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LIGHT-DUTY DIESEL EMISSION CORRECTION FACTORS FOR AMBIENT CONDITIONS

Environmental Sciences Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Research Triangle Park, North Carolina 27711

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July 1977

LIGHT-DUTY DIESEL EMISSION CORRECTION FACTORS FOR AMBIENT CONDITIONS

by

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Task 5 Interim Report
Contract No. 68-02-1777

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FORWARD

This document presents completed work on one phase (out of five) of a large contract effort characterizing diesel engine emissions. This particular segment is, therefore, an interim report of findings by Southwest Research Institute relative to the value of humidity correction factors needed for testing diesel-powered passenger cars for NO_x emissions.

Ambient air temperature, humidity, and barometric pressure influence the emission rates of pollutants from passenger cars. For example, in cold weather gasoline engines are slow to warm up, carburetor chokes remain closed longer, and hydrocarbon emissions are elevated. The emission rate of NO from a passenger car is especially sensitive to humidity. The reason is well known; namely, the higher the water vapor concentration in the engine charge, the lower the effective fuel-air mixture density must be. Thus, high humidity produces low rates of heat release, low cylinder gas temperatures, and hence low NO_x.

In emissions certification, ambient conditions can be held constant and, thus, all cars can be tested fairly relative to one another. However, not all manufacturers have the extremely expensive equipment necessary to maintain humidity and temperature constant in a dynamometer cell. Furthermore, vehicles are operated under a wide range of ambient conditions. It is, therefore, important to predict emissions under conditions other than the standard ones. Hence, statistical correction factors are needed.

At the outset of this work, correction factors were available for gasoline engine cars operated over the current Federal urban cycle and for heavy duty diesel engines at constant speeds. However, no such factors were available for diesel-powered passenger cars, a class of vehicles projected to be of increasing importance as future fuel economy goals are pursued. Consequently, the task of developing these needed factors was contracted to Southwest Research Institute.

The authors report new values for NO_x-humidity correction factors considerably smaller than those used for gasoline-powered cars. This fact represents a small credit for NO_x emissions from diesel versus gasoline engines operating in hot, humid climates. Since relatively high-powered cars were not available for this study, there is probably a danger inherent in projecting these factors to high-power-to-weight

ABSTRACT

Since emission measurements from passenger cars are performed at one standard set of ambient conditions and since emission rates of HC, CO, and NO_x are sensitive to temperature and humidity, it is necessary to determine the influence of ambient conditions on emissions from major classes of vehicles. Although such information has been available for gasoline engine powered cars for sometime, no such data were available for diesel powered passenger cars.

This report indicates that diesel HC and CO emissions are relatively insensitive to ambient conditions. Diesel NO_x emissions, however, are sensitive to humidity but to a smaller extent than gasoline engines. Humidity correction factors for NO_x emissions also appear to vary with vehicle power-to-weight ratios and are greater for higher powered vehicles.

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ratio vehicles such as the new V-8 engines due in the fall of 1977. In fact, the authors point out that the one six-cylinder vehicle tested was much more humidity-sensitive than the four-cylinder models, and plausible reasons are given for this effect.

No significant temperature or humidity effects for hydrocarbon or CO emissions were found. This is probably due to the quick warmup of diesels relative to gasoline engines. Since the range of barometric pressures available in San Antonio was small, the current results are not necessarily applicable to high altitude, low station pressure areas such as the Rocky Mountain States.

Dr. Ronald L. Bradow
Project Officer

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SECTION 1

INTRODUCTION

Light-duty, diesel-powered vehicles were included under Federal exhaust emission standards beginning with the 1975 model year,[1] recognizing that their U.S. sales volume was likely to become appreciable in the near future. At that time, as is still the case today, all diesel-powered, light-duty vehicles available to the consumer were either of foreign manufacture or were equipped with engines of foreign manufacture. These vehicles have traditionally been powered by relatively small engines, having displacements of 3 liters (183 in^3) or less. Emission test procedures for light-duty diesels have been as similar as possible to those for gasoline-powered vehicles, and emission standards for the two engine types used in light-duty vehicles have been (and probably will remain) the same.

At this writing, it appears that the diesel-powered automobile is on the threshold of a relative "population explosion" in the United States. Concern over fuel economy is one of the driving forces behind this predicted expansion, but another is certainly a desire by auto manufacturers to secure a competitive advantage by offering the consumer something novel. The vehicles which will create the boom, if it comes within the next two years or so, will be the Volkswagen and Oldsmobile diesels. Anticipating this situation, it becomes more important to refine existing emission test procedures, providing additional assurance that present and future emission standards will in fact achieve air quality goals.

To date, with the exception of continuous HC sampling and integration, calculation procedures for light-duty diesel FTP's have been the same as those for light-duty gasoline FTP's. EPA recognized in the regulations for light-duty diesels,[1] however, that the NO_x correction factor for intake air humidity (K_h) could be modified as necessary pending the availability of test data. This report contains the information required to make decisions on factors for correction of light-duty, diesel-powered vehicle emissions to standardized ambient conditions. These decisions should help to place measured diesel emissions values on a firmer base, thereby providing greater accuracy in comparison of environmental hazards associated with gasoline- and diesel-powered vehicles.

SECTION 2

CONCLUSIONS

1. Combined data from the four light-duty diesel test vehicles, using a linear model, yielded the following humidity (H) correction factor for NO_x (same for two equal slope/equal intercept variations):

$$K_h = \frac{1}{1 - 0.00217\ (H-75)},$$

where H = humidity in grains H_2O/lb_m dry air. The equations on which the factor is based displayed correlation coefficients (r^2) of 0.569 ("normalized" data) and 0.566 ("standardized" data) with the combined emissions data. This factor is very similar to that originally used for correction of NO_x emissions from heavy-duty diesels.[3]

2. On the average, a quadratic equation in H (one containing H and H^2 terms) correlated better with NO_x data than did either a linear equation in H alone or one linear in H and temperature (T). For data on individual vehicles, correlation coefficients (r^2) for the quadratic averaged 0.653, those for the linear in H averaged 0.570, and those for the linear in H and T averaged 0.594. The factor computed using quadratics in H (average of coefficients for equations using both "standardized" and "normalized" data) is

$$K_h = \frac{1}{1 - 0.00228\ (H-75) + (1.86 \times 10^{-5})\ (H-75)^2},$$

and the r^2 of the quadratic factor is 0.616 for "normalized" data and 0.613 for "standardized" data.

3. In addition to the combinations of "independent" variables already mentioned (H alone, H with T, and H with H^2), emissions were also regressed against: T alone; T and T^2; H, T, and HT; and H, T, H^2, and T^2. For NO_x, correlations were either worse than for the linear and/or quadratic in H, or else the additional complication of introducing more variables could not be justified in terms of improved correlation. For the other emissions (HC and CO), results were too mixed and/or correlations were too poor to justify computation of correction factors from the equations.

4. Emissions of HC and CO from the International 100 pickup truck equipped with Perkins 6.247 engine were more strongly dependent on humidity and temperature than those from the other vehicles. No facts are available to explain this result, but it may be related to the much lower specific loading (kg vehicle mass per available engine kW) of the Perkins engine as

compared to the others (lower specific loading would mean lower overall F/A ratios for this vehicle).

5. Combination of NO_x emission values for the four vehicles by "normalizing" them appeared to yield good data for computation of a final correction factor. This process eliminated the effect of differing NO_x emission magnitudes among the test vehicles by transforming the data to ratios of "as measured" values versus "best predicted" values at a standard humidity among the four test vehicles.

6. Use of a greater number of test vehicles would be desirable for any future research aimed at improving the statistical basis for light-duty diesel emission correction factors.

SECTION 3

VEHICLES, FUEL, AND TEST INSTRUMENTATION

Each topic of this section is treated in a separate subsection for clarity. Vehicle parameters and specifications are outlined first, followed by test fuel specifications and requirements. Instrumentation used for testing and analysis is discussed to conclude the section.

TEST VEHICLES

The four light-duty, diesel-powered vehicles used for test purposes were a Datsun 220C, an International pickup with Perkins 6.247 engine, a Mercedes 240D, and a Peugeot 504D. These vehicles are shown in Figures 1 through 4 for documentation, and descriptions of them are given in Table 1. It was planned initially to use five test vehicles, but the fifth one was not available when needed. The decision to proceed with only four vehicles, but to conduct more tests per vehicle than had been planned, was approved by the Project Officer.

The particular test vehicles used reflected availability of vehicles for EPA programs at the time testing began more strongly than they reflected the population of diesel-powered, light-duty vehicles. The Mercedes 240 and Peugeot 504 were the only diesel automobiles on the U.S. consumer market when testing began, so to that extent they could be considered representative. The other two vehicles, however, were research prototypes as far as the U.S. market was concerned. Loaded vehicle weights ranged from about 1400 to 2000 kg, and engine size ranged from 2.1 to 4.1 liters. All the engines were of the indirect injection, naturally-aspirated type, with similar injection systems (Bosch and Bosch-liscensed) and compression ratios between 21.0 and 22.2. Each vehicle was equipped with a 4-speed manual-shift transmission.

TEST FUEL PROPERTIES

All four vehicles were operated on Type 2-D emissions test fuel as specified in Federal regulations.[1] Inspection results on the particular fuel batch used, EM-238-F, are given in Table 2 along with required specifications and "national average" properties for comparison. The test fuel was well within Federal specifications for all properties except end point, at which it was coincident with the upper limit. As compared to a "national average" No. 2 fuel, the test fuel contained more sulfur and somewhat more high-boiling material. Although no hydrocarbon composition data were available in the survey data,[2] it is likely that the test fuel contained more aromatics than an average No. 2 fuel.

Figure 1. Datsun 220C.

Figure 2. International 100 with Perkins 6.247 engine.

Figure 3. Mercedes 240D.

Figure 4. Peugeot 504D.

TABLE 1. DESCRIPTION OF TEST VEHICLES

Vehicle Model Engine Model (if different)	Datsun 220C Nissan SD22	International 100 Perkins 6.247	Mercedes 240D OM616	Peugeot 504D XD90
V.I.N.	QL230-103467	4H1CODHB23906	11511710066208	504A90-2034350
Engine No. (if different)	SD22-116440	247J1042	616916-10-052895	X203043508
Body Type	4 door sedan	pickup truck	4 door sedan	4 door sedan
Loaded Weight, kg (lb_m)[a]	1551 (3419)	1982 (4370)	1492 (3289)	1402 (3091)
Inertia Equivalent, kg (lb_m)	1588 (3500)	2041 (4500)	1588 (3500)	1361 (3000)
Transmission	4 speed manual	4 speed manual	4 speed manual	4 speed manual
Displacement, l (in^3)	2.16 (132.1)	4.06 (247.7)	2.40 (146.7)	2.11 (128.9)
Cylinders	4	6	4	4
Power, kW (hp) @ rpm	52.2 (70) @ 4000	91.0 (122) @ 4000	46.2 (62) @ 4350	48.5 (65) @ 4500
Injection System	Kiki	Kiki	Bosch	Bosch
Combustion Chamber	prechamber	prechamber	prechamber	prechamber
Compression Ratio	22.0	21.1	21.0	22.2
Distance on Vehicle, km[b]	19,861	17,830	4,677	4,694

[a] curb weight plus 136 kg (300 lb_m)
[b] at end of tests

TABLE 2. PROPERTIES OF TEST FUEL, FEDERAL SPECIFICATIONS, AND "NATIONAL AVERAGES" FOR COMPARISON

Fuel Type Fuel Code	2D Test Fuel EM-238-F	Federal 2D Specification -----------	"National Average" No. 2[a] -----------
Density, g/ml	0.845	--------[b]	-----[b]
Gravity, °API	36.0	33 - 37	35.7
Cetane (D976)	48.6	42 - 50	49.3
Viscosity, CS (D445)	2.65	2.0 - 3.2	2.71
Flash Point, °C (°F)	94.(202)	54 (130) minimum	-----[b]
Sulfur, wt. % (D1266)	0.35	0.2 - 0.5	0.249
FIA:			
aromatics, %	29.8	27 (minimum)	-----[b]
olefins, %	1.6	--------[b]	-----[b]
saturates, %	68.6	--------[b]	-----[b]
Distillation (D86):			
IBP, °C (°F)	192 (378)	171-204 (340-400)	190 (374)
10% pt., °C (°F)	213 (415)	204-238 (400-460)	221 (430)
50% pt., °C (°F)	257 (495)	243-282 (470-540)	261 (502)
90% pt., °C (°F)	312 (593)	288-321 (550-610)	307 (585)
EP, °C (°F)	349 (660)	304-349 (580-660)	333 (632)
Carbon, wt. %	86.8	--------[b]	-----[b]
Hydrogen, wt. %	12.9	--------[b]	-----[b]
Nitrogen, wt. %	0.005	--------[b]	-----[b]

[a] average of five regional averages, 1976 ERDA Diesel Fuel Survey(2), not sales-weighted

[b] no specification or data

A Type 1-D diesel fuel is specified alongside the Type 2-D fuel in the heavy-duty and light-duty emission regulations,[3,1] in case a given manufacturer requires No. 1 to be used in its engines. For the test vehicles and for other market entries anticipated, however, No. 2 diesel fuel will probably continue to be recommended. The main reason for the more widespread use of No. 2 fuel is economy. Its price per unit volume is equal to or lower than No. 1 fuel, while having considerably greater density (and proportionately higher energy content) per unit volume. The only foreseeable circumstance which would move fuel usage for diesel cars toward No. 1 fuel would be a dramatic increase in urban diesel smoke and/or odor complaints as the light-duty diesel population increases.

INSTRUMENTATION AND TEST EQUIPMENT

The four diesel-powered vehicles used for test purposes were operated on a standard 2-roll chassis dynamometer, in this instance a Clayton Model CT-200 which had been modified to EC-50 configuration. This dynamometer used a 37.3 kW (50 hp) water brake absorber and a belt-driven variable inertia system to simulate road operation. Inertia and power settings were based on vehicle weight and were set according to Federal procedure.[1] For test purposes, the rear tires of the vehicles were inflated to 3.16 kg/cm^2 (45 psig) to minimize deflection on the rolls. The Datsun 220C vehicle shown in Figure 5 was operating on the chassis dynamometer.

Figure 5 also shows the position of the auxillary cooling fan in front of the vehicle, producing an air flow of approximately 2.36 m^3/sec (5000 ft^3/min). Sampling or measurement points for all the air analysis instrumentation were located within 0.6 m (2 ft) of the inlet plane of this fan. The air instrumentation included two air (dry bulb) temperature thermocouples, one forced air psychrometer, one electronic hygrometer, and a dewpoint-measuring device. Figure 6 shows another view of the instruments and sampling/measurement points with the psychrometer at upper left, perforated relative humidity/dry bulb temperature sensor for the electronic hygrometer at center, bare-tip thermocouple at bottom center, and dewpoint instrument at bottom right. The white object near top center is a small funnel to which the dewpoint instrument's sample line was attached. Another view of the area behind the fan is given by Figure 7.

Of the humidity- and temperature-measuring instruments noted above, only the electronic hygrometer output and the two dry-bulb temperatures were recorded on a continuous basis. The other instruments were monitored manually, and readings were taken from them at intervals of 2 to 5 minutes during each test. Yet another source of data was the National Weather Service, from which humidity data were obtained on an hourly basis during the days and times when tests were being conducted. The Weather Service data were not intended as primary information to be used in a statistical sense, but rather as corroboration of data obtained by our direct measurements. Accuracy of all the measurements and correlations between systems will be discussed later in the report.

Measurement of CO, NO_x, and CO_2 gaseous emissions was accomplished using a constant-volume sampler (CVS) and a set of low-concentration gas analyzers

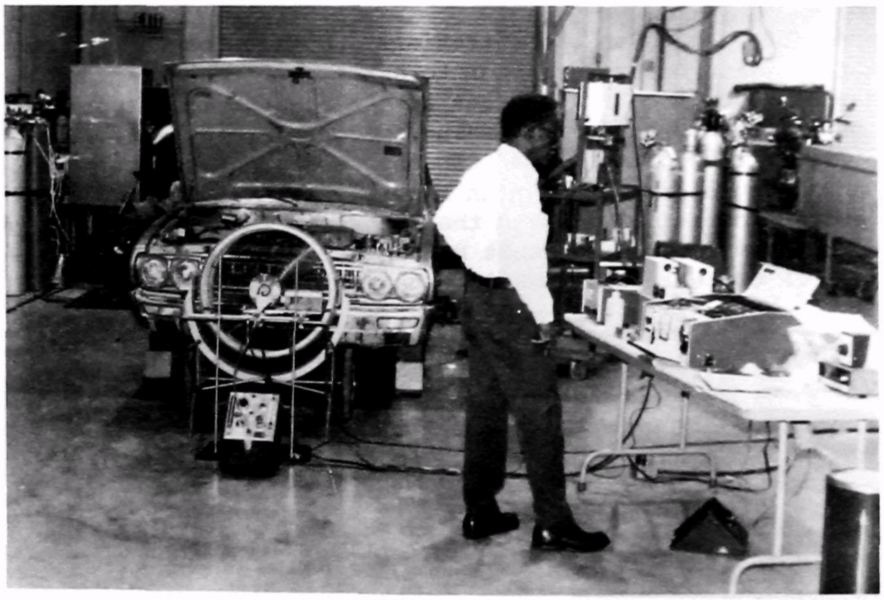

Figure 5. Datsun 220C test vehicle on dynamometer, with humidity and temperature measuring equipment.

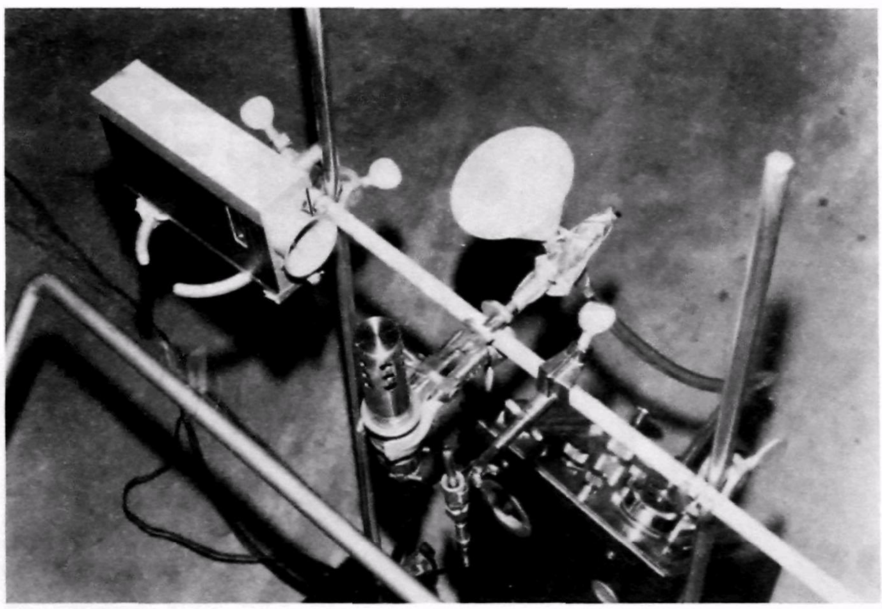

Figure 6. Details of air sampling and measurement points for humidity and temperature.

to read the diluted (bag) emission concentrations. Hydrocarbon emissions were sampled just after dilution occurred (prior to entry into the CVS), and were analyzed by a heated FID on a continuous basis. An electronic integrator provided the means of extracting an average value from the FID output. The CVS used is shown in Figure 8; and the heated FID detector/oven, control unit, chart recorder, and integrator are shown in Figure 9. Instruments used for measurement of bag concentrations (called the "bag cart") are shown in Figure 10. This cart contains a chemiluminescent NO_x analyzer, an NDIR CO_2 analyzer, and two low-range NDIR CO analyzers (one long-path and one standard).

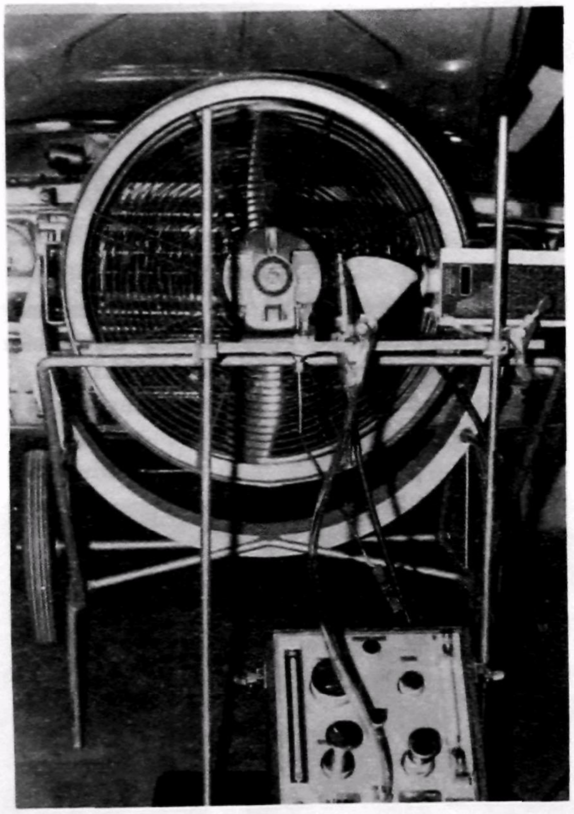

Figure 7. Second view of air sampling and measurement points.

