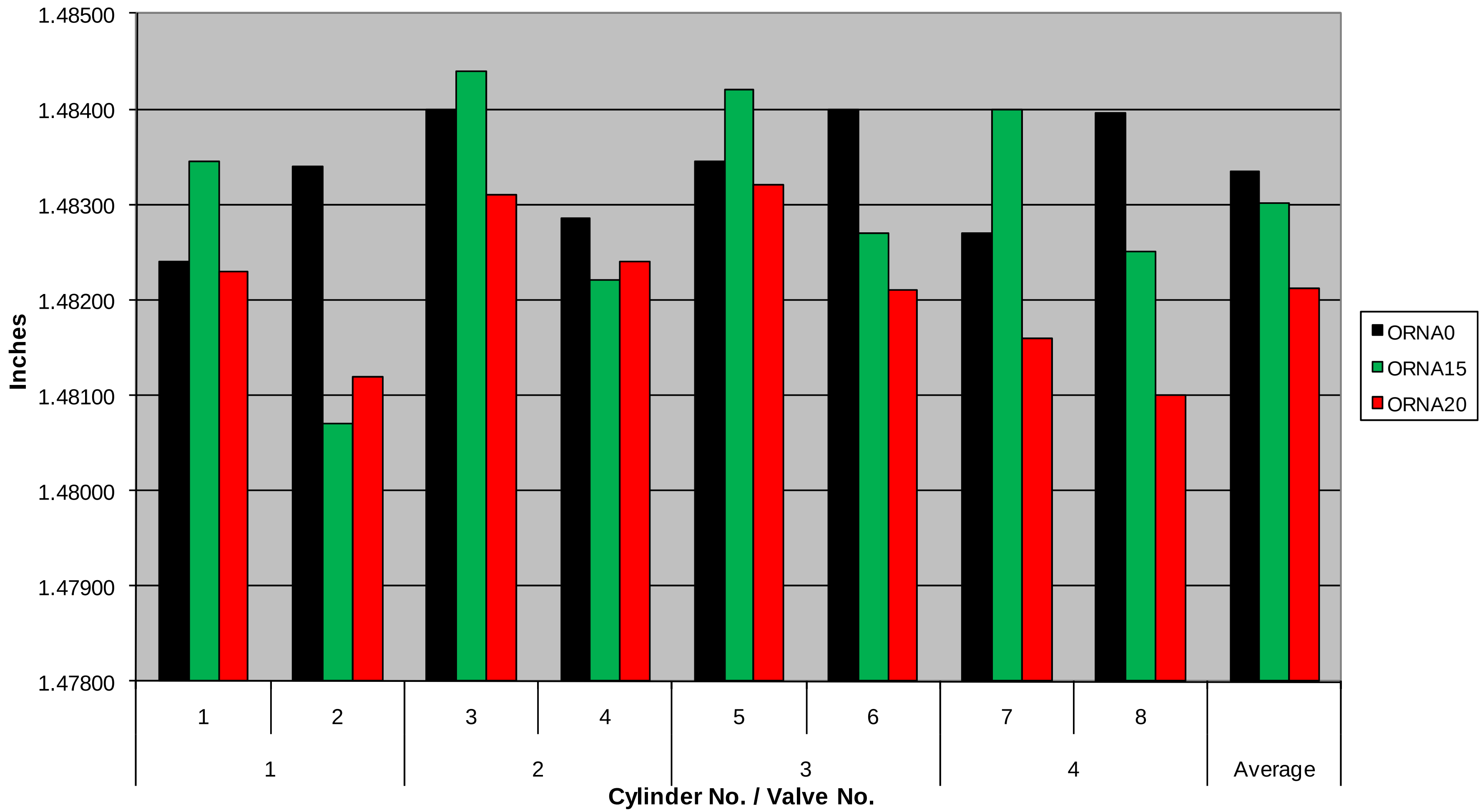
Oak Ridge National Laboratory
Proposal 08-58845 Powertrain Inspection
Valve Stem Height

Date: 28-Aug-10 Technician: JM

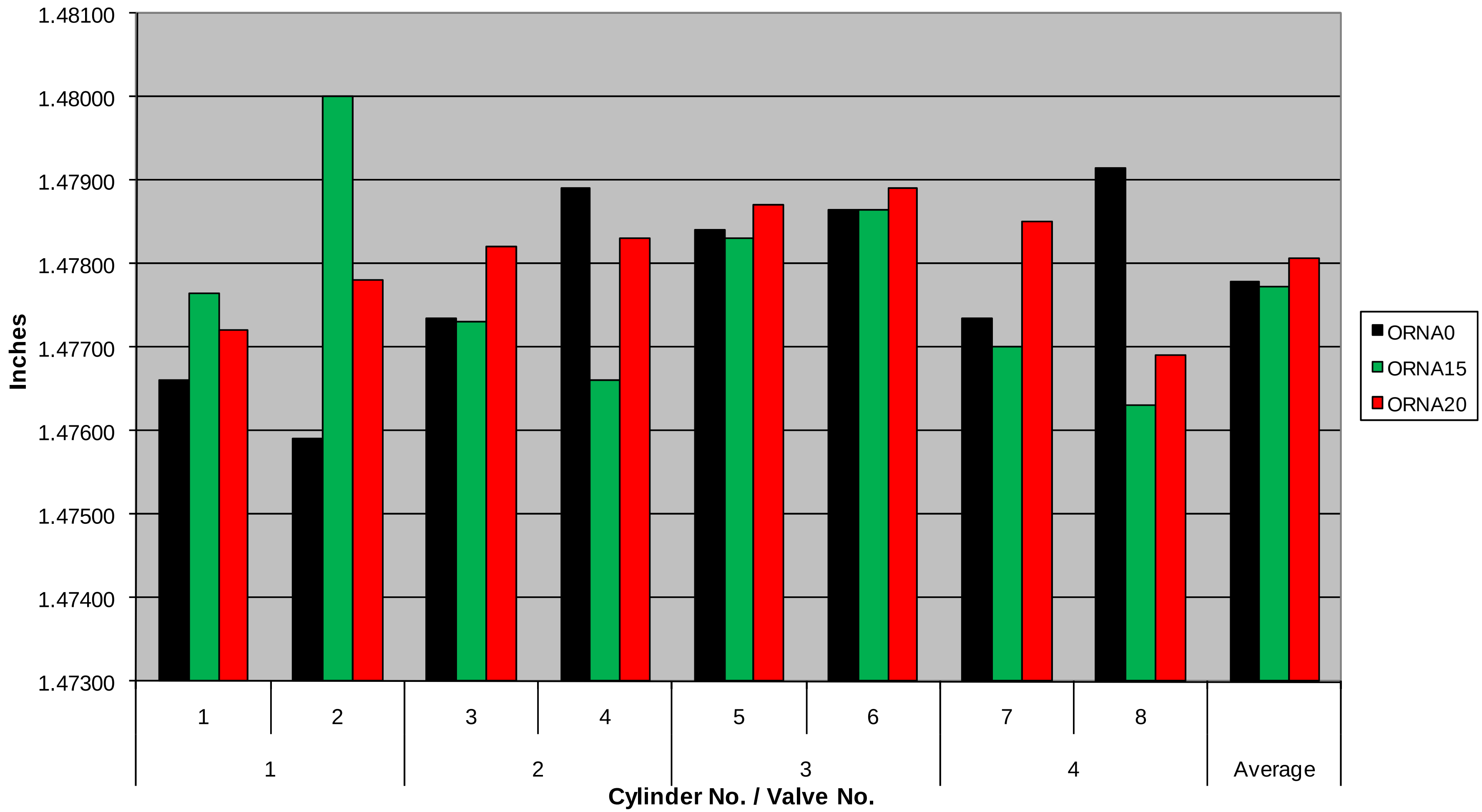
Measured from tip of valve stem to cylinder head
Measurements in inches
No specified service limit

		Intake			Exhaust		
Cylinder #	**Valve #**	**ORNA0**	**ORNA15**	**ORNA20**	**ORNA0**	**ORNA15**	**ORNA20**
1	1	1.48240	1.48345	1.48230	1.47660	1.47765	1.47720
	2	1.48340	1.48070	1.48120	1.47590	1.48000	1.47780
2	3	1.48400	1.48440	1.48310	1.47735	1.47730	1.47820
	4	1.48285	1.48220	1.48240	1.47890	1.47660	1.47830
3	5	1.48345	1.48420	1.48320	1.47840	1.47830	1.47870
	6	1.48400	1.48270	1.48210	1.47865	1.47865	1.47890
4	7	1.48270	1.48400	1.48160	1.47735	1.47700	1.47850
	8	1.48395	1.48250	1.48100	1.47915	1.47630	1.47690
Average		1.48334	1.48302	1.48211	1.47779	1.47773	1.47806
Stdev		0.00063	0.00125	0.00081	0.00117	0.00122	0.00071
Max		1.48400	1.48440	1.48320	1.47915	1.48000	1.47890
Min		1.48240	1.48070	1.48100	1.47590	1.47630	1.47690

Oakridge National Laboratory
2008 Nissan Altima
Intake Valve Stem Height Measurements at EOT



Oakridge National Laboratory
2008 Nissan Altima
Exhaust Valve Stem Height Measurements at EOT



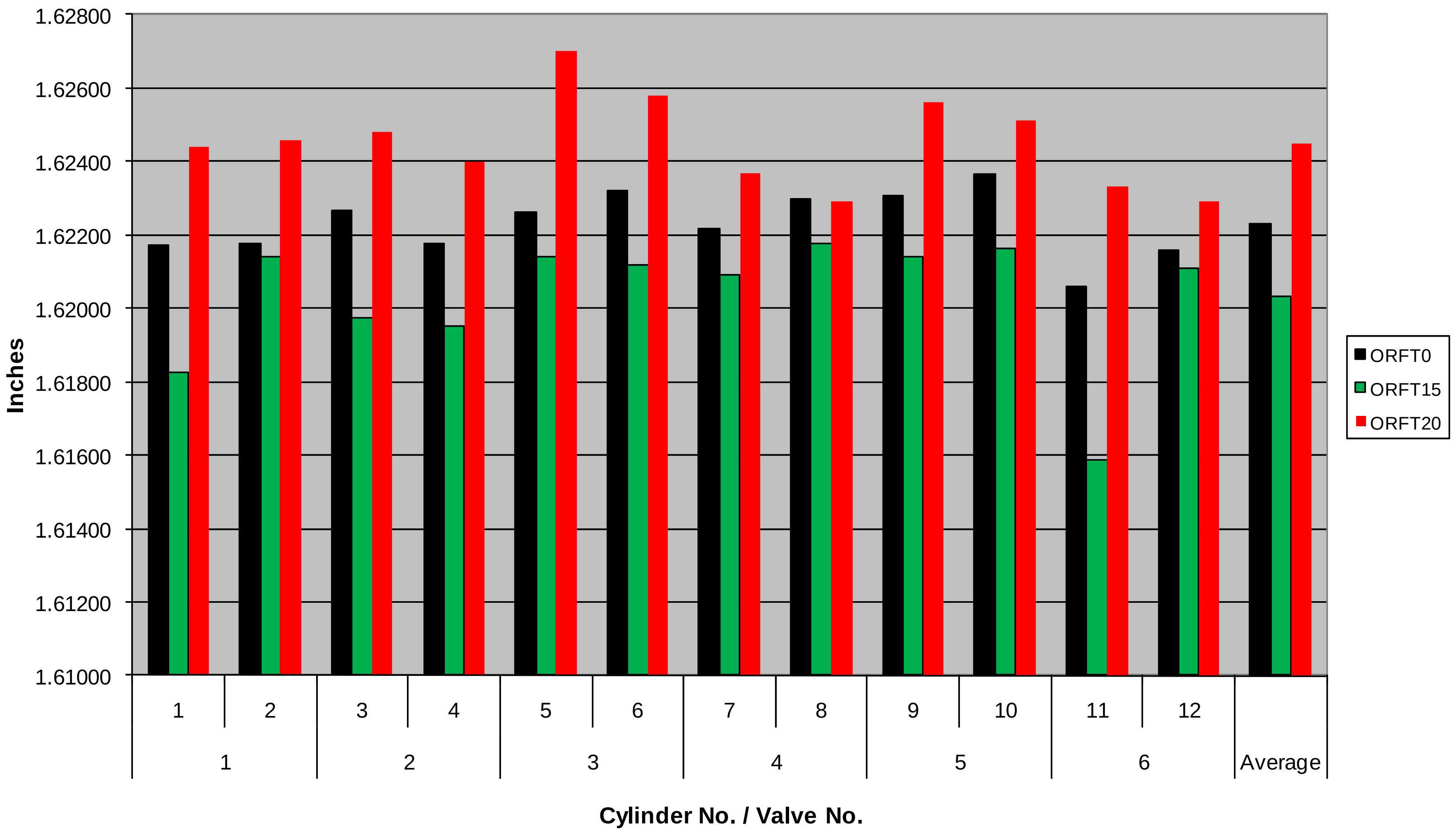
Oak Ridge National Laboratory
Proposal 08-58845 Powertrain Inspection
Valve Stem Height

Date: 31-Aug-10 Technician: JM

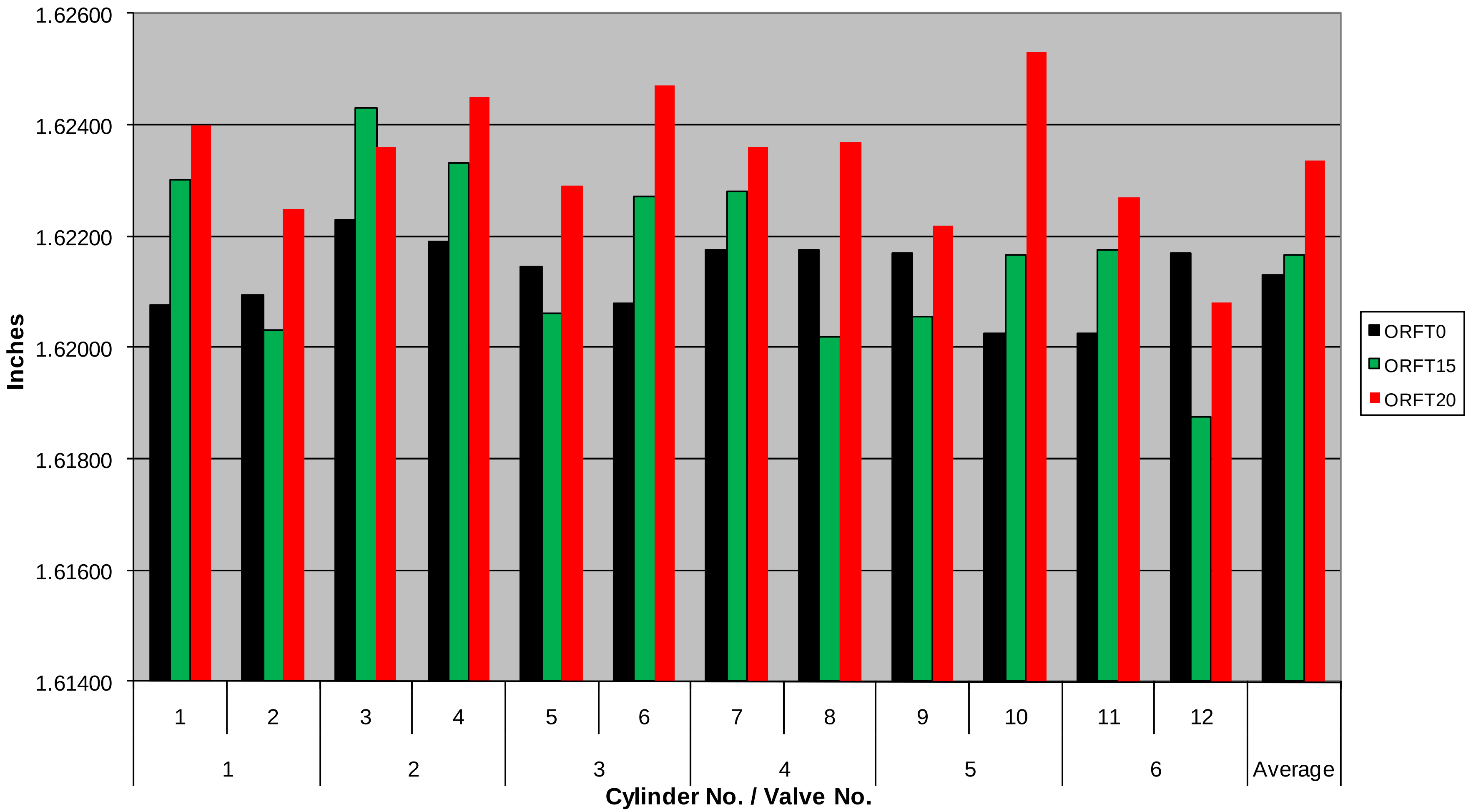
Measured from tip of valve stem to cylinder head
Measurements in inches
No specified service limit

		Intake			Exhaust		
Cylinder #	**Valve #**	**ORFT0**	**ORFT15**	**ORFT20**	**ORFT0**	**ORFT15**	**ORFT20**
1	1	1.62170	1.61825	1.62440	1.62075	1.62300	1.62400
	2	1.62175	1.62140	1.62460	1.62095	1.62030	1.62250
2	3	1.62265	1.61975	1.62480	1.62230	1.62430	1.62360
	4	1.62175	1.61950	1.62400	1.62190	1.62330	1.62450
3	5	1.62260	1.62140	1.62700	1.62145	1.62060	1.62290
	6	1.62320	1.62120	1.62580	1.62080	1.62270	1.62470
4	7	1.62215	1.62090	1.62370	1.62175	1.62280	1.62360
	8	1.62300	1.62175	1.62290	1.62175	1.62020	1.62370
5	9	1.62305	1.62140	1.62560	1.62170	1.62055	1.62220
	10	1.62365	1.62165	1.62510	1.62025	1.62165	1.62530
6	11	1.62060	1.61585	1.62330	1.62025	1.62175	1.62270
	12	1.62160	1.62110	1.62290	1.62170	1.61875	1.62080
Average		1.62231	1.62035	1.62451	1.62130	1.62166	1.62338
Stdev		0.00087	0.00177	0.00125	0.00067	0.00161	0.00124
Max		1.62365	1.62175	1.62700	1.62230	1.62430	1.62530
Min		1.62060	1.61585	1.62290	1.62025	1.61875	1.62080

Oakridge National Laboratory
2008 Ford Taurus
Intake Valve Stem Height Measurements at EOT



Oakridge National Laboratory
2008 Ford Taurus
Exhaust Valve Stem Height Measurements at EOT

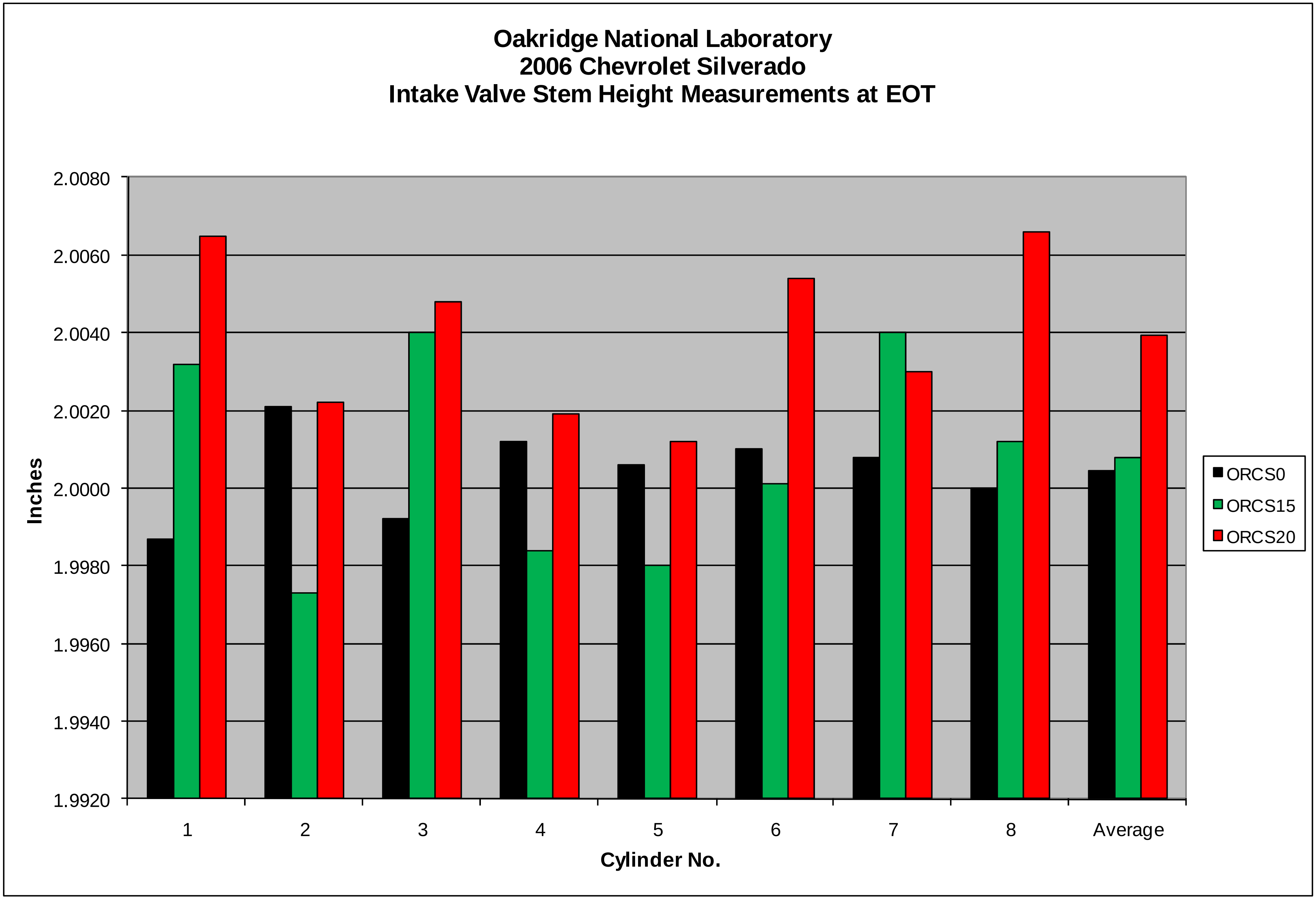


Oak Ridge National Laboratory
Proposal 08-58845 Powertrain Inspection
Valve Stem Height

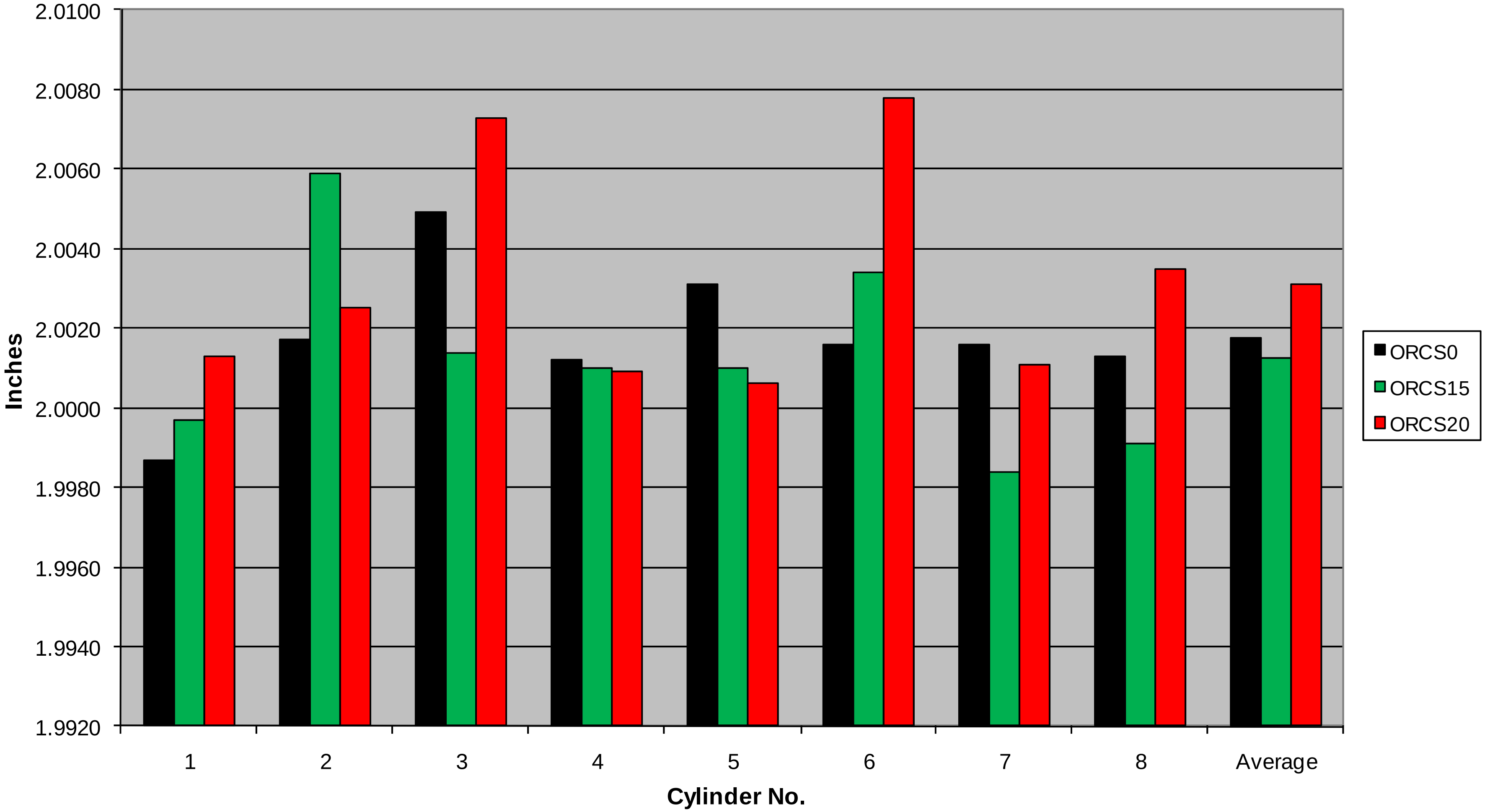
Date: 26-Aug-10 Technician: LJ

Measured from tip of valve stem to cylinder head
Measurements in inches
No specified service limit

	Intake			Exhaust		
Cylinder #	**ORCS0**	**ORCS15**	**ORCS20**	**ORCS0**	**ORCS15**	**ORCS20**
1	1.9987	2.0032	2.0065	1.9987	1.9997	2.0013
2	2.0021	1.9973	2.0022	2.0017	2.0059	2.0025
3	1.9992	2.0040	2.0048	2.0049	2.0014	2.0073
4	2.0012	1.9984	2.0019	2.0012	2.0010	2.0009
5	2.0006	1.9980	2.0012	2.0031	2.0010	2.0006
6	2.0010	2.0001	2.0054	2.0016	2.0034	2.0078
7	2.0008	2.0040	2.0030	2.0016	1.9984	2.0011
8	2.0000	2.0012	2.0066	2.0013	1.9991	2.0035
Average	2.0005	2.0008	2.0040	2.0018	2.0012	2.0031
Stdev	0.0011	0.0027	0.0021	0.0018	0.0024	0.0029
Max	2.0021	2.0040	2.0066	2.0049	2.0059	2.0078
Min	1.9987	1.9973	2.0012	1.9987	1.9984	2.0006


Oakridge National Laboratory
2006 Chevrolet Silverado
Intake Valve Stem Height Measurements at EOT
2.0080
2.0060
2.0040
2.0020
2.0000
1.9980
1.9960
1.9940
1.9920
Inches
1
2
3
4
5
6
7
8
Average
Cylinder No.
ORCS0
ORCS15
ORCS20

Oakridge National Laboratory
2006 Chevrolet Silverado
Exhaust Valve Stem Height Measurements at EOT

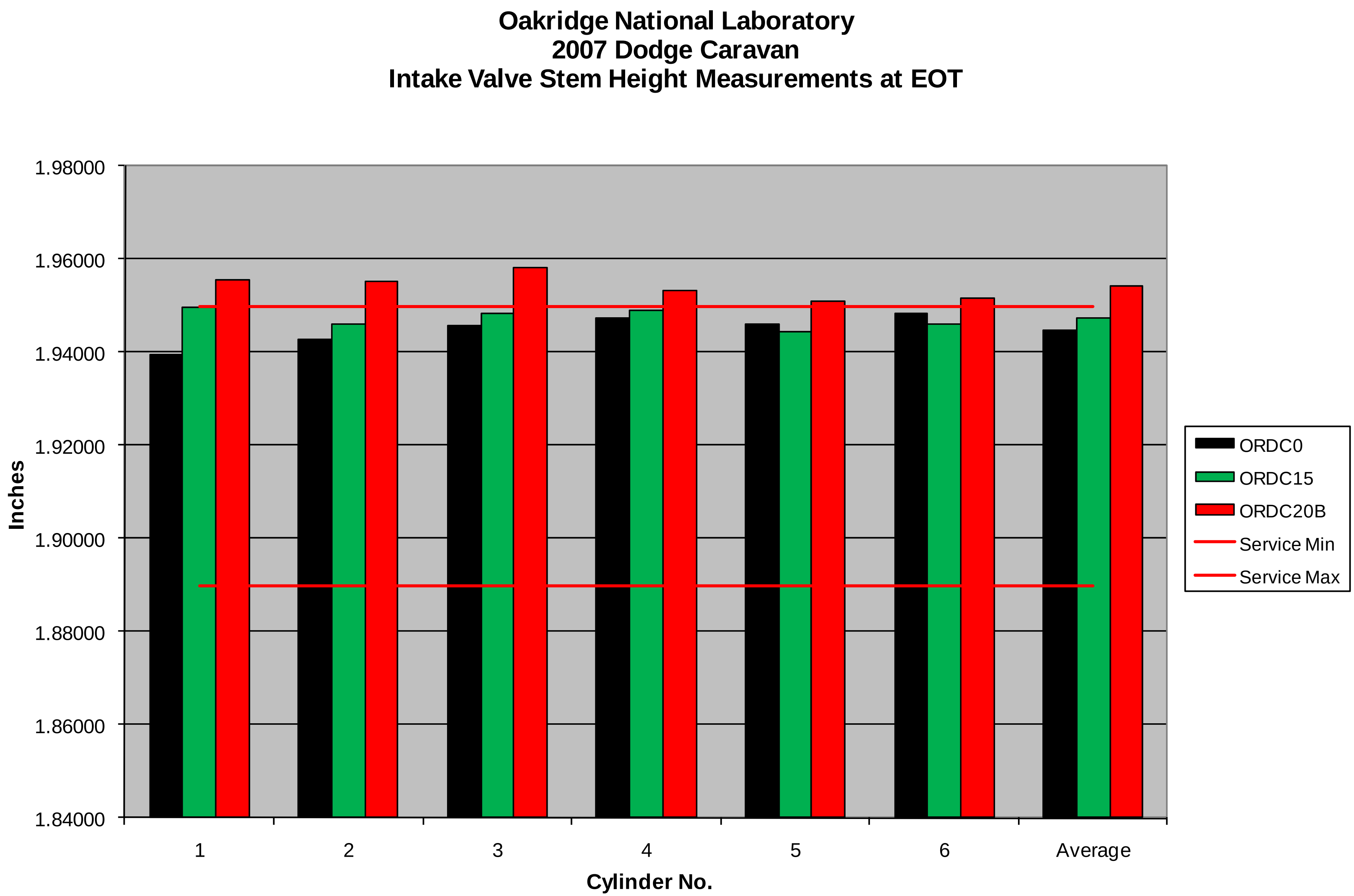


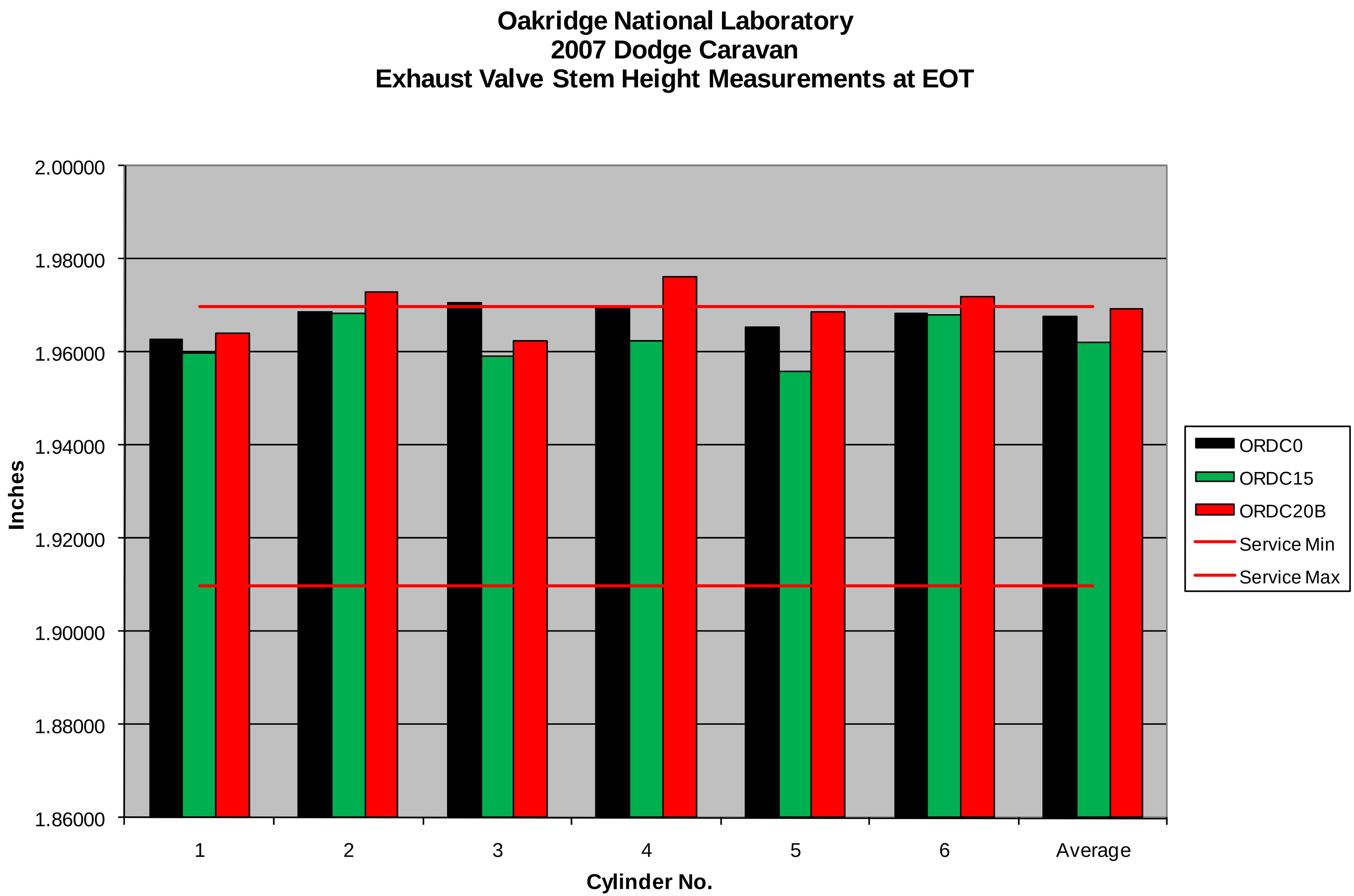
Oak Ridge National Laboratory
Proposal 08-58845 Powertrain Inspection
Valve Stem Height

Date: 12-Aug-10 Technician: LJ

Measured from tip of valve stem to the spring seat washer
Measurements in inches
Service Limits: Intake = 1.89" - 1.95" Exhaust = 1.91" - 1.97"

	Intake			Exhaust		
Cylinder #	**ORDC0**	**ORDC15**	**ORDC20**	**ORDC0**	**ORDC15**	**ORDC20**
1	1.93940	1.94975	1.9557	1.96270	1.95975	1.9640
2	1.94270	1.94620	1.9552	1.96880	1.96825	1.9730
3	1.94560	1.94850	1.9583	1.97075	1.95910	1.9626
4	1.94735	1.94895	1.9532	1.96975	1.96230	1.9762
5	1.94595	1.94445	1.9509	1.96545	1.95585	1.9687
6	1.94840	1.94610	1.9518	1.96825	1.96805	1.9720
Average	1.94490	1.94733	1.9542	1.96762	1.96222	1.9694
Stdev	0.0033	0.0020	0.0027	0.0030	0.0050	0.0053
Max	1.94840	1.94975	1.9583	1.97075	1.96825	1.9762
Min	1.93940	1.94445	1.9509	1.96270	1.95585	1.9626


Oakridge National Laboratory
2007 Dodge Caravan
Intake Valve Stem Height Measurements at EOT
1.98000
1.96000
1.94000
1.92000
1.90000
1.88000
1.86000
1.84000
Inches
1
2
3
4
5
6
Average
Cylinder No.
ORDC0
ORDC15
ORDC20B
Service Min
Service Max



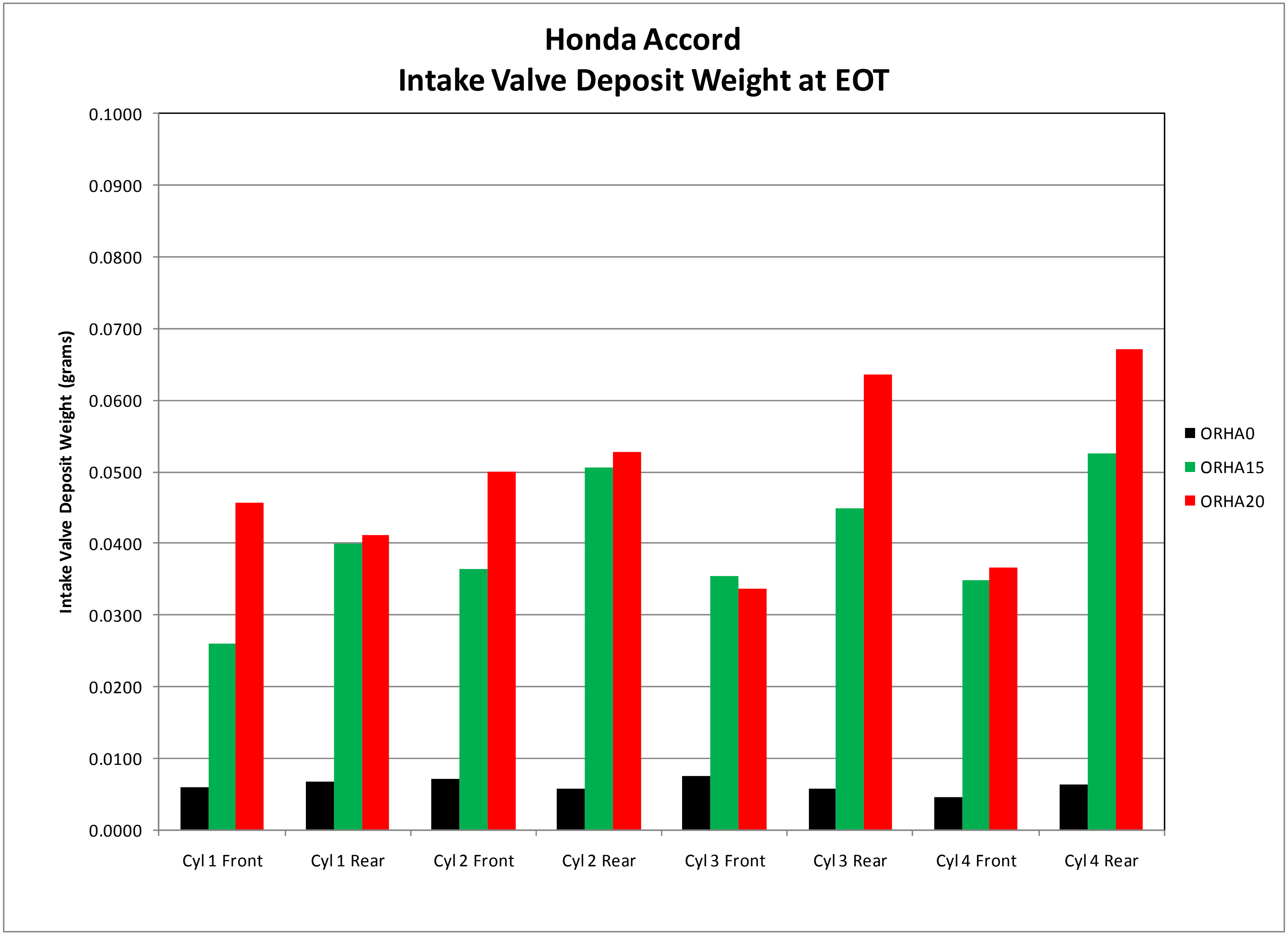
Oakridge National Laboratory
2007 Dodge Caravan
Exhaust Valve Stem Height Measurements at EOT
2.00000
1.98000
1.96000
1.94000
1.92000
1.90000
1.88000
1.86000
Inches
1
2
3
4
5
6
Average
Cylinder No.
ORDC0
ORDC15
ORDC20B
Service Min
Service Max

Appendix D
Intake Valve Deposit Weight

Oak Ridge Program E-87-2

Intake Valve Deposit Weigh in Grams

Vehicle	Cylinder 1		Cylinder 2		Cylinder 3		Cylinder 4		Cylinder 5		Cylinder 6		Cylinder 7		Cylinder 8	
Number	Front	Rear	Front	Rear	Front	Rear	Front	Rear	Front	Rear	Front	Rear	Front	Rear	Front	Rear
ORHA0	0.0059	0.0068	0.0071	0.0057	0.0075	0.0057	0.0046	0.0063								
ORHA15	0.0261	0.0399	0.0365	0.0505	0.0354	0.0448	0.0348	0.0525								
ORHA20	0.0457	0.0411	0.0500	0.0527	0.0337	0.0636	0.0366	0.0672								
ORCS0	0.0030		0.0018		0.0018		0.0025		0.0027		0.0025		0.0019		0.0018	
ORCS15	0.0489		0.0720		0.0565		0.0510		0.0325		0.0270		0.0482		0.0454	
ORCS20	0.0420		0.0866		0.0758		0.1527		0.0596		0.0622		0.0404		0.0262	
ORNA0	0.0055	0.0039	0.0042	0.0046	0.0036	0.0044	0.0034	0.0117								
ORNA15	0.0080	0.0064	0.0067	0.0055	0.0084	0.0117	0.0303	0.0531								
ORNA20	0.0098	0.0095	0.0136	0.0113	0.0144	0.0197	0.0612	0.0493								
ORFT0	0.0082	0.0084	0.0067	0.0066	0.0048	0.0066	0.0076	0.0093	0.0090	0.0082	0.0147	0.0118				
ORFT15	0.0094	0.0223	0.0199	0.0263	0.0188	0.0156	0.0200	0.0264	0.0260	0.0185	0.0208	0.0241				
ORFT20	0.0130	0.1253	0.0335	0.1168	0.0290	0.0144	0.0484	0.0347	0.0181	0.0116	0.0417	0.0475				
ORDC0	0.0228		0.0060		0.0622		0.1156		0.0092		0.0502					
ORDC15	0.0136		0.0467		0.2921		0.1148		0.0100		0.0381					
ORDC20B	0.0243		0.0195		0.1096		0.3216		0.0115		0.0402					
ORCC0	0.0101	0.0077	0.0110	0.0071	0.0091	0.0073	0.0108	0.0120								
ORCC15	0.0274	0.0217	0.0119	0.0276	0.0295	0.0178	0.0296	0.0216								
ORCC20	0.0133	0.0178	0.0090	0.0220	0.0174	0.0097	0.0263	0.0175								



