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FINAL REPORT
ISU – ERI – AMES – 72184

COMPARISON BETWEEN LEADED AND NONLEADED GASOLINE AS USED IN IOWA STATE HIGHWAY COMMISSION VEHICLES

Iowa State Highway Commission
Project HR–1002

ERI Project 908-S

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ABSTRACT

The overall objective of this experimental program was to obtain quantitative comparisons between leaded and nonleaded gasolines as used in a variety of Iowa State Highway Commission vehicles. These quantitative comparisons were to be made in terms of exhaust emissions, maintenance costs and fuel economy.

A 52-vehicle test fleet was selected for this study. This test fleet included tractors, pickup trucks, light-duty trucks, heavy-duty trucks and a few miscellaneous vehicles. Twenty-two vehicles were operated on nonleaded regular-grade gasoline and 30 vehicles were operated on leaded regular-grade gasoline.

Each month from August 1971 through May 1972, measurements of temperature, humidity, mileage, air-fuel ratio and emissions of total hydrocarbons and carbon monoxide were recorded for each vehicle under no-load conditions at idle and at 2500 rpm.

Ten pairs of vehicles were selected from the test fleet. Each pair was matched according to type, make and mileage as closely as possible. The major difference in each pair was fuel: one vehicle used leaded fuel, the other used nonleaded fuel. The 10 matched pairs were 4 pairs of pickups, 4 pairs of light-duty trucks and 2 pairs of heavy-duty trucks.

These vehicles were tested under load conditions with a chassis dynamometer located at the Des Moines Area Community College. The loads for which emission data were obtained included full, 2/3 nominal, 1/3 nominal and minimum (except for pickups), all at 2500 rpm. Measurements were recorded for load, air-fuel ratio, intake manifold vacuum, tempera-

ture, humidity and both total hydrocarbon (HC) and carbon monoxide (CO) emissions.

Exhaust emission samples were collected in Tedlar bags from the matched pair vehicles during both dynamometer tests (January and April) and also from the test fleet vehicles during March and May. These bag samples allowed oxides of nitrogen to be determined as well as paraffinic, olefinic and aromatic portions of unburned hydrocarbons.

Emission measurements yielded statistically significant (95% confidence level) differences between leaded and nonleaded gasoline. Lower HC and CO emissions existed for leaded gasoline when fleet vehicles were tested under no-load conditions. Air-fuel ratio caused larger differences in measured emissions than differences in type of gasoline.

When the matched pairs were tested under load, the leaded fuel yielded significantly higher HC emissions for pickups and heavy-duty trucks as well as higher CO emissions with light-duty trucks. However, this was mainly true at full load at which the vehicles would rarely operate.

Engine adjustment was found to be considerably more important in controlling exhaust emissions than was the type of fuel used.

No significant differences due to gasoline were observed in either maintenance costs, fuel consumption, or residue in oil during the course of this study.

Recommendations from this study are: (1) continue use of leaded fuel in all vehicles for which the test fleet is indicative; (2) establish regular tune-up schedules using exhaust emission equipment; (3) initiate an easily accessible record keeping system for consumption and maintenance items; (4) use certified reference gases to calibrate all emission measuring equipment; (5) extend the study for the lifetime of the vehicles under test so that effective comparisons can be made on maintenance items and fuel and oil consumption; and (6) prevent over specification of engine size actually needed when purchasing new vehicles.

CONTENTS

I. INTRODUCTION

During the fall of 1970, a proposal was made by the Director of Highways, J. R. Coupal, Jr., to the Highway Commissioners, to test leaded and nonleaded gasoline in actual use with the fleet of vehicles operated by the Iowa State Highway Commission. This study was to compare leaded and nonleaded regular-grade gasolines in terms of exhaust emissions, operating characteristics (i.e., vehicle type, engine speed, engine load and duty cycle), minor maintenance costs, and fuel economy. Of special interest to the Highway Commission was the cost of switching to nonleaded gasolines. Currently, the price of nonleaded gasoline is two cents per gallon more than the leaded varities and to use it in Highway Commission vehicles would cost the state of Iowa about $150,000 more per year.

A. Emission Measurements

Emission measurements include unburned hydrocarbons or waste gasoline, carbon monoxide (caused by incomplete combustion), and oxides of nitrogen (formed from the combustion of gasoline using air as an oxidant). These emissions are important because they produce, in a variety of ways, three noxious compounds. One of these is peroxyacetal nitrate (smog) which is formed from oxides of nitrogen reacting due to energy from sunlight with unburned hydrocarbons. This pollutant irritates eyes and tissue in the nose, throat and lungs. Another toxic pollutant is nitrogen dioxide which destroys lung cells and is toxic to plants as well as humans. It has been shown to cause transient pulmonary-function changes in the lungs of animals. The third toxic pollutant is carbon monoxide with which we are most familiar in terms of its dangerous nature. The fact that this gas is colorless and oderless increases its potential danger. All of these compounds are potentially far more harmful than lead because of the ease with which they can be ingested into the human body.

In the manufacture of some nonleaded gasolines, additives must be put into the mixture to replace the lead which acted primarily as an anti-knock agent and secondarily as a lubricant. These additives include small amounts of phosphorus for lubricating purposes which could result in emissions of phosphorus compounds that are potentially harmful to health.

B. Advantages vs Disadvantages of Fuels

To further complicate the situation there are some conflicting reports concerning the advantages and disadvantages of using nonleaded fuel. There has been poor statistical analysis and presentation of results; thus, one cannot ascertain whether differences reported are significant or not. Much of the existing data is for passenger cars or fleets of automobiles. Very little information is available for trucks and none to our knowledge concerning a large fleet of vehicles such as the Iowa State Highway Commission's which includes tractors, pickup trucks, light- and heavy-duty trucks as well as passenger cars.

C. Research Contract

Tests were started by Commission personnel during May, 1971 and a research contract was made with Iowa State University on July 7, 1971 for a one year research effort to perform the desired comparisons. A preliminary report was required by March 1, 1972 to assist in determining the type of gasoline the Highway Commission should use in its fleet beginning May 1, 1972 when new fuel contracts became effective. The preliminary report was presented Tuesday, February 29, 1972 to the Commissioners recommending that contracts for one additional year be signed for use of leaded gasoline at all test sites except Grundy Center and Sac City. These two test sites were to continue use of nonleaded fuel for one additional year to allow additional data to be obtained.

The detailed results herein constitute the final report on project HR-1002 for the period July 7, 1971 to July 6, 1972.

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the Iowa State Highway Commission.

II. OBJECTIVES

The overall objective of this experimental program was to obtain a quantitative comparison between leaded and nonleaded gasolines as used in a variety of Iowa State Highway Commission vehicles. This quantitative comparison was to be made in terms of exhaust emissions of unburned hydrocarbons (HC), carbon monoxide (CO) and oxides of nitrogen (NO_x), maintenance costs and fuel economy.

Other objectives of this experimental program were to: (1) establish a method of calibrating the instrumentation used in the exhaust emission measurements; (2) determine the effects of the presence of water vapor and of gas-sample temperature on the calibration technique; and (3) establish appropriate statistical methods of recording and analyzing the data pertaining to the overall objective.

III. DESIGN OF THE EXPERIMENT

A. Test Fleet Vehicles

A 52-vehicle test fleet was selected for this study. This test fleet included tractors, pickup trucks, light-duty trucks, heavy-duty trucks and a few miscellaneous vehicles. From the test fleet, 22 vehicles operating on nonleaded gasoline and 25 vehicles operating on leaded gasoline were available for testing on a regular monthly basis. Five miscellaneous vehicles from the Ames motor pool operating on leaded gasoline were available on an irregular basis.

Both the leaded and nonleaded fuels were regular grade gasoline furnished by the American Oil Company under their regular contract with the Iowa State Highway Commission. The typical research octane numbers for the leaded and nonleaded types were 94 and 90, respectively.

A few of the vehicles from the original test fleet were transferred and/or sold during the test period for reasons beyond our control. Data for these vehicles and their replacements are included in the data tabulations in the appendices. However, data for these few vehicles were not analyzed because of its incompleteness.

1. Testing Scheme

Each month from August 1971 through May 1972, measurements of temperature, humidity, mileage, air-fuel ratio and emissions of total hydrocarbons and carbon monoxide were recorded for each vehicle under no-load condition at idle and at 2500 rpm.

Temperature and humidity were measured using a sling psychrometer, air-fuel ratio was measured using a Sun 1120 Electronic Engine Tester and the total hydrocarbons (HC) and carbon monoxide (CO) were measured using a Sun Exhaust Emission Tester 910 (EET 910). Measurements of CO and HC with the EET 910 were obtained by nondispersive infrared detection (NDIR).

On several occasions, exhaust gas samples were collected in Tedlar bags for laboratory analysis to determine oxides of nitrogen, total unburned hydrocarbons, types (paraffins, olefins and aromatics) of hydrocarbons, and to obtain checks on air-fuel ratio and carbon monoxide emissions.

Bags constructed of Tedlar were selected based on the results of work done by Papa et al. (1). They investigated the effect of bag material to determine the best for exhaust-gas collection. They constructed decay curves for several hydrocarbons in bags made from various materials and determined that bags of Teflon and Tedlar had essentially no effect on the composition of the exhaust-gas sample over a period of three hours. Based on their experience, bags constructed of Tedlar were deemed necessary for these experiments and were the type used.

The oxides of nitrogen were determined in accordance with ASTM Designation D1608-67. This is the phenol-disulfonic acid procedure for measuring the concentration of total oxides of nitrogen (except N_2O) expressed as nitrogen dioxide (NO_2) in parts per million (ppm) by volume.

Total unburned hydrocarbons and types of hydrocarbons were determined by the technique of Soulages and Brieva (2). This method uses a gas chromatograph. The aromatic and olefinic hydrocarbons are selectively retained by two chemical absorbents while the saturates (paraffins) pass unaltered through the gas chromatograph. The measurements were determined by flame ionization detection (FID).

The reason for determining the fraction of total unburned hydrocarbons that are of each type (paraffins, aromatics, and olefins) is because other investigators such as Jackson (3) have found the smog-forming potential of an exhaust hydrocarbon mixture to depend upon the composition of the mixture. Jackson points out that, with reactivity differences among exhaust hydrocarbons greater than 6000 to 1, an increase, decrease or no change in smog-forming potential is conceivable, even though the total hydrocarbon concentration may be decreased.

Jackson lists relative reactivities for a large number of hydrocarbons. The paraffin group ranges from 0.0 to 1.86 with an average relative reactivity for this group of hydrocarbons around 1.5.

The aromatics range from 0.56 to 8.64 with an average value for the aromatics listed by Jackson of 3.5.

The olefins have relative reactivities ranging from 2.50 to 52.9 with an average value for the olefins listed by Jackson of 9.7.

Amounts of the various types of hydrocarbons in the exhaust gases as well as total amount of unburned hydrocarbons are important in determining the harmful aspects of this air pollutant.

The check on air-fuel ratio and carbon monoxide emissions was done by using an Orsat analyzer and assuming a hydrocarbon fuel.

Before any emission measurements were made, the air-fuel ratio at idle on each vehicle was adjusted to a reference value. This reference value was the air-fuel ratio obtained when the vehicle had last been adjusted (tuned-up) to the manufacturer's recommendations.

During the times when field testing was being performed, not all vehicles were readily available because of the particular job assignments where the vehicle was being used. Consequently, during some months certain vehicles were missed during the testing periods. In the case of tractors, some measurements were omitted during the winter months because a few of these vehicles were not used between emission testing periods.

In order to accomplish the statistical analysis, it was necessary to estimate the missing or incomplete information. The estimations were performed in two ways. If the vehicle had been used and was missed during the regular emission testing period, the emission readings for the two months adjacent to the missing month were averaged and used for the missing month data. If the vehicle had not been used, the missing data was estimated by using the previous months data. Since the vehicle was not operated there should be no difference in emissions. Estimated data obtained by either of these two methods is identified by an asterisk in the tabulations of the Appendices.

Data obtained from the test fleet measurements are tabulated in Appendices A and B. Appendix A tabulates data for the Test Fleet at idle and 2500 rpm, no load, for the ten months of testing. Appendix B tabulates data for the test fleet for March and May when bag samples were returned to the laboratory for oxides of nitrogen, total hydrocarbons and types of hydrocarbons determination.

B. Matched Pair Vehicles

Ten pairs of vehicles were selected from the initial test fleet. Each pair was matched according to type, make and mileage as closely as possible. The major difference in each pair was fuel. One vehicle of the pair used leaded fuel, while the other used nonleaded fuel. The 10 matched pairs included 4 pairs of pickups, 4 pairs of light-duty trucks and 2 pairs of heavy-duty trucks.

1. Testing Scheme

These vehicles were tested under load conditions on a chassis dynamometer at the Des Moines Area Community College. The loads for which emission data were obtained included full, 2/3 nominal, 1/3 nominal, all at 2500 rpm. Data for minimum load (typically 15 to 20% of full load) at 2500 rpm were also obtained for all vehicles except the pickups. Measurements recorded included load, air-fuel ratio, intake manifold vacuum, temperature, humidity, and both total hydrocarbon (HC) and carbon monoxide (CO) emissions. In addition, exhaust-gas samples were collected in Tedlar bags for laboratory analysis of total oxides of nitrogen, total hydrocarbons(FID), types of hydrocarbons and carbon monoxide.

Before any measurements were made, the air-fuel ratio at idle on each vehicle was adjusted to a reference value. This reference value was the air-fuel ratio obtained when the vehicle had last been adjusted (tuned-up) to the manufacturer's recommendations.

The testing procedure was the same as that used and previously described for the Test Fleet.

Data from these measurements is tabulated in Appendices C, D and E.

Appendix C tabulates the data for tests performed on the Matched Pairs during January 1972, Appendix D tabulates data for tests performed on the Matched Pairs during April 1972 and Appendix E contains data on the Matched Pairs for April 1972, when bag samples were returned to the laboratory and analyzed for oxides of nitrogen, total hydrocarbons and types of hydrocarbons both by the gas chromatograph.

C. Fuel Economy and Maintenance Costs

Operating data from selected vehicles in the Test Fleet were recorded and analyzed to determine any variation in fuel economy and maintenance costs which resulted from the type of gasoline used. These data are tabulated in Appendices F and G. Appendix F tabulates maintenance costs, Appendix G fuel and oil consumption data.

D. Miscellaneous Tests

Several miscellaneous tests were included to support and fulfill the primary objective of this experiment. Included in these miscellaneous tests were gasoline samples taken at each location and oil samples taken when the vehicle oil was changed.

The gaoline samples were analyzed by running a gasoline distillation test on each sample in accordance with ASTM Designation D86-61, determining the Reid vapor pressure in accordance with ASTM Designation D323-58 and determining the API gravity of the gasoline. In addition, each gasoline sample was analyzed for the fraction of each type (saturates, olefins and aromatics) of hydrocarbon that was in the gasoline.

This test was performed using the gas chromatograph method which was previously described under the Test Fleet testing scheme.

The oil samples were filtered to determine the amount of particulate matter in the sample in accordance with ASTM Designation F313-70. This standard was modified (size of sample used was reduced) to accomodate the difference in the amount of particulate matter contained in used crankcase oil and hydraulic oils for which this standard applies.

IV. RESULTS

A. Calibration Procedure for Sun Exhaust Emission Tester 910

All analytical methods must be calibrated at regular intervals. This can be a dynamic or static calibration, and can involve use of calibrating gases or comparison against another instrument which has been calibrated.

The Sun EET 910 which measures unburned hydrocarbons (HC) and carbon monoxide (CO) is equipped with an internal calibration system consisting of a mechanically driven chopper which prevents a known fraction of the infrared radiation from reaching the detector, thereby simulating the known absorption of HC and CO gases. Calibration is achieved by adjusting the span set control until the indicating pointers are coincident with the span set control lines on the HC and CO meters. This is done after complete warm-up and after the meters have been set to zero with no exhaust gas flowing through the tester. It was decided to check the accuracy and repeatability of the self-contained calibration system by procuring calibration HC and CO gases of certified composition. After considerable experimentation, the following observations were made.

a. Since there is considerable variation between the HC and CO certified calibration gas concentrations and the results obtained by the EET 910 using the internal span set method, it is necessary to adjust the span set control by passing calibration gas through the machine and by then adjusting the span set control until the meters indicate the actual gas composition. The meter span reading is recorded for future reference.

b. The span set remains fairly stable when adjusted as specified above. Even if the meter reading should change when the span setting check switch is engaged, readjusting the span set control to restore the original setting will result in restoring the correct calibration. The span set should be checked each 30 minutes or after each two or three vehicles are checked, and readjusted if necessary.

c. The zero drift of the machine is appreciable and is, therefore, a matter of concern. To prevent errors in measurement due to zero shift, the set line controls must be adjusted to bring the HC and CO meters to zero immediately preceding each measurement.

d. The EET 910 should be recalibrated (at least at the beginning of each half day of testing) by passing certified calibration gas through it and adjusting the span set controls until the meters indicate correctly. This should be done more frequently if an unusually large number of vehicles are checked, if there are any marked changes in atmospheric conditions, if there are any large changes in the meter readings when the span check switch is actuated, or if the operator has reason to question the readings obtained from the tester. Correct calibration can be maintained between certified gas calibrations by actuating the span check switch and verifying that the meter span readings are the same as when the calibrating gas was used, readjusting the span set control to restore the readings if necessary. A detailed procedure is included in Appendix H.

e. The uncertainly of this tester using calibrating gases is estimated to be ± 20 ppm for HC measurements. Thus, the relative error in HC measurements is much higher at the lower levels of HC emissions. For example, the uncertainty is greater than ± 10% when emissions are below 200 ppm while the uncertainly is ± 2% at an emission level of 1000 ppm.

1. Pressure, Temperature and Humidity Effects

The calibration of the Sun EET 910 possibly could be affected by atmospheric pressure, temperature, and humidity of the ambient atmosphere and by the same properties of the exhaust gas passing through the test cells of the tester. The manufacturer gives pressure (altitude) correction factors to apply to the span setting when the internal calibration system is used. However, since it was decided to use calibrating gases which will compensate for all nonstandard conditions at the time of calibration, these types of corrections are not necessary.

It was decided to investigate the effect of temperature and humidity variation of the exhaust gas. The EET 910 was calibrated with dry calibrating gas and then water-saturated calibrating gas was immediately run through the tester. The resulting readings for HC and CO agreed with the calibrating gas composition adjusted for the calculated dilution by water vapor within 10 ppm HC and 0.05% CO, which is less than the expected measurement error of the machine. The conclusion was therefore made that calibrating with a dry calibrating gas and measuring a partially saturated exhaust gas would introduce no appreciable errors. A similar test was run on the EET 910 except that the temperature of the calibrating gas (also room temperature) was allowed to vary. Since no artificial means of changing the laboratory temperature was available, about 24 hours elapsed between the original calibration and the recheck. The pressure and span settings as well as the ambient temperature had changed. Thus, no definite conclusions could be drawn about the exact effect of the exhaust gas temperature variation due to variations in all factors and their possible interactions. Frequent recalibration with certified calibration gas was relied upon to minimize effects due to changes in atmospheric pressure and temperature.

2. Hydrocarbon Comparison

An alternate determination of the unburned HC in the exhaust gas was used to provide a check on the EET 910 as well as to provide additional data about the types of hydrocarbons in the exhaust gas samples. The technique used was a subtractive absorption gas chromatograph column using a flame ionization detector (FID). This technique was used by Soulages and Brieva (2).

The column splits the flow into three branches. One branch contains a mercuric perchlorate - percholoric acid (MP-PA) absorbent which absorbs the olefinic and aromatic hydrocarbons and does not react with the paraffinic (saturates) hydrocarbons. A second branch contains a mercuric sulphate - sulfuric acid (MS-SA) absorbent which retains all olefins with 3 or more carbon atoms and does not react with aromatics and saturates. The third branch has no absorbent and therefore passes all of the hydrocarbons. Another way of saying this is that the three branches pass saturates, saturates plus aromatics, and total hydrocarbons, respectively. This permits the determination of total HC as well as the relative breakdown into the saturated, aromatic and olefinic species. The HC determination is germane to this experiment in that it gives a method of checking the calibration of the EET 910.

The EET 910 is an infrared absorption instrument having an infrared source emitting in the wavelength band of 3.4 to 3.5 microns. This is near the peak of the absorption band of hexane which was used as the calibrating gas. The hexane in nitrogen calibrating gas concentration was certified by Air Product, Inc., supplier of this mixture.

The indicated concentration from the EET 910 is in hexane equivalent on an infrared absorption basis. Other hydrocarbons overlap this absorption band but have varying absorptivities which means a varying response by the instrument to them.

The flame ionization detector (FID) responds essentially to the carbon content of the hydrocarbon gases and thus responds equally well (on a mass basis) to all kinds of hydrocarbons.

Since the two measurement methods employ different detection techniques, a difference between the EET 910 and the gas chromatograph was expected even when analyzing samples that were taken simultaneously in sample bags and returned to the laboratory. A review of current literature indicated that total HC determined by FID will be greater than HC determined by NDIR.

Different investigators report variable values for the ratio FID/NDIR with typical values in the range of 1.8 - 2.8 depending on the type of fuel and engine operating parameters. For example, Krause (4) reported an average value of FID/NDIR of 2.3. The ratio of 1.8 is recognized by the Environmental Protection Agency in the Federal Register (5) as the standard procedure for computing exhaust dilution factors.

All samples for analysis on the gas chromatograph were collected in Tedlar bags which were filled directly from the discharge of the Sun EET 910 analyzer.

The flow split of the three branches of the column and calibration of the output of the gas chromatograph was accomplished by using hexane (910 ppm) calibration gas which had been analyzed and certified by Air Products, Inc. This gas came from the same laboratory as that used to calibrate the EET 910. Therefore, all readings from the gas chromatograph were hexane equivalent.

Periodically, 1-pentene and benzene were used as test gases to verify that the absorbents were still functioning properly.

Table 1. Total hydrocarbons (ppm hexane equivalent) for Matched Vehicles (April Data).

Vehicle type	Nonleaded fuel			Leaded fuel		
	FID (GC)	NDIR (Sun)	FID/NDIR	FID (GC)	NDIR (Sun)	FID/NDIR
Pickup	194.3	73.8	2.63	276.8	101.2	2.74
Light duty	164.9	64.1	2.57	176.8	69.7	2.54
Heavy duty	194.6	80.6	2.41	226.2	95.0	2.38

Table 1 lists total hydrocarbons measured by the EET 910 (NDIR), the gas chromatograph (FID) and the ratio of gas chromatograph to EET 910 for the April tests of the Matched Pairs. The table shows that the ratio of the total hydrocarbons measured by the two techniques is approximately 2.5. Examination of the data in Appendix E indicates that there is considerable variation around this 2.5 value, especially when the value read on the EET 910 is less than 100 ppm. This is a range on the machine which is less than 5% of full scale and where a considerable error in reading can be obtained if the zero adjustment is off slightly. Also, it took approximately 10 seconds to fill the bags - the gas chromatograph will indicate an average for this period of time while the EET 910 is an instantaneous reading.

Table 2. Total hydrocarbons (ppm hexane equivalent) for Fleet Vehicles (effect of fuel on emissions).

Vehicle type	Nonleaded fuel			Leaded fuel		
	FID (GC)	NDIR (Sun)	FID/NDIR	FID (GC)	NDIR (Sun)	FID/NDIR
Pickup	121.3	50.0	2.43	174.9	109.5	1.60
Light duty	260.0	156.7	1.66	166.7	82.9	2.01
Heavy duty	355.0	138.8	2.56	361.6	165.2	2.19
Tractor	346.8	202.5	1.71	322.1	142.5	2.26

Table 3. Total hydrocarbons (ppm hexane equivalent) for Fleet Vehicles (effect of engine speed on emissions).

Vehicle type	Nonleaded fuel			Leaded fuel		
	FID (GC)	NDIR (Sun)	FID/NDIR	FID (GC)	NDIR (Sun)	FID/NDIR
Pickup	211.1	114.4	1.85	98.6	60.0	1.64
Light duty	292.2	163.7	1.78	112.2	58.3	1.92
Heavy duty	475.2	223.2	2.13	243.6	89.5	2.72
Tractor	414.0	255.6	1.62	263.1	109.4	2.40

Tables 2 and 3 tabulate the same type of information for the Test Fleet for the months of March and May. For the Test Fleet data, the ratio of total hydrocarbons by FID to NDIR varies considerably, ranging from 1.6 to 2.7. No explanation can be given for the wide variation in this ratio.

3. Carbon Monoxide Comparison

Calibration gas was used to check and adjust the span setting on the Sun EET 910 instrument before taking field measurements of carbon monoxide (CO). It was deemed necessary to check the Sun EET 910 carbon monoxide readings by a second technique. This was accomplished in two ways.

a. Carbon monoxide values obtained by the Sun EET 910 instrument were compared with carbon monoxide values obtained using an Orsat analyzer. The samples were obtained from the exhaust gases from a Kohler engine located in the Mechanical Engineering Laboratory at Iowa State University. Care was taken to be certain samples were taken simultaneously. Values for five different runs are shown in Table 4.

Table 4. Comparison of carbon monoxide values obtained by two different techniques.

Run	Sun EET 910 values (%)	Orsat analyzer values (%)
1	1.5	1.4
2	1.9	1.8
3	6.1	6.4
4	4.6	3.6
5	0.5	0.6

It should be noted that the minimum readable division (sensitivity) on the Orsat analyzer is ± 0.1%. A very favorable comparison was obtained in all cases except one.

b. When bag samples were obtained in the field, they were brought to the Mechanical Engineering Laboratory at Iowa State University and analyzed for carbon monoxide using an Orsat analyzer. Carbon monoxide values obtained using the Orsat analyzer were compared with carbon monoxide values obtained for the same run using the Sun EET 910 tester. It was found that most values were within 0.2%. This is considered excellent agreement when it is noted that the minimum readable division on the Orsat analyzer is 0.1% and that the bag samples were obtained over a period of time (about 10 seconds) and will be an average for that period while the Sun EET 910 is by comparison an instantaneous reading.

Based on the above two calibration checks, it was concluded that highly accurate carbon monoxide values are obtained from the Sun EET 910 tester if the calibrating gas is used to set the span setting before starting a field test. In the field, the span setting is also checked periodically during the test period to maintain the desired calibration.

B. Calibration Procedure for Sun 1120 Electronic Engine Tester

The Sun 1120 Electronic Engine Tester was used for measuring the air-fuel ratio. An attempt was made to verify the accuracy of this measurement by comparing the readings obtained from the Sun 1120 with values obtained by measuring the products of combustion using an Orsat analyzer and by measuring the air flow and fuel flow supplied to a small internal combustion negine.

These tests were conducted in the Mechanical Engineering Laboratory using a Kohler engine. Care was taken to be certain that the gas samples used in obtaining values from the three different techniques were taken simultaneously.

Table 5. Comparison of air-fuel ratio values obtained by three different techniques.

Run	Sun 1120 values	Orsat values	Measured air-fuel values
1	14.0	15.4	12.7
2	13.8	14.6	12.6
3	12.8	12.8	10.7
4	13.3	14.4	11.4
5	14.1	15.3	12.8

Air-fuel ratio values for five different runs using these three techniques are shown in Table 5. For the five runs, the values obtained by the three different techniques varied considerably. The same trends did exist in the air-fuel ratio values obtained by the three different techniques, indicating a possible fixed error existing in one or more of the measuring techniques.

Examination of the NO_x emission results indicated a maximum NO_x emission occurring at an air-fuel ratio of approximately 14 as measured by the Sun 1120. The commonly accepted air-fuel ratio for maximum NO_x emission is approximately 15. Based on this acceptable agreement between measured and theoretical air-fuel ratio for maximum NO_x emissions and the need to concentrate on other parts of the study, it was decided to use the air-fuel ratios as measured by the Sun 1120 as valid. For this study, there was no other instrument available for conveniently measuring air-fuel ratio in the field tests. Furthermore, since the machine had already been purchased and placed in use for approximately four months before the above described calibration was carried out, it was felt that changing the instrument would introduce more discrepancies than continuing with the Sun 1120.

C. Oxides of Nitrogen

The main deviation from the test procedure stated in ASTM Designation D-1608 was that samples were collected in Tedlar bags in the field. These samples were then returned to the Mechanical Engineering Department laboratory for analysis. The exhaust gas samples were then transferred from the Tedlar bags to an evacuated flask for the analysis described in ASTM D-1608.

On several occasions, duplicate runs were made to check on our procedure. On almost all of these duplicate runs, the second run was within 5% of the first, which was the expected repeatibility using this procedure as applied to exhaust gases from automotive engines.

D. Emission Results from the Test Fleet Vehicles

Statistical analysis of unburned hydrocarbons, carbon monoxide and air-fuel ratio as obtained from the Sun emission testing apparatus was performed by standard analysis of variance techniques (6-8). This analysis included all test fleet data obtained between August 1971 and June 1972, hereafter referred to as Test Fleet data.