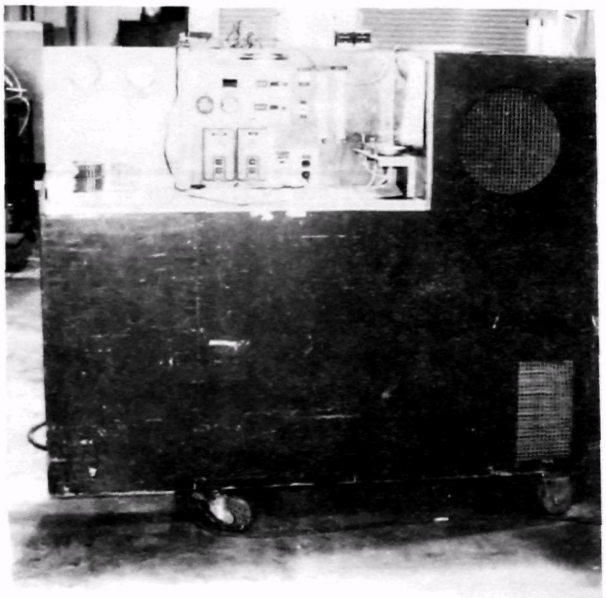

Figure 8. Constant-Volume Sampler (CVS) used for light-duty diesel exhaust sampling.

Figure 9. Details of heated hydrocarbon analysis equipment.

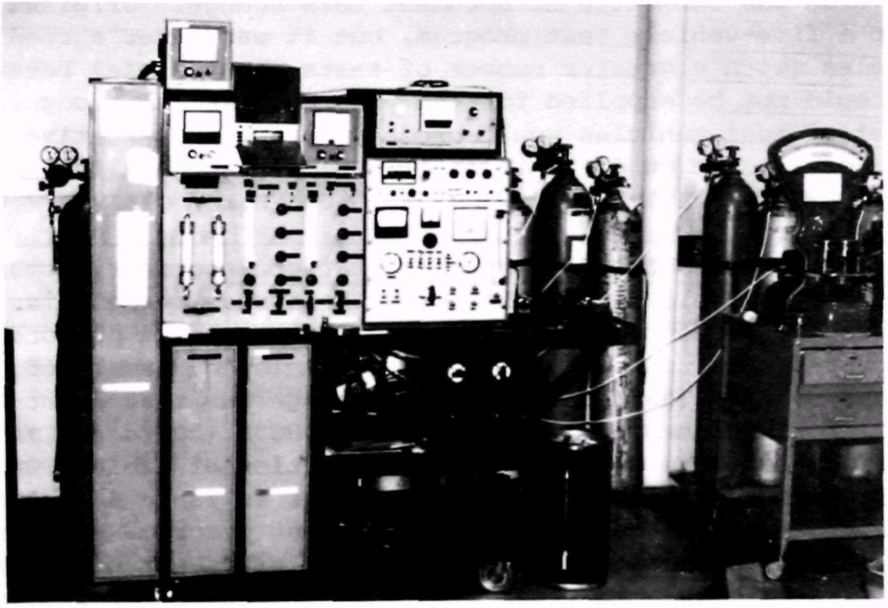

Figure 10. Instrumentation for measurement of dilute (bag) emission concentrations.

SECTION 4

EXPERIMENTAL PLAN AND TEST PROGRAM DETAILS

This section deals first with the experimental plan designed to gather meaningful data about effects of ambient conditions on light-duty diesel emissions. The second subsection covers the details of the test program as it actually occurred and the effects of deviations from the original plans. All this information constitutes the foundation on which the results and conclusions of the program are based.

EXPERIMENTAL PLAN

Following submittal of the Contract Work Plan early in the program, efforts began to assemble the apparatus required for control of intake air temperature and humidity. A problem was discovered with the planned approach, however, because it was to control properties of the engine intake air only rather than the ambient. The fallacy in the original line of thought was that "ambient" data were to be taken in a controlled airstream leading to the vehicle air intake, rather than in a totally-controlled ambient (the room). Once this problem had been thoroughly discussed, it was decided to use naturally-occurring humidity conditions with control on room temperature only. A revised Work Plan was submitted to document this change. Original plans also called for a five-vehicle test program, but it was later agreed to utilize four vehicles (with a greater number of tests per vehicle) because the fifth vehicle could not be supplied for the program. It was recognized that a greater number of test vehicles would produce more representative statistics on light-duty diesels, but other vehicles were simply not available for test purposes.

The Contract "TEST SCHEDULE", with computational corrections as necessary, is reproduced in Table 3. The specified tolerance on relative humidity for each test was ± 2 percent. It was decided that for test purposes, a slightly different set of temperatures would be employed, namely 68, 77, and 86°F (20, 25, and 30°C). The reason for this change was that light-duty FTP regulations call for test temperatures from 68 to 86°F (20 to 30°C). With this minor modification, the relative humidity portion of Table 3 was recomputed and now appears as Table 4. These conditions in Table 4 were those sought (or an approximation thereof) during the test program. Variables actually used to decide on the worth of running at a given set of ambient conditions were (or were calculated from) original independent variables; and they were temperature and specific humidity expressed in grains H_2O/lb_m dry air.

TABLE 3. CONTRACT "TEST SCHEDULE"
Note: Replications in parentheses

Humidity expressed as				Relative humidity (%) at		
wt. % H_2O	vol. % H_2O	grains H_2O/ lb_m dry air	Pd/Pw	65°F	75°F	85°F
0.50	0.802	35.2	0.992	37.8(2)	26.9(2)	-------
0.75	1.201	52.9	0.988	56.5(2)	40.2(3)	-------
1.00	1.598	70.7	0.984	75.3(2)	53.5(3)	38.6(2)
1.25	1.995	88.6	0.980	-------	66.8(3)	48.2(2)
1.50	2.390	106.6	0.976	-------	80.0(2)	57.7(2)
1.75	2.785	124.7	0.973	-------	-------	67.2(2)
2.00	3.178	142.9	0.969	-------	-------	76.7(2)

TABLE 4. REVISED TEMPERATURE AND RELATIVE HUMIDITY VALUES

Humidity as grains H_2O/lb_m dry air	Relative humidity (%) at		
	68°F (20°C)	77°F (25°C)	86°F (30°C)
35.2 (5.03)[a]	34.0	25.1	----
52.9 (7.56)	51.0	37.6	----
70.7 (10.1)	67.8	50.1	37.4
88.6 (12.7)	----	62.5	46.6
106.6 (15.2)	----	74.9	55.9
124.7 (17.8)	----	----	65.1
142.9 (20.4)	----	----	74.3

[a] values in parentheses in g H_2O/kg dry air

Noting the number of replications specified for each set of conditions given in Table 3, the original test plan called for 29 FTP's per vehicle (145 FTP's total). It was also requested that the order of the tests be randomized on a daily basis, so that the vehicles would not be tested in the same order all the time. This request was complied with by preparing a randomized daily sequence based on a table of random digits. It does not seem necessary to reproduce this sequence as a separate item, since it can be deduced readily from general data tabulations (including dates and run numbers) which are presented later in the report.

DETAILS OF THE TEST PROGRAM

The decision to use naturally-occurring humidity conditions so that room ambients could be the variables of record resulted in a somewhat different set of ambient conditions for tests on each vehicle. Room temperatures were sometimes increased by adding heat, but decreases in temperatures were not attempted due to the probability of moisture removal in the air conditioners. In a few cases, tests were conducted using a steam generator in the room to maintain humidity above ambient. Moisture addition was necessary only for some of the higher specific humidity conditions. Both humidity and temperature remained essentially constant during individual tests.

Rather than refer again to general data tabulations for actual test ambient conditions, these data are plotted in Figures 11a through 11d as compared to the planned set of ambient conditions. These graphs should make visualization of the comparison easier than would a simple tabulation. Although the humidity points did not fall exactly on the planned values in most cases, the range and distribution of points achieved should be satisfactory from a statistical standpoint. Since humidity points had to be accepted essentially as they occurred naturally, a larger number of tests had to be performed than was planned initially. A total of 174 valid tests were conducted on the four vehicles, which compares to a total of 145 planned tests on five vehicles. The tests were split quite evenly among the vehicles; with 44 being conducted on the Datsun 220C, 45 on the International/Perkins 6.247, 43 on the Mercedes 240D, and 42 on the Peugeot 504D.

Measures used to help control data quality throughout the test program included CVS propane checks, dynamometer calibrations, and NO_x converter checks. Data from each day of testing were tabulated and graphed to determine whether or not any investigation should be conducted for processing errors. The analysis instrumentation was fully calibrated on a monthly basis with gases named by EPA's Ann Arbor laboratory or with gases traceable to them. This instrumentation and these gases were further used to cross-check four NO_x calibration gases sent to SwRI by the Project Officer. The results of this cross-check are given below in Table 5; and it is apparent that agreement is quite good in the lower concentrations, but somewhat less satisfactory as the concentrations increase (disagreements up to about 4 percent). Almost all the NO_x concentrations analyzed during this program were in the range of 30 to 50 ppm (dilute sample bags). No reasons have been identified as yet for the apparent calibration differences indicated in Table 5. While absolute accuracy is important for all the emissions data, it probably is just as important for the ambient data.

KEY □ planned ▫ 1 run ⊕ 2 runs ● 3 runs

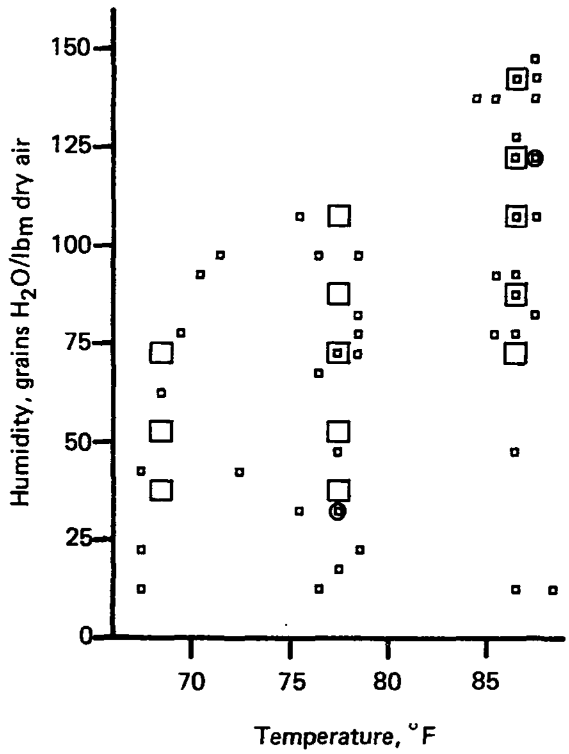

FIGURE 11a. PLANNED AND ACTUAL AMBIENT CONDITIONS, DATSUN 220C

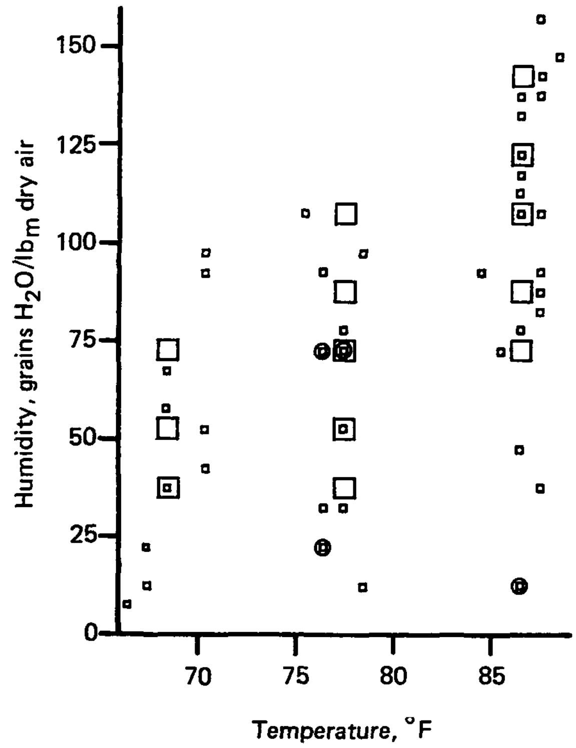

FIGURE 11b. PLANNED AND ACTUAL AMBIENT CONDITIONS, PERKINS 6.247

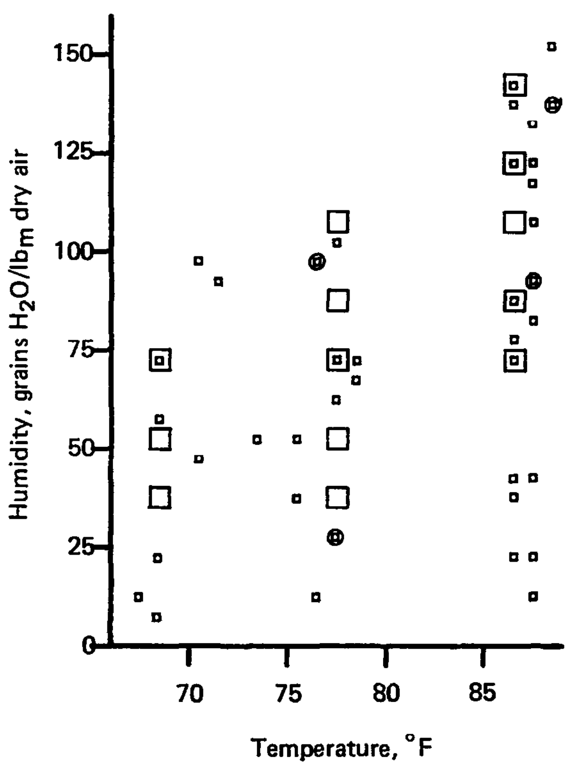

FIGURE 11c. PLANNED AND ACTUAL AMBIENT CONDITIONS, MERCEDES 240D

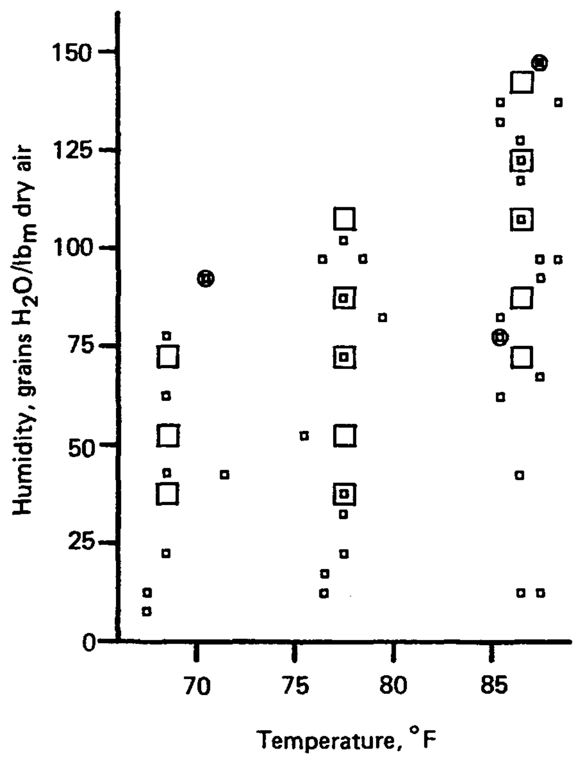

FIGURE 11d. PLANNED AND ACTUAL AMBIENT CONDITIONS, PEUGEOT 504D

TABLE 5. RESULTS OF NO_x CALIBRATION GAS CROSS-CHECK

Cylinder number	Concentration in ppm by analyzing laboratory			
	EPA-Research Triangle Park	SwRI - first check	SwRI -[a] second check	EPA-Ann Arbor
MM-2784	24.0	23.6	----	24.07
MM-2892	89.0	87.5	----	88.87
MM-2930	279.5	271.	273.	265.7
MM-2890	534.	516.	511.	505.2

[a] checked against NBS calibration gases

Data on ambient conditions were recorded continuously near the inlet of the vehicle cooling fan, which is the recommended location for such measurements. These data (dry-bulb temperature and relative humidity) were also integrated electronically, and they were read manually at intervals of approximately 2 minutes. Ambient temperature and dewpoint temperature were measured manually at somewhat longer intervals (about 5 minutes), and both wet- and dry-bulb temperatures were recorded on a similar schedule. Relative humidity data from the electronic hygrometer proved to be most reliable of the three humidity-measuring measurements. This instrument was also calibrated periodically according to ASTM recommended practice E104-51. The dewpoint instrument was used for all tests during which it operated properly, but it had to be repaired several times during the program. It was also discovered that data taken using the psychrometer were inaccurate unless an inordinate amount of time was devoted to its care and maintenance; so it was eliminated early in the program, and no psychrometer data appear in this report. The care necessary to obtain accurate psychrometer data has been discussed in the literature in some detail.(4)

It has already been noted that variation in humidity during each particular run was requested to be ± 2 percent relative humidity or less, as referred to the mean. This tolerance is, therefore, a function of several variables. It ranges from ± 2.1 grains H_2O/lb_m dry air (± 0.29 g H_2O/kg dry air) at 68°F (20°C) and 28.80 in Hg to ± 4.0 grains H_2O/lb_m dry air (± 0.57 g H_2O/kg dry air) at 86°F (30°C) and 29.78 in Hg. These acceptance bands are quite reasonable in most cases, especially for the situation in which humidity is being controlled. To determine the acceptance band for a given test, the mean relative humidity was first computed from mean specific humidity, temperature, and atmospheric pressure. Relative humidity was then permitted to vary ± 2 percent, and specific humidity was calculated for the extremes. Some runs were included in the data base which did not quite meet the ± 2 percent R.H. criterion. The additional criteria which these latter runs did meet included:

- relative humidity range within approximately ± 5 percent of mean,
- absence of variations which would invalidate time-averaged mean,
- absence of anomalous emissions data.

SECTION 5

RESULTS, ANALYSIS, AND CORRECTION FACTOR COMPUTATIONS

The first part of this section is devoted to presentation of the results in summary form and to statistical analysis of the emission and ambient data. The second and last subsection covers computation of correction factors for NO_x at non-standard humidity conditions.

RESULTS AND STATISTICAL ANALYSIS

The results of this Task were those which might have been expected after a review of previous work on studies of the relationship between emissions and ambient conditions.[5,6] Some of the trends that were observed are summarized below:

- increases in humidity were associated with substantial decreases in NO_x for all four vehicles
- changes in temperature were associated with relatively minor changes in NO_x for all four vehicles
- changes in humidity and temperature were associated with relatively minor changes in production of hydrocarbons and CO from three of the four test vehicles.

The main objective of this task, in addition to confirming existence of the above trends, was to compute the correction factors needed to correct measured emission values to those that would be expected at standard ambient conditions. All the emission correction factors which have been adopted for use in Federal emission regulations in the past are different from one another[1,3,7], so it could not be assumed, without testing, that the light-duty diesel could legitimately use one of these other factors.

Emission and ambient data, contained in Appendix A, were gathered on 174 valid FTP runs. In order to determine if any linear relationships existed between the supposed "independent" variables (humidity by three methods, temperature, and atmospheric pressure), correlation coefficients were calculated for each pair of variables. It was expected that high correlations would exist among the humidity values determined by the three methods, that temperature would be only weakly dependent on atmospheric pressure and humidity, and that humidity (regardless of method) would be essentially independent of atmospheric pressure. The correlation coefficients (r) actually calculated are presented in Table 6 and indicate the strengths of the relationships between the variables.

TABLE 6. CORRELATION COEFFICIENTS (r) BETWEEN VARIABLES OF RECORD

Independent variables	Hygrometer humidity, gr/lb_m	Dewpoint humidity, gr/lb_m	Weather service humidity, gr/lb_m	Temp. °F
dewpoint humidity, grains H_2O/lb_m dry air	0.965	——	——	——
weather service humidity, grains H_2O/lb_m dry air	0.925	0.893	——	——
temperature, °F	0.492	0.552	0.251	——
atmospheric pressure, in Hg	-0.746	-0.778	-0.710	-0.348

Although all correlations were statistically significant ($p < 0.05$ using "t" statistics), those between "independent" variables were in accord with expectations except the relationships between humidity and atmospheric pressure. All three humidity values correlated more strongly with atmospheric pressure than expected. This result was created by a local situation, namely that decreases in atmospheric pressure are frequently followed by southerly winds carrying humid air from the Gulf of Mexico. Different correlations probably exist in other areas due to differences in topography, latitude, and proximity to large bodies of water.

Since all the humidity values were highly correlated ($r \geq 0.89$) and since humidity as measured with the electronic hygrometer was the most reliable result from the methods employed, the hygrometer values alone were used in the statistical analysis. Temperature was the second variable chosen due to its weak relationship with humidity and atmospheric pressure. Finally, atmospheric pressure was not considered as an important ambient variable due to its high correlation ($r \leq -0.71$) with humidity and the expected overlap of information that would result if both these variables were included. Thus, only temperature and hygrometer humidity were chosen to be used as the independent variables in the analyses described below.