Honda Accord
Intake Valve Deposit Weight at EOT
Intake Valve Deposit Weight (grams)
0.1000
0.0900
0.0800
0.0700
0.0600
0.0500
0.0400
0.0300
0.0200
0.0100
0.0000
Cyl 1 Front
Cyl 1 Rear
Cyl 2 Front
Cyl 2 Rear
Cyl 3 Front
Cyl 3 Rear
Cyl 4 Front
Cyl 4 Rear
ORHA0
ORHA15
ORHA20

Oak Ridge Program E-87-2

Vehicle: Honda Accord ORHA0	
End of Test	Fuel: E0

Intake Valves 1 Front Through 4 Rear

Maximum IVD is Facing Camera

Front View

Oak Ridge Program E-87-2

Vehicle: Honda Accord ORHA0	
End of Test	Fuel: E0

Intake Valves 1 Front Through 4 Rear

Minimum IVD is Facing Camera

Back View

Oak Ridge Program E-87-2

Vehicle: Honda Accord ORHA15	
End of Test	Fuel: E15

Intake Valves 1 Front Through 4 Rear

Maximum IVD is Facing Camera

Front View

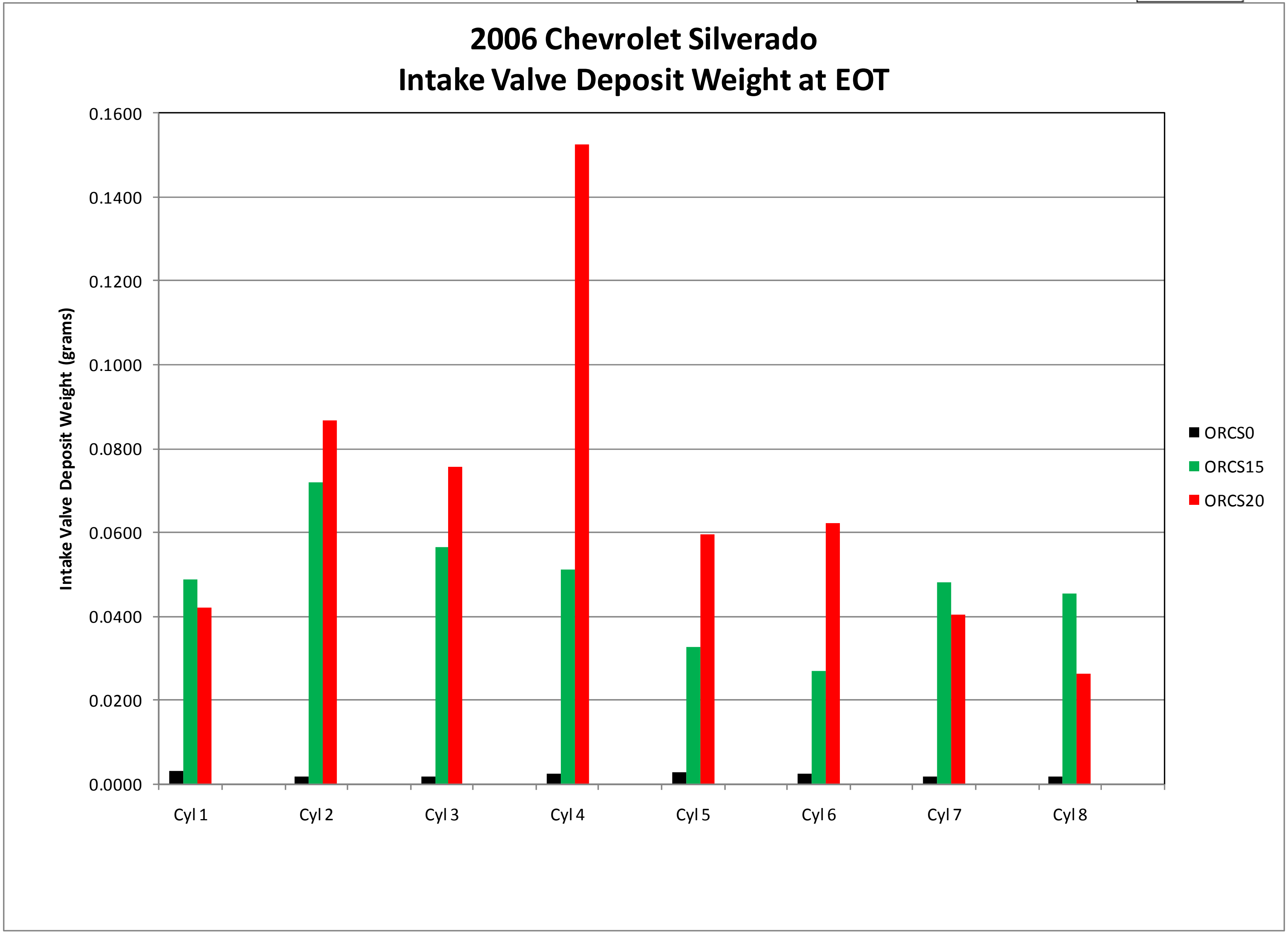
Oak Ridge Program E-87-2

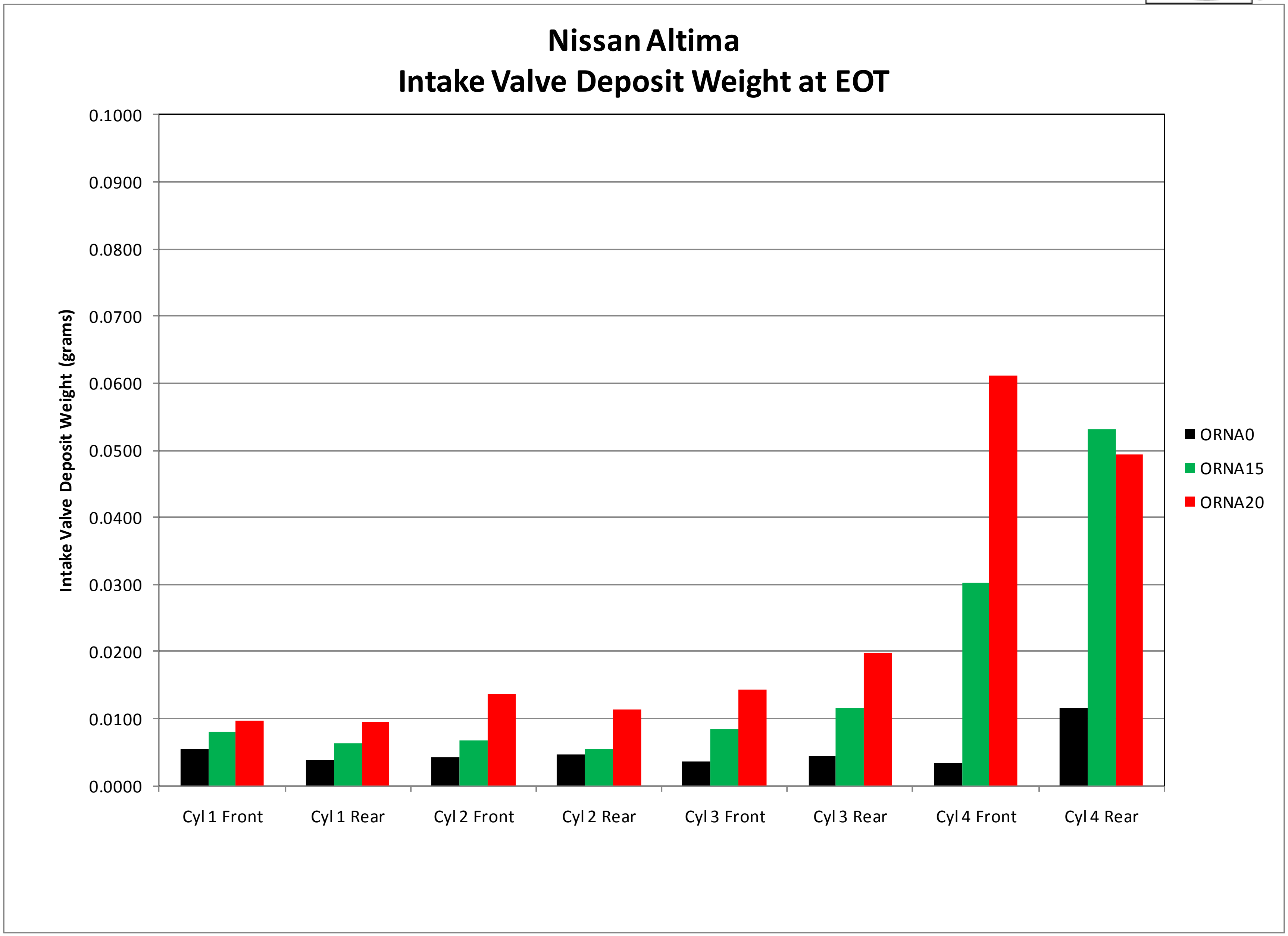
Vehicle: Honda Accord ORHA15	
End of Test	Fuel: E15

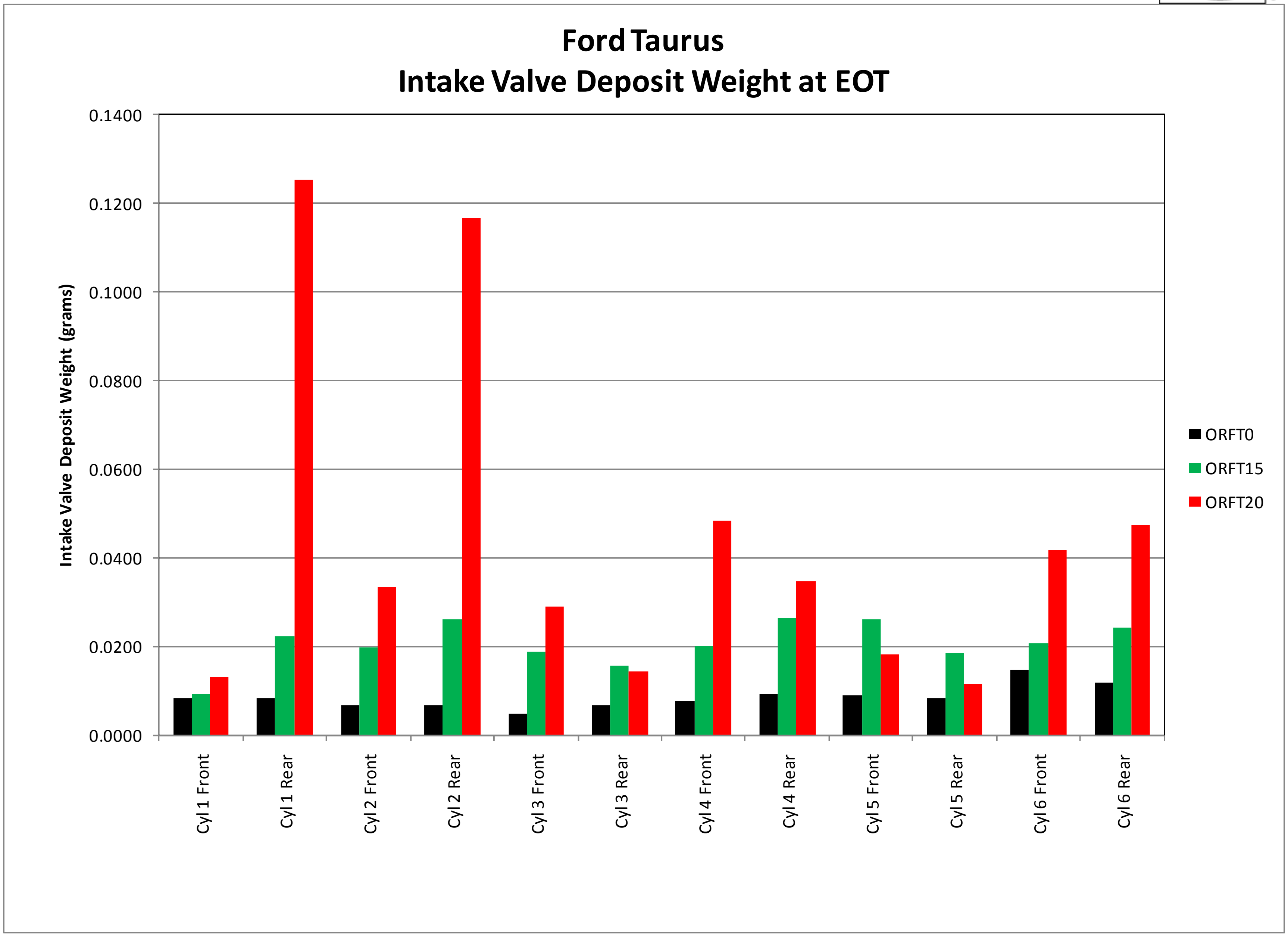
Intake Valves 1 Front Through 4 Rear

Minimum IVD is Facing Camera

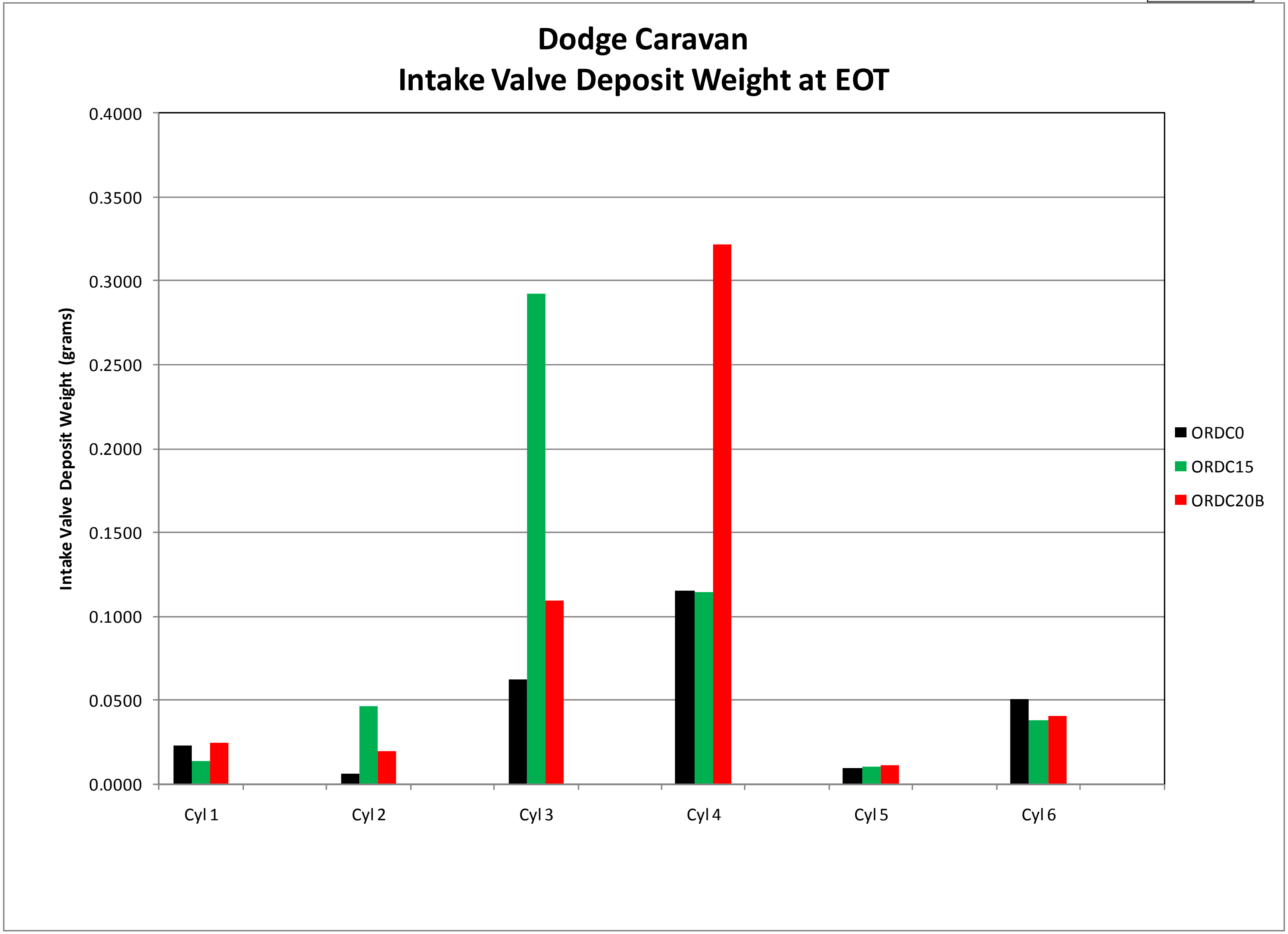
Back View

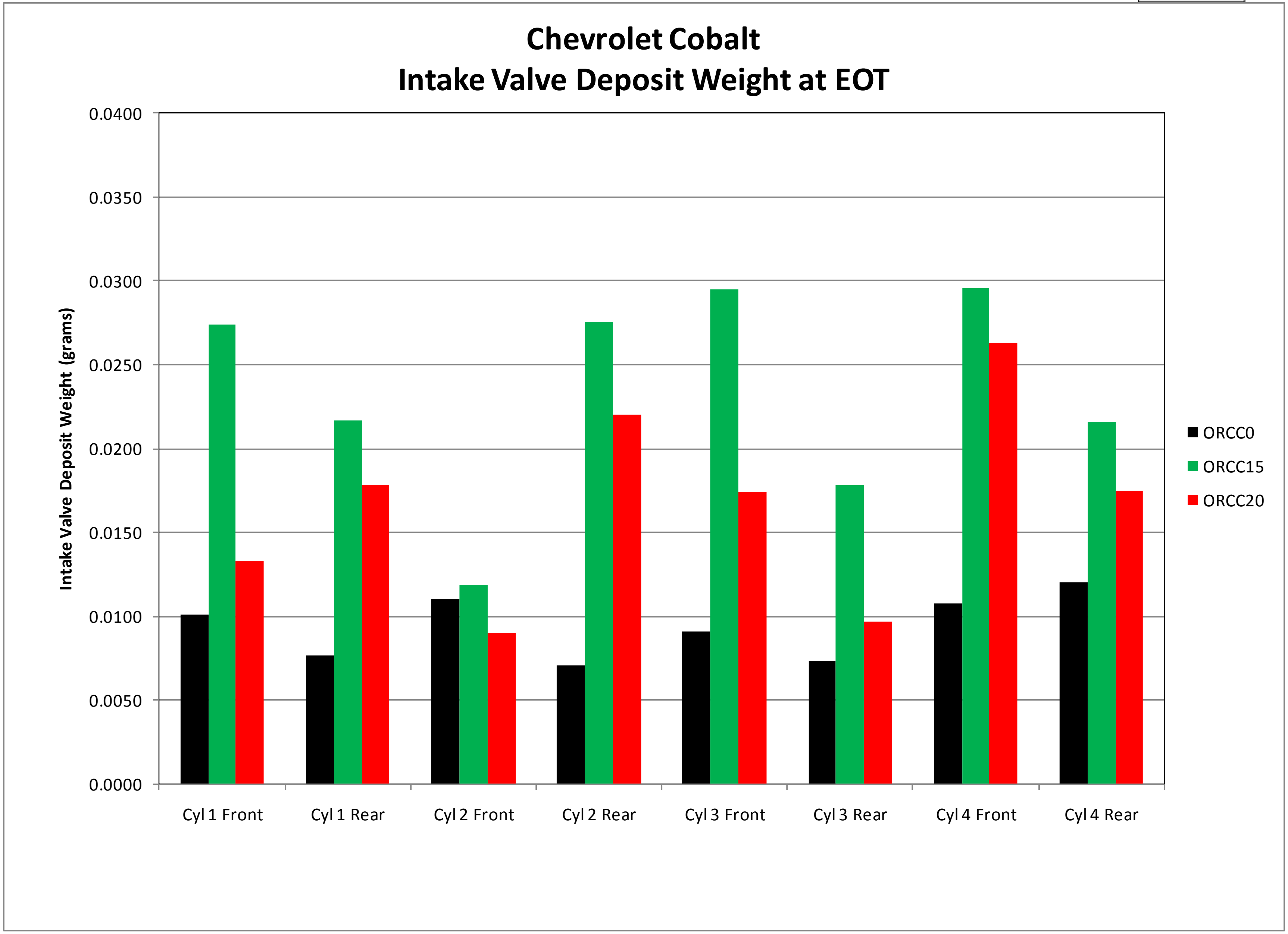

2006 Chevrolet Silverado
Intake Valve Deposit Weight at EOT
Intake Valve Deposit Weight (grams)
0.1600
0.1400
0.1200
0.1000
0.0800
0.0600
0.0400
0.0200
0.0000
Cyl 1
Cyl 2
Cyl 3
Cyl 4
Cyl 5
Cyl 6
Cyl 7
Cyl 8
ORCS0
ORCS15
ORCS20


Nissan Altima
Intake Valve Deposit Weight at EOT
Intake Valve Deposit Weight (grams)
0.1000
0.0900
0.0800
0.0700
0.0600
0.0500
0.0400
0.0300
0.0200
0.0100
0.0000
Cyl 1 Front
Cyl 1 Rear
Cyl 2 Front
Cyl 2 Rear
Cyl 3 Front
Cyl 3 Rear
Cyl 4 Front
Cyl 4 Rear
ORNA0
ORNA15
ORNA20



Ford Taurus
Intake Valve Deposit Weight at EOT
Intake Valve Deposit Weight (grams)
0.1400
0.1200
0.1000
0.0800
0.0600
0.0400
0.0200
0.0000
Cyl 1 Front
Cyl 1 Rear
Cyl 2 Front
Cyl 2 Rear
Cyl 3 Front
Cyl 3 Rear
Cyl 4 Front
Cyl 4 Rear
Cyl 5 Front
Cyl 5 Rear
Cyl 6 Front
Cyl 6 Rear
ORFT0
ORFT15
ORFT20


Dodge Caravan
Intake Valve Deposit Weight at EOT
Intake Valve Deposit Weight (grams)
0.4000
0.3500
0.3000
0.2500
0.2000
0.1500
0.1000
0.0500
0.0000
Cyl 1
Cyl 2
Cyl 3
Cyl 4
Cyl 5
Cyl 6
ORDC0
ORDC15
ORDC20B


Chevrolet Cobalt
Intake Valve Deposit Weight at EOT
Intake Valve Deposit Weight (grams)
0.0400
0.0350
0.0300
0.0250
0.0200
0.0150
0.0100
0.0050
0.0000
Cyl 1 Front
Cyl 1 Rear
Cyl 2 Front
Cyl 2 Rear
Cyl 3 Front
Cyl 3 Rear
Cyl 4 Front
Cyl 4 Rear
ORCC0
ORCC15
ORCC20

Appendix E
ASTM D5185 ICP Metals Results

Oak Ridge Used Oil Samples
August 4, 2010

					ASTM D-5185 Elemental Analysis by ICP									ASTM D-5185 Elemental Analysis by ICP														
Vehicle Number	Vehicle Number	SOT Odo.	Oil Sample Odometer (miles)	Oil Sample Test Miles	Aluminum, ppm	Antimony, ppm	Barium, ppm	Boron, ppm	Cadmium, ppm	Calcium, ppm	Chromium, ppm	Copper, ppm	Iron, ppm	Lead, ppm	Magnesium, ppm	Manganese, ppm	Molyb-denum, ppm	Nickel, ppm	Phosphorus, ppm	Potassium, ppm	Silicon, ppm	Silver, ppm	Sodium, ppm	Strontium, ppm	Tin, ppm	Titanium, ppm	Vanadium, ppm	Zinc, ppm
ORHA0	ORHAO	31,686	38,603	6,917	2	<1	<1	76	<1	2068	<1	2	7	1	24	<1	5	<1	668	6	12	<1	<5	<1	<1	<1	<1	850
ORHA0	ORHAO	31,686	75,460	43,774	1	<1	<1	58	<1	2111	<1	<1	5	<1	10	<1	<1	<1	694	6	14	<1	<5	<1	<1	<1	<1	858
ORHA0	ORHAO	31,686	115,233	83,547	1	<1	<1	54	<1	2091	<1	1	6	<1	10	<1	<1	<1	705	8	18	<1	<5	<1	<1	<1	<1	863
ORHA15	ORHA15	31,369	39,220	7,851	2	<1	<1	65	<1	2033	<1	5	8	<1	10	<1	3	<1	661	5	16	<1	6	<1	<1	<1	<1	846
ORHA15	ORHA15	31,369	77,277	45,908	1	<1	<1	44	<1	2081	<1	2	6	<1	10	<1	1	<1	710	6	15	<1	<5	<1	<1	<1	<1	847
ORHA15	ORHA15	31,369	110,419	79,050	1	<1	<1	36	<1	2065	<1	2	6	<1	11	<1	<1	<1	685	8	18	<1	<5	<1	<1	<1	<1	856
ORCS0	ORCS0	27,606	39,679	12,073	4	1	<1	44	<1	2054	<1	28	23	9	9	3	7	2	666	6	18	<1	<5	<1	<1	<1	<1	858
ORCS0	ORCS0	27,606	65,566	37,960	2	<1	<1	24	<1	2068	<1	12	13	<1	8	<1	4	<1	681	7	27	<1	<5	<1	<1	<1	<1	859
ORCS0	ORCS0	27,606	116,347	88,741	2	1	<1	27	<1	2052	<1	10	12	<1	7	<1	4	<1	664	6	23	<1	<5	<1	<1	<1	<1	839
ORCS15	ORCS15	17,152	29,410	12,258	3	<1	<1	37	<1	2048	<1	76	26	6	9	2	14	2	653	9	12	<1	56	<1	<1	<1	<1	849
ORCS15	ORCS15	17,152	55,297	38,145	2	<1	<1	22	<1	2073	<1	27	20	2	8	<1	6	1	656	12	12	<1	32	<1	<1	<1	<1	872
ORCS15	ORCS15	17,152	106,079	88,927	2	<1	<1	19	<1	2044	<1	20	25	1	8	<1	6	1	655	11	15	<1	19	<1	<1	<1	<1	847
ORNA0	ORNA0	19,284	26,784	7,500	5	<1	<1	59	<1	2080	<1	2	6	1	9	<1	4	<1	685	6	21	<1	<5	<1	<1	<1	<1	841
ORNA0	ORNA0	19,284	64,284	45,000	<1	<1	<1	28	<1	2066	<1	1	4	<1	8	<1	<1	<1	641	6	20	<1	<5	<1	<1	<1	<1	839
ORNA0	ORNA0	19,284	116,784	97,500	<1	1	<1	44	<1	2064	<1	1	5	<1	9	<1	1	<1	671	11	26	<1	<5	<1	<1	<1	<1	866
ORNA15	ORNA15	9,950	17,450	7,500	3	<1	<1	58	<1	2023	<1	6	7	2	8	2	20	<1	640	8	29	<1	56	<1	<1	<1	<1	850
ORNA15	ORNA15	9,950	54,950	45,000	2	<1	<1	34	<1	2080	<1	2	6	<1	8	<1	<1	<1	703	6	21	<1	<5	<1	<1	<1	<1	846
ORNA15	ORNA15	9,950	107,450	97,500	<1	<1	<1	47	<1	2066	<1	2	4	<1	9	<1	<1	<1	721	8	29	<1	<5	<1	<1	<1	<1	859
ORFT0	ORFT0	17,231	24,731	7,500	4	<1	<1	90	<1	2008	<1	44	15	2	10	10	6	<1	662	5	30	<1	6	<1	<1	<1	<1	812
ORFT0	ORFT0	17,231	62,231	45,000	2	<1	<1	62	<1	2010	<1	7	8	<1	10	2	1	<1	685	7	27	<1	<5	<1	<1	<1	<1	825
ORFT0	ORFT0	17,231	113,231	96,000	1	<1	<1	50	<1	1992	<1	4	5	<1	8	<1	1	<1	655	7	21	<1	<5	<1	<1	<1	<1	831
ORFT15	ORFT15	17,099	24,599	7,500	4	<1	<1	80	<1	2001	<1	43	15	1	10	9	6	<1	647	7	24	<1	6	<1	<1	<1	<1	812
ORFT15	ORFT15	17,099	62,099	45,000	2	<1	<1	62	<1	2022	<1	9	6	1	10	2	1	<1	639	7	22	<1	<5	<1	<1	<1	<1	831
ORFT15	ORFT15	17,099	113,099	96,000	1	<1	<1	57	<1	2033	<1	6	6	<1	8	<1	<1	<1	689	<5	18	<1	5	<1	<1	<1	<1	832
ORDC0	ORDC0	46,473	52,473	6,000	2	2	<1	111	<1	2090	<1	32	16	<1	9	<1	7	<1	629	5	12	<1	6	<1	<1	<1	<1	849
ORDC0	ORDC0	46,473	88,474	42,001	1	<1	<1	78	<1	2117	<1	7	11	<1	8	<1	3	<1	697	7	13	<1	<5	<1	<1	<1	<1	867
ORDC0	ORDC0	46,473	106,473	60,000	<1	<1	<1	76	<1	2132	<1	6	10	<1	8	<1	2	<1	693	8	11	<1	<5	<1	<1	<1	<1	875
ORDC15	ORDC15	40,031	46,031	6,000	4	<1	<1	105	<1	2147	<1	19	18	<1	9	<1	17	<1	694	8	13	<1	6	<1	<1	<1	<1	870
ORDC15	ORDC15	40,031	82,031	42,000	1	<1	<1	75	<1	2177	<1	6	9	<1	8	<1	2	<1	699	7	13	<1	<5	<1	<1	<1	<1	878
ORDC15	ORDC15	40,031	100,031	60,000	1	<1	<1	55	<1	2194	<1	6	8	<1	8	<1	3	<1	674	7	13	<1	6	<1	<1	<1	<1	894
ORCCO	ORCC0	38,894	46,784	7,890	4	<1	<1	1	<1	2337	<1	7	5	6	6	<1	<1	<1	616	<5	19	<1	18	<1	<1	<1	<1	720
ORCCO	ORCC0	38,894	84,176	45,282	1	<1	<1	65	<1	1999	<1	<1	5	<1	8	<1	1	<1	644	7	11	<1	<5	<1	<1	<1	<1	817
ORCCO	ORCC0	38,894	106,843	67,949	1	<1	<1	28	<1	2113	<1	<1	8	<1	8	<1	1	<1	665	5	23	<1	<5	<1	<1	<1	<1	851

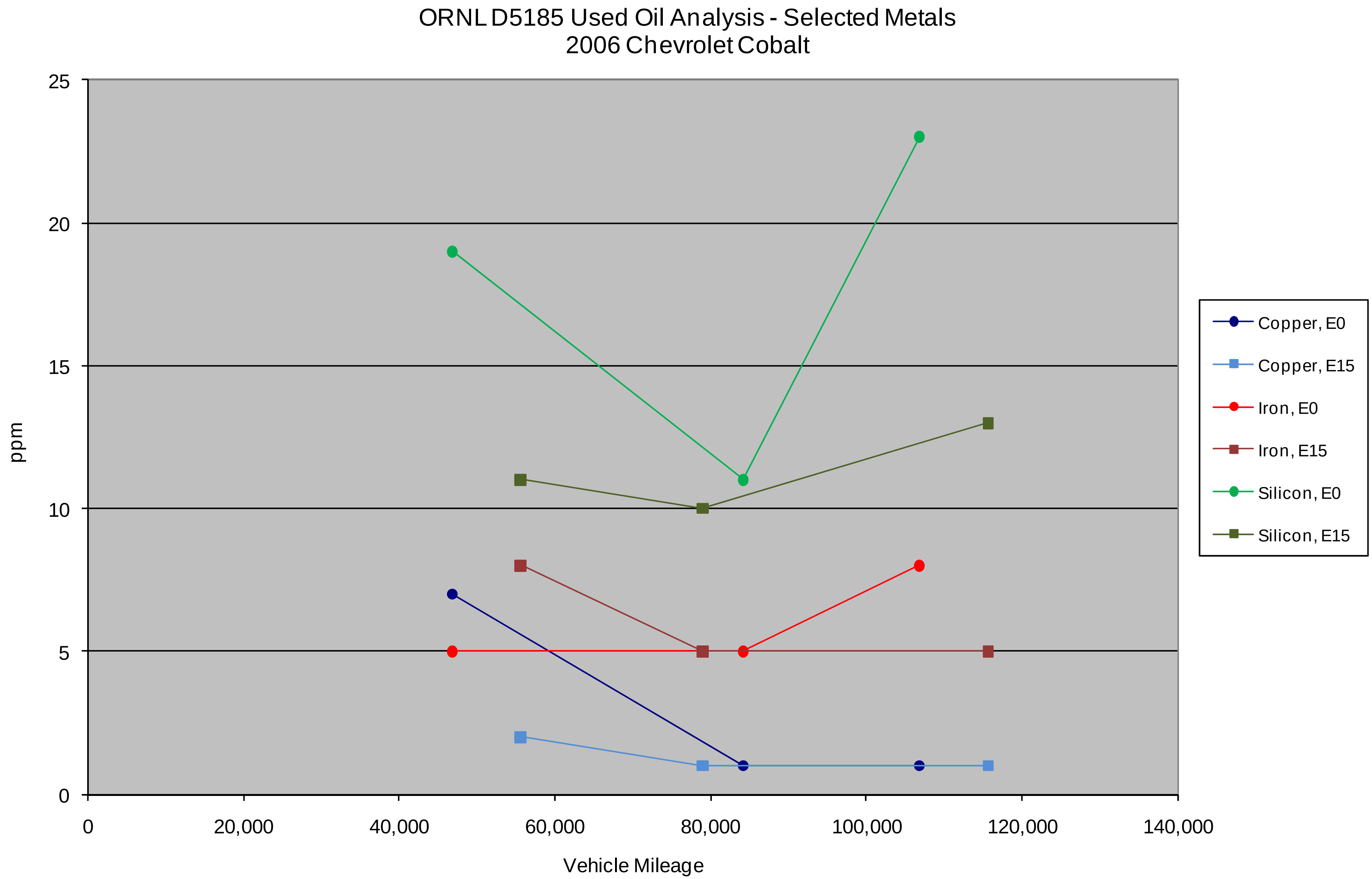
Oak Ridge Used Oil Samples
September 9, 2010

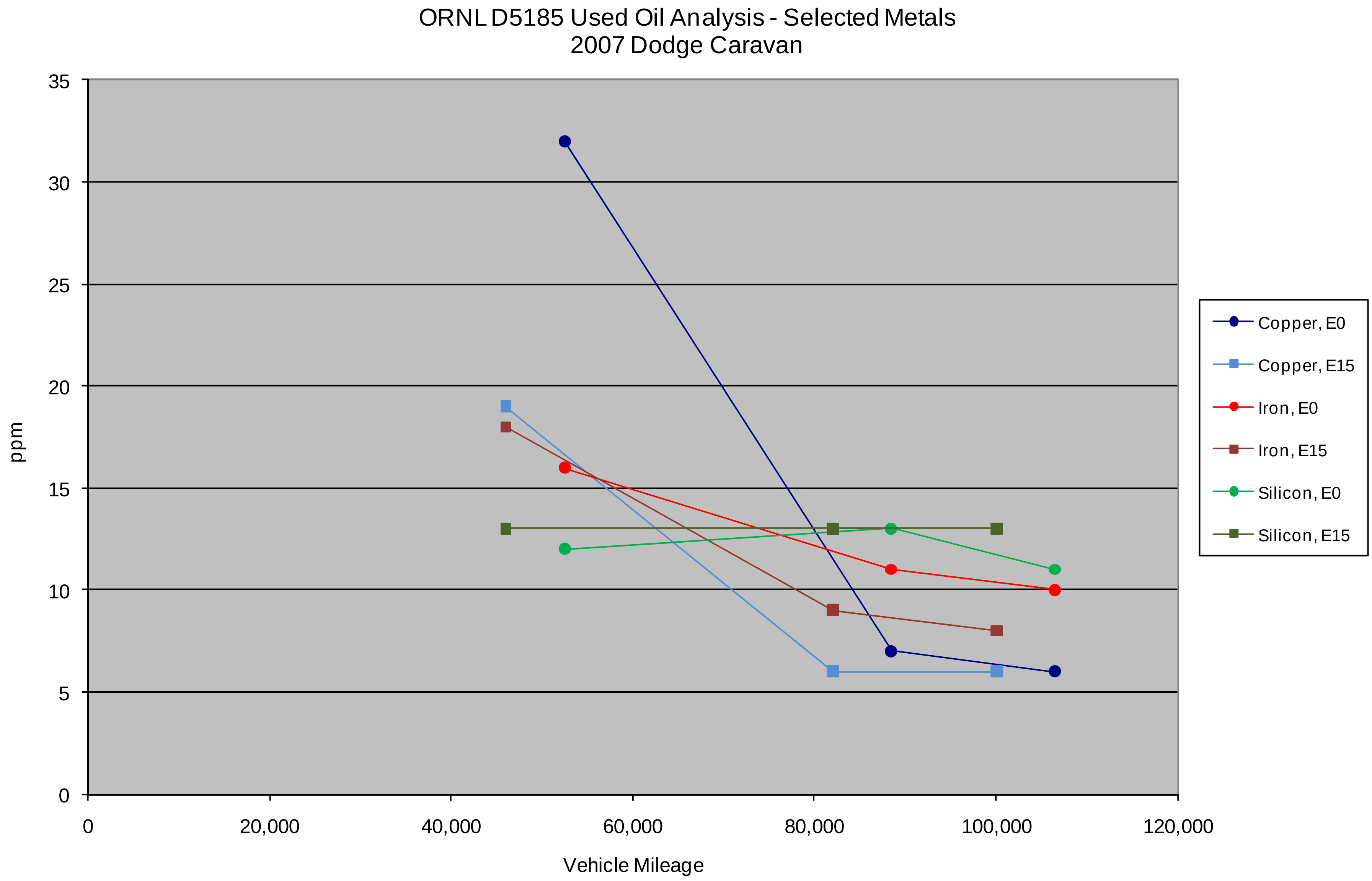
				ASTM D-5185 Elemental Analysis by ICP									ASTM D-5185 Elemental Analysis by ICP															
Vehicle Number	SOT Odo.	Oil Sample Odometer (miles)	Oil Sample Test Miles	Aluminum, ppm	Antimony, ppm	Barium, ppm	Boron, ppm	Cadmium, ppm	Calcium, ppm	Chromium, ppm	Copper, ppm	Iron, ppm	Lead, ppm	Magnesium, ppm	Manganese, ppm	Molyb-denum, ppm	Nickel, ppm	Phosphorus, ppm	Potassium, ppm	Silicon, ppm	Silver, ppm	Sodium, ppm	Strontium, ppm	Sulfur, mass %	Tin, ppm	Titanium, ppm	Vanadium, ppm	Zinc, ppm
ORHA20	34383	41556	7173	3	<1	<1	78	<1	2086	<1	3	8	<1	12	<1	13	<1	706	6	14	<1	14	<1	0.314	<1	<1	<1	890
ORHA20	34383	78425	44042	1	1	<1	45	<1	2106	<1	1	6	<1	10	<1	1	<1	703	6	14	<1	9	<1	0.314	<1	<1	<1	888
ORHA20	34383	118198	83815	1	<1	<1	34	<1	2098	<1	3	6	<1	10	<1	1	<1	712	9	15	<1	13	<1	0.315	<1	<1	<1	886
ORCS20	17287	29413	12126	3	<1	<1	38	<1	2067	<1	49	20	10	9	2	9	<1	658	<5	13	<1	11	<1	0.287	<1	<1	<1	892
ORCS20	17287	55300	38013	2	<1	<1	17	<1	2065	<1	22	15	3	8	<1	5	<1	660	5	12	<1	10	<1	0.301	<1	<1	<1	867
ORCS20	17287	93338	76051	2	<1	<1	20	<1	2033	<1	18	11	2	8	<1	3	<1	663	10	15	<1	12	<1	0.308	<1	<1	<1	885
ORNA20	10307	17807	7500	2	<1	<1	48	<1	2028	<1	5	8	<1	12	<1	21	<1	703	12	23	<1	66	<1	0.31	<1	<1	<1	888
ORNA20	10307	55307	45000	2	<1	<1	21	<1	2084	<1	2	6	<1	9	<1	<1	<1	701	12	25	<1	12	<1	0.327	<1	<1	<1	903
ORNA20	10307	107808	97501	<1	<1	<1	35	<1	2073	<1	2	5	<1	9	<1	<1	<1	728	8	29	<1	10	<1	0.328	<1	<1	<1	886
ORFT20	13082	20582	7500	4	<1	<1	63	<1	1967	<1	64	17	1	12	17	17	<1	673	8	28	<1	53	<1	0.270	<1	<1	<1	822
ORFT20	13082	58082	45000	1	<1	<1	46	<1	2015	<1	10	6	<1	10	2	1	<1	672	6	18	<1	12	<1	0.312	<1	<1	<1	839
ORFT20	13082	108868	95786	<1	<1	<1	44	<1	2036	<1	7	6	1	8	1	<1	<1	685	<5	20	<1	9	<1	0.352	<1	<1	<1	846
ORDC20B	50,809	56902	6093	2	<1	<1	86	<1	2114	<1	12	12	<1	10	<1	6	<1	700	7	13	<1	69	<1	0.297	<1	<1	<1	894
ORDC20B	50,809	92809	42000	1	<1	<1	67	<1	2147	<1	7	7	<1	8	<1	2	<1	692	8	11	<1	13	<1	0.318	<1	<1	<1	894
ORDC20B	50,809	110809	60000	1	<1	<1	51	<1	2107	<1	6	9	<1	8	<1	3	<1	683	9	14	<1	12	<1	0.324	<1	<1	<1	881
ORCC20	38499	46389	7890	2	<1	<1	55	<1	2040	<1	2	11	<1	9	<1	2	<1	710	8	11	<1	132	<1	0.307	<1	<1	<1	838
ORCC20	38499	83781	45282	<1	<1	<1	53	<1	2027	<1	2	5	<1	8	<1	<1	<1	713	8	12	<1	11	<1	0.328	<1	<1	<1	838
ORCC20	38499	106448	67949	1	<1	<1	26	<1	2046	<1	1	6	<1	8	<1	1	<1	699	8	17	<1	9	<1	0.330	<1	<1	<1	843

