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AUTOMOBILE EXHAUST EMISSION SURVEILLANCE

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1. SUMMARY AND CONCLUSIONS

The purpose of this report is to coordinate information from several programs dealing with the measurement of emissions from light-duty vehicles and to make this information available in concise form. The report supplements the previously issued publication entitled, "Automobile Exhaust Emission Surveillance: A Summary." The two documents can be used to estimate the impact of light-duty vehicle emissions on air quality and to assess the degree to which vehicles in use conform to the standards under which they were certified.

The previously published report, hereinafter referred to for the sake of convenience as APTD-1544, summarized the findings and results of three major emission surveillance programs conducted by the Environmental Protection Agency (EPA):

1. The Great Plains (Two-City) Surveillance Program, 1968-1969 Model Year Surveys (actual testing was conducted from October 1969 to October 1971).
2. The National Surveillance Program, 1970 (Six-City) and 1971 (Four-City) Model Year Surveys (actual testing was conducted from November 1970 to January 1972).
3. A Study of Emissions from Light-Duty Vehicles in Six Cities, 1957-1971 Model Year Survey (actual testing was conducted from July 1971 to June 1972).

The present report combines the findings of the above surveillance programs with three additional sources of information:

4. The Rental Vehicle Surveillance Program, March 1968 to January 1970 (actual testing conducted from March 1968 to January 1970).
5. The In-House Vehicle Surveillance Program, January 1967 to March 1970 (actual testing conducted from January 1967 to March 1970).

6. Determination of Exhaust Emissions from 1971 Model Vehicles (commonly referred to as the NO_x Baseline data) (actual testing conducted from March 1971 to April 1971).

Except for 3 and 6, both of which utilized the Constant Volume Sampling (CVS) Federal Test Procedure, all test programs employed the Federal Seven-Mode Test Procedure. Although correlation factors have been developed by EPA to relate the 7-mode and CVS Federal Test Procedures, they are based on average results of a sales-weighted sample of many different vehicles and are inappropriate for converting test results for individual vehicles. Consequently, for the purposes of this analysis, it was felt more appropriate to treat the results of tests made by the two procedures separately, without endeavoring to translate these results from one procedure to another.

1.1 SUMMARY

Hydrocarbon and carbon monoxide emissions for the vehicles tested in three major surveillance programs (Programs 1, 2, and 3) were assessed by comparing the mean emission levels measured for a given model year with applicable Federal standards. It is emphasized that such comparison is consistent with the goals of pre-1972 regulations, which were aimed at insuring that <u>average</u> vehicle emission levels meet standards. In general, hydrocarbon and carbon monoxide emissions as measured by the CVS test procedure showed a significant downward trend for late model vehicles; NO_x emissions, which were not subject to control during the model years covered by the program, tended to show a corresponding increase. Hydrocarbon and carbon monoxide emission measures for post-1968 model years showed approximately 50% and 35% reduction, respectively, from emissions measured for pre-1968 model year pre-control vehicles. On the same basis, NO_x emissions from post-1968 vehicles showed an increase of approximately 35% over pre-control vehicles. It should be noted that these test programs were conducted on as-received vehicles and that the test results may reflect to some extent the influence of such variables as state of vehicle maintenance and repair.

In an effort to assess the extent to which local climate, terrain, driving practices and other geographically differentiated factors affect emissions, vehicles were sampled in several cities, these cities being selected to span the range of such factors. Only small differences were observed in the emissions measured in the cities included in the survey, the only notable exception being Denver. Higher carbon monoxide and hydrocarbon emissions and lower NO_x emissions were observed in Denver than in the other cities, presumably because of the effect of altitude on air-fuel ratios.

The mean emission levels from 1968 and 1969 Great Plains vehicles in use by the general public were compared to emission levels from similar vehicles operated by rental vehicle companies to assess whether emissions from fleet operated vehicles differ significantly from general use vehicles and to provide an additional data source to complement the Great Plains surveillance data. Mean emission levels from the rental vehicles were consistently lower than comparable 1968 and 1969 vehicles in use by the general public. This difference, however, is consistent with the age and the associated average mileage difference between the two classes of vehicles.* The rental vehicles, with an average mileage of 7,700 miles, were tested during 1968 and 1969 while the Great Plains vehicles, with an average mileage of approximately 30,000 miles, were tested from 1969 to 1971.

Finally, the effect of maintenance was also investigated by comparison of two sets of emission data--"as-received" low mileage vehicles and low mileage vehicles which were tuned prior to testing. Based upon these comparisons, no significant maintenance effect was observed for HC and CO, as was expected, because these vehicles had very low mileage. A small but significant reduction in NO_x emissions, however, was observed on the maintained vehicles.

In summation, the Environmental Protection Agency has recognized that any realistic assessment of Federal air pollution regulations requires the monitoring of emissions from production vehicles in use by the motoring public. Consequently, this report presents a summation of six emissions programs carried out from 1967 to 1972. Although no attempt has been made to present all the data generated during the past several years, this report does present synopses of major programs.

* "Automobile Exhaust Emission Surveillance -- A Summary", (APTD-1544)

1.2 CONCLUSIONS

Automobile exhaust emission levels depend upon a variety of complex factors which vary from vehicle to vehicle. Such variables as a vehicle's accumulated mileage, state of tune or driving history all contribute to the wide dispersion in emission levels commonly exhibited by vehicles of any particular category. Consequently, two categories of vehicles, such as those tested in two different cities, may show considerable overlap of their statistical distributions even though the mean emissions for the two categories are appreciably different. Generalizations with regard to make, city or other categories of interest, therefore, are often not applicable to comparison of individual vehicles or small subsets of vehicles drawn from the two categories. On the other hand, care should be exercised in interpreting results drawn from the application of statistical techniques to categories with large sample sizes. By combining large quantities of data, it is possible to label as statistically significant a small difference in mean emission levels despite the fact that the magnitude of this difference may be too small to be of practical importance.

Finally, many of the test programs were conducted on as-received vehicles whose statistical distribution of emission levels is frequently skewed toward the high end of the distribution curve. If a hypothetical emissions distribution were symmetrical and fifty percent of the vehicles met the standard, the mean of all these vehicles would also meet the standard. This relationship does not apply, however, with a skewed distribution. If an indication of total mean emissions is desired and the emissions distribution in question is skewed, the mean emission level of a group of vehicles must be looked at independently of the percent of these vehicles which conform to the standard.

In what follows, conclusions are numbered to conform to the programs from which they were primarily drawn. The numbering sequence conforms to the previous listing of the several surveillance programs encompassed by this report. With these guidelines in mind, the results of the automobile exhaust emissions programs summarized in this report reveal the following:

1. In the Great Plains Surveillance tests of 1968 and 1969 model year vehicles in Kansas City and Houston, the following observations were made, based upon the 7x7 Federal Test Procedure.

   a. 46% of the 1968 model year vehicles with an average mileage of approximately 34,000 miles individually complied with applicable standards for HC; that is, 46% of the vehicles exhibited emission levels at or below the level allowable by the standard. Similarly, 35% were at or below standards for CO, and 23% were at or below standards for both HC and CO. Mean emission levels including Volkswagens for HC, CO and NO_{xc} were 352 ppm, 2.14% and 1275 ppm, respectively, where NO_{xc} refers to oxides of nitrogen corrected for humidity. It should be noted that Volkswagens were subject to standards different from those applicable to other vehicles during model years 1968 and 1969.

   b. 53% of the 1969 model year vehicles with an average mileage of approximately 24,000 miles were at or below applicable standards for HC, 42% were at or below standards for CO, and 30% were at or below standards for both HC and CO. Mean emission levels including Volkswagens for HC, CO and NO_{xc} were 303 ppm, 1.86% and 1453 ppm, respectively.

   c. The mean emission levels for both the 1968 and 1969 model year vehicles failed to meet the applicable standards of 275 ppm HC and 1.50% CO.

   d. Based upon 192 tests, engine adjustments resulted in reduction of 110 ppm in mean HC levels in Houston but no change in Kansas City. A 0.2% reduction in mean CO was observed in both cities. Replacing dirty air filters resulted in no significant change in HC levels but reduced CO emissions by 0.3% in both Houston and Kansas City.

Results of the maintenance survey indicate that spark plugs and breaker points were the most frequent items of maintenance.

e. Analysis of two short test cycles, the Chew Hot-Idle Mode and the Clayton KEY MODE Diagnostic Test, revealed the following:

(1) Based upon simple linear correlation, neither short test cycle is a reliable predictor of the emission levels from the cold start seven-mode test procedure.

(2) Based upon a discriminant analysis approach on 2,038 Hot Idle tests on 1968-1969 Great Plains vehicles, 83% pass/fail agreement with the seven-mode procedure was achieved. Of the 17% incorrect decisions, the Hot-Idle test failed 10.4% that should have passed and passed 6.6% which should have failed.

(3) Based upon a similar discriminant approach on 1749 KEY MODE tests on 1970 model National Surveillance vehicles, 83.5% pass/fail agreement with the seven-mode procedure was achieved. Of the 16.5% incorrect decisions, the KEY MODE test failed 11.6% that should have passed and passed 4.9% which should have failed.

These conclusions, however, do not necessarily apply to the current 1972 and 1975 Federal Test Procedures.

2. In the National Surveillance tests of 1970 and 1971 model year vehicles, the following observations were made, based upon the 7x7 Federal Test Procedure.

a. In the surveillance tests of 1970 model year vehicles with average mileages of approximately 10,000 miles in Kansas City, Houston, Los Angeles, Detroit, Denver and Washington, the following observations were made:

(1) With Denver vehicles excluded, 32% of the vehicles tested were at or below the applicable standard for HC, 35% at or below the standard for CO, and 19% were at or below standards for both HC and CO. In Denver, the corresponding percentages were 5%, 3%, and 0.3%.

(2) Mean emission levels for HC, CO and NO_{xc} for all cities except Denver were 2.83 gms/mi, 35.3 gms/mi and 4.69 gms/mi, respectively. The corresponding values for Denver were 4.25 gms/mi, 65.1 gms/mi, and 3.83 gms/mi.

(3) In general, the mean emission levels of the vehicles tested failed to meet the applicable standards of 2.2 gms/mi and 23.0 gms/mi for HC and CO, respectively.

b. In the surveillance tests of 1971 model year vehicles in Houston, Los Angeles, Detroit and Denver, the following observations were made.

(1) Low-mileage (less than 60 odometer miles) and stabilized engines showed distinct differences in the percentage of vehicles tested which were at or below applicable standards for HC, CO and both HC and CO.