Generalized linear equations were determined utilizing emissions (HC, CO, or NO_x) as the dependent variable and humidity (H) and temperature (T) as the independent variables. Linear as well as polynomial regressions were calculated for each vehicle and each pollutant. The equations were of the following forms:

(1) $\hat{E} = b_o + b_1 X$

and (2) $\hat{E} = b_o + b_1 X + b_{11} X^2$

where $\hat{E}$ = emission value predicted by the regression equation

b_o = constant term

b_1 = regression coefficient for linear effect of variable X

b_{11} = regression coefficient for quadratic effect of variable X

X = independent variable (humidity or temperature).

The coefficients obtained using equations (1) and (2) with humidity and temperature as the independent variables are contained in Appendix B. Appendix C contains computer printouts of stepwise multiple regressions conducted on individual vehicles, including analysis of variance and summary tables.

Table 7 consists of correlation comparisons between the linear and quadratic fits of humidity to emissions. Using the coefficients of determination (r^2) as a criterion, the best fits are between NO_x and humidity (average r^2 = 0.653 for quadratic fit), although all emissions are strongly associated with humidity for the International-Perkins.

TABLE 7. CORRELATION COMPARISON FOR HUMIDITY

Dependent Variable	Independent Variable(s)	Coefficients of determination (r^2) by vehicle				
		Datsun	Int'l. Perkins	Mercedes	Peugeot	Average
HC	H	0.020	0.576	0.000	0.078	0.168
	H, H^2	0.085	0.584	0.012	0.127	0.202
	Improvement	0.065	0.008	0.012	0.049	0.034
CO	H	0.050	0.697	0.002	0.000	0.187
	H, H^2	0.051	0.724	0.054	0.002	0.208
	Improvement	0.001	0.027[a]	0.052	0.002	0.021
NO_x	H	0.572	0.486	0.609	0.612	0.570
	H, H^2	0.772	0.568	0.658	0.615	0.653
	Improvement	0.200[a]	0.082[a]	0.049[a]	0.003	0.083

[a] indicates improvement was significant at the 0.05 level

Temperature was not as strongly correlated with emissions as humidity, and this weaker correlation is indicated by the coefficients of determination in Table 8. Temperature had higher correlations with CO and HC than with NO_x, particularly for the International-Perkins. Utilizing a quadratic fit, the average r^2 was 0.224 for CO, 0.176 for HC and 0.075 for NO_x. The addition of the T^2 term to the linear fit of T resulted in an average increase in r^2 of 0.074 for HC, but only 0.018 for CO and 0.015 for NO_x. Significant increases ($p < 0.05$) in r^2 occurred only when adding the T^2 term to the linear fit of T to HC for the Datsun and Mercedes.

Additional regression equations were generated to determine whether or not humidity and temperature (together) predicted emissions better than these same independent variables fit separately, as in Tables 7 and 8. Linear as well as stepwise polynomial regressions were calculated for each vehicle and each pollutant. The forms of generalized equations utilized are given as follows:

(3) $\hat{E} = b_o + b_1H + b_2T$

(4) $\hat{E} = b_o + b_1H + b_2T + b_{12}HT$

and (5) $\hat{E} = b_o + b_1H + b_2T + b_{11}H^2 + b_{22}T^2$

where $\hat{E}$, b_o, b_1, and b_{11} are as defined in equations (1) and (2) and

b_2 = regression coefficient for linear effect of T

b_{12} = regression coefficient for the interaction effect of H and T

b_{22} = regression coefficient for quadratic effect of T

H = humidity (independent) variable

and T = temperature (independent) variable.

The coefficients obtained in using equations (3), (4), and (5) with H and T are contained in Appendix B. Note that equations (4) and (5) were formed from a stepwise regression procedure in which H and T were forced into the equation. Consequently, at times only one of the quadratic terms (H^2 or T^2) entered the equation (with H and T) due to a low tolerance level on the other quadratic term.

TABLE 8. CORRELATION COMPARISON FOR TEMPERATURE

Dependent Variable	Independent Variable(s)	Coefficients of determination (r^2) by vehicle				
		Datsun	Int'l. Perkins	Mercedes	Peugeot	Average
HC	T	0.046	0.235	0.012	0.113	0.102
	T, T^2	0.131	0.295	0.115	0.165	0.176
	Improvement	0.085[a]	0.060	0.103	0.052	0.074
CO	T	0.003	0.424	0.128	0.267	0.206
	T, T^2	0.024	0.471	0.131	0.268	0.224
	Improvement	0.021	0.047	0.003	0.001	0.018
NO_x	T	0.055	0.037	0.077	0.069	0.060
	T, T^2	0.070	0.051	0.099	0.079	0.075
	Improvement	0.015	0.014	0.022	0.010	0.015

[a] indicates improvement was significant at the 0.05 level

Table 9 contains the correlation comparisons for equation (3) with equations (1) and (2), and for equations (4) and (5) with equation (3). Coefficients of determination (r^2) are again used as the criterion for determining the best fits. The average r^2 values for a fit linear in H and T were 0.194 for HC, 0.342 for CO, and 0.594 for NO_x. For a fit including the cross product term (HT), the average r^2 values were 0.254 for HC, 0.365 for CO, and 0.671 for NO_x. For the quadratic fit, they were 0.272 for HC, 0.378 for CO, and 0.673 for NO_x. Except for CO, the linear fit in H and T showed no significant improvement over the linear fit in H. This same fit was significantly ($p < 0.05$) better than the linear fit in T for NO_x on all four vehicles; for CO on the Peugeot; and for CO and HC on the International-Perkins. The results thus indicate the strong relationship that exists between NO_x and humidity for all vehicles and between all emissions and ambient data for the International-Perkins.

TABLE 9. CORRELATION COMPARISON FOR HUMIDITY AND TEMPERATURE

Dependent Variable	Independent Variable	Coefficient of determination (r^2) by vehicle				
		Datsun	Int'l Perkins	Mercedes	Peugeot	Average r^2
HC	H,T	0.047	0.588	0.013	0.128	0.194
	Improv. over H	0.027	0.012	0.013	0.050	0.026
	Improv. over T	0.001	0.353[a]	0.001	0.015	0.093
CO	H,T	0.090	0.764	0.144	0.372	0.342
	Improv. over H	0.040	0.067[a]	0.142[a]	0.372[a]	0.155
	Improv. over T	0.066	0.340[a]	0.016	0.105[a]	0.132
NO_x	H,T	0.601	0.523	0.614	0.638	0.594
	Improv. over H	0.029	0.037	0.005	0.026	0.024
	Improv. over T	0.546[a]	0.486[a]	0.537[a]	0.569[a]	0.535
HC	H,T, HT	0.063	0.591	0.031	0.330	0.254
	Improv. over H,T	0.016	0.003	0.018	0.201	0.060
CO	H,T, HT	0.095	0.781	0.207	0.378	0.365
	Improv. over H,T	0.005	0.017	0.063	0.006	0.023
NO_x	H,T HT	0.717	0.601	0.713	0.654	0.671
	Improv. over H,T	0.116	0.078	0.099	0.016	0.077
HC	H,T,H^2,T^2[b]	0.153	0.621	0.119	0.194	0.272
	Improv. over H,T	0.106[a]	0.033	0.106[a]	0.066	0.078
CO	H,T,H^2,T^2[b]	0.102	0.793	0.242	0.376	0.378
	Improv. over H,T	0.012	0.029[a]	0.098[a]	0.004	0.036
NO_x	H,T,H^2,T^2[b]	0.787	0.604	0.659	0.643	0.673
	Improv. over H,T	0.186[a]	0.081[a]	0.045[a]	0.005	0.079

[a] indicates significant improvement at 0.05 level

[b] H and T forced into equation, others entered by significance

Including the interaction term (HT) with the linear fit in H and T yielded an average increase in r^2 of 0.060 for HC, 0.023 for CO, and 0.077 for NO_x. These increases were significant ($p < 0.05$) for HC from the Peugeot and for NO_x from the other three vehicles.

The use of a quadratic equation in H and T instead of a linear fit yielded an average increase in r^2 of 0.078 for HC, 0.036 for CO, and 0.079 for NO_x. These increases were significant ($p < 0.05$) for all emissions from the Mercedes, for CO and NO_x from the International-Perkins, and for HC and NO_x from the Datsun. For the NO_x emissions, the H^2 term was the main variable influencing the significant increases.

With the exception of results for the International-Perkins, low correlations existed between CO or HC and each of the independent variables in Tables 7, 8, and 9. Both CO and HC emissions from the International-Perkins were much more sensitive to humidity and temperature than expected, and no reason is known for this anomaly. In terms of engine design, the Perkins is not considered to be so grossly different than the others as to cause such results. One statistic which does set the International-Perkins apart from the other vehicles, however, is its weight-to-power ratio (all vehicles assumed loaded as light-duty vehicles). This value, in kg/kW, is 21.8 for the International-Perkins, 29.7 for the Datsun, 32.3 for the Mercedes, and 28.9 for the Peugeot. It is not known if the weight/power statistic is related to the anomaly noted above, but it does indicate that the Perkins engine was probably operating at a lower fraction of available power than the other engines (i.e., at lower F/A). In summary, due to the overall relatively low correlations associated with HC or CO and the ambient data, and because of the unusual results of these emissions in the International-Perkins vehicle, HC and CO corrections will not be discussed further in the text. The overall results from Tables 7, 8, and 9 confirm the existence of strong and consistent associations between NO_x and humidity for all four vehicles, and it is this relationship that will be explored. Equations with H^2 and T^2 terms have also been compared to those with an HT interaction term, indicating that the quadratic form is a better predictor.

To examine the NO_x-humidity relationships in more detail, scatter plots have been constructed for each vehicle and are presented as Figures 12 through 15. The linear and quadratic equations in H have been plotted for each vehicle, and the coefficients of these equations are contained in Table 10. On the average, addition of the H^2 term increased r^2 from 0.570 to 0.653, which is a substantial improvement. Most of this improvement was made in fitting the curve for the Datsun 220C, which seemed to have a strong tendency toward "leveling off" of NO_x emissions as humidity increased above about 120 grains H_2O/lb_m dry air. Emissions of NO_x from the Datsun, International-Perkins, and Mercedes all tended to become less sensitive to humidity above some humidity level. Taking all four vehicles together, however, can still result in computation of a relationship which is useful for most ambient humidity values.

COMPUTATION OF CORRECTION FACTORS

The regression equations generated in the previous subsection (RESULTS AND STATISTICAL ANALYSIS) were restricted to data on the individual vehicles,