Data before August was not used because the calibration procedure for the Sun emission tester was such that large fixed errors could and likely did occur in the HC and CO measurements. Modification of the calibration procedure in August to use reference gases minimized the possibility of fixed error in the measurements. In addition, during the months of March and May 1972, emission samples from the Test Fleet were collected in Tedlar bags for laboratory determination of hydrocarbons and oxides of nitrogen by techniques previously described. These data are hereafter referred to as Special Test Fleet data. Analysis of variance was also performed on these data.

Initially, the Test Fleet data were analyzed according to the following statistical model:

$$y_{ijkl} = \mu + F_i + S_j + T_k + (FS)_{ij} + (FT)_{ik} + (ST)_{jk} + (FST)_{ijk} + \epsilon_{ijkl} \qquad (1)$$

where

y_{ijkl} = measured variable (HC, CO or A/F),

μ = true value of the variable being measured with no effect due to any of the following treatments,

F_i = effect or treatment caused by the fuel,

S_j = effect or treatment caused by the speed,

T_k = effect or treatment caused by the type of vehicle,

$(FS)_{ij}$ = interaction effect of fuel and speed,

$(FT)_{ik}$ = interaction effect of fuel and type,

$(ST)_{jk}$ = interaction effect of speed and type,

$(FST)_{ijk}$ = interaction effect of fuel, speed and type,

ϵ_{ijkl} = measurement error and effect for which one cannot account with the statistical model chosen.

Results of this analysis are tabulated in the "analysis of variance" table in the Appendix I.

Conclusions from Appendix I data are made by comparing the calculated F values to the critical F values. If F calculated is larger than F critical, the effect is significant. The critical F values are obtained from an F table at the desired confidence level. A 95% confidence level was selected for these experiments in view of the number of data and the magnitude of the measurement error. A 95% confidence level means that one would be stating conclusions with 95% probability or 20:1 odds of having the correct conclusion. Pertinent conclusions at the 95% confidence level are:

1. Speed, type and fuel (in order of importance) all have significant effects on both HC and CO emissions.
2. Speed and type are the only significant variable affecting air-fuel ratio (This agrees with what we know to be physically true).
3. There are significant speed-type and fuel-type interactions on HC, CO and A/F.

Since type is the one variable common to all main and interaction effects, it is evident the data should be divided by type of vehicle to avoid most of the interactions noted. Consequently, the data for each vehicle type was separately analyzed according to the following statistical model:

$$y_{ijk} = F_i + S_j + (FS)_{ij} + \epsilon_{ijk}. \qquad (2)$$

The terms in this equation have the same meaning as previously described for Eq. (1).

The analysis of variance tables for each vehicle type are included in Appendix J. A summary of conclusions from these analysis of variances tables is included in Table 6 on the following page. Several "Analysis of covariance" results are also included in this table.

The analysis of covariance is an attempt to correct the measured data or to ascertain the effects of uncontrolled variables on the measured data. Such uncontrolled variables affecting the fleet data include temperature, humidity, mileage (or aging of the vehicle), and air-fuel ratio. Hours of engine operation were used instead of mileage for the aging effect on tractors. These variables used for the correction are called covariant factors and the resulting analysis is called analysis of covariance. In this case, the statistical model changes to

$$y_{ijkl} = \text{(analysis of variance terms previously listed)} + \Sigma\beta_m\chi_m$$

where the χ's are the covariant factors and the β's are correction coefficients determined in the analysis of covariance procedure.

In Table 6 each factor significantly affecting a measured variable is listed in order of importance. Factors not significant at the 95% confidence level are not listed. Included with each factor of importance is a number signifying its relative importance. This number is the ratio of F calculated to F critical. If this number is unity, it means the factor is significant with 95% confidence (95% probability). Numbers above unity correspond to confidence or significance above the 95% probability. The relative effect of a covariant factor can be ascertained by comparing these numbers between the analysis of variance (ANOV) and the analysis of covariance (ANCOV) tabulations.

Table 6. Summary of analysis of variance and analysis of covariance for the Test Fleet vehicles.

Vehicle type	Measured variables	ANOV	ANCOV (A/F, T, H, M)	ANCOV (T, H, M)	ANCOV (T, H)
All vehicles combined	HC (NDIR)	S(36.3), T(14.4), F(2.1) S×T(4.9), F×T(2.5)			
	CO	T(42.2), S(17.0), F(2.3) S×T(10.0), F×T(8.0) F×S×T([illegible].2)			
	A/F	S(35.7), T(30.2) S×T(9.8), F×T(6.0)			
Pickup	HC (NDIR)	S(1.7), F×S(6.4)	S(1.2), F×S(8.2)	S(2.3), F(1.2), F×S(9.0)	S(2.2), F×S(8.5)
	CO	S(48.2), F(1.6), F×S(1.7)	S(41.6)	S(55.4)	S(48.0), F(1.5)
	A/F	F(5.3), S(4.6)	Not applicable	F(14.5), S(6.1)	F(5.9), S(4.9)
Light duty	HC (NDIR)	S(14.2), F(5.9), F×S(1.3)	S(3.7), F(1.0) F×S(1.8)	S(15.0), F×S(1.4)	S(14.4), F(6.8), F×S(1.3)
	CO	S(34.8), F(5.9), F×S(1.1)	S(2.2)	S(38.8), F×S(1.9)	S(34.6), F(8.6), F×S(1.0)
	A/F	S(61.8), F(3.1)	Not applicable	S(74.4)	S(68.1), F(3.0)
Heavy duty	HC (NDIR)	S(8.4)	S(7.9)	S(9.0)	S(9.0)
	CO	S(3.2), F(2.7)	F(2.5)	F(5.4), S(3.6)	S(3.2), F(2.6)
	A/F	S(6.2), F(2.6)	Not applicable	S(6.2), F(3.3)	S(6.1), F(2.5)
Tractor	HC (NDIR)	S(29.2), F(6.0)	S(29.8), F(4.5)	S(31.0), F(6.6)	
	CO	F(10.2), S(1.1)	F(6.8, S(5.3), F×S(2.0)	F(9.2), S(1.2), F×S(1.0)	
	A/F	F(2.3)	Not applicable	F(2.6), S(1.1)	

The corrections applied in the analysis of covariance technique were generally not effective in reducing the error term an order of magnitude relative to the data variation caused by other factors. Thus, the analysis of covariance tables are not presented in this report. However, the results from these analysis of covariance tables are summarized in Table 6 along with the analysis of variance for the comparison desired. Most conclusions are based on the analysis of variance results since that analysis dealt with the actual measurements as obtained without corrections and is indicative of how the vehicles were actually operating at ambient conditions. The analysis of covariance is useful in ascertaining the effects of items such as air-fuel ratio.

Conclusions from analysis of variance tabulations in Table 6 are:

1. Engine speed is the most important factor affecting HC, CO and A/F measurements on all vehicles.
2. Type of fuel is significant for HC, CO and A/F on light-duty trucks and tractors.
3. Type of fuel is significant for CO and A/F on pickups and heavy-duty trucks.
4. Fuel-speed interactions are significant in affecting HC and CO on pickups and light-duty trucks.

The following general items are noted by a comparison of analysis of variance with analysis of covariance in Table 6.

1. Analysis using all covariant factors of air-fuel ratio, temperature, humidity and mileage yields essentially the same results as the analysis of variance.
2. Covarient analysis using temperature and humidity for the trac-

tors could not be performed as these covariants didn't seem to be statistically independent.

3. The covariant analysis using air-fuel ratio as a covariant factor decreases the effect of the differences in gasolines.

The specific differences in HC, CO, and A/F measurements and how they are affected by speed and type of fuel are given by the average values of data obtained during the course of this investigation. These averages are listed in Tables 7, 8, and 9. The tabulation of Table 9 shows the emission of HC and CO to be generally lower at 2500 than at idle regardless of the fuel type. From Tables 7 and 8 it is also apparent that the effect of speed on emissions of HC and CO is more significant than effects of fuel type.

Table 7. Fleet Vehicle averages of effect of fuel on emissions for both idle and 2500 rpm. HC and CO by NDIR.

Vehicle type	No lead			Lead		
	HC (ppm)	CO (%)	A/F	HC (ppm)	CO (%)	A/F
Pickup	54.3	0.9	14.1	60.1	0.7	13.9
Light Duty	147.8	2.1	13.8	78.1	1.4	14.0
Heavy Duty	161.8	1.6	13.9	184.6	2.5	13.6
Tractor	220.4	3.6	13.4	152.6	2.5	13.6

Table 8. Fleet Vehicle averages of effect of engine speed on emissions for both leaded and nonleaded gasoline. HC and CO by NDIR.

Vehicle type	Idle			2500 RPM		
	HC (ppm)	CO (%)	A/F	HC (ppm)	CO (%)	A/F
Pickup	61.1	1.3	13.9	54.2	0.3	14.1
Light duty	158.7	2.4	13.6	56.2	0.9	14.2
Heavy duty	273.2	2.8	13.5	80.8	1.8	13.9
Tractor	276.4	3.1	13.5	119.1	3.4	13.6

Table 9. Fleet Vehicle averages of effect of engine speed on emissions for each fuel. HC and CO by NDIR.

Vehicle type	Nonleaded fuel						Leaded fuel					
	Idle			2500 rpm			Idle			2500 rpm		
	HC (ppm)	CO (%)	A/F	HC (ppm)	CO (%)	A/F	HC (ppm)	CO (%)	A/F	HC (ppm)	CO (%)	A/F
Pickup	68.5	1.3	14.0	40.2	0.4	14.2	55.5	1.2	13.9	64.7	0.2	14.0
Light duty	218.1	2.6	13.6	77.4	1.5	14.1	115.5	2.2	13.6	40.7	0.6	14.3
Heavy duty	243.6	2.2	13.6	80.0	1.0	14.1	288.0	3.0	13.5	81.3	2.1	13.8
Tractor	306.6	3.6	13.4	134.1	3.6	13.5	216.1	2.1	13.6	89.1	2.8	13.7

Conclusions for the Test Fleet data where all vehicles are tested at no load conditions are: (1) HC and CO emissions are in general significantly lower for leaded gasoline than for nonleaded gasoline; (2) air-fuel ratio is highly important in affecting all emissions measured; and (3) differences in air-fuel ratio among vehicles causes larger differences in measured emissions than differences in gasoline. Consequently, engine tune-up is probably the most important factor affecting emissions.

Data from Special Test Fleet are tabulated in Appendix K. The summary of ANOV and ANCOV for this data which included oxides of nitrogen as NO_2 and gas chromatograph analysis of the hydrocarbon types in the unburned hydrocarbons are included as Table 10. The tabulations of average values from the measurements are in Tables 11 through 16. In these tables HC1, HC2, HC3 and HCT represents, respectively, the fractions of paraffins, aromatics and olefins and total unburned hydrocarbons obtained from gas chromatograph analysis of exhaust samples. The variables HC, CO, NO_2 and A/F are the same as previously described.

Conclusions from the analysis of variance are:

1. HC3 portion of HCT depends on type of gasoline.
2. HC2 portion of HCT depends mainly on type of gasoline and secondarily on engine speed (RPM).
3. HC1 portion of HCT depends mainly on engine speed and secondarily on type of gasoline.
4. HCT depends primarily on engine speed for all vehicles except pickups and secondarily on fuel only in light duty trucks.
5. Emissions of HC, CO and NO_2 depend mainly on engine speed for all vehicles.
6. A/F is significantly affected by engine speed for all vehicles. This item should show up statistically since it is physically true.

Table 10. Summary of analysis of variance and analysis of covariance for the Special Test Fleet.

Vehicle type	Measured Variable	ANOV	ANCOV (A/F, T, H, M)	ANCOV (T, H, M)	ANCOV (T, H)
All vehicles combined	HC1	S(17.0), F(6.3), FxT(2.3)	-	-	-
	HC2	F(31.5), S(8.1)	-	-	-
	HC3	F(11.9), FxT(2.0)	-	-	-
	HCT(FID)	S(12.1), T(4.2)	-	-	-
	HC(NDIR)	S(10.8), T(1.7), FxT(1.2)	-	-	-
	CO	S(10.7), T(7.4), FxT(2.1)	-	-	-
	NO_2	S(19.8), T(2.5)	-	-	-
	A/F	S(16.0), T(4.8), FxT(1.8)	-	-	-
Pickup	HC1	F(8.3)	-	-	F(6.5)
	HC2	F(4.7)	-	-	F(4.2), S(1.4)
	HC3	-	F(1.2), FxS(1.2)	F(1.7), FxS(1.4)	-
	HCT(FID)	-	F(1.4), FxS(1.7)	F(2.0), FxS(1.9)	-
	HC(NDIR)	-	S(5.3), F(2.0), FxS(1.3)	S(5.7), F(2.2), FxS(1.3)	-
	CO	S(5.7)	S(21.8)	S(21.7)	S(5.3)
	NO_2	S(25.1)	S(1.5)	S(1.7)	S(25.4)
	A/F	S(2.0)	Not applicable	-	S(2.0)
Light duty	HC1	S(5.6), F(2.9)	S(2.0)	S(1.7)	S(5.8), F(4.0)
	HC2	F(9.3), S(4.6)	S(1.9)	S(1.7)	S(7.4), F(4.8)
	HC3	F(1.9)	F(3.1), S(3.1)	S(3.1), F(3.1)	-
	HCT(FID)	S(6.1), F(1.4)	F(2.6), S(1.4)	F(2.5), S(1.4)	S(6.6), F(3.0)
	HC(NDIR)	S(3.8), F(1.7)	S(9.6)	S(9.7)	S(3.8), F(2.2)
	CO	S(9.4), F(2.5)	S(12.0)	S(12.0)	S(9.9), F(3.7)
	NO_2	S(16.9)	S(11.7)	S(11.8)	S(16.6)
	A/F	S(13.0), F(2.1)	Not applicable	-	S(12.9), F(1.7)
Heavy duty	HC1	S(14.5)	F(3.1)	F(1.2)	S(14.5)
	HC2	F(4.0)	F(3.0)	F(1.2)	F(4.8)
	HC3	F(4.6)	-	-	F(6.6)
	HCT(FID)	S(1.9)	-	-	S(2.1)
	HC(NDIR)	S(2.5)	-	-	S(2.3)
	CO	-	S(2.3), F(2.4), FxS(2.7)	F(4.2), S(2.6), FxS(2.9)	-
	NO_2	S(9.0), F(3.4), FxS(2.6)	-	-	F(9.1), S(2.5), FxS(2.7)
	A/F	S(1.8), F(1.8), FxS(1.0)	Not applicable	F(2.4)	F(1.7), S(1.6)
Tractor	HC1	S(7.0)	F(5.7)	F(6.7)	-
	HC2	F(11.2), S(1.4)	F(5.7)	F(6.7)	-
	HC3	F(9.2)	S(1.2)	S(1.0)	-
	HCT(FID)	S(4.3)	S(3.4), F(1.6)	S(2.7), F(2.6)	-
	HC(NDIR)	S(10.9), F(1.9)	-	-	-
	CO	F(1.2)	S(2.5)	S(2.6)	-
	NO_2	S(4.3)	-	-	-
	A/F	S(1.5)	Not applicable	-	-

From the average values of test results in Tables 11 through 16, the following items are apparent:

1. HC1 portion of HCT is lower at 2500 rpm than at idle regardless of gasoline. HC1 is higher for leaded gasoline than nonleaded gasoline.
2. HC2 portion of HCT is higher at 2500 rpm than at idle regardless of gasoline. HC2 is lower for leaded gasoline than nonleaded gasoline. Thus, HC2 is opposite to the variation of HC1.
3. HC3 portion of HCT is virtually no different at 2500 rpm than at idle. HC3 is higher for leaded gasoline than nonleaded gasoline.
4. HCT is higher at idle than at 2500 rpm regardless of fuel type. No consistent difference exists in favor of leaded or nonleaded gasoline.
5. Emissions of HC and CO are higher at idle than at 2500 rpm while NO_2 emission is lower at idle than at 2500 rpm. No consistent differences exist in favor of leaded or nonleaded gasoline.

Table 11. Special Fleet* Vehicles averages** of effect of engine speed on emissions for each fuel.

	Nonleaded fuel								Leaded fuel							
	Idle				2500 rpm				Idle				2500 rpm			
Vehicle type	HC1%	HC2%	HC3%	HCT(ppm)	HC1%	HC2%	HC3%	HCT(ppm)	HC1%	HC2%	HC3%	HCT(ppm)	HC1%	HC2%	HC3%	HCT(ppm)
Pickup	33.3	34.9	31.7	157.8	25.2	44.3	30.5	84.8	42.9	22.3	34.8	243.1	43.5	24.3	32.1	106.8
Light duty	34.6	36.2	29.1	381.3	26.7	43.2	30.1	138.6	40.1	23.4	36.5	237.4	32.4	32.9	34.7	96.0
Heavy duty	40.6	33.1	26.4	533.5	28.0	43.1	28.8	176.5	41.5	17.9	40.5	446.0	29.9	21.9	48.1	277.1
Tractor	35.9	36.9	27.2	413.4	27.8	44.0	28.2	280.2	39.2	21.8	39.0	415.2	27.2	26.5	46.3	229.0

*March and May data.

**HC1, HC2, HC3 and HCT by FID.

Table 12. Special Fleet* Vehicle averages of effect of engine speed on emissions for each fuel.

	Nonleaded fuel								Leaded fuel							
	Idle				2500 rpm				Idle				2500 rpm			
Vehicle type	HC** (ppm)	CO(%)	NO_2 (ppm)	A/F	HC** (ppm)	CO(%)	NO_2 (ppm)	A/F	HC** (ppm)	CO(%)	NO_2 (ppm)	A/F	HC** (ppm)	CO(%)	NO_2 (ppm)	A/F
Pickup	63.3	1.7	28.5	13.9	36.7	0.5	117.7	14.1	145.0	1.8	22.5	13.8	74.0	0.2	144.2	14.1
Light duty	224.4	3.2	24.4	13.6	89.1	1.8	123.9	14.0	126.3	2.6	18.0	13.7	39.4	0.7	104.1	14.4
Heavy duty	191.2	2.8	16.5	13.5	86.2	1.3	163.5	14.1	239.2	3.7	10.0	13.4	91.1	3.3	53.5	13.5
Tractor	276.6	3.8	36.9	13.5	128.4	3.4	232.5	13.6	213.7	2.9	38.5	13.5	71.2	2.6	255.6	13.8

*March and May data.

**HC by NDIR.

Table 13. Fleet* Vehicle averages** effect of fuel on emissions for both idle and 2500 rpm.

Vehicle type	Nonleaded fuel HC1(%)	Nonleaded fuel HC2(%)	Nonleaded fuel HC3(%)	Nonleaded fuel HCT(ppm)	Leaded fuel HC1(%)	Leaded fuel HC2(%)	Leaded fuel HC3(%)	Leaded fuel HCT(ppm)
Pickup	29.2	39.6	31.1	121.3	43.2	23.3	33.4	174.9
Light duty	30.7	39.7	29.6	260.0	36.3	28.1	35.6	166.7
Heavy duty	34.3	38.1	27.6	355.0	35.7	19.9	44.3	361.6
Tractor	31.8	40.4	27.7	346.8	33.2	24.2	42.6	322.1

*March and May Data.

**HC1, HC2, HC3 and HCT by FID.

Table 14. Fleet* Vehicle averages** effect of engine speed on emissions for both leaded and nonleaded gasoline.

Vehicle type	Idle HC1(%)	Idle HC2(%)	Idle HC3(%)	Idle HCT(ppm)	2500 rpm HC1(%)	2500 rpm HC2(%)	2500 rpm HC3(%)	2500 rpm HCT(ppm)
Pickup	39.3	27.0	33.6	211.1	36.7	31.8	31.5	98.6
Light duty	38.0	28.3	33.7	292.2	30.2	36.8	33.0	112.2
Heavy duty	41.2	22.9	35.8	475.2	29.3	29.0	41.7	243.6
Tractor	37.0	31.9	31.1	414.0	27.6	38.1	34.3	263.1

*March and May data.

**HC1, HC2, HC3 and HCT by FID.

Table 15. Fleet* Vehicle averages of effect of fuel on emissions for both idle and 2500 rpm.

Vehicle type	Nonleaded fuel				Leaded fuel			
	HC** (ppm)	CO(%)	NO_2 (ppm)	A/F	HC** (ppm)	CO(%)	NO_2 (ppm)	A/F
Pickup	50.0	1.1	73.1	14.0	109.5	1.0	83.3	13.9
Light duty	156.7	2.5	74.2	13.8	82.9	1.6	61.0	14.0
Heavy duty	138.8	2.1	90.0	13.8	165.2	3.5	31.7	13.5
Tractor	202.5	3.6	134.7	13.6	142.5	2.7	147.1	13.7

*March and May data.

**HC by NDIR.

Table 16. Fleet* Vehicle averages of effect of engine speed on emissions for both leaded and nonleaded gasoline.

Vehicle type	Idle				2500 rpm			
	HC** (ppm)	CO(%)	NO_2 (ppm)	A/F	HC** (ppm)	CO(%)	NO_2 (ppm)	A/F
Pickup	114.4	1.7	24.7	13.9	60.0	0.4	134.2	14.1
Light duty	163.7	2.8	20.4	13.7	58.3	1.1	111.7	14.2
Heavy duty	223.2	3.4	12.2	13.4	89.5	2.6	90.2	13.7
Tractor	255.6	3.5	37.5	13.5	109.4	3.1	240.2	13.7

*March and May data.

**HC by NDIR.

. Emission Results from the Matched Pair Vehicles

For he matched pairs, each vehicle type was analyzed both by analysis of variance (ANOV) and analysis of covariance (ANCOV). In this case the measured variables were unburned hydrocarbons (HC), carbon monoxide (CO) and oxides of nitrogen measured as NO_2. The covariant factors used were temperature, humidity, barometric pressure and air-fuel ratio. Mileage was not used as a covariant factor since the vehicles were matched both on the basis of make (Dodge, Chevrolet, etc.) and mileage (age). The ANOV and ANCOV models are respectively given as:

$$y_{ijkl} = \mu + P_i + F_j + L_k + (FL)_{jk} + \epsilon_{ijkl} \tag{4}$$

$$y_{ijkl} = \mu + P_i + F_j + L_k + (FL)_{jk} + \Sigma\beta_m \chi_m + \epsilon_{ijkl} \tag{5}$$

where

y_{ijkl} = measured variable (HC, CO or NO_2, for example)

μ = true value of the variable being measured with no effect due to any of the following factors

P_i = effect caused by differences in vehicle pairs

F_j = effect caused by differences in fuels

L_k = effect caused by differences in loads

$(FL)_{jk}$ = interaction effect of fuel and load

χ_m = covarienat factors (Temperature, humidity, barometer and air-fuel ratio)

β_m = correction coefficient determined by analysis of covariant procedure.

ϵ_{ijkl} = measurement error and effect for which one cannot account with the statistical model

Analysis of variance tables for the matched pair vehicles are included in Appendix L. From this appendix tabulations of factors causing significant variation in the measured data are presented in Table 17. Both the ANOV and ANCOV results are summarized for comparison purposes in the table. This table is arranged in the same manner as previously described in the section involving Test Fleet Vehicles. Conclusions from the analysis of variance are:

1. Load is the most important factor affecting HC, CO and NO_2 emissions measured on the matched pair vehicles.
2. For a given type of vehicle (pickup, light duty, or heavy duty), the differences among pairs (Dodge, Chevrolet, etc.) are important but less significant than load in affecting HC and CO emissions.
3. Differences in pairs was only significant in affecting NO_2 emissions on the light-duty vehicles.
4. Differences between leaded and nonleaded gasoline were significant in affecting HC emissions from pickups and heavy-duty trucks and CO emission from light-duty trucks.

Table 17. Summary of analysis of variance and analysis of covariance for the matched pair vehicles.

Vehicle type	Measured variable	ANOV	ANCOV (A/F, T, H, M)	ANCOV (A/F, T, H)	ANCOV (T, H)	ANCOV (A/F, T)	ANCOV (A/F)
Pickup	HC(NDIR)	^{L}(5.2), ^{F}(1.2)	^{P}(2.4), ^{L}(1.1)	^{P}(1.7)	^{L}(6.6), ^{F}(1.0)	^{P}(2.4)	^{P}(2.6)
	CO	^{L}(20.2), ^{P}(1.3)	^{L}(1.8)	^{L}(1.9)	^{L}(20.5), ^{P}(1.4)	^{L}(1.9)	^{L}(2.6)
	NO_2	^{L}(3.0)	^{P}(2.1)	^{P}(1.2)	^{L}(3.9)	-	-
Light duty	HC(NDIR)	^{P}(6.7), ^{L}(6.4)	^{P}(11.4), ^{L}(2.7)	^{P}(8.2), ^{L}(1.3)	^{L}(9.7), ^{P}(7.9)	^{P}(5.6)	^{P}(5.7)
	CO	^{L}(10.7), ^{P}(3.6), ^{F}(1.6)	^{P}(2.4)	^{P}(1.9)	^{L}(10.6), ^{P}(2.1), ^{F}(1.5)	^{P}(2.0)	^{L}(1.2)
	NO_2	^{L}(2.7), ^{P}(1.8)	^{L}(2.9), ^{P}(2.4)	^{L}(3.2), ^{P}(2.8)	^{L}(4.1), ^{P}(1.8)	^{P}(9.1), ^{L}(3.3)	^{P}(5.9), ^{L}(3.7)
Heavy duty	HC(NDIR)	^{L}(10.3), ^{F}(1.9), ^{P}(1.6)	^{L}(3.6)	^{L}(3.9), ^{P}(2.3)	^{L}(10.2), ^{P}(1.9), ^{F}(1.7)	^{L}(4.0), ^{P}(1.2)	^{L}(5.2), ^{P}(1.8)
	CO	^{L}(8.5), ^{P}(1.7)	^{L}(3.1)	^{L}(3.4), ^{P}(2.1)	^{L}(9.4), ^{P}(1.9)	^{L}(3.4)	^{L}(4.6), ^{P}(1.6)
	NO_2	-	^{P}(1.3)	^{L}(1.2), ^{P}(1.1)	-	-	-

The specific differences in HC, CO and NO_2 measurements and how they are affected by load, vehicle type, and fuel are given by average values listed in Tables 18 through 23. The tabulations of Tables 18 and 19 show that HC and CO emissions are affected by load for all vehicle types for both fuels. HC and CO first decrease consistently from full load to about 1/3 load, then increase from 1/3 load to minimum load. The NO_2 emissions are reversed from this; that is, the NO_2 emissions increase from full load to about 1/3 load, then decrease from 1/3 to minimum load.

Table 18. Matched Vehicle averages of effect of load on emissions for nonleaded fuel at 2500 rpm.

Vehicle type	Nonleaded fuel											
	Full load			2/3 Load			1/3 Load			Minimum load		
	HC* (ppm)	CO(%)	NO_2 (ppm)	HC* (ppm)	CO(%)	NO_2 (ppm)	HC* (ppm)	CO(%)	NO_2 (ppm)	HC* (ppm)	CO(%)	NO_2 (ppm)
Pickup	102.5	5.4	806.5	56.9	1.7	1499.6	31.9	0.9	1369.1	-	-	-
Light duty	91.2	5.0	726.8	51.9	1.5	1336.5	43.8	1.7	930.1	53.1	2.4	415.9
Heavy duty	125.0	5.8	680.8	57.5	1.1	1704.5	51.3	1.1	1663.3	62.5	1.3	1169.5

*HC by NDIR.

Table 19. Matched Vehicle averages of effort of load on emissions for leaded fuel at 2500 rpm.

Vehicle type	Leaded fuel											
	Full load			2/3 Load			1/3 Load			Minimum load		
	HC* (ppm)	CO(%)	NO_2 (ppm)	HC* (ppm)	CO(%)	NO_2 (ppm)	HC* (ppm)	CO(%)	NO_2 (ppm)	HC* (ppm)	CO(%)	NO_2 (ppm)
Pickup	133.8	6.3	392.6	76.2	1.7	1155.6	52.5	0.9	1716.0	-	-	-
Light duty	103.8	4.7	731.4	46.9	0.7	1412.1	45.0	0.8	916.0	50.6	1.0	648.9
Heavy duty	160.0	4.4	816.3	60.0	2.0	1460.0	71.3	1.3	2006.0	85.0	2.0	1529.5

*HC by NDIR.

Table 20. Matched Vehicle averages* of effect of fuel on emissions for all loads (January and April data combined).

