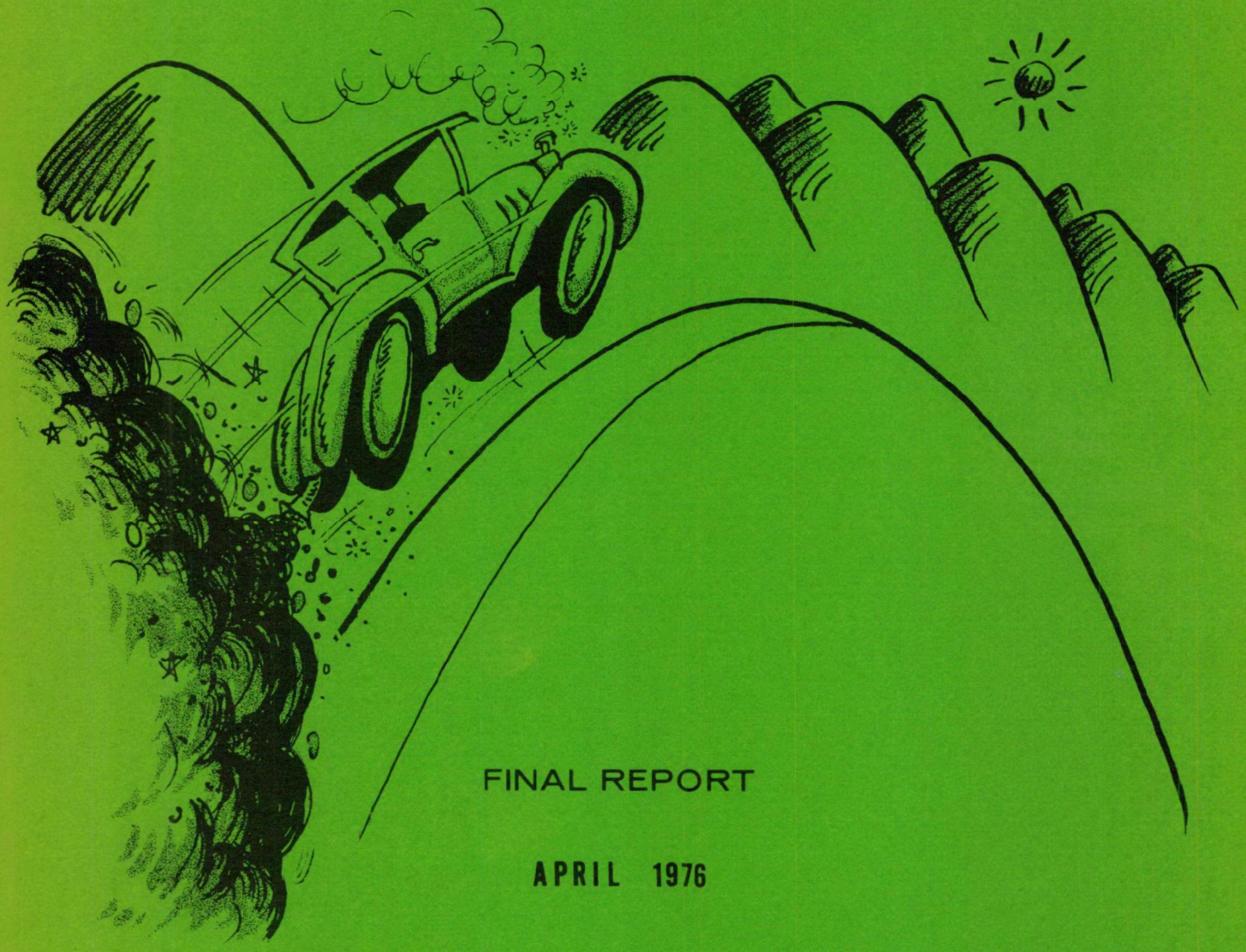
HIGH ALTITUDE VEHICULAR EMISSION CONTROL PROGRAM

VOLUME VII. EXPERIMENTAL CHARACTERIZATION OF VEHICULAR EMISSION AND ENGINE DETERIORATION



FINAL REPORT

APRIL 1976

PREPARED FOR:

STATE OF COLORADO
DEPARTMENT OF HEALTH
DENVER, COLORADO 80220

ENVIRONMENTAL PROTECTION AGENCY
REGION VIII
DENVER, COLORADO 80203

TRW

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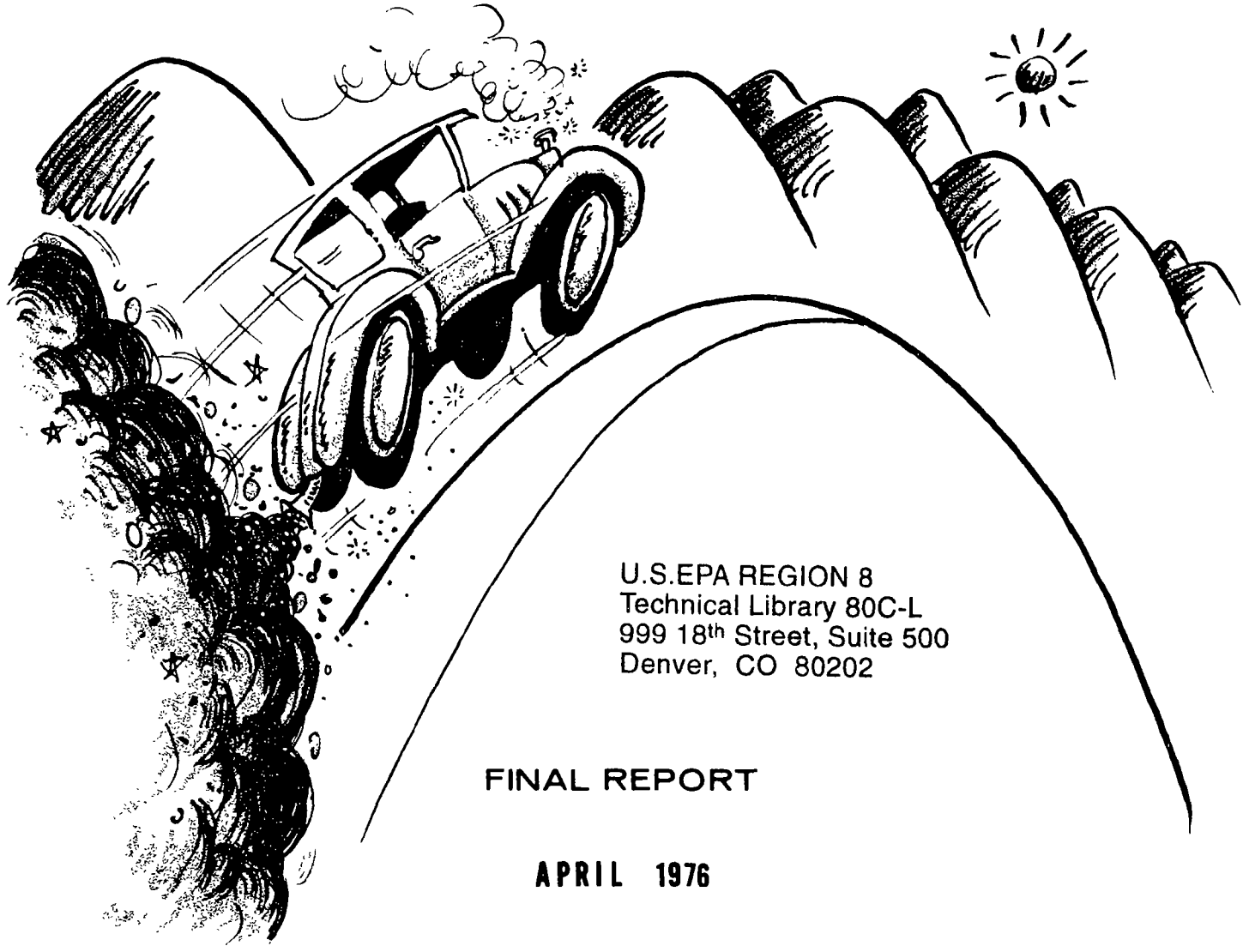

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The results and conclusions presented are based on the data developed from the deterioration test program conducted by Automotive Testing Laboratories. The extent to which these data are not representative of the vehicle population in the Denver area, however, could have a significant impact on the resultant conclusions and recommendations.

