

United States
Environmental Protection
Agency

Office of Mobile Source Air Pollution Control
Emission Control Technology Division
2565 Plymouth Road
Ann Arbor, Michigan 48105

EPA 460/3-88-006
May 1988

Air



Intake System Deposits and Gasoline/Alcohol Blends



Intake System Deposits and Gasoline/Alcohol Blends

by

Sherrill F. Martin

Southwest Research Institute
6220 Culebra Road
San Antonio, Texas 78284

Contract No. 68-03-3353
Work Assignment B-2

EPA Project Officer: Craig A. Harvey

Prepared for

ENVIRONMENTAL PROTECTION AGENCY
Office of Mobile Source Air Pollution Control
Emission Control Technology Division
2565 Plymouth Road
Ann Arbor, Michigan 48105

May 1988

This report is issued by the Environmental Protection Agency to report technical data of interest to a limited number of readers. Copies are available free of charge to Federal employees, current contractors and grantees, and nonprofit organizations - in limited quantities - from the Library Services Office, Environmental Protection Agency, 2565 Plymouth Road, Ann Arbor, Michigan 48105.

This report was furnished to the Environmental Protection Agency by Southwest Research Institute, 6220 Culebra Road, San Antonio, Texas, in fulfillment of Work Assignment No. B-2 of Contract 68-03-3353. The contents of this report are reproduced herein as received from Southwest Research Institute. The opinions, findings, and conclusions expressed are those of the author and not necessarily those of the Environmental Protection Agency. Mention of company or product names is not to be considered as an endorsement by the Environmental Protection Agency.

Publication No. EPA 460/3-88-006

FOREWORD

This report covers the effort under Work Assignment No. B-2 of EPA Contract 68-03-3353, performed for the Emission Control Technology Division, Environmental Protection Agency, 2565 Plymouth Road, Ann Arbor, Michigan 48105. The EPA Contracting Officer was Mr. E. M. Hennessey, and the Project Officer was Mr. Craig A. Harvey.

The Southwest Research Institute Project Leader was Sherrill F. Martin. Charles T. Hare, Project Manager, was involved in fiscal negotiations concerning this work assignment, and Charles M. Urban was involved in technical development of the test plan. The project was performed during the period September, 1986 through August, 1987 and was identified as SwRI Project 08-1193-002.

ABSTRACT

Six vehicles, four of them ethanol blend-fueled and two gasoline-fueled, were examined for intake system deposits. The engines were partially disassembled, photographs were taken, and deposits were evaluated by a professional rater. Elemental analysis was made of the intake valve deposits.

TABLE OF CONTENTS

	<u>Page</u>
FOREWORD	iii
ABSTRACT	iv
LIST OF FIGURES	vi
LIST OF TABLES	vii
I. SUMMARY	1
II. INTRODUCTION	3
III. TEST PLAN	5
A. Test Plan	5
1. Task 1 - Arrange for Test Vehicles and Inspection Capability	5
2. Task 2 - Inspection and Parts Replacement	6
a. Task 2A - Engines	6
b. Task 2B - Fuel Tank	6
3. Task 3 - analysis	6
B. Vehicles	7
C. Blend Fuel	8
IV. DISASSEMBLY AND INSPECTION	9
V. DEPOSIT RATINGS	17
A. Engine Components	20
1. Intake Valves	18
2. Combustion Chambers	19
3. Intake Manifold Runners and Intake Ports	19
4. Piston Crowns	19
5. Carburetor Bores	19
6. Miscellaneous Items	19
B. Fuel Tanks	20
VI. ANALYSIS OF VALVE DEPOSITS	21
VII. DISCUSSION OF PROGRAM RESULTS	23
APPENDICES	
A. Vehicle Information	
B. Rater's Reports	
C. Fuel Additive Analysis	

LIST OF FIGURES

<u>Figure</u>		<u>Page</u>
1	Intake Valves, Ford Escorts	10
2	Intake Valves, Plymouth Reliants	11
3	Cylinder Heads, Plymouth Reliants	12
4	Typical Cylinder Head, Ford Escorts	13
5	Intake Manifolds, Plymouth Reliants	14
6	Carburetor Bores, Plymouth Reliants	15
7	Fuel Tanks, Ford Escorts	16

LIST OF TABLES

<u>Table</u>		<u>Page</u>
1	Deposit Rating Summary	1
2	Test Vehicles	7
3	Ratings of Intake Valves	17
4	Ratings of Combustion Chambers	18
5	Ratings of Manifold Runners	18
6	Ratings of Intake Ports	18
7	Ratings of Piston Crowns	19
8	Ratings of Carburetor Bores	19
9	Ratings of Miscellaneous Items	20
10	Elemental Analysis of Valve Deposits	22

I. SUMMARY

Six vehicles, three Ford Escorts and three Plymouth Reliants, were borrowed from the State of Minnesota for examination of their intake system deposits. Two vehicles of each make had been operated almost exclusively on a 10% ethanol blend available at fleet headquarters, while the third had been fueled with gasoline purchased on the road. The average age of the vehicles was five years, and the average odometer reading was 63,000 miles.

The vehicles were transported to Southwest Research Institute, San Antonio, Texas, for examination. Cylinder heads, intake manifolds, and valves were removed. Fuel tanks were also removed and cut open for inspection.

Preliminary observations showed that one of the blend-fueled Reliants had extreme deposits on the intake valves. The other blend-fueled Reliant also showed very heavy valve deposits, but not to the extreme extent of the first. The gasoline-fueled Reliant had deposits which were typical of a vehicle of its age and mileage. One of the blend-fueled Escorts had heavier intake valve deposits than the other two Escorts. Other components showed either the same trend to a lesser degree or minimal differences. The rater's report is summarized in Table 1. Higher numerical ratings mean better condition or less severe deposits.

TABLE 1. DEPOSIT RATING SUMMARY

<u>Vehicle/Fuel</u>	<u>Valves</u>	<u>Manifold Runners</u>	<u>Intake Ports</u>	<u>EGR Line</u>	<u>Carburetor</u>
Ford Escort					
Gasoline	7.6	8.2	8.0	8.0	7.3
Blend, avg.	6.7	8.6	8.3	8.0	6.8
Plymouth Reliant					
Gasoline	6.3	8.0	9.2	6.0	7.0
Blend, avg.	4.2	7.5	7.0	5.2	4.2

An elemental analysis of the deposits found on the intake valves was conducted. Sulfur, iron, copper, and zinc appear to correlate with type of fuel. Magnesium, aluminum, phosphorus, potassium, iron, and nickel showed correlation with vehicle make.

II. INTRODUCTION

On September 11, 1986, Work Assignment No. B-2, entitled, "Intake System Deposits and Gasoline/Alcohol Blends," was authorized by the EPA Contracting Officer for contract 68-03-3353. The objective of this work assignment was to determine any differences in deposit-forming tendencies of gasoline versus gasoline/alcohol blends, in vehicles that have use these fuels over an extended period of time in typical everyday driving.

III. TEST PLAN

This section provides the test plan that was to be followed and describes the vehicles used in the work assignment. It also describes what is known about the fuel used in the vehicles.

A. Test Plan

The test plan was divided into three major parts. They are described in the following three sub-sections.

1. Task 1 - Arrange for Test Vehicles and Inspection Capability

Each of the potential candidate fleets of vehicles listed in Table 1 of the Appendix A "Statement of Work" (S.O.W.) will be contacted. Contact will also be made with other potential sources of vehicles, primarily local sources, if any such fleets are located. Vehicle selection (automobiles, small vans, or pickups) will be based on the criteria given under Task 1 in the S.O.W. Following identification of potentially available vehicles that apparently meet the required criteria, verification of their operating history will be obtained. It is anticipated that such verification will require on-site visits to inspect the vehicles and the records. Only vehicles having adequate operating records as required in Tasks 1 and 2A of the S.O.W. will be considered for final selection. As required, a maximum of 40 hours will be expended in identifying potentially available vehicles and in making preliminary provisions for performing the Task 2 inspections. At that time, the status will be reported verbally to the Project Officer. If conditions are such that a Project Officer decision on continuation appears appropriate, this decision will be requested.

In the event that all required information concerning the vehicles is readily provided by the vehicle sources, it will be included in the verbal report to the Project Officer. As previously stated, however, it is anticipated that a visit will be required to each of the sources of the tentatively selected vehicles. Such site visits are not included in and will be in addition to the previously stated 40 hours. Visits to each source of vehicles could be required, two are assumed for planning purposes.

It is planned to arrange for transport of the vehicles to SwRI for inspection, but potential for on-site vehicle inspection will be discussed with the sources. Conducting the inspections at SwRI will generally be more efficient, provide for better technical control, and enable better safety precautions when working with the fuel tanks. In summary, more reliable data will be obtained at lower costs. Other than reimbursing the vehicle supplier for the cost of renting a replacement vehicle, no provisions are included for any compensation or financial incentives to the suppliers of the vehicles.

The Project Officer will be notified of the vehicles selected, and his approval will be obtained prior to continuation of the project. If we are dealing with fleets operated by government organizations, limited assistance by EPA personnel (introductions to fleet managers, interagency cooperation requests, etc.) may also be requested to find vehicles.

This planned effort is based on a total of six vehicles, two having operated on gasoline and four on gasoline-alcohol blends. Depending on the actual effort involved in locating, obtaining, and evaluating the vehicles, the total number of vehicles could increase or decrease from the planned number.

2. Task 2 - Inspection and Parts Replacement

Information listed under Task 2A of the S.O.W. will be recorded for each vehicle inspected. The information related to source and operation of the vehicles will generally be obtained in Task 1, prior to final selection of the vehicles. Component inspections will be conducted by a qualified rater in accord with CRC rating procedures, where applicable. For any components or requirements not covered by a procedure, an existing procedure considered most appropriate will be adapted. Tentative inspection methods for use in this work assignment are listed in Appendix B.

a. Task 2A - Engines

Engine components listed under Task 2A of the S.O.W. will be inspected. These inspections will include the following criteria, as appropriate: deposits, wear, cracks, surface texture and discoloration.

It is planned to remove the carburetor, intake manifold, and the cylinder head(s). In addition, it will generally be necessary to remove the EGR valve and the intake and exhaust valves to conduct the requested inspections. Any valves with an "unusual" amount of deposit build-up or erosion will be replaced, as described under Task 2A of the S.O.W. Any "unusual" deposit build-up or other characteristics apparent on other components will be photographed and/or samples taken as appropriate and practical. Replacement of components, other than valves as previously described, will be done only when necessary, or when deemed appropriate based on the severity of deposits or other characteristics.

b. Task 2B - Fuel Tank

The fuel tank will be removed from each vehicle and replaced with a new fuel tank. The procedure to be followed for inspecting the in-use fuel tanks will be as follows:

- (1) Drain fuel tank and remove from vehicle (if inspection preparation is not to proceed at that time, replace several gallons of the drained fuel and seal all fuel tank openings).
- (2) Drain, or otherwise remove, all liquid fuel from the tank.
- (3) Purge the tank with nitrogen, or other appropriate inert gas, until essentially all fuel vapors are removed from the tank.
- (4) While still flowing the purge gas, cut open the fuel tank.
- (5) Inspect the tank in accord with the requirements under Task 2B of the S.O.W.

NOTE: Steps 2 through 5 will normally be completed during an 8-hr work shift, and in no case will the elapsed time exceed 24 hours.