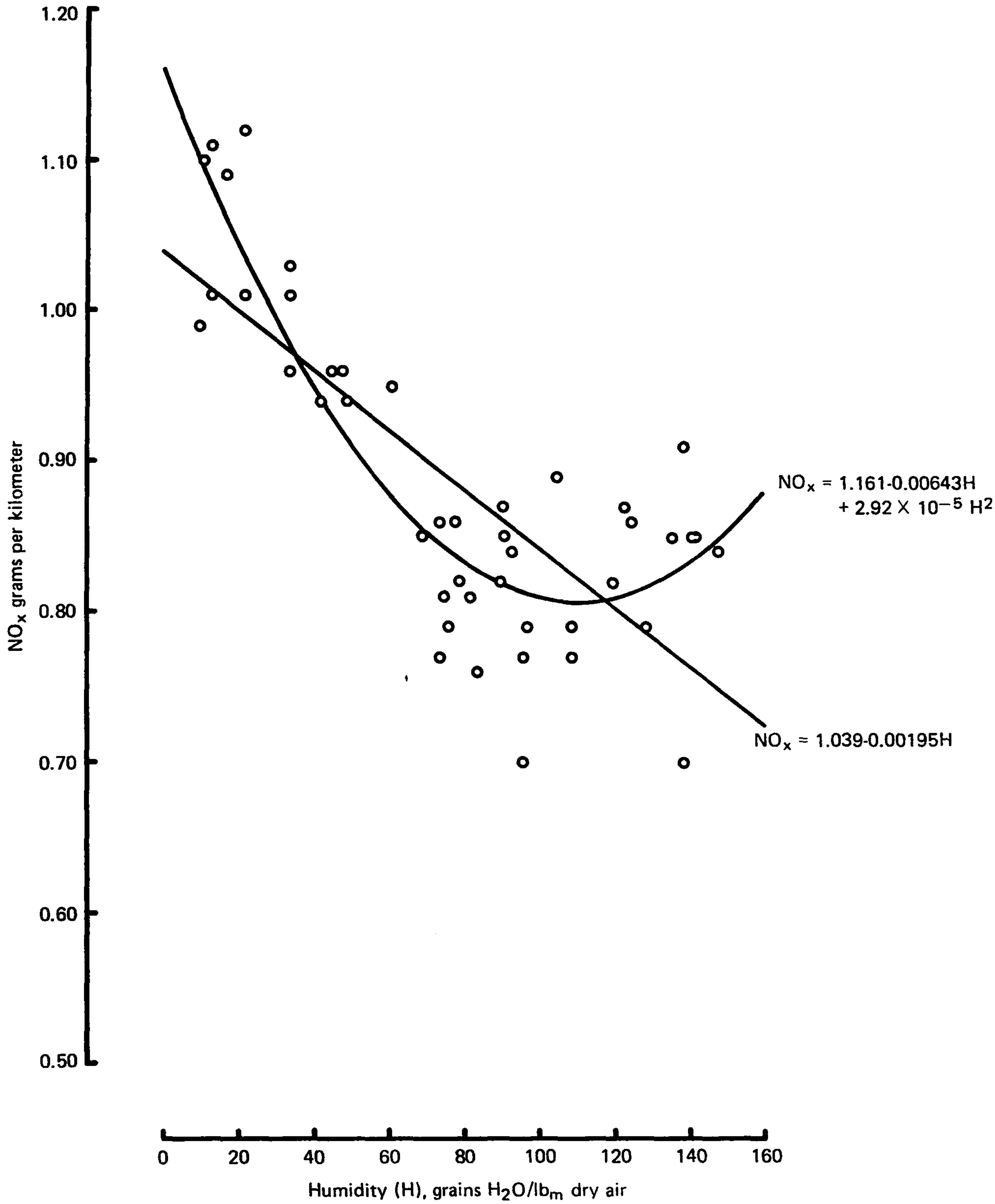

FIGURE 12. NO_x EMISSIONS AS A FUNCTION OF HUMIDITY FOR A DATSUN 220C DIESEL SEDAN

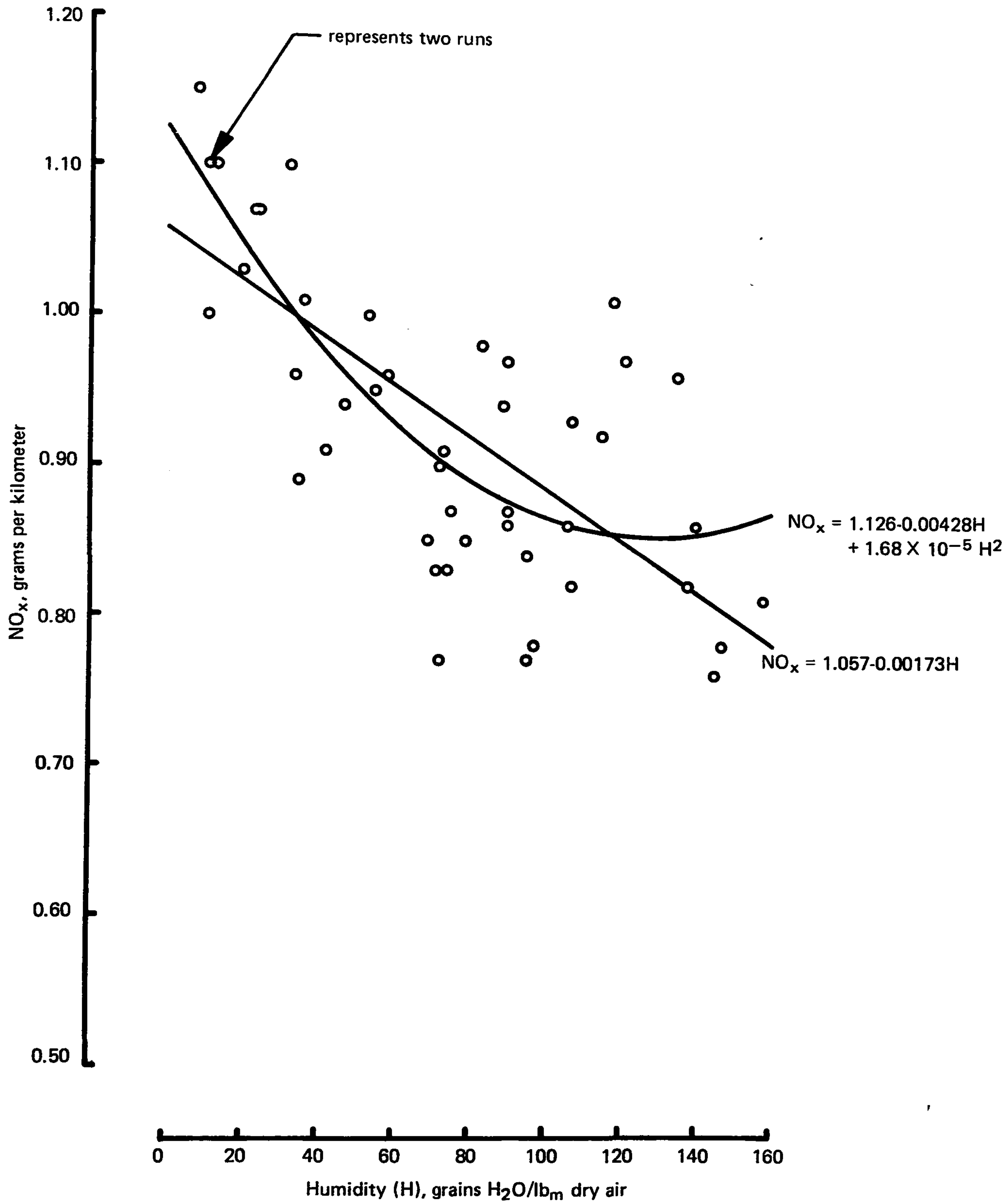

FIGURE 13. NO_x EMISSIONS AS A FUNCTION OF HUMIDITY FOR AN INTERNATIONAL PICKUP TRUCK WITH PERKINS 6.247 DIESEL ENGINE

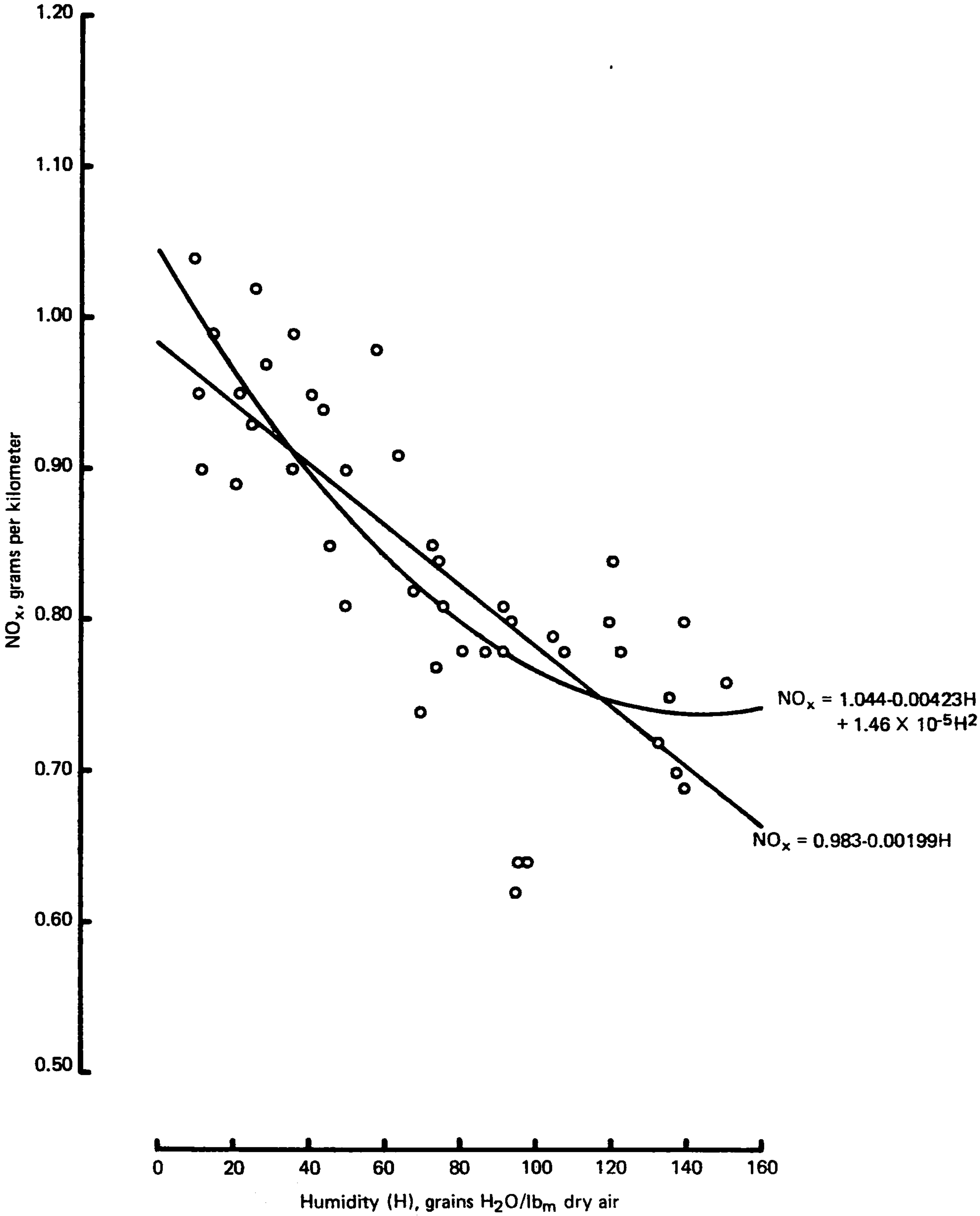

FIGURE 14. NO_x EMISSIONS AS A FUNCTION OF HUMIDITY FOR A MERCEDES 240D DIESEL SEDAN

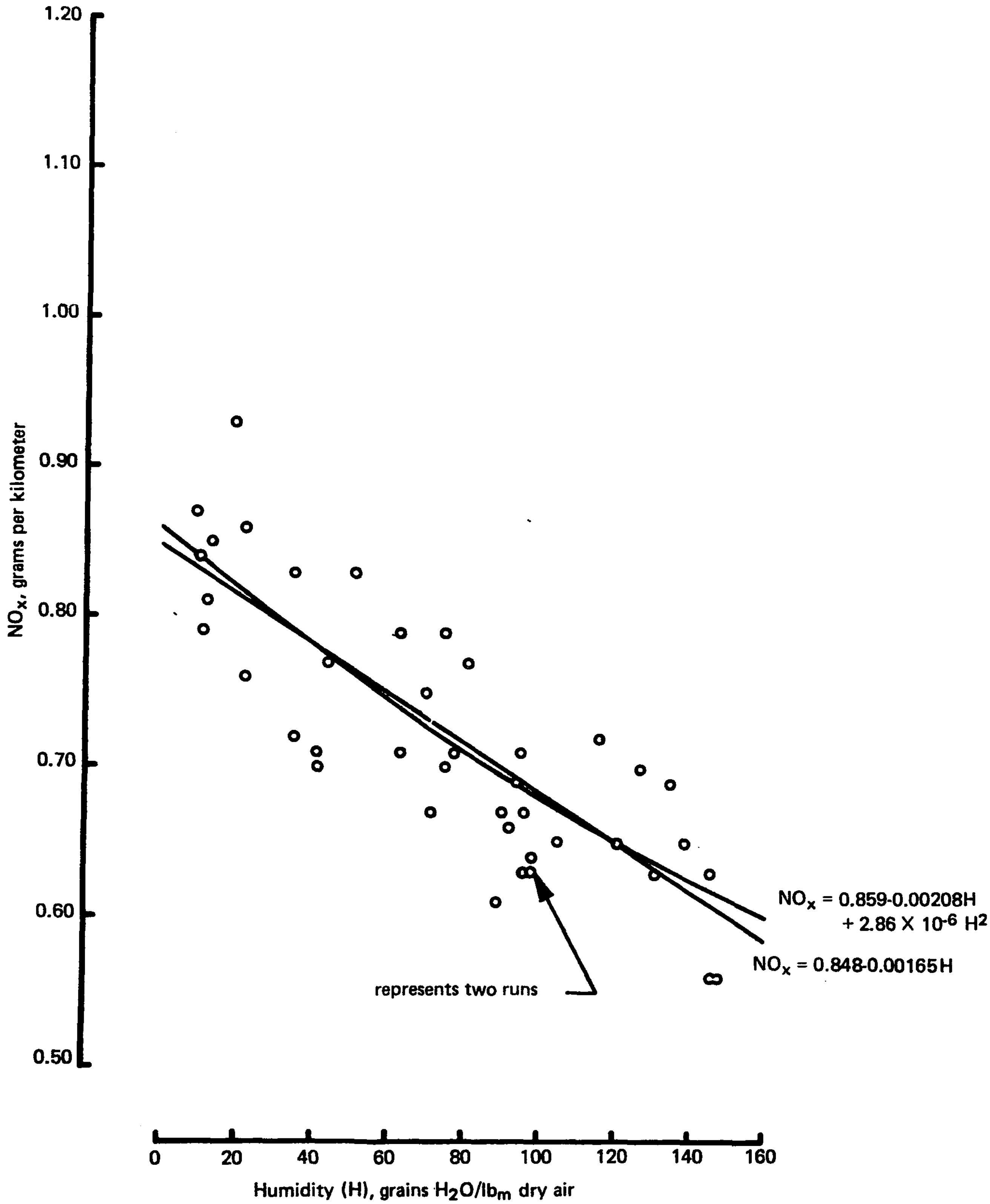

FIGURE 15. NO_x EMISSIONS AS A FUNCTION OF HUMIDITY FOR A PEUGEOT 504D DIESEL SEDAN

but the desired end result of this project is to obtain a single humidity correction factor for NO_x applicable to the whole class of light-duty, diesel-powered vehicles.

TABLE 10. COEFFICIENTS OF NO_x VERSUS HUMIDITY EQUATIONS

Equation type[a]	Vehicle	(b_o) Constant	(b_1) H coefficient	(b_{11}) H^2 coefficient	r^2
Linear	Datsun	1.039	-0.00195	-----------	0.572
	IH-Perkins	1.057	-0.00173	-----------	0.486
	Mercedes	0.983	-0.00199	-----------	0.609
	Peugeot	0.848	-0.00165	-----------	0.612
Quadratic	Datsun	1.161	-0.00643	2.92×10^{-5}	0.772
	IH-Perkins	1.126	-0.00428	1.68×10^{-5}	0.568
	Mercedes	1.044	-0.00423	1.46×10^{-5}	0.658
	Peugeot	0.859	-0.00208	2.86×10^{-6}	0.615

[a] linear form $NO_x = b_o + b_1 H$, quadratic form $NO_x = b_o + b_1 H + b_{11} H^2$

This factor would have the form

$$K_h = \frac{\text{predicted } NO_x \text{ value at } H = 75}{\text{predicted } NO_x \text{ value at } H}$$

where

linear case: $\text{predicted } NO_x = b_o + b_1 H = (b_o + 75b_1) + b_1 (H-75)$

and

quadratic case: $\text{predicted } NO_x = b_o + b_1 H + b_{11} H^2$

$$= (b_o + 75b_1 + 75^2 b_{11}) + (b_1 + 150b_{11})(H-75) + b_{11} (H-75)^2.$$

Therefore, for the linear case,

$$K_h = \frac{1}{1 + L\,(H-75)}$$

where $L = \dfrac{b_1}{b_o + 75b_1}$;

and for the quadratic case,

$$K_h = \frac{1}{1 + L(H-75) + Q(H-75)^2}$$

where $$L = \frac{b_1 + 2b_{11}\ (75)}{b_o + b_1\ (75) + b_{11}\ (75)^2}$$

and $$Q = \frac{b_2}{b_o + b_1\ (75) + b_{11}\ (75)^2}.$$

Several methods were considered for combining data from the four vehicles to obtain the correction factors, including:

1. Obtaining a humidity correction factor for each vehicle separately and then averaging the results, i.e., the regression equations for the four vehicles would have different intercepts and difference slopes.

2. Establishing statistically a commonality of "H" coefficients in the linear NO_x-humidity equations, i.e., determining a common-slope, different-intercept model for the combined four vehicles.

3. Treating all data as if it were for a single vehicle, i.e., ignoring any vehicle-to-vehicle differences in magnitude of NO_x emissions and generating a common slope and common intercept model.

The first method, unequal slopes and intercepts, yielded four regression equations relating NO_x to H with an average r^2 of 0.570, and four equations relating NO_x to H and H^2 with an average r^2 of 0.653. The resulting coefficients were presented in Table 10. Notice from Table 7 that for three of the four vehicles the quadratic fit in H is significantly better than the linear fit. Humidity correction factors for NO_x were calculated for each vehicle for both the linear and quadratic equations. The results are given in Table 11 along with the average values of L and Q that would be utilized in establishing an overall humidity correction factor.

TABLE 11. SEPARATE VEHICLE CORRECTION FACTORS[a]

Equation Type and coefficient(s)	Datsun	IH-Perkins	Mercedes	Peugeot	Average
Linear					
L	-0.00218	-0.00187	-0.00239	-0.00228	-0.00218
Quadratic					
L	-0.00244	-0.00197	-0.00251	-0.00230	-0.00230
Q	3.46×10^{-5}	1.87×10^{-5}	1.81×10^{-5}	0.40×10^{-5}	1.88×10^{-5}

[a] $K_h = \frac{1}{1 + L\ (75)}$ in linear case

$K_h = \frac{1}{1 + L\ (H-75) + Q\ (H-75)^2}$ in quadratic case

The second method, common slope and unequal intercepts, produces some useful results. It is better than the first method in that it requires only one regression equation, but it also necessitates the separate computation of four correction factors. The common slope, unequal intercept method shows that the slopes of the NO_x-humidity equations for the four vehicles are close enough together to be considered equivalent statistically. The hypothesis that the four slopes are unequal was tested by comparing the mean squared errors of the regression equations calculated with and without a parallel line assumption. The resultant F statistic was not significant at the 0.05 level, so the common slope model was not rejected. The combined regression equation, which had an r^2 of 0.722, is given after Table 12.

TABLE 12. COMMON SLOPE EQUATION COEFFICIENTS AND VALUES OF L

Vehicle	Intercept	Slope	L
Datsun	1.029	0.00183	-0.00205
Int'l.—Perkins	1.064	0.00183	-0.00197
Mercedes	0.972	0.00183	-0.00219
Peugeot	0.862	0.00183	-0.00252
		Average	-0.00218

Equation: $NO_x = b_o + b_i X_i + b_1 H$, $i = 2, 3, 4$

$$\text{where } X_i = \begin{cases} 0 \text{ if "i th" vehicle data not used} \\ 1 \text{ if "i th" vehicle date used} \end{cases}$$

Note: The intercept of the Datsun was b_o; for the IH-Perkins, $b_o + b_2$; for the Mercedes, $b_o + b_3$; and for the Peugeot, $b_o + b_4$.

Since each equation has a different intercept, the values of L in the linear K_h factors are different for each vehicle. The average value, -0.00218, is the same as the average value obtained from Method 1. Due to the difficulty in employing this method on quadratics, quadratic factors were not obtained.

The third method, common slopes and common intercepts, consisted of a simple combination of all 174 data points into a single regression equation relating NO_x to humidity. This approach was rejected due to the scatter and poor correlations resulting from combination of all the raw data. Two variations on this technique were then tried in an attempt to eliminate the adverse effects of differing NO_x magnitudes among the test vehicles.

The first variation consisted of standardizing the observed NO_x values from each vehicle by subtracting the vehicle mean NO_x and dividing by the vehicle NO_x standard deviation as follows:

$$\text{standardized } NO_x = \frac{\text{observed } NO_x - \text{mean } NO_x}{\text{standard deviation } NO_x}$$

The standardized values for all four vehicles were then combined and fit to humidity in a single regression equation. The results for the linear and quadratic fits are given below:

$$\text{standardized } NO_x = 1.362 - 0.01794\ H,\ r^2 = 0.566$$

$$\text{standardized } NO_x = 1.976 - 0.04080\ H + 0.000150\ H^2,\ r^2 = 0.631.$$

There was a significant increase ($p < 0.0001$) in the goodness of fit utilizing the quadratic equation in H as compared to the linear model.

To obtain the humidity correction factors for NO_x (unstandardized), the values of L and Q were calculated, adjusting for the different means and standard deviations of each vehicle's data. These values are given in Table 13 along with their averages. The average results are again in good agreement with Methods 1 and 2.

TABLE 13. STANDARDIZED NO_x CORRECTION FACTORS

Equation Type	Datsun	IH-Perkins	Mercedes	Peugeot	Average
Linear					
L	-0.00218	-0.00200	-0.00226	-0.00223	-0.00217
Quadratic					
L	-0.00229	-0.00210	-0.00239	-0.00235	-0.00228
Q	1.88×10^{-5}	1.72×10^{-5}	1.95×10^{-5}	1.92×10^{-5}	1.87×10^{-5}

The second variation on Method 3 consisted of computing the ratios of the observed NO_x emissions data to the predicted NO_x values at an arbitrary humidity point for each vehicle. These "normalized" data were then combined to derive a common regression equation. The equations given in Table 10, both linear and quadratic, were used to compute a predicted value for NO_x at $H = 75$ for each vehicle. Normalized NO_x values were then obtained (separately for quadratic and linear models) using the following definition:

$$\text{normalized } NO_x = \frac{\text{measured } NO_x}{\text{predicted } NO_x \text{ at } H = 75}$$

Combined equations relating normalized NO_x to humidity were then generated, and the resulting coefficients are given in Table 14. The quadratic fit yielded a significant ($p < 0.001$) improvement in correlation over the linear equation, supporting similar findings from the other methods utilized in this project. The definition of normalized NO_x forces the normalized NO_x values calculated by both the linear and quadratic equations to be 1.0 at the value $H = 75$. This second variation, using normalized NO_x values, is the only method evaluated which yields a single factor for correction of NO_x without averaging values of L and Q. The computed coefficients for the two cases are

$L = -0.00217$ for the linear case,

and $L = -0.00228$, $Q = 1.85 \times 10^{-5}$ for the quadratic case.

TABLE 14. COEFFICIENTS OF NORMALIZED NO_x VERSUS HUMIDITY EQUATIONS, ALL VEHICLES COMBINED

Equation type[a]	(b_o) constant	(b_1) H coefficient	(b_{11}) H^2 coefficient	r^2
Linear	1.163	-0.00217	-----------	0.569
Quadratic	1.274	-0.00504	1.84×10^{-5}	0.616

[a] linear form, normalized $NO_x = b_o + b_1H$;
quadratic form, normalized $NO_x = b_o + b_1H + b_{11}H^2$

These results are very similar to those obtained using the other methods, as shown in Table 15.

TABLE 15. SUMMARY OF HUMIDITY CORRECTION FACTOR RESULTS[a]

Method	Linear Case		Quadratic Case		
	Average r^2	Average L	Average r^2	Average L	Average Q
Unequal slopes and unequal intercepts	0.570	-0.00218	0.653	-0.00230	1.88×10^{-5}
Equal slopes but unequal intercepts	0.722	-0.00218	-----	--------	----------
Equal slopes and equal intercepts					
a) Std. NO_x	0.566	-0.00217	0.631	-0.00228	1.87×10^{-5}
b) Nor. NO_x	0.569	-0.00217	0.616	-0.00228	1.85×10^{-5}

[a] linear case $K_h = \frac{1}{1 + L\,(H-75)}$

quadratic case $K_h = \frac{1}{1 + L\,(H-75) + Q\,(H-75)^2}$

Correction factors representing the averages of the linear and quadratic results given in Table 15 are shown in Figure 16.

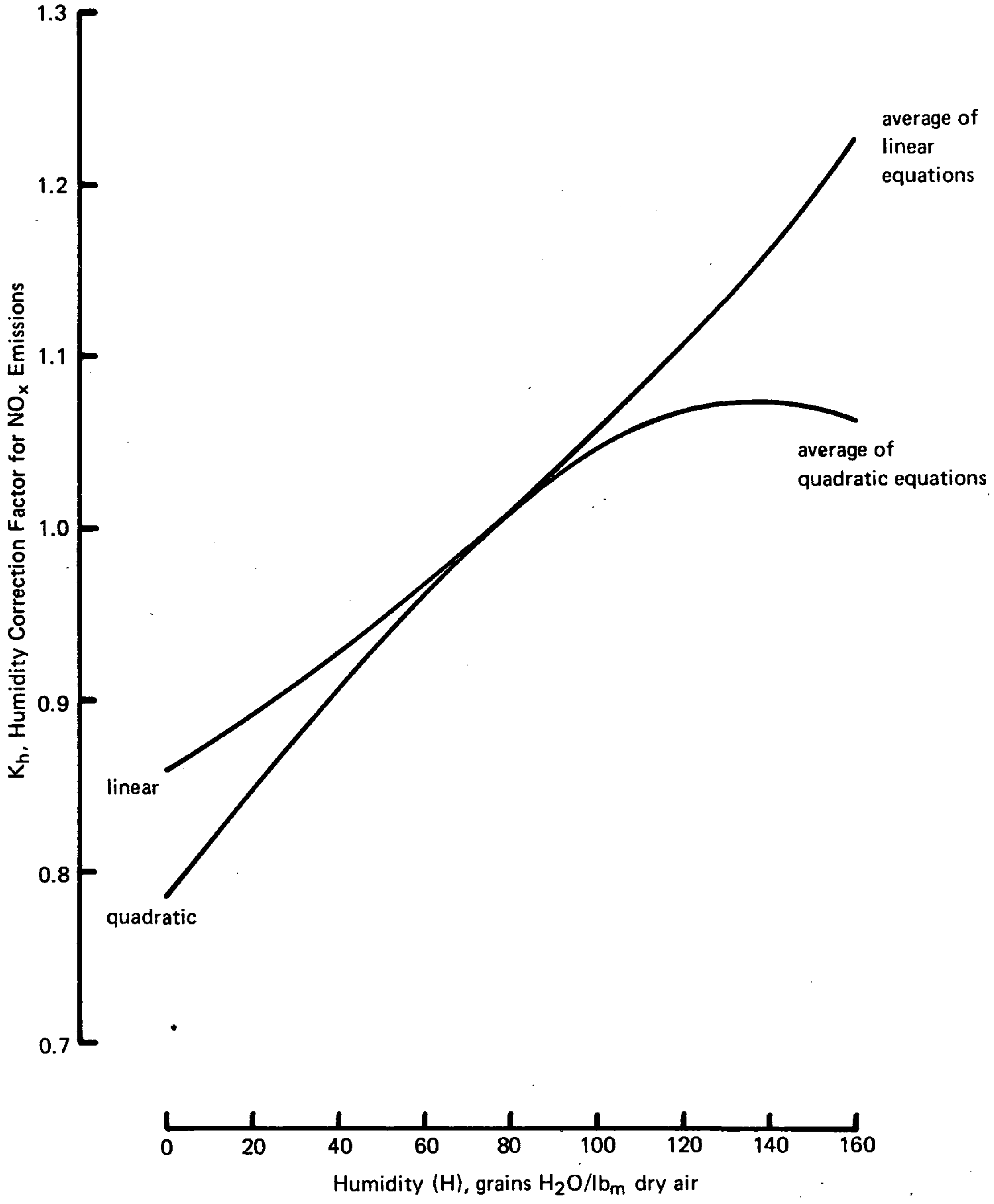

FIGURE 16. HUMIDITY CORRECTION FACTOR K_h FOR NO_x EMISSIONS AS A FUNCTION OF HUMIDITY, AVERAGE OF RESULTS GIVEN IN TABLE 15

SECTION 6

COMPARISON WITH OTHER CORRECTION FACTORS

Studies were conducted in the past on other classes of vehicles and engines with the aim of determining applicable factors for the correction of measured emissions to "standard" ambient conditions. The classes studied were light-duty, gasoline-fueled vehicles[5]; heavy-duty diesel engines[6]; and heavy-duty, gasoline-fueled vehicles. The results of these studies have appeared in corresponding Federal Emission Regulations[1,3,7,8] as correction factors for NO_x emissions, other ambient effects having been considered negligible by EPA.

The existing correction factors for NO_x are:

light-duty gasoline; $K_h = \frac{1}{1 - 0.0047\ (H-75)}$

heavy-duty diesel; $K_h = \frac{1}{1+(0.044\ F/A-0.0038)(H-75)+(-0.116\ F/A+0.0053)(T-85)}$

heavy-duty gasoline; $K_h = 0.634 + 0.00654H - 0.0000222H^2$.

In addition, a simpler correction factor was used for heavy-duty diesels through about mid-1974; and it was

$$K_h = \frac{1}{1 - 0.0025\ (H-75)} .$$

These factors can be compared to those generated by this project (results of equal slope/intercept-normalized NO_x method shown for example), which are:

based on linear equation; $K_h = \frac{1}{1 - 0.00217\ (H-75)}$

based on quadratic equation; $K_h = \frac{1}{1 - 0.00228\ (H-75) + (1.85 \times 10^{-5})\ (H-75)^2}$.