PREFACE

This report, "High Altitude Vehicular Emission Control Program," consists of seven volumes. Listed in the following are the subtitles given for each volume:

- Volume I - Executive Summary, Final Report, January 1974.
- Volume II - Experimental Characterization of Idle Inspection, Exhaust Control Retrofit and Mandatory Engine Maintenance, Final Report, December, 1973.
- Volume III - Impact of Altitude on Vehicular Exhaust Emissions, Final Report, December, 1973.
- Volume IV - Analysis of Experimental Results, Final Report, December, 1973.
- Volume V - Development of Techniques, Criteria and Standards to Implement a Vehicle Inspection, Maintenance and Modification Program, Final Report December, 1973.
- Volume VI - The Data Base, Final Report, June, 1975.
- Volume VII - Experimental Characterization of Vehicular Emission and Engine Deterioration, Final Report, April, 1976.

The first volume summarizes the general objectives, approach and results of the study. The second volume presents a detailed description of the experimental programs conducted to define the data base. Volume III reports the methods and analysis used in developing the basic relationships between mass emissions and altitude. A quantitative analysis of the results from the experimental program is presented in Volume IV. The fifth volume provides an analysis of the techniques and criteria required in establishing a vehicle emission control program for the Denver area. The actual data base developed from the experimental

program is given in Volume VI. Lastly, this volume reports the results of the six and twelve month deterioration program.

The work presented herein is the product of a joint effort by two consulting firms. Automotive Testing Laboratories (ATL) was responsible for the design and implementation of the basic experiments. TRW provided the data management and analysis of the experimental results.

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1.0 SUMMARY AND CONCLUSIONS

This report highlights the findings of the high altitude emission deterioration program. It represents an update of Volume VII, originally issued as an "Interim Report" in July 1974. Data from the planned one year program is now available and has been analyzed to derive the results presented herein. The format duplicates that of the original volume and where it is deemed useful, data contained in the six month report has been repeated in this update.

- Unauthorized Maintenance: One out of four vehicle owners returning for retest at the six month point of the program violated the no servicing agreement, having adjusted or replaced one or more of the fourteen engine components known to affect emission performance. During the second six months, no restrictions were placed on owner servicing; at the twelve month test point three out of four owners had serviced one or more of the controlled items. The net effect of this uncontrolled service is to severely limit the accuracy of calculated deterioration rates.

- Deterioration Rates:

  Six months:

  Reductions in hydrocarbons and carbon monoxide resulting from initial maintenance procedures were cancelled by engine deterioration after six months. Calculated rates for 165 vehicles:

Hydrocarbons	0.7 gm/mile/1000 miles
Carbon Monoxide	1.0 gm/mile/1000 miles

  (The unauthorized maintenance detected after six months tends to cause underestimation of the deterioration rates).

Twelve months:

Owner servicing during the second six months of the study completely swamped the deterioration effects. Hydrocarbon and carbon monoxide emissions were found to be lower at the twelve month point than had been measured at six months.

- Sample Attrition: At the six month point two thirds of the original 250 vehicle test fleet were available for retest. At the end of one year the number of vehicles available for retest was 109 of the original 250 (44%). Vehicle attrition was approximately evenly distributed with model year distributions holding within a few percentage points of the initial values throughout the test program.

- Vehicle Mileage: Vehicle miles travelled during each of the two six month segments was found to be well below Colorado Department of Health estimates for average vehicle use. Initially, it was thought that the fuel shortage experienced during the first six months of the study was responsible for the low mileage. The continuing low vehicle mileage throughout the year long program suggests that the vehicle owner volunteers were not typical of the Denver driving public in their driving patterns; perhaps the sample had a disproportionately low number of commuters in its make-up.

- Mandatory vs. Idle Inspection: Neither mode of vehicle treatment was found to give significantly greater emission reductions at the start of the program. Also, at the end of six months, deterioration rates were nearly identical for both fleets, indicating that the more expensive mandatory maintenance treatment is unjustified. The loss of emission reductions at six months for either treatment indicates the need for a semi-annual inspection/maintenance program to achieve and sustain emission reductions.

2.0 INTRODUCTION

A basic unknown in evaluating the cost-effectiveness of vehicular inspection/maintenance is the extent and characteristics of emission deterioration. Studies conducted by TRW have shown that emission deterioration can have a substantial impact on the effectiveness of the selected procedure (e.g., idle inspection).* In an attempt to assess the potential impact of emission deterioration at altitude, an experimental test program was undertaken using 250 vehicles. This project was designed to characterize emission deterioration and engine degradation for vehicles operating in the greater Denver area. The project, involving the re-test of vehicles available at the conclusion of two consecutive six month intervals recently was completed. This report presents an analysis of the results from the twelve month engine deterioration and degradation study.

The primary objective of this study was to develop emission deterioration factors which are to be utilized to evaluate the long term benefits of a mandatory inspection and maintenance program as a strategy for reducing vehicular emissions. A secondary object was to determine the extent of owner tampering, including its impact upon the effectiveness of an inspection/maintenance program, and to determine possible legislative requirements to maintain overall effectiveness of a mandatory program.

* TRW, CAPE-13-68 Research Program (1972).

3.0 PROCEDURES DEVELOPMENT

3.1 PROGRAM DESIGN

The program was designed to utilize a preconditioned and pretested sample of vehicles from which various data, pertinent to program objectives, could be obtained.

A sample of three-hundred 1964 through 1973 model-year vehicles, selected to represent that segment of the Colorado light-duty vehicle (under 6000 lbs GVW) population, was used initially to evaluate idle inspection and maintenance, emission control retrofit and mandatory engine maintenance. This segment represented about 90% of the light-duty vehicle population. All vehicles in the sample were initially subjected to inspection and maintenance. Idle emission inspections were performed at ten selected state licensed motor vehicle safety inspection stations. Station personnel were trained in advance and were required to perform inspection and maintenance of vehicles in accordance with specific procedures. All vehicles were laboratory tested in the as-received condition before delivery to the stations. Vehicles which failed station inspection and were subsequently repaired were re-tested by laboratory procedures to determine the effectiveness of station performance. A segment of the vehicle sample was then utilized to evaluate emission control retrofit and modified tune-up specifications.*

* A more complete description of the basic test procedures can be found in Volume II of this report.

Although three-hundred vehicles comprised the initial sample, the potential size of the sample available for re-test was reduced to about two-hundred and fifty vehicles.* This reduction, numbering about fifty vehicles, came about as a result of an initial loss of several vehicles which had been tested and released to owners prior to start-up of the deterioration study. A number of other vehicles comprising the initial sample were determined to be unsuitable for deterioration study purposes for various other reasons.

During the time interval following initial testing, vehicles comprising the test sample were presumably operated in a typical manner although several existing factors undoubtedly had some impact on mid-point results. The interval (August, 1973 through May, 1974), spanned the winter season with its typically cold weather and presumably had a direct effect on engine warm-up characteristics, mileage accumulation and maintenance requirements. Additionally, the fuel crisis and attendant factors were predominant throughout much of the study interval and are believed to have potentially biasing effects on study results by altering mileage accumulation patterns, fuel preference and overall vehicle useage. The effects of these variables are virtually impossible to evaluate. In any case, the project proceeded according to design.

In planning for the interval which followed initial testing, procedures for handling test vehicles exhibiting undesirable operating characteristics or component failure were devised. A maintenance

* Of the original 250 vehicles, 150 were assigned to the idle inspection fleet and 100 to the mandatory maintenance fleet. These initial group sizes were reduced (the results of attrition) to 87 and 78 vehicles, respectively.

committment was established and communicated to the vehicle owner; a vehicle prematurely returned to the laboratory for repair work was subjected to an on-the-spot inspection to establish the validity of a request for repair. In certain situations, owner dissatisfaction with some aspect of vehicle performance proved to be unfounded. In other situations, a legitimate requirement for maintenance did in fact exist. In the latter case, a loan car was issued and the test vehicle was retained for further testing amd maintenance. In this case, a series of tests identical to those performed initially was conducted, repairs to the vehicle were completed and the vehicle was returned to its owner. Data developed as a result of these procedures were retained for subsequent processing and reporting.