		Percent at or Below Standards for		
		HC	CO	Both
Total Excluding Denver:	Low Mileage	87	60	58
	Stabilized	59	49	38
Denver Only:	Low Mileage	36	2	1
	Stabilized	29	10	6

(2) Mean emission levels in gms/mi for HC, CO and NO_{xc} for low mileage and stabilized engines were as follows:

		HC	CO	NO_{xc}
Total Excluding Denver:	Low Mileage	1.47	23.7	3.16
	Stabilized	2.12	29.0	3.74

Denver Only:	Low Mileage	2.63	64.0	2.86
	Stabilized	3.16	45.2	3.19

(3) Applicable standards of 2.2 gms/mi HC and 23.0 gm/mi CO were, for the most part, exceeded by the higher mileage and correspondingly older stabilized engines, which would more nearly represent engines operating in vehicles in general use than do the low mileage vehicles.

3. Tests performed in 1971 on light-duty vehicles, model years 1957 through 1971, show a consistent downward trend in HC and CO emissions from 1957 through 1971. The trend is highlighted by the following average emission levels based upon the 1975 CVS Federal Test Procedure for pre-control and controlled vehicles, excluding Denver and for Denver alone.

	Emission Levels (gm/mi) 1975 CVS Test Procedure		
	HC	CO	NO_{xc}
Total Excluding Denver:			
Pre-Control	8.74	86.5	3.54
Controlled	4.37	53.9	4.92
Denver Only:			
Pre-Control	10.16	126.9	1.89
Controlled	6.46	92.2	2.67

These results are indicative of the effect of emission controls on air quality.

4. Results from the Rental Vehicle Surveillance Program, based upon the 7x7 Federal Test Procedure, reveal that mean emission levels for 1968 and 1969 model year rental vehicles are, in general, consistently lower than similar vehicles tested during the Great Plains program and in use by the general public.

5. Seven-Mode tests from the In-House Surveillance Program on 1968-1969 foreign and domestic vehicles indicate that manufacturers' recommended emission control maintenance practices were, in

general, adequate to control emissions for 50,000 miles. In addition, no evidence was found that manufacturers critically tuned 4,000-mile certification vehicles to meet Federal emission standards.

6. Based upon tests using the 1972 CVS Federal Test Procedure, a comparison of NO_x baseline data on 1971 model vehicles tuned prior to testing and comparable data from "as-received" 1971 model light-duty vehicles from the Six-City Study reveals no significant difference in HC or CO levels. This is not surprising because both groups of vehicles were tested in a relatively low mileage condition. Moreover, the same conclusion can be drawn from other EPA studies. Therefore, this conclusion should not be generalized to maintenance effects on the total population of in-use vehicles because low mileage vehicles represent a small percentage of the vehicle population. A small but significant reduction in NO_{xc} emissions, however, was observed in the maintained vehicles.

2. RESULTS AND DISCUSSION

This section of the report is a discussion of the findings and results of the six test programs discussed in this report. In the aggregate, these programs represent tests on over 6,500 light duty vehicles in eight cities. For convenience, the programs are listed below.

1. The Great Plains (Two City) Surveillance Program - 1968-1969 Model Year Surveys.
2. The National Surveillance Program - 1970 (Six City) and 1971 (Four City) Model Year Surveys.
3. A Study of Emissions from Light-Duty Vehicles in Six Cities - 1957-1971 Model Year Surveys.
4. The Rental Vehicle Surveillance Program - March 1968 to January 1970.
5. The In-House Vehicle Surveillance Program - January 1967 to March 1970.
6. Determination of Exhaust Emissions from 1971 Model Vehicles (commonly referred to as the NO_x Baseline Data).

Table 1 presents an overview and summary of the objectives, procedures, test locations and number of vehicles tested for each of these programs.

In order to keep these programs in perspective, a brief summary of the salient features of each test program is presented below. For clarity, the programs will be referred to not only by their names, but also by the number associated with each program in the above list.

The Great Plains (1) and National Surveillance (2) programs represent the major EPA surveillance programs for the model years 1968 to 1971. Each of these programs employed the 7-mode Federal Test Procedure and represents a significant attempt to monitor the emission levels of in-use vehicles and to determine the presence of any mileage or city effects. Similarly, the Six

City 1957-1971 Model Year Survey (3) also represents a large scale program aimed at determining the emission levels of in-use vehicles. Unlike the first two programs outlined above, however, the Six City program utilized the 1972 and 1975 Constant Volume Sampling (CVS) Federal Test Procedures and was directed mainly toward determining a nationwide emissions inventory for pre-control and controlled vehicles. All three of these programs are discussed in detail in APTD-1544 and will be discussed only in summary form in this report.

The final three programs, not discussed in the previous report, represent smaller scale programs aimed at providing additional insights into the analysis of emissions from light duty vehicles. Although these programs were not of the same magnitude as the three major surveillance programs, they have provided information useful in such areas as the assessment of the certification process and the establishment of baseline NO_x levels as required by the Clean Air Act of 1970.

The fourth program is the Rental Vehicle Surveillance Program (4). This program, which employed the 7-mode Federal Test Procedure, represents a relatively large scale surveillance program (705 test vehicles) undertaken to determine emission levels from in-use vehicles and to establish guidelines for future EPA large scale surveillance programs.

The fifth program of interest, the In-House Vehicle Surveillance Program (5), represents a unique program carried on from January 1967 to March 1970, using the 7x7 Federal Test Procedure. One of the earliest EPA Surveillance programs, the In-House program was aimed primarily at gaining better insight into the Federal Certification Procedures and any problems inherent in them. By operating a fleet of prototype, production and emission durability vehicles in a manner similar to the Federally required procedures used by the automobile manufacturers, EPA attempted to determine if prototype vehicles were critically tuned by the manufacturers to meet Federal standards, if surveillance vehicles operated by EPA differed markedly from manufacturers' durability vehicles and whether the manufacturers' recommended emissions maintenance practices were adequate to provide acceptable emissions levels over the 50,000-mile vehicle lifetime.

The final test program which will be discussed in this report is the NO_x Baseline Program (6). Under the Clean Air Act of 1970, a 90% reduction from 1971 NO_x emission levels was called for by 1976. Consequently, the establishment of the NO_x baseline level representing the average emissions from a typical well maintained 1971 model vehicle was necessary. The data gathered from 243 vehicles in this program were obtained using the 1972 CVS Federal Test Procedure. Data from those vehicles not designed to meet California NO_x standards represent the emissions baseline for 1976 standards.

The above paragraphs and Table 1 present a general overview of the test programs to be discussed in this report. In the following sections, a more detailed discussion of each program will be presented. For easy reference, the number of each of the following sections corresponds to the identification number of the six programs. It is hoped that such a numbering system will enable the reader to clearly differentiate each program and to determine from which program conclusions were drawn.

Although numerical results appearing herein have been drawn liberally from contractors' final reports for each of these programs, additional and different types of data analyses have been performed to provide additional perspectives and insights into the results and, in some cases, to broaden or refine the application of statistical methodology. In the formulation of conclusions, caution has been exercised to consider inherent sampling biases, confounding factors and other limitations that are associated with the data base. The results of data analysis have been interpreted pragmatically from the standpoint of the magnitudes of the emissions measurements as well as from the standpoint of the statistical significance levels associated with the results.

2.1 RESULTS OF THE GREAT PLAINS SURVEILLANCE PROGRAM

Contained in this section of the report are the results and findings of three major areas investigated during the Great Plains Surveillance Program. These three general areas are:

a. 1968-1969 7-mode surveillance results

b. Tests to determine efficacy of idle adjustments in reducing emissions and results of maintenance survey

c. Evaluation of short test cycles.

The seven-mode surveillance results were covered in detail in APTD-1544 and the results presented here will only highlight the important conclusions. The efficacy of idle adjustments and the evaluation of short test cycles such as the Hot Idle Mode and the Clayton KEY MODE diagnostic test were not discussed in APTD-1544, but will be covered in some detail in this report.

2.1.1 1968-1969 Surveillance Results

This section of the report represents a brief summary of the 1968-1969 surveillance data. Composite exhaust emissions data taken from each vehicle tested were based on the seven-mode, cold start test procedure as stipulated by the Federal Register appropriate to the model year tested (see Table 1). The measurement of NO_x (NO), which was not specified in the Federal Register, was performed using NDIR (non-dispersive infra-red). In all cases, an attempt was made to select the test vehicles from the motoring public according to a strategy that yielded a sample as nearly representative as possible of the vehicles that were in use (or, in the case of new models, projected to be in use).

Exhaust emissions data for each of the three principal effluents determined from measurements on 1968-1969 model vehicles tested during the Great Plains Program are shown in Table 2. These data consolidate results from the three phases of this program during which time each vehicle, on the average, accumulated approximately 15,000 miles. Included in these tables are vehicles produced by American Motors, Chrysler, Ford, General Motors and Volkswagen representing, in total, a statistical sampling of 90% of the sales for these model years. The oxides of nitrogen are expressed as NO_{xc}, the subscript "c" denoting the correction for humidity.

Although the results are expressed both in terms of concentration and grams per mile, these results should be assessed against the certification standards applicable to these models (275 ppm HC and 1.50% CO, except for VW, for which the standards are 410 ppm HC and 2.30% CO). The grams-per-mile figures are primarily presented to facilitate cross year comparisons with 1970 and 1971 National Surveillance data discussed in the next section. It is to be noted, however, that the change in basis from concentration to grams per mile is primarily one of data processing since the basic direct measurement for 1968-1971 model year vehicles was in terms of concentration. For certification of the 1970 and 1971 model year vehicles, a functional relationship was developed to calculate the vehicle exhaust volume per mile with vehicle inertia weight and transmission type as independent variables. By means of this relation, grams-per-mile values are calculable to afford a comparison of 1968, 1969, 1970 and 1971 model vehicles on a common basis. Although there were no standards for the oxides of nitrogen for these model years, the NO_x data were nonetheless measured in the surveillance studies and are included.

The major conclusions derived from the analysis of 1968 and 1969 Great Plains surveillance data are the minimal practical differences not only between emissions from Kansas City and Houston, but also between model years 1968 and 1969. Neither of these conclusions is surprising, however, in view of the geographic and climatic similarities between both cities and the emission control equipment utilized during these model years.

2.1.2 Vehicle Maintenance Results

In addition to data described in the previous section, data were also collected as part of the Great Plains surveillance effort to establish the reduction in emissions attributable to minor engine adjustments and to determine the maintenance practices of the motoring public. As the number and complexity of emission control devices increases, the effects of vehicle maintenance become increasingly vital to the furtherance of national air quality goals. Involved in the maintenance study discussed in this section are maintenance characteristics such as type, frequency and effectiveness in reducing emissions. It must be emphasized that the study reported here evaluated the effects of

maintenance on vehicle emissions using the hot start seven-mode test procedure. It is now believed that use of the 1972 or 1975 CVS Federal Test Procedures is necessary in order to relate measured emission values to their impact on air quality. Thus, the data presented here on the effects of vehicle maintenance on emissions are principally of historical interest. Results of more recent EPA studies using the 1972 and 1975 Federal Test Procedures should be used to estimate the impact on overall emissions and air quality which would result from improved vehicle maintenance practices. With these limitations in mind, the maintenance findings are summarized below. For reference purposes, Phase 1 refers to the initial test point at around 25,000 miles, while Phases 2 and 3 refer to two subsequent tests after the accumulation of approximately 4,000 and 8,000 miles, respectively, from the initial Phase 1 test.

