Characterization Report

Analysis of Gasohol Fleet Data to Characterize the Impact of Gasohol on Tailpipe and Evaporative Emissions

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Technical Support Branch
Mobile Source Enforcement Division
Office of Mobile Source and Noise Enforcement
U.S. Environmental Protection Agency

Summary

This paper presents an analysis of the data which was developed in consideration of the request from "Gas Plus" of Nebraska and the Illinois Department of Agriculture for a waiver of the limitation and prohibition from use of up to 10% ethanol in unleaded fuel. The document comprises a description of the test program that generated the data, the analyses of the data, and a discussion of results of that analysis.

Statistical analyses were conducted on the three regulated tailpipe emissions components (hydrocarbons, oxides of nitrogen, and carbon monoxide) measured in the Federal Test Procedure (FTP) and on evaporative emissions measured in the Sealed Housing for Evaporative Determination (SHED) procedure.

Due to variations in testing conditions and procedures, some of the data made available to EPA were not included in the analysis. In addition, data on fuel economy, and unregulated pollutants, are not relevant to the waiver request and hence, summarization is omitted here. */

A procedure for review was applied to the projected 50,000 mile emissions levels for regulated tailpipe and evaporative emissions of each vehicle by catalyst technology.

*/ These data will be reported seperately.

This analysis reveals that it cannot be concluded with sufficiently high confidence that a 10% ethanol - 90% gasoline mixture, "Gasohol", will not cause or contribute to the failure of more than 20% of the vehicle fleet represented by the test vehicles to meet the Federal emissions standards.

Introduction

Section 211(f)(3) of the Clean Air Act (Act) prohibits, after September 15, 1978, the distribution in commerce of any fuel or fuel additive not substantially similar to any fuel or fuel additive utilized in the certification of any model year 1975, or subsequent model year, vehicle or engine. Gasohol is such a fuel. However, the Administrator may waive this prohibition if he determines that the fuel or fuel additive, and the emission products thereof, will not cause or contribute to a failure of any emission control device or system (over the useful life of any vehicle in which such a device or system is used) to meet its certified emission standards.

On June 19, 1978, EPA received such a waiver application from "Gas Plus" Inc. of Nebraska and the Illinois Department of Agriculture.

A public hearing on the Gasohol waiver request was held on September 6, 1978. At that time, the Ford Motor Company presented data which indicated a potential problem with evaporative emissions from vehicles fueled with Gasohol.

On September 15, 1978, the statutory ban on Gasohol took effect. The Adminstrator suspended enforcement of the ban during the remainder of 180-day waiver consideration period.

During this period of suspended enforcement, the Environmental Protection Agency (EPA) and the Department of Energy (DOE) conducted a cooperative Gasohol testing program. Emissions testing programs were conducted at the following sites: EPA - Motor Vehicle Emission Laboratory (MVEL) Ann Arbor, Michigan; DOE - Bartlesville, Oklahoma; EPA - Research Triangle Park, North Carolina, and the Southwest Research Institute, Houston, Texas under contract to EPA. Additional test results were received from the EG & G Laboratory in Springfield, Virginia, EPA's Mobile Emissions Test Facility, General Motors Corporation, Ford Motor Company, Automotive Testing Laboratory in Denver, Colorado, and an earlier alcohol fuels testing program conducted at the DOE - Bartlesville laboratory.

Testing Programs

The testing programs which provided Gasohol data for EPA's consideration are described below:

1) EPA - DOE Gasohol program

Four emissions test laboratories participated in a twenty-six vehicle testing program to measure the emissions effect of the addition of 10% ethanol to unleaded fuel. EPA provided the following fuels*/ to each laboratory:

1. Indolene - the standard emissions test fuel (40 CFR 86.113-78)
2. Indolene mixed with 10% ethanol
3. A commercially available summer grade unleaded gasoline
4. The above summer grade gasoline mixed with 10% ethanol
5. A gasoline blended with 10% ethanol with Reid vapor pressure and volatility characteristics similar to Fuel 3.

The standard 1978 Federal Test Procedure (FTP) for tailpipe emissions was followed at each laboratory.

The specific characteristics of each program are listed below:

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*/ The fuels specifications are shown in Table 9 and Figure 2.

1) The EPA MVEL tested eleven vehicles; seven with oxidation catalysts and four with three-way catalysts. FTP's including the SHED procedure were performed on each vehicle. Some replicate tests were conducted as well. Three vehicles tested had been included in the earlier Ford Gasohol testing program. Because testing began before the arrival of the fuels specifically procured for this program, specification indolene was used from laboratory supplies until the program fuels arrived.

2) The EPA laboratory at the Research Triangle Park tested two oxidation catalyst vehicles. FTP's, including the SHED procedure, (including alcohol measurements) were performed on each vehicle for all five fuels. Data on evaporative emissions for the 1977 vehicle were not included in the analyses of Gasohol data because the vehicle model year predated the 1978 SHED standards.

3) The Department of Energy Research Laboratory in Bartlesville, Oklahoma tested ten vehicles, six

with oxidation catalysts and four with three-way catalysts. The FTP performed included the SHED procedure on both tailpipe and evaporative emissions (including alcohol measurements).

4) The Southwest Research Institute, under contract to EPA, tested two oxidation catalyst vehicles and one three-way catalyst vehicle on the full FTP, including the SHED procedure. Replicate tests were performed on fuels 3, 4, and 5 only.

Other sources

1) The Ford Motor Company presented test results on nine vehicles, five with oxidation catalysts and four with three-way catalysts, tested on specification indolene and indolene + 10% ethanol. The 1978 FTP, including the SHED portion, was followed for each vehicle. Additional FTP and SHED tests were performed on two of these vehicles using EPA fuels 1, 3, and 5.

2) General Motors Corporation tested one three-way catalyst vehicle on its own indolene and indolene

with 10% ethanol fuels, following the 1975 FTP. No evaporative emissions results were provided.*/

3) The EPA Mobile Emissions Test Facility and the EG&G Laboratory under contract to EPA tested three oxidation catalyst vehicles on indolene and indolene with 10% ethanol. A modified version of the 1978 FTP which did not include evaporative emissions testing was used by the EG&G Laboratory. The 1977 FTP (non-evaporative) was performed by the Mobile Emissions Test Facility.

4) The DOE Bartlesville Laboratory in an earlier alcohol fuels program tested two oxidation catalyst and two three-way catalyst vehicles on indolene and indolene with 10% ethanol added. Of these, the two three-way catalyst vehicles were retested in the EPA-DOE program and data from both test programs were used in the analysis.

*/ Additional emission tests by GM on 2 vehicles using specification indolene, indolene + 10% ethanol and adjusted RVP indolene + 10% ethanol were received to late to incorporate into this analysis. Directionally, these data show the same effect reported herein and will be incorporated into this report.

5) Prior to the September 6 hearing, Automotive Testing Laboratories, Denver, Colorado, completed a high-altitude alcohol fuels testing program on an EPA contract. Ten vehicles were tested using the 1975 FTP on indolene and indolene with 10% ethanol. Because the high altitude is expected to effect emission levels, results of the program were reviewed but not included in the analysis of Gasohol data.

