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STUDY OF VACUUM SPARK ADVANCE DISCONNECT AS AN NOx CONTROL MEASURE

FINAL REPORT

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for

Air Resources Board
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by

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ABSTRACT

A comprehensive study of the value of vacuum spark advance disconnect (VSAD) as a means for reducing oxides of nitrogen emissions from vehicles in the State of California was executed by AESi under the sponsorship of the California Air Resources Board. A sample of 100 typical 1966 through 1970 model year consumer-owned vehicles was selected on a basis proportional to the presence of these vehicles in the California vehicle population. Exhaust emission tests were performed to measure carbon monoxide, hydrocarbons, carbon dioxide, and oxides of nitrogen under four different operating conditions before and after the disconnection of the vacuum spark advance. These four operating conditions included simulated stop and go traffic driving, 50 mph level road cruise, 50 mph 8% grade and the Federal CVS driving schedule. In addition, measurements of exhaust, engine coolant, and inlet air temperatures were made before and after vacuum spark advance disconnect, under operating conditions likely to induce engine overheating. Driveability tests were perfromed on all vehicles before and after the disconnection of the vacuum spark advance. Vehicle owners also completed a driveability questionnaire after a full week of operating their vehicles with the vacuum spark advance disconnected.

Under all four testing conditions, VSAD resulted in a substantial average reduction in NO_X emissions. An average NO_X reduction of 38% was measured using the 1972 Federal test procedure. The average corresponding reduction in hydrocarbons was 13% while carbon monoxide and carbon dioxide changed only slightly. When tested under stop and go traffic conditions, NO_X decreased 29% after VSAD. Hydrocarbons, carbon dioxide and carbon monoxide were not signficantly affected under this condition. A sizeable reduction in NO_X of 51% after VSAD was observed at 50 mph cruise, with a decrease in HC and CO of 23% and 7% respectively. The reduction in NO_X at this driving condition was pronounced because the greatest differential in spark timing after VSAD occurs at high speed, part throttle load. Changes in emission levels at 50 mph 8% grade were nominal reflecting the similarity of spark timing before and after VSAD at this operating condition.

Engine coolant inlet air and exhaust temperatures increased for over half the test vehicles after VSAD. Exhaust temperatures for 50 mph 8% grade and stop and go showed substantial increases. The trend toward increased exhaust temperature and coolant temperature was not consistent, and a few vehicles experienced reductions in these and coolant temperatures. The driveability tests performed by AESi's technicians, as well as the response offered by the vehicle owners regarding driveability suggested that, on the average, a slight penalty in driveability might be anticipated. Fuel mileage as calculated from emissions data on the 1972 Federal test was penalized an average of 3.5% by VSAD. Statistical analyses of the emissions data and other quantitative results of the program are presented in this final report.

EFFECT OF VSAD ON EXHAUST EMISSIONS IN GRAMS PER MILE

	Number of Valid Tests	Hydrocarbons	Carbon Monoxide	Carbon Dioxide	Oxides of Nitrogen
STOP AND GO					
Before	98	6.25	104.11	618.42	2.96
After	98	5.94	106.04	657.51	2.10
Percent Change	98	-4.96%	+1.82%	+6.32%	-29.05%
50 MPH STEADY STATE - NORMAL ROAD LOAD					
Before	99	2.01	25.91	403.73	5.46
After	98	1.54	23.96	429.45	2.66
Percent Change	98	-23.38%	-7.52%	+6.37%	-51.28%
50 MPH STEADY STATE - 8% GRADE LOAD					
Before	79	3.82	69.37	648.89	11.89
After	71	3.69	65.74	678.89	10.53
Percent Change	70	-3.40%	-5.23%	+4.62%	-11.44%
1972 FEDERAL PROCEDURE					
Before	98	4.34	64.02	558.91	4.49
After	98	3.77	63.13	588.50	2.77
Percent Change	98	-13.13%	-1.39%	+5.29%	-38.31%

NOTE: Underline indicates statistically significant difference at the 95% confidence level.

TABLE 1

was also evaluated by the number of attempts made to start the car, the total starting time, the elapsed time for accelerating from 0 to 70 mph, and the customer's opinion of the vehicle. Table 2 summarizes the results of the driveability tests. The results suggest that VSAD results in a slight deterioration in driveability.

During two of the emission test conditions, vehicle operating temperatures were recorded. The greatest changes in operating temperatures were expected to occur under the more adverse operating conditions. The two tests involving the greatest vehicle stress were the 50 mph - 8% grade load ("grapevine") test and the stop and go test. Both tests were run with a simulated ambient temperature of 100°F. The operating temperature changes occurring in these tests are summarized in Table 3. The majority of the vehicles experienced increased coolant and exhaust temperatures after the VSAD. However, 18% to 25% of the vehicles experienced temperature decreases.

In the case of Volkswagens the tests had to be aborted because VW had no centrifugal spark advance. Disconnection of vacuum spark advance caused full retard, resulting in severe operational difficulty as well as overheating. Consequently, no VW test data are included in this study. Other automobile makes tested did not demonstrate this problem because all of them had both centrifugal and vacuum spark advance.

Tuneup information was read and recorded from each test vehicle in the as-received state and then after the VSAD. The total spark timing was the only tuneup parameter affected by the VSAD. In the 98 vehicles tested, the mean reduction in total spark timing advance was 18.1° with a standard deviation of 6.57°.

A statistically significant reduction in fuel mileage was found after the VSAD. In the 1972 Federal tests the after VSAD, average fuel mileage was 3.5% below the before VSAD average mileage. However, 19 cars experienced an increase in fuel mileage rather than a decrease.

TABLE 2

SUMMARY OF EFFECTS OF VSAD ON DRIVEABILITY

	Before VSAD	After VSAD
Customer Opinion		
Improvement	---	1
No Difference	---	73
Deterioration	---	26
Mean Demerit Points	15.4	16.3
Mean Number of Starting Attempts	1.2	1.2
Mean Start Time (seconds)	1.7	2.2
Elapsed Time 0-70 MPH (seconds)	16.4	16.5

TABLE 3

	Change in Temperature From Before VSAD	
	Grapevine (°F)	Stop & Go (°F)
Air Cleaner Inlet		
Mean Temperature Increase	2.19°	1.41°
Percent of Cars With Temperature Increases	66%	47%
Percent of Cars With Temperature Decrease	15%	29%
Engine Coolant Outlet		
Mean Temperature Increase	1.23°	3.11°
Percent of Cars With Temperature Increases	66%	58%
Percent of Cars With Temperature Decrease	21%	23%
Exhaust Tailpipe Outlet		
Mean Temperature Increase	35.73°	21.03°
Percent of Cars With Temperature Increases	80%	72%
Percent of Cars With Temperature Decrease	18%	25%

1. INTRODUCTION

In the early 1960's the State of California recognized the need to control emissions from automotive vehicles. A goal was established to reduce atmospheric pollution from automobiles, and standards were legislated by the State to control vehicular carbón monoxide (CO) and hydrocarbons (HC). In accordance with legislation, vehicle manufacturers developed various exhaust emissions control strategies. Beginning with the 1966 model year, all new vehicles sold in California were equipped with emission control systems or devices designed to meet the State's carbon monoxide and hydrocarbon standards. The strategies used initially by the manufacturers to control exhaust emissions consisted of modifying the fuel and air induction system to permit leaner operation and equipping the vehicle with a pump which injected fresh air into the hot exhaust manifold, thereby further burning pollutants such as carbon monoxide and hydrocarbons. One major vehicle manufacturer chose not to use an air pump because of expense, and adequately controlled emissions by lean carburetor operation and the use of devices which further assisted in the control of pollutants. By the middle of 1967 model year production, the manufacturers using air pumps discontinued their use on many models in favor of various carburetion and ignition system modifications and devices which resulted in more complete combustion through leaner operation.

Effective with the 1968 model year the Federal government adopted California's CO and HC emission standards, and manufacturers continued to apply basically the same strategies towards controlling emissions. As carbon monoxide emission levels diminished from these controlled vehicles, and as standards for CO and HC became more stringent, another family of pollutants, oxides of nitrogen (NO_x) began to appear in auto exhaust in greatly increasing concentrations. Nitric oxide (NO), the primary pollutant in this family of pollutants is formed when oxygen and nitrogen from the air combine under the high temperatures and pressures existing in the engine combustion chamber. The leaner air-fuel mixtures used by manufacturers to control CO and HC resulted in higher peak combustion temperatures, thereby forming higher levels of oxides of nitrogen.

The California Air Resources Board and the State legislature recognized this problem, and through legislation required that all new cars beginning with the 1971 models, meet emission standards for oxides of nitrogen. Legislation was subsequently passed requiring reduced oxides of nitrogen from the 1966 through 1970 model vehicles then in the hands of the public. Strategies were developed by numerous public and private organizations to achieve a significant NO_x reduction from cars in service. Generally, the strategies proposed directly affected combustion chamber temperatures and pressures, thereby reducing the combination of oxygen and nitrogen. The strategies utilized modification of the spark ignition timing characteristics or dilution of the fuel-air mixture with exhaust gas. One specific proposed means for achieving a reduction in NO_x was to simply disconnect the vacuum spark advance mechanism. Authorities have claimed that this method would cause a significant reduction in NO_x under the various operating conditions during which the vacuum spark advance would normally function. Widespread interest developed in the vacuum spark advance disconnect (VSAD) strategy to control oxides of nitrogen because of its relative simplicity and low cost. The possibility of reduced performance, increased fuel consumption and potential overheating problems caused concern about this control strategy.

Much of the background information relating to reduction in NO_x emissions when using the VSAD technique has been based upon the pre-1972 California emissions test procedures which provide data on a volumetric or concentration basis. Spark ignition timing is a fundamental engine operating parameter, and any change caused by VSAD could greatly affect other exhaust effluents. VSAD results in reducing engine power output and fuel economy at a given throttle setting, throughout the part throttle operating range. In order to regain the power output required by the motorist, it is necessary to increase the throttle opening, thereby increasing air and fuel flow through the engine. This increase could, on a mass basis (grams of effluent per mile) outweigh any decreases caused by reduction of combustion temperatures through the use of VSAD. For these reasons, the State Air Resources Board determined it necessary to ascertain the real effects of VSAD upon NO_x emissions as well as carbon monoxide and hydrocarbons. Therefore, the primary objective of this program is to accurately determine the effect upon NO_x, CO and HC exhaust emission levels of the vacuum spark advance disconnect NO_x control strategy.

It is known that VSAD will necessarily reduce power output at a given throttle condition. However, the effect of a reduction in part throttle power upon performance of the pertinent vehicle population is not known. Furthermore, the degree to which any change in performance is observed by the motorist is not known. A secondary objective of the program described in this report, is to determine the effect of VSAD upon vehicle performance, specifically on vehicle driveability and mileage.

A third objective of this program is to determine the nature and magnitude of any adverse effects such as overheating of the vehicle under diverse operating conditions.

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2. TECHNICAL DISCUSSION

2.1 PROGRAM DESIGN

The experimental design and planning of this program was accomplished while working closely with the Air Resources Board staff. The program objectives were carefully defined prior to the start of work. Test procedures, equipment requirements and test parameters were delineated to maximize technical and statistical validity of the program. The testing strategy was to compare each vehicle with and without the vacuum spark advance disconnect. Selection of the test fleet of the most popular 1966-1970 model year passenger cars was the first program design activity. Pre-program technical considerations suggested that a fleet size of 100 vehicles would yield sufficient data to achieve high statistical confidence. The foremost design criterion was that the fleet be representative of the consumer vehicle population. The sampling technique had been fully developed by AESi to assure close conformance of the test fleet makeup with that of the California vehicle population. The need to test each vehicle in the as-received condition was of paramount consideration in defining program procedures.

The test procedures used to adequately determine the effects of the vacuum spark advance disconnect strategy upon exhaust emissions were developed. Since any one test routine cannot fully represent all vehicle operating conditions, three routines were decided upon. These were the hot start 1972 Federal test procedure using the CVS test technique, steady state tests at 50 miles per hour, and a stop and go rush hour traffic simulation. The CVS technique has been proven to provide data truly representative of the mass or total amount of pollutants emitting from the vehicle under test. Therefore, this technique was used throughout.

One of the program objectives was to determine the susceptibility of the vehicles to overheating or other malfunctions when operating with the VSAD. In addition to normal driving schedules described above, an adverse condition was included which simulated high load operation such as that encountered when driving at 50 mph up a long, steep inclined highway. This required the use of a high ambient temperature simulator (HATS). Under this condition, the engine would heat up to maximum operating temperatures. This "grapevine" test was to be performed prior to the stop and go driving cycle to precondition the vehicle in a severe but realistic manner. To stress the vehicle even further, and disclose potential operating malfunctions with the VSAD, the "grapevine" test and stop and go cycle were to be performed under high ambient temperatures.

The potential effects of VSAD upon driveability was a concern. The ARB driveability procedure was used to assert driveability effects. Also, a survey was made of vehicle owners after having operated their vehicles with VSAD for one week.

2.2 TEST VEHICLE PROCUREMENT

The objective of the test vehicle procurement task was to obtain test vehicles of the appropriate make, model and age which were statistically representative of the California vehicle population. To satisfy this goal, AESi developed a procedure for selecting consumer owned vehicles for the program test fleet.

An nth-name sampling of 1966 through 1970 automobiles registered in the City of Los Angeles (as defined by postal zip codes) was obtained from R. L. Polk and Company. The nth-name sampling technique used by Polk resulted in the selection of a random sample by selecting the vehicles whose owners reside at every nth street address within the sample area. The randomly selected names were submitted to AESi on magnetic tape. A subsample of vehicles which best conformed to the California vehicle population profile in terms of make, model year, and number of engine cylinders was selected from this tape by the computer.

A mailing consisting of a letter and a postage-paid return card was sent to each of the vehicle owners selected in the subsample. Approximately one week after the mailing, AESi procurement specialists began to call and encourage participation from all selected vehicle owners having listed telephone numbers. In some cases, selected vehicle owners were visited personally by the procurement specialists to obtain their cooperation. Also, concurrent with the mailings, local newspapers and selected special interest groups such as the TB and Health Association were alerted of the program and encouraged to publicize the program.

After maximizing the response to the mailings, the names of all selected vehicle owners who were willing to participate in the program were resubmitted for a second level computerized selection. Based upon the additional vehicle parameters of transmission type and cubic inch displacement of the engine, as well as the original parameters of make, model year, and number of cylinders, the computer selected from the candidates those vehicles which best conformed to the California vehicle population profile. The computer also indicated any vehicles which were desired but not obtained in the procurement activity. This enabled the procurement specialists to substitute for the unobtainable vehicle.

AESi personnel then contacted the owners of the selected vehicles and asked them to deliver their vehicles to the laboratory in accordance with the testing schedule. If the selected vehicle subsequently became unavailable for one reason or another, a spare vehicle was substituted for the initially selected vehicle.

Figure 2.2-1 shows the composition of the ideal test fleet in terms of make and model year, while Figure 2.2-2 shows the actual test fleet. The only difference between ideal and actual was the substitution of a 1969 Lincoln for a 1969 Imperial. This substitution was considered reasonable since the populations of these two models were essentially equal.

Test vehicles were scheduled for testing at the laboratory in accordance with the work load and manpower availability. The program design specified that the owners were to deliver their cars to the laboratory. Each owner was contacted to set a mutually agreeable appointment. Then followup contacts were made while their vehicles were being tested.

Each participant was asked to bring his car to the laboratory twice. The first time the car was left for three days and the owner was given a loan car. The test car was then returned to the owner with the vacuum spark advance disconnected. One week later, the owner was asked to return so that he could fill out a driveability questionnaire while the vacuum spark advance on his car was being reconnected.

DESIRED TEST FLEET MAKEUP - CITY OF LOS ANGELES

Make/Year	70	69	68	67	66	TOTAL
Buic	1	1	2	2	2	8
Cadi		1			1	2
Chev	5	4	4	4	4	21
Chry	1	1	1	1		4
Dodg	1	1	2	1	2	7
Ford	4	4	4	3	4	19
Impe		1				1
Linc						0
Merc	1	1	1			3
Olds	1	1	1	1	2	6
Plym	2	2	1	2	1	8
Pont	2	2	2	2	2	10
Ramb	1		1	1	1	4
Misc	2	2	1	1	1	7
TOTAL	21	21	20	18	20	100

FIGURE 2.2-1

ACTUAL TEST FLEET MAKEUP - CITY OF LOS ANGELES

Make/Year	70	69	68	67	66	TOTAL
Buic	1	1	2	2	2	8
Cadi		1			1	2
Chev	5	4	4	4	4	21
Chry	1	1	1	1		4
Dodg	1	1	2	1	2	7
Ford	4	4	4	3	4	19
Impe						0
Linc		1				1
Merc	1	1	1			3
Olds	1	1	1	1	2	6
Plym	2	2	1	2	1	8
Pont	2	2	2	2	2	10
Ramb	1		1	1	1	4
Misc	2	2	1	1	1	7
TOTAL	21	21	20	18	20	100

FIGURE 2.2-2

2.3 FACILITIES AND EQUIPMENT

2.3.1 Facility

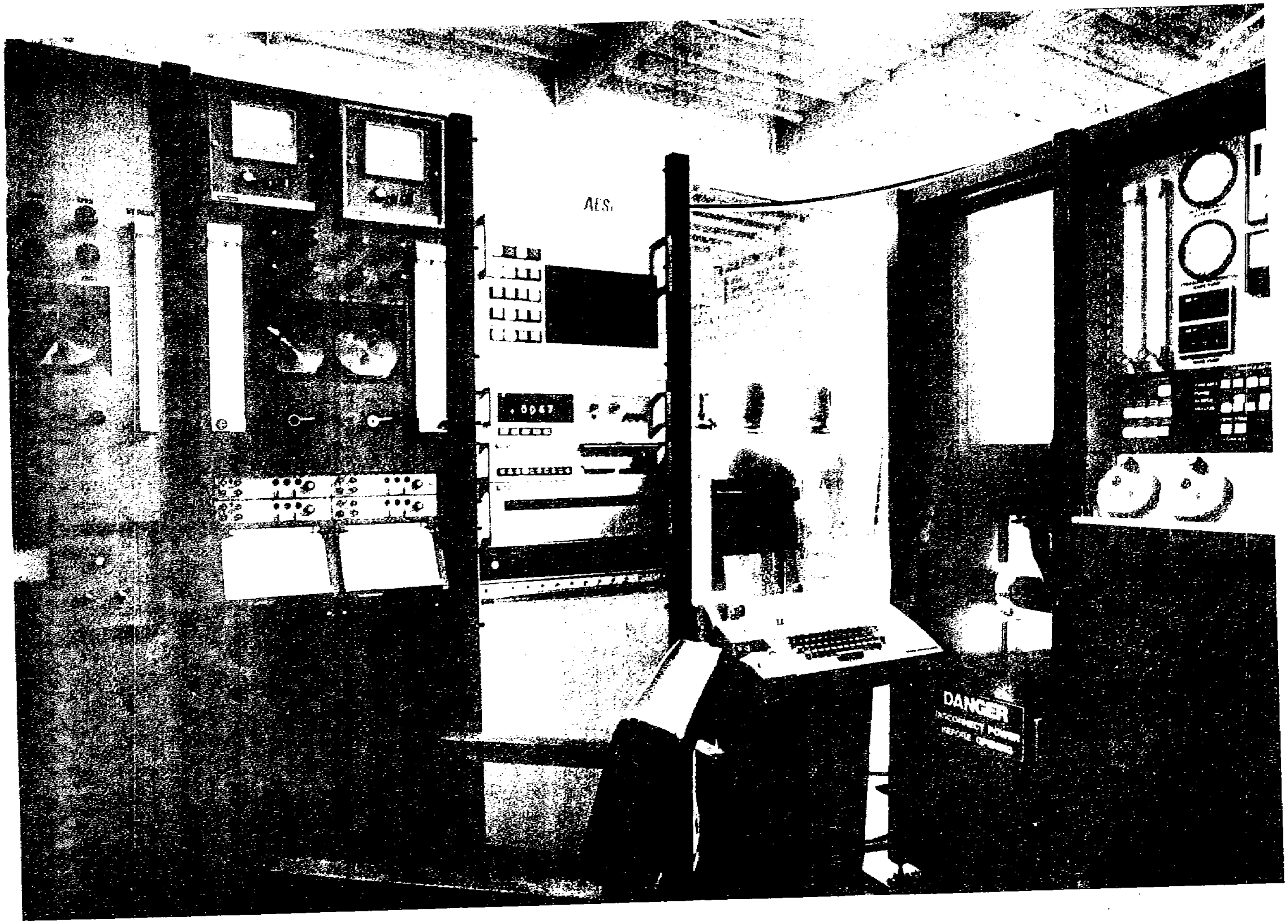
All tests were performed at AESi's Los Angeles Vehicle Emissions Testing Laboratory located at 14239 Hindry Avenue, Hawthorne, California 90250.