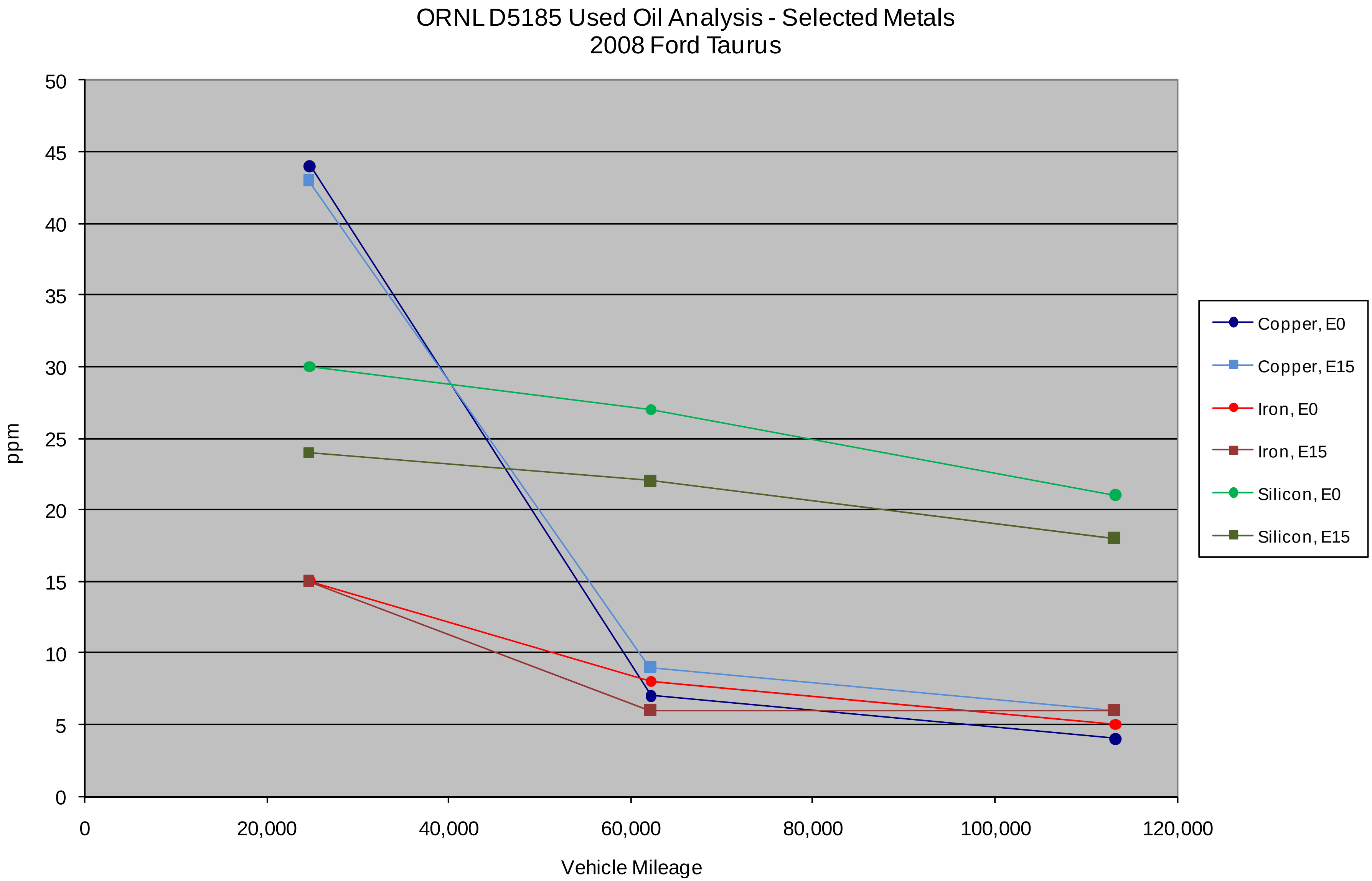
Oak Ridge Used Oil Samples

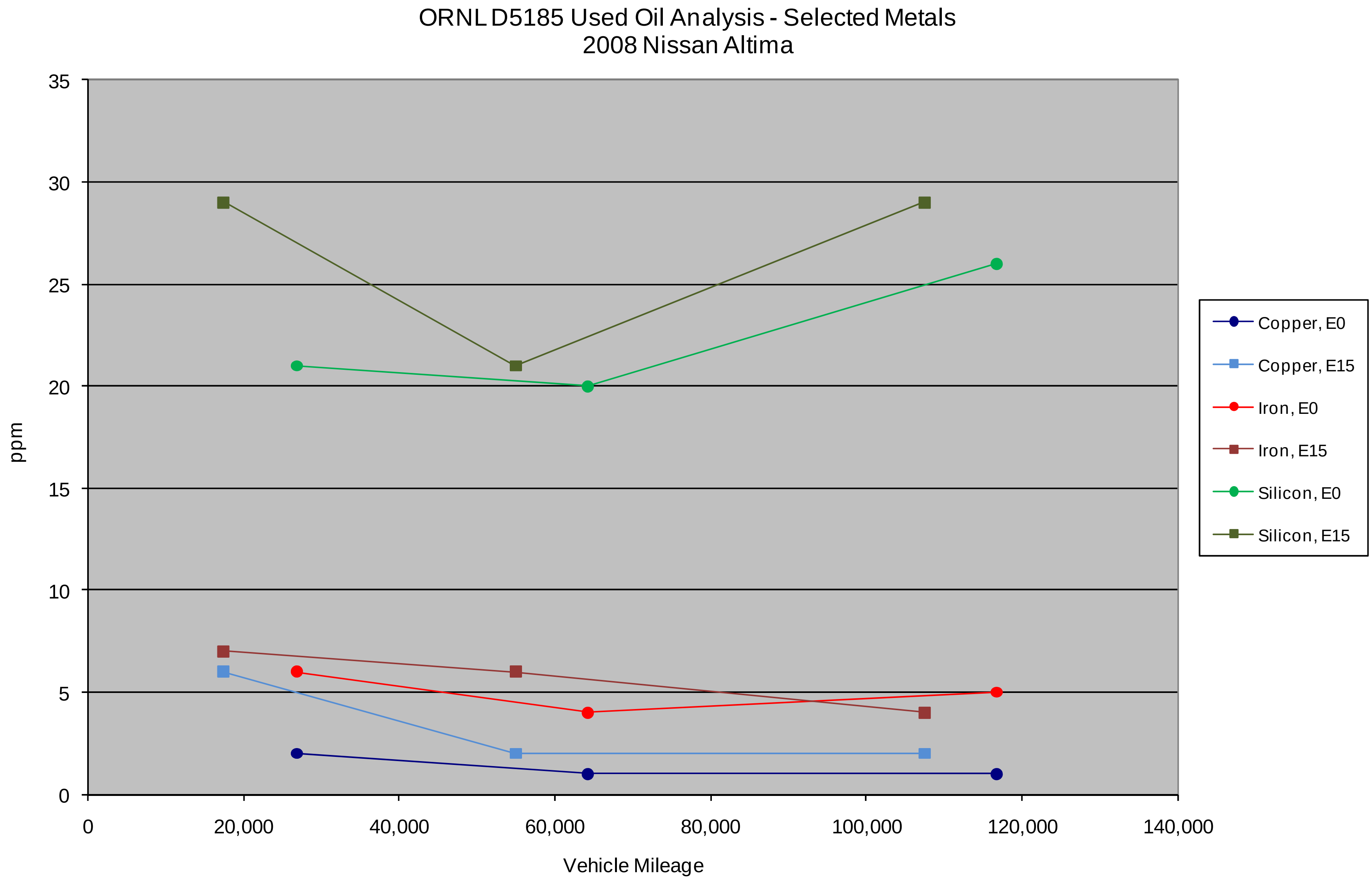
August 4, 2010

				ASTM D-5185 Elemental Analysis by ICP									ASTM D-5185 Elemental Analysis by ICP														
Vehicle Number	SOT Odo.	Oil Sample Odometer (miles)	Oil Sample Test Miles	Aluminum, ppm	Antimony, ppm	Barium, ppm	Boron, ppm	Cadmium, ppm	Calcium, ppm	Chromium, ppm	Copper, ppm	Iron, ppm	Lead, ppm	Magnesium, ppm	Manganese, ppm	Molyb-denum, ppm	Nickel, ppm	Phosphorus, ppm	Potassium, ppm	Silicon, ppm	Silver, ppm	Sodium, ppm	Strontium, ppm	Tin, ppm	Titanium, ppm	Vanadium, ppm	Zinc, ppm
OR1N	299	4,861	4,562	16	<1	4	82	<1	1969	<1	109	20	<1	11	3	641	<1	649	<5	241	<1	11	<1	1	<1	<1	793
OR1N	299	59,889	59,590	5	<1	<1	47	<1	2024	<1	<1	4	<1	40	<1	216	<1	747	5	8	<1	5	<1	<1	<1	<1	888
OR1N	299	116,610	116,311	4	<1	<1	37	<1	2032	<1	<1	3	<1	41	<1	208	<1	714	<5	6	<1	5	<1	<1	<1	<1	876
OR2N	151	7,138	6,987	30	<1	5	247	<1	1848	1	10	29	1	11	4	378	<1	682	<5	126	<1	13	<1	1	<1	<1	798
OR2N	151	62,865	62,714	16	<1	<1	43	<1	2027	<1	2	12	<1	41	<1	227	<1	784	<5	12	<1	5	<1	<1	<1	<1	897
OR2N	151	114,402	114,251	13	<1	<1	28	<1	2034	<1	<1	7	<1	39	<1	214	<1	731	5	15	<1	6	<1	<1	<1	<1	884
OR3N	127	6,220	6,093	9	<1	<1	49	<1	1960	2	9	35	<1	37	2	210	2	738	8	4	<1	46	<1	1	<1	<1	888
OR3N	127	61,890	61,763	8	<1	<1	43	<1	2251	1	2	30	<1	46	<1	254	1	824	6	5	<1	11	<1	<1	<1	<1	1010
OR3N	127	112,124	111,997	7	<1	<1	26	<1	2169	<1	2	24	<1	44	<1	237	1	758	5	5	<1	8	<1	<1	<1	<1	946
OR4N	268	7,635	7,367	34	<1	3	5	<1	1490	2	34	90	2	14	10	79	1	671	9	23	<1	11	<1	1	<1	<1	784
OR4N	268	60,025		9	<1	<1	37	<1	1903	<1	4	16	<1	40	<1	196	<1	666	5	11	<1	9	<1	<1	<1	<1	815
OR4N	268	113,006		11	<1	<1	30	<1	2036	<1	2	12	<1	44	<1	220	<1	736	5	12	<1	10	<1	<1	<1	<1	896
OR1E	122	4,958	4,836	16	<1	5	84	<1	2292	<1	125	21	1	13	3	633	<1	642	<5	237	<1	13	<1	1	<1	<1	776
OR1E	122	60,084	59,962	5	<1	<1	47	<1	2049	<1	1	5	<1	40	<1	228	<1	759	<5	8	<1	8	<1	<1	<1	<1	883
OR1E	122	116,710	116,588	5	<1	<1	35	<1	2067	<1	<1	3	<1	42	<1	219	<1	736	<5	7	<1	7	<1	<1	<1	<1	883
OR2E	70	7,247	7,177	35	<1	5	239	<1	1844	1	12	29	2	11	4	379	<1	644	5	119	<1	14	<1	2	<1	<1	794
OR2E	70	63,081	63,011	20	<1	<1	38	<1	2100	<1	2	11	<1	42	<1	222	<1	744	5	14	<1	8	<1	<1	<1	<1	915
OR2E	70	115,190	115,120	17	<1	<1	24	<1	2026	<1	2	8	<1	38	<1	213	<1	703	<5	16	<1	8	<1	<1	<1	<1	863
OR3E	227	6,402	6,175	15	<1	<1	51	<1	2007	2	10	42	<1	38	2	226	2	760	7	5	<1	53	<1	<1	<1	<1	906
OR3E	227	62,002	61,775	12	<1	<1	34	<1	2277	2	4	47	<1	45	<1	253	2	797	5	6	<1	12	<1	1	<1	<1	991
OR3E	227	112,216	111,989	8	<1	<1	24	<1	2216	<1	5	26	<1	47	<1	246	1	788	5	5	<1	11	<1	<1	<1	<1	956
OR4E	313	7,735	7,422	20	<1	4	4	<1	1925	3	35	87	3	17	14	81	<1	677	10	26	<1	15	<1	2	<1	<1	835
OR4E	313	60,220	59,907	12	<1	<1	33	<1	1997	<1	4	15	<1	41	<1	208	<1	700	6	12	<1	11	<1	<1	<1	<1	850
OR4E	313	113,151	112,838	12	<1	<1	28	<1	2062	<1	3	9	<1	45	<1	216	<1	726	6	12	<1	12	<1	<1	<1	<1	901
OR1H	641	4,837	4,196	15	<1	5	78	<1	2218	<1	152	24	1	12	3	596	<1	627	5	228	<1	14	<1	1	<1	<1	794
OR1H	641	59,911	59,270	5	<1	<1	43	<1	2072	<1	<1	6	<1	40	<1	213	<1	713	5	7	<1	11	<1	<1	<1	<1	895
OR1H	641	116,486	115,845	5	<1	<1	34	<1	2077	<1	<1	4	<1	43	<1	221	<1	742	5	7	<1	9	<1	<1	<1	<1	895
OR2H	128	7,222	7,094	32	<1	5	242	<1	1894	<1	10	25	2	11	3	372	<1	656	<5	119	<1	17	<1	1	<1	<1	813
OR2H	128	63,058	62,930	9	<1	<1	41	<1	2136	<1	1	11	<1	43	<1	230	<1	773	5	13	<1	9	<1	<1	<1	<1	936
OR2H	128	114,831	114,703	6	<1	<1	27	<1	2060	<1	<1	7	<1	39	<1	225	<1	747	5	13	<1	10	<1	<1	<1	<1	882
OR3H	375	6,290	5,915	12	<1	<1	50	<1	2005	1	9	39	<1	38	2	210	2	726	8	5	<1	55	<1	<1	<1	<1	908
OR3H	375	61,944	61,569	14	<1	<1	36	<1	2290	2	4	54	<1	46	<1	258	2	823	5	6	<1	16	<1	1	<1	<1	1011
OR3H	375	112,371	111,996	8	<1	<1	22	<1	2230	<1	3	27	<1	47	<1	240	1	767	5	5	<1	12	<1	<1	<1	<1	958
OR4H	231	7,803	7,572	26	<1	4	5	<1	1898	2	36	95	3	16	13	84	<1	709	10	27	<1	15	<1	1	<1	<1	853
OR4H	231	60,292	60,061	9	<1	<1	31	<1	2041	<1	3	19	<1	42	<1	216	<1	732	6	13	<1	12	<1	<1	<1	<1	875
OR4H	231	113,187	112,956	7	1	<1	26	<1	2115	<1	2	11	<1	45	<1	222	<1	744	6	12	<1	12	<1	<1	<1	<1	919

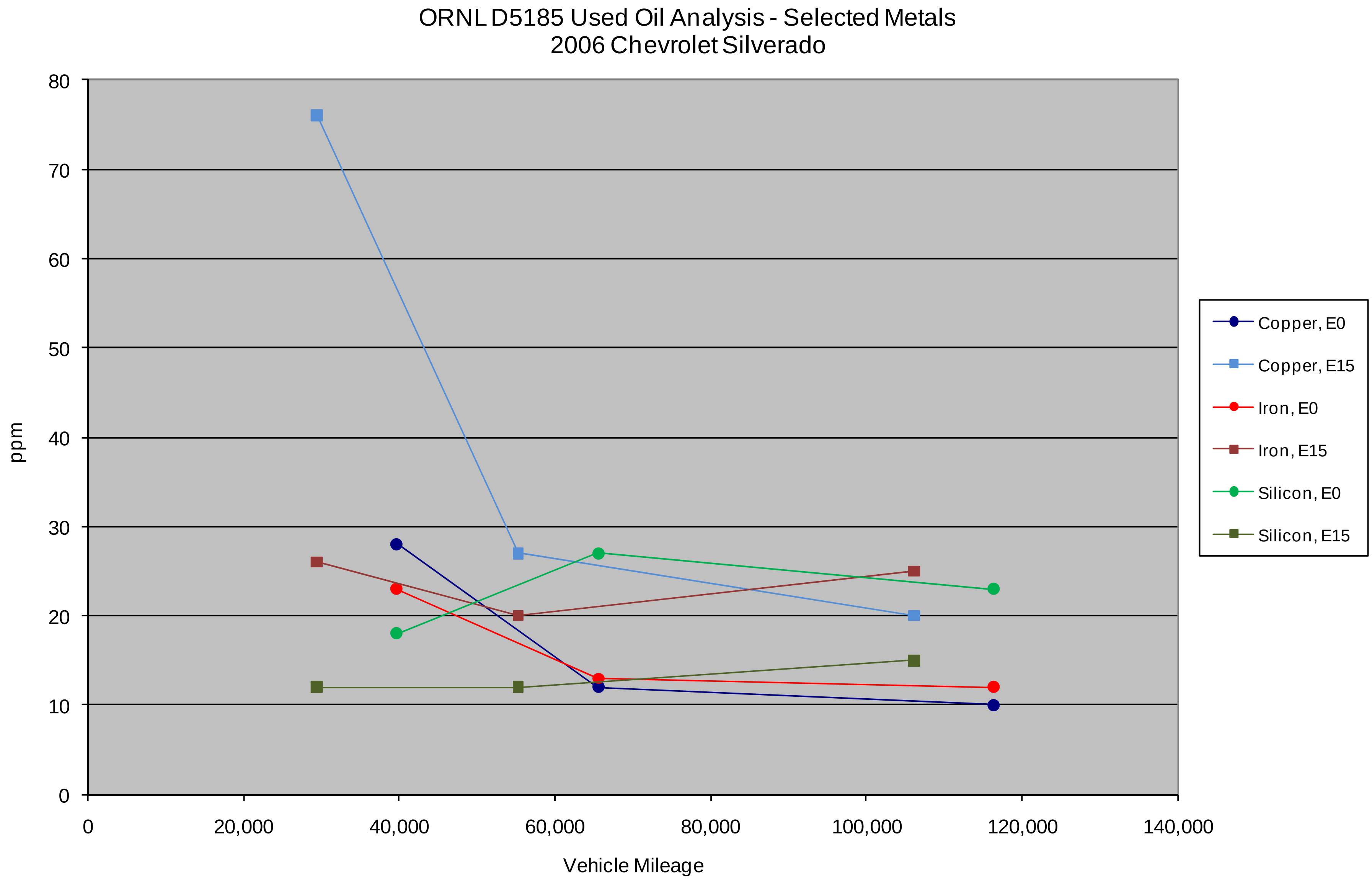

ORNL D5185 Used Oil Analysis - Selected Metals
2006 Chevrolet Cobalt
ppm
Vehicle Mileage
0
5
10
15
20
25
0
20,000
40,000
60,000
80,000
100,000
120,000
140,000
Copper, E0
Copper, E15
Iron, E0
Iron, E15
Silicon, E0
Silicon, E15


ORNL D5185 Used Oil Analysis - Selected Metals
2007 Dodge Caravan
ppm
Vehicle Mileage
0
5
10
15
20
25
30
35
0
20,000
40,000
60,000
80,000
100,000
120,000
Copper, E0
Copper, E15
Iron, E0
Iron, E15
Silicon, E0
Silicon, E15

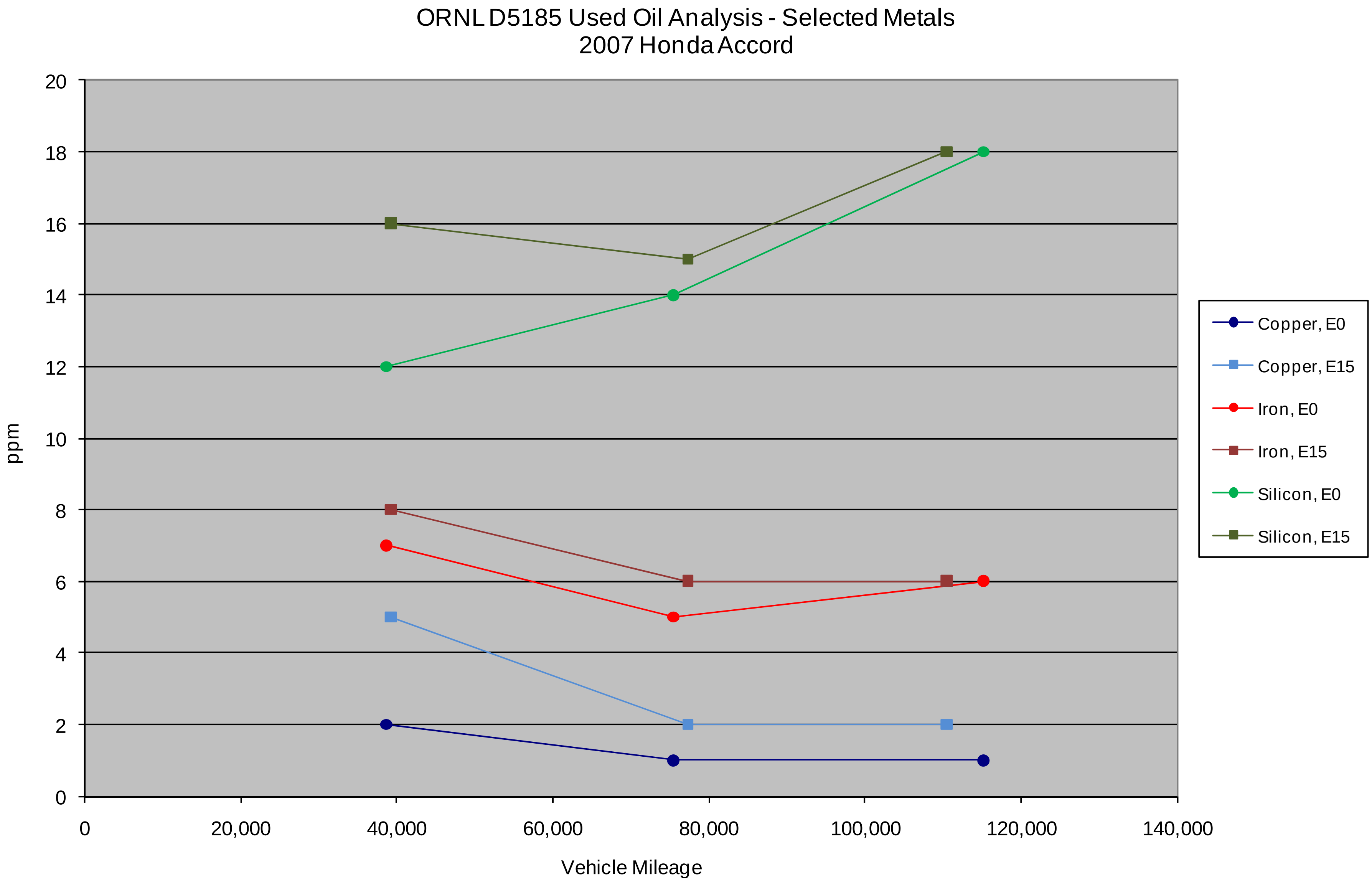

ORNL D5185 Used Oil Analysis - Selected Metals
2008 Ford Taurus
ppm
50
45
40
35
30
25
20
15
10
5
0
0
20,000
40,000
60,000
80,000
100,000
120,000
Vehicle Mileage
Copper, E0
Copper, E15
Iron, E0
Iron, E15
Silicon, E0
Silicon, E15



ORNL D5185 Used Oil Analysis - Selected Metals
2008 Nissan Altima
ppm
Vehicle Mileage
0
5
10
15
20
25
30
35
0
20,000
40,000
60,000
80,000
100,000
120,000
140,000
Copper, E0
Copper, E15
Iron, E0
Iron, E15
Silicon, E0
Silicon, E15



ORNL D5185 Used Oil Analysis - Selected Metals
2006 Chevrolet Silverado
ppm
0
10
20
30
40
50
60
70
80
0
20,000
40,000
60,000
80,000
100,000
120,000
140,000
Vehicle Mileage
Copper, E0
Copper, E15
Iron, E0
Iron, E15
Silicon, E0
Silicon, E15


ORNL D5185 Used Oil Analysis - Selected Metals
2007 Honda Accord
ppm
0
2
4
6
8
10
12
14
16
18
20
0
20,000
40,000
60,000
80,000
100,000
120,000
140,000
Vehicle Mileage
Copper, E0
Copper, E15
Iron, E0
Iron, E15
Silicon, E0
Silicon, E15

Appendix F
Fuel Pump Performance Evaluation and Inspection

ORNL Fuel Pump Measurements

Date: 8/6/2010 Temperature: 75°F

Voltage: 12.0 VDC Fuel: RE0, GA-6947

Flow: Deadhead Operator: A. Rodriguez, J. Ray

	Pump ID	Pressure (kPa)	Speed (rpm)	Current (Amps)
	ORNA0	353	5537	4.06
	ORNA15	358	5608	3.74
	ORNA20	359	5580	3.85
	ORDC0	408	7303	5.64
	ORDC15	401	7078	6.73
	ORDC20	403	7008	6.95
	ORHA0	343	6833	4.71
	ORHA15	345	6309	4.26
	ORHA20	347	6959	4.71
	ORCS0	410	5024	7.42
	ORCS15	411	5141	7.51
	ORCS20	406	5262	7.45
	ORFT0	452	7252	6.63
	ORFT15	453	6778	6.30
	ORFT20	454	7004	6.89
Module Assembly	ORCC0	398	6778	4.73
	ORCC15	403	6739	4.38
	*ORCC15 Br	412	6955	4.70
	ORCC20	430	7076	4.91
Pump Separately	ORCC0	674	6408	6.03
	ORCC15	668	6132	5.63
	*ORCC15 Br	565	6720	5.28

* Module with broken hose connector.

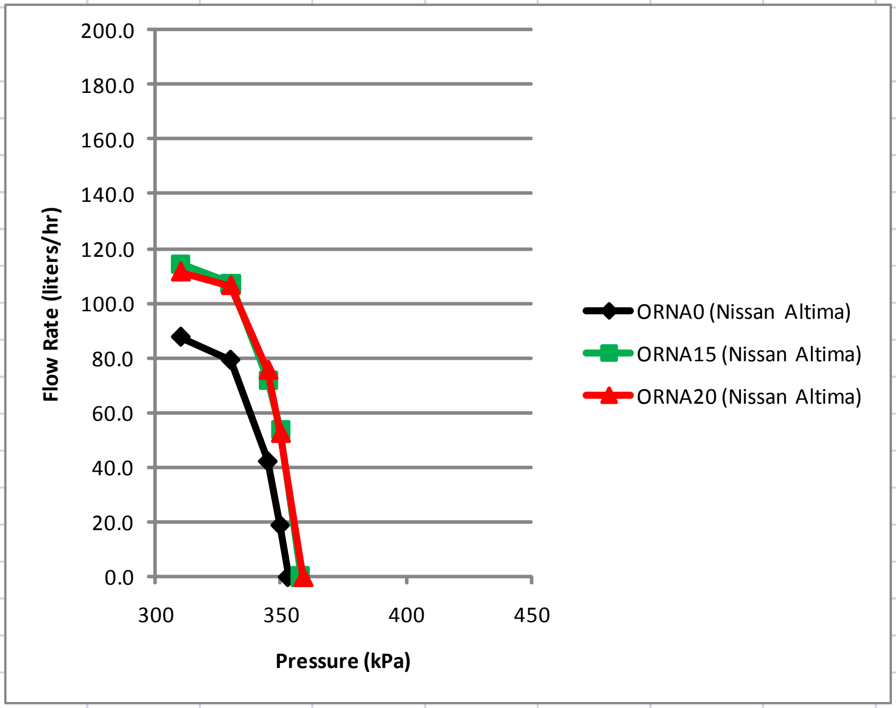
ORNL Fuel Pump Measurements

Date: 8/20/10 to 8/24/2010 Temperature: 75°F

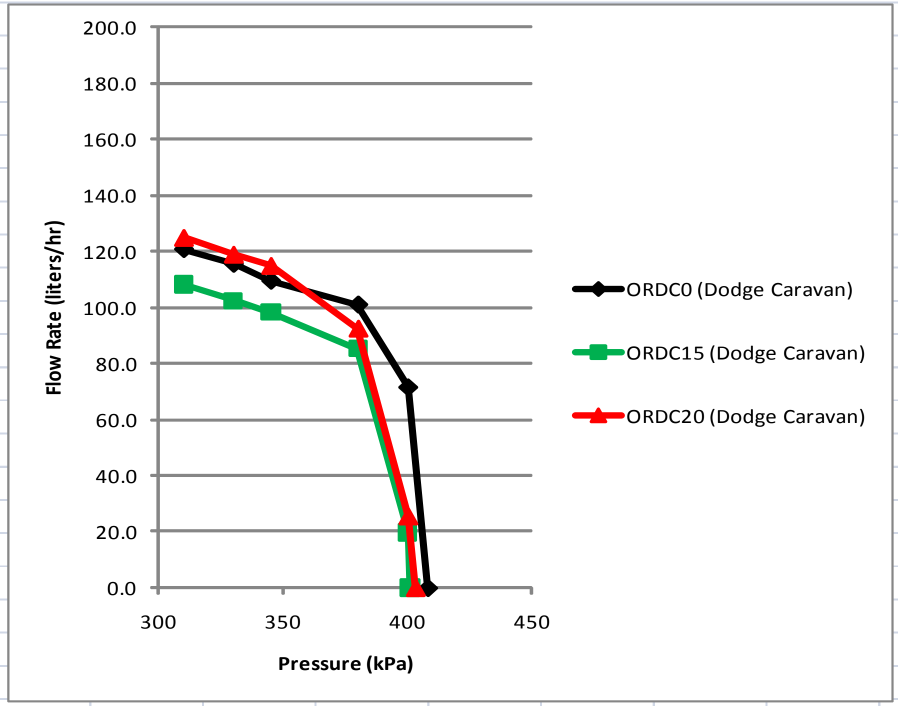
Voltage: 12.0 VDC Fuel: RE0, GA-6947

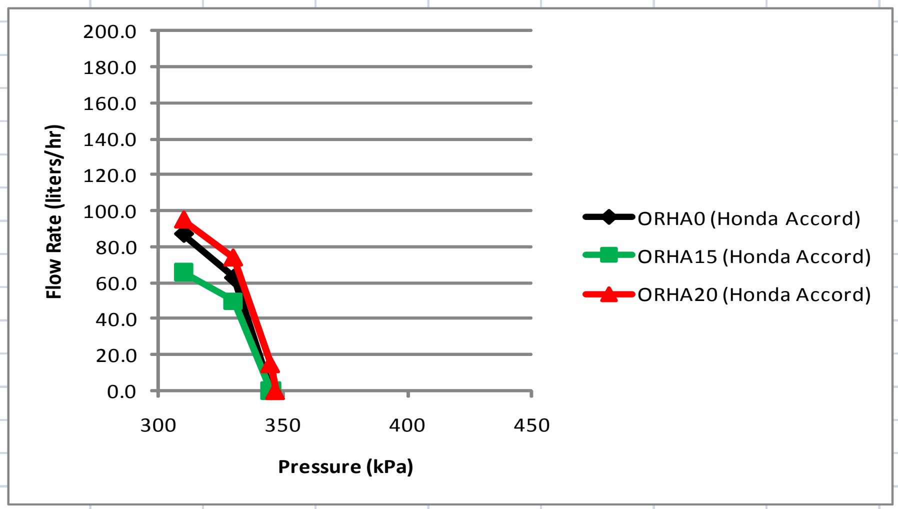
Operator: A. Rodriguez, J. Ray, S. Valentine

Pump ID	Pressure (kPa)	Flow (liters/hr)	Speed (rpm)	Current (Amps)	% Efficiency
ORNA0 (Nissan Altima)	353	0.0	5537	4.06	-
	350	18.9	5416	4.11	3.73
	345	42.2	5617	4.05	8.32
	330	79.2	5639	3.99	15.16
	310	87.6	5710	3.84	16.37
ORNA15 (Nissan Altima)	358	0.0	5608	3.74	-
	350	53.9	5680	3.71	11.77
	345	71.9	5784	3.73	15.39
	330	107.3	5798	3.67	22.33
	310	114.3	5843	3.56	23.04
ORNA20 (Nissan Altima)	359	0.0	5580	3.85	-
	350	52.5	5600	3.83	11.11
	345	75.5	5618	3.78	15.95
	330	106.4	5653	3.71	21.91
	310	111.3	5682	3.60	22.19

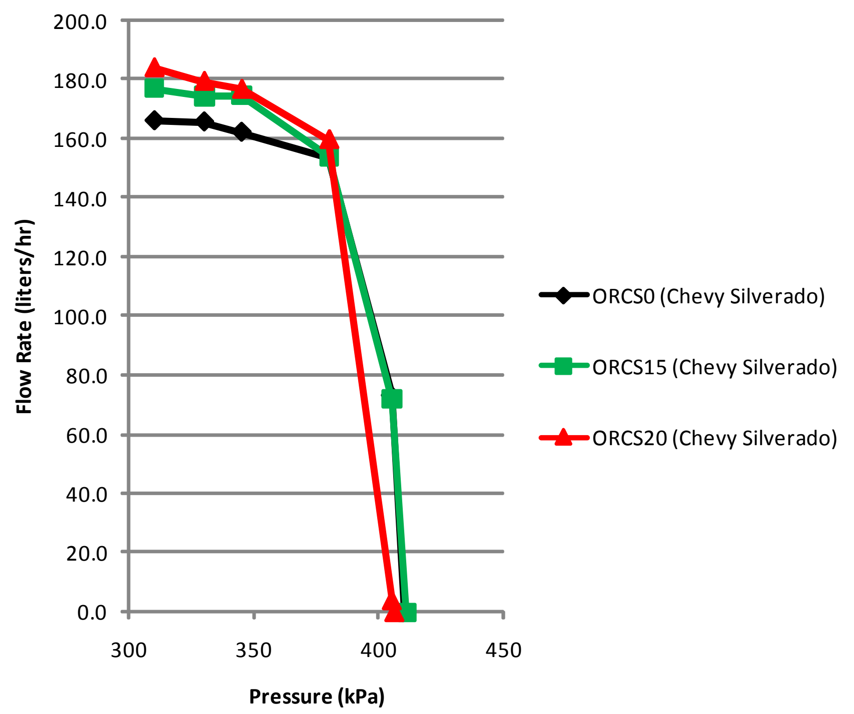


ORDC0 (Dodge Caravan)	408	0.0	7303	5.64	-
	400	71.6	7380	6.51	10.18
	380	101.1	7393	6.23	14.27
	345	109.6	7410	5.95	14.71
	330	115.6	7468	5.84	15.12
	310	120.9	7536	5.72	15.17
ORDC15 (Dodge Caravan)	401	0.0	7078	6.73	-
	400	19.7	7087	6.67	2.73
	380	85.3	7102	6.52	11.51
	345	98.2	7258	6.25	12.55
	330	102.5	7350	6.18	12.67
	310	108.3	7414	6.06	12.82
ORDC20 (Dodge Caravan)	403	0.0	7008	6.95	-
	400	25.6	7013	6.86	3.46
	380	92.6	7038	6.58	12.38
	345	115.0	7445	6.34	14.49
	330	119.0	7503	6.23	14.59
	310	125.0	7608	6.13	14.63
ORHA0 (Honda Accord)	343	0.0	6833	4.71	-
	345	0.0	6833	4.71	0.00
	330	62.8	6890	4.72	10.16
	310	87.1	6944	4.59	13.62
ORHA15 (Honda Accord)	345	0.0	6309	4.17	-
	345	0.0	6309	4.17	0.00
	330	49.8	6171	4.02	9.46
	310	65.7	6190	3.89	12.12
ORHA20 (Honda Accord)	347	0.0	6959	4.71	-
	345	14.9	6980	4.68	2.54
	330	74.0	7038	4.56	12.40
	310	95.0	7112	4.40	15.49

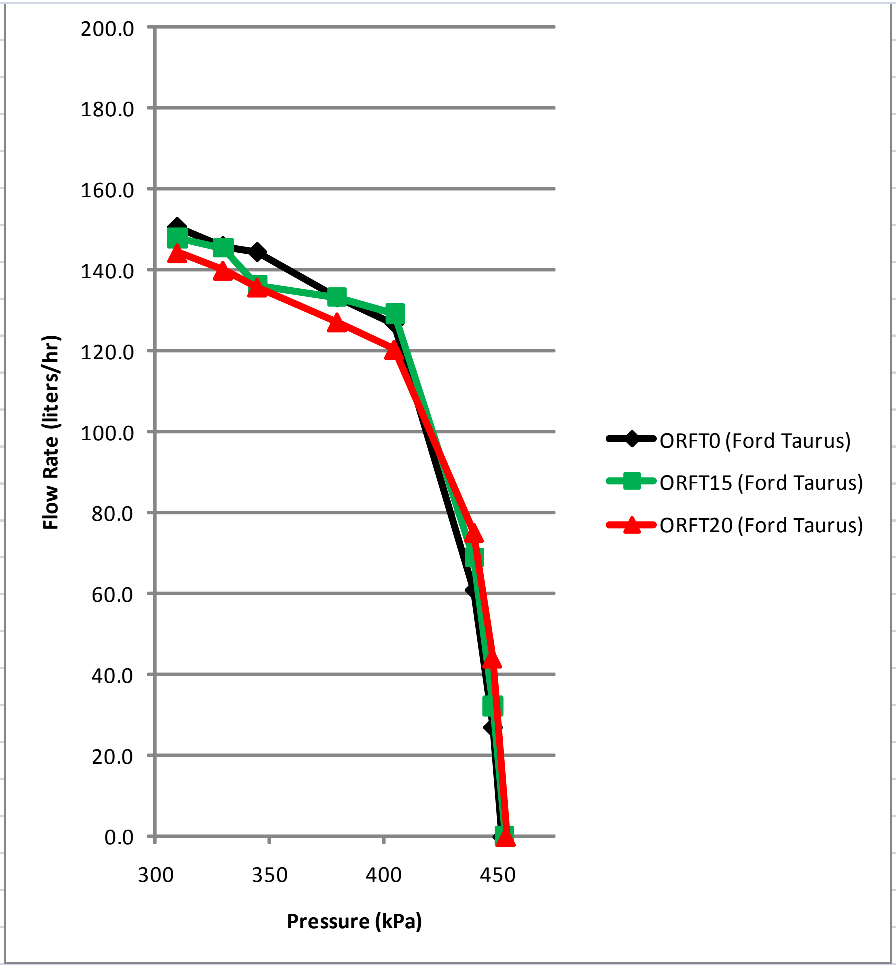




ORCS0 (Chevy Silverado)	410	0.0	5024	7.42	-
	405	73.4	5039	7.41	9.29
	380	153.9	4988	7.27	18.62
	345	162.5	5068	7.12	18.23
	330	166.0	5070	6.88	18.43
	310	166.4	5122	6.83	17.48
ORCS15 (Chevy Silverado)	411	0.0	5141	7.51	-
	405	71.9	5165	7.52	8.96
	380	154.1	5402	7.71	17.58
	345	174.9	5470	7.49	18.65
	330	174.4	5513	7.40	18.00
	310	177.0	5563	7.22	17.59
ORCS20 (Chevy Silverado)	406	0.0	5262	7.45	-
	405	4.0	5250	7.44	0.50
	380	160.0	5270	7.35	19.15
	345	177.0	5340	7.07	19.99
	330	179.7	5368	7.00	19.61
	310	184.3	5424	6.88	19.22

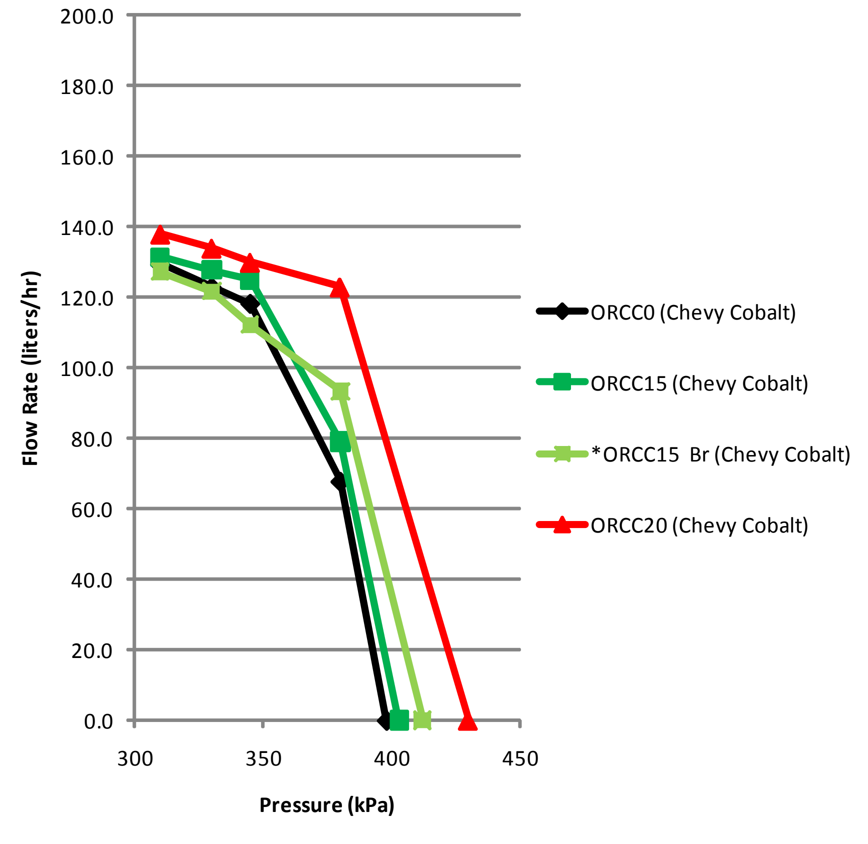


ORFT0 (Ford Taurus)	452	0.0	7252	6.63	-
	448	27.0	7220	6.62	4.23
	440	60.9	7268	6.61	9.38
	405	126.7	7366	6.34	18.74
	380	133.1	7464	6.16	19.01
	345	144.3	7610	5.88	19.60
	330	145.8	7674	5.76	19.34
	310	150.5	7723	5.58	19.35
ORFT15 (Ford Taurus)	453	0.0	6778	6.30	-
	448	32.2	6769	6.40	5.22
	440	68.9	6876	6.27	11.19
	405	129.2	7003	6.07	19.95
	380	133.3	7087	5.89	19.91
	345	136.2	7185	5.64	19.29
	330	145.4	7248	5.54	20.05
	310	147.9	7331	5.40	19.65
ORFT20 (Ford Taurus)	454	0.0	7004	6.89	-
	448	44.1	7068	6.85	6.68
	440	75.2	7025	6.80	11.26
	405	120.4	7136	6.52	17.31
	380	127.2	7233	6.30	17.76
	345	135.8	7366	6.00	18.08
	330	140.0	7440	5.85	18.28
	310	144.3	7505	5.69	18.20



ORCC0 (Chevy Cobalt)	398	0.0	6778	4.73	-
	380	67.8	6857	4.70	12.69
	345	118.3	6886	4.45	21.23
	330	122.9	6930	4.37	21.48
	310	129.4	6974	4.28	21.70
ORCC15 (Chevy Cobalt)	403	0.0	6739	4.38	-
	380	79.0	6803	4.27	16.27
	345	124.9	6876	4.11	24.27
	330	127.7	6905	4.03	24.21
	310	131.4	6954	3.93	23.99
*ORCC15 Br (Chevy Cobalt)	412	0.0	6955	4.70	-
	380	93.3	7082	4.53	18.12
	345	112.2	7155	4.36	20.55
	330	121.7	7150	4.27	21.77
	310	127.3	7194	4.19	21.80
ORCC20 (Chevy Cobalt)	430	0.0	7076	4.91	-
	380	123.0	7200	4.65	23.27
	345	130.0	7259	4.47	23.23
	330	134.0	7285	4.38	23.37
	310	138.0	7322	4.27	23.19

* Module with broken hose connector.