For the purposes of the analysis of the Gasohol data, the specification indolene and indolene with ethanol fuels were considered to be sufficiently similar to be compared without distinction in this analysis.

The set of vehicles, then, whose emissions values were analyzed consisted of 26 oxidation catalyst and 12 three-way catalyst vehicles. Of these, 14 oxidation catalyst and 8 three-way catalyst vehicles were tested on all five fuels on both the exhaust and evaporative emissions portions of the Federal Test Procedure. Appendix 1 contains a list of each test vehicle whose emissions were included in the Gasohol data base.

For many vehicles, repetitive tests were run on each fuel to establish more reliable estimates of the average emissions performance for the vehicle. For some vehicles more repetative tests were run on the exhaust emissions portion than on the evaporative emissions portion of the test.

Summarization of Data

The average emission level for each pollutant for each vehicle and test fuel is shown in Appendix 2. The list is separated by catalyst technology (oxidation catalyst vehicles and three-way catalyst vehicles). It should be noted that the summaries for vehicles which were tested by two laboratories include data from both laboratories.

Overall average emission levels by fuel and pollutant were computed for each catalyst technology from the vehicle averages. They appear in Tables 1 and 2.

Comparision of average results of fuels 1 and 2 and of fuels 3 and 4 indicates that average CO values decreased while average NOx and evaporative emissions rose with the use of alcohol in the fuel for both technology groups. The results on exhaust hydrocarbons (HC) were mixed, however. Average HC emissions values decreased with the use of both alcohol fuels (fuels 2 and 4) for oxidation catalyst vehicles but decreased between fuels 1 and 2 and increased between fuels 3 and 4 for three-way catalyst vehicles.

The significance of each of the above observations was tested using one-sided sign tests, comparing a base fuel and an alcohol fuel. The base fuel/alcohol fuel pairs considered were:

a) Fuel 1 (base) vs. Fuel 2 (alcohol)

b) Fuel 3 (base) vs. Fuel 4 (alcohol)

In each test for each pollutant the null hypothesis was that the median emission level for that pollutant was the same for both base and alcohol fuels. The alternative hypothesis for both HC and CO was that the median emissions level for the alcohol fuel was lower than that of the base fuel. The alternative hypothesis for NOx and evaporative emissions was that the median level was higher for the alcohol fuel than that of the base fuel.

Emissions levels on each base fuel were compared to emissions levels on its alcohol fuel counterpart for each vehicle tested on both fuels. From this comparison, the number of vehicles which manifested an increase in average emissions between fuels was obtained.

If there were no real difference in any emissions level attributable to a difference in fuels, the expected proportion of instances in which an increase between fuels would occur for any pollutant would be 0.5. A large proportion of observed increases in emission levels for a pollutant would indicate an adverse effect of the alcohol fuel. By a similar argument, a small proportion of increases in emission levels between fuels for a pollutant would indicate a decrease in the emissions of the alcohol fuel. Tables 3 and 4 summarize the results of these tests by catalyst technology comparing fuels 1 and 2 and fuels 3 and 4. As predicted by the comparision of average emissions for fuels 1 and 2, HC and CO emissions decreased significantly and NOx and evaporative losses increased significantly for oxidation catalyst vehicles.

For three-way catalyst vehicles, the comparison of fuels 1 and 2 showed a significant decrease in CO and a significant increase in evaporative emissions. The results of the comparision of fuels 3 and 4 were similar but indicated only significant decreases in CO and increases in evaporative emissions for both catalyst technology groups.*/

Though emission levels for pollutants differed significantly between base fuels and their alcohol mixture counterparts, the difference between emissions levels for fuels 1 and 3 was as remarkable. Table 5 displays the

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*/ Evaporative emissions are unaffected by exhaust (catalyst) technology.

results of sign tests performed comparing emissions data derived using these two fuels. These tests indicated highly significant increases in emissions levels for all pollutants and evaporative losses for oxidation catalyst vehicles and highly significant increases in NOx emissions in three-way catalyst vehicles in going from fuel 1 to fuel 3.

Estimates of the ratio of average emission levels for the following fuel combinations were calculated to assess the relative directional (Table 6):

.Fuel 2 and Fuel 1
.Fuel 4 and Fuel 3
.Fuel 3 and Fuel 1

Each fuel to fuel ratio was computed using overall averages for vehicles on which both fuels were tested.

Method of Review

A statistical method of review was established to determine whether the applicant had demonstrated that Gasohol would not cause or contribute to the failure of any vehicle to meet emission standards during its useful life. This method of review was designed as a one-sided sign test and evaluates compliance using projected 50,000 mile emissions levels. The statistical method assumes that the difference in emission levels between two fuels for a vehicle either remains constant or becomes larger over the useful life of the vehicle.

Because 50,000 mile test data were not available for any test vehicle, projected 50,000 mile emission levels for each nondevelopmental test vehicle were obtained by using average back-to-back FTP results and 50,000 mile certification data.

The sign test portion of the method of review was designed to assure with 90% confidence that the sign test would be failed if 20% or more of the vehicle fleet represented by the sample fleet were to fail to meet Federal emission standards for the fuel comparison considered.

Figure 1 depicts the risk of failing the method of review versus the true fleet failure rate for various sample sizes. It is clear from the figure that for small sample sizes the risk of failing the criterion is high for low fleet failure rates but decreases when sample fleet size is increased.

The method of review was evaluated for the following three fuel comparisons:

a) Fuel 1 with Fuel 2

b) Fuel 3 with Fuel 4

c) Fuel 1 with Fuel 3

The first two comparisons were selected to assess the effect of ethanol as a fuel additive; the third was chosen to assess the effect of the commercially available summer grade gasoline fuel compared to the indolene test fuel.

Statistical procedures for each fuel comparison were applied as follows: 50,000 mile emissions levels for each test vehicle were obtained from certification records for the test vehicle.*/ Projected 50,000 mile emissions levels for a test vehicle were computed by adding the difference between average emission levels for the two fuels to its 50,000 mile certification values. These projected values were then compared to the emission standards. A failure was scored when the projected value of any pollutant exceeded the emission standard for the vehicle. Table 7 shows the results of this analysis. Total failures for each pollutant were then compared to the critical values computed for the corresponding number of observations. If the number of failures equalled or exceeded the critical value (c) for any pollutant, the criterion was failed. Table 8 lists critical values by sample size (total number of observations) for the standard of review criterion.

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*/ The certification test results used were from the emission data vehicle of the same description as the test vehicles.

Application of the method of review was done separately by catalyst technology. Evaporative emissions results were examined in the aggregate.

Evaluation of the scores summarized in Table 7 using critical values in Table 8 resulted in the failure of the method of review by fuels containing alcohol compared to indolene and the summer grade commercial fuel compared to indolene.

Specifically, comparison of fuels 1 and 2 resulted in a failure of the criteria on evaporative losses across both catalyst technologies, on NOx for oxidation catalyst vehicles, and on HC for three-way catalyst vehicles. Comparison of fuels 3 and 4 yielded the same results, with the exception that failures occurred for both HC and CO for three-way vehicles. The fuel 1 to fuel 3 comparison, however, resulted in the largest number of projected failures. In that instance, the criteria was failed on evaporative emissions for both technologies, on all three tailpipe emissions for oxidation catalyst vehicles, and on HC for three-way catalyst vehicles.