2.3.2 Constant Volume Sampler

The equipment in this laboratory was designed and built by AESi in strict accordance with requirements stipulated in pertinent issues of the Federal Register. This equipment was designed to perform vehicle emissions tests in accordance with the 1972 through 1975 Federal Test Procedures. The AESi Constant Volume Sampler (CVS) was equipped with a number of special features to enable precise sample collection over a wide range of emission levels. Additional performance details are presented in the appendix. Figure 2.3-1 illustrates the AESi Constant Volume Sampler.

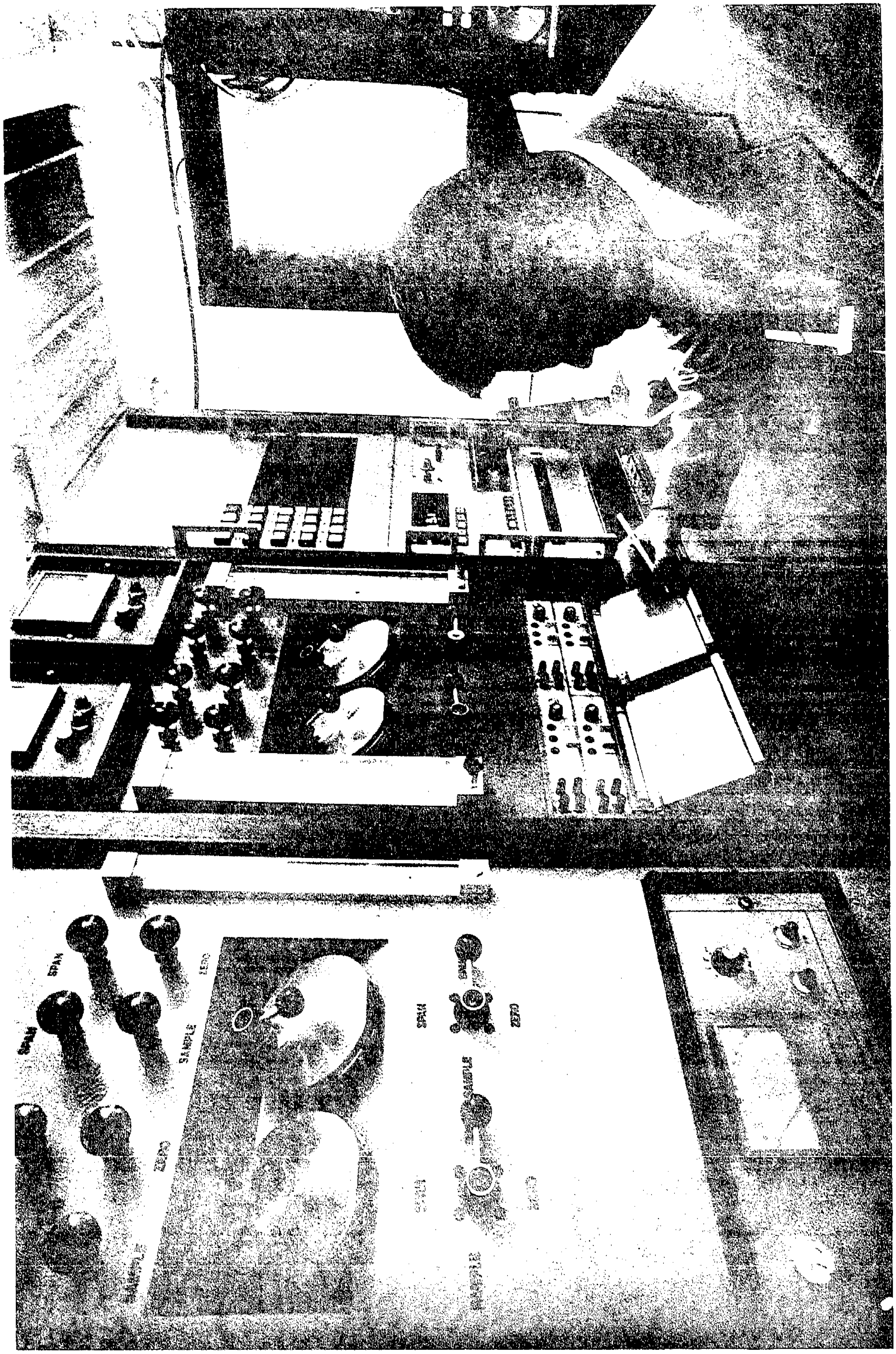
2.3.3 Exhaust Analysis Console

The exhaust analysis console used in the performance of this program was also designed for vehicle emissions testing by 1972 through 1975 Federal Test Procedure in accordance with specifications stipulated in pertinent issues of the Federal Registers. The instruments used in the exhaust analysis console were the Beckman Model 315B Nondispersive Infrared Analyzers for the measurement of carbon monoxide and carbon dioxide. A Beckman Model 400 Flame Ionization Analyzer was utilized to measure total hydrocarbons. A Thermo Electron Corporation (TECO) Model 10A Chemiluminescent Analyzer was used for the measurement of NO and NO_x. Texas Instruments Potentiometric Recorders were used in the exhaust analysis console to record all instrument signal outputs. The AESi Exhaust Analysis Console is depicted in Figures 2.3-1 and 2.3-2. Additional performance details including the instrument ranges are presented in the appendix.



AESi CONSTANT VOLUME SAMPLER and EXHAUST ANALYSIS CONSOLE

FIGURE 2.3-1



DETAIL OF AESi EXHAUST ANALYSIS CONSOLE

FIGURE 2.3-2

2.3.4 Laboratory Standard Calibration Gases

AESi maintains a complete set of laboratory standard calibration gases in Los Angeles. The contents of each cylinder were analyzed and concentrations were assigned by the Office of Air Programs of the Environmental Protection Agency in Ann Arbor. The laboratory used the standard set of gases for defining the complete instrument calibration curves and for subsequent assigning of values to the day-to-day "working" gases. There is a table delineating the laboratory standard calibration gases in the appendix.

2.3.5 Chassis Dynamometer

The Clayton Variable Inertia Chassis Dynamometer, equipped with 250 pound increment inertia loading weights and the low torque bridge (0 to 40 horsepower) was utilized in the laboratory.

2.3.6 High Ambient Temperature Simulator

An AESi designed High Ambient Temperature Simulator (HATS) was used to simulate high ambient temperature vehicle operating conditions. The HATS had a control system that is extremely sensitive to variations in cooling air temperature, and air temperature was maintained almost stable at a nominal 100°F with slow variations of ±5°F. A drawing of the HATS appears in the appendix.

2.3.7 Miscellaneous Equipment

In addition to the equipment previously described, a Varian driver aid was utilized to provide driving schedules for the various driving sequences performed during this program. In addition, an Autoscan ignition analyzer, timing light, tach-dwell meter, other tuneup equipment, and small tools were used as necessary.

2.3.8 Equipment Qualification, Calibration and Cross Check

The requirement for system qualification was ±2 percent overall accuracy. This requirement encompassed the constant volume sampler, exhaust analysis console, as well as all other testing equipment. The constant volume sampler and the exhaust analysis console were calibrated in compliance with the procedures and specifications stated in the Federal Register. The chassis dynamometer was calibrated by the coast-down technique stipulated in the Federal Register.

Daily and weekly checks were performed to insure the equipment was operating properly within the specified tolerances. A complete, detailed discussion of the qualification, calibration, and cross check procedures is presented in the appendix.

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2.4 TEST PROCEDURES

2.4.1 Vehicle and Equipment Preparation

All vehicles tested in this program were inspected upon receipt from the vehicle owner. The inspection consisted of verification of the particular make, model year, type of engine, transmission and other information pertinent to the program. In addition, a cursory inspection was performed to determine that the vehicle was operating safely and to determine if any visible damage was noted and should be called to the vehicle owner's attention.

All vehicles were tested in the as-received condition since a constraint of the program was to determine the impact of VSAD alone as an NO_x reducing strategy. A visual examination of the under-hood area was performed in order to determine that gross malfunctions of the running gear would not occur. On some vehicles items such as cracked spark plug wires, improperly installed air cleaners and leaking fuel systems were observed, but were not corrected unless a safety hazard was present.

All of the vehicle data such as dwell, basic timing at idle speed, timing at 2500 RPM, and engine displacement were measured and recorded prior to the testing. Then the temperature sensors were installed on the vehicle. The sensors were placed at the air filter inlet, in the coolant at the upper hose thermostat housing, and in front of the radiator grill area.

All test equipment was thoroughly warmed up, calibrated and inspected for proper operation prior to the performance of any tests. The chassis dynamometer was also thoroughly warmed up by either using a non-test car or an AESi company car if the dynamometer had not been used during the previous two hours. During the dynamometer warmup procedure, inertia and road load of the dynamometer were properly set for the following test car. In addition, the dynamometer speed indicator was calibrated and checked against the driver aid to insure that both speed indications were identical.

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The exhaust analysis console was normally left operating during the daylight hours. All instruments were left on a standby basis with either dry nitrogen or dry air continually flowing through them. Therefore, it was not normally necessary to perform any preparation on the exhaust analysis console prior to testing with the exception of the routine calibration procedures. In the event that the exhaust analysis console or any instruments were shut down for any length of time prior to testing, a minimum warmup period of one-half hour was required prior to use.

The constant volume sampler required approximately one hour warmup for precise measurement prior to testing if it had not been operating during the previous 24 hour period. The CVS was turned on and operated early in the morning to insure that the temperature stabilized by the time testing was initiated for the day. The CVS was connected to the vehicle used for dynamometer warmup, thereby removing exhaust from the building and warming the flexible duct and mixing plenum.

The testing sequence used in the performance of this program is shown in Figure 2.4-1. A slight modification to the procedure was made towards the end of the program to expedite its completion. With the approval of the Air Resources Board, a hot start driveability routine was substituted for the cold start driveability routine. This modification was deemed reasonable based upon negligible difference in driveability before and after VSAD with either cold start or hot start procedures.

2.4.2 Steady State 50 MPH Test

The first test performed on each vehicle was the measurement of emissions at a steady 50 mph. Each vehicle was tested as-received and the mass emissions were measured. Samples were collected by the bag method utilizing the constant volume sampler. At least one-half minute of warmup or stabilization was allowed before collection of the exhaust sample. Immediately following the as-received 50 mph steady state test, the 1972 Federal hot start test was performed. Then the distributor vacuum line was disconnected and plugged and the 50 mph steady state test was repeated to measure the mass emissions after the VSAD.

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FIGURE 2.4-1

TEST SEQUENCE

1. Establish file by car number, test number.
2. Obtain and log all vehicle data (dwell, basic timing @ 2500 RPM, idle RPM, CID, etc.).
3. Install instrumentation:
    a. Inlet air temperature at air filter inlet.
    b. Coolant temperature at thermostat housing on upper hose.
    c. Cooling air temperature ahead of radiator in grill area.
4. Warm up vehicle and dynamometer.
5. Perform steady state 50 mph test.
6. Perform EPA 1972 hot start test.
7. Disconnect distributor vacuum line and plug line.
8. Measure basic timing, timing at 2500 RPM, idle speed.
9. Repeat steady state at 50 mph test.
10. Repeat EPA 1972 hot start test.
11. Reconnect vacuum line.
12. Perform 50 mph 8% grade test with 100°F cooling air.
13. Perform stop-go cycle test with 100°F cooling air.
14. Disconnect vacuum line and plug.
15. Repeat 8% grade test at 100°F.
16. Repeat stop-go test at 100°F.
17. Reconnect vacuum line.
18. Cold soak vehicle minimum of 12 hours.*
19. Perform ARB driveability study from cold start.
20. Cold soak vehicle minimum of 12 hours.*
21. Disconnect vacuum line and plug.
22. Repeat driveability from cold start.
23. Return to owner with questionnaire.
24. After one (1) week, obtain vehicle, reconnect vacuum line, and collect questionnaire.
25. Return vehicle to owner.

*With the approval of ARB, hot start driveability test was substituted for the cold start driveability test to expedite the completion of the program.

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2.4.3 Federal (EPA) 1972 Hot Start Test

The two Federal 1972 hot start tests were performed on each vehicle in accordance with the procedures stipulated in the Federal Register. The as-received Federal hot start tests were performed immediately following the as-received 50 mph steady state test. The post VSAD Federal hot start test was run following the post VSAD 50 mph steady state test. The data accumulated during both tests were in terms of mass emissions.

2.4.4 Steady State 50 MPH With Simulated 8% Grade

One of the extreme condition tests involved running each vehicle at conditions comparable to a summer day on the "grapevine" which is a long section of steep grade north of Los Angeles on Highway U.S. 99. The average grade is 8% for a number of miles. During the summer, temperatures commonly reach 100°F on the grapevine. To simulate these conditions, vehicles were tested using the AESi High Ambient Temperature Simulator (HATS) and an increased dynamometer loading. The dynamometer loading was increased to put the engine and drive train under the stress of driving up an 8% grade. After an initial warmup period, each vehicle was run for at least two minutes at a steady 50 mph. The HATS produced a cooling air temperature of 100°F and the dynamometer simulated the 8% grade. The mass emissions were measured both before and after the VSAD. Following the completion of both of the Federal hot start tests, the as-received steady state 50 mph 8% grade test was made. After this as-received 8% grade test, the as-received stop and go test was run. Then the vacuum spark advance line was disconnected and plugged. Then the post VSAD steady state 8% grade test was run.

2.4.5 Stop and Go Cycle Test

A special test cycle was developed to simulate summer stop and go driving. In many parts of California, the summer temperatures often reach 100°F. Therefore, the test vehicles were run using the High Ambient Temperature Simulator (HATS) to simulate a cooling air temperature of 100°F.

Each vehicle was operated at a series of accels, idles, decels and cruises. This series is designed to simulate stop and go driving. The mass emissions are first measured with the vehicle in the as-received condition. Both the before and after VSAD tests were run following the corresponding 50 mph 8% grade test, thereby attempting to create a severe load on the vehicle cooling system. The 50 mph 8% grade tests produced a great deal of engine heat. Before the vehicle's cooling system could dissipate this heat the stop and go driving tests were begun. While the vehicle was simulating around town driving, the cooling system had to dissipate the engine heat already built up. The stop and go test cycle is presented in the appendix.

2.4.6 Driveability Test

Two driveability tests were run on each vehicle. Every effort was made to quantify the results of these tests. A driveability scale was developed to measure driveability problems. Each vehicle was run twice over a set 5 mile course. This course includes freeway as well as around town driving. As the driver executed each step of the course, he recorded the vehicle's driveability. A demerit scale was developed which ranged from 0 (unsatisfactory performance) to 5 (stall or backfire). The vacuum spark advance was connected during the first run of the 5 mile course. Then the vacuum spark advance was disconnected and the course was run again.

In addition to recording driveability demerits, certain other data were recorded: the number of attempts it took to start the vehicle; the total time required to start the vehicle; and the time required to accelerate from 0 to 70 mph.

After the AESi driver completed his driveability analysis, the car was returned to its owner with the vacuum spark advance disconnected. After five days, each owner was asked to return to the laboratory to fill out a questionnaire and to have the vacuum spark advance reconnected. In the questionnaire the driver was asked to compare vehicle performance before and after the VSAD. Samples of the forms and questionnaires used are in the appendix.

3. RESULTS AND CONCLUSIONS

The results presented in the following sections and the appendix include the data for all tests. In each case, the results of the before VSAD (vacuum spark advance disconnect) and after VSAD are compared. Unfortunately, some of the test vehicles could not complete certain tests. The 50 mph steady state 8% grade load test (also called the "grapevine" test) took the highest toll in vehicles. Only 70 vehicles completed both the before and after VSAD "grapevine" tests.

The two Volkswagens included in the vehicle sample proved to not be testable. These cars lack a centrifugal spark advance mechanism and rely totally on the vacuum spark advance. After the VSAD, these cars would not operate properly. Both vehicles experienced extreme overheating and rough idling after the VSAD. Therefore, all VW tests were discontinued.

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3.1 EFFECT OF VSAD ON VEHICLE EMISSIONS

This section presents the mass emissions measured before and after the vacuum spark advance disconnect (VSAD) for each of the four testing conditions. Table 3.1-1 presents the mass emissions means and standard deviations for each effluent. The before VSAD, after VSAD, the differences as well as the percent change are presented. Each mean of the differences was tested at the 95% confidence level for a significant difference in the before VSAD versus the after VSAD.

Under all four testing conditions, the NO and NO_xC (NO_x corrected for humidity) mass emissions were significantly reduced by the VSAD. The CO_2 mass emissions were increased significantly in all four test conditions indicating a possible increase in air fuel ratio and engine mass flow. There were no significant increases in CO mass emissions except in the "grapevine" (50 mph steady state 8% grade) test. Only 70 vehicles were able to complete both the before and after VSAD tests. This was the only testing condition in which there was not a significant decrease in the HC mass emissions. The small HC increase recorded in the grapevine test is not statistically significant.

Table 3.1-1 also presents the percent change in the mass emissions means between the before VSAD and after VSAD. For NO_xC the percentage reductions in the means range from 18.10% to 51.46%. Table 3.1-2 presents a summary of the effects of VSAD upon NO_x emissions. In the majority of the test vehicles, the NO_x emissions were reduced. However, a few test vehicles experienced an increase in NO_x emissions. Figure 3.1-1 presents the cumulative probability distributions of percentage decrease in NO_x expended in each of the four testing conditions.

NO_x decreased 29.05% after VSAD when tested under stop and go traffic conditions. Hydrocarbons decreased 4.96% while carbon monoxide increased 1.82% and carbon dioxide increased 5.95%. The greatest reduction in NO_x occurred under the 50 mph steady state normal load test. NO_x mass emissions were reduced 51.46%, hydrocarbons were reduced 24.14% and carbon monoxide was reduced 8.41% while carbon dioxide showed a small increase of 5.63%. The VSAD had the greatest effect on vehicle timing during this test. The greatest differential in spark timing after VSAD occurs at high speed, partial throttle load. The smallest reduction in NO_X occurred under the 50 mph steady state - 8% grade ("grapevine") test. The reduction in NO_X was 18.10% while hydrocarbons increased 2.16%, carbon monoxide increased 22.81% and carbon dioxide increased 4.03%.