Fuel Pump Teardown Comments

From the flow performance measurements, no major flow problems were uncovered. The results of the teardown evaluation revealed no significant defects or wear. Some parts had wear indications that would likely continue and eventually lead to poor pump performance given continued service of the pump. The parts noted having relatively greater or less wear (shown in their respective photo in the following pages) are listed below.

Pumps ORCS0, ORCS15, and ORCC15 Br were not included in the teardown evaluation. These three pumps were misplaced at SwRI and not available for teardown.

Pump	Component	Comment
ORNA0	Commutator	Heavy wear on trailing edge of commutator segments.
	Brushes	Wear on commutator NOT seen on mating brushes.
ORNA15	Impeller Cover, Outlet Side	Surface polishing at outer radius between high and low pressure area.
	Commutator	Heavy wear NOT seen on trailing edge of commutator segments.
ORNA20	Commutator	Heavy wear on outer radius and trailing edge of commutator segments.
	Brushes	Normal wear on brushes.
ORDC0	Impeller Cover, Inlet and Outlet	Surface polishing at outer radius between high and low pressure area.
	Sock Filter	Significant discoloration of sock filter.
ORDC15	Impeller Cover, Inlet and Outlet	Less surface polishing than seen on ORDC0.
	Commutator	Deeper radial wear grooves than ORDC0 or ORDC20.
ORDC20	Commutator	Normal to light wear on commutator.
	Brushes	Normal to light wear on brushes.

Fuel Pump Teardown Comments - continued

Pump	Component	Comment
ORHA0	Impeller Cover, Inlet and Outlet	Some surface wear on outer radius between high and low pressure area.
ORHA15	Impeller Cover, Inlet and Outlet	Some surface wear on outer radius between high and low pressure area.
ORHA20	Brushes	Heavy wear on brushes.
	Impeller Cover, Inlet and Outlet	Heavy wear on sufrace at outer radius between high and low pressure area.
ORFT0	Impeller Cover, Inlet and Outlet	Some surface wear on outer radius between high and low pressure area.
	Commutator	Heavy wear on trailing edge of commutator segments.
ORFT15	Impeller Cover, Inlet and Outlet	Some surface wear at outer radius between high and low pressure area.
ORFT20	Commutator	Heavy wear on trailing edge of commutator segments.
	Brushes	Heavy wear on brushes.
ORCC0	Commutator	Extra heavy wear on trailing edge of commutator segments.
	Brushes	Heavy wear on brushes.
ORCC15	Impeller Cover, Inlet and Outlet	No signs of surface wear at outer radius between high and low pressure area.
	Commutator	No signs of wear on trailing edge of commutator segments.
	Sock Filter	Only minor discoloration of filter element.
ORCC20	Commutator	Slight wear at trailing edge of commutator segments.
	Brushes	Heavy wear on brushes.
ORCS20	Commutator	Wear on commutator, with extra wear at trailing edges of commutator segments.
	Brushes	Light wear on brushes.

Figure F1. ORNA0 Fuel Pump Impeller with Inlet (Left) and Outlet (Right) Mating Cover.

Figure F2. ORNA0 Fuel Pump Brushes (Left) and Commutator (Right).

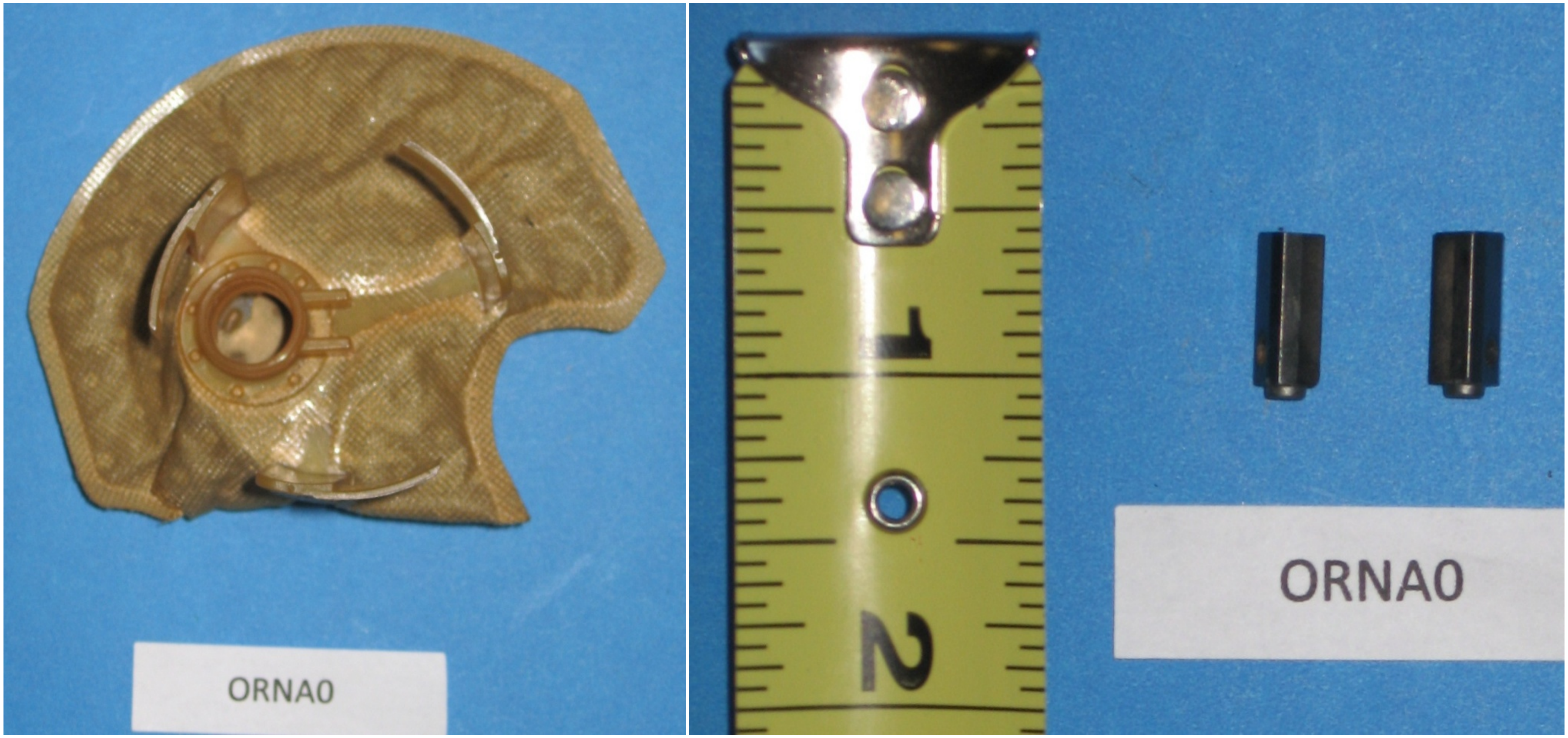


Figure F3. ORNA0 Fuel Pump Sock Filter (Left) and Brushes (Right).

Figure F4. ORNA15 Fuel Pump Impeller with Inlet (Left) and Outlet (Right) Mating Cover.

Figure F5. ORNA15 Fuel Pump Brushes (Left) and Commutator (Right).

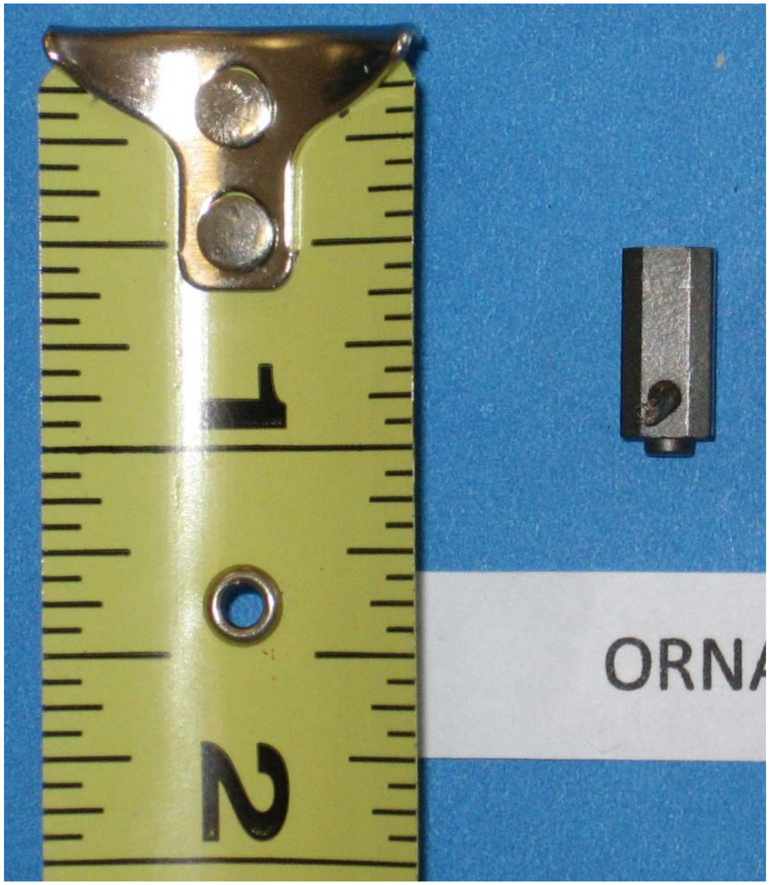


Figure F6. ORNA15 Fuel Pump Sock Filter (Left) and Brushes (Right).

Figure F7. ORNA20 Fuel Pump Impeller with Inlet (Left) and Outlet (Right) Mating Cover.

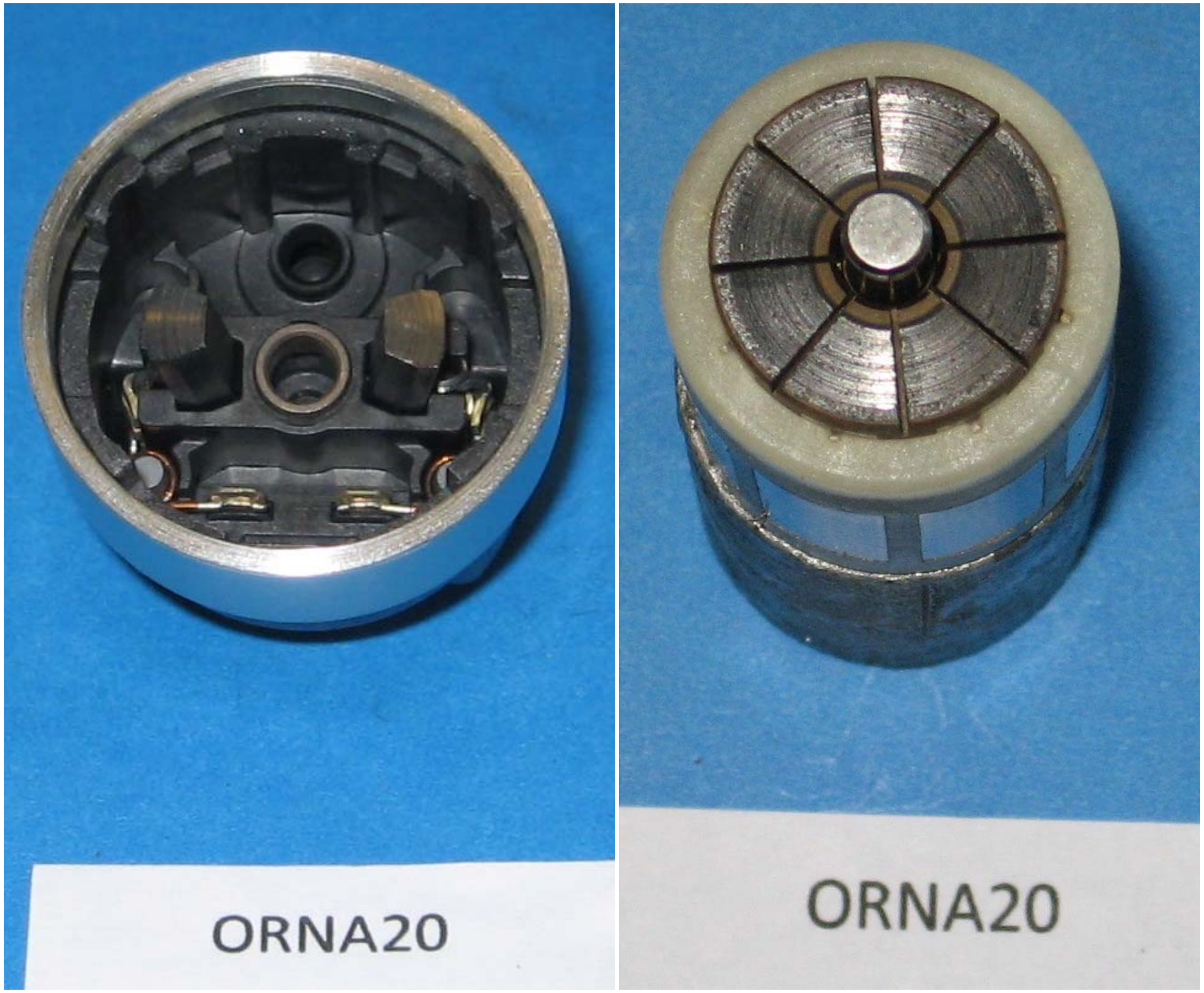


Figure F8. ORNA20 Fuel Pump Brushes (Left) and Commutator (Right).

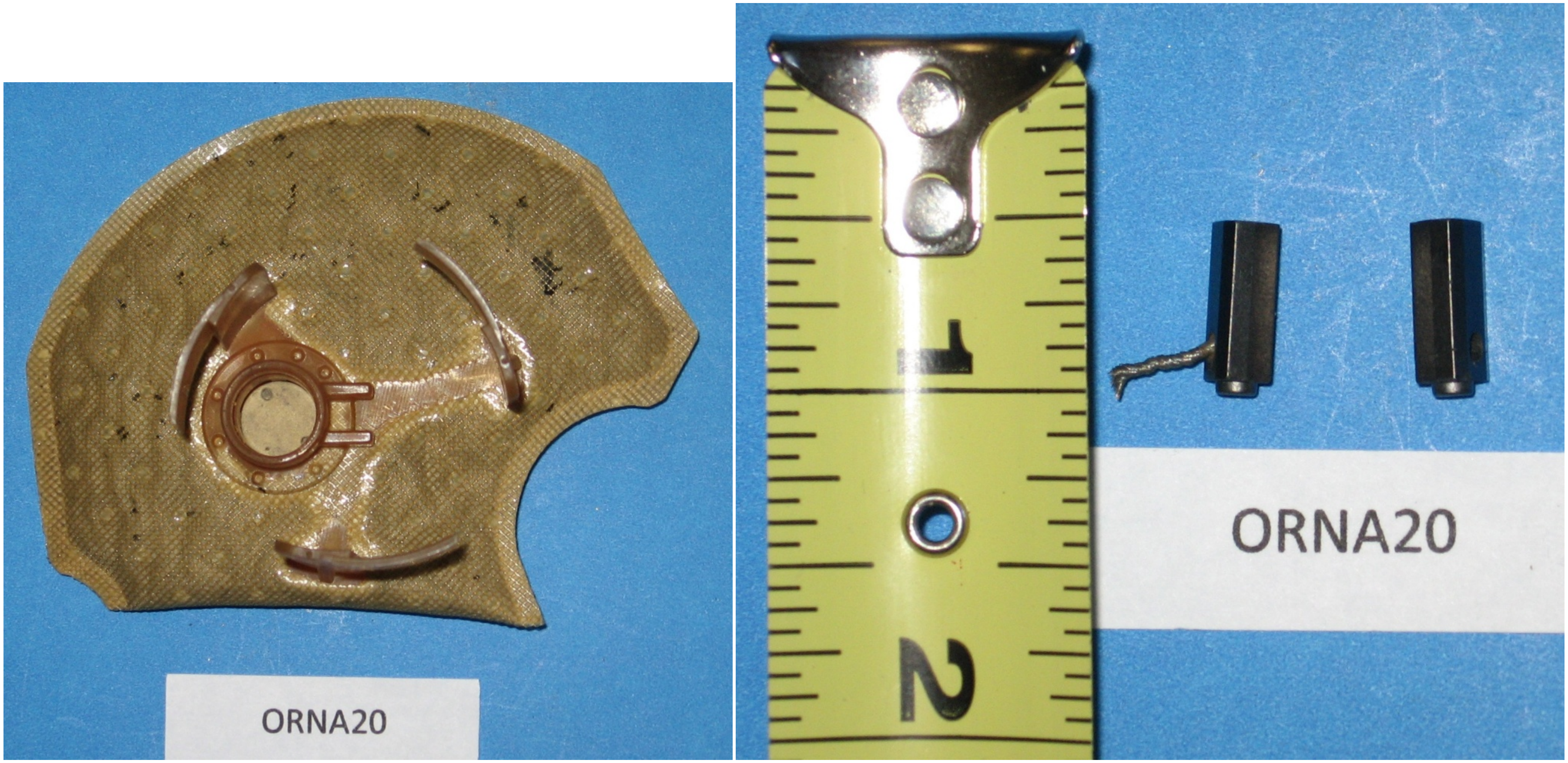


Figure F9. ORNA20 Fuel Pump Sock Filter (Left) and Brushes (Right).

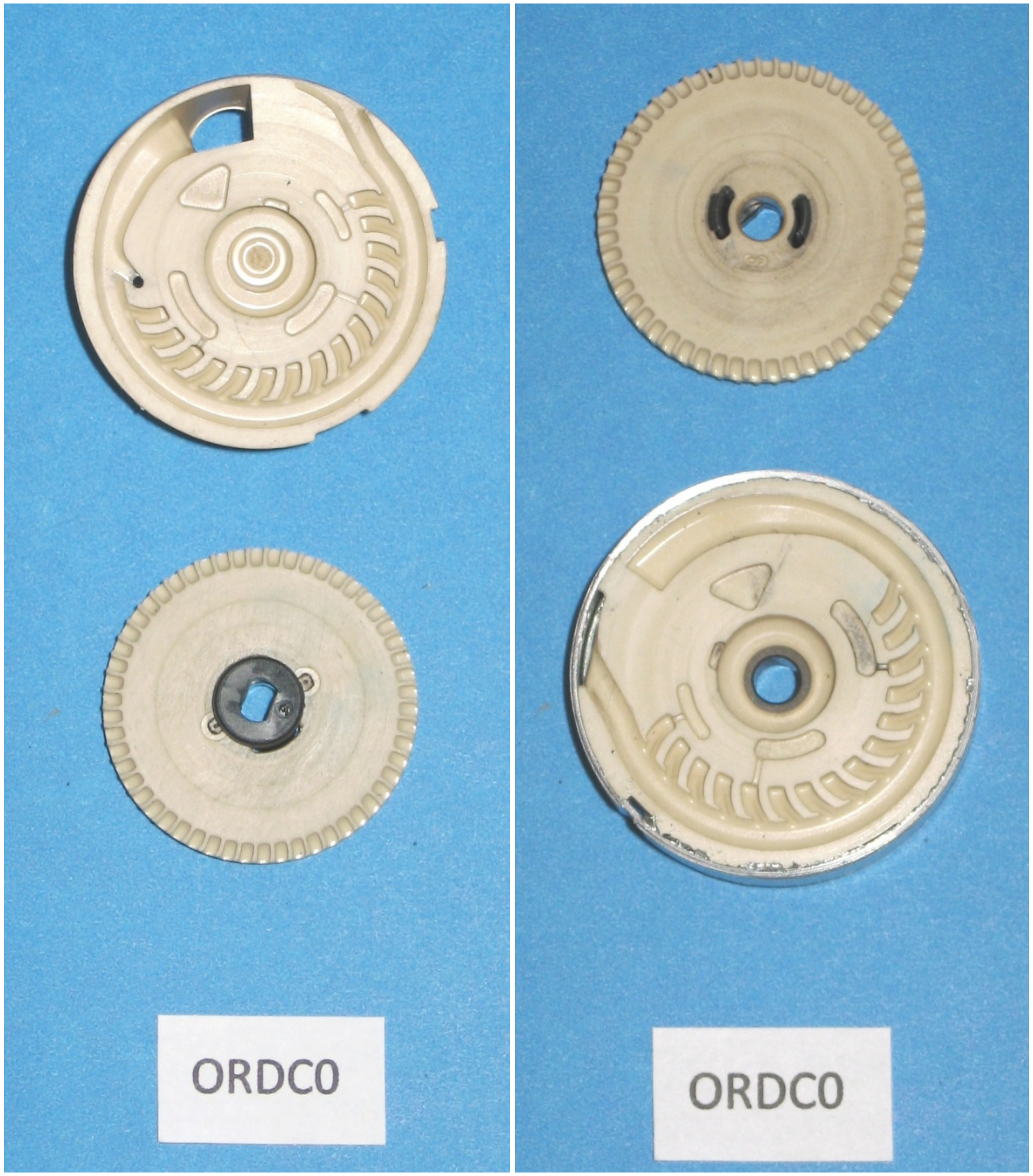


Figure F10. ORDC0 Fuel Pump Impeller with Inlet (Left) and Outlet (Right) Mating Cover.

Figure F11. ORDC0 Fuel Pump Brushes (Left) and Commutator (Right).

Figure F12. ORDC0 Fuel Pump Sock Filter (Left) and Brushes (Right).

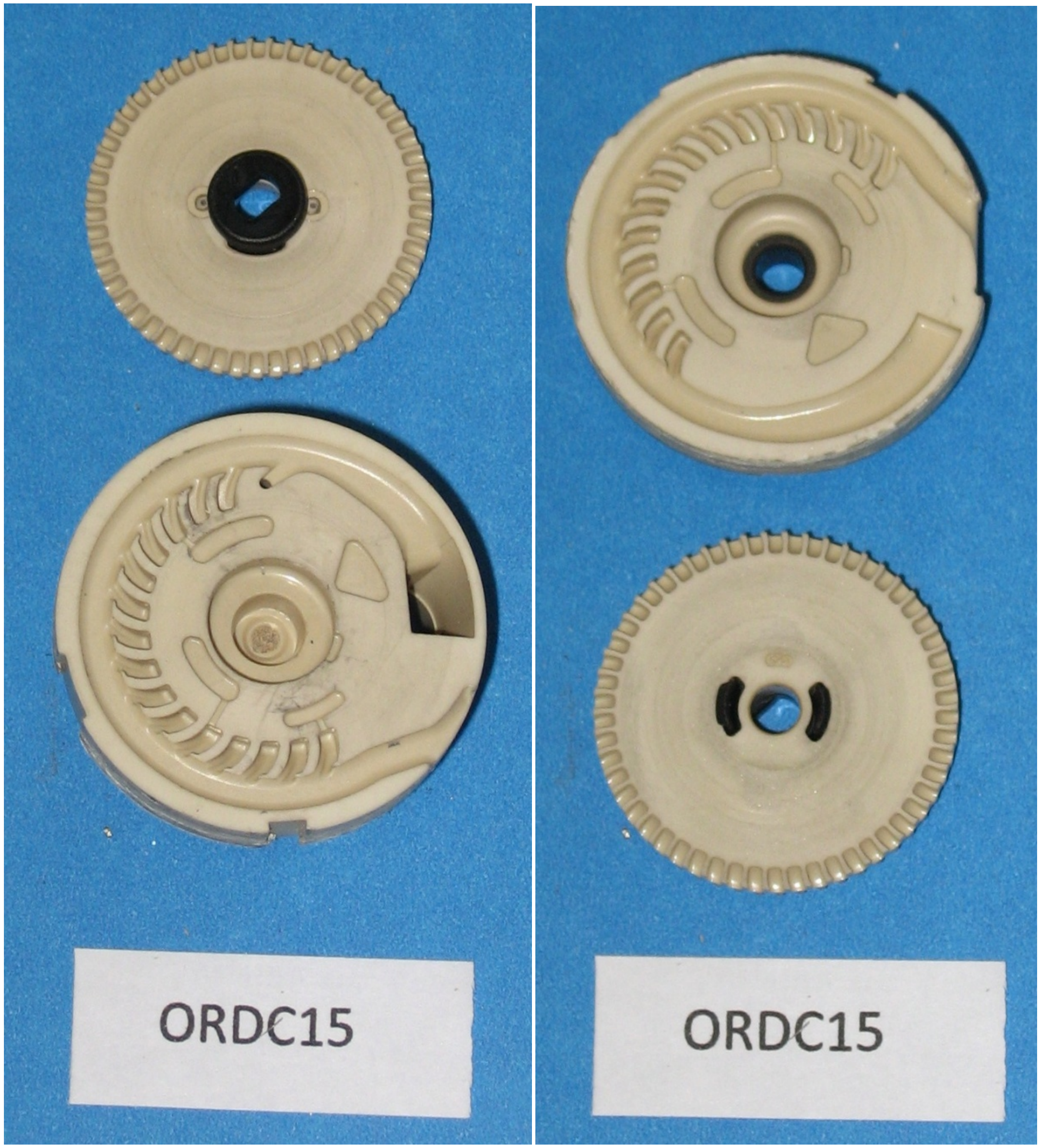


Figure F13. ORDC15 Fuel Pump Impeller with Inlet (Left) and Outlet (Right) Mating Cover.

Figure F14. ORDC15 Fuel Pump Brushes (Left) and Commutator (Right).

Figure F15. ORDC15 Fuel Pump Sock Filter (Left) and Brushes (Right).

Figure F16. ORDC20 Fuel Pump Impeller with Inlet (Left) and Outlet (Right) Mating Cover.

Figure F17. ORDC20 Fuel Pump Brushes (Left) and Commutator (Right).

Figure F18. ORDC20 Fuel Pump Sock Filter (Left) and Brushes (Right).

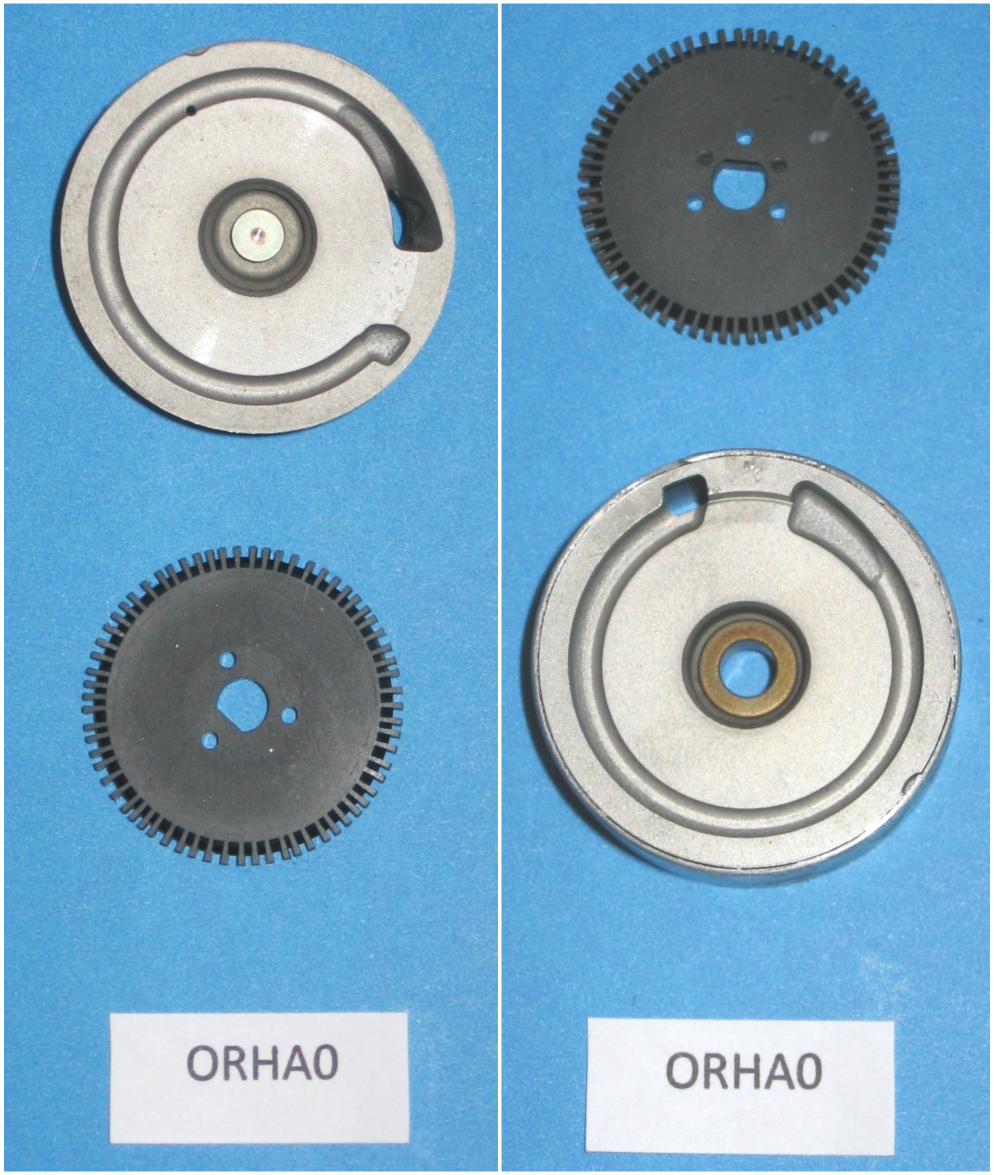


Figure F19. ORHA0 Fuel Pump Impeller with Inlet (Left) and Outlet (Right) Mating Cover.

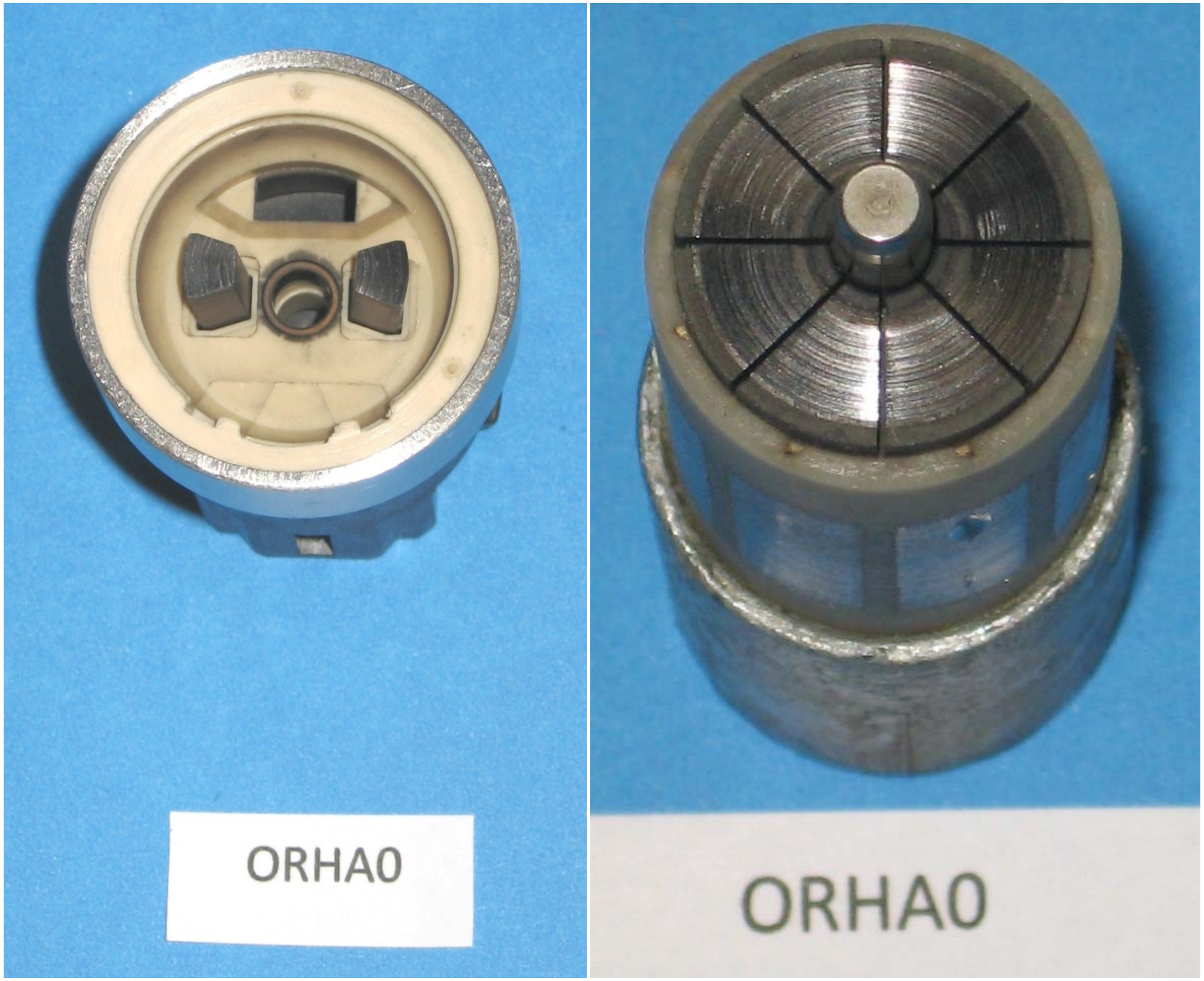


Figure F20. ORHA15 Fuel Pump Brushes (Left) and Commutator (Right).

Figure F21. ORHA0 Fuel Pump Sock Filter (Left) and Brushes (Right).

Figure F22. ORHA15 Fuel Pump Impeller with Inlet (Left) and Outlet (Right) Mating Cover.

Figure F23. ORHA15 Fuel Pump Brushes (Left) and Commutator (Right).

Figure F24. ORHA15 Fuel Pump Sock Filter (Left) and Brushes (Right).

Figure F25. ORHA20 Fuel Pump Impeller with Inlet (Left) and Outlet (Right) Mating Cover.

Figure F26. ORHA20 Fuel Pump Brushes (Left) and Commutator (Right).

Figure F27. ORHA20 Fuel Pump Sock Filter (Left) and Brushes (Right).

Figure F28. ORFT0 Fuel Pump Impeller with Inlet (Left) and Outlet (Right) Mating Cover.

Figure F29. ORFT0 Fuel Pump Brushes (Left) and Commutator (Right).

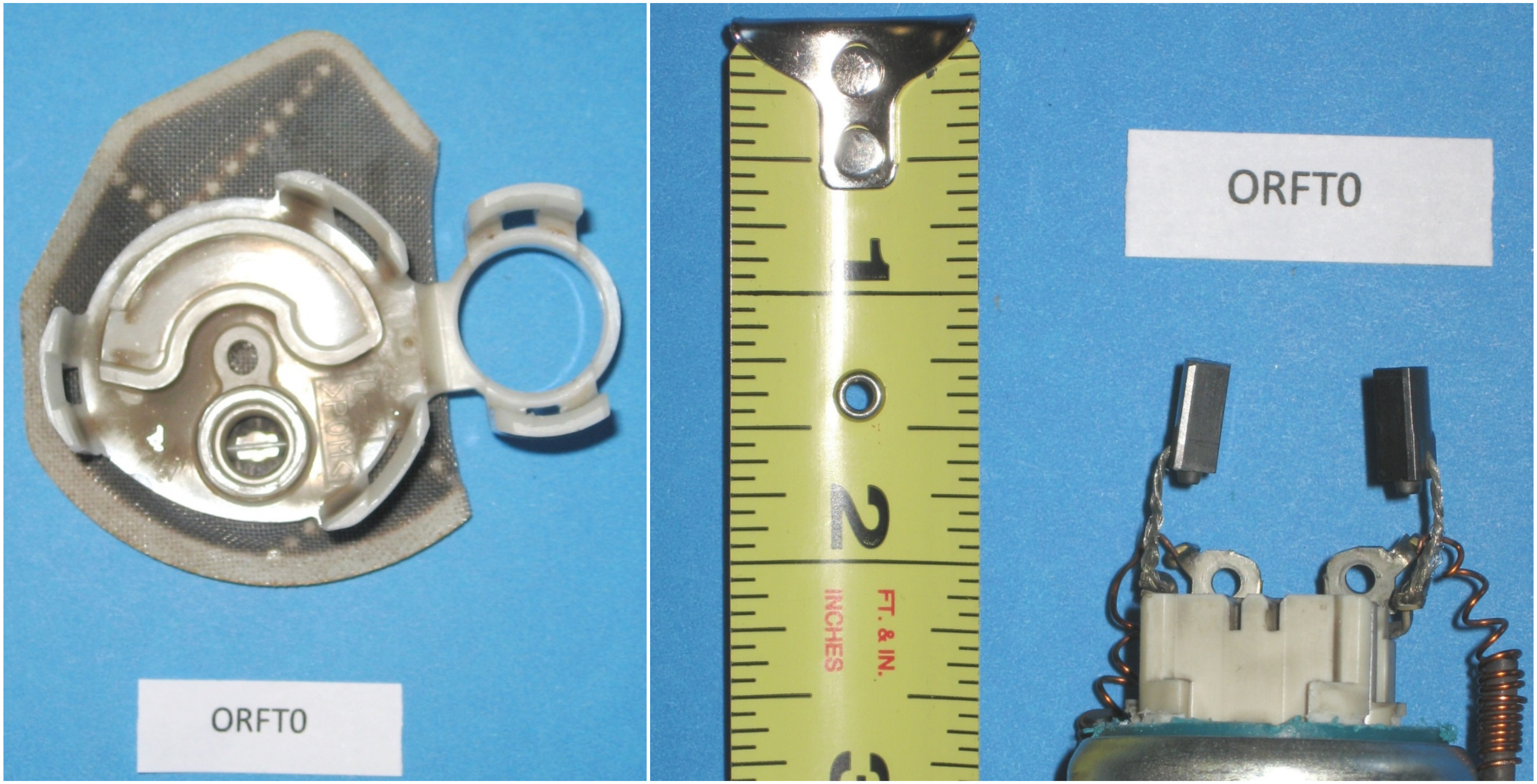


Figure F30. ORFT0 Fuel Pump Sock Filter (Left) and Brushes (Right).

Figure F31. ORFT15 Fuel Pump Impeller with Inlet (Left) and Outlet (Right) Mating Cover.

Figure F32. ORFT15 Fuel Pump Brushes (Left) and Commutator (Right).

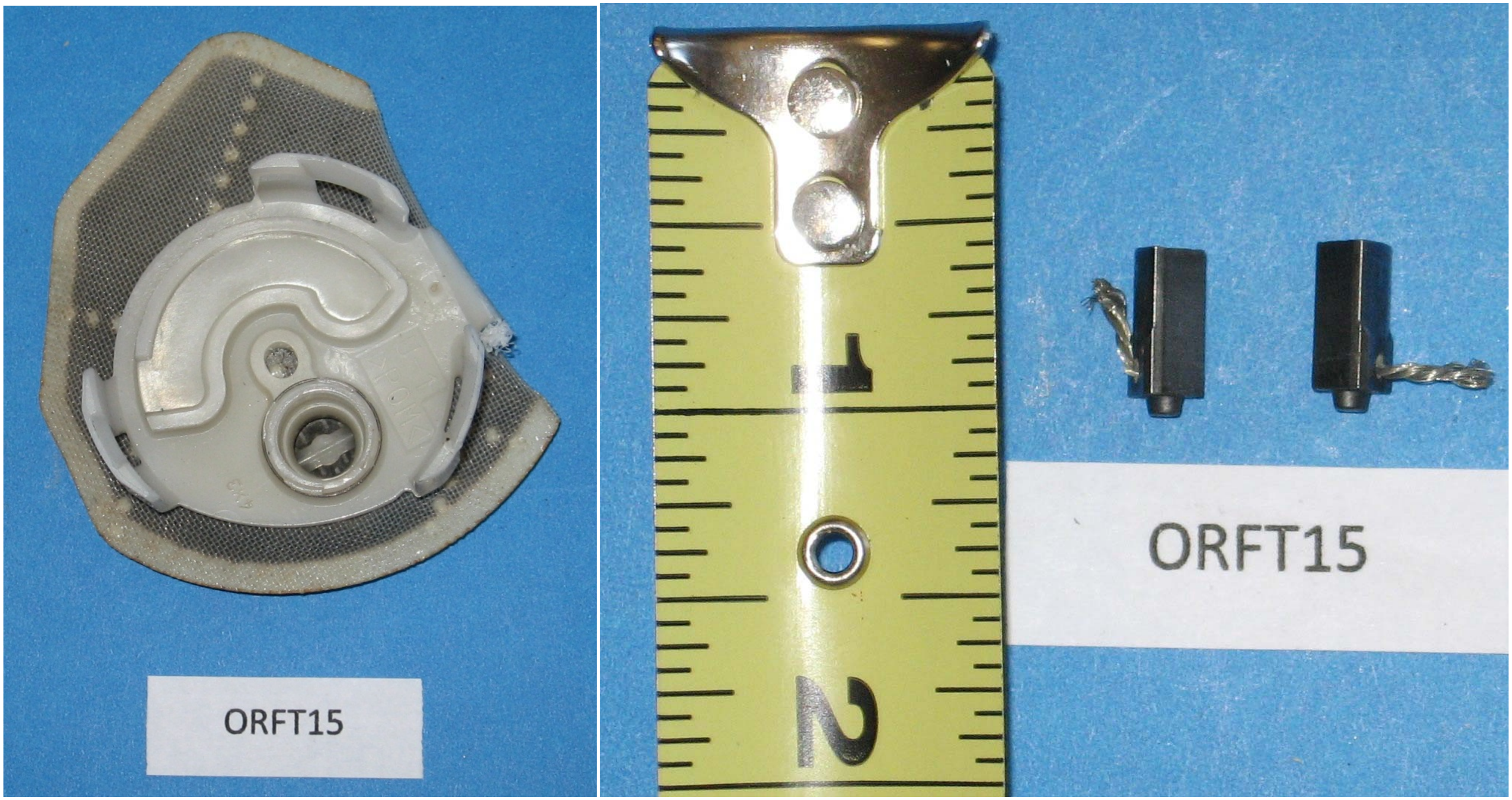


Figure F33. ORFT15 Fuel Pump Sock Filter (Left) and Brushes (Right).

Figure F34. ORFT20 Fuel Pump Impeller with Inlet (Left) and Outlet (Right) Mating Cover.