3. Task 3 - Analysis

Selected deposit samples will be analyzed to determine amount, composition, and physical characteristics. The number of samples and the specific analyses will be determined in coordination with the Project Officer. The allocation in this work plan is for a reasonable number of analyses on up to four samples, assuming that a total of six vehicles are inspected in detail.

The data collected under all tasks will be reviewed for any apparent relationship between the fuel(s)/additive(s) used and the observed condition of the inspected components.

B. Vehicles

The six vehicles used in the program were obtained from the Minnesota Department of Administration. Basic information is listed in Table 2. The blend-fueled vehicles were from the Capitol District of the Minnesota DOA. They were principally fueled at the fleet headquarters at St. Paul. Occasional "on-the-road" fueling would have occurred, which would cause a small percentage of operation on very low ethanol content fuel.

TABLE 2. TEST VEHICLES

<u>Number</u>	<u>Make</u>	<u>Model</u>	<u>Year</u>	<u>Mileage</u>	<u>Fuel</u>	<u>Engine</u>
SC239	Ford	Escort	1982	62,000	Gasoline	1.6L
SC205	Ford	Escort	1981	61,000	Blend	1.6L
SC453	Ford	Escort	1981	68,000	Blend	1.6L
C83	Plymouth	Reliant	1983	57,000	Gasoline	2.2L
C202	Plymouth	Reliant	1983	75,000	Blend	2.2L
C232	Plymouth	Reliant	1982	55,000	Blend	2.2L

The gasoline-fueled vehicles were headquartered in other cities without fleet fueling facilities. Therefore, their fueling history would be typical of other vehicles operating in Minnesota, with gasoline being purchased at retail from a variety of suppliers.

The vehicles were taken from service with an average of 63,000 miles on the odometer. Most, if not all, of the vehicles were about to be auctioned by the fleet. The Ford Escorts were 1981 and 1982 models, while the Plymouth Reliants were of 1982 and 1983 vintages.

Examination of the maintenance records showed no work which would affect the purposes of this assignment. One of the Ford Escorts, number SC205, had undergone a camshaft repair at 39,000 miles. Because this vehicle has an overhead cam engine, it is possible to remove the camshaft without disturbing the valves. No fuel tanks had been replaced. No specific oil consumption records were kept. However, excessive oil use would have been reported.

C. Blend Fuel

The blend fuel supplied to the Minnesota DOA is provided on a yearly contract basis. Gasoline and ethanol are purchased by the contractor from different suppliers and blended in the tank truck. The target blend is 10% ethanol. No corrosion inhibitor or detergent package is added to the blend by the contractor. However, analysis of the fuels indicates that an additive package was present in the blend fuels.

The producer of most of the ethanol used in the Minnesota Fleet blend confirmed that a detergent package was added to the ethanol starting early in the summer of 1986. It had been standard practice to include a corrosion inhibitor prior to that time. Therefore, the blend fueled vehicles would only have been exposed to the additional detergent for roughly nine months prior to this study. This would not be expected to clean up deposits existing before that time.

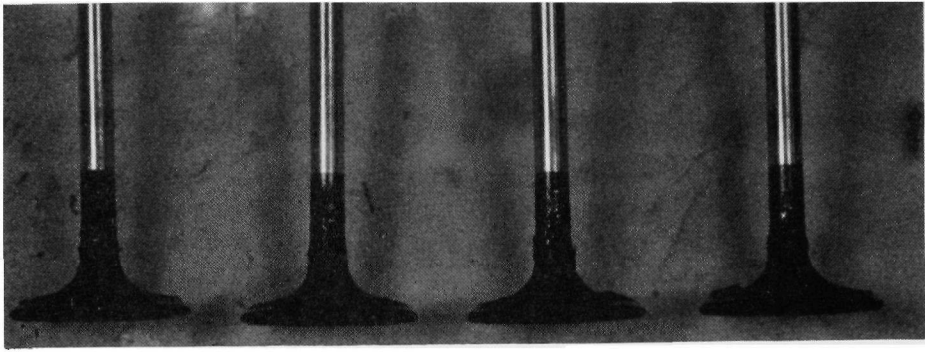
The additive analysis is included as Appendix C. Note that the blend fuels (the last four listed) all indicated higher additive content than the two gasoline samples.

IV. DISASSEMBLY AND INSPECTION

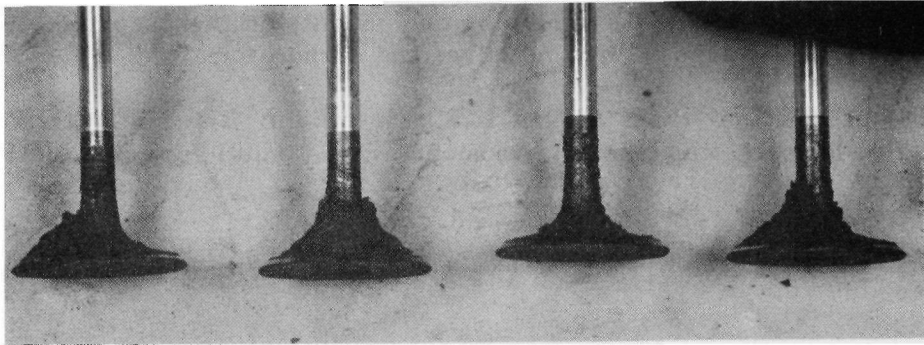
In order to perform the inspections required by the test plan, the carburetor, manifolds, cylinder head, and EGR lines were removed from each engine. In addition, the valves were removed from the heads to allow inspection and rating of the stem side of the valve heads. All fuel tanks were removed, drained, and cut open for inspections.

Figures 1 through 7 are photographs of the major components which were inspected. First shown are the intake valves. The Reliants showed the widest variation in deposits, ranging from normal to extremely heavy. Valve deposits on the Escorts ranged from light to moderate. In both cases, the vehicles which had been fueled on gasoline had the lightest deposits. The carburetors, particularly in the area under the secondary throttle, showed similar trends. Other components on the Reliants fell in line. The remaining components on the Escorts showed no clear correlation with the deposits on the valves and carburetors.

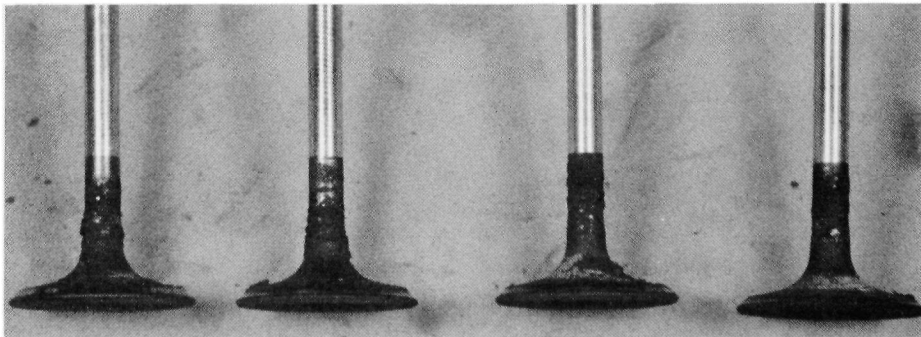
Five of the fuel tanks looked like new inside. The sixth, from one of the blend-fueled Escorts, was free of corrosion, but had a dull gray film inside.