Increased throttle loads were required to maintain 50 mph on an 8% grade. As the throttle load increases, the manifold vacuum decreases and the vacuum spark advance before VSAD is reduced. Thus the change in spark advance caused by the VSAD is reduced. The 1972 Federal test procedure involves a variety of accel, decel, cruise, and idle conditions. It is designed to simulate typical vehicle operation. The reduction in NO_X after VSAD was 38.31% under the Federal test and hydrocarbons were reduced 13.13%, carbon monoxide was reduced 1.39% and carbon dioxide increased 5.03%.

SUMMARY OF EFFECTS OF VSAD UPON EMISSIONS
IN GRAMS PER MILE

	HC		CO		CO_2		NO		NO_xC	
	Mean	Std.	Mean	Std.	Mean	Std.	Mean	Std.	Mean	Std.
STOP AND GO SEQUENCE N = 98										
Before VSAD	6.25	4.42	104.11	77.18	618.42	131.37	2.53	1.12	2.96	1.36
After VSAD	5.94	4.69	106.04	88.85	657.51	137.33	1.84	0.96	2.10	1.07
Differences	-0.31*	1.53	1.92	37.92	39.10*	73.77	-0.69*	0.86	-0.86*	1.00
Percent Change	-4.96%		+1.82%		+5.95%		-27.27%		-29.05%	
50 MPH STEADY STATE NORMAL N = 98[1]										
Before VSAD	2.01	1.44	25.91	26.97	403.73	78.79	3.85	1.45	5.46	2.41
After VSAD	1.54	1.77	23.96	33.72	429.45	79.06	2.17	0.79	2.66	1.09
Differences	-0.49*	1.20	-2.19	13.45	24.19*	37.29	-1.69*	1.06	-2.81*	1.83
Percent Change	-24.14%		-8.41%		+5.63%		-43.78%		-51.46%	
50 MPH STEADY STATE 8% GRADE N = 70[2]										
Before VSAD	3.82	2.60	69.37	88.27	648.90	125.28	7.12	2.79	11.89	5.58
After VSAD	3.69	2.98	65.74	80.77	678.89	129.11	6.47	2.47	10.53	4.75
Differences	0.01	1.62	11.56*	34.36	16.44*	60.80	-1.18*	1.69	-2.40*	2.76
Percent Change	+2.16%		+22.81%		+4.03%		-14.76%		-18.10%	
1972 FEDERAL PROCEDURE N = 98										
Before VSAD	4.34	2.74	64.02	49.22	558.91	101.16	3.35	1.21	4.49	1.86
After VSAD	3.77	2.85	63.13	50.02	588.50	112.42	2.26	0.74	2.77	1.02
Differences	-0.58*	0.76	-0.89	9.50	29.59*	49.55	-1.09*	0.81	-1.72*	1.30
Percent Change	-13.13%		-1.39%		+ 5.03%		-32.54%		-38.31%	

[1] A total of 99 before VSAD and 98 after VSAD tests were performed.

[2] A total of 79 before VSAD and 71 after VSAD tests were performed, however, only 70 vehicles had both tests valid.

*The difference is statistically significant at the 95% confidence level.

TABLE 3.1-1

SUMMARY OF EFFECTS OF VSAD UPON NO_x EMISSIONS

Item	Stop & Go Sequence	50 MPH Steady State Road Load	50 MPH Steady State 8% Grade	1972 EPA Procedure
Sample Size	98	98	70	98
Mean in Percent - NO_x Reduction	-24.29%	-46.83%	-17.54%	-33.72%
Median in Percent - NO_x Reduction	-34.33%	-52.15%	-19.74%	-38.14%
Standard Deviation in Percent	-43.55%	-19.74%	-36.06%	-22.88%
Range in Percent (-reduction, + increase)	-56.51% to +136.46%	-75.67% to +11.24%	-74.26% to +240.00%	-73.53% to +69.75%
Range in grams per mile (-reduction, + increase)	- 2.77 to + 4.94	- 7.44 to + 0.12	- 8.77 to +10.92	- 6.11 to + 1.29
Number of Vehicles With NO_x Reduction	85	95	64	94
Percent of Vehicles With NO_x Reductions	86.7%	96.9%	91.4%	95.9%
Number of Vehicles With NO_x Increase	13	3	6	4
Percent of Vehicles With NO_x Increases	13.3%	3.1%	8.6%	4.1%

TABLE 3.1-2

CUMULATIVE PROBABILITY DISTRIBUTION

PERCENT REDUCTION IN NO_x RESULTING FROM VSAD

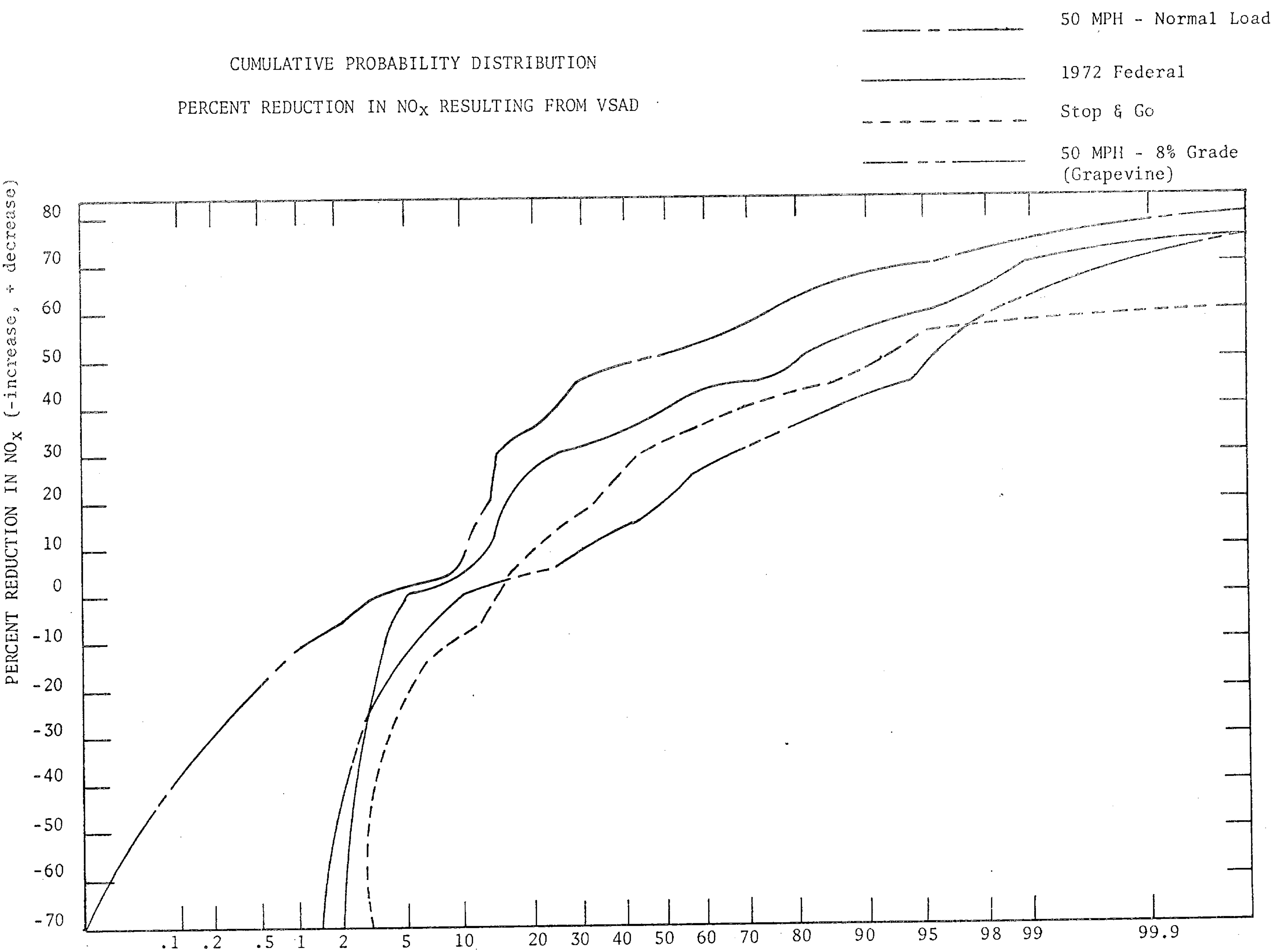

FIGURE 3.1-1

3.2 EFFECT OF VACUUM SPARK ADVANCE DISCONNECT ON VEHICLE OVERHEATING

Temperatures were measured at four different places on each test vehicle during the stop and go and the steady state-8% grade (grapevine) tests. Temperatures were measured at the air cleaner inlet, in front of the radiator grill area (grill), in the coolant at the upper hose thermostat housing (engine coolant outlet), and in the exhaust tailpipe outlet at the back of the vehicle. The grill temperatures were measured to make sure that the ambient temperatures were held relatively constant at 100°F by the High Ambient Temperature Simulator (HATS). The greatest difference in grill temperatures between the before and after VSAD test was 10°F. In most cases, this difference was less than 5°F. Table 3.2-1 presents the results of the temperature measurements at the air cleaner, engine coolant outlet and the exhaust tailpipe outlet.

In the case of the grapevine (50 mph steady state - 8% grade) test, only 70 of the 100 test vehicles were able to complete the test. The other 30 vehicles suffered extreme overheating and the tests had to be discontinued to avoid damaging the test vehicles. These 30 vehicles are included in the calculation of the percentage of cars with temperature increases in Table 3.2-1. Two vehicles were unable to complete the stop and go test because of overheating. They too are included in calculating the percent of cars with temperature increases. The vehicles unable to complete the tests were assumed to have had air cleaner inlet and engine coolant outlet temperature increases of $\geq$ 15°F and were therefore included in the percentage increase $\geq$ 15°F computations on Table 3.2-1. In the case of exhaust tailpipe outlet, the vehicles unable to complete the tests were included in the percentage of cars having an increase $\geq$ 50°F. However, since there were no actual readings made, the means and standard deviation do not include these vehicles. Had it been possible to include these vehicles, the means would have been higher.

Any increase in inlet air temperature was caused by additional heat being dissipated into the incoming air by the radiator, and additional heat being radiated by the exhaust manifold. In the grapevine test, 66% of the test vehicles experienced an inlet temperature increase and for 32% of the

EFFECTS OF VSAD UPON VEHICLE TEMPERATURES WITH SIMULATED AMBIENT TEMPERATURE OF 100°F

	Change in Temperatures From Before VSAD	
	Grapevine (°F)	Stop & GO (°F)
Air Cleaner Inlet		
Mean Temperature Increase	2.19°*	1.41°
Standard Deviation	6.65°	8.33°
Range of Temperature Changes	-20° to +15°	-40° to +27°
Percent of Cars With Increased Temperatures	66%	47%
Percent of Cars With Temperature Increases ≥ 15°	32%	8%
Percent of Cars With No Change in Temperature	19%	24%
Percent of Cars With Decreased Temperatures	15%	29%
Engine Coolant Outlet		
Mean Temperature Increase	1.23°	3.11°*
Standard Deviation	10.29°	7.59°
Range of Temperature Changes	-35° to +25°	-15° to +35°
Percent of Cars With Increased Temperatures	66%	58%
Percent of Cars With Temperature Increases ≥ 15°F	34%	11%
Percent of Cars With No Change in Temperature	13%	19%
Percent of Cars with Decreased Temperatures	21%	23%
Exhaust Tailpipe Outlet		
Mean Temperature Increase	35.73°*	21.03°*
Standard Deviation	63°	47°
Range of Temperature Change	-145° to +251°	-185° to +136°
Percent of Cars With Increased Temperatures	80%	72%
Percent of Cars With Temperature Increases ≥ 50°F	57%	21%
Percent of Cars With No Change in Temperature	2%	3%
Percent of Cars With Decreased Temperatures	18%	25%

* Statistically significant increase at 95% confidence level

TABLE 3.2-1

vehicles this increase was 15°F. In the case of the stop and go tests, 47% of the vehicles experienced an increase and 8% experienced an increase of 15°F or more.

The engine coolant outlet temperature is a direct measure of the engine coolant temperature. In the grapevine tests 66% of the vehicles experienced an increase in coolant temperature, and for 34% of the vehicles this increase was 15°F or more. In the stop and go tests, 58% of the vehicles experienced a coolant temperature increase and for 11% this increase was 15°F or more. As the engine coolant temperature increases, the engine operates at a higher temperature and the ability of the cooling system to maintain proper operating temperature diminishes. An increase in peak coolant temperature of 15°F or more may cause engine problems such as cylinder head warpage, leaking gaskets, and premature failure of cooling system components. It is noteworthy that a number of the test vehicles experienced a reduction in coolant temperatures. This occurred in 21% of the vehicles on the grapevine test and 23% on the stop and go test. In addition, there was no change in coolant temperature for 13% of the vehicles during the grapevine test and 19% during the stop and go test.

The exhaust outlet temperature was measured on each grapevine test and on each stop and go test to determine the effect of VSAD. In the case of three vehicles tested early in the program, exhaust outlet temperatures were not measured. Table 3.2-1 presents the average change in exhaust temperatures. The average exhaust temperatures increased significantly after the VSAD. In the case of the grapevine test, the average increase was 35°F. However, certain vehicles experienced a reduction in exhaust temperature after the VSAD. The results show that in the two types of adverse vehicle operating conditions as simulated in the AESi laboratory, using the High Ambient Temperature Simulator (HATS) a substantial increase in the mean exhaust temperature for the fleet was experienced. Further, 30 vehicles in the grapevine test and 2 vehicles in the stop and go test could not complete the tests because of extreme overheating. While the exact quantitative relationship between increased exhaust temperatures and higher incidence of exhaust valve burning is not precisely defined, the results of the program suggest that more exhaust valve burning will occur with VSAD than without.

Figure 3.2-1 shows the cumulative probability distribution of the change in exhaust temperature on the grapevine test, as well as the probability distribution for the stop and go test. Figure 3.2-2 shows the cumulative probability distribution of the change in engine coolant temperature for both tests. These distributions and the means do not include the vehicles unable to complete the test because of overheating. Therefore, these means are lower than what really occurred.