As a part of the surveillance program of 1968-1969 model vehicles, basic ignition timing, dwell angle and idle RPM data were measured for each vehicle. During Phase 1 of this program, readjustment of these engine parameters was effected whenever the manufacturer's specifications were exceeded by $\pm 2°$ in timing or ± 75 rpm for idle speed. These corrected settings were made following the nominal cold start, 7-mode 7-cycle test and a hot start test was then made with emissions data collected during two 7-mode hot cycles. The efficacy of the engine adjustments was assessed by comparing composite emission levels for the hot cycles (6 and 7) of the cold start and hot start tests. Based on an overall total of 192 tests, the mean HC levels were reduced by 110 ppm in Houston, but were relatively unchanged in Kansas City. On the other hand, a 0.2% reduction in mean CO was observed in both cities.

During Phases 2 and 3 attention was given to testing carburetor air filters for restricted air flow. A rejection criterion was established which failed approximately 20% of the units tested. When a filter was rejected, a new unit was installed and the effect on emissions evaluated in the identical manner described above. Tests on 123 vehicles indicated no appreciable effect on mean HC levels and a decrease of approximately 0.3% in CO. Neither engine adjustments nor air filter replacements had any significant influence on NO_{xc} levels.

In addition to the efficacy of idle adjustments described above, information on the maintenance practices of 1968-1969 model vehicle owners in Houston and Kansas City was recorded on approximately one-half (i.e., about one thousand) of the vehicles tested. Ten maintenance items were reported in the survey: ignition timing, breaker points, spark plugs, ignition cables, carburetor, PCV valve, air filter, fuel filter, valve repair and engine tune-up.

On a frequency-of-reporting basis, maintenance of spark plugs and breaker points led the list, being reported approximately 60% of the time. Ignition timing, air filter and tune-up maintenance occurred at about a 40% level. No significant differences in maintenance practices between the two reporting cities was demonstrated. There was evidence to show that the frequency at which maintenance operations were performed tended to decrease as the vehicles accumulated mileage, i.e., the newer the vehicle, the more frequent the maintenance.

2.1.3 Evaluation of Short Test Cycles

Achievement of national air quality goals as affected by automobile emissions is dependent upon the owner providing proper maintenance for his vehicle as well as for the newly manufactured vehicles meeting the certification standards. With approximately 100 million passenger vehicles currently registered in the United States, there is great interest in identifying a short, reliable test procedure that yields pass/fail results consistent with those of the lengthy, composite Federal test procedures. Evaluation data gathered during the Great Plains and National Surveillance programs on two likely candidates are summarized below. It must be emphasized that the results presented here consider the ability of short tests to evaluate seven mode FTP results. Subsequent adoption of the 1972 and 1975 CVS Federal Test Procedures as standard measures of emissions limits the applicability of these studies to illustrating the types of analyses which may be performed.

2.1.3.1 Hot-Idle Mode

Based on her investigations, Marian F. Chew* concluded that vehicular emissions as measured during the hot-idle mode constitute a reliable prediction of the pass/fail discrimination afforded by the entire seven-mode Federal test procedure if appropriate "decision values" were used (which differed from the "policy values" associated with the complete seven-mode test). In the present program, 2,038 tests were performed on 1968-1969 model vehicles in which the hot-idle mode pass/fail results were compared with those of the complete test procedure. For policy values of 275 ppm HC and 1.50% CO, the best correlation was realized when decision values of 205 ppm HC and 2.85% CO were applied to the hot-idle mode data. Agreement on pass/fail decisions at these levels was achieved on 83% of the trials. Of the disagreements, the hot-idle test failed 10.4% that should have passed; the remainder, 6.6%, were passed whereas they should have failed.

In addition to the discriminant approach discussed above, an attempt was made to predict the seven-mode composite data for each emittant based upon the mathematical relation:

$$\text{Calculated 7-Mode Composite} = a + b\ (\text{Hot Idle})$$

where a and b are constants determined by least squares analysis. Results of this analysis, however, were not encouraging since the limits of the data were too broad. More specifically, 95% of the actual 7-mode values fell within the following limits from the predicted 7-mode values in the region of best estimation:

$$HC = \pm 269 \text{ ppm}$$
$$CO = \pm 1.67\%$$
$$NO_{xc} = \pm 980 \text{ ppm}$$

The dispersion of these results and a comparison of the relative magnitude of this dispersion with the 1968 to 1969 HC and CO standards of 275 ppm and 1.5% indicate that a simple linear relation is not adequate to accurately predict 7-mode composite emission levels from hot-idle data.

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* "Auto Smog Inspection at Idle Only," SAE Paper No. 690505, May 1969.

Although the success of the linear regression approach described above was limited, the results of the discriminant approach were encouraging insofar as the efficacy of employing short test cycle procedures in predicting the pass/fail seven-mode test results is concerned. It should be noted, however, that because of the specifics of the data collection process, the idle test data constitute an integral part of the composite (seven-mode) data. The two sets of data are therefore correlated and, as a consequence, the final assessment may have been more favorable than would have been the case if the data had been obtained from independent test series.

2.1.3.2 Clayton KEY MODE Diagnostic Test

The Clayton KEY MODE diagnostic test comprises the collection of steady-state, stabilized emission data (on a concentration basis) during three operational modes: idle, low-speed cruise, and high-speed cruise. The cruise speed levels are quantified in relation to vehicle inertia weight according to the schedule below:

Inertia Weight, lbs	Idle	Low-Speed Cruise, mph	High-Speed Cruise, mph
3800 - up	(Automatic	32/35	48/50
2800 - 3750	Transmissions	29/32	44/46
2000 - 2750	in Drive)	22/25	36/38

The vehicle is operated on a dynamometer whose inertia flywheels are decoupled and the power absorption unit adjusted to an indicated 30 road-load horsepower at 50 mph. Alternate settings for vehicles with lower inertia weights are 24 hp at 46 mph or 15 hp at 38 mph.

Using results from over 2000 tests on 1970 model National Surveillance vehicles, the test contractor made a comparison of KEY MODE and seven-mode composite data for each emittant based on the following mathematical relation:

$$\text{Calculated 7-Mode Composite} = a + bKM_1 + cKM_2 + dKM_3$$

In the relation, KM_1, KM_2, KM_3 represent the three emittant concentrations from the KEY MODE low speed cruise, high speed cruise and idle modes while a, b, c,

and d are constants determined by the method of least squares. This technique is analogous to the unsuccessful linear regression on hot-idle data discussed in the previous section. Again, the analysis indicated a wide dispersion in the data with 95% of the actual 7-mode values falling within the following limits from the predicted 7-mode values in the region of best estimation:

$$HC = \pm 216 \text{ ppm}$$
$$CO = \pm 1.0\%$$
$$NO_{xc} = \pm 729 \text{ ppm}$$

As in the case of the hot-idle data, a comparison of the relative magnitude of these dispersions with the 1968 to 1969 HC and CO standards of 275 ppm and 1.5% indicate that a linear combination of KEY MODE data has limited value as an accurate predictor of emission levels as determined by the Federal Seven-Mode Test Procedure.

KEY MODE tests were also performed during the program comparing emissions from low mileage and stabilized engines in 1971-model vehicles during the National Surveillance Program. With the negative results from the earlier data in mind, a comparison was made between the data from the individual modes of the KEY MODE test with the composite data of the seven-mode test. While some of the individual modes gave better agreement for one emittant than for another, on an overall basis the low cruise mode best represented the results of the seven-mode test. This conclusion, however, does not alter the fact that the Clayton KEY MODE test is not a reliable predictor of emission levels as determined by the seven-mode seven-cycle test procedure.

In addition to the regression approach, a linear discriminant analysis similar to the Chew technique discussed in the previous section was also performed on 1749 non-Denver 1970 National Surveillance vehicles. The objective of this analysis was to determine the performance of the KEY MODE data in predicting the pass/fail results of the seven-mode test procedure. For the purposes of this analysis, two groups of data were identified--338 vehicles passing both HC and CO seven-mode Federal standards and 1411 vehicles failing these standards. A detailed discussion of the discriminant approach was pre-

sented in APTD-1544 in Appendix III. Briefly, the technique involves selecting a set of weights which when applied to several groups of data produce minimum scatter within the groups and maximum separation between the groups. The objective of this type of analysis is to highlight the differences between selected groups of data.

Based upon this linear discriminant approach, the following formula for classifying vehicles into pass/fail categories was determined.

FACTOR = -.02024 x HC - ppm High Cruise
+12.08 x CO - % High Cruise
+.00178 x NOX - ppm High Cruise

+.1446 x HC - ppm Low Cruise
+4.802 x CO - % Low Cruise
-.00103 x NOX - ppm Low Cruise

+.03364 x HC - ppm Idle
+15.14 x CO - % Idle
+.01214 x NOX - ppm Idle

By thresholding this factor to minimize the <u>total</u> number of incorrect decisions, the following decision rule was established:

If FACTOR $<$ 45. Vehicle will pass 7-mode
$>$ 45. Vehicle will fail 7-mode

Employing this technique on the 1749 test vehicles resulted in 83.5% correct <u>pass/fail</u> decisions. Of the 16.5% incorrect decisions, 4.9% passed but should have failed and 11.6% failed but should have passed.

Figure 1 presents a histogram of the discriminant factors calculated for each of the vehicles in the two groups. In figures of this type, the non-overlap of the two histograms is a measure of the success of the linear discriminant approach in predicting the pass/fail results of the seven-mode test procedure.

The 83.5% correct decisions achieved using the KEY MODE data is virtually identical to the 83.0% level achieved using the slightly different Chew technique on the hot idle data. Although no data was available from the programs covered in this report to substantiate the ability of any short test cycle to predict the pass/fail results of the CVS test procedure under which vehicles manufactured after 1972 were certified, the relative success demonstrated by the KEY MODE and hot idle tests in predicting seven-mode pass/fail results is encouraging insofar as the efficacy of employing short test cycles as an inspection test is concerned.

2.2 RESULTS OF THE NATIONAL SURVEILLANCE PROGRAM

This section of the report presents a brief compilation of the important conclusions and summary tables for the National Surveillance Program. Once again, the reader is referred to APTD-1544 for a more detailed discussion of these results.

Exhaust emissions data for each of the three principal effluents determined from measurements on 1970 model vehicles in six cities (Kansas City, Houston, Los Angeles, Detroit, Washington and Denver) are shown in Table 3. Examination of this table reveals that only Denver departs markedly from the other cities in the study. HC and CO emission values in Denver are significantly higher than in the other five cities in the program. NO_{xc} emissions, which were not subject to control during this model year, exhibited correspondingly lower levels in Denver.

