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EFFECT OF GASOLINE ADDITIVES ON GASEOUS EMISSIONS (Part II)

Environmental Sciences Research Laboratory
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EFFECT OF GASOLINE ADDITIVES ON GASEOUS EMISSIONS (PART II)

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SECTION I
INTRODUCTION

The continuing desire for lower and lower exhaust emissions demands that engines be operated in a narrow range of engine adjustment; and as lower emissions are required, the available range of engine adjustment becomes increasingly narrow. This demand for invariant engine alignment creates a great need to keep deposits from forming in sensitive areas such as the carburetor and intake manifold. The obvious way to keep these sensitive areas clean is to use an effective cleaning agent or additive in the fuels. Various suppliers have formulated many fuel additives that effectively keep these sensitive areas clean, but have given little attention to what happens to the additives during combustion and subsequent emission as exhaust.

No standard procedure has yet been specified for testing the effect of fuel additives in keeping engines clean, and no chemical procedures are available for determining the amount or character of any additive-related materials that may be emitted in the exhaust.

OBJECTIVE

The Environmental Protection Agency (EPA) has contracted with the Bartlesville (Okla.) Energy Research Center (BERC) of the Energy Research and Development Administration (ERDA) to develop a basic methodology for the standardization of test procedures involving fuel additives, and to supply information relating the effects of fuel additives upon pollutants emitted by late-model, spark-ignition, reciprocating and rotary engines. The BERC has performed investigations under three separate interagency agreements. The results of work performed under the first agreement, No. EPA-IAG-097(D), have been reported to EPA under the title,"Effect of Gasoline Additives on Gaseous Emissions"[1]. Briefly, the objective of that study was to establish a methodology for testing the effects of fuel additive. The program included tests with a nonmetallic, multifunctional cleaning additive and a metallic, octane-improving additive used in conjunction with five reciprocating engines (two stationary engines and three vehicles).

The results of work performed under the second and third agreements are presented in this report. The effect of gasoline additives upon the emission of pollutants from reciprocating engines and rotary engines was investigated. Although the engine types tested under the two agreements differ considerably, the program goals were similar, and separate reports would be redundant. Consequently, no differentiation is made between elements of the two agreements.

The purpose of the study was to determine whether additive fragments or additive-related derivatives appear in the exhaust as a result of the presence of various additives in the fuel and whether the use of these gasoline additives directly effects the character and/or composition of normally emitted exhaust components. Toward this objective, the number of fuel additives tested was increased to six, and each additive was tested with four 1974 model vehicles. Vehicle and engine classes represented were: (1) one economy vehicle with air-cooled engine, (2) two vehicles with medium-sized engines representing a high, nationwide population

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[1] Effect of Gasoline Additives on Gaseous Emissions. Environmental Protection Technology Series, Report No. EPA-560/2-75-014, 1974, 64 pp.

percentage, and (3) one medium-to-light vehicle with rotary engine. In addition, extended mileage tests were made using three of the six additives with a 1973 rotary engine mounted on a test stand.

As a result of the study, analytical methods developed specifically for nitrogen compounds have been improved, and some insight has been gained concerning the stability of several nitrogen compounds in the presence of auto exhaust.

SECTION II
CONCLUSIONS

This study was designed to produce test data from which conclusions could be drawn concerning the effect of gasoline additives upon the emissions of pollutants from spark ignition automotive engines. The scope of the study was as broad as practical and included tests of several additives with both reciprocating and rotary engines. Periodic engine adjustment checks were made to ensure their stability throughout the program.

Analytically, both "routine" and specific exhaust measurements were made in an effort to determine the fate of the additive material. Methods for the routine measurements (CO, CO_2, HC, NO_x, and aldehydes) are well established but preliminary exhaust spiking experiments with the compounds included in the specific measurements (nitrogen containing compounds other than NO_x) were necessary to eliminate repeated, nonproductive analyses.

The following are conclusions derived from the information generated by this study.

In the presence of auto exhaust, the nitrogen compounds proposed for analysis fall into one of four categories:

1. Unstable and not detectable--ammonia, alkyl and aryl amines, pyridines, alkyl (and probably aryl) nitriles, and dialkyl N-nitrosoamines.

2. Stable but not produced in detectable quantities--aryl nitro compounds.

3. Unstable but usually detectable--hydrogen cyanide and cyanogen.

4. Stable and produced in detectable quantities--alkyl nitro compounds.

Aryl nitriles were not detectable in the exhaust samples, but since their instability was not determined, nondetectability may have been the result of either decomposition or extremely low emission levels. The apparent instability of hydrogen cyanide and cyanogen may have been caused by analytical inadequacies.

At the commercially recommended dosages, the presence of the tested additives in gasoline would not have an immediate, measurable effect on the emission levels of carbon monoxide (CO), hydrocarbon (HC), oxides of nitrogen (NO_x), and aldehydes unless several active fragments were produced by each additive molecule. The recommended dosages are too small to produce (directly or indirectly) these exhaust components in quantities large enough to measurably change the normal exhaust levels unless some synergistic mechanisms were involved. Conversely, additive fragmentation or action within the exhaust could conceivably effect the much lower emission levels of CH_3NO_2, $CH_3CH_2NO_2$, HCN, and NCCN.

The data, however, presented no evidence that the presence of any of the additives in the fuel had an immediate effect upon the emission level of any of the measured exhaust components. Though the fate of additive nitrogen was not determined directly, it could, as stated previously, all appear as NO_x without measurably changing the exhaust concentration.

An inverse relationship was found to exist between NO_x and nitromethane exhaust levels of the vehicles involved in the program. The relationship of these emissions from the stationary Mazda engine did not conform to that established for the vehicles. Additional data points with NO_x emission levels in the ranges 0 to 5 and 9 to 14 grams/test are needed to completely establish the NO_x-CH_3NO_2 relationship.

Developmental experimentation specifically with cyanogen and hydrogen cyanide is needed to establish the source of, and correct the analytical nonreproducibility associated with these compounds.

SECTION III
EXPERIMENTAL APPARATUS

EXHAUST SOURCES

The vehicles, engines, and transmissions used in the program were as follows:

Vehicle	Engine	Transmission
1974 Ford sedan	351-CID	automatic
1974 Chevelle sedan	350-CID	automatic
1974 Volkswagen sedan	1,500 CC	standard
1974 Mazda sedan	rotary 2X35-CID	automatic
1973 Mazda engine	rotary 2X35-CID	automatic

The 1973 Mazda engine was mounted on a test stand and coupled to an eddy-current dynamometer with an inertial system to simulate actual vehicle driving.

The prototype staged-combustion or stratified-charge engine and the prototype 1975 catalyst-equipped medium sedan specified in the original work plans were omitted from the program by mutual consent of EPA and BERC.

ADDITIVES

The fuel additives specified in the program were all nonmetallic additives and are described below:

1. Chevron F310 (polybutene amine in a carrier oil) is a multifunctional cleaning additive and deposit modifier. F310 dosage was 1,232 lb/1,000 bbl of gasoline.

2. DuPont DMA4 (amine neutralized alkyl phosphate) is a multifunctional cleaning additive and controls carburetor deposit formation. DMA4 dosage was 15 lb/1,000 bbl of gasoline.

3. Lubrizol 8101 (succinamid) is a multifunctional dispersant-type additive. 8101 dosage was 140 lb/1,000 bbl of gasoline.

4. Texaco TFA 318 (polyisopropylene carrier oil) primarily controls induction system deposit buildup and especially prevents the adherence of deposits to the intake valve tulip. TFA 318 dosage was 220 lb/1,000 bbl of gasoline.

5. DuPont DMA 51 (carboxylate) is a multifunctional cleaning additive and deposit modifier. DMA 51 dosage was 15 lb/1,000 bbl of gasoline.

6. Lubrizol 8101 and Texaco TFA 318 described above were used in combination with a dosage of 140 lb Lubrizol 8101 plus 220 lb of Texaco TFA 318 per 1,000 bbl of fuel.

FUELS

The primary, unleaded fuel for the program was supplied by EPA. The high aromatic fuel used in the program was a blend of the EPA fuel and a heavy platformate stock. Inspection data for the fuels are presented in tables 1 and 2.

TABLE 1. - Inspection data for test fuel

Distillation ASTM D-86		
Evaporated, pct	° F	Reid vapor pressure 9.1 psia
5	112	
10	122	Specific gravity 0.7334
20	141	
30	160	FIA analysis, pct
40	172	Aromatic 23
50	194	Olefin 7
60	210	Saturate 70
70	227	
80	240	
90	285	
95	341	

Mole fraction summation

Carbon No.	Paraffins	Olefins	Aromatics
1	0	0	0
2	0	0	0
3	0	0	0
4	0.0716	0	0
5	.3795	0.0096	0
6	.0532	.0128	0.0012
7	.0642	.0270	.1436
8	.1244	.0035	.0469
9	.0219	.0024	.0208
10	.0056	0	.0096
11	.0023	0	0
Total	0.7227	0.0553	0.2221

TABLE 2. - Inspection data for high aromatic test fuel

Distillation ASTM D-86		
Evaporated, pct	° F	Specific gravity 0.7519
5	128	
10	140	FIA analysis, pct
20	162	Aromatic 30
30	182	Olefin 7
40	200	Saturate 63
50	216	
60	222	
70	240	
80	252	
90	290	
95	338	

Mole fraction summation			
Carbon No.	Paraffins	Olefins	Aromatics
1	0	0	0
2	0	0	0
3	0	0	0
4	0.0319	0	0
5	.1195	0.0036	0
6	.1467	.0090	0.0015
7	.0754	.0327	.2506
8	.1581	.0047	.0736
9	.0212	.0052	.0331
10	.0074	.0007	.0173
11	.0019	0	0
Total	0.5621	0.0619	0.3761

SECTION IV
EXPERIMENTAL DESIGN

The vehicles were acquired new and driven in moderately severe highway driving for 2,000 miles using clear test fuel to "break in" the engine and stabilize emission levels. The engines were adjusted to factory specifications and checked regularly to ensure adjustments stability. Other than the specific items referred to later in this report, no engine adjustments were changed or any items replaced (other than regular oil changes) during the test program.

All vehicles were "soaked" before testing in an appropriate 75° F area; however, the Ford and Chevrolet vehicles were tested on a large roll chassis dynamometer at ambient temperature. Efforts were made to run the test with a minimum elapsed time between the 75° F soak area and the uncontrolled ambient temperature area. The Volkswagen and Mazda vehicles were both "soaked" and tested in a controlled environment of 75° F. The stationary engine while in an uncontrolled ambient area used controlled temperature intake air.

Three separate routes or duty cycles were chosen for the different segments of the program. Each vehicle was fitted with a recording tachograph to ensure proper route profiles. The three routes were:

1. The city route, shown in figure 1, was chosen to simulate the driving cycle of the Federal test procedure. The city route contains the same number of stops, same average speed, and a similar 55 to 57 mph portion as the Federal driving cycle and requires 20 minutes to complete.

2. The combined city and highway route consisted of 1 hour spent on the city route described above followed by 1 hour of highway driving at an average speed of 55 mph, resulting in an overall average speed of about 35 mph. The highway portion involved a round trip from Bartlesville, OK to Pawhuska, OK, some 50 miles per trip.

3. The highway route (duty cycle) was used for the test stand engine only and consisted of 50 mph constant speed at road load.

Data points for each additive for the reciprocating-engine vehicles (Ford, Chevrolet, and Volkswagen) consisted of a single test point with the clear fuel followed by duplicate test points with the additive-treated fuel. Additional single tests were conducted at 500 miles and 1,500 elapsed miles with the additive-treated fuel followed by a single test with the high aromatic fuel treated with the additive. The next series of tests for the next additive was then begun without further engine conditioning. The driving cycle for the reciprocating-engine vehicles consisted entirely of the repetitive city routes previously described. All six fuel additives were used in each reciprocating-engine vehicle.

The rotary-engine vehicle tests consisted of a single data point with the clear fuel followed by duplicate data points with the additive-treated fuel. Additional single data points were collected at 1,000; 2,000; and 3,000 elapsed miles with the additive-treated fuel. The final data point consisted of a single test with the clear fuel. The vehicle was then conditioned with clear fuel for 1,000 miles of moderately severe highway driving before the series of tests with the next additive was begun. The combined city and highway driving route was used with the rotary-engine vehicle to accumulate mileage while using the fuel additives. All six fuel additives were used in the rotary-engine vehicle.

Extended mileage-accumulation tests were conducted using a rotary engine mounted on a test stand and coupled to a dynamometer and an inertia system. A series of tests for a single additive consisted of a single test with clear fuel at the start, immediately followed by duplicate tests with the additive-treated fuel. Comparison tests, one test with clear fuel, and one test with additive-treated fuel, were conducted at 1,000; 3,000; 9,000; and 15,000 elapsed miles. Single tests with the additive-treated fuel were conducted at 6,000 and 12,000 elapsed miles. The engine was then conditioned for 1,000 miles with clear fuel before tests with the next additive were begun. The highway duty cycle was used for all accumulation work with the stationary rotary engine. Three of the six fuel additives were used for the extended mileage tests with the stationary rotary engine.

ROUTINE ANALYSES

The 1975 Federal test procedure[2] was used on all vehicular and engine testing.

Analytical methods for determining exhaust components included in the program and considered to be routine are:

1. Total hydrocarbon by flame ionization detection (FID)--Beckman 400.

2. Nitrogen dioxide (NO_2) and oxides of nitrogen by chemiluminescence--Thermo Electron 10A.

3. Carbon monoxide and carbon dioxide (CO_2) by nondispersive infrared (NDIR) absorption--Beckman 315.

4. Total aldehydes by 3-methyl-2-benzothiazolone hydrozone (MBTH) colorimetry[3]--Spectronic 20.

The samples for total aldehyde analysis were metered directly from the constant volume sampling (CVS) system into the MBTH reagent solution. With this exception, samples for all routine analyses were collected from the CVS system in light-proof Tedlar bags.

ANALYSIS FOR NITROGEN COMPOUNDS

The basic methodology for nitrogen compound analysis was developed as a part of a previous study[4], and initially, these analytical procedures essentially were

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[2] U.S. Code of Federal Regulations. Title 40--Protection of Environment; Chapter I--Environmental Protection Agency; Part 85--Control of Air Pollution from New Motor Vehicles and New Motor Vehicle Engines. Federal Register, v. 39, No. 101, May 23, 1974, pp. 18076-18084.

[3] Coordinating Research Council, Inc. Oxygenates in Automotive Exhaust Gas: Part I. Techniques for Determining Aldehydes by the MBTH Method. Report No. 415, June 1968, 21 pp.

[4] Effect of Gasoline Additives on Gaseous Emissions. Environmental Protection Technology Series. Report No. EPA-650/2-75-014, 1974, 64 pp.

duplicated. A PE-900 gas chromatograph was fitted with a Coulson electrolytic conductivity detector and the appropriate column. Vapor samples were taken directly from bags containing exhaust collected according to the 1975 Federal test procedure and injected into the chromatograph via a 25 cm^3 gas-sample loop. Figure 2 shows a schematic of the analytical system. Separate injection systems were installed on the chromatograph for basic or acidic compound analysis, and each system was preconditioned with ammonia or hydrogen cyanide.

Three separate chromatographic columns provided the capability to separate and distinguish the various nitrogen-containing compounds, and a fourth column was ultimately used to obtain most of the nitrogen compound data.

Chromatographic conditions for the analysis of ammonia, light aliphatic amines, and pyridine were:

1. Column: 10 feet by 1/8 in O.D. stainless steel tubing packed with 15 pct Carbowax 600 plus 10 pct KOH on 80/100 mesh Gas-Chrom R.

2. Carrier: Helium flowing at 48 cc/min.

3. Temperature program: Hold at 25° C for 2 minutes, then program at 5° C/min to 120° C.

Substances such as acetonitrile, pyrrolidine, and cyclohexylamine also can be analyzed on this column.

Chromatographic conditions for the analysis of all of the preceding nitrogen compounds (but with less resolution), N-nitrosoamines, nitrosoaromatics, nitroaromatics, aromatic nitriles, and aromatic amines were:

1. Column: 3 feet by 1/8 in O.D. stainless steel tubing packed with 15 pct Carbowax 1540 plus 10 pct KOH on 80/100 mesh GC-22.

2. Carrier: Helium flowing at 52 cc/min.

3. Temperature program: Hold at 35° C for 2 minutes, then program at 6.5° C/min to 180° C.

Molecular size for this column is limited to about C_8.

Initial chromatographic conditions for the analysis of cyanogen, hydrogen cyanide, nitromethane, nitroethane, and acetonitrile were:

1. Column: 2-1/2 feet by 1/8 in O.D. stainless steel tubing packed with Carbopack B treated with three to four drops of H_3PO_4.

2. Carrier: Helium flowing at 42-1/2 cc/min.

3. Temperature program: Hold at -70° C for 6 minutes, then program at 13° C/min to 180° C.

Over 80 pct of the cyanogen, hydrogen cyanide, nitromethane, and nitroethane data presented in this report was obtained using the following chromatographic setup:

1. Column: 8 feet by 1/8 in O.D. stainless steel tubing packed with 80/100 mesh Chromosorb 101.

2. Carrier: Hydrogen flowing at 165 cc/min.

3. Temperature program: 0° to 180° C at 13° C/min, then purge isothermally at 280° C for 3 to 5 minutes.

Using a Soxhlet apparatus, the Chromosorb 101 was extracted for 4 to 5 hours with methanol then 1 to 2 hours with constant-boiling hydrochloric acid prior to column packing.

Nitrogen compound detection was provided by a Coulson electrolytic conductivity cell. Chromatographic effluent was fed into a quartz catalyst tube at 700° C where the nitrogen compounds were reduced to ammonia. A nickel wire bundle, about 4-1/2 inches in length, acted as the reduction catalyst.

SECTION V
VEHICLE MALFUNCTIONS

Each reciprocating-engine vehicle had an incident worth noting. Approximately 800 miles into the Chevron F310 additive test, the Ford began making a tappet-like noise; the source of the noise was found to be an untrue valve guide in the engine head. The F310 tests were completed, the head with the faulty valve guide was replaced, and tests were begun with the next additive.

A problem with the Volkswagen was encountered at about 500 miles into the test with the Lubrizol 8101 fuel additive when a cylinder misfire was noted. The misfire was caused by a loose tappet adjusting nut, and the result was a valve that was not seating and a bent push rod. The push rod was replaced and the valve readjusted. The test was continued rather than repeated from the beginning after an emission check showed the emissions to be normal.

The Chevrolet vehicle was involved in a minor accident at about 200 miles into the test using Texaco TFA 318. The accident resulted in damage to the front bumper and front fender. Exhaust emissions were not measurably affected; therefore, the test was continued.

SECTION VI
RESULTS AND DISCUSSION

The nitrogen compound classes to be analyzed were amines, pyridines, N-nitrosoamines, nitriles, and nitro compounds. Individual nitrogen compounds included were hydrogen cyanide and cyanogen. Of these compounds, only a few were found to be present in exhaust at a detectable level. Analysis of exhaust samples taken from the autos discussed in the Experimental Apparatus section of this report gave peaks corresponding to (1) cyanogen, (2) hydrogen cyanide, (3) nitromethane, and (4) nitroethane.

Using the chromatographic conditions previously described for basic and neutral compounds up to C_8, experiments were conducted in which light-proof bag samples of CVS auto exhaust were spiked with compounds representative of the remaining classes. The discussion of the results of these experiments is not offered as proof that any particular nitrogen compound is not generated in the combustion process, but as an indication of which compounds are likely to produce reliable analytical results if generated in sufficient quantity.

The spiking experiments showed that most of the proposed nitrogen compounds are unstable in auto exhaust with 30 pct or less ammonia, alkyl amines, aryl amines, pyridine, and N-nitrosoamines remaining after 30 minutes. Acetonitrile seemed to be somewhat more stable, losing about 60 pct in 60 minutes. The concentration of nitrobenzene in exhaust remained stable for more than 60 minutes.

When mixed with exhaust, several of the nitrogen compounds produce reaction products which are resolved by Carbowax 1540-KOH. The reaction products of others appear as chromatographic smears, and in some cases, both peaks and smears appear on the chromatogram. Some of the reaction products are relatively stable, but generally they too decrease in concentration upon aging.

Since the objective of the spiking experiments was to determine the stability of the nitrogen compounds when exposed to auto exhaust, only qualitative measurements were made. The quantity of nitrogen compound injected into the exhaust sample was several times that needed to produce a detectable level. This creates an unrealistic situation with respect to the expected nitrogen compound levels in exhaust, but destruction of large quantities of the nitrogen compounds indicates the capacity of exhaust to reduce small quantities to levels below the detection limit within relatively short periods.

Little effort was directed toward identifying the reaction products resulting from the spiking experiments or determining the reaction mechanisms involved. In some instances, more than one well-defined chromatographic peak appeared; in others, only the destruction of the introduced compound could be followed. The formation of N-nitrosoamines from the action of auto exhaust upon secondary alkylamines is noteworthy. Dimethylamine and diethylamine were injected into separate exhaust samples. The retention time of the major peak to appear in each of the exhaust chromatograms agreed exactly with that of the corresponding N-nitrosoamine. As previously stated, however, the N-nitrosoamine peaks were transient.

CVS exhaust samples from the vehicles involved in the program failed to show detectable levels (above 0.025 ppm nitrogen atom) of the basic compounds, nitriles, or aromatic nitro compounds. Analysis with the Carbowax 1540-KOH column was, therefore, discontinued.

The nitrogen-containing compounds proposed for analysis then fall into one of these four categories:

1. Unstable and not detectable--ammonia, alkyl and aryl amines, pyridines, alkyl (and probably aryl) nitriles, and dialkyl N-nitrosoamines.

2. Stable but not produced in detectable quantities--aryl nitro compounds.

3. Unstable but usually detectable--hydrogen cyanide and cyanogen.

4. Stable and produced in detectable quantities--alkyl nitro compounds.

The stability of alkyl nitro compounds, cyanogen, and hydrogen cyanide has not yet been discussed, and it is sufficient to say that nitromethane and nitroethane analytical results are relatively reproducible over a period of at least 1 to 2 hours. On the other hand, cyanogen and hydrogen cyanide are rather elusive, and successive analyses seldom produce like results. Unlike those compounds which are unstable and not detectable, the concentrations of cyanogen and hydrogen cyanide do not clearly diminish with time but may actually appear to increase. No reasonable explanation can be offered by the investigators for an increase of these materials in exhaust standing at room temperature, and the nonrepeatability has been attributed (at least in part) to inadequacies of the analytical method. As a matter of routine, the analytical cycle was kept as constant as practicable for all samples with respect to instrumentation and sample age. Precise procedure replication was not always possible or altogether successful, as will become apparent later in the discussion.

One recognized analytical deficiency, which defied all attempts to recify, was an interference caused by water vapor in samples analyzed for hydrogen cyanide. Even molecular nitrogen containing water vapor gave a peak with a retention time equivalent to that of hydrogen cyanide. This interference persisted regardless of the column type or chromatographic parameters (carrier, flow rate, temperature program). The detection system was essentially nitrogen compound specific, and efforts to establish the source of this unorthodox behavior were unproductive. The erratic behavior of cyanogen and hydrogen cyanide, however, cannot be explained in terms of interference alone. No corresponding water vapor interference was found for cyanogen; yet, the tests giving exceptionally high values for hydrogen cyanide generally also gave high values for cyanogen (see raw data, appendix A).

Well into the tests with DM10, peaks eluted from the Carbopack B-H_3PO_4 column began to broaden and finally became unacceptable. For about 3 weeks, experiments were conducted which were designed to determine the cause of, and eliminate, the water vapor interference with hydrogen cyanide analysis. New Carbopack B-H_3PO_4 columns, Chromosorb 101, and Carbopack B-H_3PO_4 in series with Chromosorb 101 all failed to separate the interference peak from hydrogen cyanide. Time did not permit further experimentation, and nitrogen compound analyses were resumed near the end of the DMA4 tests. At this time, Chromosorb 101 was chosen as the preferred column.

For about 1 month after exhaust testing was resumed with the Chromosorb 101 column, hydrogen cyanide and cyanogen values were exceptionally high and tended to drop as the column aged. Overnight conditioning of the column produced much higher hydrogen cyanide and cyanogen values on one occasion; and on another, inadvertent injection of air into the hot column produced the same results. The additives being tested with the vehicles during this period were primarily DMA4 and Lubrizol 8101 with high test values for the column conditioning and air injection into the hot column occurring during the DMA51 and TFA 318 tests, respectively. F310 was being tested with the stationary Mazda engine during this period. The variability for hydrogen cyanide and cyanogen during the latter part of the program was greater than would normally be expected, but the day-to-day fluctuations were not nearly so great as they were when the Chromosorb 101 column was new. The evidence then points to some analytical deficiency being responsible for the highly anomolous hydrogen cyanide and cyanogen values with sample stability possibly entering into the less radical value fluctuations.