SC 239

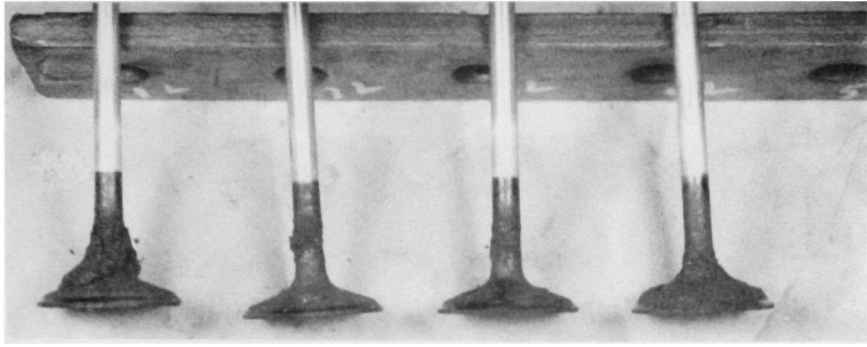


SC 205

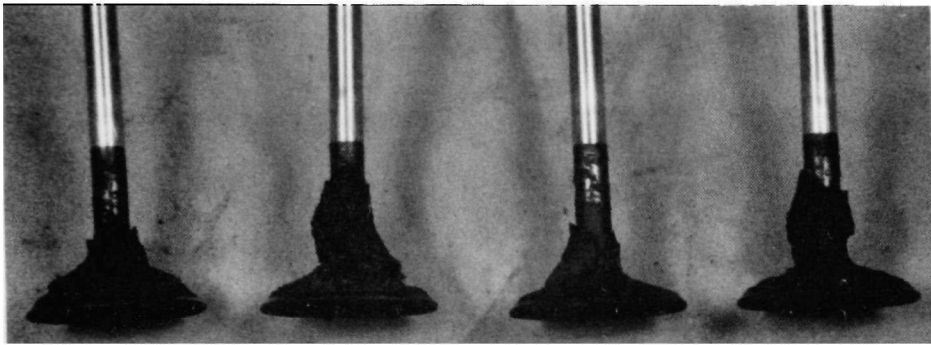


SC 453

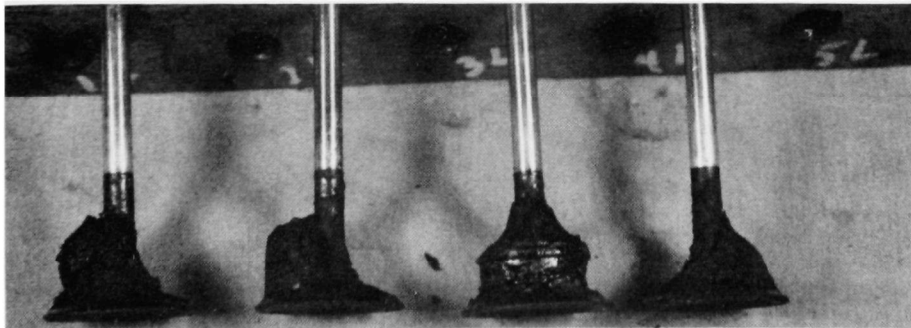
FIGURE 1. INTAKE VALVES, FORD ESCORTS



C83



C202



C232

FIGURE 2. INTAKE VALVES, PLYMOUTH RELIANTS

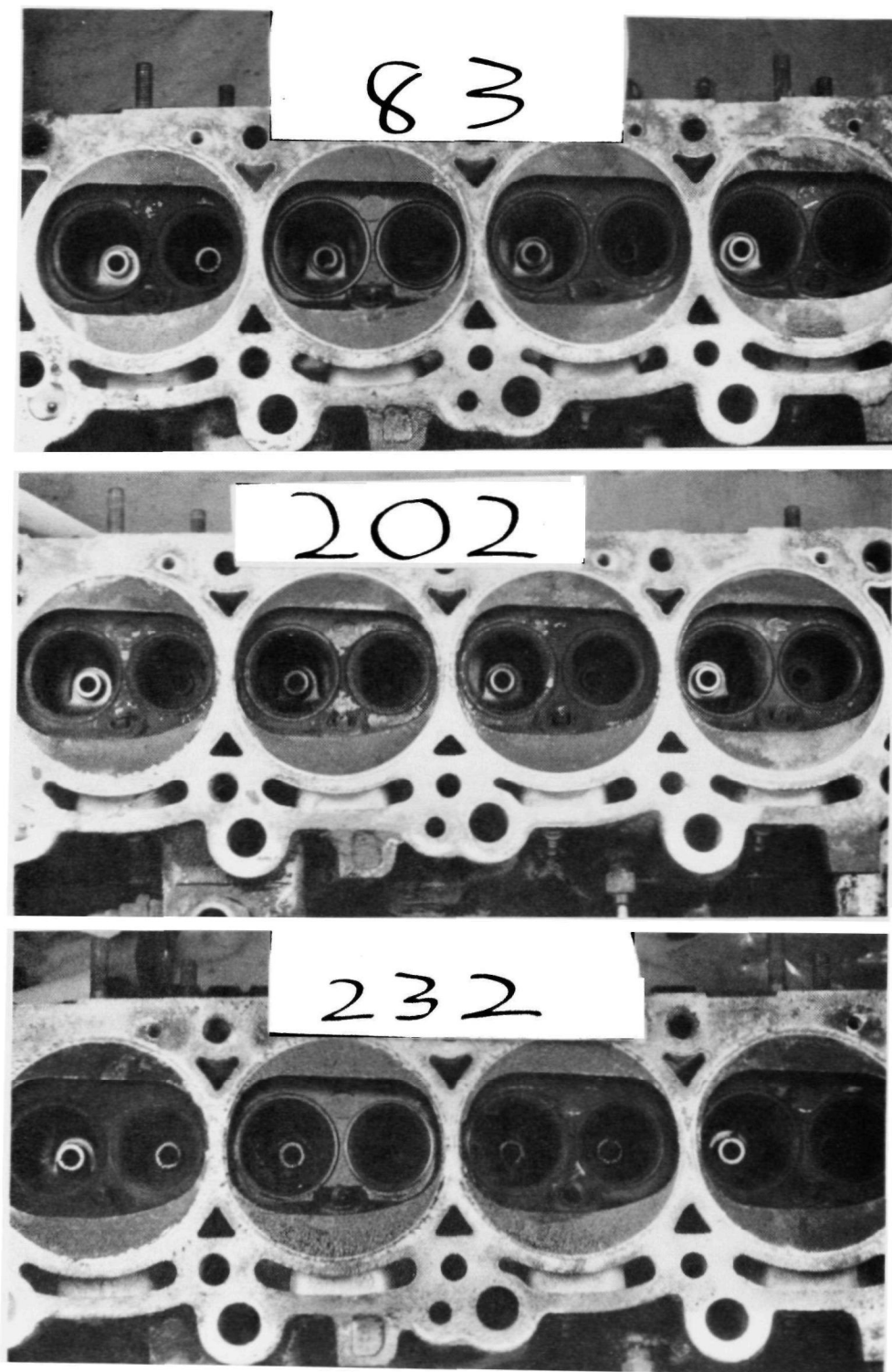


FIGURE 3. CYLINDER HEADS, PLYMOUTH RELIANTS

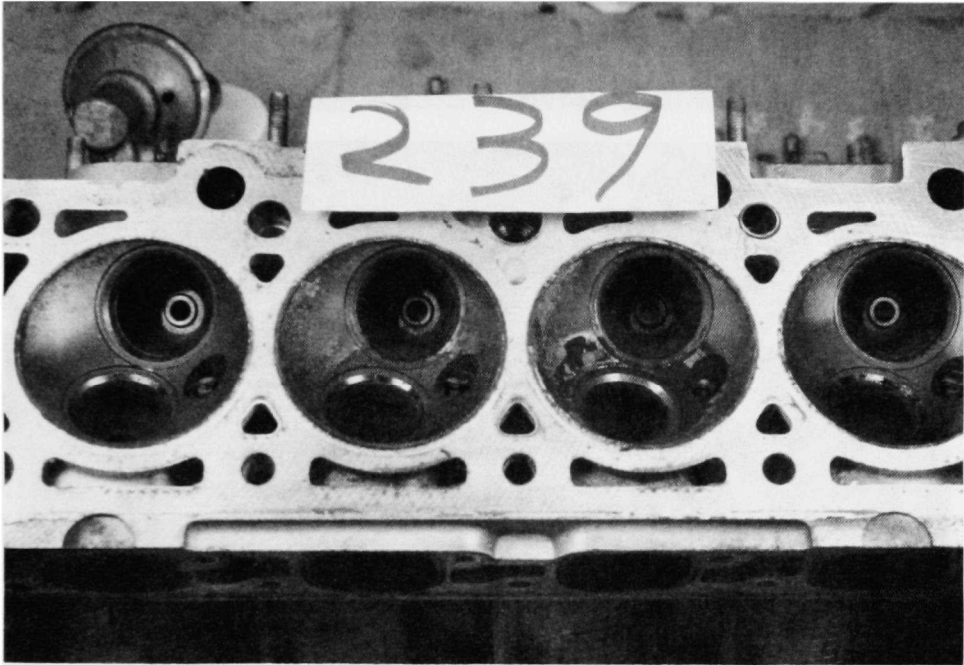
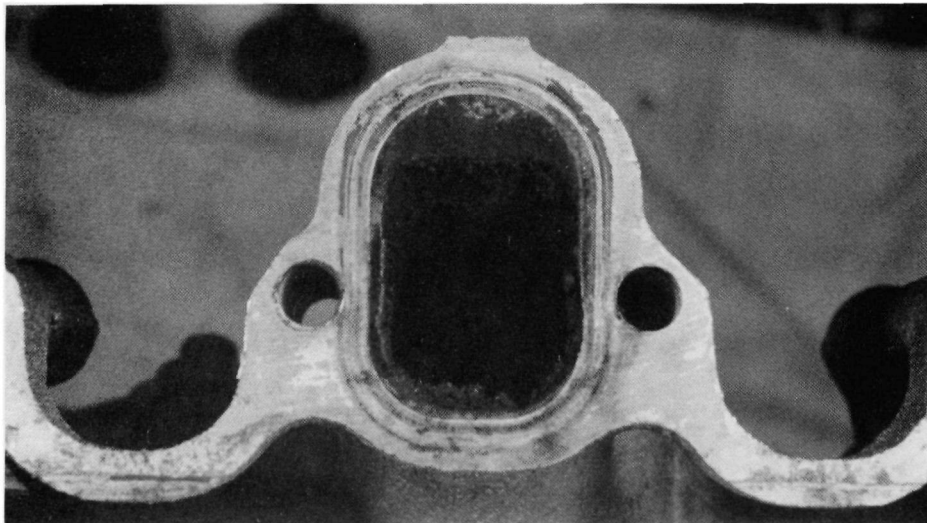
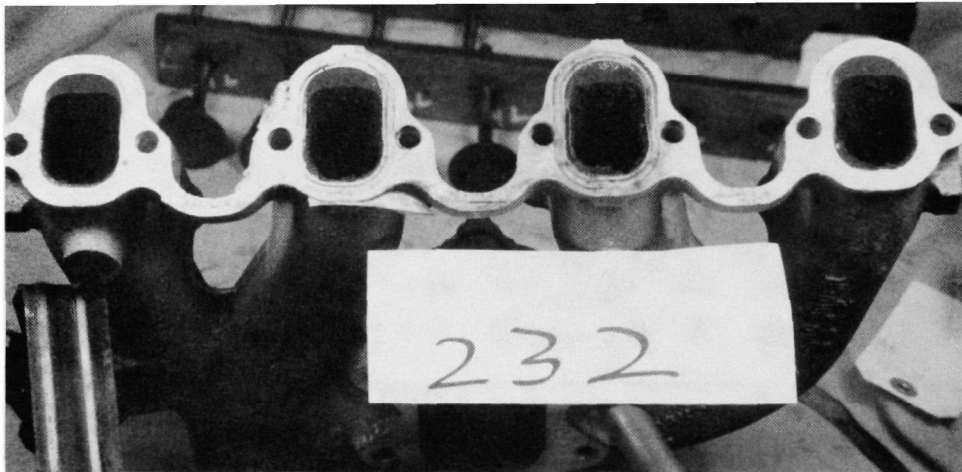
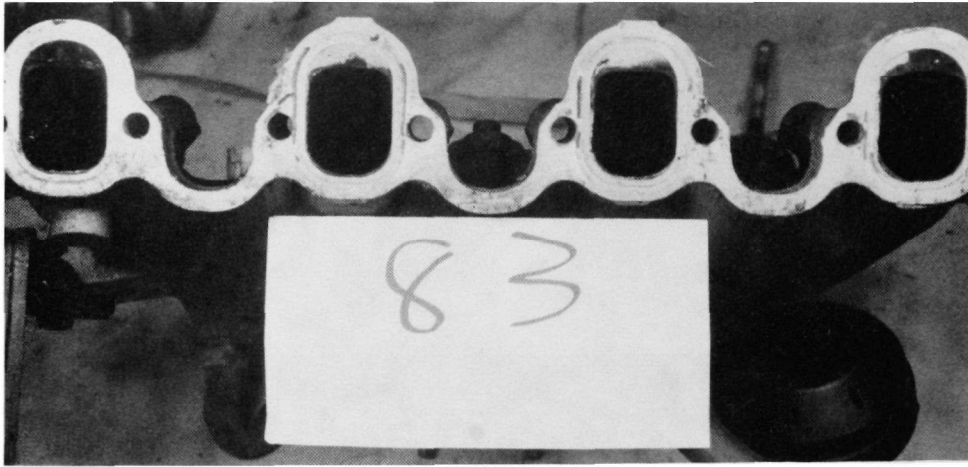
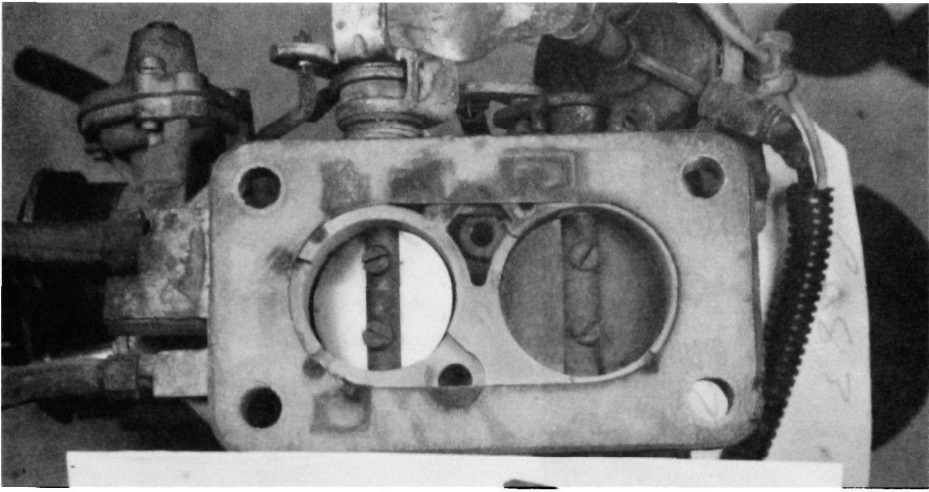