As reported earlier, two hundred and fifty vehicles of the original sample were judged suitable for retest. It was originally anticipated that a significant number of vehicles would be lost to the program for various reasons including transfer of ownership, owner relocation, accidents or negative owner reaction including loss of interest. In this respect an attrition rate of 40 percent was allowed.

After the nominal interval of six months had elapsed, vehicles were recalled for deterioration and degradation testing. An attempt to maintain an initial tolerance of 180 $\pm$ 5 days proved to be impractical and the tolerance was subsequently relaxed to 180 $\pm$ 10 days to maintain a high retest rate.

At the appropriate time, one or more attempts to contact owners whose vehicles qualified for retest were made. As anticipated, a significant number of owners had moved outside the area, had sold the

test vehicles, had expressed dissatisfaction with some aspect of the program or had simply become disinterested. On the other hand, a significant number of vehicles (165) remained available for retest. Testing procedures identical to those performed initially were then conducted. At test completion engine adjustment seals and identification marks on emission related components were inspected and the incoming status of each adjustment and component part was recorded. Data were then processed and compiled.

Throughout the retest phase of the program, laboratory instrumentation and equipment calibration and operating procedures were maintained in accordance with standards applied in the initial program. Quality control tolerances were similarly maintained and procedures relating to data auditing were applied.

At the conclusion of the six month tests, the seals and identification marks were restored where tampering had been detected. Vehicles were returned to their owners for a second six month use period identical to the first with one exception: no maintenance agreement was established with the owner. In general, they were not aware that they would be invited back for retest at the end of the next six month period.

3.2 TEST VEHICLES

Three hundred vehicles were initially selected and utilized to represent the 1964 through 1973 Colorado motor vehicle population. Approximately two hundred and fifty were prepared for the deterioration study phase. As anticipated, a significant level of attrition occurred during

the six month period and one-hundred and sixty-five vehicles were actually submitted for retest. After 12 months, only 109 vehicles remained in the test sample.

3.2.1 Vehicle Sample Composition

Table 1 shows the distribution of vehicles at the program start and at the six and twelve month retest points. Distribution by model year remained fairly stable throughout the program as shown by the "percent of sample" figures. However, in many instances some make-model year combinations were drastically reduced or eliminated by the sample dropouts at either the six or twelve month points.

3.2.2 Vehicle Preparation and Handling

Upon receipt of the vehicle for retest, an inspection of the vehicle exterior, interior and exhaust system was performed to determine incoming status. A loan car was issued to replace the test vehicle and the necessary vehicle agreement forms were completed. The vehicle was then moved to the laboratory for temperature soaking prior to emission testing and engine inspection.

After a minimum soak period of twelve hours, the vehicle fuel supply system was disconnected and reconnected to a laboratory fuel supply system. A batch of summer-grade fuel, utilized for initial testing had been retained and was used to perform the retests. Emission tests were then performed, the vehicle was relocated to another area in the laboratory and an inspection of engine components and adjustments was completed. The vehicle was then returned to its owner.

3.3 LABORATORY TESTING AND EVALUATION

Procedures employed for retest were identical to those applied initially.

Table 3-1. Sample Distribution

MODEL YEAR	1973			1972			1971			1970			1969			1968			1967			1966			1965			1964		
MONTHS AFTER START OF TEST	0	6	12	0	6	12	0	6	12	0	6	12	0	6	12	0	6	12	0	6	12	0	6	12	0	6	12	0	6	12
MAKE																														
AMMO	1	0	0	1	1	0	1	1	0	1	1	1	1	0	0	1	1	0	1	0	0	1	1	1	1	0	0	1	1	1
BUIC	1	0	0	1	0	0	1	1	1	1	0	0	2	0	0	2	2	0	2	1	1	2	0	0	2	1	1	1	1	0
CADI	1	0	0	1	0	0	1	0	0	1	1	1	1	0	0	1	0	0	1	0	0	1	0	0	1	2	1	1	1	1
CHEV	7	6	3	7	4	3	7	3	3	6	3	2	6	2	1	7	2	1	6	5	3	7	5	3	7	4	3	7	6	2
CHRY	1	0	0	1	1	1	1	1	1	1	1	0	1	0	0	1	0	0	1	1	1	1	0	0	1	0	0	1	1	1
DODG	2	1	0	2	1	1	2	0	0	2	1	1	2	1	1	2	1	1	1	1	0	2	1	1	2	1	1	1	1	1
FORD	8	4	2	8	4	3	9	6	5	8	3	2	6	2	2	5	4	3	6	6	4	7	5	4	7	7	6	4	2	1
MERC	1	0	0	1	1	1	1	0	0	1	0	0	1	1	1	1	1	0	2	1	1	1	0	0	1	1	1	1	0	0
OLDS	1	1	1	1	0	0	1	0	0	2	1	1	2	0	0	2	1	0	2	1	0	2	1	1	2	1	0	1	1	1
PLYM	3	1	1	3	3	1	3	1	1	2	2	2	2	2	1	2	1	1	2	1	1	2	1	1	2	0	0	1	1	0
PONT	1	1	1	1	1	0	2	1	0	2	1	0	2	1	0	3	0	0	3	3	3	2	2	1	2	2	2	2	0	0
VOLK	3	0	0	3	1	1	2	1	0	2	2	1	2	0	0	2	2	1	2	0	0	2	2	1	1	1	1	1	0	0
VOLV	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOYO	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DATS	1	0	0	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OPEL	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	33	16	10	33	18	11	35	17	13	30	17	11	29	10	7	30	15	7	29	20	14	30	18	13	29	19	15	22	15	8
% OF SAMPLE	11	10	9	11	11	10	12	10	12	10	10	10	10	6	6	10	9	6	10	12	13	10	11	12	10	12	14	7	9	7

Total All Vehicles

Program Start	250
6 months	165
12 months	109

3.3.1 Exhaust Emission Testing Procedures

Laboratory standard exhaust emission tests were performed in accordance with procedures outlined in Federal Register, Volume 3B, Number 124, Part III, dated June 28, 1973. Standard tests were preceeded by a minimum 12 hour temperature soak at laboratory ambient conditions (68^{o} F to 72^{o} F).

Loaded mode tests were performed in accordance with procedures outlined by Clayton Manufacturing Company of El Monte, California. Loaded mode testing and the resultant data have no direct bearing on the objectives of this phase of the study but were included in the test procedure merely to expand the data base.

Idle emission testing was performed in conjunction with loaded mode testing. Emission samples were taken at no load conditions of curb idle (drive gear for automatic transmission equipped vehicles) and 2500 engine rpm. Instrumentation and operating procedures were identical to those employed during the initial phase of testing. Both laboratory and garage-type inspection equipment (listed in Table 5 of Volume II) were employed.

Instrument and equipment calibrations established in the initial testing phase were maintained throughout the retest interval. Analytical system calibrations were established using an inventory of EPA named gases. Flow calibration of the CVS was verified using the laminar flow element with calibration traceable to the National Bureau of Standards. Dynamometer calibrations were established and verified on a regular basis using the coast-down technique. In addition, propane recovery tests, NO_x converter efficiency checks and analytical system leak checks were performed on a daily basis.

3.3.2 Engine Diagnostic Procedures

Diagnoses of engine conditions were performed at two points in the overall vehicle procedure. During loaded mode operations on the chassis dynamometer the laboratory analytical system recorders were operational for a period of about one minute. During this interval and during periods of speed changes, emission traces were observed for an indication of malfunction evidenced by abnormally high hydrocarbon (HC) or carbon monoxide (CO) levels and these observations were recorded. The HC trace also provided an indication of ignition system mis-fire.

Oxides of nitrogen (NO_x) emission controls on applicable vehicles were inspected for proper operation during loaded mode testing. A fully operational system was indicated by the absence of vacuum to the distributor at high cruise conditions.

The second point at which diagnostic procedures were applied was immediately after dynamometer tests were completed. The vehicle was removed from the dyanmometer area and a more extensive diagnostic procedure was applied. Concurrently, the inspection to determine the extent of tampering and alteration or replacement of parts was performed.

3.4 DATA PROCESSING AND MANAGEMENT

The combination of a large data base, and the necessity of a series of complex operations involved in the analysis, necessitated the use of a computerized data management system.