Conclusions

The statistical analyses performed on the Gasohol data indicate that the use of ethanol in 10% concentration in unleaded fuel has a statistically significant, adverse effect on emissions. Carbon monoxide emissions decrease and evaporative emissions increase consistently both for oxidation catalyst and three-way catalyst vehicles. Furthermore, application of the method of review shows that the data fails to demonstrate that the use of 10% ethanol as a fuel additive will not cause or contribute to the failure of any vehicles to meet emission standards.

Table 1 Average Emissions Levels by Pollutant by Fuel for All Oxidation Catalyst Vehicles

ALL PROGRAMS - OX CATALYSTS

OVERALL AVERAGES		HC[2]	CO[2]	NOX[2]	EVAP[3]
FUEL	1	0.795	8.771	1.528	3.101
VARIANCE		0.485	41.754	0.187	1.826
NO OBS[1]		24.	24.	24.	18.
OVERALL AVERAGES		HC	CO	NOX	EVAP
FUEL	2	0.665	5.326	1.706	4.728
VARIANCE		0.268	13.868	0.183	5.232
NO OBS[1]		23.	23.	23.	17.
OVERALL AVERAGES		HC	CO	NOX	EVAP
FUEL	3	0.826	9.953	1.586	5.669
VARIANCE		0.387	49.693	0.194	20.082
NO OBS[1]		19.	19.	19.	18.
OVERALL AVERAGES		HC	CO	NOX	EVAP
FUEL	4	0.653	6.705	1.704	8.878
VARIANCE		0.102	13.985	0.304	44.150
NO OBS[1]		17.	17.	17.	16.
OVERALL AVERAGES		HC	CO	NOX	EVAP
FUEL	5	0.808	7.307	1.708	8.366
VARIANCE		0.273	29.454	0.155	36.426
NO OBS[1]		19.	19.	19.	18.

1. number of observations
2. units in g/mi
3. units in g/test

Table 2 Average Emissions Levels by Pollutant by Fuel for All Three-Way Catalyst Vehicles

ALL PROGRAMS - 3-WAY CATALYSTS

OVERALL AVERAGES		HC[2]	CO[2]	NOX[2]	EVAP[3]
FUEL	1	0.338	4.864	0.666	2.194
VARIANCE		0.011	12.426	0.093	0.776
NO OBS[1]		11.	11.	11.	8.

OVERALL AVERAGES		HC	CO	NOX	EVAP
FUEL	2	0.317	3.919	0.724	3.219
VARIANCE		0.008	6.005	0.099	1.385
NO OBS[1]		11.	11.	11.	8.

OVERALL AVERAGES		HC	CO	NOX	EVAP
FUEL	3	0.370	5.696	0.648	3.303
VARIANCE		0.027	16.040	0.155	1.980
NO OBS[1]		9.	9.	9.	8.

OVERALL AVERAGES		HC	CO	NOX	EVAP
FUEL	4	0.413	5.269	0.704	4.710
VARIANCE		0.023	13.909	0.185	3.514
NO OBS[1]		9.	9.	9.	8.

OVERALL AVERAGES		HC	CO	NOX	EVAP
FUEL	5	0.440	5.680	0.719	4.478
VARIANCE		0.017	12.757	0.169	3.403
NO OBS[1]		9.	9.	9.	8.

1. number of observations
2. units in g/mi
3. units in g/test

TABLE 3

Sign Test Statistics and Confidence Levels For Comparison of Median Emission Levels of Vehicles Tested on Fuel 1 and Fuel 2

Oxidation Catalyst Vehicles

	HC	CO	NOx	EVAP
1) Increases/Observations	7/23	3/23	17/23	14/17
2) Confidence Level of Increase/Decrease	95.34 (D)	99.98 (D)	98.27 (I)	99.36 (I)

Three-Way Catalyst Vehicles

	HC	CO	NOx	EVAP
1) Increases/Observations	4/11	2/11	8/11	8/8
2) Confidence Level of Increase/Decrease	72.56 (D)	96.73 (D)	88.67 (I)	99.61 (I)

TABLE 4

Sign Test Statistics and Confidence Levels For Comparison of Median Emissions Levels of Vehicles Tested on Fuel 3 and Fuel 4

Oxidation Catalyst Vehicles

	HC	CO	NOx	EVAP
1) Increases/Observations	6/17	1/17	10/17	14/16
2) Confidence Level of Increase/Decrease	83.38 (D)	99.99 (D)	68.55 (I)	99.79 (I)

Three-Way Catalyst Vehicles

	HC	CO	NOx	EVAP
1) Increases/Observations	3/9	2/9	4/9	7/8
2) Confidence Level of Increase/Decrease	74.61 (D)	91.02 (D)	50.00 (I)	96.48 (I)

TABLE 5

Sign Test Statistics and Confidence Levels For Comparison of Median Emissions Levels of Vehicles Tested on Fuel 1 and Fuel 3

Oxidation Catalyst Vehicles	HC	CO	NOx	EVAP
1) Increases/Observations	13/17	13/17	15/17	13/16
2) Confidence Level of Increase/Decrease	97.55 (I)	97.55 (I)	99.88 (I)	98.94 (I)

Three-Way Catalyst Vehicles	HC	CO	NOx	EVAP
1) Increases/Observations	5/8	4/8	7/8	5/7
2) Confidence Level of Increase/Decrease	63.67 (I)	36.33 (I)	96.48 (I)	77.34 (I)

TABLE 6

Estimated Ratio of Mean Emissions Levels for Vehicles Operated on Different Fuels by Catalyst Technology by Pollutant by Fuel Comparison

Technology	Fuel/Fuel	HC	CO	NOx	EVAP
Oxidation Catalyst	2/1	0.835	0.633	1.120	1.521
	4/3	0.768	0.632	1.105	1.603
	3/1	1.083	1.115	1.151	1.507
Three-Way Catalyst	2/1	0.937	0.806	1.087	1.467
	4/3	1.116	0.925	1.086	1.426
	3/1	1.101	1.066	1.109	1.268

Table 7
Method of Review Analysis
(# failures/total #)

COMPARING FUELS 1 & 2

	HC	CO	NOx	EVAP
All Programs (oxidation & three-way)	1/28	0/28	2/28	[3/21
All Programs (oxidation catalysts only)	0/22	0/22	[2/22]	[3/17
All Programs (three-way catalysts only)	[1/6]	0/6	0/6	0/4

COMPARING FUELS 3 & 4

All Programs (oxidation & three-way)	1/23	1/23	[3/23]	[5/21
All Programs (oxidation catalysts only)	0/17	0/17	[3/17]	[5/16
All Programs (three-way catalysts only)	[1/6]	[1/6]	0/6	0/5

COMPARING FUELS 1 & 3

All Programs (oxidation & three-way)	[4/22]	[4/22]	[4/22]	[5/20
All Programs (oxidation catalysts only)	[2/17]	[4/17]	[4/17]	[5/16
All Programs (three-way catalysts only)	2/5	0/5	0/5	0/4