FIGURE 4. TYPICAL CYLINDER HEAD, FORD ESCORTS

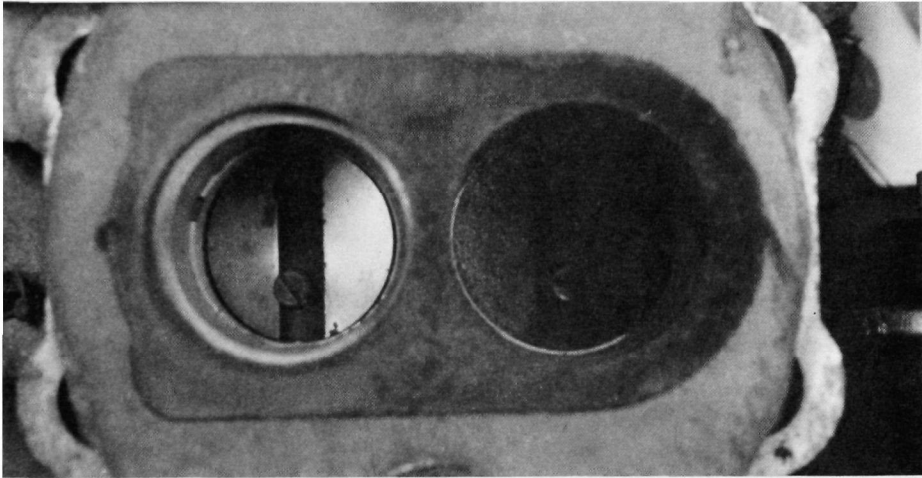


SC232 CLOSE UP

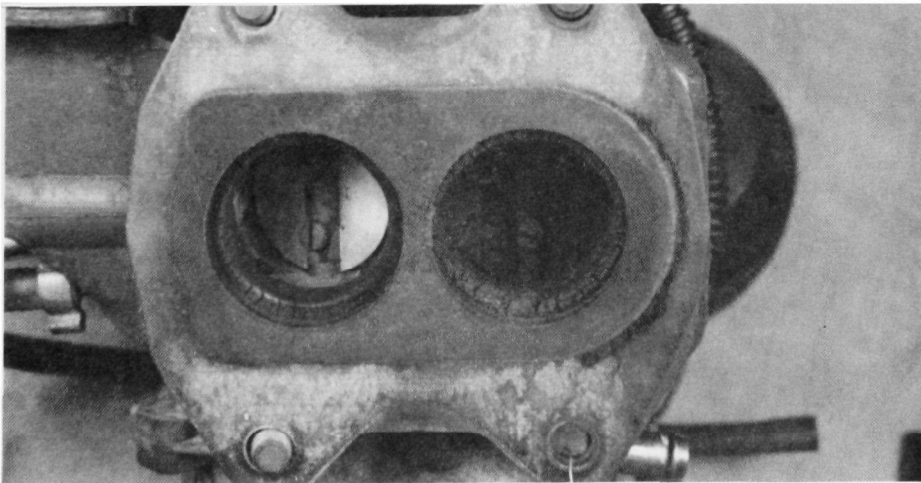
FIGURE 5. INTAKE MANIFOLDS, PLYMOUTH RELIANTS



C83



C202



C232

FIGURE 6. CARBURETOR BORES, PLYMOUTH RELIANTS

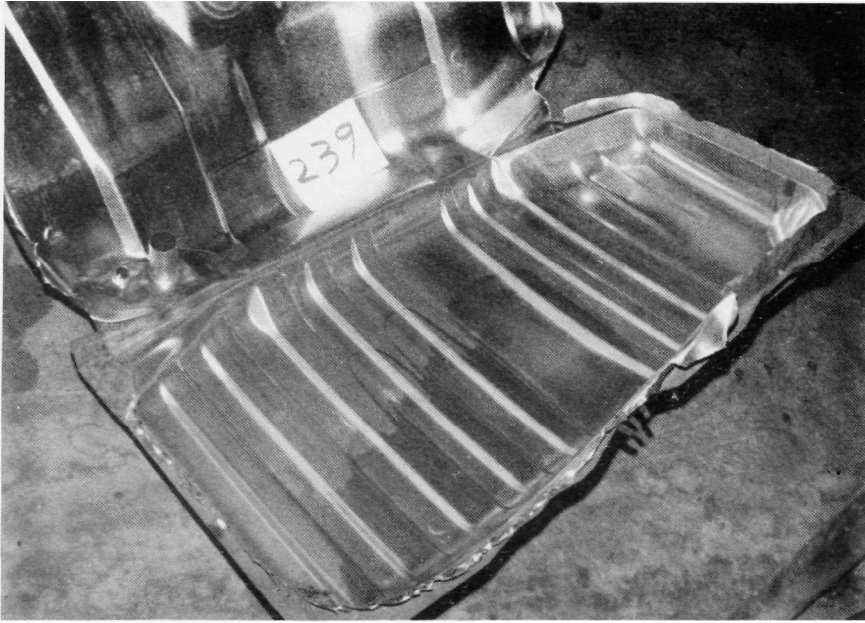


FIGURE 7. FUEL TANKS, FORD ESCORTS

V. DEPOSIT RATINGS

This section discusses the report of the rater on his examination of the engine components (Tables 3 through 9). These ratings involve subjective comparisons of the components to photographs and charts in the CRC Manual. Ratings are on a scale of 0 to 10, with 10 being the highest quality (best condition) rating. Quality control is maintained by regular attendance of the rater at CRC rating symposiums.

A. Engine Components

1. Intake Valves

Within each vehicle make grouping, the lightest deposits occurred on the gasoline-fueled vehicle. In addition to being heavier, the valve deposits were quite variable in the blend-fueled vehicles. For instance, among the Escorts, vehicle C239 (gasoline) and vehicle C453 (blend) had almost identical valve deposit ratings, but vehicle C205 (blend) was significantly worse. For the Reliants, vehicle C202 (blend) had deposits which were intermediate between those of vehicle C83 (gasoline) and C232 (blend).

It is inconceivable that the deposits on the intake valves in vehicle C232 had no effect on performance. The fleet manager confirmed that one vehicle had difficulty climbing the ramps onto the vehicle carrier, and we suspect that it was C232.

TABLE 3. RATINGS OF INTAKE VALVES

<u>Vehicle</u>	<u>Fuel</u>	<u>Cylinder</u>				<u>Avg.</u>
		<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	
SC239	Gasoline	7.6	7.6	7.6	7.6	7.6
SC205	Blend	5.7	5.5	7.0	6.0	6.0
SC453	Blend	7.4	7.6	7.1	7.4	7.4
C83	Gasoline	5.7	6.9	6.8	5.7	6.3
C202	Blend	5.8	5.8	4.8	5.1	5.4
C232	Blend	3.5	3.5	2.0	3.5	3.5

2. Combustion Chambers

All of the Escort cylinder heads were visually similar in the combustion chamber areas, therefore only one photograph is shown. The ratings confirm this similarity. The Reliant heads displayed slight visual differences, but the rater's report indicates minimal practical differences. Note that in the head from vehicle C232, some deposits can be seen caked in the area behind the intake valve, which is not part of the combustion chamber.

TABLE 4. RATINGS OF COMBUSTION CHAMBERS

<u>Vehicle</u>	<u>Fuel</u>	<u>Cylinder</u>				<u>Avg.</u>
		<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	
SC239	Gasoline	9.0	8.8	8.4	8.6	8.7
SC205	Blend	8.9	8.9	8.2	7.9	8.5
SC453	Blend	8.5	8.3	8.8	8.7	8.6
C83	Gasoline	8.5	8.1	8.1	8.2	8.2
C202	Blend	8.3	8.2	8.1	8.0	8.2
C232	Blend	8.0	7.9	7.8	7.9	7.9

3. Intake Manifold Runners and Intake Ports

With the exception of Reliant C232, the intake manifold runners and intake ports showed no correlation with fuel or vehicle. Vehicle C232 rated comparatively low, in line with the valve ratings.

TABLE 5. RATINGS OF MANIFOLD RUNNERS

<u>Vehicle</u>	<u>Fuel</u>	<u>Cylinder</u>				<u>Avg.</u>
		<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	
SC239	Gasoline	8.4	8.4	8.0	8.0	8.2
SC205	Blend	8.0	8.0	8.0	8.0	8.0
SC453	Blend	9.0	9.1	9.1	9.2	9.1
C83	Gasoline	8.0	8.0	8.0	8.0	8.0
C202	Blend	9.0	9.1	8.9	8.6	8.9
C232	Blend	7.4	6.2	5.5	5.6	6.2

TABLE 6. RATINGS OF INTAKE PORTS

<u>Vehicle</u>	<u>Fuel</u>	<u>Cylinder</u>				<u>Avg.</u>
		<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	
SC239	Gasoline	8.0	8.0	8.0	8.0	8.0
SC205	Blend	8.2	8.2	7.9	8.0	8.1
SC453	Blend	9.4	8.4	7.8	8.5	8.5
C83	Gasoline	9.2	9.0	9.0	9.4	9.2
C202	Blend	7.9	8.6	8.2	8.8	8.4
C232	Blend	6.5	4.6	3.5	7.9	5.6

4. Piston Crowns

Piston crowns showed very little variation from vehicle to vehicle. Vehicle C232 again deviated on the low rating side compared to the others.

TABLE 7. RATINGS OF PISTON CROWNS

<u>Vehicle</u>	<u>Fuel</u>	<u>Cylinder</u>				<u>Avg.</u>
		<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	
SC239	Gasoline	7.8	8.2	8.2	8.5	8.2
SC205	Blend	8.0	8.3	8.0	7.9	8.0
SC453	Blend	8.0	8.4	8.5	8.0	8.2
C83	Gasoline	8.3	8.5	8.5	8.0	8.3
C202	Blend	8.2	8.2	8.1	8.1	8.2
C232	Blend	7.8	7.9	8.0	7.5	7.8

5. Carburetor Bores

The rater was asked to evaluate only the area of the carburetor bores below the throttle plate. All were fairly normal except for C232. The extremely low rating of the C232 carburetor requires some explanation. From the photograph, Fig. 6, there appears to be very heavy deposits in the bores of the spacer below the throttle body. This material is actually a rubber-like lining which was present in this 1982 Reliant, but not in either of the others, which were both 1983 models. The rater treated this liner material as a deposit.

TABLE 8. RATINGS OF CARBURETOR BORES

<u>Vehicle</u>	<u>Fuel</u>	<u>Barrel</u>	
		<u>1</u>	<u>2</u>
SC239	Gasoline	7.5	7.1
SC205	Blend	6.2	6.4
SC453	Blend	7.2	7.4
C83	Gasoline	7.5	6.5
C202	Blend	7.5	5.4
C232	Blend	3.1	0.8

6. Miscellaneous Items

For the Escorts, the intake manifold inlet, EGR port, and EGR line showed no trends with respect to fuel. In the Reliants, C232 again showed the heaviest deposits, while the other blend-fueled Reliant had heavier deposits than the gasoline-fueled vehicle in the EGR port and line.

TABLE 9. RATINGS OF MISCELLANEOUS ITEMS

<u>Vehicle</u>	<u>Fuel</u>	<u>Intake Manifold Inlet</u>	<u>EGR Port</u>	<u>EGR Line</u>
SC239	Gasoline	8.9	7.5	8.0
SC205	Blend	8.5	7.0	8.0
SC453	Blend	9.2	7.8	8.0
C83	Gasoline	9.5	8.0	6.0
C202	Blend	9.5	6.0	5.5
C232	Blend	7.7	5.0	5.0

B. Fuel Tanks

The rater's reports on the fuel tanks (see Appendix B) confirmed the evidence of the photographs. All were in good to very good condition, with one of the Escort blend-fueled tanks (SC453) having a gray film in the bottom half.