The most striking comparison which can be made, of course, is that the light-duty diesel factor based on a linear NO_x-humidity relationship is very similar to the original (and since replaced) factor for heavy-duty diesels. This light-duty diesel factor shows less sensitivity to humidity than the light-duty gasoline factor. These relationships are given in tabular form in Table 11 and in graphical form in Figure 17. The range shown in Figure 17 for the current heavy-duty diesel factor incorporates all the expected variation

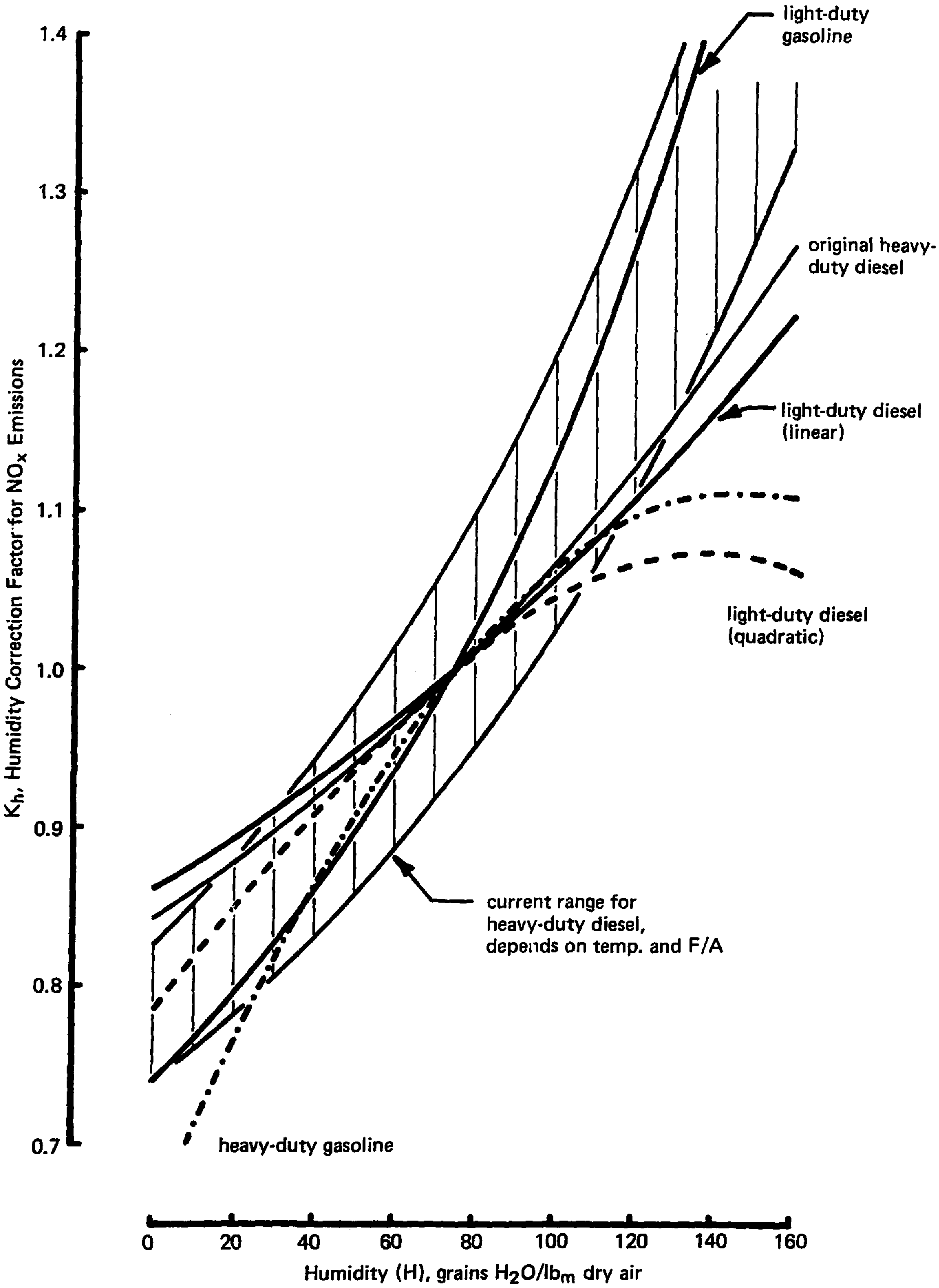

FIGURE 17. HUMIDITY CORRECTION FACTOR COMPARISON

in both test temperature (70°F to 100°F) and F/A ratio (0.005 to 0.07). This factor, by using F/A as a variable, is restricted to modal steady-state engine operation.

The heavy-duty gasoline factor and the quadratic-based light-duty diesel factor are qualitatively similar, with the gasoline factor being a stronger function of humidity. Application of either the linear-based or the quadratic-based factor computed from data acquired in this task would be a relatively simple matter, and it remains for the sponsor to decide whether or not the significantly better fit of the quadratic form is sufficient reason to deviate from the customary linear-based form for the light-duty diesel. Reasons for the differences between correction factors discussed here include not only type and size of engine, but also the differing duty cycles required to perform the various test procedures (e.g., difference between heavy- and light-duty gasoline correction factors).

TABLE 16. HUMIDITY CORRECTION FACTORS FOR NO_x IN TABULAR FORM

umidity (H), grains H_2O/ lb_m/dry air	Light-duty diesel		Heavy-duty diesel (3,8)		Light-duty gasoline (1)	Heavy-duty gasoline (7)
	Linear	Quadratic	Current, range	Original		
0	0.860	0.785	0.738 to 0.825	0.842	0.739	0.634
20	0.893	0.847	0.782 to 0.880	0.879	0.795	0.756
40	0.929	0.907	0.831 to 0.942	0.920	0.859	0.860
60	0.968	0.963	0.887 to 1.014	0.964	0.934	0.946
80	1.011	1.011	0.951 to 1.099	1.013	1.024	1.015
100	1.057	1.048	1.024 to 1.198	1.067	1.133	1.066
120	1.108	1.070	1.110 to 1.317	1.127	1.268	1.099
140	1.164	1.076	1.212 to 1.463	1.194	1.440	1.114
160	1.226	1.065	1.334 to 1.645	1.270	1.665	1.112

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1. Federal Register, Volume 38, No. 151, August 7, 1973.

2. "Diesel Fuel Oils, 1976", Technical Information Center, U.S. Energy Research and Development Administration, November 1976.

3. Federal Register, Volume 37, No. 221 (Subpart J), November 15, 1972.

4. A. Wexler and W. G. Brombacher, "Methods of Measuring Humidity and Testing Hygrometers," National Bureau of Standards Circular 512, September 28, 1951.

5. M. J. Manos, J. W. Bozek, and T. A. Huls, "Effect of Laboratory Ambient Conditions on Exhaust Emissions." Paper 720124 presented at SAE Meeting, Detroit, January 10-14, 1972.

6. S. R. Krause, D. F. Merrion, and G. L. Green, "Effect of Inlet Air Humidity and Temperature on Diesel Exhaust Emissions." Paper 730213 presented at SAE Meeting, Detroit, January 8-12, 1973.

7. Federal Register, Volume 37, No. 221 (Subpart H), November 15, 1972.

8. Federal Register, Volume 38, No. 124, June 28, 1973.

APPENDIX A

TABULAR DATA

TABLE A-1. TABULAR DATA BY RUN

Run No.	Date	Vehicle	Emissions, grams/km				Fuel, km/ℓ	gr H_2O/ lb_m air	Temp., °F	pa, in Hg
			HC	CO	NO_x	CO_2				
1	12/12/75	I.H.-Perkins	0.47	1.95	0.90	244.86	10.8	72.4	76.3	29.18
2	12/12/75	Mercedes	0.18	0.63	0.77	238.15	11.2	74.1	77.6	29.08
3	12/12/75	Datsun	0.17	0.80	0.81	222.85	12.0	74.9	78.4	29.08
4	12/15/75	Mercedes	0.13	0.63	0.90	248.44	10.8	50.4	73.1	29.28
5	12/15/75	Datsun	0.16	0.75	0.96	231.17	11.5	44.6	72.5	29.37
6	12/15/75	Peugeot	0.34	1.01	0.70	229.47	11.6	40.9	71.2	29.37
7	12/15/75	I.H.-Perkins	0.62	1.46	0.91	232.97	11.3	41.6	70.3	29.35
8	12/16/75	Mercedes	0.14	0.65	0.99	261.35	10.2	35.8	75.8	29.28
9	12/16/75	Datsun	0.12	0.76	0.96	231.24	11.5	34.3	75.2	29.28
10	12/16/75	Peugeot	0.44	1.03	0.72	234.61	11.3	35.2	77.8	29.27
11	12/16/75	I.H.-Perkins	0.59	2.01	0.96	247.37	10.7	34.3	77.1	29.24
12	12/17/75	Mercedes	0.11	0.61	0.85	235.48	11.4	45.9	70.2	29.28
13	12/17/75	Datsun	0.08	0.77	0.94	228.91	11.7	42.4	67.3	29.29
14	12/17/75	Peugeot	0.42	1.09	0.71	232.56	11.4	41.3	68.0	29.30
15	12/17/75	I.H.-Perkins	0.63	1.75	0.89	219.50	12.0	35.1	68.0	29.27
16	12/18/75	Mercedes	0.15	0.61	0.90	242.40	11.0	11.6	76.9	29.78
17	12/18/75	Datsun	0.14	0.69	0.99	218.01	12.2	10.1	76.4	29.78
18	12/18/75	Peugeot	0.37	0.95	0.84	230.91	11.5	10.4	76.0	29.78
19	12/18/75	I.H.-Perkins	0.58	1.71	1.00	232.55	11.3	10.7	79.0	29.78
20	1/7/76	Mercedes	0.10	0.69	0.99	255.01	10.5	15.0	67.1	29.40
21	1/7/76	Datsun	0.15	0.74	1.11	250.82	10.6	13.2	67.1	29.40
22	1/7/76	Peugeot	0.39	1.01	0.85	255.42	10.4	13.0	67.2	29.39
23	1/7/76	I.H.-Perkins	0.54	1.91	1.10	258.16	10.2	12.9	67.4	29.39
24	1/8/76	I.H.-Perkins	0.54	1.96	1.15	258.77	10.2	8.3	66.8	29.69
25	1/8/76	Peugeot	0.34	1.10	0.87	257.67	10.3	9.1	67.4	29.69
26	1/8/76	Datsun	Data Discarded							
27	1/8/76	Mercedes	0.15	0.67	1.04	237.25	11.3	9.8	68.4	29.60
28	1/9/76	Mercedes	Data Discarded							
29	1/9/76	Datsun	0.19	0.83	1.09	233.43	11.4	17.1	77.8	29.51
30	1/9/76	I.H.-Perkins	0.49	1.87	1.03	245.01	10.8	20.1	76.9	29.48
31	1/9/76	Peugeot	Data Discarded							
32	1/13/76	I.H.-Perkins	0.59	2.12	0.77	246.72	10.7	72.2	77.7	29.09
33	1/13/76	Datsun	0.18	0.84	0.77	239.08	11.2	73.7	77.4	29.14
34	1/13/76	Peugeot	0.51	1.00	0.67	240.72	11.0	70.8	77.2	29.12
35	1/13/76	Mercedes	0.23	0.70	0.91	256.44	10.4	63.9	77.2	29.09
36	1/14/76	Mercedes	0.17	0.69	0.93	256.81	10.4	24.6	68.1	29.60
37	1/14/76	I.H.-Perkins	0.55	1.94	1.07	259.60	10.2	24.0	67.7	29.60
38	1/14/76	Peugeot	0.39	1.03	0.76	235.07	11.3	21.8	68.0	29.60
39	1/14/76	Datsun	0.15	0.86	1.01	242.44	11.0	21.5	67.6	29.50
40	1/16/76	Datsun	0.07	0.81	1.03	241.13	11.1	33.9	77.2	29.36

(continued)

TABLE A-1 (continued)

Run No.	Date	Vehicle	Emissions, grams/km HC	CO	NO_x	CO_2	Fuel, km/ℓ	gr H_2O/ lb_m air	Temp., °F	pa, in Hg
41	1/16/76	Mercedes	0.13	0.69	1.02	261.14	10.2	26.3	77.2	29.38
42	1/16/76	I.H.-Perkins	0.50	2.04	1.07	252.37	10.5	23.2	76.8	29.38
43	1/16/76	Peugeot	0.42	0.99	0.86	237.09	11.2	21.6	77.6	29.38
44	1/19/76	Datsun	0.14	0.83	0.96	250.13	10.7	47.8	86.6	29.35
45	1/19/76	I.H.-Perkins	0.50	2.13	0.94	260.42	10.1	47.4	86.6	29.35
46	1/19/76	Mercedes	0.15	0.66	0.94	266.22	10.0	44.5	86.7	29.35
47	1/19/76	Peugeot	0.39	1.04	0.77	249.75	10.6	44.1	86.2	29.34
48	1/20/76	I.H.-Perkins	0.52	1.99	1.10	273.05	9.7	31.5	76.9	29.63
49	1/20/76	Mercedes	0.12	0.66	0.97	257.48	10.4	29.1	77.7	29.65
50	1/20/76	Datsun	0.12	0.82	1.12	252.65	10.6	21.9	78.1	29.63
51	1/20/76	Peugeot	0.40	1.07	0.93	257.28	10.3	19.2	76.9	29.59
52	1/21/76	Datsun	0.16	0.80	1.01	228.68	11.7	13.1	86.5	29.65
53	1/21/76	Peugeot	0.43	0.95	0.79	233.46	11.4	11.3	86.7	29.60
54	1/21/76	I.H.-Perkins	0.51	1.98	1.10	259.26	10.2	10.6	86.3	29.56
55	1/21/76	Mercedes	Data Discarded							
56	1/22/76	Peugeot	0.48	0.88	0.81	227.68	11.7	11.6	87.7	29.53
57	1/22/76	Datsun	0.07	0.77	1.10	229.04	11.7	11.1	88.1	29.65
58	1/22/76	I.H.-Perkins	0.59	1.93	1.10	266.63	9.9	11.2	86.0	29.48
59	1/22/76	Mercedes	0.12	0.61	0.95	238.41	11.2	10.9	87.6	29.41
60	1/23/76	Mercedes	0.13	0.59	0.95	247.04	10.8	22.3	87.3	29.20
61	2/11/76	Peugeot	0.44	1.06	0.67	251.86	10.5	89.6	77.3	29.44
62	2/11/76	Datsun	0.15	0.83	0.86	259.23	10.3	78.4	78.1	29.43
63	2/11/76	I.H.-Perkins	0.60	2.11	0.91	267.66	9.9	73.3	76.3	29.40
64	2/11/76	Mercedes	0.15	0.69	0.84	256.56	10.4	74.8	78.3	29.38
65	2/13/76	Peugeot	0.48	1.04	0.71	244.35	10.9	62.8	68.9	29.27
66	2/13/76	I.H.-Perkins	0.60	2.13	0.87	264.66	10.0	75.4	77.9	29.28
67	2/13/76	Datsun	0.13	0.79	0.85	235.51	11.3	69.1	76.7	29.28
68	2/13/76	Mercedes	0.14	0.64	0.82	250.85	10.7	68.4	78.2	29.28
69	2/16/76	Datsun	0.12	0.76	0.70	236.62	11.3	96.5	78.7	29.08
70	2/16/76	Mercedes	Data Discarded							
71	2/16/76	I.H.-Perkins	0.63	2.20	0.78	260.02	10.1	96.6	78.7	29.29
72	2/16/76	Peugeot	0.42	1.02	0.63	232.27	11.4	98.1	78.7	29.25
73	2/17/76	Datsun	0.16	0.92	0.79	253.55	10.5	108.7	87.9	28.98
74	2/17/76	I.H.-Perkins	0.75	2.79	0.82	279.71	9.4	107.4	86.8	29.03
75	2/17/76	Peugeot	0.35	1.04	0.79	247.52	10.7	63.1	85.3	28.94
76	2/17/76	Mercedes	0.10	0.67	0.95	265.76	10.1	41.1	87.2	28.88
77	2/26/76	I.H.-Perkins	0.58	2.16	0.95	265.50	9.9	54.9	70.9	29.37
78	2/26/76	Mercedes	0.08	0.68	0.98	246.98	10.8	57.7	69.0	29.35
79	2/26/76	Datsun	Data Discarded							
80	2/26/76	Peugeot	Data Discarded							

(continued)

TABLE A-1 (continued)

Run No.	Date	Vehicle	Emissions, grams/km HC	CO	NO_x	CO_2	Fuel, km/ℓ	gr H_2O/ lb_m air	Temp., °F	pa, in Hg
81	2/27/76	I.H.-Perkins	0.65	1.97	0.96	256.82	10.3	58.2	68.9	29.35
82	2/27/76	Mercedes	Data Discarded							
83	2/27/76	Datsun	0.20	0.87	0.95	236.82	11.3	61.4	68.3	29.35
84	2/27/76	Peugeot	Data Discarded							
85	3/1/76	Mercedes	0.14	0.64	0.78	238.18	11.2	92.0	71.1	29.03
86	3/1/76	Datsun	0.13	0.92	0.85	229.33	11.6	91.3	70.6	29.03
87	3/1/76	I.H.-Perkins	0.71	2.52	0.87	251.94	10.4	90.3	70.1	29.02
88	3/1/76	Peugeot	0.49	1.19	0.66	241.70	11.0	92.0	70.9	29.01
89	3/2/76	Datsun	0.14	0.83	0.79	231.78	11.5	96.8	71.0	29.05
90	3/2/76	Peugeot	0.41	1.09	0.63	238.19	11.1	95.7	70.7	29.07
91	3/2/76	I.H.-Perkins	0.68	2.29	0.84	254.02	10.3	95.0	70.2	29.05
92	3/2/76	Mercedes	0.11	0.61	0.64	212.53	12.6	97.6	70.6	29.04
93	3/3/76	Peugeot	0.47	1.03	0.64	231.95	11.4	98.3	76.5	29.06
94	3/3/76	Datsun	0.15	0.79	0.77	228.34	11.7	95.9	76.1	29.04
95	3/3/76	I.H.-Perkins	0.67	2.07	0.77	252.52	10.4	94.6	76.3	29.04
96	3/3/76	Mercedes	0.08	0.62	0.64	233.37	11.5	96.0	76.7	29.02
97	3/4/76	Mercedes	0.11	0.64	0.62	225.43	11.9	95.0	76.8	28.94
98	3/4/76	Peugeot	0.44	1.06	0.61	251.63	10.6	88.6	79.1	28.80
99	3/4/76	Datsun	0.20	0.84	0.76	236.91	11.3	83.6	78.3	28.87
100	3/4/76	I.H.-Perkins	0.72	1.97	0.83	273.91	9.6	74.5	77.3	28.83
101	3/8/76	Datsun	0.15	0.86	0.79	230.62	11.6	75.9	69.4	29.07
102	3/11/76	I.H.-Perkins	0.64	1.82	0.85	236.79	11.1	69.4	68.4	29.14
103	3/11/76	Mercedes	0.12	0.67	0.85	259.20	10.3	73.3	68.3	29.13
104	3/11/76	Peugeot	0.40	1.03	0.70	238.32	11.1	75.4	68.0	29.09
105	3/12/76	Peugeot	0.49	1.03	0.63	230.91	11.5	100.8	77.1	28.96
106	3/12/76	Mercedes	0.39	0.66	0.79	251.34	10.6	104.7	77.8	28.99
107	3/12/76	I.H.-Perkins	0.77	2.27	0.86	255.72	10.3	105.9	75.1	28.98
108	3/12/76	Datsun	0.18	0.71	0.77	224.62	11.9	108.7	75.4	28.99
109	3/19/76	Datsun	0.21	0.80	0.82	246.41	10.8	78.6	85.7	29.02
110	3/19/76	Peugeot	0.30	0.94	0.79	247.13	10.8	75.1	85.2	29.02
111	3/19/76	I.H.-Perkins	0.71	2.12	0.83	238.37	11.0	71.2	85.8	29.02
112	3/19/76	Mercedes	0.13	0.60	0.74	238.35	11.2	70.1	86.1	28.96
113	3/22/76	Peugeot	0.36	0.92	0.83	229.84	11.6	34.7	76.8	29.41
114	3/22/76	Datsun	0.19	0.77	1.01	238.24	11.2	33.9	77.3	29.43
115	3/22/76	Mercedes	0.12	0.59	0.90	236.94	11.3	36.4	86.5	29.41
116	3/22/76	I.H.-Perkins	0.75	2.14	1.01	253.96	10.4	36.3	87.3	29.37
117	3/23/76	Mercedes	0.12	0.59	0.81	227.24	11.8	50.2	75.4	29.44
118	3/23/76	Peugeot	0.29	0.83	0.83	238.23	11.2	50.6	75.8	29.42
119	3/23/76	I.H.-Perkins	0.65	2.15	1.00	258.82	10.2	52.7	77.7	29.43
120	3/23/76	Datsun	0.29	0.79	0.94	235.13	11.3	49.2	77.3	29.43

(continued)

TABLE A-1 (continued)