CUMULATIVE PROBABILITY DISTRIBUTION

CHANGE IN EXHAUST TAILPIPE OUTLET TEMPERATURE RESULTING FROM VSAD

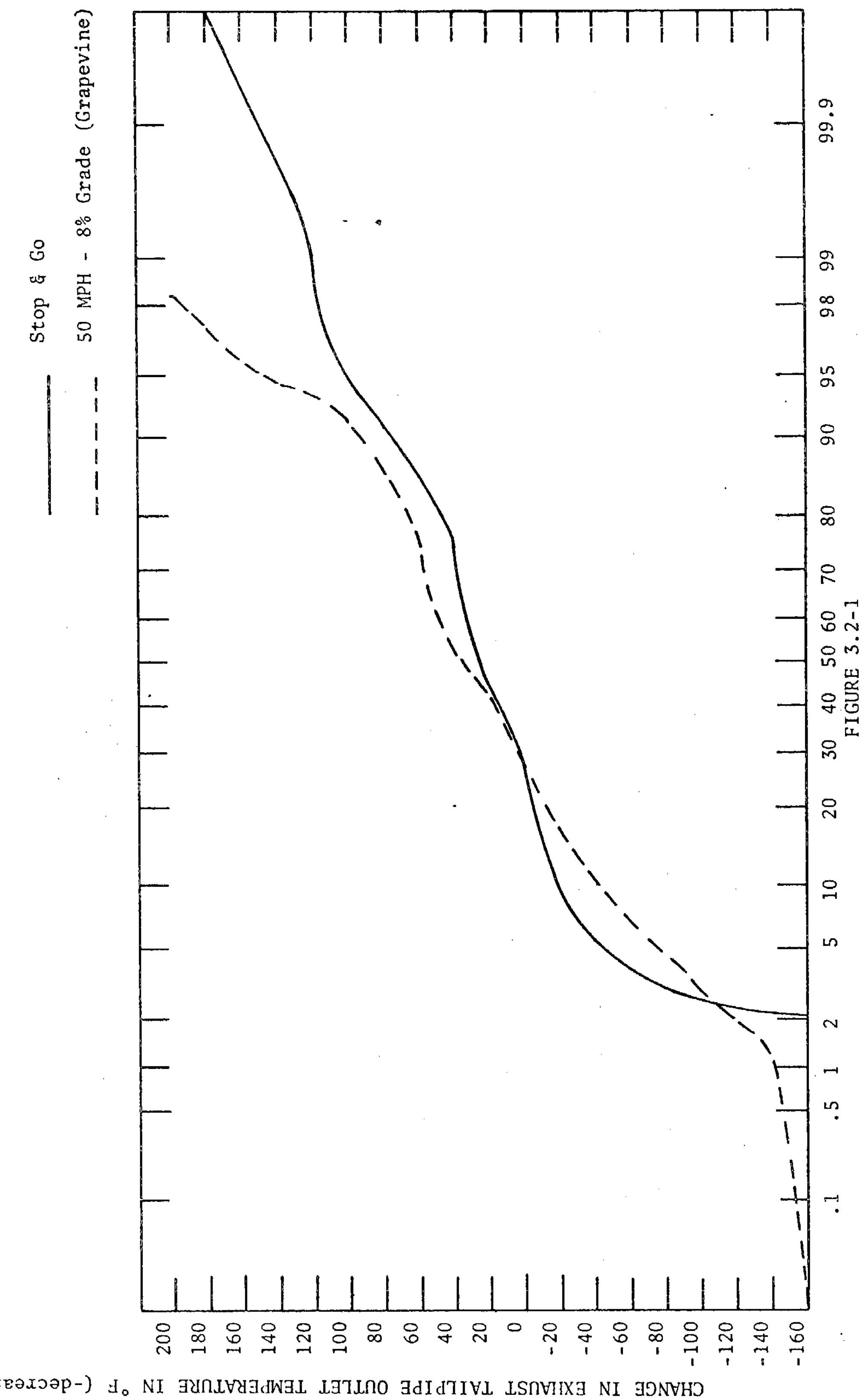

FIGURE 3.2-1

CUMULATIVE PROBABILITY DISTRIBUTION

CHANGE IN ENGINE COOLANT TEMPERATURE RESULTING FROM THE VSAD

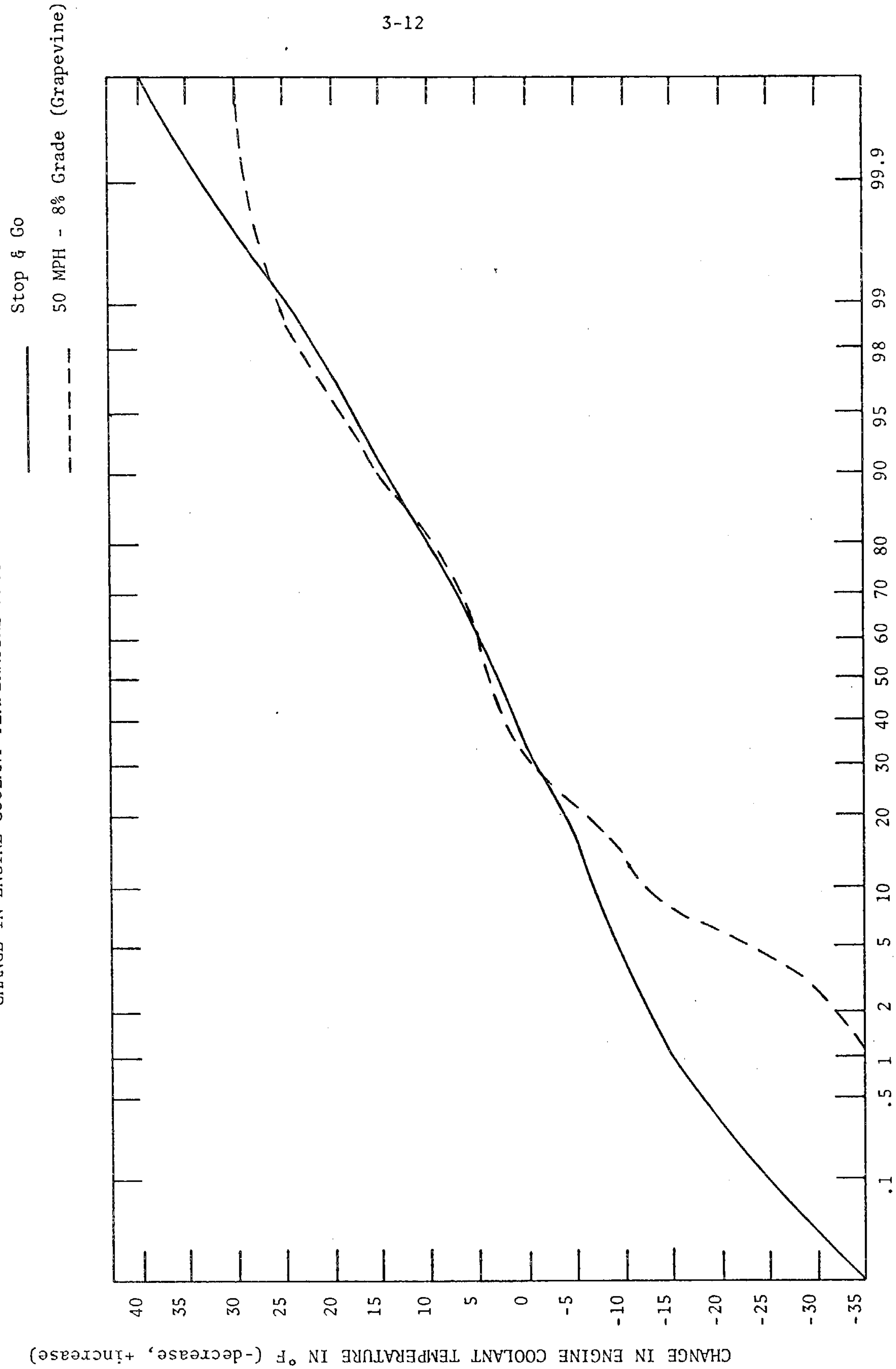

FIGURE 3.2-2

3.3 EFFECT OF VSAD ON DRIVEABILITY

Vehicle driveability is highly subjective in nature. To quantify this characteristic, a demerit system was used whereby from 0 to 5 demerits were assigned for each of the major sections of the driveability tests, with the criteria being as follows:

For satisfactory performance	0 points
For trace of malfunction	1 point
For moderate malfunction	2 points
For severe malfunction	3 points
For stall or backfire	5 points

Driveability was also evaluated on the basis of the number of attempts made to start the car, the total starting time, the elapsed time from 0 to 70 mph, and the customer's opinion of the vehicle. AESi categorized the customer's opinion of the VSAD into three areas: no noticeable difference; improvement; and deterioration. Table 3.3-1 summarizes the results of the driveability evaluation. The results suggest that VSAD causes a slight deterioration in driveability. The increase in average start time was primarily caused by one vehicle (No. 8). The starting time for this vehicle was 8 seconds before the VSAD and 60 seconds after the VSAD. This extended starting time cannot be attributed solely to VSAD. If this car is excluded from the averages, then the before VSAD start time mean is 1.6 seconds and the after VSAD mean is 1.6 seconds.

Tests were attempted on two Volkswagen vehicles, one a 1500 CC Fastback, Car Number 95, and one a standard Volkswagen, Car Number 96. Both vehicles have only vacuum controlled spark advance mechanisms (no centrifugal advance system), and were highly dependent on vacuum advance to operate satisfactorily. Both tests were aborted early in the schedule when it became obvious that the cars would not perform well enough to accomplish the driveability tests and emission test cycles.

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SUMMARY OF EFFECTS OF VSAD ON DRIVEABILITY

	Before VSAD	After VSAD
Customer Opinion		
Improvement	---	1
No Difference	---	73
Deterioration	---	26
Total Demerit Points	1512	1595
Average Demerit Points	15.4	16.3
Total Starting Attempts	118	117
Average Starting Attempts	1.2	1.2
Average Start Time (seconds)	1.7	2.2
Elapsed Time 0-70 MPH (seconds)	16.4	16.5

TABLE 3.3-1

3.4 EFFECT OF VSAD ON VEHICLE MAINTENANCE CONDITION AND MILEAGE

Tuneup information was measured and recorded for each test vehicle. The idle RPM, dwell, basic ignition timing, and ignition total timing at 2500 RPM were measured and recorded when the vehicle was received, and after VSAD.

Six vehicles were received for testing with inoperative vacuum spark advance systems. These vehicles were identified by comparing the before and after VSAD total timing at 2500 RPM. With the vacuum spark advance connected, the advance should have been much greater than after the vacuum spark advance disconnect. In the case of the six vehicles, the before and after total advances were about the same. These six vehicles also showed no significant reduction in NO_xC measurements after the VSAD.

The mean reduction in total timing for all 98 vehicles tested was 18.1° and the standard deviation was 6.57°. If the six vehicles with inoperative vacuum spark advance systems are excluded, the mean reduction in total timing for the remaining 92 vehicles was 19.3° and the standard deviation was 4.74°. The before and after tuneup data for each vehicle are presented in the appendix.

Vehicle fuel mileage in miles per gallon was calculated from the mass emission data. A carbon balance was used which assumes that the number of carbon atoms in the fuel consumed by the engine equals the number of carbon atoms in the engine exhaust. Table 3.4-1 presents the results of these calculations. There is, in both tests, a statistically significant reduction (at the 95% confidence level) in fuel mileage resulting from VSAD. In the case of the 1972 Federal test, the average reduction was 3.5%. However, some of the vehicles experienced an increase in fuel mileage. In certain vehicles this may have resulted from the vehicles being received in a very poor state of tune. It is possible that disconnecting the vacuum spark advance may have resulted in these vehicles operating under more ideal conditions.

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FUEL MILEAGE REDUCTION RESULTING FROM VSAD

50 MPH - STEADY STATE - NORMAL LOAD

Mean fuel mileage(reduction)	-0.74 m.p.g.*
Standard deviation	1.38 m.p.g.*
Average percent reduction in fuel mileage	3.7%
Percent vehicles with reduction	71.4%
Percent vehicles with increase	28.6%

1972 FEDERAL TEST

Mean fuel mileage (reduction)	-0.48 m.p.g.*
Standard deviation	1.38 m.p.g.*
Average percent reduction in fuel mileage	3.5%
Percent vehicles with reduction	80.7%
Percent vehicles with increase	19.3%

*Statistically significant reduction at 95% confidence level.

TABLE 3.4-1

4.1 TEST VEHICLE PROCUREMENT

4.1.1 Selection Procedure

The objective was to obtain test vehicles of the appropriate make, model and age which were statistically representative of the California vehicle population. To satisfy this goal, AESi developed an appropriate selection procedure which is depicted in Figure 4.1-1.

An nth-name sample of 1966 through 1970 automobiles registered in the City of Los Angeles (as defined by postal zip codes) was obtained from R. L. Polk and Company. The nth-name sampling technique used by Polk resulted in the selection of a random sample by selecting the vehicles whose owners reside at every nth street address within the sample area, where:

$$n = \frac{X}{Y}; \text{ where } X = \text{Total number of vehicle owners}$$
$$\text{and } Y = \text{Sample size}$$

The randomly selected names were submitted to AESi on magnetic tape. A subsample of vehicles which best conformed to the California vehicle population profile in terms of make, model year, and number of cylinders was selected. The subsample as selected by the computer was printed out in the format shown in Figure 4.1-2.

A mailing consisting of a letter and a postage-paid return card as shown in Figures 4.1-3 and 4.1-4 was sent to each of the vehicle owners selected in the subsample. The aura of "junk mail" was minimized by typing names and addresses of the selected vehicle owners on the letters and envelopes.

Approximately one week after the mailing, AESi procurement specialists began to call and encourage all selected vehicle owners with listed telephone numbers to participate in the program. In some cases, selected vehicle owners were visited personally by the procurement specialists to obtain their cooperation. Also, in conjunction with the mailings, local

FLOW DIAGRAM OF TEST VEHICLE SELECTION PROCEDURE

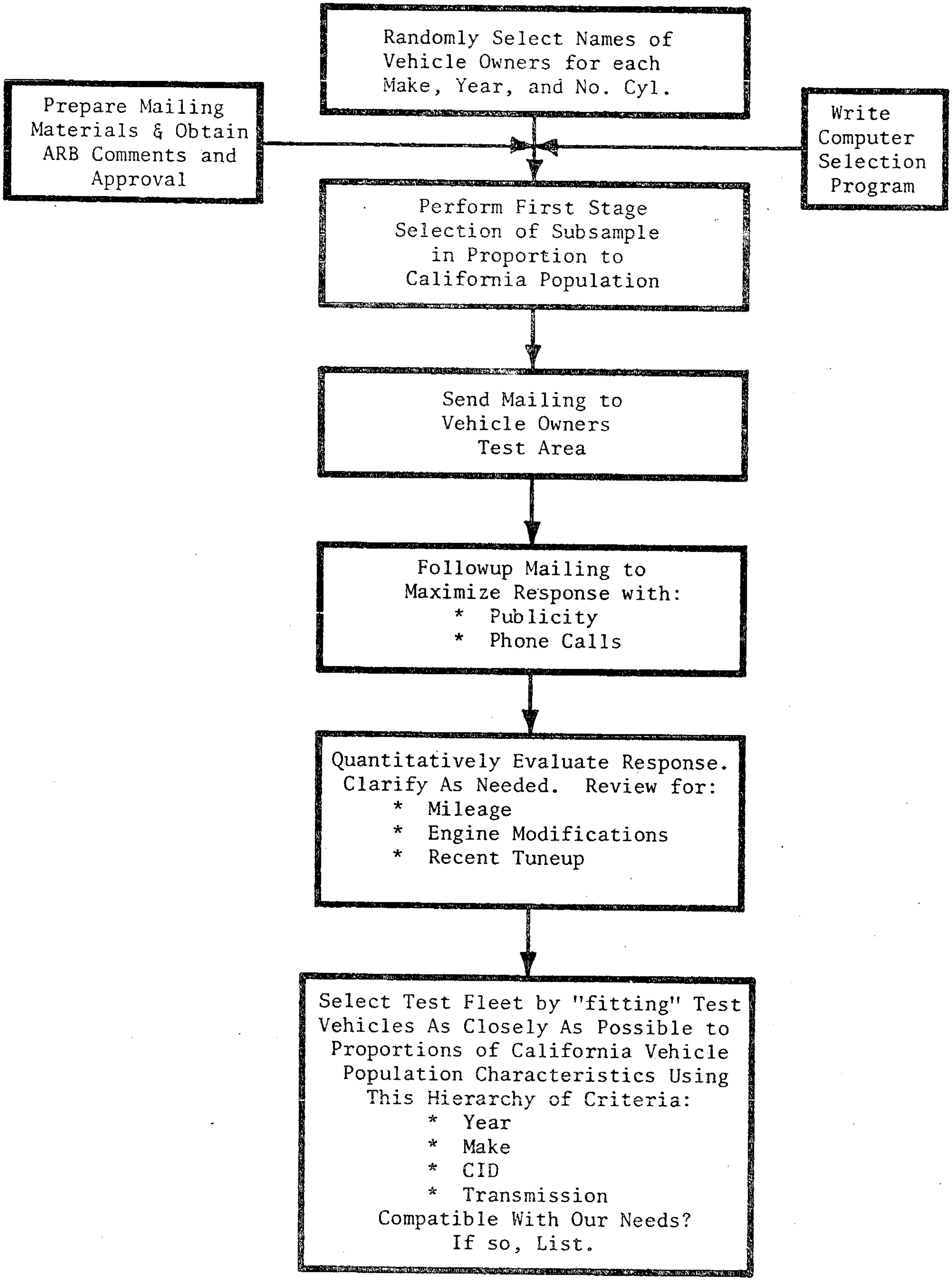

FIGURE 4.1.1

SUBSAMPLE PRINTOUT

NO.	NAME	ADDRESS	YR.	MAKE	CYL.
1009	MR. M L THOMPSON	1846 WILTON PL LOS ANGELES CA 90019	68	RIVI	8
1010	MR. H TANKERSLEY	1707 STANLEY AV LOS ANGELES CA 90019	68	RIVI	8
1011	MR. H SINCLAIR	167 ORANGE DR LOS ANGELES CA 90036	68	RIVI	8
1012	MR. D L MONTGOMERY	3701 FERNWOOD ST LYNWOOD CA 90262	68	RIVI	8
1013	MR. A DANTZLER	1225 52ND ST LOS ANGELES CA 90037	68	RIVI	8
1014	MR. A CROSSKILL	590 PLYMOUTH BL LOS ANGELES CA 90004	68	RIVI	8
1015	MR. C M CARSON	14813 CORDARY AV HAWTHORNE CA 90250	68	RIVI	8
1016	L F BESSEY	421 SYCAMORE AV LOS ANGELES CA 90036	68	RIVI	8
1017	MR. L E BERRY	2504 CUMPTON BL COMPTON CA 90220	68	RIVI	8
1018	MR. A UTECHT	16834 MERIT AV GARDENA CA 90247	68	BUIC	8
1019	MR. W D TAYLOR	234 53RD ST LOS ANGELES CA 90037	68	BUIC	8
1020	MR. F T MCFALL	5421-1/2 NORMANDIE LOS ANGELES CA 90037	68	BUIC	8
1021	MR. K LABOSCHIN	9539 CRESTA DR LOS ANGELES CA 90035	68	BUIC	8
1022	MS. E W JOHNSON	10160 CIELD DR BEVERLY HILLS CA 90210	68	BUIC	8

FIGURE 4.1-2

AESi
AUTOMOTIVE ENVIRONMENTAL SYSTEMS, INC.

LETTER SENT TO VEHICLE OWNERS

Dear Car Owner:

Automotive Environmental Systems, Inc., has used a computerized random selection process to choose your name from many owners of 1966-1970 automobiles to participate in one of the most important vehicle pollution control programs ever sponsored by the California Air Resources Board. We need your valued cooperation through volunteering your car for two or three days of testing in conjunction with this program.

The automobile has been determined to be a major contributor to air pollution in California and laws have been enacted to control the automobile as a pollutor. One of these laws requires that all 1966 through 1970 cars be modified to reduce the oxides of nitrogen emitted by these cars. One of the modifications proposed is the disconnection of the vacuum spark advance. AESi has been chosen to evaluate this measure from the standpoint of its effect on vehicle operation as well as pollution reduction. Because this law affects all 1966-1970 cars in California, typical consumer-owned vehicles are being sought for testing and the owners of such vehicles are being asked to volunteer their cars for testing.

In appreciation for your cooperation, the Air Resources Board has authorized the award of a $25 savings bond. In addition, you will be provided with a 1972 loan car for the full period your car is being tested.

Your participation in this program will be an extremely valuable contribution to the State's fight against air pollution. Please complete and return the enclosed postage paid card at your earliest convenience. This does not obligate you in any way, and you may discuss any reservations you may have regarding the program with the representative who will contact you shortly. If you have any questions whatsoever regarding the program, you are invited to contact the local representative of AESi at the above telephone number.

Very truly yours,

H. James Law, Jr.
Project Manager
Pollution Testing Program

HJL:mjl
Enclosure

FIGURE 4.1-3

FILL OUT, TEAR OFF
AND RETURN
POSTCARD TODAY!

FIRST CLASS
Permit No. 1471
San Bernardino
Ca.

BUSINESS REPLY MAIL
No Postage Stamp Necessary If Mailed In The United States

Postage will be paid by

AUTOMOTIVE ENVIRONMENTAL SYSTEMS, INC.
Vehicle Emissions Testing Laboratory
14239 Hindry Avenue
Hawthorne, California 90250

Yes, I am willing to volunteer my car for pollution testing ______ .
Make of car ______________________ .
My car's engine displacement is ______ cubic inches.
Serial Number ______________________ .
Carburetor: 1 barrel ______ 2 barrel ______
4 barrel ______ Fuel Inj. ______
Transmission: Automatic ____ Manual ____
Current mileage on my car is ______________ .

} FILL IN IF YOU HAVE THIS INFORMATION.

Vol. No. ________

Name ______________________ Phone No. ______________
PLEASE PRINT
Street No. ______________________ Best time
City ______________ Zip Code ________ to Call ______________

COMPANY USE ONLY

FILL OUT, TEAR OFF
AND RETURN
POSTCARD TODAY!

FIGURE 4.1-4

newspapers and selected special interest groups such as the TB and Health Association were alerted to the program and encouraged to publicize it.

The letters brought a spontaneous response of 11%. Followup calls raised the percentage of volunteers to 38%. The remaining 62% were unavailable for the following reasons:

1. No phone or unlisted number - 49%.
2. Vehicle sold or wrecked - 2%.
3. Prospective participant moved from area - 6%.
4. Refused to cooperate - 4%.
5. Miscellaneous - modified, faulty exhaust system, mechanically unable to complete test - 1%.

After maximizing the response to the mailings, the names of all selected vehicle owners who were willing to participate in the program were listed and resubmitted for a second level computerized selection. Based upon the additional vehicle parameters of transmission type, and cubic inch displacement of the engine, as well as the original parameters of make, model year, and number of cylinders, the computer selected from the candidates those whose vehicles best conformed to the California vehicle population profile and listed all valid candidates in the format shown in Figure 4.1-5. The code listed at the left of Figure 4.1-5 indicates the extent to which each vehicle conforms to the projected test fleet profile. Identification of the code is as follows:

11 conforms perfectly to profile
12 conforms to profile except for engine displacement
13 conforms to profile except for transmission type
21 conforms perfectly to profile but is an extra candidate and is to be retained as a spare

In addition to the conformity ranking of candidate vehicles, the computer also indicated any vehicles which were desired but not obtained in the procurement activity. This enabled the procurement specialists to substitute for the unobtainable vehicles.