VI. ANALYSIS OF VALVE DEPOSITS

One "average" looking intake valve was selected from each of four engines. These engines included two of each vehicle and two of each fueling history. An elemental analysis was made of deposit samples removed from each of these four valves (Table 10). Elements other than hydrogen, carbon, and nitrogen were determined by the X-ray fluorescence method.

The ratio of hydrogen to carbon was highest in the engine with the extreme deposits, indicating the presence of more organic material. Nitrogen, magnesium, aluminum, phosphorus, potassium, iron, and nickel appear to correlate more with the make of vehicle than with fuel type. Sulfur, iron, copper, and zinc show some correlation with fuel type. The difference between 100% and the total shown would be mostly oxygen.

TABLE 10. ELEMENTAL ANALYSIS OF VALVE DEPOSITS

<u>Vehicle</u>	<u>Fuel</u>	<u>H</u>	<u>C</u>	<u>N</u>	<u>Mg</u>	<u>Al</u>	<u>Si</u>	<u>P</u>	<u>S</u>	<u>K</u>	<u>Ca</u>	<u>Cr</u>	<u>Fe</u>	<u>Cu</u>	<u>Ni</u>	<u>Zn</u>	<u>Pb</u>	<u>Total</u>	
Escort																			
SC239	Gasoline	4.2*	53.4*	0.95*	1.7	0.12	0.19	1.8	5.7	0.57	1.2	--	1.0	0.30	0.08	2.4	1.2	74.8	
SC205	Blend	4.5	63.8	1.80	2.6	0.10	0.13	2.0	4.6	0.29	0.9	0.04	0.51	0.13	0.04	2.0	0.5	84.0	
Reliant																			
C83	Gasoline	4.9	62.1	3.19	2.9	0.04	0.10	5.4	5.8	0.08	0.9	--	0.24	0.22	--	4.5	0.50	90.9	
C232	Blend	6.5	65.4	3.47	4.2	0.04	0.16	3.5	4.4	0.12	1.5	--	0.21	0.10	--	2.7	0.71	93.0	

All values percent by mass.

*Marginal sample quantity.

VII. DISCUSSION OF PROGRAM RESULTS

On the basis of a limited sampling from one fleet of vehicles, there is evidence that vehicles being operated on ethanol-gasoline blends can develop heavier deposits in the intake system than those operated on generally-available gasolines. The reason for these heavier deposits is not clear from the present study. The ethanol producer began adding a detergent package shortly before these vehicles were pulled from service. This would not have been expected to clean up pre-existing deposits. The effect on deposits is mainly limited to the intake system, because the effect observable in the combustion chambers was minimal. There was no corrosion evident in the fuel tanks of any of the vehicles examined.

APPENDICES

- A. VEHICLE INFORMATION
- B. RATER'S REPORTS
- C. FUEL ADDITIVE ANALYSIS

APPENDIX A

VEHICLE INFORMATION

VEHICLE INFORMATION

Fleet ID No.	SC239
Make and Model	Ford Escort
Model Year	1982
Odometer Reading	62194
V.I.N.	2FABPO62XCX240987
Engine Size & Cylinders	1.6L x 4
Engine Family	Label Missing
Transmission Type	Automatic
Carburetor No.	E2EEL1A 2E17
Emission Controls	EGR/PMP/OXD/3WY
Fuel	Gasoline

VEHICLE INFORMATION

Fleet ID No.	SC205
Make and Model	Ford Escort Wagon
Model Year	1981
Odometer Reading	61307
V.I.N.	1FABPO82BW276552
Engine Size & Cylinders	1.6L x 4
Engine Family	1.6AP
Transmission Type	Automatic
Carburetor No.	E1EE NA 1F2
Emission Controls	EGR/PMP/OXD/3WY
Fuel	10% Ethanol Blend

VEHICLE INFORMATION

Fleet ID No.	SC453
Make and Model	Ford Escort Wagon
Model Year	1981
Odometer Reading	68185
V.I.N.	1FABPO820BW275464
Engine Size & Cylinders	1.6L x 4
Engine Family	1.6 AP
Transmission Type	Automatic
Carburetor No.	E1EE NA 1F1
Emission Controls	EGR/PMP/OXD/3WY
Fuel	10% Ethanol Blend

VEHICLE INFORMATION

Fleet ID No.	C83
Make and Model	Plymouth Reliant
Model Year	1983
Odometer Reading	57470
V.I.N.	1P3BP26CXDF195447
Engine Size & Cylinders	2.2L x 4
Engine Family	Label Missing
Transmission Type	Automatic
Carburetor No.	40010-2 42807086 0263
Emission Controls	EGR/PMP/ODX/3CL
Fuel	Gasoline

VEHICLE INFORMATION

Fleet ID No.	C202
Make and Model	Plymouth Reliant
Model Year	1983
Odometer Reading	74626
V.I.N.	1P3BP26C6DF195423
Engine Size & Cylinders	2.2L x 4
Engine Family	DCR2.2V2HAC3 DCRKA
Transmission Type	Automatic
Carburetor No.	40010-2 4287086 0203
Emission Controls	EGR/PMP/ODX/3CL
Fuel	10% Ethanol Blend

VEHICLE INFORMATION

Fleet ID No.	C232
Make and Model	Plymouth Reliant
Model Year	1982
Odometer Reading	54927
V.I.N.	1P3BP26B3CF218590
Engine Size & Cylinders	2.2L x 4
Engine Family	CCR2.2V2HNLX CCRKA
Transmission Type	Automatic
Carburetor No.	R9019 4227293 1042
Emission Controls	EGR/PMP/OXD/3CL
Fuel	10% Ethanol Blend

APPENDIX B
RATER'S REPORTS

INDUCTION SYSTEM RATING SHEET

TEST NO.: SC-239

DATE: 05-26-87

RATER: G. TSCHIRHART

COMBUSTION CHAMBERS

No. 1	Area	Rate	Merit	No. 2	Area	Rate	Merit
	50%	9.5	4.75		20%	9.5	1.90
	30%	9.0	2.70		50%	9.0	4.50
	20%	8.0	1.60		30%	8.0	2.40
Total.....			9.05	Total.....			8.80

No. 3	Area	Rate	Merit	No. 4	Area	Rate	Merit
	10%	9.5	0.95		30%	9.5	2.85
	20%	9.0	1.80		20%	9.0	1.80
	70%	8.0	5.60		50%	8.0	4.00
Total.....			8.35	Total.....			8.65

Comments: Avg. 8.71

VALVES
INTAKE VALVES

<u>No.</u>	<u>Rate</u>	<u>No.</u>	<u>Rate</u>	<u>No.</u>	<u>Rate</u>
<u>1</u>	7.6	<u>2</u>	7.6	<u>3</u>	7.6
<u>4</u>	7.6				

Comments: Avg. 7.60

EXHAUST VALVES

<u>No.</u>	<u>Rate</u>	<u>No.</u>	<u>Rate</u>	<u>No.</u>	<u>Rate</u>
<u>1</u>	8.0	<u>2</u>	7.8	<u>3</u>	7.9
<u>4</u>	7.8				

Comments: Avg. 7.90

INDUCTION SYSTEM RATING SHEET

TEST NO.: SC-239

DATE: 05-26-87

RATER: G. TSCHIRHART

MANIFOLD RUNNERS

No. 1	Area	Rate	Merit	No. 2	Area	Rate	Merit		
	40%	9.0	3.60		40%	9.0	3.60		
	60%	8.0	4.80		60%	8.0	4.80		
Total.....				8.40	Total.....				8.40

No. 3	Area	Rate	Merit	No. 4	Area	Rate	Merit		
	100%	8.0	8.00		100%	8.0	8.00		
Total.....				8.00	Total.....				8.00

Comments: 8.20

HEAD PORTS - INTAKE

No. 1	Area	Rate	Merit	No. 2	Area	Rate	Merit		
	100%	8.0	8.00		95%	8.0	7.60		
					5%	7.5	0.38		
Total.....				8.00	Total.....				7.98

No. 3	Area	Rate	Merit	No. 4	Area	Rate	Merit		
	95%	8.0	7.60		100%	8.0	8.00		
	5%	7.5	0.38						
Total.....				7.98	Total.....				8.00

Comments: Avg. 7.99

TEST NO. SC-239

INTAKE MANIFOLD: 8.9 Carbon Rating

EGR PORT INTO INTAKE SYSTEM: 7.5 Carbon Rating

EGR LINE: 8.0 Carbon Rating

PISTON CROWN: 1 - 7.8
2 - 8.2
3 - 8.2
4 - 8.5
Avg. **8.18**

CYLINDER BORE: 1 - Good condition, no apparent distress.
2 - Good condition, no apparent distress.
3 - Good condition, no apparent distress.
4 - Good condition, no apparent distress.

FUEL TANK: Fuel tank is in very good condition. No signs of rust or varnish.
Trace amount of foreign material in bottom of tank.

9.80 Sludge Rating
9.80 Varnish Rating

Appendix C

RECOMMENDED CARBURETOR RATING FORM

CARBURETOR MAKE _____ BBLs. _____ DATE 05-26-87 TEST # SC-239 RATER G. Tschirhart

USE SEPARATE SHEET FOR: PRIMARY BBLs. _____ SECONDARY BBLs. _____

DEPOSIT DESCRIPTION	(1) Linkage Barrel					Non-Linkage Barrel				
	% Area x		Depth Factor	= Deposit No.		% Area x		Depth Factor	= Deposit No.	
	(2) Left Side	(1) Right Side		Left Side	Right Side	Left Side	Right Side		Left Side	Right Side
Clean (no visible deposits) * 10.0 to 9.0			10.0					10.0		
Light discoloration * 9.0 to 6.0	100%	100%	7.5	7.50	7.50	95%	70%	7.5	7.12	5.25
Definite (dark) discoloration * 6.0 to < .001" thick			5.0			5%	30%	5.0	0.25	1.50
Deposit < .015" > .001" thick			2.5					2.5		
Deposit > .015" thick			0	0	0			0	0	0
	100%	100%	Total Deposit Number	7.50	7.50	100%	100%	Total Deposit Number	7.37	6.75

B-5

% OF TOTAL AREA BELOW THROTTLE PLATE AVAILABLE FOR DEPOSIT (CRC Test Sleeves (3): 40% Left; 60% Right)

$$\% \text{ Left Side} = 100 \times \frac{\text{Left Depth}}{\text{Left} + \text{Right}} = \underline{\hspace{2cm}}\%; \quad \% \text{ Right Side} = 100 \times \frac{\text{Right Depth}}{\text{Left} + \text{Right}} = \underline{\hspace{2cm}}\%$$

FOR 2/4 BBL CARBURETORS: AVG RIGHT DEPOSIT NO. = $0.5 \times (\text{RIGHT LINKAGE BARREL} + \text{RIGHT NON-LINKAGE BARREL}) = \underline{7.12}$

AVG LEFT DEPOSIT NO. = $0.5 \times (\text{LEFT LINKAGE BARREL} + \text{LEFT NON-LINKAGE BARREL}) = \underline{7.43}$

CARBURETOR MERIT RATING = (Avg. Left Dep. No. x % Available Area) + (Avg. Right Dep. No. x % Available Area)

Carburetor Merit Rating = (x) + (x) = () + () = 7.28

NOTES

1. The right side of the carburetor/sleeve is the one with idle fuel ports, transfer slot, and vac. ports.
The linkage barrel is the barrel adjacent to the carburetor linkages.
2. The left side of the carburetor/sleeve has no holes.
3. The CRC Carburetor Cleanliness Test Aluminum sleeve is considered to have 40% Left Side Available Area, 60% Right Side Available Area.