The analytical difficulties encountered during the program have largely decreased the value of the hydrogen cyanide and cyanogen information given in this report. The levels of these compounds in exhaust can, at best, only be considered as estimates, and any particular conclusions drawn must be viewed with a certain amount of reserve. The evidence, however, does strongly suggest that these compounds are commonly emitted auto exhaust components. The most likely route in establishing the source (or sources) of the analytical variability would be development of a method for direct hydrogen cyanide calibration and experimentation with known quantities of the compounds exhibiting unusually high analytical variability.

The chromatographic system for nitrogen compound analysis is illustrated in figure 2. Examples of exhaust chromatography are presented in figures 3 and 4. The original retention times on the Carbopack B-H_3PO_4 column were up to 2 minutes longer, but were shortened over a period of several days by periodic calibration with a methanol solution of nitromethane and nitroethane. Cyanogen is below the detection limit in figure 3, but the retention time is indicated. Oxides of nitrogen injected into the columns give backgrounds similar to those in the figures.

A water solution of known quantities of nitromethane and nitroethane was prepared for calibration when it became evident that the retention characteristics of the Carbopack B-H_3PO_4 column were changing and methanol was suspected as the cause of the change. There was no measurable difference in detector response to these nitro compounds eluted from either the Carbopack B-H_3PO_4 (before peak broadening occurred) or the Chromosorb 101 column. The mean and standard deviation for detector response was calculated from all of the daily calibrations made during the program and was found to be $4.05 \times 10^{-10} \pm 0.99 \times 10^{-10}$ nitrogen atom per millivolt. The noise level was 0.02mV-0.04mV and the detection limit (twice the noise level) was about 2.5×10^{-11} nitrogen atom. Considering day-to-day fluctuations of sensitivity and noise gives a limiting range of 1.2×10^{-11} - 4.0×10^{-11} nitrogen atom.

The raw data for both routine and nitrogen compound measurements are given in appendix A. All tests were made according to the 1975 Federal test procedure and values reported for the individual bags and for the weighted composite. Units are grams/test for the individual bag samples and grams/mile for the composites. Individual bag concentrations were calculated from the experimental data according to:

$$\text{bag concentration, g/test} = \frac{R \times F_R \times V \times {}^\circ R \times M \times 1630.55}{P} \tag{1}$$

where,

R = detector response (divisions)

F_R = response factor (moles/division)

V = standard volume of exhaust plus dilution air (cu ft/test)

$^\circ R$ = test temperature (degrees Rankine)

M = molecular weight (grams/mole)

P = barometric pressure (mm Hg)

Composites were calculated using the formula:

$$\text{composite, g/mi} = \frac{0.43(\text{Bag}_1\text{, g/test}) + \text{Bag}_2\text{, g/test} + 0.57(\text{Bag}_3\text{, g/test})}{7.5} \tag{2}$$

When one, or more, of the three bag samples from a test contains an immeasurable level of an exhaust component, a choice must be made concerning the calculation of the composite (formula 2). An immeasurable level can be considered to be zero or an estimate of the probable level can be made. Considering a component that is normally found in one or more of the three bag samples, it is unlikely that the level will be absolutely zero in the remaining bag or bags. Also, it is unlikely that one spark-ignition, internal-combustion engine will produce a measurable quantity of a substance and another produce absolutely zero. Therefore, maximum probable levels were estimated for bag samples falling in this category before the composite sample values were calculated. A very small (less than 0.04mV) but definite recorder deflection (cf - cyanogen, figure 4) has been designated as trace (T), and no discernible recorder deflection at the retention time of a component has been designated as below the detection limit (BDL). For composite calculations, a trace level was estimated to be no more than 2.9×10^{-5} nitrogen atom per test in sample bag No. 1 or 3 and no more than 4.9×10^{-5} nitrogen atom per test in sample bag No. 2. These values are simply those giving 0.5 to 0.75 divisions of recorder deflection at 4.0mV full scale. When a sample produced no definite recorder deflection for a component, these values were halved for the composite calculation. The estimated T and BDL levels all fall below the reported detection limit and are considered only as the maximum levels that could have been present in the samples. Calculating composite values in this manner allowed assignment of real numbers for the statistical analysis given in table 3 and discussed later in this report.

To determine the deleterious effect of a gasoline additive upon exhaust emissions, consideration must be given to both immediate and long-range emission level and composition. Immediate changes (from clear fuel to fuel with additive) in level or composition may indicate a direct effect with the additive or additive products appearing in the exhaust, or indirect effects by altering the combustion characteristics of the fuel or acting upon normally emitted products in the exhaust. Long-range changes (extended use of fuel with additive) attributable to an additive are indirect when viewed as the result of the additive's ability to alter, form, prevent formation of, or remove engine deposits. However, the immediate effect of the additive may change as deposits change.

All of the additives tested in this program are nonmetallic, engine-cleaning agents, and the engines used were *initially* clean. Therefore, changes in emissions should have resulted from the appearance of additive or additive products in the exhaust, additive action upon normally emitted products in the exhaust, and/or deposit formation. Thus, with initially clean engines and no control (a second engine operated exclusively on clear fuel) run in parallel with the extended mileage test engine, program design places emphasis upon the immediate effects of the additives even though these effects might be the result of long-term additive use.

The highest level of nitrogen in the exhaust which could be derived solely from additive was about 0.015 gram/test in the first bag. The nitrogen contents of the various additives were obtained from the manufacturers. Using these values and the dosages reported in the Experimental Apparatus section of this report, the additive-nitrogen levels in the fuel were calculated as grams nitrogen per liter fuel:

Additive	N content of fuel
F310	0.01134
Lubrizol 8101	.00513
Lubrizol 8101 + TFA 318	.00513
DMA4	.00189
DMA51	.00127

Fuel consumption and CVS system output from a Mazda vehicle test were used to calculate the maximum additive-derived nitrogen exhaust level reported above. Assuming 100 pct conversion of the additive-nitrogen to a single nitrogen compound in the exhaust, this level would give a deflection of about 25 divisions on a 4mV full-scale recorder.

By comparing the lowest maximum possible emission level for additive-nitrogen to the emission levels of the exhaust components (appendix A), it is obvious that additive-nitrogen appearance as nitric oxide or NO_2, or additive action upon any of the routinely measured exhaust components would not measurably affect their emission levels (except in the event that several active fragments were produced by each additive molecule). On the other hand, emission levels of nitromethane, nitroethane, hydrogen cyanide, and cyanogen could be affected to a large extent if one or more of these compounds were additive-related reactants or end products of the additive combustion process.

There was no immediate additive-related effect upon emissions. This is shown by comparison of emission levels obtained using fuel with additive to those obtained using high aromatic fuel with additive and clear fuel. This information is given in table 3. With the exception of those indicated as not being included in the reduced data, all values in appendix A were used for the table 3 computations. For each group of values, the mean ($\bar{x}$) is given by:

$$\bar{x} = \frac{\Sigma x}{n} \tag{3}$$

where n is the number of values within the group. The standard deviation (σ) of each group is expressed as:

$$\sigma_x = \sqrt{\frac{\Sigma x^2 - \frac{(\Sigma x)^2}{n}}{n - 1}} \tag{4}$$

and the test for the independence of two groups of values (t_i) was calculated according to the formula:

$$t_i = \frac{\bar{x} - \bar{y}}{\sqrt{\left[\frac{(n_x - 1)\,\sigma_x^2 + (n_y - 1)\,\sigma_y^2}{n_x + n_y - 2}\right]\left[\frac{1}{n_x} + \frac{1}{n_y}\right]}} \tag{5}$$

x and y representing the two groups of values being compared. In all cases, x is used to represent the values for the standard fuel with additive. Because there were only two data points for clear fuel with each additive, two t_i values were calculated for the Mazda vehicle. All t_i values enclosed by parentheses compare all values from a particular engine using a specific additive to the values from all tests of that engine using either clear or high aromatic fuel. Those t_i values not enclosed by parentheses compare the additive values only to the clear fuel values obtained during tests made using that additive. The significance of t_i increases as n for both groups being compared increases. Therefore, the enclosed t_i values are the more significant. In all cases, n for at least one of the two compared groups is as small as 4 to 7. For n values in this range, t_i shows some degree of independence between the two groups of values when its absolute value is greater than approximately 2.5. Sign denotes the direction of deviation of the y group from the x group.

TABLE 3. - Independence of emissions with and without additive

Additive	Carbon Monoxide: Emissions, g/mi (mean & S.D.) 1 Fuel with additive	2 Clear fuel	3 High aromatic fuel with additive	Test for independence ti(1&2)	ti(1&3)	Hydrocarbon: Emissions, g/mi (mean & S.D.) 1 Fuel with additive	2 Clear fuel	3 High aromatic fuel with additive	Test for independence ti(1&2)	ti(1&3)
VOLKSWAGEN										
F310	20.5±2.6	19.5	18.6	(-2.56)	(-2.59)	2.39±.29	2.39	2.38	(-1.11)	(-1.48)
DMA4	24.0±3.2	24.5	26.4	(-1.14)	(-1.24)	2.51±.14	2.35	2.78	(- .37)	(- .93)
LUB 8101	27.0±4.6	25.9	32.7	(.02)	(- .13)	2.63±.16	2.73	2.76	(.91)	(.22)
DMA51	30.6±3.2	30.6	27.8	(1.38)	(1.15)	2.63±.15	2.51	2.49	(.88)	(.18)
TFA318	29.1±2.6	30.7	28.5	(.84)	(.64)	2.47±.10	2.65	2.46	(- .81)	(-1.34)
8101+318	29.8±1.4	30.5	30.3	(1.18)	(.94)	2.58±.09	2.61	2.76	(.50)	(- .23)
Total	26.8±4.5	27.0±4.5	27.4±4.8	-0.07	-0.28	2.53±.18	2.54±.15	2.61±.18	-0.09	-0.90
FORD										
F310	31.0±3.6	39.6	39.7	(-0.95)	(-1.53)	2.61±.12	2.74	3.17	(-0.05)	(0.04)
DMA4	29.6±3.9	24.3	37.6	(-1.35)	(-2.06)	2.56±.22	2.19	2.97	(- .37)	(- .18)
LUB 8101	36.6±3.5	38.4	32.6	(.75)	(.92)	2.87±.34	2.95	2.14	(1.31)	(1.07)
DMA51	25.8±1.2	37.0	30.3	(-2.78)*	(-4.70)*	2.44±.24	2.69	2.63	(-1.13)	(- .74)
TFA318	26.7±1.9	30.2	34.6	(-2.42)	(-4.01)*	2.44±.27	2.51	2.41	(-1.09)	(- .73)
8101+318	32.3±2.0	35.4	32.4	(- .59)	(-1.12)	2.35±.13	2.64	2.30	(-1.92)	(-1.20)
Total	30.3±4.5	34.2±5.8	34.5±3.5	-1.75	-1.69	2.54±.27	2.62±.26	2.60±.40	-0.63	-0.44
CHEVROLET										
F310	37.7±5.1	34.0	33.4	(-1.69)	(-1.16)	1.21±.19	1.01	0.93	(-0.80)	(-0.50)
DMA4	40.0±7.5	59.7	51.0	(-1.13)	(- .63)	1.24±.35	1.30	1.51	(- .58)	(- .24)
LUB 8101	46.0±7.3	50.3	56.4	(- .04)	(.48)	1.30±.19	1.49	1.50	(- .36)	(.10)
DMA51	36.5±4.3	47.7	40.5	(-1.97)	(-1.44)	1.13±.12	1.27	1.49	(-1.21)	(-1.08)
TFA318	35.3±4.1	47.5	35.6	(-2.22)	(-1.70)	1.36±.27	2.08	1.02	(- .08)	(.43)
8101+318	42.0±6.3	38.1	43.7	(- .80)	(- .28)	1.22±.22	1.09	1.24	(- .71)	(- .39)
Total	39.6±6.4	46.2±9.1	43.4±8.9	-2.09	-1.23	1.24±.22	1.37±.39	1.28±.26	-1.13	-0.40
MAZDA VEHICLE										
F310	22.5±1.8	21.6±0.9		0.71(0.44)		2.40±.20	2.15±.15		1.60(3.60)*	
DMA4	18.1±3.4	18.2±0.1		- .03(-1.29)		1.81±.37	1.76±.16		.20(-0.57)	
LUB 8101	20.0±1.7	20.0±0.1		.06(-0.58)		1.78±.10	1.74±.21		.33(-1.00)	
DMA51	21.3±6.1	28.9±11.8		-1.19(-0.04)		1.59±.26	2.10±.58		-1.75(-2.18)	
TFA318	22.3±1.8	20.7±3.8		.84(0.37)		2.08±.23	2.00±.07		.44(1.21)	
8101+318	22.4±3.0	19.4±2.1		1.30(0.38)		1.90±.17	1.69±.11		1.55(-0.05)	
Total	21.1±3.4	21.4±5.3		-0.23		1.93±.34	1.91±.28		0.18	
STATIONARY MAZDA										
F310	24.2±4.3	20.6±4.1		1.58		3.03±.35	2.82±.53		0.89	
DMA4	19.0±4.0	18.9±4.8		.01		2.41±.43	2.32±.29		.42	
LUB 8101	24.7±3.2	22.4±1.6		1.44		2.99±.80	2.55±.37		1.16	
Total	22.7±4.5	20.6±3.8		1.47		2.82±.59	2.58±.44		1.37	

*No overlap of standard deviations.
( ) Each additive compared to total value for columns 2 and 3.

TABLE 3. - Independence of emissions with and without additive
Continued

Additive	Nitrogen Oxides: Emissions, g/mi (mean & S.D.) 1 Fuel with additive	2 Clear fuel	3 High aromatic fuel with additive	Test for independence ti(1&2)	ti(1&3)	Aldehydes: Emissions, g/mi (mean & S.D.) 1 Fuel with additive	2 Clear fuel	3 High aromatic fuel with additive	Test for independence ti(1&2)	ti(1&3)
					VOLKSWAGEN					
F310	3.17±.30	3.19	4.13	(-3.07)*	(-5.20)*	0.071±.012	0.077	0.082	(-1.19)	(-0.40)
DMA4	3.70±.52	3.88	4.18	(- .74)	(-1.97)	.079±.013	.070	.076	(- .15)	(.33)
LUB 8101	4.09±.11	3.88	3.86	(.77)	(- .75)	.086±.009	.084	.082	(.92)	(1.09)
DMA51	4.93±.22	4.19	4.47	(4.34)*	(3.86)*	.104±.012	.093	.099	(3.45)*	(2.88)*
TFA318	4.18±.27	4.45	3.96	(1.06)	(- .21)	.081±.004	.088	.065	(.21)	(.63)
8101+318	4.35±.31	3.95	4.71	(1.73)	(.65)	.072±.010	.067	.048	(-1.20)	(- .35)
Total	4.07±.62	3.92±.42	4.22±.32	0.54	-0.56	.082±.015	.080±.010	.075±.017	0.36	0.98
					FORD					
F310	3.13±.22	3.09	3.47	(-1.05)	(-2.13)	0.106±.034	0.109	0.131	(-1.14)	(-0.83)
DMA4	3.63±.39	2.60	3.94	(.32)	(- .21)	.140±.018	.123	.093	(1.59)	(1.66)
LUB 8101	3.70±.27	4.56	2.83	(.51)	(.01)	.122±.003	.125	.113	(- .15)	(.20)
DMA51	3.87±.54	3.76	3.75	(.86)	(.52)	.152±.007	.115	.150	(3.62)*	(3.20)*
TFA318	3.57±.26	3.22	4.00	(.17)	(- .45)	.145±.017	.151	.113	(2.08)	(2.07)
8101+318	4.00±.32	3.84	4.18	(1.31)	(1.09)	.115±.017	.117	.118	(- .85)	(- .41)
Total	3.65±.41	3.51±.69	3.70±.49	0.64	-0.23	.130±.024	.123±.015	.120±.019	0.65	0.98
					CHEVROLET					
F310	1.84±.16	2.20	2.02	(- .95)	(-1.08)	0.120±.012	0.110	0.112	(0.69)	(2.20)
DMA4	1.95±.12	2.24	1.71	(- .13)	(.07)	.117±.014	.086	.095	(.31)	(1.62)
LUB 8101	1.85±.29	2.00	1.86	(- .70)	(- .68)	.122±.006	.116	.087	(.92)	(2.84)*
DMA51	2.03±.17	1.80	1.92	(.44)	(.84)	.129±.020	.128	.114	(1.34)	(2.53)
TFA318	1.88±.31	1.62	2.14	(- .49)	(- .42)	.121±.008	.125	.105	(.80)	(2.55)
8101+318	1.94±.42	1.94	2.01	(- .14)	(- .03)	.103±.012	.119	.112	(-1.24)	(- .19)
Total	1.91±.24	1.97±.24	1.94±.15	-0.47	-0.28	.119±.014	.114±.015	.104±.011	0.70	2.32
					MAZDA VEHICLE					
F310	1.33±.16	1.20±.11		1.08(1.15)		0.162±.016	0.131±.003		2.53*(1.61)	
DMA4	1.30±.07	1.27±.04		.52(1.99)		.120±.025	.100±.013		1.07(-0.66)	
LUB 8101	1.29±.12	1.31±.06		- .26(1.34)		.141±.018	.120±.013		1.53(0.48)	
DMA51	1.18±.07	1.18±.07		- .07(-1.23)		.122±.027	.169±.098		-1.11(-0.56)	
TFA318	1.21±.03	1.16±.02		2.72*(-0.28)		.162±.025	.151±.022		.58 (1.58)	
8101+318	1.25±.04	1.23±.03		.76(0.89)		.143±.012	.127±.004		1.74*(0.55)	
Total	1.26±.10	1.22±.07		1.14		.142±.026	.133±.038		0.89	
					STATIONARY MAZDA					
F310	0.98±.22	0.96±.27		0.18		0.202±.043	0.160±.029		2.05	
DMA4	.72±.06	.69±.06		.81		.161±.047	.163±.050		- .09	
Lub 8101	.72±.15	.67±.12		.68		.218±.090	.223±.086		- .11	
Total	0.[illegible]2±.20	0.78±.22		0.47		.192±.063	.182±.062		0.48	

*No overlap of standard deviations.
( ) Each additive compared to total value for columns 2 and 3.

TABLE 3. - Independence of emissions with and without additive
Continued

Additive	HYDROGEN CYANIDE Emissions, g/mi (mean & S.D.) 1 Fuel with additive	2 Clear fuel	3 High aromatic fuel with additive	Test for independence t1(1&2)	t1(1&3)	CYANOGEN Emissions, g/mi (mean & S.D.) 1 Fuel with additive	2 Clear fuel	3 High aromatic fuel with additive	Test for independence t1(1&2)	t1(1&3)
VOLKSWAGEN										
F310	0.0115±.0028	0.0151	--	(-2.69)*	(-2.89)*	0.0001±.0000	0.0001	--	(-1.54)	(-2.32)*
DMA4	--	--	--	--	--	.0022	--	--	--	--
LUB 8101	.0208	--	0.0208	--	--	--	--	0.0028	--	--
DMA51	.0234±.0048	.0328	.0139	(- .09)	(1.02)	.0025±.0014	.0037	.0010	(1.06)	(.84)
TFA318	.0181±.0046	.0178	.0260	(-1.03)	(- .47)	.0006±.0002	.0003	.0029	(- .66)	(-1.11)
8101+318	.0204±.0028	.0297	.0187	(- .77)	(.17)	.0009±.0008	.0014	.0001	(- .57)	(-1.07)
Total	0.0185±.0056	0.0239±.0087	0.0199±.0050	-1.54	-0.44	0.0011±.0013	0.0014±.0017	0.0017±.0014	0.30	-0.77
FORD										
F310	0.0125±.0022	0.0048	--	(3.43)*	(-0.43)	0.0001±.0000	0.0001	--	(-1.00)	(-1.60)
DMA4	.0071	--	--	--	--	.0001	--	--	--	--
LUB 8101	.0343±.0062	--	0.0114	(7.76)*	(3.17)*	.0019	--	0.0014	--	--
DMA51	.0160±.0094	.0065	.0107	(1.68)	(.24)	.0011±.0008	.0009	.0006	(1.38)	(.94)
TFA318	.0140±.0039	--	.0257	(2.92)*	(- .09)	.0002±.0002	.0025	.0001	(- .59)	(-1.25)
8101+318	.0144±.0075	.0087	.0100	(1.71)	(- .01)	.0002±.0001	.0001	.0004	(- .73)	(-1.51)
Total	0.0163±.0090	0.0067±.0020	0.0145±.0075	1.79	0.37	0.0005±.0006	0.0004±.0005	0.0006±.0006	0.26	-0.45
CHEVROLET										
F310	0.0114±.0019	0.0046	--	(1.42)	(3.66)*	0.0001±.0000	0.0001	--	(-1.20)	(-1.07)
DMA4	.0028	--	--	--	--	.0001	--	--	--	--
LUB 8101	.0196±.0068	--	0.0076	(2.77)*	(4.16)*	.0004	--	0.0006	--	--
DMA51	.0087±.0057	.0033	.0049	(.30)	(.96)	.0003±.0001	.0004	.0002	(.79)	(.19)
TFA318	.0072±.0033	.0104	.0073	(- .14)	(.71)	.0003±.0001	.0002	.0001	(.52)	(.00)
8101+318	.0070±.0058	.0120	.0032	(- .18)	(.39)	.0002±.0002	.0001	.0001	(.21)	(- .16)
Total	0.0094±.0060	0.0076±.0043	0.0058±.0021	0.57	1.18	0.0002±.0001	0.0002±.0001	0.0003±.0002	-0.30	-0.30
MAZDA VEHICLE										
F310	0.0014±.0001	0.0176		(-2.12)*		0.0001±.0000	0.0001		(-1.09)	
DMA4	.0040±.0007	.0025		(- .92)		.0003±.0003	.0002		(1.03)	
LUB 8101	.0093±.0021	.0055		(2.16)		.0003±.0000	.0002		(3.06)*	
DMA51	.0084±.0040	.0100±.0033		- .48(1.19)		.0002±.0000	.0003±.0001		-1.92(.05)	
TFA318	.0083±.0030	.0050±.0010		1.45(1.37)		.0001±.0000	.0002±.0001		-1.89(-1.76)	
8101+318	.0039±.0013	.0050±.0000		-1.16(-1.50)		.0001±.0000	.0001±.0000		.00(-1.24)	
Total	0.0066±.0036	0.0060±.0029		0.43		0.0002±.0001	0.0002±.0001		0.20	
STATIONARY MAZDA										
F310	0.0182±.0220	0.0079±.0081 1/		0.98		0.0003±.0002	0.0002±.0002		0.73	
DMA4	.0030±.0018	.0014±.0008		1.93		.0001±.0000	.0001±.0000		.00	
LUB 8101	.0027±.0013	.0025±.0014		.28		.0001±.0000	.0001±.0000		.00	
Total	0.0029±.0015	0.0019±.0012		1.62		0.0001±.0001	0.0001±.0001		0.47	

*No overlap of standard deviations.
( ) Each additive compared to total value for columns 2 and 3.
1/Not included in total.