Brackets indicate failure with respect to the method of review

Table 8 Sample Sizes and Critical Values for Application of the Standard of Review with Probability of Failure Equal to 90% for a Fleet Failure Rate of 20%

Sample Size	Critical Value(c)	Exact Risk of Failure for Fleet Failure Rate of .20
10	1	.893
11	1	.914
12	1	.931
13	1	.945
14	1	.956
15	1	.965
16	2	.859
17	2	.882
18	2	.901
19	2	.917
20	2	.931
21	2	.942
22	2	.952
23	3	.867
24	3	.886
25	3	.902
26	3	.916
27	3	.928
28	3	.939
29	3	.948
30	4	.877
31	4	.893
32	4	.907
33	4	.919
34	4	.930
35	4	.939
40	5	.924
45	6	.910
50	7	.897
100	16	.920

TABLE 9 - FUEL SPECIFICATIONS FOR GASOHOL TESTING PROGRAM

Fuel	RON	MON	RVP	% 160 °F	Aromatics	Olefins	Saturates	S. G.
1	96.5	88.7	9.0	20	28.5	0.4	71.1	.7397
2	98.9	90.1	9.6	32	25.7	0.6	73.7	.7440
3	92.3	82.6	10.0	25	29.8	17.2	53.0	.7487
4	94.8	84.2	10.9	42	28.9	16.6	54.5	.7526
5	96.4	88.6	10.0	38	34.6	17.6	57.8	.7686
1978 DOE Winter Avg	92.9	83.9	12.5	36				.7354
1977 MVMA Winter Avg	92.6	84.2	12.2	36	29.5	8.0	62.6	.7356
1975 MVMA Summer Avg	92.1	84.1	10.1	30	28.9	5.8	65.2	.7402
1978 DOE Summer Avg	92.9	83.9	9.8	27	31.2	6.0	62.8	.7416

Key to Fuels

1 - Indolene Type

2 - Indolene Type/10% Ethanol mix

3 - Howell Northern Summer Grade

4 - Fuel 3/10% Ethanol mix

5 - Blended Summer Grade and 10% (volume) Ethanol to resemble Fuel 3 with respect to RVP and distillation curve.

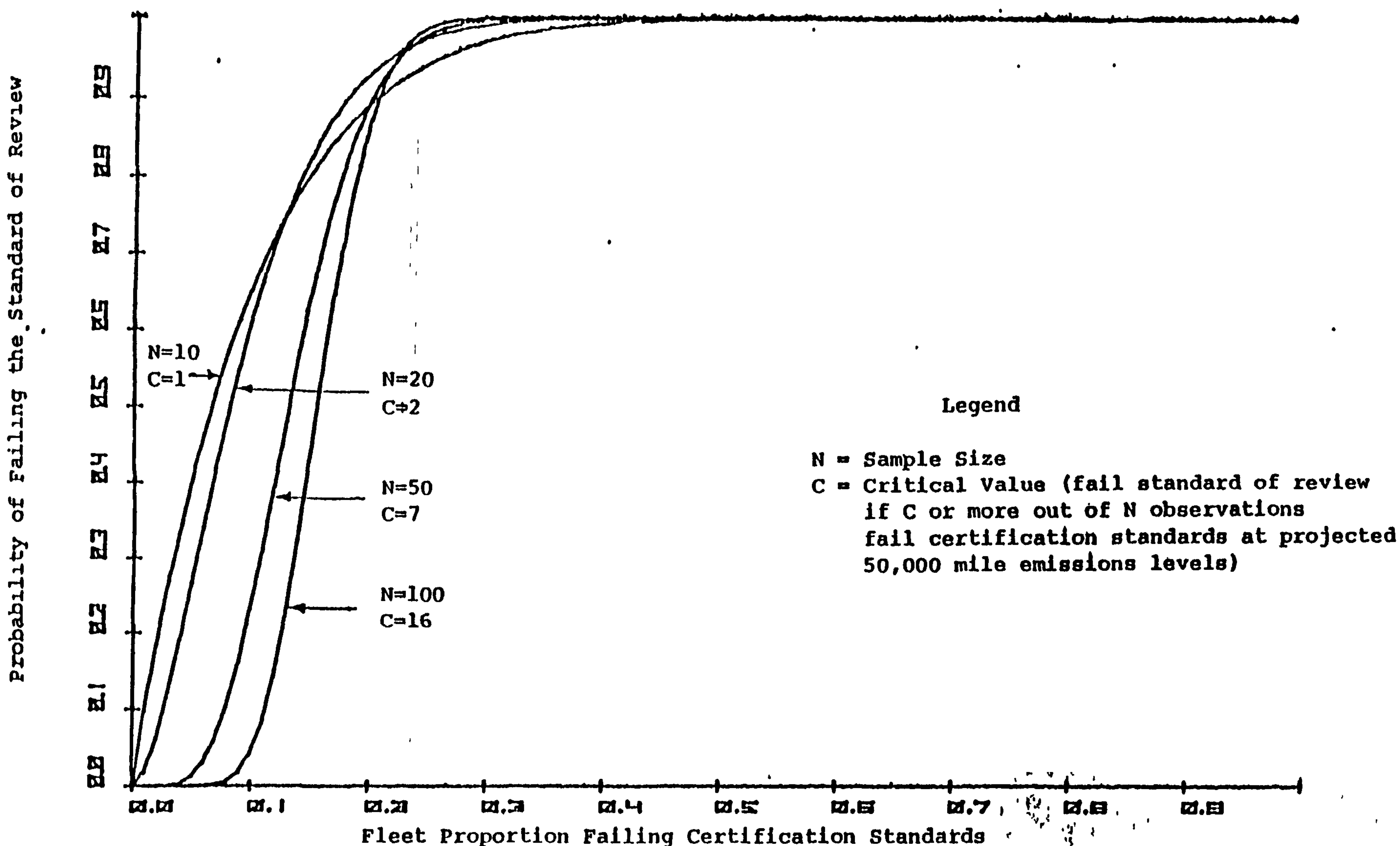
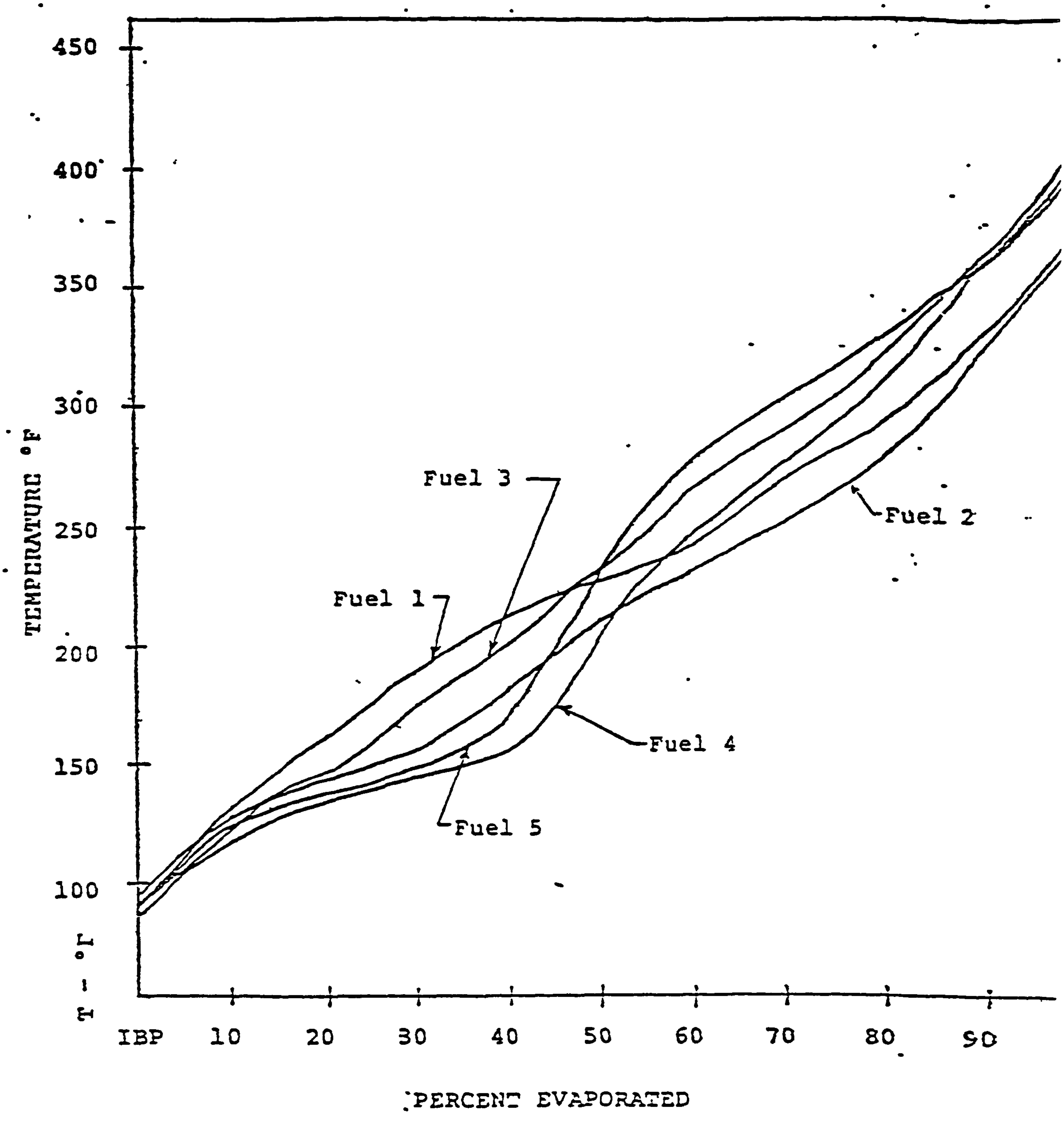