Vehicle type	Nonleaded fuel HC(ppm)	Nonleaded fuel CO(%)	Nonleaded fuel NO_2(ppm)	Leaded fuel HC(ppm)	Leaded fuel CO(%)	Leaded fuel NO_2(ppm)
Pickup	63.8	2.66	1225.1	87.5	2.94	1088.1
Light duty	60.0	2.63	852.3	61.6	1.80	927.1
Heavy duty	74.1	2.30	1304.5	94.1	2.42	1452.9

Table 21. Matched Vehicle averages* of effect of fuel on emissions for all loads (January data).

Vehicle type	Nonleaded fuel HC(ppm)	Nonleaded fuel CO(%)	Nonleaded fuel NO_2(ppm)	Leaded fuel HC(ppm)	Leaded fuel CO(%)	Leaded fuel NO_2(ppm)
Pickup	53.8	2.42	1043.0	73.8	2.73	876.1
Light duty	55.9	2.39	1142.7	53.4	1.76	1198.1
Heavy duty	67.5	2.38	1261.8	93.1	2.65	1487.8

Table 22. Matched Vehicle averages* of effect of fuel on emissions for all loads (April data).

Vehicle type	Nonleaded fuel HC(ppm)	Nonleaded fuel CO(%)	Nonleaded fuel NO_2(ppm)	Leaded fuel HC(ppm)	Leaded fuel CO(%)	Leaded fuel NO_2(ppm)
Pickup	73.8	2.91	1407.2	101.2	3.14	1216.8
Light duty	64.1	2.88	561.9	69.7	1.84	656.1
Heavy duty	80.6	2.22	1347.2	95.0	2.19	1418.1

*Matched vehic e averages in the above tables are for loads of full, 2/3, 1/3 and minimum (exce t for pickups) at 2500 rpm HCT by FID, HC by NDIR.

Table 23. Matched Vehicle averages* of effect of fuel on types of hydrocarbons in unburned hydrocarbon at all loads (gas chromatograph analysis of unburned hydrocarbons for April data).

Vehicle type	Nonleaded fuel				Leaded fuel			
	HC1(%)	HC2(%)	HC3(%)	HCT(ppm)	HC1(%)	HC2(%)	HC3(%)	HCT(ppm)
Pickup	26.1	29.3	44.6	194.3	30.0	25.7	44.3	276.8
Light duty	29.7	43.8	26.9	164.9	28.1	42.1	29.8	176.8
Heavy duty	26.0	19.3	54.7	194.6	29.9	15.0	55.1	226.2

*Matched vehicle averages in the above tables are for loads of full, 2/3, 1/3 and minimum (except for pickups) at 2500 rpm, HCT by FID, HC by NDIR.

The effect of fuel yields significantly higher HC emissions with leaded fuel for pickups and heavy-duty trucks as well as higher CO emissions for light-duty trucks. There is no significant effect of fuel on HC emissions from light-duty trucks, and no significant effect of fuel on CO emissions from pickups and heavy-duty trucks. The oxides of nitrogen expressed as NO_2 are not affected by fuel.

Note from Table 17 that analysis of covariance yields no significant effects due to differences in fuel when air-fuel ratio is included as one of the covariant factors. This result seems to indicate that if all vehicle engines could be operated at an identical air-fuel ratio, the gasoline type would have no effect on any of the measured emissions. However, differences in load, (Full, 2/3, 1/3) and matched pairs (Dodge, Chevrolet, etc.) would still significantly affect the HC, CO and NO_2 emissions.

During the month of April additional testing and analysis was performed on the matched pair vehicles such that hydrocarbon type in the unburned hydrocarbons could be ascertained. The analysis of variance table for this data is included as Appendix M and the ANOV and ANCOV results are given in Table 24. Conclusions from this table are:

1. HC1 portions of HCT is significantly affected primarily by changes in load and secondarily by differences among matched pairs of vehicles.
2. HC2 portion of HCT is mainly affected by differences among matched pairs of vehicles and secondarily by load. Fuel is of importance only for pickups. Recall that fuel significantly affected this portion of HCT in the Test Fleet Vehicles.

3. HC3 portion of HCT is mainly affected by differences among matched pairs of vehicles and secondarily by load.

4. HCT is mainly affected by load and secondarily by differences in matched pairs of vehicles.

5. HC and CO are mainly affected by load. Differences in matched pairs are important only for light-duty trucks. Differences caused by fuel are not significant.

6. NO_2 is mainly affected by differences in matched pairs and secondarily by load.

Table 24. Summary of analysis of variances and analysis of covariance from the matched pair data for April.

Vehicle type	Measured variable	ANOV	ANCOV (A/F, I, H)	ANCOV (A/F, T)	ANCOV (I, H)	ANCOV (A/F)
Pickup	HC1	L(2.7), P(2.5)	-	-	L(2.3)	P(1.3)
	HC2	P(19.5), F(1.6), L(1.4)	P(19.7)	P(20.5)	P(16.5), L(1.3)	P(23.3), F(1.3)
	HC3	P(31.2), L(1.6)	P(23.1)	P(23.6)	P(24.8), L(1.5)	P(29.0)
	HCT(FID)	L(2.0)	P(4.4), F(1.7)	P(7.5), F(6.1)	L(4.2), P(2.4)	P(1.6)
	HC(NDIR)	L(1.9)	P(3.3), F(2.1)	P(4.5), F(2.1)	L(3.1), P(2.1), F(1.6)	P(2.3)
	CO	L(4.5)	-	-	L(4.6)	-
	NO_2	P(1.9), L(1.4)	-	-	L(1.4)	P(2.1)
Light duty	HC1	L(3.1), P(1.1)	-	-	L(2.8)	-
	HC2	L(2.3), P(1.9)	F(2.9), P(1.7)	F(1.3), P(1.0)	L(2.4)	F(1.1)
	HC3	-	-	F(1.9), P(1.1)	P(1.1)	F(1.5)
	HCT(FID)	P(6.9), L(2.7)	P(19.5), F(15.5), L(1.7), FxL(1.4)	P(5.9), F(1.3)	L(2.8), P(2.6)	P(5.0), F(1.2)
	HC(NDIR)	P(12.7), L(7.0)	F(2.9), P(10.1), FxL(1.5)	P(7.6), L(2.2)	L(8.8), P(7.4), F(1.0)	P(8.0), L(2.1)
	CO	L(2.8), P(2.0)	-	-	L(4.1), F(2.7), P(1.6)	-
	NO_2	P(4.9), L(1.4)	L(1.1)	P(3.2), L(1.0)	L(1.5)	P(5.3), L(1.1)
Heavy duty	HC1	L(3.2), P(2.4), F(1.6)	FxL(1.3)	-	L(2.7)	P(1.6)
	HC2	-	-	-	-	-
	HC3	P(6.9), L(2.1)	-	P(1.6)	L(3.2)	P(6.5)
	HCT(FID)	L(3.3)	L(1.8)	L(1.7), F(1.6)	-	L(1.1)
	HC(NDIR)	L(2.8)	P(1.1), F(1.1), L(1.1), FxL(1.7)	-	-	-
	CO	L(2.2)	-	-	-	-
	NO_2	-	-	-	-	-

From Table 23, no consistent numerical differences in HC1, HC2, HC3, HCT or NO_2 are observed to be caused by differences in gasoline. However, HC is higher under load for the leaded gasoline as compared to nonleaded gasoline. Tables 18 and 19 reveal this effect to occur mainly under full load condition. At lower loads HC emissions are lower and the differences between leaded and nonleaded gasoline are much smaller. No consistent trend was noted for CO emission in terms of gasoline differences. However, it must be noted that even with these differences in averages of the measured emissions, they are not statistically significant at the 95% confidence level. Thus, difference in gasoline is not generally important in causing the differences in measured emissions. Items such as differences in air-fuel ratio and, therefore, engine tune-up are far more effective than gasoline in causing significantly different emissions among vehicles.

F. Miscellaneous Results

1. Gasoline Analysis

Results of gasoline distillation tests on both leaded and nonleaded gasoline samples are shown in Table 25. The values tabulated for a given month are averages from several samples taken during the month and include several locations. Also shown in this table are API gravity values.

Table 26 tabulates typical API gravity values and gasoline distillation data for gasoline shipped to Des Moines, Iowa, the source of the gasoline for the test locations.

Table 25. Average distillation data from fuel samples provided by the Iowa State Highway Commission.

Date	D-86 - Distillation - % Evaporated											
	Leaded fuel*						Nonleaded fuel**					
	API Grav at 60 °F	IBP (Values in °F)	10	50	90	EP	API Grav at 60 °F	IBP (Values in °F)	10	50	90	EP
Nov. 1971	63.1	94	122	196	309	359	57.9	102	128	215	316	365
Jan. 1972	60.8	103	123	205	327	373	60.0	97	120	213	321	364
Mar. 1972	62.3	98	122	199	314	362	60.6	96	124	211	316	359

*Des Moines, Boone, and Marshalltown locations.

**Grundy Center and Sac City locations.

Table 26. Typical inspection of gasoline shipped to Des Moines; data furnished by American Oil Co.

Date	D-86 - Distillation - % Evaporated											
	Leaded gasoline samples (Am. Reg.)						Nonleaded Gas samples (AMOCO-R)					
	API Grav at 60 °F	IBP (Values in °F)	10	50	90	EP	API Grav at 60 °F	IBP (Values in °F)	10	50	90	EP
July 1971	59.8	97	124	207	316	378	57.5	92	126	219	315	385
Aug. 1971	59.9	96	125	209	327	393	57.1	98	124	218	321	396
Sep. 1971	59.2	93	120	218	334	391	-	-	-	-	-	-
Oct. 1971	64.8	94	113	198	305	368	-	-	-	-	-	-
Nov. 1971	62.8	-	-	-	-	-	60.9	83	102	212	318	380
Dec. 1971	62.0	83*	114*	206*	309*	380*	60.3	90*	119*	209*	307*	387*
Jan. 1972	62.8	-	-	-	-	-	60.6	-	-	-	-	-
Feb. 1972	62.0	93*	122*	197*	291*	373*	60.6	86*	119*	207*	301*	378*
Mar. 1972	62.9	-	-	-	-	-	63.1	-	-	-	-	-

*Averages for three months.

Examination of Tables 25 and 26 shows only minor differences between data from field samples and data furnished by American Oil Company. The main difference is that the field samples had a higher initial boiling point (IBP) temperature.

Results from gasoline samples analyzed on the gas chromatograph for fraction of saturates, aromatics and olefins are shown in Table 27. These tabulated results are from samples taken at the various test locations, and are selected to cover as long a period of time as possible. Reid vapor pressure and API gravity-values are also shown.

A typical analysis of gasoline shipped to Des Moines, Iowa, is shown in Table 28.

The following conclusions are based on the data tabulated in Tables 27 and 28:

1. The percentage of aromatics in the nonleaded gasoline samples is considerably above that for leaded samples. The ratio of aromatics in nonleaded to leaded is 1.45 for the field samples and 1.2 for values supplied by an American Oil Company representative.

2. Field sample results for both leaded and nonleaded gasoline samples appear to be reversed from that supplied by American Oil Company. No apparent reason exists for this result.

3. Reid vapor pressures for the leaded field samples were slightly below those supplied by the American Oil Company representative (possibly some of the light constitutents were lost prior to our tests). The Reid vapor pressures

for the nonleaded field samples lagged the monthly values supplied by American Oil Company by several months. Field values remained below 10 through November while the supplied values were on the order of 12.5 after October. This indicates a lag between winter gasoline being delivered to Des Moines and when it actually reaches the field points, thereby leading to hard starting during the winter.

Table 27. Average hydrocarbon type, Reid vapor pressure and API values from fuel samples provided by the Iowa State Highway Commission.

Location	Date of sample	Hydrocarbon Type: Percent paraffins	Hydrocarbon Type: Percent olefins	Hydrocarbon Type: Percent aromatics	Reid vapor pressure (psi)	API at 60 °F
Leaded gasoline samples						
Des Moines	11-4-71	66.0	26.5	7.5	10.00	64.0
Ames (Williams)	11-17-71	65.8	24.6	9.6	10.55	63.6
Des Moines	11-30-71	62.7	20.0	17.3	11.25	62.2
Ames (Williams)	12-30-71	63.9	21.3	14.9	11.90	62.5
Des Moines	1-11-72	64.9	20.3	14.8	11.95	62.9
Boone	1-20-72	63.1	22.4	14.5	9.70	60.8
Des Moines	2-14-72	66.1	19.2	14.6	11.60	62.4
Des Moines	3-6-72	67.1	20.2	12.7	11.35	63.2
Boone	3-16-72	66.6	20.3	13.1	10.70	61.6
Des Moines	4-5-72	68.0	19.8	12.2	11.10	64.2
Boone	4-25-72	66.5	20.3	13.2	10.20	61.6
Des Moines	5-8-72	69.4	19.1	11.5	11.55	64.3
Average of all samples		65.85	21.17	12.99		
Nonleaded gasoline samples						
Sac City	10-22-71	51.0	30.9	18.1	7.35	58.3
Grundy Center	11-9-71	53.9	23.3	22.8	8.90	58.1
Grundy Center	11-30-71	56.5	23.9	19.6	8.80	57.7
Grundy Center	12-27-71	59.1	21.9	19.0	10.70	59.5
Grundy Center	1-2-72	60.0	22.0	17.9	11.45	60.2
Sac City	1-31-72	58.2	22.9	18.9	11.15	60.0
Grundy Center	2-23-72	59.3	22.4	18.3	11.30	60.4
Grundy Center	3-1-72	59.6	22.5	17.9	12.60	60.4
Grundy Center	3-22-72	63.1	20.8	16.1	11.90	60.8
Grundy Center	4-24-72	58.0	22.1	19.9	11.35	60.7
Average of all samples		57.87	23.27	18.35		

Table 28. Typical hydrocarbon type, Reid vapor pressure and API gravity values of gasoline shipped to Des Moines; data furnished by American Oil Company.

Date	Hydrocarbon type			Reid vapor pressure (psi)	API at 60 °F
	Percent saturates	Percent olefins	Percent aromatics		
Leaded Gasoline Samples (American Regular)					
July 1971	56	16	28	9.2	59.8
Aug. 1971	56	18	26	9.3	59.9
Sep. 1971	54	16	26	9.8	59.2
Oct. 1971	64	22	14	10.6	64.8
Nov. 1971	64	17	19	11.9	62.8
Dec. 1971	64	15	21	12.7	62.0
Jan. 1972	65	15	20	12.9	62.8
Feb. 1972	64	14	22	11.8	62.0
Mar. 1972	67	12	21	11.1	62.9
Nonleaded gasoline samples (AMOCO-R)					
July 1971	42	24	34	9.1	57.5
Aug. 1971	46	20	34	9.4	57.1
Sep. 1971	-	-	-	-	-
Oct. 1971	-	-	-	-	-
Nov. 1971	53	21	26	12.5	60.9
Dec. 1971	53	21	26	12.4	60.3
Jan. 1972	53*	21*	26*	12.2	60.6
Feb. 1972	53*	21*	26*	10.5	60.6
Mar. 1972	53*	21*	26*	10.5	63.1

*Estimated

2. Vehicle Maintenance

Maintenance data supplied by Iowa State Highway Commission for the vehicles involved in this experiment are shown in Appendix F.

At the outset of this study, it was recognized that a period of one year would be insufficient time for any statistically significant differences in maintenance costs to be detected. Thus, the mechanical condition of the engines was not established by an engine disassembly either at the beginning or end of the test period due to the prohibitive time and labor requirement for the large number of vehicles involved. Furthermore, the completeness of the data is questionable since the maintenance records for some vehicles indicate no routine maintenance items such as changes of spark plugs, etc. After considering the foregoing facts it was decided that any attempt to quantify any differences between lead and nonlead fueled vehicles on a cost basis would be inconclusive and possibly misleading.

Table 29 summarizes the comparative incidence of some maintenance items which are possibly fuel related. No significant differences appear except in the number of carburetor replacements and engine replacements of the nonleaded light-duty vehicles. Caution should be exercised in reading too much into this information dut to the previously discussed factors.

Table 29. Summary of maintenance performed on test fleet vehicles.

Maintenance items that are possibly fuel related	Pickup		Light duty		Heavy duty	
	NL*	L	NL	L	NL	L
Tuneups (replace spark plugs, etc.)	5	8	10	26	2	5
Valves ground	1	0	0	0	0	0
Carb. replaced or cleaned	1	0	5	1	2	2
Engine replaced	0	0	5	0	0	1

*NL = nonleaded and L = leaded.

The replacement of engines in the nonleaded, light-duty vehicles is not deemed to be attributable to the fuel. Other factors such as engine mileage are thought to be the major factors. Examination of the engines which were replaced did not reveal any evidence of the primary cause of failure to be fuel related.

3. Fuel Economy

Fuel and oil consumption data furnished by Iowa State Highway Commission is tabulated in Appendix G. This data has been separated by fuel type (leaded and nonleaded) and by vehicle type (pickup, light-duty, etc.). Known data on individual vehicles are tabulated along with an average value for all vehicles of a certain type and fuel. As can be seen by examination of the data in Appendix G, considerable data was not available, especially on leaded vehicles.

Table 30 summarizes the fuel consumption for the Test Fleet vehicles. No significant difference is apparant.

Table 30. Comparison of fuel consumption for Test Fleet vehicles.

Vehicle type	Nonleaded	Leaded
Pickup (miles/gallon)	11.43	11.11
Light duty (miles/gallon)	5.85	5.93
Heavy duty (miles/gallon)	2.69	2.98
Tractor (hours/gallon)	0.64	0.69

An irregularity was noticed on the records in that unusually large quantities of gasoline where added to some of the vehicles on December 31, 1971, when said vehicles were not being used and personnel were on vacation.

4. Filtration of Crankcase Oil

Testing for contamination of used crankcase oil was performed in accordance with "The Standard Method of Test for Insoluble Contamination of Hydraulic Fluids by Gravimetric Analysis," ASTM Designation F313-70.

Because of the similarities between crankcase oil and hydraulic fluids, this test specification was applicable for dtermining contaminants in used crankcase oil.

According to ASTM Designation F313-70, the insoluble contamination is determined by passing a given quantity of a fluid sample through a membrane filter disk of 0.4 to 0.8 micron pore size and measuring the resultant increase in the weight of the filter. The fluid sample is drawn through the filter by a vacuum and the insoluble contamination is collected on the surface of the filter. In addition, the filter is microscopically scanned for excessively large particles, fibers or other unusual conditions.

It was discovered that there were distinct differences between the physical properties of used crankcase oil and hydraulic fluids. First, there is a fraction of used crankcase oil that consists of water. The actual volumetric per cent composed of water depends upon operating conditions to which the crankcase oil has been subjected as well as the type of crankcase oil. For example, detergent oil has a much higher affinity for water than nondetergent oil. Thus, used crankcase detergent oil would be expected to have a higher volumetric per cent water than the used crankcase nondetergent oil.

Filtration of used crankcase oil containing water is very difficult because the electrokinetic flow-restriction phenomenon occurs with any polar molecule such as the water molecule. Thus, water must be removed if filtering is to be accomplished. It was removed from each sample tested by heating used crankcase oil above the boiling temperature of water for a period of time sufficient to allow vaporization of nearly all the water.

The second problem is the difference between volumetric per cent of the particulate matter in used crankcase oil compared to hydraulic fluids. The ASTM Test F313-70 suggests a test sample size of 100 ml of hydraulic fluid to insure measureable results. In test samples it was discovered that one-to-ten milliliters of used crankcase oil contained sufficient contaminant to clog the pores of the membrane filter. Dilutions of used crankcase oil with commercial hexane, commercial benzane, acetone, isopropyl alcohol and gasoline in ratios up to 15 parts solvent to 1 part crankcase oil were attempted. The optimal mixture was determined to be about 10 parts commercial hexane to 1 part crankcase oil. Agitating the mixture of hexane and oil during filtration yielded a slow but workable process.

Data from the oil residue tests are shown in Appendix M. Table 31 summarizes a comparison between average crankcase oil residue for vehicles operating on leaded and nonleaded gasoline. Table 32 tabulates the analysis of variance values for this data. Based on the results tabulated in Tables 31 and 32, the type of gasoline had no statistically significant effect on the amount of residue in the crankcase oil. Although considerable differences in the mean values did exist, large variations in the data for each vehicle type, regardless of gasoline, rendered these differences in mean values to be unimportant. Also, in some cases, as noted by an asterisk on items in Appendix M, it was necessary to estimate mileage between oil changes before the amount of particulate in the oil could be compared on a consistent (milligrams per mile) basis.

Table 31. Average crankcase oil residue per vehicle type (values in milligrams per mile).

Vehicle type	Nonleaded fuel	leaded fuel
Pickup	8.10	5.46
Light duty	12.83	16.00
Heavy duty	7.25	10.67

Table 32. Analysis of variance table* for crankcase oil residues.

Vehicle type	Source of variation	Sum of squares	Degrees of freedom	F calculated	F critical (95% confidence level)
Pickup	Pairs	2.451E 1	3	1.95	9.28
	Fuel	1.397E 1	1	3.32	10.13
	Error	1.261E 1	3	-	-
Light duty	Pairs	1.374E 3	7	0.75	3.79
	Fuel	4.017E 1	1	0.15	5.59
	Error	1.888E 3	7	-	-
Heavy duty	Pairs	3.838E 1	1	19.44	161.45
	Fuel	1.166E 1	1	5.91	161.45
	Error	1.974E 0	1	-	-

*Statistical model: Y = P(I) + F(J) + E(IJ).

Y = Residue in mg per mile.

P(I) = effect due to differences in pairs of vehicles.

F(J) = effect due to differences in fuel.

E(IJ) = measurement error and additional effect for which the statistical model does not account.

Note: the numbers above, e.g., 2.451E 1, represent 2.451×10^1.

V. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

The following conclusions are based on the objectives of this study and in direct relation to the detailed results presented in the previous section.

1. Some statistically significant differences between leaded and nonleaded gasoline were apparent:

   a. Conclusions for the Test Fleet data where all vehicles are tested at no-load conditions are:

      i. HC and CO emissions are in general significantly lower for <u>leaded</u> gasoline than nonleaded gasoline.

      ii. Air-fuel ratio is highly important in affecting all emissions measured.

      iii. Differences in air-fuel ratio among vehicles causes larger differences in measured emissions than differences in gasoline. Consequently, engine adjustment (tune-up) is probably the most important factor affecting emissions.

   b. Conclusions for the Matched Pair data where the vehicles were tested on a chassis dynameter are:

      i. The effect of fuel yields significantly <u>higher</u> HC emissions with <u>leaded</u> fuel for pickups and heavy-duty trucks as well as higher CO emissions with light-duty trucks.

      ii. There is no significant effect of fuel on HC emissions from light-duty trucks and no significant effect of fuel on CO emissions from pickups and heavy-duty trucks.

iii. Oxides of nitrogen expressed as NO_2 are not affected by fuel.

iv. The fuel effect on Matched Pair emissions was greatest at full load with the emissions than decreasing both in magnitude and difference due to fuel as load is reduced.

2. No significant differences were observed in either maintenance costs or fuel consumption during the course of this study. Furthermore, there were no differences that were statistically significant on the oil residue comparison.

3. Calibration of the Sun EET 910 with certified gases was found to be essential before valid measurements could be accomplished. It was determined that the uncertainty of the HC emission measurements was at least $\pm$ 10% when emissions were below 200 ppm.

4. The effects of humidity or temperature on the measurements were less than the uncertainty of the Sun EET 910.

5. Record keeping was incomplete on maintenance items, and fuel and oil consumption data. Even though additional data was requested several times. it was never supplied. This made it necessary to draw conclusions relative to the above topics with a smaller amount of data than de-

s red. However, the authors believe the conclusions drawn f om the abbreviated data are valid.

B. Recommendations

Based on the objectives of this study and the conclusions of the previous s ction the following recommendations are made:

1. C ntinue use of leaded fuel in vehicles for which our test v hicles are representative because:
    a No significant reduction in emissions would occur with use of nonleaded gasoline in view of the duty cycle of the vehicles.
    b. No emission control equipment exists on the test vehicles which the lead in the gasoline would render inoperative.
    c. No differences in short term maintenance costs or fuel consumption were apparent. No long range maintenance costs or fuel consumption trends could be established.
    d The cost of nonleaded gasoline is about 2¢/gallon higher than leaded gasoline. The cost benefit to the Iowa State Highway Commission would be approximately $150,000 per year.
2. A reassessment of type of gasoline to be used is recommende when it is known what emission control devices will be u ed to meet the more stringent 1975 federal standards. F r example, if the catalytic converter is used, nonleaded g soline must be used.

3. It is recommended that a systematic program for performing engine tune-ups with exhaust emission testing equipment be undertaken in order to minimize emissions and operating costs. This is deemed essential because engine operating conditions had a greater influence on emissions than did fuel type.
4. Initiate a record keeping system that will allow easy access and reliable data on vehicle maintenance and fuel consumption. This data can then be used to conduct a long term study on maintenance costs and fuel consumption.
5. Use the procedure described in Appendix H for calibrating the Sun EET 910 with certified reference gases.
6. Because of the large relative error in this tester at low levels of HC, it is recommended that the manufacturer of this instrument be consulted concerning its modification for measurements in the range 200 ppm or less.
7. Extend the study for the lifetime of the vehicles under test so that effective comparisons can be made on maintenance items. and fuel and oil consumption.
8. In purchasing new vehicles do not overspecify the size of engine required as the total amount of pollutants depends on amount of gasoline consumed as discussed by Conta (9).