Table 4 presents similar data for 1971 model vehicles tested in four cities (Houston, Los Angeles, Detroit and Denver). Data in this table, however, have been divided into two groups, Phase 1 and Phase 2. Phase 1 data represent vehicles tested in low mileage engine conditions (less than 60 odometer miles), while Phase 2 data represent emission levels on the same vehicles with "stabilized engines" after the accumulation of approximately 5,000 miles. The principal effect of this stabilization on emissions is believed to be the result of "wearing-in" or "seating" of valves and piston rings as well as a stabilization of combustion chamber deposits.

As in the case of 1970 model vehicles discussed above, only emission levels in Denver depart significantly from levels in the other cities. Although it is often hazardous to ascribe differences observed in test results to one particular effect or another, special unique considerations such as Denver's high altitude can be advanced as a substantive constraint affecting the compliance of Denver with emissions standards.

A summary of the seven-mode surveillance results obtained during the Great Plains and National Surveillance Programs is presented in Table 5. Contained in this table are N, the number of vehicles tested, the mean mileage of the vehicles tested and the arithmetic and geometric mean and standard deviation of the data. The interpretation and use of these figures is discussed in detail in Section 2.1 of APTD-1544.

2.3 A STUDY OF EMISSIONS FROM LIGHT DUTY VEHICLES IN SIX CITIES - 1957-1971 MODEL YEAR SURVEY

This section of the report briefly summarizes the results from a single test program devoted to the measurement of exhaust emissions from 1957 through 1971 model light-duty vehicles in six metropolitan areas. Constant Volume Sampling (CVS) test procedures were employed throughout the program and, consequently, the data presented in this section are not readily comparable to those discussed in Sections 2.1 and 2.2.

A brief overview of the program was previously presented in Table 1. The principal function was the collection of data from which average emission factors could be formulated in order to define the contribution of the automobile population to the nation's air pollution burden. To achieve this objective, the best available methodology and technology were employed to accurately determine mass emissions under vehicle operating conditions representative of road use. Since 1957-1971 model vehicles comprised more than 95% of the population as of 1971, a statistically-representative sample of this population was tested in each of the six cities which were chosen to maximize variations in climate, terrain, and urban development. Despite a somewhat limited sample for the early-year models (1957-1960), the overall sample is very representative of the overall vehicle population on the road. Data from

this program are particularly useful, therefore, in estimating the overall impact of emissions on air quality. The reader is referred to the previous report, APTD-1544, for a more detailed description of the vehicle selection procedures and test techniques. For summary purposes, it is sufficient to say that all vehicles were tested for exhaust emissions in an as-received condition. Cold start tests were performed in accord with the 1972 (CVS-C) and 1975 (CVS-CH) Federal Test Procedures (FTP). In actuality, however, only one test per vehicle was made, since diluted exhaust emissions were bagged in such a manner that vehicle mass emissions could be calculated according to both 1972 and 1975 specifications.

Mass emissions data, expressed as arithmetic and geometric means as well as their respective standard deviations, are summarized in Tables 6 and 7 for the 1972 FTP, and Tables 8 and 9 for the 1975 FTP. In addition, the percentage of vehicles with emission levels at or below the reference levels of 3.4 gms/mi HC, 39.0 gms/mi CO, and 3.0 gms/mi NO_{xc} is also presented. Although these reference levels do not represent emission standards under which the vehicles were certified, they are useful in examining time trends for vehicles of various model years in which no standards or differing standards were in effect. The results are aggregated by year and by all cities except Denver and Denver only.

The differences that are inherent in the 1972 and 1975 procedures reflect the fact that not all trips made by a vehicle originate from a "cold-start" (defined in the Federal Register as a start preceded by a 12-hour, no-use soak period). The 1972 FTP determines mass emissions from a driving schedule (LA-4) that comprises two portions, a cold-transient and a cold-stabilized. The 1975 FTP uses the same driving schedule but also adds a "hot-start" transient portion. In this latter case, emissions levels represent a weighted average of the cold start and hot start test results. Since a large fraction of the composite HC and CO emissions are generated during the fuel-rich, engine warm-up phase of the cold-transient portion of the driving schedule, the 1975 data (as compared with the 1972 data) will show lower levels of emission for these two effluents. The data of Tables 6 through 9 bear out this conclusion. On the other hand, NO_{xc} levels remain substantially uniform, the observed differences probably being attributable to experimental sources.

Trends by model year in mean emission levels and percentage of vehicles below the reference levels are well defined for all effluents. HC and CO levels show continuing decreases and reflect the impact of increasingly more stringent emission controls. Consistent with this decrease, there is observed an increase in NO_{xc} levels which, during this period of time, were not subject to control. Figure 2 which presents 1975 CVS emission levels vs the cumulative percentage of test vehicles, emphasizes these model year trends for the three pollutants.

In addition to the surveillance tests discussed above, two additional kinds of data were gathered during this program:

a. Modal emissions data for 32 accel/decel modes and five steady states.

b. Evaporative emissions data utilizing the SHED technique (SAE J171).

Since these data are not easily synopsized, the reader is referred to APTD-1544 for a complete discussion of these results.

2.4 RENTAL VEHICLE SURVEILLANCE PROGRAM

Exhaust-emission tests using the 7-mode Federal Test Procedure were performed on 1968 and 1969 model year rental vehicles representing 26 different engine classes. This program was conducted to ascertain the effectiveness of Federal exhaust emission standards on in-use vehicles. In addition, although not an original objective of the program, data from this program were used to determine whether fleet operated vehicles receiving minimum maintenance and rapidly accumulating mileage significantly differ in emission levels from vehicles in general use. Table 10 presents Great Plains surveillance data and comparable Rental vehicle surveillance data for engine classes consistingg of more than 15 vehicles. With the exception of 1968 Chevrolet 327 CID engines, the data are presented for both model years lumped. Examination of this table reveals that the rental vehicles tested exhibit consistently lower mean emission levels than comparable vehicles in general use. These differences in mean emission levels are in part explainable by the age and associated mileage

difference between the two classes of vehicles. The rental vehicles tested from 1968 to 1969 had an average mileage of 7,700 miles whereas the Great Plains vehicles had an average mileage of approximately 30,000 miles and were tested from 1969 to 1971. In addition, the rapidly accumulating mileage experienced by the rental vehicles and the as-received nature of the Great Plains vehicles further confound the difference in emissions experienced by these two groups of vehicles.

2.5 IN-HOUSE VEHICLE SURVEILLANCE PROGRAM

The In-House Vehicle Surveillance Program was established by the Division of Motor Vehicle Pollution Control (DMVPC) of the National Air Pollution Control Administration in 1968 to provide additional HC and CO emissions data for prototype and production vehicles. The DMVPC operated a fleet of 1968 prototype and 1969 production vehicles (foreign and domestic) for the purpose of accumulating mileage under actual road use conditions. The major objectives of this program were:

a. To determine whether prototype vehicles were critically tuned by manufacturers to meet Federal exhaust emission standards. The prototype vehicles in question were prototype vehicles from manufacturers' certification fleets and were driven on an accelerated mileage schedule for 4,000 miles and tested for exhaust emissions.

b. To determine whether exhaust emissions from vehicles in the prototype surveillance fleet differ substantially from the exhaust emissions from vehicles in the test track durability fleet. The prototype surveillance vehicles referred to above represent certification vehicles chosen by the DMVPC to correspond to vehicles operated by the manufacturers in their durability fleets.

c. To determine whether manufacturer's recommended maintenance practices keep production surveillance fleet vehicles within Federal emissions standards for 50,000 miles of operation.

The production surveillance vehicles were actual production vehicles chosen on the basis of three criteria. First, vehicles were chosen to give the widest representation of vehicles marketed in the U.S. Second, vehicles were chosen with engine control system combinations not in the manufacturer's durability fleets. Third, vehicles were chosen that were equivalent to those which performed marginally in the prototype surveillance fleet.

The testing and maintenance procedures applied to these vehicles are summarized below. The test track durability fleet vehicles were tested for exhaust emission levels every 4,000 miles by the manufacturer. Maintenance of these vehicles was performed in conformance with the specifications given in the Federal Register. These specifications allow for a major tune-up after 24,000 miles, but little other maintenance.

Prototype surveillance fleet vehicles were tested for exhaust emissions using the Federal coldstart emission tests at intervals of 3,000-4,000 miles. These vehicles were scheduled to be serviced in accordance with the maintenance schedule supplied in the manufacturer's Application for Certification.

In reviewing the maintenance data on these vehicles, it was found that carburetors, distributors, air injection system components, timing, and idle specifications were oftentimes changed by the manufacturer or dealer to incorporate latest production vehicle components or specifications into the prototypes. These changes were made to correct vehicle drivability problems reported by Motor Vehicle Compliance Section personnel, or to correct excessive vehicle emissions. Changes made to prototypes were incorporated into all vehicles manufactured. Data on run changes were submitted by the manufacturers to the Certification Branch before the change was made, if it were one which would affect emissions. Maintenance was performed according to manufacturer's recommendations. In addition to scheduled maintenance, vehicles were usually serviced whenever their emissions exceeded Federal standards. Complete Federal 7-mode, 7-cycle exhaust emission tests were performed in the EPA laboratories before and after both scheduled and unscheduled engine maintenance.

Production vehicle surveillance fleet vehicles were tested every 3,000-4,000 miles using the Federal cold start test procedure as stipulated in the Federal Register. All vehicles were maintained in accordance with the maintenance schedules outlined in the "Vehicle Owner's Manual" supplied with each car. In addition to scheduled maintenance, all vehicles were serviced whenever their emissions exceeded Federal standards. Furthermore, dealers or manufacturers were allowed to perform any maintenance necessary to put a vehicle back within standards, short of a major engine overhaul. Complete Federal coldstart exhaust emission tests were performed both before and after any engine maintenance.

Although the substantive conclusions which can be drawn from the In-House Surveillance Program are somewhat limited because of the small sample size present (122 vehicles) and the variety of maintenance practices employed during the program, several conclusions arise from this data. First, it appears that for the vehicles tested during this program, manufacturers did not critically tune 4,000-mile certification vehicles to meet emission standards. Second, vehicles in the prototype surveillance fleet did not perform as well, with respect to exhaust emissions, as did vehicles in the manufacturer's test track durability fleet. Finally, tests done during this program indicate that vehicle maintenance, if correctly performed and backed up by emissions measurements, will keep properly manufactured vehicles below Federal standards for exhaust emissions. It should be emphasized that the above conclusions must be tempered by the limited nature of the In-House data as well as the complicating effects introduced by maintenance practices employed.

One interesting and significant point which arises from the In-House data is illustrated in Figure 3 which presents hydrocarbon emission levels for five relatively homogeneous prototype surveillance vehicles operated over a 32,000-mile period. The significant point to be mentioned about this figure is the nonlinear trend in HC emissions with increasing mileage. A similar phenomenon was also observed for carbon monoxide emissions over this period. The decrease in HC emissions as mileage increased above 16,000 miles could seriously affect the linear regresssion techniques used to determine deterioration factors in the certification procedure. This phenomenon will be further investigated in a future EPA contract dealing with the certification process.