TABLE 3. - Independence of emissions with and without additive
Continued

Additive	NITROMETHANE Emissions, g/mi (mean & S.D.) 1 Fuel with additive	2 Clear fuel	3 High aromatic fuel with additive	Test for independence ti(1&2)	ti(1&3)	NITROETHANE Emissions, g/mi (mean & S.D.) 1 Fuel with additive	2 Clear fuel	3 High aromatic fuel with additive	Test for independence ti(1&2)	ti(1&3)
VOLKSWAGEN										
F310	0.0026±.0012	0.0041	--	(-1.65)	(-0.15)	0.0007±.0002	0.0010	--	(0.93)	(3.10)*
DMA4	.0036	--	0.0040	--	--	.0008	--	0.0005	--	--
LUB 8101	.0040	.0035	.0020	--	--	.0004	.0005	.0004	--	--
DMA51	.0042±.0009	.0038	.0028	(1.23)	(2.56)	.0004±.0001	.0004	.0004	(- .86)	(.16)
TFA318	.0030±.0007	.0027	.0020	(-1.44)	(.56)	.0004±.0001	.0004	.0004	(- .86)	(.16)
8101+318	.0030±.0003	.0039	.0029	(-2.06)	(.54)	.0004±.0000	.0004	.0004	(-1.06)	(-1.00)
Total	0.0033±.0009	0.0036±.0005	0.0027±.0008	-0.71	1.29	0.0005±.0002	0.0005±.0003	0.0004±.0000	-0.56	0.97
FORD										
F310	0.0051±.0012	0.0037	--	(0.18)	(1.37)	0.0010±.0002	0.0008	--	(0.80)	(3.28)*
DMA4	.0058	--	--	--	--	.0006	--	--	--	--
LUB 8101	.0061±.0013	.0080	0.0027	(1.04)	(2.65)*	.0006±.0002	.0014	0.0004	(- .33)	(.91)
DMA51	.0045±.0009	.0036	.0033	(- .27)	(1.04)	.0004±.0000	.0004	.0004	(-1.26)	(-1.00)
TFA318	.0043±.0008	.0048	.0051	(- .48)	(.81)	.0004±.0000	.0004	.0007	(-1.26)	(-1.00)
8101+318	.0047±.0004	.0038	.0040	(- .08)	(1.66)	.0004±.0001	.0004	.0004	(-1.14)	(- .63)
Total	0.0049±.0010	0.0048±.0019	0.0038±.0010	0.19	2.02	0.0005±.0002	0.0007±.0004	0.0005±.0002	-1.24	0.37
CHEVROLET										
F310	0.0081±.0008	0.0101	--	(-1.86)	(-3.40)*	0.0012±.0002	0.0012	--	(-1.37)	(-2.38)*
DMA4	.0132	--	--	--	--	.0025	--	--	--	--
LUB 8101	.0136±.0032	.0208	0.0123	(.13)	(1.31)	.0024±.0006	.0041	0.0025	(.28)	(1.19)
DMA51	.0118±.0008	.0094	.0093	(- .54)	(.50)	.0018±.0007	.0014	.0014	(- .59)	(- .30)
TFA318	.0113±.0017	.0121	.0124	(- .79)	(.02)	.0018±.0003	.0017	.0022	(- .63)	(- .42)
8101+318	.0109±.0020	.0138	.0112	(- .95)	(- .33)	.0018±.0005	.0027	.0017	(- .60)	(- .34)
Total	0.0113±.0024	0.0132±.0046	0.0113±.0014	-1.35	-0.03	0.0019±.0006	0.0022±.0012	0.0020±.0005	-0.98	-0.28
MAZDA VEHICLE										
F310	0.0099±.0008	0.0131		(-1.98)*		0.0016±.0000	0.0019		(-1.41)*	
DMA4	.0121±.0018	.0117		(-1.02)		.0022±.0002	.0024		(.11)	
LUB 8101	.0117±.0015	.0099		(-1.56)		.0019±.0003	.0012		(- .99)	
DMA51	.0107±.0037	.0179±.0013		-2.56*(-1.83)		.0019±.0004	.0028±.0002		-2.83*(- .95)	
TFA318	.0176±.0011	.0141±.0001		4.03*(2.93)*		.0028±.0003	.0023±.0001		1.92*(2.53)*	
8101+318	.0145±.0021	.0128±.0006		1.11 (.53)		.0022±.0005	.0018±.0000		1.04 (.23)	
Total	0.0131±.0033	0.0138±.0027		-0.53		0.0021±.0005	0.0021±.0005		0.01	
STATIONARY MAZDA										
F310	0.0126±.0032	0.0098±.0039		1.23		0.0031±.0009	0.0023±.0008		1.34	
DMA4	.0063±.0024	.0059±.0009		.39		.0013±.0005	.0012±.0003		.43	
LUB 8101	.0098±.0038	.0080±.0042		.77		.0023±.0009	.0022±.0010		.33	
Total	0.0093±.0040	0.0079±.0035		1.04		0.0022±.0010	0.0019±.0009		0.76	

*No overlap of standard deviations.
( ) Each additive compared to total value for columns 2 and 3.

For an additive to show an influence upon the production of an exhaust component, all (or at least the majority) of the engines tested should give significant t_i values (with the same sign) for that additive and that component when values obtained using fuel with additive are compared to values obtained from using clear fuel [t_i(1 & 2)]. This is not the case. The F310 influence upon hydrogen cyanide production may at first glance appear to be real with three of five engines giving t_i values with some degree of significance. However, several values for F310 are missing from the raw data, and two of the three significant t_i values are negative while the third is positive. The same arguments essentially negate a certain amount of independence shown for nitroethane and hydrogen cyanide production between the fuel with F310 and high aromatic fuel with F310 [t_i(1 & 3)].

Bar graphs have been constructed for quick, unambiguous comparison of nitrogen compound emission levels with and without the various additives tested. These data are presented in figures 5 through 8. Values for the routine emission measurements have been omitted from these graphs because of their relatively high emission levels, and cyanogen, with exceptionally high standard deviations, also has been omitted.

The duty and test cycles for the Mazda stationary engine were considerably different from those for the vehicles. The data for the Mazda engine have, therefore, been presented separately and in slightly different form from those of the vehicles. In figure 5, the mean exhaust level and standard deviation for each component from all tests with an additive are compared with those from tests made with clear fuel when that particular additive was being tested. The number of samples is shown at the lower end of each bar. Data for the four vehicles have been grouped for comparison of exhaust levels from the various vehicles as well as exhaust levels from a particular vehicle using fuel with additive or clear fuel. Each additive-labeled bar gives the mean value and standard deviation for all tests made with that vehicle using that additive in the fuel. (The tests with high aromatic fuel and additive are also included.) Each bar designated by the word "clear" gives the mean value and standard deviation for all tests made with that vehicle using clear fuel regardless of the additive being tested. The number of test values involved in calculating the mean and standard deviation is again given in each bar. Figure 6 through 8 show rather distinctive source differences for nitromethane and nitroethane emission levels and, to a lesser degree, for hydrogen cyanide emission levels. Also, including figure 5, it is obvious that the few additive test values that differ significantly from the clear fuel test values offer no evidence of an additive-related influence upon emissions.

The program was aimed primarily at determining immediate effects of several commercially available gasoline additives upon emission levels or composition. Changes in engine parameters may alter emissions serving either to create effects that are independent of additive use or to mask effects of the additive. Except in the special cases where malfunctions occurred, engine parameters were not adjusted during the program. They were, however, checked periodically to assure parametric consistency and to minimize the chance that anomolous exhaust levels or composition might occur from parameter changes and obscure possible additive effects. No radical changes in CO, HC, and NO_x emission levels occurred during the program. This is shown in figures 9 through 13 where emission levels have been plotted as a function of mileage accumulation. Because no measurable immediate effect was found for any of the additives tested, the average emission level was plotted when more than one test was made at a particular mileage. Figures 11 through 13 show good overall constancy for CO, HC, and NO_x emissions. There were gradual increases in CO and NO_x emitted by the Volkswagen (figure 9) and in NO_x emitted by the Ford (figure 10).

Nitrogen compound emission levels, as a function of accumulated mileage, are presented in figures 14 through 18. Here again, multiple test points were averaged. Considering that emission levels were quite low and that the emission scale was expanded, overall emission constancy for nitrogen compounds was good. The relatively large fluctuations from 1,500 to 4,500 miles in figures 14 through 16 and from 0 to 15,000 miles in figure 18 reflect the analytical difficulties previously discussed.

Aside from the question of additive influence upon emissions, the program data show an interesting relationship between the exhaust levels of nitrogen oxides and nitromethane. In all probability, this relationship could be extended to include nitroalkyls as a class. Oxides of nitrogen vs CH_3NO_2 was plotted for bag No. 1 of each test. All such points from the reported tests are included in figure 19. The relationship is apparent from the plotted data points; however, it seems to be more clearly defined by reduced data scatter when the stationary Mazda (points enclosed by the rectangle) is omitted. The best linear fit for the data from the four vehicles is expressed by the least squares regression equation:

$$NO_x = -202.13(CH_3NO_2) + 17.919 \qquad (6)$$

With all 118 data points, the correlation coefficient, -0.855, shows a high degree of significance for the relationship. The 95 pct confidence interval for the prediction of nitromethane was found to be $CH_3NO_2 \pm 0.002$ g/test.

With the vehicles tested, very few NO_x levels fell in the range, 9 to 14 g/test. Also, the only emission source which gave NO_x levels below 5 g/test was the stationary Mazda, and these points do not conform to the relationship discussed above. Additional data points obtained from sources emitting NO_x in these ranges are needed to determine whether the relationship is truly linear (the stationary Mazda data suggest that it may not be).

SECTION VII
REFERENCES

1. Environmental Protection Agency. Effect of Gasoline Additives on Gaseous Emissions. Environmental Protection Technology Series, Report No. EPA-560/2-75-014, 1974, 64 pp.

2. U.S. Code of Federal Regulations. Title 40--Protection of Environment; Chapter I--Environmental Protection Agency; Part 85--Control of Air Pollution from New Motor Vehicles and New Motor Vehicle Engines. Federal Register, v. 39, No. 101, May 23, 1974, pp. 18076-18084.

3. Coordinating Research Council, Inc. Oxygenates in Automotive Exhaust Gas: Part I. Techniques for Determining Aldehydes by the MBTH Method. Report No. 415, June 1968, 21 pp.

4. Environmental Protection Agency. Effect of Gasoline Additives on Gaseous Emissions. Environmental Protection Technology Series. Report No. EPA-650/2-75-014, 1974, 64 pp.