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APPENDIX A

TEST FLEET DATA

Nomenclature

SPEED

1 → Idle

2 → 2500 rpm

MILES → Miles (or hours for tractors) on odometer at time of test

HC → Unburned hydrocarbons in parts per million by nondispersive infrared (NDIR) measurement

CO → Carbon monoxide in % by NDIR

A/F → Air-fuel ratio

TEMP → Ambient temperature in degrees Rankine

HUMID → Specific humidity in grains water per pounds dry air

* → Data was not available; this point was estimated

FLEET DATA

SPEED	MILES	HC	CO	A/F	TEMP	HUMID
A-14652 UNLEADED FORD H-DUTY GRUNDY CENTER						
1	05488	0510	1.5	15.5	530	62
1	05876	0200	3.5	13.2	536	87
1	06056	0400	3.7	13.4	536	85
1	06119	0280	4.0	13.5	517	42
1	06355	0050	0.7	13.5	475	10
1	06677	0050	0.7	13.5	462	05
1	07549	0138	2.4	13.5	486	00
1	09212	0200	2.4	13.5	466	00
1	09717	0200	2.5	13.4	529	31
1	10170	0200	4.0	13.5	510	40
2	05488	0430	0.8	15.8	530	62
2	05876	0070	1.4	13.6	536	87
2	06056	0095	2.6	13.7	536	85
2	06119	0100	1.8	13.6	517	42
2	06355	0040	0.4	13.6	475	10
2	06677	0040	0.4	13.6	462	05
2	07549	0040	1.3	14.1	486	00
2	09212	0040	1.3	13.9	466	00
2	09717	0040	1.3	14.0	529	31
2	10170	0175	2.4	14.0	510	40
A-13857 UNLEADED INT'L H-DUTY SAC CITY						
1	10159	0200	0.6	14.1	530	75
1	10232	0070	0.4	13.8	544	93
1	10451	0130	0.8	13.8	522	42
1	10507	0380	1.9	13.5	522	38
1	10940	0300	2.0	13.5	491	26
1	11831	0325	2.0	13.5	496	20
1	12784	0375	2.0	13.5	451	00
1	13298	0325	2.5	13.5	504	21
1	13465	0500	3.8	13.5	535	76
1	13585	0040	2.5	13.5	510	36
2	10159	0050	1.2	14.1	530	75
2	10232	0050	1.7	14.0	544	93
2	10451	0030	0.6	13.5	522	42
2	10507	0050	0.4	13.5	522	38
2	10940	0040	0.2	14.6	491	26
2	11831	0050	0.4	14.4	496	20
2	12784	0040	0.3	14.6	451	00
2	13298	0040	0.5	14.1	504	21
2	13465	0090	1.0	14.5	535	76
2	13585	0090	1.0	14.5	510	36

FLEET DATA

SPEED	MILES	HC	CO	A/F	TEMP	HUMID
A-14670 LEADED		FORD	H-DUTY	DES MOINES		
1	04500	1575	3.8	13.4	532	72
1	04572	0775	2.8	13.0	539	01
1	05000*	0500*	2.9*	13.2*	523	48
1	05467	0220	3.0	13.4	508	44
1	06150	0088	1.4	13.0	496	28
1	06976	0263	6.8	13.0	492	24
1	07708	0238	5.5	13.0	455	00
1	09340	0150	3.3	13.0	496	15
1	09500	0200	2.1	13.0	529	30
1	09800	0400	5.5	13.0	514	47
2	04500	0215	2.2	13.6	532	72
2	04572	0125	2.2	13.5	539	01
2	05000*	0090*	1.7*	13.7*	523	48
2	05467	0060	1.2	13.8	508	44
2	06150	0050	0.8	13.6	496	28
2	06976	0065	3.7	13.6	492	24
2	07708	0090	2.5	13.6	455	00
2	09340	0050	2.0	13.6	496	15
2	09500	0090	1.7	13.8	529	30
2	09800	0100	2.6	13.6	514	47
A-14648 LEADED		FORD	H-DUTY	DES MOINES		
1	05552	0575	3.1	13.6	527	76
1	06211	0350	1.6	13.6	540	00
1	06992	0345	3.6	13.5	523	48
1	07474	0187	2.0	13.5	510	21
1	08457	0060	0.5	13.7	490	20
1	09351	0225	3.7	13.6	492	22
1	10580	0238	3.7	13.6	455	00
1	11950	0250	2.5	13.6	496	16
1	12170	0363	4.5	13.6	504	30
1	12208	0275	5.0	13.5	514	47
2	05552	0050	1.1	14.5	527	76
2	06211	0050	1.4	13.6	540	00
2	06992	0050	1.5	13.9	523	48
2	07474	0040	0.6	13.9	510	21
2	08457	0020	0.3	14.4	490	20
2	09351	0030	1.2	14.1	492	22
2	10580	0080	2.4	13.9	455	00
2	11950	0120	4.0	13.0	496	16
2	12170	0188	7.0	13.0	504	30
2	12208	0130	4.0	13.3	514	47

FLEET DATA

SPEED	MILES	HC	CO	A/F	TEMP	HUMID
A-14647 LEADED		FORD	H-DUTY	DES MOINES		
1	04597	0388	4.0	13.6	529	72
1	05157	0350	2.2	13.9	542	02
1	05177	0375	3.9	13.5	525	48
1	05336	0175	2.4	13.5	510	21
1	05783	0150	1.0	13.8	490	20
1	06396	0413	4.3	13.6	469	25
1	06844	0213	4.0	13.6	449	00
1	07000*	0244*	4.5*	13.6*	496	16
1	07522	0275	5.0	13.6	501	30
1	07590	0375	5.0	13.5	518	48
2	04597	0078	1.2	13.9	529	72
2	05157	0050	1.4	13.5	542	02
2	05177	0155	1.4	14.0	525	48
2	05336	0045	0.6	14.0	510	21
2	05783	0225	0.4	14.5	490	20
2	06396	0123	5.5	13.4	469	25
2	06844	0115	5.0	13.5	449	00
2	07000*	0124*	5.3*	13.5*	496	16
2	07522	0128	5.6	13.4	501	30
2	07590	0140	6.8	13.0	518	48
A-14634 LEADED		FORD	H-DUTY	AMES		
1	02624	0300	0.4	14.1	541	72
1	03541	0150	2.0	13.5	536	90
1	03600*	0100*	1.6*	13.5*	529	38
1	03706	0050	1.1	13.5	514	33
1	04041	0045	1.0	13.5	496	21
1	04656	0138	3.4	13.5	482	16
1	05925	0158	3.1	13.6	463	00
1	06680*	0140*	2.3*	13.6*	503	30
1	06726	0125	1.4	13.6	508	43
1	07051	0080	1.4	13.5	520	49
2	02624	0035	0.6	14.0	541	72
2	03541	0050	0.6	14.0	536	90
2	03600*	0045*	0.6*	14.0*	529	38
2	03706	0040	0.5	14.0	514	33
2	04041	0020	0.4	14.0	496	21
2	04656	0050	1.2	14.1	482	16
2	05925	0045	0.9	14.0	463	00
2	06680*	0035*	0.8*	14.0*	503	30
2	06726	0025	0.6	14.0	508	43
2	07051	0030	0.7	14.0	520	49

FLEET DATA

SPEED	MILES	HC	CO	A/F	TEMP	HUMID
A-13093 UNLEADED		CHEVY L-DUTY		GRUNDY CENTER		
1	58773	0095	3.4	13.5	530	62
1	60090	0090	2.1	13.5	533	90
1	60743	0340	6.5	13.1	536	65
1	61032	0120	3.5	13.4	517	42
1	62990	0050	2.0	13.4	475	10
1	64012	0130	3.2	13.5	466	05
1	66307	0125	3.3	13.5	476	00
1	69397	0175	4.2	13.3	466	00
1	70833	0125	3.8	13.3	494	00
1	72242	0125	4.5	13.3	512	43
2	58773	0190	3.3	13.6	530	62
2	60090	0220	3.7	13.4	533	90
2	60743	0230	2.0	14.1	536	65
2	61032	0050	1.2	14.4	517	42
2	62990	0040	0.5	14.4	475	10
2	64012	0040	0.4	14.4	466	05
2	66307	0100	0.7	14.4	476	00
2	69397	0140	5.5	13.0	466	00
2	70833	0050	5.5	13.1	494	00
2	72242	0200	5.8	13.0	512	43
A-13870 UNLEADED		FORD L-DUTY		GRUNDY CENTER		
1	50502	0450	0.9	13.0	529	58
1	50676	1300	4.4	12.8	541	92
1	51597	1500	3.6	14.3	536	85
1	52688	1500	3.6	13.0	511	35
1	54321	0400	2.4	13.6	475	10
1	55971	0400	1.7	13.4	463	05
1	57789	0400	4.0	13.4	474	00
1	60350	0350	4.2	13.4	464	00
1	61701	0300	3.8	13.4	495	00
1	63605	1200	5.0	13.4	510	43
2	50502	0030	0.4	14.0	529	58
2	50676	0250	4.4	13.1	541	92
2	51597	0200	1.9	14.1	536	85
2	52688	0200	2.9	14.0	511	35
2	54321	0150	0.5	14.0	475	10
2	55971	0150	0.4	13.5	463	05
2	57789	0175	0.9	14.4	474	00
2	60350	0150	0.9	14.3	464	00
2	61701	0050	1.1	14.5	495	00
2	63605	0300	1.5	14.5	510	43

FLEET DATA

SPEED	MILES	HC	CO	A/F	TEMP	HUMID
A-14576 UNLEADED CHEVY L-DUTY GRUNDY CENTER						
1	22548	0050	0.4	13.9	529	63
1	23089	0045	1.2	13.9	536	90
1	23760	0060	1.2	14.1	536	85
1	24407	0060	1.3	13.9	511	35
1	25610	0040	0.5	13.6	475	10
1	27419	0050	1.1	13.7	466	05
1	29318	0055	1.3	13.7	479	00
1	32027	0050	1.4	13.7	464	00
1	34814	0080	2.1	13.7	488	00
1	35734	0050	1.6	13.7	510	40
2	22548	0020	0.3	14.4	529	63
2	23089	0020	0.3	14.2	536	90
2	23760	0040	0.4	14.3	536	85
2	24407	0040	0.3	14.1	511	35
2	25610	0020	0.3	13.9	475	10
2	27419	0030	0.2	14.1	466	05
2	29318	0035	0.3	14.1	479	00
2	32027	0040	0.3	14.0	464	00
2	34814	0020	0.4	14.2	480	00
2	35734	0030	0.4	14.5	510	40
A-15369 UNLEADED INT'L L-DUTY GRUNDY CENTER						
1	15217	0095	0.7	14.6	530	62
1	15711	0090	1.0	14.1	541	92
1	16324	0130	1.3	14.0	536	90
1	17095	0250	2.0	13.8	511	35
1	18424	0040	1.0	13.8	475	10
1	20169	0400	1.4	13.8	468	05
1	21498	0100	3.0	13.8	471	00
1	24301	0150	1.8	13.8	467	00
1	26587	0275	3.0	13.8	535	58
1	27486	0275	3.2	13.8	510	40
2	15217	0030	0.6	14.6	530	62
2	15711	0040	0.8	14.3	541	92
2	16324	0070	1.0	14.6	536	90
2	17095	0070	0.8	14.6	511	35
2	18424	0050	0.2	14.6	475	10
2	20169	0030	0.5	14.6	468	05
2	21498	0040	0.4	14.4	471	00
2	24301	0035	0.8	14.2	467	00
2	26587	0060	3.5	13.6	535	58
2	27486	0080	3.5	13.8	510	40

FLEET DATA

SPEED	MILES	HC	CO	A/F	TEMP	HUMID
A-13585 UNLEADED CHEVY L-DUTY SAC CITY						
1	57585	0200	2.3	13.6	528	74
1	58766	0170	4.0	13.2	539	85
1	60435	0180	4.9	13.0	522	42
1	60665	0150	4.2	13.0	513	35
1	62131	0050	0.9	13.6	591	15
1	64293	0160	3.8	13.6	589	18
1	66889	0190	3.3	13.6	453	00
1	69132	0125	4.0	13.6	504	27
1	70640	0200	3.1	13.6	502	27
1	71719	0150	3.4	13.6	504	30
2	57585	0250	7.5	11.8	528	74
2	58766	0160	2.8	13.7	539	85
2	60435	0090	2.8	13.7	522	42
2	60665	0080	2.7	13.8	513	35
2	62131	0050	1.0	14.3	591	15
2	64293	0050	1.8	14.3	589	18
2	66889	0150	2.3	14.0	453	00
2	69132	0100	0.6	14.4	504	27
2	70640	0150	2.6	13.8	502	27
2	71719	0080	2.0	13.9	504	30
A-14264 UNLEADED CHEVY L-DUTY SAC CITY						
1	28130	0140	2.1	13.9	536	56
1	29242	0150	1.1	13.8	536	85
1	30961	0160	3.6	13.1	522	46
1	31869	0150	3.4	13.1	518	34
1	33710	0100	3.4	13.1	492	14
1	35876	0120	3.0	13.8	489	24
1	37842	0110	2.6	13.8	457	00
1	39495	0120	3.5	13.8	504	21
1	04000*	0135*	2.4*	13.8*	535	76
1	40475	0150	1.3	13.8	510	36
2	28130	0060	1.8	14.0	536	56
2	29242	0060	2.6	13.8	536	85
2	30961	0040	3.1	13.7	522	46
2	31869	0050	2.0	13.7	518	34
2	33710	0040	1.4	13.7	492	14
2	35876	0040	1.9	14.0	489	24
2	37842	0050	1.8	14.1	457	00
2	39495	0040	3.0	13.7	504	21
2	04000*	0045*	2.0*	14.0*	535	76
2	40475	0050	0.9	14.2	510	36

FLEET DATA

SPEED	MILES	HC	CO	A/F	TEMP	HUMID
A-15317 UNLEACED INT'L L-DUTY SAC CITY						
1	08989	0300	1.6	13.8	536	58
1	09492	0160	1.6	13.6	538	82
1	10594	0250	2.6	13.6	522	46
1	11101	0150	2.3	13.6	522	38
1	12227	0130	2.4	13.6	491	23
1	13445	0150	2.6	13.6	492	16
1	01550	0200	3.8	13.6	504	24
1	17539	0225	3.4	13.6	504	24
1	18282	0225	3.1	13.6	515	49
1	18675	0225	3.1	13.6	505	28
2	08989	0060	0.7	14.4	536	58
2	09492	0050	0.6	14.4	538	82
2	10594	0040	2.0	13.7	522	46
2	11101	0040	0.4	14.4	522	38
2	12227	0040	0.3	14.4	491	23
2	13445	0035	0.4	14.5	492	16
2	01550	0040	0.4	14.6	504	24
2	17539	0050	0.7	14.4	504	24
2	18282	0050	0.7	14.6	515	49
2	18675	0040	0.8	14.4	505	28
A-14680 UNLEACED GMC L-DUTY SAC CITY						
1	21590	0190	1.5	13.9	533	70
1	23238	0110	1.3	13.5	539	75
1	25530	0110	3.2	13.6	522	42
1	26965	0060	1.8	13.6	515	32
1	29110	0060	1.6	13.6	491	15
1	31326	0080	2.9	13.6	489	18
1	33450	0080	3.0	13.6	453	00
1	35325	0100	3.2	13.6	498	20
1	37222	0095	3.0	13.6	530	50
1	38067	0120	3.0	13.6	510	36
2	21590	0060	0.9	14.4	533	70
2	23238	0100	1.2	14.1	539	75
2	25530	0020	1.1	14.5	522	42
2	26965	0020	0.6	14.5	515	32
2	29110	0020	0.6	14.5	491	15
2	31326	0020	0.7	14.5	489	18
2	33450	0030	0.5	14.5	453	00
2	35325	0040	0.8	14.5	498	20
2	37222	0040	0.9	14.5	530	50
2	38067	0050	1.0	14.0	510	36

FLEET DATA

SPEED	MILES	HC	CO	A/F	TEMP	HUMID
A-14692 LEADED		GMC	L-DUTY	DES MOINES		
1	13033	0180	1.8	13.8	536	62
1	13542	0100	1.5	13.7	540	00
1	15025	0260	5.4	13.4	526	51
1	15774	0060	1.4	13.4	511	22
1	16626	0040	0.7	13.7	488	20
1	17944	0050	1.5	13.7	490	20
1	18609	0100	3.4	13.7	451	00
1	21467	0050	2.3	13.7	496	16
1	22010	0125	3.5	13.7	506	30
1	22842	0070	1.8	13.7	514	47
2	13033	0060	0.6	14.3	536	62
2	13542	0080	0.8	14.2	540	00
2	15025	0040	0.8	14.4	526	51
2	15774	0040	0.5	14.2	511	22
2	16626	0010	0.3	14.4	488	20
2	17944	0040	0.3	14.2	490	20
2	18609	0035	0.3	14.1	451	00
2	21467	0030	0.3	14.0	496	16
2	22010	0030	0.3	14.2	506	30
2	22842	0030	0.3	14.1	514	47
A-14683 LEADED		GMC	L-DUTY	DES MOINES		
1	11541	0100	1.7	13.8	531	73
1	12265	0060	1.2	13.6	539	01
1	13095	0080	1.0	13.6	525	56
1	13817	0040	0.6	13.8	511	22
1	14963	0040	0.8	13.8	488	20
1	16179	0050	0.6	13.8	490	20
1	17537	0080	3.0	13.8	451	00
1	18700	0040	1.6	13.8	495	15
1	18979	0060	1.9	13.8	506	30
1	19690	0080	2.5	13.8	514	47
2	11541	0040	0.4	14.1	531	73
2	12265	0040	0.4	14.0	539	01
2	13095	0040	0.3	14.0	525	56
2	13817	0030	0.3	14.0	511	22
2	14963	0030	0.3	14.0	488	20
2	16179	0040	0.4	14.1	490	20
2	17537	0030	0.4	14.2	451	00
2	18700	0030	0.3	14.0	495	15
2	18979	0030	0.4	14.1	506	30
2	19690	0040	0.4	14.3	514	47

FLEET DATA

SPEED	MILES	HC	CO	A/F	TEMP	HUMID
A-14698 LEADED		GMC	L-DUTY	MARSHALLTOWN		
1	21843	0080	1.7	13.7	538	03
1	23148	0040	0.6	13.9	543	95
1	24727	0050	1.2	13.6	524	40
1	26088	0040	0.7	13.8	508	44
1	28264	0050	0.5	13.6	496	28
1	29923	0125	3.0	13.6	448	00
1	32220	0040	1.4	13.6	482	16
1	35022	0040	0.8	13.6	506	30
1	36247	0040	1.3	13.6	489	21
1	37334	0100	3.0	13.6	511	47
2	21843	0030	0.4	14.2	538	03
2	23148	0025	0.3	14.2	543	95
2	24727	0040	0.3	14.2	524	40
2	26088	0030	0.3	14.2	508	44
2	28264	0040	0.3	14.2	496	28
2	29923	0040	0.3	14.2	448	00
2	32220	0050	0.4	14.4	482	16
2	35022	0050	0.4	13.9	506	30
2	36247	0030	0.4	14.4	489	21
2	37334	0030	0.3	14.3	511	47
A-14691 LEADED		GMC	L-DUTY	MARSHALLTOWN		
1	14124	0110	2.1	14.1	538	03
1	14740	0040	0.3	13.8	543	95
1	16254	0050	2.0	13.6	525	40
1	17066	0050	0.8	13.8	508	44
1	18954	0040	0.7	13.9	496	28
1	20839	0110	2.2	13.9	448	00
1	22900	0100	1.2	13.9	483	16
1	25353	0100	1.5	13.9	496	23
1	26611	0040	1.1	13.9	488	21
1	27339	0060	2.4	13.9	511	47
2	14124	0080	0.5	14.1	538	03
2	14740	0025	1.3	14.2	543	95
2	16254	0030	0.3	14.2	525	40
2	17066	0035	0.4	14.4	508	44
2	18954	0040	0.3	14.2	496	28
2	20839	0040	0.3	14.2	448	00
2	22900	0050	0.3	14.2	483	16
2	25353	0040	0.5	14.2	496	23
2	26611	0025	0.2	14.2	488	21
2	27339	0030	0.3	14.3	511	47

FLEET DATA

SPEED	MILES	HC	CO	A/F	TEMP	HUMID
A-15278 LEADEC		INT'L L-DUTY AMES				
1	12452	0300	2.2	13.9	536	00
1	13343	0100	0.9	13.7	552	86
1	14965	0125	2.7	13.8	517	27
1	16392	0050	1.0	13.4	498	12
1	17642	0100	1.8	13.4	498	34
1	19021	0225	4.5	13.4	482	16
1	20781	0280	4.5	13.4	463	00
1	22001	0225	3.8	13.4	506	30
1	22766	0175	4.0	13.4	508	43
1	23685	0140	4.5	13.4	511	54
2	12452	0045	0.8	14.8	536	00
2	13343	0045	0.5	14.2	552	86
2	14965	0040	0.7	14.0	517	27
2	16392	0040	0.3	14.6	498	12
2	17642	0040	0.3	14.6	498	34
2	19021	0040	0.4	14.7	482	16
2	20781	0100	0.4	15.0	463	00
2	22001	0045	0.8	14.6	506	30
2	22766	0050	0.6	14.7	508	43
2	23685	0050	1.4	14.7	511	54
A-15279 LEADED		INT'L L-DUTY AMES				
1	09466	0280	3.4	13.3	538	98
1	10000*	0228*	3.2*	13.4*	536	90
1	11769	0175	3.0	13.5	529	34
1	12696	0080	1.1	13.5	498	14
1	13837	0060	1.9	13.5	494	28
1	15447	0225	4.3	13.5	481	13
1	15800	0180	5.5	13.5	469	05
1	19481	0225	4.0	13.5	504	30
1	20622	0180	3.0	13.5	514	47
1	21409	0185	4.3	13.6	519	58
2	09466	0060	0.9	14.4	538	98
2	10000*	0050*	0.8*	14.4*	536	90
2	11769	0040	0.6	14.4	529	34
2	12696	0040	0.3	14.4	498	14
2	13837	0030	0.2	14.6	494	28
2	15447	0045	1.0	14.9	481	13
2	15800	0010	0.6	14.8	469	05
2	19481	0040	0.8	14.7	504	30
2	20622	0050	0.9	14.4	514	47
2	21409	0020	0.9	14.5	519	58

FLEET DATA

SPEED	MILES	HC	CO	A/F	TEMP	HUMID
A-14575 LEADED		CHEVY L-DUTY AMES				
1	21350	0050	1.5	13.8	542	80
1	22890	0050	0.9	13.5	541	98
1	24618	0040	1.8	13.9	529	38
1	26472	0040	0.7	13.9	513	22
1	28572	0040	0.7	13.9	496	21
1	31010	0050	2.0	13.9	448	00
1	33344	0020	1.1	13.9	463	00
1	36235	0050	2.0	13.9	503	30
1	38200	0040	0.9	13.9	515	47
1	38954	0100	2.2	13.9	520	58
2	21350	0035	0.3	14.0	542	80
2	22890	0040	0.3	13.9	541	98
2	24618	0020	0.3	14.4	529	38
2	26472	0020	0.2	14.2	513	22
2	28572	0020	0.2	14.3	496	21
2	31010	0020	0.2	14.6	448	00
2	33344	0020	0.2	14.4	463	00
2	36235	0035	0.2	14.3	503	30
2	38200	0025	0.3	14.2	515	47
2	38954	0025	0.3	14.1	520	58
A-15414 LEADED		INT'L L-DUTY AMES				
1	03200	0210	0.8	14.1	547	00
1	05101	0100	1.1	13.8	533	90
1	06981	0180	2.5	13.5	529	38
1	07246	0080	1.3	13.5	498	25
1	08990	0080	1.5	13.5	500	33
1	11896	0200	3.3	13.5	480	10
1	15126	0260	4.8	13.5	470	05
1	18184	0200	2.0	13.5	504	29
1	19018	0200	3.5	13.5	513	47
1	19966	0200	3.0	13.5	518	52
2	03200	0040	0.8	14.2	547	00
2	05101	0030	0.7	14.4	533	90
2	06981	0040	0.6	14.3	529	38
2	07246	0040	0.3	14.3	498	25
2	08990	0020	0.2	14.3	500	33
2	11896	0040	0.3	14.4	480	10
2	15126	0060	0.6	14.9	470	05
2	18184	0050	0.5	14.7	504	29
2	19018	0040	0.7	14.8	513	47
2	19966	0050	0.8	14.7	518	52

FLEET DATA

SPEED	MILES	HC	CO	A/F	TEMP	HUMID
A-15454 LEADED		INT'L L-DUTY AMES				
1	02454	0220	2.6	13.6	547	94
1	04932	0200	1.4	13.8	553	90
1	06725	0200	3.0	13.5	528	40
1	07440	0080	1.0	13.2	495	27
1	08561	0100	2.5	13.2	498	34
1	10871	0275	2.8	13.2	480	10
1	13137	0300	6.0	13.2	471	05
1	14886	0200	3.0	13.2	501	29
1	15098	0260	5.0	13.2	513	47
1	15979	0240	5.4	13.2	514	51
2	02454	0080	1.0	14.0	547	94
2	04932	0080	1.0	14.0	553	90
2	06725	0060	0.8	13.6	528	40
2	07440	0040	0.3	14.4	495	27
2	08561	0030	0.2	14.8	498	34
2	10871	0050	0.6	14.5	480	10
2	13137	0080	0.5	14.9	471	05
2	14886	0050	0.6	14.5	501	29
2	15098	0080	0.8	14.6	513	47
2	15979	0050	0.7	14.8	514	51
A-14269 LEADED		CHEVY L-DUTY AMES				
1	14260	0140	0.7	14.4	540	00
1	14847	0050	1.6	13.6	540	94
1	15639	0190	3.0	13.6	529	38
1	16261	0090	2.4	13.6	508	33
1	17500	0050	0.8	13.6	498	30
1	18869	0150	3.8	13.6	482	16
1	19430	0100	3.4	13.7	463	00
1	21434	0190	3.4	13.6	503	32
1	21723	0110	2.5	13.6	507	43
1	22480	0140	3.0	13.6	511	56
2	14260	0040	1.0	14.3	540	00
2	14847	0040	1.8	14.1	540	94
2	15639	0075	0.9	14.2	529	38
2	16261	0040	0.7	14.2	508	33
2	17500	0020	0.7	14.4	498	30
2	18869	0040	1.8	14.2	482	16
2	19430	0075	0.8	12.0	463	00
2	21434	0040	2.0	14.0	503	32
2	21723	0045	2.6	13.9	507	43
2	22480	0045	2.2	14.0	511	56

FLEET DATA

SPEED	MILES	HC	CO	A/F	TEMP	HUMID
A-14602 LEADED		CHEVY L-DUTY AMES				
1	05000	0100	0.5	13.8	549	96
1	07201	0050	0.6	13.8	544	10
1	07226	0050	1.5	13.8	528	32
1	07235*	0045*	1.0*	13.8*	486	25
1	07282	0040	0.6	13.8	494	26
1	07361	0045	3.0	13.8	482	10
1	07373	0110	2.5	13.8	478	13
1	07422	0100	1.5	13.8	505	28
1	07433	0100	1.7	13.8	515	53
1	07446	0080	2.1	13.8	511	52
2	05000	0040	0.2	14.1	549	96
2	07201	0040	0.3	14.0	544	10
2	07226	0040	0.5	14.2	528	32
2	07235*	0035*	0.4*	14.2*	486	25
2	07282	0030	0.3	14.4	494	26
2	07361	0030	0.3	14.3	482	10
2	07373	0030	0.4	14.3	478	13
2	07422	0035	0.4	14.3	505	28
2	07433	0040	0.4	14.0	515	53
2	07446	0040	0.4	14.4	511	52
A-14342 UNLEADED		CHEVY PICKUP	GRUNDY CENTER			
1	28245	0060	0.7	15.2	531	60
1	29088	0070	1.3	13.9	535	86
1	30109	0100	1.3	13.8	536	85
1	30845	0100	1.3	13.8	517	42
1	31939	0050	0.8	13.8	475	10
1	32776	0050	0.5	13.8	462	05
1	34235	0060	1.1	13.8	484	00
1	34837	0050	1.8	13.8	464	00
1	35786	0080	2.0	13.8	485	00
1	36705	0050	2.0	13.8	510	40
2	28245	0060	0.3	15.1	531	60
2	29088	0045	0.5	14.1	535	86
2	30109	0040	0.3	14.0	536	85
2	30845	0040	0.2	14.0	517	42
2	31939	0040	0.2	14.0	475	10
2	32776	0040	1.5	14.0	462	05
2	34235	0040	0.2	14.1	484	00
2	34837	0030	0.2	14.0	464	00
2	35786	0030	0.3	13.8	485	00
2	36705	0020	0.4	14.1	510	40

FLEET DATA

SPEED	MILES	HC	CO	A/F	TEMP	HUMID
A-14343 UNLEADED CHEVY PICKUP GRUNDY CENTER						
1	49138	0080	1.4	14.6	530	62
1	50606	0080	1.7	13.8	532	86
1	52182	0110	2.4	13.6	536	90
1	53167	0080	2.2	13.6	517	42
1	54400	0040	1.5	13.6	475	10
1	56058	0050	1.6	13.7	463	05
1	57434	0080	2.6	13.7	486	00
1	58677	0050	2.0	13.7	464	00
1	60508	0075	1.6	13.7	485	00
1	61300	0080	2.0	13.7	512	43
2	49138	0050	0.3	15.2	530	62
2	50606	0050	0.6	14.2	532	86
2	52182	0060	0.4	14.0	536	90
2	53167	0060	0.4	14.0	517	42
2	54400	0060	0.4	14.0	475	10
2	56058	0060	0.3	14.0	463	05
2	57434	0040	0.4	14.1	486	00
2	58677	0060	0.3	14.0	464	00
2	60508	0060	0.4	13.8	485	00
2	61300	0050	0.4	14.1	512	43
A-15896 UNLEADED DODGE PICKUP SAC CITY						
1	02748	0080	0.2	14.5	537	59
1	03918	0050	0.1	14.4	547	94
1	05023	0040	0.6	13.6	522	46
1	06157	0060	0.8	14.3	522	58
1	07776	0040	0.8	14.3	492	14
1	09829	0060	0.4	14.3	496	20
1	11450	0080	1.5	14.3	451	00
1	12999	0090	1.4	14.3	504	26
1	15187	0100	1.2	14.3	530	36
1	16113	0060	0.9	14.3	504	27
2	02748	0070	0.2	14.6	537	59
2	03918	0050	0.2	14.5	547	94
2	05023	0010	0.2	14.8	522	46
2	06157	0010	0.1	14.6	522	58
2	07776	0010	0.2	14.8	492	14
2	09829	0010	1.5	14.3	496	20
2	11450	0020	0.5	14.3	451	00
2	12999	0020	0.2	14.6	504	26
2	15187	0030	0.2	14.5	530	36
2	16113	0040	1.8	14.0	504	27

FLEET DATA

SPEED	MILES	HC	CO	A/F	TEMP	HUMID
A-14370 LEADED		CHEVY PICKUP AMES				
1	11441	0090	1.4	13.7	548	98
1	13138	0060	1.1	13.8	552	86
1	15040	0080	1.0	13.9	518	41
1	15887	0050	0.6	13.9	511	32
1	16298	0030	0.7	13.9	497	30
1	16400	0040	1.1	13.9	480	10
1	16880	0020	1.3	14.0	470	00
1	16924	0020	1.0	14.0	504	29
1	16925	0045	1.1	13.9	513	47
1	17103	0045	1.2	13.9	518	52
2	11441	0160	0.2	13.8	548	98
2	13138	0100	0.3	13.9	552	86
2	15040	0090	0.2	14.0	518	41
2	15887	0080	0.2	14.0	511	32
2	16298	0050	0.3	14.0	497	30
2	16400	0050	0.3	13.9	480	10
2	16880	0040	0.3	14.0	470	00
2	16924	0040	0.3	14.0	504	29
2	16925	0050	0.3	13.9	513	47
2	17103	0040	0.3	14.0	518	52
A-14368 LEADED		CHEVY PICKUP AMES				
1	12945	0090	1.2	13.9	536	00
1	15061	0090	1.4	13.8	537	83
1	17380	0070	1.8	13.8	513	40
1	19308	0040	0.4	13.9	508	33
1	20527	0040	0.9	13.9	498	34
1	20606	0080	0.9	13.9	482	13
1	20607	0040	1.1	13.9	463	00
1	20733	0050	0.9	13.9	504	40
1	21758	0075	1.0	13.9	513	50
1	22472	0050	1.2	13.9	518	52
2	12945	0080	0.2	13.9	536	00
2	15061	0080	0.3	14.0	537	83
2	17380	0050	0.2	14.2	513	40
2	19308	0060	0.2	14.0	508	33
2	20527	0050	0.2	14.3	498	34
2	20606	0050	0.2	13.9	482	13
2	20607	0060	0.2	14.2	463	00
2	20733	0060	0.2	14.1	504	40
2	21758	0050	0.2	13.9	513	50
2	22472	0100	0.2	14.0	518	52