2.6 NO_x BASELINE PROGRAM

2.6.1 Background

The nitrogen oxides (NO_x) baseline program was conducted to acquire emission data necessary so that the EPA could implement required legislation.* These data were collected during the period from March 5, 1971 to April 17, 1971, in Detroit, Michigan. The program involved testing a randomly selected sample of vehicles by the 1972 CVS-C Federal Test Procedure. The number of each engine size and make tested represented, as closely as possible, the estimated percent of this group of vehicles in the population of 1971 vehicles. Emissions of hydrocarbon, HC, carbon monoxide, CO, carbon dioxide, CO_2, and NO_{xc} were determined on a mass basis (gm/mile) for the 243 vehicles in this program.

Prior to testing, each vehicle was inspected and set to manufacturer's recommended specifications. Parameters used were ignition cam dwell, idle RPM, and basic timing. The automatic choke operation was checked and spark plugs were replaced if misfire was detected. The idle mixture was set to specification by manufacturer's recommended procedures. One percent of vehicles inspected were rejected since evidence of tampering with the emission control equipment was apparent. After the tune-up, the vehicle was soaked for a minimum of 12 hours prior to testing.

All studies reported in the original summary report, APTD-1544, were done on vehicles tested in as-received condition. The NO_x Baseline Study, on the other hand, recorded exhaust emission values of vehicles which received maintenance prior to testing. Since it was not known, however, if these vehicles were maintained by their owners before they were brought in for the test, the long term effects of good maintenance could not be deduced. These data can, however, be used to determine the effect of pre-test maintenance on emission results. The comparison of these data with in-use vehicle data obtained on an as-received basis should detect those classes of vehicles which have high emissions because they are out of adjustment. Since the NO_x baseline study was done using the

* Public Law 91-604, "The Clean Air Act," December 1970.

CVS procedure, it seemed appropriate to compare these data with 1971 vehicles from the Study of Emissions from Light Duty Vehicles in Six Cities. Before making comparisons, several assumptions were made. Since 1971 California vehicles were subject to NO_x standards, some manufacturers chose to build two versions of given models of vehicles, one version for California only and one version for the other 49 states. These two groups of vehicles are referred to as one-state vehicles and 49-state vehicles, respectively. Other manufacturers chose to build one version of a model for all 50 states. This group of vehicles is known as 50-state vehicles. The NO_x Baseline Study tested both 49-state vehicles and 50-state vehicles, depending on the model. All vehicles were from the Detroit area. The Six-City Study tested one-state vehicles, 49-state vehicles, and 50-state vehicles depending upon the model vehicle and the test location. Since Denver based vehicles exhibit exhaust emissions unlike those from the other five cities,* these vehicles were eliminated from the comparison with NO_x Baseline Study. Also, the assumption was made that all models tested in California which could have been one-state models were one-state vehicles. This is probably reasonable since one-state models were intended to be sold in California only and all vehicles tested were at most one year old and probably still in the hands of the original owners. These one-state vehicles were eliminated for comparative purposes.

The two studies tested different numbers of each make and engine size. This fact was considered in the choice of analysis. Also, the mean mileages for the two groups differed. The NO_x Baseline vehicles had a mean mileage of 7,100 miles while the Six-City vehicles had a mean mileage of 15,600 miles. A summary of the comparative emission levels for the NO_x Baseline and Six-City programs is given in Table 11. Presented there are the number of vehicles tested, mean mileage, percent of the vehicles tested with HC, CO, and NO_{xc} emission levels at or below the reference levels of 3.4, 39.0 and 3.0 gm/mi, respectively, and the mean emission levels themselves.

* "Automobile Exhaust Emission Surveillance--A Summary" (APTD-1544).

2.6.2 Analysis

Inasmuch as variation in mileage could contribute to variation in emissions, it was thought necessary to adjust both groups to a common mileage point as a prerequisite to assessment of a maintenance effect. Such adjustment can be accomplished by means of regression analysis. Upon application of the regression technique to selected make/engine-size combinations of data,* however, it was found that in all cases the slopes of the regression lines were not significantly different from zero and that adjustment for mileage differences could accordingly be ignored.

The six city and NO_x baseline data were compared to see whether a significant difference existed which could be attributed to maintenance. As was expected, no significant maintenance effect occurred for hydrocarbons or carbon monoxide in any of the subgroups of low mileage vehicles considered. However, a significant reduction in emissions of oxides of nitrogen occurred when vehicles were tuned to specifications before testing. The above observations should be tempered by noting the small sample sizes present which were frequently fewer than ten vehicles. In addition, both groups of vehicles were tested in a relatively low mileage condition. Consequently, the improvement in emission levels due to maintenance would tend to be smaller than if the vehicles had been older. Finally, the magnitude of the observed maintenance effect may have been reduced since some of the "as-received" Six-City vehicles may well have received tune-ups sufficiently close to the time they were tested.

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* It was not considered appropriate to compare groups of data across make since the data were unbalanced and arbitrary weighting of various models could influence results.

TABLES

Table 1

SUMMARY OF SEVEN-MODE AND CVS TEST PROGRAMS

SUMMARY OF SEVEN-MODE TEST PROGRAMS

NATIONAL SURVEILLANCE PROGRAM

	1968-1969 GT. PLAINS	1970 SIX CITY	1971 FOUR CITY	RENTAL VEHICLE	IN-HOUSE SURVEILLANCE
OBJECTIVES:	EVALUATE MILEAGE AND CITY EFFECTS; DETERMINE CONFORMITY WITH CERTIFICATION STANDARDS	DETERMINE CONFORMITY WITH CERTIFICATION STANDARDS; EVALUATE CITY EFFECTS	DETERMINE CONFORMITY WITH CERTIFICATION STANDARDS; EVALUATE CITY EFFECTS, COMPARE LOW MILEAGE AND STABILIZED ENGINE EMISSIONS (PAIRED TESTS).	DETERMINE CONFORMITY OF IN USE VEHICLES WITH CERTIFICATION STANDARDS. PROVIDE PLANNING DATA FOR FUTURE SURVEILLANCE PROGRAMS.	DETERMINE IF PROTOTYPE VEHICLES ARE CRITICALLY TUNED TO MEET FEDERAL STANDARDS; DETERMINE IF PROTOTYPE SURVEILLANCE VEHICLES DIFFER IN EMISSIONS FROM DURABILITY VEHICLES FLEET. DETERMINE IF MANUFACTURERS RECOMMENDED EMISSIONS MAINTENANCE PRACTICES ARE ADEQUATE OVER 50,000 MILE VEHICLE LIFETIME.
BASIC TEST PROCEDURES:	7 X 7 FTP IN ACCORDANCE WITH FEDERAL REGISTER, VOL. 31, NO. 61 (PART II), MARCH 30, 1966; EACH VEHICLE TESTED 3 TIMES, INITIALLY AND AT EACH OF TWO 4,000-MILE INTERVALS.	7 X 7 FTP IN ACCORDANCE WITH FEDERAL REGISTER, VOL. 33, NO. 108, JUNE 4, 1968 (PART II); EACH VEHICLE TESTED ONCE (MINIMUM MILEAGE REQUIREMENT 4,000 MI.).	7 X 7 FTP IN ACCORDANCE WITH FEDERAL REGISTER, VOL. 33, NO. 108, JUNE 4, 1968 (PART II); TWO PAIRED TESTS PER VEHICLE: LOW MILEAGE ENGINE (50 MILES) AND STABILIZED ENGINE (4,000-7,000 MILES).	7 x 7 FTP IN ACCORDANCE WITH FEDERAL REGISTER, VOL. 31, NO. 61, MARCH 30, 1966. EACH RENTAL VEHICLE TESTED ONCE IN "AS RECEIVED" CONDITION.	7 x 7 FTP IN ACCORDANCE WITH FEDERAL REGISTER, VOL. 31, NO. 61, MARCH 30, 1966. IF EMISSIONS EXCEEDED ALLOWABLE LEVELS VEHICLE TUNED AND RETESTED.
INSTRUMENTATION:	NON-DISPERSIVE INFRARED (NDIR) APPARATUS.	NON-DISPERSIVE INFRARED (NDIR) APPARATUS.	NON-DISPERSIVE INFRARED (NDIR) APPARATUS.	NON-DISPERSIVE INFRARED APPARATUS (NDIR)	NON-DISPERSIVE INFRARED APPARATUS (NDIR)
CITIES:	KANSAS CITY AND HOUSTON	KANSAS CITY, HOUSTON, LOS ANGELES, DETROIT, DENVER, WASHINGTON	HOUSTON, LOS ANGELES, DETROIT AND DENVER	LOS ANGELES, DETROIT	DETROIT
EMISSION STANDARDS:	275 ppm HC, 1.50% CO (410 ppm HC, 2.30% CO FOR VW)	2.2 GRAMS/MI. HC, 23.0 GRAMS/MI CO	2.2 GRAMS/MI. HC, 23.0 GRAMS/MI. CO.	2.75 PPM HC, 1.50% CO (410 PPM HC, 2.30% FOR VW)	2.75 PPM HC, 1.50% CO (410 PPM HC, 2.30% CO FOR VW
TOTAL VEHICLES TESTED:	1949	2181	389	705	122 (45 PROTOTYPE, 32 PRODUCTION, 45 DURABILITY)

SUMMARY OF CVS TEST PROGRAMS

	SIX-CITY SURVEILLANCE PROGRAM - 1957-1971 MODEL VEHICLES	NO_x BASELINE PROGRAM - 1971 MODEL VEHICLES
OBJECTIVES:	DETERMINE CONTRIBUTION TO AIR POLLUTION BY VEHICLE POPULATION RESPONSIBLE FOR 95% OF VEHICLE EXHAUST EMISSION (CIRCA 1971); COLLECT EMISSIONS DATA DURING STEADY-STATE MODES, ACCEL/DECEL DRIVING CYCLE; EVALUATE CITY EFFECTS; COLLECT EVAPORATIVE EMISSIONS DATA.	ACQUIRE BASELINE NO_x DATA FOR IMPLEMENTATION OF PUBLIC LAW 91-604, "THE CLEAN AIR ACT," DECEMBER 1970.
BASIC TEST PROCEDURES:	1972 FTP (CVS-C) AND 1975 FTP (CVS-CH). IN ACCORDANCE WITH FEDERAL REGISTER, VOL. 35, NO. 219, NOV. 10, 1970; VOL. 36, NO. 55, MARCH 20, 1971; VOL. 36, NO. 128, JULY 2, 1971. EACH VEHICLE TESTED ONCE (EXCEPT FOR SUBSET OF REPLICATES). EVAPORATIVE TESTS BY SHED TECHNIQUE (SAE J71). VEHICLES TESTED IN "AS-RECEIVED" CONDITION AND ANY MEASUREMENT OF IDLE SPEED TIMING, ETC. MADE ONLY AFTER VEHICLE TESTED.	1972 FTP (CVS-C). IN ACCORDANCE WITH FEDERAL REGISTER, VOL. 35, NO. 219, NOV. 10, 1970; VOL. 36, NO. 55, MARCH 20, 1971; VOL. 36, NO. 128, JULY 2, 1971. EACH VEHICLE TESTED ONCE AFTER BEING TUNED TO MANUFACTURERS SPECS. IF EVIDENCE OF TAMPERING WITH EMISSION CONTROL SYSTEM FOUND, VEHICLE WAS REJECTED.
INSTRUMENTATION	HC – FLAME IONIZATION ANALYZER CO, CO_2 – NON-DISPERSIVE INFRARED (NDIR) NO, NO_X – CHEMILUMINESCENT ANALYZER	HC – FLAME IONIZATION ANALYZER CO, CO_2 – NON-DISPERSIVE INFRARED (NDIR) NO, NO_x – CHEMILUMINESCENT ANALYZER
CITIES:	HOUSTON, LOS ANGELES, DENVER, CHICAGO, ST. LOUIS, AND WASHINGTON, D. C.	DETROIT
TOTAL VEHICLES TESTED:	1020	243