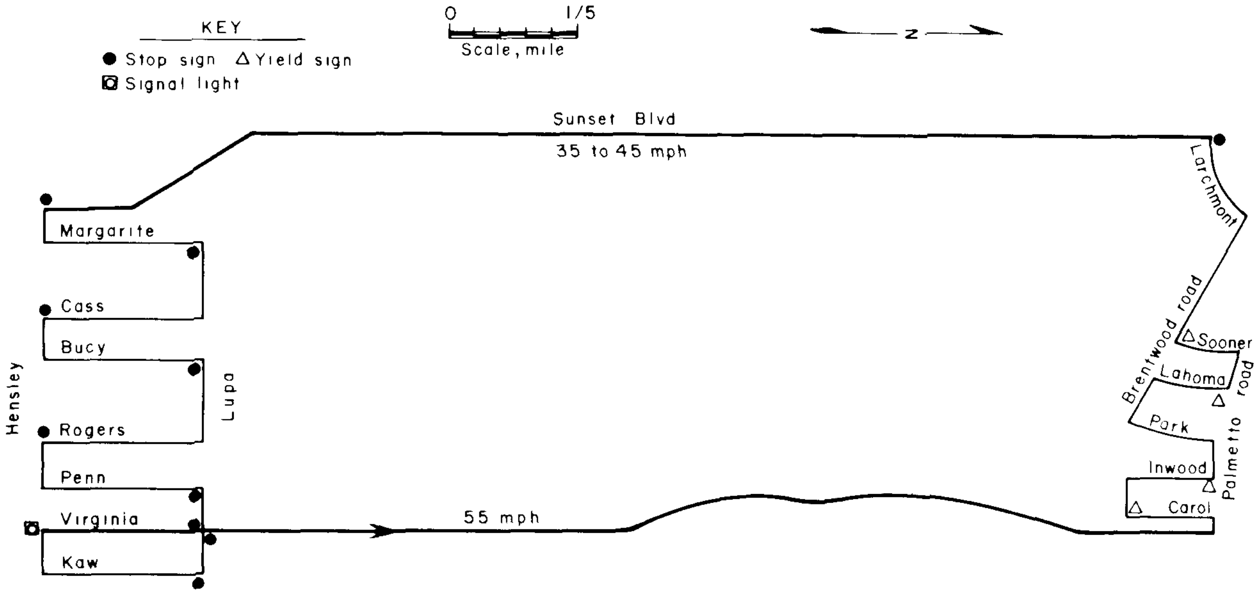

FIGURE 1. - City Route Driven for Mileage Accumulation

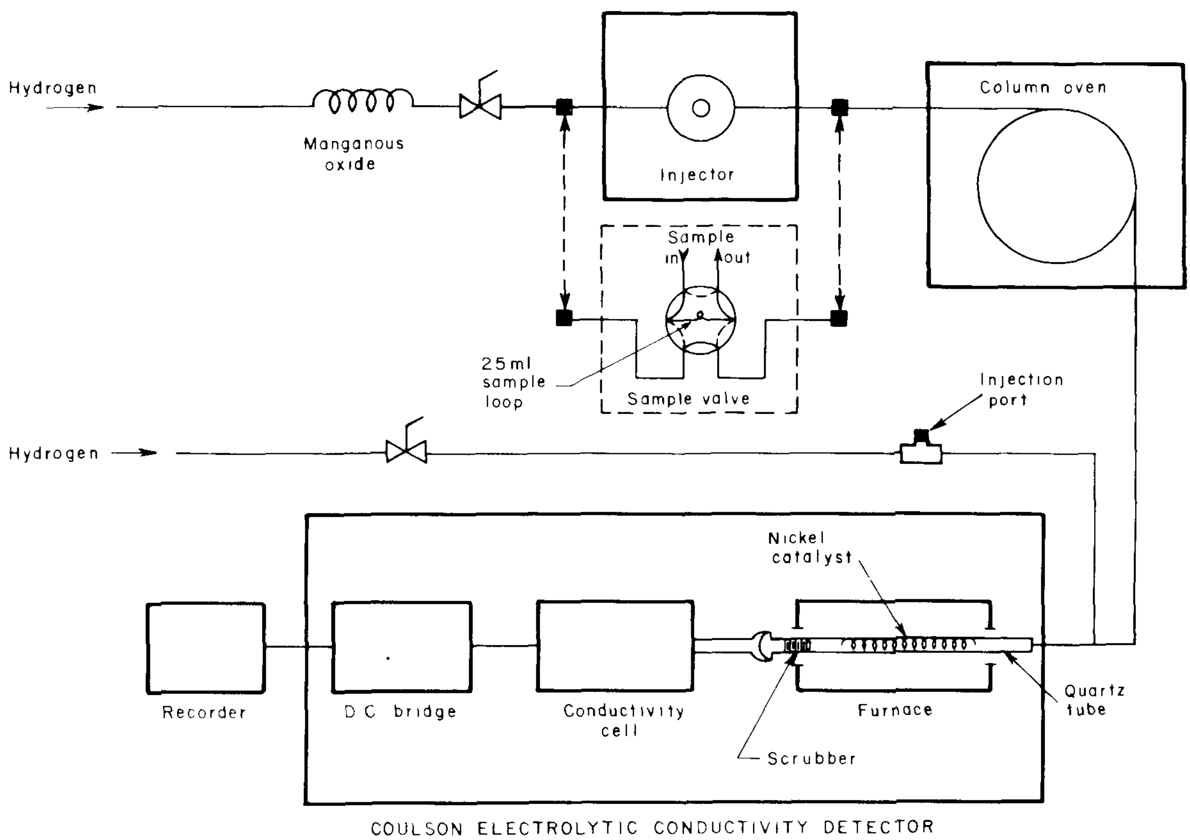

FIGURE 2. - Chromatographic System for Analysis of Nitrogen Compounds

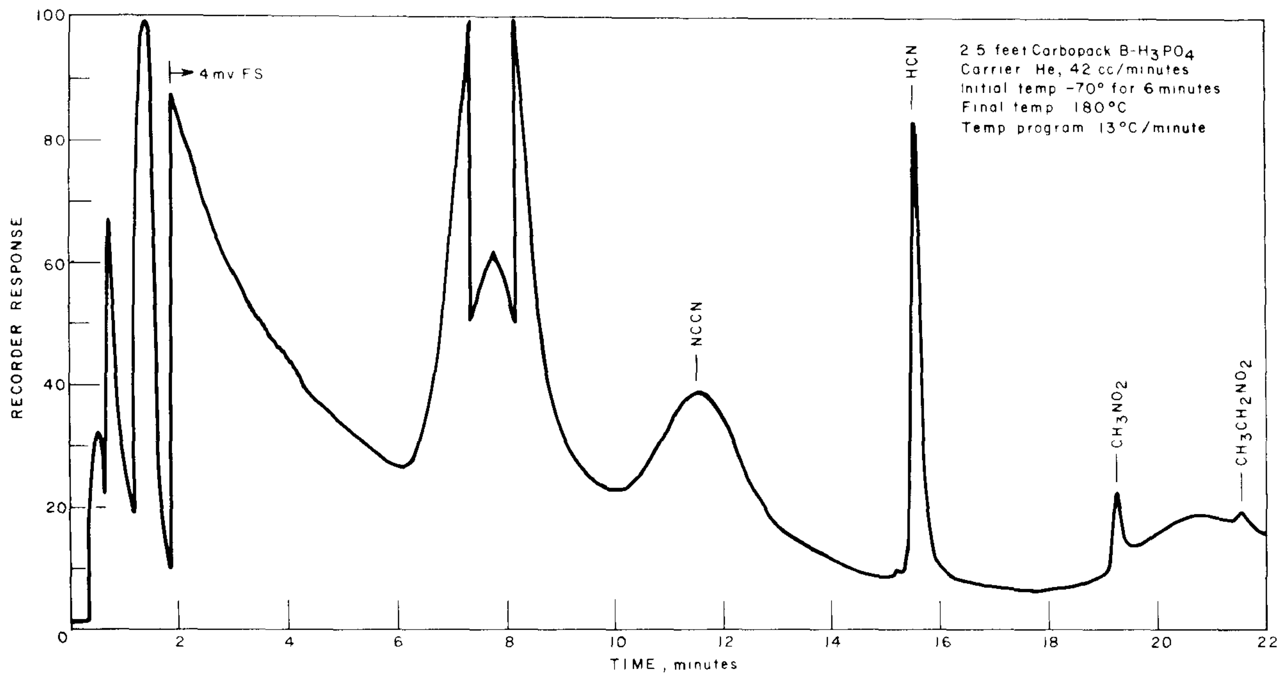

FIGURE 3. - Exhaust Analysis for Nitrogen Compounds--Carbopack Column

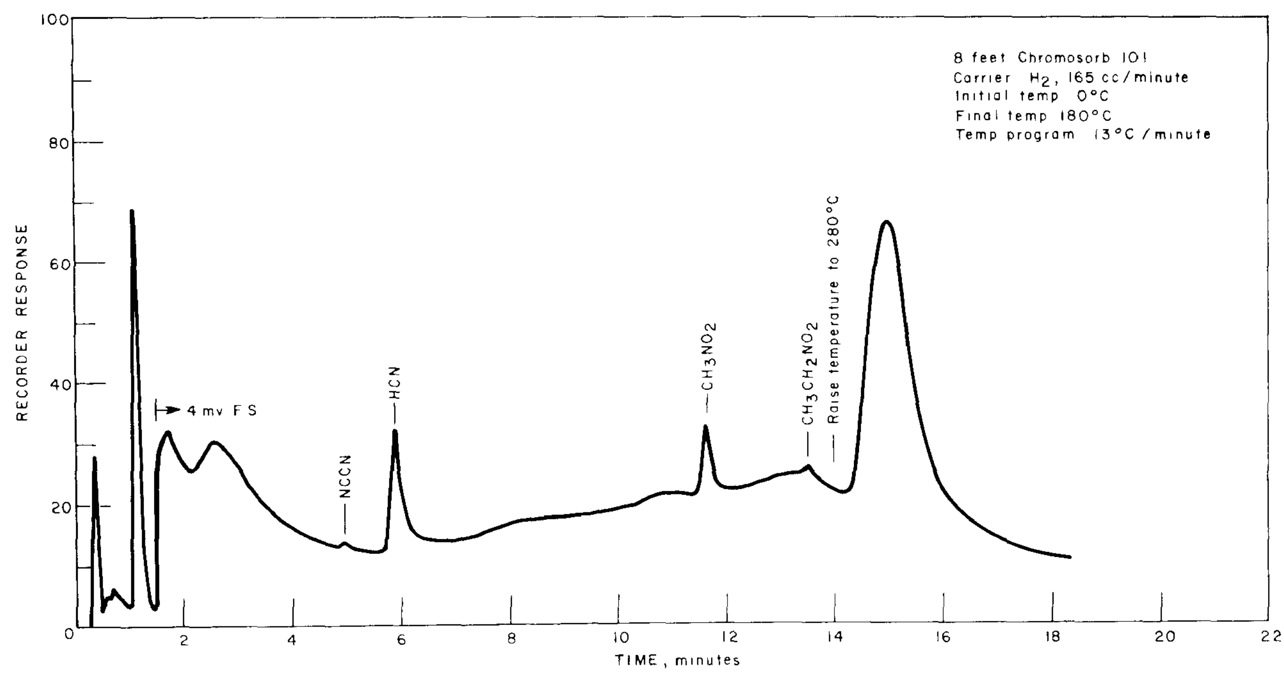

FIGURE 4. - Exhaust Analysis for Nitrogen Compounds--Chromosorb Column

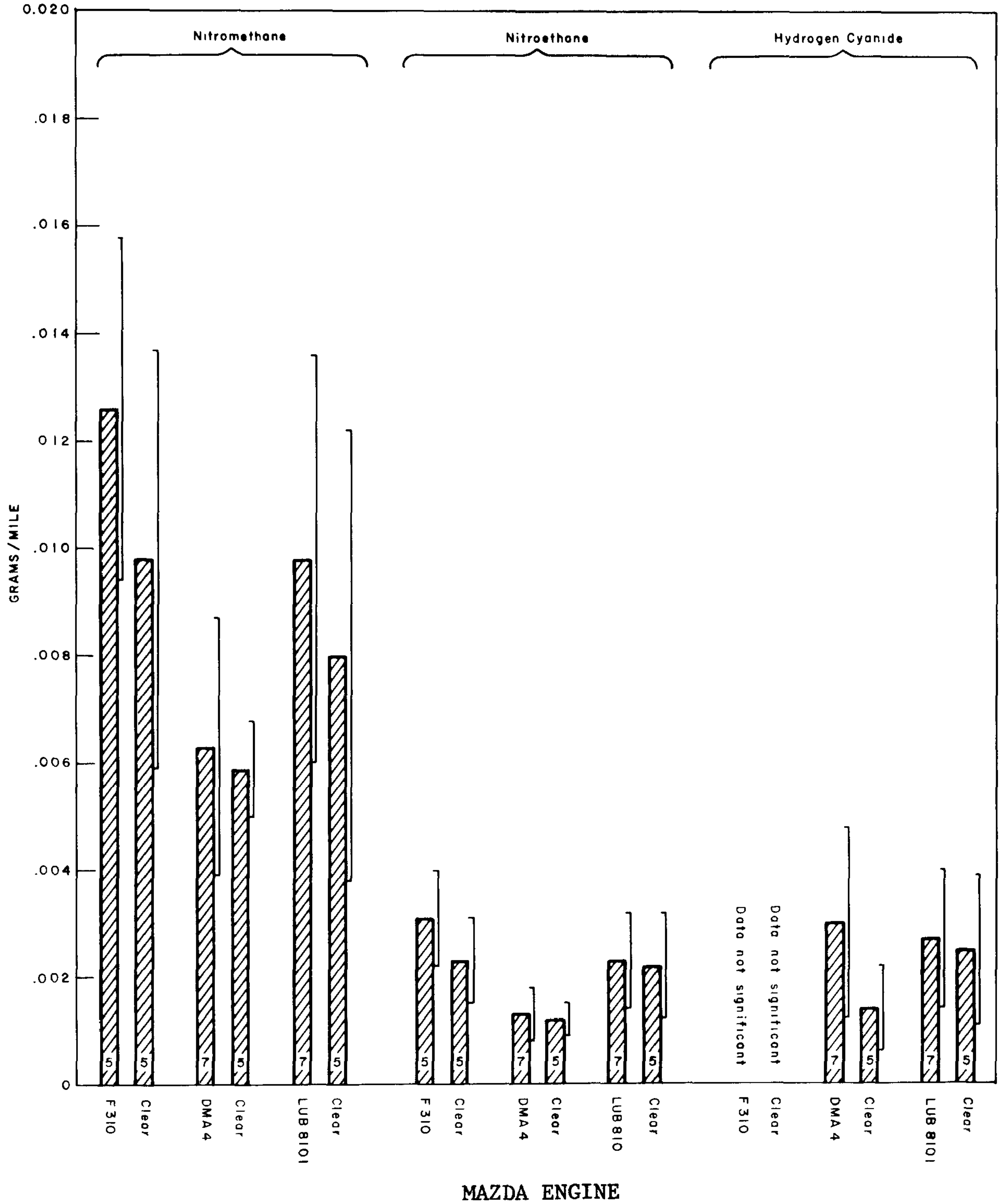

FIGURE 5. - Nitrogen Compound Emissions--Mazda Engine

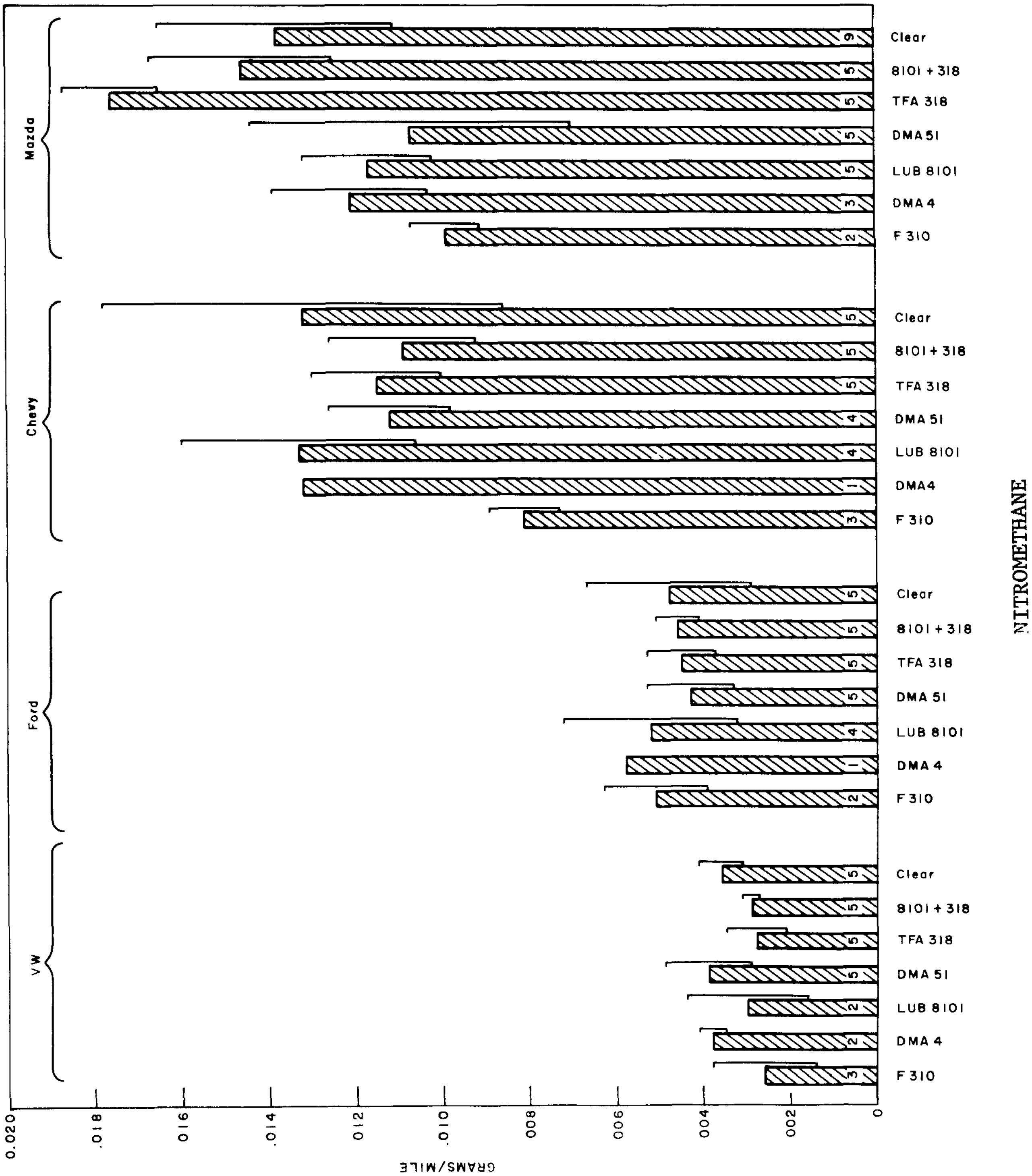

FIGURE 6. - Nitromethane Emissions

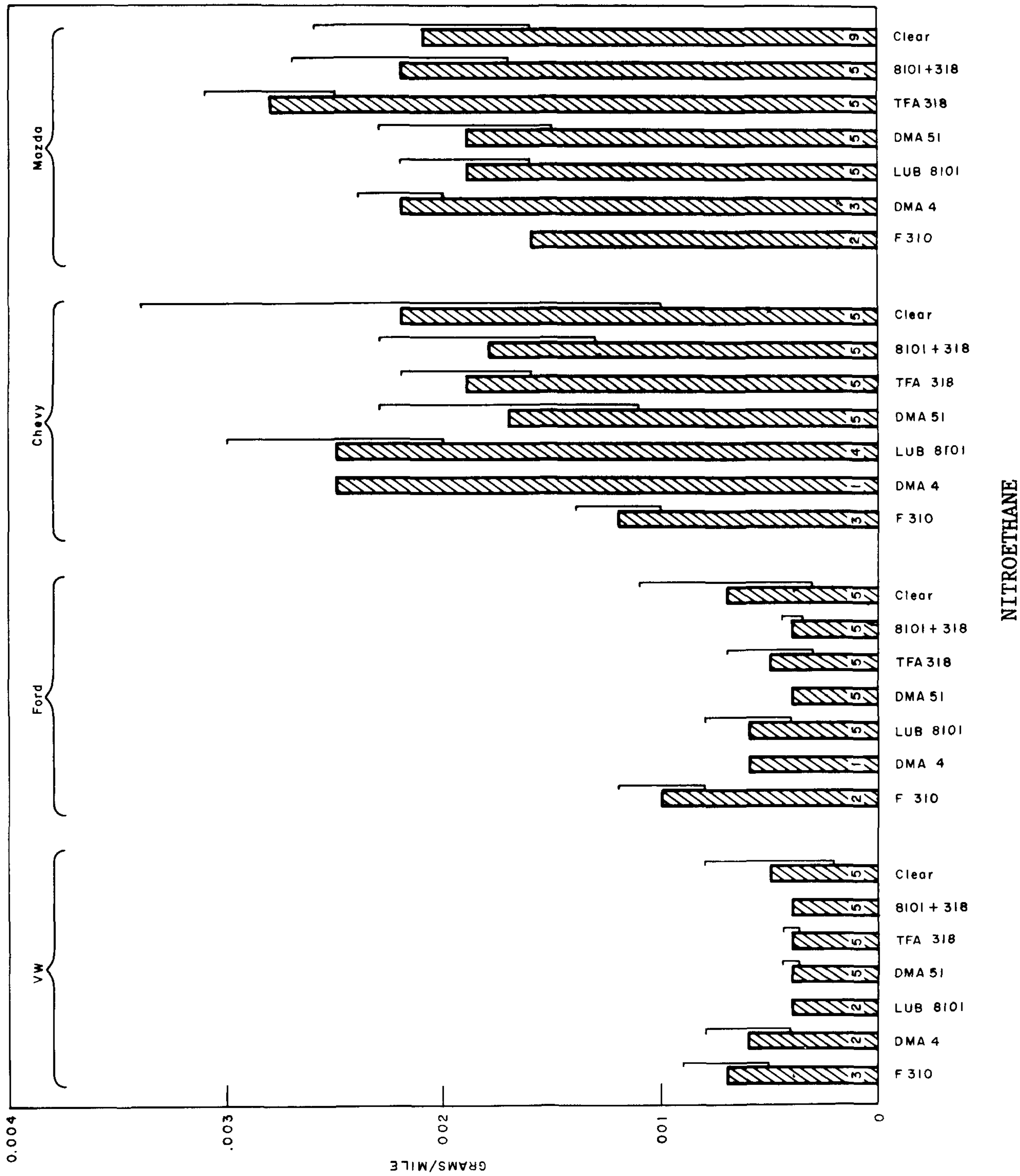

FIGURE 7. - Nitroethane Emissions

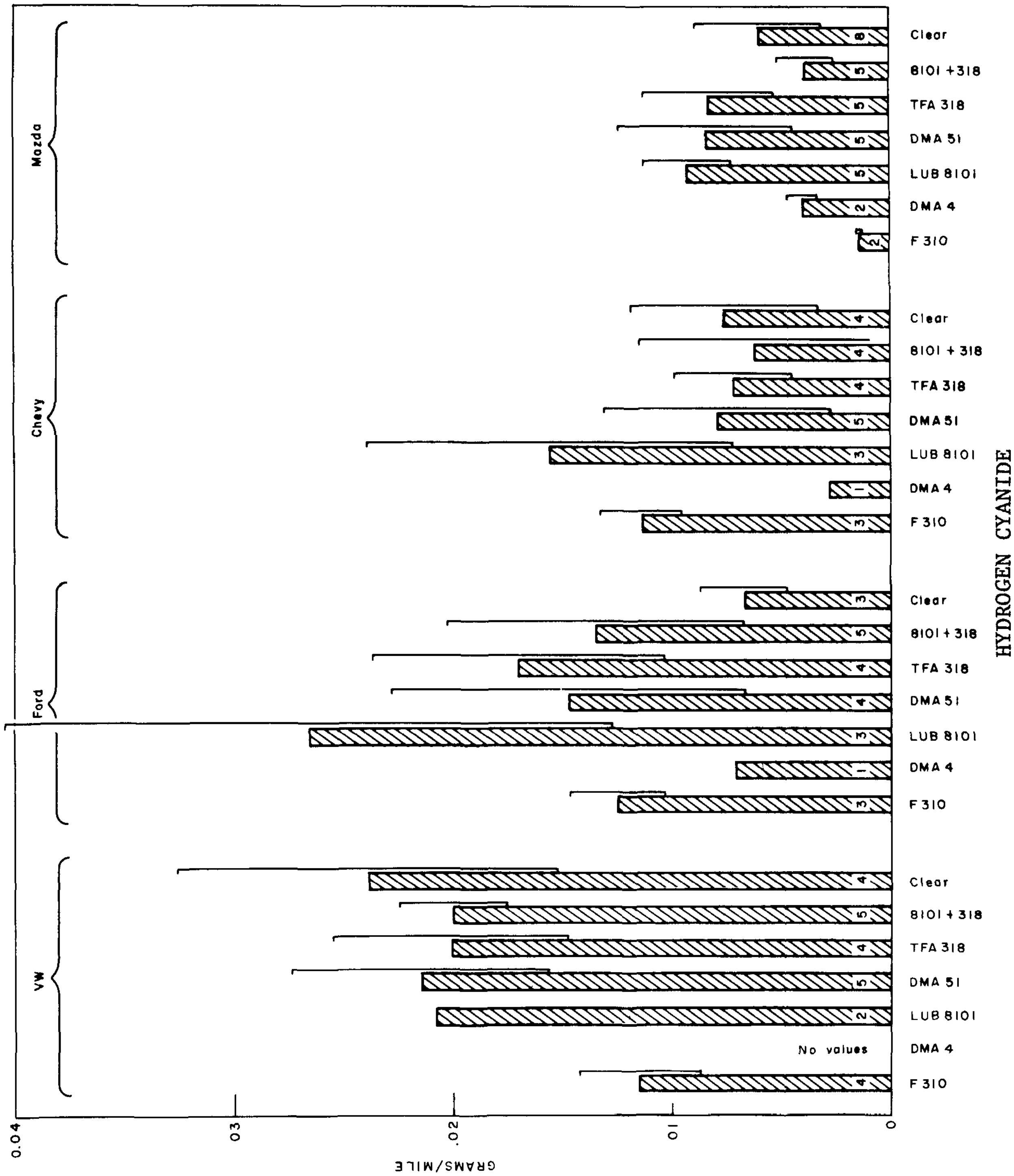

FIGURE 8. - Hydrogen Cyanide Emissions

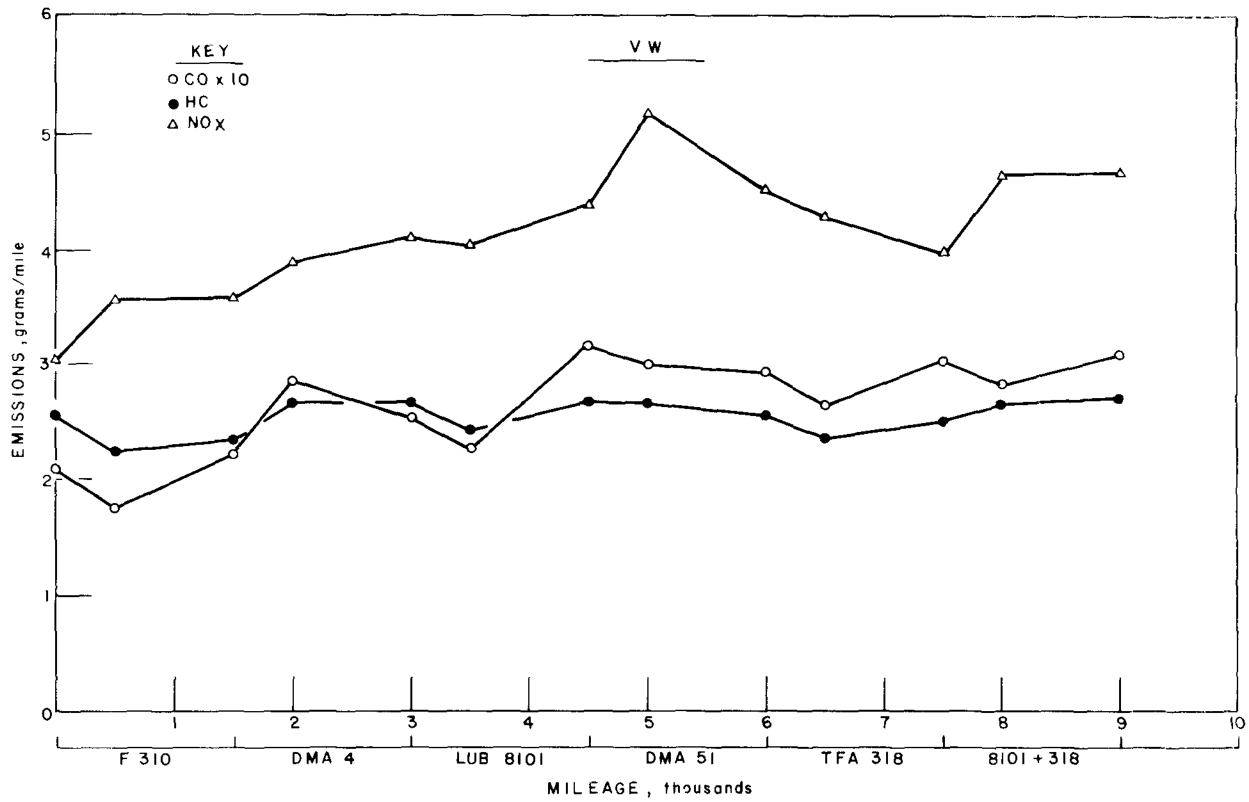

FIGURE 9. - Effect of Mileage Accumulation on CO, HC, and NO_x Emissions for the Volkswagen

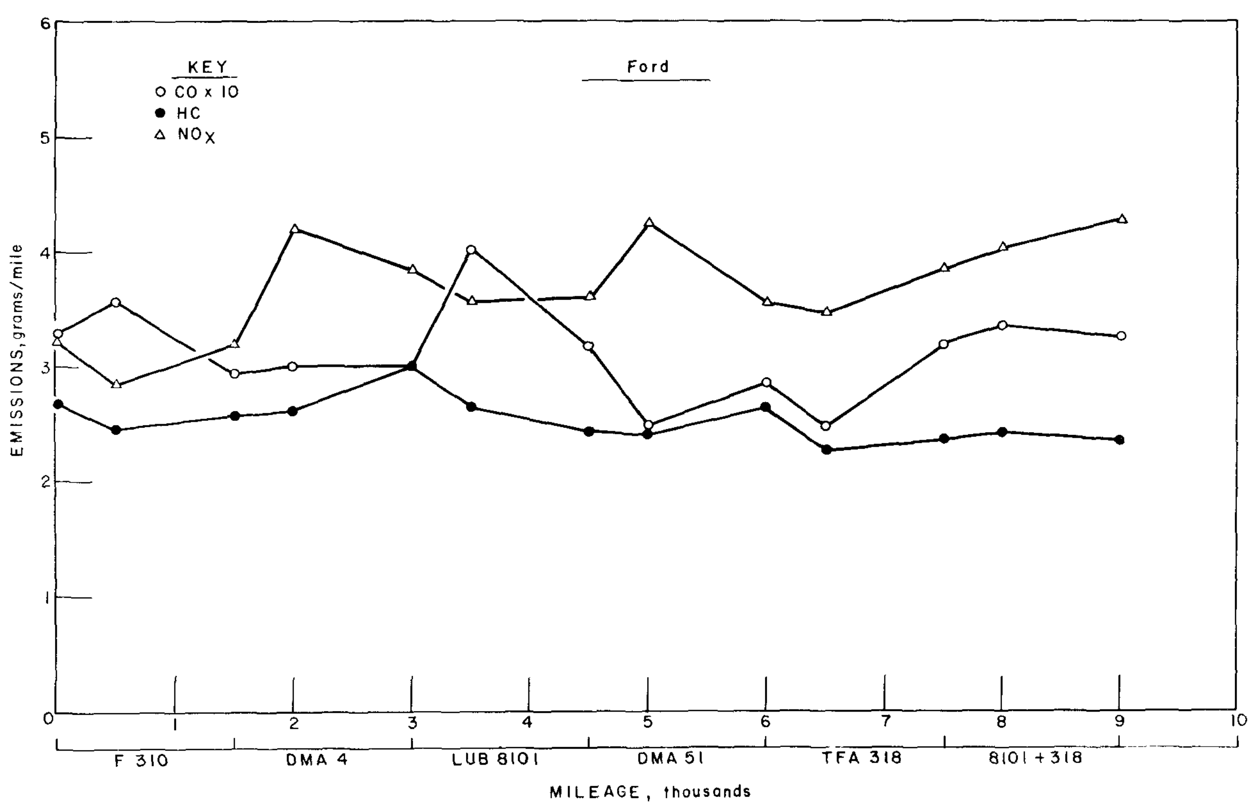

FIGURE 10. - Effect of Mileage Accumulation on CO, HC, and NO_x Emissions for the Ford

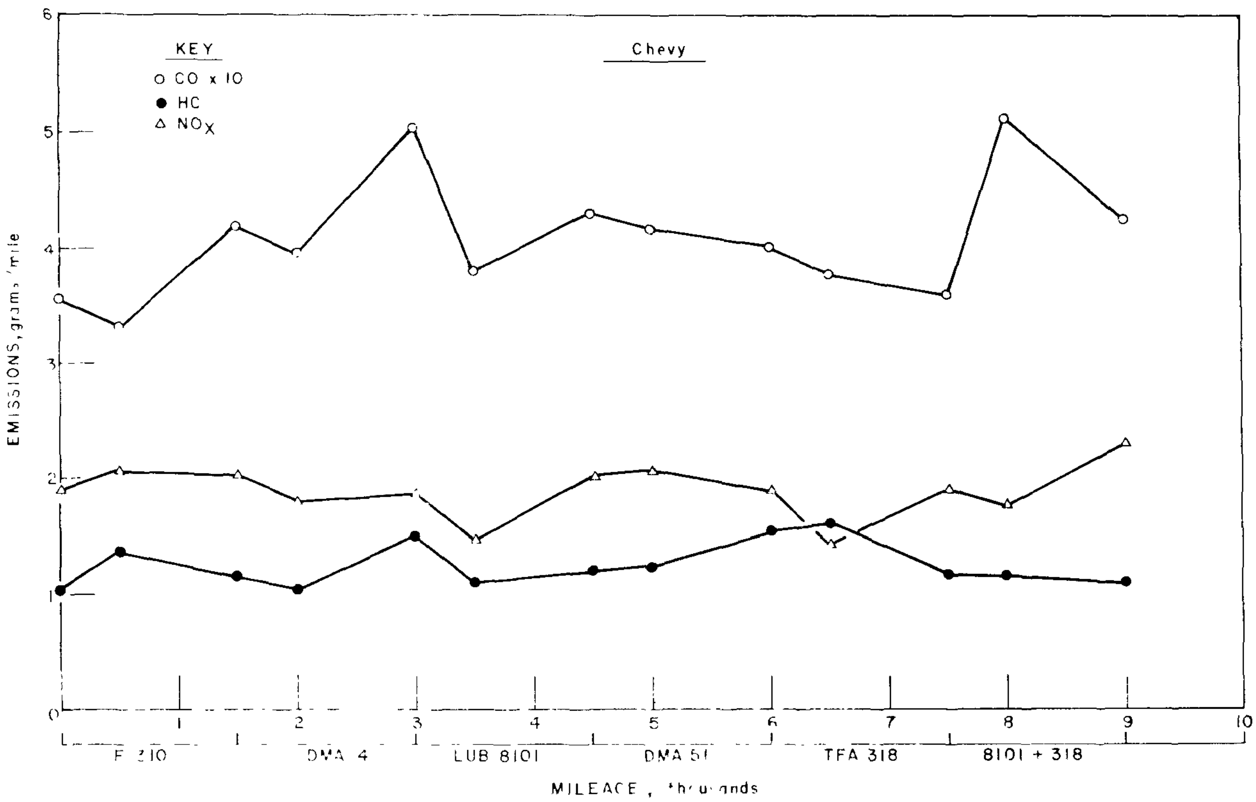

FIGURE 11. - Effect of Mileage Accumulation on CO, HC, and NO_x Emissions for the Chevrolet

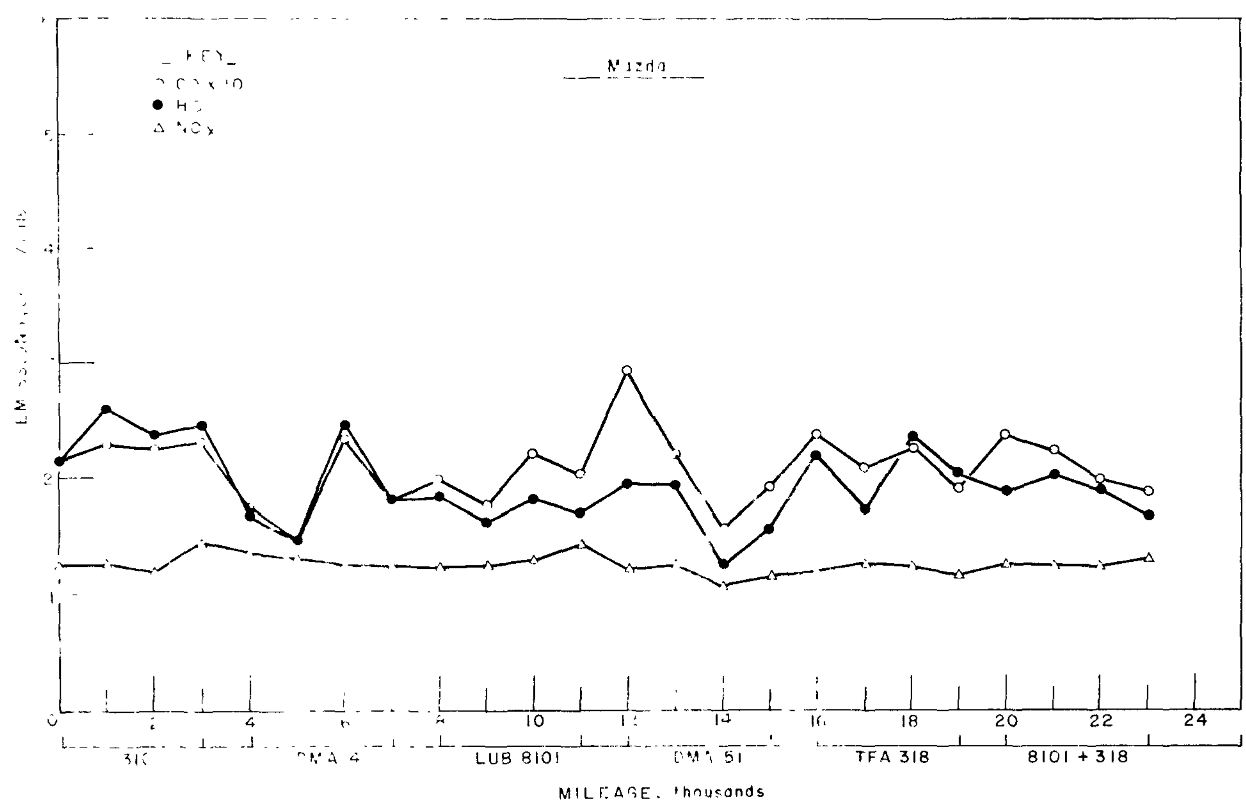

FIGURE 12. - Effect of Mileage Accumulation on CO, HC, and NO_x Emissions for the Mazda Vehicle