FLEET DATA

SPEED	MILES	HC	CO	A/F	TEMP	HUMID
A-14367 LEADED		CHEVY PICKUP AMES				
1	16368	0090	1.6	13.8	549	98
1	17386	0080	1.1	13.7	537	83
1	19244	0050	1.2	13.9	528	32
1	20811	0040	0.9	13.9	514	33
1	21949	0040	0.9	13.9	495	27
1	22305	0045	1.4	13.9	482	08
1	22306	0050	1.5	13.9	482	13
1	22318	0045	1.2	13.7	503	32
1	22477	0085	1.4	13.9	535	50
1	22601	0050	1.6	13.9	520	60
2	16368	0090	0.2	13.8	549	98
2	17386	0060	0.2	14.0	537	83
2	19244	0040	0.2	14.0	528	32
2	20811	0060	0.2	14.0	514	33
2	21949	0045	0.2	14.0	495	27
2	22305	0045	0.2	14.0	482	08
2	22306	0045	0.2	14.0	482	13
2	22318	0050	0.2	14.0	503	32
2	22477	0045	0.2	13.9	535	50
2	22601	0050	0.2	13.9	520	60
A-14369 LEADED		CHEVY PICKUP AMES				
1	16819	0080	1.6	13.8	540	00
1	17954	0080	1.5	13.7	540	94
1	18826	0060	1.8	13.5	528	40
1	19671	0050	0.9	13.9	508	33
1	20374	0020	0.8	13.9	494	28
1	20717	0040	1.3	13.9	483	12
1	21108	0040	1.3	14.0	463	00
1	21692	0040	1.3	13.9	503	29
1	21693	0080	1.8	13.9	513	47
1	22953	0050	1.5	13.9	518	52
2	16819	0120	0.2	13.9	540	00
2	17954	0100	0.3	13.8	540	94
2	18826	0040	0.2	14.0	528	40
2	19671	0050	0.2	14.0	508	33
2	20374	0040	0.2	14.0	494	28
2	20717	0070	0.2	13.9	483	12
2	21108	0080	0.1	14.0	463	00
2	21692	0090	0.2	13.9	503	29
2	21693	0090	0.3	14.0	513	47
2	22953	0040	0.2	14.1	518	52

FLEET DATA

SPEED	MILES	HC	CO	A/F	TEMP	HUMID
A-11504 UNLEADED CASE TRACTOR GRUNDY CENTER						
1	00054	0210	3.2	13.7	532	62
1	00059	0140	1.1	13.9	537	88
1	00096	0240	4.0	13.5	536	65
1	00126	0240	2.7	13.5	517	42
1	00160	0200	2.3	13.5	475	10
1	00169	0200	3.4	13.5	467	05
1	00220	0300	5.0	13.5	480	00
1	00245	0225	5.9	13.5	466	00
1	00266	0300	3.8	13.5	494	00
1	00312	0175	3.5	13.8	510	40
2	00054	0105	3.0	13.7	532	62
2	00059	0030	0.2	13.6	537	88
2	00096	0180	4.8	13.3	536	65
2	00126	0140	3.0	13.3	517	42
2	00160	0075	2.8	13.3	475	10
2	00169	0090	2.9	13.3	467	05
2	00220	0150	4.5	13.5	488	00
2	00245	0160	4.5	13.1	466	00
2	00266	0175	5.0	13.1	494	00
2	00312	0050	2.4	14.0	510	40
A-13634 UNLEADED J.D. TRACTOR GRUNDY CENTER						
1	00437	0190	2.5	13.8	532	58
1	00450*	0195*	2.8*	13.7*	536	87
1	00475	0200	3.0	13.6	537	88
1	00480*	0180*	2.7*	13.6*	517	42
1	00480*	0180*	2.7*	13.6*	475	10
1	00487	0160	2.3	13.6	466	05
1	00491	0190	3.0	13.6	488	00
1	00492	0160	3.3	13.6	466	00
1	00495	0175	3.4	13.6	490	00
1	00500	0140	3.2	13.6	512	43
2	00437	0175	5.6	12.9	532	58
2	00450*	0100*	4.8*	13.2*	536	87
2	00475	0120	4.0	13.5	537	88
2	00480*	0115*	4.4*	13.5*	517	42
2	00480*	0115*	4.4*	13.5*	475	10
2	00487	0110	4.8	13.5	466	05
2	00491	0175	4.3	13.4	488	00
2	00492	0140	4.0	13.3	466	00
2	00495	0130	4.4	13.4	490	00
2	00500	0140	4.0	13.7	512	43

FLEET DATA

SPEED	MILES	HC	CO	A/F	TEMP	HUMID
A-13662 UNLEADED INT'L TRACTOR GRUNDY CENTER						
1	00579	0380	3.2	13.3	532	58
1	00580*	0440*	3.6*	13.3*	536	87
1	00592	0500	4.0	13.3	537	88
1	00595*	0365*	3.8*	13.5*	517	42
1	00595*	0365*	3.8*	13.5*	475	10
1	00600	0225	3.5	13.8	467	05
1	00603	0250	1.6	13.8	488	00
1	00603	0250	1.2	13.8	467	00
1	00605	0225	1.4	13.8	493	00
1	00611	0250	1.5	13.8	512	43
2	00579	0110	4.6	13.3	532	58
2	00580*	0135*	4.6*	13.3*	536	87
2	00592	0160	4.6	13.3	537	88
2	00595*	0125*	3.4*	13.4*	517	42
2	00595*	0125*	3.4*	13.4*	475	10
2	00600	0090	2.2	13.4	467	05
2	00603	0125	3.4	13.7	488	00
2	00603	0100	2.7	13.6	467	00
2	00605	0100	3.5	13.7	493	00
2	00611	0125	3.8	13.7	512	43
A-15555 UNLEADED J.D. TRACTOR GRUNDY CENTER						
1	00282	0180	4.5	13.3	532	63
1	00320*	0190*	4.5*	13.4*	536	87
1	00367	0200	4.5	13.5	536	85
1	00370*	0175*	4.3*	13.5*	517	42
1	00375*	0175*	4.3*	13.5*	475	10
1	00380*	0175*	4.3*	13.5*	462	05
1	00385	0150	4.0	13.5	486	00
1	00386	0175	4.8	13.5	466	00
1	00387	0175	3.5	13.5	490	00
1	00404	0140	3.8	13.6	512	43
2	00282	0140	5.8	12.9	532	63
2	00320*	0140*	5.5*	13.2*	536	87
2	00367	0140	5.1	13.3	536	85
2	00370*	0158*	4.0*	13.4*	517	42
2	00375*	0158*	4.0*	13.4*	475	10
2	00380*	0158*	4.0*	13.4*	462	05
2	00385	0175	3.0	13.5	486	00
2	00386	0100	3.4	13.6	466	00
2	00387	0075	1.8	14.1	490	00
2	00404	0080	2.9	14.1	512	43

FLEET DATA

A-12732 UNLEADED FORD TRACTOR GRUNDY CENTER

SPEED	MILES	HC	CO	A/F	TEMP	HUMID
1	00740	0500	4.0	13.4	532	63
1	00765*	0560*	4.4*	13.3*	536	87
1	00793	0620	4.8	13.2	537	88
1	00806	0260	3.2	13.2	517	42
1	00815*	0317*	3.5*	13.2*	475	10
1	00825	0375	3.8	13.1	467	05
1	00830	0325	3.5	13.1	488	00
1	00831	0320	3.7	13.1	466	00
1	00834	0330	4.0	13.1	490	00
1	00853	0400	5.5	13.1	512	43
2	00740	0175	3.6	13.5	532	63
2	00765*	0162*	3.9*	13.4*	536	87
2	00793	0150	4.2	13.2	537	88
2	00806	0160	2.7	13.5	517	42
2	00815*	0140*	2.2*	13.7*	475	10
2	00825	0120	1.7	13.9	467	05
2	00830	0140	3.3	13.8	488	00
2	00831	0145	2.7	13.7	466	00
2	00834	0200	3.2	13.6	490	00
2	00853	0150	3.8	13.6	512	43

A-12698 UNLEADED MAS FERG TRACTOR SAC CITY

SPEED	MILES	HC	CO	A/F	TEMP	HUMID
1	00315	0800	4.0	13.0	537	59
1	00315*	0775*	4.4*	13.1*	544	93
1	00315	0750	4.8	13.2	525	44
1	00318	0380	4.5	13.2	510	33
1	00318*	0425*	4.4*	13.2*	491	26
1	00319	0475	4.2	13.2	490	17
1	00320	0350	2.7	13.2	455	00
1	00321	0450	4.5	13.2	505	23
1	00323	0350	4.5	13.2	502	27
1	00325*	0350*	4.5*	13.2*	510	36
2	00315	0180	4.2	13.0	537	59
2	00315*	0145*	3.8*	13.3*	544	93
2	00315	0110	3.3	13.6	525	44
2	00318	0060	1.8	13.8	510	33
2	00318*	0070*	2.5*	13.8*	491	26
2	00319	0080	3.2	13.7	490	17
2	00320	0050	1.5	13.9	455	00
2	00321	0090	3.0	13.7	505	23
2	00323	0090	2.3	13.8	502	27
2	00325*	0090*	2.3*	13.8*	510	36

FLEET DATA

SPEED	MILES	HC	CO	A/F	TEMP	HUMID
A-11028 UNLEADED INT'L TRACTOR SAC CITY						
1	01056	0320	1.9	13.3	533	70
1	01061	0160	1.0	13.4	545	86
1	01096	0500	6.5	13.3	522	46
1	01101	0300	3.0	13.4	517	32
1	01101*	0285*	3.5*	13.4*	491	26
1	01102	0270	4.0	13.4	490	17
1	01102	0125	1.4	13.4	454	00
1	01105	0300	2.5	13.4	504	24
1	01107	0300	3.1	13.4	502	27
1	01108	0300	5.5	13.3	505	28
2	01056	0190	5.4	13.0	533	70
2	01061	0140	4.5	12.9	545	86
2	01096	0180	7.5	12.9	522	46
2	01101	0180	6.0	13.0	517	32
2	01101*	0170*	5.8*	13.2*	491	26
2	01102	0160	5.5	13.3	490	17
2	01102	0100	2.4	13.3	454	00
2	01105	0180	5.5	13.3	504	24
2	01107	0170	5.3	13.2	502	27
2	01108	0180	5.0	13.1	505	28
A-15564 UNLEADED INT'L TRACTOR SAC CITY						
1	00380	0250	0.5	14.0	534	73
1	00389	0220	1.6	13.5	540	89
1	00499	0350	7.5	12.5	525	45
1	00509	0440	6.6	13.2	515	32
1	00527	0200	4.0	12.6	491	26
1	00570	0450	3.8	13.4	489	24
1	00601	0425	4.3	13.4	455	00
1	00606	0450	3.5	13.4	506	27
1	00613	0450	4.8	13.4	502	27
1	00630	0340	3.3	13.4	510	36
2	00380	0175	2.5	13.6	534	73
2	00389	0150	2.8	13.6	540	89
2	00499	0160	7.6	13.7	525	45
2	00509	0160	2.1	13.6	515	32
2	00527	0080	0.7	13.8	491	26
2	00570	0180	2.6	14.0	489	24
2	00601	0195	2.0	14.1	455	00
2	00606	0200	2.0	14.1	506	27
2	00613	0150	1.6	14.3	502	27
2	00630	0125	1.8	14.0	510	36

FLEET DATA

SPEED	MILES	HC	CO	A/F	TEMP	HUMID
A-13693 LEADED		J DEERE	TRACTOR	MARSHALLTOWN		
1	00588	0220	1.4	13.6	539	01
1	00614	0200	1.5	13.8	538	92
1	00626	0200	1.6	13.8	525	41
1	00634	0060	0.5	13.8	508	44
1	00636	0075	0.6	13.8	496	28
1	00637	0225	1.0	13.8	448	00
1	00652	0220	1.5	13.8	482	15
1	00661	0200	2.4	13.8	496	24
1	00667	0175	3.1	13.8	488	21
1	00669	0160	1.8	13.8	511	47
2	00588	0080	1.7	13.8	539	01
2	00614	0100	1.7	14.1	538	92
2	00626	0125	3.0	13.9	525	41
2	00634	0060	1.4	13.9	508	44
2	00636	0050	1.0	13.9	496	28
2	00637	0075	1.1	14.5	448	00
2	00652	0060	1.2	14.6	482	15
2	00661	0050	1.4	14.5	496	24
2	00667	0070	1.8	14.4	488	21
2	00669	0090	1.9	14.2	511	47
A-13668 LEADED		INT'L	TRACTOR	AMES		
1	00135	0700	2.5	13.1	542	02
1	00136*	0412*	2.0*	13.1 *	536	90
1	00137*	0412*	2.0*	13.1 *	529	38
1	00138*	0412*	2.0*	13.1 *	514	33
1	00138	0125	1.4	13.1	497	30
1	00141	0250	3.4	13.1	480	13
1	00141	0250	4.5	13.1	482	16
1	00143	0325	4.5	13.1	502	31
1	00145	0300	5.0	13.1	513	49
1	00146	0300	5.0	13.1	518	52
2	00135	0150	4.9	12.7	542	02
2	00136*	0125*	4.4 *	12.7 *	536	90
2	00137*	0125*	4.4 *	12.7 *	529	38
2	00138*	0125*	4.4 *	12.7 *	514	33
2	00138	0100	3.8	12.7	497	30
2	00141	0150	5.5	13.1	480	13
2	00141	0150	6.0	13.0	482	16
2	00143	0105	4.5	13.0	502	31
2	00145	0110	5.5	13.0	513	49
2	00146	0080	4.3	13.3	518	52

FLEET DATA

SPEED	MILES	HC	CO	A/F	TEMP	HUMID
A-13669 LEADED		INT'L	TRACTOR AMES			
1	00317	0340	0.9	14.0	541	04
1	00320*	0320*	1.6*	13.9*	536	90
1	00323	0300	2.3	13.7	529	36
1	00330*	0175*	2.0*	13.7*	514	33
1	00337	0050	0.6	13.7	497	30
1	00338	0175	3.0	13.7	480	13
1	00339	0225	3.5	13.7	482	15
1	00348	0175	2.5	13.4	502	36
1	00350	0225	3.7	13.4	513	49
1	00351	0225	2.2	13.4	536	75
2	00317	0090	2.6	13.5	541	04
2	00320*	0095*	3.3*	13.5*	536	90
2	00323	0100	4.0	13.5	529	36
2	00330*	0075*	2.5*	13.8*	514	33
2	00337	0040	1.0	14.0	497	30
2	00338	0080	3.0	13.9	480	13
2	00339	0100	2.0	14.3	482	15
2	00348	0080	2.3	13.6	502	36
2	00350	0150	3.8	13.5	513	49
2	00351	0050	2.0	13.9	536	75
A-13696 LEADED		MAS FERG	TRACTOR AMES			
1	01112	0125	0.5	14.0	547	06
1	01170	0125	0.5	13.4	533	90
1	01255	0200	0.4	13.5	521	40
1	01258	0050	0.8	13.5	504	30
1	01259	0050	1.3	13.5	496	28
1	01260 *	0050 *	1.3*	13.5*	482	16
1	01265 *	0112 *	1.8*	13.9*	463	00
1	01270 *	0175 *	2.2*	13.8*	503	30
1	01276	0175	2.2	13.8	508	43
1	01277	0150	2.6	13.8	520	49
2	01112	0106	3.5	13.0	547	06
2	01170	0100	3.5	13.6	533	90
2	01255	0125	4.0	13.7	521	40
2	01258	0060	1.9	13.7	504	30
2	01259	0060	1.4	13.7	496	28
2	01260 *	0055 *	1.4*	13.7*	482	16
2	01265 *	0055 *	1.6*	14.0*	463	00
2	01270 *	0055 *	1.8*	14.4*	503	30
2	01276	0050	1.8	14.4	508	43
2	01277	0060	2.3	13.9	520	49

FLEET DATA

SPEED	MILES	HC	CO	A/F	TEMP	HUMID
A-15098 LEADED		CHEVY	WAGON	AMES		
1	16925	0100	0.4	14.6	538	98
1	17724	0080	0.2	14.5	543	06
1	19418	0200	2.0	14.2	518	34
1	20141	0080	0.9	14.0	515	22
1	22384	0050	1.0	14.0	496	21
1	24000*	0070*	1.5*	14.0*	482	16
1	26512	0090	2.0	14.0	480	16
1	28438	0080	1.5	14.0	503	32
1	28736	0090	1.8	14.0	520	56
1	29737	0110	2.8	14.0	511	56
2	16925	0080	2.8	13.6	538	98
2	17724	0080	3.0	13.5	543	06
2	19418	0175	3.0	13.7	518	34
2	20141	0040	1.0	13.8	515	22
2	22384	0040	1.2	14.6	496	21
2	24000*	0040*	1.8*	14.3*	482	16
2	26512	0040	2.5	13.9	480	16
2	28438	0050	2.8	14.2	503	32
2	28736	0050	2.8	13.8	520	56
2	29737	0050	2.8	13.8	511	56
A-14910 LEADED		PLYMOUTH	PASS CAR	AMES		
1	33000*	0050*	0.3*	14.4*	538	98
1	35000*	0100*	2.2*	14.4*	544	06
1	37618	0080	1.4	14.4	518	40
1	40386	0080	0.2	14.4	498	20
1	42000*	0080*	1.3*	14.4*	482	16
1	45000*	0080*	1.3*	14.4*	480	16
1	46171	0080	1.3	14.4	471	00
1	48376	0100	1.3	14.4	503	32
1	51550	0110	1.2	14.4	507	44
1	53724	0200	1.3	14.4	511	52
2	33000*	0050*	0.4*	14.7*	538	98
2	35000*	0040*	0.3*	14.7*	544	06
2	37618	0020	0.3	14.9	518	40
2	40386	0060	0.1	14.4	498	20
2	42000*	0050*	0.2*	14.6*	482	16
2	45000*	0050*	0.2*	14.6*	480	16
2	46171	0040	0.2	14.7	471	00
2	48376	0040	0.2	14.6	503	32
2	51550	0020	0.2	14.7	507	44
2	53724	0040	0.3	14.8	511	52

FLEET DATA

SPEED	MILES	HC	CO	A/F	TEMP	HUMID
A-14543 LEADED		CHEVY L-DUTY	AMES			
1	10777	0100	1.5	13.8	544	50
1	12223	0050	0.7	13.9	532	91
1	13503	0050	1.2	13.5	528	30
1	13646	0050	1.2	13.7	498	28
1			.	.		
1			.	.		
1			.	.		
1			.	.		
1			.	.		
1	18800	0040	1.4	13.7	517	53
2	10777	0025	0.3	14.2	544	50
2	12223	0025	0.3	14.2	532	91
2	13503	0040	0.5	13.6	528	30
2	13646	0020	0.3	14.2	498	28
2			.	.		
2			.	.		
2			.	.		
2			.	.		
2			.	.		
2	18800	0020	0.3	14.3	517	53
A-15880 LEADED		DODGE PICKUP	DES MOINES			
1	08043	0040	0.2	14.8	510	21
1	10965	0030	0.4	14.8	488	20
1	12480	0040	0.7	14.8	491	18
1	15068	0040	0.7	14.8	450	00
1	17601	0060	0.8	14.8	493	15
1	18912	0070	0.2	14.8	530	36
1	20381	0060	0.2	14.8	508	40
2	08043	0030	0.2	14.6	510	21
2	10965	0020	0.2	14.6	488	20
2	12480	0030	0.4	14.6	491	18
2	15068	0030	0.3	14.9	450	00
2	17601	0030	0.3	14.6	493	15
2	18912	0030	0.3	14.5	530	36
2	20381	0030	0.3	14.8	508	40

FLEET DATA

SPEED	MILES	HC	CO	A/F	TEMP	HUMID
A-12232 UNLEADED FORD PICKUP SAC CITY						
1	55397	0140	2.2	00.2	527	62
1	56750	0130	2.6	13.2	545	92
1	58205	0150	3.7	13.7	522	42
1	59394	0150	2.2	13.7	517	32
1	60155	0075	3.7	13.7	491	13
2	55397	0120	3.6	13.6	527	62
2	56750	0130	3.0	13.4	545	92
2	58205	0150	4.1	13.6	522	42
2	59394	0110	2.5	13.6	517	32
2	60155	0120	1.8	13.4	491	13
A-15943 UNLEADED DODGE PICKUP SAC CITY						
1	00305	0050	0.7	14.1	493	17
1	01464	0090	1.5	14.1	455	00
1	02214	0100	1.6	14.1	504	21
1	03402	0200	2.0	14.1	541	62
1	04266	0180	2.0	14.0	512	44
2	00305	0020	0.2	14.5	493	17
2	01464	0030	0.2	14.6	455	00
2	02214	0020	1.5	14.6	504	21
2	03402	0020	0.2	14.6	541	62
2	04266	0040	0.2	14.8	512	44

FLEET DATA

SPEED	MILES	HC	CO	A/F	TEMP	HUMID
A-14941 LEADED		PLYMOUTH	PASS CAR	AMES		
1	29588	0040	0.2	14.4	507	19
1	32021	0050	0.9	14.4	496	31
1	35967	0040	0.3	14.4	469	00
1	38712	0060	0.8	14.7	480	15
1	40910	0050	1.0	14.5	503	32
1	43701	0110	0.7	14.5	525	78
1	45196	0080	0.6	14.5	539	36
2	29588	0050	0.2	14.8	507	19
2	32021	0050	0.2	14.8	496	31
2	35967	0010	0.2	14.8	469	00
2	C8712	0010	0.3	14.7	480	15
2	40910	0020	0.3	14.7	503	32
2	43701	0040	0.3	14.6	525	78
2	45196	0060	0.3	14.6	539	36
A-15192 LEADED		FORD	PICKUP	AMES		
1	34715	0100	1.1	13.5	495	27
1	36000*	0350*	2.8*	13.5*	482	16
1	38543	0600	4.5	13.5	478	13
1	41278	0400	4.2	13.5	506	30
1	43066	0800	4.0	13.5	517	57
1	43900	0700	3.8	13.5	511	56
2	34715	0040	0.3	14.8	495	27
2	36000*	0100*	0.4*	14.7*	482	16
2	38543	1300	0.4	14.6	478	13
2	41278	0180	0.4	14.2	506	30
2	43066	0060	0.4	14.4	517	57
2	43900	0090	0.3	14.6	511	56

FLEET DATA

SPEED	MILES	HC	CO	A/F	TEMP	HUMID
A-15415 UNLEADED INT'L L-DUTY GRUNDY CENTER						
1	12059	0060	0.4	13.6	500	30
1	13576	0200	3.0	13.6	480	13
1	15001	0200	3.5	13.6	471	05
1	16407	0200	2.4	13.6	505	28
1	17012	0120	2.8	13.6	540	64
1	17857	0150	3.2	13.6	515	56
2	12059	0020	0.2	14.4	500	30
2	13576	0040	1.3	14.3	480	13
2	15001	0040	1.3	14.3	471	05
2	16407	0060	1.8	14.3	505	28
2	17012	0045	0.9	14.2	540	64
2	17857	0050	1.7	14.5	515	56

APPENDIX B

SPECIAL FLEET DATA

Nomenclature

SPEED

1 → Idle

2 → 2500 rpm

HC1 → Paraffin fraction of HCT

HC2 → Aromatic fraction of HCT

HC3 → Olefin fraction of HCT

HCT → Total unburned hydrocarbon in parts per million by flame ionization detector (FID)

HC → Unburned hydrocarbon in parts per million by nondispersive infrared (NDIR) measurement

CO → Carbon monoxide in % by NDIR

NO_x → Total oxides of nitrogen in parts per million

A/F → Air fuel ratio

TEMP → Ambient temperature in degrees Rankine

HUMID → Specific humidity in grains water per pounds dry air

* → Data was not available; this point was estimated

SPECIAL FLEET DATA

SPEED	HC1	HC2	HC3	HCT	HC	CO	NOX	A/F	TEMP	HUMID
A-14652 UNLEADED FORD H-DUTY GRUNDY CENTER										
1	0.375*	0.333*	0.295*	500*	200	2.4	020*	13.5	466	00
2	0.261	0.438	0.300	073	040	1.3	223	13.9	466	00
1	0.375	0.330	0.295	502	200	4.0	016	13.5	510	40
2	0.317	0.384	0.300	325	175	2.4	205	14.0	510	40
A-13857 UNLEADED INT'L H-DUTY SAC CITY										
1	0.382	0.382	0.236	408	325	2.5	019	13.5	504	21
2	0.268	0.523	0.209	035	040	0.5	188	14.1	504	21
1	0.493	0.278	0.229	724	040	2.5	011	13.5	510	36
2	0.275	0.379	0.345	273	090	1.0	038	14.5	510	36
A-14670 LEADED FORD H-DUTY DES MOINES										
1	0.391	0.343	0.266	141	150	3.3	010	13.0	496	15
2	0.251	0.466	0.283	118	050	2.0	040	13.6	496	15
1	0.423	0.127	0.449	729	400	5.5	007	13.0	514	47
2	0.291	0.129	0.580	330	100	2.6	082	13.6	514	47
A-14648 LEADED FORD H-DUTY DES MOINES										
1	0.369	0.290	0.340	252	250	2.5	006	13.6	496	16
2	0.299	0.397	0.304	248	120	4.0	019	13.0	496	16
1	0.372	0.156	0.471	553	275	5.0	014	13.5	514	47
2	0.281	0.129	0.590	477	130	4.0	077	13.3	514	47
A-14647 LEADED FORD H-DUTY DES MOINES										
1	0.453*	0.087*	0.460*	550*	244*	4.5*	006*	13.6*	496	16
2	0.331*	0.145*	0.523*	410*	124*	5.3*	040*	13.5*	496	16
1	0.453	0.087	0.460	920	375	5.0	011	13.5	518	48
2	0.331	0.145	0.523	457	140	6.8	059	13.0	518	48

SPEED	HC1	HC2	HC3	HCT	HC	CO	NOX	A/F	TEMP	HUMID
A-14634 LEADED FORD H-DUTY AMES										
1	0.431*	0.170*	0.399*	270*	140*	2.3*	007*	13.6*	503	30
2	0.306*	0.172*	0.522*	095*	035*	0.8*	060*	14.0*	503	30
1	0.431	0.170	0.399	153	080	1.4	019	13.5	520	49
2	0.306	0.172	0.522	082	030	0.7	051	14.0	520	49
A-13093 UNLEADED CHEVY L-DUTY GRUNDY CENTER										
1	0.323	0.377	0.299	215	175	4.2	024	13.3	466	00
2	0.306	0.430	0.264	212	140	5.5	059	13.0	466	00
1	0.296	0.348	0.356	337	125	4.5	039	13.3	512	43
2	0.306*	0.430*	0.264*	300*	200	5.8	088*	13.0	512	43
A-13970 UNLEADED FORD L-DUTY GRUNDY CENTER										
1	0.356	0.353	0.291	486	350	4.2	009	13.4	464	00
2	0.209	0.516	0.275	083	150	0.9	223	14.3	464	00
1	0.492	0.263	0.245	1595	1200	5.0	011	13.4	510	43
2	0.479	0.303	0.218	401	300	1.5	161	14.5	510	43
A-14576 UNLEADED CHEVY L-DUTY GRUNDY CENTER										
1	0.341	0.419	0.240	072	050	1.4	043	13.7	464	00
2	0.359	0.416	0.225	016	040	0.3	140	14.0	464	00
1	0.301	0.365	0.334	118	050	1.6	020	13.7	510	40
2	0.274	0.389	0.337	035	030	0.4	069	14.5	510	40
A-15369 UNLEADED INT'L L-DUTY GRUNDY CENTER										
1	0.512	0.304	0.183	331	150	1.8	017	13.8	467	00
2	0.249	0.462	0.290	070	035	0.8	164	14.2	467	00
1	0.363	0.326	0.311	424	275	3.2	028	13.8	510	40
2	0.184	0.479	0.337	237	080	3.5	058	13.8	510	40