Run No.	Date	Vehicle	Emissions, grams/km HC	CO	NO_x	CO_2	Fuel, km/ℓ	gr H_2O/ lb_m air	Temp., °F	pa, in Hg
121	3/24/76	Peugeot	0.38	0.86	0.75	240.96	11.0	69.9	87.1	29.19
122	3/24/76	Mercedes	0.15	0.63	0.81	252.13	10.6	76.3	86.9	29.22
123	3/24/76	I.H.-Perkins	0.75	2.49	0.85	254.38	10.3	78.7	86.8	29.09
124	3/24/76	Datsun	0.14	0.81	0.86	242.65	11.0	75.7	86.4	29.06
125	3/29/76	Datsun	0.16	0.80	0.79	246.31	10.8	128.8	86.8	28.96
126	3/29/76	Peugeot	0.40	0.97	0.69	233.01	11.4	94.3	87.0	28.94
127	3/29/76	Mercedes	0.11	0.62	0.89	249.12	10.7	21.1	86.9	28.85
128	4/6/76	I.H.-Perkins	0.67	2.27	0.98	263.84	10.0	83.1	87.8	29.12
129	4/6/76	Datsun	0.11	0.65	0.81	226.82	11.8	82.4	87.1	29.12
130	4/6/76	Peugeot	0.34	0.95	0.77	239.27	11.1	80.8	85.8	29.10
131	4/6/76	Mercedes	0.15	0.50	0.78	227.21	11.8	81.3	87.4	29.08
132	4/14/76	I.H.-Perkins	0.66	2.59	0.97	278.80	9.4	120.7	86.8	29.15
133	4/14/76	Mercedes	0.13	0.59	0.78	253.08	10.6	122.7	86.7	29.15
134	4/14/76	Datsun	0.12	0.80	0.87	256.75	10.4	122.6	86.2	29.15
135	4/14/76	Peugeot	0.30	1.00	0.65	226.82	11.7	121.1	86.4	29.14
136	5/5/76	I.H.-Perkins	0.69	2.41	1.01	274.62	9.6	118.1	86.4	29.08
137	5/5/76	Mercedes	0.14	0.63	0.84	270.13	9.9	120.6	87.1	29.09
138	5/5/76	Datsun	0.04	0.79	0.86	250.30	10.7	124.7	87.2	29.09
139	5/5/76	Peugeot	0.31	0.92	0.70	235.26	11.3	127.4	86.0	29.04
140	5/6/76	Mercedes	0.13	0.61	0.80	268.73	10.0	119.7	87.3	29.08
141	5/6/76	Datsun	0.09	0.77	0.82	253.11	10.6	120.0	87.5	29.09
142	5/6/76	Peugeot	0.34	0.94	0.72	238.22	11.2	115.7	86.3	29.11
143	5/6/76	I.H.-Perkins	0.76	2.55	0.92	270.55	9.7	114.6	86.8	29.12
144	5/25/76	Datsun	0.15	0.86	0.91	272.27	9.8	139.5	87.7	28.99
145	5/25/76	Mercedes	0.10	0.71	0.80	268.54	10.0	139.6	88.0	28.97
146	5/25/76	I.H.-Perkins	0.83	2.83	0.96	286.52	9.2	135.2	87.0	28.95
147	5/25/76	Peugeot	0.26	0.98	0.69	246.39	10.8	135.4	88.1	28.91
148	5/27/76	Datsun	0.17	0.76	0.89	248.63	10.7	105.4	86.1	29.21
149	5/27/76	I.H.-Perkins	0.76	2.40	0.93	271.77	9.7	106.8	86.9	29.21
150	5/27/76	Mercedes	0.11	0.61	0.78	267.83	10.0	108.5	87.4	29.21
151	5/27/76	Peugeot	0.25	0.91	0.65	225.99	11.8	105.1	86.6	29.23
152	5/28/76	I.H.-Perkins	0.62	2.31	0.97	260.27	10.1	90.3	84.8	29.17
153	5/28/76	Mercedes	0.13	0.62	0.81	248.16	10.8	92.1	87.4	29.18
154	5/28/76	Datsun	0.06	0.74	0.87	240.38	11.1	90.7	87.0	29.16
155	5/28/76	Peugeot	0.33	0.94	0.71	235.80	11.3	95.2	88.2	29.14
156	5/31/76	Datsun	0.09	0.80	0.85	243.03	11.0	142.2	87.1	28.99
157	5/31/76	Peugeot	0.09	1.00	0.63	243.00	11.0	145.8	87.1	28.97
158	5/31/76	I.H.-Perkins	0.64	2.60	0.78	254.23	10.3	147,2	88.6	28.95
159	5/31/76	Mercedes	0.05	0.63	0.72	253.24	10.6	132.8	87.3	28.94
160	6/1/76	Peugeot	0.28	0.98	0.65	237.69	11.2	139.3	85.7	29.00

(continued)

TABLE A-1 (continued)

Run No.	Date	Vehicle	Emissions, grams/km				Fuel, km/ℓ	gr H_2O/ lb_m air	Temp., °F	pa, in Hg
			HC	CO	NO_X	CO_2				
161	6/1/76	Datsun	0.12	0.83	0.85	248.71	10.7	136.5	85.0	29.09
162	6/1/76	I.H.-Perkins	0.79	2.77	0.82	269.05	9.7	137.6	86.1	29.16
163	6/1/76	Mercedes	0.14	0.61	0.69	252.23	10.6	140.0	86.6	29.15
164	6/2/76	Peugeot	0.47	1.01	0.56	252.85	10.5	146.5	87.8	29.14
165	6/2/76	Datsun	0.12	0.83	0.70	262.95	10.2	138.9	85.9	29.16
166	6/2/76	I.H.-Perkins	1.00	3.03	0.76	270.22	9.7	134.9	86.4	29.16
167	6/2/76	Mercedes	0.10	0.67	0.70	268.86	9.9	137.9	86.5	29.16
168	6/3/76	Peugeot	0.35	1.00	0.67	240.36	11.1	95.9	87.4	29.15
169	6/3/76	I.H.-Perkins	0.80	2.54	0.86	264.11	9.9	90.4	87.4	29.15
170	6/3/76	Datsun	0.16	0.78	0.82	245.21	10.9	89.7	86.7	29.15
171	6/3/76	Mercedes	0.08	0.61	0.78	259.77	10.3	86.7	86.3	29.15
172	6/4/76	Datsun	0.18	0.83	0.84	248.57	10.7	92.6	85.3	29.18
173	6/4/76	Mercedes	0.12	0.60	0.80	257.21	10.4	94.2	87.7	29.12
174	6/4/76	I.H.-Perkins	0.78	2.68	0.94	263.48	10.0	88.7	87.4	29.13
175	6/4/76	Peugeot	0.41	0.96	0.71	241.12	11.0	77.3	85.1	29.13
176	6/4/76	Datsun	0.13	0.83	0.84	258.02	10.4	147.6	87.3	29.10
177	6/14/76	I.H.-Perkins	0.90	2.93	0.86	278.67	9.4	140.5	87.5	29.07
178	6/14/76	Peugeot	0.40	1.03	0.63	246.72	10.8	130.7	85.8	29.07
179	6/14/76	Mercedes	0.10	0.66	0.75	271.50	9.9	136.1	88.3	29.05
180	6/15/76	I.H.-Perkins	0.91	2.77	0.81	276.41	9.5	158.1	87.0	29.06
181	6/15/76	Mercedes	0.17	0.67	0.76	281.50	9.5	150.9	88.2	29.06
182	6/15/76	Datsun	0.15	0.85	0.85	268.25	10.0	141.4	86.3	29.06
183	6/15/76	Peugeot	0.43	0.56	0.56	245.40	10.8	147.5	87.1	29.07

APPENDIX B

COEFFICIENTS OF EQUATIONS RELATING DEPENDENT AND INDEPENDENT VARIABLES

TABLE B-1. COEFFICIENTS OF HYDROCARBON (HC) EQUATIONS

"Independent" variable(s)	Vehicle	Constant	Coefficient by "independent" variable					r^2
			H	T	H^2	T^2	HT	
H	Datsun	0.155	-1.53E-4	--------	--------	--------	--------	0.020
	I.H.-Perkins	0.503	2.16E-3	--------	--------	--------	--------	0.576
	Mercedes	0.134	-1.46E-5	--------	--------	--------	--------	0.000
	Peugeot	0.421	-5.26E-4	--------	--------	--------	--------	0.078
T	Datsun	0.255	--------	-1.39E-3	--------	--------	--------	0.046
	I.H.-Perkins	0.037	--------	7.86E-3	--------	--------	--------	0.235
	Mercedes	0.193	--------	-7.51E-4	--------	--------	--------	0.012
	Peugeot	0.679	--------	-3.71E-3	--------	--------	--------	0.113
H,H^2	Datsun	0.126	9.14E-4	--------	-6.95E-6	--------	--------	0.085
	I.H.-Perkins	0.529	1.21E-3	--------	6.22E-6	--------	--------	0.584
	Mercedes	0.120	5.10E-4	--------	-3.43E-6	--------	--------	0.012
	Peugeot	0.381	1.02E-3	--------	-1.03E-5	--------	--------	0.127
T,T^2	Datsun	-1.821	--------	5.18E-2	--------	-3.38E-4	--------	0.031
	I.H.-Perkins	4.537	--------	-1.08E-1	--------	7.39E-4	--------	0.295
	Mercedes	-2.505	--------	6.82E-2	--------	-4.37E-4	--------	0.115
	Peugeot	-2.219	--------	7.09E-2	--------	-4.76E-4	--------	0.165
H,T	Datsun	0.246	-4.97E-5	-1.24E-3	--------	--------	--------	0.047
	I.H.-Perkins	0.351	1.97E-3	2.09E-3	--------	--------	--------	0.588
	Mercedes	0.200	5.36E-5	-8.85E-4	--------	--------	--------	0.013
	Peugeot	0.634	-2.73E-4	-2.89E-3	--------	--------	--------	0.128
H,H^2,T,T^2	Datsun	-1.577	6.37E-4	4.48E-2	-4.40E-6	-2.91E-4	--------	0.153
	I.H.-Perkins	3.570	1.71E-3	-8.06E-2	1.29E-6	5.28E-4	--------	0.621
	Mercedes	-2.569	--------[a]	7.00E-2	5.51E-7	-4.50E-4	--------	0.119
	Peugeot	-1.711	6.93E-4	5.66E-2	-6.39E-6	-3.79E-4	--------	0.194
H,T, HT	Datsun	0.124	1.85E-3	2.76E-4	--------	--------	-2.31E-5	0.063
	I.H.-Perkins	0.466	4.57E-5	6.66E-4	--------	--------	2.33E-5	0.591
	Mercedes	0.074	2.20E-3	6.53E-4	--------	--------	-2.57E-5	0.031
	Peugeot	-0.022	1.08E-2	5.27E-3	--------	--------	-1.34E-4	0.330

[a] F-level (significance) insufficient for inclusion

TABLE B-2. COEFFICIENTS OF CARBON MONOXIDE (CO) EQUATIONS

"Independent" variable(s)	Vehicle	Constant	Coefficient by "independent" variable					r^2
			H	T	H^2	T^2	HT	
H	Datsun	0.779	2.84E-4	--------	--------	--------	--------	0.050
	I.H.-Perkins	1.708	7.08E-3	--------	--------	--------	--------	0.697
	Mercedes	0.639	-4.23E-5	--------	--------	--------	--------	0.002
	Peugeot	0.996	2.20E-5	--------	--------	--------	--------	0.000
T	Datsun	0.838	--------	-4.47E-4	--------	--------	--------	0.003
	I.H.-Perkins	-0.281	--------	3.15E-2	--------	--------	--------	0.424
	Mercedes	0.795	--------	-1.97E-3	--------	--------	--------	0.128
	Peugeot	1.385	--------	-4.84E-3	--------	--------	--------	0.267
H,H^2	Datsun	0.777	3.71E-4	--------	-5.66E-7	--------	--------	0.051
	I.H.-Perkins	1.843	2.07E-3	--------	3.29E-5	--------	--------	0.724
	Mercedes	0.663	-9.15E-4	--------	5.70E-6	--------	--------	0.054
	Peugeot	0.990	2.64E-4	--------	-1.61E-6	--------	--------	0.002
T,T^2	Datsun	2.029	--------	-3.10E-2	--------	1.94E-4	--------	0.024
	I.H.-Perkins	11.693	--------	-2.77E-1	--------	1.97E-3	--------	0.471
	Mercedes	1.132	--------	-1.06E-2	--------	5.46E-5	--------	0.131
	Peugeot	1.775	--------	-1.49E-2	--------	6.41E-5	--------	0.268
H,T	Datsun	0.910	4.32E-4	-1.77E-3	--------	--------	--------	0.090
	I.H.-Perkins	0.638	5.77E-3	1.46E-2	--------	--------	--------	0.764
	Mercedes	0.812	1.36E-4	-2.31E-3	--------	--------	--------	0.144
	Peugeot	1.485	6.03E-4	-6.65E-3	--------	--------	--------	0.372
H,H^2,T,T^2	Datsun	1.815	4.12E-4	-2.50E-2	--------[a]	1.48E-4	--------	0.102
	I.H.-Perkins	7.954	3.34E-3	-1.71E-1	1.55E-5	1.18E-3	--------	0.793
	Mercedes	0.876	-1.05E-3	-2.71E-3	7.97E-6	--------[a]	--------	0.242
	Peugeot	1.501	2.77E-4	-6.75E-3	2.22E-6	--------[a]	--------	0.376
H,T, HT	Datsun	0.828	1.70E-3	-7.60E-4	--------	--------	-1.53E-5	0.095
	I.H.-Perkins	1.506	-8.74E-3	3.86E-3	--------	--------	1.76E-4	0.781
	Mercedes	1.000	-3.05E-3	-4.59E-3	--------	--------	3.82E-5	0.207
	Peugeot	1.391	2.18E-3	-5.48E-3	--------	--------	-1.92E-5	0.378

[a] F-level (significance) insufficient for inclusion

TABLE B-3. COEFFICIENTS OF NITROGEN OXIDES (NO_x) EQUATIONS

"Independent" variable(s)	Vehicle	Constant	Coefficient by "independent" variable					r^2
			H	T	H^2	T^2	HT	
H	Datsun	1.039	-1.95E-3	--------	--------	--------	--------	0.572
	I.H.-Perkins	1.057	-1.73E-3	--------	--------	--------	--------	0.486
	Mercedes	0.983	-1.99E-3	--------	--------	--------	--------	0.609
	Peugeot	0.848	-1.65E-3	--------	--------	--------	--------	0.612
T	Datsun	1.180	--------	-3.68E-3	--------	--------	--------	0.055
	I.H.-Perkins	1.145	--------	-2.72E-3	--------	--------	--------	0.037
	Mercedes	1.160	--------	-4.01E-3	--------	--------	--------	0.077
	Peugeot	0.982	--------	-3.24E-3	--------	--------	--------	0.069
H,H^2	Datsun	1.161	-6.43E-3	--------	2.92E-5	--------	--------	0.772
	I.H.-Perkins	1.126	-4.28E-3	--------	1.68E-5	--------	--------	0.568
	Mercedes	1.044	-4.23E-3	--------	1.46E-5	--------	--------	0.658
	Peugeot	0.859	-2.08E-3	--------	2.86E-6	--------	--------	0.615
T,T^2	Datsun	3.247	--------	-5.67E-2	--------	3.37E-4	--------	0.070
	I.H.-Perkins	3.078	--------	-5.25E-2	--------	3.17E-4	--------	0.051
	Mercedes	3.797	--------	-7.14E-2	--------	4.27E-4	--------	0.099
	Peugeot	-0.457	--------	3.38E-2	--------	-2.37E-4	--------	0.079
H,T	Datsun	0.812	-2.21E-3	3.08E-3	--------	--------	--------	0.601
	I.H.-Perkins	0.824	-2.01E-3	3.19E-3	--------	--------	--------	0.523
	Mercedes	0.895	-2.08E-3	1.18E-3	--------	--------	--------	0.614
	Peugeot	0.676	-1.85E-3	2.34E-3	--------	--------	--------	0.638
H,H^2,T,T^2	Datsun	2.998	-6.12E-3	-4.84E-2	2.62E-5	3.16E-4	--------	0.787
	I.H.-Perkins	3.065	-3.93E-3	-5.26E-2	1.27E-5	3.52E-4	--------	0.604
	Mercedes	1.023	-4.20E-3	--------[a]	1.42E-5	3.41E-6	--------	0.659
	Peugeot	-0.233	-2.22E-3	2.61E-2	2.57E-6	-1.53E-4	--------	0.643
H,T, HT	Datsun	1.612	-1.46E-2	-6.82E-3	--------	--------	1.50E-4	0.717
	I.H.-Perkins	1.364	-1.10E-2	-3.52E-3	--------	--------	1.09E-4	0.601
	Mercedes	1.512	-1.26E-2	-6.35E-3	--------	--------	1.26E-4	0.713
	Peugeot	0.885	-3.38E-3	-2.64E-4	--------	--------	4.28E-5	0.654

[a] F-level (significance) insufficient for inclusion

APPENDIX C

STEPWISE MULTIPLE REGRESSION COMPUTER OUTPUTS

FILE HARE (CREATION DATE = 76/07/27.)
SUBFILE DATSUN

* M U L T I P L E R E G R E S S I O N *

DEPENDENT VARIABLE.. HC

VARIABLE(S) ENTERED ON STEP NUMBER 3.. HSQ

		ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
MULTIPLE R	.39170	REGRESSION	4.	.01334	.00333	1.76702	.155
R SQUARE	.15343	RESIDUAL	39.	.07358	.00189		
STD DEVIATION	.04344						

-------------------- VARIABLES IN THE EQUATION --------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
TEMP	.44778976E-01	.27821539E-01	2.5905144	6.8584751
			.116	25.14272
GEH	.63712545E-03	.65685430E-03	.94083143	.5904067
			.338	.35113
TSQ	-.29116120E-03	.17761386E-03	2.6872825	-7.0217274
			.109	-13.21661
HSQ	-.43973713E-05	.43097756E-05	1.0410628	-.6465061
			.314	-.24311
(CONSTANT)	-1.5773786	1.0803570	2.1317551	
			.152	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE

ALL VARIABLES ARE IN THE EQUATION.

VARIANCE/COVARIANCE MATRIX OF THE UNNORMALIZED REGRESSION COEFFICIENTS.

	TEMP	GEH	TSQ	HSQ
TEMP	.00077			
GEH	-.00000	.00000		
TSQ	-.00000	.00000	.00000	
HSQ	.00000	-.00000	-.00000	.00000

FILE HARE (CREATION DATE = 76/07/27.)
SUBFILE DATSUN

* M U L T I P L E R E G R E S S I O N *

DEPENDENT VARIABLE.. HC

S U M M A R Y T A B L E

STEP	VARIABLE ENTERED	VARIABLE REMOVED	F TO ENTER OR REMOVE	SIGNIFICANCE	MULTIPLE R	R SQUARE	R SQUARE CHANGE	SIMPLE R	OVERALL F	SIGNIFICANCE
1	TEMP		1.15711	.288	.21330	.04550	.04550	-.21330	1.01276	.372
	GEM		.06802	.796	.21697	.04708	.00158	-.14207		
2	TSW		3.85429	.057	.36170	.13083	.08375	-.22363	2.00694	.128
3	HSQ		1.04106	.314	.39170	.15343	.02260	-.20101	1.76702	.155

FILE HARE (CREATION DATE = 76/07/27.)
SUBFILE DATSUN

* M U L T I P L E R E G R E S S I O N *

DEPENDENT VARIABLE.. CO

VARIABLE(S) ENTERED ON STEP NUMBER 2.. TSQ

MULTIPLE R	.31916	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.10186	REGRESSION	3.	.01217	.00406	1.51219	.226
STD DEVIATION	.05179	RESIDUAL	40.	.10729	.00268		

-------------------- VARIABLES IN THE EQUATION --------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
TEMP	-.24996369E-01	.32168557E-01	.60379665 .442	-3.2657176 -2.50229
GEH	.41239522E-03	.22127261E-03	3.4735370 .070	.3259779 .04052
TSQ	.14800034E-03	.20477793E-03	.52234702 .474	3.0445363 1.19776
(CONSTANT)	1.8153172	1.2570737	2.0853721 .157	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE
HSQ	.00904	.05407	.31858021E-02 .955

F-LEVEL OR TOLERANCE-LEVEL INSUFFICIENT FOR FURTHER COMPUTATION.

VARIANCE/COVARIANCE MATRIX OF THE UNNORMALIZED REGRESSION COEFFICIENTS.

TEMP	.00103		
GEH	.00000	.00000	
TSQ	-.00001	-.00000	.00000
	TEMP	GEH	TSQ

FILE HARE (CREATION DATE = 76/07/27.)
SUBFILE DATSUN

* M U L T I P L E R E G R E S S I O N *

DEPENDENT VARIABLE.. CO

S U M M A R Y T A B L E

STEP	VARIABLE ENTERED	REMOVED	F TO ENTER OR REMOVE	SIGNIFICANCE	MULTIPLE R	R SQUARE	R SQUARE CHANGE	SIMPLE R	OVERALL F	SIGNIFICANCE
1	TEMP		1.78832	.189	.05846	.00342	.00342	-.05846	2.03077	.144
	GEH		3.90755	.055	.30022	.09013	.08672	.22460		
2	TSQ		.52235	.474	.31916	.10186	.01173	-.05330	1.51219	.226

FILE HARE (CREATION DATE = 76/07/27.)
SUBFILE DATSUN

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. NOX

VARIABLE(S) ENTERED ON STEP NUMBER 3.. TSQ

MULTIPLE R	.88710	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.78694	REGRESSION	4.	.34119	.04780	36.01274	.000
STD DEVIATION	.05211	RESIDUAL	39.	.10591	.00272		

------------------- VARIABLES IN THE EQUATION -------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
TEMP	-.48448727E-01	.33378523E-01	2.1068349 .155	-3.1128697 -4.39415
GEH	-.61215130E-02	.78805224E-03	60.340309 0	-2.3719898 -.54495
HSQ	.26232044E-04	.51705962E-05	25.738487 .000	1.6126474 .23426
TSQ	.31610019E-03	.21308987E-03	2.2005128 .146	3.1875915 2.31775
(CONSTANT)	2.9975814	1.2961440	5.3485425 .026	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE

ALL VARIABLES ARE IN THE EQUATION.