Table 2

SUMMARY OF EMISSIONS (ARITHMETIC MEANS)
FOR 1968 AND 1969 MODEL VEHICLES

	HYDROCARBONS		CARBON MONOXIDE		NO_{x_c}	
	ppm	gm/mi	Percent	gm/mi	ppm	gm/mi
1968 MODEL VEHICLES						
KANSAS CITY	320	3.81	2.04	46.3	1389	4.69
HOUSTON	385	4.48	2.25	51.3	1145	4.50
1969 MODEL VEHICLES						
KANSAS CITY	299	3.65	1.81	42.4	1562	5.34
HOUSTON	306	3.67	1.92	44.1	1337	5.33

68-69 STANDARDS: HC-275 ppm, CO-1.5% (HC-410 ppm, CO-2.3% FOR VOLKS)

Table 3

SUMMARY OF EMISSIONS (ARITHMETIC MEANS) FOR 1970 MODEL VEHICLES

	HYDROCARBONS gms/mi	CARBON MONOXIDE gms/mi	NO_{x_c} gms/mi
KANSAS CITY	2.66	33.9	4.63
HOUSTON	3.00	40.5	4.69
LOS ANGELES	2.46	32.5	5.04
DETROIT	3.08	39.4	4.27
WASHINGTON	2.99	29.8	4.82
DENVER	4.25	65.1	3.83
TOTAL EXCLUDING DENVER	2.83	35.3	4.69

70-71 STANDARDS: HC-2.2 gm/mi, CO-23 gm/mi

Table 4

SUMMARY OF EMISSIONS (ARITHMETIC MEANS)
FOR 1971 MODEL VEHICLES

	HYDROCARBONS gms/mi	CARBON MONOXIDE gms/mi	NO_{x_c} gms/mi
LOW MILEAGE ENGINES - PHASE I			
HOUSTON	1.58	27.1	3.35
LOS ANGELES	1.29	19.7	3.07
DETROIT	1.77	28.5	3.08
DENVER	2.63	64.0	2.86
STABILIZED ENGINES – PHASE 2			
HOUSTON	2.41	33.7	4.27
LOS ANGELES	1.68	25.2	3.41
DETROIT	2.77	31.5	3.80
DENVER	3.16	45.2	3.19

70-71 STANDARDS: HC-2.2 gm/mi, CO-23 gm/mi

Table 5

SUMMARY OF SEVEN-MODE EMISSIONS TESTS 1968-1971 MODEL VEHICLES

MANU-FACTURER	N	MEAN MILES (K)	% BELOW STANDARDS			HYDROCARBONS gm/mi				CARBON MONOXIDEgm/mi				NO_{X_c} gm/mi			
			HC	CO	BOTH	ARITHMETIC MEAN	SD	GEOMETRIC MEAN	SD	ARITHMETIC MEAN	SD	GEOMETRIC MEAN	SD	ARITHMETIC MEAN	SD	GEOMETRIC MEAN	SD
68 TOTAL	967	34.3	46	35	23	4.13	3.16	3.66	1.56	49.0	29.2	41.1	1.82	4.60	1.94	4.11	1.70
69 TOTAL	982	23.2	53	42	30	3.66	1.99	3.38	1.46	43.3	23.0	37.9	1.69	5.33	1.83	4.95	1.53
70 EXCLUDING DENVER	1829	11.0	32	35	19	2.83	1.53	2.60	1.48	35.3	21.9	29.2	1.89	4.69	1.73	4.36	1.49
70 DENVER	352	10.1	5	3	.3	4.25	2.39	3.92	1.45	65.1	29.3	59.1	1.56	3.83	1.51	3.53	1.52
71 PHASE 1 EXCLUDING DENVER	225	0.25	87	60	58	1.47	0.74	1.34	1.55	23.7	15.0	19.5	1.89	3.16	1.10	2.99	1.39
71 PHASE 1 DENVER	144	0.21	36	2	1	2.63	1.03	2.46	1.46	64.0	27.6	58.5	1.54	2.86	1.42	2.54	1.63
71 PHASE 2 EXCLUDING DENVER	225	5.4	59	49	38	2.12	1.22	1.86	1.68	29.0	20.0	23.0	2.02	3.74	1.52	3.46	1.49
71 PHASE 2 DENVER	144	5.2	29	10	6	3.16	4.01	2.71	1.56	45.2	22.8	39.8	1.71	3.19	1.41	2.88	1.61

Table 6

COMPOSITE EMISSION LEVELS AS DETERMINED BY 1972 TEST PROCEDURES (EXCLUDING DENVER)

YEAR	N	MEAN MILES (K)	% BELOW LEVEL †			HYDROCARBONS gm/mi				CARBON MONOXIDE gm/mi				NO_{X_c} gm/mi			
			HC	CO	NO_{X_c}	ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD
PRE-68																	
57	20	80.0	0	10	40	7.07	2.32	6.72	1.39	80.3	33.2	73.5	1.57	3.89	2.15	3.24	1.98
58	20	86.7	5	5	50	10.74	10.65	8.58	1.81	85.2	38.6	76.5	1.65	3.70	2.44	2.92	2.14
59	21	79.7	0	19	33	11.37	8.70	9.19	1.89	81.6	45.0	70.7	1.74	4.47	2.39	3.71	1.99
60	16	65.4	13	13	50	9.53	8.48	7.40	2.01	86.8	44.8	75.0	1.80	3.94	2.37	3.26	1.94
61	23	67.6	17	17	61	6.49	3.64	5.69	1.67	84.6	59.8	66.5	2.06	3.12	2.25	2.53	1.97
62	38	72.7	5	8	40	9.57	6.87	7.83	1.88	85.5	38.8	77.5	1.60	3.34	1.57	2.93	1.75
63	55	77.3	0	2	47	10.26	8.11	8.85	1.62	105.8	41.8	98.1	1.49	3.63	2.15	3.07	1.81
64	64	72.1	0	3	42	8.14	3.70	7.49	1.49	91.0	41.4	82.3	1.60	3.61	1.71	3.19	1.70
65	80	62.9	1	4	53	12.17	13.29	9.24	1.89	97.9	40.7	90.0	1.52	3.27	1.66	2.87	1.70
66*	67	61.8	2	3	45	9.20	6.18	8.07	1.61	103.3	43.2	94.3	1.56	3.44	1.71	3.01	1.75
67*	54	54.6	0	2	46	8.19	3.61	7.51	1.51	103.5	47.7	94.5	1.54	3.26	1.45	2.90	1.71
TOTAL PRE-68*	458	68.6	2	5	46	9.56	8.06	8.02	1.70	95.2	43.5	85.6	1.61	3.51	1.87	3.01	1.79
CALIFORNIA																	
66	16	65.7	19	19	38	8.72	8.64	6.62	2.00	78.1	38.3	70.2	1.61	3.23	1.44	2.91	1.64
67	17	56.4	12	6	53	6.22	3.52	5.52	1.63	81.4	38.0	74.6	1.52	3.30	1.45	2.98	1.61
CONTROLLED																	
1968	84	46.4	20	25	35	6.25	7.10	5.13	1.70	78.6	59.0	63.8	1.86	4.22	1.88	3.75	1.69
1969	89	39.5	12	10	11	5.96	4.72	5.19	1.59	73.8	36.2	66.0	1.62	5.32	2.01	4.93	1.50
1970	86	28.7	30	33	9	4.41	2.18	4.08	1.47	56.5	27.2	50.2	1.66	4.93	1.64	4.66	1.41
1971	101	15.6	61	46	13	3.44	1.38	3.21	1.45	47.5	27.2	40.4	1.80	4.75	1.73	4.42	1.48
TOTAL 68-71	360	31.9	32	29	17	4.96	4.50	4.27	1.62	63.5	40.9	53.5	1.80	4.81	1.85	4.43	1.54

* EXCLUDING CALIFORNIA 66-67

† HC - 3.4 gm/mi
CO - 39.0 gm/mi
NO_{X_c} - 3.0 gm/mi

Table 7

COMPOSITE EMISSION LEVELS AS DETERMINED BY 1972 TEST PROCEDURE (DENVER ONLY)

YEAR	N	MEAN MILES (K)	% BELOW LEVEL*			HYDROCARBONS gm/mi				CARBON MONOXIDE gm/mi				NO_{X_c} gm/mi			
			HC	CO	NO_{X_c}	ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD
TOTAL PRE-68	97	65.1	0	1	83	11.31	6.13	10.27	1.51	136.8	55.5	125.8	1.53	1.93	1.11	1.66	1.76
1968	18	42.1	0	0	83	8.74	4.08	8.00	1.53	122.9	66.1	109.9	1.60	2.38	1.11	2.19	1.50
1969	17	38.9	12	6	65	7.74	4.89	6.49	1.89	92.6	57.7	79.7	1.72	2.52	1.21	2.20	1.78
1970	17	26.0	6	0	59	7.85	4.23	6.91	1.70	111.2	39.8	103.4	1.45	2.72	1.13	2.48	1.59
1971	20	15.1	0	5	55	6.80	2.08	6.52	1.35	102.7	40.6	94.5	1.54	3.06	1.56	2.75	1.59
TOTAL 68-71	72	30.1	4	3	65	7.73	3.89	6.93	1.62	106.4	52.0	95.6	1.59	2.68	1.28	2.41	1.62

* HC - 3.4 gm/mi
CO - 39.0 gm/mi
NO_{X_c} - 3.0 gm/mi

Table 8

COMPOSITE EMISSION LEVELS AS DETERMINED BY 1975 TEST PROCEDURES (EXCLUDING DENVER)