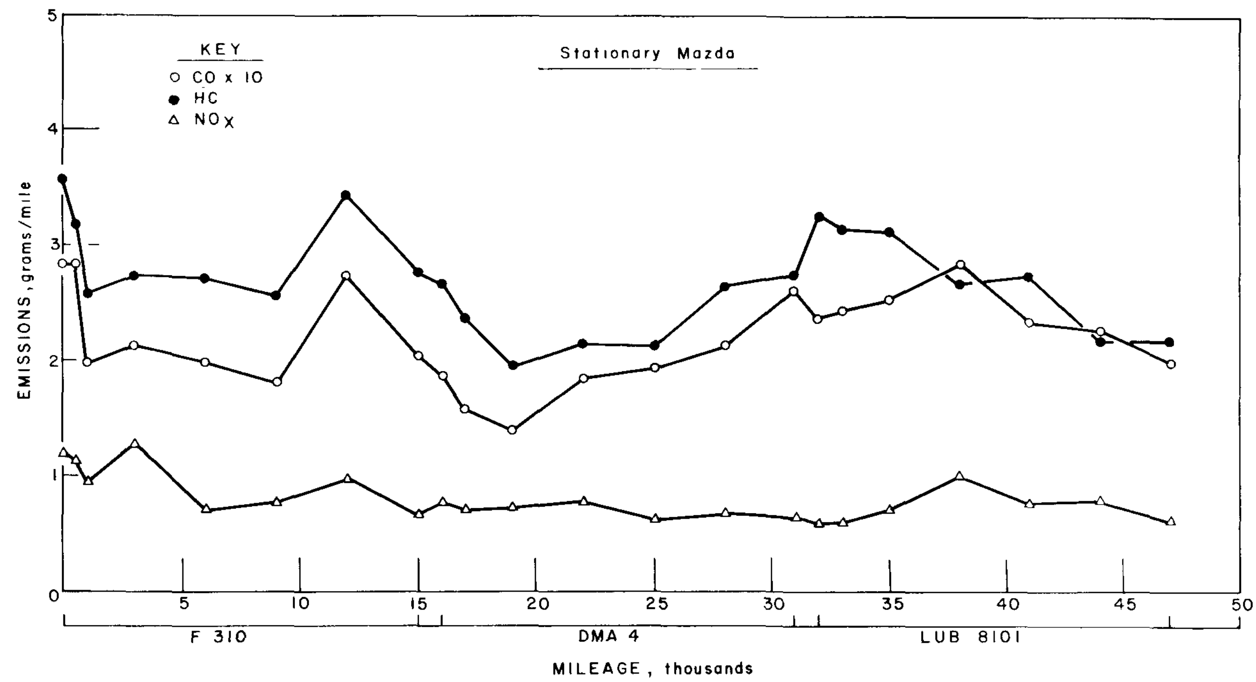

FIGURE 13. - Effect of Mileage Accumulation on CO, HC, and NO_X Emissions for the Stationary Mazda

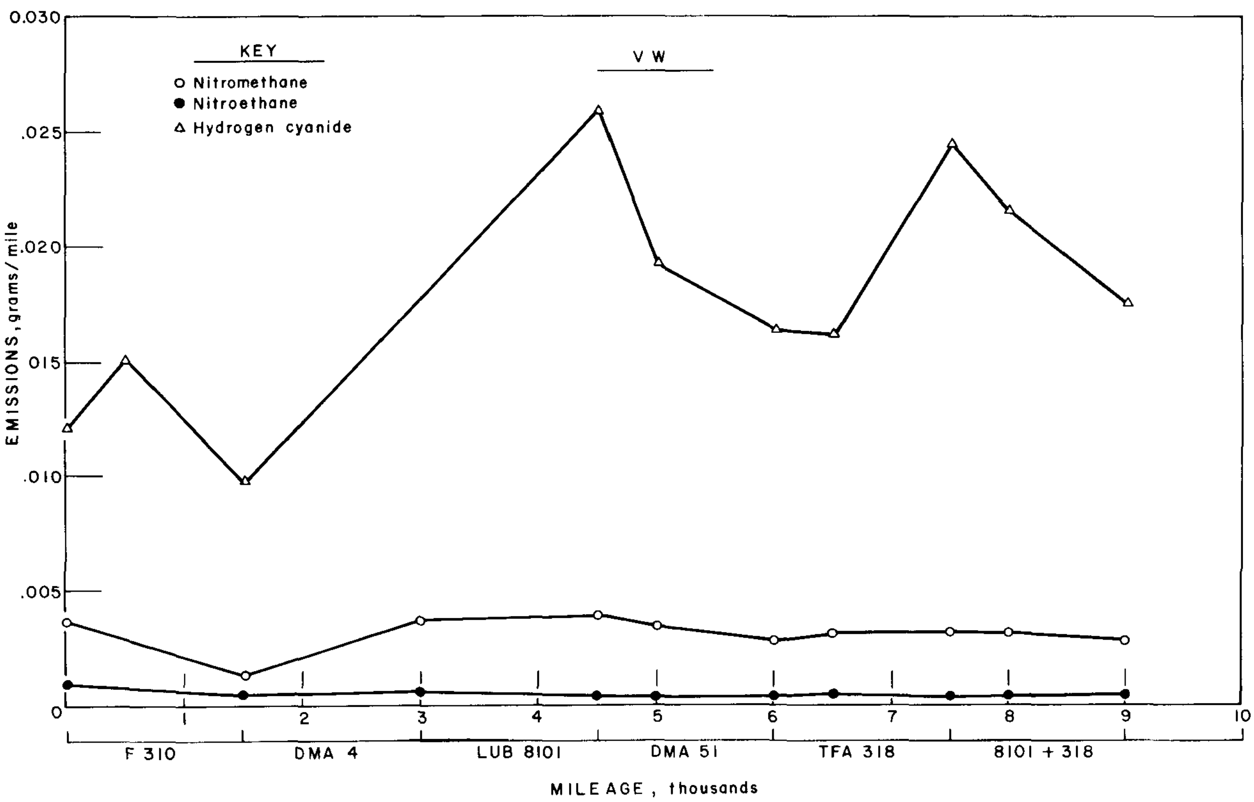

FIGURE 14. - Effect of Mileage Accumulation on Nitrogen Compound Emissions for the Volkswagen

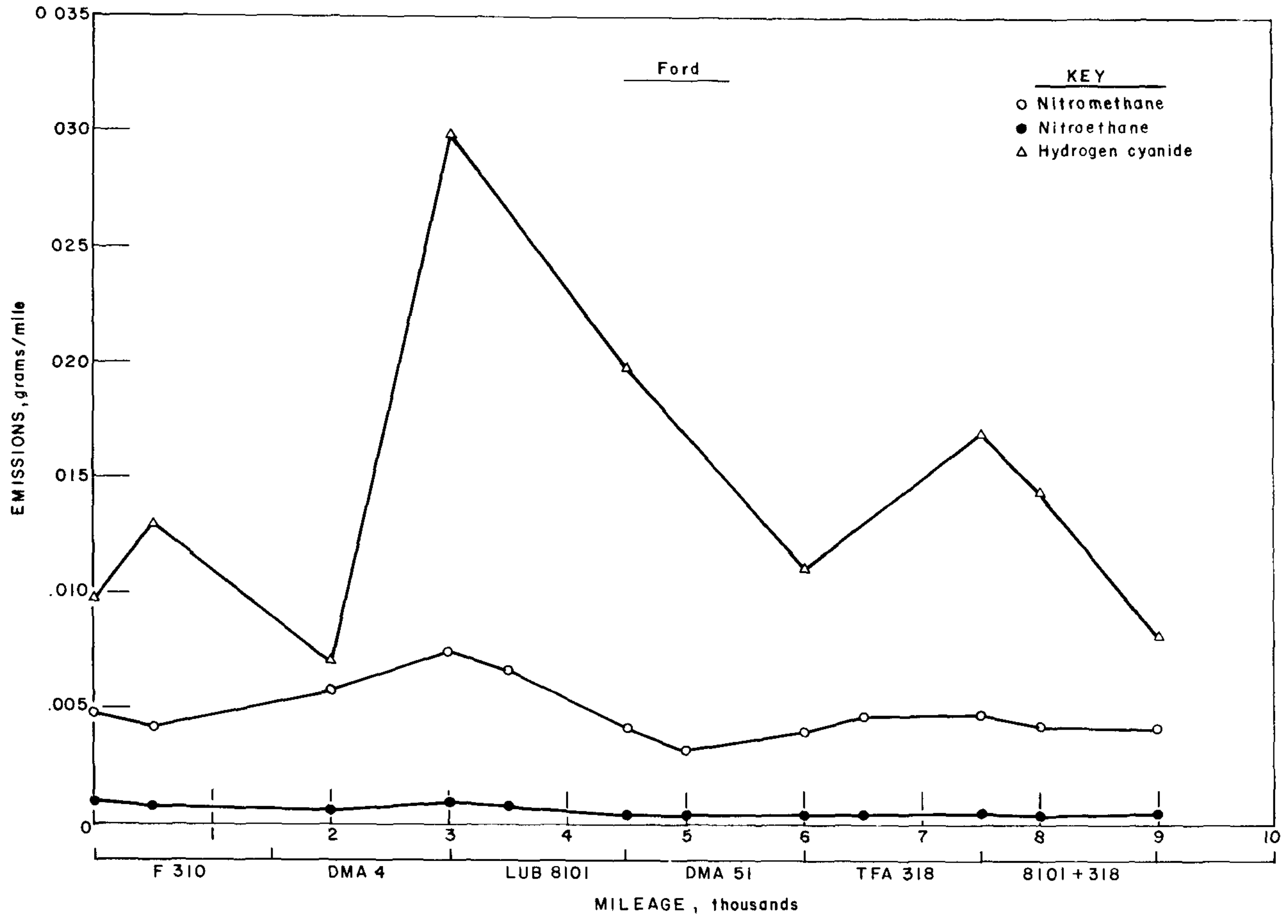

FIGURE 15. - Effect of Mileage Accumulation on Nitrogen Compound Emissions for the Ford

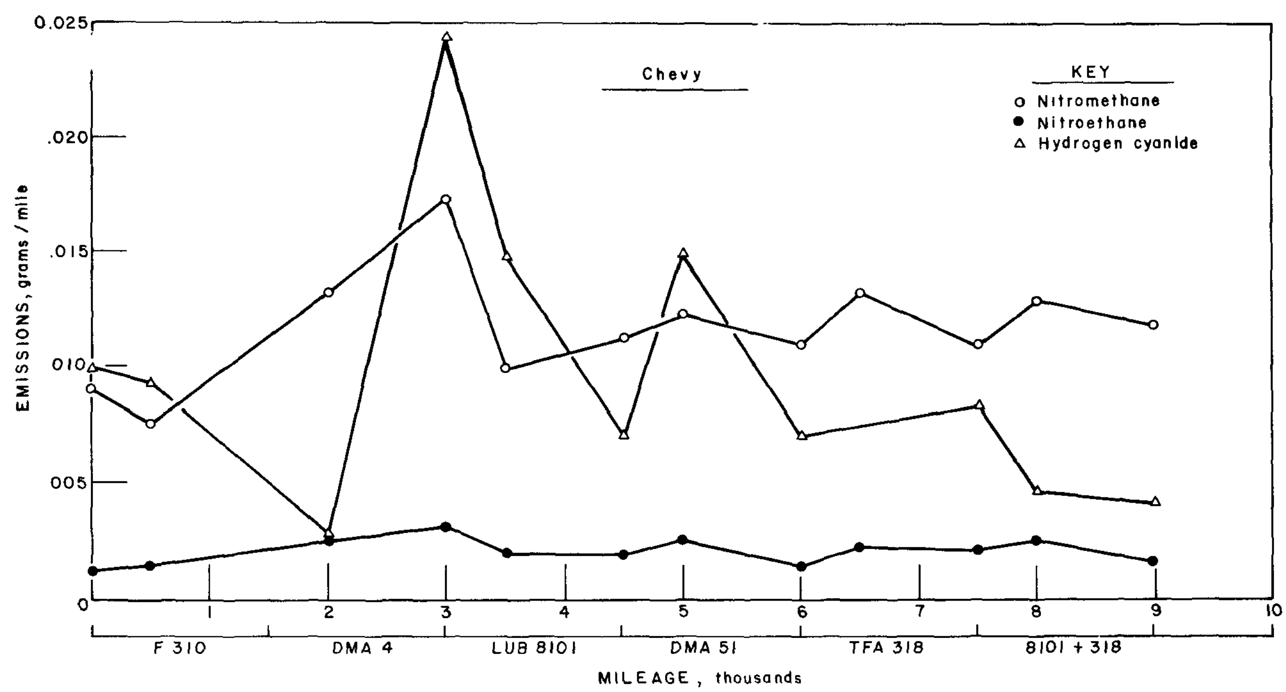

FIGURE 16. - Effect of Mileage Accumulation on Nitrogen Compound Emissions for the Chevrolet

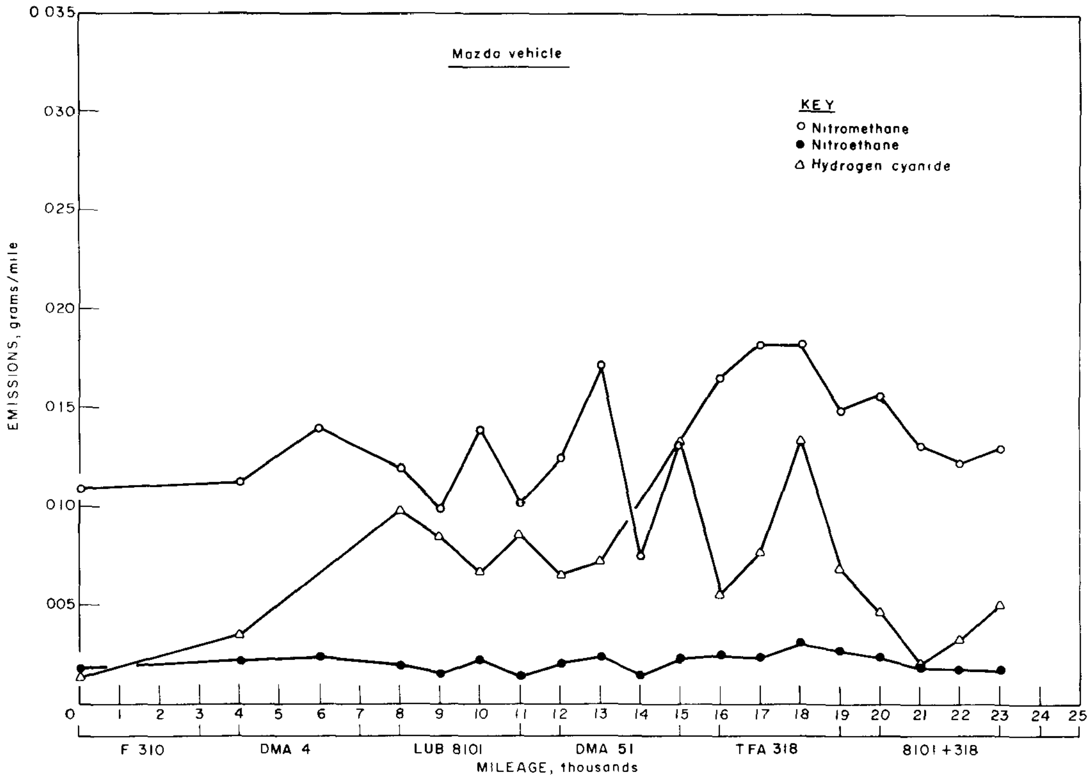

FIGURE 17. - Effect of Mileage Accumulation on Nitrogen Compound Emissions for the Mazda Vehicle

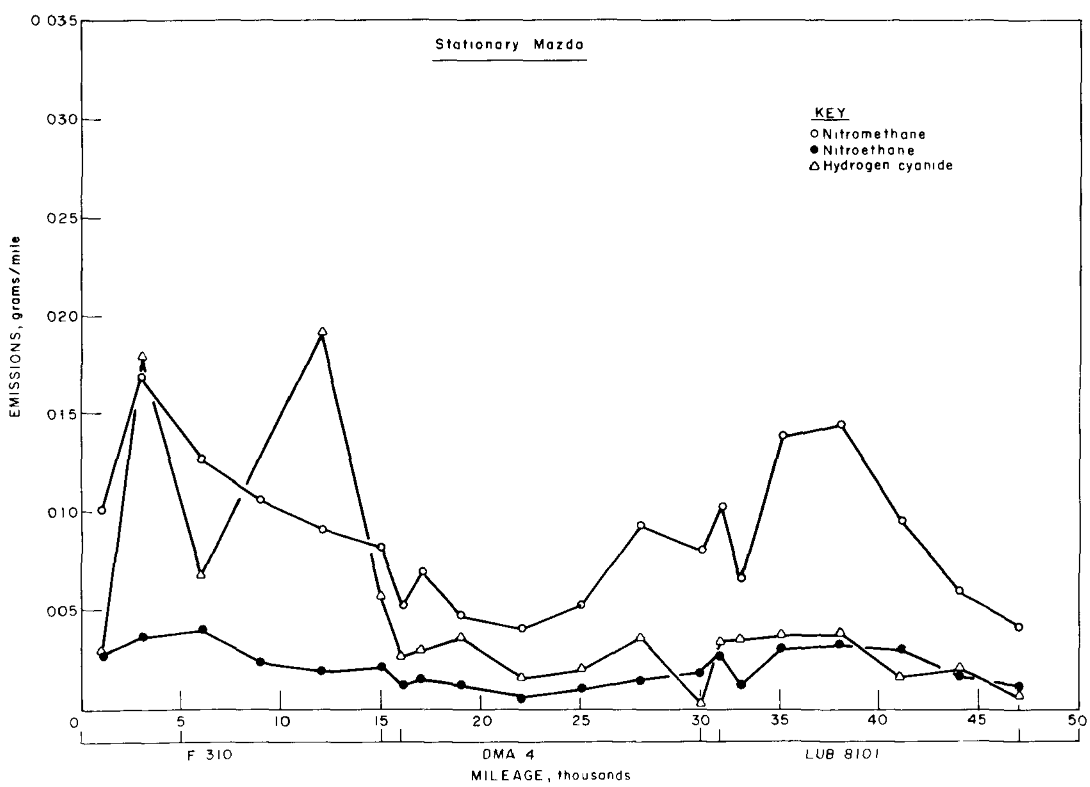

FIGURE 18. - Effect of Mileage Accumulation on Nitrogen Compound Emissions for the Stationary Mazda

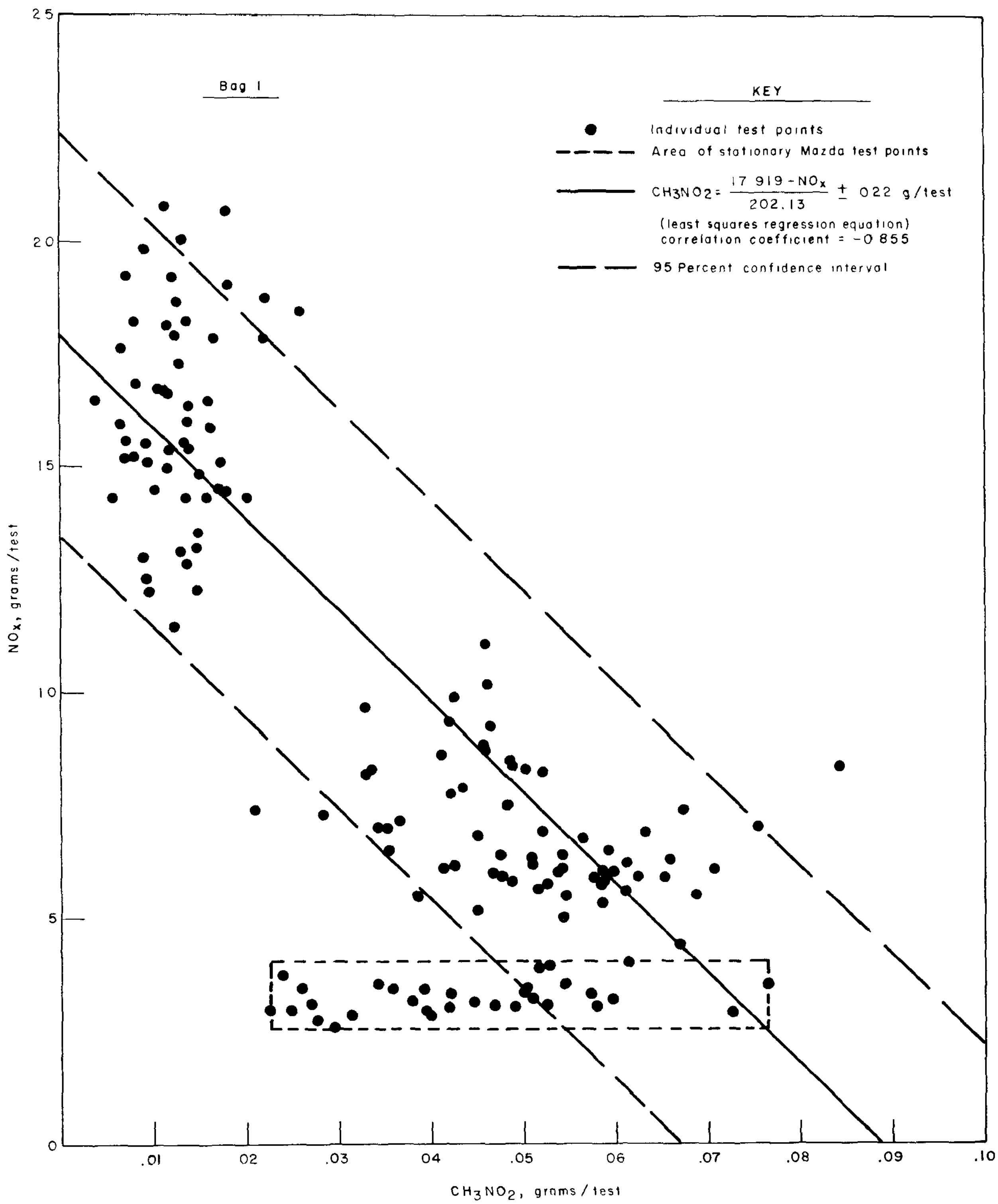

FIGURE 19. - Relationship Between NO_x and CH_3NO_2 Emission Levels

APPENDIX A. - RAW EMISSIONS DATA

TABLE A-1. - Raw emission data

(Vehicle No. 64, Volkswagen)

Fuel		Clear	TFA-318				[illegible]+TFA-313	Clear	8101+318				HA+TFA-318
Miles		0	10	20	500	1500	1510	0	10	20	500	1500	1510
Test Conditions													
Barometer		743.0	740.7	740.7	743.5	744.2	744.6	744.1	744.5	743.4	747.4	748.4	746.4
Temperature		75	75	75	75	75	75	75	75	75	75	75	75
Relative Humidity		50	50	50	59	51	56	56	51	54	50	48	48
Carbon monoxide	Bag 1, g/test	138.40	127.34	128.18	118.40	141.17	114.34	121.76	114.10	132.64	121.08	124.56	139.06
	Bag 2, g/test	113.87	105.27	113.40	96.93	134.03	116.34	126.60	120.27	123.76	107.05	131.06	112.93
	Bag 3, g/test	99.19	85.73	91.50	89.09	86.19	84.93	87.13	84.32	83.82	92.24	88.98	95.08
	Composite, g/mi.	30.6[illegible]	27.93	29.42	26.48	32.52	28.52	30.48	28.99	30.44	28.23	31.38	30.26
Hydrocarbon	Bag 1, g/test	12.51	11.93	12.25	11.12	12.21	12.91	12.18	12.86	14.23	12.60	11.55	12.66
	Bag 2, g/test	9.79	9.61	9.84	8.50	8.25	8.21	9.57	8.57	8.68	9.58	10.37	9.99
	Bag 3, g/test	8.13	6.99	7.75	7.81	8.15	8.26	8.41	7.54	7.99	8.59	7.94	9.20
	Composite, g/mi.	2.65	2.50	2.60	2.36	2.42	2.46	2.61	2.45	2.58	2.65	2.65	2.76
Oxides of nitrogen	Bag 1, g/test	18.20	15.96	17.63	17.31	15.16	15.57	15.26	14.51	16.83	18.66	19.86	19.23
	Bag 2, g/test	15.92	15.15	15.77	15.81	13.65	14.06	13.78	14.09	15.00	16.21	15.86	17.09
	Bag 3, g/test	16.85	17.03	17.21	15.39	14.54	15.73	16.23	16.63	16.57	18.27	17.72	17.53
	Composite, g/mi.	4.45	4.23	4.42	4.27	3.79	3.96	3.95	3.97	4.22	4.62	4.60	4.71
Aldehydes	Bag 1, g/test	0.322	0.307	0.311	0.291	0.268	0.250	0.241	0.218	0.245	0.304	0.265	0.235
	Bag 2, g/test	.365	.345	.341	.366	.308	.261	.274	.265	.238	.331	.311	.058
	Bag 3, g/test	.273	.248	.246	.255	.240	.203	.213	.223	.202	.268	.230	.350
	Composite, g/mi.	.083	.082	.082	.085	.075	.065	.067	.065	.064	.085	.074	.048
Nitromethane	Bag 1, g/test	0.008068	0.00671	0.00668	0.01288	0.01751	0.01336	0.007975	0.01009	0.00818	0.01251	0.009165	0.00729
	Bag 2, g/test	.01086	.009802	.01059	.01071	.01428	Trace	.01615	.01249	.01040	.01112	.00981	.01197
	Bag 3, g/test	.01088	.01312	.008468	.01182	.01264	.01084	.01659	.01348	.01230	.01241	.01109	.01162
	Composite, g/mi.	.00273	.00268	.00243	.00306	.00386	.0020	.00386	.00326	.00278	.00314	.00267	.00289
Nitroethane	Bag 1, g/test	BDL	BDL	BDL	Trace	BDL	BDL	BDL	BDL	BDL	BDL	BDL	Trace
	Bag 2, g/test	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	Bag 3, g/test	BDL	BDL	BDL	0.00238	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	Composite, g/mi.	0.0004	0.0004	0.0004	.0005	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004
Hydrogen Cyanide	Bag 1, g/test	0.04933	0.04305	0.3471	0.06360	0.1148	0.09883	0.17818	0.11361	0.12514	0.1173	0.07081	0.10365
	Bag 2, g/test	.07126	.05746	.4011	.06169	.07014	.10103	.07626	.06303	.05878	.08036	.05889	.06260
	Bag 3, g/test	.07154	.06117	.2861	.05716	.09671	.08981	.12276	.07545	.1012	.05514	.05837	.05795
	Composite, g/mi.	.01776	.01477	.09512*	.01621	.02328	.02596	.02971	.02065	.02270	.02162	.0164	.01869
Cyanogen	Bag 1, g/test	0.00373	0.00419	0.03668	0.02748	0.00359	0.02139	0.0048	0.002794	0.003672	BDL	Trace	BDL
	Bag 2, g/test	BDL	Trace	.02568	.02255	Trace	.004381	Trace	.00350	Trace	BDL	BDL	BDL
	Bag 3, g/test	BDL	BDL	.04464	.02702	.005966	.01367	.01276	.01504	.01033	Trace	Trace	BDL
	Composite, g/mi.	.0003	.0004	.00891*	.00663*	.0007	.0029	.0014	.00176	.0012	0.0002	0.0002	0.0001

*Not included in reduced data.
BDL-Below detection limit.