The data collected from the deterioration experiment has been stored as a working file on the CDC 6500 disk pack. More permanent copies of the data base are also stored on a magnetic tape and on

card files. Extensive computer software was utilized in managing and processing the data. The following data management activities were performed by TRW:

- retrieval and sorting of data
- development of graphic presentations
- statistical analysis.

A brief description of each of these data management functions is presented in the subsequent paragraphs.

Retrieval and Sorting of Test Data

The principal data handling program in the data management system, DETER, serves as the basic interface between the data base and other software. This program retrieves the selected data from disk storage and sorts it by a number of classification systems. The data can be culled in the following ways:

- CVS emissions
- Loaded modes
- Engine parameters
- Vehicle characteristics
  1) the total population
  2) sort by age group
  3) sort by manufacturer
  4) sort by make, within a manufacturer
  5) sort by engine size group
  6) sort by weight group
  7) sort by PASS/FAIL at idle inspection

Statistical Analysis

Two main statistical packages were used in processing the data relevant to the engine deterioration study.

The data handling program DETER had basic statistical capabilities built into it. It computed means, standard deviations, T-scores, and CVS emission deterioration factors.

The DETER program also was used to create an input file for the other statistical applications program (TSTAGE). The TSTAGE program performed ordinary least squares regressions. Equations were derived for the deterioration of the three CVS mass emissions (HC, CO, NO_x) as functions of the odometer readings. Dummy variables were exploited to yield independent equations for the different sort groups (i.e., age group).

4.0 EXPERIMENTAL RESULTS

This section presents the experimental results of the deterioration program. The results of the six month program have been updated to include the full year of test data. In addition, some of the concerns expressed in the interim report are explored in further detail.

4.1 UNAUTHORIZED MAINTENANCE

During the first six month period, vehicle owners were specifically requested to refrain from servicing emission affecting parts and adjustments during the period between inspections. Incentives were supplied in the form of a cash payment and the offer of free service should maintenance be necessary before the six month point.

The object of the six month experiment was to measure the change of vehicle emissions in the absence of corrective maintenance. The results, as reported previously for six months, were disappointing. Twenty-five per cent of the vehicles available for retest showed evidence of maintenance on one or more of the fourteen controlled items (parts or adjustments). Faced with this relatively large rate of unauthorized maintenance, the experimenters were presented with a serious dilemma: Determine the deterioration of the vehicle sample when one fourth of the sample has received some form of corrective maintenance.

In the interim report, the approach taken was to evaluate the extent of fleet deterioration with and without the vehicles that received unauthorized maintenance. The results in terms of vehicle emissions were reported to be not significantly different either way. Within the context of the data available, this was as far as the investigators could go in assessing

the effect of unauthorized maintenance. Left unanswered were several specific questions which must be addressed before a definite statement can be made on the true effect of owner maintenance.

1. Why was service performed at the owner's expense when specific arrangements had been made, including the offer of free service?

   Obviously, 25% of the vehicle owners were not impressed sufficiently with the incentives in the program to preclude having service performed outside the program. At this point we can only guess the motivation for their actions, but must face the unfortunate possibility that service was performed because the owners became dissatisfied with their car's performance. A missing engine, poor acceleration, stalling, hard starting, or any number of other defects may have convinced the owners immediate service was needed, and therefore they opted not to return to the test laboratory but rather to have the vehicle attended to locally. If this was the case, it is reasonable to assume that the vehicle defect(s) also resulted in changes in emission performance and would impact the results of the experiment.

2. What were the emissions of those vehicles receiving unauthorized service just before maintenance was performed?

   This data cannot be determined for this experiment since the maintenance was uncontrolled. Without this data the experiment has received a critical setback. Possibly for a large percentage of serviced vehicles, the emission performance was unchanged by the unauthorized maintenance, but considering the program incentives and the decision that the controlled items normally do affect emission performance, it seems probable that emissions did increase for these vehicles and that the unauthorized service had the effect of correcting higher emissions. The missing data then represents a serious (perhaps insurmountable) obstacle in determining correct deterioration rates for the Denver vehicle population from the available data.

3. What are the implications of the unauthorized maintenance detected in this study with regards to the enforcement of controlled inspection maintenance?

   The message to be learned from the unauthorized maintenance check is reasonably clear: A significant portion of the vehicles will be maintained by their owners outside any mandatory inspection program. Even when the alternatve of free service is offered as it was in this study, vehicle owners will spend their own money to maintain their cars. Furthermore, based on the analysis of the data, the service that is done will not degrade emission performance. On the contrary, it would appear more likely to reduce pollutants.

4.2 SAMPLE ATTRITION

Vehicle availability at the six and twelve month points was expected to be reduced relative to the size of the starting sample and the actual results match expected attrition rates (as was noted in the interim report). The attrition in the sample leads to another disquieting question: Exactly what happened to the vehicles and their owners to cause them to be unavailable at the twelve or six month test points?

No survey was planned or taken, so it is necessary once again to guess the answer to the posed question. There are two possibilities that have serious consequences for the deterioration analysis.

There is the possibility that owners of vehicles not available for retest had unauthorized maintenance performed and were embarassed to reappear with their serviced cars. For dropouts at the six month point due to this possibility, the number of vehicles receiving unauthorized maintenance could be considerably larger than the 25% detected and thereby compound the problem discussed above.

Another possible and perhaps more probable reason for vehicle non-availability at either the six month or twelve month retest points is the change of ownership during the intervals. No provisions were made to track down new owners of the vehicles in such cases so that each such change automatically caused the loss of the vehicle to the test program. Vehicle ownership changes frequently can be traced to owner dissatisfaction with the performance of their vehicles. The prospect of large repair bills can,

and often does, lead to consideration of a new or newer car. If a large number of the 141 out of 250 original test vehicles not available for retest did in fact fit this category, then there is one more reason to be concerned about the data base.

Whatever the reasons for the large sample attrition, the data base has been severly impacted by the loss of so many vehicles, unless it can be shown that the lost vehicles are randomly distributed. The two possibilities explored above are serious because they tend to discount randomness and, in fact, suggest a relationship between a "no-show" and the emission performance of the affected vehicles.

4.3 TEST SAMPLE MILEAGE

In examining the test sample for possible weaknesses, the interim report pointed out that vehicle mileage for the first six months was relatively low. It was thought that the fuel shortage and the attendant gasoline price rise combined to limit vehicle use during the period. The results for the second six month period show continued low mileage accumulation. The mileage figures are so low that it is necessary to question the make-up of the test sample as far as vehicle use patterns are concerned. Appendix A summarizes the mileage figures for all vehicles throughout the program; the numbers for a large percentage of the vehicles are below typical mileage figures supplied by the Colorado Department of Health.

The participants in the test program were volunteers from the Denver area selected mainly to form a fleet typical of the Denver vehicle population by make and model year. It is possible that in choosing the participants with the vehicle owned as the criterion may have resulted in a sample lacking in drivers typical of the population. For example, the

low mileage figures may indicate a low participation by drivers who daily commute to work. This would explain the low mileage figures throughout the one year interval of the program rather than assuming gasoline shortages/prices were still dominant. In any case, low mileage must be added to the list of problems that cropped up during the deterioration study.

4.4 VEHICLE OWNER BEHAVIOR

The preceding sections deal with some important negative aspects of the deterioration study. Now we shall examine some of the useful results that can be derived in spite of the limitations in achieving the originally planned program results.

4.4.1 Owner Tampering

The high occurrence of unauthorized maintenance in an all-volunteer program with built-in incentives designed to prevent such action provides an insight into the administration of an inspection/maintenance program. There is the concern that an inspection/maintenance program may fail to achieve its goals of reducing vehicle emissions because of owner tampering between the scheduled inspections. The six month results of the deterioration study indicate that "tampering" can be expected but rather than defeating the benefits of inspection/maintenance, the unauthorized service resulted in no significant increase in emissions when compared to the unserviced cars. Actually, a more reasonable conclusion is that the service performed by the owners preserved or even restored low emission performance to their vehicles.

4.4.2 Maintenance Patterns

In the second six month interval of the experiment, vehicle owners were generally unaware that they would be called back for retest. Obviously, the restrictions on service were automatically lifted and the vehicle owners were free to have any work done they cared to. The coded marking and part identification procedure instituted for the first six months was, however, repeated at the start of the second six months. On recall, laboratory inspectors re-inventoried the controlled items not to detect unauthorized service but to record owner maintenance patterns. Table 4-1 summarizes the results of the vehicle owner servicing surveys.