LOS ANGELES   CARS SELECTED FOR TESTING

CODE	NAME	ADDRESS	YR	MFGR	CYL	COST	TRANS	CID	SEQ#
11	7RS NADINE KROHN	REPLACEMENT	68	FORD	8	2	A	289	186
21*	LINDA CRAGER	REPLACEMENT	68	FORD	8	3	M	302	232
21*	MR. W H BRACKEN	13634 CHADRON AV HAWTHORNE CA 90250	68	FORD	8	2	A	390	96
21*	MR. M BARNETT	1307 ORANGE GRV AV LOS ANGELES CA 90019	68	FORD	8	2	A	289	315
11	MR. W PHILLEO	22917 NADINE CIR A TORRANCE CA 90505	68	PLYM	8	2	A	318	591
21*	MISS L M KELLEY	6110 OVERHILL DR 1/2 LOS ANGELES CA 90043	68	PLYM	6	1	A	225	675
11	MISS D B ARLINE	1331 COCHRAN AV LOS ANGELES CA 90019	68	RAMBL	8	2	A	290	489
11	MISS F H PARKER	855 RIDGELEY DR LOS ANGELES CA 90036	68	DODGE	6	1	A	225	621
21*	MR. M GRUMMER	1620 CREST DR LOS ANGELES CA 90035	68	DODGE	6	2	A	225	695
11	MR. F C NEGRI	229 ST ANDREWS PL LOS ANGELES CA 90004	68	PONTI	8	4	A	400	22
11	MR. W C DUKES	5100 3RD AV LOS ANGELES CA 90043	68	PONTI	8	2	A	350	596
21*	MR. K F OSTERSTOCK	32 PACKET RD PLS VRD PNSLA CA 90274	68	PONTI	8	2	A	400	543
11	MRS LANI RICHES	REPLACEMENT	68	BUICK	8	5	A	430	272
21*	MR. J BENTLEY	5021 INADALE AV LOS ANGELES CA 90043	68	BUICK	8	3	A	340	263

FIGURE 4.1-5

AESi personnel then contacted the owners of the selected vehicles and asked them to deliver their vehicle to the laboratory in accordance with the testing schedule. If a selected vehicle subsequently became unavailable for one reason or another, a spare vehicle was substituted for the initially selected vehicle. Advertising and other strategies were used in a limited number of circumstances to locate certain hard-to-find models.

4.1.2 Test Vehicle Handling

Test vehicles were scheduled for testing at the laboratory in accordance with the work load and manpower availability. Double shifts were worked from time to time to expedite the completion of the program. Accordingly, the scheduling of test vehicles was a critical task, especially since the vehicle owners were relied upon to deliver their vehicles to the laboratory. Arrangements were made with the owners of the candidate vehicles several days in advance, and the owners were again reminded of the appointments one day prior to the scheduled time of delivery. In addition, standby test vehicles were held in reserve whenever possible. These vehicles were owned by participants who were especially willing to assist in the performance of the program and could bring their vehicles to the laboratory on relatively short notice.

Virtually all of the participants required loan cars while their cars were being tested. AESi arranged with American International Rent-A-Car to provide fully insured loan cars. Each participant expected to be provided a rental car expeditiously upon his arrival at the laboratory. Thus rental car fleet scheduling at each facility was especially important. Unless a participant from the previous day had returned a rental car well in advance of the new participant's arrival, the new participant would either have to wait for the arrival of a rental car, or additional cars would be required. In the interest of expediting the program and making it as convenient as possible for the participants, AESi chose to have additional loan cars on hand to assure the immediate availability of loan cars for all participants. Each candidate in the program signed two documents in conjunction with the exchange of vehicles. The first document was a test agreement which absolved the participant of all liability relating to his vehicle while in the possession of AESi. The second document indemnified the participant from any liability arising from the use of the loan car.

4.1.3 Vehicle Information

The characteristics of the test vehicles are further defined in Figure 4.1-6. The following is a description of the various abbreviations used in the heading of Figure 4.1-6.

HEADING	DESCRIPTION
CAR #	This is a five digit number assigned each test vehicle at each facility. The order and format of test vehicles in this section are identical to that in all sections of the appendix. This arrangement is used to permit easy determination of vehicle identification.
RUN #	RUN # is a five digit sequential run number.
YR	This is a two digit number indicating the model year of the test vehicle.
MAKE	This is a four character abbreviation specifying the make of the vehicle. The first four characters of the vehicle make are always to be used. For example: Ford = FORD, Chevrolet = CHEV, Buick = BUIC, Volkswagen = VOLK.
MODEL	This is a five letter abbreviation specifying the model of the vehicle. For example: Wildcat = WILDC, Ford LTD = LTD, Pontiac Lemans = LEMAN, etc.
CID	This is a three digit number indicating the cubic inch displacement of the test vehicle. In the case of small displacement engines, it is rounded off to the nearest unit displacement. For example: Volkswagen = 96.6 cubic inches displacement is input 097.
BBL	This indicates the number of carburetor barrels or venturis. A vehicle with multiple carburetion would be entered as the total number of venturis. Example: 3 - 2 BBLS = 6.

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VEHICLE INFORMATION SUMMARY

CAR	RUN	YR	MAKE	MODEL	CID	BBL	TRN	INRT	ODOMR
00001	00502	70	FORD	FAIRL	351	2	0	4000	35531
00002	00524	69	FORD	COUNT	429	4	0	4500	25930
00003	00529	67	CHEV	CAMAR	327	4	0	3000	35689
00004	00546	66	CHEV	IMPAL	283	2	0	4000	74159
00005	00551	67	PLYM	BARRA	273	2	0	3000	51988
00006	00554	67	PONT	CATAL	400	2	0	4500	58498
00007	00555	68	PONT	TEMPE	350	2	0	4000	42790
00008	00557	70	FORD	TORIN	351	4	0	3500	24477
00009	00559	67	PONT	CATAL	400	4	0	4500	64492
00010	00560	67	FORD	FAIRL	289	2	0	3500	20735
00011	00564	70	FORD	GALAX	351	2	0	4000	45616
00012	00569	67	PLYM	BELVE	318	2	0	3500	35657
00013	00568	70	CHEV	CAMAR	307	2	0	3500	26477
00014	00573	69	PONT	GRAND	400	4	0	4000	46162
00015	00574	70	PLYM	GTX	440	4	0	4000	32514
00016	00584	69	CHEV	CONCO	350	4	0	4000	28269
00017	00585	67	RAMB	REBEL	290	2	0	3500	26934
00018	00602	70	PONT	FIREB	350	2	0	3500	34799
00019	00604	70	DATS	510	097	2	0	2250	07286
00020	00608	68	FORD	MUSTA	302	4	0	3500	31036
00021	00609	67	OLDS	CUTLA	330	2	0	3500	95461
00022	00610	70	CHEV	NOVA	307	2	0	3500	44089
00023	00612	68	CHRY	NEWYO	440	4	0	4500	70953
00024	00611	67	FORD	MUSTA	289	2	0	3000	40649
00025	00614	67	FORD	MUSTA	289	2	0	3000	41693
00026	00613	70	PONT	FIREB	350	4	3	3500	38289
00027	00615	69	MERC	MARQU	429	4	0	4500	44297
00028	00617	69	OLDS	CUTLA	350	2	0	3500	34798
00029	00616	69	FORD	MUSTA	302	2	0	3000	39215
00030	00619	69	TOYO	CROWN	138	2	4	3000	12559
00031	00618	69	DODG	CORON	383	4	0	4000	40937
00032	00620	69	CHEV	IMPAL	350	4	0	4000	19616
00033	00621	69	FORD	COUNT	390	2	0	4500	37765
00034	00622	69	CHEV	BISCA	327	2	0	4000	74149
00035	00623	69	BUIC	SKYLA	350	2	0	3500	55398
00036	00624	69	PLYM	GTX	440	4	0	4000	60852
00037	00625	68	DODG	DART	273	2	0	3500	54991
00038	00626	69	CHEV	MALIB	350	4	0	3500	29090
00039	00627	66	FORD	MUSTA	289	2	3	3000	34566
00040	00628	69	DODG	CHARG	383	4	0	4000	43770
00041	00629	70	CHEV	CAMAR	350	4	0	3500	21747
00042	00630	66	FORD	MUSTA	289	2	0	3000	78989
00043	00631	68	FORD	FAIRL	200	1	3	3500	61145
00044	00632	66	RAMB	CLASS	287	2	0	3500	57841
00045	00634	67	OLDS	CUTLA	330	4	0	3500	47863
00046	00633	66	OLDS	NINET	425	4	0	4500	71302

FIGURE 4.1-6

AESi
AUTOMOTIVE ENVIRONMENTAL SYSTEMS, INC.

VEHICLE INFORMATION SUMMARY
(Continued)

CAR	RUN	YR	MAKE	MODEL	CID	BBL	TRN	INRT	ODOMR
00047	00639	67	CHEV	MALIB	327	4	4	3500	44168
00048	00635	66	DODG	CORON	273	2	0	3500	50488
00049	00637	68	FORD	MUSTA	302	2	0	3500	59228
00050	00636	69	PLYM	VIP	383	4	0	4000	23990
00051	00638	68	BUIC	ELECT	430	4	0	4500	57241
00052	00643	68	LINC	CONTI	462	4	0	5000	88942
00053	00641	68	BUIC	SKYLA	350	4	0	4000	22928
00054	00640	66	OLDS	CUTLA	330	4	0	3500	95565
00055	00642	68	CHEV	CAMAR	327	2	0	3500	31670
00056	00645	68	CHEV	IMPAL	327	2	0	4000	49548
00057	00644	67	BUIC	SKYLA	340	4	0	3500	74743
00058	00646	70	MERC	MARQU	390	2	0	4500	51516
00059	00647	70	TOYO	MARK2	113	2	4	2500	39320
00060	00652	69	PONT	FIREB	250	4	0	3500	28275
00061	00649	69	CHRY	TOWNC	383	4	0	5000	54593
00062	00650	66	DODG	CHARG	318	2	0	3500	72924
00063	00651	67	DODG	MONAC	383	2	0	4500	85168
00064	00653	69	FORD	MUSTA	351	2	0	3500	79071
00065	00654	68	FORD	MUSTA	200	2	0	3000	67779
00066	00655	67	BUIC	LESAB	340	4	0	4500	73657
00067	00653	66	FORD	MUSTA	289	2	0	3000	78732
00068	00656	68	MERC	COUGA	302	2	0	3500	45704
00069	00670	69	DATS	510	097	2	4	2250	25243
00070	00658	69	CADI	DEVIL	472	4	0	5000	51343
00071	00660	67	CHRY	300	383	4	0	4500	33546
00072	00662	68	CHEV	BISCA	250	2	0	4000	82422
00073	00661	66	PONT	LEMAN	326	2	0	3500	45878
00074	00669	68	PONT	FIREB	350	4	0	3500	81292
00075	00664	66	FORD	MUSTA	289	2	0	3000	33381
00075	10665	66	FORD	MUSTA	289	2	0	3000	33431
00076	00668	70	FORD	MAVER	200	1	0	2750	21117
00077	00667	66	CHEV	CHEVE	194	1	0	3500	39881
00077	10674	66	CHEV	CHEVE	194	1	0	3500	39908
00078	00673	70	CHEV	TOWNS	350	2	0	4500	26949
00079	00672	66	BUIC	SKYLA	300	2	0	3500	61761
00080	00671	70	CHEV	CHEVE	396	4	4	3500	30973
00081	00676	68	PLYM	SATEL	318	2	0	3500	62236
00082	00675	66	CHEV	IMPAL	283	4	0	4000	99493
00083	00677	66	BUIC	WILDC	401	4	0	5000	50375
00083	10678	66	BUIC	WILDC	401	4	0	5000	50426
00084	00687	68	CHEV	CAMAR	327	2	0	3500	53029
00085	00679	70	DODG	CORNE	225	1	3	3500	38113
00085	10680	70	DODG	CORNE	225	1	3	3500	38160
00086	00681	68	RAMB	AMBAS	343	4	0	4000	97038

FIGURE 4.1-6 (Continued)

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AUTOMOTIVE ENVIRONMENTAL SYSTEMS, INC.

VEHICLE INFORMATION SUMMARY
(Continued)

CAR	RUN	YR	MAKE	MODEL	CID	BBL	TRN	INRT	ODOMR
00087	00684	70	PLYM	ROADR	383	4	4	3500	50765
00088	00683	70	OLDS	CUTLA	350	2	0	3500	15700
00089	00682	70	CHRY	NEWPO	383	2	0	4500	15377
00090	00685	66	PONT	GTO	389	4	0	3500	42777
00091	00686	68	CHEV	MALIB	307	2	0	3500	51796
00092	00689	66	PLYM	BELVE	383	4	0	4000	55723
00093	00688	66	CHEV	CAPRI	327	2	0	4000	33701
00094	00690	66	CADI	CALAI	429	4	0	5000	85577
00095	00692	67	VOLK	FASTB	097	1	4	2250	51944
00096	00691	68	VOLK	BEETL	091	1	4	2000	17204
00097	00694	71	DATS	1200	072	1	0	2000	10334
00098	00693	67	CHEV	IMPAL	396	4	0	4000	55915
00099	00697	70	BUIC	SKYLA	350	2	0	3500	35235
00100	00696	69	RAMB	JAVEL	290	2	0	3500	70875

FIGURE 4.1-6 (Continued)

HEADING	DESCRIPTION
TRN	This is a single digit number indicating the type of transmission used. 0 = Automatic; 3, 4, 5, 6 = Manual; specify number of gears.
INRT	INRT designates the inertia of the vehicle as a four digit number. Correct inertia may be obtained from the Federal Register, Volume 35, No. 219, Part II, page 17296.
ODOMR	This is a five digit number indicating the odometer reading of the test vehicle at the start of the test. Any ODOMR listed as 99,999 indicates that the test vehicle mileage was 100,000 miles or greater.

4.2 FACILITIES AND EQUIPMENT

4.2.1 Facility

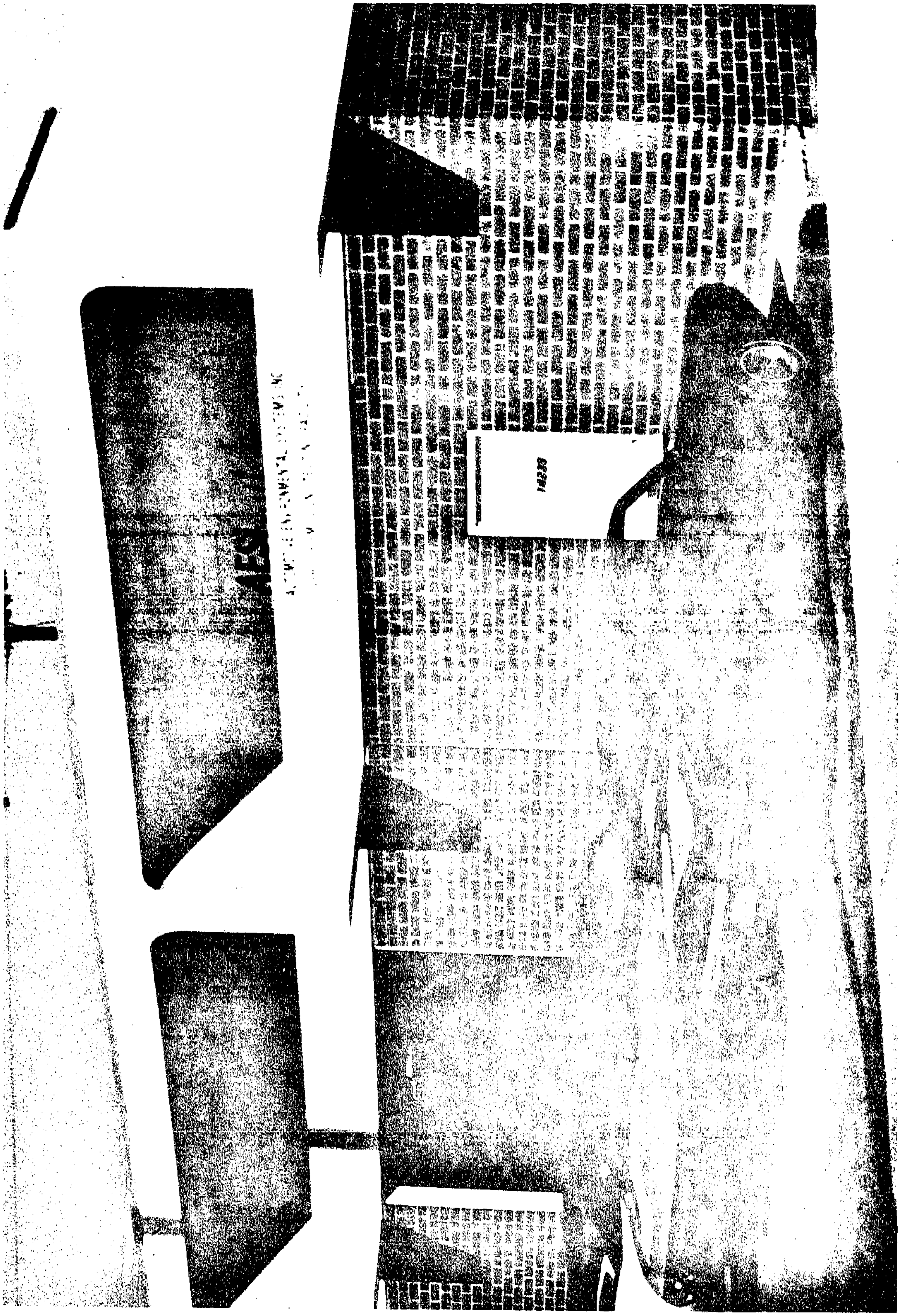
All tests were performed at AESi's Los Angeles Vehicle Emissions Testing Laboratory located at 14239 Hindry Avenue, Hawthorne, California 90250. Figures 4.2-1 and 4.2-2 illustrate the Los Angeles Laboratory.

4.2.2 Constant Volume Sampler

The equipment described in this section was designed and built by AESi in strict accordance with requirements stipulated in pertinent issues of the Federal Register for performing vehicle emissions tests in accordance with the 1972 through 1975 Federal Test Procedures. The AESi Constant Volume Sampler features a specially designed gas to water heat exchanger and temperature control circuit which allows for precise control of the sample temperature. Inlet pressure depression is adjusted by a precision butterfly valve enabling inlet pressure adjustments to within plus or minus 0.005 inches of water. Blower speed is maintained at a constant 1,125 revolutions per minute by the use of a magnetic or optical pickup and an electronic counter. All function controls are push button operated giving a confirming visual indication when each particular function is being performed. The AESi Constant Volume Sampler is well within the noise level specification imposed by the Federal Walsh-Healey Public Contracts Act and other requirements. Additional performance details of the constant volume sampler are discussed in the section dealing with qualification and cross check of testing equipment.