YEAR	N	MEAN MILES (K)	% BELOW LEVEL †			HYDROCARBONS gm/mi				CARBON MONOXIDE gm/mi				NO_{X_c} gm/mi			
			HC	CO	NO_{X_c}	ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD
PRE-68																	
57	20	80.0	0	5	40	6.63	2.32	6.25	1.42	81.4	30.7	75.6	1.50	3.83	2.19	3.17	1.99
58	20	86.7	5	10	45	10.03	10.20	7.93	1.84	78.2	36.8	69.7	1.67	3.62	2.31	2.88	2.12
59	21	79.7	0	19	38	10.80	8.24	8.70	1.88	77.3	45.9	65.8	1.79	4.49	2.55	3.64	2.08
60	16	65.4	13	19	56	8.79	8.09	6.82	1.98	81.6	43.4	70.0	1.83	3.94	2.48	3.18	2.02
61	23	67.6	26	17	61	5.94	3.27	5.20	1.68	79.7	56.8	61.8	2.12	3.06	2.35	2.43	2.04
62	38	72.7	5	8	49	8.87	6.84	7.09	1.94	78.0	36.6	69.6	1.67	3.33	1.57	2.91	1.76
63	55	77.3	0	2	53	9.43	7.76	8.04	1.65	96.5	38.4	89.2	1.50	3.64	2.15	3.08	1.82
64	64	72.1	2	13	39	7.28	3.29	6.68	1.50	81.7	38.8	73.1	1.64	3.66	1.77	3.24	1.68
65	80	62.9	0	3	49	11.18	12.62	8.36	1.92	87.9	36.8	80.8	1.51	3.37	1.66	2.97	1.70
66*	67	61.8	5	10	42	8.26	5.48	7.21	1.63	91.0	38.9	82.3	1.60	3.57	1.82	3.13	1.72
67*	54	54.6	2	6	48	7.38	3.28	6.75	1.52	93.6	44.9	85.1	1.55	3.28	1.46	2.93	1.68
TOTAL PRE-68*	458	68.5	4	8	46	8.74	7.63	7.26	1.73	86.5	40.3	77.4	1.63	3.54	1.91	3.04	1.79
CALIFORNIA																	
66	16	65.7	19	25	31	7.84	8.34	5.81	2.03	65.2	36.6	56.8	1.72	3.40	1.54	3.04	1.68
67	17	56.4	24	12	41	5.33	3.52	4.60	1.70	67.2	37.0	59.7	1.63	3.42	1.50	3.08	1.65
CONTROLLED																	
1968	84	46.4	31	34	26	5.54	7.07	4.45	1.73	67.8	57.5	52.7	1.96	4.34	1.92	3.85	1.71
1969	89	39.5	20	21	10	5.19	4.26	4.53	1.56	61.7	31.0	55.0	1.63	5.45	2.02	5.06	1.49
1970	86	28.7	41	44	11	3.90	1.95	3.60	1.46	48.2	24.7	42.0	1.72	5.05	1.67	4.78	1.40
1971	101	15.6	70	60	15	3.06	1.26	2.85	1.44	40.1	24.5	33.5	1.86	4.81	1.78	4.47	1.49
TOTAL 68-71	360	31.9	42	40	15	4.37	4.30	3.75	1.61	53.9	37.9	44.4	1.86	4.92	1.88	4.52	1.54

* EXCLUDING CALIFORNIA 66-67

† HC · 3.4 gm/mi
CO · 39.0 gm/mi
NO_{X_c} · 3.0 gm/mi

Table 9

COMPOSITE EMISSION LEVELS AS DETERMINED BY 1975 TEST PROCEDURE (DENVER ONLY)

YEAR	N	MEAN MILES (K)	% BELOW LEVEL*			HYDROCARBONS gm/mi				CARBON MONOXIDE gm/mi				NO_{X_c} gm/mi			
			HC	CO	NO_{X_c}	ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD	ARITHMETIC MEAN	ARITHMETIC SD	GEOMETRIC MEAN	GEOMETRIC SD
TOTAL PRE-68	97	65.1	0	0	83	10.16	5.59	9.24	1.49	126.9	48.5	117.4	1.51	1.89	1.12	1.61	1.79
1968	18	42.1	0	0	83	7.34	2.73	6.87	1.46	109.2	52.5	99.7	1.53	2.20	0.80	2.07	1.43
1969	17	38.9	18	12	65	6.31	3.47	5.43	1.84	76.4	47.7	65.6	1.74	2.59	1.24	2.27	1.76
1970	17	26.0	12	0	53	6.71	3.85	5.93	1.66	94.8	33.8	89.3	1.43	2.78	1.11	2.55	1.57
1971	20	15.1	5	5	50	5.68	1.45	5.51	1.29	91.1	37.6	83.1	1.58	3.08	1.60	2.75	1.62
TOTAL 68-71	72	30.1	8	4	63	6.46	2.97	5.89	1.57	92.2	43.7	83.0	1.60	2.67	1.25	2.40	1.61

* HC · 3.4 gm/mi
CO · 39.0 gm/mi
NO_{X_c} · 3.0 gm/mi

Table 10

COMPARATIVE MEAN EMISSION LEVELS
RENTAL VEHICLE AND 1968-1969 GREAT PLAINS SURVEILLANCE PROGRAMS

PROGRAM	MANUFACTURER MAKE	CID	N	MEAN MILES (K)	% BELOW STANDARDS HC	% BELOW STANDARDS CO	% BELOW STANDARDS BOTH	HC MEAN PPM	CO MEAN %
RENTAL	CHRY CORP	225	20	14.2	85	55	55	215	1.71
GT.PLAINS			75	27.4	55	40	28	314	1.97
RENTAL	CHRY CORP	318	28	8.1	82	86	75	240	1.18
GT.PLAINS			80	31.9	39	33	21	342	1.92
RENTAL	FOMOCO	302	95	10.0	37	80	37	314	1.23
GT.PLAINS			79	30.2	15	68	11	413	1.37
RENTAL	FOMOCO	390	72	12.5	75	76	64	252	1.36
GT.PLAINS			80	31.8	51	53	40	286	1.57
RENTAL	CHEVROLET	307	36	12.0	25	44	16	355	1.56
GT.PLAINS			81	27.9	20	31	9	414	1.87
RENTAL	1968 CHEV	327	48	17.0	58	42	29	289	1.76
GT.PLAINS			80	32.5	13	8	1	440	3.26
RENTAL	PONTIAC	350	21	11.2	86	38	34	215	1.61
GT.PLAINS			75	25.8	59	43	35	257	1.62
RENTAL	PONTIAC	400	21	7.1	100	48	48	177	1.50
GT.PLAINS			78	28.0	87	37	35	239	1.61
RENTAL	VOLKS	91	30	11.5	63	80	53	391	2.17
GT.PLAINS			80	26.9	43	59	35	509	2.37

*** APPLICABLE STANDARDS:HC-275PPM CO-1.5% (410PPM,2.3% FOR VOLKS) ***

Table 11

COMPARATIVE EMISSION LEVELS
NOX BASELINE PROGRAM VS SIX CITY PROGRAM

MANUFACTURER / MAKE	N		MEAN MILES (K)		HC % BELOW 3.4 GM/MI		CO % BELOW 39. GM/MI		NOX % BELOW 3.0 GM/MI		HYDROCARBONS GM/MI				CARBON MONOXIDE GM/MI				NOX GM/MI			
											NOX BASE		SIX CITY		NOX BASE		SIX CITY		NOX BASE		SIX CITY	
	NOX BASE	SIX CITY	NOX BASE	SIX CITY	NOX BASE	SIX CITY	NOX BASE	SIX CITY	NOX BASE	SIX CITY	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
49 STATE VEHICLES																						
AMC	9	3	6.1	10.2	89	100	67	100	78	0	2.73	0.70	1.99	0.42	36.2	14.7	23.9	9.3	2.43	0.80	3.16	0.05
CHRY CORP	69	8	6.6	17.3	43	25	31	12	32	0	3.67	0.85	4.34	1.37	50.9	21.0	61.2	18.1	3.51	1.45	6.06	1.55
PLYM	31	4	6.6	11.8	58	25	43	25	35	0	3.38	0.81	4.67	1.64	44.2	21.6	60.5	21.1	3.34	1.31	6.39	1.90
DODGE	17	3	6.0	24.2	47	66	29	0	24	0	3.60	0.81	3.46	0.55	51.3	19.7	54.7	13.0	3.42	1.35	5.60	1.58
CHRY	21	1	7.0	18.1	19	0	14	0	33	0	4.15	0.75	5.69		60.4	17.9	83.5		3.85	1.73	6.13	
FOMOCO	87	20	6.9	16.2	25	50	32	45	9	5	4.02	0.95	3.65	1.21	49.1	17.9	50.2	33.5	4.55	1.40	6.03	1.88
FORD	62	15	6.8	16.5	24	60	29	47	10	7	4.08	0.96	3.55	1.30	50.5	17.4	43.3	20.1	4.51	1.42	6.24	1.60
MERC	22	4	7.1	14.9	23	25	41	50	9	0	3.98	0.94	3.58	0.53	45.6	18.5	45.8	11.8	4.70	1.42	5.96	2.75
LINC	3	1	6.7	17.0	67	0	33	0	0	0	3.12	0.62	5.41		45.5	27.3	170.5		4.13	1.04	3.12	
50 STATE VEHICLES																						
AMC	3	2	5.7	15.1	67	100	67	100	100	0	3.18	0.87	2.83	0.34	34.6	6.5	27.9	2.4	2.31	0.73	3.84	0.89
FOMOCO	6	5	7.9	18.6	33	80	17	60	100	20	3.74	0.75	3.86	3.56	49.4	13.4	30.5	16.5	2.10	0.43	4.03	1.51
FORD	5	5	8.1	18.6	40	80	20	60	100	20	3.66	0.81	3.86	3.56	47.6	14.1	30.5	16.5	2.03	0.45	4.03	1.51
MERC	1	0	6.8		0		0		100		4.14				58.8				2.43			
GM	63	48	8.0	15.1	60	58	52	40	44	15	3.39	1.28	3.32	1.16	41.5	22.0	49.8	27.2	3.16	0.97	4.44	1.48
CHEV	36	27	7.1	14.8	64	63	69	44	50	19	3.25	1.05	3.14	1.12	34.9	20.0	45.6	25.2	3.02	0.67	4.34	1.45
PONT	8	8	10.9	18.3	25	25	38	25	38	12	4.51	1.47	4.09	0.94	56.6	31.1	55.7	30.7	2.81	0.95	4.49	1.52
OLDS	10	6	9.4	16.4	70	83	30	50	40	0	3.33	1.59	2.82	0.65	42.2	14.1	37.2	14.7	3.68	1.52	5.00	0.88
BUICK	7	5	7.8	12.8	57	40	29	20	29	20	3.50	1.11	4.11	1.49	54.2	20.7	82.4	28.2	3.62	0.99	3.87	1.75
CADI	2	2	6.2	7.4	100	100	0	50	50	0	1.42	0.24	2.16	0.02	51.6	4.6	40.2	15.2	2.77	1.80	5.35	3.25
VOLKS	6	3	9.2	17.3	100	33	33	33	100	100	2.61	0.45	4.90	1.46	44.6	9.7	58.6	28.3	1.46	0.43	4.89	0.43