With owner-initiated maintenance detected in over 75% of the vehicles checked after the second six month period, maintenance patterns for emission related parts and adjustments are encouraging. In the absence of controls, the results indicate that vehicle owners will not neglect the servicing of critical components, thereby preserving low emission performance on their cars. The willingness of vehicle owners to take their vehicles in for service coupled with a service establishment skilled in restoring or maintaining low emissions offers a viable means of achieving pollution control.

4.5 IMPACT OF DETERIORATION

Note:

Due to the problems relating to the data base cited above, only a limited updating of the analysis contained in the six month interim report has been performed.

Table 4-1. Summary of Vehicle Owner Maintenance

Monitored Item	Idle Fleet				Mandatory Maintenance Fleet			
	6 months[1]		12 months[2]		6 months[1]		12 months[2]	
	Number	%	Number	%	Number	%	Number	%
Ignition wires	2	2	10	18	2	3	7	13
Coil	0	0	4	7	1	1	2	4
Spark plugs	5	6	25	45	3	4	22	41
Air filter	10	11	26	47	5	6	31	57
Fuel mixture screws	0	0	6	11	2	3	7	13
Idle adjust. screws	2	2	11	20	2	3	12	23
Choke setting	2	2	6	11	2	3	7	13
Dist. adj. screw	4	5	8	15	3	4	6	11
Points adj. screw	3	3	17	31	4	5	22	41
Condenser	3	3	14	25	3	4	20	37
Rotor	2	2	13	24	2	3	18	33
Distributor cap	2	2	9	16	4	5	10	19
PCV	1	1	3	5	2	3	4	7
Sample Size	87		55		78		54	

[1]Vehicle owners requested not to perform maintenance to the items listed.

[2]Vehicle owner maintenance not controlled between six and twelve months.

4.5.1 Idle Inspection and Maintenance

The idle inspection and maintenance procedure, as detailed in Volume IV, consisted of an initial examination of the loaded modes idle HC and idle CO. If the vehicle conformed to the prescribed standards (see Table 4-2) it was left untouched, however, if it failed, a systematic program of engine maintenance was performed.

Table 4-2. Idle Inspection Pass/Fail Criteria

Measurement	Criteria	
	Pre-Controlled	Controlled
Idle HC	800 ppm	330 ppm
Idle CO	6%	4%

A brief review of the CVS mass emission results for the idle inspection and maintenance program is given in Table 4-3 for the vehicles* remaining in the idle test fleet at the end of six months.

Table 4-3. Idle Inspection: CVS Emissions for Vehicles Remaining at 6 Months

Pollutant	Pre-Maintenance		Post-Maintenance		After 6 Months		Deterioration Rate (Gm/mi/1000 mi)
	Mean (Gm/mi)	Std.Dev	Mean (Gm/mi)	Std.Dev	Mean (Gm/mi)	Std.Dev	
HC	8.18	5.38	6.99	3.57	11.09	14.11	0.50
CO	111.80	51.57	101.12	47.37	112.51	63.96	0.86
NO_x	2.64	1.42	2.60	1.41	2.37	1.33	0.00

* Individual vehicle data is summarized in Appendix B.

Table 4-4 repeats the calculations for just those vehicles remaining at the end of 12 months.

Table 4-4. Idle Inspection: CVS Emissions for Vehicles Remaining at 12 Months

Pollutant	Pre-Maintenance Mean (Gm/mi)	Pre-Maintenance Std.Dev.	Post-Maintenance Mean (Gm/mi)	Post-Maintenance Std.Dev.	After 12 Months Mean (Gm/mi)	After 12 Months Std.Dev.	Deterioration Rate (Gm/mi/1000 mi)
HC	8.33	6.33	6.80	3.92	7.57	4.85	0.09
CO	109.76	56.54	97.19	52.02	100.57	54.96	0.41
NO_x	2.64	1.42	2.66	1.44	2.51	1.35	-0.02

4.5.2 Mandatory Engine Maintenance

Vehicles in this fleet underwent engine maintenance procedures as detailed in Volume IV of this series. The pre- and post-deterioration results for those vehicles remaining at the end of six months are summarized in Table 4-5.

Table 4-5. Mandatory Maintenance: CVS Emissions Pre and Post Deterioration for Vehicles Remaining at 6 Months

Pollutant	Pre-Maintenance Mean (Gm/mi)	Pre-Maintenance Std.Dev	Post-Maintenance Mean (Gm/mi)	Post-Maintenance Std.Dev	After 6 Months Mean (Gm/mi)	After 6 Months Std.Dev	Deterioration Rate (Gm/mi/1000 mi)
HC	7.59	4.49	6.68	2.96	10.24	10.40	0.83
CO	108.65	49.99	101.97	46.76	109.50	55.40	1.04
NO_x	2.53	1.40	2.34	1.31	2.31	1.31	-0.01

Vehicle emissions measurements have been analyzed in a similar fashion for those vehicles remaining at the end of 12 months. Table 4-6 summarizes the results.

Table 4-6. Mandatory Maintenance: CVS Emissions Pre and Post Deterioration for Vehicles Remaining at 12 Months

Pollutant	Pre-Maintenance Mean (Gm/mi)	Pre-Maintenance Std.Dev.	Post-Maintenance Mean (Gm/mi)	Post-Maintenance Std.Dev.	After 12 Months Mean (Gm/mi	After 12 Months Std.Dev.	Deterioration Rate (Gm/mi/1000mi)
HC	7.60	4.29	6.98	3.09	11.09	14.11	0.50
CO	105.80	44.82	105.43	44.59	112.51	63.96	0.86
NO_x	2.63	1.49	2.33	1.37	2.37	1.33	0.00

4.5.3 Interpretation of Results

First six months:

By restricting vehicle owners from maintaining their cars, engine deterioration appears to cancel any gains achieved by Inspection/Maintenance within a six month interval. Even with 25% of the owners violating the no maintenance agreement, emissions for hydrocarbons and carbon monoxide are above the initial, pre-maintenance figures for both the idle and mandatory maintenance fleets.

Second six months:

The problems of vehicle sample attrition and owner maintenance prevent estimation of meaningful deterioration rates during the second six months. In fact, the results indicate that emissions are down compared to the six month results. Obviously, there are overriding factors at work and it seems most reasonable that maintenance by vehicle owners during this interval is the most significant. Seventy-five percent of the vehicles available at the 12 month retest point were found to have been maintained during the second six months by their owners. The reductions in hydrocarbons and carbon monoxide have to be a direct result of this maintenance.

APPENDIX A. DENVER DETERIORATION STUDY ODOMETER READINGS

This listing is extracted from vehicle inspection records at each point in the deterioration study. The column headings are defined below.

VEH NUM:	A number code assigned to each vehicle for identification throughout the program. The listing contains the code numbers of the 109 vehicles available for retest at the end of 12 months.
POST-MAINT:	The odometer reading at the time the vehicle was returned to the vehicle owner following the initial inspection and maintenance procedures.
MILES DRIVEN:	Mileage accumulated during owner use period.
6 MONTHS:	Odometer reading at 6 months.
12 MONTHS:	Odometer reading at 12 months.