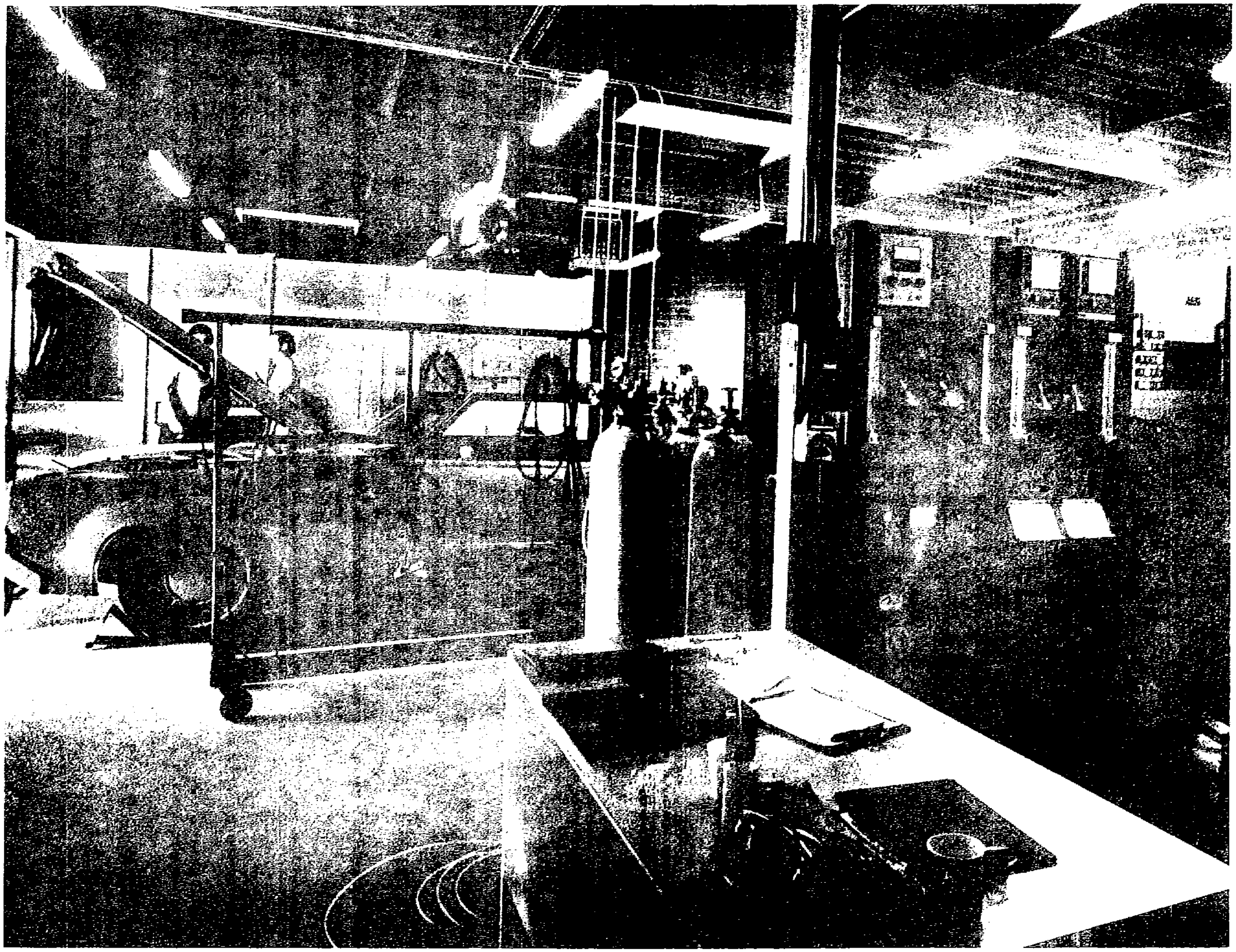
4.2.3 Exhaust Analysis Console

The exhaust analysis console used in the performance of this program was also designed in accordance with specifications stipulated in various Federal Registers for vehicle emissions testing by the 1972 and 1975 Federal Test Procedures. The instruments used in the exhaust analysis console for the measurement of carbon monoxide and carbon dioxide are the Beckman Model 315A or 315B Nondispersive Infrared Analyzers. The carbon monoxide instrument features a stacked sample cell configuration and three-range



AESi HAWTHORNE FACILITY

FIGURE 4.2-1



AESi LOS ANGELES LABORATORY SHOWING EVAPORATIVE
EMISSIONS TESTING "SHED" IN BACKGROUND

FIGURE 4.2-2

amplifier. The carbon dioxide analyzer contains the standard 1/8" sample cell with a dual range amplifier.

A Beckman Model 400 Flame Ionization Analyzer is utilized to measure total hydrocarbons. The Model 400 Flame Ionization Detector is operated with a 40% hydrogen/60% helium or nitrogen fuel mixture and special capillary to minimize the oxygen effect.

A Thermo Electron Corporation Model 10A Chemiluminescent Analyzer is used for the measurement of NO and NO_x. This instrument is equipped with 7 ranges from 0 to 10 ppm NO through 0 to 10,000 ppm NO. A thermal converter is employed to convert NO2 and other nitrogen oxides to NO.

Texas Instruments Potentiometric Recorders are used in the exhaust analysis console to record all instrument signal outputs. Table 4.2-1 indicates the ranges used for each instrument.

TABLE 4.2-1
INSTRUMENT RANGES

Instrument	AESi Range No.	Nominal Range Concentration
Carbon Monoxide	1	0 - 10.0 percent
	2	0 - 6.0 "
	4	0 - 1.2 "
	6	0 - 0.3 "
Carbon Dioxide	2	0 - 6.0 "
	3	0 - 3.0 "
Hydrocarbon	2	0 - 100 ppmC
	3	0 - 1,000 "
	4	0 - 10,000 "
NO and NO_x	4	0 - 100 ppm
	5	0 - 250 "
	6	0 - 1,000 "
	7	0 - 2,500 "

4.2.4 Laboratory Standard Calibration Gases

AESi maintains a complete set of laboratory standard calibration gases in Los Angeles. The contents of each cylinder was analyzed and concentrations were assigned by the Office of Air Programs of the Environmental

Protection Agency in Ann Arbor. The laboratory uses the standard set of gases for defining the complete instrument calibration curves and for subsequent assigning of values to the day-to-day "working" gases. The laboratory standard gases and their nominal concentrations are tabulated in Figure 4.2-3.

4.3.5 Chassis Dynamometer

The Clayton Variable Inertia Chassis Dynamometer, equipped with 250 pound increment inertia loading weights and the low torque bridge (0 to 40 horsepower) was utilized in each laboratory.

4.3.6 High Ambient Temperature Simulator

An AESi designed High Ambient Temperature Simulator (HATS) was used to simulate high ambient vehicle operating conditions and is shown in Figure 4.2-4. The HATS has a control system that is extremely sensitive to variations in cooling air temperature, and air temperature was maintained almost stable at a nominal 100°F with slow variations of ± 5°F.

4.3.7 Miscellaneous Equipment

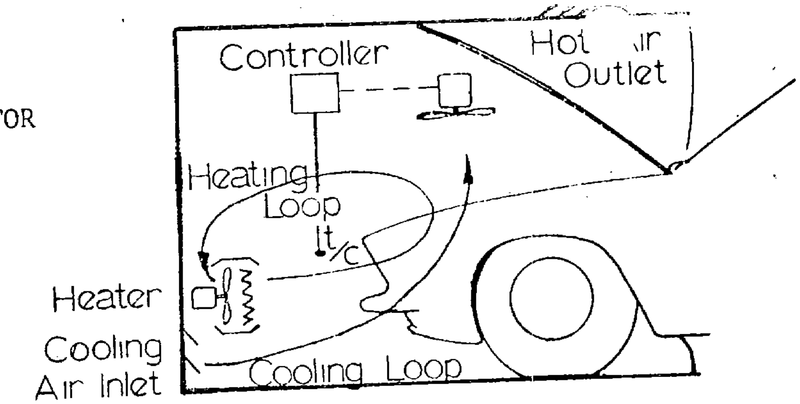
In addition to the equipment previously described, a Varian driver aid was utilized to provide driving schedules for the various driving sequences performed during this program. In addition, an Autoscan ignition analyzer, timing light, tach-dwell meter, other tuneup equipment, and small tools were used as necessary.

LABORATORY STANDARD CALIBRATION GASES

Instrument	AESi Range	Nominal Concentration
FID	2	10 ppm Carbon in Air
"	2	25 " " " "
"	2	50 " " " "
"	2	75 " " " "
"	2-3	100 " " " "
"	3	200 " " " "
"	3	310 " " " "
"	3	575 " " " "
"	3-4	1000 " " " "
"	4	1450 " " " "
"	4	4200 " " " "
"	4	8300 " " " "
"	4	12500 " " " "
CO	6	1,000 ppm CO in N_2
"	6	2,000 " " " "
"	6-4	3,000 " " " "
"	6-4	5,000 " " " "
"	4	7,500 " " " "
"	4-2	12,000 " " " "
"	2	15,000 " " " "
"	2	20,000 " " " "
"	2	40,000 " " " "
"	2	60,000 " " " "
CO_2	3	3,000 ppm CO_2 in N_2
"	3	7,000 " " " "
"	3	10,000 " " " "
"	3-2	15,000 " " " "
"	3	20,000 " " " "
"	3-2	25,000 " " " "
"	3-2	30,000 " " " "
"	2	50,000 " " " "
"	2	60,000 " " " "
NO_x	5	50 ppm NO in N_2
"	5	100 " " " "
"	5-6	200 " " " "
"	5-6	320 " " " "
"	6	480 " " " "
"	6	600 " " " "
"	6	750 " " " "
"	6	1,000 " " " "

FIGURE 4.2-3

HIGH AMBIENT TEMPERATURE SIMULATOR



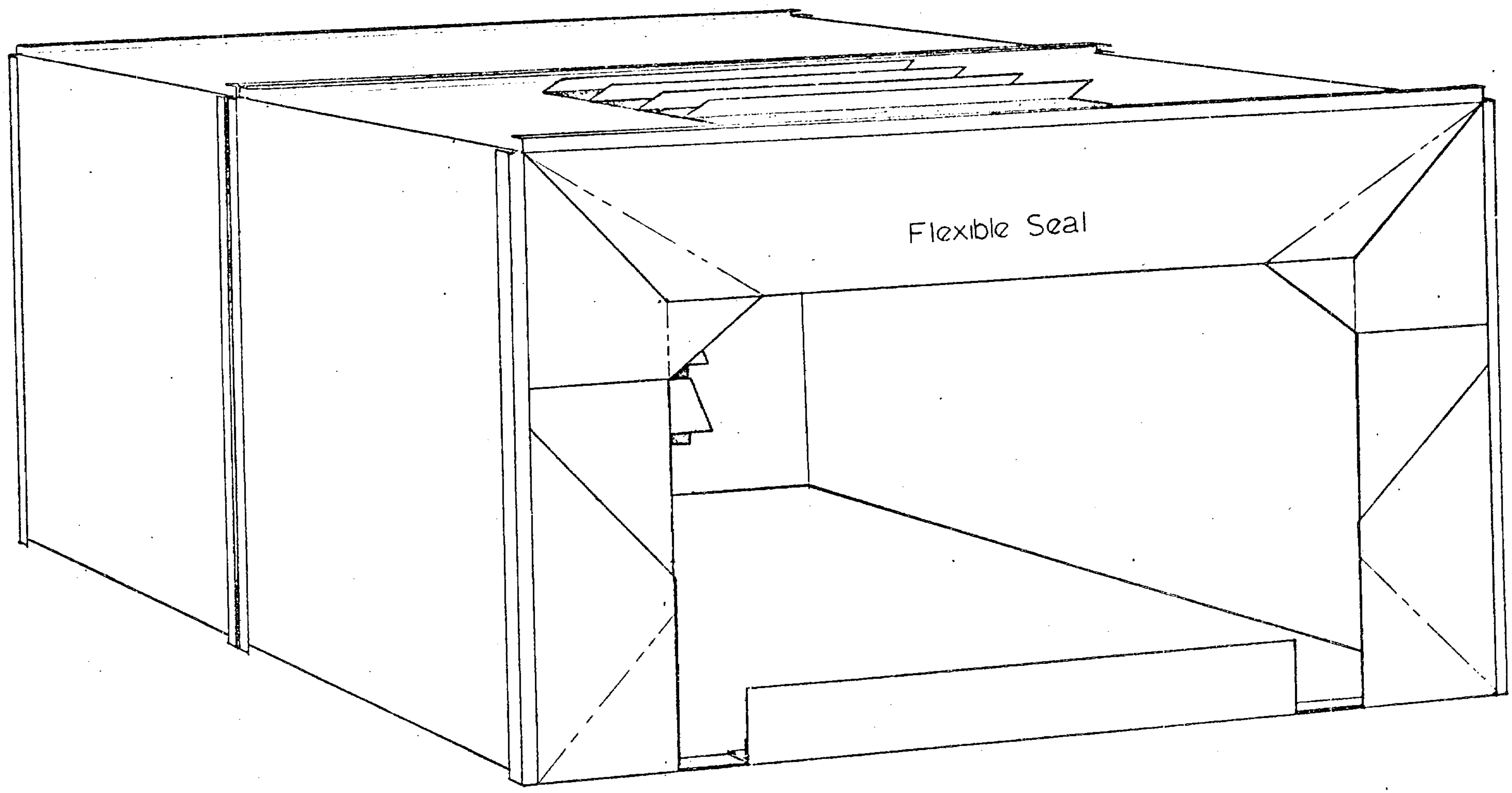


FIGURE 4.2-4

4.3 EQUIPMENT QUALIFICATION, CALIBRATION AND CROSS CHECK

The initial qualification, periodic calibration and cross check of all testing equipment was of paramount importance to the program. The wide range of effluent concentration, and high level of test precision demanded by the Air Resources Board necessitated a rigorous qualification, calibration and cross check procedure.

A new set of parameters for calibration has been added to the vehicle emissions test calibration procedures. Since the constant volume sampler is basically an exhaust mixture sampling device, any errors associated with the calibration of the CVS may be transmitted directly to the instrument system and ultimately to the final data base. The remainder of this section describes in detail the qualification, calibration and cross check procedures utilized by AESi to insure the generation of precise emission test data. Particular emphasis has been placed on the constant volume sampler since it is a relatively new piece of hardware and because of its broad application in this program.

The requirement for system qualification was ±2 percent overall accuracy. This requirement encompassed the constant volume sampler, exhaust analysis console, the primary CVS flow calibration device, and a laboratory balance. In addition, the chassis dynamometer was calibrated by the coast-down technique stipulated in the Federal Register.

4.3.1 Constant Volume Sampler

The objective of the calibration procedure was to accurately determine the volume flow rate of the constant volume sampler at the controlled temperature and inlet pressure. In conjunction with determination of the flow rate, instruments which measured mixture temperature, pressure drop, barometric pressure, wet and dry bulb temperatures and other pertinent variables had to be calibrated. Table 4.3-1 lists the parameters which were monitored, together with the dedicated monitoring instrument and the laboratory calibration standard.

TABLE 4.3-1

CONSTANT VOLUME SAMPLER CALIBRATION PARAMETERS, MONITORS, AND STANDARDS

	PARAMETER	DEDICATED MONITOR	CALIBRATION STANDARD
1.	P_P Absolute pressure on the inlet side of the blower. This pressure is determined differentially (ambient minus depression).	Magnehelic gauge reading 0" to 15" H_2O in 0.2" increments.	Meriam or Dwyer "U" tube manometer reading 0" to 50" H_2O in 0.1" increments.
2.	$\triangle P$ Differential pressure across the blower.	Magnehelic gauge reading 0" to 20" H_2O in 0.2" increments	Same as above.
3.	P_A Ambient pressure.	Meriam absolute pressure well manometer or barometer reading 0" to 38" Hg in 0.01 increments by means of a vernier.	Same as dedicated monitor.
4.	T_A Ambient temperature to correct P_A.	Glass stem thermometer.	ASTM 50F glass stem mercury filled thermometer.
5.	T_P Temperature on the inlet side of the blower.	API panel meter reading 0° to 300°F in 2° increments coupled to a type J thermocouple.	ASTM 64F glass stem mercury filled thermometer.
6.	N Number of blower revolutions during a test interval.	ERC counter with magnetic or photoelectric pick up.	60 Hertz strobe light strobotac, stop watch and electric utility line frequency specifications.
7.	E. T. Elapsed time of a test interval.	Excelsior Park stop watch reading 0 to 30 minutes in 0.2 second intervals.	Same as dedicated monitor.

The constant volume sampler mass flow at given operating conditions was calibrated against a Meriam Laminar Flow Element (LFE) Model 50 MC2-SF, Serial No. C-43051, rated at 1,000 CFM at 8" H_2O. The parameters used to measure mass flow through the LFE are shown in Table 4.3-2.

The CVS Flow Test Sheet, Figure 4.3-1, is a form used by AESi to program the accumulation of all prerequisite data as well as the orderly calculation of V_o. Of note is the time column; it is imperative that stabilization of the CVS and the instruments be attained before readings are taken at each setting.

An exhaustive set of flow calibration runs is carried out on any new CVS at the San Bernardino manufacturing facility. After both inlet and outlet sides of the CVS were pressure leak tested and other operating requirements such as the fixed 1,125 RPM were confirmed, mass flow calibration was performed which bracketed all normal operating conditions. Inlet flow testing was performed at pressures (P_p and $\triangle P$) above, equal to, and below normal operating conditions. Inlet flow testing was also performed at temperatures (T_p) above, at, and below normal operating conditions. Figure 4.3-2, entitled "Mass Flow Calibration," illustrates the method of obtaining readings during flow tests. After inlet tests had repeatedly defined V_o, outlet flow tests were conducted as verification of the inlet tests. It was not expected that outlet tests agreed perfectly with inlet tests because of approximately 60°F difference in T_L. The T_L correction factor was derived by Meriam theoretically rather than empirically; consequently, the factor is not exact. Meriam calibrates at 70°F. T_L during inlet flow testing was near 70°F, but during outlet flow tests $T_L \simeq 130$°F.

The effect on volume of various temperatures (T_p) near the normal operating T_p has been found to be less than measurable provided that $\triangle P$ was readjusted to maintain a given value. AESi also tested the effect of various back pressures at a given $\triangle P$ and found the effect to be less than measurable within obtainable limits. Nevertheless, field installations of AESi CVS's have been specified to preclude any substantial difference in back pressure between inlet flow tests and normal operating conditions.

TABLE 4.3-2

LAMINAR FLOW ELEMENT CALIBRATION PARAMETERS AND STANDARDS

	PARAMETER	CALIBRATION STANDARD
1.	ΔP_L Differential pressure across the LFE.	Meriam inclined manometer reading 0" to 8" H_2O in 0.01" increments with distilled H_2O or reading 0" to 4" H_2O in 0.02" increments with red oil. Either can be read to 0.005" H_2O.
2.	P_L Absolute pressure at the inlet side of the LFE. The pressure is determined differentially (ambient pressure minus inlet pressure).	Meriam or Dwyer "U tube" manometer reading 0" to 50" H_2O in 0.1" H_2O increments.
3.	P_A Ambient pressure.	Meriam absolute pressure well manometer or barometer reading 0" to 38" Hg in 0.01 increments by means of a vernier.
4.	$f(T_L)$ Temperature at the inlet of the LFE. Used to correct air flow for viscosity.	ASTM 50F or ASTM 64F glass stem mercury filled thermometer.
5.	$f(T_M)$ Temperature of the inclined manometer used to correct ΔP_L for indicating fluid density.	Glass stem thermometer calibrated against an ASTM 64F.

AESi AUTOMOTIVE ENVIRONMENTAL SYSTEMS, INC.