VARIANCE/COVARIANCE MATRIX OF THE UNNORMALIZED REGRESSION COEFFICIENTS.

TEMP	.00111			
GEH	-.00001	.00000		
TSQ	-.00001	.00000	.00000	
HSQ	.00000	-.00000	-.00000	.00000
	TEMP	GEH	TSQ	HSQ

FILE MARE (CREATION DATE = 76/07/27.)
SUBFILE DATSUN

* M U L T I P L E R E G R E S S I O N *

DEPENDENT VARIABLE.. NOX

S U M M A R Y T A B L E

STEP	VARIABLE ENTERED	VARIABLE REMOVED	F TO ENTER OR REMOVE	SIGNIFICANCE	MULTIPLE R	R SQUARE	R SQUARE CHANGE	SIMPLE R	OVERALL F	SIGNIFICANCE
1	TEMP		2.97058	.092	.23553	.05547	.05547	-.23553	30.91649	.000
	GEH		56.12861	0	.77543	.60130	.54582	-.75658		
2	HSQ		30.85676	.000	.88030	.77492	.17363	-.62138	45.90579	.000
3	TSQ		2.20051	.146	.88710	.78694	.01202	-.23102	36.01274	.000

FILE HARE (CREATION DATE = 76/07/27.)
SUBFILE PERKINS

* M U L T I P L E R E G R E S S I O N *

DEPENDENT VARIABLE.. HC

VARIABLE(S) ENTERED ON STEP NUMBER 3.. HSQ

MULTIPLE R	.78780	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.62063	REGRESSION	4.	.38547	.09637	16.35964	.000
STD DEVIATION	.07675	RESIDUAL	40.	.23562	.00589		

--------------------- VARIABLES IN THE EQUATION ---------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
TEMP	-.80642206E-01	.48665007E-01	2.7459411	-4.9721568
			.105	-9.68929
GEH	.17124652E-02	.10717326E-02	2.5531164	.6028778
			.118	.19227
TSQ	.52837929E-03	.31158067E-03	2.8757462	5.1114408
			.098	5.10836
HSQ	.12911756E-05	.69980422E-05	.34042191E-01	.0719545
			.855	.01414
(CONSTANT)	3.5698818	1.8804978	3.6038109	
			.065	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE

ALL VARIABLES ARE IN THE EQUATION.

VARIANCE/COVARIANCE MATRIX OF THE UNNORMALIZED REGRESSION COEFFICIENTS.

TEMP	.00237			
GEH	-.00001	.00000		
TSQ	-.00002	.00000	.00000	
HSQ	.00000	-.00000	-.00000	.00000
	TEMP	GEH	TSQ	HSQ

FILE HARE (CREATION DATE = 76/07/27.)
SUBFILE PERKINS

* M U L T I P L E R E G R E S S I O N *

DEPENDENT VARIABLE.. HC

S U M M A R Y T A B L E

STEP	VARIABLE ENTERED	VARIABLE REMOVED	F TO ENTER OR REMOVE	SIGNIFICANCE	MULTIPLE R	R SQUARE	R SQUARE CHANGE	SIMPLE R	OVERALL F	SIGNIFICANCE
1	TEMP		1.24971	.270	.48456	.23480	.23480	.48456	29.97685	.000
	GEH		36.01496	.000	.76684	.58805	.35325	.75881		
2	TSQ		3.48362	.069	.78760	.62031	.03226	.49264	22.32754	0
3	HSQ		.03404	.855	.78780	.62063	.00032	.75595	16.35964	.000

FILE HARE (CREATION DATE = 76/07/27.)
SUBFILE PERKINS

* M U L T I P L E R E G R E S S I O N *

DEPENDENT VARIABLE.. CO

VARIABLE(S) ENTERED ON STEP NUMBER 3.. HSQ

		ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
MULTIPLE R	.89065						
R SQUARE	.79325	REGRESSION	4.	4.39639	1.09910	38.36747	.000
STD DEVIATION	.16925	RESIDUAL	40.	1.14586	.02865		

------------------- VARIABLES IN THE EQUATION -------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
TEMP	-.17145556	.10731815	2.5524475	-3.5389190
			.118	-6.11899
GEH	.33359139E-02	.23634304E-02	1.9922509	.3931507
			.166	.11125
TSQ	.11840857E-02	.68711097E-03	2.9696998	3.8345758
			.093	3.40030
HSQ	.15504634E-04	.15432381E-04	1.0093858	.2892484
			.321	.05042
(CONSTANT)	7.9542854	4.1469539	3.6791198	
			.062	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE

ALL VARIABLES ARE IN THE EQUATION.

VARIANCE/COVARIANCE MATRIX OF THE UNNORMALIZED REGRESSION COEFFICIENTS.

TEMP	.01152			
GEH	-.00007	.00001		
TSQ	-.00007	.00000	.00000	
HSQ	.00000	-.00000	-.00000	.00000
	TEMP	GEH	TSQ	HSQ

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FILE HARE (CREATION DATE = 76/07/27.)
SUBFILE PERKINS

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. CO

S U M M A R Y   T A B L E

STEP	VARIABLE ENTERED	VARIABLE REMOVED	F TO ENTER OR REMOVE	SIGNIFICANCE	MULTIPLE R	R SQUARE	R SQUARE CHANGE	SIMPLE R	OVERALL F	SIGNIFICANCE
1	TEMP		11.97484	.001	.65109	.42392	.42392	.65109	68.10915	.000
	GEH		60.66867	.000	.87426	.76433	.34042	.83495		
2	TSQ		4.58385	.038	.88771	.78803	.02370	.65815	50.80854	0
3	HSQ		1.00939	.321	.89065	.79325	.00522	.84841	38.36747	.000

FILE HARE (CREATION DATE = 76/07/27.)
SUBFILE PERKINS

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. NOX

VARIABLE(S) ENTERED ON STEP NUMBER 3.. TSQ

MULTIPLE R	.77710	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.60389	REGRESSION	4.	.28535	.07134	15.24547	.000
STD DEVIATION	.06841	RESIDUAL	40.	.18717	.00468		

-------------------- VARIABLES IN THE EQUATION --------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
TEMP	-.52612743E-01	.43373539E-01	1.4714049	-3.7191462
			.232	-4.52466
GEH	-.39292019E-02	.95520042E-03	16.920753	-1.5859219
			.000	-.31576
HSQ	.12683808E-04	.62371274E-05	4.1355196	.8103868
			.049	.09939
TSQ	.35227266E-03	.27770172E-03	1.6091656	3.9070267
			.212	2.43770
(CONSTANT)	3.0654829	1.6760266	3.3453072	
			.075	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE

ALL VARIABLES ARE IN THE EQUATION.

VARIANCE/COVARIANCE MATRIX OF THE UNNORMALIZED REGRESSION COEFFICIENTS.

	TEMP	GEH	TSQ	HSQ
TEMP	.00188			
GEH	-.00001	.00000		
TSQ	-.00001	.00000	.00000	
HSQ	.00000	-.00000	-.00000	.00000

FILE HARE (CREATION DATE = 76/07/27.)
SUBFILE PERKINS

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. NOX

S U M M A R Y   T A B L E

STEP	VARIABLE ENTERED	VARIABLE REMOVED	F TO ENTER OR REMOVE	SIGNIFICANCE	MULTIPLE R	R SQUARE	R SQUARE CHANGE	SIMPLE R	OVERALL F	SIGNIFICANCE
1	TEMP		3.29449	.077	.19195	.03684	.03684	-.19195	23.05874	.000
	GEH		42.87088	.000	.72344	.52336	.48652	-.69712		
2	HSQ		6.42699	.015	.76678	.58795	.06459	-.59496	19.50117	0
3	TSQ		1.60917	.212	.77710	.60389	.01594	-.18772	15.24547	.000

FILE HARE (CREATION DATE = 76/07/27.)
SUBFILE MERCEDES

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. HC

VARIABLE(S) ENTERED ON STEP NUMBER 3.. HSQ

MULTIPLE R	.34525	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.11920	REGRESSION	4.	.01274	.00318	1.28563	.293
STD DEVIATION	.04977	RESIDUAL	38.	.09413	.00248		

-------------------- VARIABLES IN THE EQUATION --------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
TEMP	.70926714E-01	.34833746E-01	4.1459048	10.2484604
			.049	43.08841
GEH	-.65265098E-04	.80192282E-03	.66236420E-02	-.0536894
			.936	-.03637
TSQ	-.45565147E-03	.22132731E-03	4.2383373	-10.3475947
			.046	-22.50923
HSQ	.96139380E-06	.52191962E-05	.33930900E-01	.1249337
			.855	.05183
(CONSTANT)	-2.6020518	1.3538498	3.6939491	
			.062	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE

ALL VARIABLES ARE IN THE EQUATION.

VARIANCE/COVARIANCE MATRIX OF THE UNNORMALIZED REGRESSION COEFFICIENTS.

TEMP	.00121			
GEH	-.00001	.00000		
TSQ	-.00001	.00000	.00000	
HSQ	.00000	-.00000	-.00000	.00000
	TEMP	GEH	TSQ	HSQ

FILE HARE (CREATION DATE = 76/07/27.)
SUBFILE MERCEDES

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. HC

S U M M A R Y   T A B L E

STEP	VARIABLE ENTERED	VARIABLE REMOVED	F TO ENTER OR REMOVE	SIGNIFICANCE	MULTIPLE R	R SQUARE	R SQUARE CHANGE	SIMPLE R	OVERALL F	SIGNIFICANCE
1	TEMP		.53481	.469	.10847	.01177	.01177	-.10847	.27034	.765
	GEH		.06368	.802	.11549	.01334	.00157	-.01204		
2	TSQ		4.64834	.037	.34411	.11841	.10507	-.11878	1.74611	.173
3	HSQ		.03393	.855	.34525	.11920	.00079	-.03836	1.28563	.293

FILE HARE (CREATION DATE = 76/07/27.)
SUBFILE MERCEDES

* M U L T I P L E R E G R E S S I O N *

DEPENDENT VARIABLE.. CO

VARIABLE(S) ENTERED ON STEP NUMBER 2.. HSQ

MULTIPLE R	.49193	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.24200	REGRESSION	3.	.01631	.00544	4.15033	.012
STD DEVIATION	.03619	RESIDUAL	39.	.05109	.00131		

----- VARIABLES IN THE EQUATION -----

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
TEMP	-.27097443E-02	.87148296E-03	9.6680483 .003	-.4930037 -.34356
GEH	-.10536453E-02	.55144391E-03	3.6507846 .063	-1.0913775 -.12255
HSQ	.74682937E-05	.35550863E-05	5.0237772 .031	1.3038171 .08465
(CONSTANT)	.87581296	.70822536E-01	152.92545 0	

----- VARIABLES NOT IN THE EQUATION -----

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE
TSQ	-.08060	.00091	.24845263 .621

F-LEVEL OR TOLERANCE-LEVEL INSUFFICIENT FOR FURTHER COMPUTATION.

VARIANCE/COVARIANCE MATRIX OF THE UNNORMALIZED REGRESSION COEFFICIENTS.

TEMP	.00000		
GEH	.00000	.00000	
HSQ	-.00000	-.00000	.00000
	TEMP	GEH	HSQ

FILE HARE (CREATION DATE = 76/07/27.)
SUBFILE MERCEDES

* M U L T I F L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. CO

S U M M A R Y   T A B L E

STEP	VARIABLE ENTERED	VARIABLE REMOVED	F TO ENTER OR REMOVE	SIGNIFICANCE	MULTIPLE R	R SQUARE	R SQUARE CHANGE	SIMPLE R	OVERALL F	SIGNIFICANCE
1	TEMP		6.65869	.014	.35829	.12837	.12837	-.35829	3.37418	.044
	GEH		.74718	.393	.37994	.14435	.01598	-.04379		
2	HSO		5.02378	.031	.49193	.24200	.09764	.01347	4.15033	.012

FILE   HARE   (CREATION DATE = 76/07/27.)
SUBFILE   MERCEDES

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE..   NOX

VARIABLE(S) ENTERED ON STEP NUMBER   2..   HSQ

		ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
MULTIPLE R	.81191						
R SQUARE	.65920	REGRESSION	3.	.30904	.10301	25.14601	0
STD DEVIATION	.06400	RESIDUAL	39.	.15977	.00410		

---------------------- VARIABLES IN THE EQUATION ----------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
TEMP	.46671650E-03	.15410472E-02	.91719817E-01	.0321976
			.764	.04502
GEH	-.42062861E-02	.97513335E-03	18.606711	-1.6520649
			.000	-.37224
HSQ	.14256779E-04	.62865563E-05	5.1430081	.8845487
			.029	.12204
(CONSTANT)	1.0078607	.12523743	64.763867	
			0	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE
TSQ	.21180	.00041	1.7847601
			.190

F-LEVEL OR TOLERANCE-LEVEL INSUFFICIENT FOR FURTHER COMPUTATION.

VARIANCE/COVARIANCE MATRIX OF THE UNNORMALIZED REGRESSION COEFFICIENTS.

	TEMP	GEH	HSQ
TEMP	.00000		
GEH	.00000	.00000	
HSQ	-.00000	-.00000	.00000

FILE .HARE   (CREATION DATE = 76/07/27.)
SUBFILE   MERCEDES

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE..   NOX

S U M M A R Y   T A B L E

STEP	VARIABLE ENTERED	VARIABLE REMOVED	F TO ENTER OR REMOVE	SIGNIFICANCE	MULTIPLE R	R SQUARE	R SQUARE CHANGE	SIMPLE R	OVERALL F	SIGNIFICANCE
1	TEMP		.55806	.459	.27683	.07663	.07663	-.27683	31.84876	.000
	GEH		55.75084	.000	.78375	.61426	.53763	-.78031		
2	HSQ		5.14301	.029	.81191	.65920	.04494	-.70206	25.14601	0

FILE   HARE   (CREATION DATE = 76/07/27.)
SUBFILE   PEUGEOT

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE..   HC

VARIABLE(S) ENTERED ON STEP NUMBER 3.. HSQ

MULTIPLE R	.44068	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.19420	REGRESSION	4.	.05126	.01282	2.22924	.085
STD DEVIATION	.07582	RESIDUAL	37.	.21270	.00575		

-------------------- VARIABLES IN THE EQUATION --------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
TEMP	.56640379E-01	.50273304E-01	1.2693385	5.1217971
			.267	11.91522
GEH	.69271042E-03	.11045447E-02	.39331168	.3676753
			.534	.13867
TSQ	-.37868483E-03	.32164920E-03	1.3860882	-5.3683950
			.247	-6.43520
HSQ	-.63935512E-05	.72342237E-05	.78108884	-.5296585
			.383	-.12732
(CONSTANT)	-1.7109986	1.9435981	.77497266	
			.384	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE

ALL VARIABLES ARE IN THE EQUATION.

VARIANCE/COVARIANCE MATRIX OF THE UNNORMALIZED REGRESSION COEFFICIENTS.

TEMP	.00253			
GEH	-.00001	.00000		
TSQ	-.00002	.00000	.00000	
HSQ	.00000	-.00000	-.00000	.00000
	TEMP	GEH	TSQ	HSQ

FILE HARE (CREATION DATE = 76/07/27.)
SUBFILE PEUGEOT

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. HC

S U M M A R Y   T A B L E

STEP	VARIABLE ENTERED	VARIABLE REMOVED	F TO ENTER OR REMOVE	SIGNIFICANCE	MULTIPLE R	R SQUARE	R SQUARE CHANGE	SIMPLE R	OVERALL F	SIGNIFICANCE
1	TEMP		2.25686	.141	.33589	.11282	.11282	-.33589	2.86970	.069
	GEH		.69172	.411	.35817	.12824	.01546	-.27400		
2	TSQ		2.25842	.141	.42094	.17719	.04890	-.34346	2.72767	.057
3	HSQ		.78109	.383	.44068	.19420	.01701	-.32723	2.22924	.085

FILE HARE (CREATION DATE = 76/07/27.)
SUBFILE PEUGEOT

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. CO

VARIABLE(S) ENTERED ON STEP NUMBER 2.. HSQ

		ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
MULTIPLE R	.61288	REGRESSION	3.	.07105	.02368	7.62031	.000
R SQUARE	.37563	RESIDUAL	38.	.11811	.00311		
STD DEVIATION	.05575						

------------------- VARIABLES IN THE EQUATION -------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
TEMP	-.67511511E-02	.14155183E-02	22.747028	-.7211537
			.000	-.54233
GEH	.27687967E-03	.78451551E-03	.12456014	.1736031
			.726	.02117
HSQ	.22228480E-05	.50901763E-05	.19070140	.2175291
			.665	.01690
(CONSTANT)	1.5006740	.11037313	184.86129	
			0	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE
TSQ	-.00200	.00105	.14762319E-03
			.490

F-LEVEL OR TOLERANCE-LEVEL INSUFFICIENT FOR FURTHER COMPUTATION.

VARIANCE/COVARIANCE MATRIX OF THE UNNORMALIZED REGRESSION COEFFICIENTS.

TEMP	.00000		
GEH	-.00000	.00000	
HSQ	-.00000	-.00000	.00000
	TEMP	GEH	HSQ

FILE   HARE   (CREATION DATE = 76/07/27.)
SUBFILE   PEUGEOT

*   M U L T I P L E   R E G R E S S I O N   *

DEPENDENT VARIABLE..   CO

S U M M A R Y   T A B L E

STEP	VARIABLE ENTERED	VARIABLE REMOVED	F TO ENTER OR REMOVE	SIGNIFICANCE	MULTIPLE R	R SQUARE	R SQUARE CHANGE	SIMPLE R	OVERALL F	SIGNIFICANCE
1	TEMP		23.13880	.000	.51675	.26703	.26703	-.51675	11.57532	.000
	GEM		6.55446	.014	.61032	.37249	.10546	.01380		
2	HSQ		.19070	.665	.61288	.37563	.00313	.00264	7.62031	.000

FILE HARE (CREATION DATE = 76/07/27.)
SUBFILE PEUGEOT

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. NOX

VARIABLE(S) ENTERED ON STEP NUMBER 3.. HSQ

MULTIPLE R	.80181	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.64289	REGRESSION	4.	.21290	.05323	16.65255	.000
STD DEVIATION	.05654	RESIDUAL	37.	.11826	.00320		

------------------ VARIABLES IN THE EQUATION ------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
TEMP	.26146703E-01	.37486275E-01	.48650722 .490	2.1108802 2.90066
GEH	-.22215275E-02	.82360344E-03	7.2755710 .010	-1.0527248 -.23453
TSQ	-.15287658E-03	.23983763E-03	.40630040 .528	-1.9348974 -1.37003
HSQ	.25697357E-05	.53941968E-05	.22694642 .637	.1900608 .02699
(CONSTANT)	-.23339793	1.4492434	.25936498E-01 .873	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE

ALL VARIABLES ARE IN THE EQUATION.

VARIANCE/COVARIANCE MATRIX OF THE UNNORMALIZED REGRESSION COEFFICIENTS.

TEMP	.00141			
GEH	-.00001	.00000		
TSQ	-.00001	.00000	.00000	
HSQ	.00000	-.00000	-.00000	.00000
	TEMP	GEH	TSQ	HSQ

FILE HARE (CREATION DATE = 76/07/27.)
SUBFILE PEUGEOT

* M U L T I P L E R E G R E S S I O N *

DEPENDENT VARIABLE.. NOX

S U M M A R Y T A B L E

STEP	VARIABLE ENTERED	VARIABLE REMOVED	F TO ENTER OR REMOVE	SIGNIFICANCE	MULTIPLE R	R SQUARE	R SQUARE CHANGE	SIMPLE R	OVERALL F	SIGNIFICANCE
1	TEMP		2.83142	.100	.26195	.06862	.06862	-.26195	34.37877	.000
	GEH		61.36343	0	.79880	.63808	.56946	-.78218		
2	TSQ		.27768	.601	.80044	.64070	.00263	-.26524	22.58726	.000
3	HSQ		.22695	.637	.80181	.64289	.00219	-.74079	16.65255	.000

FILE HARE (CREATION DATE = 77/03/24.)
SUBFILE DATSUN

* M U L T I P L E R E G R E S S I O N *

DEPENDENT VARIABLE.. HC

VARIABLE(S) ENTERED ON STEP NUMBER 2.. HT

MULTIPLE R	.25028	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.06264	REGRESSION	3.	.00544	.00181	.89101	.454
ADJUSTED R SQUARE	-.00766	RESIDUAL	40.	.08147	.00204		
STD DEVIATION	.04513	COEFF OF VARIABILITY	31.6 PCT				

VARIABLES IN THE EQUATION

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
GEH	.18524440E-02	.23420098E-02	.62562311 / .434	1.7166090 / 1.02092
TEMP	.27560788E-03	.21916196E-02	.15814407E-01 / .901	.0422129 / .15475
HT	-.23054379E-04	.28290393E-04	.66409298 / .420	-1.8947670 / -1.04269
(CONSTANT)	.12394465	.17349106	.51038911 / .479	

VARIABLES NOT IN THE EQUATION

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE

ALL VARIABLES ARE IN THE EQUATION.