SPEED	HC1	HC2	HC3	HCT	HC	CO	NOX	A/F	TEMP	HUMID
A-13585 UNLEADED CHEVY L-DUTY SAC CITY										
1	0.260	0.432	0.308	267	125	4.0	009	13.6	504	27
2	0.304	0.433	0.263	105	100	0.5	393	14.4	504	27
1	0.319	0.350	0.331	456	150	3.4	021	13.6	504	30
2	0.233	0.394	0.373	317	080	2.0	049	13.9	504	30
A-14264 UNLEADED CHEVY L-DUTY SAC CITY										
1	0.386	0.363	0.251	246	120	3.5	041	13.8	504	21
2	0.284	0.393	0.323	120	040	3.0	115	13.7	504	21
1	0.287	0.395	0.318	360	150	1.3	036	13.8	510	36
2	0.095	0.456	0.449	100	050	0.9	017	14.2	510	36
A-15317 UNLEADED INT'L L-DUTY SAC CITY										
1	0.320	0.411	0.268	321	225	3.4	015	13.6	504	24
2	0.275	0.480	0.245	043	050	0.7	204	14.4	504	24
1	0.399	0.303	0.297	353	225	3.1	030	13.0	505	28
2	0.148	0.419	0.433	058	040	0.8	064	14.4	505	28
A-14680 UNLEADED GMC L-DUTY SAC CITY										
1	0.308	0.419	0.273	168	100	3.2	031	13.6	498	20
2	0.320	0.509	0.171	023	040	0.8	108	14.5	498	20
1	0.280	0.372	0.349	352	120	3.0	017	13.6	510	36
2	0.247	0.396	0.358	098	050	1.0	071	14.0	510	36
A-14692 LEADED GMC L-DUTY DES MOINES										
1	0.429	0.271	0.300	136	050	2.3	033	13.7	496	16
2	0.529	0.261	0.210	067	030	0.3	028	14.0	496	16
1	0.436	0.075	0.489	280	070	1.8	016	13.7	514	47
2	0.344	0.321	0.335	081	030	0.3	089	14.1	514	47

SPEED	HC1	HC2	HC3	HCT	HC	CO	NOX	A/F	TEMP	HUMID
A-14683 LEADED		GMC	L-DUTY	DES MOINES						
1	0.411	0.306	0.283	034	040	1.6	019	13.8	495	15
2	0.476	0.331	0.193	026	030	0.3	024	14.0	495	15
1	0.492	0.061	0.447	237	080	2.5	019	13.8	514	47
2	0.316	0.339	0.345	044	040	0.4	060	14.3	514	47
A-14698 LEADED		GMC	L-DUTY	MARSHALLTOWN						
1	0.471	0.293	0.236	100	040	0.8	012	13.6	506	30
2	0.278	0.568	0.153	095	050	0.4	035	13.9	506	30
1	0.406	0.069	0.525	312	100	3.0	017	13.6	511	47
2	0.366	0.296	0.338	030	030	0.3	071	14.3	511	47
A-14691 LEADED		GMC	L-DUTY	MARSHALLTOWN						
1	0.414	0.299	0.288	151	100	1.5	007	13.9	496	23
2	0.376	0.389	0.236	032	040	0.5	087	14.2	496	23
1	0.438	0.106	0.456	229	060	2.4	017	13.9	511	47
2	0.324	0.315	0.361	056	030	0.3	087	14.3	511	47
A-15278 LEADED		INT'L	L-DUTY	AMES						
1	0.401	0.333	0.266	285	225	3.8	013	13.4	506	30
2	0.274	0.431	0.294	064	045	0.8	247	14.6	506	30
1	0.365	0.183	0.452	280	140	4.5	018	13.4	511	54
2	0.279	0.198	0.522	122	050	1.4	184	14.7	511	54
A-15279 LEADED		INT'L	L-DUTY	AMES						
1	0.367	0.345	0.288	312	225	4.0	014	13.5	504	30
2	0.257	0.439	0.304	079	040	0.8	120	14.7	504	30
1	0.369	0.194	0.437	249	185	4.3	013	13.6	519	58
2	0.238	0.199	0.553	098	020	0.9	099	14.5	519	58

SPEEC	FC1	HC2	HC3	HCT	HC	CO	NOX	A/F	TEMP	HUMID
A-14575 LEACEC CFEVY L-DUTY AMES										
1	0.461	0.284	0.256	053	050	2.0	007	13.9	503	30
2	0.364	0.430	0.206	099	035	0.2	102	14.3	503	30
1	0.484	0.090	0.426	192	100	2.2	019	13.9	520	58
2	0.400*	0.322*	0.278*	320*	025	0.3	065*	14.1	520	58
A-15414 LEACEC INT'L L-DUTY AMES										
1	0.363	0.355	0.281	452	200	2.0	012	13.5	504	29
2	0.257	0.452	0.291	088	050	0.5	087	14.7	504	29
1	0.373	0.163	0.464	308	200	3.0	027	13.5	518	52
2	0.258	0.182	0.560	099	050	0.8	051	14.7	518	52
A-15454 LEACEC INT'L L-DUTY AMES										
1	0.370	0.330	0.300	500	200	3.0	019	13.2	501	29
2	0.330	0.372	0.298	157	050	0.6	219	14.5	501	29
1	0.364	0.160	0.476	405	240	5.4	036	13.2	514	51
2	0.246	0.209	0.545	116	050	0.7	168	14.8	514	51
A-14269 LEACEC CHEVY L-DUTY AMES										
1	0.316	0.375	0.308	235	190	3.4	006	13.6	503	32
2	0.318	0.356	0.325	121	040	2.0	086	14.0	503	32
1	0.356	0.211	0.433	257	140	3.0	012	13.6	511	56
2	0.330	0.196	0.475	179	045	2.2	081	14.0	511	56
A-14602 LEACEC CFEVY L-DUTY AMES										
1	0.425	0.311	0.264	119	100	1.5	016	13.8	505	28
2	0.441	0.335	0.223	043	035	0.4	073	14.3	505	28
1	0.465	0.179	0.356	156	080	2.1	026	13.8	511	52
2	0.233	0.384	0.384	031	040	0.4	089	14.4	511	52

SPEED	HC1	HC2	HC3	HCT	HC	CO	NOX	A/F	TEMP	HUMID
A-14342 UNLEADED CHEVY PICKUP GRUNDY CENTER										
1	0.370	0.358	0.271	096	050	1.8	019	13.8	464	00
2	0.278	0.454	0.268	038	030	0.2	134	14.0	464	00
1	0.374	0.292	0.335	168	050	2.0	074	13.8	510	40
2	0.282	0.389	0.330	048	020	0.4	123	14.1	510	40
A-14343 UNLEADED CHEVY PICKUP GRUNDY CENTER										
1	0.323	0.399	0.277	119	050	2.0	025	13.7	464	00
2	0.328	0.428	0.244	074	060	0.3	146	14.0	464	00
1	0.336	0.333	0.331	192	080	2.0	016	13.7	512	43
2	0.191	0.468	0.340	062	050	0.4	077	14.1	512	43
A-15896 UNLEADED DODGE PICKUP SAC CITY										
1	0.323	0.385	0.292	146	090	1.4	023	14.3	504	26
2	0.234	0.531	0.234	023	020	0.2	141	14.6	504	26
1	0.274	0.329	0.397	226	060	0.9	014	14.3	504	27
2	0.198	0.389	0.413	264	040	1.8	085	14.0	504	27
A-14370 LEADED CHEVY PICKUP AMES										
1	0.407	0.289	0.304	075	020	1.0	025	14.0	504	29
2	0.413	0.314	0.273	081	040	0.3	124	14.0	504	29
1	0.412	0.170	0.418	076	045	1.2	029	13.9	518	52
2	0.368	0.204	0.428	075	040	0.3	142	14.0	518	52
A-14368 LEADED CHEVY PICKUP AMES										
1	0.365	0.325	0.310	092	050	0.9	026	13.9	504	40
2	0.387	0.359	0.254	117	060	0.2	132	14.1	504	40
1	0.401	0.197	0.402	134	050	1.2	036	13.9	518	52
2	0.512*	0.150*	0.337*	127*	100	0.2	150*	14.0	518	52

SPEED	HC1	HC2	HC3	HCT	HC	CO	NOX	A/F	TEMP	HUMID
A-14367 LEADED CHEVY PICKUP AMES										
1	0.370*	0.309*	0.322*	100*	045	1.2	030 *	13.7	503	32
2	0.448	0.306	0.245	074	050	0.2	162	14.0	503	32
1	0.405	0.175	0.420	102	050	1.6	022	13.9	520	60
2	0.355	0.206	0.440	051	050	0.2	196	13.9	520	60
A-14369 LEADED CHEVY PICKUP AMES										
1	0.382	0.293	0.325	094	040	1.3	015	13.9	503	29
2	0.454	0.315	0.231	123	090	0.2	118	13.9	503	29
1	0.366*	0.274*	0.361 *	116*	050	1.5	020 *	13.9	518	52
2	0.424	0.221	0.354	075	040	0.2	063	14.1	518	52
A-11504 UNLEADED CASE TRACTOR GRUNDY CENTER										
1	0.343	0.414	0.242	393	225	5.9	029	13.5	466	00
2	0.335	0.413	0.251	297	160	4.5	225	13.1	466	00
1	0.366	0.358	0.275	350	175	3.5	064	13.8	510	40
2	0.234	0.430	0.336	268	050	2.4	192	14.0	510	40
A-13634 UNLEADED J.D. TRACTOR GRUNDY CENTER										
1	0.294	0.414	0.292	278	160	3.3	028	13.6	466	00
2	0.254	0.469	0.277	225	140	4.0	340	13.3	466	00
1	0.272	0.410	0.318	380	140	3.2	050	13.6	512	43
2	0.249	0.438	0.312	276	140	4.0	073	13.7	512	43
A-13662 UNLEADED INT'L TRACTOR GRUNDY CENTER										
1	0.489	0.312	0.199	306	250	1.2	066	13.8	467	00
2	0.273	0.421	0.306	244	100	2.7	202	13.6	467	00
1	0.234	0.426	0.340	351	250	1.5	042	13.8	512	43
2	0.273	0.421	0.306	305	125	3.8	074	13.7	512	43

SPEEC	FC1	HC2	HC3	HCT	HC	CO	NO^{X}	A/F	TEMP	HUMID
A-15555 UNLEACEC J.D. TRACTOR GRUNCY CENTER										
1	0.284	0.447	0.269	330	175	4.8	046	13.5	466	00
2	0.264	0.438	0.298	215	100	3.4	255	13.6	466	00
1	0.288	0.420	0.292	254	140	3.8	048	13.6	512	43
2	0.224	0.427	0.349	263	080	2.9	134	14.1	512	43
A-12732 UNLEACED FORD TRACTOR GRUNDY CENTER										
1	0.400	0.353	0.247	406	320	3.7	053	13.1	466	00
2	0.296	0.519	0.185	202	145	2.7	773	13.7	466	00
1	0.318	0.386	0.296	410	400	5.5	047	13.1	512	43
2	0.303	0.452	0.246	180	150	3.8	109	13.6	512	43
A-12698 UNLEACED MAS FERG TRACTOR SAC CITY										
1	0.409	0.293	0.298	671	450	4.5	010	13.2	505	23
2	0.297	0.421	0.282	182	090	3.0	105	13.7	505	23
1	0.409*	0.293*	0.298*	510*	350*	4.5*	009*	13.2*	510	36
2	0.297*	0.421*	0.282*	182*	090*	2.3*	090*	13.8*	510	36
A-11028 UNLEACED INT'L TRACTOR SAC CITY										
1	0.359	0.378	0.263	361	300	2.5	037	13.4	504	24
2	0.311	0.406	0.282	367	180	5.5	081	13.3	504	24
1	0.411	0.307	0.282	566	300	5.5	015	13.3	505	28
2	0.276	0.424	0.301	592	180	5.0	055	13.1	505	28
A-15564 UNLEACED INT'L TRACTOR SAC CITY										
1	0.380	0.393	0.227	601	450	3.5	011	13.4	506	27
2	0.289	0.494	0.217	327	200	2.0	825	14.1	506	27
1	0.488	0.301	0.212	448	340	3.3	036	13.4	510	36
2	0.269	0.441	0.290	358	125	1.8	187	14.0	510	36

SPEED	HC1	HC2	HC3	HCT	HC	CO	NOX	A/F	TEMP	HUMID
A-13693 LEADED J DEERE TRACTOR MARSHALLTOWN										
1	0.359	0.378	0.263	241	200	2.4	034	13.8	496	24
2	0.264	0.464	0.272	112	050	1.4	415	14.5	496	24
1	0.360	0.200	0.440	316	160	1.8	077	13.8	511	47
2	0.268	0.169	0.563	218	090	1.9	525	14.2	511	47
A-13668 LEADED INT'L TRACTOR AMES										
1	0.490	0.264	0.246	852	325	4.5	041	13.1	502	31
2	0.283	0.424	0.292	352	105	4.5	070	13.0	502	31
1	0.518*	0.131*	0.351*	254*	300	5.0	016*	13.1	518	52
2	0.293	0.126	0.582	163	080	4.3	040	13.3	518	52
A-13669 LEADED INT'L TRACTOR AMES										
1	0.340	0.353	0.307	376	175	2.5	024	13.4	502	36
2	0.250	0.412	0.338	318	080	2.3	108	13.6	502	36
1	0.498	0.097	0.405	533	225	2.2	012	13.4	536	75
2	0.322	0.136	0.542	214	050	2.0	034	13.9	536	75
A-13696 LEADED MAS FERG TRACTOR AMES										
1	0.285*	0.162*	0.553*	350*	175*	2.2*	034*	13.8*	503	30
2	0.249*	0.194*	0.557*	220*	055*	1.8*	415*	14.4*	503	30
1	0.285	0.162	0.553	400	150	2.6	070	13.8	520	49
2	0.249	0.194	0.557	235	060	2.3	438	13.9	520	49
A-15098 LEADED CHEVY WAGON AMES										
1	0.288	0.379	0.334	233	080	1.5	027	14.0	503	32
2	0.297	0.373	0.330	165	050	2.8	163	14.2	503	32
1	0.352	0.154	0.495	262	110	2.8	026	14.0	511	56
2	0.283	0.153	0.564	181	050	2.8	087	13.8	511	56

SPEED	HC1	HC2	HC3	HCT	HC	CO	NOX	A/F	TEMP	HUMID
A-15880 LEADED DODGE PICKUP DES MOINES										
1	0.325	0.375	0.302	128	060	0.8	021	14.8	493	15
2	0.479	0.307	0.214	049	030	0.3	100	14.6	493	15
1	0.398	0.173	0.430	146	060	0.2	035	14.8	508	40
2	0.230	0.234	0.536	083	030	0.3	117	14.8	508	40
A-14910 LEADED PLYMOUTH PASS CAR AMES										
1	0.388	0.317	0.295	249	100	1.3	035	14.4	503	32
2	0.228	0.458	0.287	042	040	0.2	199	14.6	503	32
1	0.389	0.112	0.499	413	200	1.3	027	14.4	511	52
2	0.224	0.372	0.404	071	040	0.3	307	14.8	511	52
A-14941 LEADED PLYMOUTH PASS CAR AMES										
1	0.283	0.355	0.362	096	050	1.0	025	14.5	503	32
2	0.242	0.424	0.334	039	020	0.3	201	14.7	503	32
1	0.349	0.202	0.449	115	080	0.6	033	14.5	539	36
2	0.208	0.280	0.512	063	060	0.3	177	14.6	539	36
A-15192 LEADED FORD PICKUP AMES										
1	0.592*	0.100 *	0.308*	600*	400	4.2	009*	13.5	506	30
2	0.497*	0.180 *	0.324*	230*	180	0.4	150*	14.2	506	30
1	0.592	0.100	0.308	1042	700	3.8	013	13.5	511	56
2	0.497	0.180	0.324	115	090	0.3	205	14.6	511	56
A-15415 UNLEADED INT'L L-DUTY GRUNDY CENTER										
1	0.377	0.351	0.272	247	200	2.4	013	13.6	505	28
2	0.265	0.422	0.313	175	060	1.8	133	14.3	505	28
1	0.347	0.204	0.449	319	150	3.2	020	13.6	515	56
2	0.226	0.256	0.518	141	050	1.7	155	14.5	515	56

APPENDIX C

MATCHED PAIR DATA FOR JANUARY 1972

Nomenclature

SPEED

1 → Idle

2 → 2500 rpm

LOAD → Engine load in horsepower

HC → Unburned hydrocarbon in parts per million by nondispersive infrared (NDIR) measurement

CO → Carbon monoxide in % by NDIR

NO_x → Total oxides of nitrogen in parts per million

A/F → Air fuel ratio

VACUUM → Intake manifold vacuum in inches of mercury

TEMP → Ambient temperature in degrees Rankine

HUMIDITY → Specific humidity in grains water per pounds dry air

BAROMETER → Barometric pressure in inches of mercury

* → Data not available; this point was estimated

MATCHED PAIR DATA FOR JANUARY 1972

SPEED	LOAD	HC	CO	NOX	A/F	VACUUM	TEMP	HUMIDITY	BAROMETER
A-14342 UNLEADED CHEVY PICKUP GRUNDY CENTER									
2	077.9	100	7.5	0200*	12.6	02.4	498	22	28.51
2	057.7	040	1.8	1401	14.3	07.5	498	22	28.51
2	031.7	020	1.4	1586	14.1	12.8	498	22	28.51
1	000.0	050	0.5	0000	13.8	19.3	462	22	28.51
A-14367 LEADED CHEVY PICKUP AMES									
2	085.4	150	7.5	0266	12.2	02.3	496	20	28.51
2	059.2	030	1.2	2033	14.2	08.0	496	20	28.51
2	030.7	010	0.6	2112	14.0	14.4	496	20	28.51
1	000.0	045	1.4	0000	13.9	19.0	482	20	28.51
A-15896 UNLEADED DODGE PICKUP SAC CITY									
2	083.3	045	2.2	1444	14.3	01.6	504	21	28.84
2	048.1	030	0.1	1082	14.7	07.6	504	21	28.84
2	028.9	025	0.2	1150	14.5	12.8	504	21	28.84
1	000.0	100	1.5	0000	14.3	18.4	504	21	28.84
A-15880 LEADED DODGE PICKUP DES MOINES									
2	075.0	160	5.2	0224	13.0	01.1	504	21	28.84
2	055.2	080	1.3	0328	14.5	06.3	504	21	28.84
2	028.6	050	0.5	0882	14.9	12.3	504	21	28.84
1	000.0	040	0.2	0000	14.8	15.4	504	21	28.84

MATCHED PAIR DATA FCR JANUARY 1972

SPEED	LOAC	HC	CO	NOX	A/F	VACUUM	TEMP	HUMIDITY	BARCMETER
A-14343 UNLEACED CHEVY PICKUP GRUNCY CENTER									
2	C84.9	180	7.5	0242	12.5	02.4	504	21	28.84
2	051.8	C75	1.0	1650	14.3	09.0	504	21	28.84
2	030.6	050	1.0	1202	14.1	13.5	504	21	28.84
1	C00.0	080	1.7	0000	13.7	18.5	504	21	28.84
A-14368 LEACEC CHEVY PICKUP AMES									
2	C85.3	090	7.5	0223	12.3	02.4	504	21	28.84
2	055.8	080	1.7	1584	14.1	08.7	504	21	28.84
2	031.7	050	1.1	1284	14.1	13.7	504	21	28.84
1	C00.0	075	0.7	0000	13.7	18.9	504	21	28.84
A-15943 UNLEACEC DODCE PICKUP SAC CITY									
2	C80.C	050	5.2	0475	13.4	01.3	481	13	29.40
2	C51.1	020	0.8	1039	14.8	06.4	481	13	29.40
2	C26.1	010	0.3	1045	14.5	11.7	481	13	29.40
1	C00.0	050	1.3	0000	14.6	16.6	481	13	29.40
A-15928 LEACEC DODGE PICKUP DES MCINES									
2	C79.5	C95	4.5	0259	13.1	01.4	484	12	29.40
2	054.9	050	1.2	0635	14.8	06.2	484	12	29.40
2	C27.1	040	0.5	0683	14.9	11.9	484	12	29.40
1	C00.0	110	2.0	0000	14.3	17.5	484	12	29.40

MATCHED PAIR DATA FOR JANUARY 1972

SPEEC	LCAC	HC	CO	NOX	A/F	VACUUM	TEMP	HUMIDITY	BAROMETER
A-15369 UNLEACED		INT'L L-DUTY		GRUNDY CENTER					
2	091.5	080	4.8	0992	13.2	01.1	502	28	28.51
2	C59.5	060	2.3	1430*	13.9	06.4	502	28	28.51
2	C37.2	050	2.0	1492	14.0	10.2	502	28	28.51
2	C17.4	100	6.4	0213	12.4	14.6	540	63	28.83
2	CCC.0	400	1.4	0000	13.8	16.0	467	28	28.51
A-15415 UNLEACED		INT'L L-DUTY		GRUNDY CENTER					
2	C88.4	085	4.0	1741	13.6	01.1	494	23	28.51
2	C58.5	030	1.2	2542	14.7	05.8	494	23	28.51
2	C39.4	040	1.3	2168	14.6	09.6	494	23	28.51
2	C16.5	125	2.3	0716	13.6	14.0	540	64	28.83
1	C00.0	200	3.0	0000	13.6	17.6	480	23	28.51
A-14576 UNLEACED		CHEVY L-DUTY		GRUNDY CENTER					
2	C98.0	050	4.5	1086	13.5	01.5	452	00	29.82
2	C63.1	030	0.4	1656	15.5	05.6	452	00	29.82
2	032.6	020	0.2	1112	15.1	09.6	452	00	29.82
2	019.6	050	0.3	0961	14.8	11.9	452	00	29.82
1	000.0	125	3.2	0000	13.9	18.0	452	00	00.00
A-14575 LEACEC		CHEVY L-DUTY		AMES					
2	C93.6	125	5.8	0558	12.7	01.3	452	00	29.82
2	C61.7	040	0.4	0880	15.1	06.0	452	00	29.82
2	031.5	020	0.2	0703	15.1	11.6	452	00	29.82
2	020.6	010	0.2	0556	15.0	13.1	452	00	29.82
1	C00.C	050	2.0	0000	13.8	18.8	452	00	29.82

MATCHED PAIR DATA FOR JANUARY 1972

SPEED	LOAC	HC	CO	NOX	A/F	VACUUM	TEMP	HUMIDITY	BARCMETER
A-14680 UNLEACED		GMC	L-DUTY	SAC CITY					
2	104.5	100	6.2	1004	12.5	01.2	504	21	28.84
2	C69.6	050	0.5	2662	14.6	06.3	504	21	28.84
2	034.8	040	0.8	1662	14.4	11.6	504	21	28.84
2	C20.0	030	1.2	0104	14.3	14.5	504	21	28.84
1	C00.0	110	3.4	0000	13.8	18.8	504	21	28.84
A-14683 LEADEC		GMC	L-DUTY	DES MOINES					
2	110.2	080	5.5	0845	12.7	01.2	504	21	28.84
2	C73.6	025	0.4	2404	14.6	05.9	504	21	28.84
2	031.8	010	0.3	0808	14.7	11.4	504	21	28.84
2	C20.C	005	0.3	0862	14.6	14.4	504	21	28.84
1	000.0	075	0.1	0000	13.7	18.9	504	21	28.84
A-15317 UNLEACED		INT'L	L-DUTY	SAC CITY					
2	097.8	080	4.8	0719	13.7	01.2	481	13	29.40
2	057.5	060	1.1	1493	15.0	07.6	481	13	29.40
2	C32.6	050	1.3	0872	14.9	12.1	481	13	29.40
2	C18.5	C45	1.4	0825	14.9	14.4	481	13	29.40
1	000.0	225	3.8	0000	13.6	18.3	481	13	29.40
A-15279 LEADEC		INT'L	L-DUTY	AMES					
2	102.2	100	3.4	C814	13.9	00.9	481	13	29.40
2	C63.1	060	0.8	1337	15.0	07.5	481	13	29.40
2	032.6	C55	1.0	1343	14.9	12.6	481	13	29.40
2	C18.3	045	1.0	C892	14.9	14.8	481	13	29.40
1	C00.0	225	4.2	0000	13.5	18.0	481	13	29.40

MATCHED PAIR DATA FOR JANUARY 1972

SPEED	LOAD	HC	CO	NOX	A/F	VACUUM	TEMP	HUMIDITY	BAROMETER
A-14652 UNLEADED	FORD	H-DUTY	GRUNDY CENTER						
2	092.1	150	7.5	0343	13.6	01.1	452	00	29.82
2	065.9	080	2.4	1951	16.0	04.0	452	00	29.82
2	028.4	040	0.9	2532	17.0	08.9	452	00	29.82
2	020.4	040	1.1	2192	17.0	10.6	452	00	29.82
1	000.0	225	6.2	0000	13.8	19.0	452	00	29.82
A-14670 LEADED	FORD	H-DUTY	DES MOINES						
2	090.9	150	7.5	0353	12.4	01.2	452	00	29.82
2	067.4	100	3.5	1301	13.8	04.4	452	00	29.82
2	034.8	085	1.5	3155	14.3	08.2	452	00	29.82
2	020.3	100	2.3	2583	14.0	10.2	452	00	29.82
1	000.0	300	6.0	0000	13.4	18.7	452	00	29.82
A-13857 UNLEADED	INT'L	H-DUTY	SAC CITY						
2	091.9	110	4.8	1111	13.5	01.4	487	18	29.33
2	059.5	020	0.3	0817	14.9	05.4	487	18	29.33
2	029.6	040	0.8	0804	14.7	11.5	487	18	29.33
2	015.5	060	1.2	0344	14.0	13.8	487	18	29.33
1	000.0	140	2.1	0000	13.3	17.5	487	18	29.33
A-13848 LEADED	INT'L	H-DUTY	DES MOINES						
2	096.3	160	3.8	1627	13.7	01.1	487	18	29.33
2	063.3	040	0.9	1547	14.8	04.5	487	18	29.33
2	031.0	050	0.6	1268	14.8	10.0	487	18	29.33
2	016.7	060	1.1	0068	14.6	13.0	487	18	29.33
1	000.0	300	1.2	0000	14.0	19.0	487	18	29.33

APPENDIX D

MATCHED PAIR DATA FOR APRIL 1972

Nomenclature

SPEED

- 1 → Idle
- 2 → 2500 rpm

LOAD → Engine load in horsepower

HC → Unburned hydrocarbon in parts per million by nondispersive infrared (NDIR) measurement

CO → Carbon monoxide in % by NDIR

NO_x → Total oxides of nitrogen in parts per million

A/F → Air fuel ratio

VACUUM → Intake manifold vacuum in inches of mercury

TEMP → Ambient temperature in degrees Rankine

HUMIDITY → Specific humidity in grains water per pounds dry air

BAROMETER → Barometric pressure in inches of mercury

MATCHED PAIR CATA FOR APRIL 1972

SPEED	LOAD	HC	CO	NOX	A/F	VACUUM	TEMP	HUMIDITY	BARCMETER
A-14342 UNLEACEC CHEVY PICKUP GRUNDY CENTER									
2	C75.5	100	7.5	C190	12.4	02.0	541	71	28.52
2	C49.C	040	1.4	1791	13.9	08.5	541	71	28.52
2	024.5	030	1.2	0238	13.8	14.3	541	71	28.52
2	CCC.C	C30	0.3		13.8	18.C	541	71	28.52
1	.	80	2.0		13.7	20.6	541	71	28.52
A-14367 LEACEC CHEVY PICKUP AMES									
2	C79.8	060	7.5	0177	12.2	01.8	542	70	28.52
2	C48.1	040	1.4	1317	13.8	09.3	542	70	28.52
2	024.6	025	0.8	1696	13.6	14.4	542	70	28.52
2	COC.C	045	0.2	0000	13.9	20.6	542	70	28.52
1	CC0.C	C65	1.4	0000	13.8	18.9	542	70	28.52
A-15896 UNLEACEC DODGE PICKUP SAC CITY									
2	C79.2	050	1.8	2556	14.0	01.2	530	38	29.13
2	C57.2	C40	0.4	2594	14.2	06.0	530	38	29.13
2	C24.8	C30	0.2	2981	13.9	13.4	530	38	29.13
2	CCC.C	030	0.2	0000	14.5	19.9	530	38	29.13
1	COC.C	100	1.2	0000	14.3	18.0	530	38	29.13
A-15880 LEACEC DODGE PICKUP DES MCINES									
2	C79.8	160	5.3	1C91	13.4	01.0	529	34	29.13
2	C59.5	150	4.1	1117	13.6	05.4	529	34	29.13
2	C28.2	C80	0.9	2946	13.9	12.9	529	34	29.13
2	CCC.C	030	0.3	C000	14.5	19.5	529	34	29.13
1	000.C	070	0.2	0000	14.5	15.7	529	34	29.13