CVS FLOW TEST # 2

SH 1 OF 1

DATE 7-17-72

SITE LA

TECH JGS

DESCRIPTION: ☑ INLET ☐ OUTLET

$V_o = (\Delta P_L \cdot 127 + 4) \int T_M \cdot \int T_L \cdot P_L \div P_P \cdot T_P \div 596250$

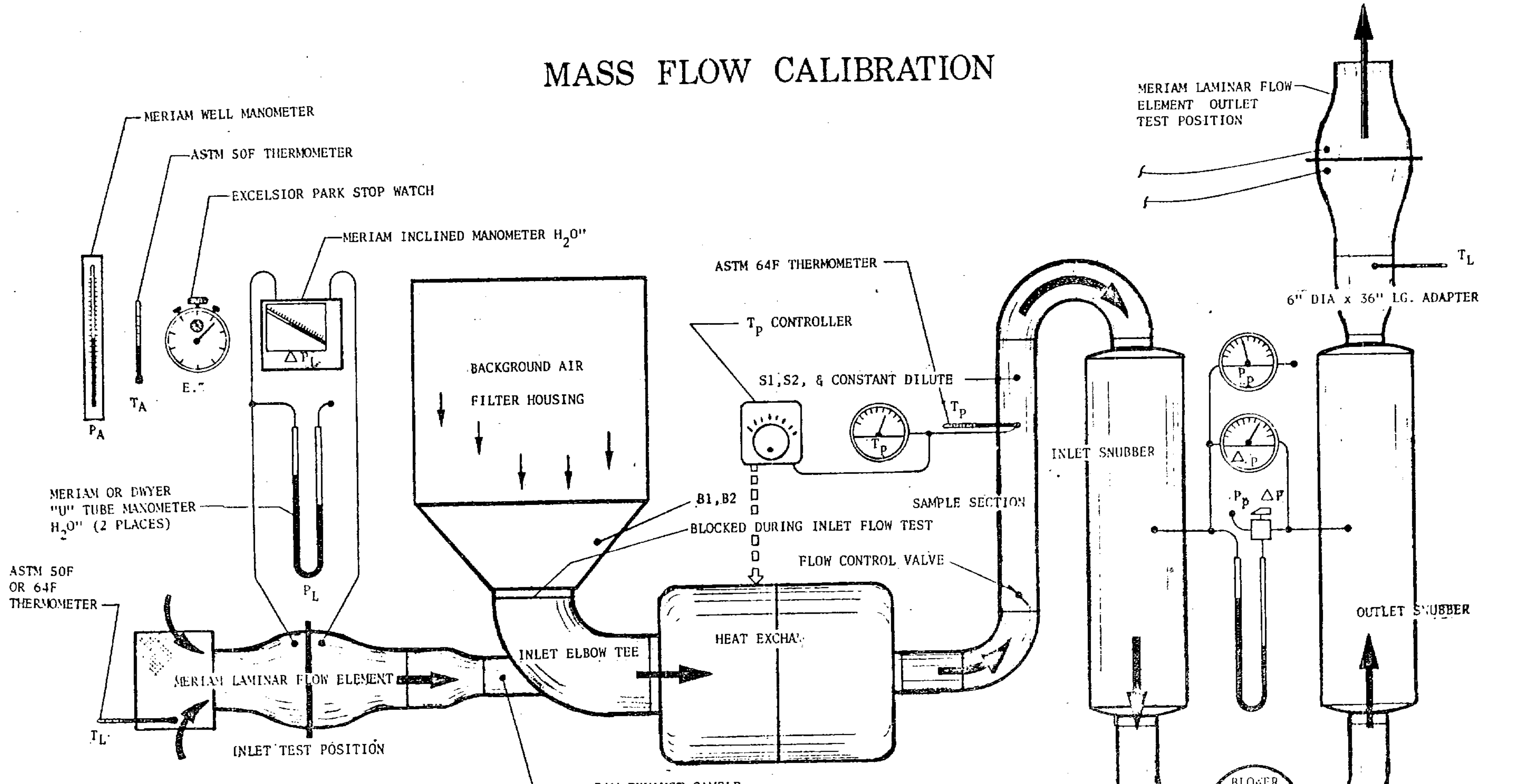
P_A cor $H_2O'' = (-0.00136 \cdot T_A\,^\circ F + 13.6912) P_A$ Hg"

STEP NO.	ΔP H_2O''	V_o $Ft^3/Rev.$	T_A °F	P_A Hg" / P_A cor H_2O''	ΔP_L H_2O''	T_M / $\int T_M$	T_L / $\int T_L$	☐+ $P_L\,\Delta H_2O''$ / ☑− P_L A H_2O''	$P_P\,\Delta H_2O''$ / P_P A H_2O''	T_P °F / T_P °R	TIME SET / READ
1.	13.2	.2967	74	29.63 / 402.7	2.37	75 / .9984	71.5 / .995	1.20 / 401.5	10.7 / 392.0	110 / 570	9:00AM / 9:18
2.	15.0	.2953		402.7	2.35 STABLE EARLY	76 / .9984	72.5 / .9916	1.20 / 401.5	12.5 / 390.2	111.5 / 571.5	9:19 / 9:26
3.	18.0	.2931		402.7	2.30	75 / .9984	70.5 / .9983	1.20 / 401.5	15.6 / 387.1	111 * / 571	9:27 / 9:35
4.	20.0	.2917		402.7	2.28	75 / .9984	71 / .9967	1.20 / 401.5	17.7 / 385.0	111 / 571	9:36 / 9:42
5.	16.0	.2947		402.7	2.325	75 / .9984	70.5 / .9983	1.20 / 401.5	13.6 / 389.2	111 / 571	9:43 / 9:51
6.	13.25	.2973		402.7	2.375	75 / .9984	71.5 / .995	1.20 / 401.5	10.7 / 392.0	110 / 570	9:52 / 10:00AM
					ZERO ✓ 0.005 HIGH RECHECK LAST POINT		~~71~~ / ~~.9967~~			~~107~~ / 567	
7.	13.25	NOT STABLE		402.7	△ 2.38	75 / .9984	71.5 / .9950	1.20 / 401.5	10.7 / 392.0	107 / 567	10:03 / 10:06
8.	13.3	.2968		402.7	2.375 ZERO GOOD	75 / .9984	72 / .9933	1.20 / 401.5	10.8 / 391.9	110 / 570	10:08 / 10:19

*CHECKED WITH PANEL METER - CAL. SPOT ON △ V_O RISES INVERSLY WITH T_P - ΔP RISES INVERSELY ALSO

FIGURE 4.3-1

MASS FLOW CALIBRATION



MASS FLOW PARAMETERS

	INPUT	DESIRED	METHOD
TEMPERATURE:			
T_A	°F	°R	°F + 459.7
T_P	°F	°R	°F + 459.7
T_L	°F	°R	°F + 459.7
PRESSURE:			
P_A	RAW Hg"	ABSOLUTE H_2O"	P_A Hg" (-0.00136 • T_A °F + 13.6912)
P_L	Δ H_2O"	ABSOLUTE H_2O"	INLET: P_A (COR) - ΔH_2O" OUTLET: P_A (COR) + ΔH_2O"
P_P	Δ H_2O"	ABSOLUTE H_2O"	P_A (COR) - ΔH_2O"
ΔP_L	ΔH_2O"	ΔH_2O"	
ΔP	Δ H_2O"	ΔH_2O"	

$$V_o = (\Delta P_L \bullet 127+4) \bullet \int T_M \bullet \int T_L \bullet P_L \div P_P \bullet T_P \div 596250$$

N (BLOWER COUNT)	DIGITAL READOUT
E.T.	DECIMAL MINUTE

Propane Recovery Tests (PRT), which are normally performed daily, require that the CVS, the sample lines, exhaust analysis console, the flame ionization detector (FID), and all supporting laboratory instruments and devices, i.e., propane cylinder, mass scale, barometer, etc., function properly and are fully calibrated. The PRT's consistently fell within a 2 percent band whose mean was within 1 percent of 100 percent recovery. The PRT's were performed in compliance with Federal Register, Volume 35, Number 219, Part II, dated November 10, 1970, Appendix C, except that the density of propane has been revised from 17.3 grams/ft.^{3} to 17.6 grams/ft.^{3} at 406.8" H_2O absolute pressure and 68°F.

4.3.2 Exhaust Analysis Console

Calibration of the exhaust analysis console (EAC) was performed regularly. Items which are checked and verified prior to individual instrument calibration include the following: 1) total EAC leak check; 2) check zero air quality with hydrocarbon free air; 3) adjust all analyzers to optimize performance as specified by individual instrument manuals; 4) check response times for all instruments. The following paragraphs describe individual analyzer optimization procedures and qualification items used by AESi.

Hydrocarbon Analyzer (Beckman Model 400)

1. Obtain maximum sensitivity using the following method:
   a. Set fuel pressure to approximately 25 psig.
   b. Set air pressure to approximately 15 psig.
   c. Light burner (allow 30 minutes for warmup).
   d. Set sample pressure to approximately 4 psig.
   e. Flow zero grade air and set zero on meter or recorder.
   f. Flow mid-range calibration gas.
   g. With calibration gas flowing through instrument, adjust air pressure to obtain maximum upscale reading.
   h. Adjust sample pressure to obtain maximum reading and best response.

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2. Develop instrument curves for ranges ten (10), one hundred (100) and one thousand (1,000). Verify results by recording results graphically.

Carbon Monoxide Analyzer (Beckman Model 315A or 315B)

1. Check and/or adjust instrument tuning.
2. Check and/or adjust demodulator switching pattern.
3. Check instrument response to water and 100% carbon dioxide (CO_2) on range 2.
4. Develop instrument curves for ranges described in Section 4.2.
5. Verify curve results graphically.

Carbon Dioxide Analyzer (Beckman Model 315A or 315B)

1. Check and/or adjust instrument tuning.
2. Check and/or adjust demodulator switching pattern.
3. Develop instrument curves for ranges described in Section 4.2.
4. Verify curve results graphically.

Oxides of Nitrogen Analyzer (TECO Model 10A)

1. Verify reaction chamber pressure to be in the 5-12 torr range.
2. Check response time through thermal converter versus bypass of thermal converter.
3. Develop instrument curves for ranges described in Section 4.2.
4. Verify curve results graphically.
5. Perform preliminary converter efficiency check.
6. Converter efficiency check will be performed as described in the Federal Register, Volume 36, Number 128, Friday, July 2, 1971.

EAC daily and weekly checks which are performed and recorded are described below:

Daily Check

1. Leak check of HC, CO, CO_2, and NO instruments.
2. NO vacuum pump check.
3. HC analyzer zero and span.
4. CO analyzer zero, gain and tune.
5. CO_2 analyzer zero, gain, and tune.
6. NO analyzer gain.

Weekly Check

1. Individual instrument curve check of each range used.
2. Converter efficiency.
3. CO response to 100% wet CO_2.

An example of the daily instrument form is presented in Figure 4.3-3. As a further guarantee that the dilute exhaust concentration was accurately determined, a known calibration gas was released into a previously purged and evacuated sample bag. Correct analysis of these bag contents insured that no error had been introduced by the bag sample transport plumbing.

4.3.3 Chassis Dynamometer

A Clayton dynamometer is used with flywheels which can be engaged to simulate vehicle inertia. The attached speedometer is driven by the rear rolls which are idlers. The flywheels and the power absorption unit are driven by the front rolls. The speedometer and the horsepower indicator are calibrated on site. The torque bridge and dash pot have been set up in accordance with manufacturer's instructions.

The speedometer is calibrated by beaming a 60 Hertz strobe light or strobotac at the rolls while an automobile is driven at a rate which causes the rolls to appear stationary. This rate is 3600 RPM. The surface velocity of the rolls at 3600 RPM is 46.3 mph. The speedometer gain control is then adjusted so that the indicator reads 46.3 mph at 3600 roller RPM. A second tach/generator is also provided and driven by the front rolls. A 0 to 12 volt DC voltmeter is connected to this second tach generator. A plot is then made showing front roll voltage versus rear roll mph. This way the speed of the front rolls can later be determined independently of the rear roll speed.

The indicated road horsepower, a figure derived electrically from RPM and torque from the power absorption unit, is plotted versus actual absorbed road horsepower, as illustrated in Figure 4.3-4, Dynamometer Road Horsepower Calibration Sheet (DRL).

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DAILY EAC

DATE	LEAK CHECK				VAC. CHECK		FID		CO			CO_2			NO	SHED-FID		PIC
	HC	CO	CO_2	NO	NO	NO_x	ZERO	GAIN	ZERO	GAIN	TUNE	ZERO	GAIN	TUNE	GAIN	ZERO	GAIN	
1/3/72	0.0	0.0	0.0	—	7.7	7.7	657	222	424	192	56	136	62	60	619	437	806	MEC
1/4/72	0.0	0.0	0.0	—	7.8	7.8	748	196	407	191	56	124	62	60	656	440	805	MEC
1/5/72	0.0	0.0	0.0	—	7.8	7.8	652	206	418	190	56	125	61	60	632	435	806	MEC
1/6/72	0.0	0.0	0.0	—	7.8	7.8	670	213	406	191	56	124	62	60	650	432	804	MEC
1/7/72	0.0	0.0	0.0	—	7.8	7.8	717	211	419	196	56	127	61	60	652	436	807	MEC

DAILY CVS

DATE	LEAK CHECK							ZERO BAG		HC BAG		PROPANE TEST				D/A 50		PIC
	B 1	B 2	S 1	S 2	S 3	S 4	CONT.	DEF.	DEF.	DEF.	DEF.	Gp	HC	Δ	%E			
1/3/72	0.0		0.0	0.0			0.0	0.9	1.0	95.0	94.9	35.7	35.2	.5	1.42	51.0		MEC
1/4 72	0.0		0.0	0.0			0.0	1.0	1.1	95.0	94.9	35.8	36.3	.5	1.38	51.0		MEC
1/5 72	0.0		0.0	0.0			0.0	1.0	1.1	95.0	94.8	35.9	35.97	.07	0.2	50.0		MEC
1/6 72	0.0		0.0	0.0			0.0	1.1	0.9	95.0	94.9	35.4	35.9	.5	1.4	50.0		MEC
1/7/72	0.0		0.0	0.0			0.0	1.2	1.0	95.0	94.9					50.0		MEC

MAINTENANCE: NONE

LABORATORY LOS ANGELES SUPERVISOR [signature] WEEK ENDING 7/8/72 LOG NO. 1004

6121a

FIGURE 4.3-3

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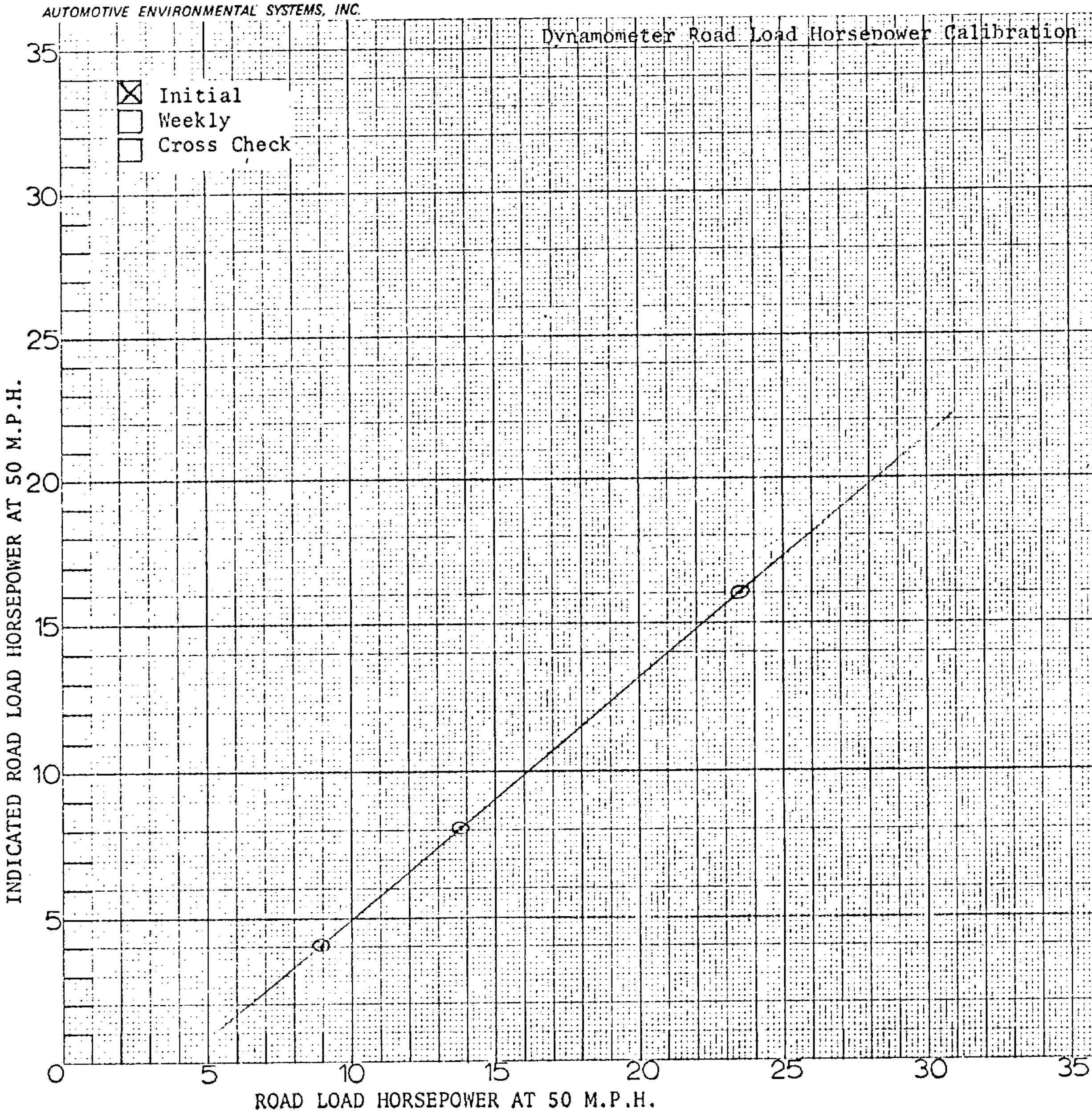
DRL

KEY: SITE LA | DATE 7-17-72

Dynamometer Road Load Horsepower Calibration

- [x] Initial
- [ ] Weekly
- [ ] Cross Check



Set Initial Flywheels to "W" at 50 M.P.H. Set Ind. R.H.P. Run Dyno. to 60 M.P.H. Lift Car Off Dyno., Time "T" From 55 to 45 M.P.H. R.H.P. = 0.06073 (W/T)

W	IRHP	T	RHP
4000	8.1	17.6	13.80
4000	16.0	10.35	23.47
4000	4.0	26.9	9.03

SUPERVISOR JGS

FIGURE 4.3-4

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4.4 DATA HANDLING AND STATISTICAL ANALYSIS

4.4.1 Data Collection

Data collection and the associated data reporting forms are extremely important items in an investigative research program such as this. AESi has developed several data forms for use in these programs such as the Test Data Sheet shown in Figures 4.4-1 and 4.4-2. These particular forms are arranged in keypunch format. Instrument scale deflections and instrument ranges are entered on these sheets after each test.

The Daily Instrument and CVS System form, CVS Propane Recovery form, and Weekly Check form, illustrated in Section 4.3, were designed to assure each instrument curve was within limits of the originally developed curve. The latter also provided for an NO_x converter check, a CO_2 response check of the CO instrument, and calibration curve update information.

Proven data handling procedures were used to insure the continuous and accurate transmission and verification of all data. The project engineer or test supervisor reviewed the test results and verified their validity. At the corporate office, the tests were logged and inspected again to determine if any errors or anomalies were present. If errors were found which were not correctable at the corporate office, the relevant questions were referred immediately to the project engineer for resolution.