TABLE A-1. - Raw emission data--Continued

(Vehicle No. 64, Volkswagen)

Fuel		Clear	LUB 8101				HA+TFA-318	Clear	DMA51				HA+TFA-318
Miles		0	10	20	500	1500	1510	0	10	20	500	1500	1510
Test Conditions													
Barometer		742.9	742.7	745.5	745.0	742.5	737.0	747.5	746.0	747.0	742.0	741.0	743.3
Temperature		75	75	75	75	75	75	75	75	75	75	75	75
Relative Humidity		49	52	55	47	50	49	49	52	50	52	49	50
Carbon monoxide	Bag 1, g/test	111.2	141.4	97.7	97.0	152.1	168.7	134.2	171.2	114.2	132.8	168.9	123.0
	Bag 2, g/test	96.9	98.4	94.0	83.3	113.4	111.8	113.0	115.7	96.8	105.3	103.9	101.2
	Bag 3, g/test	87.2	92.2	77.5	80.1	119.8	106.7	103.3	122.5	97.4	108.5	95.4	95.0
	Composite, g/mi	25.9	28.2	24.0	22.8	33.0	32.7	30.6	34.6	26.9	29.9	30.8	27.8
Hydrocarbon	Bag 1, g/test	11.90	12.49	11.31	10.97	12.91	14.89	12.49	13.51	11.03	15.04	11.66	11.28
	Bag 2, g/test	10.16	9.94	9.98	8.96	9.68	9.18	8.68	9.96	9.16	8.61	9.18	9.07
	Bag 3, g/test	9.07	8.78	8.05	8.03	10.02	9.01	8.35	9.49	9.06	8.60	7.75	8.34
	Composite, g/mi	2.73	2.71	2.59	2.43	2.79	2.76	2.51	2.82	2.54	2.66	2.48	2.49
Oxides of nitrogen	Bag 1, g/test	16.70	16.99	17.88	18.58	15.21	16.49	17.90	18.75	17.87	20.75	19.09	15.56
	Bag 2, g/test	13.12	13.45	13.91	13.44	14.35	11.90	14.59	17.75	16.57	18.22	18.06	16.92
	Bag 3, g/test	15.45	16.05	16.19	15.40	19.08	17.41	16.04	20.21	18.45	20.22	18.83	17.37
	Composite, g/mi	3.88	3.99	4.11	4.03	4.24	3.86	4.19	4.98	4.64	5.16	4.93	4.47
Aldehydes	Bag 1, g/test	0.302	0.280	0.27	0.323	0.302	0.284	0.311	0.390	0.303	0.359	0.322	0.300
	Bag 2, g/test	.357	.362	.30	.354	.408	.355	.411	.514	.459	.394	.413	.450
	Bag 3, g/test	.257	.281	.24	.263	.335	.241	.263	.403	.345	.304	.277	.289
	Composite, g/mi	.084	.086	.074	.086	.097	.082	.093	.121	.105	.096	.095	.099
Nitromethane	Bag 1, g/test	0.0112				0.0070	0.0039	0.0123	0.0221	0.0219	0.01128	0.01812	0.00926
	Bag 2, g/test	.0150				.0118	.0092	.0138	.0178	.0159	.01227	.01051	.01114
	Bag 3, g/test	.0110				.0264	.0072	.0163	.0197	.0178	.01445	.01350	.01072
	Composite, g/mi	.0035				.0040	.0020	.0038	.0051	.0047	.00338	.00346	.00283
Nitroethane	Bag 1, g/test	Trace				BDL	BDL	BDL	BDL	Trace	BDL	BDL	BDL
	Bag 2, g/test	BDL				BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	Bag 3, g/test	Trace				BDL	BDL	BDL	BDL	Trace	BDL	BDL	BDL
	Composite, g/mi	0.0005				0.0004	0.0004	0.0004	0.0004	0.0005	0.0004	0.0004	.0004
Hydrogen cyanide	Bag 1, g/test	--				0.0826	0.0538	0.1307	0.1167	0.1288	0.06303	0.09201	0.08121
	Bag 2, g/test	0.1106				.0288	.0732	.1254	.0992	.0850	.04520	.06805	.05075
	Bag 3, g/test	.1700				.1604	.1043	.1135	.1045	.1112	.1267	.06938	.03296
	Composite, g/mi	--				.0208	.0208	.0328	.0279	.0272	.01926	.01922	.01392
Cyanogen	Bag 1, g/test	0.0262				0.0242	0.0136	0.0231	0.0180	0.0237	0.00908	0.00659	0.00852
	Bag 2, g/test	.0062				.0095	.0038	.0054	.0053	.0057	.00349	BDL	BDL
	Bag 3, g/test	.0530				.0392	.0195	.0216	.0227	.0187	.02173	BDL	.00541
	Composite, g/mi	.0064*				.0056*	.0028	.0037	.0035	.0035	.00263	.0005	.0010

*Not included in reduced data.
BDL-Below detection limit.

TABLE A-1. - Raw emission data--Continued

(Vehicle No. 64, Volkswagen)

Fuel		Clear	F310				HA+TFA-318	Clear	DMA4				HA+TFA-318
Miles		0	10	20	500	1500	1510	0	10	20	500	1500	1510
Test Conditions													
Barometer		745.0	735.3	737.0	751.0	743.0	749.0	747.5	747.0	743.0	736.0	741.3	742.5
Temperature		75	75	75	75	75	75	75	75	75	75	75	75
Relative Humidity		52	49	50	50	50	50	59	52	57	59	48	52
Carbon monoxide	Bag 1, g/test	83.8	74.8	94.3	75.9	92.8	82.2	102.2	91.1	96.8	137.1	78.8	113.2
	Bag 2, g/test	72.7	72.7	89.9	64.1	80.2	69.0	92.4	87.5	93.2	103.5	75.1	100.5
	Bag 3, g/test	65.1	72.6	81.6	59.9	70.1	61.1	83.1	69.2	77.3	89.7	89.0	85.5
	Composite, g/mi	19.5	19.5	23.6	17.5	21.3	18.6	24.5	22.1	23.9	28.5	21.3	26.4
Hydrocarbon	Bag 1, g/test	12.59	16.06	14.94	11.33	9.99	12.32	10.84	10.99	12.30	12.40	10.83	11.99
	Bag 2, g/test	8.06	8.89	7.98	7.60	7.15	8.57	8.17	8.82	8.79	9.52	9.11	10.36
	Bag 3, g/test	7.77	8.34	7.67	7.38	7.35	6.97	8.40	7.06	7.82	9.14	9.14	9.40
	Composite, g/mi	2.39	2.74	2.50	2.22	2.08	2.38	2.35	2.34	2.47	2.68	2.53	2.78
Oxides of nitrogen	Bag 1, g/test	13.57	13.16	12.29	15.60	14.34	17.52	16.55	15.51	14.82	16.66	20.06	18.12
	Bag 2, g/test	10.29	10.10	9.65	11.54	10.95	13.36	12.65	10.91	10.81	12.73	14.11	14.15
	Bag 3, g/test	13.63	12.18	11.10	14.59	12.92	17.70	16.42	12.86	12.65	16.31	17.40	16.52
	Composite, g/mi	3.19	3.03	2.84	3.54	3.26	4.13	3.88	3.32	3.25	3.89	4.35	4.18
Aldehydes	Bag 1, g/test	0.33	0.347	0.303	0.321	0.278	0.324	0.198	0.298	0.192	0.295	0.365	0.272
	Bag 2, g/test	.33	.227	.270	.380	.291	.361	.328	.317	.293	.301	.399	.312
	Bag 3, g/test	.19	.101	.192	.242	.215	.201	.199	.247	.186	.263	.286	.245
	Composite, g/mi	.0774	.0578	.0680	.0875	.071	.082	.070	.078	.064	.077	.096	.076
Nitromethane	Bag 1, g/test	0.0148	0.0129	0.0147	0.0072	0.0057						0.0133	0.0152
	Bag 2, g/test	.0152	.0131	.0132	.0071	.0041						.0155	.0146
	Bag 3, g/test	.0156	.0112	.0093	--	.0057						.0104	.0159
	Composite, g/mi	.0041	.0033	.0033	--	.0013						.0036	.0040
Nitroethane	Bag 1, g/test	0.0048	0.0026	0.0027	Trace	Trace						Trace	Trace
	Bag 2, g/test	Trace	Trace	Trace	Trace	BDL						Trace	BDL
	Bag 3, g/test	.0026	Trace	Trace	--	Trace						Trace	Trace
	Composite, g/mi	.0010	.0008	.0008	--	0.0005						0.0008	0.0005
Hydrogen cyanide	Bag 1, g/test	0.0664	0.0583	0.0487	0.0693	0.0602						--	0.4990
	Bag 2, g/test	.0442	.0420	.0255	.0326	.0259						0.2208	.8575
	Bag 3, g/test	.0715	.0456	.0338	.0890	.0381						.2168	.6500
	Composite, g/mi	.0151	.0124	.0088	.0151	.0098						--	.1923*
Cyanogen	Bag 1, g/test	BDL	BDL	BDL	BDL	BDL						0.0136	--
	Bag 2, g/test	BDL	BDL	BDL	BDL	BDL						.0026	0.0398
	Bag 3, g/test	BDL	BDL	BDL	BDL	BDL						.0137	.152
	Composite, g/mi	0.0001	0.0001	0.0001	0.0001	0.0001						.0022	--

*Not included in reduced data.
BDL-Below detection limit.

TABLE A-2. - Raw emission data

(Vehicle No. 68, Ford Torino)

Fuel		Clear	F310				HA+TFA-318	Clear	DMA4				HA+TFA-318
Miles		0	10	20	500	1500	1510	0	10	20	500	1500	1510
Test Conditions													
Barometer		722.0	750.7	748.6	737.2	746.9	749.6	744.9	743.2	740.9	735.4	743.7	747.2
Temperature		81	66	63	61	74	75	70	80	78	88	82	74
Relative Humidity		46	46	52	58	55	80	68	52	52	58	70	88
Carbon monoxide	Bag 1, g/test	261.2	208.9	255.0	262.8	192.3	277.4	156.5	212.3	218.2	215.1	202.7	229.4
	Bag 2, g/test	119.4	77.2	85.9	98.6	92.8	139.4	80.0	67.1	66.6	87.7	115.2	118.4
	Bag 3, g/test	114.0	71.2	72.1	100.4	74.8	106.7	61.7	63.8	80.7	78.0	105.6	114.3
	Composite, g/mi	39.6	27.6	31.6	35.8	29.1	39.7	24.3	26.0	27.5	30.0	35.0	37.6
Hydrocarbon	Bag 1, g/test	15.35	15.98	14.38	14.17	13.48	14.97	11.66	13.15	12.20	12.54	15.63	15.96
	Bag 2, g/test	8.37	7.98	8.33	7.46	7.89	11.21	6.98	7.53	7.41	8.49	9.16	9.45
	Bag 3, g/test	9.83	8.79	8.89	8.43	12.04	10.70	7.74	8.58	9.17	9.92	9.65	10.42
	Composite, g/mi	2.74	2.65	2.61	2.45	2.74	3.17	2.19	2.41	2.38	2.61	2.85	2.97
Oxides of nitrogen	Bag 1, g/test	12.23	14.51	13.00	11.47	13.26	12.13	9.82	12.56	12.26	15.9	13.80	17.52
	Bag 2, g/test	11.36	11.38	11.30	10.15	10.82	13.46	9.42	12.64	12.60	15.3	13.19	13.80
	Bag 3, g/test	11.54	13.11	12.76	10.73	12.23	12.92	10.27	13.11	12.77	16.47	13.59	14.45
	Composite, g/mi	3.09	3.35	3.22	2.83	3.13	3.47	2.60	3.40	3.35	4.20	3.58	3.94
Aldehydes	Bag 1, g/test	0.308	0.330	0.338	0.272	0.281	0.314	0.332	0.373	0.355	0.416	0.439	0.296
	Bag 2, g/test	.409	.486	.598	.127	.497	.615	.524	.640	.502	.652	.594	.369
	Bag 3, g/test	.337	.406	.460	.305	.470	.412	.449	.566	.365	.576	.46	.351
	Composite, g/mi	.1086	.115	.134	.056	.118	.131	.123	.150	.115	.155	.139	.093
Nitromethane	Bag 1, g/test	0.0098	0.0171	0.0089	0.0123						0.0163		
	Bag 2, g/test	.0161	.0289	.0186	.0165						.0245		
	Bag 3, g/test	.0126	.0143	--	.0170						.0214		
	Composite, g/mi	.0037	.0059	--	.0042						.0058		
Nitroethane	Bag 1, g/test	Trace	0.0039	0.0047	Trace						Trace		
	Bag 2, g/test	Trace	.0044	.0053	Trace						BDL		
	Bag 3, g/test	Trace	.0040	--	Trace						Trace		
	Composite, g/mi	0.0008	.0011	--	0.0008						0.0006		
Hydrogen cyanide	Bag 1, g/test	0.0203	0.0727	0.0222	0.122						0.0192		
	Bag 2, g/test	.0107	.0443	.0332	.0310						.0200		
	Bag 3, g/test	.0297	.0565	.0582	.0234						.0436		
	Composite, g/mi	.0048	.0144	.0101	.0129						.0071		
Cyanogen	Bag 1, g/test	BDL	BDL	BDL	BDL						BDL		
	Bag 2, g/test	BDL	BDL	BDL	BDL						BDL		
	Bag 3, g/test	BDL	BDL	BDL	BDL						BDL		
	Composite, g/mi	0.0001	0.0001	0.0001	0.0001						0.0001		

BDL-Below detection limit.

TABLE A-2. - Raw emission data--Continued

(Vehicle No. 68, Ford Torino)

Fuel		Clear	TFA 318				HA+TFA-318	Clear	8101+318				HA+TFA-318
Miles		0	10	20	500	1500	1510	0	10	20	500	1500	1510
Test Conditions													
Barometer		746.5	746.9	748.2	743.6	744.9		741.4	739.5	744.6	745.2	750.3	749.7
Temperature		78	82	83	82	78	79	79	78	80	78	68	66
Relative Humidity		55		65	60	77	72	82	74.5	81	76	64	62
Carbon monoxide	Bag 1, g/test	183.8	164.65	125.6	113.04	194.78	253.2	172.1	194.0	215.2	219.20	210.4	214.1
	Bag 2, g/test	96.4	90.79	111.4	95.81	78.96	107.1	141.3	94.5	105.2	99.14	106.3	108.6
	Bag 3, g/test	89.8	66.39	94.4	71.1	61.28	76.4	87.4	74.6	95.7	100.87	87.0	74.0
	Composite, g/mi	30.21	26.59	29.22	24.66	26.35	34.60	35.35	29.40	33.64	33.45	32.84	32.38
Hydrocarbon	Bag 1, g/test	14.48	13.66	13.93	9.48	10.04	11.80	12.63	10.33	11.85	11.53	12.14	13.13
	Bag 2, g/test	7.86	8.56	9.28	8.27	7.61	8.58	9.05	7.53	8.34	8.26	8.08	7.80
	Bag 3, g/test	8.26	8.58	9.26	8.17	7.38	7.75	9.35	7.38	8.74	8.51	7.81	6.70
	Composite, g/mi	2.51	2.58	2.74	2.27	2.15	2.41	2.64	2.16	2.46	2.41	2.37	2.30
Oxides of nitrogen	Bag 1, g/test	14.35	13.23	14.34	14.85	16.01	18.28	15.41	15.42	16.35	18.13	20.69	19.17
	Bag 2, g/test	10.91	11.46	13.71	11.93	13.32	13.70	13.64	12.28	13.64	14.34	14.66	14.72
	Bag 3, g/test	12.36	12.61	14.14	13.61	14.48	14.81	15.01	14.28	16.00	14.19	16.36	14.88
	Composite, g/mi	3.22	3.25	3.73	3.48	3.83	4.00	3.84	3.61	3.97	4.03	4.38	4.18
Aldehydes	Bag 1, g/test	0.50	0.58	0.57	0.447	0.365	0.31	0.38	0.35	0.31	0.363	0.436	0.386
	Bag 2, g/test	.62	.64	.63	.591	.506	.47	.48	.44	.45	.453	.589	.478
	Bag 3, g/test	.54	.52	.50	.539	.413	.42	.40	.28	.38	.417	.464	.416
	Composite, g/mi	.151	.159	.154	.145	.120	.113	.117	.100	.107	.113	.139	.118
Nitromethane	Bag 1, g/test	0.01581	0.0147	0.01356	0.01497	0.01378	0.01357	0.01175	0.01381	0.01391	0.01156	0.01791	0.01223
	Bag 2, g/test	.01838	.01245	.01455	.01981	.02272	.02173	.01478	.02179	.02013	.01939	.01682	.01602
	Bag 3, g/test	.01887	.01259	.01426	.01619	.01808	.01919	.01525	.02024	.01835	.01439	.01553	.01521
	Composite, g/mi	.00478	.0035	.00380	.00472	.00519	.00513	.00380	.00523	.00487	.00434	.00444	.00399
Nitroethane	Bag 1, g/test	BDL	BDL	BDL	BDL	BDL	0.00734	BDL	BDL	BDL	BDL	Trace	BDL
	Bag 2, g/test	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	Bag 3, g/test	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	Trace	BDL
	Composite, g/mi	0.0004	0.0004	0.0004	0.0004	0.0004	.0007	0.0004	0.0004	0.0004	0.0004	0.0005	0.0004
Hydrogen cyanide	Bag 1, g/test	0.08331	0.1078	0.03086	0.2049	0.02645	0.0710	0.04437	0.07202	0.10074	0.09280	0.03631	0.04994
	Bag 2, g/test	.1272	.04928	.03864	>.2537	.05787	.1167	.01993	.02733	.07437	.04570	.01773	.03663
	Bag 3, g/test	.1235	.07068	.04403	.1878	.05932	.08047	.04566	.06259	.11368	.03953	.02417	.03024
	Composite, g/mi	.03112*	.0181	.0103	>.0598*	.01374	.02574	.00866	.01252	.02432	.01441	.00628	.01004
Cyanogen	Bag 1, g/test	0.01618	0.0038	BDL	0.01023	Trace	Trace	BDL	Trace	BDL	BDL	0.00308	0.003763
	Bag 2, g/test	.00659	BDL	BDL	.00366	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	Bag 3, g/test	.00966	.00168	BDL	.00656	BDL	BDL	BDL	Trace	Trace	BDL	Trace	Trace
	Composite, g/mi	.00253*	.0004	0.0001	.00157*	0.0001	0.0001	0.0001	0.0002	0.0002	0.0001	.0003	.0004

*Not included in reduced data.
BDL-Below detection limit.

TABLE A-2. - Raw emission data--Continued

(Vehicle No. 68, Ford Torino)

Fuel		Clear	LUB 8101				HA+TFA-318	Clear	DMA51				HA+TFA-318
Miles		0	10	20	500	1500	1510	0	10	20	500	1500	1510
Test Conditions													
Barometer		741.6	736.8	735.4	739.2	742.4	738.0	741.0	739.2	747.2	741.8	747.2	744.0
Temperature		92	80	86	72	74	88	78	82	72	94	94	78
Relative Humidity		64	72	74	81	58	58	72	62	55	47	45	66
Carbon monoxide	Bag 1, g/test	228.7	245.0	264.0	282.0	260.2	155.4	226.2	174.3	216.5	125.8	184.5	163.0
	Bag 2, g/test	129.4	85.6	99.9	120.7	105.7	112.3	110.9	77.0	60.0	86.5	69.9	111.9
	Bag 3, g/test	105.6	92.6	110.0	115.2	105.1	115.2	120.9	92.0	57.3	78.6	82.5	79.4
	Composite, g/mi	38.4	32.5	36.0	41.0	37.0	32.63	37.0	27.3	24.8	24.7	26.2	30.3
Hydrocarbon	Bag 1, g/test	14.85	16.16	20.30	13.86	12.99	9.60	12.39	11.99	10.96	11.32	14.51	12.84
	Bag 2, g/test	9.79	8.71	9.63	8.56	8.77	7.58	9.22	8.38	7.04	7.28	8.10	8.97
	Bag 3, g/test	10.43	10.72	11.57	9.19	9.07	7.57	9.87	9.61	7.22	10.44	10.06	9.16
	Composite, g/mi	2.95	2.90	3.33	2.63	2.60	2.14	2.69	2.54	2.12	2.41	2.68	2.63
Oxides of nitrogen	Bag 1, g/test	18.44	14.33	14.48	14.36	16.41	12.53	15.08	12.88	17.88	16.6	16.72	15.12
	Bag 2, g/test	16.73	12.59	13.18	12.76	14.95	10.31	13.51	11.13	14.57	15.6	14.18	13.54
	Bag 3, g/test	16.76	13.11	13.67	13.83	15.19	9.71	14.43	11.53	16.72	16.0	13.62	14.14
	Composite, g/mi	4.56	3.50	3.63	3.57	4.09	2.83	3.76	3.10	4.24	4.24	3.88	3.75
Aldehydes	Bag 1, g/test	0.394	--	0.365	0.434	0.48	0.43	0.37	0.44	0.49	0.57	0.50	0.81
	Bag 2, g/test	.547	0.59	.489	.489	.48	.44	.49	.60	.67	.63	.59	.52
	Bag 3, g/test	.395	.46	.417	.440	.43	.40	.38	.54	.52	.57	.495	.45
	Composite, g/mi	.125	--	.118	.124	.124	.113	.115	.147	.156	.160	.146	.150
Nitromethane	Bag 1, g/test	0.0258	--	0.0180	0.0201	0.0159	0.0092	0.0116	0.0136	0.0164	0.01175	0.01058	0.00953
	Bag 2, g/test	.0331	0.0278	.0315	.0286	.0165	.0108	.0172	.0187	.0214	.01353	.02154	.01400
	Bag 3, g/test	.0271	.0261	.0225	.0233	.0190	.0093	.0083	.0142	.0235	.01079	.01611	.01205
	Composite, g/mi	.0080	--	.0069	.0067	.0046	.0027	.0036	.0044	.0056	.0033	.00470	.0033
Nitroethane	**Bag 1, g/test**	0.0081	Trace	Trace	Trace	Trace	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	Bag 2, g/test	Trace	Trace	BDL	Trace	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	Bag 3, g/test	.0062	Trace	BDL	Trace	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	Composite, g/mi	.0014	0.0008	0.0004	0.0008	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004
Hydrogen cyanide	Bag 1, g/test	0.6611	0.3419	0.0775	0.0405	0.1981	0.0827	0.0563	0.0524	0.1025	0.4805	0.02227	0.02971
	Bag 2, g/test		.4551	.0834	.2485	.1158	.0301	.0181	.0872	.0815	.1400	.01466	.03707
	Bag 3, g/test	.6671	--	.1891	.2232	.1559	.0345	.0110	.0679	.0816	>.1023	.02684	.05267
	Composite, g/mi	--	--	.0299	.0528*	.0386	.0114	.0065	.0198	.0229	>.0540*	.00526	.01070
Cyanogen	Bag 1, g/test	0.1517	0.0306	0.0083	0.0070	0.0794	0.0113	0.0068	0.0106	0.0224	0.00287	Trace	0.00199
	Bag 2, g/test	.1022	.0228	.0086	.0128	.0217	.0027	.0029	.0047	.0089	.00166	Trace	Trace
	Bag 3, g/test	.1647	.0794	.0033	.0433	.0558	.0050	.0019	.0100	.0240	.00513	.00371	.00383
	Composite, g/mi	.0348*	.0108*	.0019	.0054*	.0117*	.0014	.0009	.0020	.0043*	.0008	.0005	.0506

*Not included in reduced data.
BDL-Below detection limit.