***** DATA BASED UPON 1972 CVS TEST PROCEDURE *****

FIGURES

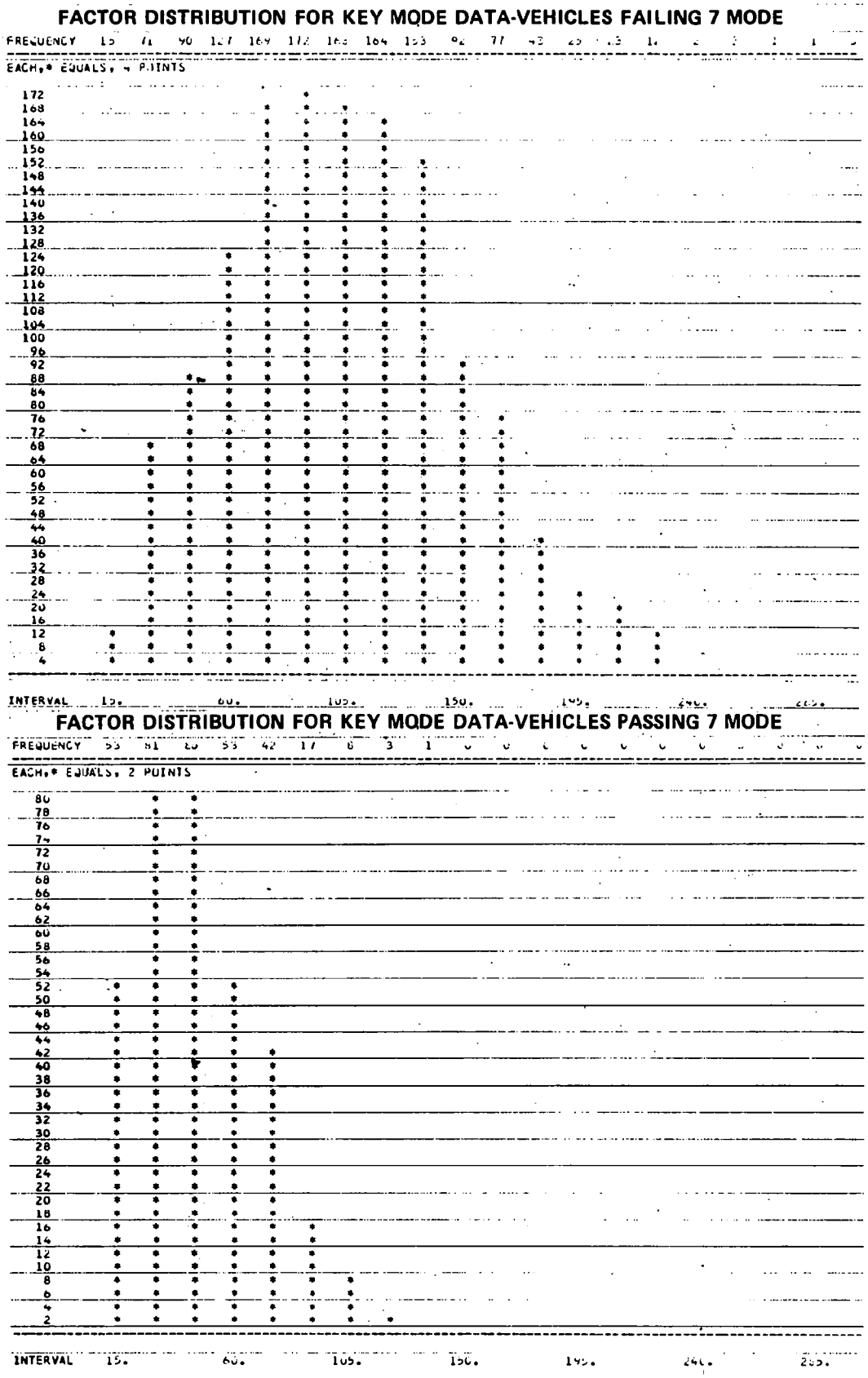

Figure 1 HISTOGRAM OF DISCRIMINANT FACTORS FOR KEY MODE DATA – PASS SEVEN MODE/FAIL SEVEN MODE

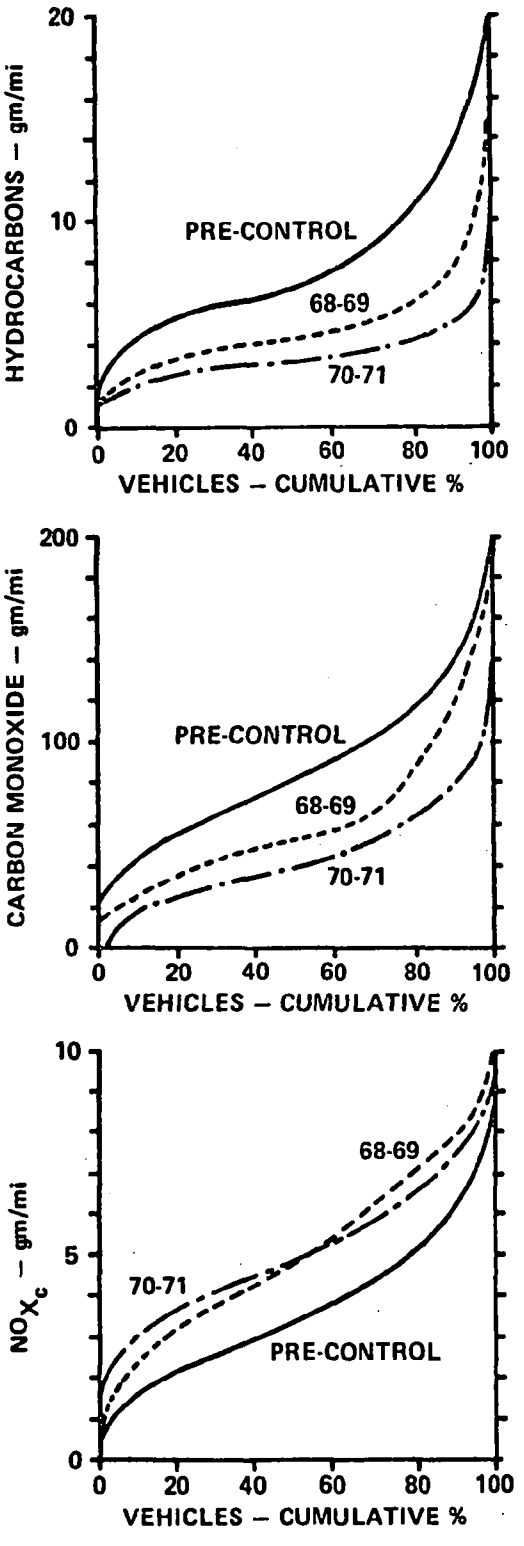

Figure 2 1975 CVS EMISSION LEVELS VS. CUMULATIVE PERCENTAGE OF TEST VEHICLES FOR PRE-CONTROL, 68-69 AND 70-71 MODEL YEARS (ALL CITIES EXCLUDING DENVER)

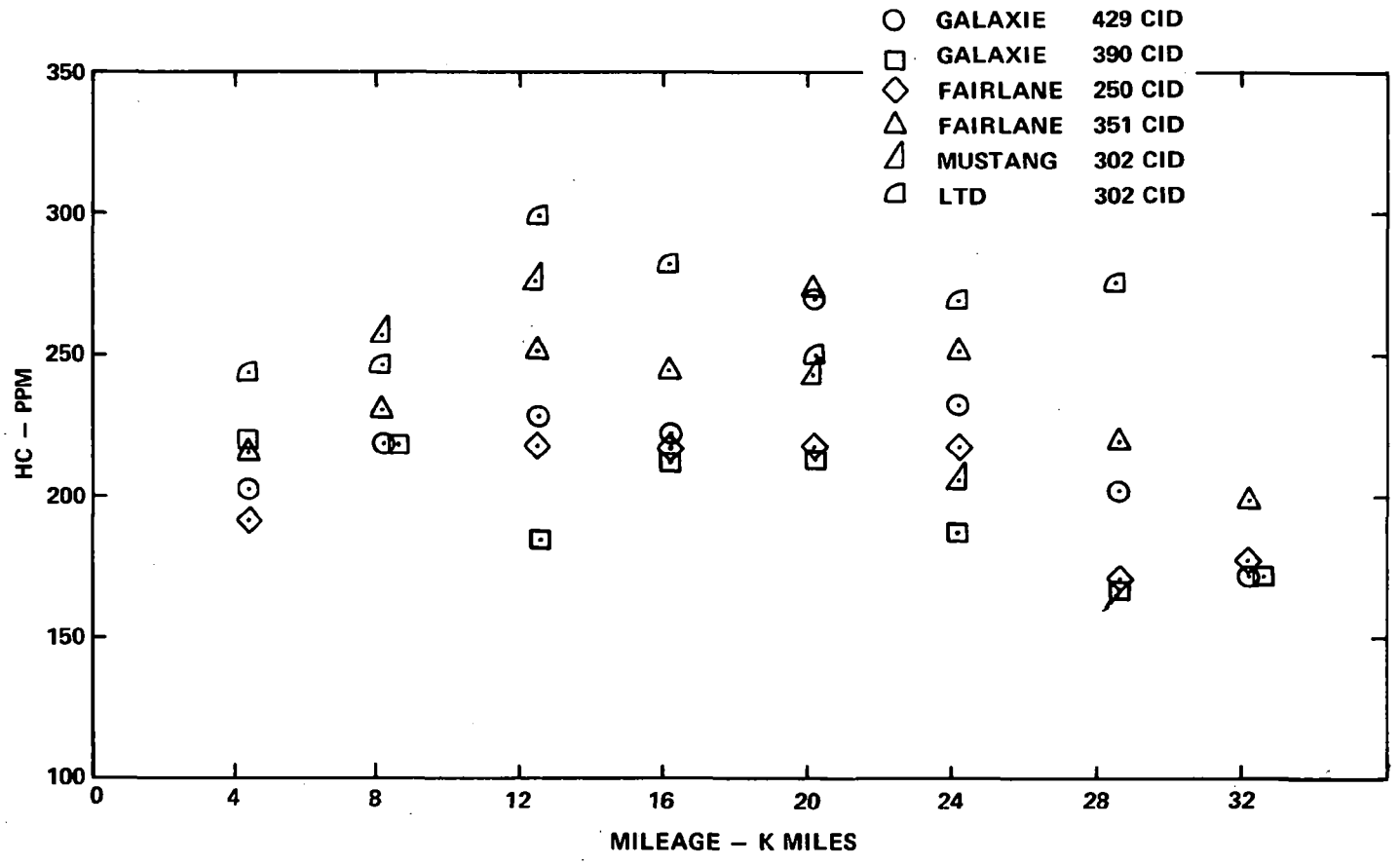

Figure 3 HYDROCARBON EMISSIONS vs MILEAGE – FIVE 1969 MODEL IN-HOUSE SURVEILLANCE FORDS