Figure 1 Probability of Failing the Standard of Review for Different Sample Sizes and Critical Values versus the True Proportion in the Fleet Failing Certification Standards

FUELS FOR GASOHOL

TEST PROGRAM

DISTILLATION CURVES



Test Vehicle Description

Appendix 1

Source	Model Year	Vehicle ID	Make/Model	Cal./Fed. Configuration	Catalyst
Ann Arbor[1]	1979	N0001	Ford Thunderbird	Developmental	Three-way
Ann Arbor[1]	1978	N0002	Ford Bobcat	California	Three-way
Ann Arbor[1]	1978	N0003	Ford Maverick	Federal	Oxidation
Ann Arbor	1979	N0004	Ford Pinto	Federal	Oxidation
Ann Arbor	1978	N0005	Pontiac Sunbird	California	Three-way
Ann Arbor	1978	N0006	Chrysler Omni	Federal	Oxidation
Ann Arbor	1978	N0007	Plymouth Salon	Federal	Oxidation
Ann Arbor	1977	N0008	Chevrolet Impala	Federal	Oxidation
Ann Arbor	1978	N0009	Buick Regal I	Federal	Oxidation
Ann Arbor	1979	N0010	Toyota Corolla	Federal	Oxidation
Ann Arbor	1978	N0011	Buick Regal II	California	Three-way
RTP[2]	1977	RMUST	Ford Mustang	Federal	Oxidation
RTP	1979	RLTDI	Ford LTD II	Federal	Oxidation
Bartlesville	1976	BOXC1	Chevrolet Impala	Federal	Oxidation
Bartlesville	1977	BOXC2	Pontiac Astre	Federal	Oxidation
Bartlesville	1977	B0001	Volvo 242	California	Three-way
Bartlesville	1978	B0002	Ford Pinto	California	Three-way
Bartlesville	1978	B0003	AMC Gremlin	Federal	Oxidation
Bartlesville	1978	B0004	Buick Century	Federal	Oxidation
Bartlesville	1978	B0005	Oldsmobile Delta 88	Federal	Oxidation
Bartlesville	1978	B0006	Ford Futura	Federal	Oxidation
Bartlesville	1978	B0007	Buick Skyhawk	California	Three-way
Bartlesville	1978	B0008	Pontiac Sunbird	California	Three-way
Bartlesville	1978	B0009	Plymouth Salon	Federal	Oxidation
Bartlesville	1978	B0010	Plymouth Horizon	Federal	Oxidation
SWRI[3]	1978	SSAAB	Saab 99GL	California	Three-way
SWRI	1978	SCHEV	Chevrolet Malibu	California	Oxidation
SWRI	1978	SMUST	Ford Mustang	Federal	Oxidation

Test Vehicle Description (cont.) Appendix 1

Source	Model Year	Vehicle ID	Make/Model	Cal./Fed. Configuration	Catalyst
Ford	1978	F0001	Ford Fiesta	California	Oxidation
Ford[1]	1978	F0002	Ford Bobcat	California	Three-way
Ford	1978	F0003	Ford Fairmont	Federal	Oxidation
Ford	1978	F0004	Ford Granada	California	Oxidation
Ford	1978	F0005	Ford Developmental	Developmental	Three-way
Ford	1978	F0006	Ford Developmental	Developmental	Three-way
Ford[1]	1978	F0007	Ford Maverick	Federal	Oxidation
Ford	1978	F0008	Ford Light Duty Truck	Federal	Oxidation
Ford[1]	1979	F0009	Ford Thunderbird	Developmental	Three-way
EG&G	1978	EMERC	Mercury Monarch	Federal	Oxidation
EG&G	1978	EAMCO	AMC Concorde	Federal	Oxidation
EG&G	1978	ETOYO	Toyota	Federal	Oxidation
General Motors	1978	GSUNB	Pontiac Sunbird	California	Three-way

Notes: [1] This vehicle was tested by both EPA - Ann Arbor and Ford Motor Company
[2] RTP - Research Triangle Park
[3] SWRI - Southwest Research Institute