4.4.2 Data Processing

After the resolution of any obvious errors the information on the Test Data Sheet was keypunched and verified by the AESi Computer Sciences Department. A specially designed edit program analyzed each data field on each card for errors or omissions. Test results were then calculated and edited by computer to determine if results were within prescribed limits. Figure 4.4-3 is an example of the signaling technique of AESi's computer edit procedure. It indicates that the emissions data was of lower magnitude than the background data. Any necessary corrections were then punched on cards and entered into the computer. A final edit was run and the completed test

FIGURE 4.4-1

EXPLANATION OF TEST DATA SHEET HEADINGS

HEADING	COMMENTS
PRJ #	PRJ # is a five digit code designating the AESi assigned project number.
CAR #	This is a five digit number assigned each test vehicle at each facility. All project 217 car numbers will use zero (0) as the first two digits.
RUN #	RUN # is a five digit sequential run number.
DATE	Date test is performed.
TIME	Four digit number. The time test was started using 24 hour clock.
PIC	This indicates the initials of the person in charge of the test at the time it is being performed.
YR	This is a two digit number indicating the model year of the test vehicle.
MAKE	This is a four character word specifying the make of the vehicle. The first four characters of the vehicle make are always to be used. For example: Ford = FORD, Chevrolet = CHEV, Buick = BUIC, Volkswagen = VOLK.
MODEL	This is a five letter word specifying the model of the vehicle. For example: Wildcat = WILDC, Ford LTD = LTD, Pontiac Lemans = LEMAN, etc.
CID	This is a three digit number indicating the cubic inch displacement of the test vehicle. In the case of small displacement engines round off to the nearest unit displacement. For example: Volkswagen = 96.9 cubic inches displacement. Input should be 97.
BBL	This indicates the number of carburetor barrels or venturis. If a given vehicle has fuel injection, an FI should be inserted instead of the number for venturis. A vehicle with multiple carburetion would be entered as total number of venturis. Example: 3 - 2 BBLS = 6.
TRN	This is a single digit number. It indicates the type of transmission used. 0 = Automatic; 3, 4, 5, 6 = Manual; specify number of gears.

FIGURE 4.4-1 (Continued)

HEADING	COMMENTS
INRT	INRT designates the inertia of the vehicle as a four digit number. Correct inertia may be obtained from the Federal Register, Volume 35, Number 219, Part II, Page 17296.
RDHP	RDHP is the road horsepower setting for the given test vehicle on the dynamometer. The Federal Register will provide the correct load settings. The data which is to be entered is that which should be used for the test.
DB	This is a two digit number indicating the dry bulb temperature in °F.
WB	This is a two digit number indicating the wet bulb temperature in °F.
BAROM	BAROM is a four digit number indicating the barometric pressure in inches of mercury.
CYL	Indicates the number of cylinders in the test vehicle engine. Single digit number.
A/C	A single digit number to indicate the presence of an air conditioning system on the test vehicle. 0 = no air conditioner; 1 = equipped with air conditioner.
EVP	This is a single digit number indicating whether or not the test vehicle is equipped with an evaporative emissions control device. 0 = no evaporative emissions control device present; 1 = the test vehicle is equipped with such a device.
EXH	EXH is a single digit which indicates the presence of an exhaust emissions control system and its type. 0 = no exhaust controls 1 = engine modifications type 2 = air injection device 3 = catalytic reactor 4 = afterburner
PCV	This indicates the presence of a positive crankcase ventilation system. 0 = no PCV control unit; 1 = PCV system present.
ODOMR	This is a five digit number indicating the odometer reading of the test vehicle at the start of the test.
FT	A two digit number indicating the fuel tank capacity of the test vehicle. Round off to the nearest gallon.

FIGURE 4.4-1 (Continued)

HEADING	COMMENTS
VTP	Vehicle type is a three digit code. Use only the first blank. 0 = light duty vehicle; 1 = off-road vehicle.

The following additional items are also part of the test data sheet:

TEMP	The CVS blower inlet temperature (°F).
PRESS	CVS blower inlet pressure as "H_2O (inches of water).
COUNT	This indicates the total number of blower revolutions for each test.
RPM	Used only for special testing.
MPH	Used only for special testing.
IRPM	Engine revolutions per minute at normal idle.
D - N	Automatic transmission selectro position - drive or neutral.
DWEL	Distributor cam angle, a two digit number in degrees.
IGNT	Basic ignition timing, expressed in degrees.
TTAD	Total ignition timing in degrees.
MECA	Ignition advance due to mechanical mechanism.
VACA	Ignition advance due to vacuum input.
SPVT	Voltage available at spark plug.
COL	Condition of coil, indicated by a + (OK) or - (defective).
IGW	Condition of high tension ignition wires, also indicated by + or -.
CHK	Condition and operation of choke, indicated by + or -.
PTC	Condition of breaker points, indicated by + or -.

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TEST DATA SHEET

	PRJ NO.	CAR NO.	RUN NO.	DATE	TIME	PIC	YR	MAKE	MODEL
0 1									

CID	BBL	TRN	INRT	RDHP	DB	WB	BARO	CYL	A/C	EVP	EXH	PCV	ODOMR	FT	VTP
				.			.								

TUNE-UP INFORMATION:

	IRPM	D-N	DWEL	IGNT	TTAD	MECA	VACA	SPVT	COL	IGW	CHK	PTC
0 2			.	.	.	.	.	.				

STEADY STATE

		R	DEF.	R	DEF.	R	DEF.	R	DEF.	R	DEF.	TEMP	PRESS	COUNT	RPM	MPH
0 3	S		.		.		.		.		.		.			.
0 4	B		.		.		.		.		.					

HOT TRANSIENT:

		HC		CO		CO_2		NO_x		NO						
		R	DEF.	R	DEF.	R	DEF.	R	DEF.	R	DEF.	TEMP	PRESS	COUNT	RPM	MPH
0 5	S		.		.		.		.		.		.			.
0 6	B		.		.		.		.		.					

HOT STABILIZED:

		HC		CO		CO_2		NO_x		NO						
		R	DEF.	R	DEF.	R	DEF.	R	DEF.	R	DEF.	TEMP	PRESS	COUNT	RPM	MPH
0 7	S		.		.		.		.		.		.			.
0 8	B		.		.		.		.		.					

TUNE-UP INFORMATION:

	IRPM	D-N	DWEL	IGNT	TTAD	MECA	VACA	SPVT	COL	IGW	CHK	PTC
0 9			.	.	.	.	.	.				

STEADY STATE

		R	DEF.	R	DEF.	R	DEF.	R	DEF.	R	DEF.	TEMP	PRESS	COUNT	RPM	MPH
1 0	S		.		.		.		.		.		.			.
1 1	B		.		.		.		.		.					

FIGURE 4.4-2

AUTOMOTIVE ENVIRONMENTAL SYSTEMS, INC.

TEST DATA SHEET

Sheet 2 of 2

1 2	PRJ NO.	CAR NO.	RUN NO.

HOT TRANSIENT:

Card		HC R	HC DEF.	CO R	CO DEF.	CO_2 R	CO_2 DEF.	NO_x R	NO_x DEF.	NO R	NO DEF.	TEMP	PRESS	COUNT	RPM	MPH
1 3	S		.		.		.		.		.		.			.
1 4	B		.		.		.		.		.					

HOT STABILIZED:

Card		HC R	HC DEF.	CO R	CO DEF.	CO_2 R	CO_2 DEF.	NO_x R	NO_x DEF.	NO R	NO DEF.	TEMP	PRESS	COUNT	RPM	MPH
1 5	S		.		.		.		.		.		.			.
1 6	B		.		.		.		.		.					

STEADY STATE

Card		R	DEF.	R	DEF.	R	DEF.	R	DEF.	R	DEF.	TEMP	PRESS	COUNT	RPM	MPH
1 7	S		.		.		.		.		.		.			.
1 8	B		.		.		.		.		.					

STOP/GO

Card		R	DEF.	R	DEF.	R	DEF.	R	DEF.	R	DEF.	TEMP	PRESS	COUNT	RPM	MPH
1 9	S		.		.		.		.		.		.			.
2 0	B		.		.		.		.		.					

STEADY STATE

Card		R	DEF.	R	DEF.	R	DEF.	R	DEF.	R	DEF.	TEMP	PRESS	COUNT	RPM	MPH
2 1	S		.		.		.		.		.		.			.
2 2	B		.		.		.		.		.					

STOP/GO

Card		R	DEF.	R	DEF.	R	DEF.	R	DEF.	R	DEF.	TEMP	PRESS	COUNT	RPM	MPH
2 3	S		.		.		.		.		.		.			.
2 4	B		.		.		.		.		.					

FIGURE 4.4-2

PROJ-03210 CAR NO.-00022 RUN NO.-00021 DATE-020472 YEAR-70 MAKE-CADI MODEL-COUPE
CID-472 TRN-0 CYL-8 ODOMR-32000 DRY BULB-74. WET BULB-53. BAROM-29.23

AD	MODE	HC	CO	CO2	NOX	T	P	N
B		66	283	961	10	120	11.00	
S	1	516	3450	32158	250			225
M		7.13	101.24	1569.35	12.63			
S	2	294	3492	7421	30			300
M		3.91	111.12	352.02	1.15			
S	3	363	3940	16561	78			150
M		9.40	233.47	1566.96	7.16			
S	4	384	2350	25751	250			206
M		3.95	51.62	974.93	9.87			
S	5	451	1780	34610	250			243
M		2.91	22.84	809.21	6.04			
S	6	372	2350	14891	57			225
M		2.30	31.34	332.70	1.16			
S	7	956	12800	47918	250			318
M		5.55	157.58	929.16	4.97			
S	8	454	3870	18399	250			225
M		2.16	40.23	307.74	4.43			
S	9	459	1200	46313	250			262
M		2.14	10.02	782.80	4.33			
S	10	637	2005	14724	75			562
M		4.04	24.55	309.20	1.52			
S	11	550	1600	47590	401			487
M		3.19	17.45	974.60	8.54			
S	12	790	3333	12256	102			393
M		6.12	52.04	302.82	2.57			
S	13	117	800	4149	16			600
M		0.39	7.94	77.71	0.15			

SAMPLE DEFLECTION 1.5 LESS THAN BACKGROUND DEFLECTION 2.2

MASS CALCULATION -5.92 NEGATIVE

S	14	81	368	655	16	431
M		0.09	0.99	-5.92	0.12	

SAMPLE DEFLECTION 1.6 LESS THAN BACKGROUND DEFLECTION 2.2

MASS CALCULATION -10.23 NEGATIVE

S	15	81	368	699	16	168
M		0.18	1.99	-10.23	0.24	
S	16	107	400	6514	21	150
M		1.49	9.32	643.10	1.38	
S	17	474	3450	34960	307	412
M		4.05	63.45	1071.83	9.77	
S	18	849	1750	8423	49	300
M		7.16	26.99	216.46	1.19	
S	19	487	3730	33909	322	337
M		3.94	65.03	973.06	9.67	
S	20	534	2725	8566	51	356
M		5.42	57.00	279.46	1.59	
S	21	902	3436	44488	236	463
M		6.26	47.55	1033.05	5.60	
S	22	449	5220	11996	80	525
M		3.23	84.21	296.05	1.97	
S	23	438	3520	25049	178	281
M		6.01	105.56	1236.13	9.00	
S	24	465	3715	38113	397	468
M		2.52	43.65	746.71	8.12	
S	25	897	1120	12776	118	337
M		5.03	10.16	226.69	2.16	
S	26	417	3800	10178	28	187
M		6.26	126.71	522.49	1.05	
S	27	459	2500	38954	405	712
M		2.95	33.65	908.17	9.87	
S	28	609	2950	11996	150	656
M		4.59	45.43	295.89	3.92	
S	29	459	3450	22008	118	337
M		6.34	103.03	1077.46	5.77	
S	30	654	5748	15782	348	393
M		3.84	70.73	301.64	7.20	
S	31	445	3650	11737	150	262
M		2.32	41.74	209.59	2.95	
S	32	443	3330	6276	38	243
M		6.57	108.73	293.64	1.58	

ERROR COUNT = 4

FIGURE 4.4.3

cards were added to a master file. Interim reports were generated from this master file. Figure 4.4-4 illustrates the typical test data printouts. Figure 4.4-5 illustrates the flow of data.

4.4.3 Calculation of Results

Results from the various test procedures performed during the program were calculated using well known and accepted techniques. The method for obtaining mass emissions on a grams per mile basis as specified in the 1972 Federal Test Procedure was generally used. Appropriate modifications were made to calculate mass emissions for the steady states and special driving cycles. The results developed by these calculations are presented in Section 3 and Section 4.5.

PROJ-01210 CAR NO.-00119 RUN NO.-00352 DATE-033172 YEAR-67 MAKE-MERC MODEL-COUGA
CID-390 TRN-0 CYL-8 ODOMR-59664 DRY BULB-75. WET BULB-71. BAROM-30.13

CT	HC	CO	CO2	NOX	NO	T	P	N
B	13	15	0	1	0	128	8.40	9510
S	844	6011	12614	63	48			
M	34.63	504.28	1666.78	8.62	6.65	NOXC=	10.16	K=1.178

CS	HC	CO	CO2	NOX	NO	T	P	N
B	8	15	0	0	0	128	8.40	16256
S	891	3556	8236	34	29			
M	62.87	509.06	1860.26	7.92	6.88	NOXC=	9.33	K=1.178

HT	HC	CO	CO2	NOX	NO	T	P	N
B	6	0	0	0	0	128	8.40	9506
S	978	4683	11552	66	54			
M	40.47	393.67	1525.80	9.12	7.47	NOXC=	10.75	K=1.178

HS	HC	CO	CO2	NOX	NO	T	P	N
B	6	15	0	0	0	128	8.40	16258
S	798	3412	8444	36	29			
M	56.40	488.42	1907.48	8.41	6.88	NOXC=	9.91	K=1.178

A/D	HC	CO	CO2	NOX	NO	T	P	N
B	8	45	0	1	0	127	8.50	19743
S	825	6500	14266	77	55			
M	70.70	1128.69	3919.14	22.03	15.61	NOXC=	25.96	K=1.178

SS4	HC	CO	CO2	NOX	NO	T	P	N
B	8	45	0	1	0	127	8.50	2250
S	917	10432	14856	57	55			
M	8.97	206.99	465.11	1.86	1.78	NOXC=	2.19	K=1.178

SS1	HC	CO	CO2	NOX	NO	T	P	N
B	8	45	0	1	0	127	8.50	2250
S	995	3840	5428	2	2			
M	9.74	75.63	169.94	0.05	0.04	NOXC=	0.06	K=1.178

SS0	HC	CO	CO2	NOX	NO	T	P	N
B	8	45	0	1	0	127	8.50	2250
S	758	3574	4804	2	2			
M	7.39	70.32	150.40	0.05	0.04	NOXC=	0.06	K=1.178

SS3	HC	CO	CO2	NOX	NO	T	P	N
B	6	60	0	1	0	127	8.50	2250
S	623	4215	10372	30	29			
M	6.09	82.79	324.73	0.96	0.94	NOXC=	1.13	K=1.178

SS6	HC	CO	CO2	NOX	NO	T	P	N
B	6	60	0	1	0	127	8.50	2250
S	623	11851	21232	149	136			
M	6.09	234.96	664.73	4.86	4.45	NOXC=	5.73	K=1.178

SC	HC	CO	CO2	NOX	NO	T	P	N
B	4	45	0	0	0	127	8.50	2372
S	710	3700	9068	42	39			
M	7.34	76.78	299.30	1.44	1.34	NOXC=	1.70	K=1.178

1 2100103520011900331720950RWK67MERCCOUGA390403500 1127571301381011596641 70
13 210010352001190 560D 440 +00 35

FIGURE 4.4-4

AESi
AUTOMOTIVE ENVIRONMENTAL SYSTEMS, INC.

COMPUTER DATA FLOW

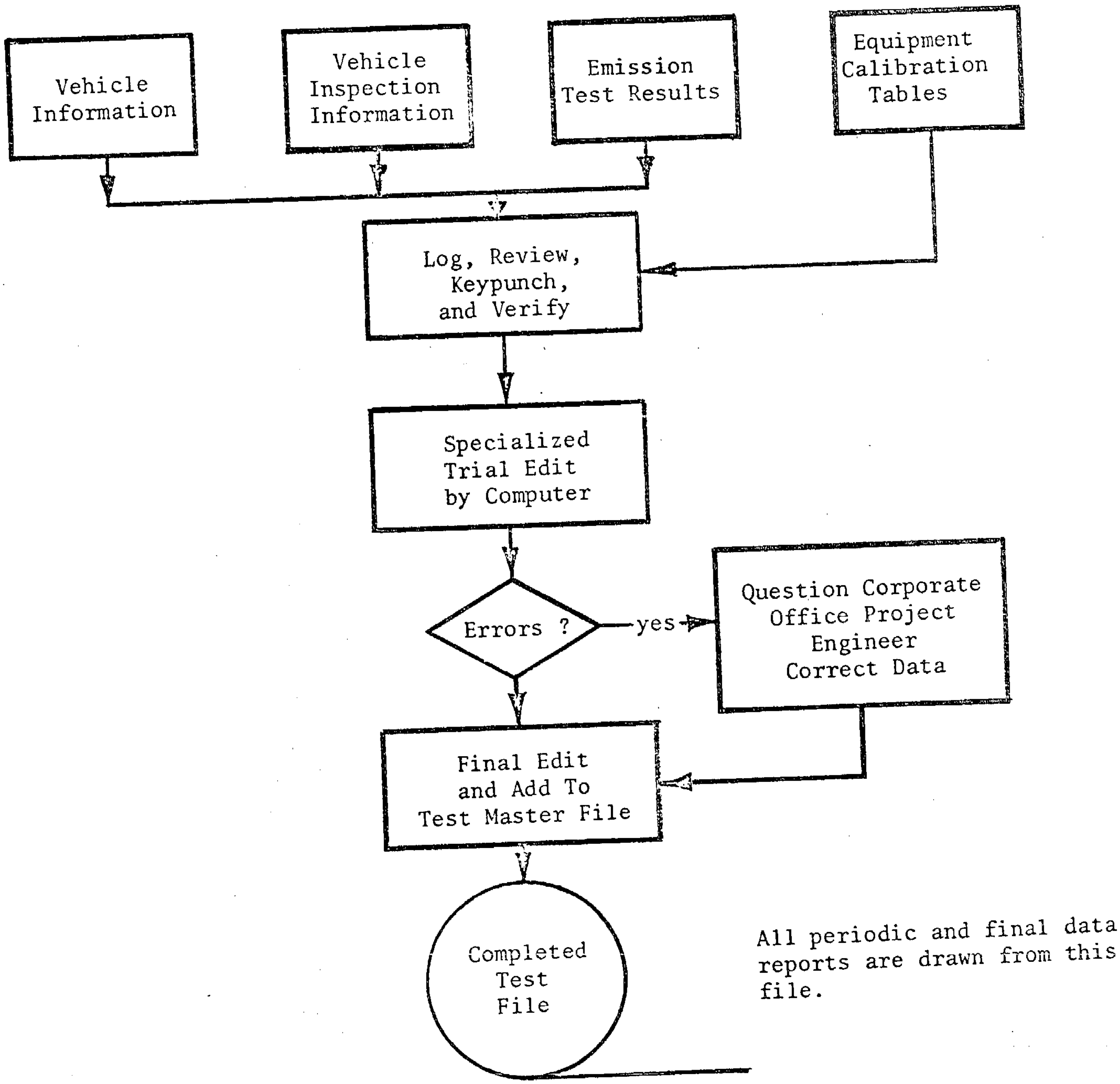

FIGURE 4.4-5