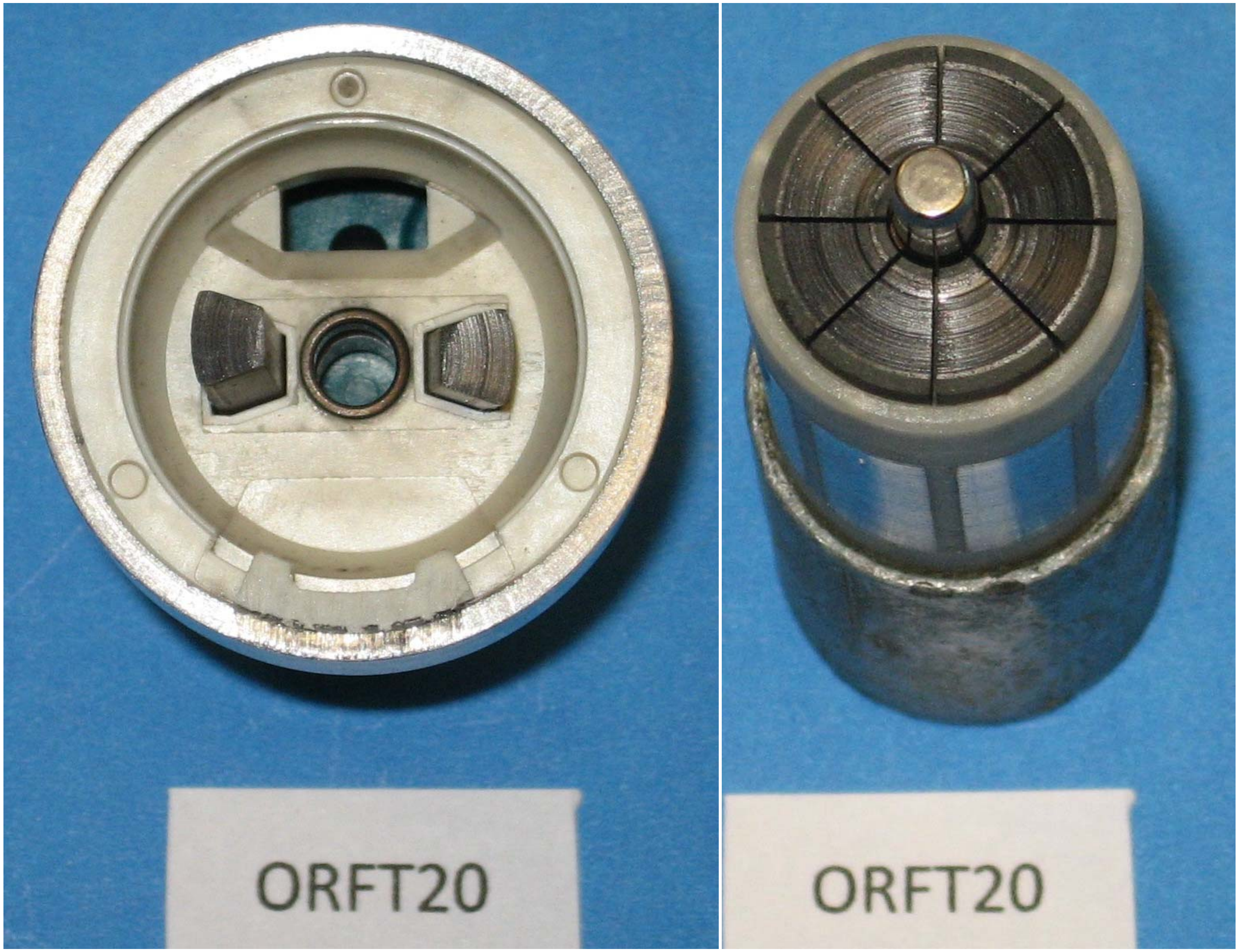


Figure F35. ORFT20 Fuel Pump Brushes (Left) and Commutator (Right).

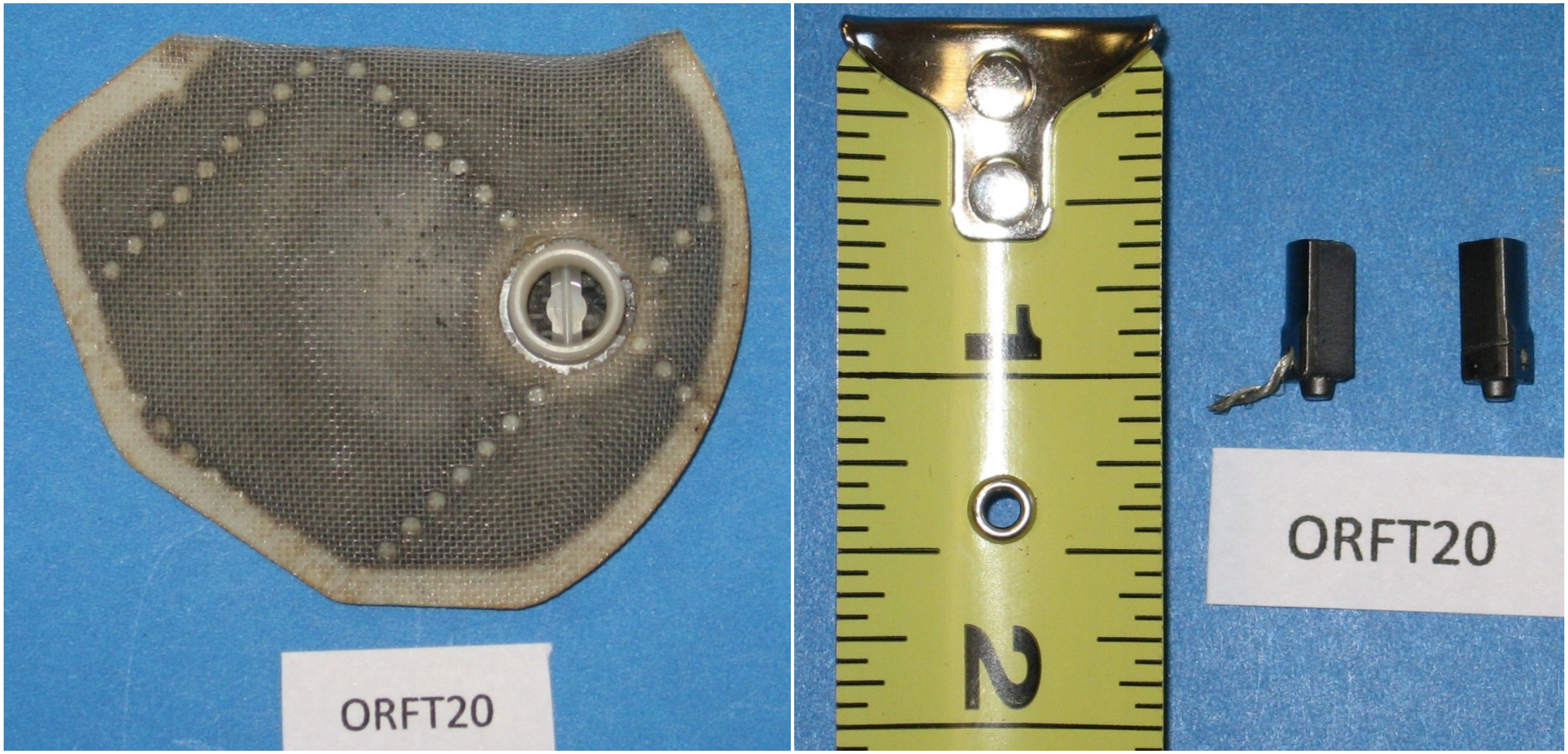


Figure F36. ORFT20 Fuel Pump Sock Filter (Left) and Brushes (Right).

Figure F37. ORCC0 Fuel Pump Impeller with Inlet (Left) and Outlet (Right) Mating Cover.

Figure F38. ORCC0 Fuel Pump Brushes (Left) and Commutator (Right).

Figure F39. ORCC0 Fuel Pump Sock Filter (Left) and Brushes (Right).

Figure F40. ORCC15 Fuel Pump Impeller with Inlet (Left) and Outlet (Right) Mating Cover.

Figure F41. ORCC15 Fuel Pump Brushes (Left) and Commutator (Right).

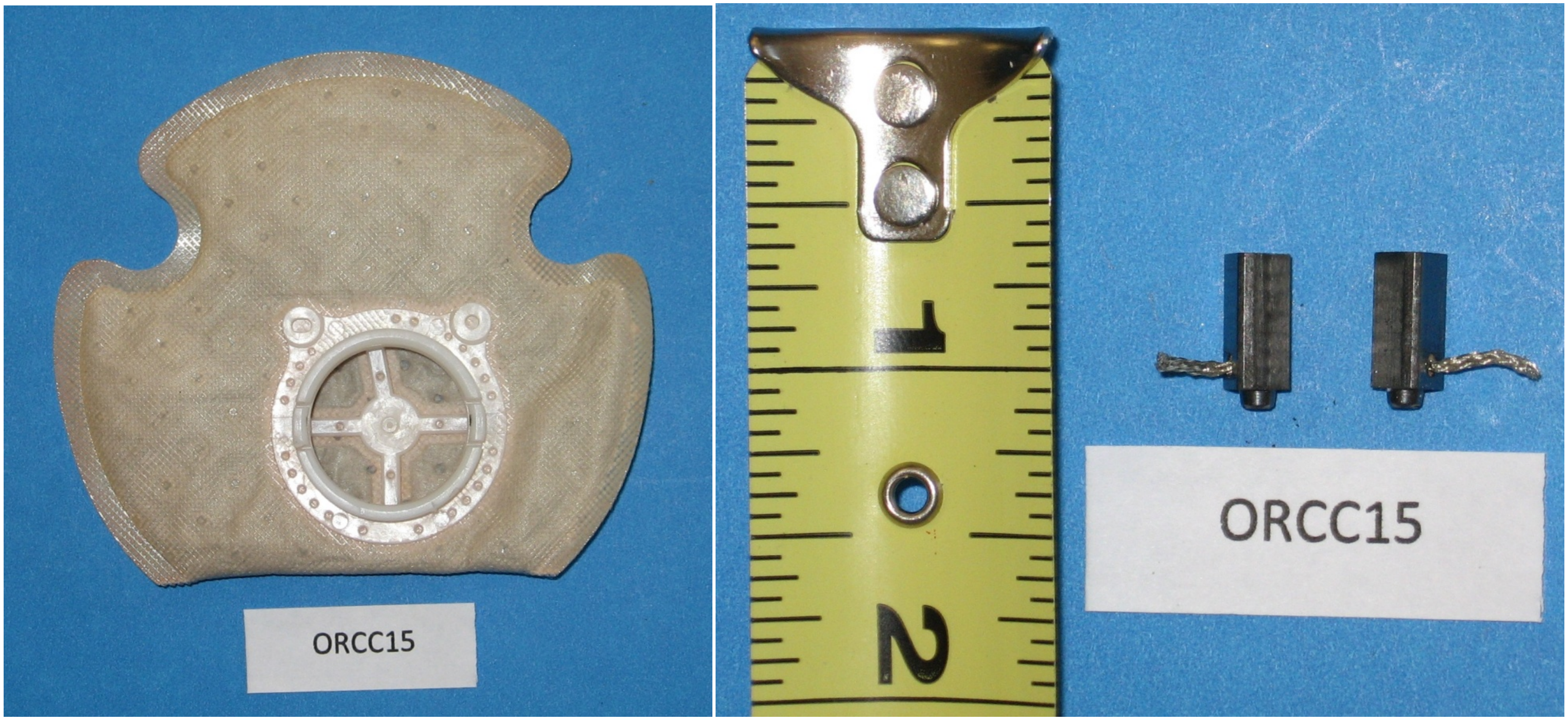


Figure F42. ORCC15 Fuel Pump Sock Filter (Left) and Brushes (Right).

Figure F43. ORCC20 Fuel Pump Impeller with Inlet (Left) and Outlet (Right) Mating Cover.

Figure F44. ORCC20 Fuel Pump Brushes (Left) and Commutator (Right).

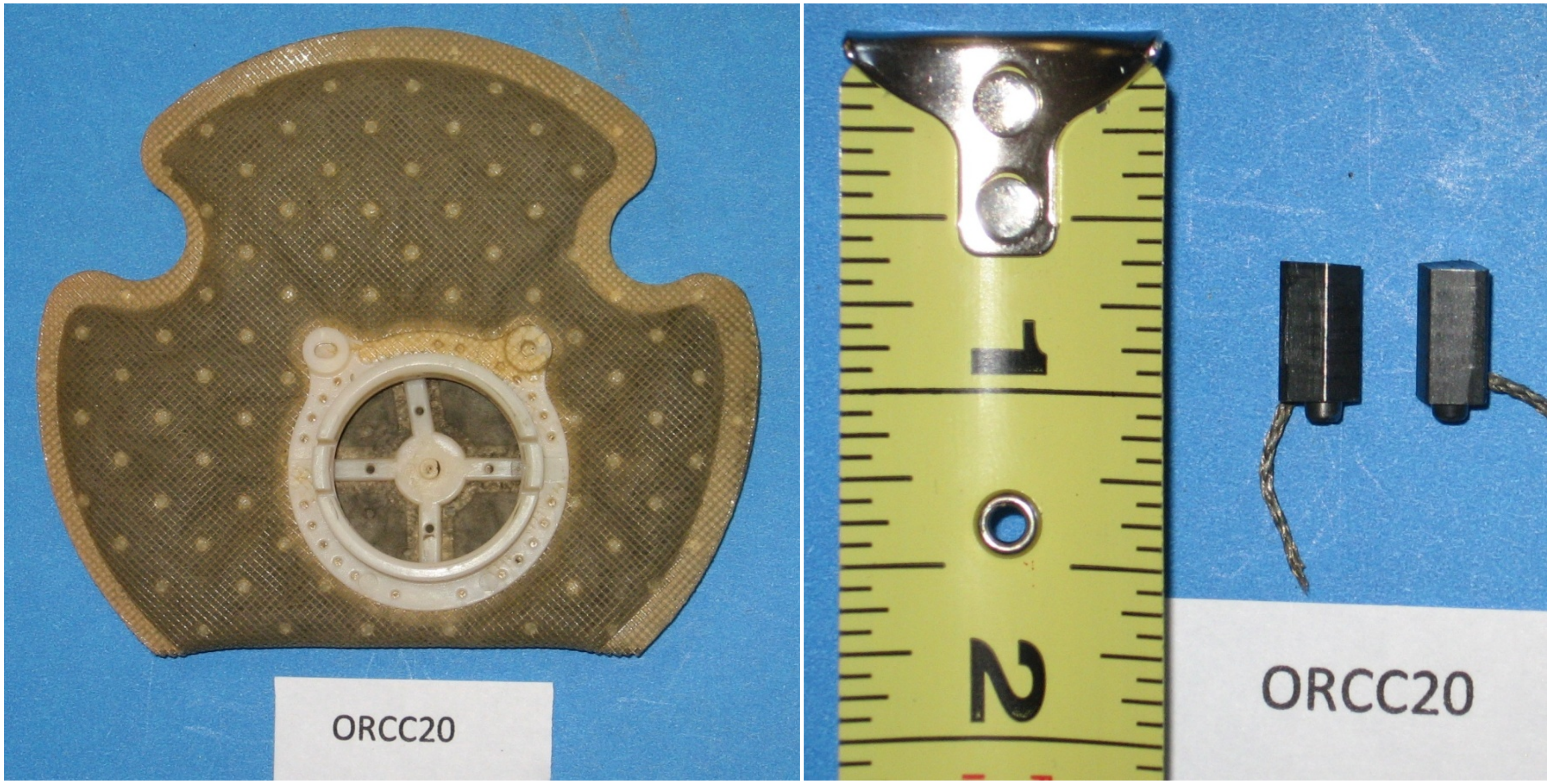


Figure F45. ORCC20 Fuel Pump Sock Filter (Left) and Brushes (Right).

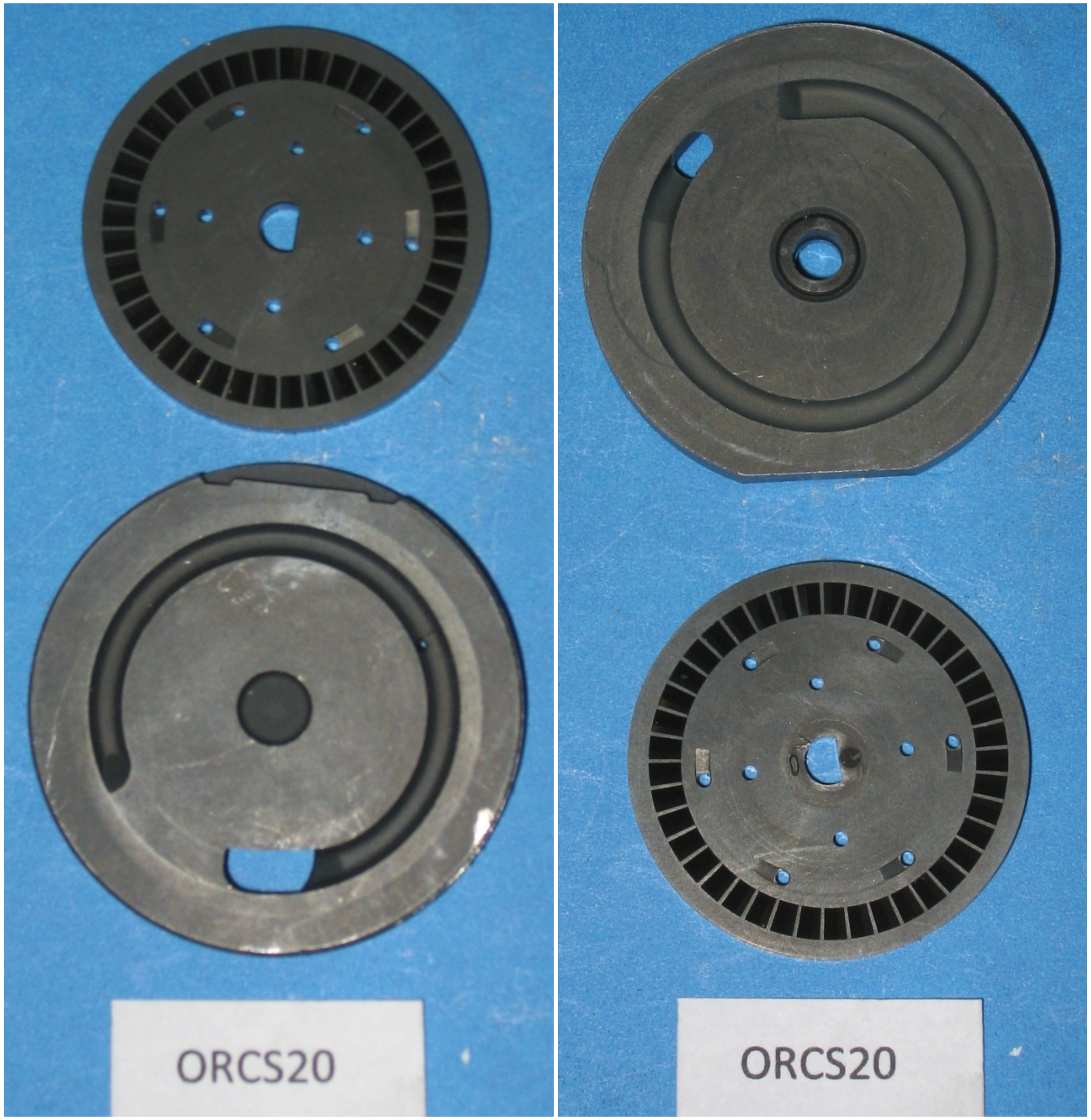


Figure F46. ORCS20 Fuel Pump Impeller with Inlet (Left) and Outlet (Right) Mating Cover.

Figure F47. ORCS20 Fuel Pump Brushes (Left) and Commutator (Right).

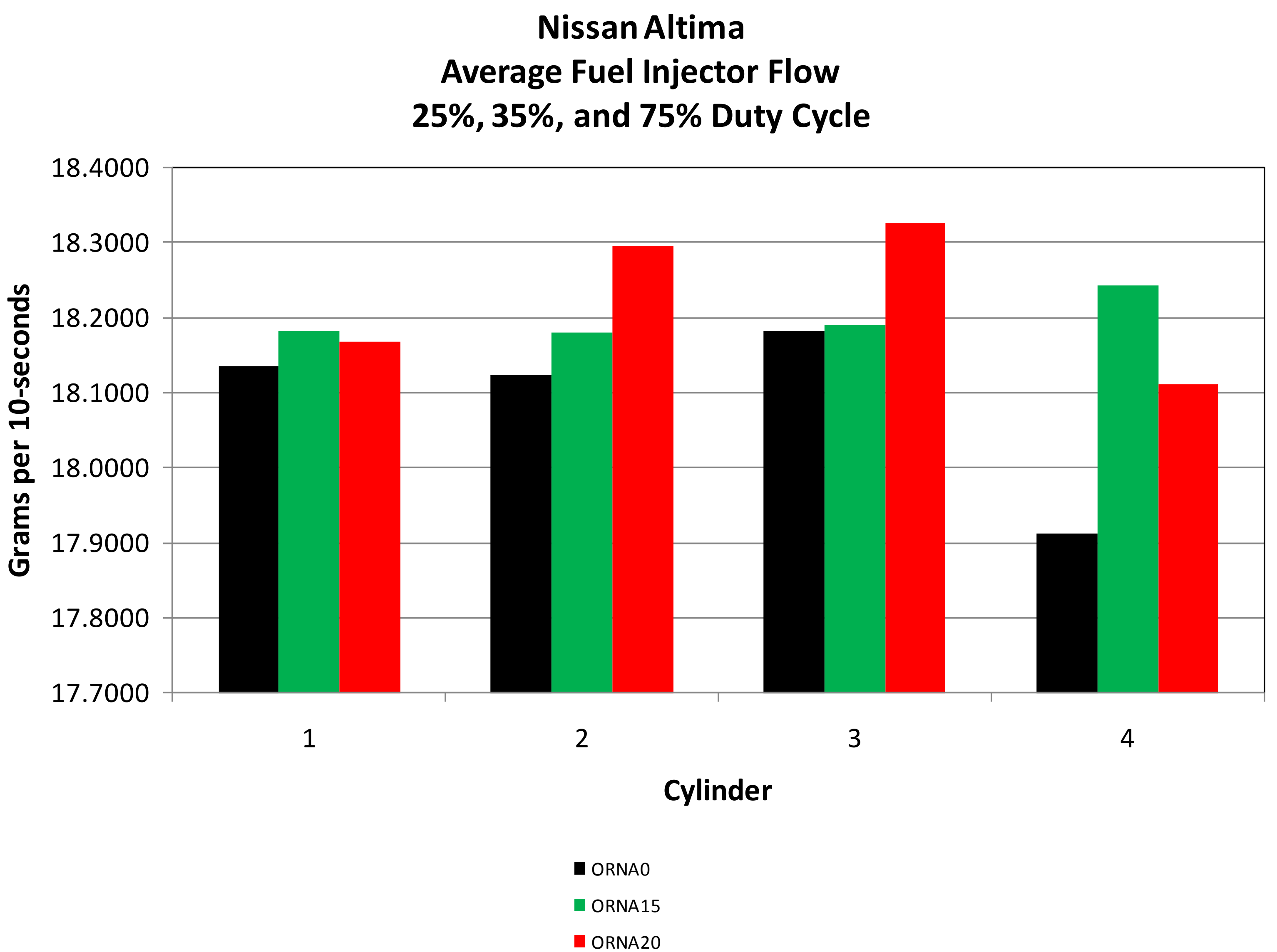
Figure F48. ORCS20 Fuel Pump Sock Filter (Left) and Brushes (Right).

Appendix G

Fuel Injector Flow Rates

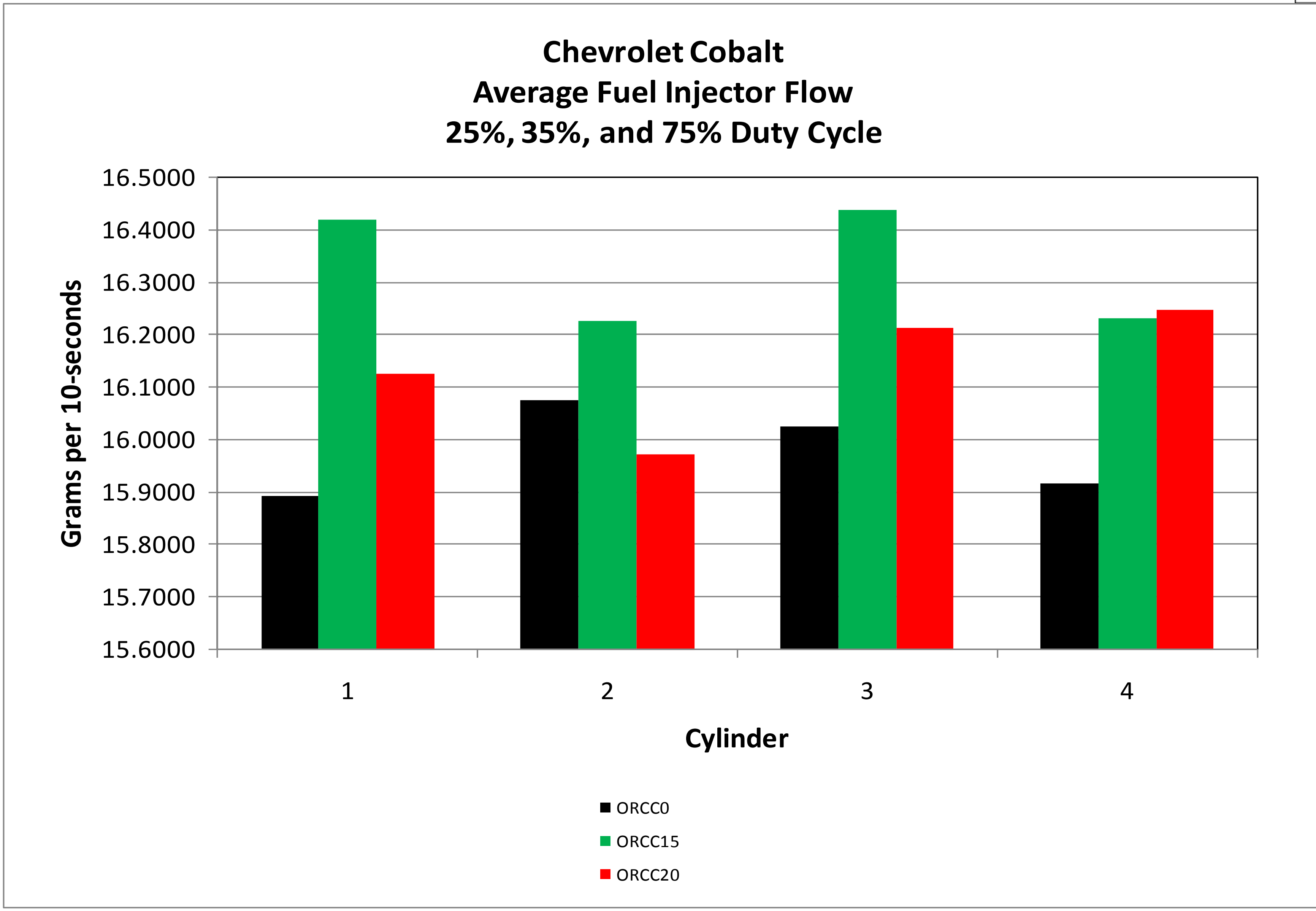
Nissan Altima

Vehicle	Date	Cylinder	75% DC (gr/10sec)	35% DC (gr/10sec)	25% DC (gr/10sec)	Average (gr/10sec)
ORNA0	7/22/2010	1	29.6000	14.3550	10.4525	18.1358
ORNA0	7/22/2010	2	29.6150	14.3100	10.4475	18.1242
ORNA0	7/22/2010	3	29.6300	14.3900	10.5250	18.1817
ORNA0	7/22/2010	4	29.2525	14.1125	10.3700	17.9117
ORNA15	7/30/2010	1	29.6350	14.3200	10.5925	18.1825
ORNA15	7/30/2010	2	29.6875	14.3800	10.4700	18.1792
ORNA15	7/30/2010	3	29.6975	14.3575	10.5150	18.1900
ORNA15	7/30/2010	4	29.7650	14.4525	10.5100	18.2425
ORNA20	9/22/2010	1	29.6050	14.3575	10.5425	18.1683
ORNA20	9/22/2010	2	29.8025	14.4800	10.6075	18.2967
ORNA20	9/22/2010	3	29.8675	14.4950	10.6175	18.3267
ORNA20	9/22/2010	4	29.5800	14.2775	10.4775	18.1117


Nissan Altima
Average Fuel Injector Flow
25%, 35%, and 75% Duty Cycle
18.4000
18.3000
18.2000
18.1000
18.0000
17.9000
17.8000
17.7000
Grams per 10-seconds
1
2
3
4
Cylinder
ORNA0
ORNA15
ORNA20

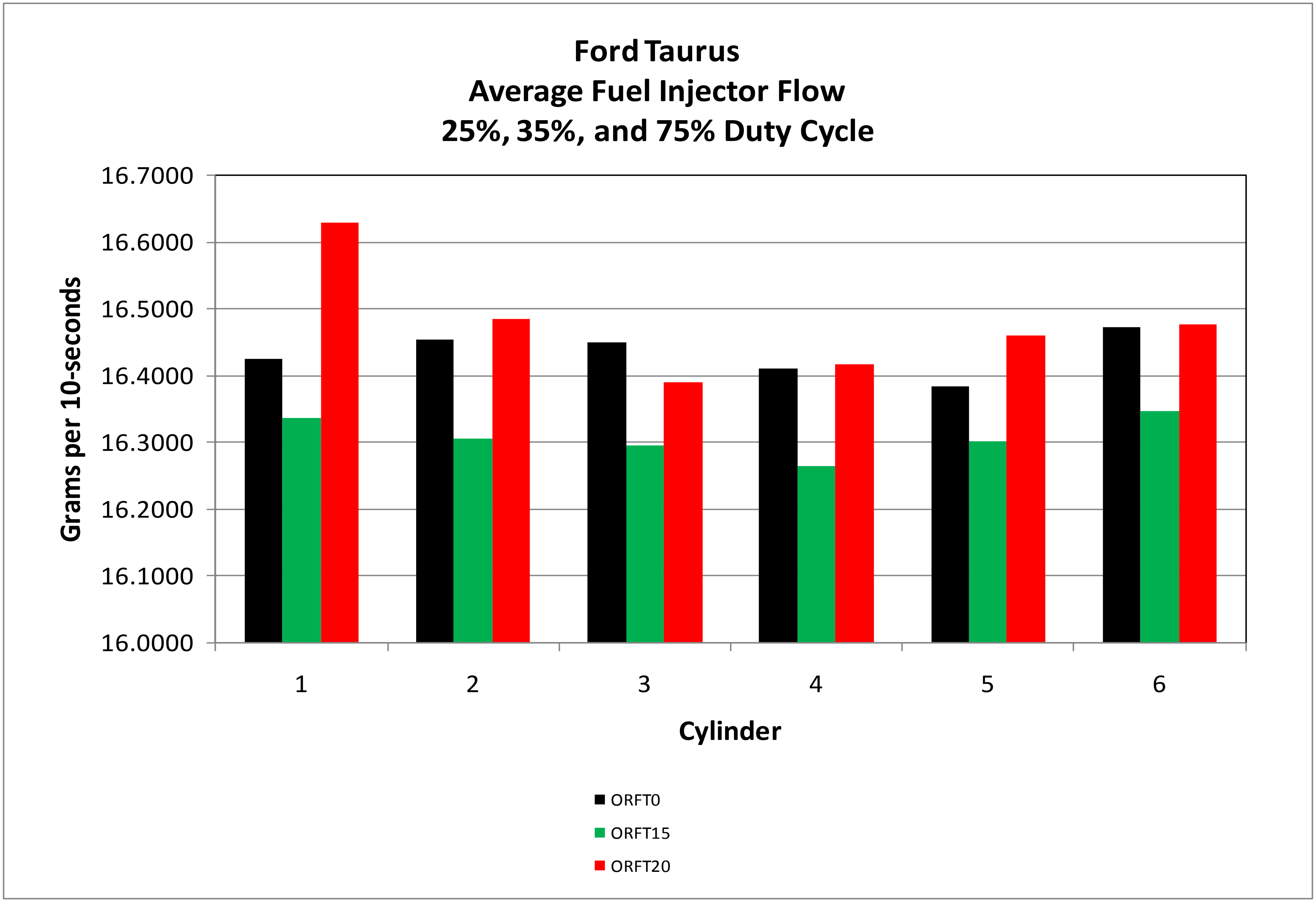
Chevrolet Cobalt

Vehicle	Date	Cylinder	75% DC (gr/10sec)	35% DC (gr/10sec)	25% DC (gr/10sec)	Average (gr/10sec)
ORCC0	8/5/2010	1	25.6475	12.6675	9.3625	15.8925
ORCC0	8/5/2010	2	25.8725	12.8550	9.5025	16.0767
ORCC0	8/5/2010	3	25.8925	12.7400	9.4400	16.0242
ORCC0	8/5/2010	4	25.7475	12.6750	9.3275	15.9167
ORCC15	8/5/2010	1	26.3075	13.1800	9.7725	16.4200
ORCC15	8/5/2010	2	26.0700	12.9925	9.6200	16.2275
ORCC15	8/5/2010	3	26.3050	13.1800	9.8300	16.4383
ORCC15	8/5/2010	4	26.0850	12.9775	9.6350	16.2325
ORCC20	9/22/2010	1	25.8450	12.9350	9.6000	16.1267
ORCC20	9/22/2010	2	25.6750	12.7900	9.4500	15.9717
ORCC20	9/22/2010	3	26.0575	13.0050	9.5775	16.2133
ORCC20	9/22/2010	4	26.0750	13.0150	9.6525	16.2475


Chevrolet Cobalt
Average Fuel Injector Flow
25%, 35%, and 75% Duty Cycle
16.5000
16.4000
16.3000
16.2000
16.1000
16.0000
15.9000
15.8000
15.7000
15.6000
Grams per 10-seconds
1
2
3
4
Cylinder
ORCC0
ORCC15
ORCC20

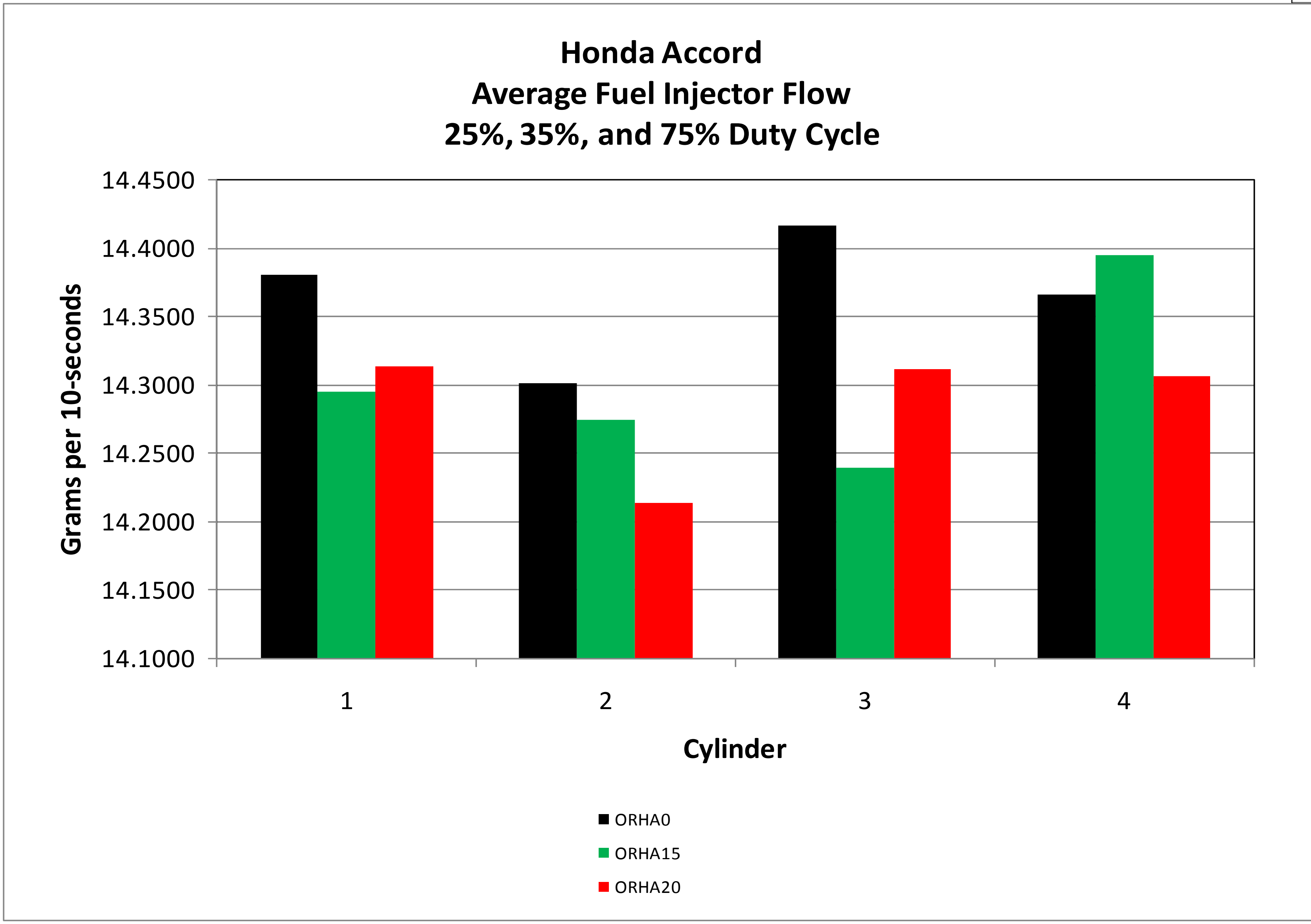
Ford Taurus

Vehicle	Date	Cylinder	75% DC (gr/10sec)	35% DC (gr/10sec)	25% DC (gr/10sec)	Average (gr/10sec)
ORFT 0	8/5/2010	1	26.9475	12.9100	9.4175	16.4250
ORFT 0	8/5/2010	2	26.9525	12.9350	9.4750	16.4542
ORFT 0	8/5/2010	3	26.9425	12.9675	9.4425	16.4508
ORFT 0	8/5/2010	4	26.9450	12.8750	9.4150	16.4117
ORFT 0	8/5/2010	5	26.9425	12.8425	9.3675	16.3842
ORFT 0	8/5/2010	6	27.0600	12.9200	9.4375	16.4725
ORFT 15	8/6/2010	1	26.7475	12.8625	9.4000	16.3367
ORFT 15	8/6/2010	2	26.6850	12.8475	9.3850	16.3058
ORFT 15	8/6/2010	3	26.6925	12.8125	9.3800	16.2950
ORFT 15	8/6/2010	4	26.6925	12.7950	9.3050	16.2642
ORFT 15	8/6/2010	5	26.7750	12.8175	9.3125	16.3017
ORFT 15	8/6/2010	6	26.8475	12.8475	9.3450	16.3467
ORFT 20	9/24/2010	1	27.2175	13.1000	9.5725	16.6300
ORFT 20	9/24/2010	2	26.9775	12.9875	9.4900	16.4850
ORFT 20	9/24/2010	3	26.8650	12.8925	9.4125	16.3900
ORFT 20	9/24/2010	4	26.8750	12.9575	9.4175	16.4167
ORFT 20	9/24/2010	5	27.0100	12.9425	9.4300	16.4608
ORFT 20	9/24/2010	6	27.0775	12.9300	9.4250	16.4775


Ford Taurus
Average Fuel Injector Flow
25%, 35%, and 75% Duty Cycle
Grams per 10-seconds
16.7000
16.6000
16.5000
16.4000
16.3000
16.2000
16.1000
16.0000
1
2
3
4
5
6
Cylinder
ORFT0
ORFT15
ORFT20

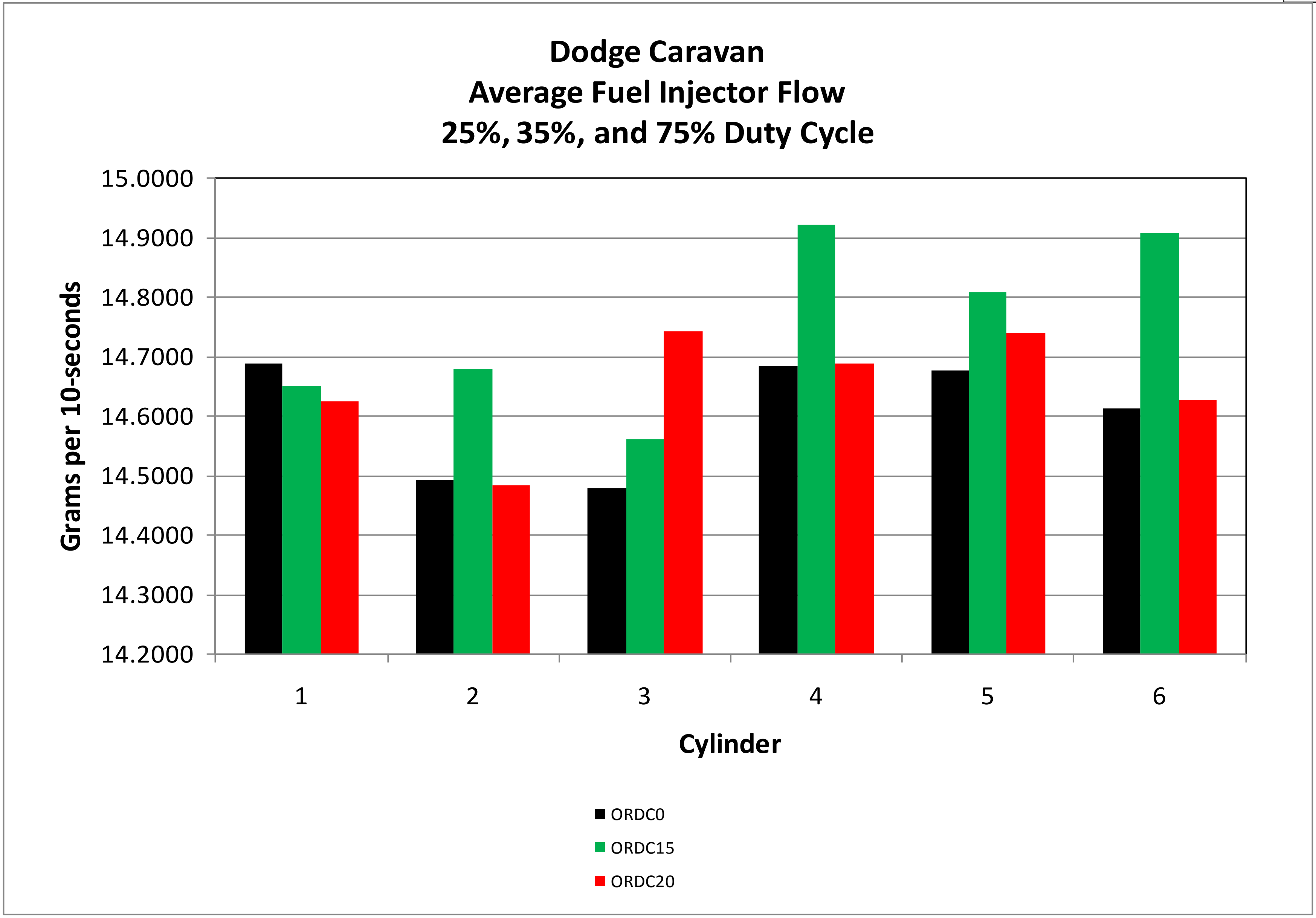
Honda Accord

Vehicle	Date	Cylinder	75% DC (gr/10sec)	35% DC (gr/10sec)	25% DC (gr/10sec)	Average (gr/10sec)
ORHA0	8/6/2010	1	23.5600	11.3150	8.2675	14.3808
ORHA0	8/6/2010	2	23.5000	11.2425	8.1625	14.3017
ORHA0	8/6/2010	3	23.6550	11.3350	8.2600	14.4167
ORHA0	8/6/2010	4	23.6450	11.2575	8.1975	14.3667
ORHA15	8/6/2010	1	23.5475	11.2000	8.1375	14.2950
ORHA15	8/6/2010	2	23.5150	11.1700	8.1375	14.2742
ORHA15	8/6/2010	3	23.4300	11.1575	8.1300	14.2392
ORHA15	8/6/2010	4	23.7525	11.2325	8.2000	14.3950
ORHA20	9/22/2010	1	23.5375	11.2325	8.1700	14.3133
ORHA20	9/22/2010	2	23.3575	11.1475	8.1375	14.2142
ORHA20	9/22/2010	3	23.5125	11.2275	8.1950	14.3117
ORHA20	9/22/2010	4	23.5250	11.2175	8.1775	14.3067