SOURCE	VEH	FUEL	N OBS	HC MEAN	HC VAR	HC STDEV	CO MEAN	CO VAR	CO STDEV	NOX MEAN	NOX VAR	NOX STDEV	EVAP MEAN	EVAP VAR	EVAP STDEV
B	0XC1	1	3	0.56	0.002	0.04	6.74	0.139	0.37	2.59	0.042	0.20	-	-	-
B	0XC1	2	3	0.61	0.005	0.07	6.87	0.442	0.66	2.44	0.045	0.31	-	-	-
B	0XC2	1	3	1.28	0.031	0.18	9.46	1.509	1.26	1.70	0.024	0.15	-	-	-
B	0XC2	2	3	0.93	0.007	0.09	6.33	0.228	0.48	1.70	0.011	0.10	-	-	-
B	0003	1	2	0.51	0.007	0.08	4.43	0.011	0.11	1.28	0.000	0.01	3.37	0.218	0.47
B	0003	2	1	0.30	0.0	0.0	3.15	0.0	0.0	1.23	0.0	0.0	4.82	0.0	0.0
B	0003	3	1	0.58	0.0	0.0	5.62	0.0	0.0	1.15	0.0	0.0	4.02	0.0	0.0
B	0003	4	1	0.56	0.0	0.0	5.47	0.0	0.0	1.21	0.0	0.0	4.89	0.0	0.0
B	0003	5	1	0.86	0.0	0.0	5.93	0.0	0.0	1.24	0.0	0.0	4.98	0.0	0.0
B	0004	1	2	0.68	0.006	0.08	10.38	3.754	1.94	1.35	0.010	0.10	4.00	7.334	2.71
B	0004	2	1	0.71	0.0	0.0	6.90	0.0	0.0	1.48	0.0	0.0	5.62	0.0	0.0
B	0004	3	1	1.46	0.0	0.0	14.02	0.0	0.0	1.77	0.0	0.0	3.61	0.0	0.0
B	0004	4	1	0.71	0.0	0.0	8.10	0.0	0.0	1.47	0.0	0.0	4.68	0.0	0.0
B	0004	5	1	0.77	0.0	0.0	9.75	0.0	0.0	1.63	0.0	0.0	5.72	0.0	0.0
B	0005	1	2	0.72	0.018	0.13	4.97	7.106	2.67	2.01	0.014	0.12	5.71	0.097	0.31
B	0005	2	1	0.53	0.0	0.0	2.97	0.0	0.0	1.55	0.0	0.0	6.33	0.0	0.0
B	0005	3	1	0.77	0.0	0.0	5.31	0.0	0.0	2.41	0.0	0.0	6.42	0.0	0.0
B	0005	4	1	0.82	0.0	0.0	7.89	0.0	0.0	2.11	0.0	0.0	9.17	0.0	0.0
B	0005	5	1	0.59	0.0	0.0	3.21	0.0	0.0	2.03	0.0	0.0	8.06	0.0	0.0
B	0006	1	2	0.63	0.014	0.12	17.36	1.767	1.33	0.68	0.005	0.07	4.71	9.202	3.03
B	0006	2	1	0.36	0.0	0.0	6.00	0.0	0.0	1.37	0.0	0.0	3.05	0.0	0.0
B	0006	3	1	1.01	0.0	0.0	20.06	0.0	0.0	1.21	0.0	0.0	1.56	0.0	0.0
B	0006	4	1	0.61	0.0	0.0	10.07	0.0	0.0	1.68	0.0	0.0	2.03	0.0	0.0
B	0006	5	1	0.74	0.0	0.0	13.35	0.0	0.0	1.72	0.0	0.0	3.36	0.0	0.0
B	0010	1	2	0.31	0.001	0.04	1.77	0.026	0.16	1.72	0.016	0.13	3.23	0.911	0.95
B	0010	2	1	0.21	0.0	0.0	1.36	0.0	0.0	2.21	0.0	0.0	4.06	0.0	0.0
B	0010	3	1	0.32	0.0	0.0	2.10	0.0	0.0	1.90	0.0	0.0	3.18	0.0	0.0
B	0010	4	1	0.33	0.0	0.0	1.61	0.0	0.0	2.00	0.0	0.0	4.49	0.0	0.0

B	0010	5	1	0,27	0,0	0,0	1,20	0,0	0,0	2,07	0,0	0,0	3,85	0,0
B	0009	1	2	1,27	0,000	0,01	18,65	2,311	1,52	1,67	0,006	0,08	5,84	13,729	3,71
B	0009	2	1	0,61	0,0	0,0	4,86	0,0	0,0	2,77	0,0	0,0	9,33	0,0	0,0
B	0009	3	1	0,95	0,0	0,0	15,50	0,0	0,0	1,67	0,0	0,0	8,79	0,0	0,0
B	0009	4	1	0,62	0,0	0,0	6,90	0,0	0,0	3,26	0,0	0,0	8,35	0,0	0,0
B	0009	5	1	0,83	0,0	0,0	8,16	0,0	0,0	2,31	0,0	0,0	5,19	0,0	0,0
E	AMCO	1	2	0,76	0,013	0,11	5,12	0,101	0,32	2,10	0,039	0,20	-	-	-
E	AMCO	2	2	0,99	0,080	0,28	5,94	0,819	0,91	1,61	0,039	0,20	-	-	-
E	MERC	1	3	0,66	0,011	0,11	4,68	0,382	0,62	1,14	0,008	0,09	-	-	-
E	MERC	2	2	0,83	0,013	0,11	2,72	0,002	0,04	1,44	0,001	0,03	-	-	-
E	TUYO	1	1	1,10	0,0	0,0	11,00	0,0	0,0	1,60	0,0	0,0	-	-	-
E	TUYO	2	1	0,90	0,0	0,0	5,00	0,0	0,0	2,20	0,0	0,0	-	-	-
F	0001	1	4	0,39	0,003	0,05	3,84	0.592	0,77	1.38	0.029	0,17	3,44	0,884	0,94
F	0001	2	4	0,39	0,009	0,09	2,77	1,039	1,02	1,67	0,005	0,07	5,60	0,969	0,98
F	0003	1	6	0,85	0,054	0,23	4,38	2,455	1,57	1,77	0,095	0,31	1,71	0,180	0,42
F	0003	2	2	0,72	0,001	0,04	5,18	0,858	0,93	1,86	0,018	0,13	1,32	0,007	0,08
F	0003	3	2	0,83	0,026	0,16	5,60	1,201	1,10	2,46	0,051	0,23	2,44	0.013	0,11
F	0003	5	3	0,79	0,000	0,02	5,18	0,075	0,27	2,40	0,004	0,06	5,85	21,418	4,63
F	0004	1	7	0,40	0,005	0,07	3,47	1,810	1,35	1,18	0,004	0,07	3,98	9,548	3,09
F	0004	2	2	0,31	0,003	0,06	1,57	0,638	0,80	1,18	0,001	0,04	6,01	9,724	3,12
F	0004	3	4	0,41	0,004	0,06	3,01	1,811	1,35	1,44	0,015	0,12	10,97	12,752	3,57
F	0004	5	3	0,50	0,005	0,07	2,50	0,147	0,38	1,68	0,043	0,21	14,88	7,828	2,80
F	0007	1	5	0,65	0,007	0,08	4,99	2,268	1,51	1,38	0,001	0,03	1,27	0,095	0,31
F	0007	2	4	0,70	0,004	0,06	3,62	0.971	0,99	1,47	0,007	0,08	6.19	16,986	4,12
F	0007	3	4	0,80	0,001	0,04	8,22	2,003	1,42	1,39	0,003	0,05	4,39	1,388	1,18
F	0007	4	2	0,82	0,001	0,04	4,75	0,245	0,49	1,55	0,001	0,04	9,53	6,625	2,57
F	0007	5	3	1,57	0,037	0,60	8,20	12,040	3,47	1,55	0,009	0,10	8,28	0,461	0,68
F	0008	1	3	0,81	0,018	0,14	9,04	7,021	2,72	2,29	0,073	0,27	2,49	0,0	0,0
F	0008	2	2	0,68	0,001	0,04	6,60	1,862	1,36	2,30	0,054	0,23	6,60	6,845	2,62
				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1,60	0,004	0,06	1,65	0,006	0,08