*CRC Varnish Rating Scale

INDUCTION SYSTEM RATING SHEET

TEST NO.: SC-205

DATE: 05-26-87

RATER: G. TSCHIRHART

COMBUSTION CHAMBERS

No. 1	Area	Rate	Merit	No. 2	Area	Rate	Merit
	20%	9.5	1.90		20%	9.5	1.90
	60%	9.0	5.40		60%	9.0	5.40
	20%	8.0	1.60		20%	8.0	1.60
Total.....			8.90	Total.....			8.90

No. 3	Area	Rate	Merit	No. 4	Area	Rate	Merit
	30%	9.0	2.70		80%	8.0	6.40
	60%	8.0	4.80		20%	7.5	1.50
	10%	7.5	0.75				
Total.....			8.25	Total.....			7.90

Comments: Avg. 8.49

VALVES
INTAKE VALVES

<u>No.</u>	<u>Rate</u>	<u>No.</u>	<u>Rate</u>	<u>No.</u>	<u>Rate</u>
<u>1</u>	5.7	<u>2</u>	5.5	<u>3</u>	7.0
<u>4</u>	6.0				

Comments: Avg. 6.0

EXHAUST VALVES

<u>No.</u>	<u>Rate</u>	<u>No.</u>	<u>Rate</u>	<u>No.</u>	<u>Rate</u>
<u>1</u>	7.5	<u>2</u>	7.5	<u>3</u>	7.5
<u>4</u>	7.5				

Comments: Avg. 7.5

INDUCTION SYSTEM RATING SHEET

TEST NO.: SC-205

DATE: 05-26-87

RATER: G. TSCHIRHART

MANIFOLD RUNNERS

No. 1	Area	Rate	Merit	No. 2	Area	Rate	Merit
	100%	8.0	8.00		100%	8.0	8.00
Total.....			8.00	Total.....			8.00

No. 3	Area	Rate	Merit	No. 4	Area	Rate	Merit
	100%	8.0	8.00		100%	8.0	8.00
Total.....			8.00	Total.....			8.00

Comments: Avg. 8.00

HEAD PORTS - INTAKE

No. 1	Area	Rate	Merit	No. 2	Area	Rate	Merit
	20%	9.0	1.80		20%	9.0	1.80
	80%	8.0	6.40		80%	8.0	6.40
Total.....			8.20	Total.....			8.20

No. 3	Area	Rate	Merit	No. 4	Area	Rate	Merit
	90%	8.0	7.20		95%	8.0	7.60
	5%	7.5	0.38		5%	7.5	0.38
	5%	7.0	0.35				
Total.....			7.93	Total.....			7.98

Comments: Avg. 8.08

TEST NO. SC-205

INTAKE MANIFOLD: 8.5 Carbon Rating

EGR PORT INTO INTAKE SYSTEM: 7.0 Carbon Rating

EGR LINE: 8.0 Carbon Rating

PISTON CROWN: 1 - 8.0

2 - 8.3

3 - 8.0

4 - 7.9

Avg. **8.05**

CYLINDER BORE: 1 - Good condition, no apparent distress.

2 - Good condition, no apparent distress.

3 - Good condition, no apparent distress.

4 - Good condition, no apparent distress.

FUEL TANK: Fuel tank is in very good condition. No signs of rust or varnish.
Trace amount of foreign material in bottom of tank.

9.80 Sludge Rating

9.80 Varnish Rating

Appendix C
RECOMMENDED CARBURETOR RATING FORM

CARBURETOR MAKE _____ BBLs. _____ DATE 05-26-87 TEST # SC-205 RATER G. Tschirhart

USE SEPARATE SHEET FOR: PRIMARY BBLs. _____ SECONDARY BBLs. _____

DEPOSIT DESCRIPTION	(1) Linkage Barrel					Non-Linkage Barrel				
	% Area x		Depth Factor	= Deposit No.		% Area x		Depth Factor	= Deposit No.	
	(2) Left Side	(1) Right Side		Left Side	Right Side	Left Side	Right Side		Left Side	Right Side
Clean (no visible deposits) * 10.0 to 9.0			10.0					10.0		
Light discoloration * 9.0 to 6.0		95%	7.5		7.12	60%	50%	7.5	4.50	3.75
Definite (dark) discoloration * 6.0 to < .001" thick	100%	5%	5.0	5.00	.25	40%	50%	5.0	2.00	2.50
Deposit < .015" > .001" thick			2.5					2.5		
Deposit > .015" thick			0	0	0			0	0	0
	100%	100%	Total Deposit Number	5.00	7.37	100%	100%	Total Deposit Number	6.50	6.25

% OF TOTAL AREA BELOW THROTTLE PLATE AVAILABLE FOR DEPOSIT (CRC Test Sleeves (3): 40% Left; 60% Right)

$$\% \text{ Left Side} = 100 \times \frac{\text{Left Depth}}{\text{Left} + \text{Right}} = \underline{\quad\quad\quad} \%; \quad \% \text{ Right Side} = 100 \times \frac{\text{Right Depth}}{\text{Left} + \text{Right}} = \underline{\quad\quad\quad} \%$$

FOR 2/4 BBL CARBURETORS: AVG RIGHT DEPOSIT NO. = $0.5 \times (\text{RIGHT LINKAGE BARREL} + \text{RIGHT NON-LINKAGE BARREL}) = \underline{6.81}$

AVG LEFT DEPOSIT NO. = $0.5 \times (\text{LEFT LINKAGE BARREL} + \text{LEFT NON-LINKAGE BARREL}) = \underline{5.75}$

CARBURETOR MERIT RATING = (Avg. Left Dep. No. x % Available Area) + (Avg. Right Dep. No. x % Available Area)

Carburetor Merit Rating = (x) + (x) = () + () = 6.28

NOTES

- The right side of the carburetor/sleeve is the one with idle fuel ports, transfer slot, and vac. ports.
The linkage barrel is the barrel adjacent to the carburetor linkages.
- The left side of the carburetor/sleeve has no holes.
- The CRC Carburetor Cleanliness Test Aluminum sleeve is considered to have 40% Left Side Available Area, 60% Right Side Available Area.

*CRC Varnish Rating Scale

INDUCTION SYSTEM RATING SHEET

TEST NO.: SC-453

DATE: 05-26-87

RATER: G. TSCHIRHART

COMBUSTION CHAMBERS

<u>No. 1</u>	<u>Area</u>	<u>Rate</u>	<u>Merit</u>	<u>No. 2</u>	<u>Area</u>	<u>Rate</u>	<u>Merit</u>
	10%	9.5	0.95		30%	9.0	2.70
	30%	9.0	2.75		70%	8.0	5.60
	60%	8.0	4.80				

Total.....8.50

Total.....8.30

<u>No. 3</u>	<u>Area</u>	<u>Rate</u>	<u>Merit</u>	<u>No. 4</u>	<u>Area</u>	<u>Rate</u>	<u>Merit</u>
	80%	9.0	7.20		10%	9.5	0.95
	20%	8.0	1.60		50%	9.0	4.50
					40%	8.0	3.20

Total.....8.80

Total.....8.65

Comments: Avg. 8.56

VALVES
INTAKE VALVES

<u>No.</u>	<u>Rate</u>	<u>No.</u>	<u>Rate</u>	<u>No.</u>	<u>Rate</u>
<u>1</u>	7.4	<u>2</u>	7.6	<u>3</u>	7.1
<u>4</u>	7.4				

Comments: Avg. 7.4

EXHAUST VALVES

<u>No.</u>	<u>Rate</u>	<u>No.</u>	<u>Rate</u>	<u>No.</u>	<u>Rate</u>
<u>1</u>	7.5	<u>2</u>	7.5	<u>3</u>	7.5
<u>4</u>	7.5				

Comments: Avg. 7.5

INDUCTION SYSTEM RATING SHEET

TEST NO.: SC-453

DATE: 05-26-87

RATER: G. TSCHIRHART

MANIFOLD RUNNERS

No. 1	Area	Rate	Merit	No. 2	Area	Rate	Merit
	100%	9.0	9.00		30%	9.5	2.85
					70%	9.0	6.30
Total.....			9.00	Total.....			9.15

No. 3	Area	Rate	Merit	No. 4	Area	Rate	Merit
	30%	9.5	2.85		40%	9.5	3.80
	70%	9.0	6.30		60%	9.0	5.40
Total.....			9.15	Total.....			9.20

Comments: 9.12

HEAD PORTS - INTAKE

No. 1	Area	Rate	Merit	No. 2	Area	Rate	Merit
	100%	9.4	9.40		50%	9.0	4.50
					40%	8.0	3.20
					10%	7.0	0.70
Total.....			9.40	Total.....			8.40

No. 3	Area	Rate	Merit	No. 4	Area	Rate	Merit
	80%	8.0	6.40		10%	9.5	0.95
	10%	7.5	0.75		50%	9.0	4.50
	10%	6.5	0.65		30%	8.0	2.40
					10%	7.0	0.70
Total.....			7.80	Total.....			8.55

Comments: Avg. 8.54

TEST NO. SC-453

INTAKE MANIFOLD: 9.2 Carbon Rating

EGR PORT INTO INTAKE SYSTEM: 7.8 Carbon Rating

EGR LINE: 8.0 Carbon Rating

PISTON CROWN: 1 - 8.0

2 - 8.4

3 - 8.5

4 - 8.0

Avg. 8.22

CYLINDER BORE: 1 - Good condition, no apparent distress.

2 - Good condition, no apparent distress.

3 - Good condition, no apparent distress.

4 - Good condition, no apparent distress.

FUEL TANK: Fuel tank has trace amount of foreign material in bottom of tank. Tank is in good condition. Bottom of tank has film like substance that is in the 4.5 range on the CRC Varnish rating scale.

Top of tank - 9.8 Sludge

Bottom of tank - 9.8 Sludge

*Non linkage throttle plate has light rust existence.