Honda Accord
Average Fuel Injector Flow
25%, 35%, and 75% Duty Cycle
14.4500
14.4000
14.3500
14.3000
14.2500
14.2000
14.1500
14.1000
Grams per 10-seconds
1
2
3
4
Cylinder
ORHA0
ORHA15
ORHA20

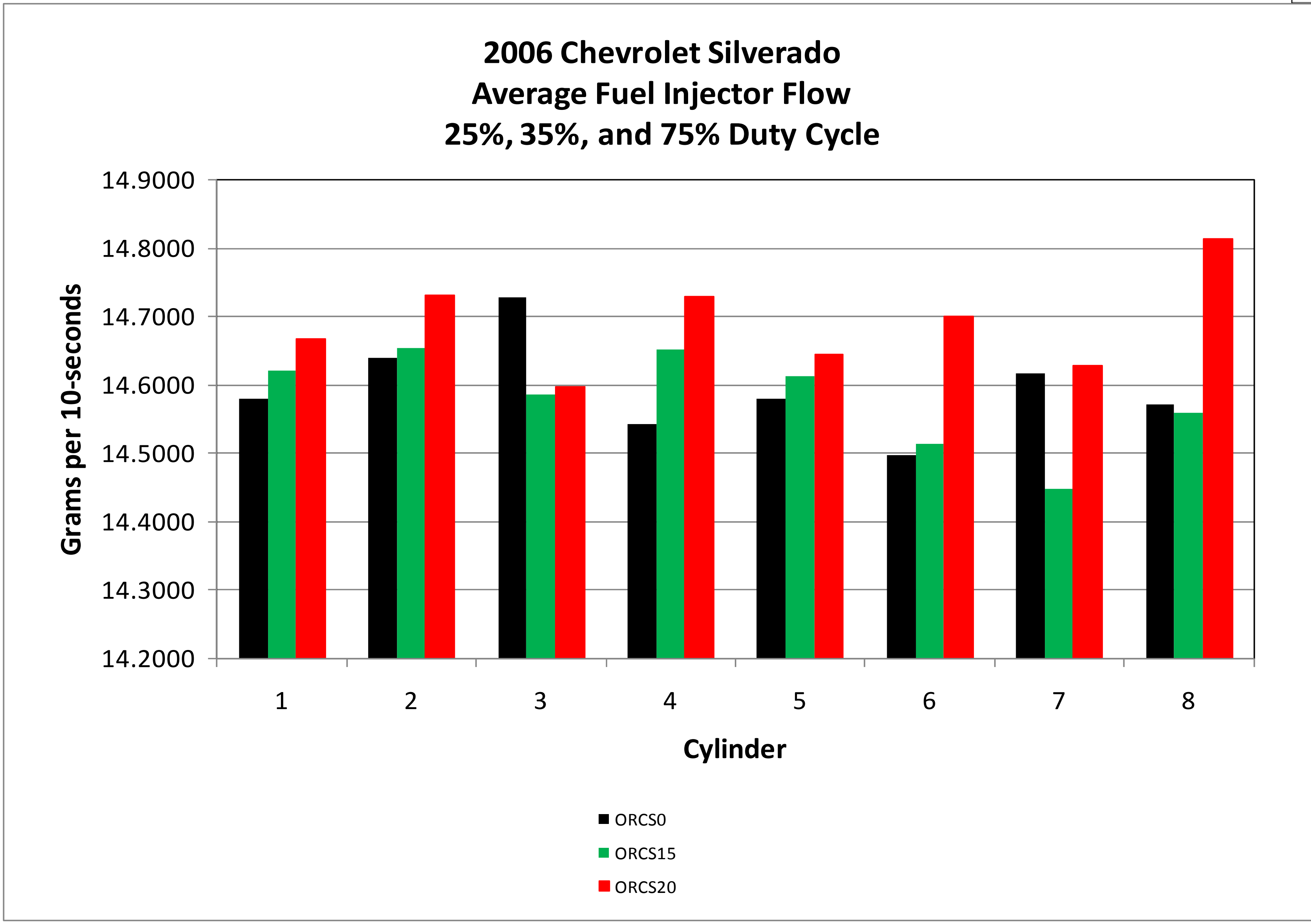
Dodge Caravan

ORDC0	8/9/2010	1	23.8650	11.6100	8.5925	14.6892
ORDC0	8/9/2010	2	23.5250	11.4625	8.4950	14.4942
ORDC0	8/9/2010	3	23.5400	11.4575	8.4400	14.4792
ORDC0	8/9/2010	4	23.8275	11.6150	8.6100	14.6842
ORDC0	8/9/2010	5	23.8350	11.6125	8.5850	14.6775
ORDC0	8/9/2010	6	23.7475	11.5750	8.5200	14.6142
ORDC15	8/9/2010	1	23.7575	11.5925	8.6025	14.6508
ORDC15	8/9/2010	2	23.7950	11.6250	8.6200	14.6800
ORDC15	8/9/2010	3	23.6175	11.5500	8.5175	14.5617
ORDC15	8/9/2010	4	24.1100	11.8525	8.8050	14.9225
ORDC15	8/9/2010	5	23.8600	11.7925	8.7750	14.8092
ORDC15	8/9/2010	6	24.0475	11.8475	8.8300	14.9083
ORDC20B	9/24/2010	1	23.6975	11.5875	8.5900	14.6250
ORDC20B	9/24/2010	2	23.4775	11.4800	8.4900	14.4825
ORDC20B	9/24/2010	3	23.8700	11.6825	8.6725	14.7417
ORDC20B	9/24/2010	4	23.8325	11.6400	8.5950	14.6892
ORDC20B	9/24/2010	5	23.9200	11.6650	8.6350	14.7400
ORDC20B	9/24/2010	6	23.7300	11.6100	8.5425	14.6275


Dodge Caravan
Average Fuel Injector Flow
25%, 35%, and 75% Duty Cycle
Grams per 10-seconds
15.0000
14.9000
14.8000
14.7000
14.6000
14.5000
14.4000
14.3000
14.2000
1
2
3
4
5
6
Cylinder
ORDC0
ORDC15
ORDC20

Chevrolet Silverado

Vehicle	Date	Cylinder	75% DC (gr/10sec)	35% DC (gr/10sec)	25% DC (gr/10sec)	Average (gr/10sec)
ORCS0	8/10/2010	1	23.6850	11.5500	8.5050	14.5800
ORCS0	8/10/2010	2	23.7175	11.6475	8.5525	14.6392
ORCS0	8/10/2010	3	23.8500	11.7050	8.6300	14.7283
ORCS0	8/10/2010	4	23.7000	11.4775	8.4525	14.5433
ORCS0	8/10/2010	5	23.6850	11.5850	8.4675	14.5792
ORCS0	8/10/2010	6	23.6600	11.4500	8.3850	14.4983
ORCS0	8/10/2010	7	23.8100	11.5725	8.4675	14.6167
ORCS0	8/10/2010	8	23.6775	11.5550	8.4850	14.5725
ORCS15	8/10/2010	1	23.7150	11.6175	8.5325	14.6217
ORCS15	8/10/2010	2	23.7475	11.6600	8.5575	14.6550
ORCS15	8/10/2010	3	23.6550	11.5975	8.5050	14.5858
ORCS15	8/10/2010	4	23.7450	11.6450	8.5650	14.6517
ORCS15	8/10/2010	5	23.7825	11.5875	8.4700	14.6133
ORCS15	8/10/2010	6	23.5225	11.5550	8.4650	14.5142
ORCS15	8/10/2010	7	23.5275	11.4125	8.4075	14.4492
ORCS15	8/10/2010	8	23.7500	11.5175	8.4100	14.5592
ORCS20	9/27/2010	1	23.7750	11.6175	8.6125	14.6683
ORCS20	9/27/2010	2	23.8900	11.7075	8.5975	14.7317
ORCS20	9/27/2010	3	23.7175	11.5525	8.5225	14.5975
ORCS20	9/27/2010	4	23.8600	11.6675	8.6600	14.7292
ORCS20	9/27/2010	5	23.7900	11.5825	8.5600	14.6442
ORCS20	9/27/2010	6	23.9150	11.6125	8.5750	14.7008
ORCS20	9/27/2010	7	23.8150	11.5675	8.5025	14.6283
ORCS20	9/27/2010	8	24.0425	11.7325	8.6675	14.8142


2006 Chevrolet Silverado
Average Fuel Injector Flow
25%, 35%, and 75% Duty Cycle
14.9000
14.8000
14.7000
14.6000
14.5000
14.4000
14.3000
14.2000
Grams per 10-seconds
1
2
3
4
5
6
7
8
Cylinder
ORCS0
ORCS15
ORCS20

Appendix H

Visual Inspection Rating of Valve Seals

Oak Ridge National Laboratory
Proposal 08-58845 Powertrain Inspection
Intake Valve Seal Rating

Date: 11-Aug-10 Technician: JR

Valve seals rated prior to removal from cylinder head
Ratings conducted in accordance with CRC Manual 21

ORHA0					
Cylinder #	Intake	Sludge	Wear	Condition	Varnish
Front 1	1	Light	Trace	Good	Medium
	2	Light	Trace	Good	Medium
2	3	Light	Trace	Good	Medium
	4	Light	Trace	Good	Medium
3	5	Light	Trace	Good	Medium
	6	Light	Trace	Good	Medium
4 Rear	7	Light	Trace	Good	Medium
	8	Light	Trace	Good	Medium

ORHA15					
Cylinder #	Intake	Sludge	Wear	Condition	Varnish
Front 1	1	Light	Trace	Good	None
	2	Light	Trace	Good	None
2	3	Light	Trace	Good	None
	4	Light	Trace	Good	None
3	5	Light	Trace	Good	None
	6	Light	Trace	1 cut on top of seal	None
4 Rear	7	Light	Trace	Good	None
	8	Light	Trace	Good	None

Oak Ridge National Laboratory
Proposal 08-58845 Powertrain Inspection
Intake Valve Seal Rating

Date: 22-Sep-10 Technician: JR

Valve seals rated prior to removal from cylinder head
Ratings conducted in accordance with CRC Manual 21

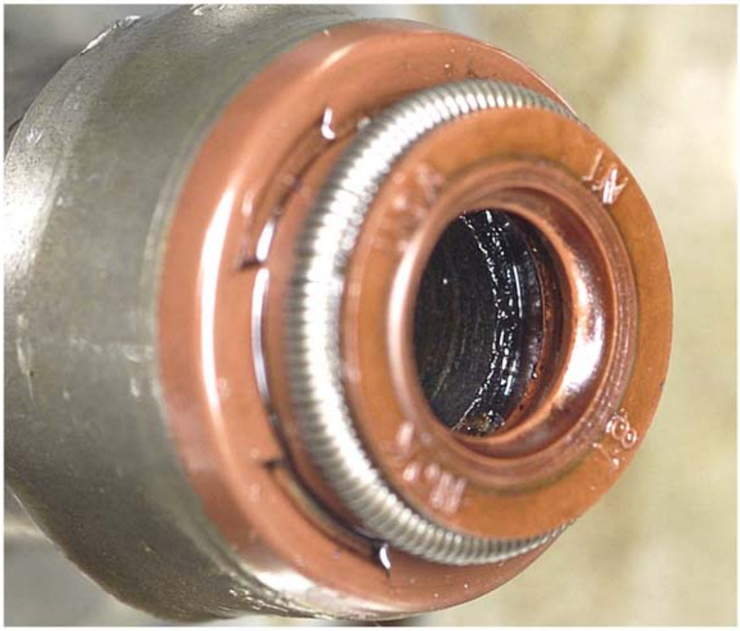
ORHA20					
Cylinder #	Intake	Sludge	Wear	Condition	Varnish
Front 1	1	Trace	Light	Good	Light
	2	Trace	Light	Good	Light
2	3	Trace	Light	Good	Light
	4	Trace	Light	Good	Light
3	5	Trace	Light	Good	Light
	6	Trace	Light	Good	Light
4 Rear	7	Trace	Light	Good	Light
	8	Trace	Light	Good	Light

Vehicle: Honda Accord ORHA0	
End of Test	Fuel: E0

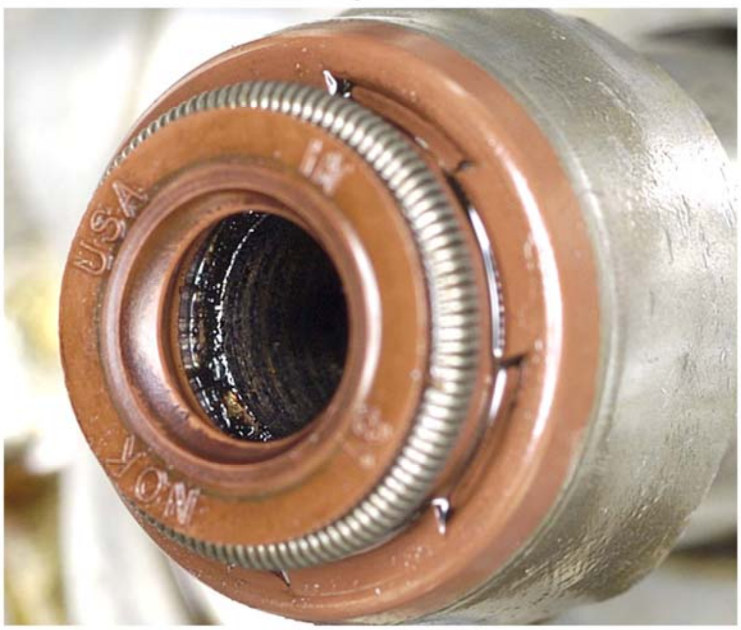
Cylinder 1 Valve 1

Intake Valve Seal (Typical)

Front Angle View



Rear Angle View

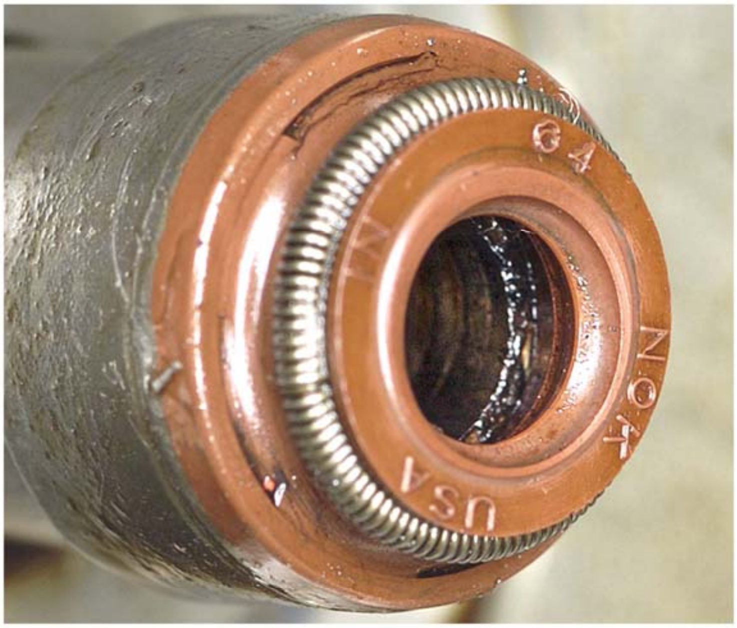


Vehicle: Honda Accord ORHA15	
End of Test	Fuel: E15

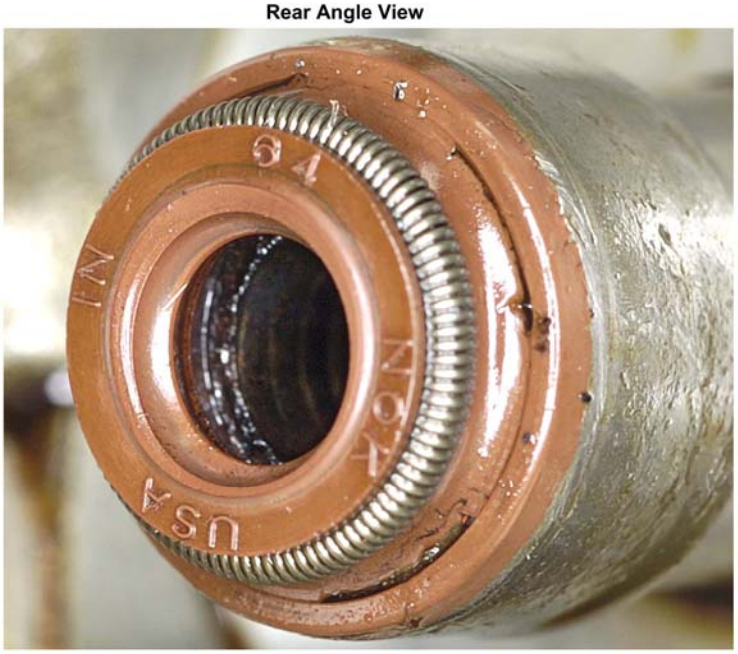
Cylinder 1 Valve 1

Intake Valve Seal (Typical)

Front Angle View



Rear Angle View

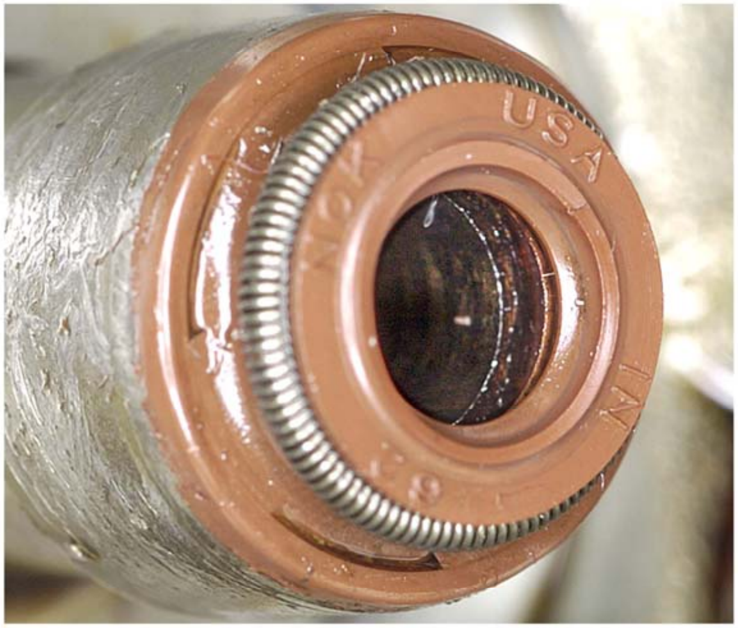


Vehicle: Honda Accord ORHA15	
End of Test	Fuel: E15

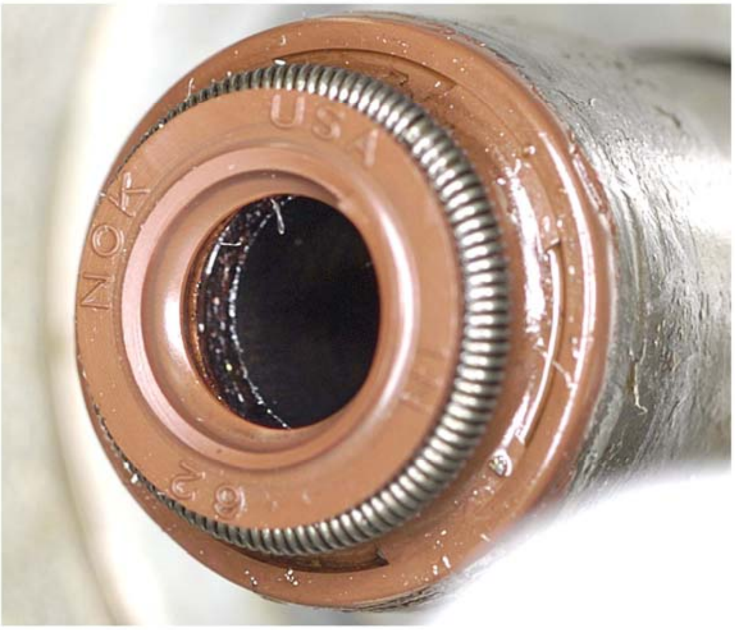
Cylinder 3 Valve 6

Intake Valve Seal (Different From Typical)

Front Angle View



Rear Angle View



Oak Ridge National Laboratory
Proposal 08-58845 Powertrain Inspection
Intake Valve Seal Rating

Date: 24-Aug-10 Technician: JR

Valve seal removal from cylinder head was necessary for rating
Ratings conducted in accordance with CRC Manual 21

ORCC0					
Cylinder #	Intake	Sludge	Wear	Condition	Varnish
Front 1	1	Medium	Medium/Heavy	Good	None
	2	Medium	Medium/Heavy	Good	None
2	3	Medium	Medium	Good	None
	4	Light/Medium	Medium/Heavy	Good	None
3	5	Light/Medium	Medium/Heavy	Good	None
	6	Light/Medium	Medium/Heavy	Good	None
4 Rear	7	Light/Medium	Medium	Good	None
	8	Light/Medium	Medium/Heavy	Good	None

ORCC15					
Cylinder #	Intake	Sludge	Wear	Condition	Varnish
Front 1	1	Medium	Medium/Heavy	Good	None
	2	Medium	Medium/Heavy	Good	None
2	3	Medium	Medium	Good	None
	4	Light/Medium	Medium/Heavy	Good	None
3	5	Light/Medium	Medium/Heavy	Good	None
	6	Light/Medium	Medium/Heavy	Good	None
4 Rear	7	Medium	Medium/Heavy	Good	None
	8	Light/Medium	Medium/Heavy	Good	None

Oak Ridge National Laboratory
Proposal 08-58845 Powertrain Inspection
Intake Valve Seal Rating

Date: 15-Sep-10 Technician: JR

Valve seal removal from cylinder head was necessary for rating
Ratings conducted in accordance with CRC Manual 21

ORCC20					
Cylinder #	Intake	Sludge	Wear	Condition	Varnish
Front 1	1	Light/Medium	Trace/Light	Good	Light
	2	Light/Medium	Trace/Light	Good	Trace/Light
2	3	Light/Medium	Trace/Light	Good	Trace
	4	Light/Medium	Trace/Light	Good	Trace
3	5	Light/Medium	Trace/Light	Good	Trace/Light
	6	Light/Medium	Trace/Light	Good	Trace
4 Rear	7	Light/Medium	Trace/Light	Good	Trace
	8	Light/Medium	Trace/Light	Good	Trace

Oak Ridge National Laboratory
Proposal 08-58845 Powertrain Inspection
Intake Valve Seal Rating

Date: 24-Aug-10 Technician: JR

Valve seal removal from cylinder head was necessary for rating
Ratings conducted in accordance with CRC Manual 21

ORNA0

Cylinder #	Intake	Sludge	Wear	Condition	Varnish
Front 1	1	Light/Medium	Trace/Light	Cracking	None
	2	Light/Medium	Trace/Light	Cracking	None
2	3	Light/Medium	Trace/Light	Cracking	None
	4	Light/Medium	Trace/Light	Cracking	None
3	5	Light/Medium	Trace/Light	Cracking	None
	6	Light/Medium	Trace/Light	Cracking	None
4 Rear	7	Light/Medium	Trace/Light	Cracking	None
	8	Light/Medium	Trace/Light	Cracking	None

ORNA15

Cylinder #	Intake	Sludge	Wear	Condition	Varnish
Front 1	1	Light/Medium	Trace/Light	Cracking	None
	2	Light/Medium	Trace/Light	Cracking	None
2	3	Light/Medium	Trace/Light	Cracking	None
	4	Light/Medium	Trace/Light	Cracking	None
3	5	Light/Medium	Trace/Light	Cracking	None
	6	Light/Medium	Trace/Light	Cracking	None
4 Rear	7	Light/Medium	Trace/Light	Cracking	None
	8	Light/Medium	Trace/Light	Cracking	None

Oak Ridge National Laboratory
Proposal 08-58845 Powertrain Inspection
Intake Valve Seal Rating

Date: 16-Sep-10 Technician: JR

Valve seal removal from cylinder head was necessary for rating
Ratings conducted in accordance with CRC Manual 21

ORNA20					
Cylinder #	Intake	Sludge	Wear	Condition	Varnish
Front 1	1	Light/Medium	Trace/Light	Good	None
	2	Light/Medium	Trace/Light	Good	None
2	3	Light/Medium	Trace/Light	Good	None
	4	Light/Medium	Trace/Light	Good	None
3	5	Light/Medium	Trace/Light	Good	None
	6	Light/Medium	Trace/Light	Good	None
4 Rear	7	Light/Medium	Trace/Light	Good	None
	8	Light/Medium	Trace/Light	Good	None

Oak Ridge National Laboratory
Proposal 08-58845 Powertrain Inspection
Intake Valve Seal Rating

Date: 23-Aug-10 Technician: JR

Valve seals rated prior to removal from cylinder head
Ratings conducted in accordance with CRC Manual 21
Seals are black in color, therefore varnish cannot be rated

ORCS0		
Cylinder #	Sludge	Wear
1	Light to Medium	Trace to Light
2	Light to Medium	Trace to Light
3	Light to Medium	Trace to Light
4	Light to Medium	Trace to Light
5	Light to Medium	Trace to Light
6	Light to Medium	Trace to Light
7	Light to Medium	Trace to Light
8	Light to Medium	Trace to Light

ORCS15		
Cylinder #	Sludge	Wear
1	Light to Medium	Trace to Light
2	Light to Medium	Trace to Light
3	Light to Medium	Trace to Light
4	Light to Medium	Trace to Light
5	Light to Medium	Trace to Light
6	Light to Medium	Trace to Light
7	Light to Medium	Trace to Light
8	Light to Medium	Trace to Light

Oak Ridge National Laboratory
Proposal 08-58845 Powertrain Inspection
Intake Valve Seal Rating

Date: 17-Sep-10 Technician: JR

Valve seals rated prior to removal from cylinder head
Ratings conducted in accordance with CRC Manual 21
Seals are black in color, therefore varnish cannot be rated

ORCS20		
Cylinder #	Sludge	Wear
1	Light to Medium	Trace to Light
2	Light to Medium	Trace to Light
3	Light to Medium	Trace to Light
4	Light to Medium	Trace to Light
5	Light to Medium	Trace to Light
6	Light to Medium	Trace to Light
7	Light to Medium	Trace to Light
8	Light to Medium	Trace to Light

Oak Ridge National Laboratory
Proposal 08-58845 Powertrain Inspection
Intake Valve Seal Rating

Date: 20-Aug-10 Technician: JR

Valve seals rated prior to removal from cylinder head
Ratings conducted in accordance with CRC Manual 21
Seals are black in color, therefore varnish cannot be rated
TOP OF SEAL EDGE: chipping or chunking on edge is normal with new seal

ORDC0		
Cylinder #	Sludge	Wear
1	Light to Medium	Trace to Light
2	Light to Medium	Trace to Light
3	Light to Medium	Trace to Light
4	Light to Medium	Trace to Light
5	Light to Medium	Trace to Light
6	Light to Medium	Trace to Light

ORDC15		
Cylinder #	Sludge	Wear
1	Light to Medium	Trace to Light
2	Light to Medium	Trace to Light
3	Light to Medium	Trace to Light
4	Light to Medium	Trace to Light
5	Light to Medium	Trace to Light
6	Light to Medium	Trace to Light

Oak Ridge National Laboratory
Proposal 08-58845 Powertrain Inspection
Intake Valve Seal Rating

Date: 13-Sep-10 Technician: JR

Valve seals rated prior to removal from cylinder head
Ratings conducted in accordance with CRC Manual 21
Seals are black in color, therefore varnish cannot be rated
TOP OF SEAL EDGE: chipping or chunking on edge is normal with new seal

ORDC20B		
Cylinder #	Sludge	Wear
1	Light to Medium	Trace to Light
2	Light to Medium	Trace to Light
3	Light to Medium	Trace to Light
4	Light to Medium	Trace to Light
5	Light to Medium	Trace to Light
6	Light to Medium	Trace to Light

Oak Ridge National Laboratory
Proposal 08-58845 Powertrain Inspection
Intake Valve Seal Rating

Date: 25-Aug-10 Technician: JR

Valve seal removal from cylinder head was necessary for rating
Ratings conducted in accordance with CRC Manual 21
Seals are black in color, therefore varnish cannot be rated

ORFT0

Cylinder #	Intake	Sludge	Wear
1	1	Light/Medium	Light
	2	Light/Medium	Light
2	3	Light/Medium	Light
	4	Light/Medium	Light
3	5	Light/Medium	Light
	6	Light/Medium	Light
4	7	Light/Medium	Light
	8	Light/Medium	Light
5	9	Light/Medium	Light
	10	Light/Medium	Light
6	11	Light/Medium	Light
	12	Light/Medium	Light

ORFT15

Cylinder #	Intake	Sludge	Wear
1	1	Light/Medium	Light
	2	Light/Medium	Light
2	3	Light/Medium	Light
	4	Light/Medium	Light
3	5	Light/Medium	Light
	6	Light/Medium	Light
4	7	Light/Medium	Light
	8	Light/Medium	Light
5	9	Light/Medium	Light
	10	Light/Medium	Light
6	11	Light/Medium	Light
	12	Light/Medium	Light

Oak Ridge National Laboratory
Proposal 08-58845 Powertrain Inspection
Intake Valve Seal Rating

Date: 22-Sep-10 Technician: JR

Valve seal removal from cylinder head was necessary for rating
Ratings conducted in accordance with CRC Manual 21
Seals are black in color, therefore varnish cannot be rated

ORFT20			
Cylinder #	Intake	Sludge	Wear
1	1	Light/Medium	Light
	2	Trace/Light	Light
2	3	Trace/Light	Light
	4	Trace/Light	Light
3	5	Light/Medium	Light
	6	Trace/Light	Light
4	7	Trace/Light	Light
	8	Trace/Light	Light
5	9	Trace/Light	Light
	10	Light/Medium	Light
6	11	Trace/Light	Light
	12	Trace/Light	Light

Appendix I

Evaporative Canister Working Capacity Test Results

TABLE I-1. EVAPORATIVE EMISSIONS CANISTER WORKING CAPACITY

Test Vehicle Set	Canister ID	Carbon Volume[a] (liters)	Butane or Gasoline Testing	Test Dates (2010)	Cycle 9 Break-through (+2 grams)	Cycle 10 Break-through (+2 grams)	Cycle 14 Break-through (+2 grams)[e]	Cycle 15 Break-through (+2 grams)[e]	Working Capacity[b,c] (grams)	Specific Working Capacity, g/L (grams/liter canister volume)
2008 Nissan Altima	ORNA00	2.05	Tested with Butane for 15 Cycles	09/07 - 09/12	90.29	104.87	108.31	108.12	108.22	52.79
	ORNA15			09/16 - 09/21	99.04	100.45	103.50	102.67	103.09	50.29
	ORNA20			09/22 - 09/26	79.40	84.15	93.70	93.31	93.51	45.61
2006 Chevrolet Cobalt	ORCC00	2.2	Tested with Butane for 15 Cycles	09/21 - 09/25	84.50	81.37	86.68	88.44	87.56	39.80
	ORCC15			09/12 - 09/16	95.59	94.04	97.16	96.83	97.00	44.09
	ORCC20			09/26 - 09/30	88.53	88.62	91.06	91.43	91.25	41.48
2007 Honda Accord	ORHA00	2.5	Tested with Butane for 15 Cycles [e]	09/23 - 09/27	101.1	98.9	99.1	98.3	98.7	39.5
	ORHA15			09/23 - 09/27	95.6	92.1	95.8	93.2	94.5	37.8
	ORHA20			10/07 - 10/12	97.4	91.9	94.9	92.2	93.6	34.4
2007 Dodge Caravan	ORDC00	2.7	Tested with Gasoline for 10 Cycles	09/26 - 09/27	173.1	172.9	d		173.00	64.07
	ORDC15			09/23 - 09/24	173.6	172.4			173.00	64.07
	ORDC20[b]			09/27 - 09/28	166.2	169.0			167.70	62.11
2008 Ford Taurus	ORFT00	2.7	Tested with Butane for 15 Cycles [e]	09/23 - 09/28	90.4	99.0	97.6	95.8	96.7	35.8
	ORFT15			09/23 - 09/27	103.3	93.8	104.3	97.7	101.0	37.4
	ORFT20			10/07 - 10/14	96.7	94.6	107.6	102.2	104.9	38.9
2006 Chevrolet Silverado	ORCS00	3.3	Tested with Gasoline for 10 Cycles	09/25 - 09/26	156.7	156.9	d		156.80	47.52
	ORCS15			09/24 - 09/25	161.6	162.2			161.90	49.06
	ORCS20			09/27 - 09/27	160.9	162.4			161.65	48.98

[a] Canister volumes provided by the vehicle manufacturers.
[b] Butane working capacity (BWC): BWC = (Cycle 14 + Cycle 15) / 2.
[c] Gasoline working capacity (GWC): GWC = (Cycle 9 + Cycle 10) / 2.
[d] Not applicable for GWC tests. GWC test complete at 10 cycles.
[e] Environmental Testing Corp results were reported as an initial purge cycle plus 14 additional cycles. Detroit Testing Laboratory reported 15 cycles of testing.

Detroit Testing Laboratory, Inc.

GENERAL DATA SHEET

CUSTOMER	**Southwest Research Institute**	DATE	**09/07/10-09/12/10**
SAMPLE DESCRIPTION/NUMBER	**Canister # 2.05 L ORNA 00**	JOB NO.	**100840038**
TEST SPECIFICATION	**BWC**	SHEET NO.	1 of 1
TEST PERFORMED	**BWC**	SAMPLE PREPARATION	
ACTUAL ENVIRONMENTAL CONDITIONS	**Ambient (23°C)**	DATA BY	**SK**
TOLERANCE/UNCERTAINTY	**N/A**	REVIEWED BY	**JS**

SAMPLE# By DTL	Pre-Test Weight (grams)	Post-Test Weight Pre-Purge (grams)	Post-Test Weight Post-Purge (grams)	Capacity of canister (Formula : Post-Pre)	Break Trough (+500mg)	Break Trough (+200mg)	Break Trough (+2 grams)	Cycle Count
2.05 L ORNA 00	1791.73	1832.22	N/A	40.49	11.65	2.78	42.49	**1**
2.05 L ORNA 00	N/A	N/A	N/A	88.12	84.98	51.63	90.12	**2**
2.05 L ORNA 00	N/A	N/A	N/A	94.60	90.65	88.90	96.60	**3**
2.05 L ORNA 00	N/A	N/A	N/A	98.01	94.02	92.33	100.01	**4**
2.05 L ORNA 00	N/A	N/A	N/A	98.51	94.65	93.11	100.51	**5**
2.05 L ORNA 00	N/A	N/A	N/A	101.37	97.10	94.98	103.37	**6**
2.05 L ORNA 00	N/A	N/A	N/A	102.81	98.63	96.78	104.81	**7**
2.05 L ORNA 00	N/A	N/A	N/A	104.78	101.14	48.06	106.78	**8**
2.05 L ORNA 00	N/A	N/A	N/A	88.29	84.25	5.70	90.29	**9**
2.05 L ORNA 00	N/A	N/A	N/A	102.87	98.78	96.99	104.87	**10**
2.05 L ORNA 00	N/A	N/A	N/A	104.07	99.85	97.86	106.07	**11**
2.05 L ORNA 00	N/A	N/A	N/A	104.56	100.14	97.83	106.56	**12**
2.05 L ORNA 00	N/A	N/A	N/A	105.10	100.73	98.38	107.10	**13**
2.05 L ORNA 00	N/A	N/A	N/A	106.31	101.96	99.71	108.31	**14**
2.05 L ORNA 00	N/A	N/A	1710.75	106.12	101.84	99.81	108.12	**15**

BWC Working Capacity = Cycle 14 =Cycle 15 / 2= BWC

BWC Working Capacity = 108.31 + 108.12 = BWC

BWC Working Capacity = 108.22 grams

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Detroit Testing Laboratory, Inc.

GENERAL DATA SHEET

CUSTOMER	Southwest Research Institute	DATE	09/16/10-09/21/10
SAMPLE DESCRIPTION/NUMBER	Canister # 2.05 L ORNA 15	JOB NO.	100840038
TEST SPECIFICATION	BWC	SHEET NO.	1 of 1
TEST PERFORMED	BWC	SAMPLE PREPARATION	
ACTUAL ENVIRONMENTAL CONDITIONS	Ambient (23°C)	DATA BY	SK
TOLERANCE/UNCERTAINTY	N/A	REVIEWED BY	JS

SAMPLE# By DTL	Pre-Test Weight (grams)	Post-Test Weight Pre-Purge (grams)	Post-Test Weight Post-Purge (grams)	Capacity of canister (Formula : Post-Pre)	Break Trough (+500mg)	Break Trough (+200mg)	Break Trough (+2 grams)	Cycle Count
2.05 L ORNA15	1805.05	1874.02	N/A	68.97	11.67	3.33	70.97	1
2.05 L ORNA15	N/A	N/A	N/A	77.36	74.65	73.64	79.36	2
2.05 L ORNA15	N/A	N/A	N/A	83.52	80.32	79.04	85.52	3
2.05 L ORNA15	N/A	N/A	N/A	88.12	84.66	82.94	90.12	4
2.05 L ORNA15	N/A	N/A	N/A	91.40	87.60	85.18	93.40	5
2.05 L ORNA15	N/A	N/A	N/A	100.68	96.48	94.11	102.68	6
2.05 L ORNA15	N/A	N/A	N/A	96.74	92.68	90.30	98.74	7
2.05 L ORNA15	N/A	N/A	N/A	97.77	93.82	91.58	99.77	8
2.05 L ORNA15	N/A	N/A	N/A	97.04	92.95	90.01	99.04	9
2.05 L ORNA15	N/A	N/A	N/A	98.45	94.34	91.34	100.45	10
2.05 L ORNA15	N/A	N/A	N/A	99.66	95.61	93.05	101.66	11
2.05 L ORNA15	N/A	N/A	N/A	100.30	96.43	94.39	102.30	12
2.05 L ORNA15	N/A	N/A	N/A	100.91	96.77	94.01	102.91	13
2.05 L ORNA15	N/A	N/A	N/A	101.50	97.72	95.95	103.50	14
2.05 L ORNA15	N/A	N/A	1722.72	100.67	96.99	24.16	102.67	15

BWC Working Capacity = Cycle 14 +Cycle 15 / 2= BWC

BWC Working Capacity = 103.50 + 102.67 = BWC

BWC Working Capacity = 103.09 grams

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Detroit Testing Laboratory, Inc.

GENERAL DATA SHEET

CUSTOMER	Southwest Research Institute	DATE	09/22/10-09/26/10
SAMPLE DESCRIPTION/NUMBER	Canister # 2.05 L ORNA 20	JOB NO.	100840038
TEST SPECIFICATION	BWC	SHEET NO.	1 of 1
TEST PERFORMED	BWC	SAMPLE PREPARATION	
ACTUAL ENVIRONMENTAL CONDITIONS	Ambient (23°C)	DATA BY	SK
TOLERANCE/UNCERTAINTY	N/A	REVIEWED BY	JS

SAMPLE# By DTL	Pre-Test Weight (grams)	Post-Test Weight Pre-Purge (grams)	Post-Test Weight Post-Purge (grams)	Capacity of canister (Formula : Post-Pre)	Break Trough (+500mg)	Break Trough (+200mg)	Break Trough (+2 grams)	Cycle Count
2.05 L ORNA20	1852.94	1900.68	N/A	47.74	47.00	46.76	49.74	1
2.05 L ORNA20	N/A	N/A	N/A	68.80	68.47	68.40	70.80	2
2.05 L ORNA20	N/A	N/A	N/A	76.55	76.31	76.26	78.55	3
2.05 L ORNA20	N/A	N/A	N/A	72.13	55.06	4.58	74.13	4
2.05 L ORNA20	N/A	N/A	N/A	73.30	72.97	72.90	75.30	5
2.05 L ORNA20	N/A	N/A	N/A	81.13	80.88	80.83	83.13	6
2.05 L ORNA20	N/A	N/A	N/A	80.24	79.71	79.59	82.24	7
2.05 L ORNA20	N/A	N/A	N/A	77.41	70.50	4.62	79.41	8
2.05 L ORNA20	N/A	N/A	N/A	77.40	72.93	33.49	79.40	9
2.05 L ORNA20	N/A	N/A	N/A	82.15	80.38	26.89	84.15	10
2.05 L ORNA20	N/A	N/A	N/A	87.71	87.11	86.98	89.71	11
2.05 L ORNA20	N/A	N/A	N/A	89.30	88.67	88.53	91.30	12
2.05 L ORNA20	N/A	N/A	N/A	91.10	90.43	90.27	93.10	13
2.05 L ORNA20	N/A	N/A	N/A	91.70	90.98	90.81	93.70	14
2.05 L ORNA20	N/A	N/A	1748.48	91.91	91.17	91.00	93.91	15

BWC Working Capacity = Cycle 14 +Cycle 15 / 2= BWC

BWC Working Capacity = 93.70 + 93.91 = BWC

BWC Working Capacity = 93.51 grams

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Detroit Testing Laboratory, Inc.