N	0004	2	3	0,47	0,003	0,06	1,90	0,130	0,36	1,87	0,011	0,11	1,91	0,148	0,38
N	0004	3	3	0,62	0,001	0,04	3,47	0,003	0,06	1,90	0,012	0,11	2,29	0,167	0,41
N	0004	4	2	0,60	0,003	0,06	2,65	0,405	0,64	1,87	0,0	0,0	3,33	0,097	0,31
N	0004	5	2	0,70	0,001	0,03	2,70	0,320	0,57	1,49	0,002	0,05	2,92	0,011	0,11
N	0006	1	2	0,42	0,000	0,01	12,55	0,005	0,07	1,04	0,003	0,06	2,92	0,224	0,47
N	0006	2	2	0,30	0,000	0,01	8,20	0,720	0,85	1,37	0,002	0,05	5,61	0,994	1,00
N	0006	3	4	0,52	0,004	0,06	18,00	3,687	1,92	1,05	0,001	0,03	7,49	0,644	0,80
N	0006	4	2	0,34	0,002	0,04	10,35	3,645	1,91	1,34	0,005	0,07	13,59	0,471	0,69
N	0006	5	2	0,37	0,000	0,02	8,65	0,045	0,21	1,44	0,001	0,04	8,69	0,051	0,23
N	0007	1	1	0,77	0,0	0,0	17,10	0,0	0,0	1,65	0,0	0,0	2,95	0,0	0,0
N	0007	3	4	0,81	0,003	0,06	19,17	5,943	2,44	1,74	0,015	0,12	7,34	0,267	0,52
N	0007	4	2	0,59	0,0	0,0	9,90	0,320	0,57	2,14	0,001	0,03	12,43	0,025	0,16
N	0007	5	2	0,76	0,005	0,07	11,55	1,805	1,34	2,19	0,005	0,07	11,14	0,461	0,68
N	0008	1	1	0,40	0,0	0,0	6,20	0,0	0,0	1,01	0,0	0,0	2,36	0,0	0,0
N	0008	2	1	0,39	0,0	0,0	3,30	0,0	0,0	1,31	0,0	0,0	2,33	0,0	0,0
N	0008	3	3	0,49	0,000	0,02	6,50	0,090	0,30	1,78	0,001	0,03	3,39	0,084	0,29
N	0008	4	2	0,49	0,008	0,09	5,10	1,280	1,13	1,48	0,0	0,0	5,30	0,072	0,27
N	0008	5	3	0,54	0,002	0,05	5,50	0,160	0,40	1,52	0,000	0,01	6,18	2,521	1,59
N	0009	1	1	0,60	0,0	0,0	6,60	0,0	0,0	1,27	0,0	0,0	2,68	0,0	0,0
N	0009	2	1	0,53	0,0	0,0	4,50	0,0	0,0	1,27	0,0	0,0	3,55	0,0	0,0
N	0009	3	3	0,60	0,002	0,04	7,23	0,163	0,40	1,46	0,002	0,05	4,49	0,123	0,35
N	0009	4	1	0,57	0,0	0,0	5,00	0,0	0,0	1,36	0,0	0,0	7,30	0,0	0,0
N	0009	5	2	0,73	0,001	0,03	6,70	0,0	0,0	1,46	0,000	0,02	7,47	0,583	0,76
N	0010	1	1	0,55	0,0	0,0	7,10	0,0	0,0	1,06	0,0	0,0	1,58	0,0	0,0
N	0010	2	1	0,57	0,0	0,0	4,90	0,0	0,0	1,36	0,0	0,0	1,59	0,0	0,0
N	0010	3	4	0,79	0,000	0,02	9,07	0,070	0,26	1,14	0,061	0,25	2,42	0,042	0,20
N	0010	4	2	0,71	0,003	0,06	5,80	0,0	0,0	1,43	0,000	0,01	3,04	0,051	0,23
N	0010	5	2	0,80	0,0	0,0	6,70	0,089	0,28	1,47	0,000	0,01	3,01	0,001	0,04
R	LTUI	1	3	0,40	0,008	0,09	8,44	14,096	3,75	1,44	0,015	0,12	1,88	0,060	0,28

R	LTDI	2	2	0.41	-0.004	0.06	7.43	6.230	2.50	1.75	0.013	0.11	4.74	0.490	0.70
R	LTDI	3	2	0.52	0.013	0.11	6.38	7.335	2.71	1.72	0.031	0.18	2.33	0.120	0.35
R	LTDI	4	2	0.38	0.013	0.11	5.58	0.026	0.16	2.13	0.008	0.09	7.19	1.901	1.38
R	LTDI	5	2	0.61	0.008	0.09	6.19	5.152	2.27	1.92	0.061	0.25	5.49	4.470	2.11
R	MUST	1	2	3.82	0.000	0.01	29.75	18.605	4.31	1.10	0.0	0.0	-	-	-
R	MUST	2	1	2.82	0.0	0.0	19.80	0.0	0.0	1.53	0.0	0.0	-	-	-
R	MUST	3	1	3.15	0.0	0.0	27.00	0.0	0.0	1.27	0.0	0.0	-	-	-
R	MUST	4	1	1.72	0.0	0.0	17.20	0.0	0.0	1.72	0.0	0.0	-	-	-
R	MUST	5	1	2.66	0.0	0.0	25.50	0.0	0.0	1.48	0.0	0.0	-	-	-
S	CHEV	3	5	0.35	0.001	0.03	3.95	0.073	0.27	0.77	0.005	0.07	20.31	45.912	6.78
S	CHEV	4	2	0.39	0.000	0.01	2.52	0.002	0.05	0.68	0.0	0.0	19.24	0.036	0.19
S	CHEV	5	2	0.41	0.0	0.0	2.81	0.051	0.23	0.81	0.013	0.11	21.63	0.001	0.03
S	MUST	3	4	0.71	0.002	0.04	6.07	0.204	0.45	1.87	0.007	0.08	6.56	16.115	4.01
S	MUST	4	2	0.83	0.016	0.13	5.08	0.162	0.40	1.49	0.000	0.01	27.28	7.220	2.69
S	MUST	5	2	0.78	0.007	0.08	5.04	0.076	0.28	1.53	0.002	0.04	23.87	0.174	0.42