SPEED	LOAC	HC	CO	NOX	A/F	VACUUM	TEMP	HUMIDITY	BARCMETER
A-14343 UNLEACED CHEVY PICKUP GRUNCY CENTER									
2	C78.0	195	7.5	0171	12.0	02.1	527	39	28.72
2	C50.C	100	2.3	1877	13.7	07.3	527	39	28.72
2	C23.1	C40	1.7	1394	13.8	14.1	527	39	28.72
2	C00.C	C60	0.4	0000	13.8	20.2	527	39	28.72
1	CCC.C	C75	1.6	0000	13.7	19.0	527	39	28.72
A-14368 LEACEC CHEVY PICKUP AMES									
2	C79.2	180	7.5	0343	12.2	02.0	529	42	28.72
2	C50.C	C70	1.5	1279	13.9	07.9	529	42	28.72
2	C27.C	040	1.2	2118	13.8	12.8	529	42	28.72
2	CCC.C	C70	0.2	0000	13.8	20.8	529	42	28.72
1	C00.0	075	1.1	0000	13.8	19.2	529	42	28.72
A-15943 UNLEACEC CCCGE PICKUP SAC CITY									
2	C82.5	100	4.2	1174	13.6	01.1	541	62	28.83
2	063.1	110	5.8	0563	13.8	07.2	541	62	28.83
2	022.9	050	0.9	1357	14.3	13.5	541	62	28.83
2	C00.0	020	0.2	000C	14.6	20.2	541	62	28.83
1	C00.C	200	2.0	0000	13.9	17.8	541	62	28.83
A-15928 LEADEC DODGE PICKUP DES MCINES									
2	C71.4	175	5.1	0558	13.2	01.C	541	62	28.83
2	C45.6	110	1.1	0952	14.0	07.0	541	62	28.83
2	021.2	125	1.3	2CC7	14.0	13.2	541	62	28.83
2	CCC.C	050	0.3	0000	14.5	19.6	541	62	28.83
1	CCC.C	100	0.8	C000	14.3	16.0	541	62	28.83

SPEED	LOAD	HC	CO	NOX	A/F	VACUUM	TEMP	HUMIDITY	BAROMETER
A-15369 UNLEADED INT'L L-DUTY GRUNDY CENTER									
2	094.5	135	7.5	0236	12.0	01.0	540	63	28.83
2	062.0	080	5.5	0497	12.9	07.2	540	63	28.83
2	027.6	080	6.0	0213	12.6	13.0	540	63	28.83
2	017.4	100	6.4	0213	12.4	14.6	540	63	28.83
2	000.0	060	3.2	0000	13.5	19.9	540	63	28.83
1	000.0	200	3.5	0000	13.6	17.6	540	63	28.83
A-15415 UNLEADED INT'L L-DUTY GRUNDY CENTER									
2	095.3	140	3.8	0716	13.4	00.8	540	64	28.83
2	055.5	090	0.9	1061	14.3	06.9	540	64	28.83
2	027.5	125	2.0	0834	13.8	12.0	540	64	28.83
2	016.5	125	2.3	0716	13.6	14.0	540	64	28.83
2	000.0	045	0.9	0000	14.2	18.8	540	64	28.83
1	000.0	120	2.8	0000	13.7	16.5	540	64	28.83
A-14576 UNLEADED CHEVY L-DUTY GRUNDY CENTER									
2	096.5	060	0.6	0279	12.9	00.9	515	49	28.78
2	056.5	020	0.4	0432	14.5	07.1	515	49	28.78
2	027.0	010	0.4	0250	14.5	12.0	515	49	28.78
2	017.2	010	0.3	0176	14.4	13.5	515	49	28.78
2	000.0	020	0.4	0000	14.2	19.6	515	49	28.78
1	000.0	080	2.1	0000	13.7	18.4	515	49	28.78
A-14575 LEADED CHEVY L-DUTY AMES									
2	097.6	080	5.8	0203	12.7	00.7	514	47	28.78
2	058.0	020	0.2	0298	14.7	06.0	514	47	28.78
2	025.8	010	0.2	0122	14.6	11.8	514	47	28.78
2	017.0	010	0.2	0154	14.4	13.2	514	47	28.78
2	000.0	020	0.3	0000	14.2	18.2	514	47	28.78
1	000.0	040	0.9	0000	13.9	17.3	514	47	28.78

SPEED	LOAD	HC	CO	NOX	A/F	VACUUM	TEMP	HUMIDITY	BAROMETER
A-14680 UNLEADED GMC			L-DUTY	SAC CITY					
2	104.5	125	7.4	1197	12.5	00.8	527	42	28.72
2	065.2	040	0.7	1926	14.5	06.9	527	42	28.72
2	036.0	030	1.4	1331	14.1	11.7	527	42	28.72
2	018.2	030	1.7	0559	14.0	14.4	527	42	28.72
2	000.0	040	0.9	0000	13.3	19.4	527	42	28.72
1	000.0	095	3.0	0000	13.4	18.7	527	42	28.72
A-14683 LEADED		GMC	L-DUTY	DES MOINES					
2	098.9	095	5.6	0646	13.1	01.0	528	40	28.72
2	069.8	030	0.4	2282	14.1	05.7	528	40	28.72
2	030.8	020	0.3	1130	14.2	12.0	528	40	28.72
2	018.3	010	0.2	0739	14.1	14.2	528	40	28.72
2	000.0	030	0.4	0000	13.9	19.6	528	40	28.72
1	000.0	060	1.9	0000	13.1	18.9	528	40	28.72
A-15317 UNLEADED		INT'L	L-DUTY	SAC CITY					
2	092.2	100	4.2	0301	13.4	00.8	514	47	28.78
2	057.8	075	0.9	0596	14.4	07.1	514	47	28.78
2	032.2	070	1.2	0509	14.3	10.7	514	47	28.78
2	018.5	060	1.4	0276	14.2	13.2	514	47	28.78
2	000.0	050	0.7	0000	14.5	19.7	514	47	28.78
1	000.0	225	3.1	0000	13.5	17.6	514	47	28.78
A-15279 LEADED		INT'L	L-DUTY	AMES					
2	089.6	125	3.8	0328	13.3	01.0	514	47	28.78
2	055.6	080	1.0	0493	14.4	07.4	514	47	28.78
2	026.7	080	1.3	0220	14.2	12.6	514	47	28.78
2	018.0	075	1.4	0556	14.2	14.2	514	47	28.78
2	000.0	050	0.9	0000	14.3	20.2	514	47	28.78
1	000.0	180	3.0	0000	13.6	18.0	514	47	28.78

SPEED	LOAD	HC	CO	NOX	A/F	VACUUM	TEMP	HUMIDITY	BAROMETER
A-14652 UNLEADED		FORD	H-DUTY	GRUNDY CENTER					
2	102.6	110	6.0	0570	12.8	01.0	530	29	29.13
2	065.4	080	0.7	2366	14.2	06.0	530	29	29.13
2	031.0	050	1.3	1621	14.1	10.9	530	29	29.13
2	019.0	075	1.4	1336	13.9	12.3	530	29	29.13
2	000.0	040	1.3	0000	14.0	20.7	530	29	29.13
1	000.0	200	2.5	0000	13.4	18.8	530	29	29.13
A-14670 LEADED		FORD	H-DUTY	DES MOINES					
2	087.5	200	2.1	0139	12.0	01.0	530	33	29.13
2	067.1	060	3.0	1018	13.6	04.2	530	33	29.13
2	042.6	075	1.5	1879	13.9	07.7	530	33	29.13
2	021.4	100	2.8	1136	13.6	10.9	530	33	29.13
2	000.0	090	1.7	0000	13.8	19.4	530	33	29.13
1	000.0	200	2.1	0000	13.4	17.5	530	33	29.13

SPEED	LOAD	HC	CO	NOX	A/F	VACUUM	TEMP	HUMIDITY	BAROMETER
A-13857 UNLEADED		INT'L	H-DUTY	SAC CITY					
2	096.2	130	4.8	0699	13.5	01.1	538	65	28.52
2	062.5	050	0.8	1684	14.4	04.9	538	65	28.52
2	033.3	075	1.2	1696	14.2	11.0	538	65	28.52
2	017.7	075	1.6	0806	14.0	13.5	538	65	28.52
2	000.0	090	1.0	0000	14.5	18.4	538	65	28.52
1	000.0	500	3.8	0000	13.3	18.4	538	65	29.52
A-13848 LEADED		INT'L	H-DUTY	DES MOINES					
2	096.3	130	4.2	1146	13.6	01.1	540	68	28.52
2	061.7	040	0.7	1974	14.5	05.1	540	68	28.52
2	030.1	075	1.4	1722	14.2	11.1	540	68	28.52
2	017.1	080	1.8	2331	14.0	13.4	540	68	28.52
2	000.0	100	1.8	0000	13.8	18.4	540	68	28.52
1	000.0	200	5.5	0000	13.1	18.5	540	68	28.52

APPENDIX E

MATCHED PAIR DATA FOR APRIL 1972 AT 2500 rpm

Nomenclature

LOAD → Engine load in horsepower

HC1 → Paraffin fraction of HCT

HC2 → Aromatic fraction of HCT

HC3 → Olefin fraction of HCT

HCT → Total unburned hydrocarbon in parts per million by flame ionization detector (FID)

HC → Unburned hydrocarbon in parts per million by nondispersive infrared (NDIR) measurement

CO → Carbon monoxide in % by NDIR

NO_x → Total oxides of nitrogen in parts per million

A/F → Air fuel ratio

VACUUM → Intake manifold vacuum in inches of mercury

MATCHED PAIR DATA AT 2500 RPM

LOAD	HC1	HC2	HC3	HCT	HC	CO	NOX	A/F	VACUUM
A-14342 UNLEADED CHEVY PICKUP GRUNDY CENTER									
TEMP=541 HUMIDITY=71 BAROMETER=28.52									
075.5	0.432	0.141	0.428	286	100	7.5	0190	12.4	02.0
049.0	0.288	0.214	0.498	163	040	1.4	1791	13.9	08.5
024.5	0.251	0.255	0.494	090	030	1.2	0238	13.8	14.3
A-14367 LEADED CHEVY PICKUP AMES									
TEMP=542 HUMIDITY=70 BAROMETER=28.52									
079.8	0.457	0.112	0.431	430	060	7.5	0177	12.2	01.8
048.1	0.286	0.183	0.531	116	040	1.4	1317	13.8	09.3
024.6	0.255	0.223	0.522	106	025	0.8	1696	13.6	14.4
A-15896 UNLEADED DODGE PICKUP SAC CITY									
TEMP=530 HUMIDITY=38 BAROMETER=29.13									
079.2	0.234	0.194	0.571	113	050	1.8	2556	14.0	01.2
057.2	0.145	0.239	0.617	042	040	0.4	2594	14.2	06.0
024.8	0.109	0.237	0.654	061	030	0.2	2981	13.9	13.4
A-15880 LEADED DODGE PICKUP DES MOINES									
TEMP=529 HUMIDITY=34 BAROMETER=29.13									
079.8	0.288	0.162	0.551	399	160	5.3	1091	13.4	01.0
059.5	0.250	0.152	0.599	370	150	4.1	1117	13.6	05.4
028.2	0.192	0.141	0.667	281	080	0.9	2946	13.9	12.9

MATCHED PAIR CATA AT 2500 RPM

LCAD	HC1	HC2	HC3	HCT	HC	CC	NOX	A/F	VACUUM
A-14343 UNLEACED CHEVY PICKUP GRUNCY CENTER									
TEMP=527 HUMICITY=39 BARCMETER=28.72									
C78.C	C.342	0.315	0.343	459	195	7.5	C171	12.0	02.1
C50.0	0.277	0.351	0.372	237	100	2.3	1877	13.7	07.3
C23.1	0.259	0.337	0.404	132	040	1.7	1394	13.8	14.1
A-14368 LEADEC CHEVY PICKUP AMES									
TEMP=529 HUMICITY=42 BARCMETER=28.72									
C79.2	C.417	0.235	0.348	372	180	7.5	0343	12.2	02.C
C5C.0	0.303	0.316	0.381	153	070	1.5	1279	13.9	07.9
C27.C	0.287	0.331	0.382	101	040	1.2	2118	13.8	12.8
A-15943 UNLEACEC DCDGE PICKUP SAC CITY									
TEMP=541 HUMICITY=62 BARCMETER=28.83									
C62.5	0.216	C.408	0.375	326	100	4.2	1174	13.6	01.1
C63.1	0.329	0.375	0.297	277	110	5.8	C563	13.8	07.2
C22.9	0.253	0.445	0.301	146	050	0.9	1357	14.3	13.5
A-15928 LEACEC DODGE PICKUP DES MCINES									
TEMP=541 HUMICITY=62 BARCMETER=28.83									
071.4	C.329	C.397	0.274	374	175	5.1	C558	13.2	01.0
C45.6	0.255	0.432	0.313	290	110	1.1	C952	14.0	07.0
021.2	0.282	0.397	0.321	329	125	1.3	1007	14.0	13.2

MATCHED PAIR DATA AT 2500 RPM

LOAD	HC1	HC2	HC3	HCT	HC	CO	NOX	A/F	VACUUM
A-15369 UNLEADED INT'L L-DUTY GRUNDY CENTER									
TEMP=540 HUMIDITY=63 BAROMETER=28.83									
094.5	0.375	0.319	0.306	335	135	7.5	0236	12.0	01.0
062.0	0.370	0.313	0.317	286	080	5.5	0497	12.9	07.2
027.6	0.372	0.308	0.320	302	080	6.0	0213	12.6	13.0
017.4	0.341	0.326	0.333	348	100	6.4	0213	12.4	14.6
A-15415 UNLEADED INT'L L-DUTY GRUNDY CENTER									
TEMP=540 HUMIDITY=64 BAROMETER=28.83									
095.3	0.361	0.356	0.283	302	140	3.8	0716	13.4	00.8
055.5	0.313	0.385	0.302	234	090	0.9	1061	14.3	06.9
027.5	0.320	0.379	0.301	279	125	2.0	0834	13.8	12.0
016.5	0.323	0.366	0.311	296	125	2.3	0716	13.6	14.0
A-14576 UNLEADED CHEVY L-DUTY GRUNDY CENTER									
TEMP=515 HUMIDITY=49 BAROMETER=28.78									
096.5	0.467	0.346	0.187	163	060	0.6	0279	12.9	00.9
056.9	0.183	0.593	0.224	028	020	0.4	0432	14.5	07.1
027.0	0.264	0.576	0.220	013	010	0.4	0250	14.5	12.0
017.2	0.174	0.567	0.258	018	010	0.3	0176	14.4	13.5
A-14575 LEADED CHEVY L-DUTY AMES									
TEMP=514 HUMIDITY=47 BAROMETER=28.78									
097.6	0.424	0.320	0.256	279	080	5.8	0203	12.7	00.7
058.0	0.179	0.495	0.326	022	020	0.2	0298	14.7	06.0
025.8	0.191	0.519	0.291	015	010	0.2	0122	14.6	11.8
017.0	0.184	0.488	0.328	015	010	0.2	0154	14.4	13.2

MATCHED PAIR DATA AT 2500 RPM

LOAD	HC1	HC2	HC3	HCT	HC	CO	NOX	A/F	VACUUM
A-14680 UNLEADED GMC L-DUTY SAC CITY									
TEMP=527 HUMIDITY=42 BAROMETER=28.72									
104.5	0.406	0.295	0.299	268	125	7.4	1197	12.5	00.8
065.2	0.179	0.538	0.283	137	040	0.7	1926	14.5	06.9
036.0	0.275	0.413	0.312	081	030	1.4	1331	14.1	11.7
018.2	0.307	0.459	0.234	089	030	1.7	0559	14.0	14.4
A-14683 LEADED GMC L-DUTY DES MOINES									
TEMP=528 HUMIDITY=40 BAROMETER=28.72									
098.9	0.429	0.259	0.312	233	095	5.6	0646	13.1	01.0
069.8	0.130	0.587	0.283	051	030	0.4	2282	14.1	05.7
030.8	0.249	0.516	0.235	014	020	0.3	1130	14.2	12.0
018.3	0.207	0.562	0.231	017	010	0.2	0739	14.1	14.2
A-15317 UNLEADED INT'L L-DUTY SAC CITY									
TEMP=514 HUMIDITY=47 BAROMETER=28.78									
092.2	0.303	0.429	0.268	198	100	4.2	0301	13.4	00.8
057.8	0.249	0.506	0.245	133	075	0.9	0596	14.4	07.1
032.2	0.246	0.504	0.249	135	070	1.2	0509	14.3	10.7
018.5	0.246	0.509	0.245	105	060	1.4	0276	14.2	13.2
A-15279 LEADED INT'L L-DUTY AMES									
TEMP=514 HUMIDITY=47 BAROMETER=28.78									
089.6	0.322	0.307	0.371	360	125	3.8	0328	13.3	01.0
055.6	0.288	0.400	0.312	238	080	1.0	0493	14.4	07.4
026.7	0.289	0.403	0.308	235	080	1.3	0220	14.2	12.6
018.0	0.280	0.395	0.326	239	075	1.4	0556	14.2	14.2

MATCHED PAIR DATA AT 2500 RPM

LOAD	HC1	HC2	HC3	HCT	HC	CO	NOX	A/F	VACUUM
A-14652 UNLEADED FORD H-DUTY GRUNDY CENTER									
TEMP=530 HUMIDITY=29 BAROMETER=29.13									
102.6	0.279	0.181	0.540	251	110	6.0	0570	12.8	01.0
065.4	0.193	0.187	0.620	124	080	0.7	2366	14.2	06.0
031.0	0.212	0.154	0.633	162	050	1.3	1621	14.1	10.9
019.0	0.218	0.154	0.628	184	075	1.4	1336	13.9	12.3
A-14670 LEADED FORD H-DUTY DES MOINES									
TEMP=530 HUMIDITY=33 BAROMETER=29.13									
087.5	0.372	0.123	0.504	251	200	2.1	0139	12.0	01.0
067.1	0.278	0.115	0.607	211	060	3.0	1018	13.6	04.2
042.6	0.234	0.153	0.614	191	075	1.5	1879	13.9	07.7
021.4	0.254	0.151	0.595	255	100	2.8	1136	13.6	10.9
A-13857 UNLEADED INT'L H-DUTY SAC CITY									
TEMP=538 HUMIDITY=65 BAROMETER=28.52									
096.2	0.339	0.225	0.436	300	130	7.5	0699	13.5	01.1
062.5	0.224	0.312	0.463	132	050	7.5	1684	14.4	04.9
033.3	0.296	0.172	0.532	202	075	2.5	1696	14.2	11.0
017.7	0.318	0.156	0.526	202	075	1.6	0806	14.0	13.5
A-13848 LEADED INT'L H-DUTY DES MOINES									
TEMP=540 HUMIDITY=68 BAROMETER=28.52									
096.3	0.409	0.124	0.467	319	130	4.2	1146	13.6	01.1
061.7	0.288	0.172	0.540	158	040	0.7	1974	14.5	05.1
030.1	0.227	0.250	0.524	156	075	1.4	1722	14.2	11.1
017.1	0.331	0.111	0.558	269	080	1.8	2331	14.0	13.4

APPENDIX F

MAINTENANCE RECORDS OF TEST FLEET

PICKUPS

Nonleaded

A-12232 Ford F100 1967 Sac City

9-2-71	new coil wire, set timing
11-2-71	tune-up
12-2-71	ground valves, surfaced heads, new coil

A-13555 Chev 10 1968 Sac City

A-14342 Chev 20 1969 Grundy Center

11-1-72	tune-up
2-1-72	new points

A-14343 Chev 1969 Grundy Center

8-4-71	tune-up, plug wires
11-1-72	tune-up

A-15896 Dodge 1971 Sac City

11-2-71	tune-up
3-6-72	carb kit

Leaded

A-14349 Chev 10 1969 Des Moines

5-25-71	tune-up

A-14367 Chev 10 1969 Ames

5-19-71	tune-up

A-14368 Chev 10 1969 Ames

5-17-71	tune-up

A-14369 Chev 10 1969 Ames

5-19-71	tune-up
11-5-71	tune-up

A-14370 Chev 10 1969 Ames

5-17-71	tune-up, plugs, points, cond

A-15192 Ames

2-10-72	tune-up
4-11-72	tune-up

A-15880 Dodge Des Moines

LIGHT DUTY

Nonleaded

A-13093 Chev. 50 1968 Grundy

- 6-2-71 carb cleaned
- 8-4-71 tune-up, valves ground
- 10-1-71 new engine
- 11-1-71 tune-up
- 3-2-72 new engine
- 4-28-72 tune-up (uses qt of oil/1000 miles)

A-13585 Chev. 1968 Sac City

- 9-2-71 new engine
- 2-4-72 uses qt of oil/800 miles

A-13870 Ford F600 1968 Grundy

- 6-25-71 new engine
- 10-1-71 new carb
- 12-1-71 new carb, tune-up

A-14264 Chev 50 1969 Sac City

- 6-3-71 new carb and front crankshaft pulley
- 11-2-71 tune-up
- 5-4-72 new engine

A-14576 Chev 50 1970 Grundy

- 4-6-71 tune-up
- 2-2-72 new carb

A-14680 GMC 1970 Sac City

- 4-13-71 tune-up
- 9-2-71 tune-up

A-15317 Int'l 1600 1970 Sac City

- 4-13-71 tune-up
- 11-2-71 tune-up

Leaded

A-14269 Chev 50 1969 Ames

- 5-19-71 tune-up
- 11-5-71 tune-up

A-14543 Chev 1970 Ames

- 5-11-71 tune-up
- 11-8-72 tune-up
- 5-11-72 tune-up

A-14575 Chev 50 1970 Ames

- 5-25-71 tune-up
- 11-5-71 tune-up
- 3-16-72 tune-up

A-1460 Chev 50 1970 Ames

- 6-15-71 tune-up

A-14683 GMC 1970 Des Moines

- 5-8-71 tune-up
- 11-3-71 tune-up

A-14692 GMC 1970 Des Moines

- 5-20-71 tune-up
- 11-3-71 tune-up
- 12-3-71 new carb

A-14691 GMC 1970 Marshalltown

- 5-19-71 tune-up
- 10-5-71 tune-up
- 3-13-72 tune-up

LIGHT DUTY (cont.)

Nonleaded

A-15369 Int'l 1600 1970 Grundy

Leaded

A-14698 GMC 1970 Marshalltown

5-21-71 tune-up
2-16-72 tune-up

A-15278 Int'l 1600 1970 Ames

5-11-71 tune-up
11-8-71 tune-up

A-15279 Int'l 1600 1970 Ames

5-10-71 tune-up

A-15414 Int'l 1600 1970 Ames

5-5-71 tune-up
11-5-71 tune-up
1-20-72 tune-up

A-15454 Int'l 1600 1970 Ames

5-5-71 tune-up
11-8-71 tune-up

HEAVY DUTY

Nonleaded

A-13857 Int'l 1700 1969 Sac City

10-20-71 tune-up
5-4-72 carb kit

A-14652 Ford 1800 1970 Grundy

4-6-71 tune-up
3-26-72 new carb
4-28-72 nee distributor

Leaded

A-14634 Ford 1970 Ames

5-25-71 tune-up
4-12-72 new engine

A-14647 Ford 1970 Des Moines

11-3-71 tune-up
1-11-72 tune-up, new carb and plug wires

A-14648 Ford 1970 Des Moines

11-3-71 tune-up
5-8-72 tune-up new carb

A-14670 Ford 1970 Des Moines

TRACTORS

Nonleaded

A-11028 Int'l 1965 Sac City

A-11504 Case Grundy Center

A-12698 Massey Ferg. 150 1967 Sac City

A-12732 Ford 1967 Grundy Center

6-25-71 new carb and coil

A-13634 John Deere 1969 Grundy

A-13662 Int'l 1968 Grundy

A-15555 John Deere 1970 Grundy

A-15564 Int'l Sac City

Leaded

A-13668 Int'l 1968 Ames

A-13669 Int'l 1968 Ames

5-10-71 new plugs
3-30-72 new muffler and tail pipe

A-13693 John Deere 1968 Marshalltown

5-28-71 tune-up

A-13696 John Deere 1968 Ames

11-9-71 tune-up, new wires
4-8-72 valves ground

Vehicle identification	Total hours	Total miles	Total gallons of gas consumed	Hours or miles per gallon of gas	Quarts of oil used for lubrication	Miles or hours per quart of oil used for lubrication	Quarts of oil consumed	Miles or hours per quart of oil consumed
Nonleaded								
Pickup								
A-12232		5,517	391.8	14.08	15	367.8	1	5517
A-13555								
A-14342		10,178	885.0	11.50	26	391.5	7	1454
A-14343		13,460	1234.5	10.90	36	373.9	22	612
A-15896		14,851	1273.8	11.66	40	371.3	7	2122
A-15943		4,958	497.0	9.98	12	413.2	4	1240
		48,964	4282.1	11.43	129	379.6	41	1194
Light duty								
A-13093		15,519	2539.8	6.11	50	310.4	20	776
A-13585		15,221	2507.0	6.07	49	310.6	15	1015
A-13870		15,818	2828.7	5.59	63	251.1	11	1438
A-14264		13,182	2447.9	5.39	35	376.6	19	694
A-14576		15,442	3000.0	5.15	56	275.8	12	1287
A-14680		18,986	3011.0	6.31	42	452.0	14	1356
A-15317		10,579	1752.8	6.04	45	235.1	8	1322
A-15369		14,096	2236.4	6.30	64	220.3	11	1281
		118,843	20323.6	5.85	404	294.2	110	1080

Vehicle identification	Total hours	Total miles	Total gallons of gas consumed	Hours or miles per gallon of gas	Quarts of oil used for lubrication	Miles or hours per quart of oil used for lubrication	Quarts of oil consumed	Miles or hours per quart of oil consumed
Heavy duty								
A-13857		3,048	864.0	3.53	38	80.2	8	381
A-14652		5,030	2144.0	2.35	72	69.9	19	265
		8,078	3008.0	2.69	110	73.4	27	299
Tractors								
A-11028								
A-11504	283.0		490.8	0.58	18	15.7	1	283
A-12698								
A-12732	164.0		339.5	0.48	17	9.6	1	164
A-13634	107.0		100.7	1.06	0	0.0	2	54
A-13662	22.0		37.6	0.59	0	0.0	0	0
A-15555	150.0		141.2	1.06	6	25.0	0	0
A-15564	524.0		840.5	0.62	18	29.1	0	0
	1250.0		1950.3	0.64	59	21.2	4	313
Leaded								
Pickup								
A-14349								
A-14367		2,045	171.0	11.96	0	0.0	0	0

Vehicle identification	Total hours	Total miles	Total gallons of gas consumed	Hours or miles per gallon of gas	Quarts of oil used for lubrication	Miles or hours per quart of oil used for lubrication	Quarts of oil consumed	Miles or hours per quart of oil consumed
A-14368								
A-14369		8,667	786.1	11.03	10	866.7	5	1733
A-14370								
A-15192								
A-15880		14,310	1295.0	11.05	32	447.2	7	2044
		25,022	2252.1	11.11	42	595.8	12	2085
Light duty								
A-14269		7,688	2007.0	3.83	35	219.7	3	2563
A-14543								
A-14575								
A-14602								
A-14683		2,948	710.0	4.15	0	0.0	5	590
A-14691		14,455	2820.0	5.13	42	344.2	29	498
A-14692		8,331	1458.0	5.71	21	396.7	0	0
A-14698		11,587	2241.0	5.17	36	321.9	8	1448
A-15278		6,709	866.0	7.86	36	205.6	1	6709
A-15279		7,065	714.0	10.97	45	155.0	6	1209
A-15414		17,774	2502.0	7.10	45	395.0	4	4444
A-15415		7,308	1088.0	6.72	54	135.3	1	7308

Vehicle identification	Total hours	Total miles	Total gallons of gas consumed	Hours or miles per gallon of gas	Quarts of oil used for lubrication	Miles or hours per quart of oil used for lubrication	Quarts of oil consumed	Miles or hours per quart of oil consumed
A-15454		8,204	1131.0	7.25	54	151.9	6	1367
		92,069	15537.0	5.93	368	250.2	63	1461
Heavy duty								
A-14634								
A-14647		3,203	1128.0	2.84	27	118.6	6	534
A-14648		4,385	1421.2	3.09	52	84.3	4	1096
A-14670								
		7,588	2549.2	2.98	79	96.1	10	759
Tractor								
A-13668								
A-13669								
A-13693	90.0		131.1	0.69	12	7.5	0	0
A-13696								
	90.0		131.1	0.69	12	7.5	0	0

APPENDIX H

CALIBRATION CHECK PROCEDURE USING CERTIFIED STANDARD GAS AND GAS CALIBRATION KIT #120-177

1. Plug power cord into 120 V, 60 Hz power source.

2. Turn EET-910 or 912 Power Switch to STANDBY positions.

3. Turn EET-910 or 912 Test Switch and valve to CALIBRATE positions.

4. Allow tester (EET-910 or 912) to reach normal operating temperature — (a minimum of 60 minutes operation in 70 °F room ambient or higher).