TABLE A-3. - Raw emission data

(Vehicle No. 67, Chevrolet)

Fuel		Clear	TFA-318				HA±TFA-318	Clear	8101+318				HA+TFA-318
Miles		0	10	20	500	1500	1510	0	10	20	500	1500	1510
Test Conditions													
Barometer		746.5	746.9	748.2	743.6	745.9	744.9	744.4	741.4	739.5	743.9	743.0	750.3
Temperature		84	87	81	85	76	79	81	78	78	80	80	68
Relative Humidity		56	64	66	60	73	78	68	86	78	81	72	64
Carbon monoxide	Bag 1, g/test	223.7	118.0	160.6	181.7	130.3	209.3	225.3	166.3	192.9	285.2	250.3	243.3
	Bag 2, g/test	132.4	114.3	101.2	102.8	93.3	112.5	118.4	118.9	107.8	132.4	86.1	129.5
	Bag 3, g/test	167.3	170.7	169.4	178.4	125.0	112.8	124.1	157.8	168.8	225.3	201.0	163.8
	Composite, g/mi	47.5	38.5	35.4	87.7	29.4	35.6	38.13	37.38	38.27	51.12	41.11	43.66
Hydrocarbon	Bag 1, g/test	11.85	7.36	5.36	12.72	6.76	5.79	6.06	7.97	5.82	7.69	5.95	6.59
	Bag 2, g/test	3.79	3.73	3.68	3.42	2.38	3.40	3.70	4.44	4.64	3.33	2.97	3.63
	Bag 3, g/test	5.01	8.38	6.02	5.37	4.19	3.12	3.34	5.87	4.11	3.75	2.89	4.97
	Composite, g/mi	2.08	1.56	1.25	1.59	1.02	1.02	1.09	1.49	1.26	1.17	.96	1.24
Oxides of nitrogen	Bag 1, g/test	6.39	8.62	8.86	8.49	7.77	8.73	8.30	7.06	7.20	7.57	11.09	9.29
	Bag 2, g/test	5.78	6.80	6.77	2.68	7.15	7.15	6.49	5.79	6.10	6.02	9.37	6.73
	Bag 3, g/test	6.85	8.67	8.32	7.63	8.04	9.04	7.92	6.33	6.86	7.00	9.02	7.64
	Composite, g/mi	1.62	2.06	2.04	1.42	2.01	2.14	1.94	1.66	1.75	1.77	2.57	2.01
Aldehydes	Bag 1, g/test	0.49	0.51	0.38	0.37	0.391	0.383	0.47	0.54	0.32	0.413	0.310	0.411
	Bag 2, g/test	.48	.60	.48	.51	.500	.420	.46	.45	.37	.432	.454	.457
	Bag 3, g/test	.43	.31	.38	.37	.396	.353	.39	.33	.25	.325	.309	.356
	Composite, g/mi	.125	.133	.114	.117	.119	.105	.119	.116	.087	.106	.102	.112
Nitromethane	Bag 1, g/test	0.05408	0.04117	0.04564	0.04846	0.04199	0.04585	0.05005	0.03525	0.03646	0.04841	0.04588	0.04659
	Bag 2, g/test	.04453	.03743	.04700	.05159	.03463	.05055	.05517	.03557	.03708	.05183	.05224	.04540
	Bag 3, g/test	.04015	.03782	.04331	.04687	.03573	.04002	.04683	.02958	.03103	.04052	.03677	.03206
	Composite, g/mi	.01208	.01022	.01217	.01321	.0097	.01240	.01378	.00901	.00939	.01276	.01238	.01116
Nitroethane	Bag 1, g/test	0.01399	0.00857	0.01155	0.00949	0.00818	0.00800	0.01194	0.00870	0.01407	0.01230	0.003796	0.00909
	Bag 2, g/test	Trace	Trace	Trace	.007605	.00654	.00834	.00995	Trace	Trace	.008283	.005743	.004098
	Bag 3, g/test	.00804	.00996	.00899	.00909	.008683	.007966	.00837	.00594	.009643	.008411	.006182	.00640
	Composite, g/mi	.0017	.0015	.0016	.00224	.00199	.00217	.0027	.00144	.00203	.0025	.0014	.00167
Hydrogen cyanide	Bag 1, g/test	0.07705	0.01371	0.02135	0.03985	0.002983	0.00706	0.05932	0.00687	0.08216	0.028897	0.02821	0.02192
	Bag 2, g/test	.01223	.02763	.02140	.1637	.007185	.03307	.04314	.01309	.06895	.01097	.01616	.007123
	Bag 3, g/test	.05707	.07755	.04153	.1539	.03614	.03314	.03749	.00755	.02252	.019806	.01518	.01366
	Composite, g/mi	.01038	.0104	.0072	.03580*	.00387	.00733	.01200	.00271	.01561	.00462	.00492	.00324
Cyanogen	Bag 1, g/test	Trace	BDL	BDL	Trace	Trace	BDL	BDL	BDL	0.00332	BDL	Trace	Trace
	Bag 2, g/test	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	Bag 3, g/test	Trace	Trace	BDL	0.004333	0.001897	BDL	BDL	BDL	.00254	BDL	Trace	BDL
	Composite, g/mi	0.0002	0.0002	0.0001	.0004	.0003	0.0001	0.0001	0.0001	.0005	0.0001	0.0002	0.0001

*Not included in reduced data.
BDL-Below detection limit.

TABLE A-3. - Raw emission data--Continued

(Vehicle No. 67, Chevrolet)

Fuel		Clear	F310				HA+TFA-318	Clear	DMA4				HA+TFA-318
Miles		0	10	20	500	1500	1510	0	10	20	500	1500	1510
Test Conditions													
Barometer		749.0	749.1	740.0	727.0	749.6	748.5	739.6	744.9	743.2	735.4	743.4	747.2
Temperature		70	62	69	70	75	65	74	64	80	80	74	62
Relative Humidity		70	70	50	48	62	66	76	72	52	65	84	80
Carbon monoxide	Bag 1, g/test	184.2	218.2	194.0	196.1	211.1	188.9	303.1	218.0	169.9	229.2	238.6	283.6
	Bag 2, g/test	107.6	105.2	113.9	95.3	148.8	103.0	187.3	123.7	94.5	117.1	152.7	151.1
	Bag 3, g/test	118.9	109.0	152.8	120.9	168.3	116.0	228.8	161.9	105.8	114.3	191.5	198.8
	Composite, g/mi	34.0	34.9	37.9	33.1	44.7	33.4	59.7	41.3	30.4	39.7	48.6	51.0
Hydrocarbon	Bag 1, g/test	4.67	5.43	4.86	8.30	7.13	4.64	7.59	7.44	3.85	5.35	7.95	9.25
	Bag 2, g/test	3.41	3.49	3.49	3.57	4.29	3.03	4.23	3.53	3.14	3.43	4.66	4.28
	Bag 3, g/test	3.85	3.55	3.77	5.68	4.92	3.49	3.91	6.90	2.92	3.66	7.19	5.37
	Composite, g/mi	1.01	1.05	1.03	1.38	1.36	.93	1.30	1.42	.86	1.04	1.62	1.51
Oxides of nitrogen	Bag 1, g/test	9.97	7.00	7.32	9.68	8.58	9.96	8.93	8.89	8.94	6.98	7.95	6.86
	Bag 2, g/test	7.30	6.08	6.01	6.78	5.71	7.26	8.09	6.75	6.89	6.39	6.37	5.52
	Bag 3, g/test	8.65	7.44	6.66	8.00	6.76	8.02	8.59	8.01	8.43	7.40	7.80	6.92
	Composite, g/mi	2.20	1.78	1.73	2.07	1.77	2.02	2.24	2.02	2.07	1.81	1.90	1.71
Aldehydes	Bag 1, g/test	0.361	0.414	0.387	0.511	0.371	0.386	0.2875	0.347	0.345	0.477	0.460	0.301
	Bag 2, g/test	.478	.467	.470	.560	.476	.473	.4044	.413	.507	.566	.483	.411
	Bag 3, g/test	.340	.342	.337	.441	.389	.348	.2015	.333	.321	.391	.420	.304
	Composite, g/mi	.110	.120	.110	.137	.114	.112	.0857	.1002	.112	.133	.123	.095
Nitromethane	Bag 1, g/test	0.0427	0.0341	0.0285	0.0328						0.0523		
	Bag 2, g/test	.0366	.0357	.0307	.0279						.0525		
	Bag 3, g/test	.0371	.0303	.0280	.0253						.0426		
	Composite, g/mi	.0101	.0090	.0079	.0075						.0132		
Nitroethane	Bag 1, g/test	0.0059	0.0060	0.0044	0.0065						0.0139		
	Bag 2, g/test	Trace	Trace	Trace	.0054						.0075		
	Bag 3, g/test	.0046	.0044	.0050	.0041						.0093		
	Composite, g/mi	.0012	.0012	.0011	.0014						.0025		
Hydrogen cyanide	Bag 1, g/test	0.0304	0.0297	0.0344	0.0384						0.0059		
	Bag 2, g/test	.0118	.0557	.0419	.0230						.0112		
	Bag 3, g/test	.0173	.0423	.0671	.0521						.0130		
	Composite, g/mi	.0046	.0123	.0127	.0092						.0028		
Cyanogen	Bag 1, g/test	BDL	BDL	BDL	BDL						BDL		
	Bag 2, g/test	BDL	BDL	BDL	BDL						BDL		
	Bag 3, g/test	BDL	BDL	BDL	BDL						BDL		
	Composite, g/mi	0.0001	0.0001	0.0001	0.0001						0.0001		

BDL-Below detection limit.

TABLE A-3. - Raw emission data--Continued

(Vehicle No. 67, Chevrolet)

Fuel		Clear	LUB 8101				HA+TFA-318	Clear	DMA51				HA+TFA-318
Miles		0	10	20	500	1500	1510	0	10	20	500	1500	1510
Test Conditions													
Barometer		741.6	736.8	735.4	738.8	743.6	738.0	741.0	742.2	747.1	741.9	747.2	744
Temperature		78	78	80	80	84	81	87	80	72	85	83	80
Relative Humidity		74	74	78	81	75	63	56	43	60	68	54	68
Carbon monoxide	Bag 1, g/test	260.6	236.0	306.9	224.5	226.8	285.8	231.0	161.5	200.2	222.0	181.8	199.9
	Bag 2, g/test	155.9	151.6	161.4	117.5	135.1	158.9	154.0	98.5	108.9	117.8	116.9	122.7
	Bag 3, g/test	191.9	160.0	217.4	124.9	178.4	247.3	182.0	116.7	121.6	117.5	134.6	166.9
	Composite, g/mi	50.3	45.9	55.6	38.0	44.6	56.4	47.7	31.3	35.2	41.5	37.8	40.5
Hydrocarbon	Bag 1, g/test	8.91	6.79	8.37	6.42	5.57	8.85	7.17	4.09	7.24	6.86	8.42	11.42
	Bag 2, g/test	4.71	4.03	4.60	3.28	3.90	3.88	3.94	3.17	2.88	3.45	2.78	3.25
	Bag 3, g/test	5.51	5.54	5.96	4.00	4.58	6.24	4.36	4.22	4.01	4.97	4.73	5.22
	Composite, g/mi	1.49	1.34	1.55	1.11	1.19	1.50	1.27	.98	1.10	1.23	1.21	1.49
Oxides of nitrogen	Bag 1, g/test	8.45	7.44	6.12	5.97	9.11	8.29	8.3	9.40	10.19	8.41	7.41	8.22
	Bag 2, g/test	6.96	7.21	6.66	4.98	7.37	6.23	6.0	6.70	7.09	7.48	6.28	6.70
	Bag 3, g/test	7.68	7.88	7.12	6.27	8.46	7.26	7.0	7.74	8.97	7.00	7.27	7.27
	Composite, g/mi	2.00	1.99	1.78	1.48	2.15	1.86	1.80	2.02	2.21	2.07	1.81	1.92
Aldehydes	Bag 1, g/test	0.430	0.428	0.387	0.377	0.54	0.285	0.40	0.43	0.42	0.44	0.78	0.56
	Bag 2, g/test	.497	.477	.490	.532	.51	.383	.54	.454	.53	.46	.61	.40
	Bag 3, g/test	.329	.402	.356	.421	.38	.026	.44	.35	.44	.41	.42	.38
	Composite, g/mi	.116	.119	.114	.125	.128	.087	.128	.112	.128	.118	.158	.114
Nitromethane	Bag 1, g/test	0.0844	0.0674	0.0541	0.0427		0.0521	0.0335	0.0419	0.0462	0.04873	0.0210	0.0330
	Bag 2, g/test	.0828	.0570	.0637	.0361		.0480	.0377	.0484	.0411	.04914	.01555	.03642
	Bag 3, g/test	.0649	.0526	.0510	.0353		.0384	.0323	.0423	.0370	.03896	.01891	.03410
	Composite, g/mi	.0208	.0155	.0155	.0099		.0123	.0094	.0121	.0109	.01230	.00471*	.00933
Nitroethane	Bag 1, g/test	0.0235	0.0094	0.0140	0.0106		0.0113	0.0080	0.0058	0.0103	0.01289	0.00526	0.00723
	Bag 2, g/test	.0137	.0079	.0119	.0062		.0080	Trace	.0070	.0058	.00885	Trace	Trace
	Bag 3, g/test	.0124	.0075	.00947	.0072		.0104	.0063	.0069	.0070	.00911	Trace	.00593
	Composite, g/mi	.0041	.0022	.0031	.0020		.0025	.0014	.00177	.0019	.00261	.0010	.0014
Hydrogen cyanide	Bag 1, g/test	0.3159	0.0137	0.0246	0.0655		0.0620	0.0083	0.0325	0.0466	0.1222	0.03224	0.00702
	Bag 2, g/test	--	.3602	.0955	.0712		.0272	.0116	.0440	.0127	.04132	BDL	.01866
	Bag 3, g/test	.6404	.3125	.1356	.0199		.0056	.0169	.0461	.0262	.03216	Trace	.02590
	Composite, g/mi	--	.0726*	.0244	.0148		.0076	.0033	.0112	.0064	.0150	.0020	.00485
Cyanogen	Bag 1, g/test	0.0125	0.0041	0.0034	0.0018		0.0026	Trace	0.0021	0.0034	0.0015	BDL	Trace
	Bag 2, g/test	.0130	.0081	.0056	BDL		Trace	Trace	BDL	BDL	Trace	BDL	BDL
	Bag 3, g/test	.0475	.0190	.0172	.0032		.0042	0.0020	.0012	.0017	Trace	BDL	Trace
	Composite, g/mi	.0061*	.0028*	.0022*	.0004		.0006	.0004	.0003	.0004	.0003	0.0001	0.0002

*Not included in reduced data.
BDL-Below detection limit.

TABLE A-4. - Raw emission data

(Vehicle No. 66, Mazda)

Fuel		Clear	F310					Clear		DMA4					Clear
Miles		0	10	20	1000	2000	3000	3010	0	10	20	1000	2000	3000	3010
Test Conditions															
Barometer		746.8	751.0	747.0	749.9	747.0	737.9	736.2	734.0	736.3	734.2	743.0	742.8	745.4	745.0
Temperature		75	75	75	75	75	75	75	75	75	75	75	75	75	75
Relative Humidity		41	49	49	50	50	50	51	52	50	49	50	49	49	49
Carbon monoxide	Bag 1, g/test	131.0	118.8	113.4	128.8	125.4	138.2	131.5	117.0	107.3	113.7	98.5	121.7	118.6	122.1
	Bag 2, g/test	33.6	28.0	29.5	30.0	35.9	43.3	33.9	23.2	22.9	21.4	20.0	28.5	21.6	24.5
	Bag 3, g/test	134.8	134.8	141.8	152.1	137.3	152.4	116.4	108.7	101.3	99.9	83.6	170.2	113.5	105.7
	Composite, g/mi	22.2	20.8	21.2	22.9	22.4	25.3	20.9	18.1	16.9	17.0	14.7	23.7	18.3	18.3
Hydrocarbon	Bag 1, g/test	17.42	19.76	18.18	23.70	19.05	22.24	20.31	16.43	16.41	15.74	13.51	17.35	16.78	16.28
	Bag 2, g/test	1.26	1.21	1.18	1.07	20.99	1.83	1.94	.45	.39	.46	.37	.66	.44	.71
	Bag 3, g/test	11.45	12.61	13.19	14.35	13.09	14.68	10.92	8.34	9.61	9.51	8.62	18.06	9.36	11.09
	Composite, g/mi	2.04	2.22	2.20	2.59	2.37	2.63	2.25	1.64	1.71	1.69	1.48	2.45	1.73	1.87
Oxides of nitrogen	Bag 1, g/test	5.78	6.76	6.04	7.03	6.19	8.32	6.05	6.52	7.09	6.96	7.24	6.10	6.50	6.05
	Bag 2, g/test	3.21	3.92	3.72	3.35	3.28	5.16	3.76	3.64	3.87	3.69	3.44	3.50	3.39	3.68
	Bag 3, g/test	4.70	5.67	5.47	5.45	5.25	5.65	5.56	5.79	6.26	5.92	5.59	5.58	5.25	5.28
	Composite, g/mi	1.12	1.34	1.26	1.26	1.19	1.59	1.27	1.30	1.40	1.34	1.30	1.24	1.22	1.24
Aldehydes	Bag 1, g/test	0.495	0.905	0.931	1.042	0.825	0.985	0.768	0.624	0.843	0.794	0.756	0.782	0.767	0.782
	Bag 2, g/test	.249	.216	.198	.210	.302	.325	.269	.064	.108	.108	.113	.176	.086	.100
	Bag 3, g/test	.883	.885	.912	1.053	.917	1.144	.704	.608	.698	.629	.604	1.266	.719	.665
	Composite, g/mi	.129	.148	.149	.168	.157	.187	.133	.091	.116	.108	.104	.164	.110	.109
Nitromethane	Bag 1, g/test	0.0533	0.0564	0.0467					0.0593	0.0756	0.0631		0.0586		
	Bag 2, g/test	.0214	.0114	.0084					.0095	.0112	.0096		.0189		
	Bag 3, g/test	.0914	.0745	.0723					.0920	.0784	.0727		.1066		
	Composite, g/mi	.0131	.0104	.0093					.0117	.0118	.0104		.0140		
Nitroethane	Bag 1, g/test	0.0072	0.0066	0.0080					0.0127	0.0134	0.0140		0.0116		
	Bag 2, g/test	Trace	Trace	BDL					Trace	BDL	BDL		BDL		
	Bag 3, g/test	.0129	.0095	.0113					.0151	.0148	.0123		.0198		
	Composite, g/mi	.0019	.0016	.0016					.0024	.0021	.0020		.0024		
Hydrogen cyanide	Bag 1, g/test	0.0711	0.0089	0.0129					0.0141	0.0090	0.0125		BDL		
	Bag 2, g/test	.0130	.0015	.0029					.0069	.0087	.0102		BDL		
	Bag 3, g/test	.155	.0081	.0049					.0107	.0235	.0314		BDL		
	Composite, g/mi	.0176*	.0013	.0015					.0025	.0035	.0045		0.0001*		
Cyanogen	Bag 1, g/test	BDL	BDL	BDL					0.0012	BDL	BDL		0.0068		
	Bag 2, g/test	BDL	BDL	BDL					BDL	BDL	BDL		BDL		
	Bag 3, g/test	BDL	BDL	BDL					Trace	BDL	BDL		.0035		
	Composite, g/mi	0.0001	0.0001	0.0001					.0002	0.0001	0.0001		.0007		

*Not included in reduced data.
BDL-Below detection limit.

TABLE A-4. - Raw emission data--Continued
(Vehicle No. 66, Mazda)

Fuel		Clear	LUB 8101					Clear		DMA51					Clear
Miles		0	10	20	1000	2000	3000	3010	0	10	20	1000	2000	3000	3010
Test Conditions															
Barometer		741.3	737.7	737.5	748.2	745.9	742.0	741.0	743.0	742.0	741.0	745.5	741.3	743.3	743.0
Temperature		75	75	75	75	75	75	75	75	75	75	75	75	75	75
Relative Humidity		48	48	50	48	48	58	51	49	49	49	49	50	59	49
Carbon monoxide	Bag 1, g/test	116.0	111.5	112.3	93.5	104.8	96.5	106.0	109.7	106.5	105.6	97.6	107.6	101.9	115.6
	Bag 2, g/test	32.6	23.6	26.4	22.5	50.4	39.6	31.4	124.0	111.0	39.5	34.5	17.2	23.2	34.7
	Bag 3, g/test	117.8	144.5	120.4	123.2	123.3	130.3	126.2	189.2	136.9	114.6	155.9	94.1	115.4	121.2
	Composite, g/mi	20.0	20.5	19.1	17.7	22.1	20.7	19.9	37.2	31.3	20.0	22.0	15.6	17.7	20.5
Hydrocarbon	Bag 1, g/test	16.80	15.24	15.50	14.09	12.92	13.94	12.16	15.71	14.46	13.78	13.70	12.58	11.78	14.78
	Bag 2, g/test	1.09	.75	.91	.62	2.37	1.53	.97	2.43	.72	1.26	1.35	.39	.66	1.32
	Bag 3, g/test	10.31	12.24	9.55	9.74	9.93	10.53	10.08	16.87	10.44	8.80	12.52	6.29	8.66	8.74
	Composite, g/mi	1.89	1.90	1.74	1.63	1.81	1.80	1.59	2.51	1.72	1.63	1.92	1.25	1.42	1.69
Oxides of nitrogen	Bag 1, g/test	6.13	5.80	5.56	6.06	6.88	7.94	6.56	6.47	6.22	5.49	5.93	5.17	5.69	5.54
	Bag 2, g/test	3.86	3.45	3.41	3.62	3.49	4.10	3.83	3.81	3.73	3.32	3.78	2.99	3.46	3.31
	Bag 3, g/test	5.37	5.57	5.31	5.46	5.80	6.44	6.07	4.57	5.14	5.16	5.29	4.86	4.98	4.86
	Composite, g/mi	1.27	1.22	1.18	1.24	1.30	1.49	1.35	1.23	1.24	1.15	1.25	1.07	1.17	1.13
Aldehydes	Bag 1, g/test	0.763	0.738	0.743	0.66	0.672	0.877	0.509	0.982	0.668	0.673	0.716	0.638	0.649	0.418
	Bag 2, g/test	.227	.155	.226	.14	.490	.319	.178	.513	.137	.231	.290	.055	.202	.254
	Bag 3, g/test	.722	.902	.763	.88	.786	.847	.751	1.495	.863	.604	1.122	.612	.711	.539
	Composite, g/mi	.129	.132	.131	.123	.164	.157	.110	.238	.122	.115	.165	.090	.118	.099
Nitromethane	Bag 1, g/test		0.0524	0.0545	0.0469	0.04509	0.04353	0.0356	0.0474	0.04238	0.03851	0.05784	0.04465	0.05161	0.06866
	Bag 2, g/test		.0147	.0214	.0094	.04687	.02544	.02086	.0393	.01299	.01900	.02868	.0044	.01309	.02998
	Bag 3, g/test		.0895	.0825	.0779	.06697	.06591	.06689	.1424	.0782	.05262	.1316	.05855	.06732	.1198
	Composite, g/mi		.0118	.0122	.0099	.01392	.01089	.00990	.0188	.01010	.00873	.01714	.0076	.00982	.01703
Nitroethane	Bag 1, g/test		0.0084	0.0097	0.00704	0.00895	0.00568	0.00375	0.0068	0.00997	0.00795	0.00971	0.010067	0.00801	0.01528
	Bag 2, g/test		BDL	Trace	BDL	.00596	Trace	BDL	Trace	Trace	Trace	Trace	BDL	Trace	Trace
	Bag 3, g/test		.0160	.0139	.01269	.01308	.00949	.00943	.0227	.01455	.00894	.01758	.00855	.00957	.02070
	Composite, g/mi		.0019	.0021	.0016	.0023	.0015	.0012	.0026	.0022	.0016	.0024	.0015	.0017	.0029
Hydrogen cyanide	Bag 1, g/test		0.0509	0.0046	0.0490	0.03280	0.06163	0.01150	0.0425	0.03995	0.04055	0.01132	0.00604	0.05261	0.09266
	Bag 2, g/test		.0351	.0141	.0200	.01063	.02820	.01269	.0139	.01162	.01137	.01685	.00220	.04196	.01960
	Bag 3, g/test		.0503	.0795	.0397	.04459	.05620	.04129	.0443	.02969	.02670	.05707	.01155	.07644	.05776
	Composite, g/mi		.0114	.0082	.0085	.0067	.01156	.0055	.0077	.00609	.00586	.00723	.00151*	.01442	.01231
Cyanogen	Bag 1, g/test		BDL	Trace	0.0031	0.001658	0.001254	Trace	Trace	Trace	Trace	Trace	BDL	Trace	0.002427
	Bag 2, g/test		BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	Bag 3, g/test		0.0036	0.0021	Trace	.001799	.00151	Trace	Trace	Trace	BDL	Trace	Trace	Trace	.00248
	Composite, g/mi		.0004	.0003	.0003	.0003	.0003	0.0002	0.0002	0.0002	0.0001	0.0002	0.0002	0.0002	.0004

*Not included in reduced data.
BDL-Below detection limit.