SOURCE	VEH	FUEL	N OBS	HC			CO			NOX			EVAP		
				MEAN	VAR	STDEV	MEAN	VAR	STDEV	MEAN	VAR	STDEV	MEAN	VAR	STDEV
S	SAAB	4	2	0.27	0.001	0.04	3.82	0.001	0.04	0.26	0.000	0.01	7.19	13.834	3.72
S	SAAB	5	2	0.32	0.003	0.06	4.10	0.012	0.21	0.28	0.000	0.01	4.01	0.761	0.08
S	SAAB	3	2	0.28	0.0	0.0	4.01	0.002	0.04	0.19	0.006	0.08	5.70	0.304	0.55
N	0005	1	2	0.22	0.000	0.01	4.70	0.000	0.26	0.66	0.000	0.01	1.40	0.001	0.04
N	0005	2	2	0.23	0.000	0.01	4.10	0.020	0.14	0.66	0.002	0.04	2.57	0.076	0.28
N	0005	3	4	0.31	0.001	0.03	5.82	0.016	0.13	0.72	0.001	0.03	1.99	0.036	0.19
N	0005	4	2	0.36	0.003	0.06	6.40	0.500	0.71	0.71	0.000	0.01	3.19	0.076	0.28
N	0005	5	2	0.50	0.005	0.07	7.40	0.080	0.28	0.76	0.000	0.01	3.64	0.500	0.71
N	0011	1	2	0.37	0.001	0.04	7.95	0.245	0.49	0.19	0.002	0.04	2.89	0.000	0.01
N	0011	2	2	0.31	0.000	0.01	6.35	0.045	0.21	0.24	0.000	0.01	3.81	0.065	0.25
N	0011	3	4	0.41	0.002	0.05	9.20	1.380	1.17	0.23	0.003	0.05	4.55	0.623	0.79
N	0011	4	2	0.40	0.001	0.04	7.90	0.080	0.28	0.24	0.000	0.01	7.14	1.843	1.36
N	0011	5	2	0.55	0.000	0.01	10.60	0.000	0.01	0.31	0.000	0.01	7.66	0.174	0.42
F	0002	1	7	0.26	0.002	0.05	2.27	0.220	0.47	0.93	0.001	0.03	1.69	0.393	0.63
F	0002	2	5	0.23	0.007	0.09	1.81	0.235	0.49	1.22	0.006	0.09	2.73	1.328	1.15
F	0002	3	4	0.26	0.000	0.02	2.22	0.096	0.31	1.08	0.002	0.04	3.52	0.793	0.89
F	0002	4	2	0.24	0.0	0.0	1.85	0.005	0.07	1.32	0.004	0.06	6.25	0.115	0.31
F	0002	5	2	0.33	0.000	0.02	2.10	0.000	0.00	1.32	0.002	0.04	5.58	0.061	0.25
F	0005	1	5	0.25	0.004	0.06	3.57	0.278	0.53	0.98	0.015	0.12	1.21	0.0	0.0
F	0005	2	3	0.33	0.101	0.32	4.16	1.161	1.08	0.96	0.013	0.11	2.05	0.0	0.0
F	0006	1	4	0.26	0.009	0.09	0.68	0.012	0.11	0.59	0.001	0.04	-	-	-
F	0006	2	2	0.40	0.005	0.07	1.04	0.003	0.06	0.70	0.0	0.0	-	-	-
F	0009	1	6	0.23	0.002	0.04	1.38	0.117	0.34	1.15	0.041	0.20	2.35	0.355	0.60
F	0009	2	5	0.21	0.000	0.01	1.29	0.075	0.27	1.16	0.001	0.03	3.61	1.019	1.01
F	0009	3	4	0.27	0.000	0.01	[illegible]	[illegible]	0.29	1.21	[illegible]	[illegible]	3.72	0.351	0.60
F	0009	4	2	0.27	0.001	[illegible]	1.00	0.020	0.14	1.17	[illegible]	[illegible]	3.11	0.598	0.77
F	0009	5	3	0.34	0.037	0.19	2.17	1.373	1.17	1.16	0.001	0.04	3.23	0.049	0.22
			-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-		

B	0001	2	4	0.37	0.012	0.11	3.91	0.772	0.88	0.24	0.012	0.11	-	-	-
B	0001	3	1	0.41	0.0	0.0	6.11	0.0	0.0	0.10	0.0	0.0	-	-	-
B	0001	4	1	0.45	0.0	0.0	5.81	0.0	0.0	0.10	0.0	0.0	-	-	-
B	0001	5	1	0.65	0.0	0.0	5.83	0.0	0.0	0.12	0.0	0.0	-	-	-
B	0002	1	5	0.39	0.004	0.07	5.24	1.113	1.06	0.79	0.009	0.10	2.19	0.018	0.13
B	0002	2	4	0.42	0.004	0.07	4.52	2.527	1.59	0.78	0.003	0.06	3.43	0.0	0.0
B	0002	3	1	0.43	0.0	0.0	4.34	0.0	0.0	0.81	0.0	0.0	2.98	0.0	0.0
B	0002	4	1	0.41	0.0	0.0	3.60	0.0	0.0	0.80	0.0	0.0	4.12	0.0	0.0
B	0002	5	1	0.45	0.0	0.0	4.53	0.0	0.0	0.80	0.0	0.0	3.06	0.0	0.0
B	0007	1	2	0.30	0.026	0.16	3.23	0.353	0.59	0.57	0.008	0.09	3.92	0.0	0.0
B	0007	2	1	0.21	0.0	0.0	2.93	0.0	0.0	0.58	0.0	0.0	5.56	0.0	0.0
B	0007	3	1	0.20	0.0	0.0	3.09	0.0	0.0	0.77	0.0	0.0	2.67	0.0	0.0
B	0007	4	1	0.65	0.0	0.0	3.68	0.0	0.0	1.01	0.0	0.0	4.11	0.0	0.0
B	0007	5	1	0.24	0.0	0.0	2.65	0.0	0.0	0.99	0.0	0.0	5.84	0.0	0.0
B	0008	1	2	0.53	0.010	0.10	13.40	8.694	2.95	0.65	0.024	0.16	1.88	0.638	0.00
B	0008	2	1	0.47	0.0	0.0	9.64	0.0	0.0	0.72	0.0	0.0	1.97	0.0	0.0
B	0008	3	1	0.75	0.0	0.0	14.36	0.0	0.0	0.71	0.0	0.0	1.28	0.0	0.0
B	0008	4	1	0.65	0.0	0.0	13.36	0.0	0.0	0.71	0.0	0.0	2.56	0.0	0.0
B	0008	5	1	0.52	0.0	0.0	11.74	0.0	0.0	0.73	0.0	0.0	1.99	0.0	0.0
G	SUN8	1	1	0.44	0.0	0.0	5.65	0.0	0.0	0.67	0.0	0.0	-	-	-
G	SUN8	2	1	0.30	0.0	0.0	3.36	0.0	0.0	0.71	0.0	0.0	-	-	-