GENERAL DATA SHEET

CUSTOMER	**Southwest Research Institute**	DATE	**09/21/10-09/25/10**
SAMPLE DESCRIPTION/NUMBER	**Canister # 2.2 L ORCC 00**	JOB NO.	**100840038**
TEST SPECIFICATION	**BWC**	SHEET NO.	1 of 1
TEST PERFORMED	**BWC**	SAMPLE PREPARATION	
ACTUAL ENVIRONMENTAL CONDITIONS	**Ambient (23°C)**	DATA BY	**SK**
TOLERANCE/UNCERTAINTY	**N/A**	REVIEWED BY	**JS**

SAMPLE# By DTL	Pre-Test Weight (grams)	Post-Test Weight Pre-Purge (grams)	Post-Test Weight Post-Purge (grams)	Capacity of canister (Formula : Post-Pre)	Break Trough (+500mg)	Break Trough (+200mg)	Break Trough (+2 grams)	Cycle Count
2.2 L ORCC00	2084.56	2116.32	N/A	31.76	7.78	2.40	33.76	**1**
2.2 L ORCC00	N/A	N/A	N/A	61.26	55.85	24.07	63.26	**2**
2.2 L ORCC00	N/A	N/A	N/A	74.84	69.49	28.62	76.84	**3**
2.2 L ORCC00	N/A	N/A	N/A	80.24	74.94	35.36	82.24	**4**
2.2 L ORCC00	N/A	N/A	N/A	87.87	82.59	40.41	89.89	**5**
2.2 L ORCC00	N/A	N/A	N/A	83.11	78.29	53.10	85.11	**6**
2.2 L ORCC00	N/A	N/A	N/A	88.77	83.44	46.09	90.77	**7**
2.2 L ORCC00	N/A	N/A	N/A	85.42	80.58	50.06	87.42	**8**
2.2 L ORCC00	N/A	N/A	N/A	82.50	76.82	9.14	84.50	**9**
2.2 L ORCC00	N/A	N/A	N/A	79.37	74.99	65.59	81.37	**10**
2.2 L ORCC00	N/A	N/A	N/A	84.25	79.32	40.30	86.25	**11**
2.2 L ORCC00	N/A	N/A	N/A	85.47	80.63	49.23	87.47	**12**
2.2 L ORCC00	N/A	N/A	N/A	84.47	80.50	78.65	86.47	**13**
2.2 L ORCC00	N/A	N/A	N/A	84.68	78.83	52.88	86.68	**14**
2.2 L ORCC00	N/A	N/A	2018.36	86.44	81.68	55.14	88.44	**15**

BWC Working Capacity = Cycle 14 +Cycle 15 / 2= BWC

BWC Working Capacity = 86.68 + 88.44 = BWC

BWC Working Capacity = 87.56 grams

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Detroit Testing Laboratory, Inc.

GENERAL DATA SHEET

CUSTOMER	Southwest Research Institute	DATE	09/12/10-09/16/10
SAMPLE DESCRIPTION/NUMBER	Canister # 2.2 L ORCC 15	JOB NO.	100840038
TEST SPECIFICATION	BWC	SHEET NO.	1 of 1
TEST PERFORMED	BWC	SAMPLE PREPARATION	
ACTUAL ENVIRONMENTAL CONDITIONS	Ambient (23°C)	DATA BY	SK
TOLERANCE/UNCERTAINTY	N/A	REVIEWED BY	JS

SAMPLE# By DTL	Pre-Test Weight (grams)	Post-Test Weight Pre-Purge (grams)	Post-Test Weight Post-Purge (grams)	Capacity of canister (Formula : Post-Pre)	Break Trough (+500mg)	Break Trough (+200mg)	Break Trough (+2 grams)	Cycle Count
2.2 L ORCC15	2088.43	2104.89	N/A	16.46	2.31	0.32	18.46	1
2.2 L ORCC15	N/A	N/A	N/A	80.65	24.86	3.52	82.65	2
2.2 L ORCC15	N/A	N/A	N/A	86.76	82.11	37.39	88.76	3
2.2 L ORCC15	N/A	N/A	N/A	89.57	85.60	83.92	91.57	4
2.2 L ORCC15	N/A	N/A	N/A	91.41	88.11	69.46	93.41	5
2.2 L ORCC15	N/A	N/A	N/A	90.49	67.15	32.39	92.49	6
2.2 L ORCC15	N/A	N/A	N/A	91.19	48.72	22.82	93.19	7
2.2 L ORCC15	N/A	N/A	N/A	93.82	44.24	20.95	95.82	8
2.2 L ORCC15	N/A	N/A	N/A	93.59	34.30	15.78	95.59	9
2.2 L ORCC15	N/A	N/A	N/A	94.04	36.82	16.50	94.04	10
2.2 L ORCC15	N/A	N/A	N/A	95.50	35.10	16.28	97.50	11
2.2 L ORCC15	N/A	N/A	N/A	95.42	32.64	15.90	97.42	12
2.2 L ORCC15	N/A	N/A	N/A	95.09	28.55	14.07	97.09	13
2.2 L ORCC15	N/A	N/A	N/A	95.16	28.79	14.08	97.16	14
2.2 L ORCC15	N/A	N/A	2021.27	94.83	26.75	13.14	96.83	15

BWC Working Capacity = Cycle 14 =Cycle 15 / 2= BWC

BWC Working Capacity = 97.16 + 96.83 = BWC

BWC Working Capacity = 97.00 grams

QCF-1041 REVISED 3/29/00

Detroit Testing Laboratory, Inc.

GENERAL DATA SHEET

CUSTOMER	**Southwest Research Institute**	DATE	**09/26/10-09/30/10**
SAMPLE DESCRIPTION/NUMBER	**Canister # 2.2 L ORCC 20**	JOB NO.	**100840038**
TEST SPECIFICATION	**BWC**	SHEET NO.	1 of 1
TEST PERFORMED	**BWC**	SAMPLE PREPARATION	
ACTUAL ENVIRONMENTAL CONDITIONS	**Ambient (23°C)**	DATA BY	**SK**
TOLERANCE/UNCERTAINTY	**N/A**	REVIEWED BY	**JS**

SAMPLE# By DTL	Pre-Test Weight (grams)	Post-Test Weight Pre-Purge (grams)	Post-Test Weight Post-Purge (grams)	Capacity of canister (Formula : Post-Pre)	Break Trough (+500mg)	Break Trough (+200mg)	Break Trough (+2 grams)	Cycle Count
2.2 L ORCC20	1818.63	1834.79	N/A	16.16	1.09	0.14	18.16	**1**
2.2 L ORCC20	N/A	N/A	N/A	75.26	68.36	7.04	77.26	**2**
2.2 L ORCC20	N/A	N/A	N/A	79.59	75.47	73.67	81.59	**3**
2.2 L ORCC20	N/A	N/A	N/A	81.98	78.13	76.65	83.98	**4**
2.2 L ORCC20	N/A	N/A	N/A	83.78	80.07	78.78	85.78	**5**
2.2 L ORCC20	N/A	N/A	N/A	84.42	80.93	63.25	86.42	**6**
2.2 L ORCC20	N/A	N/A	N/A	89.61	85.64	84.29	91.61	**7**
2.2 L ORCC20	N/A	N/A	N/A	84.55	81.04	56.51	86.55	**8**
2.2 L ORCC20	N/A	N/A	N/A	86.53	83.05	50.09	88.53	**9**
2.2 L ORCC20	N/A	N/A	N/A	86.62	83.19	42.59	88.62	**10**
2.2 L ORCC20	N/A	N/A	N/A	87.93	84.57	45.29	89.93	**11**
2.2 L ORCC20	N/A	N/A	N/A	87.64	84.34	41.01	89.64	**12**
2.2 L ORCC20	N/A	N/A	N/A	88.83	85.59	38.13	90.83	**13**
2.2 L ORCC20	N/A	N/A	N/A	89.06	72.00	29.35	91.06	**14**
2.2 L ORCC20	N/A	N/A	1734.93	89.46	77.96	37.84	91.43	**15**

BWC Working Capacity = Cycle 14 +Cycle 15 / 2= BWC

BWC Working Capacity = 91.06 + 91.43 = BWC

BWC Working Capacity = 91.25 grams

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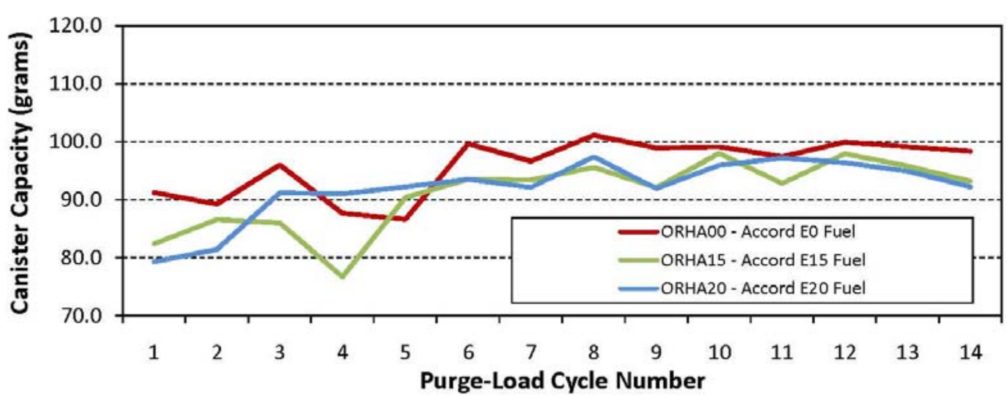
ENVIRONMENTAL TESTING CORP.
Canister Purge - Load Test Summary
Vehicle Set: 2007 Honda Accords

CANISTER ID NO.	CYCLE NO.	PRE-TEST WT. (g)	AFTER-PURGE WT. (g)	AFTER-LOAD WT. (g)	TEST START DATE	TEST ID NO.	CANISTER LOAD (g)
ORHA00	1	2804.9	2775.5	2866.7	23-Sep	911409	91.2
	2	2866.7	2774.2	2863.4	23-Sep	911422	89.2
	3	2863.4	2769.6	2865.6	24-Sep	911423	96.0
	4	2865.6	2768.7	2856.3	24-Sep	911427	87.6
	5	2856.3	2762.6	2849.2	24-Sep	911428	86.6
	6	2849.2	2759.3	2858.9	25-Sep	911435	99.6
	7	2858.9	2761.5	2858.1	25-Sep	911436	96.6
	8	2858.1	2758.8	2859.9	25-Sep	911437	101.1
	9	2859.9	2758.5	2857.4	25-Sep	911438	98.9
	10	2857.4	2756.3	2855.4	26-Sep	911439	99.1
	11	2855.4	2755.3	2852.7	26-Sep	911440	97.4
	12	2852.7	2753.1	2853.0	26-Sep	911441	99.9
	13	2853.0	2753.1	2852.2	27-Sep	911442	99.1
	14	2852.2	2751.9	2850.2	27-Sep	911443	98.3

CANISTER ID NO.	CYCLE NO.	PRE-TEST WT. (g)	AFTER-PURGE WT. (g)	AFTER-LOAD WT. (g)	TEST START DATE	TEST ID NO.	CANISTER LOAD (g)
ORHA15	1	3219.9	3193.6	3276.0	23-Sep	911414	82.4
	2	3276.0	3187.7	3274.3	23-Sep	911424	86.6
	3	3274.3	3183.7	3269.7	24-Sep	911425	86.0
	4	3269.7	3186.5	3263.2	24-Sep	911429	76.7
	5	3263.2	3172.6	3263.0	24-Sep	911430	90.4
	6	3263.0	3171.4	3264.9	25-Sep	911457	93.5
	7	3264.9	3171.6	3265.0	25-Sep	911458	93.4
	8	3265.0	3168.8	3264.4	25-Sep	911459	95.6
	9	3262.4	3166.2	3258.3	25-Sep	911460	92.1
	10	3258.3	3163.5	3261.5	26-Sep	911461	98.0
	11	3261.5	3163.2	3256.0	26-Sep	911462	92.8
	12	3256.0	3159.1	3257.0	26-Sep	911463	97.9
	13	3257.0	3159.0	3254.8	27-Sep	911464	95.8
	14	3254.8	3159.1	3252.3	27-Sep	911465	93.2

ENVIRONMENTAL TESTING CORP.
Canister Purge - Load Test Summary
Vehicle Set: 2007 Honda Accords

CANISTER ID NO.	CYCLE NO.	PRE-TEST WT. (g)	AFTER-PURGE WT. (g)	AFTER-LOAD WT. (g)	TEST START DATE	TEST ID NO.	CANISTER LOAD (g)
ORHA20	1	2798.4	2764.1	2843.4	7-Oct	911619	79.3
	2	2843.4	2754.3	2835.7	8-Oct	911620	81.4
	3	2833.8	2748.4	2839.6	8-Oct	911622	91.2
	4	2839.6	2742.6	2833.6	9-Oct	911666	91.0
	5	2833.6	2739.0	2831.2	9-Oct	911623	92.2
	6	2829.3	2732.2	2825.7	9-Oct	911635	93.5
	7	2831.2	2737.2	2829.3	9-Oct	911636	92.1
	8	2825.7	2729.6	2827.0	10-Oct	911637	97.4
	9	2827.0	2729.4	2821.3	10-Oct	911638	91.9
	10	2821.3	2726.9	2822.8	10-Oct	911639	95.9
	11	2814.3	2723.9	2821.1	11-Oct	911641	97.2
	12	2821.1	2724.0	2820.4	11-Oct	911642	96.4
	13	2820.4	2723.5	2818.4	12-Oct	911643	94.9
	14	2818.4	2724.3	2816.5	12-Oct	911644	92.2



Detroit Testing Laboratory, Inc.

GENERAL DATA SHEET

CUSTOMER	Southwest Research Institute	DATE	09/26/10-09/27/10
SAMPLE DESCRIPTION/NUMBER	Canister # 2.7 L ORDC 00	JOB NO.	100840038
TEST SPECIFICATION	GWC	SHEET NO.	1 of 1
TEST PERFORMED	GWC	SAMPLE PREPARATION	
ACTUAL ENVIRONMENTAL CONDITIONS	Hot (40°C)	DATA BY	SK
TOLERANCE/UNCERTAINTY	N/A	REVIEWED BY	JS

SAMPLE# By DTL	Pre-Test Weight (grams)	Post-Test Weight Pre-Purge (grams)	Post-Test Weight Post-Purge (grams)	Capacity of canister (Formula : Post-Pre)			Break Trough (+2 grams)	Cycle Count
2.7 L ORDC00	1908.2	2024.1	N/A	115.9			117.9	1
2.7 L ORDC00	N/A	N/A	N/A	144.4			146.4	2
2.7 L ORDC00	N/A	N/A	N/A	154.4			156.4	3
2.7 L ORDC00	N/A	N/A	N/A	161.6			163.6	4
2.7 L ORDC00	N/A	N/A	N/A	167.0			169.0	5
2.7 L ORDC00	N/A	N/A	N/A	168.5			170.5	6
2.7 L ORDC00	N/A	N/A	N/A	171.0			173.0	7
2.7 L ORDC00	N/A	N/A	N/A	171.1			173.1	8
2.7 L ORDC00	N/A	N/A	N/A	171.1			173.1	9
2.7 L ORDC00	N/A	N/A	1780.5	170.9			172.9	10

GWC Working Capacity = Cycle 9 +Cycle 10 / 2= GWC
GWC Working Capacity = 173.1 + 172.9 = GWC
GWC Working Capacity = 173.00 grams

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Detroit Testing Laboratory, Inc.

GENERAL DATA SHEET

CUSTOMER	**Southwest Research Institute**	DATE	**09/23/10-09/24/10**
SAMPLE DESCRIPTION/NUMBER	**Canister # 2.7 L ORDC 15**	JOB NO.	**100840038**
TEST SPECIFICATION	**GWC**	SHEET NO.	1 of 1
TEST PERFORMED	**GWC**	SAMPLE PREPARATION	
ACTUAL ENVIRONMENTAL CONDITIONS	**Hot (40°C)**	DATA BY	**SK**
TOLERANCE/UNCERTAINTY	**N/A**	REVIEWED BY	**JS**

SAMPLE# By DTL	Pre-Test Weight (grams)	Post-Test Weight Pre-Purge (grams)	Post-Test Weight Post-Purge (grams)	Capacity of canister (Formula : Post-Pre)			Break Trough (+2 grams)	Cycle Count
2.7 L ORDC15	1835.3	1914.8	N/A	79.5			81.5	**1**
2.7 L ORDC15	N/A	N/A	N/A	149.1			151.1	**2**
2.7 L ORDC15	N/A	N/A	N/A	157.9			159.9	**3**
2.7 L ORDC15	N/A	N/A	N/A	165.2			167.2	**4**
2.7 L ORDC15	N/A	N/A	N/A	168.4			170.4	**5**
2.7 L ORDC15	N/A	N/A	N/A	170.1			172.1	**6**
2.7 L ORDC15	N/A	N/A	N/A	171.6			173.6	**7**
2.7 L ORDC15	N/A	N/A	N/A	171.2			173.2	**8**
2.7 L ORDC15	N/A	N/A	N/A	171.6			173.6	**9**
2.7 L ORDC15	N/A	N/A	1761.5	170.4			172.4	**10**

GWC Working Capacity = Cycle 9 +Cycle 10 / 2= GWC
GWC Working Capacity = 173.6 + 172.4 = GWC
GWC Working Capacity = 173.00 grams

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Detroit Testing Laboratory, Inc.

GENERAL DATA SHEET

CUSTOMER	**Southwest Research Institute**	DATE	**09/27/10-09/28/10**
SAMPLE DESCRIPTION/NUMBER	**Canister # 2.7 L ORDC 20 B**	JOB NO.	**100840038**
TEST SPECIFICATION	**GWC**	SHEET NO.	1 of 1
TEST PERFORMED	**GWC**	SAMPLE PREPARATION	
ACTUAL ENVIRONMENTAL CONDITIONS	**Hot (40°C)**	DATA BY	**SK**
TOLERANCE/UNCERTAINTY	**N/A**	REVIEWED BY	**JS**

SAMPLE# By DTL	Pre-Test Weight (grams)	Post-Test Weight Pre-Purge (grams)	Post-Test Weight Post-Purge (grams)	Capacity of canister (Formula : Post-Pre)			Break Trough (+2 grams)	Cycle Count
2.7 L ORDC20B	1965.8	2032.3	N/A	66.5			68.5	**1**
2.7 L ORDC20B	N/A	N/A	N/A	201.1			203.1	**2**
2.7 L ORDC20B	N/A	N/A	N/A	167.5			169.5	**3**
2.7 L ORDC20B	N/A	N/A	N/A	164.0			166.0	**4**
2.7 L ORDC20B	N/A	N/A	N/A	158.8			160.8	**5**
2.7 L ORDC20B	N/A	N/A	N/A	155.1			157.1	**6**
2.7 L ORDC20B	N/A	N/A	N/A	150.5			152.5	**7**
2.7 L ORDC20B	N/A	N/A	N/A	164.2			166.2	**8**
2.7 L ORDC20B	N/A	N/A	N/A	164.2			166.2	**9**
2.7 L ORDC20B	N/A	N/A	1895.3	167.0			169.0	**10**

GWC Working Capacity = Cycle 9 +Cycle 10 / 2= GWC
GWC Working Capacity = 166.2+ 169.0 = GWC
GWC Working Capacity = 167.70 grams

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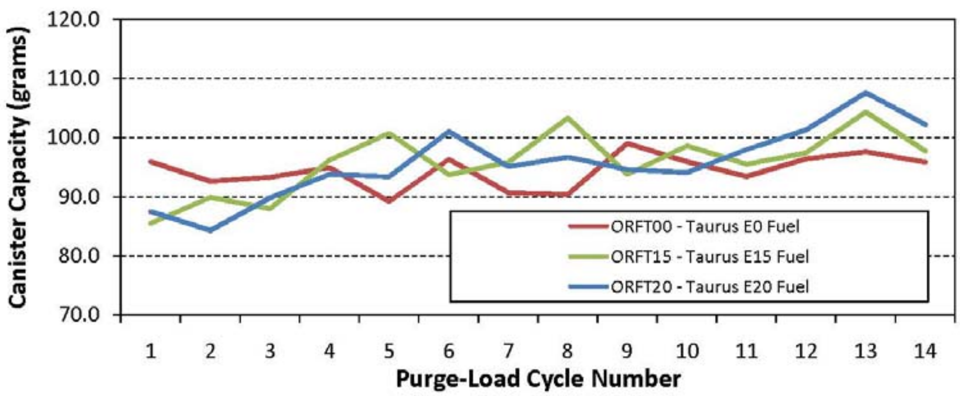
ENVIRONMENTAL TESTING CORP.
Canister Purge - Load Test Summary
Vehicle Set: 2008 Ford Taurus

CANISTER ID NO.	CYCLE NO.	PRE-TEST WT. (g)	AFTER-PURGE WT. (g)	AFTER-LOAD WT. (g)	TEST START DATE	TEST ID NO.	CANISTER LOAD (g)
ORFT0	1	2166.7	2153.4	2249.3	23-Sep	911416	95.9
	2	2249.3	2154.4	2247.0	23-Sep	911418	92.6
	3	2247.0	2149.2	2242.5	24-Sep	911419	93.3
	4	2242.5	2147.3	2242.2	24-Sep	911431	94.9
	5	2242.2	2152.6	2241.8	25-Sep	911432	89.2
	6	2241.8	2143.5	2239.8	25-Sep	911467	96.3
	7	2239.8	2148.5	2239.2	25-Sep	911468	90.7
	8	2239.2	2148.7	2239.1	26-Sep	911469	90.4
	9	2239.1	2139.8	2238.8	26-Sep	911470	99.0
	10	2170.5	2138.1	2234.0	27-Sep	911472	95.9
	11	2234.0	2141.4	2234.8	27-Sep	911473	93.4
	12	2234.8	2136.8	2233.2	27-Sep	911474	96.4
	13	2233.2	2132.7	2230.3	28-Sep	911475	97.6
	14	2230.3	2137.2	2233.0	28-Sep	911476	95.8

CANISTER ID NO.	CYCLE NO.	PRE-TEST WT. (g)	AFTER-PURGE WT. (g)	AFTER-LOAD WT. (g)	TEST START DATE	TEST ID NO.	CANISTER LOAD (g)
ORFT15	1	2244.9	2214.2	2299.7	23-Sep	911417	85.5
	2	2299.7	2207.9	2297.8	23-Sep	911420	89.9
	3	2299.8	2201.4	2289.4	24-Sep	911421	88.0
	4	2289.4	2195.3	2291.5	24-Sep	911433	96.2
	5	2291.5	2193.4	2294.1	24-Sep	911434	100.7
	6	2294.1	2193.7	2287.4	25-Sep	911446	93.7
	7	2287.4	2188.3	2284.1	25-Sep	911447	95.8
	8	2284.1	2185.7	2289.0	25-Sep	911448	103.3
	9	2189.0	2189.4	2283.2	25-Sep	911449	93.8
	10	2283.2	2185.0	2283.6	26-Sep	911450	98.6
	11	2295.0	2188.8	2284.3	26-Sep	911452	95.5
	12	2284.3	2182.8	2280.2	27-Sep	911453	97.4
	13	2280.2	2180.0	2284.3	27-Sep	911454	104.3
	14	2284.3	2180.7	2278.4	27-Sep	911455	97.7

ENVIRONMENTAL TESTING CORP.
Canister Purge - Load Test Summary
Vehicle Set: 2008 Ford Taurus

CANISTER ID NO.	CYCLE NO.	PRE-TEST WT. (g)	AFTER-PURGE WT. (g)	AFTER-LOAD WT. (g)	TEST START DATE	TEST ID NO.	CANISTER LOAD (g)
ORFT-20	1	2245.2	2221.5	2309.0	7-Oct	911614	87.5
	2	2309.0	2218.6	2302.9	8-Oct	911615	84.3
	3	2303.5	2211.1	2300.9	8-Oct	911616	89.8
	4	2300.9	2204.7	2298.5	9-Oct	911617	93.8
	5	2298.5	2200.7	2294.1	9-Oct	911618	93.4
	6	2294.1	2198.2	2299.2	9-Oct	911625	101.0
	7	2299.2	2197.9	2293.0	10-Oct	911626	95.1
	8	2293.0	2193.7	2290.4	10-Oct	911627	96.7
	9	2266.7	2189.6	2284.2	11-Oct	911628	94.6
	10	2284.2	2195.3	2289.4	11-Oct	911629	94.1
	11	2289.4	2191.0	2289.0	11-Oct	911630	98.0
	12	2289.0	2188.9	2290.2	12-Oct	911631	101.3
	13	2280.5	2183.3	2290.9	13-Oct	911632	107.6
	14	2290.9	2186.9	2289.1	14-Oct	911634	102.2



Detroit Testing Laboratory, Inc.

GENERAL DATA SHEET

CUSTOMER	**Southwest Research Institute**	DATE	**09/25/10-09/26/10**
SAMPLE DESCRIPTION/NUMBER	**Canister # 3.3 L ORCS 00**	JOB NO.	**100840038**
TEST SPECIFICATION	**GWC**	SHEET NO.	1 of 1
TEST PERFORMED	**GWC**	SAMPLE PREPARATION	
ACTUAL ENVIRONMENTAL CONDITIONS	**Hot (40°C)**	DATA BY	**SK**
TOLERANCE/UNCERTAINTY	**N/A**	REVIEWED BY	**JS**

SAMPLE# By DTL	Pre-Test Weight (grams)	Post-Test Weight Pre-Purge (grams)	Post-Test Weight Post-Purge (grams)	Capacity of canister (Formula : Post-Pre)			Break Trough (+2 grams)	Cycle Count
3.3 L ORCS00	2139.1	2191.7	N/A	52.6			54.6	1
3.3 L ORCS00	N/A	N/A	N/A	127.2			129.2	2
3.3 L ORCS00	N/A	N/A	N/A	138.2			140.2	3
3.3 L ORCS00	N/A	N/A	N/A	145.3			147.3	4
3.3 L ORCS00	N/A	N/A	N/A	148.8			150.8	5
3.3 L ORCS00	N/A	N/A	N/A	151.3			153.3	6
3.3 L ORCS00	N/A	N/A	N/A	153.3			155.3	7
3.3 L ORCS00	N/A	N/A	N/A	153.5			155.5	8
3.3 L ORCS00	N/A	N/A	N/A	154.7			156.7	9
3.3 L ORCS00	N/A	N/A	1933.5	154.9			156.9	10

GWC Working Capacity = Cycle 9 +Cycle 10 / 2= GWC
GWC Working Capacity = 156.7+ 156.9 = GWC
GWC Working Capacity = 156.8 grams

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Detroit Testing Laboratory, Inc.

GENERAL DATA SHEET

CUSTOMER	Southwest Research Institute	DATE	09/24/10-09/25/10
SAMPLE DESCRIPTION/NUMBER	Canister # 3.3 L ORCS 15	JOB NO.	100840038
TEST SPECIFICATION	GWC	SHEET NO.	1 of 1
TEST PERFORMED	GWC	SAMPLE PREPARATION	
ACTUAL ENVIRONMENTAL CONDITIONS	Hot (40°C)	DATA BY	SK
TOLERANCE/UNCERTAINTY	N/A	REVIEWED BY	JS

SAMPLE# By DTL	Pre-Test Weight (grams)	Post-Test Weight Pre-Purge (grams)	Post-Test Weight Post-Purge (grams)	Capacity of canister (Formula : Post-Pre)			Break Trough (+2 grams)	Cycle Count
3.3 L ORCS15	2227.1	2277.1	N/A	50.0			52.0	1
3.3 L ORCS15	N/A	N/A	N/A	128.3			130.3	2
3.3 L ORCS15	N/A	N/A	N/A	139.6			141.6	3
3.3 L ORCS15	N/A	N/A	N/A	147.5			149.5	4
3.3 L ORCS15	N/A	N/A	N/A	152.0			154.0	5
3.3 L ORCS15	N/A	N/A	N/A	155.8			157.8	6
3.3 L ORCS15	N/A	N/A	N/A	158.6			160.6	7
3.3 L ORCS15	N/A	N/A	N/A	159.4			161.4	8
3.3 L ORCS15	N/A	N/A	N/A	159.6			161.6	9
3.3 L ORCS15	N/A	N/A	1997.6	160.2			162.2	10

GWC Working Capacity = Cycle 9 +Cycle 10 / 2= GWC
GWC Working Capacity = 161.6 + 162.2 = GWC
GWC Working Capacity = 161.9 grams

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Detroit Testing Laboratory, Inc.

GENERAL DATA SHEET

CUSTOMER	**Southwest Research Institute**	DATE	**09/27/10-09/27/10**
SAMPLE DESCRIPTION/NUMBER	**Canister # 3.3 L ORCS 20**	JOB NO.	**100840038**
TEST SPECIFICATION	**GWC**	SHEET NO.	1 of 1
TEST PERFORMED	**GWC**	SAMPLE PREPARATION	
ACTUAL ENVIRONMENTAL CONDITIONS	**Hot (40°C)**	DATA BY	**SK**
TOLERANCE/UNCERTAINTY	**N/A**	REVIEWED BY	**JS**

SAMPLE# By DTL	Pre-Test Weight (grams)	Post-Test Weight Pre-Purge (grams)	Post-Test Weight Post-Purge (grams)	Capacity of canister (Formula : Post-Pre)			Break Trough (+2 grams)	Cycle Count
3.3 L ORCS20	2306.4	2354.1	N/A	47.7			49.7	1
3.3 L ORCS20	N/A	N/A	N/A	116.1			118.1	2
3.3 L ORCS20	N/A	N/A	N/A	129.7			131.7	3
3.3 L ORCS20	N/A	N/A	N/A	140.4			142.4	4
3.3 L ORCS20	N/A	N/A	N/A	147.7			149.7	5
3.3 L ORCS20	N/A	N/A	N/A	152.5			154.5	6
3.3 L ORCS20	N/A	N/A	N/A	155.6			157.6	7
3.3 L ORCS20	N/A	N/A	N/A	157.2			159.2	8
3.3 L ORCS20	N/A	N/A	N/A	158.9			160.9	9
3.3 L ORCS20	N/A	N/A	2045.1	160.4			162.4	10

GWC Working Capacity = Cycle 9 +Cycle 10 / 2= GWC
GWC Working Capacity = 160.9 + 162.4 = GWC
GWC Working Capacity = 161.65 grams

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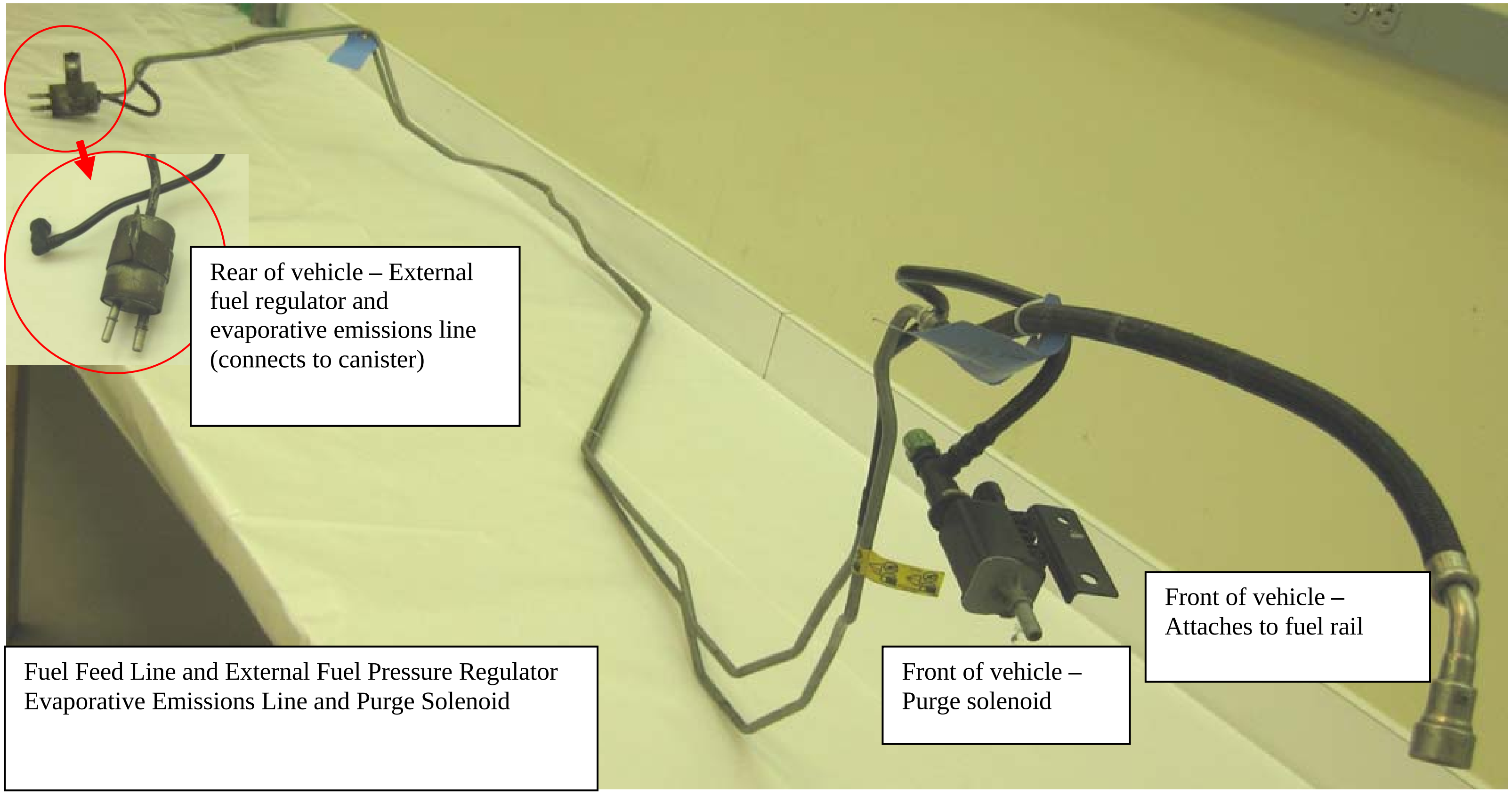
Appendix J

Visual Inspection of Fuel Tanks, Fuel Lines

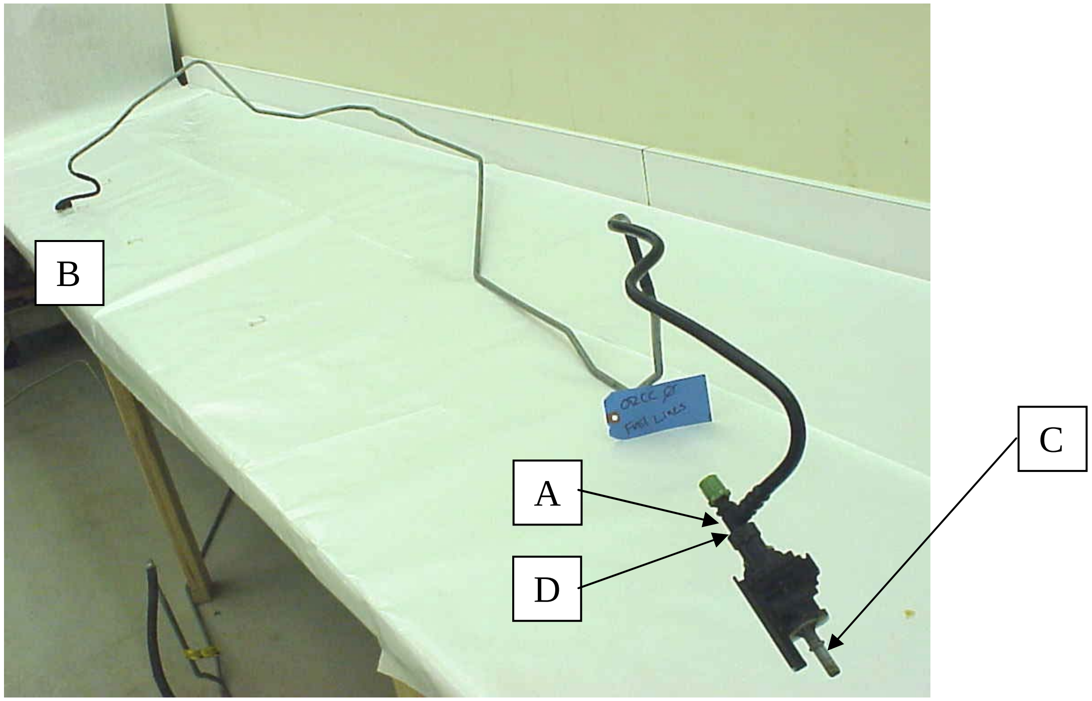
and Evaporative Emissions Lines

Chevrolet Cobalt



Fuel Feed Line

Vehicle	Visual Rating Comments	
	Front of Vehicle	Rear of Vehicle
ORCC0	15% white deposits, 85% clean O-ring rating: Good condition	Small diameter line – 2% white deposit, 98% clean Large diameter line – 100% clean
ORCC15	100% white deposit O-ring rating: Good condition	Small diameter line – 100% rust Large diameter line – 10% rust, 90% clean
ORCC20	100% white deposit O-ring rating: Good condition	Small diameter line – 5% rust, 95% clean Large diameter line – 100% rust

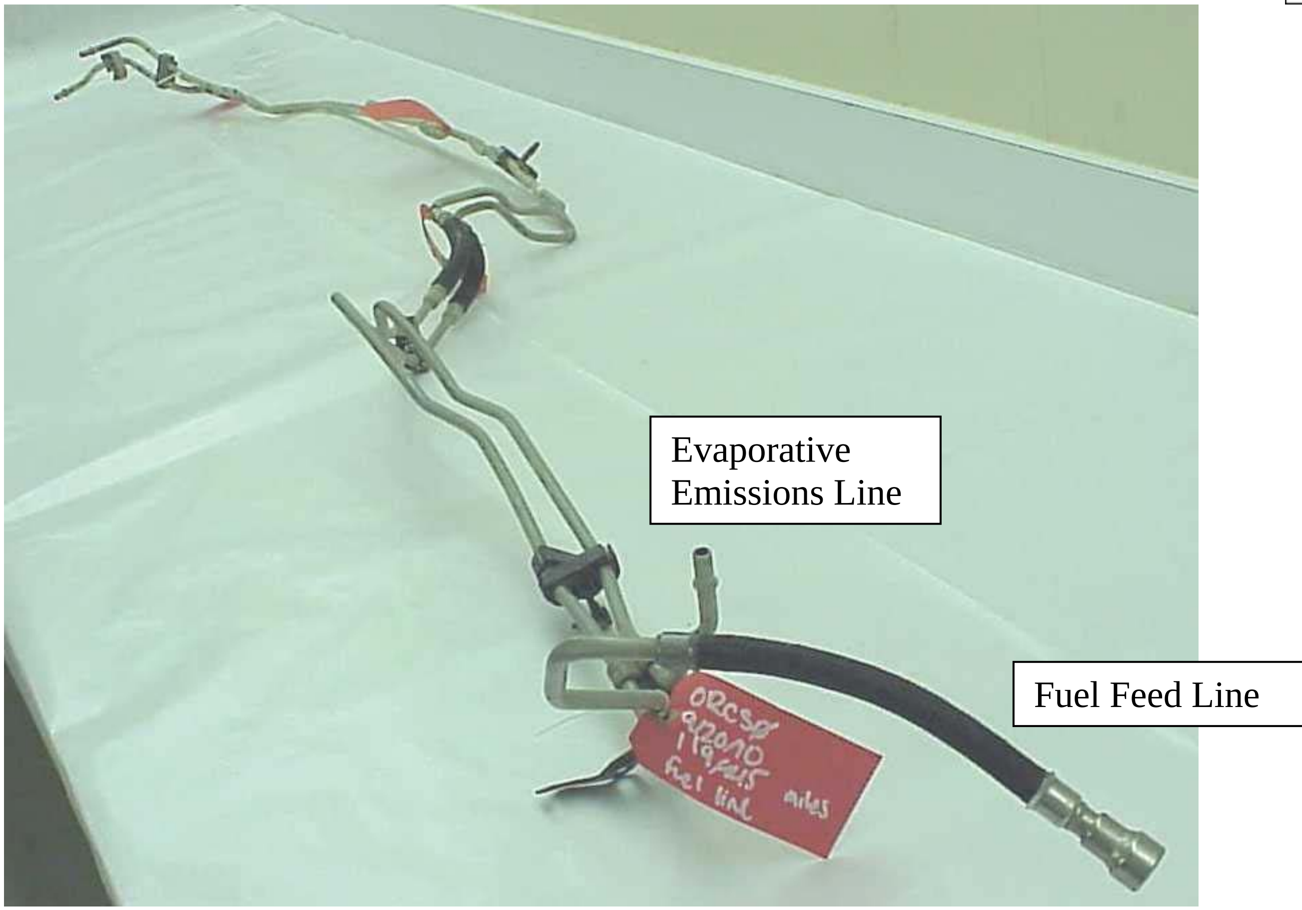


Evaporative Emissions Line

Vehicle	Visual Rating Comments	
	Front of Vehicle [A]	Rear of Vehicle [B]
ORCC0	Plastic hose rating: 90% white deposit, 10% clean O-ring rating: Good condition	Plastic line rating: 10% white deposit, 90% clean O-ring rating: Good condition
ORCC15	Plastic hose rating: Wet fuel present O-ring rating: Good condition	Hose rating: 100% clean O-ring rating: Good condition
ORCC20	Plastic hose rating: 5% brown deposit, 95% clean O-ring rating: Good condition	Plastic hose rating – 10% white deposit, 90% clean O-ring rating: Good condition

	Front of Purge Solenoid [C]	Rear of Vehicle [D]
ORCC0	100% clean	100% trace white deposit
ORCC15	100% clean	100% clean
ORCC20	100% clean	97% trace white deposit, 3% light white deposits