Appendix C RECOMMENDED CARBURETOR RATING FORM

CARBURETOR MAKE _____ BBLs. _____ DATE 05-26-87 TEST # SC-453 RATER G. Tschirhart

USE SEPARATE SHEET FOR: PRIMARY BBLs. _____ SECONDARY BBLs. _____

DEPOSIT DESCRIPTION	(1) Linkage Barrel					Non-Linkage Barrel				
	% Area x		Depth Factor	= Deposit No.		% Area x		Depth Factor	= Deposit No.	
	(2) Left Side	(1) Right Side		Left Side	Right Side	Left Side	Right Side		Left Side	Right Side
Clean (no visible deposits) * 10.0 to 9.0			10.0					10.0		
Light discoloration * 9.0 to 6.0	100%	80%	7.5	7.50	6.00	90%	100%	7.5	6.75	7.50
Definite (dark) discoloration * 6.0 to < .001" thick		20%	5.0		1.00	10%		5.0	0.50	
Deposit < .015" > .001" thick			2.5					2.5		
Deposit > .015" thick			0	0	0			0	0	0
	100%	100%	Total Deposit Number	7.50	7.00	100%	100%	Total Deposit Number	7.25	7.50

% OF TOTAL AREA BELOW THROTTLE PLATE AVAILABLE FOR DEPOSIT (CRC Test Sleeves (3): 40% Left; 60% Right)

$$\% \text{ Left Side} = 100 \times \frac{\text{Left Depth}}{\text{Left} + \text{Right}} = \underline{\hspace{2cm}}\%; \quad \% \text{ Right Side} = 100 \times \frac{\text{Right Depth}}{\text{Left} + \text{Right}} = \underline{\hspace{2cm}}\%$$

FOR 2/4 BBL CARBURETORS: AVG RIGHT DEPOSIT NO. = 0.5 x (RIGHT LINKAGE BARREL + RIGHT NON-LINKAGE BARREL) = 7.25

AVG LEFT DEPOSIT NO. = 0.5 x (LEFT LINKAGE BARREL + LEFT NON-LINKAGE BARREL) = 7.38

CARBURETOR MERIT RATING = (Avg. Left Dep. No. x % Available Area) + (Avg. Right Dep. No. x % Available Area)

Carburetor Merit Rating = (x) + (x) = () + () = 7.32

NOTES

1. The right side of the carburetor/sleeve is the one with idle fuel ports, transfer slot, and vac. ports.
The linkage barrel is the barrel adjacent to the carburetor linkages.
2. The left side of the carburetor/sleeve has no holes.
3. The CRC Carburetor Cleanliness Test Aluminum sleeve is considered to have 40% Left Side Available Area, 60% Right Side Available Area.

*CRC Varnish Rating Scale

B-13

INDUCTION SYSTEM RATING SHEET

TEST NO.: C-83

DATE: 05-25-87

RATER: G. TSCHIRHART

COMBUSTION CHAMBERS

No. 1	Area	Rate	Merit	No. 2	Area	Rate	Merit		
	50%	9.0	4.50		10%	9.0	0.90		
	50%	8.0	4.00		90%	8.0	7.20		
Total.....				8.50	Total.....				8.10

No. 3	Area	Rate	Merit	No. 4	Area	Rate	Merit		
	10%	9.0	0.90		20%	9.0	1.80		
	90%	8.0	7.20		80%	8.0	6.40		
Total.....				8.10	Total.....				8.20

Comments: Avg. 8.22

VALVES
INTAKE VALVES

<u>No.</u>	<u>Rate</u>	<u>No.</u>	<u>Rate</u>	<u>No.</u>	<u>Rate</u>
<u>1</u>	5.7	<u>2</u>	6.9	<u>3</u>	6.8
<u>4</u>	5.7				

Comments: Avg. 6.3

EXHAUST VALVES

<u>No.</u>	<u>Rate</u>	<u>No.</u>	<u>Rate</u>	<u>No.</u>	<u>Rate</u>
<u>1</u>	7.5	<u>2</u>	7.5	<u>3</u>	7.5
<u>4</u>	7.5				

Comments: Avg. 7.5

INDUCTION SYSTEM RATING SHEET

TEST NO.: C-83

DATE: 05-25-87

RATER: G. TSCHIRHART

MANIFOLD RUNNERS

No. 1	Area	Rate	Merit	No. 2	Area	Rate	Merit
	100%	8.0	8.00		100%	8.0	8.00
Total.....8.00				Total.....8.00			

No. 3	Area	Rate	Merit	No. 4	Area	Rate	Merit
	100%	8.0	8.00		100%	8.0	8.00
Total.....8.00				Total.....8.00			

Comments: 8.00

HEAD PORTS - INTAKE

No. 1	Area	Rate	Merit	No. 2	Area	Rate	Merit
	80%	9.5	7.60		70%	9.5	6.65
	20%	8.0	1.60		30%	8.0	2.40
Total.....9.20				Total.....9.05			

No. 3	Area	Rate	Merit	No. 4	Area	Rate	Merit
	70%	9.5	6.65		80%	9.5	7.60
	20%	8.0	1.60		20%	9.0	1.80
	10%	7.0	0.70				
Total.....8.95				Total.....9.40			

Comments: Avg. 9.15

TEST NO. C-83

INTAKE MANIFOLD: 9.5 Carbon Rating

EGR PORT INTO INTAKE SYSTEM: 8.0 Carbon Rating

EGR LINE: 6.0 Carbon Rating

PISTON CROWN: 1 - 8.3
2 - 8.5
3 - 8.5
4 - 8.0
Avg. **8.32**

CYLINDER BORE: 1 - Good condition, no apparent distress.
2 - Good condition, no apparent distress.
3 - Good condition, no apparent distress.
4 - Good condition, no apparent distress.

FUEL TANK: Fuel tank is in very good condition. No signs of rust.

Top of tank - **9.7 Varnish, 9.9 Sludge**
Bottom of tank - **9.0 Varnish, 9.9 Sludge**

*Non linkage throttle plate has 100% rust.

Appendix C RECOMMENDED CARBURETOR RATING FORM

CARBURETOR MAKE _____ BBLs. _____ DATE 05-25-87 TEST # C-83 RATER G. Tschirhart

USE SEPARATE SHEET FOR: PRIMARY BBLs. _____ SECONDARY BBLs. _____

DEPOSIT DESCRIPTION	(1) Linkage Barrel					Non-Linkage Barrel				
	% Area x		Depth Factor	= Deposit No.		% Area x		Depth Factor	= Deposit No.	
	(2) Left Side	(1) Right Side		Left Side	Right Side	Left Side	Right Side		Left Side	Right Side
Clean (no visible deposits) * 10.0 to 9.0			10.0					10.0		
Light discoloration * 9.0 to 6.0	100%	100%	7.5	7.50	7.50	100%	20%	7.5	7.50	1.50
Definite (dark) discoloration * 6.0 to < .001" thick			5.0			80%		5.0		4.00
Deposit < .015" > .001" thick			2.5					2.5		
Deposit > .015" thick			0	0	0			0	0	0
	100%	100%	Total Deposit Number	7.50	7.50	100%	100%	Total Deposit Number	7.50	5.50

% OF TOTAL AREA BELOW THROTTLE PLATE AVAILABLE FOR DEPOSIT (CRC Test Sleeves (3): 40% Left; 60% Right)

$$\% \text{ Left Side} = 100 \times \frac{\text{Left Depth}}{\text{Left} + \text{Right}} = \underline{\hspace{2cm}} \%; \quad \% \text{ Right Side} = 100 \times \frac{\text{Right Depth}}{\text{Left} + \text{Right}} = \underline{\hspace{2cm}} \%$$

FOR 2/4 BBL CARBURETORS: AVG RIGHT DEPOSIT NO. = 0.5 x (RIGHT LINKAGE BARREL + RIGHT NON-LINKAGE BARREL) = 6.50

AVG LEFT DEPOSIT NO. = 0.5 x (LEFT LINKAGE BARREL + LEFT NON-LINKAGE BARREL) = 7.50

CARBURETOR MERIT RATING = (Avg. Left Dep. No. x % Available Area) + (Avg. Right Dep. No. x % Available Area)

Carburetor Merit Rating = (x) + (x) = () + () = 7.00

NOTES

1. The right side of the carburetor/sleeve is the one with idle fuel ports, transfer slot, and vac. ports.

The linkage barrel is the barrel adjacent to the carburetor linkages.

2. The left side of the carburetor/sleeve has no holes.

3. The CRC Carburetor Cleanliness Test Aluminum sleeve is considered to have 40% Left Side Available Area, 60% Right Side Available Area.

*CRC Varnish Rating Scale

B-17

INDUCTION SYSTEM RATING SHEET

TEST NO.: C-202

DATE: 05-26-87

RATER: G. TSCHIRHART

COMBUSTION CHAMBERS

No. 1	Area	Rate	Merit	No. 2	Area	Rate	Merit
	30%	9.0	2.70		20%	9.0	1.80
	70%	8.0	5.60		80%	8.0	6.40
Total.....			8.30	Total.....			8.20

No. 3	Area	Rate	Merit	No. 4	Area	Rate	Merit
	10%	9.0	0.90		100%	8.0	8.00
	90%	8.0	7.20				
Total.....			8.10	Total.....			8.00

Comments: Avg. 8.15

VALVES
INTAKE VALVES

<u>No.</u>	<u>Rate</u>	<u>No.</u>	<u>Rate</u>	<u>No.</u>	<u>Rate</u>
<u>1</u>	5.8	<u>2</u>	5.8	<u>3</u>	4.8
<u>4</u>	5.1				

Comments: Avg. 5.4

EXHAUST VALVES

<u>No.</u>	<u>Rate</u>	<u>No.</u>	<u>Rate</u>	<u>No.</u>	<u>Rate</u>
<u>1</u>	7.5	<u>2</u>	7.5	<u>3</u>	7.5
<u>4</u>	7.5				

Comments: Avg. 7.5

INDUCTION SYSTEM RATING SHEET

TEST NO.: C-202

DATE: 05-26-87

RATER: G. TSCHIRHART

MANIFOLD RUNNERS

No. 1	Area	Rate	Merit	No. 2	Area	Rate	Merit
	50%	9.5	4.75		70%	9.5	6.65
	50%	8.5	4.25		30%	8.5	2.55
Total.....			9.00	Total.....			9.10

No. 3	Area	Rate	Merit	No. 4	Area	Rate	Merit
	40%	9.5	3.80		10%	9.5	0.95
	60%	8.5	5.10		90%	8.5	7.65
Total.....			8.90	Total.....			8.60

Comments: 8.90

HEAD PORTS - INTAKE

No. 1	Area	Rate	Merit	No. 2	Area	Rate	Merit
	10%	9.5	0.95		70%	9.0	6.30
	80%	8.0	6.40		20%	8.0	1.60
	5%	6.0	0.30		10%	7.0	0.70
	5%	5.0	0.25				
Total.....			7.90	Total.....			8.60

No. 3	Area	Rate	Merit	No. 4	Area	Rate	Merit
	30%	9.0	2.70		80%	9.0	7.20
	50%	8.0	4.00		20%	8.0	1.60
	10%	7.0	0.70				
	10%	7.5	0.75				
Total.....			8.15	Total.....			8.80

Comments: Avg. 8.36

TEST NO. C-202

INTAKE MANIFOLD: 9.5 Carbon Rating

EGR PORT INTO INTAKE SYSTEM: 6.0 Carbon Rating

EGR LINE: 5.5 Carbon Rating

PISTON CROWN: 1 - 8.2
 2 - 8.2
 3 - 8.1
 4 - 8.1
 Avg. 8.15

CYLINDER BORE: 1 - Good condition, no apparent distress.
 2 - Good condition, no apparent distress.
 3 - Light scratch marks, possible stuck or broken ring.
 4 - Good condition, no apparent distress.

FUEL TANK: Fuel tank is in very good condition. No signs of foreign material.