5. Set Power Switch to TEST Position, (pump on).

6. Adjust FLOW CONTROL VALVE (Access through top of tester head frame) to obtain an indication of 26 CFH as indicated on EET-910 or 912 FLOW INDICATOR.

7. Rotate SET LINE ADJUST controls on CARBON MONOXIDE AND HYDROCARBON until respective meters read on the zero SET LINE.

8. Observe meters (CO and HC) to insure that meter drift does not exceed the zero SET LINE, if meters indicate drift, allow more warm-up time.

9. Connect "CERTIFIED" STANDARD GAS to exhaust emission tester model EET-910 or 912 as outlined in (Page 12 October 1970) "Dual" Hookup for Gas Calibration Kit No. 120-177.

10. "Certified Standard Gas"

    CARBON MONOXIDE — shall be 2.5% CO in 97.5% Nitrogen (N_2) certified to actual mixture.

    HYDROCARBON — shall be 900 parts per million (PPM) (N Hexane) balance of tank to be Nitrogen (N_2) certified to actual mixture.

    (Caution!) You must extend exhaust hose outlet from EET-910 or 912 tester to a room exhaust system or through a window to the outside. Do not use in a confined area.

11. Turn EET-910 and 912 TEST SWITCH AND VALVE to TEST.

Carbon Monoxide Unit

12. Adjust output pressure (on pressure regulator, large green knob) to 5 plus or minus 1 pound per square inch (on CO tank).

13. Adjust GAS FLOW CONTROL (small black knob) to obtain an indication of 26 CFH as indicated on EET-910 or 912 FLOW INDICATOR.

14. Rotate SPAN SET CONTROL until CARBON MONOXIDE meter reads on SPAN SET line (or appropriate value of calibration gas if other than listed under item 10). Recheck set line. If meter indicates drift, repeat step 7, 8 and 14.

15. CARBON MONOXIDE meter should repeat Certified value of gas, plus or minus 1 Division. Turn CO tank valve to OFF.

Hydrocarbon Unit

16. Adjust output pressure (large green knob on pressure regulator) to 5 plus or minus 1 pound per square inch (on HC tank).

17. Adjust GAS FLOW CONTROL (small black knob) to obtain an indication of 26 CFH as indicated on EET-910 or 912 FLOW INDICATOR.

18. Rotate SPAN SET CONTROL until HYDROCARBON meter reads on SPAN SET line (or appropriate value of calibration gas if other than listed under item 10). Recheck set line. If meter indicates set line shift, repeat above procedure as required.

19. HYDROCARBON meter should repeat certified value of gas, plus or minus 2 Divisions. Turn HC tank Valve to Off.

20. If reading is not within tolerance (Hydrocarbon or Carbon Monoxide)

    a. Be sure all fittings are tight (no leaks).
    b. Flow is at proper rate (26 CFH).
    c. Gas sample is not too hot or too cold. (Use 25 ft of hose to normalize temperature.)
    d. Be sure EET-910 has reached normal operating temperature (no meter drift).
    e. If gas cylinder has been standing for a long time, the gas may have stratified. Insure proper mix by rolling cylinder or heating by means of hot water or heat lamp, etc.,
    f. If reading is not within tolerance, replace appropriate analyzer.

21. Disconnect the Calibration Gas Dual Hookup and connect the Exhaust Emission Sample Probe.

Vehicle Testing

22. With the Test Valve in the CALIBRATE position check and reset if necessary the zero reading on each meter.

23. With the Test Valve in the TEST position obtain the CO and HC meter readings. Repeat steps 22 and 23 for successive vehicle readings.

APPENDIX I

TEST FLEET ANALYSIS OF VARIANCE

ALL VEHICLES

Measured variable	Source of variation	Sums of squares	Degrees of freedom	F calculated	F critical
All vehicles					
HC (NDIR)	F	1.231E 5	1	8.07	3.84
	S	2.126E 6	1	139.28	3.84
	T	1.714E 6	3	37.44	2.60
	FxS	2.922E 4	1	1.92	3.84
	FxT	2.952E 5	3	6.45	2.60
	SxT	5.804E 5	3	12.68	2.60
	FxSxT	6.184E 4	3	1.35	2.60
	ERROR	1.319E 7	864	—	—
CO	F	1.241E 1	1	8.89	3.84
	S	9.105E 1	1	65.22	3.84
	T	4.602E 2	3	109.86	2.60
	FxS	3.538E-1	1	0.25	3.84
	FxT	8.676E 2	3	20.71	2.60
	SxT	1.087E 2	3	25.96	2.60
	FxSxT	1.272E 1	3	3.04	2.60
	ERROR	1.206E 3	864	—	—
A/F	F	2.900E-1	1	2.54	3.84
	S	1.564E 2	1	137.00	3.84
	T	2.694E 2	3	78.66	2.60
	FxS	6.000E-2	1	0.52	3.84
	FxT	5.350E 0	3	15.62	2.60
	SxT	8.710E 0	3	25.42	2.60
	FxSxT	7.200E-1	3	2.10	2.60
	ERROR	9.863E 1	864	—	—

Note: F = fuel
S = speed
T = type
1.319E 7 = 1.319×10^7

APPENDIX J

TEST FLEET ANALYSIS OF VARIANCE

VEHICLES SEPARATED BY TYPE

Measured variable	Source of variation	Sums of squares	Degrees of freedom	F calculated	F critical
Pickup					
HC (NDIR)	F	1.150E 3	1	2.39	3.91
	S	3.121E 3	1	6.50	3.91
	FxS	1.211E 4	1	25.21	3.91
	ERROR	6.532E 4	136	–	–
CO	F	9.908E-1	1	6.28	3.91
	S	2.971E 1	1	188.40	3.91
	FxS	6.687E-2	1	6.69	3.91
	ERROR	2.144E 1	136	–	–
A/F	F	1.383E 0	1	20.67	3.91
	S	1.211E 0	1	18.10	3.91
	FxS	1.812E-1	1	2.71	3.91
	ERROR	9.098E 0	136	–	–
Light duty					
HC (NDIR)	F	4.499E 5	1	22.81	3.85
	S	1.075E 6	1	54.52	3.85
	FxS	1.005E 5	1	5.10	3.85
	ERROR	7.414E 6	376	–	–
CO	F	4.622E 1	1	35.04	3.85
	S	1.767E 2	1	133.98	3.85
	FxS	5.397E 0	1	4.09	3.85
	ERROR	4.960E-2	376	–	–
A/F	F	1.488E 0	1	11.83	3.85
	S	2.991E 1	1	237.82	3.85
	FxS	4.005E-1	1	3.19	3.85
	ERROR	4.728E 1	376	–	–
Heavy duty					
HC (NDIR)	F	1.390E 4	1	0.50	3.92
	S	9.146E 5	1	32.84	3.92
	FxS	1.238E 4	1	0.44	3.92
	ERROR	3.231E 6	116	–	–

Measured variable	Source of variation	Sums of squares	Degrees of freedom	F calculated	F critical
CO	F	2.388E 1	1	10.51	3.92
	S	2.863E 1	1	12.61	3.92
	FxS	3.153E-1	1	0.14	3.92
	ERROR	2.635E 2	116	—	—
A/F	F	1.526E 0	1	10.02	3.92
	S	3.729E 0	1	24.48	3.92
	FxS	1.621E-1	1	1.06	3.92
	ERROR	1.767E 1	116	—	—
Tractor					
HC (NDIR)	F	2.447E 5	1	23.30	3.90
	S	1.196E 6	1	113.85	3.90
	FxS	2.778E 4	1	2.64	3.90
	ERROR	2.479E 6	236	—	—
CO	F	7.207E 1	1	39.99	3.90
	S	8.062E 0	1	4.47	3.90
	FxS	6.959E 0	1	3.86	3.90
	ERROR	4.253E 2	236	—	—
A/F	F	1.173E 0	1	8.90	3.90
	S	5.054E-1	1	3.83	3.90
	FxS	0.000E 0	1	0.00	3.90
	ERROR	3.112E 1	236	—	—

APPENDIX K

SPECIAL TEST FLEET VEHICLE ANALYSIS OF VARIANCE
(March and May data — all vehicles)

Measured variable	Source of variation	Sums of squares	Degrees of freedom	F calculated	F critical
All vehicles					
HC1	F	1.075E-1	1	24.55	3.90
	S	2.898E-1	1	66.17	3.90
	T	2.884E-2	3	2.20	2.65
	FxS	3.098E-3	1	0.71	3.90
	FxT	8.099E-2	3	6.16	2.65
	FxSxT	2.460E-2	3	1.87	2.65
	ERROR	7.664E-1	175	—	—
HC2	F	8.344E-1	1	122.92	3.90
	S	2.142E-1	1	31.55	3.90
	T	4.561E-2	3	2.40	2.65
	FxS	9.201E-3	1	1.36	3.90
	FxT	3.009E-2	3	1.48	2.65
	FxSxT	2.225E-2	3	1.09	2.65
	ERROR	1.188E-1	175	—	—
HC3	F	3.428E-1	1	46.26	3.90
	S	5.691E-3	1	0.77	3.90
	T	3.571E-2	3	1.61	2.65
	FxS	1.648E-3	1	0.22	3.90
	FxT	1.204E-1	3	5.42	2.65
	FxSxT	2.225E-2	3	1.00	2.65
	ERROR	1.297E 0	175	—	—
HCT (FID)	F	7.173E 3	1	0.25	3.90
	S	1.367E 6	1	47.35	3.90
	T	9.724E 5	3	11.22	2.65
	FxS	1.049E 4	1	0.36	3.90
	FxT	1.360E 5	3	1.57	2.65
	FxSxT	6.692E 4	3	0.77	2.65
	ERROR	5.054E 6	175	—	—
HC (NDIR)	F	4.930E 3	1	0.39	3.90
	S	5.303E 5	1	42.12	3.90
	T	1.713E 5	3	4.54	2.65
	FxS	5.531E 1	1	0.00	3.90
	FxT	1.237E 5	3	3.27	2.65
	FxSxT	1.472E 4	3	0.39	2.65
	ERROR	2.203E 6	175	—	—

Measured variable	Source of variation	Sums of squares	Degrees of freedom	F calculated	F critical
CO	F	2.688E-1	1	0.19	3.90
	S	6.054E 1	1	41.77	3.90
	T	8.495E 1	3	19.54	2.65
	FxS	6.914E-2	1	0.05	3.90
	FxT	2.374E 1	3	5.46	2.65
	FxSxT	4.484E 0	3	1.03	2.65
	ERROR	2.536E 2	175	—	—
NO_2	F	5.116E 3	1	0.60	3.90
	S	6.581E 5	1	77.15	3.90
	T	1.705E 5	3	6.66	2.65
	FxS	1.499E 4	1	1.76	3.90
	FxT	2.090E 4	3	0.82	2.65
	FxSxT	1.847E 4	3	0.72	2.65
	ERROR	1.493E 6	175	—	—
A/F	F	0.000E 0	1	0.00	3.90
	S	6.933E 0	1	62.21	3.90
	T	4.282E 0	3	12.81	2.65
	FxS	0.000E 0	1	0.00	3.90
	FxT	1.621E 0	3	4.85	2.65
	FxSxT	8.869E-1	3	2.65	2.65
	ERROR	1.950E 1	175	—	—
Pickup					
HC1	F	1.465E-1	1	34.76	4.20
	S	1.060E-2	1	2.52	4.20
	FxS	1.445E-2	1	3.43	4.20
	ERROR	1.180E-1	28	—	—
HC2	F	1.990E-1	1	19.90	4.20
	S	2.442E-2	1	2.44	4.20
	FxS	1.014E-2	1	1.01	4.20
	ERROR	1.356E-1	28	—	—
HC3	F	4.106E-3	1	1.11	4.20
	S	2.871E-3	1	0.78	4.20
	FxS	3.929E-4	1	0.11	4.20
	ERROR	1.035E-1	28	—	—
HCT (FID)	F	2.156E 4	1	0.60	4.20
	S	8.214E 4	1	2.28	4.20
	FxS	7.512E 3	1	0.21	4.20
	ERROR	1.010E 6	28	—	—

Measured variable	Source of variation	Sums of squares	Degrees of freedom	F calculated	F critical
HC (NDIR)	F	2.655E 4	1	1.56	4.20
	S	1.788E 4	1	1.05	4.20
	FxS	3.685E 3	1	0.22	4.20
	ERROR	4.759E 5	28	—	—
CO	F	7.007E-2	1	0.13	4.20
	S	1.340E 1	1	23.99	4.20
	FxS	3.101E 0	1	0.56	4.20
	ERROR	1.564E 1	28	—	—
NO_2	F	7.904E 2	1	1.00	4.20
	S	8.337E 4	1	105.28	4.20
	FxS	1.985E 3	1	2.51	4.20
	ERROR	2.217E 4	28	—	—
A/F	F	5.722E-2	1	1.17	4.20
	S	4.143E-1	1	8.48	4.20
	FxS	9.537E-3	1	0.20	4.20
	ERROR	1.369E-1	28	—	—
Light duty					
HC1	F	6.194E-2	1	11.49	3.98
	S	1.204E-2	1	22.33	3.98
	FxS	4.291E-5	1	0.01	3.98
	ERROR	4.314E-1	80	—	—
HC2	F	2.644E-1	1	37.01	3.98
	S	1.321E-1	1	18.49	3.98
	FxS	3.137E-3	1	0.44	3.98
	ERROR	5.715E-1	80	—	—
HC3	F	7.043E-2	1	7.66	3.98
	S	2.537E-4	1	0.03	3.98
	FxS	4.032E-3	1	0.44	3.98
	ERROR	7.361E-1	80	—	—
HCT (FID)	F	1.724E 5	1	5.77	3.98
	S	7.307E 5	1	24.46	3.98
	FxS	5.078E 4	1	1.70	3.98
	ERROR	2.390E 6	80	—	—

Measured variable	Source of variation	Sums of squares	Degrees of freedom	F calculated	F critical
HC (NDIR)	F	1.080E 5	1	6.61	3.98
	S	2.446E 5	1	14.98	3.98
	FxS	1.159E 4	1	0.71	3.98
	ERROR	1.306E 6	80	—	—
CO	F	1.371E 1	1	9.88	3.98
	S	5.174E 1	1	37.27	2.98
	FxS	9.794E-1	1	0.71	3.98
	ERROR	1.111E 2	80	—	—
NO_2	F	3.424E 3	1	1.35	3.98
	S	1.707E 5	1	67.22	3.98
	FxS	8.819E 2	1	0.35	3.98
	ERROR	2.031E 5	80	—	—
A/F	F	9.537E-1	1	8.21	3.98
	S	5.999E 0	1	51.61	3.98
	FxS	2.003E-1	1	1.72	3.98
	ERROR	9.298E 0	80	—	—
Heavy duty					
HC1	F	1.073E-3	1	0.86	4.35
	S	7.800E-2	1	62.88	4.35
	FxS	1.364E-4	1	0.11	4.35
	ERROR	2.481E-2	20	—	—
HC2	F	1.763E-1	1	17.40	4.35
	S	2.646E-2	1	2.61	4.35
	FxS	4.741E-3	1	0.47	4.35
	ERROR	2.026E-1	20	—	—
HC3	F	1.489E-1	1	20.01	4.35
	W	1.337E-2	1	1.80	4.35
	FxS	3.417E-3	1	0.46	4.35
	ERROR	1.488E-1	20	—	—
HCT (FID)	F	2.298E 2	1	0.01	4.35
	S	3.687E 5	1	8.37	4.35
	FxS	4.719E 4	1	1.07	4.35
	ERROR	8.809E 5	20	—	—
HC (NDIR)	F	3.728E 3	1	0.48	4.35
	S	8.543E 4	1	10.92	4.35
	FxS	2.480E 3	1	0.32	4.35
	ERROR	1.564E 5	20	—	—

Measured variable	Source of variation	Sums of squares	Degrees of freedom	F calculated	F critical
CO	F	1.055E 1	1	4.04	4.35
	S	5.135E 0	1	1.97	4.35
	FxS	1.725E 0	1	0.66	4.35
	ERROR	5.223E 1	20	—	—
NO_2	F	1.810E 4	1	14.59	4.35
	S	4.839E 4	1	39.01	4.35
	FxS	1.428E 4	1	11.51	4.35
	ERROR	2.481E 4	20	—	—
A/F	F	6.753E-1	1	7.69	4.35
	S	6.771E-1	1	7.71	4.35
	FxS	3.856E-1	1	4.39	4.35
	ERROR	1.756E 0	20	—	—
Tractor					
HC1	F	1.999E-3	1	0.53	4.08
	S	1.076E-1	1	28.64	4.08
	FxS	3.927E-3	1	1.05	4.08
	ERROR	1.653E-1	44	—	—
HC2	F	2.825E-1	1	45.58	4.08
	S	3.658E-2	1	5.90	4.08
	FxS	1.552E-3	1	0.25	4.08
	ERROR	2.728E-1	44	—	—
HC3	F	2.372E-1	1	37.44	4.08
	S	1.870E-2	1	2.95	4.08
	FxS	1.042E-2	1	1.64	4.08
	ERROR	2.787E-1	44	—	—
HCT (FID)	F	6.501E 3	1	0.42	4.08
	S	2.722E 5	1	17.44	4.08
	FxS	7.491E 3	1	0.48	4.08
	ERROR	6.867E 5	44	—	—
HC (NDIR)	F	3.840E 4	1	7.61	4.08
	S	2.252E 5	1	44.65	4.08
	FxS	8.392E 1	1	0.02	4.08
	ERROR	2.219E 5	44	—	—
CO	F	7.370E 0	1	5.11	4.08
	S	1.450E 0	1	1.00	4.08
	FxS	1.043E-2	1	0.01	4.08
	ERROR	6.352E 2	44	—	—

Measured variable	Source of variation	Sums of squares	Degrees of freedom	F calculated	F critical
NO_2	F	1.626E 3	1	0.06	4.08
	S	4.542E 5	1	17.47	4.08
	FxS	1.240E 3	1	0.05	4.08
	ERROR	1.144E 6	44	—	—
A/F	F	1.919E-1	1	1.67	4.08
	S	7.176E-1	1	6.25	4.08
	FxS	4.590E-2	1	0.40	4.08
	ERROR	5.050E 0	44	—	—

APPENDIX L

MATCHED PAIR VEHICLE ANALYSIS OF VARIANCE

Measured variable	Source of variation	Sums of squares	Degrees of freedom	F calculated	F critical
Pickup					
HC (NDIR)	P	1.071E 4	3	2.48	2.85
	F	6.769E 3	1	4.71	4.09
	L	4.810E 4	2	16.73	3.24
	FxL	3.406E 2	2	0.12	3.24
	ERROR	5.606E 4	39	—	—
CO	P	1.984E 1	3	3.80	2.85
	F	9.075E-1	1	0.52	4.09
	L	2.279E 2	2	65.48	3.24
	FxL	1.899E 0	2	0.55	3.24
	ERROR	6.786E 1	39	—	—
NO_2	P	2.602E 6	3	2.13	2.85
	F	2.252E 5	1	0.55	4.09
	L	7.816E 6	2	9.57	3.24
	FxL	1.415E 6	2	1.73	3.24
	ERROR	1.592E 7	39	—	—
Light duty					
HC (NDIR)	P	3.051E 4	3	18.55	2.78
	F	3.906E 1	1	0.07	4.02
	L	2.923E 4	3	17.77	2.78
	FxL	7.172E 2	3	0.44	2.78
	ERROR	2.906E 4	53	—	—
CO	P	5.077E 1	3	9.91	2.78
	F	1.114E 1	1	6.52	4.02
	L	1.522E 2	3	29.71	2.78
	FxL	2.478E 0	3	0.48	2.78
	ERROR	9.050E 1	53	—	—
NO_2	P	4.232E 6	3	5.14	2.78
	F	8.948E 4	1	0.33	4.02
	L	6.231E 6	3	7.57	2.78
	FxL	1.514E 5	3	0.18	2.78
	ERRORS	1.454E 7	53	—	—

Measured variable	Source of variation	Sums of squares	Degrees of freedom	F calculated	F critical
Heavy duty					
HC (NDIR)	P	2.813E 3	1	7.05	4.28
	F	3.200E 3	1	8.02	4.28
	L	3.746E 4	3	31.30	3.03
	FxL	1.075E 3	3	0.90	3.03
	ERROR	9.175E 3	23	—	—
CO	P	7.508E 0	1	7.22	4.28
	F	1.128E-1	1	0.11	4.28
	L	8.053E 1	3	25.83	3.03
	FxL	6.561E 0	3	2.10	3.03
	ERROR	2.390E 1	23	—	—
NO_2	P	7.293E 5	1	1.38	4.28
	F	1.763E 5	1	0.33	4.28
	L	5.178E 6	3	3.28	3.03
	FxL	4.742E 5	3	0.30	3.03
	ERROR	1.219E 7	23	—	—

APPENDIX M

MATCHED PAIR VEHICLE ANALYSIS OF VARIANCE
(April data)

Measured variable	Source of variation	Sums of squares	Degrees of freedom	F calculated	F critical
Pickup					
HC1	P	5.653E-2	3	8.16	3.29
	F	9.048E-3	1	3.92	4.54
	L	3.511E-2	2	9.76	3.68
	FxL	2.833E-3	2	0.61	3.68
	ERROR	3.465E-2	15	–	–
HC2	P	2.083E-1	3	64.07	3.29
	F	7.704E-3	1	7.11	4.54
	L	1.088E-2	2	5.02	3.68
	FxL	4.763E-4	2	0.22	3.68
	ERROR	1.626E-2	15	–	–
HC3	P	3.082E-1	3	102.66	3.29
	F	4.817E-5	1	0.05	4.54
	L	1.170E-2	2	5.85	3.68
	FxL	1.938E-3	2	0.97	3.68
	ERROR	1.501E-2	15	–	–
HCT (FID)	P	3.014E 4	3	0.98	3.29
	F	4.075E 4	1	3.98	4.54
	L	1.535E 5	2	7.50	3.68
	FxL	2.686E 3	2	0.13	3.68
	ERROR	1.535E 5	15	–	–
HC (NDIR)	P	1.403E 4	3	2.92	3.29
	F	4.538E 3	1	2.83	4.54
	L	2.280E 4	2	7.12	3.68
	FxL	1.750E 2	2	0.06	3.68
	ERROR	2.401E 4	15	–	–
CO	P	7.515E 0	3	0.84	3.29
	F	3.267E-1	1	0.11	4.54
	L	9.841E 1	2	16.53	3.68
	FxL	2.503E 0	2	0.42	3.68
	ERROR	4.465E 1	15	–	–

Measured variable	Source of variation	Sums of squares	Degrees of freedom	F calculated	F critical
NO_2	P	6.826E 6	3	6.27	3.29
	F	2.176E 5	1	0.60	4.54
	L	3.679E 6	2	5.07	3.68
	FxL	1.231E 6	2	1.70	3.68
	ERROR	5.448E 6	15	—	—
Light duty					
HC1	P	3.746E-2	3	3.34	3.07
	F	2.245E-3	1	0.60	4.32
	L	1.065E-1	3	9.48	3.07
	FxL	5.562E-4	3	0.05	3.07
	ERROR	7.862E-2	21	—	—
HC2	P	9.055E-2	3	5.89	3.07
	F	2.178E-3	1	0.43	4.32
	L	1.102E-1	3	7.17	3.07
	FxL	1.729E-3	3	0.11	3.07
	ERROR	1.077E-1	21	—	—
HC3	P	1.039E-2	3	2.10	3.07
	F	7.081E-3	1	4.29	4.32
	L	2.245E-4	3	0.05	3.07
	FxL	1.294E-3	3	0.26	3.07
	ERROR	3.466E-2	21	—	—
HCT (FID)	P	2.496E 5	3	21.15	3.07
	F	1.128E 3	1	0.29	4.32
	L	9.932E 4	3	8.42	3.07
	FxL	4.599E 3	3	0.39	3.07
	ERROR	8.260E 4	21	—	—
HC (NDIR)	P	3.197E 4	3	38.96	3.07
	F	2.531E 2	1	0.93	4.32
	L	1.762E 4	3	21.47	3.07
	FxL	1.031E 2	3	0.13	3.07
	ERROR	5.744E 3	21	—	—
CO	P	4.650E 1	3	6.06	3.07
	F	8.611E 0	1	3.36	4.32
	L	6.668E 1	3	8.68	3.07
	FxL	2.016E 0	3	0.26	3.07
	ERROR	5.375E 1	21	—	—

Measured variable	Source of variation	Sums of squares	Degrees of freedom	F calculated	F critical
NO_2	P	4.478E 6	3	14.98	4.87
	F	7.097E 4	1	0.71	4.32
	L	1.320E 6	3	4.41	3.07
	FxL	9.983E 4	3	0.33	3.07
	ERROR	2.092E 6	21	—	—
Heavy duty					
HC1	P	9.604E-3	1	13.64	5.59
	F	6.162E-3	1	8.75	5.59
	L	2.985E-2	3	14.13	4.35
	FxL	7.183E-3	3	3.40	4.35
	ERROR	4.928E-3	7	—	—
HC2	P	5.776E-3	1	3.93	5.59
	F	7.310E-3	1	4.97	5.59
	L	6.483E-3	3	1.47	4.35
	FxL	1.120E-2	3	2.79	4.35
	ERROR	1.030E 2	7	—	—
HC3	P	3.019E-2	1	38.36	5.59
	F	6.006E-5	1	0.08	5.59
	L	2.173E-2	3	9.20	4.35
	FxL	1.153E-3	3	0.49	4.35
	ERROR	5.509E-3	7	—	—
HCT (FID)	P	7.426E 2	1	0.88	5.59
	F	4.001E 3	1	4.76	5.59
	L	3.668E 4	3	14.56	4.35
	FxL	4.115E 3	3	1.63	4.35
	ERROR	5.879E 3	7	—	—
HC (NDIR)	P	5.641E 2	1	1.22	5.59
	F	8.266E 2	1	1.78	5.59
	L	1.720E 4	3	12.36	4.35
	FxL	1.805E 3	3	1.30	4.35
	ERROR	3.248E 3	7	—	—
CO	P	3.306E-1	1	0.40	5.59
	F	5.625E-3	1	0.01	5.59
	L	2.371E 1	3	9.58	4.35
	FxL	6.947E 0	3	2.81	4.35
	ERROR	5.774E 0	7	—	—

Measured variable	Source of variation	Sums of squares	Degrees of freedom	F calculated	F critical
NO_2	P	2.483E 5	1	0.95	5.59
	F	2.009E 4	1	0.08	5.59
	L	3.269E 6	3	4.18	4.35
	FxL	7.189E 5	3	0.92	4.35
	ERROR	1.826E 6	7	—	—

APPENDIX N

CRANKCASE OIL RESIDUE FOR SELECTED SAMPLES FROM TEST FLEET

Vehicle A number	Gasoline type	Vehicle type	Miles on oil	Weight of reside (mg/mile)
14652	Nonleaded	Heavy duty	621	3.45
13857	Nonleaded	Heavy duty	490	11.05
13093	Nonleaded	Light duty	1566	4.63
13870	Nonleaded	Light duty	2031	14.38
14576	Nonleaded	Light duty	2110	9.42
15369	Nonleaded	Light duty	1481	3.75
13585	Nonleaded	Light duty	1947	2.16
14264	Nonleaded	Light duty	1900	4.08
14680	Nonleaded	Light duty	2077	7.71
15317	Nonleaded	Light duty	1628	56.52
14342	Nonleaded	Pickup	2025	7.60
14343	Nonleaded	Pickup	1772	7.06
15896	Nonleaded	Pickup	1948	7.06
15943	Nonleaded	Pickup	2023	10.68
14670	Leaded	Heavy duty	550*	8.27
14647	Leaded	Heavy duty	554	13.06
14575	Leaded	Light duty	1500*	19.20
14683	Leaded	Light duty	1500*	36.31
15279	Leaded	Light duty	1750	17.97
15415	Leaded	Light duty	1950	6.40
14269	Leaded	Light duty	1736	2.82

Vehicle A number	Gasoline type	Vehicle type	Miles on oil	Weight of reside (mg/mile)
14698	Leaded	Light duty	1924	9.85
15278	Leaded	Light duty	1400*	31.62
15414	Leaded	Light duty	1400	3.82
15880	Leaded	Pickup	1984	4.46
14368	Leaded	Pickup	1643	1.63
14369	Leaded	Pickup	1600*	8.49
14370	Leaded	Pickup	489	7.25

*Estimated.