2006 Chevrolet Silverado



Fuel Feed Line

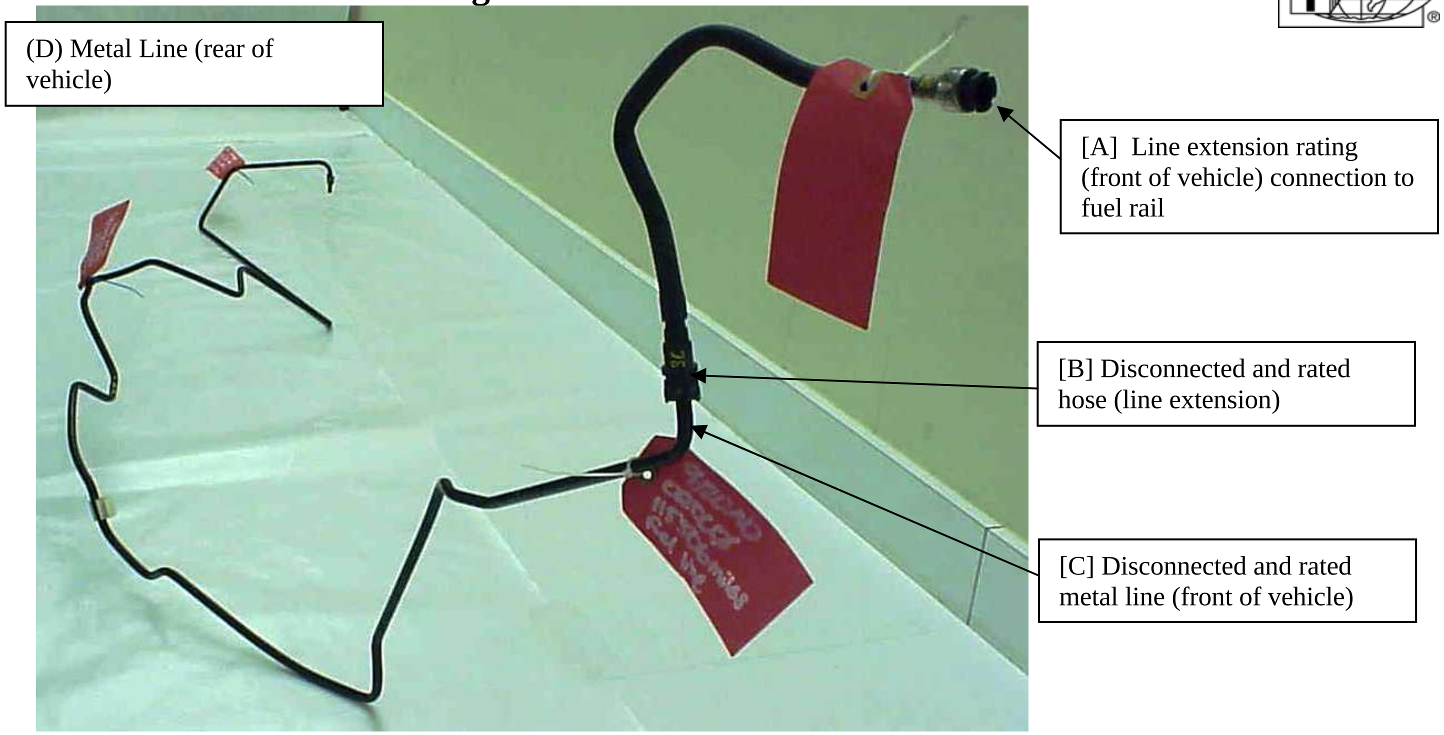
Vehicle	Visual Rating Comments	
	Front of Vehicle	Rear of Vehicle
ORCS0	Hose, 10% white deposit O-ring (yellow), good condition – (black) good condition	100% clean
ORCS15	Hose, 100% clean O-ring (yellow), good condition – (black) good condition	5% rust, 95% clean
ORCS20	Hose, 100% clean O-ring (yellow), good condition – (black) good condition	95% clean, 5% white deposits

2006 Chevrolet Silverado

Evaporative Emissions Line

Vehicle	Visual Rating Comments	
	Front of Vehicle	Rear of Vehicle
ORCS0	90% clean, 10% white deposits	100% rust deposits
ORCS15	100% clean	100% rust deposits
ORCS20	30% clean, 10% white deposits, 60% light gray deposits	100% rust deposits

Dodge Caravan



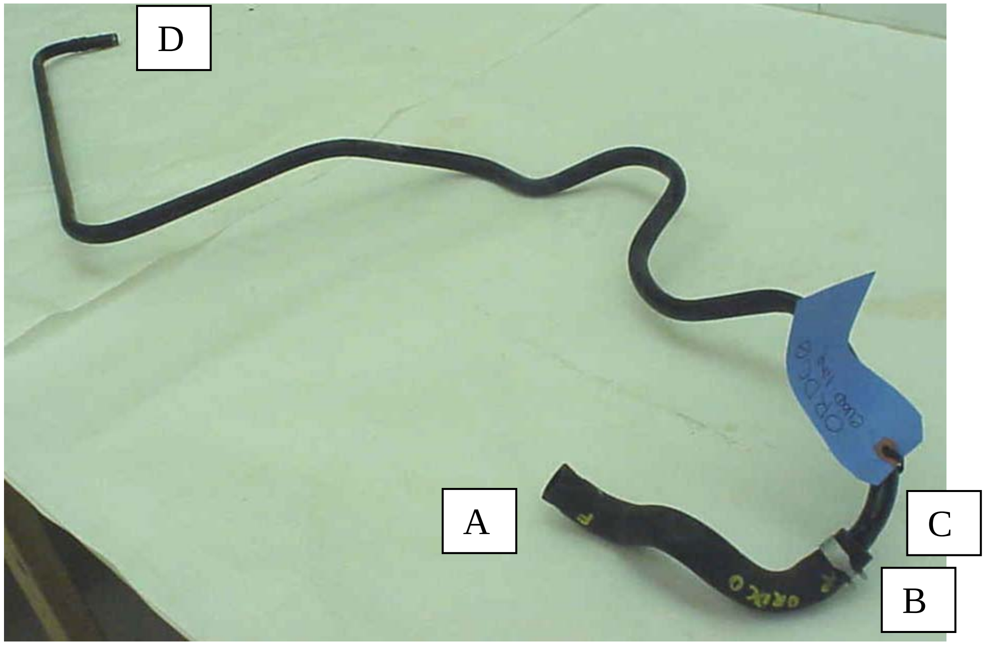
Fuel Feed Line Metal Line

Vehicle	Visual Rating Comments	
	[C] Front of Vehicle (attaches to the line extension)	[D] Rear of Vehicle
ORDC0	100% clean	10% rust, 90% clean
ORDC15	100% clean	20% rust, 80% clean
ORDC20B	100% clean	100% clean

Fuel Feed Line – Line Extension

Vehicle	Visual Rating Comments	
	[A] Front of Vehicle (connection to the fuel rail)	[B] Rear of Vehicle
ORDC0	80% white deposits, 20% rust – O-ring good condition	100% clean, O-ring in good condition
ORDC15	75% white deposits, 25% rust – O-ring good condition	100% clean, O-ring in good condition
ORDC20B	90% white deposits, 10% rust – O-ring good condition	100% clean, O-ring in good condition

Dodge Caravan



Evaporative Emissions Line – Rubber Hose

Vehicle	Visual Rating Comments	
	[A] Front of Vehicle	[B] Rear of Hose
ORDC0	10% white deposit, 90% clean	15% white deposit, 85% clean
ORDC15	2% white deposit, 98% clean	5% white deposit, 95% clean
ORDC20B	1% white deposit, 99% clean	100% clean

Evaporative Emissions Line

Vehicle	Visual Rating Comments	
	[C] Front of Vehicle (attaches to the line extension)	[D] Rear of Vehicle
ORDC0	90% white deposit, 10% clean	97% clean, 3% debris
ORDC15	43% white deposit, 57% clean	1% white deposit, 99% clean
ORDC20B	1% white deposit, 99% clean	10% clean

Ford Taurus

Fuel Feed Line

Vehicle	Visual Rating Comments	
	Front of Vehicle	Rear of Vehicle
ORFT0	100% clean, o-ring: good condition	2% rust: 98% clean
ORFT15	100% clean, o-ring: good condition	100% clean
ORFT20	100% clean, o-ring: good condition	2% rust: 98% clean

Ford Taurus

Evaporative Emissions Line

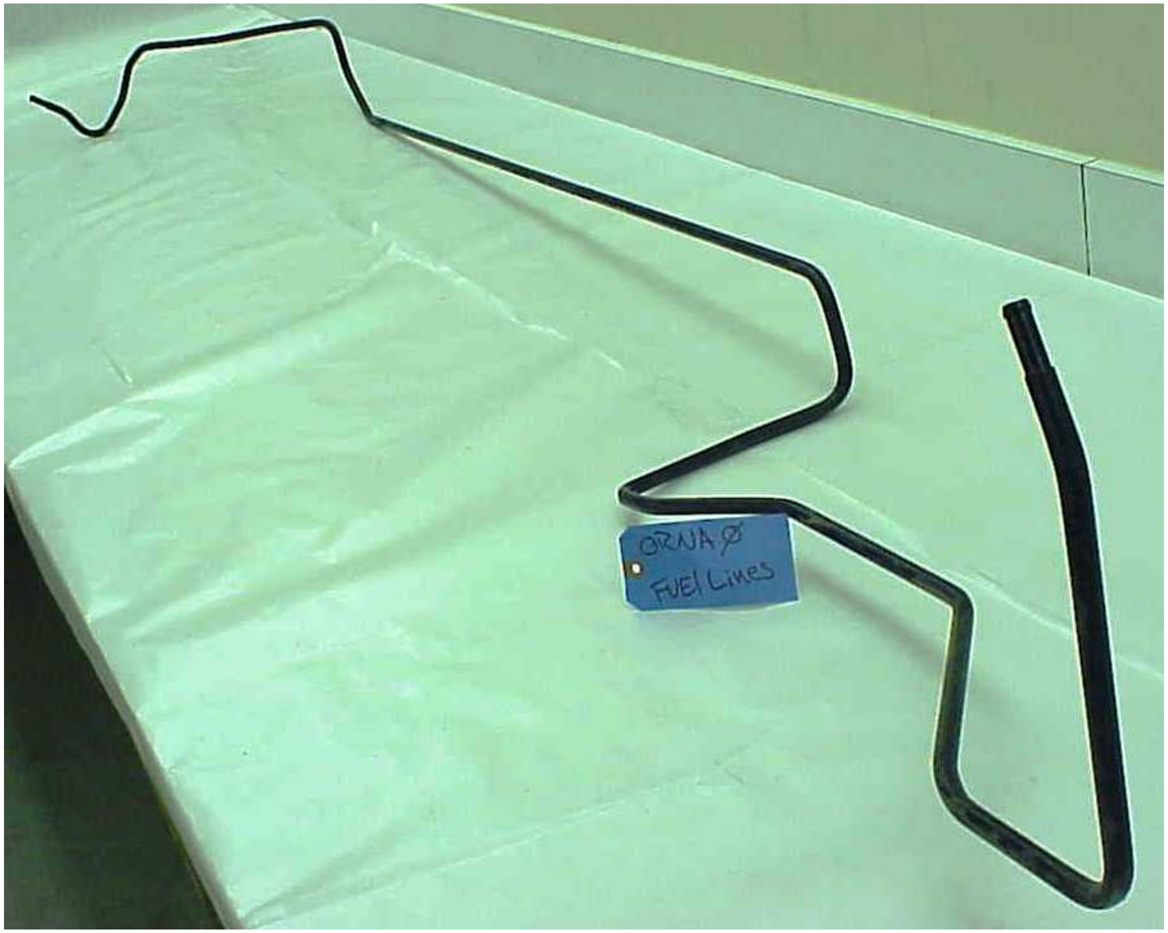
Vehicle	Visual Rating Comments	
	Front of Vehicle	Rear of Vehicle
ORFT0	100% white deposit – O-ring in good condition	100% clean, O-ring in good condition
ORFT15	100% clean, O-ring in good condition	100% clean, O-ring in good condition
ORFT20	100% clean, O-ring in good condition	100% clean, O-ring in good condition

Nissan Altima

Fuel Feed Line

Vehicle	Visual Rating Comments	
	Front of Vehicle	Rear of Vehicle
ORNA0	Hose rating, 100% clean, o-ring in good condition	100% clean, no deposits
ORNA15	Hose rating, 100% clean, o-ring in good condition	100% clean, no deposits
ORNA20	Hose rating, 100% clean, o-ring in good condition	100% clean, no deposits

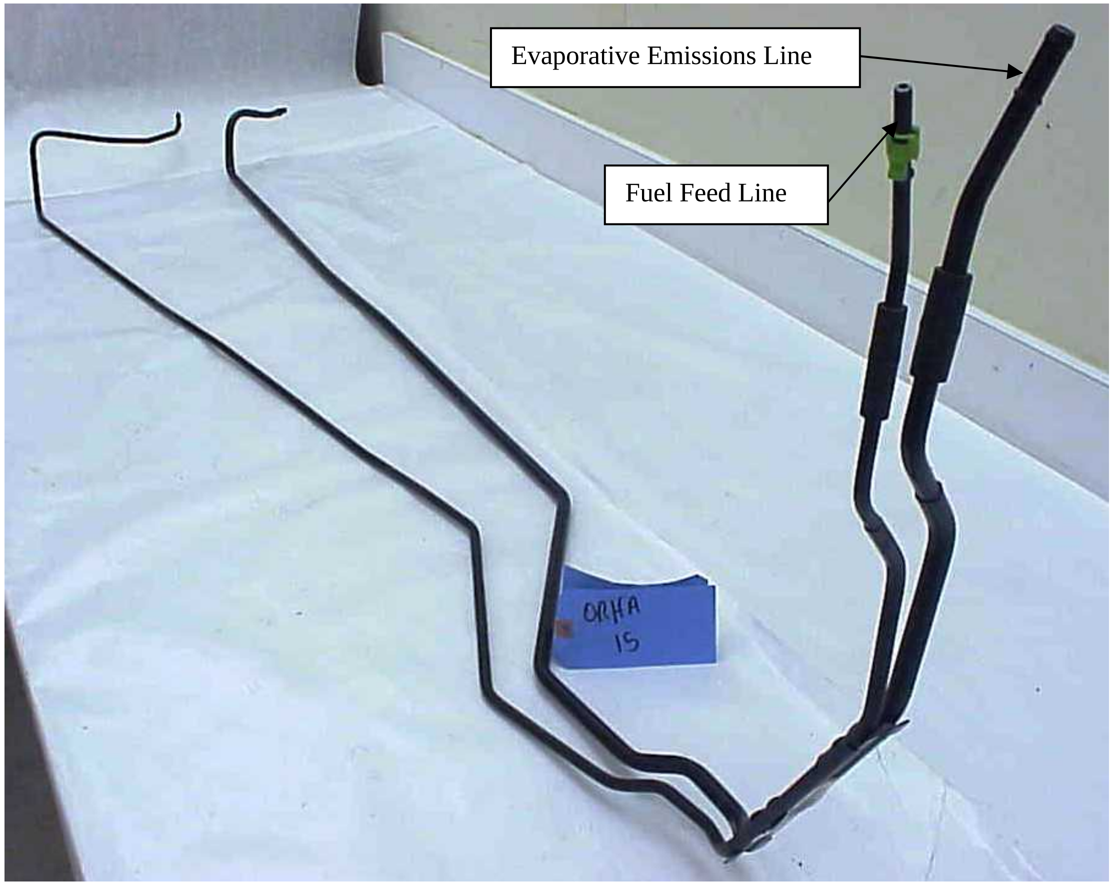
Nissan Altima



Evaporative Emissions Line

Vehicle	Visual Rating Comments	
	Front of Vehicle	Rear of Vehicle
ORNA0	100% clean	100% clean
ORNA15	100% clean	100% clean
ORNA20	100% clean	3% white deposit, 97% clean

Honda Accord



Fuel Feed Line

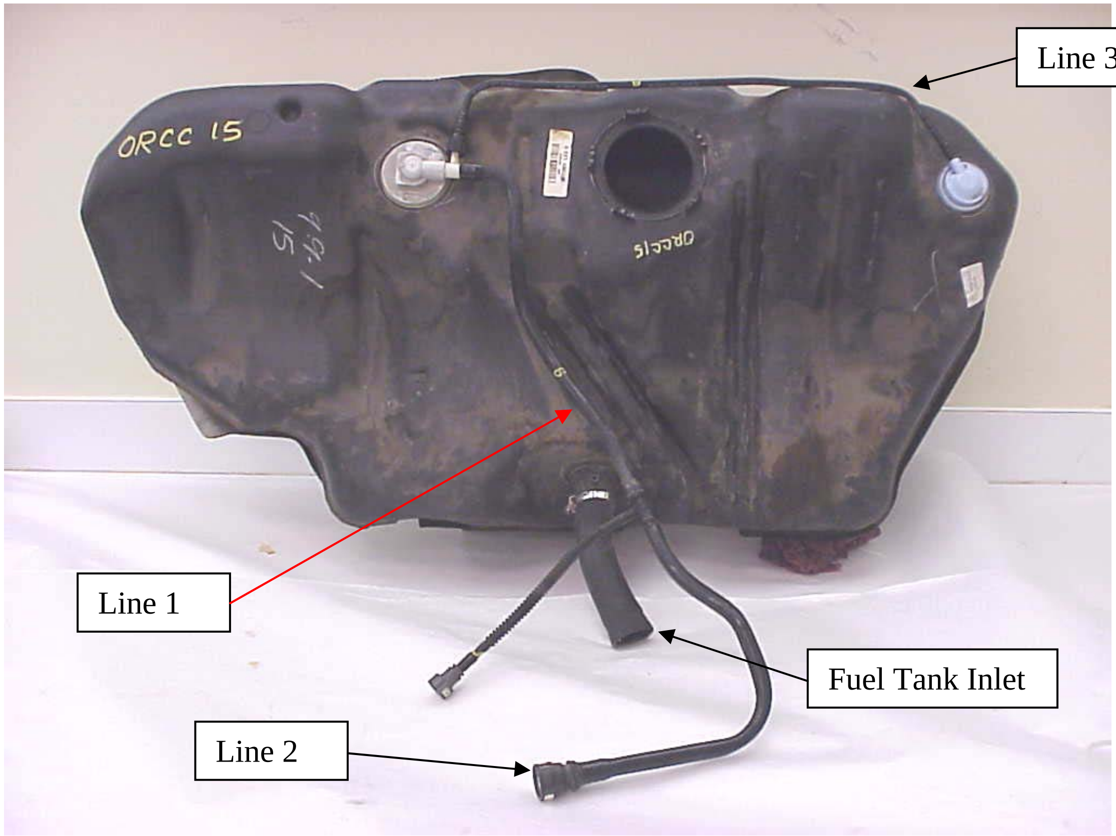
Vehicle	Visual Rating Comments	
	Front of Vehicle	Rear of Vehicle
ORHA0	100% clean	100% clean
ORHA15	100% clean	100% clean
ORHA20	100% clean	100% clean

Honda Accord

Evaporative Emissions Line

Vehicle	Visual Rating Comments	
	Front of Vehicle	Rear of Vehicle
ORHA0	100% clean	2% white deposit, 98% clean
ORHA15	100% clean	5% rust deposits, 95% clean
ORHA20	100% clean	5% rust deposits, 95% clean

Chevrolet Cobalt Fuel Tank Ratings

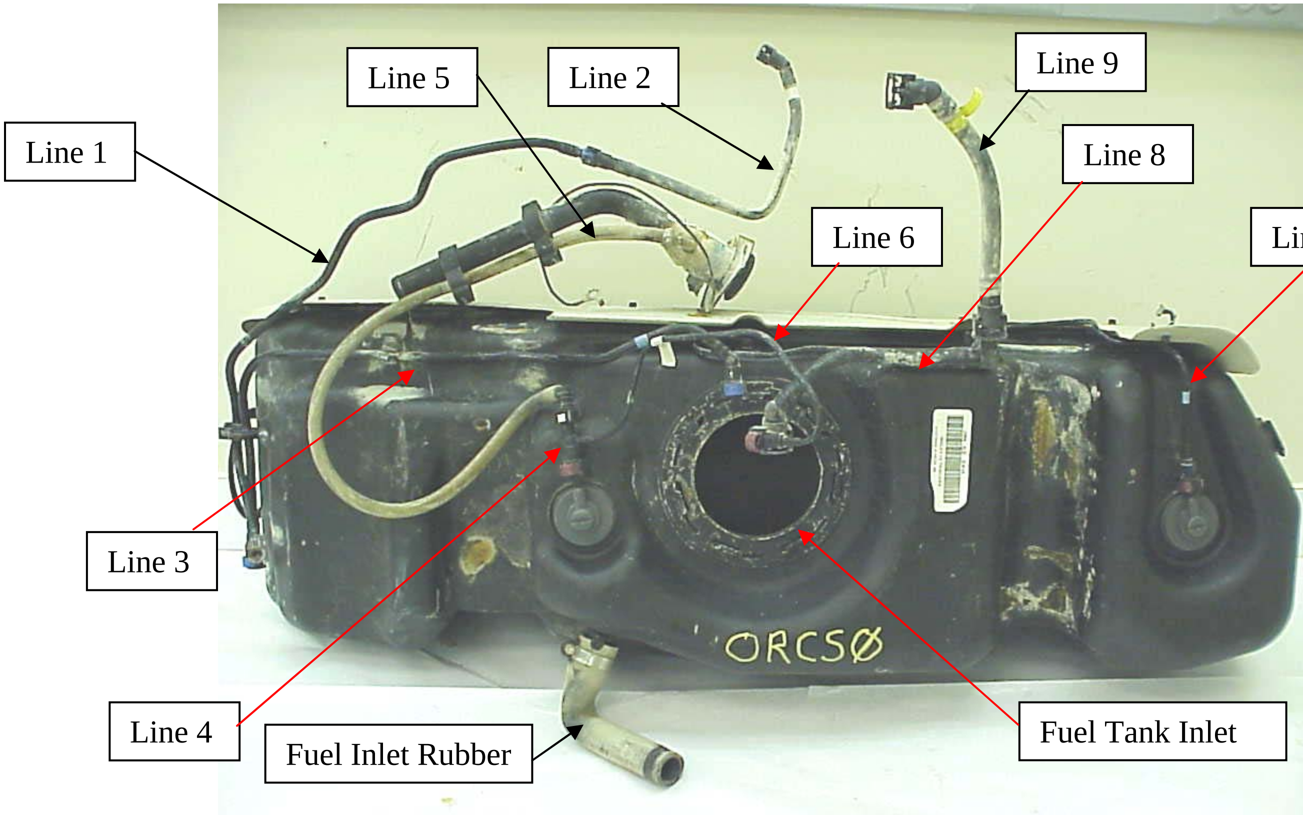


Vehicle	Visual Rating Comments		
	Inside Tank Rating	Fuel Tank Inlet	Tank Inlet Rubber Hose
ORCC0	4% debris, 96% clean	100% clean	100% clean
ORCC15	4% debris, 96% clean	100% clean	2% debris, 98% clean
ORCC20	5% debris, 95% clean	98%, 2% debris	Missing

Chevrolet Cobalt Fuel Tank Ratings

Line	ORCC0	ORCC15	ORCC20
Line 1	3% white deposits, 97% clean	3% white deposits, 2% debris, 95% clean	10% debris, 90% clean
O-rings	Good condition	Good condition	Good condition
Line 2	12% debris, 88% clean	1% debris, 99% clean	2% debris,3% white deposits, 95% clean
O-rings	Good condition	Good condition	Good condition
Line 3	3% white deposits, 5% debris, 92% clean	7% debris, 93% clean	10% debris, 90% clean
O-rings	Good condition	Good condition	Good condition

Chevrolet Silverado Fuel Tank Ratings

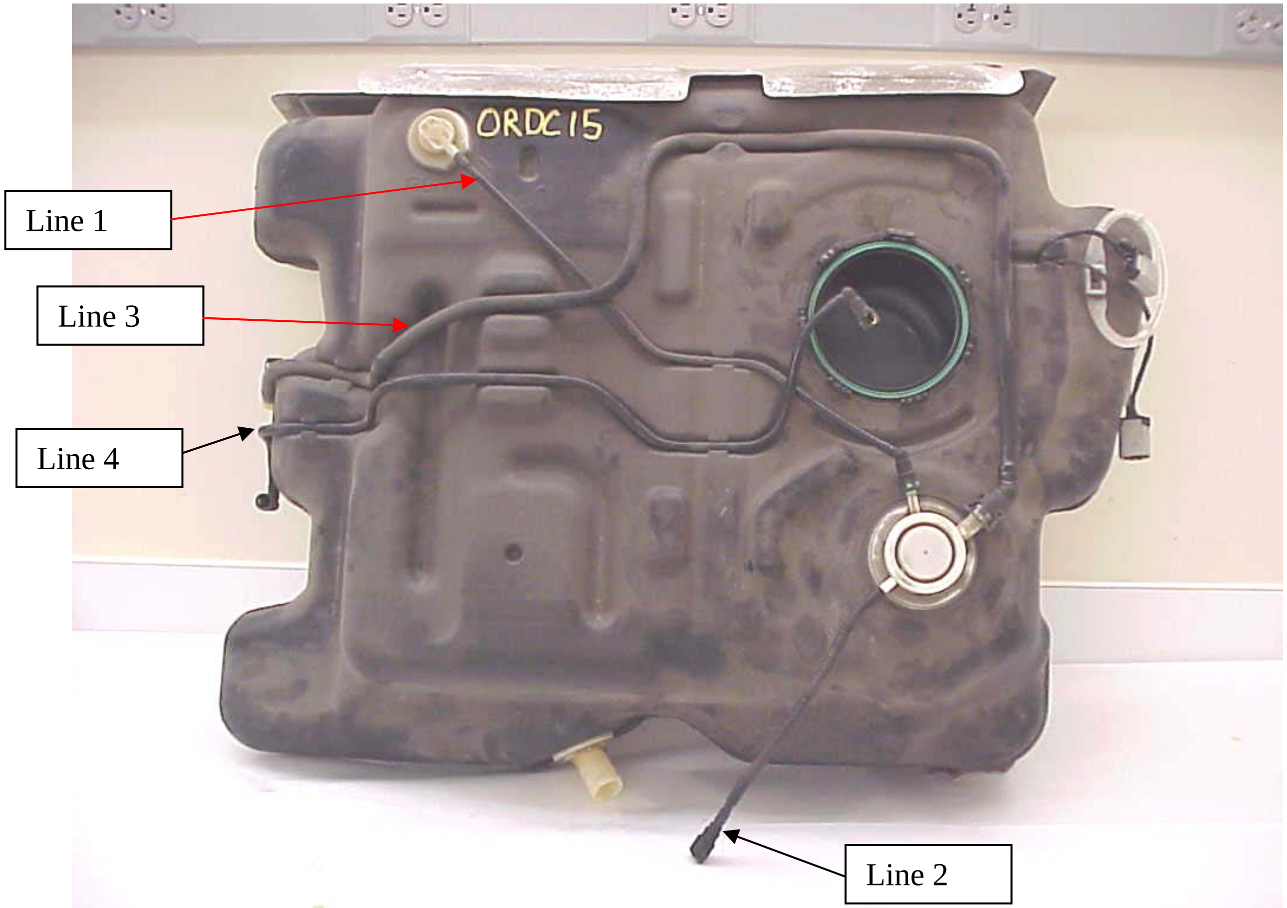


Vehicle	Visual Rating Comments			
	Inside Tank Rating	Fuel Tank Inlet	Tank Inlet Rubber Hose	Gasoline Pump Line
ORCS0	5% rust, 5% debris, 90% clean	5% deposits, 95% clean	100% clean	5% debris, 2% rust, 93% clean
ORCS15	5% debris, 95% clean	100% clean	100% clean	Missing
ORCS20	5% debris, 95% clean	100% clean	100% clean	Missing

Chevrolet Silverado Fuel Tank Ratings

Line	ORCS0	ORCS15	ORCS20
1 outside front	100% debris	90% white deposits, 10% clean	100% clean
Line 1 attached to line 2	100% clean	100% clean	100% clean
O-rings on outside	Good condition	Good condition	Good condition
Line 2 attached to line 1	2% debris, 98% clean	Missing	Missing
Line 2 outside	5% debris, 95% clean O-ring good condition	Missing	Missing
Line 3 outside front	5% debris, 95% clean O-ring good condition	100% clean O-ring good condition	100% clean O-ring good condition
Line 3 outside rear	5% debris, 95% clean O-ring good condition	20% debris, 80% clean O-ring good condition	100% clean O-ring good condition
Line 4	10% white deposit, 5% debris, 85% clean – O-rings in good condition	100% clean	100% clean O-rings in good condition
Line 5 attached to line 4	50% white deposits, 50% clean O-ring good condition	40% white deposits, 60% clean O-ring good condition	Missing
Line 5 attached to gas pump line	100% clean	50% debris, 50% clean	Missing
Line	ORCS0	ORCS15	ORCS20
Line 6 attached to line 4	100% clean	100% clean	100% clean
O-rings	O-rings good condition	O-rings good condition	O-rings good condition
Line 7	10% debris, 90% clean	50% white deposit, 50% clean	100% clean
O-rings	O-rings good condition	O-rings good condition	O-rings good condition
Line 8 attached to line 7	3% white deposits, 97% clean	10% white deposits, 90% clean	100% clean
O-rings	O-rings good condition	O-rings good condition	O-rings good condition
Line 9 attached to lines 7&8	2% white deposits, 93% debris, 5% clean	60% white deposits, 40% clean O-rings good condition	Missing

Dodge Caravan Fuel Tank Ratings

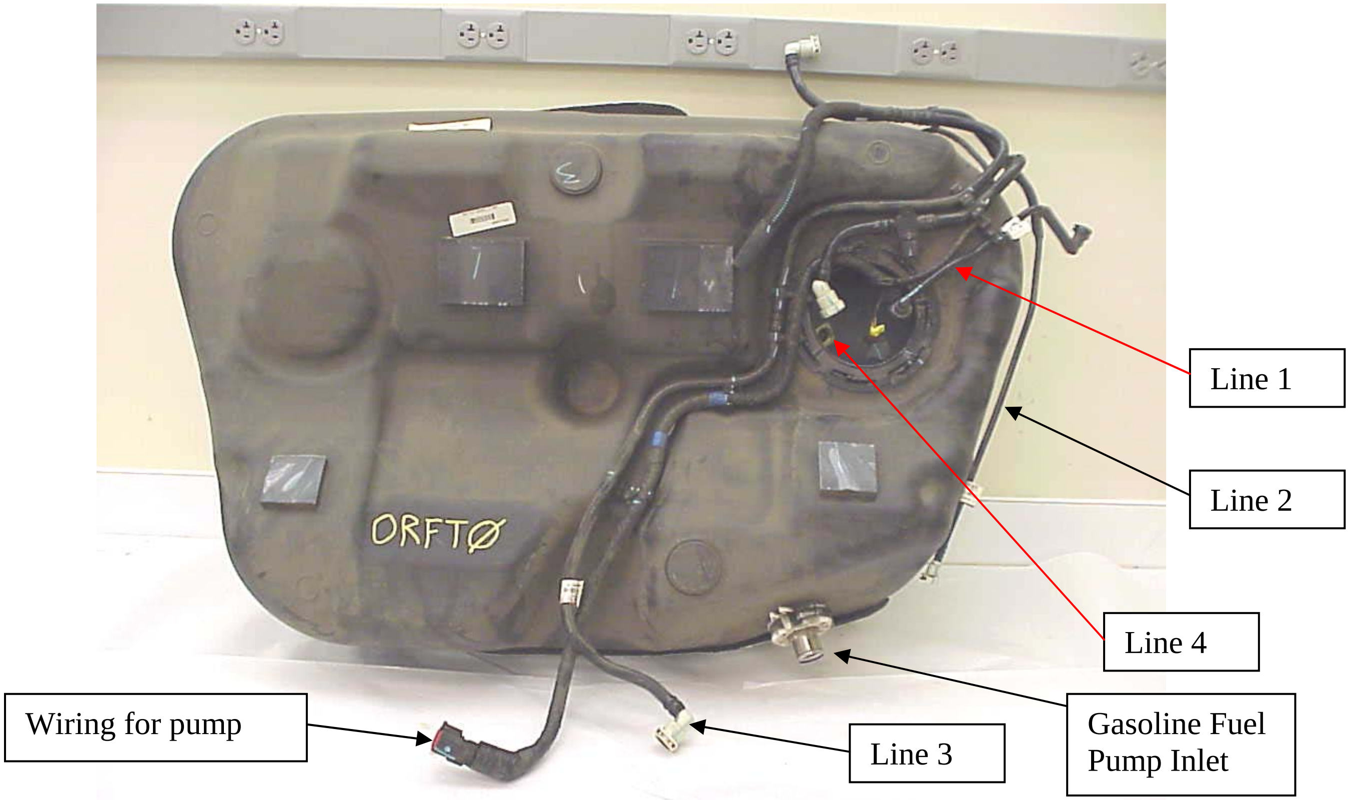


Vehicle	Visual Rating Comments		
	Inside Tank Rating	Fuel Tank Inlet	Fuel Pump Module O-Ring
ORDC0	1% debris, 1% rust, 98% clean	100% clean	Good condition
ORDC15	1% debris, 99% clean	100% clean	Good condition
ORDC20	2% debris, 98% clean	1% debris, 99% clean	Missing

Dodge Caravan Fuel Tank Ratings

Line	ORDC0	ORDC15	ORDC20
Line 1	100% white deposits	40% white deposits & 60% clean	20% white deposits & 80% clean
O-Rings	Good condition	Good condition	Good condition
Line 2	100% clean	100% clean	100% clean
O-Ring	Good condition	Good condition	Good condition
Line 3	20% deposit and 80% clean	30% white deposit and 70% clean	100% clean
O-Rings	Good condition	Good condition	Good condition
Line 3 Outside	10% white deposits	100% clean	3% debris, 97% clean
O-Ring	Good condition	Good condition	Good condition
Line 4	100% clean	100% clean	100% clean
O-Rings	Good condition	Good condition	Good condition
Line 4 Outside	100% clean	100% clean	100% clean
O-Ring	Good condition	Good condition	Good condition

Ford Taurus Fuel Tank Ratings

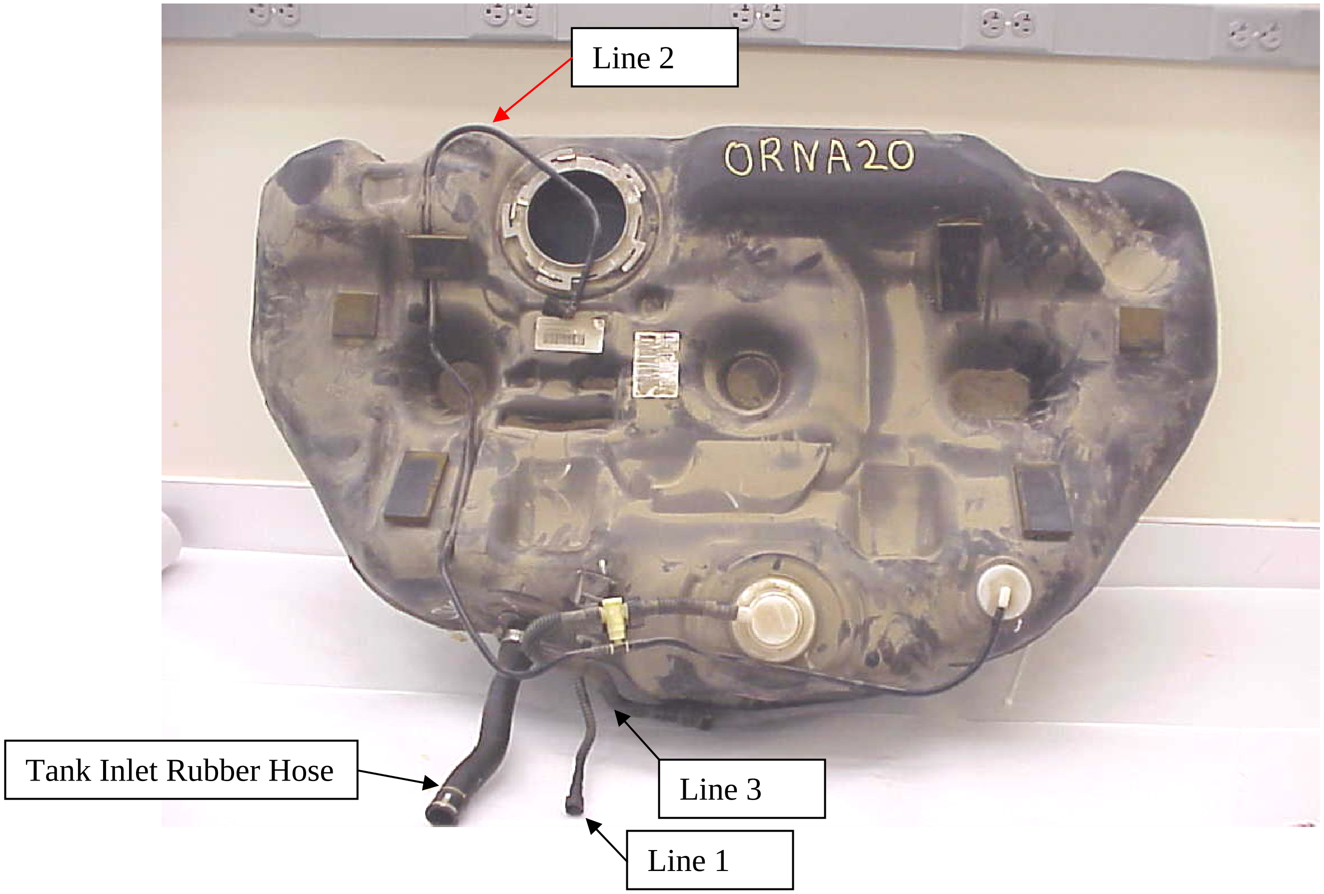


Vehicle	Visual Rating Comments	
	Inside Tank Rating	Fuel Pump Inlet Line
ORFT0	1% debris, 99% clean	100% clean
ORFT15	100% clean	100% clean
ORFT20	100% clean	100% clean

Ford Taurus Fuel Tank Ratings

Line	ORFT0	ORFT15	ORFT20
Line 1	100% clean	Missing	Missing
O-ring	Good condition	Missing	Missing
Line 1 outside of tank	5% rust and 95% clean	Missing	Missing
Line 2 to open hole	100% clean	1% debris, 99% clean	100% clean
O-rings	Good condition	Good condition	Good condition
Line 2 front side	100% clean	100% clean	100% clean
O-rings	Good condition	Good condition	Good condition
Line 2 rear side	8% debris, 92% clean	10% debris, 90% clean	100% clean
O-rings	Good condition	Good condition	Good condition
Line 3 to front side	30% debris, 70% clean	30% debris, 70% clean	Missing
O-ring	Good condition	Good condition	Missing
Line 3 going to rear side	5% white deposits, 95% debris	100% deposits	Missing
O-ring	Good condition	Good condition	Missing
Line 4	100% clean	100% clean	2% debris, 98% clean
O-ring	Good condition	Good condition	Good condition

Nissan Altima Fuel Tank Ratings

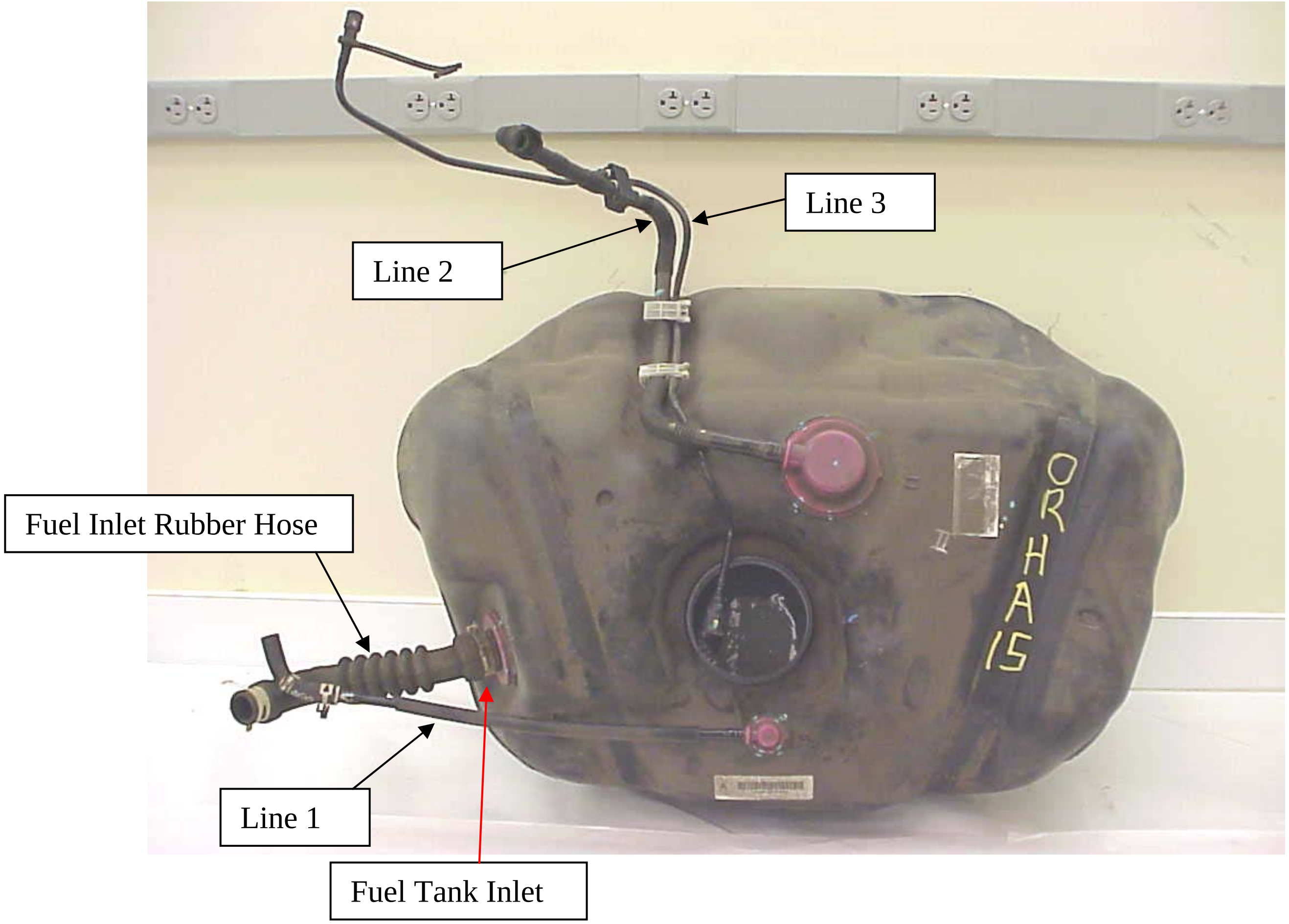


Vehicle	Visual Rating Comments			
	Inside Tank Rating	O-Ring	Gasoline Tank Inlet	Tank Inlet Rubber Hose
ORNA0	1% debris, 99% clean	Good condition	100% clean	100% clean
ORNA15	100% clean	Good condition	100% clean	100% clean
ORNA20	1% debris, 99% clean	Good condition	100% clean	100% clean

Nissan Altima Fuel Tank Ratings

Line	ORNA0	ORNA15	ORNA20
Line 1 outside of tank O-ring	90% clean, 10% debris	100% clean	90% clean, 10% debris
	Good condition	Good condition	Good condition
Line 2 outside of tank O-rings	98% clean, 2% debris	100% clean	100% clean
	Good condition	Good condition	Good condition
Line 3 outside of tank O-rings	99% clean, 1% debris	99% clean, 1% debris	100% clean
	Good condition	Good condition	Good condition

Honda Accord Fuel Tank Ratings



Vehicle	Visual Rating Comments		
	Inside Tank Rating	Fuel Tank Inlet	Tank Inlet Rubber Hose
ORHA0	100% clean	100% clean	10% debris, 90% clean
ORHA15	100% clean	100% clean	5% white deposits, 95% clean
ORHA20	3% debris, 97% clean	100% clean	Missing

Honda Accord Fuel Tank Ratings

Line	ORHA0	ORHA15	ORHA20
Line 1 Rubber hose	100% clean	100% clean	100% clean
	5% debris, 95% clean	100% clean	100% clean
Line 2 O-rings	2% white deposits, 98% clean	100% clean	2% white deposits, 98% clean
	Good condition	Good condition	Good condition
3 going to open hole	Missing	100% clean O-rings in good condition	100% clean O-rings in good condition
3 going to outside front	Missing	100% clean O-rings in good condition	100% clean O-rings in good condition