DENVER DETERIORATION STUDY
ODOMETER READINGS

VEH. NUM.	POST-MAINT.	MILES DRIVEN	6 MONTHS	MILES DRIVEN	12 MONTHS
012	63004	3199	66203	2558	68761
014	49237	3310	52547	3489	56036
015	60240	2264	62504	3140	65644
016	59003	6704	65707	5411	71118
017	51045	4849	55894	5333	61227
024	99340	3422	102762	1972	104734
026	84961	3923	88884	4065	92949
027	72548	5321	77869	2585	80454
028	89020	2488	91508	2305	93813
029	59585	2886	62471	3395	65866
031	60672	5188	65860	6567	72427
037	52629	2067	54696	1856	56552
038	54529	1675	56204	2441	58645
040	19445	1548	20993	1520	22513
043	20583	3166	23749	2590	26339
045	5414	3168	8582	3820	12402
048	64033	3614	67647	3083	70730
053	42474	337	42811	352	43163
060	45946	3414	49360	5804	55164
063	42005	1799	43804	5543	49347
064	64875	8974	73849	5389	79238
066	37361	3162	40523	4683	45206
072	12834	3498	16332	1923	18255
073	22051	2844	24895	2338	27233
074	73336	2971	76307	4690	80997
075	12609	2678	15287	2385	17672
076	21887	688	22575	765	23340
078	20434	3382	23816	4189	28005
079	35284	2816	38100	3875	41975
083	16300	1667	17967	2541	20508
090	22467	1697	24164	2258	26422
091	6704	3408	10112	3127	13239
093	20817	5708	26525	4255	30780
096	76369	2190	78559	2754	81313
104	58630	4180	62810	2338	65148
107	76078	2569	78647	2828	81475
109	64169	3064	67233	3069	70302
115	64860	4412	69272	6064	75336
118	71128	5910	77038	4321	81359
122	42146	3769	45915	3597	49512
126	33735	3564	37299	2896	40195
127	48219	2676	50895	2344	53239
129	73598	2918	76516	3449	79965
130	92515	1762	94277	1709	95986

VEH. NUM.	POST-MAINT.	MILES DRIVEN	6 MONTHS	MILES DRIVEN	12 MONTHS
132	89782	8438	98220	11580	109800
133	45898	7806	53704	10676	64380
140	48553	2188	50741	2700	53441
142	25592	2586	28178	2681	30859
143	38659	2449	41108	2375	43483
149	78274	4525	82799	6039	88838
153	130460	3337	133797	4808	138605
158	33747	2653	36400	3517	39917
161	47191	2562	49753	2235	51988
166	12474	6011	18485	6489	24974
168	48575	1977	50552	2092	52644
170	81058	6495	87553	5969	93522
171	71092	2796	73888	3716	77604
175	21117	6656	27773	8219	35992
177	29493	2868	32361	9490	41851
179	17115	10342	27457	10732	38189
180	76747	5114	81861	6864	88725
181	42449	3121	45570	3179	48749
185	29881	4386	34267	3643	37910
187	4725	1922	6647	3705	10352
190	8056	2103	10159	3468	13627
191	22266	2688	24954	1270	26224
196	36250	5774	42024	1776	43800
197	11175	2820	13995	4263	18258
207	11511	2353	13864	3899	17763
208	27615	3243	30858	3373	34231
211	63652	6136	69788	7676	77464
212	51835	3115	54950	1284	56234
213	61637	6339	67976	7533	75509
218	16372	6880	23252	10246	33498
222	68526	2224	70750	2792	73542
235	78046	2933	80979	2287	83266
238	51016	423	51439	3239	54678
239	84309	7233	91542	6650	98192
245	77348	6894	84242	4153	88395
247	46034	3149	49183	4253	53436
249	30259	7895	38154	8726	46880
251	6702	3653	10355	5051	15406
252	9599	2496	12095	6793	13888
258	83016	2127	85143	2042	87185
260	23677	584	24261	1328	25589
261	68680	8955	77635	9332	86967
270	95217	11995	107212	19137	126349
271	59028	2398	61426	3287	64713
272	92494	2149	94643	1956	96599
273	47305	4409	51714	4115	55829
276	73426	3415	76841	2121	78962
278	59885	3516	63401	3251	66652
279	3829	9851	13680	6820	20500

VEH. NUM.	POST-MAINT.	MILES DRIVEN	6 MONTHS	MILES DRIVEN	12 MONTHS
280	96491	2989	99480	2525	102005
286	65609	0	65609	7057	72666
287	17998	2671	20669	4241	24910
291	52667	5548	58215	4195	62410
292	29533	5061	34594	4868	39462
293	19843	5827	25670	8132	33802
296	52813	2582	55395	3541	58936
300	6817	4229	11046	3260	14306
307	29124	1672	30796	3517	34313
309	74369	5290	79659	6306	85965
312	8589	4593	13182	3823	17005
314	20440	3104	23544	3681	27225
321	12130	1112	13242	1153	14395
325	16385	5653	22038	6799	28837
326	76050	5846	81896	5663	87559
327	51836	9151	60987	8141	69128

APPENDIX B. DENVER DETERIORATION DATA

A summary of the vehicle inspection data at each point in the Denver deterioration study. The column headings are defined below:

VEH NUM: A number code assigned to each vehicle for identification throughout the program. The listing contains the code numbers of the 109 vehicles available for retest at the end of 12 months.

PRE-MAINTENANCE: Measured emissions for hydrocarbons (HC), carbon monoxide (CO) and nitrogen oxide (NO_x) in grams/mile for vehicles at the initial inspection point of the program.

POST-MAINTENANCE: Measured emissions after maintenance procedures have been completed. Data for "PRE" and "POST" listings for vehicles passing program standards on initial inspection.

ODOM: Vehicle odometer reading at given test point.

AFTER 6 MONTHS: Measured emissions after 6 months of owner operation.

AFTER 12 MONTHS: Measured emissions after 12 months of owner operation.

TAMP: Indication of extent of owner performed maintenance during interval. "LOW" indicates one to four of the fourteen controlled items showed evidence of maintenance. "HIGH" indicates more than four items maintained.

LISTING OF DENVER DETERIORATION DATA
(CVS 1975)

VEH. NUM.	PRE-MAINTENANCE HC	CO	NOX	POST-MAINTENANCE HC	CO	NOX	ODOM.	AFTER 6 MONTHS HC	CO	NOX	ODOM.	TAMP	AFTER 12 MONTHS HC	CO	NOX	ODOM.	TAMP
12	7.63	117.7	2.27	7.67	117.7	2.27	63004	6.62	125.8	1.94	66203	LOW	6.32	107.0	2.02	68761	LOW
14	9.55	99.0	1.37	9.55	99.0	1.37	49237	7.60	92.8	1.83	52547	NONE	7.97	90.2	1.77	56036	HIGH
15	13.43	146.4	.67	9.13	109.4	.77	60240	14.73	174.5	.39	62504	LOW	11.60	164.2	.59	65644	HIGH
16	7.08	118.9	1.55	7.08	118.9	1.55	59003	6.87	131.1	1.24	65707	LOW	7.82	153.6	.97	71118	HIGH
17	10.43	172.6	1.54	8.92	162.3	1.16	51045	7.22	178.8	.93	55894	HIGH	43.36	234.2	.70	61227	HIGH
24	7.62	221.1	.59	5.59	125.5	1.16	99340	7.80	174.3	1.47	102762	LOW	8.53	162.4	1.50	104734	HIGH
26	6.01	85.0	4.51	6.01	85.0	4.51	84961	5.97	85.4	4.08	88984	NONE	4.98	63.3	5.67	92949	LOW
27	7.28	111.3	1.64	7.28	111.3	1.64	72548	12.41	161.1	.99	77869	LOW	10.98	103.9	1.55	80454	LOW
28	15.35	202.0	1.47	7.45	181.2	.80	89020	6.50	173.6	.57	91508	NONE	35.94	180.1	.73	93813	LOW
29	11.15	193.9	.61	8.29	158.9	.90	59585	11.43	196.9	.71	62471	NONE	12.45	173.9	.80	65866	LOW
31	8.24	152.9	1.26	7.90	151.0	1.25	60672	9.93	171.9	.69	65860	NONE	8.71	185.9	.70	72427	LOW
37	8.85	129.5	1.67	12.51	145.8	1.02	52629	15.96	169.8	1.11	54696	LOW	11.08	150.9	.80	56552	HIGH
38	8.02	167.3	3.31	8.02	167.3	3.31	54529	13.45	196.3	2.53	56204	NONE	11.98	230.3	1.28	58645	LOW
40	4.55	48.8	5.37	3.89	47.7	3.40	19445	4.38	63.9	3.78	20993	NONE	3.98	47.0	3.36	22513	LOW
43	5.68	62.4	2.43	4.62	61.4	2.33	20587	4.75	83.4	2.09	23749	NONE	4.39	62.7	1.64	25339	LOW
45	3.81	94.2	3.07	3.62	86.5	3.14	5414	4.36	97.6	4.20	8582	NONE	3.79	86.3	3.22	12402	LOW
48	9.03	56.1	9.08	9.03	56.1	9.08	64033	6.26	69.7	6.64	67647	NONE	5.55	65.5	5.73	70730	NONE
53	7.33	94.7	3.33	5.72	57.8	3.82	42474	6.31	63.0	4.42	42811	NONE	6.36	64.0	4.87	43163	LOW
60	5.55	173.1	2.22	5.55	173.1	2.22	45946	5.53	141.6	2.35	49360	LOW	3.99	116.0	2.43	55164	HIGH
63	10.11	168.1	1.68	10.58	159.8	1.57	42005	7.75	123.3	2.00	43804	LOW	7.25	104.6	2.55	49347	LOW
64	4.43	68.1	5.24	4.43	68.1	5.24	64875	5.02	71.7	6.24	73849	HIGH	4.09	71.9	2.82	79238	HIGH
66	6.69	70.7	2.64	5.27	63.7	2.76	37361	4.77	60.9	3.50	40523	NONE	3.48	29.9	2.39	45206	HIGH
72	2.66	40.1	2.52	2.51	21.9	2.53	12834	2.49	30.7	3.22	16332	LOW	2.98	39.8	3.18	18255	LOW
73	4.55	44.8	3.53	4.06	46.9	3.78	22051	5.01	48.0	3.41	24895	NONE	5.47	64.3	4.93	27233	NONE
74	6.92	88.7	5.02	7.42	100.9	2.71	73336	9.14	104.3	2.27	76307	LOW	7.55	87.1	2.08	80997	LOW
75	7.40	75.3	1.49	3.99	54.4	1.35	12609	5.67	71.5	1.20	15287	NONE	5.48	97.5	.73	17672	LOW
76	8.74	208.6	.65	8.74	208.6	.65	21887	9.83	199.1	.78	22575	NONE	14.20	237.3	.78	23340	LOW
78	4.86	87.6	4.93	4.86	87.6	4.93	20434	11.99	84.7	4.05	23816	NONE	5.39	97.9	3.86	28035	LOW
79	6.05	90.7	4.28	4.95	64.3	5.35	35284	14.84	94.9	5.64	38100	NONE	4.79	78.7	4.17	41975	LOW
83	4.44	83.2	1.78	4.62	52.2	2.55	16300	3.88	45.9	1.85	17967	LOW	4.82	73.5	2.21	20508	LOW