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FILE HARE (CREATION DATE = 77/03/24.)
SUBFILE DATSUN

* M U L T I P L E R E G R E S S I O N *

DEPENDENT VARIABLE.. HC

S U M M A R Y T A B L E

STEP	VARIABLE ENTERED	VARIABLE REMOVED	F TO ENTER OR REMOVE	SIGNIFICANCE	MULTIPLE R	R SQUARE	R SQUARE CHANGE	SIMPLE R	OVERALL F	SIGNIFICANCE
1	GEH		.06802	.796	.14207	.02018	.02018	-.14207	1.01276	.372
	TEMP		1.15711	.288	.21697	.04708	.02689	-.21330		
2	HT		.66409	.420	.25028	.06264	.01556	-.16652	.89101	.454

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FILE    HARE      (CREATION DATE =  77/03/24.)
SUBFILE    DATSUN

* * * * * * * * * * * * * * * * * * * * * * *   M U L T I P L E    R E G R E S S I O N   * * * * * * * * * * * * * * * * * * * * * * *

DEPENDENT VARIABLE..     CO

VARIABLE(S) ENTERED ON STEP NUMBER   2..   HT

MULTIPLE R              .30843        ANALYSIS OF VARIANCE     DF       SUM OF SQUARES        MEAN SQUARE           F      SIGNIFICANCE
R SQUARE                .09513        REGRESSION                3.             .01136             .00379        1.40175           .256
ADJUSTED R SQUARE       .02726        RESIDUAL                 40.             .10809             .00270
STD DEVIATION           .05198        COEFF OF VARIABILITY      6.5 PCT

--------------------- VARIABLES IN THE EQUATION ---------------------        ---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE              B          STD ERROR B          F            BETA         VARIABLE      PARTIAL    TOLERANCE        F
                                                 ------------   ----------                                           ------------
                                                 SIGNIFICANCE   ELASTICITY                                           SIGNIFICANCE

GEH         .16952829E-02    .26976160E-02    .39493369      1.3400370
                                                .533          .16658
TEMP       -.75959288E-03    .25243908E-02    .90541692E-01  -.0992390
                                                .765         -.07604
HT         -.15315045E-04    .32585951E-04    .22088986     -1.0736654
                                                .641         -.12349
(CONSTANT)  .82824407        .19983360       17.178278
                                                .000

ALL VARIABLES ARE IN THE EQUATION.
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FILE HARE (CREATION DATE = 77/03/24.)
SUBFILE DATSUN

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE..   CO

S U M M A R Y   T A B L E

STEP	VARIABLE ENTERED	VARIABLE REMOVED	F TO ENTER OR REMOVE	SIGNIFICANCE	MULTIPLE R	R SQUARE	R SQUARE CHANGE	SIMPLE R	OVERALL F	SIGNIFICANCE
1	GEH		3.90755	.055	.22460	.05045	.05045	.22460	2.03077	.144
	TEMP		1.78832	.184	.30022	.09013	.03969	-.05846		
2	HT		.22089	.641	.30843	.09513	.00500	.14713	1.40175	.256

FILE HARE (CREATION DATE = 77/03/24.)
SUBFILE DATSUN

* M U L T I P L E R E G R E S S I O N *

DEPENDENT VARIABLE.. NOX

VARIABLE(S) ENTERED ON STEP NUMBER 2.. HT

MULTIPLE R	.84690	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.71724	REGRESSION	3.	.35654	.11885	33.82065	.000
ADJUSTED R SQUARE	.69603	RESIDUAL	40.	.14056	.00351		
STD DEVIATION	.05928	COEFF OF VARIABILITY	6.7 PCT				

------------------- VARIABLES IN THE EQUATION ------------------- ---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY	VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE
GEH	-.14625953E-01	.30762230E-02	22.605428	-5.6673265				
			.000	-1.30204				
TEMP	-.68226000E-02	.28786859E-02	5.6170885	-.4369493				
			.023	-.61879				
HT	.15049097E-03	.37159348E-04	16.401544	5.1717867				
			.000	1.09943				
(CONSTANT)	1.6119419	.22788000	50.036432					
			.000					

ALL VARIABLES ARE IN THE EQUATION.

FILE HARE (CREATION DATE = 77/03/24.)
SUBFILE DATSUN

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. NOX

S U M M A R Y   T A B L E

STEP	VARIABLE ENTERED	VARIABLE REMOVED	F TO ENTER OR REMOVE	SIGNIFICANCE	MULTIPLE R	R SQUARE	R SQUARE CHANGE	SIMPLE R	OVERALL F	SIGNIFICANCE
1	GEH		56.12861	0	.75658	.57241	.57241	-.75658	30.91649	.000
	TEMP		2.97058	.092	.77543	.60130	.02889	-.23559		
2	HT		16.40154	.000	.84690	.71724	.11594	-.71028	33.82065	.000

FILE HARE (CREATION DATE = 77/03/24.)
SUBFILE PERKINS

* M U L T I P L E R E G R E S S I O N *

DEPENDENT VARIABLE.. HC

VARIABLE(S) ENTERED ON STEP NUMBER 2.. HT

MULTIPLE R	.76859	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.59073	REGRESSION	3.	.36690	.12230	19.72636	0
ADJUSTED R SQUARE	.56079	RESIDUAL	41.	.25419	.00620		
STD DEVIATION	.07874	COEFF OF VARIABILITY	11.9 PCT				

------------------ VARIABLES IN THE EQUATION ------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
GEH	.45689925E-04	.37200389E-02	.15085021E-03	.0160853
			.990	.00513
TEMP	.66572961E-03	.33367271E-02	.39806533E-01	.0410469
			.843	.07999
HT	.23283294E-04	.44896636E-04	.26894360	.7274363
			.607	.21402
(CONSTANT)	.46552991	.26233312	3.1491181	
			.083	

------------------ VARIABLES NOT IN THE EQUATION ------------------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE

ALL VARIABLES ARE IN THE EQUATION.

FILE HARE (CREATION DATE = 77/03/24.)
SUBFILE PERKINS

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. HC

S U M M A R Y   T A B L E

STEP	VARIABLE ENTERED	VARIABLE REMOVED	F TO ENTER OR REMOVE	SIGNIFICANCE	MULTIPLE R	R SQUARE	R SQUARE CHANGE	SIMPLE R	OVERALL F	SIGNIFICANCE
1	GEM		36.01496	.000	.75881	.57579	.57579	.75881	29.97685	.000
	TEMP		1.24971	.270	.76684	.58805	.01226	.48456		
2	HT		.26894	.607	.76859	.59073	.00268	.76795	19.72636	0

FILE HARE   (CREATION DATE = 77/03/24.)
SUBFILE PERKINS

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE..   CO

VARIABLE(S) ENTERED ON STEP NUMBER 2..   HT

MULTIPLE R	.88402	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.78149	REGRESSION	3.	4.33120	1.44373	48.87735	0
ADJUSTED R SQUARE	.76550	RESIDUAL	41.	1.21105	.02954		
STD DEVIATION	.17187	COEFF OF VARIABILITY	7.7 PCT				

------------------ VARIABLES IN THE EQUATION ------------------   ---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY	VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE
GEH	-.87405575E-02	.81198098E-02	1.1587415	-1.0301093				
			.288	-.29149				
TEMP	.38614717E-02	.72831468E-02	.28110437	.0797025				
			.599	.13781				
HT	.17580826E-03	.97996863E-04	3.2185050	1.8387660				
			.080	.48000				
(CONSTANT)	1.5064888	.57260019	6.9219563					
			.012					

ALL VARIABLES ARE IN THE EQUATION.

FILE HARE (CREATION DATE = 77/03/24.)
SUBFILE PERKINS

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. CO

S U M M A R Y   T A B L E

STEP	VARIABLE ENTERED	VARIABLE REMOVED	F TO ENTER OR REMOVE	SIGNIFICANCE	MULTIPLE R	R SQUARE	R SQUARE CHANGE	SIMPLE R	OVERALL F	SIGNIFICANCE
1	GEH		60.66867	.000	.83495	.69714	.69714	.83495	68.10915	.000
	TEMP		11.97484	.001	.87426	.76433	.06719	.65109		
2	HT		3.21850	.080	.88402	.78149	.01715	.86454	48.87735	0

FILE HARE (CREATION DATE = 77/03/24.)
SUBFILE PERKINS

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. NOX

VARIABLE(S) ENTERED ON STEP NUMBER 2.. HT

MULTIPLE R	.77545	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.60132	REGRESSION	3.	.28414	.09471	20.61335	0
ADJUSTED R SQUARE	.57215	RESIDUAL	41.	.18838	.00459		
STD DEVIATION	.06778	COEFF OF VARIABILITY	7.3 PCT				

------------------- VARIABLES IN THE EQUATION -------------------   ---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY	VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE
GEH	-.11045576E-01	.32024694E-02	11.896159	-4.4582643				
			.001	-.88763				
TEMP	-.35183869E-02	.28724878E-02	1.5002748	-.2487115				
			.228	-.30258				
HT	.10943738E-03	.38650160E-04	8.0173119	3.9200009				
			.007	.72000				
(CONSTANT)	1.3643542	.22583467	36.498332					
			0					

ALL VARIABLES ARE IN THE EQUATION.

FILE HARE (CREATION DATE = 77/03/24.)
SUBFILE PERKINS

* M U L T I P L E R E G R E S S I O N *

DEPENDENT VARIABLE.. NOX

S U M M A R Y T A B L E

STEP	VARIABLE ENTERED	VARIABLE REMOVED	F TO ENTER OR REMOVE	SIGNIFICANCE	MULTIPLE R	R SQUARE	R SQUARE CHANGE	SIMPLE R	OVERALL F	SIGNIFICANCE
1	GEH		42.87088	.000	.69712	.48598	.48598	-.69712	23.05874	.000
	TEMP		3.29449	.077	.72344	.52336	.03739	-.19195		
2	HI		8.01731	.007	.77545	.60132	.07796	-.65162	20.61935	0

FILE   HARE   (CREATION DATE = 77/03/24.)
SUBFILE   MERCEDES

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE..   HC

VARIABLE(S) ENTERED ON STEP NUMBER   2..   HT

MULTIPLE R	.17706	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.03135	REGRESSION	3.	.00335	.00112	.42074	.739
ADJUSTED R SQUARE	-.04316	RESIDUAL	39.	.10351	.00265		
STD DEVIATION	.05152	COEFF OF VARIABILITY	38.8 PCT				

-------------------- VARIABLES IN THE EQUATION -------------------- ---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY	VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE
GEH	.21986035E-02	.25277297E-02	.75654121	1.8086495				
			.390	1.22533				
TEMP	.65293415E-03	.21758736E-02	.90047457E-01	.0943448				
			.766	.39667				
HT	-.25713871E-04	.30194268E-04	.72524697	-1.8775986				
			.400	-1.18123				
(CONSTANT)	.74260979E-01	.17439934	.18131415					
			.673					

ALL VARIABLES ARE IN THE EQUATION.

FILE HARE (CREATION DATE = 77/03/24.)
SUBFILE MERCEDES

* M U L T I P L E R E G R E S S I O N *

DEPENDENT VARIABLE.. HC

S U M M A R Y T A B L E

STEP	VARIABLE ENTERED	VARIABLE REMOVED	F TO ENTER OR REMOVE	SIGNIFICANCE	MULTIPLE R	R SQUARE	R SQUARE CHANGE	SIMPLE R	OVERALL F	SIGNIFICANCE
1	GEH		.06368	.802	.01204	.00014	.00014	-.01204	.27034	.765
	TEMP		.53481	.469	.11549	.01334	.01319	-.10847		
2	HT		.72525	.400	.17706	.03135	.01801	-.03374	.42074	.739

FILE HARE (CREATION DATE = 77/03/24.)
SUBFILE MERCEDES

* M U L T I P L E R E G R E S S I O N *

DEPENDENT VARIABLE.. CO

VARIABLE(S) ENTERED ON STEP NUMBER 2.. HT

MULTIPLE R	.45541	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.20740	REGRESSION	3.	.01398	.00466	3.40169	.027
ADJUSTED R SQUARE	.14643	RESIDUAL	39.	.05343	.00137		
STD DEVIATION	.03701	COEFF OF VARIABILITY	5.8 PCT				

------------------ VARIABLES IN THE EQUATION ------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
GEH	-.30511038E-02	.18159400E-02	2.8230007	-3.1603670
			.101	-.35488
TEMP	-.45937776E-02	.15631639E-02	8.6363629	-.8357797
			.006	-.58243
HT	.38205151E-04	.21691789E-04	3.1020808	3.5126126
			.086	.36628
(CONSTANT)	.99961839	.12528979	63.655670	
			0	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE

ALL VARIABLES ARE IN THE EQUATION.

FILE   HARE   (CREATION DATE = 77/03/24.)
SUBFILE   MERCEDES

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE..   CO

S U M M A R Y   T A B L E

STEP	VARIABLE ENTERED	VARIABLE REMOVED	F TO ENTER OR REMOVE	SIGNIFICANCE	MULTIPLE R	R SQUARE	R SQUARE CHANGE	SIMPLE R	OVERALL F	SIGNIFICANCE
1	GEH		.74718	.393	.04379	.00192	.00192	-.04379	3.37418	.044
	TEMP		6.65869	.014	.37994	.14435	.14244	-.35829		
2	HT		3.10208	.086	.45541	.20740	.06304	-.06561	3.40164	.027

FILE   HARE   (CREATION DATE = 77/03/24.)
SUBFILE   MERCEDES

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE..   NOX

VARIABLE(S) ENTERED ON STEP NUMBER   2..   HT

MULTIPLE R	.84429	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.71283	REGRESSION	3.	.33418	.11139	32.26827	0
ADJUSTED R SQUARE	.69074	RESIDUAL	39.	.13463	.00345		
STD DEVIATION	.05875	COEFF OF VARIABILITY	7.0 PCT				

------------------ VARIABLES IN THE EQUATION ------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
GEH	-.12587118E-01	.28826868E-02	19.065916 .000	-4.9437421 -1.11391
TEMP	-.63503231E-02	.24814212E-02	6.5492362 .014	-.4380933 -.61259
HT	.12598231E-03	.34434307E-04	13.385557 .001	4.3920459 .91895
(CONSTANT)	1.5116098	.19888941	57.763839 0	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE

ALL VARIABLES ARE IN THE EQUATION.

FILE HARE (CREATION DATE = 77/03/24.)
SUBFILE MERCEDES

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. NOX

S U M M A R Y   T A B L E

STEP	VARIABLE ENTERED	VARIABLE REMOVED	F TO ENTER OR REMOVE	SIGNIFICANCE	MULTIPLE R	R SQUARE	R SQUARE CHANGE	SIMPLE R	OVERALL F	SIGNIFICANCE
1	GEM		55.75084	.000	.78031	.60888	.60888	-.78031	31.84876	.000
	TEMP		.55806	.459	.78375	.61426	.00538	-.27683		
2	HT		13.38556	.001	.84429	.71283	.09856	-.74364	32.26877	0

FILE HARE (CREATION DATE = 77/03/24.)
SUBFILE PEUGEOT

* M U L T I P L E R E G R E S S I O N *

DEPENDENT VARIABLE.. HC

VARIABLE(S) ENTERED ON STEP NUMBER 2.. HT

MULTIPLE R	.57402	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.32950	REGRESSION	3.	.08698	.02899	6.22470	.002
ADJUSTED R SQUARE	.27657	RESIDUAL	38.	.17699	.00466		
STD DEVIATION	.06825	COEFF OF VARIABILITY	17.9 PCT				

------------------ VARIABLES IN THE EQUATION ------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
GEH	.10773406E-01	.32840635E-02	10.761752	5.7182846
			.002	2.15671
TEMP	.52740384E-02	.29626108E-02	3.1691104	.4769134
			.083	1.10948
HT	-.13427484E-03	.39762369E-04	11.403674	-6.2899857
			.002	-2.20869
(CONSTANT)	-.21902942E-01	.23230040	.88900660E-02	
			.925	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE

ALL VARIABLES ARE IN THE EQUATION.

FILE HARE (CREATION DATE = 77/03/24.)
SUBFILE PEUGEOT

* M U L T I F L E R E G R E S S I O N *

DEPENDENT VARIABLE.. HC

S U M M A R Y T A B L E

STEP	VARIABLE ENTERED	VARIABLE REMOVED	F TO ENTER OR REMOVE	SIGNIFICANCE	MULTIPLE R	R SQUARE	R SQUARE CHANGE	SIMPLE R	OVERALL F	SIGNIFICANCE
1	GEH		.69172	.411	.27900	.07784	.07784	-.27900	2.86970	.064
	TEMP		2.25686	.141	.35817	.12829	.05044	-.33589		
2	HT		11.40367	.002	.57402	.32950	.20121	-.33149	6.22470	.002

FILE HARE (CREATION DATE = 77/03/24.)
SUBFILE PEUGEOT

************************* M U L T I P L E   R E G R E S S I O N *************************

DEPENDENT VARIABLE.. CO

VARIABLE(S) ENTERED ON STEP NUMBER 2.. HT

MULTIPLE R	.61502	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.37825	REGRESSION	3.	.07159	.02385	7.70582	.000
ADJUSTED R SQUARE	.32916	RESIDUAL	38.	.11761	.00310		
STD DEVIATION	.05563	COEFF OF VARIABILITY	5.6 PCT				

------------------- VARIABLES IN THE EQUATION -------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
GEH	.21846353E-02	.26771178E-02	.66592133 .420	1.3697631 .16700
TEMP	-.54844433E-02	.24150745E-02	5.1570820 .029	-.5858448 -.44057
HT	-.19222070E-04	.32413668E-04	.35167699 .557	-1.0636750 -.12074
(CONSTANT)	1.3909860	.18936769	53.955258 .000	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE

ALL VARIABLES ARE IN THE EQUATION.

FILE   HARE   (CREATION DATE = 77/03/24.)
SUBFILE   PEUGEOT

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE..   CO

S U M M A R Y   T A B L E

STEP	VARIABLE ENTERED	VARIABLE REMOVED	F TO ENTER OR REMOVE	SIGNIFICANCE	MULTIPLE R	R SQUARE	R SQUARE CHANGE	SIMPLE R	OVERALL F	SIGNIFICANCE
1	GEH		6.55446	.014	.01380	.00019	.00019	.01380	11.57532	.000
	TEMP		23.13880	.000	.61032	.37249	.37230	-.51675		
2	HT		.35168	.557	.61502	.37825	.00575	-.05322	7.70582	.000

FILE HARE (CREATION DATE = 77/03/24.)
SUBFILE PEUGEOT

* M U L T I P L E R E G R E S S I O N *

DEPENDENT VARIABLE.. NOX

VARIABLE(S) ENTERED ON STEP NUMBER 2.. HT

MULTIPLE R	.80893	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.65437	REGRESSION	3.	.21670	.07223	23.98143	.000
ADJUSTED R SQUARE	.62708	RESIDUAL	38.	.11446	.00301		
STD DEVIATION	.05488	COEFF OF VARIABILITY	7.6 PCT				

------------------- VARIABLES IN THE EQUATION ------------------- ---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY	VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE
GEH	-.53758062E-02	.26409922E-02	4.1433628	-2.5474565				
			.049	-.56753				
TEMP	-.26440314E-03	.23824850E-02	.12316090E-01	-.0213458				
			.912	-.02933				
HT	.42798547E-04	.31976271E-04	1.7914406	1.7899235				
			.189	.37126				
(CONSTANT)	.88535199	.18681233	22.460576					
			.000					

ALL VARIABLES ARE IN THE EQUATION.

FILE HARE (CREATION DATE = 77/03/24.)
SUBFILE PEUGEOT

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. NOX

S U M M A R Y   T A B L E

STEP	VARIABLE ENTERED	VARIABLE REMOVED	F TO ENTER OR REMOVE	SIGNIFICANCE	MULTIPLE R	R SQUARE	R SQUARE CHANGE	SIMPLE R	OVERALL F	SIGNIFICANCE
1	GEH		61.36349	0	.78218	.61180	.61180	-.78218	34.37827	.000
-	TEMP		2.83142	.100	.79880	.63808	.02628	-.26195		
2	HT		1.79144	.189	.80843	.65437	.01629	-.75075	23.48143	.000

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

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15. SUPPLEMENTARY NOTES

16. ABSTRACT

Since emission measurements from passenger cars are performed at one standard set of ambient conditions and since emission rates of HC, CO, and NO_x are sensitive to temperature and humidity, it is necessary to determine the influence of ambient conditions on emissions from major classes of vehicles. Although such information has been available for gasoline engine powered cars for sometime, no such data were available for diesel powered passenger cars.

This report indicates that diesel HC and CO emissions are relatively insensitive to ambient conditions. Diesel NO_x emissions , however, are sensitive to humidity but to a smaller extent than gasoline engines. Humidity correction factors for NO_x emissions also appear to vary with vehicle power-to-weight ratios and are greater for higher powered vehicles.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
*Air pollution *Automobiles *Diesel Engines *Exhaust emissions *Correction *Temperature *Humidity		13B 13F 21G 21B 04B

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