TABLE A-4. - Raw emission data--Continued

(Vehicle No. 66, Mazda)

Fuel		Clear	TFA318					Clear		TFA318 + 8101					Clear
Miles		0	10	20	1000	2000	3000	3010	0	10	20	1000	2000	3000	3010
Test Conditions															
Barometer		741.5	744.6	745.3	743.0	744.4	743.6	743.1	743.3	742.5	744.2	742.5	742.3	748.4	747.3
Temperature		75	75	75	75	75	75	75	75	75	75	75	75	75	75
Relative Humidity															
Carbon monoxide	Bag 1, g/test	117.26	123.76	115.02	98.93	98.65	89.12	89.40	116.30	209.31	124.90	111.44	116.54	101.13	100.25
	Bag 2, g/test	45.83	39.17	54.09	45.61	46.30	46.17	46.82	40.26	40.48	38.11	36.46	23.62	35.35	30.05
	Bag 3, g/test	138.79	154.39	134.52	120.51	140.35	117.72	87.15	115.31	122.42	150.50	143.56	131.53	119.96	107.11
	Composite, g/mi	23.38	24.05	24.03	20.91	22.50	20.21	17.99	20.80	26.70	23.68	22.16	19.83	19.63	17.90
Hydrocarbon	Bag 1, g/test	15.84	17.97	14.91	12.99	16.28	14.56	14.01	15.37	13.35	17.42	16.30	17.04	14.20	13.41
	Bag 2, g/test	2.48	1.81	2.82	2.04	2.41	2.28	2.53	1.43	1.73	1.53	1.51	.79	1.29	1.14
	Bag 3, g/test	10.68	12.11	10.74	9.26	14.21	2.39	10.67	9.16	9.99	12.13	11.44	10.57	9.69	9.12
	Composite, g/mi	2.05	2.19	2.05	1.72	2.34	2.08	1.95	1.77	1.75	2.12	2.01	1.89	1.72	1.61
Oxides of nitrogen	Bag 1, g/test	5.86	5.93	6.04	6.17	6.27	5.60	5.34	6.08	5.98	6.34	6.15	6.27	6.30	5.81
	Bag 2, g/test	3.40	3.55	3.57	3.69	3.44	3.46	3.44	3.73	3.58	3.58	3.54	3.48	3.76	3.54
	Bag 3, g/test	4.96	5.05	5.12	5.36	5.36	5.18	4.93	4.81	5.51	5.52	5.38	5.40	6.00	5.88
	Composite, g/mi	1.17	1.20	1.21	1.25	1.23	1.18	1.14	1.21	1.24	1.26	1.23	1.22	1.32	1.25
Aldehydes	Bag 1, g/test	0.765	0.791	0.865	0.713	0.789	0.752	0.735	0.730	0.682	0.759	0.785	0.796	0.796	0.793
	Bag 2, g/test	.409	.343	.553	.383	.337	.291	.284	.274	.317	.290	.290	.141	.242	.185
	Bag 3, g/test	.882	1.040	1.052	.738	.766	.803	.729	.679	.734	.841	.920	.800	.955	.713
	Composite, g/mi	.166	.170	.203	.148	.148	.143	.135	.130	.137	.146	.154	.125	.151	.124
Nitromethane	Bag 1, g/test	0.04870	0.06222	0.05971	0.07058	0.06120	0.06107	0.0585	0.05374	0.06541	0.06564	0.04153	0.05109	0.05095	0.0587
	Bag 2, g/test	.03574	.03700	.05290	.05236	.03876	.03794	.0334	.03532	.04411	.03643	.03096	.01815	.02782	.0243
	Bag 3, g/test	.08786	.11183	.1056	.09574	.12491	.09512	.0818	.07175	.09350	.1095	.08696	.09185	.09265	.0748
	Composite, g/mi	.01424	.01699	.01851	.0183	.01816	.0158	.0140	.01324	.01673	.01694	.01311	.01232	.01367	.0123
Nitroethane	Bag 1, g/test	0.00874	0.01150	0.01023	0.01069	0.01575	0.01186	0.0130	0.00928	0.01146	0.01395	0.006537	0.006835	0.00732	0.0084
	Bag 2, g/test	Trace	Trace	.00729	Trace	Trace	.00874	Trace	Trace	.006002	.00674	Trace	Trace	Trace	Trace
	Bag 3, g/test	.01628	.01830	.01567	.01649	.02297	.01601	.0150	.00985	.01492	.01635	.01346	.01270	.01131	.0107
	Composite, g/mi	.0022	.0025	.0028	.0024	.0031	.0031	.0024	.0018	.00258	.0029	.0019	.0018	.0018	.0018
Hydrogen cyanide	Bag 1, g/test	0.03014	0.01046	0.04099	0.04754	0.09157	0.07248	0.0521	0.03596	0.05144	0.03330	0.01191	0.02602	0.02663	0.0261
	Bag 2, g/test	.00826	.02058	.01529	.02548	.01818	.00776	.0080	.009071	.004057	.009841	.003596	Trace	.004525	Trace
	Bag 3, g/test	.01895	.0356	.02484	.02080	.07610	.03721	.0218	.02270	.01320	.01645	.01123	.02198	.04056	.0437
	Composite, g/mi	.00426	.0061	.00627	.0077	.01345	.0080	.0057	.00499	.00449	.00446	.00201	.0033	.00521	.0050
Cyanogen	Bag 1, g/test	Trace	BDL	BDL	Trace	BDL	BDL	BDL	BDL	BDL	0.001102	BDL	BDL	BDL	BDL
	Bag 2, g/test	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	Bag 3, g/test	Trace	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	Composite, g/mi	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	.0002	0.0001	0.0001	0.0001	0.0001

*Not included in reduced data.
BDL-Below detection limit.

TABLE A-5. - Raw emission data

(Mazda Stationary Engine)

Fuel		Clear	F310			Clear	F310	Clear	F310	Clear	F310		Clear	F310	Clear
Miles		0	230	450	933	1170	3020	3040	5960	8960	8970	11821	11832	14650	14660
Test Conditions															
Barometer		742.0	749.0	739.5	743.2	735.3	739.1	741.6	741.6	746.0	742.4	732.6	735.1	742.4	742.4
Temperature		72	70	76	80	84	82	80	74	70	72	70	75	70	74
Relative Humidity		42	62	60	48	62	80	78	78	68	73	91	73	61	58
Carbon monoxide	Bag 1, g/test	100.6	174.5	174.2	121.9	118.5	137.8	93.5	134.9	113.7	115.8	159.7	153.1	148.8	131.0
	Bag 2, g/test	81.9	42.5	54.7	42.8	28.8	44.51	29.2	30.1	25.3	33.8	84.3	55.7	50.7	37.7
	Bag 3, g/test	120.9	193.4	144.5	113.3	101.0	126.8	125.0	107.6	87.2	109.8	109.6	125.0	92.5	78.0
	Composite, g/mi	25.9	30.4	28.3	21.3	18.3	23.5	18.8	19.9	16.5	19.4	28.7	25.7	22.3	18.5
Hydrocarbon	Bag 1, g/test	23.8	31.45	29.93	26.66	22.20	22.81	18.21	26.13	25.9	23.93	27.61	29.79	29.17	27.42
	Bag 2, g/test	6.65	1.75	2.25	1.61	1.22	3.33	1.92	1.35	1.03	1.27	2.92	3.32	4.03	2.38
	Bag 3, g/test	18.22	18.81	15.27	12.62	13.23	16.19	15.41	13.58	11.73	14.36	20.73	15.78	10.79	8.42
	Composite, g/mi	3.64	3.47	3.18	2.70	2.44	2.98	2.47	2.71	2.51	2.63	3.55	3.35	3.03	2.53
Oxides of nitrogen	Bag 1, g/test	5.52	5.78	5.13	4.37	3.96	5.05	4.43	2.93	3.20	3.50	3.91	3.73	3.07	3.12
	Bag 2, g/test	3.74	3.05	3.30	2.64	2.50	4.29	4.64	2.18	1.98	2.65	2.88	2.80	2.15	2.16
	Bag 3, g/test	5.58	5.43	5.30	4.44	5.20	5.44	5.58	3.34	3.33	4.05	6.54	2.73	2.67	2.65
	Composite, g/mi	1.24	1.15	1.14	.94	.96	1.27	1.30	.71	.70	.86	1.10	.87	.67	.67
Aldehydes	Bag 1, g/test	1.077	--	1.419	1.251	0.912	1.356	0.99	1.083	1.04	1.092	1.08	1.18	1.64	1.41
	Bag 2, g/test	.1071	--	.305	.201	.106	.50	.29	.16	.05	.139	.64	.415	.723	.357
	Bag 3, g/test	1.02	--	1.135	1.039	.848	.94	1.17	.89	.753	1.02	1.39	.88	.823	.667
	Composite, g/mi	.152	--	.208	.177	.131	.216	.185	.148	.123	.159	.255	.190	.253	.179
Nitromethane	Bag 1, g/test					0.0526	0.0544	0.0668	0.0727	0.0596	0.0766	0.0515	0.0239	0.0578	0.0447
	Bag 2, g/test					.0095	.0622	.0379	.0220	.0131	.0056	.0304	.0163	.0285	.0156
	Bag 3, g/test					.0772	.0863	.0912	.0733	.0725	.0702	.0694	.0307	.0335	.0267
	Composite, g/mi					.0101	.0180	.0158	.0127	.0107	.0105	.0123	.0059	.0097	.0067
Nitroethane	Bag 1, g/test					0.0162	0.0130	0.0133	0.0155	0.0134	0.0157	0.0132	0.0069	0.0132	0.0119
	Bag 2, g/test					Trace	.0142	.0063	.0125	Trace	BDL	Trace	BDL	.0085	Trace
	Bag 3, g/test					.0190	.0194	.0221	.0176	.0159	.0156	.0163	.0085	.0079	.0066
	Composite, g/mi					.0029	.0041	.0033	.0039	.0025	.0023	.0025	.0013	.0025	.0017
Hydrogen cyanide	Bag 1, g/test					0.0177	0.1275	0.0671	BDL	BDL	BDL	0.0381	0.0943	0.0354	0.0089
	Bag 2, g/test					.0084	.0854	.0578	BDL	BDL	BDL	.2980	.0745	.0217	.0188
	Bag 3, g/test					.0090	.0479	.0253	0.0871	BDL	BDL	.1702	.0514	.0306	.0133
	Composite, g/mi					.0028	.0223	.0135	.0067	0.0001*	0.0001*	.0549*	.0192	.0072	.0040
Cyanogen	Bag 1, g/test					BDL	BDL	BDL	BDL	Trace	0.0017	BDL	BDL	Trace	BDL
	Bag 2, g/test					BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	Bag 3, g/test					BDL	BDL	BDL	Trace	0.0044	.0016	0.0081	BDL	BDL	BDL
	Composite, g/mi					0.0001	0.0001	0.0001	0.0002	.0005	.0003	.0007	0.0001	0.0001	0.0001

*Not included in reduced data.
BDL-Below detection limit.

TABLE A-5. - Raw emission data--Continued

(Mazda Stationary Engine)

Fuel		Clear	LUB 8101		Clear	LUB 8101	Clear	LUB 8101		Clear	LUB 8101		Clear
Miles		0	0	800	800	2850	2860	5880	8876	8887	11710	14730	14740
Test Conditions													
Barometer		744.5	744.5	755.5	755.5	745.9	745.9	741.4	743.9	743.9	746.9	739.5	744.0
Temperature		90	80	80	95	78	82	90	80	86	82	79	62
Relative Humidity		36	60	64	36	72	69	64	79	73	74	79	82
Carbon monoxide	Bag 1, g/test	109.02	123.56	118.3	119.42	124.2	113.2	128.4	127.90	126.57	124.60	112.26	120.70
	Bag 2, g/test	69.56	89.00	97.3	62.29	89.5	75.4	94.1	56.47	67.38	62.79	47.06	48.75
	Bag 3, g/test	83.00	90.62	97.0	84.79	98.5	99.1	111.3	105.18	103.96	94.55	86.71	91.58
	Composite, g/mi	21.83	25.84	27.13	21.60	26.53	24.07	28.37	22.80	24.14	22.70	19.30	20.38
Hydrocarbon	Bag 1, g/test	19.81	25.25	24.90	20.57	21.45	19.00	22.72	22.13	22.07	20.67	21.28	23.51
	Bag 2, g/test	5.78	10.33	11.55	3.05	8.64	7.53	2.83	3.81	4.59	2.78	2.35	2.58
	Bag 3, g/test	9.18	14.11	15.30	7.27	10.40	12.56	13.14	13.02	10.89	8.40	7.52	7.32
	Composite, g/mi	2.60	3.90	4.13	2.14	3.17	3.05	2.68	2.77	2.70	2.19	2.10	2.25
Oxides of nitrogen	Bag 1, g/test	2.95	2.88	2.72	2.95	3.06	3.30	4.07	3.06	3.40	3.16	2.97	2.54
	Bag 2, g/test	1.85	1.83	1.80	2.12	2.15	2.62	3.79	2.57	3.03	2.94	2.32	1.84
	Bag 3, g/test	2.26	2.48	2.44	2.37	2.93	2.98	3.54	2.80	2.93	2.96	2.83	2.02
	Composite, g/mi	.59	.60	.58	.63	.65	.77	1.01	.73	.82	.80	.70	.54
Aldehydes	Bag 1, g/test	1.04	--	1.33	1.21	1.30	1.19	1.10	0.88	0.98	0.893	0.951	1.143
	Bag 2, g/test	.76	--	1.36	.27	1.00	1.53	1.17	.914	.56	.230	.245	.231
	Bag 3, g/test	.53		1.00	.39	.67	1.18	.97	.77	.73	.530	.60	.486
	Composite, g/mi	.201		.334	.234	.260	.362	.292	.164	.187	.122	.133	.133
Nitromethane	Bag 1, g/test	0.03940	0.03992	0.02751	0.02270	0.04676	0.04214	0.06146	0.05253	0.0502	0.03790	0.02446	0.02935
	Bag 2, g/test	.03598	.05055	.04044	.01094	.05812	.06251	.05406	.02641	.0274	.01449	.008764	.009343
	Bag 3, g/test	.02038	.03544	.03046	.01476	.03915	.04402	.04822	.04480	.0347	.02377	.01872	.01815
	Composite, g/mi	.00860	.01172	.00928	.00388	.0134	.0141	.01439	.00993	.0092	.00590	.00399	.00430
Nitroethane	Bag 1, g/test	0.01072	0.009858	0.00389	0.00536	0.00967	0.01023	0.01308	0.01556	0.0143	0.00915	0.005476	0.005149
	Bag 2, g/test	.01227	.009868	.00596	Trace	.01274	.01265	.01364	.009676	.0096	.00577	Trace	Trace
	Bag 3, g/test	.007798	.01027	.005910	.00359	.009378	.00954	.00995	.01146	.0104	.005096	.003567	.003210
	Composite, g/mi	.00284	.00265	.00146	.0011	.0030	.00301	.00332	.00305	.0029	.00168	.0011	.0010
Hydrogen cyanide	Bag 1, g/test	0.03283	0.03336	0.03288	0.02037	0.01867	0.02661	0.01441	0.01463	0.0063	0.01895	0.00922	0.003357
	Bag 2, g/test	.002767	.007645	.00721	.00978	.0104	.01053	.01761	Trace	.0067	.004166	BDL	Trace
	Bag 3, g/test	.005908	.01366	.01205	.00827	.006635	.01778	.008581	.005276	.0091	.004289	.003206	Trace
	Composite, g/mi	.00269	.00376	.00376	.00309	.0030	.00433	.0038	.0014	.0019	.00196	.0009	.0004
Cyanogen	Bag 1, g/test	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	Bag 2, g/test	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	Bag 3, g/test	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	Composite, g/mi	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

BDL-Below detection limit.

TABLE A-5. - Raw emission data--Continued

(Mazda Stationary Engine)

Fuel		Clear	DMA4		Clear	DMA4	Clear	DMA4		Clear	DMA4		Clear
Miles		0	0	1000	1000	3000	3000	6000	9000	9000	12000	15000	15000
Test Conditions													
Barometer		743.6	743.8	748.1	748.1	749.6	749.6	743.4	743.2	743.2	746.5	744.3	742.8
Temperature		82	92	70	78	69	82	86	81	92	84	80	78
Relative Humidity		63	49	56	44	62	42	69	51	31	60	67	75
Carbon monoxide	Bag 1, g/test	124.9	121.4	118.7	116.3	104.5	105.6	106.5	108.3	106.3	117.5	118.1	156.1
	Bag 2, g/test	36.1	42.8	23.5	23.2	23.5	23.4	50.6	41.7	64.2	64.8	85.7	76.6
	Bag 3, g/test	84.7	86.4	85.4	73.1	60.1	64.3	72.6	76.5	81.1	77.2	104.8	89.8
	Composite, g/mi	18.4	19.2	16.4	15.3	13.7	14.1	18.4	17.6	20.8	21.2	26.2	26.0
Hydrocarbon	Bag 1, g/test	25.18	26.10	28.03	24.06	22.81	21.10	20.02	17.55	19.59	20.95	19.96	24.75
	Bag 2, g/test	2.18	3.18	1.88	1.24	1.73	1.29	2.85	1.52	4.61	5.41	6.34	3.85
	Bag 3, g/test	10.66	11.59	9.56	7.94	6.52	6.67	8.16	7.55	9.55	9.45	12.22	8.12
	Composite, g/mi	2.54	2.80	2.58	2.17	2.03	1.89	2.15	1.78	2.46	2.64	2.92	2.55
Oxides of nitrogen	Bag 1, g/test	3.42	3.51	3.68	3.37	3.36	3.35	3.46	3.09	2.82	3.18	3.07	3.02
	Bag 2, g/test	2.46	2.57	2.19	2.22	2.27	2.29	2.61	2.06	1.84	2.21	1.93	2.15
	Bag 3, g/test	3.13	3.36	2.83	2.74	2.83	2.79	3.24	2.80	2.15	2.87	2.72	2.94
	Composite, g/mi	.76	.80	.71	.70	.74	.71	.79	.66	.60	.69	.64	.68
Aldehydes	Bag 1, g/test	1.03	1.20	1.27	1.18	1.05	1.222	1.08	1.87	1.32	1.16	1.05	0.84
	Bag 2, g/test	.23	.37	.19	.16	.21	.157	.28	.121	.74	.65	.83	.29
	Bag 3, g/test	.98	.60	.58	.59	.46	--	.58	.52	.78	.75	.88	.47
	Composite, g/mi	.164	.163	.142	.134	.122		.143	.107	.233	.210	.237	.122
Nitromethane	Bag 1, g/test	0.0357	0.0341	0.0546	0.0574	0.0392	0.0501	0.02605	0.02686	0.03109	0.05082	0.04196	0.04900
	Bag 2, g/test	.0088	.0736	.0143	.0071	.0057	Trace	.00949	.0063	.02139	.03155	.03275	.01481
	Bag 3, g/test	.0229	.0219	.0315	.0278	.0193	.0208	.01771	.02207	.02387	.02897	.03379	.02328
	Composite, g/mi	.0050	.0054	.007′	.0064	.0045	.0049	.00410	.0041	.0065	.00932	.0094	.0066
Nitroethane	Bag 1, g/test	0.0084	0.0087	0.0.	0.0117	0.0102	0.0120	0.00471	0.00747	0.00658	0.01042	0.01332	0.01290
	Bag 2, g/test	BDL	Trace	Tra	BDL	BDL	BDL	BDL	BDL	Trace	Trace	Trace	Trace
	Bag 3, g/test	Trace	.0049	.0070	.0050	.0060	Trace	Trace	Trace	.004839	.00549	.00929	.00606
	Composite, g/mi	.0009	.0014	.0017	.0013	.0013	.0011	.0007	.0008	.0012	.0015	.0020	.0017
Hydrogen cyanide	Bag 1, g/test	0.0121	0.0451	0.0190	0.0047	0.0734	0.0182	0.00884	0.02725	0.02618	0.02112	0.003107	Trace
	Bag 2, g/test	BDL	.0090	.0156	.0062	BDL	BDL	.00367	Trace	BDL	.01183	Trace	BDL
	Bag 3, g/test	.0038	.0034	.0078	.0148	.0188	.0046	.00750	.00544	.00435	.01076	Trace	Trace
	Composite, g/mi	.0011	.0040	.0038	.0022	.0057	.0015	.00156	.0021	.0019	.00360	.0004	0.0002
Cyanogen	Bag 1, g/test	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	Bag 2, g/test	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	Bag 3, g/test	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	Composite, g/mi	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

BDL-Below detection limit.

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/2-76-026	2.	3. RECIPIENT'S ACCESSION NO.
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15. SUPPLEMENTARY NOTES

Supplements and Extends, Part I

16. ABSTRACT

A study has been conducted to determine the effects of nitrogen-containing fuel additives in gasoline on regulated and nonregulated automotive emissions. Methodology was developed to measure possible nitrogen-containing compounds and was used to analyze the emissions from a variety of cars without catalysts. No effects due to the additives could be discerned. Of the nonregulated nitrogen compounds analyzed, ammonia, amines, nitriles, nitrosoamines, and aryl nitro compounds were not detected; HCN, cyanogen, and alkyl nitro compounds were measured. Emission data are included from a rotary engine (Mazda), an air-cooled engine (Volkswagen), and two standard V-8 engines (Chevrolet and Ford). Six nitrogen-containing additives chosen for their common usage were tested.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Evaluation	*Nitrogen organic cpds.		14G
Gasoline	*Nitrogen inorganic cpds.		21D
*Fuel additives	Chemical analysis		21K
Automotive engines			21J
*Exhaust emissions			13B
Air pollution			07C
			07B
			07D

18. DISTRIBUTION STATEMENT Release to Public	19. SECURITY CLASS *(This Report)* UNCLASSIFIED	21. NO. OF PAGES 61
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