LISTING OF DENVER DETERIORATION DATA
(CVS 1975)

VEH.	PRE-MAINTENANCE			POST-MAINTENANCE				AFTER 6 MONTHS					AFTER 12 MONTHS				
NUM.	HC	CO	NOX	HC	CO	NOX	ODOM.	HC	CO	NOX	ODOM.	TAMP	HC	CO	NOX	ODOM.	TAMP
90	3.48	43.2	3.66	3.48	43.2	3.66	22467	3.41	48.1	3.96	24164	NONE	3.51	43.6	3.39	26422	NONE
91	3.34	42.9	2.94	3.69	42.6	3.51	6704	4.36	61.3	3.87	10112	NONE	4.32	58.8	2.86	13239	HIGH
93	3.96	80.8	3.49	3.14	39.6	4.67	20817	3.35	45.6	5.37	26525	NONE	4.16	74.5	2.67	30780	HIGH
96	33.62	188.6	1.06	13.33	244.7	.60	76369	14.16	231.5	.78	78559	NONE	10.14	210.6	.59	81313	NONE
104	8.55	178.8	1.45	6.33	136.1	1.48	58630	7.59	162.7	1.89	62810	NONE	6.46	144.7	1.85	65148	HIGH
107	8.38	69.7	1.51	6.96	98.6	1.21	76078	10.53	107.8	1.23	78647	LOW	34.95	95.6	1.11	81475	HIGH
109	8.06	107.4	2.01	8.06	107.4	2.01	64169	9.85	106.4	2.49	67233	NONE	8.91	95.6	2.05	70302	NONE
115	12.82	171.2	1.77	13.15	187.5	1.19	64950	17.96	225.4	.89	69272	LOW	15.93	211.2	1.09	75336	LOW
118	4.80	73.1	3.02	4.80	73.1	3.02	71128	5.36	86.4	2.36	77038	NONE	7.47	111.7	2.60	81359	HIGH
122	10.80	115.2	2.74	11.95	129.0	2.33	42146	13.93	122.7	2.48	45915	LOW	12.88	141.0	2.01	49512	LOW
126	9.04	145.4	2.71	7.56	120.3	2.44	33735	7.31	72.7	3.57	37299	LOW	8.39	121.4	3.06	40195	HIGH
127	7.86	102.3	4.59	5.85	65.4	2.40	48219	9.69	135.8	2.58	50895	NONE	10.00	142.7	2.73	53239	NONE
129	8.73	155.8	1.74	6.66	133.6	1.04	73598	10.27	135.8	1.27	76516	NONE	5.96	146.8	.93	79965	LOW
130	8.03	67.6	2.77	8.03	67.6	2.77	92515	7.89	66.1	3.01	94277	NONE	8.31	73.5	2.28	95996	LOW
132	5.47	79.6	2.08	5.77	87.6	1.50	89782	4.23	92.3	1.94	98220	NONE	5.27	75.2	1.52	109800	LOW
133	7.15	35.1	6.30	4.82	73.4	1.83	45898	8.14	100.8	2.15	53704	NONE	8.61	117.5	3.05	64380	NONE
140	5.76	126.1	1.66	9.44	160.4	2.13	48553	37.15	160.3	1.63	50741	NONE	9.52	169.3	2.24	53441	NONE
142	4.25	55.3	3.63	3.31	58.4	2.14	25592	3.36	49.7	2.33	28178	LOW	3.68	44.8	3.05	30859	LOW
143	8.22	83.7	3.30	7.85	73.1	3.76	38659	7.87	80.8	4.03	41188	NONE	8.49	93.4	3.53	43483	NONE
149	8.56	123.6	3.80	9.21	91.8	3.32	79274	13.61	150.4	2.64	82799	NONE	6.98	103.3	4.47	88838	HIGH
153	8.92	153.3	1.02	9.15	181.8	.86	130460	8.79	167.3	.67	133797	NONE	8.12	161.8	1.04	138605	LOW
158	5.13	69.3	4.20	5.13	69.3	4.20	33747	4.76	65.2	4.08	36400	NONE	5.10	65.4	3.44	39917	NONE
161	4.43	27.0	5.05	5.09	23.4	6.98	47191	4.58	32.8	5.07	49753	NONE	4.05	32.9	5.35	51988	NONE
166	5.77	67.8	2.14	6.31	78.5	1.56	12474	5.92	73.9	1.83	18485	NONE	4.59	64.1	2.47	24974	NONE
168	10.31	116.2	2.23	7.25	88.5	1.92	48575	14.16	126.7	.78	50552	NONE	8.79	103.0	.96	52644	NONE
170	10.81	133.6	1.98	7.03	97.3	2.27	81058	6.64	109.4	1.26	87553	NONE	5.29	100.9	1.85	93522	LOW
171	13.64	156.7	2.17	13.77	147.6	2.66	71092	11.21	129.4	2.15	73888	NONE	11.89	138.1	2.58	77604	HIGH
175	5.28	70.2	3.09	4.56	84.1	2.06	21117	4.94	83.3	1.97	27773	NONE	4.44	53.8	3.22	35932	LOW
177	36.63	322.1	.95	5.02	74.3	2.85	29493	5.23	77.1	2.70	32361	LOW	14.05	200.4	2.07	41851	NONE
179	2.83	65.6	1.48	3.80	68.5	1.91	17115	4.44	102.9	1.47	27457	NONE	4.40	88.0	1.27	38189	LOW

LISTING OF DENVER DETERIORATION DATA
(CVS 1975)