Top of tank - 9.9 Varnish, 9.9 Sludge, 9.0 Rust Rating
Bottom of tank - 9.9 Varnish, 9.9 Sludge

Appendix C RECOMMENDED CARBURETOR RATING FORM

CARBURETOR MAKE _____ BBLs. _____ DATE 05-26-87 TEST # C-202 RATER G. Tschirhart

USE SEPARATE SHEET FOR: PRIMARY BBLs. _____ SECONDARY BBLs. _____

DEPOSIT DESCRIPTION	(1) Linkage Barrel					Non-Linkage Barrel				
	% Area x		Depth Factor	= Deposit No.		% Area x		Depth Factor	= Deposit No.	
	(2) Left Side	(1) Right Side		Left Side	Right Side	Left Side	Right Side		Left Side	Right Side
Clean (no visible deposits) * 10.0 to 9.0			10.0					10.0		
Light discoloration * 9.0 to 6.0	100%	100%	7.5	7.50	7.50	30%		7.5	2.25	
Definite (dark) discoloration * 6.0 to < .001" thick			5.0			70%	100%	5.0	3.50	5.00
Deposit < .015" > .001" thick			2.5					2.5		
Deposit > .015" thick			0	0	0			0	0	0
	100%	100%	Total Deposit Number	7.50	7.50	100%	100%	Total Deposit Number	5.75	5.00

% OF TOTAL AREA BELOW THROTTLE PLATE AVAILABLE FOR DEPOSIT (CRC Test Sleeves (3): 40% Left; 60% Right)

$$\% \text{ Left Side} = 100 \times \frac{\text{Left Depth}}{\text{Left} + \text{Right}} = \underline{\hspace{2cm}}\% ; \quad \% \text{ Right Side} = 100 \times \frac{\text{Right Depth}}{\text{Left} + \text{Right}} = \underline{\hspace{2cm}}\%$$

FOR 2/4 BBL CARBURETORS: AVG RIGHT DEPOSIT NO. = $0.5 \times (\text{RIGHT LINKAGE BARREL} + \text{RIGHT NON-LINKAGE BARREL}) = \underline{6.25}$

AVG LEFT DEPOSIT NO. = $0.5 \times (\text{LEFT LINKAGE BARREL} + \text{LEFT NON-LINKAGE BARREL}) = \underline{6.62}$

CARBURETOR MERIT RATING = (Avg. Left Dep. No. x % Available Area) + (Avg. Right Dep. No. x % Available Area)

Carburetor Merit Rating = (x) + (x) = () + () = 6.44

NOTES

1. The right side of the carburetor/sleeve is the one with idle fuel ports, transfer slot, and vac. ports.
The linkage barrel is the barrel adjacent to the carburetor linkages.
2. The left side of the carburetor/sleeve has no holes.
3. The CRC Carburetor Cleanliness Test Aluminum sleeve is considered to have 40% Left Side Available Area, 60% Right Side Available Area.

*CRC Varnish Rating Scale

B-21

INDUCTION SYSTEM RATING SHEET

TEST NO.: C-232

DATE: 05-25-87

RATER: G. TSCHIRHART

COMBUSTION CHAMBERS

<u>No. 1</u>	<u>Area</u>	<u>Rate</u>	<u>Merit</u>	<u>No. 2</u>	<u>Area</u>	<u>Rate</u>	<u>Merit</u>
	100%	8.0	8.00		80%	8.0	6.40
					20%	7.5	1.50
Total.....			8.00	Total.....			7.90

<u>No. 3</u>	<u>Area</u>	<u>Rate</u>	<u>Merit</u>	<u>No. 4</u>	<u>Area</u>	<u>Rate</u>	<u>Merit</u>
	50%	8.0	4.00		80%	8.0	6.40
	50%	7.5	3.75		20%	7.5	1.50
Total.....			7.75	Total.....			7.90

Comments: Avg. 7.89

VALVES
INTAKE VALVES

<u>No.</u>	<u>Rate</u>	<u>No.</u>	<u>Rate</u>	<u>No.</u>	<u>Rate</u>
<u>1</u>	3.5	<u>2</u>	3.5	<u>3</u>	2.0
<u>4</u>	3.5				

Comments: Avg. 3.1

EXHAUST VALVES

<u>No.</u>	<u>Rate</u>	<u>No.</u>	<u>Rate</u>	<u>No.</u>	<u>Rate</u>
<u>1</u>	7.5	<u>2</u>	7.5	<u>3</u>	7.5
<u>4</u>	7.5				

Comments: Avg. 7.5

INDUCTION SYSTEM RATING SHEET

TEST NO.: C-232

DATE: 05-25-87

RATER: G. TSCHIRHART

MANIFOLD RUNNERS

No. 1	Area	Rate	Merit	No. 2	Area	Rate	Merit	
	80%	7.5	6.00		30%	6.5	1.95	
	20%	7.0	1.40		70%	6.0	4.20	
Total.....				7.40	Total.....			
					6.15			

No. 3	Area	Rate	Merit	No. 4	Area	Rate	Merit	
	100%	5.5	5.50		30%	6.0	1.80	
					70%	5.5	3.85	
Total.....				5.50	Total.....			
					5.65			

Comments: 6.18

HEAD PORTS - INTAKE

No. 1	Area	Rate	Merit	No. 2	Area	Rate	Merit	
	50%	8.0	4.00		10%	8.0	0.80	
	50%	5.0	2.50		30%	6.0	1.80	
					20%	4.0	0.80	
					40%	3.0	1.20	
Total.....				6.50	Total.....			
					4.60			

No. 3	Area	Rate	Merit	No. 4	Area	Rate	Merit	
	50%	4.0	2.00		90%	8.0	7.20	
	50%	3.0	1.50		10%	7.0	0.70	
Total.....				3.50	Total.....			
					7.90			

Comments: Avg. 5.62

TEST NO. C-232

INTAKE MANIFOLD: 7.7 Carbon Rating

EGR PORT INTO INTAKE SYSTEM: 5.0 Carbon Rating

EGR LINE: 5.0 Carbon Rating

PISTON CROWN: 1 - 7.8

2 - 7.9

3 - 8.0

4 - 7.5

Avg. 7.80

CYLINDER BORE: 1 - Good condition, no apparent distress.

2 - Good condition, no apparent distress.

3 - Good condition, no apparent distress.

4 - Good condition, no apparent distress.

FUEL TANK: Fuel tank is in very good condition. No signs of foreign material.

Top of tank - 9.9 Sludge, 9.9 Varnish Rating

Bottom of tank - 9.9 Sludge, 9.9 Varnish Rating

Appendix C
RECOMMENDED CARBURETOR RATING FORM

CARBURETOR MAKE _____ BBLs. _____ DATE 05-25-87 TEST # C-232 RATER G. Tschirhart

USE SEPARATE SHEET FOR: PRIMARY BBLs. _____ SECONDARY BBLs. _____

DEPOSIT DESCRIPTION	(1) Linkage Barrel					Non-Linkage Barrel				
	% Area x		Depth Factor	= Deposit No.		% Area x		Depth Factor	= Deposit No.	
	(2) Left Side	(1) Right Side		Left Side	Right Side	Left Side	Right Side		Left Side	Right Side
Clean (no visible deposits) * 10.0 to 9.0			10.0					10.0		
Light discoloration * 9.0 to 6.0	15%	5%	7.5	1.12	0.38			7.5		
Definite (dark) discoloration * 6.0 to < .001" thick	5%	5%	5.0	0.25	0.25	10%	20%	5.0	0.50	1.00
Deposit < .015" > .001" thick	80%	90%	2.5	2.00	2.25			2.5		
Deposit > .015" thick			0	0	0	90%	80%	0	0	0
	100%	100%	Total Deposit Number	3.37	2.88	100%	100%	Total Deposit Number	0.50	1.00

B-25

% OF TOTAL AREA BELOW THROTTLE PLATE AVAILABLE FOR DEPOSIT (CRC Test Sleeves (3): 40% Left; 60% Right)

$$\% \text{ Left Side} = 100 \times \frac{\text{Left Depth}}{\text{Left} + \text{Right}} = \underline{\hspace{2cm}} \%; \quad \% \text{ Right Side} = 100 \times \frac{\text{Right Depth}}{\text{Left} + \text{Right}} = \underline{\hspace{2cm}} \%$$

FOR 2/4 BBL CARBURETORS: AVG RIGHT DEPOSIT NO. = 0.5 x (RIGHT LINKAGE BARREL + RIGHT NON-LINKAGE BARREL) = 1.94

AVG LEFT DEPOSIT NO. = 0.5 x (LEFT LINKAGE BARREL + LEFT NON-LINKAGE BARREL) = 1.94

CARBURETOR MERIT RATING = (Avg. Left Dep. No. x % Available Area) + (Avg. Right Dep. No. x % Available Area)

Carburetor Merit Rating = (x) + (x) = () + () = 1.94

NOTES

- The right side of the carburetor/sleeve is the one with idle fuel ports, transfer slot, and vac. ports.
The linkage barrel is the barrel adjacent to the carburetor linkages.
- The left side of the carburetor/sleeve has no holes.
- The CRC Carburetor Cleanliness Test Aluminum sleeve is considered to have 40% Left Side Available Area, 60% Right Side Available Area.

*CRC Varnish Rating Scale

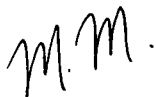
APPENDIX C
FUEL ADDITIVE ANALYSIS

SOUTHWEST RESEARCH INSTITUTE

INTER-DEPARTMENTAL MEMORANDUM

TO: Sherrill Martin

FROM: Michelle Miller



SUBJECT: Additive Analysis of samples C-83, SC-239, SC-453, SC-205
C-202 and C-232

October 6, 1987

The following are the results from the analysis:

<u>Sample #</u>	<u>Unwashed Gum (mg/50ml)</u>	<u>Additive A* (ppma)</u>
C-83	2.2	4.1
SC-239	1.5	0.0
SC-453	6.3	17.9
SC-205	9.8	28.7
C-202	11.3	155.6
C-232	13.7	11.0

Sample C-202 has normal amount of additive A added. In this particular test procedure a high unwashed gum content correlates with the amount of additive added. With this in mind, the high unwashed gum value for C-232 could mean there is an additive that was undetected by our procedure.

*Additive A's name cannot be given out. This is confidential information between the sponsor and Southwest Research Institute.

MM:chl



TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA 460/3-88-006		2.	3. RECIPIENT'S ACCESSION NO.	
4. TITLE AND SUBTITLE Intake System Deposits and Gasoline/Alcohol Blends			5. REPORT DATE May 1988	
			6. PERFORMING ORGANIZATION CODE	
7. AUTHOR(S) Sherrill F. Martin			8. PERFORMING ORGANIZATION REPORT NO.	
9. PERFORMING ORGANIZATION NAME AND ADDRESS Southwest Research Institute Department of Emissions Research 6220 Culebra Road Ann Arbor, Michigan 48105			10. PROGRAM ELEMENT NO.	
			11. CONTRACT/GRANT NO. 68-03-3353	
12. SPONSORING AGENCY NAME AND ADDRESS Environmental Protection Agency 2565 Plymouth Road Ann Arbor, Michigan 48105			13. TYPE OF REPORT AND PERIOD COVERED Final (Sept. 1986 - Aug. 1987)	
			14. SPONSORING AGENCY CODE	
15. SUPPLEMENTARY NOTES				
16. ABSTRACT Six vehicles, four of them ethanol blend-fueled and two gasoline-fueled, were examined for intake system deposits. The engines were partially disassembled, photographs were taken, and deposits were evaluated by a professional rater. Elemental analysis was made of the intake valve deposits.				
17. KEY WORDS AND DOCUMENT ANALYSIS				
a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS		c. COSATI Field/Group
Deposits Engine Valves Blends Intake Systems Fuel Tanks Fuel Additives Ehtanol		Gasohol Blend Fuels Intake Deposits		
18. DISTRIBUTION STATEMENT Release Unlimited		19. SECURITY CLASS (This Report) Unclassified		21. NO. OF PAGES 40
		20. SECURITY CLASS (This page) Unclassified		22. PRICE