VEH. NUM.	PRE-MAINTENANCE HC	CO	NOX	POST-MAINTENANCE HC	CO	NOX	ODOM.	AFTER 6 MONTHS HC	CO	NOX	ODOM.	TAMP	AFTER 12 MONTHS HC	CO	NOX	ODOM.	TAMP
180	6.32	69.1	6.73	6.76	100.9	3.41	76747	5.97	84.3	4.64	81861	NONE	29.42	92.1	3.19	88725	HIGH
181	7.05	92.3	3.07	5.64	103.5	2.04	42449	5.75	94.8	2.25	45570	NONE	5.08	92.3	2.38	48749	HIGH
185	5.45	50.1	2.52	3.67	34.9	1.89	29881	3.49	44.9	1.59	34267	NONE	3.27	25.5	2.15	37910	LOW
187	4.72	90.6	1.98	4.39	83.5	1.85	4725	4.63	87.2	1.53	6647	NONE	4.70	75.6	2.08	10352	LOW
190	3.62	51.2	3.05	3.62	51.2	3.05	8056	3.94	66.7	2.36	10159	NONE	4.30	61.7	3.01	13627	NONE
191	14.82	138.8	1.36	14.34	151.2	1.38	22266	10.78	138.1	1.18	24954	LOW	9.21	116.0	1.35	26224	LOW
196	4.86	49.6	5.72	4.28	53.8	4.59	36250	5.69	70.4	4.91	42024	NONE	4.35	47.9	4.90	43800	LOW
197	5.28	80.2	3.03	5.28	80.2	3.03	11175	5.13	96.6	1.69	13995	NONE	3.62	55.5	1.88	18258	NONE
207	5.09	35.4	4.04	5.09	35.4	4.04	11511	3.49	30.0	2.79	13864	NONE	5.63	24.0	5.13	17763	NONE
208	4.37	42.2	3.61	4.36	46.6	2.91	27615	3.75	45.2	3.43	30858	NONE	2.56	26.8	3.62	34231	HIGH
211	28.93	121.0	3.54	4.93	111.4	2.49	63652	5.67	141.7	1.68	69788	NONE	5.17	98.2	2.32	77464	NONE
212	15.29	165.4	.79	12.12	141.8	1.16	51835	15.34	88.4	1.12	54950	LOW	14.32	160.1	.66	56234	LOW
213	14.15	158.7	2.28	14.15	158.7	2.28	61637	10.67	148.0	2.51	67976	NONE	10.09	121.1	1.30	75509	LOW
218	6.10	99.8	1.52	6.24	120.8	.91	16372	5.29	115.5	1.07	23252	NONE	5.54	103.3	1.33	33498	LOW
222	6.32	76.0	3.02	6.32	76.0	3.02	68526	4.35	44.2	3.42	70750	NONE	5.31	53.0	2.45	73542	NONE
235	24.44	238.5	1.50	27.60	248.2	1.98	78046	15.58	336.8	1.89	80979	LOW	13.07	243.5	1.19	83266	NONE
238	9.63	115.7	3.32	10.83	205.2	.57	51016	14.86	260.7	.57	51439	NONE	15.42	238.1	.91	54678	NONE
239	4.66	101.7	.87	4.16	61.8	1.98	84309	4.49	63.2	2.15	91542	NONE	6.75	128.9	1.01	98192	LOW
245	7.53	91.7	1.60	8.41	112.6	.89	77348	7.66	55.8	1.44	84242	HIGH	11.18	95.9	1.40	88395	HIGH
247	6.43	80.4	6.10	4.17	25.1	5.59	46034	4.05	23.1	6.12	49183	NONE	16.12	19.4	6.22	53436	HIGH
249	7.52	157.5	1.62	5.73	124.5	1.56	30259	9.91	180.9	1.36	38154	NONE	8.58	178.7	1.81	46880	NONE
251	3.15	71.1	1.47	3.08	78.6	1.22	6702	2.66	63.5	1.58	10355	LOW	3.00	64.9	2.35	15406	NONE
252	4.07	77.9	1.08	3.20	59.0	1.26	9599	4.40	59.0	1.48	12095	NONE	4.32	58.0	1.85	18888	LOW
258	7.54	156.9	2.21	8.89	167.5	2.15	83016	9.49	232.5	1.63	85143	LOW	9.06	173.7	3.29	87185	LOW
260	5.81	138.7	1.83	5.81	138.7	1.83	23677	5.40	121.2	1.84	24261	NONE	6.74	102.7	3.81	25589	NONE
261	4.66	85.5	1.25	5.97	118.0	1.16	68680	4.84	68.2	1.97	77635	NONE	5.98	107.8	1.59	86967	LOW
270	3.26	42.3	3.56	3.26	42.3	3.56	95217	3.80	37.0	6.53	107212	NONE	3.61	38.2	5.66	126349	HIGH
271	10.33	157.2	1.62	8.20	153.2	1.20	59028	9.29	138.0	1.17	61426	NONE	19.97	342.8	.30	64713	HIGH
272	8.52	153.8	2.87	6.67	116.5	3.12	92494	43.87	198.0	1.23	94643	NONE	94.43	233.2	.85	96599	NONE
273	6.28	125.3	2.06	6.96	113.1	3.81	47305	5.24	93.2	3.72	51714	NONE	5.83	102.9	2.75	55829	LOW

LISTING OF DENVER DETERIORATION DATA
(CVS 1975)

VEH.	PRE-MAINTENANCE			POST-MAINTENANCE				AFTER 6 MONTHS					AFTER 12 MONTHS				
NUM.	HC	CO	NOX	HC	CO	NOX	ODOM.	HC	CO	NOX	ODOM.	TAMP	HC	CO	NOX	ODOM.	TAMP
276	8.88	125.1	3.04	7.00	118.5	3.10	73426	9.27	128.7	3.62	76841	NONE	10.79	142.4	3.82	78962	HIGH
278	6.20	87.2	2.95	6.20	87.2	2.95	59885	5.37	92.4	2.36	63401	NONE	5.80	93.7	1.86	66652	NONE
279	3.34	59.7	2.85	3.34	59.7	2.85	3829	3.39	51.5	2.57	13680	NONE	3.76	47.2	3.96	20500	LOW
280	13.12	178.5	1.01	13.07	165.3	.97	96491	51.80	153.2	1.47	99480	NONE	14.39	199.9	.74	102005	LOW
286	6.70	113.5	1.94	14.95	140.0	2.33	65609	7.77	106.3	2.90	65609	NONE	6.36	104.1	2.04	72666	NONE
287	5.89	135.9	2.50	5.35	112.4	2.70	17998	4.57	69.8	3.43	20669	NONE	5.90	115.9	2.96	24910	NONE
291	6.15	116.5	2.29	12.70	114.8	2.53	52667	36.27	105.9	2.89	58215	NONE	25.42	116.3	2.31	62410	LOW
292	5.67	52.7	3.59	5.48	43.9	4.62	29533	5.75	44.5	3.42	34594	NONE	5.39	40.4	4.38	39462	HIGH
293	6.32	137.7	1.17	9.37	154.0	1.53	19843	9.84	217.9	.65	25670	NONE	6.42	111.5	1.74	33802	HIGH
296	13.19	126.6	2.80	6.66	82.3	3.23	52813	6.16	79.6	3.48	55395	NONE	5.47	71.2	4.06	58936	HIGH
300	4.81	78.3	1.77	3.59	59.8	1.78	6817	3.99	63.4	1.58	11046	NONE	3.65	55.0	1.43	14306	HIGH
307	4.67	75.5	3.37	4.33	74.3	2.69	29124	3.72	68.4	2.15	30796	NONE	4.30	71.0	2.53	34313	NONE
309	5.82	105.8	2.48	6.30	110.6	3.34	74369	4.44	67.0	3.34	79659	NONE	5.85	74.4	3.47	85965	LOW
312	3.89	63.1	1.90	4.94	100.2	2.15	8589	4.08	64.1	2.15	13182	NONE	4.63	71.9	2.28	17005	LOW
314	8.19	100.7	2.15	6.86	87.3	1.75	20440	28.78	69.7	2.61	23544	NONE	5.08	83.6	1.68	27225	HIGH
321	3.65	57.2	3.26	2.80	22.2	3.52	12130	2.48	22.6	3.13	13242	LOW	2.91	24.2	3.57	14395	LOW
325	5.84	106.6	2.05	5.96	120.2	1.65	16385	5.27	100.5	3.14	22038	NONE	4.69	106.5	2.92	28837	HIGH
326	6.59	153.2	1.54	4.37	147.8	.95	76050	5.59	157.2	.92	81896	HIGH	12.55	41.5	3.91	87559	HIGH
327	5.50	61.7	3.06	4.06	33.3	3.53	51836	4.92	95.5	1.77	60987	NONE	11.03	76.6	2.59	69128	LOW